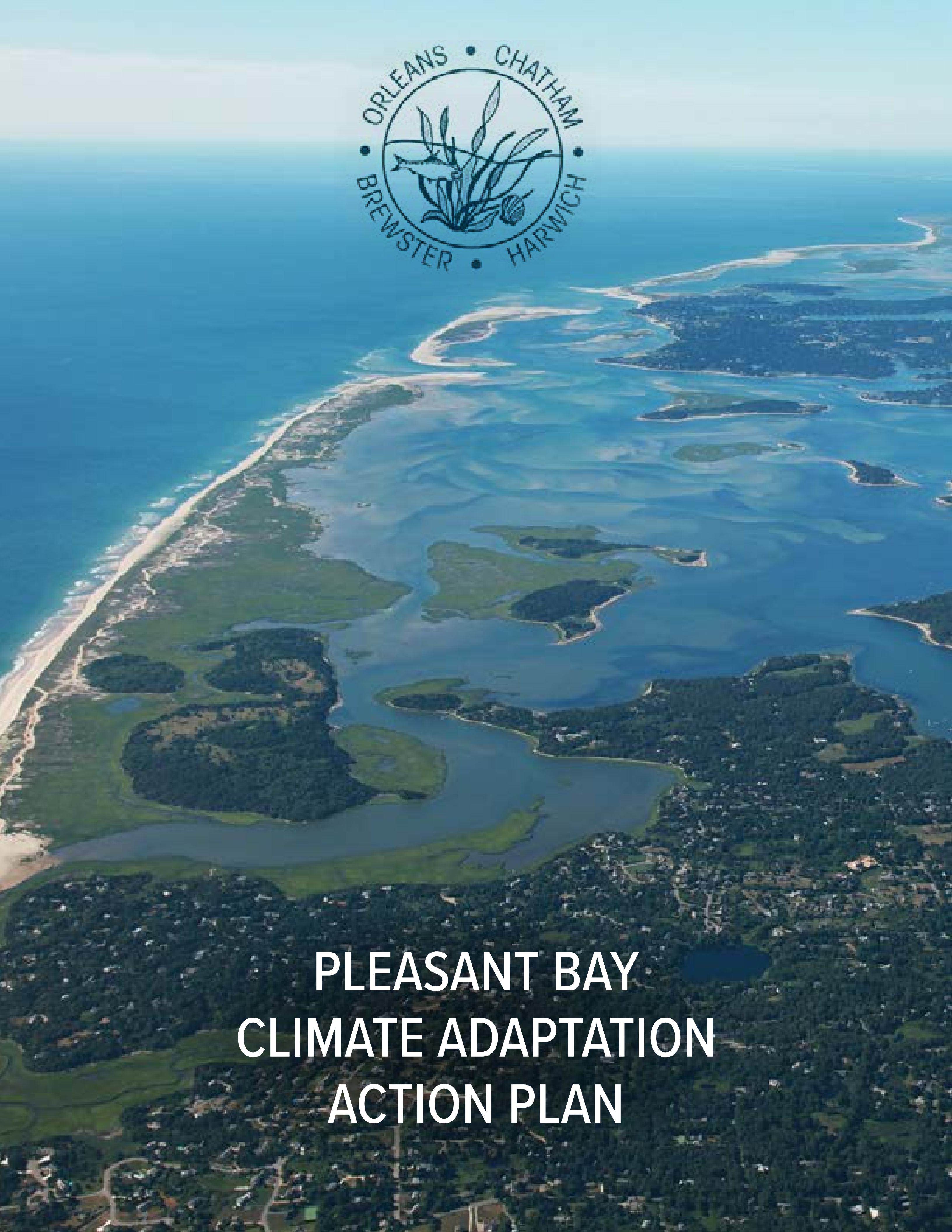
ORLEANS • CHATHAM • BREWSTER • HARWICH



PLEASANT BAY CLIMATE ADAPTATION ACTION PLAN

Prepared by the Pleasant Bay Alliance, 2024
Cover Photo by Spencer Kennard

PLEASANT BAY CLIMATE ADAPTATION ACTION PLAN

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Pleasant Bay estuary may experience sea level rise of 4 to 8 feet by 2100, along with more frequent and intense storms. Water surface temperatures in the Bay may increase 20°F by 2050. Nearly 72% of intertidal resource areas could be lost to increased water levels. Salt marsh and eelgrass, which provide habitat, buffer storm surge, filter pollutants and store carbon, are susceptible to changes in water level and water temperature. Low-lying public water access facilities as well as water, wastewater and stormwater infrastructure face threats of inundation due to sea level rise and storm surges. These climate effects threaten our ability to access and enjoy the waters of Pleasant Bay, and they also affect the Bay's ability to function as an estuary and contribute to the sustainability of our oceans.

The Pleasant Bay Climate Adaptation Action Plan (CAAP) was developed by the Pleasant Bay Alliance and technical and community partners from 2022-2024 with funding from the Massachusetts Vulnerability Preparedness Action Grant program.

The goal of the Climate Adaptation Action Plan is to protect the Bay's estuarine resources and low-lying public access sites and infrastructure from climate-induced adverse effects.

Development of the CAAP was focused on four main tasks:

1) Assessing climate impacts to the barrier beach and inner shoreline, and identifying appropriate planning, monitoring or resilience measures.

2) Assessing climate impacts to public access facilities and water, wastewater and stormwater infrastructure, and developing conceptual resilience plans for selected sites.

3) Assessing climate impacts to the health and sustainability of two species critical to the functioning of the estuary: eelgrass and salt marsh; and developing measures to protect and restore these resources.

4) Engaging the broader community in building awareness of climate threats facing Pleasant Bay, and identifying community resilience priorities.

The results of these tasks are described in Sections 2 and 3 of the Climate Adaptation Action Plan. Recommendations for increasing the resiliency of Pleasant Bay through building municipal capacity, monitoring and technical assessments, regulatory measures, resilience planning for infrastructure, restoration of salt marsh and eelgrass, and community engagement, are outlined in Section 4. Section 5 includes links to technical studies which provide greater detail about climate threats to Pleasant Bay and strategies to increase resilience.

The Climate Adaptation Action Plan provides a foundation for regional coordination to increase the resilience of Pleasant Bay. This is a living document to be updated and refined as progress is achieved and more is learned about climate change and its impacts on Pleasant Bay resources.

SECTION 1. OVERVIEW OF THE CLIMATE ADAPTATION ACTION PLAN (CAAP)

1.1 CLIMATE RESILIENCE FOR PLEASANT BAY

Pleasant Bay is an area of extraordinary natural resources and beauty. The estuary is the largest on Cape Cod, and a state-designated Area of Critical Environmental Concern. The estuary encompasses approximately 7,000 acres of salt water surface area, 71 miles of shoreline, three tidal rivers, four bay islands, and is hydrologically connected to 48 acres of fresh surface water in 11 ponds. The Bay's watershed encompasses 21,000 acres in four towns.

Pleasant Bay is one of the most biologically diverse and productive marine habitats on the East Coast. Estuaries act as nurseries for a wide variety of fish, shellfish and other aquatic life that are part of the food web for sustainable ocean fisheries. The Bay's extensive marshes, beaches and tidal flats provide habitat for migratory birds and other wildlife.

The Bay is also a popular recreational resource for sailing, wind surfing, power boating, kayaking, fishing, shellfishing, bird watching, and beach going. In addition to homes and businesses, the shoreline supports twenty-seven public access points that provide access to Bay waters for many activities, including shellfish harvesting by individual and small-scale commercial enterprises.

All of the ways we use and enjoy Pleasant Bay—including its extensive ecological and recreational benefits—are currently at risk due to climate effects. These climate effects include rising water levels, more frequent and stronger storms, and increasing ocean temperatures. Over time these effects threaten our ability to access and enjoy the waters of Pleasant Bay. They also affect the Bay's ability to function as an estuary and contribute to the sustainability of ocean life.

By 2100, tide levels in Pleasant Bay could see an increase of four to eight feet due to sea level rise. If realized, this increase would result in considerable changes along the Nauset barrier beach and Pleasant Bay inner shoreline. Without adaptation measures to address sea level rise, the resulting effects could reduce community resilience, diminish public access to the water, limit the effectiveness of water, wastewater and stormwater infrastructure, and diminish the ecological functioning of the estuary.

In anticipation of changing conditions, the Pleasant Bay communities of Brewster, Orleans, Chatham and Harwich have completed town-wide Municipal Vulnerability Preparedness (MVP) plans to identify resilience threats and priority actions. However, none of the plans offers a wholistic view of the resilience needs of the Pleasant Bay estuary. Under the locally approved Resource Management Plan for the Pleasant Bay Area of Critical Environmental Concern, the Pleasant Bay Alliance is charged with coordinating inter-municipal efforts related to coastal vulnerability and resiliency in Pleasant Bay. The Alliance's work in the area of coastal vulnerability and resiliency builds on extensive previous technical studies and monitoring undertaken by the Alliance and others over more than a decade.

In 2022, the Pleasant Bay Alliance was awarded an MVP Action Grant to develop a Pleasant Bay Climate Adaptation Action Plan (CAAP). To develop the CAAP, the Alliance obtained technical support from Center for Coastal Studies, Wright-Pierce, Cape Cod Cooperative Extension, Cape Cod National Seashore and Boston University. Community partners in the development of the CAAP included: Friends of Pleasant Bay, Friends of Chatham Waterways, Pleasant Bay Community Boating, Orleans Pond Coalition, and Woods Hole Sea Grant. The CAAP was formulated as a logical next step in the Alliance's multi-year efforts to promote resilience within the

estuary, and to address a number of priority concerns and actions identified in the local MVP plans. The CAAP provides an opportunity to build on prior research and growing public interest and concern regarding the effects of sea level rise and increased storm intensity in and around Pleasant Bay.

1.1.1 PURPOSE OF THE CLIMATE ADAPTATION ACTION PLAN

The overarching goal of the CAAP is to protect the Bay's estuarine resources and low-lying public access sites and infrastructure from climate-induced adverse effects.

The following objectives guided the development of the CAAP:

- Using the best available science and research tools to assess climate threats to barrier beach, salt marsh and other intertidal resources, sub-tidal eelgrass resources, inner shoreline and low-lying public access points and water protection infrastructure in Pleasant Bay.
- Identifying creative adaptation solutions that utilize best practices and maximize use of nature-based approaches to protect natural coastal processes and enhance resilience of the barrier beach, inner shoreline, and threatened resources, public water protection infrastructure (e.g., stormwater or wastewater management) and public access.
- Engaging diverse stakeholders in the four surrounding communities, including climate vulnerable populations, in understanding climate threats and developing a Climate Adaptation Action Plan prioritizing resilience strategies and actions necessary to achieve the project goal.

Development of the CAAP was focused on four main tasks:

1) Assessing climate impacts to the barrier beach and inner shoreline, and identifying appropriate planning, monitoring or resilience measures (led by Center for Coastal Studies).

2) Assessing climate impacts to a cross-section of public access sites and public water, wastewater and stormwater infrastructure, and developing conceptual resilience plans for eight case study sites (led by Wright-Pierce).

3) Assessing climate impacts to the health and sustainability of two species critical to the functioning of the estuary: eelgrass (led by Department of Earth and Environment, Boston University, Northeast Coastal and Barrier Network, and National Park Service) and salt marsh (led by National Park Service); and developing measures to monitor, protect and restore salt marsh and eelgrass resources.

4) Engaging the broader community in building awareness of climate threats facing Pleasant Bay and other coastal resources areas, and conveying the community resilience priorities to be addressed in the CAAP (led by Ridley & Associates and Pleasant Bay Alliance).

1.1.2 ORGANIZATION OF THE CAAP

The CAAP reflects the resilience priorities of Pleasant Bay stakeholders, and provides a blueprint for action to increase climate resilience in and around the estuary. The CAAP recommends specific planning, monitoring and adaptation measures the Pleasant Bay Alliance and technical and community partners can rely on to prepare for the anticipated impacts of climate change, guard against the loss of public infrastructure, and maintain the health and functioning of natural resources that are essential for a healthy estuary.

The CAAP is organized in the following five sections:

***This Overview of the Climate Adaptation Action Plan for Pleasant Bay*, Section 1**, discusses what is at stake with resilience planning for the Pleasant Bay estuary, the climate science used to estimate potential climate threats to resources and infrastructure, feedback on resilience priorities conveyed by community stakeholders, and the resulting goals and structure of this CAAP.

Section 2, *Projected Climate Threats to Pleasant Bay*, summarizes the key anticipated climate impacts to the Nauset barrier beach and Pleasant Bay inner shoreline, to low-lying public access locations and to low-lying public water, wastewater and stormwater infrastructure. This section also assesses the potential for climate effects that could undermine the Bay's functioning as an estuary by contributing to the loss of eelgrass and salt marsh resources.

Section 3, *Resilience Strategies for Pleasant Bay,* provides a comprehensive overview of measures designed to prepare for and mitigate against the climate threats identified in Section 2. These measures will encompass planning and regulatory changes, nature-based resource protection and restoration, design and retrofit of public infrastructure, and community capacity building and engagement.

Section 4, *Action Plan,* provides a detailed action plan to implement the resource strategies identified in Section 3, indicating relative priority, responsible parties and resources needed for implementation.

Section 5, *Appendices*, is a list of the science-based reports generated in support of the CAAP. Live links are provided to all reports generated during the two-year MVP grant period to identify resilience adaptations and measures and formulate the CAAP.

1.2 DRIVERS OF CHANGE

1.2.1 SEA LEVEL RISE AND STORM SURGES

Sea level is the starting elevation upon which storm surge and waves interact with the shoreline. As sea level increases over time, low-lying coastal areas will be submerged more frequently. As a result, coastal storms having the current intensity will be able to reach further inland and cause more erosion and flooding damage. Those impacts will be even more severe if storm surges also increase over time. All global climate models predict an increase in sea level; however, uncertainty about our future world-wide carbon emissions results in a wide range of sea level rise projections. While some level of adaptation is needed for all sea level rise projections, the most extreme projections make many adaptation strategies less feasible.

The Commonwealth has endorsed projections of sea level rise for Massachusetts from the Northeast Climate Adaptation Science Center (NECASC) at UMass Amherst. The NECSAC model projections do not incorporate estimates of storm surge, which can be an important consideration in certain types of resilience planning, such as roads and other infrastructure. Therefore, the state has encouraged the use of the Massachusetts Coast Flood Risk Model (MCFRM) which models a combination of sea level rise and storm surge, and therefore more closely approximates flooding during a real storm. The MCFRM incorporates NECASC 's "High" scenario (8 feet by 2100) for the sea level rise portion of the model.

For Pleasant Bay, the sea level rise projections under the NECASC high/MCFRM projection exceed a level of increase that can be reasonably anticipated based on local data collection. The rate observed locally over the last 20 years is very close to the NECASC Intermediate-Low sea level rise projection of 4 feet by 2100.

Therefore, the CAAP has adopted a dual approach for incorporating sea level rise projections into resilience planning in Pleasant Bay. For public investments that are longer term (e.g., water, wastewater and stormwater infrastructure) the CAAP uses a sea level rise projection of 8 ft by 2100, which has a higher level of certainty (99.5%) that this amount of sea level rise will not be exceeded. Analysis for these types of resilience plans will incorporate storm surge. For adaptation investments that can be more easily modified (e.g., beach nourishment) the CAAP uses a sea level rise projection of 4 ft by 2100, which has a lower level of certainty (83%) that this amount of sea level rise will not be exceeded. This projection is comparable to the NESCAC intermediate low prediction, and closely tracks trends based on locally collected data. Incorporation of storm surge is less significant for these types of resilience plans.

TABLE 1 Sea Level Rise Projections from the Northeast Climate Adaptation Science Center

NE CASC Intermediate-Low	NE CASC Intermediate-High	NE CASC High	NE CASC Extreme
Unlikely to exceed (83% probability) given a high emissions pathway	Extremely unlikely to exceed (95% probability) given a high emissions pathway	Extremely unlikely to exceed (99.5% probability) given a high emissions pathway	Exceptionally unlikely to exceed (99.9% probability) given a high emissions pathway
2100 = 4.0'	2100 = 5.0'	2100 = 7.6'	2100 = 10.3'

Table credit – Wright Pierce

Figure 1 Projections of SLR over Time

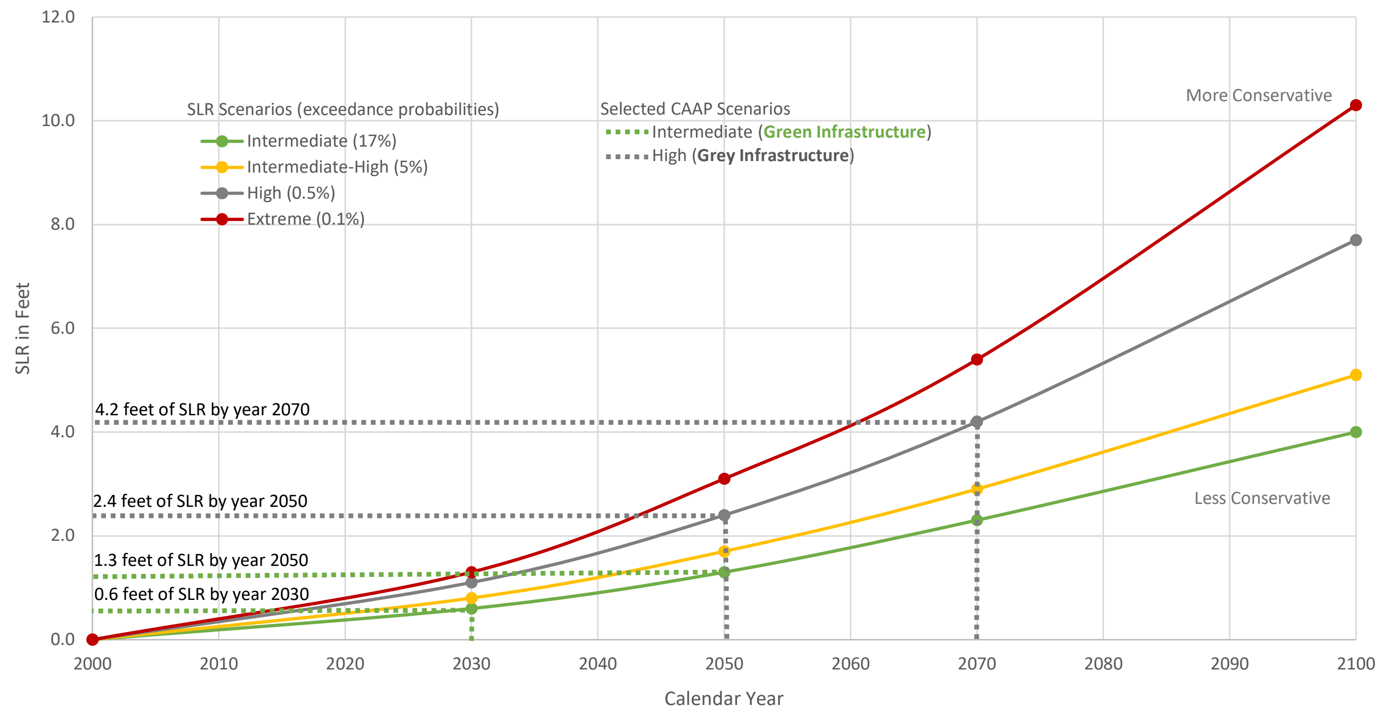


Figure credit – Wright Pierce

1.2.2 OTHER RESILIENCE FACTORS

FREQUENCY AND INTENSITY OF STORMS

In recent history the “Blizzard of ‘78” had been the storm of record for Boston and areas to the north of Cape Cod. However, the January 4, 2018 storm, approximately 9.66 ft NAVD88 (or 15.16 ft local mean low low water), at the Boston tide gage, surpassed the total water level for the 1978 storm for much of the same area and is the new storm of record used in this study.

Many coastal communities are experiencing periodic, severe flooding associated with relatively short duration, high intensity coastal storms. The term storm tide refers to the rise in water level experienced during a storm event resulting from the combination of storm surge and the astronomical (predicted) tide level. The maximum level of the storm tide is also referred to as the total water level (TWL) by the National Weather Service. Storm tides are referenced to datums, either to vertical geodetic datums (e.g., NAVD88 or NGVD29) or to local tidal datums (e.g., mean lower low water (MLLW) or mean low water (MLW)). Storm surge refers to the increase in water level associated with the presence of a coastal storm. As the arithmetic difference between the actual level of the storm tide and the predicted tide height, storm surges are not referenced to a datum.

In addition to the magnitude of the storm surge, the time at which the maximum surge occurs relative to the stage of the astronomical tide is a critical component of the maximum storm tide elevation experienced during any particular storm.

WATER TEMPERATURES

In addition to sea level rise, water temperatures in Pleasant Bay could increase by more than 2°F in the next 30 years. Sea surface temperatures in the Northeast US are rising quickly. The current average rate of increase on the Northeast US Shelf is 0.7°C ± 0.2°F per decade (Alexander et al., 2018). Changing in water temperature can have significant impacts on marine biota, including population shifts, alterations in community structure and diversity, and changes in plant phenology and the timing of other ecosystem-level events and processes (Parmesan and Yohe, 2003; Doney et al., 2012).

Without adaptation, increases in sea level, storm surge and sea surface temperatures could reduce community resilience, diminish public access to the water, limit the effectiveness of water protection infrastructure, and diminish ecological function of the estuary.

1.3 COMMUNITY ENGAGEMENT

Community consensus around resilience concerns and priority actions to increase resilience in Pleasant Bay is a major focus of the CAAP. The Alliance worked with a coalition of local organizations to design opportunities for stakeholders to participate in the development of the CAAP. The organizations—Friends of Pleasant Bay, Friends of Chatham Waterways, Orleans Pond Coalition, Pleasant Bay Community Boating and Woods Hole Sea Grant—represent a range of Pleasant Bay stakeholders. Outreach events included:

- The Pleasant Bay Climate Resilience Community Forum attended by approximately 60 people was held at the Chatham Community Center on October 21, 2023.

- Four informational videos were produced and distributed through the social media networks of participating organizations.

- Three virtual workshops were held in November 2023 to allow more in-depth discussion on climate impacts and resilience options for: (1) inner shoreline and intertidal resources; (2) barrier beach eelgrass and salt marsh; and (3) public access and water, wastewater and stormwater infrastructure.

- The Pleasant Bay Alliance sponsored an online survey to gain community input into climate resilience issues of concern and gage response to various optional resilience strategies. The survey was available on the Alliance website from October through December 2023. The survey was publicized through a media release, and through outreach to community stakeholders and through member outreach to other partnering organizations.

1.3.1 RESULTS OF COMMUNITY SURVEY

One hundred sixty-four (164) people responded to the online community survey, including both year-round and seasonal residents. The vast majority of participants consider one of the Pleasant Bay towns their primary address, and half or more use the bay for beach walking, enjoying views from Route 28, or kayaking/canoeing/paddle-boarding. Among the key findings of the survey:

Three-quarters or more of respondents are somewhat or very concerned about the following: loss of salt marsh (90%), loss of eelgrass (88%), shoreline erosion (85%), loss of public beach (79%), loss of shellfishing areas (76%), and loss of natural sediment movement (74%). Changes to these natural features rated of higher concern than loss of access for swimming (64%), boating (67%), overwash of roads (63%) and emergency services (63%), each of which are somewhat or very concerning to two-thirds of respondents.

- Three-quarters or more of respondents support the following resilience measures: purchasing land for salt marsh migration; restricting shoreline access to restore saltmarsh, restricting waterways access to restore eelgrass, rebuilding stormwater systems, and making water mains more resilient.

- More than half of respondents support the following resilience measures: increasing shoreline erosion regulations, elevating low roads and replacing culverts, rebuilding ramps and parking at town landings, purchasing land for public beaches and landings, and increasing sand replenishment.

- The top four resilience priorities are: purchase of land to allow salt marsh to migrate landward (59%), restrict access to shoreline areas to restore salt marsh (43%), restrict access to areas of waterways to restore eelgrass (37%), and increase stringency of shoreline management regulations to reduce hardening (37%).

SECTION 2. CLIMATE THREATS TO PLEASANT BAY

INTRODUCTION

This section summarizes key findings of a series of studies undertaken to assess climate threats to critical natural resources and infrastructure in or adjacent to the Pleasant Bay estuary:

2.1 Vulnerability of the Nauset Barrier Beach system was evaluated by Center for Coastal Studies.

2.2 Shoreline and nearshore impacts were assessed through multiple studies. Storm Tide Pathways and intertidal resources were assessed by Center for Coastal Studies; climate threats to public access, water, wastewater and stormwater infrastructure were assessed by Wright-Pierce.

2.3 Loss of Resources and Estuarine Function through impacts to eelgrass and salt marsh resources were evaluated by researchers from Boston University and National Park Service.

Links to these reports are found in Section 5 of the CAAP.

2.1 VULNERABILITY OF NAUSET BARRIER BEACH

The Pleasant Bay inner shoreline is protected by the Nauset barrier beach. Changes in the barrier beach can have both negative and positive impacts to natural resources as well as public and private infrastructure. For example, the changing of position of the tidal inlets which conduct tidal flow directly impacts water quality within the Bay. Other impacts from inlet migration include, but are not limited to, changes in inundation frequency, safety of navigation for the fishing fleet and recreational boaters, and ability of salt marsh to keep pace with sea level rise.

Understanding how the Nauset barrier beach is expected to evolve annually and seasonally can better inform management decisions. Other past studies of Pleasant Bay show a dynamic barrier island/tidal inlet system exhibits a 140-year cycle of inlet formation, inlet migration/barrier elongation and new inlet formation (Giese, et al, 2009). Recent studies also show that the 140-year cycle, as well as the present inlet evolution, are likely being affected by sea level rise (Borrelli, et al., 2016) and coastal engineering structures in Chatham Harbor (Giese, et al, 2020).

An assessment of the vulnerability of the barrier beach to sea level rise was undertaken as part of this CAAP. Multiple temporal and spatial scales of analyses were undertaken to place annual and seasonal change in the system into both spatial and temporal context. Using lidar data available from 2014 to 2021, change was quantified in the areas of overlapping data between those two time periods. (Figure 2). This analysis quantifies three general compartments of shoreline evolution showing areas of predominant 'barrier-rollover', little to no rollover and mixed levels of rollover, see Figure 2 A, B and C respectively. This provides managers with a quantitative analysis of barrier health on which to base future decisions.

Key conclusions of the survey are:
Changes seen between the 2014 and 2021 lidar data sets can be roughly broken down into 3 coastal compartments (Figure 2). The northernmost section (A) sees mostly deposition with some erosion starting from Nauset Beach in Orleans down to the southern part of Pochet Island. There is considerable deposition in the backbarrier areas which is a positive trait for barrier islands within a regime of sea level rise. This is a textbook example of 'barrier rollover', a strong indicator that the barrier is keeping pace with sea level rise. This increase in elevation is caused by the

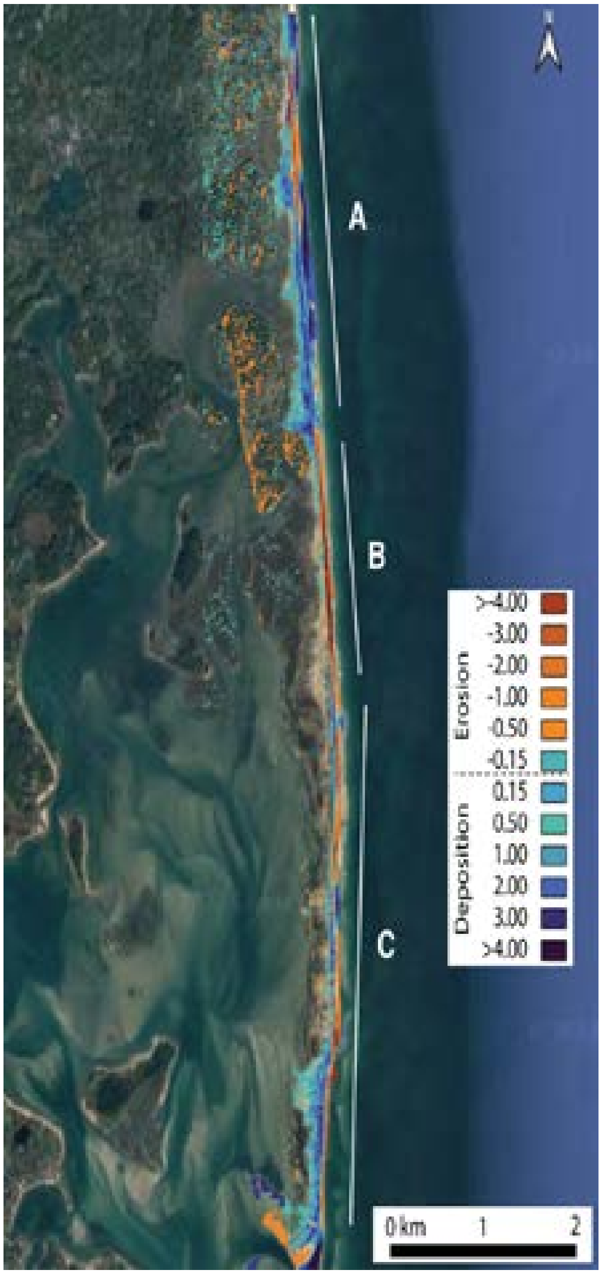


FIGURE 2. Surface difference between 2014 - 2021

deposition of sediment between 2014 to 2021. This is likely due to either overwash occurring during high water level events, such as during storms, carrying sediment and ocean water across the barrier and depositing in low-lying areas along the backbarrier shoreline, and/or wind-blown sand.

The central section (B) is the only section where there is erosion with little to no deposition. In this instance it is not as problematic as one would initially assume because of the width and height of the barrier is very likely preventing overwash from occurring.This segment also has extensive saltmarsh backing the barrier. This warrants attention because over time deposition in this area would indicate that the barrier will be able to keep pace with sea level rise going forward and a lack of deposition could represent a shift in the evolution of the barrier.

The southernmost section (C) sees erosion along most of the open ocean shoreline and deposition along most of the backbarrier shoreline. This also is indicative of a barrier that is able to keep pace with sea level rise. In fact, the areas closest to the inlet in this section are seeing some of the highest levels of deposition along the barrier. Overall, the barrier north of the 2007 inlet has seen deposition in backbarrier areas in the form of washover fans and other depositional features as well as erosion along much of the shoreline. The abrupt shifts in shoreline orientation between compartments B and C are a function of longer term processes such as sea level rise and changes in angles of wave approach, similar to those that led to a clockwise shift in the orientation of the outer beach of Cape Cod from the 1880s through the early part of the 21st century (Giese, et al, 2007).

From 2014-2021 erosion occurred along much of the open ocean shoreline. This erosion occurred along the beach as well as the primary dune. This type of erosion is common along much of Cape Cod. Although approximately 30 m of erosion (Figure 2) over 7 years yields an annual rate of 4.3 m/yr rather than the typical long-term erosion rate of approximately 1 meter per year on the outer beach. Annual rates of erosion are only averages for a given period of time and 3 to 4 m of erosion per year is not unprecedented for short periods of time. However, if this trend were to continue it would constitute a regime shift for these barriers.

Surveys conducted via Unoccupied Aerial Systems, or drones, document trends of seasonal changes (erosion/deposition) along the study area are similar to that of the medium-term trends seen in the lidar data. From the fall of 2022 through to the spring of 2023 we see changes of 6-8 meters in the highwater line. This is common among open ocean beaches and indicates the natural variability expected in such environments. This is not uncommon in the Nauset Barrier spit, whereas North Beach island seems to be undergoing large amounts of deposition along the southernmost portions of the island from fall to spring.

2.2 SHORELINE AND NEARSHORE IMPACTS

2.2.1 STORM TIDE PATHWAYS ALONG THE PLEASANT BAY SHORELINE

Storm Tide Pathways (STPs) are defined as relatively narrow, low-lying areas or pathways that, based on their elevation, are likely to convey coastal flood waters inland. Often, stopping flow at the elevation at which the STP would be overtopped could prevent inundation of significant inland areas. In addition to storm events, low-lying coastal areas are often experiencing inundation associated with nuisance, or 'sunny day' flooding, storm surge and sea level rise. The elevations at which coastal waters will begin to flow through a STP and the nature of the impacted areas can be used by municipal managers to evaluate and prioritize mitigation responses.

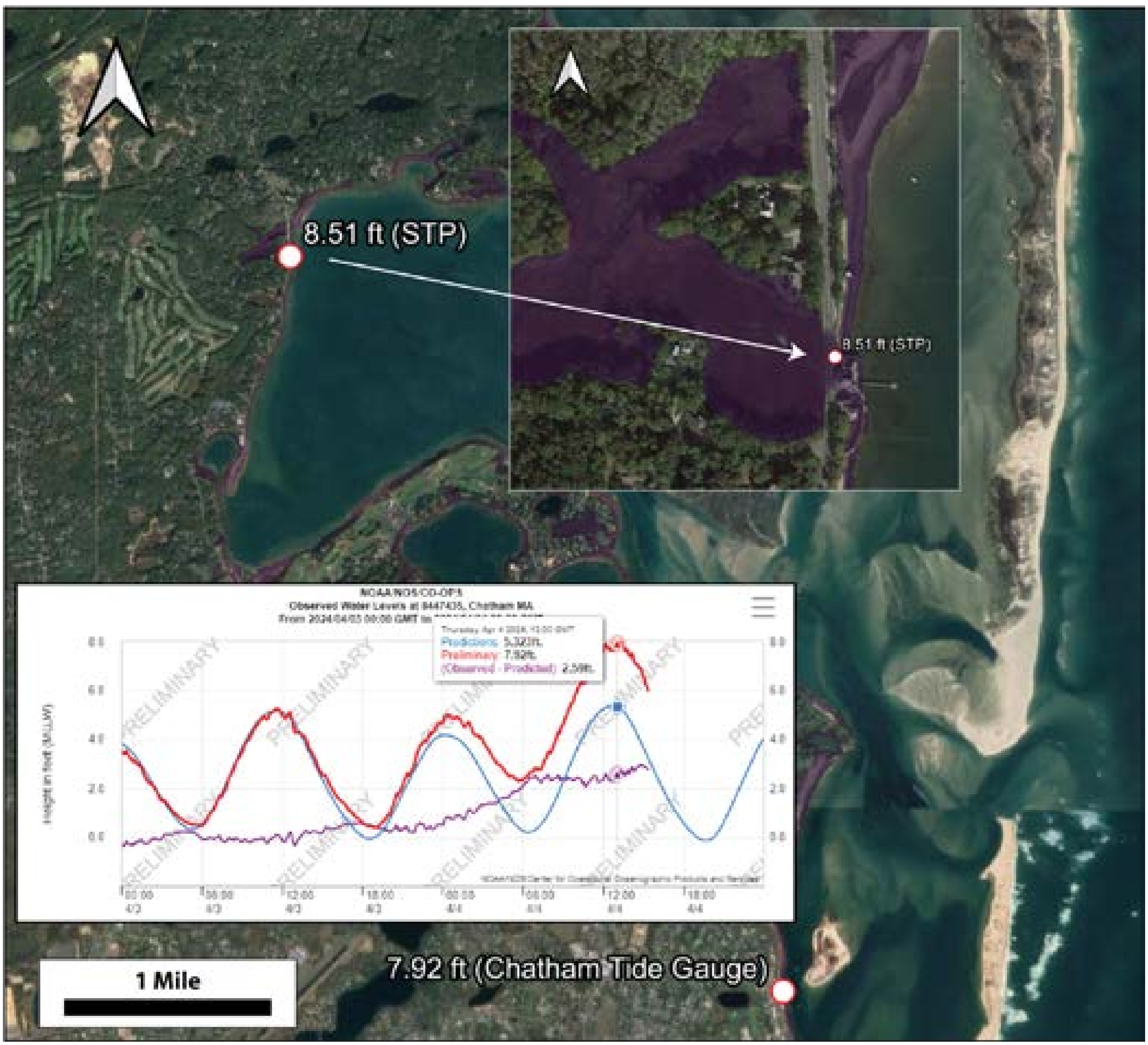
During the first phase of the project 105 potential STPs were identified along the mainland shoreline of Pleasant Bay in Chatham, Harwich, and Orleans. Although none were found in Brewster, flooding that occurs through STPs found in the other three towns will likely affect areas within Brewster. The surveys were conducted in the spring of 2023. Each potential STP identified in the desktop analysis was inspected and assessed in the field and the location moved when observations determined that it was necessary to reflect topographic conditions. During the field work 37 pathways (35.2% of the total) were moved more than one (1) meter horizontally from their original position determined in the desktop analysis to better reflect current conditions.

To illustrate how STPs can be used to guide local management decisions, on April 3, 2023 a mapped STP (elevation 8.5 ft. NAVD88) began to flood, however, the real-time total water level recorded at NOAA's tide gage at the Chatham Fish Pier was reading 7.92 ft. During events such as this example, a STP could be used to anticipate flooding, allowing time for public works departments to attempt to mitigate inundation with sandbags, portable flood walls, etc., and/or prepare to block routes or redirect traffic, which can be critical for the public and first responders. The flooding of this STP which was above the Total Water Level for this event highlights the role of 'wave-setup' which is the increase in water elevation resulting from winds acting upon the water and creating waves functionally increasing the water level alongshore for short periods of time. This storm has strong easterly winds that contributed to the wave setup. As noted above an increase in water depths in the Bay can allow larger waves to be formed inundating areas that would not otherwise have been flooded.

FIGURE 3. Storm Tide Pathways

The first phase of this study has identified 13 STPs that are only 12 inches above the project storm of record within Pleasant Bay. This means there are 13 locations that have never flooded in recorded history, but are less than 1 ft above the storm of record. These 13 locations when flooded 12 inches above the storm of record represent 250.9 acres of potential flooding. It is unikely that local managers are prepared for this extent of flooding that could occur as a result of a 1 ft increase in water levels.

FIGURE 4. A storm event on April 3rd 2024 in Pleasant Bay. Flooding occurred along a STP that was above the real-time total water level as recorded at a nearby tide gage. This is evidence of the utility of the mapping of high-resolution, high accuracy STPs as well as an example of 'wave-setup' resulting from a storm event with strong easterly winds.



2.2.2 LOW-LYING PUBLIC ACCESS AND WATER PROTECTION INFRASTRUCTURE

Eight Pleasant Bay locations were selected to enable an evaluation of risks and potential remedies related to increased water levels at public boat landings, and at water, wastewater and stormwater infrastructure. The selected case studies represent a broad range of uses, settings and risks for damage related to lea level rise and increased storm surges. These eight locations are shown in Figure 5.

FIGURE 5. Eight Case Study Sites for Analysis

PUBLIC ACCESS TO THE BAY

- Meetinghouse Pond Pier and Boat Ramp in Orleans
- Crows Pond Landing in Chatham
- Cow Yard Landing in Chatham

WATER MAINS AND HYDRANTS

- Orleans main on Route 28 bridge over Tar Kiln Stream
- Brewster mains at headwaters of Tar Kiln Stream
- Harwich mains at intersection of Bay Road and Route 28

WASTEWATER PUMP STATION

- Harwich pump station on Harden Lane

STORMWATER FACILITIES

- Stormwater treatment system at Lonnie's Pond in Orleans

This project has identified the components of municipal assets that are at varying degrees of risk. The assets are characterized by their current elevations, for later comparison with projections of sea level rise and storm surge. Measures will be proposed to reduce the impacts of sea level rise on these municipal assets. The likelihood of sea level reaching the key elevations will be evaluated to establish appropriate timing and design life of improvements.

2.2.2.1 PUBLIC ACCESS TO THE BAY

The boat ramps at the case study locations extend from the current water level up to about 8 to 10 feet, except for the ramp at Crows Pond which extends only to elevation 3 feet. The pier at Meetinghouse Pond is inaccessible at elevation 3.5 feet, and the ramp itself will be submerged at elevation 4 to 5 feet, and subject to wave damage at even lower still-water elevations. Boat storage areas at the case study locations will begin to be submerged at 4- to 5-foot elevations at Meetinghouse Pond and Cow Yard landing, but at only 2 to 3 feet at Crows Pond. Encroachment on parking areas will occur at elevations of 6 to 8 feet

2.2.2.2 WATER MAINS AND HYDRANTS

At the case study locations, water mains are located above 10 feet in elevation (near Tar Kiln Stream) but at only about 2 feet in the Harwich case study area. Access to hydrants will be hampered at water surface elevations of 6 feet in Harwich. There is a risk of road washout, and damage to the water mains, at all three locations, with the Harwich and Orleans locations most exposed to wave actions. Damage to these water mains will cut off water supply to homes and hydrants. As sea level rises, increased corrosion can be expected, particularly at the Orleans and Harwich locations.

2.2.2.3 WASTEWATER PUMP STATION

The Harwich pump station is located in a cul-de-sac which will be inaccessible when water levels rise above 12 feet. Over-topping of the wet well and damage to the standby electrical generator will occur at water elevations above 13 feet. This station's location at the headwaters of Muddy Creek protects it against wave action.

2.2.2.4 STORMWATER TREATMENT SYSTEM

The existing stormwater treatment system at Lonnie's Pond in Orleans will be overtopped at water elevations over 5.5 feet. Impacts on the herring run will occur at elevation 4.5 feet.

Table 2 summarizes the potential impacts on structures and uses at the selected sites.

SITE	USES	RISKS	KEY ELEVATIONS	
1. Meetinghouse Pond Landing	Launch of motorized boats	Submergence of ramp	Upper parking area	19.5 to 22
	Launch of canoes, kayak, SUPs	Erosion of ramp	Lower parking lot	8.5 to 18.5
	Small boat storage	Submergence of storage area	Boat storage area	4.5 to 8
	Boarding floating boats	Boarding floating boats	Walkway area towards pier	3.5 to 5
	Parking for boat ramp area	Parking for boat ramp area	Top of pier planking	4.8
	Stormwater system	Stormwater system	Bottom of pier stringers	3.9
			Boat ramp elevation range	0 to 8.5
2. Lonnie's Pond SW Treatment	Stormwater treatment	Disruption of stormwater treatment	Top of storm treat system	5.5 to 6
	Herring passage	Disruption of fish passage	Catch basin elevation	5.5 to 6
	Freshwater drainage to ocean	Saltwater intrusion to freshwater pond	Top of fish passage channel	~4.5
	Boat ramp	Submergence of boat ramp	Boat ramp elevation range	0 to 10
	Ecological area	Loss of parking and access	Road elevations (accessibility)	5.5 to 6.5
3. Water Main on Tar Kiln Bridge	Public water distribution	Wave damage to water line	Bottom of pipe	12.6 to 14.6
		Discontinuity of potable water services	Top of pipe	(utility bay)
		Damage to the water line connections	Bridge cross-members (bottom)	9.6
		Erosion of abutment near buried line	Bridge pier (bottom)	10.7
		Pipe and hangar corrosion	Bank elevations on abutments	~10
4. Brewster Water Main - low lying	Public water distribution	Damage to water line	Bottom of pipe	>10.5
	Hydrants for fire suppression	Discontinuity of potable water services	Top of pipe	
	Shut off valves	Discontinuity of emergency fire services	Hydrant elevations	>35
		Pipe corrosion	Ground/road elevations (accessibility)	>14.5
		Loss of hydrant valve access		
5. Harwich Water Main - low lying	Public water distribution	Damage to water line	Bottom of pipe	>2
	Hydrants for fire suppression	Discontinuity of potable water services	Top of pipe	
	Shut off valves	Discontinuity of emergency fire services	Hydrant elevations	site specific, but >10
		Pipe corrosion		
			Road elevations (accessibility)	>6
6. Harwich Wastewater Pump Station	Wastewater transmission	Damage to the wastewater PS	Bottom of generator	14
		Discontinuity of wastewater services	Bottom of grinder unit enclosure	14
			Top of the wet well	13.5
			Electrical pedestal top of slab	14
			grade at PS	13
7. Crows Pond Boat Ramp	Launch of canoes, kayak, SUPs	Submergence of ramp	Parking lot area	6 to 11
	Small boat storage	Erosion of ramp	Boat storage area	2 to 3
	Parking for boat ramp area	Submergence of storage area	Sandy area from parking lot to boat ramp area	3 to 7
		Submergence of boat ramp		
		Damage to boat ramp	Boat ramp elevation range	-1 to 3
		Loss of parking and access	Bottom of boat ramp supports	<-1
8. Cow Yard Boat Ramp	Launch of canoes, kayak, SUPs	Submergence of ramp	Parking Lot Area	7 to 9
	Small boat storage	Erosion of ramp	Boat Storage Area	5 to 8.5
	Parking for boat ramp area and emergency vehicles	Submergence of storage area	Boat ramp elevation range	0 to 9
		Submergence of pier		
		Damage to pier		
		Loss of parking and access		

TABLE 2. Structures, Uses and Impacts at Selected Sites

2.2.3 LOSS OF RESOURCES AND ESTUARINE FUNCTION

2.2.3.1 LOSS OF INTERTIDAL RESOURCES

TABLE 3. Estimated Mean Sea Level in Nauset Beach/Pleasant Bay under Low, Mid and High Sea Level Rise Scenarios.

YEAR	LOW (3 mm/yr)	MID (6 mm/yr)	HIGH (9 mm/yr)
2040	0.20 m (0.7 ft)	0.28m (0.5 ft)	0.35m (1.1 ft)
2070	0.29 m (1.0 ft)	0.46m (1.5 ft)	0.62m (2.0 ft)
2100	0.38 m (1.2 ft)	0.64m (2.1 ft)	0.89m (2.9 ft)

Data from Borrelli, et al., 2016

This analysis was designed to update previous work commissioned by the Pleasant Bay Alliance. In 2016 Borrelli et al., provided a study that looked at, in part, the impacts variable rates of sea level had on the spatial extent of intertidal areas in Pleasant Bay. That study used effective rates of 1, 2 and 3 ft of sea level rise, low, mid and high, respectively, by 2100 at 30-year intervals: 2040, 2070 and 2100. (Table 3). The findings for that study saw decreases in intertidal areas under the low and mid sea level rise scenarios with a slight increase in area under the high scenario as new areas were becoming inundated by 2100.

However, given the complex nature of the present study and improvements in climate and sea level rise models it was determined that a rate of 1-2 ft would be used for green and grey infrastructure by 2050, respectively, and single value of 4 ft would be used by 2100. In order to provide a simple and straightforward analysis here that can be easily compared with the previous work we chose to use 1.5 ft for our 2050 analysis rather than a range of 1-2 feet for the green and gray infrastructure (Table 4).

TABLE 4. Sea Level Rise scenarios for 2050 and 2100.

Year	2050	2100
SLR (ft)	1.5	4
MHW @ Chat. Hbr (m)	4.47	6.97
MLW @ Chat. Hbr (m)	2.55	5.05

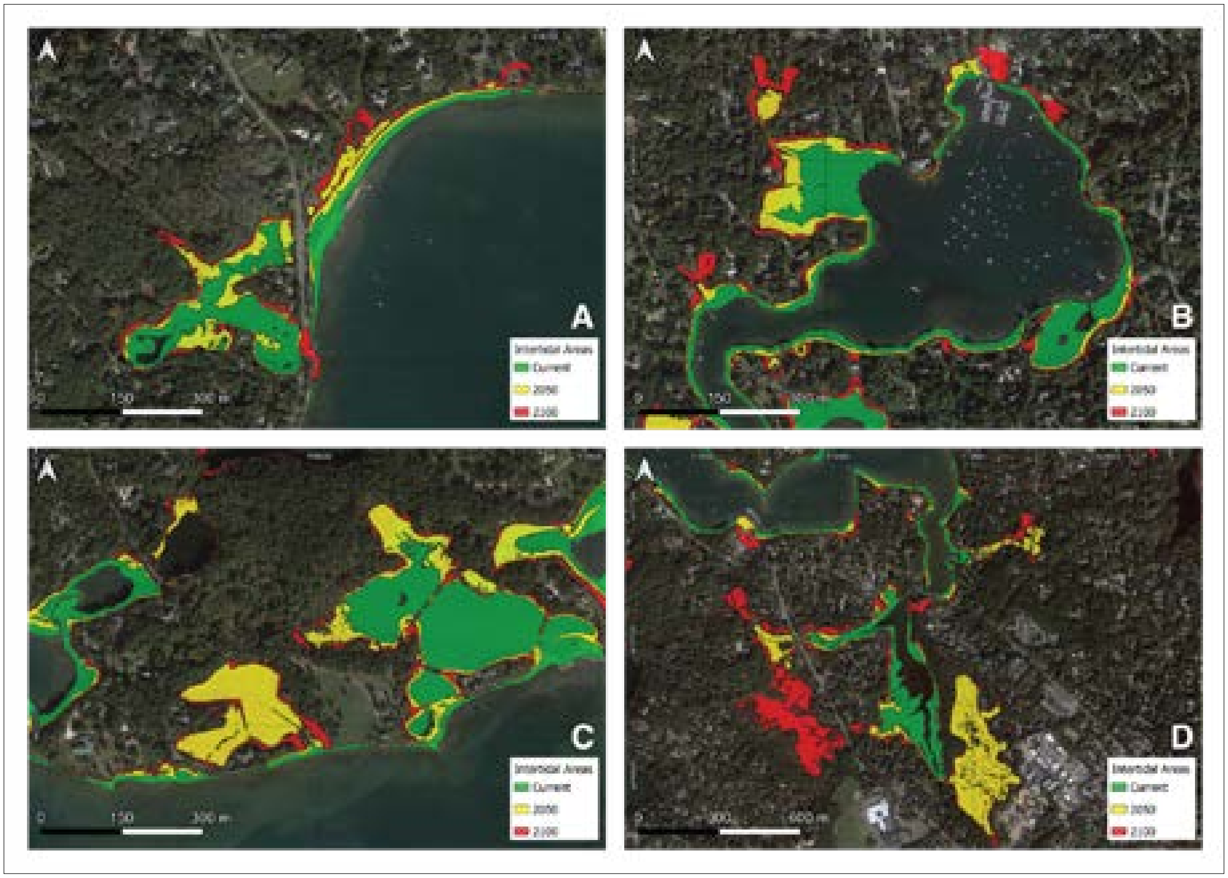


FIGURE 6. Four areas of Pleasant Bay showing current intertidal area (green) with projections in 2050 (yellow) and 2100 (red).

Figure 6 shows four different areas in Pleasant Bay with regards to changes in intertidal area. In the northwest corner of *Big Bay* (Figure 6A) the green areas indicate the current extent of intertidal area, by 2050 with 1.5 feet of sea level rise the intertidal area are shown by the yellow areas, which has been reduced substantially. The areas that were intertidal, colored green, in the current time period are now subtidal or always underwater in 2050. By 2100 the intertidal area decreases further in this area. This is due to the steep sides of the coastal features. Similar to the fate of some salt marshes there is no space available for the intertidal zone to migrate into as sea level rises. In panel B of Figure 6, we see Meetinghouse Pond in Orleans at the three different time periods. Current intertidal areas are greatly reduced by 2050. While there are some gains from 2050 to 2100 there is still a net loss in this area. Further, those intertidal zones shown in 2100 may not be suitable or feasible for twice daily inundation by the tides. Panel C in Figure 6, the northern shore of *Big Bay,* shows some of the most dramatic gains and losses in intertidal areas. In the center right of the figure, large intertidal areas shown in green are lost by 2050, with further loss by 2100, but in the lower left of center area a large gain in intertidal area is shown in 2050 but is lost by 2100. In Panel D we see large areas of gain in 2050 and 2100 but again these areas may not be feasibly inundated, and more site-specific work is needed in the future.

As mentioned above the 2016 study saw a slight increase in intertidal resource by 2100. Using the greater rates of sea level rise in this study that same pattern is not seen. Here we see intertidal loss throughout the time period even though new areas are being inundated in 2050 and 2100. (Table 5).

TABLE 5. Intertidal area in Pleasant Bay.

Pleasant Bay	2021	2050	2100
Total Area (acres)	412.2	247.9	117.9

A 40% decrease (164 acres) in intertidal resources is documented between 2021 and 2050, and a further 47% decrease (130 acres) between 2050 and 2100. A 72% loss of intertidal areas (294.3 acres) was shown from 2021 through 2100. This represents a rate of 5.6 acres/yr from 2021 through 2050, 2.6 acres/yr from 2050 – 2100 or 3.7 acres /yr from 2021 – 2100. The rate of decrease in the second interval is likely due to the overall decrease in available intertidal areas as opposed to decreasing rates of sea level.

2.2.3.2 LOSS OF SALT MARSH

The coasts of Pleasant Bay support extensive marsh systems that provide significant ecological and socio-economic values, ranging from fish and wildlife habitat to buffering shoreline resources from the effects of storms. These natural resources are fundamental to these coastal communities and the Cape Cod National Seashore. The loss and degradation already experienced by these marshes from historical human activities, such as road crossings, filling, and hardened shorelines, is exacerbated by accelerated sea level rise and wave-induced erosion associated with climate change.

Salt marsh loss is a three-dimensional problem. Sea level rise, waves and sediment deficits are primary factors contributing to widespread salt marsh loss. Waves cause edge erosion of marshes and rising sea levels lead to inundation. Marshes naturally gain elevation by trapping sediment and by accumulation of root mass. However, these internal processes can be compromised by a lack of sediment movement through the marsh, and other factors that affect root mass accumulation. Marshes naturally seek to migrate landward, but migration potential depends on multiple factors including land slope, tidal inundation frequency, salinity of surface waters, vegetation cover and adjacent land uses.

Salt marsh loss and degradation is occurring at an alarming rate across the Northeast. The loss of some of these marsh areas is unavoidable, regardless of measures taken to restore or protect them. However, some areas have potential for rrestoration and conservation. As sea level continues to rise, concerted efforts to conserve and restore some marsh areas is critical to maintaining the ecological, cultural, recreational and economic benefits that salt marshes provide for local communities.

2.2.3.3 LOSS OF EELGRASS

The value of eelgrass meadows to coastal environments is well documented. Eelgrass meadows are recognized for their high biodiversity, providing food and habitat to various organisms including microbes, invertebrates, and vertebrates such as fish and bay scallops, which in turn attract larger predators like bluefish and striped bass (Green and Short 2003). Eelgrass meadows are also a significant global carbon sink and sequester and store large amounts of carbon in sediments, which is key to combatting global climate change (Fourqurean et al., 2012; Rohr et al., 2018; Novak et al. 2021). In addition, eelgrass meadows serve as filters and improve water quality and clarity of coastal ecosystems through the direct trapping of suspended particles and the retention of organic matter (Short and Short 1984; Ward et al. 1984; Short et al. 2007).

Pleasant Bay is currently vegetated with 1,070 acres of eelgrass. Eelgrass in Pleasant Bay is found in the low intertidal zone to approximately 3.5 m below mean low water with the greatest extent found in Little Pleasant Bay, which occupies the estuary's shallow upper basin. Since 1951, eelgrass has declined by 55% due to increased nutrients and suspended sediments entering waterways from increased watershed development. Notable areas where eelgrass has been wiped out by nutrient enrichment include Round Cove and Muddy Creek (PBA MEP, 2020).

Eutrophication and sedimentation contribute to the loss of eelgrass by decreasing the amount of light available to eelgrass for photosynthesis. Additionally, in systems with high nutrient loadings, epiphytes and fast-growing macroalgae outcompete eelgrass as they uptake nutrients more effectively and have relatively lower light requirements (Short et al., 1987). Other anthropogenic activities that have had direct impacts on eelgrass distribution by reducing water clarity and/or uprooting plants include dredge and fill, land reclamation, dock and jetty construction, and bottom disturbing fishing practices (Short and Wyllie-Echeverria 1996; Moore and Short 2006; Neckles et al. 2005).

There is also increasing evidence that warming sea surface temperature (SST), due to climate change, is maybe further threatening eelgrass populations. In Northern Europe, the performance and survival of eelgrass was severely impacted when plants were exposed to water temperatures ≥25° C during a series of heat waves (Reusch et al., 2005; Nejrup and Pedersen, 2008; Ehlers et al., 2008). Likewise, complete vegetative dieback was observed in Chesapeake Bay, VA, USA, following a period when water temperatures exceeded 30° C (Moore and Jarvis, 2008). More recently, Plaisted et al. (2022) found a reduction in the probability of eelgrass presence in meadows of the northeast USA corresponded to above average SST during summer months. While seagrasses can tolerate small increases in temperature (Campbell et al., 2006; Winters et al., 2011), prolonged periods of high temperature, when respiration exceeds photosynthesis, can lead to an impaired carbon balance, resulting in reduced growth and survival (Lee et al., 2005; Lee et al., 2007a; Marín-Guirao et al., 2016, 2018; Perez and Romero, 1992).

SECTION 3. PLEASANT BAY RESILIENCE STRATEGIES

This section explores the resilience strategies put forward as part of the CAAP, and the initial recommended actions to implement each strategy:

3.1 Build Municipal Capacity for Climate Resilience

3.2 Undertake Monitoring and Technical Assessments to Support Resilience

3.3 Promote Climate Resilient Regulations and Policies

3.4 Promote Climate Resilient Planning and Design for Infrastructure

3.5 Support Restoration and Rehabilitation of Salt Marsh, Eelgrass and other Coastal Wetland Resources

3.6 Promote Community Stewardship and Engagement

These strategies are put forward as a starting point for enhancing the resilience of Pleasant Bay's natural resources, as well as infrastructure needed to facilitate water access and protect water quality. They are part of a larger effort to address the broad spectrum of climate vulnerabilities addressed in the communities' Municipal Vulnerability Preparedness (MVP) plans.

3.1 BUILD MUNICIPAL CAPACITY FOR CLIMATE RESILIENCE

A Community Resilience Forum was held in October 2023 to provide an opportunity for community input into the development of the CAAP. Among the topics discussed, forum participants questioned whether the four Alliance member towns were placing sufficient emphasis on climate resilience in developing policies, planning projects and capital budgeting.

The CAAP is a starting point for building municipal capacity to incorporate climate resilience in planning and budgeting. The following recommendations are provided to facilitate municipal capacity-building.

RECOMMENDED ACTIONS

3.1.1 Formalize an approach to identifying and prioritizing prospective resiliency measures, planning and design of enhancement, and implementation of solutions.

3.1.2 Support evaluation of the need and efficacy of a dedicated town position to promote climate resilience. A designated town staff person could take the lead in overseeing resilience planning and implementation, and serve as a "clearing house" across all town departments, boards and committees.

3.1.3 Support creation or administration of town policies to include resilience in departmental budgets and all capital planning and budgeting (particularly for water, wastewater and coastal access infrastructure) to ensure that resilience enhancements are on an equal footing with other town infrastructure needs. The towns should be actively seeking opportunities for joint municipal projects where resiliency enhancements can be made as adjuncts to other municipal projects such water and sewer main installations or roadway improvements.

3.1.4 Establish metrics for resilience success, particularly for resilience of coastal resources, water and wastewater infrastructure, and shoreline public access. First among these would be to adopt town-wide elevation thresholds so there is more uniformity in assessing sea level rise impacts and planning for enhancements.

3.2 UNDERTAKE MONITORING AND TECHNICAL ASSESSMENTS TO SUPPORT RESILIENCE

Ongoing monitoring and technical assessments provide assurance that rigorous science-based information is available to support resilience planning in Pleasant Bay. For more than two decades, the Pleasant Bay Alliance has sponsored the Citizen Water Quality Monitoring Program in concert with the Friends of Chatham Waterways, Orleans Fresh and Marine Water Quality Advisory Committee and Harwich Natural Resources Department. For close to two decades, the Alliance has sponsored tide gage monitoring conducted by the Center for Coastal Studies. These long-term data sets provide invaluable insights into changing conditions in a dynamic system. In particular, the water quality data has been relied upon to inform municipal investments in wastewater infrastructure needed to reduce nitrogen loading and protect the health of the Bay. The following monitoring and technical assessments are recommended by the CAAP to inform resilience planning in Pleasant Bay.

RECOMMENDED ACTIONS

3.2.1 Monitor and analyze tide levels in Pleasant Bay and Chatham Harbor. In 2007 the Alliance began working with Dr. Graham Giese to expand the collection, analysis and reporting of tide gauge data in Pleasant Bay. Currently tide gauges are deployed at the Fish Pier (by NOAA) and Meetinghouse Pond (by Cape Cod National Seashore.) This collaboration in support of tide data monitoring and analysis should continue. Additional tide gauge monitoring locations should be considered if indicated by the data analysis. The Alliance will work with other research partners to support the continuation of the NOAA tide gauge at the Chatham Fish Pier.

3.2.2 Conduct aerial imagery and spatial analysis of the Nauset barrier beach system. Understanding how barrier islands evolve annually and seasonally can better inform management decisions when changes occur. Building on the barrier beach assessment described in the CAAP, this task will continue the use high resolution aerial data to assess and monitor the vulnerability of the Nauset barrier beach to climate effects, and predict geomorphology of the barrier beach.

3.2.3 Monitor and assess shoreline intertidal resources. Intertidal wetland resources are vulnerable to sea level rise. A 2017 study showed that Pleasant Bay could lose up to 196 acres or 50% of its intertidal resources by 2100 due to sea level rise. Analysis for the CAAP revised that estimate to 294 or 72%. While differences in lidar products, such as resolution, seasonality of data collection, etc., likely accounts for a small percentage of change seen in comparisons these datasets, the likely increase in anticipated impact is dramatic. Continued monitoring of intertidal resources with emphasis on high priority areas adjacent to public infrastructure is proposed.

3.2.4 Monitor water quality and implement measures to reduce land-based pollution and decreasing nutrient and sediment run-off, reducing or eliminating the use of fertilizers and persistent pesticides and increasing filtration of effluent.

3.2.5 Monitor existing eelgrass meadows in the harbor using a hierarchical framework to detect and predict changes so that appropriate management strategies can be developed. The monitoring approach would include three tiers that are integrated across spatial scales and sampling intensities (see Neckles et al. 2012).

- Tier 1 monitoring would involve mapping eelgrass in Pleasant Bay every three to five years to provide large-scale information on seagrass distribution and meadow size.
- Tier 2 monitoring involves conducting bay-wide, quadrat-based assessments of eelgrass percent cover and canopy height at permanent sampling stations following a spatially distributed random design.
- Tier 3 monitoring involves continuing high-resolution measurements of seagrass condition (percent cover, canopy height, total and reproductive shoot density, biomass, and seagrass depth limit) at a representative index site in the system.

3.2.6 Monitor salt marshes for vulnerability and restoration potential. The National Park Service Cape Cod National Seashore undertakes the following monitoring efforts to track the health of salt marsh in Pleasant Bay and elsewhere in the Cape Cod National Seashore:

- Salt marsh vegetation surveys
- Tidal wetland elevation monitoring
- Water level and water quality monitoring

It is recommended that this monitoring continue and be augmented by monitoring of intertidal resources described in 3.2.3 above.

3.2.7 Update the assessment of salt marsh vulnerability. With funding from the MA Coastal Zone Management Coastal Resiliency Grant Program, the Alliance worked with Center for Coastal Studies to develop an Assessment of Marsh Shoreline Vulnerability in Pleasant Bay (2022). The term 'vulnerability' must be defined in relation to a specific set of drivers, here we intend to define salt marsh vulnerability as it relates coastal erosion with regards to waves, tidal currents, and human alterations, as well as the ability of the salt marsh to naturally respond to changes, such as migrating into areas as a result of sea level rise, the availability of such areas. Lastly, the overall resiliency of the salt marsh with respect to development and/or changing natural processes. This assessment should be updated every five to seven years.

3.2.8 Estimate the economic value of nitrogen attenuation provided by salt marsh. The Pleasant Bay Alliance has been instrumental in facilitating the first-in-the-Commonwealth watershed permit issued by Massachusetts Department of Environmental Protection. The permit establishes nitrogen removal requirements for each of the four watershed towns. Pleasant Bay salt marshes naturally attenuate significant amount of watershed nitrogen load. If those marshes dwindle in size or lose their inherent attenuative capacity, the watershed towns will see their nitrogen removal responsibilities increase along with their financial burden. Therefore, it is believed that the monetary value of existing salt marshes is a pertinent criterion in any plan for protection and restoration.

Prior studies sponsored by the Pleasant Bay Alliance have estimated the cost of the nitrogen removal technologies adopted by the four watershed towns. That information can be used to estimate the monetary value of salt marsh attenuation. Should that significant ecological service decline or be eliminated, the towns will be faced with additional large capital expenditures. The public knowledge of those costs should create a strong support for any restoration efforts that are proposed. The survey conducted by the Alliance in the current CAAP clearly documents the public's interest in the preservation of natural coastal resources. This proposed study can add to that support.

3.2.9 Assess the current and potential carbon storage value of salt marsh and eelgrass in Pleasant Bay. coastal wetlands and seagrass beds store massive amounts of carbon that would otherwise contribute to global climate change. Coastal wetlands store large quantities of carbon at a rate faster than even tropical forests. Carbon storage is now recognized as a significant public benefit of coastal wetland restoration. An accurate assessment of the carbon storage capacity of salt marsh and eelgrass in Pleasant Bay will help to build public support for salt marsh and eelgrass protection and restoration efforts.

3.3 PROMOTE CLIMATE RESILIENT REGULATIONS AND POLICIES

In 2017 the Pleasant Bay Alliance released *Guidelines for Managing Erosion in Pleasant Bay* as a resource to property owners and regulators seeking to increase the resilience of property while not negatively affecting the functioning of coastal landforms and the processes of sediment erosion, transport or deposition essential for healthy coastal resource areas. The guidelines advocate the use of the spectrum of erosion management strategies, beginning with those least likely to interfere with sediment processes, and requiring rigorous alternatives assessment for use of hard engineered structures where they are eligible under state and local laws. Adherence to these guidelines is a recommendation of the CAAP.

Since that time, several other significant efforts have been underway to develop model regulatory tools that towns can use to increase climate resilience.

- MA Department of Environmental Protection (DEP) has issued draft regulations, providing performance standards for Land Subject to Coastal Storm Flowage (LSCSF).
- The Cape Cod Commission is developing a number of resilience tools:
    - A model coastal resiliency bylaw has been released, which is focused on the "goals of promoting natural resource migration and reducing risk in the floodplain due to sea level rise. The model bylaw has been drafted to be inserted, on a stand-alone basis, as a self-contained article within an existing local wetlands bylaw. Towns can adapt the bylaw to fit their needs, including having the Conservation Commission adopt certain elements (such as performance standards) as Local Regulations, rather than as part of the Bylaw. The model bylaw has been structured to be consistent with the anticipated DEP regulations."
    - Coastal resiliency wetlands regulations are being developed to accompany the model bylaw.
    - A zoning bylaw is being developed to address development in the velocity zone.
    - A model communications framework is available to help explain the purpose and features of the bylaw and regulations to stakeholders.
    - Flood Area Design Guidelines have been developed to provide assessment tools and design strategies "for reducing or eliminating hazards from sea level rise and storm surge to life and the built environment while also protecting the region's distinctive character and historic resources, both in the short term and the long term."

RECOMMENDED ACTIONS

Coastal Resilience Wetlands Bylaw and Regulations

3.3.1 Work with Conservation Commissions and other stakeholders in the four Alliance towns to evaluate the Coastal Resilience bylaw and regulations developed by the Cape Cod Commission, and adopt provisions that will enhance resilience of coastal wetlands in Pleasant Bay and elsewhere in the towns.

3.3.2 Continue to promote the application of performance criteria and design standards found in the *Guidelines for Managing Erosion in Pleasant Bay.* The guidelines seek to ensure that selected measures provide a means for property owners to manage erosion while sustaining the natural process of sediment transport and deposition needed for a healthy coastal system.

The guidelines reinforce local, state and federal regulations intended to protect the functioning of coastal dunes, banks, marshes and beaches that rely on the movement of sediment. These features buffer storm surges, and provide significant habitat and extensive recreational opportunities. Measures such as coastal armoring, while intended to prevent short-term erosion, actually reduce the amount of sand in the system available to sustain these critical features.

The guidelines call for an evaluation of alternatives to managing erosion starting with those that cause the least interruption of natural sediment movement, to those that have greater potential to interrupt sediment movement. Design guidance is provided for a wide range of erosion management measures.

Land Use and Development

3.3.3 Work with Planning Boards and other stakeholders in the four Alliance towns to evaluate the model zoning bylaw for development in the flood plain when it is available, and to adopt provisions that will enhance resilience and safety within the flood plain.

3.3.4 Promote awareness and use of *Flood Area Design Guidelines prepared by the Cape Cod* commission as a tool for reducing or eliminating hazards from sea level rise and storm surge to life and the built environment while also protecting the region's distinctive character and historic resources.

Stormwater Management

3.3.5 Review and implement selected measures from *Pleasant Bay Alliance – Regional Stormwater Management Bylaw Review* (June 2021). The following priority actions align with the towns' requirements to comply with Municipal Separate Storm Sewer System (MS4) requirements, or will significantly improve management of stormwater runoff.

3.3.5.1 Implement more stringent stormwater management regulations for the Pleasant Bay watershed, such as:

- Requiring Low Impact Developments (LIDs) to the maximum extent practicable and incentivizing LID and green infrastructure best management practices (BMPs) through "by right" processes making the permitting and implementation easier for town employees, boards, and developers

- Requiring that new and redevelopment stormwater control measures (SCMs) be optimized for nitrogen removal, or specifically designed to remove the contaminant of concern (e.g., phosphorus or nitrogen) depending on nearby resource areas

3.3.5.2 More widespread installation of LID stormwater management techniques (bioretention, swales, filter strips) can be facilitated by permitting their construction on land held in common, such as open space protected within Open Space Residential Development (OSRD) zoning districts.

3.3.5.3 Providing options to reduce impervious surfaces in new and redevelopment projects is a priority action item that aligns with the year four MS4 permit requirement to identify and assess the potential for reducing impervious areas (MS4 §2.3.6). Suggestions for ways to facilitate this include:

- Allowing use of permeable paving

- Creating formulas for shared parking for uses with different peak demand periods

- Establishing landscaping requirements for parking areas that include designing non-bermed vegetated islands with bioretention functions

- Reducing the required radii for cul-de-sacs (35 feet is optimal).

To best adapt stormwater treatment designs to improve climate resilience, regulations should reference the most updated data on storm intensities from the Northeast Climate Center or the NOAA 2014 Atlas.

3.3.6 Evaluate the Benefit and Feasibility of Recommendations from the Southeast New England Program Stormwater Technical Assistance Network

A report by the Southeast New England Program Stormwater Technical Assistance Network identified climate resilience as the primary stormwater issue within the Pleasant Bay region. According to the report, there is no more significant benefit or opportunity associated with effective stormwater management than ensuring the long-term resilience of the region to the impacts of climate change. The four Pleasant Bay communities have an opportunity to expand their own institutional financing capacity by creating regional funding and financing processes. The report recommendations possible opportunities for expanding investments in stormwater management across the PBA region as well as the specific role that PBA can provide in scaling stormwater investments in support of both water quality restoration and climate resilience and adaptation.

3.3.6.1 Create a regional Municipal Separate Storm Sewer System permit compliance program. Water quality restoration as a financing driver is the result of the associated permit requirements. The most basic of these regulatory requirements in regard to stormwater is the Municipal Separate Storm Sewer System (MS4) permit program, which represents the baseline of stormwater management activities. The six MS4 minimum control measures (MCM) are just that—the minimum level of effort that is required to maintain stormwater compliance. However, the MCM's also create an opportunity to generate implementation efficiencies, thereby increasing the restoration impact of stormwater programs within each of the four PBA communities. The primary recommended next steps are to:

- Conduct a detailed fiscal analysis of the existing cost of compliance in each community and the opportunities for reducing costs through collaboration; and,
- Revise the PBA intermunicipal agreement to include and enable formal MS4 collaboration.

3.3.6.2 Draft a stormwater masterplan to identify potential interjurisdictional stormwater management projects. In addition to the MS4 permit requirements, the four PBA communities are subjected to a watershed-wide water quality permit that limits nutrient emissions to Pleasant Bay. While the existing regulatory and financing systems limit the opportunities for collectively addressing stormwater management needs, there may be opportunities to finance and implement stormwater projects collaboratively. This will require the development of a stormwater masterplan. PBA is a uniquely appropriate institution to lead this effort.

3.3.6.3 Expand the scope of the Pleasant Bay Alliance to include coordinating a collective long-term response to climate resilience and adaptation. Our final recommendation focuses on what will certainly be a long-term financing challenge facing the PBA communities: mitigating the impacts of climate change. In the short-term the necessary focus of the four communities should be on stormwater related flooding risks identified in each community's MVP. In the long-term, the focus will require expanding to other infrastructure needs. In other words, stormwater management, coupled with the existing and potential capacities of PBA, provide a uniquely innovative and effective starting point for directly managing and financing regional climate adaptation.

3.4 PROMOTE CLIMATE RESILIENT PLANNING AND DESIGN FOR INFRASTRUCTURE

The CAAP includes an assessment of eight critical infrastructure locations in Pleasant Bay: three low-lying water mains; one wastewater pump station, one stormwater management system, and three public access sites. The climate threats to these facilities are documented in Selection of Case Study Sites and Establishments of Threshold Elevations by Wright-Pierce. Recommended resilience enhancements from this analysis are presented in a report entitled Recommended Adaptation Measures for Public Access and Water Protection Infrastructure by Wright-Pierce, and are summarized below. The assessment of climate threats and proposed adaptations provide a model approach to extending resilience planning to other infrastructure adjacent to Pleasant Bay and in other coastal areas.

This section also discusses plans to use the information contained in the final report Mapping Storm Tide Pathways in Pleasant Bay, Cape Cod, Massachusetts prepared by Center for Coastal Studies. Storm Tide Pathways analysis developed for the CAAP to support protection of low roads. This work will be undertaken in cooperation with the Cape Cod Commission's low-lying roads program.

Lastly, this section highlights the Jackknife Harbor Beach living shoreline project, which will be the first living shoreline project to be permitted and constructed on Pleasant Bay, and is a model for resilient protection and restoration of salt marsh and low-lying public access.

Wastewater Infrastructure

There is currently limited public wastewater infrastructure in the Pleasant Bay watershed. Planning for coastal resilience should focus on the proper siting and design of new wastewater facilities, as opposed to modifications to existing systems.

RECOMMENDED ACTIONS

3.4.1 Wastewater Infrastructure

3.4.1.1. Harden Lane Pump Station

Harwich wastewater pump station at Harden Lane. The Harden Lane Pump Station is the lowest-lying piece of wastewater infrastructure in Harwich, so the findings of this study indicate that Harwich's sewer system is not particularly vulnerable to the impacts of sea level change in the Pleasant Bay watershed. However, over the long term, the pump station could be at risk of damage due to sea level rise, leading to possible inaccessibility of the pump station and discontinuity of service. Recommended enhancements include:

- The water levels in the wet well are monitored by instrumentation that tells the pump when to turn on. If there is infiltration or inflow getting into the pipes or wet well, the pumps would have to turn on more frequently to keep up with the flow. This may be worsened in future planning scenarios with more saturated soils and potentially inflow contributing to higher flows to the station.

- The Town should monitor sea level rise to judge the necessity of re-grading the vehicular access to this station. Based on that monitoring, a design should be developed for re-grading as appropriate.

- The four Pleasant Bay watershed towns should recognize the good design of this pump station (key elements of wastewater infrastructure several feet above the FEMA 100-year base flood elevation) as an example for new wastewater collection systems. It is also recommended that the watershed towns consult the MC-FRM and Storm Tide Pathway datasets in addition to FEMA mapping, when siting new infrastructure.

3.4.2 Water Supply Infrastructure

3.4.2.1 Brewster Water Main near Tar Kiln Road

This study of the lowest-lying water system infrastructure in Brewster (off Tar Kiln Road) shows the minimal risk for that system with respect to sea level rise. It illustrates the type of routine surveillance that is needed over time to ensure embankment stability for water main protection.


Hydrant
Water Main
All elevations shown in NAVD88
Mass DOT Route 28
Bay Rd
Pleasant Bay
N
Feet
0 50 100 200
Harwich Water Main Site Plan
Climate Adaptation Action Plan
Pleasant Bay Alliance
PROJ NO:
21324
DATE:
6/28/2023
WRIGHT-PIERCE
Engineering a Better Environment
FIGURE:
7

Recommended enhancements include:

- The buried water mains near Tar Kiln Road have a low risk of impact from sea level rise and storm surges, warranting periodic observation but no immediate action. It is recommended that the Town monitor water level rises and slope stability at this location. Any observed signs of erosion or pipe exposure should warrant future action to protect the pipeline. Replacement of pipes with HDPE or another non-ferrous material should be considered in this location once pipes have reached the end of their service life and are to be replaced.

3.4.2.2 Orleans Water Main on Tar Kiln Bridge

The Orleans Water Department owns a water main on the Route 28 bridge over Tar Kiln Stream. The bridge is owned and maintained by Mass DOT, but the water main and the main's connection to the bridge are maintained by the Town of Orleans. The pipe is a 12-inch cast iron water main with pipe insulation that is attached to the underside of the bridge on the inland (western) side of the bridge. The pipe supports were recently replaced in 2021 with all new stainless-steel connections that provide a robust attachment to the underside of the bridge. It is estimated that the pipe is original to the 1960s; that is, the pipe is approximately 60 years old.

The Orleans water main on Tar Kiln bridge is securely attached to the DOT-maintained bridge structure. No near-term structural improvements are needed. It is recommended that the following non-structural improvements be taken:

- While the pipe supports are new and in good condition, the water pipe itself is estimated to be original to the 1960s and should be periodically inspected to ensure that it is in good condition. The increased exposure to corrosive sea water that is expected with the 2070 storm surge and wave crest elevations could further deteriorate the pipe. In addition, there is a low level of risk for the pipe being damaged by debris from storm surges. The pipe is tucked up in a utility bay under the bridge which helps to protect it now, but in future sea level scenarios, that area may see more potential for impacts and should be inspected following significant storms.

- The Town should coordinate with MassDOT to determine its maintenance and rehabilitation/replacement timeframes. Obviously, the pipe's resilience is contingent on the bridge maintaining functionality and safety. Therefore, close coordination with the MassDOT is a best practice.

3.4.2.3 Harwich Water Mains at Bay Road and Rt. 28

One of the water mains that the Town of Harwich owns and maintains is located in a low-lying area at the intersection of Bay Road and Route 28. At that location, Route 28 is immediately adjacent to Pleasant Bay at the mouth of Muddy Creek. The lowest roadway elevation at this location is approximately 6 feet, which would put the pipe a few feet below that at approximate elevation 2 to 3 feet. The current mean high-water elevation for this area is about 2.3, meaning that a very small increase in sea level (of only 0.5 feet) could result in a water table rise sufficient to saturate the soils around the pipe. The risk of corrosion will increase over time as the pipe gets more frequently introduced to salt water. Wave impacts will also become more frequent as sea level rises and storms increase in intensity and could pose wash-out risks to the road and buried water utilities. Traveling further north on Route 28, or further west on Bay Road, the road elevations increase quickly to be well above 20 feet. There is approximately 300 feet of Route 28 and about 300 feet of Bay Road below elevation 10 feet. Further stretches of the road could be inundated within a longer time horizon, or sooner if they also are experiencing wave action from coastal storms.

The buried water mains near Bay Hill Road have potential impacts that warrant further observation but likely no immediate action. Strengthening Route 28 against erosion will provide indirect protection of those water main against possible wash-out. It is recommended that the following non-structural improvements be taken:

- The Town should regularly monitor the water surface elevations of the bay to determine to what degree water may be encroaching toward the roadway and to check for signs of erosion, Signs of erosion or pipe exposure should trigger a project to make the pipeline more stable and make roadway repairs. If water surface elevations rise to the point of allowing salt water encroachment, it may be necessary to preplace a section of this water main with corrosion-resistant materials.

- The Harwich Fire Department would develop a protocol for providing for fire-fighting and emergency access to this low-lying area, recognizing that access to two home and a nearby hydrant may be difficult due to inundation of the roadway.

3.4.3 Stormwater Management Systems

3.4.3.1 Lonnie's Pond Stormwater Treatment, Boat Ramp and Herring Run

While there are many stormwater outfalls to Pleasant Bay, there are very few stormwater treatment systems. Improvements for resiliency will therefore be largely related to the integrity of stormwater piping, not stormwater treatment. As water main resilience is closely dependent on roadway integrity, so too are stormwater management systems. The Lonnie's Pond stormwater treatment system (Figure 8) reviewed here could be replaced immediately, but that work should be integrated with the proposed raising of Herring Brook Way and improvements now being planned for the nearby herring run to Pilgrim Lake. Such stormwater improvements could also be integrated with proposed extensions of the Orleans sewer system. The combining of several municipal projects will allow better coordination of the designs and result in cost savings. Stormwater improvements at the Lonnie's Pond boat ramp are another project that is best accomplished in conjunction with the sewer line installation.

These municipal assets at Lonnie's Pond should be strengthened against sea level rise, and that is best accomplished as part of a project to elevate the low section of Herring Brook Way. It appears that up to 400 feet of the road would need to be elevated for protection to elevation 10 feet, and up to 1000 feet for protection to elevation 20 feet. Such roadway changes would have a major impact on the assets considered here, so improvements to these assets must be planned with that potential road work in mind.

There are multiple portions of the Lonnie's Pond site that would be impacted by future climate scenarios. The following recommendations are provided for each component of the site.

- Town should proceed with the NRCS-funded upgrading of the herring run to preserve the functionality and integrity of the herring run from further degradation. Before that project proceeds further, the design concept should be modified to include raising about 400 feet of Herring Brook Way.

- The Town should remove the outdated StormTreat system and replace it with an appropriately designed and sized stormwater treatment system. The stormwater design and replacement should be part of the sewer extension project.

- The Town should provide guidance to the four low-lying homes on the east side of Herring Brook Road on the placement and elevations of the individual grinder pump stations that will be installed by those homeowners to allow them to connect to the new public sewer. Protective measures against buoyancy forces should be implemented.

- Stormwater improvements should be made at the boat ramp as part of the Herring Brook Way construction during the sewer project. These improvements could include a grassy swale coming from Herring Brook Way down the side of the boat ramp and/or consideration of infiltration technology on site. These improvements should be consistent with the Town's policy of addressing stormwater issues on roadways where new sewer lines are being installed.

3.4.4 Public Access to the Bay

There are over 60 locations of public access to the Bay, of which three were evaluated in this study. Conditions vary markedly around the Bay, so it will be beneficial to expand this limited evaluation to look at more of these many points of access.

The CAAP evaluation of the Orleans municipal landing on Meetinghouse Pond, off Barley Neck Road, illustrates the importance of a long-term plan for a multi-use facility. The water access benefits of this site will gradually be reduced as sea level rises, shortening the effective length of the boat ramp and encroaching on the boat storage area. During that early period, the pier will be largely free from impact, but will be more and more susceptible to inundation at high tide. Funds should be set aside for the eventual reconstruction of that pier at a higher elevation, with the understanding that earlier reconstruction might be needed because of storm damage.

The Chatham municipal landings at Crows Pond and Cow Yard are the lowest-lying case study areas and the ones most susceptible to early impacts of sea level rise. Improvements should include extensions to the boat launching areas, site grading changes to better address stormwater issues and revisions to boat storage areas. Both of these study areas are accessed by low-lying roads (Fox Hill Road and Old Harbor Road). This study has documented how site access will be limited by flooding of these access roads. While plans for enhancements for water


Storm Treatment
Boat Ramp
Fish Passage
All elevations shown in NAVD88
Herring Brook Way
Lonnie's Pond
Top of Fish Passage Channel: ~4.5
Storm Treat System: 5.5 to 6
Pilgrim Lake
N
Feet
0
100
200
Lonnie's Pond Stormwater Outfall, Boat Launch, and Herring Run Site Plan
Climate Adaptation Action Plan
Pleasant Bay Alliance
PROJ NO:
21324
DATE:
6/28/2023
WRIGHT-PIERCE
Engineering a Better Environment
FIGURE:
8
CLM W:\GIS_Development\Projects\MA\~OTHER\PleasantBayAlliance\21324_CoastalResiliencyStudy\MXDs\PleasantBay_Area_Projects.aprx

access should begin, as a practical matter, significant investments should not be made until there is a funded plan to elevate sections of the access ways. That is of particular importance for Fox Hill Road, where flooding will not only impede access to the Crow Pond landing but will isolate many homes located on Nickerson Neck, with very serious health and safety considerations.

Parking is limited at all of the Bay access case studies and will become more limited due to sea level rise or as a result of other site enhancements. Off-site locations for additional parking should be considered, although not part of this investigation.

Natural area enhancements can be accomplished as part of resilience projects. Salt marsh renovations are possible at the Meetinghouse Pond case study site and adjacent to the Crows Pond landing.

3.4.4.1 Meetinghouse Pond Landing, Orleans

Meetinghouse Pond Town Landing is located off Barley Neck Road in Orleans (Figure 9). The Town Landing provides access to the tidally-influenced Meetinghouse Pond and facilitates multiple recreational uses by providing Orleans residents an unpaved boat ramp, a boat storage area, and a wooden pier leading to a floating dock. The pier was constructed in 2010. New stormwater infrastructure was installed in 2019 along with parking improvements to the site.

There are multiple aspects of the Meetinghouse Pond Town Landing that will be impacted by sea level rise, at varying elevations. With the expected gradual loss of functionality, the Town must establish a threshold frequency of inundation that is unacceptable. With that uncertainty in mind, physical improvements are proposed for the boat storage area, the pier, and the ramp to the pier, as follows:

- At the time when the boat storage area becomes inundated frequently, the boat storage area and the walkway to the pier must be modified.
  - A new boat storage should be constructed elsewhere on site, with potential to construct vertical dinghy storage on the north edge of the parking lot to minimize impacts on parking.
  - The salt marsh should be restored within the area of the current walkway and current boat storage area. Depending on the viability of the substrate and future water surface elevations, the area should be restored to salt marsh to preserve the ecosystem and to fortify the area as a natural erosion control measure. With proper grading, the marsh can provide attenuation of stormwater contaminant loads from the portions of the site not tributary to the existing stormwater system.
- At the time when the frequency of pier inundation begins to be unacceptable (perhaps by 2030, when an estimated 1.2 feet of sea level rise in combination with storms could overtop the planking), it should be rebuilt at a higher elevation, with associated revisions to the walkway to the pier.
  - The top of pier planking should be raised to an elevation of 8 to 9 feet, with the design to withstand up to 6-foot submergence without being structurally damaged or impacting lighting/electrical amenities.
  - Another possibility would be to raise the pier all the way to the MC-FRM water surface elevation (12.6 feet for 2050).
  - A new accessway to the pier is proposed, which assumes that the pier walkway will begin in the lower parking lot.
  - Modifications will be needed to the ramp leading from the pier to the floats, based on the selected elevation of the pier.

3.4.4.2 Crows Pond Landing, Chatham

Crows Pond Landing is a Town-owned boat ramp on Crows Pond, located off Fox Hill Road in Chatham (Figure 10). The landing consists of a concrete ramp that was installed in 1989, with riprap embankments along each of its sides. The access drive leaves Fox Hill Road and drops steeply to the beach. There is an unpaved parking area along both sides of the drive and there is a bare-sand storage area for small boats on the beach on either side of the ramp. The concrete ramp is located at elevations -1 to 3 feet and the approach to the boat ramp runs from the lower parking lot area at elevation 6 to the high end of the ramp.

The Crows Pond Landing will very quickly be impacted by future sea level rise and storm surges. Water levels at elevation 6.3 (expected by 2050 during highest astronomical tides) will inundate much of the boat storage, parking, and the ramp. While not a part of this study, it appears that up to 400 feet of the Fox Hill Road would need to be elevated for protection to elevation 8 feet, and up to 500 feet for protection to elevation 10 feet. Such roadway changes would have a major impact on the assets considered here, so improvements to these assets must be planned with that potential road work in mind. There are long term structural recommendations that would be associated with Fox Hill Road but this study proposes specific actions at the study site. Physical improvements are proposed for the boat storage area, the pier, and the ramp to the pier, as follows:

Extending and rebuilding the existing boat ramp shoreward with a higher top-of-ramp elevation would extend the conditions where the ramp could still function without being submerged. Depending on the design of Fox Hill Road upgrades, the top of the extended ramp might be about elevation 8 feet. Regrading the surrounding area would be necessary to maintain walkability of the site, and it is recommended that additional boat storage be included at a higher elevation (potentially vertical boat storage racks) in order to prevent washout of the existing boat storage area. In order to preserve the parking capacity on site, land acquisition may be necessary. If there is enough land under town ownership to improve parking along the access drive, that would be a great improvement, but parking could also be incorporated on the side of Fox Hill Road if the town were to undertake a roadway upgrading project. Stormwater drainage through the site should also be considered, because an upgrading of Fox Hill Road would significantly impact drainage conditions. The enhancements can only be implemented in conjunction with reconstruction of Fox Hill Road, so significant costs should be deferred, and the Town should focus on non-structural actions until then. As a short-term improvement, the Town could improve parking along the access drive.

It is recommended that the following non-structural measures be taken:

- The storm tide pathway analysis indicates that Fox Hill Road will begin to flood at elevation 7.2 feet. By elevation 7.9, the roadway will become impassable to vehicles, which would cut off accessibility to the rest of Nickerson Neck for all residents and for emergency vehicles. By elevation 8.3, the flooding hydraulically connects Crows Pond with Pleasant Bay at Jackknife Beach. The boat launch is a less critical piece of infrastructure than the roadway, so the Town's interests are best served by letting the boat ramp stay in service until elevation 8 is consistently reached and focus attention on the Fox Hill Roadway. Planning for the Fox Hill Roadway modifications is recommended as a non-structural action associated with the Crows Pond Landing site.
- Fox Hill Road was a candidate for detailed evaluation as part of the Cape Cod Commission's Low-Lying Roads project but was not selected. The Town should embark on a parallel study, to include this portion of Fox Hill Road, to evaluate other low-lying roads in Town. The town could use the lessons learned in the Low Lying Roads project to make the access to the Fox Hill Road more resilient.
- Town should develop a plan for addressing the boat storage area, recognizing it is likely to become inaccessible and the town should put forth new rules and requirements to make sure that boat owners are moving their boats to a designated secondary location at the appropriate time. The town could monitor the storm elevations until the water reaches elevation 3 feet at a frequency of two or more per year, then planning for a new boat storage area and potentially prohibiting boat owners from using the old storage area to prevent damage to the boats and/or site. The new boat storage could potentially include vertical storage within the existing site but at a higher elevation. The beach area where the boats are currently stored should be revegetated to try to prevent future erosion around the site, recognizing the presence of a salt marsh to the west.

3.4.4.3 Cow Yard Landing, Chatham

Cow Yard Landing is a Town-owned boat ramp located in Chatham off Old Harbor Road. The landing provides direct public access to Pleasant Bay and Chatham Harbor and was originally laid out in 1890 with minor improvements in 2007 and 2008. The launch area is all sand and gravel leading down to the beach and has no paved areas. The parking for the site is restricted to one side of the road coming into the site, and it is very crowded in the summer. Some boats are stored on the beach along the waterfront, and there is no other infrastructure at this site. Near this site is the discharge point of a portion of the MassDOT stormwater system draining Route 28, which reaches the ocean through a low area just south of the landing.

Cow Yard landing will be inundated early in the planning period. The low areas on site are connected to similar marshy and low-lying areas on either side of Old Harbor Road. Accordingly, any significant capital expense at the Cow Yard landing should be coordinated with the significant roadwork needed on Old Harbor Road to allow access to the site.

It is recommended that the following non-structural measures be taken:

- The Town should develop a plan for improvements to Old Harbor Road that would allow access to homes in the area during high-water events that will become increasingly frequent. Once the most feasible upgrading plan is determined for Old Harbor Road, it can be expanded to also consider improvements to Cow Yard Landing.
- The Town should develop protocols for emergency vehicle access to Old Harbor Road, including provisions for responding to life-safety events at Cow Yard Landing.


Boat Ramp
Boat Storage
Parking Area
Sandy Walkway Area
Tax Parcel
All elevations shown in NAVD88
Fox Hill Road
Crows Pond
N
Feet
0 37.5 75
Crows Pond Landing Site Plan
Climate Adaptation Action Plan
Pleasant Bay Alliance
PROJ NO: 21324
DATE: 6/28/2023
WRIGHT-PIERCE
Engineering a Better Environment
FIGURE: 10

3.4.5 Jackknife Harbor Beach Living Shoreline

The salt marsh that borders the tidal channel into Muddy Creek, along the backside of Jackknife Beach, has been evolving for decades based on natural estuarine and climate changes to the system and anthropogenic changes to the system. The constantly evolving conditions and active recreational use have stressed the perimeter of the salt marsh leading to ongoing loss of marsh vegetation.

The proposed living shoreline restoration project seeks to address the loss of marsh bank by stabilizing and restoring the marsh bank along the channel through nature-based stabilization methods. The living shoreline design incorporates a number of innovative living shoreline elements. These methods incorporate salt marsh substrate, sills to redirect tidal currents off the bank, and shellfish (ribbed mussels) to strengthen and stabilize the existing and new marsh bank. High marsh along the travel way will be restored utilizing a cobble-reinforced technique to reestablish the marsh and adapt to climate change and sea level rise.

The Project will advance a solution to increase the resilience of a portion of the Pleasant Bay shoreline at a highly visible and popular public recreation and shore access location. The Project proposes a combination of marsh protection techniques that are not in use on Cape Cod and have not yet been permitted in Massachusetts. The advancement of this project through permitting and construction will lay the groundwork for subsequent living shoreline projects in Pleasant Bay, Cape Cod and other Massachusetts coastal communities.

Recommended Action: Support permitting and construction of the Jackknife Harbor Beach Living Shoreline Project, with ongoing performance monitoring.

3.4.6 Low-lying Roads and Storm Tide Pathways

This CAAP complements ongoing work by the Towns in coordination with Cape Cod Commission to address climate impacts to low-lying roads. This work should continue, and low-lying road segments identified in the towns but not selected for further assessment under the Cape Cod Commission's low-lying roads initiative should be evaluated for possible future resilience enhancements.
The Storm Tide Pathways assessment developed for the CAAP provides additional information related to low-lying areas that facilitate the inland propagation of stormflow. The Alliance and partners will continue to work with the Town's to understand and rely upon the Storm Tide Pathways as a tool for prioritizing and designing resilient road infrastructure.

The Storm Tide pathways data will be available for posting on the stormtides.org site and the Cape Cod Commission's Resilient Cape Cod site.

Recommended Actions: Provide technical support to towns to review Storm Tide Pathways and evaluate mitigation alternatives.

- Initial focus will be on the 13 Storm Tide Pathways that are 6-12 inches above the Storm of Record, which account for 20-30 acres of flooding impact.
- Assess low-lying roadways that were not included in the Cape Cod Commission low-lying road study to identify any that intersect with the Storm Tide Pathways, such as Fox Hill Road in Chatham.

3.5 SUPPORT RESTORATION AND REHABILITATION OF SALT MARSH AND EELGRASS

3.5.1 Salt Marsh Restoration

There are 180 hydrologically distinct salt marsh units in Pleasant Bay totaling approximately 1,200 acres. Using a methodology developed by scientists at Cape Cod National Seashore and US Geological Survey, these salt marsh units were evaluated for their expected longevity based on current characteristics of vegetation cover and elevation, and projected sea level rise. This analysis found that there are 13 sites totaling 131 acres that are expected to survive more than 3000 years and should be protected; 61 sites totaling 437 acres that are expected to survive 125-300 years and should be monitored; 92 sites totaling 565 acres that are expected to survive 25-124 years and should be restored; and 14 sites totaling 31 acres that should be abandoned, as their projected life span is less than 25 years.

Identifying vulnerable marshes and appropriate restoration or other adaptation strategies requires consideration of multiple factors, but ultimately a coherent geospatial characterization of the marsh is necessary as a first step. Through a prior NPS-funded project, a more spatially robust framework was developed to objectively assess where management action is needed to mitigate marsh area and functional value losses. Marsh units were delineated into marsh complexes with geomorphically relevant parcels (~ 3 ha each). Once units were mapped, data was spatially integrated across these units to create the UnVegetated-Vegetated marsh Ratio (UVVR), which has proven useful in identifying marshes that are in danger of deterioration and open-water conversion (Ganju et al., 2017; Ackerman et al., 2021). The UVVR is fundamentally connected to sea level rise and sediment deficits and is essential for quantifying ecosystem services such as carbon sequestration, wave attenuation, and habitat provision. In combination with elevation and sea level rise projections, the UVVR was used to calculate a sediment-based marsh unit lifespan (Ganju et al., 2020) which provides an objective, temporal metric to guide restoration investments. Using this data, marsh units across Pleasant Bay were placed into potential management categories (Figure 11).

FIGURE 11. Map of Pleasant Bay showing results of the analysis of potential management action alternatives based on metrics of marsh vulnerability and persistence, e.g., marsh elevation, vegetation cover, and estimated lifespan. The marsh units were categorized by potential management action alternatives, protection (blue), monitor for change (purple), restoration (orange), abandon/no action (dark red).

Using the new data on marsh integrity and lifespan and the resulting prioritization of marshes for management action, the proposed work will provide the municipalities, the park, and partners with critical scientific information and a rigorous, collaboratively-derived decision analysis tool. The analysis will be comprehensive and relevant, and can be implemented immediately to make timely, defensible, and actionable decisions to address the urgent need to improve marsh integrity and mitigate marsh losses.

It is critical that managers be provided tools to evaluate realistic management options and long-term strategies to make science-based decisions for these threatened resources. Marsh management and restoration efforts can be logistically complex and costly, and available resources often limit the scope of activities that can be implemented at a given marsh. Thus, we propose to develop a decision-making framework for evaluating marsh management strategy alternatives for a set of the prioritized marsh units within the Pleasant Bay system. The set of marshes will be identified as highly vulnerable and also extremely valuable to the resiliency of Pleasant Bay. The proposed process and decision support tool will apply new marsh vulnerability data to create objectives and evaluate a suite of management strategies and their implementation feasibility in a set of priority marshes in Pleasant Bay. Further, we propose a set of pilot projects to start the process of strategy implementation and develop simple processes for accomplishing results-oriented outcomes in marshes that will serve as a template for future marsh management efforts.

The results of this work will provide Pleasant Bay with an objective, science-based framework for assessing marsh management options and identifying optimal strategies to meet management objectives within the context of projected sea level rise scenarios.

RECOMMENDED ACTIONS

3.5.1.1 The first objective of the proposed work will be to develop a decision analysis tool to evaluate the effectiveness and feasibility of a suite of marsh management action alternatives for a set of priority marshes within Pleasant Bay. The first step of this work is to gather existing data (UVVR, elevation, tide range, adjacent land uses, etc.) and to identify data gaps for each priority marsh within Pleasant Bay. This data gathering step includes lifespan distributions across priority marsh units using a sea-level rise scenario of 100cm sea level rise by 2100. We will examine a suite of management strategies for each unit, including, but not limited to, re-vegetation, hydrology restoration, elevation augmentation, erosion control (e.g., living shoreline). We will apply the Lifespan Tool developed by scientists at the US Geological Survey to assess how restoration of vegetation and/or elevation will affect the specific marsh unit longevity. This tool allows the user to evaluate the change in longevity of the marsh unit in response to different restoration actions. By using marsh-specific data we can better test potential outcomes of various strategies or combinations of strategies for marshes of Pleasant Bay.

3.5.1.2 For the second objective, we will use the information developed to date, and the preliminary outcomes of the decision analysis tool to identify 2-3 opportunities to implement pilot projects for marsh management actions. Marshes where the management action has a high level of feasibility and can be accomplished on a short time frame, will be prioritized for pilot efforts. At least one priority marsh will be selected for which the preferred management action is to place the marsh into a higher level of protection due to its longevity and high quality. For this "protection" pilot, we will develop a protection plan and critical communication products to fully implement its new protection status. The protection plan and communication products will serve as templates for future efforts to develop and enforce protection of other high quality marsh areas within Pleasant Bay. Prioritizing the long-term survival of high-quality existing marshes will be fundamental to the future resiliency of the Pleasant Bay system. And, at least one priority marsh will be selected for which the preferred management action is to undergo active restoration activities. For this "restore" pilot, we will develop an implementation plan with relevant partners (municipalities, Pleasant Bay, Alliance, Cape Cod National Seashore), and begin implementation of the agreed upon restoration action plan.

3.5.1.3 Identify next steps to restore 209 acres of salt marsh with less than 15-75-year life span - explore options to improve UVVR.

3.5.2 Eelgrass

Pleasant Bay is currently vegetated with 433 ha (1,070 ac) of eelgrass. This is 55% less than was present in the 1950s. We developed a site selection model to prioritize sites for restoration and rehabilitation using multiple scenarios and identified an area larger than the current extent of eelgrass (520 ha; 1,285 ac). The first scenario identified sites for future restoration activities assuming an Sea Surface Temperature increase of 1.95°C. The second scenario identified sites for rehabilitation activities that are not light-limited and currently have low eelgrass abundance.

The first scenario identified multiple high priority sites for restoration with a rating of 3 (total area of 69 ha or 171 ac). The model also identified moderate priority sites with a rating of 2 (total area of 76 ha or 187 ac), and low priority sites with a rating of 1 (total area of 109 ha or 270 ac (Table 6). The majority of the high priority sites are located in three regions: 1. between Barley Neck, Pochet Island and Sampson Island; 2. east of Nauset Beach, west of Sipson Island; and 3. between

Sipson Island and Hog Island within Little Pleasant Bay. Unfortunately, some of these high priority sites are also located in areas containing conflicting uses (Figure 8b; Table 1; Supplemental Figure 2) and should be avoided unless a management activity is implemented to ensure restoration success (see management options below).

The second scenario identified sites for rehabilitation that receive > 20% SI and have low percent cover (<25%). There were multiple high priority sites for rehabilitation with a rating of 3 (total area of 55 ha or 137 ac), moderate priority sites with a rating of 2 (total area of 75 ha or 186 ac), and low priority sites with a rating of 1 (total area of 136 ha or 327 ac; Figure 9a; Table 2; Supplemental Figure 3). The majority of the high priority sites identified for rehabilitation are located in between and west of Hog Island and Sipson Island in the system and only a few areas were also located in areas containing conflicting uses (Figure 9b; Table 2; Supplemental Figure 4).

There was an adequate amount of information available for the development of model to support both scenarios. We had current bay-wide eelgrass distribution and abundance data, as well as light and sediment. Bathymetry and wave exposure information were also incorporated via the USGS model results predicting future temperature conditions in the system. In addition, we received information on conflicting uses (docks and piers, moorings, and aquaculture) to include in our final maps as these areas may influence eelgrass transplant success. Water quality information was lacking in spatial resolution to incorporate it as a layer in the model. However, it is unlikely that higher resolution data would influence the output for each scenario.

High failure rates of eelgrass restoration projects will persist if appropriate site selection standards and metrics are not applied (Fonseca, 2011). Though many variables may contribute to seagrass presence or absence, modeling those critical to restoration in a particular area can maximize the potential for success. Furthermore, from a management perspective, it is often more feasible to measure and monitor those variables that can be removed or improved to facilitate restoration success. Now that multiple areas have been prioritized for restoration and rehabilitation, we strongly recommend continuing to "Phase II" of the site selection process as described in Short et al. (2002). Phase II involves evaluating sites with high scores by conducting a test transplanting effort. The survival of test transplants is highly indicative of eelgrass habitat suitability and provides the best indication of how well a large-scale transplanting effort will succeed at a given site. For Pleasant Bay, we recommend using the results of scenario 1 (Figure 8; Supplemental Figures 1 and 2) and test-transplanting vegetative shoots and seeds at multiple sites with a score of 3 to evaluate eelgrass habitat suitability for restoration. Sites within conflicting uses should be avoided. For rehabilitation, we recommend using the results of scenario 2 (Figure 9; Supplemental Figures 3 and 4) and seeding at multiple sites with a score of 3 and outside of conflicting use zones.

Table 2 shows the number of high, moderate and low priority sites and associated acres suitable for eelgrass rehabilitation in Pleasant Bay.

The study developed for the CAAP provides important information on where to target restoration and rehabilitation efforts in Pleasant Bay. It is apparent that eelgrass in these systems is exposed to high nutrient loading from fertilizers and sediments, as well as water temperatures that can inhibit growth and/or survival. As the climate continues to warm, eelgrass in the harbors will continue to be exposed to increased water temperatures and periods of thermal stress. However, eelgrass can survive if other environmental parameters that promote growth and expansion are optimal/or and effective management strategies are developed. Below are some options for potential management actions that have been shown elsewhere to improve eelgrass health and facilitate recovery in the harbor.

TABLE 6. Priority Areas for Eelgrass Restoration

Category	All Sites	Sites outside of Conflicting Use Areas
Low priority: rating = 1	109 ha (270 ac)	66 ha (162 ac)
Moderate priority: rating = 2	76 ha (187 ac)	41 ha (100 ac)
High priority: rating = 3	69 ha (171 ac)	46 ha (113 ac)

RECOMMENDED ACTIONS

3.5.2.1 Implement a project that aims to reduce climate vulnerability of eelgrass meadows in Pleasant Bay. Specifically, the project will move seeds from multiple populations in the region and use them to restore a ¼ acre plot and rehabilitate a 1-acre plot. Both plots were identified in Phase I of the MVP action grant as areas that are suitable for the establishment and growth of eelgrass considering increases in sea surface temperature (SST) of 1.95°C by 2050. The success of these plots will be monitored for one year following transplantation using well-vetted pilot-restoration techniques. The methods used in this project will identify the best donor populations for this system that can be used for future large-scale restorations. More importantly, our methods are transferable to other systems in Cape Cod and can be used to guide additional climate-adapted restorations.

3.5.2.2 Develop a plan to restore high priority restoration sites. Approximately 113 acres has been identified as high priority for restoration. The plan should include consistent metrics for site selection and steps for implementation.

3.5.2.3 Develop a plan to restore moderate priority sites. Approximately 100 acres has been identified as moderate priority for restoration. The plan should include consistent metrics for site selection and steps for implementation.

3.5.2.4 Develop a plan to restore low priority sites. Approximately 162 acres has been identified as moderate priority for restoration. The plan should include consistent metrics for site selection and steps for implementation.

3.5.2.5 Continue to improve water quality within Pleasant Bay by reducing land-based pollution and decreasing nutrient and sediment run-off, reducing or eliminating the use of fertilizers and persistent pesticides and increasing filtration of effluent. The reduction in nutrients within the system will lead to a reduction in nuisance algae which limit the amount of light available to eelgrass for growth. Moreover, if plants are no longer light-stressed they will be able to tolerate longer periods of thermal stress caused by climate change. The Alliance towns are working under the Pleasant Bay Watershed Permit to reduce watershed nitrogen load and achieve nutrient concentrations in Pleasant Bay that are consistent with healthy estuarine ecology.

3.5.2.6 Raise awareness about the socio-economic and ecological values of eelgrass is critical in building support for seagrass conservation. Volunteer monitoring programs can be effective in increasing public awareness of the value of eelgrass meadows and the threats to their survival. Community monitoring programs, such as SeagrassNet, successfully promote stewardship, reinforce the value of eelgrass habitats and collect data about the condition of this species. Public education programs should identify actions that individuals can take to reduce stresses on eelgrass in this system. For example, boaters can avoid anchoring and running their propellers through eelgrass meadows. Creating moorings in eelgrass meadows can be discouraged and/or those areas can be closed temporarily to allow meadows to self-rehabilitate. Traditional moorings could also be replaced with conservation moorings to eliminate chains dragging on the bottom.

3.6 COMMUNITY STEWARDSHIP AND ENGAGEMENT

3.6.1 Build engagement and stewardship needed to address climate threats to Pleasant Bay and other coastal areas on Cape Cod, by expanding opportunities for schools to interact with and understand the dynamic estuarine environment, and by developing a resilience curriculum for local schools to incorporate into their science programs.

3.6.2 Outreach and Engagement
Community consensus around resilience concerns and priority actions to increase resilience in Pleasant Bay is a major focus of the CAAP. The Alliance works with a coalition of local organizations to design opportunities for stakeholders to participate in the development of the CAAP. The organizations—Friends of Pleasant Bay, Friends of Chatham Waterways, Orleans Pond Coalition, Pleasant Bay Community Boating and Woods Hole Sea Grant—have extensive member and/or social media networks.

RECOMMENDED ACTIONS

- Conduct robust outreach and education in support of adoption of the Coastal Resilience Bylaw and Regulations and other high priority action items identified in the CAAP.
- Host an annual Pleasant Bay Climate Resilience Community Forum. The first such forum held at the Chatham Community Center on October 2023 was attended by approximately 60 people.
- Create new video content to complement the four informational videos produced and distributed through the social media networks of participating organizations.
- Develop an annual report on resilience activities for broad distribution in the community.

SECTION 4. ACTION PLAN

	RESILIENCE STRATEGIES	TIMELINE
3.1.0	**Municipal Resilience Capacity Building**	
3.1.1	Formalize an approach to identifying and prioritizing prospective resiliency measures, planning and design of enhancement, and implementation of solutions.	By 2030
3.1.2	Support evaluation of the need and efficacy of a dedicated town position to promote climate resilience.	By 2030
3.1.3	Support creation or administration of town policies to include resilience in departmental budgets and all capital planning and budgeting.	By 2030
3.1.4	Establish metrics for resilience success, particularly for resilience of coastal resources, water and wastewater infrastructure, and shoreline public access	By 2030
3.2.0	**Monitoring and Technical Assessments to Support Resilience**	
3.2.1	Monitor tide levels in Pleasant Bay and Chatham Harbor.	Ongoing
3.2.2	Conduct aerial imagery and spatial analysis of barrier beach	By 2030
3.2.3	Monitor Shoreline Intertidal Resources	By 2030
3.2.4	Continue to monitor water quality	Ongoing
3.2.5	Employ three tier eelgrass monitoring	By 2030
3.2.6	Continue Cape Cod National Seashore monitoring of salt marsh vegetation, marsh elevation, water level and water quality	Ongoing
3.2.7	Update the Assessment of Salt Marsh Vulnerability	By 2030
3.2.8	Assess economic value nitrogen removal from salt marsh	By 2030
3.2.9	Assess the current and potential carbon storage value of salt marsh and eelgrass in Pleasant Bay.	By 2050
3.3 Regulatory Measures to Enhance Resilience		
	Floodplain Resilience	
3.3.1	Work with town boards and commissions to evalaute and adopt the model Coastal Resilience Wetland bylaw and regulations developed by the Cape Cod Commission	By 2030
3.3.2	Review local conservation regulations for consistency with Guidelines for Erosion Management in Pleasant Bay	Ongoing
3.3.3	Work with town boards and commissions to evaluate and adppt adoption of model zoning bylaw for development in the flood plain	By 2030
3.3.4	Promote Flood Area Design Guidelines prepared by the Cape Cod Commission as a resource available to flood plain property owners and for reference in municipal site plan review.	By 2030
	Stormwater	
3.3.5	Review and implement selected measures from Pleasant Bay Regional Stormwater Management Bylaw Review	By 2030
3.3.6	Evaluate the Benefit and Feasiblity of Recommendations from the Southeast New England Program Stormwater Technical Assistance Network	By 2050

PRIORITY	BUDGET	PARTIES
High	Within Town and Pleasant Bay Alliance budgets	Towns of Brewster, Chatham, Harwich and Orleans, and Pleasant Bay Alliance
High	Town and Pleasant Bay Alliance budgets	Towns of Brewster, Chatham, Harwich and Orleans, and Pleasant Bay Alliance
High	Town and Pleasant Bay Alliance budgets	Towns of Brewster, Chatham, Harwich and Orleans, and Pleasant Bay Alliance
High	Town and Pleasant Bay Alliance budgets	Towns of Brewster, Chatham, Harwich and Orleans, and Pleasant Bay Alliance
High	Pleasant Bay Alliance budget	Pleasant Bay Alliance, Center for Coastal Studies
High	Grant	Pleasant Bay Alliance, Center for Coastal Studies
High	Grant	Pleasant Bay Alliance, Center for Coastal Studies
High	Pleasant Bay Alliance budget	Pleasant Bay Alliance, Friends of Chatham Water Ways, Harwich Natural Resources Department, Orleans Fresh and Marine Water Quality Task Force
High	Grant	Boston University, Cape Cod National Seashore
High	Cape Cod National Seashore budget	Cape Cod National Seashore
Medium	Grant	Pleasant Bay Alliance, Center for Coastal Studies
High	Grant	Wright Pierce
Medium	Grant	TBD
High	Grant	Pleasant Bay Alliance, Brewster, Chatham, Harwich, Orleans Conservation Commissions, Cape Cod Commission
High	Pleasant Bay Alliance budget	Pleasant Bay Alliance, Brewster, Chatham, Harwich, Orleans Conservation Commissions
High	Grant	Pleasant Bay Alliance, Brewster, Chatham, Harwich, Orleans Planning Boards, Cape Cod Commission
High	Pleasant Bay Alliance budget	Pleasant Bay Alliance, Brewster, Chatham, Harwich, Orleans Planning Boards, Cape Cod Commission
High	Grant	Towns of Brewster, Chatham, Harwich and Orleans, and Pleasant Bay Alliance
Medium	Grant	Towns of Brewster, Chatham, Harwich and Orleans, and Pleasant Bay Alliance

	RESILIENCE STRATEGIES	TIMELINE
3.4.0	**Resilience Planning**	
3.4.1	**Implement resilience enhancements for wastewater**	
3.4.1.1	Harden Lane Pump Station	By 2070
3.4.2	**Implement resilience enhancements for water supply infrastructure**	
3.4.2.1	Brewster water mains at Tar Kiln and Route 28	By 2070
3.4.2.2	Harwich water main at Route 28	By 2070
3.4.3	**Implement resilience enhancements for stormwater**	
3.4.3.1	Lonnie's Pond stormwater	By 2030
3.4.4	**Implement resilience enhancements for public access sites**	
3.4.4.1	Meetinghouse Pond Landing	By 2050
3.4.4.2	Crows Pond Landing	By 2050
3.4.4.3	Cow Yard Landing	By 2050
3.4.5	Permit and construct the Jackknife Harbor Beach living shoreline project	By 2030
3.4.6	Provide Technical Support for Use of Stormtide Pathways	By 2030
3.5.0	**Support Restoration and Rehabilitation of Salt Marsh and Eelgrass**	
3.5.1	**Salt Marsh Restoration and Pilot Project**	
3.5.1.1	Develop decision support tool for site selection	By 2030
3.5.1.2	Identify restoration and protection pilot project sites	By 2030
3.5.1.3	Develop implementation plan and initiate implementation of pilot projects	
3.5.1.4	Identify next steps to restore 209 acres of salt marsh with less than 15-75 year life span - explore options to improve UVVR	By 2030
3.5.2	**Eelgrass**	
3.5.2.1	Implement a project that aims to reduce climate vulnerability of eelgrass meadows in Pleasant Bay	By 2030
3.5.2.2	Identify steps to restore high priority restoration sites - 113 acres	
3.5.2.3	Identify steps to restore moderate priority sites - 100 acres	By 2050
3.5.2.4	Identify steps to restore low priority sites - 162 acres	By 2070

PRIORITY	BUDGET	PARTIES
Low	Retrofit	Town of Harwich
Low	Retrofit funding	Town of Brewster
Low	Retrofit funding	Town of Harwich
Medium	Retrofit funding	Town of Orleans
High	Grant	Pleasant Bay Alliance; Town of Chatham
Medium	Design & Construction funding	Town of Chatham
Medium	Design & Construction funding	Town of Orleans
High	Grant, Chatham Community Preservation Act	Town of Chatham
High	Grant	Pleasant Bay Alliance, Brewster, Chatham, Harwich, Orleans Planning Departments, Center for Coastal Studies
High	Grant	Cape Cod National Seashore; Pleasant Bay Alliance
High	Grant	Cape Cod National Seashore; Pleasant Bay Alliance
High	Grant	Cape Cod National Seashore; Pleasant Bay Alliance
High	Grant	Boston University, Cape Cod National Seashore; Pleasant Bay Alliance
		Boston University, Cape Cod National Seashore; Pleasant Bay Alliance
Medium	Grant	Boston University, Cape Cod National Seashore; Pleasant Bay Alliance
Low	Grant	Boston University, Cape Cod National Seashore; Pleasant Bay Alliance

	RESILIENCE STRATEGIES	TIMELINE
3.5.2.5	Implement nutrient management measures to improve water quality	Ongoing
3.5.2.6	Implement an eelgrass education program, including focus on boating activity and use of conservation moorings	by 2030
3.6.0	**Community Engagement and Capacity Building**	
3.6.1	Build Stewardship through Expanded Educational Programs	by 2030
3.6.2	Outreach and Engagement	Ongoing

PRIORITY	BUDGET	PARTIES
High	Town budgets	Towns of Brewster, Chatham, Harwich and Orleans under Pleasant Bay Watershed Permit
High	Grant	Pleasant Bay Alliance, Friends of Pleasant Bay, Pleasant Bay Community Boating, Friends of Chatham Waterways, Orleans Pond Coalition
High	Grant	Friends of Pleasant Bay, Pleasant Bay Community Boating
High	Grant	Pleasant Bay Alliance, Friends of Pleasant Bay, Pleasant Bay Community Boating, Friends of Chatham Waterways, Orleans Pond Coalition

SECTION 5. RESOURCES

- MAPPING STORM TIDE PATHWAYS IN PLEASANT BAY, CAPE COD, MASSACHUSETTS

Mark Borrelli, PhD, Center for Coastal Studies

- NAUSET BARRIER BEACH VULNERABILITY (Years 1 and 2)

Mark Borrelli, PhD, Center for Coastal Studies

- CLIMATE IMPACTS TO PLEASANT BAY INTERTIDAL RESOURCE AREAS

Mark Borrelli, PhD, Center for Coastal Studies

- SELECTION OF CASE STUDY SITE AND ESTABLISHMENTS OF THRESHOLD ELEVATIONS

Michael D. Giggey, P.E.; Maeve Carlson, P.E., Wright-Pierce

- RECOMMENDED ADAPTATION MEASURES FOR PUBLIC ACCESS AND WATER PROTECTION INFRASTRUCTURE

Michael D. Giggey, P.E.; Maeve Carlson, P.E., Wright-Pierce

- A SITE SELECTION MODEL FOR EELGRASS RESTORATION AND ENHANCEMENT FOR PLEASANT BAY, MA

Alyssa B. Novak, PhD, Boston University; Holly K. Plaisted, National Park Service

- SALT MARSH RESILIENCY ASSESSMENT

Sophia E. Fox, PhD, Cape Cod National Seashore

ACKNOWLEDGEMENTS

The preparation of the Climate Adaptation Action Plan was supported by grant from the Commonwealth of Massachusetts Municipal Vulnerability Preparedness (MVP) Program. Many thanks to Courtney Rocha, MVP Southeast Regional Coordinator, for her guidance throughout this project.

The Pleasant Bay Alliance would like to acknowledge and thank the following partners for their contributions to this project:

TOWN OF BREWSTER
Chris Miller*
Kimberley Crocker Pearson*

TOWN OF CHATHAM
Gregory Berman*
Robert Duncanson*
DeeDee Holt*
Ted Keon*
Janet Williams*

TOWN OF HARWICH
Dolly Howell*
Dan Pelletier*
Allin Thompson*

TOWN OF ORLEANS
Walter North*
Drusy Henson*
George Meservey*
Mike Solitro*

CAPE COD COMMISSION
Heather McElroy
Tara Nye Lewis

CAPE COD NATIONAL SEASHORE
Sophia Fox
Geoffrey Sanders

BOSTON UNIVERSITY
Alyssa Novak

CENTER FOR COASTAL STUDIES
Mark Borrelli
Dan Solazzo
Pedro P.G.M. Santos

NORTHEAST COASTAL BARRIER NETWORK
Holly Plaisted

WRIGHT PIERCE
Maeve Carlson
Michael Giggey

FRIENDS OF PLEASANT BAY
Allison Coleman
Maia Ward

FRIENDS OF CHATHAM WATERWAYS
Michele Moloney-Kitts

PLEASANT BAY COMMUNITY BOATING
Dorothy Bassett

ORLEANS PONDS COALITION
Eric Spengler

CAPE COD COOPERATIVE EXTENSION/WOOD HOLE OCEANOGRAPHIC INSTITUTION SEA GRANT
Shelly McComb

PLEASANT BAY ALLIANCE
Carole Ridley
*Steering & Technical Committee Members

pleasantbay.org