

Memorandum – Coastal Engineering Review

Fire Island National Seashore (FIIS) – Bayside Erosion: Determining Nature Based Solution Options for Managing/Protecting Priority Bayside Shoreline Erosional Hotspots

TAR 21363

November 2022

BACKGROUND

As climate change and sea level rise (SLR) continue to impact Fire Island National Seashore's (FIIS or the Seashore) natural and cultural resources, and infrastructure, there has been a recognition that management practices need to adapt and evolve. To address these changing needs, the park hosted a two-day workshop in May 2021 that brought together subject matter experts to better understand current conditions related to erosion and impacts resulting from relative SLR and what nature-based solution options might be available to address these coastal erosion challenges. The Seashore is interested in pursuing nature-based solutions at bayside erosional hot spots to build resilience and restore ecosystem services that have been damaged or lost.

Four focus areas within FIIS were identified as being the highest priority erosional hot spots: Carrington Track, Talisman, Sailors Haven, and Point O' Woods. The Seashore is in the process of further prioritizing these four areas given the high cost of nature-based solution implementation. Additionally, the Seashore would like to see results in one or more of these hot spots before considering similar solutions for other areas.

TECHNICAL ASSISTANCE REQUEST

The Seashore has requested an evaluation to determine, from the different types of nature-based solutions that have been used in other east coast areas, which methods have the potential to work best on the bayside shoreline of FIIS. There will eventually be a need for compliance with the National Environmental Policy Act (NEPA), so having viable alternatives for the impact analysis is highly desirable.

FIIS lies along the south shore of Long Island in Suffolk County, New York. FIIS encompasses over 19,500 acres of upland, tidal, and submerged lands along a 26-mile stretch of the 32-mile barrier island, part of a much larger system of barrier islands and bluffs stretching from New York City to the eastern end of Long Island at Montauk Point (figure 1). Seventeen residential communities that predate FIIS's authorization in 1964 are interspersed among the federal lands on Fire Island. Commercial hospitality development began as early as 1855, with several of the communities having been established prior to the 1930s. FIIS's enabling legislation includes provisions for private land to be retained and developed (NPS 2021a).

REVIEW OF THE FIRE ISLAND NATIONAL SEASHORE WORKSHOP RECOMMENDATIONS

The Fire Island National Seashore Bay Shoreline Management 2021 Workshop (NPS 2021a) provided an important opportunity for Seashore staff, subject matter experts, and engaged stakeholders to review available data on the impacts of erosional hot spots on the bayside of Fire Island, identify key information gaps, and explore the application of nature-based approaches to address those impacts.

The topical presentations, in conjunction with the five breakout groups actively engaged over the two-day event, provided the basis for meeting the goals outlined for the workshop. Participants provided important feedback. In addition, there was considerable alignment across participant feedback, with common themes emerging from each of the breakout groups. Synthesizing the themes that emerged from those discussions resulted in a discrete set of recommendations and priority concepts:

- Given the extent of a shared bio-geophysical setting, the breadth of similar impacts, and a long history demonstrating that the activities conducted at one site have implications at other sites, there was broad recognition that proposed management activities should be explored within a whole-systems context.
- If a determination is made that additional data are required to inform management approaches at a specific site, every effort should be made to provide those data for the whole system (e.g., Great South Bay hydrodynamic sediment transport model).
- Detailed site assessments, in conjunction with pre- and post-implementation monitoring, are fundamental to evaluating project effectiveness and impacts within a whole-systems context.
- The Carrington Tract, Talisman, Sailors Haven, and Point O'Woods were the four highest priority erosional hotspots identified for the workshop. Since several of the erosional hotspots occur on federal property, FIIS managers should engage in an internal review effort to determine which locations should be addressed, and to prioritize those in need of intervention.

NEXT STEPS

Recognizing that it might be difficult to fund projects in all four of the areas discussed at the workshop, it was determined that FIIS will need to identify priority areas. FIIS (along with designated subject matter experts) will use the information from the workshop to determine which types of shoreline projects would best fit the shoreline dynamics. When the best fit project types have been decided, FIIS will complete NEPA compliance to determine which alternative(s) would have the best outcome. With completion of NEPA compliance, FIIS would then move forward with securing project funding for implementation.

Figure 1. Fire Island is part of a larger barrier island system that stretches from New York City to Montauk Point with islands separated by tidal inlets in the west (Nordstrom et al 2016).



HISTORICAL AND EXISTING CONDITIONS

Historical Conditions

The four highest priority erosional hotspots identified by the National Park Service (from west to east) are Point O'Woods, Sailors Haven (approximately 1.5 miles from Point O'Woods), Carrington Tract (approximately 2.8 miles from Point O'Woods), and Talisman (approximately 5 miles from Point O'Woods), all located along the northern shore of Fire Island in Great South Bay, as shown on Figure 2. The barrier islands along Long Island's southern shoreline are dynamic features that have been migrating landward since the last ice age 20,000 years ago (Nordstrom et al 2016). Recent studies indicate the islands move in a continuous process where sand is transported across the island from the ocean to the bay, causing landward migration. There are three primary ways that sand can be transported across a barrier island: inlet formation, overwash processes, and eolian (or wind) transport. Geologic evidence suggests that historically, inlets were far more important than either overwash or the wind in terms of moving sand landward and driving barrier migration (Tanski 2012). The flood tidal shoals created by historical inlets provided the platform that allows the island to maintain itself while moving landward over time in response to rising sea level (Figure 3). Regardless of the actual mechanisms by which the barrier islands move in response to the rise in sea level, they have moved landward over the historical time frame of thousands of years (Tanski 2012).

Figure 2. Overview of the four identified areas for a potential pilot project (NPS 2021a).

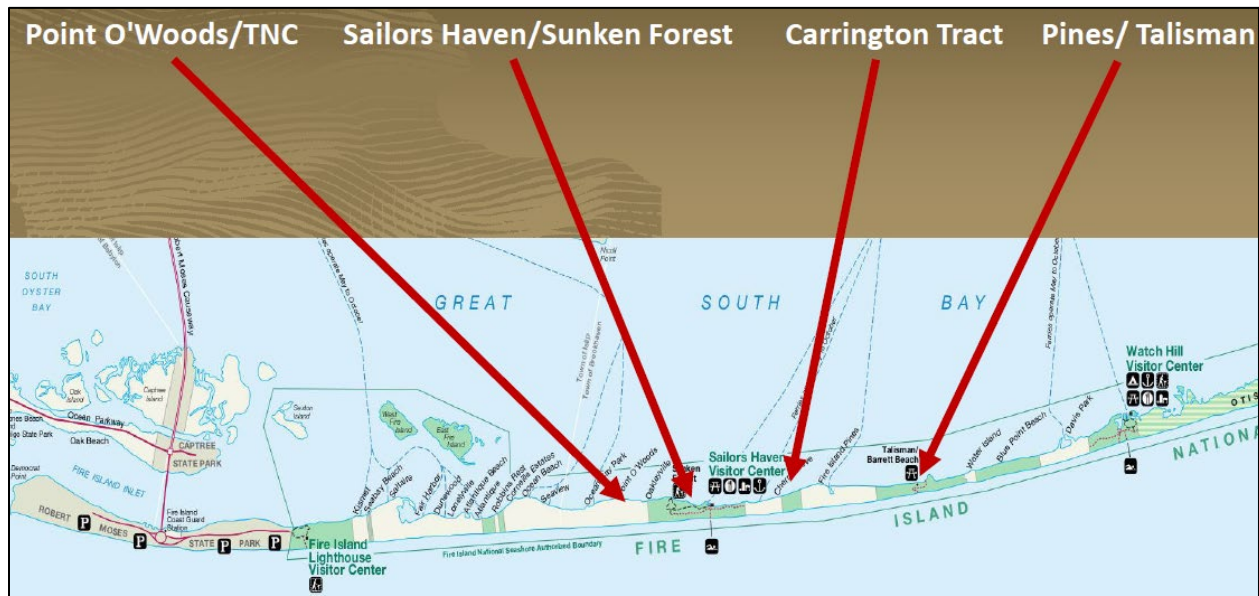
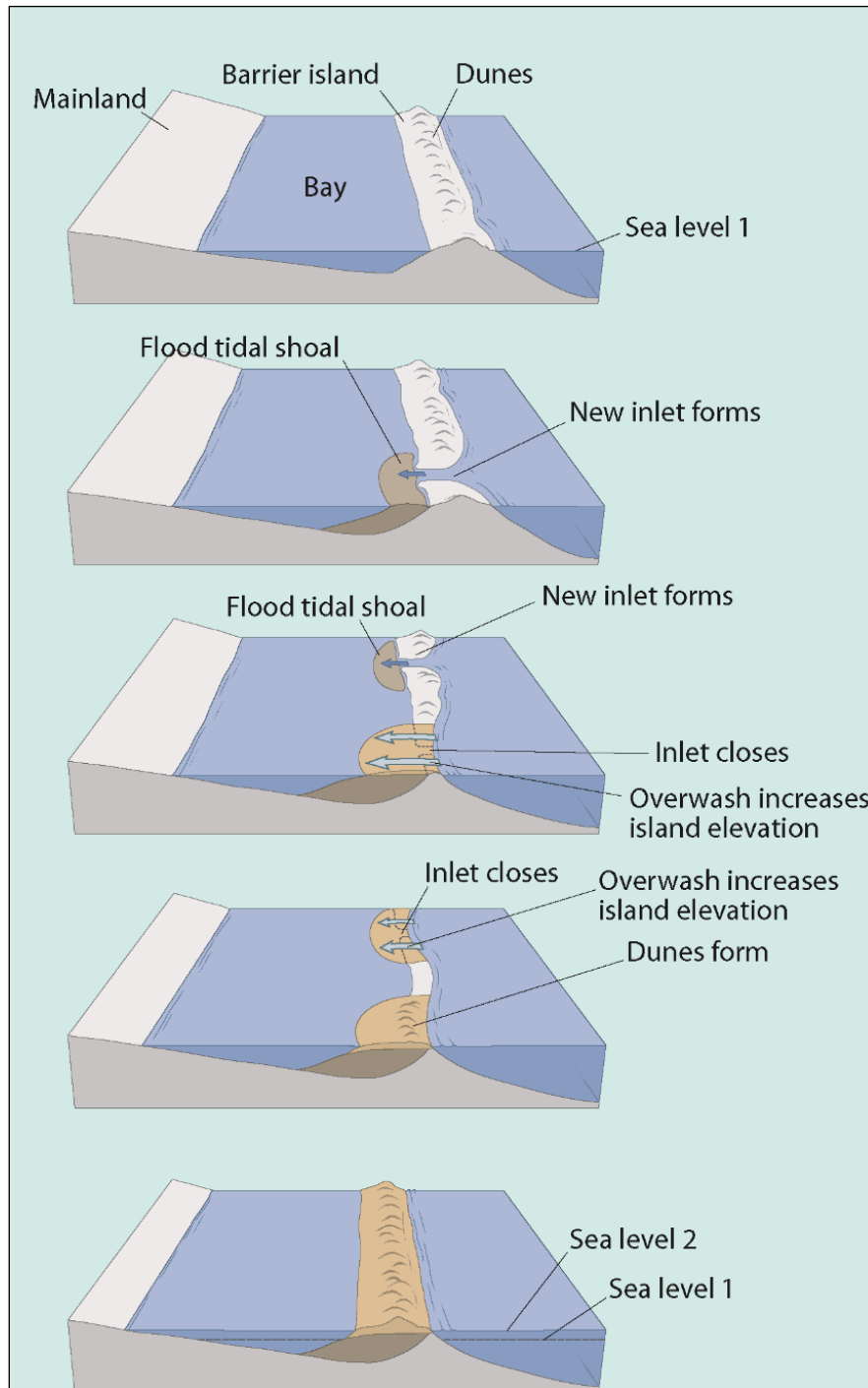


Figure 3 – A simplified schematic of barrier island migration on the south shore of Long Island in response to sea level rise. Inlets transport sand to the bays in the form of tidal shoals which provides the platform that allows the island to move landward. Overwash processes then raise the elevation of the island. This is a slow process occurring over periods of hundreds to thousands of years (Tanski 2012).



Existing Conditions

The north shore (bayside) of Fire Island is protected from open ocean conditions, so it experiences a smaller tidal range and wave heights, allowing salt marshes to form.

An oceanographic buoy was deployed in the middle of Great South Bay from 1 November 2011 to 30 April 2013 to support a beach study at Sailors Haven. Data from this study are presented here as existing typical tide and wind conditions for all four hot spot erosional sites. Fetch distances for generation of waves are 7.5 miles to the northwest and 9.3 miles to the northeast. Great South Bay experiences microtidal conditions, where mean tidal range is 0.69 feet; spring tidal range is 0.79 feet (Nordstrom et al 2016). Water depths in the bay are often less than 5 feet within 0.6 miles of the shoreline (Nordstrom et al 2016, USACE 2004).

Wind conditions from the 2011-2013 (18 month) deployment period are presented in Figure 5. The shoreline trend for all four sites is nearly east-west, and winds from the south do not contribute to generation of large bay waves that might impact the bayside of Fire Island. The strongest winds (Figure 5) impacting the bayside were from the west and north. Based on the frequency and magnitude of winds blowing at an acute angle from the west, it is expected that longshore sediment transport is from west to east (Nordstrom et al 2016).

In addition to natural energy from wind and waves, these four sites are located within a seasonal ferry service from Sayville, NY that provides transportation to Sailors Haven, Cherry Grove, Fire Islands Pines, and Water Island. Talisman/Barrett Beach is located west of the Sayville-Water Island ferry route; Carrington Track is located between the Sayville-Fire Island Pines and Sayville-Cherry Grove ferry routes; and Sailors Haven has a ferry route that enters the marina (figure 6). These ferry wakes create an increased energy environment from June through September, transporting passengers 7 days a week approximately every 2 hours during daylight hours (Sayville Ferry Service 2022), which in conjunction with wake generated by recreational boat users contributes to increased shoreline erosion rates in the area.

The ferry terminals on Fire Island are monitored as part of shellfish surveys by the New York State Department of Environmental Conservation (NYSDEC), as shown by the green and yellow sampling symbols on figure 6 (NYSDEC 2022). This monitoring shows that there are viable and clean shellfishing conditions at each of the terminals. While there are no sampling locations at each of the NPS sites of interest, it is probable that these shellfish growing conditions are continuous along the north shore of Fire Island.

Figure 4. Water depths in Great South Bay in meters. Approximate NPS locations of interest are denoted with black stars (adapted from USACE 2004).

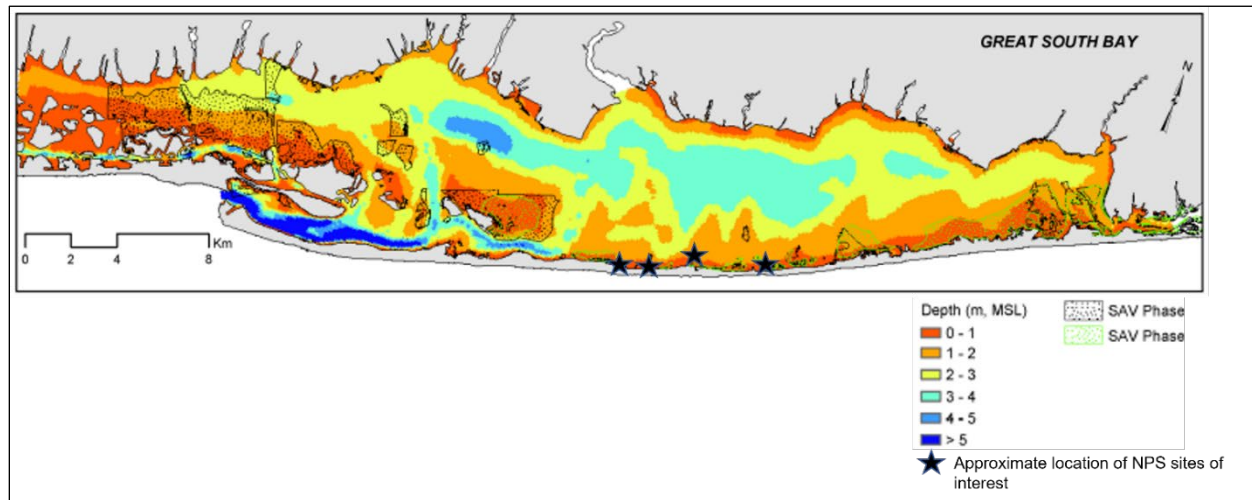


Figure 5. Wind rose for winds blowing onshore of the north shore of Fire Island. Data are hourly averages from the buoy shown in figure 4 for 1 November 2011 to 30 April 2013. The shoreline trend is azimuth 86-266. The spoke lengths indicate the percentage of time winds blow from that direction and the colors within each band indicate the strength of the wind (Nordstrom et al 2016).

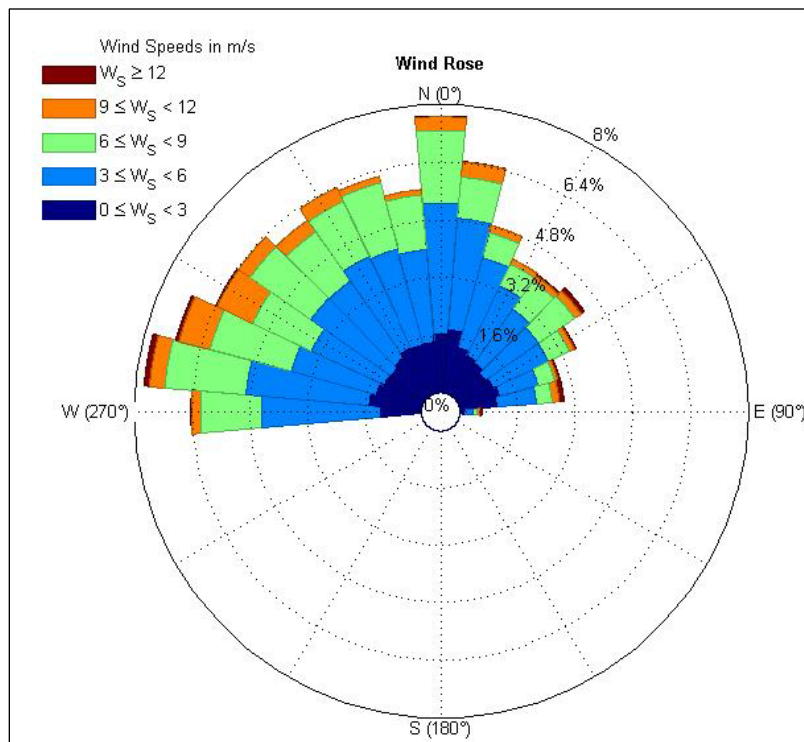
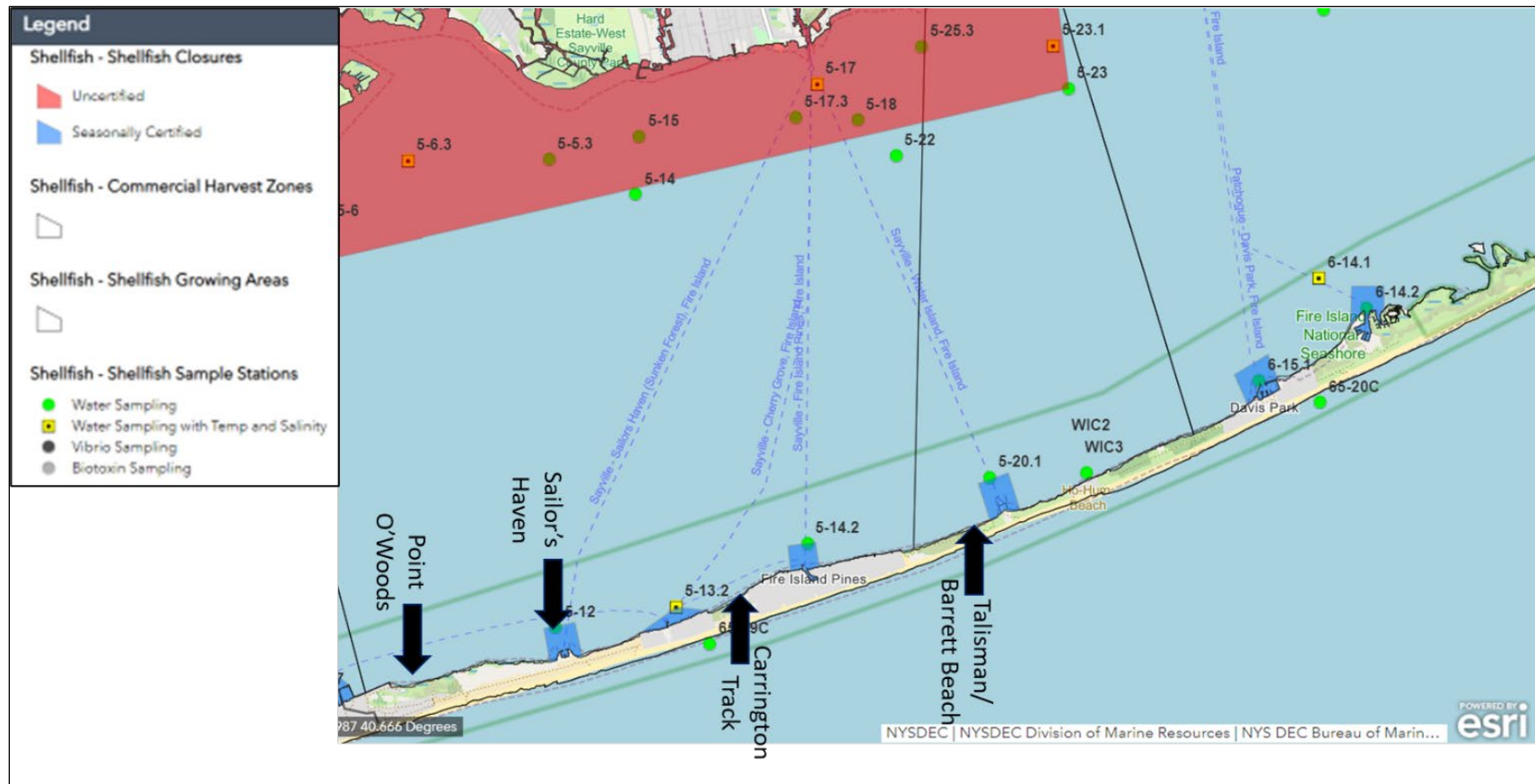


Figure 6. New York State Department of Environmental Conservation (NYSDEC) shellfish mapper, showing areas of seasonally certified shellfishing (blue shading), shellfish sampling stations (green or yellow symbols), and ferry routes (dotted blue lines) (adapted from NYSDEC 2022).



EXISTING MANAGEMENT STRATEGY

The overall management of Fire Island has focused on nourishing ocean side beaches with dunes mechanically maintained at set locations and dimensions. Minimal nourishment has been provided to the north shore (bayside) of the island. While this plan is proactive in maintaining these highly valuable oceanside resources, it was discussed in the workshop if Fire Island will be managed in the future to allow for rollover. Rollover is the natural process by which barrier islands migrate landward where sediment is moved from oceanside dunes to bayside backshore areas to create areas for new dunes to build (NPS 2021a).

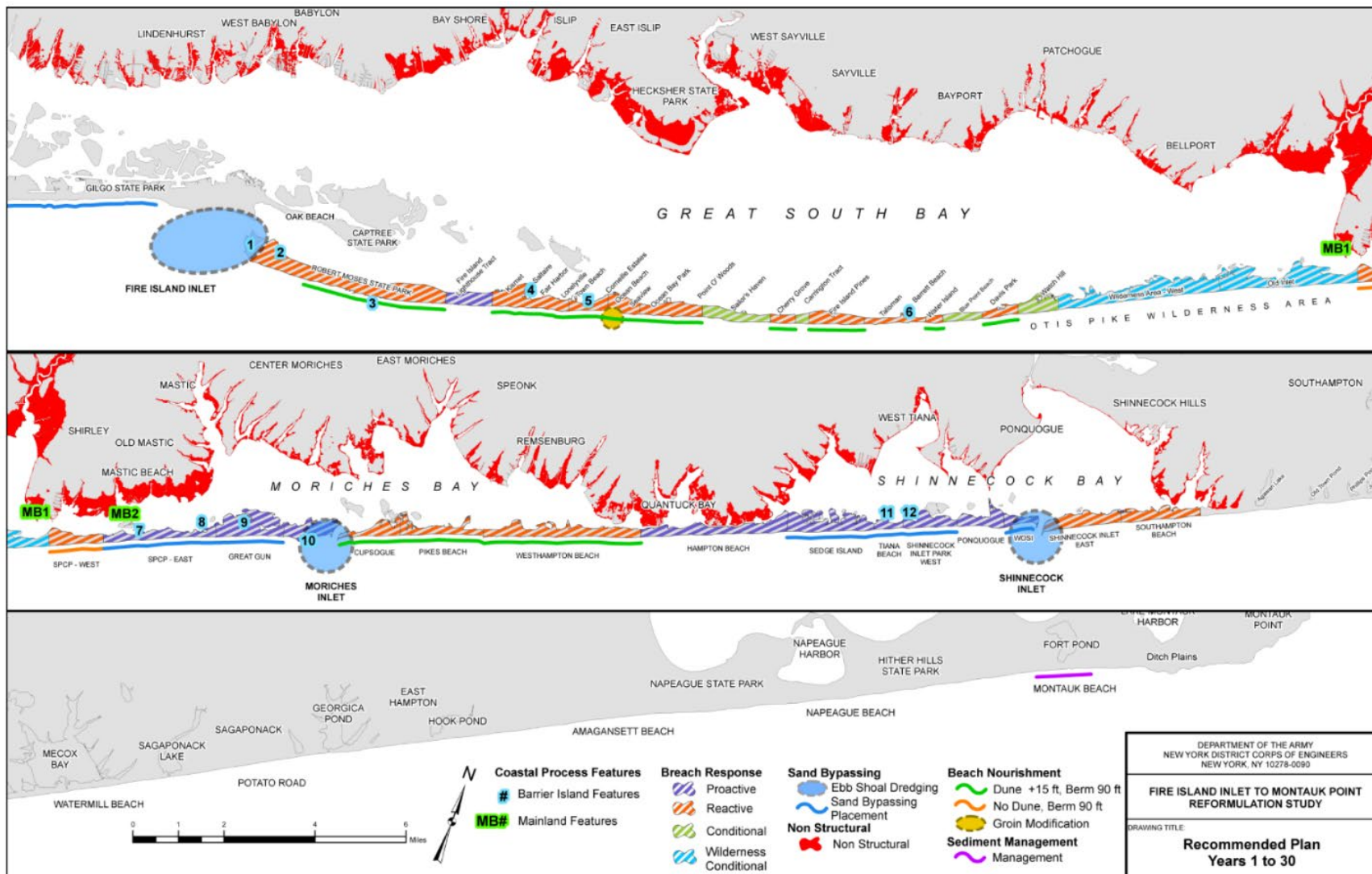
The Fire Island to Montauk Point, New York Combined Beach Erosion Control and Hurricane Protection Project (FIMP) was developed “to identify a long-term solution to manage the risk of coastal storm damages along the ... Atlantic Coast of Long Island, New York” (USACE 2020a) by managing risk to Fire Island, which protects Long Island from storm events. The following details of this plan are provided in USACE (2020a). FIMP was initiated in 1960 but only recently approved (USACE 2020a) and funded, receiving \$1.7 billion in federal funding in May 2022. Dredging and nourishment that has occurred to date on Fire Island (such as that discussed above) was all completed as part of interim projects or state or locally funded projects. The main goals of FIMP include dune management/nourishment along the south shore (oceanside) of Fire Island, breach management, inlet management, and coastal processes restoration. FIMP dune and breach management projects are shown in figure 7. Specifically, for NPS federally owned lands:

- Figure 7 shows that FIMP only includes dune management/nourishment on the oceanside beaches, not on the bayside. The FIMP dune management plan includes nourishing and constructing dunes at a specific height in a specific location, artificially keeping them in a static position and lessening the possibility of material migrating to the north, bayside shores. Because the FIMP dune management occurs along the oceanside of the National Park Service, there is a greater probability that through overwashes and aeolian transport, material can migrate to the bayside.
- There are two different breach management methods shown in figure 7 for four proposed study areas within NPS federally owned lands, reactive closure, and conditional closure. Reactive closure applies to Talisman because “there is an acknowledgement of the high vulnerability of breaching, deep water in the back bay, and new infrastructure that connects communities east and west of this location” (USACE 2020a). Conditional closure allows a short period of time to assess if the breach will close naturally. If on day 60 the breach has not closed naturally, mechanical closure is to be implemented (USACE 2020a). As noted previously, these planned methods to close a breach eliminate a transport pathway for sediment to be delivered to the bayside shores.
- Inlet management for the Fire Island Inlet states that the inlet will be dredged on a two-year interval; the expected 1.3 million cubic yards of material per cycle is to be placed at Gilgo and Robert Moses State Park (oceanside) beaches.
- Coastal processes restoration in the area of the NPS bayside sites of interest includes reestablishing the natural coastal processes along the Great South Bay shoreline at Sites T-2 (Sunken Forest, located west of Point O’Woods), and T-3 (Reagan Property, located between Carrington Tract and Talisman) by removing/burying bulkheads, regrading eroding shorelines,

and stabilizing shoreline using vegetated gabions. The timing of these activities is not discussed, but when completed, these actions will likely improve sediment transport along the bayside shoreline.

In addition to dredging by USACE, routine dredging happens in numerous sites along Fire Island to maintain navigation channels to Fire Island communities and NPS facilities. The Seashore maintains channels for access to three areas: Sailors Haven, Barrett Beach/Talisman, and Watch Hill. The frequency of dredging varies based on sedimentation rates, storm events, and funding, but the Seashore has noticed an increase in the frequency of dredging is required. Both Watch Hill and Barrett Beach/Talisman are scheduled to be dredged in 2022. Additionally, many of the communities on Fire Island dredge their channels, with frequency varying for the same reasons noted above for the Seashore.

Figure 7. FIMP recommended plan for Fire Island sediment management (USACE, 2020a).



SEA LEVEL RISE

To understand the existing coastal flood risk, the corresponding Federal Emergency Management Agency (FEMA) flood insurance study and flood insurance rate map were reviewed to determine the base flood elevation (BFE) for the region (FEMA 2009). The BFE represents the 100-year flood event, including the effects of both storm surge and wave heights.

To understand future coastal flood risk in the study area, relative sea level rise (RSLR) projections calculated for the region (available from the Montauk, NY NOAA station, 851056) were added to existing tidal datum information. Tidal datum information for the study area is represented by the nearest NOAA tidal station, the Seaview Ferry Dock station (8514779; NOAA 2022a).

The regional interagency projections are shown in table 1 for five different scenarios, described in Sweet et al. 2022. The estimated rate of RSLR fluctuates significantly depending on the projected impacts of climate change. For a conservative approach, the recently updated 2022 Intermediate-High scenario was used to assess the future risk to the area of interest. Using this projection scenario, the amount of estimated RSLR is 1.58 feet by 2050 and 5.24 feet by 2100. Note these values are bolded in table 1. The aerial in figure 8 shows that the area of interest would experience significant flooding during the 100-year event and this flood risk would increase as a result of RSLR.

Table 1. Relative Sea Level Rise Scenarios (Sweet et al. 2022)

Year	Low (feet)	Intermediate-Low (feet)	Intermediate (feet)	Intermediate-High (feet)	High (feet)
2030	0.65	0.70	0.73	0.77	0.76
2040	0.89	0.98	1.04	1.13	1.17
2050	1.12	1.26	1.38	1.58	1.70
2060	1.31	1.53	1.77	2.10	2.40
2070	1.47	1.79	2.20	2.76	3.31
2080	1.59	2.04	2.71	3.48	4.35
2090	1.73	2.28	3.34	4.34	5.54
2100	1.87	2.50	4.03	5.24	6.67
2150	2.60	3.90	7.31	8.64	11.83

Notes: baseline year 2000

Based on the review of the four focus areas, each site has similar offshore elevations and shoreline slopes. Carrington Tract was chosen as the representative location for this review as it is the approximate geographic midway point between all four sites. A cross-sectional analysis was performed to help visualize existing and future coastal risk. A shore perpendicular transect was established in the study area, shown in the bottom panel of Figure 8, and the elevations along this transect were extracted from the USACE topobathymetric model (USACE 2020b).

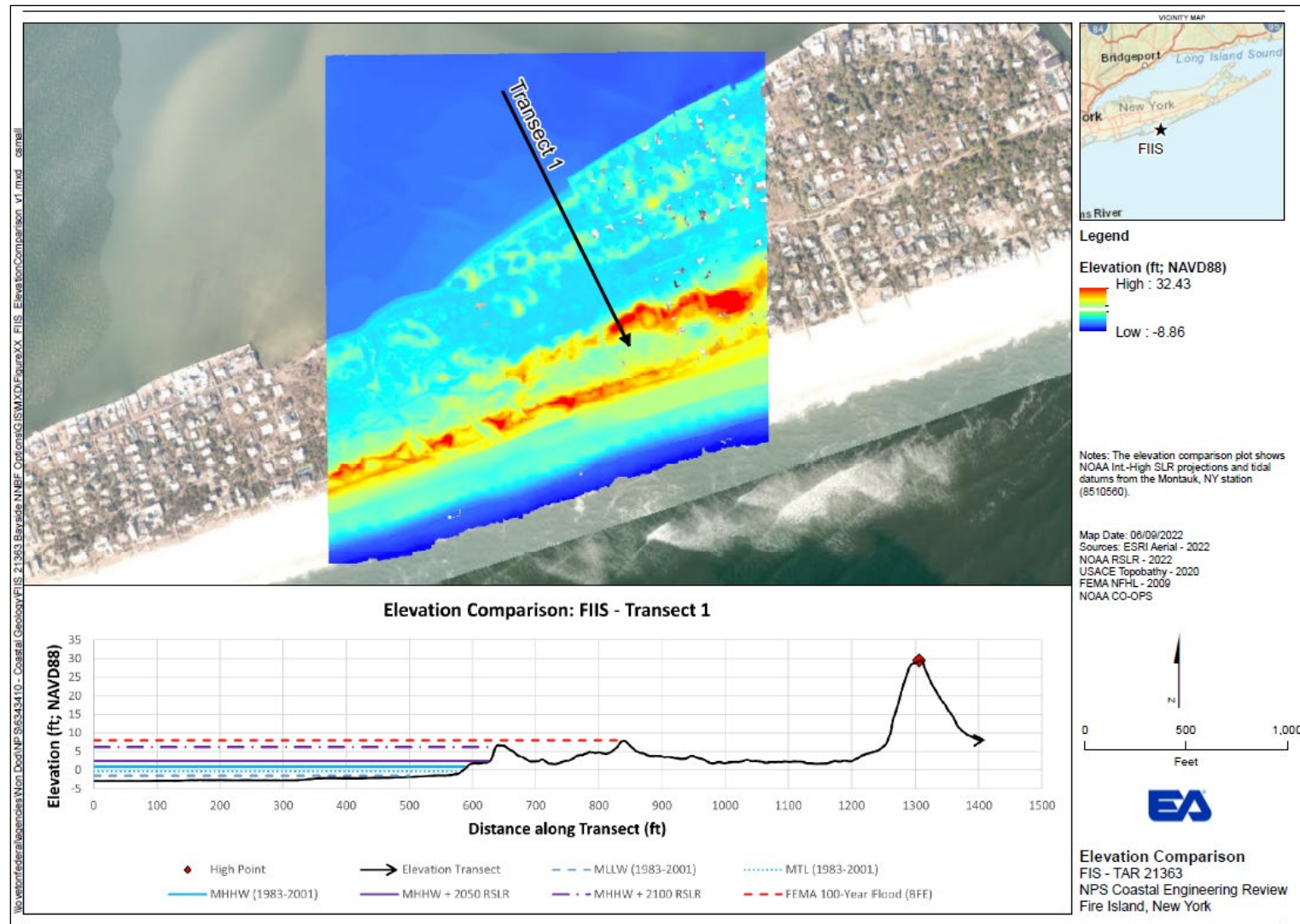
The NOAA tidal datums are referenced to the current National Tidal Datum Epoch (NTDE) that covers 1983-2001 and has a baseline year of 1992 (mid-point). The RSLR projections have a baseline year of

2000. The NOAA-published northeast vertical offset of 0.10 feet was used to account for the gap in SLR between the two baseline years (Sweet et al. 2022) so that the final projection elevations shown in the lower panel of figure 8 are referenced to NTDE.

The following elevations were plotted to compare scenarios, all referenced to NAVD88 and NTDE:

- The FEMA 100-year flood value of 8 feet (FEMA 2009)
- The mean higher high water (MHHW) datum for the NOAA Seaview Ferry Dock station's (8514779) of 0.88 feet (NOAA, accessed 2022)
- The mean tide level (MTL) datum for the NOAA Seaview Ferry Dock station's (8514779) of 0.16 feet (NOAA, accessed 2022)
- The mean lower low water (MLLW) datum for the NOAA Seaview Ferry Dock station's (8514779) tidal datum of -0.56 feet (NOAA, accessed 2022)
- The 2050 projected MHHW value of 2.6 feet for 2050, calculated by adding the NOAA Intermediate-High RSLR projection (Sweet et al. 2022) and the regional offset of 0.10 ft for 1992-2000 to the current MHHW datum
- The 2100 projected MHHW value of 6.22 feet, calculated by adding the NOAA Intermediate-High RSLR projection (Sweet et al. 2022) and the regional offset of 0.10 ft for 1992-2000 to the current MHHW datum

Figure 8 – Relative Sea Level Rise Profile Comparison for current conditions with year 2050 and 2100 projections.



REVIEW OF THE FOUR SITES

This section provides a review of each of the four sites (shown in figure 2), listing the likely benefits and difficulties associated with each. Due to the general location of all four sites within the confines of FIIS, they will present significant logistical challenges, as construction access will be difficult from both directions. There are limited access roads from the land side, and the bayside depths of 5 feet up to a half mile offshore (Nordstrom et al 2016) will limit the size and capacity of construction barges.

Based on the physical data collected during the 2011 – 2013 buoy deployment by Nordstrom et al (2016), it can be assumed that tidal currents are low in the area due to the small tidal range in Great South Bay; therefore, the dominant energy affecting the system at each of the four sites will derive from wind and waves, particularly during storms. The NPS workshop identified multiple challenges to designing effective coastal resilience alternatives. For any given design option of interest, the full engineering design will require additional data collection, such as bathymetry, wave dynamics, and current velocities, to ensure best outcomes. As noted previously, this barrier island is dynamic and continues migrating landward, as it has historically. The southern coast (oceanside) beach of Fire Island is maintained through the FIMP agreement, this maintenance is intended to maintain beach width lost to storm events and could slow migration of the island. Erosion mitigation options for the north shore (bayside) that are adaptable or easily adjusted should be prioritized so that they can be implemented as needed to address future shoreline changes.

Talisman

Also referred to as Barrett Beach, Talisman is the easternmost at-risk area identified by the Seashore. This area is approximately 2,400-feet long and the shoreline has eroded approximately 30-60 feet since 1969, increasing from east to the maximum loss occurring at the westernmost extent. Talisman is located on the narrowest area of the island where a potential pilot design could be selected, measuring approximately 500-feet wide from the highest dune elevation on the ocean side to the bayside. This makes the area a potential site for overwash and possible breaching during a severe storm event (figure 9). To the west of this site there is a mile of hardened shoreline in the form of bulkheads before reaching the Carrington Tract site. Midway along the hardened shoreline to the west is the Sayville ferry terminal, providing service to Fire Island Pines.

The breakout group from the FIIS workshop noted that ferry channel dredging and placement plans are important as a potential nourishment source (NPS 2021a). This channel is not under the jurisdiction of USACE. The community in this area is dedicated to increasing the submerged aquatic vegetation (SAV) population, citing it as an option to reduce energy reaching the shore (NPS 2021a). Additionally, the breakout group noted that local communities have a funding mechanism for beach nourishment that can be used, however, details on this were not provided (NPS 2021a).

Figure 9 – Talisman showing approximately 30 to 60 feet of shoreline erosion between 1969 (red line) and 2021 imagery (NPS 2021a).



Carrington Tract

This 1,700-foot section of shoreline is located between long sections of private property armored by engineered structures. To the east of this area is a mile of hardened shoreline before reaching Talisman/Barrett Beach, with the Sayville Ferry terminal located in the middle of this section; to the west is a half mile of hardened shoreline before it reaches an unprotected beach that flanks the western side of Sailors Haven Marina. This shoreline has lost an almost uniform 165 feet due to erosion and SLR since 1969 (figure 10). In addition to erosion, this area has low-lying roads that flood during periods of heavy rain and winter thaw, making emergency egress difficult and posing a general public safety risk.

The breakout group from the FIIS workshop noted concern for the Sayville Ferry wakes as well as an overall lack of physical data on fetch, sand transport, groundwater, wind, and wave direction/energy. There was also a concern about groundwater movement and stormwater runoff during storms draining to the bay on the Cherry Grove side (western side of site). There was a suggestion to partner with Cherry Grove to help regulate shellfishing in the area and to create paths to better protect this site (NPS 2021a).

Figure 10 – Carrington Tract showing approximately 165 feet of shoreline erosion between 1969 (red line) and 2021 imagery (NPS 2021a).



Sailors Haven

The Sailors Haven Marina is protected by a wooden sheet pile bulkhead that projects about 377 feet into the bay (figures 11 and 12). The beach on the western side of the marina has experienced up to 60 feet of erosion since 1969 and the beach on the eastern side has lost approximately 100 feet of shoreline in this same time span. The sides of the bulkhead are comprised of a series of segments with different orientations relative to shoreline trend. The landward bulkhead segment on the west side is built at a 30-degree angle to the shoreline to displace the location of wave scour farther west. The differences in orientation along the sides of the structure result in a complex pattern of wave reflection. (Nordstrom et al 2016).

The marina's position creates an obstruction to the longshore sediment transport along the bay shoreline, and recreational vessel traffic using the marina create wakes that likely exacerbate ongoing erosion. A sediment feeder beach pilot project was created adjacent to this site in 2011 where 1,747 cubic yards of material dredged from the marina entrance channel were placed along a 246-foot length of upland at a

height similar to the eroding bluff (Nordstrom et al 2016). Lessons learned from this study are discussed in the following sections.

The breakout group for this site at the FIIS workshop supported nourishment as well as a structural solution to keep sand on the shoreline, such as construction of living shorelines on either side of the marina or a structure that would slow the movement of a feeder beach, similar to the one attempted by Nordstrom et al 2016 (NPS 2021a).

Figure 11 – West Side of Sailors Haven Marina showing approximately 60 feet of shoreline erosion between 1969 (purple line) and 2021 imagery (NPS 2021a).



Figure 12 – East Side of Sailors Haven Marina showing approximately 100 feet of shoreline erosion between 1969 (red line) and 2021 imagery (NPS 2021a).



Point O'Woods

Located at the westernmost end of the identified area, Point O'Woods is the widest section of island, which decreases the probability of overtopping from the ocean side (figure 13). There is a marina and hardened seawall to the west of this site, both of which interrupt sediment transport. A logistical construction concern is that the main road is located much closer to the ocean than the bay. Although figure 12 does not include historic shoreline positions, it can be assumed that the current shoreline used to be continuous with the hardened shoreline to the west of it. This would mean that the current shoreline has eroded approximately 50-70 feet since 1969.

The breakout group from the workshop brought up two important factors to consider for all bayside locations: quality of bottom material (soft mud could create issues for construction and placement of alternatives) and ice scour that can occur in winter (NPS 2021a). Both factors could impact any potential solution at the sites.

Figure 13 – Aerial image of Point O'Woods showing the 2021 shoreline (NPS 2021a). While aerial imagery from 1969 is not available for this site, assuming it was contiguous with hardened features, the current shoreline would have eroded approximately 50-70 feet since 1969.



POTENTIAL COASTAL RESILIENCE OPTIONS

The bayside erosion on Fire Island is accelerating and is anticipated to worsen with the effects of climate change including SLR. The National Park Service has previously examined and rejected the implementation of hardened, engineered options such as riprap and seawalls, as these options provide limited, local relief while exacerbating the erosion at adjacent areas. This section provides a discussion of possible options for implementation of various nature-based feature alternatives as well as overall management policies and adaptive capacity considerations. Natural and nature-based features include dunes, marshes, submerged aquatic vegetation, marine forests, beach nourishment, and oyster reefs. These natural features provide important ecosystem services including wave attenuation, reducing shoreline erosion, increasing shoreline protection, and providing increased habitat opportunities for flora and fauna.

The following bayside recommendations relating to nature-based solutions as well as other management-based strategies were presented in the Fire Island Integrated Climate Change Vulnerability Assessment

(Babson 2021). The recommendations have been organized into categories for presentation in this document and are discussed in the following sections:

Nature Based Wave Dissipation Features

- Evaluate options for wave dissipation features such as oyster castles and wave attenuation devices.

Beach Nourishment

- Incorporate system-wide sediment transport and geomorphology into any localized management decisions for the bayside system
- Plan for and continue studying feeder beaches. Feeder beaches are a management option for areas impacted by sediment disruption due to bulkheads and marinas.

Management Policies

- Allow breaches to persist and allow overwash to the bayside: this is a long-term way the bayside system can maintain its sediment budget. Under current policy, which the Seashore helped develop, only breaches within the wilderness can be evaluated for allowing to persist and evolve naturally. Breaches in other areas of the Seashore must be closed by mechanical measures if they do not close within 60 days of formation (USACE 2020a).
- Initiate discussions with federal and state partners regarding the use of dredged material from planned dredging projects to assess if some dredged materials can be used for bayside shoreline restoration.

Adaptive Capacity

- Plan for changes at Sailors Haven. The proximity between Sailors Haven and the Sunken Forest, a globally rare maritime forest habitat, presents potential conflicts between what should be done to protect different resources.
- Consider longer term options for replacing facility functions: these could include replacing the maintenance shop or housing at vulnerable locations to mobile facilities such as on a barge that could be removed in storm season.
- Lead conversations about preparing for change with the communities and partners. As the Seashore considers more creative adaptation options, regulatory agencies will also need to consider more creative options, especially within the communities. While some actions will be reactive to storms, preparation for change will need to be proactive.
- While the dynamic nature of some habitats and landforms means that, in general, many natural resources are at low or moderate vulnerability, the characteristics that enable them to respond to change are limited in areas where they intersect with infrastructure and other resources.
- Include geomorphic dynamism to advise facilities and resource management actions to help further understand and guide action.

Nature Based Wave Dissipation Features

Each of the four sites would benefit from wave dissipation features. These can take a variety of forms including wave attenuation devices and oyster castles, as well as nature-based options including SAV and marsh restoration or creation.

Wave Attenuation Devices/Oyster Castles (WADs) – WADS have had success reducing erosion in protected, restricted tidal range environments similar to the sites at FIIS, in areas such as Louisiana and Florida along the Gulf of Mexico. These features are placed offshore in a grid-like pattern to dissipate wave energy before it reaches the shore and can lead to sediment accumulation on the shore-side of the structures. These structures can also be designed to act as recruitment sites for filter-feeders (oysters and clams) which can also add to the wave attenuation effectiveness. These structures are sometimes known as oyster castles or reefballs and are seeded with native shellfish to reduce wave impact, provide enhanced ecological habitat for other biota, and improve water quality. An example deployment is depicted in figure 14. The structures are built out of porous concrete, however, new technologies such as 3D printers can incorporate dredged material within the structures and produce a more natural form to the units. This type of technology could greatly improve the sustainability of production and deployment of WADs by lessening the need for resources to create the structures and reducing transport requirements of materials.

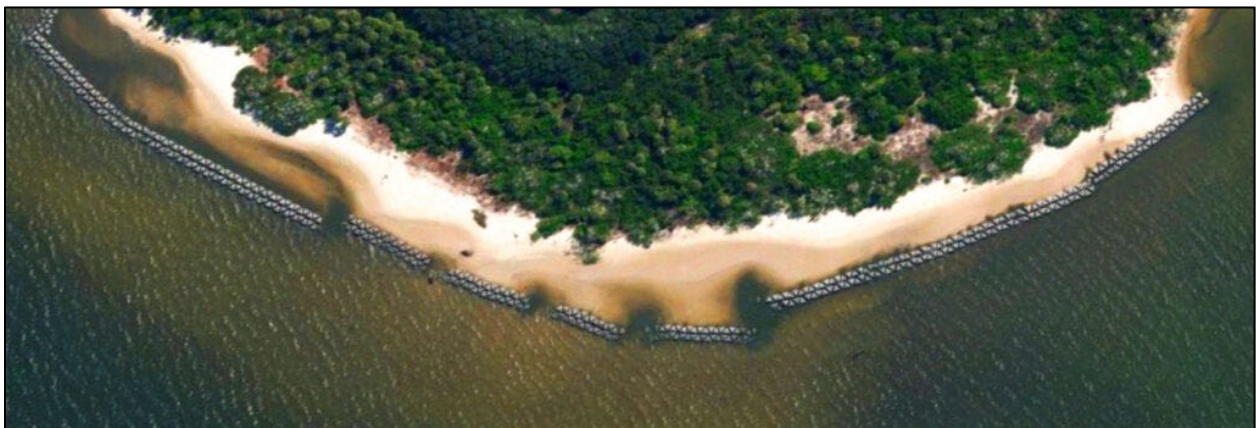
The design height and distance offshore of these structures are determined by storm wave heights and area of the active coastal zone, therefore, additional data or modeling would need to be completed to determine the appropriate design and placement at each site. Figure 15 shows an example of a beach which has accreted in an area immediately behind a deployed structure.

The length of WAD arrays would vary with location, starting at existing hardened structures and tying in to either neighboring structures or local topography, as appropriate. The height of these features can be designed to accommodate for SLR and for being adaptively raised in the future, depending on the specific type designed.

Figure 14 – An example of Oyster Castles (Mordecai Land Trust 2020)



Figure 15 – An example of continuous lines of Wave Attenuation Devices deployed offshore to mitigate erosion at an Audubon site in Florida, from Living Shoreline Solutions (livingshorelinesolutions.com, 2022).



Submerged Aquatic Vegetation Restoration – Submerged Aquatic Vegetation (SAV) restoration is ongoing across multiple bays of the south shore of Long Island (NPS 2021a). SAV naturally attenuates wave energy and improves water quality while also providing habitat for marine life. Shinnecock Bay, located immediately east of Great South Bay and connected through Narrow Bay, was recently recognized as a new “Hope Spot” by Mission Blue, an international organization that supports the protection of oceans worldwide through decade-long efforts by Stony Brook University researchers (Stony Brook News 2022). This collaborative effort has attributed its SAV restoration success to increasing filter-feeder populations (clams, oysters, etc.), which then improve water quality and overall clarity. This allows light to penetrate to deeper depths, creating conducive conditions for SAV to thrive.

Although SAV naturally attenuates wave energy and slows coastal erosion, it is not as robust as other wave attenuation features. SAV measures are best used in addition to wave attenuation options to increase overall water quality and environmental health. SAV is also sensitive to SLR and thus adaptation measures, including possible sediment placement, would be needed in the future to maintain viable SAV beds in the area.

Tidal Marshes (Wetlands) Creation or Restoration – Tidal marshes, a type of wetlands, also provide an opportunity for wave dissipation. Tidal marshes are sensitive to water depth and are therefore more successful when designed at appropriate elevations within existing tidal ranges. Achieving these target elevations within the project areas could be achieved with placement of additional sediment as part of beach nourishment (see discussion below). These areas in the intertidal zone could then be seeded with wetland plantings.

Factors to be considered for implementing tidal wetland restoration include turbidity/water clarity, salinity, depth, and water temperature, which will also dictate possible species to include. As sea level increases, an adaptive management strategy such as thin layer placement can increase elevation of the beds to allow the vegetation to persist as the water rises.

Living Shoreline –The combination of elements described in this section including oyster castles, marsh, and SAV, along with beach or sediment nourishment can create what is commonly known as a living shoreline. An effectively designed living shoreline can protect against erosion from wave energy by using native vegetation and sediment and is a commonly deployed strategy (Hardaway et al. 2013). Living shorelines also provide ecosystem services, such as habitat, water quality improvement, and food production. A living shoreline design may or may not include, depending on wave energy, an integrated structure parallel to the shore which could be comprised of natural elements (Bridges et al. 2021), such as oyster castles. Additional sediment may be added behind the structure on which wetland and transitional upland vegetation would be planted (CCRM 2019).

Wave Dissipation Features by Site – Additional wave data will be needed for each of the NPS sites of interest. While tide ranges and fetch distances are small within Great South Bay, the sites are within active seasonal ferry routes and winter storms are common in the area, both of which add higher energy waves to the system. Potential designs for wave dissipation features and other measures at each site are provided in table 2.

Table 2. Potential wave dissipation feature deployment options for each NPS site

NPS Site	Proposed Design of Wave Dissipation Feature	Additional Notes
Talisman	▪ Tie in to hardened shoreline at easternmost end ▪ Continuous line parallel to shore and connect back to existing shoreline to the west to break wave energy coming from the Water Island ferry service, length of approximately 2,000 feet. ▪ WADS/oyster castles provide fish passage by their design; artificial reefs to include gaps every ~100 feet to allow for this. ▪ Approximate footprint area of this feature is 20,000 square feet (0.5 acre)*	▪ SAV restoration was cited by this site breakout group as a goal and would be feasible landward of wave dissipation features ▪ Tidal wetlands could also be created if sediment/beach nourishment is incorporated.
Carrington Tract	▪ Continuous line parallel to shore, tying in to hardened shorelines to the east and west of site, length of approximately 1,750 feet ▪ WADS/oyster castles provide fish passage by their design; artificial reefs to include gaps every ~100 feet to allow for this. ▪ Approximate footprint area of this feature is 17,500 square feet (0.4 acre)*	▪ SAV restoration possible at this site ▪ Tidal wetlands could also be created if sediment/beach nourishment is incorporated.
Sailors Haven	▪ Diagonal alignment from marina entrance outwards to existing shoreline, immediately fronting the areas of high erosion to the east and west of the marina. Each about 800 feet in length. ▪ WADS/oyster castles provide fish passage by their design; artificial reefs to include gaps every ~100 feet to allow for this ▪ Approximate footprint area of this feature is 16,000 square feet (0.4 acre)*	▪ SAV restoration possible at this site ▪ Tidal wetlands could also be created if sediment/beach nourishment is incorporated.
Point O'Woods	▪ Tie in to hardened shoreline at easternmost end ▪ Continuous line parallel to shore and connect back to existing shoreline to the west, 2,500 feet in length ▪ WADS/oyster castles provide fish passage by their design; artificial reefs to include gaps every ~100 feet to allow for this ▪ Approximate footprint area of this feature is 25,000 square feet (0.6 acre)*	▪ SAV restoration possible at this site ▪ Tidal wetlands could also be created if sediment/beach nourishment is incorporated.

* This assumes a maximum size layout where WADS are placed in double rows for the full length of the site. Each WAD is assumed to be 4-feet wide and there is approximately 2 feet between each WAD for a total width of 10 feet.

Beach Nourishment

The bayside system would undoubtedly benefit from the recommendation to incorporate system-wide sediment transport and geomorphology considerations into any localized management decisions (Babson 2021). The patchwork of hardened shorelines has removed sediment from the system, disrupting natural sediment transport patterns and exacerbating erosion along the unprotected areas of shoreline. Continuing to study feeder beaches and considering some other forms of beach nourishment are excellent recommendations for the bayside system.

Beach nourishment is an option that would need continued maintenance, monitoring, and a reliable sediment source. Nourishment combined with the wave attenuation features would decrease the frequency of maintenance and increase the probability of success. Modeling hydrodynamics and waves would be required at each site to maximize design life of beach nourishment and to understand what the equilibrated nourishment profile would conform to.

There are three potential forms of nourishment for each NPS location, described below.

In-place nourishment – This would include placing a set volume of material in a template of set dimensions at each site. The microtidal environment on the bayside and any existing salt marsh habitat are sensitive to sudden elevation changes. Due to the minimal existing beach at each site, the template would need to be extensive and could be set to match historical shorelines.

Landward or offshore feeder beaches – The landward feeder beach would be a similar design to the feeder beach at Sailors Haven, where sediment is placed up-current. This nourished sediment would then migrate with normal sediment transport to nourish adjacent beaches. The offshore feeder beach form of nourishment would include creating an offshore stockpile of material that migrates shoreward to nourish the shoreline. Modeling of each site would be required to determine if this option is feasible; hydrodynamic conditions need to be conducive for this process to be successful.

The feeder beach study at Sailors Haven provides important physical data for the Great South Bay as well as lessons learned for beach nourishment in this area. During this project, sediment from the feeder beach moved downdrift (westward) of the fill/nourished area rapidly in wave-like pulses, causing accretion of the inner low tide terrace, burying marsh peat outcrops on the foreshore, and creating a higher and wider washover platform on the marshes. It caused landforms downdrift in several stages — from erosion (pre-nourishment) to accretion to stability to erosion again.

A suggested outcome of this study was to stockpile more dredged material upland and place it along the shore more frequently but in smaller quantities so that downdrift areas could adjust to the influx of material (Nordstrom et al 2016). This option may work well at Sailors Haven, where there is high quality material that is dredged from the access channel frequently. Modeling to optimize the volume and length of the feeder beach to determine how often it would need to be replenished would be required.

For the remaining three sites, nourishment material would need to be identified for this to be a feasible option. The Talisman breakout group noted that local ferry channels are not federal and therefore are not managed by FIMP. Routine dredging activities along Fire Island, by the Seashore and communities both, may provide reliable sediment sources. Further research is needed to determine where this material would

be disposed. Identified material would need to be tested to ensure it is clean and compatible with placement sites.

Potential nourishment design configurations for each site are provided in table 3. As noted in the previous section, portions of the nourished areas could be placed at elevations conducive to establishing tidal marsh to improve resilience of the sediment to transport forces. NOAA has 2020 DEM data available for areas above low tide, which can be used to aid in future design efforts (NOAA 2022b).

Table 3. Potential beach nourishment deployment options at each NPS site of interest

NPS Site	Proposed Design	Additional Notes
Talisman	- Placement for a feeder beach at the eastern-most extent of area to allow east to west sediment transport - Proposed in-place nourishment would be placed at 2.6 ft NAVD (2050 projected MHHW) for the full 2,000 ft length. The 2020 available LiDAR has missing data for this site; however, the other sites were used to estimate placement volume range: 8,600 to 23,200 cubic yards depending on berm width*	- Expect time of year restrictions for placement - Need to identify source of material
Carrington Tract	- Placement for a feeder beach would be at the eastern-most extent of area to allow east to west sediment transport - Proposed in-place nourishment would be placed at 2.6 ft NAVD (2050 projected MHHW) for the full 1,750 length. Placement volumes are estimated to range from 7,500 to 20,300 cubic yards depending on berm width used*	- Expect time of year restrictions for placement - Located between multiple Sayville ferry terminals; dredging these could be potential material sources
Sailors Haven	- Placement for a feeder beach would be at the eastern-most extent of area to allow east to west sediment transport - Proposed in-place nourishment would be placed at 2.6 ft NAVD (2050 projected MHHW) for the full 1,500 length. Placement volumes are estimated to range from 6,400 to 17,400 cubic yards depending on berm width*	- Expect time of year restrictions for placement - Marina dredging provides reliable source of material, would need to test based on regulatory requirements
Point O'Woods	- Placement for a feeder beach would be at the eastern-most extent of area to allow east to west sediment transport - Proposed in-place nourishment would be placed at 2.6 ft NAVD (2050 projected MHHW) for the full 2,500 length. Placement volumes are estimated to range from 10,700 to 29,000 cubic yards depending on berm width*	- Expect time of year restrictions for placement - Need to identify source of material

*Volume ranges were developed using berm widths ranging from 20 to 50 feet wide and a 1V:10H slope

Management Policy Considerations

Breach management for Fire Island is addressed in a comprehensive plan prepared by USACE in cooperation with the Seashore (USACE 2020a). As discussed under the *Existing Management Strategy*, above, the current plan requires closure of breaches within 60 days of breach formation, except for breaches that form in the Otis Pike Fire Island High Dune Wilderness Area. If breaches were not immediately closed, but instead were allowed to evolve naturally, it would alter sediment transport and ecological conditions within the bay. Breaches are an important conduit for the transport of littoral drift into back bays and salt marsh systems on the bayside of barrier islands (Methratta et al 2016). While the episodic nature of breaches makes them difficult to predict and therefore plan for or manage, they are an important part of barrier island evolution. This has been documented by the breach in the Otis Pike Fire Island High Dune Wilderness created by Hurricane Sandy on October 29th, 2012. This breach is located within Great South Bay approximately 7.5 miles west of the Talisman Site. Over the years since the initial breach formation, numerous scientists, including those at the Seashore, have studied and documented changes to the breach and the conditions of the Great South Bay. Studies showed that the opening of the breach resulted in improved ecosystem health. Post-breach changes caused Great South Bay to be more characteristic of a mature ecosystem, exhibiting increased species richness and abundance, and more desirable characteristics such as improved water quality, system health, stability, and resilience to disturbance (Methratta et al 2016). The Great South Bay Project is a research project designed to understand “the biogeochemistry of the Bay and its effect on pelagic and benthic communities” (SMAS/SBU 2022). Since the formation of the wilderness breach, researchers associated with The Great South Bay Project have produced annual reports documenting changes to physical parameters associated with the wilderness breach. Data shows that the opening of the breach resulted in increased salinity and decreased water temperatures tied to the influx of ocean water through the breach and movement within the bay. As the breach has naturally begun to close, salinity, temperature, and water quality are reverting back to conditions similar to prior to the breach (Flagg 2022). As of October 2022, the breach has completely closed and there is no regular exchange of water between the bay and the ocean through this area.

An additional management policy that could be revisited is the allocation of dredged material from federal navigation channels and other dredging projects, including those implemented by the Seashore. FIMP specifies locations for dredged material placement, which do not include the four sites the Seashore is evaluating, but FIMP has had multiple reformulations throughout its history. It is possible that bayside nourishment could be considered in future FIMP management plans. As noted above, it is also possible for the Seashore and Fire Island communities who routinely dredge navigation channels for access to Fire Island to consider using that dredged material for restoration purposes.

Adaptive Management Considerations

While the discussed alternatives will reduce erosion and provide flood relief, they will not be able to fortify Fire Island against the projected SLR rates over the longer term. As indicated by the RSLR projections within this document, the project area has significant vulnerability to climate change as it faces SLR stressors from both the bay and the ocean.

Adaptive capacity, or the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences of climate change

(IPCC 2014 in NPS 2021b), is a key consideration for FIIS. The adaptive recommendations and considerations presented at the FIIS workshop in 2021 are important steps in providing resilience at the sites. The information regarding adaptive capacity which was created based on the results of the 2021 workshop should be incorporated into the considerations of design life for the coastal design solutions being proposed within this document. This will make certain that the designs chosen meet the design goals for the specified time frame.

Finally, it is also important to consider managed retreat in the context of the overall plan and timing for coastal solutions at the site, which would allow for the timely movement of anthropogenic resources, including cultural resources, to areas outside of flood impact zones. In such a scenario, natural resources would be left to conform to the ongoing changes in the environment.

CONCLUSIONS

The problems facing Fire Island and the NPS lands on the island are significant, immediate, and complicated. The best outcome to reduce erosion at all sites would be expected by combining an offshore wave attenuation feature with one of the three nourishment options. These two elements would complement each other by maximizing the design life of nourishment while also increasing water quality and clarity by seeding the offshore reef or WADs. Modeling is strongly encouraged to also help maximize the lifecycle of the structures and nourishment, understand the expected transport of material after placement, and to help with developing effective design option(s).

While these options present short term achievable projects in localized areas, continued planning for regional SLR and impacts to the sites will need to continue. Having plans in place when episodic events occur, such as storms or breaches, reduces the response time and therefore the impact those events have on the larger system. It is also important to keep in mind that regulatory agencies will need to consider more creative options within communities (Babson, 2021). To do this, agencies will need to make certain that project concepts are supported by sound engineering and scientific data and these NPS sites provide an excellent location to help facilitate these next steps for FIIS.

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