TECHNICAL MEMORANDUM

DATE October 3, 2022 **JOB NO.** 2021-0262

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Task 1.2 - Technical Memorandum

1.0 Executive Summary

This technical memorandum describes work completed by Woods Hole Group, working under contract to the Town of Barnstable, to review and update conceptual alternatives from a previous 2016 study for long-term resiliency at Sandy Neck Beach Park. The goals of the project are to identify conceptual alternatives that will help restore/enhance long-term coastal and economic resiliency at the Park for a minimum of 50 years. Six (6) conceptual alternatives from the 2016 study were reviewed and updated (Alternatives #2, #3, and #5A through #5D) and two (2) new alternatives (Alternatives #6 and #7) were developed as part of the current study. Alternatives #2 and #3 involve the use of “hard” and “soft” engineering structures buried within the footprint of the existing dune to protect the parking lot, while Alternatives #5A through #5D, #6, and #7 involve relocation of Park assets through managed site reconfiguration to enhance resiliency of the site. The feasibility of off-site parking was also evaluated as a way to supplement the capacity of the beach parking lots.

The technical review included the following components:

- Model studies to determine level of protection provided by each alternative to 20-, 50-, and 100-year storms under present-day sea level conditions, as well as expected sea levels in 2030, 2050, and 2070,

- Calculations of wave overtopping and runup, where appropriate (Alternative #2),

- Revised designs where warranted to improve performance,

- Probabilities of flooding across the site under present-day sea level conditions, as well expected sea levels in 2030, 2050, and 2070,

- Development of new alternatives to address issues related to gatehouse operations, vulnerability of flooding at the gatehouse, emergency vehicle access, and ORV air-up/air-down capacity,

- Updates to the opinion of probable costs for each alternative which include initial construction costs and maintenance over the 50-year project lifetime,

- Updates to the benefit to cost ratios and rankings for the conceptual alternatives.

Key findings of the study are summarized in the following bullets and in the Summary of Findings graphic below.

- Alternatives #2, #5A through #5D, and #6 provide protection for the parking lot for storms up to the 100-year event through the period 2070. Alternative #3 leaves the parking lot vulnerable to damage during a 100-yr event with current day water levels, and Alternative #7 results in damage to the parking lot during a 100-year storm by 2050. Alternatives #3 and #7 do not meet the goal of providing protection for a minimum of 50 years, while the other alternatives do meet this goal.

- Continued nourishment of the dune will be required for all alternatives. Annual nourishment will be needed for Alternatives #2 and #3; alternatives involving managed site reconfiguration will require dune nourishment approximately every 5 years.

- Alternative #2 does not meet the performance standards for work in a coastal dune or barrier beach per the Massachusetts Wetlands Protection Regulations 310 CMR 10.28 and 10.29 and is considered to be unpermittable. The remining alternatives are permittable but will likely require mitigation activities to offset unavoidable impacts to wetland resources.

- Alternatives #2, #3, and #5A through #5D would make no changes to the current parking capacity of 200 vehicles. Alternative #6 would create 203 parking spaces, and Alternative #7 would reduce the number of spaces to 164.

- Alternatives #2, #3, and #5A make no changes to the current number of air-up/air-down spaces. Increased numbers of air-up/air-down spaces are provided with the remaining alternatives.

- The managed site reconfiguration alternatives that include dune restoration (Alternatives #5A through #5D, #6, and #7) will serve to enhance/protect the existing coastal resources. Alternatives that involve relocation of the ORV access trail (Alternatives #2, #5B through #5D, #6, and #7) will enhance wildlife habitat by restoring connectivity within existing spadefoot toad habitat.

- Alternatives #2, #6, and #7 address issues related to gatehouse operations, vulnerability of flooding at the gatehouse, and emergency vehicle access, while the other alternatives do not address these issues.

- Initial construction costs are lowest for Alternative #2 and highest for Alternatives #6 and #7; however, when considering maintenance costs over the 50-year project lifetime, Alternatives #2 and #3 are 1.8 to 2.7 times greater than the other alternatives.

- Benefit to cost ratios are lowest for Alternatives #2 and #3, and highest for the other alternatives.

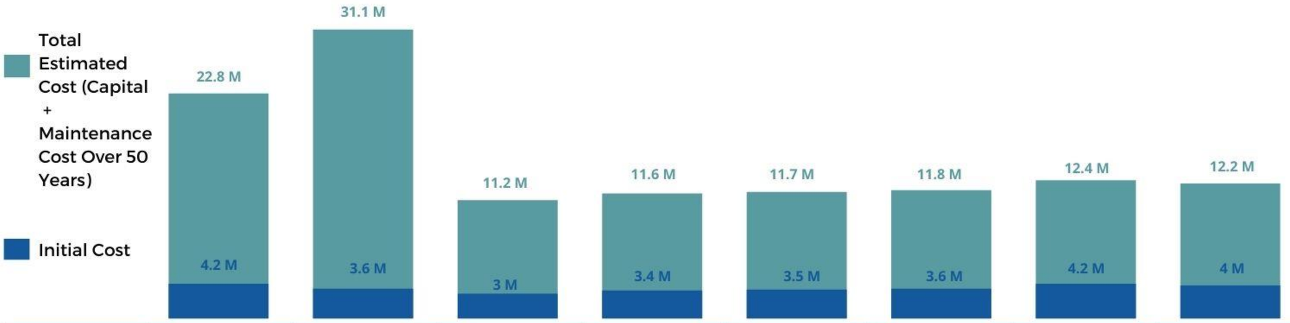
- State and federal opportunities for construction funding through grants would be available for any of the managed site reconfiguration alternatives (#5A through #5D, #6, and #7).

- When the alternatives were ranked according to benefit/cost ratio, performance and longevity, permittabiilty, and impacts/benefits to resources area, Alternatives #2 and #3 ranked the lowest, and the managed site reconfiguration alternatives (#5A through #5D, #6, and #7) ranked the highest).

- Off-site parking was evaluated as a way to supplement the capacity of the parking lots with any of the conceptual alternatives but was not considered as a stand alone alternative that would eliminate the need for improved coastal resiliency at the Park.

This technical memorandum provides a detailed evaluation of eight (8) conceptual alternatives considered for long-term resiliency at Sandy Neck Beach Park. At this point, the Town is tasked with selecting up to three (3) alternatives from the eight (8) conceptual alternatives. The selected conceptual alternatives will be taken through a more detailed design process during which revisions will be made to address comments received from the Town, Sandy Neck Board, public, and local and state regulatory agencies. Construction and long-term maintenance costs will also be updated based on the revised designs. A final report will be generated with a recommendation for a preferred alternative. Once the Town has selected a preferred alternative, environmental permits will be obtained, and the Town can move forward with planning for construction.

Alternative Type	“hard” Engineering Structure	"Soft" Engineering Structure	Managed Site Reconfiguration					
Alternative Number	2	3	5A	5B	5C	5D	6	7



	2	3	5A	5B	5C	5D	6	7
Permitability	LOW	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE
Likelihood of Receiving Grant Funding	LOW	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE
Number of Parking Spaces	200	200	200	200	200	200	203	164
Air-up/ Air-down	4 up/ 6 down	4 up/ 6 down	4 up/ 6 down	10 up/ 9 down	10 up/ 10 down	10 up/ 10 down	12 up/ 17 down	30 up/ 15 down
Frequency of Nourishment	Annual	Annual	Every 5 Years	Every 5 Years	Every 5 Years	Every 5 Years	Every 5 Years	Every 5 Years
Level of Protection	HIGH	LOW	HIGH	HIGH	HIGH	HIGH	HIGH	MODERATE
Benefit/Cost Ratio	2.24	1.64	4.56	4.4	4.37	4.33	4.12	4.19
Enhance/ Protect Coastal Resources	MODERATE	LOW	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE
Enhance Wildlife Habitat	HIGH	LOW	LOW	HIGH	HIGH	HIGH	HIGH	HIGH
Improves Emergency Access	HIGH	LOW	LOW	LOW	LOW	LOW	HIGH	HIGH
Improves Gatehouse Operations	HIGH	LOW	LOW	LOW	LOW	LOW	HIGH	HIGH
Reduces Gatehouse Vulnerability	HIGH	LOW	LOW	LOW	LOW	LOW	HIGH	HIGH
Total Rating Value (TRV)	5.24	2.64	10.56	10.4	10.37	10.33	10.12	9.19

HIGH MODERATE LOW

2.0 Introduction

Woods Hole Group is under contract with the Town of Barnstable for the project entitled *Evaluation, Permitting & Design of the FY22 Sandy Neck Beach Facility Relocation*. Work covered under the current Woods Hole Group contract is a continuation of a study completed in 2016 which developed and evaluated long-term coastal resiliency alternatives for Sandy Neck Public Beach, Barnstable, MA (CLE Engineering, 2016). This technical memorandum presents the results of a review and update of the 2016 study called for in Task 1.2 of the contract.

The purpose of Task 1.2 was to review the work completed in 2016 and conduct supplemental analyses needed to update and/or improve the conceptual designs based on an independent coastal engineering evaluation. Woods Hole Group was tasked with reviewing the following six (6) conceptual alternatives from the 2016 study:

- Alternative #2 – Stone Revetment with Vegetated Sand Cover
- Alternative #3 – Bio-Engineered Sand-Filled Coir Bags with Vegetated Sand Cover
- Alternative #5A – Relocate/Reconfigure Parking Lot
- Alternative #5B – Relocate/Reconfigure Parking Lot & ORV Access; Reconfigure Existing Air-Down Area
- Alternative #5C – Relocate/Reconfigure Parking Lot & ORV Access with Screening Trees; Relocate Existing Air-Up/Air-Down Areas
- Alternative #5D – Relocate/Reconfigure Parking Lot & ORV Access with Screening Dune; Relocate Existing Air-Up/Air-Down Areas

Where warranted, results from the independent coastal engineering evaluation were used to update and/or modify the 2016 alternatives. Additional information gathered from the Department of Public Works (DPW) and Sandy Neck Park staff was used to guide the development of the following two (2) new alternatives:

- Alternative #6 – Relocate/Reconfigure Parking Lot & ORV Access; Relocate and Expand Number of Air-Up/Air-Down Areas; Relocate Gatehouse and Add Emergency Vehicle Access to Beach
- Alternative #7 – Partial Relocation/Reconfiguration of Parking Lot & ORV Access; Relocate and Expand Number of Air-Up/Air-Down Areas; Relocate Gatehouse and Add Emergency Vehicle Access to Beach

The consulting team of Woods Hole Group, Tighe & Bond, and Goddard Consulting are on the Town's Working Group for this project, with other representatives from the DPW, Barnstable Marine and Environmental Affairs (MEA), Sandy Neck Board, and Massachusetts Coastal Zone Management (CZM).

This technical memorandum provides a general description of each alternative along with a graphic depicting its physical location within the Park. Information on the longevity and performance of each alternative towards providing resiliency for the parking lot is provided, environmental permitting requirements/difficulties are discussed, and impacts/benefits to wetland resources and protected species are addressed. Construction costs and long-term maintenance costs for each alternative over a 50-year time horizon are also provided. These evaluation criteria are used to rank the alternatives and provide the Town with data necessary to make an informed decision on three (3) alternatives they would like to advance to the next design stage.

3.0 Technical Updates to 2016 Study

The 2016 study included a desktop study to understand sediment transport rates and patterns along the Sandy Neck Beach coastline. The purpose of the study was to calculate annualized rates and directions of sediment transport, identify erosional hotspots, and identify the location of the dune at a point 50-years into the future so that conceptual alternatives could be developed for protection of the parking lot. The 2016 approach utilized the numerical model SWAN 2D to evaluate normal/average annual waves along the beach. The wave model results were then used to drive a second 1D model to calculate rates and directions of sediment transport along the shoreline. Important findings from the 2016 study included the following:

- no distinct erosional patterns were identified as the shoreline shows periodic variations (i.e., erosion and accretion) on the order of +/- 30 feet;
- the shore-attached nearshore bar plays an important role in wave transformation and sediment transport dynamics;
- net annual rate of sediment transport is 30,000 cubic yards/yr directed towards the east;
- 50-yr dune erosion line is located approximately 70 ft behind the northern (bay side) edge of the current parking lot (Figure 1).

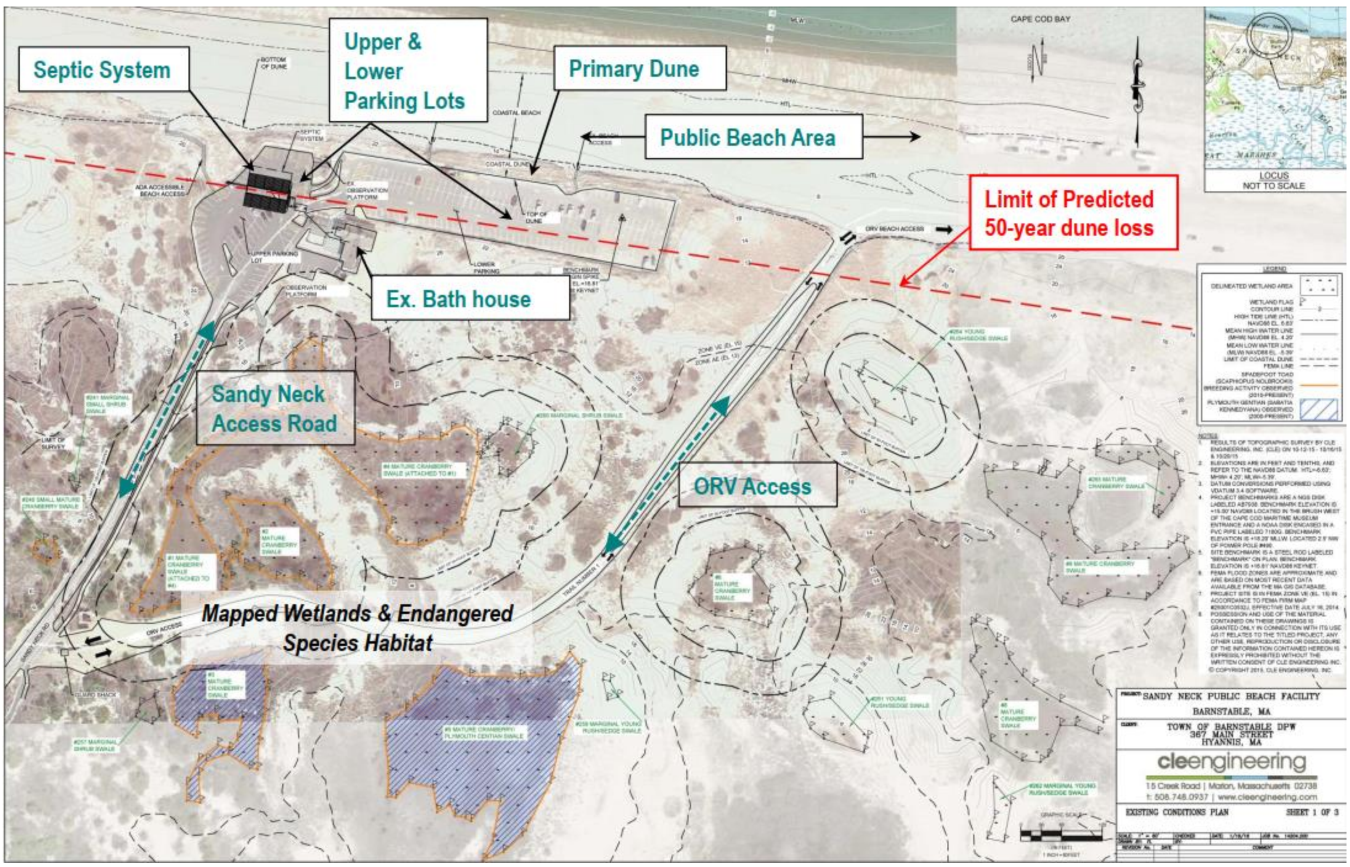


Figure 1. CLE Engineering map of Sandy Neck Park showing the limit of predicted 50-yr dune loss (red dashed line).

The current 2022 study builds on the prior 2016 work by evaluating the effects of storm driven erosion and sea level rise so that the ability of the conceptual alternatives to provide protection for the parking lot can be more fully analyzed. The current study includes the following components:

- Update Existing Conditions Data: Obtain existing recent and high-quality data sets for winds, waves, water levels, topography, and bathymetry that can be used for supplemental modeling and design. Where necessary, collect additional field data to fill data gaps.
- Develop Present Day and Future Wave Conditions and Water Levels: Develop a suite of return period storm scenarios (i.e, 20-, 50-, and 100-year events) for both present and future day that incorporates sea level rise.

- Dune Performance Modeling: Conduct performance modeling for existing conditions and the 2016 conceptual alternatives by determining morphological response of the beach and dune system to present day and future storm waves and water levels.
- Present Day and Future Flooding Conditions: Conduct a flooding pathway and inundation analysis to evaluate the impacts of storm flooding on the site during present day and future sea level conditions.

3.1 Update Existing Conditions Data

Updated data describing the topography of the Park and the nearshore bathymetry were obtained to capture present day conditions. A topographic survey was conducted by a Woods Hole Group Professional Engineer & Land Surveyor in June and July 2022 to establish existing conditions and to locate the parking lot and other existing structures. Figure 2 shows the areas captured during the survey. The topographic data were supplemented with 2018 USACE NCMP Topobathy Lidar DEM: East Coast (CT, MA, ME, NC, NH, RI, SC)) between the land and nearshore region, as well as the Topobathymetric Model for the New England Region States of New York, Connecticut, Rhode Island, and Massachusetts, 1887 to 2016, generated by OCM Partners (2022) in the offshore region. These Digital Elevation Models (DEM) integrate various disparate light detection and ranging (LiDAR) and bathymetric data sources into a common 3D database, which is made available to the public. These data sets were combined into a single topobathymetric data set referenced to the North American Vertical Datum of 1988 (NAVD) in units of feet, for later use with the dune performance modeling.

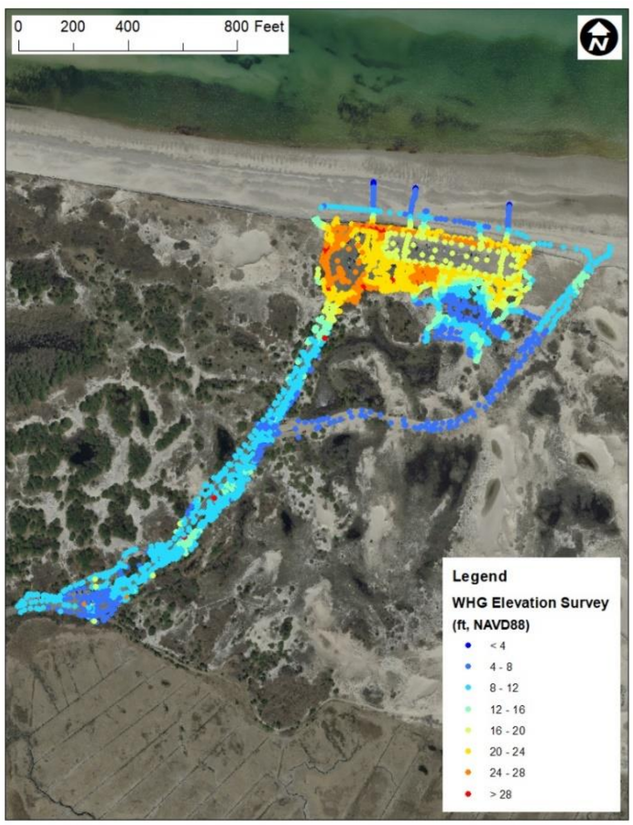


Figure 2. Woods Hole Group topographic survey data collected for Sandy Neck Park in June-July 2022.

Grab samples were also collected from the beach and dune at Sandy Neck Park to help characterize the sediments. The samples were then sent to a laboratory for grain size analysis. The results showed that the beach is composed of medium-grained sand (D_{50} of 0.40 to 0.43 mm) and the dune is composed of fine-grained sand (D_{50} of 0.18).

3.2 Develop Present Day and Future Water Levels and Wave Conditions

Water level and wave condition information needed for the dune performance modeling were obtained from the Massachusetts Coast - Flood Risk Model (MC-FRM). MC-FRM is a model developed by Woods Hole Group for the Massachusetts Department of Transportation (MassDOT) that helps property owners, planners, and policy makers determine how to cost-effectively build resilience and plan for expected changes resulting from climate change and sea level rise. MC-FRM provides comprehensive, high-resolution, probabilistic information on present coastal flood risks and how they are expected to change with future sea level rise and storm intensification for the entire Massachusetts Coast. A summary of water levels extracted from MC-FRM for various return period (years) or annual percent chance occurrence (%) storm events in the Sandy Neck Beach area, both in present and future day, is provided in Table 1. For comparison, stillwater elevations for return period storms from the FEMA Flood Insurance Study are also provided in Table 1. As can be seen, the MC-FRM water levels are within several tenths of a foot of the FEMA water level for each storm event in present day but are much greater for future planning horizons.

Table 1. Extreme Water Levels for Return Period Storms in Present and Future Day for the Sandy Neck Beach Area.

Storm Event		MC-FRM Water Levels (ft, NAVD88)				FEMA Water Levels (ft, NAVD88)
Return Period (years)	**Annual Chance Percent Occurrence (%)**	**Present Day**	**2030**	**2050**	**2070**	**Present Day**
20	5%	9.0	10.1	11.7	13.5	N/A
50	2%	9.6	10.7	12.3	14.1	9.6
100	1%	10.1	11.1	12.8	14.7	9.9
200	0.5%	10.5	11.5	13.4	15.2	N/A
500	0.2%	11.1	12.1	14.0	15.8	10.9
1,000	0.1%	11.5	12.5	14.5	16.3	N/A

Wave height information for the return period storm events at Sandy Neck Beach was also extracted from the MC-FRM database. For wave period, the US Army Corps of Engineers (USACE) North Atlantic Comprehensive Coastal Study (NACCS) was utilized, as wave period data are not available from MC-FRM. Wind speeds associated with the different return period storms were calculated using a 50-year long wind record from the Cape Cod Gateway Airport (HYA), formerly Barnstable Municipal Airport. This represents the closest long-term record of wind data to Sandy Neck, which is approximately 6 miles away. Table 2 provides a summary of wind and wave height parameters developed for the site and used for the subsequent dune performance modeling.

Table 2. Wind Speeds, Wave Heights, and Wave Periods for Present Day Return Period Storms for the Sandy Neck Beach Area.

Storm Return Period (years)	Annual Percent Chance Occurrence (%)	Wind Speed (mph)	MC-FRM Wave Height (feet)	NACCS Wave Period (seconds)
5	20%	52.9	16.1	6.5
10	10%	59.7	17.8	7.1
20	5%	66.2	19.6	7.5
50	2%	74.7	21.9	7.9
100	1%	81	23.6	8.1
200	0.50%	87.3	25.4	8.3
500	0.20%	95.6	27.7	8.4
1,000	0.10%	101.9	29.4	8.5

3.3 Dune Performance Modeling

The Woods Hole Group modeled storm-induced morphological change of the beach and dune system at Sandy Neck Park using the cross-shore one-dimensional (1-D) XBeach model. The model was used to evaluate changes to the beach and dune during the 20-, 50-, and 100-year storm events under present day water levels, as well as elevated water levels due to sea level rise in 2030, 2050, and 2070. The ability of the conceptual alternatives to protect the parking lot, both now and in the future, was also evaluated with the model.

To provide a frame of reference for interpretation of the performance modeling of the 20-, 50-, and 100-year storms, the return period associated with flooding caused by past storms impacting Sandy Neck Beach is provided in Figure 3. The graph shows that winter storm Grayson in January 2018 produced a storm surge that was near a 130-year return period, while winter storm Riley in March 2018 produced a surge with a ~ 38-year return period.

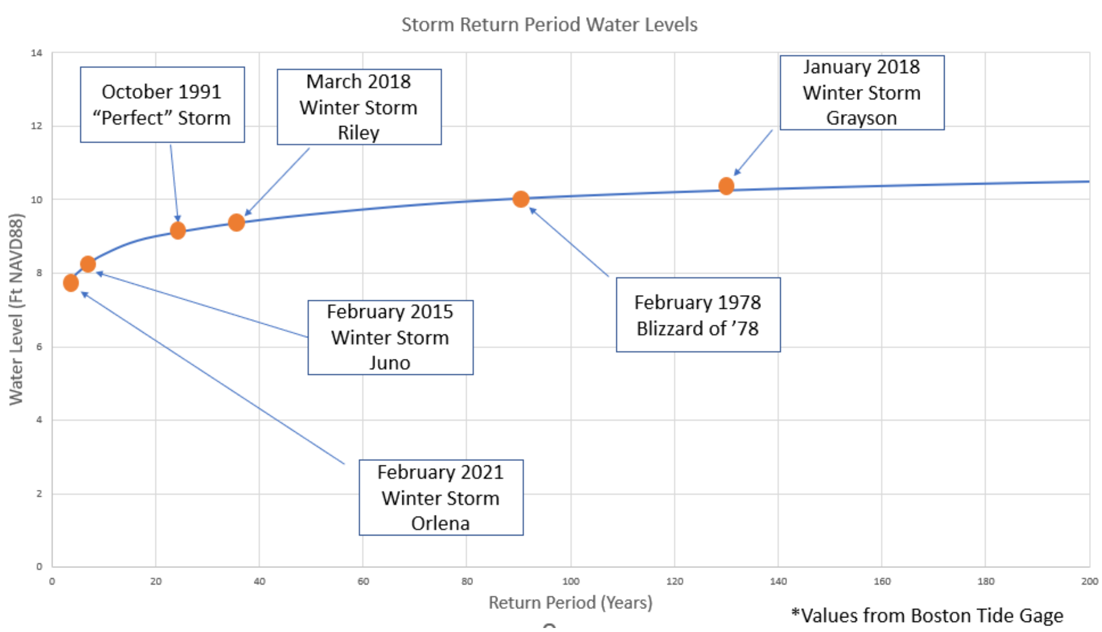


Figure 3. Return periods for water levels produced by past storms impacting the Sandy Neck Beach Park area.

Water levels, wind speeds, wave heights and periods from Tables 1 and 2 were used as input to the model. The grain size of sediments on the beach and dune was assumed to be 0.3 mm based on the average grain size of the collected sediment samples. The model was run along two (2) shore normal transects that extended seaward from the back of the parking lot to an approximate water depth of 50 feet (Figure 4). Transect 1 was sited through the upper parking lot and transect 2 was sited through the lower parking lot. Elevations for each transect were extracted from the topobathymetry data described above in Section 3.1.

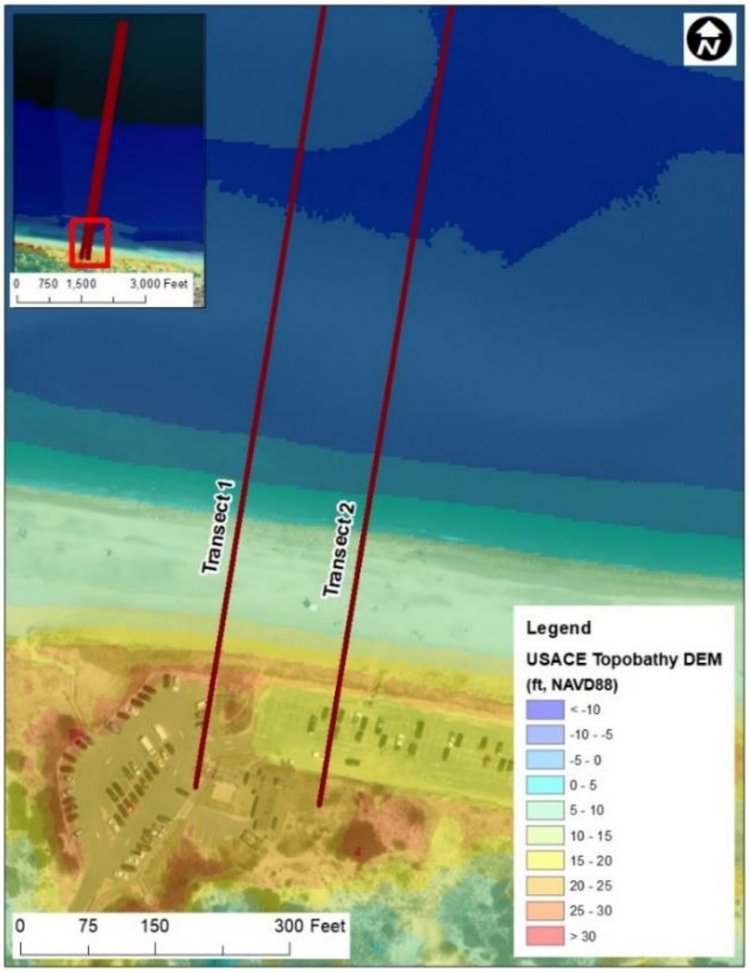


Figure 4. Transect locations used with the XBeach model and topobathymetry at Sandy Neck Beach Park.

Results from model simulations of the 20-, 50-, and 100-yr storms acting on the existing beach at Transect 2 are shown in Figure 5. The top panel shows results for present day water levels and the subsequent panels show results for 2030, 2050, and 2070 water levels. Each figure shows the existing (initial) cross-shore beach and dune profile at Transect 2, and then the resulting final eroded profiles for each of the storm scenarios.

With present day water levels, the existing dune is eroded by each storm event, but the parking lot does not start to be eroded or undermined until the 100-year storm event. By 2030 the parking lot is eroded by the 50-year storm, and by 2050 the parking lot is damaged during the 20-year storm. By 2070, erosion caused by the 50- and 100-year storms erodes most of the lower parking lot. These results show that future sea level rise will result in increased damage to the parking lot for smaller scale storms. The results also demonstrate the vulnerability of the parking lot and highlight the need for proactive steps by the Town of Barnstable to enhance resiliency of the Park.

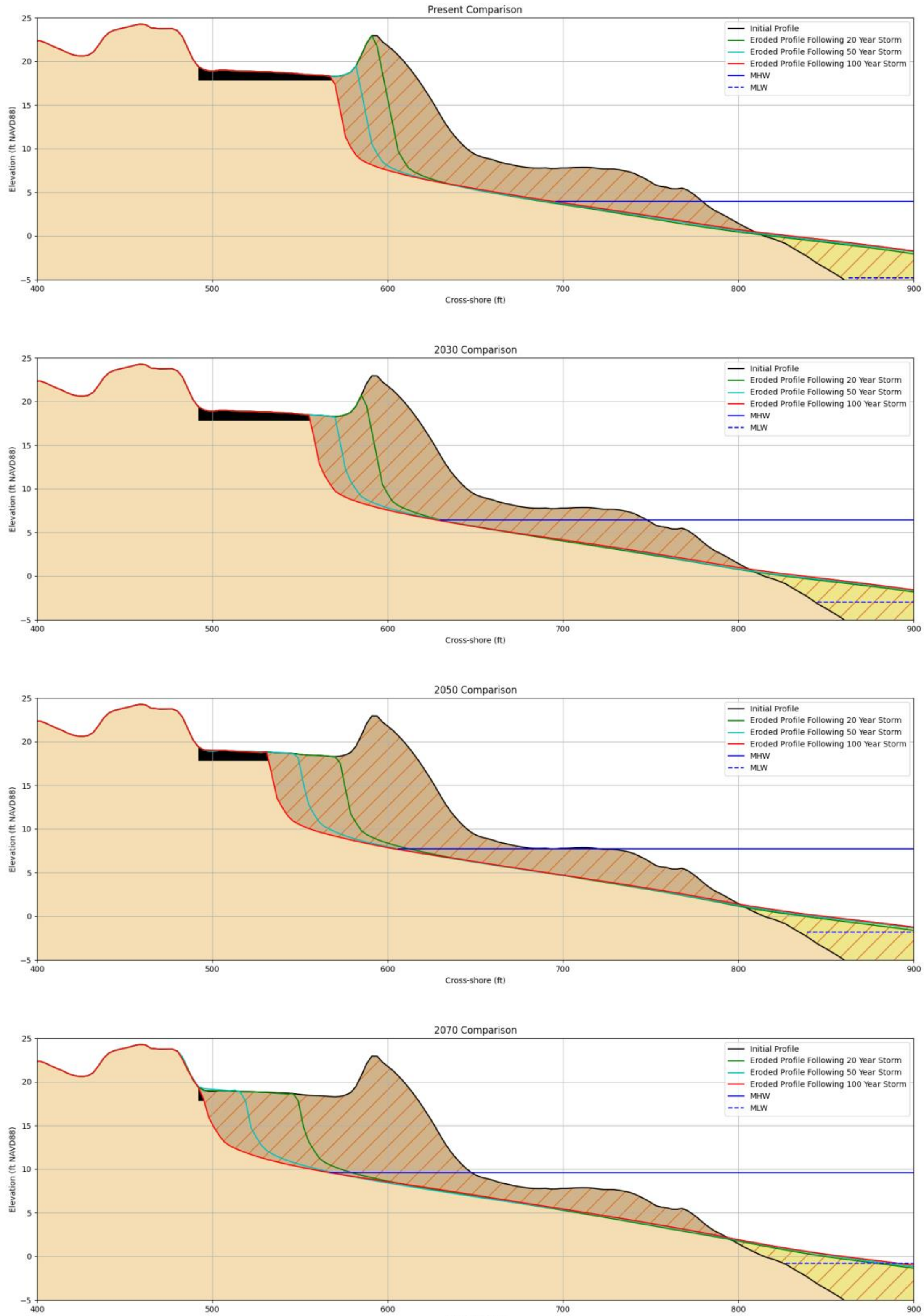


Figure 5. XBeach storm simulations at Transect 2 for present day conditions (top), 2030, 2050, and 2070 (bottom).

3.4 Evaluate Present Day and Future Flooding Conditions

Data from MC-FRM were used to assess the probabilities of flooding across the site under present-day sea level conditions as well as during sea levels expected in 2030, 2050, and 2070. Figures 6 through 9 illustrate the chance of flooding within any given year at Sandy Neck Park for each time horizon. A 0.1% chance storm has a 1 in 1,000 chance of occurring each year (i.e, the 1,000-year storm) and a 1% chance storm has a 1 in 100 chance of occurring each year (i.e., the 100-year storm).

While every effort has been made to assure the accuracy and correctness of the MC-FRM data presented, it is acknowledged that inherent mapping inaccuracies are present due to interpolation between MC-FRM calculation nodes. Further, areas of the coast that experience rapid changes in geomorphology during storm events, such as dunes along barrier beaches, may not be fully characterized in the MC-FRM dataset. As a result, the maps presented for Sandy Neck Beach Park should be interpreted as representations of potential exposure to flooding in relation to existing topographic conditions.

Review of Figures 6-9 show that the Park is vulnerable to storm surge flooding under present day conditions, with vulnerability increasing through 2070. The area of the gatehouse along the entrance road is most vulnerable, showing a 25% to 100% probability of annual flooding with present day conditions, increasing to 100% annual probability by 2050 and beyond. The current ORV trail through the dunes is also vulnerable, with a 2% to 5% chance of annual flooding in 2030 and a 100% chance of annual flooding in 2050 to 2070. The upper and lower parking lots are shown to be safe from flooding through 2070; however, with erosion of the frontal dune not accounted for in the MC-FRM model, it is a high probability that the lower parking lot will be vulnerable to flooding from Cape Cod Bay. Lastly, while the concession building is shown to be vulnerable to flooding under present day conditions and all out years, survey data collected as part of this study indicate that the first-floor elevation is above the projected most severe flood elevations for the 0.1% chance storm through 2070.

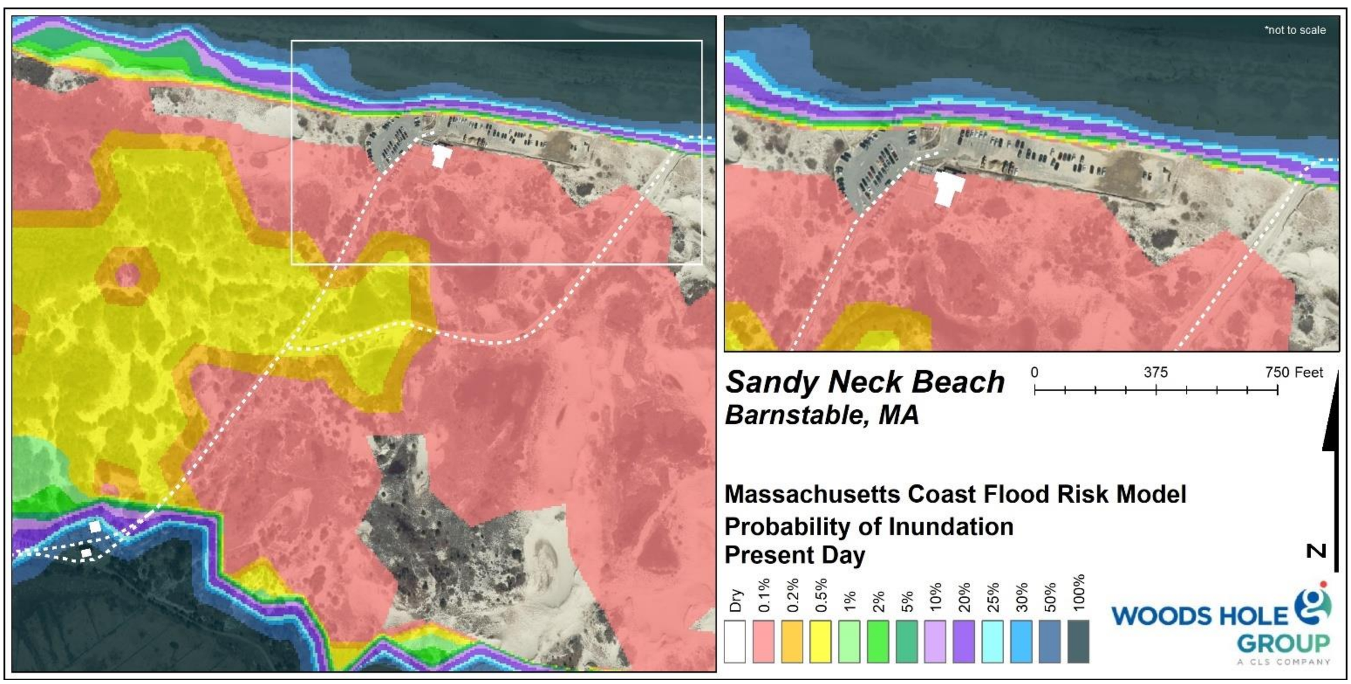


Figure 6. MC-FRM probabilities of inundation for present day sea level.

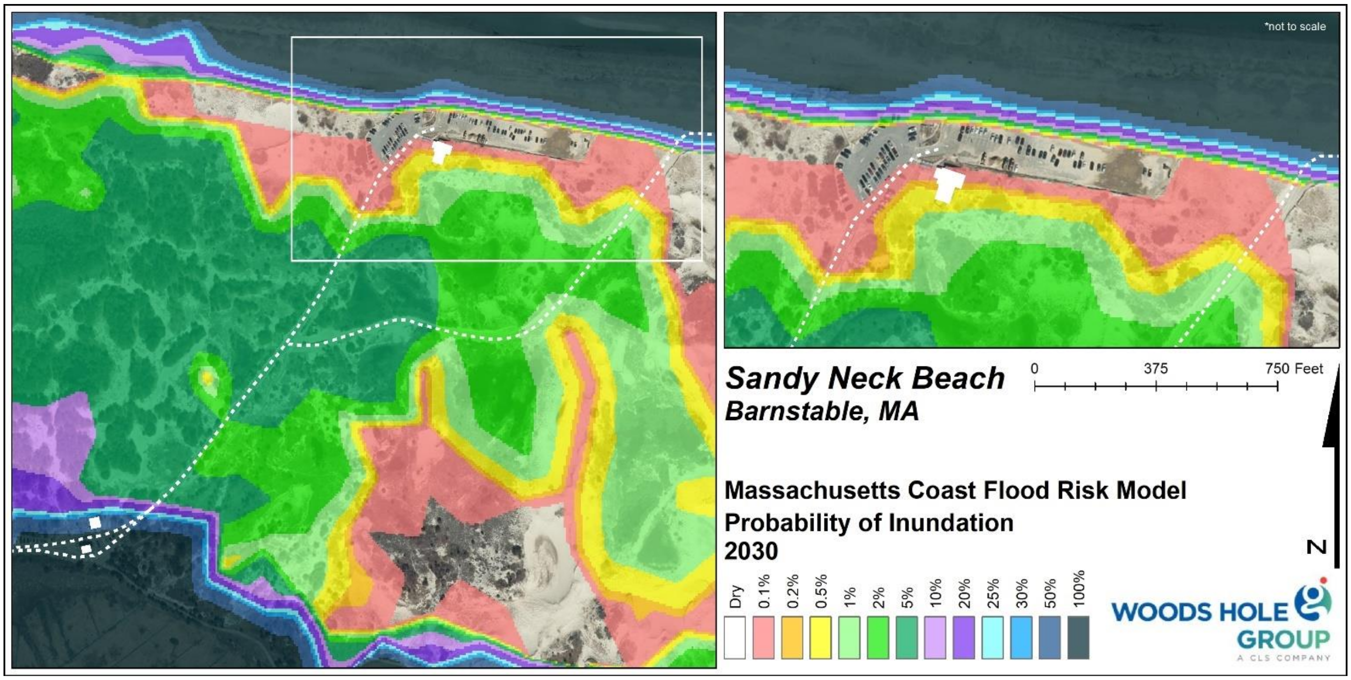


Figure 7. **MC-FRM probabilities of inundation for projected sea levels in 2030.**

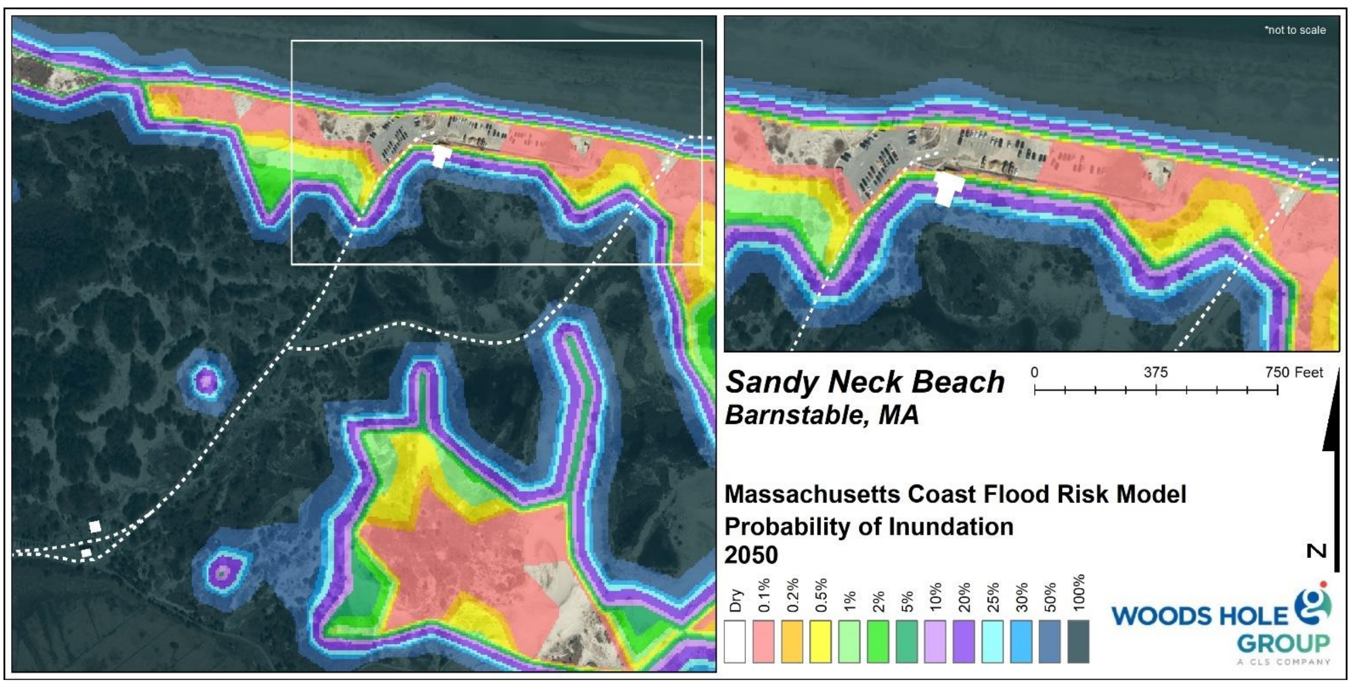


Figure 8. **MC-FRM probabilities of inundation for projected sea levels in 2050.**

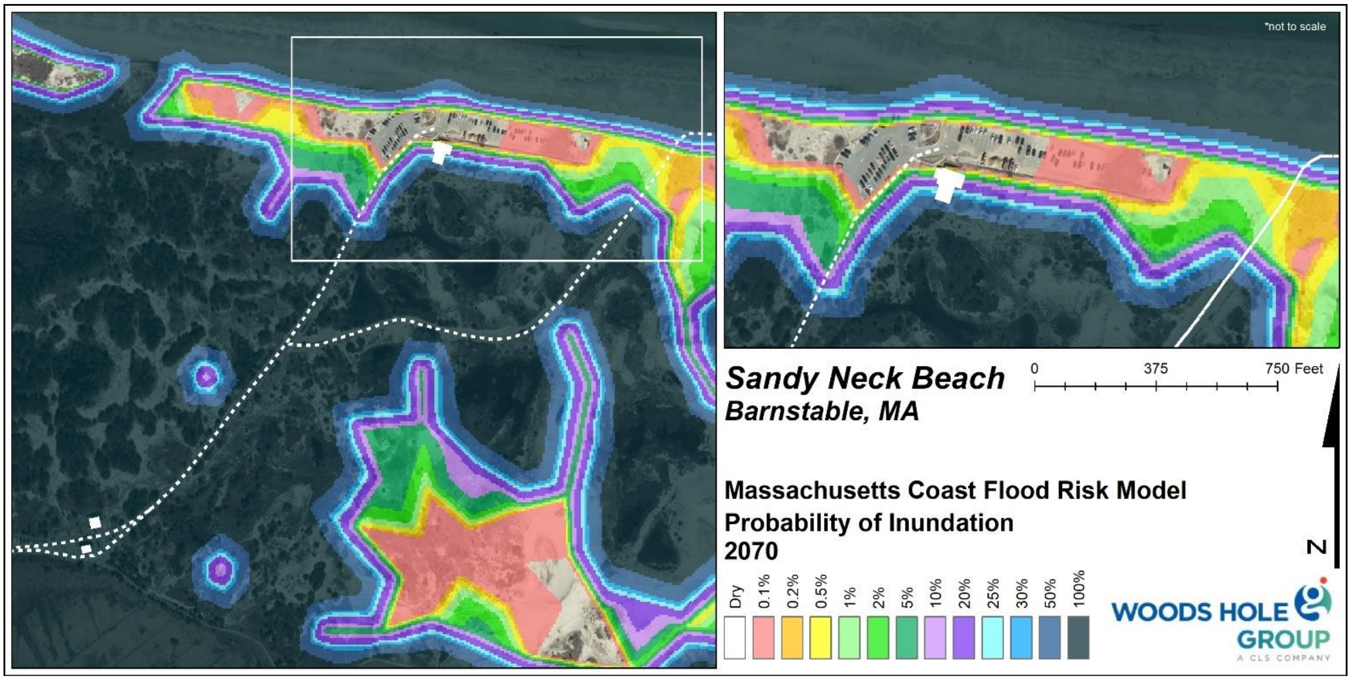


Figure 9. **MC-FRM probabilities of inundation for projected sea levels in 2070.**

Figure 10 shows the extents of mean higher high water (MHHW) for present day, 2030, 2050, and 2070 across the Sandy Neck Beach Park, based on data from the MC-FRM dataset. The risks of flooding from daily tides initiate from Barnstable Harbor on the back side of the barrier beach. As soon as 2030, daily tidal flooding could be expected along the low-lying marsh trail that begins near the gatehouse and runs along the back of the barrier beach. By 2050 daily tidal flooding could begin to impact access to the Park as the gatehouse area and entrance road will likely be inundated around the time of MHHW. Flooding impacts could also be expected along the existing ORV trail starting in 2050. By 2070 the extent of daily tidal flooding can be expected to expand across the entrance road near the gatehouse and at lower lying sections of the road leading to the main Park area.

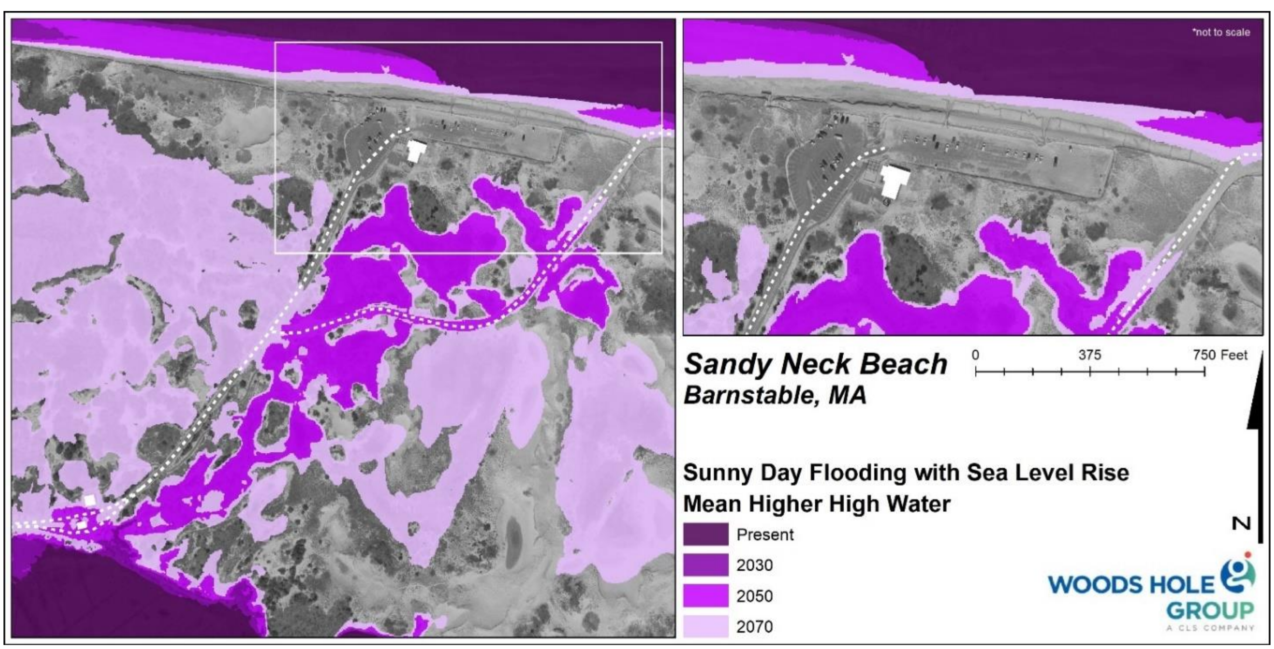


Figure 10. **Projected flooding during MHHW during present day, 2030, 2050, and, 2070 time horizons.**

4.0 Conceptual Alternative Updates and Performance Modeling

Conceptual alternatives selected by the Town from the 2016 report (Alternatives #2, #3, #5A through #5D) were evaluated for performance in protecting the parking lot given the 20-, 50-, and 100-year storm events, using present day sea levels as well as protected sea levels in 2030, 2050, and 2070. Engineering reviews of the conceptual alternative designs were conducted, and in some cases the designs were modified to include a more robust solution. Two (2) new conceptual alternatives (Alt #7 and #8) were also developed to address needs expressed by the Town. The following sections of the technical memo provide a brief description of each alternative, as well as results from the performance modeling, a discussion of permittability, impacts to resource areas, and estimated costs for initial construction and maintenance over a 50-year period.

4.1 Alternative #2 – Stone Revetment with Vegetated Sand Cover

Description: Conceptual Alternative #2 includes the construction of 656 linear feet of stone revetment along the seaward side of the existing upper and lower parking lots (Figure 11). Once constructed, the revetment would essentially be located in the area of the existing dune. The crest elevation of the revetment would match the existing grades of the upper and lower parking lots, with a crest width of 10 feet. The revetment would have a seaward slope of 1.5H:1V and would include three (3) layers of differently sized stones. Toe stones sized at 5-tons would anchor the structure at elevation 3.4 ft NAVD88. Following construction of the revetment, it would be covered with sand to replicate the existing dune. Beachgrass would be planted on the face of the restored dune to aid in sand stabilization, and a minimum of four (4) feet of sand would be required to be maintained across the face of the revetment on an annual basis. The 2016 plan was modified to reroute the ORV access trail behind the concession building and parking lot, move the gatehouse and a new entrance booth to the top of the hill near the entrance to the upper parking lot, and add a stormwater management system to the lower parking lot and repave.

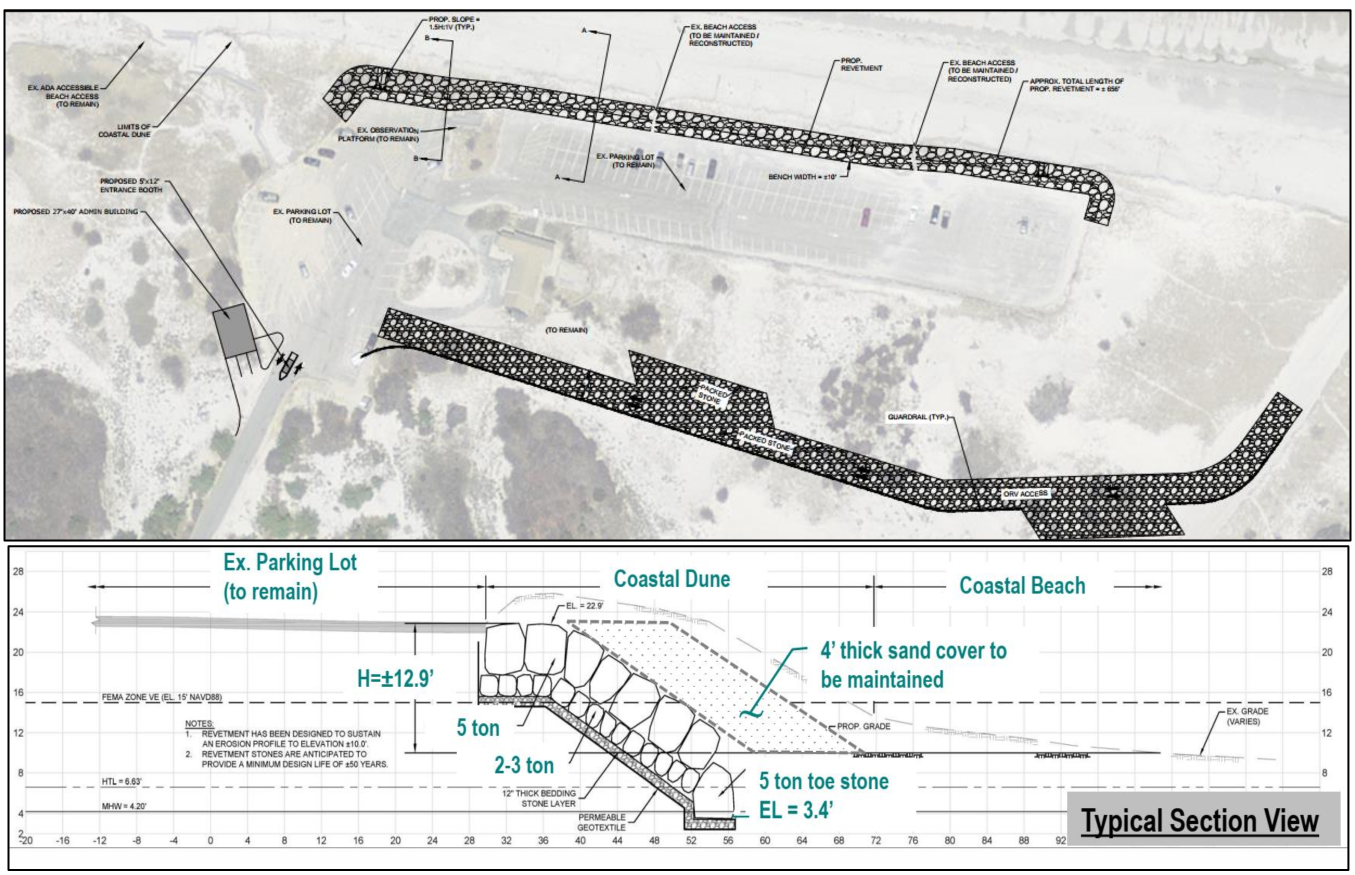


Figure 11. Plan view (top) and cross-section (bottom) of conceptual Alternative #2 from the 2016 study.

Performance & Longevity: Performance modeling of Alternative #2 for present day water levels at Transect 2 is shown in Figure 12. The model indicates that the 50- and 100-year storms erode the sand dune/cover in front of the revetment, leaving the stones exposed for future storms, until such time as the revetment can be covered with additional sand. The 20-year storm erodes a significant portion of the dune, leaving a thin veneer of sand across the face of the revetment. Model runs for water levels in 2030, 2050, and 2070 show complete removal of the sand dune/cover in front of the revetment for all storms simulated. While the revetment "holds the line" in preventing erosion of the parking lot, waves striking the hard engineering structure cause scour at the base of the revetment, leading to loss of beach width and volume. If nourishment material is not maintained following storms, this scour could lead to undermining and eventual failure of the structure. Even in years when the sand cover is not completely eroded, it would be important follow an annual program of dune nourishment to ensure adequate sand cover and sediment supply to the barrier beach system.

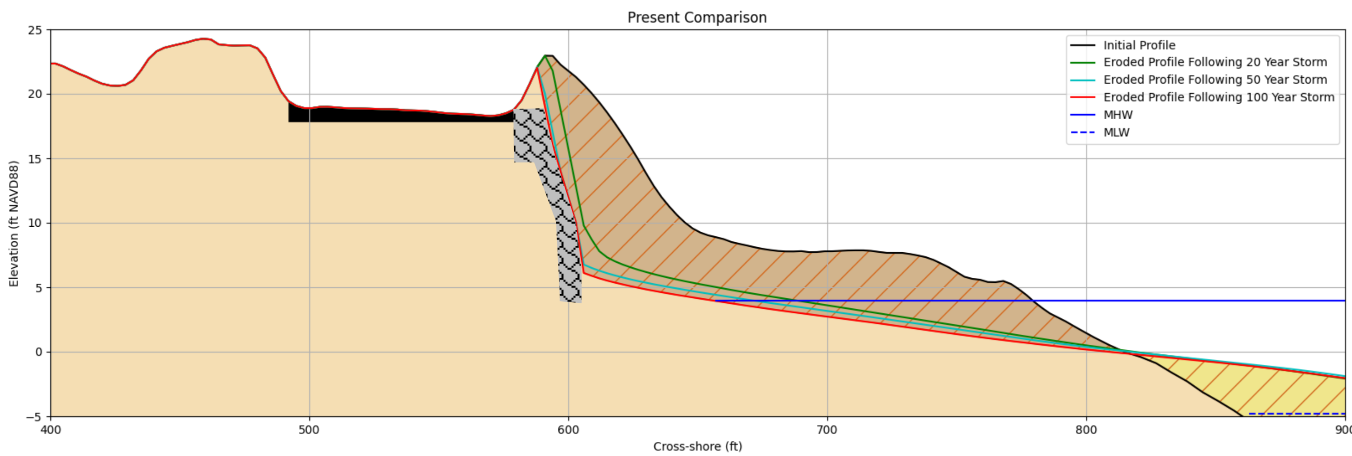


Figure 12. XBeach storm simulations for Alternative #2 with present day sea level showing the initial and eroded profiles for Transect 2.

Once the sand cover erodes and the face of the revetment is exposed, additional damages from wave runup and overtopping can be expected. The USACE Coastal Engineering Manual (CEM) relates overtopping rates to the potential for structure damage. Table 3 shows the calculated overtopping rates for Alternative #2 given the various return period storm scenarios. Red highlighted cells indicate storm and water level scenarios likely to cause damage to the revetment, yellow cells indicate conditions unsafe to park or drive in the parking lot behind the revetment, and grey highlighted cells indicate conditions unsafe for pedestrians on the parking lot behind the revetment. The results indicate that the revetment is potentially damaged during all storms in 2070, and there is potential for damage in 2050 during the 50 and 100-year storm events. These more damaging events will likely require significant repairs or replacement of the revetment before its 50-year design lifetime has been met.

Table 3. Overtopping Rates and Damage Potential for Various Return Period Storms and Climate Conditions.

Year	Storm Return Period	Overtopping Rate (liters/s per m) Initital Transect 1	Initital Transect 2	Eroded Transect 1	Eroded Transect 2
2070	100	**48.48**	**585.74**	**320.82**	**1307.58**
	50	**21.77**	**388.09**	**179.12**	**956.50**
	20	**4.76**	**180.84**	**62.05**	**534.81**
2050	100	**0.10**	**22.24**	**23.42**	**270.12**
	50	0.01	**4.10**	**5.83**	**117.14**
	20	0.00	**0.19**	**0.46**	**25.76**
2030	100	0.00	0.01	**0.55**	**24.13**
	50	0.00	0.00	0.02	**2.96**
	20	0.00	0.00	0.00	0.01
Present Day	100	0.00	0.00	0.01	**1.71**
	50	0.00	0.00	0.00	0.01
	20	0.00	0.00	0.00	0.00

(red=damage to the revetment; yellow=damage to vehicles in the parking lot; grey=damage to pedestrians in the parking lot)

Permittability: The conceptual design for the Alternative #2 revetment sites the structure in coastal dune and barrier beach resources, both of which are protected under the Massachusetts Wetlands Protection Regulations 310 CMR 10.28 and 10.29, respectively. The regulations recognize coastal dunes and barrier beaches as important resources that provide storm damage prevention and flood control functions for neighboring resources and upland areas. 310 CMR 10.28(3) indicates that projects on coastal dunes must not have an adverse effect on the coastal dune by:

(a) Affecting the ability of waves to remove sand from the dune;
(b) Disturbing the vegetative cover so as to destabilize the dune;
(c) Causing any modification of the dune form that would increase the potential for storm or flood damage;
(d) Interfering with the landward or lateral movement of the dune;
(e) Causing removal of sand from the dune artificially; or
(f) Interfering with mapped or otherwise identified bird nesting habitat.

Construction of the Alternative #2 revetment in the coastal dune at Sandy Neck Beach would not comply with performance standards c, d, or f listed above, and as such, it is not a permittable project under the Massachusetts Wetlands Protection Regulations. In addition to not complying with the regulations, it is likely the structure would result in increased erosion of the natural dune at the ends of the structure (i.e., end effect erosion) and scour at the toe of the structure could also cause lowering of the beach elevation in front of the revetment. The conclusion that Alternative #2 is not permittable under 310 CMR 10.28 and 10.29 is consistent with findings in the 2016 study.

Resource Area Impacts/Benefits: The conceptual design for Alternative #2 would impact approximately 18,368 square feet of coastal dune and barrier beach resource. The structure would also be located within estimated habitat of rare wildlife. In addition to the adverse impacts to coastal dune, coastal beach, and barrier beach discussed above, the project would also impact habitat for protected shorebirds. The 1.5H:1V slope of the structure and overlying sand cover is considered too steep for the passage of the shorebirds, and the project would likely result in a prohibited Take of state-listed species, as determined by the Natural Heritage and Endangered Species Program (NHESP).

Costs: Updated construction costs for installation of a new stone revetment with a vegetated sand cover are summarized in Table 4. Total costs including initial construction, annual nourishment, beachgrass plantings, and revetement maintenance over a 49-year period are summarized in Table 5. The cost estimates assume that mobe/demobe costs will be 10% of the revetment construction cost and annual sand nourishment volumes will be equal to the average of the nourishment volumes placed on the beach since 2013. A unit cost of $30/cubic yard was assumed for the purchase, trucking, and spreading of nourishment material. While this cost is higher than what the Town has paid in the past, it is similar to current market rates on the Cape.

Table 4. Construction Cost Estimate for Alternative #2.

Alternative #2: Stone Revetment with Vegetated Sand Cover					
Item	**Unit**	**Description**	**Quantity**	**Unit Price**	**Amount**
1	Lump sum	Mobe/Demobe	1	$131,200	$131,200
2	Cubic yards	Excavate and replace dune sand	25,000	$15	$375,000
3	Linear feet	Install stone revetment	656	$2,000	$1,312,000
4	Each	Replace walkways	2	$2,000	$4,000
5	SY	Removal/Disposal of Pavement in Ex. Lower Parking Area	4300	$25	$107,500
6	SY	New Paved Parking Lot (Lower Lot)	4300	$100	$430,000
7	SF	Bioretention Swale	3530	$100	$353,000
8	Square feet	Beachgrass plantings	23,430	$1.50	$35,145
9	Lump sum	New entrance booth	1	$20,000	$20,000
10	Lump sum	New administration building	1	$270,000	$270,000
11	Linear feet	Granite curbing	200	$90	$18,000
12	Square yards	New pavement	50	$100	$5,000
13	Square yards	Packed Stone – Relocated ORV Accessway	2,140	$45	$96,300
14	Linear feet	Timber safety rail	1,010	$100	$101,000
15	Lump sum	Wetland replication/restoration of existing ORV access trail	1	$100,000	$100,000
				Subtotal	$3,358,145
				25% Contingency	$839,536
				TOTAL ESTIMATED COST	**$4,197,681**

Table 5. Alternative #2 Cost Estimates for Construction and Maintenance Over 50-Years.

Alternative No.	Description	Estimated Initial Construction Costs	Estimated Maintenance Costs (49 Years)			Total Estimated Cost
			Description	Budgeted Cost/Event	Total (49 Years incl 3.8% annual inflation)	Initial Construction + Maintenance Over 50 Years
2	Stone revetment with vegetated sand cover	$4.2 mil	Annual sand nourishment (49 events at 3,624 cy/yr)	$108,720	$15.5 mil	**$22.8 mil**
			Annual beachgrass plantings (49 events at 4,000 sq ft/yr)	$6,000	$0.9 mil	
			Revetment repair & maintenance (every 10 yrs)	$196,800	$2.2 mil	

4.2 Alternative #3 – Bio-Engineered Sand-Filled Coir Bags with Vegetated Sand Cover

Description: Conceptual Alternative #3 from the 2016 study includes an 800 linear foot long bio-engineered sand-filled coir bag array along the seaward side of the existing coastal dune (Figures 13a & b). The array would consist of sand filled coir bags with varying dimensions (4x3 ft and 5.4 ft) stacked 3 to 4 bags high. The base row of coir bags would be anchored in place with 4-inch square wooden posts. The stacked coir bag array would be covered with a minimum of 3 feet of compatible sand following a slope seaward at 1.5H:1V. Jute erosion matting would be placed on top of the sand cover and planted with beachgrass. Sand fencing along the toe of the sand cover would be added to encourage sand accumulation. To provide additional resiliency and protect the coir bags from degradation, sand cover would be maintained across the face of the coir array on an annual basis.

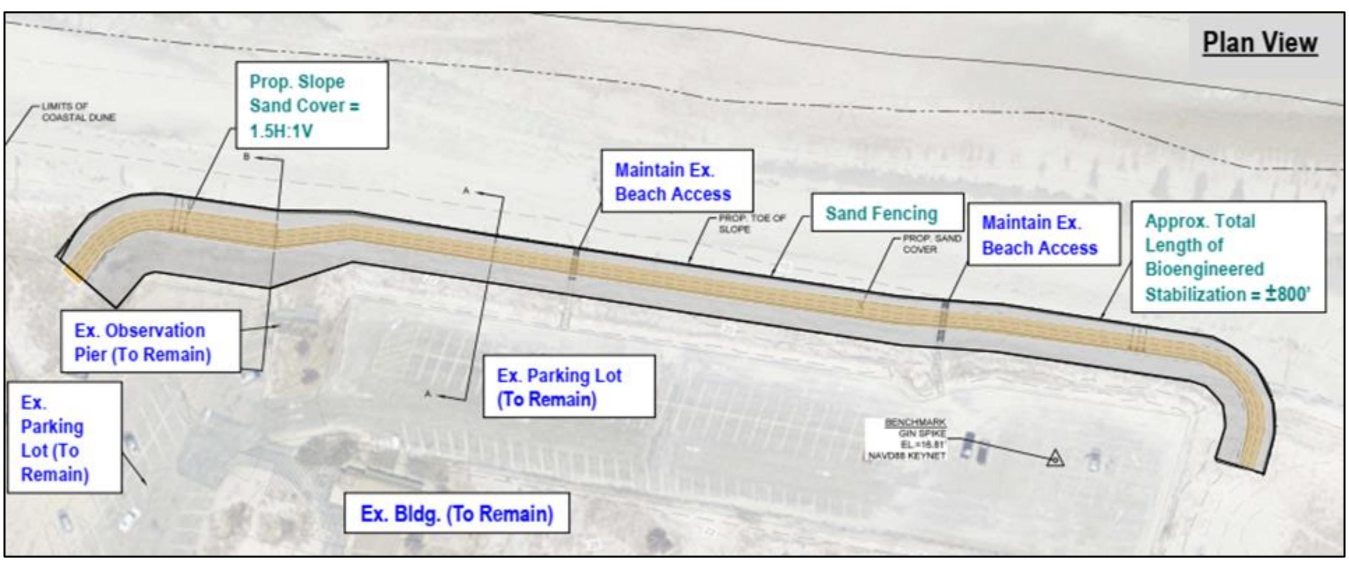


Figure 13a. Plan view of conceptual Alternative #3 from the 2016 study.

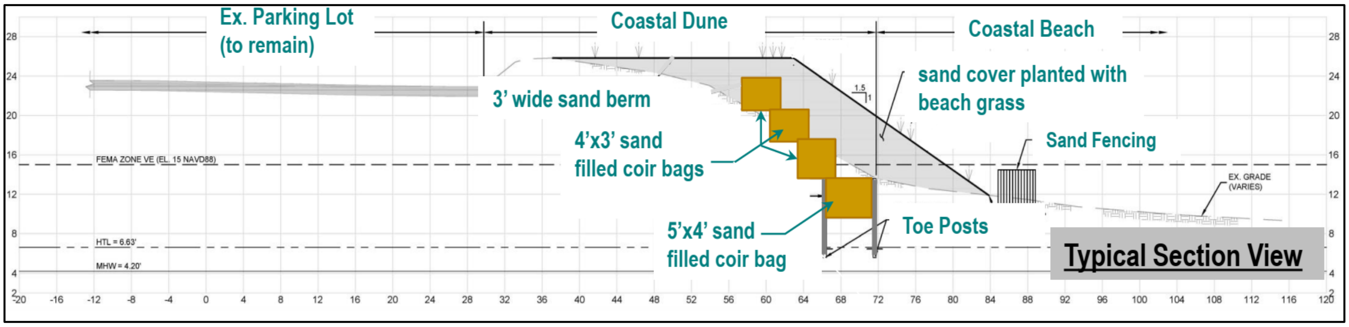


Figure 13b. Cross-section of conceptual Alternative #3 from the 2016 study.

Based on review of the Alternative #3 design elements and experience with similar structures, Woods Hole Group engineers made modifications to the conceptual design to improve the performance of the coir bags (Figure 14). The modifications included moving the coir bags away from the seaward face of the dune to the edge of the current parking lot and building a pyramid shaped array with two (2) layers of bags instead of four (4). Bags at the bottom of the array would be anchored using 10-12-inch diameter posts spaced 6 feet apart. The entire system would be covered with approximately 30 ft of sand to restore the profile of the current dune, and sturdy drift fence would be installed along the toe of the restored dune. Moving the array closer to the parking lot allows for more extensive sand cover over the system that will provide enhanced protection during storms. The pyramid shaped design with larger posts also provides more stability and minimizes potential failure observed on other systems where damage to the bottom bag has caused the upper bags to collapse. Use of a sturdy drift fence in place of sand fencing will provide enhanced protection for the dune sediment covering the sand-bag array.

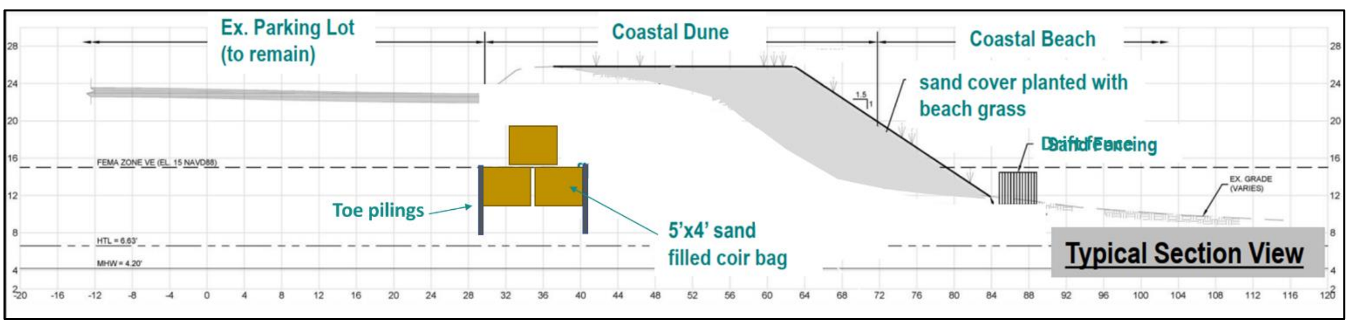


Figure 14. Cross-section of modified Alternative #3.

Performance & Longevity: Performance modeling of the modified Alternative #3 concept for present day water levels at Transect 2 is shown in Figure 15. The simulations show that 50- and 100-yr storms erode all of the sand cover in front of the coir bags leaving them exposed to direct wave action. Once the bags are exposed, the potential for failure of the array increases significantly as direct wave activity can cause the bags to lose sediment and shift in position. Figure 16 shows an example of a coir bag array with five (5) tiers where storm damage has eroded the sand cover, causing deflation of the bottom and intermediate bags. With Alternative #3 once the bags are exposed, the parking lot behind the coir bags would be susceptible to undermining and damage from direct wave action. Areas susceptible to damage are indicated by the zone of erosion in Figure 15. As would be expected, the potential for erosion of the sand dune cover and damage of the coir bag array increases as sea levels rise in 2030, 2050, and 2070. Damage to the upper parking lot with modified Alternative #3 would not impact the existing septic system, although erosion from a 50- or 100-year storm in out years 2050 and 2070 could approach the northern edge of the septic system.

The design life of a coir bag system is typically 5 to 7 years provided sand cover is maintained to protect from direct wave action and ultraviolet degradation of the coir. By placing the coir bags along the back side of the dune, as opposed to the seaward side with the 2016 design, the design life could likely be extended to 10 years, as the potential for exposure would be reduced. However, even in years when the sand cover is not completely eroded, it would be important follow an annual program of dune nourishment to ensure adequate sand cover and sediment supply to the barrier beach system.

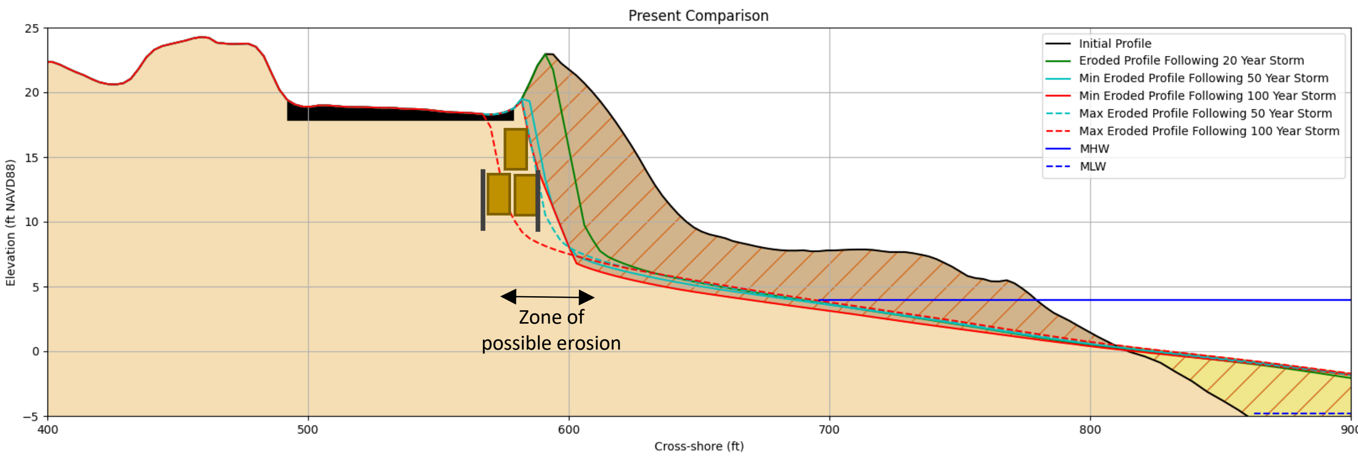


Figure 15. XBeach storm simulations for modified Alternative 3 with present day sea level showing initial and eroded profiles at Transect 2.

Figure 16. Example of failed sand-filled coir bag system.

Permittability: Coir bag shore protection systems have been permitted in coastal dunes by local and state regulatory agencies in Massachusetts. When considering compliance with the Massachusetts Wetlands Protection Regulations, these systems differ from stone revetments like the one evaluated for Alternative #2. Coir bag arrays tend to absorb wave energy thereby reducing the potential for storm or flood damage caused by scour in front of the system. Once exposed to direct wave action, sand inside the bags can leach out and provide a source of sediment for the beach. The primary volume of the coir bags is composed of sand and as such they do not cause removal of sand from the dune artificially. And finally, the coir bag arrays are generally considered to be temporary structures that need repair and/or replacement on a regular basis. For these reasons, local and state regulatory agencies have found bio-engineered coir bags to comply with the performance standards for work in coastal dunes and barrier beaches.

Given that Sandy Neck Beach Park is located in an Area of Critical Environmental Concern (ACEC) with habitat for state and federally listed species, there will be increased scrutiny of any shore protection design; however, successful permitting for similar projects in the state suggest that a coir bag system could be approved at this site. Additional permits required for Alternative #3 would include a Certificate from the Secretary of Energy and Environmental Affairs (MEPA) on an Environmental Notification Form (ENF), an Order of Conditions from the Barnstable Conservation Commission/MA DEP, and a determination from from NHESP that the project will not result in an adverse impact to the resource area habitats of state-listed wildlife species pursuant to the Wetlands Protection Act and will not result in a prohibited Take pursuant to the Massachusetts Endangered Species Act (MESA).

Resource Area Impacts/Benefits: The conceptual design for modified Alternative #3 would impact approximately 24,000 square feet of coastal dune and barrier beach resource. The structure would also be located within estimated habitat of rare wildlife. The 1.5H:1V slope of the structure and overlying sand cover is considered too steep for the passage of the shorebirds, and NHESP would likely require a 10H:1V slope on the face of the restored dune to avoid a prohibited Take of state-listed species.

Costs: Updated construction costs for installation of the modified coir bag array with vegetated sand cover and drift fence are summarized in Table 6. Total costs including initial construction, annual nourishment, beachgrass plantings, and coir bag repair/replacement over a 50-year period are summarized in Table 7. The cost estimates assume that mobe/demobe costs will be 10% of the revetment construction cost and annual sand nourishment volumes will be equal to the average of the nourishment volumes placed on the beach since 2013. As with Alternative #2, a unit cost of $30/cubic yard was assumed for the purchase, trucking, and spreading of nourishment material to reflect current market rates on the Cape. Reconstruction of one-half of the coir bag array was assumed every ten (10) years.

Table 6. Construction Cost Estimate for Modified Alternative #3.

3.1 Alternative #3: Bio-Engineered Sand-Filled Coir Bags with Vegetated Sand Cover					
Item	**Unit**	**Description**	**Quantity**	**Unit Price**	**Amount**
1	Lump sum	Mobe/Demobe	1	$200,000	$200,000
2	Cubic yards	Excavate and replace dune sand	25,000	$15	$375,000
3	Linear feet	Install coir bags	800	$2,500	$2,000,000
4	Each	Anchor pilings	267	$750	$200,000
6	Sq feet	Erosion blankets	28,800	$0.24	$6,912
7	Each	Replace walkways	2	$2,000	$4,000
8	Linear feet	Drift fence	800	$20	$16,000
9	Square feet	Beachgrass plantings	28,800	$1.50	$43,200
				Subtotal	$2,845,112
				25% Contingency	$710,278

TOTAL ESTIMATED COST	$3,556,390

Table 7. Modified Alternative #3 Cost Estimates for Construction and Maintenance Over 50-Years.

<table>
<tr><th rowspan="2">Alternative No.</th><th rowspan="2">Description</th><th rowspan="2">Estimated Initial Construction Costs</th><th colspan="3">Estimated Maintenance Costs (49 Years)</th><th>Total Estimated Cost</th></tr>
<tr><th>Description</th><th>Budgeted Cost/Event</th><th>Total (49 Years incl 3.8% annual inflation)</th><th>Initial Construction + Maintenance Over 50 Years</th></tr>
<tr><td rowspan="3">2</td><td rowspan="3">Bio-engineered sand-filled coir bags with vegetated sand cover</td><td rowspan="3">$3.6 mil</td><td>Annual sand nourishment (49 events at 3,624 cy/yr)</td><td>$108,720</td><td>$15.5 mil</td><td rowspan="3">$31.1 mil</td></tr>
<tr><td>Annual beachgrass plantings (49 events at 4,000 sq ft/yr)</td><td>$6,000</td><td>$0.9 mil</td></tr>
<tr><td>Coir bag replacement (400 linear feet every 10 yrs)</td><td>$1.0 mil</td><td>$11.1 mil</td></tr>
</table>

4.3 Alternatives #5A-5D: – Relocate/Reconfigure Parking Lot with Options for Relocating the ORV Access, Reconfiguring the Air-Up/Air-Down Areas and Providing Screening with Trees and/or Dunes

Description: The 2016 conceptual Alternatives #5A, #5B, #5C, and #5D make efficient use of the areas around the existing parking lots and bath house building. All of the 5A thru 5D alternatives reuse the southern portion of the existing upper parking lot and relocate the lower lot outside of the predicted limit of 50-year dune loss. The four concepts include a new interpretive learning center, a 10 x 14-foot guard shed, and vegetated bioswales for stormwater management. Each concept provides approximately 228 parking spaces. Restoration of the primary dune is shown on the plans developed for each concept; however, proposed grading of the dune is not provided, and it is unclear as to the feasibility of ADA access to the beach. It is assumed that means of pedestrian access to the beach would be maintained using the existing paths. A plan-view and cross-section view of conceptual Alternative #5D is shown in Figure 17.

The existing septic system, which is located beneath the upper parking lot, is shown as to-remain in its current location with the new primary dune shown to be constructed over portions of the existing septic system. It is unclear how this configuration would meet current Title 5 requirements for leach field depths. The conceptual plans for each of the four concepts were developed utilizing an aerial image as the base plan rather than utilizing an existing conditions survey. This limits the evaluation of possible impacts that any required topographic changes may have for each concept. Additionally, the conceptual alternates presented did not appear to consider the regulatory agency comments that the pavement area of the proposed lots must not exceed the pavement area of the existing parking lots.

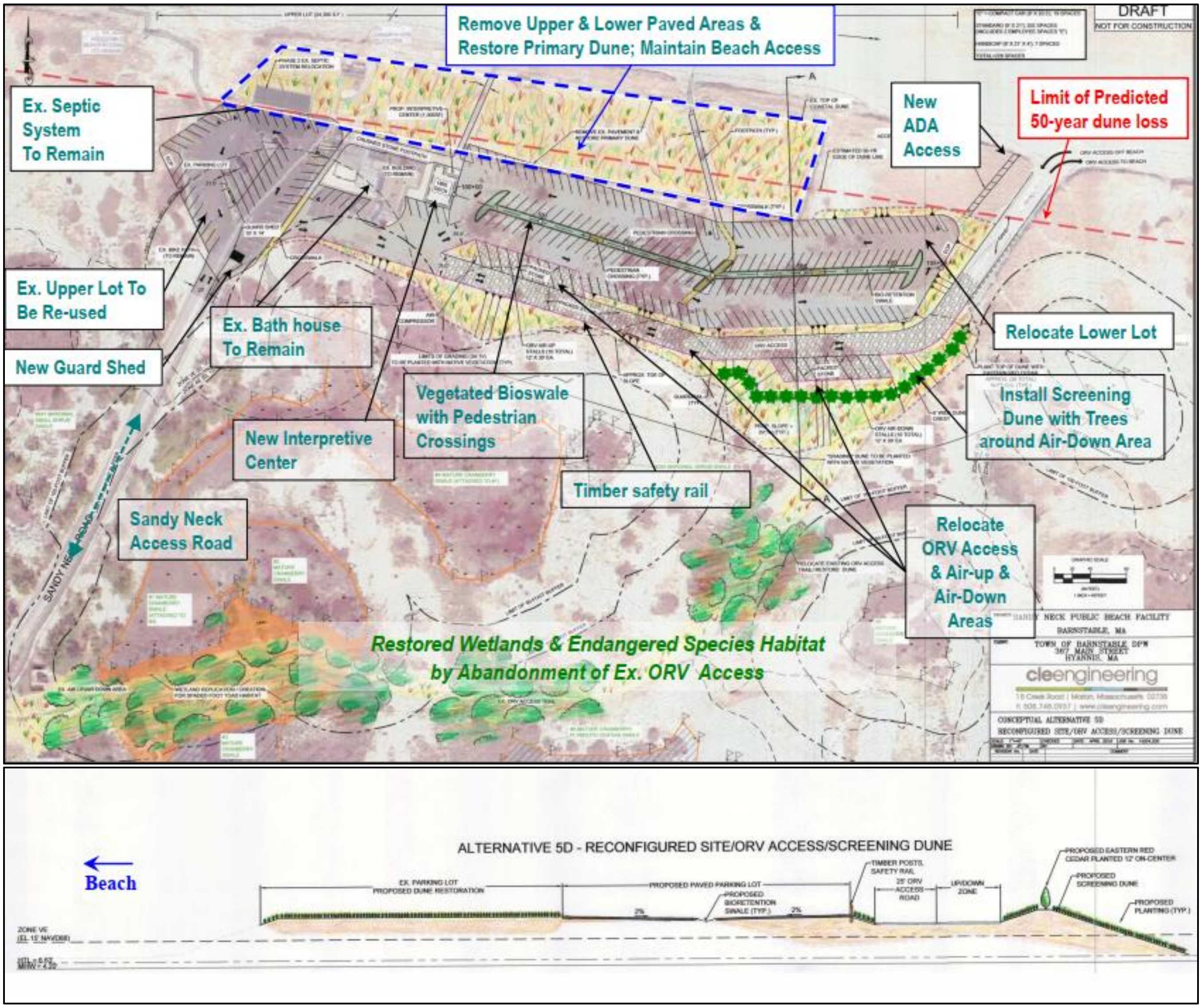


Figure 17. Plan view (top) and cross-section (bottom) of conceptual Alternative #5D from the 2016 study.

In addition to the primary design elements described above, conceptual Alternatives #5A, #5B, #5C, and #5D include the following additional components:

- Conceptual Alternative #5A utilizes the existing off-road vehicle (ORV) trail which directs users to the air-up/air-down site off Sandy Neck Road. That site contains two compressors capable of providing air to four vehicles at one time and space to accommodate approximately six other vehicles within the gravel staging area.
- Conceptual Alternative #5B is a copy of Alternative #5A, with the addition of a dedicated two-lane gravel ORV access trail from the upper parking lot to the beach, located on the back side of the relocated parking lot. It also includes 10 gravel parking spaces to be used for air-up prior to vehicles entering the paved access road. In this concept, the existing ORV trail is shown to be restored with additional dune sand and native vegetation.
- Conceptual Alternative #5C is very similar to Alternative #5B, with the addition of 10 gravel air-down spaces and landscape screening with trees adjacent to the dedicated ORV access road behind the

relocated parking lot. The existing ORV trail is again shown as being restored with a sand dune and native vegetation.

- Conceptual Alternative #5D is a copy of Alternative #5C, with the addition of enhanced screening around the air-down spaces using trees and a sand dune feature. It is noted that the additional landscaping and dune construction included with this alternative may not be necessary for a visual buffer/screening, since the area is lower in elevation that other areas of the site.

Performance & Longevity: Performance modeling of the four (4) Alternative #5 concepts are identical since the primary dune remains the same with each alternative. Model results for sea level conditions in 2070 at Transect 2 are shown in Figure 18. Crest elevations for the restored primary dune were assumed to be 28 and 23.2 ft NAVD88 for Transects 1 and 2, respectively. The results indicate that the more landward reconfigured parking lot is safe from erosion, even with a 100-year storm and higher sea levels in 2070. For the 100-yr storm scenario, approximately 38 feet of dune remains to protect the parking lot. With the higher return period 50- and 20-year storms, approximately 53 and 68 feet of dune remains to protect the parking lot. To maintain a healthy and protective coastal dune over the 50-year time horizon, renourishment would be required approximately every 5 years.

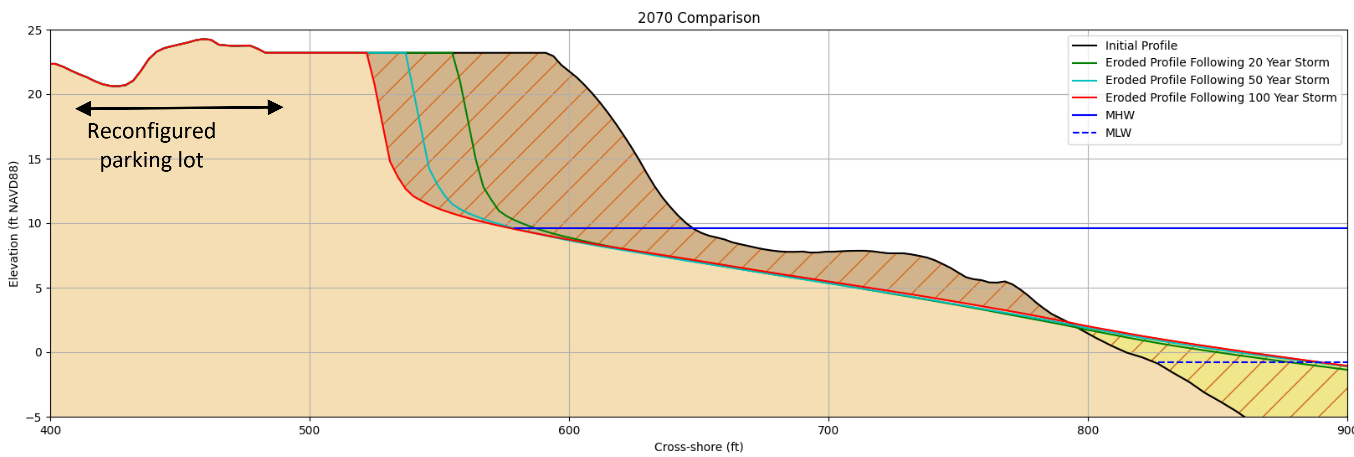


Figure 18. XBeach storm simulations for Alternatives #5A through #5D with predicted 2070 sea level showing initial and eroded profiles for Transect #2.

Permittability: Conceptual Alternatives #5A through #5D are likely permittable based on discussions with the regulatory agencies during the prior 2016 study. The agencies indicated that the footprint of paved areas on site should not be increased and impacts to critical resources such as vernal pools and habitat for state-listed species must be minimized. Currently conceptual Alternatives #5A through #5D result in a small increase in impervious area. As such, the designs will need to be modified to reduce the area of paved surface if the Town chooses to proceed with any one of these alternatives. Impacts to spadefoot toad and vernal pool habitat are lower with Alternatives #5B, #5C, and #5D as the ORV trail is rerouted behind the reconfigured parking lot and the existing ORV trail is restored. These alternatives also restore connectivity of the spadefoot toad habitat, which is currently bisected by the ORV trail. Because impacts to spadefoot toad habitat cannot be avoided with any of the Alternative #5 concepts, the NEHSP indicated during the 2016 study that the parking lot relocation alternatives would result in a "take" of Eastern Spadefoot Toad; however, a Conservation Permit could be issued provided that impacts are minimized and appropriate mitigation measures are agreed upon. Mitigation measures could include on-site mitigation at a 2:1 ratio or a fee payment to NHESP for use in habitat restoration.

Once the Town has selected a short-list of three (3) preferred alternatives, meetings will be scheduled with the regulatory agencies to discuss the permitting strategy and necessary mitigation actions. As with conceptual Alternative #3, permits for Alternative #5 would be required from MEPA, Barnstable Conservation Commission/MA DEP, and NHESP.

Resource Area Impacts/Benefits: The conceptual designs for Alternatives #5A through #5D would impact coastal dune, barrier beach, and estimated habitat of rare wildlife resources. Reconfiguration of the parking lot would alter approximately 41,200 sq ft of resource area; however, an area roughly equal in size would be restored to coastal dune/barrier beach. Of the four (4) alternatives, impacts to resource areas would be the smallest with Alternative #5A, as the design does not include relocation of the existing ORV trail. Alternatives #5C and #5D would have the greatest resource area impacts as they include additional air-up/air-down spaces.

Costs: Updated construction costs for the Alternative #5 options are included in Tables 8-11. Updates to the previous Opinion of Probable Construction Costs (OPC) from the 2016 study were made to reflect current construction costs. Previous assumptions that the parking lot could be milled and overlayed are no longer feasible due to the poor condition of the pavement and the costing was updated to reflect installation of new pavement. Curbing in the parking lots was also added to effectively direct runoff into the stormwater management features. Total costs including initial construction, annual maintenance of the parking lot and stormwater systems, periodic dune nourishment and beachgrass plantings are provided in Table 12.

Table 8. Updated Preliminary Construction Cost Estimate for Alternative #5A.

Alternative #5A: Relocate/Reconfigure Parking Lot					
Item	**Unit**	**Description**	**Quantity**	**Unit Price**	**Amount**
1	SY	Removal/Disposal of Pavement in Ex. Parking Areas (Upper & Lower Lot)	5,900	$25	$147,500
2	CY	Sand Fill - New Parking Lot (Lower Lot)	5,240	$30	$157,200
3	SY	Relocated/New Paved Parking Lot (Lower Lot)	7,300	$100	$730,000
4	SY	Mill/Resurface Existing Parking Lot (To Remain - Upper Lot)	2,575	$50	$128,750
5	SY	New Pavement (Upper Lot)	130	$100	$13,000
6	CY	Sand Fill - New Pavement (Upper Lot)	175	$30	$5,250
7	SF	Bioretention Swale	3,450	$100	$345,000
8	CY	Restoration of Primary Dune	5,900	$30	$177,000
9	SF	Am. Beach Grass Planting (Old Parking Area & Side Slopes of New Parking)	75,700	$1.50	$113,550
10	LS	Misc. Planting	1	$10,000	$10,000
11	LS	Misc. Landscaping	1	$15,000	$15,000
12	LF	Install Timber Safety Rail	725	$100	$72,500
13	LS	Exist. Beach Access #1 & #2 Modifications	1	$25,000	$25,000
14	LF	New ADA Mobi-Mat (Seasonal)	100	$150	$15,000
15	LS	New Seasonal Guard Shed (Including Electrical)	1	$50,000	$50,000
16	LS	NHESP Mitigation Fee	1	$50,000	$50,000
17	LF	Granite Curbing	2,000	$90	$180,000
Signage & Pavement Marking (5% of New Pavement Costs)					$43,590
Earthwork (10% of Sand Fill Costs)					$29,800
			Subtotal		$2,294,640
			Contingency (25% of Subtotal)		$573,700
			Mobilization/Demobilization (5% of Subtotal)		$114,740
			TOTAL ESTIMATED COST		**$2,983,080**

Table 9. Updated Preliminary Construction Cost Estimate for Alternative #5B.

Alternative #5B: Relocate/Reconfigure Parking Lot & ORV Access; Reconfigure Existing Air-Down Area					
Item	**Unit**	**Description**	**Quantity**	**Unit Price**	**Amount**
1	SY	Removal/Disposal of Pavement in Ex. Parking Areas (Upper & Lower Lot)	5,900	$25	$147,500
2	CY	Sand Fill - New Parking Lot (Lower Lot)	7,550	$30	$226,500
3	SY	Relocated/New Paved Parking Lot (Lower Lot)	7,300	$100	$730,000
4	SY	Mill/Resurface Existing Parking Lot (To Remain - Upper Lot)	2,575	$50	$128,750
5	SY	New Pavement (Upper Lot)	130	$100	$13,000
6	CY	Sand Fill - New Pavement (Upper Lot)	175	$30	$5,250
7	SY	Packed Stone - Relocated ORV Accessway	2,140	$45	$96,300
8	SY	Packed Stone Air-Down Area (5B Only)	830	$45	$37,350
9	SY	Relocate Paved Bike Path (5B Only)	300	$60	$18,000
10	SF	Bioretention Swale	3,450	$100	$345,000
11	CY	Restoration of Primary Dune	5,900	$30	$177,000
12	SF	Am. Beach Grass Planting (Old Parking Area & Side Slopes of New Parking)	76,235	$1.50	$114,353
13	LS	Misc. Planting	1	$10,000	$10,000
14	LS	Misc. Landscaping	1	$15,000	$15,000
15	LF	Install Timber Safety Rail	1,010	$100	$101,000
16	LS	Exist. Beach Access #1 & #2 Modifications	1	$25,000	$25,000
17	LF	New ADA Mobi-Mat (Seasonal)	100	$150	$15,000
18	LS	New Seasonal Guard Shed (Including Electrical)	1	$50,000	$50,000
19	LS	Wetland Replication/Restoration at Exist. ORV Accessway	1	$100,000	$100,000
20	LS	NHESP Mitigation Fee	1	$50,000	$50,000
21	LF	Granite Curbing	2,000	$90	$180,000
Signage & Pavement Marking (5% of New Pavement Costs)					$43,590
Earthwork (10% of Sand Fill Costs)					$42,500
			Subtotal		$2,651,793
			Contingency (25% of Subtotal)		$663,000
			Mobilization/Demobilization (5% of Subtotal)		$132,590
			TOTAL ESTIMATED COST		**$3,447,383**

Table 10. Updated Preliminary Construction Cost Estimate for Alternative #5C.

Alternative #5C: Relocate/Reconfigure Parking Lot & ORV Access with Screening Trees; Relocate Existing Air-Up/Air-Down Areas					
Item	**Unit**	**Description**	**Quantity**	**Unit Price**	**Amount**
1	SY	Removal/Disposal of Pavement in Ex. Parking Areas (Upper & Lower Lot)	5,900	$25	$147,500
2	CY	Sand Fill - New Parking Lot (Lower Lot)	8,510	$30	$255,300
3	SY	Relocated/New Paved Parking Lot (Lower Lot)	7,300	$100	$730,000
4	SY	Mill/Resurface Existing Parking Lot (To Remain - Upper Lot)	2,575	$50	$128,750
5	SY	New Pavement (Upper Lot)	130	$100	$13,000
6	CY	Sand Fill - New Pavement (Upper Lot)	175	$30	$5,250
7	SY	Packed Stone - Relocated ORV Accessway	2,140	$45	$96,300
8	SF	Bioretention Swale	3,450	$100	$345,000
9	EA	Screening Trees (Eastern Red Cedar)	25	$850	$21,250
10	CY	Restoration of Primary Dune	5,900	$30	$177,000
11	SF	Am. Beach Grass Planting (Old Parking Area & Side Slopes of New Parking)	76,235	$1.50	$114,353
12	LS	Misc. Planting	1	$10,000	$10,000
13	LS	Misc. Landscaping	1	$15,000	$15,000
14	LF	Install Timber Safety Rail	1,075	$100	$107,500
15	LS	Exist. Beach Access #1 & #2 Modifications	1	$25,000	$25,000
16	LF	New ADA Mobi-Mat (Seasonal)	100	$150	$15,000
17	LS	New Seasonal Guard Shed (Including Electrical)	1	$50,000	$50,000
18	LS	Wetland Replication/Restoration at Exist. ORV Accessway	1	$100,000	$100,000
19	LS	NHESP Mitigation Fee	1	$50,000	$50,000
20	LF	Granite Curbing	2,000	$90	$180,000
Signage & Pavement Marking (5% of New Pavement Costs)					$43,590
Earthwork (10% of Sand Fill Costs)					$47,800
			Subtotal		$2,655,893
			Contingency (25% of Subtotal)		$664,000
			Mobilization/Demobilization (5% of Subtotal)		$132,800
			TOTAL ESTIMATED COST		**$3,452,693**

Table 11. Updated Preliminary Construction Cost Estimate for Alternative #5D.

Alternative #5D: Relocate/Reconfigure Parking Lot & ORV Access with Screening Dune; Relocate Existing Air-Up/Air-Down Areas					
Item	**Unit**	**Description**	**Quantity**	**Unit Price**	**Amount**
1	SY	Removal/Disposal of Pavement in Ex. Parking Areas (Upper & Lower Lot)	5,900	$25	$147,500
2	CY	Sand Fill - New Parking Lot (Lower Lot)	11,180	$30	$335,400
3	SY	Relocated/New Paved Parking Lot (Lower Lot)	7,300	$100	$730,000
4	SY	Mill/Resurface Existing Parking Lot (To Remain - Upper Lot)	2,575	$50	$128,750
5	SY	New Pavement (Upper Lot)	130	$100	$13,000
6	CY	Sand Fill - New Pavement (Upper Lot)	175	$30	$5,250
7	SY	Packed Stone - Relocated ORV Accessway	2,140	$45	$96,300
8	SF	Bioretention Swale	3,450	$100	$345,000
9	EA	Screening Trees (Eastern Red Cedar)	26	$850	$22,100
10	CY	Restoration of Primary Dune	5,900	$30	$177,000
11	SF	Am. Beach Grass Planting (Old Parking Area & Side Slopes of New Parking)	89,865	$1.50	$134,798
12	LS	Misc. Planting	1	$10,000	$10,000
13	LS	Misc. Landscaping	1	$15,000	$15,000
14	LF	Install Timber Safety Rail	1,075	$100	$107,500
15	LS	Exist. Beach Access #1 & #2 Modifications	1	$25,000	$25,000
16	LF	New ADA Mobi-Mat (Seasonal)	100	$150	$15,000
17	LS	New Seasonal Guard Shed (Including Electrical)	1	$50,000	$50,000
18	LS	Wetland Replication/Restoration at Exist. ORV Accessway	1	$100,000	$100,000
19	LS	NHESP Mitigation Fee	1	$50,000	$50,000
20	LF	Granite Curb	2,000	$90	$180,000
Signage & Pavement Marking (5% of New Pavement Costs)					$43,590
Earthwork (10% of Sand Fill Costs)					$62,500
			Subtotal		$2,765,288
			Contingency (25% of Subtotal)		$691,400
			Mobilization/Demobilization (5% of Subtotal)		$138,270
			TOTAL ESTIMATED COST		**$3,594,958**

Table 12. Updated Preliminary Cost Estimates for Construction and Maintenance Over 50-Years for Alternatives #5A through #5D.

Alternative No.	Description	Estimated Initial Construction Costs	Estimated Maintenance Costs (49 Years)			Total Estimated Cost
			Description	Budgeted Cost/ Event	Total (49 Years incl 3.8% annual inflation)	Initial Construction + Maintenance Over 50 Years
5A	Relocate/ Reconfigure Parking Lot	$3.0 Mil	Sand Nourishment (9 events at 7,249 cy/ event)	$217,470	5.6 Mil	**11.2 Mil**
			Beach Grass Plantings (9 events at 46,840 sq ft/yr)	$70,290	1.2 Mil	
			Annual Maintenance of Lot	$10,000	1.4 Mil	
5B	Relocate/ Reconfigure Parking Lot & ORV Access; Reconfigure Existing Air-Down Area	$3.4 Mil	Sand Nourishment (9 events at 7,249 cy/ event)	$217,470	5.6 Mil	**11.6 Mil**
			Beach Grass Plantings (9 events at 46,840 sq ft/yr)	$70,290	1.2 Mil	
			Annual Maintenance of Lot	$10,000	1.4 Mil	
5C	Relocate/ Reconfigure Parking Lot & ORV Access with Screening Trees; Relocate Existing Air-Up/Air-Down Areas	$3.5 Mil	Sand Nourishment (9 events at 7,249 cy/ event)	$217,470	5.6 Mil	**11.7 Mil**
			Beach Grass Plantings (9 events at 46,840 sq ft/yr)	$70,290	1.2 Mil	
			Annual Maintenance of Lot	$10,000	1.4 Mil	
5D	Relocate/ Reconfigure Parking Lot & ORV Access with Screening Dune; Relocate Existing Air-Up/Air-Down Areas	$3.6 Mil	Sand Nourishment (9 events at 7,249 cy/ event)	$217,470	5.6 Mil	**11.8 Mil**
			Beach Grass Plantings (9 events at 46,840 sq ft/yr)	$70,290	1.2 Mil	
			Annual Maintenance of Lot	$10,000	1.4 Mil	

4.4 Conceptual Alternative #6 – Relocate/Reconfigure Park Lot & ORV Access; Relocate and Expand Number of Air-Up/Air-Down Areas; Relocate Gatehouse and Add Emergency Vehicle Access to Beach

Description: Conceptual Alternative #6 was developed by Tighe & Bond and Woods Hole Group using the topographic survey data collected during the summer of 2022 and updated wetland delineations. The ground survey and wetland delineation allowed for consideration of topographic constraints at the site and review of the existing parking lot in order to match the existing area of pavement in developing the conceptual alternative. This alternative also addresses modifications necessary to streamline gatehouse operations, reduce vulnerability of the gatehouse to flooding, and provide emergency access to the beach from the parking lot.

Alternative #6 includes a new entrance booth, a new 25 x 40-ft administration building, two emergency access paths, 29 air-up/air-down spaces, and 203 parking spaces in the re-configured parking lots (Figure 19). Stormwater management for this alternative includes the previously proposed rain gardens that have been expanded to include a formal stormwater management/natural habitat area which will allow the parking lot to better mitigate extreme storm events. Similar to some of the previous concepts, Concept 6 makes use of a separate ORV access road from the upper parking lot which allows the staff to more efficiently monitor the traffic at the site and to ensure that users are parking in the appropriate designated areas. This concept also locates all the vulnerable infrastructure outside the limits of the predicted 50-year dune loss, which provides significant resiliency from wave-induced coastal erosion.

Performance & Longevity: Performance of the dune in protecting conceptual Alternative #6 is identical to that of Alternative #5. Essentially, the dune will provide protection for the relocated parking lot through 2070 with a 100-year storm event. To maintain a healthy and protective coastal dune over the 50-year time horizon, renourishment would be required approximately every 5 years.

Permittability: The permittability of conceptual Alternative #6 is essentially the same as Alternative #5. The same type and number of permits would be required for this alternative as for Alternative #5.

Resource Area Impacts/Benefits: Conceptual Alternative #6 would impact coastal dune, barrier beach and estimated habitat of rare wildlife resources. Just as with the Alternative #5 scenarios, there would be over 40,000 sq ft of impact to the resource areas, with a nearly equal area restored as coastal dune/barrier beach. In comparison with the Alternative #5 scenarios, impacts to resource areas with this alternative would be greater due to the increased number of air-up/air-down stations and the new administration building.

Costs: Estimated construction costs for Alternative #6 are provided in Table 13 and total costs including initial construction, annual maintenance of the parking lot and stormwater systems, periodic dune nourishment and beachgrass plantings are provided in Table 14.

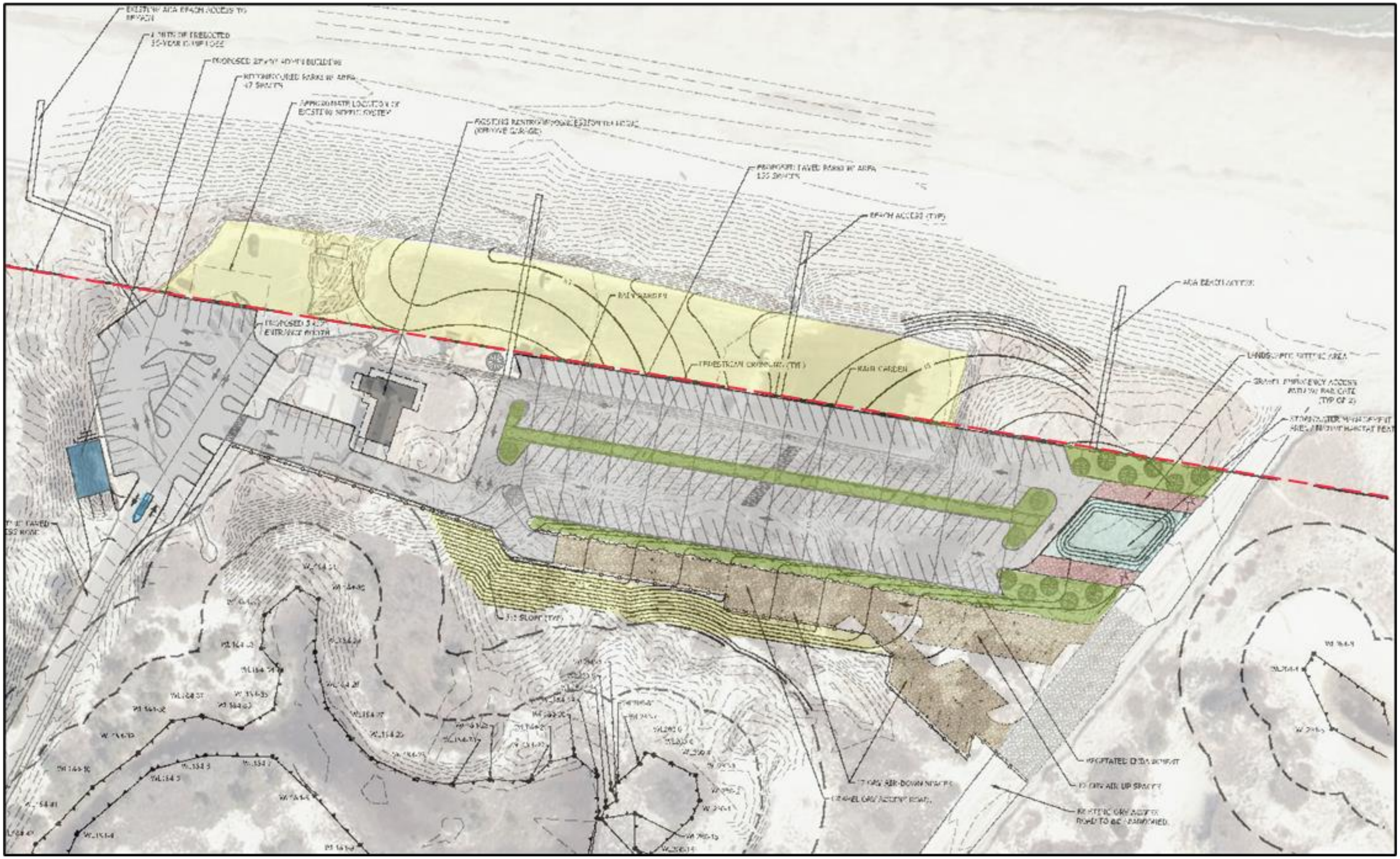


Figure 19. Plan view of new conceptual Alternative #6.

Table 13. **Preliminary Construction Cost Estimate for Alternative #6.**

***3.1* Alternative #6: Relocate/Reconfigure Park Lot & ORV Access; Relocate and Expand Number of Air-Up/Air-Down Areas; Relocate Gatehouse and Add Emergency Vehicle Access to Beach**					
Item	**Unit**	**Description**	**Quantity**	**Unit Price**	**Amount**
1	SY	Removal/Disposal of Pavement in Ex. Parking Areas (Upper & Lower Lot)	8,500	$25	$212,500
2	CY	Sand Fill - New Parking Lot (Lower Lot)	11,180	$30	$335,400
3	SY	Relocated/New Paved Parking Lot (Lower Lot)	6,000	$100	$600,000
4	SY	New Pavement (Upper Lot)	2,400	$100	$240,000
5	CY	Sand Fill - New Pavement (Upper Lot)	175	$30	$5,520
6	SY	Packed Stone - Relocated ORV Accessway	2,400	$45	$108,000
7	SF	Bioretention Swale	4,170	$100	$417,000
8	LS	Proposed Admin Building	1	$270,000	$270,000
9	CY	Restoration of Primary Dune	5,900	$30	$177,000
10	LS	Stormwater Management Area	1	$10,000	$10,000
11	SF	Am. Beach Grass Planting (Old Parking Area & Side Slopes of New Parking)	87,000	$1.50	$130,500
12	LS	Misc. Planting	1	$10,000	$10,000
13	LS	Misc. Landscaping	1	$15,000	$15,000
14	LF	Install Timber Safety Rail	800	$100	$80,000
15	LS	Exist. Beach Access #1 & #2 Modifications	1	$25,000	$25,000
16	LF	New ADA Mobi-Mat (Seasonal)	100	$150	$15,000
17	SY	Gravel Emergency Access Path with Bar Gate	300	$35	$10,500
18	LS	New Entrance Booth	1	$20,000	$20,000
19	LS	Wetland Replication/Restoration at Exist. ORV Accessway	1	$100,000	$100,000
20	LS	NHESP Mitigation Fee	1	$50,000	$50,000
21	LF	Granite Curbing	3,500	$90	$315,000
Signage & Pavement Marking (5% of New Pavement Costs)					$43,590
Earthwork (10% of Sand Fill Costs)					$62,500
			Subtotal		$3,222,250
			Contingency (25% of Subtotal)		$805,600
			Mobilization/Demobilization (5% of Subtotal)		$161,120
			TOTAL ESTIMATED COST		**$4,188,970**

Table 14. Preliminary Cost Estimates for Construction and Maintenance Over 50-Years for Alternative #6.

Alternative No.	Description	Estimated Initial Construction Costs	Estimated Maintenance Costs (49 Years)			Total Estimated Cost
			Description	Budgeted Cost/Event	Total (49 Years incl 3.8% annual inflation)	Initial Construction + Maintenance Over 50 Years
6	Relocate/ Reconfigure Park Lot & ORV Access; Relocate and Expand Number of Air-Up/Air-Down Areas; Relocate Gatehouse and Add Emergency Vehicle Access to Beach	$4.2 Mil	Sand Nourishment (9 events at 7,249 cy/ event)	$217,470	5.6 Mil	**12.4 Mil**
			Beach Grass Plantings (9 events at 46,840 sq ft/yr)	$70,290	1.2 Mil	
			Annual Maintenance of Lot	$10,000	1.4 Mil	

4.5 Conceptual Alternative #7 – Partial Relocation/Reconfiguration of Parking Lot & ORV Access; Relocate and Expand Number of Air-Up/Air-Down Areas; Relocate Gatehouse and Add Emergency Vehicle Access to Beach

Description: Similar to the previous alternative, conceptual Alternative #7 uses the new topographic survey and wetland data to inform the design. This alternative also addresses modifications necessary to streamline gatehouse operations, reduce vulnerability of the gatehouse to flooding, and provide emergency access to the beach from the parking lot.

The conceptual design for Alternative #7 maintains much of the existing upper parking lot as well as the entrance driveway to the lower parking lot (Figure 20). To reduce the overall impact on wetland resources, Alternative #7 maintains approximately one-half of the existing lower parking lot, along the south side of the lot. The seaward one-half of the parking lot would be relocated behind (south) the existing parking area. The conceptual design also includes a new entrance booth, dedicated ORV driveway behind the new portion of parking lot, emergency access paths, and 25 x 40-foot administration building. A total of 194 parking spaces would be included with this layout along with an additional 15 air-down and 30 air-up spots for off-road vehicles. By reusing portions of the existing lower parking lot, some of the proposed infrastructure would be located within the limits of predicted 50-year dune loss. The design for Alternative #7 was guided by results of the dune performance modeling that showed a dune buffer in front of the Alternatives #5 and #6 relocated parking lot of approximately 38 feet after a 100-yr storm event in 2070. This suggested complete relocation of the parking lot as planned with Alternatives #5 and #6 may not be necessary to provide the desired level of resiliency.

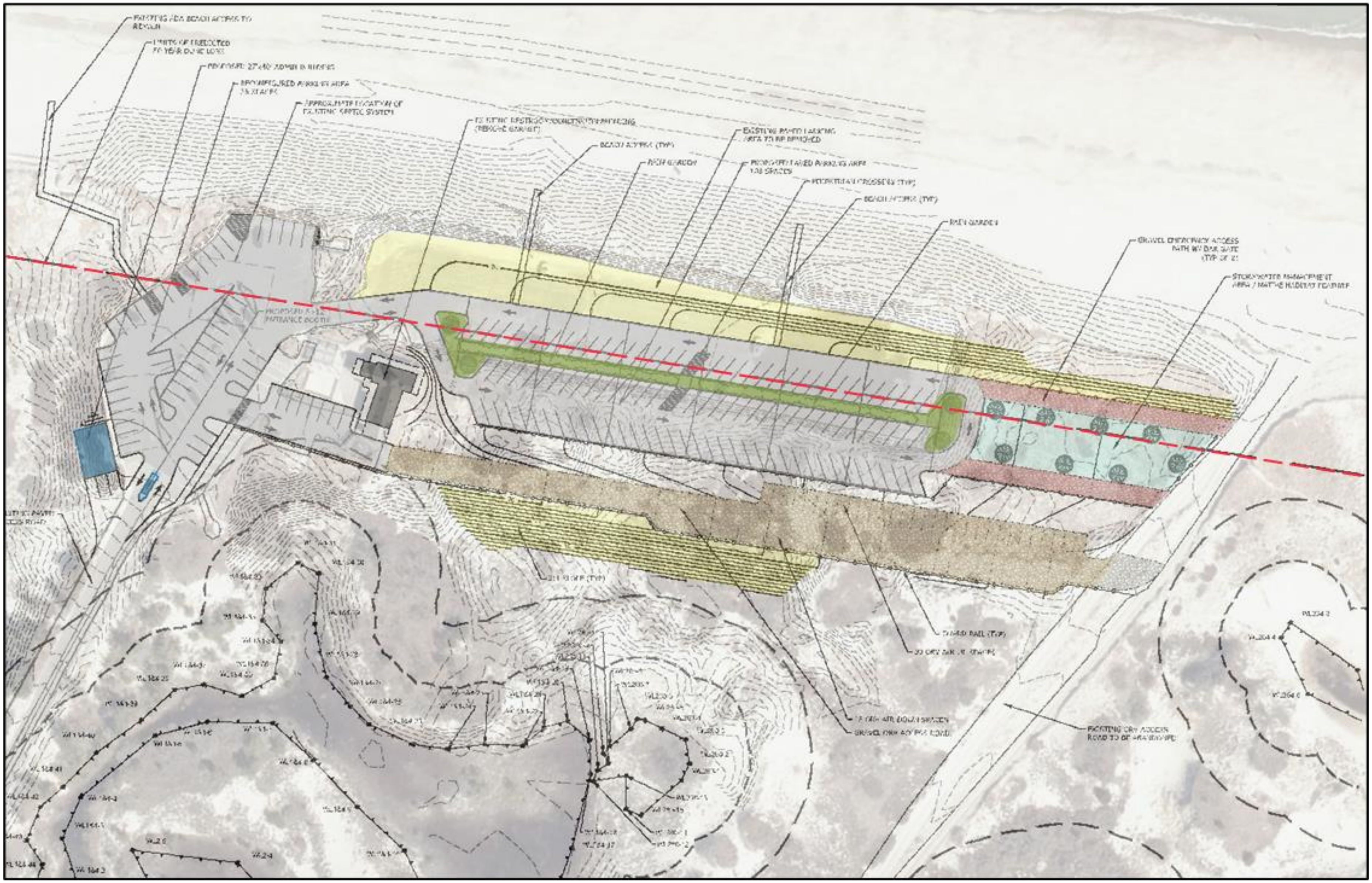


Figure 20. Plan view of new conceptual Alternative #7.

Performance & Longevity: Results from dune performance modeling for conceptual Alternative #7 during 20-, 50- and 100- year storm events and projected sea levels in 2030 and 2070 are shown in Figures 21 and 22. The results indicate that the partially relocated parking lot would be safe from erosion, even with a 100-yr storm and higher sea levels in 2030. By 2050, the parking lot would be damaged during the 100-yr storm, and erosion caused by the 50-yr storm would be at the seaward edge of the parking lot. To maintain a healthy and protective coastal dune over the 50-year time horizon, renourishment would be required approximately every 5 years.

Permittability: Since resource area impacts associated with Alternative #7 would be reduced over the previous Alternatives #5 and #6, it is safe to assume that this alternative would be permittable. The same type and number of permits would be required for this alternative as for Alternatives #5 and #6. It is also likely that the requirements for mitigation, either in the form of on-site mitigation or a fee payment to NHESP would be reduced over Alternatives #5 and #6.

Resource Area Impacts/Benefits: Conceptual Alternative #7 would impact approximately 20,600 sq ft of coastal dune, barrier beach and estimated habitat of rare wildlife resources, and approximately 10,300 sq ft of coastal dune would be restored. This alternative reduces impacts to the resource areas and helps to mitigate existing impacts to spadefoot toad habitat by relocating the ORV trail.

Costs: Estimated construction costs for Alternative #7 are provided in Table 15 and total costs including initial construction, annual maintenance of the parking lot and stormwater systems, periodic dune nourishment and beachgrass plantings are provided in Table 15.

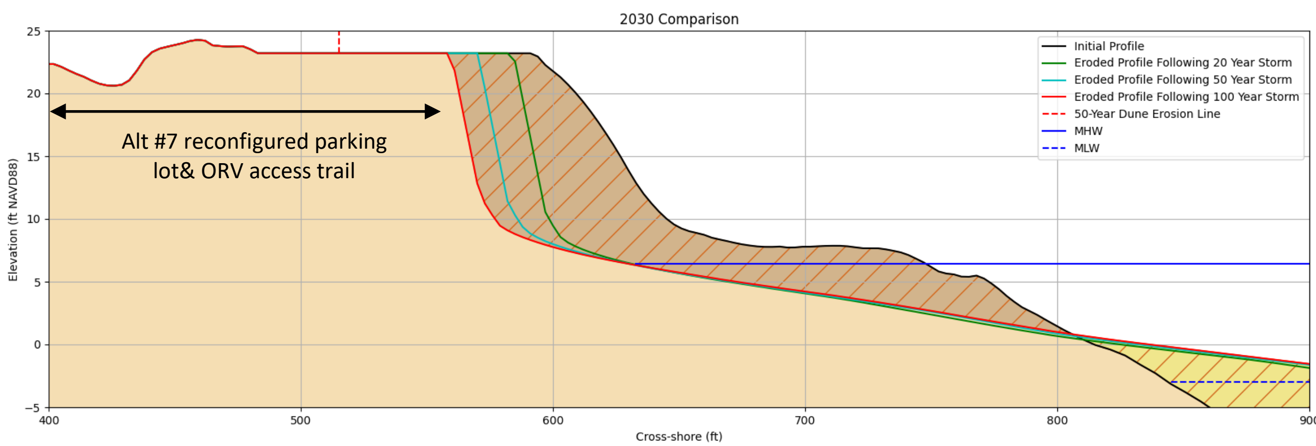


Figure 21. XBeach storm simulations for Alternative #7 with predicted 2030 sea level showing initial and eroded profiles for Transect #2.

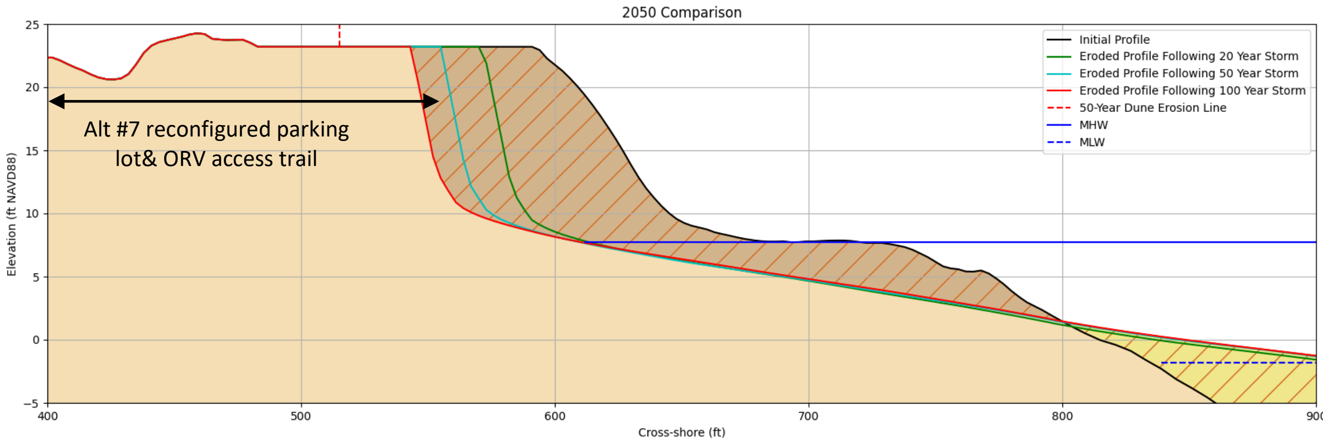


Figure 22. XBeach storm simulations for Alternative #7 with predicted 2050 sea level showing initial and eroded profiles for Transect #2.

Table 15. **Preliminary Construction Cost Estimate for Alternative #7.**

Item	Unit	Description	Quantity	Unit Price	Amount
***3.1* Alternative #7: Partial Relocation/Reconfiguration of Parking Lot & ORV Access; Relocate and Expand Number of Air-Up/Air-Down Areas; Relocate Gatehouse and Add Emergency Vehicle Access to Beach**					
1	SY	Removal/Disposal of Pavement in Ex. Parking Areas (Upper & Lower Lot)	8500	$25	$212,500
2	CY	Sand Fill - New Parking Lot (Lower Lot)	9950	$30	$298,500
3	SY	Relocated/New Paved Parking Lot (Lower Lot)	4300	$100	$430,000
4	SY	New Pavement (Upper Lot)	3350	$100	$335,000
5	CY	Sand Fill - New Pavement (Upper Lot)	175	$30	$5,250
6	SY	Packed Stone - Relocated ORV Accessway	2500	$45	$112,500
7	SF	Bioretention Swale	3530	$100	$353,000
8	LS	Proposed Admin Building	1	$270,000	$270,000
9	CY	Restoration of Primary Dune	5900	$30	$177,000
10	LS	Stormwater Management Area	1	$10,000	$10,000
11	SF	Am. Beach Grass Planting (Old Parking Area & Sideslopes of New Parking)	71000	$1.50	$106,500
12	LS	Misc. Planting	1	$10,000	$10,000
13	LS	Misc. Landscaping	1	$15,000	$15,000
14	LF	Install Timber Safety Rail	1300	$100	$130,000
15	LS	Exist. Beach Access #1 & #2 Modifications	1	$25,000	$25,000
16	LF	New ADA Mobi-Mat (Seasonal)	100	$150	$15,000
17	SY	Gravel Emergency Access Path with Bar Gate	625	$35	$21,875
18	LS	New Entrance Booth	1	$20,000	$20,000
19	LS	Wetland Replication/Restoration at Exist. ORV Accessway	1	$100,000	$100,000
20	LS	NHESP Mitigation Fee	1	$50,000	$50,000
21	LF	Granite Curbing	3600	$90	$324,000
Signage & Pavement Marking (5% of New Pavement Costs)					$38,250
Earthwork (10% of Sand Fill Costs)					$55,700
			Subtotal		$3,089,775
			Contingency (25% of Subtotal)		$772,500
			Mobilization/Demobilization (5% of Subtotal)		$154,490
			TOTAL ESTIMATED COST		**$4,016,765**

Table 16. Preliminary Cost Estimates for Construction and Maintenance Over 50-Years for Alternative #7.

Alternative No.	Description	Estimated Initial Construction Costs	Estimated Maintenance Costs (49 Years)			Total Estimated Cost
			Description	Budgeted Cost/Event	Total (49 Years incl 3.8% annual inflation)	Initial Construction + Maintenance Over 50 Years
7	Partial Relocation/ Reconfiguration of Parking Lot & ORV Access; Relocate and Expand Number of Air-Up/Air-Down Areas; Relocate Gatehouse and Add Emergency Vehicle Access to Beach	$4.0 Mil	Sand Nourishment (9 events at 7,249 cy/ event)	$217,470	5.6 Mil	**12.2 Mil**
			Beach Grass Plantings (9 events at 46,840 sq ft/yr)	$70,290	1.2 Mil	
			Annual Maintenance of Lot	$10,000	1.4 Mil	

4.6 Evaluation of Supplementary Parking

The parking lot at Sandy Neck Beach is unique in that it serves a variety of stakeholders who use the parking lot for varying purposes and lengths of time. The 2003 Long Range Natural Resource Management Plan for Sandy Neck Barrier Beach noted the demand for increased parking at the Beach Facility. As a part of the evaluation of conceptual alternatives for protection of the parking lot, a preliminary assessment of supplementary off-site parking resources was performed to explore how to meet the demand for parking during the peak season. Criteria identified by the Town as being important to a successful off-site parking operation include the following: use of existing town property or private property that can be purchased or leased, capacity for a minimum of 100 parking spaces, location within an 8 mile radius of the Park, and availability for 18 peak days during the summer season.

The evaluation of supplementary parking resources explored the following items:

- Identification of potential options for off-site parking;
- Transportation between one or more off-site parking lots and the Park; and
- Parking substitutes

Off-Site Parking Options

Work to identify parcels that meet the town's criteria is still ongoing and will be summarized in a follow-on report. As a first cut however, Figure 23 shows land in the vicinity of Sandy Neck Beach Park that is owned by the Town of Barnstable, Town of Sandwich, and other privately owned land. While Barnstable already owns several parcels near Sandy Neck, most contain wetlands or are too small to provide adequate parking. Existing large parking lots within 8 miles of the Park are limited. These include Cape Cod Community College (5.9 miles), Sandwich High School (5.2 miles), the Barnstable County

Court House (7.7 miles). An intertown agreement would need to be negotiated with the Town of Sandwich for the use of the High School parking lot, and similar arrangements would be needed for the use of the Cape Cod Community College and Court House parking lots. Further considerations need to be examined regarding the use of existing town land or private land that could be purchased or leased. Once identified, these sites need to be evaluated for acreage, zoning, wetlands, and existing conditions that would be suitable for supporting a parking lot.

Figure 13. Parcels owned by the Towns of Barnstable and Sandwich in the vicinity of Sandy Neck Beach.

<u>Transportation Between Off-Site Parking and Sandy Neck Beach Park</u>

To meet the peak weekend demand during the summer, the Town could explore operation of a Town-managed shuttle program or attaining a contract with a local bus service to transport patrons between Sandy Neck Beach Park and one or more off-site lots. This approach could help provide further access to Sandy Neck Beach during peak days when on-site parking spaces are full, reduce traffic on Route 6A and Sandy Neck Road, and reduce visitors' parking frustrations. Further analysis must be conducted to explore how a shuttle program would function and what operational costs would be incurred. The feasibility of a shuttle program needs to be examined concerning ridership, routes, fee structure, and accessibility. Operational costs must be explored, including bus transportation expenses, contracts, employee hiring and pay, insurance requirements, and marketing resources.

Alternatively, the Town could investigate use of the Cape Cod Regional Transit Authority (CCRTA) to provide shuttle service between the off-site parking locations and the Park. CCRTA currently operates in all of Cape Cod's Communities and is an established transportation infrastructure that provides a low-cost fair option for riders. A ride on the CCRTA is $4 round trip ($2 round trip for those Age 60+ and disabled), whereas a day beach pass to a location such as the Sandy Neck parking lot costs $25. A transit option provided by the CCRTA would allow visitors an alternative that guarantees access to Sandy Neck.

For this option, the Town would need to collaborate with the CCRTA to explore how ridership could be expanded to support the Town's needs for off-site parking. As the CCRTA works to develop its routes, the Town could coordinate with the CCRTA to include a shuttle that stops at Sandy Neck (and potentially other beaches in Town) and designated off-site parking sites. This action would help the Town expand access to the Beach Facility, not only for visitors who want to attend the beach when the lot is full but also for those who are currently unable due to ADA access or socioeconomic barriers. Costs associated with using the CCRTA to provide beach access were not available in time for the technical memorandum.

Parking Substitutes

This option evaluates ways to maximize the use of the available parking spaces for daily visitors. Possible options that could provide increased access for daily visitors could include:

- Staff Parking— Seasonal staff such as lifeguards and concession staff utilize the parking lot during weekend hours. More parking at the gatehouse could be provided for staff to free up spots in the main parking lot for daily visitors.
- Carpooling Incentives— Certain parking spots could be designated for cars with multiple riders. This action would encourage individuals to minimize the number of vehicles they bring to the beach.
- Overnight Parking Management— Even though Bodfish beach hours end at 10 PM each day, cars are left overnight at the parking lot by people visiting the summer camps and ORV owners. Sandy Neck staff begin each morning with a partially full parking lot. Currently, tickets are issued to cars left overnight; however, these tickets are not always paid and do not offer much incentive to remove the vehicles. Changes to the management policies and practices regarding these spaces could improve access to Sandy Neck. This could include contracting with a local tow company to enforce a policy for no overnight parking.
- Bike Infrastructure— During the 2011 site improvements, a pedestrian pathway was designed to connect the gatehouse to the Beach facility. With this access in mind, the site could incentivize travel to the beach by bike. Bike racks could be added to the site, as well as adding charging stations for electric bikes.
- Gatehouse Rentals- The staff at Sandy Neck could explore alternatives that would incentivize individuals to leave their cars at home. This could include expanding services to provide rentals for commonly used items such as beach chairs, umbrellas, coolers, and beach wagons.

While a variety of off-site parking options could be implemented that would increase the number of parking spaces for daily visitors, and potentially increase access to the Park for visitors not currently able to visit the beach, these options alone will not be enough to make up for parking lost due to expected erosion and storm damage if the Town does not move forward with a long-term resiliency plan. The potential for off-site parking should be pursued by the Town in parallel with implementing the long-term resiliency plan. This will give the Town time to pilot the off-site parking options to determine the most successful approach.

5.0 Alternatives Ranking

To help the Town with decisions on selecting and moving forward with additional design on three (3) top alternatives, the benefit-cost analysis from the 2016 study was updated. The benefit of developing a more resilient Park through any of the alternatives evaluated above was assumed to be equal to the annual revenue generated by the Park. The average revenue for fiscal years 2018 through 2021 reported in the Sandy Neck Conservation Commission Report (2021) was $1,021,676. Over 50-years this amounts to a total monetary benefit of $51,083,800. Using this value, the benefit to cost ratio was calculated for each alternative (Table 17). Higher benefit to cost ratios indicate that the alternative is expected to have a positive net value to the Town.

Table 17. Benefit to Cost Ratio for Sandy Neck Beach Resiliency Alternatives.

Alt. No.	Alternative Type	Project Description	Total Estimated Cost (Capital + Maintenance Cost Over 50 Years)	Benefit/Cost (B/C Ratio)
2	Conventional “hard” Engineering Structure	Stone Revetment with Vegetated Sand Cover	$22.8 Million	2.24
3	“Soft” Engineering Structure	Bio-Engineered Sand-Filled Coir Bags with Vegetated Sand Cover	$31.1 Million	1.64
5A	Managed Site Reconfiguration	Parking Lot Relocation & Reconfiguration	$11.2 Million	4.56
5B		Parking Lot & ORV Access Relocation with Re-use of Existing Air-Down Area	$11.6 Million	4.40
5C		Parking Lot & ORV Access Relocation with Screening Trees; Relocate Existing Air-Up/Air-Down Areas	$11.7 Million	4.37
5D		Parking Lot & ORV Access Relocation with Screening Dune; Relocate Existing Air-Up/Air-Down Areas	$11.8 Million	4.33
6		Relocate/Reconfigure Parking Lot & ORV Access; Relocate and Expand Number of Air-Up/Air-Down Areas; Relocate Gatehouse and Add Emergency Vehicle Access to Beach	$12.4 Million	4.12
7		Partial Relocation/ Reconfiguration of Parking Lot & ORV Access; Relocate and Expand Number of Air-Up/Air-Down Areas; Relocate Gatehouse and Add Emergency Vehicle Access to Beach	$12.2 Million	4.19

Rating values for each alternative calculated during the 2016 study were also updated (Table 18). Alternatives with the highest rating value represent the most viable long-term resiliency alternative with respect to the following factors:

- Benefit-cost ratio
- Performance & Longevity

- Permittability
- Resource Area Impacts/Benefits

Table 28. Rating Matrix for Sandy Neck Beach Resiliency Alternatives.

Alt. No.	Project Description	RATING PARAMETERS AND VALUES					Total Rating Value (TRV)
		B/C Ratio	Permit Difficulty	Protection Rating	Enhance/ Protect Coastal Wetland Resources	Enhance Wildlife Habitat	
		Calc. Value	0 = High 1 = Mod 2 = Low	0 = Low 1 = Mod 2 = High	0 = Low 1 = Mod 2 = High	0 = Low 1 = Mod 2 = High	
2	Stone Revetment with Vegetated Sand Cover	2.24	0	2	0	1	5.24
3	Bio-Engineered Sand-Filled Coir Bags with Vegetated Sand Cover	1.64	1	0	0	0	2.64
5A	Parking Lot Relocation & Reconfiguration	4.56	1	2	1	0	8.56
5B	Parking Lot & ORV Access Relocation with Re-use of Existing Air-Down Area	4.40	1	2	1	2	10.40
5C	Parking Lot & ORV Access Relocation with Screening Trees; Relocate Existing Air-Up/Air-Down Areas	4.37	1	2	1	2	10.37
5D	Parking Lot & ORV Access Relocation with Screening Dune; Relocate Existing Air-Up/Air-Down Areas	4.33	1	2	1	2	10.33
6	Relocate/Reconfigure Parking Lot & ORV Access; Relocate and Expand Number of Air-Up/Air-Down Areas; Relocate Gatehouse and Add Emergency Vehicle Access to Beach	4.12	1	2	1	2	10.12
7	Partial Relocation/ Reconfiguration of Parking Lot & ORV Access; Relocate and Expand Number of Air-Up/Air-Down Areas; Relocate Gatehouse and Add Emergency Vehicle Access to Beach	4.19	1	1	1	2	9.19

6.0 Summary and Key Findings

This technical memorandum reports on an evaluation of alternatives for building resiliency to coastal storms and sea level rise at Sandy Neck Beach Park. Of the eight (8) alternatives evaluated, six (6) were developed during the previous 2016 study and two (2) new alternatives were developed as part of the current study. Evaluation criteria included benefit/cost ratio, permittability, level of protection provided to Park infrastructure, and benefits/impacts to wetland resources and wildlife habitat. Rating scores were developed for each alternative based on these criteria, with higher rating scores indicative of alternatives that met the evaluation criteria (Table 18). Work presented in this technical memorandum is intended to help guide the Town in the selection of three (3) top alternatives, for which more detailed design and evaluation will take place so that a single preferred alternative can be selected for improving coastal resiliency at the Park.

Key findings of the study for each alternative are summarized in the following Table 19.

Table 19. Key Findings of Sandy Neck Beach Resiliency Alternatives.

Alternative	Findings	Rating Score
#2	Provides protection for existing parking lot during storms and future sea levels; however, this alternative is not permittable and would cause adverse impacts to the beach. Requires annual dune nourishment.	5.35
#3	Provides protection for existing parking lot during present day water levels and high return period storms (i.e., 20-year events), but parking lot becomes vulnerable during lower return period storms (i.e., 50- to 100-year events). Does not address vulnerability of gatehouse to flooding. Costs associated with initial construction and long-term maintenance are high. Requires annual dune nourishment.	2.64
#5A	Provides protection for relocated parking lot during storms and future sea levels. Does not address existing impacts to wildlife habitat at ORV trail and will likely require on-site mitigation for impacts to Spadefoot Toad habitat. Does not address vulnerability of gatehouse to flooding. Allows for dune renourishment every 5 years.	8.56
#5B	Provides protection for relocated parking lot during storms and future sea levels. Addresses impacts to wildlife habitat at ORV trail but will still likely require on-site mitigation for impacts to Spadefoot Toad habitat. Does not provide adequate air-up/air-down space or vulnerability of gatehouse to flooding. Allows for dune renourishment every 5 years.	10.40
#5C	Provides protection for relocated parking lot during storms and future sea levels. Addresses impacts to wildlife habitat at ORV trail but will still likely require on-site mitigation for impacts to Spadefoot Toad habitat. Does not address vulnerability of gatehouse to flooding but includes vegetative screen of ORV air-up/air-down areas. Allows for dune renourishment every 5 years.	10.37
#5D	Provides protection for relocated parking lot during storms and future sea levels. Addresses impacts to wildlife habitat at ORV trail but will still likely require on-site mitigation for impacts to Spadefoot Toad habitat. Does not address vulnerability of gatehouse to flooding but includes vegetative and dune screening of ORV air-up/air-down areas. Allows for dune renourishment every 5 years.	10.33
#6	Provides protection for relocated parking lot during storms and future sea levels. Addresses impacts to wildlife habitat at ORV trail but will still likely require on-site mitigation for impacts to Spadefoot Toad habitat. Reduces vulnerability of gatehouse to flooding, improves gatehouse operations and provides access between beach and parking area for emergency vehicles. Allows for dune renourishment every 5 years.	10.12
#7	Provides protection for relocated parking lot during storms and future sea levels. Addresses impacts to wildlife habitat at ORV trail. Requires less on-site mitigation for impacts to Spadefoot Toad habitat than previous alternatives. Reduces vulnerability of gatehouse to flooding, improves gatehouse operations and provides access between beach and parking area for emergency vehicles. Allows for dune renourishment every 5 years.	9.19