Point of Pines and Riverside Area Coastal Resilience Feasibility Report

June 30, 2021

Delivering a better world

Prepared for:

City of Revere
Revere, MA

Prepared by:

AECOM
250 Apollo Drive
Chelmsford, MA 01824
aecom.com

Table of Contents

1. Introduction 1
2. Climate Predictions 4
   2.1 Temperature Increases 4
   2.2 Precipitation and Groundwater 4
   2.3 Sea Level Rise and Coastal Flooding 5
3. Proposed Short-Term Protection Measures 13
   3.1 Short-Term Flood Barriers 13
   3.2 Short-Term Stormwater Management 15
   3.2.1 Bioswales 16
   3.2.2 Raingardens 16
   3.2.3 Impervious Surface Removal/Reduction 17
   3.2.4 Wetland restoration 18
   3.2.5 Living Shoreline 18
   3.2.6 Backflow Prevention 19
   3.2.7 Drainage Infrastructure 19
   3.2.8 Short-Term Stormwater Management Summary 19
4. Proposed Long-Term Protection Measures 20
   4.1 Residential Neighborhoods 21
   4.2 Critical Infrastructure 25
   4.3 Non-Structural Mitigation and Adaptive Community Management 26
5. Unprotected and Repetitive Loss Properties 28
   5.1 Unprotected Properties 28
   5.1.1 Commercial Businesses along Southwest Side of Route 1A 28
   5.1.2 Commercial Businesses along Riverfront Area 28
   5.2 Repetitive Loss Structures 28
6. Implementation Costs and Cost Effectiveness 29
   6.1 Implementation Costs 29
   6.2 Cost Effectiveness 29
7. Integrating Co-Benefits into Resilience Strategies 30
   7.1 Introduction to Community and Ecological Co-Benefits 30
   7.2 Further Design Development Guided by Community Engagement 30
   7.3 Integrating Co-benefits Into Flood-risk Reduction 33
   7.4 Inland Stormwater Management Design with Co-benefits 40
   7.5 Conclusion 40
8. Funding Opportunities 41
9. Implementation Schedule 48
10. Conclusion 50
11. Bibliography 51
A. Appendix A: Task 1 Stakeholder Workshop #1 Meeting Minutes and Presentation 58
B. Appendix B: Task 1 Stakeholder Workshop #2 Meeting Minutes and Presentation 95
C. Appendix C: Task 1 Stakeholder Workshop #3 Meeting Minutes and Presentation 118
D. Appendix D: Task 2 Past Studies, Case Studies, and Historical Data Memorandum 164
E. Appendix E: Task 2 Climate Science and Vulnerability Assessment Memorandum 193
F. Appendix F: Task 3 Short-Term Resilience Measures Memorandum, Including Beach Management Plan and Emergency Response Plan Recommendations 232
G. Appendix G: Task 4 Coastal Resilience Toolkit Memorandum 370

H. Appendix H: Task 5 Feasibility of Coastal Resiliency Tools Memorandum ... 395

Figures

Figure 1-1: Property Ownership and Environmental Justice Communities in Study Area ... 2
Figure 2-1: Changes to return period storms (City of Cambridge, 2015) ... 5
Figure 2-2: Relative Sea Level Rise (Boston – NOAA 2017) ... 6
Figure 2-3: Sea Level Rise Inundation Area (MA Sea Level Rise and Coastal Flooding Viewer) ... 8
Figure 2-4: Annual Probability of Coastal Flooding for 2030 (1.2 feet of SLR) ... 10
Figure 2-5: Annual Probability of Coastal Flooding for 2050 (2.4 feet of SLR) ... 11
Figure 2-6: Annual Probability of Coastal Flooding for 2070 (4.2 feet of SLR) ... 12
Figure 3-1: Short-Term Alignments ... 13
Figure 3-2: Alignment A Short-Term Measures ... 14
Figure 3-3: Alignment B1 Short-Term Measures ... 15
Figure 3-4: Riverfront Green Infrastructure Opportunities ... 17
Figure 4-1: Alignments A, B1, & C – 2020 1%, 2030 10% Storm ... 21
Figure 4-2: Alignments A, B1, & C – 2030/2050/2070 1%, 2030 5% Storm ... 22
Figure 4-3: Alignment A Elevations ... 23
Figure 4-4: Alignment B1 Elevations ... 23
Figure 4-5: Alignment C Elevations ... 24
Figure 4-6: Critical Facilities in the Study Area ... 26
Figure 7-1: Resiliency Design Goals ... 30
Figure 7-2: Integrating Engagement into the Design Phase ... 31
Figure 7-3: Refining Site Understanding and Alignment Opportunities ... 32
Figure 7-4: Gathering Program Priorities and Opportunities ... 32
Figure 7-5: Refining Infrastructure Design and Character ... 33
Figure 7-6: Flood-Risk Reduction with Co-benefits Matrix ... 34
Figure 7-7: Existing Condition Type 1 : Beach-side Residential ... 34
Figure 7-8: Existing Condition Type 2 : River-side Residential ... 35
Figure 7-9: Existing Condition Type 3 : Transportation Corridor ... 35
Figure 7-10: Existing Condition Type 4 : Industrial Meets Residential ... 35
Figure 7-11: Vegetative Screening Examples ... 36
Figure 7-12: Art Treatment Examples ... 36
Figure 7-13: Integrated Seating Examples ... 37
Figure 7-14: Cantilever Walkway Examples ... 37
Figure 7-15: Bermed Edge Examples ... 38
Figure 7-16: Beach Promenade Examples ... 38
Figure 7-17: Submerged Habitat Examples ... 39
Figure 7-18: Living Shoreline Examples ... 39
Figure 7-19: Rain Garden and Bioswale Examples ... 40
Figure 9-1: Implementation Schedule ... 49

Tables

Table 2-1: Temperature Indicators for Suffolk County, MA (Resilient MA) ... 4
Table 2-2: Probability of exceeding median global mean sea level change scenarios in 2100 ... 6
Table 2-3: Tidal Datums at Lynn Harbor (NOAA Station #8443187) ... 7
Table 2-4: Timing of Permanent Inundation due to Sea Level Rise ... 7
Table 4-1: DFE for Flood Class Design 2 ... 20
Table 4-2: DFE for Flood Class Design 3 ... 20
Table 4-3: Maximum Height of Intervention Alignments ... 24

Table 4-4: Maximum Height of Intervention Critical Buildings 26
Table 6-1: Planning Level Cost Estimate 29
Table 8-1: Funding Opportunities for Resilience Tools 42

1. Introduction

The City of Revere is a developed municipality in Suffolk County, Massachusetts located between the North Shore and Boston proper. The population of Revere has grown by approximately 7 percent since 2010. The City's current population is approximately 53,700. Comparatively, the population of Massachusetts at large has grown by 6 percent since 2010. According to Next Stop Revere, Revere's Master Plan, the population will reach 66,700 by 2030 and 73,700 by 2040, an increase of 42 percent above the City's 2010 population.

The population of Revere is 78.1 percent white, comparable to that of the Commonwealth at large. While the share of residents identifying as African American, some other race, or two or more races has increased since 2010, the percent of residents identifying as American Indian and Alaska Native or Asian has decreased in that time period. Conversely, the percent of Revere residents who identify as Hispanic or Latino has increased by over 50 percent since 2010. The percent of Revere residents who identify as Hispanic or Latino is nearly three times that of Massachusetts at large. An analysis of U.S. Census American Community Survey (ACS) data revealed the median household income, mean household income, and per capita income in Revere are 30 percent, 38 percent, and 43 percent below those of Massachusetts at large, respectively.

The social and economic conditions of Revere demonstrate the City is growing faster than that of Massachusetts at large, has significantly more ethnic diversity than Commonwealth at large, and has greater unemployment and lower household and per capita incomes than the Commonwealth at large. Amidst increasing development pressures, the City is committed to building its reputation at the forefront of regional collaboration, climate resiliency, and mitigation programs, open space use, housing strategies, workforce development support, and economic development strategies (Revere, 2020). Furthermore, the City is committed to improving its resiliency in the face of increasing climate challenges through comprehensive climate mitigation and resiliency strategies (Revere, 2020).

Revere is a coastal community and as such, it is vulnerable to severe hazards from climate change threats, such as sea level rise, coastal storm surge, and erosion. The City of Revere Municipal Vulnerability Preparedness (MVP) Summary of Findings Report identified the Point of Pines / Riverside area as the portion of the city most vulnerable to climate change impacts. This Point of Pines / Riverside Area Coastal Resiliency Feasibility Study (hereafter, Resiliency Feasibility Study) was initiated in response to a top priority action identified from the MVP Program, which is to conduct a feasibility study to determine the best strategies to mitigate flooding, erosion, and storm impacts in the Point of Pines / Riverside area (hereafter, Study Area). The Resiliency Feasibility Study was conceived as an integrated coastal protection initiative for the City of Revere. The Resiliency Feasibility Study consists of stakeholder workshops, five memoranda and one final report aimed to evaluate the flood vulnerability and potential mitigation options for the Study Area. The Resiliency Feasibility Report includes an implementation plan that identifies prioritized action items, responsibilities, and potential funding sources, and includes the following sections:

1. Introduction
2. Climate Predictions
3. Proposed Short-Term Protection Measures
4. Proposed Long-Term Protection Measures
5. Unprotected and Repetitive Loss Properties
6. Implementation Costs and Cost Effectiveness
7. Integrating Co-Benefits into Resilience Strategies
8. Implementation Schedule

Following a brief overview of the Study Area, the Introduction reviews work completed in previous tasks of the Resiliency Feasibility Study that contribute to the final Resiliency Feasibility Report.

The Point of Pines Peninsula is in the northeast section of the City of Revere. Aside from the northeast portion of the community, much of the Point of Pines / Riverside community is considered an Environmental Justice community, based on income statistics determined by the 2010 U.S. Census, as shown in the yellow shaded area Figure 1-1.

Figure 1-1: Property Ownership and Environmental Justice Communities in Study Area

Flooding is not a new concern to the Study Area. The region was the subject of Coastal Flood Protection studies conducted by the U.S. Army Corps of Engineers (USACE) between 1984 and 1990. The 1984 USACE reports recommended rock revetments, sand dune development, beach nourishment, seawalls/dikes along the Revere and Lynn ocean fronts, and a tidal floodgate system at the mouth of the Saugus River as interventions to mitigate coastal flooding. While the USACE recommendations were ultimately not implemented due to concerns raised by the Massachusetts Executive Office of Environmental Affairs at that time, dune plantings and seawall repairs were carried out by other entities.

This Resiliency Feasibility Study, consisting of six interconnected tasks, takes a fresh look at potential resilience and adaptation measures. Copies of presentations and memoranda prepared as part of Tasks 1 through 5 are included as appendices to this report.

Task 1: Stakeholder Outreach and Engagement included three stakeholder workshops aimed at engaging key stakeholders to obtain input into the Resiliency Feasibility Study. The first workshop informed participants about the objectives of the Resiliency Feasibility Study while the second workshop focused on sharing the findings of Task 2, Task 3, and Task 4 with the objective to obtain input on criteria used to assess feasibility of coastal resilience options to be incorporated into Task 5. The third workshop presented the findings of Task 5. Task 1 deliverables included presentation and comment summaries for each of the three stakeholder workshops.

Task 2: Assess Current and Future Conditions included a literature review of nine previous studies and reports directly related to the Study Area. Task 2 also included a review of coastal resilience case studies with similar geographic, social, environmental, and physical features to inform the Resiliency Feasibility Study in addition to a review of existing surveys, critical facilities mapping, navigational charts, and documentation of historical storm events with associated damages. Task 2 deliverables included the Past Studies, Case Studies, and Historical Data Memo and the Climate Science and Vulnerability Assessment Memo. The review of current and historical weather conditions, studies, assessments, testimonials, and maps of the City of Revere undertaken to complete the Past Studies, Case Studies, and Historical Data Memo reestablished the prior conclusions stated in 1986. The review shows how vulnerable the City is to the imminent coastal threats that climate change presents. Erosion, sea level rise and flooding have been coastal hazards affecting the Point of Pines and Riverside communities for years and are only becoming more severe. The Climate Science and Vulnerability Assessment Memo concluded that changing climate presents substantial threats to the Study Area. As sea levels rise, stormwater will become increasingly more difficult to manage and groundwater is likely to rise along with the adjacent coastal waters, further taxing the stormwater management system and slowing receding flood waters. It was further concluded that existing erosion hot spots may be accelerated by higher sea levels and increased storm intensities, and eventually undermine the integrity of nearby roadways and coastal flood protection structures.

Task 3: Identify Short-Term Resilience Measures identified near-term and lower cost actions that can be implemented as longer-term interventions are designed, permitted, and constructed. Task 3 included the development of a beach management plan and revisions to the City’s existing emergency response plan to be implemented in the event of an extreme weather event. Of the 12 short-term resilience measures identified in Task 3, it was concluded that Aquafence, Tiger Dams, Tubewall and Stoplogs would be the best deployable measures for the Point of Pines Peninsula because they can all withstand coastal loading.

Task 4: Develop Coastal Resilience Toolkit delivered a coastal resilience toolkit and accompanying memorandum to identify potential permanent structural, non-structural, and nature-based adaptation measures that could be used to increase climate resilience in the Study Area. Task 4 identified key design components of each concept and provided recommendations for implementation scenarios for each option to be used as a resource for future climate resilience projects for the City of Revere and other coastal municipalities in the Commonwealth. The Task 4 Memorandum concluded that the various adaptation tools identified have unique applications and performance; each is appliable to a distinctive set of conditions and goals. For this reason, a range of tools in various combinations will likely be needed to protect the Study Area.

Task 5: Assess Feasibility of Coastal Resilience Options delivered a multi-criteria decision matrix assessing the feasibility of coastal resilience options, considering ability to control predicted floodwaters, relative cost and funding opportunities, ownership, community acceptance, conservation restriction requirements, and permitting complexity. As indicated in the Task 5 Memo, A variety of tools may be needed to increase the resilience of the Study Area, including barrier measures that control future floodwaters predicted to occur due to climate change which are costly and challenging to permit, as well as smaller stormwater management measures such as Green Infrastructure which may add additional co-benefits such as habitat and water quality improvement. The initial evaluation of implementation tools identified as most feasible for protecting residential areas and other critical assets in the Study Area was identified for further refinement in the Task 6 Feasibility Report.

Task 6: This Resiliency Feasibility Report summarizes recommendations that are the culmination of work completed on the five preceding tasks described above. Readers are referred to the individual memoranda completed as part of Tasks 2 through 5 (see appendices) for additional background details evaluated and developed as part of the Resiliency Feasibility Study that culminated in the recommendations included in this report.

2. Climate Predictions

Existing and future climate conditions in the Study Area were evaluated as a part of Task 2. Changes to temperature, precipitation, sea level, and storm surge were detailed in the Task 2 Climate Science Review and Vulnerability Assessment Memo. The following sections provide a summary of the future climate predications.

2.1 Temperature Increases

As shown in Table 2-1, temperatures in the Study Area are projected to increase significantly with the median number of days above 90° F projected to double from 11 days in the baseline period (2001-2005) to 22 days by 2030 and to increase by more than triple by 2070 (Resilient MA, 2020). Additionally, the median number of frost days (days below 32° F) are projected to decrease by over 10-percent from the baseline period of 112 days to 100 days by 2030 and by almost 30-percent by 2070.

Table 2-1: Temperature Indicators for Suffolk County, MA (Resilient MA)

Temperature Indicator	Baseline (2001-2005) (Days)	Percentile of Model/Scenario Output	2030s (2028-2032) (Days)	2050s (2048-2052) (Days)	2070s (2068-2072) (Days)	2090s (2088-2092) (Days)
Annual number of days hotter than 90° F	11	90th	32	52	69	96
		Median (50th)	22	30	38	44
		10th	12	14	16	13
Annual number of days cooler than 32° F	112	90th	87	79	49	32
		Median (50th)	100	93	81	76
		10th	115	113	115	106

Rising temperatures and extended heat waves can pose significant health risks, particularly in high exposure settings such as beaches and public recreation areas as well as homes and businesses without air conditioning.

2.2 Precipitation and Groundwater

Precipitation is projected to increase in frequency and intensity though the changes are much more modest compared to the projected changes to temperature. A recent study for the City of Cambridge shows that lower frequency precipitation events are projected to increase more significantly in intensity than higher frequency events (City of Cambridge, 2015). Figure 2-1 shows projected changes to the 10-year, 25-year, and 100-year 24-hour return period storms for nearby Cambridge, MA. Storm return period refers to the average recurrence interval associated with a particular storm intensity and duration. For example, the 10-year, 24-hour storm has an average recurrence interval of 10 years and an annual probability of occurrence equal to 10-percent (1/10).

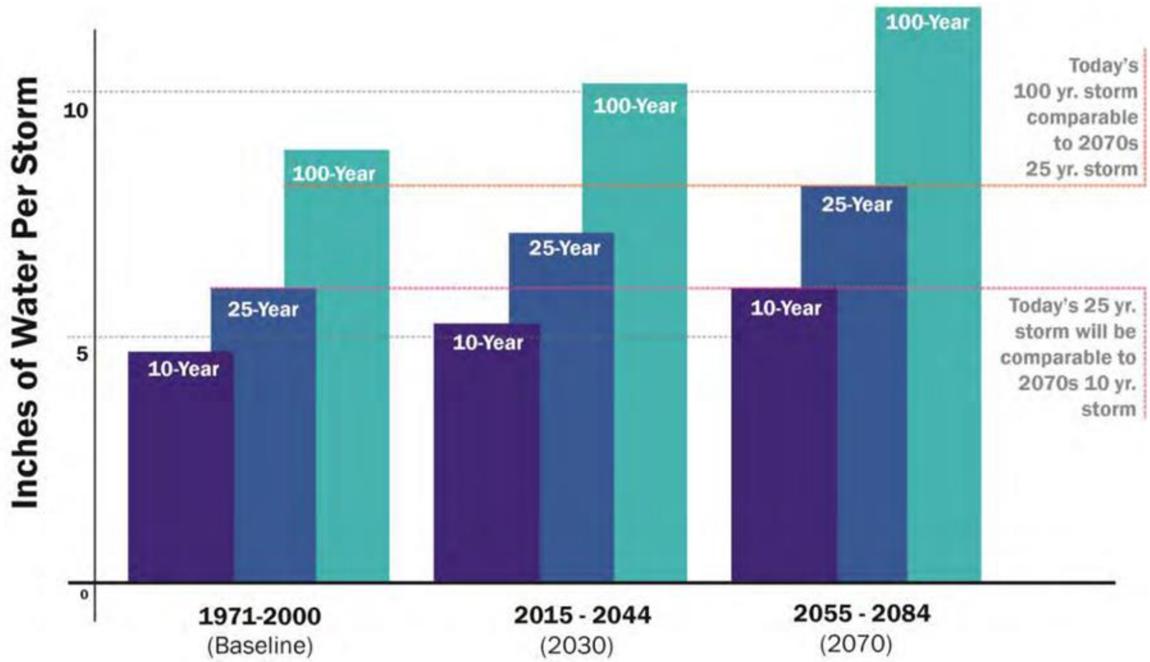

Figure 2-1: Changes to return period storms (City of Cambridge, 2015)

Stormwater flooding is exacerbated by the Study Area's relatively high groundwater table which is controlled by the surrounding tide elevations (USACE 1984). As sea levels rise, the groundwater table will rise with it, diminishing the available storage in the ground and increasing both the intensity and duration of stormwater flooding and ponding when precipitation events occur.

2.3 Sea Level Rise and Coastal Flooding

Coastal flooding and sea level rise (SLR) pose significant environmental threats to the Study Area. SLR projections developed by the National Oceanic and Atmospheric Administration (NOAA) in 2017 for Boston (Gauge 8443970) are shown in Figure 2-2 along with the sea level change values used by the Woods Hole Group for the Massachusetts Coast Flood Risk Model (MC-FRM). NOAA 2017 SLR values are based on estimates of the probability of global sea level change. The Low scenario is not included in Figure 2-2 due to high probability of exceedance. The horizontal lines shown in Figure 2-2 represent the SLR assumptions used in this analysis.

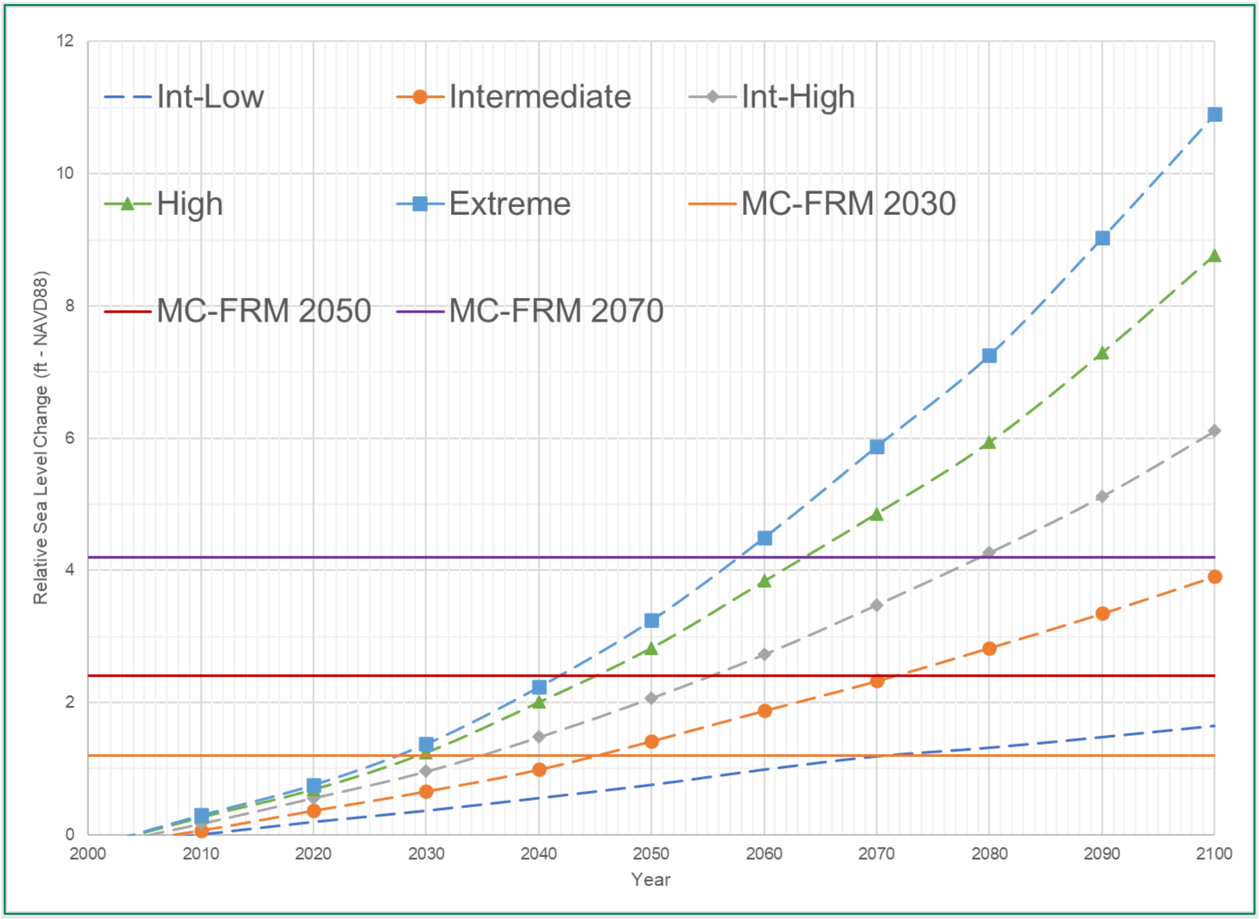

Figure 2-2: Relative Sea Level Rise (Boston – NOAA 2017)

Table 2-2 shows the estimated probability of exceedance for SLR scenarios presented in Figure 2-2.

Table 2-2: Probability of exceeding median global mean sea level change scenarios in 2100

Global Mean Sea Level Rise Scenario	RCP4.5	RCP8.5
Low (0.3 m)	98%	100%
Intermediate-Low (0.5 m)	73%	96%
Intermediate (1.0 m)	3%	17%
Intermediate-High (1.5 m)	0.5%	1.3%
High (2.0 m)	0.1%	0.3%
Extreme (2.5 m)	0.05%	0.1%

As sea levels rise, daily high tide conditions creep farther and farther inland and areas where homes and beaches were once located become unusable and uninhabitable. Homes on Mills Avenue that currently experience flooding on days with especially high astronomical tides could become permanently inundated with as little as 1 to 2 feet of sea level rise as shown in Figure 2-3. Table 2-3 shows tidal datums from nearby Lynn Harbor. With four feet of sea level rise, the majority of the Study Area would become permanently inundated, including residential areas, businesses, and large segments of Route 1A. Table 2-4 shows the approximate range of possible timing of permanent inundation based on the NOAA projections provided in Figure 2-2 .

Table 2-3: Tidal Datums at Lynn Harbor (NOAA Station #8443187)

Tidal Datum	Water Surface Elevation (feet – NAVD88*)
Mean Higher High Water (MHHW)	4.624
Mean High Water (MHW)	4.184
Mean Sea Level (MSL)	-0.316
Mean Low Water (MLW)	-4.976
Mean Lower Low Water (MLLW)	-5.316

*Converted to NAVD88 from MLLW using VDatum (https://vdatum.noaa.gov/)

Table 2-4: Timing of Permanent Inundation due to Sea Level Rise

Sea Level Rise	Approximate SLC Projection Timing		
	Earliest	*Intermediate*	*Latest*
+1 Foot	2025	2040	2060
+2 Feet	2037	2063	>2100
+3 Feet	2048	2084	>2100
+4 Feet	2056	2100	>2100

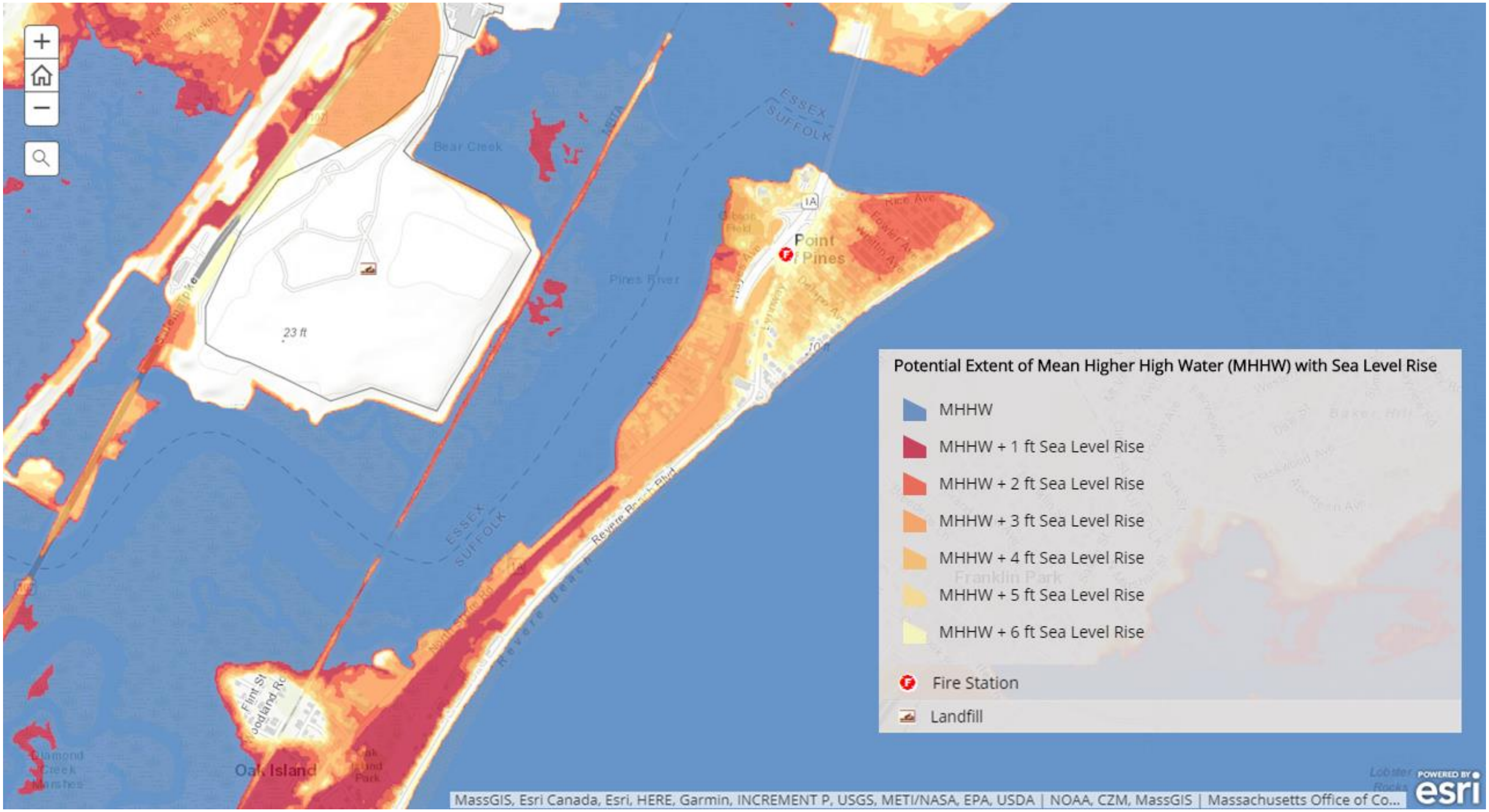

Figure 2-3: Sea Level Rise Inundation Area (MA Sea Level Rise and Coastal Flooding Viewer)

In addition to the threat of permanent inundation, coastal flooding due to storm surge is also exacerbated by SLR. Almost the entire Study Area is currently located within the effective floodplain of the Federal Emergency Management Agency (FEMA) 1-percent annual chance exceedance (ACE) event—a term used to define a flood event having a 1-percent chance of being equaled or exceeded in any given year . As sea levels rise, the annual probability of flooding for any given location increases and areas that previously would rarely flood may flood more often. Figure 2-4, Figure 2-5, and Figure 2-6 show probability of coastal flooding predicted by the MC-FRM for the following planning periods:

- 2030 – 1.2 feet of SLR
- 2050 – 2.4 feet of SLR
- 2070 – 4.2 feet of SLR

A 100-percent annually probability of flooding implies that the location is likely to be flooded at least once a year.

By 2030, most residential areas east of the Lynnway have approximately 75-percent annual probability of flooding and by 2050 almost all residential areas have reached the same annual flood probability. The critical facilities in the Study Area will also face increasing vulnerability. The fire station is on relatively high ground but is expected to have over 30-percent annual probability of flooding by 2050 and over 70-percent probability by 2070. The adult day care center is expected to have 15-percent annual probability of flooding by 2050 and over 70-percent annual probability of flooding by 2070. The wastewater pump station is expected to have approximately 25-percent annual probability of flooding by 2050 and a 75-percent annual probability of flooding by 2070. The stormwater pump station and the Point of Pines Yacht Club are expected to have over 70-percent annual probability of flooding by 2030 while the expected probability of flooding for most of Route 1A south of the General Edwards Bridge ranges from approximately 40-percent to 75-percent in 2030. Almost the entirety of the Route 1A corridor south of the General Edwards Bridge is expected to have a 75-percent annual probability of flooding by 2050. The three southernmost bus stops are expected to have over 70-percent annual probability of flooding by 2030. In the southern portion of the Study Area, businesses and residential areas along Revere Beach Boulevard have an annual probability of flooding ranging from 60-percent to 75-percent. The primary source of flooding in the southernmost portion of the Study Area is still the Pines River, though flood risk reduction provided by the higher elevations along the Atlantic coast are significantly diminished. Businesses along the Pines River west of Route 1A in the southern portion of the Study Area with relatively higher ground elevations are expected to have annual-probabilities of flooding ranging from 20-percent to 60-percent by 2030 while the Broadsound Tuna Club is expected to have annual flood probabilities ranging from 70-percent to 90-percent by 2030. By 2070, the entire southern portion of the Study Area is expected to have annual flood probabilities exceeding 75-percent.

Storm surge events of increasing intensity can significantly degrade natural flood risk reduction features such as the dunes along the Atlantic Coast as well as man-made flood risk reduction infrastructure such as seawalls and revetments. Thus, more frequent maintenance and repair of flood risk reduction measures is also an important and costly impact to consider resulting from SLR.

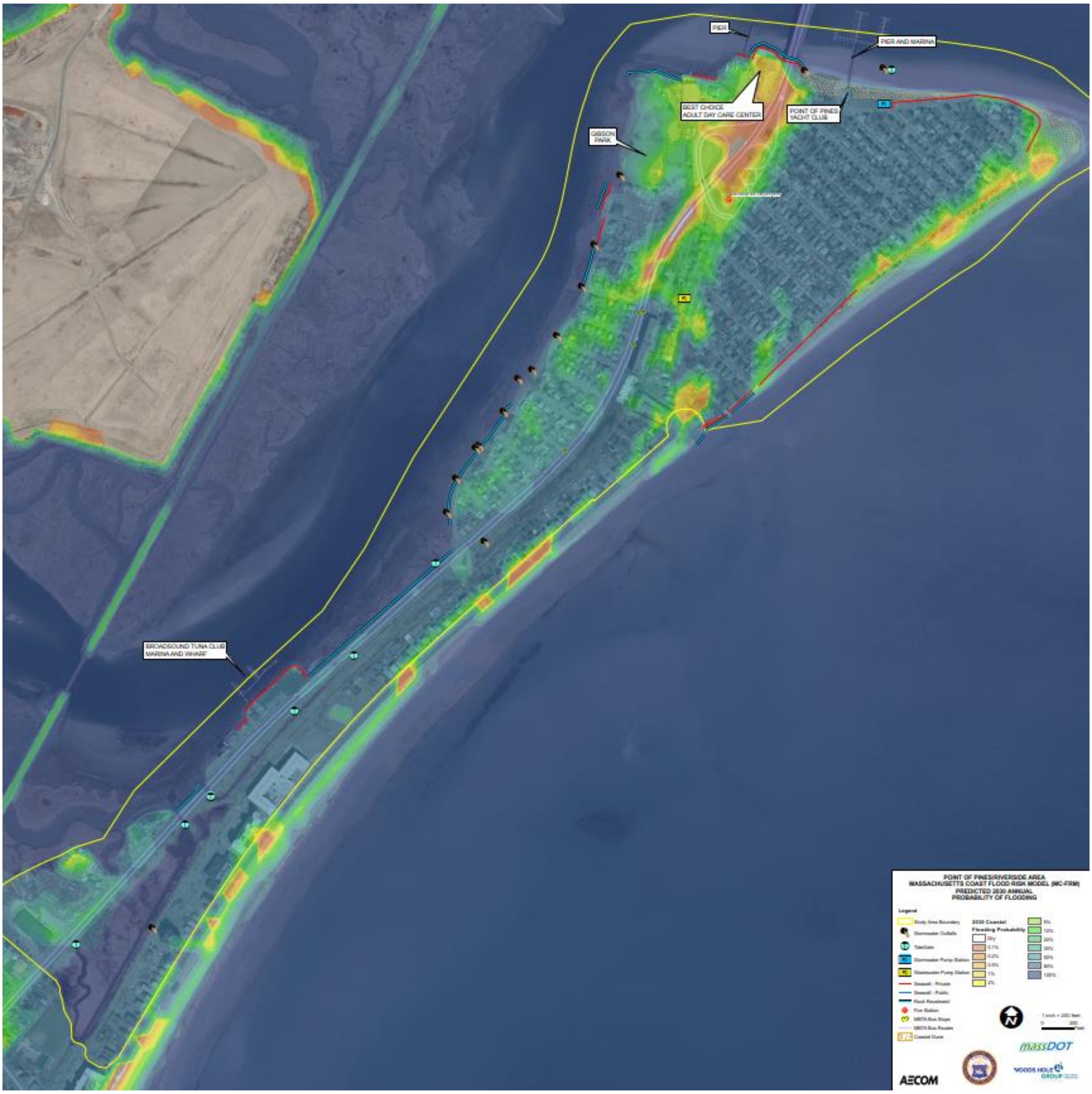

Figure 2-4: Annual Probability of Coastal Flooding for 2030 (1.2 feet of SLR)

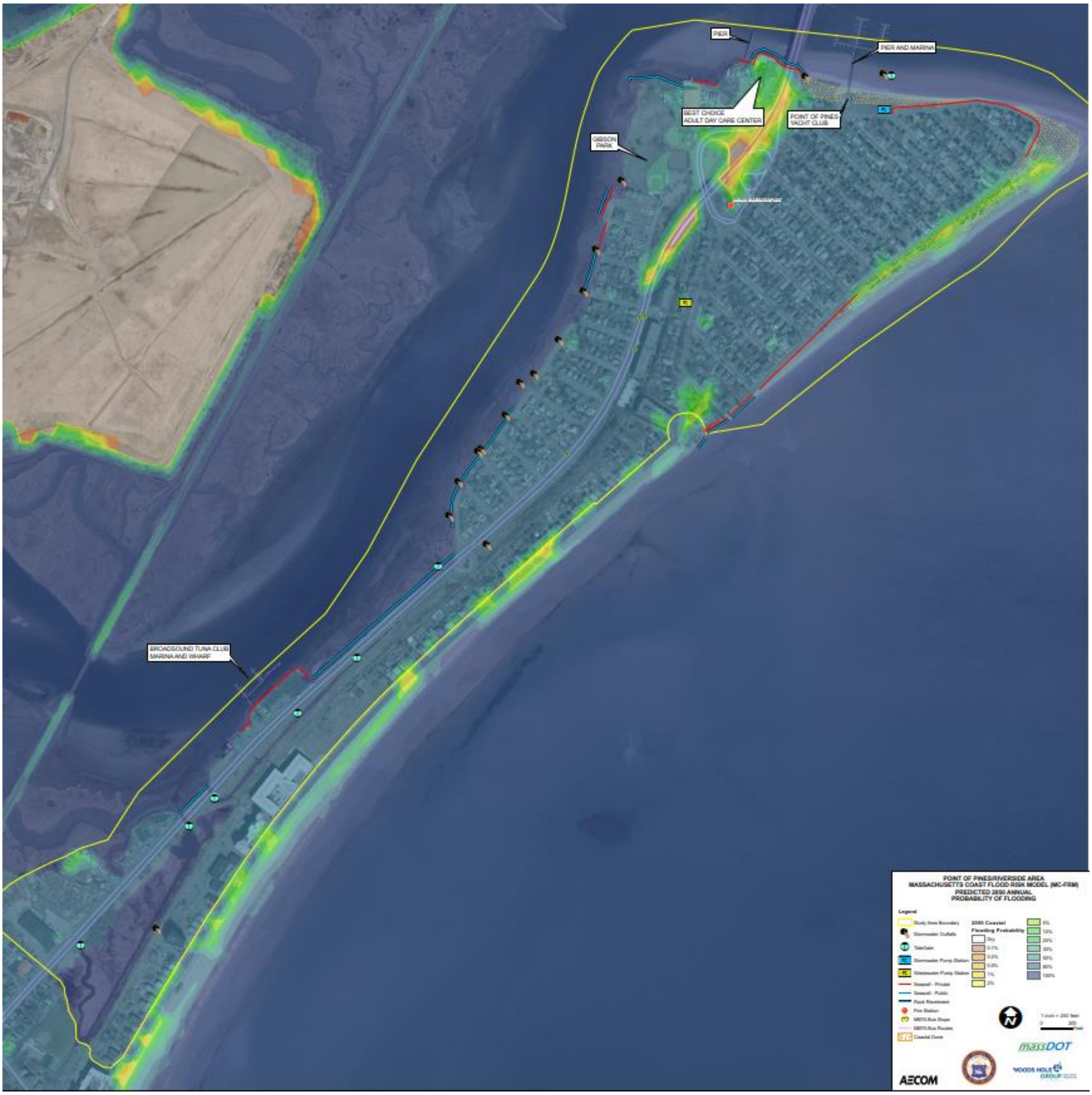

Figure 2-5: Annual Probability of Coastal Flooding for 2050 (2.4 feet of SLR)

Figure 2-6: Annual Probability of Coastal Flooding for 2070 (4.2 feet of SLR)

3. Proposed Short-Term Protection Measures

3.1 Short-Term Flood Barriers

The Task 3 Short-Term Resilience Measures Memo identified short-term risk reduction, potential deployable and on-site measures to mitigate flood damages. Case studies for each of the short-term measures were provided and the six deployable and five on-site measures were evaluated against the following feasibility criteria:

- Geometric constraints
- Coastal loading
- Structural system
- Offsite storage/deployment
- Visual impact
- Cost

Based on the analysis, Aquafence, Tiger Dams, Tubewall and Stoplogs were found to be the best deployable measures for the Point of Pines Peninsula because they are all able to withstand coastal loading. Although these systems are all temporarily deployable, Aquafence panels must be anchored into the ground using tie-down anchors, while Stoplogs require a permanent foundation with on-site anchors for the posts to be secured to.

All the on-site measures including DefenCell, Geocell RDFW, Hesco Barriers, Trap Bags, and Sandbag Walls can also withstand coastal loading and would be viable options for the project site. However, stacking Hesco Barriers, Trap Bags, and Sandbag Walls to a desired height will have high visual impact when placed on site. These short-term resilience measures can be implemented as temporary protection while longer-term resilience interventions are being developed.

Two alignments were proposed to protect the main residential neighborhoods of the Study Area in the Task 3 Short-Term Resilience Measures Memo, shown in Figure 3-1 below. Alignment A was proposed to protect the Riverside community on the western side of the peninsula and Alignment B was proposed to protect the Point of Pines community on the eastern side. Along each of these alignments there are specific areas where the ground elevation lowers, creating a higher vulnerability for flooding. Adding stop-gap flood risk reduction measures in these areas may provide a level of short-term protection against low level inundation for the vulnerable communities.

Figure 3-1: Short-Term Alignments

Figure 3-2 showcases the existing the ground elevation profile along alignment A. Based on this graph, there are two areas of low-lying elevation which are shown in orange. These locations occur at the northern and southern areas along Mills Ave.

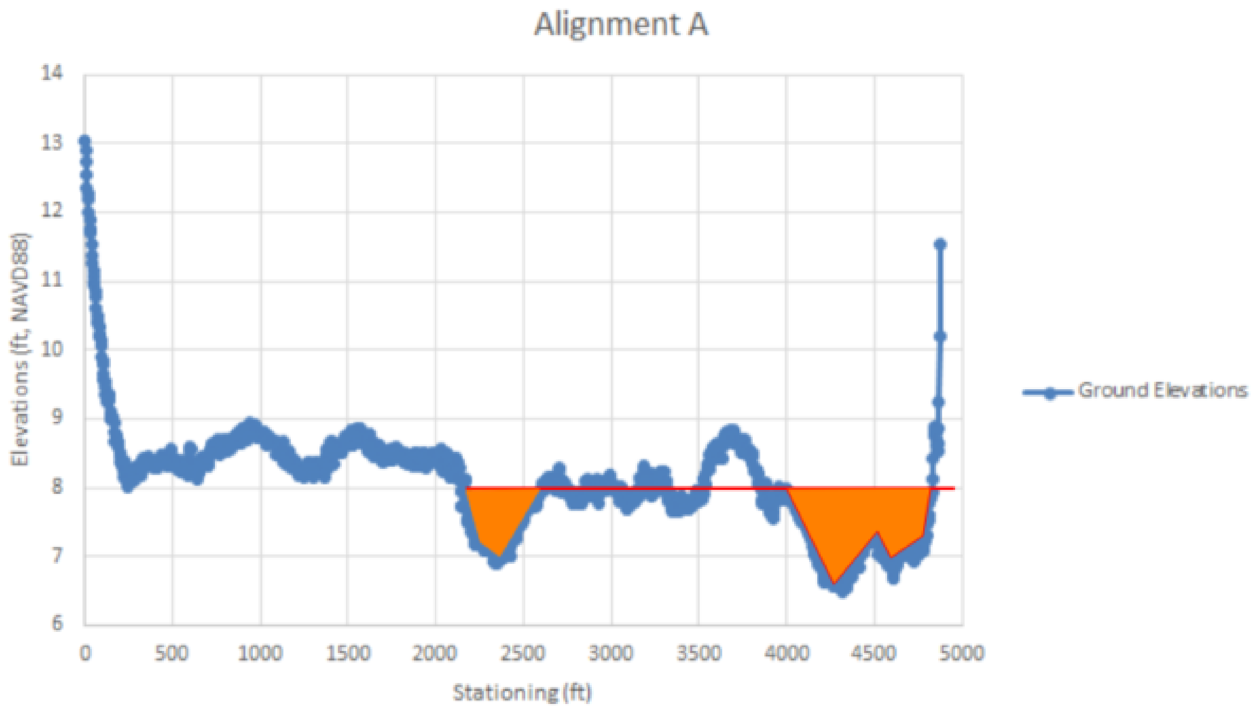

Figure 3-2: Alignment A Short-Term Measures

Figure 3-3 showcases the existing the ground elevation profile along alignment B1. Based on this graph, the lowest lying elevations occur where Rice Ave runs along the northern side of the peninsula.

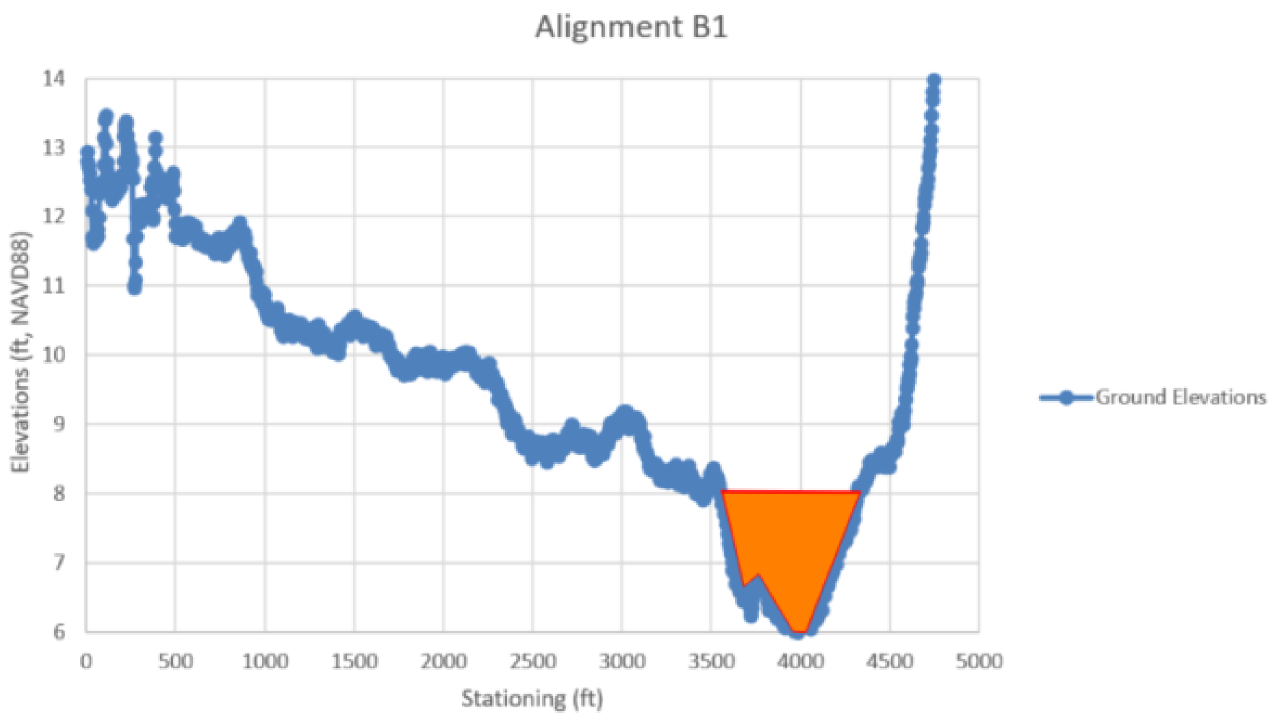

Figure 3-3: Alignment B1 Short-Term Measures

Adding stop-gap flood-risk reduction measures in these low-lying areas may help prevent tidal and low-level inundation flooding. AECOM has performed an evaluation of water levels based on the NOAA tide gauge located in Boston (Station #8443970). Water levels for the 30-year period from 1/1/1990 through 6/28/2021 were considered in order to determine how many floods on average could possibly be prevented each year due to the presence of stop-gap measures. The analysis reveals that on average there were approximately 46 days each year with water levels between 6 feet and 7 feet NAVD88 and approximately 5 days each year with water levels between 7 feet and 8 feet NAVD88. Water levels greater than 8 feet NAVD88 occurred on 14 days throughout the entire 30-year period considered. Additional analysis of the relationship between the ground elevation and low-level inundation flooding is required to determine the potential benefits of stop-gap flood-risk reduction measures and the necessary elevation these areas would need to be raised to.

The following next steps must be considered to pursue short-term flood risk reduction for design storms. First, the design storm must be chosen. The measures will be evaluated based on the Height of Intervention (HOI) and loading requirements for the chosen storm. Additionally, temporary measures that are compatible with the structural and geographical constraints of the proposed alignments described above must be selected.

Furthermore, drainage and seepage considerations will need to be evaluated for the proposed alignments and the protection of the critical assets. Additional geotechnical information will be needed for any flood-risk reduction measures that require structural foundations. Community and stakeholder engagement will also be a critical step to ensure that the proposed measures will work cohesively with the existing features to provide protection. Lastly, an operation and maintenance plan must be developed that includes identification of potential storage areas, a deployment team and schedule, and any machinery required for transport and deployment.

Additionally, there are four critical assets identified in the Task 3 Short Term Resilience Measures Memo that may be individually protected using deployable measures identified in Task 3.

3.2 Short-Term Stormwater Management

There may be significant financial and social barriers to realizing long-term climate adaptation strategies, resulting in an “implementation gap” between strategy formulation and project implementation. Short-term protection measures build adaptation capacity by establishing accessible solutions to bridge the implementation gap. This section provides information on the following short-term protection measures followed by an assessment on the feasibility of implementing such protection measures to mitigate future anticipated flooding and sea level rise:

- Bioswales
- Raingardens
- Impervious Surface Removal/Reduction
- Wetland Restoration
- Living Shorelines
- Backflow

3.2.1 Bioswales

Bioswales are a nature-based solution that utilizes low-lying areas or troughs that use plant materials and specialized soil mixes to absorb, treat, and convey stormwater run-off, resulting in an aesthetically pleasing alternative to traditional gray infrastructure solutions to flooding. Bioswales can mitigate flood damages by reducing the overall volume of stormwater runoff and reducing the flow rate that is received by larger stormwater systems.

Bioswales provide environmental benefits by improving water quality. Bioswales are designed to filter the “first flush” following a rainstorm, that is the initial surface water and often the most polluted runoff of a rainstorm as it moves downstream. Through reducing stormwater runoff velocity and filtering contaminants, bioswales improve groundwater recharge compared to traditional gray infrastructure drainage solutions, and further improve groundwater quantity and quality. When installing bioswales there should be a minimum 5-foot clearance from the bottom of the bioswale to the high groundwater table. It is not recommended that bioswales be installed in location with low infiltration rates as such environments will lead to standing water. Changes to the groundwater table resulting from SLR should be evaluated and considered when designing bioswales.

Bioswales are traditionally linear in nature and are most effective when sited adjacent to impervious surfaces such as parking lots, along roadways and sidewalks, or when installed as enhancement to natural or existing drainage swales. However, bioswales can be installed in any location with a slop less than five percent. Due to the risk of erosion, bioswales should not be installed in areas with steep or unstable slopes.

Bioswales deliver additional ecologic, social, and economic co-benefits. When creating new habitat or replacing traditional gray infrastructure, bioswales increase biodiversity. Because bioswales are typically linear in nature, they provide the potential for increased habitat connectivity or pollinator pathways. When installed between roadways and sidewalks, bioswales provide a buffer between active users of the transportation network and motor vehicles, enhancing safety and the user experience. Lastly, bioswales deliver economic benefits as research suggests that shoppers are willing to pay 9 to 12 percent more for goods in business districts having a high-quality urban canopy and landscape (Wolf, 2014).

The Riverfront District along the Pines River in the northwest portion of the Study Area is the primary location that offers an opportunity for siting Green Infrastructure such as bioswales. This area was the subject of a master planning effort by the City, which culminated in the release of a Riverfront Master Plan final report dated January 2021. The area includes the former Boat Works site, the G&J Towing site, and Gibson Park. The Boat Works and G&J sites are privately held parcels proposed for redevelopment, while Gibson Park is a municipal property. Green infrastructure could be sited throughout the parcels in the Riverside District, either directly by the City on municipal property, or by redevelopers of private parcels based on requests and requirements implemented through the City permitting process. The January 2021 Master Plan identifies the concepts of including rain gardens, bioswales, and porous pavement at Gibson Park and the adjacent privately held parcels.

3.2.2 Raingardens

Like bioswales, a raingarden is a depression containing native shrubs, perennials, and flowers, generally formed on a natural slope. Raingardens are designed to temporarily hold and infiltrate water runoff from impervious surfaces such as roofs, driveways, lawns, and parking lots and can remove up to 90 percent of nutrients and chemicals and up to 80 percent of sediments from stormwater runoff. Raingardens improve groundwater recharge compared to traditional lawns as they infiltrate 30 percent more water than conventional lawns. Raingardens can also reduce nuisance flooding from rainstorms, resulting in hazard mitigation benefits. Furthermore, depending on the design, raingardens can provide ecological benefits by providing natural habitat for birds and pollinators.

Raingardens have similar siting requirements as bioswales; they should be installed on a relatively flat site with a slope of no more than 15 percent. A general rule is that raingardens should cover between 10 and 20 percent of the square footage of the area of impervious surface they are serving. Raingardens are typically smaller scale than bioswales, which allow them to be constructed on single family residential properties. However, when constructed on larger sites, raingardens may receive excess runoff from other low impact development strategies such as bioswales, green parking lots, or green roofs. Raingardens differ from traditional gardens in that 6 to 12 inches of topsoil is typically removed and replaced with tillage, compost, and sand to increase water infiltration.

As stated in the discussion of bioswales, the Riverfront District along the Pines River in the northwest portion of the Study Area is the primary location that offers an opportunity for siting Green Infrastructure (GI) such as raingardens.

Opportunities for GI in the Riverfront area identified in the Revere Riverfront Master Plan, such as raingardens and bioswales, are shown in Figure 3-4.

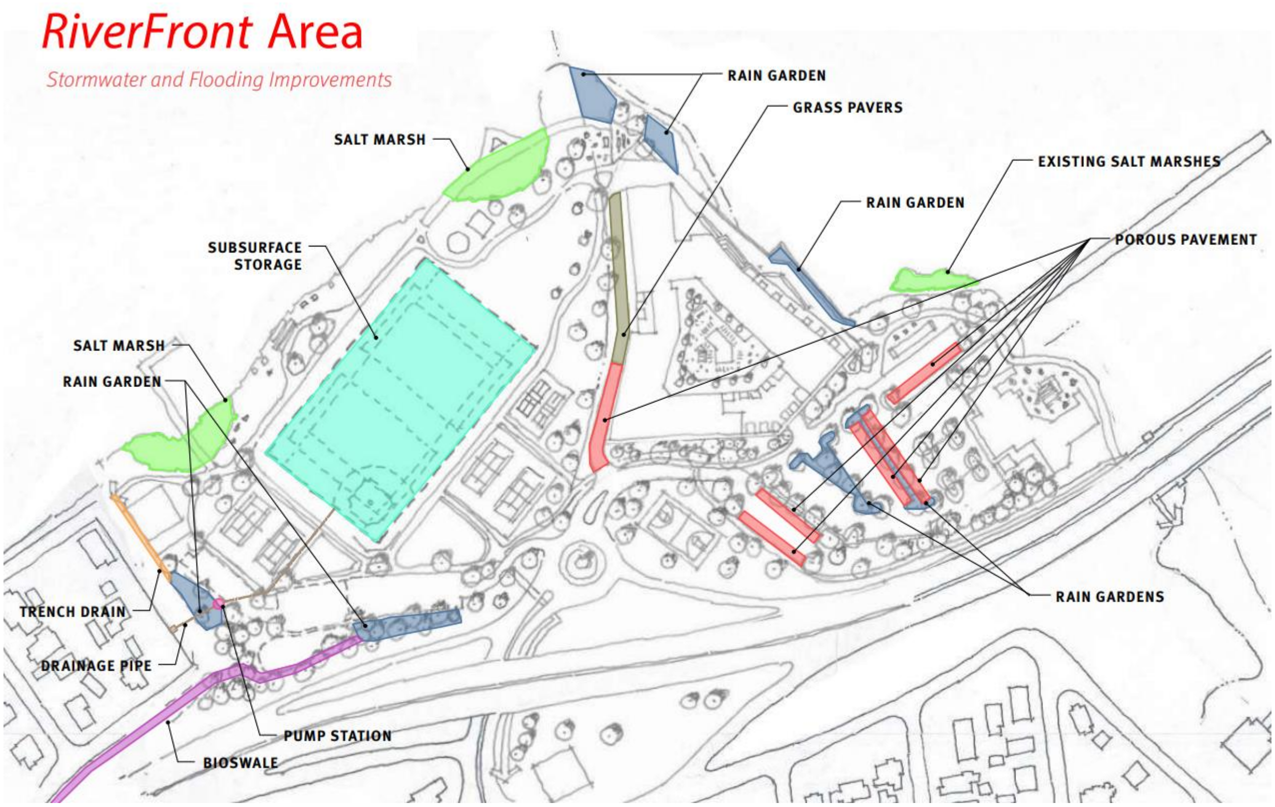

Figure 3-4: Riverfront Green Infrastructure Opportunities

A challenging factor for GI tools is often the identification of locations for implementation or retrofits. Much of the Study Area is heavily developed with numerous residential properties and privately owned businesses, which makes siting of GI challenging without consensus and stakeholder buy-in from private property owners. Installation of GI would likely require demonstration of water quality benefits and avoidance of unanticipated adverse flooding effects.

3.2.3 Impervious Surface Removal/Reduction

Impervious cover is a significant influence of hydrologic resources because it alters the natural landscape and redirects precipitation as runoff instead of allowing it to infiltrate the ground. Impervious cover describes landscape surfaces that cannot infiltrate or absorb rainfall, such as driveways, roads, parking lots, and rooftops. Impervious cover increases stormwater run-off and degrades water quality as it picks up pollutants such as pesticides, oil, debris, sediment, salt, bacteria, and fertilizers. Furthermore, impervious cover inhibits groundwater recharge, which limits the replenishing of groundwater resources, potentially lowering the groundwater table. Reduced volumes of water to recharge base flows due to impervious cover can exacerbate drought in water-scarce regions, and increased stormwater runoff from impervious surface can increase flood impacts in flood-prone locations such as Point of Pines. Watersheds degraded by high concentrations of impervious cover are more likely to experience larger floods of increased frequency.

Removal of impermeable surface materials, when combined with permeable pavement or vegetation establishment, is intended to reduce stormwater runoff rate and volume, as well as associated pollutants transported from the site by stormwater runoff. Strategic urban design provides one strategy to reduce impervious cover. Streets and parking lots are frequently over-built in developed environments. Reducing the width of streets and sidewalks and the size of parking lots can reduce impervious cover from future development. Street layout provides an additional opportunity to reduce pervious cover, though such design is challenging to implement in previously developed communities. Where it is not feasible to reduce the size of streets and parking lots, use of alternate materials such as pervious concrete or uncemented brick can reduce pervious surfaces. Additional strategies include use of alternate driveway materials, such as sand and gravel.

Due to the land usage in the Study Area, implementation of impervious surface reduction is challenging due to the existing land use within the Study Area. The land use is predominantly residential, connected by roadways that serve as key access points which, resultantly, cannot be reduced. While it is feasible to eliminate some relatively small areas of impervious surface, parking lots associated with private businesses such as the Point of Pines Yacht Club, Broadsound Tuna Club, The Marina at the Wharf, Rick’s Auto Collision, Maxim Crane Works, and businesses along Revere Beach Boulevard account for the majority of impervious surface aside from roads and homes in Study Area. Reduction of any available or unused impervious surfaces would not provide enough infiltration to control predicted future flood waters from inundating sections of the Study Area. However, since planning for redevelopment in the Riverside District is currently underway, the City can consider requirements for strategic design that will minimize new impervious cover and potentially reduce existing impervious cover in this portion of the study area.

3.2.4 Wetland restoration

Restoring previously filled wetlands can assist with resiliency by absorbing and storing excess floodwaters, which may prevent some coastal floodwaters from entering a target area. According to the U.S. EPA, wetland restoration is the manipulation of a former or degraded wetland’s physical, chemical, or biological characteristics to return its natural functions. Primary wetland restoration practices include re-establishment, the rebuilding of a former wetland, and rehabilitation, which repairs the functions of a degraded wetland.

Wetlands improve community resilience through delivering natural flood mitigation benefits. Wetlands serve as natural buffers, acting as sponges to limit the frequency and intensity of floods. Coastal wetlands provide additional flood mitigation benefits, protecting the built environment from storm surge resulting from hurricanes and severe summer and winter storms.

The Study Area is heavily developed with numerous residential properties and privately owned businesses, there are limited opportunities for wetland restoration in the Study Area. Salt marsh already exists in many areas which are not currently developed, including the area southeast of Route 1A and the shoreline along the Gibson Park parcel. Restoration of wetlands in other areas of the Study Area would require removal of existing pavement and associated business uses, which is unlikely to receive a high rate of community acceptance. One area that has potential for additional salt marsh restoration would be the northern shore along the Riverside District, adjacent to existing salt marsh at Gibson Park. The Revere Riverfront Master Plan identifies additional salt marsh restoration in this area also.

3.2.5 Living Shoreline

Living shorelines are a Green Infrastructure (GI) technique that provides a nature-based approach to shoreline protection and flood mitigation. Living shorelines leverage natural elements such as plants and other vegetation to stabilize natural ecosystems and are valuable for aiding in erosion protection along a shore while also providing co-benefits of habitat and water quality improvement. While nature-based approaches do not always adequately address risk level, most shorelines are suitable to implement living shoreline practices depending on the location, erosion and flood risk, and land and water uses.

The height of living shorelines is limited by the height of the existing land and therefore this tool is not aimed at excluding flood water and would not protect the Study Area from inundation due to predicted future coastal events. However, living shorelines consisting of coir logs with native vegetation could be incorporated into portions of the Study Area coastline for the co-benefits it provides. There is an existing rock revetment along Route 1A in the southern portion of the Study Area. Adding a living shoreline in this location may be feasible but would require integration with the existing rock revetment. Another potential location for implementing a living shoreline would be along the shore of the Riverfront District in the G/J Towing parcel, in conjunction with the wetland restoration tool identified above. The 2021 Riverfront Master Plan identifies that bank in this area is eroded and includes portions of deteriorated granite block, concrete, and pavement. The bank in this area could be improved through restoration with a living shoreline, either directly by the City, or by redevelopers of the private parcel based on requests and requirements implemented through the City permitting process.

3.2.6 Backflow Prevention

Backflow is any reversal in the flow of water from its indented direction of flow. Backflow prevention measures are interventions that add redundancy to the Study Area's existing stormwater management system to direct tidal water seaward.

Backflow prevention would possibly control some tidal water from portions of the Study Area if these measures do not already exist on tidal outfalls present in the Riverfront District or along Route 1A in the southern part of the Study Area. Because these tidal outfalls are currently inundated at high tide, adding backflow prevention will not necessarily protect against future sea level rise. However, they will add some resiliency to the Study Area to minimize additional intrusion of floodwaters to interior areas during high tides now and in the future. The Revere Riverfront Master Plan indicates that some of the tidal outfalls may have backflow controls already, however some of the outfalls are crushed and some previously installed controls may no longer be functional. In addition, some outfalls on Route 1A are owned by the Massachusetts Department of Transportation and may not include functional backflow controls. Inspecting and improving backflow controls in the tidal outfalls would assist in managing floodwater intrusion into the Study Area.

3.2.7 Drainage Infrastructure

Reports from City staff, officials, and residents have indicated that there is an existing drainage issue in the Mills River residential area and that new drainage infrastructure may be needed to address existing flooding issues in this neighborhood. These conditions will worsen under the future predicted climate change scenarios discussed above. An inventory of existing drainage infrastructure is recommended, along with inspection of existing components to confirm functionality and need for repairs. In addition, a drainage model of the neighborhood that simulates existing and proposed conditions is recommended to identify repairs and upgrades that would address existing drainage issues as well as protect against the future conditions predicted to occur due to increased SLR, storm surge, and precipitation, as discussed above in Section 2.

3.2.8 Short-Term Stormwater Management Summary

Deployable barriers may provide some temporary relief if implemented in current low topography areas that currently experience inundation during frequent "King Tide" events. However, implementation of these requires further study and design and over time will become overwhelmed by predicted future high tides. While GI techniques, impervious surface removal/reduction strategies, and backflow protection measures will improve resiliency of the Study Area, these strategies alone will not protect the Study Area from the most pressing effects of SLR.

4. Proposed Long-Term Protection Measures

To provide additional risk reduction, potential long-term structural, nonstructural, and nature-based resiliency tools were identified in the Task 4 Coastal Resilience Toolkit Memo. The feasibility of these tools regarding their ability to protect the Study Area was then evaluated in the Task 5 Feasibility of Coastal Resilience Tools Memo. This section summarizes proposed long-term protection measures for residential neighborhoods and critical infrastructure and includes a review of non-structural mitigation and adaptive community management strategies.

To establish a feasible design storm for the critical assets that need risk reduction from sea level rise and coastal surge, the FEMA FIRM maps and the Massachusetts Coast Flood Risk Model (MC-FRM) data provided by the Woods Hole Group/Massachusetts Department of Transportation (WHG/MassDOT) were incorporated and compared in Tables 3-1 and 3-2 below. To calculate the 2020 100-year storm design flood elevation (DFE), freeboard was added to the BFE shown on the FEMA FIRM maps. To calculate the 2030 100, 20 and 10-year storm DFEs, freeboard was added to the DFEs provided by WHG/MassDOT, since WHG stated that their MC-FRM DFEs were not inclusive of freeboard. It should be noted that the DFEs provided by the WHG /MassDOT are based on two representative elevations provided from the MC-FRM model, and are not identified for any particular site; final design of any flood risk reduction measures would necessitate additional detailed modelling to determine site specific values.

Freeboard is included in the DFEs of all the design storms listed below in Table 4-1 and Table 4-2. Freeboard was identified based flood design guidance in the American Society of Civil Engineers (ASCE) Publication 24-14. This publication identifies Class 3 buildings and structures as those that "*pose a high risk to the public or significant disruption to the community should they be damaged….or fail*", including community centers, care facilities, and water/sewage treatment plants and recommends two feet of freeboard for this class of structure. The ASCE flood design guidance identifies most buildings as Class 2, including most residential, commercial, and industrial facilities, and recommends one foot of freeboard for this class of building. The DFEs for flood design class 2 were used in evaluating protection for residential areas and the DFEs for flood design class 3 were used in evaluating the critical infrastructure buildings. A summary of the DFEs are listed in Table 4-1 and Table 4-2 below, and the applicability of these DFEs to the critical residential areas and buildings are discussed in the sections that follow.

Table 4-1: DFE for Flood Class Design 2

Design Storm	DFE Ocean Side (ft)	DFE River Side (ft)
FEMA 2020 1% (100-year storm)	12	11
MC-FRM 2030 1% (100-year storm)	13.4	11.6
MC-FRM 2030 5% (20-year storm)	12.3	10.7
MC-FRM 2030 10% (10-year storm)	11.7	10.3
MC-FRM 2050 1% (100-year storm)	15.6	13.4
MC-FRM 2070 1% (100-year storm)	17.4	15.2

Table 4-2: DFE for Flood Class Design 3

Design Storm	DFE Ocean Side (ft)	DFE River Side (ft)
FEMA 2020 1% (100-year storm)	13	12
MC-FRM 2030 1% (100-year storm)	14.4	12.6
MC-FRM 2030 5% (20-year storm)	13.3	11.7
MC-FRM 2030 10% (10-year storm)	12.7	11.3
MC-FRM 2050 1% (100-year storm)	16.6	14.4
MC-FRM 2070 1% (100-year storm)	18.4	16.2

4.1 Residential Neighborhoods

To protect the residential areas on the Point of Pines Peninsula, alignments A, B1, and C were developed. Alignment A was developed to protect the Riverside community, Alignment B1 to protect the Point of Pines community and Alignment C to protect the community southeast of Route 1A, known as Oak Island. To meet the variety of DFEs summarized above, two versions of each alignment were proposed and are shown in Figure 4-1 and Figure 4-2 below. Figure 4-1 represents the alignments required protect the communities from the 2020 1-percent annual probability, which would also provide protection against the 2030 10-percent annual probability storms based on the tie-in locations to high ground. Figure 4-2 represents the alignments required to protect the communities against the 2030, 2050, and 2070 1-percent annual probability flood event based on the tie-in locations to high ground. The height of a barrier along the alignments would vary depending for each these three flood events, with the tallest barrier needed for the 2070 event, lowest barrier required for the 2030 event, and intermediate height required for the 2050 event. In comparison to Figure 4-1, the alignments in Figure 4-2 have an increased length to reach high ground and a more robust flood risk reduction system to meet the higher DFEs. Although difficult to discern in Figures 4-1 and 4-2, the southern tie-in for Alignment C extends slightly further south for the 2030/2050/2070 1-percent annual probability event than for the 2020 1-percent event. The southern tie-in for Alignment C is problematic due to the need to cross private residential yards to connect to high ground, based on the LIDAR data available. For all alignments, additional detailed survey would be needed to confirm tie-in locations.

Figure 4-1: Alignments A, B1, & C – 2020 1%, 2030 10% Storm

Figure 4-2: Alignments A, B1, & C – 2030/2050/2070 1%, 2030 5% Storm

To create the alignments, a variety of flood risk reduction measures were proposed in the Task 5 Feasibility of Coastal Resiliency Tools Memo. These measures include flip up gates across streets to maintain existing openings, fixed flood walls in lieu of the existing median along Route 1A, fixed or glass topped flood walls along Mills and Rice Ave and aquafence deployables. The height of intervention (HOI) of these measures is dependent the design storm. Alignment specific HOIs are detailed further and in Table 4-3 below.

Alignment A runs along the western side of the peninsula and was developed to protect the Riverside community from the flooding coming across Mills Ave. The minimum grade along this alignment, as shown in Figure 4-3 below, is approximately 6.3 ft. Based on this, the maximum HOIs range between 4.0 and 8.9 ft.

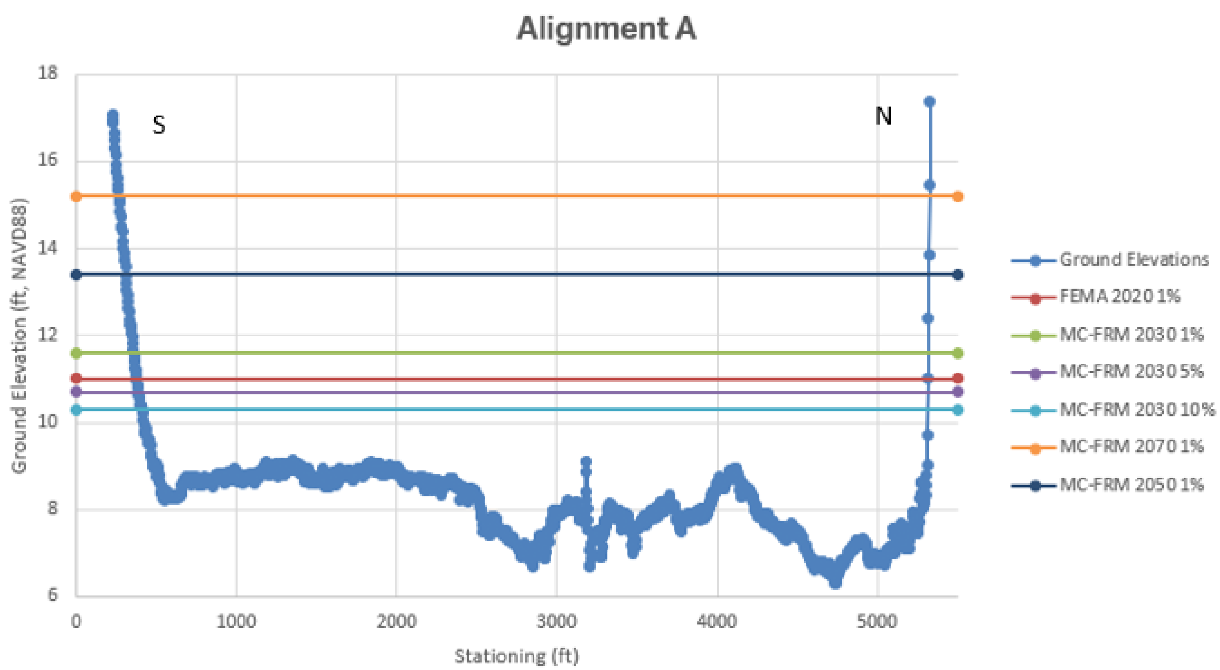

Figure 4-3: Alignment A Elevations

Alignment B runs along the eastern side of the peninsula and was developed to protect the Point of Pines community from the flooding coming across Rice Ave. The minimum grade along this alignment, as shown in Figure 4-4 below, is approximately 5.7 ft. Based on this, the maximum HOIs range between 6.0 and 11.7 ft.

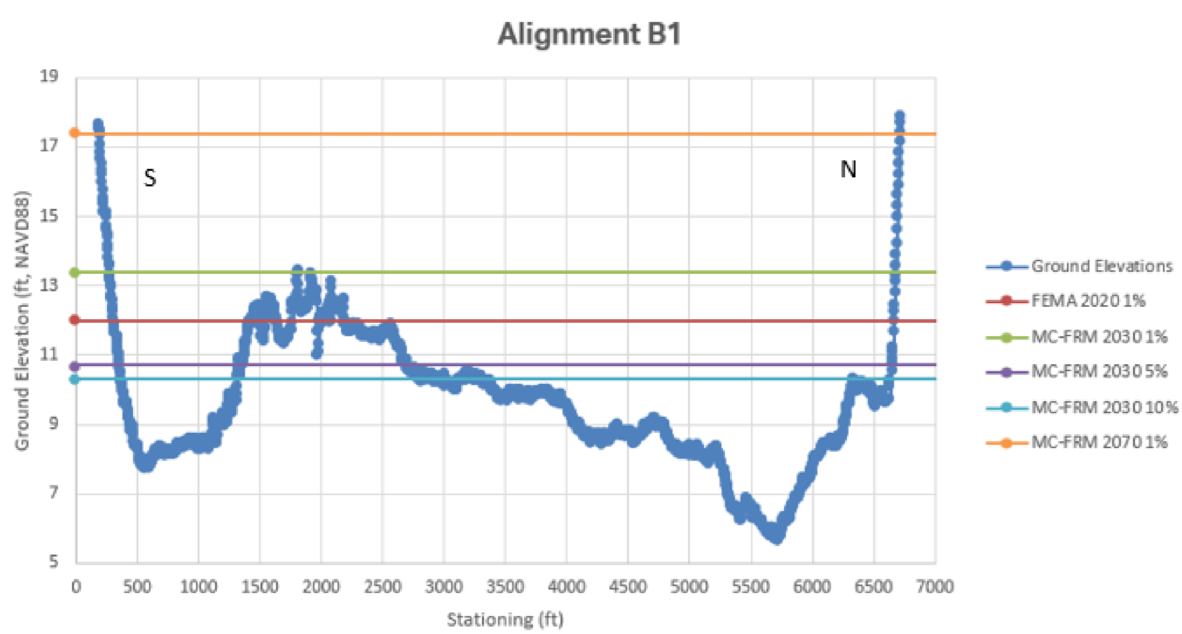

Figure 4-4: Alignment B1 Elevations

Alignment C runs along the center of the peninsula and was developed to protect the Oak Island community southeast of Route 1A. The minimum grade along this alignment, as shown in Figure 4-5 below, is approximately 5.7 ft. Based on this, the maximum HOIs range between 3.5 to 8.4 ft. It should be noted that protection for flooding from the ocean-side of Revere Beach southeast of Route 1A was not evaluated as part of this study since there is an existing sea wall present along Revere Beach that is owned by the Massachusetts (MA) Department of Conservation and Recreation (DCR) which provides some protection against ocean flooding. As noted in the Task 2.1

memorandum prepared as part of the current feasibility study, MA DCR is currently undertaking a pilot project to assess the vulnerabilities of natural, cultural and recreational resources to climate change at the Revere Beach Reservation and their study will identify recommendations for increasing resilience at the Revere Beach area, which is adjacent to the Study Area evaluated in this Feasibility Report.

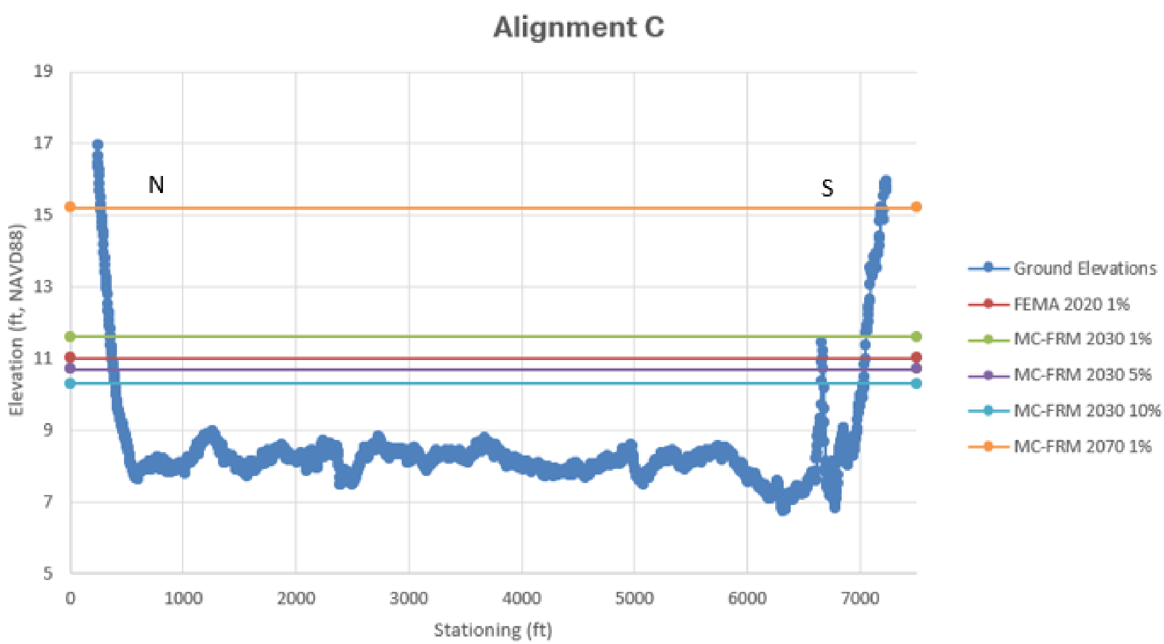

Figure 4-5: Alignment C Elevations

Table 4-3 provides a summary of the maximum HOIs for each design storm.

Table 4-3: Maximum Height of Intervention Alignments

	Alignment A	Alignment B	Alignment C
Min Grade (ft)	6.3	5.7	6.8
FEMA 2020 1%	4.7	6.3	4.2
MC-FRM 2030 1%	5.3	7.7	4.8
MC-FRM 2030 5%	4.4	6.6	3.9
MC-FRM 2030 10%	4.0	6.0	3.5
MC-FRM 2050 1%	7.1	9.9	6.6
MC-FRM 2070 1%	8.9	11.7	8.4

Additional details regarding the alignments

To move forward in providing long-term flood risk reduction, the following next steps may be pursued. First the design storm for which a flood risk reduction strategy is to protect against must be chosen. This decision will impact the location and size of the measures proposed along the alignment. To confirm existing grade elevations and to identify any utilities and substructures, further survey work must be performed. To develop the structural design and analyze seepage underneath the alignment, a geotechnical investigation is also necessary. A coastal model will be required to determine site specific DFEs, provide coastal loading, and overtopping volumes. Additionally, it may be necessary to create an interior drainage model to evaluate the impact of both precipitation and coastal surge on the system and the need for pump stations to assist with post-storm drainage. Community and stakeholder engagement will also be a critical step in the furthering the design process as it is crucial that the flood risk reduction system work cohesively with the existing site and provide protection and enhancement to the residential community. Lastly, operations and maintenance requirements shall also be considered, considering both local requirements and requirements for FEMA certification.

4.2 Critical Infrastructure

There are four critical buildings within the project site, including the stormwater pump station, wastewater pump station, adult day care and fire station, as shown in Figure 4-6. To protect these buildings against future storms, long-term measures may include evacuation procedures, dry flood proofing, and elevating buildings. Based on the DFEs listed in Table 4-2 above, which provides DFE requirements for critical facilities, the approximate HOIs for each design storm are listed in Table 4-4 below.

Early warning and evacuation is recommended for the Adult Day Care Center, in order to avoid trapping individuals inside a structure surrounded by floodwaters. The City is currently implementing repairs to the stormwater pump station and will be evaluating floodproofing as part of the ongoing work. A new fire station is currently under design and proposed for construction on the same site as the current fire station. City staff have verbally indicated that the initial design plans for the new fire station identify the ground floor on at 11.5 NAVD88, which is below all of the DFEs described above in Table 4-2; the design for the new fire station should be evaluated in regard to elevating the building or incorporating floodproofing measures.

As-built plans for the wastewater pump station provided by City staff were reviewed; these plans detail upgrades performed at the wastewater pump station facility but are not record drawings. However, based on the plans reviewed, the wastewater pump station is constructed of masonry walls that were not designed for water pressure. Additionally, the existing building has not been floodproofed. The required height of intervention for the wastewater pump station varies from a minimum 1.3ft for the 2030 10% storm to a maximum of 6.2ft for the 2070 1% storm. Since the walls are not designed to withstand flood loading, they would need to be replaced and reinforced in order to protect the existing building from future flooding conditions. Since the building is small, it would likely be more cost effective to replace the entire building (with reinforced masonry walls, a concrete roof slab, and waterproofed doors/windows), rather than floodproofing the existing building.

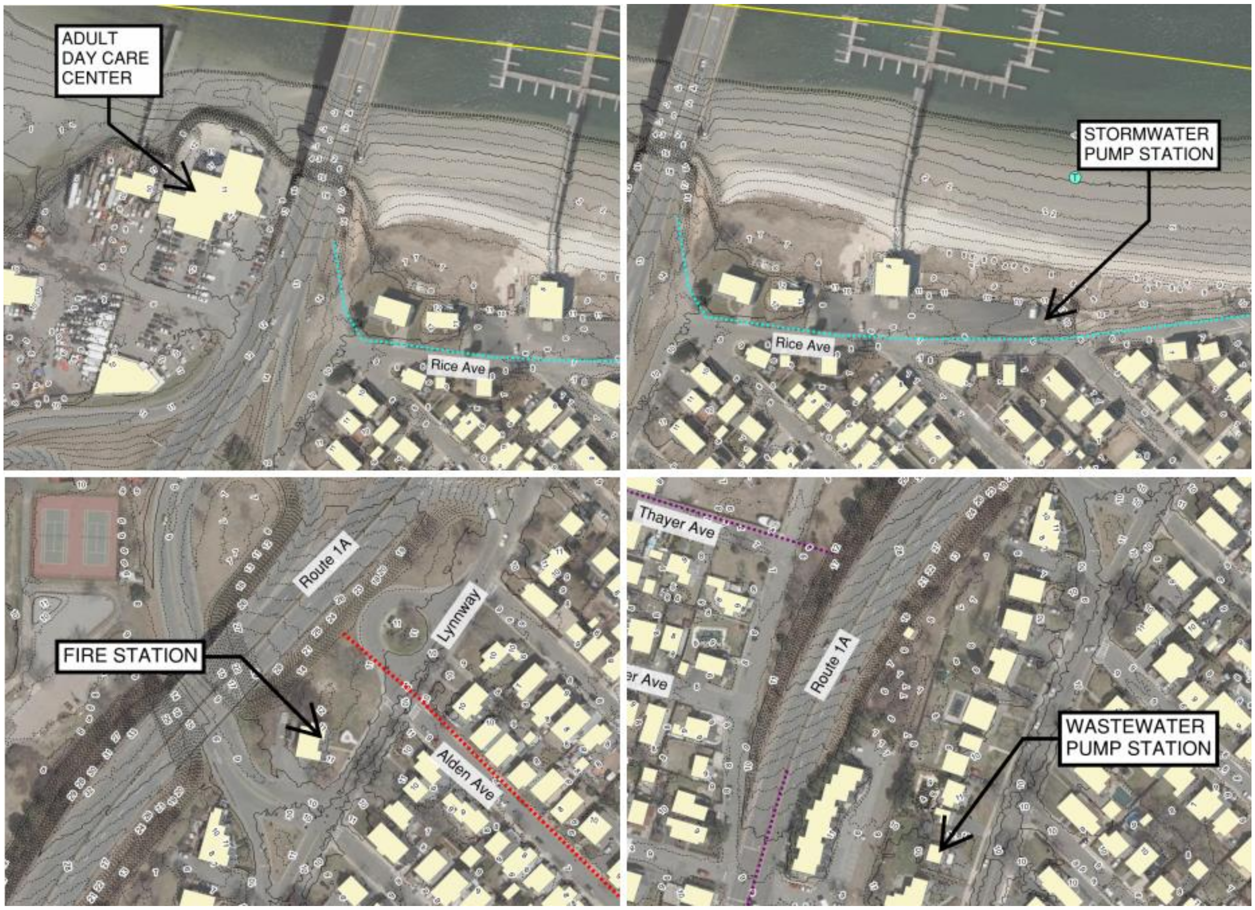

Figure 4-6: Critical Facilities in the Study Area

Table 4-4: Maximum Height of Intervention Critical Buildings

Design Storm	Wastewater Pump Station MAX HOI (ft)	Stormwater Pump Station MAX HOI (ft)	Adult Day Care Center MAX HOI (ft)	Fire Station MAX HOI (ft)
2020 1% DFE	2	4	4	2
2030 1% DFE	2.6	5.4	4.6	3.4
2030 5% DFE	1.7	4.3	3.7	2.3
2030 10% DFE	1.3	3.7	3.3	1.7
2050 1% DFE	4.4	7.6	6.4	5.6
2070 1% DFE	6.2	9.4	8.2	7.4

To move forward in providing long-term risk reduction, the following next steps may be pursued. First the design storm must be chosen. This decision will impact the location, size and type of measures pursued. To confirm the existing makeup and integrity of each building, further structural investigation is required.

4.3 Non-Structural Mitigation and Adaptive Community Management

Structural flood mitigation measures mitigate damages by reconstructing landscapes through use of levees, seawalls, and floodgates, non-structural flood mitigation eliminates flood damages by removing people and property from flood-prone areas. Non-structural flood mitigation techniques include voluntary property acquisition, buyouts, and permanent relocation as well as structure elevation and dry floodproofing.

While traditional structural mitigation measures can appear to be the only practical approach to future conditions flood risk management, they can become extremely costly and may significantly alter the communities they are intended to preserve. The term “adaptive community management” is used here to encompass a broader holistic approach to addressing community resiliency that includes the creative use of tools such as zoning and floodplain ordinances, development permit conditions, voluntary buyouts, and leasebacks. Moreover, adaptive community management and other non-structural approaches are often overlooked or dismissed due to misinformation as well as emotional, political, and social challenges associated with their consideration and implementation. While voluntary property acquisition, buyouts, and permanent relocation are of the most effective flood mitigation strategies, they are also of the most politically sensitive and therefore, should be considered with caution.

Particularly when considering long-term adaptation strategies to deal with some of the more daunting potential hazards associated with climate change, the costs can outweigh the benefits associated with structural flood mitigation strategies. When this is the case, it would be wise to proactively consider how managed retreat could be implemented either for portions of the community or, eventually, for the entire community. Given the uncertainties associated with climate change, adaptive community management strategies can be tied to specific climate thresholds or events in the future as decided upon by the community to ensure preparedness without taking unnecessary or premature actions. More information is provided on assessing the cost-effectiveness of a mitigation action in Section 6.

Although many communities often choose to wait until disaster strikes to consider some of these more challenging issues, inaction leads to greater costs both financially and emotionally for the community. Many non-structural approaches can take decades to effectively implement and will require careful planning if they are to be successful. Communities can only stand to benefit from taking the time to research possible adaptive community management strategies and seriously consider these options alongside more traditional structural approaches.

5. Unprotected and Repetitive Loss Properties

This section provides an overview of the properties that would remain unprotected by the recommended alignments due to engineering and topographic constraints as well as an analysis of repetitive loss properties in the Study Area.

5.1 Unprotected Properties

As described in Section 4.2, three alignments were developed to protect the residential areas on the Point of Pines Peninsula. Alignment A was developed to protect the Riverside community, Alignment B1 to protect the Point of Pines community, and Alignment C to protect the community south of Route 1A. However, these alignments leave several commercial business districts in the Study Area unprotected. In addition, commercial businesses along the southwest side of Route 1A and commercial businesses in the Riverfront area are not protected by the proposed alignments. These portions of the Study Area are described in further detail in the ensuing paragraphs.

5.1.1 Commercial Businesses along Southwest Side of Route 1A

Alignment C is intended to protect the communities south of Route 1A in the southeastern are of the peninsula. Alignment C recommends replacing the median of Route 1A with floodwall, which would connect as a continuation of the median floodwall in Alignment A with a flip up gate at the Mills Ave crossing to maintain egress and extend southwards before veering west onto Dashwood Street. However, this alignment would leave several commercial businesses, such as The Marina Restaurant & Bar, Broad Sound Tuna Club, Rick’s Auto Collision, Oceanview Kennel & Pet Resort, Maxim Crane Works, and Dunkin’ Donuts.

5.1.2 Commercial Businesses along Riverfront Area

Like Alignment C, Alignment A recommends constructing a floodwall along the median of Route 1A in the western half of the Study Area south of Gibson Park. Alignment A would wrap around Mills Ave, protecting the landside residential properties. Alignments B and B1 recommend constructing a floodwall along Rice Avenue to protect the eastern half of the peninsula.

Together, Alignments A, and B/B1 protect the eastern half of the peninsula. However, the alignments leave several commercial businesses in the Riverfront Area in the northwest portion of the peninsula exposed. Businesses exposed include the Mirage , Fowler Marine, G J Towing, and G/C Carting.

5.2 Repetitive Loss Structures

A geospatial analysis of National Flood Insurance Program (NFIP) data provided by the City revealed there are 74 structures within the Study Area that have filed flood insurance claims since 1978. There have been 243 claims paid in that time totaling $3.7 million, resulting in an average payout of $15,200 (2021$). Every structure identified in the NFIP database in the Study Area is a repetitive loss structure. Given the high implementation costs compared to the number of structures avoided, the City may want to consider the costs and benefits associated with acquisition of vulnerable structures in the study area in addition to the costs and benefits associated with the floodwalls described below.

While the analysis of NFIP losses demonstrate the community is vulnerable to flooding, NFIP data alone does not convey the full extent of flood risk. Despite the mandate that all federally backed mortgages must include flood insurance for all properties within the 100-year floodplain, known as the Special Flood Hazard Area (SFHA), the take-up rate in the SFHA is 30 percent (Kousky et al., 2018). The mandate does not apply to properties that do not have a mortgage, which suggests that properties that have been in the same family for decades are less likely to have flood insurance. In addition to the stated flood insurance coverage gap, flood insurance does not always cover the full cost of flood damages. In conclusion, the analysis of NFIP losses in the Study Area alone do not capture the full extent of flood risk.

6. Implementation Costs and Cost Effectiveness

This section summarizes implementation costs and determinants of cost effectiveness.

6.1 Implementation Costs

A planning-level cost estimate was prepared for each of the proposed alignments and critical infrastructure buildings for the 2020, 2050 and 2070 1-percent annual probability storms. Alignment A Option 1 includes the glass floodwall option along Mills Ave, while Alignment A Option 2 includes the concrete floodwall option. The critical facilities estimate includes the stormwater and wastewater pump stations. This estimate was based on experience from other projects and was created as a planning level estimate. Assumptions were used for geotechnical and site or civil conditions. Costs associated with permitting were not included. Due to the lack of existing information, a -30 percent +50-percent contingency was applied. This estimate has been escalated to the midpoint of 2025 and 2026 costs and is summarized in Table 6-1 below. The full cost estimate is included in Appendix A.

Table 6-1: Planning Level Cost Estimate

Flood Protection	Cost Min			Cost Max		
	2020 1%	*2050 1%*	*2070 1%*	*2020 1%*	*2050 1%*	*2070 1%*
Alignment A Option 1	$10.1 M	$17.0 M	$17.6 M	$21.5 M	$36.5 M	$37.6 M
Alignment A Option 2	$7.5 M	$15.9 M	$16.9 M	$16.1 M	$34.0 M	$36.1 M
Alignment B1	$7.3 M	$23.4 M	$24.8 M	$15.6 M	$50.1 M	$53.1 M
Alignment C	$9.3 M	$20.2 M	$21.4 M	$19.9 M	$43.2 M	$45.8 M
Critical Buildings	$0.9 M	$1.4 M	$1.8 M	$1.9 M	$2.9 M	$3.8 M

6.2 Cost Effectiveness

FEMA Hazard Mitigation Assistance (HMA) programs, which include the Hazard Mitigation Grant Program (HMGP), Building Resilient Infrastructure and Communities (BRIC), and the Flood Mitigation Assistance Program (FMA) provide Federal funding opportunities for flood mitigation projects such as the floodwalls discussed above. However, in order to be eligible for Federal funding, a project must be demonstrated to be cost effective through the completion of a benefit-cost analysis (BCA) resulting in a benefit-cost ratio (BCR) equal or greater than 1.0.

A BCA is a method that determines the future risk reduction benefits of a hazard mitigation project and compares those benefits to its costs (FEMA, 2020). The BCA is used to estimate the ratio of a project's benefits associated with the reduction or elimination of long-term risk relative to its costs. Benefits, in the context of a mitigation project, are defined as future losses prevented or reduced by a mitigation project (FEMA, 2009). Net benefits from a flood mitigation project are equal to the difference between estimated flood damages before mitigation and estimated flood damages following completion of the mitigation alternative. The results of a BCA include the present value of costs and benefits and the sum of the expected annual damages avoided over the useful life of the project (FEMA, 2009).

A BCR of 1.0 or greater indicates that FEMA expects that funded projects will meet the objective of reducing risk and future disaster costs in excess of the costs of mitigation, whereas a BCR of less than 1.0 indicates that the project is not cost-effective, based on the allowable benefits (U.S. Department of Homeland Security, 2020), Resultantly, in order to be eligible for HMA programs, it must be demonstrated that the flood protection measures reduce damages by an amount greater than the costs identified in Table 6-1, in addition to operating and maintenance costs, over their anticipated service life of the project. Benefits are calculated based on damages avoided, which are a function of the improvement value of affected structures; therefore, it is uncertain if the benefits of avoiding losses in the Study Area are greater than the costs of the proposed long-term protection measures. More detail regarding losses and a more refined construction cost estimate would be needed to evaluate whether the required BCR could be met.

7. Integrating Co-Benefits into Resilience Strategies

7.1 Introduction to Community and Ecological Co-Benefits

Designing for coastal resiliency is a multidisciplinary process that addresses considerable challenges and vulnerabilities from climate change threats, such as sea level rise, coastal storm surge, and erosion. The approach takes into account flood-risk reduction, community benefits and ecological benefits into the design project. During the next phase of design, the flood-risk reduction designs are an opportunity to reduce flood-risk while additionally providing improved ecology and community quality of life. This integrated three-pronged approach is illustrated in Figure 7-1 below.

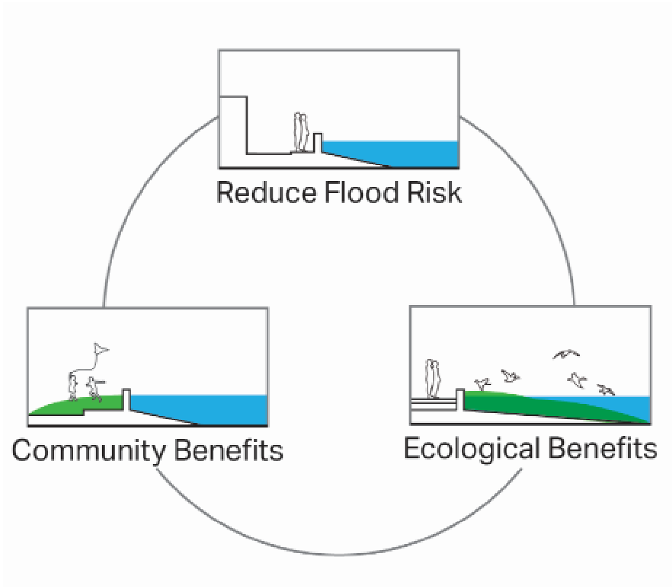

Figure 7-1: Resiliency Design Goals

Flood-risk reduction infrastructure is typically located on an edge between water and community and can be a conduit for creating an amenity that addresses community needs and climate change solutions. The climate change conditions and challenges are described in detail earlier in this report. Given the scale and complexity of these challenges and associated infrastructure, the combined merger of flood risk reduction, community improvements, and ecological benefits can assist in establishing a holistic design that is contextually appropriate and supported by the community.

In the preliminary design phase, the resiliency designs can be assessed for opportunities to provide ecological and community co-benefits. Ecological co-benefits can include the protection of ecological resources such as enhancement of water quality, regional biodiversity, and ecosystem resiliency, as well an improved habitat. Community co-benefits can include such things as improvement of civic, cultural, and recreational opportunities which can contribute to improved quality of life in the Project Area. This process capitalizes on and enhances existing community assets while responding to the realities of coastal waterfront risks.

The coastal flood challenges in Revere are significant and as discussed earlier in this document, addressing these challenges are necessary for long-term resilience. Smaller, inland storms are also a challenge in Revere and although solutions to these challenges cannot reduce coastal flood-risk, design elements such as green infrastructure, can be integrated into the preliminary design phase to provide improved water quality, ecology, and stormwater management for inland storm events. Green infrastructure design elements can be part of a holistic and integrated comprehensive resilient design approach for the area.

7.2 Further Design Development Guided by Community Engagement

The process of bringing a feasibility study into preliminary and final design entails detailed site investigations, design studies, community and stakeholder engagement, permitting, environmental compliance, and design development. By integrating community engagement in the design approach, the design team is able to address community concerns and values in the design approaches for flood hazard risk reduction elements. Understanding community concerns and feedback throughout the design phase process is necessary in order to align design decisions with community and stakeholder input. These flood risk reduction elements should be considered within the existing and proposed land uses, ecological resources, and future climate predictions. This process facilitates the development of design approaches based on flood-risk goals, community needs and broad stakeholder support.

Several key approaches will assist in the success of a final resilience project:

- Development of an integrated design team with multidisciplinary expertise in coastal engineering, civil engineering, landscape architecture, ecological resources, and community engagement;
- Alignment of the engagement schedule and design schedule for critical milestones and deliverables;
- Incorporation of ecological and community co-benefits into the flood-risk reduction infrastructure;
- Definition of design objectives with the community;
- Selection ofdesign storms and associated height of interventions with the community;
- Creation of context-sensitive design solutions responding to community needs

Community engagement is key to successful projects. By engaging and collaborating with the general public and numerous stakeholders, soliciting relevant input, and providing timely information throughout all phases of the project, the engagement process can serve to:

- Clarify information regarding flood-risk, climate change, and resilience;
- Build an understanding of community priorities for alignment locations and types, integrated public realm program and amenities and design intervention materials;
- Collect feedback on the design qualities and features most important to community members;
- Show design options based on constraints;
- Inform the design team during design development

Community engagement strategies should be tailored to the specific needs, concerns, and experiences of the Revere communities and employ a variety of strategies and tools in order to maximize access to information and feedback opportunities for community members, with a focus on historically marginalized and under-represented communities. A recommended design process is described below and includes:

- Creating a Design Phase Engagement Strategy
- Deepening the Understanding of Site Context and Discussing Flood-risk Alignment Footprints
- Assessing Public Realm and Ecological Opportunities and Community Priorities
- Refining Designs and Experiential Character of the Project

Figure 7-2: Integrating Engagement into the Design Phase

Community Engagement is an iterative process that should respond to the design phases and community composition. Developing an engagement strategy will provide important information to the design at strategic times within the design phase. A variety of engagement tools can be used successfully and should be interactive, informative, and accessible. Selecting appropriate engagement tools is tied to the design process and selected tools should be accessible, relatable, interactive, and dynamic in order to provide the greatest value to the design team and community. These tools can be digital and in-person, with easy to understand terminology and visuals. Access should be considered for the location, date and time of each in-person event, as well as the languages in which information is provided both in auditory interpretation and print translations.

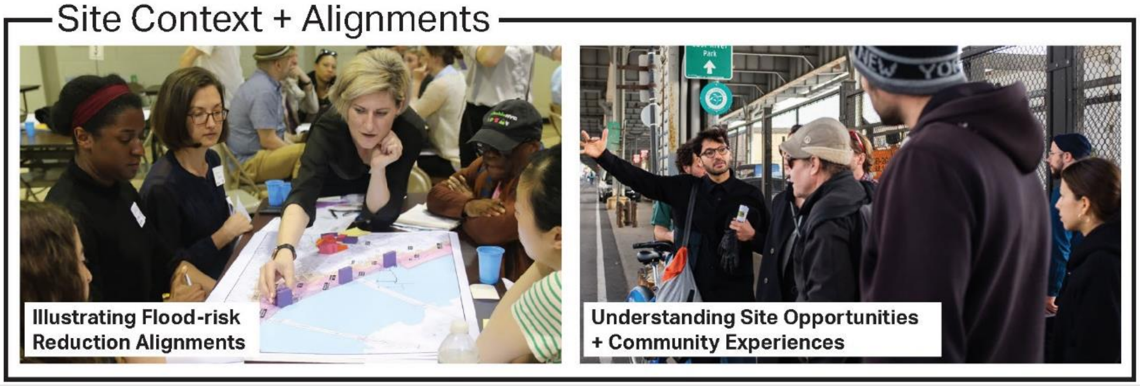

Figure 7-3: Refining Site Understanding and Alignment Opportunities

Early efforts in the design phase process focus on project goals, design criteria to guide decision-making, site condition understanding, and potential locations of interventions. As the design and engagement process begins, it is important to be clear with the community on project goals, project needs, project site conditions and constraints, and potential alignment opportunities. Establishing this understanding with the community will set important expectations early in the process. Hearing community and stakeholder input on the goals, design criteria, and responses to alignment opportunities will guide the early design process. Gathering this input can be done with public workshops with hands-on mapping or tactile activities. On-site walking tours can be another useful tool to consider.

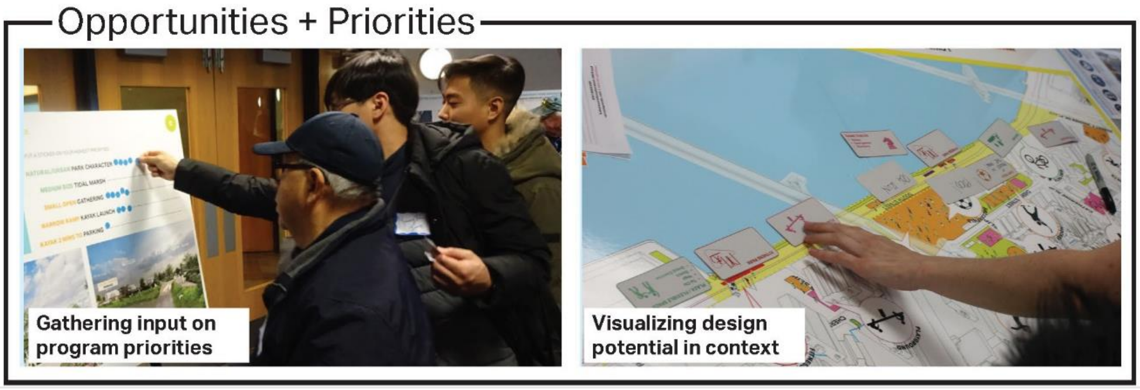

Figure 7-4: Gathering Program Priorities and Opportunities

As the design and engagement process progresses, it is important to show the community what input has been heard during the process and how that was incorporated into the design process. Once the design criteria are established and refined alignment opportunities are discussed, gathering community input regarding program opportunities and priorities is appropriate. Some locations will be within a residential setting, or a more natural setting. Some alignment conditions will have space for interventions with a larger footprint, while others may require design strategies suited to a more narrow footprint. Showing these constraints alongside potential character and program options will help guide the design to best meet community needs. The community's capacity for operations and maintenance should be determined as well. Tools such as preference survey activities, design charettes, and program game cards are examples of activities to consider for gathering this type of information.

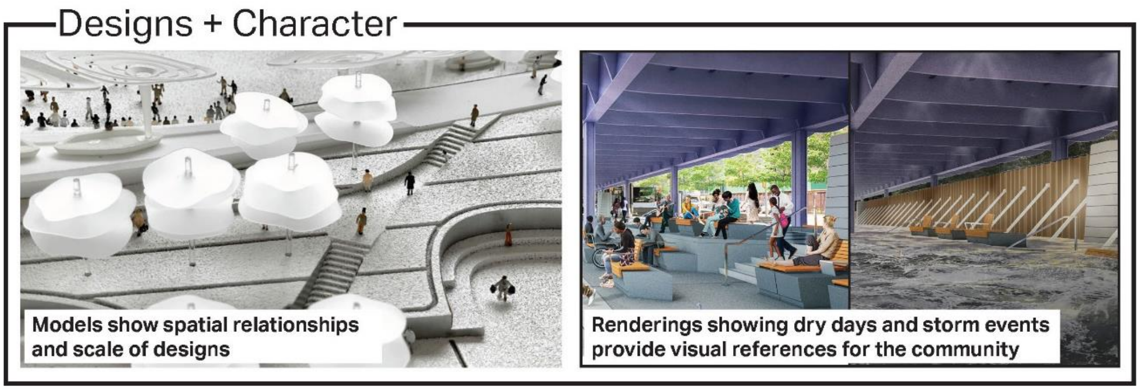

Figure 7-5: Refining Infrastructure Design and Character

Once an understanding of community priorities and site opportunities is refined, final design can progress and should respond to community input. Using a variety of engagement tools is important to illustrate the scale, context, design qualities, and expected experiences with each flood-risk reduction element. Designs should be shown in a way that illustrates how feedback informed the design. Designs can be represented in several ways, for example, through physical models, renderings of experiences, plans, or videos.

7.3 Integrating Co-benefits Into Flood-risk Reduction

As the design progresses from feasibility into the next design phase, it will be important to consider approaches that meet all three resilience goals: flood risk reduction, ecological enhancement, and community improvements. There are many strategies that can assist in achieving these goals and should be selected based on site conditions and community and stakeholder input as described in the previous section. As stated in this Feasibility Report, the primary long-term flood-risk reduction infrastructure recommended includes flood walls and deployables. Anchored by a comprehensive engagement strategy, in the next phase of design, the design team can determine the best ways to integrate community and ecological co-benefits into the flood-risk reduction infrastructure based on community input and site conditions.

The location of existing infrastructure, such as parks, roadways, transit systems, stormwater systems, subsurface utilities, land ownership, and foundation structures for various types of infrastructure, will influence the available footprint for the final designed project. The size and availability of the footprint area then influences the type of potential designed elements that can be constructed.

Maintaining beach and waterfront access and preserving views of the water are important design criteria in coastal resiliency projects. Access can be achieved through integrated ramps, stairs, and deployables as appropriate. These design criteria should be integrated into the designed solutions regardless of the infrastructure type.

Eight examples of strategies for integrating community and ecological co-benefits into food-risk reduction infrastructure are shown in Figure 7-6 and range in size from narrow to wide footprints, as well as in hardscape or more vegetated (soft) character.

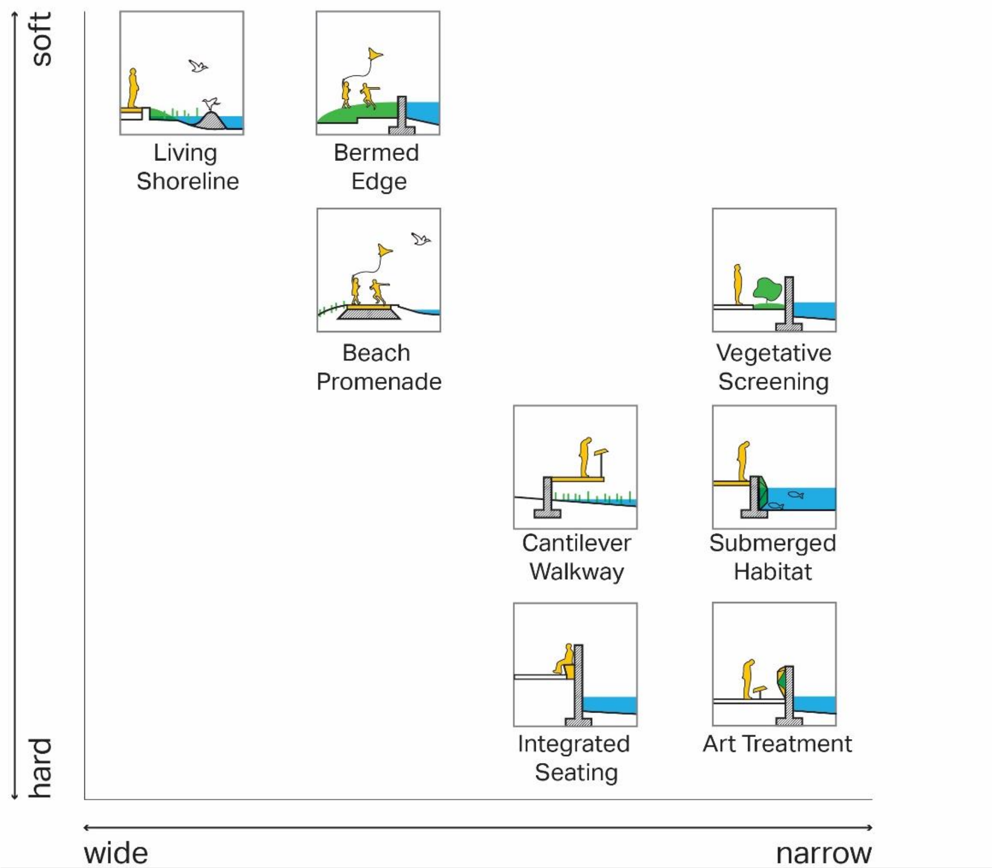

Figure 7-6: Flood-Risk Reduction with Co-benefits Matrix

These initial examples can assist in illustrating potential visual, ecological, and community character that can be integrated into a variety of flood-risk reduction strategies. These examples include: vegetative screening, art treatments, integrated seating, cantilever walkway, bermed edge, beach promenade, living shoreline and submerged habitat. In all examples, there is potential for a hybrid of flood-risk reduction and ecological and community benefits. Some examples primarily utilize surface treatments, while others extend the infrastructure into a wider landscape and public realm. Descriptions and example images of each strategy are shown later in this section.

Within the Study Area, there are four primary existing land use typologies within the flood-risk reduction feasibility focus areas. These typologies are shown in Figure 7-7.

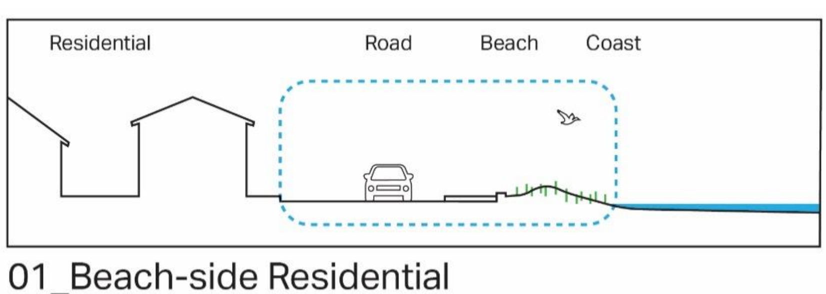

Figure 7-7: Existing Condition Type 1 : Beach-side Residential

The Beach-side Residential zone describes the interface between residential properties and Ocean Side. Maintaining beach access and waterfront views is likely to be important in this location. Co-benefit integration in this typology can include strategies such as art treatments, integrated seating, bermed edge, and beach promenade.

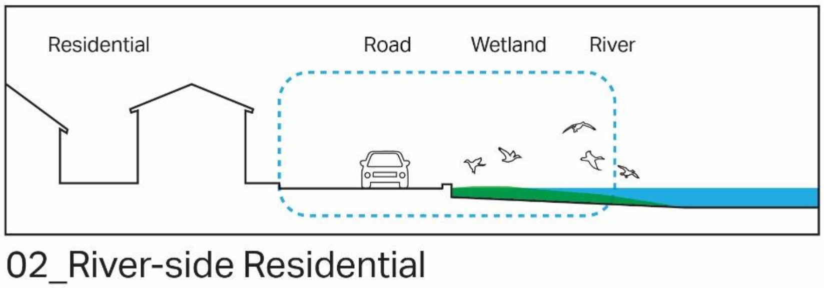

Figure 7-8: Existing Condition Type 2 : River-side Residential

The River-side Residential zone describes the interface between residential properties and the river side. Maintaining waterfront access and waterfront views is likely to be important in this location. Co-benefit integration in this typology can include strategies such as art treatments, integrated seating, cantilever walkway, bermed edge, submerged habitat and living shoreline.

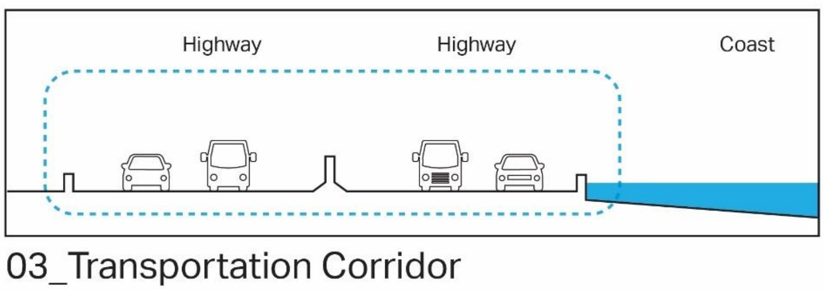

Figure 7-9: Existing Condition Type 3 : Transportation Corridor

The Transportation Corridor zone describes the highway corridor of 1A. The conditions vary widely along this corridor and interface with wetlands and residential neighborhoods. Public gathering is not expected to be necessarily as part of the strategy in this zone, however pedestrian and vehicular road crossing will be important. Co-benefit integration in this typology can include strategies such as art treatments, vegetative screening, submerged habitat and living shoreline, although the applicability of these potential strategies vary widely depending on the location along the corridor.

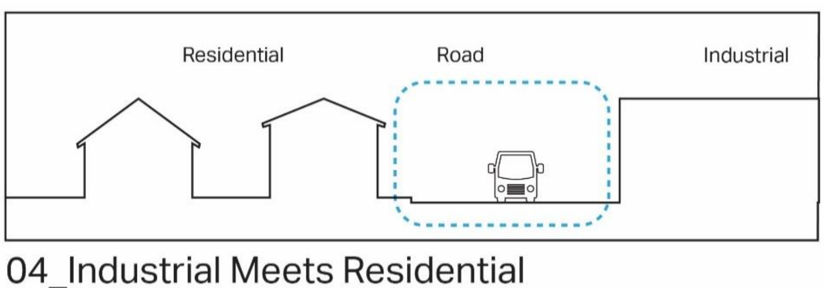

Figure 7-10: Existing Condition Type 4 : Industrial Meets Residential

The Industrial Meets Residential zone describes the interface between residential properties and industrial property and is primarily inland. Screening and some public amenities for adjacent residents may be appropriate in this zone. Co-benefit integration in this typology can include strategies such as art treatments, vegetative screening, and integrated seating.

Examples of eight potential strategies for integrating community and ecological benefits into flood-risk reduction infrastructure are below. As mentioned above not every strategy would be appropriate for every zone within the project area. Strategies to consider should be based on land uses, community priorities, waterfront access, safety, and operations and maintenance capabilities.

Figure 7-11: Vegetative Screening Examples

Vegetated Screening creates a condition affix or in front of the flood risk infrastructure for plantings to grown. This provides increased biodiversity and better visual integration into the community.

Figure 7-12: Art Treatment Examples

Art treatments such as murals or sculptural design approaches to the flood-risk reduction infrastructure provide aesthetic and cultural value to the community. They could also include environmental education.

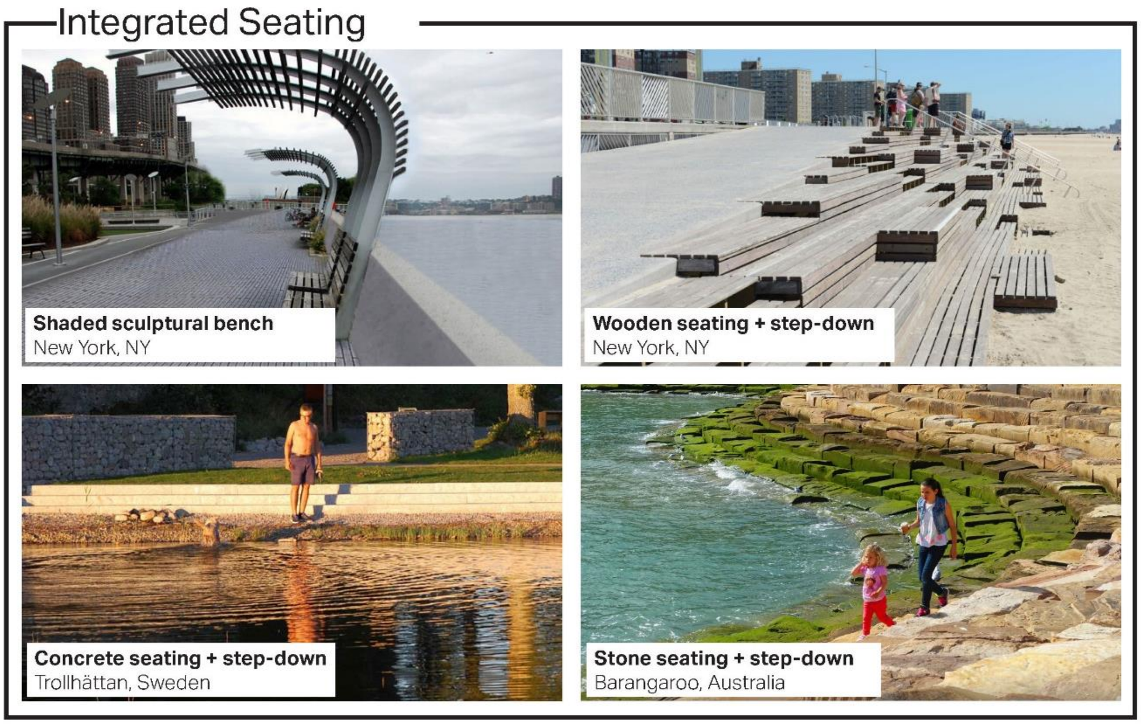

Figure 7-13: Integrated Seating Examples

Integrating seating into flood-risk infrastructure can provide a passive recreational use for the community as well as improved access and interaction with the water.

Figure 7-14: Cantilever Walkway Examples

A cantilever walkway builds a pedestrian access path affixed to flood-risk reduction infrastructure. This allows unique recreational opportunities, waterfront views, and additional space for ecological habitat.

Figure 7-15: Bermed Edge Examples

Integrating bermed earthwork allows for public access on the flood-risk reduction infrastructure as well as waterfront access and increased biodiversity.

Figure 7-16: Beach Promenade Examples

Beach promenades provide pedestrian access along beach properties while integrating flood-risk reduction into the footprint. This provides recreation, waterfront views, and coastal or dune habitat.

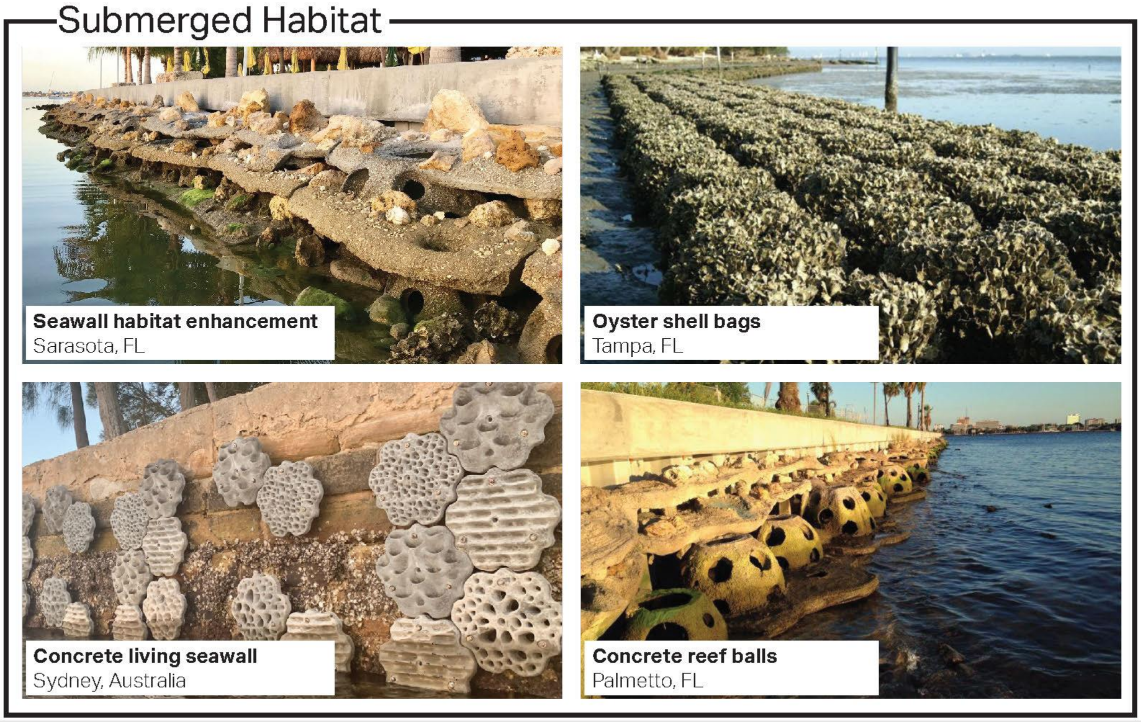

Figure 7-17: Submerged Habitat Examples

Submerged habitat systems integrated into flood walls foster underwater and tidal wildlife naturally resilient to flooding, wave action and coastal conditions. This is also a good opportunity for education.

Figure 7-18: Living Shoreline Examples

Designing vegetated edge at the shoreline can provide wave attenuation, environmental education opportunities, and habitat creation. Flood-risk reduction can be integrated at the shore or in water.

7.4 Inland Stormwater Management Design with Co-benefits

As discussed in Section 3, stormwater management of inland flooding is an important component to resilience design but will not achieve the level of long-term flood-risk reduction desired for larger coastal storm events and the impacts of sea level rise without coastal flood-risk infrastructure interventions. However, as green infrastructure and stormwater management components are refined in design, these features should be seen as part of a holistic water management strategy. Additionally, community and ecological elements can be incorporated into the designs of these systems. For example, rain gardens and bioswales can be designed to include co-benefits such as public art, public seating, pathways, integrated public parks, and environmental education signage. Figure 7-19 provides visual examples of bioswales and raingardens.

Figure 7-19: Rain Garden and Bioswale Examples

Various green infrastructure strategies can assist with the storage or treatment of stormwater in addition to providing placemaking, improved water quality, and biodiversity.

7.5 Conclusion

Integrating community and ecological components into flood-risk reduction infrastructure allows challenging infrastructure to be a multi-faceted community asset. Through a community engagement process, the design team can address important community factors such as operations and maintenance capacity, primary program priorities, waterfront access issues, and can address community values through infrastructure and public realm design to improve the long-term resilience in Revere.

8. Funding Opportunities

Funding opportunities are typically determined by the ownership of the project site as well as the nature of the activity. Most projects located on private land are unavailable for government funding, whereas state of municipal projects may be eligible for a variety of grant programs. The MVP Action Grants typically require that, although feasibility studies may address potential projects on privately held land, grant funding for the construction of a project must be completed on lands held by municipal, state, or federal agencies or government bodies, lands held by non-profit conservation organizations, or lands held privately with consent of private owners. To be eligible for an Action Grant, applications that propose a project on privately owned property must be "accompanied by a letter signed by the property owner(s) demonstrating their commitment to pursue the project's stated restoration goals and actions" or evidence must be provided that the property will be sold to an entity that is committed to these goals. To be eligible for an MVP Action Grant in particular, the City would need to have legal access to the project area prior to executing the project. Most other state or federal funding opportunities also require that the project occur on publicly owned or accessible land. Table 8-1 identifies grant funding opportunities that may be available for the resiliency tools.

Table 8-1: Funding Opportunities for Resilience Tools

Eligible Resiliency Tools	Funding Opportunities	Requirements	Website
All: Floodproof Buildings, Relocate Buildings, Elevate Buildings, Elevate Roadways, Building Codes, Offshore Structures, Coastal Structures, Pump Stations, Living Shorelines, Deployables, Public Education, Land Acquisition, Green Infrastructure, Impervious Surface Reduction, Flood Storage Areas, Bioretention, Backflow Prevention, Dune Protection/Restoration, Wetland Restoration, Evacuation Procedures	Coastal Zone Management (CZM) Coastal Resilience Grants	Project eligible for the CZM Coastal Resilience Grant must be located within the 78 municipalities located within the Massachusetts coastal zone. Nonprofit organizations that own vulnerable coastal property are also eligible to apply. The purposed project must meet one of the five project categories: detailed vulnerability and risk assessment, proactive planning, redesign and retrofits and shoreline restoration. The project proposal must include coastal hazards management, climate adaptation, needs for assistance, project description, public benefit and interest, transferability, timelines, budget, project management and partners and the overall project quality.	https://www.mass.gov/service-details/coastal-resilience-grant-program
Elevate Buildings, Elevating roadways, Evacuation Procedures, Floodwalls, Land Acquisition, Flood Controls	Massachusetts Emergency Management Agency (NEMA) Hazard Mitigation Assistance Grant Program	Projects covered under this funding source must address one of the following concerns: stormwater, drainage and culvert improvements, flood control, property acquisition, slope stabilization, infrastructure protection, seismic and wind retrofits, structure elevation. Applicants must have a FEMA-approved Local Natural Hazard Mitigation Plan in place prior to applying for funding. Applicants must include a formal Benefit-Cost Analysis (using FEMA-approved BCA V6.0 software) to document the project's cost effectiveness in their application. Community participation in the National Flood Insurance Program (NFIP) may also require for subapplicant and project eligibility.	https://www.commbuys.com/bso/external/bidDetail.sdo?bidId=BD-21-1042-CZM-ENV40-61020&parentUrl=activeBids

Coastal Structures, Wetland Restoration, Living Shorelines, Dune Protection/Restoration, Wetland Restoration, Evacuation Procedures, Public Education	National Fish and Wildlife Foundation (NFWF) National Coastal Resiliency Fund	Applicants that are eligible for NFWF fund are: non-profit 501(c) organizations, state and territorial government agencies, local governments, municipal governments, Tribal governments and organizations, educational institutions, or commercial organizations. Projects that receive funding focus on community capacity building and planning, site assessment and preliminary design, final design and permitting, and, restoration and monitoring. Applicants must submit a project proposal explaining what the project consist of, activities proposed, the outcome of the project, stakeholder's engagement, project team, and photos of the project site.	https://www.nfwf.org/programs/national-coastal-resilience-fund/national-coastal-resilience-fund-2021-request-proposals

Flood Storage Area, Green Infrastructure, Impervious Surface Reduction, Bioretention, Backflow Prevention, Dune Protection/Restoration, Wetland Restoration	Statewide Water Management Act Grant	Eligible entities for this grant consist of MA public water suppliers or municipalities with a valid Water Management Act permit. Qualified topics consist of: planning project for specific watershed or subwatershed that improved ecological conditions or identify water capacity of the water; conservation projects that will reduce the demand for water within a municipal or a watershed; and withdrawal mitigation projects that: improve or increase instream flow, wastewater projects that keep water local, stormwater management projects that improve recharge, reduce impervious cover and/or improve water quality, water supply operational improvements, habitat improvement, demand management, reduction of wastewater inflow and infiltration, and other projects that can be demonstrated to mitigate the impacts of water withdrawals. Applicants must submit a project proposal that has a problem statement with a brief narrative explaining objective and project activities; scope of service; project schedule; proposed project team and project manager; detailed budget; and the following attachments: maps, reports or links to reports, drawings, designs, photographs, resumes of key staff, examples of similar projects, support letters and other supporting material. These attachments are not included in the 6-page limit for the narrative proposal. When supporting documents are lengthy or oversized, applicants can include the information in a zip file with a table of supporting materials, with summary description of the contents. A contact list should also be submitted with the proposal.	https://www.mass.gov/doc/water-management-act-statewide-grants-fy2021-request-for-responses/download
Building Code, Floodproof Buildings, Relocate Buildings, Elevate Building	Federal Emergency Management Agency (FEMA) Building Resilient Infrastructure and Communities (BRIC)	Local governmental, tribal governments, state agencies and tribal agencies are eligible to apply for BRIC. Subapplicants can also apply for funding, subapplicants consist of local governments, including cities, townships, counties, special district governments, state agencies, and Tribal governments. As a requirement, subapplicants must have a FEMA approved Local hazard mitigation plan by the application deadline. Projects that are eligible to obtain funding through this source consist of building code activities, partnerships, project scoping, mitigation, planning and planning related activities. Applications must be submitted electronically through FEMA GO and must include environmental planning and historical preservation (EHP)	https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities/before-apply#eligibility

		review; completed EHP checklist, at least one nature-based solution per project; milestone schedule; demonstrate cost-effectiveness; and provide management cost.	
Green Infrastructure, Pump Stations, Green Infrastructure, Impervious Surface Reduction, Flood Storage Areas, Bioretention, Backflow Prevention	Department of Environmental Protection (DEP) State Revolving Fund Loan (SRF) Clean Water Program	Funding is available to cities, towns, water, and wastewater districts. The loan is a subsides 2% loan that can be used for the construction of publicly owned water supply facilities, water pollution abatement facilities, and implementation of non-point source management projects. Projects that focus on nutrient reduction may be eligible for 0% interest loans. The applicant must already have communities appropriated the necessary local project funds or have committed to a schedule to obtain those funds. Eligible construction project covered under the Clean Water Program of the SRF loan are: Combined Sewer Overflow (CSO); new wastewater treatment facilities and upgrades of existing facilities; infiltration/inflow correction; wastewater collection systems; nonpoint source abatement projects such as landfill capping, community programs that update septic systems (Title 5), brownfield remediation, pollution prevention and stormwater remediation. Nonstructural project that are eligible for the SRF loan are green infrastructure planning projects that aim to correct nonpoint source concerns and identify pollutant sources along with providing remediation strategies, and wastewater nutrients management. To apply for funding, the applicant must submit a Project Evaluation Form which should include project schedule and cost, and a project evaluation including a project narrative.	https://www.mass.gov/state-revolving-fund-srf-loan-program https://www.mass.gov/service-details/srf-clean-water-program
Land Acquisition	Division of Conservation Services Local Acquisitions for Natural Diversity (LAND) Grant	To obtain funding through the LAND grant project must include the acquisition of a forest; fields; wetlands; wildlife habitat; unique natural; cultural; or historic resources; unique natural; cultural; or historic resources; and some farmlands. To apply for funding an appraisal report, cover letter signed by an authorized town or city official giving the project manager permission to apply for the grant on behalf of the town, town meeting or city council, project description, property map, conservation restriction draft, Project reviews from: Massachusetts Natural Heritage and Endangered Species Program and Massachusetts Historical Commission and proof of land stewardship practice must be submitted.	https://www.mass.gov/service-details/local-acquisitions-for-natural-diversity-land-grant-program

	Parkland Acquisitions and Renovations for Communities (PARC) Grant Program	Any town with a population of 35,000 or more year-round residents, or any city regardless of size, that has an authorized park/recreation commission is eligible to participate in the program. Communities that are smaller than 35,000 may still qualify for funding. Projects that are eligible for funding consist of acquisition of parklands, development of new parks and improvements to an existing park. The PARC must include application form signed by an authorized signatory for the applicant organization, municipal open space, and recreation plan (if not already on file with DCS). For acquisition projects, appraisal report(s)are required.	https://www.mass.gov/service-details/parkland-acquisitions-and-renovations-for-communities-parc-grant-program https://www.mass.gov/doc/parkland-acquisitions-and-renovations-for-communities-parc-grant-program-bid-fy-21/download
Offshore Structures, Coastal Structures, Impervious Surface Reduction, Flood Storage Areas, Bioretention, Backflow Prevention, Dune Protection/Restoration, Wetland Restoration, Public Education	EEA Municipal Vulnerability Preparedness Municipal Vulnerability Preparedness (MVP) Action Grant	Funding through the Executive Office of Energy and Environmental Affairs (EEA) MVP Action Grant is available for municipalities that have received designation from the EEA as an MVP Community. Projects that receive funding through this grant must provide monthly updates, project deliverables and a brief project case study that describes lessons learned throughout the project. The municipal is required to match 25% of the total project cost using cash or in-kind contributions. Proposals for this grant must include: a completed online application; project scope and budget; MVP yearly progress report describing any relevant work towards advancing community priorities since earning MVP designation; a statement of match; letter of support from landowners, partners and the public; an attachment describing the design, permitting and construction (if applicable); Draft Town Meeting or City Council vote language for land acquisition projects (if applicable);Climate Resilience Design Standards Tool attachment (Optional). The application should also include 1 of the 9 MVP Programs (core values can be views here: https://www.mass.gov/doc/mvp-core-principles/download).	https://www.mass.gov/service-details/mvp-action-grant
Coastal Structures, Deployables, Dune Protection/Restoration	EEA Dams and Seawall Repair or Removal Program Grants	Municipalities and nonprofit organizations are eligible to apply for funding. Eligible projects consist of repairing or the removal of dams, leaves, seawalls, and coastal structures. The program provided funding for the completion of designs and permit applications that repair or remove dams, seawalls and other coastal infrastructure, and levees. The program also supports the construction of dam repairs or removals along with construction of seawalls and other coastal infrastructure, and levees. Applicant are eligible to apply for a loan through the program that also support the construction phase of repair or removal of dams, seawalls and other coastal infrastructure, and levees.	https://www.mass.gov/service-details/dam-and-seawall-repair-or-removal-program-grants-and-funds

Public Education	MassDEP 319 Grants	Funding is available to any public or private Massachusetts organization. Eligible projects: implementation of measures that address the prevention, control, and abatement of NPS pollution; target the major source(s) of nonpoint source pollution within a watershed/subwatershed; contain an appropriate method for evaluating the project results; and must address activities that are identified in the Massachusetts NPS Management Plan. The application must be submitted by email and must include: a proposal with administrative summary, project description, scope of services, project budget, and project milestone schedule; the following three forms signed electronically: Contractor Authorized Signatory Listing Form; An Equal Opportunity/Affirmative Action Policy Statement; and the required Disadvantaged Business Enterprise Documentation and Forms.	https://www.mass.gov/doc/ffy-2022-s-319-nonpoint-source-pollution-competitive-grant-program-request-for-responses-0/download

9. Implementation Schedule

In the pursuit of providing resiliency in the Point of Pines Peninsula, the following conceptual planning-level implementation schedule was created. The high-level schedule displayed in Figure 9-1 shows the proposed timeline for the design and construction of both short-term and long-term flood risk reduction measures including community and stakeholder engagement, environmental compliance and assessment and permitting.

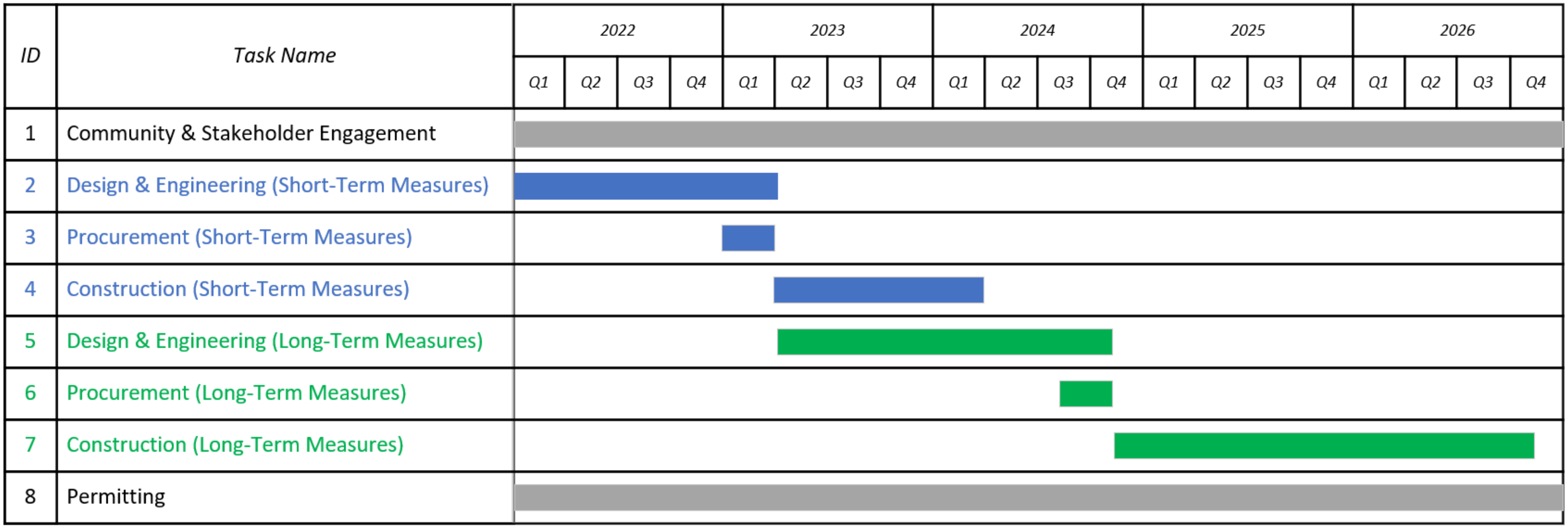

Figure 9-1: Implementation Schedule

10. Conclusion

A variety of tools may be needed to increase the resilience of the Study Area, including barrier measures that control future floodwaters predicted to occur due to climate change which are costly and challenging to permit, as well as smaller stormwater management measures such as Green Infrastructure which may add additional co-benefits such as habitat and water quality improvement . Based on the feasibility analysis, protection measures for the future predicted conditions in 2030 may only be feasible for the 10-year storm due to the heights of flood walls that would be required for protection and their associated cost as well as impact on quality of life for residents living in an increasingly isolated future condition surrounded by encroaching waters. Protection for storms larger than the 10 -year storm in 2030, as well as flooding predictions for 2050 and 2070, may not be possible without a larger-scale tool that expands beyond the existing study area.

11. Bibliography

City of Cambridge, Climate Change Vulnerability Assessment, November 2015. Retrieved http://envision.cambridgema.gov/wp-content/uploads/2016/08/Cambridge_November2015_FINAL-web.pdf

City of Revere, Next Stop Revere, January 2020. Retrieved https://www.revere.org/next-stop-revere/plan-report

Delaware NEMO, Impervious Cover, University of Delaware, n.d. Retrieved http://nemo.udel.edu/manual/chap2web.pdf

Federal Emergency Management Agency, Benefit-Cost Analysis, December 2020. Retrieved https://www.fema.gov/grants/guidance-tools/benefit-cost-analysis

Federal Emergency Management Agency, Final BCA Reference Guide, June 2009. Retrieved https://www.fema.gov/sites/default/files/2020-04/fema_bca_reference-guide.pdf

Green Roofs for Healthy Cities, About Green Roofs, n.d. Retrieved https://greenroofs.org/about-green-roofs

Groundwater Foundation, All About Rain Gardens, 2021. Retrieved https://www.groundwater.org/action/home/raingardens.html

Interreg 2 Seas, Short Term Adaptation for Long Term Resilience to Climate Change, European Union, n.d. Retrieved https://www.interreg2seas.eu/en/star2cs

Kousky, Carolyn, Howard Kunreuther, Brett Lingle, and Leonard Shabman, The Emerging Private Residential Flood Insurance Market in the United States, July 2018. Retrieved http://d1c25a6gwz7q5e.cloudfront.net/reports/07-13-18-Emerging%20Flood%20Insurance%20Market%20Report.pdf

National Association of City Transportation Officials, Urban Street Design Guide, n.d. Retrieved https://nacto.org/publication/urban-street-design-guide/street-design-elements/stormwater-management/bioswales/

National Oceanic and Atmospheric Administration, What is a living shoreline? 2021. Retrieved https://oceanservice.noaa.gov/facts/living-shoreline.html

Naturally Resilient Communities, Bioswales, n.d. Retrieved http://nrcsolutions.org/bioswales/

Naturally Resilient Communities, Raingardens, n.d. Retrieved http://nrcsolutions.org/rain-gardens/

Resilient MA, Climate Change Clearinghouse for the Commonwealth, 2020. Retrieved https://resilientma.org/datagrapher/?c=Temp/county/tx90/ANN/25025/

Rhode Island Department of Environmental Management, The Need to Reduce Impervious Cover to Prevent Flooding and Protect Water Quality, May 2010. Retrieved http://www.dem.ri.gov/programs/bpoladm/suswshed/pdfs/imperv.pdf

U.S. Census Bureau, American Community Survey 5-year estimates. 2020. Retrieved https://data.census.gov/cedsci/

U.S. Department of Homeland Security, Notice of Funding Opportunity FY 2020 Building Resilient Infrastructure and Communities, 2020. Retrieved https://www.fema.gov/sites/default/files/2020-08/fema_fy20-bric-notice-of-funding-opportunity_federal-register_August-2020.pdf

U.S. Environmental Protection Agency, Watershed Academy Web, 8 Tools of Watershed Protection in Developing Areas, Tool 1: Land Use Planning, n.d. Retrieved https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=1280

U.S. Environmental Protection Agency, Principles of Wetland Restoration, n.d. Retrieved https://www.epa.gov/wetlands/principles-wetland-restoration

Virginia Institute of Marine Sciences, Living Shorelines, Center for Coastal Resources Management, 2020. Retrieved https://www.vims.edu/ccrm/outreach/living_shorelines/index.php

Wolf, Kathleen L., Water and Wellness: Green Infrastructure for Health Co-Benefits, Stormwater Report, April 2, 2014. R