ERDC TR-22-14

Engineer Research and Development Center

US Army Corps of Engineers®
Engineer Research and Development Center

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

Engineering With Nature® Program

Swan Island

Monitoring and Adaptive Management Plan

Paula E. Whitfield, Jenny L. Davis, Amanda S. Tritinger, Danielle M. Szimanski, Rebecca R. Golden, Joe Z. Gailani, Michael T. Ramirez, Brook D. Herman, Matt Whitbeck, and Jeffery K. King

August 2022

The US Army Engineer Research and Development Center (ERDC) solves the nation's toughest engineering and environmental challenges. ERDC develops innovative solutions in civil and military engineering, geospatial sciences, water resources, and environmental sciences for the Army, the Department of Defense, civilian agencies, and our nation's public good. Find out more at www.erdc.usace.army.mil.

To search for other technical reports published by ERDC, visit the ERDC online library at https://erdclibrary.on.worldcat.org/discovery.

Swan Island

Monitoring and Adaptive Management Plan

Brook D. Herman, Jeffrey K. King

Environmental Laboratory
US Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180

Amanda S. Tritinger, Joe Z. Gailani, Michael T. Ramirez

Coastal and Hydraulics Laboratory
US Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180

Paula E. Whitfield

National Oceanic and Atmospheric Administration
National Centers for Coastal Ocean Science
1305 East-West Highway
Silver Spring MD 20910

Jenny L. Davis

National Oceanic and Atmospheric Administration
National Centers for Coastal Ocean Science
101 Pivers Island Road
Beaufort, NC 28516

Danielle M. Szimanski

US Army Corps of Engineers–Baltimore District
2 Hopkins Plaza
Baltimore, MD 21201

Rebecca R. Golden

Maryland Department of Natural Resources
580 Taylor Avenue
Annapolis, MD 21401

Matt Whitbeck

US Fish and Wildlife Service
2247 Key Wallace Drive
Cambridge, MD 21613

Final Technical Report (TR)

Approved for public release; distribution is unlimited.

Prepared for USACE Engineer Research and Development Center
Vicksburg, MS 39180

Under EWN Work Unit <DOER-EWN RT 19-15>

Abstract

Swan Island is a 10.12 ha island located in the Maryland waters of the Chesapeake Bay. Because of its value as a natural wave break for the town of Ewell on nearby Smith Island, as well as the ongoing erosion and subsidence of the island, in 2019 US Army Corps of Engineers (USACE)–Baltimore District placed 45,873 m^3 of dredged sediment and planted 200,000 marsh plants.

This restoration provided an opportunity to quantify the engineering (that is, resilience) and ecological performance of the island, postplacement. The lack of quantitative data on the performance of natural features such as islands has led to perceived uncertainties that are often cited as barriers to implementation. To address these data gaps, a multidisciplinary collaboration of five government entities identified project objectives and monitoring parameters through a series of mediated workshops and then developed a conceptual model to articulate those parameters and the linkages between them.

This monitoring and adaptive management plan (MAMP) documents those monitoring parameters and procedures and can serve as an example for other scales, regions, and research questions. Documenting research and monitoring efforts may help to foster widespread acceptance of nature-based solutions such as islands.

Contents

Figures and Tables

Figures

Tables

Preface

The project was funded by the US Army Engineering Research and Development Center (ERDC), Engineering With Nature® (EWN®) program under Work Unit DOER-EWN RT 19-15. Dr. Todd Bridges was the National Lead and Dr. Jeffrey King was the deputy national lead of the EWN program.

At the time of publication, Mr. James Lindsay was chief, EPR; and Mr. Warren P. Lorentz was division chief, EP. The deputy director of ERDC–Coastal and Hydraulics Laboratory (CHL) was Mr. Keith Flowers, and the director was Dr. Ty Wamsley. Mr. Mark R. Graves was the chief, Environmental Systems Branch (EEC); and Mr. Mark D. Farr was the division chief, Ecosystem Evaluation and Engineering Division (EE) branch. Ms. Sheryl Carrubba was Headquarters–US Army Corps of Engineers (USACE) Acting Navigation Business Line Manager, and Mr. Charles E. Wiggins, ERDC-CHL, was the ERDC technical director for Civil Works and Navigation, Research, Development, and Technology Transfer portfolio. The deputy director of ERDC–Environmental Laboratory was Dr. Jack Davis, and the director was Dr. Edmond J. Russo Jr.

We appreciate Victor Gonzalez and Cary Talbot for their thorough and extensive review of this documentation through the publication process. Additional thanks to Margaret Owensby and Leigh Provost who provided valuable assistance in this process. The authors would like to acknowledge Leigh Provost, Margaret Owensby, Victor Gonzalez, Cary Talbot, and Daniel Farrar for providing their review of this report.

COL Christian Patterson was commander of ERDC, and Dr. David W. Pittman was the director.

1 Introduction

In 2019, US Army Corps of Engineers (USACE)–Baltimore District placed 60,000 cu yd (45,873 m^3)* of sediment dredged from a nearby navigation channel on Swan Island and planted 200,000 intertidal plants. Following sediment placement and planting, the approximately 4.9 ha of low-lying and fragmented marsh was transformed into a higher-elevation feature that supports a more diverse range of plant communities. This restoration is expected to lead to increased resilience and enhanced ecological benefits in the local area.

Uncertainties related to island performance, especially in terms of capacity to reduce waves and erosion, present significant barriers to implementation of projects like Swan Island. Consequently, this restoration project presented an opportunity for the Swan Island Project Team, a multiagency collaboration, to investigate the engineering and ecological performance of Swan Island. Research such as this technical report can be used to foster widespread acceptance of nature-based solutions.

In collaboration with USACE's Engineering With Nature® (EWN) program, staff members from the US Army Engineer and Research Development Center (ERDC), USACE–Baltimore District, the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Coastal Ocean Science (NCCOS), the Maryland Department of Natural Resources (MDDNR), and the US Fish and Wildlife Service (USFWS) developed this monitoring and adaptive management plan (MAMP) to track progress towards project objectives, establish performance criteria to determine project success, and guide decisions on adaptive management actions for long-term maintenance of the island.

This technical report provides a model for duplicating these efforts at future restoration sites, ensuring transferability of the approach to

* For a full list of the spelled-out forms of the units of measure and unit conversions used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office, 2016), 248–52 and 245–47, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

different systems and regions, and will be updated periodically as the site and research matures over time.

1.1 Background

Swan Island, part of the Martin National Wildlife Refuge (MNWR), is located in the Maryland waters of the Chesapeake (Figures 1 and 2). Since 1942, Swan Island has experienced 2–3 m of erosion and 4.5 mm of relative sea level rise per year (USFWS 2014, Figure 3). Prior to restoration, the low-lying eastern side of Swan Island consisted of fragmented, low marsh at suboptimal elevations, with large unvegetated bare patches (Figure 4). Given the importance of Swan Island both as a natural wave break for the town of Ewell on nearby Smith Island and as a migratory bird habitat, USACE developed and implemented a beneficial-use and restoration plan to use dredged sediments from nearby federal navigation channels to increase the surface elevation of the island and thereby support a higher diversity of vegetation types (that is, habitat).

1.2 Objective

The objective of this MAMP is to track progress towards meeting project goals and measuring success. Furthermore, it will serve as a blueprint for documenting the monitoring approach (what, how, and how often data are collected), reporting and data management, roles and responsibilities, performance metrics, and decision thresholds for adaptive management action (Folse 2020a; Folse 2020b; Herman et al. 2020).

Figure 1. Geographic location of Swan Island within the Maryland waters of the Chesapeake Bay.

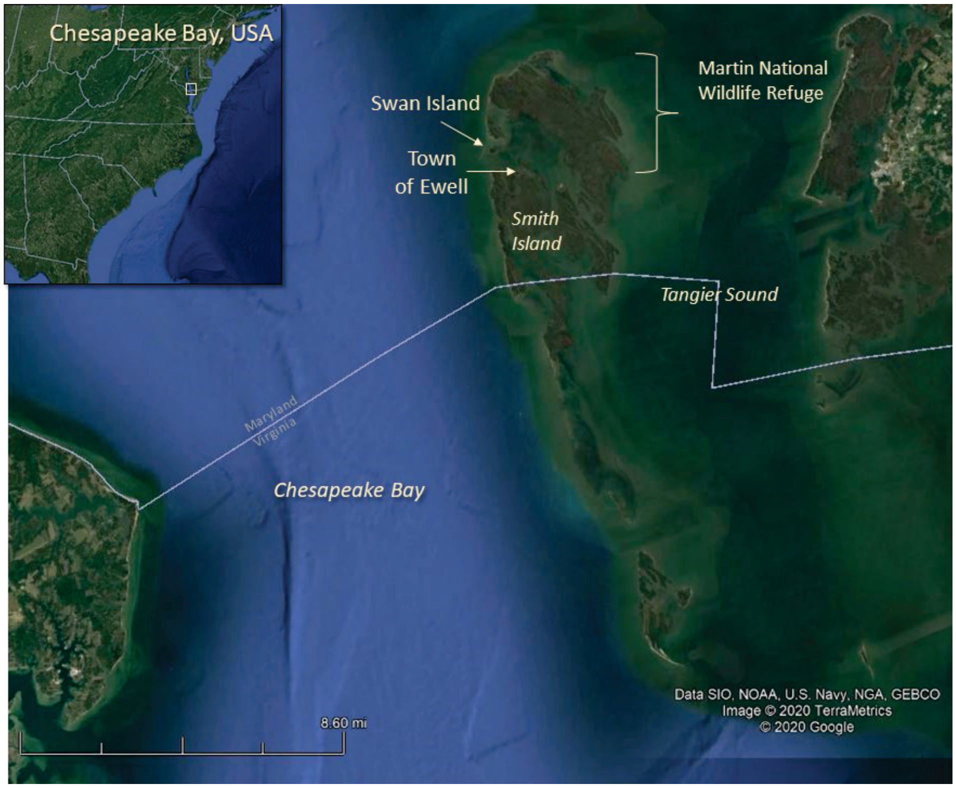


Figure 2. A map of Swan Island illustrating its proximity to the town of Ewell on nearby Smith Island and Chesapeake Bay waves.

Figure 3. Map that includes Swan Island and part of the Martin Wildlife Refuge (MNWR). *Red polygons* and *lines* indicate areas of erosion from 1942 to 2013 and *areas of yellow* indicate sediment accretion (reproduced with permission from USFWS 2014, 21).

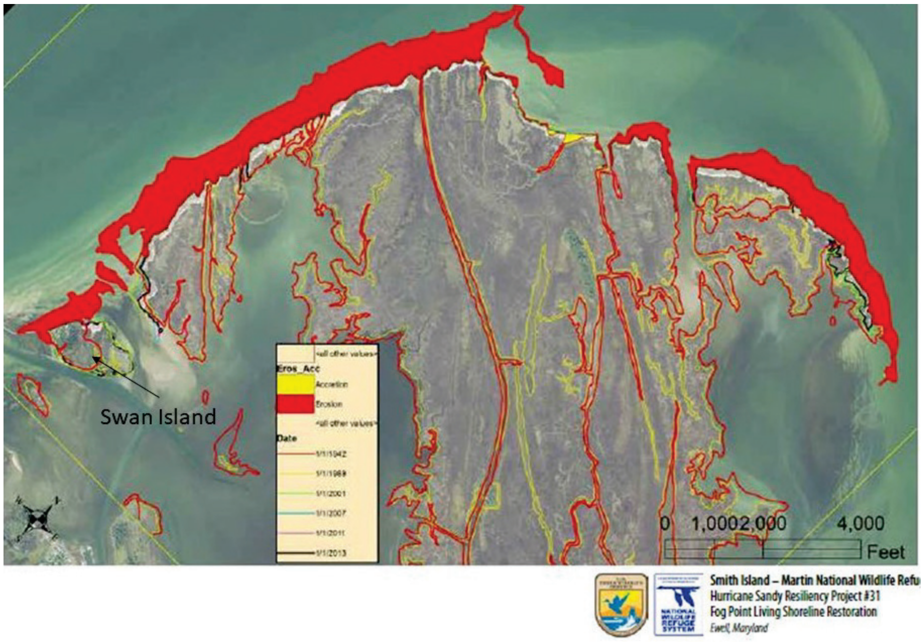
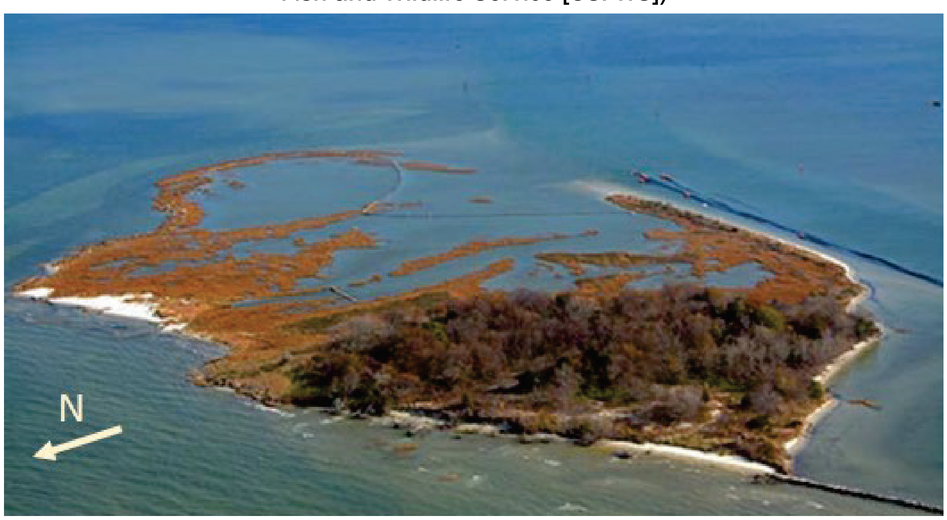


Figure 4. Swan Island in 2017 prior to sediment placement and planting. (Photo credit: US Fish and Wildlife Service [USFWS])



1.2.1 Sediment placement

Maintenance dredging of the Big Thorofare and Twitch Cove channels by USACE–Baltimore District occurred between November 2018 and March 2019 (Figure 5). Containment for the dredged material was placed earlier, in November 2017, and consisted of two layers of coir logs held in place by wooden stakes. This containment was designed to keep sediment from affecting the lower-elevation submerged aquatic vegetation (SAV) bed directly to the south of the coir logs, known as *the bight* (Figure 6). Approximately 45,873 m^3 of material was dredged using a hydraulic cutterhead dredge and placed via pipeline with mechanical grading to ensure target elevations were met. The restoration plan included the creation of low dunes and establishment of an elevation gradient to support high and low intertidal marsh. Inadvertent spillage of sediment around the western end of the containment raised sediment elevations within the bight; further details are included in Section 0 in the evaluation and adaptive management portion of this report. Final grading of the placed sediments was completed in April 2019 according to the planned design (Figure 6).

1.2.2 Native vegetation planting

Planting of native vegetation (corresponding to high and low marsh) obtained from local nursery growers started in late spring 2019 and was completed in July 2019. The final island profile included regions of dune (Zone A), transition between dune and high marsh (Zone B), high marsh (Zone C), and low marsh (Zone D) (Table 1, Figure 6). In addition, the shoreline adjacent to Dune 2 (located on the eastern end of the placement area) was reinforced with concrete armoring units, or *ajax*, stacked to form a 2 ft (0.61 m) tall barrier to protect against further erosion (Figure 7). During placement two factors caused the sediment to be placed at a higher elevation than planned: (1) the material was sandier than anticipated, which caused greater stacking, and (2) a lack of precision on the part of the contractor while placing material. As a result, the final planting regime was limited to *Sporobolus pumilus* (formerly *Spartina patens)* and *Sporobolus alterniflorus* (formerly *Spartina alterniflora)*, with the latter planted at elevations of <0.61 m mean lower low water (MLLW) and *S. pumilus* at all elevations above this level. Planting was done on a grid with 0.3–0.46 m centers with 5 cm nursery grown plugs during May and July 2019.

Figure 5. Federal navigation channels. The source of sediment for the Swan Island restoration are indicated by the *red lines*.

Figure 6. Satellite image of Swan Island from 2015 with the intended planting design based on elevation.

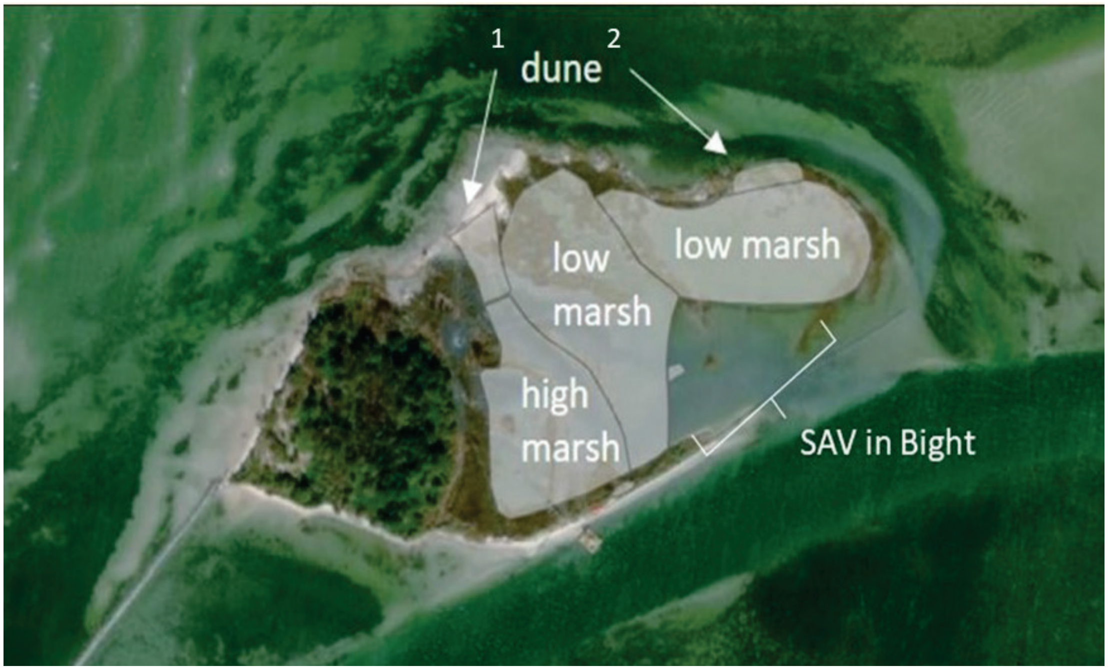


Table 1. Original restoration and planting design elements for Swan Island.

Zone	Vegetation region	Species	Design elevations
A	Dune region 1	American beach grass (*Ammophila brevigulata*)	Western end of placement area, designed to +4.5 ft (1.37 m) MLLW NAVD88
A	Dune region 2	American beach grass (*A. brevigulata*)	Eastern end of placement area, designed to +3 ft (0.91 m) MLLW NAVD88 Shoreline was reinforced with concrete armor units (aka *ajax*) stacked 2 ft (0.61 m) high (Figure 6) to protect against further erosion
B	Transition between dune and high marsh	Bitter switch grass, switch grass *(Panicum amarum*, *P. virgatum)*	Designed to +3 ft (0.91 m) MLLW NAVD88
C	High marsh	Salt-meadow cordgrass *(Sporobolus pumilus* formerly *Spartina patens)*	Designed to +3 ft (0.91 m) MLLW NAVD88
D	Low Marsh	Smooth cordgrass (*Sporobolus alterniflorus*, previously *Spartina alterniflora*)	Designed to +2 ft (0.61 m) MLLW NAVD88

Note: MLLW—mean lower low water; NAVD88—North American vertical datum 1988

Figure 7. Concrete ajax extending 30.48 m on the north side of the island adjacent to easternmost dunes. (Photo credit: USACE)

1.3 Approach

The restoration of Swan Island is expected to have significant benefits in terms of increases in habitat area and diversity and resilience of Swan Island to future sea level rise and abatement of erosive losses for the town of Ewell on adjacent Smith Island.

Measuring project success toward these objectives requires an understanding of the system dynamics of islands in the Chesapeake Bay. Sea level rise, land subsidence, and lack of sediment all contribute to the erosion of Chesapeake Bay islands (relative sea level rise [RLSR) per 4.5 mm) (USFWS 2014; Kearney and Stevenson 1991). From 1993 to 2008, 15 Tangier Sound Islands lost 21% of their area (Erwin et al. 2011). Since 1942, Swan Island has lost 2–3 m per year, primarily on the north side of the island (Figure 3). Prior to restoration, there was also extensive low-marsh fragmentation and exposure of bare areas (Figure 4).

Potential uncertainties for project success are those factors that may affect the ability to achieve project restoration objectives. Project uncertainties generally fall into two categories: (1) frequency and magnitude of inundation and (2) vegetation establishment success. Vegetation success is of particular importance to overall project success, given its key role in reducing erosion.

Other project uncertainties include sea level rise, storminess, subsidence, and sediment compaction, which may lead to greater inundation and erosion of the island (Table 2).

Table 2. Sources of uncertainties of the Swan Island restoration.

Key uncertainty	How the uncertainty could affect project success
Sea level rise, subsidence, sediment compaction, storminess	• increased wave overtopping and erosion most likely on the north side of the island • reduction in growth and cover of intertidal marsh and increased cover of SAV[a] or increase of open-water area.
Success of vegetation establishment and plantings	• lack of vegetation establishment or planting success would increase the loss of sediment from the island through erosion and lead to limited ability to trap additional sediments. • delayed high- and low-marsh habitat creation

[a] SAV—submerged aquatic vegetation

1.4 Further research questions

Through a series of ERDC-facilitated workshops, the project team identified project objectives and monitoring parameters and developed a conceptual model to articulate the primary parameters and linkages between them (Figure 8, Herman et al. 2020). This MAMP is a culmination of this effort and is the blueprint that the project team will follow to track progress in meeting project objectives.

The overarching objective is to evaluate the capacity of Swan Island in reducing wave impact and erosion on nearby shorelines (that is, engineering performance) and the resilience of the island to storms, sea level rise, and other environmental stressors. Additional objectives to address ecological performance and benefits include addressing specific questions, such as the following:

1. How have the restoration actions influenced the capacity of Swan Island to provide protection from wave energy to the town of Ewell?
2. How have the restoration actions influenced the storm and flood protection and the habitat benefits provided by Swan Island?
3. How will the protective capacity and habitat provided by Swan Island be influenced by sea level rise?
4. What are the short-term and long-term habitat trade-offs associated with sediment placement at Swan Island?

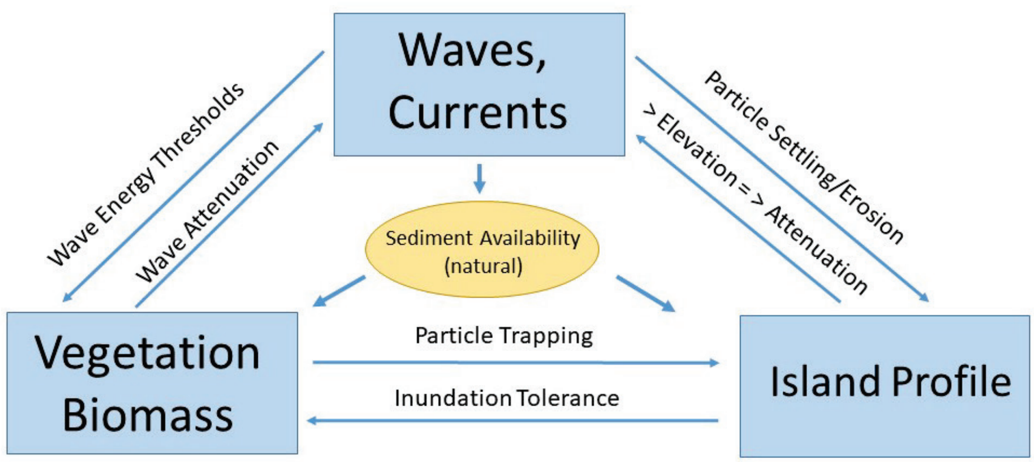
To address these questions, a series of integrated hydrodynamic and ecological models are being developed to evaluate the linkages between the island's physical and ecological processes (Herman et al. 2021).

1.5 Integrated hydrodynamic and ecological modeling

The monitoring plan is guided in large part by the parameters identified in the simplified resilience conceptual model developed to address primary project objectives (Figure 8; Herman et al. 2020; Davis et al. 2022). This model includes the following parameters: water movement (waves and currents), plant biomass, elevation (island profile and nearshore bathymetry), and sediment supply.

The Swan Island integrated hydrodynamic and ecological models will consist of multiple modules representing four habitats: dune, high marsh, low marsh, and SAV. The habitat modules will be coupled together to project the long-term dynamics of the island system as the island changes and matures. For a more detailed examination of the integrated hydrodynamic and ecological modeling development and process, see Herman et al. 2021.

Figure 8. Simplified model to include primary components deemed essential for understanding island resilience performance (that is, engineering performance) over time (reproduced from Davis et al. 2022, 45). CC BY 4.0.



2 Monitoring Protocols

Monitoring is an important component for any adaptive management plan, both to determine decision criteria and metrics and thresholds for action and to measure project success in meeting objectives. Generally, the monitoring parameters fall into three main categories, which are largely based on the conceptual model: ecological, topographic, and hydrodynamic (Table 3). More specifically these parameters include water movement (waves and currents), plant biomass, elevation (island profile and nearshore bathymetry) and sediment supply (Figure 8; Davis et al. 2021; Herman et al. 2020).

Additional parameters include sediment characteristics, water quality, and bird and oyster abundance surveys (Table 3). These parameters may also be used in the modeling effort or to examine additional questions related to the performance and benefits of the sediment placement action.

Table 3. Monitoring data collection summary per metric and conceptual model component, if applicable.

Model component	Metric	Collection method
Ecological	Percentage of vegetative cover in intertidal zone for four planting zones: high marsh, low marsh, dune, and transition zones; canopy height	Quadrat visual observation[a]
	Percent vegetative cover in subtidal zone	Quadrat visual observation[a]
	Drone-based habitat mapping	UAS
Topographic	Drone-based elevation profile	UAS
	Shoreline position	RTK GPS
	Vegetation plot elevation	RTK GPS
	Tidal inundation	Site-specific datums established, using five-minute water-level data collected on the platforms
	Sediment accretion	Feldspar
Hydrodynamic	Wave height	Acoustic doppler current profiler (ADCP) 90-day download cycle
	Currents	
	Water level (continuous)	ADCP and CTD
	Total suspended solids	Water samplers (Teledyne ISCO, Lincoln, Nebraska)
Sediment characteristics	Sediment bulk density	Core
	Sediment carbon content	Core
	Porewater sulfide (10 cm depth)	Push-point sampler with peristaltic pump
	Sediment pH	Core
Water quality	Dissolved oxygen	CTD, 90-day download cycle
	Turbidity	
	Salinity	
	pH	
	Water pressure (depth)[a]	
	Temperature	
	Redox potential	
Air	Air pressure	Barometer
Oysters	Oyster abundance	Towed oyster dredge, quadrat visual observation[a]
Birds	Migratory bird surveys	Annual SHARPs surveys from May to July

Note: UAS—unmanned aerial system; RTK GPS—real-time kinematic global position system; CTD—conductivity (salinity); SHARPs—Saltmarsh Habitat and Avian Research Program.

[a] NCVS—North Carolina visual survey method for determining percent cover (Peet et al. 1998).

2.1 Ecological—vegetation

2.1.1 Preplacement surveys

2.1.1.1 Intertidal—high and low marsh

Before sediment addition, the island was dominated by low-lying *Sporobolus alterniflorus* marsh, which was the focus of preplacement sampling. The full elevation range occupied by *S. alterniflorus* marsh was divided into 10 cm bins, and three vegetation sampling plots (1 m^2) were established at irregularly selected locations randomly within each bin. At each plot, total percent cover by species was estimated according to the North Carolina vegetation survey (NCVS) approach (Peet et al. 2018). One quarter of each plot was destructively harvested for analysis of total standing biomass by clipping all vegetation with scissors at the sediment surface. No dune or transition vegetation species were sampled prior to sediment placement.

Preplacement sampling was conducted in August 2018. Intertidal sampling efforts were concentrated on the southern side of the island because of time constraints and the challenges associated with navigating interior regions of the island because of highly compressible sediments (Figure 9).

2.1.1.2 Subtidal—submerged aquatic vegetation (SAV)

To document potential impacts of restoration activities on SAV within the bight on the southern side of the island, the team established long-term monitoring plots using the protocols of the MDDNR living resources assessment group (Landry and Golden 2018). Briefly, two transects were established, with one in each lobe of the bight, across the full length of the SAV bed in August 2018. Ten long-term monitoring plots were established at fixed distances (full length of transect divided by 10) across each transect. Total percent cover of SAV was estimated visually, and the length of five randomly selected stems was recorded. Orthometric elevation was determined by real-time kinematic global positioning system (RTK-GPS) at 5 m intervals along the full length of each transect. Relative water depth (cm) was also recorded at each plot, and plot location was documented with a handheld GPS.

Figure 9. Locations of preplacement vegetation surveys conducted in September 2018 are indicated by the *green* and *yellow dots*.

2.1.2 Postplacement surveys

2.1.2.1 Intertidal—dune, transition, high and low marsh

After sediment placement and planting was established, permanent vegetation monitoring plots were chosen using a stratified random approach designed to capture the full range of elevations and vegetative species in the placement area. Four (4) baselines were established, one at the crest of each dune region (Zone A, B), one at the boundary between the transition area associated with the eastern dune and the adjacent low-marsh area (Zone B, C), and one along the boundary between the low marsh and high marsh in the western portion of the placement area (approximately the 0.61 m contour) (Zone C, D) (Figure 10). This placement was intended to capture conditions across the extent of each designed elevation and vegetation zone (dune, transition, high marsh, and low marsh). A random number generator was used to determine the placement of perpendicular transects along each baseline. All transects extended the full length of the vegetative zone or 100 m, whichever was greater. Five long-term monitoring plots were established at equal distances along each transect (for example, for a 100 m baseline, the intervals would be 25 m, 0–25 m, 25–50 m, 50–75 m, and 75–100 m). In all, 20 plots were established in each vegetative planting zone (dune, transition, high marsh, and low marsh; Figures 5 and 6). At each plot percent coverage was documented per species in 1 m^2 PVC quadrats using NCVS categories (Peet et al. 1998), the total number of planting units (individual plugs) counted, and the height of the five tallest stems measured.

Postplacement vegetation surveys were conducted in August 2019 by NCCOS and in 2020 by the Engineering Associates consulting firm because of COVID-19–related travel restrictions.

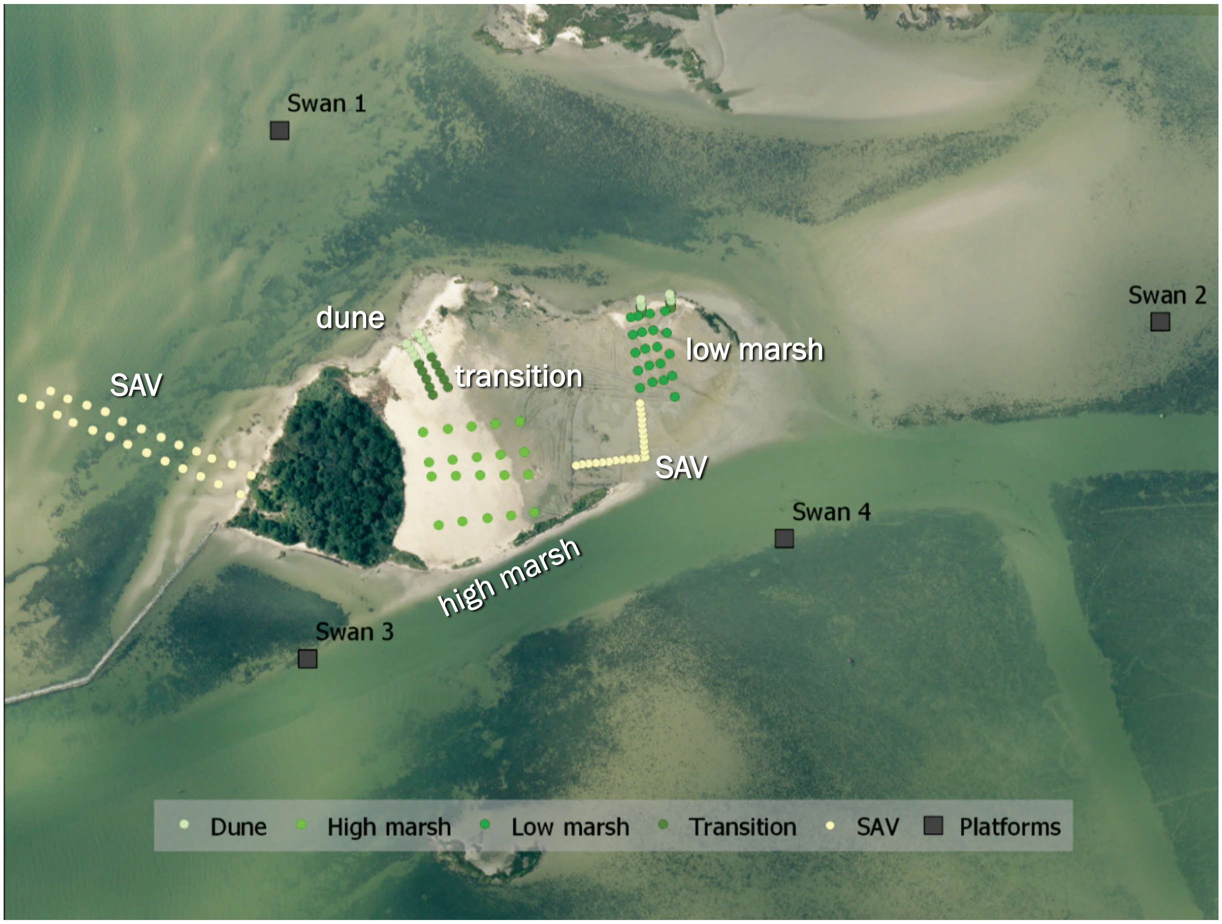
2.1.2.2 Subtidal—SAV

SAV data were collected within the fixed monitoring plots that were established preplacement. Within each plot, percent cover by species was estimated in a 0.25 m^2 quadrat, and the length of the four tallest shoots within each plot was recorded. Relative water depth (cm) was also recorded at each plot, and plot location was documented with a handheld GPS. Postplacement sampling was conducted in August 2019 by MDDNR and in September 2020 by Engineering Associates because of COVID-19–related travel restrictions and logistics challenges.

2.1.3 Unmanned aerial system (UAS)–based surveys

Drone operations to capture imagery are described below in Section 2.2.2. Drone-based imagery for habitat classification change analysis was collected in 2019 and 2020.

Figure 10. Monitoring plan site layout for Swan Island postrestoration monitoring. Platforms housing hydrodynamic instruments are shown as *squares*. Vegetation monitoring is depicted as a *circle*. Elevations were also taken at vegetation locations on the island.



2.2 Topographic—elevations

2.2.1 Vegetation plot elevation

The orthometric elevation of each permanent vegetation monitoring plot, with the exception of SAV plots, was established by RTK-GPS referenced to a USACE benchmark in Ewell, Maryland (USACE 857 1,117 Tidal 2). Only low-marsh vegetation plot elevations were measured prior to restoration (in 2018). Dune and intertidal vegetation plot elevations were measured two years postrestoration (in 2019 and 2020). Postplacement orthometric elevations of the SAV sampling plots that fell within the bight on the southern side of the island were determined from the high-resolution, image-based, digital elevation model DEM (described below) using the Extract Values to Points tool in Arc Map 10.7 (Esri, Redlands, California). Relative water depth (cm) was also recorded at each plot, and plot location was documented with a handheld GPS.

2.2.2 UAS-based surveys

In addition to elevation profiles with the ground-based RTK GPS, unmanned aerial systems (UAS) flights were conducted to create an island DEM and to develop an island-scale vegetation classification map. Both products will be used to document change over time.

In 2019 and 2020, flights were conducted during low tide at an altitude of 120 ft with a DJI Phantom 4 Pro equipped with 20 MP camera with a 1-inch CMOS (complementary metal oxide) sensor (DJI, Shenzhen, China). A neutral density polarizing filter (ND8-PL) was used to minimize glare. Flights were conducted along preplanned transects to maintain consistent overlap among images (75% front and 65% side overlap). In 2019 this process resulted in a total of 590 images and a ground resolution of 1.1 cm/pixel.

Photogrammetry products, including a DEM and orthophotomosaic of the placement area, were created in Agisoft Metashape (Agisoft, St. Petersburg, Russia) and optimized with the use of 24 ground control points distributed evenly across the area of interest. The coordinates of each ground control point were established via RTK-GPS referenced to a USACE benchmark in Ewell, Maryland (USACE 857 1,117 Tidal 2). Elevation data collected at intertidal vegetation monitoring plots (80 points total) were used to assess the accuracy of the DEM.

2.2.3 Sediment accretion and consolidation

To measure sediment accretion directly a feldspar layer (marker horizon) was placed within three (3) 0.25 m^2 quadrats on three (3) separate transects, for a total of nine (9) quadrats. This will allow us to measure the amount of accretion directly through coring. In addition, sediment accretion and consolidation or compaction of the sediment may be estimated from changes in elevation of the DEM using cut-and-fill analysis within Arc Map 10.7.

2.2.4 Shoreline position

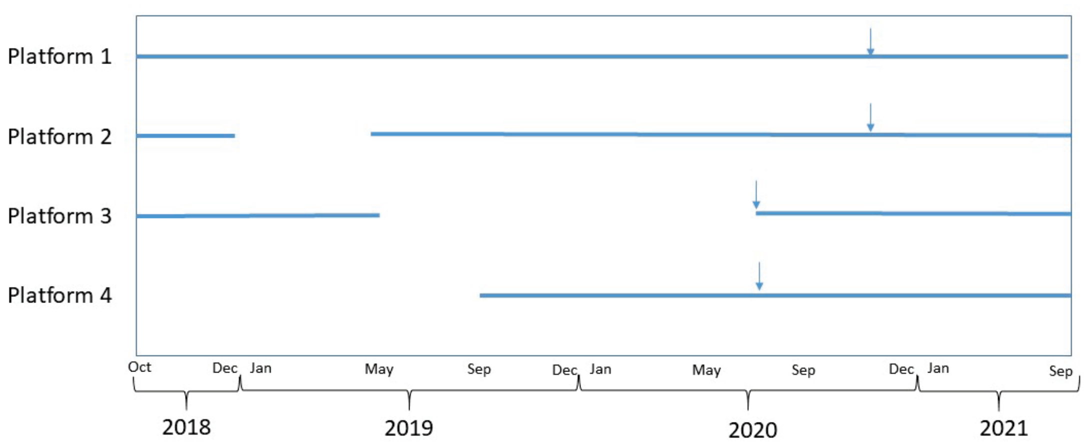
The position of the shoreline on the northern and southern side of the island was established using RTK-GPS continuous topographic survey with a bicycle-mounted rover conducted at low tide in 2018 and 2019 but not in 2020. This information may be used to clarify and evaluate other image-based products or for evaluation of adaptive-management options.

2.3 Hydrodynamic data collection

Four platforms were also installed around Swan Island (Figure 10). On each platform an Acoustic Doppler Velocimeter (ADV; manufactured by Nortek, Rud, Norway), Aquatroll (In-Situ, Fort Collins, Colorado) 600 data sonde (aka CTD), a Solinst barometer (Solinst Canada, Georgetown, Ontario), and a Teledyne ISCO (Teledyne ISCO, Lincoln, Nebraska) water sampler, were installed. All sensors are downloaded and serviced every 90 days as logistics and COVID-19 restrictions allow. ISCO samplers are sampled every 24 days.

Initially in October 2018, three platforms (1, 2, and 3) were installed in the waters surrounding Swan Island to document wave energy and the movement of water and particles around the island. Platform 1 collected data continuously from the time of installation through January 2020 (Figure 11). Platform 2 became nonfunctional in early December 2018, was brought back online in May 2019, and continued to collect data through January 2020. Platform 3 became nonfunctional in May 2019, was replaced in its original location in August 2020, and has been collecting data continuously up until June 2021. Platform 4 was installed in September 2019 and has been collecting continuously until September 2021 when all the platforms were removed.

Figure 11. Hydrodynamic data collection on four platforms around Swan Island from October 2018 to September 2021. The *blue line* indicates the data-collection time periods from the platforms around the island. The *arrows* indicate the dates when the ISCO water samplers (Teledyne ISCO, Lincoln, Nebraska) were installed.



2.3.1 Waves and currents

The ADV collects water pressure and velocity in three directions (x, y, and z). From the pressure and z-velocity, the wave height data are calculated. In addition, the x and y (east and north) directions represent the current values. These data are being collected at 16Hz for a single 10-minute window every 3 hours. This collection frequency is designed to maximize instrument battery life while facilitating the capture of the full range of conditions that occur during each 90-day data-collection interval.

2.3.2 Water level

Both the ADV and CTD (Aqua Troll 600 Multiparameter Sonde) on all platforms are collecting water level via water pressure. No other devices are measuring water levels. The measurements should be nearly identical, as the instruments are mounted within 5 cm of each other. The CTDs and barometers were initially programmed to collect data at 15-minute intervals until October 2019, at which point their collection frequency was shortened to 5-minute intervals to be consistent with the NOAA Center for Oceanographic Products and Services (CO-OPs) methods for calculating accurate water level.

2.3.3 Total suspended solids

In August 2020, ISCO samplers were installed on platforms 3 and 4. ISCOs were installed on platforms 1 and 2 in November 2020 (Figure 10). ISCO samples are serviced every 24 days. Local USFWS personnel retrieve the ISCO samples and ship them to ERDC's Environmental Laboratory (EL). Each ISCO collects 750 mL of water every day at 1200 UTC for 24 days; the bottles then need to be replaced.

2.4 Other data-collection parameters

2.4.1 Island sediment characteristics

Island sediment characteristics were collected preplacement in all vegetation plots, with the exception of subtidal SAV plots. Postplacement sediment samples were collected within the vegetation plots established along the second transect along each baseline (dune, transition, high, low marsh), not in the SAV. Sediment cores (3.5 cm diameter by 10 cm deep) were collected for analysis of bulk density and organic carbon content, and a porewater sample (10 cm depth) was taken for analysis of hydrogen sulfide from every plot along the transect.

Cores were dried at 60°C for 72 hours and then weighed to determine the sediment bulk density, then ground and subsampled for analysis of carbon content. Carbon content was determined by elemental analysis with a Costech ECS 4010 Elemental Analyzer. A single porewater sample (10 cm deep) was also collected using a push-point sampler and peristaltic pump with gas-tight tubing, was filtered (using 0.45 um nylon filters) in the field into zinc acetate, and was returned to the laboratory for analysis of porewater hydrogen sulfide content with Cline's method (Cline 1969). Sediment and porewater samples were restricted to 10 cm in depth to capture conditions in the active root zone.

2.4.1.1 Sediment bulk density

A single core (3.5 cm diameter by 10 cm deep) was collected from each plot along one full transect in each zone (either the longest transect or the second one from the beginning of the baseline if all transects were of equal length). Coring tubes were inserted by hand or by light hammering with a rubber mallet (evidence of compaction was noted) and extruded in the field. Core samples were dried at 60°C for 72 hours and then weighed to estimate sediment bulk density. Cores were collected in 2018 preplacement areas and 2019 postplacement areas. No sediment cores were collected in 2020.

2.4.1.2 Sediment carbon content

After the sediment cores were weighed for bulk density, the entire core was ground by hand with a mortar and pestle, and a subsample of the ground material was further homogenized in a ball mill. The resulting powder was subsampled in triplicate for analysis of organic carbon content on an HP elemental analyzer. Prior to analysis, samples were acidified by dropwise addition on 1 N (normal solution) hydrochloric acid (until no bubbling occurs) to remove carbonate.

2.4.1.3 Porewater inorganic nutrient content

Samples for inorganic nutrients were collected from 10 cm depths with a push-point sampler and peristaltic pump. Samples were filtered in the field through 0.45 µM PES (polyethersulfone) filters and stored frozen until analysis of hydrogen sulfide, ammonium, and phosphate was conducted using standard spectrophotometric methods (Parsons et al. 1984).

2.4.1.4 Sediment pH

To date, sediment pH has not been analyzed from sediment cores. There are plans to collect these data in August 2021.

2.4.2 Water quality

The CTDs on all the platforms are also collecting water-quality characteristics such as conductivity, temperature, pressure, pH, oxidation-reduction potential, conductivity, dissolved oxygen, and turbidity (nephelometric turbidity unit [NTU]). These parameters can be used to calculate salinity and derive qualitative estimates of total dissolved solids and total suspended solids from NTUs. The CTDs and barometers were initially programmed to collect data at 15-minute intervals until October 2019, at which point their collection frequency was shortened to 5-minute intervals to be consistent with the NOAA CO-OPs methods for calculating accurate water level.

2.4.3 Oyster presence and abundance

2.4.3.1 Preplacement 2018

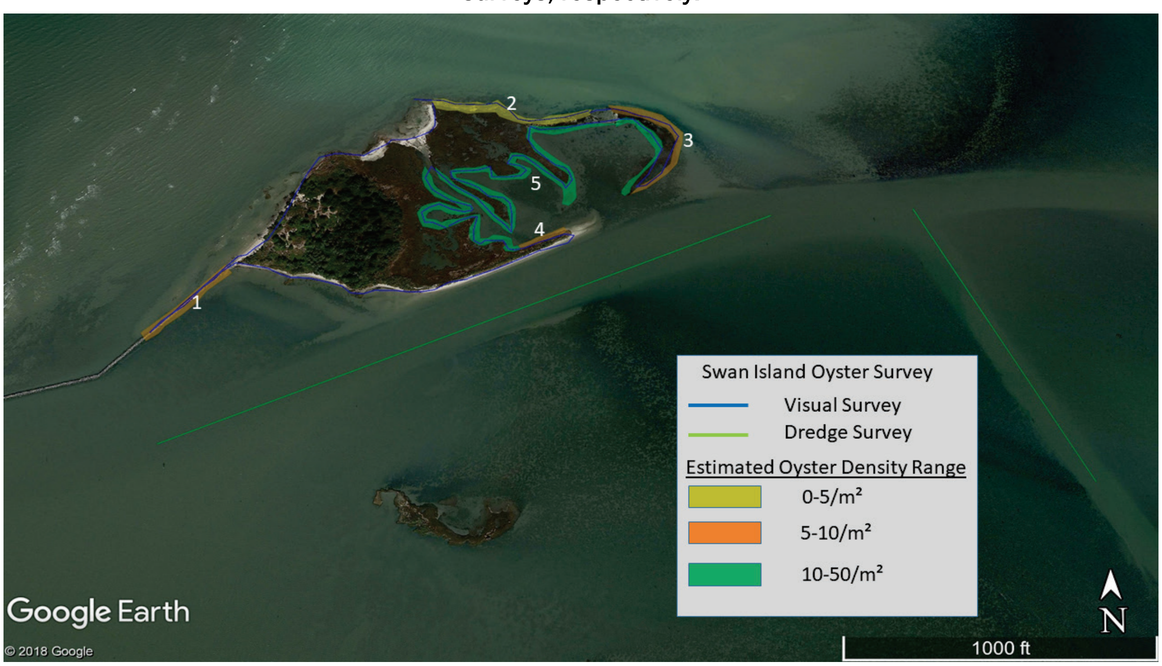
Because of the lack of oyster population data on Swan Island, a two-stage sampling approach was used to assess oyster presence, distribution, and abundance. Using the estimated intertidal zone of the shoreline of Swan Island as the survey area, two teams of researchers walked in opposite directions performing a visual survey to determine the locations of favorable oyster habitat (for example, hard substrata including riprap, rocks, gravel, shell fragments on sand or mud, and mud flats with marsh grass). Areas deemed suitable habitat were recorded onto a preprinted aerial image of Swan Island, and five distinct regions were identified using continuity of similar habitats. Within each region, a semiquantitative systematic sampling approach was used (Chesapeake Bay Program 2011). As researchers walked the full extent of these regions, they stopped approximately every 5 m to observe and record oyster abundance per 1 m^2.

During the systematic search, all locations were recorded with a Garmin 73 multisport GPS device.

Timed dredge tows were used to detect the presence and measure the abundance of oysters in the subtidal zone of the adjacent Big Thorofare navigation channel. Three consecutive 30-second dredge tows were pulled beginning at a point located at (38.001658, −76.048574) and turning to follow the path of the navigational channel at point (38.004648, −76.038578), ending at (38.001090, −76.037093) near the town of Ewell.

Preplacement surveys indicated the presence of oysters at densities ranging from 5 to 50 per m^2, with the greatest densities detected along the shoreline of the embayment on the southern side of the island (Figure 12). No oysters were detected in the dredge surveys of the channel.

Figure 12. Prerestoration oyster abundance. Shoreline color represents observed oyster density within each stretch of shoreline. Numbers (*1–5*) indicate discrete zones of oyster habitat. *Blue* and *green* lines represent the path of the visual and dredge-based oyster surveys, respectively.



2.4.3.2 Postplacement 2019

No formal oyster survey was conducted during or after the 2019 sampling season. The shoreline within the embayment that previously housed the greatest density of oysters was covered in sediment and graded to high intertidal elevations, rendering this area no longer suitable for oyster habitat. No measurable changes in oyster densities along regions of the shoreline that were unmodified are anticipated.

2.4.4 Migratory bird surveys

Annual SHARP (Saltmarsh Habitat and Avian Research Program) bird surveys are conducted each year from May to July by the USFWS. The first survey in 2021 was on 8 June. The SHARP surveys focus on breeding birds (https://www.tidalmarshbirds.org/, "Saltmarsh" 2021). Because of the small size of the island, multiple independent surveys are not possible. Therefore, these data will provide a qualitative description of the birds inhabiting the island. In addition, the USFWS conducts the annual Midwinter Waterfowl Survey (https://migbirdapps.fws.gov/mbdc/databases/mwi/aboutmwi_allflyways.htm) for the Smith Island complex (includes MNWR). In Maryland, the surveys are low-level aerial surveys flown from a fixed-wing aircraft. The survey dates back to 1955 and is flown in early January.

3 Evaluation and Adaptive Management

Evaluation and adaptive management of natural and nature-based features (NNBF) include six key components: plan, design, build, monitor, evaluate and adapt (de Looff et al. 2021; Craig and Ruhl 2014; Greig et al. 2013). At the time of this writing, Swan Island is three years postconstruction in the monitoring and adaptive management phases. The metrics and performance criteria will be used to make adaptive-management decisions and improve restoration outcomes. Potential adaptive-management actions are based on the trend of metrics or the status of the established performance criteria, or both (Table 4).

Table 4. Example metrics, performance criteria, and potential adaptive-management actions if criteria are not met.

Metric	Performance criteria in determining project success	Adaptive management action
Percent intertidal vegetative cover	Percent cover in planted regions increases to 50%–75%	Replant failing areas, consider use of different species if significant changes in elevation have occurred
Marsh surface elevation	Maintain design elevations for low-, high-marsh, and dune habitat; expect to increase (+) over time	Add additional sediment if surface elevations do not maintain a range necessary for the intended habitat type
Shoreline position	Maintain shoreline position	Implement a living shoreline or wave break to protect shoreline; sediment placement and planting on perimeter to build out the island
Percent subtidal vegetative cover	Percent cover in affected area increases to preplacement levels or regional levels, or both	Need to consider unintended consequences or habitat trade-offs, such as converting subtidal habitat to intertidal

Section 2.0 and Table 3 includes additional model components and monitoring programmatic data that have not been included in this current MAMP. The data are being analyzed and used to develop ecological and hydrodynamic models that will be used in future development of the Swan Island MAMP. This next-level modeling MAMP will include an extensive review of the following data: waves and currents, water level, total suspended solids, island sediment characteristics, water quality, and migratory bird surveys to provide additional feedback on how to predict and plan for a resilient island feature.

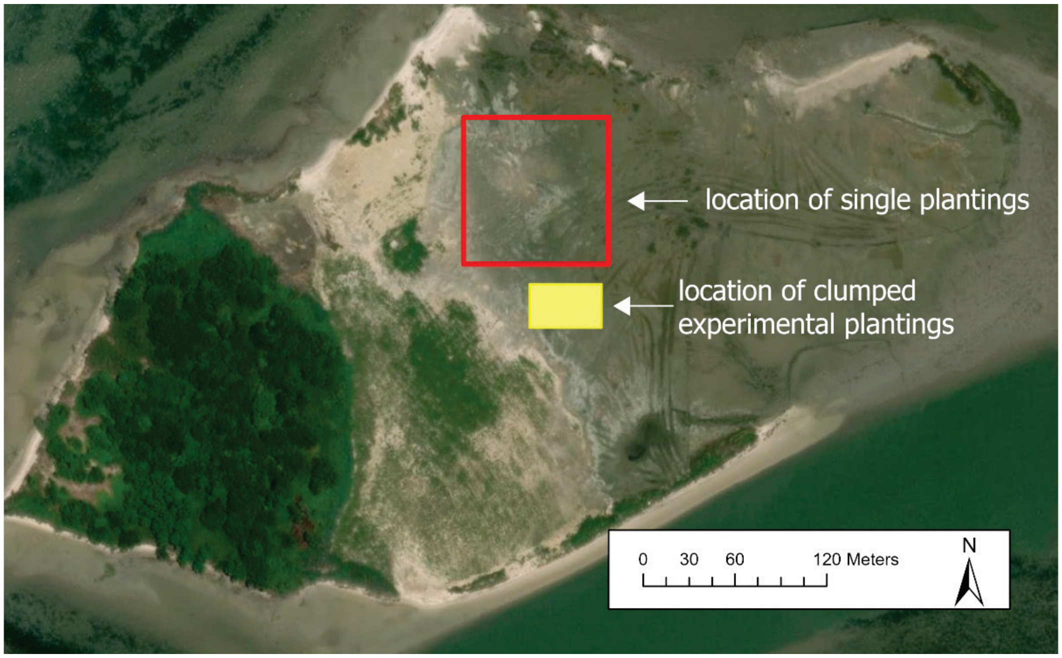
3.1 Project status and adaptive management options

Preliminary results indicate the footprint of Swan Island has been successfully raised to intertidal or higher elevations. The extent to which the current elevation profile is maintained will be a function of the degree of compaction that occurs within the filled regions (both within the placed and underlying sediments) and sediment erosion on the northern side of the island. Aerial imagery from 2020 indicates the high marsh adjacent to the forested area is thriving, while the plantings within the low-marsh zone did not survive. Low-marsh plants that survived the sediment placement are beginning to colonize the bare sediment through lateral expansion into adjacent unvegetated regions. However, significant gaps in vegetative cover remain within the low-marsh area (Figure 13), such that the intertidal plant cover performance criteria threshold (Table 4) measuring project success has not been met. The pace of vegetative colonization will also influence the stability of placed sediments. A thick vegetative canopy is instrumental in moderating the impact of waves on the sediment surface and in determining the likelihood that sediments are mobilized and removed from the island by flowing waters.

Figure 13. Drone aerial imagery from 2019 (*top*) and 2020 (*bottom*). (Photo credit: NOAA)

In response to performance criteria not being met, the USFWS planted 22,000 *Sporobolus alternifolus* plants in June 2021, of which 19,800 *S. alternifolus* plants were installed on 0.46 m centers. Another 2,200 plants were also installed to create an experimental approximately 13×20 m grid with clumps of 9 plants planted on 0.46 m centers (Figures 14 and 15). Clumped planting strategies have been shown to result in increased survival and plant vigor in shoreline *S. alternifolus* plantings (Silliman et al. 2015).

Figure 14. Planting locations in June 2021. The *red square* is the area where individual plants on 0.6 m centers were installed, and the *yellow rectangle* indicates the location where experimental clumped plantings (with nine plants per clump) were installed on 1 m centers at elevations thought to be optimal for growth.



To mitigate the uncertainty in projects like this, construction of islands will require monitoring and adaptive management to achieve desired performance and benefits. As long as monitoring and adaptive management is planned for, beneficial-use opportunities like Swan Island can be seized so that sediment can be kept in the system, ecosystems can be maintained, and coastal resilience can be increased. It is necessary to monitor these projects through the collection of data. Additionally, if in scope, those data can be used to develop the next generation of models that can predict the performance of island features and account for uncertainty in project planning. By monitoring data and developing models (Part 2 of the Swan Island MAMP will share model development), lessons may be learned and adapted for postconstruction.

Figure 15. Clumped plantings on Swan Island in June 2021. (Photo credit: NOAA)

3.2 Lessons learned

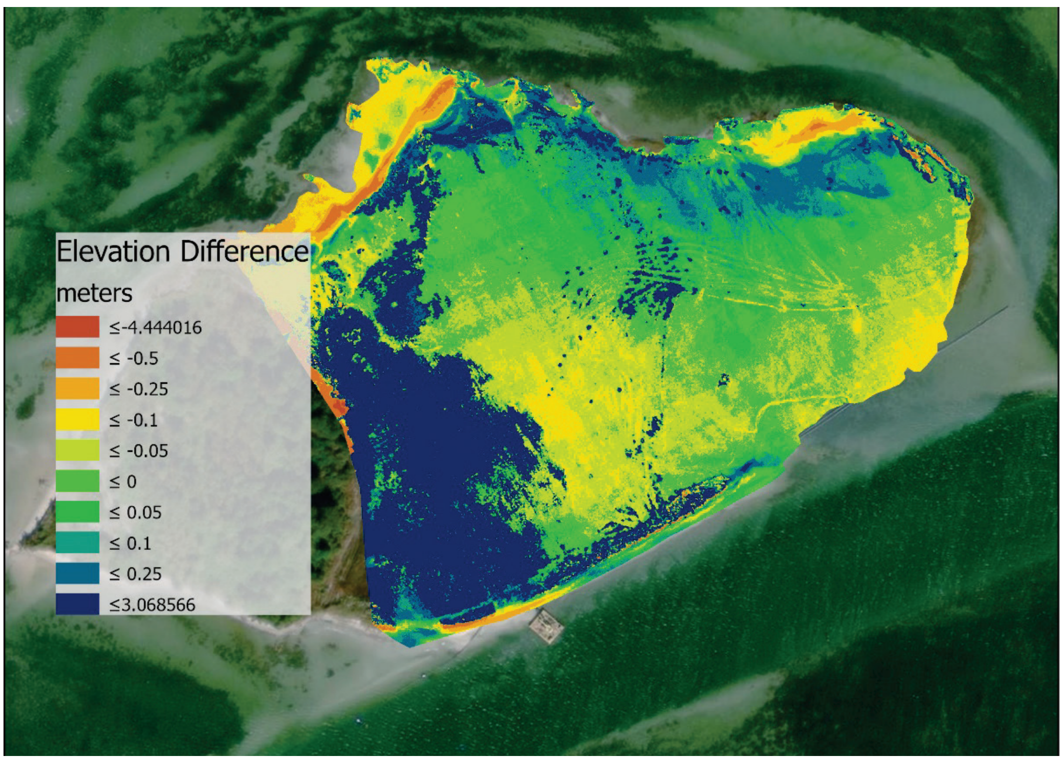
This project is still in the preliminary stages of data collection and monitoring, but the approach described in this technical report has been successful in allowing the project team to efficiently communicate and coordinate project activities to meet objectives. With the data currently collected, the project team will investigate the research questions posed in Section 1.4, among others, and continue to refine and evaluate integrated hydrodynamic and ecological models. Further, the upfront preparation that began in 2019, with a series of the iterative modeling workshops, helped the project team to clearly articulate early on the project objectives and to develop a conceptual model to guide the selection of monitoring parameters.

During sediment-placement activities, dredged material transported across the coir-log barrier resulted in a net increase in elevation within the subtidal bight initially of approximately 30 cm, subsequently covering most of the SAV. It is unclear whether this increase was the result of direct leakage during pumping activities or redistribution of sediments associated with tidal flooding of Zone D. The added sediments buried the

SAV aboveground biomass and seedbank that was present in 2018, but there was evidence of sparse SAV shoots (<1% cover) in August 2019 and more in 2021.

Documenting habitat trade-offs such as this one can serve as a good lesson learned and show the value of considering contingencies and contractor accountability prior to project commencement to manage project outcomes if they differ from approved plans. Monitoring the SAV and elevations over time will allow the project team to quantify both the short-term and long-term impacts to the approximately 0.8 ha SAV bed. From 2019 to 2020, elevation decreased slightly in the area of the bight, either because of erosion or compaction (Figure 16).

Figure 16. Elevation change in meters NAVD88 between September 2019 and September 2020. The >3 m increase shown in *dark blue* on the western side of the island is due to high marsh growth. (Image credit: NOAA)



4 Project Management Points of Contact (POCs)

Project management points of contact (POCs)		
USACE and ERDC	Modeling and project coordination	Amanda.S.Tritinger@erdc.dren.mil
USACE and ERDC	Project coordination	Jeffrey.K.King@usace.army.mil
USFWS	Permitting, monitoring and adaptive management	rmatt_whitbeck@fws.gov
NOAA-NCCOS	Research and project coordination	jenny.davis@noaa.gov
USACE–Baltimore District	Construction and adaptive management actions	Danielle.M.Szimanski@usace.army.mil

Note: USACE—US Army Corps of Engineers; ERDC—Engineer Research and Development Center; USFWS—US Fish and Wildlife Service; NOAA-NCCOS— National Oceanic and Atmospheric Administration–National Centers for Coastal Ocean Science

Data management points of contact (POCs) for each data type are listed below. Data are shared as needed for collaboration on integrated models and other analyses.

Component	Metric	Lead POC
Ecological	Island (intertidal/dune) vegetation surveys	jenny.davis@noaa.gov
	Subtidal vegetation surveys	rebecca.golden@maryland.gov
Topographic	Island elevations (plots, drone-based), shoreline position, sediment accretion and consolidation	jenny.davis@noaa.gov
Hydrodynamic	ADV, CTD, barometer, ISCO sampler instrumentation download and deployment	Joe.Z.Gailani@usace.army.mil Amanda.S.Tritinger@usace.army.mil Michael.T.Ramirez@erdc.dren.mil
	Waves, currents, water level, turbidity, total suspended solids, data for modeling and water quality	Amanda.S.Tritinger@usace.army.mil Joe.Z.Gailani@erdc.dren.mil
Island sediment characteristics	Sediment bulk density, sediment carbon content, pH, pore water sulfide	jenny.davis@noaa.gov
Oysters	Presence and abundance	jason.spires@noaa.gov
Birds	SHARP surveys	matt_whitbeck@fws.gov

5 Summary

The lack of quantitative information on island engineering and ecological performance, in particular its ability to reduce wave energy and erosion and potential impacts to subtidal habitats, is often cited as a barrier to implementation. On-the-ground island projects combined with pre- and postconstruction monitoring to evaluate island performance and benefits are required to advance this practice. Addressing these uncertainties requires multidisciplinary collaborations to conduct applied research and document lessons learned for the entire project life cycle, from planning and design to adaptive management. This MAMP, in addition to providing a roadmap for the Swan Island project, is intended to provide an example of monitoring protocols transferable to other research questions, regions, ecosystems, and scales. Documenting the monitoring and adaptive management approaches is key to ensuring the transferability of the approach and may help to foster widespread acceptance of nature-based solutions.

Bibliography

Chesapeake Bay Program. 2011. *Restoration Goals, Quantitative Metrics and Assessment Protocols for Evaluating Success on Restored Oyster Reef Sanctuaries*. Report of the Oyster Metrics Workgroup submitted to the Sustainable Fisheries Goal Implementation Team of the Chesapeake Bay Program. https://www.chesapeakebay.net/channel_files/17932/oyster_restoration_success_metrics_final.pdf.

Cline, Joel D. 1969. "Spectrophotometric Determination of Hydrogen Sulfide in Natural Waters." *Limnology and Oceanography* 14, no. 3 (May): 454–58. https://doi.org/10.4319/lo.1969.14.3.0454.

Craig, Robin K., and J.B. Ruhl 2014. *Designing Administrative Law for Adaptive Management*. 67 Vanderbilt Law Review 1. Vanderbilt Public Law Research Paper No. 13-6. University of Utah College of Law Research Paper No. 18. https://dx.doi.org/10.2139/ssrn.2222009.

Davis, Jenny, Paula Whitfield, Danielle Szimanski, Becky R. Golden, Matt Whitbeck, Joe Gailani, Brook Herman, Amanda Tritinger, Sally C. Dillon, and Jeffrey King. 2022. "A Framework for Evaluating Island Restoration Performance: A Case Study from the Chesapeake Bay." *Integrated Environmental Assessment and Management* 18, no. 1 (January): 42–48. https://doi.org/10.1002/ieam.4437.

Erwin, R. Michael, David F. Brinker, Bryan D. Watts, Gary R. Costanzo, and David D. Morton. 2011. "Islands at Bay: Rising Seas, Eroding Islands, and Waterbird Habitat Loss in Chesapeake Bay (USA)." *Journal of Coastal Conservation* 15, no. 1 (September): 51–60. https://doi.org/10.1007/s11852-010-0119-y.

de Looff, Harry, Tim Welp, Natalie Snider, and Rinse Wilmink. 2021. "Adaptive Management." In *International Guidelines on Natural and Nature-Based Features for Flood Risk Management*, edited by Todd S. Bridges, Jeffrey K. King, Jonathan D. Simm, Michael W. Beck, Georganna Collins, Quirjin Lodder, and Ram K. Mohan, 270–318. Vicksburg, MS: US Army Engineer Research and Development Center. https://dx.doi.org/10.21079/11681/41946.

Folse T. 2020a. *Monitoring and Adaptive Management Plan for Deepwater Horizon NRDA Project: Barataria Basin Ridge and Marsh Creation Project–Spanish Pass Increment*. Coastal Protection and Restoration Authority of Louisiana. Washington, DC: National Oceanic and Atmospheric Administration. https://www.gulfspillrestoration.noaa.gov/sites/default/files/Final_MAMPlan_SpanishPass_092120_508.pdf.

Folse T. 2020b. *Monitoring and Adaptive Management Plan for Deepwater Horizon NRDA Project: Lake Borgne Marsh Creation Project–Increment 1*. Washington, DC: National Oceanic and Atmospheric Administration. https://www.gulfspillrestoration.noaa.gov/sites/default/files/Final_MAMPlan_LakeBorgne_092120_508.pdf.

Gailani, Joseph, Paula Whitfield, Enda Murphy, Jurre de Vries, Gordon Thomson, Wendell Mears, and Danielle Szimanski. 2021. "Islands." In *International Guidelines on Natural and Nature-Based Features for Flood Risk Management*, edited by Todd S. Bridges, Jeffrey K. King, Jonathan D. Simm, Michael W. Beck, Georganna Collins, Quirjin Lodder, and Ram K. Mohan, 501–58. Vicksburg, MS: US Army Engineer Research and Development Center. https://dx.doi.org/10.21079/11681/41946.

Grant, William E., and Todd M. Swannack. 2008. *Ecological Modeling: A Common-Sense Approach to Theory and Practice*. Blackwell Publishing, Malden Maine.

Greig, Lorne A., David R. Marmorek, Carol Murray, and Donald C. E. Robinson. 2013. "Insight into Enabling Adaptive Management." *Ecology and Society* 18 (3): 24. https://dx.doi.org/10.5751/ES-05686-180324.

Guannel, Greg, Katie Arkema, Peter Ruggiero, and Gregory Verutes. 2016. "The Power of Three: Coral Reefs, Seagrasses, and Mangroves Protect Coastal Regions and Increase Their Resilience." *PLOS ONE* 11 (7): e0158094. https://doi.org/10.1371/journal.pone.0158094.

Herman, Brook, Todd M. Swannack, Jeffrey K. King, Paula E. Whitfield, Jenny Davis, Danielle Szimanski, Duncan B. Bryant, and Joseph A. Gailani. 2020. *Proceedings from the US Army Corps of Engineers (USACE) and the National Oceanic and Atmospheric Administration (NOAA)–National Ocean Service (NOS): Ecological Modeling Workshop*, 11–12 April 2019, Cambridge, Maryland: US Fish and Wildlife Service Blackwater National Wildlife Refuge Visitors Center. ERDC/EL SR-20-1. Vicksburg, MS: US Army Corps of Engineers Engineer Research and Development Center. https://hdl.handle.net/11681/36095.

Kearney, Michael S., and J. Court Stevenson. 1991. "Island Land Loss and Marsh Vertical Accretion Rate Evidence for Historical Sea-Level Changes in Chesapeake Bay." *Journal Coastal Research*. 7, no. 2 (Spring): 403–15. https://journals.flvc.org/jcr/article/view/78484/75890.

Landry, J. Brooke, and Rebecca R. Golden. 2018. "In situ Effects of Shoreline Type and Watershed Land Use on Submerged Aquatic Vegetation Habitat Quality in the Chesapeake and Mid-Atlantic Coastal Bays." *Estuaries and Coasts* 41, no. 1 (September): 101–13. https://doi.org/10.1007/s12237-017-0316-0.

Parsons, Timothy R., Yoshiaki Maita, and Carol M. Lalli. 1984. *A Manual of Chemical and Biological Methods for Seawater Analysis*. Elmsford, NY: Pergamon Press. https://doi.org/10.1016/B978-0-08-030287-4.50003-7.

Peet, Robert K., Thomas R. Wentworth, and Peter S. White. 1998. "A Flexible, Multipurpose Method for Recording Vegetation Composition and Structure." *Castanea* 63, no. 3 (September): 262–74. https://www.jstor.org/stable/4033979.

Silliman, Brian R., Elizabeth Schrack, Qiang He, Rebecca Cope, Amanda Santoni, Tjisse van der Heide, Ralph Jacobi, Mike Jacobi, and Johan van de Koppel. 2015. "Facilitation Shifts Paradigms and Can Amplify Coastal Restoration Efforts." In *Proceedings of the National Academy of Sciences* 112, no. 46 (November): 14295–300. https://doi.org/10.1073/pnas.1515297112.

"Saltmarsh Habitat and Avian Research Program." 2022. https://www.tidalmarshbirds.org/.

USFWS (US Fish and Wildlife Service). 2014. *Smith Island Martin National Wildlife Refuge: Hurricane Sandy Resiliency Project #31 Fog Point Living Shoreline Restoration*. Report November 3, 2014. Prepared by Perini Management Services, Coastline Design, Vanasse Hangen Brustlin, Coastal Design and Construction, and Sustainable Science. Hadley, MA: US Fish and Wildlife Service–Division of Contracting and General Services.

USFWS. 2021. "Midwinter Waterfowl Survey." https://migbirdapps.fws.gov/mbdc/databases/mwi/aboutmwi_allflyways.htm.

Abbreviations

ADCP	Acoustic doppler current profiler
ADV	Acoustic doppler velocimeter
CO-OPS	Center for Operational Oceanographic Products and Services
CTD	Conductivity (salinity), temperature, and depth
DEM	Digital elevation model
EL	Environmental Laboratory
ERDC	Engineer Research and Development Center
EWN	Engineering With Nature
MAMP	Monitoring and adaptive management plan
MDDNR	Maryland Department of Natural Resources
MLLW	Mean lower low water
MNWR	Martin National Wildlife Refuge
NAV88	North American Vertical Datum 1988
NCCOS	National Centers for Coastal Ocean Science
NCVS	North Carolina visual survey
NNBF	Natural and nature-based features
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric turbidity unit
PES	Polyethersulfone

POC	Point of contact
RSLR	Relative sea level rise
RTK GPS	Real-time kinematic global positioning system
SAV	Submerged aquatic vegetation
SHARPs	Saltmarsh Habitat and Avian Research Program
UAS	Unmanned aerial system
USACE	US Army Corps of Engineers
USFWS	US Fish and Wildlife Service

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)
08/01/2022

2. REPORT TYPE
Final

3. DATES COVERED (From - To)
FY19–FY22

4. TITLE AND SUBTITLE
Swan Island:
Monitoring and Adaptive Management Plan

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT

6. AUTHOR(S)
Paula E. Whitfield, Jenny L. Davis, Amanda S. Tritinger, Danielle M. Szimanski, Rebecca R. Golden, Joe Z. Gailani, Michael T. Ramirez, Brook D. Herman, Matt Whitbeck, and Jeffery K. King

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
US Army Engineer Research and Development Center (ERDC)
Coastal and Hydraulics Laboratory (CHL)
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

See reverse

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC TR-22-14

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army Engineer Research and Development Center
Coastal and Hydraulics Laboratory
3909 Halls Ferry Road
Vicksburg, MS 39018-6199

US Army Engineer Research and Development Center
Environmental Laboratory
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

See reverse

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Civil Direct—Funding Account Code U4368804, AMSCO Code 089500
DOER-EWN RT 19-15

14. ABSTRACT
Swan Island is a 10.12 ha island located in the Maryland waters of the Chesapeake Bay. Because of its value as a natural wave break for the town of Ewell on nearby Smith Island, as well as the ongoing erosion and subsidence of the island, in 2019 US Army Corps of Engineers (USACE)–Baltimore District placed 45,873 m3 of dredged sediment and planted 200,000 marsh plants.

This restoration provided an opportunity to quantify the engineering (that is, resilience) and ecological performance of the island, postplacement. The lack of quantitative data on the performance of natural features such as islands has led to perceived uncertainties that are often cited as barriers to implementation. To address these data gaps, a multidisciplinary collaboration of five government entities identified project objectives and monitoring parameters through a series of mediated workshops and then developed a conceptual model to articulate those parameters and the linkages between them.

This monitoring and adaptive management plan (MAMP) documents those monitoring parameters and procedures and can serve as an example for other scales, regions, and research questions. Documenting research and monitoring efforts may help to foster widespread acceptance of nature-based solutions such as islands.

15. SUBJECT TERMS
Islands-- Chesapeake Bay Region (Md. and Va.); Dredging.; Dredging spoil; Marsh plants; Vegetation management; Restoration ecology

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Amanda S. Tritinger
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (include area code)
Unclassified	Unclassified	Unclassified	SAR	47	(601) 634-4664

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) (concluded)

US Army Engineer Research and Development Center
Environmental Laboratory
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

National Oceanic and Atmospheric Administration
National Centers for Coastal Ocean Science
1305 East West Highway
Silver Spring, MD 20910

USACE–BaltimoreDistrict
2 Hopkins Plaza
Baltimore, MD 21201

US Fish and Wildlife Service
Chesapeake Bay Marshlands National Wildlife Refuge Complex
2145 Key Wallace Drive
Cambridge, MD 21613

Maryland Department of Natural Resources
580 Taylor Avenue
Annapolis, MD 24101

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) (concluded)

National Oceanic and Atmospheric Administration
National Centers for Coastal Ocean Science
1305 East West Highway
Silver Spring, MD 20910

USACE–BaltimoreDistrict
2 Hopkins Plaza
Baltimore, MD 21201

US Fish and Wildlife Service
Chesapeake Bay Marshlands National Wildlife Refuge Complex
2145 Key Wallace Drive
Cambridge, MD 21613

Maryland Department of Natural Resources
580 Taylor Avenue
Annapolis, MD 24101