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Thin-layer placement for habitat enhancement on Gull Island, NJ during navigation dredging.

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EDITOR'S NOTE

This issue of the journal is the first of two consecutive issues focused on beneficial use of dredged sediments. This issue includes 3 technical papers that demonstrate the efficacy of beneficially using sediments from dredging projects in disparate environments and for different purposes.

The first paper presents an interesting case study using sediment dredged from the Lower Mississippi River to offset subsidence in south Louisiana. This paper was led by one of our talented WEDA Young Members. This is an exciting development and I look forward to more younger members participating in the journal. A special thanks to Ms. Rebecca Gardner of AnchorQEA for fostering this paper.

The second paper describes a case study in New Jersey where dredged sediment was separated and treated to facilitate beneficial use. This is a great example of innovation in an urbanized area where limited space is available for sediment processing and disposal costs encourage beneficial uses. The third paper describes an innovative approach to using dredged sediment with significant fines content for beach nourishment during a case study in Tampa Bay, FL.

The timing of these papers is particularly important. Interest in beneficial uses has varied historically with the availability of disposal capacity. The current spike in beneficial use interest seems to have stronger legs, primarily because of recent public interest in sustainability and Engineering with Nature®. Significantly increasing the rate of beneficial use from the current rate of about 40% will require a strong commitment to overcome a plethora of factors that impede beneficial use. These papers provide three excellent examples of how this is being achieved.

Don Hayes
October 2020

Restoring Marsh Habitat with Beneficial Use of Dredged Sediment from a Riverine Environment

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ABSTRACT

Using dredged sediment from riverine environments is a critical component of large-scale (projected multi-billion dollar) restoration efforts in coastal Louisiana (USA) to decrease losses sustained from coastal land loss. West Bay (Louisiana) USA is a 12,000-acre sub-delta adjacent to the Mississippi River that typifies risks of coastal land loss (e.g., loss of critical marsh habitat and threatened navigation banklines), with approximately 70% (ca. 8,000 acres) conversion from marsh to open water since the 1950s. To restore habitats at the scale of projects like West Bay, sustainable approaches are needed. Recently, there has been substantial progress in using restoration strategies that align with Engineering with Nature® (EWN®) principles, a U.S. Army Corps of Engineers (USACE) initiative supporting more sustainable practices for delivering economic, environmental and social benefits through collaborative processes. This study documents the progress of restoring marsh habitat in West Bay through an uncontrolled sediment diversion from the Mississippi River and a series of sequenced dredged sediment placement events to inform future projects aimed to strategically place dredged sediment via application of EWN principles. To achieve this objective, this study documents the historical context and successes of the restoration strategies in West Bay from 2002-2019. The creation of a large uncontrolled diversion (20,000 cfs) in 2003 in combination with Sediment Retention Enhancement Devices (SREDs; created in 2009, 2013, 2015) were successful in using sediment-laden water from the Mississippi River to promote marsh creation. In addition to the sediment diverted from the river, over 37 million cubic yards (MCY) of sediment placed from dredging projects from 2002-2019 facilitated the restoration of over 2,400 ac of land in the formerly open waters of West Bay. Documenting progress and lessons learned of large-scale restoration projects like West Bay are crucial to the success of future restoration investments.

Keywords: Mississippi River; West Bay; sediment diversion; marsh; beneficial use

INTRODUCTION

Coastal Louisiana is an economically robust region with critical marsh habitat, commercial fisheries, navigation and port infrastructure, and energy supply that is a key asset worth billions of dollars to the nation's infrastructure (CPRA 2012). However, this area is historically sensitive to shoreline erosion, subsidence, sea level rise, and habitat loss, with an estimated rate of 16 square

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miles of land lost per year (predominately marsh) between 1985 and 2010 (Couvillion et al. 2011). The rapid rate and extent of marsh loss in coastal Louisiana has been attributed to anthropogenic activity that has led to altered sediment distribution patterns (e.g., river channelization; Andrus and Bentley 2007) and subsidence (Kolker et al. 2011); today, sea level rise and other aspects of climate change risk accelerating habitat loss (Jankowski et al. 2017). Erosion of marshes in coastal Louisiana is threatening shallow-water and marsh habitat, flood risk management function, and navigation bank stability (CPRA 2012). West Bay is a sub-delta in Louisiana located adjacent to the lower Mississippi River navigation channel near the Head of Passes which typifies the effects of marsh loss (Figure 1). By the early 2000s, the 12,000-acre West Bay area lost over 8,000 acres of marsh, mostly through conversion to open water (LDNR-CRD 2003). This led to concerns about the loss of coastal habitat, and threats to bankline stability of the adjacent Mississippi River federal navigation channel. For these reasons, West Bay is the focus of a large-scale coastal restoration effort aimed to restore marsh habitat.

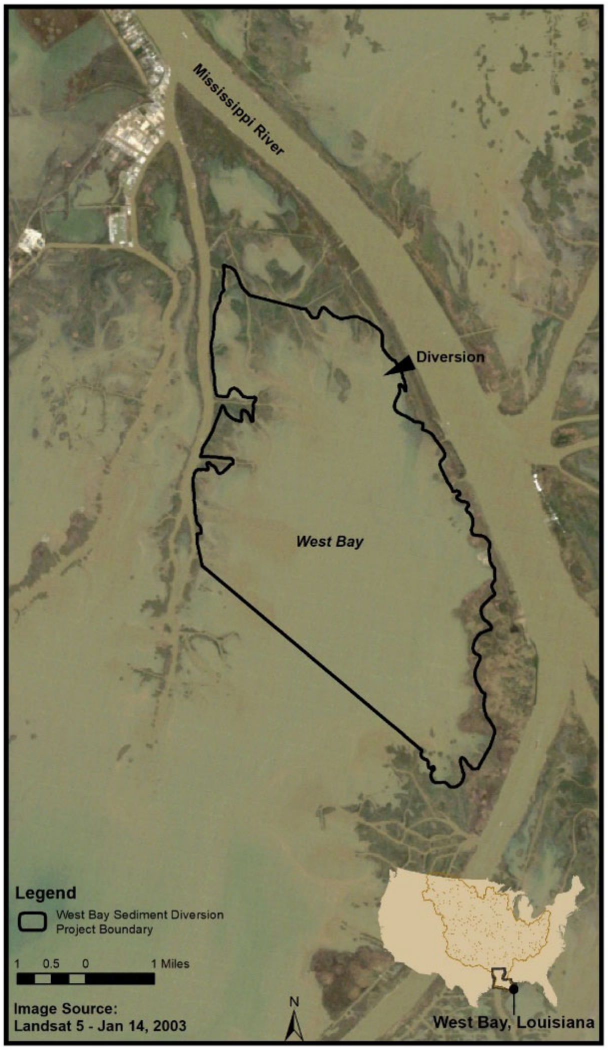

Figure 1. West Bay, LA project area prior to diversion construction and subsequent restoration activities.

In 2003, the West Bay area was approved for restoration under the authority of the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA; Title III; Public Law 101-646). Restoration goals were as follows: 1) increase the land:water ratio, 2) increase mean elevation in the wetlands, and 3) promote marsh habitat. To achieve these goals, beneficial use of dredged sediment was identified as a critical component to restore degraded areas along with the design and construction of dynamic berm structures that mimic natural process for promoting sediment retention and land formation (LDNR-CRD 2003). The proposed mitigation strategy focused on marsh creation and revegetation via construction of an uncontrolled diversionary channel from the Mississippi River, contributing 20,000-50,000 cfs discharge into the wetland, and the beneficial use of dredged sediment through strategic and direct placement. Direct placement involves placing sediment as a permanent or semi-permanent feature that will support navigation, flood risk reduction, or environmental restoration, and where intended benefits occur at the sediment placement site. Strategic placement represents placement of dredged sediments in a manner such that sediments can be redistributed by natural forces from the placement location to areas where sediments are needed (Gailani et al. 2019). At the project initiation, major activities in West Bay were facilitated by CWPPRA sponsored actions. Over time, restoration activities shifted, where federal maintenance dredging program actions prevailed as the project progressed. At times, stakeholder views and subsequent restoration strategies did not align; therefore, this project also highlights progress in light of differing stakeholder objectives and values.

Successfully overcoming mesoscale ecosystem challenges involves identifying actions that can be taken to better align and integrate engineering and natural systems to produce more socially acceptable, economically viable, and environmentally sustainable projects. Engineering With Nature® (EWN®) is a USACE initiative that supports more sustainable practices, projects, and outcomes by working to intentionally align natural and engineering processes to efficiently and sustainably deliver economic, environmental and social benefits through collaborative processes (Bridges et al. 2014; Gerhardt-Smith and Banks 2014; *www.engineeringwithnature.org*). The EWN initiative implements in practice Working with Nature (WwN) principles developed by The World Association for Waterborne Transport Infrastructure (PIANC) that similarly seeks to achieve environmental, social, and economic benefits through strategic use of natural processes in navigational infrastructure (PIANC 2018). Projects demonstrating these principles illustrate the use of science and engineering to maximize natural processes to produce practical operational efficiencies that support substantiated economic, social, and environmental benefits while continuing to meet project objectives. The West Bay project is a successful example of how a long-term project using various beneficial use strategies implementing EWN and WwN principles can reverse coastal land loss while ensuring the integrity of the federal navigation channel in the adjacent Mississippi River (Bridges et al. 2018).

The overall objective of this study was to document the progress of restoring marsh habitat in West Bay using an uncontrolled diversion and a series of sequenced beneficial use dredging placement events. This information will be used to promote better understanding of how the strategic and beneficial use of dredged sediment in riverine environments can restore ecosystem function and improve bankline stability using EWN and WwN principles. To achieve this objective, this report documents the West Bay sediment diversion and restoration activities from 2002-2019. Specifically, this report documents: 1) the historical background of the West Bay sediment diversion, construction and effectiveness of Sediment Retention Enhancement Devices (SREDs) and strategic dredged sediment placement to accelerate subaerial growth; 2) the changes in elevation, land:water ratios, and emergent vegetation in West Bay following the restoration activities; and 3) the EWN concepts and principles applied during the project.

APPROACH AND METHODS

The West Bay project achievements were assessed using a combination of methods. First, historical documentation of the West Bay (29°10'33.0"N 89°18'31.0"W) project land creation features were assembled and reviewed based on peer-reviewed literature, government reports, and non-governmental organization reports. Historical project event timelines and stakeholder contributions to the project were provided through discussions with the USACE New Orleans District and collaborators (i.e., Coalition to Restore Coastal Louisiana; The Water Institute of the Gulf, National Wildlife Foundation; The University of New Orleans, Tulane University) who were involved in the project. Historical activities were organized and presented chronologically: 1) diversion creation, 2) SRED construction, and 3) strategic or direct placement of dredged sediments for land creation (other than SREDs).

To evaluate land changes in West Bay project area, remotely sensed data derived from satellite and/or aircraft were combined with historical data to address current sediment bed elevations, land:water ratios, and emergent vegetation. The assessment of land changes pre- and post-restoration activities was generated through object-oriented image classification of Landsat satellite imagery (30-meter pixel resolution) using ENVI® software. Two unobscured satellite images were selected for analysis, one prior to restoration activity (December 21, 2002) and one after restoration activity (January 10, 2019); the 2019 image displayed restoration activities from 2003 through 2018. Two categories were identified in the analysis, water and land. The water classification included open water features, floating and submerged aquatic vegetation and suspended sediment. The land classification included subaerial land features such as marsh and bare land. Land changes between the classified images were produced using ENVI® Thematic Change Workflow tool. West Bay project acreage statistics for land:water for each classification date (2002 and 2019) and land changes between the two were generated using ArcGIS® zonal statistics tool.

Emergent vegetation in West Bay was assessed using the 2013 National Landcover Dataset (NLCD) produced by the Multi-Resolution Land Characteristics (MRLC) consortium (https://www.mrlc.gov). The nationwide dataset was derived from image classification of Landsat imagery (30-meter pixel resolution). The landcover categories within the dataset for the West Bay project include open water, barren land, herbaceous, woody wetlands, and emergent herbaceous wetlands. Acreage totals for each category for the West Bay project area were generated using the ArcGIS® zonal statistics tool. Additionally, this study reviewed reports of vegetation surveys on restored land in West Bay conducted in 2015 by the Coastal Protection and Restoration Authority (CPRA) (Plitsch et al. 2017), who documented information on plant species composition, percent cover, and relative abundance.

RESULTS AND DISCUSSION

History of West Bay Restoration Activities

In 2003, prior to habitat restoration, the West Bay project area was 88% open water and 12% freshwater marsh and tidal flats, with a total area of 12,294 ac (4,975 ha) (Figure 1; LDNR-CRD 2003). Initial restoration goals were to net 9,831 acres of restored land (i.e., subaerial growth; 76% of project area) in West Bay over the planned 20-year project life (CPRA 2004). The documented restoration activities included: 1) construction of an uncontrolled diversion (2003), 2) construction of SREDS (2009, 2013, and 2015), 3) strategic placement of dredged sediment utilizing flows through the diversion (2012), and 4) direct placement of sediment for land creation (2002-present).

Construction of the Uncontrolled Diversion (2003)

Diverting sediment-laden water from a large river into an abandoned sub-delta wetland basin (i.e., converted to open water) is a restoration tool for maintaining or enlarging deltaic wetlands (Khalil et al. 2011; Allison et al. 2017) by mimicking crevasse splay formations which naturally develop during the evolution of deltas (Coleman 1988). Whereby the settling of sediment from the crevasse forms a splay and promotes subaerial growth as sediment continues to accumulate (Boyer et al. 1997). The time between a natural crevasse opening and subaerial growth can be several decades, with cycles of growth and eventual subsidence estimated to be as long as 100-200 years (Wells and Coleman 1987). The West Bay sediment diversion project has an ambitious goal of achieving nearly 10,000 acres (˜80% of project area) of subaerial growth over 20 years (CPRA 2004). West Bay is a large open-ended receiving basin, and involves a more aggressive strategy including construction of sediment retention structures to accelerate sediment accumulation (USACE 2001). Benefits of creating artificial crevasses for building marsh habitat in Louisiana were realized in the 1980s and 90s, following a number of smaller scale (discharge rate <4,000 cfs) diversion projects located in the lower Mississippi River delta region (e.g., South Pass, Pass-a-Loutre, Loomis Pass; Trepagnier 1994; LDNR-CRD 2003; Plitsch 2017). Concepts of larger-scale diversions were evaluated during the same period, in the mid-1980s, through a Loss and Marsh Creation (LLMC) study, which determined that sediment diversions were potentially viable methods for marsh creation (USACE 2001).

Building on prior successes and feasibility studies, a logical solution for reversing the land loss experienced in West Bay was to create an uncontrolled diversion from the Mississippi River. It was hypothesized that a large diversion (crevasse) discharging into a large open-ended receiving basin would successfully create subaerial deposits that would lead to the colonization of native vegetation (Trepagnier 1994). Following an extensive analysis of the feasibility and potential environmental impacts on constructing a diversion in West Bay, the project was approved on the 1st Priority List under the authority of the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA; Title III; Public Law 101-646).

The federal and state sponsors for the West Bay project include USACE and CPRA, formerly known as the Louisiana Department of Natural Resources Coastal Restoration Division (LDNR-CRD) who led the efforts to define the long-term project objectives (USACE 2001; LDNR-CRD 2003; CPRA 2004). The location of the notch for the diversion was aimed to mimic a natural crevasse splay that was documented in the vicinity of the project area circa 1838 (Allison et al. 2017). In November 2003, the diversion was created in the west bankline of the lower Mississippi River using hydraulic dredging (4.7 miles upstream of the Head of Passes; Figure 2) and was designed to deliver an approximate discharge of 20,000 cfs. River flow data from December 2003 to June 2019 indicated that average flow at the entrance of the diversion was 28,974 cfs (n=170), approximately 6% of the flow from the Mississippi River (USACE 2019).

The sand fraction of the suspended sediment load is anticipated to be the most significant particle size contributing to early stages of land building processes (Dean et al. 2014). Allison et al. (2017) noted that silt-sized sediment would not be a significant contributor in the early stages of land building within the basin, but fine sediment retention would increase after colonization of marsh vegetation. Estimates of the sand fraction (0.064 to 0.25 mm) in the suspended sediment load in the lower Mississippi river and diversion channel typically range from 5-40% and are dependent on flow velocities (Yuill et al. 2016). Estimates of sediment loads in the Mississippi River near Empire, LA (˜22 miles upstream of diversion) ranged from 100-800 10^3 tons suspended sediment/day, and the sand fraction ranging from 1-150 10^3 tons/day (Allison and Meselhe 2010). Yuill et al. (2016) modeled sand fraction loading in the diversion channel for a 10-year time period (2004-2014) and noted that the sand flux entering the diversion was proportional to the flow velocity. Although diversion channel morphology changes during the time period translated to highly variable sand loads (250-750% differences), during low (8,800 m^3/s) and high river flow velocities (21,000 m^3/s) the sand flux was estimated to be ˜0.1 and ˜100 kg/s, respectively (Yuill et al. 2016). Between 2004 and 2014, the sand loading to the system was estimated to be the highest in 2009, corresponding to the development of a scour hole in the diversion contributing to higher flow discharges into the bay. Allison and Meselhe (2010) indicated that annualized transport of sediment (particularly sand) into the West Bay diversion would likely be limited to brief intervals at high energy discharge phases that could flush stored sediments from the bedload (sand) into the reach (Allison and Meselhe 2010).

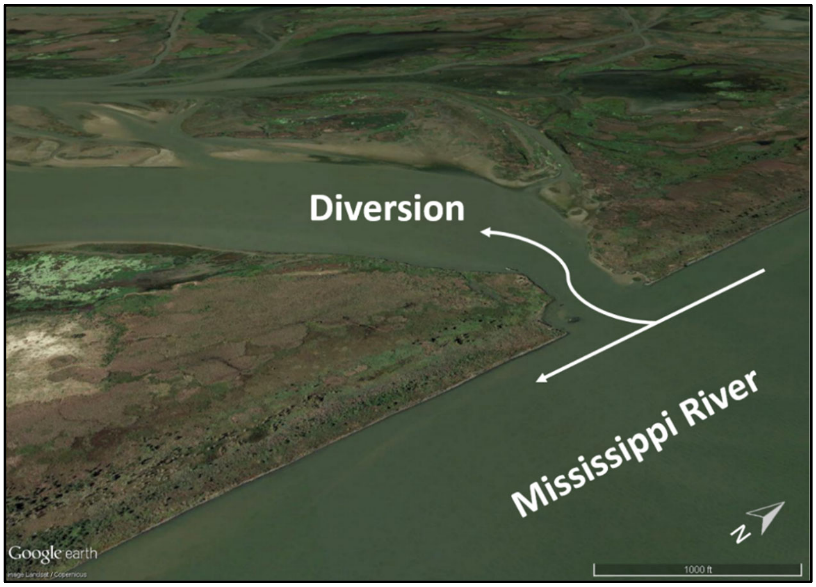

Figure 2. West Bay, LA diversion channel. Note: Arrows indicate direction of water flow. Source: LA 29°10’50.50’’N; 89°18’16.20’’E. Google Earth. November 11, 2016.

Since 2003, several monitoring efforts have reported the hydrodynamic and morphological evolution of the diversion and the performance in terms of subaerial growth (e.g., Barras et al. 2009; Kolker et al. 2011, 2012; Yuill et al. 2016; Plitsch 2017; Allison et al. 2017). At 10 years post-diversion construction, hydrodynamic and sediment transport modeling data indicated that the diversion shifted from erosional processes to depositional processes, favoring the deposition of sediments (Yuill et al. 2016). However, it was evident that in the first five years post-diversion construction, the rate of land emergence in the basin was minimal. Thus, the application of SREDs were pursued to increase the sediment trapping efficiency of the basin.

Construction of Sediment Retention Enhancement Devices (SREDs) (2009, 2013, 2015)

Prior to the construction of the first sediment retention device in 2009, Kolker et al. (2012) studied the dynamics of sediment bound radioisotopes (e.g., ^{7}Be) to understand recent sedimentary evolution in the bay. Results indicated that the maximum sediment deposition occurred downstream of the West Bay project boundary where sediment flow was dominated by the artificial crevasse and flow from Grand Pass (Kolker et al. 2012). The results provided evidence that a higher proportion of turbulent waters were moving through the West Bay project area prior to deposition. To accelerate sediment accumulation in this dispersive area, five temporary earthen berms (SREDs) were constructed over a six-year period downstream of the artificial crevasse and orientated perpendicular to the diverted flow, using sandy sediment dredged from the Pilottown Anchorage Area (PAA) in the adjacent Mississippi River (Table 1; Figure 3). The SREDs were designed to provide temporary reduced flow velocity by diverting flow through and around the berm and to reduce fetch and local scour and to allow more time for the suspended sediment to deposit before moving downstream. The SREDs were constructed by hydraulically pumping sediment through temporary pipelines to the placement sites. Because the SRED was considered sacrificial by design, the armoring of the berms (e.g., rip-rap) was not considered and eventual deformation by current and wave conditions was expected.

In 2009, sediment dredged from the PAA was placed at the Cherie Island Site to construct the first SRED approximately 2 miles downstream of the artificial crevasse. In 2013, sediment from the PAA dredging project was used to construct three additional SREDs (range 1.5 to 2.5 miles

Table 1. Description of sediment retention enhancement devices (SREDs) constructed in West Bay below the artificial crevasse using sediment dredged from the Mississippi River.

Year	SRED	Dredged Sediment Volume (cy)	Land Created (Acres)	Project
2009	1	386,233	35	CWPPRA PAA
2009	2	1,325,614	97	CWPPRA PAA
2013	3	1,308,435	86	
2013	4	328,567	13	
2015	5	2,299,295	80	USACE HDDA

CWPPRA = Coastal Wetlands Planning, Protection, and Restoration Act; PAA = Pilottown Anchorage Area maintenance dredging; USACE = US Army Corps of Engineers; HDDA = Hydraulic Dredging Disposal Area maintenance dredging

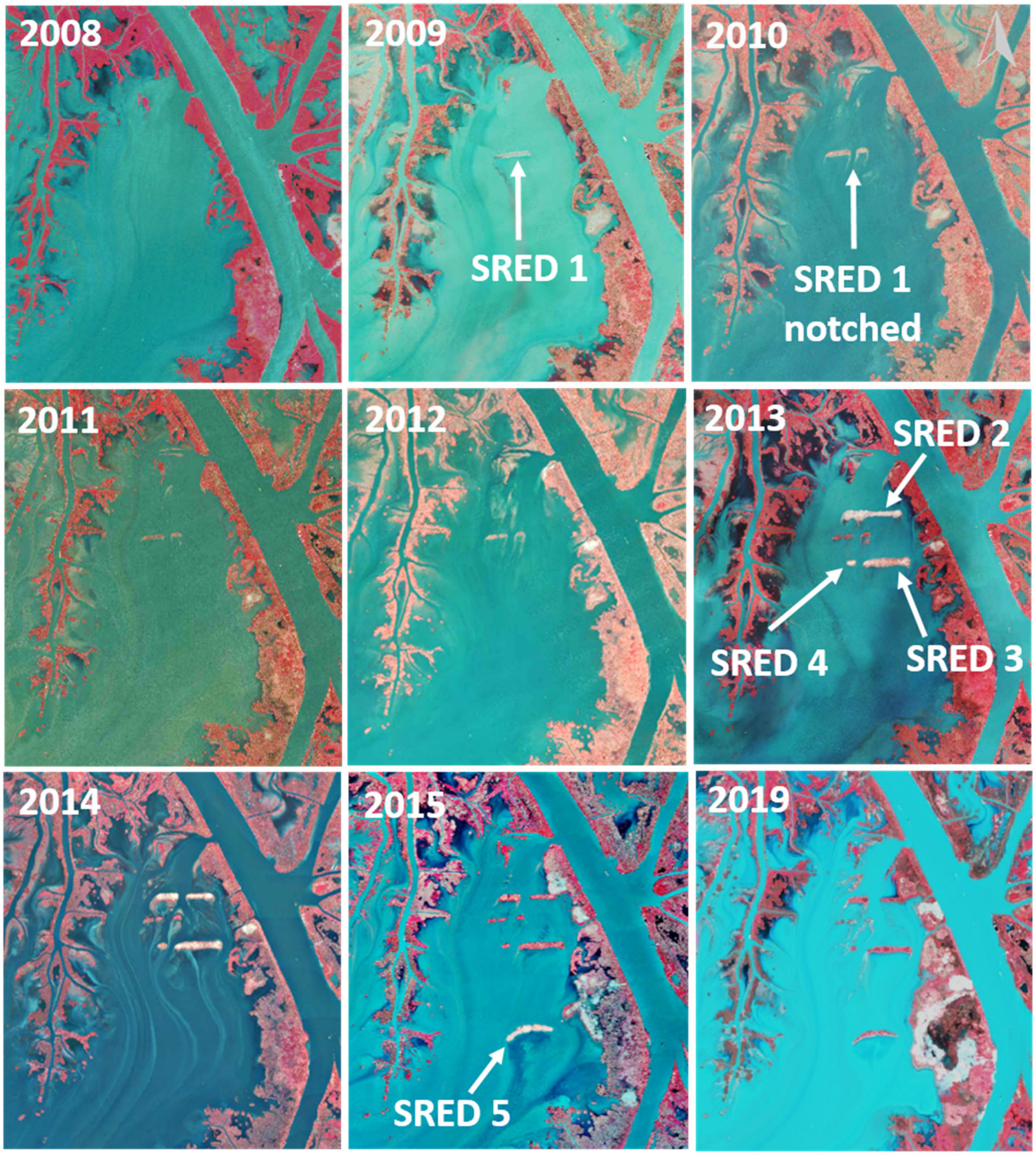

Figure 3. Construction Timeline of West Bay Diversion and Sediment Retention Enhancement Devices (SREDs) and Restoration of Coastal Habitat through Beneficial Use of Dredged Sediment.

downstream). In 2015, one additional SRED was constructed approximately 4.3 miles downstream using sediment from the hopper dredge disposal area (HDDA) with partial funding under the Louisiana Coastal Area Beneficial Use of Dredged Material (LCA-BUDMAT) program. The purpose of this fifth SRED was different in that it was designed and placed to reduce erosive wave action from the Gulf of Mexico that could impact the other four SREDs. After construction, an excavator was used to notch the SREDs (i.e., remove a section of the SRED), varying in location and width, to allow water to flow through the SREDs with the intent to diversify the physical habitat (e.g., depth, velocity, and sediment composition) behind each SRED (Pennington et al. 1988; Jacobson et al. 2004). The SREDs provided protection, allowing for the settling of sediment immediately behind and adjacent to the berms. With time, the SREDs were incorporated into the subaerial structures.

The effect of SREDs on the receiving basin sediment transport was modeled by Allison et al. (2017) who found that when SREDs were removed via various modeling scenarios, flow velocities through the diversion channel and receiving basin increased. This is similar to the results of Kolker et al. (2012) who studied the diversion prior to the construction of the first SRED and found that although sediment deposition was occurring in the receiving basin, the maximum sediment deposition occurred downstream of the project area. Allison et al. (2017) estimated that during low flow discharges during 2013 (after construction of SREDs 1-4), the basin retention of sediments ranged from 4-60% and 40-100% for silt and sand, respectively.

The first documented subaerial growth as a result of the diversion (i.e., not beneficial use of sediment) was observed in 2011 in the north part of the bay immediately west of the diversion and upstream of the first 2009 SRED. This coincides with the historic 2011 Mississippi River flood event plume that was described by Falcini et al. (2012) as “a focused, high-momentum jet emerging from the leveed Mississippi, and delivered sediment far offshore”. It is unclear exactly how the 2011 event formed or shaped the landscape in West Bay, but there was an obvious increase in magnitude of deposition during this period, suggesting local effects impacting timing and magnitude of sediment movement through the artificial crevasse allowed for a greater rate of deposition. This also shows the importance of geomorphic events such as large floods to the contribution of land growth. The construction of the SREDs also could be considered among the strategic placement actions taken in the bay.

Strategic Placement of Dredged Sediment (2012)

Strategic placement strategies in West Bay included “seeding” the entrance to the diversion and creation of marshes expanding out from and reinforcing the navigation channel bankline. The “seeding” was accomplished by placing the dredged sediment in a semi-confined method where the only retention features were adjacent landforms. In 2012, approximately 600,000 CY of dredged sediments were discharged immediately adjacent to the flow path of the diversion channel to allow natural hydrodynamic processes to erode and redistribute the sediments out into the bay. Diversion flows from the Mississippi River ranged from 19,000 to 46,000 cfs during the placement activities in 2012.

Direct Placement of Dredged Sediment (2003-current)

Since project inception, the creation of marsh in West Bay via beneficial use of dredged sediment from the diversion construction and maintenance dredging of the PAA was a primary restoration goal (LDNR-CRA 2003) with the focused placement areas on the west bank line of the navigation channel (eastern bank of West Bay; Figure 4). In 2003 during the initial construction of the diversion channel, approximately 1.5 MCY of dredged sediment were used to convert open water

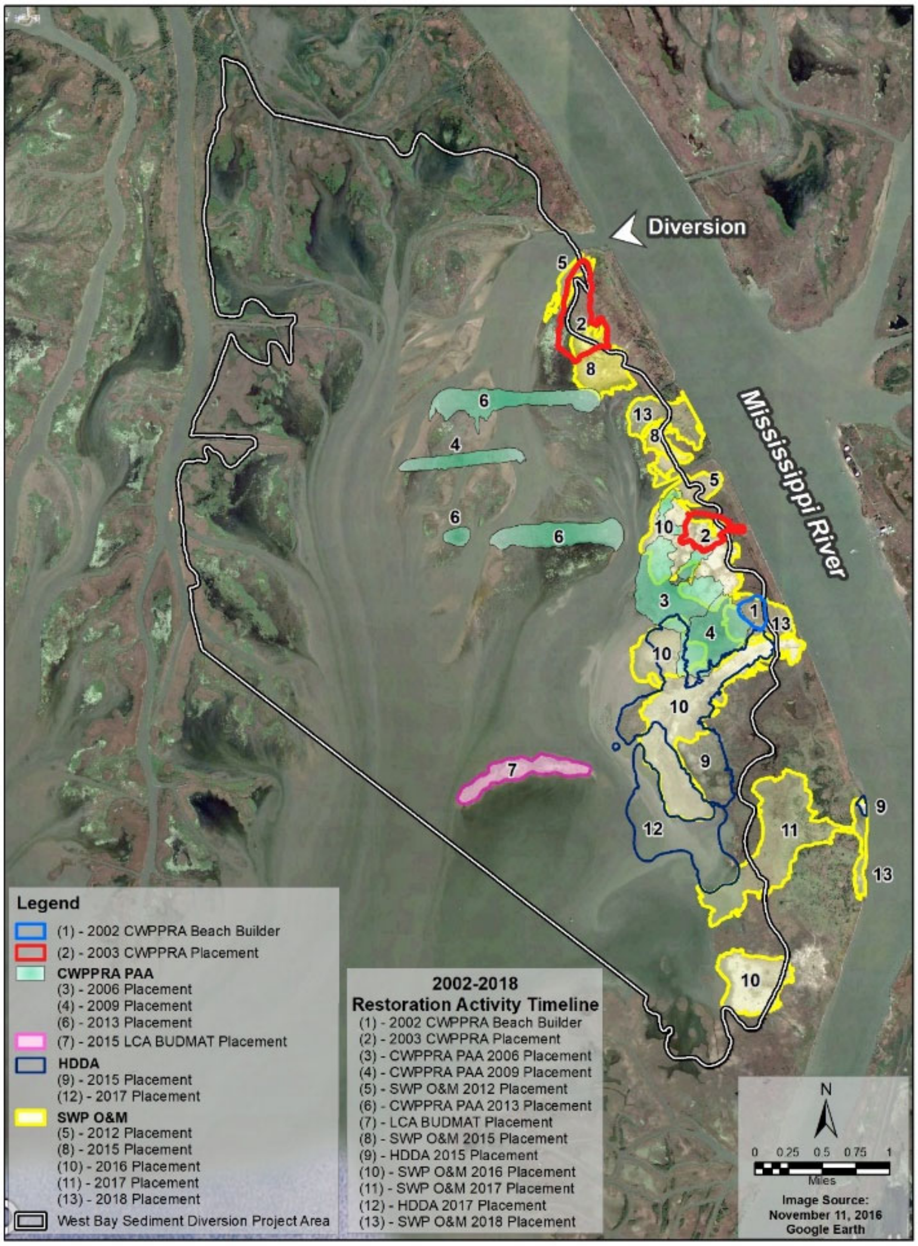

Figure 4. West Bay placement activities from 2002 to 2018 for marsh creation and nourishment overlaid on 2016 imagery.

areas into marsh (Figure 4). In 2006, during maintenance dredging of the PAA, approximately 2 MCYs were used to create land. Additionally, dredged sediment removed during maintenance of the navigation channel near PAA was used from 2013-2018 for additional habitat creation (Figure 4). These direct placements were performed during routine maintenance dredging of the Federal navigation channel as part of the channel's base disposal plan. In total, approximately 37 MCY were used for the specific purpose of marsh restoration in West Bay, with 2,641 ac of land created (Plitsch 2017; USACE 2019; Figures 4 and 5).

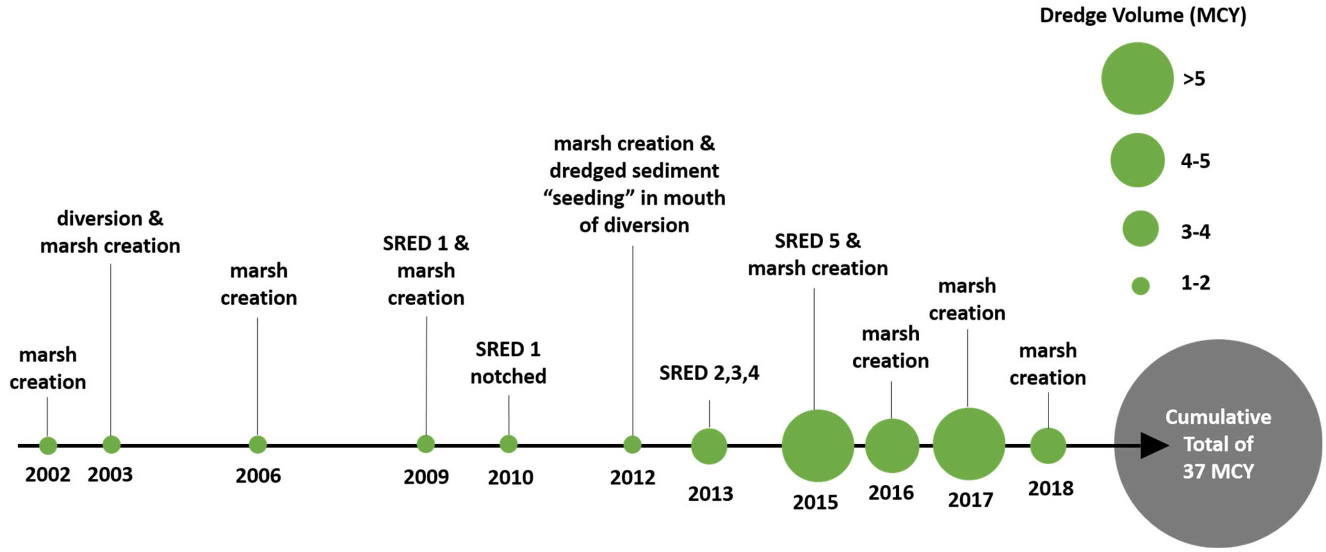

Figure 5. Timeline of major dredging placement events in West Bay, LA from 2002 to 2018. Note: million cubic yards (MYC); sediment retention enhancement devices (SREDs).

West Bay Transformation and Benefits

Monitoring data from 2002 to 2019 indicate that progress is being made to achieve the West Bay CWPPRA project goals. Based on a combination of the restoration strategies using the uncontrolled diversion, strategic and direct placement of dredged sediment, and dynamic berms (SREDs) utilizing EWN concepts, several quantifiable benefits have been observed.

Changes in bathymetry

To make informed decisions on the variety of restoration activities in West Bay, knowledge of the spatial and temporal distribution of natural sedimentation processes, including deposition, transport, and erosion, is important (Wells and Coleman 1987). Comparison of volumetric measurements of sediment changes based on bathymetric surveys conducted in 2003, 2006, 2009, 2011, and 2015, were used to monitor subaqueous and subaerial growth in West Bay. Early in the project, between 2003 and 2009, there was a volumetric decrease of over 14 MCY of sediment from the West Bay receiving area, indicating that there was still a net loss of sediment in West Bay (Barras et al. 2009). Between 2009 and 2011, approximately 1.9 MCY of dredge sediment was placed in the receiving basin; however, there was an overall decrease of 0.3 MCY in the receiving area providing evidence that sediment deposition in receiving bay areas outside of dredged sediment placement sites was minimal. However, between 2011 and 2015, the receiving basin increased by 17.2 MCY of which approximately 28% was the result of direct placement of dredged sediment. Thus, 12.4 MCY was deposited in receiving bay areas outside of the dredged sediment placement sites marking the first substantial sediment accretion in the bay in decades (Plitsch 2017).

Investigation of the depositional dynamics of West Bay using radioisotopes (i.e., ^{7}Be, ^{137}Cs) further confirmed the modest estimates of accretion in 2009 prior to the SRED construction

(Kolker et al. 2012). Estimated rates of sediment accumulation from 2003 to 2009 were approximately 3 cm/year deposition rate across West Bay (Kolker et al. 2012). At those rates, it would take decades to begin to fill in much of the bay which ranged in depth from 0 to 3 meters (Barras et al. 2009). After the construction of the 2009 SRED, subaerial growth increased in the north section of the bay upstream of the SREDs following the 2011 flood event (Kolker et al. 2012). This provides evidence of the ability for SREDs to increase the rate and extent of sediment deposition by reducing flow velocity in the bay. It is hypothesized that there will be a similarly positive relationship of land formation following the sediment loading introduced into West Bay from the more recent 2019 lower Mississippi River flood event. Additional bathymetric surveys are scheduled in West Bay in 2021 (Plitsch 2017).

Land:water analysis

Overall, the rate of land loss in the West Bay area (ca. 12,000 ac) has decreased from 23.8 ac/yr (±4.6) from 1984 to 2009 to 12.4 ac/yr (±19.9) from 2001 to 2009 (Barras et al. 2009). Following the diversion creation, it was evident from bathymetric surveys that shoaling was outpacing relative sea level rise, with approximately 20 cm of sediment deposited between 2003 and 2009 (Kolker et al. 2012). This was in spite of the influence of a number of large hurricanes that occurred in this region within this timeframe with periods of elevation loss (e.g., Katrina in 2005; Andrus and Bentley 2007). More recently, in 2014, sand and silt retention in West Bay ranged from 40-100% and 4-60%, respectively (Allison et al. 2017). Through direct placement activities, approximately 37 MCY of dredged sediment has been placed in the project area between 2002 and 2019. During 2016, subaerial growth was evident from satellite imagery near the entrance of the diversionary channel and SREDs (Figure 6). From strategic and beneficial use of dredged sediment projects, over 2,641 ac of land were directly created in the West Bay project area (based on the documentation at time of placement). More recently, land:water analysis of 2019 satellite imagery indicate similar trends, with 2,224 ac of restored land in the West Bay project area as compared to pre-restoration (2002) actions (Figure 7). Much of the land converted to water during the 2002 to 2019 period shown in Figure 7 was outside of the influence of beneficial use activities in the area. These land acreage estimates should be considered conservatively low, as the Mississippi River was at flood stage during the time the satellite imagery was captured (river stage in New Orleans 14-16 ft; NGVD88; http://rivergages.mvr.usace.army.mil); as such, the higher water level obscures the land creation.

Emergent vegetation and habitat analysis

Analysis of historic land cover data provides insight into the timeline of marsh habitat emergence within the West Bay project area following restoration activities. Land cover data from the National Land Cover Database (NLCD; USGS 2019) was reviewed from 2013, the year of the creation of SREDs 2, 3, and 4. In 2013, the West Bay project area was dominated by emergent wetland habitat, with approximately 1,840 acres classified as emergent herbaceous wetlands (Figure 8). Interestingly, the emergence of marsh habitat is observed on SRED 1, which was created 4 years prior to the date the satellite image was taken.

The first ground vegetation survey performed in West Bay to document the emergence of wetland species in placement areas and SREDs was conducted shortly after the completion of SRED 5 in

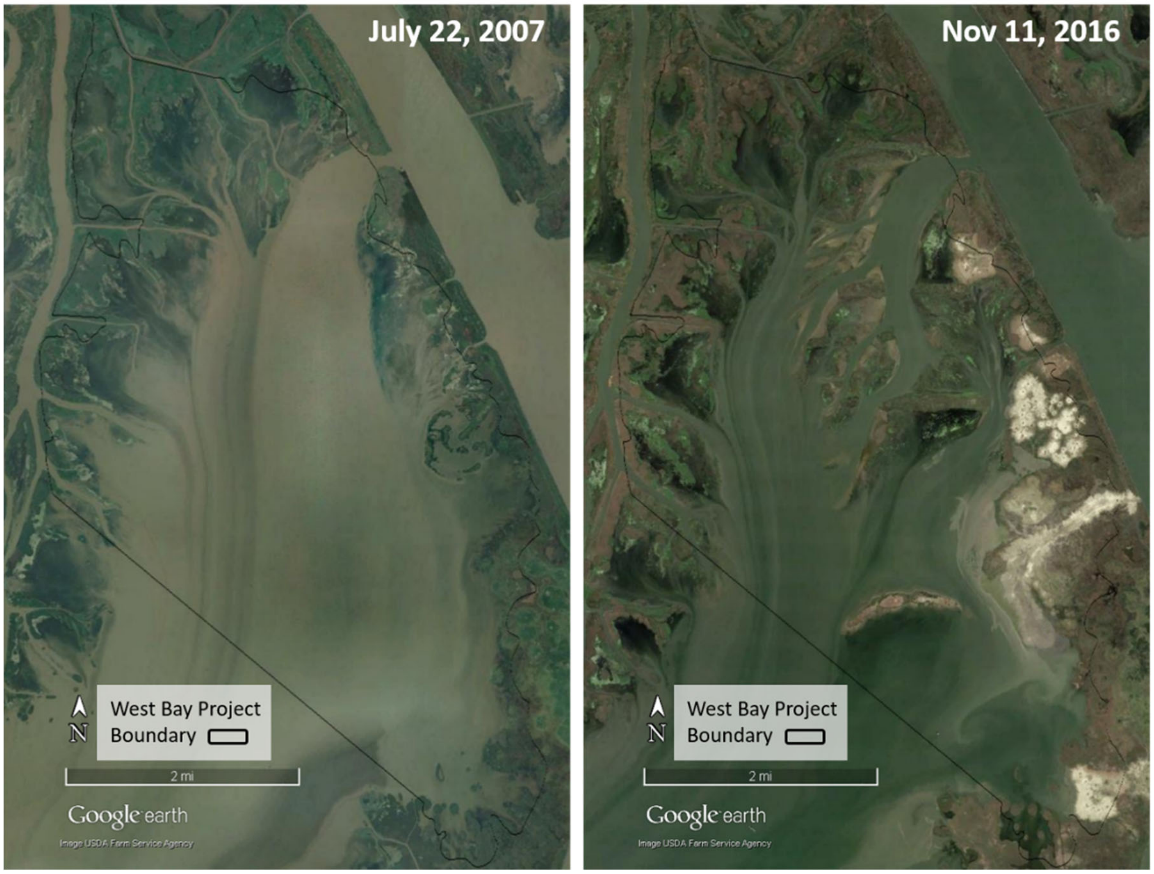

Figure 6. Land changes in the West Bay project area from 2007 to 2016. Note: New Orleans river stage height 6.49 ft (July 2007); 4.35 ft (November 2016). Image source: West Bay, LA 29°10’50.50’’N; 89°18’16.20’’E. Google Earth. July 22, 2007 and November 11, 2016.

2015 as documented in Plitsch (2017). Survey areas were established to include placement areas that ranged from newly created (<5 years old; n=15 sites) to more established beneficial use sites created in 2003 (n=4 sites; Plitsch 2017). Overall, the vegetative percent cover of the survey areas ranged from <1% to 15.5%. Plitsch (2017) observed that the new land generated from dredge placement grew vegetation quickly (i.e., within a single growing season). In terms of species diversity, the beneficial use placement sites near the diversion entrance had the highest species richness. Some of the dominant species of vegetation observed in 2015 included *Phragmites australis* (common reed); *Schoenoplectus deltarum* (delta bulrush); *Leptochloa fusca* (sprangletop); *Zizania aquatic* (wildrice); *Vigna luteola* (hairypod cowpea); *Alternanthera philoxeroides* (alligator weed); and *Polygonum punctatum* (dotted smartweed). As anticipated with newly formed or emergent land, the SREDs and associated mud-flats had the least diversity of the survey sites, with approximately 5-8 species each. These sites were dominated by annual wildrice (*Z. aquatica*), which was also the singular species associated with the SRED mudflats (Plitsch 2017). The newly created habitat was classified as fresh-intermediate marsh (Plitsch et al. 2017).

To interpret the quality of these newly created vegetative areas, the Floristic Quality Index (FQI) was applied to these data by Plitsch (2017). The FQI’s are rated from 0-100, with higher scores indicating better habitat quality. These scores reflect both the percent cover values and the

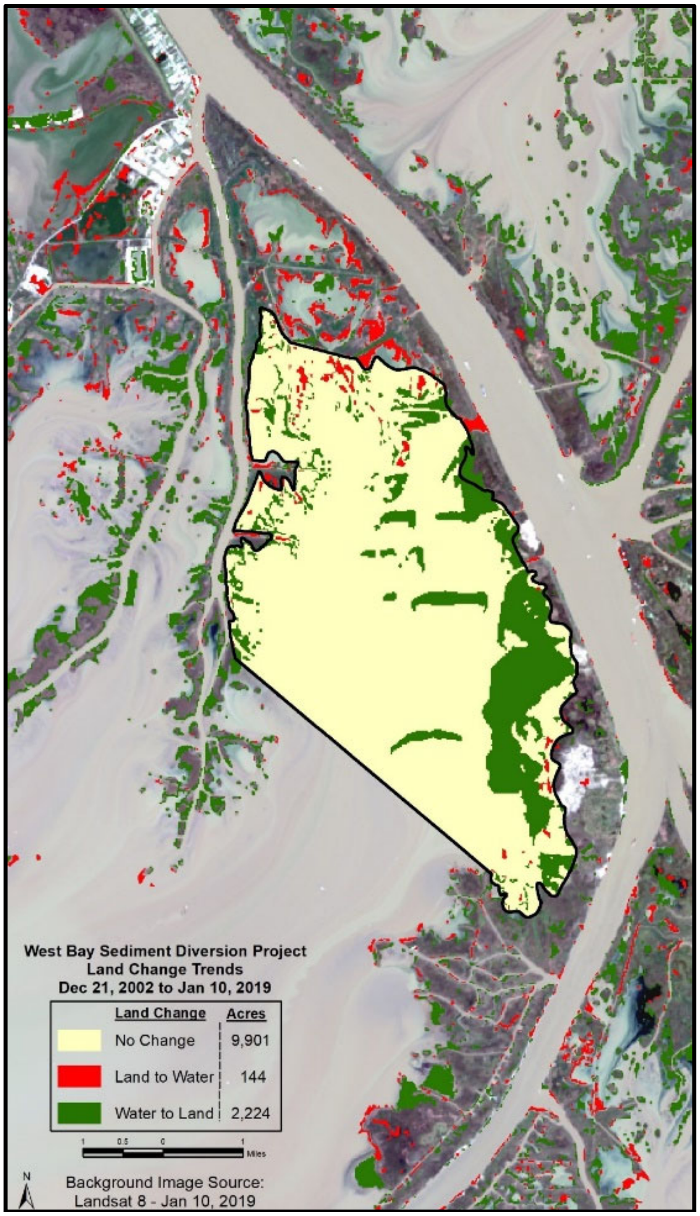

Figure 7. Land change trends from 2002 to 2019 in the West Bay project area.

“coefficient of conservatism” value, to infer a species tolerance to disturbance and fidelity to habitat. FQI scores for the Mississippi River Delta are generally less than 20. For this initial survey of West Bay, the FQI was 34, indicated that in 2015 the newly developed land was providing better than regional average habitat quality. Additionally, observational data obtained from 2019 aerial surveys and visual observations of personnel operating in the project area indicates an abundance of ungulates (e.g., grazing cows) and migratory birds (USACE 2019). Establishment of wetland vegetation at the time of emergence of land supports further land creation through mechanisms of sediment trapping by the root mass and above-ground biomass (Dean et al. 2014). Creating fresh/intermediate marshes is important to many of the recreationally and commercially important wildlife, which depend on a productive marsh habitat. The creation of marsh in West Bay has the

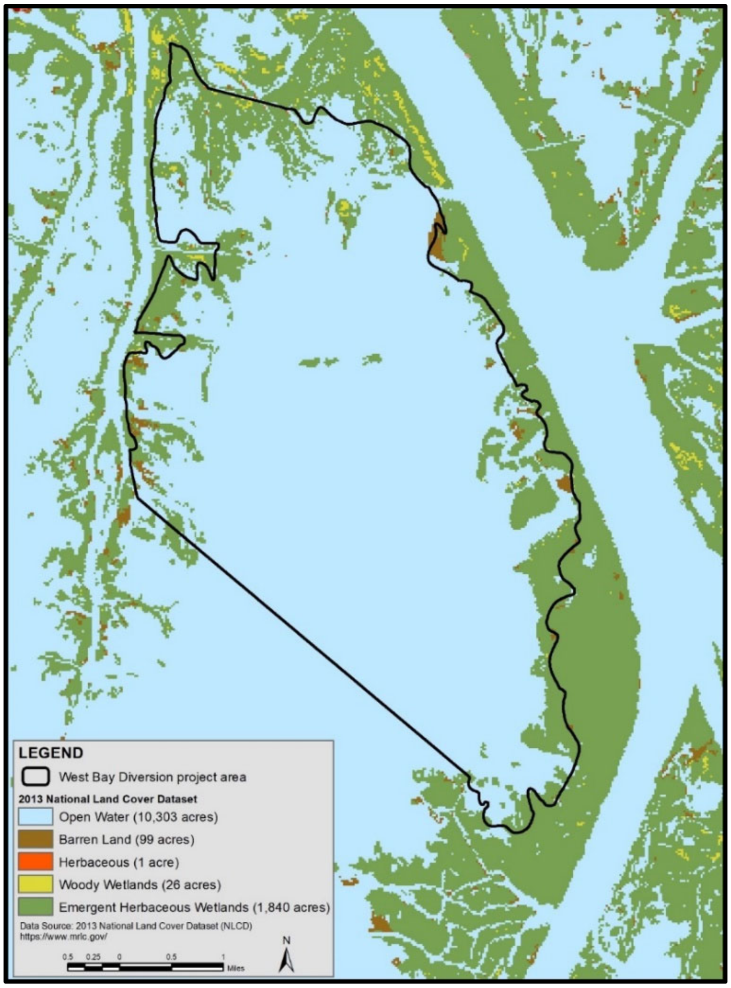

Figure 8. West Bay land cover analysis based on 2013 National Land Cover Dataset (NLCD; USGS 2019).

potential to positively impact wildlife resources, including recreationally important wildlife (e.g., big and small game, migratory birds, and waterfowl benefit considerably from marsh creation) (USACE 2001).

Application of Engineering with Nature Principles

The West Bay project implemented two distinct aspects of EWN that contributed to achieving project objectives of restoring marsh habitat and enforcing eroded navigation channel banklines: construction of the SREDs and strategic placement of dredged sediment. The SREDs are dynamic berms constructed of dredged sediment that are designed to direct nature's energy to achieve project objectives; in this case to increase settling of sediments entering the bay via the diversion and reducing erosive wave action from the open waters of the Gulf of Mexico. The strategic placement of dredged sediment near the mouth of the diversion in 2012 used nature's energy to distribute sediments into the bay via more natural processes. Such techniques have been used successfully on other riverine projects in coastal Louisiana (e.g., Foran et al. 2018). The beneficial use of dredge sediment in West Bay thereby provided multiple benefits yielding a "triple-win" outcome: economic (decreased placement costs and reduced future maintenance of the adjacent Federal navigation channel, livestock grazing), environmental (submergent and emergent habitat restoration) and social benefits (recreation and storm protection).

SUMMARY AND CONCLUSIONS

In this paper we document the historical context and progress of restoring marsh habitat in West Bay. Temporary earthen berms (i.e., SREDS), sequenced dredged sediment placement events, and a large flood, in conjunction with an uncontrolled diversion from the Mississippi River helped to maximize the rate and extent of sediment retention in West Bay between 2002 and 2019. Added value of marsh restoration through the beneficial use of dredge sediment was ecologically meaningful, with the majority of restored marsh directly attributed to the 37 MCY of dredged sediment both directly and strategically placed within the system to restore approximately 2,200 acres of land. As land has been restored it has naturally vegetated to create emergent marsh habitat. To continue to accelerate this restoration process, the USACE New Orleans District has developed long-term placement plans for beneficial use of dredged sediments in the area.

Overall, based on a review of the sediment diversion and restoration activities from 2002-2019, a few key observations were made:

- Uncontrolled diversions can take decades before subaerial creation of land is fully realized; therefore, future project goals should reflect these realities.
- Large flood events (like those experienced in 2011) likely contributed substantially to sediment transport and accretion in the West Bay basin.
- SREDs constructed using strategic and direct placement of dredge sediment directly contributed to increase the rate and extent of sediment retention.
- Strategic and beneficial use of dredged sediment were ecologically meaningful contributions to land restoration.

To date, West Bay remains one of the few large-scale (>20,000 cfs) uncontrolled diversion projects that the authors are aware of on the Mississippi River with the designed purpose of restoring wetlands using natural deltaic processes. Thus, lessons learned from this project are invaluable to future restoration investments for similar projects. In coastal Louisiana alone, it is estimated that ca. $18 billion will be spent on marsh creation using dredged sediment and $5 billion will be spent on sediment diversions in ongoing and future projects as part of the CPRA master plan for a sustainable coast (CPRA 2012). Thus, for future projects in riverine environments in Louisiana and elsewhere, there is a persistent need to document progress of existing riverine sediment diversion projects to inform future work.

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REFERENCES

Allison, M.A., and Meselhe, E.A. (2010). The use of large water and sediment diversions in the lower Mississippi River (Louisiana) for coastal restoration. *Journal of Hydrology*, 387(3-4):346-360.

Allison, M.A., Yuill, B.T., Meselhe, E.A., Marsh, J.K., Kolker, A.S., Ameen, A.D. (2017). Observational and numerical particle tracking to examine sediment dynamics in a Mississippi River delta diversion. *Estuarine, Coastal and Shelf Science* 194:97-108.

Andrus, T.M., and Bentley, S.J. (2007). Sediment flux and fate in the Mississippi River Diversion at West Bay: Observation study. *Coastal Sediments '07* pp.722-735.

Barras, J.A., Padgett, W.C., Sanders, C.B. (2009). Aerial and Bathymetric Spatial Change Analysis of the West Bay Sediment Diversion Receiving Area, Louisiana for US Army Engineer District, New Orleans (MVN) Report. Vicksburg, MS: U.S. Army Engineering Research and Development Center., 39p.

Boyer, M.E., Harris, J.O., Turner, R.E. (1997). Constructed crevasses and land gain in the Mississippi River delta. *Restoration Ecology* 5(1):85-92.

Bridges, T.S., Bourne, E.M., King, J.K., Kuzmitski, H.K., Moynihan, E.B., Suedel, B.C. (2018). Dredged sediment in an uncontrolled diversion: West Bay Louisiana, United States. In: Engineering with Nature: An Atlas. ERDC/EL SR-18-8. Vicksburg, MS: U.S. Army Engineering Research and Development Center. 261p.

Bridges, T.S., Lillycrop, J., Wilson, J.R., Fredette, J.T., Suedel, B.C., Banks, C.J., Russo, E.J. (2014). Engineering with Nature promotes triple-win outcomes. *Terra et Aqua* 135:17–23.

Coleman, J.M. (1988). Dynamic changes and processes in the Mississippi River delta. *Geological Society of America Bulletin* 100:999-1015.

Couvillion, B.R., Barras, J.A., Steyer, G.D., Sleavin, W., Fischer, M., Beck, H., Trahan, N., Griffin, B., Heckman, D. (2011). Land area change in coastal Louisiana from 1932 to 2010: U.S. Geological Survey Scientific Investigations Map 3164, scale 1:265,000, 12p.

CPRA (Coastal Protection and Restoration Authority). (2012). Louisiana's Comprehensive Master Plan for a Sustainable Coast. Baton Rouge: State of Louisiana. 190p.

CPRA. (2004). West Bay Sediment Diversion (MR-03) Fact Sheet. [Accessed online June 15, 2019: https://lacoast.gov/new/Projects/Info.aspx?num=mr-03]

Dean, RG., Well, JT., Fernando, H.J., Goodwin, P. (2014). Sediment Diversions on the Lower Mississippi River: Insight from Simple Analytical Models. *Journal of Coastal Research* 30(1):13-29.

Falcini, F., Khan, N.S., Macelloni, L., Horton, B.P., Lutken, C.B., McKee, K.L., Santoleri, R., Colella, S., Li, C., Volpe, G., D'Emidio, M., Salusti, A., Jerolmack, D.J. (2012). Linking the historic 2011 Mississippi River flood to coastal wetland sedimentation. *Nature Geoscience* 5(11):803.

Foran, C.M., Burks-Copes, K.A., Berkowitz, J., Corbino, J., and Suedel, B.C. (2018). Quantifying Wildlife and Navigation Benefits of a Dredging Beneficial Use Project in the Lower Atchafalaya River: A Demonstration of Engineering With Nature®. *Integrated Environmental Assessment and Management* 14(6):759-768.

Gailani, J., Brutsché, K.E., Godsey, E., Wang, P., and Hartman, M.A. (2019). Strategic Placement for Beneficial Use of Dredged Material. ERDC/CHL SR-19-3. Vicksburg, MS, U.S. Army Engineering Research and Development Center.

Gerhardt-Smith, J. M., and C. J. Banks. (2014). USACE *Regional Sediment Management and Engineering with Nature 2013 Workshop Summary*. ERDC TN-EWN-14-3. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Jacobson, R.B., Elliott, C.M., Johnson, H.E. (2004). Assessment of shallow water availability in modified dike structures, Lower Missouri River, 2004. Open File Report 2004-1409. U.S. Geological Survey.

Jankowski, K.L., Törnqvist, T.E., Fernandes, A.M. (2017). Vulnerability of Louisiana's coastal wetlands to present-day rates of relative sea-level rise. *Nature Communications* 8:14792

Khalil, S.M., Raynie, R.C., Muhammad, Z., Killebrew, C. (2011). Overview of coastal restoration in Louisiana. *Shore and Beach* 79(3):4-11.

Kolker, A.S., Allison, M.A., Hameed, S. (2011). An evaluation of subsidence rates and sea-level variability in the northern Gulf of Mexico. *Geophysical Research Letters* 38(21).

Kolker, A.S., Miner, M.D. and Weathers, H.D. (2012). Depositional dynamics in a river diversion receiving basin: The case of the West Bay Mississippi River Diversion. *Estuarine, Coastal and Shelf Science*, 106, pp.1-12.

Louisiana Department of Natural Resources, Coastal Restoration Division (LDNR-CRD). (2003). Monitoring Plan for West Bay Sediment Diversion. Baton Rouge, Louisiana. 11p.

Pennington, C.H., Shields, F. Douglas, Jr., Sjostrom, J.W., Myers, K.A. (1988). Biological and Physical Effects of Missouri River Spur Dike Notching. Miscellaneous Paper EL-88-11, Vicksburg, MS: U.S. Army Engineer Research and Development Center.

PIANC. 2018. Guide for Applying Working With Nature to Navigation Infrastructure Projects. Environmental Commission Working Group 176. PIANC, Brussels, Belgium. 101 p.

Plitsch, E. (2017). 2016 Operations, Maintenance, and Monitoring Report for West Bay Sediment Diversion (MR-03). Coastal Protection and Restoration Authority of Louisiana, New Orleans, Louisiana.

Trepagnier, C.M. (1994). Near coastal waters pilot project: Crevasse splay portion. Final report to U.S. EPA Region VI, Grant No. X-006518-01-2. Louisiana Department of Natural Resources, Coastal Restoration Division. Baton Rouge, Louisiana. 37 p., plus appendices.

United States Army Corps of Engineers (USACE). (2001). West Bay Sediment Diversion, Plaquemines Parish, Louisiana. Final Environmental Impact Statement. October 2001. New Orleans District (MVN). 71p., plus appendices.

USACE. (2019). West Bay Diversion Survey Data and River Stage Summary. Unpublished data sourced from USACE New Orleans (MVN). NGVD88; http://rivergages.mvr.usace.army.mil

USGS. (2019). National Land Cover Database. [Accessed on August 18, 2019; https://www.usgs.gov/centers/eros/science/national-land-cover-database]

Wells, J.T., and Coleman, J.M. (1987). Wetland loss and the subdelta life cycle. *Estuarine, Coastal and Shelf Science* 25(1):111-125.

Yuill, B.T., Khadka, A.K., Pereira, J., Allison, M.A., and Meselhe, E.A. (2016). Morphodynamics of the erosional phase of crevasse-splay evolution and implications for river sediment diversion function. *Geomorphology* 259:12-29.

Utilization of Passive and Active Mechanical Dewatering Technologies to Process Navigational Dredged Material on a Small Footprint

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ABSTRACT

The Office of Maritime Resources (OMR) of the New Jersey Department of Transportation (NJDOT) is responsible for maintaining 200 nautical miles of shallow draft navigation channels statewide. The Shark River Channel and Spur and Shark River Bay, Monmouth County, New Jersey provide access for recreational and commercial marine traffic including commercial fishing. As is true along much of New Jersey's coastline, the bay's densely developed geography has made it very difficult to find a suitable location to manage dredged material. Maintenance dredging of the channels was last authorized by the U.S. Army Corps of Engineers (USACE) in 1985 and considered again in the late 1990s through the 2000s. However, the lack of an operationally sized dewatering space stalled the project for many years while local officials debated solutions. The landfall of Superstorm Sandy in the fall of 2012 caused sand, mud, and silt shoaling that severely impacted navigation and jeopardized the local economy, significantly increasing the pressure to find a solution. In January 2018, the project team completed the hydraulic dredging of 68,417 cubic yards (CY) of sediment from approximately 1.6 miles of the Shark River Channel and Spur. The project depth was 6.0 feet below mean low water, plus 1.0 foot of allowable overdredging. The dredging and dewatering operations occurred in three phases and included both passive (geobags) and active (hydrocyclones and belt filter presses) mechanical dewatering techniques. All sediment was or will be beneficially used for beach replenishment, daily landfill cover, or in a future shoreline stabilization project. This paper will review strategies used for dewatering, specific challenges addressed, costs, and how this project could be replicated for other projects in densely developed areas where traditional management methods are not viable.

Keywords: Dredging, dredged material management, mechanical dewatering, passive dewatering, beneficial use.

INTRODUCTION

The Shark River Bay is an 800-acre saltwater embayment on the Atlantic Coast of New Jersey in Monmouth County. It is almost completely surrounded by residential development and small scale commercial and recreational marine enterprises. The Shark River Channel and the Shark River Channel Spur are shallow draft navigation channels located in Belmar Borough and Neptune City, Neptune and Wall Townships. The channels provide access to the Atlantic Ocean via the Shark River Inlet. The U.S. Army Corps of Engineers (USACE) is responsible for the maintenance of

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the Shark River Inlet channel, whereas the New Jersey Department of Transportation's (NJDOT) Office of Maritime Resources (OMR) is responsible for the maintenance of the two State channels.

The Shark River Channel runs 6,400 linear feet from the Belmar Marina to Shark River Hills. The Shark River Spur channel provides an additional 2,300 linear feet along the Shark River Hills community (Figure 1). The design width of both channels is 100 feet with 3:1 side slopes. The permitted dredging template for this project was 6.0 feet below Mean Low Water (MLW) plus 1.0 foot of allowable over-depth. Surveys performed in December 2014 indicated that there were approximately 75,000 cubic yards (CY) of material in the Shark River Channel and 26,000 CY of material in the Spur Channel for a total of a little over 101,000 CY. It is of note that this compares to a total volume of 77,000 CY that was in the same channels just prior to Superstorm Sandy in the fall of 2012. Consequently, the Shark River channels project was considered a high priority in New Jersey's Superstorm Sandy recovery program.

Most dredging in the Atlantic shore region of New Jersey is performed via hydraulic cutterhead pipeline dredge and dewatered in confined disposal facilities (CDFs). Historically, a CDF in Wall Township had been used for maintenance dredging of these channels; however, the site was no longer available. In the 1990s, the Borough of Belmar had successfully performed maintenance dredging of their marina with mechanical equipment and dewatered the material in a gravel parking lot on their site. The small volume (less than 10,000 CY) of dredging required a very small footprint to dewater - less than an acre. However, the restoration of the State channels would require the dewatering and placement of over 100,000 CY of material. While the Federal inlet channel is mostly sand and can be placed in a nearshore berm for beach replenishment, the State channels are typically mixed sand and silt which are not suitable for beach placement. Several alternatives for dredged material management had been explored over the years, including ocean

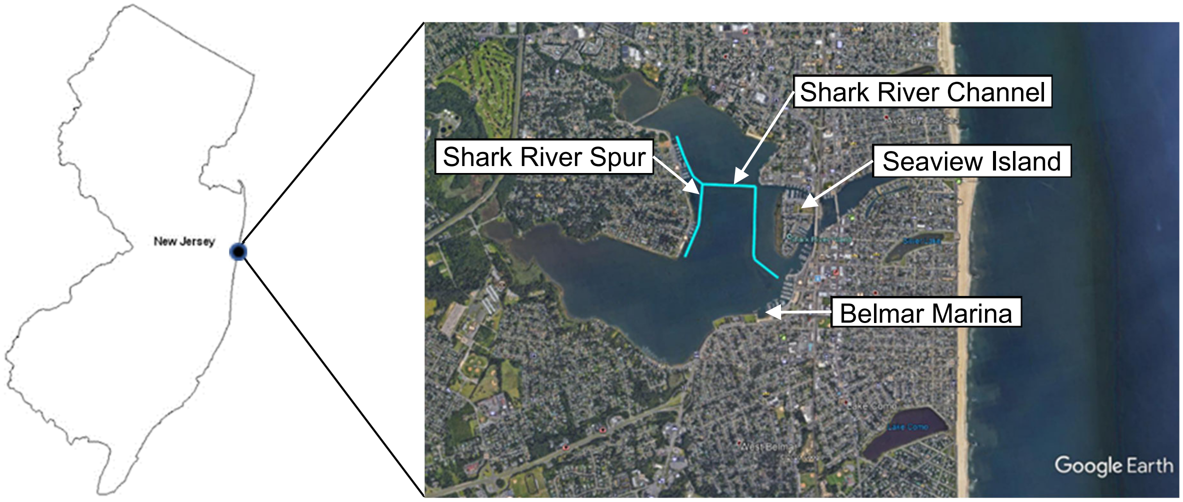

Figure 1. Site location of dredging project, Shark River Bay, Monmouth County, New Jersey.

disposal and upland placement following processing with Portland cement, but these were either prohibitively expensive, logistically impossible, or environmentally unacceptable. Consequently, maintenance dredging of the channels had not been performed since 1985 and navigation was becoming difficult, if not dangerous. The additional shoaling from Superstorm Sandy only made matters worse.

As the need to find solutions became critical, the NJDOT OMR took a hard look at alternative dredged material management options. No changes had occurred in the availability of the CDF, nor was ocean disposal any more practicable. The State of New Jersey has encouraged the use of dredged material in a variety of habitat restoration projects (Douglas *et al*., 2019); however, there were no potential projects in the area that would require the necessary volume. This left some type of upland processing and off-site placement as the only viable option. In general practice, there are three main categories of dewatering technology available: mechanical (both active and passive), chemical, and biological (Howard, 2019). Chemical and biological technologies are typically used in combination with other techniques or objectives or are used in the maintenance of disposal areas. Mechanical dewatering, using a combination of active and passive techniques, has been used successfully in both mechanical and hydraulic dredging operations of both clean and contaminated sediments (Averett and Estes, 2011). Given the time and equipment available, it was decided that either active or passive dewatering technologies had the potential to provide acceptable results at a reasonable cost.

The next challenge was finding a suitable site in the highly developed Shark River area. After evaluating several publicly owned sites with access to the waterfront, only two locations were deemed viable: a 1.3-acre gravel parking lot located in the Belmar Marina (905 NJ-35, Borough of Belmar, New Jersey) and a 2.5-acre public park located at Seaview Island (417 Seaview Circle, Township of Neptune, New Jersey). Further complicating matters, the dredging season in New Jersey is notoriously short due to permit restrictions and the long recreational boating season. All work would need to be conducted in the fall of any given year. While the placement of processed dredged material can often be problematic, Monmouth County was able and willing to accept the dewatered dredged material for landfill cover at their nearby waste recovery facility.

Due to the constraints of the project, it was decided that rather than specify a treatment train, OMR would evaluate proposals from contractors in a two-step process. A team of technical experts would evaluate the proposals and select the least cost option from among the acceptable proposals. Three proposals were received. All were considered technically acceptable. The contract was awarded to Mobile Dredging and Video Pipe of Chester, Pennsylvania on October 26, 2015.

METHODOLOGY

Sediment Characterization

A total of 14 vibracore samples were taken across the project footprint to characterize the sediments. These cores were combined into five composite samples for analysis. Semi-volatiles, pesticides, polychlorinated biphenyls (PCBs), metals, grain size, and total organic carbon were analyzed according to New Jersey Department of Environmental Protection (NJDEP) requirements using U.S. Environmental Protection Agency (USEPA) standard methods. The results of these analyses are presented in Table 1.

Table 1. Summary characterization of sediment dredged from Shark River channels.

Constituent	Composite A	Composite B	Composite C	Composite D	Composite E
% Sand	62.8	24.9	35.6	4.2	11.5
% Silt	23.7	60.8	48.5	76.4	68.6
% Clay	13.5	14.3	15.9	19.4	19.9
TOC (mg/kg)	12752	27511	23867	38509	35087
Benzo(a)pyrene (μg/kg)	370	<180	<180	<180	<180

The dredged material was a mixture of sand, silt, and clay, typical of maintenance dredged material in the area. The bulk sediment chemistry for four of the five composites were all below New Jersey Residential cleanup standards, meaning that it was considered suitable by the permitting agencies for most beneficial uses. Only a slight exceedance of the polycyclic aromatic hydrocarbon (PAH) benzo(a)pyrene was detected in one composite sample (New Jersey Residential criteria is 200 micrograms per kilogram [μg/kg]). This compound and level is typical for areas in the New Jersey coast with substantial recreational boat traffic. Given that the beneficial use identified was landfill daily cover, this was not considered a problem.

Treatment Bench Testing

To determine the proper geotextile to be used in the passive system, as well as to parameterize the mechanical dewatering equipment, a bench scale "bag" test was conducted on a sample of dredged material from the site. Results were used to set the polymer type and dosage and indicated that the treatment system would be able to achieve permit requirements (Table 2), although there was some concern about suspended solids. However, due to the small site, there was inadequate space for a final polishing tank large enough to be useful. It was decided that a turbidity curtain would be installed at the discharge point to capture any remaining solids.

Permit Conditions

Two of the primary constraints on the project from the beginning were the permit and site conditions imposed. In New Jersey, both State (NJDEP) and Federal (USACE) permits are

Table 2. Results of initial bench bag filter test.

Contaminant of Concern	Ambient Background	Bag Effluent
Total Suspended Solids mg/L	60	195
Hg (total/dissolved) mg/L	<0.00022/<0.001	<0.00022/<0.001
Cu (total/dissolved) mg/L	0.14/0.13	0.12/0.079
As (total/dissolved) mg/L	<0.015/<0.01	0.035/0.035
Total PCB (aroclors) μg/L	<0.5	<0.5
Total DDT μg/L	<0.1	<0.1
Chlordane μg/L	<2.0	<2.0

required for every dredging project. Both the State and Federal permits prohibited dredging from January 1 to June 30 of any given year to protect winter flounder and anadromous fish. In addition, the effluent was required to be monitored regularly for total and dissolved metals, pesticides, and PCB congeners in order to comply with a Total Maximum Daily Load agreement. A turbidity curtain was required to be installed at the discharge point to the bay to retain any solids that might be discharged during operations. Should effluent concentrations for any constituent exceed ambient background concentrations, adaptive management procedures up to and including cessation of operations were required. Although not a permit condition, the local community discouraged dredging operations between Memorial Day and Labor Day due to heavy recreational boat traffic. Channel closures to facilitate efficient dredging operations would not be allowed and move-on-demand procedures were required.

Dredging

The dredge plant used for the project was a Barracuda 12-inch by 10-inch cutter-suction dredge (12-inch intake pipe diameter, 10-inch discharge pipe diameter) with a draft of 32 inches (Figure 2). The rear spuds were 29 feet tall and the bow spud was 31 feet. The dredge was equipped with Dredge Pack®, two global positioning system (GPS) antennas, and an inclinometer. To verify stage, two tideboards were used; one mounted to a fixed structure near the dewatering sites and the other mounted on the dredge. Periodically, the shore crew read the tide board and communicated the reading via radio to the dredge to double-check the accuracy of the tide board located on the dredge.

Between 4,000 and 7,000 feet of 10-inch high-density polyethylene (HDPE) floating pipeline was used to convey the dredged material to the dewatering sites. In areas where the floating pipeline intersected a navigable channel, the pipeline was submerged and secured to the bottom of the

Figure 2. Barracuda 12-inch cutterhead pipeline dredge working in Shark River Bay.

channel using cement blocks and anchors. The floating portions of the pipeline were signed, marked, and lit according to U.S. Coast Guard (USCG) regulations.

Processing

Due to site availability, site size, and schedule constraints caused by environmental windows, the project was eventually broken into three phases. Both Phases I and II were planned to take place on the Belmar Marina parking lot site. The contracts for the project were not finalized until late October of year one, leaving insufficient time to mobilize, install, and test the originally proposed mechanical dewatering equipment. Geotextile bags, on the other hand, could be installed relatively quickly, allowing for several weeks of dredging in year one (Phase I) before the permit window closed on December 31. Once the bags were filled, the material would continue to dewater through the winter months and could be removed in the spring prior to the start of the next dredging season on June 30. During the second season (Phase II), it was believed there would be sufficient time to prepare the site, install and test the mechanical dewatering equipment, as well as complete the dredging. However, due to a government shutdown of transportation projects statewide, the mechanical dewatering did not begin until September 7, preventing the project from being completed before the start of the environmental window. The Belmar Marina parking lot was not available for a third season; but a second site, on nearby Seaview Island, was available. For a variety of reasons including schedule, cost, and proximity to residents, it was decided to use geosynthetic bags to dewater the remaining material in the channels during Phase III.

Passive Dewatering System

A system comprised of TenCate GT500 geosynthetic bags (TenCate Geosynthetics Americas, Pendergrass, Georgia) were utilized for passive dewatering in Phases I and III. An effluent containment area was created by installing a geotextile fabric surrounded by hay bales. A plastic liner was then placed over the geotextile fabric and the hay bales. Rebar stakes were driven through the hay bales to anchor the system in place.

Both sites were graded to ensure positive drainage to one corner of the containment area. A sump hole was constructed at this low point to allow for the placement of a pump which was used to discharge water back to the bay. As required by the permit, the discharge point was surrounded with turbidity curtain to retain any solids that might be lost during operation.

For Phase I, seven 40-foot by 100-foot geotubes were arranged in a single layer within the containment area and connected by a manifold. A pump and a polymer tank were installed in the northwest corner of the site. (Figure 3). The polymer used was SNF Polymer 331 (SNF Holding Company, Riceboro, Georgia). A dosage rate up to a maximum of four pounds per dry ton was used depending on the drainage efficiency or appearance of the discharge.

For Phase III, 18 geosynthetic tubes of various sizes were arranged in three layers with 10 tubes in the first layer, seven tubes in the second layer and one tube in the third layer. The tubes were sized to maximize the available footprint; ranging in width from 60 to 80 feet and in length from 72 to 256 feet. A polymer tank and pump were installed in the southeast corner of the site. A 10-inch non-nuclear density meter was installed on the system's intake pipeline to monitor the solids

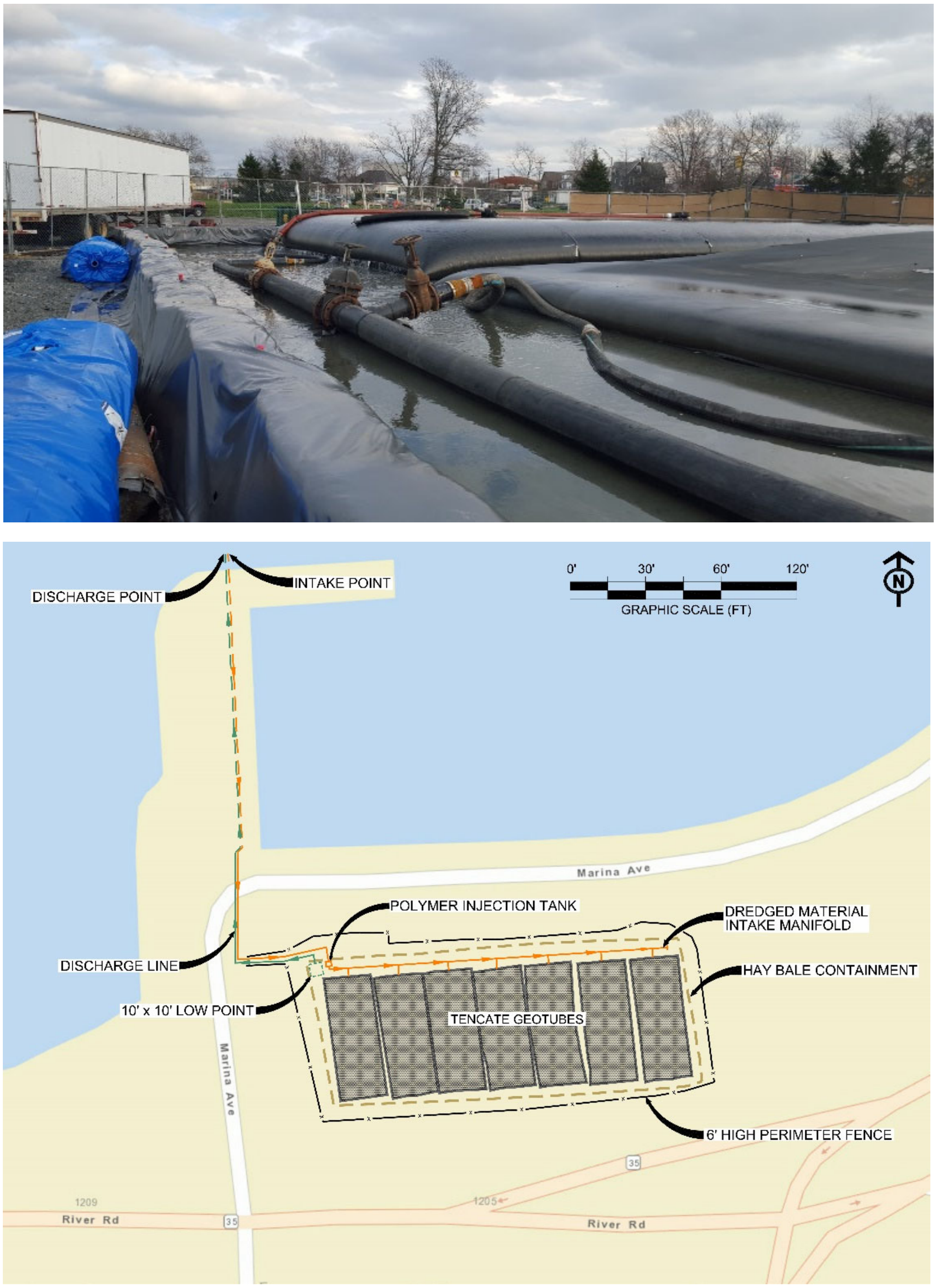

Figure 3. Site layout and photograph of Phase I passive dewatering system

content of the dredge slurry and allow for adjustments in polymer dosage (Figure 4). Polymer (SNF Polymer #3310) dosage rate was adjusted as in Phase I up to a maximum of 4.0 pounds per dry ton. Polymer dosage was doubled and allowed to age for 45 minutes prior to addition at the end of October in order to improve the performance of the system. The discharge point for Phase III was under the Route 35 bridge. As in Phase I, the discharge point was surrounded by a turbidity curtain to retain any solids that might be lost during operation.

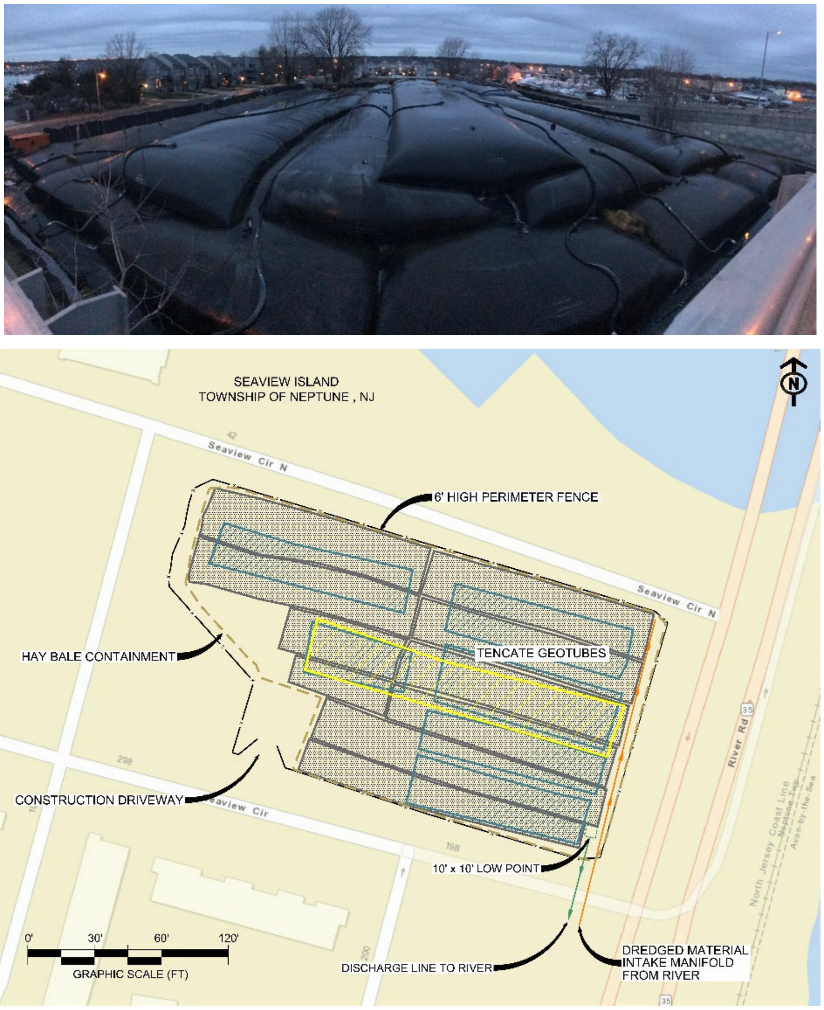

Figure 4. Site layout and photograph of Phase III passive dewatering system

Once the geosynthetic tubes were filled and dredging operations ceased, the tubes were left to dewater in place. The sump was observed daily until discharge ceased approximately eight weeks later. The length of this time period was impacted by weather conditions such as freezing temperatures, and significant snow and rainfall. Material condition was observed through portals on the top of each tube. Once the material was considered suitably dewatered, the tubes were cut open and the material loaded into trucks for transport to the Monmouth County Reclamation Center (MCRC) landfill.

Active Dewatering System

Following the removal of the dewatered sediment from Phase I, the entire parking lot was cleared and paved to ensure a stable and level surface for the equipment and to facilitate storage and transportation of the processed sediment. An active mechanical dewatering system comprised of hydrocyclones and belt filter presses was used during Phase II of the project (Figure 5). The dredged material slurry entered two hydrocyclone tanks (Tri-flow #1 and Tri-flow #2), which

Figure 5. Photograph and equipment layout for active dewatering system used in Phase II.

separated the debris and coarse material (sand) from the slurry using shaker screens. Sand and debris were removed to a stockpile area. The effluent from the tanks, now consisting of water and fine material (silt and clay), was pumped from the Tri-flow tanks into a thickener tank. As the thickener tank filled, the fine material settled to the bottom of the tank. The overlying clean water was then pumped back to the Bay at the discharge point, using the same pipe as was used in Phase I. As with the passive system, the discharge point was surrounded with a turbidity curtain to contain any solids that might be lost during operation.

The fine material that collected at the bottom of the thickener tank was pumped into the mixing tank where polymer (SNF polymer #3310) was added. This tank kept the articles in suspension before being pumped to the belt presses. The belt presses processed the fine material into the form of dry layer cake (Figure 6). The polymer mix ratio was adjusted as needed to ensure that the desired filter cake was achieved up to a maximum of two pounds per dry ton. Throughout the first few weeks of Phase II dredging operations, belt presses were added and replaced as needed. The

Figure 6. Filter cake from belt filter presses used in Phase II.

project started with five belt presses, but as many as eight large belt presses were used to provide redundancy and maintain production.

The filtrate from the belt presses was then pumped to a clarifier tank where additional time was allowed for solids not processed by the system to settle out prior to discharge. As fine material accumulated in the clarifier, the sediment was recovered and pumped back to the mixing tank to be processed by the belt presses.

The low point of the dewatering site was located behind the belt presses. If at any time the collection pans under the belt presses overflowed, the water pooled in the low point where it was pumped into the thickener tank via a small sump pump. Material from the hydrocyclones and belt filter presses was allowed to accumulate on the paved apron and periodically removed using a bucket loader. The material was segregated by type in the stockpile area prior to loading and transport to the landfill. Transport operations were essentially concurrent with processing for the duration of Phase II.

Sampling and Testing

During all three Phases, water samples were taken periodically to evaluate system performance and to comply with permit conditions. During each event, samples were taken from the effluent stream and at the discharge point to the Bay, inside the turbidity curtain. An ambient sample was taken from the crew boat, in the general location of the dredge plant, but outside of the work area to avoid the plume of resuspended dredged material from the operation. Samples were analyzed by a New Jersey certified laboratory for total suspended solids, total and dissolved metals, pesticides, and PCB congeners (due to the short processing period, congener sampling was not performed during Phase I). Unfortunately, these results often took considerable time to obtain, making the data difficult to use for adaptive management purposes. Consequently, adjustments to the system were made based on visual observation of the effluent plume at the point of discharge.

Beneficial Use

Most of the dredged material, once dewatered, was placed into triaxle trucks for transport to the MCRC, located about 9.0 miles away in Tinton Falls, New Jersey, where it was utilized as daily landfill cover. The scales located at MCRC were used to track the tonnage of dredged material being delivered. A small amount of sandy material from Phase II was used to replenish the nearby public beach at Memorial Park in Neptune City.

RESULTS

Phase I Dredging and Dewatering

A total of 4,011 CY of sediment was removed from the channels during Phase I over 15 dredging days and placed into geotextile bags. Once filled, the geosynthetic bags were left to dewater for 171 days. Starting on June 7, the bags were cut open, and the material was excavated. A total of 4,830 tons of material was transported to MCRC in 182 trucks over seven days (Table 3).

Phase II Dredging and Dewatering

A total of 43,798 CY of material was removed from the channels during Phase II over 69 dredging days and dewatered using the active mechanical dewatering plant. A total of 46,888 tons of material was transported to MCRC in 1,816 trucks over the course of 78 days (Table 3). Concurrent with this operation, an additional 25 truckloads, carrying approximately 658 tons of sand were taken to the Memorial Park public beach in Neptune City and graded into place for replenishment. The recovered debris was trucked to MCRC and disposed of as solid waste.

Phase III Dredging and Dewatering

A total of 20,608 CY of sediment was removed from the channels during Phase III over 49 dredging days and placed into geotextile bags. Once filled, the bags were left to dewater for 260 days. Starting on June 18, the bags were cut open, and the material was excavated. A total of 12,048 tons of material was transported to MCRC in 472 trucks over 18 days (Table 3).

Approximately 11,000 CY of dredged material was stockpiled on the eastern half of the dewatering site for Neptune Township's future use. The stockpile was graded to 5.0 to 6.0 feet high with a gradual slope and 3:1 side slopes. A total of 142 loads of topsoil was applied to the entire site and a Tall Fescue Grass Seed Blend was applied to prevent erosion while awaiting beneficial use in a future shoreline restoration project.

Table 3. Project Detail Summary

	Phase I	**Phase II**	**Phase III**
Mobilization Start Date	11/30/2015	6/16/2016	7/28/2017
Dredging Start Date	12/18/2015	9/7/2016	9/21/2017
Transport End Date	6/7/2016	1/4/2017	7/13/2018
Phase End Date	6/15/2016	2/2/2017	11/2/2018
Sediment Volume (cy)	4,011	43,798	20,608
Dredging Days	15	69	49
Process Days	171	69	260
Transport Days	7	78	18

Chemical Monitoring

Due to historical water quality problems in the shallow system of Shark River Bay, the NJDEP had established a Total Maximum Daily Load program for the entire bay. This meant that the project could not be a significant contributor of several parameters of concern. Monitoring was conducted by taking samples of the effluent, at the point of discharge inside the turbidity curtain, and of the ambient bay water. While total suspended solids ranged widely from 15 to 713 milligrams per liter (mg/L) (Figure 7), and Total PCB congeners ranged from 24.5 to 74,200 picograms per liter (pg/L) in the effluent (Figure 8), overall the concentrations of both parameters at the point of discharge were very similar to or lower than background. Concentrations of other parameters of interest, such as copper (Cu), arsenic (As), mercury (Hg), Dichlorodiphenyltrichloroethane (DDT), and chlordane, were typically at or below detection.

DISCUSSION

Dredging

A total of 68,417 CY of sediment was dredged from the channels using a hydraulic cutterhead pipeline dredge with minimal over-dredging for a period of 222 calendar days (133 dredging days) over three dredging seasons, averaging 514 CY per dredging day. This is typical of maintenance dredging projects in coastal New Jersey, indicating that the treatment systems were not an impediment to efficient dredging operations. A total of 52,492 CY of sediment was removed from the Shark River channel and 15,925 CY was removed from the Shark River Spur channel. Both channels achieved the design depth of at least 6.0 feet and the design width of 100 feet.

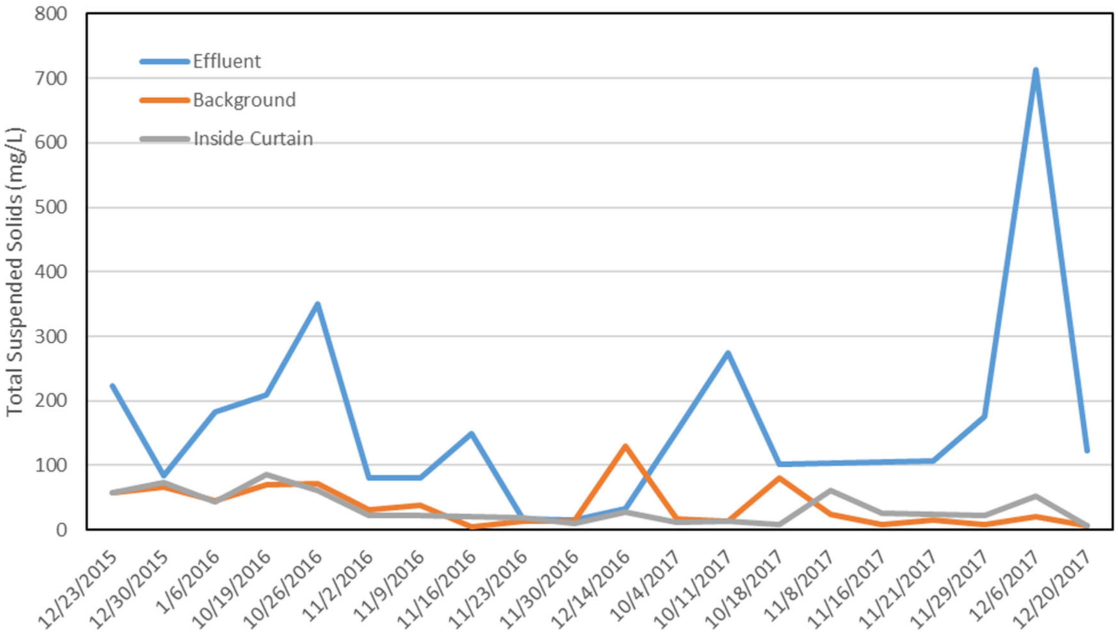

Figure 7. Summary of Total Suspended Solids in discharge from dewatering system as compared to site background and inside the discharge curtain.

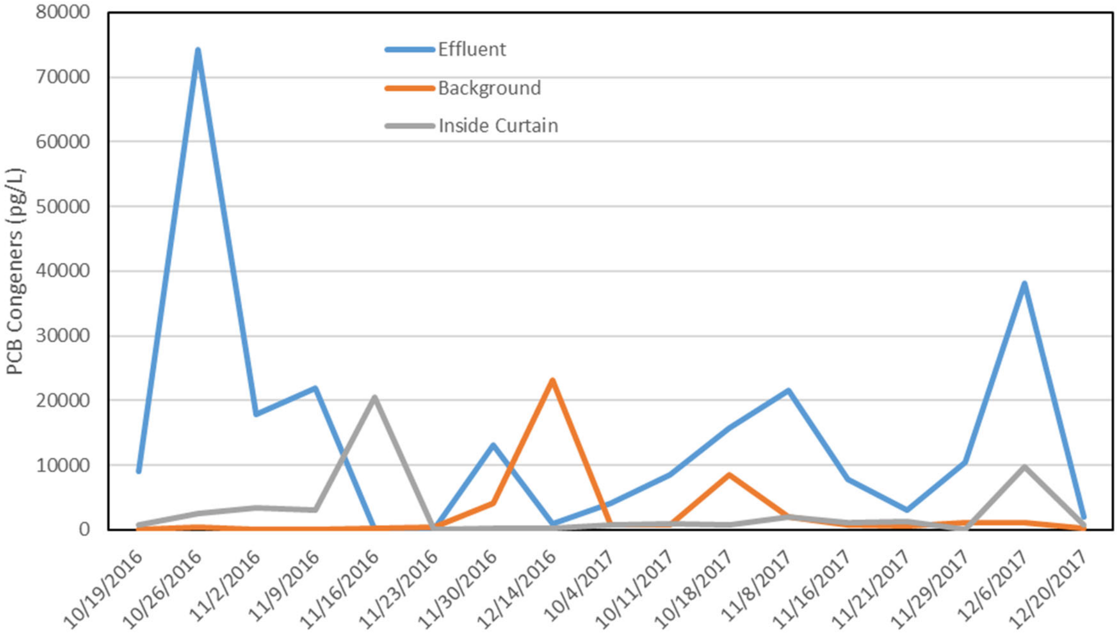

Figure 8. Summary of Total PCB Congeners in discharge from dewatering system as compared to project background and at the point of discharge during Phase II and III.

Processing

A total of 24,618 CY of material was dewatered and transported for beneficial use using TenCate geotextile bags over a period of 456 days (two phases). The time for processing material in this manner is divided into three phases: the loading of the geosynthetic bags, the dewatering period, and the unloading of the bags followed by transport. A total of 43,798 CY of material was dewatered using active mechanical dewatering equipment and transported for beneficial use over a period of 105 days. Transport of dewatered material was essentially concurrent with processing.

The typical rate of dredging for small hydraulic cutterhead dredges in coastal New Jersey, assuming an efficiency of 50 percent, is about 500 CY per day. During this project, dredging ranged from 267 CY per day to 421 CY per day when using geosynthetic tubes for processing, and 635 CY per day when using the belt filter presses for processing. The time required for passive dewatering did not impact the dredge plant in this case but could cause a problem if there was insufficient space for more or larger bags to accommodate a longer dredging period or faster dredge rate, or if the space was only available for a limited time.

Beneficial Use

A total of 63,767 tons of dewatered dredged material was taken to the Monmouth County Reclamation Center for use as daily cover and a total of 658 tons of sand was taken to the beach at Memorial Park in Neptune City. In addition, approximately 11,000 CY of dewatered dredged material was left on Seaview Island for future use by Neptune Township.

Discharge Quality

One of the challenges associated with using mechanical dewatering during a navigational dredging project is being able to synchronize the dredging and processing. On a small footprint, not only must the processing system be sized to the site rather than the maximum production rate of the dredge, there is no room for surge storage to allow for adjustments in the treatment train. Thickening of the sediment to facilitate flocculation and retention of solids is highly dependent on pH, temperature, percentage solids in the dredge slurry, organic matter (TOC), and grain size (Howard, 2019), all of which are notoriously variable in navigational dredging. This required the operator to continuously monitor the discharge quality and make adjustments on the fly, and these adjustments took time to take effect. Changes to the process treatment train included increasing the size of process tanks, reprocessing some portion of the effluent, changes in polymer dosage, or diverting material through a longer or shorter portion of the train. Consequently, the discharge was not consistently free of solids. It should be noted that additional sediment sampling in advance of dredging, while not required for permitting, may have assisted the contractor in planning for this variability. In this case, a turbidity curtain was deployed at the discharge to serve as a final clarifier and to capture any unretained solids during system adjustments. A small dredge was deployed to remove any solids that built up inside the turbidity curtained area of the marina; however, the amount of dredging required here was very small, less than 1200 CY, and this volume likely includes material that was already present in the berth.

Since the material contained relatively low levels of contamination, the use of the turbidity curtain as a clarifier was seen as a necessary sacrifice to allowing the dredging project to move forward efficiently. With more contaminated sediment, this may not be a viable option. In this case, despite effluent quality being variable, samples of the water just inside the turbidity curtain revealed that there was likely no increase in concentrations of contaminants of concern relative to ambient concentrations in the bay. In fact, ambient bay concentrations were often higher than those near the discharge point for TSS and PCB congers (Figures 7 and 8). While this does mean that water quality in this shallow bay continues to suffer from ongoing sources of contamination (primarily stormwater), there is no evidence that the project impacted water quality.

Weather Delays

Considerable difficulty was experienced with both types of equipment due to cold weather. While the permit restrictions prohibited in water work after December 31 (a nine-day work extension was granted in Phase I), work was significantly curtailed in all three phases as the weather became colder. Freezing conditions resulted in mechanical difficulties and reduced the drainage efficiency of the geosynthetic tubes. Cold weather has been shown in other projects to affect project schedules and dewatering efficiency (Howard, 2019).

Small Footprint

Working on the small footprints of the two sites, as well as scheduling constraints, proved to be the greatest challenges faced by the project team. With limited sites available, and other uses being prevented during site occupancy, there was considerable pressure to complete the project as rapidly as possible. As it was, both sites had to be utilized despite the additional site preparation time and alternating techniques that were required. Proximity to local residences and working within an operating marina also required sensitivity and flexibility on the part of the contractor. In addition to noise and light concerns, limiting night-time operations; additional public scrutiny meant strict attention to the appearance of the site and maintenance of site screening. Truck traffic was carefully monitored and street cleaning was required to keep sediment off the roadways.

Operationally, there was limited room for keeping redundant equipment or moving components of these complex treatment systems. There was also no room for additional holding space of effluent to allow for reprocessing should the system not achieve performance specifications or permit requirements. The large amount of sediment processed in Phase III required that geosynthetic tubes be stacked. While this is considered an appropriate way to increase field capacity according to the manufacturer, it does increase on-site logistical and safety concerns as well as increasing the difficulty in monitoring material status and when removing the sediment once dewatered.

Schedule

The project duration of slightly more than three years is not indicative of the number of actual dredging/processing days due to the highly restrictive work windows allowed by the dredging permit. Dredging was prohibited by permit between January 1 and June 30. In addition, the high recreational boating traffic in the Shark River Bay from Memorial Day to Labor Day makes maintenance operations challenging, if not dangerous. Consequently, dredging operations were limited to the last four months of the year. The actual number of dredging days for the entire project was 133; the number of dewatering days was 509, and the number of days for transporting material was 103. For Phase I and III, the dredging and dewatering initially occurred simultaneously, but dewatering continued for a considerable period after dredging ceased. For Phase II, dewatering and transportation were concurrent with dredging. Taking all of this into consideration, the dredging, processing, and placement of 68,417 CY took a total of 561 days over the course of three years between December of 2015 and November of 2018.

Cost

The cost of the project was relatively high for shallow draft navigation, with a combined per CY price of $107.61. The unit cost for Phase I was $113.00, for Phase II was $98.00, and for Phase III was $127.00. This does not include the cost of transportation of the material to the beneficial use site, which was provided courtesy of Monmouth County in exchange for the material. However, the cost does reflect the need for three mobilizations. Although Phase I and Phase II utilized the same footprint, the treatment techniques were different and required completely different equipment and use of the site.

SUMMARY

- Both active and passive mechanical dewatering techniques can be utilized in a navigational dredging contract on a small footprint in close proximity to residences.
- Episodic reductions in dredge efficiency should be anticipated, but overall project efficiencies were not significantly impacted.
- Experience and familiarization with the equipment and treatment is essential.
- In preparation for adjustments in treatment train, redundant equipment may be stored off-site.
- Additional sampling of the sediment beyond what is required by permitting agencies may help to prepare for changes in sediment characteristics over the course of the project.
- Turbidity curtains can be used to increase the footprint of the treatment train, provided the material being dredged is essentially free of contaminants.
- Weather delays can be significant
- Careful attention to housekeeping, noise, and truck traffic management are required.

REFERENCES

Averett, DE and TJ Estes. 2011. “Physical separation process demonstrations,” ERDC TN-DOER-T10. Dredging Operations and Environmental Research Program, US Army Corps of Engineers, Vicksburg, MS.

Douglas, WS, MJ Marano, S Flanigan, D Fanz, and S Mars. 2019. “Ensuring sustainable marine transportation by beneficially using dredged material to support marsh ecosystems in coastal New Jersey” *Proceedings of the Western Dredging Association Dredging Summit & Expo ’19, Chicago, IL, USA*, June 4-7, 2019.

Howard, E. 2019. “Stabilization of dredged materials in Ohio: an investigation of mechanical, chemical and biological dewatering techniques.” University of Akron, Akron, OH.

2014 Egmont Key Beneficial Use of High Fines Material Using Traditional Versus Cross Shore Swash Zone Placement

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ABSTRACT

The periodic maintenance dredging of the Tampa Harbor Entrance Channel commenced during the fall of 2014 through the winter season with beach placement on Egmont Key National Wildlife Refuge and State Park. Due to severe erosion on Egmont Key, the State of Florida Department of Environmental Protection (FDEP) made an exception to Florida Administrative Code (FAC) 62B-41.007 (2)(j)(k) otherwise known as the "Sand Rule" criteria for beach placement of a maximum allowance of an average of 10% fines (defined as sediment passing the 0.063 mm sieve) for maintenance dredging material. Geotechnical borings collected from the shoaled materials in the channel indicate an average composite "fines" content of 20.7% within the dredge prism. The constructed project involved beach placement of the dredged material using the traditional trapezoidal placement method and a unique placement method referred to as "cross shore swash zone (CSSZ) placement". The CSSZ placement is constructed by discharging material directly into the swash zone of the beach until a salient forms and then extending the discharge line perpendicular offshore until a "point" feature is created in the shoreline. Once placed, the CSSZ geomorphic point feature is highly erosive and functions as a feeder beach composed of sediments that are well sorted, or "washed" of their finer fraction of sediments. The traditional and CSSZ placement operations occurred approximately 0.8 km (0.5 mi) apart on Egmont Key and allowed for a comparison of the two placement methodologies in terms of: geomorphologic evolution, compaction, volumetric loss or bulking, anecdotal turtle nesting density, initial coarsening of the placement material (fines loss), initial and chronic turbidity and potential best management practices (BMP) to minimize beach footprint impacts as well as reduce construction cost.

Keywords: fines, sand rule, dredged material disposal, cross shore swash zone placement, beach nourishment.

INTRODUCTION

The beneficial use of dredged material has become an increasingly important consideration when performing navigational dredging. Many coastal areas are eroding and could benefit from placement of sediment removed from adjacent dredging projects. Often, the construction cost of placing material beneficially results in cost savings to a project; however environmental restrictions, coordination, and schedule creep can inhibit these beneficial projects from being

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realized. There are numerous environmental considerations related to beneficial placement of sediment in coastal areas, for example, turbidity, sedimentation, shoreline escarpments, ponding on the beach berm, cementation, or sediment color changes. A significant increase in turbidity may result in light attenuation or burial of benthic resources (Erftemeijerab et al., 2012). Direct beach placement methodologies can lead to short-term geomorphic changes that impact sea turtle nesting and other animals (Crain et al., 1996). Sediment color can alter the temperature of the beach, impacting nesting sea turtle sex ratios or resulting in non-viable clutches (Milton et al, 1997). To mitigate some of the potential impacts from coastal beach placement, the FDEP puts criteria established in the Florida Administrative Code (FAC) into coastal beach placement project permits (Joint Coastal Permits (JCP)).

From 19 November 2013 through early March 2014, under contract for the US Army Corps of Engineers (USACE), Great Lakes Dredge and Dock (GLDD) dredged the Tampa Harbor Entrance Channel and placed the dredged sediments on the highly eroded Egmont Key National Wildlife Refuge. Due to the severe erosion on the westward Gulf of Mexico facing beaches of Egmont Key and the fact that it is a State Park, an allowance for material exceeding the FAC 62B-41.007 (2)(j)(k), also known as the “Sand Rule” criteria of a maximum of 10% fines (defined as sediment passing the 0.063 mm sieve) for maintenance dredging material was made. The fines content of the navigation sediments ranged from 0.5-80%, with a composite average of 20.7% passing the 0.063 mm (No. 230 standard sieve). This fines content exceedance has been accepted at Egmont Key for previous maintenance dredging projects, in 2000, 2006 and 2011.

The constructed project involved beach placement of material using a traditional trapezoidal placement template method and a unique placement method referred to as “cross shore swash zone placement” (CSSZ). The traditional trapezoidal placement is characterized by an approximately 60 m (200 feet) wide and 1.2 m (4 feet) high flat berm, with tapered end transitions to unfilled portions of the beach. The CSSZ placement method involves discharging material directly into the swash zone of the beach until a salient begins to form and then extending the discharge line offshore until a “point” feature has been created in the shoreline. For this Tampa Harbor maintenance dredging event with placement on Egmont Key, the traditional trapezoidal placement and the CSSZ placement operations occurred with a 0.5-mile separation between their respective nearest placement extents allowing for a comparison of the methodologies with minimal interaction (Figure 1), (Maglio, et.al. 2015).

The Tampa Harbor maintenance dredging project was the first project to utilize the CSSZ method in Florida since a maintenance dredging event in 1972 at Mayport, Florida (Figure 2). CSSZ placement has the potential to be less costly than current beach placement methods and aligned with the approaches of “strategic placement.”

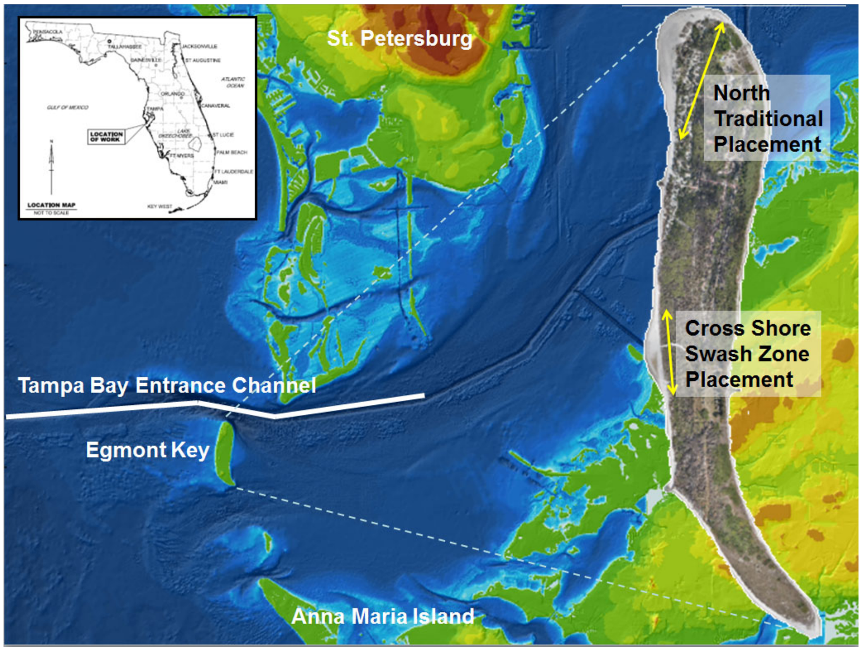

Figure 1. Location map of Egmont Key, FL and placement areas (bathymetry image from, Tyler et al. 2007).

Figure 2. Cross Shore Swash Zone placement in Mayport, FL in 1972.

Given the unique nature of the CSSZ placement and high fines content, there was significant interest in monitoring the CSSZ placement on Egmont Key by the USACE, resource agencies (U.S. Fish and Wildlife Service (USFWS), FDEP, Florida Fish and Wildlife Conservation Commission (FWCC)), and academia (University of South Florida (USF)). The potential ecological impacts resulting from the winnowing of the fines during and post placement is a significant deterrent preventing these types of material being used on a regular basis. The objective of this study was to quantify and bracket the temporary construction and longer-term ecological impacts within the natural littoral system. As a result of this collaboration and intertwined objectives, the following types of data were collected and are presented and discussed in this paper. Geomorphic changes: USF monthly beach profile surveys, USACE Jacksonville District Unmanned Aerial Vehicle (UAV) orthorectified imagery collection.

Dredging and placement processes: in-situ vibracore/sub-sampling of the navigation sediments, pre- and post-beach berm/nearshore sediment sampling, beach slurry sampling, berm compaction measurements using cone penetrometer, Munsell color, volumetric losses, and grain size analysis.

Turbidity and Light Attenuation: in water data collection of existing background conditions, long term monitoring, initial and chronic turbidity measurements using numerous YSI turbidimeters that measure nephelometric turbidity units, light sensors, and photosynthetically active radiation (PAR) sensors.

Photography: UAV aerials, fixed web enabled camera systems.

DREDGING OPERATIONS

The dredging project was conducted using two GLDD hopper dredges, including the Dodge Island (November and December 2014) and the Padre Island (January through March 2015). Both hopper dredges used bow pump-out capabilities to send material to the placement areas using a pipeline as shown in Figure 3.

Prior to the commencement of dredging, the GLDD and USACE noted the presence of naturally occurring hydrogen sulfide gas accumulated in the dredge sediments from seepage from the underlying strata in many of the dredging areas. Because hydrogen sulfide gas is heavier than air, it can collect in the dredge's hopper and render a person unconscious, creating a problem while walking on a narrow gangway in a dredging vessel in the open ocean. This was quickly recognized as a health and safety issue and the order of work was adjusted to best address the concerns. The dredges used on this project underwent several retrofits including a positive pressure air system for the house and a new air filtration system.

Figure 3. The Dodge Island, a GLDD hopper dredge, pumping out material to Egmont Key, FL on 16 December 2014.

Figure 4. Traditional beach placement at northern end of Egmont Key, FL, 26 December 2014. Photo courtesy of GLDD.

The traditional trapezoidal fill template at the northern end of Egmont Key used a Y-valve and two placement cells with longitudinal dikes with intermediate spurs to increase settlement and minimize material lost to the active swash zone as shown in Figure 4. The use of this placement design with a Y-valve with two cells allows for one side to be closed down for extending outfall pipes without having to stop discharge. Placement of dredged material occurred at the north end of the island from 19 November 2013 to 28 December 2014 and then from 21 January to 5 February 2015.

The CSSZ fill was constructed by running a single pipeline down the beach to the discharge point. The discharge pipe was directed seaward and the contractor continuously pumped material into the nearshore creating a salient. Depending on the production rate, wave energy, and offshore slope, the contractor was able to pump for days or weeks without having to move the discharge location. The shore perpendicular discharge method, in the proper circumstances, will build a feeder beach that allows for a smaller direct placement footprint on an existing beach while inputting a similar quantity of material into a littoral system. The CSSZ placement may provide a reduction in construction costs as compared to direct beach placement projects due to less manpower and equipment required on the beach to support the placement operations, allowing less consumption of fuel and overall resources. The CSSZ placement occurred from 9 February to 6 March 2015. Figure 5 shows the completed northern beach placement, as well as the CSSZ placement being constructed.

DATA COLLECTION AND RESULTS SUMMARY

Geotechnical Core Borings

In April 2013, the USACE Multipurpose Vessel Snell (M/V Snell) collected thirty-nine 1.8-meter (6 feet) length, 10 cm (4 inch) diameter cores from the navigation Channel dredge template. On April 5, 2013 the cores were delivered to University of South Florida Coastal Research Laboratory

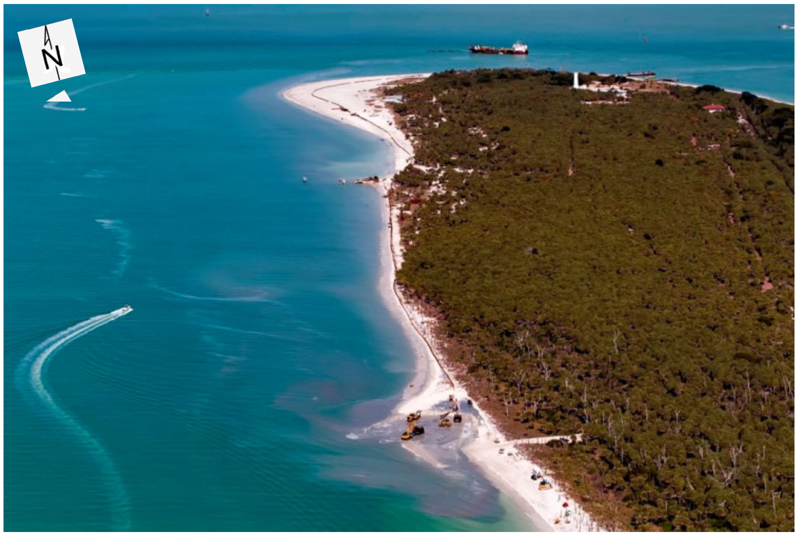

Figure 5. Shore based pipeline and CSSZ placement in center of Egmont Key, FL, 21 February 2015. Photo courtesy of GLDD.

(USF-CRL) for processing and analysis. The cores were split lengthwise using a circular saw with one half being archived and the other half used for sediment sampling and analysis (Tyler 2016).

The 39 borings were subsampled at discrete sediment layers for a total of 80 individual samples used to determine the sediment grain size characteristics in the shoaled channel areas (Brutsche et.al, 2019). One 200 g discrete sample was taken from each distinctive layer within a core greater than 30 cm (Tyler 2016). Boring elevations were noted and only materials in the dredging template were included in the in-situ material analysis. The percentage of fines in the in-situ samples ranged from 0.5 to 80.7%. The average composited fines percentage was 20.7%. The locations of the core borings to the centerline of the navigation channel are shown in Figure 6.

Pre- and Post-Construction Berm Sampling

Surficial samples of the beach berm were collected in segments by hand coring the in-situ material using a 3.8 cm (1.5 inch) diameter polycarbonate tube to a depth of 15 cm (6 inch). Subsequent subgrade samples were collected in the same manner by extending the hole incrementally downward. USACE Engineer Research and Development Center (ERDC) and USF collected 6 pre- and 21- post construction berm samples. The surficial sediment samples were collected in triplicate for sediment grain size characteristics and color measurements. The material samples were identified based on timing of collection and location into pre-construction existing beach berm, post-construction traditional trapezoidal placement and the post-construction CSSZ placement.

Grain Size Analysis of Fines Loss

The contractor's daily dredge logs and the USACE Dredge Quality Management (DQM) system's continuous location and dredging state information were used to correlate where dredging occurred in relation to where the material was placed. Geotechnical core boring logs were geospatially

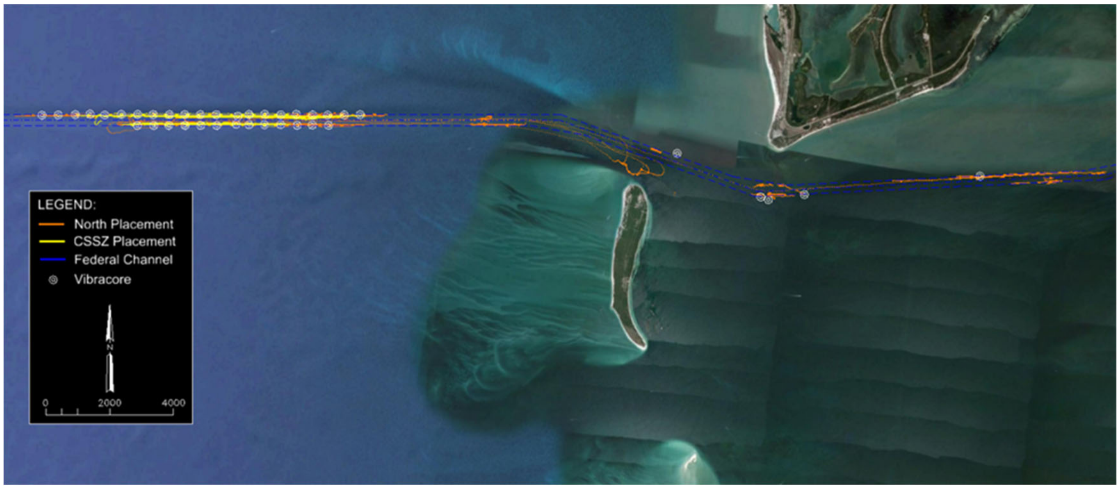

Figure 6. Dredge Quality Management (DQM) heat map showing areas of dredging in relation to placement area.

traced from the dredge area to determine the average fines content deposited in the traditional and the CSSZ placement areas. Figure 6 shows where materials originated that were placed in the north traditional placement in orange, and the CSSZ placement area in yellow. Table 1 shows the number of samples collected and the average percent fines passing the 0.063 mm (No. 230 sieve) for the existing beach prior to construction, the total composite for the full project and the broken out traditional placement and CSSZ placement areas. Sieve analysis shows that the pre-construction beach had an average of 0.03% fines present and the channel material averaged over 20% fine material by weight. The dredged and placed material averages 0.5% fines, which is well within the

Table 1. Grain size analysis sampling at Egmont Key average *in situ* in channel material numerically separated into traditional placement versus CSSZ placement, native beach, newly placed material further separated into traditional placement versus Cross Shore Swash Zone placement.

	# of Samples	**Avg. % by wt. passing 0.063 mm sieve**
Pre-construction berm	6	0.03
In situ channel composite	80	20.7
Channel material placed in the traditional placement area	45	20*
Channel material placed in the CSSZ placement area	35	24*
Post-construction composite berm	21	0.51**
Post-construction berm in the traditional placement area	14	0.52**
Post-construction berm in the CSSZ placement area	7	0.49**

* Based on DQM and core boring data
**Sampling occurred within 72 hours of placement completion

10% fines criteria for the beneficial use of channel material allowed by the “Sand Rule.” Composite sieve analyses of the pre- and post-construction beaches demonstrates a forty-fold decrease in fines percentage from the channel to the final beach placement fill.

Munsell Color

Surficial sediment samples of the *in-situ* channel material, pre-construction existing beach, composite post-construction beach that was further subdivided into the traditional placement and CSSZ placement areas, were analyzed for Munsell Color. Munsell color classifies color by hue, chroma and value. The Munsell color “hue” indicates the relationship of the color to red, yellow, green, blue, and purple. The Munsell color “chroma" relates the color strength or departure from a neutral of the same lightness. The Munsell color “value” ranges from 1 to 8 and relates the darkness of the sediment; the lower the Munsell value, the darker the material, see Table 2 (Munsell, 2000). For this study, surficial sediment samples were moistened in a laboratory using a misting bottle just prior to being measured in triplicate for hue, value, and chroma using a Konica Minolta digital colorimeter (CR-400). The aperture of the instrument is 0.5 cm so the colorimeter was moved for each reading to a different area of the sample to account for mottling of the sediment. The color of sediment in a coastal system can have an effect on the temperature and temperature gradient in the berm. Many biological species are affected by the thermal gradient of the dry berm. The primary species of concern are nesting sea turtles that can experience changes in hatching success and sex ratios with small perturbations in berm temperature (Hays et al., 2001; Weber et al., 2011; Naro-Maciel et al., 1999). The Munsell value is the indicator that correlates sediment color and temperature; the darker the sediment, the more solar radiation it absorbs thus it has a hotter temperature.

The *in situ* channel material, which contained a higher percentage of darker color fines (silt, clay and organic content), was on average darker than the existing native beach sediments. Due to fines and organics loss during construction, the material retained on the post-construction beach is on average lighter in color value than the parent channel material. The CSSZ Munsell value was identical to the pre-construction beach. The traditional trapezoidal beach placement area was darker than the pre-construction beach due to shell content in the fill.

Table 2. Munsell color of pre-construction berm, *in situ* channel material, composite post-construction berm, the traditional placement and the CSSZ placement.

Location	Number of Samples	Average Munsell Value	**
Pre-construction berm	13	5.9†	░
In situ channel	80	4.36*	▓
Post-construction composite berm	24	5.3†	▒
Post-construction berm in the Traditional placement area	16	5.0†	▒
Post-construction berm in the CSSZ placement area	8	5.9†	░

* Munsell measurements taken using standard visual Munsell color chart.
† Triplicate Munsell measurements of hue, value, and chroma were collected from three areas on each moist sand sample using a digital colorimeter (CR-400, Konica Minolta, Osaka, Japan).
**Munsell color values are inversely related to darkness; i.e. darker samples have lower Munsell values.

Cone Penetrometer – Pre- and Post-Construction Compaction Estimation

A standard Humboldt Mfg. Co.© cone penetrometer was used to smoothly penetrate the upper 15 cm (6 inch) at each location and measure the maximum resistance value. This was repeated for 15 to 30 cm (6 to 12 inch) and 30 to 45 cm (12 to 18 inch) depths. The maximum reading on the dial was read and logged during each 15 cm (6 inch) increment. In the mid-1980's, observations of turtle nesting decreases on nourished beaches resulted in investigations into various beach properties that may be causal factors (Nelson, et al., 1987). Compaction, which results in a reduction in the volume of the sand to a greater density and shearing resistance, as well as a reduction in the ability to penetrate the sand, has shown some correlation to reduced turtle nesting and changes in turtle nest size and cavity shape (Moulding and Nelson, 1988). Pre- and post-construction hand push cone penetrometer measurements have been used for several decades as a proxy to estimate the compaction of newly placed beaches. The pre-construction cone penetrometer measurement locations on Egmont Key are shown in Figure 7.

There were 19 locations sampled for compaction using a hand pushed proving ring cone penetrometer during the pre-placement data collection event. Along each of the USF lines, there were also discrete samples tested. They were averaged for each portion of the beach profile: foreshore, berm, and dune. The samples were distributed along the western shoreline of Egmont Key. The results of the pre-placement cone penetrometer sampling are shown in Table 3.

The post-construction cone penetrometer locations are shown in Figure 8. The sampling locations are randomly scattered throughout the two placement areas.

There were 21 discrete locations sampled for the post-construction compaction monitoring, (Maglio, et.al. 2015). The results of the pre-placement cone penetrometer sampling are shown in Table 4.

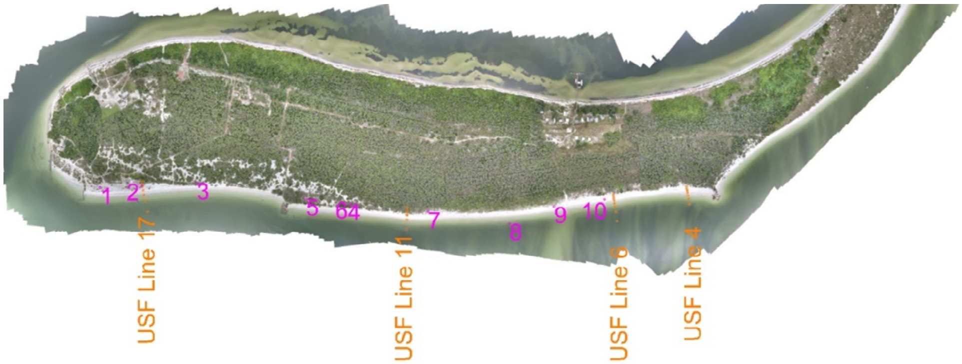

Figure 7. Pre-construction cone penetrometer testing locations at Egmont Key, FL with the 6 October 2014 UAV aerial.

Table 3. Cone penetrometer pre-construction sampling statistics.

Depth (cm (in))	0-15 (0-6)	15-30 (6-12)	30-45 (12-18)
Min (kPa (psi))	689 (100)	689 (100)	1365 (198)
Max (kPa (psi))	3999 (580)	4826 (700)	4254 (617)
Avg (kPa (psi))	2020 (293)	2799 (406)	3151 (457)
Median (kPa (psi))	2034 (295)	2972 (431)	3551 (515)
Number of samples	19	18	13
Refusals	0	1	5
Refusal (%)	0	6	38

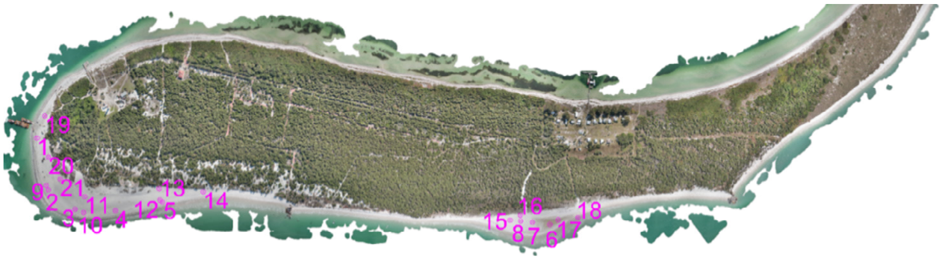

Figure 8. Post-construction cone penetrometer testing locations at Egmont Key, FL with the 16 March 2015 UAV aerial.

Table 4. Cone penetrometer post-construction sampling statistics totaled for all areas and separated into the north traditional and CSSZ placement areas.

North Traditional Placement			
Depth (cm (in))	0-15 (0-6)	15-30 (6-12)	30-45 (12-18)
Min (kPa (psi))	1034 (150)	862 (125)	1379 (200)
Max (kPa (psi))	4137 (600)	4826 (700)	4137 (600)
Avg (kPa (psi))	2337 (339)	3620 (525)	2985 (433)
Median (kPa (psi))	2241 (325)	4137 (600)	3447 (500)
Number of samples	14	10	6
Refusals	4	4	3
Refusal (%)	29	40	50
CSSZ Placement			
Min (kPa (psi))	345 (50)	1724 (250)	2068 (300)
Max (kPa (psi))	3275 (475)	4482 (650)	3792 (550)
Avg (kPa (psi))	2158 (313)	3020 (438)	3020(438)
Median (kPa (psi))	1896 (275)	3378 (490)	3103 (450)
Number of samples	7	7	6
Refusals	0	1	2
Refusal (%)	0	14	33

The refusals experienced during cone penetrometer measurements were the result of root balls, large shells, gravel, or shell hash lenses; not the result of overly compacted sediment. Post-construction shell hash lenses were routinely encountered when sampling due to the layering effect that occurs during hydraulically placed heterogeneous materials. The cone penetrometer measurements show no meaningful difference between pre- and post-construction, with slightly higher measurements and more refusals encountered in the upper 30 cm (12 inch) post-construction. There was a large amount of variability in the pre- and post-construction data with these measurements mostly being within the regulatory threshold of 3,447 kPa (500 psi). The traditional north placement area was slightly more compact on average than the CSSZ area and had a greater percentage of refusals. Analyses of comparison found no statistically significant differences between the observed measures. The increased refusals at the northern traditional trapezoidal placement area were partially due to a greater percent of shell hash placed in this area.

Dredging and Placement Volumes

Sediment losses are inherent in the hopper dredging process. When material is dredged from a channel and pumped into the hopper's bin, the carrier water (water that is mixed with the sediment to make it a pumpable slurry) is typically allowed to overflow out of the hopper through the use of internal fluid level control weirs. The carrier water often contains suspended material that is a primary source of losses. When material is re-slurried and pumped out of the dredge to the beach, material is once again transported by carrier water with any runoff losses at this point changing the character of the material remaining as beach fill. There are many other factors that affect the loss of material in the dredging process, including but not limited to: erosion, compaction, density, placement methodologies, surveying techniques, and equipment operations. Table 5 contains volume information, provided by GLDD, showing the material measured at the three major points in the dredging and placement process: material removed from the channel, material manually measured within the hopper, and dredged material surveyed on the beach by USF out to the toe of the profile. The material dredged and removed from the channel was measured using pre- and post-hydrographic surveys conducted by the USACE for payment purposes. The material pumped to the beach was estimated by the contractor for each load using ullage tables compared against vessel

Table 5. Volume of material dredged from channel, pumped to the beach from the dredge's hopper, and surveyed at the beach post-construction and associated percentages.

Location	Cubic Meters ((m3) (cy))	Percent of Total (%)
Traditional (North) Placement Area		
Dredged in Channel	382,306 (500,037)	100.0%
Pumped to Beach	244,437 (319,712)	63.9%
Surveyed on Beach	204,900 (268,000)	53.6%
Cross Shore Swash Zone Placement Area		
Dredged in Channel	138,011 (180,512)	100.0%
Pumped to Beach	81,979 (107,225)	59.4%
Surveyed on Beach	61,547 (80,500)	44.6%

displacement subtracting the estimated quantity of standing water in the hopper to estimate the actual hopper sediment load. The beach profiles were surveyed using traditional land surveying techniques employing a rod and Real-time Kinematic (RTK) system. It is estimated that any of these survey volumes could be as much as plus or minus 30 percent.

The loss of dredged material is a significant concern to the USACE, resources agencies, and contractors performing the work. Previous estimates were conducted for offshore borrow sites to determine the portion of sediment lost during the dredging and placement process. The southeast Florida Sediment Assessment and Needs Determination (SAND) study looked at dredging losses based on region-wide project performance and estimated that approximately 15% of the sediment volume is lost during hopper loading and hydraulic placement of sediment (Ousley et al, 2014). The SAND study estimates were made for offshore borrow areas on the east coast of Florida and included only sources with less than 5% fines. Given the fact that this project had material that was a composite 20% fines in-situ, losses should be proportionally greater in the +30% range. Because this was a beneficial use of navigational dredging material project rather than a beach nourishment, fewer protocols were employed to contain the placed material in the placement area, and thus greater losses were expected. Furthermore, this project used a hopper dredge with turtle exclusion devices (TED). TEDs are designed to plow into the seabed, at least 15 cm (6 inch) and push a pressure wave of sediment in front of the drag head to exclude the entrainment of sea turtles (Henriksen et al., 2015). The use of TEDs plows the seabed and furrows a portion of material to the side of the trough created (Figure 9). The majority of the sediment dredged in this project was contained at the outer toes of the channel in relatively narrow bands, thus TEDs could be responsible for a portion of material lost during active dredging.

Profile Surveys

The USF-CRL collected cross shore profile surveys along Egmont Key prior to construction in September 2014 and then following construction in March and August 2015 (Figures 10 to 15).

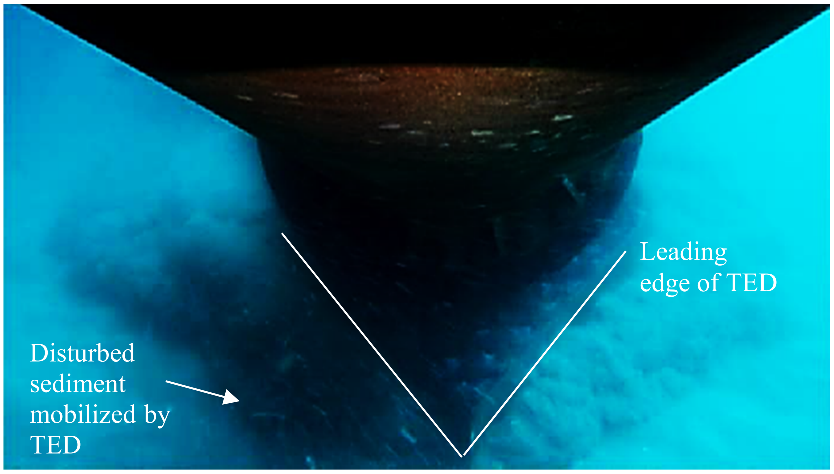

Figure 9. Pressure wave and sediment redistribution generated by TED in operation at Ft. Pierce, FL (Henriksen, J. et al., 2015).

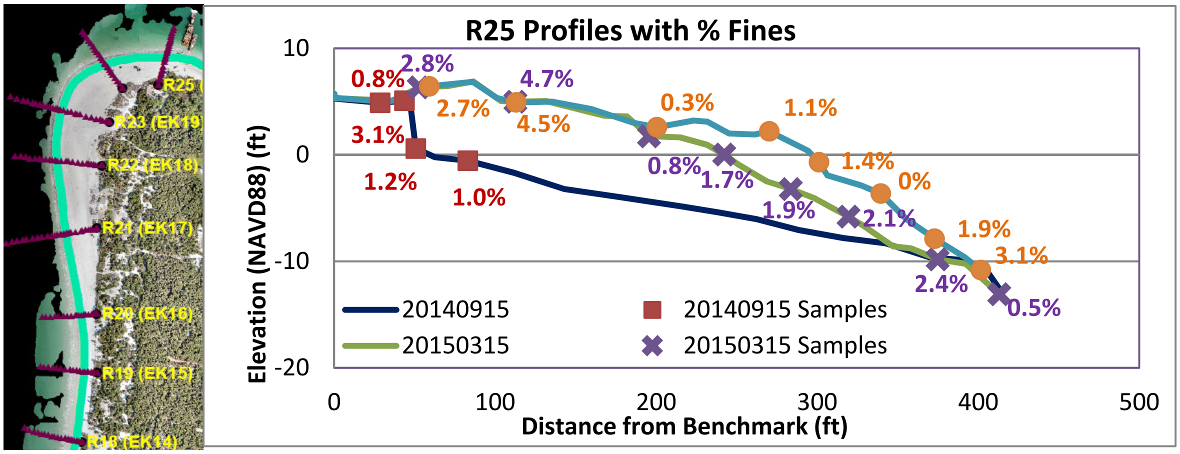

Figure 10. Profile line R-25 across the northern tip of Egmont Key in the traditional placement area.

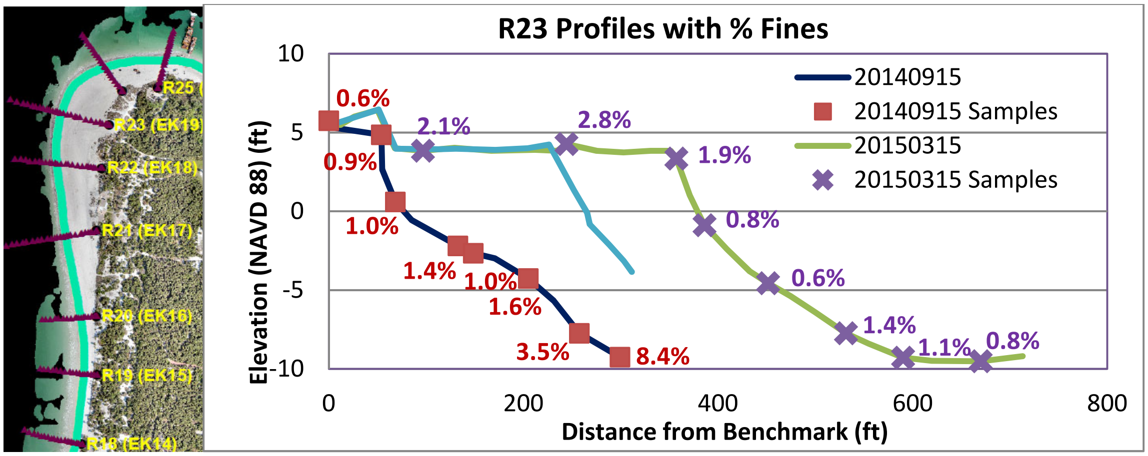

Figure 11. Profile line R-23 across the widest part of the traditional fill area on Egmont Key.

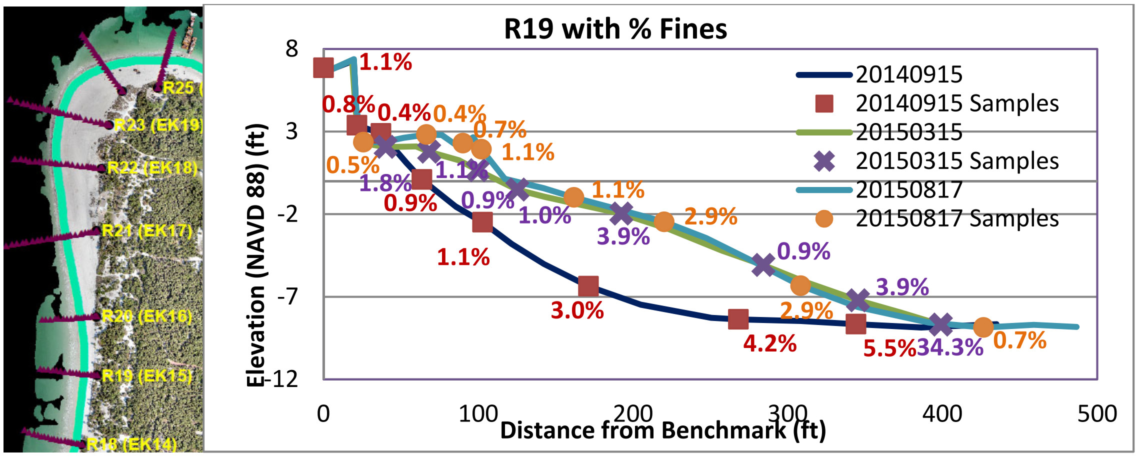

Figure 12. Profile line R-19 across the southern taper area of the traditional fill area on Egmont Key.

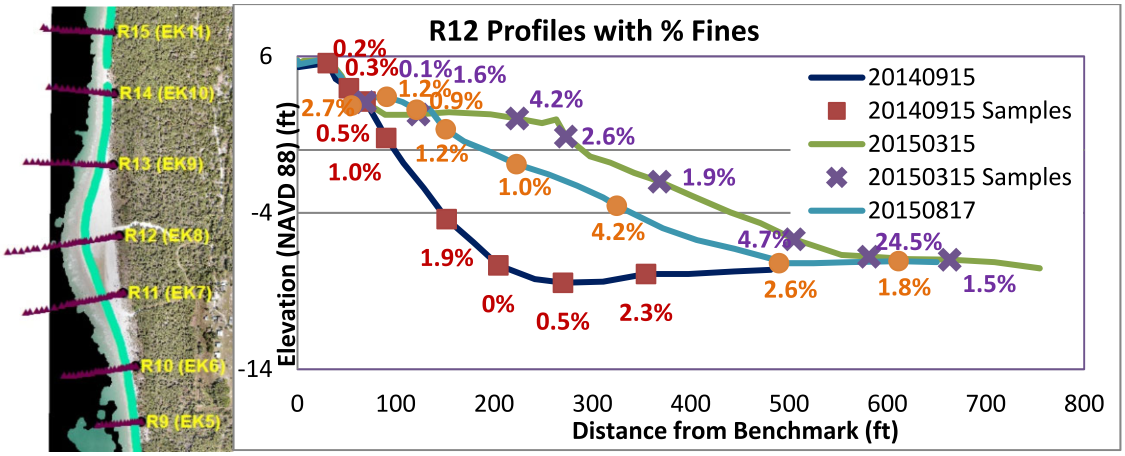

Figure 13. Profile line R-12 across the point of the CSSZ placement on Egmont Key.

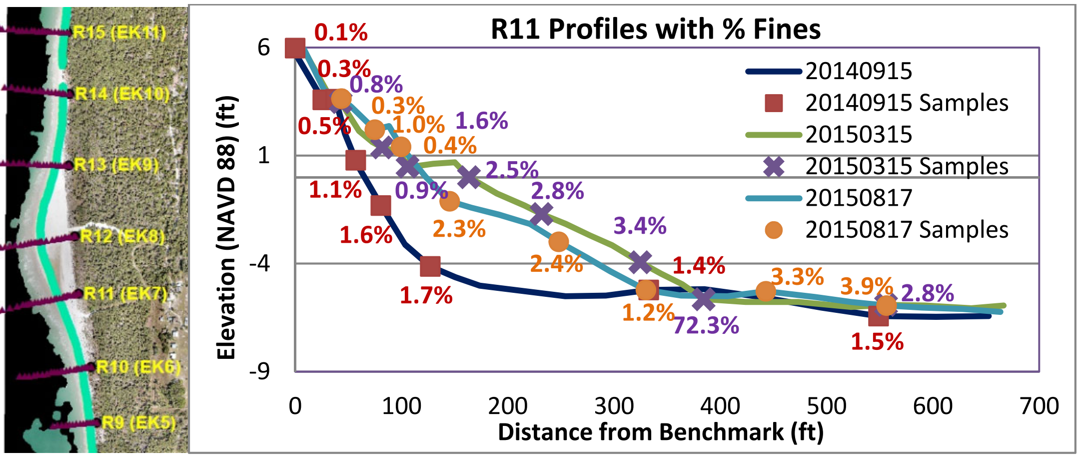

Figure 14. Profile line R-11 moving south along the CSSZ placement area taper on Egmont Key.

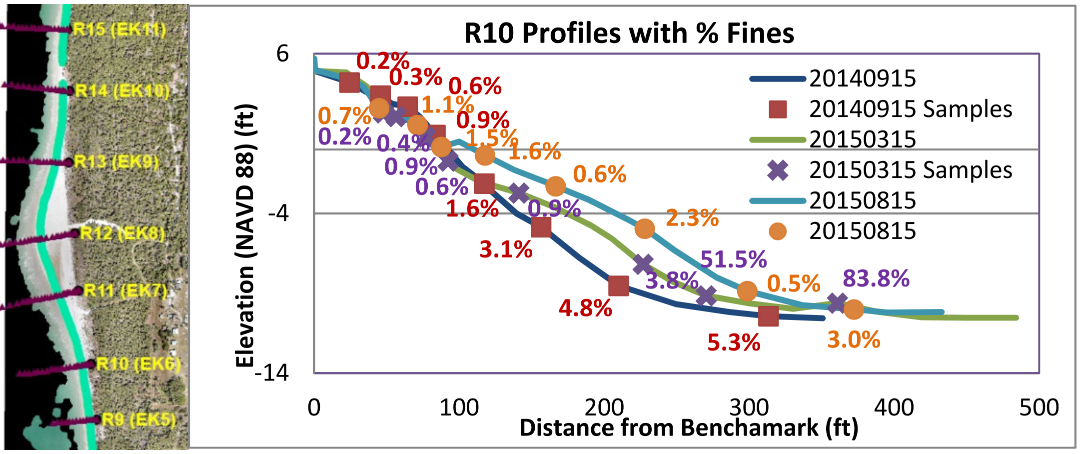

Figure 15. Profile line across the southern most portion of the CSSZ area on Egmont Key.

Surficial sediment samples were taken along the cross-shore profile lines. In the traditional trapezoidal placement area, the extent of the fill area is shown in Figure 11 with sediment loss during equilibration. Comparing the erosion in Figure 11 to the accretion in Figure 10 and lack of change in Figure 12, it can be concluded that the berm equilibrated relatively quickly following construction, due to the timing of the placement during the winter season and the Gulf exposed nature of the area. The sediments were eroded from the wide portion of the berm and moved northward around the tip of the island and southward alongshore. Sediment sampled in the north placement area did not capture a high presence of fine sediments pre-, during, or post-construction. Fine sediments were eroded from the northern placement area during construction and carried to a less active and slightly sheltered portion of the beach profile, as shown in Figure 12. The high percentage of fines were ultimately resuspended and no longer found along the profile five months post-construction.

At the CSSZ placement area the widest portion, Profile R-12, of the constructed berm equilibrated with minor adjustment to the dry berm elevation, but most of the sediment movement occurred in the intertidal portion of the fill template. Unlike the traditional placement area where the bulk of the material moved north and wrapped around to the lee of the island, sediment moved predominately south from the point feature.

The sediment sampled in the cross shore of the CSSZ placement indicate that the fines content that was delivered to the beach originally deposited at the furthest offshore extent of the fill (toe of fill) but by the next sampling event five months later, the fine sediments had moved out of the system beyond the areas sampled. For the August 2015 sampling period (five months after placement), the material in the deposited berm contained less than 5% fine material in all samples. The fines at the toe were dispersed by winter wind and wave (Nor'easter) events.

UAV Geospatial Data Collection

The USACE Jacksonville District manages an unmanned aerial vehicle (UAV) program that uses an electrically powered, fully autonomous, hand-launched airplane with an onboard global positioning system (GPS), inertial navigation system (INS), camera, and computer. The Jacksonville District is the USACE South Atlantic Division's Center of Expertise for UAV Operations. The UAV platform focuses on the rapid acquisition of high-resolution aerial surveys to support various USACE infrastructure and natural resource monitoring efforts in land and aquatic environments. This UAV platform collects geo-referenced visible and color-infrared imagery at a resolution between 2 and 10 centimeters that are much higher resolution than traditional aerial photography (USACE, 2015).

At the Egmont Key site, there have been four UAV flights to date: just prior to project commencement, at mid-project completion, immediately post-completion, and five months post completion. From the UAV imagery of Egmont Key, geomorphic changes in response to the placement of maintenance material show that the salient CSSZ feature equilibrated within the five-month monitoring period which was corroborated by the shoreline profile surveys (Figure 16).

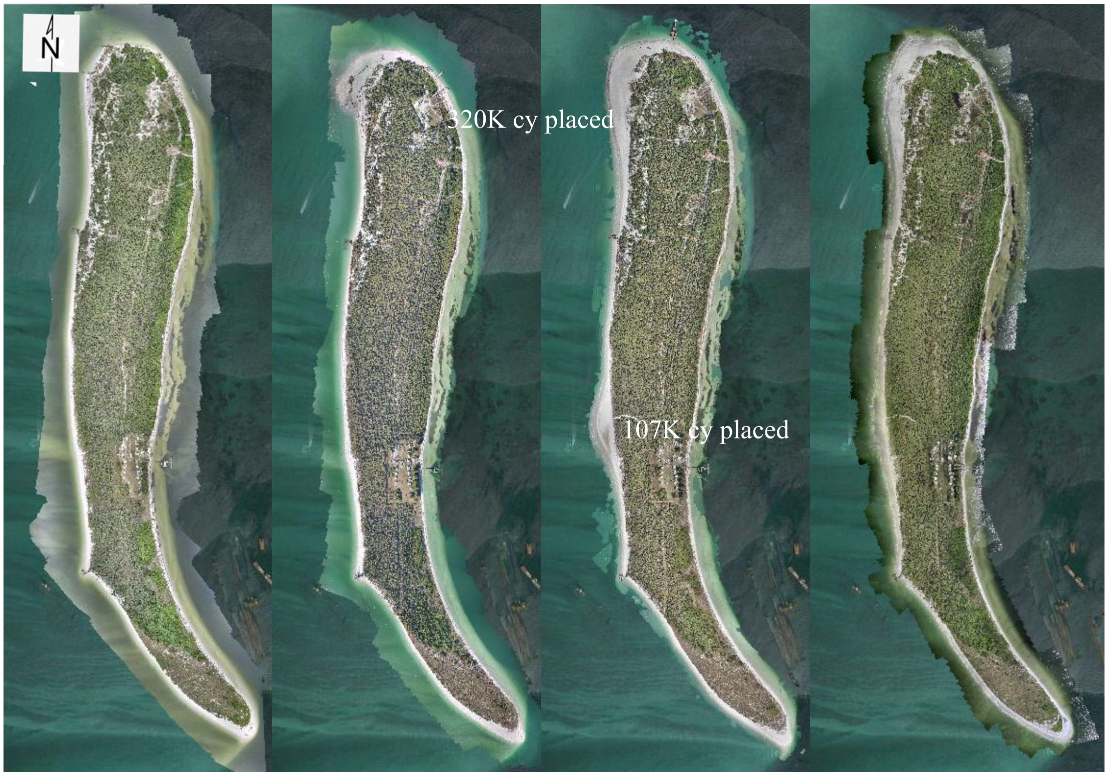

Figure 16. UAV aerial mosaics (left to right) pre-placement 6 October 2014, during placement 16 December 2015, ten days post-placement 16 March 2015, five months post-placement 17 August 2015.

The CSSZ placement essentially put sediment into the littoral system in an unconfined manner. The bulk of this material was placed into the swash zone below mean sea level as demonstrated in Figure 17.

The material once put into the swash zone was quickly mobilized and spread alongshore, predominantly towards the south (Figure 18).

Light Attenuation and Turbidity Monitoring

Turbidity associated with dredging is a concern for projects, especially those involving a relatively large percentage of fine material. Turbid water can have negative impacts to environmental resources by attenuating light and hindering photosynthetically active radiation (PAR) for the organisms in the water column and on the sea floor (Goodwin and Michaelis, 1984). Current regulatory standards in the State of Florida state that the turbidity associated with a dredging project may not exceed 29 NTUs above background conditions when measured 500 ft (150 m) from the discharge point. PAR may be a more relevant measure for impacts to habitats than turbidity because it measures light in the spectrum from 400-700 nm, that is the portion of the spectrum associated with photosynthesis and is not a proxy measurement of environmental impact, but rather a measurement of direct impact.

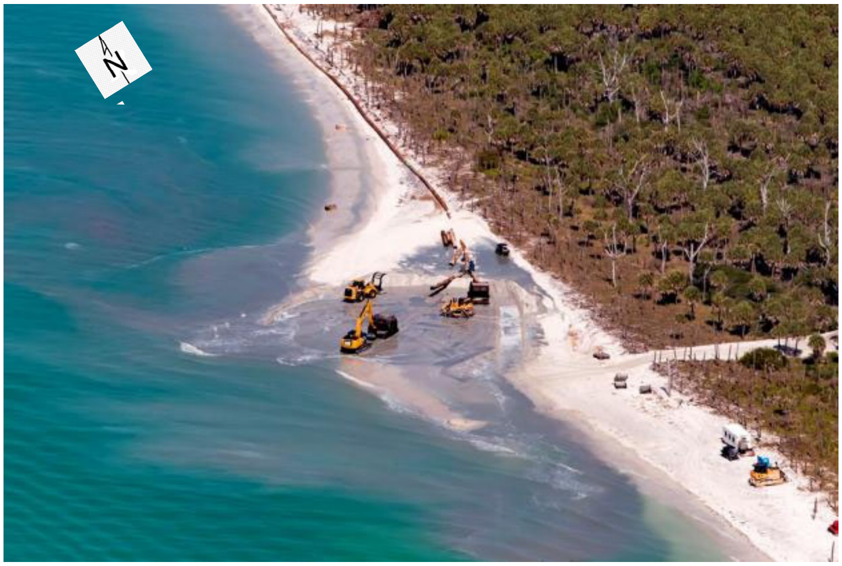

Figure 17. Aerial of CSSZ placement on 21 February 2015, approximately at Mid-placement construction, courtesy of GLDD (Brutsche et al, 2019).

Figure 18. Aerial of CSSZ placement on 29 April 2015, seven weeks post placement, courtesy of GLDD (Brutsche et al, 2019).

At Egmont Key turbidity, light, and PAR were measured using a YSI6600, HOBOs, and LiCORs and Odysseys, respectively. Instrument arrays were placed around Egmont Key prior to commencement of dredging until several months after the project ended to determine the spatial and temporal extent of the dredge plume. Three main types of mounts were deployed; PVC pipes, buoys, and tires, each containing at least two instruments spaced approximately 1.4 ft apart to determine attenuation through the water column (Figure 19).

The base station contained the YSI600 with two LiCORs attached and two Odysseys to directly relate turbidity and PAR and was located just outside of the northern beach nourishment template

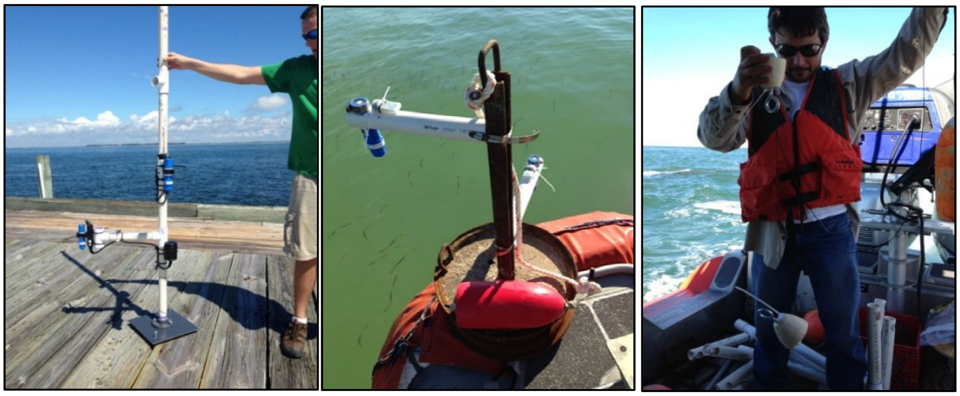

Figure 19. Types of mounts from left to right: pipe, tire, and buoy.

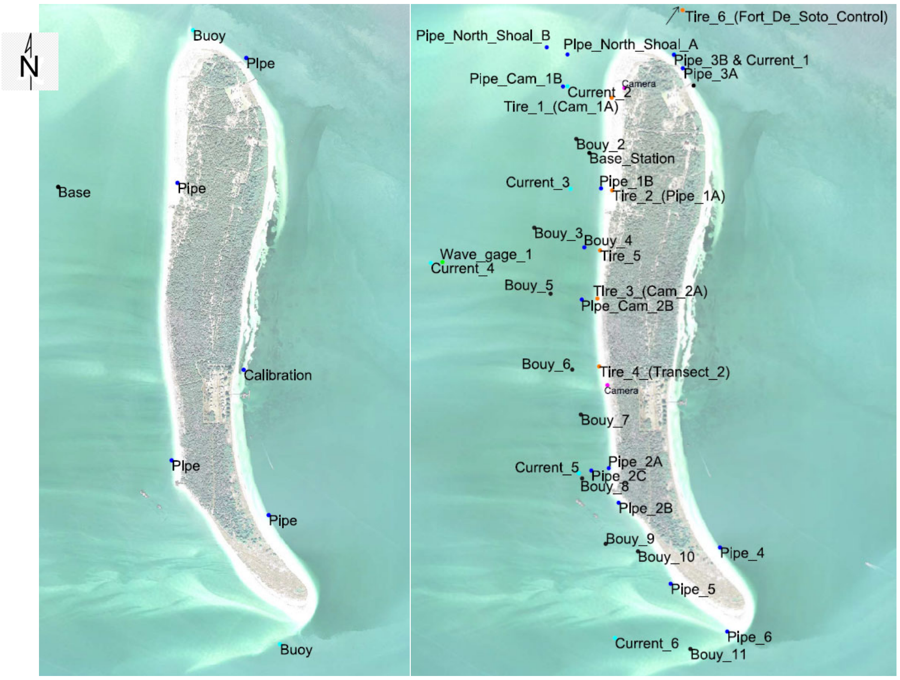

Figure 20. Deployment location of sensors for monitoring turbidity and light attenuation from 1 October to 7 November (left) and 14 November to 15 December (right).

(Figure 20). It is important to note that the base station was much closer to the placement location during dredging and placement than the required compliance testing and because it was located at the bottom of the water column, it measured much higher NTUs than compliance samples. Also, during deployment, the base station may have settled deeper into the substrate, putting the instruments closer to the sea floor, where it could have potentially captured the effects of bedload transport and in addition recorded higher levels of turbidity. There were no observed or measured exceedances of turbidity standards set in the environmental permit during or following dredging and placement.

Figure 21 shows the turbidity and light attenuation coefficient background conditions prior to dredging, while the bottom plot illustrates the wind speeds and wave directions during that time.

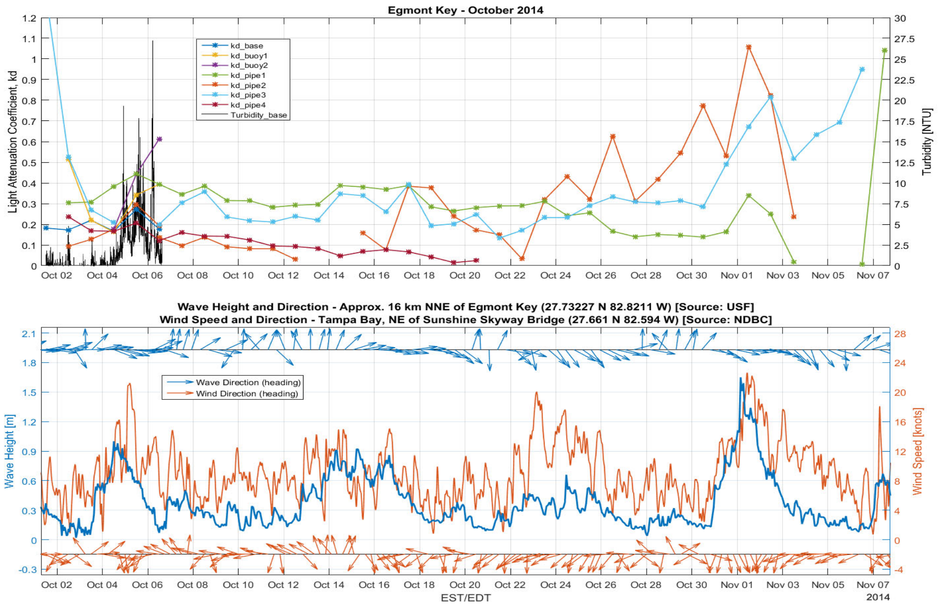

Figure 21. Turbidity, light attenuation coefficient, wind and wave speed and direction, Oct. – Nov. 2014.

The base station was removed on 6 October 2014, and turbidity measurements ceased. Many of the light attenuation sensors were left in place until 15 December 2014.

Figure 22 illustrates results of turbidity and light attenuation coefficient measurements during the initial dredging period. As expected, during the dredging and placement from 19 November to 28 December, turbidity increased to above background conditions and as turbidity increased the light attenuation coefficient did as well. Periods of time with stronger winds and larger waves due to the passage of cold fronts increased the level of turbidity through the water column, see 5 October and 1, 18, 26 November 2014. The various data sets are grouped by the area they were located at: north, east, and west.

Once dredging and placement operations were no longer active, turbidity went back down to background conditions very rapidly, see 28 December in Figure 23. Another point of interest is that during a cold front passage at the beginning of January, turbidity levels far exceeded background conditions, see spike on 5 January 2015, even though there was no dredging occurring at that time. It is possible that fines contained in previously placed sediment were winnowed (mobilized) during these events. However, given that the background sites recorded a similar light attenuation spike implies that natural, ambient conditions have the potential to episodically greatly exceed current regulatory standards.

Throughout the months of January and February 2015, consistent wind and wave events impacted the island, occurring on 24 and 26 January and 3, 10, and 17 February. A significant weather event occurred at the same time as the resumption of dredging on 24 January 2015, resulting in the completion of only two loads before weather caused dredging to cease for approximately twenty hours (Figure 24). The placement location of dredged material changed from the North Placement Area to the CSSZ Placement area on 9 February 2015. Once the discharge location was moved to

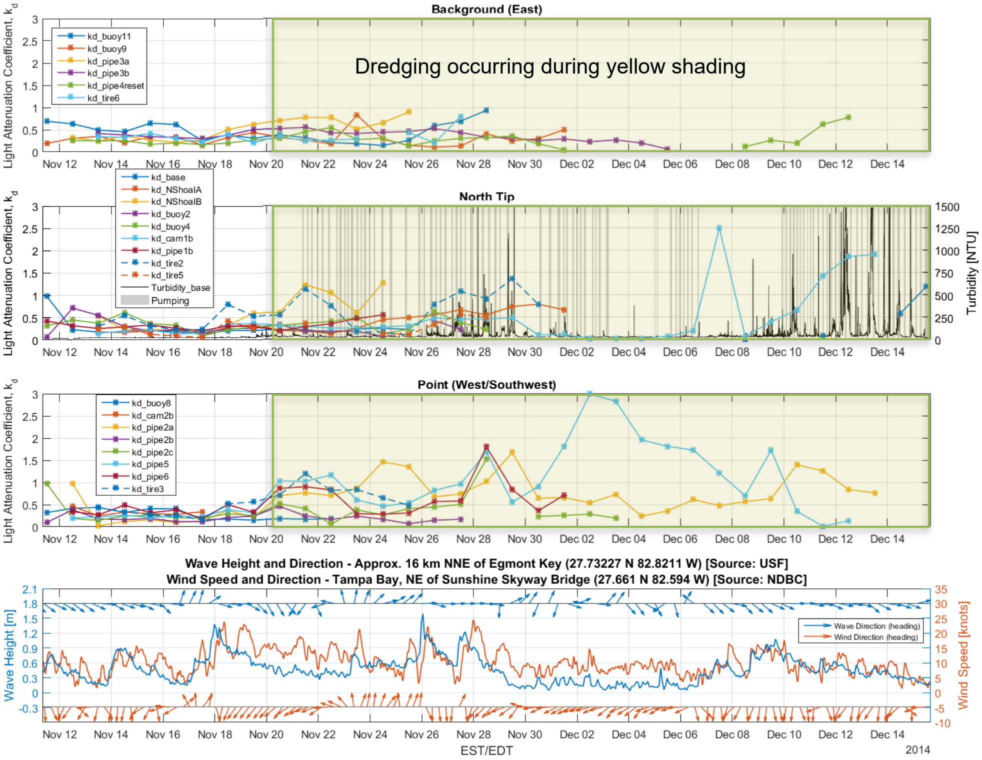

Figure 22. Turbidity, light attenuation coefficient, wind speed and wave direction for Nov. – Dec. 2014.

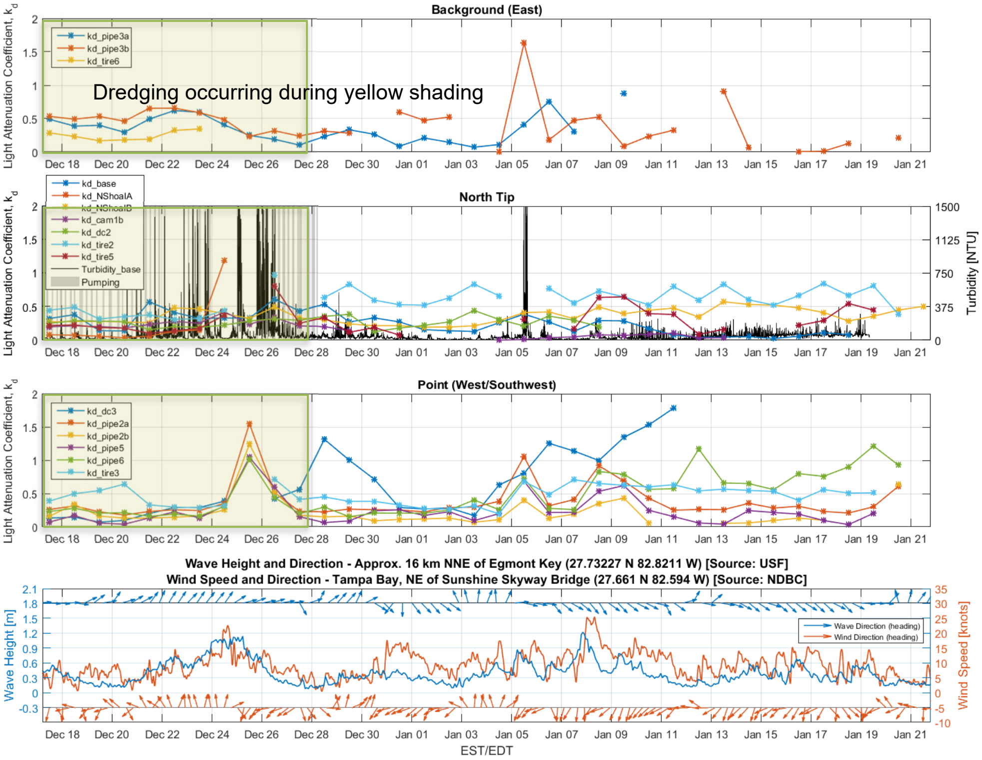

Figure 23. Turbidity, light attenuation, wind speed and wave direction for Dec. 2014 – Jan. 2015.

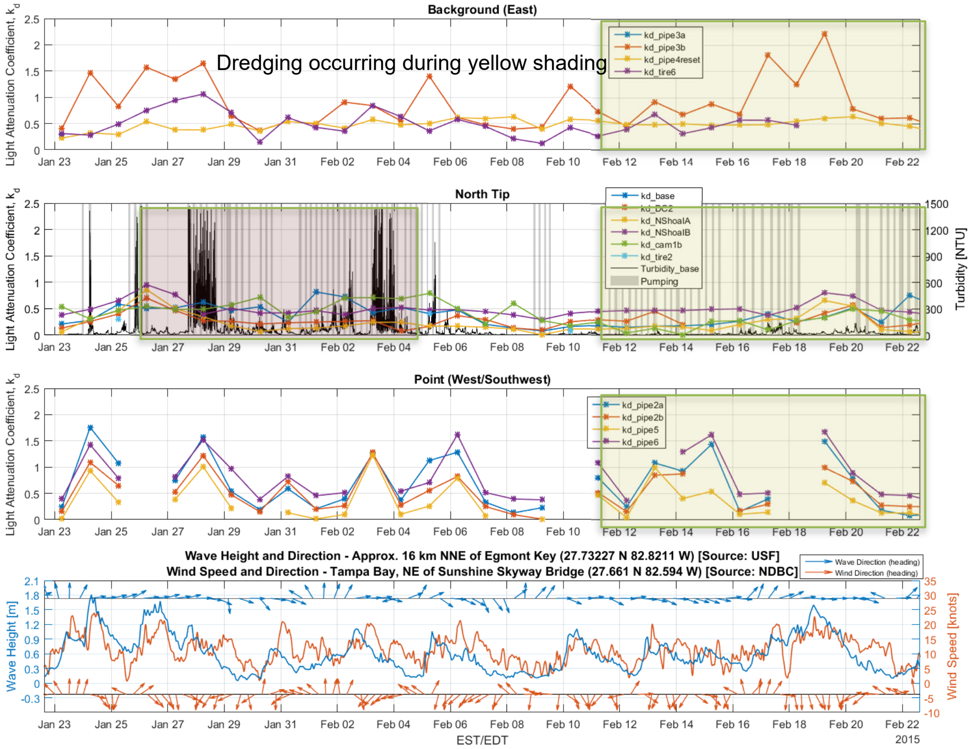

Figure 24. Turbidity, light attenuation coefficient, wind speed and wave direction for late Jan. - Feb. 2015.

the CSSZ placement area, spikes in turbidity measured at the base station ceased until the next southerly weather event on 26 February 2015 (Figure 25).

DISCUSSION AND CONCLUSIONS

Even though the material dredged and placed at the beach had high fines content (+20%), the post-construction beach placement areas were comparable in their geotechnical properties to the pre-construction beach in terms of grain size, color, and compaction; the high fines content seems to have had no effect on the resulting beach.

The contractor did not control the placement of dredged material at the traditional placement area to the same degree as a normal beach nourishment project because the project objectives were measured by clearing the navigation channel, not constructing a beach. Sediment discharge was virtually uncontrolled at the CSSZ placement area, with the exception of the discharge screen for large debris. This resulted in a significant loss of volume of the material ultimately placed on the dry beach, as presented in Table 5. There were requirements on the quality of material placed at the beach in terms of grain size, color, compaction, and deleterious materials and this was not an issue during the project as the data shows (Maglio et.al, 2015).

Typical beach placement operation requires two bulldozers, two pipe front end loaders, and an excavator. The CSSZ operation, if used to reduce the footprint and associated activity at the placement operation, could remove the need for multiple pieces of equipment and personnel from the beach. The necessary equipment to successfully operate a standard CSSZ placement would be

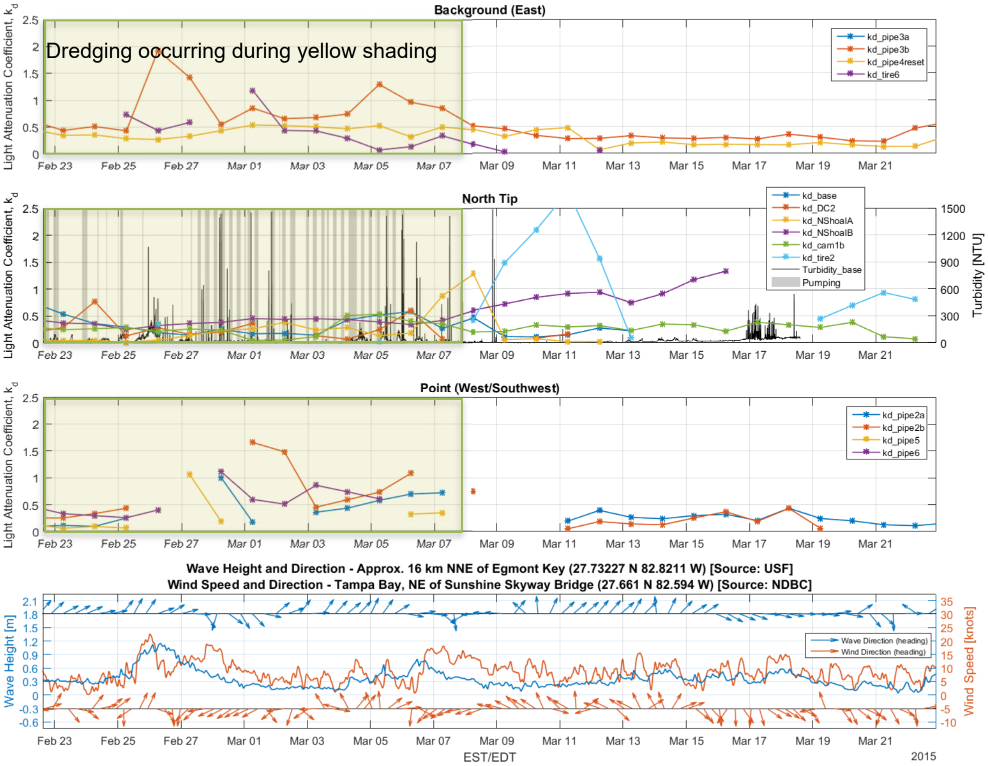

Figure 25. Turbidity, light attenuation coefficient, wind speed and wave direction for late Feb. - Mar. 2015.

a pipe moving front end loader and one excavator. This would remove three pieces of equipment from the beach and their operators, thus reducing beach placement operational costs and down time. Tilling would no longer be necessary when employing the CSSZ method as demonstrated by this project and this would be an additional savings over traditional beach placement.

The beneficial use placement event on Egmont Key was a significant success in placing "unsatisfactory material" per the FAC onto a critically eroded shoreline, providing benefits including coastal protection, habitat restoration, and recreational opportunities. The potential positive economic and environmental outcomes of the CSSZ placement method are as follows:

- Because the discharge slurry was being pumped directly into the relatively high energy swash zone, the fine material and organics were immediately "washed" out of the material that settled to form the new salient beach.
- This washing allowed for an immediate "lightening" of the placed sediment color (Munsell value).
- Since this material is discharged into the active beach, it allowed for littoral processes to sort the sediments into the appropriate portion of the equilibrium beach profile based on grain size.
- This discharge method built a feeder beach that allowed for a smaller direct footprint on the existing shoreline from placement operations. This could be a desirable placement method when minimized beach impacts are required.
- It may provide an example to reduce construction costs on future beach placement projects

by reducing manpower and equipment on the beach to support the operations. Depending on the production rate, wave energy, and offshore slope, a contractor may be able to discharge sediments for days without having to move their discharge location.

- CSSZ placement has the potential to be less costly and fully align with the concept of "strategic placement" approaches.

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REFERENCES

Brutsche, K.E., Maglio, C.K., Tyler, Z.J., Ousley, J.D., Wang, P. (2019) *Beneficial Use of Dredged Material with Increased Fine Sediment Content: A Case Study at Egmont Key, Florida* ERDC/CHL TR-19-11, June.

Crain, D.A., Bolten, A.B., Bjorndal, K.A. (1996) *Effects of beach nourishment on sea turtles: review and research initiatives*. Restoration Ecology, Vol. 3, No. 2, pp. 95-104, June.

Erftemeijerab, P.L., Riegl, B., Hoeksemad, B.W., Todd, P.A. (2012) *Environmental impacts of dredging and other sediment disturbances on corals: A review*. Marine Pollution Bulletin, Volume 64, Issue 9, Pages 1737-1765, September.

Goodwin, C.R., and Michaelis, D.M. (1984). *Appearance of Water Quality of Turbidity Plumes Produced by Dredging in Tampa Bay, Florida.* United States Geological Survey, Water-Supply Paper 2192.

Hays, G.C., J.S. Ashworth, M.J. Barnsley, A.C. Broderick, D.R. Emery, B.J. Godley, A. Henwood and E.L. Jones, (2001). *The importance of sand albedo for the thermal conditions on sea turtle nesting beaches*. *OIKOS* 93:87-94.

Henriksen, J. Warwick, M., Munger, R. and Kay, S. (2015) *Engineering analysis of turtle exclusion device*. Proceedings of the Western Dredging Association and Texas A&M University Center for Dredging Studies' Dredging and Summit and Expo 2015, Houston, TX, June 22-25

Maglio, C.K., Ousley, J.D., Hershorin, A.G. and Mora, M.A. (2015). *Tampa harbor maintenance dredging with Egmont key beneficial reuse of high silt content material using a traditional template versus cross shore swash zone placement*. Proceedings of the Western Dredging Association and Texas A&M University Center for Dredging Studies' "Dredging Summit and Expo 2015", Houston, Texas, USA, June 22-25.

Milton, S.L., Schulman, A.A., Lutz, P.A. (1997). *The Effect of Beach Nourishment with Aragonite versus Silicate Sand on Beach Temperature and Loggerhead Sea Turtle Nesting Success*. Journal of Coastal Research 13, no. 3, page 904-15, 1997.

Moulding, J.D. and D.A. Nelson (1988). *Beach nourishment issues related to sea turtle nesting. Symposium on Coastal Water Resources*. American Water Resources Association, Wilmington, NC, p. 87-93.

Munsell Soil Color Charts (2000). Gretagmacbeth, New Windsor, NY.

Naro-Maciel, E., N. Mrosovsky, M.A. Marcovaldi (1999). *Thermal Profiles of Sea Turtle Hatcheries and Nesting Areas at Praia do Forte, Brazil*. *Chelonian Conservation and Biology*, 3(3):407-413

Nelson, D.A., K.A. Mauck, J. Fletemeyer (1987). *Physical effects of beach nourishment on sea turtle nesting, Delray Beach Florida*. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 24pp.

Ousley, J.D., E. Kromhout, M.H. Schrader, L. Lillycrop (2014). *Southeast Florida sediment assessment and needs determination (SAND) study*. ERDC/CHL TR-14-10, Vicksburg, MS, 319pp.

Tyler, D., Zawada, D.G., Nayegandhi, A., Brock, J.C., Crane, M.P., Yates, K.K., and Smith, K.E.L. (2007). *Topobathymetric data for Tampa Bay, Florida: U.S. Geological Survey Open-File Report 2007-1051* (revised), U.S. Department of Interior http://pubs.usgs.gov/of/2007/1051/.

Tyler, Z. (2016). *Morphodynamics of Egmont Key at the Mouth of Tampa Bay: West-Central Florida*. Thesis, University of South Florida. http://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=7615&context=etd

USACE Jacksonville District, Unmanned Aerial Vehicle, website accessed May 2015. http://www.saj.usace.army.mil/Missions/UnmannedAerialVehicle.aspx

Weber, S.B., A.C. Broderick, T.G.G. Groothuis, J. Ellick, B.J. Godley, J.D. Blount (2011). *Fine-scale thermal adaptation in a green turtle nesting population. Proc. of the Royal Society*, published online, downloaded from rspb.royalsocietypublishingl.org on September 22, 2011.

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