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Point of Pines and Riverside Area Coastal Resilience Feasibility Study

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Coastal Resilience Toolkit– DRAFT

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.

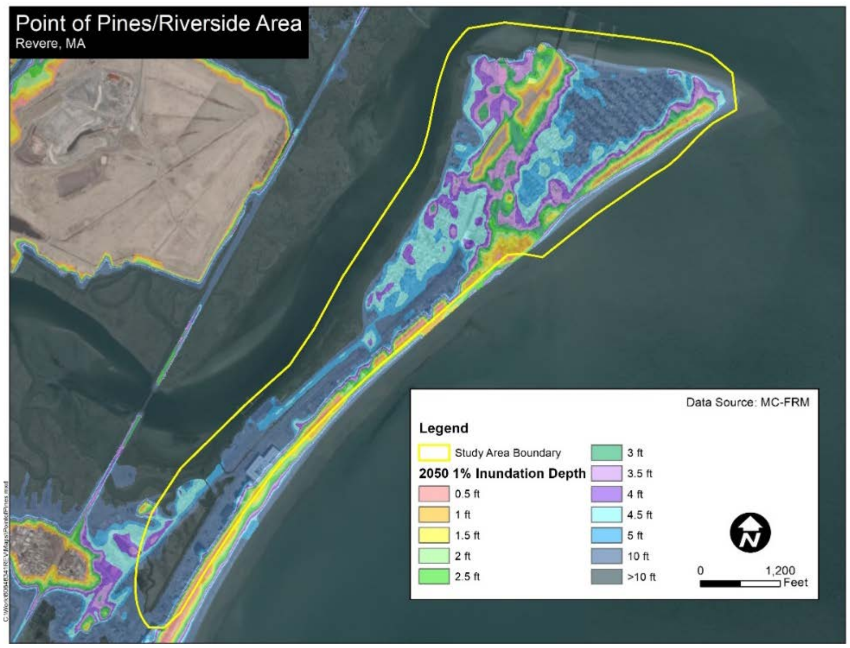


Figure 2.1 - Flooding Probability for a 1% 2050 Coastal Storm

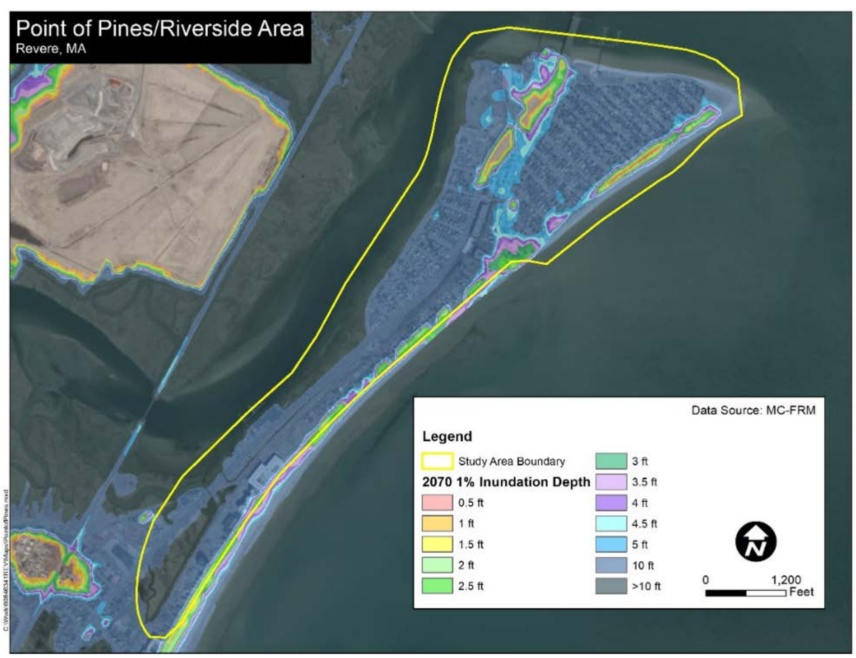


Figure 2.2 - Flooding Probability for a 1% 2070 Coastal Storm

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.

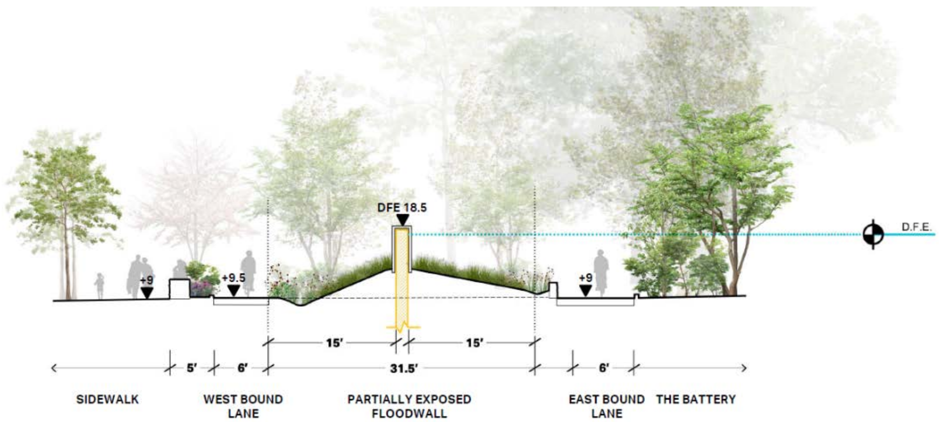


Figure 3.10 – Partially Exposed Floodwall used in South Battery Park City Resiliency Project

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.

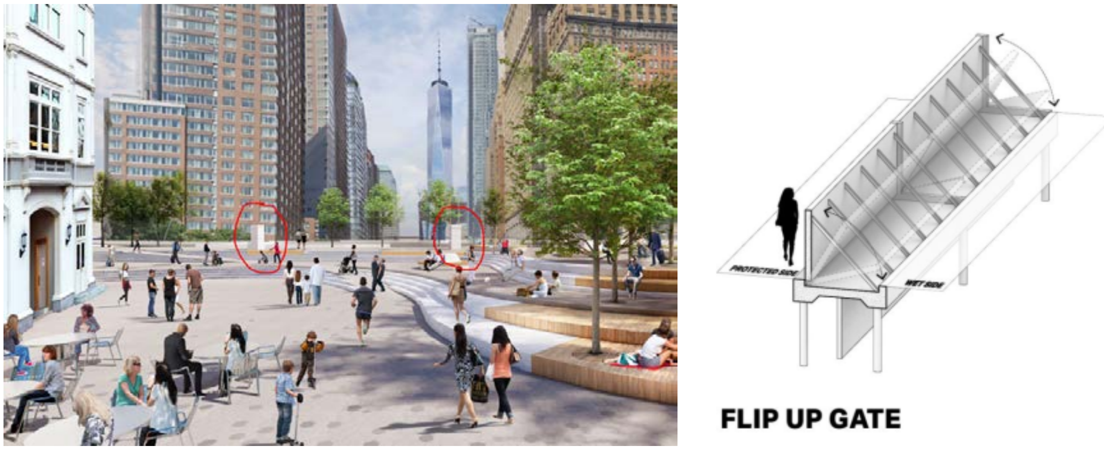


Figure 3.11 – Flip Up Deployable Gate used in Pier A Plaza of South Battery Park City

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.

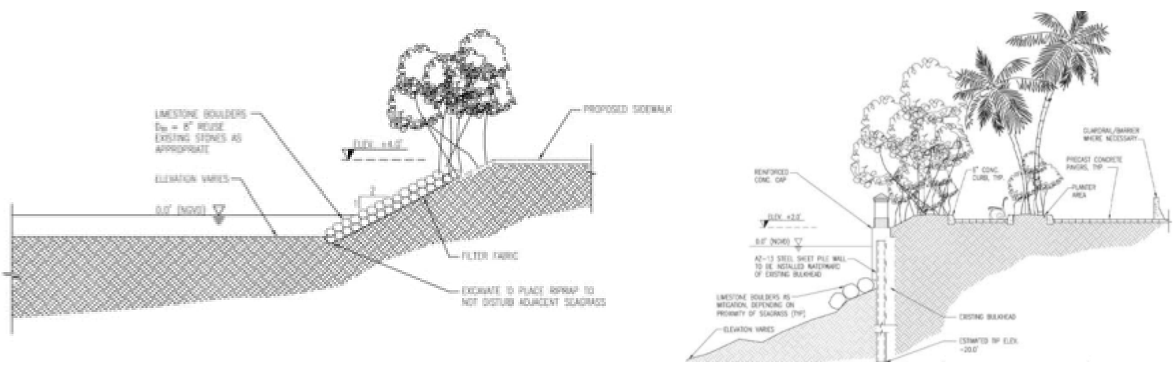


Figure 3.12 - Rip Rap Revetment in Miami Beach

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.

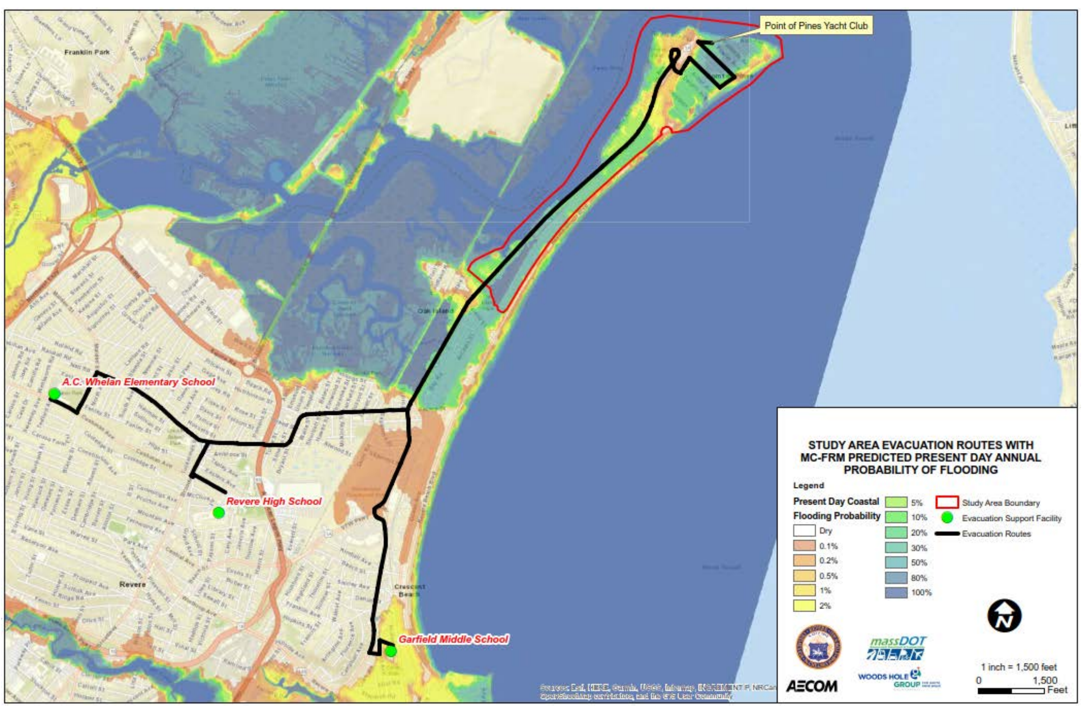
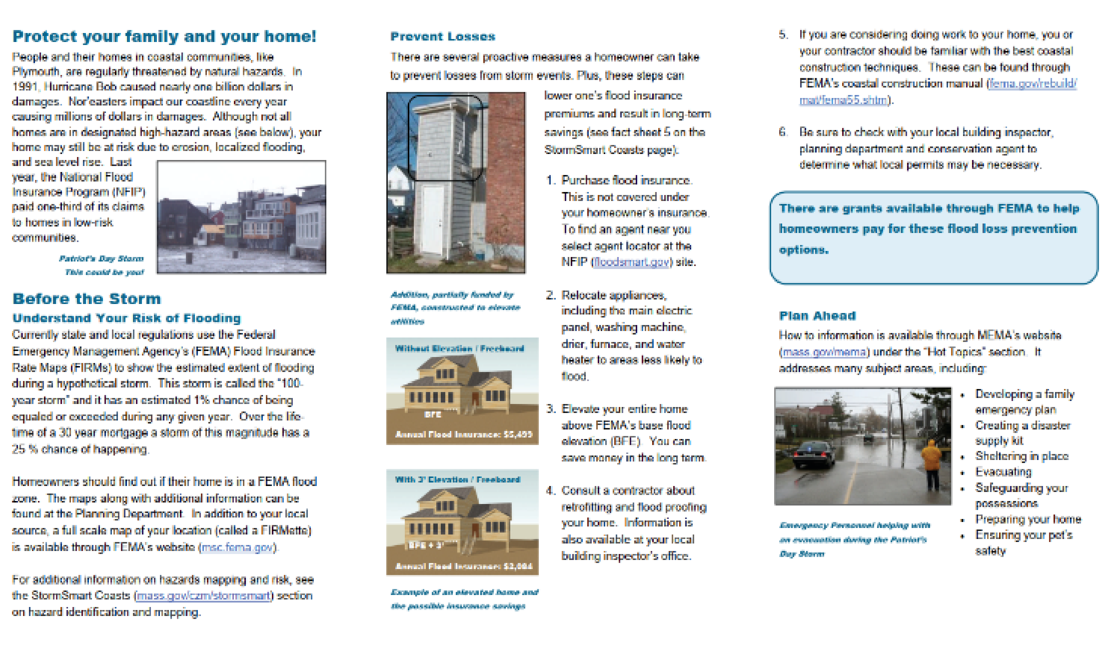


Figure 3.16 - Emergency Evacuation Routes

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).

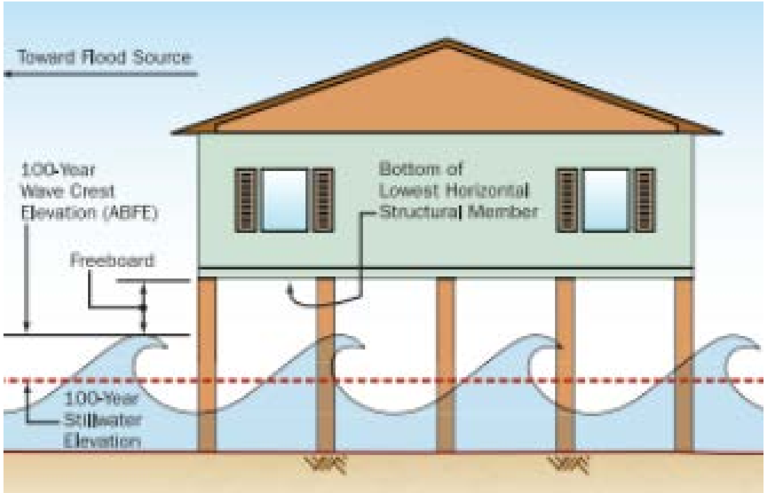


Figure 3.18: Structure Elevated Above Base Flood Elevation. Source: University of Connecticut

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

6. Bibliography

Charleston Post and Courier. January 26, 2021.
https://www.postandcourier.com/rising-waters/charleston-faces-an-existential-choice-wall-off-the-rising-ocean-or-retreat-to-high-ground/article_f581b3a4-8edd-11ea-b5fa-ef8ba31c0a65.html

Climate-ADAPT. Accessed April 16, 2021
https://climate-adapt.eea.europa.eu/metadata/adaptation-options/floating-or-elevated-roads/#websites

Commonwealth of Massachusetts. Accessed April 16, 2021
https://www.mass.gov/service-details/duxbury-kingston-and-plymouth-coastal-hazards-awareness

Dewberry. Accessed April 16, 2021
https://www.dewberry.com/news/blog/post/blog/2018/10/18/five-prominent-flood-resistant-building-techniques

Federal Emergency Management Agency, Planning Considerations: Evacuation and Shelter-in-Place, July 2019.
https://www.fema.gov/sites/default/files/2020-07/planning-considerations-evacuation-and-shelter-in-place.pdf

FEMA. November 2020. Building Codes Save: A Nationwide Study.
https://www.fema.gov/sites/default/files/2020-11/fema_building-codes-save_study.pdf

FEMA. Accessed April 14, 2021.
https://www.fema.gov/pdf/plan/floodplain/fema301_section5.pdf

FEMA, undated. Overview: Flood Hazard Mapping Updates. Accessed April 19, 2021.
https://msc.fema.gov/msccontent/Flood_Hazard_Mapping_Updates_Overview_Fact_Sheet.pdf

Flood Control International. Accessed April 16, 2021
https://floodcontrolinternational.com/products/flip-up-flood-barriers/

Greenroof.com. Accessed April 16, 2021
https://www.greenroofs.com/projects/church-of-jesus-christ-of-latter-day-saints-lds-conference-center/

Ground Engineering. Accessed April 16, 2021
https://www.geplus.co.uk/news/york-flood-storage-area-approved-23-11-2020/

Lake Superior Streams. Accessed April 16, 2021
https://www.lakesuperiorstreams.org/stormwater/toolkit/bioretention.html

LoftSixFour. Accessed April 16, 2021
https://loftsixfour.com/blog/3-reasons-you-need-to-be-part-of-utahs-green-rooftop-amenity-race/

Measurit Technologies LTD. Accessed April 16, 2021
https://www.measurit.com/tideflex-case-studies/never-be-stuck-in-the-mud-with-tideflex

Mechanical Solutions, Inc. Accessed April 16, 2021
https://www.mechsol.com/case-study/new-orleans-flood-control-pumping-stations-vibration-analysis/

Mladenovic, Marina Babic, Structural and non-structural measures in flood risk management, Jaroslav Cerni Institute, November 2015.
http://www.savacommission.org/dms/docs/dokumenti/events/workshop_on_flood_risk_management_measures_and_links_to_eu_wfd/presentations/03.pdf

National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management. Accessed April 14, 2021. https://coast.noaa.gov/digitalcoast/training/kinston-flood-risk.html

Naturally Resilient Communities. Accessed April 16, 2021a. http://nrcsolutions.org/beaches-and-dunes/

Naturally Resilient Communities. Accessed April 16, 2021b. http://nrcsolutions.org/south-cape-may-meadows-cape-may-point-new-jersey/

Virginia Association of Soil and Water Conservation Districts. Accessed April 16, 2021 https://vaswcd.org/impervious-surface-removal

Western Carolina University. July 1, 2019 https://www.coastalreview.org/wp-content/uploads/2019/07/NTB-July-1-2019.pdf

Wired Gov. Accessed April 16, 2021 https://www.wiredgov.net/wg/news.nsf/articles/Plans+for+a+flood+storage+area+in+York+approved+by+planning+chiefs+23112020091500?open

Woods Hole Group. July 2017 https://www.conservationgateway.org/ConservationPractices/Marine/crr/Documents/Final_StateofthePractice_7.2017.pdf

United Kingdom Environmental Agency. Accessed April 16, 2021 https://www.gov.uk/guidance/thethamesbarrier#:~:text=The%20Thames%20Barrier%20spans%20520,position%20across%20the%20River%20Thames

University of Delaware. Complete Communities Toolbox. Accessed April 19, 2021. https://www.completecommunitiesde.org/planning/sustainable/flood-ready

U.S. Army Corps of Engineers (USACE). March 2017 https://www.researchgate.net/publication/318238801_Marsh_restoration_using_thin_layer_sediment_addition_Initial_soil_evaluation#:~:text=Current%20efforts%20are%20utilizing%20thin%20layer%20applications%20of,wetland%20complex%20located%20near%20Avalon%2C%20New%20Jersey%2C%20USA

U.S. Environmental Protection Agency (US EPA). Accessed April 2021a. https://www.epa.gov/wetlands/wetlands-restoration-definitions-and-distinctions

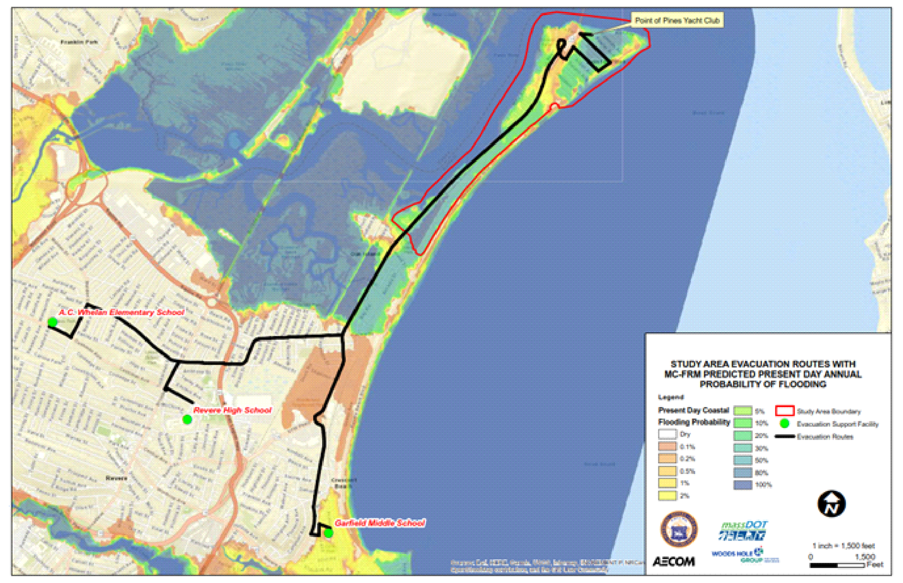
U.S. Environmental Protection Agency (US EPA). Accessed April 16, 2021b. https://www.epa.gov/water-research/stormwater-management-and-green-infrastructure-research

Vaughan, Ellen and Jim Turner, undated. The Value and Impact of Building Codes, Environmental and Energy Study Institute. Accessed April 19, 2021. https://www.eesi.org/files/Value-and-Impact-of-Building-Codes.pdf

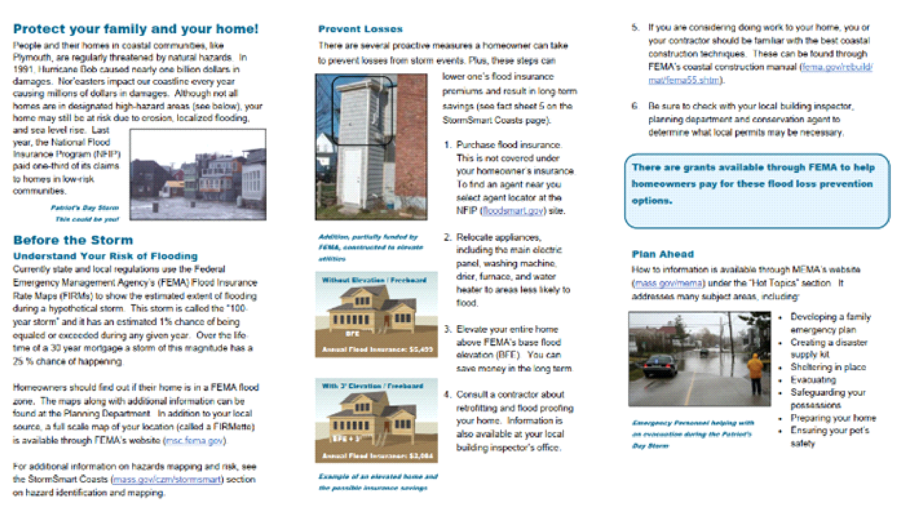
Appendix A - Resiliency Toolkit

THE TOOLKIT

NON-STRUCTURAL MEASURES



EVACUATION PROCEDURES



PUBLIC EDUCATION

LOCAL BUILDING CODE

LAND ACQUISITION

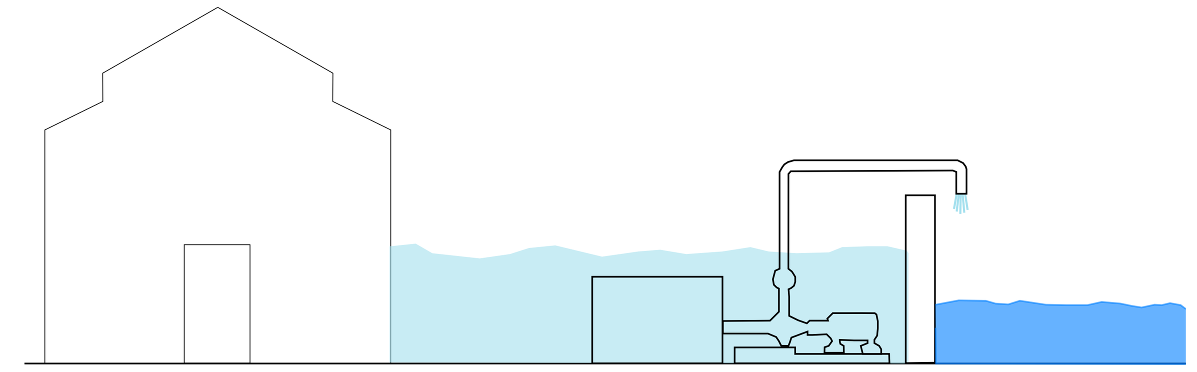
NATURE BASED ADAPTATION

BEACH/ DUNE PROTECTION AND EROSION CONTROL

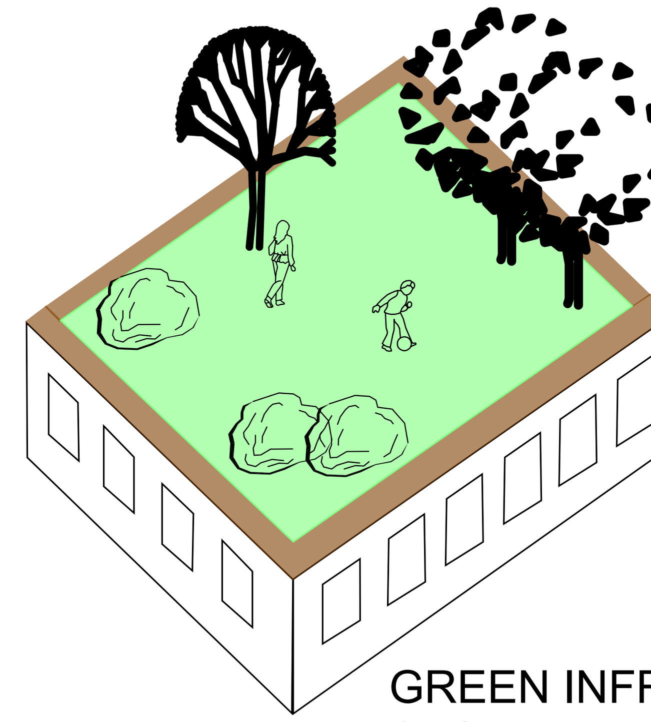
WETLAND AND HABITAT PRESERVATION AND RESTORATION

LIVING SHORELINES

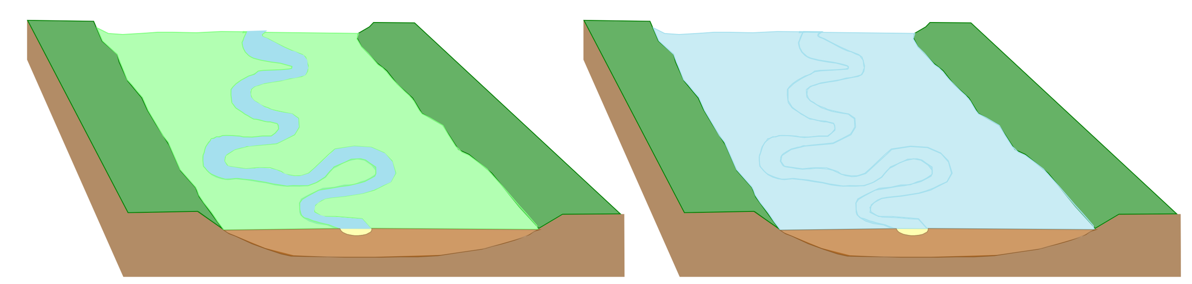
STORMWATER MANAGEMENT



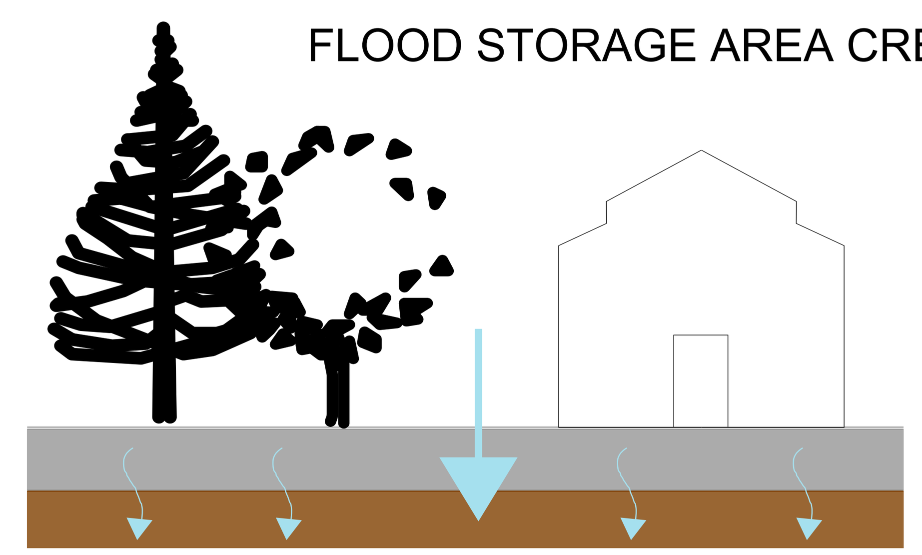
PUMP STATIONS



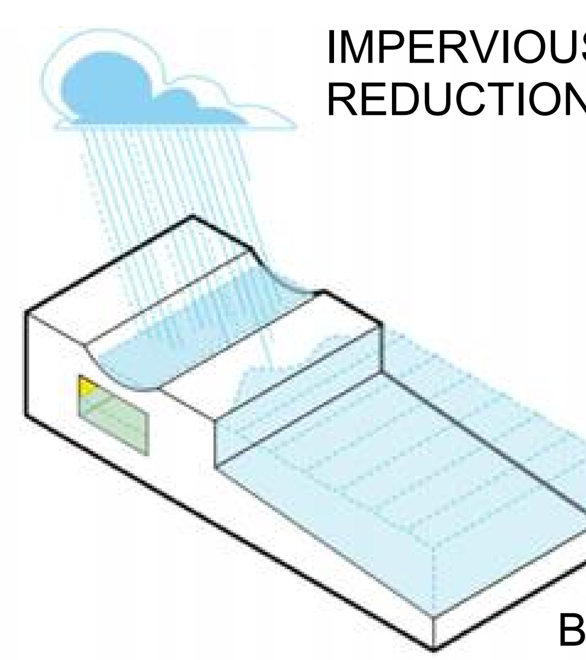
GREEN INFRASTRUCTURE FOR STORMWATER MANAGEMENT



FLOOD STORAGE AREA CREATION



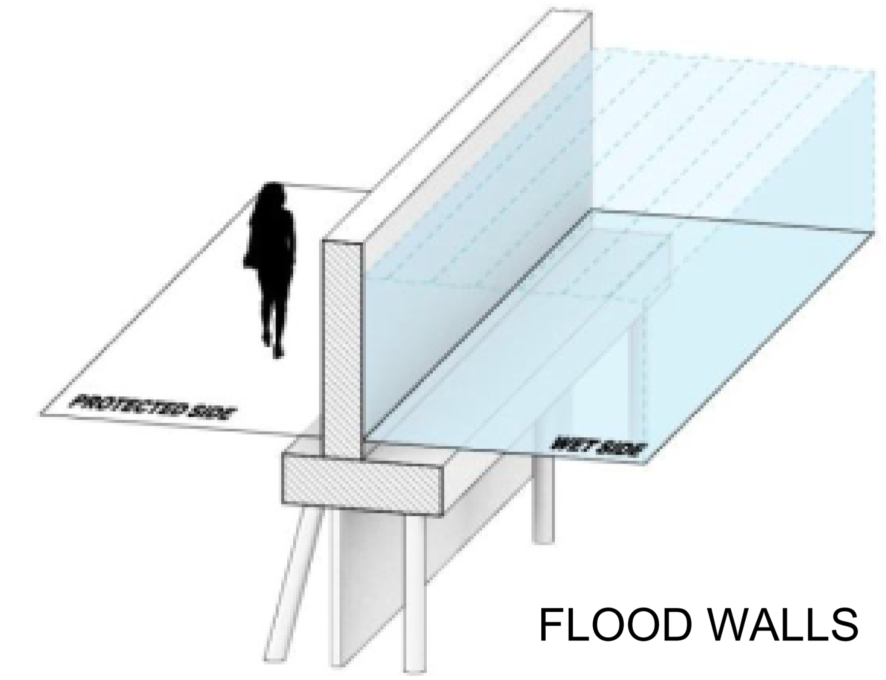
IMPERVIOUS SURFACE REMOVAL/ REDUCTION



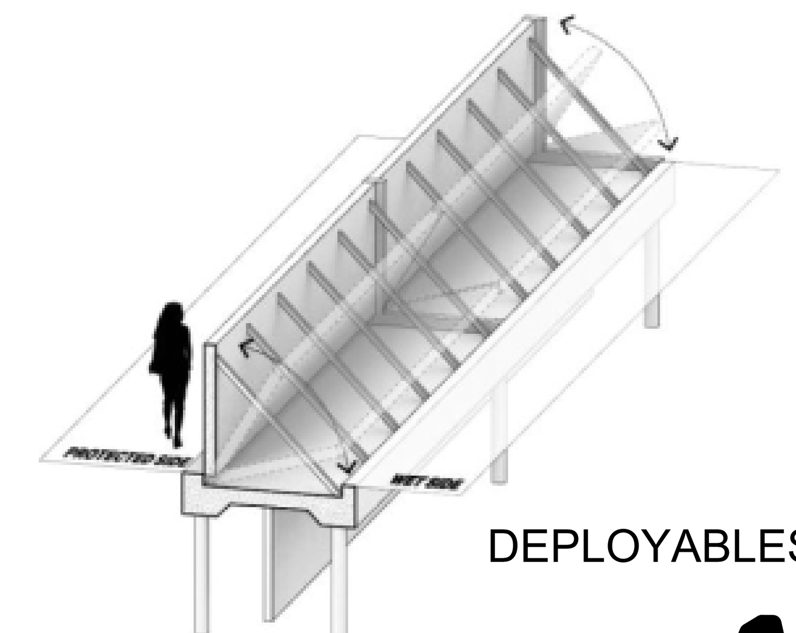
BIORETENTION BASIN

BACKFLOW PREVENTION

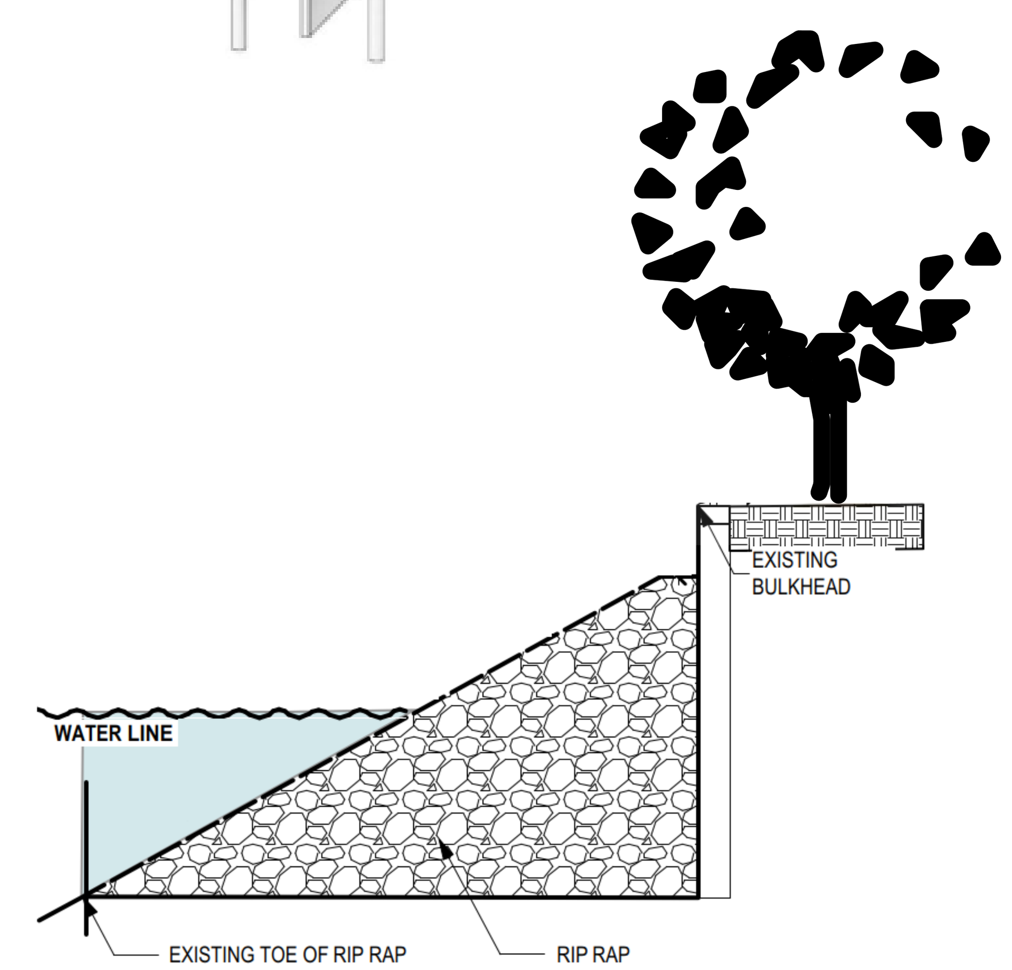
FLOOD RISK REDUCTION MEASURES



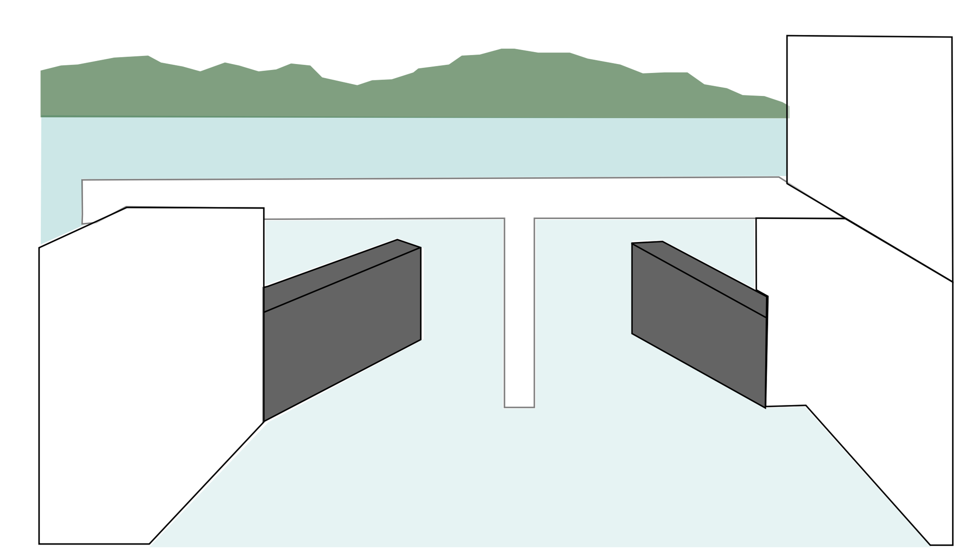
FLOOD WALLS



DEPLOYABLES

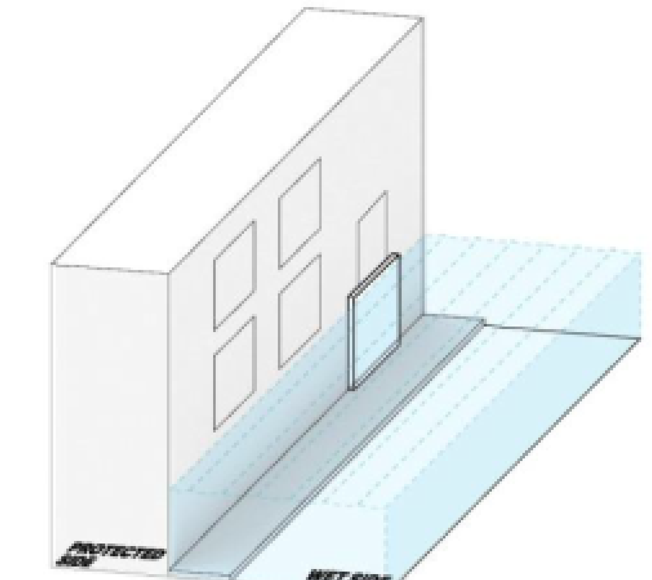


COASTAL STRUCTURES

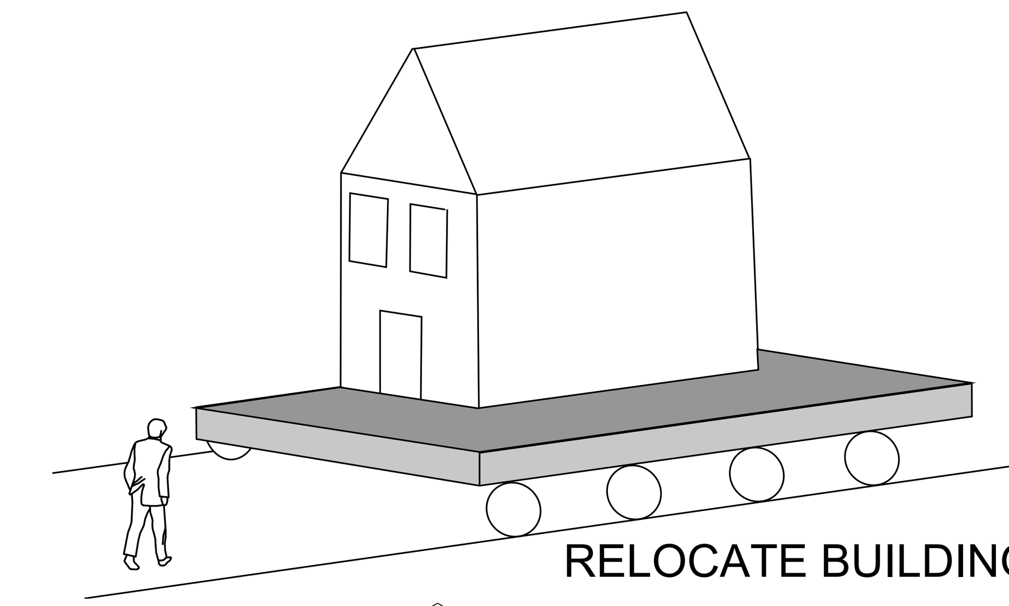


OFFSHORE STRUCTURES

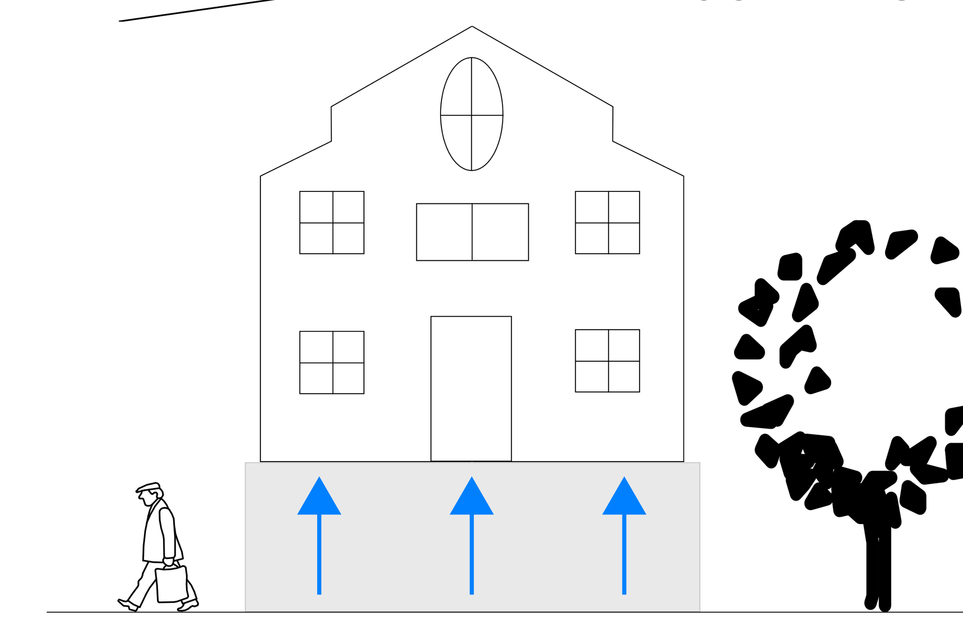
CRITICAL INFRASTRUCTURE RISK REDUCTION MEASURES



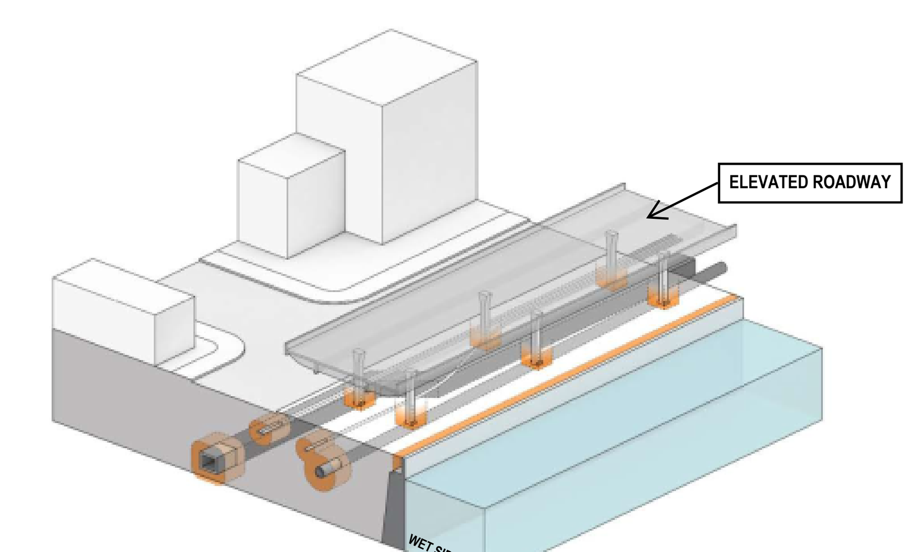
FLOODPROOF BUILDINGS



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.