A. Appendix A: Task 1 Stakeholder Workshop #1 Meeting Minutes and Presentation

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Meeting Minutes

Staleholder Workshop #1	**Meeting date**	**Attendees**
Coastal Resilience Feasibility Study for the Point of Pines/Riverside Area – Review MVP Proccess, Scope, Schedule, Discussion	December 15, 2020	See Section 1.0 for attendee list
Time	**Location**	
6:00PM	Virtual Zoom Meeting	
AECOM project number	**Prepared by**	
60646341	Aaron Weieneth	

Subject: Coastal Resilience Feasibility Study for the Point of Pines/Riverside Area – Stakeholder Workshop #1

1.0 Introductions

- Attendees: AECOM: Amanda Shanahan, Aaron Weieneth, Brian Stobbie, Rickey Torres-Cooban

  City of Revere: Elle Baker, Frank Stringi, Ward 5 Councilor John Powers, Joe Maglione, Robert O'Brien, Paul Argenzio, Nick Moulaison

  Project Partners: Carolyn Meklenburg (MVP Regional Support Staff), Greg Robbins (DCR), Steve Miller (MassDOT), Loretta LeCentra (Riverside Area Resident), John Polcari (Point of Pines Beach Association)

  Community Members: Elaine Hurley, JD Jaramillo
- Elle Baker made introductions and turned things over to Aaron Weieneth for the formal presentation. A PDF of the presentation is attached to these notes and provides additional details.
- Aaron introduced project and meeting agenda and continued with presentation

2.0 Update on MVP Program to Date

- Point of Pines/Riverside Area coastal resilience study was determined as top priority action from MVP planning grant process.
- Presented past flooding/storm events and reviewed existing FEMA flood hazard zone mapping.
- Massachusetts Coast Flood Risk Model (MC-FRM) provides projected coastal flooding for the study area due to sea level rise and coastal storms. It does not take into consideration high precipitation events or inland flooding.
- MC-FRM provides results for Present Day, 2030, 2050, and 2070.
- Two main MC-FRM data products:
  - Annual Coastal Flood Exceedance Probability – shows likelihood that a location will be flooded
  - Estimated flood depth – anticipated depth of flood water in affected areas
- Property ownership considerations: mix of municipal, private, and state-owned properties in the study area.
- Past studies have been conducted. Time to take a fresh look to identify potential coastal resilience adaptation measures.
- City was awarded a MVP Action Grant to conduct a new feasibility study.

3.0 MVP Action Grant Scope of Work

- Aaron provided an overview of the following six tasks that comprise the MVP Action grant scope of work:
  - Task 1: Stakeholder Outreach and Engagement

- Task 2: Assessment of Current and Future Conditions
- Task 3: Identify Short-Term Resilience Measures
- Task 4: Develop Coastal Resilience Toolkit
- Task 5: Assess Feasibility of Coastal Resilience Options
- Task 6: Point of Pines and Riverside Area Coastal Resilience Feasibility Report

4.0 Project Schedule

- The coastal resilience feasibility study was kicked off in October 2020 and the project performance period extends through June 2021. A detailed schedule was included in the presentation.

5.0 Potential Collaboration Opportunities

- Noted there are several other projects underway in the study area, including:
  - Boatyard project – potential community rowing/boating access
  - Boston Region MPO Route 1A Corridor Vulnerability Assessment
  - DCR Revere Beach Reservation Vulnerability Assessment
  - RiverFront District Master Plan
  - Boatyard project
- Presented some detail on stormwater and flooding control measures for the RiverFront District Master Plan. Noted the Point of Pines and Riverside Area Coastal Resilience Feasibility Study will take into consideration recommendations that come out of the master planning effort.

6.0 Stakeholder and Project Partner Feedback and Discussion

- Elle Baker: City of Revere submitted an application to the Army Corps of Engineers to revisit a study conducted in the 1990s that recommended a regional flood gate across the Saugus River, along with other proposed flood protection measures. Will hear from the Corps in late spring/early summer with an update. (Note: Additional detail on the Regional Saugus River Floodgate Project is available online: https://saugusriverfloodgates.com/.)
- Bob O'Brien: The primary focus of the study is coastal flooding rather than inland flooding which includes rain events. He thinks that rain events contribute to flooding that the Riverside Area is currently experiencing. How will the study take into account inland flooding?
  - Aaron: MC-FRM mapping does not factor in extreme precipitation events, but we will be looking at precipitation data that is available from ResilientMA and other sources. The City doesn't have its drainage system modeled in this area, but we have anecdotal information and other resources we can draw from. Have to be careful when building berms and seawalls to account for inland drainage. Otherwise the coastal interventions may result in impoundment areas.
  - Brian Stobbie followed up stating they are dependent on one another; don't want to retain water and have ponding.
- Bob O/Brien: Noted the study is looking at Riverside and Point of Pines together, but the study should make distinctions between them given the varying coastal conditions.
- Steve Miller: There is a big difference between storm surge and piped infrastructure. Generally speaking, storm surge overwhelms precipitation factor. Tide gates are used to prevent inland flooding from the coast. The Boston Water and Sewer Commission (BWSC) did a study of piped infrastructure and how it interfaced with projected coastal conditions.
- Elaine Hurley: Live on River Avenue and stated her neighborhood floods regularly during King tides and dependent on which way the wind blows. Stated she believes the Saugus River flood gate is needed to alleviate the backshore flooding along the Pines River. Elaine worked with steering committee for the Corps study for 4 years.
  - Elle reiterated that the City wants to revive the regional flood gate project.
- Bob O'Brien: Referenced the Boston Region Metropolitan Planning Organization (MPO) Route 1A vulnerability assessment study. Important that whatever comes out of the Point of Pines/Riverside Area study compliment MPO study.
  - Steve Miller: Got the MPO involved because there is a need for a regional solution for supply chain and general commuting routes that are on the coasts. Hoping the MPO study will consider the susceptibility to Route 1A to

routine flooding in the future, and what that means to the neighborhoods and cities that Route 1A connects. He wants a wider lens than just Revere for how the coast looks in the future.

- Bob O'Brien: Will the Saugus River Floodgate project be among the options that we will consider?
  - Aaron: Yes it will be considered and noted in this study, it is a regional project that is outside the scope of the MVP Action grant study. This is not something Revere alone can take on, but is an important part of a regional solution moving forward.
  - Frank Stringi: It is the "save-all" solution for the region. It was authorized in 1992 and ready for construction, but the Commonwealth's Executive Office of Energy and Environmental Affairs stopped it due to concerns about the emphasis on the structural approach. The City is working to get that project back on the front burner and bring it back to life.
  - Bob O'Brien: If it becomes part of the recommendation of this study, it can support pushing a regional solution forward and advocating for it on other projects.
- Councilor Powers: How can we abate the overtopping by the old boat house in the Riverside area in the near-term without seawalls?
  - Aaron: Both short-term and long-term solutions will be evaluated as part of the study. A short-term measure could be temporary barriers that are deployable when storms or extreme high tides are forecast.
  - Nick Moulaison: Mills Ave to the Marina needs immediate attention
- Robert O'Brian – Existing infrastructure is failing. Need to look at what is in place and not functioning.
  - Joe Maglione: Have dug out some lines/outfalls. Sand has washed back and is covering them. Special permit is required in order to go onto the beach with equipment. They dig out outfalls by hand sometimes. A lot of the pipe is corrugated. Lot of study to do in there.
  - Elle: Important to look at the condition of existing infrastructure as part of the study, and what improvements are needed.
- Councilor Powers: Noted that on Gilbert Avenue, every time there was a storm it used to flood. The City cleaned out the outfall pipes and put flapper valves on some. Powers asked if flapper valves can be installed on Wadleigh Avenue as well. Believes there is a landing nearby that has an 8- or 10-inch outfall. Also asked if jersey barriers can help.
  - Joe Maglione: Noted some of the outfalls in this area have filled in/been clogged with sand. Stated jersey barriers will not help as part of a temporary solution because the water will flow between/around them; they are not watertight.
- Bob O'Brien: This study is needed to come up with longer lasting solutions that will not be wrecked by the next big storm.
- Carolyn Meklenburg: Expressed excitement and availability to support project.

7.0 Next Steps

- Project Partners meeting scheduled for late January 2021.
- Second stakeholder workshop will be conducted in February 2021 to share available findings from Tasks 2, 3, and 4.

City of Revere

Coastal Resilience Feasibility Study for the Point of Pines/Riverside Area – Stakeholder Workshop #1

December 15, 2020

AECOM

Coastal Resilience Feasibility Study for the Point of Pines/Riverside Area – Stakeholder Workshop #1

Elected Officials

- Mayor Brian Arrigo
- Ward 5 Councilor, John Powers

Revere City Staff

- Robert O'Brien – Director, Revere Office of Planning and Development
- Elle Baker – Project Planner
- Frank Stringi – City Planner
- Don Ciaramella, Superintendent Water, Sewer and Drain
- Joe Maglione – Assistant Superintendent Water, Sewer and Drain
- Paul Argenzio – Superintendent Revere Department of Public Works
- Nick Moulaison – Conservation Commission

Project Consultants – AECOM

- Aaron Weieneth – Project Manager
- Brian Stobbie – Coastal Engineer
- Ricky Torres-Cooban – Resilience Specialist
- Amanda Shanahan – Water Resources Engineer

Project Partners

- Loretta LeCentra – Riverside Area Resident
- Elaine Hurley – Riverside Area Resident
- John Polcari – Point of Pines Beach Association
- Angela Sawaya – Point of Pines Beach Association
- Stacy Livote – The Marina Restaurant
- Carolyn Meklenburg – MVP Regional Coordinator
- Greg Robbins – DCR Waterways
- Mary Lester – Saugus River Watershed Council
- Michelle O'Toole – MEMA, Hazard Mitigation Planning
- Brian Lajiness – MBTA, Manager of Emergency Operations
- Steve Miller –MassDOT, Climate Change Project Manager

Agenda

1. Welcome and Introductions
2. Update on Municipal Vulnerability Preparedness (MVP) Program
3. Coastal Resilience Feasibility Study Scope of Work
4. Project Schedule
5. Collaboration Opportunities
6. Discussion
7. Next Steps

Municipal Vulnerability Preparedness Program

- City completed the MVP Planning Grant process in 2019, implementing a Community Resilience Building Workshop framework
- Core Project Team established
- State certified MVP provider, AECOM, engaged

Municipal Vulnerability Preparedness Program

Point of Pines / Riverside Area was identified as the most vulnerable area

AECOM

Municipal Vulnerability Preparedness Program

Top Priority Actions Based on Voting

Number of Votes	Action
21	*Seawall construction and rehabilitation in the Point of Pines / Riverside area.*
11	***Conduct a feasibility study to determine the best strategies to mitigate flooding, erosion, and storm impacts in the Point of Pines / Riverside area.***
8	Reconstruct seawall to mitigate flooding in the Beachmont area.
8	Dredge and maintain Town Line Brook in the northwest side of Revere.
7	Liaison between City and State to position for funding sources and increase communication city-wide, especially in regions with dense and/or diverse populations, such as Sales Creek.
7	Encourage thoughtful future development in relation to flooding and drainage in the Oak Island / Revere Beach area and throughout the city.
7	Investigate permit process for sand transfer to mitigate coastline erosion in the Point of Pines / Riverside area.

Point of Pines / Riverside Area Existing Conditions

Dune erosion

Seawall deterioration

Sand deposition / accretion near West Channel

Sand overtopping seawall

Point of Pines / Riverside Area Existing Conditions

Photo Credit: John Polcari

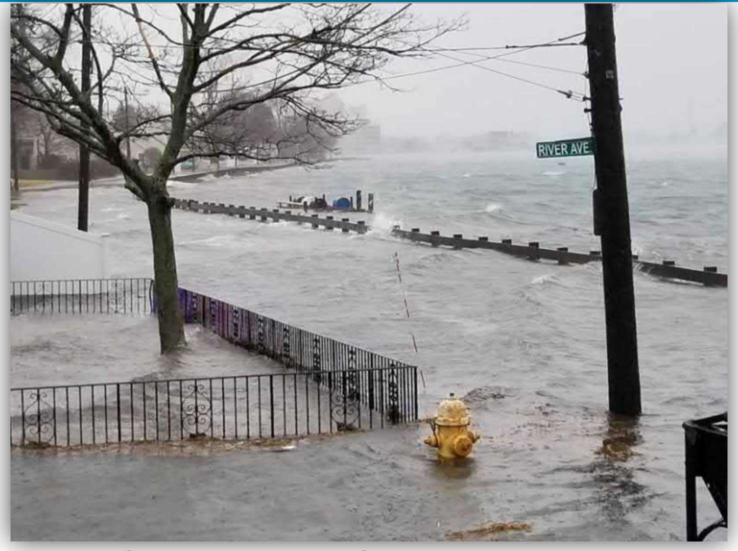
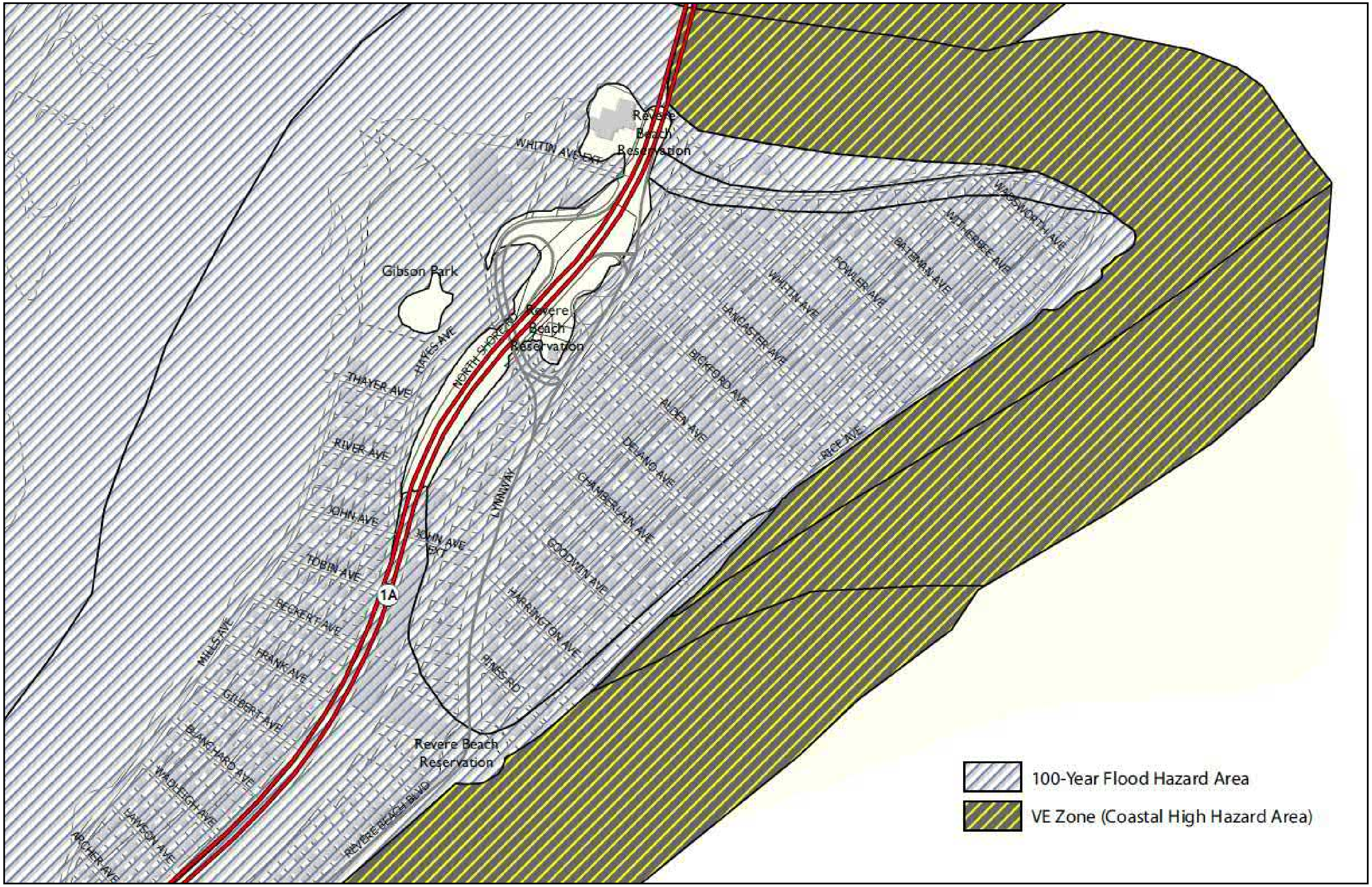


Photo Credit: Loretta LaCentra

Photo Credit: Elaine Hurley

Photo Credit: John Polcari

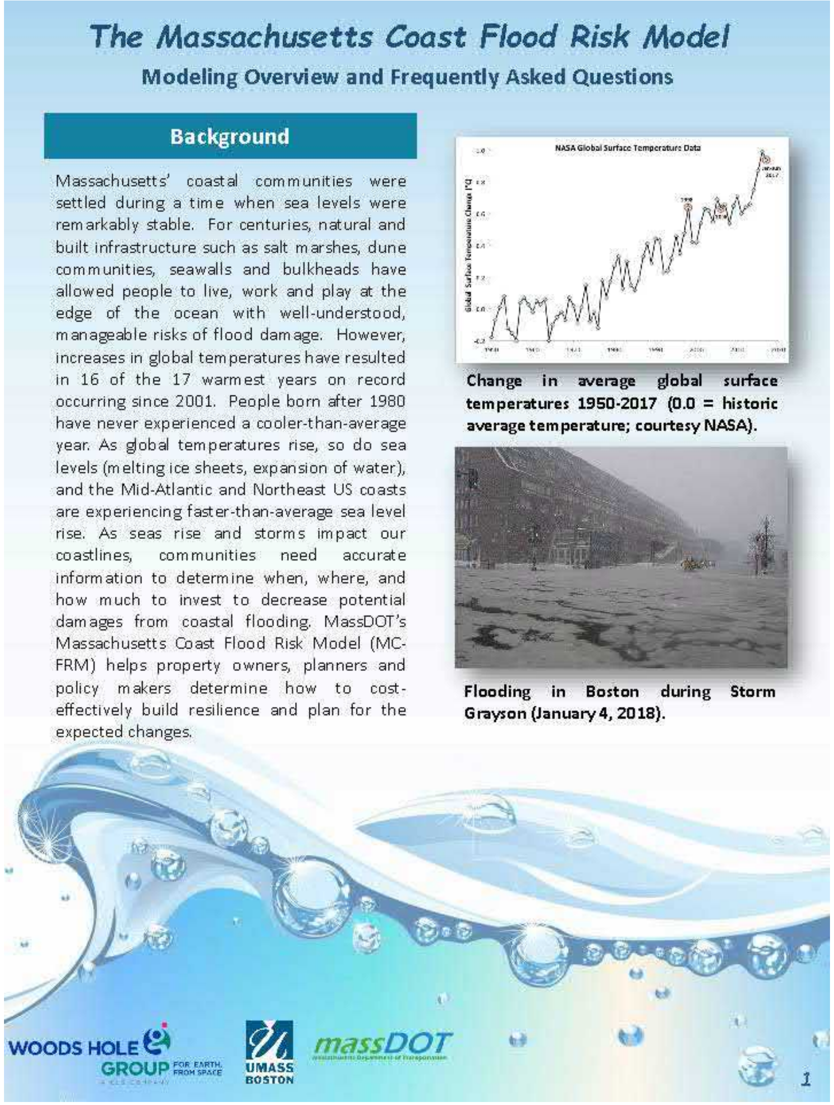
Current FEMA Flood Zone Mapping



Source: MassGIS, FEMA NFHL 1/29/2019

Projected Coastal Flooding

- Central Artery/Tunnel Vulnerability and Adaptation Assessment completed in 2015
  - Created the Boston Harbor Flood Risk Model (BH-FRM) to identify risk and depth of water resulting from storm surge induced coastal flooding
- Massachusetts Coast Flood Risk Model (MC-FRM)
  - Expanded to model entire coast and islands
  - Sea level rise and coastal storms (not extreme precipitation)
  - Used to support regional scale vulnerability analysis and conceptual adaptation strategies
  - Results for Present Day, 2030, 2050, and 2070 (2100 under development)



The Massachusetts Coast Flood Risk Model

Modeling Overview and Frequently Asked Questions

Background

Massachusetts' coastal communities were settled during a time when sea levels were remarkably stable. For centuries, natural and built infrastructure such as salt marshes, dune communities, seawalls and bulkheads have allowed people to live, work and play at the edge of the ocean with well-understood, manageable risks of flood damage. However, increases in global temperatures have resulted in 16 of the 17 warmest years on record occurring since 2001. People born after 1980 have never experienced a cooler-than-average year. As global temperatures rise, so do sea levels (melting ice sheets, expansion of water), and the Mid-Atlantic and Northeast US coasts are experiencing faster-than-average sea level rise. As seas rise and storms impact our coastlines, communities need accurate information to determine when, where, and how much to invest to decrease potential damages from coastal flooding. MassDOT's Massachusetts Coast Flood Risk Model (MC-FRM) helps property owners, planners and policy makers determine how to cost-effectively build resilience and plan for the expected changes.

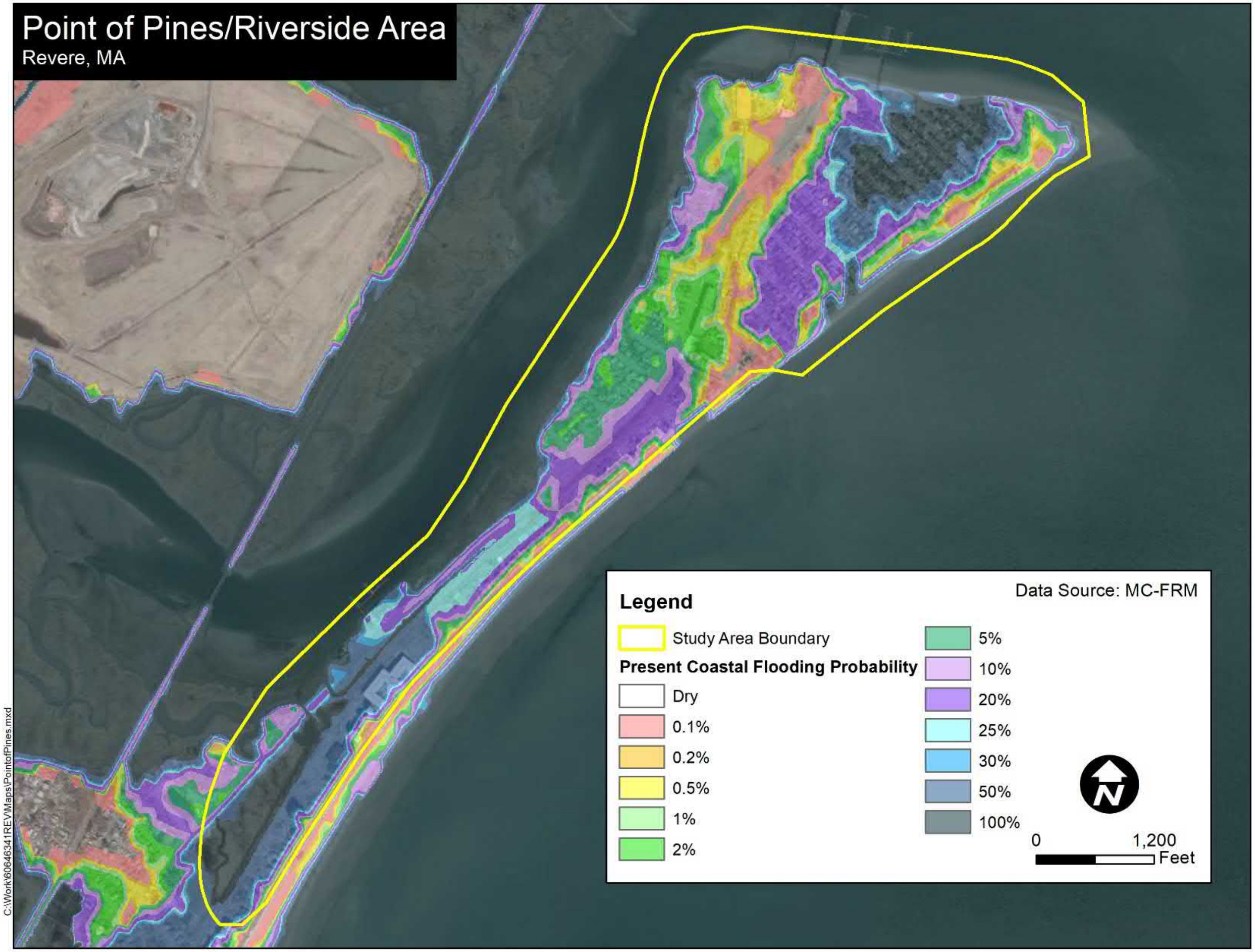
Change in average global surface temperatures 1950-2017 (0.0 = historic average temperature; courtesy NASA).

Flooding in Boston during Storm Grayson (January 4, 2018).

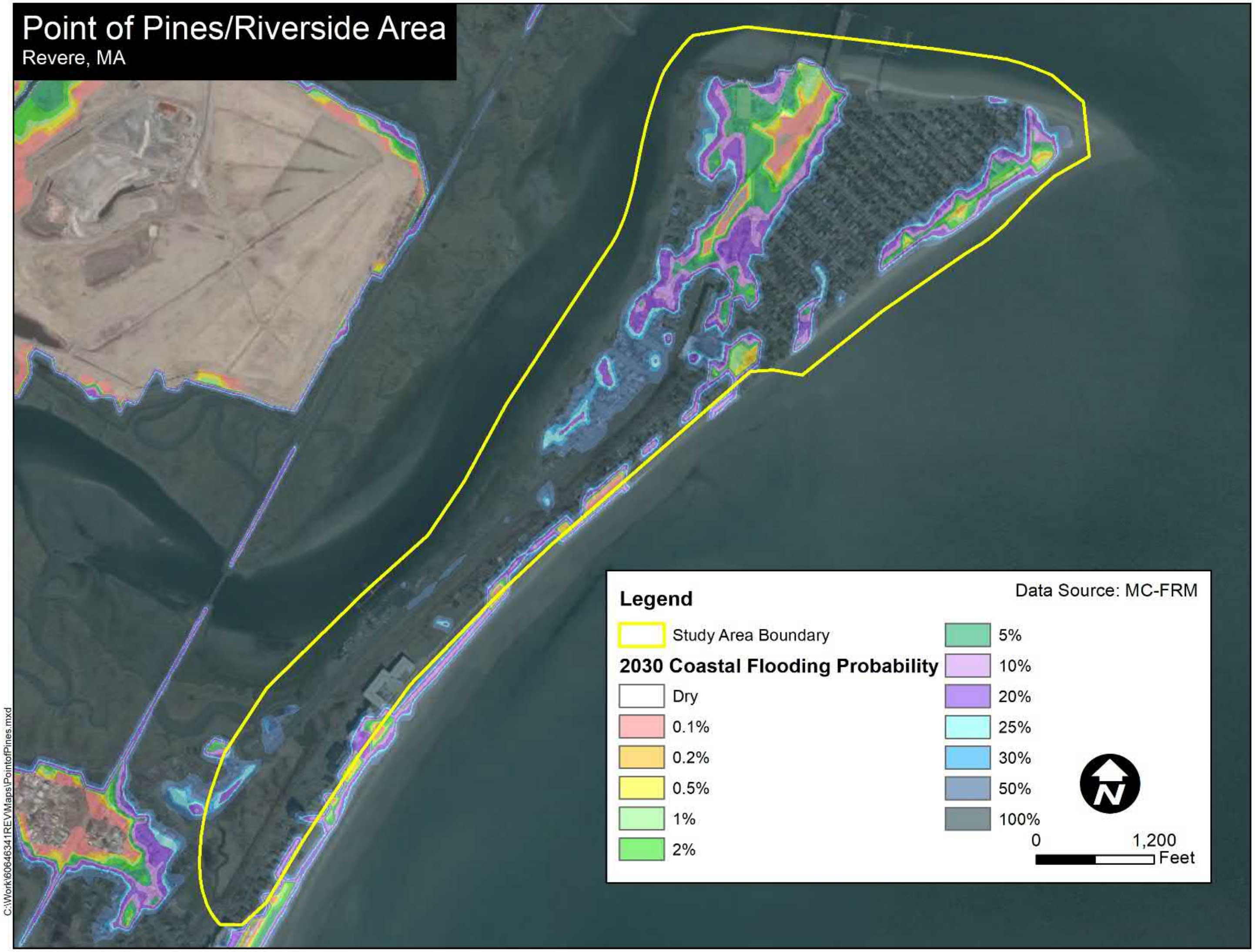
Projected Coastal Flooding

- Annual Coastal Flood Exceedance Probability (ACFEP)
  - Shows the "likelihood" that a location will be flooded
  - Ranges from 0.1% (probability associated with the 1,000-year water surface elevation) to 100% (1-year return period, not the average high tide)
- Estimated Flood Depth
  - Anticipated depth of flood water in affected areas
  - Available for 1% ACFEP (100-year), 0.5% ACFEP (200-year), and 0.1% ACFEP (1,000-year)

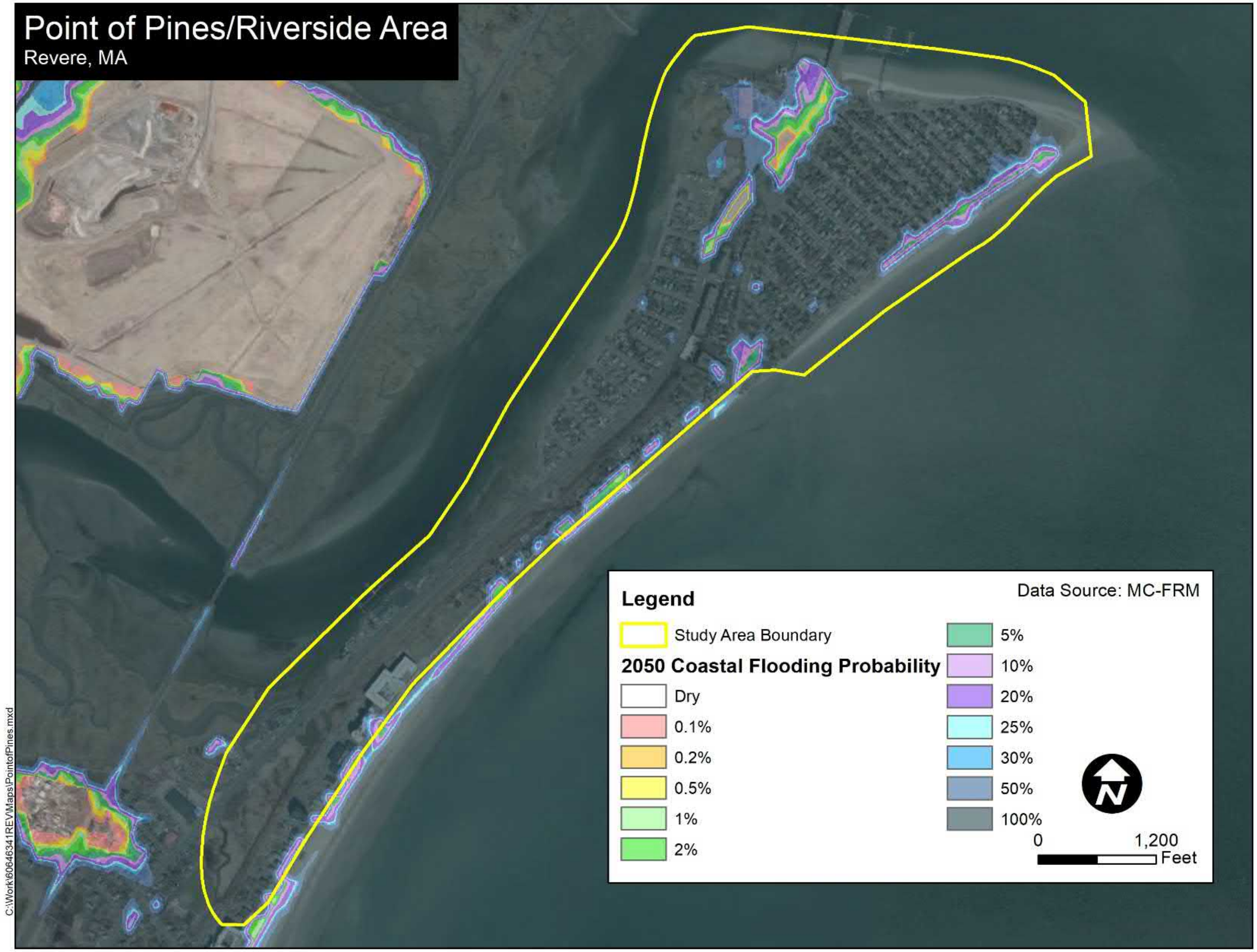
Projected Coastal Flooding – Present Day



Projected Coastal Flooding – 2030



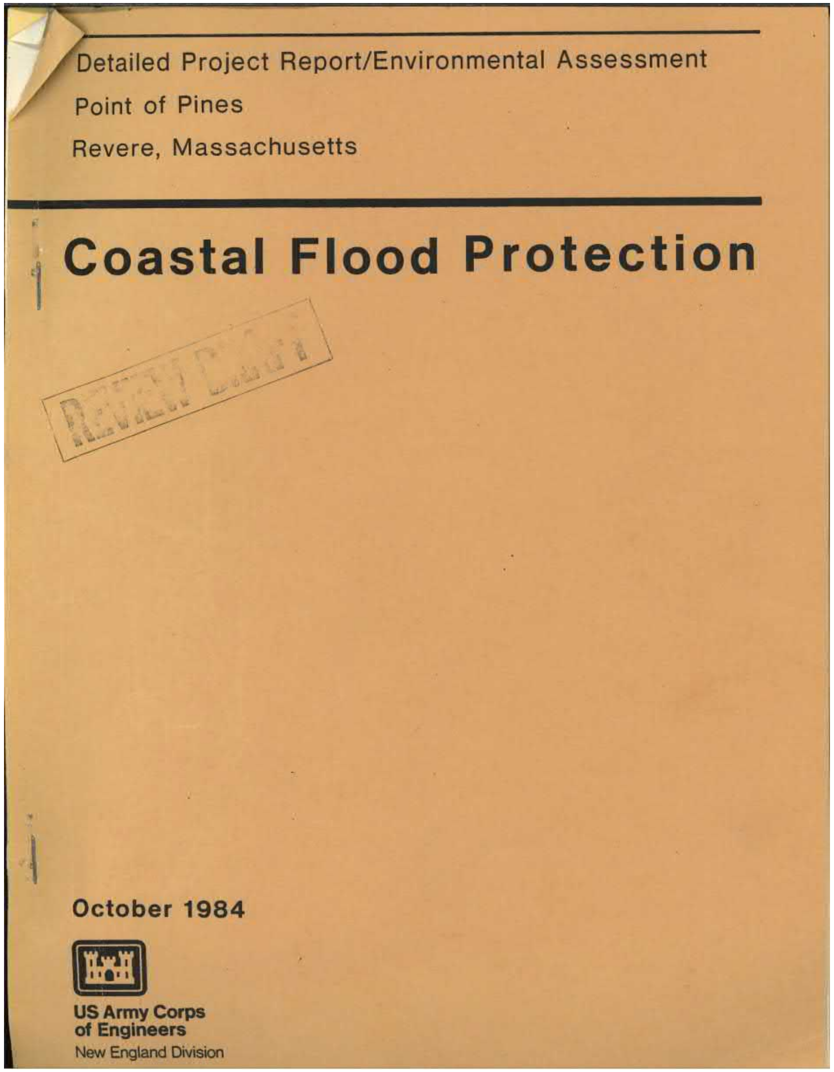
Projected Coastal Flooding – 2050



Projected Coastal Flooding – 2070

Not a New Concern

- Subject of a Coastal Flood Protection study conducted by the U.S. Army Corps of Engineers in 1984
- Recommendations:
  - Rock revetments
  - Sand dune development
  - Beach nourishment
  - Concrete seawall
- Study not implemented
- Dune plantings and seawall repairs carried out by others


Detailed Project Report/Environmental Assessment
Point of Pines
Revere, Massachusetts

Coastal Flood Protection

REVIEW DRAFT

October 1984

US Army Corps
of Engineers
New England Division

Property Ownership Considerations

Time to Take a Fresh Look

- Conduct a new feasibility study to identify potential resilience/adaptation measures
- Identified as a priority action during the MVP planning process
- City awarded a FY2020 MVP Action Grant

MVP Action Grant Scope of Work

- Feasibility study will include:
  - Task 1: Stakeholder Outreach and Engagement
  - Task 2: Assessment of Current and Future Conditions
  - Task 3: Identify Short-Term Resilience Measures
  - Task 4: Develop Coastal Resilience Toolkit
  - Task 5: Assess Feasibility of Coastal Resilience Options
  - Task 6: Point of Pines and Riverside Area Coastal Resilience Feasibility Report

Task 1: Stakeholder Outreach and Engagement

First Workshop:

- Present feasibility study scope of work
- Seek early community input

Second Workshop:

- Share findings from Tasks 2 through 4
- Assess feasibility of coastal resilience options

Third Workshop:

- Present findings of study
- Discuss action items moving forward

Task 2: Assessment of Current and Future Conditions

- Review past studies and reports relevant to project area
- Identify and review up to 5 coastal resilience case studies to inform feasibility study
- Obtain and review existing coastal survey, mapping, and other historical data
- Deliverables: Past Studies and Case Study Memo, Climate Science and Vulnerability Assessment Memo

https://www.revere.org/revere-beach

Task 3: Identify Short-Term Resilience Measures

- Identify temporary and near-term and lower cost actions to implement immediately

- Beach Management Plan will be created
- Emergency Response Plan will be updated
- Point of Pines Beach Association to provide existing concerns

https://floodcontrolinternational.com/products/noaq-boxwall/

Task 4: Develop Coastal Resilience Toolkit

- Identify structural, non-structural, and nature based adaptation measures for climate resilience in the Point of Pines and Riverside Area
- Toolkit will include design components and implementation scenarios for each options

- Example Options:
  - Beach/dune protection
  - Flood storage area creation
  - Wetland preservation and restoration
  - Coastal structures
  - Green infrastructure for stormwater management
  - Living shorelines
  - Floodproofing buildings

Task 5: Assess Feasibility of Coastal Resilience Options

- Develop decision matrix assessing feasibility of various coastal resiliency options
- Matrix will assess:
  - Cost and funding opportunities
  - Ownership
  - Community acceptance
  - Conservation and permitting requirements
  - Identify responsible parties

Task 6: Point of Pines and Riverside Area Coastal Feasibility Report

- Final report including an implementation plan identifying:
  - Action items
  - Responsibilities
  - Potential funding sources

Project Schedule

Proposed Schedule for Point of Pines and Riverside Area Coastal Resilience Feasibility Study

Task	October		November		December		January		February		March		April		May		June	
Task 0: Kick-off meeting with Town, EEA, and Consultant		■																
Task 1: Stakeholder Outreach and Engagement																		
Sub-task 1.1 Workshop #1					■													
Sub-task 1.2 Workshop #2									■									
Sub-task 1.3 Workshop #3															■			
Task 2: Assess Current and Future Conditions																		
Sub-task 2.1 Past Studies and Case Study Memo		■	■	■	■	■	■											
Sub-task 2.2 Climate Science and Vulnerability Assessment Memo		■	■	■	■	■	■	■										
Task 3: Identify Short-Term Resilience Measures																		
Sub-task 3.1 Draft Memo			■	■	■	■	■	■										
Sub-task 3.2 Final Memo									■									
Task 4: Develop Coastal Resilience Toolkit																		
Sub-task 4.1 Draft Memo/Toolkit						■	■	■	■	■								
Sub-task 4.2 Final Memo/Toolkit											■	■						
Task 5: Assess Feasibility of Coastal Resilience Options																		
Sub-task 5.1 Draft Memo										■	■	■	■					
Sub-task 5.2 Final Memo														■	■			
Task 6: Point of Pines and Riverside Area Coastal Resilience Feasibility Report																		
Sub-task 6.1 Draft Report														■	■	■		
Sub-task 6.2 Final Report																	■	■

Collaboration Opportunities

- Other ongoing projects in the study area
  - Boston Region MPO Route 1A Corridor Vulnerability Assessment
  - DCR Revere Beach Reservation Vulnerability Assessment
  - RiverFront District Master Plan
  - Boatyard project

RiverFront District Master Plan

RiverFront District Master Plan

Stormwater and Flooding Review

- There are 5 tributary drainage areas in the Study area
  - Thayer Ave Area
  - Gibson Park Area
  - The western part of the G&J Property
  - The northern part of the G&J Property
  - Mirage Site
- No storage capacity beyond surface flooding
- The outfalls are tidally influenced – can't discharge when the tide is up

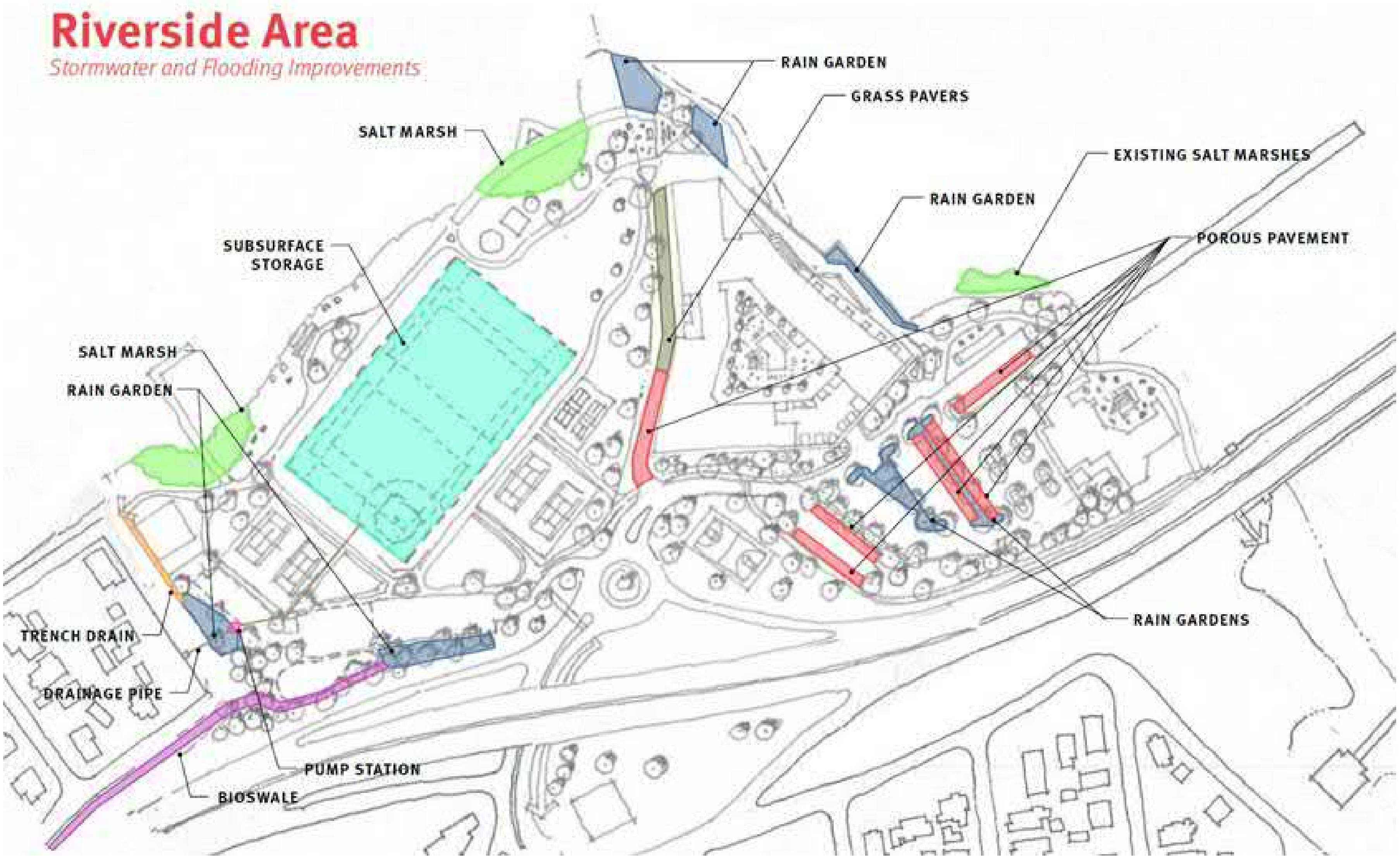
RiverFront District Master Plan

RiverFront District Master Plan

Stormwater and Flooding Proposed Improvements

- Providing relief and storage for the neighborhood and Gibson Park
  - Tie into existing infrastructure on Thayer Ave to provide a "relief valve"
  - Provide a toe drain and raingardens for surface runoff
  - Bioswales and raingardens along North Shore Road to remove flow that currently goes into the neighborhood
  - Subsurface storage under the field
- 210 ft x 360 ft could allow 1.62 to 2.0 acre-feet of storage
- This could store rainfall volume of a 4-inch to a 4.6-inch storm event (10 yr return period)

RiverFront District Master Plan



Stakeholder and Project Partner Feedback and Discussion

Photo credit: Ricci LeCentra

Next Steps

- Second workshop: February 2021
  - Share findings from Tasks 2, 3, and 4
- Third workshop: May 2021
  - Share coastal feasibility study results
  - Discuss climate resiliency actions moving forward

Questions? Please contact Elle Baker, Open Space and Environmental Project Planner at ebaker@revere.org

B. Appendix B: Task 1 Stakeholder Workshop #2 Meeting Minutes and Presentation

AECOM Imagine it. Delivered.

Meeting Minutes

Meeting Name	Meeting date	Attendees
Coastal Resilience Feasibility Study for the Point of Pines/Riverside Area – Stakeholder Workshop #2	February 23, 2021	See Section 1.0 for attendee list
Time	**Location**	
6:00PM	Virtual Zoom Meeting	
AECOM project number	**Prepared by**	
60646341	Aaron Weieneth	

Subject: Coastal Resilience Feasibility Study for the Point of Pines/Riverside Area – Stakeholder Workshop #1

1.0 Introductions

- Attendees:

  AECOM: Amanda Shanahan, Aaron Weieneth, Brian Stobbie, Rickey Torres-Cooban, Tom Touchet, Kira Murphy

  City of Revere: Elle Baker, Frank Stringi, Robert O'Brien, Paul Argenzio, Don Ciaramella

  Project Partners and Other Stakeholders: Carolyn Meklenburg (MVP Regional Support Staff), Steve Miller (MassDOT), Loretta LeCentra (Riverside Area Resident), Jack Polcari (Point of Pines Beach Association), Eric Lampedeccio (Study Area Resident)

- Elle Baker made introductions and turned things over to Aaron Weieneth for the formal presentation. A PDF of the presentation is attached to these notes and provides additional details. Webinar format held on Zoom. The workshop was recorded and also broadcast live on RevereTV and streamed on the City's YouTube channel.
- Aaron Weieneth introduced project and meeting agenda and continued with presentation

2.0 Past Studies and Case Studies (Aaron Weieneth presented)

- Aaron reviewed the past studies and case studies being used by the project team to advise feasibility study.
- He then reviewed ongoing projects within the current project area as well as relevant case studies such as the Breezy Point, NY reconstruction study.

3.0 Climate Science and Vulnerability Assessment (Ricky Torres-Cooban presented)

- Ricky reviewed the draft climate science and vulnerability assessment memo.
- Ricky noted the focus is geared towards sea level rise and coastal flooding, although temperature and precipitation were included.
- Ricky then reviewed City and State-owned critical assets within the study area that AECOM identified in this memo.
- He noted the City does not have mapping for inland flooding, but the team spoke with City members regarding stormwater issues in the study area. Ricky noted the groundwater table is high, which leads to greater flooding issues when a precipitation event coincides with a high tide.
- According to the Massachusetts shoreline change project and datasets, the shorelines within the study area are stable. However, local sources have identified erosion issues along Mills Avenue, Riverside Avenue, and Kerry's Circle. Accretion is also occurring along the northern edge of the Point of Pine by the mouth of the Saugus River.
- Probability and pathways of coastal flooding were evaluated. Ricky noted that flooding in some portions of the study area (particularly along Mills Avenue) is currently happening without any large associated weather event (i.e. during high and king tides).

- The main source of data for the coastal flooding analysis is the Massachusetts Coast Flood Risk Model (MC-FRM). The MC-FRM simulates hundreds of thousands of storms that could occur in the area and generates probability of exposure based on those events and how they play out in the local area. Higher probability areas result in flooding that occurs with a low-level storm event (i.e. a storm with a more frequent recurrence interval).
- Ricky presented the predicted present-day annual probability of flooding results from the MC-FRM for the study area. Where there are two red arrows on the map on the slide shown, there is an existing seawall that is not well represented in the model; in this case the flooding might be exaggerated a little bit. There is another flood pathway on Thayer Avenue and Mills Avenue, but arrows are in orange because the limits of the flooding do not extend inland very far. On Rice Avenue, flooding us usually due to the overtopping of an existing seawall, so this is not necessarily a direct flood pathway. There is another flood pathway Where Mills Avenue meets North Shore Road.
- Ricky then presented the future conditions for the study area and showed the sea level rise predictions from NOAA. Earliest prediction for 1 ft rise is 2025.
- Ricky noted a comparison of existing infrastructure to future flood levels was conducted as part of the assessment.
- Ricky then went over the annual probability of coastal flooding for 2030 based on the MC-FRM results, where it shows flooding will occur at least once a year in the majority of residential areas within the study area. By 2050, the flooding is projected to be widespread.
- Within 40 to 60 years, large areas are predicted to become inundated by daily high tides. Structures along the Pine River and along the northern shoreline near the Point of Pines Yacht Club will lose their ability to provide flood risk reduction as sea levels rise.

4.0 Flood Protection Measures (Kira Murphy presented)

- Kira noted AECOM applied the following criteria for short-term resilience measures: geometric constraints, coastal loading, offsite storage/deployment, and visual impacts.
- First looked at deployable measures. They require an implementation plan, deployment team, and offsite storage location. These measures have a very low visual impact because you do not see them on a daily basis.
- For on-site measures, no deployment is required and they are always on site, but there can be a significant visual impact. Typically these include earth filled structures that area stacked.
- Kira reviewed various potential options and where they could be located within the study to mitigate flooding in the near term. She then noted AECOM looked at critical assets that are likely to be inundated during a current 100-year storm. This would be appropriate locations to use deployable barriers.
- The proposed alignments shown on map in slide in the presentation are preliminary and need more design.

5.0 Beach Management Plan (Tom Touchet presented)

- Tom discussed near term and lower cost options identified in the Beach Management Plan, including 10 categories of recommendations.
- Categories mentioned included:
  - Update record keeping system to include storm events, storm related damage, maintenance, who performed maintenance, should be continually updated (living document).
  - Monitoring of infrastructure and site conditions. This includes conducting annual conditions surveys of things like seawalls, walkways, and sand fences, and suggesting recommendations for repair or replacement.
  - Routine and periodic maintenance such as periodic removal of manmade trash/debris.
  - Potential closure and restoration of existing access paths involves closure and restoration of certain portions of beach to better establish dunes for storm events.
  - Sand augmentation, which includes the addition of sand to augment dunes and the beach in the planning area.
  - Sand fence installation includes adding sand fencing in addition to what has already been installed to further capture sand and maintain dune structures.
  - Elevated walkways to allow beach access but allow sand to migrate underneath walkway. This helps with the establishment of plants and protects plants from foot traffic.

  - Vegetation planting to help stabilize dunes and hold sand in place during weather events.
  - Rare species preservation.
  - Public outreach, like a QR code to educate public.
- Tom then reviewed beach access pathways. Based on modeling, Chamberlain Avenue and Delano Avenue (with Alden Avenue as a potential third) would be recommended for closure due to mapped flood inundation in that area. He then listed other pathways that could remain open with elevated walkways.
- Tom also showed specific locations where elevated walkways could be constructed as well as sand/dune plants added to restore dunes.

6.0 Emergency Response Plan Recommendations (Amanda Shanahan presented)

- Amanda noted that one of the elements of the short-term resilience measures task was to review the City's existing emergency response plan and to identify recommendations based on findings from the study.
- Recommendations include adding decision points for considering coastal flooding impacts on emergency response plan actions and to evaluate/review key access and evacuation routes.

7.0 Coastal Resiliency Toolkit (Kira Murphy presented)

- Kira provided an overview of the development of the Coastal Resiliency Toolkit, which will identify permanent adaptation measure options considered for the study area.
- The toolkit is comprised of three categories:
  - Structural
  - Nature-based
  - Non-structural measures
- Criteria that will be applied to determine the feasibility of the adaptation measure options include relative cost, funding opportunities, ownership, community acceptance, conservation restriction requirements, responsible parties, design criteria, and structural requirements.

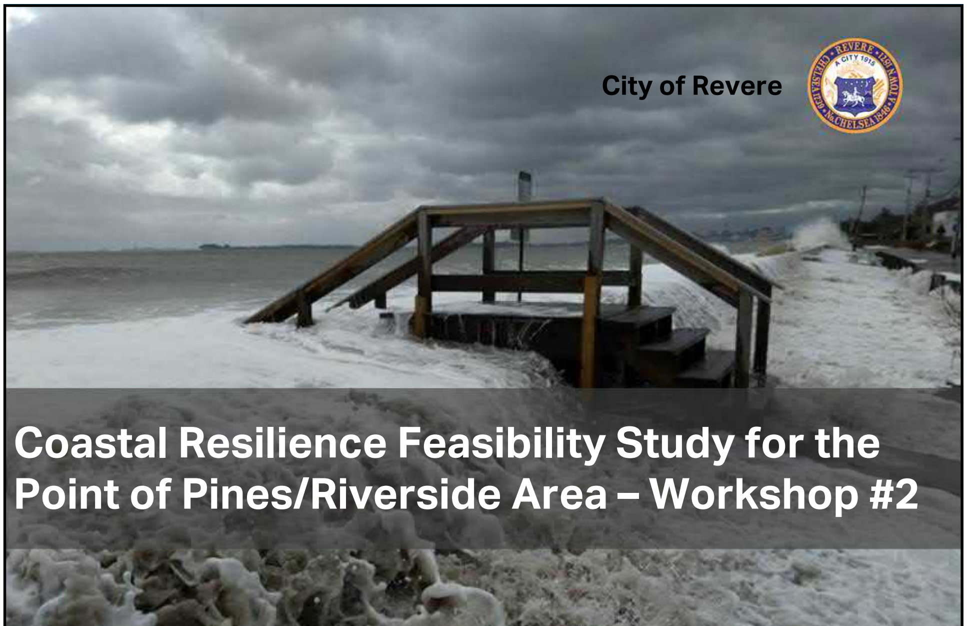
8.0 Wrap Up (Aaron Weieneth presented)

- Aaron reviewed the project schedule, which concludes in June 2021.
- The third and final stakeholder workshop, which is scheduled to take place in April, will look at findings from Tasks 4 and 5 and provide an update on Task 6 (Coastal Resilience Feasibility Report).

9.0 Discussion

- Bob O'Brien noted that the recently approved RiverFront Master Plan includes stormwater resiliency measures for a portion of the study area and thinks we should integrate the two projects. The City's new fire station that will be constructed near Route 1A and proposed reconstruction of the General Edwards Bridge (which spans the Saugus River) should play a role in what we are recommending to the City.
- Elle echoed what Bob stated in regards to the RiverFront Master Plan - specifically plans for Gibson Park and proposed underground stormwater storage near Mills Avenue. These projects could work hand in hand to provide resiliency in that area on a regular basis.
- Steve Miller noted the MC-FRM includes a number of scenarios, which gives the City the chance to prioritize what they want to do at various timesteps so they do not necessarily have to plan for 2100 upfront and have the enormous capital expenditure. Things can change, so he advised the City to keep that in mind as it prepares its budget and consider regional approaches to how various neighboring communities are approaching this.
- Elle stated they will be trying to work with four surrounding communities on coastal resilience efforts and submitted an application for grant funding to establish a regional group.
- Don Ciaramella of 215 Rice Avenue stated there used to be an extensive network of paths to beach before the beach association made dedicated pathways to minimize damage to vegetation.
- Eric Lampedeccio who lives in the study area voiced his thanks to everyone who is participating in the feasibility study.

- Bob O'Brien mentioned increases in flood insurance rates and wonders if recommendations can be used to recruit the insurance industry to finance initiatives that will help to prevent financial losses they will see in the future.
- Jack Polcari thanked Don Ciaramella for the work he did with the planting of dune grass. Regarding the Draft Beach Management Plan, Jack noted that elevated walkways would be expensive. He believes sand fencing, vegetation planting, and walkway closures are more realistic options to proceed with.
- Aaron Weieneth noted the Beach Management Plan will be updated to reflect existing sand fencing.
- Elle Baker noted there are areas that need beach nourishment, and there is a need to prioritize these areas prior to additional vegetation planting.
- Bob O'Brien referenced the important of documenting things and getting photos from community members to create a timeline to aid in identifying the changing coastline.
- Don Ciaramella noted he feels the Point of Pines area is off and running and they have the ability to pump water out that comes in. Flooding in the Riverside portion of the study area is his primary concern because the frequent flooding is already occurring. This portion of the study area needs help now, and the City needs to consider permanent solutions such as installation of sea walls and a pump station.
- Frank Stringi referenced the City's cleanup efforts that are required following a coastal storm event. More and more sand is overtopping the sea walls and coming into streets. There is a need to think about increasing equipment and staffing capacity to accommodate more frequent cleanup needs.
- Steve Miller cautioned that when it comes to deployable measures, the City needs to consider who can deploy the materials. Often there is a need to rely on contractors due to limited staffing and local capacity.



Coastal Resilience Feasibility Study for the Point of Pines/Riverside Area – Workshop #2

February 23, 2021

AECOM

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Coastal Resilience Feasibility Study for the Point of Pines/Riverside Area – Stakeholder Workshop #2

Elected Officials

- Mayor Brian Arrigo
- Ward 5 Councilor, John Powers

Revere City Staff

- Robert O'Brien – Director, Revere Office of Planning and Development
- Elle Baker – Project Planner
- Frank Stringi – City Planner
- Don Ciaramella, Superintendent Water, Sewer and Drain
- Joe Maglione – Assistant Superintendent Water, Sewer and Drain
- Paul Argenzio – Superintendent Revere Department of Public Works
- Nick Moulaison – Conservation Commission

Project Consultants – AECOM

- Aaron Weieneth – Project Manager
- Ricky Torres-Cooban – Resilience Specialist
- Kira Murphey – Structural Engineer
- Tom Touchet – Environmental Scientist
- Amanda Shanahan – Water Resources Engineer

Project Partners

- Loretta LeCentra – Riverside Area Resident
- Elaine Hurley – Riverside Area Resident
- John Polcari – Point of Pines Beach Association
- Angela Sawaya – Point of Pines Beach Association
- Stacy Livote – The Marina Restaurant
- Carolyn Meklenburg – MVP Regional Coordinator
- Greg Robbins – DCR Waterways
- Mary Lester – Saugus River Watershed Council
- Michelle O'Toole – MEMA, Hazard Mitigation Planning
- Brian Lajiness – MBTA, Manager of Emergency Operations
- Steve Miller –MassDOT, Climate Change Project Manager

POINT OF PINES / RIVERSIDE RESILIENCE City of Revere 2 AECOM

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Agenda

1. Welcome and Introductions
2. Draft Past Studies and Case Studies Memo
3. Draft Climate Science and Vulnerability Assessment Memo
4. Draft Short-Term Resilience Measures Memo
5. Draft Point of Pines Beach Management Plan
6. Coastal Resilience Toolkit In Development
7. Criteria for Feasibility Review of Resilience Options
8. Questions and Discussion
9. Next Steps

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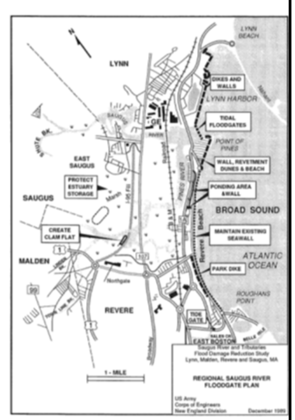
Draft Past Studies and Case Studies Memo

- Route 1A Corridor Vulnerability Assessment, 2020
  - Pilot Study to identify problems and recommend solutions to make Route 1A more resilient.
- Revere MVP Planning Workshop Findings Report, 2019
  - Identified top climate change hazards and vulnerabilities in the City and ranked priority adaptation actions.
- Revere Hazard Mitigation Plan, 2015
  - Report focused on identifying natural hazards and providing a list of future response actions needed promote resilience in the event of a natural hazard occurrence.
- USACE Revere Beach Erosion Control Report, 1991
  - Discussed primary reasons for beach advancement and shoreline erosion and suggested potential mitigation strategies for beach preservation.
- USACE Flood Damage Reduction Study for the Saugus River and Tributaries, 1990
  - Investigation of potential regional solutions to protect against coastal flooding.



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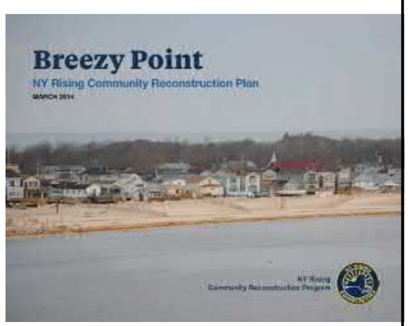
Draft Past Studies and Case Studies Memo

- RiverFront Master Plan (approved)
  - Exploring redevelopment opportunities and challenges related to the district in and around Gibson Park.
  - Identifying targeted interventions to reduce the impact of extreme events.
- Waterfront Access Development 29 Thayer Ave (ongoing)
  - Planning report for waterfront development.
  - Develop waterfront facilities for rowing activities.
  - Create public waterfront access facility.
- Revere Beach Reservation Vulnerability Assessment (ongoing)
  - Being conducted by MA Department of Conservation and Recreation

Draft Past Studies and Case Studies Memo

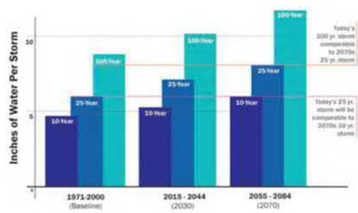
- Coastal Resiliency Planning, Falmouth, 2020
  - MVP planning process evaluated high priority areas in Falmouth vulnerable to flooding and erosion and recommended actions to provide resilience.
- Manchester-by-the-Sea Sawmill Brook Restoration, 2019
  - Recommended salt marsh planning and flexible block retaining wall with public stairway providing access to water.
- Resilient Cape Cod Project, 2018
  - Focused on identifying natural hazards effecting Cape Cod and developing a Coastal Planner tool.
- Climate Ready Boston, 2016
  - Established the roadmap for the City of Boston to plan for the impacts of climate change and build a resilient future, with an emphasis on addressing coastal flooding.
- Breezy Point – NY Rising Community Reconstruction Plan, 2014
  - Focused on coastal adaptation strategies to help mitigate effects of future climate change events on the Rockaway Peninsula in Queens, NY.



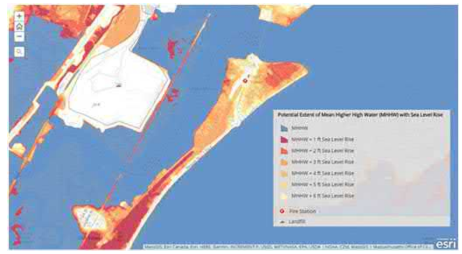
Draft Climate Science and Vulnerability Assessment Memo

Climate Science Review

- Temperature
- Precipitation
- Sea level change and coastal flooding



Source: Cambridge CCVA, 2015



Source: MA Sea Level Rise and Coastal Flood Viewer

Temperature Indicator	Baseline (Days)	Percentile of Model/Scenario Output	2030s (Days)	2050s (Days)	2070s (Days)	2090s (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

Source: Resilient MA

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Draft Climate Science and Vulnerability Assessment Memo

Critical Assets to City and State Infrastructure

- Sea walls and rock revetment
- 4 bus stops
- General Edwards Bridge
- 5 highway culverts
- 7 tide gates
- 15 stormwater outfalls
- 1 wastewater pump station
- 1 stormwater pump station
- 1 fire station
- 1 adult day care center
- Gibson Park

POINT OF PINES / RIVERSIDE RESILIENCE City of Revere 8 AECOM

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Draft Climate Science and Vulnerability Assessment Memo

Existing Conditions
Vulnerability

- Stormwater and groundwater
- Erosion
- Coastal flooding
  - Probability of flooding
  - Pathways of flooding

9/22/2020 Flooding on Mills Avenue
Source: City of Revere

Draft Climate Science and Vulnerability Assessment Memo

Understanding Flood Exceedance Probabilities
Massachusetts Coast Flood Risk Model (MC-FRM)

- Annual chance that a location will be inundated by coastal flood waters
- Calculated by simulating hundreds to thousands of storms
  - Hurricanes
  - Nor'easters
- High probability areas are at greater flood risk
- Low probability areas are less likely to be inundated by a flood event

Example:

1% (.01) annual probability of exceedance = 1% (1 in 100) annual chance of being equaled or exceeded in any given year

Predicted Present Day Annual Probability of Flooding

FIGURE A-1
POINT OF PINES/RIVERSIDE AREA
MASSACHUSETTS COAST FLOOD RISK MODEL (MC-FRM) PREDICTED PRESENT DAY ANNUAL PROBABILITY OF FLOODING - EAST

POINT OF PINES / RIVERSIDE RESILIENCE City of Revere 11 AECOM

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Predicted Present Day Annual Probability of Flooding

FIGURE A-5
POINT OF PINES/RIVERSIDE AREA
MASSACHUSETTS COAST FLOOD RISK MODEL (MC-FRM) PREDICTED PRESENT DAY ANNUAL PROBABILITY OF FLOODING - MID

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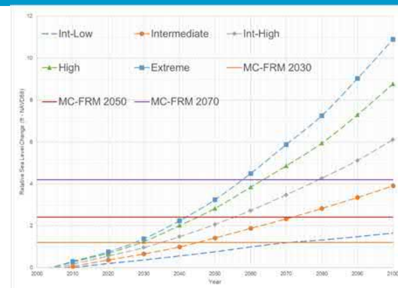
Draft Climate Science and Vulnerability Assessment Memo

Future Conditions Vulnerability

- Stormwater and groundwater
- Erosion
- Coastal flooding
  - Probability of flooding
  - Timing of permanent inundation
  - Comparison of existing infrastructure to future flood levels



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

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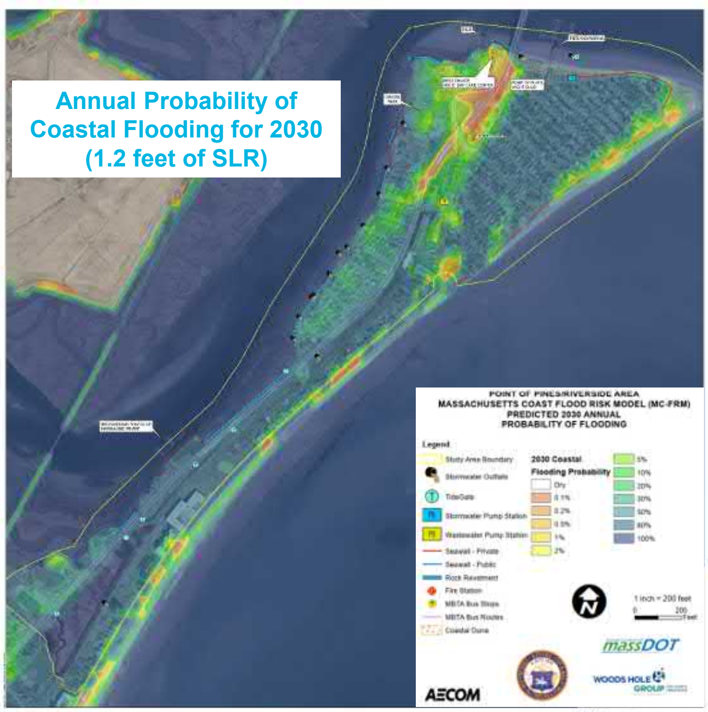

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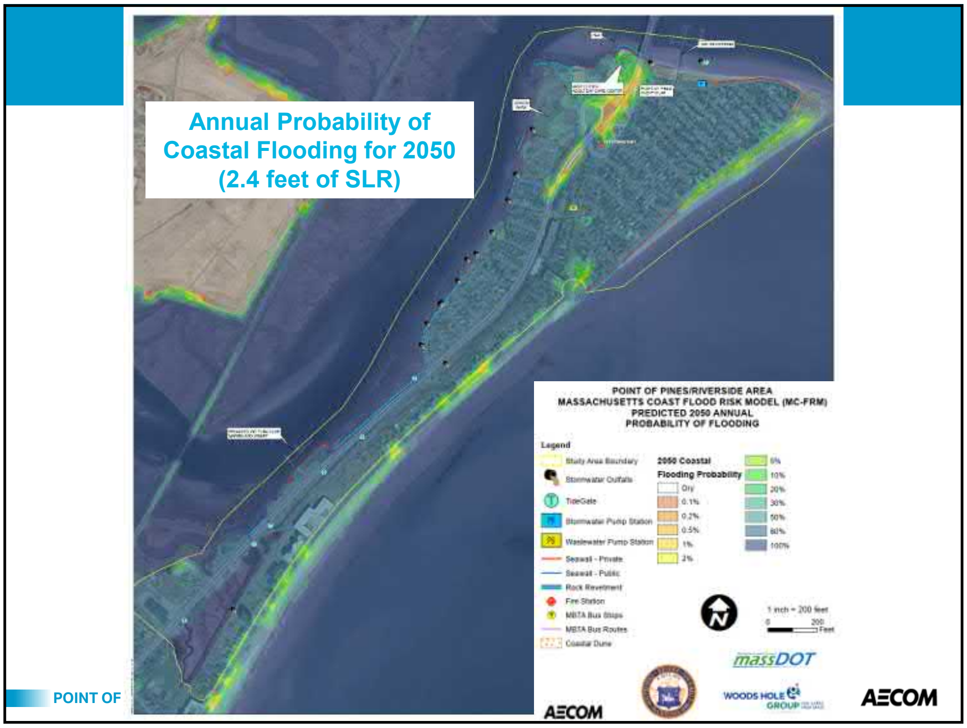
Annual Probability of
Coastal Flooding for 2050
(2.4 feet of SLR)
POINT OF PINES/RIVERSIDE AREA
MASSACHUSETTS COAST FLOOD RISK MODEL (MC-FRM)
PREDICTED 2050 ANNUAL
PROBABILITY OF FLOODING
Legend
Study Area Boundary
Stormwater Outfalls
TideGate
Stormwater Pump Station
Wastewater Pump Station
Seawall - Private
Seawall - Public
Rock Revetment
Fire Station
MBTA Bus Stops
MBTA Bus Routes
Coastal Dune
2050 Coastal
Flooding Probability
Dry
0.1%
0.2%
0.5%
1%
2%
5%
10%
20%
30%
50%
80%
100%
1 inch = 200 feet
0
200
Feet
massDOT
WOODS HOLE GROUP
AECOM
AECOM
POINT OF

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Annual Probability of
Coastal Flooding for 2070
(4.2 feet of SLR)
POINT OF PINES/RIVERSIDE AREA
MASSACHUSETTS COAST FLOOD RISK MODEL (MC-FRM)
PREDICTED 2070 ANNUAL
PROBABILITY OF FLOODING
Legend
Study Area Boundary
Stormwater Outfalls
TideGate
Stormwater Pump Station
Wastewater Pump Station
Seawall - Private
Seawall - Public
Rock Revetment
Fire Station
MBTA Bus Stops
MBTA Bus Routes
Coastal Dune
2070 Coastal
Flooding Probability
Dry
0.1%
0.2%
0.5%
1%
2%
5%
10%
20%
30%
50%
80%
100%
1 inch = 200 feet
0
200
Feet
massDOT
WOODS HOLE GROUP
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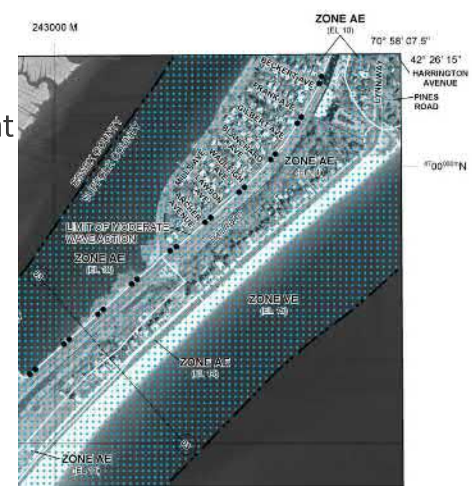
Draft Climate Science and Vulnerability Assessment Memo- Conclusions

- Within 40 to 60 years, large areas are predicted to become become inundated by daily high tides
- Four coastal flood pathways identified as the most vulnerable shoreline locations where flood waters are currently able to overtop the shoreline and cause widespread inland flooding
- Structures along the Pines River to the west and along the northern shoreline near the PoP Yacht Club are most vulnerable to storm surge and rapidly lose their ability to provide flood risk reduction as sea levels rise

Draft Short-Term Resilience Measures Memo- Screening Criteria

- Geometric Constraints
- Coastal Loading
- Structural System
- Offsite Storage/Deployment
- Visual Impact



Draft Short-Term Resilience Measures Memo

Deployable Measures

- Require storage at a secondary location
- Require a deployment team/plan
- Less visual impact


Aquafence, Brooklyn, NY


Tiger Dams Lumberton, NC


Stop Logs, Aquarium Station, Boston, MA


Tubewall Sheffield, England

Draft Short-Term Resilience Measures Memo

On-Site Measures

- No deployment required
- Significant day to day visual impact


DefendCell, California


Hesco Barriers, Kane Berm, Hackensack, NJ


Sandbag Wall Cape Girardeau, MO


TrapBags, Sarasota, FL

Draft Short-Term Resilience Measures Memo

Resiliency Measure	Max Height	Coastal Loading	Anchor System Required	Storage/ Deployment Required	Visual Impact	Material Cost per LF
Aquafence	9 ft	✓[1]	✓	✓	Low	$$$
Tiger Dams	32 ft	✓	✓	✓	Low	$
Tubewall	40 in	✓	X	✓	Low	$$
Stoplogs	14 ft	✓	✓	✓	Low	$$$
Boxwall	20 in	X	X	✓	Low	$
INERO Flood Panel	5 ft	X	X	✓	Low	$$$
DefenCell	15 ft	✓	X	X	Medium	$
Geocell RDFW	72 in	✓	X	X	Medium	$$
Hesco Barriers	20 ft	✓	X	X	High	$
Trap Bags	42 ft	✓	X	X	High	$
Sandbag Wall	42 ft	✓	X	X	High	$

1. Coastal AE Only

Draft Short-Term Resilience Measures Memo – Locations for Short-Term Risk Reduction Measures

Draft Beach Management Plan

- Purpose of plan is to provide near-term and lower cost actions that can be implemented
  – Plan includes 10 categories of recommended actions

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Draft Beach Management Plan

Recommendations include:

- Establishment and use of a record-keeping system
- Monitoring of infrastructure and site conditions
- Routine and periodic maintenance
- Potential closure and restoration of some existing access paths
- Sand augmentation
- Sand Fence Installation
- Elevated walkways
- Vegetation Planting
- Rare species preservation
- Public education, outreach, and signage

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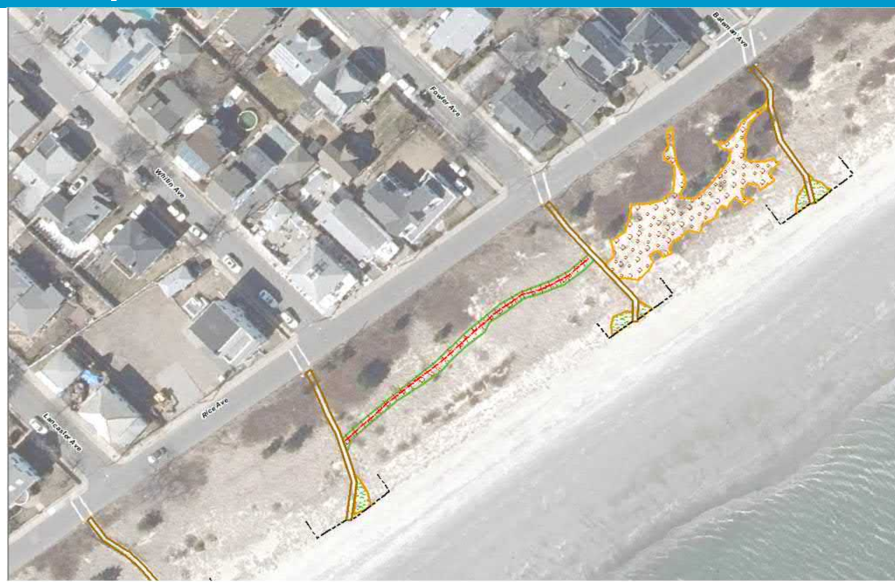
Beach Access Pathways

- Fewer beach access paths are better from an ecological, flood protection, and erosion minimization perspective
- Pathways proposed for potential closure due to higher risk of flooding include:
  - Chamberlain Ave.
  - Delano Ave.
  - (Alden Ave.)
- However, if pathways remain open, they could be constructed as elevated walkways:
  - Wadsworth Ave.
  - Witherbee Ave.
  - Bateman Ave.
  - Fowler Ave.
  - Whitin Ave.
  - Lancaster Ave.
  - Bickford Ave.

Draft Beach Management Plan – Graphic Example

Draft Beach Management Plan – Graphic Example



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Draft Beach Management Plan – Graphic Example

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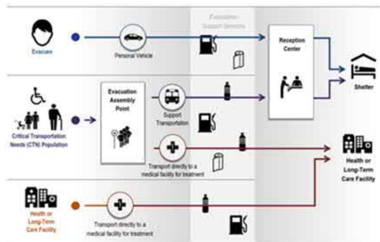
Emergency Response Plan

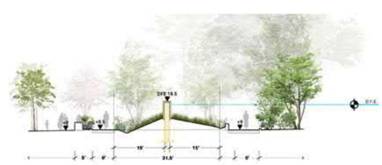
- Outline Strategy for Sheltering-in-Place versus Evacuation
- Three Emergency Shelters
  - A.C. Whelan Elementary School
  - Garfield Middle School
  - Revere High School
  - Senior Center
- Recommendations
  - Add Decision Points to Consider Coastal Flooding Impacts on recommended actions
  - Key Access Route Review



Development of Coastal Resilience Toolkit

Permanent Adaptation Measures to be Considered

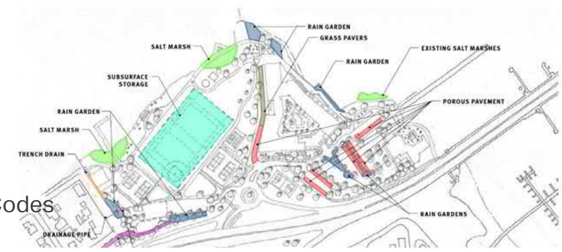
- Structural
  - Flood storage area creation
  - Bioretention basins
  - Green infrastructure for stormwater managen
  - Impervious surface removal/reduction
  - Coastal
  - Offshore structures
  - Pump stations
  - Elevating roadways
  - Elevating buildings
  - Relocating buildings
  - Floodproofing buildings
  - Riverfront masterplan
    - Decreasing Tributary Area/Relocating Stormwater
    - New Pump Station near Boatworks



Development of Coastal Resilience Toolkit

Permanent Adaptation Measures to be Considered

- Nature-Based
  - Beach/dune protection and erosion control
  - Wetland and habitat preservation and restoration
  - Living shorelines
- Non-Structural
  - Land Acquisition
  - Public Education
  - Evacuation Procedures
  - Local Building and Zoning Codes



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Criteria for Feasibility Assessment

- Relative Cost
- Funding Opportunities
- Ownership
- Community Acceptance
- Conservation Restriction Requirements
- Permitting Requirements
- Responsible Parties
- Structural Requirements
- Design Criteria

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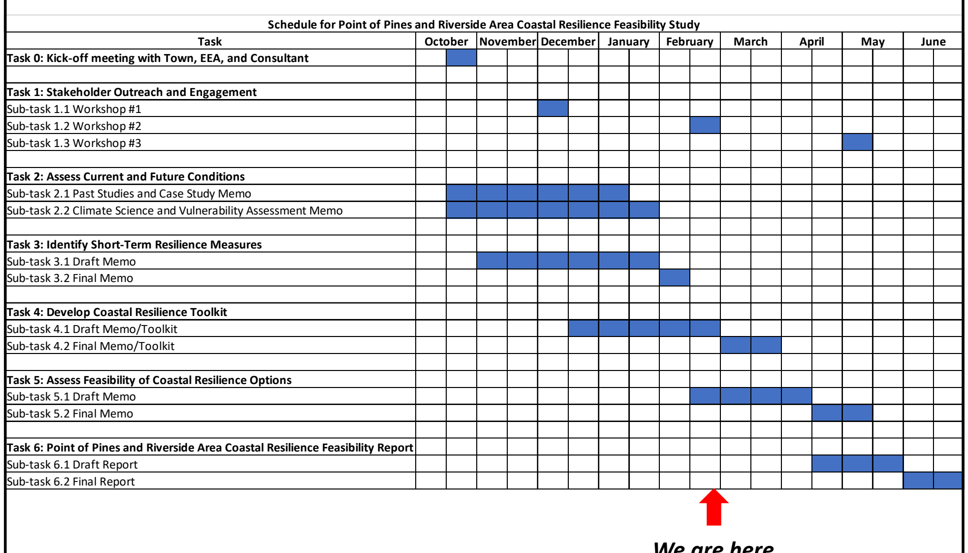
Recap of Preliminary Findings

- Not starting at square one – many resources and past studies are informing the project
- Areas along the Pines River to the west and along the northern shoreline near the PoP Yacht Club are most vulnerable to storm surge and rapidly lose their ability to provide flood risk reduction as sea levels rise
- Short-term measures can be implemented to provide some relief
- While the focus of the study is to identify resilience actions that Revere can take, a regional solution involving neighboring communities should be explored

Project Schedule



Next Steps

- Third stakeholder workshop: TBD, early May
  - Findings from Task 4: Develop Coastal Resilience Toolkit
  - Findings from Task 5: Assess Feasibility of Coastal Resilience Options
  - Update on Task 6: Feasibility Report, Including Implementation Plan Identifying Priority Action Items

Questions? Please contact Elle Baker, Open Space and Environmental Project Planner at ebaker@revere.org

C. Appendix C: Task 1 Stakeholder Workshop #3 Meeting Minutes and Presentation

Meeting Minutes

Stakeholder Workshop #3 Coastal Resilience Feasibility Study for the Point of Pines/Riverside Area	**Meeting date** June 15, 2021	**Attendees** See Section 1.0 for attendee list
Time 6:00PM	**Location** Virtual Zoom Meeting	
AECOM project number 60646341	**Prepared by** Tom Redstone	

Subject: Coastal Resilience Feasibility Study for the Point of Pines/Riverside Area – Stakeholder Workshop #3

1.0 Introductions

- Attendees:

  AECOM: Jennifer Doyle-Breen, Kira Murphy, Aaron Weieneth, Brian Stobbie, Ricky Torres-Cooban, Tom Redstone

  City of Revere: Elle Baker, Frank Stringi, Bob Hunt, Paul Argenzio, Ward 5 Councilor John Powers

  Project Partners: John Polcari (Point of Pines Beach Association), Carolyn Meklenburg (MVP Regional Support Staff), Greg Robbins (DCR)

- Elle Baker and Aaron Weieneth made introductions and opening remarks before turning the discussion over to Jennifer Doyle-Breen and other AECOM staff for the remainder of the presentation. A PDF of the presentation is attached to these notes and provides additional details.
- Jennifer cautioned that the findings to be presented are planning level estimates and were determined using the best available data to the Commonwealth.

2.0 Review of Future Conditions

- Jennifer provided a recap of Workshop #2, re-orienting attendees to the existing and projected future conditions of the Point of Pines / Riverside Study Area (Study Area):
  - Included a review of the current sea level and visualized the impacts of 1-foot of sea level rise (anticipated to occur around 2030 in the MassDOT/Woods Hole Group MC-FRM model). As shown in the visual, it is anticipated the southwest portion of the Study Area will be most affected by 1-foot of sea level rise.
  - Included a visual of the impacts of 2-feet of sea level rise (anticipated to occur around 2050 in the MassDOT/Woods Hole Group MC-FRM model). As shown in the visual, the area of the Boatworks property is anticipated to experience flooding from 2-feet of sea level rise.
  - Included a visual of the impacts of 4-feet of sea level rise (anticipated to occur around 2070 in the MassDOT/Woods Hole Group MC-FRM model). As shown in the visual, much of the Study Area is anticipated to be inundated during daily high tides by 2070.
  - The next 30 to 50 years may be a tipping point for the Study Area as a significant portion is likely to be inundated by water during a typical high tide.

3.0 Coastal Resilience Toolkit

- Jennifer continued with a summary of strategies that were included in the Coastal Resilience Toolkit. This included a review of the following flood risk reduction measures that were assessed:
  - Flood walls
  - Deployable structures

  - Offshore structures
  - Elevating roadways
  - Elevating buildings
  - Relocating buildings
  - Floodproofing buildings
- A review of the following stormwater management strategies was provided:
  - Flood storage area creation
  - Bioretention basins
  - Green infrastructure
  - Impervious surface removal
  - Pump stations
  - Backflow prevention
- Nature-based coastal resilience adaptation options included:
  - Beach/dune protection/restoration
  - Wetland/habitat preservation/restoration
  - Living shorelines
- Non-structural adaptation options included:
  - Land acquisition
  - Public education
  - Evacuation procedures
  - Local building and zoning codes
- A Resilience Toolkit one-page flyer was developed that can be shared with other coastal Massachusetts communities that are also looking at coastal resilience measures.

4.0 Criteria for Feasibility Review of Resilience Options

- Jennifer outlined the following criteria for the feasibility review of resilience options:
  - Control of future predicted floodwaters
  - Funding opportunities
  - Ownership
  - Community acceptance
  - Conservation restriction requirements
  - Permitting complexity
  - Relative cost

5.0 Results of Feasibility Decision Matrix

- Feasibility summary was provided for the following resilience tools:
  - Flood barriers/deployables – due to the relatively high cost these are most feasible when used for protecting large residential neighborhoods.
  - Floodproofing/relocation – this tool is not feasible for individual residences, but applicable to protecting individual critical community buildings.

- Backflow prevention – all stormwater outfalls discharging to the Pines River should be evaluated to assess whether this tool is currently in place, and if not repairs/new backflow prevention measures should be installed.
- Stormwater flood storage – may be feasible at Gibson Park, per the Riverside Master Plan although further confirmation required during preliminary design.
- Pump station - may be feasible adjacent to Mills Avenue/Gibson Park, per the Riverside Master Plan although further confirmation required during preliminary design.
- Impervious cover reduction – may be feasible at Riverfront District as area is redeveloped.
- Living shorelines– may be feasible at Riverfront District as area is redeveloped
- Salt marsh restoration/creation – may be feasible at Riverfront District as area is redeveloped
- Dune protection/restoration – measures for dune protection at Point of Pines Beach Association dunes were outlined in Beach Management Plan and may be feasible with low cost; dune restoration in this area will be challenging due to high cost and low potential for grant funding
- Emergency response – updates to the existing Emergency Response Plan are needed

6.0 Resilience Options

- Kira Murphy continued the presentation with a review of the details of potential flood barrier options; she began with a review of anticipated inundation depths at the following scenarios:
  - 2030 1-percent annual probability storm
  - 2070 1-percent annual probability storm
- Presentation continued with a summary of the design flood elevations necessary to protect Class 2 (large residential areas) and Class 3 (critical infrastructure) developments from the projected 1-percent annual probability storms in 2030 and 2070.
- Alignment A:
  - Designed to protect the Mills Road neighborhood adjacent to the Pines River. The Alignment A, 1-percent maximum Height of Intervention (HOI) ranges from 4.7 feet (2020) to 8.9 feet (2070).
  - Protection from the 2020 1-percent annual probability storm includes a combination of flood walls and deployables. Deployable flip-up gates are proposed at Route 1A.
  - Protection from the 2070 1-percent annual probability storm includes lengthening the median flood wall along Route 1A and increasing HOI.
- Alignment B:
  - Designed to protect the Point of Pines side of the peninsula. The Alignment B1, 1-percent maximum HOI ranges from 4.2 feet (2020) to 9.6 feet (2070).
  - Measures for 2030 10% storm begin with flip up gates at southern tie in and along Bryce Ave, fixed floodwalls, and deployables such as flip up gates or aquafence.
  - Flip up gates are flush with grade, can be self-rising, may rise with buoyancy during floods, or with manual power. Flip up gates have been implemented throughout US and do not require a lot of above grade space.
  - Protection from the 2070 1-percent annual probability storm includes extending the alignment on the northern and southern areas. The alignment would need to extend towards Carey Circle and through private property to tie in to Route 1A.
- Alignment C:
  - Designed to protect the neighborhoods south of Route 1A. The Alignment C, 1-percent maximum HOI ranges from 4.3 feet (2020) to 8.5 feet (2070).
  - Southern tie-in would fall outside of the project Study Area and would require constructing a floodwall along the backyards of private residential properties as well as in close proximity to the Railroad Right of Way.

- Kira provided a review of the maximum 1-percent HOI needed I to protect critical infrastructure assets (wastewater pump station, stormwater pump station, adult daycare facility, and fire station) at 2020, 2030, and 2070 projections.
- Kira concluded her section with planning level cost estimates for flood protection scenarios evaluated.
- Aaron Weieneth ended the presentation with the following conclusions:
  - There are many applicable tools to be considered, no “one size fits all” strategy exists.
  - Residential protection to the 2030 10-year storm is feasible.
  - It is challenging to protect beyond the 2030 10-year storm due to the lack of high ground in the Study Area, costs, and impacts on the quality of life.
  - Floodproofing of the wastewater and stormwater pump stations and fire station is under evaluation.
  - Larger scale/regional solutions may be more cost effective.

7.0 Questions and Discussion

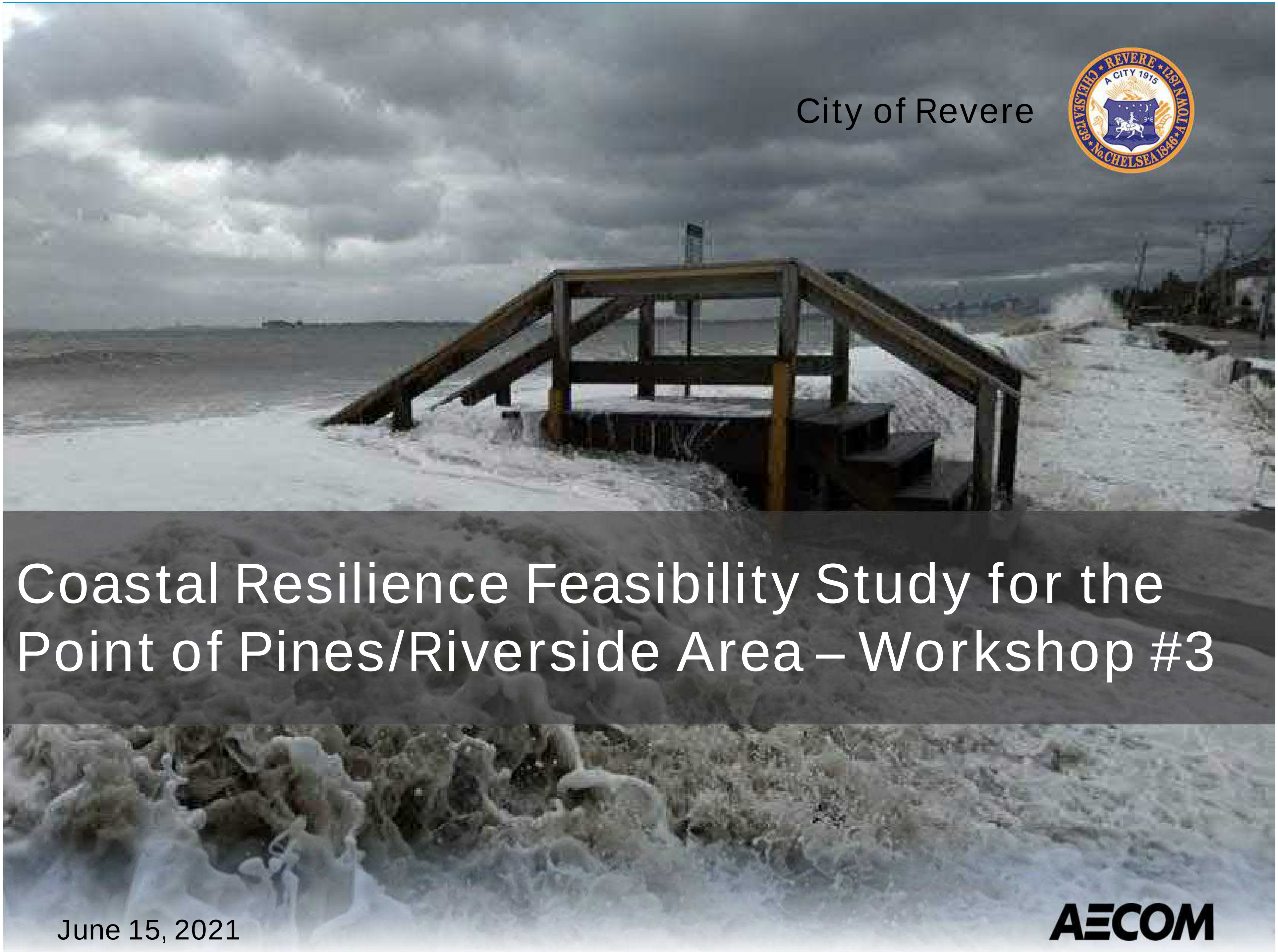
- Elle noted there is an ongoing regional study with Saugus, Lynn, Everett, and Malden to evaluate regional solutions.
- Goal of regional study is to expand upon work completed in Revere and work completed for other MVP analyses and join together.
- Councilor Powers asked what can be done in the immediate future to abate overtopping on certain areas of Mills Avenue. People are currently experiencing flooding on Mills Avenue and residents have no real protection.
  - Aaron noted that the Task 3 deliverable focused on short term actions that could address immediate needs. Materials are available through this study and final report will address short term measures that could be addressed and evaluated.
  - Elle responded that Workshop 2 covered a variety of different options that could be used when City is aware of a storm coming. Options include temporary walls and barriers; these options require less permitting so they could be implemented at a faster pace on a temporary basis while the City is seeking longer term solutions.
  - Jen noted that there is an option of constructing a flood barrier along Mills Avenue in an incremental fashion, such that the wall could be raised over time as needed, with the initial height targeted at lower high tide challenges.
  - Frank stated the engineering department is looking at redesigning the Point of Pines stormwater pump station, which would need take a floodwall into consideration. City consultants other than AECOM are currently designing upgrades that can handle stormwater protection. Design in preliminary stages but could be completed in the next couple years. Upgrades to the existing stormwater pump station along with dune area management plan would provide temporary flood protection for more frequent storms. Efforts have been undertaken internally by the City to address frequent storm problems. City is headed in a proactive direction.
  - Aaron listed the following deployable short-term resilience measures: aquafence, tiger dams, stop logs, and tube walls. On-site measures have visual impacts but reduce risk of not being able to deploy in time.
- Paul Argenzio asked about the process from this point on. He asked whether the City is looking to prioritize certain elements of report or is the report to be presented as a whole?
  - Elle stated that an internal team will review comments and recommendations and prioritize according to funding strategies. The City needs to take information and data available and discuss options with stakeholders. Ideally will establish a consensus and move forward with plan. Success of overall project requires buy-in from private landowners.
- Bob Hunt agreed with sentiment to build wall to withstand increased SLR as it continues to rise.
  - Suggested that for Alignment C, it is not only necessary to put a wall along North Shore Road (i.e, Route 1A), but improvements along Revere Beach are necessary as well. Bob suggested that elevations at Cary Circle on Point of Pines are off by about 3 feet based on flood levels that occurred in 1978. Recommended the I-95 coarse embankment is the cheapest way to protect the Study Area.

8.0 Next Steps

- Stakeholder comments are due to the City by Friday, June 18.

- Study to conclude by June 30.

City of Revere



Coastal Resilience Feasibility Study for the Point of Pines/Riverside Area – Workshop #3

June 15, 2021

AECOM

Coastal Resilience Feasibility Study for the Point of Pines/Riverside Area – Stakeholder Workshop #3

Elected Officials

- Mayor Brian Arrigo
- Ward 5 Councilor, John Powers

Revere City Staff

- Robert O'Brien – Director, Revere Office of Planning and Development
- Elle Baker – Project Planner
- Frank Stringi – City Planner
- Don Ciaramella, Superintendent Water, Sewer and Drain
- Joe Maglione – Assistant Superintendent Water, Sewer and Drain
- Paul Argenzio – Superintendent Revere Department of Public Works
- Nick Moulaison – Conservation Commission

Project Consultants – AECOM

- Aaron Weieneth – Project Manager
- Kira Murphy – Structural Engineer
- Ricky Torres-Cooban – Resilience Specialist
- Jennifer Doyle-Breen– Water Resources/Regulatory Specialist
- Brian Stobbie – Vice President, Engineering

Project Partners

- Loretta LeCentra – Riverside Area Resident
- Elaine Hurley – Riverside Area Resident
- John Polcari – Point of Pines Beach Association
- Angela Sawaya – Point of Pines Beach Association
- Stacy Livote – The Marina Restaurant
- Carolyn Meklenburg – MVP Regional Coordinator
- Greg Robbins – DCR Waterways
- Mary Lester – Saugus River Watershed Council
- Michelle O'Toole – MEMA, Hazard Mitigation Planning
- Brian Lajiness – MBTA, Manager of Emergency Operations
- Steve Miller –MassDOT, Climate Change Project Manager

Agenda

1. Welcome and Introductions
2. Review of Future Conditions
3. Coastal Resilience Toolkit
4. Criteria for Feasibility Review of Resilience Options
5. Results of Feasibility Decision Matrix
6. Resilience Options
7. Questions and Discussion
8. Next Steps

Mean Higher High Tide – Current NOAA

C:\Work\60646341REV\Maps\SLR.mxd

Mean Higher High Tide – 1 Foot SLR NOAA

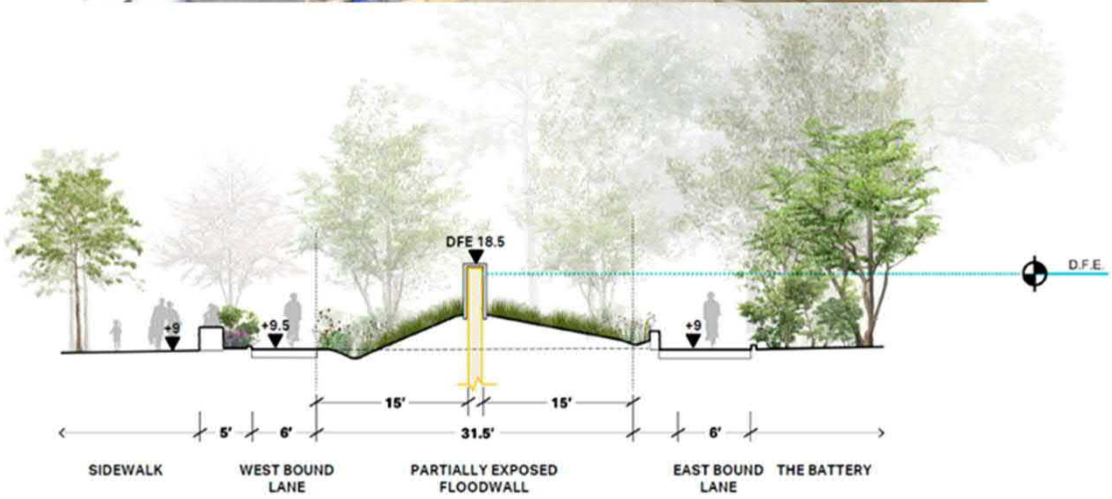
Mean Higher High Tide – 2 Feet SLR NOAA

Mean Higher High Tide – 4 Feet SLR NOAA

Coastal Resilience Toolkit –Adaptation Measures

Flood Risk Reduction Measures

- Flood Walls
- Deployable Structures
- Offshore structures
- Elevating roadways
- Elevating buildings
- Relocating buildings
- Floodproofing buildings



Coastal Resilience Toolkit – Adaptation Measures

Stormwater Management

- Flood storage area creation
- Bioretention basins
- Green infrastructure
- Impervious surface removal
- Pump stations
- Backflow Prevention

Coastal Resilience Toolkit –Adaptation Measures

Nature-Based

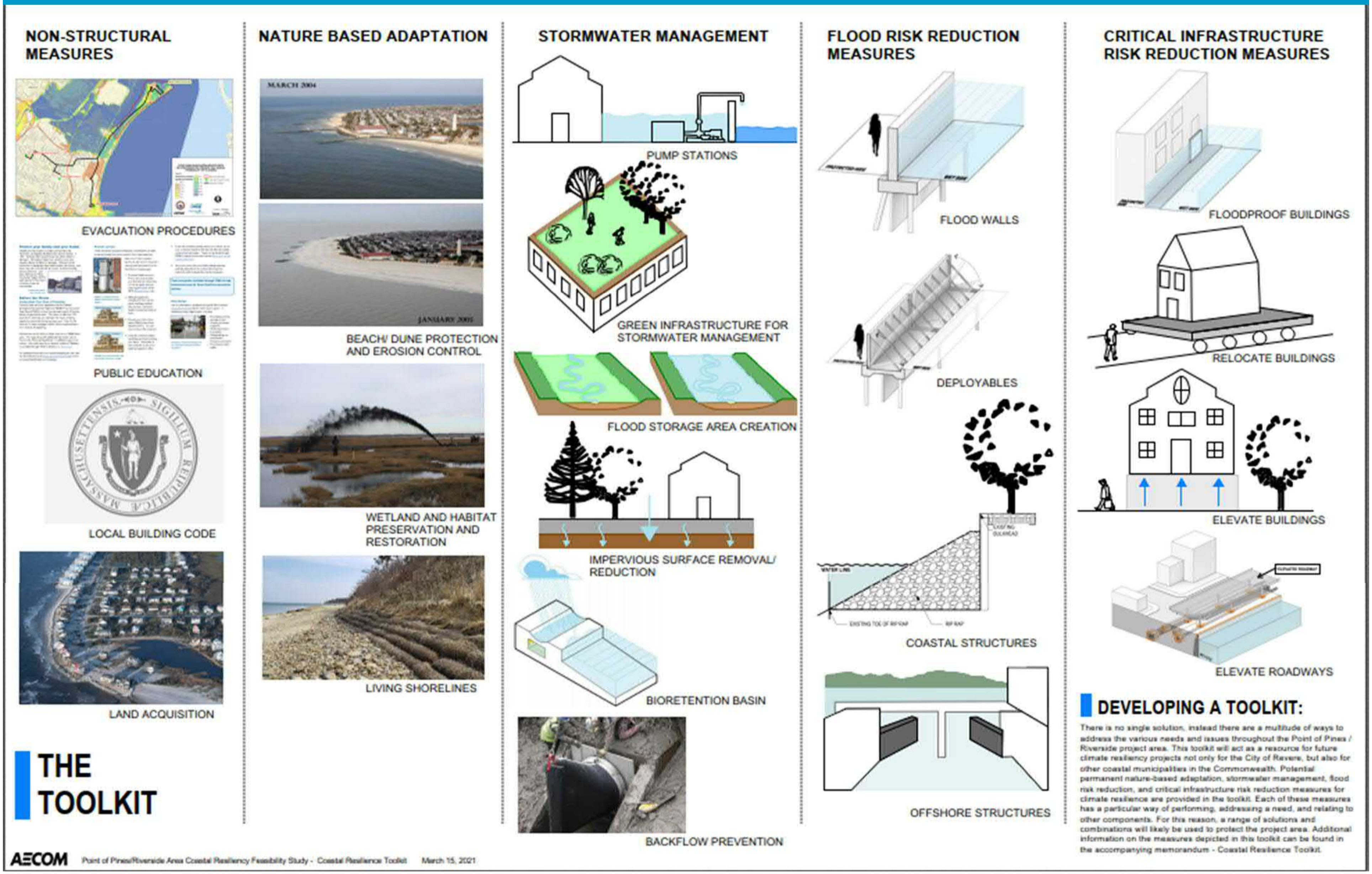
- Beach/dune protection/restoration
- Wetland/habitat preservation/restoration
- Living shorelines

Non-Structural

- Land Acquisition
- Public Education
- Evacuation Procedures
- Local Building and Zoning Codes

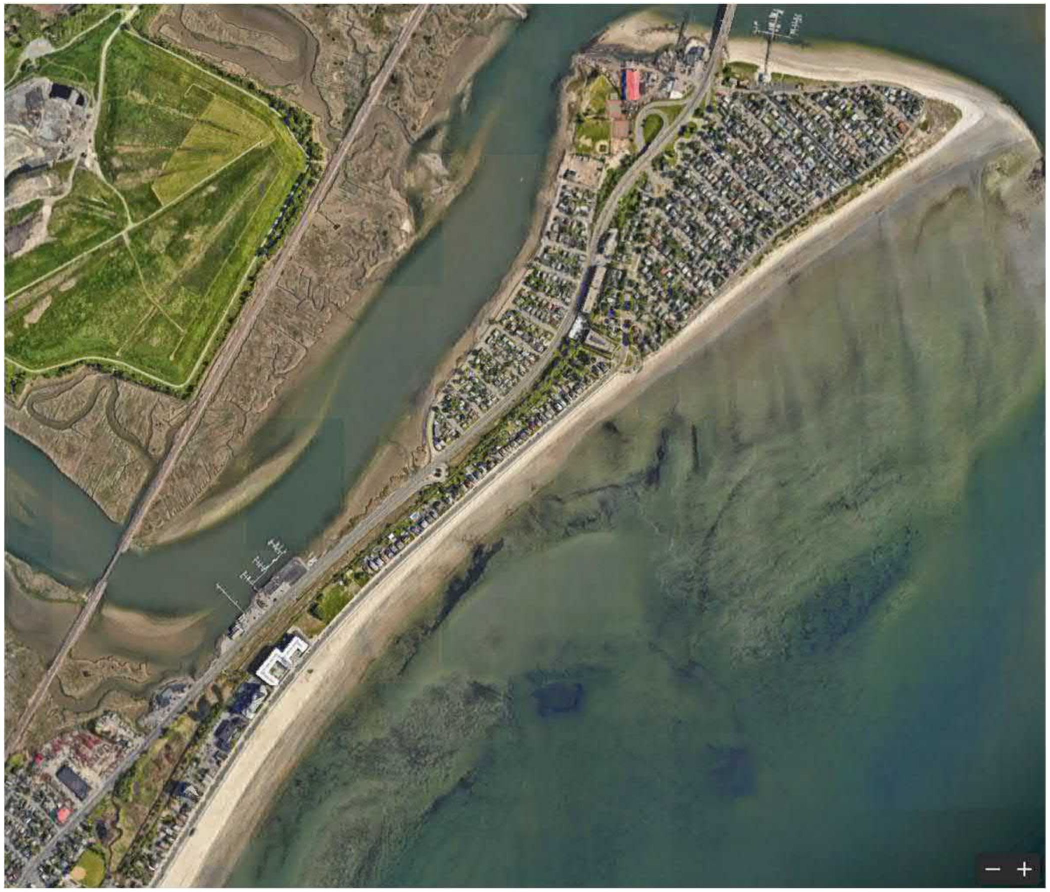
Credit: Western Carolina University, 2019

Resilience Toolkit



Criteria for Feasibility Assessment

- Control of Future Predicted Floodwaters
- Funding Opportunities
- Ownership
- Community Acceptance
- Conservation Restriction Requirements
- Permitting Complexity
- Relative Cost



Feasibility Summary

Resilience Tool	Feasibility Summary
Flood Barriers/Deployables	Costly but feasible for protecting relatively expansive residential areas
Floodproofing/Relocation	Feasible for individual critical community buildings
Backflow Prevention	Feasible and critical for all stormwater outfalls
Stormwater Flood Storage	May be feasible at Gibson Park per Riverside Master Plan
Pump Station	May be feasible at Mills Avenue; further drainage analysis needed
Impervious Cover Reduction	Feasible for Riverfront District
Living Shorelines	Feasible for Riverfront District
Salt Marsh Restoration/Creation	Feasible for Riverfront District
Dune Protection/Restoration	PoP dune protection feasible; restoration challenging
Emergency Response	Updates needed

Feasibility Summary

Resilience Tool	Feasibility Summary
Flood Barriers/Deployables	Costly but feasible for protecting relatively expansive residential areas
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Dune Protection/Restoration	PoP dune protection feasible; restoration challenging
Emergency Response	Updates needed

INUNDATION DEPTH | 2030 1% STORM

FIGURE A-14
POINT OF PINES/RIVERSIDE AREA
MASSACHUSETTS COAST FLOOD RISK MODEL (MC-FRM) PREDICTED 2030 WATER DEPTHS DUE TO 1 PERCENT ANNUAL CHANCE EXCEEDANCE (ACE) STORM - EAST

INUNDATION DEPTH | 2070 1% STORM

FIGURE A-16
POINT OF PINES/RIVERSIDE AREA
MASSACHUSETTS COAST FLOOD RISK MODEL (MC-FRM) PREDICTED 2070 WATER DEPTHS DUE TO 1 PERCENT ANNUAL CHANCE EXCEEDANCE (ACE) STORM - EAST

INUNDATION DEPTH | 2030 1% STORM

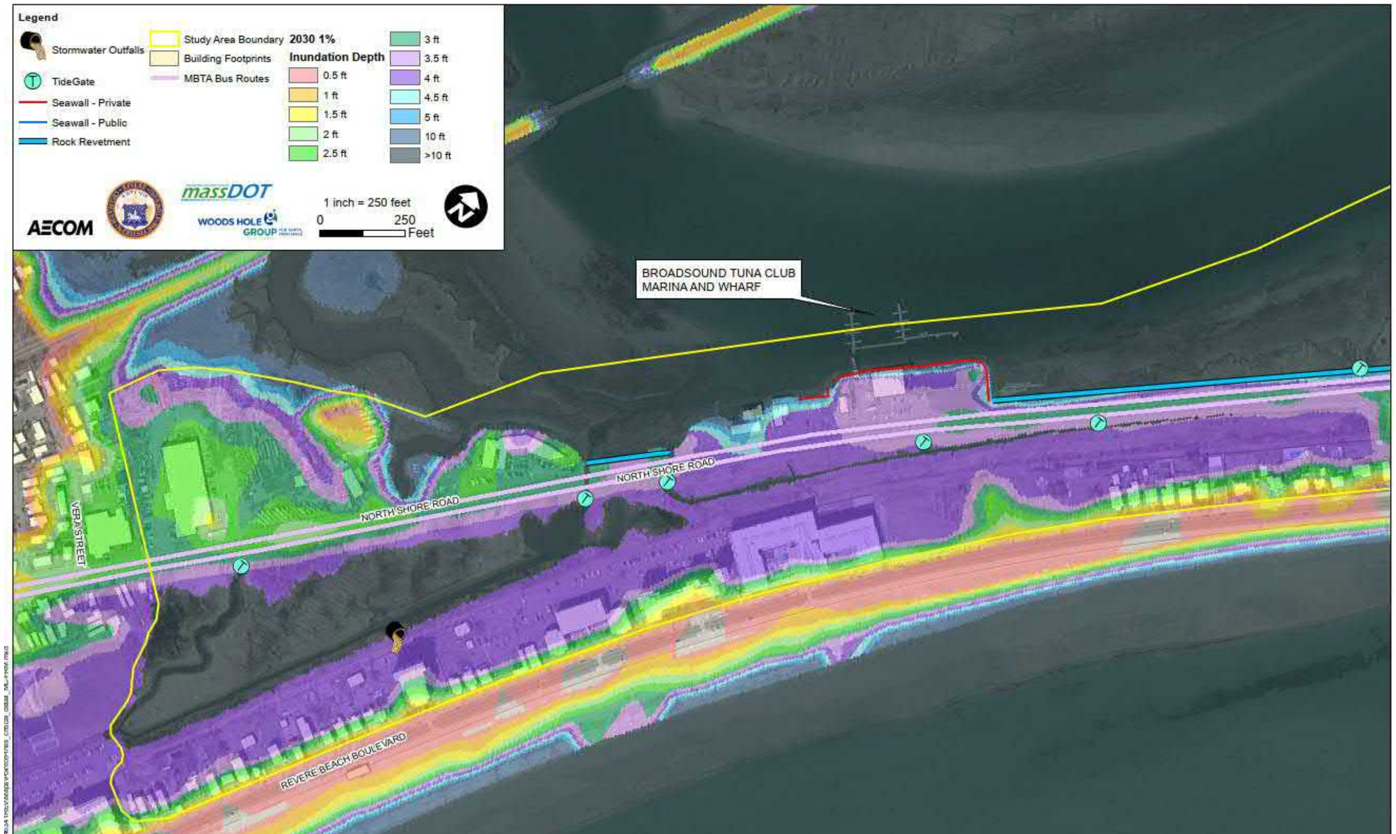


FIGURE A-22
POINT OF PINES/RIVERSIDE AREA
MASSACHUSETTS COAST FLOOD RISK MODEL (MC-FRM) PREDICTED 2030 WATER DEPTHS DUE TO 1 PERCENT ANNUAL CHANCE EXCEEDANCE (ACE) STORM - WEST

INUNDATION DEPTH | 2070 1% STORM

FIGURE A-24
POINT OF PINES/RIVERSIDE AREA
MASSACHUSETTS COAST FLOOD RISK MODEL (MC-FRM) PREDICTED 2070 WATER DEPTHS DUE TO 1 PERCENT ANNUAL CHANCE EXCEEDANCE (ACE) STORM - WEST

DESIGN FLOOD ELEVATIONS

FLOOD DESIGN CLASS 2

Design Storm	DFE Ocean Side (ft)	DFE River Side (ft)
FEMA 2020 1%	12	11
MC-FRM 2030 1%	13.4	11.6
MC-FRM 2070 1%	17.4	15.2

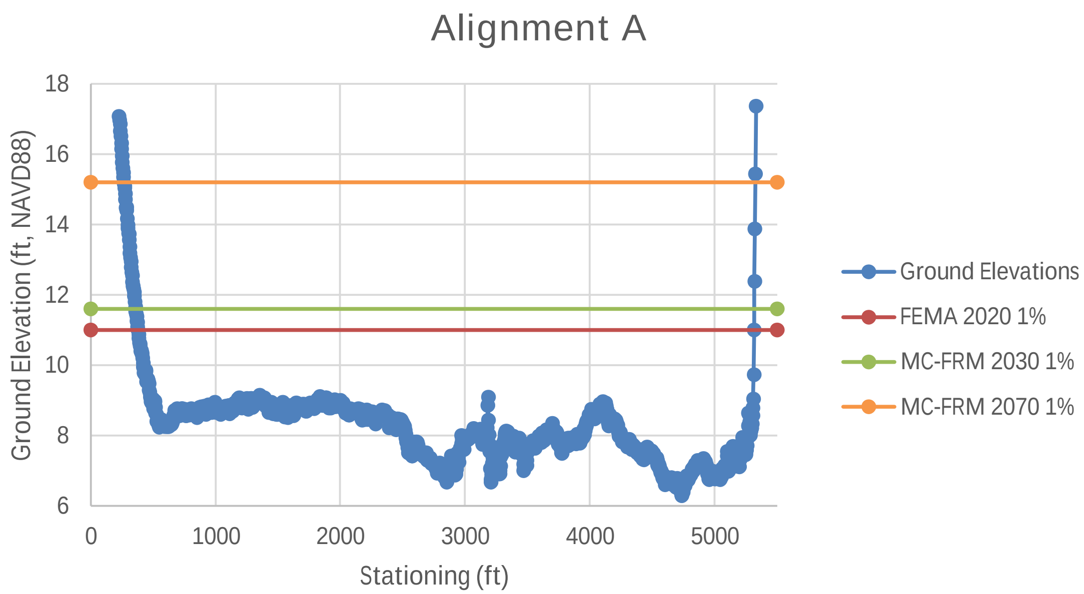
FLOOD DESIGN CLASS 3

Design Storm	DFE Ocean Side (ft)	DFE River Side (ft)
FEMA 2020 1%	13	12
MC-FRM 2030 1%	14.4	12.6
MC-FRM 2070 1%	18.4	16.2

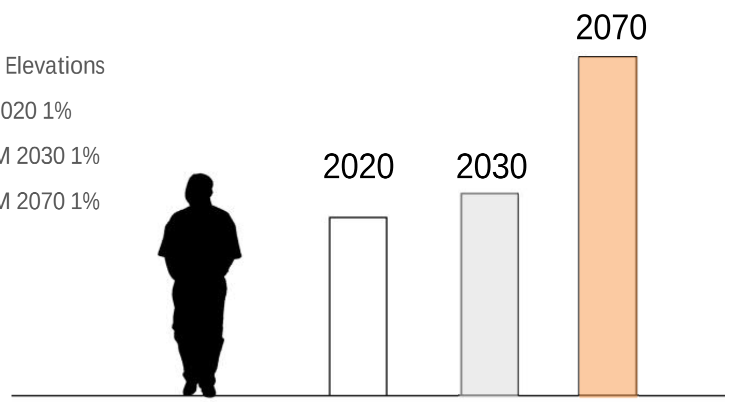
ALIGNMENT | DESIGN STORM FEASIBILITY

ALIGNMENT A

ALIGNMENT A | PROFILE



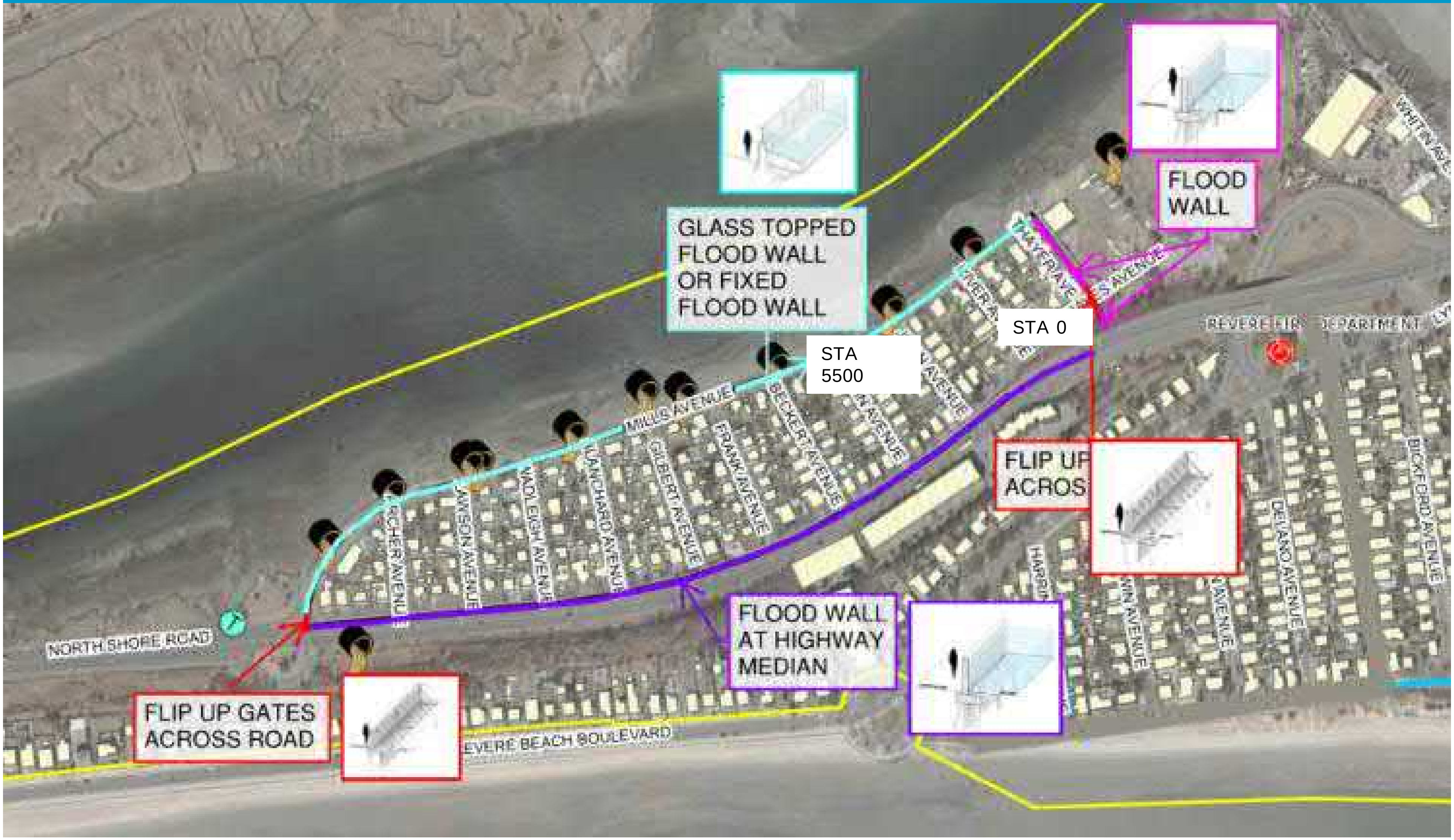
- Min Grade El. 6.3’
- 2020 1% Max HOI 4.7’
- 2030 1% Max HOI 5.3’
- 2070 1% Max HOI 8.9’



ALIGNMENT A | 2030 1% STORM

AECOM

ALIGNMENT A | 2070 1% STORM



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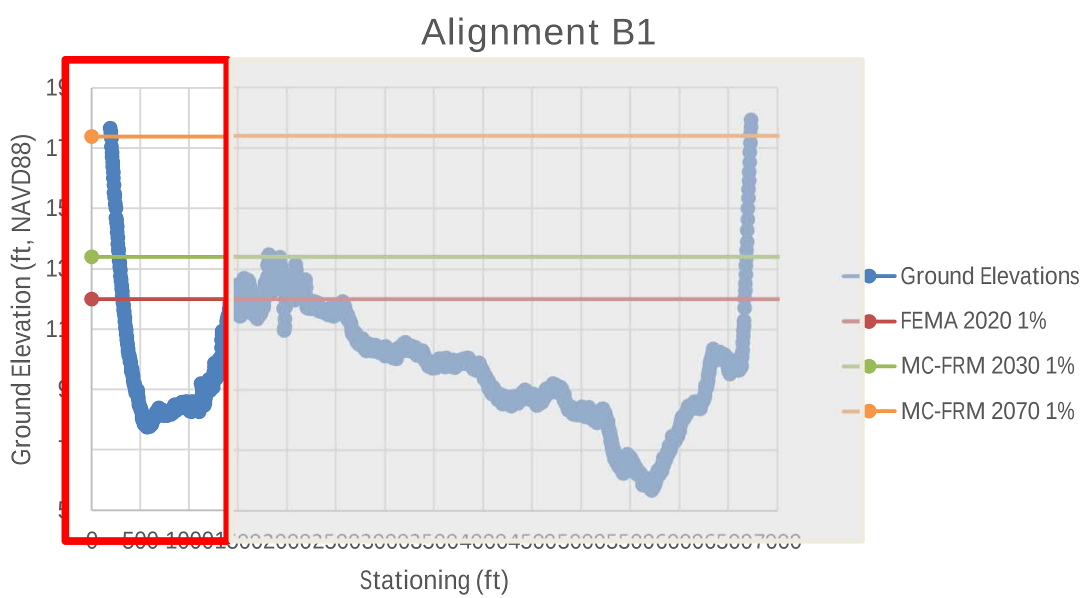
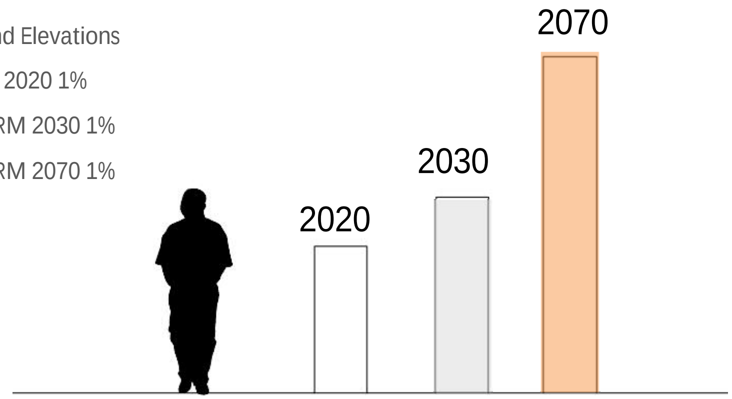
ALIGNMENT B

ALIGNMENT | DESIGN STORM FEASIBILITY

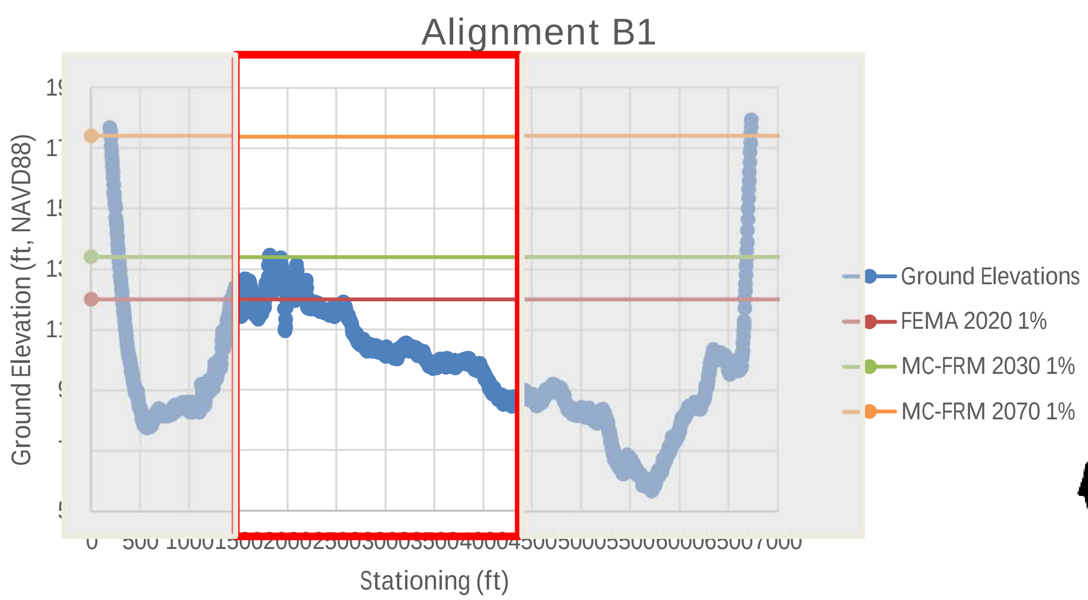
ALIGNMENT B | PROFILE STA 0 - 1500



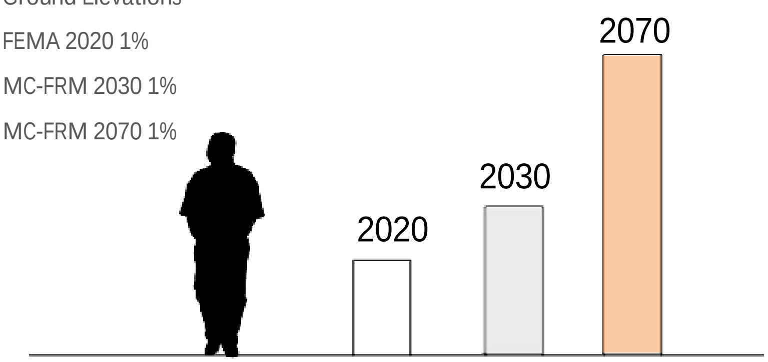
- Min Grade El. 7.8'
- 2020 1% Max HOI 4.2'
- 2030 1% Max HOI 5.6'
- 2070 1% Max HOI 9.6'



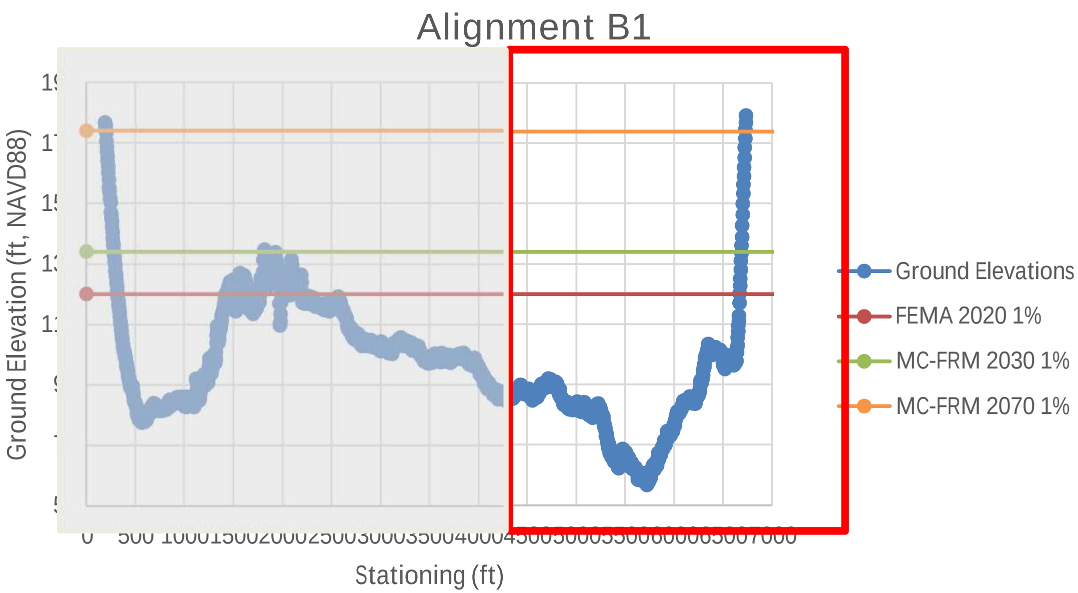
ALIGNMENT B | PROFILE STA 1500 - 4000



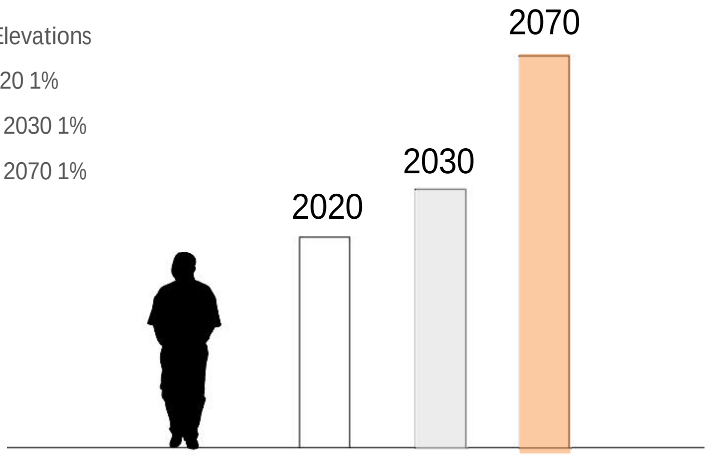
- Min Grade El. 9.5'
- 2020 1% Max HOI 2.5'
- 2030 1% Max HOI 3.9'
- 2070 1% Max HOI 7.9'



ALIGNMENT B | PROFILE STA 4000-7000

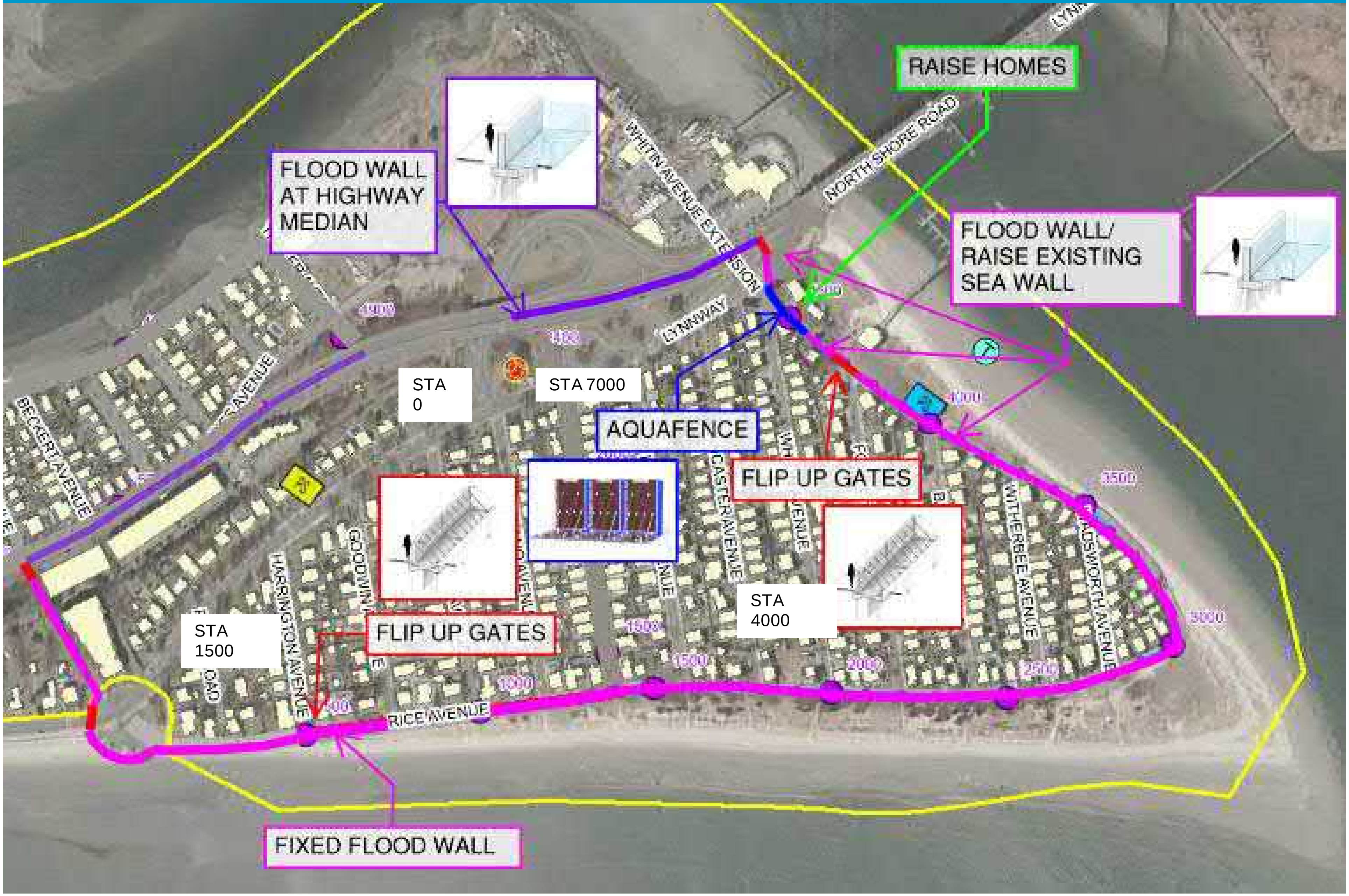


- Min Grade El. 5.7’
- 2020 1% Max HOI 6.3’
- 2030 1% Max HOI 7.7’
- 2070 1% Max HOI 11.7’



ALIGNMENT B | 2030 10% STORM

ALIGNMENT B | 2070 1% STORM



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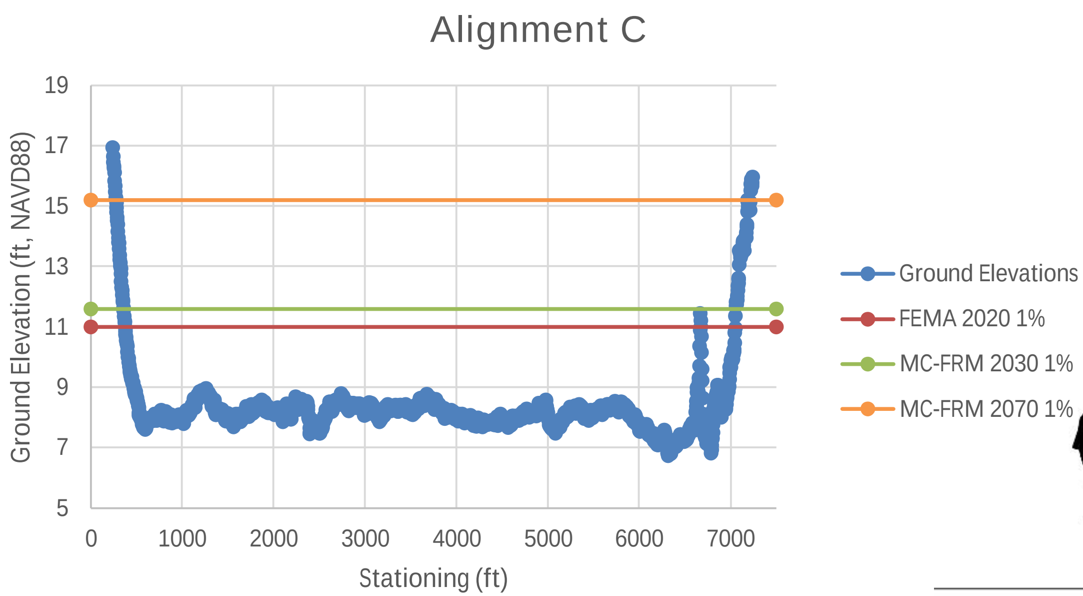
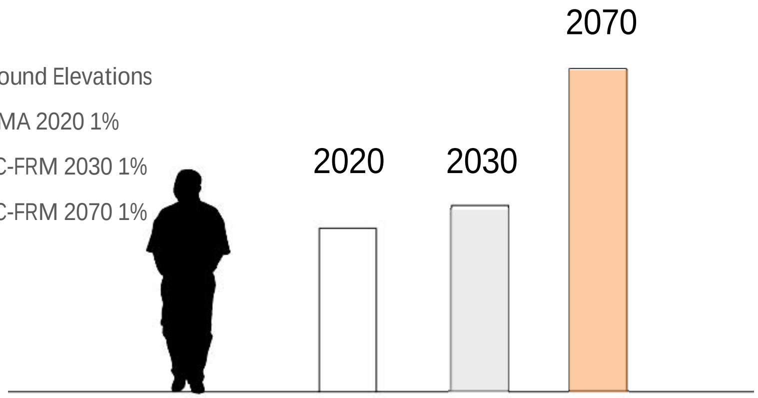
ALIGNMENT C

ALIGNMENT C | OVERVIEW

ALIGNMENT C | PROFILE



- Min Grade El. 6.8’
- 2020 1% Max HOI 4.3’
- 2030 1% Max HOI 4.9’
- 2070 1% Max HOI 8.5’



ALIGNMENT C | SOUTHERN TIE IN

- 2030 1% DFE 11.6’
- 2070 1% DFE 15.2’
- Tie in outside project area
- Existing Railroad
- Private Property

CRITICAL INFRASTRUCTURE

CRITICAL INFRASTRUCTURE

Design Storm	Wastewater HOI (ft)	Stormwater HOI (ft)	Adult Daycare HOI (ft)	Fire Station HOI (ft)
FEMA 2020 1%	2	4	4	2
MC-FRM 2030 1%	2.6	5.4	4.6	3.4
MC-FRM 2070 1%	6.2	9.4	8.2	7.4

PLANNING LEVEL COST ESTIMATE

2020 100-YEAR STORM ESCALATED TO 2025

Flood Protection	Cost Min	Cost Max
Alignment A Option 1	10.1 M	21.5 M
Alignment A Option 2	7.5 M	16.1 M
Alignment B1	7.3 M	15.6 M
Alignment C	9.3 M	19.9 M
Critical Buildings	0.9 M	1.9 M

2070 100-YEAR STORM ESCALATED TO 2025

Flood Protection	Cost Min	Cost Max
Alignment A Option 1	17.6 M	37.6 M
Alignment A Option 2	16.9 M	36.1 M
Alignment B1	24.8 M	53.1 M
Alignment C	21.4 M	45.8 M
Critical Buildings	1.8 M	3.8 M

Conclusions

- Many applicable tools – no “one size fits all”
- Residential protection to 2030 10-year storm feasible
- Challenging to protect beyond 2030 10-year storm
    - Lack of high ground
    - Cost
    - Quality of life
- Floodproofing of pump and fire stations under evaluation
- Early evacuation of adult day care center
- Larger scale/regional solutions may be more cost effective

Next Steps

- Feasibility Report to be finalized by June 30
- Ongoing regional study with Saugus, Lynn, Everett and Malden to evaluate regional solutions

Questions? Please contact Elle Baker, Open Space and Environmental Project Planner at ebaker@revere.org

D. Appendix D: Task 2 Past Studies, Case Studies, and Historical Data Memorandum

AECOM
250 Apollo Drive
Chelmsford, MA 01824
aecom.com

Project name:
Point of Pines and Riverside Area Coastal Resilience Feasibility Study

Project ref:
60646341

To:
Elle Baker, Project Planner, City of Revere
Frank Stringi, City of Revere

From:
Aaron Weieneth
Taelise Ricketts
Amanda Shanahan
Jennifer Doyle-Breen

CC:
File

Date:
April 19, 2021

Past Studies, Case Studies, and Historical Data Memo – Final

1. Introduction

Resiliency is essential for coastal communities such as the City of Revere, MA. These coastal communities are likely to face severe hazards from climate change threats including sea level rise, coastal surge, and erosion. The purpose of this Memorandum is to provide an overview of historical research and studies conducted for the City of Revere Point of Pines (PoP)/Riverside area, as well as present applicable case studies from similar communities. Over the past few decades, the PoP/Riverside area has been susceptible to coastal hazards such as flooding, beach erosion and sea level rise. This Memorandum is the first task in a six-task feasibility study that will provide the City with an overview of both historic and present hazards that the City faces in the PoP and Riverside areas, which will be referred to as the Study Area. This is the first of five technical memoranda that will be provided as part of the feasibility study; the findings from the five technical memoranda as well as three stakeholder meetings will be summarized in a final report which will also include an implementation plan identifying prioritized action items, responsibilities and potential funding sources to address coastal vulnerabilities in the Study Area. The information summarized in this Memorandum provides a basis to evaluate past, current, and future coastal threats as well as recommendations for potential mitigation measures to increase the climate resiliency of this portion of the City of Revere.

2. Past Studies and Reports for the Point of Pines and Riverside Area

The Study Area has experienced hazards due to flooding and coastal storms for over three decades. In that time, a number of studies have been conducted by the US Army Corps of Engineers (USACE), the City, as well as local planning organizations to describe and recommend solutions for flooding. This section summarizes the past studies conducted, their findings, and associated recommendations. Information from these past studies will be considered as short- and long-term resilience measures are identified as part of the current study. Key points of the relevant past studies are provided in Table 1 below, starting with the most recent, followed by a short summary of each study.

Table 1: Summary of Past Studies and Reports for the Point of Pines and Riverside Area

Title	Author	Date of Source	Source Overview	Definition of Study Area	Summary of Findings	Recommendations
Boston Region Metropolitan Planning Organization's Route 1A Corridor Vulnerability Assessment	Boston Regional Metropolitan Planning Organization	November 2020	The objective of this pilot study was to work with MassDOT and the City of Revere to identify problems and develop recommendations to make Route 1A more resilient. Route 1A was selected for the pilot study because portions of the road are both located in natural low-lying areas with elevations less than 10 feet above sea level and close to the flood pathways of the Pines River estuary to the north and the Chelsea Creek estuary to the south.	Route 1A near Pines River	The corridor is highly vulnerable to coastal flooding resulting from high tides, storm surge, rainstorms, and inundation from sea level rise - all hazards that are expected to worsen in the future	• **Structural Recommendations:** - Installation of bulkheads and breakwaters to rescue shoreline erosion. - Plant marsh vegetation - Installation of edging devices and Rock Sills, Revetment and Bulkhead - Raise roads and upgrade culverts • **Non-Structural Recommendations:** - Regulatory policy and pricing/incentive policy - Structure acquisitions or relocations - Flood proofing of structures - Implementing flood warning systems - Flood preparedness planning -Establishment of land use regulations - Emergency response plans

Municipal Vulnerability Preparedness Summary of Findings Report	AECOM	June 2019	This report discussed the climate change concerns and solutions that Revere residents established during the Municipal Vulnerability Preparedness (MVP) workshops. The MVP Program provides cities and towns with monetary and technical support to begin the process of planning for climate change resiliency and implementing priority projects. This report identified the top climate change hazard for the City of Revere, identifying actions to promote resilience and potential solutions.	Beachmont, Point of Pines/ Riverside, Oak Island/Revere Beach, West/North Revere and Sales Creek	The top hazards that the City of Revere faces consist of: -Coastal Flooding - Erosion - Extreme Temperatures/ High Temperatures - High Winds - High(er) Water Table - Hurricanes and Nor'easters - Inland Flooding -Invasive Species - Sea Level Rise - Severe Storms and Winter Storms	• **Beachmont:** - Reconstruct seawall and revetments. -Install levee and/or natural berm to prevent flooding of properties that abut the marsh. - Dredge Belle Isle Creek. - Improve emergency access and reduce hazards to vehicles by changing one-way traffic patterns and encouraging use of public parking garages during high tide and storm events. • **Point of Pines / Riverside** - Construct and rehabilitate seawall. Install snow fencing and restore dunes. - Increase public safety and access to shelters for evacuation and construct a new fire station. - Reduce exposure to pollution by prohibiting an increase to volume of fill/waste at the Wheelabrator landfill. - Conduct feasibility study to determine the best mitigation plan to address flooding, erosion, and storm impacts. - Investigate and streamline the permit process for sand transfer between the vicinity of the PoP Yacht Club, where it is accreting, and PoP Beach Association, where there is coastal erosion. • **Oak Island / Revere Beach** - Upgrade drainage system to help control flooding. - Beach nourishment and erosion control. - Repair, replace, and install flood gates. - Promote thoughtful future development with respect to flooding and drainage. Implement best management practices and include natural flood storage in new developments. - Build a new high school. - Create and establish multilingual communication. - Repurpose Route 1A oil tanks for stormwater storage.

						• **West / North Revere** - Seek funding for and develop a program to dredge and maintain Town Line Brook. • Identify illegal sewer hookups. - Develop a program or policy to install emergency generators at and maintain pumping stations. - Reduce illegal dumping through surveillance. - Expand Route 1 travel lanes, • **Sales Creek** - Develop municipally-administered vulnerability assessments for homeowners. - Distribute multilingual information. - Develop, promote, and incentivize green infrastructure, and new and/or retrofitted stormwater and green building standards. - Liaison between City and State to position for funding sources and increase communication. - Incorporate MVP findings into the City's Master Plan and Hazard Mitigation Plan updates.
City of Revere Hazard Mitigation Plan (HMP)	Metropolitan Area Planning Council	June13,2015	The HMP planning is a proactive effort to identify actions that can be taken to reduce the dangers to life and property from natural hazard events.	City of Revere	The coastal area of the City of Revere is subject to floods, hurricanes, tornadoes, coastal hazards, earthquakes, brush fires and extreme temperatures. Geographically, the City is extremely vulnerable to tsunamis and winter storms.	• Provide backup power at all sewer pump stations. • Install a diesel generator at the Reservoir pumping station. • Install tide gates at Route 1. • Install a new sewer pump stations at Martin Street and Oak Island. • Construct a seawall along Miller Avenue from North Shore Road to Alden Avenue. • Construct a seawall from Cary Circle to Alden Avenue
USACE Revere Beach Erosion Control Report	United States Army Corps of Engineers	1991	This report discusses beach erosion at Revere Beach.	Revere Beach Reservation	Revere Beach Reservation was only 4 ft above mean low water level, rendering the area vulnerable to coastal flooding.	• Widening the beach. • Elevating the beach area so that it is higher above the Mean Low Water (MLW) level

USACE Flood Damage Reduction Study for the Saugus River and Tributaries	United States Army Corps of Engineers	1990	This is a feasibility investigation carried out in partial response to the 1969 SENE study authority. This report presents the USACE investigation of potential regional solutions to serious and recurring coastal flooding problems in eastern Massachusetts.	Lynn, Saugus and Revere	The study summarizes coastal flooding problems and alternative solutions, including hydrology and hydraulics, water quality, design, costs. geotechnical issues, real estate needs, and economics of the alternatives.	• **Non-structural:** -Maintaining existing beaches, seawalls, tides gates and ponding area - Development of flood preparedness plan • **Structural:** - Tide gate along Sales Creek - Dike installation behind Revere Beach - Develop a wall to protect ponding area in the North end of Revere -Stone revetment installation along PoP shorefront from Carey Circle - Installation of tidal floodgates by the mouth of the Saugus River and installation of 10 flushing gates, 9 of which will be installed on the Lynn side of the navigation gates and 1 on the Revere side - Dike installation in Lynn Harbor
USACE Environmental Impact Statement/Environmental Impact Report for Flood Damage Reduction Study for the Saugus River and Tributaries	United States Army Corps of Engineers	1989	This source summarized the coastal flooding problems in the study area and alternative solutions; described the selected plan, implementation responsibilities of the plan; identified environmental resources in the study area, and the potential impacts of alternative solutions as required by the Federal (NEPA) and State (MEPA) environmental processes.	Lynn, Saugus, Malden and Revere	The study area is impacted by sea level rise, flooding and degrading shorefront structures. Flooding impacted the Ocean Ave and Wonderland MBTA stations	• **Overview:** -Seawall at Revere Beach from Eliot Circle to Carey Circle must be maintained. -A tide gate is required to protect Crescent Beach and Garfield School. -Raise park land that is bounded by Ocean Avenue and Revere Beach Boulevard. -Install a new concrete wall that extends from the Boulevard sidewalk along the north side of the Seaview Condo driveway. • **Point of Pines:** -Heighten existing seawall - Rebuild damaged seawalls
USACE Pines River Navigation Report and Environmental Assessment	United States Army Corps of Engineers	1986	This report detailed and selected a plan to alleviate issues with anchorage in the study area along with the overall channel condition. The report also analyzed small improvements for small	West of Lynn Harbor where Pine and Saugus River joins	There was a shortage of recreational anchorage in Lynn and Revere areas, Pine River was one of the areas impacted by the shortage. The Pine River had a vast amount of	• The recommended plan consisted of the construction of an access channel along with anchorage areas.

			commercial fishing vessels and recreational crafts at the Pine River.		recreational and small commercial fishing fleets. The lack of recreational anchorage resulted in overcrowding in areas of the harbor that have a sufficient water depth. Shoaling that occurred within the river channel caused tidal delays. The lack of recreational anchorage and traffic within the channel discouraged growth and declined navigational efficiency.	
USACE Saugus River Navigation and Environmental Assessment	United States Army Corps of Engineers	1986	The study investigated whether navigational improvements are necessary within the Saugus River and Pine River.	Saugus River in Saugus and Lynn MA	The problem observed in the study area was that there was a lack of navigational system that could provide a safe and efficient utilization of the water. The channel leading to and from the harbor is narrow and shallow as well which restricts vessel traffic, creating a hazardous two-way navigation. The shallowness of the channel also resulted in icing, making it difficult for fishing	• Deepen and widen the channel to alleviate traffic and construction of new anchorage areas to meet current and future demands.
USACE Coastal Flood Protection Report and Environmental	United States Army Corps of Engineers	1986	This report summarizes the coastal flooding problems in the study area and alternative solutions by describing the selected plan, implementation responsibilities, identifies	Revere Beach Reservation, Lynn Harbor,	There was a considerable amount of erosion along seawalls at the beach. SLR posed issues for the beach and the surrounding	• Flooding Mitigation: Installation of breakwaters, seawalls or revetments, beach restoration and nourishment, dikes, floodwalls, sand dune development

Assessment for Point of Pines			environmental resources in the study, area and potential impacts of alternative solutions, as required by the Federal (NEPA) and state (MEPA) environmental processes.	PoP, Saugus River	area. All the study areas are subject to flooding	

1986 United States Army Corps of Engineers (USACE) Coastal Flood Protection Report and Environmental Assessment for Point of Pines

This report focused on the coastal flooding concerns that impacted Revere Beach Reservation, Lynn Harbor, PoP and the Saugus River. The report found that along Revere Beach Reservation, there was a significant amount of erosion along the seawalls. In 1986, the existing revetments were insufficient to protect the Study Area from flooding and storm surge, and these revetments are still those present in the Study Area.

Reach A is a 230 ft. long located adjacent to the north end of Revere Beach and consist of 12 ft. high vertical concrete wall extending in a semi-circle around Carey Circle. The top of this Reach has an elevation of 15 ft NGVD. Reach B is a 440 ft. long section with an average top elevation of 15 ± ft. NGVD. Reach C is 430 ft. long section with a top elevation of 15 ± ft. NGVD. Reach D is a 430 ft. long section with a top elevation of 14± ft. NGDV. Reach E is the longest section of beachfront extending for about 1,720 ft to the mouth of Saugus River. The top elevation varies between 12.1 and 16.6 ft NGVD. Reach F is a 970 ft. long section that extends on the western side of Saugus River and has a top elevation of 12 ft NGVD that is located adjacent to Rice Avenue. Lastly, Reach F extends 730 ft from Reach F to the embankment of North Shore Road at the General Edwards Bridge. **Figure 1 below** displays the Reaches, proposed actions and the station numbers. Figure 1 is taken directly from the 1986 report, and therefore its resolution of the figure is not very high, which makes it difficult to view the reaches identified at the time.

The proposed revetment would start with a transitional section in Reach A. The top elevation of the revetment would gradually increase from 13.6 ft NGVD to 16 ft t NGVD at station 0 +00 as displayed in **Figure 1**. This proposed revetment would remain the same elevation until station 10 +00. At station 14 +00, the top elevation of the revetment wall would decrease to 14.5 ft. NGVD. The proposed revetment would have an 8 ft. armor stone.

Another structural recommendation was to install a 36-inch gravity drain that would extend from Rice Ave. to the east side of the existing pumping station east of Reach G. The proposed gravity drain will extend from a new catch basin on Rice Avenue through the line of protection east of the existing pump station. The proposed gravity drain would be equipped with flap gates and an emergency sluice gate closure at the line of protection. With the addition of the gravity drain the drainage system would have a maximum capacity of 100 cubic feet per second (cfs).

The recommended plan also consisted of raising the elevations of the existing sand dunes. The existing sand dunes had a top elevation between 12.1 to 16.6 ft. NGVD. In Reach E, the existing sand dunes would be raised to a continuous elevation of 14 ft . NGVD, beach grass and plants would also be planted to stabilize the dune. In order to raise the elevation of the sand dune an estimated 6,700 cubic yards of sand fill would be needed. The seawalls located at Reach F would be raised to a top elevation of 13.3 ft. NVGD by adding a pre-casted concrete wall to the top of the existing seawall along the northern side of Rice Ave. along the Saugus River.

The recommendations were developed based off an approximated Standard Project Northeaster (SPN) tide of 13 feet NGVD. This tide level was approximated by calculating the maximum storm surge and adding that value to the maximum probable high tide.

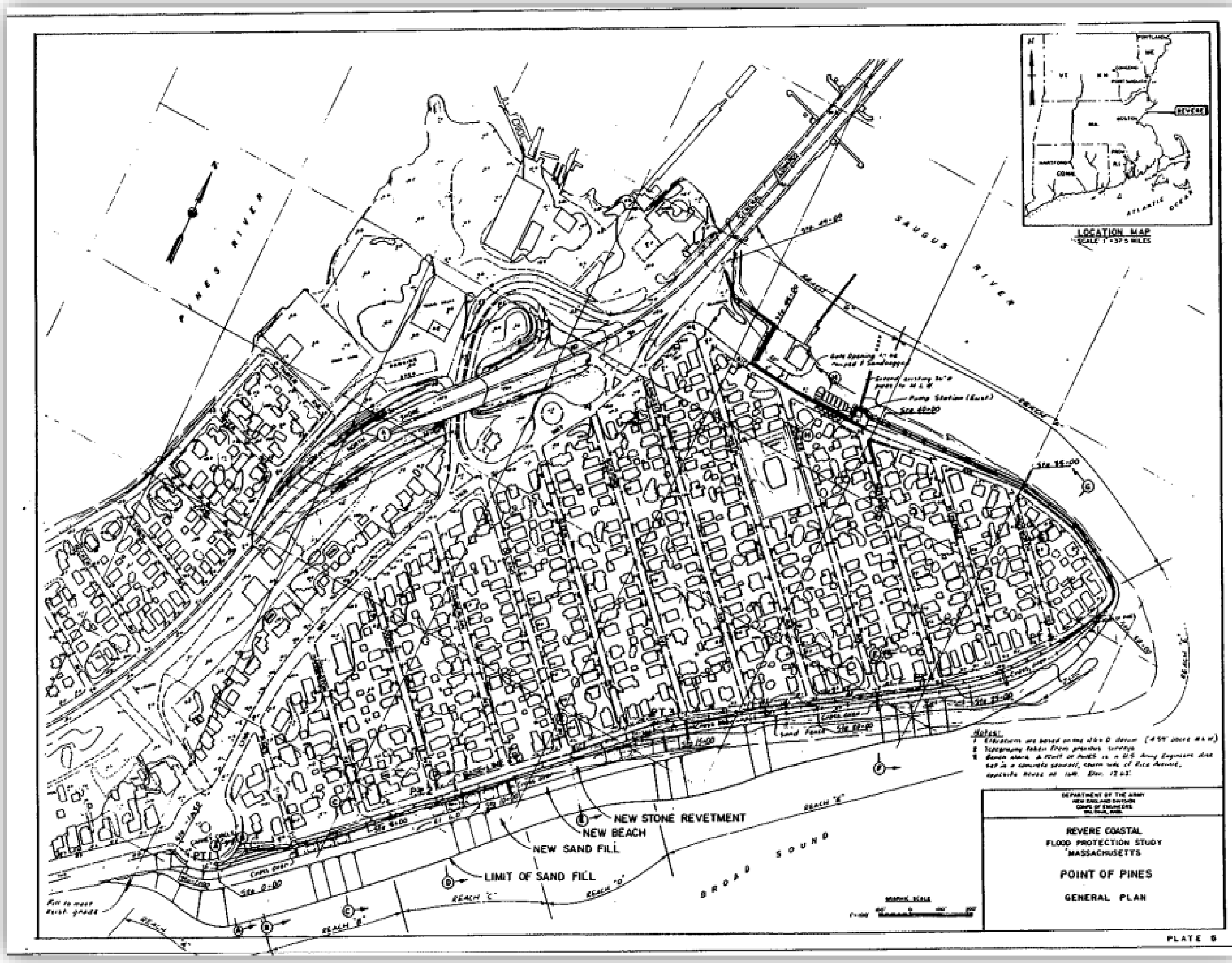


Figure 1: Locations of Proposed Actions and Reaches

1986 USACE Pines River Navigation Report and Environmental Assessment

This report addressed concerns regarding a shortage of recreational anchorage locations within the Pines River channel. The shortage of recreational anchorage posed a problem for the city of Revere and Lynn. Within the Pines River, there were a large number of recreational and small commercial fishing fleets, and the shortage of anchorages resulted in overcrowding in certain areas of the River, resulting in watercraft traffic and delays. Shoaling within the river also caused delays for watercraft due to tidal restrictions on water depths needed for safe navigation. This overcrowding and lack of anchorage negatively impacted economic growth. The USACE recommended a plan to increase anchorage areas as well as construction of an improved access channel. The recommended plan consisted of construction of an access channel spanning 6,500 ft. at the confluence of the Saugus and Pine River, upstream of the head of navigation. The 2,500 ft. downstream of the channel was proposed to be dredged to a depth of 8 ft. 4,000 feet upstream of the channel would be dredged to 6 feet Mean Low Water (MLW) and width of 80 feet. Dredging was also proposed to create a 5-acre (ac.) anchorage area with a depth of 6 ft. MLW along the western side of the downstream channel. The recommended plan would require the removal of 76,500 cubic yards of material. The plan was intended to mitigate shoaling in the channel as well as alleviate water vessel congestion and delays.

1986 USACE Saugus River Navigation and Environmental Assessment

This study analyzed potential navigational improvements within the Saugus and Pine River. The navigational issues within the Saugus River consisted of a narrow and shallow channel which resulted in a hazardous navigation area. In addition, the shallowest areas of the channel were prone to freezing, rendering fishing in these areas difficult. The recommended plan suggested the development of a wider and deeper channel through Lynn Harbor, Saugus River and Pine River to mitigate traffic and hazardous traveling conditions. The construction of a 3-acre anchorage area and basin were also recommended. The report recommended that the area would have to be dredged 6 ft MLW in order to construct the anchorage area and basin. Two additional anchorage areas were proposed upstream of Western Avenue. The recommended plan required dredging and the removal of 162,000 cubic yards of existing material.

1989 USACE Flood Damage Reduction Study for the Saugus River and Tributaries

In this report, the USACE presented a descriptive plan on how to mitigate the damaging effects of sea level rise, flooding, and degrading shoreline in Lynn, Revere, Saugus and Malden. An overview of USACE recommendations for flood damage reduction can be observed in **Figure 2**. The USACE suggested both structural and non-structural recommendations to mitigate flooding damage. Non-structural recommendations consisted of maintaining and enhancing existing structures without reconstructing them. As described below, one of the more significant recommendations in the report was the construction of a floodgate at the mouth of the Saugus River to provide regional flood protection.

The non-structural recommendations were to maintain existing seawalls, tides gates and ponding area within the study area. In 1989, the ponding area was 20 acres and was located along North Shore Road (i.e. Route 1A), which is located on the north end of Revere Beach. Part of this recommendation included protection of the existing ponding area by installation of a wall. If water levels were to exceed the ponding area’s capacity, water would flow over North Shore Road into the estuary, where the water levels would be regulated by a floodgate. The recommendations included a 3 to 4-foot-high gravity wall to be located along the top of an old railroad embankment located between Route 1A and the Seaview Condominiums on Revere Beach Boulevard. The USACE also proposed a 500-foot-long wall that would be located at the south end of the ponding area. This 500-foot wall was recommended to prevent flooding on Oak Island Street. It was also recommended that the project sponsor develop a flood preparedness plan. The USACE would prepare an Operation and Management (O&M) Plan, which would provide information that could be used in the development of the Flood Preparedness Plan.

Structural recommendations consisted of the installation of a tide gate along Sales Creek and a dike behind Revere Beach. USACE also recommended the construction of a wall revetment along Point of Pines as displayed in **Figure 3**.

Other structural recommendations consisted of the installation of tidal floodgates by the mouth of the Saugus River; ten flushing gates on the left and right side of the navigation gates along Lynn and Revere; and a dike in Lynn harbor. The recommended tidal floodgates consisted of 1,290 ft. of structures at the mouth of the Saugus River, including a navigational gate, ten flusher gates and two concrete gravity wall sections. The proposed navigational and flushing gates are displayed in **Figures 4 and 6.** These gates would initially close two to three times a year for approximately an hour or two during the peak of the tides. In the conceptual design, the gates were envisioned to open as tides retreated back to the level of estuary. If sea level rise approached 2 feet, the floodgate would close more often; the study predicted that the gates might experience up to closures 200 times a year to provide protection for the 50-year flood level. In general, the proposed floodgates were envisioned to close whenever the tides were projected to rise to or above 8 feet elevation NGVD. Both the navigational and flushing gates were identified as 730 feet long with 8,800 sq. ft of gated opening at 0 NGVD, mid-tide. To prevent scour, a 30-foot wide stone structure was identified along the edge of the gate. Concrete gravity walls were situated at each end of the floodgate, including a 140 ft. long wall in Lynn and 420 ft long wall in Revere. The proposed floodgate would connect to 8,900 ft. of dikes and walls along Lynn Harbor.

Another structural recommendation was to raise the elevation of land in a park along Ocean Avenue and Revere Beach Boulevard, as displayed in **Figure 5.** Raising the ground elevation in the park was intended to enable the formation of a dike consisting of impervious surfaces, with a peak elevation of 23 ft.

The USACE structure recommendations for PoP are displayed in **Figure 6**. A new 1,550-foot long revetment was proposed to be installed along the PoP shorefront to an elevation of 16 ft. NGVD. Another 1,600-foot long revetment was proposed to be installed underneath the existing sand dunes, including armor stone and an elevation of 14 ft NGVD. Recommendations for PoP also included raising the height of the existing seawall an additional 1 to 3 feet and re-building damaged seawalls. PoP and Park recommendations were optimized for the 100-year flood level. The other recommendations are optimized to provide full SPN level of protection.

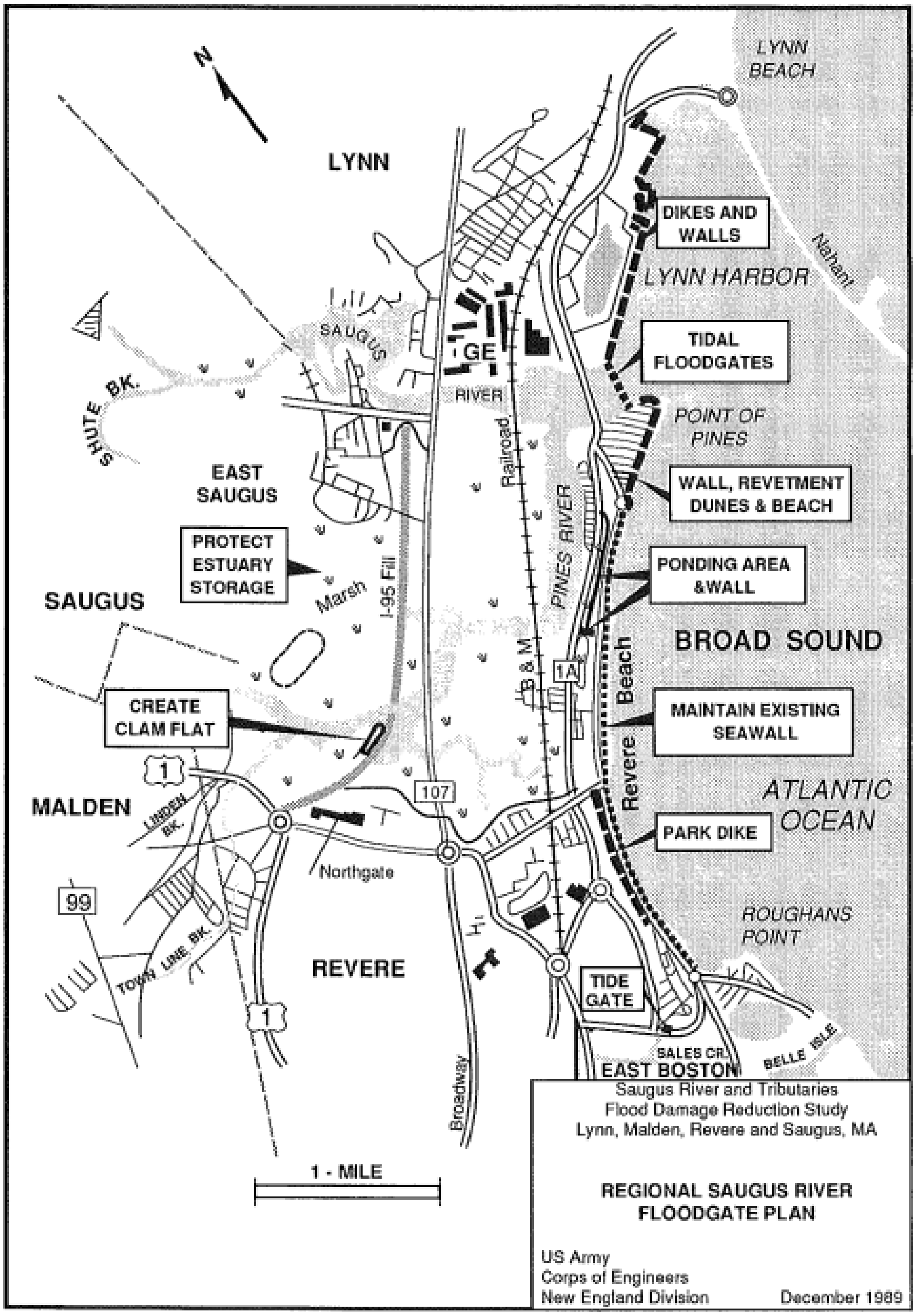


Figure 2: Overview of Flood Damage Reduction Recommendations

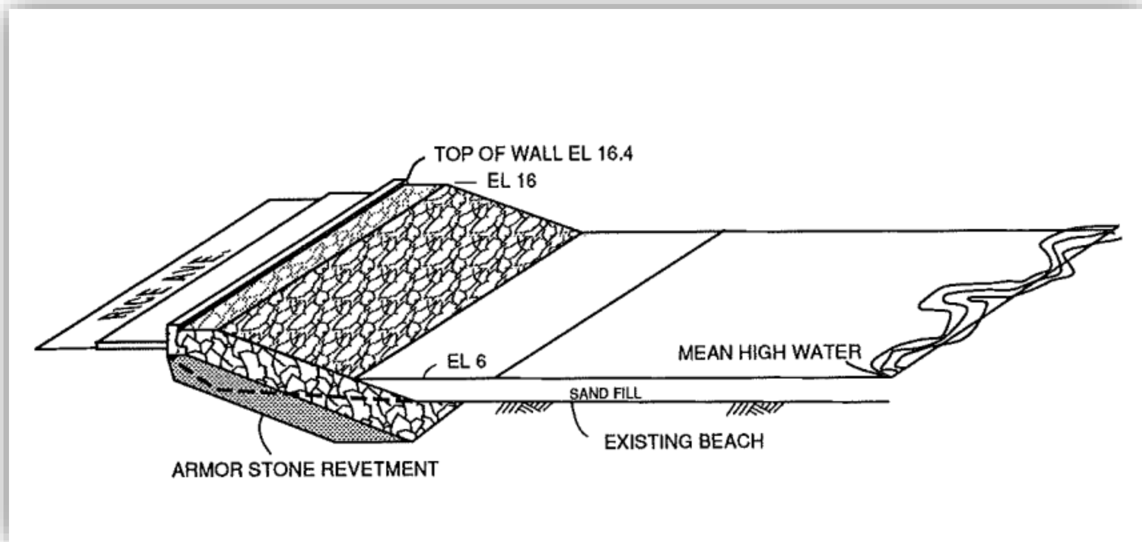


Figure 3: Proposed Revetments for Point of Pines

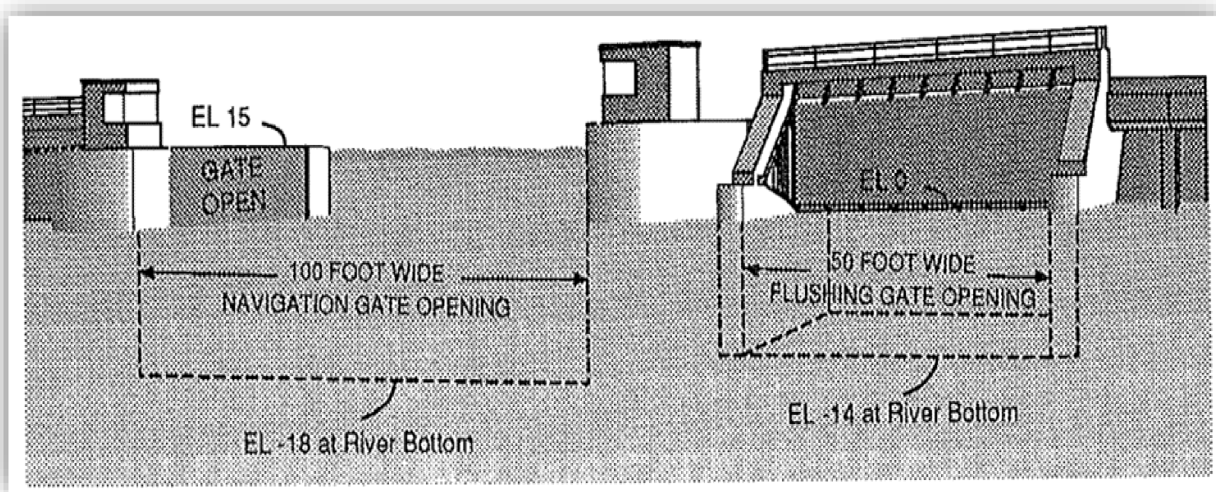


Figure 4: Proposed Navigation and Flushing Gate

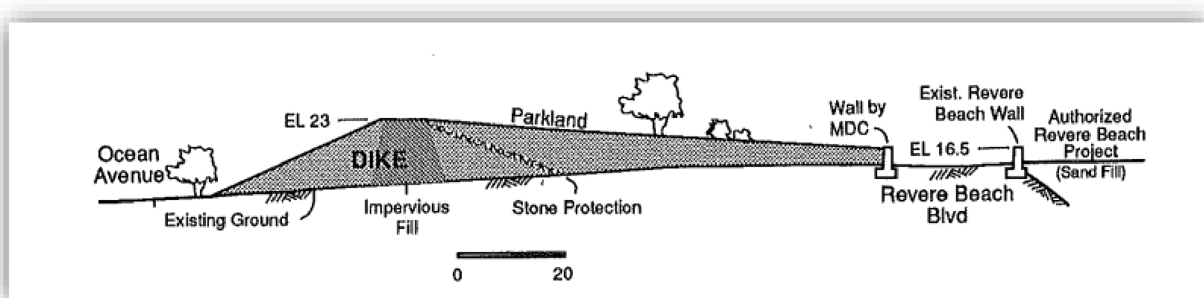


Figure 5: Proposed Park Dike

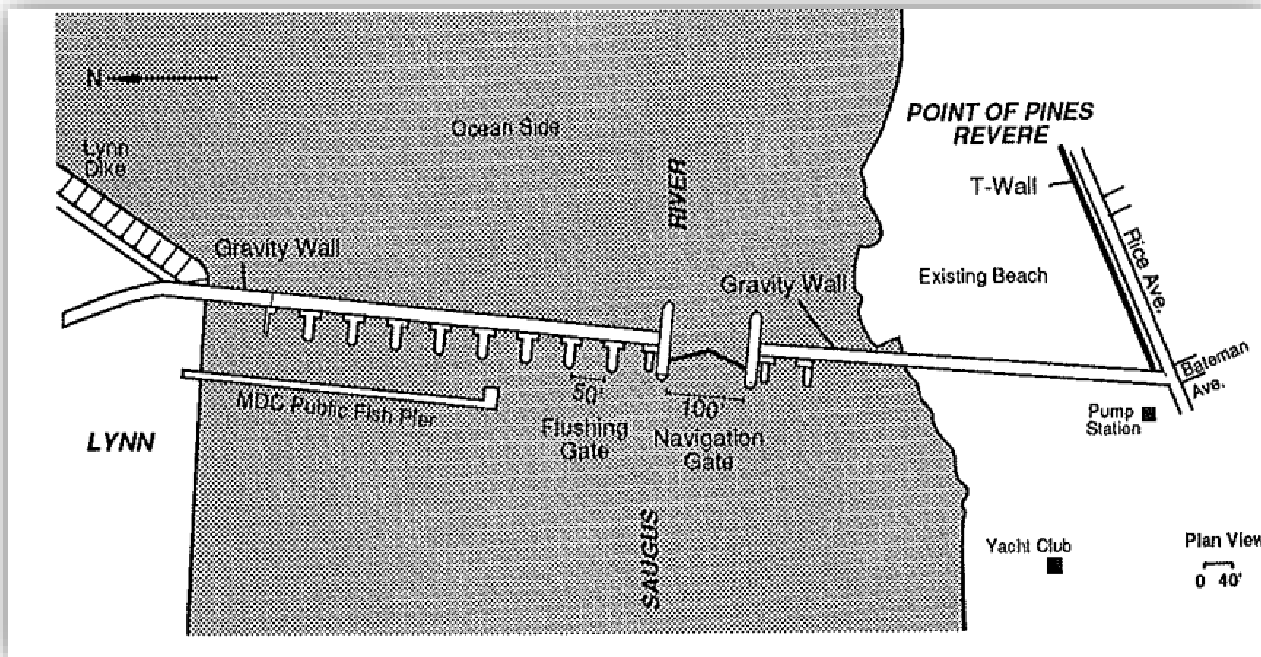


Figure 6: Point of Pines Structural Recommendation Overview

1991 USACE Revere Beach Erosion Control Report

This report focused on beach erosion issues at Revere Beach Reservation. The report identified that Revere Beach Reservation was only 4 ft. above MLW which made the seawall structures vulnerable to the daily erosion from saltwater and sedimentation. The USACE stated in the report that the primary reasoning for the advancement was due to development along the shore and natural erosion. The recommended plan suggested widening Revere Beach Reservation by placing sand fill along 13,000 ft. of beach fronting the Metropolitan District Commission Reservation to a backshore elevation of 18 ft. above MLW. The design included an elevated area consisting of fill material, resulting in the area being above MLW, which reduced the surface area impacted by tides, waves and currents. It was estimated that 800,000 cubic yards of sand fill would be needed for construction. These recommendations provide an adequate amount of protection against the storm surge and sea level conditions in 1991. The recommendation would not provide complete protection for hurricane and any infrequent major storm events.

2015 City of Revere Hazard Mitigation Plan

Hazard Mitigation planning is a proactive effort to identify actions that can be taken to reduce the dangers to life and property from natural hazard events. In the communities of the Boston region of Massachusetts, hazard mitigation planning tends to focus most on flooding, the most likely natural hazard to impact these communities. The Federal Disaster Mitigation Act of 2000 requires all municipalities that wish to be eligible to receive FEMA funding for hazard mitigation grants, to adopt a local multi-hazard mitigation plan and update this plan in five-year intervals. Planning for the Revere Hazard Mitigation Plan (HMP) update was led by the Revere Local Hazard Mitigation Planning Committee, composed of staff from several different City Departments. This committee discussed where the impacts of natural hazards most affect the City, goals for addressing these impacts, and hazard mitigation measures that would benefit the City.

The 2015 HMP summarized hazards faced by the City of Revere in the period up to 2014. The report found that the City is subjected to floods, hurricanes, tornadoes, coastal hazard, earthquakes, brush fires and extreme temperatures. There are many areas in the City that were vulnerable to the effects of flooding. During high tide and storm events, overtopping occurred at Eliot Circle, Revere Beach from Cary Circle to Eliot Circle, and the seawall located at the PoP on Miller Ave. Areas vulnerable to storm surge and high tide events were also identified in this report, including Cary Circle to Alden Avenue, Rice Ave. near the Yacht Club, and the Winthrop

Parkway Neighborhood. Furthermore, the Belle Isle Ave. neighborhood is susceptible to flooding during a storm surge that results in overtopping from Belle Isle Inlet. The report also found that Revere is extremely vulnerable to tsunamis and winter storms based on its geographical location and topography. Recommendations discussed in the report consisted of the installation of a 24- in. drainage pipeline along lower Pear Avenue; purchasing three 8 and 12-in. trailer mounted diesel pumps and hoses; the installation of a diesel generator at 17 sewer pump stations and at the Reservoir pumping station; and the installation of a tide gate along Rout 1A. The report recommended the addition of a seawall from Cary Circle to Alden Avenue and along Miller Avenue from North Shore Road to Alden Avenue. The final recommendation was for the City to install new sewer pump stations at Martin Street and Oak Island.

2019 Municipal Vulnerability Preparedness (MVP) Summary of Findings Report

This report summarized climate change concerns and solutions that Revere residents established during the MVP workshops. The top City hazards identified by the attendees included: coastal and inland flooding, erosion, extreme temperatures, sea level rise, hurricanes and severe storms. There were five areas in Revere that the MVP groups focused on Beachmont, PoP and Riverside, Oak Island and Revere Beach, West and North Revere and Sales Creek. Within the Beachmont area, there are several neighborhoods that are vulnerable to flooding. There are portions of Beachmont that are within the 100-year and 500-year FEMA Floodplain. This region is home to schools, pump stations, a tide gate, and areas designated as Areas of Critical Environmental Concern by the State. The Majority of the PoP/Riverside Ara excluding Route 1A, is located within the 100-year floodplain. The Point of Pines Yacht Club, Point of Pines Beach, and associated piers, docks, and water access points are exposed to wind and storm surge. Sales Creek and West and North Revere are located within the 100 100-year floodplain. Some of the most severe flooding occurs in the vicinity of Belle Isle Marsh and Rumney Marsh during high tide rainstorm events. MVP workshop participants noted that flooding resulted in the pollution of nearby marshes, wetlands, and other surface water bodies due to associated sediment and nutrient loading. Many recommendations were made for the Study Area. The top priority action items were to construct a seawall and in the PoP and Riverside area; to conduct feasible studies to determine the best mitigation methods for flooding, erosion, and storm impacts in the PoP and Riverside area; rehabilitate the existing seawalls to mitigate flooding in the Beachmont area; dredge and maintain Town Line Brook in the northwest side of Revere; form a liaison between the City of Revere and the State for funding sources and improve communication between the City and State; promote future developments in relation to flooding and drainage in the City; investigate permit process for sand transfer to mitigate coastline erosion in the PoP and Riverside area. All the recommendations suggested by the workshop would allow Revere to be more resilient against one of its major threats - flooding.

2020 Boston Region Metropolitan Planning Organization's (MPO) Route 1A Corridor Vulnerability Assessment

The MPO conducted a community survey and identified Route 1A as a location to conduct a pilot study. During the study, the MPO identified that the Study Area is vulnerable to high tides, flooding, storm surge and sea level rise. Currently, Route 1A has a flood probability between 10 percent to 20 percent with a 1 percent flood depth of approximately 1.5 ft. Within the next 10 years, the flood probability increases to 20 to 25 percent with a flood depth between 2 to 3.5 ft. With a flood probability of 100 percent in 30 to 50 years, Route 1A is likely to be overtopped as often as once a year. The estimated 1 percent annual chance event in 30 to 50 years, is predicted to have flood depths ranging from 5 to 10 ft. The MPO provided both structural and non-structural recommendations for Route 1A. The structural recommendations consisted of installing bulkhead, breakwater, edging devices rock sills and revetment structures, planting wetland vegetation, and raising the roads to upgrade culverts. The non-structural recommendations were to develop an emergency response plan, a flood preparedness plan and establish land use regulations. The MPO recommended that the City acquire certain structures and possibly relocate those structures, along with flood-proofing structures. Lastly, it was recommended that a flood warning system should be implemented.

Figure 7: High Tide Flood Frequency of the Study Area Limits

3. Ongoing Relevant Projects in the Project Area

Riverfront Master Plan

The Riverfront Master Plan is an in-progress initiative lead by the Revere Office of Strategic Planning & Economic Development. The goal of the Plan is to analyze and discuss current challenges and opportunities for the districts within and near Gibson Park, the Riverside neighborhood, and the PoP area. The report will focus on coastal flooding, climate resiliency, green spaces, transportation and development within the study area, along with the City of Revere as a whole. The mayor of Revere, Mayor Arrigo, selected the advisory group for this project, consisting of community advocates, neighborhood representatives and city officials. The group will provide feedback and input throughout the study. four public meetings were held between November 2020 and December 2020.

The preliminary draft report recommends non-structural improvements including to incorporation of a public pier in Gibson Park that could be used for public fishing, or a gangway and a float for excursions and water taxi services. Another recommended non-structural improvement is to develop a community boating area, which would provide opportunities for community rowing. One of the structural improvements recommended is to combine the eastern portion of the Boatworks location with Gibson Park to provide extra parking, recreational and stormwater management space for the study area. This improvement would also result in the existing revetment wall to be rebuilt with additional stones and rip rap. The wall would be built to a height that protects the area from storm surge. The last structural improvement was to convert the northwestern portion of the waterfront to a salt marsh**.** Other recommendations and potential developments can be observed in **Figure 8**.

Figure 8: Riverfront Master Plan Conceptual Designs

Rowing Facility and Long-Term Uses for Gibson Park

This project will develop waterfront access for rowing. The St. Mary's rowing team will be the primary users of the new waterfront access. After the initial access for rowing is completed, there may be further developments on the waterfront to create a public waterfront access facility for Revere. The preliminary investigations will consist of an above-water and underwater investigation of the existing waterfront infrastructure along the 250 ft. shoreline. The underwater investigation will begin at the shoreline and extend 200 ft. into the river. When the preliminary investigation is completed, the City will be provided with a preliminary planning report that will detail the waterfront access options both for the rowing team and a future public access facility as well. The report will also include schematic plans of options, planning and construction processes, regulatory and permits required; a project schedule; potential challenges and design considerations; a rough initial cost for the project, and potential funding sources.

Department of Conservation and Recreation Climate Change Vulnerability Assessment

The Department of Conservation and Recreation (DCR) is undertaking a pilot project to assess the vulnerabilities of natural, cultural and recreational resources to climate change at three of its properties. One of these properties is Revere Beach Reservation. Although Revere Beach Reservation is excluded from the project area of the Feasibility Study, the source is included in this memo for informational purposes only.

The project involves analyzing existing asset data and gathering additional data. The data collected and analyzed will assist DCR in providing recommendations for each of the project areas. The recommendations will be based off climate change projections and relevant site conditions. The results of the assessment are expected at the end of Fiscal Year 2021.

4. Relevant Case Studies

In order to successfully assess and recommend climate mitigation strategies and actions for this feasibility study, research was conducted to identify strategies implemented by other communities of similar geographic location, vulnerabilities to climate hazards, topography, and population. The City can use the research performed by other municipalities to advise this feasibility study and next steps in the project process. Similar studies and projects in the northeast region of the country and are summarized and presented below. Each text section describes the applicable case study's goals and solutions and includes a summary statement in bold that identifies how each study's conclusion applies to the current scope and goals of this project.

Table 2: Summary of Relevant Case Studies

Title	Author	Date of Source	Source Overview	Definition of Study Area	Summary of Findings	Recommended Options
Coastal Resiliency Planning for Surf Drive, Falmouth, MA	Woods Hole Group, Inc.	2020	This study discussed the MVP planning process undertaken by the Town after conducting a climate change flood vulnerability assessment. It evaluated high priority areas and infrastructure in Falmouth that are vulnerable to climate change events, in particular flooding and erosion due to sea level rise. This study recommended actions the Town can take to protect infrastructure, improve resiliency of natural resources and ecosystems, and maintain coastal resources to preserve Town's cultural identity around the Surf Drive Area.	Falmouth, MA - Surf Dr	The most common actions for the studied area discussed throughout the workshops were flood mitigation through natural and structural barriers, promote public awareness and education, and abandonment of maintenance for vulnerable areas.	• Beach/dune nourishment for vulnerable roadway sections • Remove existing pavement along beach barriers and construct extended bridge • Construct tall flood barrier (i.e. seawall) • Abandon Surf Dr • Cease maintenance along Surf Dr • Research and develop policies for phasing out Town services to private homes and roads in vulnerable areas • Engage in public outreach to prepare residents for future changes

Title	Author	Date of Source	Source Overview	Definition of Study Area	Summary of Findings	Recommended Options
Climate Ready Boston - Climate Resiliency Study	City of Boston & Green Ribbon Commission	2016	Climate Ready Boston used three climate projection scenarios to develop an extensive feasibility study for 7 Boston neighborhoods. This was done by examining various strategies for climate adaptation that differed in time and cost. The City prepared a vulnerability assessment and used those findings to prepare climate resiliency initiatives which addressed the impacts of future climate change.	Boston, MA	The findings of this study suggested implementing various community engagement efforts, land use planning, infrastructure adaptation planning, adapted structures, and development of financial strategies and governance structures.	• Flood protection systems • Adapted buildings • Green Infrastructure • Feasibility study for energy solutions
Resilient Cape Cod Project	Cape Cod Commission	2018	In this study, CCC and partners developed a tool and public outreach program to investigate the environmental and socio-economic efforts of local and regional coastal resiliency strategies in hopes of enhancing the resilience of communities to the effects of extreme weather, climate hazards, and changing ocean conditions. This study focused on the effects of erosion, storm surge, and sea level rise.	Cape Cod, MA	The study produced The Coastal Planner - a communication and decision support tool which is used to communicate the impacts of coastal threats and adaptation strategies, including cost and benefits, and implications for local infrastructure and ecosystems.	• Do nothing • Beach nourishment, dune restoration • Offshore Reefs • Coastal Armoring • Structure elevation •Wetland and salt marsh restoration • Retrofitting existing utilities, roadways, and structures for flooding • Living shoreline • Regulation of development

Title	Author	Date of Source	Source Overview	Definition of Study Area	Summary of Findings	Recommended Options
Manchester, MA Sawmill Brook Restoration	Tighe & Bond	2019	This MVP funded feasibility study describes a 5-year planning process to restore Sawmill Brook in Manchester-by-the-Sea. Goals for this project included: fish passage improvement, wildlife habitat enhancement, public safety, and aesthetics. These goals must be balanced with flood mitigation and climate change resiliency. This study includes a permit level design for the preferred restoration project for Central Pond.	Sawmill Brook, Manchester-by-the-Sea	Work completed under the grant included identification of town owned land along the eastern banks of Central Pond, reducing the required number of easements for the restoration project, geotechnical studies, and public outreach to discuss analysis of alternatives for the restoration design	• Salt marsh planting • Flexible block retaining wall with public stairway access to water
Breezy Point - NY Rising Community Reconstruction Plan	Multiple Engineering Consulting Firms	2014	This study looks at the Breezy Point Community coastal resiliency project as a proposed project for the NYRCR Program. This study examines long term initiatives that will protect and enhance the community and outlines a comprehensive approach for reconstruction based on a 7-month planning process.	Breezy Point, located at the end of the Rockaway Peninsula in Queens, New York	The study produced various recommendations and strategies to mitigate the effects of sea level rise, erosion, and extreme weather events due to climate change. The goals of these mitigation efforts are to improve and expand coastal protection, strengthen community resilience, and protect and bolster infrastructure.	• Enhanced dune walkways • Bayside coastal protection • Natl. Park Service collaboration • Boulevard elevation • Housing elevation study •Multi-purpose community relief center • Summer store relocation • Repaired docks • Stormwater drainage improvements

2020, Coastal Resiliency Planning for Surf Drive

This study, performed by the Woods Hole Group, Inc. (WHG), discusses the MVP Planning Process undertaken by the Town of Falmouth, MA after conducting a climate change flood vulnerability assessment on a coastal road (Surf Drive). Similar to the Revere MVP planning process and feasibility study, the Surf Dr. planning study evaluated high priority areas and infrastructure in Falmouth that are vulnerable to climate change events; in particular, flooding and erosion due to sea level rise. The Surf Drive area is particularly vulnerable to inundation during a storm and typically requires frequent maintenance in the form of debris clearing and road damage repairs. This study recommended various actions the Town can take to protect infrastructure, improve resiliency of natural resources and ecosystems, and maintain coastal resources to preserve Town's cultural identity around the Surf Drive Area. The possible actions were for the Town to perform beach and dune nourishment/rehabilitation in vulnerable roadway areas, remove existing pavement along beach barriers, construct a seawall, abandon Surf Dr., cease maintenance, and research phasing out public maintenance to the Surf Dr. area. All recommended options were presented with a cost-benefit assessment. **The presented recommendations for the Surf Dr. road will be a beneficial asset when examining the PoP and Riverside areas in Revere due to similarities in residential use, coastal proximity, and existing infrastructure.**

2016, Climate Ready Boston - Climate Resiliency Study

Climate Ready Boston used three climate projection scenarios to develop an extensive feasibility study for seven Boston neighborhoods under the MVP Planning Process. This was done by examining various strategies for climate adaptation that differed in time and cost. The City prepared a vulnerability assessment and used those findings to prepare climate resiliency initiatives, which addressed the impacts of future climate change. The findings of this study suggested implementing various community engagement efforts, land use planning, infrastructure adaptation planning, adapted structures, and development of financial strategies and governance structures. Notable actions included flood protection systems, adapted buildings, green infrastructure, and a future feasibility study for energy solutions. Flood protection systems include the construction of large harbor barriers, use of temporary flood barriers, creation of coastal tree canopies, and building protective and floodable waterfront parks. Green infrastructure and adapted building options discussed in the plan include retrofitting buildings with solar panels and microgrids, creating bioswales, and elevating buildings and mechanical systems out of flood range. **Although Boston is much larger than Revere, the geographic location, population diversity, goals and strategies are similar and will be useful in advising the feasibility study for the Study Area.**

2018, Resilient Cape Cod Project

In this study, Cape Cod Commission (CCC) and partners developed a tool and public outreach program to investigate the environmental and socio-economic efforts of local and regional coastal resiliency strategies in hopes of enhancing the resilience of Cape Cod communities to the effects of extreme weather, climate hazards, and changing ocean conditions. Similar to the Revere feasibility study, this study focused on the effects of erosion, storm surge, and sea level rise. The study produced The Coastal Planner - a communication and decision support tool which is used to communicate the impacts of coastal threats and adaptation strategies, including cost and benefits, and implications for local infrastructure and ecosystems. Also parallel to the Falmouth MVP study, the recommendations included in this study were beach nourishment, offshore reefs, coastal armoring in the form of seawalls and barriers, wetland and marsh restoration, infrastructure retrofitting, developing a living shoreline, and regulation development. **Revere's feasibility study can draw from the adaptation strategies set forth in this project in terms of cost, impacts to local infrastructure and ecosystems, and overall project feasibility.**

2018, Manchester, MA Sawmill Brooke / Central Pond Restoration

This MVP funded feasibility study describes a 5-year planning process to restore Sawmill Brook in Manchester-by-the-Sea. Goals for this project included: fish passage improvement, wildlife habitat enhancement, public safety, and aesthetics. These goals must be balanced with flood mitigation and climate change resiliency. This study includes a permit level design for the preferred restoration project for Central Pond. Work completed under the grant included identification of town owned land along the eastern banks of Central Pond, reducing the required number of easements for the restoration project, geotechnical studies, and public outreach to discuss analysis of alternatives for the restoration design. **Although a different scope than the Revere study, it sheds light on the 'next steps' in the planning and design process on how to bring a project idea into action.**

2014, Breezy Point – New York Rising Community Reconstruction Plan

This study examines the Breezy Point Community Coastal Resiliency Project as a proposed project for the New York Rising Community Reconstruction (NYRCR) Program. This study looks at long term initiatives that will protect and enhance the communities located on the westernmost end of the Rockaway Peninsula in Queens that make up the Breezy Point Community. This community faces threats from future climate change in the form of flooding from sea level rise, extreme weather events, and coastal erosion. The plan outlines a comprehensive climate-based approach for reconstruction based on a 7-month planning process that identified strategies for building economic and social resiliency in the area. Resilience goals would be achieved by improving and expanding coastal protections, strengthening community resilience, and protecting and bolstering current and future infrastructure. Recommendations from the study include enhancing dune walkways, elevating the boulevard, a housing elevation study, relocating summer stores, building bay seawalls and armored dunes, improving stormwater drainage, and collaborating with the National Parks Service to identify vulnerabilities on NPS land that threaten the Breezy Point Community. **The Breezy Point Community mirrors the Revere PoP/Riverside Community in that they are both coastal peninsulas with similar vulnerabilities looking to build resiliency towards the increased threats from climate change. Revere can implement the cost, risk, regulatory, and general project findings from this study as various strategies are assessed for the feasibility study.**

5. Historical Data

In examining resilience strategies to mitigate the impacts of future climate change, it is necessary to understand the area's geographic layout as well as any current vulnerabilities that have been illuminated by past natural hazard events. This section summarizes historical information that has been gathered in the form of surveys, maps, charts, studies, and records of historical events that will inform this feasibility study of ongoing vulnerabilities in order to prioritize future mitigation strategies and actions.

Thayer Boat Yard Existing Survey

The Thayer Boat Yard, also known as North Shore Boat Works, is a 1.15-acre parcel located on the northwesterly end of the Revere Beach peninsula along Thayer and Hayes Ave, bordered by Gibson Park to the north (See Figure 5 below). The boatyard/marina facility has existed since the early 1900s and has historically been a location where significant flooding has occurred due to its proximity to the ocean and low elevation. The lot has been assessed for potential development on numerous occasions, two of which were in 1989 and 2006. The boatyard consists of a dirt lot containing a one-story building on the southwestern side of the property closest to the waterfront, a parking area, and storage for boats, equipment, and parts on the remaining lot area. The property has an approximate <0.5% slope from the upland area to the shoreline, which consists of a bulkhead retaining wall and riprap. Most notably, the 1920 mean high water mark, as displayed on the 2006 survey, encroaches 10-15 ft onto the boatyard property. Because the property sits at a low elevation on the water's edge with little protection from rising tides, it is in danger of continual coastal flooding with sea level rise.

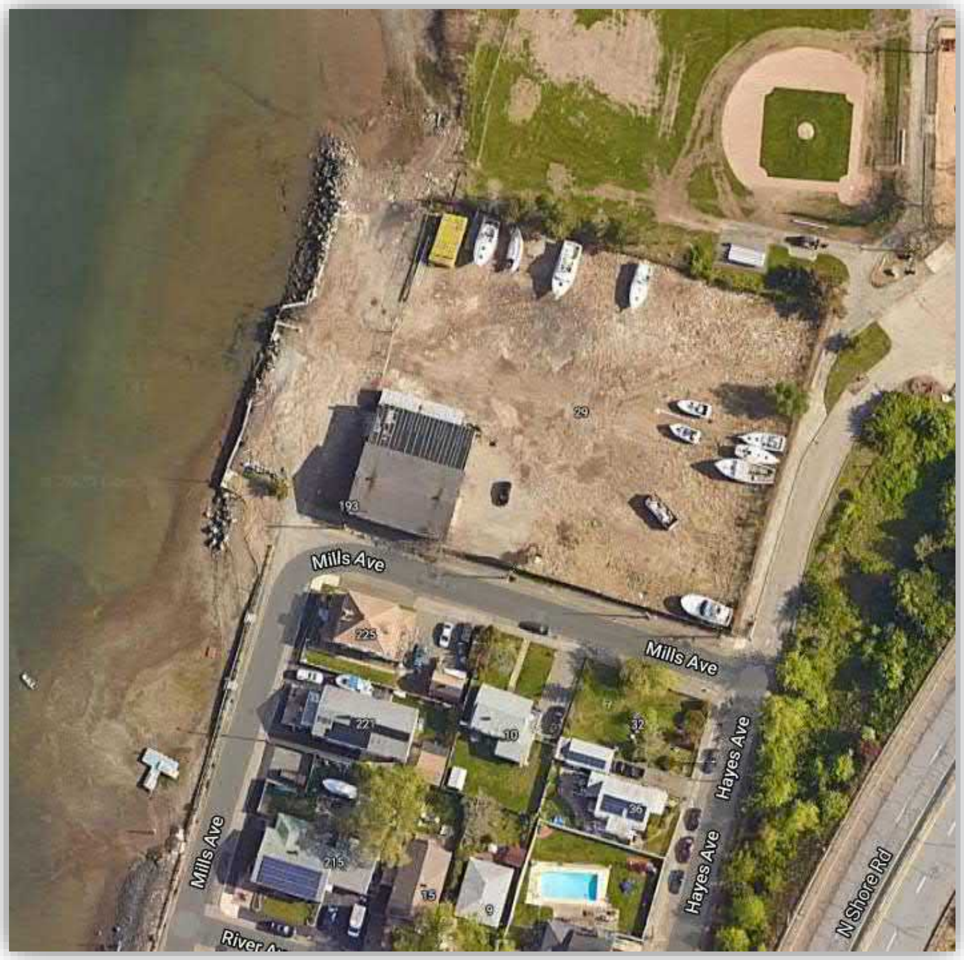


Figure 9: Thayer Boat Yard, 2020 Aerial Photo

Navigational Charts

The Study Area is a peninsula located within the Broad Sound, just west of Nahant. As displayed on the NOAA navigational chart (see Figure 6 below), the Study Area is in a low-lying bay within the Sound, surrounded by sandy tidal flats extending significantly into the bay on the eastern side. A channel extends from the deep Sound up to the Saugus River, crossing under the General Edwards Bridge located on the northern point of PoP. The channel edges the sandy area on the northeastern side of PoP at a low tide depth of 8 ft. Just beyond the sandy shores around the PoP, the water depth drops to between 0.5 to 8 ft in the surrounding shallow bay. The high tide depth in the PoP area is typically between 9.5 -10.5 ft at a normal high tide but was recorded at over 12 ft in 2018.

Figure 10: NOAA Navigational Chart, Point of Pines, Revere, MA, 2016

Historical Storm Events

Revere has experienced numerous coastal storms over the past few decades, largely in the form of nor'easters. Most notably were the well-known Blizzard of 1978 and the more recent Winter Storm Grayson that occurred in the winter of 2018 causing severe flooding and evacuations in Revere. In 1978, the City experienced a tide surge creating a 100-year water level, causing extensive damage to 25% of the City's homes. Dubbed as the 'bomb cyclone', the storm in 2018 resulted in almost identical levels of severe flooding paired with precipitation and cold temperatures, which caused infrastructure damage and the evacuation of 20 people from their homes, some needing emergency assistance.

The revere Hazard Mitigation Plan, last updated in 2014, lists a total of 17 natural disasters that triggered federal or state disaster declarations since 1991 in Revere. City specific flood data was unavailable at the time the plan was written, but the county in which Revere is located experienced six flooding events since 1996 totaling $25.733 million dollars in property damages.

This plan also notes the repetitive loss structures in Revere, which are properties that have filed two or more flood claims of $1,000 or more in any given 10-year period. That number of properties has increased from 249 in 2005 to 293 in 2014. 270 of these properties are located within a FEMA flood zone and are mostly comprised of single or multi-family residences.

Coastal Erosion and Shoreline Change

Coastal shorelines change in response to wind, tides, waves, sea level rise, human interaction, and climate variation that influence the movement of sand and sediment. Shorelines are shaped by the gain and loss of sand and sediment due to these influences. Revere is situated in such a way that the Study Area is exposed to waves and wind on the eastern side facing Broad Sound, pushing sand towards the northern tip of the peninsula. This northern area of PoP sees a constant deposit of sand from the southern Riverside shoreline, which can result in the blockage of tide gates and stormwater structures. These conditions are exacerbated in the winter months when weather conditions are typically more severe in comparison to the calmer summer months. The Coastal Erosion Commission reported in 2015 that attempting to halt the natural process of erosion through seawall construction or other hard structures will only worsen the problem by eliminating downdrift from sediment held behind the structure. In Revere, beach nourishment has taken place on several occasions to rehabilitate the dunes for natural storm protection.

The Massachusetts Hazard Mitigation Plan references a study which examined coastal erosion along the shorelines in Massachusetts and found that 68% (513 miles) of Massachusetts shoreline exhibited long-term erosion and 30% (226 miles) showed long-term accretion. Approximately 46% of the Massachusetts shoreline is eroding at one foot or less per year. Sea level rise and coastal flooding contribute to coastal change and are frequent events along the coast of Massachusetts. Flooding has been increasing as a result of sea level rise and land sinking over the last 100 years. If climate change trends continue, coastal flooding will become more frequent as oceans warm and glaciers melt, resulting in higher risk for coastal communities such as Revere. When sea levels rise, smaller storms will exhibit the same amount of damage as larger storms do currently.

Massachusetts Office of Coastal Zone Management’s (MA CZM) Shoreline Change Project

The MA CZM 2010 Shoreline Change report analyzed historical shoreline changes on the New England and Mid Atlantic coasts. Throughout the report, long and short-term trends and rates of erosional change were examined. The project also studied how different coastal communities are impacted by coastal erosion. The study found that New England and Mid Atlantic sandy shorelines are subjected to a long-term erosion rate of 65 percent and a short-term rate of 60 percent. The study suggested that the erosion rates are caused by sea level rise. The effects of sea level rise can be mitigated by beach nourishment projects and thoughtful engineered structures, as suggested by the study. Beach nourishment was noted as a highly effective option because it slows down the rate of which sand recedes, allowing the rate of erosion to stabilizes or slow down.

6. Conclusion

The review of current and historical weather conditions, studies, assessments, testimonials, and maps of the City of Revere reestablishes the prior conclusions stated in 1986 – they show 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. Measures to mitigate the effects of these hazards will need to be prioritized by the City in order to prevent future damage as climate change exacerbates these conditions. The historical data from this area has shown that sea level rise in conjunction with high tides have resulted in the increased frequency of coastal flooding in the PoP and Riverside communities. Furthermore, due to its positioning in the Broad Sound, the Study Area has also been exposed to erosion and shoreline change as wind, currents, and waves alter sand placement on the Riverside and Point of Pines coasts. The historical data collected from Revere, paired with local case studies, will be used to inform the next steps in this feasibility study, which will ultimately be used to develop a coastal resiliency toolkit for Revere to utilize when addressing future climate change threats.

7. Acronyms

Ac.	Acres
Ft. or ft.	Feet
In. or in.	Inches
MLW	Mean Low Water
MVP	Municipal Vulnerability Preparedness
MPO	Metropolitan Planning Organization
NYRCR	New York Rising Community Reconstruction
NGVD	National Geodetic Vertical Datum
PoP	Point of Pines
USACE	United States Army Corps of Engineers

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E. Appendix E: Task 2 Climate Science and Vulnerability Assessment Memorandum

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250 Apollo Drive
Chelmsford, MA 01824
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Project name:
Point of Pines and Riverside Area Coastal Resilience Feasibility Study

Project ref:
60646341

To:
Elle Baker, Project Planner, City of Revere
Frank Stringi, City of Revere

CC:
File

From:
Aaron Weieneth
Jennifer Doyle-Breen
Ricky Torres-Cooban

Date:
April 19, 2021

Climate Science Review and Vulnerability Assessment Memo

1. Introduction

The changing global climate presents unprecedented challenges for coastal communities. This Memorandum is part of the second task in a six-task feasibility study that will provide the City of Revere with an overview of both historic and present hazards that the City faces in the Point of Pines (PoP) and Riverside areas, which will be referred to as the Study Area. This is the second of four technical memoranda that will be provided as part of the feasibility study; the findings from the four technical memoranda as well as three stakeholder meetings will be summarized in a final report which will also include an implementation plan identifying prioritized action items, responsibilities and potential funding sources to address coastal vulnerabilities in the Study Area. The information presented in this Memorandum provides an overview of the most recent projections for future climate conditions followed by a discussion of existing and future climate hazard vulnerability as well as their potential impacts to the Study Area.

2. Climate Science Review and Identification of Data Sources

This section is focused on describing projected changes to temperature, precipitation, and coastal flooding. The climate hazards included in this section and the remaining sections of this memorandum were selected based on their relative impacts to the community as well as availability of future conditions climate hazard projections. Climate data sources, assets critical to the Study Area, and existing flood risk reduction infrastructure are also presented in this section.

2.1 Data Sources

A wealth of information on future climate hazards is available for the Greater Boston Area. Table 2-1 summarizes the primary data sources for each of the climate hazards considered in this section. Additional references are documented in the Bibliography (Section 7).

Table 2-1. Future Conditions Climate Data Sources

Climate Hazard	Primary Source
Temperature	Resilient MA (http://resilientma.org/)
Precipitation	Resilient MA (http://resilientma.org/)
Coastal Flooding and Sea Level Rise	Massachusetts Coast Flood Risk Model (MC-FRM) NOAA 2017 Sea Level Rise Projections (https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf)

Resilient MA climate projections are available for counties in Massachusetts and are based on statistically downscaled output from 14 general circulation models (GCMs) selected for their performance in the Northeast region of the United States. Two Representative Concentration Pathways (RCPs) are included as future greenhouse gas emission scenarios—RCP4.5 and RCP8.5. RCP 8.5 is the "worst case" scenario included in the most recent Intergovernmental Panel on Climate Change (IPCC) set of scenarios, representing unabated emissions without any advances in technology or implementation of any climate action measures, while RCP 4.5 represents a more optimistic "stabilization" scenario where atmospheric greenhouse gas concentrations increase until mid-century (~2050) after which concentrations remain stable until 2100. Resilient MA values are presented as 10^{th}, 50^{th}, and 90^{th} percentiles of the 28 projections in order to represent the range of plausible values spanning the various models and both emissions scenarios.

The Massachusetts Coast Flood Risk Model (MC-FRM)—developed through a collaboration between the Woods Hole Group, the Massachusetts Department of Transportation (MassDOT), and the University of Massachusetts Boston—is the primary source of flood risk information used in this analysis. Output from this modeling effort provides the most comprehensive and robust coastal flood risk data available for the study area to date as it dynamically simulates hundreds to thousands of possible storms including both hurricanes and nor'easters and provides flood exceedance probabilities at a high spatial resolution for existing and future conditions.

2.2 Temperature

Table 2-1 summarizes key temperature projections for Suffolk County based on Resilient MA. Temperatures in the study area are projected to increase significantly with the median number of days above 90° F projected to double from the baseline period (2001-2005) by 2030 and to increase by more than triple by 2070 (Resilient MA 2020). Additionally, the median number of frost days (below 32° F) are projected to decrease by over 10% by 2030 and almost 30% by 2070.

Table 2-2. 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

The Fourth National Climate Assessment (USGCRP 2018) discusses the implications of these changes for the Northeast Region as a whole and notes that winter temperatures have increased at three times the rate of summer temperatures. The result is a decrease in seasonality, with warmer late-winter and early-spring temperatures as well as erratic temperature changes triggering early and sudden snow melts as well as early budbreak that may result in damage to natural and agricultural resources when temperatures drop again.

As summer temperatures rise and extreme heat waves become increasingly prevalent, risks to human health also increase as well as potential loss of functionality and durability of infrastructure such as roads, overhead power lines, and air conditioning systems. Annual heat-related mortality in Boston was 2.9 deaths per 100,000 people from 1985 to 2016. It is projected that this rate will at least double by the 2020s. It is also projected that the rate may reach 10.5 per 100,000 under a moderate emissions scenario or even reach 19.3 deaths per 100,000 under the RCP 8.5 emissions scenario by the 2080s (City of Boston 2019). As seen in Figure 1, the number of heat related deaths each year is projected to triple in Boston (City of Boston 2017).

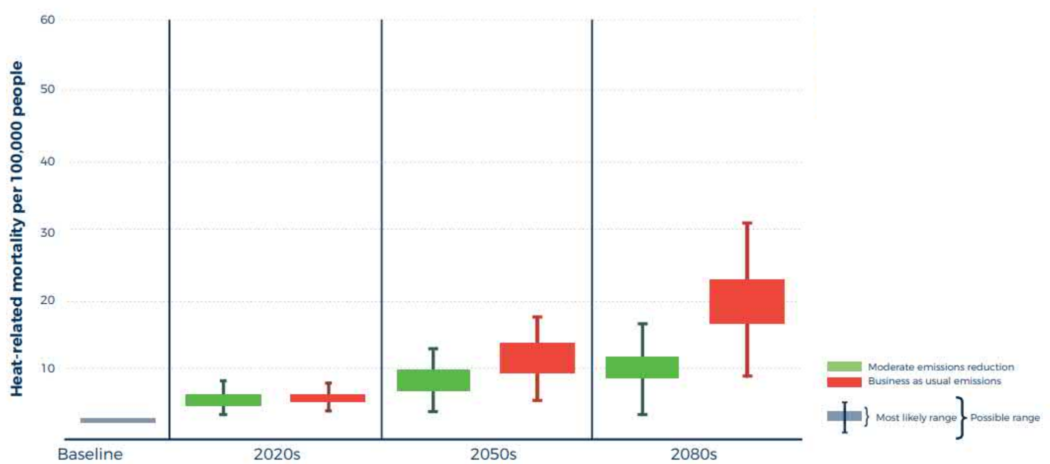

Figure 2-1: Projected Annual Heat-Related Deaths in Boston

(City of Boston 2017)

2.3 Precipitation

Precipitation is projected to increase in frequency and intensity though the changes are much more modest compared to the projected changes to temperature. As shown in Table 2-2, median total annual precipitation is projected to stay approximately the same by 2030 and increase by 2 inches by 2070. Extreme precipitation is more difficult to represent in GCMs than extreme temperature due to limited observational data as well as the fact that model spatial resolutions are typically too coarse to resolve localized precipitation events (Flato et al 2013). As a result, the increased uncertainty is demonstrated in the range of values for the precipitation projections which include the possibility for decreases in total annual precipitation of as much as 6 inches by 2050 on the lower range (10th percentile) and increases as high as 14 inches on the upper range (90th percentile).

Table 2-3. Projections for Total Annual Precipitation (Resilient MA)

Precipitation Indicator	Baseline (2001-2005) (Inches)	Percentile of Model/Scenario Output	2030s (2028-2032) (Inches)	2050s (2048-2052) (Inches)	2070s (2068-2072) (Inches)	2090s (2088-2092) (Inches)
Total annual Precipitation	48	90th	56	62	60	61
		Median (50th)	48	50	50	51

		10th	42	42	40	45

The Massachusetts State Hazard Mitigation and Climate Adaptation Plan defines heavy precipitation events as those accumulating over 1 inch of precipitation in a 24-hour period (Commonwealth of Massachusetts 2018). Table 2-3 shows the projected increase in the number of days with precipitation over one inch and over two inches. Again, median increases are expected to be modest with the number of days with precipitation above 1 inch staying approximately the same until the 2090s and the number of days with precipitation above 2 inches remaining approximately the same through the end of the century.

Table 2-4. Number of precipitation days above a threshold (Resilient MA)

Precipitation 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 with precipitation > 1"	9	90th	12	13	14	14
		Median (50th)	8	9	9	10
		10th	6	6	6	7
Annual number of days with precipitation > 2"	1	90th	2	2	3	3
		Median (50th)	1	1	1	1
		10th	0	1	1	1

It is important to note that the downscaled GCM precipitation output only provides simulated daily total values. Because of the Clausius-Clapeyron relation between temperature and pressure, as temperature increases the atmosphere can hold greater quantities of moisture, which leads to higher-intensity events. Thus, while the number of days with precipitation greater than one or two inches are not projected to increase significantly in total, it is very likely that the way the sub-daily precipitation events will occur could result in increased flash flood risk.

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 2-2 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% (1/10).

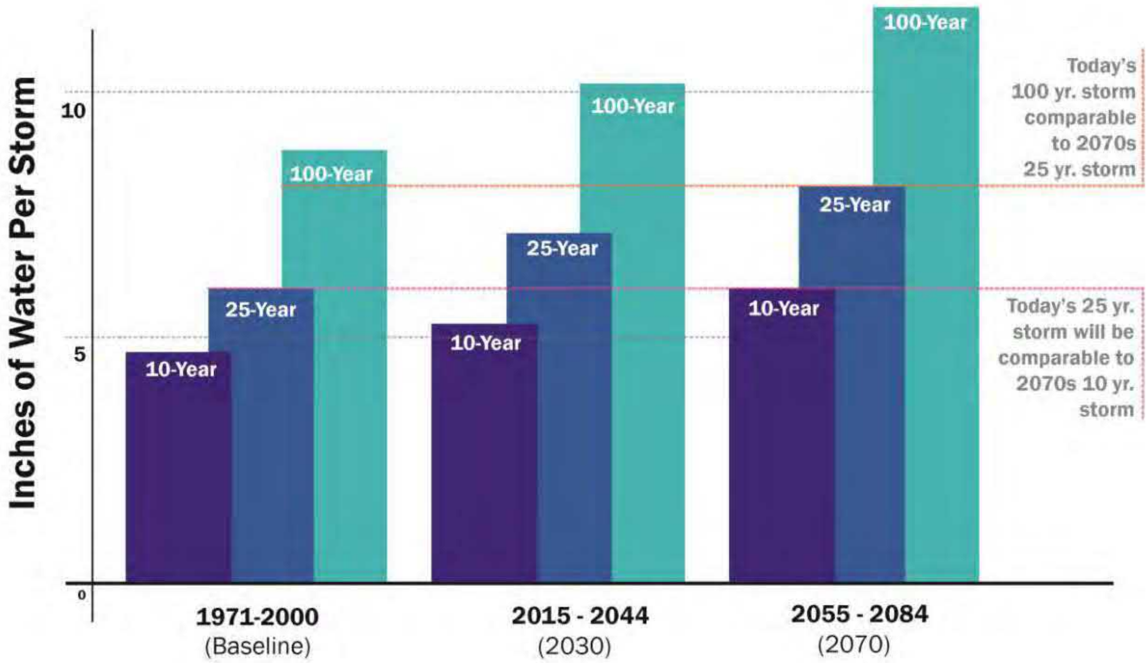

Figure 2-2. Changes to return period storms (City of Cambridge, 2015)

2.4 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 2-3 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. Table 2-5 shows the estimated probability of exceedance for SLR scenarios presented in Figure 2-3. The Low scenario is not included in Figure 2-3 due to high probability of exceedance.

Table 2-5. 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%

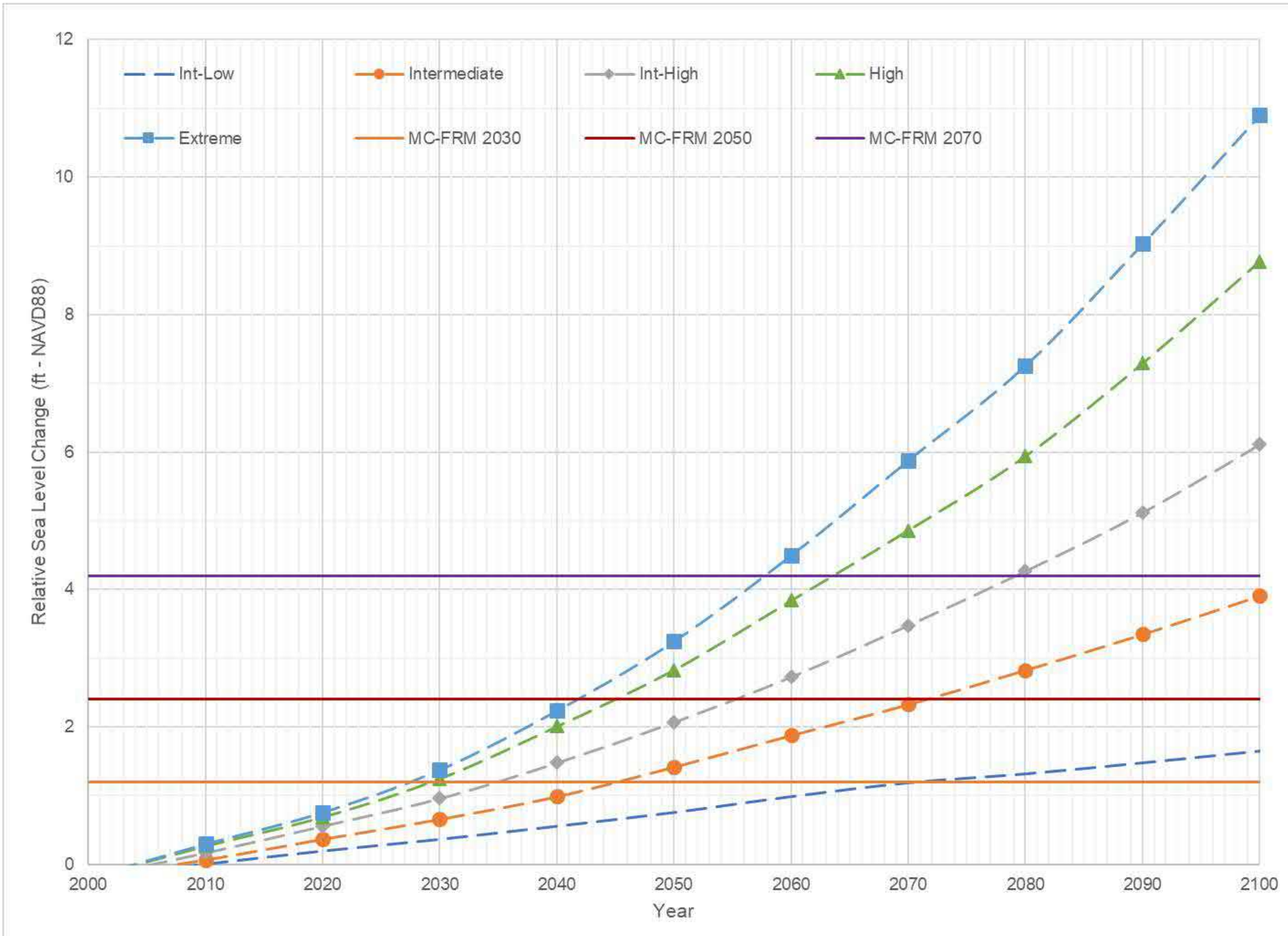

Figure 2-3. Relative Sea Level Rise (Boston - NOAA 2017)

As demonstrated by the range of values associated with each year, SLR rates are uncertain and become more uncertain further into the future. For example, SLC rates range from 0.37 feet to 1.38 feet in 2030, a difference of approximately one foot, compared to the rates for 2070 which span 1.19 feet to 5.88, a difference of over 4.5 feet. Accordingly, it is important to consider both the projected timing of SLR and the impacts that a given amount of SLR would have on the community. Figure 2-4 shows the areas of impact associated with existing average tide conditions (MHHW) and sea level rise values ranging from one to six feet.

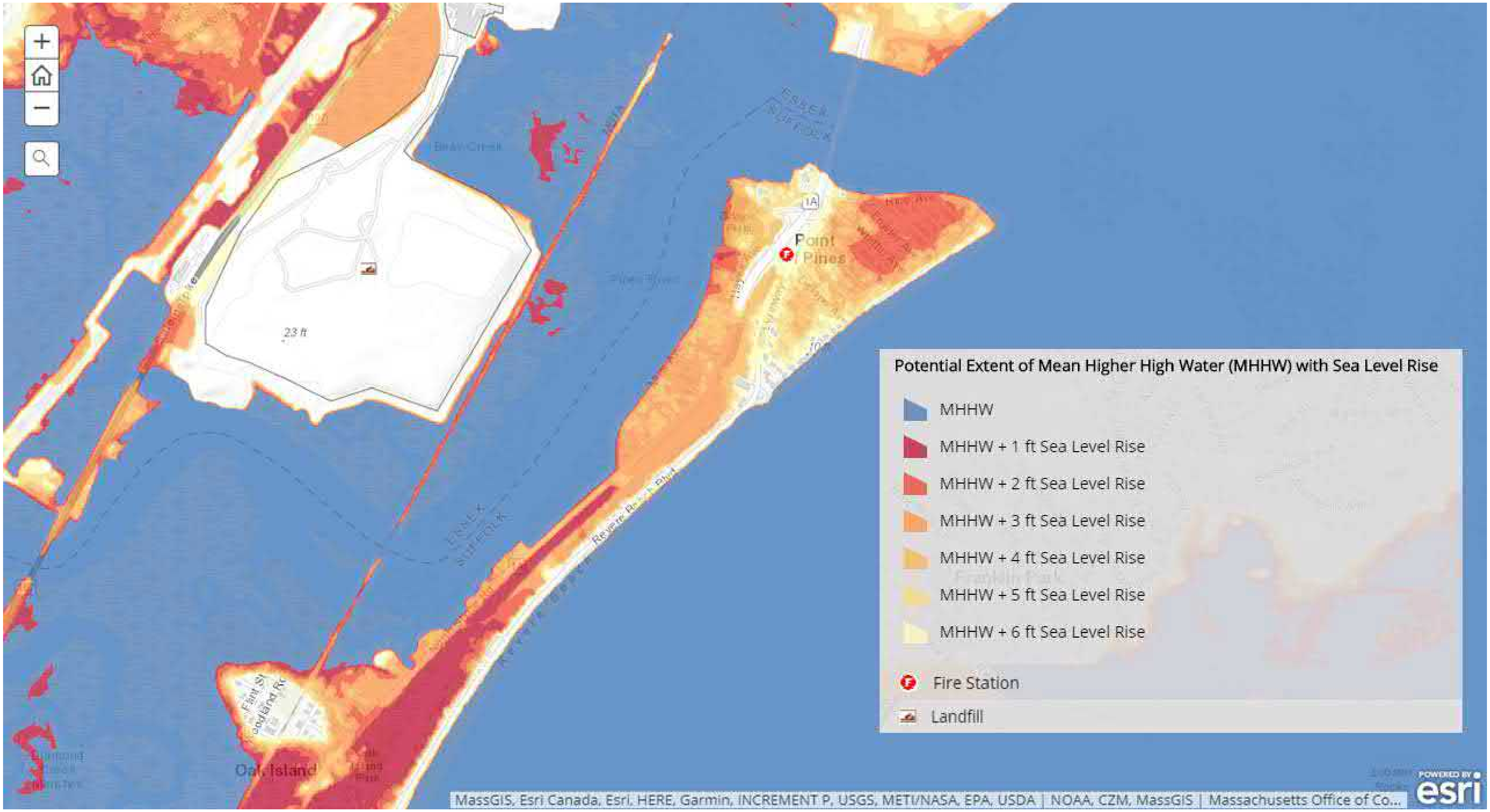

Figure 2-4. Sea Level Rise Inundation Areas (MA Sea Level Rise and Coastal Flooding Viewer)

3. Summary of Study Area and Identification of Key Resources

The Point of Pines/Riverside Area comprises approximately 130 acres within the City of Revere and is located approximately 7 miles northeast of the City of Boston in Suffolk County at the mouth of the Saugus River. The topography of this coastal community is generally low-lying and characterized by a central vein of higher ground elevations along Route 1A and the Lynnway which peaks near the General Edwards Bridge to the north and gently slopes down to the Pines River to the west and the Atlantic Ocean to the east. Figures 3-1, 3-2, 3-3, and 3-4 show the study area as well as the identified critical community assets.

While the Point of Pines/Riverside Area Study Area is primarily residential, the following critical community assets were identified within the study area for consideration in this assessment:

- Sea walls and rock revetment
- 4 bus stops
- General Edwards Bridge
- 5 highway culverts
- 7 tide gates
- 15 stormwater outfalls
- 1 wastewater pump station
- 1 stormwater pump station
- 1 fire station
- 1 adult day care center
- Gibson Park

The five highway culverts (not shown in Figures 3-1, 3-3, or 3-4) are located at approximately the same locations as the northernmost five tide gates along Route 1A in the southern portion of the Study Area. The culvert and tide gates are part of a passive control system built and maintained by MassDOT that manage the adjacent wetland areas. Conversations with City Staff suggest that these tide gates are not typically used to create additional flood storage during storm events, and since these assets are managed by MassDOT, the City has limited ability to operate or maintain these structures though they may be overdue for maintenance. Both pump stations are also equipped with backup generators. Other state-owned assets along Revere Beach were not included in this memorandum.

Other priority community assets were identified within the study area as follows:

- Point of Pines Yacht Club
- Broadsound Tuna Club Marina and Wharf
- A variety of businesses along Route 1A and Revere Beach Boulevard including:
    - Maxim Crane Works
    - Oceanview Kennels
    - Rick’s Auto Collision

Table 3-1 lists the major coastal and inland shoreline flood risk reduction structures located within the study area. Known elevations for the top of some of these features have been identified from past studies conducted in the Study Area, which were described in the Task 2.1 technical memorandum. Locations of the structures listed in Table 3-1 are shown in Figure 3-2. Additionally, photos of structures are included in Appendix B.

Figure 3-1. Point of Pines Study Area and Critical Assets (Overall)

Figure 3-2. Point of Pines Study Area and Critical Assets (East)

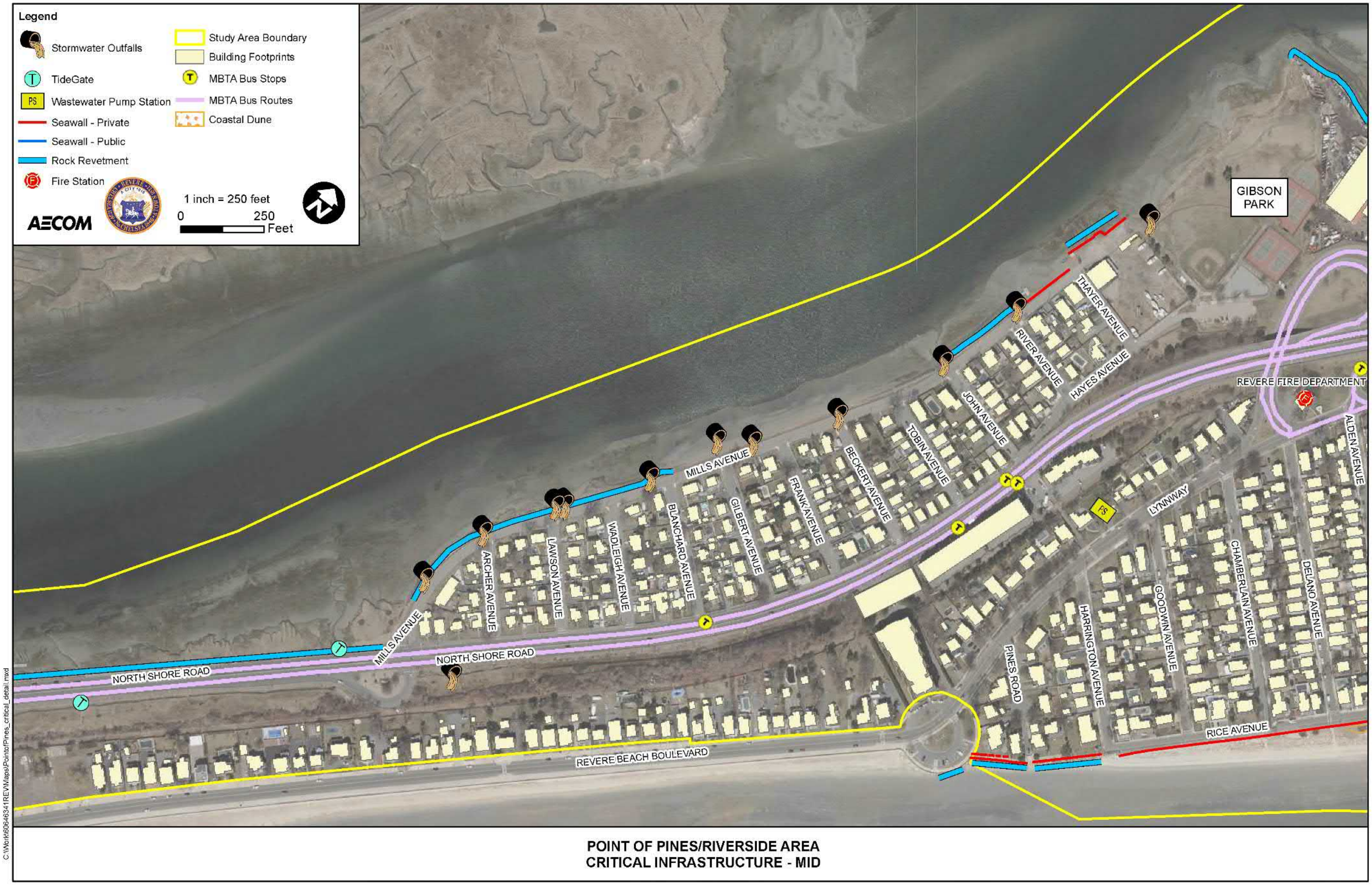

Figure 3-3. Point of Pines Study Area and Critical Assets (Mid)

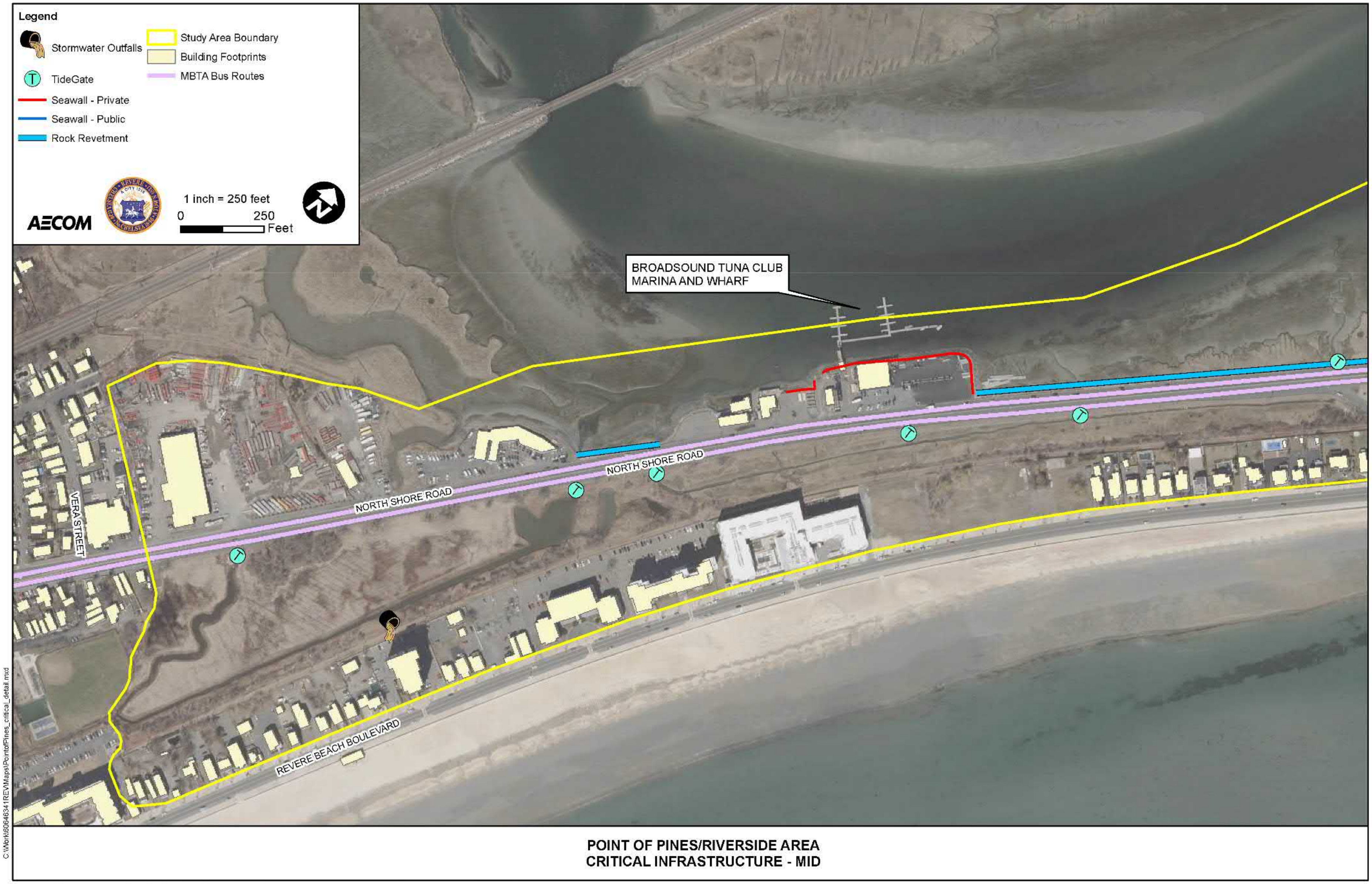

Figure 3-4. Point of Pines Study Area and Critical Assets (West)

Table 3-1. Inventory of Major Coastal Structures and Elevations (See Figure 3-2 for map of locations)

Location #	Structure Type	Geographic Location	Elevation - NAVD88 (feet)	Description	Source
1	Revetment	near North Shore Road (Route 1A)	Not Available	-	-
2	Marina	near 543 North Shore Road (Route 1A)	Not Available	-	-
3	Revetment	near North Shore Road (Route 1A)	Not Available	-	-
4	Revetment	near the intersection of North Shore Road (Route 1A) and Mills Ave.	Not Available	-	-
5	Jersey barrier/sea wall	near the intersection of Mills Ave. and Blanchard Ave.	Not Available	-	-
6	Revetment and/or sea wall	near the intersection of Mills Ave. and River Ave.	Not Available	-	-
7	Revetment and/or sea wall	near the intersection of Mills Ave. and Thayer Ave.	Not Available	-	-
8	Sea wall	near Whitin Avenue Extension	Not Available	-	-
9	Pier	near Fowler Marine and Whitin Avenue Extension	Not Available	-	-
10	Sea wall	near Mirage Restaurant	Not Available	-	-
11	Marina and Pier	at Point of Pines Yacht Club (28 Rice Ave.)	Not Available	-	-
12	Sea wall	near 75 Rice Ave.	11.2	Elevation at top of wall	USACE Point of Pines Coastal Flood Protection Report 1984.pdf, Page 19

Location #	Structure Type	Geographic Location	Elevation - NAVD88 (feet)	Description	Source
13	Sea wall	near 157 Rice Ave.	11.8	Elevation at top of wall	USACE Point of Pines Coastal Flood Protection Report 1984.pdf, Page 19
14	Dunes	near 197 Rice Ave.	11.3 to 15.8	Range of top elevations of sand dunes in this area	USACE Point of Pines Coastal Flood Protection Report 1984.pdf, Page 19
15	Dunes	near 265 Rice Ave.	11.3 to 15.8	Range of top elevations of sand dunes in this area	USACE Point of Pines Coastal Flood Protection Report 1984.pdf, Page 19
16	Seawall	near 349 Rice Ave.	14.2	Elevation at top of rock revetment	USACE Point of Pines Coastal Flood Protection Report 1984.pdf, Page 19
17	Stop Log Structure	Seaward end of Pines Rd.	Not Available	-	-
18	Sea wall + Revetment	near Carey Circle	14.2	Elevation at top of wall	USACE Point of Pines Coastal Flood Protection Report 1984.pdf, Page 19
19	Sea wall	near 640 Revere Beach Blvd.	Not Available	-	-

Location #	***Structure Type***	***Geographic Location***	***Elevation - NAVD88 (feet)***	***Description***	***Source***
20	Sea wall	near 570 Revere Beach Blvd.	Not Available	-	-

Figure 3-5. Major coastal structure locations

4. Existing Conditions Vulnerability Assessment

This section discusses existing conditions climate vulnerabilities for the Study Area. Understanding the existing vulnerabilities is an essential first step in planning for future changes to climate hazards and may aid in prioritizing adaptation strategies.

4.1 Stormwater and Groundwater

East of the Lynnway, stormwater is managed by a pump station and outfall/tide gate located to the northeast (Figure 3-1). A 24-inch collector pipe conveys stormwater flows to the pump station which are then pumped to the outfall and into the Saugus River. The stormwater outfall here is fitted with a tide gate/flap gate which is meant to prevent backflow during high tides. Based on conversations with City Staff, the pump station has been regularly maintained and performs well during precipitation events. Pumped stormwater is most efficiently released when the tides have sufficiently receded which limits the ability of the pump station to clear away flooded areas and can result in ponding that can last for multiple days.

Stormwater flooding is exacerbated by the relatively high groundwater table which is controlled by the surrounding tide elevations (USACE 1984). Figure 4-1 shows the low-lying areas within the study area where stormwater flooding and ponding is most impactful. The combination of low ground elevations and a high groundwater table necessitates constant sump pump operation for many homes and, during precipitation events, can result in flooding of basements as well as prolonged ponding conditions above ground according to City Staff.

West of the Lynnway, residential areas are drained by a series of ten stormwater outfalls along Mills Avenue (Figure 3-1). Outflow is driven by gravity and is controlled by the downstream water surface elevations of the tidal Pines River. As described by City Staff, many of these outfalls are in relatively poor condition and have been restricted by accumulating sediment and debris. Although maintenance and clearing of these outfalls has occurred, it has historically been very difficult to regularly maintain the outfalls due to spatial and environmental constraints. Accordingly, stormwater flooding and ponding are also relatively frequent hazards in this area.

Figure 4-1. Low-lying Areas in Point of Pines/Riverside

4.2 Erosion

Although shorelines throughout the Study Area have been relatively stable, erosion and accretion are areas of concern in a few important locations. Figure 4-2 shows short term shoreline change trends and historic shorelines as reported by the Massachusetts Shoreline Change Project (https://mass-eoeea.maps.arcgis.com/apps/MapSeries/index.html?appid=80fc0c7ef5e443a8a5bc58096d2b3dc0). Littoral drift generally moves sand northward along the coast and results in accretion of the northeastern end of the study area. The shoreline along the mouth of the Saugus River has also experienced accretion though at a slower rate than along the Atlantic coast.

In addition to the general overview of shoreline change provided by the Massachusetts Shoreline Change Project, conversations with City Staff revealed some nuances to the existing shoreline condition of the Study Area. Due to wave action, erosion has been known to occur along the shoreline near Carey Circle. Additionally, erosion has been observed along the Pines River, requiring shoreline stabilization in some areas in order to protect the structural integrity of Mills Avenue.

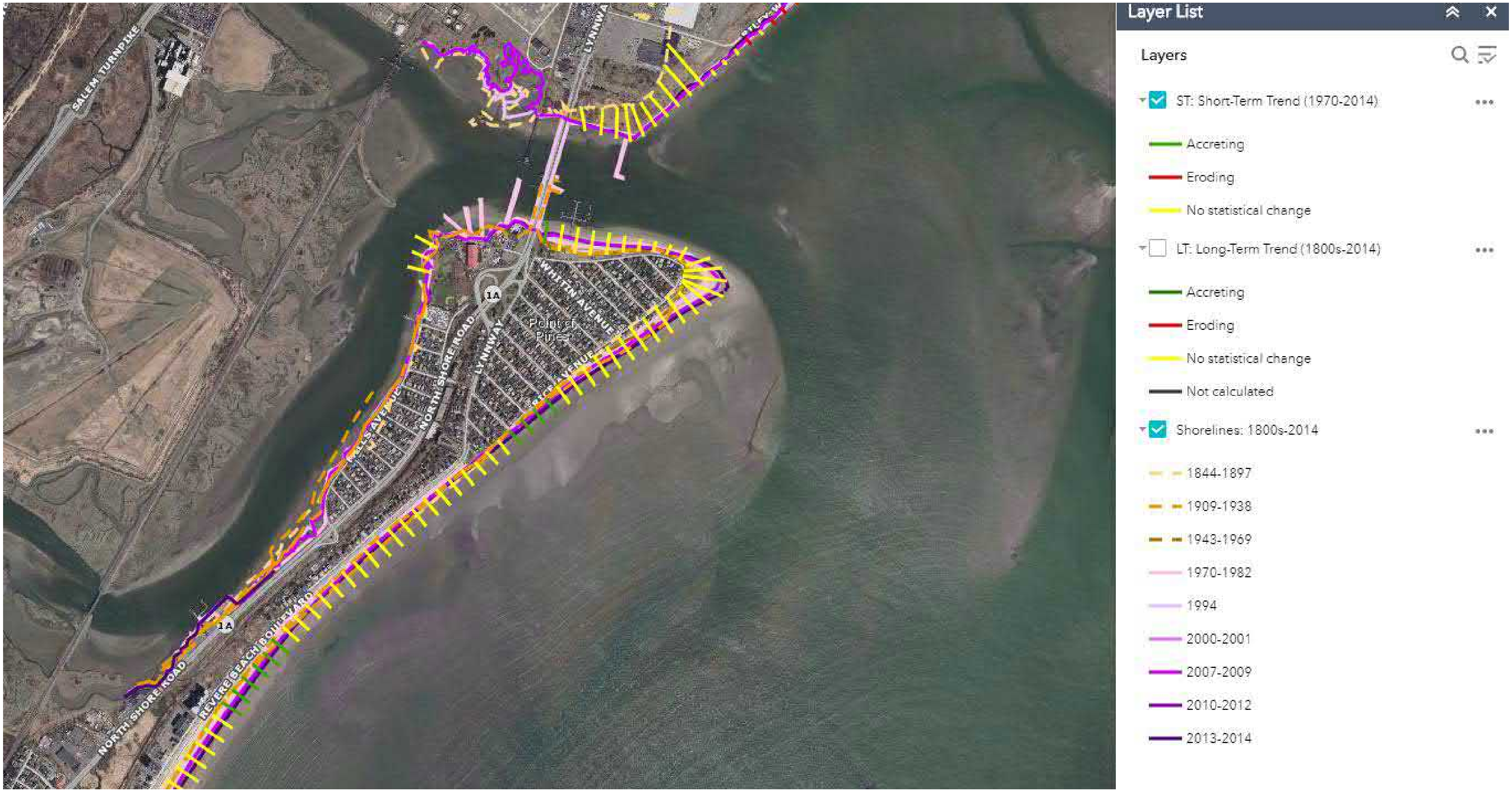

Figure 4-2. Shoreline Change and Historic Shorelines (Draft Massachusetts Coastal Erosion Viewer)

4.3 Coastal Flooding

Like many coastal communities across the U.S. and the world, the Study Area is already facing regular coastal flooding when tides are high. Almost the entire community is located within the floodplain of the Federal Emergency Management Agency (FEMA) 1% 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. The 1% ACE event is often referred to as the 100-year flood event which refers to the average recurrence interval associated with the flood event (1 in 100 annual chance in this case). For example, the 10-year flood event has an average recurrence interval of 10 years and an annual probability of occurrence equal to 10% (1/10). Due to the community's location at the mouth of a river, this event may occur due to any number of combinations of coastal storm surge and high riverine flows; however, since coastal water levels in the Study Area are predominantly controlled by the Atlantic Ocean, the following discussion considers coastal flooding as primarily due to storm surge.

Figure 4-3 shows the FEMA 1% ACE floodplain for the Study Area. All identified assets and all residential areas are inundated by the 1% ACE except for the fire station, demonstrating the exceptional threat posed by coastal flooding for the Study Area in existing conditions. Figure 4-4 presents the estimated annual probability of flooding for the Study Area as evaluated by the MC-FRM. The floodplain associated with the 1% ACE event is approximately equivalent to the area with probability of flooding less than or equal to 1%. A 100% probability of flooding implies that the location is likely to be flooded at least once a year. Again, the flood risk presented by the MC-FRM results is staggering with residential areas east of the Lynnway having at least 20% annual probability of inundation. Along the Pines River, most residential areas have around 1% annual flood probability though some areas near Thayer Boat Yard are between 5% and 20%. In the southern portion of the study area, businesses and residential areas along Revere Beach Boulevard benefit from higher elevations along the Atlantic shoreline but most areas still have an annual probability of flooding around 40% due to lower elevations on the Pines River side which allow Route 1A to be overtopped. The tide gates along Route 1A function primarily to maintain flow into and out of the adjacent wetlands and may further increase the vulnerability of this area during coastal surge events. Businesses along the Pines River west of Route 1A in the southern portion of the study area have relatively higher ground elevations and have annual probabilities of flooding less than 10% with the exception of the Broadsound Tuna Club which has annual flood probabilities as high as 60% - 80% in some areas. Additional maps showing the inundation depths associated with the 1% ACE event as well as probability of flooding for existing conditions as evaluated by the MC-FRM analysis are included in Appendix A.

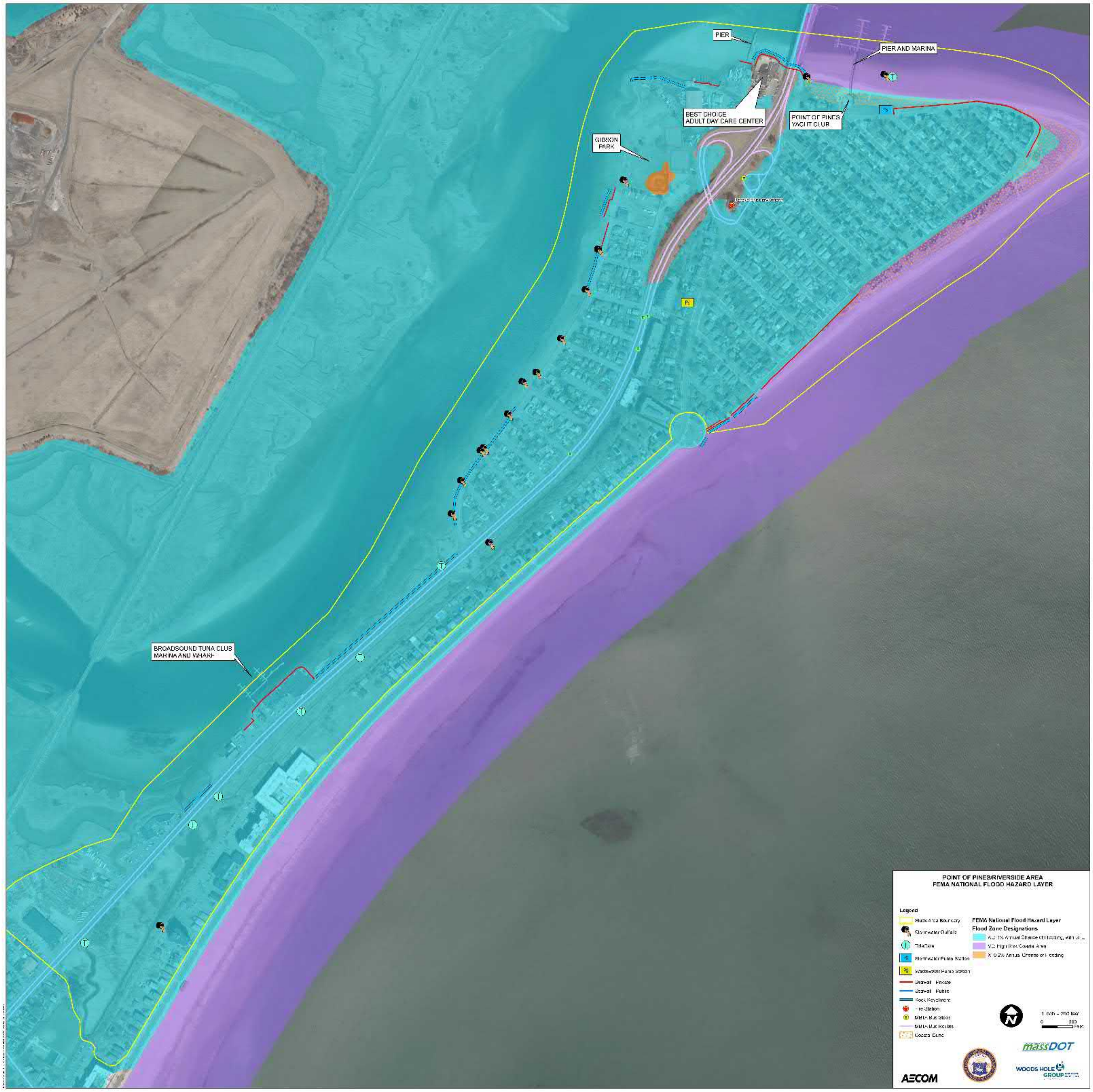

Figure 4-3. FEMA National Flood Hazard Layer for the Study Area

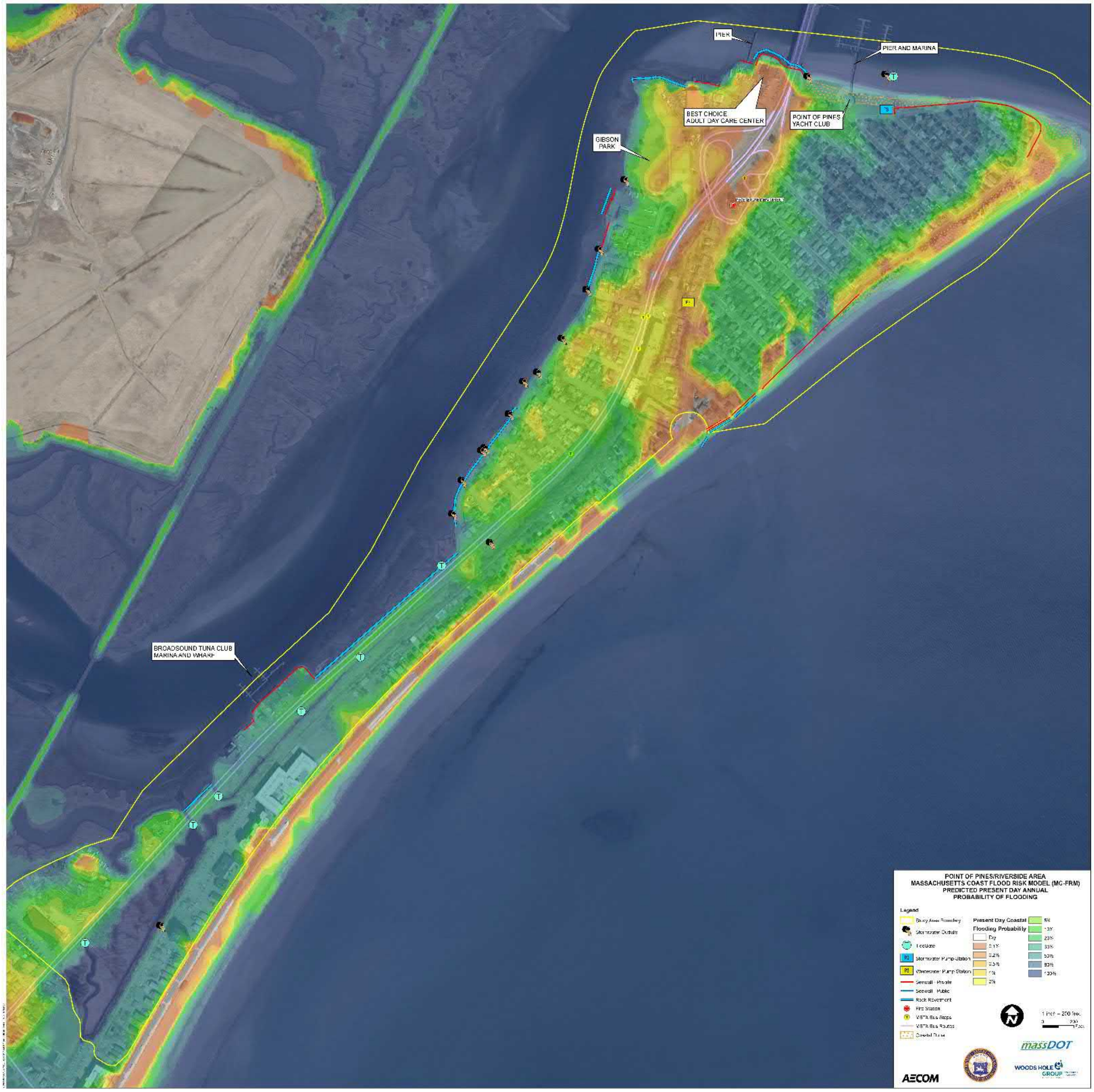

Figure 4-4. Annual Probability of Flooding for Existing Conditions (MC-FRM)

4.3.1 Pathways of Flooding

Analysis of coastal flood probability layers reveals the most vulnerable locations along the shoreline where floodwaters enter and inundate inland areas. Identifying and understanding these pathways of coastal flooding is critical to developing flood risk reduction measures. Figures 5-5 and 5-6 show the primary coastal flood pathways identified for the Study Area

In the northern part of the Study area in the Point of Pines and Riverside Area near the General Edwards Bridge, there are three primary low-lying areas along the shoreline where coastal floodwaters enter inland areas and create widespread inundation. These locations are indicated by the two red arrows and one orange arrow in Figure 5-5. Red arrows indicate higher coastal flood probability than the orange arrow. In addition to these low-lying areas that are most vulnerable to flooding, there is an area along the eastern shoreline where wave run-up and overtopping of the sea wall are causing flooding for some homes along Rice Avenue, as indicated by the red circle in Figure 5-5. Communications with the Woods Hole Group confirmed that while the model does include dunes and sea walls along the Atlantic coast to the east, the lower sea wall on the north side was not included as it was considered too low in elevation to impact the low frequency events that are the focus of the modeling effort. As a result, it is likely that probability of flooding is overestimated somewhat for this area. Elevation of the seawall along Rice Avenue to the north where the two red arrows indicate the most critical flood pathways is 11.2 feet NAVD88 (Table 3-1).

An additional coastal flood pathway was identified farther south in the study area. This coastal flood pathway is indicated by the orange arrow in Figure 5-6.

Coastal flood events with probabilities lower than 5% ACE result in widespread flooding from most of the Pines River shoreline and the northern shoreline along the mouth of the Saugus River is almost entirely overtopped by events with probability lower than 20% ACE.

Figure 4-5. Pathways of Flooding (East)

Figure 4-6. Pathways of Flooding (Mid)

4.3.2 Flood Exceedance Probabilities

In addition to the existing coastal flood probabilities shown in Figure 4-4, the MC-FRM analysis generated water surface elevations associated with coastal flood exceedance probabilities. Existing conditions water surface elevations of coastal flood exceedance probabilities are presented in Table 4-1 for the Atlantic Ocean and the Pines River. Compared to the FEMA 1% ACE stillwater elevations of 9.2 ft NAVD88 (FEMA 2016), the MC-FRM 1% ACE water surface elevations are within 0.2 feet for the Study Area.

Table 4-1. Existing Conditions Water Surface Elevations of Coastal Flood Exceedance Probabilities (MC-FRM)

Exceedance Probability (%)	**Ocean Side (near intersection of Rice and Lancaster)**	**Pines River**
	Water Surface Elevation (ft-NAVD88)	*Water Surface Elevation (ft-NAVD88)*
0.1	10.2	10.1
0.2	9.9	9.8
0.5	9.4	9.3
1	9.1	9.0
2	8.7	8.6
5	8.2	8.1
10	7.8	7.8
20	7.4	7.4
25	7.3	7.2
30	7.2	7.1
50	6.8	6.7

5. Future Conditions Vulnerability Assessment

This section presents the results of the future conditions climate change vulnerability assessment. The analysis is primarily focused on coastal flood hazards, which present the greatest threat to the Study Area. The potential effects of climate change on precipitation and stormwater flooding, erosion, and groundwater are discussed qualitatively based on available information.

5.1 Stormwater and Groundwater

Stormwater flooding is a persistent problem throughout the Study Area and is likely to worsen with climate change into the future. Stormwater modeling was not available for quantitative consideration of this hazard in this assessment, but conversations with City Staff confirm relatively high frequency of flooding due to stormwater and inform the following discussion.

As discussed in Section 2.3 of this document, average annual precipitation is likely to increase slightly or stay the same until the end of the century for the study area. However, increases to less frequent storm intensities and increased overall flash flood risk make stormwater and groundwater flooding hazards of significant concern for the future. Removal of stormwater is restricted by the surrounding waters for the entire study area, particularly in the western portion where outflows are not pumped, as are groundwater levels. Sea level rise will further diminish the efficacy of the existing stormwater management system while simultaneously increasing groundwater levels.

5.2 Erosion

Sea level rise may alter or intensify existing coastal processes and shoreline change trends as larger areas of the coast become subject to tidal and wave action. Existing erosion along the Pines River is likely to increase over time along with erosion near Carey Circle; however, long term changes to the shoreline and the coastal processes that shape it cannot be confidently predicted without more detailed modeling and coastal analysis.

5.3 Coastal Flooding

Sea level rise and its impact on daily tides as well as storm surge is discussed in this section. Given the extremely high vulnerability of the Study Area to coastal flooding and the overwhelming impacts associated with sea level rise values greater than 3 feet, this section is focused on impacts that are most likely to occur in the near-term with the understanding that long-term climate change impacts can only be mitigated through large-scale measures capable of significantly altering the community's present state. Nevertheless, modeling results for 2030, 2050, and 2070 are presented in this section.

5.3.1 Probability of Flooding

The annual chance of a coastal flood occurring in a given location within the study area is presented in this subsection. The depth of coastal flooding is not quantified as this is a purely probabilistic analysis; however, the probabilities here can be understood to correspond to a flood event of the same annual chance or recurrence interval as discussed previously in Section 4.3. Thus, the coastal floodplain associated with the 1% ACE is approximately equivalent to the area with probability of flooding less than or equal to 1%. A 100% probability of flooding implies that the location is likely to be flooded at least once a year. As sea levels rise, the probability of coastal flooding for any given location within the study area increases. Figures 5-1, 5-2, and 5-3 show probability of coastal flooding predicted by the MC-FRM, for the planning periods of 2030 (1.2 feet of SLR), 2050 (2.4 feet of SLR), and 2070 (4.2 feet of SLR), respectively. Additional maps showing the inundation depths associated with the 1% ACE coastal event as well as probability of coastal flooding for future conditions as evaluated by the MC-FRM analysis are included in Appendix A.

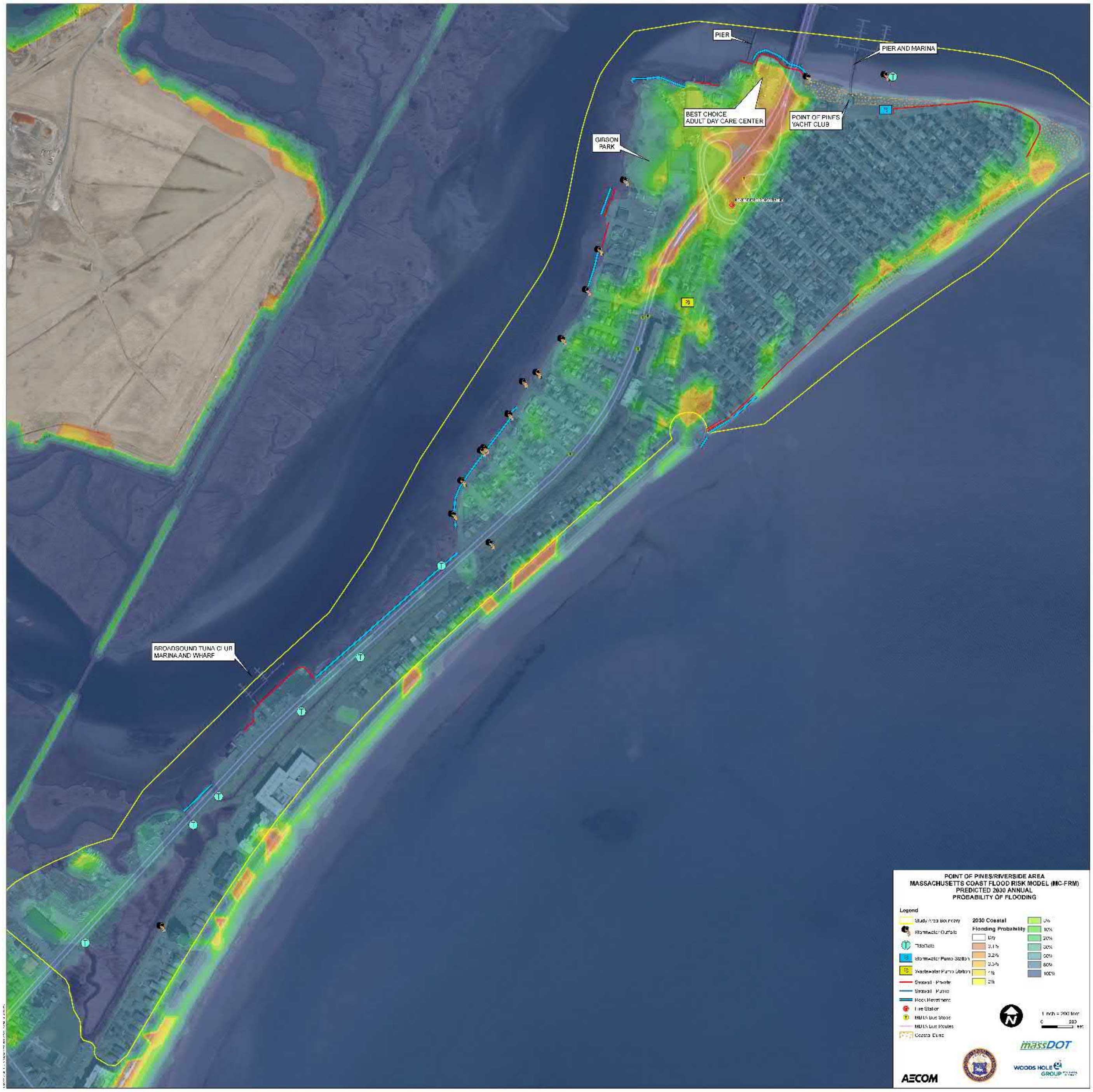

Figure 5-1. Annual Probability of Coastal Flooding for 2030 (1.2 feet of SLR)

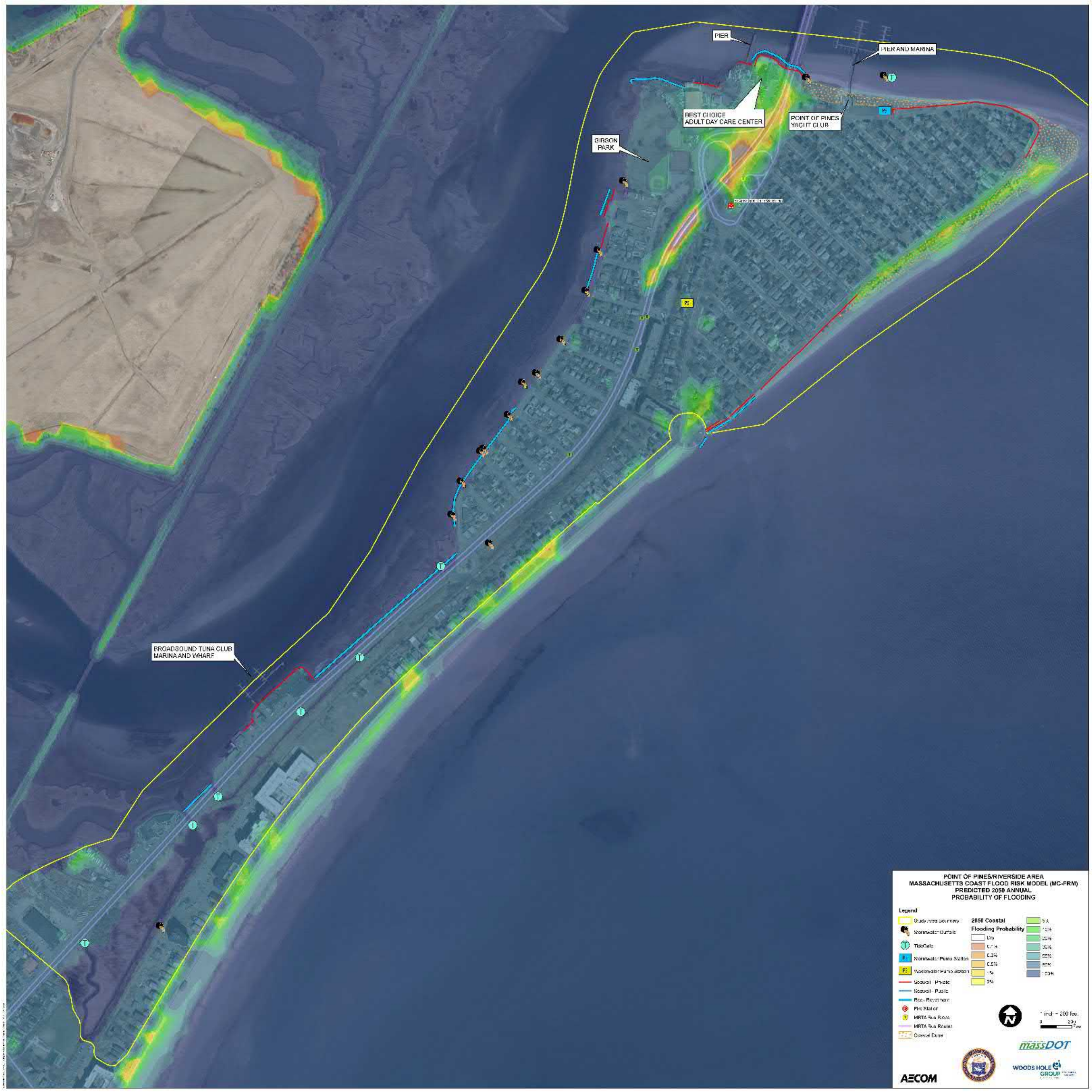

Figure 5-2. Annual Probability of Coastal Flooding for 2050 (2.4 feet of SLR)

Figure 5-3. Annual Probability of Coastal Flooding for 2070 (4.2 feet of SLR)

By 2030, most residential areas east of the Lynnway have approximately 75% annual probability of flooding and by 2050 almost all residential areas have reached the same annual flood probability. The fire station is on relatively high ground but has over 30% annual probability of flooding by 2050 and over 70% probability by 2070. The adult day care center has 15% annual probability of flooding by 2050 and over 70% annual probability of flooding by 2070. The wastewater pump station has approximately 25% annual probability of flooding by 2050 and also reaches 75% by 2070. The stormwater pump station and the Point of Pines Yacht Club have over 70% annual probability of flooding by 2030 while most of Route 1A south of the General Edwards Bridge ranges from approximately 40% to 75% in 2030 and is almost entirely 75% by 2050. The three southernmost bus stops have over 70% 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 around 60% - 75% with the primary source of flooding still being 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 have annual probabilities of flooding from 20% - 60% by 2030 while the Broadsound Tuna Club has annual flood probabilities from 70% - 90% by 2030. By 2070, the entire southern portion of the study area has annual flood probabilities over 75%.

5.3.2 Timing of Permanent Inundation

Permanent inundation occurs when daily high tides inundate a given area, rendering it effectively part of the ocean and no longer part of the inhabitable landmass. As shown in Figure 2-4, permanent inundation due to one foot of sea level rise is relatively minimal though it already results in the loss of some residential areas along Mills Avenue. Two feet of sea level rise results in permanent inundation of large areas east of the Yacht Club as well as along Mills Ave, and three feet of sea level rise is sufficient to permanently inundate the majority of the Point of Pines community. Comparing Figures 2-3 and 2-4, it is possible to develop approximate timing associated with different levels of inundation based on NOAA's 2017 projections for Boston. Table 4-1 shows the possible timing of permanent inundation associated with one to three feet of sea level rise for Point of Pines.

Table 5-1. 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

5.3.3 Flood Exceedance Probabilities

In addition to flood probabilities, the MC-FRM analysis generated water surface elevations associated with flood exceedance probabilities for future conditions. Water surface elevations associated of flood exceedance probabilities are presented in Tables 5-2 and 5-3 for the Atlantic Ocean and the Pines River, respectively.

Table 5-2. Future Conditions Water Surface Elevations of Flood Exceedance Probabilities (Ocean Side)

Exceedance Probability (%)	2030 (1.2 feet of SLR)	2050 (2.4 feet of SLR)	2070 (4.2 feet of SLR)
	Water Surface Elevation (ft-NAVD88)	*Water Surface Elevation (ft-NAVD88)*	*Water Surface Elevation (ft-NAVD88)*
0.1	11.4	13.1	15.0
0.2	11.1	12.7	14.6
0.5	10.6	12.2	14.0

1	10.3	11.8	13.6
2	9.9	11.4	13.2
5	9.4	10.8	12.7
10	9.0	10.4	12.3
20	8.6	10.0	11.8
25	8.5	9.8	11.6
30	8.4	9.7	11.5
50	8.0	9.2	11.0

Table 5-3. Future Conditions Water Surface Elevations of Flood Exceedance Probabilities (Pines River)

Exceedance Probability (%)	**2030 (1.2 feet of SLR)**	**2050 (2.4 feet of SLR)**	**2070 (4.2 feet of SLR)**
	Water Surface Elevation (ft-NAVD88)	*Water Surface Elevation (ft-NAVD88)*	*Water Surface Elevation (ft-NAVD88)*
0.1	11.3	13.1	15.0
0.2	11.0	12.7	14.6
0.5	10.5	12.2	14.0
1	10.2	11.8	13.6
2	9.8	11.4	13.2
5	9.3	10.8	12.6
10	9.0	10.4	12.2
20	8.6	9.9	11.7
25	8.4	9.7	11.5
30	8.3	9.6	11.4
50	7.9	9.1	10.9

Water surface elevations can be compared to known structure elevations in order to quantify loss in flood risk reduction over time. Table 5-4 shows the results of the comparison. The seawall along the Atlantic coast is the most resilient structure while the seawall and the dunes to the north and northeast, respectively, significantly diminish in flood risk reduction over time.

Table 5-4. Comparison of known structure elevations (from Table 3-1) to exceedance probabilities

Location #	**Structure**	**Lowest Elevation (feet - NAVD88)**	**Overtopping WSEL Probability of Exceedance (2030)**	**Overtopping WSEL Probability of Exceedance (2050)**	**Overtopping WSEL Probability of Exceedance (2070)**
12	Sea wall (near 75 Rice Ave)	11.2	0.1%	2%	30%
13	Sea wall (near 157 Rice Ave)	11.8	-	0.5%	10%
14	Dunes (near 197 Rice Ave)	11.3	0.1%	2%	30%
15	Dunes (near 265 Rice Ave)	11.3	0.1%	2%	30%

16	Sea wall (near 349 Rice Ave)	14.2	-	-	0.2%
18	Sea wall + Revetment (near 640 Revere Beach Blvd.)	14.2	-	-	0.2%

6. Conclusions

The 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. 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.

Of greatest concern is the effect sea level rise will have on tide levels and coastal storm surge events. Within 40 to 60 years, large areas of the community may become permanently inundated by daily high tides. Four coastal flood pathways were identified in this memorandum as the most vulnerable shoreline locations where flood waters are currently able to overtop the shoreline and cause widespread inland flooding. Comparison of the elevations of coastal flood risk reduction structures to projected coastal water surface elevation exceedance probabilities show that areas along the Pines River to the west and along the northern shoreline near the PoP Yacht Club are the most vulnerable to storm surge and rapidly lose their ability to provide flood risk reduction as sea levels rise. These locations along with the flood probabilities and water surface elevation exceedance probabilities will inform the next steps of this project where mitigation strategies will be developed.

7. Acronyms

ACE	Annual Chance Exceedance
FEMA	Federal Emergency Management Agency
Ft. or ft	Feet
GCM	General Circulation Model
IPCC	Intergovernmental Panel on Climate Change
MassDOT	Massachusetts Department of Transportation
MC-FRM	Massachusetts Coast Flood Risk Model
MHHW	Mean Higher High Water
NAVD88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
PoP	Point of Pines
RCP	Representative Concentration Pathway
SLR	Sea Level Rise
USACE	United States Army Corps of Engineers

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F. Appendix F: Task 3 Short-Term Resilience Measures Memorandum, Including Beach Management Plan and Emergency Response Plan Recommendations

POINT OF PINES BEACH MANAGEMENT PLAN (DRAFT)

Revere, Massachusetts

Submitted to:
Elle Baker (Project Planner) - City of Revere

Submitted by:

AECOM

April 15, 2021

Contents

Beach Management Plan

List of Attachments

1.0 Purpose and Objective

The purpose of this Beach Management Plan is to provide the Point of Pines Beach Association and other stakeholders (such as the City of Revere and private landowners) with near-term and lower cost actions that can be implemented as longer-term climate resilience interventions are designed, permitted, and constructed. Some of the recommended options presented below will require the filing of environmental permit applications. This Beach Management Plan includes a discussion of existing conditions, recommended management activities, and regulatory considerations.

2.0 Background and Existing Conditions

2.1 Geographic Extent of Beach Management Plan

The Point of Pines Beach is located in the northeastern portion of the City of Revere, Massachusetts (Attachment A – Figure 1 (Locus Map)). The geographic area covered by this beach management plan is generally an inverted "L" shape, with the northern end in the vicinity of the Point of Pines Yacht Club and the southern end terminating near Pines Road and Carey Circle (Attachment A – Figure 2 (Overview)). The northern portion of the beach borders on the Saugus River near the Revere/Lynn town line while the southern portion borders on Broad Sound and the Atlantic Ocean to the east. Rice Avenue generally forms the upgradient (landward) boundary of the beach management plan area. The linear distance of shoreline within the Point of Pines Beach Management Area is approximately 0.94 miles.

2.2 Beach Access

Parking options for Point of Pines Beach are limited, with parking available at Carey Circle. However, several pedestrian access paths to the beach are present on the north side of Rice Ave. in the northern portion of the beach management area and numerous pedestrian access paths are present in the vicinity of the intersections of Rice Avenue with Wadsworth Ave., Witherbee Ave., Bateman Ave., Fowler Ave., Whitin Ave., Lancaster

Ave., Bickford Ave., Alden Ave., Delano Ave., Chamberlain Ave., Goodwin Ave., Harrington Ave., and the end of Pines Rd. Many of these footpaths cross the dunes to reach the beach.

2.3 Point of Pines Beach Association and Management Plan Responsibility

The Point of Pines Beach Association (POPBA) is responsible for the majority of the Beach Management Plan area of interest. The segment of beach under POPBA control extends from the Point of Pines Yacht Club in the north to Chamberlain Ave. in the south, with the exception of four small parcels owned by the City of Revere in the vicinity of Fowler Ave. POPBA was founded in 1949 as an organization for the common ownership of 35 acres of Point of Pines Beach. Annual dues are charged for membership in the association and access to the portion of the Point of Pines Beach controlled by POPBA is restricted to members only.

It is anticipated that the responsibility of implementing the recommendations below along with any necessary permitting would be the responsibility of the Point of Pines Beach Association, unless alternative arrangements are made with the City of Revere or other entities. Since the majority of the proposed actions would take place on private property and access to the POP Beach is for “members only” which restricts access to the general public, public funding is not anticipated to be available for the proposed recommendations if the current public access restrictions continue .

2.4 Wetland Resource Areas

As per MassGIS data layers (MassGIS 2017a; MassGIS 2017b) and aerial imagery (MassGIS 2019), wetland resources present within the Beach Management Plan area that are jurisdictional under the Massachusetts Wetlands Protection Act (WPA; MGL Ch. 131 s. 40), its implementing regulations (310 CMR 10.00), and Title 16 Environment Chapter 16.04 Wetlands Protection of the Revere City Ordinances include: Coastal Bank, Coastal Dune, Coastal Beach, and Land Subject to Storm Flowage (Attachment A - Figure 3 and Figure 4).

2.4.1 Coastal Bank

Coastal Bank is defined in the WPA Regulations at 310 CMR 10.30(2) as “the seaward face or side of any elevated landform, other than a coastal dune, which lies at the landward edge of a coastal beach, land subject to tidal action, or other wetland.” The top of Coastal Bank is found at the seaward facing edge of the top of the existing seawalls and stone revetments within the beach management area. Specifically, this includes the top edge of the cement seawall that runs from the eastern end of the Point of Pines Yacht Club, paralleling the curve of Rice Avenue, to Wadsworth Avenue; the top edge of the seawall that parallels Rice Avenue from Alden Avenue to Harrington Avenue; the top edges of the segments of seawall and stone revetments between Harrington Avenue and Pines Road; and the top edges of the stone revetment segments between Pines Road and Carey Circle.

2.4.2 Coastal Dune

Coastal Dune is defined in the WPA Regulations at 310 CMR 10.28(2) as “any natural hill, mound or ridge of sediment landward of a coastal beach deposited by wind action or storm overwash. Coastal dune also means sediment deposited by artificial means and serving the purpose of storm damage prevention or flood control.” Coastal Dunes are located within the beach management plan area east of the Point of Pines Yacht Club to where Coastal Dune tapers to the seawall near Witherbee Avenue along Rice Avenue; then beginning again as Rice Avenue begins to curve southward, with Coastal Dune continuing parallel along Rice Avenue, tapering out seaward of the seawall between Goodwin Avenue and Harrington Avenue along Rice Avenue. Dune vegetation is generally dominated by American beachgrass (*Ammophila breviligulata*) and accompanied by a variety of other herbaceous plant species (including seaside goldenrod (*Solidago sempervirens*)), depending on the location. Woody vegetation such as sporadic pine (*Pinus* sp.) and patches of beach rose (*Rosa rugosa*) and other shrubs are present, particularly on the central and landward sides of the Coastal Dunes.

2.4.3 Coastal Beach

Coastal Beach is defined in the WPA Regulations at 310 CMR 10.27(2) as “unconsolidated sediment subject to wave, tidal and coastal storm action which forms the gently sloping shore of a body of salt water and includes tidal flats. Coastal beaches extend from the mean low water line landward to the dune line, coastal bank line or the seaward edge of existing human-made structures, when these structures replace one of the above lines, whichever is closest to the ocean." Coastal Beach exists along the entire Beach Management Plan area and lies seaward of the Coastal Dunes where present and in the absence of Coastal Dunes, Coastal Beach lies seaward of Coastal Bank. Coastal Beach is shown in Attachment A – Figure 3 based on MassDEP wetland data layers. It should be noted that the specific extents of resource areas shown by MassDEP (particularly Coastal Beach) may differ from actual field conditions.

2.4.4 Land Subject to Coastal Storm Flowage

Land Subject to Coastal Storm Flowage is defined in the WPA Regulations at 310 CMR 10.27(2) as "land subject to any inundation caused by coastal storms up to and including that caused by the 100-year storm, surge of record or storm of record, whichever is greater." The entire Beach Management Plan area is mapped as FEMA 100-year floodplain, with the vast majority of the area as Zone VE (high risk coastal area velocity zone) and lesser components of Zone AE.

2.5 Rare Species

The Massachusetts Natural Heritage and Endangered Species Program (NHESP) has mapped Estimated Habitats of Rare Wildlife (EH 1064) and Priority Habitats of Rare Species (PH 1491) within the entire Beach Management Plan area (MassGIS 2017c; MassGIS 2017d) (Attachment A – Figure 5). Although formal coordination has not been conducted with NHESP as part of this Beach Management Plan, it is anticipated that mapped habitat of rare species likely includes Piping Plover (*Charadrius melodus*) as this species has been observed at Point of Pines Beach (Figure 1 below). Piping plovers are currently listed as Threatened at both the Massachusetts and Federal levels and would need to be considered when implementing any of the recommendations in this Beach Management Plan. Additional information regarding Piping Plovers is provided in Attachment F.

Figure 1. Piping Plover (*Charadrius melodus*) observed at Point of Pines Beach in 2020.

3.0 Recommended Management Activities

The recommendations provided in this section represent a balance between preserving and restoring the natural functions of the dune and beach resources and providing a beach resource for recreational purposes. Some of these recommendations have been implemented in the past or are currently being implemented and should continue while other recommendations are new and should be considered for implementation. Since beach and dune systems are naturally dynamic, some of the recommendations presented below should be reviewed periodically as conditions change within the beach management area.

The recommendations below are organized by several categories: recordkeeping, monitoring, routine and periodic maintenance activities, vegetation planting, construction activities, rare species preservation, and public education, outreach and signage.

3.1 Recordkeeping

Recordkeeping is an important part of a beach management plan and should be established if no recordkeeping system currently exists. One or more individuals should be identified as recordkeepers for the Beach Management Plan and records can be kept either electronically or in written form. The record keeping system should include: dates and locations of the work performed, details of the work performed, equipment used, number of personnel used, duration of the work, photographs, any follow up activities recommended and timing of those follow up activities.

Recordkeeping can also include entries for notable storms that have impacted the beach as well as the extent of damage and changes to the beach and/or dune topography and locations affected. Records can be created after each notable storm and following each management or monitoring activity.

3.2 Monitoring

Conduct annual condition surveys of infrastructure elements (seawalls, walkways, sand fence, etc.) to identify damage or deterioration and suggest recommendations for repair or replacement as needed. Observations of any portions of infrastructure that are owned by the City of Revere should be relayed to the City for follow-up. Information regarding the location and ownership of shoreline stabilization infrastructure is provided in Attachment C. The ownership table provided in Attachment C assumes that the owner of the parcel is also the owner of the shoreline stabilization infrastructure on that particular parcel, which is based on the best information currently available. As noted in Attachment C, the vast majority of seawalls in the project area are privately owned, based on available parcel ownership data available from the City's on-line data, and so repairs would require coordination with the respective owners. Dates of observations regarding damage or deterioration and recommendations should be included as part of the recordkeeping system.

Volunteer-based monitoring activities could also include bi-annual dune and beach profiling by establishing known elevation points (benchmarks) at specific intervals/locations along the landward edge of the beach. Elevation transects can then be generated at each location from Rice Avenue to slightly below mean low water and compared over time to assess changes to the beach profile and identify areas that may be eroding faster than others by evaluating changes in elevation, volume, and shoreline position. Based on the results, portions of the beach and dunes can be prioritized for sand augmentation/restoration activities.

3.3 Routine and Periodic Maintenance

3.3.1 Removal of manmade trash and debris

According to the Point of Pines Beach Association website (http://popba.net/), beach cleaning events are conducted on a regular basis (typically quarterly) during the year. The removal of manmade trash and debris (including bottles, cans, plastic bags, other plastic items, fishing line and other fishing gear, cigarette butts, wood pilings, pieces of lumber, buoys, lobster traps, etc.) within the beach management plan area (including dunes, as necessary) should continue on a routine basis. In addition, trash removal should also occur after storm events should manmade objects wash up on the shore. A carry-in/carry out trash policy should continue to be enforced and added to signage where necessary. Natural wrack (dislodged vegetation, plant fragments, seeds, seaweed, etc.) should be left in place as long as it doesn't present a safety hazard. Natural wrack is an important component of the shoreline ecosystem and provides a vital natural food source for coastal birds (including rare bird species) by providing habitat for invertebrates and other organisms. In addition, when sand becomes entrapped in wrack, especially in the upper beach zone, nutrients in the buried wrack can help support the germination of seeds mixed with the wrack, which in turn can support the stabilization via vegetation of the foredune area.

3.3.2 Repair of walkways, seawall, guardrails, etc.

The repair of wooden stairs, replacement of faded or damaged signage, damaged seawalls, and other structures should be performed on an as-needed basis within the beach management plan area. The missing guardrail at Witherbee Avenue should be replaced as shown in Attachment B – Figure 4 to help prevent unauthorized access across the dunes.

3.4 Construction Activities

3.4.1 Closure of Some Pathways Across the Dunes

Elimination of unnecessary dune paths should be considered in order to protect the dune from continual plant destruction and erosion. Priority areas include the paths identified on Figures 3, 4, 5, 6, and 7 in Attachment B. This includes the undesignated pathways extending north and east from the swing set area (east of Wadsworth Avenue) and the pathway connecting the Wadsworth and Witherbee Avenue beach access paths (the pathway that parallels Rice Avenue). A mix of shrub plantings can be used in these locations to discourage further use as a pathway as well as segments of sand fencing (see Section 3.4.3). Educational signage could be installed indicating that the pathways are in the process of being revegetated which will contribute to the stability and health of the dunes.

Currently, every side street along Rice Avenue has its own pathway that cuts across the dune system to reach the beach, effectively segmenting the dune system at every block. Pathway lengths across the dunes generally decrease as one moves from north to south within the beach management plan area. Although conversion of many of these at-grade pathways to elevated walkways over the dunes is presented in Attachment B, an alternative is to consider closing lesser-used pathways (or every other pathway) and replant with native vegetation, which will help reduce the segmentation of the dune and minimize pathways for storm surge flow to reach Rice Avenue and the residences adjacent to it. The approximate distance from block to block is approximately 200 feet, so closure of an existing path to benefit the stability of the dune and minimize storm surge pathways should not result in a substantial access burden for most residents. An example of paths that should be considered high priorities for closure include Chamberlain and Delano Avenues, with Alden Avenue as an additional possibility (due to the proposed tie-in of augmented sand and plants (dune building) with the native dune system in this area).

The Massachusetts Coastal Flood Risk Model (MCFRM) for present-day annual probability of flooding within the management area predicts an annual flooding probability of 80% to 100% in the vicinity of Chamberlain and Delano Avenues (see the red circled area in Figure 2 below). As a result, Chamberlain and Delano Avenues appear to be the most important areas identified along this stretch of Point of Pines Beach for protection through path closure and dune building. Other pathways in other portions of the management area, particularly the most heavily used paths, could be kept, but consideration should be given to the installation of elevated walkways for these remaining pathways as discussed in Section 3.4.4.

Figure 2. Massachusetts Coastal Flood Risk Model (MCFRM) predicted present-day flooding including the Beach Management Plan area.

3.4.2 Sand Augmentation

The addition of sand on the coastal beach (beach nourishment), creation of artificial dunes or augmentation of existing dunes can be implemented within the beach management plan area. The purpose of sand augmentation is to increase the ability of the coastal beach and coastal dunes to provide storm buffers, flood control, sediment to adjacent beaches, mitigate ongoing erosion, and to enhance the beach management plan area as a recreational resource.

No “soft engineering” shoreline stabilization option will permanently stop all erosion or storm damage within the Beach Management Plan area, but the ability of stabilization options to provide protection depends on many factors, including the specific design and exposure to a particular storm event. All stabilization options will require maintenance to various degrees and frequencies. The design of sand augmentation projects should take into consideration the establishment of stable slope angles, compatible sediments (grain size, grain shape, and color) as well as other factors, such as existing rare species habitat.

Within the beach management area, sparsely vegetated relatively open areas that may favor piping plovers were avoided, including the northeastern sandy point of the management area. Areas identified for sand augmentation include the areas shown on Figures 1 through 8 in Attachment B. Potential sand augmentation areas include: areas where existing footpaths to the beach may be discontinued and could be replanted; the vegetated low dune along the northern periphery of the management area that has been eroded, exposing plants’ root systems (from the Yacht Club, westward towards the sandy point); portions of existing dunes where footpaths have eroded the dune surface or have burned due to unauthorized fires (fireworks, etc.) and should be replanted; and the stretch of shoreline from Pines Road to Alden Avenue that may benefit from beach nourishment and dune augmentation since the beach and dunes in this segment are fairly narrow. The sand augmentation options presented here can be further modified as needed during project design and permitting. Please see Attachment E – MassCZM (Massachusetts Office of Coastal Zone Management) StormSmart Coasts Fact Sheet #1 for additional details regarding artificial dunes and dune nourishment.

3.4.3 Sand Fence Installation

According to the POPBA Fall 2019 newsletter (http://popba.net/wp-content/uploads/2019/11/POPBA__Fall2019.pdf), sand fencing installation was identified as a goal for POPBA. In the Summer of 2020, sand fencing was installed along many of the existing access paths in the Beach Management Plan area as shown in Attachment D. Installation of sand fence around Coastal Dunes is a relatively low-cost option that will help to promote sand accumulation, dune growth, and dune grass and other vegetation protection. Sand fences will also help minimize foot traffic across the dunes, further protecting dune stability. Sand fencing can be installed along the base of and perpendicular to eroded dune sections to trap windblown sand and help rebuild the dune. When wind blows through sand fencing, the fence creates drag that reduces wind velocity and sand particles settle out and are deposited either behind the sand fence or at the base of the fence. Activities to install sand fence should be performed by hand within jurisdictional resource areas (e.g. Coastal Dune, Coastal Beach, etc.) to avoid impacts to existing vegetation. Posts used to support the fencing should be untreated wood posts since steel posts will rust and may pose a hazard to beachgoers and wildlife. Sand fence slat spacing is typically comprised of a 1:1 ratio of open space to slat material.

Potential locations for sand fencing were identified in Figures 1 through 8 (Attachment B) along dune edges and access paths. Where sand fencing is proposed along access paths or at the seaward entrance of access paths, the fencing will help guide pedestrians to the path and minimize damage from foot traffic. In other locations, sand fencing is proposed to be installed perpendicular to the shoreline to help capture blowing sand, but not create a barrier to movement between the dunes and shoreline for rare bird species or other wildlife that may be present. The fencing locations shown can be adjusted as needed so the seaward end of the fence is not reached by high tides or minor storms. Vegetative plantings can accompany the installation of sand fencing in the locations shown on the figures in Attachment B. MA NHESP should be consulted for any proposed sand fencing project to verify compatibility with rare species that may be present.

3.4.4 Elevated walkways

According to the POPBA Fall 2019 newsletter (http://popba.net/wp-content/uploads/2019/11/POPBA__Fall2019.pdf), walkway installation was identified as a goal for POPBA. If not properly designed, beach access boardwalks, walkways, and stairways can cause erosion and increase storm damage by creating pathways for wind and water damage as well as inhibiting the growth of plants that stabilize dunes. Elevated walkways are recommended for high traffic access paths within the beach management plan area. Elevated walkways allow sand movement of the dunes below them and allow light to reach the dune surface in close proximity to the walkway, helping to support plants that further contribute to dune stability. Walkways should be no wider than 4 feet and no longer than necessary to provide access to the beach. Adequate elevation of the walkway is needed for plant growth and to allow the natural movement of sand under and around the walkway. Walkways should be elevated on posts or piles at least 2 feet above the grade of the surrounding dune to allow mobility of sand and growth of plants, taking into consideration site-specific factors so natural dune accretion doesn't begin to envelope the walkways prematurely. Walkways should be oriented so that they are not perpendicular to the shoreline. This is most important for the segment of elevated walkway in close proximity to the toe of the dune and upper elevations of the beach (Figure 3 below). These seaward segments of boardwalk could also be designed so that they could be removed (temporarily disassembled) and stored (assuming storage is available) to prevent winter storm damage or designed so they can be easily repairable if damage by storms.

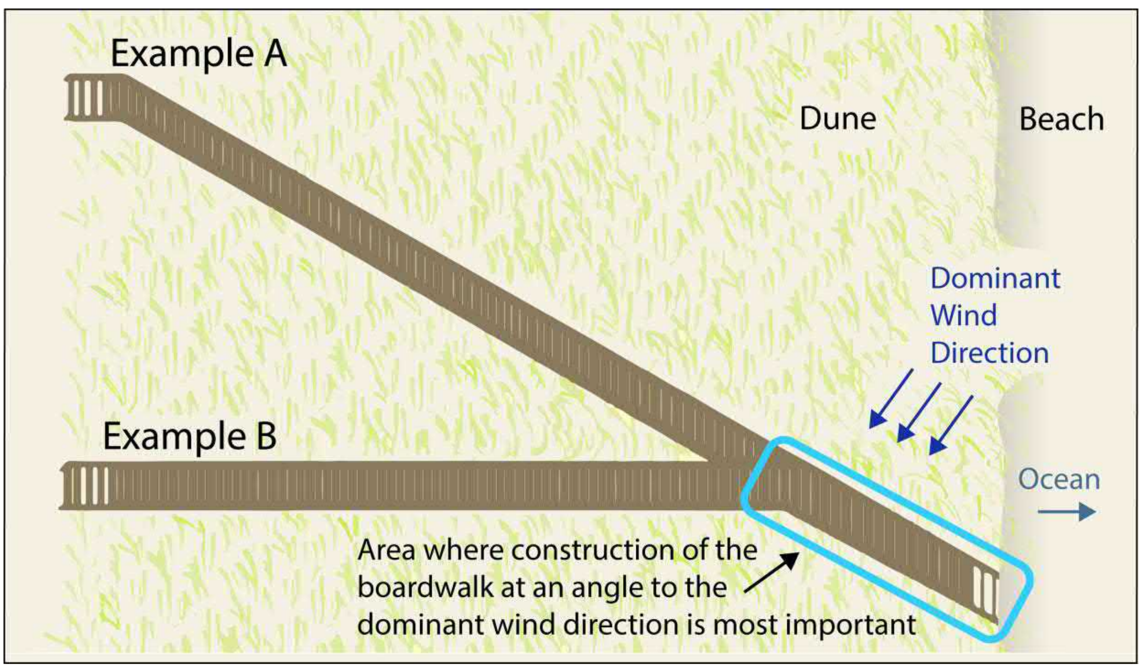

Figure 3. MassCZM guidance regarding proper orientation of elevated walkways.

Where walkways are oriented beyond the footprint of existing paths, the old portions of the paths should be filled with compatible sand and replanted with native salt-tolerant vegetation. Decking and materials used should be selected for durability and compatibility with the dune environment (for example, composite decking and wooden support structures and handrail components. Elevated walkways can begin in the vicinity of the trail head at Rice Avenue and terminate several feet beyond the toe of the dune.

Potential locations for elevated walkways were identified in Attachment B - Figures 1 through 8 and include the pathway just east of the Yacht Club parking lot, Wadsworth Avenue, Witherbee Avenue, Bateman Avenue, Fowler Avenue, Whitin Avenue, Lancaster Avenue, Bickford Avenue, Goodwin Avenue, and Pines Road. While the locations of potential elevated boardwalks are suggested here in this beach management plan, the final locations and design chosen can be prioritized based on a variety of considerations including long-term dune stability, rare species habitat protection, light availability for dune vegetation, and volume of typical foot traffic, among others. Please see Attachment E for additional details regarding the construction of elevated walkways.

Figure 4. Example of an elevated walkway over dunes (Newburyport, MA).

Figure 5. Example of an elevated walkway constructed of a combination of composite decking and wooden framing and handrails (Newburyport, MA).

3.5 Vegetation Planting

The dunes within the beach management plan area are susceptible to erosion from human traffic, wind, rain, high tides, storm events, and other factors. Vegetation on the dunes plays a particularly important role in helping to: hold the dunes together as a result of their root systems; slow wind speeds at the surface of the dunes which in turn helps to trap blowing sand; absorb the impact of rain on the surface of the sand helping to buffer erosion; and provide wildlife habitat value including a source of seed and cover for some species of wildlife, among other benefits.

Vegetation planting within the beach management plan area can be performed in existing dune areas that currently have no vegetation or sparse vegetation as a result of pedestrian traffic or erosion or can also be included in areas identified for sand augmentation once the sand has been placed, which can help stabilize bare sand areas and help build dune volume. Unlike solid manmade structures such as seawalls, vegetated areas can help absorb and dissipate wave energy rather than reflect it to other areas which can exacerbate erosion and other storm-related damage.

Dunes susceptible to erosion within the beach management plan area can be planted with American beachgrass and other native salt-tolerant dune vegetation discussed below. American beachgrass naturally occurs at Point of Pines beach and is the preferred dune restoration species in areas that are susceptible to blowing sand since it quickly establishes a dense root system, helps to rapidly accumulate blowing sand, and is able to withstand a certain level of overwash. More landward portions of the dunes that are less susceptible to direct wave and overwash action can be planted with a mix of grasses such as little bluestem (*Schizachrium scoparium*) and purple lovegrass (*Eragrostis spectibilis*) and woody plant species such as bearberry (*Arctostaphylos uva-ursi*), beach heather (*Hudsonia tomentosa*), Northern bayberry (*Myrica pensylvanica*), and beach plum (*Prunus maritima*). These species are less adapted to overwash and are therefore better choices for more landward portions of the dunes. Larger woody species (trees and shrubs) should not be planted on the face of banks because their height and weight can destabilize the bank and make them vulnerable to toppling by erosion or high winds as noted in Fact Sheet #3 in Attachment E. It should be noted that pines (*Pinus* sp.) as well as a variety of woody shrubs and mixed grasses are currently thriving on the landward portions of the dunes within the beach management area. The native species currently present (which also include some of the species indicated above) can serve as example species to be planted in these landward areas since they are adapted to thrive in existing conditions.

Planting of the species indicated above can generally occur early to mid-spring when moisture levels of the dunes are relatively higher or September through the winter if conditions allow. Planting work should be conducted by hand, and care should be taken to protect existing vegetation. Watering of newly installed plants could occur on an as-needed basis. The addition of organic compost to the planting holes, particularly woody plantings, may help the establishment of root systems as a result of aiding in water retention. For plantings on areas where sand has been brought in, plantings often benefit from a limited application of water-soluble time-release fertilizer approximately a month after planting.

Sources of erosion as mentioned above include human traffic, wind, rain, high tides, and storm events and should be addressed in conjunction with proposed planting in order to improve the potential success of the plantings. Measures can include restricting pedestrian traffic through an area to be planted, establishing stable slope angles prior to planting if needed, etc. Additional considerations should include supplemental watering of newly installed plants since their smaller root systems will take time to develop. Vegetation planting projects will likely require ongoing maintenance to increase the chance of success. Maintenance requirements can include watering and replacing dead plants until the planted vegetation becomes successfully established. Once established, woody species (depending on the specific species) could be pruned annually to encourage lower, thicker growth. However, this work should only be performed by a professional familiar with how the specific woody species present will react to a pruning regime. Invasive plants within the beach management plan area should be removed and replaced with native salt-tolerant plants.

Many areas were identified for vegetation planting within the beach management plan area. These specific locations are shown in Attachment B on Figures 1 through 8 and are identified by planting unit type. Two types of planting units are identified and include American beachgrass and mixed grasses/mixed woody plants, respectively. Please see Attachment E – MassCZM StormSmart Coasts Fact Sheet #3 for additional details regarding vegetation plantings.

3.6 Rare Species Preservation

MA NHESP should be consulted to verify the rare species that may be present within the Beach Management Plan area. Shorebird surveys can be conducted at Point of Pines Beach in coordination with MA NHESP and Mass Audubon. Trained observers can be used to monitor for nest sites. If nest sites are observed, an exclusionary zone can be established around each nest site (for example, a 150-foot radius zone) using posts, rope from post to post (or other methods), and signage to alert beachgoers to avoid the area(s). Nest sites should be monitored until the chicks have fledged and post and signs can be removed for the remainder of the season. During active nesting and fledging periods, POPBA should ensure that any maintenance activities or proposed actions including beach raking, trash removal, project construction, etc. are staffed appropriately with wildlife stewards to ensure chicks and adults are not harassed, injured or killed by these activities and in accordance with MA NHESP and USFWS guidelines.

3.7 Public Education, Outreach and Signage

According to the POPBA Fall 2019 newsletter (http://popba.net/wp-content/uploads/2019/11/POPBA__Fall2019.pdf), many signs that had been posted in scattered locations near each beach path entrance were consolidated onto a single sign, which resulted in a more coherent signage look where messages from separate signs could instead be viewed on a single sign. The locations of signage (consolidated and unconsolidated) within the management area are not included in Attachment B. Depending on the recommended action that is implemented, additional signage or publication of educational materials (flyer boxes at trail heads and/or on the POPBA website) may be useful in educating beachgoers on the importance and fragility of the dune and beach system in an attempt to engage members to be informed stewards of the Point of Pines Beach. Although physical printed flyers containing educational materials could be installed at each beach path entrance as an option, QR codes (two-dimensional square barcode) could also be used. The advantage of using QR codes is that beachgoers with smartphones could read the QR codes which would launch a webpage displaying pertinent information without the need to print flyers as well as minimize the potential for paper waste from discarded flyers on the beach. As described above, educational signage could be installed in the swing set area and at the Wadsworth Avenue and Witherbee Avenue paths to discourage pedestrians from using non-designated pathways across the dunes and the minimize unwanted foot traffic as the plantings establish.

Additional signage could be installed for any paths that will be closed under the beach management plan, directing pedestrians to the nearest available designated path. The same sign could also contain text explaining why it is important to close that particular path (storm damage prevention, dune/habitat health, etc.)

As an additional public education and outreach option, presentations and/or tours can be given of the beach and dune system to educate POPBA members on the ecology of the system. Presentation leaders can include knowledgeable POPBA members, Revere Conservation Commission members, or invited speakers from environmental organizations and agencies.

4.0 Regulatory Considerations

Below is a list of the most applicable regulatory considerations within the beach management plan area organized by governmental level:

4.1 Local Level

City of Revere Conservation Commission

The Revere Conservation commission administers the Massachusetts Wetlands Protection Act (WPA; MGL Ch. 131 s. 40), its implementing regulations (310 CMR 10.00), and Title 16 Environment Chapter 16.04 Wetlands Protection of the Revere City Ordinances.

The purpose of the City of Revere's Chapter 16.04 ordinance (Wetlands Protection) is to protect the wetlands of the city by controlling the activities deemed to have a significant effect upon wetland values, including but not limited to the following: public or private water supply, groundwater, flood control, erosion control, storm damage prevention, water pollution, fisheries, shellfish, wildlife, recreation and aesthetics (collectively, the "interest protected by this chapter"). As per the Ordinance, "*No person shall remove, fill, dredge, alter or build upon or within one hundred feet of any bank, fresh-water wetland, coastal wetland, beach, dune, flat, marsh, meadow, bog, swamp, or upon or within one hundred feet of lands bordering on the ocean or upon or within one hundred feet of any land under said waters or upon or within one hundred feet of any land subject to tidal action, coastal storm flowage, flooding or inundation, or within one hundred feet of the one-hundred-year storm line, other than in the course of maintaining, repairing or replacing, but not substantially changing or enlarging, an existing and lawfully located structure or facility used in the service of the public and used to provide electric, gas, water, telephone, telegraph and other telecommunication services, without filing written application for a permit so to remove, fill,* *dredge, alter or build upon, including such plans as may be necessary to describe such proposed activity and its effect on the environment, and receiving and complying with a permit issued pursuant to this chapter*."

Jurisdiction of the Revere Conservation Commission includes any activity within a resource area, or within 100 feet of a resource area, that will remove, fill, dredge, build upon, degrade, or otherwise alter an area subject to protection under the bylaw.

Actions such as dune or beach nourishment, vegetation plantings, sand fence installation, walkway installation, etc. would require the filing of a Notice of Intent with the Revere Conservation Commission and MassDEP. The permit issued by the Revere Conservation Commission would be an "Order of Conditions".

4.2 State Level

Massachusetts Wetlands Protection Act and its Implementing Regulations

Similar to the City of Revere Wetland Protection Ordinance, the Massachusetts Wetlands Protection Act (WPA; MGL Chapter 131 §40) states: "*No person shall remove, fill, dredge or alter any bank, riverfront area, fresh water wetland, coastal wetland, beach, dune, flat, marsh, meadow or swamp bordering on the ocean or on any estuary, creek, river, stream, pond, or lake, or any land under said waters or any land subject to tidal action, coastal storm flowage, or flooding, other than in the course of maintaining, repairing or replacing, but not substantially changing or enlarging, an existing and lawfully located structure or facility used in the service of the public and used to provide electric, gas, sewer, water, telephone, telegraph and other telecommunication services, without filing written notice of his intention to so remove, fill, dredge or alter, including such plans as may be necessary to describe such proposed activity and its effect on the environment and without receiving and complying with an order of conditions and provided all appeal periods have elapsed*."

In addition to regulations regarding work within the 100-foot Buffer Zone, the coastal portion of the WPA regulations within 310 CMR 10.00 includes jurisdiction over work within Coastal Bank, Coastal Dune, Coastal Beach, and Land Subject to Coastal Storm Flowage. Work within these areas for projects such as dune or beach nourishment, vegetation plantings, sand fence installation, walkway installation, etc. would require the filing of a Notice of Intent simultaneously with the Revere Conservation Commission and MassDEP. Although the Revere Conservation Commission is ultimately the issuing authority for the Order of Conditions, MassDEP has the authority to rule on any appeal of local Conservation Commission decisions including any pertaining to Point of Pines Beach proposed actions. The appeal of any Order of Conditions is required to follow the procedures set forth in the WPA 310 CMR 10.00. MassDEP also provides comments on Notices of Intents (i.e. wetland permit applications) filed with municipal Conservation Commissions, and therefore may submit comments to the Revere Conservation Commission for their consideration during review of any NOI submitted under the MA WPA.

Massachusetts Environmental Policy Act (MEPA)

The Massachusetts Executive Office of Energy and Environmental Affairs (EEA) implements the Massachusetts Environmental Policy Act (MEPA; 301 CMR 11). MEPA review is required for projects exceeding certain thresholds that are undertaken by a state agency, require a permit issued by a state agency, or involve financial assistance by a state agency. When a project meets or exceeds review thresholds established in 301 CMR 11.03, the project proponent is required to submit an Environmental Notification Form (ENF) as part of the MEPA review process. Depending on the thresholds met or exceeded beyond the requirements for an ENF, project proponents may also need to prepare and submit a Draft and possibly Final Environmental Impact Report (EIR). The culmination of the MEPA review process is the issuance of a Certificate from the Secretary of Environmental Affairs. MEPA thresholds for an Environmental Notification Form (ENF) may potentially be met or exceeded depending on the scope of recommendations chosen and include: greater than two acres of disturbance of designated priority habitat, as defined in 321 CMR 10.02, that results in a take of a state-listed endangered or threatened species or species of special concern; alteration of coastal dune, barrier beach or coastal bank; and/or new fill or structure or expansion of existing fill or structure, except a pile-supported structure, in a velocity zone or regulatory floodway. Proposed actions ultimately chosen will need to be checked against the MEPA review thresholds to determine if the proposed action is subject to MEPA review.

Coastal Zone Management Act

The Massachusetts Office of Coastal Zone Management (MassCZM) implements the federal Coastal Zone Management Act in Massachusetts. Projects requiring federal funding or federal permitting that also exceed certain MEPA thresholds must obtain a Coastal Zone Management Federal Consistency Certification and demonstrate that the project is consistent with the policies of MassCZM.

Massachusetts Division of Fisheries and Wildlife

The Massachusetts Endangered Species Act (MESA; 321 CMR 10.00) requires agency review for any non-exempt activity within sites mapped by the Massachusetts Natural Heritage and Endangered Species Program (NHESP) as Estimated Habitats of Rare Wildlife (for projects under the Massachusetts WPA) and/or Priority Habitats of Rare Species (for projects under MESA). Mapped habitat, including both Estimated and Priority Habitat, exists within the entire Beach Management Plan area. Activities within Estimated Habitat would be reviewed by MassDFW as part of a submittal of a Notice of Intent under the MA WPA. A formal request for MESA review, via the submission of a MESA Project Review Checklist package, would be needed for any non-exempt activity within Priority Habitat. MassDFW review under MESA would be required for dune or beach nourishment, vegetation plantings, sand fence installation, walkway installation, etc. Issuance of a MESA permit for these activities would likely include a requirement for baseline monitoring of shorebird occurrence and nesting, along with associated report to MA DFW.

Massachusetts Department of Environmental Protection (MassDEP) Waterways Program

Massachusetts Waterways Regulations at 310 CMR 9.00 indicate that a Chapter 91 License or Permit application would need to be submitted for work within all waterways, including all flowed or filled tidelands. Activities requiring a License Application include any construction, placement, excavation, addition, improvement, maintenance, repair, replacement, reconstruction, demolition or removal of any fill or structures, not previously authorized, or for which a previous grant or license is not presently valid. Activities requiring a Permit Application include any beach nourishment, dredging, and any disposal involving the subaqueous placement of unconsolidated material below the low water mark, among other activities.

Massachusetts Department of Environmental Protection – 401 Water Quality Certification

314 CMR 9.00 is applicable for any activity proposed that would result in a discharge of dredged material, dredging, or dredged material disposal greater than 100 cubic yards that is also subject to federal regulation. Such projects would require the submittal of a 401 Water Quality Certification permit application to MassDEP. These activities may include coastal engineering structure installation or maintenance, among other projects. Reviews are divided into Major Projects (5,000 cubic yards of dredging or more) and Minor Projects (less than 5,000 cubic yards of dredging). Beach nourishment activities with a Final Order of Conditions issued under M.G.L. c. 131, § 40 do not need a 401 WQC. Proposed activities would need to be reviewed further to determine if a 401 WQC is required.

4.3 Federal Level

US Army Corps of Engineers – New England District

The US Army Corps of Engineers (USACE) regulates construction and other work in navigable waterways under Section 10 of the Rivers and Harbors Act of 1899, and has authority over the discharge of dredged or fill material into "waters of the United States", which includes wetlands under Section 404 of the Clean Water Act. Within the Beach Management Area, this includes the discharge of fill material below the high tide line. Depending on the specific project and levels of impact, a 404 application would be submitted under the Massachusetts Programmatic General Permit or as an Individual Permit. Submittals for authorization under the Massachusetts General Permit (GP) include self-verification (SV) or a preconstruction notification (PCN) depending on the proposed level of impact and other factors. If conditions of an SV or PCN cannot be met, then an individual permit (IP) is required. Depending on the scope of work chosen under these recommendations and the equipment involved, GP 1 (Maintenance), GP 5 (Dredging, Disposal of Dredged Material, Beach Nourishment, and Rock Removal and Relocation), GP 7 (Bank and Shoreline Stabilization), and/or GP 14 (Temporary Construction, Access, and

Dewatering) may apply. Specifics of the most applicable General Permits are discussed below:

GP 1: Activities authorized under GP 1 include the repair, rehabilitation, or replacement of any previously authorized, currently serviceable structure, or fill and temporary structures, fills, and work, including the use of temporary mats, necessary to conduct the maintenance activity.

GP 5: Activities authorized under GP 5 includes new, maintenance, and improvement dredging with the disposal of dredged material use for beach nourishment provided the Corps finds the dredged material suitable; and beach nourishment from upland sources.

GP 7: Activities authorized under GP 7 include Bank and shoreline stabilization activities in waters of the U.S. necessary for erosion control or prevention, such as vegetative stabilization, sills, rip rap, revetment, gabion baskets, stream barbs, and bulkheads, or combinations of techniques (e.g., living shorelines), provided the activity meets all of the following criteria: (a) No material is placed in excess of the minimum needed for erosion protection; (b) No material is of a type, or is placed in any location, or in any manner, that will impair surface water flow into or out of any waters of the U.S.; and (c) No material is placed in a manner that will be eroded by normal or expected high flows (properly anchored native trees and treetops may be used in low energy areas. An IP would be required for breakwaters, groins or jetties.

GP 14: Activities authorized under GP 14 include temporary structures, work, and discharges, including cofferdams, necessary for construction activities or access fills or dewatering of construction sites that are not authorized under another GP activity. An IP would be required for (a) Permanent structures or impacts; (b) Temporary impacts in tidal waters that are >1 acre; >5000 SF in saltmarsh, mud flats, or riffle and pool complexes; or >1000 SF in vegetated shallows; (c) Use of cofferdams to dewater wetlands or other aquatic areas to change their use; (d) Temporary stream crossings (see GPs 8 - 10); (e) Structures or fill left in place after construction is completed.

The scope of any proposed action under this beach management plan would need to be reviewed to determine what level of authorization may be needed under US Army Corps of Engineers jurisdiction. Projects that require an IP will also require an individual 401 Water Quality Certification (WQC) from the Massachusetts Department of Environmental Protection (MassDEP) and Coastal Zone Management (CZM) individual consistency concurrence from the Massachusetts Office of CZM. Any activity under these GPs that requires authorization under §404 of the CWA for the discharge of dredged or fill material into waters of the U.S. also requires applicants to obtain a §401 water quality certification (WQC) from the State (hereinafter referred to as "§401 WQC") or a Final Order of Conditions from the town or city which serves as the WQC.

Federal Endangered Species Act – Section 10

As indicated in Section 2.5, piping plover is currently listed as "Threatened" at the federal level and would need to be considered when implementing any of the recommendations in this Beach Management Plan. Additional species may also be listed at the federal level within the Beach Management Plan area although formal consultation has not been conducted at this time. "Threatened" means a species is likely to become endangered within the foreseeable future. The U.S. Fish and Wildlife Service (FWS) is the lead federal agency for administering the Endangered Species Act (ESA). Section 9 of the Endangered Species Act lists the actions that are prohibited under the legislation. Although there are some exceptions, the ESA generally prohibits importing, exporting, taking, possessing, selling, and transporting species that are designated as threatened or endangered. A "take" includes: harassing, harming, pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting the species or to attempt to engage in any such conduct. Harm is further defined by FWS to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Under Section 10 of the ESA, certain activities may be permitted through the FWS as long as they are consistent with conservation of the species in question. An incidental take permit applies to non-federal entities that believe their activities may result in a take of an endangered or threatened species. For activities that are otherwise legal, an entity must submit an application for an incidental take permit, as well as a habitat conservation plan (HCP) that helps to minimize and mitigate the negative impacts of the activity. In addition to the requirements of Sections 9 and 10 of the ESA, under Section 7 of the ESA, any federally initiated project, issuance of a federal permit, or provision of federal funding requires the federal agency to consult with the FWS regarding potential impacts to protected species.

5.0 Summary

In summary, this Beach Management Plan provides the Point of Point of Pines Beach Association and other stakeholders with several options that can be implemented in the near-term and at lower costs actions while longer-term climate resilience interventions are designed, permitted, and constructed. As with any coastal environment subject to wind, waves, and storm action, the options presented will require periodic maintenance as needed. However, proper application of the recommendations described above will serve to enhance the Point of Pines Beach's ability to provide valuable storm damage functions, wildlife habitat and rare species protection, and recreational opportunities for Point of Pines Beach Association members.

The recommended actions above fall into two general categories: those that can be implemented immediately at relatively low cost and with no required agency coordination or permits (or very little coordination/approval) and those that will require greater cost and increased agency coordination and permitting. The recommended actions identified above are listed below in order of priority, beginning with low cost/low permitting requirements to those recommendations that involve higher cost/more involved permitting:

- Recordkeeping
- Monitoring (annual infrastructure condition surveys, observations of trash and debris, bi-annual dune and beach profiling)
- Public education and outreach programs
- Removal of manmade trash and debris
- Replacement of signage as needed and installation of new signage, depending on location

- Pathway closure to the public
- Replacement of the missing wooden guardrail at Witherbee Avenue
- Minor repairs of existing wooden stairs
- Rare species preservation (installation of temporary posts, rope, signage, etc.)
- Sand fence installation
- Vegetation planting
- Seawall repair
- Installation of elevated walkways
- Sand augmentation including dune construction

6.0 References

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MassGIS 2017d. MassGIS Data: NHESP Priority Habitats of Rare Species. August 2017. https://docs.digital.mass.gov/dataset/massgis-data-nhesp-priority-habitats-rare-species

MassGIS 2019. MassGIS Data: USGS Color Ortho Imagery (2019). Spring 2019. https://docs.digital.mass.gov/dataset/massgis-data-usgs-color-ortho-imagery-2019

MassCZM 2020a. CZM StormSmart Coasts Publications. CZM StormSmart Coasts Publications | Mass.gov

MassCZM 2020b. CZ-Tip - Basics of Building Beach Access Structures that Protect Dunes and Banks. CZ-Tip - Basics of Building Beach Access Structures that Protect Dunes and Banks | Mass.gov

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ATTACHMENT A

Figures

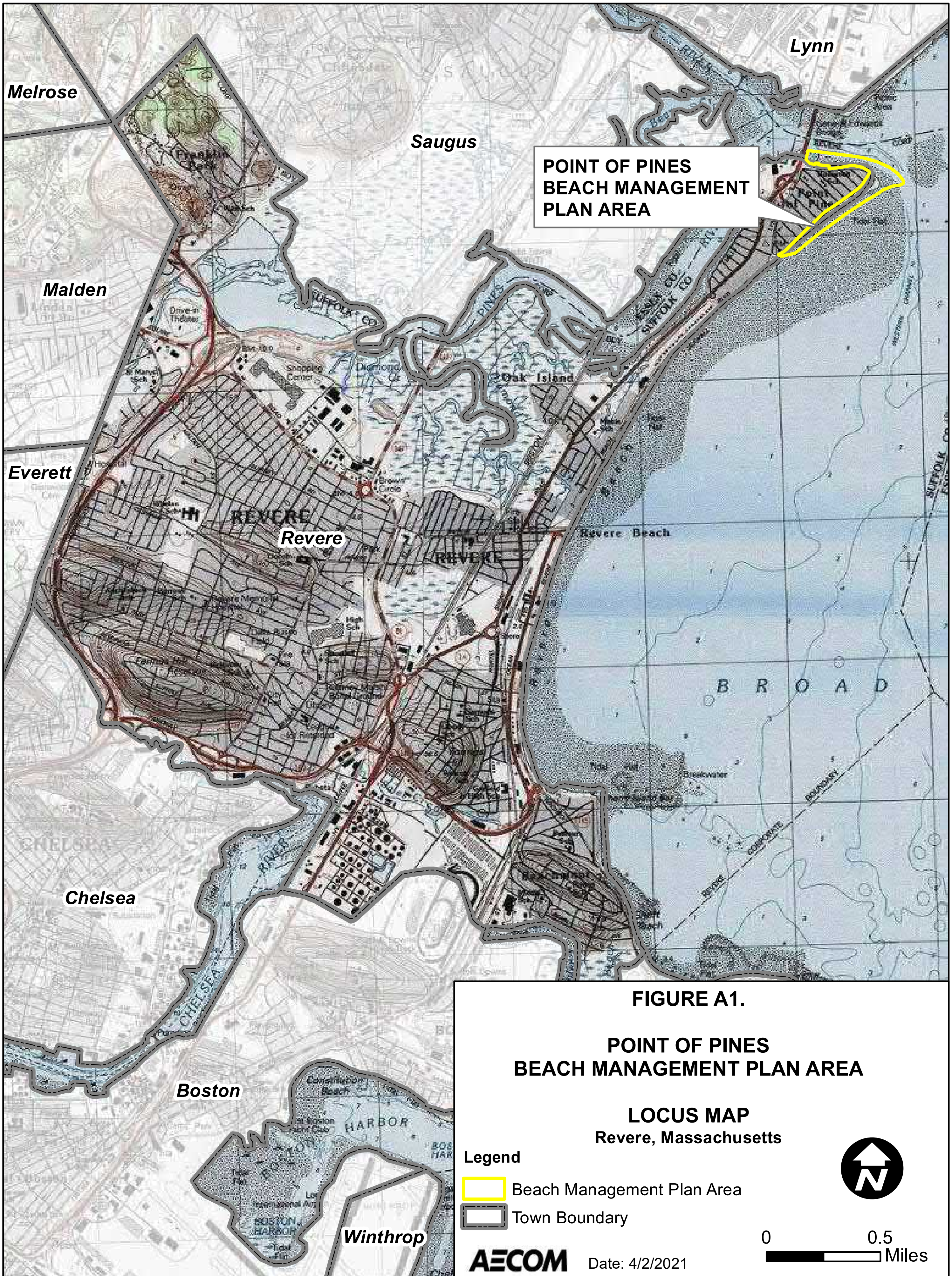

FIGURE A1.

POINT OF PINES
BEACH MANAGEMENT PLAN AREA

LOCUS MAP
Revere, Massachusetts

AECOM

Date: 4/2/2021

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FIGURE A2.

POINT OF PINES
BEACH MANAGEMENT PLAN AREA

OVERVIEW
Revere, Massachusetts

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FIGURE A3.

**POINT OF PINES
BEACH MANAGEMENT PLAN AREA**

**MASSDEP WETLAND RESOURCE AREAS IN
THE VICINITY OF POINT OF PINES BEACH**
Revere, Massachusetts

Legend

Seawall - Private

Beach Management Plan Area

MassDEP Wetlands

BARRIER BEACH SYSTEM
BARRIER BEACH-COASTAL BEACH
BARRIER BEACH-COASTAL DUNE
BARRIER BEACH-SALT MARSH
ROCKY INTERTIDAL SHORE
SALT MARSH
TIDAL FLAT

NOTE: The extent of resource areas shown on this map is based on the MassDEP Wetlands Datalayer (https://www.mass.gov/info-details/massgis-data-massdep-wetlands-2005; Updated December 2017). The extent of Coastal Beach shown by MassDEP may differ from actual field conditions.

AECOM

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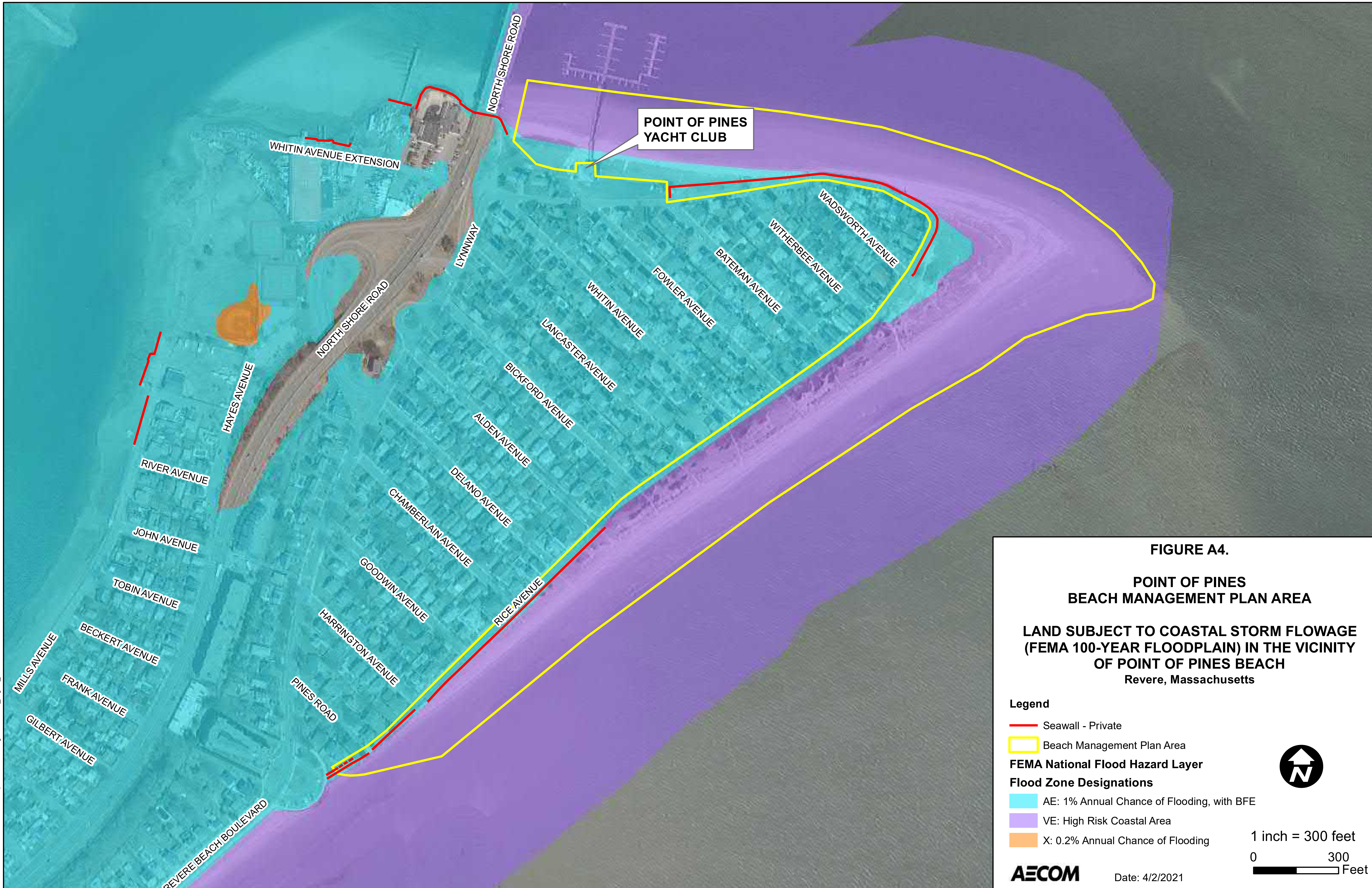

FIGURE A4.

POINT OF PINES BEACH MANAGEMENT PLAN AREA

LAND SUBJECT TO COASTAL STORM FLOWAGE (FEMA 100-YEAR FLOODPLAIN) IN THE VICINITY OF POINT OF PINES BEACH
Revere, Massachusetts

FIGURE A5.

POINT OF PINES BEACH MANAGEMENT PLAN AREA

MA NHESP EXTIMATED HABITATS OF RARE WILDLIFE (EH 1064) AND PRIORITY HABITATS OF RARE SPECIES (PH 1491) IN THE VICINITY OF POINT OF PINES BEACH

Revere, Massachusetts

ATTACHMENT B

Recommended Actions Maps

POINT OF PINES BEACH MANAGEMENT PLAN AREA

RECOMMENDED ACTION - OVERVIEW

Revere, Massachusetts

Legend

- Seawall - Private
- Beach Management Plan Area
- Guardrail Installation
- Path Closure and Restoration
- Proposed Elevated Boardwalk
- Sand Fence
- American Beachgrass
- Mixed Grasses/Mixed Woody Plantings
- Sand Augmentation w/American beachgrass
- Sand Augmentation w/Mixed Grasses/Woody Plantings

NOTES:
Existing sand fence (installed in Summer 2020) is not shown on this map.

Some signs within the Beach Management Area have been consolidated (sign locations not shown on this map).

1 inch = 300 feet

0 300 Feet

AECOM

Date: 4/2/2021

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FIGURE B1.

POINT OF PINES
BEACH MANAGEMENT PLAN AREA

RECOMMENDED ACTION - DETAIL 1
Revere, Massachusetts

Legend

- Seawall - Private
- Beach Management Plan Area
- Proposed Elevated Boardwalk
- Sand Fence
- Sand Augmentation w/American beachgrass

NOTE: Some signs within the Beach Management Area have been consolidated (sign locations not shown on this map).

AECOM

Date: 4/2/2021

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FIGURE B3.

POINT OF PINES BEACH MANAGEMENT PLAN AREA

RECOMMENDED ACTION - DETAIL 3
Revere, Massachusetts

Legend

- Seawall - Private
- Beach Management Plan Area
- Path Closure and Restoration
- Proposed Elevated Boardwalk
- Sand Fence
- American Beachgrass
- Sand Augmentation w/American beachgrass
- Sand Augmentation w/Mixed Grasses/Woody Plantings

NOTE: Some signs within the Beach Management Area have been consolidated (sign locations not shown on this map).

1 inch = 50 feet

0 25 50 Feet

AECOM

Date: 4/2/2021

FIGURE B4.

POINT OF PINES BEACH MANAGEMENT PLAN AREA

RECOMMENDED ACTION - DETAIL 4

Revere, Massachusetts

FIGURE B5.

POINT OF PINES
BEACH MANAGEMENT PLAN AREA

RECOMMENDED ACTION - DETAIL 5
Revere, Massachusetts

Legend

- Beach Management Plan Area
- Path Closure and Restoration
- Proposed Elevated Boardwalk
- Sand Fence
- Mixed Grasses/Mixed Woody Plantings
- Sand Augmentation w/American beachgrass
- Sand Augmentation w/Mixed Grasses/Woody Plantings

NOTES:
Existing sand fence (installed in Summer 2020) is not shown on this map.

Some signs within the Beach Management Area have been consolidated (sign locations not shown on this map).

1 inch = 50 feet

0 25 50 Feet

AECOM

Date: 4/2/2021

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FIGURE B6.

POINT OF PINES
BEACH MANAGEMENT PLAN AREA

RECOMMENDED ACTION - DETAIL 6
Revere, Massachusetts

Legend

- Seawall - Private
- Beach Management Plan Area
- Path Closure and Restoration
- Proposed Elevated Boardwalk
- Sand Fence
- Mixed Grasses/Mixed Woody Plantings
- Sand Augmentation w/American beachgrass
- Sand Augmentation w/Mixed Grasses/Woody Plantings

NOTES:
Existing sand fence (installed in Summer 2020) is not shown on this map.

Some signs within the Beach Management Area have been consolidated (sign locations not shown on this map).

1 inch = 50 feet

0 25 50 Feet

AECOM

Date: 4/2/2021

FIGURE B7.

POINT OF PINES BEACH MANAGEMENT PLAN AREA

RECOMMENDED ACTION - DETAIL 7

Revere, Massachusetts

Legend

- Seawall - Private
- Beach Management Plan Area
- Path Closure and Restoration
- Proposed Elevated Boardwalk
- Sand Fence
- Sand Augmentation w/American beachgrass
- Sand Augmentation w/Mixed Grasses/Woody Plantings

NOTES:
Existing sand fence (installed in Summer 2020) is not shown on this map.

Some signs within the Beach Management Area have been consolidated (sign locations not shown on this map).

1 inch = 50 feet

0 25 50 Feet

AECOM

Date: 4/2/2021

FIGURE B8.

POINT OF PINES BEACH MANAGEMENT PLAN AREA

RECOMMENDED ACTION - DETAIL 8

Revere, Massachusetts

Legend

- Seawall - Private
- Beach Management Plan Area
- Proposed Elevated Boardwalk
- Sand Fence
- Sand Augmentation w/American beachgrass
- Sand Augmentation w/Mixed Grasses/Woody Plantings

1 inch = 50 feet

0 25 50 Feet

AECOM

Date: 4/2/2021

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ATTACHMENT C

Shoreline Stabilization Infrastructure Information:

Table 1. Shoreline Stabilization Infrastructure
Segments and Owners

Shoreline Stabilization Structures Overview and Detail Figures

Table 1. Shoreline Stabilization Infrastructure Segments and Owners

Shoreline Stabilization Segment Information*							Owner Information**				
Structure ID	**Shoreline Stabilization Type**	**Primary Material**	**Map-Block-Parcel ID**	**Ownership**	**Site Address**	**Zoning**	**Owner**	**Address**	**City**	**State**	**Zip Code**
248-014-192O-023-001	Bulkhead/Seawall	Concrete	14-192O-23	Private	0 RICE AVE	RB	POINT OF PINES BEACH ASSOC INC	24 DELANO AVE	REVERE	MA	02151
248-014-192O-023-002	Bulkhead/Seawall	Concrete	14-192O-23	Private	0 RICE AVE	RB	POINT OF PINES BEACH ASSOC INC	24 DELANO AVE	REVERE	MA	02151
248-013-192O-UNK-001	Bulkhead/Seawall	Concrete	13-192O-7	Private	0 RICE OPPOSITE AVE	RA	JIANG LIMEI	369 RICE AVE	REVERE	MA	02151
			14-0-UNK	Private	0 RICE AVE	RB	POINT OF PINES BEACH ASSOC INC	24 DELANO AVE	REVERE	MA	02151
			14-192O-9	Private	0 RICE AVE	RA	ZINGARIELLO CARMINE	76 DELANO AVE	REVERE	MA	02151
			13-192O-3	Private	0 RICE OPPOSITE AVE	RA	ODONNELL JAMES F	40 HARRINGTON AVE	REVERE	MA	02151
			13-192O-5	Private	0 GOODWIN (OPPOSIT AVE	RA	CURRTELLI FAMILY TRUST	53 GOODWIN AVE	REVERE	MA	02151
			13-192O-8	Private	0 RICE AVE	RA	345 RICE AVE LLC	11 FERNCROFT WAY	MALDEN	MA	02148
			13-192O-4	Private	0 RICE OPPOSITE AVE	RA	LIBERATORE SUZANNE	391 RICE AVE	REVERE	MA	02151
			14-0-UNK	Private	0 RICE AVE	RB	POINT OF PINES BEACH ASSOC INC	24 DELANO AVE	REVERE	MA	02151
			13-192O-6	Private	0 RICE OPPOSITE AVE	RA	RICCIO DAVID	375 RICE AVE	REVERE	MA	02151
			13-192O-UNK	Private							
248-013-192O-001-001	Bulkhead/Seawall	Concrete/Stone	13-192O-1	Private	0 RICE OPPOSITE AVE	RA	JOANN BERTOLINO REVOCABLE TRUST	415 RICE AVE	Revere	MA	02151
			13-192N-4	Private	26 PINES RD	RA	PETER A CERBONE FAM IRREVOCABL	26 PINES RD	REVERE	MA	02151
248-013-192N-005-001	Revetment	Stone	13-192N-4	Private	26 PINES RD	RA	PETER A CERBONE FAM IRREVOCABL	26 PINES RD	REVERE	MA	02151
			13-192N-5	Private	32 PINES RD	RA	CERBONE MERYL	26 PINES RD	REVERE	MA	02151
248-013-192N-008-001	Revetment	Stone	13-192N-8	Private	33 PINES RD	RA	TRANIELLO RALPH E	33 PINES RD	REVERE	MA	02151
			13-192N-7	Private	35 PINES RD	RA	WUNDERLICH KENNETH	35 PINES RD	REVERE	MA	02151
248-013-192N-008-004	Bulkhead/Seawall	Stone	13-192N-8	Private	33 PINES RD	RA	TRANIELLO RALPH E	33 PINES RD	REVERE	MA	02151
248-013-192N-008-003	Bulkhead/Seawall	Stone	13-192N-8	Private	33 PINES RD	RA	TRANIELLO RALPH E	33 PINES RD	REVERE	MA	02151
248-013-192N-008-002	Bulkhead/Seawall	Stone	13-192N-8	Private	33 PINES RD	RA	TRANIELLO RALPH E	33 PINES RD	REVERE	MA	02151
248-009-192R-001-001	Bulkhead/Seawall	Stone	13-192N-8	Private	33 PINES RD	RA	TRANIELLO RALPH E	33 PINES RD	REVERE	MA	02151

Please Note: Owners of land where shoreline stabilization structures are located are also assumed to own those structures.

*Source: MORIS - CZM's Onlime Mapping Tool (http://maps.massgis.state.ma.us/map_ol/moris.php)

**Source: MassGIS (http://maps.massgis.state.ma.us/map_ol/oliver.php)

POINT OF PINES
BEACH MANAGEMENT PLAN AREA

SHORELINE STABILIZATION STRUCTURES - OVERVIEW
Revere, Massachusetts

Legend

Seawall - Private

Beach Management Plan Area

1 inch = 300 feet

0 300 Feet

AECOM

Date: 4/2/2021

FIGURE C1.

POINT OF PINES BEACH MANAGEMENT PLAN AREA

SHORELINE STABILIZATION STRUCTURES - DETAIL 1

Revere, Massachusetts

Date: 4/2/2021

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FIGURE C2.

**POINT OF PINES
BEACH MANAGEMENT PLAN AREA**

SHORELINE STABILIZATION STRUCTURES - DETAIL 2
Revere, Massachusetts

Legend

- Seawall - Private
- Beach Management Plan Area
- Parcels with Private Seawall
- Change in Seawall ID

1 inch = 50 feet

0 25 50 Feet

AECOM

Date: 4/2/2021

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FIGURE C3.

POINT OF PINES
BEACH MANAGEMENT PLAN AREA

SHORELINE STABILIZATION STRUCTURES - DETAIL 3
Revere, Massachusetts

Legend

- Seawall - Private
- Beach Management Plan Area
- Parcels with Private Seawall

1 inch = 50 feet

0 25 50 Feet

AECOM

Date: 4/2/2021

FIGURE C4.

POINT OF PINES
BEACH MANAGEMENT PLAN AREA

SHORELINE STABILIZATION STRUCTURES - DETAIL 4
Revere, Massachusetts

Legend

Seawall - Private
Beach Management Plan Area
Parcels with Private Seawall

1 inch = 50 feet
0 25 50 Feet

AECOM Date: 4/2/2021

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FIGURE C5.

POINT OF PINES
BEACH MANAGEMENT PLAN AREA

SHORELINE STABILIZATION STRUCTURES - DETAIL 5
Revere, Massachusetts

Legend

- Seawall - Private
- Beach Management Plan Area
- Parcels with Private Seawall
- Change in Seawall ID

1 inch = 50 feet

0 25 50 Feet

AECOM

Date: 4/2/2021

ATTACHMENT D

Existing Sand Fence Photos

Representative Photos of Sand Fencing in the Point of Pines Beach Management Plan Area – Revere, Massachusetts

NOTE: Photos are arranged from south to north. All photos were taken in February 2021.

Figure 1.

Figure 2.

Figure 3.

Figure 4.

Figure 5.

Figure 6.

Figure 7.

Figure 8.

Figure 9.

ATTACHMENT E

MassCZM StormSmart Fact Sheets

and Guidance Documents

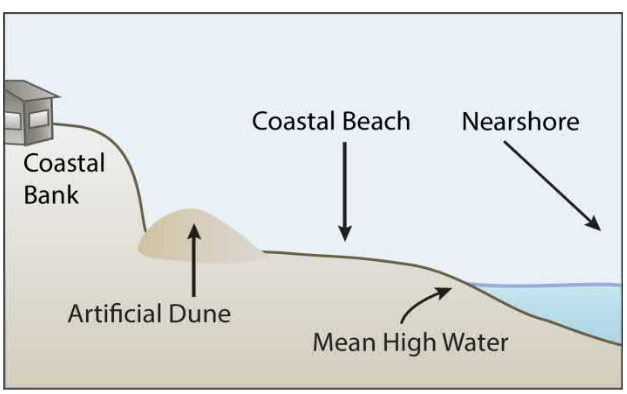
StormSmart Properties Fact Sheet 1: Artificial Dunes and Dune Nourishment

The coast is a very dynamic environment and coastal shorelines—especially beaches, dunes, and banks—change constantly in response to wind, waves, tides, and other factors such as seasonal variation, sea level rise, and human alterations to the shoreline system. Consequently, many coastal properties are at risk from storm damage, erosion, and flooding. Inappropriate shoreline stabilization methods can actually do more harm than good by exacerbating beach erosion, damaging neighboring properties, impacting marine habitats, and diminishing the capacity of beaches, dunes, and other natural landforms to protect inland areas from storm damage and flooding. StormSmart Properties—part of the Massachusetts Office of Coastal Zone Management's (CZM) StormSmart Coasts Program—provides coastal property owners with important information on a range of shoreline stabilization techniques that can effectively reduce erosion and storm damage while minimizing impacts to shoreline systems. This information is intended to help property owners work with consultants and other design professionals to select the best option for their circumstances.

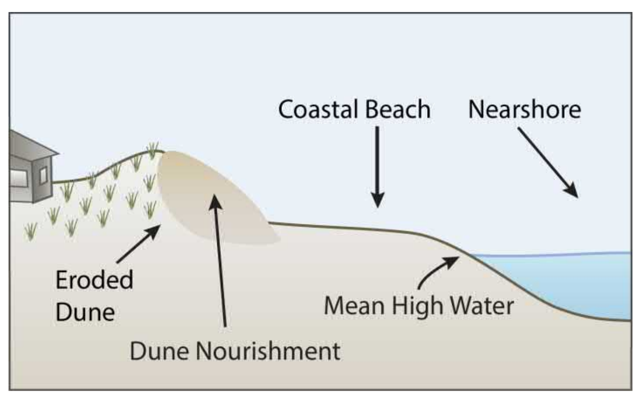
What Are Artificial Dunes and Dune Nourishment?

A dune is a hill, mound, or ridge of sediment that has been deposited by wind or waves landward of a coastal beach. In Massachusetts, the sediments that form beaches and dunes range from sand to gravel- and cobble-sized material. An artificial dune is a shoreline protection option where a new mound of compatible sediment (i.e., sediment of similar size or slightly coarser) is built along the back of the beach, seaward of the area to be protected. (Artificial dunes may be called cobble berms when larger pebble- and cobble-sized materials are used.) Dune nourishment provides shoreline protection by adding compatible sediment to an existing dune. With artificial dunes and dune nourishment, sediment is brought in from an offsite source, such as a sand and gravel pit or coastal dredging project.

No shoreline stabilization option permanently stops all erosion or storm damage. The level of protection provided depends on the option chosen, project design, and site-specific conditions such as the exposure to storms. All options require maintenance, and many also require steps to address adverse impacts to the shoreline system, called mitigation. Some options, such as seawalls and other hard structures, are only allowed in very limited situations because of their impacts to the shoreline system. When evaluating alternatives, property owners must first determine which options are allowable under state, federal, and local regulations and then evaluate their expected level of protection, predicted lifespan, impacts, and costs of project design, installation, mitigation, and long-term maintenance.



This diagram shows an artificial dune built seaward of an eroding coastal bank to protect the bank from further erosion that could endanger the house.



This diagram shows a dune nourishment project that added sediment to the seaward side of an eroded dune to enhance the ability of the dune to protect the house.

Artificial and nourished dunes can be used in conjunction with many other techniques for erosion management. See the following StormSmart Properties fact sheets on related techniques: *Controlling Overland Runoff to Reduce Coastal Erosion*, *Planting Vegetation to Reduce Erosion and Storm Damage*, *Bioengineering - Coir Rolls on Coastal Banks*, *Sand Fencing*, and *Beach Nourishment*.

How Artificial Dunes and Dune Nourishment Reduce Storm Damage

Dunes provide a physical buffer between the sea and inland areas—a buffer that can naturally shift during storms. As waves hit a dune and its sediments move and shift, the wave energy is absorbed, protecting landward areas from the full brunt of the storm. The height, length, and width of a dune relative to the size of the predicted storm waves and storm surge (water buildup above the average tide level) determines the level of protection the dune can provide. The recommended size for an artificial or nourished dune will depend on the desired level of protection, the predicted wave energy and storm surge for the area, and site constraints (such as beach width and proximity to sensitive resource areas).

Artificial and nourished dunes not only increase the direct level of protection to inland areas by acting as a physical buffer, the added sediment from dune projects supports the protective capacity of the entire beach system (i.e., dune, beach, and nearshore area). Sand eroded from the dune during a storm is not lost or wasted, but added to the surrounding beach and nearshore area where it dissipates wave energy, reducing the strength of incoming storm waves. But to maintain the dune as an effective physical buffer, sediment must be added regularly to keep dune's height, width, and volume at appropriate levels.

The photo on the left shows a dune nourishment project where sand was added in front of the eroded face of an existing dune. The sand was planted with beach grass to enhance the protection provided to the house behind it.

***In the project shown in the photo below, a dune that was severely eroded during the Blizzard of '78 was nourished with a combination of sand, gravel, and cobble—sediments of the same size range as the natural dune. The highest point of the dune is about 20 feet above sea level. This photograph was taken in October 2008, demonstrating how well the dune has held up over time.* (Photos: CZM)**

Relative Benefits and Impacts Compared to Other Options

Under the Massachusetts Wetlands Protection Act, new hard structures are typically prohibited on all beaches and dunes. On coastal banks, hard structures are only allowed when necessary to protect buildings permitted before August 10, 1978, and only if no other alternative is feasible. In many cases, dune projects and other non-structural alternatives are therefore the only options available for reducing erosion and storm damage on coastal properties.

The major benefit of artificial dunes and dune nourishment projects is that unlike seawalls, rock revetments, or other "hard" shoreline stabilization structures, dunes dissipate wave energy rather than reflecting waves onto beaches or neighboring properties. The design of a hard structure affects how much wave energy is reflected, for example vertical walls reflect more wave energy than sloping rock revetments. These reflected waves erode beaches in front of and next to a hard structure, eventually undermining and reducing the effectiveness of the structure and leading to costly repairs. This erosion also results in a loss of dry beach at high tide, reducing the beach's value for storm damage protection, recreation, and wildlife habitat. Hard structures also impede the natural flow of sand, which can cause erosion in down-current areas of the beach system. Dune projects, however, increase protection to landward areas while allowing the system's natural process of erosion and accretion to continue. In addition, because of their more natural appearance, dunes can be more aesthetically pleasing than hard structures.

In general, therefore, the impacts of dune projects are relatively minor when compared to hard structures. The most significant factor in determining the potential impact is the proximity of the dune project to sensitive habitats. For example, dune projects near salt marsh, horseshoe crab spawning grounds, and other sensitive habitats can smother plants and animals if dune sediments are eroded quickly and carried to these areas. In addition, dune projects in nesting habitat for protected shorebird and turtle species (i.e., species that are considered endangered, threatened, or of special concern in Massachusetts) can inhibit nesting success.

Other potential impacts from dune projects can be caused by using sediment of an inappropriate grain size or building a dune with a slope that is too steep. If the sediments brought in are finer than the existing beach sediments, they can erode quickly and may smother nearby sensitive areas, such as shellfish and eelgrass. If the introduced sediments are too large, they may not move and shift as intended and can therefore reflect wave energy, causing erosion of the beach in front of or near the dune. As for the slope, steep dunes are unstable and erode rapidly. This can cause a scarp, which looks like a carved out area in the dune with an almost vertical slope. Scarps can make beach access dangerous and impede the movement of wildlife over the dune.

Design Considerations for Dune Projects

This section covers a variety of factors that should be considered to minimize adverse impacts and ensure successful design, permitting, construction, and maintenance of an artificial dune or dune nourishment project.

Appropriate Locations

Dune projects are appropriate for almost any area with dry beach at high tide and sufficient space to maintain some dry beach even after the new dune sediments are added to the site. Dune projects can be used in combination with other natural coastal landforms or hard structures.

Sacrificial Dunes - Dunes constructed in areas with narrow beaches at high tide are often called "sacrificial dunes" because they are expected to provide relatively short-term protection before they are eroded and need to be replaced. Sacrificial dunes are typically constructed when there are fewer shoreline protection options available due to regulatory or physical limitations. With sacrificial dunes, it is often appropriate to use coarser sediments than the existing beach and dune to provide greater protection and increase project longevity.

For example, artificial dunes can be placed seaward of an eroding bank to reduce bank erosion or seaward of an existing rock revetment or seawall to minimize wave reflection that exacerbates beach erosion and undermines the structure.

In areas with no beach at high tide, the protection provided by dune projects is relatively short-lived because the added sediments are readily eroded and redistributed to the nearshore by both regular waves and tides and storms. In these situations, increasing the width of the beach through beach nourishment may be a preferred shoreline protection option (see *StormSmart Properties Fact Sheet 8: Beach Nourishment*). For projects on narrow beaches where the seaward part of a dune would be reached by extreme high tides or minor storm tides, the dune will likely erode quickly and require frequent maintenance to retain the level of protection the project was designed to provide.

"Compatible" Sediments - Size, Shape, Color, and Texture

Dune projects require the use of compatible sediments—sediments that are too fine will erode quickly, reducing project effectiveness and potentially impacting nearby resource areas, while sediments that are too large may not move and shift as intended and could increase erosion and other problems. Consequently, the percentage of sand-, gravel-, and cobble-sized sediment should match, or be slightly coarser than, the existing beach/dune sediments.

Using sediments with slightly larger grain sizes can provide improved erosion control and storm damage protection. More energy is needed to move this larger material, absorbing wave energy more effectively and eroding less readily. In addition, when a dune is overtopped during a storm, the sand is typically moved seaward into the beach system (where it dissipates wave energy). The larger sediments shift landward and provide direct protection from storm waves. However, because of the potential impacts of using material that is too large, decisions about the range of sediment sizes (i.e., percentage of sand, gravel, and cobble) should be based on specific site conditions, potential impacts, and the desired level of shoreline protection. In addition, if sediments with larger grain sizes shift to the beach area during a storm, they can negatively affect the quality of the beach for recreation and habitat for protected species.

The shape of the material brought in is also important, primarily for larger-grained sediments (gravel and cobble). These sediments should be rounded (like natural beach sediments) rather than angular (crushed). Rounded grains readily roll and slide against each other, and this movement dissipates more wave energy. If rounded material is not used, the ability of the dune to move and shift can actually be reduced rather than improved by the project.

The color and texture of the sediment purchased for a dune project can affect the aesthetics of the site—but because this impact is temporary and does not interfere with the way the shoreline system functions, addressing it is optional. As for color, some sediment from upland sources appears orange when compared to the typical white-to-gray color of Massachusetts dunes. The orange hue is often due to iron staining, which does bleach out in the sun over time. With texture, some compatible sediment sources contain a small percentage of fine silt, which can stick to recreational beach users. Although the silt naturally blows or washes away with time, "washed" sediment with lower silt content can be requested from inland sand and gravel pits.

Volume of Material

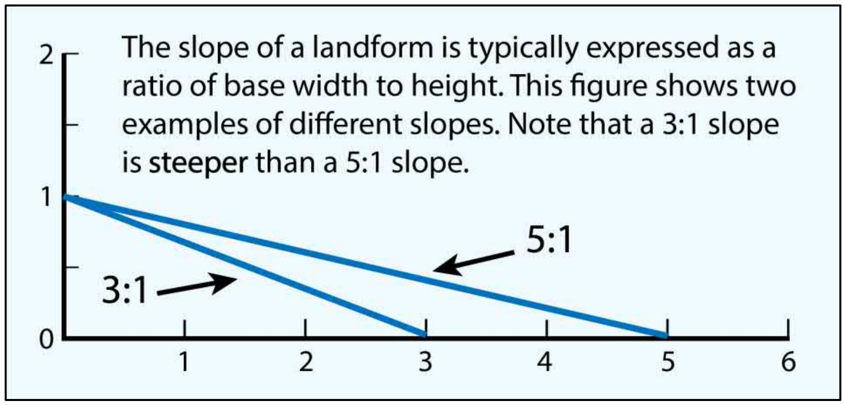
The volume of sediment needed for a dune project will depend on: 1) the elevation of the beach and existing dune (if any) relative to the predicted water level during a major coastal storm event, and 2) the level of protection desired. The lower the existing beach/dune and the higher the predicted water level during a storm, the greater the volume of material that is needed to achieve a certain level of protection.

Vegetation and Sand Fencing for Erosion Control

Planting the dune with native, salt-tolerant, erosion-control vegetation with extensive root systems is highly recommended to help hold the sediments in place. However, planting may be restricted in nesting habitat for protected shorebirds and turtles. Sand fencing can also be installed to trap windblown sand to help maintain and build the volume of a dune. See StormSmart Properties fact sheets *Planting Vegetation to Reduce Erosion and Storm Damage* and *Sand Fencing* for more information. Christmas trees are not recommended for trapping sand because a large section of the dune is disturbed when they are removed by waves, increasing dune erosion. Placing brush and other dead plant material on the dune can prevent living plants from becoming established, causing further destabilization. Christmas trees and brush can also degrade nesting habitat for protected shorebirds by physically occupying otherwise suitable nesting habitat and impeding chick movement.

Dune Slope

Steep dunes are unstable and may erode rapidly and cause problematic scarps. To avoid this problem, the seaward slope of the dune should typically be less than 3:1 (base:height). The slope selected for the project will be based on the existing beach and dune slope, the width of the dry beach, and the grain size of the dune sediments. In addition, there should be some dry beach between the dune and the average high tide line to prevent rapid erosion.



Minimizing Impacts to Habitat and Wildlife

Impacts to sensitive habitats can be avoided by placing dunes as far landward as possible and using sediments of appropriate size. For dune projects proposed in or adjacent to nesting habitat for protected shorebirds and turtles, the slope and height of the dune, time of year for construction, and density of vegetation planted may need to be modified to allow for successful nesting. The Natural Heritage and Endangered Species Program of the Massachusetts Division of Fisheries and Wildlife can provide information on the species listed as endangered, threatened, and of special concern in Massachusetts, including their location and any special design or permitting requirements under state regulations. For projects proposed near horseshoe crab spawning habitat, work should not be done during the spawning season. The Massachusetts Division of Marine Fisheries can provide additional information on horseshoe crab protection. Dune projects may also smother existing vegetation that helps to stabilize the area, an impact that can typically be addressed by replanting similar vegetation on the new dune.

Heavy Equipment Use

Access for heavy equipment must be carefully planned to avoid destruction of existing vegetation; creation of ruts; destabilization of banks, beaches, or other landforms; impacts to wildlife and nesting habitat for protected shorebird and turtle species; and related impacts. In addition, heavy equipment operators should avoid running over the dune multiple times, which can compact sediments and prevent them from moving and shifting to effectively dissipate wave energy. When mechanical equipment is being used, contractors should keep hazardous material spill containment kits on-site at all times in case there is a release of oil, gasoline, or other toxic substances.

Permitting and Regulatory Standards

Most options for addressing coastal erosion, storm damage, and flooding are likely to require a permit under the Massachusetts Wetlands Protection Act through the local Conservation Commission. Additional permits may be needed from the Massachusetts Department of Environmental Protection (MassDEP) Waterways Program and the U.S. Army Corps of Engineers if the project footprint extends below the mean high water line or seaward of the reach of the highest high tide of the year, respectively. Permits or approvals may also be required from other state agencies and local departments, depending on the project location and the work involved. Often, Conservation Commission staff are available to meet with applicants early in the design process to go over the important factors that need to be considered.

Generally, regulatory programs are supportive of projects that add sediment to the beach and dune system rather than proposing a hard structure. To obtain a permit, projects need to be designed with appropriate sediment and should not be located in sensitive resource areas (e.g., salt marsh), which are protected by the various regulatory programs.

Professional Services Required

A coastal geologist, engineer, or other environmental professional with expertise in designing dune projects should be consulted to: 1) identify regulatory requirements and ensure the project fully conforms with those requirements; 2) determine the conditions at the site that will affect the project (such as the width of dry beach above high tide, wave exposure, and predicted flood elevations); 3) determine if other shoreline stabilization techniques are needed in addition to the dune project; 4) determine the appropriate grain-size range to be used by taking and analyzing sediment samples of the existing beach and dune; 5) recommend appropriate volumes of sediment for various levels of protection; 6) select appropriate plant species and develop planting and maintenance plans; 7) identify the best time of year to install the various components of the project; 8) prepare plans for permitting; 9) develop an access plan if heavy equipment is needed; and 10) prepare design specifications for construction. The consultant can also oversee permitting, construction, monitoring, and maintenance of the project. For dune projects with gravel or cobble, it is particularly important that the consultant have direct experience designing shore-protection projects using this type of material.

Project Timeline

It may take as little as four to six months to have a dune project designed, permitted, and installed, assuming that only a Massachusetts Wetlands Protection Act permit is required—but it can take longer, depending on the factors involved. Factors influencing this timeline include the contractor's experience with designing and permitting similar projects, completeness of permit applications, special considerations in the permitting process (such as objections by abutters, sensitive resources to be protected, and availability of access for construction), the need for special timing to avoid impacts (e.g., a prohibition on construction during endangered species nesting season), and/or weather conditions during construction.

Maintenance Requirements

Regular maintenance of dune projects will include adding sediment to retain the desired level of protection. The amount of sediment that should be added and how frequently it is needed will depend, in part, on the proximity of the dune to the reach of high tide, the frequency and severity of storms, the initial design of the dune (e.g., grain size, volume, height, and slope), and how established the root system of any vegetation is before a storm hits. For dune projects that include plantings, plants should be replaced (at the appropriate time of year) if they are removed by storms or die (until the plants become fully established, losses are more common). See *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage* for more information for more information. A schedule and plan for replacing sediments and plants should be included in the original permit application for the project so that maintenance can be conducted without additional permitting.

Project Costs

With dune projects, there are typically a range of options available that give increasing levels of protection with increased construction costs. In general, the greater the quantity of sediment that is used in the project, the greater the construction costs, the lower the maintenance costs, and the greater the level of protection provided for the site. In addition, whenever you hire a professional to conduct work on your property, total costs are expected to vary significantly based on site-specific considerations. The considerations that most influence the costs of dune projects are the severity of erosion, the width and elevation of the beach, the volume and availability of sediment needed, the complexity of project design and permitting, and the size and location of the proposed dune. For comparison with other shoreline stabilization options, dune projects typically have relatively low design and permitting costs, low construction costs, and low maintenance costs. See the StormSmart Properties chart, *Relative Costs of Shoreline Stabilization Options* (PDF, 99 KB), for a full comparison.

Additional Information

Artificial or nourished dunes can be used in conjunction with many other techniques for erosion management. See the following CZM StormSmart Properties fact sheets for additional information:

- *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage*
- *StormSmart Properties Fact Sheet 4: Bioengineering - Coir Rolls on Coastal Banks*
- *StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks*
- *StormSmart Properties Fact Sheet 6: Sand Fencing*
- *StormSmart Properties Fact Sheet 8: Beach Nourishment*

The following publications and websites also provide valuable information on dunes:

- *Beach Nourishment: MassDEP's Guide to Best Management Practices for Projects in Massachusetts* (PDF, 2 MB) describes the steps for beach nourishment projects, which are very similar to dune projects. The *Technical Attachments* (PDF, 1 MB) give detailed information on sampling beach sediments, evaluating offsite source material, and monitoring project performance.
- CZM's Coastal Landscaping website focuses on landscaping with salt-tolerant vegetation to reduce storm damage and erosion and includes information on appropriate plants, planting plans, invasive species, and tips on plant care, along with links to other references.
- CZM's *Landscaping to Protect Your Coastal Property from Storm Damage and Flooding fact sheet* (PDF, 962 KB) gives specific information for homeowners on appropriate plants for erosion control in coastal areas.
- *Coastal Dune Protection and Restoration—Using 'Cape' American Beachgrass and Fencing* (PDF, 3 MB) by the Woods Hole Sea Grant and Cape Cod Cooperative Extension Program includes case studies and tips on dune restoration, along with information on preserving shorebird habitat and understanding the permit process.
- *Salisbury Beach Dune Walkover Access Design Standards* (PDF, 14 KB) gives general design standards for walkways over coastal dunes that minimize potential adverse effects. These standards are widely applicable.
- *The Ballston Beach Barrier Dune Restoration Project* (PDF, 1 MB) documents innovative sand fencing techniques used to restore a dune on a barrier beach in Truro.

- CZM's *Environmental Permitting in Massachusetts* gives brief descriptions of major environmental permits required for projects proposed in Massachusetts.
- *Guidelines for Barrier Beach Management in Massachusetts* (PDF, 12 MB), which was produced by the Massachusetts Barrier Beach Task Force in 1994, provides an overview of the Massachusetts Wetlands Protection Act Regulations and the function of beaches, dunes, and other resource areas (in Chapter 2). It also gives information on various erosion management techniques, their potential impacts, and measures to minimize those impacts (Chapter 5).
- Massachusetts Wetlands Protection Act Regulations (310 CMR 10.00) cover work in wetland resource areas and buffer zones.
- The Natural Heritage and Endangered Species Program website provides information on protected species in Massachusetts, habitat maps, and regulatory review for projects in or adjacent to these habitats.
- The Massachusetts Division of Marine Fisheries can provide information on horseshoe crab protection and other fisheries resources.
- The Massachusetts Ocean Resource Information System, or MORIS, is a web-based mapping tool for interactively viewing coastal data. It includes shoreline change data, which should be considered when evaluating and designing shoreline stabilization projects. Other data layers in MORIS (such as endangered species habitat, shellfish, and eelgrass) can help identify sensitive resource areas within or near the project site.

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StormSmart Properties Fact Sheet 2: Controlling Overland Runoff to Reduce Coastal Erosion

The coast is a very dynamic environment and coastal shorelines—especially beaches, dunes, and banks—change constantly in response to wind, waves, tides, and other factors such as seasonal variation, sea level rise, and human alterations to the shoreline system. Consequently, many coastal properties are at risk from storm damage, erosion, and flooding. Inappropriate shoreline stabilization methods can actually do more harm than good by exacerbating beach erosion, damaging neighboring properties, impacting marine habitats, and diminishing the capacity of beaches, dunes, and other natural landforms to protect inland areas from storm damage and flooding. StormSmart Properties—part of the Massachusetts Office of Coastal Zone Management's (CZM) StormSmart Coasts Program—provides coastal property owners with important information on a range of shoreline stabilization techniques that can effectively reduce erosion and storm damage while minimizing impacts to shoreline systems. This information is intended to help property owners work with consultants and other design professionals to select the best option for their circumstances.

What Is Runoff and How Does It Cause Coastal Erosion?

Runoff is rainwater, snowmelt, and water from irrigation systems and other sources that does not soak into the ground or evaporate, but instead flows over the ground surface. Runoff causes erosion when water falling on and/or running across bare or sparsely vegetated areas dislodges soil and other sediments. When runoff flows over a coastal bank, dune, or beach, it can erode these landforms from above and exacerbate other coastal erosion problems.

Channels or gullies on the face of a bank or dune are a sign of a runoff problem. As shown in the photograph on the right, sediment carried by runoff is often deposited in a fan-shaped pile at the base of the slope. The channels and fan-shaped deposits are both indicators that runoff is eroding the bank. Similarly, runoff can erode soil from behind concrete seawalls and under rock revetments (i.e., shoreline stabilization structures constructed of sloping rock), causing them to slump or collapse. Indicators that runoff may be contributing to the failure of seawalls and revetments include channels in the bank above the structure or sinkholes behind the structure. If overland sources of runoff are not successfully managed, the effectiveness of other shoreline stabilization techniques can be compromised.

No shoreline stabilization option permanently stops all erosion or storm damage. The level of protection provided depends on the option chosen, project design, and site-specific conditions such as the exposure to storms. All options require maintenance, and many also require steps to address adverse impacts to the shoreline system, called mitigation. Some options, such as seawalls and other hard structures, are only allowed in very limited situations because of their impacts to the shoreline system. When evaluating alternatives, property owners must first determine which options are allowable under state, federal, and local regulations and then evaluate their expected level of protection, predicted lifespan, impacts, and costs of project design, installation, mitigation, and long-term maintenance.

Runoff has eroded a channel in this bank face, exacerbating the coastal erosion problem. Some of the eroded material has been deposited in a fan-shaped mound at the base of the bank. **(Photo: CZM)**

General Approaches to Runoff Control

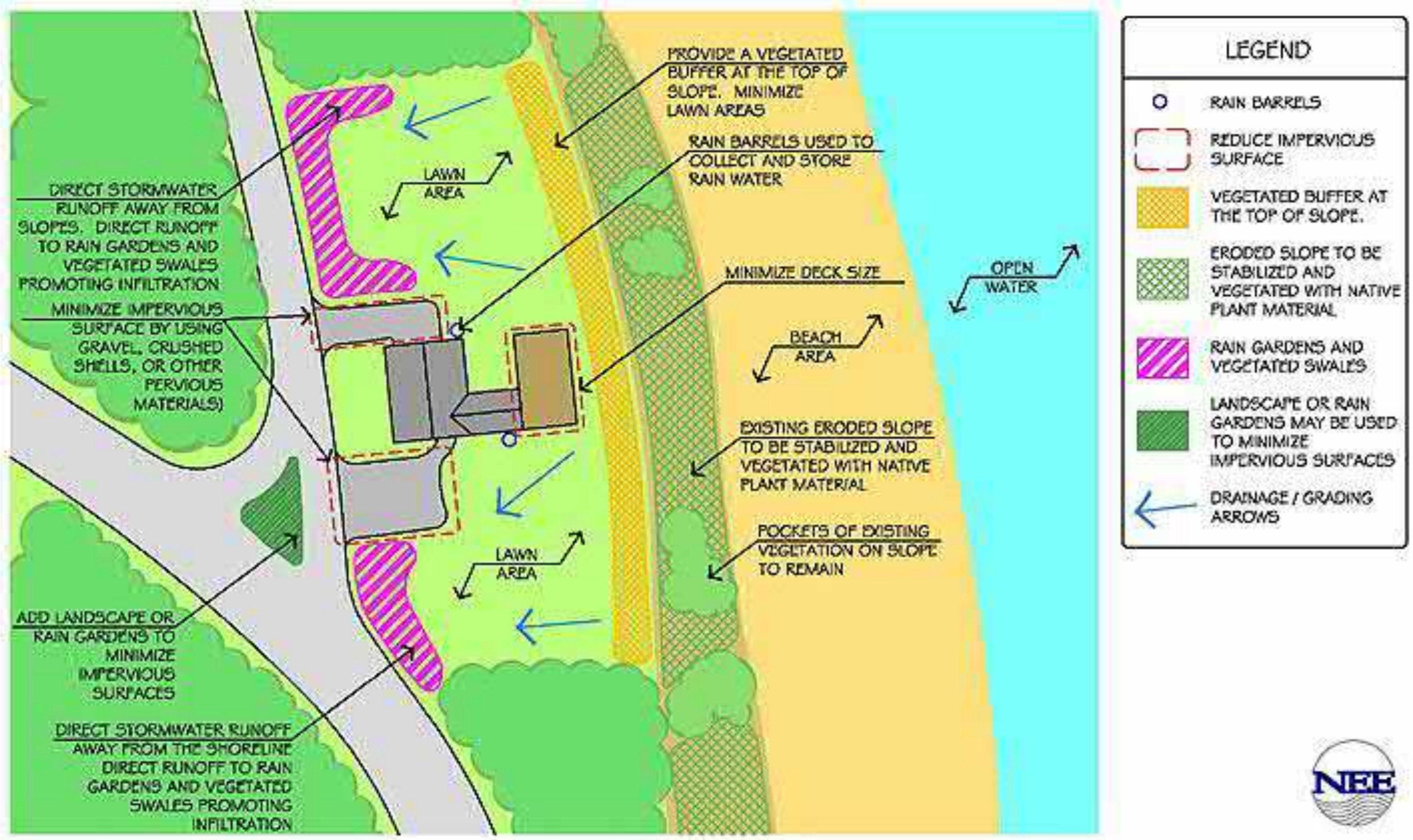
Controlling runoff from upland sources helps reduce a significant cause of erosion on many beaches, dunes, and banks. Efforts to control runoff focus on reducing the quantity and velocity of water flowing across the land surface and changing the direction of flow as necessary to address specific erosion problems. Runoff control approaches include:

- Removing and reducing impervious surfaces (i.e., pavement, concrete, and other impermeable materials) and planting natural vegetation to help slow the flow of runoff and allow the water to naturally seep into the ground. For example, converting asphalt or concrete driveways to grass, crushed-shell, or other surfaces that allow water to soak into the ground is an excellent way to reduce impervious surfaces.
- Capturing runoff so that it can be infiltrated into the ground over a broad area or reused for irrigation.
- Redirecting the flow of water away from erosion-prone areas by regrading the ground surface, constructing a barrier of soil or other sediment (known as a berm), and removing landscaping elements that channel runoff.
- Maintaining the soil's natural capacity to absorb water by preventing saturation from lawn watering and other irrigation.

Several options are available for installing grass driveways, including this grass and paver system. As with all runoff control options, site conditions and potential impacts should be fully evaluated in project design. **(Photo: CZM)**

Runoff control techniques should address the specific patterns and sources of runoff on the site based on a comprehensive evaluation of site conditions. These conditions include the location and extent of impervious and vegetated surfaces, soil types, slope and elevations on the property, and sources and amounts of water coming from both on- and off-site. An experienced professional may need to be consulted for additional guidance regarding project design, and the local Conservation Commission should be contacted about permitting.

This lawn was regraded to slope inland, and a buffer of native shrubs was planted along the top of the bank to stabilize the area and direct runoff away from the bank. These measures reduced runoff flowing over the bank so that a bioengineering project with natural fiber blankets, coir rolls, and vegetation could be successfully installed. **(Photo: CZM)**



This figure demonstrates how a typical coastal property could be modified to reduce runoff and where appropriate runoff control techniques could be sited. **(Graphic: New England Environmental, Inc.)**

The following factors should be addressed to ensure that the runoff control options selected do not create unintended negative impacts:

- **Channelization of Runoff** - Improperly managing runoff can have negative impacts, particularly if the runoff is channelized or redirected onto adjacent properties where it inadvertently increases erosion and flooding issues or where it would impact sensitive environmental resources, such as salt marsh. To avoid these impacts, runoff control options should include components that redirect and spread the flow of water across a broad vegetated area or into a rain garden or vegetated swale (i.e., specially constructed depressions in the ground that are planted with vegetation).
- **Protected Species and Other Sensitive Resources** - If a project is proposed in or adjacent to nesting habitat for protected shorebird or turtle species (i.e., species that are considered endangered, threatened, or of special concern in Massachusetts), project modifications may be required. For example, timing restrictions or other special conditions may be necessary to avoid digging up and destroying rare turtle nests. In addition, planting vegetation in open sandy areas may be prohibited because this habitat is needed for piping plovers and diamond-backed terrapin nesting. Additional information on protected species is available from the Natural Heritage and Endangered Species Program of the Massachusetts Division of Fisheries and Wildlife. Project modifications may also be necessary in horseshoe crab spawning areas, and information is available from the Massachusetts Division of Marine Fisheries. Finally, projects must be designed to protect any nearby wetland resources, such as salt marsh and eelgrass beds.
- **Impermeable Soil Layers on Banks** - When there is an impermeable layer of soil (like clay) underlying permeable sediments in a coastal bank, water that infiltrates into the ground may flow along this impermeable layer toward the bank face. This concentration of water flow may exacerbate erosion where the water breaks out onto the bank face. The runoff control techniques described below may address this issue. However, it is not

always obvious that this situation exists and is exacerbating erosion on a bank. Therefore, professional assistance may be needed to identify the problem and determine the most appropriate techniques to address it.

Design Considerations for Common Runoff Control Techniques

The following section describes a variety of techniques that can be used to help control runoff erosion problems. Specific suggestions for proper design, construction, and implementation are listed for each technique.

Reduce Impervious Surfaces

Reducing the area covered by impervious surfaces slows overland flow and allows water to naturally seep into the ground. To reduce impervious cover:

- Construct driveways or patios with pea stone, gravel, crushed shells, or other pervious materials, rather than using impermeable pavement or concrete.
- Avoid the use of dense-graded aggregate, stone dust materials, and other products that prevent water from permeating into the ground on driveways, patios, or walkways. These products are designed to eliminate voids in the compacted surface, which causes these areas to become impervious.
- Minimize the footprints of proposed buildings and impervious surfaces as much as possible.

Additional Benefit - Improved Coastal Water Quality
Contaminants carried in runoff can significantly harm coastal water quality. Oils and greases washed from roadways and driveways and pesticides from lawns can introduce toxins to coastal waters. Bacteria in runoff can lead to closed shellfish beds and swimming areas. Nutrients from fertilizers, pet waste, or septic systems can lead to nuisance plant or algae growth, which can reduce oxygen supplies (leading to fish kills and odors) and shade out eelgrass beds. Runoff control techniques allow the runoff to seep into the ground where some contaminants may be filtered out by the soil or absorbed by plant roots, minimizing contamination of coastal waters.

Replace Lawns with Natural Plantings

Lawns exacerbate runoff issues because water readily runs over mowed grass and the soils under lawns tend to compact to create an impervious surface. Replacing lawn with longer grass, shrubs, and other vegetation can therefore significantly improve runoff problems. Where possible:

- Restrict the use of mowed lawns to areas needed for pathways and recreation.
- Avoid mowing the lawn right up to the edge of the dune, bank, beach, or marsh (which has the added advantage of keeping people back from the edge—foot traffic may exacerbate erosion).

Extensive irrigated lawns that slope seaward have exacerbated the erosion of this coastal bank. **(Photo: CZM)**

Plant Vegetated Buffers

Vegetated buffers are strips of high grasses, shrubs, and other plants (other than lawn). These buffers absorb runoff, slow its overland flow, and break the impact of raindrops or wave splash. The plant roots also bind the soils and help improve the stability of the area. See *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage* for additional information on using plants for coastal erosion control. To improve the success of runoff control projects:

- Plant vegetated buffers 5-10 feet in width landward of the top of the bank, dune, or beach to be protected.
- Plant salt-tolerant grasses with extensive root systems to provide more immediate erosion control. Though trees and shrubs may look more stable, grasses can grow more quickly and effectively stabilize large areas and require less maintenance to thrive.
- Plant native and salt-tolerant species that are adapted to local conditions and require less maintenance, watering, and pest control.
- Select appropriate species for site conditions, plant at the appropriate time of year (generally spring or fall), and follow the specific instructions for watering, fertilizing, and general care and maintenance.
- Plant trees far enough back from the top of coastal banks to ensure that their weight does not contribute to bank instability.
- If trees on or near the bank are leaning, they may increase instability of the bank and may need to be pruned or removed.
- Do not place dead plant material, such as lawn clipping, brush, and discarded Christmas trees, on a bank or other coastal area. These dead plant materials limit the natural growth and establishment of plants and do not have roots that help bind soils together. Many municipal landfills accept yard waste for composting.
- Some of the most effective plants for vegetated buffers in coastal areas include beach plum, bayberry, Virginia or Carolina rose, arrowwood viburnum, sweet fern, and bearberry.

Fertilizer can cause nuisance plant or algae growth that can degrade water quality. The nitrogen in fertilizer is a particular problem in coastal waters. Consequently, the use of fertilizer on vegetated buffers, as in all coastal areas, should be limited as much as possible. When designed and maintained correctly, vegetated buffers actually filter out nitrogen and other contaminants from inland sources, helping to reduce coastal water contamination.

Install Vegetated Swales and Rain Gardens

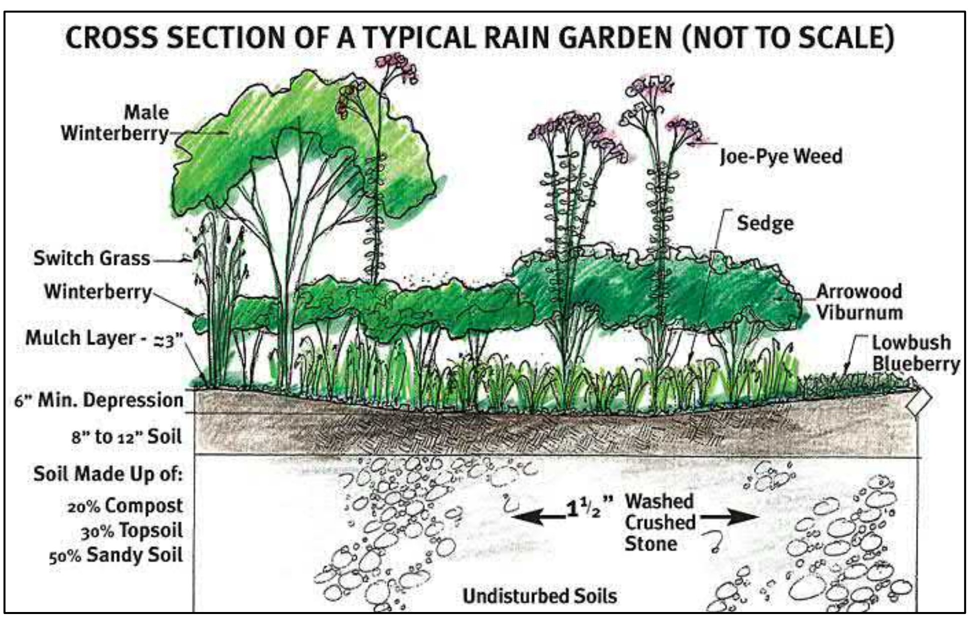
Vegetated swales are channel-like depressions in the ground used to slow, filter, and direct water to another location. Rain gardens are wider and flatter depressions that allow for the maximum collection and infiltration of water. Swales and rain gardens both use plants that tolerate both wet and dry conditions to ensure plant survival (swales often use grasses, while rain gardens are planted with a mix of grasses, perennials, shrubs, and trees).

A large rain garden. **(Photo: Massachusetts Bays National Estuary Program)**

To maximize effectiveness and prevent problems:

- Place swales/rain gardens downslope from a downspout, driveway, or other impervious surface in a relatively flat area (with less than a 5% slope), at least 50 feet away from septic systems, 100 feet away from wells, and 10 feet away from a dwelling foundation. Regrade the area if necessary to create an appropriate location for the swale/rain garden. Consult with your municipal board of health before installing a rain garden or swale near a septic system or well to make sure the proposed setback is sufficient.
- Locate vegetated swales/rain gardens as far away from the top of a bank as possible to reduce the amount of groundwater that may flow toward the bank face and potentially cause erosion.
- Determine the appropriate size of the swale/rain garden needed to effectively capture the runoff based on average yearly rainfall, soil infiltration rates, the size of the area that runoff is draining from, and impervious surface cover. Swales and rain gardens constructed in wetland resource areas will need to meet specifications contained in the *Massachusetts Stormwater Handbook* if a permit is required by the Conservation Commission.
- Plant a series of interconnected swales/rain gardens if one is too small to hold and infiltrate the amount of water flowing into it.
- If necessary, add amendments to clay or poorly drained soils to increase the infiltration capacity of the swale/rain garden. Some of the existing soil may need to be removed and replaced with a layer of gravel, planting soil mix, and mulch.
- To help prevent runoff from washing out the mulch or soil in large storm events, consider installing a temporary erosion-control blanket made of natural fibers over the swale/rain garden to stabilize the soil until the plants become established. (See *StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks* for further information.) In addition, if concentrated flow is being introduced from a driveway, downspout, or other source, spread a layer of crushed stone across the entrance point where the water comes into the swale/rain garden to slow the speed of the flow.

As with vegetated buffers, select appropriate plants for site conditions, plant at the appropriate time of year (generally spring or fall), and follow the specific planting and care instructions. (See *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage* for other tips.)



Adapted illustration courtesy of Comprehensive Environmental, Inc.

Regrade Site to Direct Water Away from the Shoreline

Regrading the area landward of a bank, dune, or beach can ensure that runoff flows away from the shoreline. With this technique:

- Grade the site to slope toward vegetated swales or rain gardens. As mentioned above, swales/rain gardens should be placed well away from the top of a bank.
- To prevent basement flooding, do not direct the water toward a dwelling.
- To prevent erosion of the regraded area, consider covering exposed soils with a temporary erosion-control blanket and successfully plant the area as soon as possible. See the *StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks*.
- Avoid regrading work during heavy rains when exposed soils are more vulnerable to erosion.
- Avoid making slopes too steep, which will accelerate the flow of runoff and may cause additional erosion problems. Consult a professional for site-specific assistance in determining the appropriate slope.

Construct a Vegetated Berm

A berm (i.e., a mound of soil or other sediment built as a barrier) can be used as a “speed bump” to slow the flow of runoff. It is important to:

- Strategically construct vegetated berms to address specific runoff problems. For example, place a berm landward of the top of a coastal bank to redirect runoff away from the shoreline, or use a berm as a barrier to block or redirect runoff from roads, other properties, and other offsite sources.
- Determine the height and overall shape of the berm based on site conditions, such as soil characteristics, existing vegetation, site slope, and volume of water flowing toward the berm. The steeper the slope of the site, the faster the water will be flowing, requiring a higher berm to redirect the flow. As for shape, a berm is generally more stable when its base is twice the width of its height.
- Select sediments to construct the berm based on the amount of runoff. For average water flow, a mix of sediments (such as well-drained soil and sand) provides an effective physical barrier while also allowing for infiltration. For higher water flow, coarser materials (such as sand and gravel) provide greater flow-through and infiltration (to avoid the pooling of water behind the berm).
- Cover the berm with a layer of topsoil and plant/seed the area to stabilize the soil (see *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage*).
- Consider using a short-term natural fiber blanket to stabilize the berm while the plants get established (see *StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks*).

Capture Roof Runoff

Significant quantities of rainwater and snowmelt run into roof downspouts. This water can be directed into a rain barrel, where it can be stored for reuse as irrigation water, or into a system designed to immediately infiltrate the water into the ground, such as a drywell or a French drain. When using these techniques:

- Place rain barrels below downspouts (55 gallon drums are the most common size for rain barrels). Cut the downspout to fit directly into the rain barrel. Special adaptations can be used, such as a spigot to attach hoses to reuse the water or an overflow hose to direct any overflow away from the foundation. Rain barrels should have a screen and cover to keep out mosquitoes, leaves, and debris.

- Design the drywells/French drains to channel water away from foundations. For sites directly adjacent to banks, French drains are generally preferred over drywells because they disperse the water infiltration, which helps ensure that the water successfully seeps into the ground and does not flow toward the bank face.
- Base the storage capacity of the drywell/French drain on the quantity of roof runoff, as well as on the depth of the water table. The bottom of the drywell/French drain should be at least two feet (but preferably four feet) above the seasonal high groundwater level.
- Drywells need to be at least 10 feet from building foundations, 50 feet from vegetated wetlands or tops of coastal banks, 50 feet from any component of a septic system, and 100 feet from wells.

Avoid or Reduce Watering of Lawns and Plants

Watering less keeps soils from becoming saturated, allowing them to more effectively soak up rainwater and other runoff. To water less:

- For the first year, if necessary, use a temporary irrigation system (such as drip tubing on a timer) while newly planted vegetation becomes established (see the planting instructions for specific watering requirements). Once the plants are established, watering is only required during extreme drought.
- When nature does not provide enough water to keep a lawn green and growing, allow it to go dormant. Though it may appear dead, this dormant state allows grass to preserve the vital parts of the plant during times of heat and low moisture and revive with the first saturation.
- Avoid cutting grass too short (generally no shorter than 2 inches). Taller grass has a deeper and more extensive root system, which enables the lawn to better withstand heat and drought.
- Plant less lawn grass and more drought-tolerant grasses and vegetation.

Slow the Flow of Water

By allowing water to spread out and flow over a wider vegetated surface, infiltration will increase, erosive forces will decrease, and runoff will be reduced. Specifically:

- Reduce the use of walls, solid fencing, curbs, etc., that concentrate runoff and create channels and gullies.
- Design discharge points for downspouts or other conduits of water to avoid causing scour, gullies, erosion, or alteration to vegetation. Place splash blocks or level spreaders (structures designed to uniformly distribute concentrated flow over a large area), or small amounts of gravel, at these discharge points to minimize erosion.
- Eliminate curbs or small retaining walls for defining the boundaries (such as between a driveway and lawn), which can channelize runoff and concentrate erosive forces. Replace curbs or walls with vegetated swales or rain gardens that promote infiltration and avoid channelization.
- If road runoff is an issue on your property, contact your town or city to determine if there is a drainage easement (an attachment to a property deed which states that access to part of the property is given to a third party, usually a community, for the purpose of maintaining drainage). If there is no easement, consider rain gardens parallel to the roadside to promote infiltration of road runoff. If there is an easement, work with your local officials to address the issue.

Heavy Equipment Use

If heavy equipment is needed for a project to address runoff, equipment access must be carefully planned to avoid destruction of existing vegetation; creation of ruts; destabilization of banks, beaches, or other landforms; impacts to wildlife and protected species habitat; and related impacts. When mechanical equipment is being used, contractors should keep hazardous material spill containment kits on-site at all times in case there is a release of oil, gasoline, or other toxic substance.

Permitting and Regulatory Standards

Most options for addressing runoff will likely require a permit under the Massachusetts Wetlands Protection Act through the local Conservation Commission if they are within 100 feet of any "wetland resource area" defined under the Act (these resource areas include coastal banks, dunes, beaches, and floodplains). For very large projects, additional permits may be needed from the local, state, or federal agencies. Permits or approvals may also be required from other state agencies and local departments, depending on the location and the work involved. Often, Conservation Commission staff are available to meet with applicants early in the design process to go over the important factors that need to be considered.

Generally, regulatory programs are supportive of runoff control projects, provided they do not interfere with the ability of coastal landforms to naturally move and shift. To obtain a permit, projects need to be designed to minimize impacts to neighboring properties and sensitive resource areas (e.g., beaches and dunes) and prevent impacts to salt marsh, which is protected by the various regulatory programs.

Professional Services Required

Certain techniques that do not alter the property, such as reducing lawn irrigation or installing a rain barrel, can be easily done by the homeowner without a permit. Other simple projects, like planting a buffer strip of native vegetation along the top of a bank or replacing a paved driveway with crushed shell, can often be permitted and conducted by the homeowner in consultation with the local Conservation Commission. A homeowner may also be able to install rain garden or vegetated swale, depending on the complexity of the design. Because of the impacts that can be caused by inappropriately directed runoff, however, projects in or adjacent to sensitive resource areas (e.g., endangered species habitat) or that redirect the flow of runoff are likely to require professional services. A registered professional civil engineer, registered landscape architect, or other environmental professional with experience in managing runoff and landscaping for runoff control can be chosen to: 1) study the landscape and identify the current runoff sources under various storm conditions; 2) identify options to increase permeability, reduce channelization, and redirect runoff away from the shoreline without impacting sensitive resource areas or neighboring properties; 3) determine if any permits are required for the project; 4) identify regulatory requirements and ensure the project fully conforms with those requirements; 5) prepare plans for permitting; 6) prepare design specifications for construction; and, if needed, 7) oversee construction, monitoring, and maintenance.

Project Timeline

It may take as little as two to six months to design, permit, and install a runoff control project, assuming only a Massachusetts Wetlands Protection Act permit is required—but it can take longer, depending on the factors involved. Factors influencing this timeline include the contractor's experience with designing and permitting similar projects, completeness of permit applications, special considerations in the permitting process (such as objections by abutters and sensitive resources to be protected), the need for special timing to avoid impacts (e.g., a prohibition on construction during endangered species nesting season), and/or the weather conditions during construction.

Maintenance Requirements

Many runoff control techniques, such as reducing impervious surfaces and regrading the site away from the shore, require no maintenance when designed and installed successfully. Other techniques require only routine maintenance similar to other yard maintenance requirements. For example, runoff reduction projects using live plants require replacement of dead plants and may require watering during periods of drought.

For rain barrels, debris must be cleared away from the inlets on a regular basis. In addition, unless the rain barrel can withstand freezing temperatures, it should be cleaned out at the end of the fall and stored indoors. Keep roof gutters and other pipes clean to minimize the amount of sediment and other particulates that may enter a rain barrel, dry well, or French drain. Dry wells and French drains should be inspected regularly and cleaned to maintain proper function and drain time, which is 72 hours or less. If soils become compacted or clogged, they will not be able to handle additional water and may cause water to back up. The dry well or French drain may need to be replaced if drain times fall below the specified requirements.

When rainfall exceeds levels the project was designed to handle, more intensive maintenance activities are necessary. For example, a berm may require reconstruction if it is eroded or may need to be replanted if vegetation is damaged during severe rains (immediate repairs may be needed to ensure no further deterioration). After a severe rain event is a good time to evaluate whether the runoff control project functioned as intended. A brief consultation with the professional who designed the project can help to determine whether any modifications are needed.

Project Costs

With runoff control projects, there is typically a range of options available that address increasing runoff quantities. In addition, whenever you hire a professional to conduct work on your property, total costs are expected to vary significantly based on site-specific considerations. The considerations that most influence the costs of runoff control projects are the severity of erosion, volume of runoff that needs to be redirected, size of the area that needs to be addressed, quality of materials used, and complexity of project design and permitting. In addition, the type of runoff control and size of the area to be addressed will determine the construction and maintenance costs. In comparison with shoreline stabilization options, runoff control projects typically have relatively low costs for design and permitting, construction, and maintenance. See the StormSmart Properties chart, *Relative Costs of Shoreline Stabilization Options* (PDF, 99 KB), for a full comparison.

Additional Information

Related techniques covered in the CZM StormSmart Coasts menu of shoreline stabilization options are *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage* and *StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks*.

The following resources also provide valuable information on runoff control:

- CZM's Coastal Landscaping website includes information on landscaping coastal areas with salt-tolerant vegetation to reduce storm damage and erosion.
- CZM's *Landscaping to Protect Your Coastal Property from Storm Damage and Flooding fact sheet* (PDF, 962 KB) gives specific information for homeowners on appropriate plants for erosion control in coastal areas.
- CZM's CZ-Tip - Keep Waterways Clean by Filtering Pollutants with Plants discusses reducing runoff impacts by planting vegetated buffers.
- The Massachusetts Department of Environmental Protection's (MassDEP) Vegetated Buffer Strips: Slow the Flow to Protect Water Quality explains how vegetated buffer strips function and how to create them.
- The U.S. Environmental Protection Agency's (EPA) National Menu of Stormwater Best Management Practices has searchable fact sheets on berms, regrading, swales, and other stormwater control practices.
- EPA's GreenScaping: The Easy Way to a Greener, Healthier Yard provides information on yard maintenance to reduce water usage.
- *Rain Gardens Across Maryland* (PDF, 14 MB) discusses locating, siting, and designing rain gardens and calculating impervious surfaces (rainfall depths and plant species are specific to Maryland).

- CZM's *Environmental Permitting in Massachusetts* briefly describes major environmental permits required for projects proposed in Massachusetts.
- Massachusetts Wetlands Protection Act Regulations (310 CMR 10.00) cover work in wetland resource areas and buffer zones.
- MassDEP's *Erosion & Sedimentation Control Guidelines* (PDF, 4 MB) give best management practices for managing sediment and runoff.
- MassDEP's *Massachusetts Stormwater Handbook* provides design specifications for rain gardens, drywells, and swales.
- The Natural Heritage and Endangered Species Program website provides information on protected species in Massachusetts, habitat maps, and regulatory review for projects in or adjacent to these habitats.
- The Massachusetts Division of Marine Fisheries can provide information on horseshoe crab protection and other fisheries resources.
- The Massachusetts Ocean Resource Information System, or MORIS, is a web-based mapping tool for interactively viewing coastal data. MORIS data layers, such as endangered species habitat and shellfish, can help identify sensitive resource areas within or near the project site.

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StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage

The coast is a very dynamic environment and coastal shorelines—especially beaches, dunes, and banks—change constantly in response to wind, waves, tides, and other factors such as seasonal variation, sea level rise, and human alterations to the shoreline system. Consequently, many coastal properties are at risk from storm damage, erosion, and flooding. Inappropriate shoreline stabilization methods can actually do more harm than good by exacerbating beach erosion, damaging neighboring properties, impacting marine habitats, and diminishing the capacity of beaches, dunes, and other natural landforms to protect inland areas from storm damage and flooding. StormSmart Properties—part of the Massachusetts Office of Coastal Zone Management's (CZM) StormSmart Coasts Program—provides coastal property owners with important information on a range of shoreline stabilization techniques that can effectively reduce erosion and storm damage while minimizing impacts to shoreline systems. This information is intended to help property owners work with consultants and other design professionals to select the best option for their circumstances.

How Vegetation Reduces Erosion and Storm Damage

Dunes, banks (also known as bluffs), and other coastal landforms are susceptible to erosion from tides, currents, wind, and coastal storms. Overland runoff, which is the water from rain, snowmelt, sprinklers, and other sources that does not readily soak into the ground or evaporate but instead flows over the ground surface, can also cause erosion by dislodging vegetation, sand, gravel, and other sediments. Salt-tolerant plants with extensive root systems can help address both kinds of coastal erosion problems. First, plant roots hold sediment in place, helping to stabilize the areas where they are planted. Second, by absorbing water, breaking the impact of raindrops or wave-splash, and physically slowing the speed and diffusing the flow of overland runoff, plants reduce runoff erosion. Vegetation also helps trap windblown sand, which is particularly important for building dune volume, increasing the dune's ability to buffer inland areas from storm waves, erosion, and flooding. Finally, high grasses, shrubs, and other vegetation can be planted to limit foot traffic in erosion-prone areas.

Vegetation can be used in conjunction with many other techniques for erosion management. See the following StormSmart Properties fact sheets on related techniques: *Artificial Dunes and Dune Nourishment*, *Controlling Overland Runoff to Reduce Coastal Erosion*, *Bioengineering - Coir Rolls on Coastal Banks*, *Bioengineering - Natural Fiber Blankets on Coastal Banks*, *Sand Fencing*, and *Beach Nourishment*.

No shoreline stabilization option permanently stops all erosion or storm damage. The level of protection provided depends on the option chosen, project design, and site-specific conditions such as the exposure to storms. All options require maintenance, and many also require steps to address adverse impacts to the shoreline system, called mitigation. Some options, such as seawalls and other hard structures, are only allowed in very limited situations because of their impacts to the shoreline system. When evaluating alternatives, property owners must first determine which options are allowable under state, federal, and local regulations and then evaluate their expected level of protection, predicted lifespan, impacts, and costs of project design, installation, mitigation, and long-term maintenance.

Beachgrass was planted to stabilize an eroded dune and trap windblown sand to build dune volume. **(Photo: CZM)**

A variety of salt-tolerant vegetation was planted on the face of this bank to stabilize fill added to address bank erosion. **(Photo: CZM)**

Shrubs were planted at the top of this bank to slow runoff. On the bank face, natural fiber blankets were installed to hold soils in place until the erosion-control vegetation could get established. **(Photo: CZM)**

Relative Benefits and Impacts Compared to Other Options

The major benefit of vegetation projects is that unlike seawalls, rock revetments, or other “hard” shoreline stabilization structures, vegetated areas absorb and dissipate wave energy, rather than reflecting or redirecting waves onto beaches or neighboring properties. The design of a hard structure affects how much wave energy is reflected, for example vertical walls reflect more wave energy than sloping rock revetments. These reflected waves erode beaches in front of and next to a hard structure, eventually undermining and reducing the effectiveness of the structure and leading to costly repairs. This erosion also

Under the Massachusetts Wetlands Protection Act, new hard structures are typically prohibited on all beaches and dunes. On coastal banks, hard structures are only allowed when necessary to protect buildings permitted before August 10, 1978, and only if no other alternative is feasible. In many cases, vegetation projects and other non-structural alternatives are therefore the only options available for reducing erosion and storm damage on coastal properties.

results in a loss of dry beach at high tide, reducing the beach's value for storm damage protection, recreation, and wildlife habitat. Other benefits of vegetation projects are that they preserve the natural character of the coastal environment and provide wildlife habitat.

In general, the impacts of vegetation projects are relatively minor when compared to other options. Vegetation projects in habitat for protected species (i.e., species that are considered endangered, threatened, or of special concern in Massachusetts), however, do have the potential to cause significant impacts, such as removing open sand areas needed for successful nesting of piping plovers and diamond-backed terrapins. Even the planting of native plant species can cause impacts in these areas. See Design Considerations below for information on addressing this issue.

Design Considerations for Vegetation Projects

This section covers a variety of factors that should be considered to minimize adverse impacts and ensure successful design, permitting, construction, and maintenance of vegetation projects.

Appropriate Locations

Vegetation projects are appropriate for virtually any dune or bank along the coast where sand and other sediments are exposed to wind and waves. Because it is relatively difficult to get vegetation established in areas that are regularly inundated or overwashed by tides and waves, however, the longevity and effectiveness of these projects can be limited in certain locations. The techniques discussed in Protecting Plants below can help address this issue.

Protecting Plants

Plants are most vulnerable before their root systems become established. Techniques that can help stabilize dunes and banks while plants get established include: 1) installing natural fiber blankets on the ground surface before planting to hold soils in place while roots get established (see *StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks*), 2) using temporary baffles of natural-fiber material to shelter plants from wind, and 3) installing sand fencing to help slow wind, trap sand, and reduce erosion (see *StormSmart Properties Fact Sheet 6: Sand Fencing*). Combining these techniques is more effective than using only one method. On banks, another method to protect the soil around newly planted live vegetation is to plant a salt-tolerant seed mix on the exposed soil. The plants that grow from seed can quickly stabilize the soil so it is not washed away while the live plants are becoming established.

Another important factor for successful plant establishment and survival is water availability. Since new plants with their smaller root systems have a limited capacity to find water in the surrounding soil, a consistent supplementary source of water should be provided directly to these plants while their root systems and foliage are developing. For large planting projects, the use of a temporary, automated irrigation system may be warranted for up to three summers following planting. See the Watering section below for additional details and cautions on using automated irrigation systems.

To further ensure the success of planting projects, sources of erosion, including upland runoff and waves, should be identified and addressed as part of the site evaluation and design process. Runoff should be reduced or redirected to give the vegetation the best chance of survival (see *StormSmart Fact Sheet 2: Controlling Overland Runoff to Reduce Coastal Erosion* for details). In areas subject to regular erosion from waves, tides, currents, wind, and coastal storms, additional techniques should be considered to improve site protection. For example, beach nourishment (i.e., adding sediments like sand, gravel, and cobble to widen the beach—see *StormSmart Fact Sheet 8: Beach Nourishment*) can protect vegetation projects by widening beaches in areas with relatively narrow beaches at high tide. For bank projects, dense rolls of natural fiber called coir rolls can protect newly planted areas (see *StormSmart Fact Sheet 4: Bioengineering - Coir Rolls on Coastal Banks*), hay bales can be staked at the base of the bank to provide a short-term buffer from tide and waves, and artificial dunes can be constructed with sediment from an off-site source to buffer the base of the bank (see *StormSmart Properties Fact Sheet 1: Artificial Dunes and Dune Nourishment*).

In addition, to protect dune and bank vegetation, pedestrian access to the shoreline should be restricted to designated access paths or walkways and the number of access points should be limited as much as possible. Often, multiple properties can use a common access point. The size of access structures should be minimized as much as possible to limit shading impacts to vegetation.

Lightweight, natural-fiber, erosion-control fabric was installed on this bank to protect the plants from wind until the roots could get established. Boards were placed on top of wooden stakes to provide access during construction, which minimized impacts to the bank from foot traffic. The photo on the right was taken one year after planting. **(Photos: New England Environmental, Inc.)**

An Added Consideration on Banks - Establishing a Stable Slope

On banks, a stable slope is essential for project success. If the bottom of the bank has eroded and its slope is steeper than the upper portion of the bank, the bank is likely unstable. Even when heavily planted with erosion-control vegetation, banks with unstable slopes are extremely vulnerable to slumping or collapse that can endanger property landward of the bank. Before planting vegetation, therefore, the bank slope should be stabilized.

Ideally, soil of a similar type to that on the bank or beach is brought in as fill and added to the lower part of the bank to create a slope that matches or is less steep than the upper slope. However, if adding fill brings the toe of the bank within the reach of high tides, the fill will erode quickly and undermine the rest of the bank. In these cases, regrading the bank slope by removing sediment from the top of the bank may be a better option. While removing part of the upper portion of the bank does reduce the land area between the top of the bank and the property, it can be done in a controlled fashion that improves the overall stability and storm-damage prevention capacity of the bank. And if the slope is not stabilized, bank collapse during a storm could cause substantially more loss of land area to the sea. In addition, any investment in vegetation and other methods to prevent erosion on an unstable bank will be lost if the bank collapses. On sites where the top of the bank is well vegetated with mature, salt-tolerant species with extensive roots, the appropriate approach to stabilize the bank should be carefully developed by a professional with extensive experience successfully stabilizing similar sites.

Sediment was added to this eroding bank to create a shallower and more stable slope before the vegetation was planted. The lower bank was planted with grasses and the upper section with mixed grasses and shrubs. (Photo: CZM)

Plant Selection

Specific site conditions—including wind, salt, soil type and quality, moisture, shifting sands, frequency of coastal storms, and exposure to waves and overwash—dictate the plant species that can grow successfully. Native, salt-tolerant species are recommended for coastal use because they are well adapted to the harsh conditions, require less maintenance to grow and thrive, and provide more diverse food and shelter for wildlife. In addition, only plants with extensive root systems should be selected for erosion-control projects.

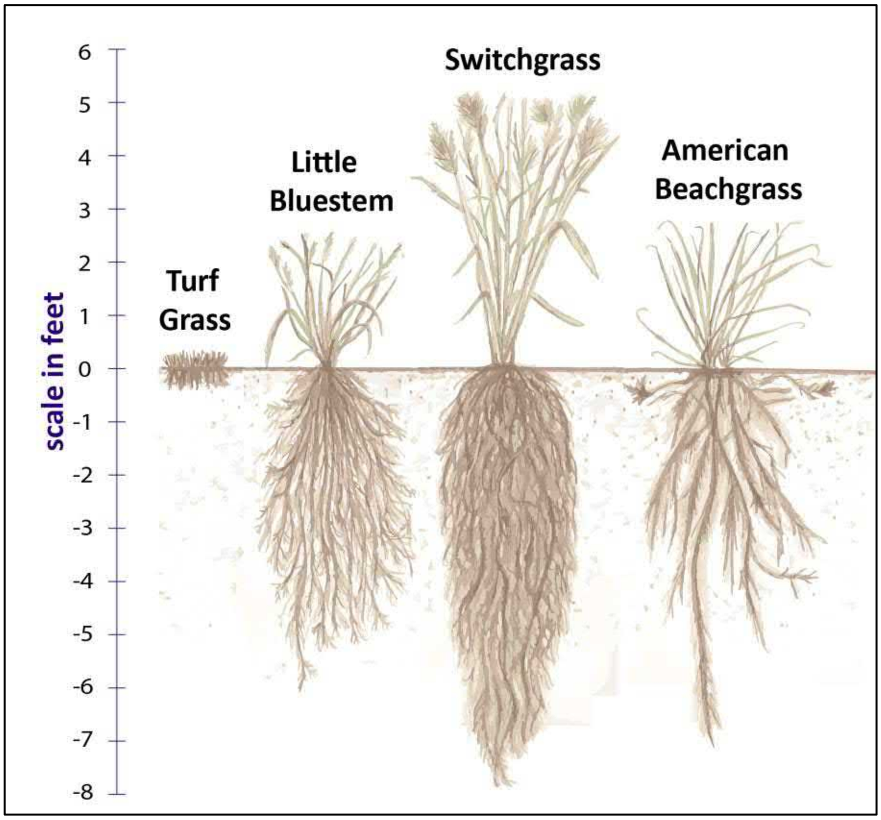
On dunes (particularly those closest to the beach where wind and wave action are strongest), American beachgrass is the best species to use for initial plantings. Beachgrass quickly establishes a dense root system, rapidly accumulates sand, and is very resilient to being overwashed by waves. For beachgrass to thrive, it should be planted in a location where wind-blown sand will reach the plants. Other plants recommended for use in combination with beachgrass include little bluestem, purple lovegrass, and seaside goldenrod. Further landward in dunes and beyond the reach of regular wave action, shrubs such as beach heather, lowbush blueberry, bayberry, and beach plum can be planted with grasses to add diversity and improve erosion control.

On banks, switchgrass, saltmeadow cordgrass, little bluestem, and other grasses can stabilize exposed areas quickly with their fast-growing, fibrous root systems. While American beachgrass is helpful for initial bank stabilization, it will not thrive on banks that receive little blowing sand. In these areas, it should be planted with other recommended species that will take over as the beachgrass fades. Shrubs, low groundcovers, and perennials that have extensive surface areas and root systems can be used to intercept heavy rainfall and help shelter and stabilize the underlying soils.

Northern bayberry, bearberry, and marsh elder are excellent shrubs for protecting underlying soil in coastal areas. Shrubs are best used higher up on the bank where they are not exposed to waves, and planting a mix of grasses around newly planted shrubs can help stabilize the area while the shrubs become established. Trees and large shrubs should not be planted on the face of a bank because their height and weight can destabilize the bank and make them vulnerable to toppling by erosion or high winds. Existing trees on banks can be pruned back to help address this problem.

It is important to plant a diversity of native species because a stand of only one plant is more susceptible to complete die-out from drought, disease, or pests.

CZM's [Coastal Landscaping website] provides additional detailed information on appropriate plants for storm damage prevention and flood control on dunes and banks.



Turf grass has a very shallow root system compared to these other plants recommended for erosion control. **(Figure redrawn from illustration by Dede Christopher of the Tennessee Valley Authority, Benefits of Riparian Zones)**

Use Only Live Plants for Erosion Control

Only live plants should be used since brush, lawn clippings, and other dead plant materials prevent live plants from getting established and have no roots to bind soils. Discarded Christmas trees are a particular problem because they leave large, destabilizing holes when they are ripped out by waves. Sand fencing is a much more effective option and does not impede the natural growth of live plants. See *StormSmart Properties Fact Sheet 6: Sand Fencing* for details.

Never Plant Invasive Plants

Invasive species (i.e., introduced species that thrive at the expense of native plants) should never be planted in coastal areas. Oriental bittersweet, bush honeysuckle, vine honeysuckle, autumn olive, and porcelain berry vine are particularly problematic coastal invasives because they have shallow roots, spread rapidly, and can secrete toxic compounds that prevent the growth of other plants. Japanese knotweed is another common invasive that is a problem on coastal sites. Although knotweed has deep roots, it can easily be torn out of the ground, taking large chunks of the soil with it. Because of these growth characteristics, even dense stands of these six species do little to reduce erosion by storm waves, runoff, and wind.

Removing/Replacing Invasive Plants

Invasive plants should be removed and replaced with appropriate native plants if they are preventing establishment of erosion-control vegetation. Because of their tenacity, successful control of invasive plants can take years to accomplish and may require perpetual monitoring and management. This effort is particularly warranted when bank stability is severely compromised by the invasive plant or when unruly and overgrown invasives can be replaced with lower-growing native species to stabilize the bank and improve coastal views.

INVASIVE PLANTS THAT HINDER EROSION CONTROL

Bush Honeysuckle

(Photo: Leslie J. Mehrhoff, University of Connecticut)

Vine Honeysuckle

(Photo: Chuck Bargeron, University of Georgia)

Oriental Bittersweet

(Photo: James R. Allison, Georgia Department of Natural Resources)

Autumn Olive

(Photo: Leslie J. Mehrhoff, University of Connecticut)

Porcelain Berry Vine

(Photo: Nancy Loewenstein, Auburn University)

Japanese Knotweed

(Photo: Jan Samanek, State Phytosanitary Administration)

All photos courtesy of Bugwood.org with specific acknowledgements given.

The photo on the left shows a densely vegetated bank that looks stable, but isn't. The invasive black locust, Asiatic bittersweet, and autumn olive growing on the bank do not have deep, dense roots that help hold soils in place. The photo on the right shows a close up of the exposed soils and erosion at the site. In addition, the roots of these invasive plants secrete toxic compounds and the thick branches shade the area, both of which inhibit the growth of native plants that could stabilize the soil. **(Photos: Wilkinson Ecological Design)**

Removing invasive plants to replace them with native species, however, can temporarily destabilize the bank. For sites where bank regrading is not needed, invasive plants should be cut off at ground level, keeping the roots in place to minimize site disturbance. Many invasive plants can be effectively eliminated by applying limited amounts of herbicide to the cut stems, which kills the remaining root material. Herbicides can only be used in areas where they are allowed by local regulations. A direct and targeted application of herbicides, as opposed to spraying, helps to minimize adverse impacts to existing native vegetation, soils, groundwater, and coastal waters. Invasive plants should also be removed by hand when possible, rather than with heavy equipment. For sites where regrading is needed, the roots of invasive plants can be pulled out to minimize resprouting.

Regardless of the method used, when vegetation is cut or removed, the exposed soils will become more vulnerable to erosion from wind, rain, and waves. Proper scheduling and sequencing of invasive species removal and replanting with native species will minimize this problem, as will the use of other soil stabilization techniques. Consultation with a professional experienced in replacing invasives with native plants in erosion-prone areas is recommended, as the techniques and timing vary between plants.

Time of Planting

Although specific timing varies based on the plant species selected, most vegetation should be planted in early-to-mid spring (when the growing season has started and moisture levels are relatively high) to promote root growth and successful plant establishment. Beachgrass, however, typically does best when planted in unfrozen ground from mid-November through early April, except in areas exposed to strong wind or waves, where it should be planted in early spring to reduce the likelihood it will be washed or blown away in winter storms.

Watering

Established native plants typically do not require watering. When planted at the appropriate time of year, some newly planted species, such as American beachgrass planted on dunes, also do not require watering.

In both dune and bank areas, some supplemental irrigation may be necessary to ensure success in certain circumstances. For most newly planted vegetation, it is generally recommended that a temporary, automated irrigation system be used from April through October during the first two to three growing seasons until the roots can effectively find and absorb water from the surrounding soils. These irrigation rates can typically be reduced each year, with only minimal water needed in the third year, if at all. For American beachgrass and other plants that do not typically require initial watering, temporary irrigation (i.e., for 4-6 months) is needed when these species are planted in the hot, dry summer months.

Permanent irrigation systems and heavy watering are unnecessary and are not recommended, not only because established plants do not require watering (with the exception of times of drought), but also because excess water from permanent irrigation systems generally exacerbates dune and bank erosion and can even lead to bank failure. Excess water on dunes can also reduce soil salinity levels and allow plants that will not survive in the long-term to out-compete appropriate erosion-control plants.

Temporary irrigation systems, such as aerial heads, are good for providing water to large areas of plugs and seeds, while soaker hoses and drip tubing are effective for supporting container plantings, such as shrubs. A timer may be appropriate to deliver a sufficient amount of water (enough to infiltrate well into the soil to help plants develop deep roots) at desired times (often early morning when less water is lost to the heat of the day). The temporary irrigation lines should be left at the surface (so soils will not be disturbed when the lines are removed) and the system should be removed at a determined time (such as when a local Conservation Commission issues a Certificate of Compliance for the project around year 3).

Various methods to improve water retention and nutrient content in the plants and soils can also help significantly boost the survival rates of plants, such as the application of wetting agents (e.g., Yucca extract), beneficial microbes, and organic compost. A professional may need to be contacted to help determine the most appropriate watering methods and applications that will ensure plant establishment while avoiding impacts to coastal resource areas.

Fertilizer

Because sandy soils are typically dry and lack nutrients, it may be necessary to add some organic matter such as compost before planting. For coastal settings, it is appropriate to select plants that require little fertilizer. If the plant label indicates that fertilizer is needed the first year, use only the minimum amount necessary and use slow-release fertilizers composed of water-soluble materials to prevent coastal water pollution. On artificial or nourished dunes where sand has been brought in from off-site, a limited application of time-release fertilizer 30 days after planting is often needed.

Wildlife Protection

Because vegetation can alter habitat, care must be taken with vegetation projects in protected species habitat. Selecting appropriate types of vegetation (e.g., grass vs. shrubs) and increasing the spacing between plantings can reduce impacts to nesting habitat for protected shorebirds and turtles. Detailed guidance is available from the Natural Heritage and Endangered Species Program of the Massachusetts Division of Fisheries and Wildlife.

Heavy Equipment Use

If heavy equipment is needed for a vegetation project, equipment access must be carefully planned to avoid destruction of existing vegetation; creation of ruts; destabilization of banks, beaches, or other landforms; impacts to wildlife, particularly nesting habitat for protected shorebirds and turtles; and related impacts. When mechanical equipment is being used, contractors should keep hazardous material spill containment kits on-site at all times in case there is a release of oil, gasoline, or other toxic substances.

Permitting and Regulatory Standards

Most options for addressing coastal erosion, storm damage, and flooding are likely to require a permit under the Massachusetts Wetlands Protection Act through the local Conservation Commission. Permits or approvals may also be required from other state agencies and local departments, depending on the location and the work involved. Generally, regulatory programs are supportive of projects that naturally stabilize dunes and banks with vegetation rather than proposing a hard structure. However, before bringing in a backhoe (or even a shovel or pruning shear) to do any kind of landscaping work on a coastal property, contact your local Conservation Commission to determine if a permit is necessary.

Professional Services Required

Simple dune and bank planting projects may be done by the homeowner after permits have been obtained if needed. More complex projects that involve regrading, however, are likely to require professional services. A landscape architect, biologist, engineer, or other environmental professional with experience designing erosion-control projects in coastal areas using native, salt-tolerant plantings may need to be consulted to: 1) identify regulatory requirements and ensure the project fully conforms with those requirements; 2) determine the conditions at the site that will affect the project (such as the amount of sun or shade, high winds, wave exposure, runoff, and foot traffic); 3) identify invasive species, oversteepened slopes, runoff problems, areas of increased erosion due to adjacent hard structures or development, or other issues that must be considered as part of project design; 4) determine if other shoreline stabilization techniques are needed in addition to vegetation; 5) select appropriate plants and develop a planting and maintenance plan; 6) determine volume and composition of fill, if needed; 7) identify the best time of year to install various components of the project; 8) develop an access plan if heavy equipment is needed; 9) determine what, if any, fertilizer or irrigation is needed; 10) prepare plans for permitting; and 11) prepare design specifications for construction. The consultant can also oversee construction, monitoring, and maintenance of the project.

Project Timeline

It may take as little as two to three months to design, permit, and install a vegetation project, assuming that only a Massachusetts Wetlands Protection Act permit is required. To expedite the process, hire a consultant with appropriate experience in designing and permitting similar projects, make sure that regulatory applications are complete, and anticipate and address special considerations, such as abutter concerns, construction access issues, or time-of-year restrictions (due to endangered species issues, for example). Often, Conservation Commission staff are available to meet with applicants to go over the important factors that need to be considered early in the design process.

Maintenance Requirements

Vegetation projects require ongoing maintenance to ensure their success. Maintenance requirements will vary greatly depending on site conditions. As with all vegetation projects, watering, replacing dead plants, and similar maintenance is initially required to ensure that the vegetation that has been planted becomes successfully established. In areas subject to high rates of erosion and frequent coastal storm damage, plants may need to be replaced frequently on an ongoing basis, particularly when vegetation is not combined with other shoreline stabilization techniques. Planted areas should be inspected regularly and vegetation should be replanted or replaced as necessary. Any area damaged by storms should be restored to pre-storm conditions as soon as possible—an eroded area will continue to deteriorate and will expand rapidly if it is left oversteepened, unvegetated, and exposed to the wind, tides, runoff, and storms. If erosion or plant die-off occurs during the winter, it may not be possible to re-establish plants until the growing season begins in the spring. Other temporary measures can be used to stabilize the site, including adding fill and using natural fiber blankets (see *StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks*). A schedule and plan for replacing sediments and vegetation should be included in the original permit application for the project so that maintenance can be conducted without additional permitting.

Project Costs

With vegetation projects, there are typically a range of options available that give increasing levels of protection with increased construction costs. In addition, whenever you hire a professional to conduct work on your property, total costs are expected to vary significantly based on site-specific considerations. The considerations that most influence the costs of vegetation projects are the severity of erosion, the size of the area to be stabilized, the type of runoff control needed, the type and number and size of plants selected, and the need for other temporary site-stabilization techniques or regrading. For comparison with other shoreline stabilization options, vegetation projects typically have relatively low design and permitting costs, low construction costs, and low maintenance costs. See the StormSmart Properties chart, *Relative Costs of Shoreline Stabilization Options* (PDF, 99 KB), for a full comparison.

Additional Information

Vegetation can be used in conjunction with many other techniques for erosion management. See the following CZM StormSmart Properties fact sheets for additional information:

- *StormSmart Properties Fact Sheet 1: Artificial Dunes and Dune Nourishment*
- *StormSmart Properties Fact Sheet 2: Controlling Overland Runoff to Reduce Coastal Erosion*
- *StormSmart Properties Fact Sheet 4: Bioengineering - Coir Rolls on Coastal Banks*
- *StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks*
- *StormSmart Properties Fact Sheet 6: Sand Fencing*
- *StormSmart Properties Fact Sheet 8: Beach Nourishment*

The following resources also provide valuable information on vegetation:

- CZM's Coastal Landscaping website focuses on landscaping with salt-tolerant vegetation to reduce storm damage and erosion and includes information on appropriate plants, planting plans, invasive species, and tips on plant care, along with links to other references.
- CZM's *Landscaping to Protect Your Coastal Property from Storm Damage and Flooding fact sheet* (PDF, 962 KB) gives specific information for homeowners on appropriate plants for erosion control in coastal areas.
- *Coastal Dune Protection and Restoration—Using 'Cape' American Beachgrass and Fencing* (PDF, 3 MB) by the Woods Hole Sea Grant and Cape Cod Cooperative Extension Program includes case studies and tips on dune restoration, along with information on preserving shorebird habitat and understanding the permit process.
- CZM's *Environmental Permitting in Massachusetts* gives brief descriptions of major environmental permits required for projects proposed in Massachusetts.
- *Salisbury Beach Dune Walkover Access Design Standards* (PDF, 14 KB) gives general design standards for walkways over coastal dunes that minimize potential adverse effects. These standards are widely applicable.
- *Guidelines for Barrier Beach Management in Massachusetts* (PDF, 12 MB), which was produced by the Massachusetts Barrier Beach Task Force in 1994, provides an overview of the Massachusetts Wetlands Protection Act Regulations and the function of beaches, dunes, and other resource areas (in Chapter 2). It also gives information on various erosion management techniques, their potential impacts, and measures to minimize those impacts (Chapter 5).
- Massachusetts Wetlands Protection Act Regulations (310 CMR 10.00) cover work in wetland resource areas and buffer zones.
- The Natural Heritage and Endangered Species Program website provides information on protected species in Massachusetts, habitat maps, and regulatory review for projects in or adjacent to these habitats.
- The Invasive Plant Atlas of New England provides a comprehensive web-accessible database of invasive and potentially invasive plants in New England.
- The Massachusetts Ocean Resource Information System, or MORIS, is a web-based mapping tool for interactively viewing coastal data. MORIS data layers, such as endangered species habitat and shellfish, can help identify sensitive resource areas within or near the project site.

www.mass.gov/stormsmart-coasts-program

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StormSmart Properties Fact Sheet 4: Bioengineering - Coir Rolls on Coastal Banks

The coast is a very dynamic environment and coastal shorelines—especially beaches, dunes, and banks—change constantly in response to wind, waves, tides, and other factors such as seasonal variation, sea level rise, and human alterations to the shoreline system. Consequently, many coastal properties are at risk from storm damage, erosion, and flooding. Inappropriate shoreline stabilization methods can actually do more harm than good by exacerbating beach erosion, damaging neighboring properties, impacting marine habitats, and diminishing the capacity of beaches, dunes, and other natural landforms to protect inland areas from storm damage and flooding. StormSmart Properties—part of the Massachusetts Office of Coastal Zone Management's (CZM) StormSmart Coasts Program—provides coastal property owners with important information on a range of shoreline stabilization techniques that can effectively reduce erosion and storm damage while minimizing impacts to shoreline systems. This information is intended to help property owners work with consultants and other design professionals to select the best option for their circumstances.

What Are Bioengineering and Coir Rolls?

Coastal bioengineering projects reduce erosion and stabilize eroding shorelines by using a combination of deep-rooted plants and erosion-control products made of natural, biodegradable materials, such as coir rolls. Coir rolls are cylindrical rolls that span 12 to 20 inches in diameter, are packed with coir fibers (i.e., coconut husk fibers), and are held together with mesh. The rolls are typically 10- to 20-feet long and can be stitched together to provide continuous shoreline coverage. In contrast, coir envelopes are coir fabric filled with sand. Coir envelopes have very different impacts and design considerations and should not be confused with coir rolls.

As with all coastal bioengineering projects, salt-tolerant vegetation with extensive root systems is used with coir rolls to help stabilize the site. The vegetation is planted directly into the coir rolls and on the surrounding site. For important instructions on using plants in bioengineering projects, see the *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage*, which includes specific information on how vegetation reduces erosion and storm damage; instructions on selecting, properly planting, and caring for appropriate species; tips on maximizing the effectiveness of vegetation projects and minimizing impacts; and specifics on project design and implementation.

No shoreline stabilization option permanently stops all erosion or storm damage. The level of protection provided depends on the option chosen, project design, and site-specific conditions such as the exposure to storms. All options require maintenance, and many also require steps to address adverse impacts to the shoreline system, called mitigation. Some options, such as seawalls and other hard structures, are only allowed in very limited situations because of their impacts to the shoreline system. When evaluating alternatives, property owners must first determine which options are allowable under state, federal, and local regulations and then evaluate their expected level of protection, predicted lifespan, impacts, and costs of project design, installation, mitigation, and long-term maintenance.

This fact sheet focuses on the use of coir rolls on coastal banks (also known as bluffs), where coir rolls are typically installed at the toe (i.e., base) of the bank—although they can also be installed up the bank face. In coastal areas, coir rolls can also be used to help reduce erosion problems created by hard structures (i.e., seawalls and revetments). See "Appropriate Locations" in the Design Consideration section below for additional information.

This coir roll has been planted with vegetation prior to installation. **(Photo: Wilkinson Ecological Design)**

Coir rolls are often used in conjunction with other techniques for erosion management, such as natural fiber blankets, runoff control, and beach nourishment. Natural fiber blankets are woven mats of natural fibers that are used to stabilize the ground surface while plants become established. Runoff control projects reduce and slow the flow of water over the ground surface, reducing coastal erosion problems. Beach nourishment adds sediment (i.e., sand, gravel, and cobble) from an off-site source to address beach erosion issues. See the following StormSmart Properties fact sheets for more information: *Controlling Overland Runoff to Reduce Coastal Erosion*, *Bioengineering - Natural Fiber Blankets on Coastal Banks*, and *Beach Nourishment*.

How Coir Rolls Reduce Storm Damage on Coastal Banks

If the toe of a bank is eroding, the upper bank may collapse even if it is well vegetated. Coir rolls can be used to protect and stabilize the toe by providing a physical barrier that buffers waves, tides, and currents, reducing erosion of exposed sediments.

Coir rolls provide stability and protection to the site while the vegetation planted in and above the rolls becomes established. As the coir rolls disintegrate, typically over 5-7 years, the plants take over the job of site stabilization. The dense root systems of the plants hold sand, gravel, and soils in place and help reduce erosion from rain, wind, tides, and waves. In addition, by taking up water directly from the ground and breaking the impact of raindrops or wave-splash, the plants slow the rate and reduce the quantity of upland water runoff that can lead to erosion.

For sites exposed to high wave energy, it may be necessary to replace and maintain coir rolls at the toe of the bank to provide longer-term stability. If the beach in front of the bank is narrow or narrows over time, if the beach elevation is too low or erodes down over time, or if the shoreline has a steep drop off below the low tide line, it may be necessary to combine bioengineering with other techniques, such as dune and beach nourishment, to ensure a successful project. (See the following StormSmart Properties fact sheets for more information: *Artificial Dunes and Dune Nourishment* and *Beach Nourishment*.) A professional with demonstrated success installing bioengineering projects in dynamic environments should be consulted to assess each site and make recommendations regarding the appropriate technique or combination of techniques.

Waves and tides eroded the toe of this bank, causing this collapse of a well vegetated section of the bank face. **(Photo: CZM)**

Top left: This photo shows an exposed bank that was eroding at two feet per year before coir rolls and erosion-control vegetation were installed.

Bottom left: This photo shows the site during installation of the coir rolls, which were placed at the toe and up the face of the bank. Natural fiber blankets were also installed on the bank face. The site was then planted with salt-tolerant vegetation.

Bottom right: This photo shows the same site 10 years after project completion. (Note: This site has survived Hurricane Irene and Hurricane Sandy.)

(Photos: New England Environmental)

Relative Benefits and Impacts Compared to Other Options

Coir rolls provide direct, physical protection to a bank. Because they are made from natural, biodegradable materials and are planted with vegetation, coir rolls absorb much more wave energy than seawalls, rock revetments, or other "hard" shoreline stabilization structures, which reflect significantly more of the wave energy that hits them onto beaches or neighboring properties. The design of a hard structure affects how much wave energy is reflected, for example vertical walls reflect more wave energy than sloping rock revetments. These reflected waves erode beaches in front of and next to a hard structure, eventually undermining and reducing the effectiveness of the structure and leading to costly repairs. This erosion also lowers the elevation of the beach in front of the structure, ultimately leading to a loss of dry beach at high tide and reducing the beach's value for storm damage protection, recreation, and wildlife habitat. Coir roll projects also allow some natural erosion from the site while hard structures impede virtually all natural erosion of sediment. Without this sediment supply, down-current areas of the beach system are subject to increased erosion. In addition, coir rolls can often be installed without the use of mechanized equipment that can significantly impact the site. Because they are made with natural fibers and planted with vegetation, coir rolls also help preserve the natural character and habitat value of the coastal environment.

Like all shoreline stabilization options, however, coir roll projects can result in negative impacts when inappropriately designed or sited. While less severe than with hard structures, coir rolls can reflect some wave energy and they can inhibit the natural supply of sediment to down-current areas. Coir rolls made with synthetic materials or covered in wire mesh can cause additional significant impacts. Synthetic and wire mesh that remains after the rolls are degraded or is found on rolls that have been ripped away from a bank during a storm has the potential to entangle wildlife, disrupt navigation (e.g., by getting wrapped around boat propellers), and harm recreational beach users (e.g., rusted wire can puncture bare feet). To help address this issue, local officials often require identification tags to be sewn on coir rolls when they are installed to ensure proper disposal if the rolls are dislodged from the project site. In addition, wire mesh should not be used on coastal sites and the use of synthetic mesh should be minimized. For sites with higher wave energy, it is often necessary to use high density rolls (7-9 pounds per foot) in the bottom row, which are only available with synthetic mesh. This targeted use of synthetic materials is preferable to using more structural options such as a rock revetment to stabilize the site, which have greater adverse impacts.

Under the Massachusetts Wetlands Protection Act, new hard structures are typically prohibited on all beaches and dunes. On coastal banks, hard structures are only allowed when necessary to protect buildings permitted before August 10, 1978, and only if no other alternative is feasible. In many cases, coir roll projects and other non-structural alternatives are therefore the only options available for reducing erosion and storm damage on coastal properties.

Design Considerations for Coir Rolls on Coastal Banks

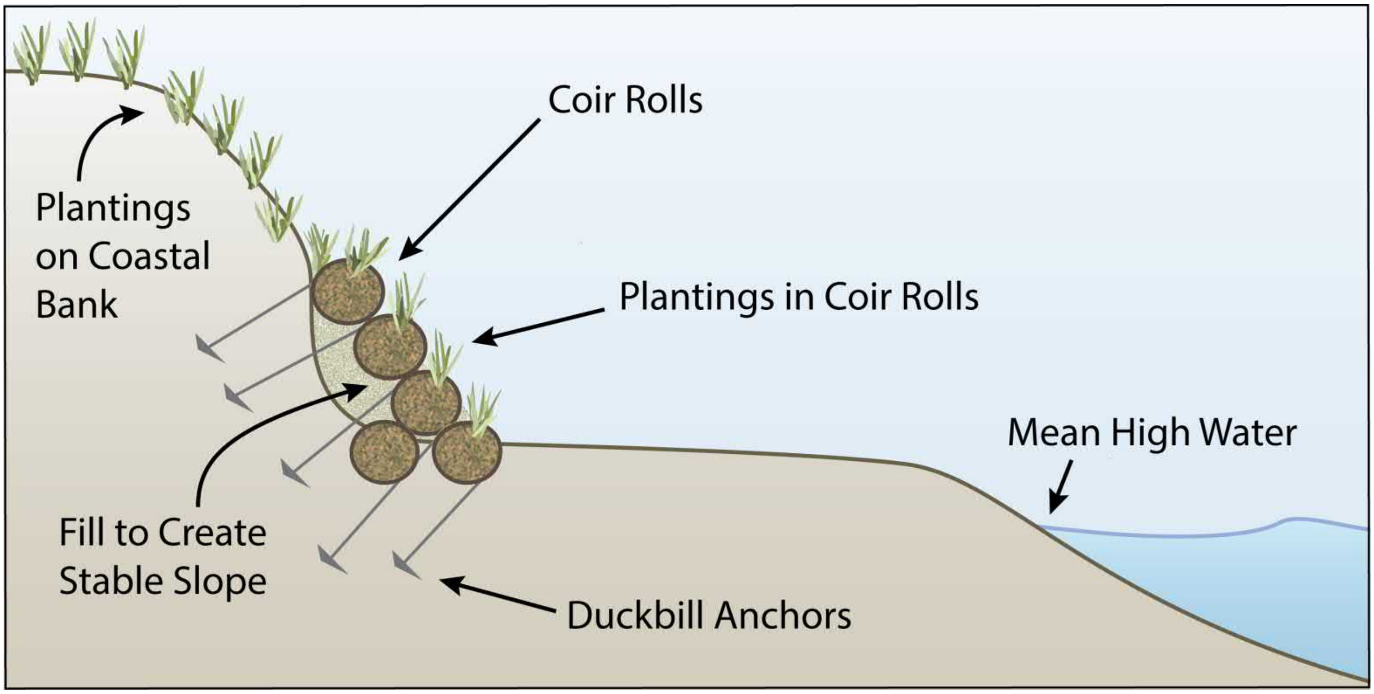
This section covers a variety of factors that should be considered to minimize adverse impacts and ensure successful design, permitting, construction, and maintenance of coir roll bioengineering projects on a coastal banks.

Appropriate Locations

For coastal bank projects, coir rolls can be used on both sheltered sites and sites exposed to wave energy. However, they are most effective in areas with higher beach elevations with some dry beach at high tide, where the rolls are not constantly subject to erosion from tides and waves. If the dry beach is narrow, the beach elevation is relatively low, and/or the site is exposed to moderate wave energy, more than one row of coir rolls will likely be needed on the face of the bank, as well as at the base. In these exposed conditions, the rolls will have a shorter lifespan and will require more frequent maintenance such as resetting, anchoring, or replacement. Additional erosion-control options may be needed at these sites, such as beach nourishment (see *StormSmart Properties Fact Sheet 8: Beach Nourishment*). It is essential to have a site-specific evaluation conducted by a professional with demonstrated experience and success implementing coir roll projects in exposed settings to determine the viability of coir rolls in these areas.

A coir roll, natural fiber blanket, and fill were installed to minimize erosion at the end of this bulkhead. **(Photo: Wilkinson Ecological Design)**

In some cases, coir rolls can also be used to effectively reduce erosion from hard structures such as seawalls. Coir rolls can be effectively installed at the base of and next to hard structures to help reduce erosion problems under the structure and on neighboring properties. They are also used on the face of the bank above the structure to stabilize the area.



Cross-section of a bioengineering project on a bank in an exposed setting.

Establishing a Stable Slope

On banks, a stable slope is essential for project success. If the bottom of the bank has eroded and its slope is steeper than the upper portion of the bank, the bank is likely unstable. Even when heavily planted with erosion-control vegetation, banks with unstable slopes are extremely vulnerable to slumping or collapse that can endanger property landward of the bank. Before installing coir rolls or planting vegetation, therefore, the bank slope should be stabilized.

Ideally, soil of a similar type to that on the bank or beach is brought in as fill and added to the lower part of the bank to create a slope that matches or is less steep than the upper slope. However, if adding fill brings the toe of the bank within the reach of high tides, the fill will erode quickly and undermine the rest of the bank. In these cases, regrading the bank slope by removing sediment from the top of the bank is a better option. While removing part of the upper portion of the bank does reduce the land area of the property, it can be done in a controlled fashion that improves the overall stability and storm-damage prevention capacity of the bank. And if the slope is not stabilized by either adding fill at the bank toe or regrading the top of the bank, bank collapse during a storm could cause substantially more loss of land area to the sea. In addition, any investment in coir rolls, vegetation, and other site stabilization methods will be lost if the bank collapses. On sites where the top of the bank is well vegetated with mature, salt-tolerant species with extensive roots, the appropriate approach to stabilize the bank should be carefully developed by a professional with extensive experience successfully stabilizing similar sites.

Removing/Replacing Invasive Plants

Invasive plants (i.e., introduced species that thrive at the expense of native plants) should be removed and replaced with appropriate native plants if they are preventing establishment of erosion-control vegetation on a bank. This effort is particularly warranted when bank stability is severely compromised by the invasive plant. Because of their tenacity, successful control of invasive plants can take years to accomplish and may require perpetual monitoring and management. Effective ways to manage invasive species on the bank should therefore be incorporated into project design. See *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage* for more information.

Controlling Erosion from Overland Runoff and Other Sources

To help ensure the success of newly planted vegetation, sources of erosion on the site—including upland runoff and waves—should be identified and addressed as part of the site evaluation and design process. If overland runoff is causing erosion, this runoff should be reduced or redirected to give newly planted vegetation the best chance of survival (see *StormSmart Properties Fact Sheet 2: Controlling Overland Runoff to Reduce Coastal Erosion* for details). In areas subject to regular erosion from waves, tides, currents, wind, and coastal storms, additional techniques can be used to improve site protection. For example, beach nourishment (i.e., adding sediments, such as sand, gravel, and cobble to widen the beach—see *StormSmart Fact Sheet 8: Beach Nourishment*) can protect coir roll projects by widening beaches in areas with relatively narrow beaches at high tide.

Protecting Vegetation

In addition to controlling erosion (see above), other steps should be taken to protect vegetation. Exposed areas should not be planted during the winter when the plants are dormant because wind or waves are likely to pull them out before they can get established. To prevent trampling of plants, pedestrian access to the shoreline should be restricted to designated access paths or walkways and the number of access points should be limited as much as possible. Often, multiple properties can use a common access point. To limit shading impacts to vegetation, access structures should be elevated on open pilings and their size should be minimized as much as possible.

Maintaining Sediment Supply to the System

Bank erosion is an important source of sediment to beaches and dunes in the shoreline system. To maintain this sediment supply, projects using two or more rows of coir rolls can bring in sediment from an offsite source on a regular basis (e.g., annually and after major storms) and place it on the beach in front of the rolls. This sediment will also help provide storm damage protection to the site by dissipating wave energy before it reaches the bank.

Minimizing Reflected Wave Energy

The ends of a coir roll project should be carefully designed to minimize any redirection of waves onto adjacent properties. Tapering the rolls down in number and height so that the project blends in to the adjacent bank helps address this problem.

This bioengineering project with coir rolls, natural fiber blankets, and vegetation was designed to minimize erosion on the adjacent property. At the end of the property, the number of rolls was tapered down to one and the bank's slope was reduced and blended in to the adjacent bank. **(Photo: CZM)**

Project Installation and Coir Roll Anchoring

Coir rolls should be placed end to end and laced together with jute or coir twine to create continuous rolls parallel to the shoreline. The rolls are typically anchored by stakes on the seaward side of the rolls, earth anchor systems, or a combination of these two techniques. Wooden stakes are biodegradable but do not always hold well in areas with higher wave energy. Earth anchors, which are typically used for sites exposed to higher rates of erosion, consist of a metal duckbill anchor that extends into the bank and is connected to the coir roll by wire cables. Although earth anchors are not biodegradable, exposed portions of the cable system can be cut off and removed after the coir rolls have broken down to reduce marine debris impacts.

The anchoring system is critical to the success of the project. A professional is needed to determine the appropriate number and type of anchors for the site. It is also essential that the installation be carefully supervised and conducted by contractors with experience installing projects that have survived multiple storms. Anchors may need to be tightened after a period of time. To improve the longevity of the project, a professional can monitor the rolls over time and identify needed maintenance.

Coir rolls should be fully covered with sediment or tied into the existing bank at both ends of the project to minimize the potential for waves to get behind the rolls and erode the bank. The project can fail if the ends of the coir rolls become exposed.

Coir Roll Configuration and Size

The number of rows of coir rolls needed and their diameter depend on: 1) how exposed the site is to waves, 2) how frequently waves reach the base of the bank, and 3) the steepness of the bank face. In more sheltered sites or on relatively shallow bank slopes, one or two rows of 12-inch-diameter coir rolls may be sufficient. In more exposed areas and on steeper banks, multiple rows of 20-inch-diameter rolls may be needed up the face of the bank to provide effective site stabilization. The bottom row of coir rolls is often buried during installation to prevent undermining by beach erosion during a storm. In some cases, two side-by-side rows of rolls are installed at the base to provide more stability for the rows of rolls above.

Density of Coir Fibers

How densely the coconut husk fibers are packed into the coir rolls is also an important design element. While more densely packed rolls provide greater initial erosion protection, loosely packed rolls can be more heavily planted (because the vegetation can be easily inserted into the roll). This heavy planting allows the plants to become established more quickly, allowing the plant roots to effectively stabilize the site as the coconut fibers degrade. Both high-density and low-density coir rolls can be used together when heavily planted low-density rolls are installed adjacent to high-density rolls to help ensure the high-density rolls become vegetated over time. The professional designing the project should determine where rapid plant colonization or initial structural integrity is most important and then design a mix of rolls accordingly.

Reducing Damage from Sun Exposure

Plants can be used to shade the rolls and slow the degradation of the coir fibers that occurs from exposure to sunlight. The coir rolls can also be covered with sediment and natural fiber blankets (woven mats of natural fibers) to shade the coir rolls and slow degradation.

Heavy Equipment

While heavy equipment is not typically needed for coir roll projects, a mini-excavator or other small mechanized equipment may be necessary. Minimizing the use of heavy equipment can help reduce temporary disturbances from the project. Access for any equipment must be carefully planned to avoid destruction of existing vegetation; creation of ruts; destabilization of banks, beaches, or other landforms; impacts to wildlife and nesting habitat for protected shorebird species (i.e., species that are considered endangered, threatened, or of special concern in Massachusetts); and related impacts. When mechanical equipment is being used, contractors should keep hazardous material spill containment kits on-site at all times in case there is a release of oil, gasoline, or other toxic substances.

Wildlife and Fisheries Protection

If the project is proposed in or adjacent to habitat for protected wildlife species or horseshoe crab spawning areas, there may be limitations on the time of year that the project can be constructed. Information about the location of these resources and special permitting requirements is available from the Natural Heritage and Endangered Species Program of the Massachusetts Division of Fisheries and Wildlife (for protected wildlife species) and the Massachusetts Division of Marine Fisheries (for horseshoe crabs).

Permitting and Regulatory Standards

Most options for addressing coastal erosion, storm damage, and flooding are likely to require a permit under the Massachusetts Wetlands Protection Act through the local Conservation Commission. Additional permits may be needed from the Massachusetts Department of Environmental Protection (MassDEP) Waterways Program and the U.S. Army Corps of Engineers if the project footprint extends below the mean high water line or seaward of the reach of the highest high tide of the year, respectively. Permits or approvals may also be required from other state agencies and local departments, depending on the location and the work involved. Often, Conservation Commission staff are available to meet with applicants to go over important factors that need to be considered early in the design process.

Generally, regulatory programs are supportive of projects that use non-structural approaches to manage coastal erosion, such as coir rolls and vegetation, as opposed to hard structures. To obtain a permit, projects need to be designed to comply with regulatory requirements, including minimizing or avoiding impacts to sensitive resource areas such as horseshoe crab spawning areas and protected species habitat, which are protected by the various regulatory programs.

Professional Services Required

An environmental professional with significant experience designing, implementing, and successfully maintaining coir rolls and vegetation projects in coastal areas should be chosen to: 1) identify regulatory requirements and ensure the project fully conforms with those requirements; 2) determine the size, density, and number of rows of coir rolls needed based on site conditions (such as erosion history; exposure to winds, wave climate, and soil types; and runoff patterns); 3) determine whether natural fiber blankets, beach nourishment, or other techniques should be used in conjunction with the rolls; 4) identify any additional site conditions (including oversteepened slopes, erosion from overland runoff, and the presence of invasive species) that must be addressed; 5) select plant species and develop a plan for planting and plant maintenance; 6) identify the volume and composition of fill (if needed to re-establish a stable slope); 7) determine the best time of year to install the various components of the project; 8) develop an access plan if heavy equipment is needed; 9) prepare plans for and oversee permitting; 10) prepare design specifications and oversee construction; and 11) monitor and maintain the project. To ensure that essential design elements are appropriately implemented, *construction should be conducted by a contractor with experience installing coir roll projects that have survived multiple storms and carefully supervised by a consultant with significant experience and demonstrated success with coastal coir roll projects. Monitoring and maintenance by a consultant with significant experience is also strongly recommended.*

Project Timeline

It may take as little as four to eight months to have a bioengineering project with coir rolls designed, permitted, and installed, assuming that only a Massachusetts Wetlands Protection Act permit is required—but it can take longer, depending on the factors involved. Factors influencing this timeline include the contractor’s experience with designing and permitting similar projects, completeness of permit applications, special considerations in the permitting process (such as objections by abutters, sensitive resources to be protected, and availability of access for construction), the need for special timing to avoid impacts (e.g., a prohibition on construction during endangered species nesting season), special timing needed for planting vegetation, and/or weather conditions during construction.

Maintenance Requirements

Bioengineering projects with coir rolls and vegetation require ongoing maintenance to ensure their success. Maintenance needs will depend, in part, on the proximity of the coir rolls to the reach of high tide, the elevation and width of the beach, the frequency and severity of storms, and how established the plants are before a storm hits. To maintain the project's designed level of protection, the coir rolls and vegetation should be inspected regularly, particularly after rain and coastal storms. Any storm damage should be addressed immediately to avoid further deterioration—this includes replacing any sediment that erodes around the coir rolls, resetting or replacing coir rolls as needed, and replanting vegetation (which may have to be conducted at the appropriate time of year). The more frequently high tides and waves reach and overtop the coir rolls, the higher the likely erosion rate and deterioration rate of the rolls. Erosion rates will be even higher if the site is not vegetated. Because the replacement of sediment and plants removed by storms is typically necessary, the original permit application should include a maintenance plan. This plan should specify any replacement materials and activities that may be used on the site and how the site will be accessed so that maintenance can be conducted without additional permitting.

Experience with what works, what doesn't, and how to adjust a design as site conditions change is very important to the success of bioengineering projects, particularly in coastal areas. Therefore, it is strongly recommended that the consultant who designed the project be involved in the monitoring and maintenance after any erosion from rain or coastal storms.

Project Costs

With coir roll projects, a range of options are available that give increasing levels of protection with increased construction costs. In addition, whenever you hire a professional to conduct work on your property, total costs are expected to vary significantly based on site-specific considerations. The considerations that most influence the costs of coir roll projects on coastal banks are: the severity of erosion, the width and elevation of the beach in front of the bank, the grading needed to create a stable slope, the diameter and number of rows of rolls, and the type and size of plants selected.

For comparison with other shoreline stabilization options, the relative costs for coir roll projects are:

- Low-medium for design and permitting.
- Medium-high for construction.
- Low-medium for maintenance.
- Low for mitigation.

See the StormSmart Properties chart, *Relative Costs of Shoreline Stabilization Options* (PDF, 99 KB), for a full comparison.

Additional Information

Bioengineering with coir rolls can be used in conjunction with many other techniques for erosion management. See the following CZM StormSmart Properties fact sheets for additional information:

- *StormSmart Properties Fact Sheet 1: Artificial Dunes and Dune Nourishment*
- *StormSmart Properties Fact Sheet 2: Controlling Overland Runoff to Reduce Coastal Erosion*
- *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage*
- *StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks*
- *StormSmart Properties Fact Sheet 8: Beach Nourishment*

The following publications and websites also provide valuable information on bioengineering with coir rolls and vegetation:

- CZM's Coastal Landscaping website includes information on landscaping coastal areas with salt-tolerant vegetation to reduce storm damage and erosion.
- CZM's *Landscaping to Protect Your Coastal Property from Storm Damage and Flooding fact sheet* (PDF, 962 KB) gives specific information for homeowners on appropriate plants for erosion control in coastal areas.
- Woods Hole Sea Grant's Marine Extension Bulletin, *Biodegradable Erosion Control* (PDF, 723 KB), provides information on various components of a coir roll project for coastal erosion control.
- CZM's *Environmental Permitting in Massachusetts* briefly describes major environmental permits required for projects proposed in Massachusetts.
- *Guidelines for Barrier Beach Management in Massachusetts* (PDF, 12 MB), which was produced by the Massachusetts Barrier Beach Task Force in 1994, provides an overview of the Massachusetts Wetlands Protection Act Regulations and the function of beaches, dunes, and other resource areas (in Chapter 2). It also gives information on various erosion management techniques, their potential impacts, and measures to minimize those impacts (Chapter 5).
- Massachusetts Wetlands Protection Act Regulations (310 CMR 10.00) cover work in wetland resource areas and buffer zones.
- The Natural Heritage and Endangered Species Program website provides information on protected species in Massachusetts, habitat maps, and regulatory review for projects in or adjacent to these habitats.
- The Massachusetts Division of Marine Fisheries can provide information on horseshoe crab protection and other fisheries resources.
- The Massachusetts Ocean Resource Information System, or MORIS, is a web-based mapping tool for interactively viewing coastal data. MORIS data layers, such as endangered species habitat and shellfish, can help identify sensitive resource areas within or near the project site.

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StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks

The coast is a very dynamic environment and coastal shorelines—especially beaches, dunes, and banks—change constantly in response to wind, waves, tides, and other factors such as seasonal variation, sea level rise, and human alterations to the shoreline system. Consequently, many coastal properties are at risk from storm damage, erosion, and flooding. Inappropriate shoreline stabilization methods can actually do more harm than good by exacerbating beach erosion, damaging neighboring properties, impacting marine habitats, and diminishing the capacity of beaches, dunes, and other natural landforms to protect inland areas from storm damage and flooding. StormSmart Properties—part of the Massachusetts Office of Coastal Zone Management's (CZM) StormSmart Coasts Program—provides coastal property owners with important information on a range of shoreline stabilization techniques that can effectively reduce erosion and storm damage while minimizing impacts to shoreline systems. This information is intended to help property owners work with consultants and other design professionals to select the best option for their circumstances.

What Are Bioengineering Projects and Natural Fiber Blankets?

Coastal bioengineering projects reduce erosion and stabilize eroding shorelines by using a combination of deep-rooted plants and erosion-control products that are made of natural, biodegradable materials. Natural fiber blankets are mats made of natural fibers, such as straw, burlap, and coconut husk, which is also called coir. Some natural fiber blankets are made of loosely woven coir twine and others are made of straw, coconut, or a mix of fibers held together with netting made from coir or other materials. The blankets are used to help reduce erosion of exposed soil, sand, and other sediments from wind, waves, and overland runoff.

No shoreline stabilization option permanently stops all erosion or storm damage. The level of protection provided depends on the option chosen, project design, and site-specific conditions such as the exposure to storms. All options require maintenance, and many also require steps to address adverse impacts to the shoreline system, called mitigation. Some options, such as seawalls and other hard structures, are only allowed in very limited situations because of their impacts to the shoreline system. When evaluating alternatives, property owners must first determine which options are allowable under state, federal, and local regulations and then evaluate their expected level of protection, predicted lifespan, impacts, and costs of project design, installation, mitigation, and long-term maintenance.

Vegetation growing up through a natural fiber blanket. **(Photo: Wilkinson Ecological Design)**

Woven coir blanket.

Stitched fiber blanket.

(Photos: Coir Green "Environmentally Friendly")

In this bank stabilization project, a natural fiber blanket was installed on the face of the bank and vegetation was planted through it. A coir roll was also installed at the base of the bank. **(Photo: CZM)**

For important instructions on using plants in bioengineering projects, see the *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage*. This fact sheet includes specific information on how vegetation reduces erosion and storm damage, tips on maximizing the effectiveness of vegetation projects and minimizing impacts, specifics on project design and implementation, and instructions on selecting, properly planting, and caring for appropriate species.

Natural fiber blankets are frequently used with other techniques for erosion management, such as coir rolls (cylindrical rolls packed with coconut husk fibers) and runoff control projects. See the following StormSmart Properties fact sheets: *Controlling Overland Runoff to Reduce Coastal Erosion* and *Bioengineering - Coir Rolls on Coastal Banks*.

How Natural Fiber Blankets Stabilize Slopes and Help Reduce Erosion

Natural fiber blankets are used on non-vegetated portions of banks to prevent erosion while native salt-tolerant vegetation with extensive root systems becomes established on the site. A salt-tolerant seed mix is spread across the area before the natural fiber blanket is secured, and then live vegetation is planted through the blanket. The blanket helps hold sand, soil, and other sediments in place by protecting the surface from erosion caused by wind, salt spray, and flowing water. The seeds grow quickly and also help secure the soil surface while the larger live plants become established and begin to spread. The blanket also retains moisture to promote seed growth and protect the roots of the live plants. As the natural fibers in the blanket disintegrate over 6 to 24 months, depending on the density and type of fiber blanket selected, the dense root systems of the plants take over the job of stabilizing the site.

A natural fiber blanket was installed on this bank and vegetation was planted through the blanket while the plants were dormant. **(Photo: CZM)**

Relative Benefits and Impacts Compared to Other Shoreline Stabilization Options

Natural fiber blankets and vegetation provide direct, physical protection to reduce erosion of bare soils. Because they are made from natural, biodegradable materials and are planted with vegetation, natural fiber blankets absorb much more wave energy than seawalls, rock revetments, or other "hard" shoreline stabilization structures, which reflect significantly more of the wave energy that hits them onto beaches or neighboring properties. The design of a hard structure affects how much wave energy is reflected, for example vertical walls reflect more wave energy than

Under the Massachusetts Wetlands Protection Act, new hard structures are typically prohibited on all beaches and dunes. On coastal banks, hard structures are only allowed when necessary to protect buildings permitted before August 10, 1978, and only if no other alternative is feasible. In many cases, natural fiber blanket projects and other non-structural alternatives are therefore the only options available for reducing erosion and storm damage on coastal properties.

sloping rock revetments. These reflected waves erode beaches in front of and next to a hard structure, eventually undermining and reducing the effectiveness of the structure and leading to costly repairs. This erosion also lowers the elevation of the beach in front of the structure, ultimately leading to a loss of dry beach at high tide and reducing the beach's value for storm damage protection, recreation, and wildlife habitat. Natural fiber blanket projects also allow some natural erosion from the site while hard structures impede virtually all natural erosion of sediment. Without this sediment supply, down-current areas of the beach system are subject to increased erosion. In addition, natural fiber blankets can often be installed without the use of mechanized equipment that can significantly impact the site. Because they are made with natural fibers and planted with vegetation, natural fiber blankets also help preserve the natural character and habitat value of the coastal environment.

Bioengineering projects using natural fiber blankets can cause minor impacts that may be effectively minimized through appropriate project design (see Design Considerations below). However, projects using blankets made of synthetic materials, which do not degrade readily in the coastal environment, can cause significant impacts. For example, synthetic materials washed into the ocean during storms or exposed at the ground surface can entangle wildlife, and unlike natural fiber blanket materials, the synthetic materials will remain in the environment for long periods of time. Therefore, the use of blankets made with synthetic fibers is strongly discouraged for coastal projects.

Design Considerations for Natural Fiber Blanket Projects

This section covers a variety of factors that should be considered to minimize adverse impacts and ensure successful design, permitting, construction, and maintenance of natural fiber blanket bioengineering projects.

Appropriate Locations

Natural fiber blankets can be installed on almost any coastal bank to help stabilize soils while plants become established. However, they are most effective in areas with higher beach elevations with some dry beach at high tide, where the toe of the bank is not constantly subject to erosion from tides and waves. Blankets are typically installed over the entire surface of a non-vegetated bank, but they may also be placed in specific areas where a bank is devoid of vegetation. Blankets will not prevent erosion on unstable slopes or in areas subject to erosion from high tides or storm waves.

On banks where the toe is subject to erosion from tides or storm waves, it may be appropriate to combine natural fiber blankets and vegetation with other shoreline stabilization options. Coir rolls can be installed to protect the base of the bank (see *StormSmart Properties Fact Sheet 4: Bioengineering - Coir Rolls on Coastal Banks*). Sediments can also be brought in from off-site sources to increase beach width and dune volume to help dissipate wave energy before it reaches the bank (see *StormSmart Properties Fact Sheet 1: Artificial Dunes and Dune Nourishment* and *StormSmart Properties Fact Sheet 8: Beach Nourishment*).

Establishing a Stable Slope

On banks, a stable slope is essential for project success. If the bottom of the bank has eroded and its slope is steeper than the upper portion of the bank, the bank is likely unstable. Even when heavily planted with erosion-control vegetation, banks with unstable slopes are extremely vulnerable to slumping or collapse, which can endanger property landward of the bank. Before planting vegetation, therefore, the bank slope should be stabilized.

Ideally, any existing invasive vegetation is removed and soil of a similar type to that on the bank or beach is brought in as fill and added to the lower part of the bank to create a lower slope that matches or is less steep than the upper slope. However, if adding fill brings the toe of the bank within the reach of high tides, the fill will erode quickly and undermine the rest of the bank. In these cases, regrading the bank slope by removing sediment from the top of the bank is a better option. While removing part of the upper portion of the bank does reduce the land area of the property, it can be done in a controlled fashion that improves the overall stability and storm damage prevention capacity of the bank. And if the slope is not stabilized by either adding fill at the bank toe or regrading the top of the bank, bank collapse during a storm could cause substantially more loss of land area to the sea. In addition, any investment in natural fiber blankets, vegetation, and other site stabilization methods will be lost if the bank collapses. On sites where the top of the bank is well vegetated with mature, salt-tolerant species with extensive roots, the appropriate approach to stabilize the bank should be carefully developed by a professional with extensive experience successfully stabilizing similar sites.

Removing/Replacing Invasive Plants

Invasive plants (i.e., introduced species that thrive at the expense of native plants) should be removed and replaced with appropriate native plants if they are preventing establishment of erosion-control vegetation on a bank. This effort is particularly warranted when bank stability is severely compromised by invasive plants. Because of their tenacity, successful control of invasive plants can take years to accomplish and may require perpetual monitoring and management. Effective ways to manage invasive species on the bank should therefore be incorporated into project design. See *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage* for more information.

Protecting Vegetation

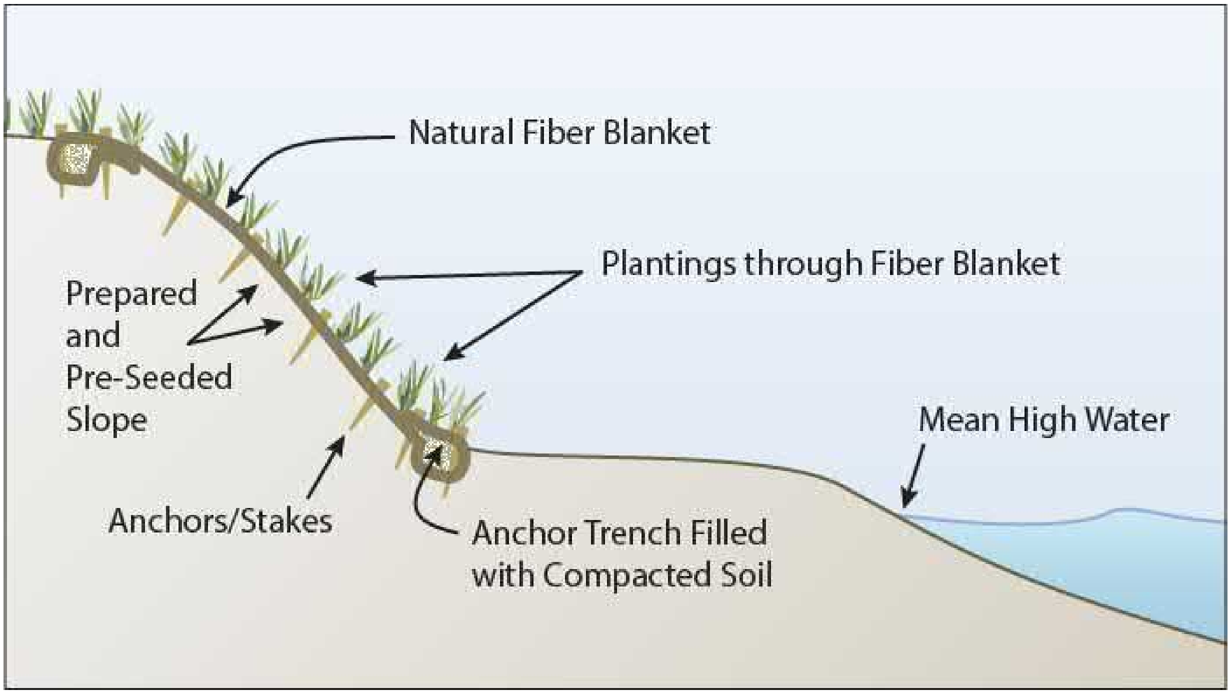
To help ensure the success of newly planted vegetation, sources of erosion on the site, including upland runoff and waves, should be identified and addressed as part of the site evaluation and design process. If surface runoff is causing erosion, it should be reduced and/or redirected to give newly planted vegetation the best chance of survival (see *StormSmart Properties Fact Sheet 2: Controlling Overland Runoff to Reduce Coastal Erosion* for more detail). In addition, exposed areas should not be planted during the winter when the plants are dormant because wind or waves are likely to pull them out before they can get established. See *Storm Smart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage* for more planting tips. To further protect the bank, pedestrian access to the shoreline should be restricted to designated access paths or walkways and the number of access points should be limited as much as possible. Often, multiple properties can use a common access point. To limit shading impacts to vegetation, access structures should be elevated on open pilings and their size should be minimized as much as possible.

Preparation of the Site Surface

Natural fiber blankets are most effective when vegetation, rocks, twigs, and other debris have been removed to create a smooth surface so that the blankets are placed in close contact with the soil or sediments. If the blanket is not in close contact with the ground surface, vegetation shoots may push the blanket up instead of growing through it, causing a “tent” effect. Such tenting allows overland runoff to flow under the blanket and across the ground surface, causing erosion. Plants growing under the blanket will also have difficulty getting established at the site.

Project Installation and Blanket Anchoring

To best protect the site from surface runoff, the rolls of natural fiber blanket should be installed from the top to the bottom of the bank rather than horizontally across the bank. Blankets should be placed so that they overlap by 6 to 12 inches to prevent exposure of the ground surface if the blanket edges curl. To ensure close contact is maintained between the natural fiber blanket and the ground surface, the blanket must be anchored down. Stakes or staples are hammered through the blanket and into the ground to hold the blanket in place. These stakes or staples range from 6 to 24 inches in length and are made of metal, wood, or a biodegradable corn/gluten mix. In coastal settings, anchors made of biodegradable materials should be used to minimize environmental impacts in case they are dislodged from the site. In addition, staples should be installed and maintained so that they stay flush to the ground. In sandy soils, longer staples or stakes will be required to anchor the natural fiber blankets.



This figure shows a natural fiber blanket that has been installed using anchor trenches and planted with live plants. To promote project success, the bank surface was seeded with a mix of salt-tolerant grasses and stakes were installed throughout the blanket to ensure close contact with the ground surface.

Oak stakes are used to anchor the natural fiber blanket installed on this bank. A notch in the stake is used as a stop to hold biodegradable coir twine to secure the blanket to the ground surface. Vegetation was planted through the blanket.
(Photo: Cape Organics, Inc.)

When natural fiber blankets are used to cover the entire slope of a bank, anchor trenches are often used. Anchor trenches are small depressions, typically 6-12 inches deep by 6 -8 inches wide that are dug parallel to the shoreline. In this approach, the blankets run from an anchor trench at the top of the bank, down the bank face to another anchor trench at the bottom of the slope. The trenches are backfilled with sediments similar to those found on the bank or beach and compacted so water will flow evenly over the blanket and not under it.

Blanket Types and Density

Erosion-control blankets are manufactured with a variety of different materials intended for a range of uses, including linings for stormwater impoundments and slope stabilization adjacent to highways. Only blankets composed of natural fibers held together with mesh made of natural fibers are recommended for coastal stabilization projects. Photodegradable mesh is not recommended because the plants used to stabilize the site will shade the blanket, preventing sunlight from helping to break down the mesh.

The blanket material, its thickness, and the density of the weave should be based on a variety of project conditions, such as the steepness of the bank slope and exposure to wind and waves. Coconut and jute are stronger and more durable, so they are typically used on areas with the most significant erosion issues, such as steep slopes in more exposed areas, while straw may be used in areas with lower erosion potential. Typical blanket weights are 400, 700, and 900 grams per square meter. The thicker the blanket and the denser the weave, the stronger and more durable it is. For most coastal projects, the 900 weight blanket will be the most durable and provide the longest bank protection.

Heavy Equipment

If heavy equipment is needed for a natural fiber blanket project, equipment access must be carefully planned to avoid destruction of existing vegetation; creation of ruts; destabilization of banks, beaches, or other landforms; impacts to wildlife and nesting habitat for protected shorebird and turtle species (i.e., species that are considered endangered, threatened, or of special concern in Massachusetts); and related impacts. When mechanical equipment is being used, contractors should keep hazardous material spill containment kits on-site at all times in case there is a release of oil, gasoline, or other toxic substances.

Wildlife and Fisheries Protection

If the project is proposed in or adjacent to habitat for protected wildlife species or horseshoe crab spawning areas, there may be limitations on the time of year that the project can be constructed. Information about the location of these resources and special permitting requirements can be obtained from the Natural Heritage and Endangered Species Program of the Massachusetts Division of Fisheries and Wildlife (for protected wildlife species) and the Massachusetts Division of Marine Fisheries (for horseshoe crabs). (Please note this fact sheet focuses on banks. Natural fiber blankets are typically not appropriate for use on dunes, particularly in habitat for protected shorebirds and turtles.)

Permits and Regulations

Most options for addressing coastal erosion, storm damage, and flooding are likely to require a permit under the Massachusetts Wetlands Protection Act through the local Conservation Commission. Additional permits may be needed from the Massachusetts Department of Environmental Protection (MassDEP) Waterways Program and the U.S. Army Corps of Engineers if the project footprint extends below the mean high water line or seaward of the reach of the highest high tide of the year, respectively. Permits or approvals may also be required from other state agencies and local departments, depending on the location and the work involved. Often, Conservation Commission staff are available to meet with applicants early in the design process to go over the important factors that need to be considered.

Generally, regulatory programs are supportive of projects that involve non-structural approaches to managing coastal erosion, such as bioengineering projects with natural fiber blankets and vegetation, as opposed to hard structures. To obtain a permit, projects need to be designed to comply with regulatory requirements, including minimizing or avoiding impacts to sensitive resource areas (e.g., horseshoe crab spawning habitat and endangered species habitat), which are protected by the various regulatory programs.

Professional Services Required

A landscape architect, biologist, engineer, or other environmental professional with experience designing, permitting, implementing, and successfully maintaining bioengineering projects in coastal areas should be consulted to: 1) identify regulatory requirements that must be addressed and ensure the project fully conforms with those requirements; 2) determine the conditions at the site, such as the history of erosion, exposure to wind and waves, soil types, and runoff patterns that will affect the choice of materials for the site; 3) identify any existing conditions including over-steepened slopes and the presence of invasive species that must be considered as part of the design; 4) identify the appropriate natural fiber blanket and vegetation for the site conditions; 5) identify the volume and composition of fill, if needed; 6) identify the best time of year to install the various components of the project; 7) develop an access plan if any heavy equipment is needed; 8) prepare plans for and oversee permitting; and 9) prepare design specifications for and oversee construction. It is also recommended that the consultant be involved in the monitoring and maintenance of these projects.

Project Timeline

It may take as little as two to six months to have a bioengineering project with natural fiber blankets and vegetation designed, permitted, and installed, assuming only a Massachusetts Wetlands Protection Act permit is required. It can take longer, however, depending on the factors involved. Factors influencing this timeline include the contractor's experience with designing and permitting similar projects, completeness of permit applications, special considerations in the permitting process (such as objections by abutters, sensitive resources to be protected, and availability of access for construction), the need for special timing to avoid impacts (e.g., a prohibition on construction during endangered species nesting season), special timing needed for planting vegetation, and/or weather conditions during construction.

Maintenance Requirements

Bioengineering projects with natural fiber blankets and vegetation require ongoing maintenance to ensure their success. Maintenance requirements will vary greatly depending on site conditions. As with all bioengineering projects, maintenance is initially required to ensure that the vegetation that has been planted becomes successfully established (such as watering and replacing dead plants). Blankets and plantings should also be inspected frequently and areas of erosion, areas where the blanket is no longer in contact with the soil, and stakes or staples that are not flush with the ground should be addressed immediately to avoid further deterioration. Other maintenance activities include replacing eroded fill, re-establishing a smooth surface under the blanket, re-anchoring or replacing blankets as needed, and reseeding and replanting vegetation at the appropriate time of year. The frequency of maintenance needed will largely depend on the proximity of the bank to the reach of high tide and the frequency and severity of rain events and coastal storms. Because the replacement of sediment and plants removed by storms is typically necessary, the original permit application should include a maintenance plan. This plan should specify any replacement materials and activities that may be used on the site and how the site will be accessed so that maintenance can be conducted without additional permitting.

Project Costs

With bioengineering projects, a range of options are available that give increasing levels of protection with increased construction costs. In addition, whenever you hire a professional to conduct work on your property, total costs will vary significantly based on site-specific considerations. The considerations that most influence costs of natural fiber blanket projects are the severity of erosion, condition of the existing site (e.g., proximity of the eroded area to the high tide line), density of the blanket selected, type and size of plants selected (plugs are less expensive than plants in containers), need for regrading, amount of fill required, presence of invasive species, and complexity of project design and permitting. For comparison with other shoreline stabilization options, bioengineering projects with natural fiber blankets have relatively low design and permitting costs, low construction costs, and low maintenance costs. See the StormSmart Properties chart, *Relative Costs of Shoreline Stabilization Options* (PDF, 99 KB), for a full comparison.

Additional Information

Bioengineering projects with natural fiber blankets can be used in conjunction with many other techniques for erosion management. See the following CZM StormSmart Properties fact sheets for additional information:

- *StormSmart Properties Fact Sheet 1: Artificial Dunes and Dune Nourishment*
- *StormSmart Properties Fact Sheet 2: Controlling Overland Runoff to Reduce Coastal Erosion*
- *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage*
- *StormSmart Properties Fact Sheet 4: Bioengineering - Coir Rolls on Coastal Banks*
- *StormSmart Properties Fact Sheet 8: Beach Nourishment*

The following publications and websites also provide valuable information on bioengineering with natural fiber blankets and vegetation:

- CZM's Coastal Landscaping website includes information on landscaping coastal areas with salt-tolerant vegetation to reduce storm damage and erosion.
- CZM's *Landscaping to Protect Your Coastal Property from Storm Damage and Flooding fact sheet* (PDF, 962 KB) gives specific information for homeowners on appropriate plants for erosion control in coastal areas.
- CZM's *Environmental Permitting in Massachusetts* briefly describes major environmental permits required for projects proposed in Massachusetts.
- *Guidelines for Barrier Beach Management in Massachusetts* (PDF, 12 MB), which was produced by the Massachusetts Barrier Beach Task Force in 1994, provides an overview of the Massachusetts Wetlands Protection Act Regulations and the function of beaches, dunes, and other resource areas (in Chapter 2). It also gives information on various erosion management techniques, their potential impacts, and measures to minimize those impacts (Chapter 5).
- Massachusetts Wetlands Protection Act Regulations (310 CMR 10.00) cover work in wetland resource areas and buffer zones.
- The Natural Heritage and Endangered Species Program website provides information on protected species in Massachusetts, habitat maps, and regulatory review for projects in or adjacent to these habitats.
- The Massachusetts Division of Marine Fisheries can provide information on horseshoe crab protection and other fisheries resources.
- The Massachusetts Ocean Resource Information System, or MORIS, is a web-based mapping tool for interactively viewing coastal data. MORIS data layers, such as endangered species habitat and shellfish, can help identify sensitive resource areas within or near the project site.

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StormSmart Properties Fact Sheet 6: Sand Fencing

The coast is a very dynamic environment and coastal shorelines—especially beaches, dunes, and banks—change constantly in response to wind, waves, tides, and other factors such as seasonal variation, sea level rise, and human alterations to the shoreline system. Consequently, many coastal properties are at risk from storm damage, erosion, and flooding. Inappropriate shoreline stabilization methods can actually do more harm than good by exacerbating beach erosion, damaging neighboring properties, impacting marine habitats, and diminishing the capacity of beaches, dunes, and other natural landforms to protect inland areas from storm damage and flooding. StormSmart Properties—part of the Massachusetts Office of Coastal Zone Management's (CZM) StormSmart Coasts Program—provides coastal property owners with important information on a range of shoreline stabilization techniques that can effectively reduce erosion and storm damage while minimizing impacts to shoreline systems. This information is intended to help property owners work with consultants and other design professionals to select the best option for their circumstances.

What Is Sand Fencing?

Sand fencing, also called snow fencing, is designed to help capture sand to build dunes. It is typically made of thin, wooden slats that are connected with twisted wire to wooden or metal stakes. While other fence materials such as plastic, polyethylene, and metal are sometimes used to trap sand, they are not recommended for coastal use because of the impacts they can cause. See Design Considerations below for details on impacts of other materials.

No shoreline stabilization option permanently stops all erosion or storm damage. The level of protection provided depends on the option chosen, project design, and site-specific conditions such as the exposure to storms. All options require maintenance, and many also require steps to address adverse impacts to the shoreline system, called mitigation. Some options, such as seawalls and other hard structures, are only allowed in very limited situations because of their impacts to the shoreline system. When evaluating alternatives, property owners must first determine which options are allowable under state, federal, and local regulations and then evaluate their expected level of protection, predicted lifespan, impacts, and costs of project design, installation, mitigation, and long-term maintenance.

Sand fencing was installed along the base of and perpendicular to this eroded dune to trap windblown sand and help rebuild the dune. **(Photo: CZM)**

How Sand Fencing Reduces Storm Damage

Sand fencing reduces storm damage on coastal properties by helping to build up dunes. As wind blows through the sand fencing, the fencing creates a drag that reduces the wind speed. At lower speeds, the wind can no longer carry sand, which is deposited at the base of or behind the fence. The resulting accumulation of sand and other sediment helps build the dune. Because larger dunes provide greater levels of protection from storm waves and storm surge (the rise in sea level above the average tide level caused by onshore winds), the sediment trapped by sand fencing increases the dune's capacity to protect landward areas. In addition, sand fencing is often used to keep people off the dunes and direct them toward boardwalks and other designated beach access paths to prevent damage to both the dune and erosion-control vegetation.

Sand fencing can be used in conjunction with many other techniques for erosion management. See the following StormSmart Properties fact sheets on related techniques: *Artificial Dunes and Dune Nourishment*, *Planting Vegetation to Reduce Erosion and Storm Damage*, *Bioengineering - Coir Rolls on Coastal Banks*, *Bioengineering - Natural Fiber Blankets on Coastal Banks*, and *Beach Nourishment*.

Relative Benefits and Impacts Compared to Other Options

Under the Massachusetts Wetlands Protection Act, new hard structures are typically prohibited on all beaches and dunes. On coastal banks, hard structures are only allowed when necessary to protect buildings permitted before August 10, 1978, and only if no other alternative is feasible. In many cases, sand fencing projects and other non-structural alternatives are therefore the only options available for reducing erosion and storm damage on coastal properties.

Sand fencing provides a low-cost, easy-to-install, and effective way to help build up dunes and protect inland areas from storm damage. Unlike seawalls, rock revetments, or other "hard" shoreline stabilization structures, properly designed sand fencing projects do not reflect or redirect waves onto beaches or neighboring properties. The design of a hard structure affects how much wave energy is reflected, for example vertical walls reflect more wave energy than sloping rock revetments. These reflected waves erode beaches in front of and next to a hard structure, eventually undermining and reducing the effectiveness of the structure and leading to costly repairs. This erosion also results in a loss of dry beach at high tide, reducing the beach's value for storm damage protection, recreation, and wildlife habitat. Hard structures also impede the natural flow of sand, which can cause erosion in down-current areas of the beach system. Sand fencing projects, however, increase protection to landward areas while allowing the system's natural process of erosion and accretion to continue.

In general, the impacts of sand fencing projects are relatively minor compared to other options. The most significant factor is the proximity of the fencing to sensitive habitats, particularly nesting habitat for protected shorebird and turtle species (i.e., species that are considered endangered, threatened, or of special concern in Massachusetts). Sand fencing traps lighter, fine-grained sand, creates steeper slopes, and otherwise physically alters the area in a way that impedes shorebird nesting. These birds prefer relatively flat dune areas with coarser sand. The fencing also is a physical barrier that can block unfledged chicks from getting from their nests to their food source, and the posts or stakes can serve as perches for hawks and other predators that feed on the chicks. Another negative impact occurs when fencing destroyed during a storm becomes marine debris. Slats, posts, and wire littered on the beach or floating in the water are not only unsightly, they can harm people and wildlife. For example, wire can entangle wildlife and broken slats can puncture the bare feet of recreational beach users. Certain sand fencing designs and materials, such as sturdy drift fencing and plastic fencing, have additional impacts. See the Design Considerations section for details.

Design Considerations for Sand Fencing Projects

This section covers a variety of factors that should be considered to minimize adverse impacts and ensure successful design, permitting, construction, and maintenance of sand fencing.

Appropriate Locations

Because of its relatively low cost and minor impacts, sand fencing is appropriate at almost any site (except where it may impact protected shorebird and turtle species)—as long as the fencing is not reached by daily high tides and waves from minor storms. Sand fencing can be installed to build up an existing dune, build a dune at the base of an existing bank, or build a dune in low-lying areas where there is blowing sand. Sand fencing can also be strategically placed to direct pedestrian traffic to a designated access point to minimize dune impacts from foot traffic.

Fence Placement

Sand fencing should be installed as far landward as possible, well behind the high tide line, to minimize potential impacts to beachgoers and wildlife and to protect the fencing from storm waves. If waves and tides regularly reach the sand fencing, there will be erosion around the fencing and it will likely be destroyed during a storm. Sand fencing can be installed using a variety of designs, including a single line of fencing parallel to the shoreline, double rows of fencing, a zigzag configuration, and a line of fencing with attached spurs running perpendicular to the dominant wind direction.

In this project, an artificial dune was built at the base of an eroding bank and heavily planted with erosion-control vegetation. Sand fencing was installed to help trap sand to build the artificial dune. **(Photo: CZM)**

Fence Posts

Post material and size should be carefully considered in project design. As for material, only untreated wooden posts are recommended for use on coastal beaches and dunes. Metal posts rust and become a hazard to public safety and marine life, fiberglass posts often shatter when they break and leave dangerous shards on the beach, and wooden posts treated with preservatives do not break down very quickly and remain a marine debris hazard for much longer than untreated wood if lost in a storm. The larger the posts, the more potential for erosion around the base from wind and water, so smaller posts are recommended to minimize scour (i.e., the erosion of sediment around a stationary object). The recommended post size is no larger than 2x4 inches for rectangular posts and 3 inches in diameter for circular posts.

Space Between Slats

Based on a review of available information, sand fencing with 50% open space and 50% slats optimizes sand deposition. If wider slats are used, more erosion is likely to occur around the fencing from wind and waves. Wider gaps between slats promote scour of the sand rather than sand deposition.

Fence Installation

The number of fence posts should be limited as much as possible to avoid excessive erosion from scour. Posts should be spaced at least 4 feet apart and should be buried several feet into the sediment to withstand erosion and waves. A minimum depth of 4 feet below the surface is optimal.

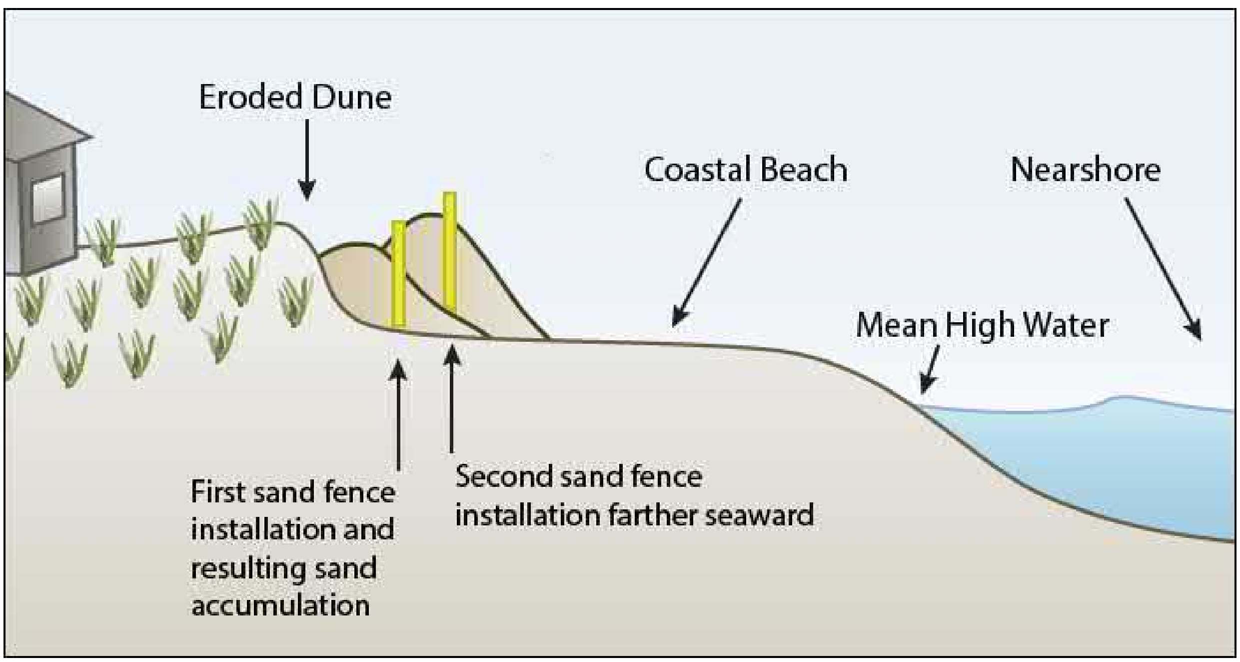
If waves and tides are routinely damaging the sand fencing, it has likely been installed too close to the high tide line. If there is no room at the site to move the fencing landward, additional or alternative shoreline stabilization strategies are likely warranted. Dune nourishment, construction of artificial dunes, and beach nourishment are often combined with sand fencing and vegetation to provide a wider beach and greater level of storm damage protection (see the following StormSmart Properties fact sheets: *Artificial Dunes and Dune Nourishment*, *Planting Vegetation to Reduce Erosion and Storm Damage*, and *Beach Nourishment*).

Vegetation

Whenever possible, native plants that are salt-tolerant and have extensive root systems should be planted as part of a sand fencing project, generally on the landward side of the fencing. These plants are extremely effective at holding sediments in place and help to stabilize windblown sand accumulated by sand fencing. For more information, see *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage*. Please note that planting may be restricted in nesting habitat for protected shorebird species and only live vegetation should be used. Christmas trees are not recommended for trapping sand because a large section of the dune is disturbed when they are removed by waves, increasing dune erosion. Putting brush and other dead plant material on banks or dunes can prevent living plants from becoming established, further destabilizing the area. Christmas trees and brush can also degrade nesting habitat for protected shorebird species by physically occupying otherwise suitable nesting habitat and impeding chick movement.

Additional Rows of Fencing

As shown in the figure below, when sand builds up and buries the fencing (i.e., when the fence is approximately two-thirds buried by sand), an additional row of sand fencing may be installed to continue to help the dune grow (if there is sufficient space available above the high tide line).



This diagram shows where a second row of sand fencing was installed to trap sand after the initial row became partially buried.

Wildlife Protection

Sand fencing may be prohibited in or adjacent to nesting habitat for protected bird and turtle species. At some sites, the location, linear extent, size of the openings, time of year for construction, and other design details may need to be modified so that birds can successfully nest. The Natural Heritage and Endangered Species Program of the Massachusetts Division of Fisheries and Wildlife can provide information on the species listed as endangered, threatened, and of special concern in Massachusetts, including their location and any special design or permitting requirements under state regulations.

Marine Debris

To minimize impacts if fencing is washed out in a storm and becomes marine debris, only fencing made of thin slats of untreated wood connected with twisted wire should be used in coastal areas. These materials break down relatively quickly in the marine environment and consequently have fewer impacts than plastic fencing or other fencing made of non-degradable materials. The posts/stakes, slats, and other fencing materials can be labeled to facilitate identification, recovery, and disposal of any components that are damaged and washed off site in a storm.

Heavy Equipment Use

Access for heavy equipment to deliver fence components, vegetation, or sediment to the site must be carefully planned to avoid destruction of existing vegetation; creation of ruts; destabilization of banks, beaches, or other landforms; impacts to wildlife, particularly protected species; and related impacts. When mechanical equipment is being used, contractors should keep hazardous material spill containment kits on-site at all times in case there is a release of oil, gasoline, or other toxic substances.

Sturdy Drift Fencing

This sturdy drift fencing is constructed in a zigzag pattern parallel to the shoreline with 2x3-inch vertical and horizontal cross-members attached to 6- to 8-inch posts. As described above, this type of fencing is not recommended because of its adverse impacts. **(Photo: CZM)**

Sturdy drift fencing is a type of sand fencing constructed with more robust structural elements than standard wire and slat fencing (see photograph below). The components are nailed together and the fence is constructed in a zigzag pattern. Typically used in areas subject to strong waves, this fencing option is intended to break some of the wave energy before it reaches the bank or dune landward of it, rather than to capture blowing sand. This type of structural fencing can increase erosion issues because: 1) the larger the posts used in a sand fencing project, the greater the level of erosion around the posts; 2) the fence acts as a physical barrier that interferes with the natural flow of sediment along the shoreline, particularly when this fencing is installed on narrow beaches and/or in close proximity to the water; and 3) the fence can cause a wind-tunnel effect, increasing erosion of non-vegetated sediments landward of the fence. Sturdy drift fencing also uses significantly more wood and nails than traditional sand fencing, and the wood is thicker and takes longer to break down in the marine environment. This fencing therefore increases marine debris impacts and threatens public safety when significant numbers of nails are left on the beach after the fencing is damaged during storms. Like traditional sand fencing, sturdy drift fencing negatively impacts nesting areas for protected shorebird and turtle species. In most cases, therefore, thin wooden slat and twisted wire sand fencing is recommended over sturdy drift fence to trap sand. If the fence will be reached by daily high tides and waves from minor storms, additional alternative shoreline stabilization strategies are likely warranted. Dune nourishment, construction of artificial dunes, and beach nourishment are often combined with sand fencing and vegetation to provide a wider beach and greater level of storm damage protection (see the following StormSmart Properties fact sheets: *Artificial Dunes and Dune Nourishment*, *Planting Vegetation to Reduce Erosion and Storm Damage*, and *Beach Nourishment*).

If sturdy drift fencing is used, ways to reduce the potential impacts and increase the longevity and effectiveness of the project include: 1) installing the fencing far enough landward so that it will not be reached by tides or typical storm waves (i.e., these projects will be affected by severe storms but should not be impacted by regularly occurring storms); 2) adding sediment with a similar or slightly coarser grain size to the existing beach and/or dune (called beach and dune nourishment) when the fencing is installed to minimize impacts to natural sediment flow and enhance the longevity of the fencing; 3) periodically adding additional sediment to "renourish" the beach system; 4) labeling fence components and actively retrieving any debris generated by storm damage; 5) cutting notches in the boards at the bottom of the fence for animal access; and 6) avoiding use in nesting habitat for protected shorebirds and turtles.

Other Types of Fencing Are Not Recommended in Dunes

Sand fencing is the only type of fencing that should be used in dunes. In some cases, rows of closely spaced posts have been installed as anchors for sand bags or as part of a shoreline stabilization project. Although these closely spaced posts have been referred to as fencing, they act as a solid wall, reflecting wave energy and increasing erosion of the beach. Because of their adverse impacts, rows of posts are strongly discouraged.

The row of posts installed at the base of this bank is acting like a solid wall, reflecting wave energy and exacerbating beach erosion and erosion of neighboring properties. **(Photo: Greg Berman, Woods Hole Oceanographic Institution Sea Grant Program)**

There are many other types of fencing that have been inappropriately used in dunes, including chain link and solid privacy fences. Chain link fences rust and become a marine debris and public safety hazard when damaged and/or torn out in a storm. Solid privacy fences interfere with the natural movement of the dune and therefore impede the dune's ability to provide storm damage protection. These two types of fencing are typically used for establishing property lines or for stopping sand from blowing onto parking areas. As an alternative, native vegetation can help trap blowing sand and stabilize dunes while serving as a privacy buffer. For more information on the use of vegetation in dunes, see *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage*.

A solid fence prevents the natural movement of this dune. **(Photo: CZM)**

Permitting and Regulatory Standards

Most options for addressing coastal erosion, storm damage, and flooding are likely to require a permit under the Massachusetts Wetlands Protection Act through the local Conservation Commission. Permits or approvals may also be required from other state and federal agencies and local departments, depending on the location and the work involved. Generally, regulatory programs are supportive of projects that work to trap windblown sand and build dunes, so permits are not always required for sand fencing. To obtain a permit, sand fencing projects need to be designed to avoid adverse impacts to habitat for protected species and sited landward of the reach of daily tides and regular storms.

Professional Services Required

Simple fencing projects may be done by the property owner after permits have been obtained if needed. Projects in or adjacent to protected shorebird and turtle habitat and in areas with very narrow dry beach may require professional services. A professional with expertise in designing fencing projects can be consulted to: 1) identify regulatory requirements and ensure the project fully conforms with those requirements; 2) determine the conditions at the site that will affect the project (such as the width of dry beach above high tide, wave exposure, and predicted flood elevations); 3) select plant species and develop a planting and plant maintenance plan; 4) identify the best time of year for installation; 5) prepare plans for permitting; 6) develop an access plan if heavy equipment is needed; and 7) prepare design specifications for construction. The consultant can also oversee permitting, construction, monitoring, and maintenance of the project.

Project Timeline

It may take as little as two to three months to complete a sand fencing project, assuming that only a Massachusetts Wetlands Protection Act permit is required, but it can take longer depending on the factors involved. Factors that affect how long it takes to design, permit, and install a sand fencing project include the contractor's experience with designing and permitting similar projects, completeness of permit applications, special considerations in the permitting process (such as objections by abutters, sensitive resources to be protected, and availability of access for construction), the need for special timing to avoid impacts (e.g., restrictions on construction during nesting season for protected species), and/or weather conditions during construction. Often, Conservation Commission staff are available to meet with applicants to go over the important factors that need to be considered early in the design process.

Maintenance Requirements

Regular maintenance of fencing projects will include retrieving damaged fencing components and replacing deteriorated or storm-damaged fence sections. Maintenance needs will depend, in part, on the proximity of the fencing to the reach of high tide and the frequency and severity of storms. A schedule and plan for replacing fencing should be included in the original permit application so that maintenance can be conducted without additional permitting.

Project Costs

The costs of sand fencing projects are most influenced by the type of fencing and posts selected, the length of the area to be fenced, and the complexity of project design and permitting. In addition, the size and location of the fence will affect construction and maintenance costs, as well as the level of protection provided by the project. Fences that are too close to the high tide line will likely require more frequent maintenance. In comparison with other shoreline stabilization options, sand fencing projects typically have relatively low design and permitting costs, low construction costs, and low maintenance costs. See the StormSmart Properties chart, *Relative Costs of Shoreline Stabilization Options* (PDF, 99 KB), for a full comparison.

Additional Information

Sand fencing can be installed in conjunction with many other techniques for erosion management. See the following CZM StormSmart Properties fact sheets for additional information:

- *StormSmart Properties Fact Sheet 1: Artificial Dunes and Dune Nourishment*
- *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage*
- *StormSmart Properties Fact Sheet 4: Bioengineering - Coir Rolls on Coastal Banks*

- *StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks*
- *StormSmart Properties Fact Sheet 8: Beach Nourishment*

The following publications and websites also provide valuable information:

- CZM's Coastal Landscaping website includes information on landscaping coastal areas with salt-tolerant vegetation to reduce storm damage and erosion.
- CZM's *Landscaping to Protect Your Coastal Property from Storm Damage and Flooding fact sheet* (PDF, 962 KB) gives specific information for homeowners on appropriate plants for erosion control in coastal areas.
- *Coastal Dune Protection and Restoration—Using 'Cape' American Beachgrass and Fencing* (PDF, 3 MB) by the Woods Hole Sea Grant and Cape Cod Cooperative Extension Program includes case studies and tips on dune restoration, along with information on preserving shorebird habitat and understanding the permit process.
- CZM's *Environmental Permitting in Massachusetts* briefly describes major environmental permits required for projects proposed in Massachusetts.
- *Guidelines for Barrier Beach Management in Massachusetts* (PDF, 12 MB), which was produced by the Massachusetts Barrier Beach Task Force in 1994, provides an overview of the Massachusetts Wetlands Protection Act Regulations and resource areas, along with information on various erosion management techniques, their potential impacts, and measures to minimize those impacts.
- *Salisbury Beach Dune Walkover Access Design Standards* (PDF, 14 KB) gives general design standards for walkways over coastal dunes that minimize potential adverse effects. These standards are widely applicable.
- *The Ballston Beach Barrier Dune Restoration Project* (PDF, 1 MB) documents innovative sand fencing techniques used to restore a dune on a barrier beach in Truro.
- Massachusetts Wetlands Protection Act Regulations (310 CMR 10.00) cover work in wetland resource areas and buffer zones.
- The Natural Heritage and Endangered Species Program website provides information on protected species in Massachusetts, habitat maps, and regulatory review for projects in or adjacent to these habitats.
- The Massachusetts Ocean Resource Information System, or MORIS, is a web-based mapping tool for interactively viewing coastal data. MORIS data layers, such as endangered species habitat and shellfish, can help identify sensitive resource areas within or near the project site.

www.mass.gov/stormsmart-coasts-program

Commonwealth of Massachusetts
Charlie Baker, Governor

Executive Office of Energy and Environmental Affairs
Matthew A. Beaton, Secretary

Massachusetts Office of Coastal Zone Management
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StormSmart Properties Fact Sheet 7: Repair and Reconstruction of Seawalls and Revetments

The coast is a very dynamic environment and coastal shorelines—especially beaches, dunes, and banks—change constantly in response to wind, waves, tides, and other factors such as seasonal variation, sea level rise, and human alterations to the shoreline system. Consequently, many coastal properties are at risk from storm damage, erosion, and flooding. Inappropriate shoreline stabilization methods can actually do more harm than good by exacerbating beach erosion, damaging neighboring properties, impacting marine habitats, and diminishing the capacity of beaches, dunes, and other natural landforms to protect inland areas from storm damage and flooding. StormSmart Properties—part of the Massachusetts Office of Coastal Zone Management's (CZM) Stormsmart Coasts Program—provides coastal property owners with important information on a range of shoreline stabilization techniques that can effectively reduce erosion and storm damage while minimizing impacts to shoreline systems. This information is intended to help property owners work with consultants and other design professionals to select the best option for their circumstances.

What Are Seawalls and Revetments?

Seawalls and revetments are types of coastal engineering structures that run parallel to the shoreline. Also known as "armoring" or "hard structures," coastal engineering structures provide a physical barrier that directly protects inland areas. Seawalls are vertical walls that are typically constructed of concrete or stone, while revetments are sloping structures typically composed of rock (also called "rip rap"). Seawalls and revetments provide storm damage protection and erosion control from waves, tides, currents, and storm surge (water build up above the average tide level). They can be used in both exposed areas with high wave energy, as well as in areas with more sheltered conditions (e.g., relatively low wave energy). As discussed below, seawalls and revetments can significantly alter the coastal system and may have adverse impacts on the project site and neighboring properties. Because these effects are now well understood, *new construction* of these hard structures is only allowed in very limited circumstances. This fact sheet addresses the more common practice of repair and reconstruction of *existing* seawalls and revetments. Given the technical and permitting issues involved with seawall and revetment repair and reconstruction projects, a coastal engineer should be consulted for site-specific advice.

> **No shoreline stabilization option permanently stops all erosion or storm damage. The level of protection provided depends on the option chosen, project design, and site-specific conditions such as the exposure to storms. All options require maintenance, and many also require steps to address adverse impacts to the shoreline system, called mitigation. Some options, such as seawalls and other hard structures, are only allowed in very limited situations because of their impacts to the shoreline system. When evaluating alternatives, property owners must first determine which options are allowable under state, federal, and local regulations and then evaluate their expected level of protection, predicted lifespan, impacts, and costs of project design, installation, mitigation, and long-term maintenance.**

This concrete seawall was built to protect the homes and infrastructure behind it. This seawall has a curved face built into the top of the wall, which redirects some of the reflected water and waves away from the wall. **(Photo: CZM)**

This rock revetment was installed on the lower part of a coastal bank, while salt-tolerant vegetation was planted to protect the upper bank. **(Photo: CZM)**

Bulkheads - Also a type of hard structure constructed parallel to the shoreline, bulkheads are vertical walls designed to hold soil in place and prevent it from sliding or slumping into the water. Although they may also provide some protection from waves and tides, bulkheads are not typically appropriate to address coastal erosion. They are typically made of wood, steel or vinyl sheeting, granite blocks, or concrete and are primarily used around developed harbors and marinas. Their vertical structure allows them to provide docking space for vessels in sheltered areas where wave action is relatively limited. The design considerations for bulkheads are similar to those recommended for seawalls (see below). A coastal engineer should be consulted for site-specific advice when bulkhead repairs are needed.

This steel bulkhead is built to hold the soil under this parking lot in place. **(Photo: CZM)**

Hard Structures - Their Role, History, and Impacts

Coastal engineering structures were originally utilized to prevent erosion and protect development and infrastructure from waves and storm surge. The unintended effects of hard structures on the shoreline system were not initially well understood, however, and significant long-term impacts have been documented in areas where these structures were constructed. While seawalls and revetments can help protect landward property and infrastructure from waves and tides, they do not stop (and may exacerbate) erosion. As natural erosive forces continue to remove sediment over time, beaches in front of the hard structures are diminished and can eventually be completely lost. Seawalls and revetments themselves can also exacerbate erosion problems by reflecting waves onto the beach in front of them or onto neighboring properties. As these sources of erosion continue, more of the hard structure is exposed, causing more wave reflection and erosion. Over time, the structure can become undermined, reducing its shoreline protection capacity, increasing maintenance costs, and ultimately leading to total structure failure. When used on coastal banks (also known as bluffs), seawalls and revetments prevent erosion of these landforms, which halts the natural supply of sand and other sediment to the shoreline system. The result is that beaches and dunes in downdrift (i.e., down current) areas experience increased erosion rates. Therefore, these structures not only affect the property owner, they also affect the natural resources necessary for storm damage prevention, recreation, and wildlife habitat.

The beach in front of this concrete seawall eroded, undermining the structure. (Photo: CZM)

Erosion of the beach in front of this revetment created a depression at the base of the structure. (Photo: CZM)

Alternatives to Revetments in Front of Seawalls - To address seawall undermining, small rock revetments have often been installed in front of seawalls to protect the structure from collapse. As erosion continues, however, the small revetment may also be undermined—leading to designs that consider a larger revetment. A larger revetment will extend farther seaward, increasing the frequency and intensity of interactions between the structure and tides, waves, and currents and further worsening beach erosion. The result can be a succession of larger structures, increased wave reflection and erosion, and loss of beach, with the beach being permanently replaced by the hard structures. Erosion-control options that add sediments in front of the structure, like beach nourishment and cobble berms, can be used instead to effectively protect upland development and infrastructure, reducing impacts to neighboring properties, and maintaining beach resources and habitat. In addition, adding a revetment does not effectively stop waves and water from overtopping the seawall during storms. In many cases, overtopping and storm damage are more effectively reduced by adding sediment seaward of the wall to dissipate wave energy before it reaches the structure. This practice is referred to as beach nourishment (see *StormSmart Properties Fact Sheet 8: Beach Nourishment* for additional information).

Repair and Reconstruction - An Opportunity to Improve Performance and Reduce Impacts

As the impacts of hard structures have become better understood over the last 50 years, recommended design practices for seawalls and revetments have advanced significantly. Any repair or reconstruction project—whether minor repairs or complete reconstruction—should therefore include design improvements based on the best available techniques to reduce impacts, improve structure longevity, and minimize maintenance costs. Typically, the more work the structure needs, the greater the opportunity for incorporating improvements into the redesign. Investing in significant improvements and best management practices can cost more in the short term, but such improvements reduce costs associated with mitigating for adverse effects of the structure and can significantly improve the protection provided in a major coastal storm. In addition, if minor repairs are simply patches that make the structure look better, they may not do enough to prevent the structure from failing in a storm, which would result in significant damage to the property and infrastructure landward of it.

Design Considerations for Repair or Reconstruction of Seawalls and Revetments

This section covers a variety of options that should be considered as part of seawall and revetment repair and reconstruction projects to minimize adverse impacts, maximize structure longevity, reduce maintenance costs, and ensure successful design, permitting, and construction of the project.

This bulkhead has deteriorated and erosion has occurred landward of it. When reconstructed, the bulkhead should be replaced with a sloping rock revetment to dissipate energy more effectively and reduce wave reflection. In addition, the toe of the revetment should be constructed at the base of the eroding bank to minimize regular interaction with waves and tides. This improved placement will reduce impacts to the beach and extend the life of the structure. **(Photo: CZM)**

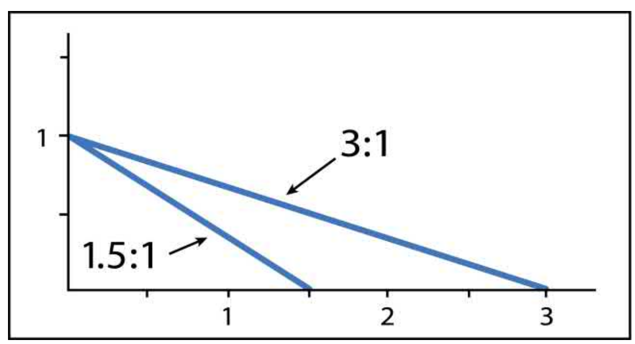
Placement

To minimize interaction with waves and tides and therefore reduce erosion to the fronting beach and adjacent areas, seawalls and revetments should be located as far landward as possible. When repairing or replacing an existing seawall or revetment, therefore, the structure should not be extended farther seaward. In addition, if erosion is occurring behind an existing structure, to minimize impacts, the structure should be pulled back to the base of the landward landform to prevent continued erosion from undermining the structure. Leaving the structure in place and using fill to reclaim land will likely continue the cycle of erosion. Seawalls and revetments should also conform to the natural shape of the shoreline without any segments extending seaward from the main structure, which would focus wave energy on the parts of the structure closer to the sea. This focused wave energy exacerbates erosion of the beach and reduces the longevity of the structure. In addition, the structure should not extend farther seaward than those on adjacent properties and every effort should be made to align the ends of the structure with adjacent structures.

Slope

Sloping structures dissipate wave energy (i.e., reduce wave strength) more effectively than vertical structures. Therefore, when seawalls need significant repairs or reconstruction, replacing them with sloping rock revetments that do not extend farther seaward should be considered.

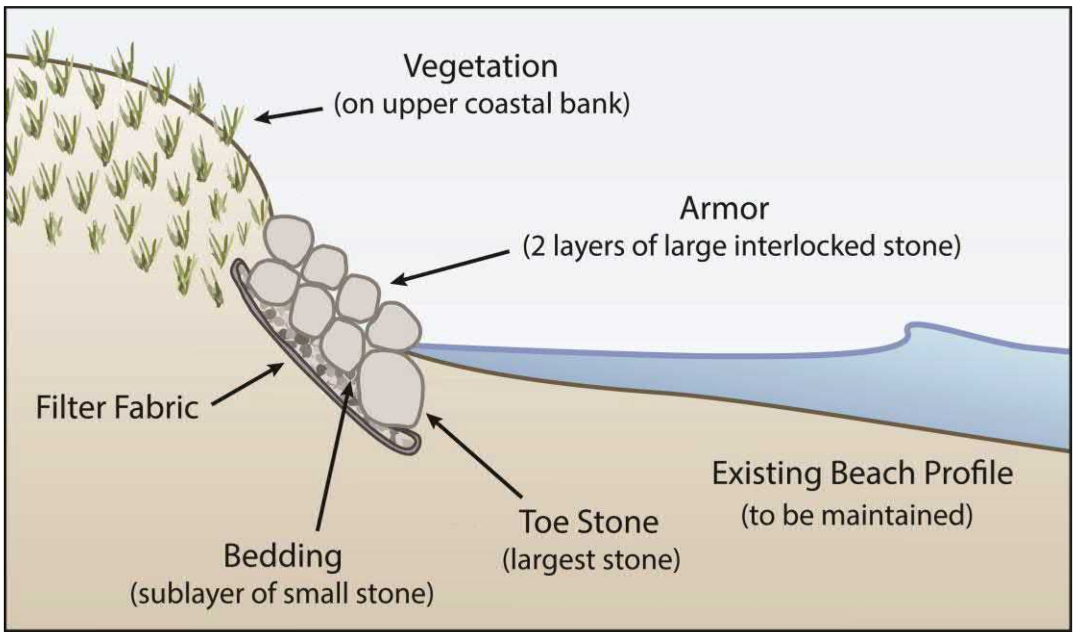
In addition, shallow slopes minimize wave reflection that causes erosion. Revetments should ideally have a slope no steeper than 1.5:1 to limit erosion of fronting beaches and adjacent properties. A coastal engineer can recommend an appropriate slope based on site-specific conditions, including beach width and elevation, bank height, erosion rate, wave energy, and integrity of the structure.



The slope is typically expressed as a ratio of the width of a structure's base to its height, or horizontal to vertical. This figure shows two examples of different slopes.

Reconstruction offers an excellent opportunity to reduce the steepness of a revetment. To achieve a shallower slope without extending the structure farther seaward, the bank or other landform behind the revetment can be regraded and the top of the structure moved landward. Though this landward extension results in a loss of ground surface between the revetment and the development or infrastructure behind it, the property will be better protected through the increased longevity of the structure and reduced erosion rates.

The vertical seawall at this site has been undermined and is failing. In this case, there is room on the site to replace the vertical wall with a sloping rock revetment that does not extend farther seaward onto the beach. **(Photo: CZM)**



Schematic of a typical revetment on a coastal bank.

Curved Face for the Top of the Seawall

Vertical seawalls reflect water straight down and straight up. The wave energy that is reflected downward erodes the beach, while the wave energy that goes up into the air can overtop the structure and cause erosion behind the wall, potentially damaging the development or infrastructure being protected. If the seawall cannot be replaced with a revetment, a curved face can be added to the top of a vertical concrete seawall to help direct some of the reflected water and waves out and away from the wall. A coastal engineer will need to evaluate the applicability and potential effectiveness of this approach for each site.

Waves are reflected by this vertical seawall, causing energy to be deflected straight down on the beach and straight up and over the wall, damaging the building behind it. **(Photo: CZM)**

Beach and Dune Nourishment

Beaches and dunes naturally dissipate energy associated with waves, tides, and currents. Therefore, the best way to reduce the wave energy that hits seawalls and revetments is to maintain the beach in front of these structures. In areas where there is a wide enough beach, dunes can provide additional protection. With an older seawall or revetment, the beach in front of the structure has often eroded over time. Replacing and maintaining these natural buffers can prolong the structure's longevity and minimize its adverse impacts—and can also provide a recreational beach. To build up beaches (and dunes where appropriate), "compatible" material (i.e., sediment of a similar size) is brought in from an offsite source and added to the beach. After the initial nourishment project is completed, sediment is added to maintain the desired beach and/or dune volume according to a monitoring and maintenance plan that includes details for determining when, how much, and what type of sediment should be added. Depending on erosion rates and storm impacts, sediment could be required on an annual basis, and will likely be necessary after coastal storms. See the following StormSmart Properties fact sheets for more information on where beach and dune nourishment are appropriate: *Artificial Dunes and Dune Nourishment* and *Beach Nourishment*, as well as the guidance document, *Beach Nourishment: MassDEP's Guide to Best Management Practices for Projects in Massachusetts* (PDF, 2 MB).

In most cases, the sediment added to the beach or dune is not permanent. How long it remains in front of the seawall or revetment will vary depending on many factors, including: the initial width of the dry beach, the length of beach where sediment is added, wave energy, erosion rate, grain size and volume of sediment added, and storm frequency and intensity. A coastal geologist or coastal engineer with experience designing beach and dune nourishment projects can make recommendations for the grain size and volume of sediment needed. When this added sediment erodes, it is not "lost" to the system—it moves into nearshore areas and/or alongshore to the adjacent shoreline where it dissipates wave energy, protects the shoreline, and improves wildlife habitat. And in many cases, this eroded sediment moves back onshore during the summer and after storms. See these StormSmart Properties fact sheets for design considerations to help reduce erosion of added sediment: *Artificial Dunes* and *Dune Nourishment* and *Beach Nourishment*.

On coastal banks, when a seawall or revetment is undergoing significant repairs or reconstruction, the project should also specifically include provisions to add sediment to compensate for the fact that the bank is no longer acting as a source of sediment to the beach system. Adding this sediment will also help maintain the beach volume in front of the structure, increasing its longevity. The minimum volume of sediment required should be based on the historic shoreline erosion rate, the height of the bank, and the length of the project. A professional with experience designing beach nourishment projects can make recommendations regarding the volume of sediment that will be needed. A monitoring plan should be implemented to document the change in beach elevation in front of the structure, along with beach and bank erosion adjacent to the structure. This plan should include requirements for adding sediment when beach elevation falls to a certain level. In addition, any sediment excavated from the beach as part of the repair or reconstruction project should be placed on the beach after construction to maintain the volume of sediment in the beach system.

Surface Texture and Chinking in Revetments

Rough surfaces dissipate more wave energy than smooth surfaces. Therefore, when individual rocks in revetments are replaced or repositioned, or when the structure is reconstructed, the seaward face should be rough instead of flat and smooth. The coastal engineer designing the project can specify the type of rock to use and how to build the structure to maximize dissipation of wave energy.

The surface of the rocks in this sloping revetment is relatively smooth and the spaces between the rocks have been filled with cement, further smoothing the structure. Smoother surfaces such as this reflect wave energy outward onto the beach and upward toward the house rather than dissipating the energy. The results are increased overtopping of the wall by waves, resulting in erosion and storm damage. **(Photo: CZM)**

In addition, no grout (e.g., cement) should be used in between the rocks in revetments because it smoothes the surface. Chinking (filling gaps with stones) should also only be done to the extent needed to structurally stabilize the revetment. Filling every void with small stones should be avoided because it reduces wave dissipation, and the small stones can become projectiles in a storm. Adequate void space between rocks also provides better habitat for marine species. Marine animals cannot hide or attach to flat, high energy surfaces. Rough surfaces with spaces in between rocks also reduce wave energy and provide spaces for encrusting organisms, like shellfish and anemones, and hiding spots for small fish. Through this approach, the area will be more diverse and biologically productivity, resulting in a more environmentally friendly seawall.

Structure Height

The higher the seawall or revetment, the more surface area there is to reflect wave energy. Therefore, projects that raise the height of an existing seawall or revetment must be considered carefully in light of the additional erosion that may be caused by wave energy reflected downward. The design height of seawalls and revetments is typically determined by balancing the desired level of protection to landward areas with construction costs and the need to minimize erosion of the fronting beach, which can compromise the structure in the future.

For sites with high banks, the bank itself also serves as a vertical buffer to waves and storm surge. Rather than increasing the height of the structure in these areas, efforts can be made to stabilize the upper bank using vegetation, natural fiber blankets, and/or coir rolls. See the following StormSmart Properties fact sheets for information on these techniques: *Planting Vegetation to Reduce Erosion and Storm Damage*, *Bioengineering - Coir Rolls on Coastal Banks*, and *Bioengineering - Natural Fiber Blankets on Coastal Banks*.

The bank above this revetment was stabilized with natural fiber blankets and native, salt-tolerant vegetation. **(Photo: Wilkinson Ecological Design)**

Water overtopping this seawall in a storm eroded the lawn and sediments behind it. Replacing the sediment and planting salt-tolerant vegetation may help to reduce erosion in future storms. **(Photo: CZM)**

For sites without high banks, raising the height of the structure may be appropriate to provide protection from overtopping waves during large storm events. However, the increased wave reflection will likely result in greater beach erosion. Where appropriate, an alternative approach would be to add sediment to the beach and/or dune seaward of the structure to dissipate wave energy before it reaches the structure. Salt-tolerant vegetation with deep roots can also be used in conjunction with natural fiber blankets to address erosion behind seawalls and revetments. See the following StormSmart Properties fact sheets for more information: *Artificial Dunes and Dune Nourishment*, *Planting Vegetation to Reduce Erosion and Storm Damage*, and *Beach Nourishment*.

Transition to Adjacent Properties

During repair and reconstruction, it may be necessary to consider changes to reduce "end effects"—the increased erosion and storm damage to adjacent properties caused by the seawall or revetment. Unless the structure connects to an existing structure on an adjacent property, it should be shortened so that it ends approximately 15 to 20 feet from the property line (where feasible and where adequately protective of the building on the site). The ends of the structure should also be tapered so that both its elevation and slope are gradually reduced to further minimize end effects.

The end effects of this concrete seawall are causing erosion of the bank and damage to the parking area on a neighboring property. **(Photo: CZM)**

Natural fiber blankets, coir rolls, artificial dunes, beach nourishment, and vegetation should also be considered for use at the end of the structure to both reduce end effects and provide the needed protection to the property. See the following StormSmart Properties fact sheets: *Artificial Dunes and Dune Nourishment*, *Planting Vegetation to Reduce Erosion and Storm Damage*, *Bioengineering - Coir Rolls on Coastal Banks*, *Bioengineering - Natural Fiber Blankets on Coastal Banks*, and *Beach Nourishment*.

Coir rolls, natural fiber blankets, and fill were installed to prevent erosion at the end of this bulkhead. **(Photo: Wilkinson Ecological Design)**

Controlling Erosion from Overland Runoff and Other Sources

To help ensure the success and longevity of a repaired or reconstructed structure, all sources of erosion on the site—including upland runoff and waves—should be identified and addressed as part of the site evaluation and design process. Signs that overland runoff or wave overtopping has caused erosion around seawalls and revetments include erosion of sediment behind seawalls or under revetments and sinkholes behind structures. If overland runoff is causing erosion, this runoff should be reduced or redirected (see *StormSmart Properties Fact Sheet 2: Controlling Overland Runoff to Reduce Coastal Erosion* for details).

Seawall repair or reconstruction projects should include improvements to the drainage system to prevent pressure from building up behind the wall due to wave overtopping or ponding of rainwater. This pressure is one potential cause for structural failure.

To minimize soil erosion behind seawalls and under revetments—which can compromise the integrity of the structure and potentially cause it to fail—woven filter fabric should be placed between the structure and the ground surface during construction (see figure above of a cross section of a revetment). The fabric holds the sediment in place, while the water drains.

Beach Access

According to the requirements of the Massachusetts Public Waterfront Act, coastal property owners are required to maintain public access along the shore for the purposes of "fishing, fowling, and navigation." With hard structures, the best way to protect shoreline public access is to keep the structure as far landward as possible and maintain the height of the beach in front of the structure. When erosion results in no fronting beach at mean high tide, then the reconstruction or repair of the structure will require a license from the Massachusetts Department of Environmental Protection (MassDEP) Waterways Program that specifies how the property owner will maintain required public access. For additional details on these requirements, see the MassDEP Waterways Program web page.

Protecting Existing Vegetation

Vegetation plays an important role in erosion prevention and shoreline protection. Therefore, any destroyed or damaged vegetation should be replaced after project completion. If damaged vegetation consisted of invasive species, large trees that may have been destabilizing the top of the coastal bank or dune, or plants with shallow root structures, the vegetation may be replaced with native grasses and/or shrubs that are more appropriate for erosion control. See *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage* for more information on the use of native, salt-tolerant species for erosion control, as well as information on how to protect newly planted vegetation while it gets established.

Minimizing Impacts to Habitat, Wildlife, and Fisheries

During repair or reconstruction, changes should be incorporated into a hard structure's design to reduce impacts to sensitive habitats. These changes include reducing the amount of wave reflection and erosion caused by the structure, as well as addressing the impact of the structure on sediment levels in the beach system. Any loss of sediment caused by the hard structure can result in erosion to and eventual loss of habitat for shorebirds and other species. In addition, redesigning seawalls to include shelves and crevices within the intertidal and subtidal areas provides more habitat for marine animals, including shellfish.

Restrictions on the time of year when repair or reconstruction can be conducted may also be required to avoid impacts to protected species. The Natural Heritage and Endangered Species Program of the Massachusetts Division of Fisheries and Wildlife can provide information on the species listed as endangered, threatened, and of special concern in Massachusetts, including their location and any special design or permitting requirements under the Massachusetts Endangered Species Act and the rare wildlife sections of the Wetlands Protection Act. The Massachusetts Division of Marine Fisheries Habitat Program can provide information on fish and shellfish species and locations that may have special design or permitting requirements.

Heavy Equipment Use

Access for heavy equipment must be carefully planned to avoid destruction of existing vegetation; creation of ruts; destabilization of banks, dunes, or other landforms; impacts to wildlife and nesting habitat for protected shorebird and turtle species; and related impacts. To the extent possible, heavy equipment operators should avoid running over beaches multiple times, which can compact sediments and prevent them from moving and shifting to effectively dissipate wave energy. When mechanical equipment is being used, contractors should keep hazardous material spill containment kits on-site at all times in case there is a release of oil, gasoline, or other toxic substances.

Permitting and Regulatory Standards

Most seawall and revetment repair and reconstruction projects are likely to require a permit under the Massachusetts Wetlands Protection Act through the local Conservation Commission. Additional licenses and permits may be needed from MassDEP and the U.S. Army Corps of Engineers if the project footprint extends below the mean high water line or seaward of the reach of the highest high tide of the year, respectively. Depending on the project location and the work involved, permits or approvals may also be required from other state agencies and local departments, particularly for larger projects. Massachusetts Environmental Policy Act (MEPA), Massachusetts Endangered Species Act, and CZM federal consistency review requirements may apply. Often, Conservation Commission staff, as well as state and federal agencies as applicable, are available to meet with applicants early in the design process to go over the important factors that need to be considered during the design and permitting.

Permitting requirements are typically more stringent for hard structures than for non-structural alternatives, such as beach and dune nourishment. However, regulatory programs are generally supportive of repair and reconstruction projects that are designed to reduce the adverse impacts being caused by the structure. Projects that have been designed so that the repaired or reconstructed structure is within the same general footprint as the existing structure (i.e., does not extending farther seaward) and include mitigation for any impacts to the fronting, adjacent, and downdrift beaches and banks and dunes generally have fewer issues during permit review and authorization.

Professional Services Required

A coastal engineer with expertise in designing, repairing, and reconstructing coastal engineering structures should be consulted to: 1) identify regulatory requirements and ensure the project fully conforms with those requirements; 2) determine the conditions at the site that will affect the project (such as the width of dry beach above high tide, wave exposure, and predicted flood elevations); 3) assess the condition of the structure and the level of protection it is providing; 4) determine what design changes are needed to reduce the impacts of the structure and increase its longevity; 5) develop a monitoring and mitigation plan to address sediment loss to the beach system (i.e., the loss of sediment from armoring of sediment-source banks and increased erosion of the fronting beach); 6) determine if other shoreline stabilization techniques are needed in addition to the structure; 7) identify the best time of year to install the various components of the project; 8) prepare design plans for permitting; 9) develop an access plan for heavy equipment; and 10) prepare design specifications for construction. The consultant can also oversee permitting, construction, monitoring, mitigation, and maintenance of the project. As with hiring any contractor, consider meeting with multiple engineers to compare how they would address site-specific design issues.

Project Timeline

It may take six to eight months or more to have a repair or reconstruction project designed, permitted, and completed, assuming that only a Massachusetts Wetlands Protection Act permit is required—but it can take longer, depending on the factors involved. Factors influencing this timeline include the extent of the proposed repairs or reconstruction, whether the proposed work mitigates for adverse impacts of the existing structure, the contractor’s experience with designing and permitting similar projects, completeness of permit applications, special considerations in the permitting process (such as objections by abutters, sensitive resources to be protected, and availability of access for construction), the need for special timing to avoid impacts (e.g., a prohibition on construction during endangered species nesting season), and/or weather conditions during construction.

Monitoring, Mitigation, and Maintenance Requirements

As described in the design considerations section, regular maintenance of coastal engineering structures will likely include adding sediment to maintain the fronting beach. The amount of sediment that should be added and how frequently it is needed will depend, in part, on the proximity of the structure to the reach of high tide, the frequency and severity of storms, and the type and design of the structure (e.g., rough-faced sloping rock revetment vs. vertical wall). Pulling the structure back from the high tide line and reducing its steepness helps to minimize the need for maintenance and mitigation. A monitoring plan developed during the permitting process should specify the volume and grain size of sediment that should be placed on the beach, how the beach elevation will be monitored, who the monitoring reports will be submitted to, and when additional sediment may be needed to mitigate for beach erosion.

Other maintenance activities can include resetting rocks if they have moved or shifted significantly, re-chinking, adding soil behind the structure to replace eroded material, re-vegetating eroded areas behind the structure, filling cracks in concrete seawalls, and replacing rotted wood or metal components. For projects that include planting vegetation, the plants should be replaced (at the appropriate time of year) if they are removed by storms or die (until the plants become fully established, such losses are more common). See *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage* for more information. A schedule and plan for replacing sediments and plants should be included in the original permit application and approved as ongoing conditions of the permit so that maintenance can be conducted without additional permitting.

Project Costs

With projects involving repair or reconstruction of coastal engineering structures, permitting, design, and construction costs will vary depending on the extent of repairs needed and site-specific considerations. Maintenance costs will depend, in part, on the amount of sediment needed to maintain beach levels, as well as factors such as storm damage and erosion levels. Adding this sediment, however, can lower the costs of maintaining the structure itself. The considerations that most influence the costs of repair or reconstruction projects are the condition of the structure, severity of erosion, width and elevation of the beach, complexity of project design and permitting, and size and location of the proposed structure. For comparison with other shoreline stabilization options, reconstruction projects typically have relatively high design and permitting costs and high construction costs. Repair projects will vary depending on the amount of work to be done, but they typically are also relatively high. While yearly maintenance costs for repair and construction projects are relatively low, long-term maintenance costs (i.e., future major repairs or reconstruction) are high and costs to mitigate for adverse impacts are medium. For a full comparison, see the StormSmart Properties chart, *Relative Costs of Shoreline Stabilization Options* (PDF, 99 KB).

Additional Information

Many other erosion management techniques can be used in conjunction with repair and reconstruction projects to minimize the adverse impacts of these structures and increase their longevity. See the following CZM StormSmart Properties fact sheets for additional information:

- *StormSmart Properties Fact Sheet 1: Artificial Dunes and Dune Nourishment*
- *StormSmart Properties Fact Sheet 2: Controlling Overland Runoff to Reduce Coastal Erosion*
- *StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage*
- *StormSmart Properties Fact Sheet 4: Bioengineering - Coir Rolls on Coastal Banks*
- *StormSmart Properties Fact Sheet 5: Bioengineering - Natural Fiber Blankets on Coastal Banks*
- *StormSmart Properties Fact Sheet 8: Beach Nourishment*

The following publications and websites also provide valuable information on repair or reconstruction of seawalls and revetments:

- *Maintaining Shoreline Erosion Control Structures* (PDF, 2 MB) by the New York Sea Grant Program includes information on how to determine if coastal engineering structures need maintenance.
- CZM's Inventories of Seawalls and Other Coastal Structures web page includes information on the cost of repairs and reconstruction of seawalls.
- *Beach Nourishment: MassDEP's Guide to Best Management Practices for Projects in Massachusetts* (PDF, 2 MB) describes the steps for beach nourishment projects. The *Technical Attachments* (PDF, 1 MB) give detailed information on sampling beach sediments, evaluating offsite source material, and monitoring project performance.
- The U.S. Army Corps of Engineers *Coastal Engineering Manual* provides detailed guidance on the importance of using site-specific information on coastal erosion and other processes, as well as planning and design considerations.
- Massachusetts Wetlands Protection Act Regulations (310 CMR 10.00) cover work in wetland resource areas and buffer zones.
- Massachusetts Public Waterfront Act (Chapter 91) covers requirements for protecting public trust rights in tideland areas, such as with projects seaward of the current mean high tide line.
- CZM's *Environmental Permitting in Massachusetts* gives brief descriptions of major environmental permits required for projects proposed in Massachusetts.
- CZM's Public Rights Along the Shoreline web page explains the ownership of tidelands in Massachusetts and describes the scope of public and private rights under the Public Trust Doctrine.
- *Guidelines for Barrier Beach Management in Massachusetts* (PDF, 12 MB), which was produced by the Massachusetts Barrier Beach Task Force in 1994, provides an overview of the Wetlands Protection Act Regulations and the function of resource areas, along with information on various erosion management techniques.
- CZM's Coastal Landscaping website focuses on landscaping coastal beaches, dunes, and banks with salt-tolerant vegetation to reduce storm damage and erosion.
- CZM's *Landscaping to Protect Your Coastal Property from Storm Damage and Flooding fact sheet* (PDF, 962 KB) gives specific information for homeowners on appropriate plants for erosion control in coastal areas.
- The Natural Heritage and Endangered Species Program website provides information on threatened and endangered species in Massachusetts, maps of Estimated and Priority Habitats, and details on regulatory review for projects in or adjacent to these habitats.
- The Massachusetts Division of Marine Fisheries can provide information on protection of fisheries resources.
- The Massachusetts Ocean Resource Information System, or MORIS, is a user-friendly, web-based mapping tool for interactively viewing coastal data. It includes shoreline change data, which should be considered when evaluating and designing erosion-control or shoreline-stabilization projects. Other data layers in MORIS, such as endangered species habitat, shellfish, and eelgrass, can be used to help identify sensitive resource areas within or near the project site.

www.mass.gov/stormsmart-coasts-program

Commonwealth of Massachusetts
Charlie Baker, Governor

Executive Office of Energy and Environmental Affairs
Matthew A. Beaton, Secretary

Massachusetts Office of Coastal Zone Management
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StormSmart Properties Comparison Chart - Relative Costs of Shoreline Stabilization Options

With shoreline stabilization projects, there are typically a range of options available that give increasing levels of protection with increased costs. In addition, whenever you hire a professional to conduct work on your property, total costs are expected to vary significantly based on site-specific considerations. These considerations include the severity of erosion, condition of the existing site (e.g., proximity of the eroded area to the high tide line), exposure to wind and waves, frequency of storm events, proximity to endangered or threatened species habitat, and complexity of project design and permitting. The following table provides relative costs for permitting, construction, maintenance, and mitigation for various shoreline stabilization techniques to reduce erosion, flooding, and storm damage.

Technique	**Relative Costs**				
	Design and Permitting	**Construction**	**Expected Maintenance Frequency**[1]	**Average Annual Maintenance Costs**[2]	**Average Annual Mitigation Costs**[3]
Artificial Dunes & Dune Nourishment	Low	Low	1-5 years	Low	None
Controlling Overland Runoff	Low	Low	5-20 years	Low	None
Planting Vegetation	Low	Low	1-3 years	Low	None
Bioengineering - Coir Rolls on Coastal Banks	Low-Medium	Medium-High	1-3 years	Low-Medium	Low
Bioengineering - Natural Fiber Blankets on Coastal Banks	Low	Low	1-3 years	Low	None
Sand Fencing	Low	Low	3-5 years	Low	None
Beach Nourishment	Medium	Low-Medium	5-10 years	Low	Low
Rock Revetments - Toe Protection	High	High	10-20 years	Low	Low- Medium
Rock Revetments - Full Height (up to predicted flood zone elevation)	Very High	Very High	20-25 years	Low	Medium
Seawall	High-Very High	Very High	25-40 years	Low	Medium-High

COST ESTIMATES *(average cost per linear foot of shoreline)*
Low: <$200
Medium: $200-500
High: >$500-1,000
Very High: >$1,000

[1]The frequency of required maintenance is highly dependent on storm severity and frequency and shoreline exposure. See StormSmart Properties fact sheets for details on maximizing longevity.
[2]Estimated, annual costs averaged over the life of the project to maintain project components, assuming the project is designed and installed properly.
[3]Estimated, annual costs averaged over the life of the project to compensate for the technique's adverse effects.

Source: CZ-Tip - Basics of Building Beach Access Structures that Protect Dunes and Banks | Mass.gov

CZ-Tip - Basics of Building Beach Access Structures that Protect Dunes and Banks

Find ways to get to, protect, and enjoy the coast with tips from the Massachusetts Office of Coastal Zone Management (CZM).

Boardwalks, walkways, stairways, and other structures that provide beach access over dunes and banks can cause erosion and increase storm damage if not properly designed. Potential problems include limiting the growth of plants that stabilize the shoreline and creating wind and water channels that lead to scour, erosion, and flooding of landward properties. Properly designed access structures not only minimize these impacts, but actually provide significant benefits—they help to define and maintain pedestrian access in one location, discourage widespread trampling of vegetation, allow for the natural movement of sand and other sediment, and stabilize dunes and banks to help protect coastal properties from waves, wind, erosion, storm surge, and flooding.

This tip covers the importance of vegetation for dune and bank stability, the benefits of elevated access structures, permitting requirements, and recommended design and construction methods for access structures.

Vegetation and Dune and Bank Stability

Salt-tolerant plants with extensive root systems help stabilize dunes and banks—roots hold sediments in place and leaves and stems absorb water, break the impact of raindrops or wave splash, and slow and diffuse the flow of overland runoff. Plants can also help trap windblown sand, which is particularly important for building dunes and buffering inland areas from storm waves, erosion, and flooding. For more information on the benefits of coastal plants on dunes and banks, see the Massachusetts Office of Coastal Zone Management's (CZM) StormSmart Properties Fact Sheet 3: Planting Vegetation to Reduce Erosion and Storm Damage.

American beachgrass is particularly useful for stabilizing dunes because it is extremely hardy and grows readily on the coast. In addition, its fast-growing rhizomes (underground stems) effectively stabilize sediments and allow for quick establishment of new plants. (For more on the benefits of beachgrass for dune stability, see CZ-Tip - Dune Building with Beachgrass.)

Elevated Structures

Pathways at ground level do not define and designate pedestrian access to the beach as clearly as elevated structures and can lead to the trampling of nearby beachgrass and other stabilizing vegetation. In addition, since low pathways are not always clearly visible, pedestrians often inadvertently create additional pathways to get to the beach. Dune plants, including beachgrass, are vulnerable to being trampled—walking directly over or through a dune can kill dune plants and create landslides, bare spots, and the potential for dune blowouts (i.e., areas where strong winds “blow out" sand and form a depression), as well as lower the overall height and stability of the dune. Walking over banks can also kill vegetation, leading to landslides, erosion, and reduced bank stability.

Boardwalks, walkways, and stairways are therefore preferable to at-grade pathways. Not only are they clearly visible and defined, they also allow for the growth of stabilizing vegetation and the natural movement of sand and sediments beneath them. (In some circumstances, however, at-grade rollout structures used on a seasonal basis are a good option—see “**Sectional, Adjustable, and Temporary Design Elements**” below for more information.)

Permits First!

Because activities on the coast can easily impact natural resources and neighboring properties, they are strictly regulated. The construction or replacement of a boardwalk, walkway, or stairway on or near a dune, bank, or beach will require a permit under the Massachusetts State Building Code, as well as a permit through your local Conservation Commission and the Massachusetts Department of Environmental Protection's (MassDEP) Wetlands and Waterways Program. (Contact your city or town for local permit applications and requirements.) Though a permit is required, the Wetland Protection Act Regulations allow and encourage pedestrian walkways on dunes, provided that they are designed to minimize the disturbance to vegetation and promote the ability of dunes to move, shift, and migrate. Construction of structural accessways may also warrant review by the Natural Heritage and Endangered Species Program (NHESP) to ensure there are no conflicts with bird nesting habitat or other species requirements. Depending on project location and the work involved, other permits or approvals may also be required, such as under the state’s Chapter 91: Public Waterfront Act and its Waterways Regulations (310 CMR 9.00) and the federal Rivers and Harbors Act and Program Regulations.

Design and Construction Tips

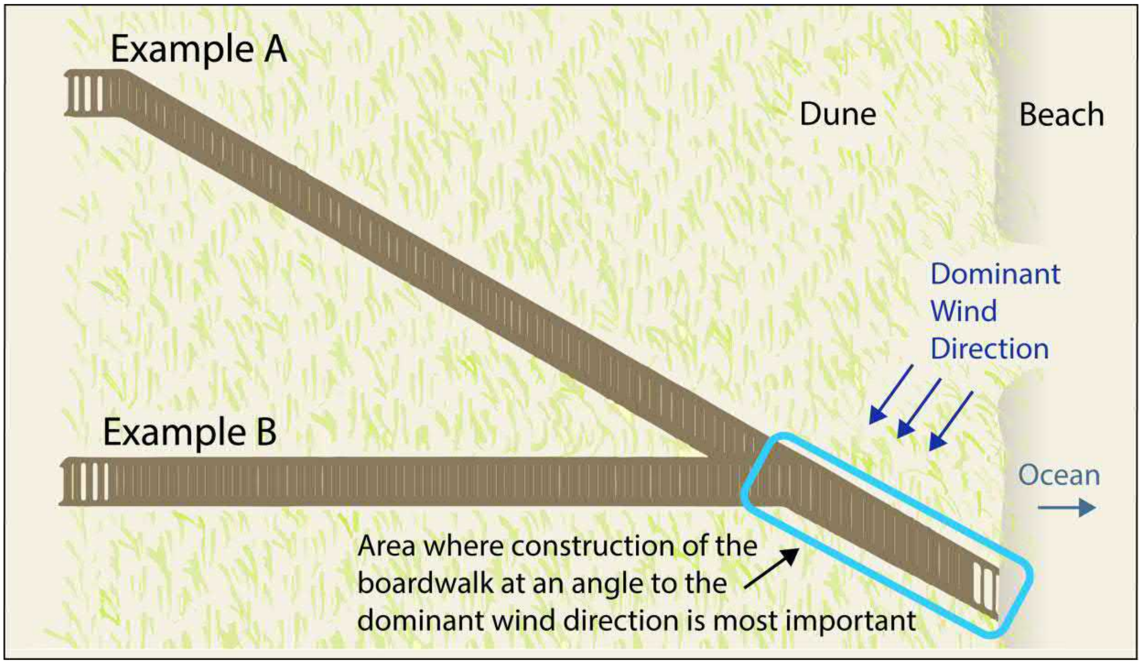
To rebuild pedestrian accessways in a way that minimizes impacts to coastal dunes and banks, follow these design and construction guidelines:

- **Size** - Overly large structures on coastal dunes and banks limit growth of beachgrass or other salt-tolerant vegetation. In general, boardwalks, walkways, and stairways should be no wider than 4 feet (and preferably narrower) and extend no longer than necessary to provide access to the beach (see "**Orientation**" below for more details).
- **Elevation** - Sufficient elevation is important for plant growth and to allow the natural movement of sand and other sediments under and around the structure. For dunes, elevating the structure on posts or pilings without footings—and at least 2 feet above the grade of the surrounding dune—will allow for easy movement of sand or sediments, dune growth, and enough sunlight to penetrate under the structure for plant growth. It is important to elevate the access structure 2 feet above the grade of the surrounding dunes (and not just 2 feet above the dune directly below the structure) to ensure elevation is maintained after the dune builds back up. For banks, elevating the structure at least 2 feet above grade allows for the growth of stabilizing vegetation and the natural movement of bank sediments to feed area beaches.

This boardwalk is elevated 2 feet above the surrounding grade to allow sunlight to penetrate, plants to grow, and sediments to move.

- **Additional Options for Increasing Sunlight** - The elevated structure can be built with additional elements that help reduce shading impacts on plants. Sections of metal grate with openings can be used for the walkway's surface, or planks can be spaced 1 inch apart (enough space to allow sunlight to penetrate under the structure, but not enough to impede safe access on the walkway). For stairways, using treads without risers will also reduce shading effects on plants.

- **Orientation** - Avoid the creation of damaging wind or wave tunnels by properly orienting the boardwalk, walkway, or stairway across the dune. The recommended approach is to construct the structure at an angle away from the dominant wind and wave direction (see Example A in the figure below). As long as the walkway section closest to the beach is oriented in this manner, a break in the angle can be constructed in the more sheltered area further inland to reduce the length of the walkway (see Example B).



Boardwalks correctly constructed at an angle to the dominant wind direction.

Roll-out, sectional, at-grade boardwalk

- **Sectional, Adjustable, and Temporary Design Elements** - Access structures can be built with elements to reduce impacts over time, such as the use of breakaway sections to minimize impacts to the stability of the underlying dune or bank if a section is destroyed. An alternative to permanent elevated structures on dunes is the seasonal use of roll-out, at-grade, sectional boardwalks. These temporary structures can be removed during the off-season to reduce the potential for storm debris and to allow the dune to function unimpeded when wind-driven sediment transport is generally higher and the demand for beach access is reduced.

- **Reducing Overland Runoff Issues** - Another consideration, particularly on coastal banks, is overland runoff (rainwater, snowmelt, and water from irrigation systems and other sources that does not soak into the ground or evaporate, but instead flows over the ground surface). Generally, runoff should be redirected away from the top of the bank, particularly at the access point of the structure, to avoid creating a gully and erosion of the bank face. The area under the walkway can also be planted to stabilize the soils and sediments. See CZM's StormSmart Properties Fact Sheet 2: Controlling Overland Runoff to Reduce Coastal Erosion for more information.
- **Time of construction** - Construction activities should be timed to minimize or avoid impacts if they are in or adjacent to endangered or threatened species habitat (contact NHESP for additional information). In addition, construction that will remove plant cover and expose areas to erosion during the storm season (winter) is not recommended. When planting, allow enough time for beachgrass to grow in the spring or fall to be able to provide protection and stability to the underlying landform.
- **Materials** - When deciding the type of construction material to use for your structure, consider materials that will resist rot and other deterioration. Though pressure treated wood is effective, it contains arsenic, which poses health risks to you and the environment. See MassDEP's Q&A: Pressure Treated Wood page for information on the health risks associated with this product. Other options include non-arsenic-containing hardwoods (such as cedar and redwood), wood composites, and non-wood alternatives such as metals and plastics.
- **Maintenance** - General maintenance is typically required to ensure the longevity of the structure, such as repairing and replacing sections. Any components of the structure that are damaged or broken should be removed to ensure public safety and natural sediment movement.

ATTACHMENT F

MA NHESP Rare Species Fact Sheet

Natural Heritage
& Endangered Species
Program

www.mass.gov/nhesp

Massachusetts Division of Fisheries & Wildlife

Piping Plover
Charadrius melodus

State Status: **Threatened**
Federal Status: **Threatened**

GENERAL DESCRIPTION: The Piping Plover is a small, stocky shorebird with pale brownish gray or sandy-colored plumage on its backside, with a white breast, forehead, cheeks, and throat, a black streak on the forecrown extending from eye to eye, and a black breastband which may not always form a complete circle. Its coloration gives it excellent camouflage in sandy areas. The average Piping Plover is 15 to 17 cm (6 to 7 in.) long, with a wingspan of 35 to 40 cm (14 to 16 in.). The tail is white at the base and tip, but dark in the middle. It has yellow-orange legs and its short bill is yellow-orange with a black tip in the summer, but turns completely black during the winter. In general, females have darker bills and lighter plumage than males. The Piping Plover runs in a pattern of brief starts and stops; in flight, it displays a pair of prominent white wing stripes. Its call is a series of piping whistles.

SIMILAR SPECIES: The Piping Plover is similar to the Semipalmated Plover (*Charadrius semipalmatus*) in size, shape, and coloration. However, the Semipalmated Plover is a darker brown in color, and has much more black on its head than the Piping Plover. The Semipalmated Plover does not breed in Massachusetts but is present on sandy beaches and intertidal flats from late July to early September during its southward migration.

HABITAT: Piping Plovers in Massachusetts nest on sandy coastal beaches and dunes, which are relatively flat and free of vegetation. Piping Plovers often build their nests in a narrow area of land between the high tide line and the foot of the coastal dunes; they also nest in Least Tern colonies. Nesting may also occur on vegetated dunes and in eroded areas behind dunes.

RANGE: During spring and summer, the Atlantic Coast population of Piping Plovers nests from the Newfoundland south to North Carolina. In winter they migrate farther south, from North Carolina to Florida, the Gulf of Mexico, and the Caribbean. Other populations of Piping Plovers nest along rivers on the Northern Great Plains and along the shores of the Great Lakes, migrating to the Gulf of Mexico in the winter.

POPULATION STATUS IN MASSACHUSETTS: The Atlantic Coast population of Piping Plovers is listed as Threatened at both the state and federal levels. In 2005, 475 breeding pairs nested at about 100 sites.

Massachusetts has the largest breeding population of Piping Plovers along the Atlantic Coast.

LIFE CYCLE / BEHAVIOR: As soon as Piping Plovers return to their breeding grounds in Massachusetts in late March or April, the males begin to set up territories and attract mates. Territorial rivalry between males is very strong; adjacent male Piping Plovers mark off their territories by running side by side down to the waterline. Each bird takes turns, one running forward a few feet, then waiting for the other to do likewise. Nests are usually at least 200 feet apart; the nesting pair will confront any intruding Piping Plover which approaches the nest. Male Piping Plovers also defend feeding territories encompassing beach front adjacent to the nesting territory.

Courtship consists of a ritualized display by the male, who flies in ovals or figure-eights around a female, then displays on the ground by bowing his head, dropping his wings, and walking in circles around the female. The male also scrapes shallow depressions in the sand at potential nest sites. The female then chooses one of these nesting sites, usually in a flat, sandy area. The nest itself is a shallow depression which is often lined with shell fragments and small pebbles, which may aid in camouflaging the eggs. Female Piping Plovers typically lay four eggs per clutch, one egg every other day over a week's time. The eggs are sandy gray in color with dark brown or black spots, and all hatch within 4 to 8 hours of each other. Both parents take part in incubating the eggs until they hatch 26-28 days later.

The young chicks leave the nest within hours after hatching and may wander hundreds of meters before they become capable of flight. When threatened by predators or human intruders, the young run or lie motionless on the sand while their parents often pretend to have broken wings in an effort to attract the intruder's attention away from the chicks. Young Piping Plovers are brooded by their parents for 3 to 4 weeks and finally fledge 4 to 5 weeks after hatching, at which time they leave the nesting area.

Piping Plovers feed on marine worms, mollusks, insects, and crustaceans. They forage along the waterline, on mudflats at low tide, and in wrack (seaweed, marsh vegetations and other organic debris deposited by the tides) along the beach. Foraging behavior consists of running a short distance, then staring at the ground with the head tilted to one side, often standing on one foot while vibrating the other foot on the ground, and finally pecking at the food item it has detected in the sand.

Piping Plovers begin to migrate southward between late July and early September, although occasional stragglers remain behind until late October. Adult birds often return to the same nesting area every spring, although they usually change mates from year to year. Young birds may nest anywhere from a few hundred feet to many miles from where they were hatched.

Updated 2015

A Species of Greatest Conservation Need in the Massachusetts State Wildlife Action Plan

G. Appendix G: Task 4 Coastal Resilience Toolkit Memorandum

AECOM
250 Apollo Drive
Chelmsford, MA 01824
aecom.com

Project name:
Point of Pines and Riverside Area Coastal Resilience Feasibility Study

Project ref:
60646341

To:
Elle Baker, Project Planner, City of Revere
Frank Stringi, City of Revere

CC:
File

From:
Aaron Weieneth
Jennifer Doyle-Breen
Tom Touchet
Kira Murphy
Carina Tracy
Tom Redstone

Date:
June 30, 2021

Coastal Resilience Toolkit– FINAL

1. Introduction

The Point of Pines / Riverside Area Coastal Resiliency Feasibility Study was conceived as an integrated coastal protection initiative for the City of Revere. The study consists of six memoranda aimed to evaluate the flood vulnerability and potential mitigation options for the Project area (Figure 1.1). This memorandum is the fourth of six in the series and provides potential permanent structural, non-structural, and nature-based adaptation measures that could be used for climate resilience. Attached to this memorandum in Appendix A is a coastal resilience toolkit that may act as a resource for future climate resilience projects. This toolkit may be used not only for the City of Revere's Point of Pines/Riverside Area Resiliency Study, but also for other coastal municipalities in the Commonwealth.

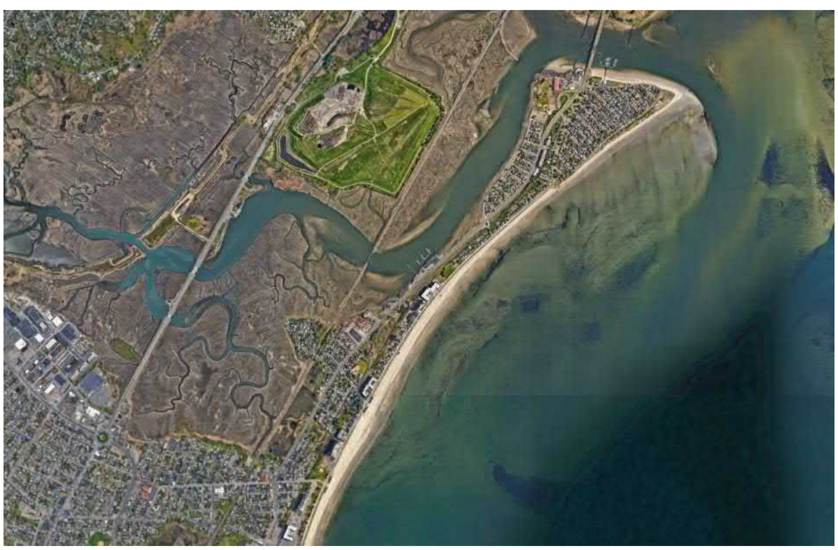


Figure 1.1 – Google Earth Image of Project Site

2. Vulnerability to Flooding

The Point of Pines/Riverside Area peninsula is located in the northeast section of the City of Revere. Based on the Massachusetts Coastal Flood Risk Model (MC-FRM) data shown in Figure 2.1 below, about 75% of the project area is projected to be inundated with more than 4 feet and up to 10 feet of water in 2050's 100-year storm conditions. As shown in Figure 2.2, almost 90% of the project area will be inundated with 10 feet of water in 2070's 100-year storm. As described in the Task 3 memorandum, the FEMA firm indicates that the entire peninsula is within the present day 100-year storm flood plain. The eastern side of the peninsula is within the coastal VE zone, as it is subject to harsher coastal waves, and the western side is within the coastal AE zone.

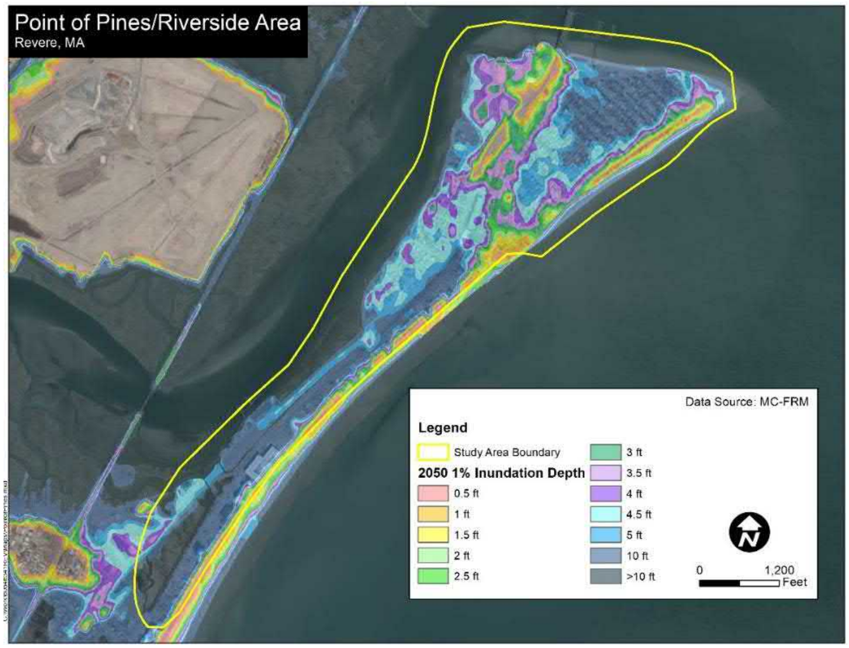


Figure 2.1 - Flooding Probability for a 1% 2050 Coastal Storm

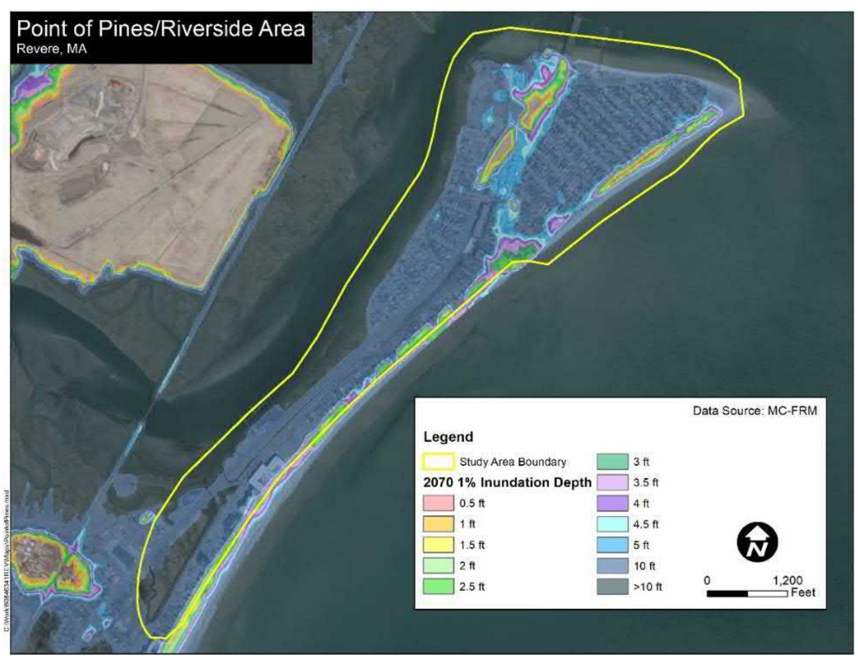


Figure 2.2 - Flooding Probability for a 1% 2070 Coastal Storm

3. Coastal Resilience Toolkit

3.1 Structural

3.1.1 Pump Stations

Definition/Design Components

Stormwater pump stations help protect areas by pumping away large volumes of water, thereby minimizing the occurrence of flooding. Many cities and municipalities are located on or near bodies of water, creating a need for large, reliable pumping systems capable of handling large volumes of water.

Figure 3.1 – Pump Station in New Orleans

Case Study

In response to the flood damage to New Orleans by Hurricane Katrina, the pumping capacity was increased at the 17th Street and London Avenue canals, allowing for future worst-case hurricane drainage to be pumped out of the city and into Lake Pontchartrain (Figure 3.1). The design and construction of the pumping stations involved several massive pumping platforms, 33 huge vertical turbine pumps, diesel engines, gearboxes, and piping. It wasn't until the 2008 season that the platforms and pumps were tested by Gustav, a strong Category 2 Hurricane. Under those severe conditions, the pumps were found to operate as designed in a superb manner, keeping the potential flood waters from Gustav safely in check.

3.1.2 Green Infrastructure for Stormwater Management

Definition/Design Components

Green infrastructure practices for stormwater management mimic natural habitats and absorb excess water. This reduces the amount of pollution in receiving waters. Green infrastructure practices include permeable pavements, rain gardens, bioretention cells (or bioswales), vegetative swales, infiltration trenches, green roofs, planter boxes, rainwater harvesting (rain barrels or cisterns), rooftop (downspout) disconnection, and urban tree canopies.

Figure 3.2 - Green Roof in Salt Lake City

Case Study

The Assembly Building for the Church of Jesus Christ of Latter-Day Saints in Salt Lake City, Utah is designed to accommodate 21,000 congregants. Given that this is a large structure in a fast-growing urban jungle, it is an ideal piece of infrastructure for a green roof. The roof balcony terrace and orchestra levels of the auditorium are integrated with an extensive system of fountains exterior stairs gardens and a five-acre rooftop alpine meadow (Figure 3.2). The green roof slowly absorbs stormwater and releases the remainder slowly over the period of a few hours as opposed to sending large volumes of contaminated rain water to the streets below, exacerbating flooding and increasing erosion. The Church of Jesus Christ of Latter-Day Saints Conference Center won the 2003 Green Roofs for Healthy Cities Award of Excellence in the New Combination category.

3.1.3 Flood Storage Area Creation

Definition/Design Components

The purpose of a flood storage area is to help reduce peak flows in a body of water, therefore reducing flooding. During heavy rain, the flood storage area structure fills with water, temporarily holding back flood water and reducing the flood risk to properties nearby. Once the flood has passed the water in the storage area will subside. Flood storage areas can consist of above-ground areas or below-ground storage.

Figure 3.3 - Flood Storage Area on the River Foss

Case Study

Proposals to create a flood storage area on the River Foss in North Yorkshire, England have been approved by York City Council. During a flood event, the level of the River Foss can rise rapidly exposing properties, roads, and land to the risk of severe flooding. The new flood storage area (Figure 3.3) will better protect 490 vulnerable homes between Strensall and The Groves area of York from flooding. Materials for building the embankment for the storage area will be taken from within the site, creating pits which fill with water and act as permanent shallow ponds. These areas are not like reservoirs and do not store water permanently. They are designed to be dry in normal weather conditions and only fill up for short periods during large flood events.

3.1.4 Impervious Surface Removal/Reduction

Definition/Design Components

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. Water then re-enters the ground naturally and can flow back to the stream system. Patios, walkways, parking areas, and driveways can all be converted to pervious areas that increase infiltration to groundwater. Gardens, lawns, and permeable pavers all can be used in place of the impervious area removed.

Figure 3.4 - Porous Pavement in Portland

Case Study

A prime example of these structures comes from Portland, Oregon, where one of the nation's largest porous asphalt parking lots went into place early last year (Figure 3.4). It is located at the Port of Portland on the Columbia River and covers 46 acres of land. The parking lot is used to store Hyundai cars until they can be shipped to dealers. In areas totaling 11 acres—where delivery trucks travel heavily—the pavement is standard dense-graded asphalt. Over the remaining 35 acres, contractor Lakeside Industries of Portland paved a 3-in. course of open-graded porous asphalt. The native river sand along the Columbia River, which easily absorbs water from the parking lot, made the choice of porous asphalt a natural.

3.1.5 Bioretention Basins

Definition/Design Components

Bioretention basins are landscaped depressions or shallow basins used to slow and treat on-site stormwater runoff. Stormwater is directed to the basin and then percolates through the system where it is treated by a number of physical, chemical, and biological processes. The slowed, cleaned water is allowed to infiltrate native soils or directed to nearby stormwater drains or receiving waters.

Figure 3.5 - Bioretention Basin at Lutsen Resort

Case Study

Figure 3.5 illustrates a detention basin in an old gully at Lutsen Resort in Lutsen, MN traps sediment and reduces velocity of runoff through development. This gully used to carry runoff from above the highway, but water was diverted when the highway was built, leaving the gully much drier.

3.1.6 Floodproofing buildings

Definition/Design Components

If relocating or elevating the building isn't feasible, then wet or dry floodproofing can reduce the risk of flood damage. Dry floodproofing techniques make the building watertight so that floodwaters cannot enter. Floodproof doors, windows and deployable panels are often used to seal existing openings. Wet floodproofing techniques allow the water to enter the structure but use flood damage resistant materials, hydrostatic openings, and protection of key equipment and contents to limit the damage.

Figure 3.6 – Glass Flood Proof Windows at NYU Kimmel Security Room

Case Study

Figure 3.6 above provides an example of dry floodproofing NYU Kimmel Security Room. Standard windows and frames are replaced with flood proof glass windows. These windows are built to resist flood and debris impact loads. With all other components of the building (doors, walls, etc.) also dry flood proofed, there is no need for a static or deployable flood barrier around the perimeter of the building.

3.1.7 Relocating Buildings

Definition/Design Components

Building relocation is a mitigation measure that can offer the greatest protection from future flooding. It involves moving an entire building to another location on the same lot or to another lot, usually outside the floodplain.

Figure 3.7 – Flooded Properties in Kinston, North Carolina

Case Study

Kinston, a city of about 20,000 in Lenoir County, North Carolina, suffered repeated flood losses during the 1990s (Figure 3.7). After Hurricanes Fran, Dennis, and Floyd damaged or flooded more than 75 percent of the county's homes, the community embarked upon a comprehensive approach to improve resilience. Flood-prone properties such as the ones shown in Figure 3.7 above were purchased, and whole neighborhoods were relocated to higher ground. As a result, natural floodplain functions were restored, and the purchase of the first 100 homes saved approximately $6 million in avoided flood losses during the next big storm.

3.1.8 Elevated Buildings

Definition/Design Components

Elevating buildings is a resilience measure that raises a building above the flood level. The building can be physically lifted, and an elevated foundation system can be built underneath it. Alternatively, a lower floor can be abandoned, or in some cases, the building can be demolished entirely, and a new elevated building can be designed in accordance with local codes and standards.

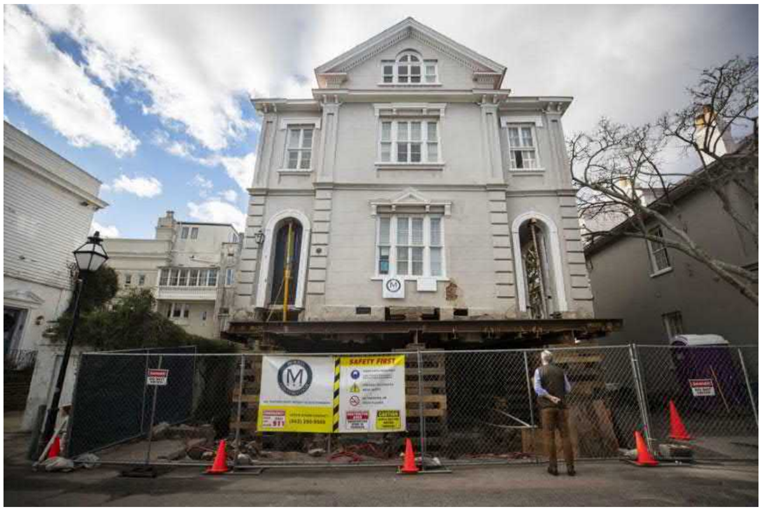


Figure 3.8 – House being elevated in Charleston, South Carolina

Case Study

Figure 3.8 illustrates a house that is in the process of being raised on Water Street in Charleston on Friday, February 7, 2020.

3.1.9 Elevated Roadways

Definition/Design Components

Road transport infrastructure that is prone to flooding can be raised to serve as a more reliable evacuation route. Elevated roads can look like a fixed bridge or can be a road on top of a bank, thus elevated with sand.

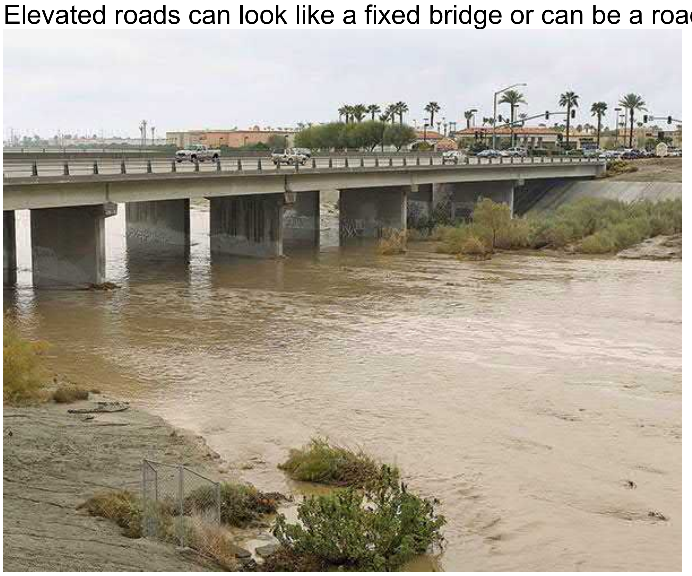


Figure 3.9 – Elevated roadway in Coachella Valley

Case Study

The Coachella Valley is an arid desert region averaging less than 3 inches of rain per year. However, the surrounding mountains are subject to much higher rainfall rates which can produce unpredictable, damaging, and even deadly flash flooding events throughout the Coachella Valley. Roadways are elevated as shown in Figure 3.9 above to preserve evacuation routes during a flash-flood event.

3.1.10 Flood Walls

Definition/Design Components

A flood wall is a static vertical barrier built to temporarily contain waters which may rise to unusual levels during seasonal or extreme weather events. Flood walls are engineered structures usually built of concrete to minimize inundation risks for a single structure or multiple structures. Flood walls are typically used in locations where space is scarce, such as cities, densely developed areas, or where building levees or dikes would interfere with other interests, such as existing buildings, historical architecture or commercial use of embankments. Flood walls can be buried, partially exposed as shown in Figure 3.10, or fully exposed. Seepage barriers are also often used in conjunction with flood walls to provide flood protection.

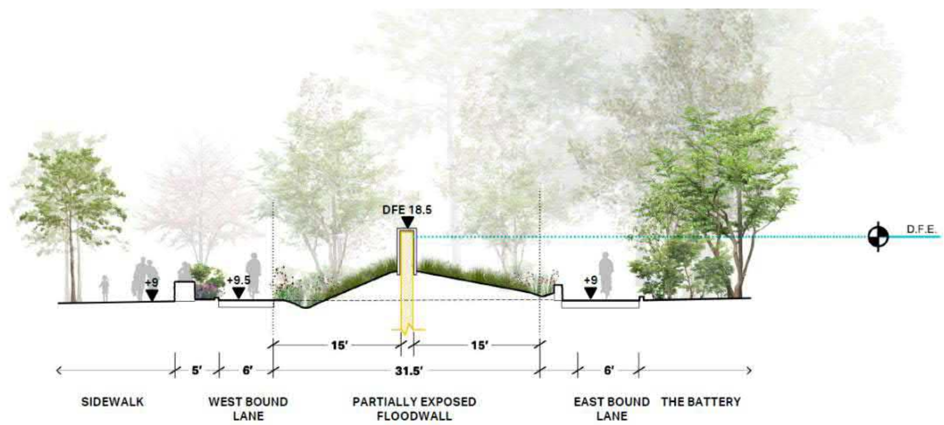


Figure 3.10 – Partially Exposed Floodwall used in South Battery Park City Resiliency Project

Case Study

The South Battery Park City Resiliency project is one of four interrelated resiliency projects to protect Battery Park City from the threats of storm surge and sea level rise. The South Battery Park City Resiliency Project aims to construct a continuous flood barrier from the Museum of Jewish Heritage, through Wagner Park, across Pier A Plaza, and along the northern border of Historic Battery Park. Due to the unique landscape and environmental constraints presented in each section of the project area, several various types of risk reduction measures have been proposed. In the Battery Park segment of the project area, a partially exposed floodwall is constructed to a design flood elevation of 18.5 feet as shown in Figure 3.10 to protect critical roads and infrastructure in Lower Manhattan.

3.1.11 Deployable Structures

Definition/Design Components

Deployable flood barriers are designed to maintain pedestrian and vehicle access during typical conditions and only deployed before the onset of an extreme weather event. Examples of deployable structures include flip-up gates, swing gates, and sliding gates. These deployable measures can be activated by a push button, automatically triggered by sensors, or operated manually. Flip up gates are stowed on site in situ and can also be deployed using hydraulics. Seepage barriers are also often used in conjunction with deployable structures to provide flood protection.

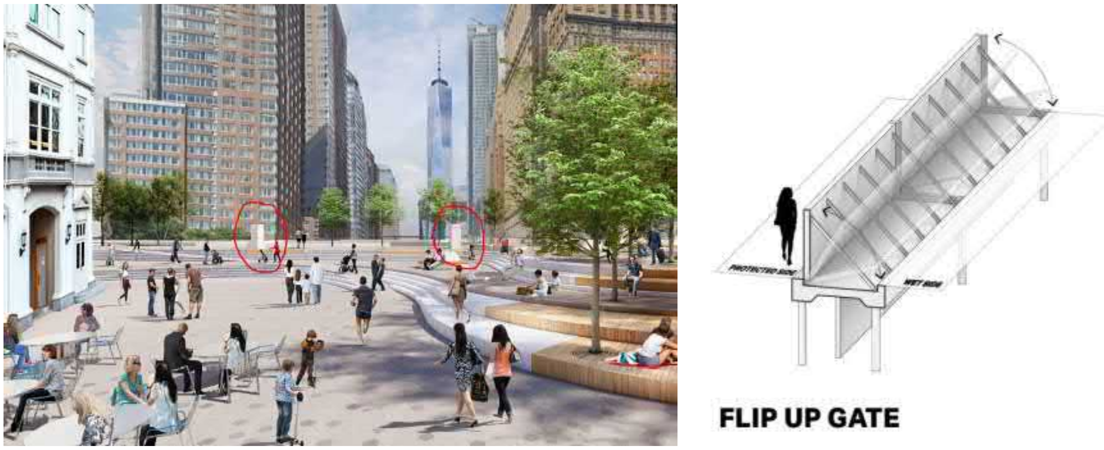


Figure 3.11 – Flip Up Deployable Gate used in Pier A Plaza of South Battery Park City

Case Study

As mentioned above, the South Battery Park City Resiliency Project aims to construct a continuous flood barrier from the Museum of Jewish Heritage, through Wagner Park, across Pier A Plaza, and along the northern border of Historic Battery Park. In Pier A Plaza, flip up gates will be used to protect Battery Place and other roads located behind the Plaza. There are usually permanent posts, two of which are shown in Figure 3.11 above, that the gates when deployed will lock into in order to form a continuous barrier.

3.1.12 Coastal Structures (seawall, bulkheads revetments, breakwaters)

Definition/Design Components

Coastal structures are built along the shoreline to protect coastal areas from erosion cause by wave action, currents, and flooding during heavy seas. Bulkhead and seawalls are constructed of a variety of materials including rubble mounds, granite masonry, or reinforced concrete. They are usually supplemented by steel or concrete sheet pile driven into the soil and are strengthened by wales and brace type piles. Breakwaters are typically large rubble- or precast concrete unit mound structures and revetments are sloping structures formed by layering stone or concrete.

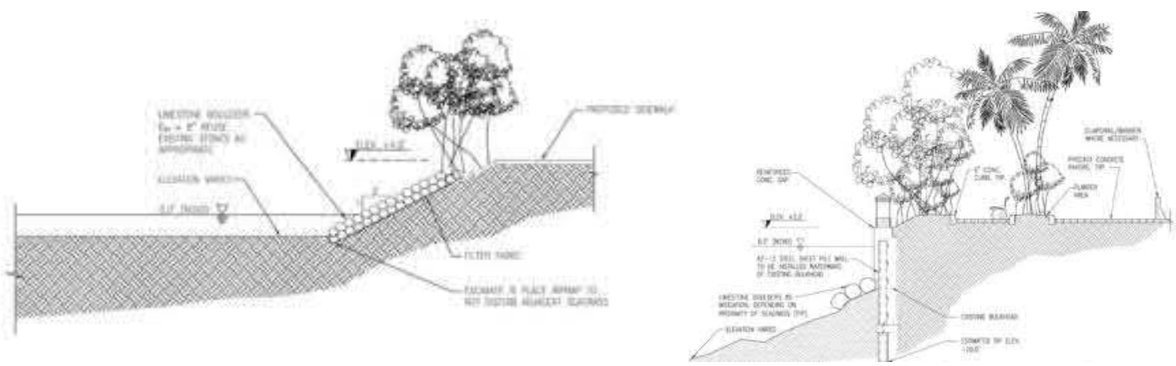


Figure 3.12 - Rip Rap Revetment in Miami Beach

Case Study

As a part of the City of Miami Beach, Florida Right-of Way Infrastructure Improvement Program, coastal structures were implemented to provide flood protection along the Oceanfront Indian Creek Greenway. A shown in Figure 3.12 above, a rip rap revetment constructed of limestone boulders was built up along the shoreline up to the new sidewalk.

3.1.13 Offshore Structures

Definition/Design Components

Offshore structures such as tide gates and surge barriers protect estuaries against storm surge flooding and related wave attack. These barriers also prevent excessive intrusion of salt-water wedges during high-water episodes. Typically, these offshore structures are made of a series of movable gates that normally stay open to let the flow pass but will be closed when storm surges exceed a certain level.

Figure 3.13 - Tide Gates in the Thames River

Case Study

The tide gates on the Thames River, referred to as the Thames Barrier, span 1,700 ft across the River near Woolwich, and protect 48 square miles of central London from flooding caused by tidal surges. The barrier consists of 10 steel gates that can be raised into position across the River Thames (Figure 3.13). When raised, the main gates stand as high as a 5-story building. The barrier is closed under storm surge conditions to protect London from flooding from the sea. The Thames Barrier will then remain closed over high water until the water level downstream of the Thames Barrier has reduced to the same level as upstream. Once leveled, the Thames tidal gates are opened, allowing the water upstream to flow out to sea with the outward-bound tide.

3.1.14 Backflow Prevention

Definition/Design Components

Backflow prevention devices are stormwater control devices that are either attached to the discharge end of a stormwater outfall pipe or structure or installed within the pipe to prevent rising waters outside of the stormwater system from entering into the system. Backflow prevention devices may include flap gates/valves, duckbills, inline check valves, self-regulating tide gates, and other designs.

Figure 3.14 Replacement of a metal flap valve device with a duckbill backflow prevention device

Case Study

A metal flap valve on a tidal section of the Parrett River located in Bridgewater, England was constantly blocked due to mud and silt buildup. As a result of these continual maintenance issues, the existing metal flap valve was replaced with a new duckbill valve (Figure 3.14). The duckbill valve was chosen for this application due to its ability to free-drain and in most cases, self-clear.

3.2 Non-Structural

Non-structural climate adaptation measures are important components of coastal resiliency planning. With regard to flood damage reduction strategies to improve coastal resilience, a non-structural flood damage reduction strategy is one that does not alter the water surface elevation of the coastline or neighboring streams and water bodies. Whereas structural flood mitigation strategies, such as flood control dams, detention basins, and flood diversion channels modify a community's risk to flooding, non-structural flood mitigation strategies such as community awareness and preparedness, land use zoning, and property acquisition modify a community's exposure and vulnerability to flooding.

3.2.1 Land Acquisition

Definition

Targeted land acquisition can be used as a tool for enhancing coastal resilience via the purchasing of strategically important or perpetually vulnerable privately-owned property by public entities. The goal of targeted acquisition is to reduce and/or prevent repeated storm-related property damage and associated public expenditures. After acquisition, existing structures are demolished or relocated, and no additional permanent structures are built (other than public access or public amenities, depending on the property involved and ultimate plan for the property). Land acquisition can be used in conjunction with wetland and other habitat preservation and restoration as necessary.

Figure 3.15 - Vulnerable private properties on North Topsail Beach, North Carolina

Case Study

A major difficulty in considering targeted acquisitions as a coastal management tool for most communities is the lack of any analysis of the costs versus. benefits. In the absence of a cost/benefit analysis, most communities view acquisitions as cost prohibitive. Although beach nourishment can provide benefits for protecting coastal development, targeted acquisitions can help protect the littoral processes of barrier beaches and eliminate the potential damage to problematic coastal properties thereby minimizing the resulting federal, state, and local capital expenditures. Targeted acquisitions can also maximize the value of other nearby resources or assets. The Western Carolina University Program for the Study of Developed Shorelines performed a targeted land acquisition analysis for 347 vulnerable coastal properties on Northern Topsail Beach (NTB) in North Carolina (2019; Figure 3.16). Their study examined the estimated 30-year cost for beach nourishment versus land acquisition of targeted vulnerable properties. The study concluded that a modest raise in property taxes over the same 30-year period would be more than enough to cover these targeted acquisitions as compared to beach nourishment activities if there is no state cost-sharing for beach nourishment.

A worst-case property acquisition cost is assumed at $30.1 million dollars. The 30-year cost for beach nourishment with state cost sharing at North Topsail Beach is $7.7 million. However, without state cost-sharing, the long-term net cost of beach nourishment to NTB increases to $39.3 million. Potential sources of supplemental funding for acquisition such as private foundations, federal funding, and property tax increases were not considered in the initial analysis. However, the study found that if property taxes increased one cent per $100 of assessed value, the revenue from the increase would result in $58 million dollars over 30 years, which would be more than enough to cover these targeted acquisitions as compared to beach nourishment activities (Western Carolina University, 2019).

3.2.2 Evacuation Procedures

Definition

While some natural emergencies provide several days of advance notice prior to the start of an evacuation, other natural emergencies are considered “no-notice” events that require immediate response. It is the responsibility of local emergency management agencies to develop community evacuation procedures that respond to all potential hazards and scenarios.

The first step of preparing a local evacuation plan to improve coastal resiliency is to identify vulnerable flood-prone locations. Flood-prone locations can be identified using historical records and hydrology and hydraulics (H&H) modeling techniques. Sea, Lake, and Overland Surges from Hurricanes (SLOSH) models developed by the National Weather Service (NWS) identify locations in coastal communities that are vulnerable to hurricane storm surge. FEMA's Risk Mapping, Assessment, and Planning (Risk MAP) program provides additional resources to identify a community's flood risk. Within coastal Massachusetts, the Massachusetts Coast Flood Risk Model (MC-FRM), which was developed through a collaboration between the Woods Hole Group, the Massachusetts Department of Transportation (MassDOT), and the University of Massachusetts, is an additional source of flood risk reduction.

Evacuation procedures should identify the community's evacuation route network and pre-defined evacuation shelters. Detailed traffic studies should be performed to prepare for large-scale community-wide evacuations. It is critical to identify vulnerable populations who are at greater risk of requiring evacuation and to identify vulnerable populations that are likely needing special assistance to reach their destinations of refuge. These populations include those with access and functional needs, populations without access to a private vehicle, children and unaccompanied minors, and populations experiencing homelessness. Local governments should engage the entire community to conduct awareness briefings and preparedness training so that community stakeholders are aware of what may be expected of them in the event of a required evacuation.

Case Study

The City of Revere is equipped with a comprehensive Emergency Operation Plan in which decision support tools are provided to assist in evacuation or shelter in place actions. The City has allocated three buildings as evacuation shelters for residents should the need for evacuation occur. In Figure 3.17 below, the evacuation route from the Point of Pines/Riverside area to any these shelters is within the flood inundation zone.

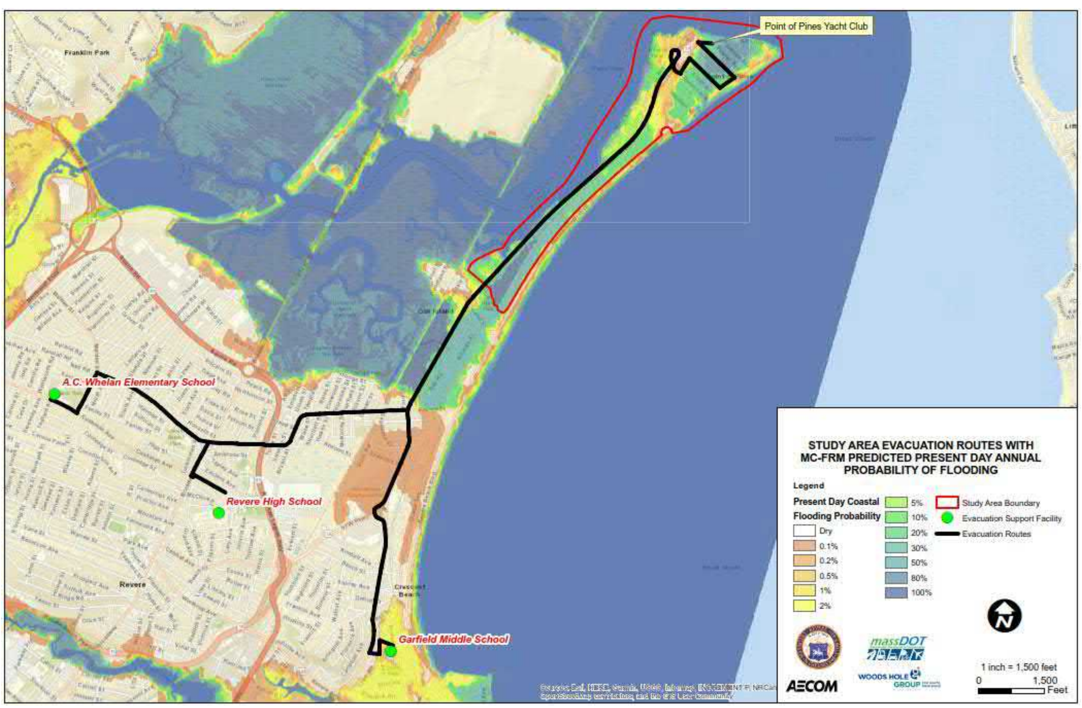


Figure 3.16 - Emergency Evacuation Routes

3.2.3 Public Outreach and Education

Definition

Public outreach and education are important components of coastal resiliency planning. Outreach and education efforts can take many forms, including written materials (brochures, mailings, etc.), videos, public presentations, and training courses/workshops.

Protect your family and your home!

People and their homes in coastal communities, like Plymouth, are regularly threatened by natural hazards. In 1991 Hurricane Bob caused nearly one billion dollars in damages. Nor'easters impact our coastline every year causing millions of dollars in damages. Although not all homes are in designated high-hazard areas (see below), your home may still be at risk due to erosion, localized flooding, and sea level rise. Last year, the National Flood Insurance Program (NFIP) paid one-third of its claims to homes in low-risk communities.

Patriot's Day Storm
This could be you!

Before the Storm

Understand Your Risk of Flooding

Currently state and local regulations use the Federal Emergency Management Agency's (FEMA) Flood Insurance Rate Maps (FIRMs) to show the estimated extent of flooding during a hypothetical storm. This storm is called the "100 year storm" and it has an estimated 1% chance of being equaled or exceeded during any given year. Over the life time of a 30 year mortgage a storm of this magnitude has a 25 % chance of happening.

Homeowners should find out if their home is in a FEMA flood zone. The maps along with additional information can be found at the Planning Department. In addition to your local source, a full scale map of your location (called a FIRMette) is available through FEMA's website (msc.fema.gov).

For additional information on hazards mapping and risk, see the StormSmart Coasts (mass.gov/czm/stormsmart) section on hazard identification and mapping.

Prevent Losses

There are several proactive measures a homeowner can take to prevent losses from storm events. Plus, these steps can lower one's flood insurance premiums and result in long term savings (see fact sheet 5 on the StormSmart Coasts page).

Addition, partially funded by FEMA, constructed to elevate utilities.

Example of an elevated home and the possible insurance savings

1. Purchase flood insurance. This is not covered under your homeowner's insurance. To find an agent near you select agent locator at the NFIP (floodsmart.gov) site.
2. Relocate appliances, including the main electric panel, washing machine, drier, furnace, and water heater to areas less likely to flood.
3. Elevate your entire home above FEMA's base flood elevation (BFE). You can save money in the long term.
4. Consult a contractor about retrofitting and flood proofing your home. Information is also available at your local building inspector's office.
5. If you are considering doing work to your home, you or your contractor should be familiar with the best coastal construction techniques. These can be found through FEMA's coastal construction manual (fema.gov/rebuild/mat/fema55.shtm).
6. Be sure to check with your local building inspector, planning department and conservation agent to determine what local permits may be necessary.

There are grants available through FEMA to help homeowners pay for these flood loss prevention options.

Plan Ahead

How to information is available through MEMA's website (mass.gov/mema) under the "Hot Topics" section. It addresses many subject areas, including:

- Developing a family emergency plan
- Creating a disaster supply kit
- Sheltering in place
- Evacuating
- Safeguarding your possessions
- Preparing your home
- Ensuring your pet's safety

Emergency Personnel helping with an evacuation during the Patriot's Day Storm

Figure 3.17 - Flood hazard brochure for Plymouth, MA

Case Study

The Massachusetts Office of Coastal Zone Management (CZM) launched a pilot program for coastal hazard awareness for three coastal towns in Massachusetts: Duxbury, Kingston, and Plymouth. Similar to many coastal towns in Massachusetts, coastal resources such as coastal beaches, coastal banks, barrier beaches, salt marshes, salt ponds, and tidal flats in these towns experience coastal storm impacts including high winds and waves. The main goal of these three towns was to improve future coastal floodplain development trends through targeted education and outreach. Massachusetts CZM helped these towns achieve this goal by the development of a public information brochure regarding flood hazards and through targeted workshops (Figure 3.17). The brochure focused on concise descriptions of flood risk, preventing losses from flooding events, and proper planning for future flooding events. Workshops were targeted toward local officials and builders and included topics such as "no adverse impact" approaches to ensure development would not worsen flooding, low impact development techniques to reduce inundation impacts, construction site erosion control and stormwater management, and floodplain building techniques.

3.2.4 Local Building Code

Definition

While modern building codes are one of the most effective ways to mitigate natural hazards and reduce disaster loss, 65 percent of local jurisdictions lack modern building codes (FEMA, no date). Local building codes are intended to protect structures and the people and property inside them from flooding, windstorms, earthquakes, and other natural hazards and extreme weather events. Adoption and enforcement of contemporary building codes reflects a community's awareness of risk and commitment to maximizing its resilience. Local building codes establish reliable minimum construction standards that reduce vulnerability to and financial losses resulting from natural hazards and severe weather events. Building codes should be periodically updated to incorporate innovation and assure that newly constructed buildings include the most up-to-date disaster-resistant technologies.

To improve resilience from flooding, basic standards require that the lowest floor of a structure be above what is identified in the FEMA-delineated 100-year flood event; that is the water surface elevation that would result from a 1-percent annual probability flood event. However, communities are encouraged to adopt ordinances requiring freeboard elevation above the 1-percent annual probability flood event to account for the anticipated effects of climate change and sea level rise. As shown in Figure 3.19, the example structure has a freeboard clearance above the 1-percent annual probability flood event (identified in Figure 3.19 as 100-Year Wave Crest Elevation).

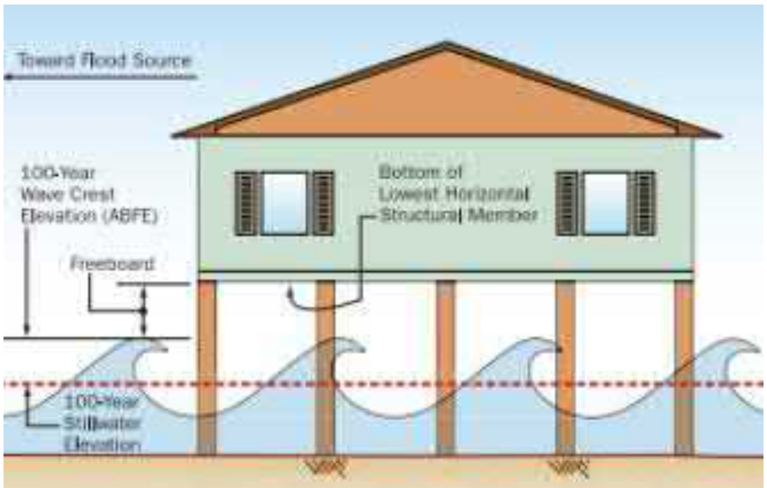


Figure 3.18: Structure Elevated Above Base Flood Elevation. Source: University of Connecticut

Case Study

The adoption of building codes provides significant financial benefits to communities. It is estimated that the adoption of the adoption of International Codes in Massachusetts yields an estimated $6.1 million in annual benefits, by reducing damages from flooding, hurricane wind, and seismic events (FEMA, 2020).

Per the 9th Edition of the Massachusetts Building Code, the design and construction of new buildings and structures located in flood hazard areas, shall be in accordance with Chapter 5 of ASCE 7 and ASE 24. Depending on the flood zone in question, the minimum structural elevation requirements are based on the base flood elevation and listed in section 1612.4. This version of the Massachusetts Building Code references the 2015 IBC. Any buildings or structures that were built prior and do not meet the elevation minimums provided may be subject to flooding and potential damage. If possible, it is recommended to raise older structures to the recommended elevation for maximum protection.

3.3 Nature Based Adaptation

3.3.1 Living Shorelines

Definition/Design Components

A living shoreline is a bioengineered natural infrastructure solution designed to assist in stabilizing a shoreline. It often consists of natural fiber products such as coir logs (coconut husk fiber) or natural fiber blankets planted with live native plants adapted to conditions at the site, but can also include the strategic placement of sand, stone fill, or other structural and organic materials for the purpose of stabilizing a shoreline. Living shorelines are a natural alternative to hard infrastructure such as concrete seawalls. Living shorelines can often provide additional benefits by providing wildlife habitat and carbon sequestration services.

Figure 3.19 - A living shoreline project in Orleans, MA

Case Study

An eroding toe of slope in Orleans, Massachusetts was stabilized by Wilkinson Ecological Design for a private homeowner using living shoreline techniques (Figure 3.14). The design included a stacked array of coir logs that were pre-planted with native coastal grasses at their nursery facility and transported to the site. The coir logs were fastened in place with cables and duck bill anchors. The vegetation in the coir logs was dormant at the time the photo was taken.

3.3.2 Beach/Dune Protection and Erosion Control

Definition/Design Components

Beaches are generally defined as stretches of sand or smaller loose particles (such as pebbles, shells, or gravel) that exist between the water and the land. Dunes are landforms that occur when there is a sufficient supply of sand or sediment and strong enough wind to promote sediment transport and, often, some type of an obstacle – vegetation being the most common – that allows the blown sand to accumulate. Beaches and dunes are naturally dynamic environments and will fluctuate in size and shape year to year based on the effect of wind, waves, tides, and storm events. These processes are essential to the ongoing maintenance of the natural system and, if interrupted or suspended, can have great negative impacts on the size and shape of the coastline and the ability of the system to provide flooding and erosion control benefits. A beach's size, width, slope, shape, and sand volume help determine how well the beach can protect a developed area during a storm. Beaches are capable of reducing impacts from coastal storms by acting like a buffer along the coastal edge and absorbing and dissipating the energy of breaking waves, either seaward or on the beach itself. Dunes serve as more of a barrier between the water's edge and inland areas, taking the brunt of larger storm surges. The wider a beach or dune system is, and the more space between the sea and any developed or populated areas, the more effective and efficient the system will be at reducing the impacts of coastal hazards.

Figure 3.20 - Beach replenishment around Cape May Point, New Jersey (before left photo) and after (right photo)

Case Study

Cape May Point is a small coastal community in New Jersey that has experienced significant storm damage over the years, particularly in 1991 and 1992, resulting in more than $75 million dollars in damage. These events prompted a diverse group of stakeholders to discuss options for a comprehensive shoreline restoration project. Following a USACE feasibility study and the obtainment of funding, 1,400,000 cubic yards of sand were used to construct a 1-mile long, 18-ft tall sand dune, widen 2 miles of beach, and restore freshwater wetlands and improve drainage culverts to improve drainage and help prevent flooding. The benefits of the beach and dune project also included increased beach nesting habitat for coastal bird species and an increase in ecotourism as a result. When Superstorm Sandy hit the New Jersey coastline in 2012, the newly created dune around Cape May Point were not breached.

3.3.3 Wetland and Habitat Preservation and Restoration

Definition/Design Components

Wetland and other habitat preservation and restoration is a management practice that protects existing areas that provide food and shelter for wildlife and also seeks to repair degraded areas to reinstate conditions that were previously valuable for wildlife survival and reproduction .Restoration at its simplest definition is the "return of an ecosystem to a close approximation of its condition prior to disturbance" (US EPA). While preservation activities focus on maintaining existing ecosystem functions and values, restoration aims to restore degraded ecosystem functions and values. Both preservation and restoration are valuable tools for coastal resiliency because coastal wetlands and other resource areas help protect upland areas from coastal storm damage by providing valuable services such as wave energy dissipation, flood water storage, and other important functions.

Figure 3.21 - Thin layer sediment augmentation in a wetland in Avalon, New Jersey

Case Study

One example of a type of wetland restoration to facilitate climate resiliency in response to wetland subsidence or inundation from rising sea levels that exceeds sediment accretion rates is thin layer sediment augmentation. This process typically involves the application of a thin layer of sediment slurry (dredge material) via a high-pressure nozzle across a wetland area. In the example above (Figure 3.17), thin layers of sediment were applied to a wetland complex in Avalon, New Jersey. Dredged sediments from the federally-maintained New Jersey Intracoastal Waterway following Superstorm Sandy were used for the application. Sediment placement depths ranged from 5-20 cm in vegetated areas and up to 50 cm in open water portions of the marsh. Initial results suggested that smooth cordgrass (*Spartina alterniflora*) responded well to thin layer sediment placement and buried marsh soils remained microbially active.

4. Conclusion

There are a multitude of ways to address the various needs and issues throughout the Point of Pines / Riverside Area project area but must be identified with a benefit and costs analysis. The long-term flood risk reduction measures discussed in this memorandum and the attached toolkit will act as a resource for future climate resiliency projects not only for the City of Revere, but also for other coastal municipalities in the Commonwealth. Potential permanent risk reduction measures were grouped into nature-based adaptation, stormwater management, flood protection, and critical infrastructure protection in the toolkit. Each of these measures has a particular way of performing, addressing a need, and relating to other components. For this reason, a range of solutions and combinations will likely be used to protect the project area.

5. Acronyms

Ac.	Acres
Ft. or ft	Feet
In. or in	Inches
MC-FRM	Massachusetts Coastal Flood Risk Model
MLW	Mean Low Water
MPO	Metropolitan Planning Organization
NYRCR	New York Rising Community Reconstruction
NGVD	National Geodetic Vertical Datum
PoP	Point of Pines
USACE	United States Army Corps of Engineers

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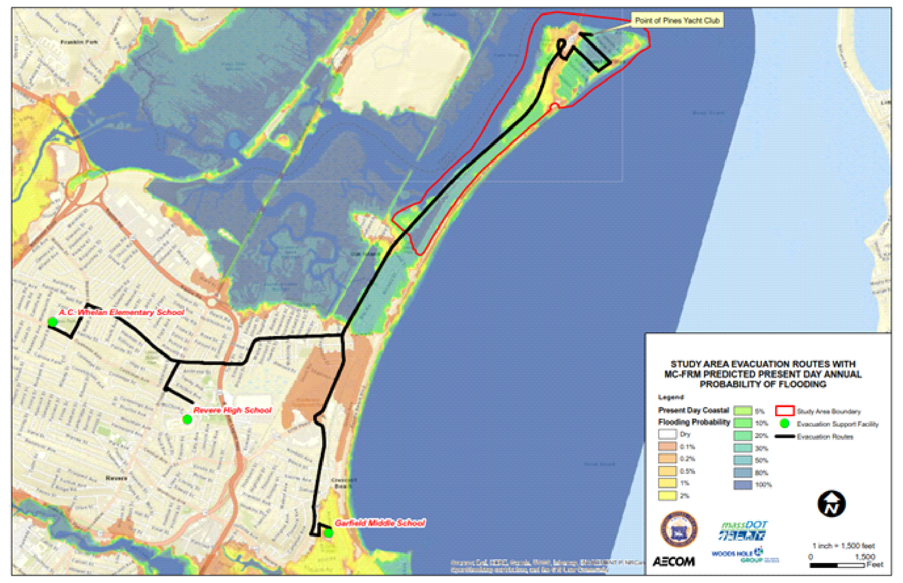
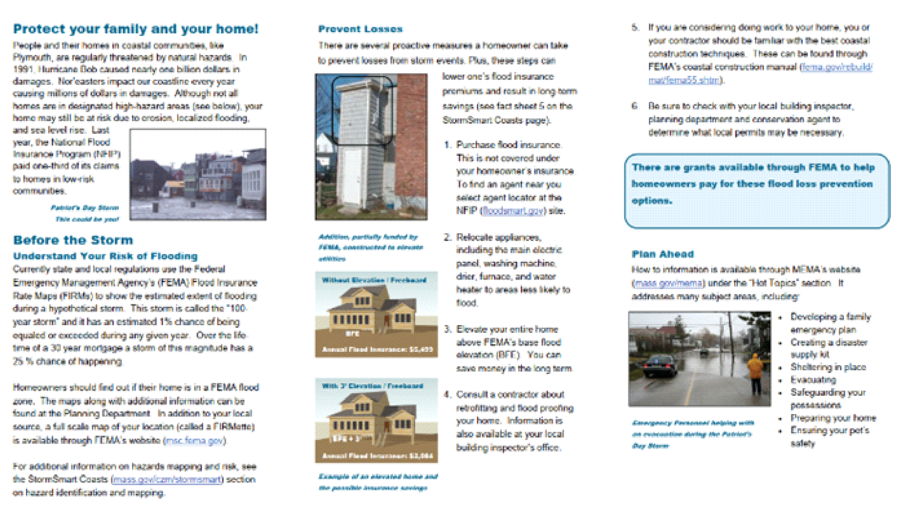
Appendix A - Resiliency Toolkit

NON-STRUCTURAL MEASURES



EVACUATION PROCEDURES



PUBLIC EDUCATION

LOCAL BUILDING CODE

LAND ACQUISITION

THE TOOLKIT

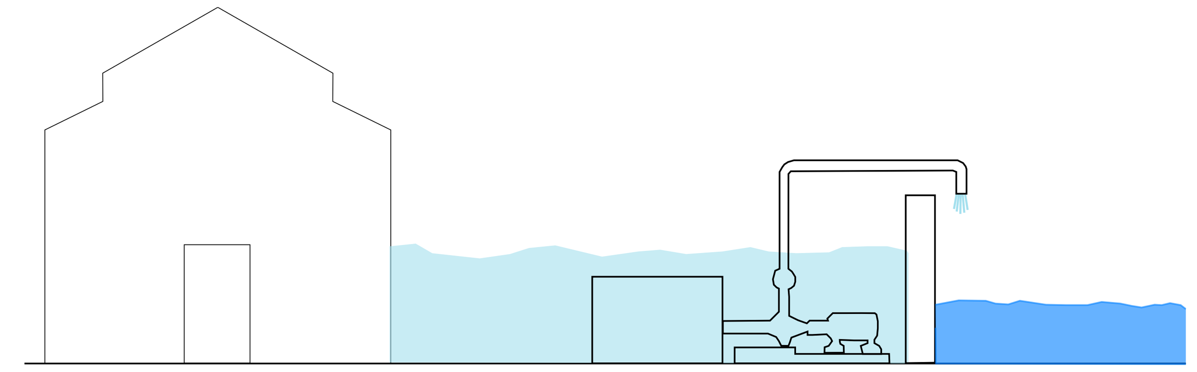
NATURE BASED ADAPTATION

BEACH/ DUNE PROTECTION AND EROSION CONTROL

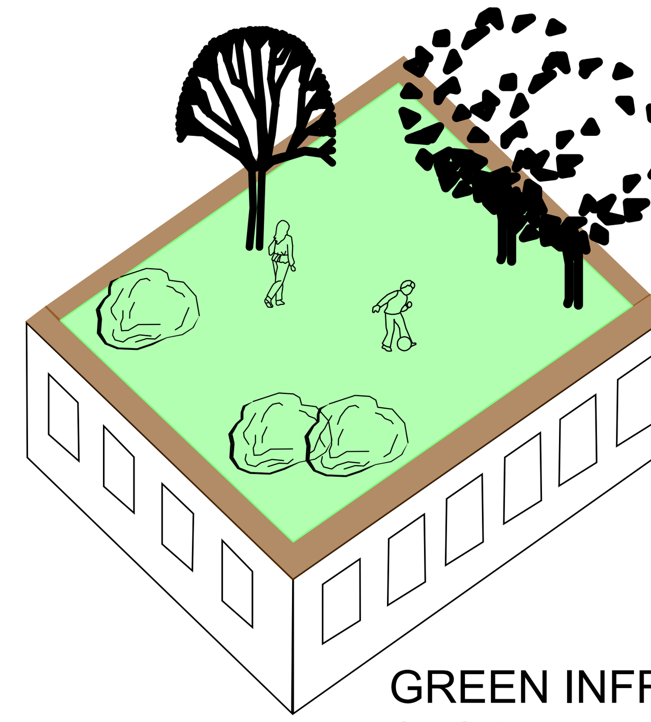
WETLAND AND HABITAT PRESERVATION AND RESTORATION

LIVING SHORELINES

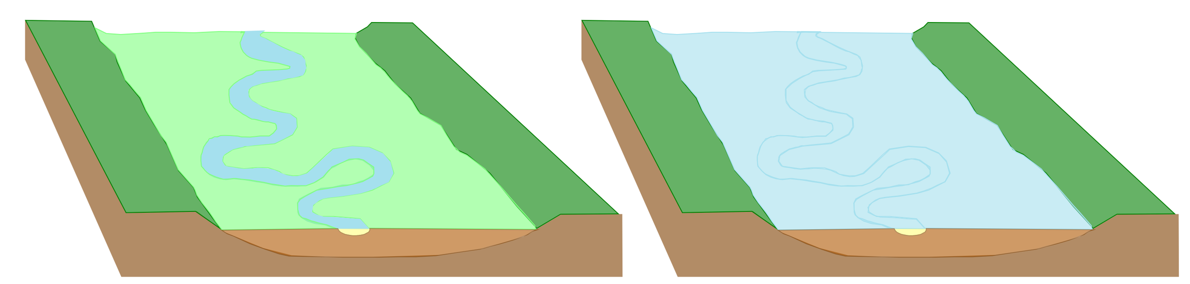
STORMWATER MANAGEMENT



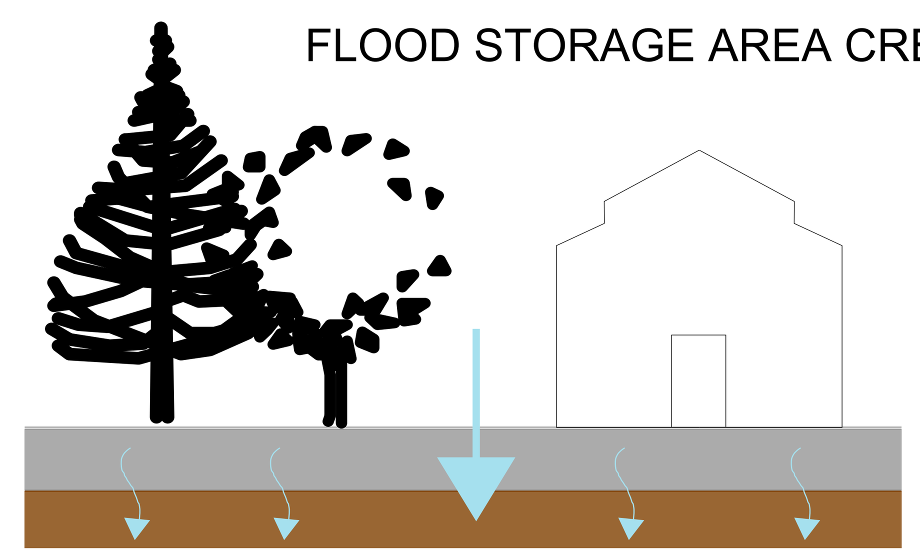
PUMP STATIONS



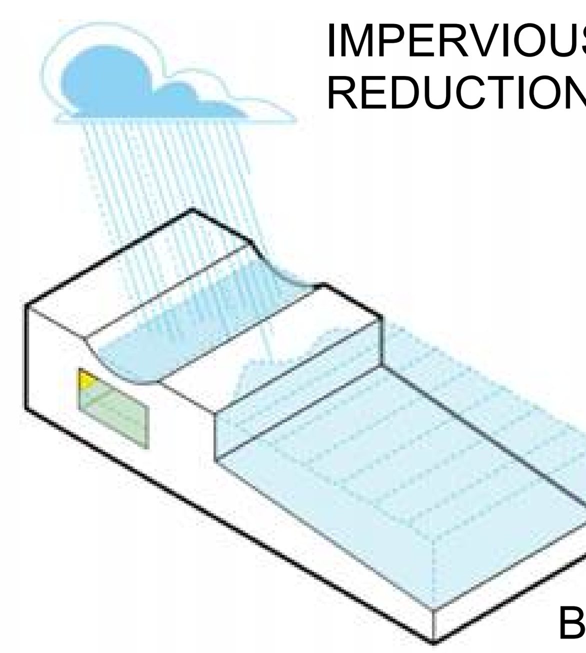
GREEN INFRASTRUCTURE FOR STORMWATER MANAGEMENT



FLOOD STORAGE AREA CREATION



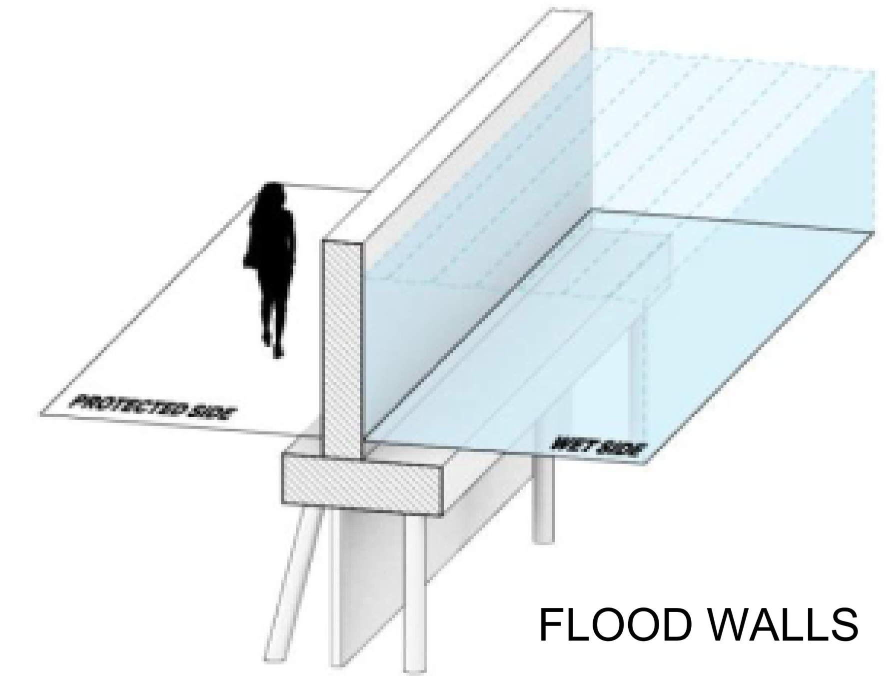
IMPERVIOUS SURFACE REMOVAL/ REDUCTION



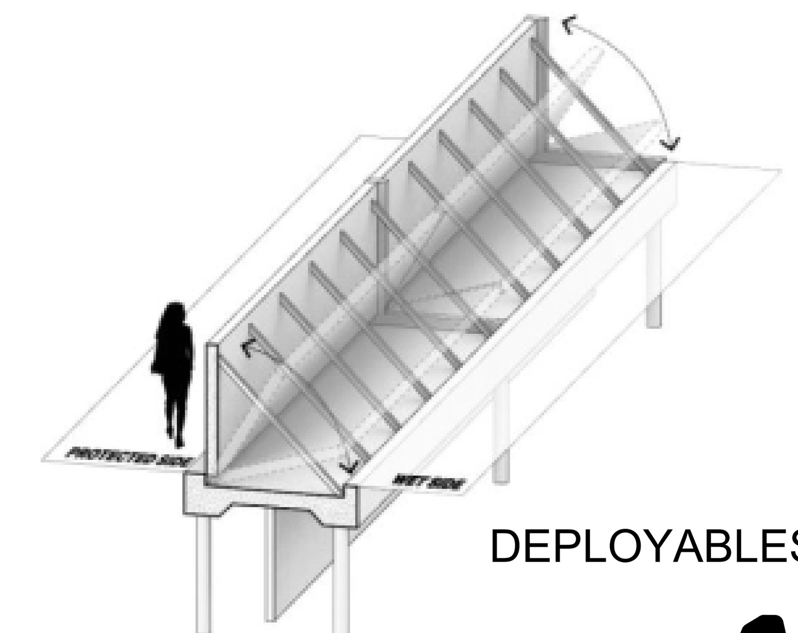
BIORETENTION BASIN

BACKFLOW PREVENTION

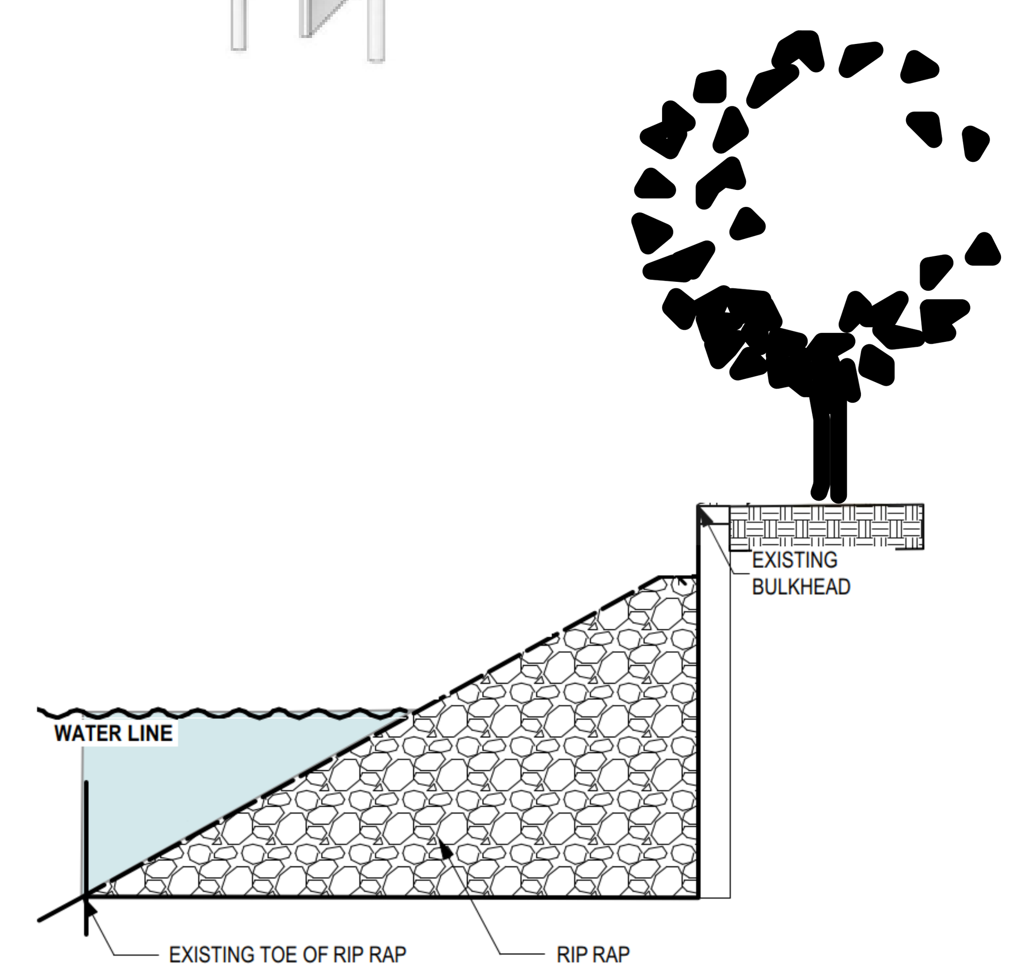
FLOOD RISK REDUCTION MEASURES



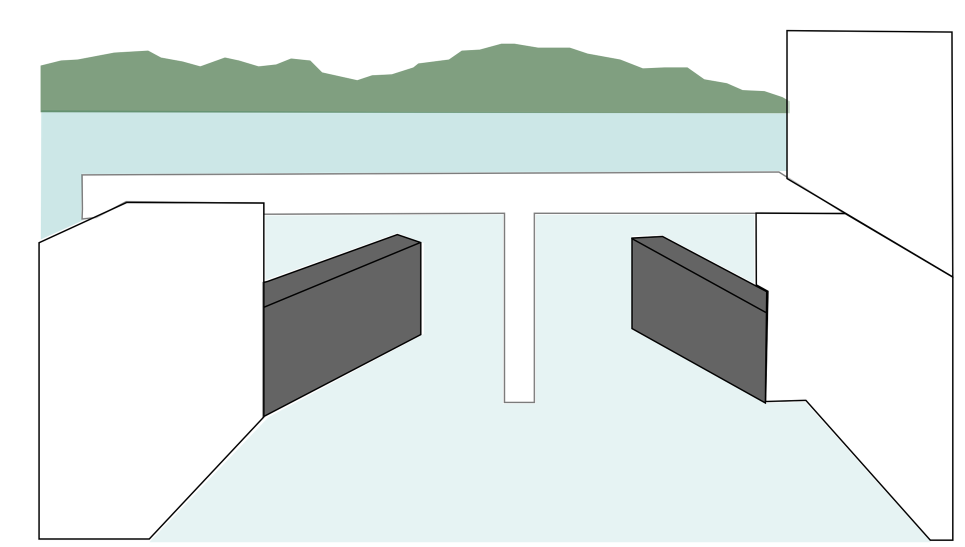
FLOOD WALLS



DEPLOYABLES

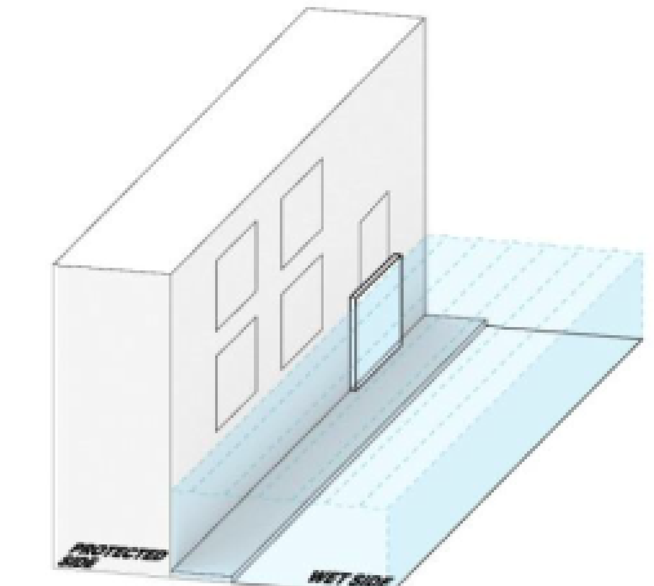


COASTAL STRUCTURES

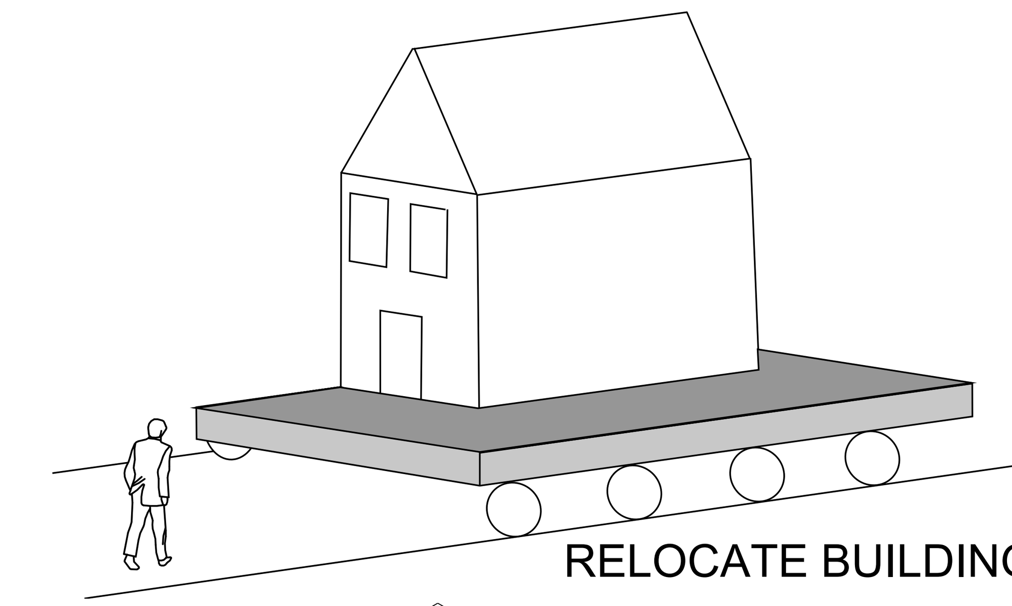


OFFSHORE STRUCTURES

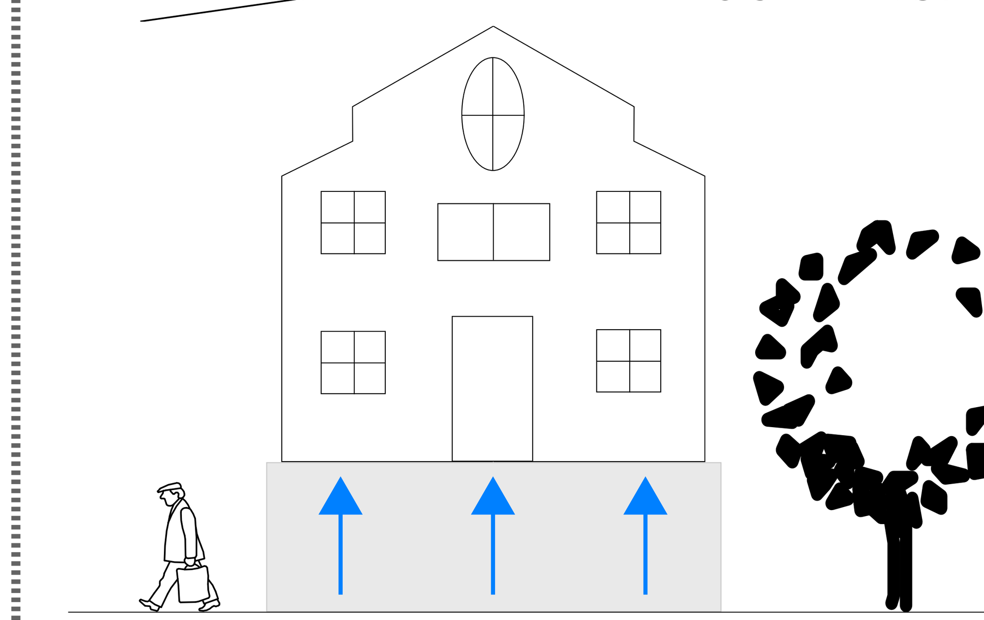
CRITICAL INFRASTRUCTURE RISK REDUCTION MEASURES



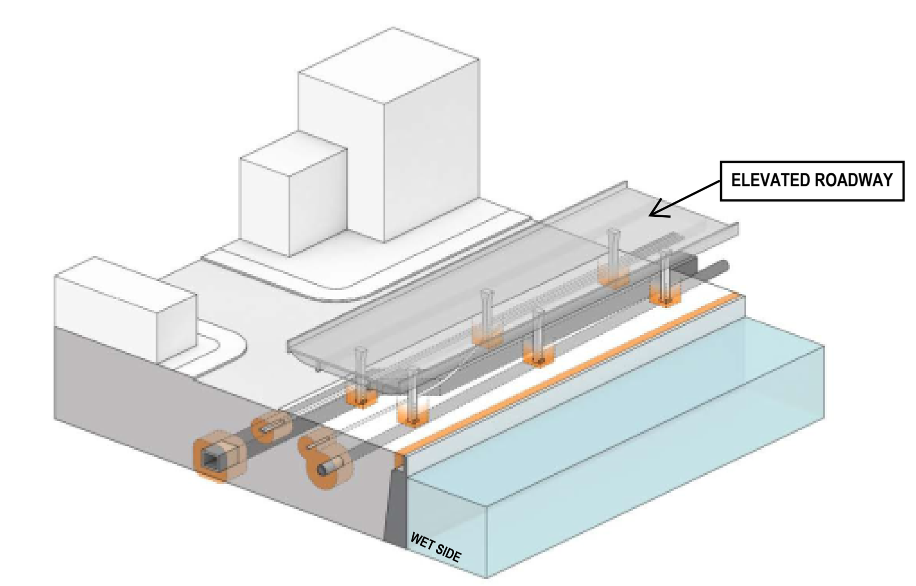
FLOODPROOF BUILDINGS



RELOCATE BUILDINGS



ELEVATE BUILDINGS



ELEVATE ROADWAYS

DEVELOPING A TOOLKIT:

There is no single solution, instead there are a multitude of ways to address the various needs and issues throughout the Point of Pines / Riverside project area. This toolkit will act as a resource for future climate resiliency projects not only for the City of Revere, but also for other coastal municipalities in the Commonwealth. Potential permanent nature-based adaptation, stormwater management, flood risk reduction, and critical infrastructure risk reduction measures for climate resilience are provided in the toolkit. Each of these measures has a particular way of performing, addressing a need, and relating to other components. For this reason, a range of solutions and combinations will likely be used to protect the project area. Additional information on the measures depicted in this toolkit can be found in the accompanying memorandum - Coastal Resilience Toolkit.

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

AECOM
250 Apollo Drive
Chelmsford, MA 01824
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Project name:
Point of Pines and Riverside Area Coastal Resilience Feasibility Study

Project ref:
60646341

To:
Elle Baker, Project Planner, City of Revere
Frank Stringi, City of Revere

CC:
File

From:
Aaron Weieneth
Jennifer Doyle-Breen
Kira Murphy
Carina Tracy
Taelise Ricketts

Date:
June 30, 2021

TASK 5 Feasibility of Coastal Resiliency Tools-FINAL

1. Introduction

The Point of Pines / Riverside Area Coastal Resiliency Feasibility Study was conceived as an integrated coastal protection initiative for the City of Revere. The 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. In the Task 3 memorandum, temporary resiliency measures were identified and proposed to protect critical and community assets. The critical assets included the two main residential areas and four buildings shown in Figure 1-1 below. To protect the residential areas, three alignments were presented: Alignment A along Mills Ave and Route 1A on the River Side and Alignments B1 and B2 along Rice Ave on the Ocean Side. Other community assets included the infrastructure along Revere Beach Boulevard as well as six individual buildings in the southern portion of the Study Area; the area including and surrounding Gibson Park in the northern portion of the Study Area; and the Point of Pines Yacht Club in the northern portion of the study area.

Figure 1-1 Three Potential Alignments and Critical Infrastructure

In the May 4, 2021 Task 4 memorandum potential permanent structural, nonstructural, and nature-based resiliency tools were identified. This memorandum evaluates the feasibility of the long-term resiliency options identified in the Task 4 memorandum in regard to their ability to protect critical assets and increase resiliency in the Study Area. Parallel with the Coastal Resiliency Feasibility Study, the City of Revere has undertaken a master planning effort for the Riverfront District, which includes the area of Gibson Park, the vacant Riverside Boat Works parcel, the G/J tow/salvage yard, the former Mirage site, portions of Route 1A, the Point of Pines Yacht club, and the former Alden Mills Fire Station. Resiliency recommendations from the Riverfront Master Plan are also identified below.

2. Existing Conditions

The Point of Pines Peninsula is in the northeast section of the City of Revere. To evaluate existing conditions, a LIDAR survey was used to determine the high and low elevation points along the peninsula. For the purpose of this memo, the study was divided into the following sub-areas, shown in Figure 2-1 below, for purposes of resiliency tool evaluation: Point of Pines; Mills Avenue (Ave); Gibson Park; and southern Route 1A. As described in the Task 2 memorandum regarding climate science and vulnerability, the flooding flow paths to the Mills Ave., Gibson Park and southern Route 1A portions of the study area originate from the Pines River side (River Side) of the project area, whereas the Point of Pines residential area experiences flooding primarily from the Ocean side of the peninsula. The River Side has an average elevation of +7.5 ft and is located adjacent to the Gibson Park area evaluated as part of the Riverfront Master Plan. The Ocean Side is along the eastern edge of the peninsula and varies between +6.5 and +11 ft. Route 1A runs along the middle of the peninsula and is the highest point of elevation reaching +33 ft on the northern end. All elevations are measured with respect to NAVD88.

Figure 2-1 – Google Earth Image of Project Site

3. Vulnerability to Flooding

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 (1%) storm design flood elevation (DFE), freeboard was added to the BFE shown on the FEMA FIRM maps. To calculate the 2030 100 (1%), 20 (5%) and 10-year (10%) storm DFEs as well as the 2070 100-year (1%) storm, 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 at the shoreline 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 Tables 3-1 and 3-2. Freeboard was identified based on the 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 3-1 and Table 3-2 below, and the applicability of these DFEs to the critical residential areas and buildings are discussed in the sections that follow.

Table 3-1 – DFE for Flood Design Class 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 2070 1% (100-year storm)	17.4	15.2

Table 3-2 – DFE for Flood Design Class 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 2070 1% (100-year storm)	18.4	16.2

4. Resiliency Tools

As described in the Task 4 memorandum, there are a variety of tools that can be used to increase resilience. The tools fall into a few main categories and provide a range of protection. For example, some of the tools, such as floodwalls, and deployables, are barrier measures that can provide a high level of protection against flood and surge waters; while others are less able to control rising floodwaters on a small scale but they may be able to either withstand or potentially recover from flooding, such as green infrastructure;. The 21 tools that will be evaluated for feasibility of implementation in the Study Area are listed below. There is not a "one fits all" solution, and different tools may be more applicable and feasible in certain applications within the Study Area.

Non-Structural Measures

- Evacuation Procedures
- Public Education/Outreach
- Local Building Code
- Land Acquisition

Nature Based Adaption Measures

- Beach/Dune Protection/Restoration
- Wetland Habitat Preservation and Restoration
- Living Shorelines

Stormwater Management Measures

- Pump Stations
- Green Infrastructure
- Flood Storage Area Creation
- Impervious Surface Removal/Reduction
- Bioretention Basins
- Backflow Prevention

Flood Risk Reduction Measures

- Flood Walls
- Deployable Structure
- Coastal Structures (seawall, bulkhead, revetment, breakwater)
- Offshore Structures (tide gates, surge barriers)

Critical Infrastructure Risk Reduction Measures

- Floodproofing Buildings
- Building Relocation
- Building Elevation
- Roadway Elevation

5. Feasibility Criteria

To evaluate the various resiliency tools under consideration, several factors were considered that affect feasibility and value of implementation. Each criterion considered is identified and described below in regard to its salient characteristics that may affect feasibility of implementation. The 21 resiliency tools were screened against the following criteria: protection against future predicted flooding conditions, funding opportunities, ownership, community acceptance, conservation restriction requirements, permitting requirements, and cost.

5.1 Protecting Against Future Sea Level/Surge

The first criterion used to assess the feasibility of the various resiliency tools was the ability to control future flood waters resulting from sea level rise and coastal surge. To determine if it was feasible to protect the critical assets against the DFEs of each design storm, two main factors were considered: the height of intervention (HOI) and the tie in location. The minimum HOI is equal to the difference between the DFE and the ground elevation. For instance, if the DFE is +12 ft and the minimum ground elevation is +7 ft, the HOI is 5 ft. This means the flood risk reduction measure at that location must be at least 5 ft tall. Each barrier measure starts and ends at a high ground tie in location, which is defined as a point where the ground elevation is equal or exceeds the DFE. This prevents flood waters from traveling around the protection measure and inundating the low-lying areas that are being protected by the risk reduction system. If the ground elevation in a tie in area doesn't meet a certain DFE, the measure cannot protect against that design storm.

Based on this requirement, the following five resiliency tools were identified as potentially achieving protection, pending confirmation that ground elevations are conducive to achieving a tie into a high ground location: floodproof buildings, elevate buildings, flood walls, deployables and dune protection. The remaining 16 measures were unable to meet this requirement but may be beneficial in adding other resiliency benefits.

5.2 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 5-1 identifies grant funding opportunities that may be available for the resiliency tools.

Table 5-1 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 (MEMA) 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) review; completed EHP checklist, at least one nature-based solution per project; milestone schedule; demonstrate cost-effectiveness; and provide management cost.	https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities/before-apply#eligibility
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	https://www.mass.gov/service-details/local-acquisitions-for-natural-diversity-land-grant-program

		Massachusetts Historical Commission and proof of land stewardship practice must be submitted.	
	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

5.3 Ownership

Ownership refers to who owns the property where the proposed measure will be located. Ownership will be classified as either public land or private land. As described in the above funding opportunities section, the opportunity to receive project funding is directly related to the project's location. Typically, it is a challenge for most municipalities to conduct a project on privately-held land and this arrangement requires additional effort to coordinate and manage, and would require written agreements of responsibilities and understanding of various commitments related to the project on private property in order to facilitate a successful project .

5.4 Community Acceptance

Community acceptance is an important factor in the success of a project. This criterion is subjective and evaluates whether the implementation of the proposed measure would have a negative or positive effect on the current area's aesthetics and whether it would conflict with the existing uses of the area. The community acceptance of the mitigation measures was rated as favorable or unfavorable.

5.5 Conservation Restriction Requirements

Massachusetts Executive Office of Energy and Environmental Affairs (EEA) MVP Action Grants are only issued to projects that include a conservation restriction or other mechanism that assures the "continued presence and effectiveness of such Projects". If MVP Action Grant funds are used for land acquisition, the City would need to be the fee simple owner of the property or obtain a conservation restriction for the property. Thus, the need for a conservation restriction would apply to projects on privately owned property or property acquisition of parcels that will not be owned by the City.

5.6 Permitting Requirements

The potential resilience tools would involve permit complexity ranging from low to high based on the amount and location of ground disturbance, if any. Planning and procedural tools, such as evacuation procedures, public education, relocation of structures outside of the Study Area, and land acquisition, might not require permits or approvals from any environmental resource agencies such as the Conservation Commission, MassDEP or the MA Division of Fisheries and Wildlife (MassDFW). The vast majority of the Study Area includes a resource area which, when work is proposed within it, would trigger the need for approval under the Massachusetts Wetlands Protection Act (WPA), at a minimum.

Almost all of the Study Area is mapped as FEMA 100-year floodplain, which is regulated as Bordering Land Subject to Flooding (BLSF) or Land Subject to Coastal Storm Flowage (LSCSF) under the Massachusetts Wetlands Protection Act (WPA) and triggers the need to file a Request for Determination of Applicability (RDA) or Notice of Intent (NOI) with the Conservation Commission and MassDEP. Any work that involves fill in BLSF requires creation of an equal volume of compensatory flood storage volume and an elevation above the existing 100-year floodplain. Thus, construction of a new above-ground structure, such as a pump station or elevated road, would require the construction of a compensatory flood storage area, which may be challenging given that most of the project area is already mapped as FEMA 100-year floodplain. It may be possible to locate some tools below grade and/or there may be existing fill above ground level that could be removed to provide compensatory flood storage area to off-set any BLSF fill. Work in BLSF or LSCSF for tools that do not involve floodplain fill, such as floodproofing or elevating buildings, temporary deployment of flood barriers, backflow prevention and impervious surface reduction, would have low level of permitting complexity even though some coordination with the Conservation Commission would likely be necessary.

The Point of Pines Beach area is mapped as estimated and priority habitat by MassDFW between the Route 1A Bridge and continuing east and south along the coast. Most work on the beach, except for limited activities that don't involve effects on land contours or vegetation, would trigger the need for a Massachusetts Endangered Species Act (MESA) Permit. Greater than two acres of disturbance of designated priority habitat, as defined in 321 CMR 10.02, that results in a take of a state-listed endangered or threatened species or species of special concern triggers the need for submittal of an ENF and subsequent MEPA review. The Pont of Pines beach also includes wetland resource areas regulated under the MA WPA, including Coastal Bank, Coastal Dune, and Coastal Beach, and Barrier Beach. Any alteration of these resource areas triggers the need to file an Environmental Notification Form (ENF) with the Massachusetts Environmental Policy Act (MEPA) office for review, public/agency comments, and identification of whether or not an Environmental Impact Report (EIR) must be prepared for further MEPA and agency review.

Much of the perimeter of the Study Area and portions of the interior are regulated under Chapter 91 as filled or flowing tideland. Installation of permanent structures in Chapter 91 jurisdictional area requires either obtaining a Chapter 91 License or amending a previously issued License if one exists. Tools that would be located in Chapter 91 jurisdictional area were deemed to have a moderate degree of permitting complexity.

The Rumney Marsh Area of Environmental Concern (ACEC) is a 2,800-acre estuary located northwest of the Study Area. The ACEC includes salt marsh, tidal flats, and shallow subtidal channels and provides important habitat for a wide variety of birds and other wildlife. The boundary of the Rumney Marsh ACEC extends onto portions of the Riverside District, including Gibson Park, the Riverside Boat Works parcel to the south, and the G/J Towing parcel to the north. Any work within an ACEC triggers the need to file an ENF for review and comment under the Massachusetts Environmental Policy Act. Given the opportunity for multiple state agencies and the public to review and provide input to any work in an ACEC, any tools that would be implemented at Gibson Park or the adjacent parcels within the ACEC were deemed to have a moderate degree of permitting complexity.

5.7 Relative Cost

The final criterion used to screen the measures was the total financial cost associated with implementing and operating each measure. For the initial evaluation of each tool, the cost was represented as $, $$, $$$ or 'varies'. For some measures, such as floodproof buildings or deployables, the cost can be highly variable depending on the combination of mitigation measure(s) implemented or level of desired protection. Measures with a high associated cost are measures that require extensive infrastructure improvements such as elevate roadways, coastal structures, offshore structures, floodwalls, pump stations, and land acquisition.

6. Feasibility Assessment Results

Table 6-1 provides a multi-criteria decision matrix that summarizes the results of the criteria evaluation for all 21 resiliency tools and provides a conclusion regarding relative feasibility for implementation. Many of the criteria were relatively straightforward to evaluate against the resiliency tools. The evaluation of the criterion regarding protection against future sea level rise/coastal surge required more detailed evaluation of the ground surface elevations as compared to the DFEs described above in Section 3.0 to evaluate feasibility of implementation. The text below summarizes salient points considered in the feasibility evaluation.

6.1 Flood Barriers (Flood Walls, Coastal Structures, and Deployables)

Flood barriers are important for protecting residential areas and other critical assets in the Study Area that cannot be relocated and cannot withstand frequent flooding. These tools tend to be relatively costly, and community acceptance in some locations may be low if the flood barriers block recreational access, obstruct views, or divide neighborhoods. Consequently, these tools are considered feasible for protecting critical assets such as residential neighborhoods or other Class 3 buildings necessary for maintaining important community functions. Floodwalls are anticipated to involve a moderate level of permitting, depending on their location and size. Any of these within the study area would likely involve work within BLSF, although given that their purpose is to reduce flooding these may not require compensatory flood storage creation. However, demonstration of flood benefits and lack of adverse flooding effects on adjacent areas may be required depending on location.

As described in the Task 2 memorandum, there are three primary residential areas in the Study Area: the Point of Pines neighborhood, the Mills Avenue neighborhood, and residences in the area southeast of Route 1A.

Table 6-1 Permanent Risk Reduction Measures Decision Feasibility Matrix

	Control of Future Predicted Floodwater	Funding Opportunities	Ownership	Community Acceptance	Conservation Restriction Requirements	Permitting Complexity	Cost	Summary
Floodproof Buildings	High	Multiple	City or Private	High	Not Applicable	Low	$-$$	Feasible at low cost/low permitting
Relocate Buildings	Medium	Multiple	City or Private	Low	Not Applicable	Low	$$	Not feasible for individual residences; may be applicable to individual critical buildings
Elevate Buildings	Medium	Multiple	City or Private	Medium	Not Applicable	Moderate	$$	Not feasible for individual residences; may be applicable to individual critical buildings
Elevate Roadways	High	Multiple	City or MassDOT	Low	Not Applicable	Moderate	$$$	Not feasible due to permitting and logistical constraints
Flood Walls	High	Multiple	City or Private	Medium	Not Needed	Moderate/ Depends on Location	$	Feasible to protect large areas/ individual buildings
Deployables	High	Multiple	City	High	Not Needed	Low	$$$	Feasible to protect large areas/ individual buildings
Coastal Structures	High	Multiple	City or Private	High	Not Needed	High	$$	Costly, difficult to permit
Offshore Structures	High	Multiple	City , State, and/or Federal	Medium	Not Applicable	High	$$$$	Extremely costly and permitting very challenging; larger perspective required
Pump Stations	High	Multiple	City	High	Not Applicable	Moderate	$$$	May be beneficial as ancillary measures;

								interior drainage analysis required
Green Infrastructure	Low	Multiple	City or Private	High	Not Needed	Moderate/ Depends on Location	$$	Most feasible location is in Riverside District
Flood Storage Area	Medium	Multiple	City	Medium	Not Needed	Moderate	$$	Most feasible location is in Riverside District
Impervious Surface Reduction	Low	Multiple	City or Private	Medium	Not Applicable	Low	$$	Most feasible location is in Riverside District
Bioretention Basin	Medium	Multiple	City	High	Not Needed	Moderate	$$	Likely infeasible due to high groundwater
Backflow Prevention	Medium	Multiple	City or MassDOT	High	Not Applicable	Low	$$	Should be implemented where not existing
Dune Protection/ Restoration	High	Limited Funding Opportunity due to current private ownership	Private	High	Based on guidance from the MVP program, a conservation restriction is needed for work on private property if grant funds desired	High	$	Implementation will be challenging due to high cost, current private ownership, and complex permitting
Wetland Restoration	Low	Multiple	City	High	May be applicable for work on private property	Moderate	$	Limited opportunities, although potential sites in Riverside District
Living Shorelines	Low	Multiple	City	High	Not Needed	High	$	Limited opportunities, although potential sites in Riverside District

Evacuation Procedures	Low	Multiple	City	High	Not Applicable	Not Applicable	$	Recommendations included in Task 3 Memorandum
Public Education	Low	Multiple	City	High	Not Applicable	Not Applicable	$	Continued implementation beneficial, but will not protect from future inundation
Building Code	Low	Multiple	City	High	Not Applicable	Not Applicable	$	Building Codes adhere to International Standards and implementation should continue
Land Acquisition	Low	Multiple	City	Medium	Might be applicable	Not Applicable	$$$	May be desirable for repetitive loss properties

There are also four critical buildings in the Study Area. Section 6.2 discusses the flood barrier options for the three residential areas, and Section 6.3 discusses the feasibility of flood barriers for the critical building assets.

6.1.1 Residential Areas

6.1.1.1 Alignment A

Alignment A is intended to protect the River Side of the peninsula south of Gibson Park. The northern tie in for this alignment, shown in Figure 6-1**Error! Reference source not found.**, is proposed between Hayes Avenue and the western edge of Route 1A. The existing elevations increase quickly here from +9 to +30, which makes this tie in location feasible for any of the proposed design storms.

Figure 6-1 Alignment A Northern Tie-In

The southern tie in for Alignment A, shown in Figure 6-2 below, is proposed between River and John Ave at the median of Route 1A. The existing elevations increase quickly here from +6 to +20, which makes this tie in location feasible for any of the proposed design storms.

Figure 6-2 Alignment B Southern Tie-In

The HOI along Alignment A is shown in in the profile in Figure 6-3**Error! Reference source not found.** below. For this study, the tie in locations were both stopped at +17 since this elevation encompasses all the proposed design storms.

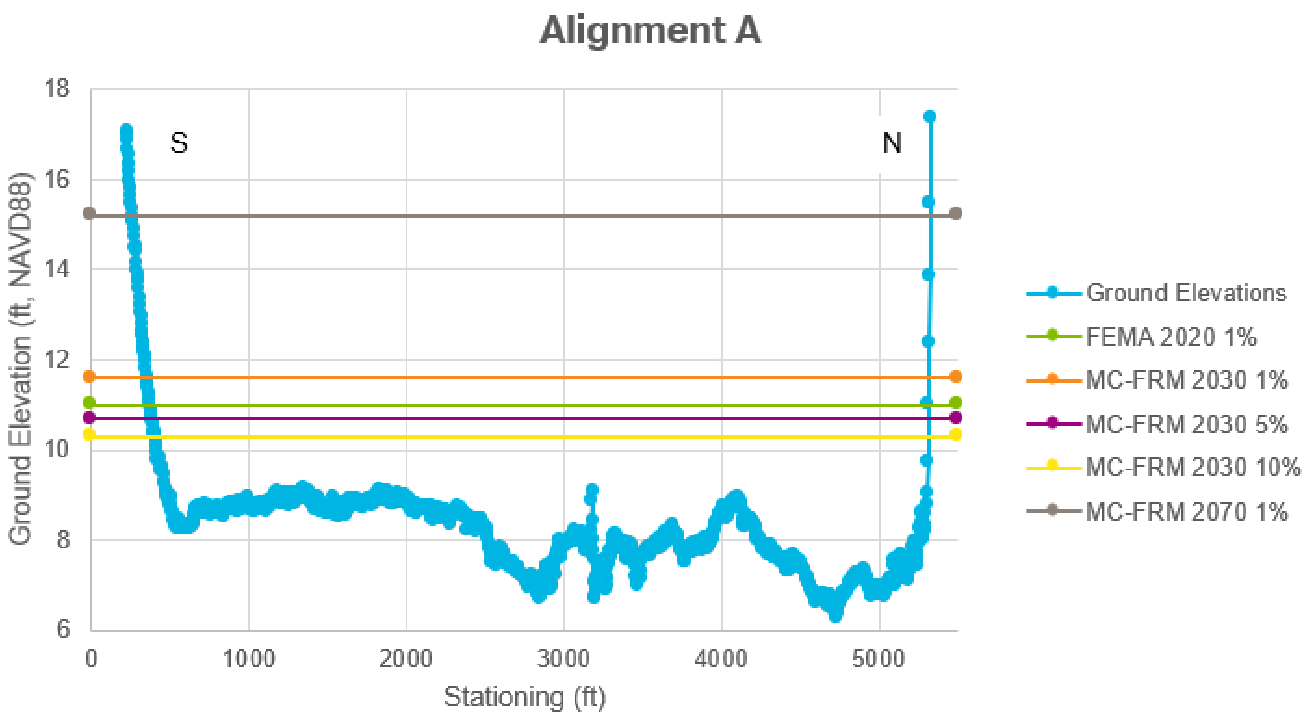

Figure 6-3 Alignment A Profile

A summary of the HOIs and tie in locations in relation to the proposed design storms are listed in Table 6-2 below.

Table 6-2 Alignment A Feasibility

Design Storm	MAX HOI (ft)	Northern Tie In	Southern Tie in
2020 1% DFE	4.7	Feasible	Feasible
2030 1% DFE	5.3	Feasible	Feasible
2030 5% DFE	4.4	Feasible	Feasible
2030 10% DFE	4.0	Feasible	Feasible
2070 1% DFE	8.9	Feasible	Feasible

6.1.1.2 Alignment B1

Alignment B1 is intended to protect the Ocean Side of the peninsula. The first southern tie in for this alignment, shown in Figure 6-4 below, is proposed between Rice and Harrington Avenue. The existing elevation here is +12 ft, which makes this tie in location feasible for only the 2020 100-year and the 2030 10-year design storms.

To meet the larger design storms, the alignment must be lengthened. The second southern tie in for this alignment shown in Figure 6-5 below, is proposed at the high ground at Route 1A. However, to reach this location, the alignment would have to run on the private properties between Carey Circle and Harrington Avenue as well as the properties between Carey Circle and Route 1A.

Figure 6-4 Alignment B1 Southern Tie-In Rice

Figure 6-5 Alignment B1 Southern Tie-In Route 1A

The northern tie in for Alignment B1, shown in Figure 6-6 below, is proposed just east of Route IA. The existing elevations increase from +10 to +17 here, which makes this tie in location feasible for any of the proposed 2020 and 2030 design storms. To protect against the 2070 1% design storm, the alignment must be lengthened to a tie in point along route 1A shown in Figure 6-7 below.

Figure 6-6 Alignment B1 Northern Tie-In

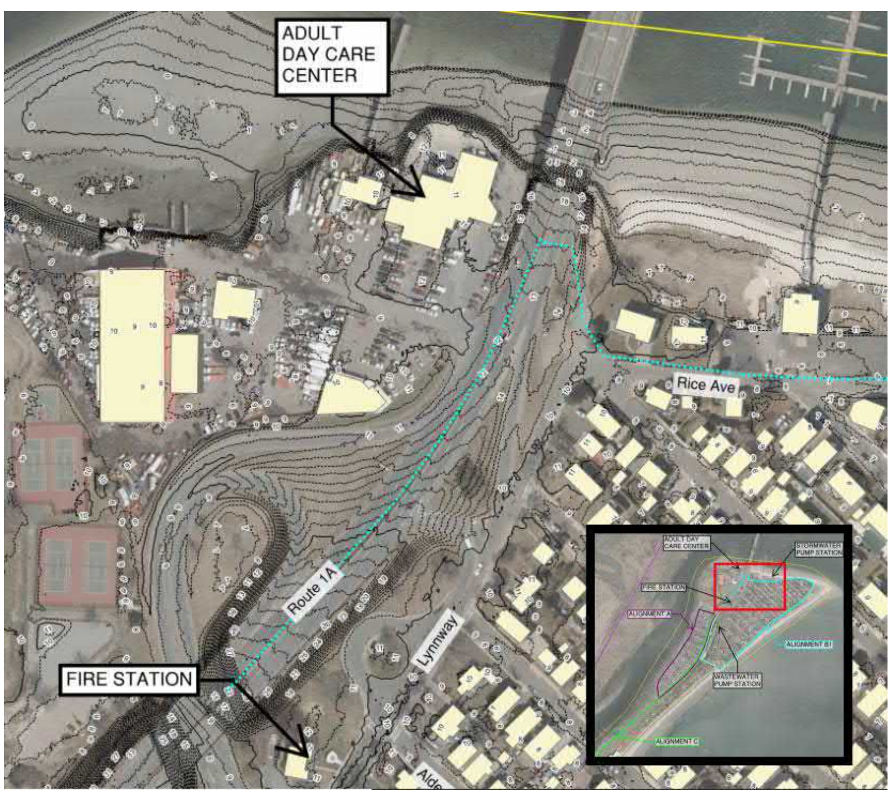

Figure 6-7 Alignment B1 Northern Tie In

The HOI along Alignment B1 is shown in in the profile in Figure 6-8**Error! Reference source not found.** below. For this study, the northern tie in location was stopped at +18 since this elevation encompasses all the proposed design storms.

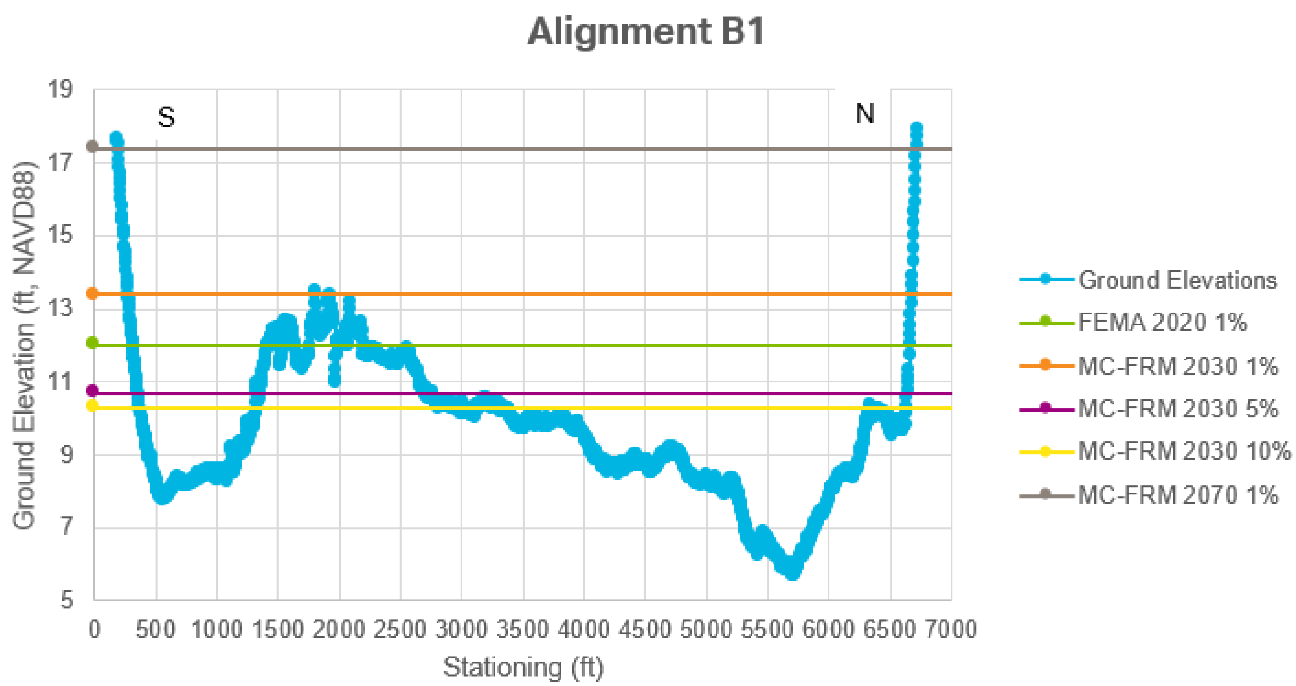

Figure 6-8 Alignment B1 Profile

A summary of the HOIs and tie in locations in relation to the proposed design storms are listed in Table 6-3 below.

Table 6-3 Alignment B1 Feasibility

Design Storm	MAX HOI (ft)	Northern Tie In (Lynnway)	Northern Tie In (Route 1A)	Southern Tie In (Rice Ave)	Southern Tie In (Route 1A)
2020 1% DFE	6.3	Feasible	Feasible	Feasible	Feasible
2030 1% DFE	7.7	Feasible	Feasible	Not Feasible	Feasible
2030 5% DFE	6.6	Feasible	Feasible	Not Feasible	Feasible
2030 10% DFE	6.0	Feasible	Feasible	Feasible	Feasible
2070 1% DFE	11.7	Not Feasible	Feasible	Not Feasible	Feasible

6.1.1.3 Alignment B2

Alignment B2 is intended to protect the Ocean Side of the peninsula. The southern tie options for this alignment are proposed to be the same as alignment B1 and are detailed above in section 6.1.1.2. The northern tie in for this alignment, shown in Figure 6-9 below, is proposed east of Route 1A parallel to Alden Ave. The existing elevations increase from +11 to +24 here, which makes this tie in location feasible for any of the proposed design storms.

Figure 6-9 Alignment B2 Northern Tie-In

The HOI along Alignment B2 is shown in in the profile in Figure 6-10**Error! Reference source not found.** below. Due to the many challenges described in section 7.3, this alignment was only considered for the 2020 and 2030 design storms.

A summary of the HOIs and tie in locations in relation to the proposed design storms are listed in Table 6-4 below.

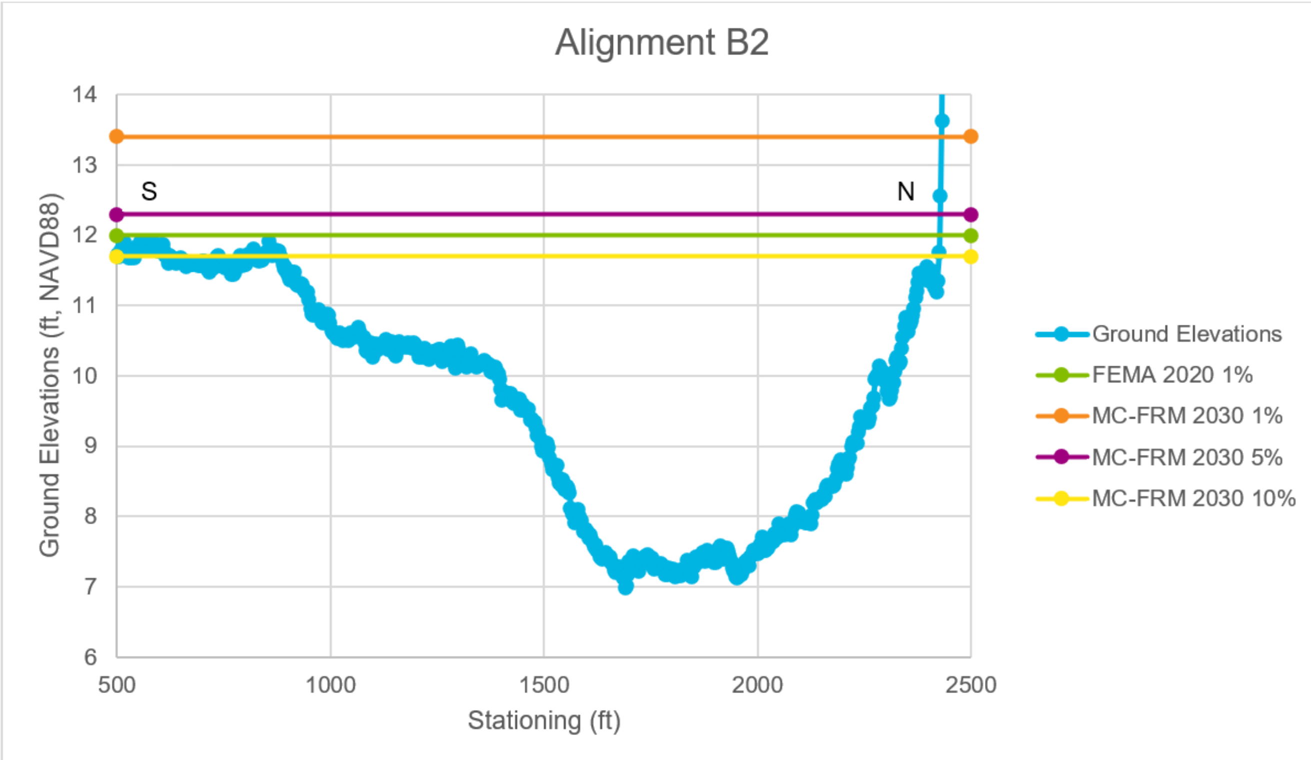

Figure 6-10 - Alignment B2 Profile

Table 6-4 Alignment B2 Feasibility

Design Storm	MAX HOI (ft)	Northern Tie In	Southern Tie In (Rice Ave)	Southern Tie In (Route 1A)
2020 1% DFE	5.1	Feasible	Feasible	Feasible
2030 1% DFE	6.5	Feasible	Not Feasible	Feasible
2030 5% DFE	5.4	Feasible	Not Feasible	Feasible
2030 10% DFE	4.8	Feasible	Feasible	Feasible

6.1.1.4 Alignment C

Alignment C is intended to protect the communities south of Route 1A in the southeastern are of the peninsula. The first southern tie in for this alignment, shown in Figure 1-1.The northern tie in for Alignment C1, is the same location as Alignment A shown in shown in Figure 6-1 above.

The HOI along Alignment C1 is shown in in the profile in Figure 6-11**Error! Reference source not found.** below. For this study, the northern tie in location was stopped at +17 since this elevation encompasses all the proposed design storms.

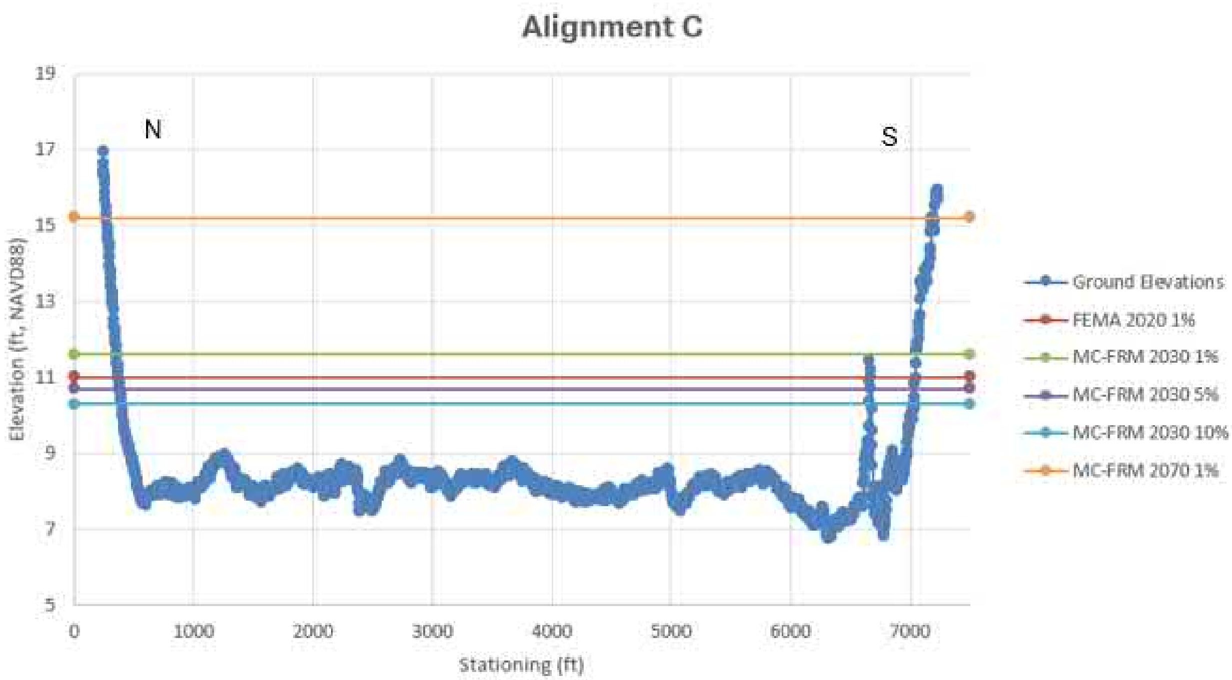

Figure 6-11 Alignment C Profile

A summary of the HOIs and tie in locations in relation to the proposed design storms are listed in Table 6-5 below.

Table 6-5 Alignment B2 Feasibility

Design Storm	MAX HOI (ft)	Northern Tie In	Southern Tie In
2020 1% DFE	4.2	Feasible	Feasible
2030 1% DFE	4.8	Feasible	Feasible
2030 5% DFE	3.9	Feasible	Feasible
2030 10% DFE	3.5	Feasible	Feasible
2070 1% DFE	8.4	Feasible	Feasible

6.1.2 Critical Buildings

The four critical buildings in this study are the Adult Day Care Center, the Stormwater Pump Station, the Wastewater Pump Station, and the Fire Station. Based on the existing elevations shown in Figure 6-12 below, the respective HOI for each building and design storm is listed in Table 6-6. Since the proposed method of protection of the buildings does not require tying into high ground, the feasibility of a northern and southern tie in is not considered for these buildings.

Figure 6-12 Critical Building Elevations

Table 6-6 - Critical Infrastructure Feasibility

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
2070 1% DFE	6.2	9.4	8.2	7.4

For the purpose of this study, the Wastewater Pump Station and Adult Day Care center HOIs are based on the River Side DFE and the Fire Station and Stormwater Pump Station HOIs are based on the Ocean Side DFE. Design of any flood risk reduction measures would necessitate additional site-specific values.

6.1.3 Design Storm Feasibility

A summary of the design storm feasibility for the proposed alignments and critical buildings is detailed in Table 6-7 below.

Table 6-7 – Design Storm Feasibility

Design Storm	Alignment A	Alignment B1 (Rice to Lynnway)	Alignment B1 (Route 1A to Route 1A)	Alignment B2 (Rice to Route1A)	Alignment B2 (Route 1A to Route 1A)	Critical Infrastructure
2020 1% DFE	Yes	Yes	Yes	Yes	Yes	Yes
2030 1% DFE	Yes	Not Feasible	Yes	Not Feasible	Yes	Yes
2030 5% DFE	Yes	Not Feasible	Yes	Not Feasible	Yes	Yes
2030 10% DFE	Yes	Yes	Yes	Yes	Yes	Yes
2070 1% DFE	Yes	Not Feasible	Yes	Not Pursued	Not Pursued	Yes

6.2 Relocate Buildings

Relocating buildings requires significant cost and may be logistically challenging due to the lack of available area within the Study Area for relocation, considering that most of the area is predicted to be inundated at a high frequency in the future. In addition, most buildings in the study area that are at risk are private residential buildings and thus relocation is likely to have low community acceptance and be infeasible from a practical perspective. Only two buildings, the adult day care center and the stormwater pump station, are public at-risk buildings that could be considered for relocation, although potential sites are limited. It may be feasible to relocate the adult day care center outside of the Study Area, although this may face community acceptance challenges if this facility serves the local population.

6.3 Floodproofing Buildings

Floodproofing buildings is a relatively low-cost resiliency tool when targeting a single critical building but is costly to implement for a large number of residential homes. It would achieve the goal of controlling floodwaters and may be an effective tool to implement for targeted individual critical buildings in the Study Area that cannot be relocated and are important to providing critical functions for the community during storm events.

6.4 Elevate Buildings

Like floodproofing, elevating buildings may be appropriate for individual critical community assets but is likely to be impractical for the City to implement on a wide scale for individual homes due to high costs and logistical challenges. Residents could consider this tool for their individual properties, although it would be costly for an individual homeowner to implement and therefore was deemed feasible only for individual municipal buildings of key importance.

6.3 Elevate Roadways

Elevating roadways is challenging due to the utilities that are often located within roads and the interface of most roads with driveways to private residences and businesses. It would be very costly to relocate utilities and also potentially infeasible in many locations to raise the main roadway elevations above the elevations of adjacent driveways. Raising Rice Ave, Mills Ave, and Route 1A was deemed infeasible for these reasons. As discussed above, many of the roads within the Study Area are in BLSF; adding fill in these areas would require finding an equivalent volume in the same general area where compensatory flood storage could be created. Because this tool was evaluated unfavorably in comparison to most of the screening criteria, it determined to have low feasibility for the study area.

6.4 Offshore Structures

Offshore structures are high in cost and are not feasible for protecting the study area unless evaluated on a larger-scale basis to protect an area inclusive of, but not restricted to, the Study Area. Coastal structures are typically large barriers made up of a series of gates that would be used to prevent water levels from increasing during a storm surge. Any large offshore structures would need to be built at the mouth of the Broad Sound if they were going to protect the entire study area. This tool has an extremely high cost, and extensive permitting requirements. The City has previously considered recommended offshore structures from the United States Army Corps of Engineers (USACE). In 1990 USAE published the *Flood Damage Reduction Study for the Saugus River and Tributaries.* The structural recommendations in the report were the installation of tidal floodgates by the mouth of the Saugus River; ten flushing gates on the left and right side of the navigation gates along Lynn and Revere; and a dike in Lynn harbor. The recommended floodgate also contained two concrete gravity wall sections as well. Given the numerous permitting review and approvals required for off-shore structures adjacent to and connecting to the beach coastal or off-shore structures near the beach would entail highly complex permitting. Implementation of the 1990 project requires additional study to confirm previous modelling assumptions, update of cost, and evaluate conformance with current regulatory conditions; these evaluations are beyond the scope of the current MVP Action Grant Feasibility Study. Given the extremely high cost, required input from multiple municipalities, and complex modelling required, this tool was deemed infeasible in the context of this Feasibility Study, however additional evaluation in larger context may be warranted.

6.5 Pump Stations

Although pump stations will not control floodwaters from inundating an area by themselves, they can be used in conjunction with a barrier tool to remove excess precipitation. A stormwater pump station exists already in the Point of Pines neighborhood and may be beneficial in the Mills Avenue and/or Gibson Park area to address future predicted coastal flooding and increased precipitation. The Riverfront Masterplan recommends the installation of a pump station adjacent to Gibson Park. The utility of a pump station in this location could be confirmed based on an interior drainage analysis, which would also be needed to size the pump station. In the southern end of the Study Area, given the long narrow and low-lying topography present, a pump station is unlikely to provide a valuable function since there is not a discrete area where floodwaters are contained, existing wetlands provide some storage, and the area is able to naturally drain after a storm event. It may be possible to locate a pump station below grade and/or there may be existing fill above ground level that could be removed to provide compensatory flood storage area to off-set any BLSF fill; therefore, permitting for this tool was identified as moderately complex.

6.6 Green Infrastructure

Green infrastructure (GI) tools such as permeable pavement, rain gardens, and vegetative swales do not provide a barrier to control floodwaters, but they can help with creating a resilient stormwater management system that can manage predicted increases in rainfall due to climate change and also provide co-benefits such as environmental sustainability and improved water quality. There are multiple funding opportunities for green infrastructure on public property, and these tools typically receive high community acceptance rates while being relatively low-cost measures to implement. A challenging factor for Green Infrastructure 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 private property consensus. Installation of GI would likely require demonstration of water quality benefits and avoidance of unanticipated adverse flooding effects on adjacent areas and therefore was considered to entail a moderate degree of permitting complexity.

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. 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 a 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.

6.7 Flood Storage Area

Flood storage areas would not control predicted higher flood waters or coastal surge from the Study Area, but could be used to contain water either above or below ground if water can be directed to the storage facility without adversely affecting residences and critical facilities. Locations for at-grade flood storage areas in the study area are limited as the area is already heavily developed other than existing wetlands, which provide natural storage, and the parcels in the Riverside District discussed above. Since the Riverside District municipal property includes playing fields, there would be low community acceptance for converting this area into a dedicated storage facility. Although the playing fields currently do provide some amount of storage during a flood event, it is not possible to increase storage to address future predicted climate change events without raising elevations around the site to contain water, which would have low acceptance as this would conflict with the existing uses of the site. Below-ground storage at the playing fields may be a feasible measure and between 1.62- and 2.34-acres feet of below-ground storage was identified as a recommendation in the January 2021 Master Plan. Implementation of a below-ground flood storage area at Gibson Park requires additional evaluation of geotechnical and water table conditions at the site, as well as a hydraulic evaluation to assess mechanisms for water to enter and exit the underground storage facility. Installation of below-grade flood storage would likely require demonstration of water quality benefits and avoidance of unanticipated adverse flooding effects on adjacent areas, and would be subject to MEPA review via an ENF; therefore this tool was considered to entail a moderate degree of permitting complexity.

6.8 Impervious Surface Reduction

Implementation of impervious surface reduction (ISR) in the Study Area is not feasible on a large scale due to the land usage of the study area. The land usage is primarily residential properties connected by public roadways that are key access points and most of this impervious surface is not feasible to reduce. There may be relatively small areas of impervious surface in pockets throughout the Study Area that could be removed and replaced with either permeable pavement or vegetated area, but other than roads and homes, the majority of impervious surface in Study Area is at 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 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, ISR can help with creating a resilient landscape that can infiltrate some additional rainfall to offset predicted increases due to climate change and also provide co-benefits such as environmental sustainability and improved water quality. The most feasible location for ISR would be in the Riverside District discussed above, at either Gibson Park or in one of the properties proposed for redevelopment. The January 2021 Riverfront Master Plan includes a recommendation to convert hard-packed gravel areas on the parcels proposed for redevelopment into vegetated greenspace.

6.9 Bioretention Basin

Due to high groundwater throughout the study area, infiltration from bioretention basins may be difficult to achieve. In addition, similar to Green Infrastructure discussed above, it would be challenging to identify locations throughout the Study Area for bioretention basins since much of the area is heavily developed with numerous residential properties and privately owned businesses. Given these constraints, it is not feasible to implement enough basins to achieve a sufficient volume to contain future predicted flood waters and prevent them from inundating portions of the study area in the future. However, bioretention basins can help with creating a resilient landscape that can infiltrate some additional rainfall to offset predicted increases due to climate change and also provide co-benefits such as environmental sustainability and improved water quality. It is possible that bioretention basins could be sited 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. Implementation of bioretention basins in this portion of the Study Area would require additional investigation of groundwater levels to confirm seasonal high-water levels, however it is likely that subsurface conditions may preclude implementation.

6.10 Backflow Prevention

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. Since 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 2021 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 MassDOT 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.

6.11 Dune Protection/Restoration

Dune protection and restoration could assist with minimizing predicted future coastal floodwaters in the area of Point of Pines (PoP). These are the only coastal dunes in the Study Area. Areas for dune restoration were detailed in the Beach Management Plan included as part of the Task 3 memorandum. However, feasibility of implementing the measures in the Beach Management Plan may be limited by lack of opportunities for public funding, unless the Point of Pines Beach Association is able to raise funds for dune restoration or some tools outlined in the Beach Management Plan are low cost/easy to implement measures that volunteers in the PoP Association may be able to implement, but the restoration measures require substantial funds to implement. In addition, there are numerous permitting challenges associated with dune restoration, due the presence of NHESP mapped Priority/Estimated habitat, the need to file an ENF for MEPA review, and the need for compliance with MassDEP WPA performance standards for work on coastal dune. Given the numerous permitting review and approvals required for work on the Point of Pines Beach as well as the multiple opportunities for public and agency review and comment, permitting for work on the beach, including dune restoration, was identified as highly complex. Similarly, coastal or off-shore structures near the beach would entail highly complex permitting.

6.12 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. There are multiple funding opportunities for wetland restoration. Because much of 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 January 2021 Master Plan identifies additional salt marsh restoration in this area also. Due to the small area available for salt marsh creation, this tool by itself is unlikely to substantially reduce predicted future coastal flooding in the Study Area, but the area could flood and recover after a storm event, and over time, may build up sediments such that the restored salt marsh area may increase in elevation to keep pace with rising sea levels.

6.13 Living Shorelines

Living shorelines are valuable for aiding in erosion protection along a shore while also providing co-benefits of habitat and water quality improvement. 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 area of 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.

6.14 Evacuation Procedures

Modifications to the current evacuation procedures were recommended as part of Task 3 of this study. Implementation of these recommendations will serve to better manage emergency situations but will not prevent the Study Area from increasing inundation by coastal flood waters in the future.

6.15 Public Education

The City should continue to use public education in conjunction with other public outreach programs to inform the public on the City's efforts towards resiliency measures and public safety. Increased public education regarding future flooding conditions in the Study Area will allow residents to better plan for emergency flooding events but will not prevent homes and business from inundation from coastal flood waters in the future. Dissemination of predicted future conditions may help residents and businesses in the area to make informed decisions regarding their properties and how best to manage them to address future conditions.

6.16 Building Code

The City currently relies on the Massachusetts Building Code, which includes adherence to International Building Codes that require that structure elevations be raised above flood levels. The City should continue to keep building codes as up to date as possible in conjunction with future climate change predictions and apply these codes to any new property developments.

6.17 Land Acquisition

To evaluate the feasibility of land acquisition as a permanent resiliency measure the determination would need to be made of how many properties would need to be purchased that are in flood zones. This measure rates low on the community acceptance scale but there could be the possibility for FEMA grant funding for some homes that have a history of reporting repetitive losses if the owner was receptive. Land acquisition could be evaluated further by the City as they would need to be the buyer or purchase agency in this scenario.

7. Implementation

An initial evaluation of implementation of the tools identified as most feasible for protecting residential areas and other critical assets in the Study Area is included below, and will be further refined as part of the Final Task 6 Feasibility Report for the project, based on discussion and input from the City of Revere. Based on DFE analysis above, the FEMA 2020 1% storm and the MC-FRM 2070 1% storm were chosen for further elevation detailed below.

For this study, this section focuses only on the above grade structure. To achieve the protection of a comprehensive flood protection system, site specific interior drainage and geotechnical conditions must be studied further.

7.1 Alignment A

Alignment A is proposed to protect the western half of the peninsula south of Gibson Park. The version of alignment A required to protect against the 2020 1% storm is shown in below in Figure 7-1, and the version of alignment A required to protect against the 2070 1% storm is show in Figure 7-2**Error! Reference source not found.**. The main differences between these versions are that the 2070 1% version has slightly extended tie ins to reach high ground and will need to be a more robust system overall to reach the higher DFE.

To create both versions of this alignment, a variety of different flood risk reduction measures are proposed. Along Mills Ave on the water, a glass floodwall is proposed to preserve views, flip up gates could be used across streets to mitigate traffic disruptions, and fixed flood walls could be used in areas where vertical barriers currently exist.

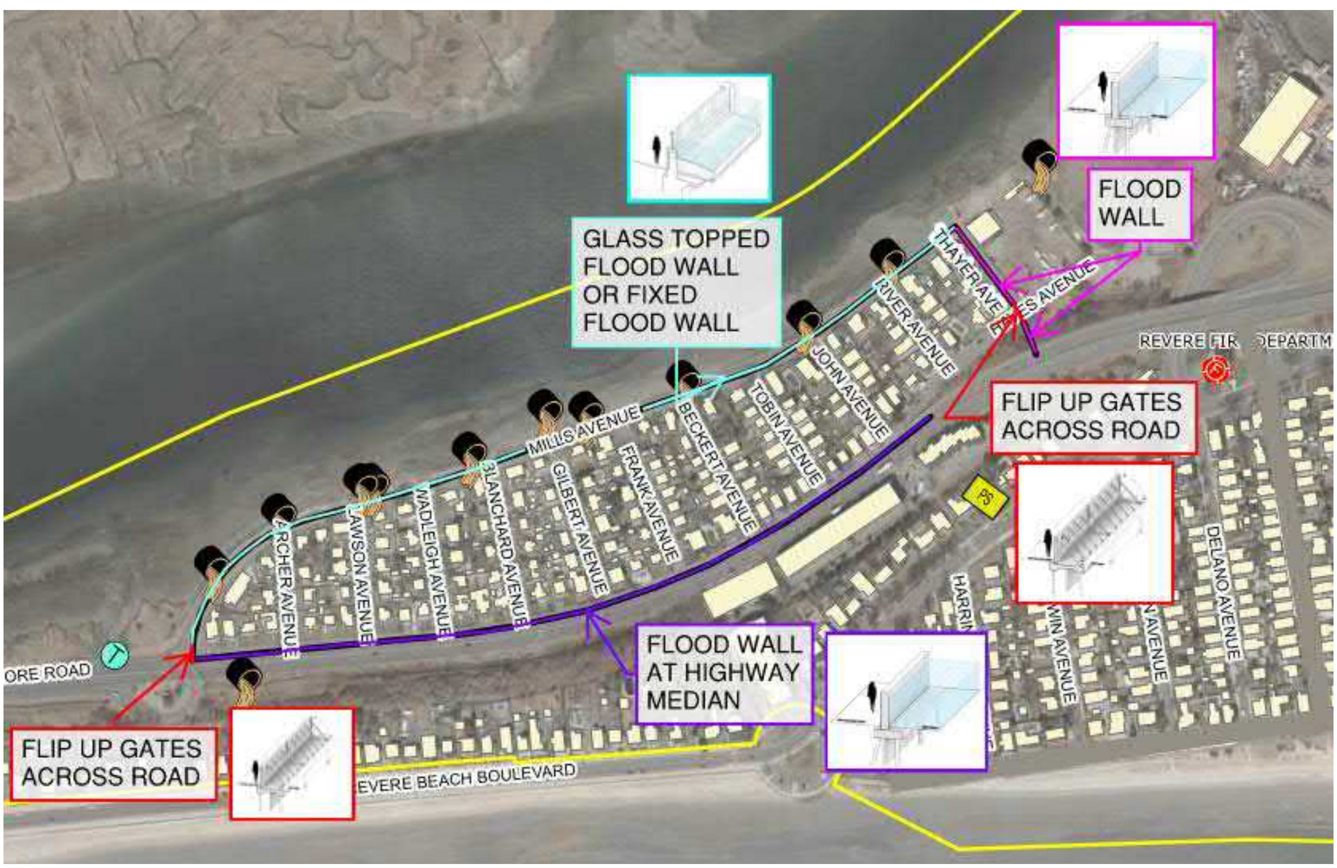

Figure 7-1 Alignment A Flood Risk Reduction Measures 2020 1% Storm

Figure 7-2 Alignment A Flood Risk Reduction Measures 2070 1% Storm

Alignment A begins at the start of Thayer Ave, just west of Route 1A. A fixed floodwall is proposed from the tie in point and down the vegetated slope towards Hayes Ave. Across Hayes Ave, flip up gates are proposed to allow for current traffic operations to remain in place in the absence of a storm. The flip up gates are shown in Figure 7-4 below and will tie into the fixed floodwall on either side of Hayes Ave. On the west side of Hayes Avenue, the fixed floodwall will continue again along the northern side of Thayer Ave replacing the existing fence and acting as a barrier between the road and the parking/storage lot to the north. The proposed location for this wall is shown in Figure 7-3**Error! Reference source not found.** below. To enhance visual appeal, the floodwall can be clad with a variety of finishes and potentially amendments to foster recreational co-use of the wall.

Figure 7-3 Thayer Avenue Proposed Flood Wall

Figure 7-4 Thayer Ave Flip Up Gates

The fixed floodwall along Thayer Ave will tie into the proposed floodwall at the northwestern corner of the intersection between Thayer and Mills Ave. Option 1 is a glass flood wall that can be used to protect the homes on and behind Mills Ave, while preserving river views for the residents. Alternatively, a fixed flood wall may be used in lieu of the glass as option 2. The glass flood wall will continue south along the western side of Mills Ave, along the same line where the existing barrier between Mills Ave and the water is currently located in Figure 7-5 below.

Figure 7-5 Mills Ave Glass Flood Wall

The glass flood wall is proposed to run along the western side of Mills Ave until the intersection with Route 1A. Flip up gates will tie in to the glass flood wall along the water-side Mills Ave and run across the western half of Route 1A. See Figure 7-6. The flip ups will connect to the fixed flood wall proposed at the median of Route 1A.

Figure 7-6 Mills Ave Route 1A Intersection Flip Up Gates

The last segment of Alignment A will consist of a fixed flood wall acting as a median between the western and eastern lanes of Route 1A as shown in Figure 7-7 below. The fixed flood wall will replace the existing highway median, serving as both and barrier between opposite traffic and a flood risk reduction measure. The fixed flood wall will continue down the center of Route 1A until the grade reaches the tie elevation.

Figure 7-7 Route 1A Flood Wall as Median

7.2 Alignment B1

Alignment B1 will protect the eastern half of the peninsula. The version of alignment B1 required to protect against the 2020 1% storm is shown in Figure 7-8 below, and the version of alignment B required to protect against the 2070 1% storm is show in Figure 7-9. To protect against the 2070 1% storm, the length of the B1 alignment must increase significantly at both the northern and southern tie in to reach high ground.

To create both versions of this alignment, a variety of different flood risk reduction measures are proposed. Along Rice Ave, a fixed wall is proposed along the shoreline, flip up gates will be used across streets to mitigate traffic disruptions, and fixed flood walls will be used in areas where vertical barriers currently exist. Due to site constraints, an Aquafence barrier is proposed at the western end of Rice Ave. Although the Aquafence barrier was defined as temporary measure in memorandum 3, it can also be used as part of a permanent flood alignment.

Figure 7-8 Alignment B1 Flood Risk Reduction Measures 2020 1% Storm

Figure 7-9 Alignment B1 Flood Risk Reduction Measures 2070 1% Storm

Alignment B1 required to protect against the 2070 1% and the 2030 1% and 5% storms begins at the median of Route 1A . The first segment of this alignment will consist of a fixed flood wall acting as a median between the western and eastern lanes of Route 1A as shown in Figure 7-10 below. The fixed flood wall will replace the existing highway median, serving as both and barrier between opposite traffic and a flood risk reduction measure.

Figure 7-10 Route 1A Flood Wall as Highway Median

Flip up gates will tie into the fixed flood wall and run across the eastern half of Route 1A. Once the alignment crosses Route 1A, a fixed flood will stretch from the eastern side of Route 1A straight down to the intersection of Carey Circle and Revere Beach Boulevard. Again, flip gates will be used across Revere Beach Boulevard to maintain vehicle access. The flip gates are shown in Figure 7-11 below.

Figure 7-11 Carey Circle Flip Up Gates

A fixed flood wall will tie into the flip up gates, wrapping the eastern edge of Carey Circle and continuing in front of several beachfront private properties until it meets Harrington Ave as shown in Figure 7-12.

Figure 7-12 Existing Beachfront Properties

Alignment B1 required to protect against the 2020 1% storm will begin at the end of Harrington Ave at the +12 ft contour on the northern side of the street. Flip up gates are proposed to run across Rice Ave to ensure traffic on Rice Ave is not obstructed. The flip up gates will tie into the eastern edge of Rice Ave.

Figure 7-13 Harrington Ave Flip Up Gates

Option 2 in this area would be create a fixed flood wall along the coastline. The fixed flood wall will continue north along the eastern edge of Rice Ave and wrap around the northern end of the peninsula.

Figure 7-14 Rice Ave Flood Wall

On the northern tip of the peninsula to the east and west of the Yacht Club parking entrance, a fixed flood wall is proposed. As shown in Figure 7-15, the flood wall would replace the existing fence. The fixed wall would tie into the flip up gates proposed in front of the Yacht Club parking entrance as shown in Figure 7-16 below. Flip up gates are necessary here to preserve traffic flow in and out of the parking lot.

Figure 7-15 Rice Ave, East and West of Yacht Club Flood Wall

Figure 7-16 Rice Ave Behind Yacht Club Flip Up Gates

In order to maintain access to the driveways of the two homes on the western end of Rice Ave, a deployable flood risk reduction measure is required. However, due to the location of these homes along Rice Ave, flip up gates are not feasible as the permanent posts would be located in the street, obstructing traffic along Rice Ave. Thus, a temporary deployable barrier such a Aquafence is proposed to be installed during a storm event behind these two homes as shown in Figure 7-17 below. The temporary deployable barrier would tie into the fixed flood wall along Rice Ave on either side of the two homes.

Figure 7-17 Rice Ave Homes Aquafence

Alignment B1 ends at +12 ft just north of the intersection between Rice Ave and Lynnway. A fixed flood wall will tie in to the temporary deployable system on Rice Ave behind the two homes and run up the vegetated slope to the east of Route 1A shown on the left side of Figure 7-18.

Figure 7-18 End of Rice Ave Flood Wall

Alignment B1 required to protect against the 2070 1% and the 2030 1% and 5% storms will continue beyond the end of Rice Ave. This alignment will consist of a fixed flood wall as it runs up the elevated slope beyond Rice Ave towards Route 1A as shown below in Figure 7-19.

Figure 7-19 Rice Ave to Route 1A

Flip up gates will be used as the alignment crosses the eastern half of Route 1A at the northern tip of the peninsula as shown in Figure 7-20.

Figure 7-20 Route 1A Flip Up Gates

The final stretch of the alignment will contain a fixed floodwall acting as the median for Route 1A similar to the beginning of the alignment.

Based on this proposed alignment, there are a few houses that are left unprotected on the flood side. To provide flood protection, it is recommended to raise the buildings so that they are out of the flood plain. Based on the existing elevations shown in Figure 7-21, there are 10 homes that would need to be raised if version 1 of alignment B1 is implemented and 2 homes that would need to be raised if version 2 of alignment B is implemented. It should also be noted that the existing Yacht Club would fall on the flood side of the alignment. It may be possible to protect the Yacht Club with building specific protection measures, however additional information is needed to further evaluate this possibility, including details regarding the building layout, presence/absence of a basement, and whether any flood protection measures currently exist.

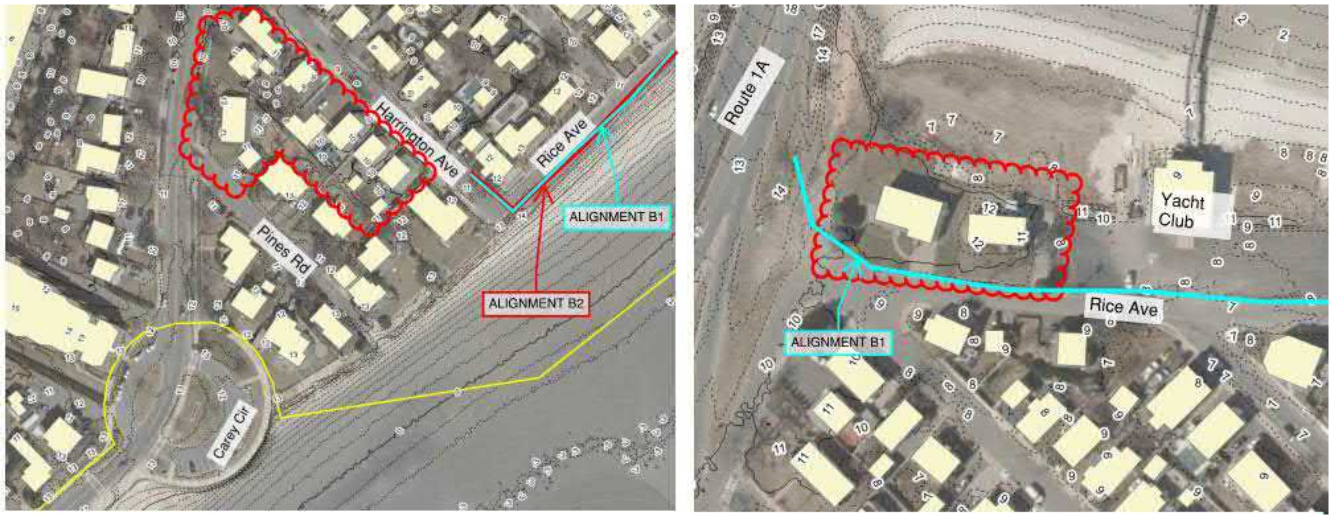

Figure 7-21 Residential Homes on Flood Side

7.3 Alignment B2

Alignment B2 is intended to protect about one third of the homes on the eastern half of the peninsula. This alignment was proposed as a shorter alternative to B1. The proposed flood risk reduction measures along the alignment are shown below in Figure 7-22. Alignment B2 will begin the same way as B1 with a flip up gate crossing Rice Ave at the end of Harrington. The flip up will tie into a dune or raised seawall along Rice Ave. Alignment B2 takes a different path from B1 at Alden Ave where flip up gates are proposed crossing Rice and along Alden until high ground of +12 is achieved. Based on the existing conditions along Alden Avenue, as shown in Figure 7-23 below, flip up gates are the only viable measure due to traffic, driveways and property line restrictions.

However, this alignment is likely not feasible due to constructability and the residential division that it causes. Installing flip up gates of this length would require a significant amount of construction and would have a large impact on the residences on both sides of Alden Ave. Furthermore, once constructed, the gates would only protect one side of the street. For the purpose of this study, Alden Ave was chosen as the dividing road, but the same issue would occur if the alignment turned up any of the side roads off Rice Ave. Therefore, for the purpose of this study alignment B2 was not studied further.

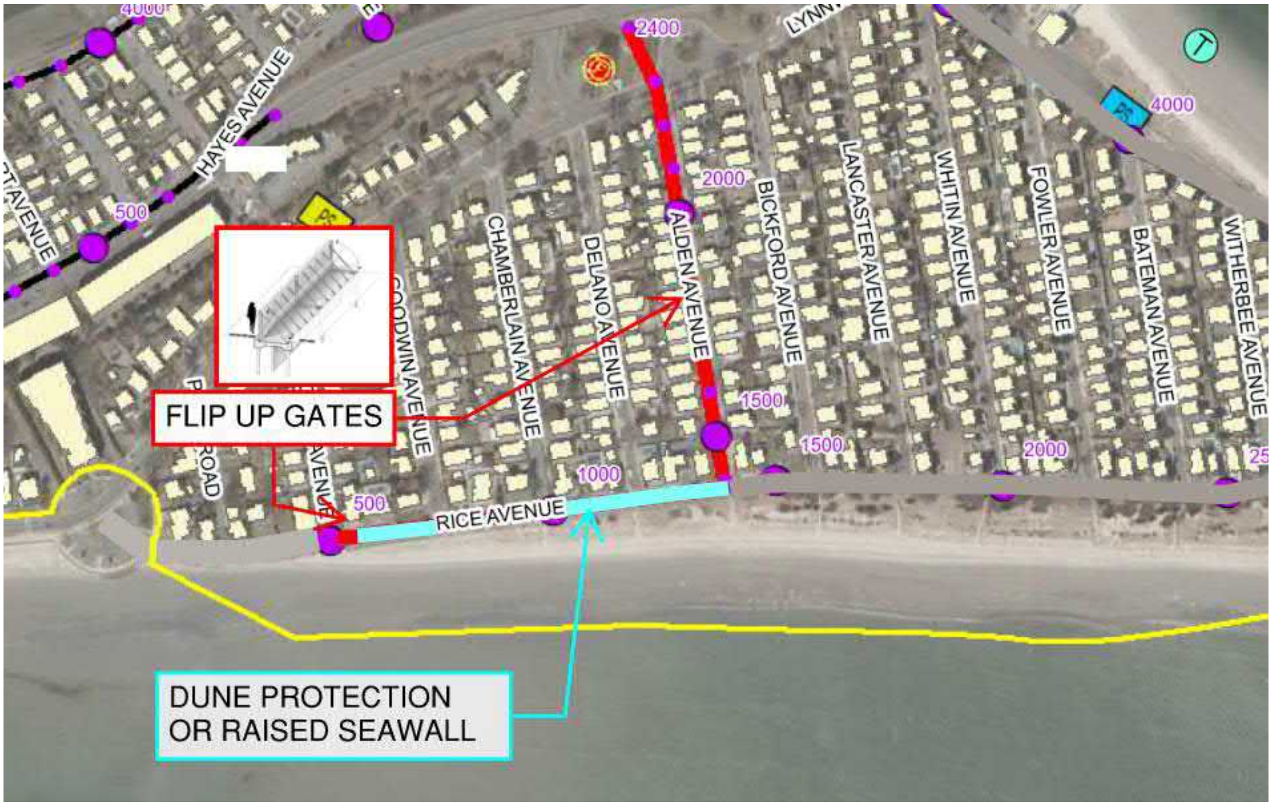

Figure 7-22 Alignment B2 Flood Risk Reduction Measures

Figure 7-23 Alden Ave

7.4 Alignment C

To protect the residential areas along Revere Beach Boulevard on the southeast side of Route 1A, the proposed recommendation is to replace the median of Route A with a fixed floodwall as shown in Figure 7-24 below. On the northern side, this floodwall 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. Due to the lack of existing high ground in the southern project area, to reach high ground, the floodwall would have to be continued slightly northwest of the project area limits. To protect against the 2070 1% storm versus the 2020 1% storm, the tie ins of Alignment C will need to be slightly extended to reach high ground and the alignment will need to be a more robust system overall to reach the higher DFE.

Figure 7-24 Alignment C

Figure 7-25 - Southern Route 1A Floodwall as Median

7.5 Critical Buildings

Figure 7-26 Fire Station

The Fire Station shown in Figure 7-26 is currently being rebuilt in a nearby location.

7.5.1 Wastewater Pump Station

The wastewater pumps station, shown in Figure 7-27, is located to the east of Route 1A. Based on the size of the pump station, the proposed recommendation is to lift and floodproof/elevate the building or rebuild it in the same location at a higher elevation.

Figure 7-27 Wastewater Pump Station

7.5.2 Stormwater Pump Station

The stormwater pump station, shown in Figure 7-28, is located to the North of Mills Ave. Based on the size of the stormwater pump station, the proposed recommendation is to lift and floodproof/elevate the building or rebuild it in the same location at a higher elevation.

Figure 7-28 Stormwater Pump Station

7.5.3 Adult Day Care Center

The adult day care center, shown in Figure 7-29 below, is located at the Northern end of the Peninsula. Based on its size, the proposed recommendation is to create a comprehensive evacuation plan to ensure that all occupants can reach safety prior to a storm.

Figure 7-29 Adult Day Care Center

7.6 Cost

A high-level cost estimate was prepared for each of the proposed alignments and critical infrastructure buildings. Alignment A Option 1 includes the glass floodwall option along Mills Ave, while Alignment A Option 2 includes the concrete floodwall option. This estimate was based on costs from other projects and was created as a planning level estimate and is not a construction cost estimate. Assumptions were used for geotechnical conditions and permitting was not included. Due to the lack of existing information, a -30% +50% contingency was applied. This estimate has been escalated to the midpoint of 2025 and 2026 costs and is summarized in **Error! Reference source not found.** below.

Table 7-1 Cost Estimate 2020 1% Storm

Flood Protection	Cost Min	Cost Max
Alignment A Option 1	10.1 M	21.5 M
Alignment A Option 2	7.5 M	16.1 M
Alignment B1	7.3 M	15.6 M
Alignment C	9.3 M	19.9 M
Critical Buildings	0.9 M	1.9 M

Table 7-2 Cost Estimate 2070 1% Storm

Flood Protection	Cost Min	Cost Max
Alignment A Option 1	17.6 M	37.6 M
Alignment A Option 2	16.9 M	36.1 M
Alignment B1	24.8 M	53.1 M
Alignment C	21.4 M	45.8 M
Critical Buildings	1.8 M	3.8 M

8. Summary

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 . An initial evaluation of implementation of the tools identified as most feasible for protecting residential areas and other critical assets in the Study Area was completed and will be further refined as part of the Final Task 6 Feasibility Report for the project, based on discussion and input from the City of Revere.   Based on DFE analysis above, protection measures for the future predicted conditions in 2030 is only feasible for the 10-year storm and 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.

9. Acronyms

ACEC	Area of Critical Environmental Concern
ASCE	American Society of Civil Engineers
BLSF	Bordering Land Subject to Flooding
CZM	Coastal Zone Management
DEP	Department of Environmental Protection
DFE	Design Flood Elevation
EEA	Executive Office of Energy and Environmental Affairs
EIR	Environmental Impact Report
ENF	Environmental Notification Form
FEMA	Federal Emergency Management Agency
Ft. or ft	Feet
HOI	Height of Intervention
In. or in	Inches
LAND	Local Acquisitions for Natural Diversity
LSCSF	Land Subject to Coastal Storm Flowage
MAssDFW	Massachusetts Division of Fisheries and Wildlife
MC-FRM	Massachusetts Coastal Flood Risk Model
MEMA	Massachusetts Emergency Management Agency
MEPA	Massachusetts Environmental Policy Act
MESA	Massachusetts Endangered Species Act
MVP	Municipal Vulnerability Preparedness
NFWF	National Fish and Wildlife Foundation
NGVD	National Geodetic Vertical Datum
PARC	Parkland Acquisitions and Renovations for Communities
PoP	Point of Pines
SRF	State Revolving Fund Loan

USACE	United States Army Corps of Engineers

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