Resilient Winthrop

Designing Coastal Community Infrastructure for Climate Change

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Financial assistance provided by the Executive Office of Energy & Environmental Affairs (EEA), through the Massachusetts Office of Coastal Zone Management (CZM), under the FY17 Coastal Community Resilience Grant Program. This program provides financial and technical resources to advance new and innovative local efforts to increase awareness of climate impacts, identify vulnerabilities, and implement measures to increase community resilience.


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Contents

List of Tables

List of Figures

List of Appendices

RESILIENT WINTHROP: Executive Summary

Living in a coastal community, most Winthrop residents are not surprised by the likelihood of increased coastal flooding as a result of climate change. They have experienced more intense, frequent storms in recent years and seen the effect that the combined impact of storm surge and sea level rise can have upon the shoreline. Residents expect that areas experiencing coastal flooding, and perhaps increased flooding, will continue to experience flooding in the future if preventative measures are not taken. That being said, most residents have *not* thought much about how increased coastal flooding could impact the infrastructure systems that support their daily lives, and change the natural resources that are an important part of the physical character of the town.

Based on the Boston Harbor Flood Risk Model (BH-FRM), approximately 480 acres of Winthrop's 1.6 square miles is within a coastal flooding area in present day, 500 acres in 2030, and 800 acres in 2070 at a 1% chance water level. The 1% chance water level depicts the flood impacts of a storm event that occurs every 100 years. While the flood area doesn't expand dramatically in future years due to the geographic and topographic lay of the land (e.g. series of drumlins connected by low lying land), the depth of flooding during a storm event does increase dramatically looking to 2070.

From a regional perspective, coastal flooding in Winthrop has the potential for widespread impacts given the Town's geographic location within Boston Harbor and as the only landside connection to the Massachusetts Water Resource Authority's Deer Island Wastewater Treatment Plant. Winthrop is an important part of the Boston Harbor Flood Barrier Study, which is being led by UMass Boston with support from the Barr Foundation.

The criticality of Winthrop to the region broadens the resilience dialogue and heightens the need for proactive adaptation planning.

CLIMATE CHANGE

"any significant change in the measures of climate lasting for an extended period of time, including major changes in temperature, precipitation, or wind patterns."

- US EPA (2014)

Figure E-1 Locus Map
Winthrop's location within Boston Harbor

Contained within the Winthrop mapped coastal flooding areas are critical public infrastructure assets/facilities that support daily life in Winthrop - sewer pump stations, evacuation routes, a substation, pressure reducing valve stations, Winthrop High School, Beach Fire Station, and Town Landing, for example.

Each of these assets/facilities are critical for:

Public Safety & Emergency Services: How important is the asset to community evacuation and disaster response operations?

Social & Economic Activities: How important is the asset to providing people with access or service to their homes and jobs?

Public Health & Environment: How important is the asset to controlling human exposure to pollutants and secondary impacts to the natural environment?

Area of Service Loss: Who is impacted by the loss of or damage to the core functions of the asset?

The last criticality criteria accounts for the fact that loss or damage from coastal flooding could be limited to one property or a neighborhood, it could also have widespread impacts to the town or region.

Assessment Process and Findings

This Climate Change Vulnerability Assessment followed a three step identify-prioritize-strategize process focused on the vulnerability of public infrastructure and natural resources to coastal flooding.

Identify: What areas of Winthrop are at risk of coastal flooding? What public infrastructure is located in these areas?

Eight (8) primary flood areas were identified within Winthrop. Withing these areas, there were sixteen (16) critical public infrastructure assets/facilities susceptible to coastal flooding.

Prioritize: How critical is this infrastructure and what is the likelihood that it will flood?

Assets/facilities were ranked by criticality independent of flood risk. Highest ranked assets included Shirley Street, Argyle Street Substation, emergency evacuation routes, and the pump station. Factoring in the probability of flooding led to certain assets/facilities becoming a higher or lower priority. Pump stations and key emergency evacuation routes received the highest risk score and thus priority.

The following table shows the prioritized critical public infrastructure in Winthrop. Town officials and the consulting team all took part in the prioritization process.

Strategize: How can Winthrop adapt to coastal flooding to help protect the critical public infrastructure in town?

Based on priority ranking, one asset type (pump stations) and four flood areas (Belle Isle Marsh, Ingleside Park, Lewis Lake, and Point Shirley) were selected for concept designs. Creative adaptation concepts of various scales (site-specific vs. shoreline) were considered, each of which addressing the technical aspects of coastal flooding and advancing community and environmental goals.

Complementary to the assessment's focus on publicly-owned infrastructure systems was consideration of the impact of sea level rise and storm surge to natural resources. The Commonwealth's Sea Level Affecting Salt Marshes Model (SLAMM) shows the likely progression of wetland migration across Winthrop over the next several decades.

A large portion of the projected wetland transitions and expansions are predicted to occur in the existing open areas of Winthrop, including, but not limited to, wetlands adjacent to the Winthrop Cemetery and Coughlin Park. These areas will likely experience significant changes in land cover and wetland type and may offer opportunities for natural resource management and/or expansion due to the changing climate.

Table E-1 Prioritized Critical Public Infrastructure

PRIORITY RANK	CRITICAL PUBLIC INFRASTRUCTURE	FLOOD AREA	SECTOR
1	Pico Sewer Pump Station	Fishermen's Bend	Water and Wastewater
2	Pleasant Court Sewer Pump Station	Belle Isle Marsh	Water and Wastewater
3	Washington Street (town evacuation route)	Lewis Lake	Transportation - Roadway
4	Main Street (town evacuation route)	Belle Isle Marsh	Transportation - Roadway
5	Pleasant Street (town evacuation route)	Ingleside Park	Transportation - Roadway
6	Beach Fire Station	Lewis Lake	Buildings
7	Winthrop High School	Lewis Lake	Buildings
8	Pressure Reducing Valve Station (Bayview Avenue)	Point Shirley	Water
9	Pressure Reducing Valve Station (Underhill Street)	Winthrop Beach	Water
10	Shirley Street (town evacuation/MWRA truck route)	Point Shirley	Transportation
11	Public Landing	Point Shirley	Transportation - Maritime
12	Pressure Reducing Valve Station (Revere Street)	Belle Isle Marsh	Water
13	Revere Street Sewer Pump Station	Belle Isle Marsh	Water and Wastewater
14	Belle Isle Bridge	Belle Isle Marsh	Transportation - Roadway
15	Power Substation (Argyle Street)	Belle Isle Marsh	Energy
16	Loring Road Boat Ramp	Ingleside Park	Transportation - Maritime

Figure E-2 Map of 2030 Flood Areas and Adaptation Locations

Adaptation Concepts

Shoreline Adaptations

Shoreline strategies for four focus areas were advanced to concept designs. The concept designs were modeled for effectiveness using the BH-FRM for the 1% chance flood depth in 2030 (the depth of flooding relative to sea level and storm surge during a 100 year storm event). The height of each adaptation was modeled at this elevation, plus one foot of freeboard (e.g. a 4-foot projected water surface elevation would be modeled for a 5-foot-tall barrier). Each adaptation should allow for additional linear or vertical modifications to account for changes in future conditions. The following tables contain general information and cost estimates for each adaptation concept.

Table E-2 Shoreline Adaptation Concept Information

FLOOD AREA	APPROX. 2030 FLOOD AREA (ACRES)	CRITICAL PUBLIC INFRASTRUCTURE	1% CHANCE FLOOD DEPTH (FEET)		RECOMMENDED ADAPTATION CONCEPT	POTENTIAL HEIGHT OF INSTALLATION (FEET)	POTENTIAL LENGTH OF INSTALLATION (FEET)	MODELED EFFECTIVENESS FOR FLOOD PROTECTION UNDER 1% CHANCE FLOOD DEPTH (2030)	2030 COST OF CONSTRUCTION*	2070 ADDITIONAL COST*
			2030	2070						
Belle Isle Marsh	106	Main Street (Evacuation Route & Deer Island Trucking Route)	2'-25"	6'	Planted berm / elevated sidewalk with knee wall along Morton Street right-of-way.	1'-3"	625	Relatively ineffective solely along Morton Street. Needs to extend further west & south along the inlet.	$$$	$$$-Engineered flood barrier
Ingleside Park	38	Pleasant Street (Evacuation Route)	8"	3'-5"	Hybrid seawall, with seating & planting adjacent to Donovan's Beach.	1'-9"	325	Effective as a coastal flood adaptation.	$$$	$$-Engineered flood barrier
Lewis Lake	153	Washington Avenue (Evacuation Route, Winthrop High School)	1'-5"	4'-25"	Flood barrier at Washington Avenue.	2'-6"	900	Effective as a coastal flood adaptation, if culvert & tide gate system at Crystal Cove work as intended.	$$$	$$
Point Shirley	88	Shirley Street/Tafts Avenue (Evacuation & Deer Island Trucking Route)	12"	4'	Beach nourishment / dune creation at Yirrell Beach (pending design study).	Pending design study	3,850	Effective in reducing wave overtopping & flood depth levels if properly engineered.	$	$$$$$
					Dune creation at Yirrell Beach (pending design study).				$$$$ to $$$$$	$$$$$

* Estimates include approximate cost of materials and labor for installation. Estimates do not include design, permitting, right-of-way acquisition, construction mobilization and demobilization, operations, or maintenance.

Key to Estimated Range of Costs:

$ = <$100,000 ; $$ = $100,000 to $500,000 ; $$$ = $500,000 to $3,000,000 ; $$$$ = $3,000,000

Site Specific Adaptations

Three major sewer pump stations in town are identified within BH-FRM flood areas. These stations collect and distribute hundreds of thousands of gallons of sewage each day. The stations are at specific low points in the community to collect neighborhood waste and pump it out to the larger sewer mains. Pump station retrofits such as perimeter walls and dry floodproofing techniques and other information are identified in the following table. These adaptation measures may also be applied to other asset types, private residences and commercial buildings.

Table E-3 Pump Station Adaptation Concept Information

PUMP STATION ADAPTATION TYPE	CONSTRUCTION COST ESTIMATE*
Stop Logs	$4,000 - $6,000 each
Watertight Exhaust Ducts	$10,000 - $15,000 each
Watertight Floor Hatches	$10,000 - $15,000 each
Repoint Building Façade 5-feet above grade	$20 - $30 per square foot
Waterproof Building Façade 5-feet above grade	$5 - $10 per square foot
Raise Outdoor Equipment Pads	$500 – $1,000 each
Raise Electrical Equipment Supports	$10 - $20 each
Work Platforms for Raised Electrical Equipment	$50 - $100 each
5-ft Concrete Perimeter Wall	$300 - $500 per linear foot

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Following completion of this assessment, the next step for the Town is to advance the concept designs and assessment recommendations towards implementation and expand the resilience discussion to include consideration of other climate-related hazards and community assets. Doing so will require a commitment from the Town, its residents and business owners, and agency partners to advance community resilience at all scales in the short and long term.

In Fall 2017, the Town will begin a community resilience building workshop process as part of the Commonwealth's Municipal Vulnerability Preparedness (MVP) Program. This Program expands the focus from just coastal flooding to include consideration of other climate-related hazards such as increased precipitation and heat, for example. Results of the workshop and planning efforts will be used to inform existing local plans, grant applications, budgets, and policies.

This study was completed with a cross section of input from residents at two public meetings and the help of the Project Management Team which included representation from the Town Manager's Office, Department of Public Works, Fire Department, Police Department, Conservation Commission, Massachusetts Office of Coastal Zone Management and the consultant team from Stantec and Woods Hole Group.

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1 VULNERABILITY ASSESSMENT PURPOSE

Many small coastal communities in Massachusetts have experienced the waves, high winds, and severe flooding that are delivered by Nor'easters and hurricanes. These storms can damage homes, cause power outages, and impact local and regional infrastructure and operations. Sea levels are anticipated to rise more than six inches over the next 15 years, and more than three feet over the next 50 years. Climate change is expected to cause higher high tides and longer, more intense, and more frequent storms. Therefore, it is important for coastal communities like Winthrop to prepare for an unpredictable future environment.

As the Commonwealth advances an integrated climate change strategy (Executive Order 569), Massachusetts communities are working to implement policies and adaption measures at the regional and local level to enhance resiliency and climate preparedness. At the regional level, the Metro Mayors Coalition set climate preparedness as its programmatic priority, and established the Metro Boston Climate Preparedness Taskforce. The Taskforce is working to shape and drive forward increased collaborations that advance regional resiliency.

STUDY GOAL:

To identify and prioritize critical public infrastructure vulnerable to coastal flooding and explore adaptation measures to improve infrastructure and natural resource resilience over a range of future conditions.

View of the Winthrop Water Tower as seen from Pico Beach

Row boat on flooded Shirley Street, November 1932,
Courtesy of the Boston Public Library, Leslie Jones Collection.

Through participation on the Taskforce and a review of municipal priorities, the Town of Winthrop has proactively begun to design and construct improvements to reduce the impacts of coastal flooding at critical infrastructure locations. Efforts like the Winthrop Hazard Mitigation Plan, Winthrop Harbor Plan, and Coughlin Park Green Infrastructure Study have exhibited the Town's commitment to assessing the vulnerability levels and existing conditions of both the built and natural environment. Other state and federally funded efforts to address coastal flooding in Winthrop include improvements along Winthrop Shore Drive, Winthrop Beach, Tafts Avenue, and Lewis Lake.

Each of these infrastructure improvement projects addresses flooding issues in different areas of Winthrop. However, the Town recognizes the need to take a step back and evaluate critical infrastructure at a Town-wide level. This vulnerability assessment will assist the Town with the prioritization and strategic implementation of projects to help infrastructure assets and areas most at risk from coastal flooding become more resilient. This information will also inform individual home-owners about what they might expect on their own properties, regarding future coastal flooding.

COMMUNITY RESILIENCE

"the capability to anticipate risk, limit impact, and bounce back rapidly through survival, adaptability, evolution, and growth in the face of ... change."

- Definitions of Community Resilience: An Analysis (A CARRI Report)

2

VULNERABILITY ASSESSMENT PROCESS

Source: Winthrop town website

Settled in 1630, Winthrop is one of the oldest communities in the United States. At 1.6 square miles and an estimated population of 17,500, Winthrop is also one of the smallest and most densely populated municipalities in Massachusetts. With 8.3 miles of tidal shoreline and a small geographic footprint, Winthrop is particularly vulnerable to coastal flooding from sea level rise and climate change.

The increasing chance of coastal flooding threatens Winthrop's shoreline, including public facilities, infrastructure, recreational areas, and coastal ecosystems. Today, approximately 45% of the 1.6 sq mi town is within a flood zone. That's nearly 480 acres. By 2030, it could increase to 50% (500 acres), and 60% (800 acres) by 2070.

VULNERABILITY:

"Structures, systems, populations, or other community assets as defined by the community, that are susceptible to damage and loss from hazard events."

- FEMA Local Mitigation Plan Review Guide (2011)

Considering this, the goal of this climate change vulnerability assessment is to evaluate potential impacts of coastal flooding in the Town of Winthrop, based on what we know about extreme weather and sea level rise, and to identify measures to protect critical public infrastructure.

A 3-step process was followed for this assessment:

IDENTIFY

What areas of Winthrop are at risk of coastal flooding? What public infrastructure is located in these areas?

The assessment begins by explaining the development history of Winthrop and the areas of the Town most likely to experience coastal flooding based on sea level rise projections and a wide range of potential storm events. This information allows us to locate existing public infrastructure and natural resources within seven vulnerable areas of the Town. (Chapters 3, 4 &5)

PRIORITIZE

How critical is this infrastructure and what is the likelihood that it will flood?

The next step includes evaluating identified public infrastructure assets based on how critical they are to the community-at-large, and how likely they are to flood in present day, 2030, and 2070. The result is a total risk score that can be used as the basis for prioritizing investments. (Chapter 6)

STRATEGIZE

How can Winthrop adapt to coastal flooding to help protect the critical public infrastructure in town?

The last part of the assessment recommends site-specific, shoreline, and policy or regulatory measures to improve the resilience of critical public infrastructure. It also lays the foundation for follow on efforts and future implementation phases. (Chapters 7-12)

Throughout the assessment process, critical infrastructure, potential areas of flooding, and neighborhoods were targeted through the cooperative engagement of a consultant team, residents, and the input of Town staff.

The Town established a Project Management Team (PMT) to facilitate and manage project implementation. The Team met on multiple occasions to share local knowledge, review datasets, and discuss preliminary concepts. The PMT includes:

- Joe Domelowicz Jr., Assistant to the Town Manager for Grants and Economic Development
- Steve Calla, Department of Public Works Director
- Terrence Delehanty, Police Chief
- Paul Flanagan, Fire Chief
- Kara Campbell, Conservation Agent
- Lisa Engler & Patricia Bowie, Coastal Zone Management (CZM)
- Staff from the consultant team at Stantec and Woods Hole Group

April 5, 2017 public meeting at EB Newton,

Two public meetings were held throughout the project to gather local knowledge and opinion:

The first public meeting was held on April 5, 2017 at EB Newton to:

- explain the purpose and scope of the project
- present the Boston Harbor Flood Risk Maps (BH-FRM) modeling by Woods Hole Group
- provide an opportunity to ask questions.

An open house and public meeting was held on May 23, 2017 at Winthrop Town Hall to:

- present the BH-FRM modeling for future years 2030 and 2050 (Chapter 3)
- explain how critical infrastructure was identified and selected (Chapter 6)
- present potential adaptation measures for sites and shorelines throughout town (Chapter 7)
- provide an opportunity to comment and ask questions.

A meeting was also held with the Department of Conservation and Recreation (DCR) on June 12, 2017. A subsequent meeting will be scheduled with the Massachusetts Water Resources Authority (MWRA) to discuss the findings of this assessment.

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3

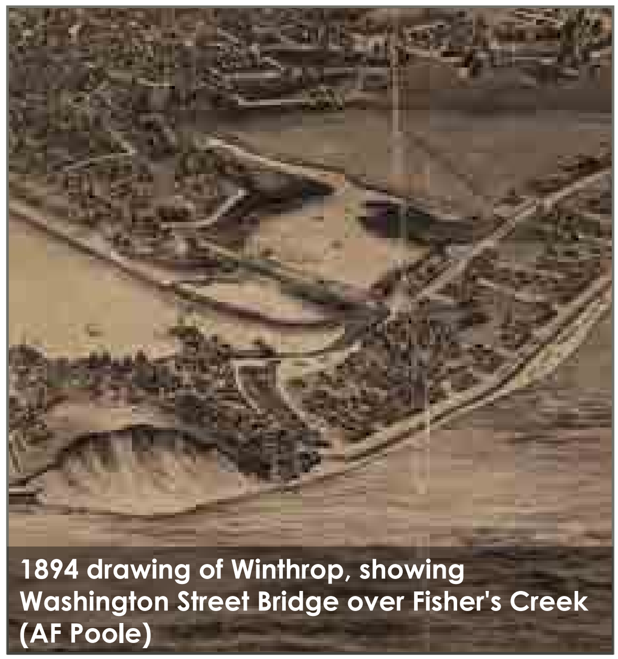
IDENTIFY: Future Areas of Coastal Flooding

This section focuses on understanding where Winthrop has and is experiencing flooding, where there are likely future flooding locations, and what has been done to address the flood risk. Once the challenge locations are known, a conversation can be had regarding potential adaptation measures and means of project funding.

Coastal flooding occurs when the waves, storm surge, and tides overtop the shoreline and low-lying areas become submerged. While there are additional factors that contribute to flooding within our built environments (such as intense precipitation events that can cause a rising water table and increase in stormwater runoff from roofs, roadways, and parking areas), coastal based flooding is the focus of this vulnerability assessment. Additional localized flooding should also be assessed as part of future studies.

Coastal Development in Winthrop

Winthrop was settled by Europeans in 1635 (MHC, 1981). Historic mapping shows four farming plots during this period, and a small fishing village at Point Shirley by the mid-18th century. These maps also illustrate the marsh land and open water that has filled over the years due to natural events and human activity. The most notable changes include Fisher's Creek and Shirley Gut.



1894 drawing of Winthrop, showing Washington Street Bridge over Fisher's Creek (AF Poole)

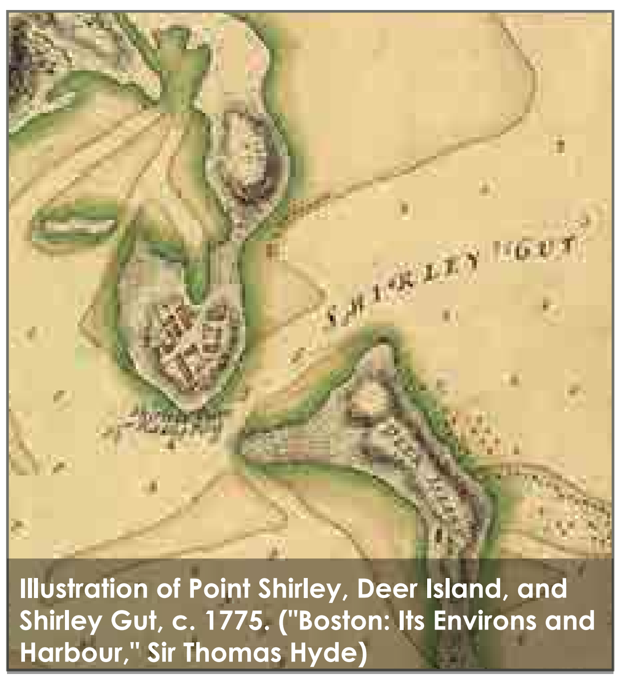


Illustration of Point Shirley, Deer Island, and Shirley Gut, c. 1775. ("Boston: Its Environs and Harbour," Sir Thomas Hyde)

Figure 3-1 Fisherman's Bend, October 2016, at typical high tide (left) and King Tide (right) (mycoast.org King Tide Report by Joanne Anderson)

KING TIDE

The King Tide is the highest predicted high tide of the year at a coastal location. It is above the highest water level reached at high tide on an average day

- US EPA (https://www.epa.gov/cre/king-tides-and-climate-change)

Lewis Lake was previously an extensive marsh surrounding Fisher's Creek. It was open to Boston Harbor until the mid-19th century, but was bridged in the 1880s and subsequently filled, with a tide gate installed in the early 20th century (MHC, 1993). Shirley's Gut once separated Point Shirley from Deer Island. By the 20th century, sand drifted into the narrow waterway, and the Hurricane of 1938 finally filled it, connecting Winthrop to Deer Island (Culhane et. al.). Locations such as these are common around town, where low lying, previously wet land is now developed.

The existing high tide elevation is currently between 9 and 10 feet. Sea level rise can be gaged during King Tides (Figure 3-1). This extreme tide event suggests what the average high tide may look like within the next half century (DeCosta-Klipa, 2016). Of note, the King Tide on October 17-19, 2016 was between one and two feet higher than a normal high tide.

The areas of filled tidelands and the rising sea level give some indication of where the water wants to go during storms and/or high tide events. This idea is emphasized in the historic and present account of the flooding in Winthrop, as well as the future coastal flood modeling, presented in this chapter.

Historic and Current Flooding Locations

Several recorded and anecdotal storm events, specific to coastal flooding, were noted in the 2014 Winthrop Hazard Mitigation Plan (HMP), including:

- 16 coastal flood events between 2006 and 2014, resulting in $3.11 million in property damage.
- 40 heavy snowfall events between 1996 and 2014, including $9.6 million in property damage.
- Ten severe winter storms recorded between 1978 and 2013 – seven of which occurred after the year 2000.

The coastal flood of 1978 (blizzard) remains the record high flooding event in Winthrop to date. After the Blizzard of 1978, high water marks inventoried by the United States Geological Survey, U.S. Army Corps of Engineers, and Massachusetts Department of Public Works were recorded between 9.5 and 12 feet above Mean Sea Level. (HMP, 2014)

The Federal Emergency Management Agency (FEMA) uses historical climate information to estimate potential damages from natural hazards. Flood zones are modeled to define areas at risk of flooding. The areas are illustrated on Flood Insurance Rate Maps (FIRMs), which identify properties required to obtain flood insurance.

The FIRMs issued in 2016 for Winthrop show approximately 45% of town within the 1% annual chance flood (also known as the 100-year storm).

Anecdotal information regarding local flooding, gathered from the town during the 2014 Winthrop Hazard Mitigation Plan, supports the FEMA data. In addition to identifying various seawalls and headwalls (Woodside Ave, Somerset Ave, Sargent St, Cottage Park Rd), areas of local flooding included:

- A Yirrell Beach
- B Shirley Street Neighborhood
- C Lewis Lake
- D Ingleside Park
- E Lower Nahant Avenue
- F Coughlin Park
- G Bayou Street Neighborhood

A more in-depth review of these areas is included as part of Chapter 5 of this vulnerability assessment.

Figure 3-2 Town-Identified Areas of Local Flooding

Boston Harbor Flood Risk Model (BH-FRM)

A scientifically accurate, dynamic, robust, and probability-based analysis of potential flooding in Winthrop is key to effectively evaluate the risks of future sea level rise and storm surge. This allows the Town to identify and prioritize areas and assets within probable areas of flooding. Then potential adaptation options can be studied in order to build overall resilience for the community. Using established techniques and previously generated model data from work with the Massachusetts Department of Transportation, probabilistic flood information forms the basis for the vulnerability assessment in the Town of Winthrop.

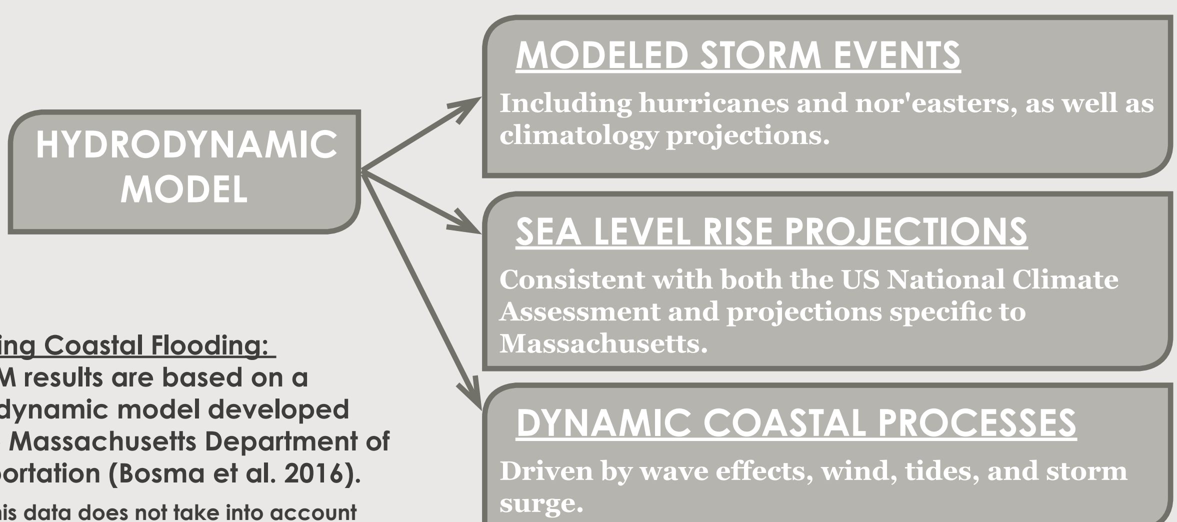
Sea level rise and storm surge can be modeled in a number of different ways. This assessment utilizes the Boston Harbor Flood Risk Model (BH-FRM) to provide results for the Town of Winthrop. The model, called the Boston Harbor Flood Risk Model (BH-FRM), is used to provide the results for the Town of Winthrop.

Concern about potential impacts to the City of Boston from future storms drove the creation of the BH-FRM – a model with the best representation of the physical processes, as well as accurate and higher resolution predictions of inundation due to the combination of sea level rise and storm surge. The hydrodynamic modeling utilized for the BH-FRM was geared towards a physics-based approach to determine the water level increases and flooding, and provided results to identify specific locations that may require adaptation alternatives.

For this project, Woods Hole Group (WHG) has produced two types of BH-FRM maps to illustrate potential impacts to areas of coastal flooding:

1. The probability, or likelihood, of coastal flooding today and in future years 2030 and 2070 (Figure 3-3). A range of percent chance spans from 100% (annual storm condition) to 0.1% (a one in 1,000 chance storm – a less frequent, more intense occurrence).
2. Depth of flooding, relative to sea level (Figure 3-4). These maps show different depths for present day, 2030, and 2070, associated with both the 1% (1 in 100) and 0.1% chance floods.

For more in-depth information about the BH-FRM, see Appendix D.



Mapping Coastal Flooding:
BH-FRM results are based on a hydrodynamic model developed for the Massachusetts Department of Transportation (Bosma et al. 2016).

Note: This data does not take into account inland freshwater flooding or stormwater.

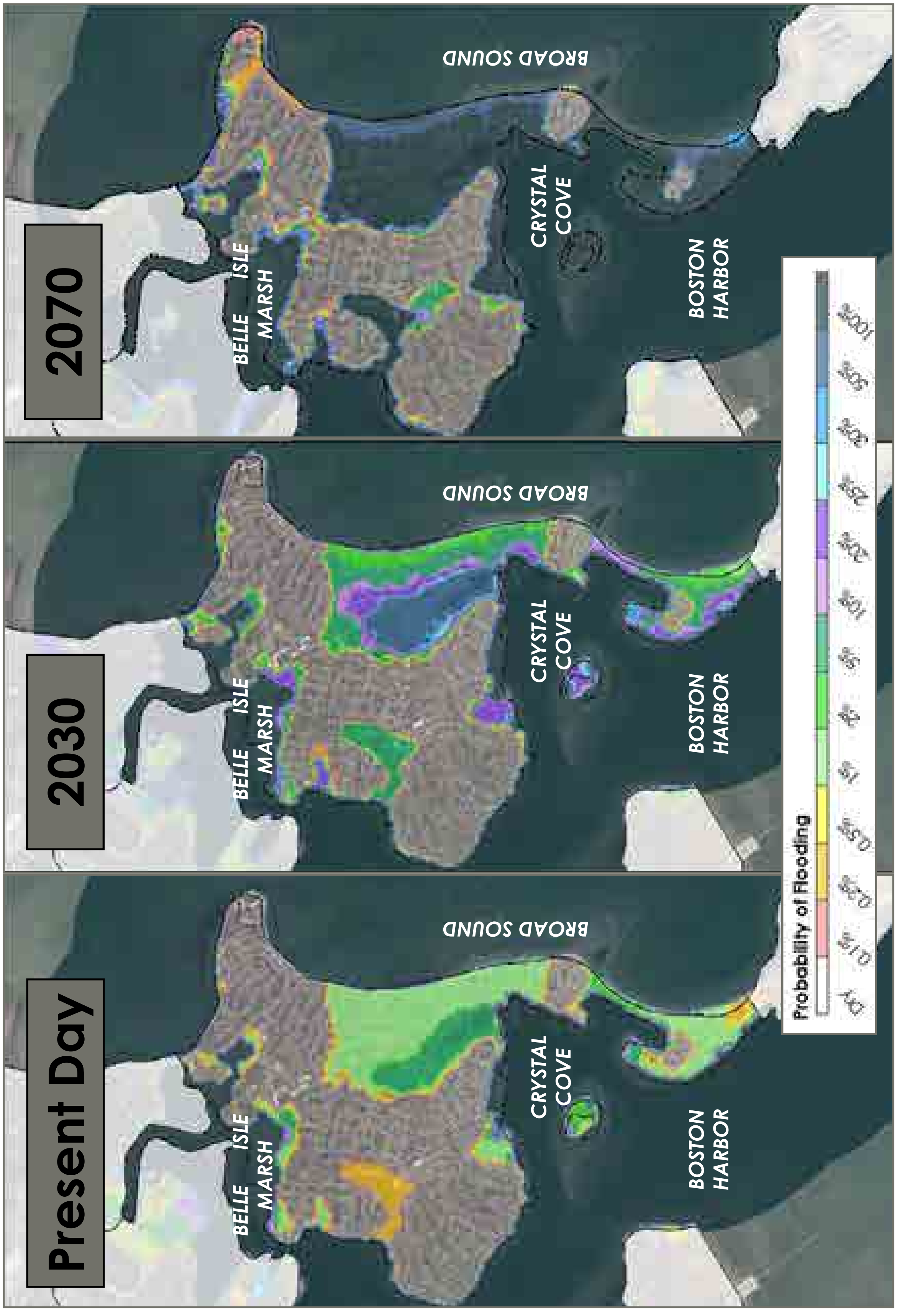


Figure 3-3 Winthrop Areas of Probable Flooding

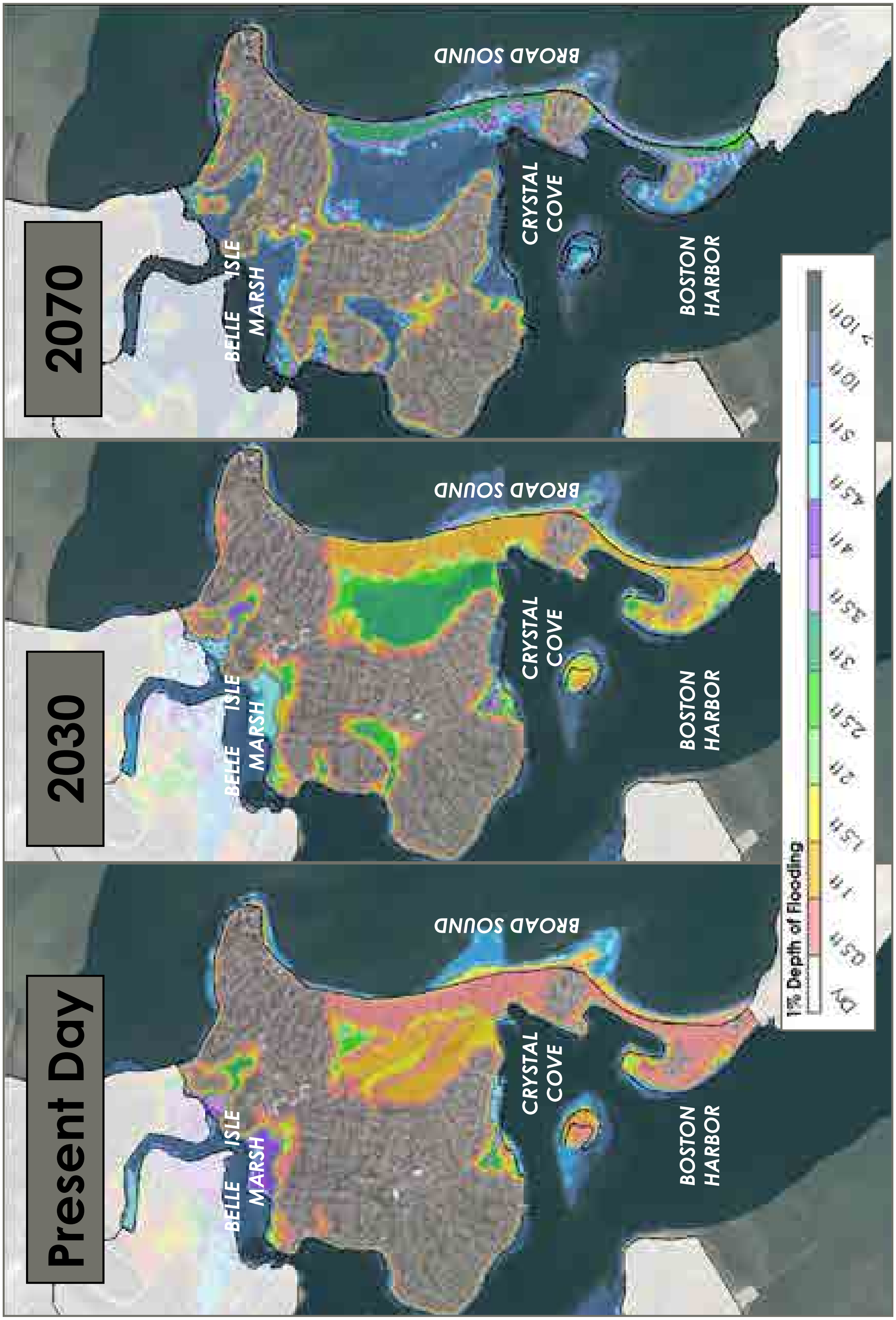


Figure 3-4 Winthrop Depth of Flooding (1% Chance water level)

Natural Resource Modeling

Climate change, with increased storm intensity, changes in precipitation patterns, and global sea-level rise will exacerbate already difficult coastal management issues related to both infrastructure and natural resources (Bosma et al., 2015). Recent studies have identified sea-level rise as one of the most certain and potentially destructive impacts of climate change (Meehl et al., 2007). Coastal wetlands are among the most susceptible ecosystems to climate change, especially accelerated sea-level rise. (Nicholls et al. 2009) points out that coastal wetlands, including salt marshes and intertidal areas, could experience substantial area losses due to sea-level rise. Because coastal wetlands are extremely productive ecosystems, and provide a variety of ecosystem services, such as flood protection, waste assimilation, nursery areas for fisheries, and conservation and recreation benefits, such loss would have a high human cost.

Recognizing the threats posed by climate change and sea-level rise, the Massachusetts Office of Coastal Zone Management (CZM) desired to assess and analyze the effects of sea-level rise on coastal wetlands for the Commonwealth of Massachusetts (Woods Hole Group, 2016). The project's intent was to simulate the effects of sea-level rise using an ecological model and implement the model at its highest level of complexity.

The model selected to evaluate the impact of sea level rise on coastal resources was the Sea Level Affecting Marshes Model (SLAMM), originally developed with EPA funding in the 1980s. The SLAMM model attempts to capture the major coastal processes, at least at a rudimentary level, involved in wetland conversions and shoreline modifications expected to occur over a long term.

The results of the marsh migration modeling are intended to be used for future coastal planning in a number of ways. For instance, model results from this project can be used to identify areas with barriers to landward migration of salt marshes. These results can therefore serve as a guide for development and implementation of adaptation strategies for coastal managers and policymakers to proactively address potential impacts from long-term sea-level rise. The results produced for the Town of Winthrop have been extracted from the larger CZM Commonwealth of Massachusetts project for this assessment. More in-depth information on SLAMM is provided in Appendix F.

The SLAMM results (Figure 3-6) project some minor wetland expansion and loss of upland area in 2030. This expansion will occur at the fringes of existing wetlands in areas that are already designated as open space, and should not interfere with existing development much differently than in current conditions. By 2070, sea-level rise is projected to induce large scale shifts across Winthrop, including transitions from irregularly flooded marsh to regularly flooded marsh, expansion of wetlands into transitional marsh scrub-shrub habitat, expansion of beach and tidal flat areas, conversion of inland open water to estuarine open water, and expansion of open ocean water areas (Figure 3-6, right panel).

Figure 3-5 Areas where Wetland Mitigation will be Limited by Existing Development

Some areas of potential wetlands migration will be limited by (and will interfere with) existing development (Figure 3-5). These areas include:

- (a) Commercial/industrial areas in the vicinity of Argyle Street
- (b) Residential areas south of Banks Street and Morton Street
- (c) Residential/commercial areas adjacent to the Belle Isle Bridge
- (d) Residential areas around Pico Avenue
- (e) Residential/industrial areas around Seaview Avenue
- (f) Residential/commercial/municipal areas surrounding Lewis Lake Park and the Winthrop Golf Course
- (g) Residential/commercial areas along Shirley Street (from Sturgis Street to Crystal Cove Avenue
- (h) Residential areas southeast of Coughlin Park

Due to the high density of development and impervious surface in these areas of Winthrop it is unlikely that they will be allowed to transition to wetland. These developed areas will likely experience higher water tables, increased salt water intrusion, day to day nuisance flooding (due to a higher daily tides), and higher frequency of storm flooding. Therefore, these areas will likely need additional protection in the future or retreat options under normal tidal conditions (accounting for sea-level rise).

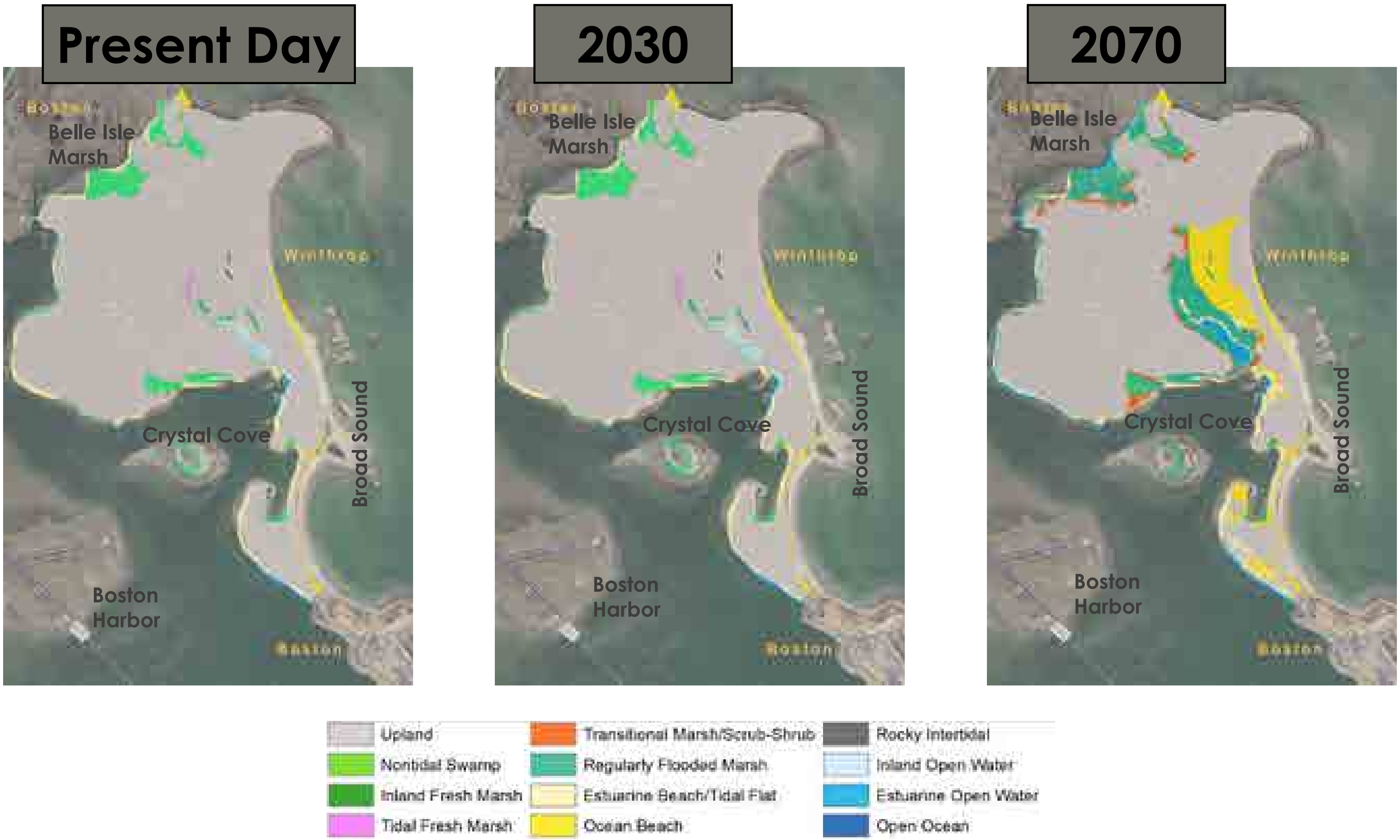


Figure 3-6 Winthrop SLAMM Maps

These results are part of the Statewide Modeling the Effects of Sea Level Rise on Coastal Wetlands for Massachusetts Coastal Zone Management. (Woods Hole Group, 2016).

A large portion of the projected wetlands transitions and expansions are predicted to occur in the existing open areas of Winthrop, including:

- Wetlands adjacent to the Winthrop Cemetery
- Lewis Lake Park and the Winthrop Golf Course
- Wetlands adjacent to Pico Beach
- Coughlin Park

These areas will likely experience significant changes in land cover and wetland type and may offer opportunities for natural resource management and/or expansion due to the changing climate. More detailed information on the changes to these four areas and recommended adaptations are discussed in Chapter 9.

Figure 3-7 2070 SLAMM Model with Existing Development

4

IDENTIFY: Critical Public Infrastructure

The combination of future sea level rise and storm events has the potential to damage important public infrastructure, such as evacuation routes and sewer pumping stations, within identified coastal flood areas throughout Winthrop. Due to climate change, these locations are in danger of becoming subject to conditions for which they were not designed. Without proper planning, damage could become more frequent, take longer and cost more to repair, and entail more socioeconomic disruption (EEA, 2011).

Figure 4-1 Town-Identified Critical Public Infrastructure Locations

The 2012 Hazard Mitigation Plan identified 97 critical infrastructure locations susceptible to a variety of hazard events (flooding, fire, earthquake, etc.). These included facilities important for disaster response and evacuation and those where additional assistance might be needed during an emergency (HMP, 2014).

For this vulnerability assessment, the 2012 list has been narrowed and edited by the Project Management Team (PMT) to include 16 critical public infrastructure locations within areas susceptible to coastal flooding:

- A Beach Fire Station
- B Belle Isle Bridge
- C Loring Rd. Boat Ramp
- D Main Street (evacuation route)
- E Pico Sewer Pump Station
- F Pleasant Court Sewer Pump Station
- G Pleasant Street (evacuation route)
- H Power Substation (Argyle Street)
- I Pressure Reducing Valve Station (Bayview Ave)
- J Pressure Reducing Valve Station (Revere St)
- K Pressure Reducing Valve Station (Underhill St)
- L Public Landing
- M Revere St. Sewer Pump Station
- N Shirley Street (evacuation route)
- O Washington Street (evacuation route)
- P Winthrop High School

PUBLIC INFRASTRUCTURE

includes Town-owned assets as well as state infrastructure and private utility assets that provide critical public services.

For this assessment, critical public infrastructure includes transportation corridors, water, wastewater, and stormwater systems, buildings, energy and transmission systems, natural resources (dunes, beaches, salt marsh, etc.), open space, and recreational facilities. The following sections of this chapter describe why this infrastructure is important to the Town and region, and what elements are susceptible to coastal flood damage.

Shoreline Structures

Shoreline structures in Winthrop include stone revetment, concrete seawalls, bulkheads, breakwaters, and groins. The Massachusetts Office of Coastal Zone Management (CZM) provides inventory and assessment data for coastal infrastructure via the Massachusetts Ocean Resource Information System (MORIS) data. Publicly-owned structures, identified by the 2009 MORIS data, includes six structures owned by the Massachusetts Department of Conservation and Recreation (DCR) and 27 town-owned structures in various levels of condition. Half of the identified public shoreline structures were assessed as needing moderate to significant levels of rehabilitation.

How are shoreline structures vulnerable to coastal flooding?

Shoreline structures have long been used as the first line of defense against the crashing waves of the sea. As sea levels rise and storms become stronger and more frequent, these structures become more susceptible to damage. Erosion of the soils on the sea side of the structures may expose wall foundations and cause walls to fail.

Stone revetment and concrete seawall along Winthrop Parkway and Upland Road

Buildings

Throughout Winthrop, building infrastructure includes commercial, residential, institutional, and governmental facilities. Public buildings include schools, municipal offices, an emergency operations center, library, public works facilities, fire and police stations, and the U.S. Post Office. Many of these buildings are in the central business district, which is elevated approximately 30 feet above the Winthrop shoreline, and are out of projected flood areas. Buildings at lower elevations may be susceptible to flood impacts.

How are buildings vulnerable to coastal flooding?

Some of these buildings are within BH-FRM flood areas. Flooded buildings are particularly susceptible to water damage or collapse. In addition, sea level rise will result in higher groundwater elevations, which could compromise building foundations that are not supported on piles.

Transportation

Winthrop's transportation infrastructure includes a network of roads and maritime facilities that are critical for the regional movement of people, equipment, and goods. Roadways are vital for the Town, as nearly 80% of working residents commute outside of Winthrop daily. By contrast, few commute into Town, with 70% of local jobs filled by Winthrop residents. Damage to roadway networks due to coastal flooding would have significant economic, social, and emergency response impacts.

Road

The road network in Winthrop includes a combination of numbered highways (Route 145), major local collectors (e.g. Main Street, Revere Street, Winthrop Shore Drive), and minor local arterials (e.g. Highland Avenue, Lincoln Street).

To access the town, vehicles travel via Route 145, o Winthrop Parkway or across the Belle Isle Bridge (Main Street). Winthrop Parkway connects the town to Revere along a narrow strip of land between the Belle Isle Marsh and

How are roads vulnerable to coastal flooding?

Flood water can make roadways unpassable to automobile traffic. Typically, when there are 4- to 6-inches of water on the surface, drivers are hesitant to cross. The force from flood waters can also destroy roadway pavement and lead to washouts. Sea level rise will result in higher groundwater elevations, which could flood the roadbed and lead to road collapse. Bridges and culverts are also vulnerable to flood damage. As the depth and strength of flood waters increase, the streambed surrounding these structures can erode or wash out, causing damage or collapse.

Town Landing, today

Broad Sound. The Belle Isle Bridge, at the western end of Main Street, crosses the Belle Isle Inlet, connecting Winthrop to East Boston. This bridge was replaced in 2013 to address the poor condition of the structure.

The Massachusetts Bay Transportation Authority's (MBTA) Paul Revere Transportation Bus Service serves the community with approximately 90 stops throughout Winthrop, divided between two bus routes. These routes also connect to MBTA's Blue Line Orient Heights Station, which is located ½ mile west of the Winthrop/East Boston border. From this station, riders can travel west to Boston (Bowdoin Station) or north to Revere (Wonderland Station). In 2013, nearly 500,000 riders used the 712 and 713 MBTA Paul Revere Bus Service. Including both the Paul Revere Bus Service and MBTA Blue Line, roughly 20% of Winthrop residents use public transportation to commute to work. (Winthrop, 2005)

With only two roadways to access the Winthrop peninsula, the resilience of transportation infrastructure is particularly important for emergency evacuation and response. Roads play an important role in disaster recovery efforts by providing access to damaged areas for emergency responders and construction equipment. On a regional scale, coastal flooding also has the potential to impact the primary travel route to the MWRA's Deer Island Sewage Treatment Plant (treating wastewater from 2.5 million people in the Greater Boston area), where 300-500 personnel provide 24-hour operations and maintenance.

Winthrop Road Infrastructure

Maritime

Public maritime infrastructure in Winthrop includes several small boat ramps, a mooring field in Crystal Cove, with space for 800-900 recreational boats, and the Winthrop Town Landing.

The Town Landing is the only public maritime facility in Winthrop. Located on Shirley Street, the facility includes a marina, boat ramp, pier, and the harbormaster's office. Public services at the marina include boat slips, a pump-out station, and a davit crane. The town landing was built on tidelands (previously submerged), filled sometime in the mid-1900s. The stone revetment protection wall along the shoreline has been recently repaired.

Charter boats can use Town Landing as a pick-up and drop-off location. The boat ramp in this location is used as an operating center for emergency vehicles, such as the harbormaster patrol boats and the Winthrop Fire Boat. In the winter, the Town Landing parking lot holds cars, typically parked on the street, during a Snow Emergency Parking Ban.

The pier at Town Landing serves the Winthrop Ferry, which provides commuter services to Rowes Wharf in Boston. Implemented in November 2015, the ferry also provides access to Georges Island and Lovells Island, two of the Boston Harbor Islands managed by the National Park Service. The ferry runs from May to October, during peak commute times, with limited weekend service. The 2001 Winthrop Commuter Boat Feasibility Study found that most riders would travel either from homes in Winthrop to downtown Boston, or from South Shore residences to work at the Deer Island Sewage Treatment Plant.

Town Landing area, in the 1930s
Source: Winthrop Historical Commission (www.facebook.com/ Winthrop-Historical-Commission-1482925941926459/

How is maritime infrastructure vulnerable to coastal flooding?

A significant storm event could cause considerable damage to maritime infrastructure. An increased frequency of storms could compromise structural integrity over time. At Town Landing, waves could overtop the stone revetment, damaging the harbormaster's building and parking area. Flooding could also result in inland debris entering Crystal Cove, which would impair mobilization of emergency response watercraft.

Air

The eastern shore of Boston Logan International Airport, managed by the Massachusetts Port Authority (Massport), is within Winthrop town boundaries. Approximately 900 Winthrop residents work at the facility (MAPC and CTPS, 2004).

Massport prepared a Disaster Infrastructure Resiliency Plan (DIRP) in 2014/2015 including a hazard analysis of sea level rise and storm surge, and recommendations for short-term adaptation strategies. Additionally, the Critical Assets Resiliency Report in 2014, developed concept and operation plans for the airport facilities. This assessment does not address Logan Airport given Massport's efforts to improve and protect its infrastructure from coastal flooding.

Water and Wastewater

Water and wastewater systems in Winthrop are owned by the Department of Public Works (DPW) Water Division and Massachusetts Water Resources Authority (MWRA).

The Town and MWRA-owned and maintained water tower holds roughly 1 million gallons of water for several communities served by the MWRA. The tower is located on Faunbar Avenue in the Cottage Hill neighborhood and is a major landmark seen around town and beyond. The tower sits on the eastern edge of the hill, roughly 120 feet above sea level, and is vulnerable to coastal erosion that has been reducing the land area adjacent to the tower.

Sewer pumping stations within Winthrop are located at Revere Street, Pico Avenue, and Pleasant Court. Recently updated, the stations are elevated, well-constructed structures, with water resistant flood panels. There are also emergency generators located at each pump station.

Massachusetts Water Resources Authority (MWRA) owns and maintains over two miles of 24-inch diameter sewer main, which channels sewage from the Revere town boundary through Winthrop for treatment at the Deer Island Sewage Treatment Plant. Another 108-inch MWRA main through town directs sewerage from East Boston to Deer Island. The 108-inch main was built in 1891 and plays a vital role in wastewater treatment for 43 communities and 2.5 million people (Baldwin, 2006). Entering the town at the Belle Isle Bridge, the pipeline to Deer Island through Winthrop is nearly three miles long. The underlying issue of this critical sewage line is its location within floodplain areas and the condition of the pipeline. Analyzation of the line is currently underway to comprehend what is needed to update/reconstruct the pipeline

How is the water and wastewater system vulnerable to coastal flooding?

Erosion and transportation infrastructure washout could have secondary impacts on underground piping systems. Rising sea levels and the consequent rising groundwater elevations could also cause soils to shift, particularly at boundaries between different soil types. Movement and loss of soil strength places stress on pipes and joints, and can cause significant damage.

Stormwater

The stormwater system within Winthrop includes over 20 miles of underground piping, outfalls, catch basins, and manholes. Approximately 115 outfalls are installed throughout the Town in low-lying areas to help relieve inland flooding during storm events. The majority of these outfalls do not have check valves to block water from the ocean from entering the system at the headwalls.

Winthrop Stormwater Infrastructure

How is the stormwater system vulnerable to coastal flooding?

When a heavy storm or tidal event occurs, the Town's drainage systems can fill up and cause flooding at the street level. Future sea level rise and storm events will worsen flooding conditions by increasing the volume of water to the system and blocking outfall locations. Like other underground utilities, erosion and transportation infrastructure washout, and movement and loss of soil strength can cause significant damage to stormwater pipelines.


Outfalls with check valves at Tafts Avenue

Natural Resources and Open Space


Yirrell Beach

Winthrop offers many beaches, conservation areas, parks, and recreation facilities to the public. The Town owns many of these resources, with exception of Belle Isle Marsh and Winthrop Shore Reservation, which are publicly owned and managed by the Massachusetts Department of Conservation and Recreation (DCR).

Beaches:

Winthrop Beach – Approximately 1 mile long, Winthrop Beach is the Town's largest beachfront resource. Owned by the DCR, Withrop Beach provides vital wildlife habitat, shoreline protection, and coastal beauty that attracts residents and brings visitors to Town.

Yirrell Beach – As a Town-owned resource, Yirrell Beach stretches for about 0.7 miles along the eastern coast of Point Shirley. Yirrell Beach acts as not only a shoreline protection, but as another recreational open space for residents to enjoy.

Donovan's Beach – Located across Pleasant Street from Ingleside Park, Town-owned Donovan's Beach gives Winthrop residents waterfront access and beautiful sunset views of the City of Boston. It also provides shoreline protection from the Boston Harbor during coastal flooding events.

Pico Playground & Beach –Located adjacent to Fishermen's Bend Marsh, the Pico Playground and Beach are Town-owned recreational facilities. At approximately 0.7 acres, these resources give the public access to Snake Island and Crystal Cove.

Salt Marsh:

Fishermen's Bend – Owned by the Town, Fishermen's Bend contains a salt marsh and public access paths. At approximately 7.5 acres, the marsh currently provides protection to residential properties during flooding events such as the King Tide.

Belle Isle Marsh – Encompassing around 250 acres of salt marsh and tidal flats, the Belle Isle Marsh provides an array of recreational and ecological services. As a DCR-owned property, and shared between the communities of Revere, East Boston, and Winthrop, the Belle Isle Marsh contains various walking paths and conservation habitats that serve as integral components of Winthrop's community. The salt marsh provides habitat to species such as the piping plover, upland sandpiper, cord grass, and seabeach needlegrass, enhancing ecological diversity.

(Photo by Winthrop Parks Committee https://winthropparks.wordpress.com/)

Parks:

Lewis Lake/Winthrop Golf Club – Located in the center of Winthrop, Lewis Lake and the Winthrop Golf Club serve as vital recreational assets for the Town. These Town-owned resources play an important economic role within the Town, as visitors and residents frequent the open space, including walking paths and a 9-hole golf course.

Coughlin Park – Renovated in 2014, Town-owned Coughlin Park provides a range of recreational resources for Winthrop residents. It contains a playground, sports facilities, and waterfront amenities.

Ingleside Park – At around 10 acres, Ingleside Park serves as a hub for Winthrop recreational and community activities. Owned by the Town, this park includes a playground, skating rink, picnic areas and other sports facilities. Ingleside is a crucial part of Winthrop's open space, as it is located within the center of the town and can host many public events and sports activities.

How are natural resources vulnerable to coastal flooding?

Coastal flooding and higher groundwater elevations have the potential to permanently damage hard and natural surfaces. Beaches and coastal wetlands provide ecological benefits including flood protection, absorption of pollutants, and habitat for fish and shellfish (Bosma et. al., 2014). Coastal erosion and sea level rise will diminish these resources, which are crucial to community health and safety.

Energy

Winthrop's energy infrastructure includes facilities for energy production, transmission, storage, and distribution. Facilities include substations, electric lines and street lights, and natural gas systems.

National Grid supplies Winthrop with electric power. The company manages two power substations within town. Beginning in 2009, National Grid conducted an extensive, three phase project that upgraded and connected the two substations to ensure future service reliability for residents. New equipment, connection lines and distribution lines were installed in both locations, primarily on preexisting utility poles (Domelowicz, 2011).

Natural gas service is also supplied by National Grid via underground lines.

How is energy infrastructure vulnerable to coastal flooding?

Substation facilities and power distribution lines are vulnerable to roadway erosion/washout which can cause service interruptions or considerable damage to equipment. Increased flooding and groundwater levels also have the potential to threaten this infrastructure which can cause public health and environmental hazards.

Telecommunications

Comcast cable currently provides telecommunication services to the Town of Winthrop.

Five communication towers within Winthrop are located at:

- Public Safety Communication Tower at Faunbar Avenue
- Cell tower at United Methodist Church
- Cell tower at Fellows hall
- Cell tower at St. Johns the Evangelist Church
- Cell tower at the Expert Auto

How is telecommunication infrastructure vulnerable to coastal flooding?

Telecommunication systems are susceptible to failure or destruction due to increased flooding and groundwater levels. These conditions can weaken foundations that support overhead poles and expose underground conduits to increased water and salinity levels. Prolonged inundation could compromise short term and long term system integrity and function, and reduce the overall lifespan of system components (e.g. sheathing and cabling).

5

IDENTIFY: Likely Flood Areas in Winthrop

Flooding can arise from multiple factors. Coastal flooding occurs along tidal waterways due to winds, waves, storm surge, and tides. Inland sources contribute to flooding from stormwater runoff, overflows of natural or structured drainage systems, and/or rising water table levels. It is important to understand the relationship between these systems to get a complete view of flooding issues within a community. However, the purpose of this assessment is to specifically focus on the protection of assets and areas most at risk from the coastal effects of storm surges and sea level rise, or coastal flooding. Therefore, there may be areas within Town that flood during heavy precipitation events that are not predicted to occur based on this assessment.

Although Winthrop's entire 8.3 mile coastline is vulnerable to coastal flooding, evaluating the results of the Boston Harbor Flood Risk Model (BH-FRM) brings to attention eight larger, regional flood areas. These highlighted locations (Figure 5-1) are already known to flood during coastal storms. The eight BH-FRM Flood Areas in Winthrop include:

- Belle Isle Marsh
- Nahant Avenue
- Winthrop Beach
- Lewis Lake
- Point Shirley
- Fishermen's Bend Marsh
- Ingleside Park
- Girdlestone Road

Figure 5-1 Town-Identified Areas of Local Flooding

The following pages assess each area by reviewing current conditions, recent initiatives, and BH-FRM mapping. This will help to further prioritize identified public infrastructure (Chapter 6) and recommend potential adaptation measures (Chapter 7) to address coastal flooding.

Belle Isle Marsh

The Belle Isle Marsh is located at the northern end of Winthrop, and is also bordered by East Boston and Revere. This natural resource is owned and managed by the Department of Conservation and Recreation, as well as the towns of Winthrop and Revere. This nearly 300 acre salt marsh is one of the largest remaining in the Metropolitan Boston area. Habitats within the area include salt marsh, a tidal creek, salt pans, and upland park land. The area is home to a large list of bird species, including State-listed species of Endangered, Threatened, or Special Concern status.

As shown in Table 5-1, the area of flooding in Winthrop, adjacent to the marsh, contains a range of land uses and several public infrastructure points.

Winthrop Avenue, view toward Upland Road

Short Beach Creek at Belle Isle Marsh

Revere Street Sewer Pump Station and Pressure Reducing Valve Station

Table 5-1 Flood Area Existing Conditions – Belle Isle Marsh

LAND USES	Mostly residential, with some industrial business on Argyle Street and commercial properties near the Belle Isle Bridge, natural resources & open space
ASSOCIATED WATERBODIES	Boston Harbor & Belle Isle Inlet
PUBLIC SHORELINE STRUCTURES	Stone revetment (<5 feet high) along Morton Street from Fairview Street to the Town Cemetery 5- to 10-foot stone revetment, below the Town Cemetery 5- to 10-foot bulkhead/seawall at Short Beach 10- to 15-foot stone revetment along Seawall Avenue
PUBLIC BUILDINGS	Pleasant Court Sewer Pump Station Revere Street Sewer Pump Station Pressure Reducing Valve Station at Revere Street
TOTAL BUILDINGS	240
TRANSPORTATION INFRASTRUCTURE	Belle Isle Bridge to East Boston Winthrop Parkway Land Bridge to Revere Main Street, Pleasant Street, Morton Street & other local roadways Winthrop Harbor Walk & Eco Park
WATER AND WASTEWATER INFRASTRUCTURE	Pleasant Court Sewer Pump Station Winthrop Parkway Sewer Pump Station Underground local and MWRA sewer mains Pressure Reducing Valve Station at Revere Street
STORMWATER INFRASTRUCTURE	Underground system, catch basins, and outfalls
ENERGY INFRASTRUCTURE	Argyle Street Substation Electric & natural gas distribution system
TELECOMMUNICATIONS INFRASTRUCTURE	Cable and telephone lines
NATURAL RESOURCES & OPEN SPACE	Belle Isle Marsh Short Beach Fort Banks Playground Kilmartin trail and footbridge

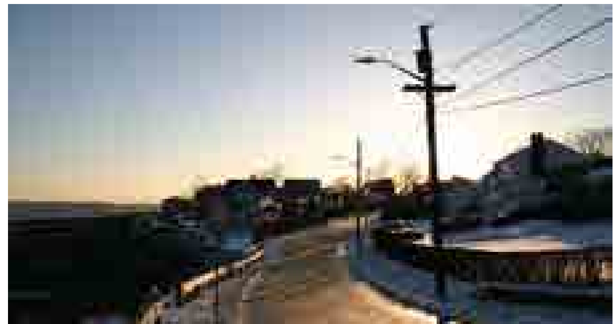
Considering the vulnerable low-lying land within this flood area, many residences, businesses, and facilities near the marsh will become more susceptible to inundation from sea level rise and coastal storms over the next 15 years. The BH-FRM mapping suggests that intense storm events in 2030 may push enough water into the marsh to flood Main Street by six inches.

Table 5-2 Probable Future Flooding – Belle Isle Marsh

SIZE OF FLOOD AREA	Today: 95 Acres (9% of Winthrop) 2030: 106 Acres (10% of Winthrop) 2070: 135 Acres (13% of Winthrop)
TOWN-IDENTIFIED FLOOD AREAS / ISSUES	Bayou Street Neighborhood – undersized drainage line backs up in high precipitation events (HMP, 2014)
CURRENT INITIATIVES / CONSTRUCTION PROJECTS	Belle Isle Marsh Marine Ecology Park (path along Morton Street, with a passive recreation park, lookout area, footbridge to the Belle Isle Cemetery.
PROBABLE FUTURE FLOOD AREAS	Portions of Argyle Street and Golden Drive Morton Street Main Street
CRITICAL PUBLIC INFRASTRUCTURE (2030 FLOOD AREA)	Pleasant Court Sewer Pump Station Main Street Stone Revetment, seawalls & bulkheads
ADDITIONAL CRITICAL PUBLIC INFRASTRUCTURE (2070 FLOOD AREA)	Belle Isle Bridge Argyle Power Substation Revere Street Sewer Pump Station Pressure Reducing Valve Station at Revere Street Winthrop Traffic Control Point at Winthrop Parkway and Revere Street Winthrop Traffic Control Point at Main Street

Nahant Avenue

The rocky shoreline of this northeastern section of Winthrop includes residences along Nahant Avenue, and a portion of Grovers Avenue and Seawall Avenue. The area is entirely residential, with views of Broad Sound toward Revere.



Seawall Avenue looking toward Nahant Avenue Flood Area

Nahant Avenue properties have a high water table

Table 5-3 Flood Area Existing Conditions – Nahant Avenue

LAND USES	Residential
ASSOCIATED WATERBODIES	Broad Sound
PUBLIC SHORELINE STRUCTURES	None
PUBLIC BUILDINGS	None
TOTAL BUILDINGS	45
TRANSPORTATION INFRASTRUCTURE	Local roadways
WATER AND WASTEWATER INFRASTRUCTURE	Local underground lines
STORMWATER INFRASTRUCTURE	Underground system, catch basins, and outfalls
ENERGY INFRASTRUCTURE	Electric and natural gas distribution systems
TELECOMMUNICATIONS INFRASTRUCTURE	Cable and telephone lines
NATURAL RESOURCES & OPEN SPACE	Pond Street Playground

The coastline here is vulnerable to flooding from a combination of high groundwater, tidal surge, and high precipitation. During a site visit on March 23, 2017, water was observed seeping up from the ground at the intersection of Nahant and Grovers Avenues. Anecdotal information was provided from a resident at the first Public Meeting, noting that homes in this area are almost always operating pumps to remove water from their basements. The 2014 update of the Town's Hazard Mitigation Plan identifies two homes as repetitive loss properties by the FEMA National Flood Insurance Program. The 2030 BH-FRM shows that homes in this area could see about ½ to one foot of flooding during a 1% chance water surface elevation.

Table 5-4 Probable Future Flooding – Nahant Avenue

SIZE OF FLOOD AREA	Today: 4 Acres (<1% of Winthrop) 2030: 8 Acres (1% of Winthrop) 2070: 23 Acres (2% of Winthrop)
TOWN-IDENTIFIED FLOOD AREAS / ISSUES	Undersized drain lines fill up and flood the neighborhood during coastal storms and high tide (MAPC, 2014)
CURRENT INITIATIVES / CONSTRUCTION PROJECTS	2014 Hazard Mitigation Plan identified replacing the undersized drainage line and upgrading the existing drainage outfall headwall and installing a flapper valve as priority mitigation measures for this area.
BH-FRM MAPPED FLOOD AREAS (2030-2070)	Upland Road Seawall Avenue, from Upland Road to Highland Avenue Nahant Avenue, through Highland Avenue, and Pond Street
CRITICAL PUBLIC INFRASTRUCTURE (2030 FLOOD AREA)	None
ADDITIONAL CRITICAL PUBLIC INFRASTRUCTURE (2070 FLOOD AREA)	None

Winthrop Beach

The Winthrop Beach flood area, located on the eastern shore of town, is a combination of public facilities, private homes, and commercial properties. The barrier beach is owned and operated by the Massachusetts Department of Conservation and Recreation (DCR), and provides community benefits like storm protection, recreation, and tourism.

Shoreline sandbar/breakwater structures at Winthrop Beach

Table 5-5 Flood Area Existing Conditions – Winthrop Beach

LAND USES	Residential, commercial, natural resources & open space, recreational property (State-owned beach)
ASSOCIATED WATERBODIES	Broad Sound
PUBLIC SHORELINE STRUCTURES	Stone mound groins at Charles Street, Beacon Street, Wave Way, Coral Avenue, Neptune Avenue 5- to 15-foot seawall & stone revetment along Winthrop Shore Drive Five Sisters (15 feet +)
PUBLIC BUILDINGS	None
TOTAL BUILDINGS	670
TRANSPORTATION INFRASTRUCTURE	Local roadways
WATER AND WASTEWATER INFRASTRUCTURE	Local underground lines
STORMWATER INFRASTRUCTURE	Underground MWRA sewer main and water line Local underground utility lines Pressure Reducing Valve Station at Underhill Street
ENERGY INFRASTRUCTURE	Electric and natural gas distribution systems
TELECOMMUNICATIONS INFRASTRUCTURE	Cable and telephone lines
NATURAL RESOURCES & OPEN SPACE	Winthrop Shore Beach

The topography of the Winthrop Beach Flood Area slopes from Winthrop Shore Drive down to Shirley Street. Since the early 1900s, the Commonwealth has made many efforts to help reduce coastal flooding behind the beach.

The 2030 BH-FRM model calculates that there is potential for extreme coastal storm events to flood the area between Winthrop Shore Drive and Shirley Street to approximately 1-foot deep. A significant amount of flooding in this area is caused by wave run-up and overtopping (see above photo). Coastal storm waves will pulse volumes of water landward and flow through the Winthrop Beach infrastructure towards Lewis Lake.

Table 5-6 Probable Future Flooding– Winthrop Beach

SIZE OF FLOOD AREA	Today: 86 Acres (8% of Winthrop) 2030: 88 Acres (9% of Winthrop) 2070: 91 Acres (9% of Winthrop)
TOWN-IDENTIFIED FLOOD AREAS/ISSUES	Ocean winds and waves overtop the seawalls during coastal storm events, flooding Winthrop Shore Drive, adjacent roadways, and residential properties.
CURRENT INITIATIVES / CONSTRUCTION PROJECTS	DCR has designed and constructed a beach nourishment project and repairs to shoreline structures. Construction of a streetscape project, including drainage improvements along Winthrop Shore Drive, is scheduled to begin this year.
BH-FRM MAPPED FLOOD AREAS (2030-2070)	From Winthrop Beach in the east to Shirley Street at the west From Veterans Road in the north, to Crystal Cove Avenue at the south
CRITICAL PUBLIC INFRASTRUCTURE (2030 FLOOD AREA)	Shirley Street & Tafts Avenue (Route 145) - evacuation/trucking route Regional sewer main Pressure Reducing Valve Station at Underhill Street
ADDITIONAL CRITICAL PUBLIC INFRASTRUCTURE (2070 FLOOD AREA)	None

1932 storm along Winthrop Shore Drive, Courtesy of the Boston Public Library, Leslie Jones Collection.

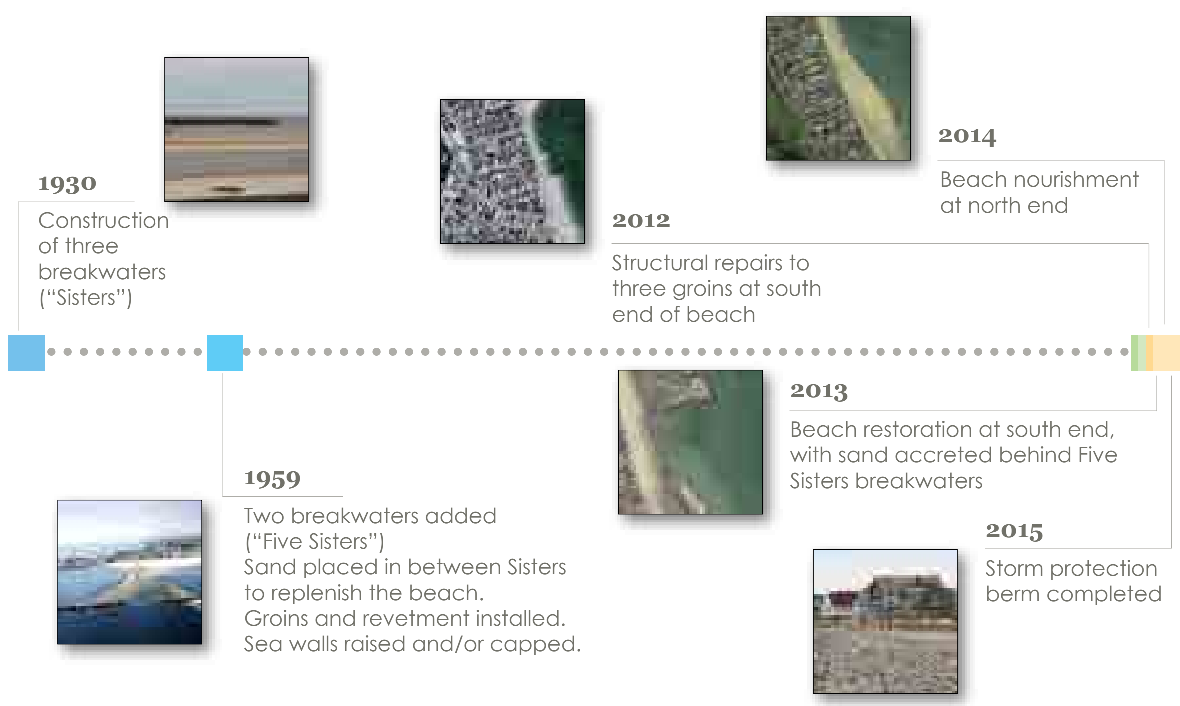


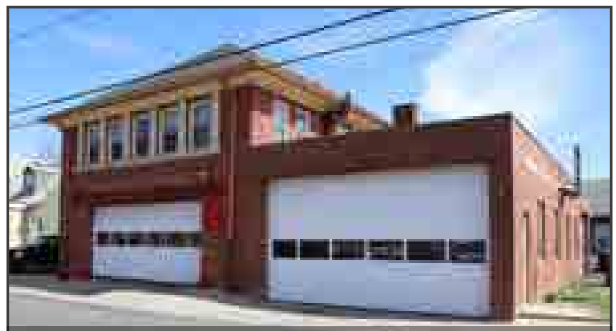
Figure 5-2 Timeline of Storm Structure Construction along Winthrop Beach

Lewis Lake

Before the construction of a steam railroad loop and construction of Washington Street in the late 19th century, Lewis Lake was a small tidal stream, known as Fisher's Creek, with adjacent marshland (MHC, 1981). Due to the history here, infrastructure in this flood area has been developed on what would historically have been salt marsh.

The Town of Winthrop owns much of the land in this central area of the community: Lewis Lake Park and Daw Playground, the Golf Club property, and Winthrop High School athletic fields. In addition to these public recreational and institutional properties, the fringes of the Lewis Lake flood area include residential and commercial land uses. Important public infrastructure includes Route 145 (Washington Avenue and Veterans Road) and the Beach Fire Station which are vital to the Town's security and safety.

Winthrop High School



Shirley Street Fire Station

Table 5-7 Flood Area Existing Conditions - Lewis Lake

LAND USES	Athletic fields/parks, natural resources, residential, waterfront, a large amount of open space, neighborhoods, small businesses, high school, golf club, cemetery
ASSOCIATED WATERBODIES	Crystal Cove - Lewis Lake - Broad Sound
PUBLIC SHORELINE STRUCTURES	Lewis Lake Tide Gate
PUBLIC BUILDINGS	Beach Fire Station Winthrop High School
TOTAL BUILDINGS	440
TRANSPORTATION INFRASTRUCTURE	Shirley Street, Tafts Avenue (Route 145) and Veterans Road are evacuation and trucking routes
WATER AND WASTEWATER INFRASTRUCTURE	Underground MWRA sewer main and water line Local underground lines Pressure Reducing Valve Station at Underhill Street
STORMWATER INFRASTRUCTURE	Lewis Lake is a major catchment area for the town Drainage swale recently installed / cleared out around perimeter of golf course Undergroud system, catch basins, outfalls
ENERGY INFRASTRUCTURE	Electric transmission and distribution system Natural gas distribution system
TELECOMMUNICATIONS INFRASTRUCTURE	Cable and telephone lines
NATURAL RESOURCES & OPEN SPACE	Lewis Lake (including Norman F. Daw Playground and section of Winthrop Harborwalk) High School Stadium and ball fields Golf Club

The area surrounding Lewis Lake experiences flooding due to the build-up of silt in Lewis Lake, which decreases the ability of the Lake to properly drain (MAPC, 2014). The 2014 update of the Town's Hazard Mitigation Plan identifies three single family homes and two multi-family buildings as repetitive loss properties by the FEMA National Flood Insurance Program.

Where the Lewis Lake Flood Area and the Winthrop Beach Flood Area meet, (in the vicinity of Shirley Street,) they are both likely to contribute to flooding (around 50 structures are partially in both flood areas). Lewis Lake is also a major catchment area, collecting stormwater from approximately 1/2 of the community. It is recommended that these occurrences are studied holistically, so that an appropriate approach to resiliency may be taken.

Winthrop Golf Course Drainage at Veterans Road

Table 5-8 Probable Future Flooding – Lewis Lake

SIZE OF FLOOD AREA	Today: 140 Acres (14% of Winthrop) 2030: 153 Acres (15% of Winthrop) 2070: 165 Acres (16% of Winthrop)
TOWN-IDENTIFIED FLOOD AREAS/ISSUES	Lewis Lake is a critical stormwater storage area (drains half of town). Lake overflows during storm events, causing flooding in surrounding area (HMP, 2014)
CURRENT INITIATIVES / CONSTRUCTION PROJECTS	Drainage improvements along Veterans Road Drainage swale around Golf Club perimenter Lewis Lake Tide Gate
BH-FRM MAPPED FLOOD AREAS (2030-2070)	From Crystal Cove to Revere Street – Shirley Street – Bowdoin Street in the north
CRITICAL PUBLIC INFRASTRUCTURE (2030 FLOOD AREA)	Evacuation/trucking route Regional sewer main Beach Fire Station
ADDITIONAL CRITICAL PUBLIC INFRASTRUCTURE (2070 FLOOD AREA)	None

Point Shirley

Land use within the Point Shirley Flood Area includes residential properties, commercial, and recreational facilities. Sandwiched between the Boston Harbor on the west and Broad Sound to the east, many residences within the area are regularly exposed to inundation and wave action.

On the harbor side, Coughlin Park includes a salt marsh, tidal flats and beach area. The park offers recreational facilities including basketball courts, water access, and walking trails. The shoreline wraps around a cove area called "The Basin" to the Winthrop Town Landing. Town Landing is also identified as critical public infrastructure, as it includes a public boat ramp and ferry service to Boston. Located on Shirley Street, across the Basin from Coughlin park, Town Landing was built on filled tideland in the mid-20th century.

Between Coughlin Park and Town Landing are approximately 50 privately-owned properties.

Yirrell Beach

MBTA Paul Revere Bus at Shirley Street

Other important public infrastructure includes the Pressure Reducing Valve Station at Bayview Avenue and Winthrop Town Landing. Point Shirley, via Shirley Street and Tafts Avenue, is also the key access route for emergency equipment to reach the neighborhood and the Deer Island Sewage Treatment Plant. Prolonged flooding of these roadways could have negative social, environmental, and economic impacts.

Table 5-9 Flood Area Existing Conditions – Point Shirley

LAND USES	High Density and Multi-Family Residential, natural resources and open space, commercial, marina
ASSOCIATED WATERBODIES	Broad Sound, Boston Harbor
PUBLIC SHORELINE STRUCTURES	10- to 15-foot stone revetment at Town Landing 5- to 10-foot seawall/revetment along Shirley Street (adjacent to Town Landing) 5- to 10-foot seawall from the top of Yirrell Beach to Petrel Street 5- to 10-foot bulkhead/seawall/revetment along Grand View Avenue (Shirley Street to north of Deep Water Street) 10- to 15-foot stone revetment along Grand View Avenue (from Bayview Ave to south of Foam Street)
PUBLIC BUILDINGS	None
TOTAL BUILDINGS	545
TRANSPORTATION INFRASTRUCTURE	Shirley Street to Tafts Avenue / local roadways
WATER AND WASTEWATER INFRASTRUCTURE	Sewer main to Deer Island
STORMWATER INFRASTRUCTURE	Underground system, catch basins, outfalls
ENERGY INFRASTRUCTURE	Electric transmission and distribution system Natural gas distribution system
TELECOMMUNICATIONS INFRASTRUCTURE	Cable and telephone lines
NATURAL RESOURCES & OPEN SPACE	Yirrell Beach

The 2014 Winthrop Hazard Mitigation Plan identified Point Shirley as the most frequently flooded area of Winthrop. The flat and narrow areas of this flood zone make it susceptible to storm surges and waves from the ocean, and additional flooding from Boston Harbor. High water levels measured after the Blizzard of 1978 were recorded at elevation 12.67 feet at Elliot Street (existing elevation at this site is about 10 feet).

During northwest winds and coastal storms, Coughlin park faces coastal erosion and inundation. The Town has completed a feasibility assessment to evaluate design installations that could help slow the erosion. The process has identified green infrastructure along the western shoreline as the best alternative to increase coastal resilience of the park.

The coastal flood modeling for this area estimates that the Point Shirley Association (on the corner of Shirley Street and Pebble Ave) could experience around a foot of flooding during a 1% chance water level in 2030. The same location and storm could see four feet of water during a severe storm in 2070.

Table 5-10 Probable Future Flooding – Point Shirley

SIZE OF FLOOD AREA	Today: 84 Acres (8% of Winthrop) 2030: 88 Acres (9% of Winthrop) 2070: 90 Acres (9% of Winthrop)
TOWN-IDENTIFIED FLOOD AREAS/ISSUES	Point Shirley is the most frequently flooded area in town. Area is subject to decreased sediment, coastal erosion, and shoreline change. Existing seawall at Yirrell Beach is occasionally breached, and doesn't cover area between Wyman Street to Deer Island. Local efforts have been made for protection and repairs, but this area remains a top priority for flooding mitigation. Area is subject to decreased sediment, coastal erosion, and shoreline change. Coughlin Park experience coastal erosion and flooding during higher northwest wind events and coastal storms. Area is also subject to decreased sediment and shoreline change.
CURRENT INITIATIVES / CONSTRUCTION PROJECTS	Grandview Avenue seawall was upgraded and heightened by two feet from Billows Street to Coughlin Playground Drainage pipelines have been enlarged along Shirley Street and Tafts Avenue to increase the stormwater capacity of the system.
BH-FRM MAPPED FLOOD AREAS (2030-2070)	All of Point Shirley, with exceptions of the highest elevation around Unding Avenue
CRITICAL PUBLIC INFRASTRUCTURE (2030 FLOOD AREA)	Evacuation / trucking route Point Shirley Association
ADDITIONAL CRITICAL PUBLIC INFRASTRUCTURE (2070 FLOOD AREA)	None

Fishermen’s Bend

The Fishermen’s Bend Flood Area is primarily marsh land. The coastline also includes tidal flats, beach and a small dune. These natural resources have been acquired by the Town and are managed by the Conservation Commission. There are walking trails within the marsh, and the Pico Playground and Beach provide recreational opportunities the surrounding neighborhood. Residential properties abutting the beach and salt marsh are also included in the Fishermen’s Bend Flood Area.

Sea walls in this area have been previously identified for upgrades. The Pico Avenue Sewer Pump Station may see 1 ½ feet of flooding during a 1% chance water surface elevation in 2030, and potentially more than four feet in 2070.

Pico Avenue Sewer Pump Station

Entrance to Pico Park

Table 5-11 Flood Area Existing Conditions – Fishermen's Bend

LAND USES	Salt marsh & beach, residential, commercial, recreation
ASSOCIATED WATERBODIES	Crystal Cove, Boston Harbor
PUBLIC SHORELINE STRUCTURES	Stone groin at the end of Pico Avenue 5- to 10-foot seawall/stone revetment along Frances Street 5- to 10-foot seawall at Woodside Avenue
PUBLIC BUILDINGS	None
TOTAL BUILDINGS	145
TRANSPORTATION INFRASTRUCTURE	Neighborhood Roads
WATER AND WASTEWATER INFRASTRUCTURE	Underground system
STORMWATER INFRASTRUCTURE	Underground system, catch basins, outfalls
ENERGY INFRASTRUCTURE	Electric transmission and distribution system Natural gas distribution system
TELECOMMUNICATIONS INFRASTRUCTURE	Cable and telephone lines
NATURAL RESOURCES & OPEN SPACE	Fishermen's Bend Marsh Pico Park Pico Beach

Table 5-12 Probable Future Flooding – Fishermen's Bend

SIZE OF FLOOD AREA	Today: 30 Acres (3% of Winthrop) 2030: 35 Acres (3% of Winthrop) 2070: 43 Acres (4% of Winthrop)
TOWN-IDENTIFIED FLOOD AREAS/ISSUES	Woodside seawall and headwall experiences coastal surge flooding during storm events
CURRENT INITIATIVES / CONSTRUCTION PROJECTS	The sewer pump station has backup generation capacity.
BH-FRM MAPPED FLOOD AREAS (2030-2070)	Crystal Cove to Pleasant Street in the north Fishermen's Bend Marsh to Sunnyside Avenue in the west
CRITICAL PUBLIC INFRASTRUCTURE (2030 FLOOD AREA)	Pico Sewer Pump Station
ADDITIONAL CRITICAL PUBLIC INFRASTRUCTURE (2070 FLOOD AREA)	None

Ingleside Park

The Ingleside Park Flood Area stretches between Donovan's Beach on the west side of the peninsula, and the Arthur T. Cummings Elementary School near the civic center of Winthrop. The beach and park are both owned by the Town. Many public amenities are within the flood area, including access to Boston Harbor with views of Boston's skyline, walking trails, athletic fields, tennis courts, basketball courts, a skateboard park, playground and public skating rink. Residences border much of the park perimeter, with the Central Business District adjacent to the southeast of the flood area.

On an 1859 "Map of Boston and its Vicinity" by Henry Francis Walling, (Norman B. Leventhal Map Center, Boston Public Library), the Ingleside Park area appears as a tidal stream and low-lying marsh. William H. Clark's *History of Winthrop Massachusetts* described The area was described as a swamp, in the area as swampland and noted that it was filled in 1936 with funds from the Public Welfare Department (Clark, 1952).

The flood pathway to Ingleside Park is at Donovan's Beach, likely the same location that the tidal stream once entered the swamp. The park floods often, (mostly from precipitation events,) and anecdotal conversations within town noted a couple of buildings within the Central Business District run pumps nearly all the time. Existing drainage infrastructure is being assessed (by others) at Ingleside Park. The facility is at sea level, with drain pipe discharging at Donovan's Beach. There is a valve on the existing outfall that shuts down during heavy tides. (MAPC, 2014)

Pleasant Street

View of City of Boston from Donovan's Beach

The coastal flood modeling for this area shows that Pleasant Street may be flooded to a depth of 8 inches in during a 1% chance water surface elevation in 2030, making the roadway impassible. The same location and storm could see 3.5-feet of water during a severe storm in 2070.

Table 5-13 Flood Area Existing Conditions – Ingleside Park

LAND USES	Civic, school, residential, commercial, natural resources and open space
ASSOCIATED WATERBODIES	Boston Harbor
PUBLIC SHORELINE STRUCTURES	Concrete seawall (<5 feet high) at Donovan's Beach
PUBLIC BUILDINGS	None
TOTAL BUILDINGS	150
TRANSPORTATION INFRASTRUCTURE	Pleasant Street (Route 145), local roadways, walking trails
WATER AND WASTEWATER INFRASTRUCTURE	Underground system
STORMWATER INFRASTRUCTURE	Underground system, catch basins, outfalls
ENERGY INFRASTRUCTURE	Electric transmission and distribution system Natural gas distribution system
TELECOMMUNICATIONS INFRASTRUCTURE	Cable and telephone lines
NATURAL RESOURCES & OPEN SPACE	Donovan's Beach, Ingleside Park

Table 5-14 Probable Future Flooding – Ingleside Park

SIZE OF FLOOD AREA	Today: 28 Acres (3% of Winthrop) 2030: 37 Acres (4% of Winthrop) 2070: 65 Acres (6% of Winthrop)
TOWN-IDENTIFIED FLOOD AREAS/ISSUES	The park is at sea level, and may benefit from a pump station (MAPC, 2014)
CURRENT INITIATIVES / CONSTRUCTION PROJECTS	The Town constructed dikes in the park, around two homes, to temporarily reduce flooding in the area (MAPC, 2014)
BH-FRM MAPPED FLOOD AREAS (2030-2070)	Shoreline from Loring Road Boat Ramp to Lincoln Street Ingleside Park area, with potential to cross Pauline Street and move southeast along Putnam Street and Woodside Avenue
CRITICAL PUBLIC INFRASTRUCTURE (2030 FLOOD AREA)	Pleasant Street
ADDITIONAL CRITICAL PUBLIC INFRASTRUCTURE (2070 FLOOD AREA)	None

Girdlestone Road

Pleasant Park Yacht Hall at Belle Isle Pier

The Girdlestone Road Flood Area is north of Ingleside Park and south of Main Street. The area includes the Pleasant Park Yacht Club, Atlantis Marina Condominiums/Boat Facilities, and a residential neighborhood.

Table 5-15 Flood Area Existing Conditions – Girdlestone Road

LAND USES	Private recreation, residential
ASSOCIATED WATERBODIES	Boston Harbor
PUBLIC SHORELINE STRUCTURES	None
PUBLIC BUILDINGS	None
TOTAL BUILDINGS	115
TRANSPORTATION INFRASTRUCTURE	Pleasant Street (Route 145), neighborhood roads, boat slips
WATER AND WASTEWATER INFRASTRUCTURE	Underground system
STORMWATER INFRASTRUCTURE	Underground system, catch basins, outfalls
ENERGY INFRASTRUCTURE	Electric and natural gas distribution systems
TELECOMMUNICATIONS INFRASTRUCTURE	Cable and telephone lines
NATURAL RESOURCES & OPEN SPACE	None

Flood waters appear to enter the Girldestone Road Flood Area at the Pleasant Park Yacht Club boat ramp. This area should be addressed, as Pleasant Street and the adjacent neighborhoos could experience two feet of flooding during a 1% chance water surface elevation in 2030.

Table 5-16 Probable Future Flooding – Girdlestone Road

SIZE OF FLOOD AREA	Today: 9 Acres (1% of Winthrop) 2030: 12 Acres (1% of Winthrop) 2070: 19 Acres (2% of Winthrop)
TOWN-IDENTIFIED FLOOD AREAS/ISSUES	None mentioned.
CURRENT INITIATIVES / CONSTRUCTION PROJECTS	None
BH-FRM MAPPED FLOOD AREAS (2030-2070)	Pleasant Street to Beal Street, including Girdlestone Road and a portion of Tileston Road
CRITICAL PUBLIC INFRASTRUCTURE (2030 FLOOD AREA)	Pleasant Street (Route 145) evacuation route
ADDITIONAL CRITICAL PUBLIC INFRASTRUCTURE (2070 FLOOD AREA)	None

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6 PRIORITIZE: Critical Public Infrastructure

Shirley Street at Town Landing

With critical public infrastructure and the likely areas of flooding in town identified, the next step in the assessment process is to systematically evaluate and prioritize critical infrastructure at the Town-wide level. This process will enable the Town to make strategic and cost-effective investments in the locations that are most at risk from coastal flooding.

Calculating Risk

There are many different mathematical models that can be used to calculate a risk score to prioritize infrastructure assets/ facilities. For this study, the goal was to use a system that was simple to follow and easily communicated.

A five-tier qualitative rating system (assigned 1 to 5) was developed for determining the consequence that flooding would have on any given asset. The rating score is multiplied by the likelihood that assets may flood under present day, 2030, and 2070 scenarios using the Boston Harbor Flood Risk Model (BH-FRM) results. A weighting factor for the probability of flooding is also included in the calculation. Assets within present day flood areas are given higher weighting than those at risk in future years:

- 60% weighting within the present-day flood areas
- 30% weighting for 2030
- 10% weighting for 2070.

The assets/facilities can then be evaluated, in order of priority, based on the total score. In other words, the higher the score, the higher the priority to investigate adaptation measures for the infrastructure.

Consequence

The consequence of failure score, calculated for each asset/facility, was based on adding together individual ratings (1 through 5) for each of the following four criticality criteria:

Area of Service Loss: Who is impacted by the loss of or damage to the core functions of the asset?

Public Safety & Emergency Services: How important is the asset to community evacuation and disaster response operations?

Social & Economic Activities: How important is the asset to providing people with access or service to their homes and jobs?

Public Health & Environment: How important is the asset to controlling human exposure to pollutants and secondary impacts to the natural environment?

It is recognized that there is a certain level of interpretation or subjectivity applied when assigning consequence ratings.

Probability

The likelihood of flooding under present day, 2030, and 2070 scenarios is based on data developed using the BH-FRM. A data point was created using geographic information systems (GIS) for each public infrastructure asset within the BH-FRM. Based on a critical elevation at each location, an estimated depth of flooding was determined where the flood event is likely to impair an asset in any given year (a 0.1% to 100% chance). In some cases, any depth of water would put a location at risk, whereas other locations can sustain core functions even with a few inches of water. The possibility that the water depth starts to harm an asset's core functions is calculated into the score. A detailed table of this data for each asset is included in Appendix G (Probability of Exceedance Curve Data extracted from the BH-FRM).


Shirley Street Neighborhood from Yirrell Beach

Winthrop Fire Station

Figure 6-1 Prioritized Critical Public Infrastructure in Winthrop

Winthrop's Critical Public Infrastructure Priorities

Based on the methodology described above and outlined in more detail in Appendix G, critical public infrastructure is prioritized in Table 6-1.

Table 6-1 Critical Public Infrastructure Risk Scores and Ranking

RANK	CRITICAL INFRASTRUCTURE	FLOOD AREAS	CRITICALITY TOTAL	% PROBABILITY OF FLOODING			TOTAL RISK SCORE
				PRESENT	2030	2070	
1	Pico Sewer Pump Station	Fishermen's Bend	15	5	25	100	307.5
2	Pleasant Court Sewer Pump Station	Belle Isle Marsh	15	2	25	100	280.5
3	Washington Street (town evacuation route)	Lewis Lake	15	2	20	100	258
4	Main Street (town evacuation route)	Belle Isle Marsh	18	0.5	5	100	212.4
5	Pleasant Street (town evacuation route)	Ingleside Park	15	0.2	5	100	174.3
6	Beach Fire Station	Lewis Lake	14	1	5	100	169.4
7	Winthrop High School	Lewis Lake	13	1	5	100	157.3
8	Pressure Reducing Valve Station (Bayview Ave)	Point Shirley	13	1	5	100	157.3
9	Pressure Reducing Valve Station (Underhill St)	Winthrop Beach	13	0.5	2	100	141.7
10	Shirley St (town evacuation/MWRA truck route)	Point Shirley	20	0.5	10	20	106
11	Public Landing	Point Shirley	10	0	0.5	50	51.5
12	Pressure Reducing Valve Station (Revere Street)	Belle Isle Marsh	13	0	0.2	30	39.78
13	Revere St. Sewer Pump Station	Belle Isle Marsh	15	0	0.1	20	30.45
14	Belle Isle Bridge	Belle Isle Marsh	18	0	0	2	3.6
15	Power Substation (Argyle Street)	Belle Isle Marsh	18	0	0	2	3.6
16	Loring Rd. Boat Ramp	Ingleside Park	4	0	0	1	0.4

The pump station prioritization process emphasizes the importance of focusing on protecting wastewater/sewer infrastructure and keeping evacuation/trucking routes open. The next chapters will focus on providing adaptation strategies for these types of infrastructure.

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7
STRATEGIZE: Living with Coastal Waters

With evacuation routes and water/wastewater facilities identified as the Town's highest priority infrastructure in Chapter 6, the next step is to strategize how these places may become more resilient in the face of sea level rise, coastal storm surge, and related coastal flooding.

Before discussing potential resilience approaches, there are some important points to make:

1. **Adaptation measures will need to be implemented over time, in coordination with public and private partners.** The key is to advance strategies at all scales, in a coordinated manner, to address coastal flooding risks in the short term and long term.

2. **No adaptation installation is a fail-safe solution as no amount of modeling or planning can fully predict the future.** This is an important reality that focuses our attention on identifying strategies that provide public benefits in the near term and are flexible enough to work over a range of future conditions.
   - In addition to reducing the effects of coastal flooding, adaptation measures can include additional public benefits such as improved public access to the waterfront and protection / enhancement of natural resources.
   - Flexible approaches that grow with sea level rise may include adaptable ecological installations, natural berms, or other waterfront structures that can be adjusted vertically in height or expanded along the shoreline.


Coughlin Park Shoreline. Source: Woods Hole Group

Clever adaptation strategies that are flexible and offer multiple community benefits are more likely to gain the community and financial support needed for implementation.

3. **Once the adaptation measure is installed, ongoing support will help ensure the installation is successful.** When selecting an adaptation measure, an analysis of alternatives will help find the best installation for the community. Alternatives should include a variety of installation types and consider:
   - » Cost - depending on the type, quantity, and/or scale of measures chosen, they can cost a few thousand, or millions of dollars.
   - » Operations and maintenance – who will design, install, and maintain the retrofits? If the installation requires pre-storm preparation, who will respond to flood warnings? Who will manage clean-up efforts after the flood?
   - » Training – will the installation require human intervention?
   - » Supporting measures – is the installation able to work on its own, or is it most effective if combined with other measures?

For the purpose of this assessment, three different scales of climate change adaptation strategies are considered. Listed under each, are critical public infrastructure that will be the focus of adaptation measures in this assessment:

Site-specific installations that protect a single property or asset (Chapter 8):

- Pump Stations
- Beach Fire Station
- DPW Building

Shoreline/area-wide strategies that could protect multiple properties (Chapter 9):

- Main Street, near the Belle Isle Bridge
- Pleasant Street, at Ingleside Park
- Washington Avenue, at Lewis Lake
- Shirley Street, on Point Shirley

Policy- or regulation-based measures to provide town-wide protection standards (Chapter 10):

- New construction
- Redevelopment projects


Winthrop Beach

The strategies in this assessment focus on Town-owned facilities, or within public right-of-way, to provide the Town with installations that are within their own control and can be implemented in the near term. This focus does not discount the importance of understanding how other public service providers are modifying their facilities to coastal flooding. As part of the assessment process, the project team met with the Massachusetts Department of Conservation and Recreation (DCR) to present the findings of the Boston Harbor Flood Risk Model (BH-FRM) and discuss resilience initiatives the agency is working on or have considered.

This report should open the door for other follow-up discussions about community-level resilience planning and future implementation phasing. Meetings with other service providers in town could include:

- Massachusetts Water Resources Authority (MWRA)
- Massachusetts Port Authority (Massport)
- Massachusetts Department of Transportation (MassDOT)
- Eversource

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8 STRATEGIZE: Site-Specific Adaptation Measures

As identified on the critical infrastructure mapping (Figure 6-1), there are several important utility facilities scattered throughout the community. This section looks specifically at site and building retrofits for public utilities and structures. However, these adaptation measures may also be applied to other asset types, private residences and commercial buildings.

Overview of Site Adaptation Types

Sometimes, moving critical resources out of the flood zone is the most feasible option for resilience. While it may seem obvious to either relocate or raise structures and equipment for flood protection, each infrastructure type and location requires consideration of the potential benefits and drawbacks.

Relocating structures or equipment would offer the most protection to infrastructure within an area subject to flooding. It seems to make the most sense to avoid the threat of flooding by moving away from it. However, with pump stations, pressure valves, and substations, associated utility lines and building connections may not be a feasible option. If relocation is physically feasible, steps for implementation include securing a new property and funding, and identifying challenges of construction or movement of the infrastructure.

Elevated building. Source: StormSmart Coasts

Elevating critical infrastructure above projected flood depths can also protect assets from flood damage. This may include raising entire buildings, certain utilities, or equipment. Elevating these assets will require adequately designed foundations that will exceed potential flood water depths and manage flood water velocities, wind, and earthquake loads.

Oftentimes critical infrastructure cannot be moved or raised, and other adaptation measures must be explored.

Wet floodproofing can allow an asset to withstand flooding, and recover more quickly after the water has receded. Types of wet floodproofing include building with flood resistant materials, anchoring equipment (for instance, fuel tanks), and installing quick disconnects for appliances that may short out or be filled with contaminated water during a flood. Flood vents and pumps can prevent walls from collapsing due to high water levels or water saturated soils. However, pumps must be timed appropriately, to match the exterior flood levels as they recede.

Dry floodproofing strategies rely on exterior building walls to act as a flood barrier. To help create a watertight building, sealants or impermeable layers can be applied to walls and floors. Flood shields and watertight access hatches can also contribute to building protection. Flood shields are temporary installations to barricade doors and windows.

Inside the buildings, backflow valves can prevent contaminated water from entering a building through sewer or drain pipes. And, as a backup measure, pumps are recommended to remove water that may still penetrate dry floodproofing measures

Perimeter Barriers can be permanent or temporary vertical structures aimed at preventing flood waters from reaching a particular asset. Permanent barriers include sea walls or bulkheads. Temporary barriers are stored locally and installed prior to a flood event. Semi-permanent barriers are a combination of these, often a knee wall is built to a certain height with an option to add temporary structures to adapt to higher flood elevations. Alternatives to hard structures include berms or levees. These are earthen mounds, sometimes with a structural base, designed to block flood waters from entering certain areas.

Although they can be quite effective, barriers only offer protection to a specific height, so overtopping is still possible. Another consideration, for temporary installations, is that the wall components may require storage space, personnel training for installation, and enough warning time to install the structure.

SCADA (Supervisory Control and Data Acquisition) systems allow facilities to be controlled from remote locations. Technologies such as this can help raise awareness of flood risk to assets and issue warnings that may reduce damages or prevent failure of components.

Flood Shield
Source: Flood Control International

Example of dry floodproofing
Source: Flood C.I.

Revere Street Pressure Reducing Valve Station

Table 8-1 Range of costs for site adaptations

RECOMMENDED ADAPTATION CONCEPT	COST*
Relocate	$ - $$$$$
Elevate	$ - $$$$
Wet- or Dry Floodproofing	$ - $$$
Perimeter Barriers	$ - $$$$$
Communication Improvements (e.g. SCADA)	$ - $$$

* estimates are initial capital costs, and do not include annual expenses required to maintain the measure over the design life. It is assumed that the measures will be installed on publicly-owned property. Table adapted from *Amtrak NEC Climate Change Adaptation Plan- Phase III Pilot Study*, March 2017

Key to Estimated Range of Costs:

$	< $100,000
$$	$100,000 to $500,000
$$$	$500,000 to $3,000,000
$$$$	$3,000,000 to $10,000,000
$$$$$	> $10,000,000

Potential Strategies for Sewer Pumping and Pressure Reducing Valve (PRV) Stations

Three major sewer and wastewater pumping stations in town are identified within BH-FRM flood areas – Pico Avenue, Revere Street, and Pleasant Court. These stations collect and distribute hundreds of thousands of gallons of sewerage each day. The stations are at specific low points in the community to collect neighborhood waste and pump it out to the larger sewer mains.

The station at Revere Street is also home to a Pressure Reducing Valve Station (PRV), which is where the Department of Public Works (DPW) controls potable water flow into Winthrop.

Table 8-2 presents the modeled flood depths that may occur during a 1% chance water surface elevation (one chance in 100, or 100-year water level). These stations were recently updated with raised first floors, water resistant floor panels, and generator upgrades.

Dry floodproofing techniques could be applied, including the installation of flood doors on the stations. Potential walls could be built to at least the 2030 flood depth with 1-foot of freeboard. Walls should be designed to be able to adapt, in height, to future conditions in response to climate change and sea levels rise. Implementation, including cost estimates and potential permitting requirements, is explored in Chapter 11.

Table 8-2 Potential Sewer Pump Station Flood Depths and Adaptation Installations

WATER/ WASTEWATER STATION	POTENTIAL DEPTH OF FLOODING (IN FEET; 1% CHANCE WATER LEVEL)			POTENTIAL WALL HEIGHT (FLOOD WATER LEVEL PLUS 1-FT FREEBOARD)			POTENTIAL WALL PERIMETER	
	PRESENT DAY	2030	2070	PRESENT DAY	2030	2070	SURROUND EXISTING BUILDING	REPLACE EXISTING FENCE
Pleasant Court	0’-9”	2’-0”	4’-9”	1’-9”	3’-0”	5’-9”	150’	200’
Pico Avenue	0’-9”	1’-6”	4’-4”	1’-9”	2’-6”	5’-4”	120’	175’
Revere St Sewer Pump Sta	Dry	Dry	2’-3”	-	-	3’-3”	120’	275’ (surrounding both buildings)
Revere St PRV	Dry	Dry	2’-3”	-	-	3’-3”	140’	

9 STRATEGIZE: Shoreline Adaptation Measures

Yirrell Beach

> "Every storm makes changes; and every change has its consequences. Undoubtedly we can keep the present area of Winthrop, and perhaps even persuade the ocean to enlarge it rather than wear the shore line away. However, it must be remembered that this will only be so if constant vigilance is maintained and the walls and breakwaters kept in repair."
>
> *William H. Clark, The History of Winthrop 1952*

Area-wide strategies should be considered for long, linear infrastructure, or when several assets are grouped within one focus area. Strategies focused at the shoreline and within the community can make these locations more resilient to coastal flooding.

These strategies will require significantly more time and effort to finance, design, permit, and construct than the site-specific installations presented above. However, they are also typically more cost effective by providing protection for multiple public and private assets. The strategies may range from a couple of hundred linear feet shoreline, to a couple thousand linear feet, and involve a combination of public and private properties.

To make installations like this possible, it is crucial to open communication between the Town, property owners, community, and regulatory agencies early in the planning process to gain support, develop partnerships, secure funding, and set realistic project timelines.

Where feasible, natural systems and processes should be employed to help protect the Town from coastal flooding and provide ecological benefits. The potential for "green infrastructure" installations exist where large areas of natural resources (e.g. beach, tidal flats, or salt marsh) line the shore. However, in many locations in Winthrop, the constructed environment may limit this type of installation, and engineered barriers are more likely to be utilized. Here, more traditional "gray infrastructure" is appropriate.

Green Infrastructure

Existing and constructed green infrastructure has proven ecological benefits for coastal communities. Green infrastructure includes, but is not limited to, salt marsh and dune restoration, and living shorelines. A living shoreline may involve planting salt marsh and fringe marsh behind a biodegradable coir or rock sill, and creating tidal channels to enhance restoration and drainage. The ecological benefits include:

- Absorption of wave energy.
- Erosion protection.
- Water quality improvement.
- Habitat for wildlife and plant species.
- Visual character enhancement along the shoreline.

In addition, some of these systems maintain themselves after storms and flood events, and adapt to changes in sea level rise (NOAA, 2015).

Living Shoreline after construction

Living shoreline after vegetation growth
NOAA's Coxsackie State Boat Launch Living Shoreline Project (Source: noaa.gov)

Careful study of the proposed green infrastructure location, and plans from experienced designers will help avoid adverse impacts to existing habitat and wildlife. Other considerations include project cost and maintenance requirements, as storm events can alter infrastructure and reduce its effectiveness.

Gray Infrastructure

Humans have always been attracted to water, and the shoreline of Winthrop is no exception. The Town is completely built out (MAPC, 2014), with buildings and pavement abutting beaches and other wetlands. Gray infrastructure, or hard engineered structures (e.g. sea walls, stone revetment, drainage pipes and outfalls, etc.) have made this build out possible.

Pico Beach Seawall (gray infrastructure

However, these hard structures, to various degrees, may reflect wave energy. This can cause erosion to adjacent properties or fronting coastal resources (e.g. beaches, dunes, etc.). Over time, the structures themselves may be undermined by the erosion of the beach in front of it, causing eventual collapse and costly repair. In addition, beach erosion over time can limit areas for recreation, wildlife habitat, and ability of this natural resource to provide wave attenuation.

One benefit to constructing these steel and/or concrete structures is that they can be vertically extended over time. This would allow wall height to be increased in phases as data regarding future impacts from sea level rise and storm surges is refined.

In some situations, a concrete cap or wall may benefit from aesthetic details, to soften the visual impact. Concrete form liners can be designed with patterns to create an artistic statement and/or announce a particular place or neighborhood. Another way to break up a large wall could be to integrate elements such as art, planters, or terracing.


Hybrid installation example

Hybrid Installations

Some locations may benefit from a hybrid of green and gray infrastructure to provide protection for a wider range of potential flood depths. Coastal wetland plantings and berms can be designed to manage low to medium tidal flooding, where engineered walls could be provided for additional storm surge protection (NOAA, 2015).

In any case, shoreline installations can be designed, not only to create barriers to coastal flooding, but also provide an opportunity to benefit the surrounding community. These benefits may include improved public access to the waterfront and/or enriching an area's visual character.

Conceptual Design

Of the eight flood areas identified in Chapter 5, the Project Management Team (PMT) identified four locations for further study. The following criteria was used to select the locations:

- Includes the highest ranked critical infrastructure identified in Chapter 6
- Can use public property to install the adaptation
- Locations will illustrate different types or combinations of adaptation measures

Due to these criteria, potential installations described in this chapter include:

Belle Isle Marsh Flood Area – planted berm with sidewalk along Morton Street right-of-way

Ingleside Park Flood Area – hybrid sea wall, with seating and planting adjacent to Donovan's Beach

Lewis Lake Flood Area – flood barrier at Washington Avenue

Point Shirley Flood Area – beach nourishment/dune creation at Yirrell Beach


Belle Isle Marsh from Morton Street

The following sections discuss the probable flood entry points at each location, and a near-term adaptation that is intended to withstand a 1% chance water level in the modeled 2030 conditions. Future adaptations will require more focused location studies and conversations with property owners, neighborhoods, local boards, state agencies, and other interested parties. The materials on the following pages have been structured to allow each flood area section to be extracted from the assessment in support of future implementation phases. The sections can serve as an education packet for working group meetings, support communication efforts with public and private partners, and be included in future funding applications. Implementation, including estimated cost and potential permitting, is explored in Chapter -.

As outlined throughout this report, the scope of this study is to address only the effects of coastal flooding and sea level rise to the town. The following concept designs are not intended to reduce the effects of inland precipitation and storm drainage patterns. It is recommended that further study be conducted to address inland flooding in concert with the information in this report. Potential outcomes could include:

- Identification of flood areas and depths inclusive of all coastal and inland flooding
- Selection of locations and design types for stormwater upgrades, including pipe upsizing and green infrastructure (plants and infiltration systems to help "Soak Up the Rain" see EPA website for more information)
- Restoration of streams and wetlands
- Conceptual design for additional adaptation measures

Figure 9-1 Map of Adaptation Locations

BELLE ISLE MARSH FLOOD AREA

The Belle Isle Inlet once flowed freely over the tidal flats that were filled to construct Logan Airport in the 1920s (Massport website). Today, this opening between Winthrop and East Boston is just under 200-feet wide, traversed by the Belle Isle Bridge. The bridge is the primary evacuation route for the Winthrop community and Deer Island Wastewater Treatment Plant employees. It was recently reconstructed with the low member of the structure about one- to two-feet above the BH-FRM mapped 1% chance water level. In 2030, the bridge is projected to be only six-inches above the 1% chance water level.

Ultimately, raising the bridge and approach roadways should be explored. However, the design process to construct the 2013 bridge faced firm height restrictions from the Federal Aviation Administration (FAA). Because the FAA is unlikely to change the bridge height restriction in the near term, further study of potential scour and debris impacts is suggested. The bridge evaluation may also consider bridge components, connections, and lifecycle for replacement or elevation. Bridge adaptations may include additional riprap to help protect foundations against swiftly moving flood waters, and defend against debris impacts. Structural upgrades can also increase resistance to flood waters and floating debris.

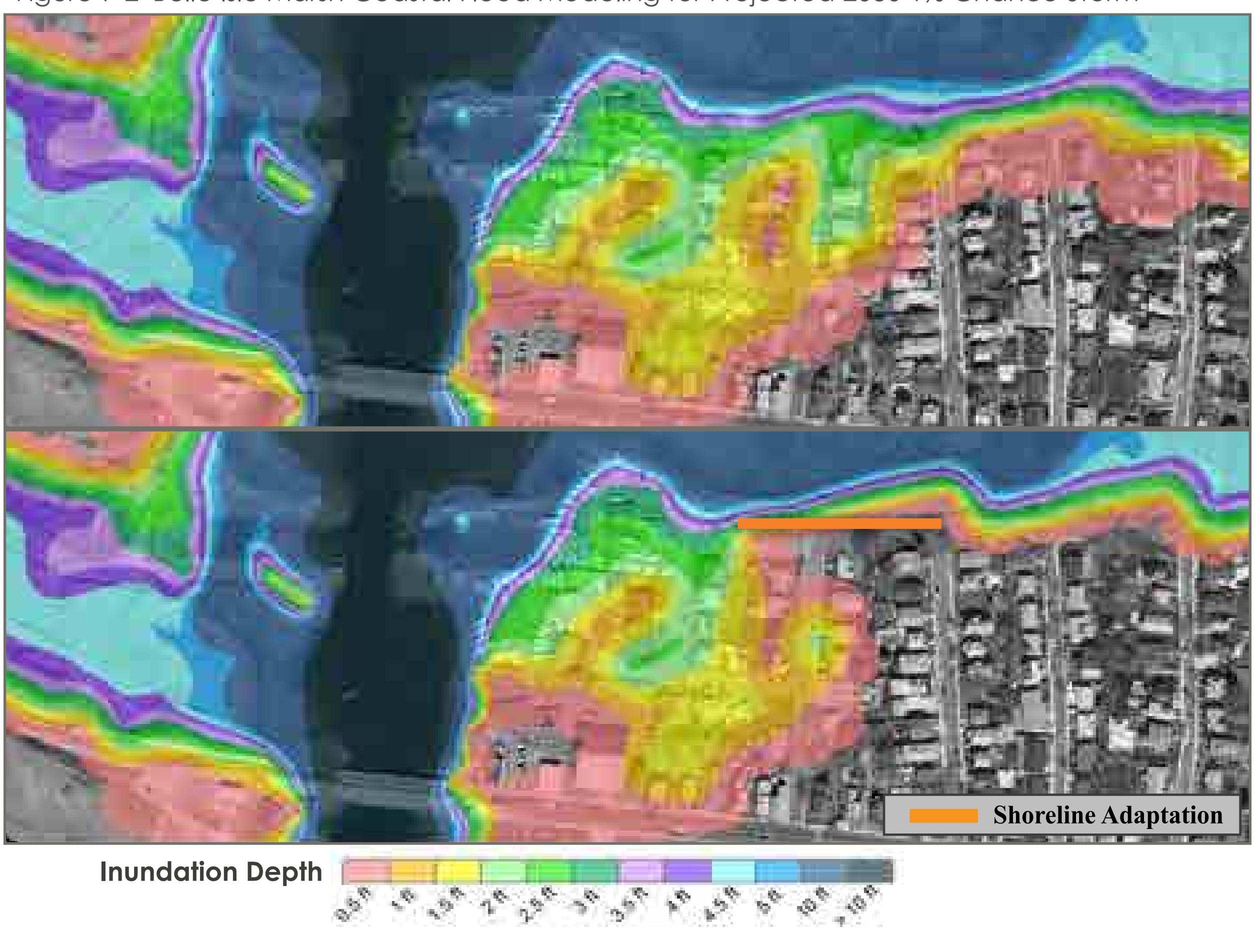
Although the bridge is not estimated to be overtopped by flood waters, the approaches to the bridge are. During a 1% chance water surface elevation in 2030, Main Street could experience as much as 6” of flooding, making it impassible. Although not part of this study, Saratoga Street, on the East Boston side of the bridge, is also at risk of flooding. On the Winthrop side of the bridge, there are two flood pathways identified by the BH-FRM: one along Morton Street, and another on private property at the west end of Morton Street (Figure 9-4).

Public Infrastructure Adaptation Recommendations

To help keep the water off Main Street in 2030, the assessment team studied the feasibility of a hybrid infrastructure installation along Morton Street (from Pleasant Street to Fairview Street; Figure 9-4). In addition to being identified as a flood pathway, the roadway right-of-way is within the Town's control. As such, the right-of-way was determined, by the PMT, to be a good location to start looking at resilience options. A planted berm was identified for study along Morton Street to discourage flood water from entering the area. The berm could include a walking path to tie in with existing plans for the Town's [Belle Isle Marsh Marine Ecology Park and Marsh Walk](). Plans for the new park are currently designed to connect Pleasant Street to a new passive recreation park on Morton Street. From the new park, the trail will connect with existing walking trails to the north of Belle Isle Cemetery.

A planted berm along Morton Street was modeled by the Woods Hole Group, using the BH-FRM, to identify whether it could reduce the identified flood depth along Main Street. Flood modeling of the installed berm did prove to be effective for some of the adjacent Morton Street neighborhood, but ineffective for reducing flooding on Main Street. This shows that both flood pathways must be addressed for the adaptation to be effective.

Figure 9-2 Belle Isle Marsh Coastal Flood Modeling for Projected 2030 1% Chance Storm



If Main Street is to remain passable during future coastal flood events, there must be discussions with private property owners along the shoreline, between the bridge and Morton Street. Suggestions could be made to repair/modify existing shoreline structures, install new structures, or create living shorelines. If agreements with private owners are not possible in these locations, additional measures must be considered landward of the flood pathways to protect Main Street and the pump station.

Supporting measures, considering inland flooding will also need to be addressed. Existing drainage pipes could be enlarged to hold more water during a storm event. Check valves should be installed at existing outfalls to prevent coastal water from entering the stormwater system. Additionally, green infrastructure installations along Morton Street, and streets perpendicular to it, may promote stormwater infiltration to reduce flood depths.

Natural Resource Recommendations

Due to sea-level rise, the marsh along the northeastern shores of Winthrop will want to expand inland over the next several decades (Appendix F). No immediate adaptations are required to maintain the natural resources in this area. However, in the long-term, and during storm events, more frequent overbank flooding can be expected to surrounding properties and the fringe marsh areas may be expected to expand. Smaller, proactive restoration measures could be considered along the shorelines to protect infrastructure and provide natural resource expansion and protection. Potential options could consider living shoreline applications and targeted thin layer deposition projects that would involve the placement of clean, compatible sediment in thin layers on the existing salt marsh to assist the elevations in keeping up with the rising tidal increases.

Figure 9-3 Potential Flood Levels at the Belle Isle Bridge

Flood Area: Belle Isle Marsh

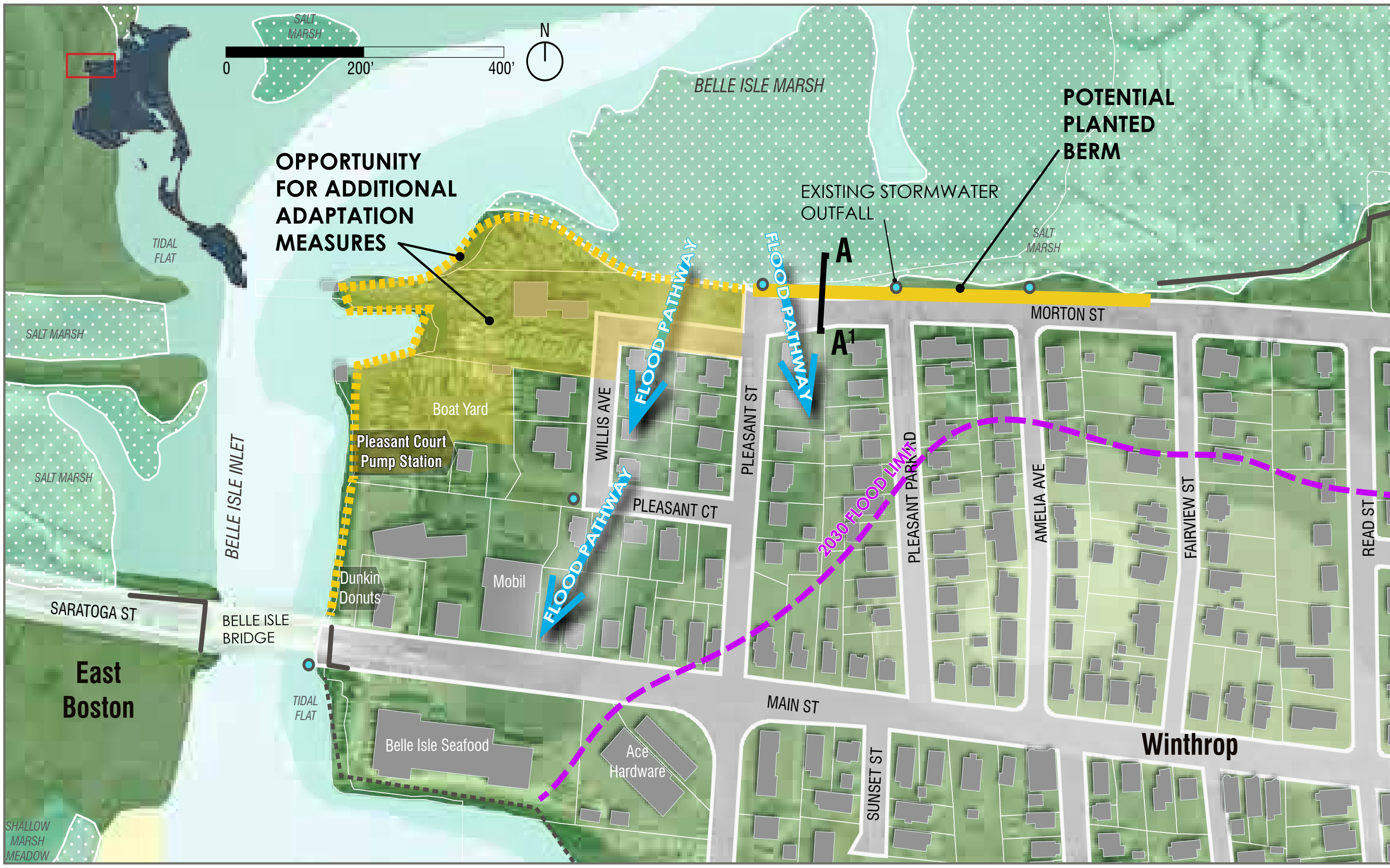


Figure 9-4 Morton Street Concept Plan

Figure 9-5 Section A-A' (Morton Street)

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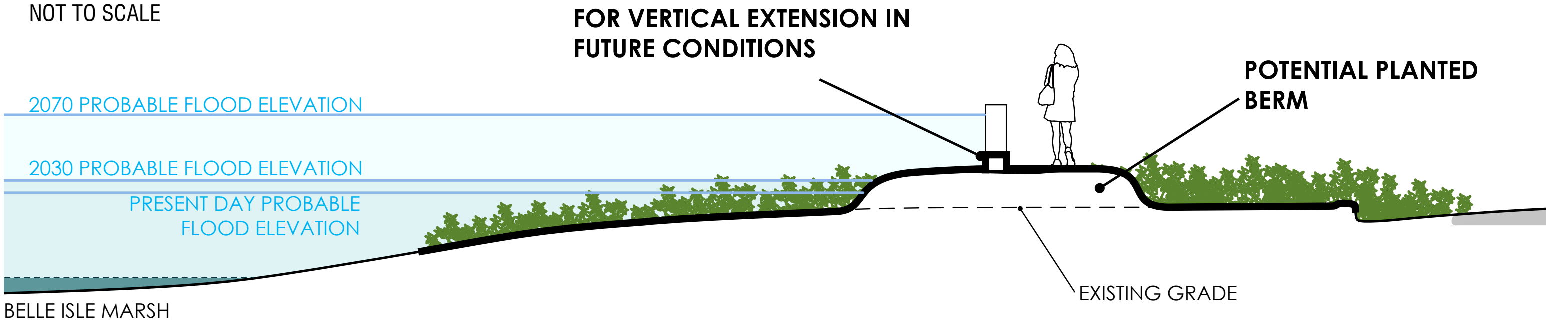
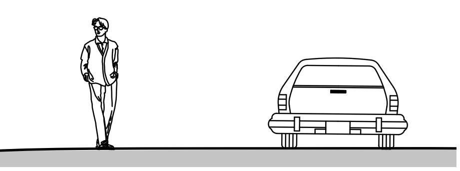


2030 FLOOD AREA SIZE	Approximately 106 acres (10% of Winthrop)
CRITICAL INFRASTRUCTURE WITHIN FLOOD AREA	Main Street (evacuation and Deer Island trucking route)
2030 1% CHANCE STORM FLOOD DEPTH	2'-3" (at Morton Street)
REVIEWED ADAPTATION	A planted berm along Morton Street may reduce the identified flood path, and reduce the flood depth along Main Street.
MODELED EFFECTIVENESS	Relatively ineffective. The berm protects a few homes, but generally the flood water will still enter the area west of the Morton Street installation.
ADAPTATION LIMITATIONS	The berm cannot protect Main Street on its own. Barriers offer protection to only a certain elevation, so overtopping is possible.
POTENTIAL SUPPORTING MEASURES	Upsize stormwater pipes, installing flapper valves on all outfalls. Discuss potential adaptations with private property owners between the Belle Isle Bridge and Morton Street (e.g. repair/modify existing shoreline structures and/or install green infrastructure).

Figure 9-6   Potential Morton Street Flood Levels



MORTON STREET

INGLESIDE PARK FLOOD AREA

As discussed in Chapter 5, Ingleside Park was swamp land until it was filled in 1936 (Clark, 1952). The flood pathway to Ingleside Park is at Donovan's Beach, assumed to be the same location where a tidal stream once entered the swamp. Coastal flooding on Pleasant Street could be 8-inches deep by 2030, making this roadway impassible during a major storm (Figure 9-9).

Public Infrastructure Adaptation Recommendations

The modeled 1% chance water surface elevation in 2030 shows water overtopping the existing 3-foot high seawall at Donovan's Beach. Shoreline improvements could include a hybrid wall, as shown on Figure 9-10, to

View toward Boston from Donovan's Beach

Southbound view along Pleasant Street (Donovan's Beach on right) increase the height of the barrier, infiltrate stormwater, and provide erosion control at the beach, habitat for wildlife, and seating to beach users.

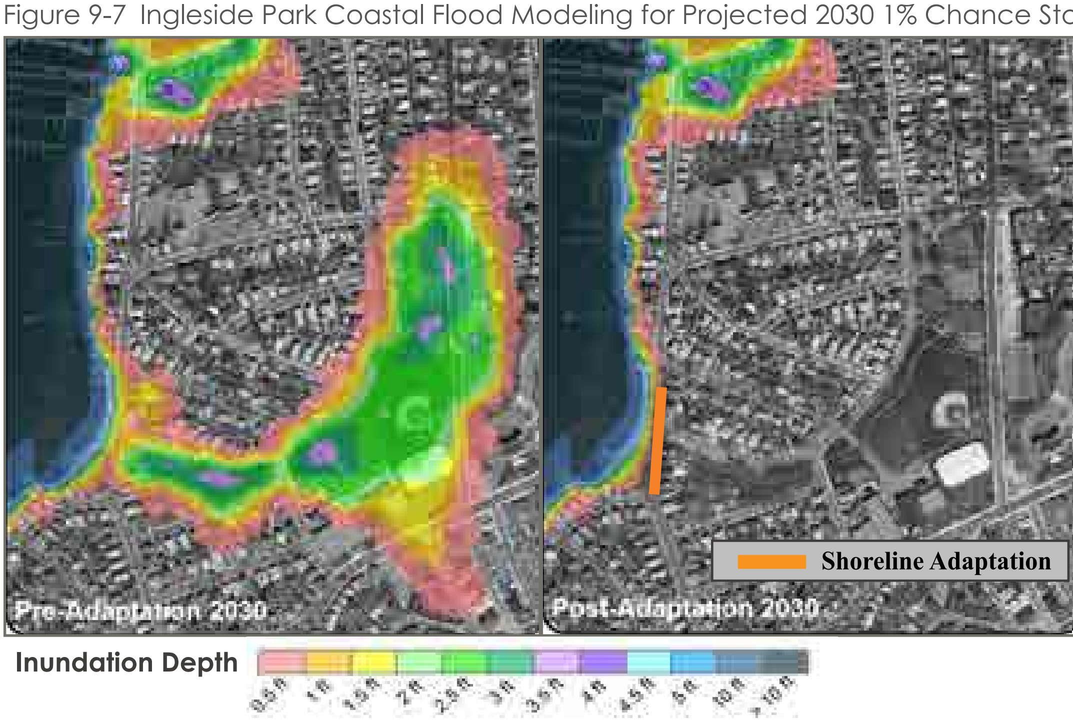
From the results of the BH-FRM, the PMT considered a 1.5-foot high wall installation all along the Donovan's Beach property line. WHG modeling of this installation shows it to be an effective adaptation measure to prevent storm surge from entering a large area under 2030 conditions.

However, Ingleside Park does drain a considerable amount of stormwater from development on the west side of Winthrop. To effectively adapt to future climate change conditions, other supporting measures must be studied to consider stormwater runoff and increased ground water levels due to sea-level rise. These measures may include enlarging drainage pipes to hold more water during a storm event, installing flapper valves to prevent coastal water from entering the stormwater system, and installing green infrastructure along roadways and in open spaces to promote stormwater infiltration and reduce flood depths. Depending on future effects of sea-level rise and increased precipitation at the park, the feasibility of restoring the 19th century stream may also be considered.

Natural Resource Recommendations

Office of Geographic Information (MassGIS) wetlands data, mapped by the Massachusetts Department of Environmental Protection (DEP), identifies a strip of salt marsh extending from just south of the Loring Road Boat Ramp to just north of Donovan's Beach. Although living shorelines are beneficial in some coastal areas, it is not recommended here. Construction along the beach could cause sediments to adversely impact the existing salt marsh system. The proposed hybrid wall will still provide some level of ecological benefits, as well as other public amenities.

Figure 9-7 Ingleside Park Coastal Flood Modeling for Projected 2030 1% Chance Storm



Flood Area: Ingleside Park

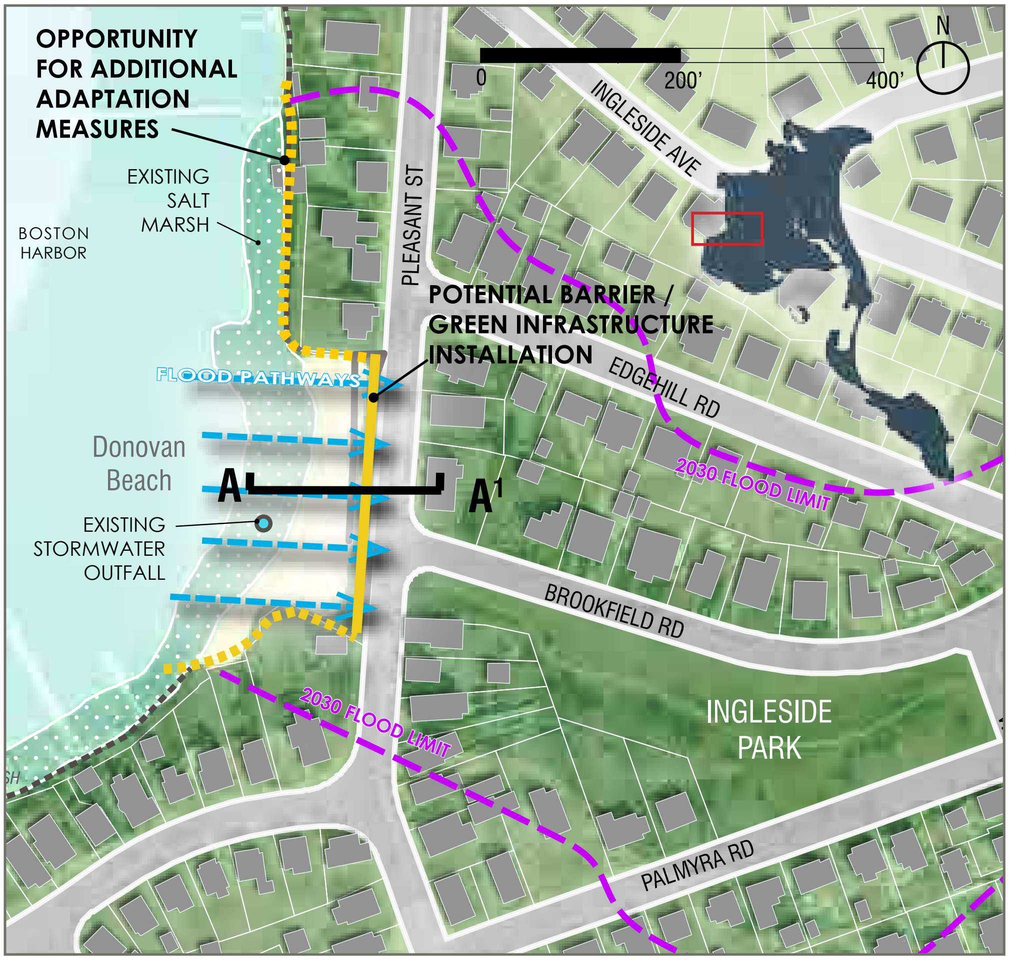


Figure 9-8 Pleasant Street Concept Plan

Figure 9-9 Potential Pleasant Street Fl

2030 FLOOD AREA SIZE	Approximately 38 acres (4% of Winthrop)
CRITICAL INFRASTRUCTURE WITHIN FLOOD AREA	Pleasant Street (Evacuation Route)
2030 1% CHANCE STORM FLOOD DEPTH	8"
REVIEWED ADAPTATION	Replacement of existing seawall with taller, adaptable flood barrier and planted seat walls. The green infrastructure on the beach-side of the barrier will provide ecological and recreational community benefits.
MODELED EFFECTIVENESS	Effective as a coastal flood adaptation
ADAPTATION LIMITATIONS	Ingleside Park drains nearly 100 acres in town & this adaptation does not consider inland precipitation. Flood barriers offer protection to only a certain elevation, so over-topping is possible.
POTENTIAL SUPPORTING MEASURES	Upsize stormwater pipes, installcheck valves at all outfalls Repair and/or modification of adjacent existing shoreline structures Install green infrastructure in town to promote stormwater infiltration & reduce runoff Stream restoration feasibility study

Figu
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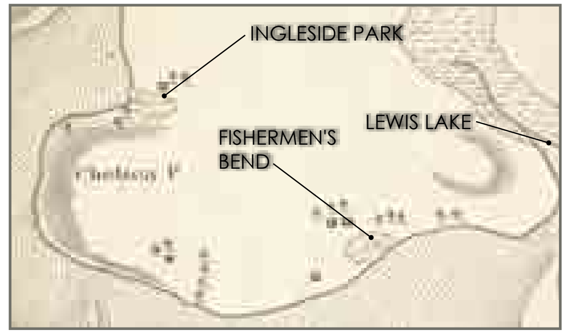
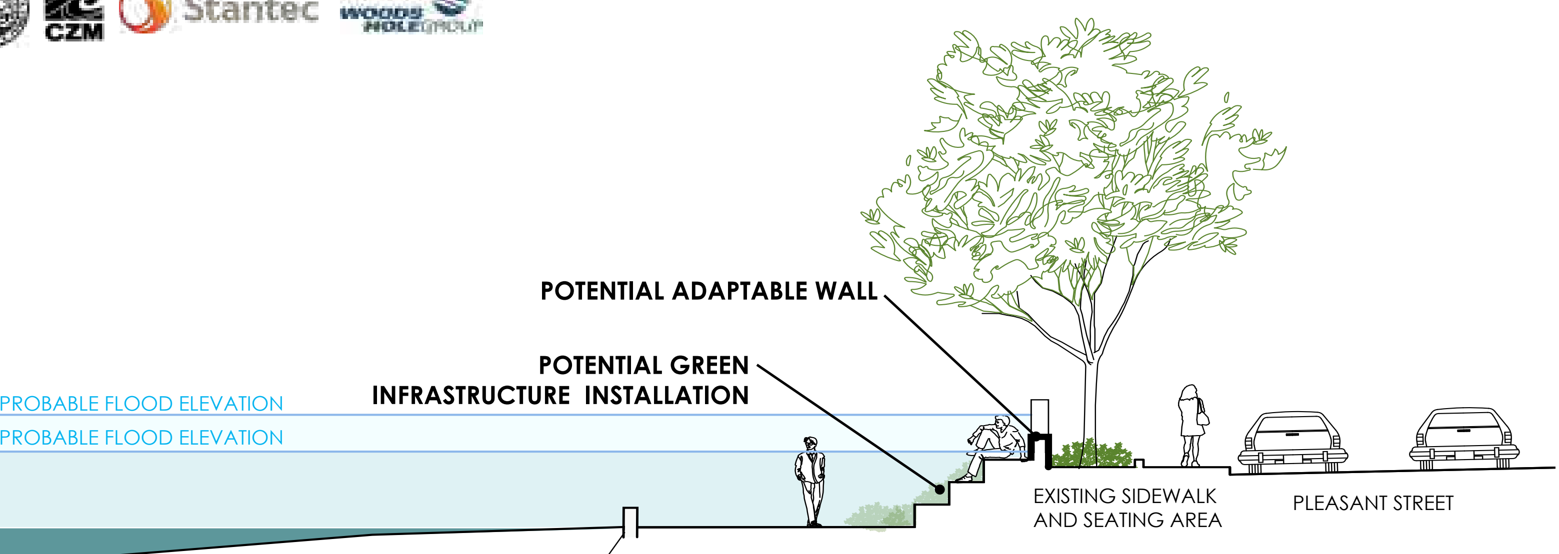
ood Levels



FORMER WETLAND SYSTEM AT INGLESIDE PARK. 1817 MAP OF BOSTON HARBOR, SURVEYED BY ALEXANDER WADSWORTH

WATER-SIDE STEPS/PLANTINGS AT CALGARY RIVERWALK, CANADA



re 9-10 Section A-A' (Pleasant Street)

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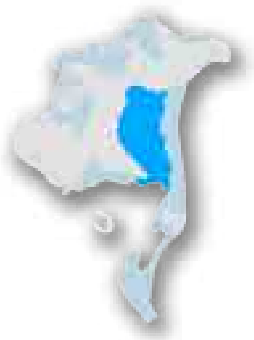
LEWIS LAKE FLOOD AREA



Where it was once open to the harbor, Lewis Lake is now landlocked with a single outfall and a tide gate to regulate its holding capacity. Prior to the turn of the 20th century, Lewis Lake was an extensive wetland system, including Fishers Creek, a tidal stream. When Winthrop began to grow as a vacation destination, a steam train line was constructed to deliver tourists from Boston to the town center and Winthrop Beach. A railroad bridge was built over the wetlands and, several years later, another bridge was constructed connecting Washington Avenue to Shirley Street. Soon after, the Washington Avenue bridge connection was filled to create a roadway and adjacent parcels. Though the rail line was eventually demolished, part of the railroad bridge bed, near Washington Avenue, remains.

Today, Lewis Lake collects stormwater drainage from approximately half of the town. The water table is high, and the identified area of coastal flooding also experiences flooding from extended amounts of precipitation. During the 1% chance flood in 2030, Washington Avenue could be under eight inches of coastal flood water (Figure 9-14).

Public Infrastructure Adaptation Recommendations

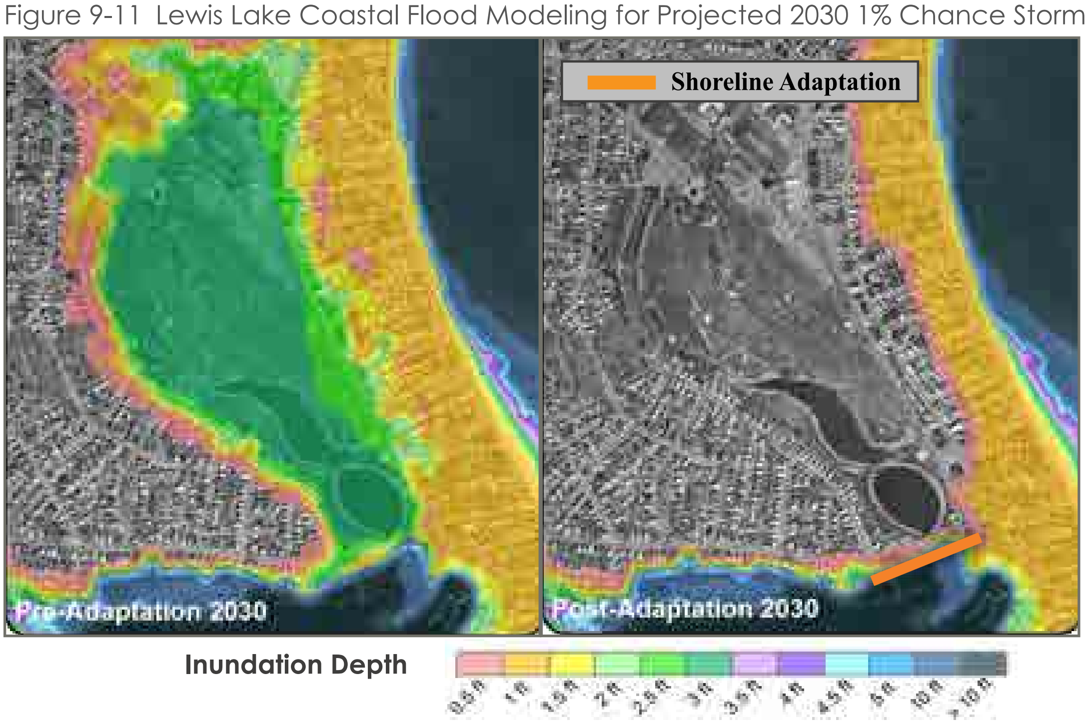
The path of coastal flooding in the Lewis Lake flood area comes from Crystal Cove (Figure 9-12). This armored shoreline is privately owned. Therefore, the PMT considered a flood barrier along the Washington Street right-of-way in front of these properties. Because of this, careful planning would be required to keep open access to the Elks Club and residential properties of flood emergencies.

The barrier would be installed at the back of the sidewalk, and could be designed to extend vertically, adapting to future conditions. Consideration of staff availability to respond to flood warnings and receive appropriate training is important to the success of this type of installation.

When the Lewis Lake flood area is modeled with this adaptation installation in place, it is fairly effective at obstructing the coastal flood water. This assumes that the culvert and tide gate system at the south side of Washington Avenue work as intended. However, it is still likely that there will be significant flooding at Lewis Lake, due to precipitation during a storm event. Poor drainage will lead to flooding in this area even with the coastal adaptation in place.

Discussions of access and protection is necessary with the property owners on the south side of Washington Avenue. Instead of installing a barrier along Washington Avenue, a combined effort to install the barrier and green infrastructure at the shoreline could also expand the protection area to include these private assets. Other long-term opportunities for exploration include raising Washington Avenue or reconstructing a bridge and restoring the creek. Creek restoration is further discussed in the below paragraphs.

Figure 9-11 Lewis Lake Coastal Flood Modeling for Projected 2030 1% Chance Storm



Natural Resource Recommendations

Wetlands at Lewis Lake Park and the Winthrop Golf Course primarily include inland open water, regularly flooded marsh, and tidal fresh marsh resources. The SLAMM maps show minor changes by 2030 at the inland fringes of these marshes as salt laden water is able to further penetrate upstream in the system. Very small inland portions of the regularly flooded marsh areas begin to convert to tidal fresh marsh. By 2070, much of the park and golf course shows transition to open estuarine water and regularly flooded marsh, and expanded regularly flooded marsh, tidal flat and transitional scrub shrub areas into available upland areas.

In the long-term, and during storm events, more frequent and expanded flooding can be expected throughout the Lewis Lake open space area, with additional inundation to adjacent developed areas due to storm surge. Long term choices regarding the future use of this open space will need to be considered. There is potential to restore the whole complex to its natural wetland state by reconnecting Lewis Lake to Boston Harbor and removing upstream impediments to flow and compliment with edge protection for the surrounding communities and infrastructure. This approach would restore the area to its historic condition of an ecologically beneficial salt marsh complex.

Lewis Lake area in 1894 (aerial drawing by AF Poole)


High water table at Winthrop Golf Club property

Living shoreline solutions along the edges of developed areas would protect against future storm surge while also providing additional habitat resources. Restored wetland areas and living shoreline installations could also be integrated with elevated walkways, kayak/canoe launches, and hybrid infrastructure to enhance recreational opportunities and waterfront interaction throughout this area. As such, there is a unique opportunity to create a long-term vision of an expanded, but different, recreation resource in this area for the Town of Winthrop. However, protection of this area could also be considered through appropriate mitigation efforts at Washington Avenue and appropriate tide gate control. If the Town opts to try to maintain existing recreational uses, this area would need to continue to be fortified through adaptations along Washington Avenue. Even then, eventually fresh water drainage will be a significant problem for this area due to increased mean water elevations in Crystal Cove. As such, increased flooding over the mid- to long-term would be expected in this area.

Flood Area: Lewis Lake

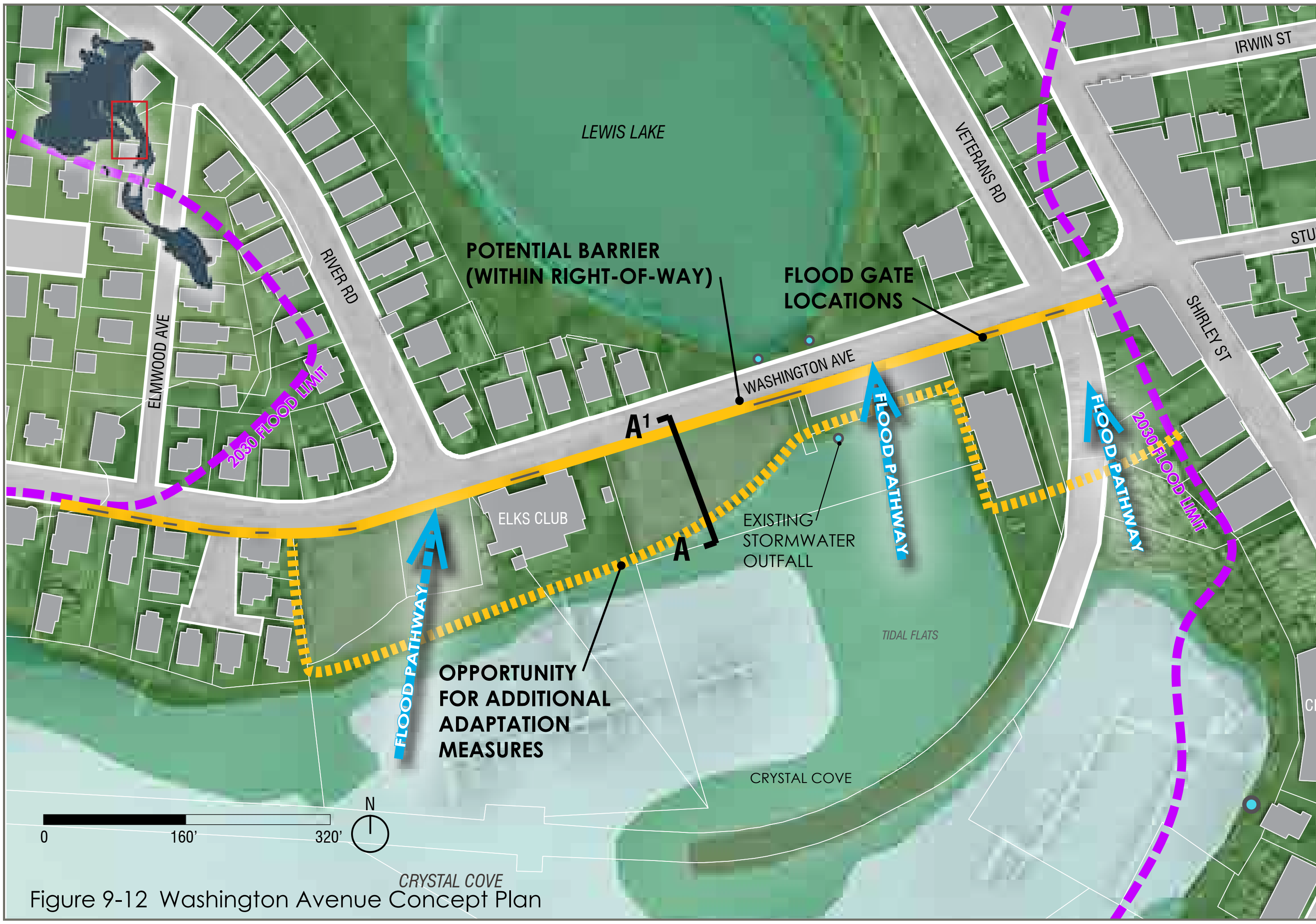


Figure 9-12 Washington Avenue Concept Plan

EXAMPLE FLOOD GATES (SOURCE: FLOODCONTROLINTERNATIONAL.COM)

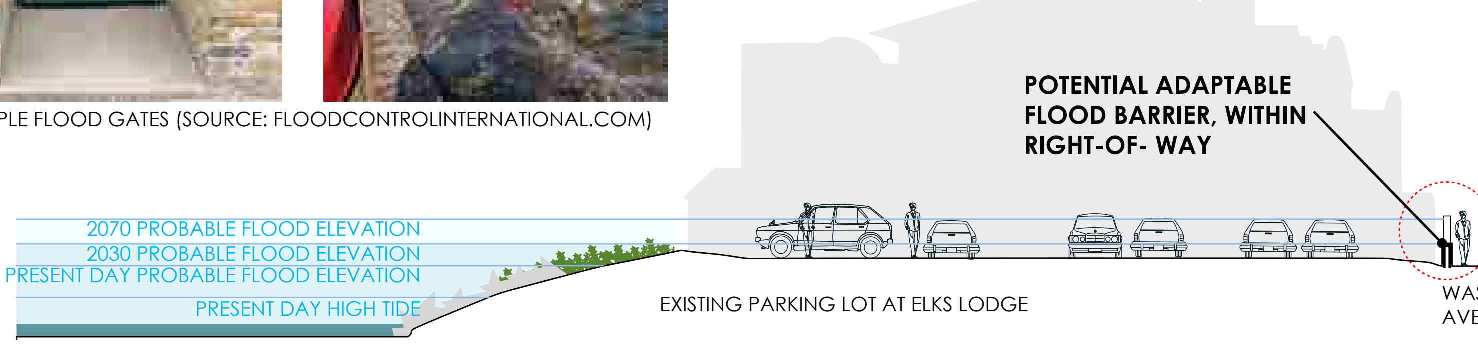


Figure 9-13 Section A-A[1] (Washington Avenue)

NOT TO SCALE

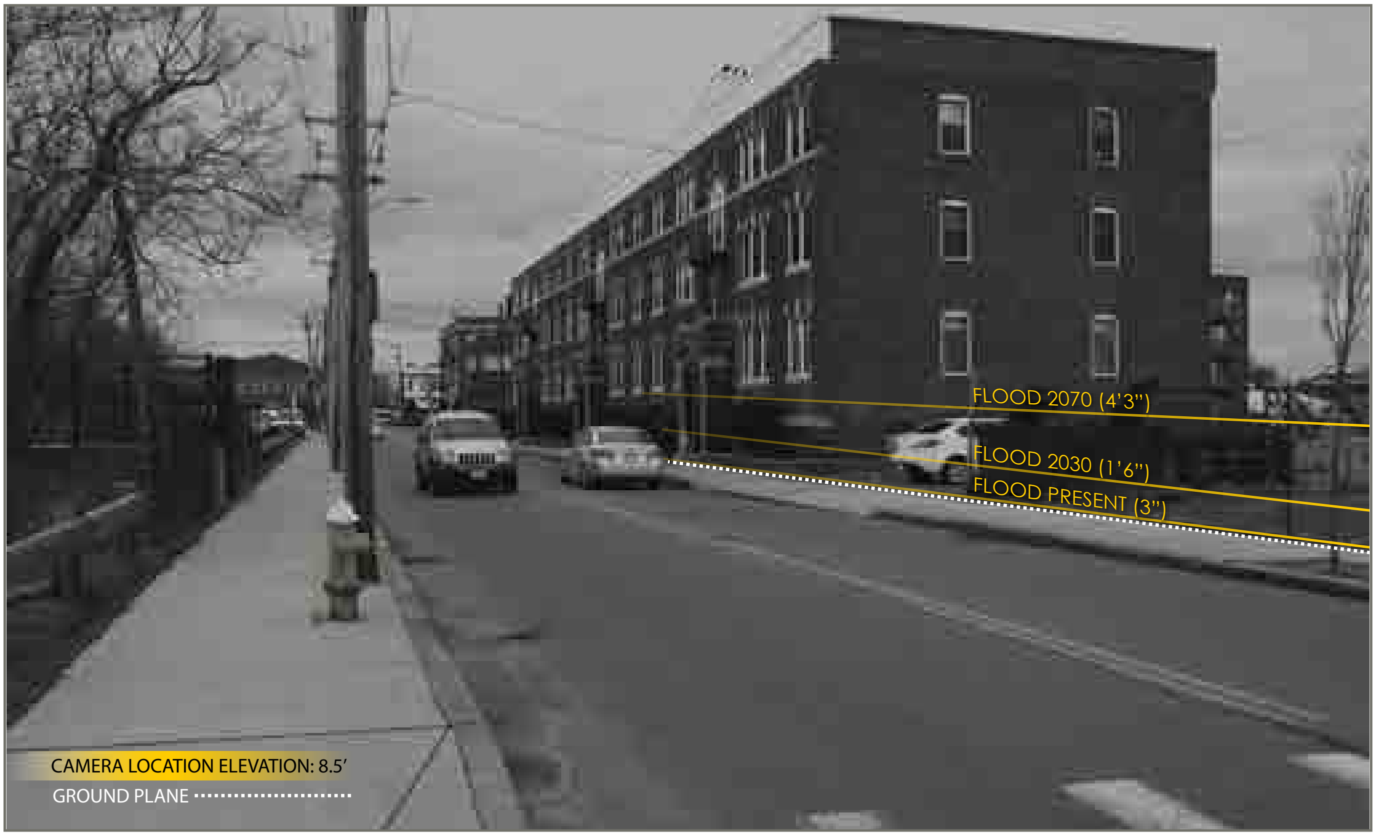
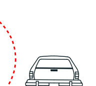
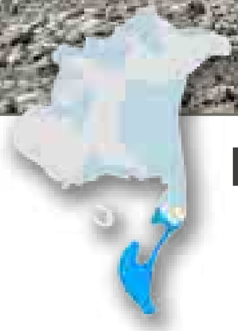


Figure 9-14 Potential Washington Avenue Flood Levels

2030 FLOOD AREA SIZE	Approximately 153 Acres (15% of Winthrop)
CRITICAL INFRASTRUCTURE WITHIN FLOOD AREA	Washington Avenue evacuation route, Winthrop High School
2030 1% CHANCE STORM FLOOD DEPTH	1'-6"
REVIEWED ADAPTATION	Vertical barrier within the Washington Avenue right-of-way, with an option working with private property owners to construct the barrier along Crystal Cove.
MODELED EFFECTIVENESS	Barrier is fairly effective at obstructing coastal flood water.
ADAPTATION LIMITATIONS	Adaptation effectiveness assumes that the culvert and tide gate system at the south side of Washington Avenue work as intended. Flood Barriers offer protection to only a certain elevation, so overtopping is possible. Flood gates require personnel and adequate response time. Significant flooding is still anticipated at Lewis Lake, due to precipitation during a storm event. Poor drainage will lead to flooding in this area even with the coastal adaptation in place.
POTENTIAL SUPPORTING MEASURES	Upsize stormwater pipes, install check valves at all outfalls Repair/modify existing shoreline structures





POINT SHIRLEY FLOOD AREA

First settled in the 1600s, Point Shirley has a long history of flooding and storm damage. (MHC, 1981). The shore has shifted, filled, and receded over time from both natural sediment movement and development restrictions.

Public Infrastructure Adaptation Recommendations

Because there are multiple coastal factors affecting the Point Shirley and Shirley Street neighborhoods, maintaining the present conditions of these areas cannot be expected to endure with climate change. A muti-faceted approach will be required over time to adapt to increased coastal storms and sea level rise.

Recent projects that the Town has constructed or proposed include:

- Drainage upgrades along Tafts Avenue, including enlarged pipelines to hold more stormwater during coastal flood events and duckbill valves to block water entering the stormwater system from Boston Harbor.
- Annual Sand dune creation
- Shoreline enhancement at Coughlin Park

The PMT identified Yirrell Beach as the most likely location for a Town-installed adaptation measure. Beach nourishment/dune creation was modeled to see whether this type of adaptation could make Shirley Street more resilient to climate change. The Point Shirley flood area will still get overtopped with the adaptations in place but the overtopping is much less significant, and may be reduced drastically for the full range of storms. The dune and beach nourishment also shows reduction of probability and depth levels in the area. A beach and dune system needs to be properly engineered where, being designed and installed correctly, it could provide even more resiliency than indicated in this assessment. For example, the correct slope and width of the beach berm and dune elevation combination can make a big difference.

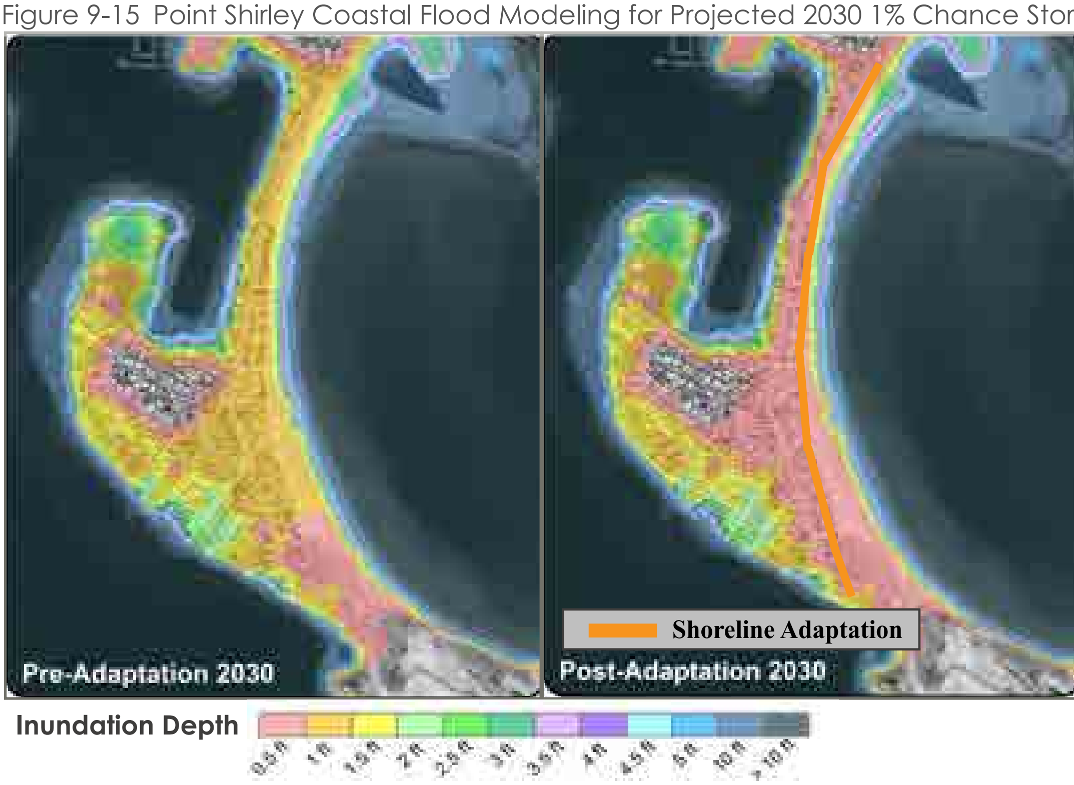
Additional steps to help the Point Shirley flood area become more resilient to coastal flooding include:

- Fund a study for beach nourishment and/or dune creation along Yirrell Beach.
- Continue to update the drainage system with larger pipes and check valves at all outfalls.
- Coordinate with property owners along the western shoreline of Point Shirley to create a consistent sea wall/ bulkhead. Today's varying heights and gaps in the barrier make it easier for higher tides to infiltrate the neighborhood.
- Coordinate with property owners within The Basin to consider salt marsh restoration from Coughlin Park to Winthrop Town Landing
- Provide educational, floodproofing, and/or home raising programs

Natural Resource Recommendations

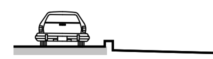
Irregularly flooded marsh and tidal flat resources currently exist along the Coughlin Park shoreline. By 2070, a large portion of the upland area of Coughlin Park could convert to beach and tidal flat without intervention. It is our understanding that there are ongoing projects to bolster the shoreline at Coughlin Park, which are not discussed in this document to avoid redundancy.

Figure 9-15 Point Shirley Coastal Flood Modeling for Projected 2030 1% Chance Storm



Flood Area: Point Shirley

Figure 9-16 Point Shirley Concept Plan



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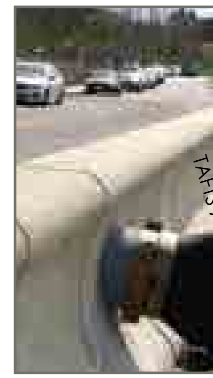

STORMWATER COLLE
UPSIZED & TIDE GATE
INSTALLED AT OUTFAL

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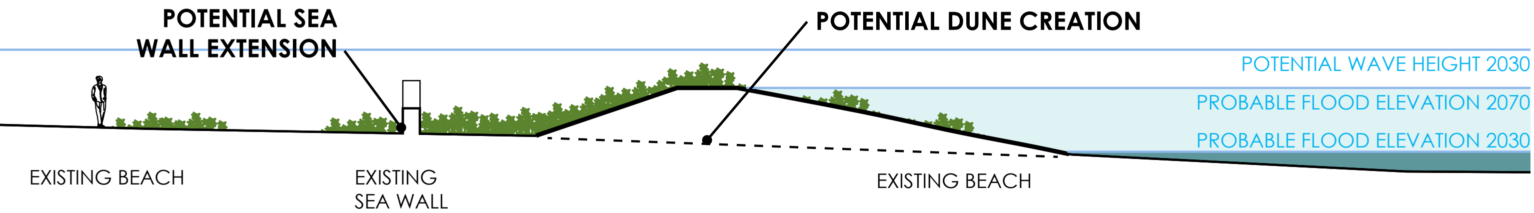

tion A-A' (Yirrell Beach)

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CHECK VALVES HAVE BEEN
LLS ALONG TAFTS AVENUE.

BEACHGRASS PLANTED TO STABILIZE AN ERODED DUNE, SOURCE: MA CZM, STORMSMART PROPERTIES FACT SHEET 3.

LIVING SHORELINE INSTALLATION, BEAUFORT, NC, SOURCE: NOAA.GOV

OD AREA SIZE	Approximately 88 acres (9% of Winthrop)
ASTRUCTURE WITHIN OD AREA	Shirley Street/Tafts Avenue (Evacuation & Deer Island Trucking Route)
NCE STORM FLOOD DEPTH	6" to 12" plus wave run-up and overtopping
D ADAPTATION	Beach nourish-ment / dune crea-tion at Yirrell Beach (pending design study)
EFFECTIVENESS	Effective in reducing wave overtopping & flood depth levels if properly engineered.
ON LIMITATIONS	No installation can be designed to eliminate wave run-up and overtopping. Natural installations (i.e. dune and salt marsh creation, beach nourishment) need space to grow over time.
L SUPPORTING EASURES	Coughlin Park shoreline stabilization project. Continue stormwater improvements to increase the capacity of pipes and install check valves were installed at the outfalls. Repair/modification of existing shoreline structures. Explore living shorelines at additional locations in the area.

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10

STRATEGIZE: Regulation and Policy

Sunset view from Donovan's Beach, Source: Winthrop town website

The coastal flooding and sea level rise, discussed throughout this report, will require collective actions across both public and private properties. When considering policy and regulatory changes, the Town will need to reach out to local groups, boards, commissions, and residents to educate them on the topics of coastal storms, local drainage systems, and predicted sea level rise. This can foster discussions on how the community might adapt to coastal flooding related to climate change. Discussions could address questions such as:

What can the local government and individual property owners do to adapt to projected coastal flooding and other impacts of climate change?

- What steps should be taken to further defend against rising flood waters?
- How, and at what point, should the community consider a managed retreat from the shoreline?
- Where should funds be directed first? What are the priorities?

With community involvement, these questions can be addressed and decisions can be made on how Winthrop can look toward a resilient future. This may include the development of local regulations and policies overseen by the local government.

Municipal Regulations

Winthrop's current regulations can be adapted to prepare for projected water levels. Existing town ordinances should be reviewed and updated to increase the resiliency of Winthrop's built environment. Regulatory modifications may be required to facilitate retrofits of existing buildings and ensure new developments are constructed to consider the flood challenges Winthrop faces, along with changes that can be made to reduce the Town's contributions to climate change:

Town of Winthrop Entrance Sign

Site-specific adaptations:

- **Site Plan Review** should be updated to reflect sea level rise and the projected flood areas.
- **Resiliency review check-lists** for each board/commission in town should be developed to consider the ability of buildings and land to withstand, endure, and recover from severe weather events and flooding.
- **A special permit process** could allow existing homes in flood areas to be raised above local building height limitations.

Area-wide adaptations:

- **Update Winthrop's Wetlands Protection bylaws** to restrict vegetation clearing in flood zones along coastal areas.
- Continue to **enforce the Town's Floodplain Zoning District** and associated building regulations for floodplain areas. Update this district to remain consistent with FEMA guidelines and floodplain mapping.
- Consider creating a new **flood zone overlay district** to regulate new construction within 1% chance flood areas.

Policy and Planning

Climate adaptation presents Winthrop with opportunities for carefully managed growth and investment that ensure existing neighborhoods can thrive, new neighborhoods are ready for the changing climate, and jobs are created and expertise developed for long-term growth and protection. The following policies are recommended for Town implementation to further prepare for coastal flooding and sea level rise in the future.

- In conjunction with the goals of the Open Space and Recreation Plan:
    - » Identify coastal lands to be protected and pursue acquisition of those parcels;
    - » Acquire vacant properties in identified probable areas of flooding
    - » Revegetate eroded areas where needed with conservation planting programs to protect sensitive areas as well as enhance the aesthetics of the beach areas.
- A section on Climate Change Preparedness could be included in the update of the Town's master plan, to develop policy principles and actions for climate change preparedness. Development of best management practices (BMPs) should be considered and implemented to encourage developers and home owners to follows guidance and standards for properties in projected flood areas.
- Town-funded projects could be required to incorporate sustainable practices to address the probable impacts of future coastal storms and sea level rise.
- Site-specific review of community facilities in projected flood zones should be considered for adaptation measures and resilience plans, as illustrated in Chapters 8 & 9.
- Recent Center Business District (CBD) Master Plan could re-evaluate certain policies considering probable coastal flooding and sea level rise. (e.g. height requirements, densities, CBD footprint, stormwater/green infrastructure/ renewable energy requirements, etc.)
- Winthrop's emergency response plan should be reviewed, considering information provided in this study, to prepare for and minimize flood damage from coastal storms and sea level rise. This would include facility- and/ or site-specific instructions (pre-and post-storm actions/maintenance), and relocating important equipment outside of the flood areas.
- Town should identify groups and agencies with special interests in Winthrop, and create a special task force to identify flood issues and shared goals, and work together to achieve them. The group could include:
    - » Department of Conservation and Recreation
    - » Massachusetts Water Resources Authority
    - » Massachusetts Port Authority
    - » Community leaders / groups
    - » Private land-owners

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11

STRATEGIZE: Implementation

Every project needs a budget, to meet special requirements, and to have funding mechanisms in place. The adaptation measures explored in Chapters 8 and 9 are reviewed in this chapter for cost, permitting, and funding to assist Winthrop in moving forward with implementation.

Range of Costs

Costs for site retrofits have been estimated in Table 11-1. The estimate includes initial materials and labor, but not the cost of design, permitting, and maintenance. These costs can vary depending on the size and location of the adaptation measures and should be investigated if a specific adaptation measure is being considered.

Table 11-1 Range of costs for Pump Station adaptations

ADAPTATION TYPE	COST ESTIMATE*
Stop Logs	$4,000 - $6,000 each
Watertight Exhaust Ducts	$10,000 - $15,000 each
Watertight Floor Hatches	$10,000 - $15,000 each
Repoint Building Façade 5-feet above grade	$20 - $30 per square foot
Waterproof Building Façade 5-feet above grade	$5 - $10 per square foot
Raise Outdoor Equipment Pads	$500 – $1,000 each
Raise Electrical Equipment Supports	$10 - $20 each
Work Platforms for Raised Electrical Equipment	$50 - $100 each
5-ft Concrete Perimeter Wall	$300 - $500 per linear foot

* Estimates include approximate cost of materials and labor for installation. Estimates do not include design, permitting, right-of-way acquisition, construction mobilization and demobilization, operations, or maintenance.
Key to Estimated Range of Costs: $ = <$100,000 ; $$ = $100,000 to $500,000 ; $$$ = $500,000 to $3,000,000 ; $$$$ = $3,000,000 to $10,000,000 ; $$$$$ = > $10,000,000

Table 11-2 Range of costs for shoreline / area adaptation

FLOOD AREA	APPROX. 2030 FLOOD AREA (ACRES)	CRITICAL PUBLIC INFRASTRUCTURE	1% CHANCE FLOOD DEPTH (FEET) 2030	1% CHANCE FLOOD DEPTH (FEET) 2070	RECOMMENDED ADAPTATION CONCEPT	POTENTIAL HEIGHT OF INSTALLATION (LINEAR FEET)	POTENTIAL LENGTH OF INSTALLATION (LINEAR FEET)	MODELED EFFECTIVENESS FOR FLOOD PROTECTION UNDER 1% CHANCE FLOOD DEPTH (2030)	2030 COST OF CONSTRUCTION*	2070 ADDITIONAL COST*
Belle Isle Marsh	106	Main Street (Evacuation Route & Deer Island Trucking Route)	2'-25"	6'	Planted berm / elevated sidewalk with knee wall along Morton Street right-of-way.	1-3"	625	Relatively ineffective solely along Morton Street. Needs to extend further west & south along the inlet.	$$$	$$$-Engineered flood barrier
Ingleside Park	38	Pleasant Street (Evacuation Route)	8"	3'-5"	Hybrid seawall, with seating & planting adjacent to Donovan's Beach.	1-9"	325	Effective as a coastal flood adaptation.	$$$	$$-Engineered flood barrier
Lewis Lake	153	Washington Avenue (Evacuation Route, Winthrop High School)	1'-5"	4'25"	Flood barrier at Washington Avenue.	2-6"	900	Effective as a coastal flood adaptation, if culvert & tide gate system at Crystal Cove work as intended.	$$$	$$
Point Shirley	88	Shirley Street/ Tafts Avenue (Evacuation & Deer Island Trucking Route)	12"	4'	Beach nourishment / dune creation at Yirrell Beach (pending design study).	Pending design study	3,850	Effective in reducing wave overtopping & flood depth levels if properly engineered.	$	$$$$$
					Dune creation at Yirrell Beach (pending design study).				$$$$ to $$$$$	$$$$$

*Estimates include approximate cost of materials and labor for installation. Estimates do not include design, permitting, right-of-way acquisition, construction mobilization and demobilization, operations, or maintenance. Key to Estimated Range of Costs: $ = <$100,000 ; $$ = $100,000 to $500,000 ; $$$ = $500,000 to $3,000,000 ; $$$$ = $3,000,000 to $10,000,000 ; $$$$$ = > $10,000,000


Flagging salt marsh boundaries at Coughlin Park, Summer 2016, Source: Woods Hole Group

Environmental Permitting

Environmental permitting requirements are an important consideration for every project and especially for coastal projects proximate to natural, cultural, and recreational resources along the shoreline. Each adaptation concept recommended in this Assessment will require some level of environmental permitting under public laws.

Determining the required permitting begins with an understanding of environmental resources at each adaptation site. The next step is to identify location-specific design strategies to avoid/minimize construction impacts to those resources. The extent of anticipated impacts informs the need for specific permits which in turn impacts the overall project schedule. Each permit has a related agency review time frame and some approvals are pre-requisites to others. Often the environmental permits are on the critical path to advertise a project for construction, which emphasizes the importance of carefully managing the environmental permitting process.

Table 11-3 outlines potential permits or clearances often needed for shoreline construction. Early coordination with local officials and regulatory agencies is recommended to obtain a comprehensive list of all required permits at the start of each project. In addition to the identified permits, additional technical studies may be needed. For example, in the Belle Isle Marsh Flood Area, sites south of Main Street have a history of oil and hazard material releases. Soil testing is recommended in this area, and state approvals identifying appropriate disposal methods and locations may be required. Likewise, in the Point Shirley Flood Area, recently released Natural Heritage and Endangered Species Program (NHESP) mapping shows potential habitat for protected species such as the Grasshopper Sparrow, Upland Sandpiper, Piping Plover, Common Tern, and Lest Tern. Potential species and habitat field assessments may be needed to verify the absence/presence of these species in each project area.

When the Town is applying for funding for these projects, the timelines associated with each permit should be factored into the proposed project schedule. This includes the agency review time frames for each permit/ approval and any Time of Year restrictions placed on the project which may impact the construction schedule. Depending on the funding program, it may be necessary to phase the project over a few funding cycles to account for the permitting time frames. For example, propose preliminary design and some permitting in year one, final design and permitting in year two, and construction starting in year three. The phasing strategy will vary depending upon the funding cycles and required period of performance.

Table 11-3 Potential Permits Needed for Shoreline Construction

ENVIRONMENTAL PERMIT OR APPROVAL (AGENCY)	FLOOD AREA Recommended Adaptation Measure/Location & Environment		
	Belle Isle Marsh Planted Berm with Sidewalk Along Morton Street	**Ingleside Park** Hybrid sea wall, with seating and planting adjacent to Donovan's Beach	**Lewis Lake** Flood barrier at Washington Avenue
LOCAL			
Notice of Intent (NOI) / Order of Conditions (OOC) Massachusetts, M.G.L. c.131, §40 and the Winthrop Wetlands Protection Ordinance (Winthrop Conservation Commission and MassDEP)	●	●	●
STATE			
Massachusetts Environmental Policy Act (MEPA) – Environmental Notification Form (ENF) M.G.L. c. 30, §61-62H (MA Executive Office of Energy and Environmental Affairs)	●		
Massachusetts Endangered Species Act (MESA) - Project Review M.G.L c.131A (Natural Heritage and Endangered Species Program of the MA Department of Fish & Wildlife)	●		
Section 106 / Chapter 254 Historic Review - Project Notification Form (PNF) Section 106 of the National Historic Preservation Act of 1966 / M.G.L. c. 9, §§ 26-27C as amended by St. 1988, c. 254 (Massachusetts Historical Commission)	●	●	●
Section 401 Water Quality Certification (WQC) Federal Water Pollution Control Act, 33 U.S.C. 1341 et seq., §401 / Massachusetts Clean Water Act, M.G.L. c. 21, §26-53 (MassDEP)	If impacts to wetland resources / Mean High Water exceed thresholds	If impacts to wetland resources / Mean High Water exceed thresholds	If impacts to wetland resources / Mean High Water exceed thresholds
Chapter 91 Water Dependent License or Permit Public Waterfront Act, M.G.L. c. 91 (MassDEP)		●	●
FEDERAL			
Coastal Zone Management (CZM) Federal Consistency Review Federal Coastal Zone Management Act, 16 U.S.C. §1451 et seq./ Massachusetts Coastal Zone Management Act, M.G.L. c. 21A, §2, 4 (MA Office of CZM)			
Section 404 Massachusetts General Permits (GP) from U.S. Army Corps of Engineers (USACE) – Preconstruction Notification (PCN) Federal Clean Water Act, 33 U.S.C. c. 1344 §404 et seq. / Rivers and Harbors Act, 33 U.S.C. c.403 §10 (US Army Corps of Engineers, New England District)	If impacts below Mean High Water	If impacts below Mean High Water	If impacts below Mean High Water

al Resources **Point Shirley** Beach Nourishment / dune creation along Yirrell Beach	**ACTION**	**PROCESS**
●	Temporary or permanent alteration of wetland resource areas and/or work in a regulated buffer to these areas.	Submit NOI application to local Conservation Commission. Copy mailed to MassDEP Northeast Region Office. Requires abutter mailings, legal notice, site visit, and public hearing.
●	Exceed MEPA review thresholds and require a permit from a State agency /department / board / commission / authority or utilize state funds. Potential thresholds include work within an Area of Critical Environmental Concern (Rumney Marsh) and alteration of barrier beach (Yirrell Beach) or salt marsh (Donovan's Beach), for example.	Submit ENF to EEA. Copies mailed to MEPA directed distribution list. Notice published in Environmental Monitor and local newspaper. A site visit is typically held.
●	Work within mapped areas of priority and estimated habitat (14th Edition Natural Heritage Atlas, draft).	Submit Project Review Form or file for Streamlined NOI/MESA review to show the project does not result in "Take" of habitat, or provides mitigation for habitat impacts.
●	Requires funding, licenses, or permits from any state or federal governmental agency.	Submit PNF to MHC. Copies mailed to MA Bureau of Underwater Archeological Resources, Tribal Historic Preservation Officer, and local historic commission (as appropriate).
If impacts to wetland resources / Mean High Water exceed thresholds	If a project impacts more than 5,000 square feet of wetlands, or requires more than 100 cubic yards of dredging, MA DEP must review its compliance with state water quality standards.	Submit WQC application to MassDEP with sediment analysis (for dredging). Public Notice published in local newspaper. A complete application includes Tthe following approvals: OOC, MEPA Certificate (as appropriate).
●	Licenses required for any project located in, on, over, or under tidal waters (flowed tidelands) or filled tidelands. Permits are required for dredging.	Submit new or amended Chapter 91 license or permit application to MassDEP. Public Notices mailed to abutters and state agencies, and published in local newspaper. A complete application includes the following approvals: OOC, WQC, and MEPA Certificate.
If impacts below Mean High Water	Project within a coastal zone requires funding, licenses, or permits from any federal governmental agency. CZM Consistency Review ensures compliance with standards of the MA CZM plans.	Complete a federal consistency application to describe how the project is consistent with relevant CZM program policies. Requires public notice & decisions on all applicable state licenses /permits
If impacts below Mean High Water	Fill/excavation in wetlands and waterways (Section 404). Project must meet a detailed set of criteria for each type of construction activity in, on, or over aquatic environments to receive the GP.	Submit PCN to Corps New England District. Corps publishes a Public Notice. A complete application includes the following approvals: MHC sSection 106, MESA, OOC, WQC, Ch.91.

Potential Funding Sources

The adaptation strategies discussed in this assessment vary in terms of probable construction costs and implementation timeline. They include combination of green and gray elements, and depending on the location, will help protect specific sites, areas of Town, and/or broader regional priorities.

As these strategies vary, so will the approach to funding. The Town should set aside some funds in the capital budget to help advance some of the smaller scale strategies and/or serve as a match to other grant programs. The ability to leverage funds for the recommended adaptation strategies will depend on the availability of funding, and the ability to phase each strategy to meet identified funding targets.

Potential programs and project partners could include a combination of federal and state agencies, financial institutions, property owners, and non-profit foundations.

Federal and state agencies release various funding opportunities. The availability and focus of these funding programs vary from year to year based on administration priorities and budgets. These programs have been, and will continue to be, highly competitive. Winthrop has been fortunate in prior years to have received grants for various types of infrastructure improvement projects. Some of these grants have been specifically focused on infrastructure resilience such as the Point Shirley Drainage Improvements and Coughlin Park Green Infrastructure Study, as well as the completion of this assessment. In addition, state agencies and quasi-state agencies such as DCR and MWRA are funding infrastructure improvements to upgrade their facilities located within the Town.

Potential federal and state partners and programs include:

- FEMA Hazard Mitigation Assistance Program
- NOAA Sea Grant Program and Coastal Ecosystem Resiliency grants
- U.S. Fish & Wildlife Service Coastal Resilience Program grants
- Massachusetts Coastal Resilience grants
- Massachusetts Dam and Seawall Repair and Removal Fund
- Massachusetts Seaport Economic Council grants
- MassWorks Infrastructure Program

Funding assistance from **financial institutions** can take on various forms. MassDevelopment (a quasi-state real estate financing agency) has state-wide authority to create and fund Property Assessed Clean Energy (PACE) finance programs, making it easier for municipalities to structure C-PACE financing for properties in their town and allow renewable energies to grow in Massachusetts. In the future, the Massachusetts PACE program could be broadened from a renewables focus to also include resilience investments similar to what Connecticut is doing. The Connecticut commercial and residential PACE programs, C-PACE and R-PACE respectively, provide access to private financing for qualifying resiliency investments—including hurricane and flood-proofing.

At the local level, Massachusetts municipalities also sell bonds to financial institutions to borrow money needed to pay for improvements to various municipal assets ranging from buildings and facilities to roadway infrastructure to emergency response equipment. In addition to Massachusetts Municipal Bonds ('munis'), there are also topic focused bonds such as green bonds, that fund a specific project or type of project. The Town could consider bonding the design and construction of a specific adaptation as part of a future bond program.

The Town should also be proactive in its efforts to work with **property owners** to integrate resilient design elements into future development and redevelopment projects. These property owners include private residential and commercial owners, as well as public agencies such as the DCR and MWRA. The probability of coastal flood mapping (Appendix D) and site adaption types (Chapter 8) will help these owners make more informed decisions about the desired level of protection. A particular group of owners in one part of Town may also be interested in pooling together their financial resources to help protect their properties. Some of the funding programs available to the Town, such as FEMA's Hazard Mitigation Assistance Program. can also help fund adaptation strategies at a property scale. The Town should make property owners aware of funding opportunities as they become available.

Non-profit foundations may also be interested in supporting the Town's resilience efforts. Entities such as the Kresge Foundation, Barr Foundation, and Rockefeller Foundation are funding climate-resilience planning and design efforts with local and non-profit partners in the metro-Boston area. These foundations support projects that take an integrated approach to building community resilience. The strategies and grantmaking priorities of each foundation change in response to internal interest areas and national trends.

If the municipal budget can't support the required level of investment and bonding is not an option, the Town could consider implementing **District Improvement Financing** (DIF, geographic focused) or a **Stormwater Utility** (topic focused). Essentially these financing mechanisms impose a supplemental benefit assessment on the owner's property tax for a specific purpose. Each of these mechanisms are allowable under Massachusetts law and often involve complementary zoning updates.

The major takeaway – the Town will need to be creative in its approach to funding adaptation strategies. Infrastructure adaptation at a Town-wide level is expensive and will need to be phased over time as new projects or upgrades are proposed, or as standalone projects as funding allows. Public-private partnerships may prove beneficial to advancing these strategies in the near term.

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12

STRATEGIZE: Next Steps

Sunrise from Winthrop Beach

This assessment lays the framework for Winthrop's efforts to build community resilience. The Town has systematically identified, prioritized, and strategized areas of Town and critical infrastructure most at risk of coastal flooding under present day and future climate conditions. The next step is to advance the assessment recommendations and expand the resilience discussion to include consideration of other climate-related hazards and community assets.

The next steps to advance the assessment recommendations include:

- Remain active in the Boston Metro Mayors Coalition Climate Preparedness Task Force
- Review the Boston Harbor Flood Barrier Study being led by UMass Boston working for the Barr Foundation
- Educate residents and business owners on how they can prepare for coastal flooding now and in the future
- Be proactive in integrating resilient design elements into future public and private development and redevelopment projects

- Set aside funds in the Town's capital budget for the recommended adaptation measures
- Phase adaptation measures based on synergies with other capital improvement projects and funding availability
- Pursue grants and other funding opportunities to leverage town funds

In addition, in Fall 2017, the Town will begin a community resilience building workshop process as part of the Commonwealth's Municipal Vulnerability Preparedness (MVP) Program. This Program expands the focus from just coastal flooding to include consideration of other climate-related hazards such as increased precipitation and heat, for example. It will also expand the discussion to include a comprehensive assessment of infrastructural, societal, environmental, and economic components of the Town. The workshop process will follow a similar identify-prioritize-strategize framework. The workshop process will identify key climate-related hazards, vulnerabilities and strengths, develop adaptation actions, and prioritize next steps. Results of the workshop and planning efforts will be used to inform existing local plans, grant applications, budgets, and policies. The Town-wide mapping and evaluation of coastal flooding completed as part of this assessment will be beneficial to the workshop process.

Again, the takeaway is that the Town does not need to do this alone or all at once. While the impacts of climate change are already being felt locally, the Town's ability to respond to increased coastal flooding and other climate-related hazards will take time and funding. Most importantly, improving community resilience will require a commitment from the Town, its residents and business owners, and agency partners to advance a multilayered resilience strategy.

Appendix A - Glossary of Terms and Abbreviations

Terms

1% CHANCE FLOOD DEPTH	The depth of flooding relative to sea level and storm surge during a 100 year storm event.
1% CHANCE WATER LEVEL/ SURFACE ELEVATION	The probable water elevation from a storm event that occurs ever 100 years.
ADAPTATION	Adjustment or modification to a particular situation or circumstance.
DRY FLOODPROOFING	Protecting a building from floodwaters by creating an impermeable barrier on the outside. (ex. Flood doors, watertight access hatches, and wall and floor sealants)
EXECUTIVE ORDER 569	Executive Order signed by Governor Baker, which lays out an approach to further reduced greenhouse gas emissions, safeguard residents, municipalities and business from the impacts of climate change, and build a more resilient Commonwealth.
COASTAL GREEN INFRASTRUCTURE	Built ecological systems and processes intended to absorb wave energy, reduce erosion, and improve water quality. Coastal examples include constructed wetlands, urban forests, green roofs, green streets, living shorelines, and rain gardens.
COASTAL GRAY INFRASTRUCTURE	Engineered coastal structures, including seawalls, bulkheads, and stone revetments.
COASTAL HYBRID INFRASTRUCTURE	A combination of green and gray infrastructure. Coastal examples include coastal wetland plantings and berms with engineered walls.
HYDRODYNAMIC MODELING	Modeling based on mathematical representations of the processes that affect coastal water levels such as riverine flows, tides, waves, winds, storm surge, sea level rise, and wave set-up, at a fine enough resolution to identify site specific locations that may require adaptation alternatives.
INUNDATION	The flooding of low-lying coastal land caused by severe weather.
KING TIDE	The highest predicted high tide of the year at a coastal location. It is above the highest water level reached at high tide on an average day.
PERIMETER BARRIER	Permanent or temporary vertical structure that surrounds a particular asset to deter waters.
RESILIENCE	The capability to anticipate risk, limit impact, and bounce back rapidly through survival, adaptability, evolution, and growth in the face of ... change. (Definitions of Community Resilience: An Analysis - A CARRI REPORT)

RISK SCORE	(Consequence of Failure x Probability of Flooding) - Score to prioritize infrastructure assets/facilities. Rated through a five-tier qualitative rating system (Severe to None).
STORM SURGE	An abnormal rise of water generated by a storm, over and above the normal tide ranges.
VULNERABILITY	Structures, systems, populations or other community assets as defined by the community that are susceptible to damage and loss from hazard events. (FEMA Local Mitigation Plan Review Guide 2011)
WET FLOODPROOFING	Allows an asset to withstand flooding, and recover more quickly after the water has receded (ex. Building with flood resistant materials and anchoring equipment.

Abbreviations

ADCIRC	Advanced Circulation
AUL	Activity and Use Limitation
BH-FRM	Boston Harbor-Flood Risk Model
BMPS	Best Management Practices
CBD	Center Business District
CIP	Capital Improvement Program
CZM	Massachusetts Office of Coastal Zone Management
DCR	Department of Conservation and Recreation
DIRP	Disaster Infrastructure Resiliency Plan
DPW	Department of Public Works
ENF	Environmental Notification Form
EEA	Executive Office of Energy and Environmental Affairs
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
GIS	Geographic Information Systems
LIDAR	Light Detection and Ranging
MA CZM	Massachusetts Office of Coastal Zone Management
MASSDOT	Massachusetts Department of Transportation
MASSGIS	Massachusetts Office of Geographic Information
MASSPORT	Massachusetts Port Authority
MBTA	Massachusetts Bay Transportation Authority
MEPA	Massachusetts Environmental Policy Act
MESA	Massachusetts Endangered Species Act

MORIS	Massachusetts Ocean Resource Information System
MVP	Municipal Vulnerability Preparedness
MWRA	Massachusetts Water Resources Authority
NHESP	Natural Heritage and Endangered Species Program
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
OOC	Order of Conditions
PCN	Preconstruction Notification
PMT	Winthrop Project Management Team
PRV	Pressure Reducing Valve Station
SCADA	Supervisory Control and Data Acquisition
SLAMM	Sea Level Affecting Marshes Model
SLR	Sea Level Rise
SWAN	Simulating Waves Nearshore
USACE	U.S. Army Corps of Engineers
WHG	Woods Hole Group
WQC	Water Quality Certification

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Appendix C - Inundation Modeling

Overview

In order for the Town of Winthrop to effectively evaluate the risks of climate change, and specifically sea level rise and storm surge, to their coastal community and public assets, a scientifically accurate, dynamic, robust, and probability based analysis of potential flooding is a key element of a vulnerability assessment. This allows for the Town to identify and prioritize potential impacted areas and assets, and then determine potential adaptation options to build overall resilience for the community. Using established techniques and previously generated model data from work with Massachusetts DOT, probabilistic flood information forms the basis for the vulnerability assessment in the Town of Winthrop.

The Boston Harbor Flood Risk Model

Although there are various options for modeling sea level rise and storm surge, the most accurate approach for assessing combined storm surge risk and sea level rise conditions is through the implementation of hydrodynamic models that include the physical processes that are associated with storm climatology and propagation. The model, called the Boston Harbor Flood Risk Model (BH-FRM) is the model used to provide the results for the Town of Winthrop. Data from the Boston Harbor Flood Risk Model (BH-FRM) has been successfully applied and used in Boston, MA and the Boston Harbor Area for assessing potential vulnerabilities in the Central Artery tunnel system.

The BH-FRM was a joint collaboration between MassDOT, Woods Hole Group, and UMass Boston under a FHWA grant that aimed to assess the vulnerability of the Central Artery/Tunnel Project (CA/T) to climate change (specifically SLR and storm surge). As one of the most valuable components of Massachusetts' transportation infrastructure, its maintenance, protection and enhancement were a priority for the Commonwealth. The importance of modeling potential effects of sea level rise and storm surge for the CA/T was especially evident after Hurricane Sandy hit the New York Coastline, which had devastating impacts to vital transportation and city infrastructure.

Concern about potential impacts to the City of Boston from future storms drove the creation of the BH-FRM – a model with the best representation of the physical processes, as well as accurate and higher resolution predictions of inundation due to the combination of sea level rise and storm surge. The hydrodynamic modeling utilized for the BH-FRM was geared towards a physics-based approach to determine the water level increases and flooding, and provided results to identify specific locations that may require adaptation alternatives.

BH-FRM Components

BH-FRM is a comprehensive flood risk model that can accurately assess flooding risk under present day and future climate change conditions. The modeling system is comprised of the Advanced CIRCulation model (ADCIRC), a two-dimensional, depth-integrated, long wave, hydrodynamic model for coastal areas, inlets, rivers and floodplains that in this application is used to predict storm surge flooding; and the unstructured grid version of Simulating Waves Nearshore model (UNSWAN), a wave generation and transformation model. The ADCIRC model is tightly coupled with UNSWAN, dynamically exchanging physical processes information during each time step, to provide an complete and accurate representation of water surface elevations, winds, waves, velocities, and flooding along the coastline and upland areas.

The model explicitly and quantitatively incorporates climate change influences on sea level rise, tides, waves, storm track, and storm intensity. The model computations use a site-specific model grid that covers the coast line and open water of the Boston Harbor but also propagated overland. This grid was developed by interlacing multiple meshes with varying grid resolution (coarse, intermediate and fine) and resulted in a mesh that could capture all critical topographic and bathymetric features that influence flow dynamics within the system. The resulting mesh has a resolution of 10 meters or less (as low as 2-3 meters in the CA/T study area), and was developed using topographic and bathymetric data from the Boston Harbor area. A variety of boundary conditions were set before modeling could begin and included (but were not limited to) tidal constituents, freshwater input, bottom friction, direction wind reduction, and even the understanding dam operations in the area influence flood control.

Model Calibration and Validation

While the models used in the BH-FRM pilot project are rooted in sound science and utilized standard governing equations of water motion, the propagation of water through a unique geographic setting results in site-specific variations that may require adjustment of model parameters to more accurately represent the real-world system. For example, in an urban landscape, an area consisting of numerous buildings will influence flow differently than a marsh, which will influence flow differently than a parking area, which will influence flow differently than a sub-tidal estuary. For these types of cases, it is reasonable to adjust parameters, such as frictional factors within accepted bounds to better represent the water propagation. As such, the BH-FRM model was calibrated using both normal tidal conditions and representative storm events for the northeast (Blizzard of 1978). The calibrated model was then validated to another storm event (Perfect Storm) to ensure accuracy.

Sea Level Rise and Storm Climatology

Sea level rise modeling scenarios in BH-FRM include 2030 and 2070 time horizons. The SLR scenarios bracket ranges that span multiple time horizons consistent with scenarios from the United States National Climate Assessment (Parris et al, 2012). The final SLR values were adjusted for local subsidence following Kirshen et al. (2008). Local subsidence is approximately 1.1 mm/year or approximately 0.4 feet per 100 years. The SLR projections used for 2030 and 2070 in the BH-FRM were 0.62 feet (19 cm) and 3.2 feet (30 cm) respectively.

The BH-FRM also models a statistically-robust sample of storms, including tropical (hurricanes) and extra-tropical (nor'easters) and is based on the region's existing and evolving climatology. Tropical storms were specifically selected based on a screening process that evaluated storm tracks capable of entering the northeast area, thereby potentially impacting the Boston Harbor region. However, tropical storms are less common in the Northeast, therefore, it was critical to develop a series of extra tropical storms for simulation in BH-FRM. Existing and historical meteorological and water level data was used to pair storm surge events with individual storms to identify specific extra-tropical storms that were or could be typical for the Boston Harbor area.

The probabilistic modeling approach simulates a statistically robust set of storms (both tropical and extra-tropical) for each climate change and/or Sea Level Rise (SLR) scenario through a Monte Carlo statistical approach. Results of the Monte Carlo simulations are used to generate Cumulative Probability Distribution Functions (CDFs) of the storm surge water levels at a high degree of spatial precision. In particular, an accurate and precise assessment of the exceedence probability of combined SLR and storm surge, provided at high spatial resolution help decision makers identify areas of existing vulnerability requiring immediate action, as well as, areas that benefit from present planning for future preparedness. Results of the Monte Carlo approach also produce a statistically robust, spatially variable map of risk for each given SLR scenario that can be used to determine the potential need for adaptation, and the timing for potential adaptation, at each facility and for each infrastructure asset.

For more information regarding the specific inputs and computational capabilities of the BH-FRM, refer to the MassDOT-FHWA Pilot Project Report.

BH-FRM Outputs

Flood exceedance probability is defined as the probability of flood water encroaching on the land surface at a particular location for a given climate time frame. Maps show flood exceedance probabilities across Winthrop for near future climatic conditions (represented by the 2030 scenario) and late 21st century conditions (represented by the 2070 scenario). Exceedance probabilities shown on these maps range from 0.1% (0.001, otherwise known as the 1000-year flood level) to 100% (the annual storm water surface elevation level). These maps can be used to identify locations, structures, assets, etc. that lie within different risk levels within the area. For example, a building that lies within the 2% flooding exceedance probability zone would have a 2% chance of flooding in that year (under the assumed climatology). In other words, in each year there is a 2% percent chance that this location will get wet. Stakeholders can then determine if that level of risk is acceptable, or if some action may be required to improve resiliency, engineer an adaption, consider relocation, or implement an operational plan.

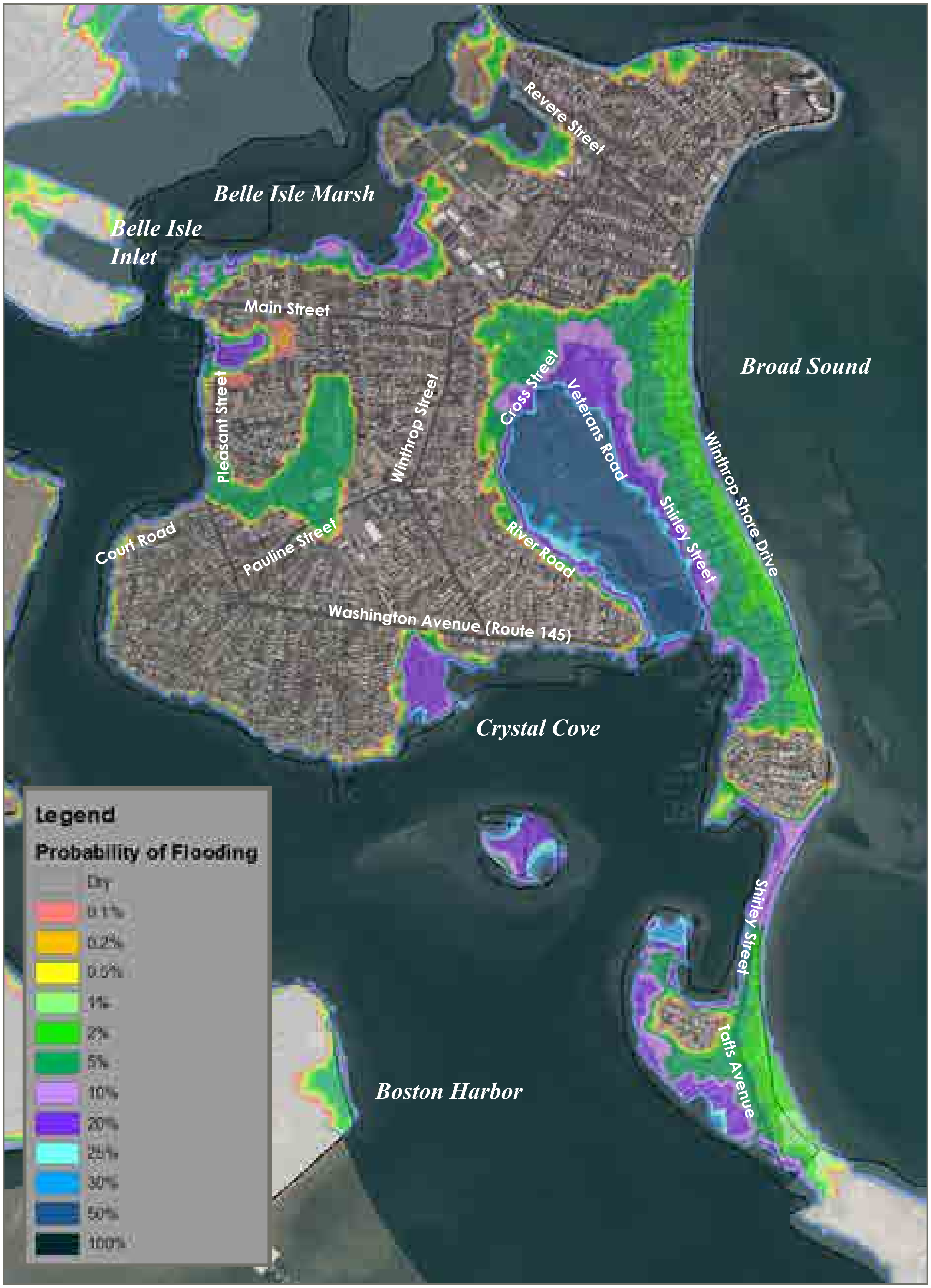
By comparing the 2030 flood probability map to the 2070 flood probability map, individual structures, assets, and areas can be assessed to determine how flooding is changing as a function of time and the overall influence of climate change projections can also be evaluated. These maps can also be used to assess flood entry points and pathways and thereby identify potential regional adaptations.

The probability of flooding maps provide stakeholders the ability to determine if areas, buildings, etc. are expected to be flooded and at what probability flooding is expected to be initiated. This is important for weighing the tolerance for risk and evaluating when adaptation options may need to be considered. Perhaps equally as important is the magnitude, or depth, of flooding expected. Therefore, depth of flooding map can be created for any given flooding probability level. For the Town of Winthrop, 1% (100-yr) and 0.1% (1000-yr) depth maps have been created showing flood depths (at 0.5 ft increments). As such, the depth of flooding can also be evaluated when assessing the risk to a system.

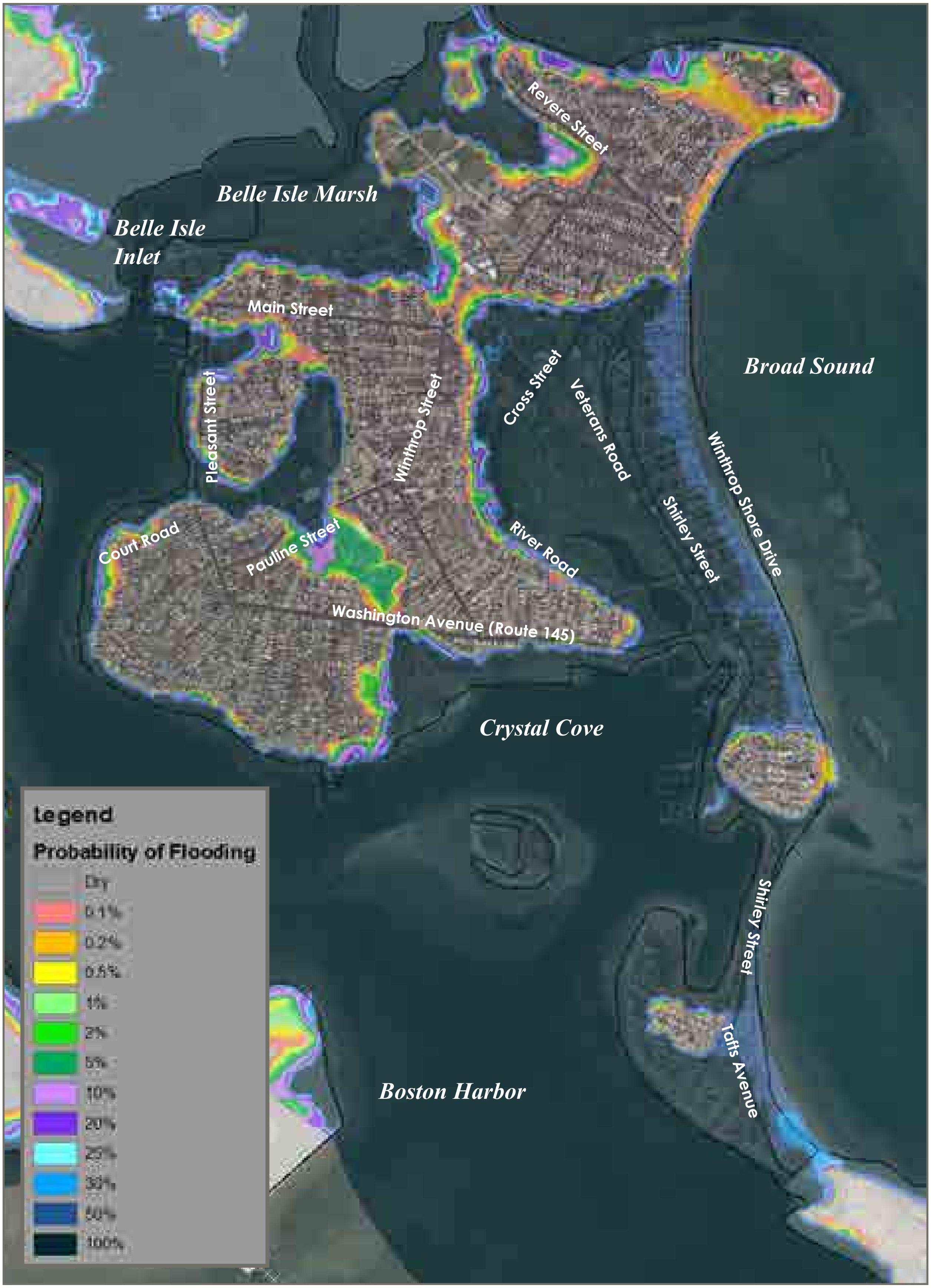
Appendix D - Boston Harbor Flood Risk Model (BH-FRM) Mapping

Areas of Probable Flooding (2013)

Areas of Probable Flooding (2030)



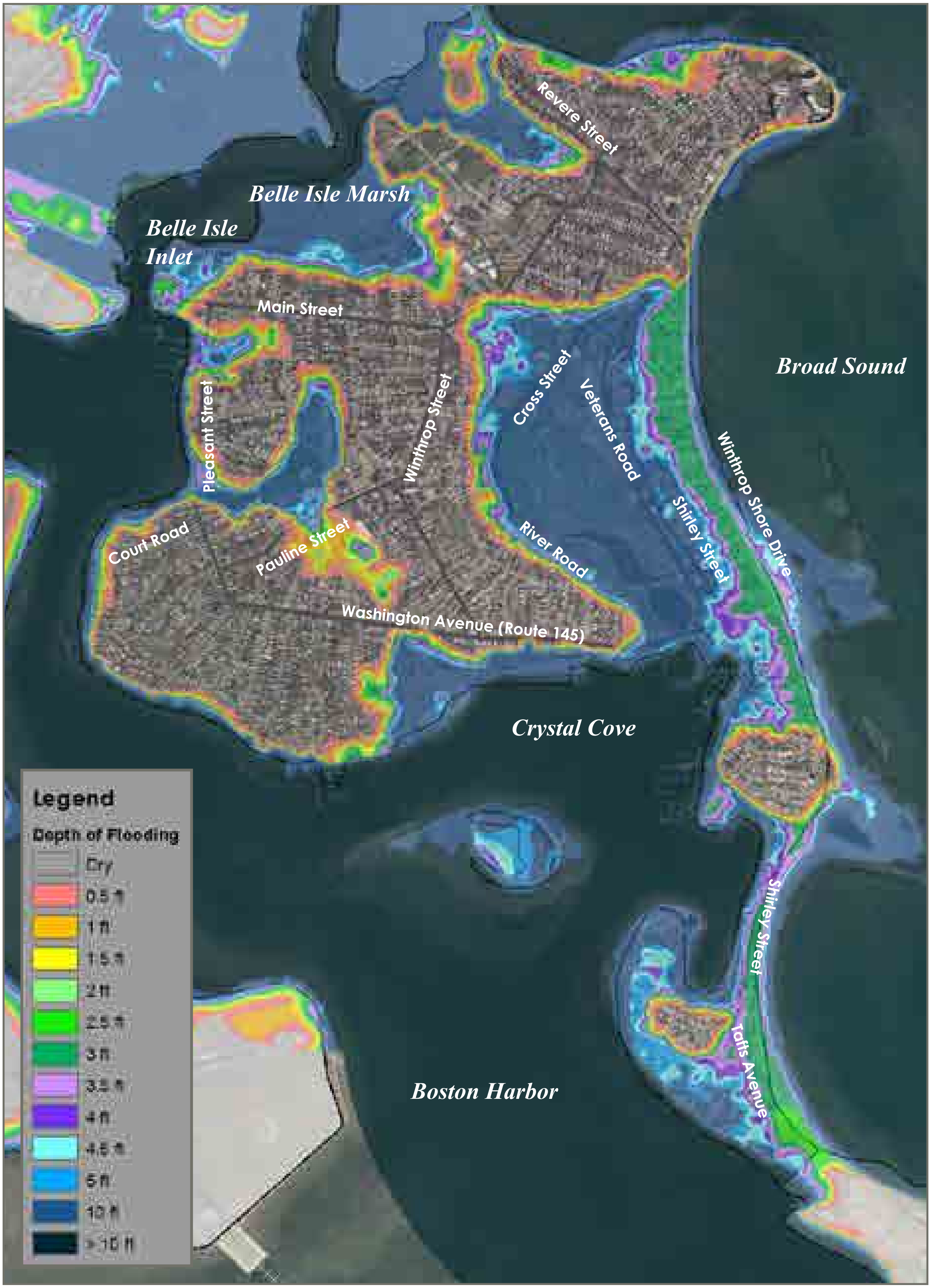
Areas of Probable Flooding (2070)



Depth of Flooding - 1% Chance Water Level (2013)

Depth of Flooding - 1% Chance Water Level (2030)

Depth of Flooding - 1% Chance Water Level (2070)



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Appendix E - Probability of Exceedance Curve Data

BEACH FIRE STATION						
APPROX. CRITICAL ELEVATION (FT)	7.12					
	2013		2030		2070	
EXCEEDANCE PROBABILITY	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)
0.1	wet	<0.5	wet	1.0-1.5	wet	4.0-4.5
0.2	wet	< 0.5	wet	1.0-1.5	wet	3.5-4.0
0.5	wet	< 0.5	wet	1.0-1.5	wet	3.5-4.0
1	wet	< 0.5	wet	0.5-1.0	wet	3.0-3.5
2	dry	dry	wet	0.5-1.0	wet	3.0-3.5
5	dry	dry	wet	< 0.5	wet	2.5-3.0
10	dry	dry	dry	dry	wet	2.0-2.5
20	dry	dry	dry	dry	wet	1.5-2.0
25	dry	dry	dry	dry	wet	1.5-2.0
30	dry	dry	dry	dry	wet	1.5-2.0
50	dry	dry	dry	dry	wet	1.0-1.5
100	dry	dry	dry	dry	wet	0.5-1.0

* All elevation in NAVD-88

BELLE ISLE BRIDGE						
APPROX. CRITICAL ELEVATION (FT)	12.26					
	2013		2030		2070	
EXCEEDANCE PROBABILITY	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)
0.1	dry	dry	10.80	-1.46	14.1	1.84
0.2	dry	dry	10.50	-1.76	14.0	1.74
0.5	dry	dry	10.20	-2.06	13.5	1.24
1	dry	dry	10.10	-2.16	12.8	0.54
2	dry	dry	dry	dry	12.5	0.24
5	dry	dry	dry	dry	12.2	-0.06
10	dry	dry	dry	dry	11.6	-0.66
25	dry	dry	dry	dry	10.8	-1.46
30	dry	dry	dry	dry	10.7	-1.56
50	dry	dry	dry	dry	10.4	-1.86
100	dry	dry	dry	dry	dry	dry

LORING RD BOAT RAMP						
APPROX. CRITICAL ELEVATION (FT)	12.56					
	2013		2030		2070	
EXCEEDANCE PROBABILITY	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)
0.1	9.70	-2.86	10.5	-2.06	14.1	1.54
0.2	9.60	-2.96	10.20	-2.36	14.0	1.44
0.5	9.00	-3.56	10.10	-2.46	13.5	0.94
1	8.30	-4.26	9.90	-2.66	12.8	0.24
2	8.10	-4.46	9.70	-2.86	12.5	-0.06
5	7.80	-4.76	9.20	-3.36	12.2	-0.36
10	7.20	-5.36	8.90	-3.66	11.6	-0.96
20	7.10	-5.46	8.30	-4.26	11.0	-1.56
25	7.00	-5.56	8.20	-4.36	10.8	-1.76
30	6.90	-5.66	8.10	-4.46	10.7	-1.86
50	6.70	-5.86	7.90	-4.66	10.4	-2.16
100	6.28	-6.28	7.28	-5.28	9.8	-2.76

* All elevation in NAVD-88

MAIN STREET						
APPROX. CRITICAL ELEVATION (FT)	9.00					
	2013		2030		2070	
EXCEEDANCE PROBABILITY	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)
0.1	9.8	0.8	10.8	1.8	14.1	5.1
0.2	9.7	0.7	10.5	1.5	14.0	5.0
0.5	9.1	0.1	10.2	1.2	13.5	4.5
1	8.8	-0.2	10.1	1.1	12.8	3.8
2	8.30	-0.7	9.9	0.9	12.5	3.5
5	dry	dry	9.10	0.1	12.2	3.2
10	dry	dry	8.80	-0.2	11.6	2.6
20	dry	dry	8.50	-0.5	11.0	2.0
25	dry	dry	8.10	-0.9	10.8	1.8
30	dry	dry	dry	dry	10.7	1.7
50	dry	dry	dry	dry	10.4	1.4
100	dry	dry	dry	dry	9.80	0.8

PICO SEWER PUMP STATION						
APPROX. CRITICAL ELEVATION (FT)	8.50					
	2013		2030		2070	
EXCEEDANCE PROBABILITY	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)
0.1	9.8	1.30	10.80	2.30	14.1	5.60
0.2	9.7	1.20	10.50	2.00	14.0	5.50
0.5	9.1	0.60	10.20	1.70	13.5	5.00
1	8.8	0.30	10.00	1.50	12.8	4.30
2	8.6	0.10	9.90	1.40	12.5	4.00
5	8.5	0.00	9.10	0.60	12.2	3.70
10	dry	dry	8.90	0.40	11.6	3.10
20	dry	dry	8.60	0.10	11.0	2.50
25	dry	dry	8.50	0.00	10.8	2.30
30	dry	dry	dry	dry	10.7	2.20
50	dry	dry	dry	dry	10.4	1.90
100	dry	dry	dry	dry	9.8	1.30

* All elevation in NAVD-88

PLEASANT COURT SEWER PUMP STATION						
APPROX. CRITICAL ELEVATION (FT)	8.08					
	2013		2030		2070	
EXCEEDANCE PROBABILITY	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)
0.1	9.8	1.72	10.8	2.72	14.1	6.02
0.2	9.7	1.62	10.5	2.42	14.0	5.92
0.5	9.1	1.02	10.2	2.12	13.5	5.42
1	8.8	0.72	10.1	2.02	12.8	4.72
2	8.30	0.22	9.9	1.82	12.5	4.42
5	dry	dry	9.10	1.02	12.2	4.12
10	dry	dry	8.80	0.72	11.6	3.52
20	dry	dry	8.50	0.42	11.0	2.92
25	dry	dry	8.10	0.02	10.8	2.72
30	dry	dry	dry	dry	10.7	2.62
50	dry	dry	dry	dry	10.4	2.32
100	dry	dry	dry	dry	9.80	1.72

PLEASANT STREET						
APPROX. CRITICAL ELEVATION (FT)	9.19					
	2013		2030		2070	
EXCEEDANCE PROBABILITY	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)
0.1	9.70	0.51	10.5	1.31	14.1	4.91
0.2	9.60	0.41	10.20	1.01	14.0	4.81
0.5	dry	dry	10.10	0.91	13.5	4.31
1	dry	dry	9.90	0.71	12.8	3.61
2	dry	dry	9.70	0.51	12.5	3.31
5	dry	dry	9.20	0.01	12.2	3.01
10	dry	dry	dry	dry	11.6	2.41
20	dry	dry	dry	dry	11.0	1.81
25	dry	dry	dry	dry	10.8	1.61
30	dry	dry	dry	dry	10.7	1.51
50	dry	dry	dry	dry	10.4	1.21
100	dry	dry	dry	dry	9.8	0.61

* All elevation in NAVD-88

POWER SUBSTATION - ARGYLE ST.						
APPROX. CRITICAL ELEVATION (FT)	11.78					
	2013		2030		2070	
EXCEEDANCE PROBABILITY	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)
0.1	dry	dry	dry	dry	14.0	2.22
0.2	dry	dry	dry	dry	13.9	2.12
0.5	dry	dry	dry	dry	12.8	1.02
1	dry	dry	dry	dry	12.5	0.72
2	dry	dry	dry	dry	12.2	0.42
5	dry	dry	dry	dry	dry	dry
10	dry	dry	dry	dry	dry	dry
20	dry	dry	dry	dry	dry	dry
25	dry	dry	dry	dry	dry	dry
30	dry	dry	dry	dry	dry	dry
50	dry	dry	dry	dry	dry	dry
100	dry	dry	dry	dry	dry	dry

PRESSURE REDUCING VALVE STATION - BAYVIEW						
APPROX. CRITICAL ELEVATION (FT)	9.45					
	2013		2030		2070	
EXCEEDANCE PROBABILITY	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)
0.1	wet	<0.5	wet	1.5-2.0	wet	4.5-5.0
0.2	wet	< 0.5	wet	1.5-2.0	wet	4.5-5.0
0.5	wet	< 0.5	wet	1.5-2.0	wet	4.0-4.5
1	wet	< 0.5	wet	1.0-1.5	wet	3.5-4.0
2	dry	dry	wet	0.5-1.0	wet	3.5-4.0
5	dry	dry	wet	< 0.5	wet	3.0-3.5
10	dry	dry	dry	dry	wet	2.5-3.0
20	dry	dry	dry	dry	wet	2.0-2.5
25	dry	dry	dry	dry	wet	2.0-2.5
30	dry	dry	dry	dry	wet	1.5-2.0
50	dry	dry	dry	dry	wet	1.0-1.5
100	dry	dry	dry	dry	wet	0.5-1.0

* All elevation in NAVD-88

PRESSURE REDUCING VALVE STATION - REVERE ST.						
APPROX. CRITICAL ELEVATION (FT)	**10.30**					
	2013		**2030**		**2070**	
EXCEEDANCE PROBABILITY	**WATER SURFACE ELEVATION (FT)**	**WATER DEPTH (FT)**	**WATER SURFACE ELEVATION (FT)**	**WATER DEPTH (FT)**	**WATER SURFACE ELEVATION (FT)**	**WATER DEPTH (FT)**
0.1	dry	dry	10.80	0.50	14.0	3.70
0.2	dry	dry	10.50	0.20	13.9	3.60
0.5	dry	dry	dry	dry	13.5	3.20
1	dry	dry	dry	dry	12.8	2.50
2	dry	dry	dry	dry	12.5	2.20
5	dry	dry	dry	dry	12.2	1.90
10	dry	dry	dry	dry	11.6	1.30
20	dry	dry	dry	dry	11.0	0.70
25	dry	dry	dry	dry	10.8	0.50
30	dry	dry	dry	dry	10.7	0.40
50	dry	dry	dry	dry	dry	dry
100	dry	dry	dry	dry	dry	dry

PRESSURE REDUCING VALVE STATION - UNDERHILL						
APPROX. CRITICAL ELEVATION (FT)V	**9.45**					
	2013		**2030**		**2070**	
EXCEEDANCE PROBABILITY	**WATER SURFACE ELEVATION (FT)**	**WATER DEPTH (FT)**	**WATER SURFACE ELEVATION (FT)**	**WATER DEPTH (FT)**	**WATER SURFACE ELEVATION (FT)**	**WATER DEPTH (FT)**
0.1	9.80	0.35	10.8	1.35	14.1	4.65
0.2	9.70	0.25	10.5	1.05	14.0	4.55
0.5	9.40	-0.05	10.1	0.65	13.5	4.05
1	dry	dry	10.0	0.55	12.8	3.35
2	dry	dry	9.9	0.45	12.5	3.05
5	dry	dry	dry	dry	12.2	2.75
10	dry	dry	dry	dry	11.6	2.15
20	dry	dry	dry	dry	11.0	1.55
25	dry	dry	dry	dry	10.8	1.35
30	dry	dry	dry	dry	10.7	1.25
50	dry	dry	dry	dry	10.4	0.95
100	dry	dry	dry	dry	9.8	0.35

*All elevation in NAVD-88

PUBLIC LANDING						
APPROX. CRITICAL ELEVATION (FT)	10.56					
	2013		2030		2070	
EXCEEDANCE PROBABILITY	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)
0.1	dry	dry	10.8	0.24	14.1	3.54
0.2	dry	dry	10.5	-0.06	14.0	3.44
0.5	dry	dry	10.2	-0.36	13.5	2.94
1	dry	dry	dry	dry	12.8	2.24
2	dry	dry	dry	dry	12.5	1.94
5	dry	dry	dry	dry	12.2	1.64
10	dry	dry	dry	dry	11.6	1.04
20	dry	dry	dry	dry	11.0	0.44
25	dry	dry	dry	dry	10.8	0.24
30	dry	dry	dry	dry	10.7	0.14
50	dry	dry	dry	dry	10.4	-0.16
100	dry	dry	dry	dry	dry	dry

REVERE ST SEWER PUMP STATION						
APPROX. CRITICAL ELEVATION (FT)	10.56					
	2013		2030		2070	
EXCEEDANCE PROBABILITY	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)
0.1	dry	dry	10.80	0.24	14.0	3.44
0.2	dry	dry	dry	dry	13.9	3.34
0.5	dry	dry	dry	dry	13.5	2.94
1	dry	dry	dry	dry	12.8	2.24
2	dry	dry	dry	dry	12.5	1.94
5	dry	dry	dry	dry	12.2	1.64
10	dry	dry	dry	dry	11.5	0.94
20	dry	dry	dry	dry	11.0	0.44
25	dry	dry	dry	dry	dry	dry
30	dry	dry	dry	dry	dry	dry
50	dry	dry	dry	dry	dry	dry
100	dry	dry	dry	dry	dry	dry

* All elevation in NAVD-88

SHIRLEY STREET						
APPROX. CRITICAL ELEVATION (FT)	7.80					
	2013		2030		2070	
EXCEEDANCE PROBABILITY	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)
0.1	9.8	2	10.8	3	14.1	6.3
0.2	9.7	1.9	10.5	2.7	14	6.2
0.5	9.1	1.3	10	2.2	13.5	5.7
1	dry	dry	9.9	2.1	12.8	5
2	dry	dry	9	1.2	12.5	4.7
5	dry	dry	8.9	1.1	12.2	4.4
10	dry	dry	8	0.2	11.6	3.8
20	dry	dry	dry	dry	11	3.2
25	dry	dry	dry	dry	10.8	3
30	dry	dry	dry	dry	10.7	2.9
50	dry	dry	dry	dry	10.4	2.6
100	dry	dry	dry	dry	9.8	2

WASHINGTON STREET						
APPROX. CRITICAL ELEVATION (FT)	8.46					
	2013		2030		2070	
EXCEEDANCE PROBABILITY	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)	WATER SURFACE ELEVATION (FT)	WATER DEPTH (FT)
0.1	9.8	1.34	10.8	2.34	14.1	5.64
0.2	9.7	1.24	10.5	2.04	14.0	5.54
0.5	9.1	0.64	10.2	1.74	13.5	5.04
1	8.70	0.24	10.0	1.54	12.8	4.34
2	8.60	0.14	9.90	1.44	12.5	4.04
5	dry	dry	9.10	0.64	12.2	3.74
10	dry	dry	8.70	0.24	11.6	3.14
20	dry	dry	8.50	0.04	11.0	2.54
25	dry	dry	dry	dry	10.8	2.34
30	dry	dry	dry	dry	10.7	2.24
50	dry	dry	dry	dry	10.4	1.94
100	dry	dry	dry	dry	9.80	1.34

* All elevation in NAVD-88

WINTHROP HIGH SCHOOL						
APPROX. CRITICAL ELEVATION (FT)	**7.25**					
	2013		**2030**		**2070**	
EXCEEDANCE PROBABILITY	**WATER SURFACE ELEVATION (FT)**	**WATER DEPTH (FT)**	**WATER SURFACE ELEVATION (FT)**	**WATER DEPTH (FT)**	**WATER SURFACE ELEVATION (FT)**	**WATER DEPTH (FT)**
0.1	9.80	2.55	10.8	3.55	14.1	6.85
0.2	9.70	2.45	10.5	3.25	14.0	6.75
0.5	9.40	2.15	10.2	2.95	13.5	6.25
1	8.60	1.35	10.0	2.75	12.8	5.55
2	dry	dry	9.9	2.65	12.5	5.25
5	dry	dry	8.9	1.65	12.2	4.95
10	dry	dry	dry	dry	11.6	4.35
20	dry	dry	dry	dry	11.0	3.75
25	dry	dry	dry	dry	10.8	3.55
30	dry	dry	dry	dry	10.7	3.45
50	dry	dry	dry	dry	10.4	3.15
100	dry	dry	dry	dry	9.8	2.55

* All elevation in NAVD-88

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Appendix F - Winthrop Natural Resource Evolution Summary

Winthrop Natural Resource Evolution Summary

These results are part of the Statewide Modeling the Effects of Sea Level Rise on Coastal Wetlands for Massachusetts Coastal Zone Management. (Woods Hole Group, 2016).

Background

Climate change, with increased storm intensity, changes in precipitation patterns, and global sea-level rise will exacerbate already difficult coastal management issues related to both infrastructure and natural resources (Bosma et al., 2015). Recent studies have identified sea-level rise as one of the most certain and potentially destructive impacts of climate change (Meehl et al., 2007). Coastal wetlands are among the most susceptible ecosystems to climate change, especially accelerated sea-level rise. Nicholls et al. (2009) points out that coastal wetlands, including salt marshes and intertidal areas, could experience substantial area losses due to sea-level rise. Because coastal wetlands are extremely productive ecosystems, and provide a variety of ecosystem services, such as flood protection, waste assimilation, nursery areas for fisheries, and conservation and recreation benefits, such loss would have a high human cost.

Recognizing the threats posed by climate change and sea-level rise, the Massachusetts Office of Coastal Zone Management (CZM) desired to assess and analyze the effects of sea-level rise on coastal wetlands for the Commonwealth of Massachusetts (Woods Hole Group, 2016). The project's intent was to simulate the effects of sea-level rise using an ecological model and implement the model at its highest level of complexity.

The model selected to evaluate the impact of sea level rise on coastal resources was the Sea Level Affecting Marshes Model (SLAMM), originally developed with EPA funding in the 1980s. The SLAMM model attempts to capture the major coastal processes, at least at a rudimentary level, involved in wetland conversions and shoreline modifications expected to occur over a long term.

The results of the marsh migration modeling are intended to be used for future coastal planning in a number of ways. For instance, model results from this project can be used to identify areas with barriers to landward migration of salt marshes. These results can therefore serve as a guide for development and implementation of adaptation strategies for coastal managers and policymakers to proactively address potential impacts from long-term sea-level rise. The results produced for the Town of Winthrop have been extracted from the larger CZM Commonwealth of Massachusetts project for this particular study.

Input Data

High resolution elevation data may be the most important Sea Level Affecting Marsh Migration (SLAMM) model data requirement, since the elevation data demarcate not only where salt penetration is expected, but also the frequency of inundation for wetlands and marshes when combined with tidal range data. Input elevation data also helps define the lower elevation range for beaches, wetlands and tidal flats, which dictates when they should be converted to a different land-cover type or open water due to an increased frequency of inundation.

For this project, LiDAR was acquired from MassGIS. The majority of the state was covered with the 2011 USGS LiDAR for the Northeast project, and this covers the Winthrop area. In order to reduce processing time within the SLAMM model, areas of higher elevation within each regional panel that are unlikely to be affected by coastal processes, such as sea level rise, were excluded prior to processing; all areas above an elevation of 60 feet (NAVD88) were clipped from the input files.

Wetland Classification Information

The 2011 wetland layer developed by the National Wetlands Inventory (NWI) is used as the baseline source for the wetlands input file for marsh migration modeling.

Utilizing the NWI data had two key benefits over the 1990s MassDEP wetland layer. First, the NWI data not only provided a more recent dataset, but also more closely temporally matches that of the LiDAR datasets.

The second benefit to utilizing the NWI data is that it streamlined the conversion between source wetland categories and Sea Level Affecting Marsh Migration (SLAMM) model wetland codes. The documentation provided with the SLAMM software contains a key to convert each NWI classification to the wetland classification system used by SLAMM. A summary of this conversion key is present in Table 1.

Sea Level Rise Projections

The Sea Level Rise (SLR) projections are consistent with those used in the BH-FRM modeling to produce the inundation risk maps. As such, there SLR used in the marsh migration modeling is consistent with the values used it the flood risk modeling for the Town of Winthrop.

Additional data input

Additional model input includes, but is not limited to, accretion rates (marsh, beach, etc.), erosion rates, tidal range and attenuation, freshwater parameters, dikes and dams, and impervious surfaces. For complete details, see the Statewide Modeling: the Effects of Sea Level Rise on Coastal Wetlands for Massachusetts Coastal Zone Management. (Woods Hole Group, 2016).

Table F-1 NWI Category to SLAMM code conversion table.

		NWI Code Characters					
SLAMM Code	**SLAMM Name**	**System**	**Subsystem**	**Class**	**Subclass**	**Water Regime**	**Notes**
1	Developed Dryland	U					Upland
2	Undeveloped Dryland	U					Upland
3	Nontidal Swamp	P	NA	FO, SS	1, 3 to 7, None	A,B,C,E,F,G,H,J,K, None or U	Palustrine Forested and Scrub-Shrub
4	Cypress Swamp	P	NA	FO, SS	2	A,B,C,E,F,G,H,J,K, None or U	Needle-leaved Deciduous Forest and Scrub-Shrub
5	Inland Fresh Marsh	P	NA	EM, f**	All, None	A,B,C,E,F,G,H,J,K, None or U	Palustrine Emergents; Lacustrine and Riverine Nonpersistent Emergents
		L	2	EM	2, None	E,F,G,H,K, None or U	
		R	2, 3	EM	2, None	E,F,G,H,K, None or U	
6	Tidal Fresh Marsh	R	1	EM	2, None	Fresh Tidal N, T	Riverine and Palustrine Freshwater Tidal Emergen
		P	NA	EM	All, None	Fresh Tidal S, R, T	
7	Transitional Marsh / Scrub Shrub	E	2	FO, SS	1, 2, 4 to 7, None	Tidal M, N, P, None or U	Estuarine Intertidal, Scrub-shrub and Forested (ALL except 3 subclass)
8	Regularly Flooded Marsh	E	2	EM	1, None	Tidal N, None or U	Only regularly flooded tidal marsh; No intermittently flooded "P" water regime
9	Mangrove	E	2	FO, SS	3	Tidal M, N, P, None or U	Estuarine Intertidal Forested and Scrub-shrub, Broad-leaved Evergreen
10	Estuarine Beach	E	2	US	1,2	Tidal N,P	Estuarine Intertidal Unconsolidated Shores
		E	2	US	None	Tidal N,P	Only when shores
11	Tidal Flat	E	2	US	3,4, None	Tidal M, N, None or U	Estuarine Intertidal Unconsolidated Shore (mud or organic) and Aquatic Bed; Marine Intertidal Aquatic Bed
		E	2	AB	All, Except 1	Tidal M, N, None or U	
		E	2	AB	1	P	Specifically for wind-driven tides on the south coast of TX
		M	2	AB	1, 3, None	Tidal M, N, None or U	
12	Ocean Beach	M	2	US	1, 2	Tidal N, P	Marine Intertidal Unconsolidated Shore, cobble-gravel, sand
		M	2	US	None	Tidal P	
13	Ocean Flat	M	2	US	3, 4, None	Tidal M, N, None or U	Marine Intertidal Unconsolidated Shore, mud or organic, (low energy coastline)
14	Rocky Intertidal	M	2	RS	All, None	Tidal M, N, P, None or U	Marine and Estuarine Intertidal Rocky Shore and Reef
		E	2	RS	All, None	Tidal M, N, P, None or U	
		E	2	RF	2, 3, None	Tidal M, N, P, None or U	
		E	2	AB	1	Tidal M, N, None or U	
15	Inland Open Water	R	2	UB, AB	All, None	All, None	Riverine, Lacustrine, and Palustrine Unconsolidated Bottom, and Aquatic Beds
		R	3	UB, AB, RB	All, None	All, None	
		L	1, 2	UB, AB, RB	All, None	All, None	
		P	NA	UB, AB, RB	All, None	All, None	
		R	5	UB	All	Only U	
16	Riverine Tidal Open Water	R	1	All, Except EM	All, None, Except 2	Fresh Tidal S, R, T, V	Riverine Tidal Open Water
17	Estuarine Open Water	E	1	All	All, None	Tidal L, M, N, P	Estuarine subtidal
18	Tidal Creek	E	2	SB	All, None	Tidal M, N, P; Fresh Tidal R, S	Estuarine intertidal streambed
19	Open Ocean	M	1	All	All	Tidal L, M, N, P	Marine Subtidal and Marine Intertidal Aquatic Bed and Reef
		M	2	RF	1, 3, None	Tidal M, N, P, None or U	
20	Irregularly Flooded Marsh	E	2	EM	1, 5, None	P	Irregularly Flooded Estuarine Intertidal Emergent marsh
		E	2	US	2, 3, 4, None	P	Only when these salt pans are associated with E2EMN or P
21	NotUsed						
22	Inland Shore	L	2	US, RS	All	All Nontidal	Shoreline not pre-processed using tidal range elevations
		P	NA	US	All, None	All Nontidal, None or U	
		R	2, 3	US, RS	All, None	All Nontidal, None or U	
		R	4	SB	All, None	All Nontidal, None or U	
23	Tidal Swamp	P	NA	FO, SS	All, None	Fresh Tidal R, S, T	Tidally influenced swamp

As part of the model setup, Massachusetts Coastal Zone Management made the decision to not incorporate impervious surface data directly into the SLAMM runs. Allowing the SLAMM model to utilize the impervious layer would “protect” developed upland areas (i.e. impervious areas would not be allowed to convert to other land cover types); however, this approach would have prohibited marshes and wetlands from expanding into currently “developed” areas. While in reality this may likely happen (marsh migration would halt at the impervious boundary), this approach to the modeling does not inform stakeholders where the marsh may desire to migrate given the elevation landscape if the impervious features were absent. Since one of the project goals was to determine how and where the marsh may want to migrate in response to sea-level rise, it was desired to determine what system were susceptible to ecological losses due to inability to adjust to the changing climate both independent of the impervious landscape and with it in place. As such, the SLAMM model simulations were run without the impervious layers (to show where natural resources would like to migrate in absence of anthropogenic influences) and subsequently the impervious layer was also overlain on the results to indicate where areas may likely not be subject to natural resource migration due to the built environment. In Winthrop, which is predominantly developed, the impervious overlay illustrates the limited areas that are available for natural resource migration.

Figures 1 through 3 show the wetland classification areas for 2011, 2030, and 2070 timeframes, respectively, for the Town of Winthrop. Figures present maps with no impervious overlay (left hand panel in each figure) and with impervious overlay (right hand panel in each figure). Figure 1 presents the current conditions, as defined by the NWI. Subsequently, Figure 2 shows the change in wetland classification locations projected to 2030, impacted by SLR. Similarly, Figure 3 shows the change in wetland classification locations projected to 2070, impacted by SLR. These results use similar SLR rates as utilized for the inundation mapping in the BH-FRM results.

Community wide

The SLAMM results project some minor wetland expansion and loss of upland area in 2030. This expansion will occur at the fringes of existing wetlands in areas that are already designated as open space, and should not interfere with existing development to any degree much different than current conditions (Figures 1 and 2). By 2070, SLR is projected to induce large scale shifts across Winthrop, including transitions from irregularly flooded marsh to regularly flooded marsh, expansion of wetlands into transitional marsh scrub-shrub habitat, expansion of beach and tidal flat areas, conversion of inland open water to estuarine open water, and expansion of open ocean water areas (Figure 3, left panel). Some areas of potential wetlands migration will be limited by (and will interfere with) existing development (Figure 3, right panel). These areas include:

- Commercial/industrial areas in the vicinity of Argyle Street
- Residential areas south of Banks Street and Morton Street
- Residential/commercial areas adjacent to the Saratoga Street bridge
- Residential areas around Pico Avenue
- Residential/industrial areas around Seaview Avenue
- Residential/commercial/municipal areas surrounding Lewis Lake Park and the Winthrop Golf Course
- Residential/commercial areas along Shirley Street (from Sturgis Street to Crystal Cove Avenue
- Residential areas southeast of Coughlin Park

Due to the high density of development and impervious surface in these areas of Winthrop is it unlikely that they will be allowed to transition to wetland. These developed areas will likely experience higher water tables, increased salt water intrusion, day to day nuisance flooding (due to a higher daily tides), and higher frequency of storm flooding. Therefore, these areas will likely need additional protection in the future or retreat options under normal tidal conditions (accounting for SLR).

A large portion of the projected wetlands transitions and expansions are predicted to occur in the existing open areas of Winthrop, including:

- Wetlands adjacent to the Belle Isle Cemetery
- Lewis Lake Park and the Winthrop Golf Course
- Wetlands adjacent to Pico Beach
- Coughlin Park

These areas will likely experience significant changes in land cover and wetland type and may offer opportunities for natural resource management and/or expansion due to the changing climate.

Wetlands adjacent to the Belle Isle Cemetery

- In the relative near term (between 2011 and 2030), there are minimal changes to the wetlands adjacent to Belle Island Cemetery, which primarily consists of open water, irregularly flooded marsh, and tidal flat resources. At the inland fringes of these marshes, there are some minor changes by 2030 as salt laden water is able to further penetrate upstream in the system. Inland portions of the irregularly flooded marsh areas begin to convert to transitional scrub shrub areas. By 2070, a majority of the wetland system has transitioned to regularly flooded marsh, and expanded transitional scrub shrub areas into available upland areas.
- No immediate adaptations are required for this area in terms of natural resources as the marshes can be allowed to advance naturally for normal tidal conditions; however, in the long-term, and during storm events, more frequent overbank flooding can be expected to surrounding properties and the fringe marsh areas may be expected to expand. Smaller proactive restoration measures could be considered along the shorelines to protect infrastructure and provide natural resource expansion and protection. Potential options could consider living shoreline applications and targeted thin layer deposition projects that would involve the placement of clean, compatible sediment in thin layers on the existing salt marsh to assist the elevations in keeping up with the rising tidal increases.
- Lewis Lake Park and the Winthrop Golf Course
- In the relative near term (between 2011 and 2030), there are minimal changes to the wetlands at Lewis Lake Park and the Winthrop Golf Course, which primarily consists of inland open water, regularly flooded marsh, and tidal fresh marsh resources. At the inland fringes of these marshes, there are some minor changes by 2030 as salt laden water is able to further penetrate upstream in the system. Very small inland portions of the regularly flooded marsh areas begin to convert to tidal fresh marsh. By 2070, a majority of the park and golf course has transitioned to open estuarine water and regularly flooded marsh, and expanded regularly flooded marsh, tidal flat and transitional scrub shrub areas into available upland areas.

- No immediate adaptations are required for this area in terms of natural resources as the marshes can be allowed to advance naturally for normal tidal conditions; however, in the long-term, and during storm events, more frequent and expanded flooding can be expected throughout the open space area with additional inundation to adjacent developed areas due to storm surge. Long term choices regarding the future use of this open space will need to be considered. There is potential to restore the whole complex to its natural wetland state by reconnecting Lewis Lake to Boston Harbor and removing upstream impediments to flow and compliment with edge protection for the surrounding communities and infrastructure. This approach would restore the area to its historic condition of an ecologically beneficial salt marsh complex. Living shoreline solutions along the edges of developed areas would protect against future storm surge while also providing additional habitat resources. Restored wetland areas and living shoreline solutions could also be integrated with elevated walkways, kayak/canoe launches, and hybrid infrastructure to enhance recreational opportunities and waterfront interaction throughout this area. As such, there is a unique opportunity to create a long-term vision of an expanded, but different, recreation resource in this area for the Town of Winthrop. However, protection of this area could also be considered through appropriate mitigation efforts at Washington Street and appropriate tide gate control. If the Town opts to try to maintain existing recreational uses, this area would need to continue to be fortified through adaptations along Washington Avenue. Even then, eventually fresh water drainage will be a significant problem for this area due to increased mean water elevations in Crystal Cove. As such, increased flooding over the mid- to long-term would be expected in this area.

Wetlands adjacent to Pico Beach

- In the relative near term (between 2011 and 2030), there are minimal changes to the wetlands adjacent to Pico Beach, which primarily consist of irregularly flooded marsh and tidal flat resources. At the inland fringes of these marshes, there are some minor changes by 2030 as salt laden water is able to further penetrate upstream in the system. Inland portions of the irregularly flooded marsh areas begin to convert to transitional scrub shrub areas. By 2070, a majority of the wetland system has transitioned to regularly flooded marsh, and expanded transitional scrub shrub areas into available upland areas.
- No immediate adaptations are required for this area in terms of natural resources as the marshes can be allowed to advance naturally for normal tidal conditions; however, in the long-term, and during storm events, more frequent flooding can be expected to surrounding properties and the fringe marsh areas may be expected to expand. Smaller proactive restoration measures could be considered along the shorelines to protect infrastructure and provide natural resource expansion and protection. Potential options could consider living shoreline applications and restoration of dune and beach resources seaward of the wetland areas could simultaneously provide storm protection, habitat resources, and enhanced recreational opportunities for Winthrop.

Coughlin Park

- In the relative near term (between 2011 and 2030), there no predicted changes to the resources at Coughlin Park, which primarily consist of irregularly flooded marsh and tidal flat resources. By 2070, a large portion of the upland area of Coughlin Park could convert to beach and tidal flat without intervention.
- It is our understanding that there are ongoing projects to bolster the shoreline at Coughlin Park, which are not discussed in this document to avoid redundancy.

Figure 1. 2011 Wetland classification areas in Winthrop (impervious areas removed).

Figure 2. 2011 Wetland classification areas in Winthrop (impervious areas included).

Figure 3. 2030 Wetland classification areas in Winthrop (impervious areas removed).

Figure 4. 2030 Wetland classification areas in Winthrop (impervious areas included).

Figure 5. 2070 Wetland classification areas in Winthrop (impervious areas removed).

Figure 6. 2070 Wetland classification areas in Winthrop (impervious areas included).

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Appendix G - Critical Public Infrastructure Scoring Guidance

HOW CRITICAL IS THE ASSET?				
RATING	**AREA OF SERVICE LOSS**	**PUBLIC SAFETY AND EMERGENCY SERVICES**	**SOCIAL AND ECONOMIC ACTIVITIES**	**PUBLIC HEALTH & ENVIRONMENT**
5	Regional	Loss of regional evacuation of response route Major (regional) service disruption	Town/regional loss	Significant pollution event (failure of a regional sewer main, flooding of a pump system) Permanent loss or major damage to a significant regional resource
4	Town-wide	Loss of local evacuation or response route Loss of emergency response and medical centers- no alternatives	Loss of transportation access or service to multiple neighborhoods Little major commerical impacts (single facility)	Significant pollution event (failure of a major sewer main , flooding of a pump system) Permanent loss or major damage to a significant local environmental resource
3	Multiple Areas / Neighborhoods	No loss of evacuation route, but major delays Loss of medical centers	Loss of transportation access or service to one neighborhood Loss of school, reasonable alternative available in Winthrop	Significant pollution event (flooding of a pump system) Temporary damage to a significant environmental resources
2	Single Area / Neighborhood	No major impacts to emergency response Minor utilitiy service disruption	No complete loss of transportation access or service, but inconvenience	Minor environmental impacts associated with erosion No major pollution implications
1	Single Property	No impact	No impact	No impact

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Appendix H - Infrastructure Criticality Matrix

NAME	TOTAL	AREA OF SERVICE LOSS	COMMENTS	PUBLIC SAFETY AND EMERGENCY SERVICES	COMMENTS	SOCIAL & ECONOMIC ACTIVITIES	COMMENTS	PUBLIC HEALTH & ENVIRONMENT	COMMENTS
MWRA Sewer Main	**20**	5	infrastructure with regional importance	5	infrastructure with regional importance	5	regional wastewater line - regional issue	5	significant (regional) implications
Belle Isle Bridge	**18**	5	evacuation route of regional importance	5	evacuation route of regional importance	5	regional evacuation route	3	
Main Street (town evacuation route)	**18**	5	evacuation route of regional importance	5	evacuation route of regional importance	5	regional evacuation route	3	
Shirley Street (town evacuation/ MWRA truck route)	**20**	5	infrastructure with regional importance	5	evacuation route of regional importance	5	regional evacuation route	5	
Power Substation (Argyle Street)	**18**	4	community-wide utility disruption	5	Service beyond Winthrop	5	major utility disruption	4	
Winthrop Water Tower	**16**	4		5	Critical to UASI for telecommunications	5		2	

NAME	TOTAL	AREA OF SERVICE LOSS	COMMENTS	PUBLIC SAFETY AND EMERGENCY SERVICES	COMMENTS	SOCIAL & ECONOMIC ACTIVITIES	COMMENTS	PUBLIC HEALTH & ENVIRONMENT	COMMENTS
Pico Sewer Pump Station	15	3	neighborhood issue	4	community utility disruption	4	loss of service to neighborhood	4	significant pollution event
Pleasant Court Sewer Pump Station	15	3	neighborhood issue	4	community utility disruption	4	loss of service to neighborhood	4	significant pollution event
Revere St. Sewer Pump Station	15	3	neighborhood issue	4	community utility disruption	4	loss of service to neighborhood	4	significant pollution event
Winthrop DPW Building	15	4	community-wide operation center	3		5	town-wide loss of service	3	
Pleasant Street (town evacuation route)	15	4	evacuation route of local importance	4	evacuation route of local importance	4	local evacuation route	3	
Washington Street (town evacuation route)	15	4	evacuation route of local importance	4	evacuation route of local importance	4	local evacuation route	3	
Beach Fire Station	14	4	essential equipment	4	houses personnel/ equipment for emergency services	3	neighborhood service loss	3	
High School	13	3	town-wide facility	3	potential shelter location	5	town loss	2	

NAME	TOTAL	AREA OF SERVICE LOSS	COMMENTS	PUBLIC SAFETY AND EMERGENCY SERVICES	COMMENTS	SOCIAL & ECONOMIC ACTIVITIES	COMMENTS	PUBLIC HEALTH & ENVIRONMENT	COMMENTS
Pressure Reducing Valve Station (Bayview Ave)	13	3	neighborhood issue	3	neighborhood utility disruption	4	loss of service to neighborhood	3	
Pressure Reducing Valve Station (Revere Street)	13	3	neighborhood issue	3	neighborhood utility disruption	4	loss of service to neighborhood	3	
Pressure Reducing Valve Station (Underhill Street)	13	3	neighborhood issue	3	neighborhood utility disruption	4	loss of service to neighborhood	3	
Winthrop Parkway	13	3	closed during storms due to flooding	4	closed during storms due to flooding	3	regional evacuation route	3	
Gorman/ Fort Banks Elementary School	11	3	secondary emergency shelter	3	local shelter location	3	loss of school, alternative available	2	no major pollution implications
Public Landing	10	1	evacuation route	2	secondary evacuation option	5	town/regional access route	2	

NAME	TOTAL	AREA OF SERVICE LOSS	COMMENTS	PUBLIC SAFETY AND EMERGENCY SERVICES	COMMENTS	SOCIAL & ECONOMIC ACTIVITIES	COMMENTS	PUBLIC HEALTH & ENVIRONMENT	COMMENTS
Point Shirley Association	**8**	2	emergency response center / staging site	2	serves as a mustering point for Police and Fire for major events	2	inconvenience	2	
Loring Rd. Boat Ramp	**4**	1	site use is not critical to the function of the community	1	no impact	1	no impact	1	no impact

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Appendix I - Critical Infrastructure Risk Scores

CRITICAL INFRASTRUCTURE NAME	CRITICALITY TOTAL	% PROBABILITY OF FLOODING			RISK SCORE
		PRESENT	2030	2070	
Pico Sewer Pump Station	15	5	25	100	307.5
Pleasant Court Sewer Pump Station	15	2	25	100	280.5
Washington Street (town evacuation route)	15	2	20	100	258
Main Street (town evacuation route)	18	0.5	5	100	212.4
Pleasant Street (town evacuation route)	15	0.2	5	100	174.3
Beach Fire Station	14	1	5	100	169.4
High School	13	1	5	100	157.3
Pressure Reducing Valve Station (Bayview Ave)	13	1	5	100	157.3
Pressure Reducing Valve Station (Underhill Street)	13	0.5	2	100	141.7
Shirley Street (town evacuation/MWRA truck route)	20	0.5	10	20	106
Point Shirley Association	8	1	5	100	96.8
Public Landing	10	0	0.5	50	51.5
Pressure Reducing Valve Station (Revere Street)	13	0	0.2	30	39.78
Revere St. Sewer Pump Station	15	0	0.1	20	30.45
Belle Isle Bridge	18	0	0	2	3.6
Power Substation (Argyle Street)	18	0	0	2	3.6
Loring Rd. Boat Ramp	4	0	0	1	0.4
MWRA Sewer Main	20	0	0	0	0
Winthrop Water Tower	16	0	0	0	0
Winthrop DPW Building	15	0	0	0	0
Winthrop Parkway	13	0	0	0	0
Gorman/ Fort Banks Elementary School	11	0	0	0	0

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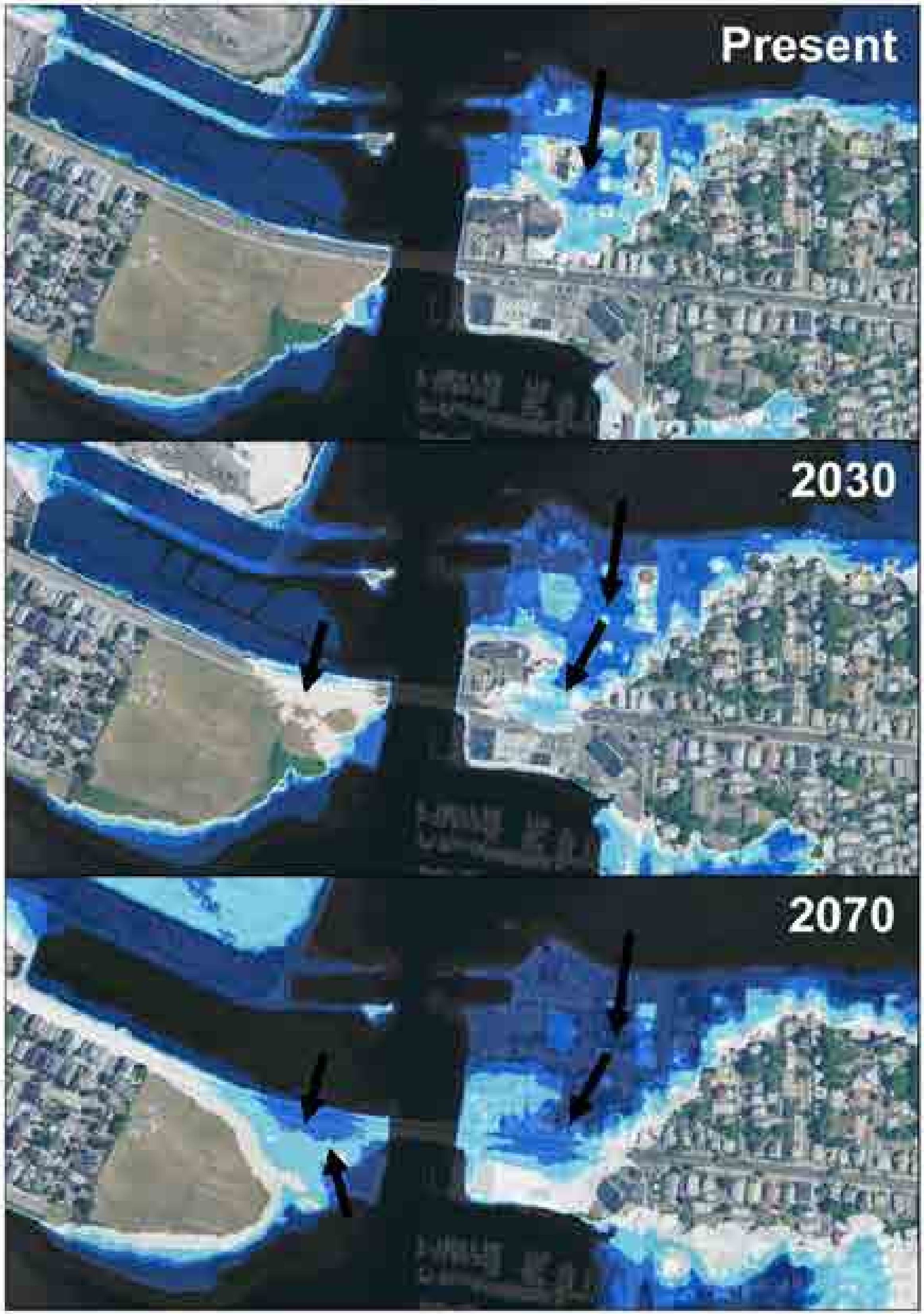
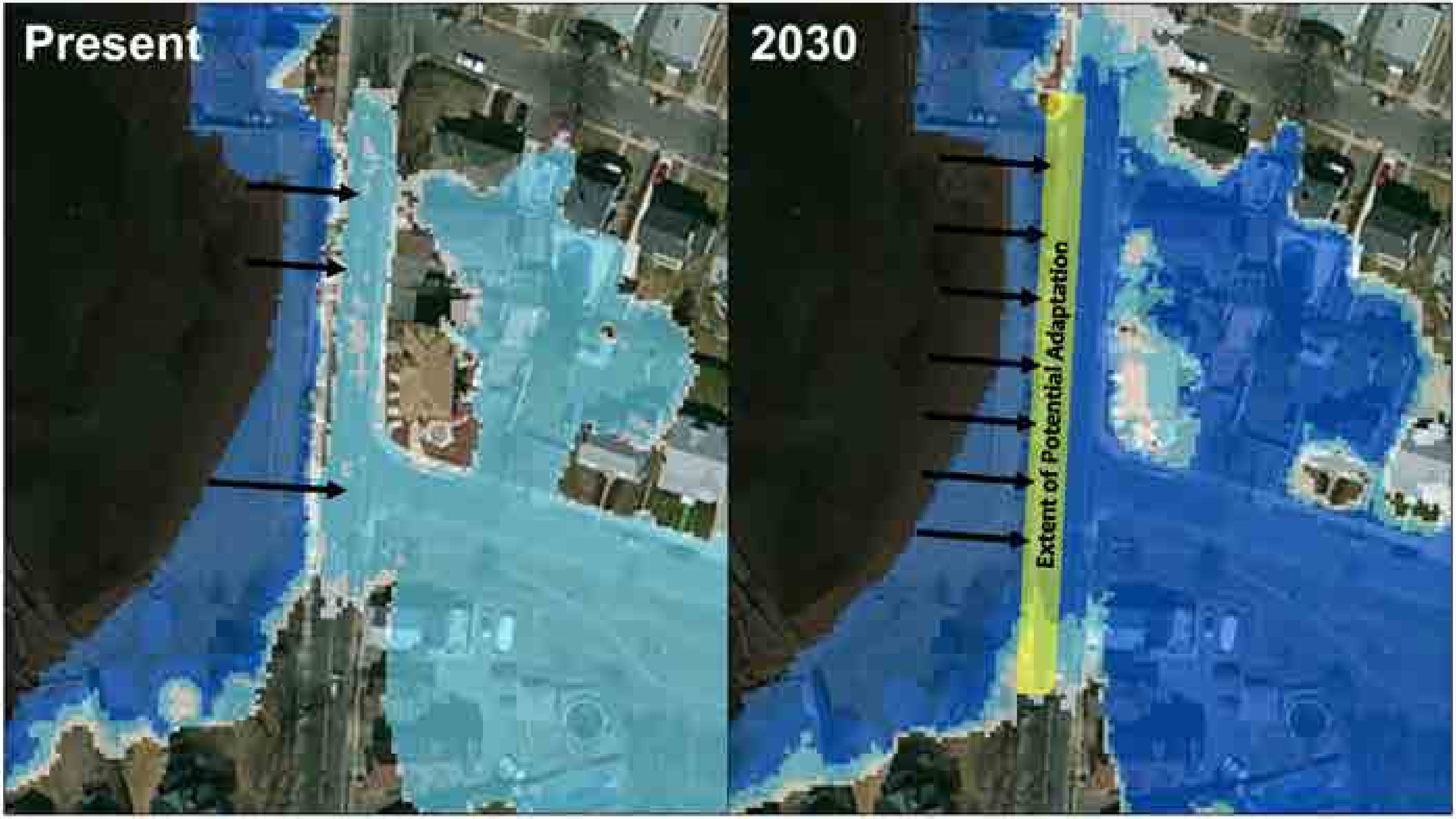
Appendix J - Modeled Flood Pathways



Winthrop, MA

Belle Isle Bridge
Local Flood Pathway Analysis



Winthrop, MA

Pleasant Street at Ingleside Park Local Flood Pathway Analysis

Winthrop, MA

Argyle Street Substation and Winthrop Parkway Pump Station
Local Flood Pathway Analysis

UMASS BOSTON
University of New Hampshire
massDOT

Winthrop, MA
Washington Avenue Local Flood Pathway Analysis

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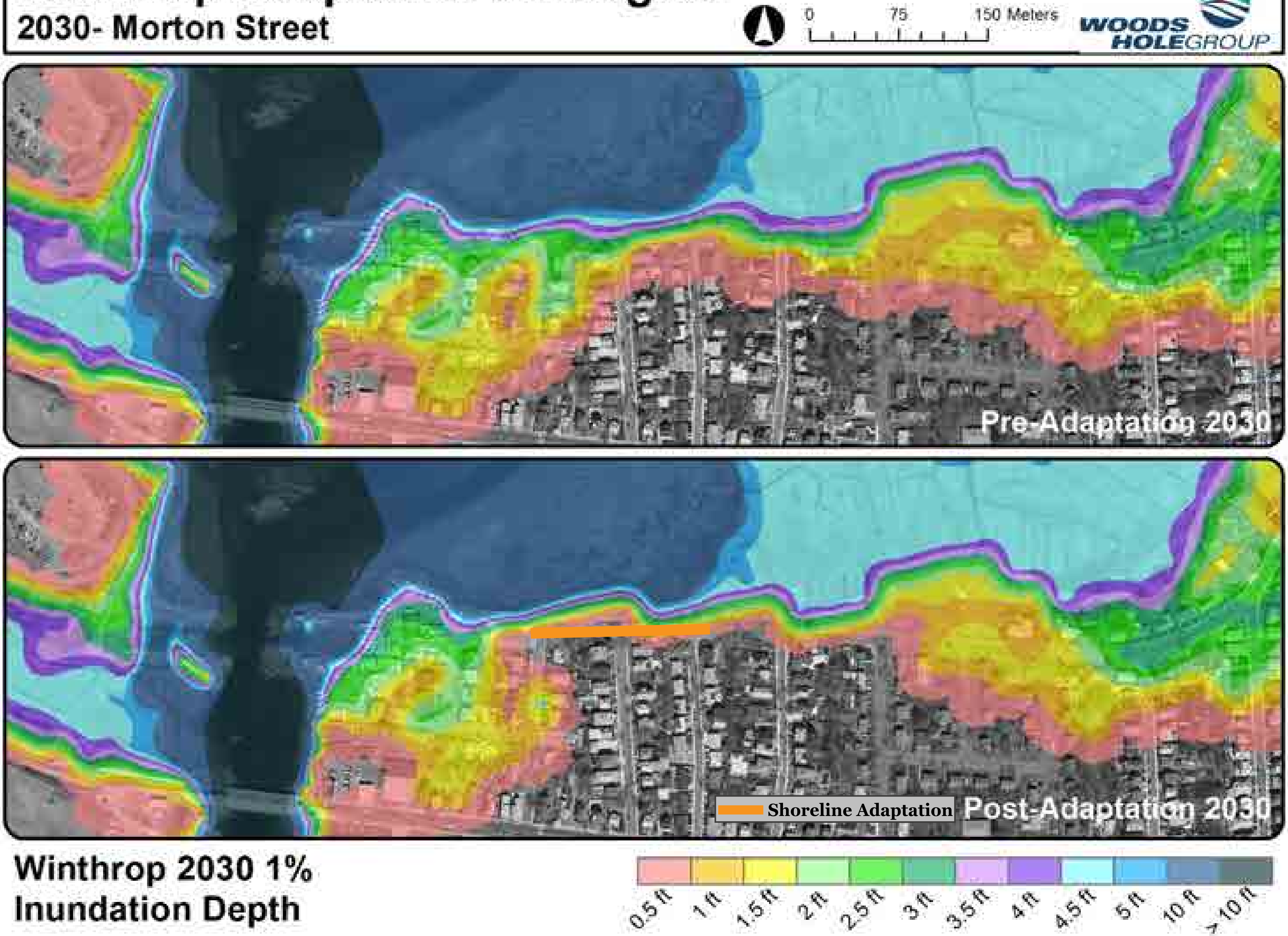
Appendix K - Modeled Adaptation Measures

Winthrop Adaptation Strategies

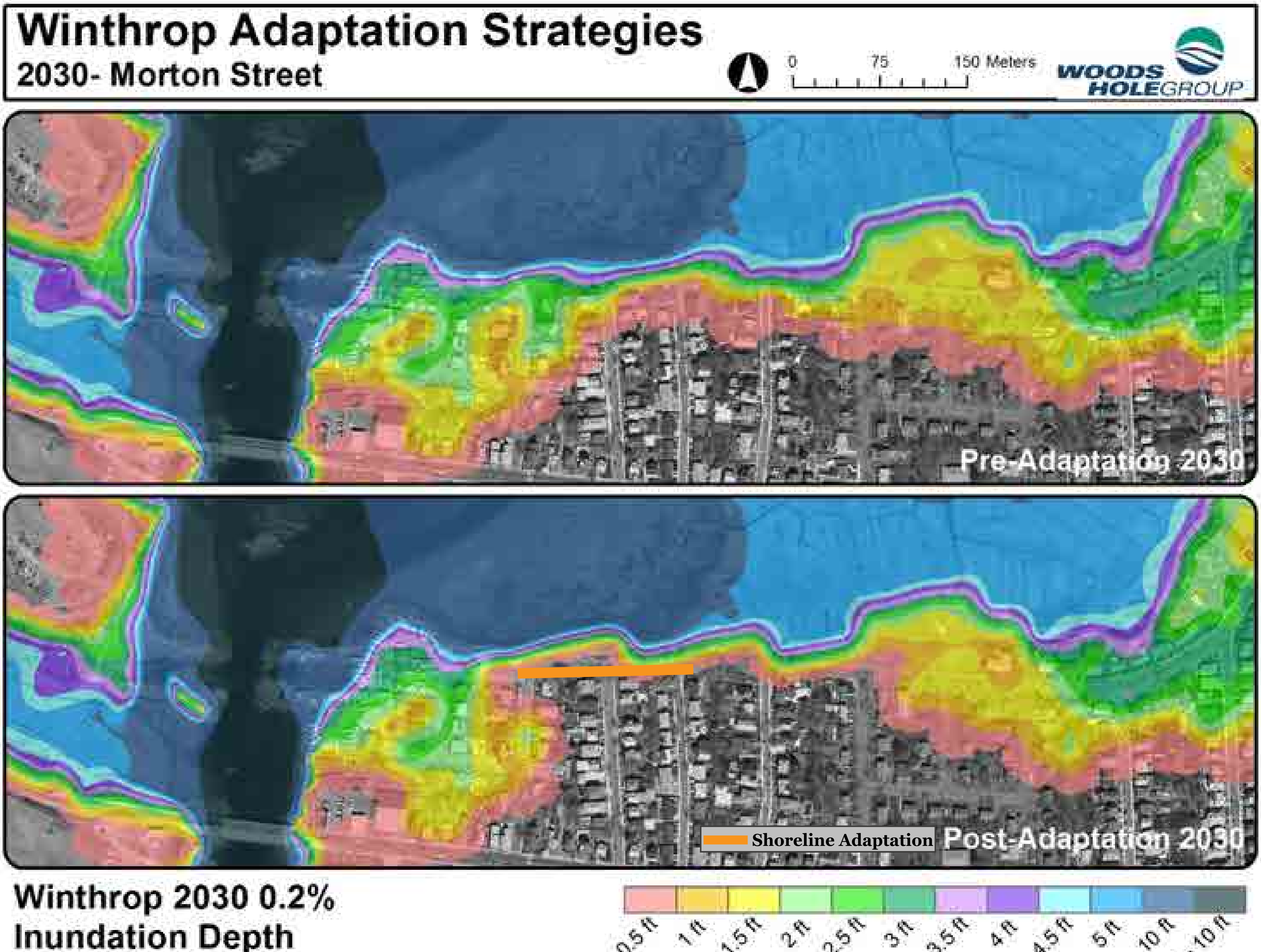
2030- Morton Street



Winthrop 2030 1%
Inundation Depth

Winthrop Adaptation Strategies

2030- Morton Street



Winthrop 2030 0.2%
Inundation Depth

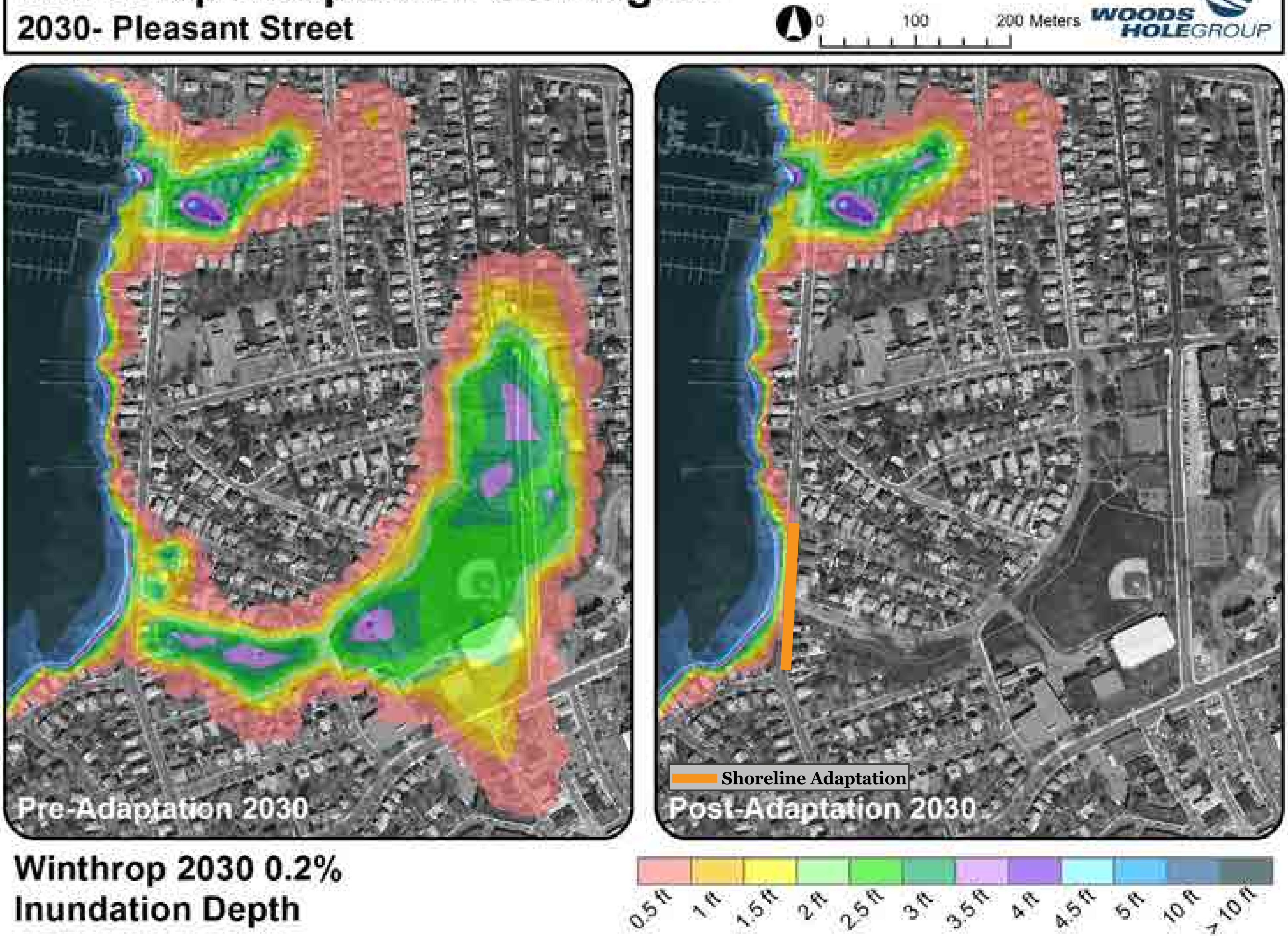
Winthrop Adaptation Strategies

2030- Pleasant Street

Winthrop 2030 1% Inundation Depth

Winthrop Adaptation Strategies

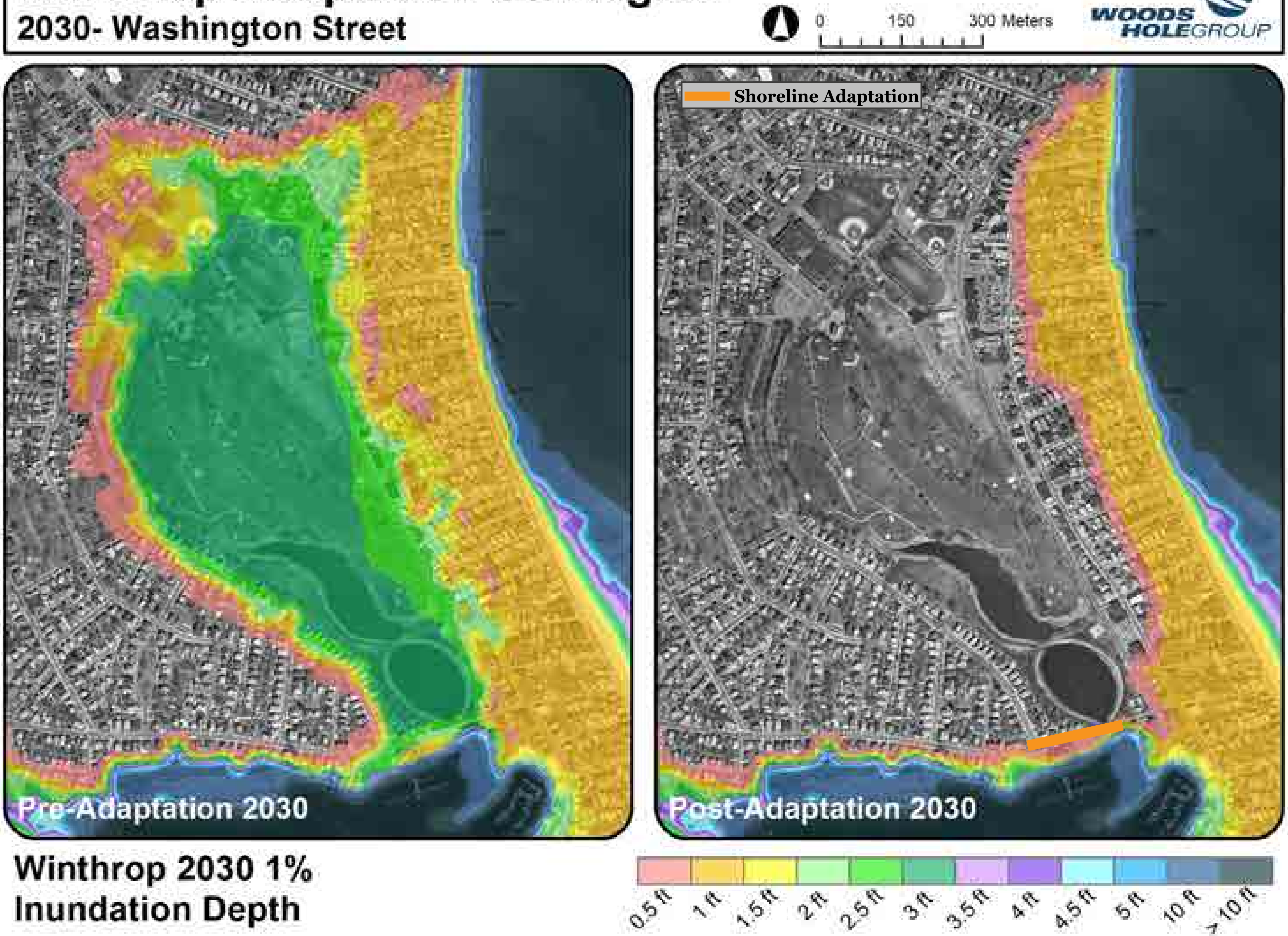
2030- Pleasant Street



Winthrop 2030 0.2% Inundation Depth

Winthrop Adaptation Strategies

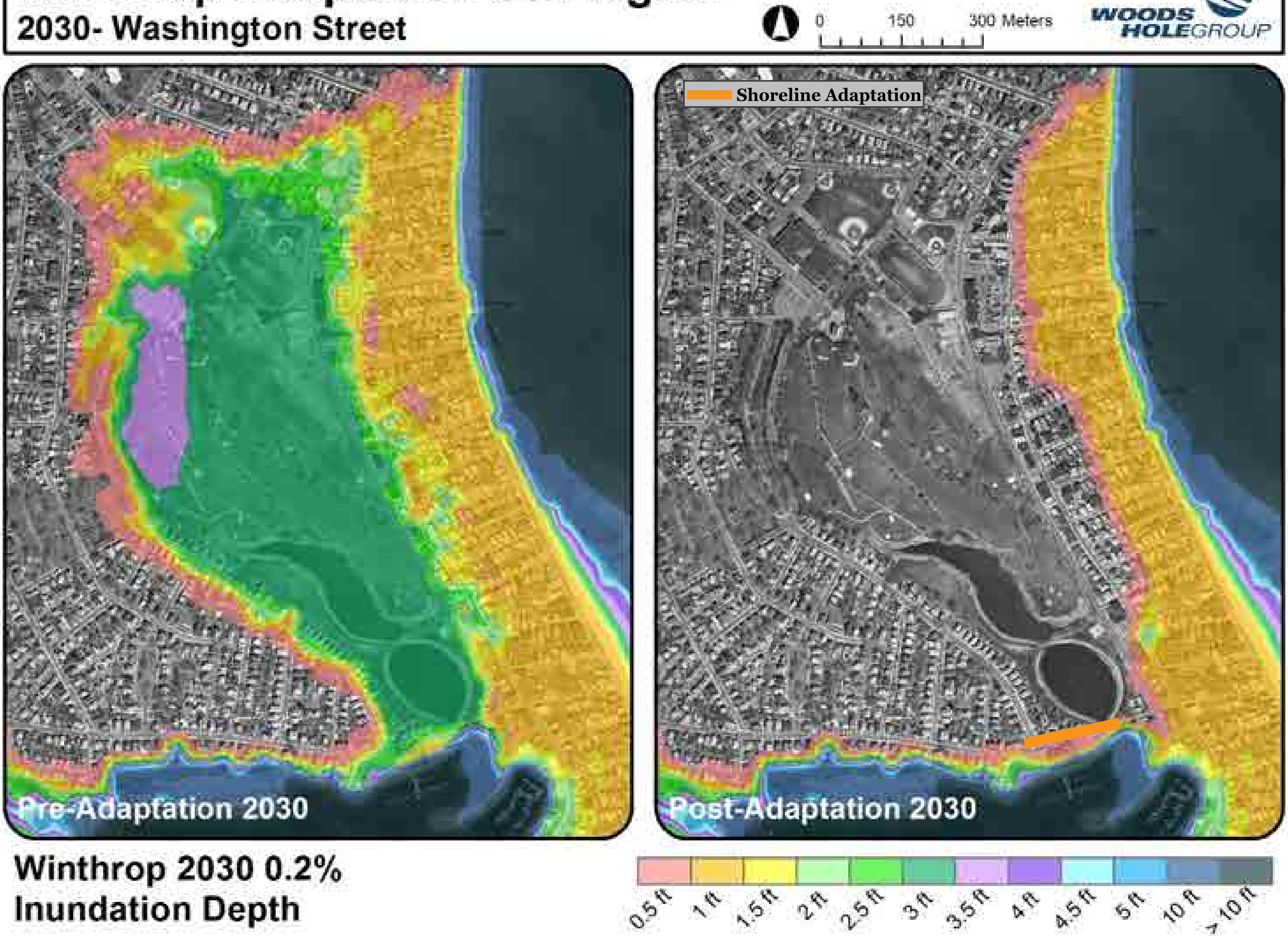
2030- Washington Street



Winthrop 2030 1% Inundation Depth

Winthrop Adaptation Strategies

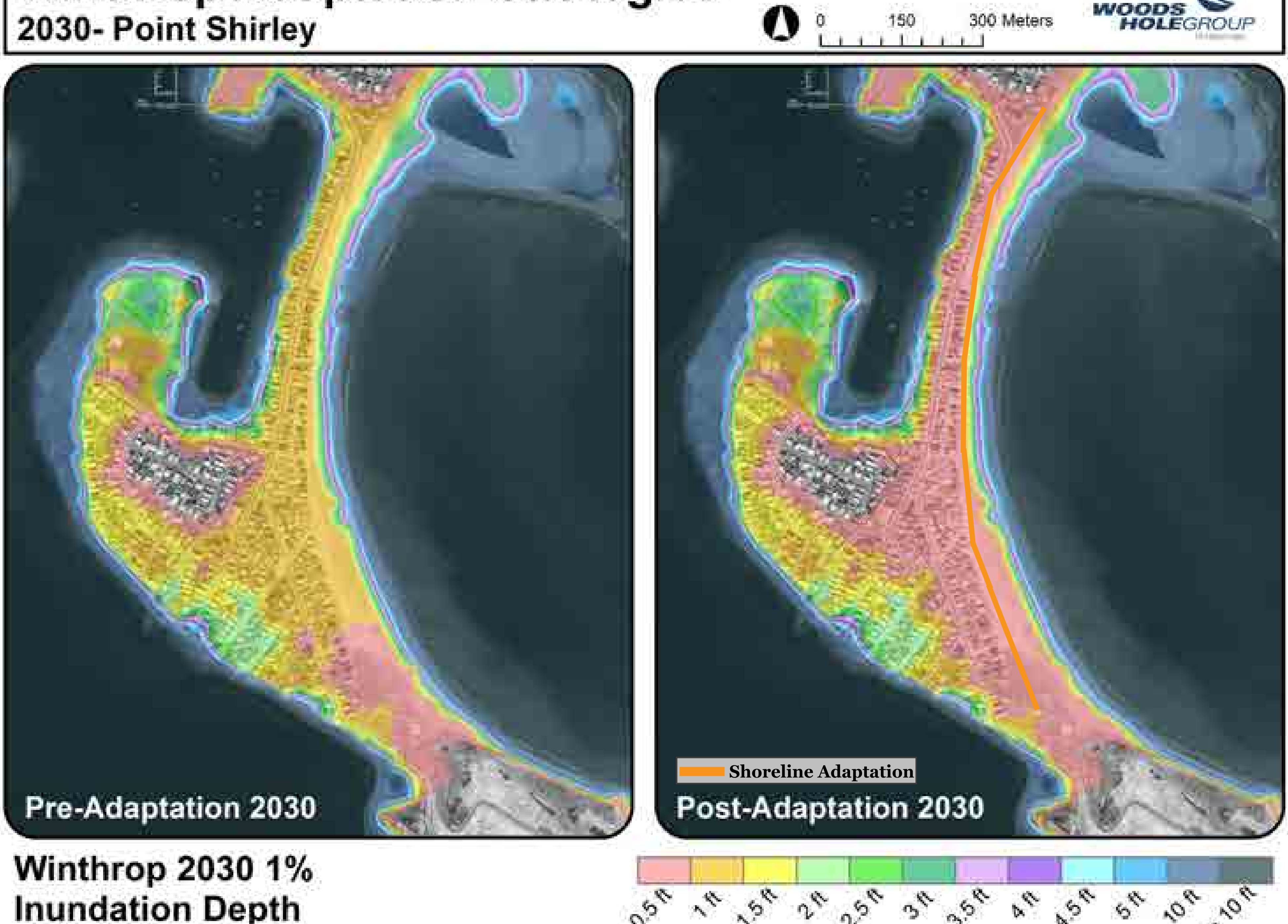
2030- Washington Street



Winthrop 2030 0.2%
Inundation Depth

Winthrop Adaptation Strategies

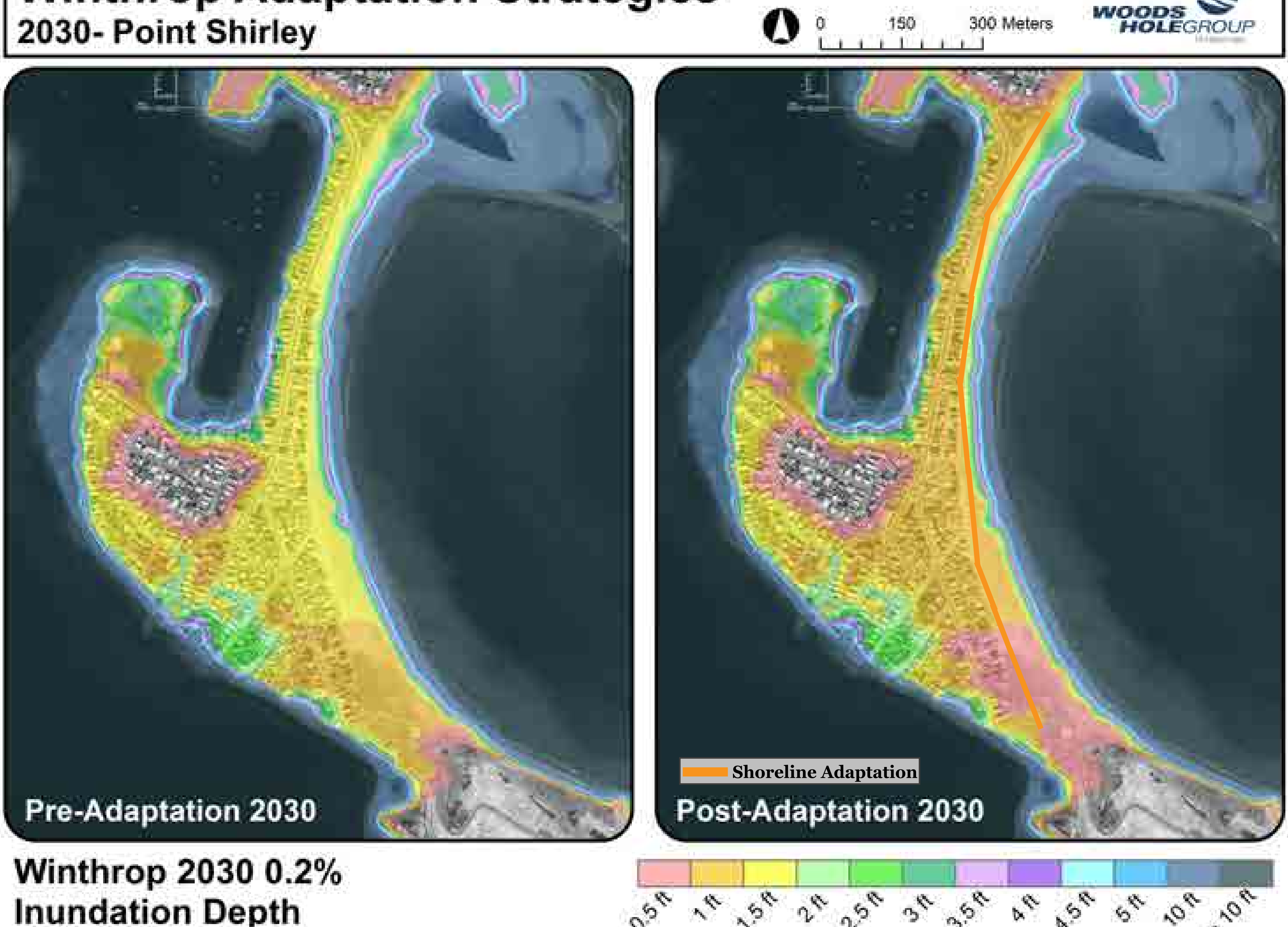
2030- Point Shirley



Winthrop 2030 1% Inundation Depth

Winthrop Adaptation Strategies

2030- Point Shirley



Winthrop 2030 0.2% Inundation Depth

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