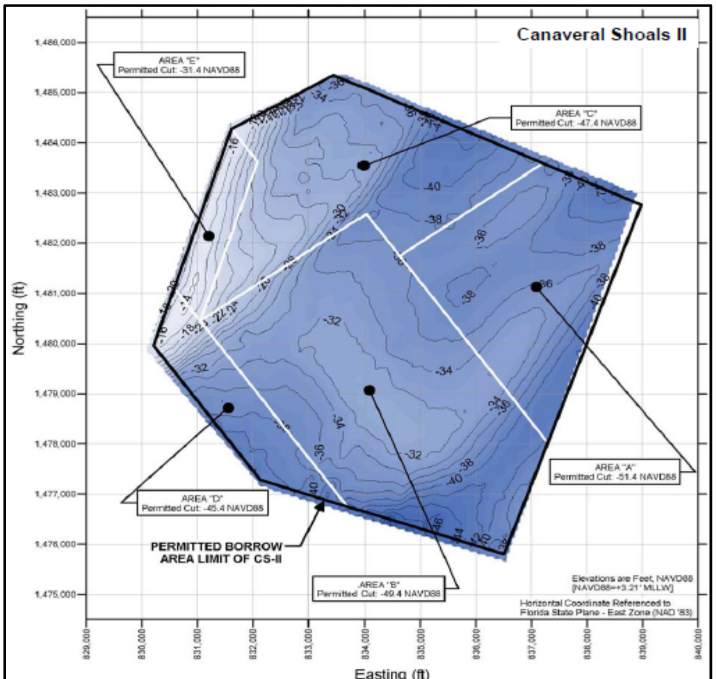
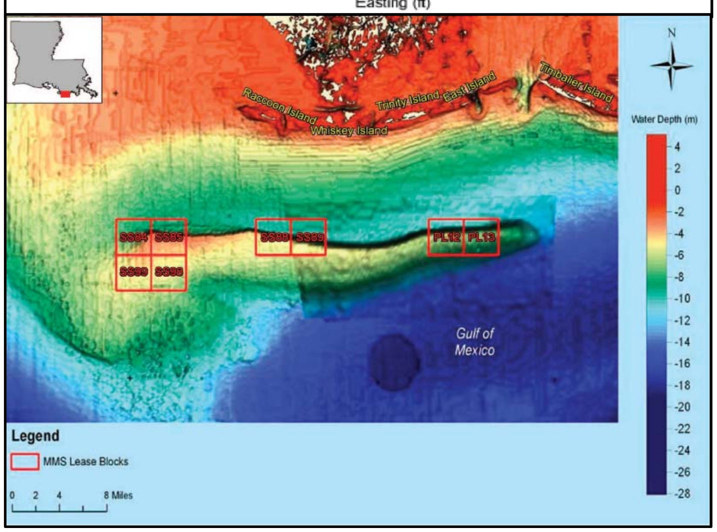
OCS Study
BOEM 2018-062

Managing Dredge Impacts by Optimizing the Use of Sand Resources





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Managing Dredge Impacts by Optimizing the Use of Sand Resources

December 2018

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Prepared under BOEM Award M15PG00033

by

U.S. Army Corps of Engineers
Engineering Research and Development Center

US Department of the Interior
Bureau of Ocean Energy Management
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DISCLAIMER

This study was funded, in part, by the US Department of the Interior, Bureau of Ocean Energy Management (BOEM), Environmental Studies Program, Washington, DC, through Interagency Agreement Number M15PG00033 with the U.S. Army Corps of Engineers. This report has been technically reviewed by BOEM, and it has been approved for publication. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the US Government, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

REPORT AVAILABILITY

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CITATION

Coor JL, Bates M, Fox-Lent C. 2017. Managing dredge impacts by optimizing the use of sand resources. Sterling (VA): U.S. Dept. of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2018-062. 7 p plus appendices.

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Abbreviations and Acronyms

BOEM	Bureau of Ocean Energy Management
CO	Contracting Officer
COR	Contracting Officer’s Representative
ERDC	Engineering Research and Development Center
IA	interagency agreement
MCDA	multi-criteria decision analysis
OCS	outer continental shelf
PI	Principle Investigator
SAJ	South Atlantic–Jacksonville District
SSM	sediment source management
SSMP	sand source management plan
SSST	sand source selection tool
USACE	U.S. Army Corps of Engineers

1 Introduction

Outer Continental Shelf (OCS) sand resources are finite and need to be managed carefully. The typical beach nourishment and/or coastal restoration project involves an initial large-scale construction phase followed by smaller-scale, regularly scheduled maintenance cycles. The sediment used for initial construction and subsequent maintenance is often dredged from the same sand resource area, which can equate to frequent dredging of the same or adjacent seafloor for a period of 50 years or longer. In coastal areas where sand is scarce and multiple use conflicts are common, a single sediment source could also be used by multiple stakeholders for the construction of several adjacent beach fill or coastal restoration projects. Large volumes of sand may also be needed to recover from severe storms such as Hurricane Sandy. These circumstances can lead to rapid resource depletion and the need to identify, characterize, and delineate additional sediment sources.

Different types of sand bodies are dredged to different cut depths over various footprints. In many instances, the approach to managing dredging intensity (location, duration, and frequency) is not systematically planned, so transport distance and dredge productivity are the primary determinants of where dredging occurs. Fill performance, funding availability, environmental construction windows, and dredge plant availability typically drive when and where dredging occurs. This current approach is not conducive to long-term, responsible, and sustainable resource management.

Dredging can have direct and indirect effects on physical, biological, and archaeological resources (Nairn et al., 2004). Each dredging event diminishes not only the availability of sand resources, but also lowers the profile of the sand resource, which can potentially cause physical effects such as changes in local and residual hydrodynamics, substrate composition, and morphologic response of the sand body. These interrelated effects, which can be magnified during multiple dredging events, could disturb the ecosystem function of sensitive biological habitats and resources in the vicinity of the sediment source. Such physical changes could also cause unanticipated indirect impacts on archaeological resources that are otherwise protected by exclusion zones.

The management of OCS sand resources is often a multifaceted challenge to balance various engineering and design requirements, economic and environmental considerations, and stakeholder needs. OCS management strategy would likely benefit from advanced planning using a systematic framework incorporating long-term project design, engineering, and economic requirements while considering sand resource availability and environmental impact-minimizing techniques.

The goal of the present project is to develop a reproducible planning process to optimize the utilization of repetitive-use sediment sources. The process will use multi-criteria decision analysis (MCDA) to evaluate and quantify technical, environmental, economic, and societal factors in context with potential management and monitoring measures. The planning process will use an efficient computer-based MCDA tool to facilitate sediment source management (SSM). The MCDA tool will assist in the development of SSM plans (SSMPs) by quantifying or ranking the various evaluation factors. The tool will accept input data, when applicable, in formats used by the Bureau of Ocean Energy Management (BOEM). The MCDA tool will include a software reference manual and tutorial with sufficient detail to enable an untrained professional to use the application.

2 Development of Sediment Source Management Process

The Engineer Research and Development Center (ERDC) created a sand source selection tool (SSST). The SSST will assist in the development of SSMPs by quantifying or ranking the various evaluation factors within a given sand source. To demonstrate benefits and costs of this planning process, we developed two draft SSMPs to optimize two OCS sediment resources characterized by frequent dredging and multiple users: Canaveral Shoals II, FL, and Ship Shoal, LA.

Additional information on the two SSMPs may be found in Appendix D.

The SSST is a Microsoft® Excel-based spreadsheet tool that implements decision analysis for a collaboratively developed criteria tree (see Section 3.2). Users are required to input the 1) names of the sand source site alternatives to be assessed, 2) value functions for each criterion, 3) measurement or assessment of each alternative for each criterion, and 4) weights for each criterion indicating the relative importance of the criterion relative to the other criteria in the tree. The tool provides users with a set of rubrics to guide the scoring of environmental, organizational, and sustainability criteria. The output of the tool is a table with the overall score, and level-1 criteria scores, for each of the alternatives. Generated graphs also show the relative scores for these alternatives. Both a user's manual and a tutorial are provided to assist in utilizing the tool.

The sand source management planning process will outline a method that can be utilized to demonstrate the costs and benefits of optimizing sand sources undergoing frequent dredging by either single or multiple users. An SSMP should include compilation and analysis of sand and sediment source characteristics, environmental resources information, best management practices, and cost-benefit data. An SSMP could combine the results of the SSST with inherent knowledge, expert analysis, and interpretation. Finally, the SSMP should include lessons learned from previous projects, both within the region and those that are similar in nature to the proposed project.

Additional information on the SSST methodology may be found in the SSST Reference Manual in Appendix C. Additional information on the SSMP methodology may be found in the SSMP Comprehensive Work-Flow Manual, located in Appendix D.

3 Meetings

There have been three (3) formal meetings for this project including the kickoff/scoping meeting held in New Orleans, LA; MCDA planning meeting held in Atlanta, GA; and final meeting held in Sterling, VA. An informal meeting was held in Jacksonville, FL.

3.1 Kickoff/Scoping Meeting

The kickoff/scoping meeting for "Managing Dredge Impacts by Optimizing the Use of Sand

Resources" was held on 5 October, 2015, at the Intercontinental Hotel in New Orleans, LA, in conjunction with the BOEM Gulf of Mexico working group meeting. The attendees included Paul Knorr, Doug Piatkowski, Mike Miner, Jennifer Culbertson, Lora Turner, and Jase Ousley. The meeting began with the evaluation factors listed in Task 1 of the Statement of Work (SOW). BOEM stated that they would like the ranking factors in the MCDA application to output to a format that could be incorporated into spatial databases. Output tables in Excel format will meet this request. ERDC recognized that the current optimization effort may be followed by spatial analysis in the future and should be a consideration in development of the MCDA application. BOEM staff referred to a British Marine Aggregates Producers Association tool that is produced in the UK and they said that they would provide a link to it for ERDC to use as reference. BOEM recommended that ERDC coordinate with Mike Sessions from the U.S. Army Corps of Engineers (USACE) Mobile District, DQM group, for the dredging intensity script that was written for MATLAB under a separate effort with BOEM. BOEM requested that time intensity of dredging as a parameter that should be included in the evaluation factors. BOEM stated that they expect the literature review to contain references to fundamental studies on the evaluation factors sufficient to allow the working group to make decisions on the impacts of the factors. The group discussed an example of weighting criteria comparing the impacts of using a less constructible sediment source with odd angles versus the cost of investigating a magnetometer hit to remove dredging buffers. BOEM and ERDC reviewed the deliverables and discussed formats. BOEM said they would provide examples for all deliverables. ERDC asked what BOEM envisioned for the planning process, and both agreed that any planning process would fit within the current USACE process and include developing the MCDA application with the established evaluation criteria. Both BOEM and ERDC agreed to continue regular dialog as the project moves forward.

3.2 MCDA Planning Meeting

The Sand Source Management: MCDA Planning Meeting was held on 10–11 May, 2016, in Atlanta, Georgia. Participants included in-person representatives from BOEM, USACE, ERDC, Jacksonville, Mobile, Philadelphia, and New England Districts, as well as from Humiston & Moore Engineers, Mississippi State University, CB&I, Applied Technology Management, and Coastal Protection & Restoration Authority of Louisiana. Additional participants from BOEM, USACE, academia, state regulatory agencies, and private firms participated via the webinar. Dr. Paul Knorr of BOEM—and Contracting Officer's Representative (COR) of the project—presented the major issues challenging the management of OCS resources. The MCDA approach was previously determined in the Interagency Agreement (IA) to be the technical approach for this project. Matthew Bates of the USACE ERDC presented an introduction to the MCDA process and case studies that utilize the approach for other sediment management applications.

The objective of the MCDA tool development was identified as determining the suitability of a sub-region within a shoal or other sediment source for use as placement material in a project area. A draft criteria tree was presented for discussion, feedback, and revision. The initial version included four top-level criteria: Sediment Match to Project, Borrow Site Access, Environmental Concerns, and Future Site Usability (Figure 1), with a number of sub-criteria for each.

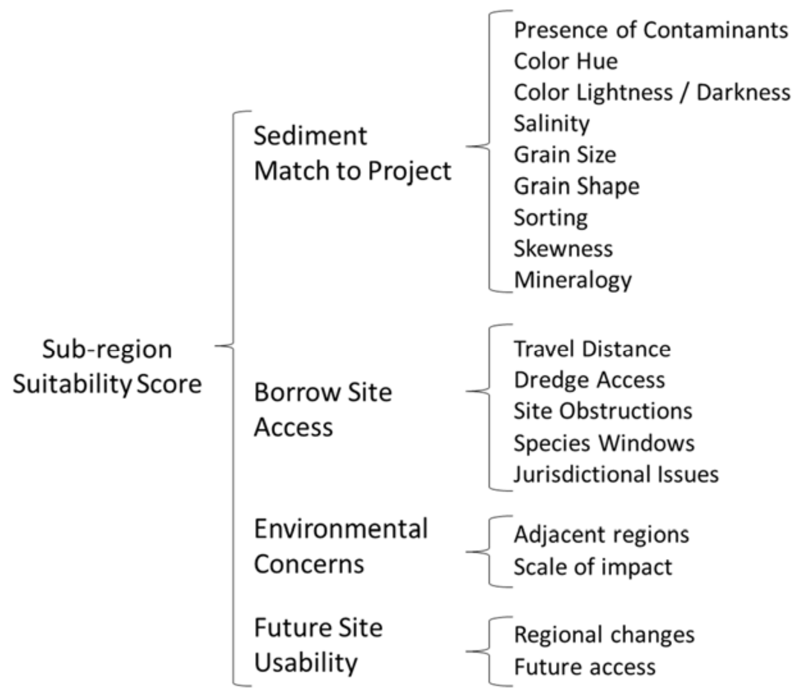

Figure 1. Initial criteria tree draft.

USACE ERDC team members developed the draft criteria tree based on initial discussions with BOEM's Paul Knorr and members of the USACE Jacksonville District. The meeting participants were guided through a structured discussion to assess and validate the proposed framework. The issues to consider were 1) whether the existing tree captured all of the relevant decision factors, 2) if the assessment of each criterion will differ among sub-regions of the sediment source, and 3) how each criterion could be measured or described.

Through the 1.5-day meeting presentation, discussions, and response sessions, the criteria tree was revised (Figure 2).

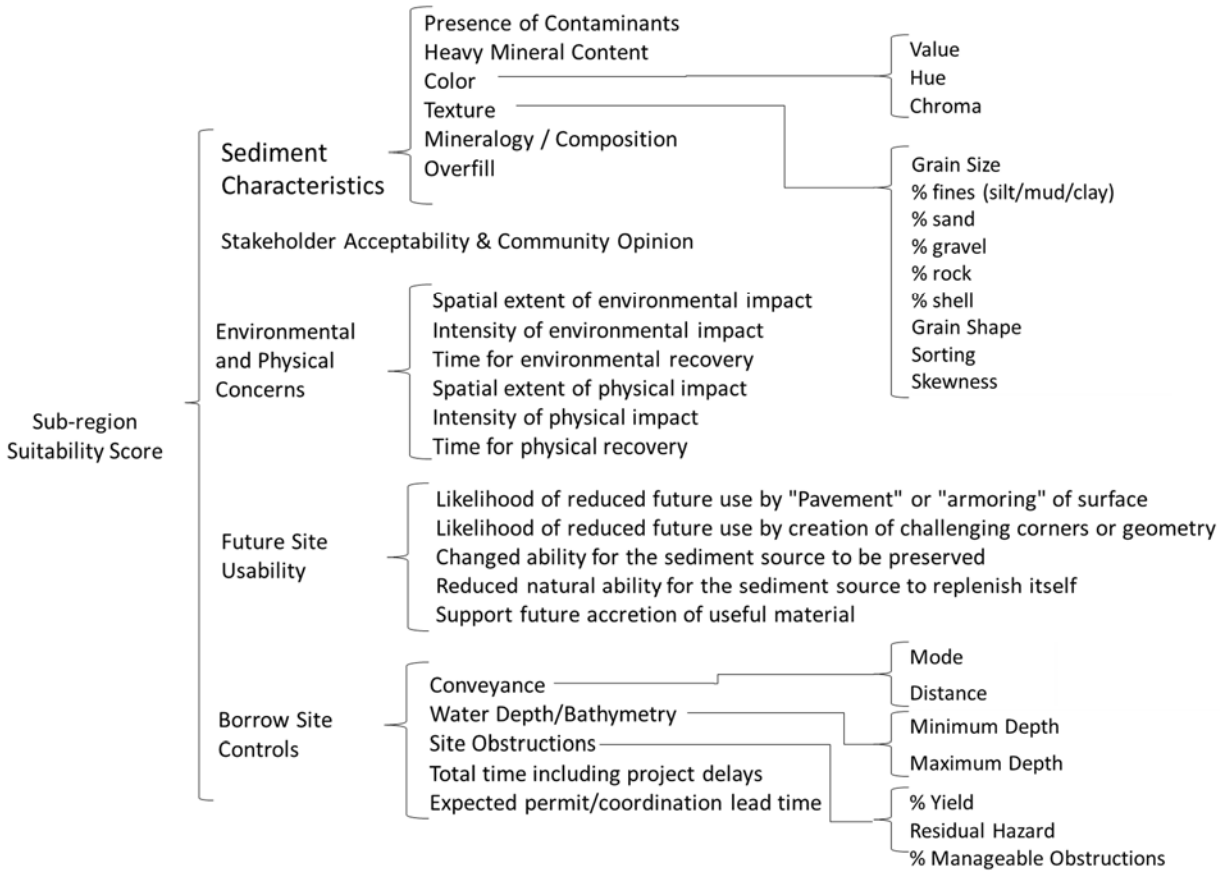

Figure 2. Updated criteria tree resulting from planning meeting.

The “Sediment Match to Project” was renamed “Sediment Characteristics,” and the project engineers and geologists in the group provided revisions to the list of relevant criteria, terminology, and metrics typically used to assess sediment characteristics. “Borrow Site Access” was revised to “Borrow Site Controls” as it was determined that the issues of concern are the controls on cost, time, and effort of accessing a site, rather than whether access is possible or not. The group concluded that rather than describe the specifics of all possible jurisdictional, permitting, and dredging windows within the tool, users could estimate the total lead time and delays based on the conditions of a specific project or location. Additionally, the group determined that Site Obstructions could be considered as a combination of Manageable Obstructions (such as old pipelines that could be removed, or challenging dredging boundaries and geometries) and Residual Hazards, which are those about which nothing can be done (such as archaeological sites). The “Environmental Concerns” criterion was expanded to include “Physical Concerns” as well. Although many of the experienced project managers, both federal and private, were uncertain if and how the spatial extent and intensity of such impacts could be determined ahead of time, discussions with researchers in the ERDC Environmental Lab suggest that there are heuristics that can be used to estimate such impacts and that the category is important to long-term resource sustainability and should not be excluded simply because it is challenging to measure. The sub-criteria for “Future Site Usability” were expanded to explicitly list the major issues for future use based on experience of the participants. Finally, “Stakeholder Acceptability & Community Opinion” was added as a top-level criterion to be assessed qualitatively by the project team based on communication and feedback during the project development and public outreach.

During the final part of the meeting, participants were introduced to the process of developing a weighting scheme for an MCDA. It was decided that the weights for most criteria would be project specific and will need to be calculated at the point of use for the tool; however, the relative weights within the "Sediment Characteristics" criterion should largely be based on engineering principles and professional experience and therefore can be built into the tool. Within a week after the meeting, participants received a link to an online questionnaire asking them to respond to a set of questions about weighting the Sediment Characteristics sub-criteria. Results of the questionnaires and follow-up conversations with coastal scientists in the ERDC were used to complete the tool development over the next few months.

3.3 Final Meeting

The final meeting for "Managing Dredge Impacts by Optimizing the Use of Sand Resources" was held on 21 March, 2017, at the Bureau of Ocean Energy Management, 45600 Woodland Rd., Sterling, VA. The attendees included Paul Knorr, Geoff Wikel, Jeff Reidenauer, Doug Piatkowski, Jeff Waldner, Leighann Brandt, David Diamond, Deena Hansen, Doreen Vega, and Jennifer Bucatari from BOEM; and Jennifer Coor, Cate Fox-Lent, and Mary Cialone from USACE/ERDC. The meeting began with a brief introduction and summary of the inception of the project by Paul Knorr. Jennifer Coor then gave a brief presentation summarizing Task 1 and discussing the two deliverables: the literature review and data dictionary (see Appendix A). Cate Fox-Lent gave a presentation summarizing Tasks 2 and 3 on the MCDA Planning Meeting and the development process of the SSST. After a short discussion, a demonstration of the SSST was given. Jennifer Coor gave a presentation summarizing Task 4, which included developing an SSMP planning process/manual, and applying those techniques and the SSST to two sand sources: Canaveral Shoals, FL, and Ship Shoal, FL. There was another discussion period, and Paul Knorr closed the meeting.

4 Official Correspondence

Throughout the course of the IA, the ERDC team members changed, requiring the principle investigator (PI) and schedule to be changed.

The IA between BOEM and ERDC began on 5 October, 2015, and had a performance period of 1 year, with the expected completion date of 4 October, 2016. Christy Tardiff was the Contracting Officer (CO) and Paul Knorr was the COR with BOEM; Jase Ousley was the PI with ERDC. In January 2016, Jase Ousley left ERDC, and there was a transition period while a new PI and team was assembled. In February 2016, the PI role was transitioned to Mary Cialone at ERDC. Jennifer Coor, USACE-South Atlantic–Jacksonville District (SAJ), and Matthew Bates, ERDC, became the Technical Leads.

Three extensions were granted during the course of the IA. The first was approved in March 2016 to allow the new project team the same time as the original team to provide quality products and schedule a necessary planning meeting. The second extension was granted during the first quarter FY17 because BOEM did not provide to USACE the necessary data to write the sand source management plans with sufficient time to analyze the data, run the SSST, and create an SSM. The third extension was granted in March 2017 for USACE and ERDC to finalize all reports and deliverables in coordination with BOEM.

5 Monthly Updates

A copy of all of the progress reports are provided in Appendix E.

6 Summary

This IA between BOEM and ERDC produced an SSST that looks at a combination of factors (sediment characteristics, future site usability, borrow site controls, stakeholder and community opinion, and environmental and physical concerns) in order to optimize the use of a given frequent or multiple-user sand source. SSMPs were written for Canaveral Shoals II, FL, and Ship Shoal, LA, utilizing the SSST, creating a planning process and work-flow manual. Additionally, a literature review and data factor dictionary were generated.

7 References

Nairn, R., T. Kenny, F. Marván, J. Michel, R. Newell, and N. Bray, 2004. Review of existing and emerging environmentally friendly offshore dredging technologies. BOEM 2004-076.

Appendix A. Task 1 Deliverables

A-1 Data Dictionary

1 General Terminology

A general background of common terminology and processes are provided as reference to be used throughout the subsequent sections of the dictionary.

1.1 Beach

The zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation (usually the effective limit of storm waves). The seaward limit of a beach--unless otherwise specified--is the mean low water line. A beach includes foreshore and backshore. (USACE)

1.2 Beach nourishment, or artificial nourishment

The process of replenishing a beach with material (usually sand) obtained from another location. (USACE)

1.3 Continental shelf

(1) The zone bordering a continent extending from the line of permanent immersion to the depth, usually about 100 m to 200 m, where there is a marked or rather steep descent toward the great depths of the ocean. (2) The area under active littoral processes during the Holocene period. (3) The region of the oceanic bottom that extends outward from the shoreline with an average slope of less than 1:100, to a line where the gradient begins to exceed 1:40. (USACE)

1.4 Deflation

The separation and removal of loose material (such as sands, silts, and clays) from coarse material (gravels, cobbles) on a beach or other surface, such as the seafloor, by either wind or ocean currents. (Modified from USACE)

1.5 Existing beach

The granular sediments, usually sand moved by the sea, composing the modern beach, which has been modified through beach nourishment. (Modified from USACE)

1.6 Marine armoring

Substrate characteristic in which the coarse grains are separated from fine grains. This typically is caused by deflation and is most commonly observed in deserts, although the phenomena is also observed on the sea floor. May also be referred to as marine asphalt.

1.7 Native beach

The granular sediments, usually sand moved by the sea, composing the modern beach, which has not been modified through beach nourishment. (Modified from USACE)

1.8 Placement area, or project area

Location along the existing or native beach where compatible sand will be placed during beach nourishment.

1.9 Sand

Sediment particles, often largely composed of quartz, with a diameter of between 0.062 mm and 2 mm, generally classified as fine, medium, coarse or very coarse. Beach sand may sometimes be composed of organic sediments such as calcareous reef debris or shell fragments. (USACE)

1.10 Sand source, or borrow area

The location from which sand will be obtained for beach nourishment purposes. Sand sources are commonly located offshore on the outer continental shelf (OCS) or within inlet shoals and contain beach compatible sand. The sand source is commonly referred to as a borrow area.

1.11 Shoal

(noun) A detached area of any material except rock or coral. The depths over it are a danger to surface navigation. Similar continental or insular shelf features of greater depths are usually termed banks. Shoals are commonly dredged as a sand source for beach nourishment. (Modified from USACE)

2 Resource Characteristics and Technical Requirements

Many technical aspects, such as engineering and geotechnical analyses, are required during the beach nourishment process. Therefore, it is necessary that the resource characteristics of both the sand source, or borrow area, and placement site be well understood.

2.1 Engineering requirements

Certain engineering information is determined through modeling and analysis and incorporated into the design of the beach nourishment project.

2.1.1 Advance fill

Volume required beyond the design template to account for anticipated erosion over the project renourishment interval.

2.1.2 Beach profile

A cross-section taken perpendicular to a given beach contour; the profile may include the face of a dune or sea wall, extend over the backshore, across the foreshore, and seaward into the nearshore zone. (USACE)

2.1.3 Compatibility

The likeness of the material in the sediment source to the material on the existing fill site with respect to granularmetric similarity, chemical composition, color. Compatibilty can be determined using the overfill factor. (James, 1975)

2.1.4 Construction template

Template that is utilized for construction and includes both the design template and advance fill. The construction template is the sum of the project design and advance fill volumetric requirements.

2.1.5 Design berm height

The height of the planned berm, to be constructed, relative to a given datum.

2.1.6 Design berm slope

The slope of the planned berm, to be constructed, as determined by the (vertical) change in elevation across the (horizontal) berm width.

2.1.7 Design berm width

The horizontal width of the planned berm, to be constructed, from the toe of dune to the mean high water line (MHWL).

2.1.8 Design template

Minimum project dimensions required to attain the stated project benefits. This is the minimum beach cross-section that must remain throughout the project life to realize the project storm reduction benefit.

2.1.9 Design volume

The amount of sediment that meets established sediment quality criteria, excluding material in buffer zones around environmental or cultural resources. (Ousley et al., 2014)

2.1.10 Desired sand quality

Sediment quality is related to grain size, shape, sorting, color, and mineralogy and the similarity of the sediments in the borrow material to the sediments in the beach fill placement area.

2.1.11 Dredge recovery method

There are two primary dredging methods to recover sand from the ocean floor for beach nourishment purposes. Trailing suction hopper dredges (TSHD) are the most common type of equipment for beach restoration and coastal protection projects that use OCS as the sand source because the water depth, distance from the project site, project size, oceanographic conditions, etc. of typical borrow areas are best suited to this type of dredging operation. A TSHD is self-propelled, deploys the suction dredge, and stores the dredged material in hoppers located in the hull of the ship. The second dredging method utilizes a cutterhead which excavates material from the borrow area and create a slurry that is pumped into a pipeline for transport to the placement or disposal site. Spider and hopper barges are less oftrn used, but may be used for long distances or where pipelines would hinder navigation. (Modified from USACE)

2.1.12 Dredge quality management (DQM) operational plan

The National Dredging Quality Management (DQM) Program is the USACE's next generation automated dredging monitoring system and analysis tool for the modern USACE dredging manager. The mission of the National DQM Program is to provide the USACE dredging manager with a nationally-standardized, low-cost remote monitoring and documentation system. This system provides the Corps with timely data access, multiple reporting formats, full technical support, including dredge certifications, data quality control, database management, and support for the DQM operating system. Sensors on the dredge continually monitor dredge activities, operations, and efficiency. Information from these sensors is routed to the National DQM Support Center for data processing, storage and publishing. (USACE)

2.1.13 Fill frequency, or renourishment interval

The time between the initial construction and subsequent maintenance events.

2.1.14 Granularmetric similarity

The degree that sediments in a sediment source and a fill area match with respect to sediment distribution and sorting. Granularmetric similarity is represented by calculating an over-fill ratio. (USACE)

2.1.15 Overfill factor

A volume factor which may be used to calculate an intentional overfill volume to compensate for volume loss during the initial construction. A comparison of overfill factors from various sand source locations is used to determine which of the proposed sand sources will provide the lowest placement volume. This term is also known as overfill ratio. (Modified from USACE)

2.1.16 Project design

The results of the plan formulation of the project, including the determination of the beach fill placement site, borrow areas, beach design (berm height, berm slope, berm width, nourishment cycle, etc.), and monitoring.

2.1.17 Renourishment factor

Estimates long term relative erosion rates of borrow materials with respect to native materials. This is done by assuming all grains have a finite residence time in the local littoral system before being transported offshore or alongshore. The renourishment factor is primarily a measure of relative long-term stability. Renourishment factor values greater than one predict the borrow material will erode at a higher rate than the native beach. Conversely, values of less than one predict the borrow material is more stable than the native material. (Modified from USACE)

2.2 Regional sediment transport dynamics

The regional sediment transport dynamics at both the sand source, or borrow area, and placement site must be considered in beach nourishment projects. Changes in bathymetry at either location can cause perturbations to adjacent shorelines or interrupt sediment pathways that impact down drift shorelines.

2.2.1 Pre-excavation current

The normal current field prior to the removal of sediment from a borrow area.

2.2.2 Post-excavation current

The current field after the removal of sediment from a borrow area.

2.2.3 Sediment

(1) Loose, fragments of rocks, minerals or organic material which are transported from their source for varying distances and deposited by air, wind, ice and water. Other sediments are precipitated from the overlying water or form chemically, in place. Sediment includes all the unconsolidated materials on the sea floor. (2) The fine grained material deposited by water or wind. (USACE)

2.2.4 Sediment cell

In the context of a strategic approach to coastal management, a length of coastline in which interruptions to the movement of sand or shingle along the beaches or nearshore sea bed do not significantly affect beaches in the adjacent lengths of coastline. (USACE)

2.2.5 Sediment sink

Point or area at which beach material is irretrievably lost from a coastal cell, such as an estuary, or a deep channel in the seabed. (USACE)

2.2.6 Sediment source

Point or area on a coast from which beach material is supplied, such as an eroding cliff, or river mouth. (USACE)

2.2.7 Sediment source recovery time

The amount of time for the excavated area to return to its prior ecological value. This could be either physical recovery of sediment (infilling of a hole) or for benthic species to return to the area.

2.2.8 Sediment source refill rate

The rate at which the excavated area (in)fills with sediment falling out of suspension from the post-dredge current field.

2.2.9 Turbidity

A measure of water clarity, describing how much the material suspended in water decreases the passage of light through the water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances. These materials are typically in the size range of 0.004 mm (clay) to 1.0 mm (sand). Turbidity can affect both the color and clarity of the water. (USACE)

2.3 Sediment characteristics

Information about the grain size characteristics of the native beach material can provide information about the coastal processes in the area. Systematic variations in median grain diameter along the beach, or evidence of natural tracers in the sand, may suggest the direction of net longshore transport.

Grain size characteristics are quantified based on sieve analyses of samples which are collected throughout the project domain and are a critical design parameter. Samples acquired on the profile between the berm crest (or mean high water line) and a water depth corresponding to the position of the typical storm bar should be used to characterize native beach sand for the purpose of assessing the compatibility of sand from potential borrow sources. Compatibility of borrow and native beach material is primarily based on grain size characteristics, and to a lesser extent on color. (USACE)

2.3.1 Color

The color of sediment is important during the identification for sediment sources when considering beach compatibility and habitat function. Sediment color is determined using the Munsell color system, which was developed to describe sediment color using Hue, Value and Chroma. The Hue indicates the color's relation to red, yellow, green, blue and purple. Value indicates the sediment's lightness or darkness where a value of 10 is white and a value of 0 is black. Chroma indicates the intensity (richness) of the color or difference from a neutral color of the same lightness (USDA, 1993).

2.3.2 Grain size (mean)

Grain size is defined as the diameter equivalent of the arithmetic mean of the logarithmic frequency distribution. In the analysis of beach sands, it is taken as the grain diameter determined graphically by the intersection of a straight line through selected boundary sizes, (generally points on the distribution curve where 16 and 84 percent of the sample is coarser by weight) and a vertical line through the median diameter of the sample.

The mean grain size is most commonly used to capture the size of sediment in a sediment source. Often, for characterizing a sediment source the mean grain size is a weighted composite of the discrete samples that were taken from cores throughout the spatial extent of the sediment source. (USACE)

2.3.3 Grain size (median)

The diameter which marks the division of a given sand sample into two equal parts by weight, one part containing all grains larger than that diameter and the other part containing all grains smaller. (USACE)

2.3.4 Heavy mineral percentage

The percent, by weight, of sediment particles composed of heavy minerals (rutile, zircon, ilmenite, etc.), as determined through magnetic separation or liquid separation methods. May also be estimated as a visual percent.

2.3.5 Minerology

Sediment mineralogy plays an important role in the function of a beach. Beach sediments are commonly composed of a wide variety of minerals including quartz, carbonate, aragonite, feldspar, heavy minerals, among others. In some cases, mineral matter can seep into the pores of sediments and cause cementation, which affects the porosity and permeability of the sediments. (Nelson, 2013)

2.3.6 Percent carbonate

The percent, by weight, of sediment particles composed of calcium carbonate, or calcite, as determined through acid dissolution or loss on ignition.

2.3.7 Percent silt

The percent, by weight, of sediment particles with a grain size between 0.004 mm and 0.062 mm, i.e. coarser than clay particles but finer than sand. (Modified from USACE)

2.3.8 Percent visual shell

The percent, as determined by visual estimate, of sediment particles composed of calcium carbonate, or calcite, and are in the form of whole or broken shell.

2.3.9 Sediment distribution

Found by sieving an individual sediment sample and weighing the percent retained on each sieve. The cumulative sediment distribution is plotted on a log-normal graph. (USACE)

2.3.10 Sorting

Sediment sorting refers to the standard deviation of the mean grain size. It captures the range of grain sizes in a sediment distribution. A sediment with a phi less than 0.5 is said to be poorly graded (engineering) or well sorted (geology) and contains a limited variety of grain sizes. Likewise, a sediment with a phi greater than 1.0 is said to be well graded (engineering) or poorly sorted (geology) and contains a wider range of sediment sizes. The sorting can be found using several methods, but the Method of Moments is most common. (Modified from Folk, 1974)

2.3.11 Skewness

The degree of asymmetry within the sediment distribution, typically caused by an excess of coarse or fine particles. (Boggs, 2001)

2.4 Sediment source characteristics

The characteristics of the sediment source, or borrow area, are vital to beach nourishment projects, as the sand must be compatible with the placement site, and must contain a large enough volume of sand required to sustain the lifetime of the project design.

2.4.1 Area

The spatial extent of the sand source, or borrow area, in the horizontal plane.

2.4.2 Bathymetry

The measurement of depths of water in oceans, seas, and lakes relative to a vertical datum; also information derived from such measurements. For example, for sand mining purposes, bathymetry is used to map morphological features such as shoals on the OCS. (Modified from USACE)

2.4.3 Recoverable thickness

The thickness of the sediment deposit that can be recovered during excavation of the sediment source. Factors that influence the recoverable thickness include sediment quality, environmental regulations, and dredging equipment capability and capacity.

2.4.4 Ruggedness

The insensitivity of a test method to departures from specified test or environmental conditions. (American Society for Testing and Materials)

2.4.5 Salinity

The concentration of dissolved salts within a body of water, and measured as the number of grams of salt per thousand grams of sea water, usually expressed in parts per thousand. (Modified from USACE)

2.4.6 Substrate

(1) A substance or layer that underlies something, or on which some process occurs, in particular either soft (sandy) substrate or hard (rock) substrate along the OCS. There are several conditions where OCS dredging can lead to changes in substrate characteristics. (2) Substrate may also apply to the surface or material on or from which an organism lives, grows, or obtains its nourishment. (Modified from USACE)

2.4.7 Volume

The volume of available sediment in a delineated sand source, or borrow area. This can either be the total volume or a design volume. The total volume is the amount of sediment that meets established sediment quality criteria excluding material in buffer zones around environmental or cultural resources.

2.4.8 Water chemistry

Refers to the chemical aspects of the water column, including pH, salinity, dissolved oxygen, nutrient levels, and contaminants, among others.

2.4.9 Water depth

The vertical distance from a specified datum to the sea floor where the sediment source resides. (USACE)

2.4.10 Water temperature

The temperature or temperature gradient of the water column.

3 Environmental Considerations

While there is no official definition to fully encompass environmental consideration, a wide variety of topics are considered in the context of this project. These considerations include, but are not limited to, cultural concerns, infaunal benthic communities, fish habitats, climate, flora and fauna, safety avoidance areas, and contaminants.

Emphasis within this section of the report is placed on various organisms, because species variety, population density and biomass of benthic fauna may be suppressed by as much as 60-90% within dredged areas. Previous studies have shown the suppression is reduced during the recovery process following cessation of dredging, but may be significant in areas with coarse deposits for at least half of the overall recovery time, or at least 6-10 years. In sandier deposits, recovery times are likely to be shorter (approximately 2-4 years). (Nairn et al., 2004)

3.1 Archaeological avoidance area

Some regions of the seafloor must be avoided due to archaeological concerns, such as shipwrecks, Paleo-Indian sites, and other concerns.

3.1.1 Archaeological sites

An archaeological site is any location that contains the physical evidence of past human behavior that allows for its interpretation. The term archaeology site refers both to sites that are either eligible or listed on the National Register (historic properties) as well as those that do not qualify for the National Register. Historical archaeology sites can be found in both terrestrial (upland) and/or underwater environments. (Advisory Council on Historic Preservation)

3.1.2 Shipwrecks

The partial or total destruction of a ship at sea, commonly by storm or collision, resulting in the vessel sinking to the seafloor. The sunken vessels are both important to history and create underwater habitat. (Modified from National Park Service)

3.2 Areas adjacent or down-current of sediment source or transport

Areas either adjacent to, or down current from, either the sand source (borrow area) or beach placement site may potentially experience various effects as a result of beach nourishment activities because these activities are essentially a perturbation to the system.

3.3 Benthic communities

Organisms that live in and on the bottom of the ocean floor. These organisms are known as benthos, and include worms, clams, crabs, lobsters, sponges, and other tiny organisms that live in the bottom sediments. Benthos include both filter feeders and deposit feeders. (U.S. Environmental Protection Agency)

3.4 Dredging operational windows

Those periods of time when dredging and disposal operations can take place without unacceptable impacts on species and habitats and other resources of concern. These time windows should be assessed for both technological scenarios to identify clearly the changes in window length and timing associated with the implementation of different technological approaches. (Modified from Florida Department of Environmental Protection and Florida Fish and Wildlife Conservation Commission)

3.4.1 Bird window

Period of time during which shorebirds are not nesting on the beach (either solitary or in colonies), and beach nourishment activities may take place. (Modified from Florida Fish and Wildlife Conservation Commission)

3.4.2 Turtle window

Period of time during which turtles are not nesting on the beach, and beach nourishment activities may take place. (Modified from Florida Fish and Wildlife Conservation Commission)

3.4.3 Weather window

(1) Period of time during which weather is favorable (safe), and beach nourishment activities may take place. (2) The state of the atmosphere with respect to wind, temperature, cloudiness, moisture, pressure, etc. Weather refers to these conditions at a given point in time (e.g., today's high temperature), whereas Climate refers to the "average" weather conditions for an area over a long period of time (e.g., the average high temperature for today's date). (National Weather Service)

3.5 Endangered Species

The classification provided to an animal or plant in danger of extinction within the foreseeable future throughout all or a significant portion of its range. (U.S. Fish and Wildlife Service)

3.6 Environmental Recovery Period

Period of time for short-term and cumulative impacts from dredging that lead to loss or reduced stability of benthic habitats, including recolonization by an altered biological community, to return to pre-dredge conditions. The need for a recovery period is based on the direct removal of benthic habitat along with infaunal and epifaunal organisms that are incapable of avoiding the dredge, resulting in significant reductions in the number of individuals, number of species, and biomass. (Nairn et al., 2004)

3.6.1 Essential fish habitat (EFH)

Those waters and substrate necessary to fish to spawn, breed, feed, or grow to maturity (MSA § 3(10)). For the purpose of interpreting the definition of essential fish habitat: "waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish; "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities; "necessary" means the habitat is required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle. (National Marine Fisheries Service)

3.6.2 Hard substrate, or hard bottom

This substrate includes particles of organic and inorganic matter combined in a consolidated substrate that sessile organisms, such as sponges and corals, maintain as a temporary or permanent site of residence. (Modified from USACE)

3.6.3 Mangrove

A tropical tree with interlacing prop roots, confined to low-lying brackish areas. The root systems provide habitat for oysters and juvenile fishes, among other organisms. (Modified from USACE)

3.6.4 Oyster Reef

As older oysters die, they form the foundation for the oyster reef and live oysters form a living layer atop and around the structure of older, nonliving shells. Oyster reefs form a complex ecosystem on and within their matrices and provide large surface areas for attachment by other sessile organisms such as barnacles, tunicates, mussels, sea anemones, and tube worms. (NOAA)

3.7 Fauna

The entire group of animals found in an area. (USACE)

3.7.1 Amphibians

Ectothermic, tetrapod vertebrates which occupy a wide variety of habitats. Amphibians use their skin as a secondary respiratory surface and are often ecological indicators. (American Museum of Natural History)

3.7.2 Coral

(1) (Biology) Marine coelenterates (Madreporaria), solitary or colonial, which form a hard external covering of calcium compounds or other materials. The corals which form large reefs are limited to warm, shallow waters, while those forming solitary, minute growths may be found in colder waters at great depths. (2) (Geology) The concretion of coral polyps, composed almost wholly of calcium carbonate, forming reefs and tree-like and globular masses. May also include calcareous algae and other organisms producing calcareous secretions, such as bryozoans and hydrozoans. (USACE)

3.7.3 Coral Reef

A coral-algal mound or ridge of in-place coral colonies and skeletal fragments, carbonate sand, and organically-secreted calcium carbonate. A coral reef is formed around a wave-resistant framework, usually of older coral colonies. (USACE)

3.7.4 Fish

Fishes are animals that live and swim in the water, are cold-blooded, breathe using gills, have backbones, have a scaly skin, and have various fins instead of limbs. The four (4) most common groups are jawless fishes, cartilaginous fishes, lobe-fined fishes, and ray-fined fishes. (Field Museum of Natural History)

3.7.5 Infaunal biota

The aggregate of organisms that burrow into and live in the bottom deposits, or sediments, of the ocean. Benthic animals that live in the substrate of a body of water, especially in a soft sea bottom (i.e. sandy sediments). Infauna usually construct tubes or burrows and are commonly found in deeper and subtidal waters. Clams, tubeworms, and burrowing crabs are infaunal animals. (Smithsonian Institute)

3.7.6 Mammals

Have at least three characteristics not found in other animals: three middle ear bones, hair, and the production of milk by modified sweat glands called mammary glands. Hair has several functions, including insulation, color patterning, and aiding in the sense of touch. All female mammals produce milk from their mammary glands in order to nourish newborn offspring. (Field Museum of Natural History)

3.8 Flora

The entire group of plants found in an area. (USACE)

3.8.1 Algae

Algae are photosynthetic organisms that occur in most habitats. They vary from small, singlecelled forms to complex multicellular forms, such as the giant kelps that grow to 65 meters in length. (Smithsonian Institute)

3.8.2 Sea grass

Members of marine seed plants that grow chiefly on sand or sand-mud bottom. They are most abundant in water less than 9 m deep. Common types are: Eel grass (Zostera), Turtle grass (Thallasia), and Manatee grass (Syringodium). (USACE)

3.9 Munitions and Explosives of Concerns (MEC)

This term, which distinguishes specific categories of military munitions that may pose unique explosives safety risks includes: (A) Unexploded ordnance (UXO), as defined in 10 U.S.C. 101(e)(5); (B) Discarded military munitions (DMM), as defined in 10 U.S.C. 2710(e)(2); or (C) Munitions constituents (e.g., TNT, RDX), as defined in 10 U.S.C. 2710(e)(3), present in high enough concentrations to pose an explosive hazard. (Department of Defense)

3.10 Presence of Contaminants

A variety of harmful substances, including heavy metals, oil, TBT, PCBs and pesticides, can be effectively 'locked into' the seabed sediments in ports and harbors. These contaminants can often be of historic origin and from distant sources. The dredging and disposal processes can release these contaminants into the water column, making them available to be taken up by animals and plants, with the potential to cause contamination and/or poisoning. (Jones et al., 2000)

3.11 Safety Avoidance Areas

In addition to possible unexploded munitions and cultural resources, anthropogenic hazards are also present, as pipelines and fiberoptic cables cover parts of the seafloor and should be avoided for safety reasons.

3.11.1 Cable lines

Cable lines are commonly buried in the sandy seabed. These cables are typically used for power and telecommunication.

3.11.2 Pipelines

A pipeline, also known as marine, subsea or offshore pipeline that is laid on the seabed or below it, inside a trench. Submarine pipelines are used primarily to carry oil or gas, but transportation of water is also possible. (Dean, 2010)

4 Cost and Benefits of Sediment Source

A given sediment source has a variety of costs and benefits associated with it that must be evaluated during the beach nourishment process.

4.1 Benefits

All benefits resulting from the construction of the project, including recreation, environmental, storm damage protection, beach erosion control, and shoreline stabilization, among others.

4.2 Changes in ecosystem services

The project, and associated dredging, will cause changes at the sediment source. These changes could be positive or negative. Examples include benefits to navigation, overuse of borrow area and declination of benthic communities, etc.

4.3 Construction costs

Costs associated with constructing a designed beach nourishment project, including those incurred at the sand source and beach placement site.

4.3.1 Booster pump

A dredge pump located in the discharge line between the initial dredge pump at the borrow site and discharge point. The booster pump adds head pressure (energy) to the dredge system so that maximum production can be maintained as the pipeline is extended. (Modified from USACE)

4.3.2 Demobilization cost

Costs associated with removing the dredge and all earth moving equipment from the project site at the end of the beach nourishment process.

4.3.3 Distance to sand source (centroid)

The distance, in miles, from the centroid of the beach placement site to the centroid of the sand source (borrow area).

4.3.4 Earth moving equipment

Machines, attachments, and derived machinery designed for loosening, picking-up, moving, transporting and/or distributing earth, or to grade earth and rock. Among the machines included here are tractor-dozers, loaders, backhoe-loaders, excavators, dumpers, scrapers, pipelayers, trenchers, landfill compactors, cable excavators, and rollers. (American National Standards Institute)

4.3.5 Mobilization

Costs associated with bringing the dredge and all earth moving equipment to the project site at the beginning of the beach nourishment process.

4.4 Local community opinion

During the National Environmental Protection Act (NEPA) process community members that may potentially be impacted by the project are able to express their views on a given action (dredging and placing sediment in this case) during a public forum and for the record. (U.S. Environmental Protection Agency)

4.4.1 Tribal consultation

Consultation is a process that aims to create effective collaboration between the Federal agencies and Indian tribes and to inform Federal decision-makers about potential tribal concerns with the project/nourishment process?. Consultation is built upon government-to-government exchange of information and promotes enhanced communication that emphasizes trust, respect, and shared responsibility. Communication is to be open and transparent without compromising the rights of Indian tribes or the government-to-government consultation process. (U.S. Fish and Wildlife Service)

4.5 National Environmental Policy Act (NEPA) costs

NEPA establishes the broad national framework which protects the environment. NEPA's basic policy is to assure that all branches of government give proper consideration to the environment prior to undertaking any major federal action that significantly affects the environment. During the NEPA process, an environmental assessment (EA) or environmental impact statement (EIS) will be produced with Federal agency concurrence. This process can be expensive due to data collection, data analysis, producing the documents, and the length of time of the process. (U.S. Environmental Protection Agency)

4.6 Permitting costs

Fees related to obtaining all necessary environmental and regulatory state and federal permits to conduct beach nourishment activities at a given beach placement site using a sand source (borrow area).

4.7 Practicality and cost of management measure and monitoring

After the initial construction of a beach nourishment project, both the project site and sand source are monitored to determine the pre- to post-project changes. These changes are typically physical or biological.

4.7.1 Biological monitoring

Monitoring conducted to measure the biological health within, and within the immediate surrounding vicinity, of the project area and borrow area (sand source). Methods typically include geophysical surveys (side scan sonar) and diver profiles. (Modified from Florida Department of Environmental Protection)

4.7.2 Hydrographic survey

A survey that has as its principal purpose the determination of geometric and dynamic characteristics, such as bathymetry, of bodies of water, and features within those bodies. (Modified from USACE)

4.7.3 Physical monitoring (and surveying)

Monitoring conducted to measure the physical changes due to beach nourishment within, and in the immediate surrounding vicinity, of the project area and borrow area (sand source). Methods typically include geophysical surveys (bathymetric surveys, aerial photography) and beach topographic profiles. (Modified from Florida Department of Environmental Protection)

4.7.4 Topographic survey

A survey which has, for its major purpose, the determination of the configuration (relief) of the surface of the land and the location of natural and artificial objects thereon. (USACE)

5 Best Management Practices

Best management practices (BMPs) are commonly utilized in order to better manage the sediments in the system such that sand sources are optimized. It is the goal that BMPs allow for regional sediment management, longer nourishment intervals, and better conservation of sediment resources leading to longer lasting sand sources.

5.1 Dredging technique

Dredging techniques are needed that will: 1) preserve sediment characteristics similar to pre-existing conditions for the surface substrate; and 2) avoid creation of anoxic conditions within dredge pits.

5.1.1 Rotating dredge areas

Dredging offshore sand sources, or borrow areas, in a rotating pattern, similar to a rest-rotation grazing system, in order to allow for sources to refill more effectively.

5.1.2 Selectively dredging accreting area

Employ best engineering and management practices to design the offshore sand sources, or borrow areas, such that the recently accreted portion of the feature will be dredged. This will allow the feature to remain stable and recover for future use.

5.1.3 Selectively dredging leading edge of shoal

Employ best engineering and management practices to design the inlet sand sources, or borrow areas, such that the recently accreted portion of the feature will be dredged. This will allow the feature to remain stable and recover for future use.

5.2 Projected use

Most beach nourishment projects are planned with a lifetime of 15 to 50 years. As such, the project must be designed so that the sand sources are also able to meet these needs, or additional sand sources must be found.

5.2.1 Expected frequency of future events

Equivalent to the renourishment interval, that is, the predicted time between the initial construction and subsequent maintenance projects.

5.2.2 Expected magnitude of future events

The predicted volume of sand necessary to nourish the beach in subsequent maintenance events.

5.3 Specific Management Measures

Similar to best management practices, specific management measures can be taken to increase the success of a beach nourishment project and sand source.

5.3.1 Maximize recovery from ecosystem perturbations

Increase the likelihood for recovery of the benthic communities and fisheries communities within one year of the dredging event.

5.3.2 Minimize overall dredging intensity

Decrease the amount of pressure experienced by a given sand source, or borrow area, and its benthic community by notover dredging.

5.3.3 Minimize persistent effects

Decrease the long term effects experienced by a given sand source, or borrow area, and its benthic community by not over dredging.

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A-2 Literature Review

Multi-Criteria Decision Analysis (MCDA) Applications

Linkov, I., Sahay, S., Kiker, G., Bridges, T., Seager, T.P. Multi-criteria decision analysis: framework for managing contaminated sediments. In: Levner, E., Linkov I, editors. Stategic Management of Marine Ecosystems. Amsterdam: Kluwer; 2004.

Often, environmental decision makers deal with multi-faceted problems that involve many different stakeholders that have different priorities and objectives. Such decision makers typically need to utilize multidisciplinary knowledge that combines natural, physical, and social sciences, medicine, politics, and ethics. Decision makers for environmental management projects typically receive input from four categories: modeling/monitoring results, risk analysis, cost/benefit analysis, and stakeholder preferences. However, a systemic methodology to combine these quantitative and qualitative inputs to rank project alternatives has yet to be fully developed for environmental decision making. As such, multi-criteria decision analysis (MCDA) tools can be applied to environmental decision making by quantifying value judgments based on multiple criteria, and scoring different project alternatives using a systematic analysis which overcomes the limitations of unstructured individual or group decision making, facilitating the selection of a preferred course of action.

Decision-making is essential within government and regulatory agencies. While federal agencies must consider social and political factors, the decision analysis process does not usually provide significant consideration of these issues. The U.S. Army Corps of Engineers (USACE) used the Principles and Guidelines (P&G) framework and National Economic Development (NED) benefits to choose between alternatives until 1999. After which, the USACE planning procedures were updated to combine economic development and ecosystem restoration alternatives through a multi-criteria/trade-off methodology. The U.S. Environmental Protection Agency (EPA) used a decision-making process which conformed to the EPA mission, but did not effectively encourage stakeholders to participate, integrate perspectives, learn about new alternatives, and build a consensus. Now the EPA is utilizing a Life Cycle Assessment (LCA) method and has developed the Framework for Responsible Environmental Decision-Making (FRED), which provides a foundation for linking indicator results with technical and economic factors for decision-makers when quantifying the environmental performance of competing products. The U.S. Department of Energy (DOE) has a significant number of guidance documents, systems, and processes in use to determine, manage and communicate risk, though there is there is a great need for comparative risk assessment tools, risk management decision trees, and risk communication tools which will allow site managers to better communicate with stakeholders and regulators. As such, DOE developed new guidance breaking the decision-making process into eight steps: define the problem, determine the requirements, establish project goals, identify alternative methods/products, define criteria of concern, select an appropriate decision-making tool for the situation, evaluate alternatives against criteria, and validate solution against the problem statement. There are five (5) methods for selecting among alternative in a decision-making tool: pros and cons analysis, Kepner-Trego (K-T) analysis, analytical hierarchy process, multi-attribute utility theory, and cost-benefit analysis. The European Union (EU) primarily uses environmental risk assessment, cost-benefit analysis, life cycle assessment, and multi-criteria decision analysis as the primary analytical tool to support environmental decision-making.

MCDA has been applied in the management of contaminated sediments, and other related areas, such as fishery management, remediation, optimization of water resources, and management of other resources. A straw man application of MCDA for sediment management utilizes a three-tiered framework, consisting of bringing together the right people, describing the process in the center of the overall decision process, and then picking the right tools to utilize in the decision-making process. However, typically when utilizing MCDA with complex environmental decision-making, there will be trade-offs between divergent criteria. By utilizing and integrating MCDA principles and tools with existing decision-making approaches, including risk and cost/benefit analysis, decisions makers will be able to make more effective, efficient, and credible decisions, especially in the environmental realm.

Critto, A., Cantarella, L., Carlon, C., Giove, S., Petrzzelli, G., & Marcomini, A. (2006). Decision support-oriented selection of remediation technologies to rehabilitate contaminated sites. Integrated Environmental Assessment and Management, 2,273-285.

MCDA was used to rank remediation technologies for the rehabilitation of contaminated sites and was applied to a case study in Porto Marghere, Italy. Critto et al., 2006 presented a method which selects a set of technologies from a pool based on applicability to site-specific conditions, then ranks the selected technologies using MCDA. Six macrocriteria were identified with additional evaluative criteria identified from literature review, which were applied to nine alternatives. Costs applied to the case study were also obtained from reviewing other case studies. Weights were estimated using Saaty numerical scale/DESYRE system. MCDA was chosen due to a clear and reproducible procedure, in addition to the ability to include expert analyses. The results indicated that the MCDA methodology reasonably selected remediation technologies based on technical features and the requirements of available technologies. Additionally, environmental conditions of concern at the site were also taken into consideration, along with remediation objectives and chemical contamination levels.

Linkov, I., Satterstrom, F. K., Kiker, G., Batchelor, C., Bridges, T., & Ferguson, E. (2006). From comparative risk assessment to multi-criteria decision analysis and adaptive management: Recent developments and applications. Environment International, 32(8), 1072-1093.

Linkov et al., 2006 reviews some of the more commonly used comparative risk assessment (CRA) and MCDA approaches in environmental policy and decision making - and builds on the concepts presented in Linkov et al., 2004. Multi-attribute utility theory (MAUT), analytical hierarchy process (AHP), and outranking tools were the MCDA methodologies focused on for remediation of contaminated sediments and aquatic ecosystems, reduction of contaminants, allocation of water and coastal resources, and management of other resources. MAUT relies on development of utility functions that describe the benefit obtained from each increment of each decision criterion. AHP uses a series of pairwise comparisons of importance among all of the criteria, Outranking methods directly rank alternatives by assessing if there is enough information to say that one is better then, or at least as good as, another. By application of the previously mentioned MCDA methods and tools, adaptive management strategies may be applied to environmental decision making, specifically in situations where management objects are regularly revisited and accordingly revised. Adaptive management utilizing MCDA allows the user to create a model of the system being managed, a range of management choices, monitoring and evaluation of the possible outcomes, a mechanism for incorporating lessons learned into future decisions, and a collaborative structure for stakeholder participation and learning. Regulatory agencies, such as NOAA, DOE, DOI, and the EPA, among others, are already utilizing MCDA and adaptive management strategies. Further, Linkov et al., 2006 applied a combined MCDA/adaptive management approach to a case study with data derived from MCDA done by Kiker and Bridges on a New York/New Jersey Harbor, showing that overall rankings may change based on various criteria weights and user inputs. Adaptive management is recommended as an overall planning and procedural framework, and is recommended to make structured, logical decisions concerning management options.

Linkov, I., Satterstrom, F. K., Yatsalo, B., Tkachuk, A., Kiker, G. A., Kim, J., Bridges, T.S., Seager, T.P, Gardner, K. (2007). Comparative assessment of several multi-criteria decision analysis tools for management of contaminated sediments. In Environmental security in harbors and coastal areas (pp. 195-215). Springer Netherlands.

MCDA is typically utilized for problems of soring alternatives into various groups, or categories, and screening alternatives. The tools within MCDA allow for the ranking of alternatives, selecting the “best alternative” from a given set of alternatives, and designing a new action or alternative to meet project goals. Additionally, there are two primary schools within the MCDA methods: value functions and outranking. Value function methodologies include multiattribute value theory (MAVT), multiattribute utility theory (MAUT), simple multi-attribute rating technique (SMART), preference rations in multiattribute evaluation (PRIME), preference assessment by imprecise ratio statements (PAIRS), and simple PAIRS (SPAIRS). Outranking methods use a comparison of alternatives, and utilize the elimination and choice expressing reality (ELECTRE) and preference ranking organization method for enrichment evaluations (PROMETHEE) methods. Linkov et al., 2007 utilized three different MCDA methods (MAVT, outranking, and AHP) on two case studies (Cocheco river and NY/NJ Harbor; alternatives of wetland restoration, cement manufacturing, upland brownfield disposal, and cement stabilization) and the resulting selection of sediment management alternatives were compared. PROMETHEE, AHP, SMART, PRIME, SWING methodologies were used. A comparative analysis of results based on different methods demonstrates similar ranking orders for alternatives with the 2 case studies considered.

Bates, M.E., Sparrevik, M., Lichy, N., & Linkov, I. (2014). The value of information for managing contaminated sediments. Environmental Science and Technology, 48, 9478-9485.

Value of Information (VOI) prioritizes research to inform selection of sediment capping strategy in Greenland fjord system. The study assesses three weighting schemes based on three utility functions—a cost reduction focused weighting scheme, an environmental benefits scheme, and a balanced objectives weighting scheme—in order to demonstrate the difference in rankings that might be obtained by decision makers with different priorities . PROMETHEE II outranking MCDA with Monte Carlo ran and compares decision confidence across scenarios with differing degrees of remaining uncertainty. Value of Information analysis extends this assessment to consider how likely any given alternative is likely to change in frequency as the top ranked alternative if the uncertainty associated with each criterion could be eliminated. Such work is used to identify scientific research priorities and guide investment decisions.

Collier, Z.A., Bates, M.E., Wood, M.D., Linkov, I. (2014). Stakeholder engagement in dredged material management decisions. Science of the Total Environment, 496,248-256.

MCDA implemented in a multi-stakeholder setting in order to generate recommendations on dredged material place for Long Island Sound's Dredged Material Management Plan. A multi-criteria model was built by incorporating various stakeholder organizations. Resulting model included several alternatives, criteria, and sub-criteria relevant to stakeholder interests and preferences. The work demonstrated that through guided workshops, seeming intractable conflicts among stakeholders can be overcome as participants focus on and agree to the criteria that are important to making the decision about sediment management courses of action rather trying to directly discuss the alternative courses of action themselves. If stakeholder can collaboratively develop the decision making process, then the outcome should be acceptable to all. The decision criteria selected were environmental media (aquatic, terrestrial, air), ecological receptors (birds, fish, shellfish, benthic, mammals, plants, other), human welfare (health and social impacts), and economic (short term and long term impacts).

Manap, N., Voulvoulis, N. (2014). Risk-based decision-making framework for the selection of sediment dredging option. Science of the Total Environment, 496, 607–623. doi:10.1016/j.scitotenv.2014.07.009

Manap and Voulvoulis, 2014 develops a decision-making framework to identify the best sediment dredging option, using case studies in Malaysia. Options were based on four dredging aspects: environmental, socio-economical, managerial, and technical. MCDA methods were utilized in order to select a dredging method which would reduce the impacts of dredging and lower the cost of environmental quality analysis and management. This methodology helps decision makes look at dredging from an integrated and holistic point of view, which may lead to more sustainable practices. This study recommends a three stage framework for dredging companies: screening, prioritizing areas of dredging based on contamination or the concern for further investigation, and meeting with stakeholders to select the best dredging option that balances economic, environmental, and technical aspects.

Jiang, Y. X., Liu, Y. S., Ying, G. G., Wang, H. W., Liang, Y. Q., & Chen, X. W. (2015). A new tool for assessing sediment quality based on the Weight of Evidence approach and grey TOPSIS. Science of the Total Environment, 537, 369-376.

Developed a sediment quality assessment tool using grey TOPSIS (a mathematical calculation of MCDA) and Weight of Evidence (WOE). Weight of Evidence is a weighted sum approach to aggregation of data to estimate a value when only relevant, but not perfectly applicable, information is available. Examples include studies done at different times, in different location, with slightly different methods, or related target subjects. TOPCIS and WOE were applied here to a case study of the sediment of Donjiang River Basin (20 different sites). Three lines of evidence with accompanying metrics were used to assess sites.

Rosén, L., Back, P. E., Söderqvist, T., Norrman, J., Brinkhoff, P., Norberg, T., ... & Döberl, G. (2015). SCORE: A novel multi-criteria decision analysis approach to assessing the sustainability of contaminated land remediation. Science of the Total Environment, 511, 621-638.

The SCORE MCDA-method was developed to provide transparent assessment of sustainability of possible remediation alternatives for contaminated sites. Key criteria fell under economic, environmental, and social sustainability domains and were based on literature, interviews, and focus group meetings. It was applied to a case study at the Hexion site in Gothenburg area, Sweden. Four remediation alternatives were identified and were scored on the 18 key criteria proposed in the SCORE model. Weights were based on expert opinions and stakeholder interviews and three scenarios were considered to illustrate differing preferences. 10,000 Monte Carlo simulations were run to assess the variability in outcomes. SCORE framework is designed to be flexible and transparent, making it possible to account for alt and upcoming perspectives on sustainability.

Existing Technical Issues and Solutions

Environmental Impacts

Benthos Effects

Kenny, A.J., Rees, H.L. 1994. The Effects of Marine Gravel Extraction on the Macrobenthos: Early Post-dredging Recolonization. Marine Pollution Bulletin: 28 (7), 442-447.

Approximately 70% of an area of sea bed, totaling 50,000 t, was removed to a depth of approximately 0.3m by a suction-trailer dredge off the English east coast. Post survey inspections showed the drag head had left tracks, and when those tracks crossed the sea bed was lowered by up to 2 m, and contained a layer of sand ripples 1-2 cm thick. Five sediment samples were collected from a treatment (dredge) and reference site before and after dredging; sediment analyses and benthic assemblage counts were performed on each sample. The results showed that the percent gravel at the dredge site increased from 30% pre-dredge to 50% post-dredge (March to May, respectively), while the reference site remained the same at 36%. Furthermore, the number of benthic species remained constant at the reference site (35), but decreased from 38 to 13 at the dredge site. Seven months after dredging, some recolonization had occurred, as the number of species had increased from 13 to 26.

Kenny, A.J., Rees, H.L. 1996. The Effects of Marine Gravel Extraction on the Macrobenthos: Effects 2 Years Post-Dredging. Marine Pollution Bulletin: 32 (8/9), 615-622.

Kenny and Rees, 1996 provides an update to the project presented in Kenny and Rees, 1994. Further analysis was conducted on the sand ripples within the dredge tracks, and underwater video showed that the ripples changed direction with the prevailing tidal direction. ADCP data and underwater cameras showed a significant amount of sediment transport occurred within the region post-dredging. Within 2 years, the dredge tracks, which were up to 2 m deep, had infilled and were only slightly apparent as features using side-scan sonar. Additionally, the reference site has maintained the pre-dredge sediment distribution (fine sand), and the dredge site has shown an increase in coarse sediment and gravel. From seven months to two years post dredge the benthic assemblage increased from 26 to 30, indicating the rarer benthic species have still not returned post-dredge. The reference site has maintained the same number of benthic species as pre-dredge conditions.

Colosio, F., Abbiati, M., Airoldi, L. 2007. Effects of beach nourishment on sediments and benthic assemblages. Marine Pollution Bulletin. 54, 1197-1206.

Beach nourishment was carried in 2002 by placing 800.000 m^3 out along 8 different shorelines totaling 50 km of coastline along the Emilia Romagna Region located along the North Adriatic Sea in Italy. Of these, 3 shores had offshore breakwaters, 2 contained groins, and 2 did not contained any hard shore protection structures. The sand source sediments were relict sands, and were classified as a fine sand with trace organics. Five sets of 15 samples were collected at 9 shores 1 year after sand placement: 3 nourished, 3 nourished with breakwaters, and 3 non-nourished (reference) sites. The samples underwent grain size analysis and benthic assemblage counts. The results indicated that while the percent sand/silt/clay were similar for each placement site, the nourished shore now had sand coarser than the non-nourished beach and the shore with a nourished beach and a breakwater has finer sand than the non-nourished beach. Furthermore, the benthic assemblage for the nourished shore is significantly lower than the non-nourished beach, and while the number of species is similar between the nourished beach protected by the breakwater, it contains benthic species which are typical of marshes/lagoons and prefer finer grained sediments.

Waye-Barker, G.A., McIlwaine, P., Lozach, S., Cooper, K.M. 2015. The effects of marine sand and gravel extraction on the sediment composition and macrofaunal community of a commercial dredging site (15years post-dredging). Marine Pollution Bulletin: 99, 207-215.

The study site is offshore Felixstowe, southeast England, has water depths of approximately 27-35 m Lowest Astronomical Tide, a maximum tidal velocity of 1.17 m/s, and covers and area of 0.3 km^2. Between 1971 and 1996, 10.2 million tonnes of sand and gravel were extracted from the license boundary of Area 222. As Environmental Impact Assessments (EIAs) were not required in 1971 when the site was licensed, the site was subject to screening processes to obtain necessary sand:gravel ratios. Samples were collected in 2011 from two reference sites outside the license boundary, and two sites (high and low intensity) within the license boundary. The samples underwent sediment analysis, benthic assemblage counts, and the data was analyzed using statistics. The results indicated that 15 years after the cessation of dredging, there was a significant amount of recovery in both the sediment and macrofaunal composition within the area of high dredging intensity. Further, the physical nature of the seafloor of Area 222 has become similar to that prior to dredging. As one of only a few studies of this kind, it reinforces that biological recovery takes longer for longer periods of physical disturbance. By comparison, the low intensity dredging site within Area 222 recovered within half the time of the high intensity dredging site.

Fish and Coral Effects

Bak. R.P.M. 1978. Lethal and Sublethal Effects of Dredging on Reef Corals. Marine Pollution Bulletin: 9 (1), 14-16.

A study on coral growth on the southwest coast of Curacao was interrupted when a channel was dredged through Piscadera Bay. The growth study was conducted 700 m northwest of the dredging site on a fringing reef. Prior to dredging, light conditions were measured at coral communities in 12-13 m water depth. In the days following the commencement of dredging, the water contained a high number of suspended sediments, and the surface waters contained less than 1% illumination. Within the first week, the reef, except the corals, was covered in approximately 1 cm of sediment. Plating colonies at depths of 15-25 m were unable to reject sediment and died. Water conditions improved during the second week of dredging, as the currents changed and pushed the suspended sediments away from the reef. However, it was shown that the dredging may influence coral growth rates by decreasing light values, causing energy consuming sediment rejection, and the effect of the sediment on the food supply of the corals.

Lindeman, K.C., Snyder, D.B. 1999. Nearshore hardbottom fishes of southeast Florida and effects of habitat burial caused by dredging. Fishery Bulletin: 97, 508-525.

This study quantified nearshore hardbottom fish assemblages on the southeast Florida coast over a 27 month period; one hardbottom habitat site was buried from a beach restoration project 12 months into the study. The spatial and temporal attributes of fish assemblages of 3 hardbottom sites were characterized, abundances of different life stages were compared, and the effects of dredge burial on the numbers of individuals and species were compared with a control site. The results showed that 36 families of fishes were seen among the 3 hardbottom sites; 86 taxa and 10,491 individuals were seen at all sites. At all sites, juveniles were the most abundant life stage among the top 10 species; 8 of the 10 most abundant taxa by site were represented by early life stages. Prior to habitat burial, all sites had were similar in both species composition and relative abundance; beach nourishment ended in April 2015 and surveys through May 1996 reported no exposed hardbottom or fishes within the site. This suggests that most adult fishes live further offshore and primarily younger life stage fishes live nearshore and are subject to effects from habitat burial from beach nourishment. It is suggested that the current lack of information on the short- and long-term effects of nearshore burial be further studies, especially with the implications of anthropogenic effects in south Florida.

Other Biological Effects

Goldberg, W. M. 1989. Biological effects of beach restoration in south Florida: The good, the bad and the ugly. In: LS Tait (ed.) Beach Preservation Technology: Problems and Advancements in Beach Nourishment. Florida Shore and Beach. 19-27.

Southeast Florida is known for its tourism and beautiful beaches, which started being nourished as early as 1970. However, there are two ways for beach nourishments to have biological impacts: at the offshore borrow area and at the beach placement site. Placing sand on the beach can result in compaction, burial, and resuspension. Offshore at the sand source, biological impacts can include mechanical damage, sediment loading, and turbidity. While some projects turned out well (Delray Beach, 1984), others resulted in silt being deposited on nearshore hardbottom coral reef communities (Hallandale Beach, 1971 and Miami Beach, 1977-1982). The results of these projects suggested attention be paid to the dredge type, distance from the borrow site to hardbottom, size of the mixing zone for turbidity, and standardizing biological monitoring data.

Peterson, C.H., Bishop, M.J. 2005. Assessing the Environmental Impacts of Beach Nourishment. BioScience: 55 (10), 887-896.

Beach sand is a complex, productive, and unique habitat which supports nesting sea turtles, shorebirds, invertebrates, and feeds a variety of fish, among other roles. Data on fish, macroinvertebrates, and shorebirds was collected from literature, unpublished studies, and field collection. Statistical analyses showed that most studies (84%) overlook formal statistical analysis of how a physical change could cause a biological response. Furthermore, 73% of the studies misinterpreted at least some results, 22% included attempts to interpret biological responses to physical processes, and 56% lacked support from evidence and analysis. The study suggests reviewing biological monitoring guidelines, better funding of process-oriented science, and stricter state and federal permitting restrictions, among others.

Turtle Effects

Crain, D.A., Bolten, A.B., Bjorndall, K.A. 1995. Effects of Beach Nourishment on Sea Turtles: Review and Research Initiatives. Restoration Ecology: 3 (2), 95-104.

Beach nourishment has the potential to change some of the physical characteristics required for nesting sea turtles. Characteristics of beach sand that influence turtle nesting include sand grain size, grain shape, silt/clay content, sand color, compaction, moisture content, composition, and other factors. Compaction is a problem caused by beach nourishment, but does not occur on every project. Increased compaction on beaches may leased to decreased turtle nesting success by preventing a female from being able to excavate a nest. Additionally, escarpments can prohibit a turtle from nesting and nourished beaches typically have shallower nests. All aspects of the sand to be obtained from the borrow source can potentially impact the turtle eggs in the nest during development. It is suggested that biological and physical parameters be addressed concenring the effects of nourishment on sea turtles. Furthermore, 11 recommendations are provided for engineers and biologists: stop conceptualizing nourishment as a single entity, utilize standard methods and incorporate necessary comparisons when assessing biological effects of nourishment, determine the natural variation in beach compaction and water potential and relate the values to sea turtle nesting success, test effect of tilling on compaction and nesting and hatching success, determine the effects of aragonite sand on sex of hatchlings, determine effects of toxins on embryos and survival, determine nutrient and mineral requirements of eggshell, determine how nourishment effects nest architecture, determine effects of nourishment on predation, determine effects of nourishment on imprinting, and publish findings of studies.

Brock, K.A., Reece, J.S., Ehrhart, L.M. 2009. The Effects of Artifical Beach Nourishment on Marine Turtles: Differences between Loggerhead and Green Turtles. Restoration Ecology: 17 (2), 297-307.

Sea turtle nesting success is typically directly related to the stability and quality of the nesting environment. Loggerhead and green sea turtle species prefer steeply sloped beach, moderate- to high-energy beaches, with a shallow sloped offshore, providing the conditions to dig a deep nest cavity above the mean high water line. Three measures of nesting success were described: hatching success, emerging success, and reproductive output. It was hypothesized that a single beach nourishment event would not have a significant impact on nesting success. Other studies have shown that the first nesting season post nourishment is significantly below average, with a return to average levels during the second or third post nesting season post nourishment. This study also showed a decreased number of nests on nourished beaches compared to nourished beaches during the first nesting season post nourishment, though there was less of a decrease for green sea turtles. However, reproductive success is not altered by the nourishment processes. Total reproductive output is shown to be a better estimate of positive project effects. It was suggested that as Loggerheads like to nest closer to the water, those nests are more at risk during beach equilibrium post nourishment.

Physical Impacts

Sedimentation Effects

Hitchcock, D.R., Bell, S. 2004. Physical Impacts of Marine Aggregate Dredging on Seabed Resources in Coastal Deposits: 20 (1), 101-114.

In the United Kingdom, marine aggregate mining is a vital part of the economy, with approximately 23 million tonnes of sand and gravel aggregate coming from an area of licensed seabed just 179 km^2 in 2000. Field investigations showed that the effects dredging were limited in proximity to within a few hundred meters of the active zone. The granulometry of the collected sediments show the area is comprised of >50-60% gravel, though some samples are primarily sand or show an increase in silt. Data suggests that dredging created a near bed turbidity plume approximately 2-4 m thick, extending 4.5 km beyond the dredge site. ADCP data within the dredge license boundary has confirmed the presence of a near bed turbidity plume. Additionally, the seabed morphology has been changed and dredge pits up to 4 m thick have been created as a result of aggregate dredging. However, overall the physical resources appear to be largely unaffected unless directly affected from dredging. Further, benthic biological resources appear to be able to cope with the stresses induced by minor changes in sediment type.

Appendix B. Task 2 Deliverables

B-1 Planning Meeting Agenda

Development of a Multi-Decision Criteria Analysis (MCDA) Tool to Optimize the Long-Term Use of OCS Sand Borrow Areas

10–11 May 2016

Location:

Sam Nunn Atlanta Federal Center
61 Forstyth Street, SW
Atlanta , Georgia 30303
Social Security Administration (SSA) 20th Floor Conference Room

10 May	Task Description	Speaker/Discussion Lead
8:30-8:45	Project overview Description of the Need for Sand Resource Optimization Role of the MCDA tool	Paul Knorr
8:45-9:15	Participant and team member introductions	Mary Cialone
9:15-10:00	Group discussion of user perspectives and experience as they relate to this project & tool Understanding universal versus site-specific parameters Additional items in the factor dictionary	Cate Fox-Lent Jennifer Coor
10:00-10:45	Introduction of MCDA methods Discussion of their usefulness, application, & limitations	Matthew Bates Cate Fox-Lent
10:45-11:00	Break	
11:00-11:15	Group discussion: Q&A: application of MCDA techniques for optimizing use of sand resources	Matthew Bates Cate Fox-Lent
11:15-12:15	Development of sand resource management best practices list (facilitated group discussion)	Cate Fox-Lent Jennifer Coor Matthew Bates
12:15-13:30	Lunch	
13:30-14:15	Draft criteria hierarchy Draft MCDA tool inputs and outputs, mockup, similar examples	Cate Fox-Lent Matthew Bates Jennifer Coor

14:15-17:00	Group discussion of criteria and metrics relevant to optimizing the use of sand resources (interactive)	Matthew Bates Cate Fox-Lent

* All of these discussions should remain focused within the scope and intended use-case of the tool.
I.e., "Could this lead to any difference in interpretation of the suitability of various sub-regions?"

11 May	**Task Description**	**Speaker/Discussion Lead**
8:30-9:15	Review value functions and their purpose Group discussion about value functions	Matthew Bates Cate Fox-Lent
9:15-10:00	Exercise: specifying value functions (or continued group discussion if it seems like consensus is emerging there)	Cate Fox-Lent (small group discussions)
10:00-10:15	Break	
10:15-11:00	Review of weights and their purpose; presentation of the weighting process; group discussion (e.g., of potential weights)	Matthew Bates Cate Fox-Lent
11:00-11:45	Exercise: weighting criteria (individually)	Cate Fox-Lent (individual exercises)
11:45-12:00	Project timeline, deliverables, and next steps	Mary Cialone
12:00-12:30	Wrap-up/Closing Remarks	Paul Knorr

* All of these discussions should remain focused within the scope and intended use-case of the tool.
I.e., "Could this lead to any difference in interpretation of the suitability of various sub-regions?"

B-2 Planning Meeting Handouts

Multi-Criteria Decision Analysis (MCDA) tool

USACE MCDA tool developers want to share their thoughts and get your feedback on what the tool is envisioned as doing and how the stakeholder meeting will support that. Some details are summarized below.

***Thoughts on the tool's primary contributions:**

- We see primary the value of the tool in helping project managers make more sustainable decisions about borrow area management.

- We see the insights/recommendations from the tool as complementary to (rather than redundant of) the detailed processes the Corps already has in place for technical engineering on an individual project basis.

- The tool, as we currently envision it, will help users develop a big-picture, regional understanding of how well balanced expected OCS sand resource demands are with expected borrow area sand availability in the long term (e.g., over a several-decade time horizon). Furthermore, it will help users estimate, based on factors like sand characteristics, distance, environmental concerns, cost, etc., which OCS resources are likely to be in greatest and least demand over that period.

- By looking across many individual projects, the tool's outputs will be less technically detailed for any particular project but will be able to provide additional long-term and regional insights across all projects (insights that may not currently exist in the Corps' or other entities' planning processes).

***Thoughts on the tool's inputs, outputs, & operations:**

- The tool will draw from user inputs about expected demand for sand throughout the region and over the long term (e.g., a planning horizon of several decades. Including estimates for Federal, State, & Local, etc. demand, as much as is possible).

- The tool will draw from default or user supplied data about expected sand availability at borrow areas in the region.

- The tool's decision model will incorporate criteria from the draft factor dictionary and identified at the stakeholder meeting.

- The tool will ask the user to score different sand use areas (e.g., beaches) and borrow areas with respect to different criteria. For example, by asking questions about the physical composition of sand available or needed, the distance between sites, whether or not certain environmental considerations exist for those sites, etc.

- Based on consideration of all of these details, the tool will estimate the expected demand for each OCS sand resource.

- Most importantly, the tool will identify which borrow areas are likely to have greater demand than availability, thus requiring projects to share their use or supplement their use with 'less suitable' sand from other sources.

- Because the tool is looking at evaluating supply and demand over the longer term, it can be used to identify which projects will probably need to share the most and the least, but will not be detailed enough to justifiably say that project X vs. Y & Z needs to use an alternative (e.g., 'inferior') borrow area in year 10 vs. 5 or 30.

- Even so, the tool's outputs will still provide many useful insights to project managers to help them make sustainable use decisions in each year on a project-by-project basis, in light of what else they now know is expected in their region.

- Either as part of the tool or in an accompanying document, we will provide a list of good practices for sustainable management of shared OCS sand resources. (This will provide helpful suggestions for project planners as they move into formulating their detailed project specs.)

***At the stakeholder meeting, we plan to seek input from the broader beach nourishment community to:**

- Provide suggestions for the list of good practices for managing shared OCS sand resources.

- Develop a list of criteria relevant for estimating the expected demand for a resource and matching expended demand to available supply. This will build from relevant criteria identified in the draft factor dictionary, will add new factors that the stakeholder group identifies, and will structure and group factors into similar themes (e.g., physical characteristics, environmental concerns, cost-related concerns, etc.).

- Identify specific measurable, score-able, or estimate-able metrics for each criterion, so that the criteria can be treated consistently in our quantitative spreadsheet tool. (This moves beyond describing criteria names.)

- Weight the relative importance of the different criteria in the context of our use case.

- Develop normalizing value functions that identify which input values represent a lot & a little (or good & bad, desirable & undesirable) scores for each metric. (These value functions are what will enable the transform raw scores into utility/suitability scores).

- (In the tool, we can provide regional templates with many of these values pre-populated, but the underlying details will be editable by the user to ensure that the tool can remain useful for other regions and as details change.)

- (We hope to get through all of these topics at the stakeholder meeting, but we are prepared to follow up with the group afterwards by phone and email, if necessary, to get what we need to finish the tool's decision model.)

B-3 Planning Meeting Summary

The Sand Source Management: MCDA Planning Meeting was held on 10–11 May, 2016, in Atlanta, Georgia. Participants included in-person representatives from BOEM, USACE, ERDC, Jacksonville, Mobile, Philadelphia, and New England Districts, as well as from Humiston & Moore Engineers, Mississippi State University, CB&I, Applied Technology Management, and Coastal Protection & Restoration Authority of Louisiana. Additional participants from BOEM, USACE, academia, state regulatory agencies, and private firms participated via the webinar. Dr. Paul Knorr of BOEM—and Contracting Officer's Representative (COR) of the project—presented the major issues challenging the management of OCS resources. The MCDA approach was previously determined in the Interagency Agreement (IA) to be the technical approach for this project. Matthew Bates of the USACE ERDC presented an introduction to the MCDA process and case studies that utilize the approach for other sediment management applications.

The objective of the MCDA tool development was identified as determining the suitability of a sub-region within a shoal or other sediment source for use as placement material in a project area. A draft criteria tree was presented for discussion, feedback, and revision. The initial version included four top-level criteria: Sediment Match to Project, Borrow Site Access, Environmental Concerns, and Future Site Usability (Figure 1), with a number of sub-criteria for each.

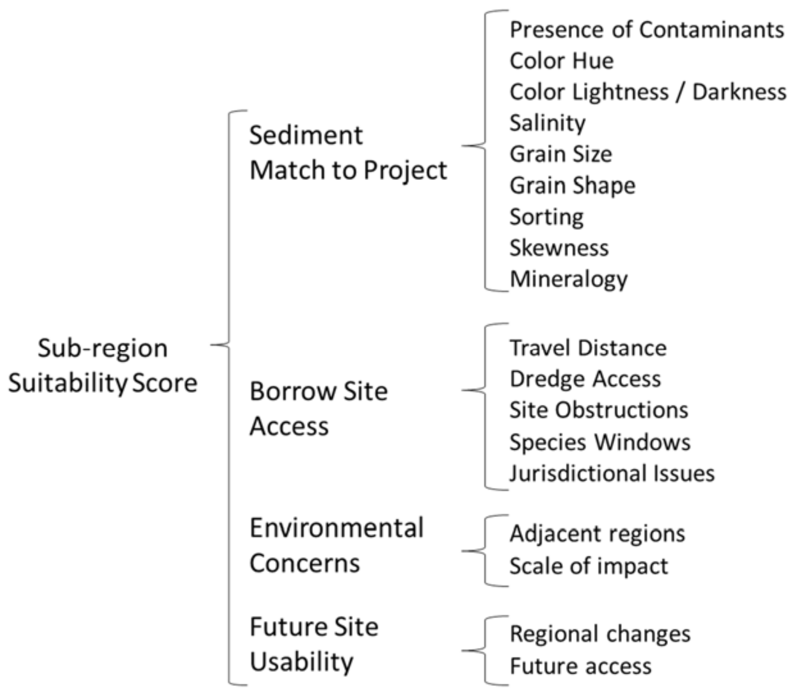


Figure 3. Initial criteria tree draft.

USACE ERDC team members developed the draft criteria tree based on initial discussions with BOEM's Paul Knorr and members of the USACE Jacksonville District. The meeting participants were guided through a structured discussion to assess and validate the proposed framework. The issues to consider were 1) whether the existing tree captured all of the relevant decision factors, 2) if the assessment of each criterion will differ among sub-regions of the sediment source, and 3) how each criterion could be measured or described.

Through the 1.5-day meeting presentation, discussions, and response sessions, the criteria tree was revised (Figure 2).

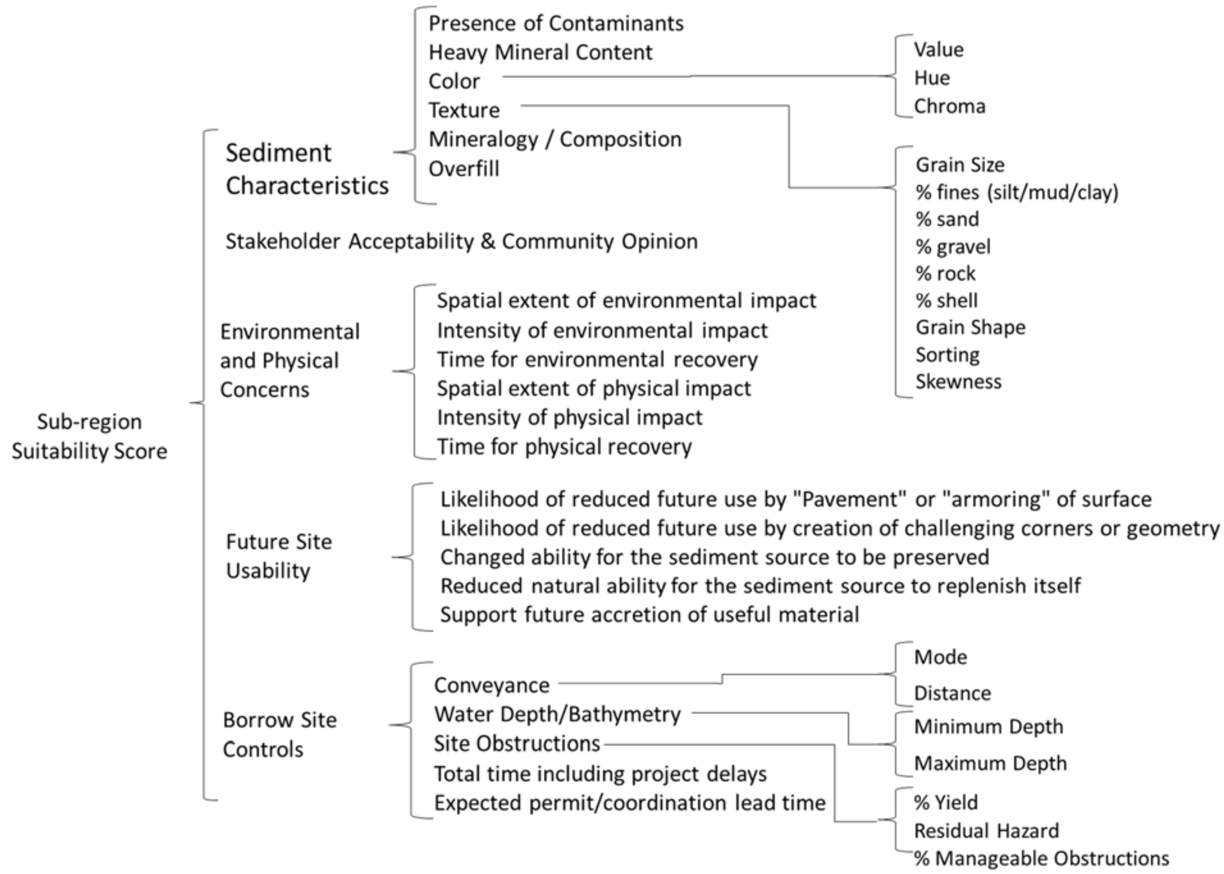


Figure 4. Updated criteria tree resulting from planning meeting.

The “Sediment Match to Project” was renamed “Sediment Characteristics,” and the project engineers and geologists in the group provided revisions to the list of relevant criteria, terminology, and metrics typically used to assess sediment characteristics. “Borrow Site Access” was revised to “Borrow Site Controls” as it was determined that the issues of concern are the controls on cost, time, and effort of accessing a site, rather than whether access is possible or not. The group concluded that rather than describe the specifics of all possible jurisdictional, permitting, and dredging windows within the tool, users could estimate the total lead time and delays based on the conditions of a specific project or location. Additionally, the group determined that Site Obstructions could be considered as a combination of Manageable Obstructions (such as old pipelines that could be removed, or challenging dredging boundaries and geometries) and Residual Hazards, which are those about which nothing can be done (such as archaeological sites). The “Environmental Concerns” criterion was expanded to include “Physical Concerns” as well. Although many of the experienced project managers, both federal and private, were uncertain if and how the spatial extent and intensity of such impacts could be determined ahead of time, discussions with researchers in the ERDC Environmental Lab suggest that there are heuristics that can be used to estimate such impacts and that the category is important to long-term resource sustainability and should not be excluded simply because it is challenging to measure. The sub-criteria for “Future Site Usability” were expanded to explicitly list the major issues for future use based on experience of the participants. Finally, “Stakeholder Acceptability & Community Opinion” was added as a top-level criterion to be assessed qualitatively by the project team based on communication and feedback during the project development and public outreach.

During the final part of the meeting, participants were introduced to the process of developing a weighting scheme for an MCDA. It was decided that the weights for most criteria would be project specific and will need to be calculated at the point of use for the tool; however, the relative weights within the “Sediment Characteristics” criterion should largely be based on engineering principles and professional experience and therefore can be built into the tool. Within a week after the meeting, participants received a link to an online questionnaire asking them to respond to a set of questions about weighting the Sediment Characteristics sub-criteria. Results of the questionnaires and follow-up conversations with coastal scientists in the ERDC were used to complete the tool development over the next few months.

Appendix C. Task 3 Deliverables

C-1 SSST Reference Manual

Sand Source Selection Tool

Reference Manual

Background

The Sand Source Selection Tool (SSST), available on the BOEM Marine Minerals Program website, was develop to aid project planners in ranking alternative sand sources based on suitability for use at the placement site, but also considering impediments to efficient dredging, potential environmental impacts, and long term sustainability of site use. The tool is intended for use in early stages of site selection in order to prioritize the options to consider for further feasibility study.

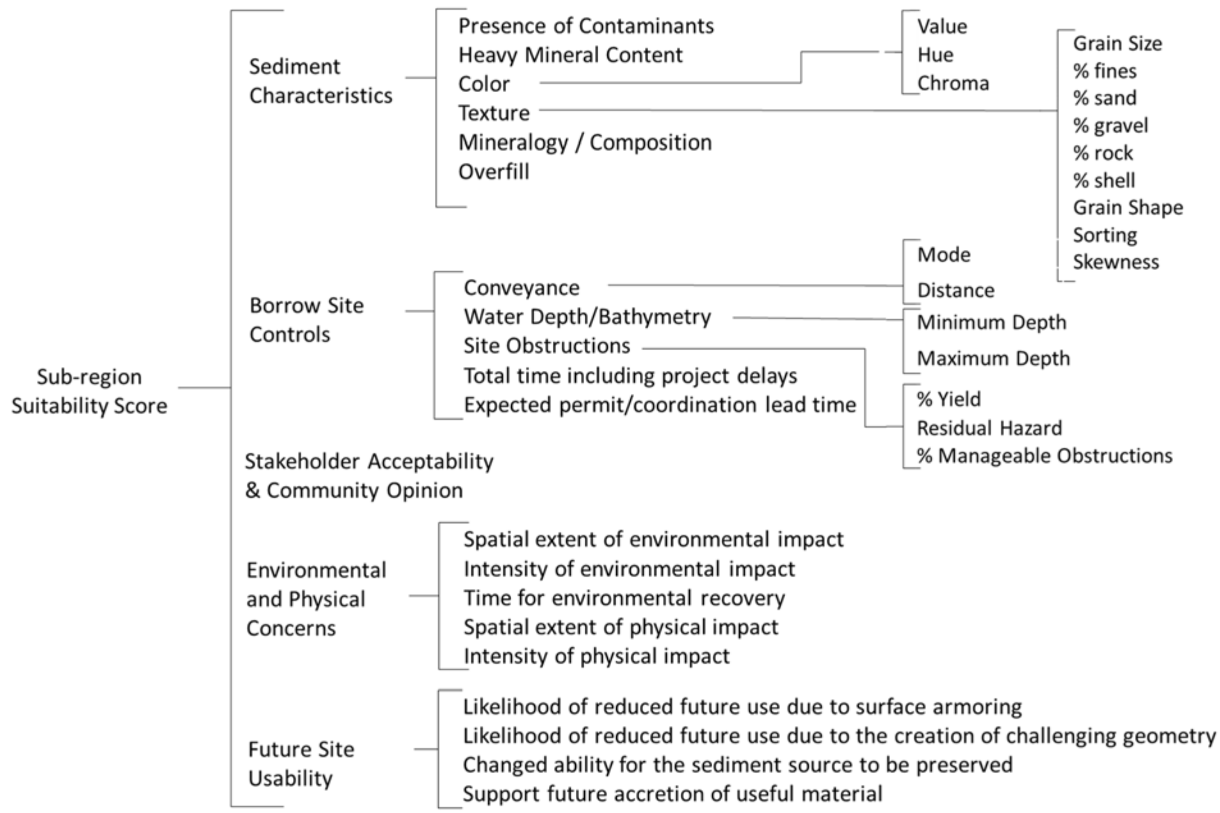
The tool implements a multi-criteria decision analysis (MCDA) approach to perform this assessment and ranking. MCDA is a method aimed at supporting decision makers faced with making decisions that are characterized by uncertainty and possibly conflicting objectives. MCDA methods allow decision-makers to address their problems by evaluating, rating, and comparing different alternatives, based on multiple criteria, combining both qualitative and quantitative data and information sources. MCDA aims to provide decision-makers with clarity as to the nature of the trade-offs inherent in their decision problems, through an iterative and transparent process. MCDA methods are rooted in risk and decision science, providing a systematic and analytical approach for integrating possibly disparate sources of information, together with an understanding of uncertainty and risk preferences, enabling the coherent evaluation and ranking of project alternatives.

MCDA generally consists of the following summary steps:
1. Creating a hierarchy of objectives and criteria relevant to the decision at hand;
2. Weighting the relative importance of each objective and criterion;
3. Scoring how well each alternative performs on each criterion;
4. Combining scores across criteria to produce an aggregate score for each alternative being evaluated.

Because the ultimate decision-making process is subjective and involves numerous stakeholders within the Federal and state governments, industry, and other parties, and because tradeoffs between various difficult-to-compare decision criteria are necessary, the MCDA methodology adds structure and transparency to the process. The method allows both qualitative and quantitative data to be aggregated together. Rather than force the user to collect costly data, this approach provides the opportunity to do an early stage screening-level assessment using professional experience and judgement when some data is not yet available. MCDA is a reasonable compromise tool that allows integration of technical and historical data with stakeholder value judgments. MCDA allows us to understand overall stakeholder view points and identify areas of potential compromise.

Selection Criteria

The objective is to determine suitability of each alternative sand source site for use in the proposed project. A group of experts from the Bureau of Ocean Energy Management, US Army Corps of Engineers, academia and industry were convened to develop a set of criteria on which to assess the alternatives. Five top level criteria (sediment characteristics, borrow site controls, stakeholder acceptability, environmental/physical concerns, and future site usability) were identified, with several sub-criteria for each criterion. The full criteria hierarchy is shown below.



Sand Source Selection Tool

The SSST consists of eight tabs: two informational, **5 tabs that require data input**, and a tab displaying results. The end goal when utilizing the Sand Source Selection Tool is to determine a total utility score for each alternative option, which will then be used to quantitatively compare options. The following pages describe what information is required input on each tab and provides information about how to develop value functions, score, and weights. The best practice is to move through the tabs sequentially: Alternatives→Criteria→Value Functions→Alternative Scores→Weights→Results. On each tab, the yellow-highlighted cells require the user to make a selection or input information.

Alternatives Tab

The first step is for borrow site information to be entered into the Alternatives tab.

- ***Names of Borrow Site Alternatives –*** Options that the user wishes to compare should be entered in this column. If some project sand source options include combinations of sub regions, each combination should be listed as a separate alternative (e.x. "All A", "B1+B2", "A1+B2", etc.) It may be possible that sand properties can still meet project requirements but sustainability can be improved by using a combination of regions.
- ***Quantity Available in Millions of Cubic Yards (MCY) –*** Estimates for total quantity of suitable material in the area of each alternative should be recorded here. If alternatives consist of multiple borrow sites, the total quantity available may be represented by the sum or the intended portion to be utilized. Users may wish to change the units to fit their preference. *If no quantities have been estimated, enter zeroes (0) so the tool will function properly.* The quantity is not explicitly incorporated into the decision model but is displayed along with the model outputs to provide a comprehensive view of the alternatives.
- ***Approximate or Estimated Cost –*** If information is available, approximate cost should be reported here per unit volume of material, for the total project, or both. *Otherwise, enter dollar signs ($) so the tool will function properly.* Cost is also not explicitly incorporated into the model (although many of the criteria have the potential to affect cost). The cost will be displayed on the Results tab to allow comparison with the model output.
- ***Notes (optional) –*** Any other relevant site-specific notes may be entered in this column (e.g. types of obstructions or general limitations). Unlike the other three columns, *this section need not be filled for the tool to function properly*; it exists only as a place for users to keep track of useful information that may be helpful to consider and to record this information for future use.

Criteria Tab

This tab lists the five top level criteria that will be used to assess the alternatives. The tool identifies and separates these five top level criteria as:

1) Sediment Characteristics
2) Borrow Site Controls
3) Stakeholder Acceptability & Community Opinion
4) Environmental & Physical Concerns
5) Future Site Usability

Sediment Characteristics are shared characteristics between the native beach sediment and borrow site sediment, meaning the scores for this criteria represent a comparison. The other criteria assess the challenges and impacts that may be associated with the project. Borrow Site Controls and Stakeholders consider physical and organizational constraints that may restrict the type of equipment that can be used or requirements that may increase the project time. Environmental and Physical Concerns and Future Site Usability consider how the sand source site will be changed by the dredging activity and whether that may limit future use of the site.

A few decisions about how to measure the criteria must be indicated on this page.

- **Measured Below** – if this option is selected, you will be prompted to enter the data for the sub-criteria listed below. This option allows the user to input specific data on sand or site properties, if available. On the Value Functions tab the user will indicate the desired properties for the placement site.

- **5 Point Score** – if this option is selected, a total score for this criterion can be estimated using professional experience and judgement. On the Alternative Scores tab the user will indicate how well the sand or site properties meet the need of the project. Information is provided in the Rubrics tab (and in Appendix A of this document) to guide the user in developing a score. On this scale, 1 always represents the lowest utility (least preferred option, poorest match) and 5 the highest utility (most preferred option, best match), regardless of how the criteria is worded.

One of these options must be selected for each of the six criteria that contain a yellow drop-down box on the Criteria tab. When the Measured Below option is selected, the underlying Level 3 Criteria will become visible. Data can later be entered directly in the model for the specific traits described, such as grain size distributions for the Texture criteria, or conveyance mode and distance for the Conveyance criteria.

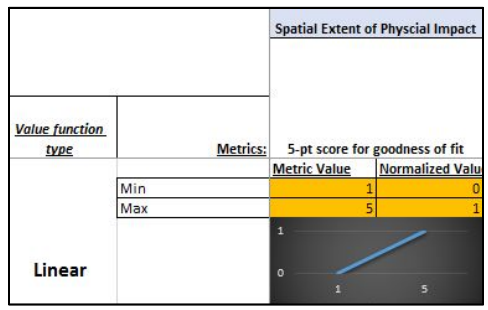
Often the precise level of data will not be available to decision makers early on in the decision making process, which is the reason the simpler option to utilize a qualitative 5-point scale may be selected.

Value Functions Tab

A value function describes the added value to the project of each incremental change in a criterion. The function should increase in the direction of more preferred characteristic and decrease in the direction of less preferred characteristics. If a set of characteristics are equally values, the function should be horizontal. Some examples of value functions are described below.

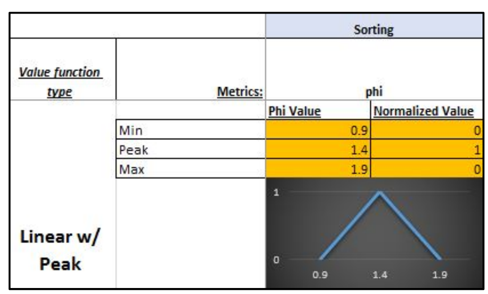
The user must enter information about their preferences in the Value Function tab. These 'reference graphs' will be used to evaluate the performance scores of the alternatives and translate them into numbers on a uniform scale (0-1) so they can then be used in the tool's calculations. A score of 0 represents the least preferred possibility to the decision maker (lowest utility), and a score of 1 the most preferred (highest utility). **Only one value function may be used for each criterion**; if more than one type of function is populated with data, the tool will not function properly. **A value function must encompass the range of the alternatives in the tool.** There are three types of value functions that the user may choose from:

- **Linear Function** is the simplest type of value function and is used when the value of the criterion improves uniformly in one direction. A common use of the linear function is for cost or distance. For many projects, every dollar or mile reduction in the project scope improves the outcome. All criteria that are measured through a 5-pt scale will use the linear function (many should already exist in the Value Function tab). It uses the upper and lower limits of the scale to create a utility graph. A score of 1 on the 5-pt scale will receive a uniform scale score of 0, and a 5 will receive a uniform scale score of 1. Every point between these two extremes will receive a proportionate score.



- The **Linear with Peak Function** is chosen when a specific quantity/parameter is desired and the value drops off as the parameter moves away from the target. An example of the Linear with Peak function is likely to occur in the selection of preference for grain size distribution, where it is preferred that phi equal 1.4, but a range of 0.9 to 1.9 is acceptable with decreasing value away from 1.4, and anything outside of this range is equally unacceptable. Remember: each alternative under consideration must be represented. If one alternative has a phi of 0.5, the piecewise function should be used to create a graph with a horizontal line at 0 from 0.5 to 0.9 in addition to the two sloping lines.

  In theory, this function could also be used as "Linear with Minimum" in a case where there exists a range of unacceptable values, outside of which are more acceptable values.



- The **Piecewise Linear Function** is used to build more complex value function. For instance, the time-centered criteria may choose to utilize this formula because of user preference for shorter project times. For example, 1 week would be ideal, but 2 or 3 weeks is still acceptable, and anything more than 10 weeks is unacceptable.
  This function may also be chosen for criteria that do not follow the same trend throughout the range of values (e.g. they may have one or multiple peaks). This can also be used to represent a step function with specific thresholds where all scores between the thresholds have the same value. Note: It is necessary for the percent value column to have Piece 1 as the lowest value and the last piece as the highest in order for values on the x-axis to display properly.

		Total Dredging Time (including expected project delays due to safety, windows, etc.)	
Value function type	**Metrics:**	*weeks*	
		Time Value	Normalized Valu
Piecewise Linear	Piece 1 (Lowest Value)	1	1
	Piece 2	2	0.95
	Piece 3	4	0.85
	Piece 4	6	0.65
	Piece 5	8	0.35
	Piece 6	10	0
	Piece 7	12	0
	Piece 8		
	Piece 9		
	Piece 10		
	Piece 11		
	Piece 12 (Highest Valu		

weeks

Alternative Scores Tab

As discussed in the introduction, the flexibility of the tool to incorporate qualitative as well as quantitative scoring allows it to be used both in early screening and feasibility studies as well as later when more specific data is available. It is possible for criteria measurement units to be determined by the user (e.g. using days or months instead of weeks for Total dredging time).

The **Scoring Rubric tab** details information on what to consider when assigning scores for criteria that use the 5-point scale. (The Scoring Rubrics are also replicated in Appendix A of this document.) The rubrics were developed using input from over 20 interviews with subject matter experts. These rubrics are intended to be a guide but users may wish to develop their own specific rules for how criteria should be scored. These decisions should be documented so that the tool can support the iterative project planning process.

Scores must be entered in the yellow boxes on the Alternative Scores tab. These boxes are juxtaposed with white boxes (may be hidden for some criteria) within the same criterion. Inside the white boxes, the normalized values (on a scale of 0-1) will appear. This is done by a cross-referencing of the scores inputted with their corresponding, previously-entered value functions. If value functions have not yet been devised and entered, the tool will not be able to normalize the scores entered on the Alternative Scores tab, and the tool will not work.

Once all scores have been entered and checked for accuracy, **the "Update All" button in the top left corner of the Alternative Scores tab must be pressed** in order to perform the underlying calculations and populate the normalized scores. These normalized scores are what the tool utilizes to perform the final steps of the analysis.

Weights Tab

The relative importance of the criteria to the overall decision objective are entered into the Weights tab. Here, the user will indicate how much each sub-criterion influences its parent criterion score. Although not necessary, it may be helpful to first rank the criteria in each group from highest to lowest importance. The "RANK" cells are optional and are not involved in the calculation. Then follow the rank order of the criteria to enter the relative weight to assign to each one. **Criteria must each be assigned numerical scores quantifying their relative importance in the "SCORE" cells**.

For example, if Sediment Characteristics is ranked first, give this option a score of 100. If Future Site Usability is ranked second, and is almost equally as important, give it a score of 90 or 95. If Future Site Usability is ranked second but is only half as important, give it a 50. Continue down the rank order list. Each sub-criterion should have a score less than or equal to the one ranked above it. Score do not have to multiples of 5 or 10 and can include fractions. If an entire criterion is not relevant for the current study, it can be given a rank of zero (e.g. contaminants or metals may not be of concern for some types of site selections). **The scale employed is not important; what is essential are the *relative* difference in scores between criteria**. A scale of 0 to 10 is also commonly used.

The weighting scores entered by the user are automatically normalized into values in the "WEIGHT" cells by dividing the score for that criterion by the sum of scores in that group. These weights, which are also displayed graphically in the Total Weight chart and the Criteria-Level Weights charts, are the values utilized by the tool's calculations.

Results Tab

The **Results** tab displays the outcomes of the analysis in both table and graph form. The Overall Scores, which describe the total utility of each alternative and are the central piece of information to be considered by the decision-maker, are shown in the yellow column. These top-level scores provide the user with information about the order of preference for each alternative, given all of the criteria as well as the how strong the preference is. Two site selection alternatives with similar scores could be considered almost equally preferred. There may be a case with one clearly preferred option or several options may be equally acceptable to multiple stakeholders. The top-level scores are also displayed alongside the cost and volume amount, providing additional context for decision making.

In addition, the tool also produces scores for the second-level criteria, which may be employed to compare which alternatives perform better with respect to each of the five main criteria. The user should perform a simple check for reasonableness of the results. If results are drastically different than expected, or if there are problems with the results that highlight a flaw in the model (e.g. Alternative Y has poor performance scores for most criteria, but results show it to be the best option), the user may go back and reconsider the value function and weighting scheme they assigned, or check that the scores entered properly align with true values. In addition, the tool may be run multiple times with different weighting schemes in order to find which alternatives will perform better across a range of perspectives (e.g. from the perspective of a time and efficiency focused stakeholder or an environmentally focused stakeholder). If there are alternatives which drastically underperform others, it may be a logical choice to entirely disregard them for later project stages.

Best Practices

Many decisions remain following the use of the Sand Source Selection Tool. The following best management practices have been recommended by subject matter experts that have a detailed understanding of Outer Continental Shelf dynamics and extensive experience in sand borrowing projects. The eighteen subject matter experts that contributed to this list offered two types of guidance: *specific direction* and *general considerations*. The objective of collating these practices is to assist future OCS sand borrowers in the following:

- → ensuring longevity of limited sand resources
- → limiting environmental and physical impacts of dredging
- → preventing resource overuse / depletion
- → balancing short term and long term needs
- → improving operational efficiency
- → limiting cost/hassle
- → ensuring equitable use across current and future stakeholders

The recommended best practices and considerations are divided into the following four categories:

1) Planning
2) Operating – Physical Component
3) Operating – Environmental Component
4) Stakeholder Engagement

Planning

1) **Plan with a *holistic* view of the erosion and OCS sand-replacement cycle**
   - Before opting to remove sand from OCS features, prioritize alternative methods of erosion control and implement strategies to extend the life of existing beachfills
2) **Limit use of renewable sites to match or exceed their renourishment rate**
   - Dredging at a rate similar to a site's renourishment rate will help prevent overuse or removal of the feature.
   - Plan projects so that the predicted time between initial fill and subsequent maintenance is similar to or greater than the renourishment interval.
   - *Note: Many of the sand features on the OCS do not experience renourishment. They are relic sand features that are considered finite. Therefore, this practice will not apply.*
3) **Develop a *Borrow Area Conservation Plan***
   - The *Borrow Area Conservation Plan* should outline exactly where a dredger should excavate and how much volume to remove to ensure that all of the desired sand gets taken and that each dredging event leaves behind enough sand for the next dredging event or no sand at all.
   - An efficient layout will help conserve limited resources.
4) **Use the first sand resource in its entirety before moving on to the second resource**
   - Select a resource that has the exact volume needed (or as close as possible) so that the entire resource can be utilized.

- Completely exhausting the permitted borrow amount from one sub-area before moving on to a second sub-area will extend the life of sand resources.

5) Avoid leaving behind small amounts of sand that are uneconomical to collect in the future

- When leaving behind sand, leave the sediment in areas with sufficient vertical layers to be economically justifiable for future dredging.
- For example, if a borrow area has a vertical sand depth of four feet, do not remove two feet from the entire area; instead remove four feet from *half* of the area and leave the other half with sufficient depth for future dredging.

6) Factor in infilling – both the infilling rate and sediment type – when determining borrow volume

- For example, if infilling material consists primarily of mud, aim for 80-90% of the sand volume on the first pass so that very little material is left at risk of being covered by mud, rendering a second pass unviable.

7) Incentivize dredge operators performing the work to do a clean and thorough job

- Provide detailed specifications and guidance and encourage the dredgers not to rush through a project in an effort to make the most money possible; reward efficiency and sustainability.

8) Employ "beneficial use" from another dredge project

- If material removed from another dredge operation (such as a channel project) is usable, prioritize its use before using an OCS feature.

9) Do not automatically exclude borrow areas that appear to have elevated silt content

- Placement material often has slightly different characteristics than the collected material and may be more compatible than what was detected at the borrow site.
- It may be feasible to use sand from an under-utilized area that has 85% sand content rather than an over-utilized area that has 90% sand content.

10) Do not automatically exclude borrow areas if wave models show a potential increase in erosion along the shoreline

- There is always uncertainty in wave modeling and variability between what happens in the models and what happens in nature.
- Consider the accuracy of the wave model projection. A model may show a 1% increase in erosion, but it is very unlikely that the model is accurate to such a low limit of detection.

11) Optimize post-dredging geometry to limit environmental and physical impacts

- Analyzing the geometry of the deposit and modeling changes in the geometry is the most effective, and most economical, way to limit environmental and spatial impacts.
- If an assessment shows that the current plan will result in adverse environmental and physical impacts, then the geometry should be reassessed and model iterations should be run to identify the optimal geometry that minimizes disturbances.

12) Consider the trade-offs between mitigation strategies and future borrow area usability

- Consider how a mitigation strategy that has short term benefits may have adverse effects on the longevity of the borrow site.
- For example, do not focus entirely on screening MEC/UXO to the extent that surface rock is displaced and completely armors the site, preventing any future use of the site. Resources are being closed prematurely due to armoring from MEC screens. If efficiency

is only 33% due to MEC screens, then dredgers need to go to three times as many borrow areas to collect the required volume.

13) **Consider tradeoffs between sand removal efficiency and cost**
   - As many of the OCS sand features are finite, removal operations should be executed as efficiently as possible, even if there are negative implications for near-term cost.
   - For example, using a shorter dredge pipe will result in higher cost but will have a higher recovery efficiency because less energy will be required at the dredge head and less material will be stirred up and potentially lost. Using a longer dredge pipe may be cheaper up-front, but more energy will be required resulting in lower capture efficiency and a more rapidly exhausted resource. Short-term costs that improve efficiency can delay the long-term costs related to exploration of alternatives and longer transport distances as resources are used up.

14) **Consider the tradeoffs between environmental impacts and risks to high value resources**
   - Removing sand from a borrow area that will result in higher turbidity and some impact to the ecosystem but no risk to high value resources may be a better option than removing sand from a borrow area that will result in no turbidity and no impact to the ecosystem but poses a risk to high value resources.
   - A mild ecosystem disturbance may be an acceptable consequence if it allows dredgers to avoid operating at a site that poses a risk to a high value resource.

Operating – Physical Component

1) **Minimize overall dredging intensity and persistent effects**
   - To decrease the amount of pressure experienced by a borrow area, avoid repeating excavations in sensitive areas (i.e. avoid following the same linear route through a recovering benthic community).

2) **Rotate renewable dredge areas**
   - Dredge renewable offshore sand sources in a rotating pattern, similar to a rest-rotation crop or grazing system, in order to allow sand sources to refill or the ecology to recover more effectively.
   - *Note: Many of the sand features on the OCS are not renewable. Therefore, this practice will not apply.*

3) **Selectively dredge the accreting area or leading edge**
   - Prioritize dredging at the recently accreted portion of the feature, or the leading edge.
   - This will allow the feature to remain more stable and it will allow natural recovery for future use (whereas sand on other parts of the feature may not regenerate).
   - *Note: Many of the sand features on the OCS do not accrete. Therefore, this practice will not apply.*

4) **Avoid leaving a gravel lag**
   - Prioritize the use of uniform sand ridges that typically do not have gravel in them in order to avoid leaving a gravel lag that can prevent future use.

5) **Spread out draw areas to limit physical impacts**
   - If modeling suggests that there will be a significant physical impact from the current dredge plan, spread out the draw areas.

- For example, instead of taking all of the volume from the top of a shoal, take it in evenly spaced increments and leave a rolling ridgeline or make a cone shape. Alternatively collect the volume from the slope of the ridge rather than the top.

6) **Define a the maximum dredge depth according to the context of the specific sand resource**
   - When defining maximum dredge depths, be more qualitative and consider the context of the resource and what a reasonable dredge depth is for that resource.
   - For example, a one-size-fits-all recommended dredge depth of six feet may not be optimal for every borrow area on the OCS.
7) **Construct reinforced side slopes**
   - If the slope is too steep or vertical, the sand structure may adjust or redistribute too quickly and destroy habitat. Avoiding this may require leaving some material behind to reinforce the slope.
8) **When making step cuts, make sure that the wall sizes between cells are consistent**
9) **Use turbidity curtains when coral reefs are down-current from a dredge project**
10) **Leave behind a flat surface – avoid digging a hole**
    - The priority should be to dredge shoals away first.
    - It is generally better to remove down to a flat surface rather than to start with a flat surface and create a deep hole.
11) **Consider the tradeoffs between shallow cuts and deep cuts**
    - If the borrow volume from a resource amounts to one half of the total volume available at a borrow area, consider whether to take the volume from the entire surface area, one layer at a time, or from a deeper cut into just a portion of the surface area. The first option prevents holes that may cause changes in wave propagation, while the second option preserves surface area vital to the benthic community.
    - Find a good balance between maintaining surface area for the benthic organisms without leaving a geometry that will affect wave propagation.
12) **Consider the tradeoffs between the different types of dredges**
    - For example, if suspended sediment is of critical concern, prioritize a trailing suction hopper dredge to reduce turbidity.

Operating – Environmental Component

1) **Prioritize protection of endangered species**
   - Always utilize species-specific practices designed to reduce the impact of dredging (e.g. turtle deflector/excluder)
2) **Prioritize borrow-area alternatives that allow for maximum recovery from ecosystem perturbations**
3) **Designate an environmental "refuge patch" within the borrow area**
   - For example, if ecological communities are expected to be densest on the crest of a shoal, leave a portion of the crest intact to help seed flora and fauna recovery.
   - This action may speed up the recolonization of the dredged areas of the shoal as the shoal physically adjusts to sand being removed.
4) **Prioritize borrow areas that replenish with the same type of habitat**

- For example, when choosing between two equally viable borrow areas – one that will replenish excavated sand with more sand and one that will replenish with mud – select the area that replenishes with sand in order to maintain consistency of habitat.

5) **Mitigate the effects of lost surface area**
   - For benthic organisms that rely on the surface area of a shoal, create notches that will increase the surface area of the shoal. Alternatively, compensate for lost surface area nearby.
   - If an environmental assessment shows that the benthic organisms at the site will be severely impacted, then the best strategy to reduce that impact is to minimize surface area disturbance.
6) **Consider the tradeoffs between efficiency and overall dredge time**
   - Perform operational adjustments that can help protect the habitat.
   - For example, dredging in strips rather than a large square may have lower impact on the macroinvertebrate system but may have higher impacts on other elements of the ecosystem because of longer dredge times.
7) **Consider the tradeoffs between the geometry of the feature and the impacts to the macroinvertebrate ecosystem**
   - A small, deep hole will harm fewer benthic organisms initially but will result in lower dissolved oxygen in the hole, whereas a large, shallow hole will harm more benthic organisms initially but will result in higher dissolved oxygen and potentially faster recovery because the environment can still sustain the oxygen demands of the organisms.
   - Uniform dredging may maintain the shape of the feature but may remove more macroinvertebrates from the top layer, whereas dredging focused in specific areas may have a lower impact on macroinvertebrates but a large impact on feature shape.

Stakeholder Engagement

1) **Form a stakeholder working group**
   - Stakeholders should form a working group that openly discloses information about use of shared sand resources (planned projects, volumes, timing, etc.).
   - This can serve as a mechanism for reviewing data and discussing the results of physical and biological monitoring projects. Sharing data can prevent stakeholders from repeating assessments that have already been performed.
2) **Maximize transparency between stakeholders**
   - All stakeholders – federal/state/regional governments, regulators, fishing industry, etc. – can avoid political disputes, resentment, and litigation by eliminating underhand tactics that result in short-term gains for one party and long-term issues for the cooperative as a whole.
3) **Share projections of future OCS resource use**
   - When developing a project that will require repeated nourishment over time, estimate the ballpark timeframe and volume of future events and share this information with interested parties who may also have a stake in the regional OCS sand resources.
4) **Include commercial fishing groups in the pre-dredge planning process**

- This way, specific high-value fishing areas at the borrow site can be removed from consideration and the remaining sub-areas can be considered for dredging.
- Early compromise can save a team from having to perform expensive borrow site investigations and can also reduce litigation costs.

5) **Develop a detailed inventory of OCS sand resources to manage stakeholder expectations**
   - The best way to preserve a finite resource is to know exactly what is available.
   - Know the spatial distribution of the resources and understand the available sand volume at each site – this dictates how much flexibility stakeholders have.
   - If a resource is stand-alone then it is likely to get used more regularly, especially if there are multiple stakeholders sharing the site. Knowing the inventory of the available resources in the area can help ensure that one resource is not being overly impacted.
   - An inventory will also help with communication to stakeholders. If stakeholders understand that volume is limited they will be more amenable to volume controls and longer periods between dredge events, and more willing to compromise to preserve the resource.
6) **Perform a detailed *regional* Environmental Impact Statement before allowing multiple stakeholders to share sand resources in a region**
   - A simple Environmental Assessment is not thorough enough to evaluate the impacts to essential fish habitat, ecological recovery time, archaeological features, etc.
   - Allowing stakeholders to come into a region and borrow sand from a feature based solely on the results of a single Environmental Assessment may have serious adverse impacts for the stakeholders closest to the resource.
7) **Share sand quality fairly**
   - Do not take the best sand and leave scraps for other stakeholders.
   - Consider offering some advantage to the party that performed the assessments that identified the resource as viable.
8) **Consider replacing the term "competitive use" with "shared use" in project communications**
   - "Competitive" implies there is a winner and a loser. The objective should be reasonable compromise across stakeholders without resentment.

Appendix A: Scoring Rubrics

Criterion	very poor	poor	moderate	good	very good
Color	Compared to the other alternatives, provide a score for how well suited the color of the sand source is for the planned use. Consider: - how well the color matches existing material at the placement site. - how well suited the color is for any intended animal habitat.				
Texture	Compared to the other alternatives, provide a score for how well suited the texture of the sand source is for the planned use. Consider: - appropriateness of grain shape, grain size, and size distribution. - how well the texture matches existing material at the placement site. - how well suited the texture is to achieve the beach slope or other placement area performance criteria.				
Mineralogy / Composition	Compared to the other alternatives, provide a score for how well suited the mineral composition of the sand source is for the planned use. Consider: - how well the composition matches existing material at the placement site, independant of color or texture. - relative composition of carbonate, silica, or exotics. - if a required threshold for mineral composition is likely to be met.				
Conveyance	Compared to the other alternatives, provide a score for dredge type suitability. A high score should indicate that multiple dredge types are appropriate. A low score should indicate that that type of equipment is highly constrained. Consider: - the distance of sediment transport between the borrow area and the placement area. - the efficiency of the potential dredge/transport type, whether scow, hopper, or pipeline. - the complexity of the sand body and the suitability of different dragheads.				
Water Depth / Bathymetry	Compared to the other alternatives, provide a score for how how much of a challenge the bathemetry of the area will present for the the project Consider: - the maximum and minimum water depth and any contraints the water depth imposes on the type or timing of equipment use. - any entrance channels to the borrow site, or other bathymetric features that influence the direction from which the borrow site can be accessed.				
Site Obstructions	Compared to the other alternatives, provide a score for the quality of the borrow area with respect to permanent obstructions that may constrain the project Consider: - presence of rock, munitions, site geometry, undesirable cover, navigation routes, oil and gas pipelines, cables, wind farms, archaeological artifacts, hard bottom, essential fish habitat, aquaculture. - required buffers or coverage of any obstructuctions. - the possibility of unmarked hazards to exist, including fiber optic cables or munitions. - any resulting increase in complexity of dredging or reduction in percent yield as a result of the obstructions.				
Portion of Obstructions Clearable or Controllable	Compared to the other alternatives, provide a score for the quality of the borrow area with respect to any permanent, clearable, or controllable obstructions Consider: - the number of oil and gas pipelines and/or cables crossing the site and the extent to which they are adequately covered. - sensitive cover-- including hardbottom, aquaculture, and essential fish habitat -- and the buffers around each. - obstructions -- including archaeological artificats, munitions, navigation routes, and windfarms -- and the buffers around each . - the potential for unidentified hazards to exist, including munitions or cables, that will require extra caution during all dredging activities. - any existing site obstructions that can be removed or managed to reduce interfence with sand retrieval. - legacy oil and gas pipelines that should have been removed but were granted a waiver. - effort and time required to remove the obstructions. - whether obstructions will be removed at the time of dredging or before.				

Stakeholder Acceptability & Community Opinion	**very poor** **poor** **moderate** **good** **very good** Compared to the other alternatives, provide a score for the expected acceptability of the sand source plan by stakholders and community members Consider: - a range of stakeholders: residents, county, state, other federal agencies, environmental organizations, labor or economic groups. - potential concerns about: water quality, threatened and endangered species, migratory species, noise, visual aesthetics impacts. - past response to similar work in the region. - recent or proposed legislation for which the current work might be considered precedent-setting.
Spatial Extent of Environmental Impact	**very poor** **poor** **moderate** **good** **very good** Compared to the other alternatives, provide a score for the likely or expected spatial extent of environmental impact Consider: - regional habitat context; the area of habitat impaired realtive to the regional amount of the same habitat. - accessibility of that nearby habitat and the ability for communities to relocate. - potential for suspended sediments given the baseline turbidity of the area. - potential for dredge plumes to move beyond the dredge site (especially to coral reefs). - full picture for extent of spatial impact, including the dredge site and the transport route.
Intensity of Environmental Impact	**very poor** **poor** **moderate** **good** **very good** Compared to the other alternatives, provide a score for the likely or expected intensity of environmental impact Consider: - species present; impact on endangered species will almost always be high. - amount of benthic habitat removed relative to total habitat at the borrow site. - how rare is the habitat that is impacted. - duration and/or frequency of the dredging activity realtive to the ability/thresholds of local species to withstand disruption. - changes to substrate characterisitics and sediment landscape (holes, mounds, new formations) that may affect on-site species distribution. - impact to water quality if no infilling occurs. - impact to future breeding at the site. - important subpopulations of affected species (juveniles/females). - rate of recovery for individual species (different than time for full ecosystem recovery). - spatial distribution of species and concentration in an area, population at the shoal relative to a region - is one regional species congregated at a very high density at the borrow site? consider how much we know about the ecosystem at the borrow site and how much uncertainty we have. Do we know why the fish are congregated there? Do we know for sure they won't go somewhere else?
Time for Environmental Recovery	**very poor** **poor** **moderate** **good** **very good** Compared to the other alternatives, provide a score for the likely or expected time of environmental recovery Consider: - will species return or be permanently displaced? - short and long term effects for migrating species that only periodically use the space . - short and long-term effects on benthic community. - consider full "ecosystem recovery" versus just biomass recovery. - full ecosystem recovery represents a complete return to the pre-dredge species types, species distributions, and trophic transfers. - consider regional recovery rates and habitat specific accretion rate. Note: objective measures for fast or slow recovery vary by location. Reasonable recovery may be 1-4 year. Most species cannot recover to 100% within 6 months, but for some, 1-2 year may be considered fast.
Spatial Extent of Physical Impact	**very poor** **poor** **moderate** **good** **very good** Compared to the other alternatives, provide a score for the likely or expected spatial extent of physical impact Consider: - changes in wave attenuation due to sand removal. - changes in coastal erosion rate relative to the historical record. - length of coastline impacted by change in wave energy. - changes in sediment transport; potential for chain reaction on shoals between the borrow area and the shorline. - nearest coastline and effect of changes in water energy and direction on scour, erosion, and accretion. Note: don't typically see physical impacts beyond 1,000 feet from the dredge site, that's why the buffer to artifacts and pipelines is 1,000 feet Note: don't typtically see wave regime effects when dredge site is greater than 40 feet deep.

Intensity of Physical Impact	**very poor** **poor** **moderate** **good** **very good** Compared to the other alternatives, provide a score for the likely or expected intensity of physical impact Consider: - volume of sediment removed relative to volume of sand source site as a whole. - distribution of the total volume extracted, whether more from the shore side or off-shore side of the sand feature. - changes in sediment characterisitics that may affect the stability or the sand feature, resulting in shoal collapse or rapid settling. - changes to the the relative height or shape of the sand formation (holes, linear scars, ridges). - if such changes are within the depth of closure where wave height may be affected. - how change in wave climate in the sub area will affect the rest of the bottow site. - how change in wave climate will affect wave height at the shore. - the importance of any affected onshore resources (infrastructure, landmark, economically important recreation site). - expected frequency of dredging activity at the site. Note: A 10-20% change in wave height may be acceptbale but should be monitored, while greater changes could be a serious concern; however, the evaluation will be site specific. Note: NMFS has a mid-atlantic threshold for what volume is too much to extract; may exist for other locations as well.
Likelihood of Reduced Future Use due to Surface Armoring	**very poor** **poor** **moderate** **good** **very good** Compared to the other alternatives, provide a score for the likelihood of reduced future use of this site due to armoring of the surface. (N/A if site is single use.) Consider: - liklihood that drege method with create "pavement" or "deflation" by using filters or dumping large rock back on the seafloor. - naturally exisitng hardbottom that will be exposed when dredge activity is complete and will result in a new buffer area.
Likelihood of Reduced Future Use due to the Creation of Challenging Geometry	**very poor** **poor** **moderate** **good** **very good** Compared to the other alternatives, provide a score for the liklihood of reduced future use of this site due to creation of challenging dredge geometry. Examples inlcude small, disconnected pockets of dredgeable material, non-linear dredge area boundaries, acceptable material left in thin layers. (N/A if site is single use.) Consider: - thickness of desireable sediment layer and quality of substrate material. - type of dredge head to be used and precision with respect to depth and lateral tolerance. - penalities for dredging overdepth that may incentivize leaving some good sediment at the site. - configuration of any existing pipelines, archeological features, or potential for munitions, along any required buffers.
Changed Ability for the Sediment to be Preserved	**very poor** **poor** **moderate** **good** **very good** Compared to the other alternatives, provide a score for how well this proposed project will preserve the site as a quality sand resource (N/A if site is single use.) Consider: - the quality and stability of the off site features that provide sediment to the area. - sediment transport processes. - the likelihood for hurricanes or major storms that may expedite adjustment or sediment transport processes. - changes to the erosional environment that may result in the loss or degredation of the surface material, including redistribution of the existing volume in to a layer too thin to dredge. - if the site can naturally replenish, how will the rate or ability to replenish be affected. Note: In some areas, at 1 mile offshore, recovery rate is considered "very slow" if the accretion is 1/10 of a foot over 5 years; at 3 miles offshore, sediment transport process is even slower; almost all extractions will be essentially permanent. Note: Consider the water depth; in the Gulf, rapid recovery is 3-5 years; in the Atlantic, 5 years is rapid and 5-10 years is fast; this rate is a function water depth
Support Future Accretion of Useful Material	**very poor** **poor** **moderate** **good** **very good** Compared to the other alternatives, provide a score for the likelihood that the current project will support future accection of useful material (N/A is site is single use.) Consider: - new bathymetry that will affect the type of material transported to the site. - development of features adjacent to the site that may act as screens or change flow rate that could change the percent of course/fines. - changes to the energy regime that will impact the amount and type of new sediment deposited. - the utility of different types of new material, for example, some regions may be able to benefically use accreted mud and silt, while others may be able to utilize course material. - hurricanes or other events that may expedite adjustment or sediment transport to the site.

C-2 SSST Tutorial

Sand Source Selection Tool

New User Tutorial

Introduction

The Sand Source Selection Tool (SSST) described in the companion reference manual was developed to guide project planners when ranking alternative sand sources based on suitability for use at the placement site and implements a multi-criteria decision analysis (MCDA) approach to perform this assessment and ranking. The SSST also considers impediments to efficient dredging, potential environmental impacts, and long term sustainability of site use in the ranking process and is intended for use in early stages of site selection in order to prioritize the options to consider for further feasibility study. This document provided a tutorial for using the SSST, a theoretical beach nourishment project that was created to demonstrate the functions of the SSST. The demonstration project described in this tutorial is referred to as the Sandy Shoal project.

The proposed Sandy Shoal project area requires 1.2 Million Cubic Yards (MCY) for initial nourishment, and an additional 0.4 MCY once every 7 years following. With no other borrow sites identified in the region, this project is likely to be a large drain on the available resources over the coming decades. For this reason it is necessary for the dredging of sand resources to take place in a sustainable manner, ensuring resource availability for the future. This tool supports sustainable sand sourcing by helping the user weigh advantages and disadvantages and assess the tradeoffs associated with each sand source alternative. This may involve using uncommon alternate approaches to extracting resources in order to avoid future engineering challenges and roadblocks in decades to come (e.g. dredging larger areas less intensively, as opposed to a small area at high intensity).

Three main borrow sites have been identified on the Outer Continental Shelf (OCS). Figure 1 shows a simplified version of the borrow sites, detailing the approximate dimensions of dredgeable material. The sites are separated by thin layers of sand substrate that have been determined to be unsatisfactory due to nearly-exposed bedrock, high gravel composition, and low abundance of suitable material. It is estimated that Site A, the northernmost site, contains 1.2 million cubic yards (MCY) of extractable sand, while Site B has 2.1 MCY, and Site C about 1.3 MCY. These values were approximated based on site area and approximate depth of extractable material.

Secondary investigations identified that although there is a great degree of uniformity in sediment characteristics, Site B has significantly deeper deposits on the eastern slope than the western slope. For this reason, the site was divided into two areas, Area B1 (east side) and Area B2 (west side).

Although the sites identified have distinguishing characteristics, there are many similarities that make the determination of best areas to use difficult. This Sand Source Selection tool will help document and assess the differences and similarities to identify a sustainable long-term project plan.

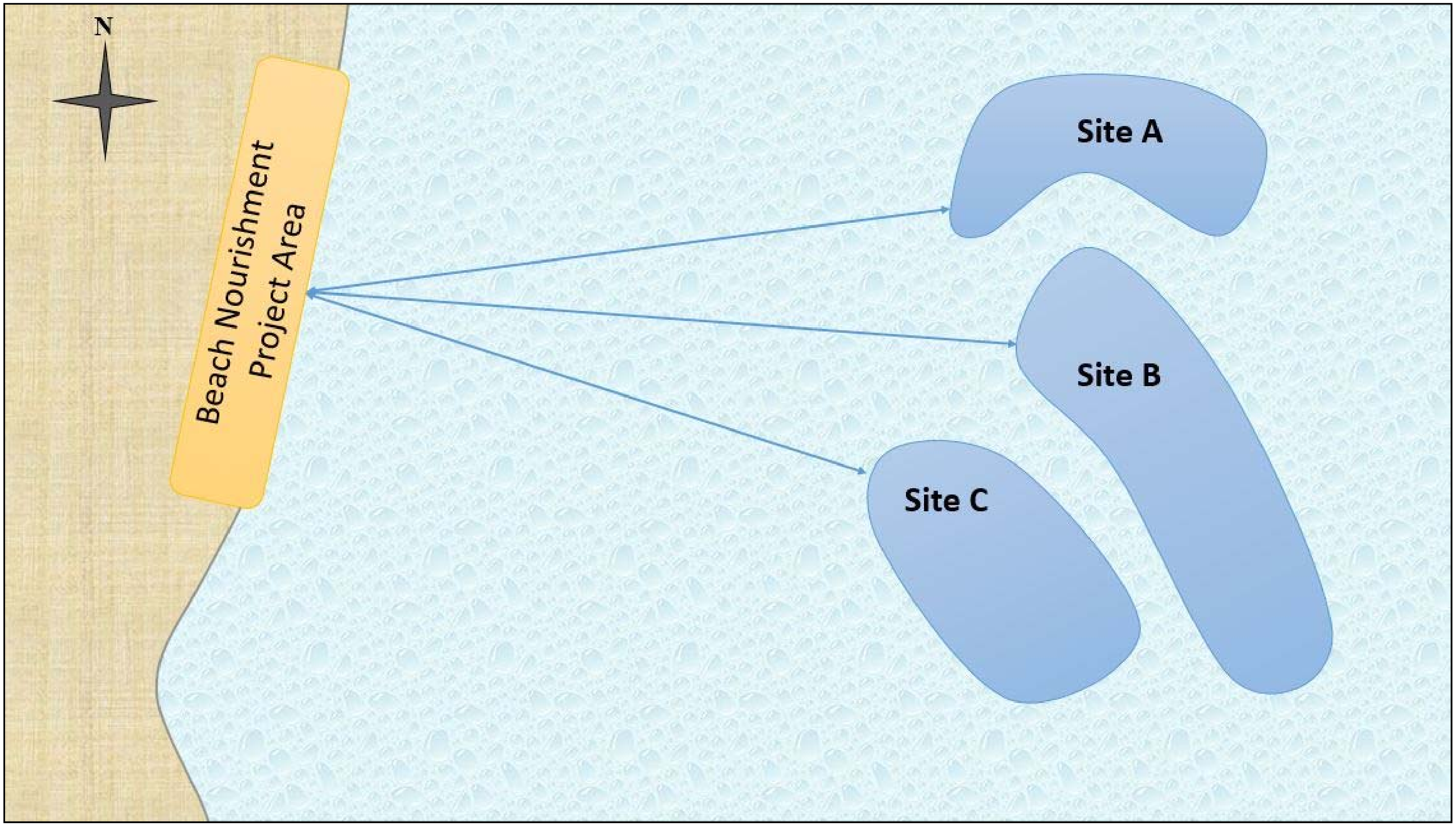


Figure 1. Initial proposed borrow sites for the Sandy Shoal beach nourishment project.

Alternatives Tab

Four Alternatives for sand sourcing that would meet the beach nourishment project need were chosen:

1) Site A
2) Sites A+C
3) Site B
4) Site C + Area B1

It would have been possible for many more alternatives to be included; in some situations, virtually every combination may be equally likely to produce the most sustainable dredging plan. However, project managers determined that these 4 alternatives had the best chance at filling the project area requirements with the highest degree of sustainability. Table 1 lists the information associated with each alternative.

Because initial calculations for quantities available were performed for individual sites, it was necessary for the project managers to sum available quantities for alternatives comprised of multiple sites, which involved an estimation for the percentage of sand within Site B-Area B1.

Costs per unit volume ($/CY) for each alternative were estimated in the early stages of the project based on similar past project. These were merely estimates, and were updated multiple times over the course of the project.

It was noted that Site B had a considerable, uneven distribution of sand resources within its boundaries: Roughly 65% existed on the eastern half (Area B1), which is farther from the project area, and so may significantly impact cost due to travel distance. In addition, project research identified the various site obstructions that affect the specified borrow sites (Figure 2). These concerns were briefly logged in the Notes column on the Alternatives Tab.

> An Essential Fish Habitat (EFH) partially overlaps the western boundary of Site A and impedes accessibility to a significant portion of the borrow site, severely decreasing available material and (depending on permitting) may need to be circumvented by vessels transporting dredging equipment and dredged material to and from the site- resulting in higher than anticipated costs.
>
> A gas pipeline partially intersects the southern ends of Site C and Area B2. The buffer zone, in which dredging is not allowed for safety reasons, extends into a small portion of Area B1 as well.
>
> A shipwreck, which is an historic archaeological site that must be avoided during dredging operations, was identified near the western portion of Site C. These obstructions, the actual dredgeable area (in green) within each borrow site, and conveyance routes to avoid the EFH are shown in Figure 3.

Table 1. Snapshot of Alternatives tab for Sandy Shoal project.

Names of Borrow Site Alternatives	Quantity Available in Millions of Cubic Yards (MCY)	Approximate or Estimated Cost	Notes
A	1.2	$5.00/CY	Partially inaccessible due to overlapping Essential Fish Habitat, may provide probolems for conveyance.
A + C	2.5	$4.05/CY	Site C has Shipwreck and Gas pipeline in addition to Site A's EFH
B	2.1	$2.60/CY	~65% of available quantity lies on the Eastern half (Area B1), which is farther from the Project Area
B1 + C	2.4	$2.30/CY	These represent deepest deposits. Gas pipeline/ Shipwreck.

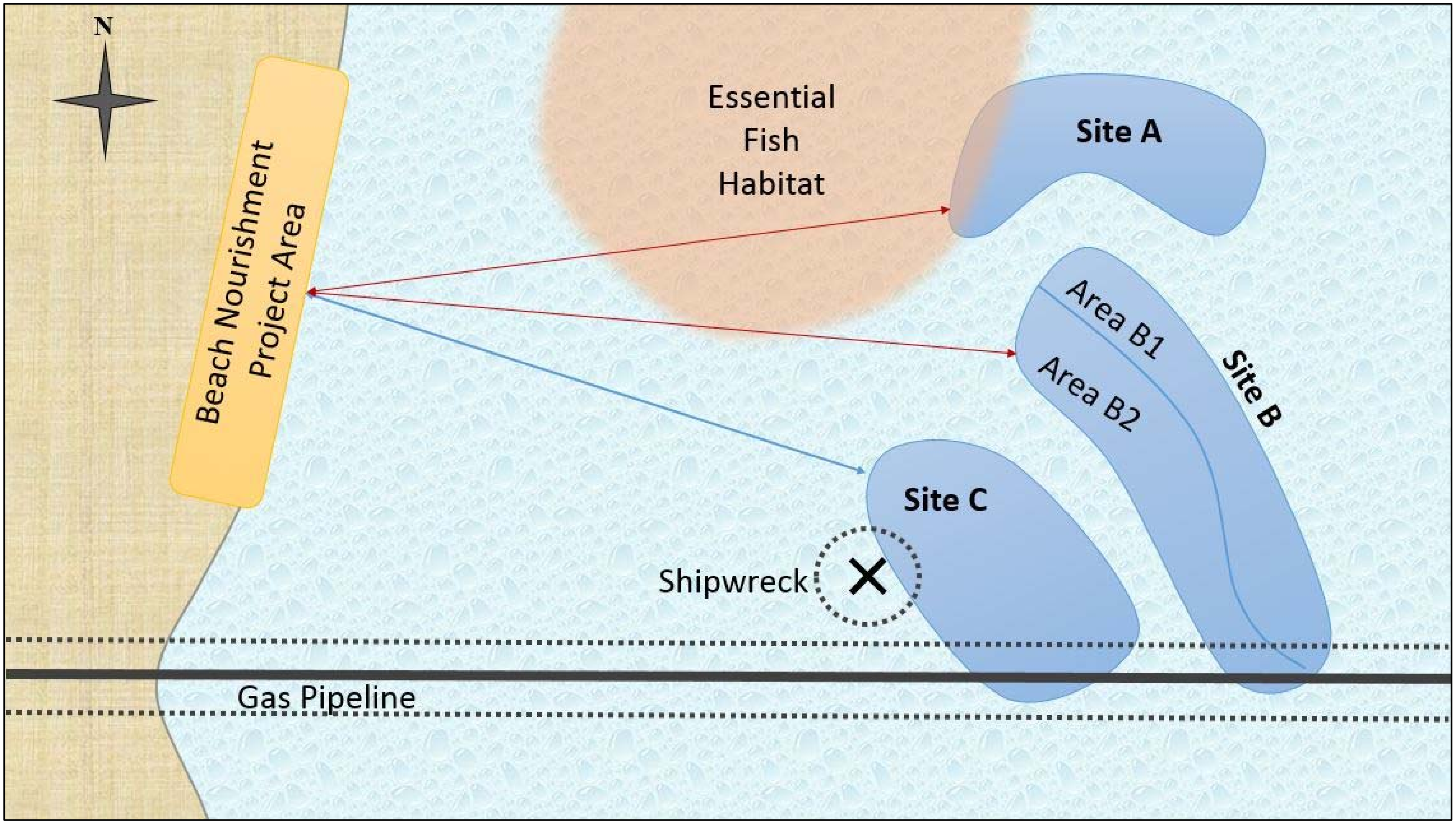


Figure 2. Region showing site obstructions.

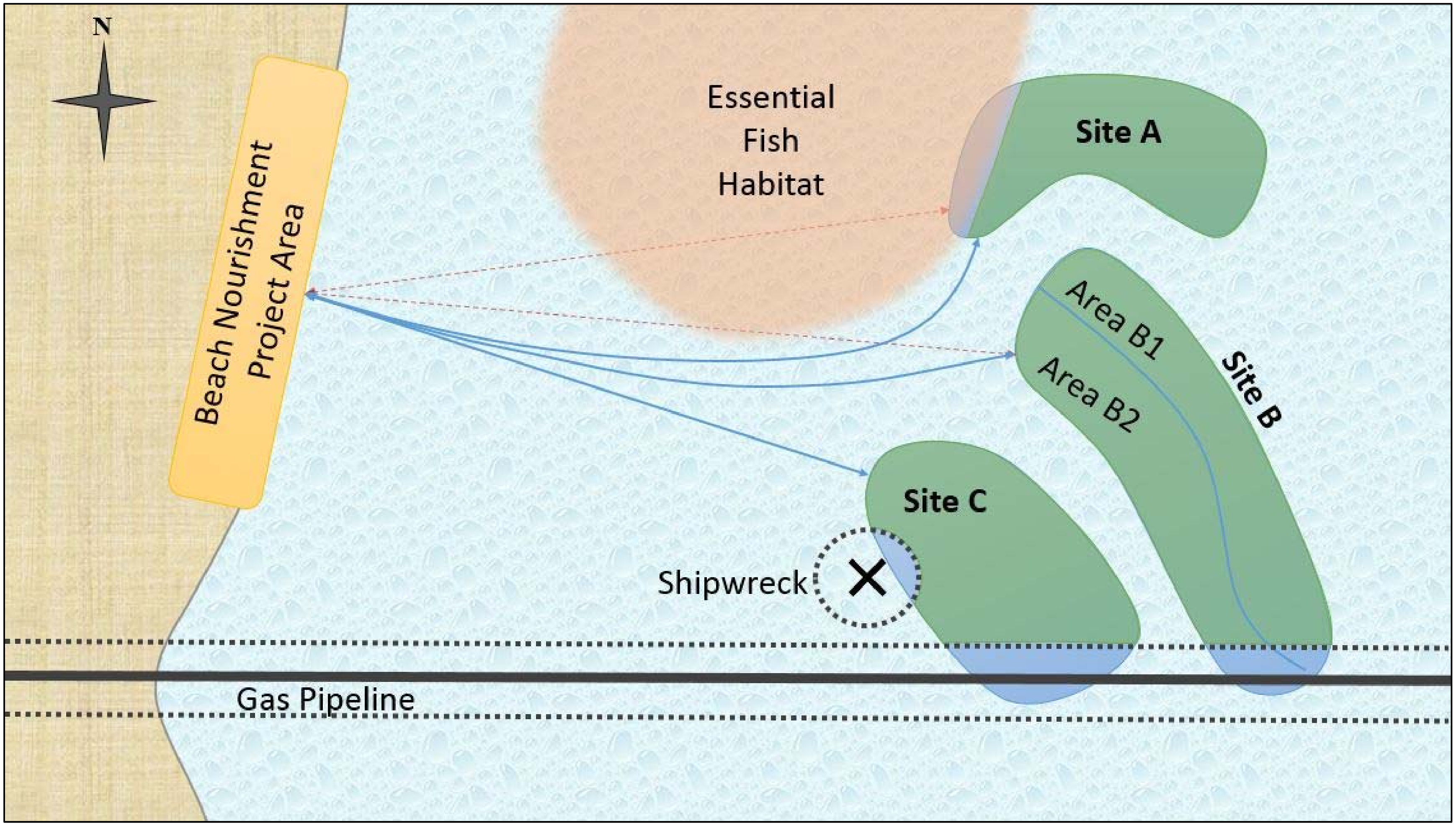


Figure 3. New map of region showing site obstructions, alternate routes, and total dredgeable area (in green) within each borrow site.

Criteria Tab

For this demonstration, project managers chose to utilize a 5-point scale for the Color, Texture, Mineralogy/ Composition, and Water Depth/ Bathymetry criteria; and measured characteristics for the Conveyance and Site Obstructions criteria.

- There were no formal analyses done for sediment Color and Texture, making measurements for those characteristics unavailable until further investigations could be performed. They chose to proceed with the analysis using estimated relative values on the 5-point scale that were provided by investigations of small sediment samples.

- Mineralogy & Composition were not analyzed either due to the high cost of the assessment, but was assumed with reasonable certainty that the composition of minerals at any of the proposed borrow sites would be similar enough to the project area.

- Through use of their depth sounders, vessels on site determined that the Water Depth and Bathymetry throughout all proposed sites would not be problematic for any dredge type. Although this information could have been included in the tool, it would have been superfluous; only characteristics that display a difference in performance will influence the overall results (i.e. scores that are the same for every alternative are nullified). For simplicity, project managers chose to utilize the 5-point scale for the Water Depth/ Bathymetry criteria, where every site received the same score of 5.

- Conveyance distance was measured through the utilization of GPS and satellite imagery, and dredging industry experts notified project managers of the available modes of conveyance that would be practical for each borrow site. Because this information was readily available at low cost, these measured characteristics could be directly utilized in the model.

- Site obstructions were mapped using GIS software, allowing new dimensions where dredging is permissible to be pared from the initial proposed areas. This, along with approximations of sediment distribution within sites, was used to determine an estimate of percent yield for each alternative. 5-point scores for Residual Hazard and Portion of obstructions clearable or controllable were estimated by BOEM, with aid from dredging industry experts. Although these measured characteristics are more subjective than attributes for other level 2 criteria (e.g. texture), project managers determined that their utilization would strengthen the overall analysis.

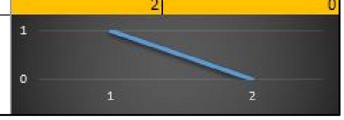
Value Functions Tab

- Any criteria that are measured through a 5-point scale utilize a Linear Function where the Metric Values were 1 and 5, and the Normalized values were 0 and 1 respectively, as the Reference Manual states is required by the tool. These graphs have a positive slope (indicating those criteria should be maximized), where higher values represent higher utility. Many, if not all, of these criteria should be pre-populated with value function information

		Support Future Accretion of Useful Material	
Value function type	Metrics:	5-pt score for goodness of fit	
		Metric Value	Normalized Value
	Min	1	0
	Max	5	1
Linear			

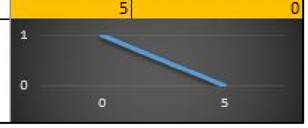
- Presence of Contaminants should also be pre-populated in the tool. This criterion is measured on a binary scale, where 1 represents that contaminants are a non-issue, and 2 signifies a potential issue.

		Presence of Contaminants	
Value function type	Metrics:	*binary (1: non-issue, 2: potential issue)*	
		Binary Value	Normalized Score
	Min	1	1
	Max	2	0
Linear			



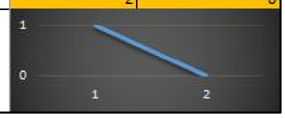
- The graph for Heavy Mineral Content has a negative slope (indicating this criterion should be minimized), because project managers for this demonstration prefer that borrowed sediment have a low percentage of heavy minerals, in anticipation that mineral extraction may be necessary between dredging and deposition on the project area for sediments with a high percentage.

		Heavy Mineral Content	
Value function type	Metrics:	%	
		Percent Value	Normalized Score
	Min	0	1
	Max	5	0
Linear			



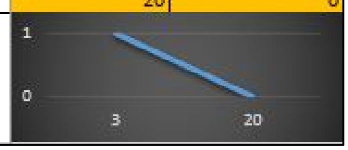
- The Overfill Ratio criterion was also chosen to be minimized, because the larger the overfill ratio, the higher the volume of sediment that must be dredged to meet the project area fill requirement. A ratio of 1 signifies that no extra sediment will need to be deposited. Any ratio larger than 2 was determined to be unacceptable to the project.

		Overfill Ratio	
Value function type	Metrics:	ratio	
		Ratio Value	Normalized Value
	Min	1	1
	Max	2	0
Linear			



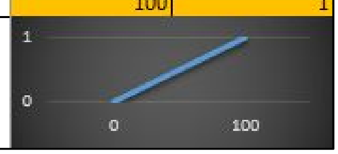
- The lower limit for Conveyance Distance was set at 3 nautical miles as that is the shortest straight-line distance between the shore and borrow areas (Site C). Because this is the shortest distance, this value represents the highest utility. As distance increases, utility steadily decreases up to 20 nautical miles. Sites beyond this distance are determined to be equally undesirable.

		Conveyance Distance	
Value function type	Metrics:	nautical miles	
		Distance Value	Normalized Value
	Min	3	1
	Max	20	0
Linear			



- Percent Yield, like the criteria that utilize 5-point scales, was chosen to be maximized. The closer the yield is to 100%, the less useable material will be left at the site. For this reason, higher percentage values equate to higher utility.

		% Yield (due to site obstructions)	
Value function type	Metrics:	%	
		Percent Value	Normalized Valu
	Min	0	0
	Max	100	1
Linear			



- The two criteria that did not utilize the Linear Function (Total Dredging Time and Expected Permit/Coordination Time) were described using a Piecewise Linear Function. Project managers understandably prefer a shorter project time, because the longer the total operating time including dredging delays (e.g. safety, weather delays, dredging windows, etc.), the more costly the project is to the dredging contractor. It was decided that anything more than 10 weeks for dredging time or 5 months for permitting time was unacceptable. Up until that limit however, utility gradually decreases as time increases. In the case of total dredge time, small increases have minimal impact on the project outcome, but larger increases in time have greater negative impacts. The negative impacts are due to the dredge time extending beyond the limits of the available window that avoids spawning and migrating period for important species.

		Total Dredging Time (including expected project delays due to safety, windows, etc.)	
Value function type	Metrics:	*weeks*	
		Time Value	Normalized Valu
Piecewise Linear	Piece 1 (Lowest Value)	1	1
	Piece 2	2	0.95
	Piece 3	4	0.85
	Piece 4	6	0.65
	Piece 5	8	0.35
	Piece 6	10	0
	Piece 7	12	0
	Piece 8		
	Piece 9		
	Piece 10		
	Piece 11		
	Piece 12 (Highest Valu		

weeks

		Expected Permit/ Coordination time (e.g. due to tribal & jurisdictional issues)	
Value function type	Metrics:	*months*	
		Time Value	Normalized Valu
Piecewise Linear	Piece 1 (Lowest Value)	0	1
	Piece 2	1	1
	Piece 3	2	0.9
	Piece 4	3	0.65
	Piece 5	4	0.35
	Piece 6	5	0
	Piece 7	6	0
	Piece 8		
	Piece 9		
	Piece 10		
	Piece 11		
	Piece 12 (Highest Valu		

months

Because project managers decided against using measured characteristics for the Color, Texture, and Mineralogy/Composition criteria, the Linear with Peak Function was not utilized in this implementation of the model. It is possible this function might be used for other criteria in certain circumstances, but none were necessary for this project.

Alternative Scores Tab

Most performance scores were determined from information gathered during borrow site identification and initial investigations. When there was lack of data, project manager consulted colleagues, academics, state liaisons, and industry experts to determine best estimates.

The information on performance for each alternative is shown in Table 2. Notice the scoring methods that were employed in the initial score assignment; many do not align with those utilized in the tool. In order to run the tool, these user-generated, qualitative descriptions had to be translated into the numerical values needed to run the tool. The Scoring Rubrics provided in the Sand Source Selection tool were used to make this conversion. The resulting numerical scores are shown in Table 3. A description of the scoring process is described below.

There were six criteria that received "null scores" (i.e. their scores were the same across all alternatives, resulting in effective exclusion from the model). Null scores may be changed if additional information is gathered in later stages of the project to differentiate between alternatives.

- It was determined that Presence of Contaminants would not be a problem at any of the borrow sites due to no history of in situ contamination or spills, no local waste outlets, no history of use of the area for a disposal site and no clear physical evidence to suggest otherwise.
- Mineralogy and Composition was not formally investigated due to the high cost of the analysis, but brief visual investigations supported the assumption that mineral composition was likely close enough between the project area and each of the borrow sites that it would not favor one alternative over another.
- Possible Conveyance Modes for site alternatives were advised by dredging industry experts. Because all proposed Borrow Sites are over 2 miles from the project area, conveyance through a hydraulic pipeline was determined to be unsuitable. As a result, experts predicted that trailing suction hopper dredges, towed barges, or self-propelled barges were equally likely to be employed across all site alternatives, depending on the type of dredge utilized.
- Water Depth and Bathymetry was determined not to pose a problem to dredging operations, so for the sake of simplicity each alternative received the highest score.
- Although not scientifically investigated due to the extremely high cost of the endeavor, marine ecologists from NOAA suggested that the required Time for Environmental Recovery would likely not vary drastically between sites due to their close proximity. Given the type and health of the ecosystems in the region, and the fact that these borrow sites are relatively small in the greater picture, the experts gave the rough estimate of 3-4 years for total environmental recovery. At this early stage, project managers chose to nullify this criterion, but expect that more accurate scores will be assigned when environmental impact assessments are performed later in the study.
- There was no evidence that any alternative would Support Future Accretion of Useful Material more than another. However, if information arises in later project stages, scores may be assigned.

The Scoring Rubric Tab was to determine a score on a five-point scale to describe the relative performance for the 11 criteria that were described this way. Scores for each criterion had to be translated by project managers from the users' original descriptions onto the 5-point scale. When assigning scores for the alternatives that encompassed multiple borrow sites, an average of the characteristics was used with consideration given to the proportion of total material in each site.

- Color scores were determined through visual comparisons between small samples of sand from each borrow site. Site A appeared to be an exact match to the project location, Site C was fairly close but a slightly different color value, and Site B was a similar but darker value than C and therefore received the lowest score.

Color			
A	A+C	B	C+B1
very good	good	pretty good	pretty good
5	4	3.5	3.5

- Some Texture characteristics were quickly measured from the site samples, but the small size of the samples made a formal analysis difficult at this point in the project. Resulting scores were mainly determined by subjective investigation of sand texture. Investigators basically agreed that Site A once again was almost an exact match to the existing sand at the beach nourishment sites, Site C was very close, and Site B was acceptable but seemed to have larger sand grains that were significantly sharper to the touch.

Texture			
A	A+C	B	C+B1
very good	close enough	medium	good
5	4.5	3	4

- Residual hazard was concluded to be low at all of the sites but slightly higher at Site C. Site C is expected to have some unmapped but existing debris associated with the archaeological site and previous oil and gas exploration in the area.

Residual Hazard			
A	A+C	B	C+B1
unlikely	possible in C	unlikely	possible in C
4	3	4	3

- The Portion of Site Obstructions Clearable or Controllable describe the degree to which obstructions can be managed. If the oil and gas pipeline is no longer in use, the owner can be asked to remove it, or ensure that it is covered to the required depth. The EFH and shipwreck cannot be substantially managed, but are also not significant impediments to dredging. Alternative 3 (Site B) receives the highest score.

Portion of Site Obstructions Clearable/Controllable			
A	A+C	B	C+B1
moderate	moderate	good	moderate
3	3	4	3

- Determination of Stakeholder Acceptability and Community Opinion was influenced mainly by expected interference with the Essential Fish Habitat. Because commercial and recreational fishing are a major contributor to the local economy, community opinion was strongly against dredging in Site A because of concern for impacting species of interest in the EFH. For this reason, Alternative 1 (Site A) received the lowest score and Alternative 2 (A+C) only scored slightly better. There was no objection from stakeholders or the community to dredging in Sites B or C.

Stakeholder Acceptability & Community Opinion			
A	A+C	B	C+B1
concerning	slightly concerning	not concerning	not concerning
2	3	5	5

- The Spatial Extent of Environmental Impact was determined mainly by the proposed dredging area and the proximity of potential sensitive habitats. The main direction of flow in the region is to the southwest. Plumes from dredging at Site A are not expected to have significant impact on the EFH, nor are plumes from dredging at other sites. The substrate between the sites is largely exposed bedrock. The greatest impact will be to benthic communities at the sites. Site B has the largest footprint and Site A has the smallest.

Spatial Extent of Environmental Impact			
A	A+C	B	C+B1
smallest	medium	largest	fairly large
4	3	1	2

- Evaluation of the Intensity of Environmental Impact was done using a previous assessment of the benthic communities. Although the communities have likely evolved since the survey was completed, the relative difference between the sites is expected to remain the same. Since sand recovery will involve complete removal of the shoal surface, areas with low biodiversity and low abundance of benthic organism and habitat are expected to have a lower impact (and therefore high scores) than areas with more abundance and more diversity.

Intensity of Environmental Impact			
A	A+C	B	C+B1
High	fairly high	fairly low	medium
1	2	4	3

- The Spatial Extent of Physical Impact was determined solely on the total dredgeable area calculated for each alternative. Alternative 1 is the smallest, Alternatives 2 and 4 are the largest and roughly the same size, and Alternative 3 was mid-sized, relative to the other alternatives. It was predicted that because all of the borrow sites were deeper than 40 feet, there would be no effects on wave regime, and physical impacts typically do not extend beyond 1,000 feet from dredging location, thus changes in the erosion rates at the beach are not likely.

Spatial Extent of Physical Impact			
A	A+C	B	C+B1
smallest	large	medium	large
4.5	3	3.5	3

- Examinations of the Intensity of Physical Impact were done by comparison of the volume of sediment to be removed compared to the amount available for each alternative and the shape and formation of existing sand features. If Site A is chosen, all 1.2 MCY of available sediment would require removal for the initial nourishment project, representing the highest dredging intensity by far. In contrast, less than half of the available sediment will be removed if Alternatives 2 or 4 are chosen (48% and 45% respectively), and Alternative 3 only slightly over half (57%). However, the project team decided this may not fully reflect the intensity of physical impacts due to the non-uniform distribution of sand resources within Site B. Deposits in this area gradually deepen towards the eastern side, where the sea-floor then slopes off significantly for miles. Dredging in area B1 will have a higher total physical impact due to the possibility of sediment loss to the east both during and after dredging activities. It is expected that dredging in area B2 as well, may contribute to the "collapse" of this sand formation.

Intensity of Physical Impact			
A	A+C	B	C+B1
fairly high	fairly low	medium	medium-low
2	4	3	3.5

These factors, like many others that need to be considered in the scoring stage, can be contradictory; it is up to the assessor to sum the positive and negative aspects of each alternative for each criterion.

- The Likelihood of Reduced Future Use due to Surface Armoring was ascertained through brief investigations of course gravel and boulder content visible in the substrate. Armoring at Site A was determined to be very unlikely because the site appeared to have no gravel content. Site B, although not abundant, had more gravel visible on the seafloor. Boulders at Site C were common on the western side, and coarse gravel was visible throughout the area, which greatly increased the probability of surface armoring for the two alternatives that included this site. An examination of the distribution of gravel and boulders throughout the depth of extractable material, as well as the presence and depth of bedrock within each site would strengthen these estimations, and may be done at a later project stage.

Likelihood of Surface Armoring			
A	A+C	B	C+B1
very unlikely	improbable	unlikely	possible
5	3.5	4	3

- The Likelihood of Reduced Future Use due to Creation of Challenging Corners or Geometry was determined through consultation with dredging industry experts. Buffer zones for obstructions and borrow site dimensions were examined for areas where dredges may have problems fully extracting material. The shape of Site A, and the overlapping EFH on the western side of Site A, made extracting a large portion of suitable material outside of the buffer zone impractical. The shipwreck, whose circular buffer zone extends into the center of the western side of Site C, also played a large role in creating inaccessible pockets of dredgeable material. For these reasons, Alternatives 1 and 2 received the lowest score. Dredging methods were not known to the project manager at this early stage of the project, but inclusion of this information would strengthen these scores.

Likelihood of the Creation of Challenging Geometry			
A	A+C	B	C+B1
high	high	low	moderate
2	2	4	3

- Evidence for the Changed Ability for Sediment to be preserved was provided through information gathered during initial site investigations. There was no indication that dredging in Sites A + C would result in alteration of sediment preservation, but the slope of Site B gave project managers concern. Area B1, the side with deeper deposits, lies just to the west of a significantly steeper slope that extends for miles. It is a reasonable assumption that dredging at the bottom of this slope could enable sediment deposited throughout Site B to be transported out of the borrow site to the east during dredging activities or future disturbances (e.g. hurricanes, earthquakes), making them unavailable to future dredging efforts. For this reason, Alternative 3 received the lowest score for this criterion because dredging in both Areas B1 + B2 has the highest probability of affecting preservation. Alternative 4, which would involve dredging in Area B1, was scored only slightly better.

Changed Ability for Sediment to be Preserved			
A	A+C	B	C+B1
probably won't change	probably won't change	probably will change	may change slightly
4	4	2.5	3

The remaining 6 criteria relied on characteristics that were measured during initial site investigations or concluded through research. Project managers were able to employ their measurement units directly in the tool.

- Percentage measurements for Heavy Mineral Content were obtained from a 2003 USGS investigation of the area that was performed to assess the economic viability of mining coastal and OCS sand resources for titanium extraction. The study suggested that heavy mineral content in the region covering the borrow sites ranged from 0.5% in the northern part of the region to 1.2% towards the south, with a semi-regular gradation in between. These concentrations were determined to be too low for mining to be economically feasible (> 5%). Estimated percentages were assigned for each borrow site, and values for alternatives comprised of multiple zones were averaged across sites. Including additional heavy minerals in the analysis would strengthen results, but this information was not available in the early project stages.

Heavy Mineral Content			
A	A+C	B	C+B1
0.6	0.85	0.9	1.1

- The Overfill ratios for each alternative were ranked by examining the percent of fine sediment present in the small samples taken from each borrow site. Site A had almost no fines, and so it was assumed that almost no overfill would be required. Site C had more fines than Site A, but not enough to cause concern. However, Site B contained a large portion of fine sediment, resulting in a higher overfill ratio required for Alternative 4 and even higher for Alternative 3. A project planner estimated the associated overfill ratios for each alternative.

Overfill			
A	A+C	B	C+B1
1.05	1.1	1.3	1.2

- Conveyance Distance was measured in nautical miles through the use of GPS and satellite imagery, taking into account indirect routes made necessary by the EFH.

Conveyance Distance			
A	A+C	B	C+B1
5.2	5.2	4	4.6

- Percent Yield was calculated by dividing the approximate quantity of accessible material by the total quantity available. Estimations of sediment distribution within each site and the use of GIS software to map site obstructions were applied to calculate the quantity of accessible material.

Percent Yield			
A	A+C	B	C+B1
65	65	90	80

- For this project the Total Dredging Time (in weeks), was calculated based solely on the surface area to be dredged, assuming the same dredge type would be utilized for each site alternative and that it is more efficient to dredge a smaller footprint to a deeper depth than a larger surface area. Alternative 1 was the smallest, and so would take the least time. Alternatives 2 and 3 were similar enough in size that the expected dredging time would likely be the same. And Alternative 4 is the largest, resulting in the longest total dredging time. If a hopper dredge is selected, the values should be revised to take into account the transport distance to the placement site.

Total Dredging Time			
A	A+C	B	C+B1
2	4	4	4.5

- The Expected Permit and Coordination Time (in months) was highest for Alternative 1 because of the interference with the EFH and additional modeling that may be required before a permit can be issued. The other site obstructions may also lengthen the permitting and coordination time while plans for dredging activities are examined for compliance with buffer zones. Because Site B has the fewest and least intense site obstructions, it has the shortest expected time.

Expected Permit/Coordination Time			
A	A+C	B	C+B1
3	2	1.5	2

Table 2 – User Generated scoring information.

		Borrow Site Alternatives			
Criteria	Scoring Method	**A**	**A+C**	**B**	**C+B1**
Presence of Contaminants	binary	no	no	no	no
Heavy Mineral Content	%	0.6	0.85	0.9	1.1
Color	subjective scale	very good	good	pretty good	pretty good
Texture	subjective scale	very good	close enough	medium	good
Mineralogy / Composition	subjective scale	similar enough	similar enough	similar enough	similar enough
Overfill	ratio	1.05	1.1	1.3	1.2
Conveyance Mode	any restrictions?	same restrictions	same restrictions	same restrictions	same restrictions
Conveyance Distance (max)	nautical miles	5.2	5.2	4	4.6
Water Depth / Bathymetry	subjective scale	not a problem	not a problem	not a problem	not a problem
% Yield (due to site obstructions)	%	65	65	90	80
Residual Hazard	subjective scale	unlikely	possible in C	unlikely	possible in C
Portion of Obstructions Clearable/Controllable	fraction	moderate	moderate	good	moderate
Total Dredging Time (including expected delays)	weeks	2	4	4	4.5
Expected Permit/Coordination Time	months	3	2	1.5	2
Stakeholder Acceptability & Community Opinion	subjective scale	concerning	slightly concerning	not concerning	not concerning
Spatial Extent of Environmental Impact	subjective scale	smallest	medium	largest	fairly large
Intensity of Environmental Impact	subjective scale	High	fairly high	fairly low	medium
Time for Environmental Recovery	subjective scale	3-4 years	3-4 years	3-4 years	3-4 years
Spatial Extent of Physcial Impact	subjective scale	smallest	large	medium	large
Intensity of Physical Impact	subjective scale	fairly high	fairly low	medium	medium-low
Likelihood of Surface Armoring	subjective scale	very unlikely	improbable	unlikely	possible
Likelihood of the Creation of Challenging Geometry	subjective scale	high	high	low	moderate
Changed Sediment Preservation Ability	subjective scale	probably won't change	probably won't change	probably will change	may change slightly
Support of Future Accretion of Useful Material	subjective scale	unknown	unknown	unknown	unknown

Table 3 – Translated scoring information entered into the tool.

		Borrow Site Alternatives			
Criteria	Scoring Method	A	A+C	B	C+B1
Presence of Contaminants	binary	1	1	1	1
Heavy Mineral Content	%	0.6	0.85	0.9	1.1
Color	5-pt score for goodness of fit	5	4	3.5	3.5
Texture	5-pt score for goodness of fit	5	4.5	3	4
Mineralogy / Composition	5-pt score for goodness of fit	4	4	4	4
Overfill	ratio	1.05	1.1	1.3	1.2
Conveyance Mode	5-pt score for # methods allowed	3	3	3	3
Conveyance Distance (max)	nm	5.2	5.2	4	4.6
Water Depth / Bathymetry	5-pt score for goodness of fit	5	5	5	5
% Yield (due to site obstructions)	%	65	65	90	80
Residual Hazard	5-pt score for goodness of fit	4	3	4	3
Portion of Obstructions Clearable/Controllable	5-pt score for goodness of fit	3	3	4	3
Total Dredging Time (including expected delays)	weeks	2	4	4	4.5
Expected Permit/Coordination Time	months	3	2	1.5	2
Stakeholder Acceptability & Community Opinion	5-pt score for goodness of fit	2	3	5	5
Spatial Extent of Environmental Impact	5-pt score for goodness of fit	4	3	1	2
Intensity of Environmental Impact	5-pt score for goodness of fit	1	2	4	3
Time for Environmental Recovery	5-pt score for goodness of fit	4	4	4	4
Spatial Extent of Physcial Impact	5-pt score for goodness of fit	4.5	3	3.5	3
Intensity of Physical Impact	5-pt score for goodness of fit	2	4	3	3.5
Likelihood of Surface Armoring	5-pt score for goodness of fit	5	3.5	4	3
Likelihood of the Creation of Challenging Geometry	5-pt score for goodness of fit	2	2	4	3
Changed Sediment Preservation Ability	5-pt score for goodness of fit	4	4	2.5	3
Support of Future Accretion of Useful Material	5-pt score for goodness of fit	3	3	3	3

Weights Tab

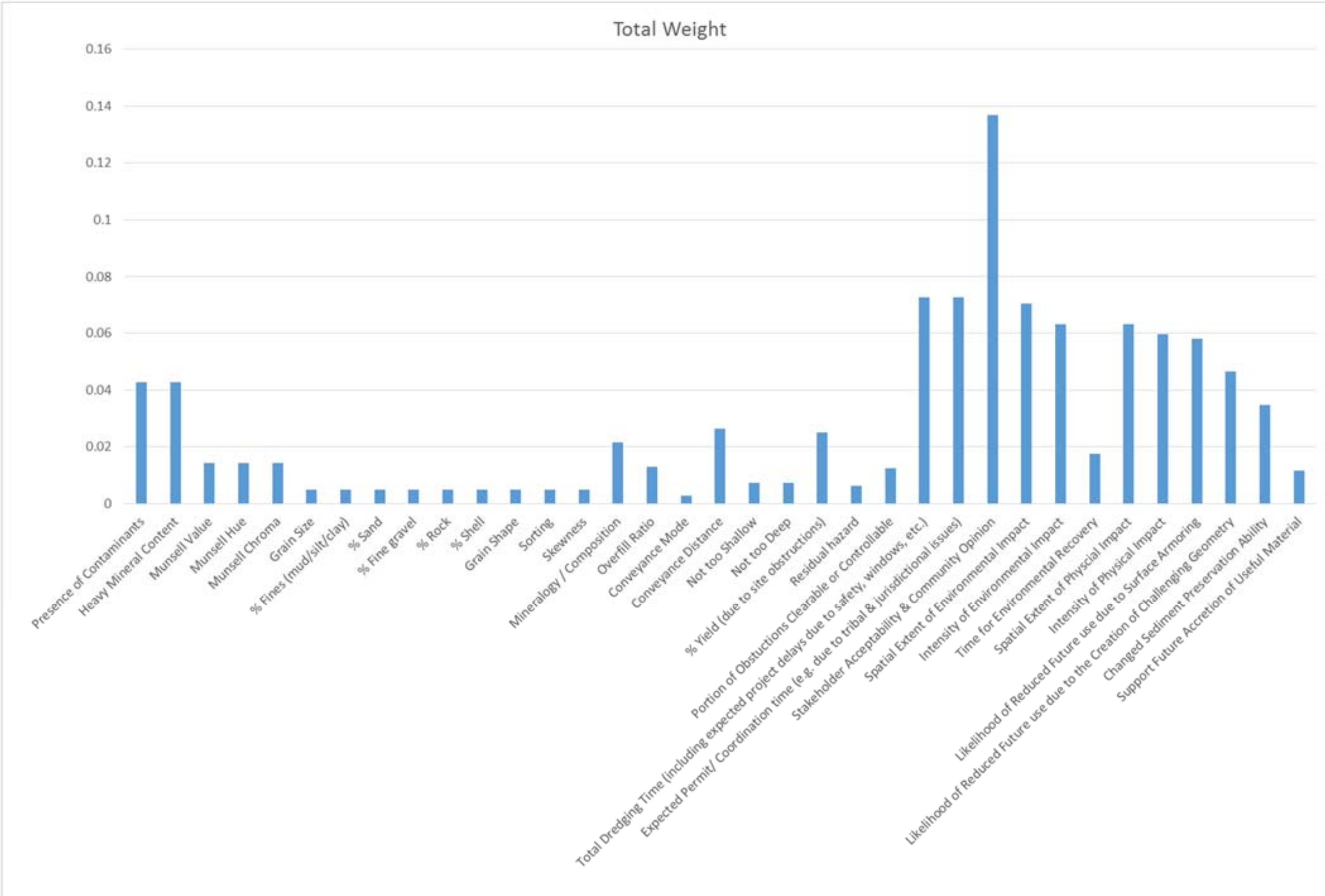
For the Sandy Shoal project, project managers developed weights using sand source selection experience and knowledge of the most important local concerns in order to devise an accurate weighting distribution for the implementation of the tool. Groups of criteria, where there was difficulty in assigning scores, were first ranked in order of importance.

The complete set of weights that were agreed upon during this early stage of the project are listed in Table 4. However, as more information is gathered while the project continues, these weights may be altered in later project stages to reflect any changes. Notice weights for omitted and null criteria are still calculated and displayed though they have no effect on resulting recommendations.

Figure 4 shows how the current weighting scheme results in relative contribution of each lowest-level criterion to the overall objective. In this view, the stakeholder engagement criterion seems to have the greatest influence. However, the stakeholder engagement does not have any sub-criterion. When the other sub-criterion are aggregated, the relative contribution of each main-level criterion is as shown in Figure 5.

Table 4 – Weight distribution utilized for the tool.

Main Criteria (Level 1)	RANK	SCORE	WEIGHT	Sub-Criteria (Level 2)	RANK	SCORE	WEIGHT	Sub-Sub-Criteria (Level 3)	RANK	SCORE	WEIGHT	Total Weight
Sediment Characteristics*	3	75	0.20548	Presence of Contaminants		10	0.20833					0.042808219
				Heavy Mineral Content		10	0.20833					0.042808219
				Color		10	0.20833	Munsell Value		1	0.33333	0.014269406
								Munsell Hue		1	0.33333	0.014269406
								Munsell Chroma		1	0.33333	0.014269406
				Texture		10	0.20833	Grain Size		1	0.11111	0.004756469
								% Fines (mud/silt/clay)		1	0.11111	0.004756469
								% Sand		1	0.11111	0.004756469
								% Fine gravel		1	0.11111	0.004756469
								% Rock		1	0.11111	0.004756469
								% Shell		1	0.11111	0.004756469
								Grain Shape		1	0.11111	0.004756469
								Sorting		1	0.11111	0.004756469
								Skewness		1	0.11111	0.004756469
				Mineralogy / Composition		5	0.10417					0.02140411
				Overfill Ratio		3	0.0625					0.012842466
Borrow Site Controls	2	85	0.23288	Conveyance		2	0.125	Conveyance Mode	2	1	0.09091	0.002646326
								Conveyance Distance	1	10	0.90909	0.026463263
				Water Depth / Bathymetry		1	0.0625	Not too Shallow		1	0.5	0.007277397
								Not too Deep		1	0.5	0.007277397
				Site Obstructions		3	0.1875	% Yield (due to site obstructions)		4	0.57143	0.024951076
								Residual hazard		1	0.14286	0.006237769
								Portion of Obstuctions Clearable or Controllable		2	0.28571	0.012475538
				Total Dredging Time (including expected project delays due to safety, windows, etc.)		5	0.3125					0.072773973
				Expected Permit/ Coordination time (e.g. due to tribal & jurisdictional issues)		5	0.3125					0.072773973
Stakeholder Acceptability & Community Opinion	5	50	0.13699									0.136986301
Environmental & Physical Concerns	1	100	0.27397	Spatial Extent of Environmental Impact	1	100	0.25641					0.070249385
				Intensity of Environmental Impact	2	90	0.23077					0.063224447
				Time for Environmental Recovery	4	25	0.0641					0.017562346
				Spatial Extent of Physcial Impact	2	90	0.23077					0.063224447
				Intensity of Physical Impact	3	85	0.21795					0.059711978
Future Site Usability	4	55	0.15068	Likelihood of Reduced Future use due to Surface Armoring	1	5	0.38462					0.057955743
				Likelihood of Reduced Future use due to the Creation of Challenging Geometry	2	4	0.30769					0.046364594
				Changed Sediment Preservation Ability	3	3	0.23077					0.034773446
				Support Future Accretion of Useful Material	4	1	0.07692					0.011591149



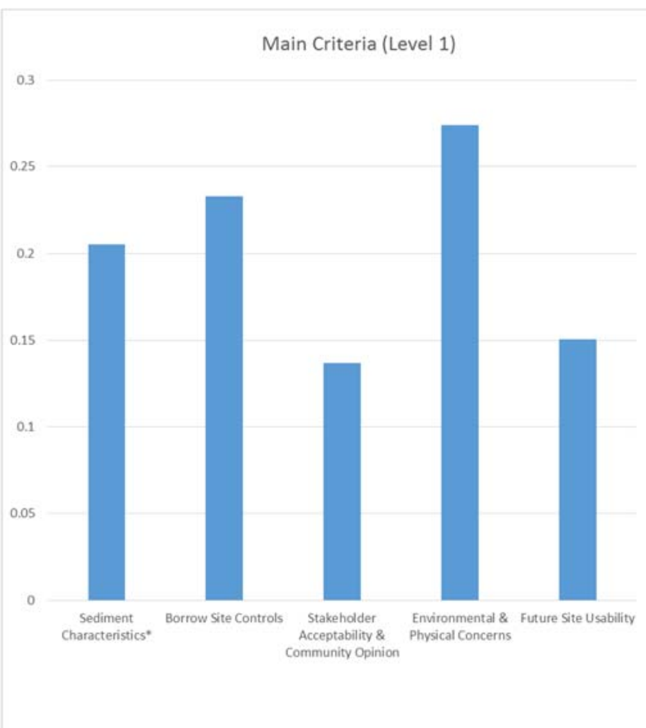


Figure 4 (above) — Total contribution of each bottom-tier criterion to the overall source selection objective, according to the weighting scheme described in Table 4.

Figure 5 (left) — Total contribution of top-tier criterion to the overall source selection objective, according to the weighting scheme described in Table 4.

Results Tab

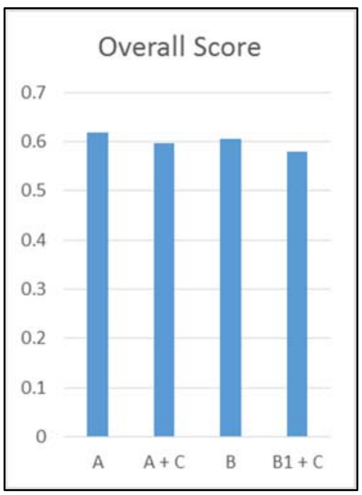
Table 5 reports the overall scores calculated by the tool as well as the sub-scores for each of the top-level criteria. Figure 6 provides graphs of the scores for visual comparison.

The results show that Alternative 1 (Site A) marginally outcompetes the other options overall for the Sandy Shoal beach nourishment project. Looking at the scores of the main level criteria in Figure 6, it is interesting to note that the alternative ranking for Sediment Characteristics (b) is exactly opposite to the rankings of the alternatives for Borrow Site Controls (c). The situation where the best sand match is also the most challenging to obtain is a reason why project managers may turn to a tool like this to provide additional insight. Also of note, is that while Environmental and Physical Controls were identified as one of the most important factors (Figure 5), the scores for all 4 alternatives are very similar and so this is not a criterion that is driving the final outcome. A challenge for the project manager moving forward will be to communicate the benefits of Alternative 1, especially as it received the lowest estimated stakeholder acceptability. The results of this tool can help document that stakeholder concerns were taken into account, but that Site A performs well on Future Site Usability, and Environmental and Physical Concerns, in addition to being a good sand type match. In fact, in selecting Alternative 1, the project team will be accepting the trade-off of more challenging Borrow Site Controls for the benefits of long-term sustainability.

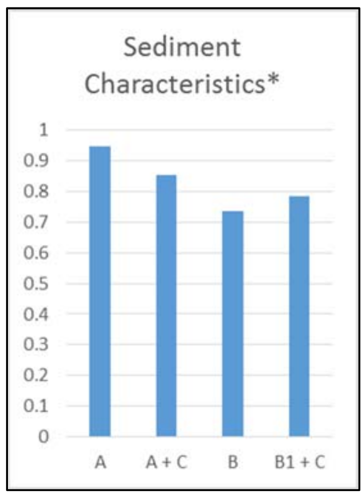
Project managers plan to explore different weighting schemes in order to test the sensitivity of the results. If the pattern emerges that Alternatives 2 and 4 always underperform the other alternatives, the project team can feel confident moving forward with initial feasibility and design of Alternatives 1 and 3 only.

Table 5. Results for the Sandy Shoal project showing the overall scores for each alternative, as well as scores for the main-level criteria for each alternative.

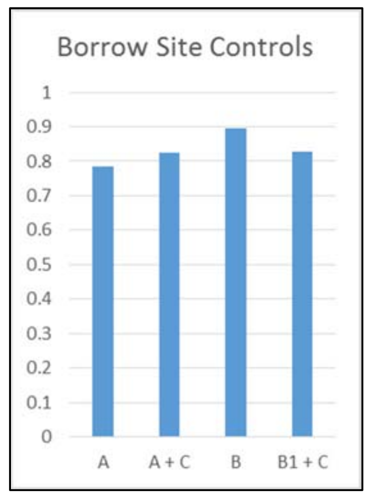
Names of Borrow Site Alternatives	Quantity Available in Millions of Cubic Yards (MCY)	Approximate or Estimated Cost	Overall Score	Sediment Characteristics*	Borrow Site Controls	Stakeholder Acceptability & Community Opinion	Environmental & Physical Concerns	Future Site Usability
A	1.2	$5.00/CY	0.619	0.95	0.78	0.03	0.50	0.67
A + C	2.5	$4.05/CY	0.597	0.85	0.82	0.07	0.51	0.53
B	2.1	$2.60/CY	0.605	0.74	0.89	0.14	0.47	0.64
B1 + C	2.4	$2.30/CY	0.580	0.79	0.83	0.14	0.48	0.50



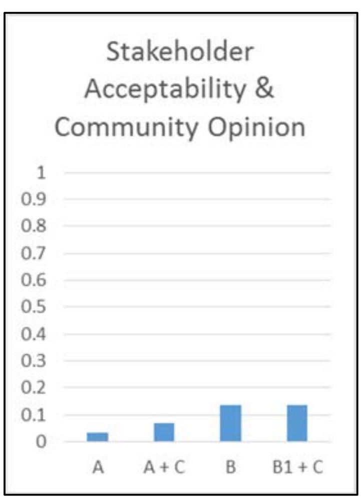
a. Overall Scores



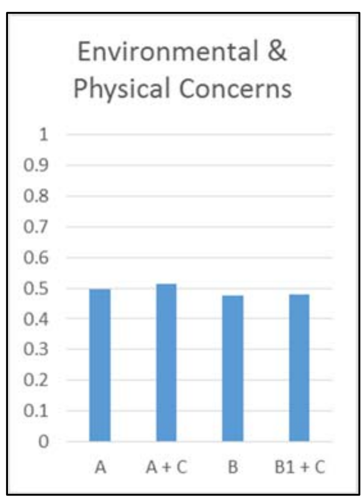
b. Criterion 1 Scores



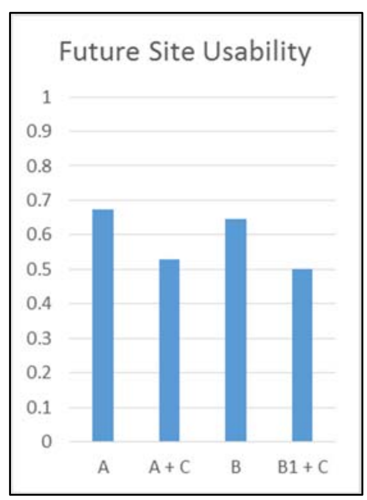
c. Criterion 2 Scores



d. Criterion 3 Scores



e. Criterion 4 Scores



f. Criterion 5 Scores

Figure 6 – Overall Scores

Appendix D. Task 4 Deliverables

D-1 SSMP—Canaveral Shoals II

Canaveral Shoals II Sand Source Management Plan Utilizing Multi-Criteria Decision Analysis (MCDA) in a Sand Source Selection Tool (SSST)

Prepared for:

U.S. Department of the Interior
Bureau of Ocean Energy Management
Marine Minerals Program
IA No. M15PG00033

Prepared by:

Jennifer L. Coor, Ph.D., P.G.
U.S. Army Corps of Engineers

January 2017

Executive Summary

The management of Outer Continental Shelf (OCS) sand resources is often a multifaceted challenge due to various engineering and design requirements, economic and environmental considerations, and stakeholder needs that must be balanced. The Canaveral Shoals II (CSII) sand source, located offshore Cape Canaveral, Brevard County, Florida, presently contains approximately 20 million cubic yards of beach compatible sand, and it is used to restore and periodically nourish the Federal and non-federal beaches of Brevard County.

The primary value of the sand source selection tool (SSST) is in helping project managers make more sustainable and long term borrow area use decisions within offshore sand resource areas. The tool will do this by providing output that includes both relative scores for different factors for each sub-region of a borrow area, and a list of recommended practices. The tool could assist in decision-making that mitigates the effects of cumulative dredging on the same sediment source while maximizing use of that finite resource.

The insights and recommendations from the SSST are complementary to (rather than redundant of) the detailed processes that USACE and non-federal entities already have in place for sand source identification and technical engineering on an individual project basis. The results of the SSST show that CSII is both a suitable and sustainable source of sand for the Brevard County beaches.

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Introduction

Outer Continental Shelf (OCS) sand resources are finite and require careful management. The typical beach nourishment and/or coastal restoration project, especially in Florida, involves an initial large-scale construction phase followed by smaller-scale, regularly scheduled maintenance cycles at regular intervals. The sediment used for initial construction and subsequent maintenance is often dredged from the same sand resource area, which can equate to frequent dredging of the same or adjacent seafloor for a period of 50 years or longer, though most OCS leases are for one-time events. In coastal areas where sand is scarce and multiple use conflicts are common, a single sediment source could also be used by multiple stakeholders for the construction of several adjacent beach fill or coastal restoration projects. Large volumes of sand may also suddenly be necessary to recover from severe storms such as Hurricane Sandy in 2012. Both circumstances can lead to rapid resource depletion and the need to identify, characterize, and delineate additional sediment sources.

Different types of sand bodies are dredged to different cut depths over various footprints, creating complex dredge patterns and increased project costs. In many instances, the approach to managing dredging intensity (location, duration, and frequency) is not systematically planned and transport distance and dredge productivity is the primary determinant of where dredging occurs. Fill performance, funding availability, environmental construction windows, and dredge plant availability typically drive when and where dredging occurs. This current approach is not conducive to long term, responsible and sustainable resource management. However, dredging simple dredge patterns with reasonable distances from the placement site is conducive to long term planning and project costs.

Dredging can have both direct and indirect effects on physical, biological, and archaeological resources. Each dredging event diminishes not only the availability of sand resources, but the profile of the sand body or sheet, which can potentially cause physical effects, such as changes in local and residual hydrodynamics, substrate composition, and the morphologic response of the sand body. These interrelated effects, which can be magnified during multiple dredging events, could disturb the ecosystem function of sensitive biological habitats and resources in the vicinity of the sediment source. Such physical changes could also cause unanticipated indirect impacts on archaeological resources that are otherwise protected by exclusion zones.

The environmental effects from recurrent dredging of the same sand source are a common concern of environmental resource managers. As such, BOEM has worked with National Marine Fisheries Service (NMFS) Habitat Conservation Division and their federal partners to develop site-specific and regional strategies to minimize cumulative dredging intensity and frequency, thereby reducing potential impacts on Essential Fish Habitat (EFH), benthic communities, and federally managed fish species. The preparation of sediment source management (SSM) plans would support BOEM’s resource management mission, and could help focus National Environmental Policy Act

(NEPA) analysis, EFH consultation, and National Historic Preservation Act (NHPA) Section 106 coordination to promote more desirable environmental and stewardship outcomes.

The management of OCS sand resources is often a multifaceted challenge due to various engineering and design requirements, economic and environmental considerations, and stakeholder needs that must be balanced. This OCS management strategy would likely benefit from advanced planning using a systematic framework incorporating long-term project design, engineering, and economic requirements while considering sand resource availability and minimizing environmental impacts.

Multi-Criteria Decision Analysis

Environmental decision makers often deal with problems that involve multiple stakeholders that have different priorities and objectives. Such decision makers typically need to utilize multidisciplinary knowledge that combines natural, physical, and social sciences, politics, and ethics. Decision makers for environmental management projects typically receive input from four categories: scientific research, modeling/monitoring results, risk analysis, cost/benefit analysis, and stakeholder preferences. However, a systemic methodology to combine these quantitative and qualitative inputs to rank project alternatives has yet to be fully developed for environmental decision making. As such, multi-criteria decision analysis (MCDA) tools can be applied to environmental decision making by quantifying value judgments based on multiple criteria. Scoring different project alternatives using a systematic analysis which overcomes the limitations of unstructured individual or group decision making facilitates the identification of a preferred course of action.

MCDA is typically utilized for problems of sorting alternatives into various groups, or categories, and screening alternatives. The tools within MCDA allow for the ranking of alternatives, selecting the “best alternative” from a given set of alternatives, and designing a new action or alternative to meet project goals. Two primary methodologies within the MCDA approaches include value functions and outranking. Value functions rely on the development of utility functions that describe the benefit obtained from each increment of each decision criterion, while outranking directly ranks alternatives by assessing if there is enough information to say that one is better than, or at least as good as, another. Adaptive management utilizing MCDA allows the user to create a model of the system being managed, a range of management choices, monitor and evaluate the possible outcomes, a mechanism for incorporating lessons learned into future decisions, and a collaborative structure for stakeholder participation and learning. When utilizing MCDA with complex environmental decision-making, there will be trade-offs between divergent criteria. By utilizing and integrating MCDA principles and tools with existing decision-making approaches, including risk and cost/benefit analysis, decisions makers will be able to make more effective, efficient, and credible decisions.

Objectives

The goal of the present project is to develop a reproducible planning process to optimize the utilization of repetitive-use sediment sources. The process will use MCDA to evaluate and quantify technical, environmental, economic, and societal factors in context with potential management and monitoring measures. The planning process will use an efficient computer-based MCDA tool to facilitate SSM. The MCDA tool will assist in the development of SSM plans by quantifying or ranking evaluation factors. The tool will accept input data, when applicable, in formats used by BOEM. MCDA methods were utilized in order to select dredging opportunities which would reduce the impacts of dredging and lower the cost of environmental quality analysis and management. This methodology helps decision makers look at dredging from an integrated and holistic point of view, which may lead to more sustainable practices. MCDA is a powerful decision making support tool which does not replace the human thought process, but rather assists in decision making by removing biases and allowing for various factors to be weighted according to importance. Although the sites identified have distinguishing characteristics, there are many similarities that make the determination of best areas to use difficult. This Sand Source Selection Tool (SSST) will help document and assess the differences and similarities to identify a sustainable long-term project plan.

This document will discuss the background of the Canaveral Shoals II (CS II) offshore sand source, SSST inputs and methods, results of the SSST, discussion and interpretation of results, conclusions, and lessons learned. The background section includes the geographic setting of the region, the local geology, describes the sand source, and describes and quantifies (when possible) the input criteria to the SSST. The methodology section briefly discusses the steps for entering data into the SSST to gain meaningful results. The results section presents the data from the SSST. The discussion section describes the results and optimization in terms of best management practices and lessons learned. Lastly, the conclusion section summarizes any conclusions about optimizing the sand source.

Background

Geographic Setting

Brevard County is located along the central east coast of Florida bordering the Atlantic Ocean. Coastal features characterizing the county include Cape Canaveral to the north and Sebastian Inlet to the south with a barrier island connecting the two. The shoreline is relatively straight trending north-northwest to south-southeast, with the exception of the curvature created by the cape feature. The barrier island ranges in width from approximately 10 miles at the Cape to a few hundred feet just north of Patrick AFB. The upland base elevations and dune heights along the island range from 9 to 25 feet NGVD. The barrier island is separated from the mainland by the Mosquito Lagoon and

Banana River to the north and the Indian River Lagoon which runs the length of the county.

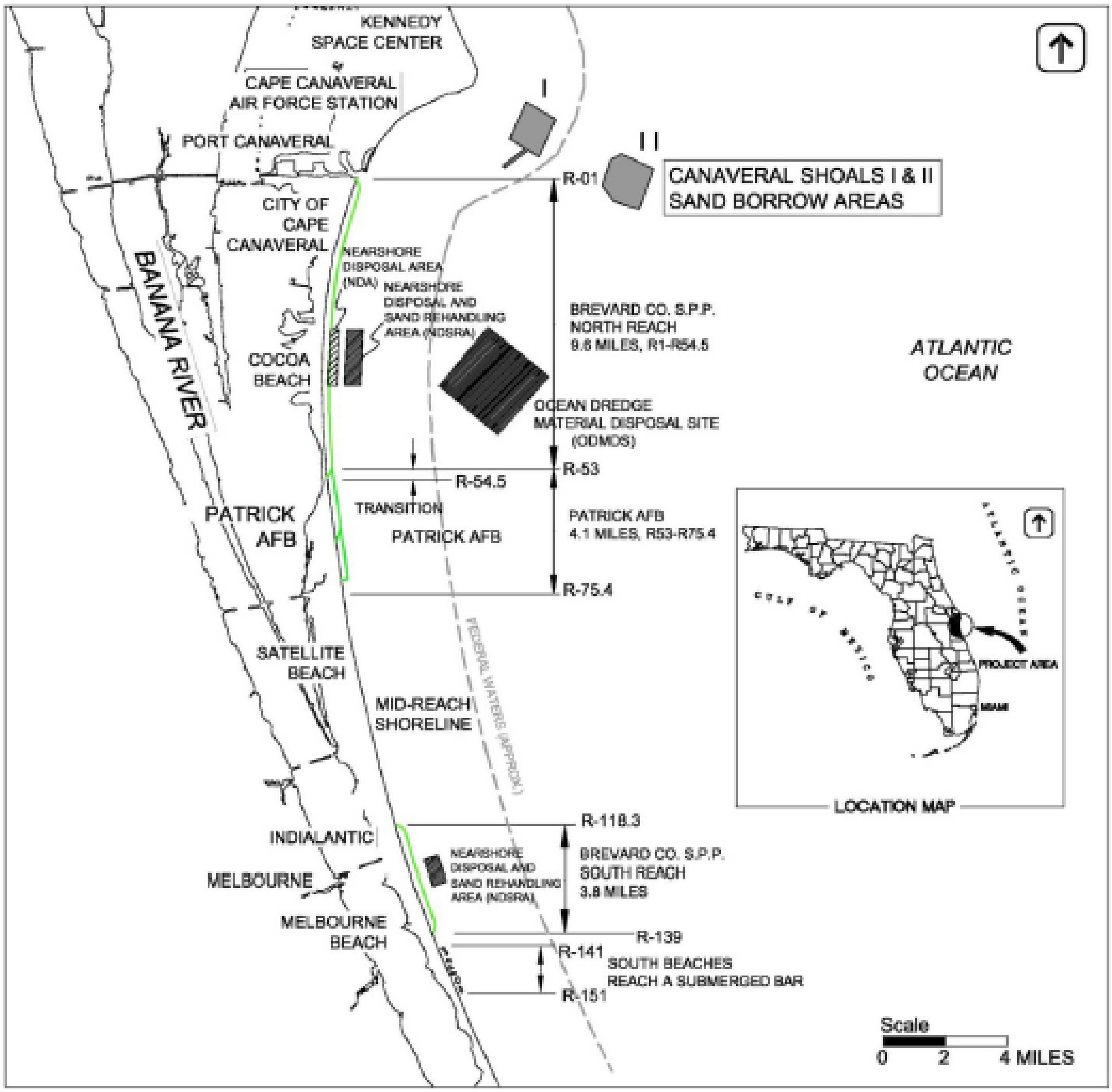

Figure 1. Location map of Canaveral Shoals II offshore sand source used to replenish Brevard County beaches.

Local Geology

The barrier beach sediments along Brevard County are primarily fine to medium grained quartz sand with varying percentages of silt and shell content. The sand is Holocene in age and is perched on older lithified coquina rocks of the Pleistocene Anastasia Formation. These coquina rocks, as well as Sabellarid worm rock, can be observed in the surf zone along the central portion of the county between Indialantic Beach and

Patrick AFB. In general, the dune height, foreshore slope, shell content, and mean grain size increase from north to south along the county (Olsen, 1989).

The borrow area is located on “Southeast Shoals,” a large and contiguous deposit of sand of littoral origin that extends approximately seven miles southeast of Cape Canaveral. This shoal, as well as the cuspate foreland of the Cape, is associated with modern littoral processes, dominated by southerly directed transport and southerly migration of the shoals and ridge system at False Cape attendant to the Holocene transgression. The modern coastal region, including the shoreface and inner continental shelf, is typified by medium Holocene sands overlying marine clay. The shoals are actively changing in configuration as evidenced by recent granular abrasion and by changes in bathymetry surveyed since 1878, and have generally broadened and thickened. Additional description of the geology of the area is found in Brown et al. (1962), Uchupi (1968), Meisburger and Duane (1969, 1971), Meisbuerger and Field (1975), and Randdazzo and Jones (1997).

<u>Sand Source</u>

Canaveral Shoals II (CSII) is an open ocean borrow site (**Figure 2**), roughly 5 miles from its nearest landward point (Cape Canaveral Air Force Station). It is approximately 6,000 x 6,500 feet with existing depths ranging from -11 to -42 feet. From the core borings and sediment analysis, the substrate of the site consists of beach quality sand (medium sand with a significant shell fraction) which meets the criteria of the Florida Sand Rule, Florida Administrative Code (F.A.C.) 62B-41.007(2)(j). CSII was first developed in the mid-1990’s, and had an total (unpermitted) volume of 34 mcy. The sand source was permitted in 1998 with a volume of 24.6 mcy due to the depth of the available geotechnical data, and after regular dredging and nourishment of Brevard County beaches and Patrick AFB, there is now approximately 20 million cubic yards of sand available in CS II (

Table 1).

Tides are semidiurnal, with a mean range of approximately 4 feet. The ocean waves have significant wave heights of 1 to 1.5 m, with 8 to 10 second wave periods being the most prevalent. East-northeast wave incidence is dominant (88% of annual offshore conditions), with modest southerly reversal principally during the summer months. Currents in the area are associated with tidal variations and local winds and vary in direction, with magnitudes typically less than 0.5 ft/s. Gulf Stream currents typically occur 15 to 40 miles east of the Cape and do not directly affect the subject area.

Table 1. Canaveral Shoals II subregions.

Dredge Option	Volume 1998 (mcy)	Volume 2014 (mcy)	Cut Depth (NAVD88)
A	6.01	4.41	-51.4
B	8.08	5.13	-49.4
C	7.71	7.16	-47.4
D	1.65	1.51	-45.4
E	1.14	2.17	-31.4
Total	24.52	20.38	N/A

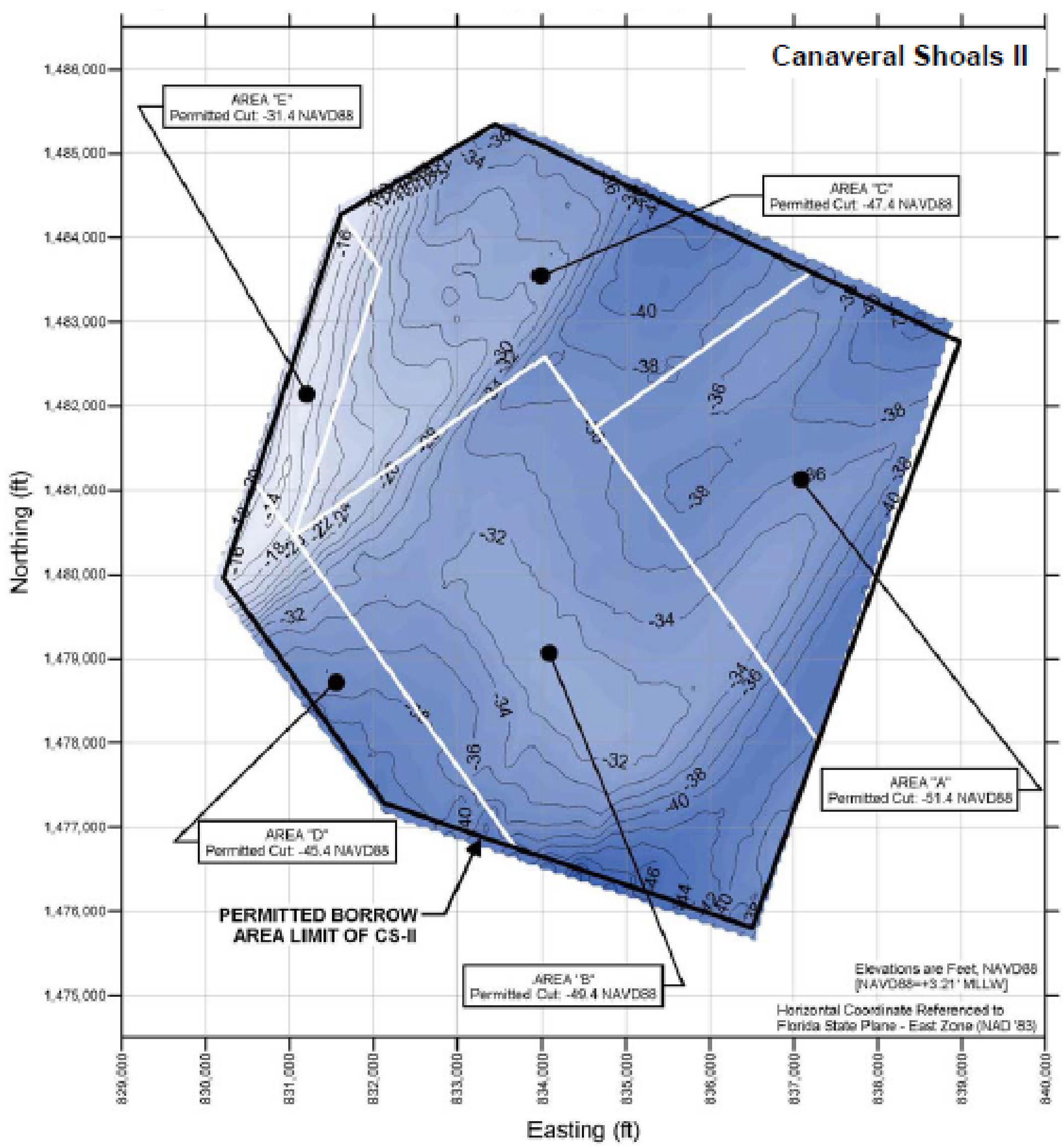

Figure 2. Canaveral Shoals II offshore sand source, showing subregions A through E, and associated permitted dredge depths.

Input Criteria for SSST

Sediment Characteristics

There were 30 vibracore borings collected in May 1998 to define the nature and depth of the seabed sediments. The vibracore boring logs, grain size analyses, and shell content analyses are summarized in Olsen (1998). From the core borings and sediment analysis, the surficial beach quality sand deposit is a minimum of 9 feet thick and is greater than 15 feet thick at 90% of the core locations. The total volume of beach compatible sand available within the site is estimated to be 34 million cubic yards when it was first developed in 1998. The sand is coarse relative to the local beach sand, having an overfill ratio of 1.0 for Brevard North Reach and South Reach, and contains a significant shell fraction. The median grain size of the samples ranges from 0.18 mm to 0.56 mm, with an average of 0.35 mm. The samples shell content (measured as percent calcium carbonate content) ranges from 34% to 53% with an average of 43%.

There is little to no trend in grain size or sorting variation with depth below the seabed, or with location across the borrow area. The borrow source is therefore considered to be fairly uniform, or homogenous, in sediment characteristics within the limits of the proposed borrow area.

Borrow Site Controls

The proposed action would occur between November 1 and April 30 in order to avoid most sea turtle nesting activities. The project would be constructed with one or more hopper dredges. Hopper dredging is expected to occur over approximately 163 days to obtain the necessary volume. The time estimated to complete each dredge and placement cycle, including idle time, is approximately 12 hours per load. Hopper dredging would be limited to a relatively small footprint in the designated borrow area. Efficient dredging practice entails excavating sand in 2 to 5 foot thicknesses along relatively straight and adjacent runs along the seabed. The sand dredged from the hydraulic suction heads would be discharged into the vessel's open hopper, and most of the seawater effluent would spill over the sides of the hopper. The hopper dredges would transport the dredged material a distance of approximately 24 miles to the pump-outs positioned approximately 0.5 to 1 miles from shore (USACE, 1998). The material would be pumped directly from the hopper barge via pipeline to the beach. The placement and relocation of the nearshore mooring buoys used during pump-out may involve the use of tender tugboats and a pipeline hauler or crane. Alternatively, dredged material may be placed by the hopper dredged into previously permitted rehandling areas and henceforth dredged from the rehandling area and pumped onto the beach via a cutterhead pipeline dredge. The permitted 4,500 feet alongshore by 2,450 feet wide rehandling area is located centrally along the project beach fill area between 2,600 feet and 5,050 feet from shore. Use of the rehandling area is at the Contractor's option.

The sand will be excavated from the borrow area by hopper dredge, transported to the project site, and either pumped from the hopper dredge to the beach nourishment area via pipeline or temporarily placed to a nearshore rehandling site from which it will be transferred to the beach nourishment area via cutterhead pipeline dredge.

A hopper dredge uses its pumps and seawater to hydraulically transfer sand from the hopper to the beach, where land-based equipment (bulldozer and front end loaders) spread and shape the sand. Sand dikes are pushed up to channel the pipe's discharged slurry and to promote the settling of sand upon the beach. The nearshore mooring buoy is typically moved to a new location after the beach fill has been constructed along 1 or 2 miles to either side of the offloading buoy.

Hopper dredging activity will be limited to a small area within the borrow area limits. Efficient dredging practice, and prudent design, entails dredging material in 2 to 5 feet thicknesses at a time along long, straight adjacent runs. Dredging the quantity estimated for the project's construction is anticipated to directly involve (impact) an area of about 8000 feet by 1500 feet.

An archaeological survey was conducted in 2001 and identified eight anomalies from a 1999 survey. These anomalies were determined to be debris from the space program and potentially significant cultural resources. Avoidance during dredging operations by at least 200 feet is recommended. Significant impacts to cultural resources I the borrow area are not anticipated provided avoidance is followed.

Environmental and Physical Concerns

Potential environmental impacts to the borrow area were determined through an Environmental Impact Statement (EIS) is 1996, and Environmental Assessments (EA) completed in 1998, 2005, and 2009. Benthic resources were determined to have possible mortality for nonmotile invertebrates in the immediate area of dredging. Temporary and localized defaunation from bottom disturbance, sub-lethal effects from elevated turbidity, burial, and habitat degradation. Long term suppression not expected due to dredging intervals and highly adaptive benthic assemblages. Recolonization of physically dominated environment expected to occur within 2-3 years. Fish and Essential Fish Habitat (EFH) may experience possible entrainment and sub-lethal effects from turbidity, noise, and burial. Effects are expected to be minor because of species mobility, avoidance behavior, and widespread occurrence of comparable habitat.

Possible trophic effects from benthic disturbance and locally reduced prey. EFH could be temporarily and locally physically disturbed by dredging or beach shaping activity. Long term suppression not expected due to dredging intervals and widely available habitat. Physical oceanography may be impacted by the modification of offshore bathymetry having minor effects in offshore sediment transport pathways, incident wave field, and longshore transport. Infilling anticipated over long-term. Threatened and endangered species may become entrained in the dredge leading to injury and mortality in sea turtles. Noise and vessel collision may lead to injury and mortality of marine mammals. Effects to marine turtles and marine mammals may be avoided or minimized with protective measures. Water quality impacts are temporary (elevated turbidity, decreased dissolved oxygen) to the water column in the borrow area.

Future Site Usability

The cumulative impacts for CS II, as currently proposed including the past and future use, are expected to be minor to possibly moderate. Of primary concern are long-term impacts to nearshore hardbottom near certain placement sites.

Methods

For the data from the Canaveral Shoals II sand source, a combination of the 5-point scale and measured characteristics was utilized. Measured characteristics were entered for Sediment Characteristics and Borrow Site Controls criteria; and the 5-point scale was utilized for Stakeholder Acceptability and Community Opinion, Environmental and Physical Concerns, and Future Site Usability (**Figure 3**).

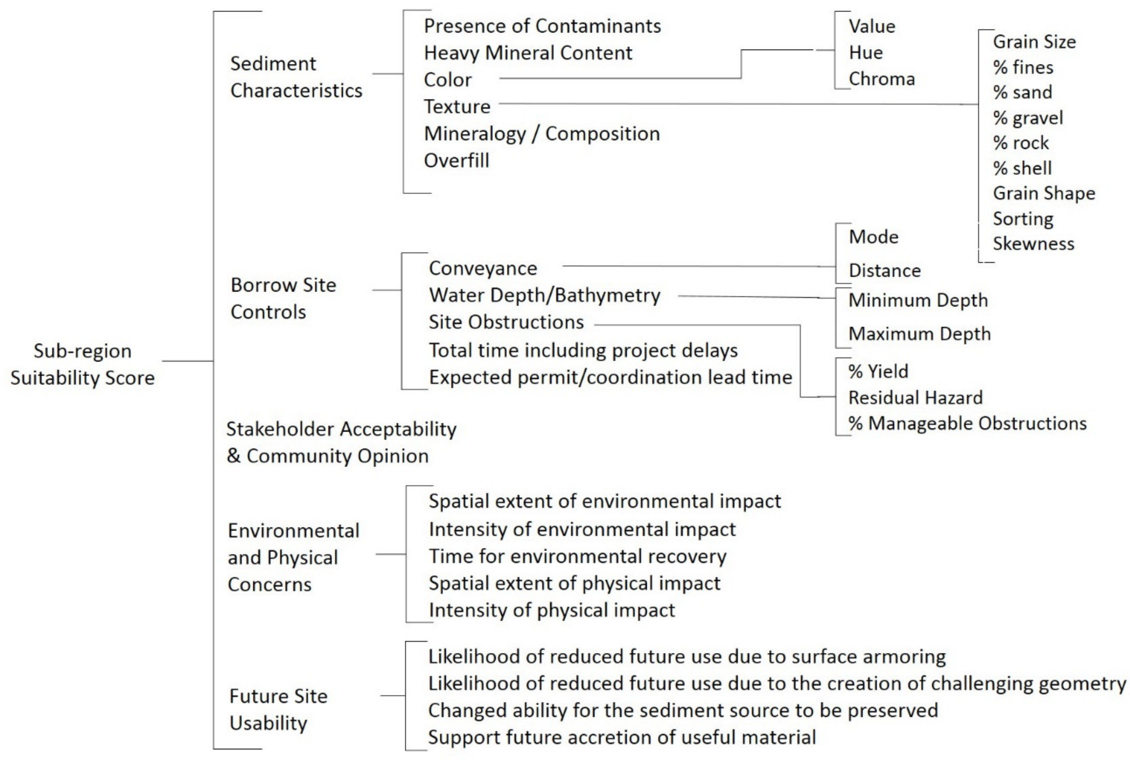

Figure 3. Input criteria for SSST.

Measured data

Data specific to the sediment characteristics (**Table 2**) and borrow site controls were entered into the SSST Criteria Tab. Subsequently, value functions were entered to indicate the appropriate properties for the placement site. Millions of cubic yards of material from Canaveral Shoals II have been placed on all of the Brevard County Beaches for restoration and periodic nourishment purposes since 1998.

Table 2. Sediment characteristics of Canaveral Shoals II.

Dredge Option	Mean (mm)	Mean (Phi)	Median (Phi)	Sorting (Phi)	% Fines	% Fine Gravel	Skewness	% Sand
A	0.38	1.4	1.54	0.87	0	0.17	-1.21	98.77
B	0.41	1.28	1.53	1.01	0	1.52	-1.41	96.51
C	0.41	1.3	1.53	1.05	0	1.38	-1.29	96.67
D	0.37	1.44	1.57	0.75	0	0	-0.91	99.55
E	0.45	1.14	1.26	0.77	0	0.21	-1.46	98.62
1998 BA Composite	0.39	1.36	1.52	1	0	0.83	-1.26	97.43
2014 BA Composite	0.40	1.32	1.56	0.97	0	0.97	-1.34	97.43

5 point scale

Any criteria that are measured through a 5-point scale utilize a Linear Function where the Metric Values were 1 and 5, and the Normalized values were 0 and 1 respectively, as the Reference Manual states is required by the tool. These graphs have a positive slope (indicating those criteria should be maximized), where higher values represent higher utility. On this scale, 1 always represents the lowest utility (least preferred option, poorest match) and 5 the highest utility (most preferred option, best match), regardless of how the criteria is worded.

Value Functions

Three types of value functions can be used, though only linear functions and piecewise linear functions were used to refine the calculations in the SSST. Linear functions are the simplest type of value function and is used when the value of the criterion improves uniformly in one direction. A common use of the linear function was for cost, distance, contaminants, heavy minerals, conveyance mode and distance, water depth, and site obstructions.

The piecewise linear function is used to build more complex value function. This function may also be chosen for criteria that do not follow the same trend throughout the range of values (e.g. they may have one or multiple peaks). This can also be used to represent a step function with specific thresholds where all scores between the thresholds have the same value. A common use of the piecewise linear function was for sediment characteristics, specifically Munsell color and texture.

Scoring

Scores were entered in the Alternative Scores tab. The SSST normalizes the values (on a scale of 0-1) by a cross-referencing the scores inputted with their corresponding, previously-entered value functions. These normalized scores are what the tool utilizes to perform the final steps of the analysis.

Table 3. Weights from applying MCDA tool to Canaveral Shoal II sand source.

Main Criteria (Level 1)	RANK	SCORE	WEIGHT	Sub-Criteria (Level 2)	RANK	SCORE	WEIGHT	Sub-Sub-Criteria (Level 3)	RANK	SCORE	WEIGHT	Total Weight
Sediment Characteristics*		1	0.25	Presence of Contaminants		1	0.23513					0.058782036
				Heavy Mineral Content		0.25	0.05878					0.014695509
				Color		1	0.23513	Munsell Value		1	0.33333	0.019594012
								Munsell Hue		1	0.33333	0.019594012
								Munsell Chroma		1	0.33333	0.019594012
				Texture		1	0.23513	Grain Size		1	0.11111	0.006531337
								% Fines (mud/silt/clay)		1	0.11111	0.006531337
								% Sand		1	0.11111	0.006531337
								% Fine gravel		1	0.11111	0.006531337
								% Rock		1	0.11111	0.006531337
								% Shell		1	0.11111	0.006531337
								Grain Shape		1	0.11111	0.006531337
								Sorting		1	0.11111	0.006531337
								Skewness		1	0.11111	0.006531337
				Mineralogy / Composition		0.753	0.17705					0.044262873
				Overfill Ratio		0.25	0.05878					0.014695509
Borrow Site Controls		0.5	0.125	Conveyance		0.25	0.17241	Conveyance Mode		0.5	0.33333	0.007183908
								Conveyance Distance		1	0.66667	0.014367816
				Water Depth / Bathymetry		0.5	0.34483	Not too Shallow		0.5	0.5	0.021551724
								Not too Deep		0.5	0.5	0.021551724
				Site Obstructions		0.5	0.34483	% Yield (due to site obstructions)		0.75	0.375	0.016163793
								Residual hazard		0.75	0.375	0.016163793
								Portion of Obstuctions Clearable or Controllable		0.5	0.25	0.010775862
				Total Dredging Time (including expected project delays due to safety, windows, etc.)		0.1	0.06897					0.00862069
				Expected Permit/ Coordination time (e.g. due to tribal & jurisdictional issues)		0.1	0.06897					0.00862069
Stakeholder Acceptability & Community Opinion		0.5	0.125									0.125
Environmental & Physical Concerns		1	0.25	Spatial Extent of Environmental Impact		0.5	0.2					0.05
				Intensity of Environmental Impact		0.5	0.2					0.05
				Time for Environmental Recovery		0.5	0.2					0.05
				Spatial Extent of Physcial Impact		0.5	0.2					0.05
				Intensity of Physical Impact		0.5	0.2					0.05
Future Site Usability		1	0.25	Likelihood of Reduced Future use due to Surface Armoring		0.5	0.25					0.0625
				Likelihood of Reduced Future use due to the Creation of Challenging Geometry		0.5	0.25					0.0625
				Changed Sediment Preservation Ability		0.5	0.25					0.0625
				Support Future Accretion of Useful Material		0.5	0.25					0.0625

Weighting

The relative importance of the criteria to the overall decision objective were entered into the Weights Tab in the "Score" cell in order to indicate how much each sub-criterion influences its parent criterion score (**Table 3**). Although not necessary, it may be helpful to first rank the criteria in each group from highest to lowest importance (though this variable is not included in the final calculation). Alternately, the actual score given to each component is not important, but the relative difference in the relative weight to assign to each component is important. In this case, a 0 to 1 scale was used, with 0 being a not important factor (i.e., heavy minerals), and 1 being the most important factor (sediment characteristics and environmental/physical impacts).

The total weight (**Figure 4**) is calculated from Level 1, Level 2, and Level 3 criteria. As Sediment Characteristics and Borrow Site Controls include all three levels of data criteria, the multiplication of all of these factors tend to cause smaller values than criteria with fewer levels of data, such as Stakeholder Acceptability and Future Site Usability.

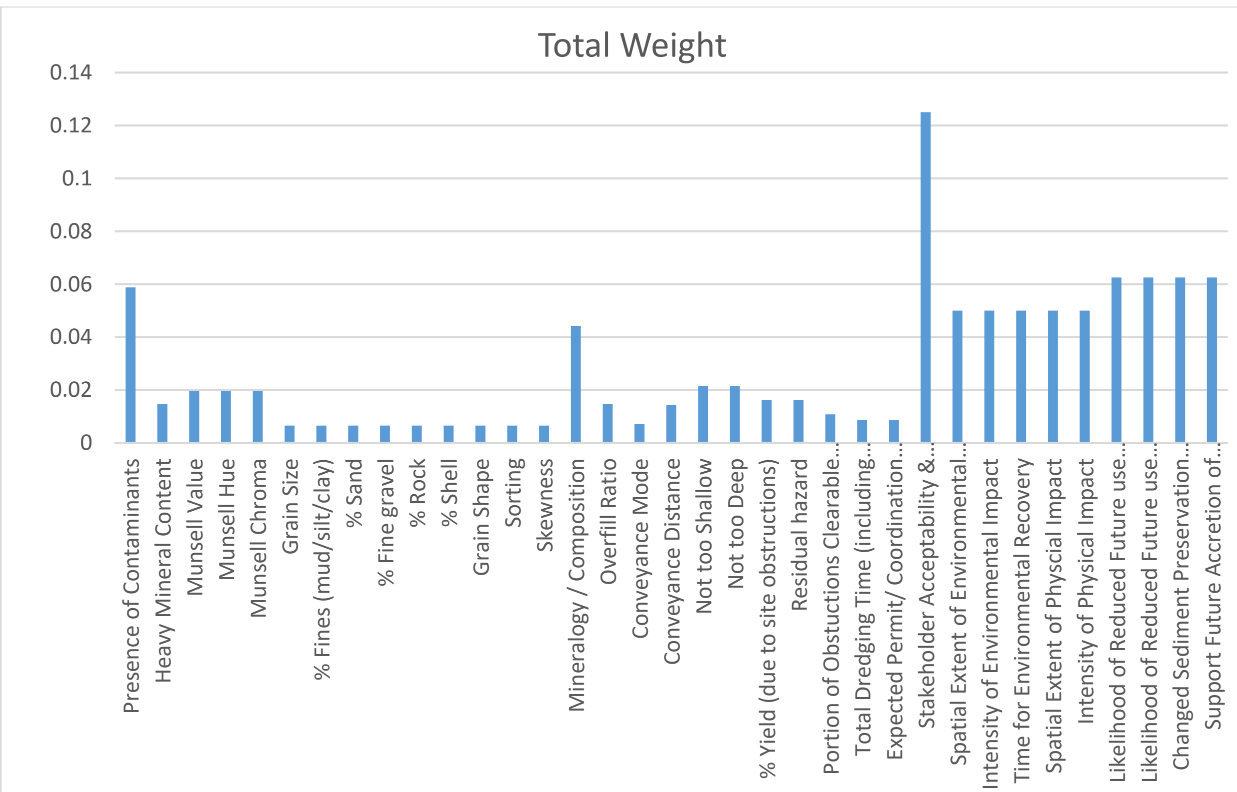

Figure 4. Weights of individual criteria within SSST for Canaveral Shoals II.

Results

The Overall Scores, which describe the total utility of each alternative and are the central piece of information to be considered by the SSST, are shown in the yellow column. These top-level scores provide the user with information about the order of preference for each alternative, given all of the criteria as well as the how strong the preference is (**Table 4**). All five site selection alternatives have similar scores and could be considered almost equally preferred. The top-level scores for main criteria are displayed alongside the cost and volume amount, providing additional context for decision making.

Table 4. Final weights scoring dredge areas within Canaveral Shoals II.

Names of Borrow Site Alternatives	Quantity Available in Millions of Cubic Yards (MCY)	Approximate or Estimated Cost	Overall Score	Sediment Characteristics*	Borrow Site Controls	Stakeholder Acceptability & Community Opinion	Environmental & Physical Concerns	Future Site Usability
A	6.01	$$$	0.689	0.66	0.71	0.13	0.80	0.88
B	8.08	$$	0.687	0.68	0.68	0.13	0.85	0.81
C	7.71	$$$	0.661	0.66	0.65	0.13	0.85	0.75
D	1.65	$	0.688	0.62	0.69	0.13	0.85	0.88
E	1.14	$$	0.697	0.67	0.65	0.13	0.85	0.88
2014	19.5	$$	0.683	0.67	0.69	0.13	0.85	0.81
1998	24.59	$$	0.684	0.67	0.69	0.13	0.85	0.81

The sediment characteristics for each subregion of CSII are very similar, as the sand source is considered to be homogenous. However, the SSST shows that subregion D has less desirable sand when compared to the remainder of the sand source (**Figure 5**). The material in subregion D is well sorted, but is of a finer grain size than the majority of the sand source, and may erode more quickly than sand from another portion of the sand source.

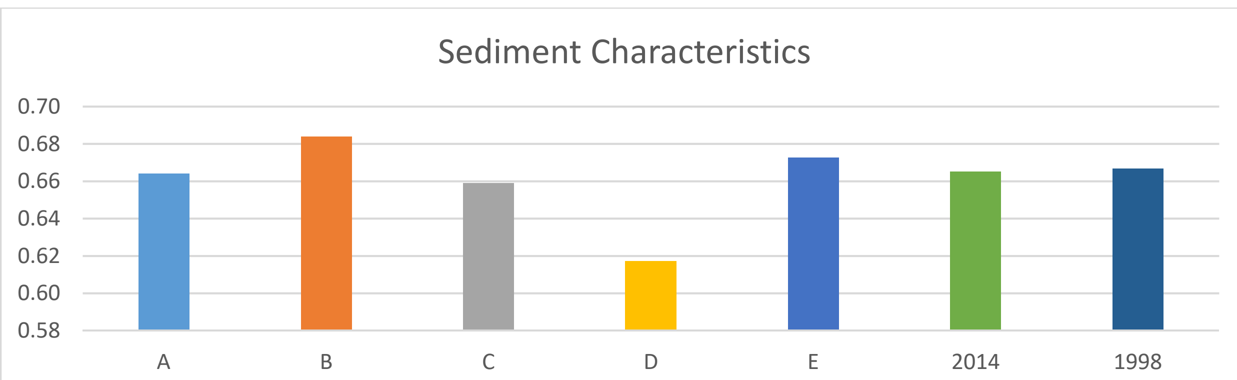

Figure 5. Final results of sediment characteristics for Canaveral Shoals II subregions.

The borrow site controls (including factors such as conveyance mode and distance, bathymetry, site obstructions, total dredging time, and permitting time) show that subregion A would be the best choice and subregion C would be the least effective choice (**Figure 6**). As dredging time and permitting time would essentially be the same, and any conveyance mode could be used within CSII, the primary factors are site obstructions, conveyance distance, and bathymetry. The design of subregion C could limit the percent yield, and it is the furthest away from all placement sites. Subregion E has a shallow dredge depth and may be difficult to work in.

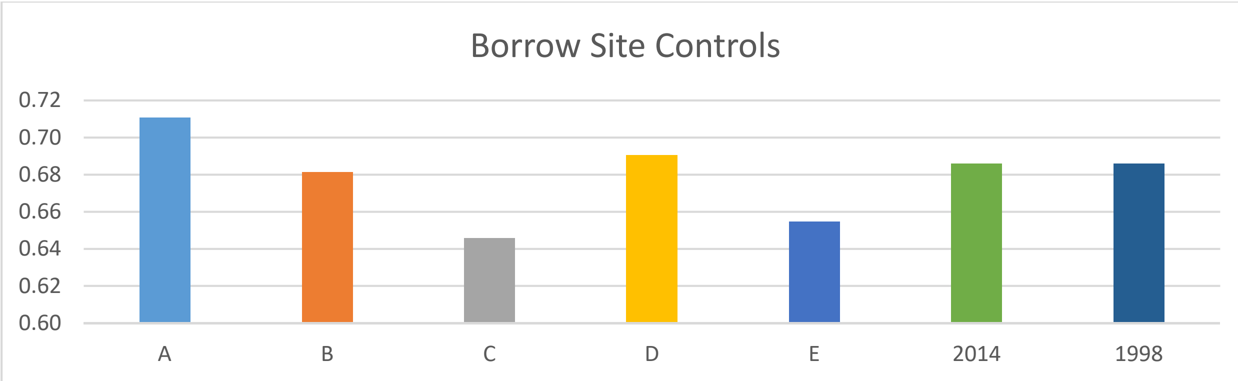

Figure 6. Final results of borrow site controls for Canaveral Shoals II subregions.

All subregions of CSII had the same level of Stakeholder Acceptability and Community Opinion (**Figure 7**). It is not likely that this factor had a large input on the overall utility score.

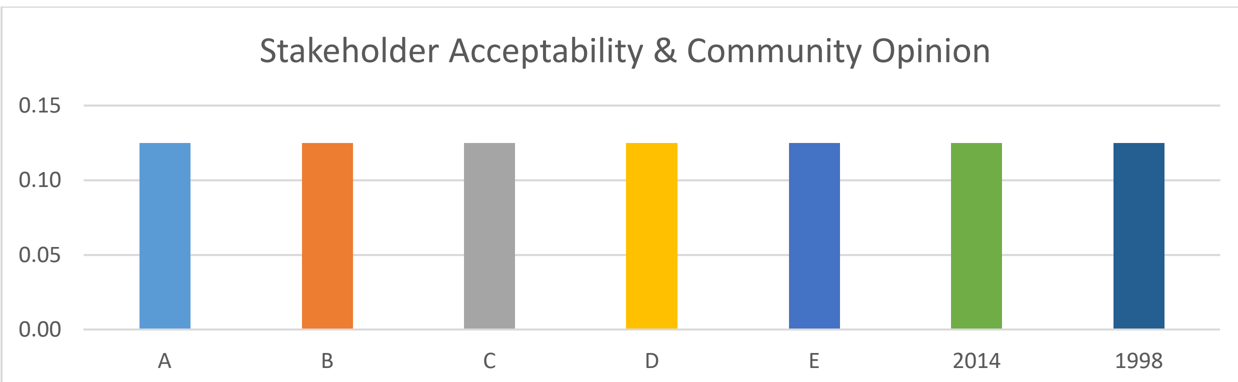

Figure 7. Final results of stakeholder acceptability and community opinion for Canaveral Shoals II subregions.

Subregion A had the largest potential for Environmental and Physical Concerns, as there are several pieces of space debris that may have historic significance and are mitigated by avoidance (**Figure 8**). It is expected that all subregions will recover from infaunal impacts within several years after a dredging event.

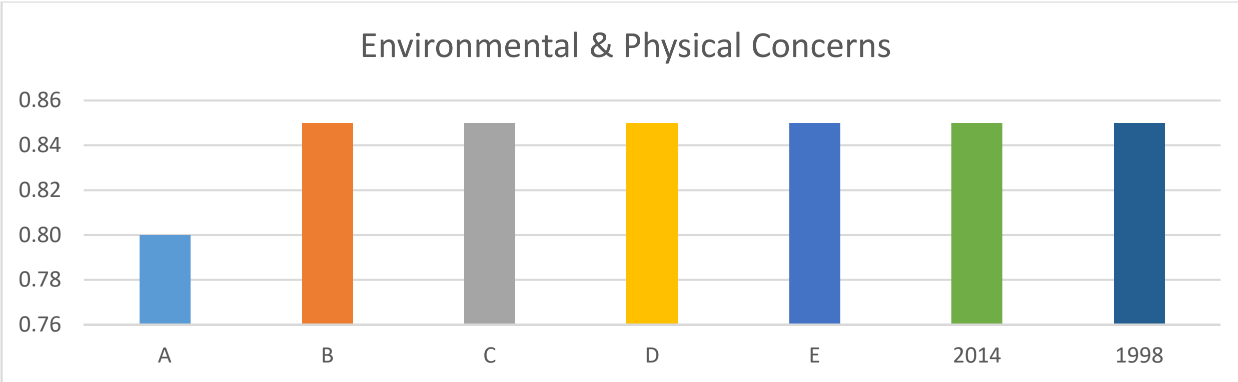

Figure 8. Final results of environmental and physical concerns for Canaveral Shoals II subregions.

The Future Site Usability (including factors such as accretion, surface armoring, siltation, and creation of challenging geometires) show that subregions A, D, and E would be the better choices and subregion C would be the least effective choice (**Figure 9**). The design of subregion C could limit the percent yield, and it is the furthest away from all placement sites.

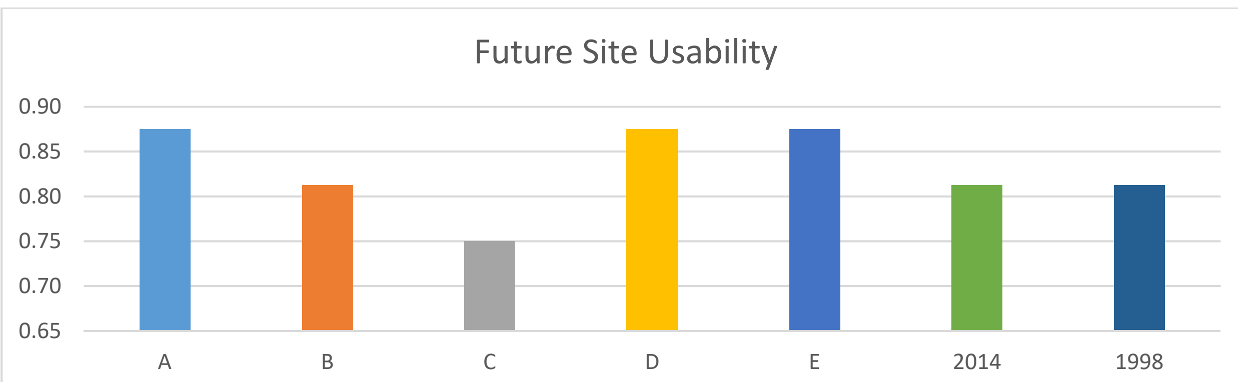

Figure 9. Final results of future site usability for Canaveral Shoals II subregions.

Overall, the SSST utility shows that the CSII sand source is an excellent match with the Brevard County beaches, having a score of 0.683 for the overall sand source (**Figure 10**). The individual subregion scores range between 0.661 (subregion C) and 0.697 (subregion E). Subregion C has a unique design and may be difficult to dredge. Subregion E is in relatively shallow water, and naturally accretes due to the unique pattern of sand movement around Cape Canaveral. However, as CSII is a homogenous sand source, there is little variation in the overall utility results.

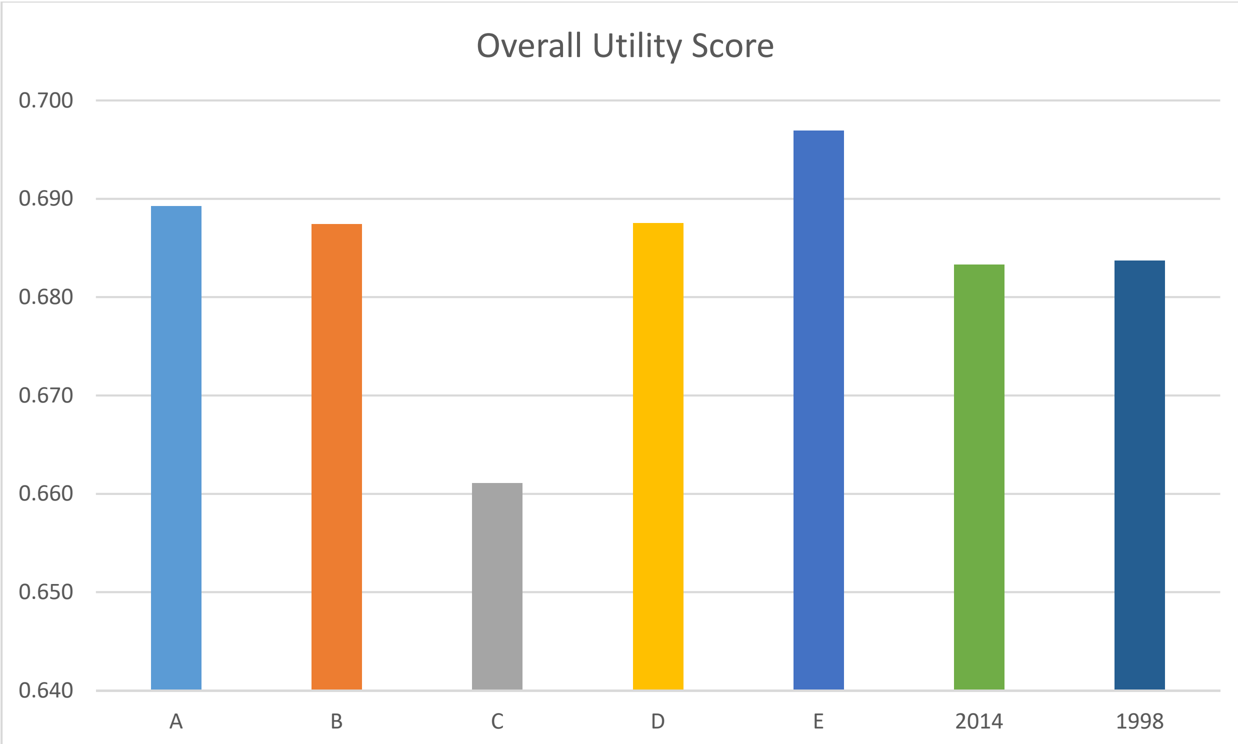

Figure 10. Final results of the overall scoring for Canaveral Shoals II subregions.

Discussion

The SSST primary value is in helping project managers make more sustainable and long term borrow area use decisions within offshore sand resource areas. It will do this by providing output that includes both relative scores for different factors for each sub-region of a borrow area, and a list of recommended practices. The tool could assist in decision-making that mitigates the effects of cumulative dredging on the same sediment source while maximizing use of that finite resource.

The insights/recommendations from the SSST are complementary to (rather than redundant of) the detailed processes USACE and non-federal entities already have in place for sand source identification and technical engineering on an individual project basis.

Best Management Practices

Many decisions remain following the use of the SSST. The following best management practices have been recommended by subject matter experts that have a detailed understanding of OCS dynamics and extensive experience in sand borrowing projects. The subject matter experts that contributed to this list offered two types of guidance: specific direction and general considerations. The objective of collating these practices is to assist future OCS sand borrowers in the following: ensuring longevity of limited sand resources; limiting environmental and physical impacts of dredging; preventing resource overuse / depletion; balancing short term and long term needs; improving operational efficiency; limiting cost/hassle; and ensuring equitable use across current and future stakeholders.

The recommended best practices and considerations are divided into the following four categories: Planning, Physical Operations, Environmental Operations, and Stakeholder Engagement

Planning

- Plan with a *holistic* view of the erosion and OCS sand-replacement cycle
- Limit use of renewable sites to match or exceed their renourishment rate
- Develop a *Borrow Area Conservation Plan*
- Use the first sand resource in its entirety before moving on to the second resource
- Avoid leaving behind small amounts of sand that are uneconomical to collect in the future
- Factor in infilling – both the infilling rate and sediment type – when determining borrow volume
- Incentivize dredge operators performing the work to do a clean and thorough job
- Employ “beneficial use” from another dredge project
- Do not automatically exclude borrow areas that appear to have elevated silt content
- Do not automatically exclude borrow areas if wave models show a potential increase in erosion along the shoreline
- Optimize post-dredging geometry to limit environmental and physical impacts
- Consider the trade-offs between mitigation strategies and future borrow area usability
- Consider tradeoffs between sand removal efficiency and cost
- Consider the tradeoffs between environmental impacts and risks to high value resources

Physical Operations

- Minimize overall dredging intensity and persistent effects
- Rotate renewable dredge areas
- Selectively dredge the accreting area or leading edge
- Avoid leaving a gravel lag
- Spread out dredge areas to limit physical impacts
- Define a the maximum dredge depth according to the context of the specific sand resource
- Construct reinforced side slopes
- When making step cuts, make sure that the wall sizes between cells are consistent

- Use turbidity curtains when coral reefs are down-current from a dredge project
- Leave behind a flat surface – avoid digging a hole
- Consider the tradeoffs between shallow cuts and deep cuts
- Consider the tradeoffs between the different types of dredges

Environmental Operations

- Prioritize protection of endangered species
- Prioritize borrow-area alternatives that allow for maximum recovery from ecosystem perturbations
- Designate an environmental "refuge patch" within the borrow area
- Prioritize borrow areas that replenish with the same type of habitat
- Mitigate the effects of lost surface area
- Consider the tradeoffs between efficiency and overall dredge time
- Consider the tradeoffs between the geometry of the feature and the impacts to the macroinvertebrate ecosystem

Stakeholder Engagement

- Form a stakeholder working group
- Maximize transparency between stakeholders
- Share projections of future OCS resource use
- Include commercial fishing groups in the pre-dredge planning process
- Develop a detailed inventory of OCS sand resources to manage stakeholder expectations
- Perform a detailed *regional* Environmental Impact Statement before allowing multiple stakeholders to share sand resources in a region
- Share sand quality fairly
- Consider replacing the term "competitive use" with "shared use" in project communications

Conclusions

The results of the SSST show that all of the subregions within CSII are compatible with the Brevard County beaches, and are viable options for both beach restoration and periodic nourishment. The smaller grain size in subregion D and the geometry of subregion C lead to these to subregions having an overall lower score than the other subregions, and lowering the overall sand source composite score. Subregions A, B, and E are the preferential options individually, but using best management practices, it would be recommended to run the SSST utility again with combinations of subregions (such as combining C+E).

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D-2 SSMP—Ship Shoal

Ship Shoal, LA Sand Source Management Plan Utilizing Multi-Criteria Decision Analysis (MCDA) in a Sand Source Selection Tool (SSST)

Prepared for:

U.S. Department of the Interior
Bureau of Ocean Energy Management
Marine Minerals Program
IA No. M15PG00033

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U.S. Army Corps of Engineers

March 2017

Executive Summary

The management of Outer Continental Shelf (OCS) sand resources is often a multifaceted challenge due to various engineering and design requirements, economic and environmental considerations, and stakeholder needs that must be balanced. The Ship Shoal sand source, located offshore the Isle Denieres, Louisiana, was estimated to contain more than 1,734 million cubic yards of sand (Penland, 1988) that can be used to restore and maintain the coastal system of Louisiana.

The primary value of the sand source selection tool (SSST) is in helping project managers make more sustainable and long term borrow area use decisions within offshore sand resource areas. The tool will do this by providing output that includes both relative scores for different factors for each sub-region of a borrow area, and a list of recommended practices. The tool could assist in decision-making that mitigates the effects of cumulative dredging on the same sediment source while maximizing use of that finite resource.

The insights and recommendations from the SSST are complementary to (rather than redundant of) the detailed processes that USACE and non-federal entities already have in place for sand source identification and technical engineering on an individual project basis.

Ship Shoal has been historically used for nourishing both the beaches with sandy sediments and marshes with silty sediments, as it is a near perfect sand source for all Louisiana projects. While there are some issues with EFH and oil and gas infrastructure (pipelines and platforms), the results of the SSST show that Ship Shoal is both a suitable and sustainable source of material to continue nourishing the coastal system of Louisiana.

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Introduction

Outer Continental Shelf (OCS) sand resources are finite and require careful management. Some beach nourishment and/or coastal restoration projects involve an initial large-scale construction phase followed by smaller-scale, regularly scheduled maintenance cycles at regular intervals, while others are a one-time event. The sediment used for initial construction and subsequent maintenance is often dredged from the same sand resource area, which can equate to frequent dredging of the same or adjacent seafloor for a period of 50 years or longer; most OCS leases are for one-time events. In coastal areas where sand is scarce and multiple use conflicts are common, a single sediment source could be used by multiple stakeholders for the construction of several different beach fill or coastal restoration projects. Large volumes of sand may also suddenly be necessary to recover from severe storms such as Hurricane Katrina in 2005 and Hurricane Sandy in 2012. Both circumstances can lead to rapid resource depletion and the need to identify, characterize, and delineate additional sediment sources.

Different types of sand bodies are dredged to different cut depths over various footprints, creating complex dredge patterns and increased project costs. In many instances, the approach to managing dredging intensity (location, duration, and frequency) is not systematically planned so transport distance and dredge productivity are primary determinant of where dredging occurs. Fill performance, funding availability, environmental construction windows, and dredge plant availability also drive when and where dredging occurs. This current approach is not conducive to long term, responsible, and sustainable resource management. However, dredging simple dredge patterns within reasonable distances from the placement site is a component of long term planning and controlling project costs.

Dredging can have both direct and indirect effects on physical, biological, and archaeological resources. Each dredging event diminishes not only the availability of sand resources, but the profile of the sand body or sheet, which can potentially cause physical effects, such as changes in local and residual hydrodynamics, substrate composition, and the morphologic response of the sand body. These interrelated effects, which can be magnified during multiple dredging events, could disturb the ecosystem function of sensitive biological habitats and resources in the vicinity of the sediment source. Such physical changes could also cause unanticipated indirect impacts on archaeological and anthropogenic resources that are otherwise protected by exclusion zones.

The management of OCS sand resources is often a multifaceted challenge due to various engineering and design requirements, economic and environmental considerations, and stakeholder needs that must be balanced. The existing OCS management strategy would benefit from advanced planning using a systematic framework incorporating long-term project design, engineering, and economic requirements while considering sand resource availability and minimizing environmental impacts.

Multi-Criteria Decision Analysis

Environmental decision makers often deal with problems that involve multiple stakeholders that have different priorities and objectives. Such decision makers typically need to integrate multidisciplinary knowledge that combines natural, physical, and social sciences, politics, and ethics. Decision makers for environmental management projects typically receive input from five categories: scientific research, modeling/monitoring results, risk analysis, cost/benefit analysis, and stakeholder preferences. However, a systemic methodology to combine these quantitative and qualitative inputs to rank project alternatives has yet to be fully developed for environmental decision making. As such, multi-criteria decision analysis (MCDA) tools can be applied to environmental decision making by quantifying value judgments based on multiple criteria. Scoring different project alternatives using a systematic analysis which overcomes the limitations of unstructured individual or group decision-making facilitates the identification of a preferred course of action.

MCDA is typically utilized for problems of sorting alternatives into various groups, or categories, and screening alternatives. The tools within MCDA allow for the ranking of alternatives, selecting the “best alternative” from a given set of alternatives, and designing a new action or alternative to meet project goals. Two primary methodologies within the MCDA approaches include value functions and outranking. Value functions rely on the development of utility functions that describe the benefit obtained from each increment of each decision criterion, while outranking directly ranks alternatives by assessing if there is enough information to determine if one is better than, or at least as good as, another. Adaptive management utilizing MCDA allows the user to create a model of the system being managed, develop a range of management choices, monitor and evaluate the possible outcomes, identify a mechanism for incorporating lessons learned into future decisions, and a provide collaborative structure for stakeholder participation and learning. When utilizing MCDA with complex environmental decision-making, there will be trade-offs between divergent criteria. By utilizing and integrating MCDA principles and tools with existing decision-making approaches, including risk and cost/benefit analysis, decision makers will be able to make more effective, efficient, and credible decisions.

Objectives

The goal of the present project is to develop a reproducible planning process to optimize the utilization of repetitive-use sediment sources. The process will use MCDA to evaluate and quantify technical, environmental, economic, and societal factors in context with potential management and monitoring measures. The planning process will use an efficient computer-based MCDA tool to facilitate sand source management

(SSM). The MCDA tool will assist in the development of SSM plans by quantifying or ranking evaluation factors. The tool will accept input data, when applicable, in formats used by BOEM. MCDA methods were utilized in order to select dredging opportunities which would reduce the impacts of dredging and lower the cost of environmental quality analysis and management. This methodology helps decision makers look at dredging from an integrated and holistic point of view, which may lead to more sustainable practices. MCDA is a powerful decision support tool which does not replace the human thought process, but rather assists in decision making by removing biases and allowing for various factors to be weighted according to importance. Although the sites identified have distinguishing characteristics, there are many similarities that make the determination of best areas to use difficult. This Sand Source Selection Tool (SSST) will help document and assess the differences and similarities to identify a sustainable long-term project plan.

This document will discuss the background of the Ship Shoal sand source, SSST inputs and methods, results of the SSST, discussion and interpretation of results, conclusions, and lessons learned. The background section includes the geographic setting of the region, the local geology, describes the sand source, and describes and quantifies (when possible) the input criteria to the SSST. The methodology section briefly discusses the steps for entering data into the SSST to gain meaningful results. The results section presents the data from the SSST. The discussion section describes the results and optimization in terms of best management practices and lessons learned. Lastly, the conclusion section summarizes any conclusions about optimizing the sand source.

Background

The loss of coastal marsh land and retreat of Louisiana’s sandy barrier shoreline has emphasized the need for coastal restoration projects. Offshore sand shoals such as Ship Shoal have been identified as potential sand resources for restoration of barrier islands and other projects along the mainland shoreline. It is important to restore and maintain Louisiana’s barrier islands as they are integral in reducing incident wave energy at the marshland perimeter, especially during storms (i.e. hurricane and cold fronts), maintain estuarine function and conditions, and provide unique habitat for threatened and endangered species and nesting seabirds (Kulp, 2002; Roberts 2013). In order to restore and maintain Louisiana’s barrier islands, sand in sufficient quantities compatible with existing barriers must be found, such as those in OCS waters (Khalil et al., 2007). Louisiana has a complex and difficult geologic framework for finding sufficient sand resources that is made more difficult by the demands of the oil and gas industry.

Geographic Setting

Ship Shoal is located approximately 12 miles offshore the Terrebonne shoreline of Louisiana (Figure 1). This region includes the Isles Denieres, which were badly eroded when Hurricane Katrina passed over the region in 2005.

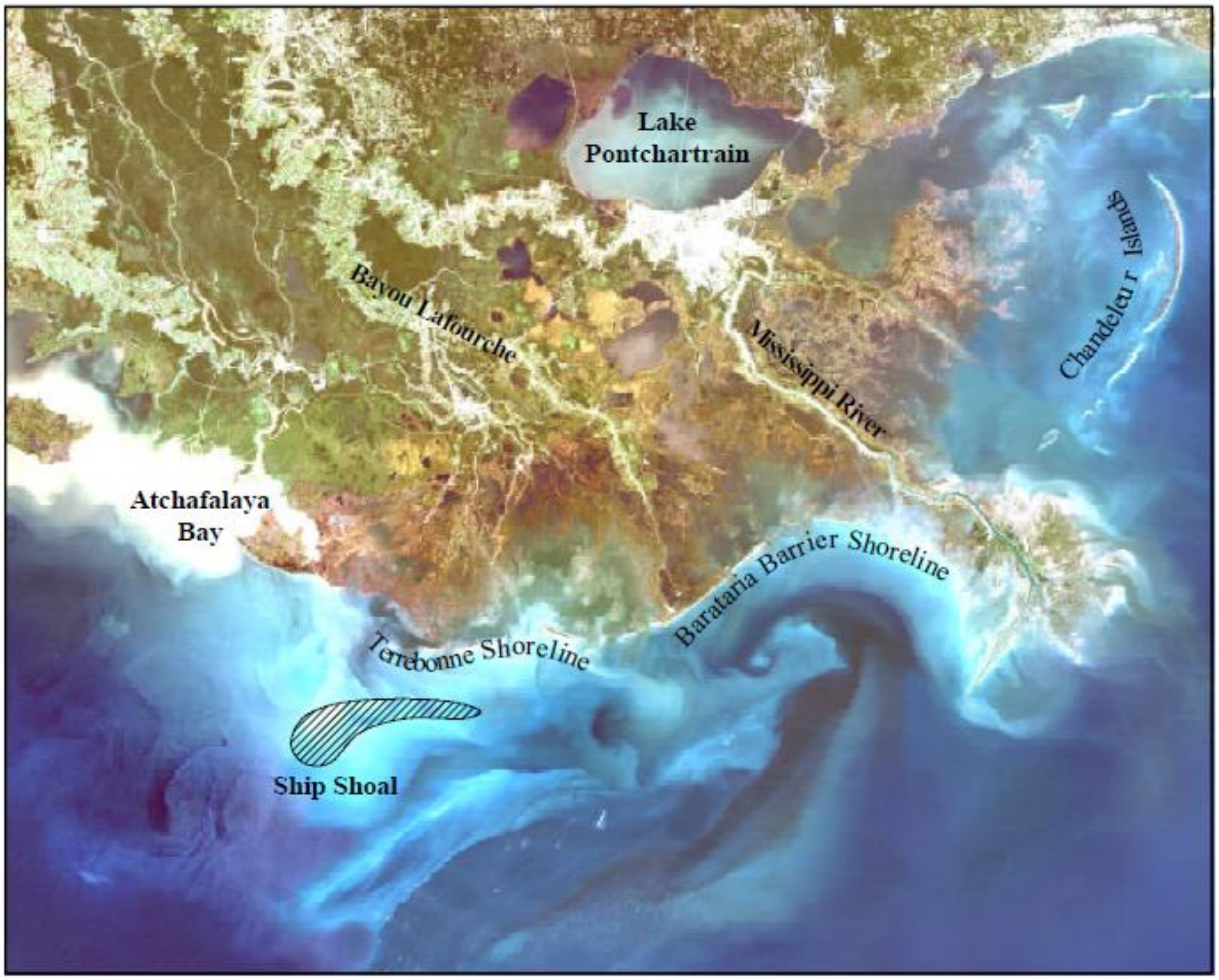

Figure 1. Location of Ship Shoal, offshore Terrebonne shoreline.

Local Geology

The geomorphologic and shallow stratigraphic framework of the Mississippi River delta plain and Louisiana inner-continental shelf has been created by fluvial and marine depositional processes that have been ongoing for at least the last 7,000 years (Frazier, 1967). Regressive depositional episodes are characterized by the seaward advance of tributaries, resulting in the construction of deltaic headlands and a progressively more seaward-located coastline. In the Ship Shoal area, the most recent phase of constructional deposition is primarily attributed to progradation of the Maringouin deltaic complex (Frazier, 1967).

Ship Shoal is the easternmost and largest of a group of inner-shelf shoals that developed on the Louisiana continental shelf as a result of deltaic abandonment and marine transgression. The shoal is an asymmetric, landward-skewed sedimentary body approximately 50-km long, marking the minimum seaward extent of early to mid-Holocene Maringouin deltaic deposition. Widths across the central part of the shoal range between 4 and 8 km, whereas on the eastern and western ends shoal width ranges between 5 and 10 km. Relative to the surrounding shelf, relief of the shoal varies from between approximately 7 m on the western end to approximately 5 m in the central and eastern portions of the shoal. The water depths above the shoal range between approximately 3 m over the western end to 8 m on the eastern-edge.

Numerous researchers have previously investigated the sedimentology, stratigraphy, and morphology of Ship Shoal (e.g., Kraweic, 1966; Frazier, 1967; Penland et al., 1981). A variety of methods, including vibracores, surface grab samples, and high resolution seismic profiling have been utilized in these investigations.

Sand Source

Ship Shoal is about 50 km (31 mi) long by 8 km (5 mi) wide, but is narrow on eastern and western portions. Estimates of sand volume in the shoal are quite varied, though early estimates from Penland (1988) estimated over 1,734 million cubic yards of sand available. However, the large sandy deposits in Ship Shoal are operationally constrained by the presence of oil and gas infrastructure and obstructions (pipeline, flow lines, rigs, abandoned pipes, wrecks), etc. that preclude excavation in many areas.

For the purpose of this sand source management plan (SSMP), Ship Shoal Blocks 84, 85, 98, and 99 (Western Ship Shoal), Ship Shoal Blocks 88 and 89, and South Pelto Blocks 12 and 13 were chosen as prospective borrow areas within Ship Shoal (Figure 2). From the existing information, large areas of this portion of Ship Shoal were determined to be comparatively free of oil and gas obstructions.

Sea-floor change analysis conducted for the time period 1880's to 1930's indicates that the landward edge of Ship Shoal accreted 42.5 x 10^6 m^3 of sediment. For the analysis period between 1930 and 1980 the landward edge accreted 43.3 x 10^6 m^3 and the seaward slope eroded 62.1 x 10^6 m^3. Accretion along the landward edge was most likely the result of redeposition of sediment that had been moved from the seaward face of the shoal. The deficit between eroded and accreted material is likely attributable to offshore-onshore transport and dispersal of sediment that has been reworked by storm events impacting the shelf (Kulp et al., 2002).

Review of the available literature, vibracore data, and geophysical data provide the available volumes for the dredge options shown in **Figure 2** and **Table 1**. Within Ship Shoal Blocks 88 and 89, interpretation of vibracores and geophysical data helped to identify about 13.2 x 106 m^3 (17.4 X 10^6 yd^3) of clean sand. South Pelto blocks 12 and 13 contains approximately 21.6 x 106 m^3 (29.2 x 10^6 yd^3) of clean sand containing less than 5% silt (Khalil et al., 2007). Using the reflector that is interpreted to define the base of the sand-rich facies of western Ship Shoal Blocks 84, 85, 98, and 99 and considering existing infrastructure and associated setback buffer distances, a total volume of extractable restoration quality sand was estimated to be 107.75 x 10^6 m^3 (141.03 x 10^6 yd^3) (Roberts, 2013).

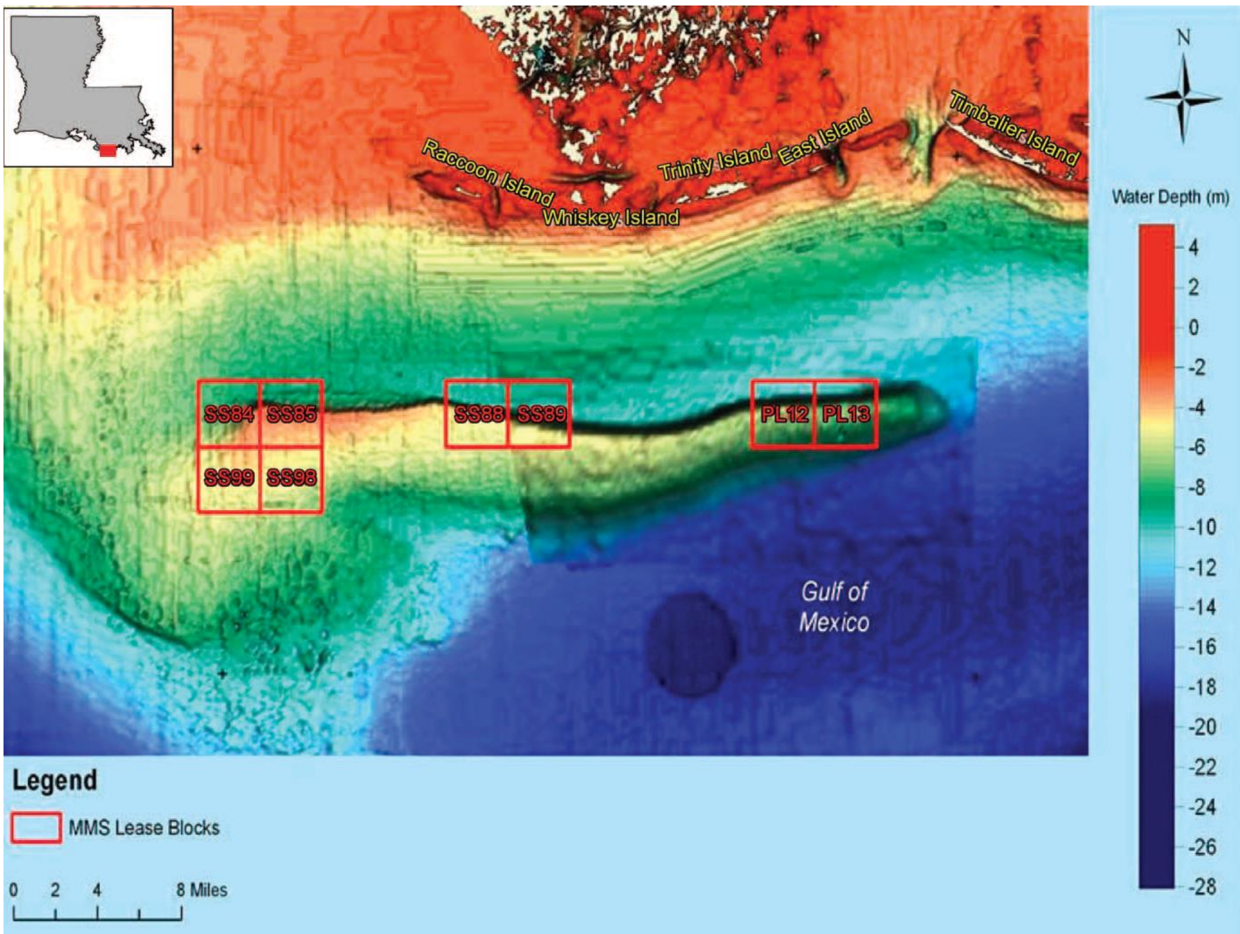

Figure 2. Bathymetric map of Louisiana OCS showing Ship Shoal and Western Ship Shoal (Block 84/85/98/99), Ship Shoal 88/89, and South Pelto (Blocks 12/13), from Khalil et al, 2010.

Table 1. Ship Shoal dredge options.

Dredge Option	Volume 2010 (mcy)	Average Sand Thickness (ft)
South Pelto 12/13	21.6	13-20
Ship Shoal 88/89	13.2	12-18
Western Ship Shoal 84/85/98/99	107.7	13.5
Total	142.5	N/A

Input Criteria for SSST

Sediment Characteristics

Krawiec (1966) examined the textural character and mineralogy of Ship Shoal and the adjacent shelf with grab samples taken along south-trending transects of the western and eastern shoal. Compositional analysis and grain-size statistics indicated that Ship Shoal consists predominantly of fine-grained, quartz sand and is substantially more sand rich than adjacent parts of the shelf.

Frazier (1967) mapped the subaqueous lithofacies in the Ship Shoal region on the basis of percent sand. Ship Shoal was indicated to contain between 75 - 100% sand. Much of the surrounding shelf was shown to consist of silty clay. Williams et al. (1989) combined previous datasets with their own to map seven major lithofacies in the Ship Shoal area that were determined based on sand content. Quartz sand, consistent with the results of Krawiec (1966), was found to be a primary constituent of the surficial sediment; much of Ship Shoal contained 90 to 99% sand.

Based on these datasets, a series of seven facies units were found to characterize Ship Shoal and the underlying inner shelf deposits to a ravinement surface. However, the upper three facies that are most relevant to sand resources include the (1) shoal crest, (2) lower shoal or shoal front, and (3) shoal base. So, Facies 1, 2 and 3 represent the extent of Ship Shoal facies (Figure 2). As described by Penland et al. (1988), facies 1, consisting of 99% sand is located within the upper 5 m of the shoal and consists of very-well sorted, well-rounded quartz sand. The sand grain size coarsens upward within the unit from 0.13 mm at the base to 0.15 to 0.18 mm at the top. Facies 2 underlying Facies 1 is a massive body of moderately sorted, very fine to fine sand (0.12 to 0.15 mm). The thickness ranges from 1.2 m (3.9 ft) to 3.4 m (11.1 ft). Facies 3 ranges from about 50 to 75% sand that can be described as poorly sorted, very fine-grained unit with inter-bedded layers of silty clay. Mean grain size ranges from about 0.10 to 0.13 mm.

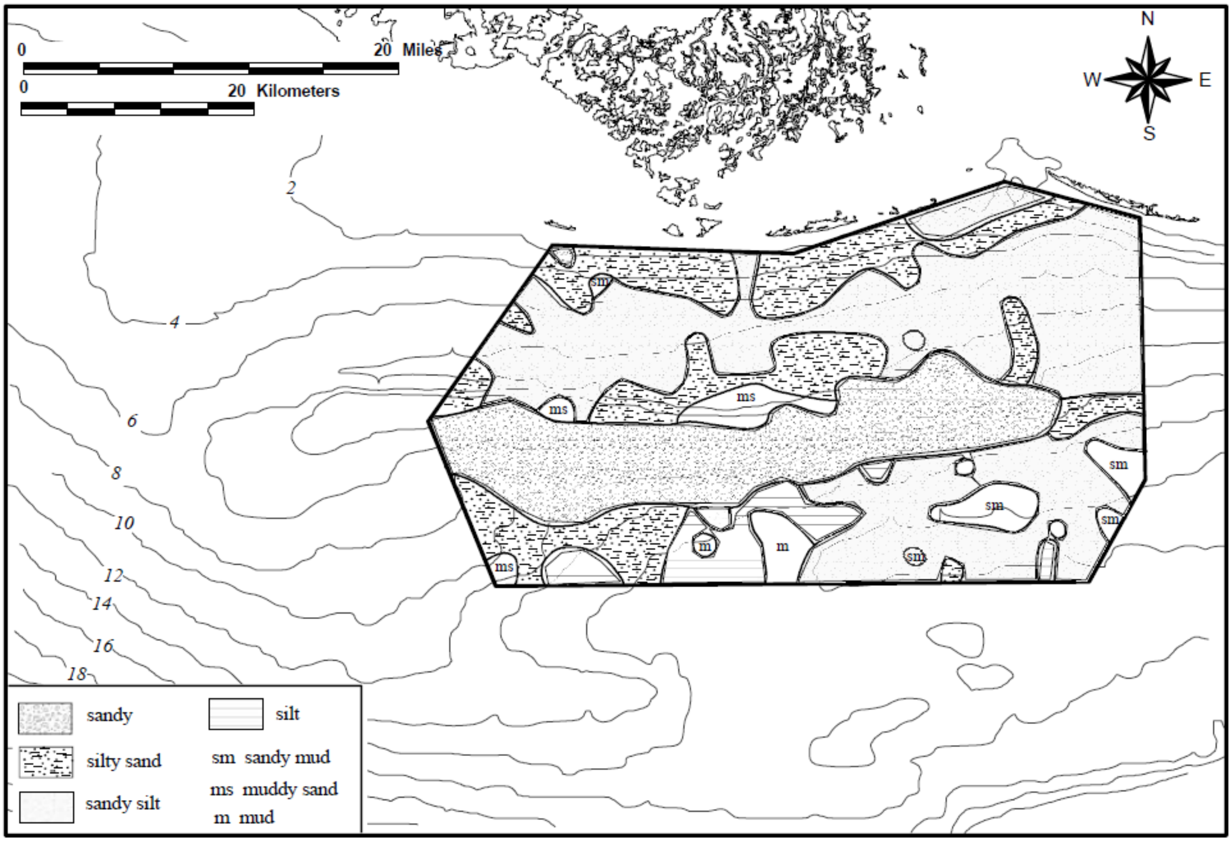

Figure 3. Map of major sedimentary facies in Ship Shoal (Kulp et al, 2002).

Borrow Site Controls

There have been many dredging and beach fill projects in the United States. However, very few of these have utilized borrow sites with distances of more than a few miles from the restoration location. In Louisiana, the U.S. Army Corps of Engineers (USACE) routinely dredges navigation channels using the dredge spoil to create new habitats. Barrier island restoration has historically occurred using sands from nearshore borrow areas and channels or inland ridges.

The availability of detailed information regarding dredge operations and costs in the United States has been limited due to industry competition. However, research indicates that pipelines are most appropriate for short distances (less than 3 mi) between borrow sites and fill locations. Hopper dredges are better suited for borrow areas 3 to 5 miles away and tugs and scows are the best alternative for longer distances (Chisholm, 1989). There are three basic types of dredging operations: 1) hydraulic, 2) mechanical, and 3) a combination of hydraulic and mechanical.

Hydraulic dredging techniques include the hopper, side casting, and hydraulic-pipeline and plain-suction dredges. This method is favored by the USACE for channel dredging in navigation channels and restoration through dredge spoil. Mechanical dredging moves material by removal and relocation. Clamshell, dipper, and ladder dredges are examples of mechanical dredging. Combination dredges loosen material mechanically and then transport it hydraulically. Cutterhead dredges are an example of a combination dredge. This type of technique limits dredging to the capacity of the barge and is efficient on upland disposal sites. However, cutter dredges are designed to operate in calm water and not offshore.

The selection of which dredging equipment is best suited for restoration depends on the physical characteristics, quantity, and dredging depth of the material, as well as the distance to disposal area.

Environmental and Physical Concerns

Potential environmental impacts to the borrow area were determined through an Environmental Assessment (EA) in 2004. Benthic resources will likely have possible mortality for nonmotile invertebrates in the immediate area of dredging, temporary and localized defaunation from bottom disturbance, sub-lethal effects from elevated turbidity, burial, and habitat degradation. Long-term suppression is not expected due to dredging intervals and highly adaptive benthic assemblages. Recolonization of physically dominated environment is expected to occur within 2-3 years. Fish and Essential Fish Habitat (EFH) may experience possible entrainment and sub-lethal effects from turbidity, noise, and burial. Effects are expected to be minor because of species mobility, avoidance behavior, and widespread occurrence of comparable habitat.

Possible trophic effects can be attributed to benthic disturbance and locally reduced prey. EFH could be temporarily and locally physically disturbed by dredging or beach shaping activity. Long term suppression is not expected due to dredging intervals and widely available habitat. Physical oceanography may be impacted by the modification of offshore bathymetry having minor effects in offshore sediment transport pathways, incident wave field, and longshore transport. Infilling is anticipated over long-term. Threatened and endangered species may become entrained in the dredge leading to injury and mortality in sea turtles. Noise and vessel collision may lead to injury and mortality of marine mammals. Impacts to sea turtles and marine mammals may be avoided or minimized with protective measures. Water quality impacts are temporary (elevated turbidity, decreased dissolved oxygen) and limited to the water column in the borrow area.

Future Site Usability

The cumulative impacts for Ship Shoal, as currently proposed including the past and future use, are expected to be minor to possibly moderate. Of primary concern are changes to the location of oil and gas platforms and pipeline corridors.

Methods

For the data from the Ship Shoal sand source, a combination of the 5-point scale and measured characteristics was utilized. Measured characteristics were entered for Sediment Characteristics and Borrow Site Controls criteria; and the 5-point scale was utilized for Stakeholder Acceptability and Community Opinion, Environmental and Physical Concerns, and Future Site Usability (Error! Reference source not found. **4**).

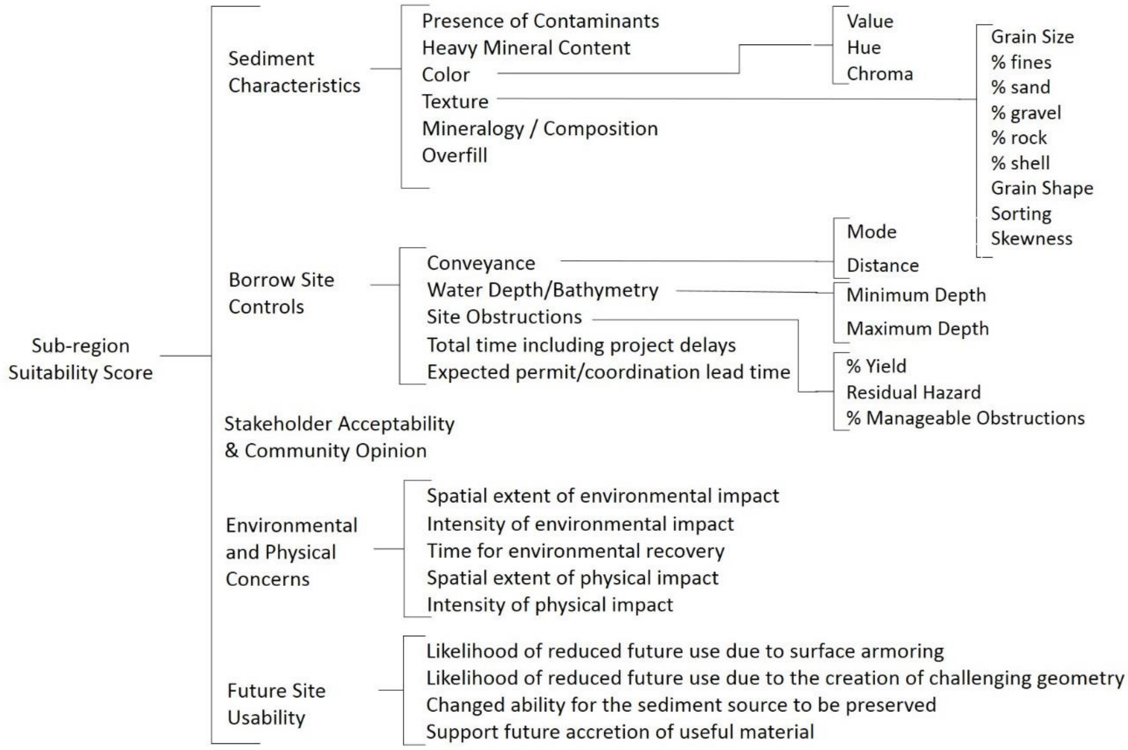

Figure 4. Input criteria for SSST.

Measured data

Data specific to the sediment characteristics (**Table 2**) and borrow site controls were entered into the SSST Criteria Tab. Subsequently, value functions were entered to indicate the appropriate properties for the placement site. Millions of cubic yards of material from Ship Shoal have been placed on all of the Gulf Coast Beaches for restoration and periodic nourishment purposes.

Table 2. Sediment characteristics of Ship Shoal.

Dredge Option	Mean (mm)	Mean (Phi)	Sorting (Phi)	% Fines	% Fine Gravel	Color
South Pelto 12/13	0.17	2.5	0.47	<5		Dark gray
Ship Shoal 88/89	0.15	2.7	0.34	<5	1.66	Dark gray
Western Ship Shoal 84/85/98/99	0.15	2.74	0.35	<5		Dark gray

5 point scale

Any criteria that are measured through a 5-point scale utilize a Linear Function where the Metric Values were 1 and 5, and the Normalized Values were 0 and 1 respectively, as the Reference Manual states is required by the SSST (ERDC, 2016). These graphs have a positive slope (indicating those criteria should be maximized), where higher values represent higher utility. On this scale, 1 always represents the lowest utility (least preferred option, poorest match) and 5 the highest utility (most preferred option, best match), regardless of how the criteria is worded.

Value Functions

Three types of value functions can be used, though only linear functions and piecewise linear functions were used to refine the calculations in the SSST. Linear functions are the simplest type of value function and is used when the value of the criterion improves uniformly in one direction. A common use of the linear function was for cost, distance, contaminants, heavy minerals, conveyance mode and distance, water depth, and site obstructions.

The piecewise linear function is used to build more complex value function. This function may also be chosen for criteria that do not follow the same trend throughout the range of values (e.g. they may have one or multiple peaks). This can also be used to represent a step function with specific thresholds where all scores between the thresholds have the same value. A common use of the piecewise linear function was for sediment characteristics, specifically Munsell color and texture.

Scoring

Scores were entered in the Alternative Scores tab. The SSST normalizes the values (on a scale of 0-1) by a cross-referencing the scores inputted with their corresponding, previously-entered value functions. These normalized scores are what the tool utilizes to perform the final steps of the analysis.

Table 3. Weights from applying MCDA tool to Ship Shoal sand source.

Main Criteria (Level 1)	RANK	SCORE	WEIGHT	Sub-Criteria (Level 2)	RANK	SCORE	WEIGHT	Sub-Sub-Criteria (Level 3)	RANK	SCORE	WEIGHT	Total Weight
Sediment Characteristics*		1	0.23529	Presence of Contaminants		1	0.26645					0.062694942
				Heavy Mineral Content		0.25	0.06661					0.015673736
				Color		0.5	0.13323	Munsell Value		1	0.33333	0.010449157
								Munsell Hue		1	0.33333	0.010449157
								Munsell Chroma		1	0.33333	0.010449157
				Texture		1	0.26645	Grain Size		1	0.11111	0.006966105
								% Fines (mud/silt/clay)		1	0.11111	0.006966105
								% Sand		1	0.11111	0.006966105
								% Fine gravel		1	0.11111	0.006966105
								% Rock		1	0.11111	0.006966105
								% Shell		1	0.11111	0.006966105
								Grain Shape		1	0.11111	0.006966105
								Sorting		1	0.11111	0.006966105
								Skewness		1	0.11111	0.006966105
				Mineralogy / Composition		0.753	0.20064					0.047209291
				Overfill Ratio		0.25	0.06661					0.015673736
Borrow Site Controls		0.5	0.11765	Conveyance		0.25	0.17241	Conveyance Mode		0.5	0.33333	0.006761325
								Conveyance Distance		1	0.66667	0.01352265
				Water Depth / Bathymetry		0.5	0.34483	Not too Shallow		0.5	0.5	0.020283976
								Not too Deep		0.5	0.5	0.020283976
				Site Obstructions		0.5	0.34483	% Yield (due to site obstructions)		0.75	0.375	0.015212982
								Residual hazard		0.75	0.375	0.015212982
								Portion of Obstuctions Clearable or Controllable		0.5	0.25	0.010141988
				Total Dredging Time (including expected project delays due to safety, windows, etc.)		0.1	0.06897					0.00811359
				Expected Permit/ Coordination time (e.g. due to tribal & jurisdictional issues)		0.1	0.06897					0.00811359
Stakeholder Acceptability & Community Opinion		0.75	0.17647									0.176470588
Environmental & Physical Concerns		1	0.23529	Spatial Extent of Environmental Impact		0.5	0.2					0.047058824
				Intensity of Environmental Impact		0.5	0.2					0.047058824
				Time for Environmental Recovery		0.5	0.2					0.047058824
				Spatial Extent of Physcial Impact		0.5	0.2					0.047058824
				Intensity of Physical Impact		0.5	0.2					0.047058824
Future Site Usability		1	0.23529	Likelihood of Reduced Future use due to Surface Armoring		0.5	0.25					0.058823529
				Likelihood of Reduced Future use due to the Creation of Challenging Geometry		0.5	0.25					0.058823529
				Changed Sediment Preservation Ability		0.5	0.25					0.058823529
				Support Future Accretion of Useful Material		0.5	0.25					0.058823529

Weighting

The relative importance of the criteria to the overall decision objective were entered into the Weights Tab in the "Score" cell in order to indicate how much each sub-criterion influences its parent criterion score (**Table 3**). Although not necessary, it may be helpful to first rank the criteria in each group from highest to lowest importance (though this variable is not included in the final calculation). Alternately, the actual score given to each component is not important, but the relative difference in the relative weight to assign to each component is important. In this case, a 0 to 1 scale was used, with 0 being an unimportant factor (i.e., heavy minerals), and 1 being the most important factor (sediment characteristics and environmental/physical impacts).

The total weight (**Figure 5**) is calculated from Level 1, Level 2, and Level 3 criteria. As Sediment Characteristics and Borrow Site Controls include all three levels of data criteria, the multiplication of all of these factors cause smaller values than criteria with fewer levels of data, such as Stakeholder Acceptability and Future Site Usability.

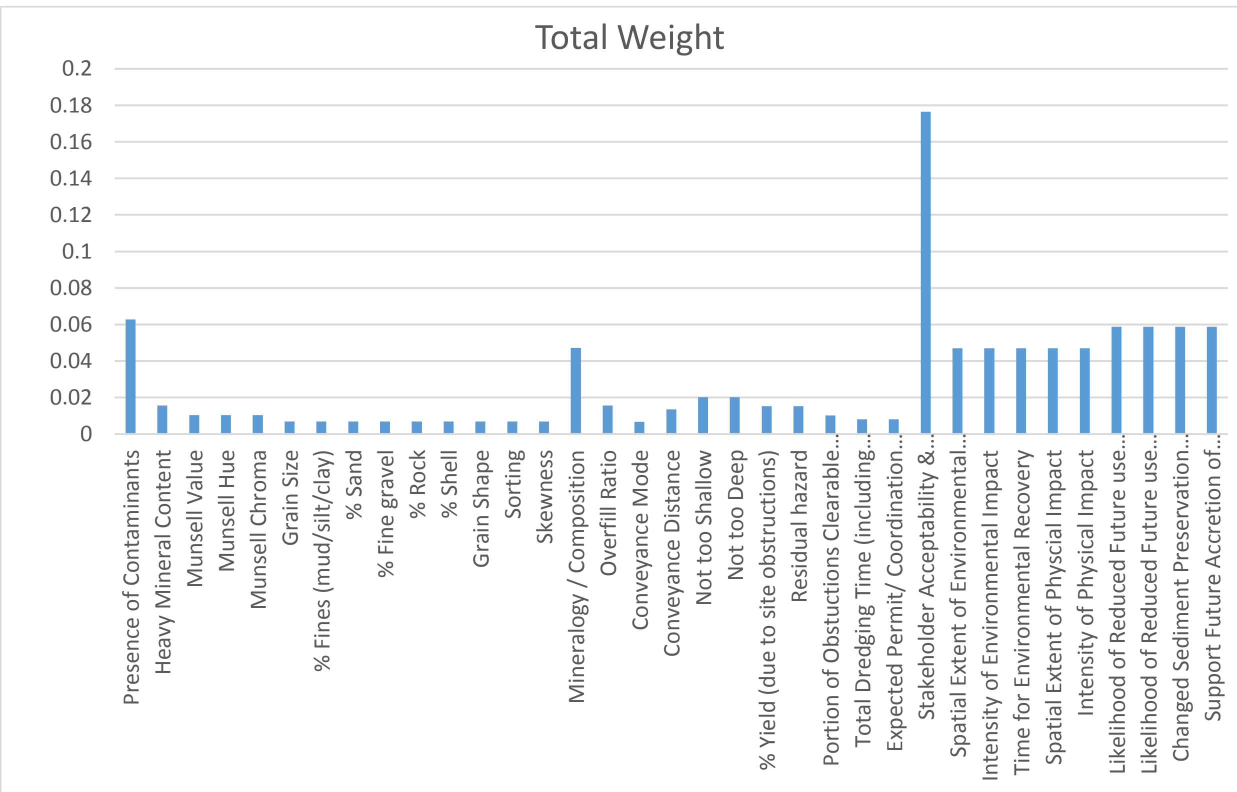

Figure 5. Weights of individual criteria within SSST for Ship Shoal.

Results

The Overall Scores, which describe the total utility of each alternative and are the central piece of information to be considered by the SSST, are shown in the yellow column. These top-level scores provide the user with information about the order of preference for each alternative, given all of the criteria as well as the how strong the preference is (**Table 4**). All five site selection alternatives have similar scores and could be considered almost equally preferred. The top-level scores for main criteria are displayed alongside the cost and volume amount, providing additional context for decision making.

Table 4. Final weights scoring dredge areas within Ship Shoal.

Names of Borrow Site Alternatives	Quantity Available in Millions of Cubic Yards (MCY)	Approximate or Estimated Cost	Overall Score	Sediment Characteristics*	Borrow Site Controls	Stakeholder Acceptability & Community Opinion	Environmental & Physical Concerns	Future Site Usability
South Pelto 12/13	21.6	$$	0.682	0.48	0.57	0.18	1.00	1.00
Ship Shoal 88/89	13.2	$$	0.697	0.51	0.64	0.18	1.00	1.00
Western Ship Shoal	107.7	$$$	0.707	0.48	0.79	0.18	1.00	1.00

The sediment characteristics for each subregion of Ship Shoal are very similar, as the sand source is considered to be homogenous. However, the SSST shows that South Pelto 12/13 and Western Ship Shoal has less desirable sand when compared to the remainder of the sand source, as it is finer than the remainder of Ship Shoal (**Figure 6**). However, as the placement location for this hypothetical example is in the Isle Denieres, which has a fine grained sand on the existing beach, and fine grained sand can also be used to restore marshes, this does not have a significant outcome on the final scores.

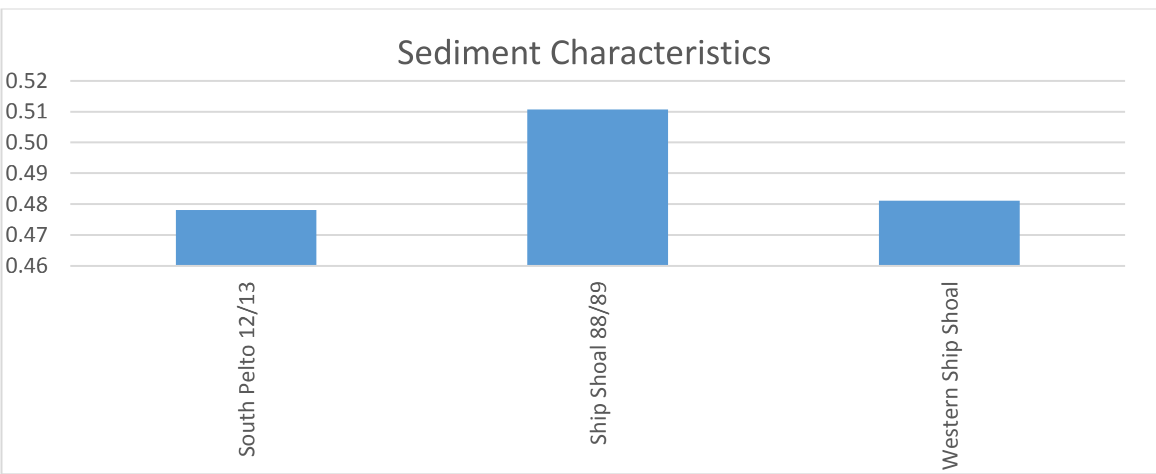

Figure 6. Final results of sediment characteristics for Ship Shoal subregions.

The borrow site controls (including factors such as conveyance mode and distance, bathymetry, site obstructions, total dredging time, and permitting time) show that Western Ship Shoal has the fewest borrow site controls, and South Pelto 12/13 has the highest number of site controls making this the least effective choice (**Figure 7**). As dredging time and permitting time would essentially be the same, and any conveyance mode could be used within Ship Shoal, the primary factors are site obstructions, conveyance distance, and bathymetry. The design South Pelto could limit the percent yield due to the high percentage of area covered or affected by oil and gas infrastructure.

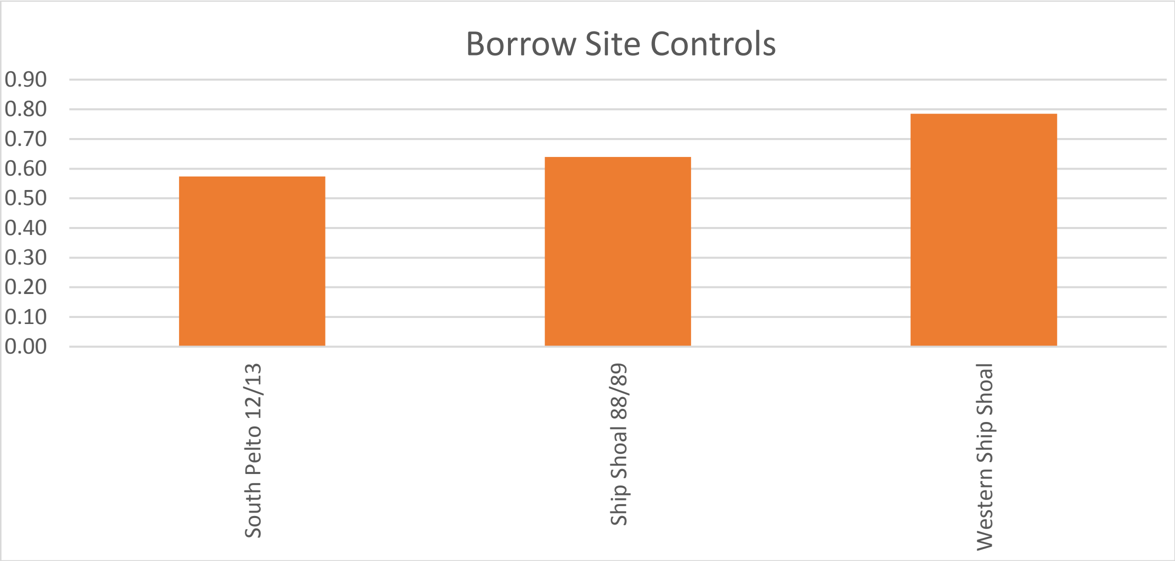

Figure 7. Final results of borrow site controls for Ship Shoal subregions.

All subregions of Ship Shoal had the same level of Stakeholder Acceptability and Community Opinion (**Figure 8**). This factor had no impact on the overall utility score.

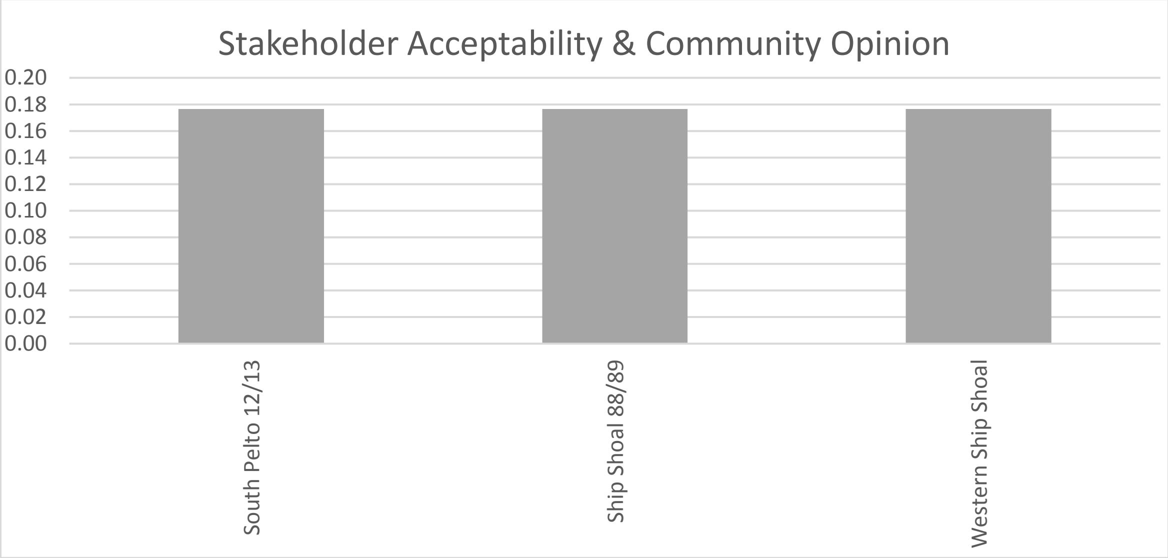

Figure 8. Final results of stakeholder acceptability and community opinion for Ship Shoal subregions.

All subregions had the same Environmental and Physical Concerns, as there are the possibility for future oil and gas infrastructure in all subregions, as well as endangered species (**Figure 9**). It is expected that all subregions will recover from infaunal impacts within several years after a dredging event.

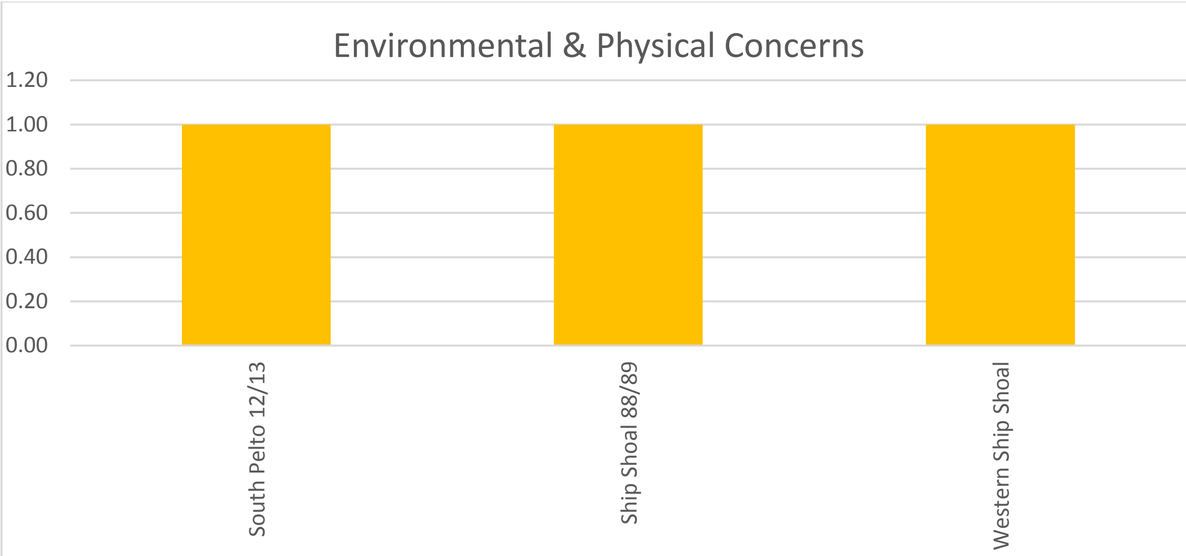

Figure 9. Final results of environmental and physical concerns for Ship Shoal subregions.

The Future Site Usability (including factors such as accretion, surface armoring, siltation, and creation of challenging geometires) show that all subregions are suitable choices (**Figure 10**). Although as mentioned previously, South Pelto 12/13 could limit percent yield based on oil and gas infrastructure.

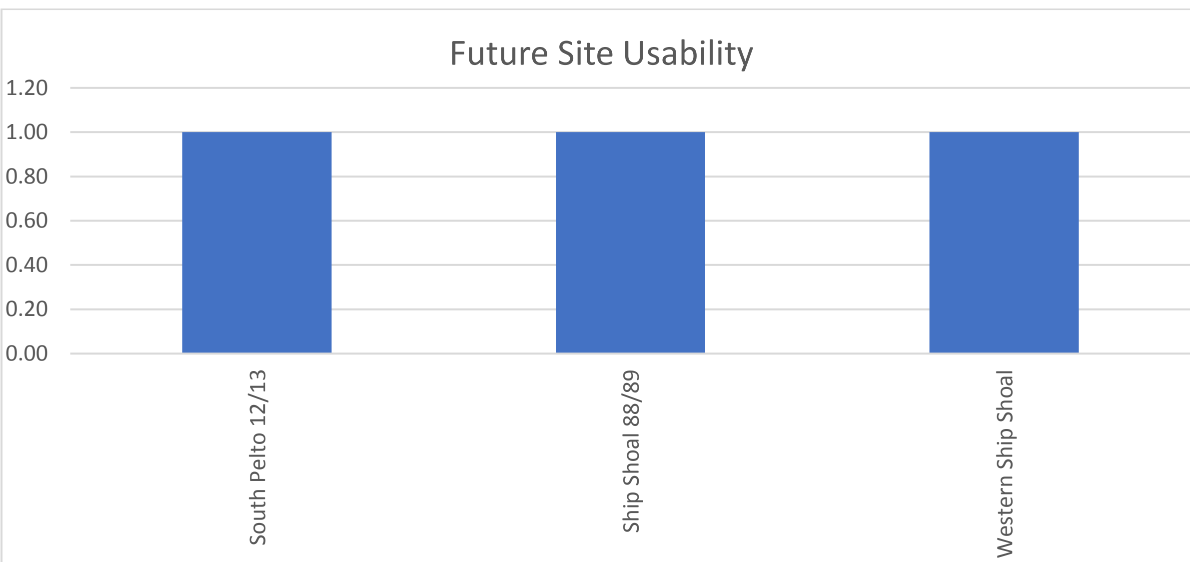

Figure 10. Final results of future site usability for Ship Shoal subregions.

Overall, the SSST utility shows that the Ship Shoal sand source is an a viable, sustainable sand source for restoring and nourishing the coastal system of Louisiana, having a score ranging from 0.683 for to 0.708 for the overall sand source of Ship Shoal (**Figure 11**). South Pelto scored lowest due to the oil and gas infrastructure, while

Western Ship Shoal scored the highest due to it being clear from oil and gas infrastructure, and having a large, recharging sand volume.

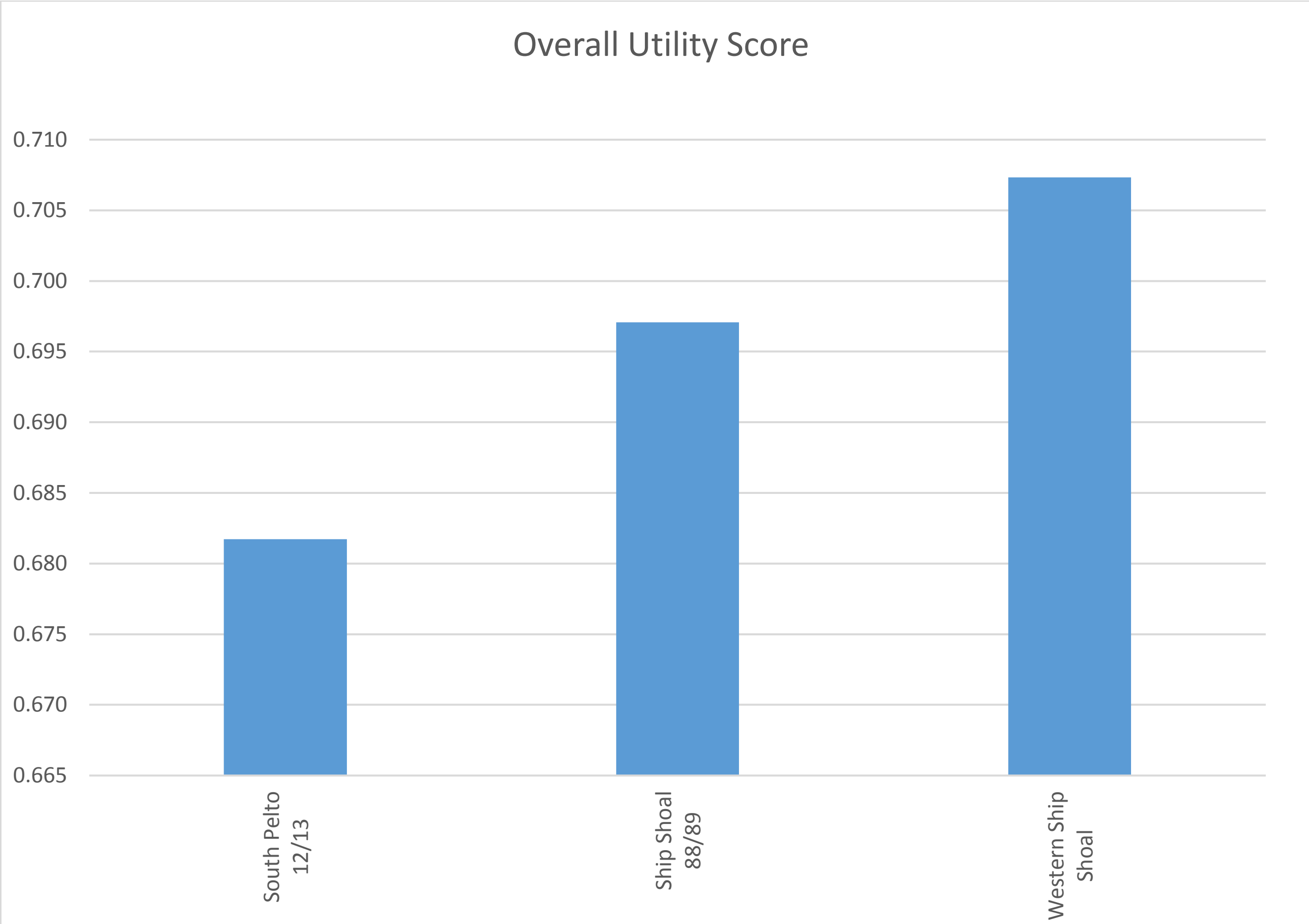

Figure 11. Final results of the overall scoring for Ship Shoal subregions.

Discussion

The SSST primary value is in helping project managers make more sustainable and long term borrow area use decisions within offshore sand resource areas. It will do this by providing output that includes both relative scores for different factors for each sub-region of a borrow area, and a list of recommended practices. The tool could assist in decision-making that mitigates the effects of cumulative dredging on the same sediment source while maximizing use of that finite resource.

The insights/recommendations from the SSST are complementary to (rather than redundant of) the detailed processes USACE and non-federal entities already have in place for sand source identification and technical engineering on an individual project basis.

Best Management Practices

Many decisions remain following the use of the SSST. The following best management practices have been recommended by subject matter experts that have a detailed understanding of OCS dynamics and extensive experience in sand borrowing projects. The subject matter experts that contributed to this list offered two types of guidance: specific direction and general considerations. The objective of collating these practices is to assist future OCS sand borrowers in the following: ensuring longevity of limited sand resources; limiting environmental and physical impacts of dredging; preventing resource overuse / depletion; balancing short term and long term needs; improving operational efficiency; limiting cost/complexity; and ensuring equitable use across current and future stakeholders.

The recommended best practices and considerations are divided into the following four categories: Planning, Physical Operations, Environmental Operations, and Stakeholder Engagement

Planning

- Plan with a *holistic* view of the erosion and OCS sand-replacement cycle
- Limit use of renewable sites to match or refill faster than the anticipated renourishment rate
- Develop a *Borrow Area Conservation Plan*
- Use the first sand resource in its entirety before moving on to the second resource
- Avoid leaving behind small amounts of sand that are uneconomical to collect in the future
- Factor in infilling – both the infilling rate and sediment type – when determining borrow volume
- Incentivize dredge operators performing the work to do a clean and thorough job
- Employ “beneficial use” from another dredge project
- Do not automatically exclude borrow areas that appear to have elevated silt content
- Do not automatically exclude borrow areas if wave models show a potential increase in erosion along the shoreline
- Optimize post-dredging geometry to limit environmental and physical impacts
- Consider the trade-offs between mitigation strategies and future borrow area usability
- Consider tradeoffs between sand removal efficiency and cost
- Consider the tradeoffs between environmental impacts and risks to high value resources

Physical Operations

- Minimize overall dredging intensity and persistent effects
- Rotate renewable dredge areas

- Selectively dredge the accreting area or leading edge
- Avoid leaving a gravel/coarse lag layer
- Spread out dredge areas to limit physical impacts
- Define a the maximum dredge depth according to the context of the specific sand resource
- Construct reinforced side slopes
- When making step cuts, make sure that the wall sizes between cells are consistent
- Use turbidity curtains when coral reefs are down-current from a dredge project
- Leave behind a contoured surface that lowers the profile while retaining the pre-existing morphology – avoid digging a “borrow pit”
- Consider the tradeoffs between shallow cuts and deep cuts
- Consider the tradeoffs between the different types of dredges

Environmental Operations

- Prioritize protection of endangered species
- Prioritize borrow-area alternatives that allow for maximum recovery from ecosystem perturbations
- Designate an environmental “refuge patch” within the borrow area
- Prioritize borrow areas that replenish with the same type of habitat
- Mitigate the effects of lost surface area
- Consider the tradeoffs between efficiency and overall dredge time
- Consider the tradeoffs between the geometry of the feature and the impacts to the macroinvertebrate ecosystem

Stakeholder Engagement

- Form a stakeholder working group
- Maximize transparency between stakeholders
- Share projections of future OCS resource use
- Include commercial fishing groups in the pre-dredge planning process
- Develop a detailed inventory of OCS sand resources to manage stakeholder expectations
- Perform a detailed *regional* Environmental Impact Statement before allowing multiple stakeholders to share sand resources in a region
- Share sand quality fairly
- Consider replacing the term “competitive use” with “shared use” in project communications

Conclusions

The results of the SSST show that all of the subregions within Ship Shoal are compatible and sustainable for the Louisiana coastal system, and are viable options for both beach and marsh restoration and periodic nourishment. It is the recommendation of this manual to utilize Western Ship Shoal as it is identical in grain size to most of the Louisiana shoreline, has no oil and gas obstructions, and a large volume.

References

Chisholm, T.A., 1991. Dredging Aspects of Aggregate Mining from Ship Shoal, *in* Characterization of the Development Potential of Ship Shoal Sand for Beach Replenishment of Isles Dernieres. Report prepared by Louisiana Geological Survey for U.S. Minerals Management Service under cooperative agreement #14-12-0001-30404.

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Frazier, D.E., 1967, Recent deltaic depositions of the Mississippi River: their development and chronology, Gulf Coast Association of geological societies Transactions, v.27, p. 287- 315.

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Krawiec, W., 1966, Recent sediments of the Louisiana inner continental shelf. Houston, Texas: Rice University, Doctoral thesis, 139 p.

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Penland, S., R. Boyd, D. Nummedal and H.H. Roberts, 1981, Deltaic barrier development on the Louisiana coast: Transaction Gulf Coast Association of Geological Societies, v. 31, p. 471-176.

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D-3 SSMP—Manual

Sand Source Management Plan
Comprehensive Work-Flow Manual

Prepared for:

U.S. Department of the Interior
Bureau of Ocean Energy Management
Marine Minerals Program
IA No. M15PG00033

Prepared by:

Jennifer L. Coor, Ph.D., P.G.
U.S. Army Corps of Engineers

March 2017

Introduction

This document will outline a planning process that can be utilized to demonstrate the costs and benefits of optimizing sand sources which undergo frequent dredging by either single or multiple users. Sand and sediment source characteristics, environmental resources information, best management practices, and a cost-benefit analysis should be compiled and analyzed in preparation of creating a sand source management plan (SSMP). An SSMP will combine the results of the Sand Source Selection Tool (SSST) with inherent knowledge, expert analysis, and interpretation. Finally, the SSMP should include lessons learned from previous projects, both within the region and those that are similar in nature to the proposed project.

Suggested Structure of SSMP

The SSMP should include the basic sections of any scientific manuscript – introduction, background, methodology, results, discussion, and conclusions. It is highly recommended that an executive summary be provided.

Executive Summary

The executive summary portion of the SSMP should be written last, and should provide a written summary of the overall findings of the report. Important items to discuss include the study area, project description, and any significant problems/lessons learned during the implementation of the SSST and synthesis of the SSMP.

Introduction

The introduction portion of the SSMP should briefly describe the proposed project and provide relevant background information. It should contain a brief summary of overall sand availability, environmental concerns, dredging practices, and analytical methods that will be used within the SSMP. It is possible to combine the introduction with the background, based upon the preferences of the author(s).

Background

The background section of the SSMP is the most important and the most time intensive, as all of the data inputs to the SSST are described in this section. This section should start with the geographic setting, local geology, and basic information on the sand source. Figure 1 shows a tree of the input criteria for the SSST. It is recommended that each criteria heading be discussed within this section of the document. Additional information on each input criteria may be found in the SSST Reference Manual (ERDC 2016).

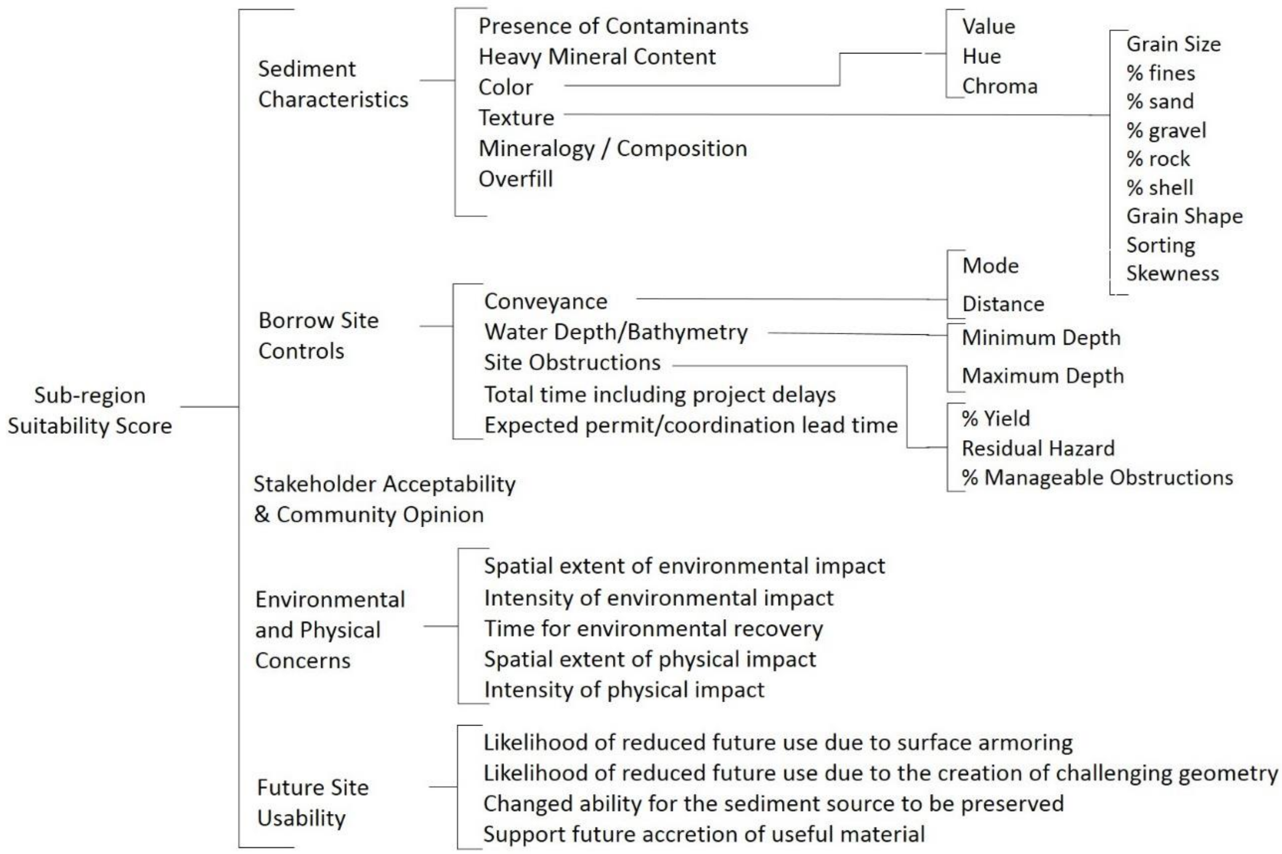

Figure 1. Input criteria tree for SSST.

Sediment Characteristics

The sediment characteristics section should summarize the geotechnical investigations that have been conducted at the sand source. Preferably, a composite value for each applicable sediment characteristic for both the sand source and each sub-region, or each project option, is found in the project literature, or calculated from data within the project literature.

The most important criteria of this section is the sediment texture. This includes the mean (or median) grain size (mm or phi), percent fines, percent sand, percent gravel, percent rock (if applicable), percent shell, grain shape, sorting, and skewness. These characteristics, in addition to color (hue, value, and chroma), are the primary components of compatibility analyses between sand source and beach placement sites.

The presence of contaminants, heavy mineral content, mineralogy/composition, and overfill ratio are also included in the sediment characteristics.

Borrow Site Controls

The borrow site controls section should summarize the conveyance, bathymetry, and site obstructions at the sand source and total project time and permitting/coordination time. The conveyance includes the dredge method (hopper, cutter-suction, etc.) and distance to the placement site. The water depth/bathymetry documents the range of water depths at the sand source. The site obstructions describe the overall expected percent yield of the sand source, description of any residual hazards (such as pipelines, cables, UXO, etc.), and the percent of manageable obstructions (such as diver cleared cultural resources). This information is typically found in the project literature.

It is important to factor in the time necessary to coordinate with State and Federal agencies and obtain all required permits. Similarly, it is important to have a realistic project schedule that includes project delays. This information is typically gained through talking to experts in the field, or examining historic project contract documents. For a hypothetical case, these two criteria are not necessary.

Stakeholder Acceptability and Community Opinion

The stakeholder acceptability and community opinion can be found in National Environmental Policy Act (NEPA) documents, as there may be a required public comment period. Local, State, and Federal agencies, non-governmental organizations, and stakeholders are all able to make comments during this period. The extent of stakeholder acceptability will be documented in relative terms (e.g. Alternative A is more acceptable or expects less opposition than Alternative B).

Environmental and Physical Concerns

Environmental and physical concerns describe five biophysical aspects of the sand source; this information may be obtained from project literature or subject matter experts. The spatial extent of the environmental impacts describes both how likely benthic communities can relocate to nearby habitat or the anticipated extent of turbidity impacts. The intensity of the environmental impact is an indicator of potential changes and impacts to water quality, pelagic, and benthic species. The time for environmental recovery is a consideration of the short and long-term impacts to the benthic community. The spatial extent of the physical impact describes the potential physical changes to the sediment transport or wave climate regimes due to dredging the sand source. The intensity of the physical impact is attributable to expected dredging frequency and the volume of sand removed.

Future Site Usability

Future site usability encompasses four criteria describing physical changes to the sand source during the dredging process; this information can be obtained from subject matter experts. The likelihood of reduced future use due to surface armoring describes the possibility of coarse shell and rock either being sidecast or left behind at the dredge site, rendering underlying material inaccessible. The likelihood of reduced future use due to the creation of challenging geometry describes problems with low percent yield due to small angles, non-linear sub-regions, and varying dredge depths within the sand source. The changed ability for the sediment source to be preserved is an indicator of the stability of the sand source, or how long the sand source is expected to be able to support a project. Lastly, the support future accretion of useful material is the probability that conditions will exist for new material to accrete within the sand source.

Methods

The SSST should be utilized to analyze the data described in the Background section.

1. The first step is filling out the “Intro” tab.
2. Second, in the “Alternatives” tab, fill in the various sub-regions or dredge options, and respective available volume and approximate cost (can be alpha or numeric).
3. Third, set the value functions for each of the criteria in Figure 1 in the “Value Functions” tab based on either the required or desired criteria for the placement site.
4. Next, in the “Alternative Scores” tab, the criteria in Figure 1 can be input to the SSST as either measured data or ranked on a 5-point scale, where 1 is very poor and 5 is very good, under each of the appropriate headings – on the left of the two blank columns. Once all data has been entered, click the ‘update all’ to bring in the information from the “Value Functions” tab.
5. Finally, go to the “Weights” tab. The criteria may be ranked to help the user develop the weighted scores, but this is not necessary for the SSST to function. The criteria must then be scored; assistance from a subject matter expert may be necessary. The score represents how relatively important an individual criterion is. The user can use any value for the score, as these will all be normalized (i.e., 0 to 100, 1 to 10, etc.). The Weight will then be calculated, giving the total weight for each criteria.

Additional information on the SSST methodology may be found in the SSST Reference Manual (ERDC 2016).

Results

The “Results” tab shows the overall score for each sub-region, or project option, and also calculates the score for each Level-1 criterion (Figure 1). The overall score and each Level-1 criterion score has a histogram graphically showing the relationships between the sub-regions, or project options.

Additionally, the “Weights” tab provides a histogram for the total weights for all bottom-level criteria, and displays histograms for total weights for Level-2 and Level-3 criteria.

Additional information on the SSST results may be found in the SSST Reference Manual (ERDC 2016).

Discussion

The discussion section should describe the application of the SSST for the project, summarize the results, and determine if the utility was relevant for the project. The challenges faced and lessons learned from the project and utilizing the SSST, as well as best management practices, should also be discussed.

Conclusions

The conclusions should be a short section that briefly describes the project, most important results, and summary of the relevant findings of the results.

Lessons Learned

It is highly recommended to begin searching project literature early to become familiar with the sand source. Furthermore, an inexperienced author should consult a subject matter expert prior to utilizing the SSST and writing an SSMP.

References

ERDC. 2016. Sand Source Selection Tool Reference Manual.

Appendix E. Task 5 Deliverables

E-1 Monthly Reports and Updates

DEPARTMENT OF THE ARMY
ENGINEER RESEARCH AND DEVELOPMENT CENTER, CORPS OF ENGINEERS
COASTAL AND HYDRAULICS LABORATORY
WATERWAYS EXPERIMENT STATION, 3909 HALLS FERRY ROAD
VICKSBURG, MISSISSIPPI 39180-6199

REPLY TO ATTENTION OF

CEERD-HN-C 27 October 2015

MEMORANDUM FOR the Department of the Interior, Bureau of Ocean Energy Management, Marine Minerals Program.

SUBJECT: October 2015 Progress Report, “Managing Dredge Impacts by Optimizing the Use of Sand Resources”

1. Progress during October 2015 included:
    a. Conducted Initial Scoping Meeting with BOEM in conjunction with the BOEM Gulf of Mexico work group meeting,
    b. Provided the first Initial scoping meeting summary,
    c. Internally coordinated with the ERDC librarian and initiated the literature review.
    d. Initiated MCDA planning meeting activities: team identification, cost estimates, facilitators etc.
2. Work planned for November 2015 includes:
    a. Working on first draft of the Literature Review for MCDA criteria.
    b. Working on first draft evaluation factor dictionary.
3. Please contact me with any questions at 601-634-4035 or email Jase.D.Ousley@usace.army.mil.

Jase D. Ousley
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VICKSBURG, MISSISSIPPI 39180-6199

REPLY TO ATTENTION OF

CEERD-HN-C 27 November 2015

MEMORANDUM FOR the Department of the Interior, Bureau of Ocean Energy Management, Marine Minerals Program.

SUBJECT: November 2015 Progress Report, "Managing Dredge Impacts by Optimizing the Use of Sand Resources"

1. Progress during October 2015 included:
   a. Received literature review sources from ERDC Library,
   b. Draft MCDA literature review and evaluation factor dictionary at 75% complete,
   c. MCDA planning meeting activities: team identified, planning efforts underway.
2. Work planned for December 2015 includes:
   a. Complete draft of the literature review for MCDA criteria.
   b. Complete draft evaluation factor dictionary.
3. Please contact me with any questions at 601-634-6044 or email Jase.D.Ousley@usace.army.mil.

Jase D. Ousley
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REPLY TO
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CEERD-HN-C 27 November 2015

MEMORANDUM FOR the Department of the Interior, Bureau of Ocean Energy Management, Marine Minerals Program.

SUBJECT: December 2015 Progress Report, "Managing Dredge Impacts by Optimizing the Use of Sand Resources"

1. Progress during December 2015 included:
    a. Draft MCDA literature review and evaluation factor dictionary at 85% complete,
    b. MCDA planning meeting activities: planning efforts underway, facilitator identified.
2. Work planned for January 2016 includes:
    a. Complete draft of the literature review for MCDA criteria and evaluation factor dictionary.
    b. Solidify the meeting plans
    c. Organize the team for an introduction on the project prior to the in-person meeting
3. Please contact me with any questions at 601-634-6044 or email Jase.D.Ousley@usace.army.mil.

Jase D. Ousley
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CEERD-HN-C 22 January 2016

MEMORANDUM FOR the Department of the Interior, Bureau of Ocean Energy Management, Marine Minerals Program.

SUBJECT: January 2016 Progress Report, "Managing Dredge Impacts by Optimizing the Use of Sand Resources"

1. Progress during January 2016 included:
   a. The project PI has been transitioned. The new PI responsibilities will be shared by Tayna Beck (ERDC-CHL), Jen Coor (USACE Jacksonville) and Matthew Bates (ERDC-EL).
   b. The MCDA meeting wil be held on 1-2 February in Jacksonville. A Webinar will be available. Logistics for the meeting are almost complete (space, AV equipment, recording equipment, facilitator, note keeper, etc.)
   c. The evaluation factor dictionary will be submitted on Monday, 25-Jan-2016.
   d. The draft version of the MCDA tool is underway and will be presented at the MCDA meeting.
2. Work planned for February 2016 includes:
   a. During the next month, the draft evaluation factor dictionary will be submitted and the MCDA meeting will be held. Following the meeting, transcription and delivery of the meeting notes will be completed.
   b. The MCDA literature review will be completed and submitted.
3. Please contact Tanya Beck with any questions at 601-634-2603 or email Tanya.M.Beck@usace.army.mil.

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REPLY TO
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CEERD-HF-CI 26 February 2016

MEMORANDUM FOR the Department of the Interior, Bureau of Ocean Energy Management, Marine Minerals Program.

SUBJECT: February 2016 Progress Report, "Managing Dredge Impacts by Optimizing the Use of Sand Resources"

1. Progress during February 2016 included:
    a. The project PI has been transitioned with responsibilities shared by Mary Cialone (PI, ERDC-CHL), Jen Coor (Tech POC, USACE Jacksonville) and Matthew Bates (Tech POC, ERDC-EL). A phone meeting was held to solidify the roles of each PI. In addition, the USACE project team held a webinar to review the path forward and status of the MCDA tool.
    b. A 90-day extension of the Interagency Agreement (IAA) was requested and is pending approval.
    c. The draft evaluation factor dictionary was revised and has been put on hold pending approval of the adjusted schedule. The final dictionary will be submitted 30 days after the MCDA planning meeting.
    d. The literature review is on hold pending approval of the adjusted schedule.
    e. SAJ and ERDC will meet 29 Feb 2016 to plan the MCDA meeting for the March timeframe. Agenda and materials for a ½-day MCDA meeting have been developed and the draft plan for a 2-day MCDA workshop has been initiated in anticipation of the revised IA.
    f. A draft of the decision support framework (MCDA tool) is partially developed and will be presented at the initial MCDA meeting. Further revisions and development will be made during the stakeholder meeting based on practitioner/expert participation, validation, and confirmation of the draft.

2. Work planned for March 2016 includes:
    a. The MCDA meeting will be planned and held. Following the meeting, transcription and delivery of the meeting notes will be completed.
    b. The MCDA literature review will be completed and submitted.
    c. The evaluation factor dictionary will be revised based on the MCDA meeting results and will be submitted NLT 30 days after the MCDA meeting.

3. Please contact Mary Cialone with any questions at 601-634-2139, Mary.A.Cialone@usace.army.mil, or, Tanya Beck at 601-634-2603, Tanya.M.Beck@usace.army.mil.

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REPLY TO
ATTENTION OF

CEERD-HF-CI 25 March 2016

MEMORANDUM FOR the Department of the Interior, Bureau of Ocean Energy Management, Marine Minerals Program.

SUBJECT: March 2016 Progress Report, "Managing Dredge Impacts by Optimizing the Use of Sand Resources"

1. Progress during March 2016 included:
   a. A 90-day extension of the Interagency Agreement (IAA) was approved.
   b. SAJ and ERDC met on 29 Feb-1 Mar 2016 to plan the MCDA meeting for the April/May timeframe. After coordinating availability of key members/presenters, the meeting is scheduled for 10-11 May 2016 in Jacksonville, Florida.
   c. A draft agenda for a 2-day MCDA meeting have been developed including session topics, presenters, and timing required to cover each topic.
   d. Summaries of the vision for the MCDA tool and the goal of the MCDA meeting were provided to the oversight committee for review and approval.
   e. The invitee list developed for the initial planning meeting that was scheduled for February was reviewed and an estimated/target number of attendees (40-60) was determined. For the earlier meeting, 89 people were invited to attend and 48 responded positively, representing federal and state agencies, dredgers, academia, consultants, and FSBPA.

2. Work planned for April 2016 includes:
   a. The MCDA team will meet to review the agenda and discuss details of the material that will be presented in each session. The MCDA team will then review the agenda with the oversight committee and request any suggested agenda changes from the oversight committee.
   b. The MCDA meeting plans and agenda will be refined and finalized based on input from the oversight committee. Following the meeting, transcription and delivery of the meeting notes will be completed.

3. Please contact Mary Cialone with any questions at 601-634-2139, Mary.A.Cialone@usace.army.mil, or, Tanya Beck at 601-634-2603, Tanya.M.Beck@usace.army.mil.

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REPLY TO
ATTENTION OF

26 Apr 2016

CEERD-HF-CI

MEMORANDUM FOR the Department of the Interior, Bureau of Ocean Energy Management, Marine Minerals Program.

SUBJECT: April 2016 Progress Report, "Managing Dredge Impacts by Optimizing the Use of Sand Resources"

1. Progress during April 2016 included:
   a. The MCDA tool development team held internal discussions with USACE and District offices to develop support for the stakeholder meeting in May.
   b. The MCDA tool development team met via webinar with the USACE oversight committee to review the draft agenda and discuss details of the material that will be presented at the May meeting. The oversight committee had the opportunity to suggest agenda changes and request clarification on specific presentation topics. The MCDA team has incorporated suggested changes into the final agenda.
   c. The MCDA tool development team also held a phone meeting with BOEM (Paul Knorr) to discuss and refine the document describing the goal of the May meeting and purpose of the MCDA tool. From this discussion, it was clearly stated that the intent of the MCDA tool is as a long-term planning tool for better management of sediment resources.
   d. The MCDA planning meeting date and venue were finalized as 10-11 May 2016 in Atlanta, Georgia. An invitation was sent out via email to approximately 90 potential attendees. A webinar meeting has been arranged for those who cannot attend in person.

2. Work planned for May 2016 includes:
   a. The MCDA planning meeting will be held in Atlanta, Georgia on 10-11 May. Following the meeting, transcription and delivery of the meeting notes will be completed.
   b. The literature review is in draft form, and will be completed on 15 Jun 2016.
   c. The MCDA tool is in demo/draft form, and will be completed based on input obtained at the MCDA planning meeting on 10-11 May 2016. The completion date is 15 Aug 2016.
   d. The evaluation-factor dictionary is in draft form, and will be completed on 15 Jun 2016, after the MCDA planning meeting.

3. Please contact Mary Cialone with any questions at, Mary.A.Cialone@usace.army.mil, 601-634-2139, or, Tanya Beck at Tanya.M.Beck@usace.army.mil, at 601-634-2603.

Mary A. Cialone

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REPLY TO
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31 May 2016

CEERD-HF-CI

MEMORANDUM FOR the Department of the Interior, Bureau of Ocean Energy Management, Marine Minerals Program.

SUBJECT: May 2016 Progress Report, "Managing Dredge Impacts by Optimizing the Use of Sand Resources"

1. Progress during May 2016 included:
   a. The Multi-Criteria Decision Analysis (MCDA) tool planning meeting was held in Atlanta, Georgia on 10-11 May 2016 to bring together subject matter experts to contribute to the development of a MCDA tool for sand source management. Between 30 and 40 participants attended in person or on-line for the 1.5-day meeting. Participants were asked to share with the MCDA tool development, factors they considered important for optimizing long-term sand source management for coastal and navigation projects. Participants included BOEM and USACE as well as academia and some private consultants.
   b. Following the MCDA tool planning meeting, a questionnaire was sent to all participants asking for additional feedback on the relative priorities (weights) of the different criteria and sub-criteria within the sediment characteristics category. Two responses have been received to date.
   c. The MCDA presentation material was updated based on feedback and discussion at the meeting. The revised version of the presentation material was sent back to the participants.
   d. Work on the literature review commenced following the planning meeting.
   e. Revisions to the draft data dictionary commenced following the planning meeting.

2. Work planned for June 2016 includes:
   a. The draft literature review will be completed.
   b. The evaluation-factor dictionary will be completed.
   c. A follow-up message will be sent to all planning meeting participants to gather more information for criteria weighting. The responses will be compiled and begin to be included in the tool development and manual.

3. Please contact Mary Cialone with any questions at, Mary.A.Cialone@usace.army.mil, 601-634-2139, or, Tanya Beck at Tanya.M.Beck@usace.army.mil, at 601-634-2603.

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REPLY TO
ATTENTION OF

24 Jun 2016

CEERD-HF-CI

MEMORANDUM FOR the Department of the Interior, Bureau of Ocean Energy Management, Marine Minerals Program.

SUBJECT: Jun 2016 Progress Report, "Managing Dredge Impacts by Optimizing the Use of Sand Resources"

1. Progress during Jun 2016 included:
   a. The Evaluation Factor Dictionary was completed and submitted as a deliverable to BOEM. The dictionary provides general terminology and information on resource characteristics and technical requirements, environmental considerations, costs and benefits, and best management practices that are common to dredging and beach nourishment.
   b. A draft criteria tree was previously developed by USACE based on initial discussions with BOEM. The MCDA Planning Meeting that was held in May, guided participants through a structured discussion of the draft criteria tree to assess and validate the proposed framework. A summary document discusses the draft and updated criteria tree that resulted from the MCDA Planning Meeting. The document was submitted as a deliverable to BOEM.
   c. A follow-up message was sent to all planning meeting participants to gather more information for criteria weighting. The responses were compiled and are beginning to be included in the tool development.
   d. MCDA tool development has been initiated with transformation of the discussion results and revised criteria tree into a spreadsheet model by defining the criteria in terms of value functions based on the metrics of assessment. The background computations that aggregate the criteria through each level of the criteria tree to produce a single score per alternative are also under development for the model implementation.
   e. The draft literature review compilation was initiated.

2. Work planned for July 2016 includes:
   a. The draft literature review will be completed.
   b. MCDA tool development will continue.

3. Please contact Mary Cialone with any questions at, Mary.A.Cialone@usace.army.mil, 601-634-2139, or, Tanya Beck at Tanya.M.Beck@usace.army.mil, at 601-634-2603.

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REPLY TO ATTENTION OF

29 Jul 2016

CEERD-HF-CI

MEMORANDUM FOR the Department of the Interior, Bureau of Ocean Energy Management, Marine Minerals Program.

SUBJECT: Jul 2016 Progress Report, "Managing Dredge Impacts by Optimizing the Use of Sand Resources"

1. Progress during Jul 2016 included:
   a. Work on the draft literature continued and is approximately 50% completed.
   b. A second follow-up message was sent to all planning meeting participants to gather more information for criteria weighting. The responses were compiled and included in the tool development.
   c. Major development of the MCDA tool took place this month with transformation of the discussion results and revised criteria tree into a spreadsheet model by defining the criteria in terms of value functions based on the metrics of assessment. A draft of the MCDA tool will be available in mid-August.

2. Work planned for Aug 2016 includes:
   a. The draft literature review will be completed.
   b. The development team is seeking additional input from those not represented at the MCDA Planning Meeting in order to get additional input on the criteria hierarchy and metrics as well as to expand the list of recommended best practices.
   c. The draft MCDA tool will be completed and available for application to the two sediment source management (SSM) plans.

3. Please contact Mary Cialone with any questions at, Mary.A.Cialone@usace.army.mil, 601-634-2139, or, Tanya Beck at Tanya.M.Beck@usace.army.mil, at 601-634-2603.

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REPLY TO
ATTENTION OF

29 Aug 2016

CEERD-HF-CI

MEMORANDUM FOR the Department of the Interior, Bureau of Ocean Energy Management, Marine Minerals Program.

SUBJECT: Aug 2016 Progress Report, "Managing Dredge Impacts by Optimizing the Use of Sand Resources"

1. Progress during Aug 2016 included:
   a. The MCDA literature synthesis was completed and forwarded to the sponsor.
   b. Interviews with BOEM, federal agencies, and industry experts (total of 18 interviews) continued in August to gather additional input and feedback on the draft framework developed at the MCDA Planning meeting held in Atlanta. The information gathered resulted in minor changes to the criteria, but also provided better context and descriptions for evaluating the criteria. The information gathered is also being incorporated into a "Best Practices" document that will be incorporated into the MCDA reference manual.
   c. The draft MCDA software tool was completed and provided to other team members for application to the two sediment source management (SSM) plans.

2. Work planned for Sep 2016 includes:
   a. The MCDA software reference manual will be completed.
   b. The MCDA software tutorial will be completed.
   c. The first draft SSM plan will be completed.

3. Please contact Mary Cialone with any questions at, Mary.A.Cialone@usace.army.mil, 601-634-2139, or, Tanya Beck at Tanya.M.Beck@usace.army.mil, at 601-634-2603.

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REPLY TO ATTENTION OF

20 Dec 2016

CEERD-HF-CI

MEMORANDUM FOR the Department of the Interior, Bureau of Ocean Energy Management (BOEM), Marine Minerals Program.

SUBJECT: FY17-Q1 Progress Report, "Managing Dredge Impacts by Optimizing the Use of Sand Resources"

1. Progress during Oct-Dec 2016 included:
   a. The MCDA software reference manual was completed and sent to BOEM for review and approval.
   b. The MCDA software tutorial manual and tool was completed and sent to BOEM for review and approval.
   c. Ship Shoal and Canaveral Shoal data were received from BOEM in December.

2. Work planned for Jan 2017 includes:
   a. The draft SSM plan for Ship Shoal will be completed.
   b. The draft SSM plan for Canaveral Shoal will be initiated.
   c. The draft of the SSM plan process manual will be initiated.

3. Please contact Mary Cialone with any questions at, Mary.A.Cialone@usace.army.mil, 601-634-2139, or, Tanya Beck at Tanya.M.Beck@usace.army.mil, at 601-634-2603.

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E.2 Summary of Final Meeting

The final meeting for "Managing Dredge Impacts by Optimizing the Use of Sand Resources" was held on 21 March, 2017, at the Bureau of Ocean Energy Management, 45600 Woodland Rd., Sterling, VA. The attendees included Paul Knorr, Geoff Wikel, Jeff Reidenauer, Doug Piatkowski, Jeff Waldner, Leighann Brandt, David Diamond, Deena Hansen, Doreen Vega, and Jennifer Bucatari from BOEM; and Jennifer Coor, Cate Fox-Lent, and Mary Cialone from USACE/ERDC. The meeting began with a brief introduction and summary of the inception of the project by Paul Knorr. Jennifer Coor then gave a brief presentation summarizing Task 1 and discussing the two deliverables: the literature review and data dictionary (see Appendix A). Cate Fox-Lent gave a presentation summarizing Tasks 2 and 3 on the MCDA Planning Meeting and the development process of the SSST. After a short discussion, a demonstration of the SSST was given. Jennifer Coor gave a presentation summarizing Task 4, which included developing an SSMP planning process/manual, and applying those techniques and the SSST to two sand sources: Canaveral Shoals, FL, and Ship Shoal, FL. There was another discussion period, and Paul Knorr closed the meeting.

Department of the Interior (DOI)

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

Bureau of Ocean Energy Management (BOEM)

The mission of the Bureau of Ocean Energy Management is to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way.

BOEM Environmental Studies Program

The mission of the Environmental Studies Program is to provide the information needed to predict, assess, and manage impacts from offshore energy and marine mineral exploration, development, and production activities on human, marine, and coastal environments. The proposal, selection, research, review, collaboration, production, and dissemination of each of BOEM's Environmental Studies follows the DOI Code of Scientific and Scholarly Conduct, in support of a culture of scientific and professional integrity, as set out in the DOI Departmental Manual (305 DM 3).