Collins Cove to Willows Resilience Study Final Report

City of Salem, MA

Project number: 60693313

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Table of Contents

Figures

Tables

1. Introduction

This report summarizes the findings of a resilience study conducted in the Collins Cove to Willows area of Salem, a portion of the city that has a history of experiencing both inland and coastal flooding. With climate change projections indicating a worsening situation, the need for a comprehensive resilience study and development of a resilience planning framework for this area has become imperative. The primary goal of this study was to conduct a thorough assessment of the vulnerability and risk of the Collins Cove to Willows area, specifically related to coastal and inland flooding, and develop resilience options for identified priority areas. Also, a strong public engagement effort was completed to ensure the voices of those living in the study area were incorporated into the assessment.

The study report sections and attached appendices include:

1. Introduction
2. Summary of Public Involvement and Community Engagement
3. Emergency Response Plan / Alternative Access Routes
4. Vulnerability Assessment Results
5. Resilience Options for Priority Areas
6. Funding Opportunities
7. Implementation Plan
8. Conclusion
9. Bibliography

Appendix A Public Involvement and Community Engagement Materials
Appendix B Past Studies and Available Data Memo
Appendix C Vulnerability Assessment and Modeling Results Memo
Appendix D Resilient Coastal Parks Toolkit
Appendix E Resilience Options Memo
Appendix F Emergency Response Plan

This study was funded by a Municipal Vulnerability Preparedness (MVP) Action Grant that was awarded to the City by the Massachusetts Executive Office of Energy and Environmental Affairs (EEA).

1.1 Background of Study Area

The City of Salem is a developed municipality in Essex County, Massachusetts located along the North Shore. The City's current population is approximately 45,435, and it has grown by approximately 9 percent since 2010. Comparatively, the population of Massachusetts at large has grown by 6 percent since 2010. An analysis of U.S. Census American Community Survey (ACS) data revealed the median household income, mean household income, and per capita income in Salem are 23 percent, 30 percent, and 13 percent below those of Massachusetts at large, respectively. The social and economic conditions of Salem demonstrate the City is growing faster than that of Massachusetts at large and has lower household and per capita incomes than the Commonwealth at large.

The study area encompasses Environmental Justice (EJ) populations and Climate Vulnerable Populations, who face heightened risks associated with climate change impacts. Addressing the needs of these communities is crucial, as they reside in areas with limited evacuation routes surrounded by coastal hazards. Many organizations and agencies, such as the North Shore Community Development Corporation, Salem Housing Authority, and Lifebridge, provide housing and services to the most vulnerable populations to climate change impacts (Resiliency Building Workshop, 2019). The City is committed to making sure these organizations and agencies are able to continue to provide resilient housing in the face of increasing climate challenges through comprehensive climate mitigation and resiliency strategies.

Salem is a coastal community that is vulnerable to severe hazards from climate change threats, such as sea level rise, coastal storm surge, stormwater flooding, and erosion. The City of Salem Municipal Vulnerability Preparedness (MVP) Summary of Findings Report identified several streets in the Collins Cove to Willows study area as some of the city's most vulnerable to climate change impacts (SSCW, 2020). This study was initiated in response to a top priority action identified from the MVP Program to conduct a study to determine the best strategies to mitigate flooding, erosion, and storm impacts in the Collins Cove to Willows study area (Figure 1-1).

Figure 1-1. Study Area and City-Owned Property

1.2 Report Sections

This report aims to provide a roadmap for enhancing the resilience of the Collins Cove to Willows area, safeguarding its residents, critical facilities, and natural resources from the escalating threats posed by climate change. Copies of presentations and memoranda prepared as part of Tasks 1 through 5 for this study are included as appendices to this report.

The tasks are summarized as follows:

Task 1: The City and its consultants, AECOM and Salem Sound Coastwatch (SSCW), conducted a kick-off meeting with the Executive Office of Energy and Environmental Affairs (EEA) to review the proposed project's scope, schedule, and budget. This task also included the City's completion and submittal of monthly progress reports by the 30th of each month of the grant period to the Northeast Region MVP Coordinator and development of a final project case study.

Task 2: Throughout the resilience study, the City and its consultants engaged the community and key stakeholders and gathering feedback on vulnerabilities and risks in the study area. This included City officials, residents, neighborhood associations, businesses, and relevant organizations. Special attention was given to involving Environmental Justice populations in the vulnerable Collins Cove area. Outreach materials were distributed through various channels, and local stories of flooding were collected. Three workshops were held, serving as a project kickoff, sharing findings, and presenting draft results. Community leaders and liaisons played vital roles, and an online platform facilitated community participation.

Task 3: Task 3 involved reviewing available information and assessing current and future vulnerability and risks to coastal and inland flooding. Past studies and reports related to the study area were reviewed, including climate change vulnerability assessments, infrastructure inventory reports, and resilience plans. Ownership of shoreline properties was confirmed, and existing surveys, facility mapping, and historical storm events were examined. The Massachusetts Coast Flood Risk Model (MC-FRM) and FEMA data were used to evaluate storm surge, sea level rise, erosion rates, and potential inundation areas. The storm drainage system's vulnerability to climate change impacts and potential alternatives were assessed through a drainage analysis using a dynamic model created with GIS data and PCSWMM software. Future conditions, including increased rainfall and tide levels, were considered. The model results informed the identification of resilience options such as larger stormwater pipes, seawall heights, and tide gates.

Task 4: Building on Task 3, a list of potential resilience options was developed based on the identified vulnerabilities and risks in the study area. A multi-criteria decision matrix was created to assess feasibility, considering factors such as cost, funding, ownership, community acceptance, and climate projections. The findings were summarized in a memo, acknowledging the need for future hydrologic modeling. A toolkit of resilience options for coastal parks was developed, serving as a resource for Salem and other coastal municipalities. Additionally, an emergency response plan was developed, which included the identification of evacuation routes and support for impacted residents during extreme weather events.

Task 5: The Collins Cove to Willows Resilience Study Report (i.e., this report) summarizes recommendations that are the culmination of work completed on the four preceding tasks described above. Readers are referred to the individual memoranda completed as part of Tasks 2 through 5 (see appendices) for additional background details evaluated and developed as part of the Resiliency Study that culminated in the recommendations included in this report.

2. Summary of Public Involvement and Community Engagement

Inclusive public engagement played an important role in this resilience study, which included a workshop series, walk and talks, a project website (publicinput.com/CollinsCove2Willows), and an ESRI StoryMap (https://arcg.is/0Xrian). The primary means for engagement was through the workshop events, which included in-person, virtual, and hybrid events. These meetings aimed to gather insights from residents, experts, and stakeholders to better understand the challenges posed by flooding and develop effective mitigation strategies. The meetings were held on the following dates:

- November 29, 2022
- February 27, 2023
- May 23, 2023

The first Public Meeting took place in-person and was well attended, with 49 community members providing their information and an estimated 70 participants throughout the night. The meeting featured presentations by SSCW, the City of Salem, and AECOM, and displayed maps of the study area. Attendees engaged in discussions and shared their observations of flooding on neighborhood maps. The second and third Public Meetings, which were virtual and hybrid respectively, had lower attendance but provided valuable insight, nonetheless. The meetings provided the opportunity for attendees to mark areas of concern on maps to share their insights. Appendix A provides a summary of the workshops and other public engagement measures that were implemented for the project.

3. Emergency Response Plan / Alternative Access Routes

As part of the Collins Cove to Willows Resilience Study, a review of the Salem Comprehensive Emergency Management Plan (CEMP) was conducted to evaluate its efficacy and identify potential areas for improvement in emergency response actions within the study area (Figure 1-1). The focus of the evaluation was to aid planning for emergency response efforts during coastal flooding events that are expected to be influenced by future impacts of climate change.

The review was summarized in a memorandum (Appendix B) which includes an overview of the current CEMP, outlining its key components, strategies, and procedures. It also presents recommendations for potential additions or modifications to the plan, specifically addressing the anticipated challenges and vulnerabilities associated with climate change in the study area by consulting the Massachusetts Coast Flood Risk Model (MC-FRM) (Woods Hole Group, 2021). This model, which is described in more detail in Section 4 Vulnerability Assessment Results, served as a valuable resource, providing essential information and insights regarding areas prone to flooding in the study area. The model's GIS output layers were mapped along with evacuation routes and points (Figure 3-1) to identify potential gaps or discrepancies in the emergency response strategies for vulnerable locations could be identified. The recommendations made in the memorandum aim to strengthen the city's emergency response capabilities, incorporate climate resilience considerations, and improve the safety and well-being of residents in the study area.

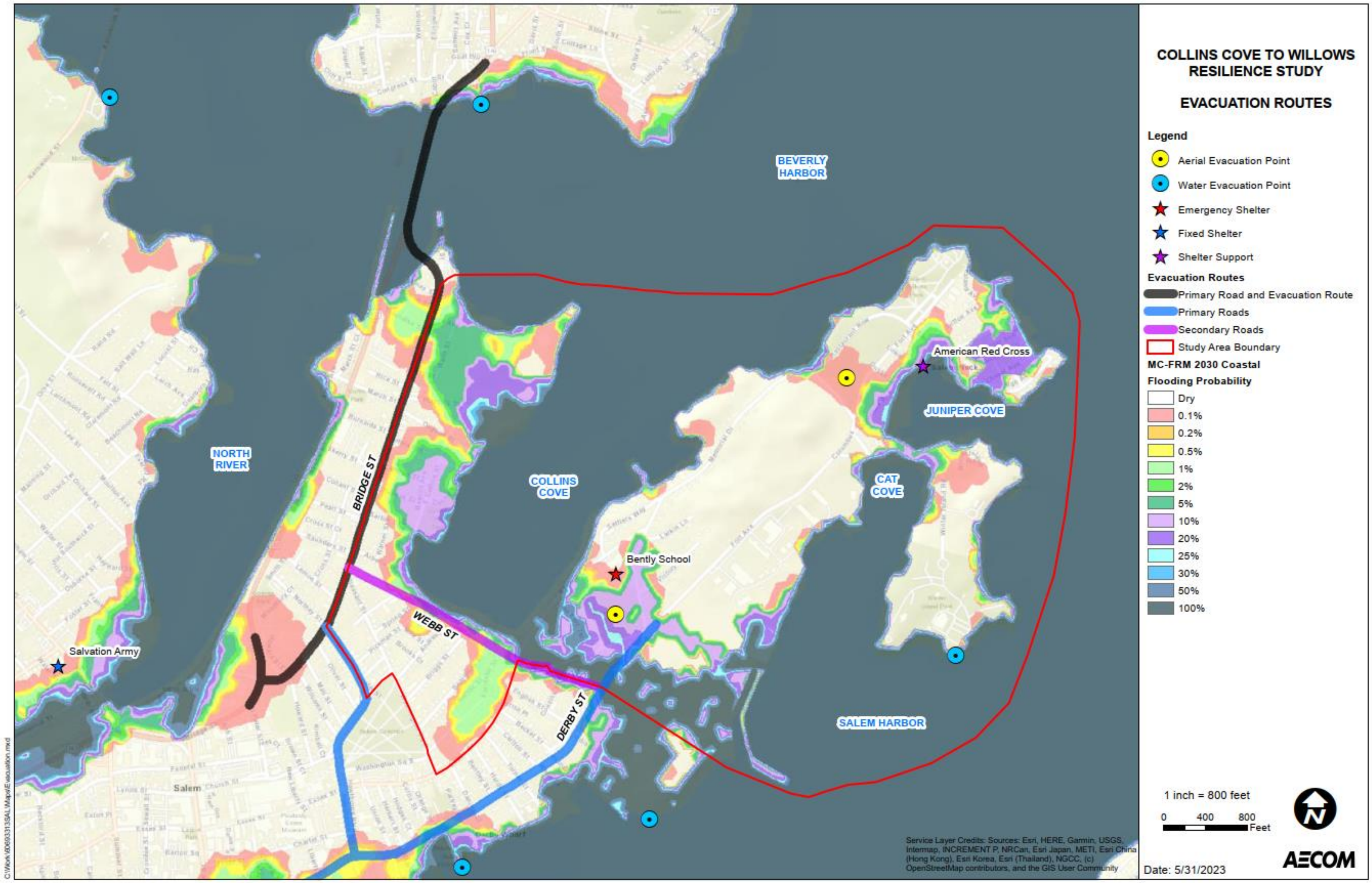

Figure 3-1: Evacuation Routes, Critical Infrastructure, and 2030 MC-FRM Annual Probability of Flooding

By addressing the need for revisions and incorporating climate change considerations into the CEMP, the City of Salem can proactively adapt its emergency response protocols to the evolving risks posed by coastal flooding and other climate-related hazards (e.g., rain, wind). The proposed additions outlined in the memorandum will serve as valuable insights and recommendations for enhancing the effectiveness and resilience of the CEMP, ultimately improving the City's ability to respond promptly and effectively to emergencies within the study area and safeguard the community's welfare.

4. Vulnerability Assessment Results

The Vulnerability Assessment and Modeling Results Memo (Appendix C) was part of the third task of the study which provided the City of Salem with an overview of historic, present, and future vulnerability and risk due to sea level rise, storm surge, and precipitation-based (stormwater) flooding in the Collins Cove to Willows study area and prioritized the most vulnerable areas. The vulnerability assessment was informed by a review of past studies and available information (Appendix D). The following sections discuss the climate stressors, as they were addressed in the Vulnerability Assessment and Modeling Results Memo.

4.1 Climate Stressors

Coastal Flooding and Sea Level Rise

The Massachusetts Coast Flood Risk Model (MC-FRM) was the primary data source used to assess current and future vulnerability to coastal flooding. Developed through collaboration between the Woods Hole Group, MassDOT, and the University of Massachusetts Boston, the MC-FRM provides several flood products for both present day and future conditions. The latest sea level rise projections released by NOAA in 2022 were incorporated into the vulnerability analysis.

Several areas within the study area were identified as highly vulnerable to coastal flooding in the City's Comprehensive Emergency Management Plan (2022) and Hazard Mitigation Plan 2020 Update. These areas included Willows Park neighborhood, Bridge Street, and other parts of Collins Cove. The FEMA effective national flood hazard map overlaid on critical infrastructure and coastal structures showed that a significant portion of the study area is located within the floodplain of the 1% annual chance exceedance (ACE) event, commonly referred to as the 100-year flood event.

Precipitation

Since the MC-FRM data set provides projected coastal boundary conditions but does not consider projected precipitation events, the Cornell University's methodology was selected as the data source for projected precipitation. The Cornell 100-year storm event precipitation depths for 2030, 2050, and 2070 planning horizons are presented in the Vulnerability Assessment Memo and applied to the Hydraulic & Hydrologic (H&H) model developed for this study.

The H&H model network was developed to represent the existing drainage network and topography in the study area. Although flow meter data was not available for calibration, the model was verified based on observations and measurements from a December 23, 2022 storm event and an Atlas-14 1-year depth 24-hour duration storm event under average tidal conditions. The model incorporated tidal data derived from NOAA's tide gauge in Boston Harbor, adjusted to reflect the differences in geographical and timing conditions between Boston and Salem. Flood depth measurements and pictures were gathered during field observations, confirming that the model accurately represented flooding due to storm surge events. Public feedback confirmed that flooding in representative areas was consistent with observed conditions during high-intensity rainfall events.

Erosion and Shoreline Change

Two studies were utilized to assess erosion and shoreline change in the study area. The Massachusetts Office of Coastal Zone Management shoreline study was used to evaluate both shore term and long-term shoreline change, to identify erosion-prone areas. Overall, the study found long term rates in the Study

Area to be mostly stable, with a few pockets of erosion and accretion. The most severe long-term erosion was found in Collins Cove (approximately -1.3 ft/year), along the southeastern end. The short-term shoreline changes rates show conditions with no statistically significant change (characteristic of cyclical change) along most of the Study Area shoreline, with one distinct area of erosion in Collins Cove. This stretch of beach at the end of Planters Street (approximately -3.0 ft/year), shows heavy short-term erosion as it is the only stretch of shoreline on the northwestern side of Collins Cove that is not protected by rock or manmade structure. While the historical trends show relatively stable existing conditions along most of the Study Area shoreline, the vulnerability of the shoreline is increasing as sea levels rise, structures continue to degrade, and weather patterns change.

Future erosion predictions considering sea-level rise were investigated through the FEMA Region I Coastal Erosion Study, which projected shoreline change for three different planning horizons. Based on analysis of the FEMA study, sections of pocket beach were identified as having a higher erosion risk. Some of these more vulnerable areas include:

- Bridge Street Beach (Between Bill and Bob's Roast Beef and National Grid)
- Collins Cove
- Dead Horse Beach
- Fort Pickering Beach
- Juniper Cove
- Juniper Beach 1 and 2
- Waikiki Beach

These beaches all are projected to erode a minimum of 150 feet by the year 2100 under the NOAA high SLR projection.

4.2 Priority Areas

In addition to characterizing the climate hazard vulnerability of the Study Area, the vulnerability assessment identified and prioritized the most vulnerable areas to provide focus to the development of resiliency solutions in the next phase of this study. The most vulnerable areas were determined by analyzing the severity of pluvial/stormwater and coastal flooding using the MC-FRM and H&H modeling results for the 2050-time horizon. Priority was given to areas experiencing both hazards, with a focus on residential areas and the presence of critical infrastructure or major roads. The 2050-time horizon was chosen as it strikes a balance between near-term vulnerability and a realistic timeframe for implementing resilience measures. Specific areas within the study boundary and city-owned parcels were identified, as depicted in Figure 4-1.

A selection process was developed and implemented to identify and prioritize the most vulnerable areas within the Study Area (Table 4-1). The selection process considered vulnerability to stormwater/pluvial flooding, coastal flooding, erosion, and community vulnerability. The following five priority areas were identified through the selection process as described in the Vulnerability Assessment and Modeling Results Memo:

1. Bridge St (North)
2. Osgood - Arbella – Bridge St
3. Bay View – Columbus Ave
4. Webb St
5. Planters St

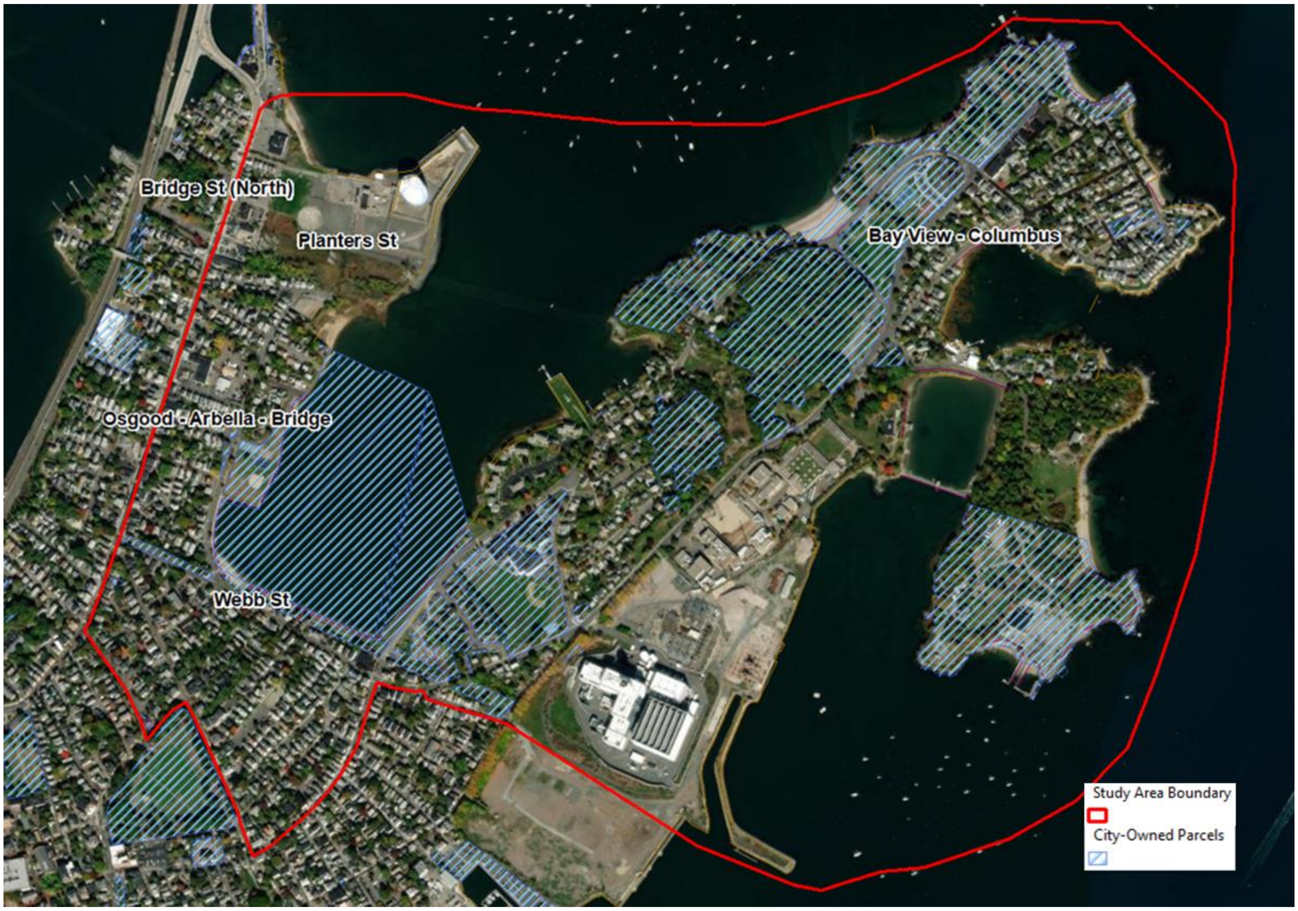

Figure 4-1. Selected Priority Areas

Table 4-1. Priority Area Selection Criteria Scores

Impacted Areas	Pluvial Flood Vulnerability		Coastal Flood Vulnerability		Erosion Vulnerability	Community Vulnerability		Score
	Stormwater Flooded Area (2050 5-yr)	*Stormwater Flood Depth (2050 5-yr)*	*MC-FRM Annual Coastal Flood Probability (2050)*	*Spring Tide Coastal Flooded Area (2050)*	*2050 Intermediate Erosion*	*Evacuation Route / Major Road*	*Environmental Justice*	
Bridge St (North)	3	2	2	2	3	3	3	18
Bay View - Columbus	2	2	3	3	3	3	0	16
Osgood - Arbella - Bridge	3	2	3	2	3	0	3	16
Webb St	1	1	3	1	3	3	3	15
Planters St	1	2	3	3	3	0	3	15
Szetela Lane - Lee Fort Terr	2	2	3	3	0	0	3	13
Winter Island Rd	1	2	3	1	3	3	0	13
Juniper Ave	2	2	3	1	3	0	0	11
Forrester - Essex St	3	2	3	1	0	0	0	9
Memorial Drive	2	2	3	1	0	0	0	8

5. Resilience Options for Priority Areas

In the Task 3 Vulnerability Assessment and Modeling Results Memo, specific areas within the study area were chosen based on identified vulnerabilities, risks, and application of priority area selection criteria (Figure 4-1). The Task 4 Resilient Coastal Parks Toolkit (Appendix E) identified potential measures, including non-structural, stormwater management, nature-based shoreline protection, and structural flood risk reduction, to enhance resilience. The Resilience Options Memo (Appendix F) then evaluated the feasibility of the outlined resilience options, in terms of their effectiveness in protecting key areas within the study area. The options were classified into non-structural measures, stormwater management, nature-based shoreline protection, and structural flood risk reduction. A more detailed description of the options can be found in the Resilient Coastal Parks Toolkit. It is important to consider that there is no universal solution that fits all scenarios, and the suitability and feasibility of different resilience options may vary within the study area based on specific applications. The feasibility of these resilience projects was rated based on relative cost, funding opportunities, ownership, community acceptable, permitting complexity, and the effectiveness in providing protection against future flooding. Applicable resilience options are shown Table 5-1. A summary of the findings for each priority area is provided in the following sections.

5.1 Bridge Street (North)

The Bridge Street (North) area is vulnerable to a variety of flooding impacts as discussed in the Task 3 Vulnerability Assessment and Modeling Results Memo including pluvial, coastal, and erosion. The highest risks are from stormwater flooding (2050, 5-year event) and erosion (2050 intermediate erosion).

Resilience strategies that are applicable to this area and would provide improved protection from stormwater flooding include:

- Stormwater outfall backflow prevention
- Impervious surface removal/reduction
- Bioretention basins and rain gardens
- Stormwater system improvements
- Green roofs

Although erosion is a risk for this area, typical erosion control measures such as living shorelines are not applicable for this region and new hardened shorelines are unlikely to be permitted in this area.

Resilience strategies that are applicable to this area and would provide improved protection from coastal flooding include:

- New levee or berm
- Floodproofing Buildings
- Road elevation

5.2 Planters Street

The Planters Street area is vulnerable to a variety of flooding impacts as discussed in the Task 3 Vulnerability Assessment and Modeling Results Memo including pluvial, coastal, and erosion. The highest risks are from coastal flooding (2050 tides and surge) and erosion (2050 intermediate erosion).

Resilience strategies that are applicable to this area and would provide improved protection from coastal flooding include:

- New levee or berm
- Flood gates
- Floodproofing Buildings

Resilience strategies that are applicable to this area and would provide improved protection from erosion include:

- Living shorelines

Although stormwater flooding is not the highest risk hazard, some risk from stormwater flooding is present. Resilience strategies that are applicable to this area and would provide improved protection from stormwater flooding include:

- Impervious surface removal/reduction
- Green roofs

5.3 Osgood – Arbella - Bridge

The Osgood – Arbella - Bridge area is vulnerable to a variety of flooding impacts as discussed in the Task 3 Vulnerability Assessment and Modeling Results Memo including pluvial, coastal, and erosion. This area has a high risk from all three hazard types: stormwater flooding (2050, 5-yr event), coastal flooding (2050 tides and surge), and erosion (2050 intermediate erosion).

Resilience strategies that are applicable to this area and would provide improved protection from stormwater flooding include:

- Stormwater outfall backflow prevention
- Impervious surface removal/reduction
- Stormwater system improvements
- Green roofs

Resilience strategies that are applicable to this area and would provide improved protection from coastal flooding include:

- New levee or berm
- Harbor barrier
- Elevate existing seawall / shoreline height increase
- Building elevation
- Building acquisition
- Floodproofing buildings

Although erosion is a risk for this area, typical erosion control measures such as living shorelines are not applicable for this region and new hardened shorelines are unlikely to be permitted in this area.

5.4 Webb Street

The Webb Street area is vulnerable to a variety of flooding impacts as discussed in the Task 3 Vulnerability Assessment and Modeling Results Memo including pluvial, coastal, and erosion. This area has a high risk from two hazard types: coastal flooding (2050 tides and surge) and erosion (2050 intermediate erosion).

Resilience strategies that are applicable to this area and would provide improved protection from coastal flooding include:

- New levee or berm
- Harbor barrier
- Building elevation
- Building acquisition
- Floodproofing buildings
- Road elevation

Resilience strategies that are applicable to this area and would provide improved protection from erosion include:

- Living shorelines

Although stormwater flooding is not the highest risk hazard, some risk from stormwater flooding is present. Resilience strategies that are applicable to this area and would provide improved protection from stormwater flooding include:

- Stormwater outfall backflow prevention
- Stormwater system improvements
- Impervious surface removal/reduction
- Additional temporary stormwater storage / subsurface infiltration basin
- Green roofs

5.5 Bay View - Columbus

The Bay View - Columbus area is vulnerable to a variety of flooding impacts as discussed in the Task 3 Vulnerability Assessment and Modeling Results Memo including pluvial, coastal, and erosion. This area has a high risk from two hazard types: coastal flooding (2050 tides and surge) and erosion (2050 intermediate erosion).

Resilience strategies that are applicable to this area and would provide improved protection from coastal flooding include:

- Elevate existing seawall / shoreline height increase
- Floodproofing buildings
- Road elevation
- Alternative access route

Resilience strategies that are applicable to this area and would provide improved protection from erosion include:

- Living shorelines
- Juniper avenue breakwater

Although stormwater flooding is not the highest risk hazard, some risk from stormwater flooding is present. Resilience strategies that are applicable to this area and would provide improved protection from stormwater flooding include:

- Stormwater outfall backflow prevention
- Impervious surface removal / reduction
- Bioretention basin / rain garden
- Stormwater system improvements
- Additional temporary stormwater storage / subsurface infiltration basin
- Green roofs

Table 5-1. Resilience Options as Applicable to Priority Areas

Resilience Option	Type of Hazard Protection	Priority Area				
		Bridge Street North	Planters Street	Osgood-Arbella-Bridge	Webb Street	Bay View - Columbus
Stormwater Outfall Backflow Prevention	Coastal	x		x	x	x
Impervious Surface Removal/Reduction	Stormwater	x	x	x	x	x
Bioretention Basin/Rain Garden	Stormwater	x				x
Stormwater System Improvements	Stormwater	x		x	x	x
Alternative Access Route (Island Ave)	Coastal / Stormwater					x
Additional Temporary Stormwater Storage/Subsurface Infiltration Basin	Stormwater				x	x
Living Shorelines	Erosion		x		x	x
Elevate Existing Seawall/Shoreline Height Increase	Coastal			x		x
Building Elevation	Coastal / Stormwater			x	x	
Building Acquisition	Coastal / Stormwater			x	x	
New Levee/Berm	Coastal	x	x	x	x	
Green Roofs	Stormwater	x	x	x	x	x
Harbor Barrier	Coastal		x	x	x	
Floodproofing Buildings	Coastal / Stormwater	x	x	x	x	x
Road Elevation	Coastal / Stormwater	x			x	x
Juniper Ave Breakwater	Erosion					x

6. Funding Opportunities

The availability of project funding is primarily determined by two factors: the ownership of the project site and the proposed activity. Projects on privately owned land are generally not eligible for government funding, while those owned by state or municipal entities have access to various grant programs. Specifically for MVP Action Grants, funding is designated for projects implemented on lands owned by government agencies, non-profit conservation organizations, or private lands with owner consent. To qualify for grants on privately owned property, a commitment letter from the owner(s) or evidence of future transfer to a committed entity is required. It is important to note that the City must have legal access to the project area before executing an MVP Action Grant or most other state or federal funding opportunities, which typically require projects to be conducted on publicly owned or accessible land.

Table 6-1 provides an overview of potential grant funding opportunities for resiliency tools, assisting the City in identifying and securing the necessary financial resources for implementing resilience projects. Understanding the requirements and limitations associated with funding opportunities empowers the City to strategically plan and pursue grants that align with its objectives of enhancing resilience in the study area.

Table 6-1. Funding Opportunities for Resilience Tools

Funding Opportunities	Source	Categories	Approximate Submission Month	Other Notes
Coastal Zone Management (CZM) Coastal Resilience Grants Program	State	Infrastructure, Stormwater Management, Environmental, Land Acquisition, Education, Emergency	June	Match Requirements
Massachusetts Emergency Management Agency (MEMA) Hazard Mitigation Assistance Grant Program	State	Infrastructure, Emergency, Land Acquisition	December	Maximum grant award amount: $15,000,000
National Fish and Wildlife Foundation (NFWF) National Coastal Resiliency Fund	Federal	Infrastructure, Environmental, Emergency, Education	June	No maximum award
Flood Mitigation Assistance Grant Program (FEMA)	Federal	Infrastructure, Environmental, Education	January	Match requirements
Federal Emergency Management Agency (FEMA) Building Resilient Infrastructure and Communities (BRIC)	Federal	Infrastructure	January	Maximum grant award amount: $2,000,000
Department of Environmental Protection (DEP) State Revolving Fund Loan (SRF) Clean Water Program	State	Infrastructure, Environmental, Stormwater	Revolving Fund	The standard terms are 2% interest for 20 years.
Division of Conservation Services Local Acquisitions for Natural Diversity (LAND) Grant	State	Land Acquisition	July	Maximum grant award amount: $500,000
Parkland Acquisitions and Renovations for Communities (PARC) Grant Program	State	Land Acquisition	July	Maximum grant award amount: $500,000
EEA Municipal Vulnerability Preparedness Municipal Vulnerability Preparedness (MVP) Action Grant	State	Infrastructure, Stormwater, Environmental, Education	May	Maximum grant award amount: $3,000,000
EEA Dams and Seawall Repair or Removal Program Grants	State	Infrastructure, Environmental, Emergency	February	Maximum grant award amount: $2,000,000
MassDEP 319 Grants	State	Education	November	-

7. Implementation Plan

To enhance resilience in the Collins Cove to Willows study area, a comprehensive conceptual planning-level implementation schedule was devised. The primary objective of this schedule is to outline the proposed timeline for the design and construction of flood risk reduction measures, encompassing both short-term and long-term strategies. Additionally, it considers important aspects such as community and stakeholder engagement, environmental compliance, and assessment, as well as the permitting process. The high-level schedule, as depicted in Figure 7-1, provides an overview of the proposed timeline for the various stages of implementation. It serves as a guide for project managers, stakeholders, and the local community, offering transparency and a clear understanding of the overall project timeline. It is important to note that the schedule may be subject to adjustments and modifications as the project progresses, considering factors such as unforeseen challenges, budgetary considerations, and regulatory requirements.

The first phase of the schedule focuses on community and stakeholder engagement. This stage is essential to ensure that the perspectives, concerns, and suggestions of the local community and other stakeholders are taken into consideration throughout the planning and implementation process. This phase involves organizing public meetings, workshops, and consultations to gather valuable input from residents, businesses, community organizations, and relevant agencies. It aims to foster collaboration and inclusivity, enabling a comprehensive understanding of the needs and aspirations of those directly impacted by flood risk.

Simultaneously, environmental compliance and assessment activities are undertaken to evaluate the potential impact of the flood risk reduction measures on the environment. These assessments involve studying the local ecology, hydrology, and other environmental factors to develop strategies that minimize any adverse effects on the ecosystem. This phase also entails compliance with relevant environmental regulations and obtaining necessary permits to ensure that the proposed measures align with environmental protection guidelines.

Once community engagement and environmental assessments are complete, the design phase commences. During this stage, experts and engineers utilize the gathered data, stakeholder input, and environmental considerations to develop detailed plans for flood risk reduction measures. These designs incorporate a combination of short-term and long-term strategies that aim to enhance the area's resilience against flooding events. Short-term measures may include improving drainage systems, or implementing early warning systems, while long-term measures could involve constructing floodwalls or creating green infrastructure to mitigate flood impacts. After the designs are finalized, the construction phase begins. This stage involves the physical implementation of the proposed flood risk reduction measures according to the approved designs.

The goal of following this conceptual schedule is to help establish a resilient framework that addresses flood risk in the Collins Cove to Willows study area. The integration of community engagement, environmental compliance, and careful planning results in the identification of flood risk reduction measures ultimately safeguard the community and its environment against the potential consequences of flooding events.

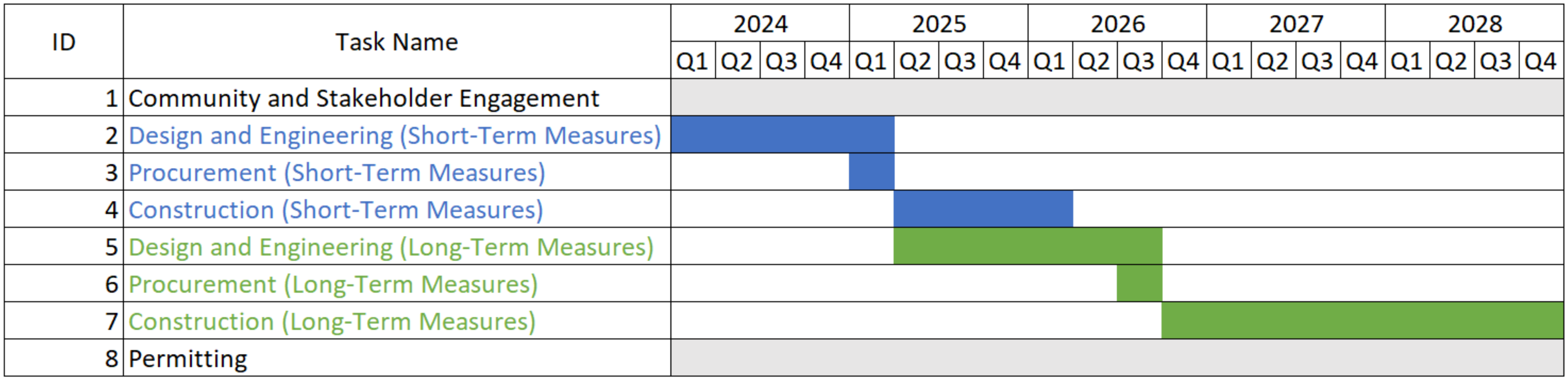

Figure 7-1: Conceptual Implementation Schedule

8. Conclusion

To increase the resilience of the Collins Cove to Willows Study Area, a combination of tools discussed in this report as part of the project addressed future flood risks resulting from climate change. When considering the feasibility of the implementation of appropriate protection measures for future predicted conditions, it is important to note that certain limitations may arise. Feasibility analyses may reveal that protection measures for beyond 2030 have limitations and adverse impacts on the quality of life for residents. For example, flood barriers may obstruct scenic views, limit access to water bodies, and create a sense of isolation as the community becomes increasingly surrounded by encroaching waters.

Decision-makers and stakeholders must weigh the benefits and trade-offs associated with different tools and strategies to achieve the desired level of resilience while considering the long-term sustainability and livability of the area. The implementation costs may also be prohibitive, which would warrant the consideration of regional or watershed-wide flood management strategies. Implementing comprehensive flood risk reduction measures and planning at a broader geographical scale allows for a more integrated and coordinated approach to address the challenges posed by more severe future flood events. Continuous monitoring, evaluation, adaptive management, and collaboration among stakeholders are vital to taking the next steps towards design development and implementation.

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Appendix A: Public Involvement and Community Engagement Materials

Collins Cove to Willows Resilience Study

Salem Sound Coastwatch Project Deliverables

Nov. 29th, 2022

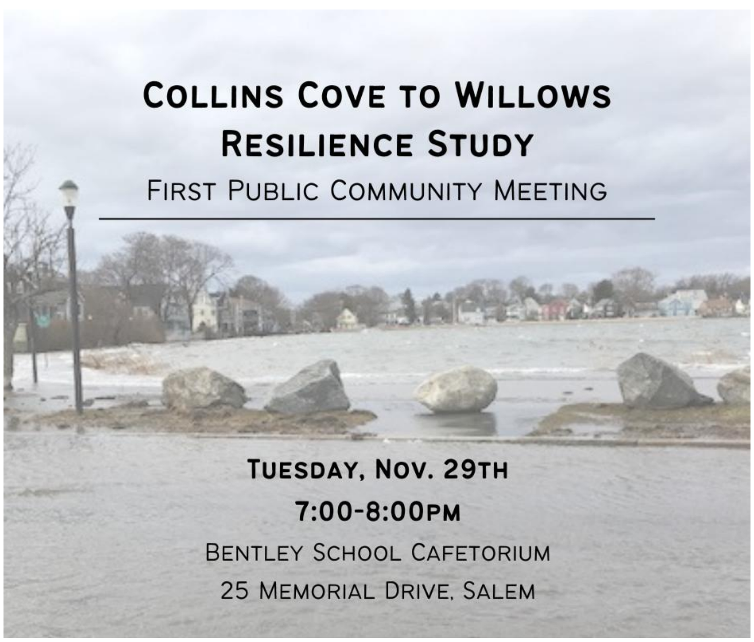
First Public Meeting

Summary: The first Public Meeting was held in-person at Bentley Academy Innovation School (Salem) and was well attended, with 49 community members providing their names, addresses, and contact information on the sign-in sheet, and a total estimated 70 participants attending throughout the night. The meeting began with Salem Sound Coastwatch (SSCW), the City of Salem, and AECOM representatives providing a presentation to the attendees that outlined the purpose of the workshop, an overview of the project objectives, and details of the study. Four large study area maps were displayed on easels at the front of the room and included the MC-FRM future flooding predictions, FEMA Flood Hazard Overlay, City-owned property, and the 1875 U.S. Coast and Geodetic Survey. Attendees enjoyed observing these displayed maps and conversed with each other and SSCW, the City, and AECOM representatives as they studied the maps. Participants were also asked to provide their observations of coastal and stormwater flooding on large, printed neighborhood maps around the room. Attendees placed numbered stickers on areas of concern and then wrote a description of the flooding on index cards. Overall, the meeting was well-received by community members, who appreciated the opportunity to learn about the study and provide their intimate knowledge of the area.

Recording of the First Public Meeting:

Collins Cove to Willows Resilience Study Workshop 11/29/22

Advertised on social media (Facebook, Instagram), SSCW SoundNet Newsletter, distributed by City Counsillors, and via the Public Input Page.



Join the City of Salem, AECOM, and Salem Sound Coastwatch to learn about this study and share your personal observations, photos, and stories of flooding in your neighborhood.

For more information, please visit: publicinput.com/CollinsCove2Willows

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Feb. 1st, 2023

History of Collins Cove Virtual Presentation

Summary: The History of Collins Cove presentation featured historian Sally McMurry and SSCW Director, Barbara Warren. It was held virtually on Feb. 1, 2023. Fifty-seven participants joined the presentation. Many were engaged and active in the chat, asking great follow-up questions that demonstrated their interest and desire to learn more. Overall, the presentation was well-received in the community.

Presentation Recording: https://vimeo.com/795311593

Advertised on social media (Facebook, Instagram) and our SoundNet Newsletter.

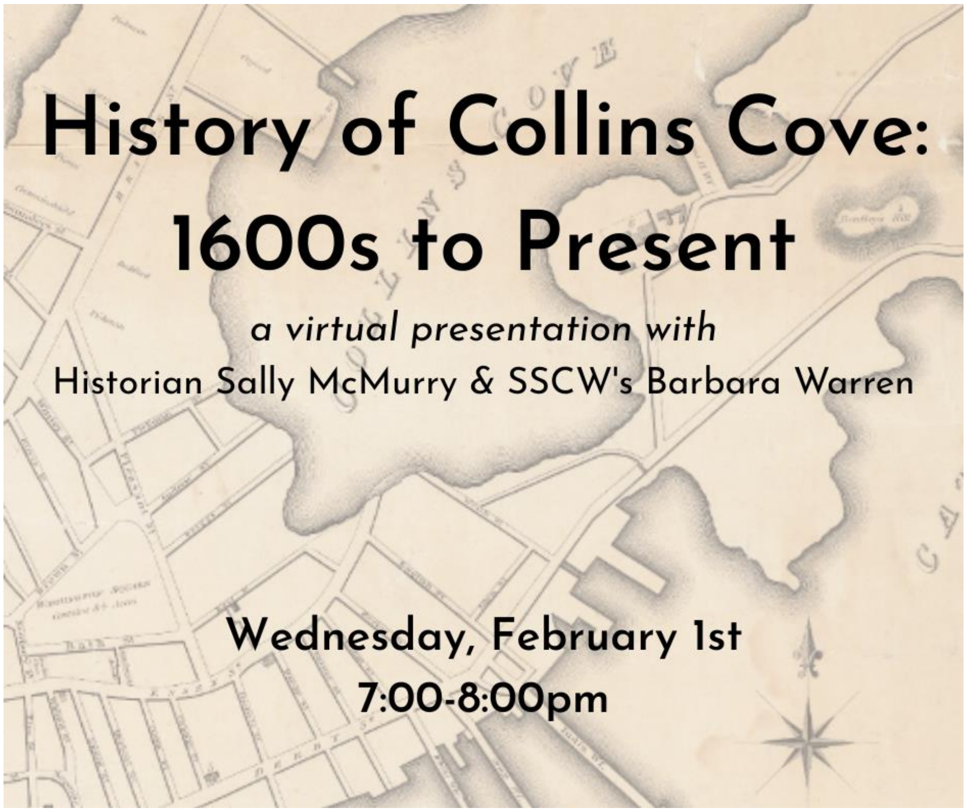
On Wednesday February 1st at 7pm, SSCW's Executive Director Barbara Warren and Sally McMurry, professor emerita of history at Pennsylvania State University and former president of the Agricultural History Society, will be virtually presenting a history of Collins Cove. They will be exploring how it has evolved alongside Salem's own development, from fishing, tanneries, rope walks, freight train tracks, poorfarm, and now recreation, and how Collins Cove's changing historical shoreline impacts residents to this today.

During the Collins Cove living shoreline project, Sally worked with SSCW to gather an immense amount of historical information. We are pleased to have this opportunity to share it with you.

Join through the Zoom link below:

https://us02web.zoom.us/j/84762921809...

#collinscove #salemma #salemsound #shoreline #community #history #development



Feb. 27th, 2023

Second Public Meeting

Summary: The Second Public Meeting was held virtually over Zoom, with 15 participants in attendance. The meeting included representatives from Salem Sound Coastwatch (SSCW), the City of Salem, and AECOM providing a recap of the first workshop and an update on the vulnerability and risk assessments and preliminary results. Possible resilience options were shared, as well as an update to the Emergency Response Plan. Finally, the meeting concluded by sharing resilience priorities and advertising upcoming engagement events. Throughout the presentation, participants were asked poll questions to gather additional information. The Q&A at the end of the meeting was active with participants asking thoughtful questions.

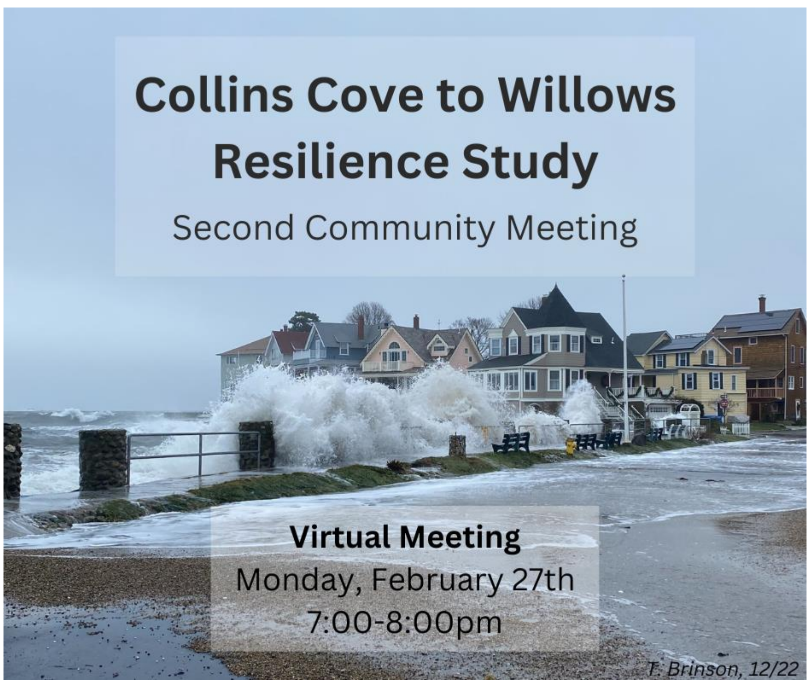
Recording of Second Public Meeting:

https://cityofsalem1-my.sharepoint.com/personal/dduhamel_salem_com/_layouts/15/stream.aspx?id=%2Fpersonal%2Fddu hamel%5Fsalem%5Fcom%2FDocuments%2FPublicShare%2FGMT20230228%2D000635%5FRecording%5F1920x1080%2Emp4&ga=1

Advertised on social media (Facebook, Instagram), SSCW SoundNet, and via the Public Input Page.

New date! Due to the Salem Mayoral Candidate Forum, the Collins Cove to Willows Second Community Meeting will be held virtually on Monday, February 27th 7:00-8:00pm.

Join the City of Salem, AECOM, and Salem Sound Coastwatch for the second workshop for the Collins Cove to Willows Resilience Study. Since our last community meeting, a coastal flood and stormwater simulation has been developed. This model uses your input, observations of the December 23rd storm, city infrastructure, and predictive models of future sea level rise and increased storms. We will share this and a Resilient Coastal Parks Toolkit to seek your feedback. Your ideas are key as we develop potential adaptation strategies to lessen flooding and improve emergency access during storm events. We look forward to hearing from you!



March 6th, 2023

Bridge Street Neighborhood Association Meeting

Summary: Alison Frye represented Salem Sound Coastwatch while attending the Bridge Street Neighborhood Association's meeting on March 6th, from 5:45-7:45pm. There, she shared updates about the Collins Cove to Willows Resilience Study as part of their "City News" segment. This announcement was shared with participants in person, over Zoom, and recorded. In addition to describing the goals of the current study and relevant findings, Alison also promoted the open community liaison position and announced upcoming engagement events. Neighborhood community members were active in asking questions about climate risks, future trends, and solutions to coastal flooding.

March 19th, 2023

Walk and Talk Event #1: Collins Cove

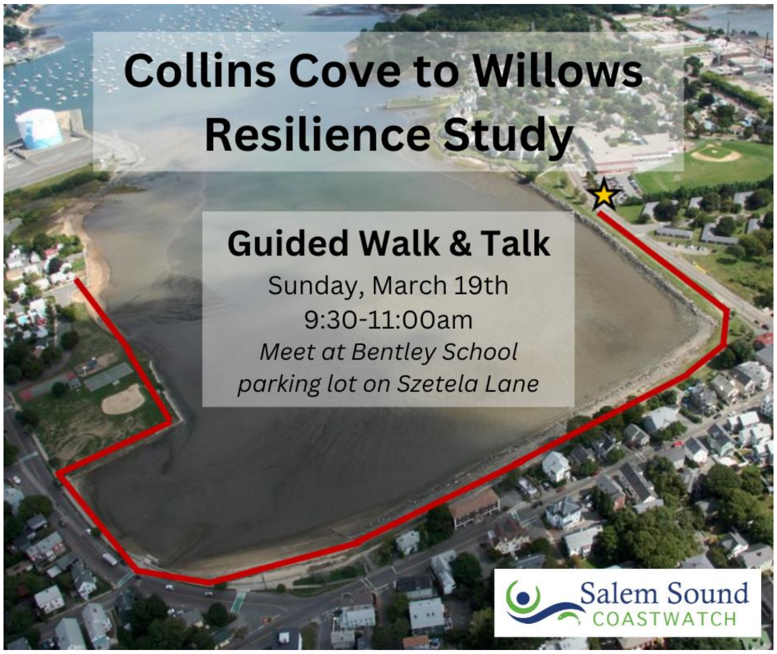
Summary: Barbara Warren and Alison Frye from Salem Sound Coastwatch led a guided Walk and Talk of the Collins Cove area, from Szetela Lane to Connors Road on Sunday, March 19th from 9:30-11:00am. Fifteen Collins Cove/Willows residents were in attendance, as well as Tyler Brinson from AECOM, who noted residents' experiences with flooding and explained stormwater solutions. Barbara (SSCW) provided an update to the study and discussed the history of the area, as well as explained the predicted future conditions. Printed displays of the historic shoreline (1850), flooding depth graphs at key locations, Chapter 91 designation areas, and 2030 flooding probability maps were shown to participants as supplemental material.

Photo from Walk and Talk:

Advertised on social media (Facebook and Instagram), our SoundNet Newsletter, and shared by City Counsillors/Neighborhood Groups.

"Join us for a Collins Cove Walk & Talk! Led by Salem Sound Coastwatch, we will walk around the cove discussing its history and flooding issues both now and in the future. Your ideas are key as we develop potential adaptation strategies to lessen flooding and improve emergency access during storm events. We look forward to seeing you!

No advance registration required. Please direct questions to Salem Sound Coastwatch info@salemsound.org or 978-741-7900."



April 16th, 2023

Walk & Talk #2: Willows Emergency Route

Summary: Salem Sound Coastwatch led a guided Walk and Talk of the Salem Willows area on April 16th from 4:00-5:15pm. Six Salem residents were in attendance, though only one was a resident of the Willows community. However, two other Willows residents were consulted while walking through the neighborhood. Barbara Warren and Alison Frye (SSCW) discussed the current and future flooding impacts of the area as we walked throughout the Willows neighborhood, from Steps Beach in Juniper Cove, to Juniper Beach, and Salem Willows Park. Printed displays of the Willows' historic shoreline (1850) and 2030 flooding probability maps were shown to participants as supplemental material. Residents reflected on the most recent storm (Dec. 2022) and the coastal and inland flooding that occurred as a result. The one Willows resident in attendance suggested a potential access route for emergency vehicles during a flooding event (Fig. 1), entering the Willows neighborhood from the Salem Willows Park by Island Avenue off Sutton Ave.

Fig. 1

Photos from Walk & Talk #2:


SLOW
CHILDREN
NO
PARKING

Advertised on social media (Facebook and Instagram), our SoundNet Newsletter, and distributed throughout the Willows Neighborhood Group.

Salem Willows Evacuation Route Walk & Talk:

Collins Cove to Willows Resilience Study

Sunday, April 16th, 4:00 - 5:00pm

Meet at Steps Beach, Salem Willows, 30 Bay View Ave., Salem

Join us for our second Walk & Talk for Salem's Collins Cove to Willows Resilience Study. We'll be discussing possible emergency evacuation route(s) for the Willows neighborhood during flooding events. Your ideas are key as potential strategies are developed to lessen flooding and improve emergency access during storm events. We look forward to seeing you! No advance registration required. Please direct questions to Salem Sound Coastwatch, info@salemsound.org or 978-741-7900.

May 23rd, 2023 – 7:00-8:30pm

Third Public Meeting

Location: Hybrid, Salem City Hall Annex or via Zoom

Summary: The format for the Third Public Meeting was hybrid, with the option to join either in-person at the Salem City Hall Annex or virtually via Zoom. Four participants attended in-person and 8 participants joined virtually, with a total of 12 attendees. Barbara Warren and Alison Frye, from Salem Sound Coastwatch, provided a sign-in sheet and name tags for in-person attendees. The meeting commenced with Deb Duhamel (City of Salem) describing the project objectives and providing a recap of the Second Public Meeting. Representatives from AECOM, Aaron Weieneth and Tyler Brinson, described the vulnerability and risk assessment results, which included coastal flooding, pluvial flooding from rainfall, and areas of coastal erosion. AECOM's Matthew Mullally described the scoring guidelines for priority areas and introduced the study's top five priority areas. Preliminary resilience options for each of the identified priority areas were introduced. Finally, the meeting concluded by sharing alternative access routes and describing next steps as the study is finalized. The Q&A at the end of the meeting was active with (mainly in-person) participants asking thoughtful questions, perusing the maps around the room, and providing valuable feedback with the presenters.

Recording of Presentation:

https://cityofsalem1-my.sharepoint.com/personal/dduhamel_salem_com/_layouts/15/stream.aspx?id=%2Fpersonal%2Fdduhamel%5Fsalem%5Fcom%2FDocuments%2FPublicShare%2FGMT20230523%2D230606%5FRecording%5F1920x1080%2Emp4&ga=1

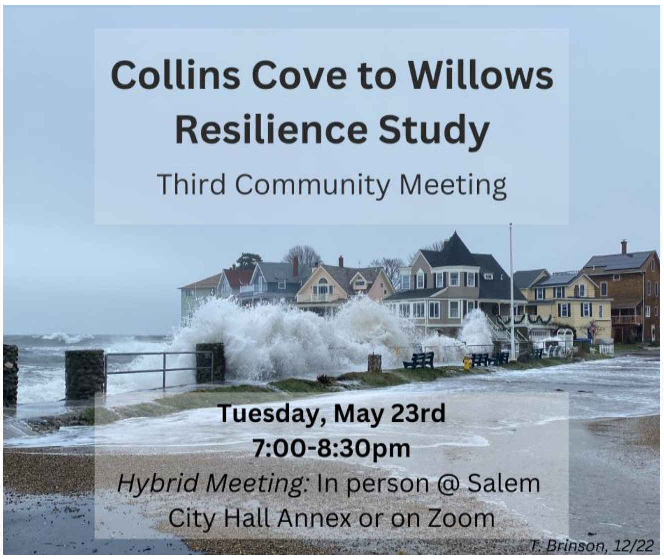
Advertised: Advertised on SSCW newsletter and social media (Facebook and Instagram). An e-mail blast was sent to previous public meeting attendees two weeks prior to and the day of the meeting. City Councilors shared SSCW social media posts. The meeting was also posted on City of Salem's Calendar and the study's Public Input Page.

"Join the City of Salem, AECOM, and Salem Sound Coastwatch for the third and final stakeholder workshop for the Collins Cove to Willows Resilience Study. We will share the progress since our last workshop, which includes final vulnerability assessment results for coastal and inland flooding and identification of potential adaptation strategies to address current and projected flooding in priority areas. Your feedback during the workshop will be used to refine the adaptation strategies that have been identified, as the City works to finalize the study by the end of June. We look forward to hearing from you!

Location: Hybrid. The meeting will be held in person on the first floor of the Salem City Hall Annex (98 Washington Street), with the option to join remotely via Zoom.

Please visit the Public Input page for more information: https://publicinput.com/u8500

Zoom link to join the meeting remotely:
https://us02web.zoom.us/j/86010197148?pwd=M1YwSEJvejJ5NjFDRjE2SGFJTm5jUT09



August 30th, 2023 – 5:00-6:15pm

Collins Cove Cleanup

Location: Collins Cove, Salem

Summary: Salem Sound Coastwatch's Barbara Warren and Alison Frye, with support from Chris Marchese and Susan Marsh, led a public Coastsweep Cleanup of the Collins Cove waterfront on Wednesday, August 30th. Twenty-three volunteers attended to collect marine debris and other coastal trash from the Collins Cove playground, beach, and living shoreline. They learned about the issues with marine debris, the vital habitat that this area provides, and discussed the risks associated with flooding, as part of the Collins Cove to Willows Resilience Study. In total, 225 lbs of trash was collected from this area, including the living shoreline blanket, food wrappers, small plastic pieces, and cigarette butts.

This event was advertised on SSCW's social media (Facebook and Instagram), our SoundNet Newsletter, and distributed via the public Coastsweep website.

November 5th, 2023 – 9:30-11:00am

Leefort Terrace Community Meeting

Location: Leefort Terrace Housing Authority, Salem

Summary: Salem Sound Coastwatch's Barbara Warren and Alison Frye led a community meeting for residents of Leefort Terrace, a State Public Housing development for elderly and disabled households adjacent to Collins Cove in Salem, MA. The President of the Leefort Terrace Organization, Shannon Bailey, was hired to help SSCW distribute the invitations, set up the community room, and share her story on the Story Map. Eight members of the Leefort Terrace Community and one neighbor (Forrester Street) attended the meeting to learn about the project. Everyone who attended had no prior knowledge of the Collins Cove to Willows Resilience Study, but some had local flooding experiences. Barbara and Alison projected the completed Story Map and discussed each section. Participants were fascinated by the history of Collins Cove, the "Stories from your Neighbors" section, and projected flood risk in the area. In exchange for their attendance, participants were given gift cards to Target and Market Basket at the conclusion of the meeting. Participants were very appreciative of being informed and expressed interest in remaining engaged with the project.

This event was advertised by distributing flyers door-to-door, as well as mailing flyers to residents.

Appendix B: Emergency Response Plan

Collins Cove to Willows Resilience Study: Emergency Response Plan

1. Introduction

The Salem Comprehensive Emergency Management Plan (CEMP) serves as a vital guidance document that establishes a comprehensive framework for coordinating emergency management activities within the city. It plays a crucial role in facilitating a coordinated multi-agency response to various events that require support, ensuring effective preparedness and response measures. The City of Salem relies on this plan to make informed decisions swiftly and execute efficient evacuation or shelter-in-place procedures in the event of an emergency.

As part of the ongoing Collins Cove to Willows Resilience Study, a review of the CEMP was conducted to evaluate its efficacy and identify potential areas for improvement in emergency response actions within the study area (Figure 1). The focus of the evaluation was on emergencies occurring during coastal flooding events that are expected to be influenced by future impacts of climate change.

This memorandum provides a summary of the current CEMP, outlining its key components, strategies, and procedures. It also presents recommendations for potential additions or modifications to the plan, specifically addressing the anticipated challenges and vulnerabilities associated with climate change in the study area. These recommendations aim to strengthen the city's emergency response capabilities, incorporate climate resilience considerations, and improve the safety and well-being of residents and critical infrastructure in the study area.

By addressing the need for revisions and incorporating climate change considerations into the CEMP, the City of Salem can proactively adapt its emergency response protocols to the evolving risks posed by coastal flooding and other climate-related hazards (e.g., rain, wind). The proposed additions outlined in this memorandum will serve as valuable insights and recommendations for enhancing the effectiveness and resilience of the CEMP, ultimately improving the city's ability to respond promptly and effectively to emergencies within the study area and safeguard the community's welfare.

2. Comprehensive Emergency Management Plan Review

The CEMP provides a framework to the City's Chief Municipal Official and other community officials on which timely and effective decisions can be based. Government and community leaders are often forced to make decisions with limited time in highly dynamic settings to safeguard lives, property, and the environment. The framework of the CEMP was primarily based on the Federal Response Plan (FRP), the National Response Framework (NRF) and National Preparedness Goal. It is compliant with the National Incident Management System, Incident Command System (NIMS/ICS), and the Comprehensive Preparedness Guide (CPG) 101 Version 2 national standards. The CEMP is also compatible with the state-level, Massachusetts CEMP. The CEMP establishes centralized command and control (C2), communication, real-time Situation Reports (SITREPS), progress metrics, and available resources to be used during emergency response situations.

The CEMP addresses two types of response scenarios:

- Planned or Anticipated Incidents: Incidents that can be planned for in advance such as a hurricane, a winter storm, extreme temperatures, major crowd events or VIP visits, etc., and;
- Immediate Response Incidents: such as a major traffic accident, airplane crash, tornado, hurricane, earthquake, fire, hazmat incident, terrorism, active shooter, kidnapping, major crime, etc.

Figure 1: Map of Salem Sound and the Study Area

To address these scenarios, the CEMP includes checklists to provide guidance for emergency events. One such checklist is an Execution Checklist in Attachment 5 which details each Emergency Management Director (EMD) expected action in an emergency event. Another checklist for the Department of Public Works is provided in Attachment 8, which provides expected action in the case of an emergency event.

Although these checklists are important parts of the CEMP, it is important to recognize that the CEMP is not meant to solely be a detailed emergency checklist or "quick action" guide. Instead, it is a preparedness document that requires understanding and regular exercise during non-emergency conditions. Fundamentally, it is a planning document meant to provide a framework, guidance, and insight into city wide strategic thinking and decision-making as it relates to the phases of emergency management.

The CEMP contains detailed information about the situation (e.g., population, language, geography, infrastructure) so that users can use their knowledge of the city during an emergency. The CEMP also details plans to work with neighboring communities and response organizations to integrate actions. For coastal hazards, the CEMP describes the threat of coastal flooding, storms, and hurricanes, but does not provide detailed action plans for specific storms.

3. Flooding Locations

Considering the entire study area is in a Zone A hurricane evacuation zone as defined by the state (Figure 2), it is critical that proper preparation is in place. To support a comprehensive assessment of vulnerable locations and their inclusion in the Comprehensive Emergency Management Plan (CEMP), the review process performed for this Emergency Response Plan involved consulting the Massachusetts Coast Flood Risk Model (MC-FRM; Woods Hole Group, 2021). This model served as a valuable resource, providing essential information and insights regarding areas prone to flooding in the study area. The model's GIS output layers were mapped along with evacuation routes and points to identify potential gaps or discrepancies in the emergency response strategies for vulnerable locations could be identified.

Figure 3 illustrates the MC-FRM annual flooding probabilities of the study area under existing conditions and identifies the nearest currently defined evacuation route (i.e., Bridge Street) in addition to the primary and secondary roads (i.e., Derby Street and Webb Street) located in the study area. Figure 4 shows the 2030 annual flooding probabilities in the study area. The only designated evacuation route in the study area is Bridge Street. This area would see an increase in annual flooding probability up to 5% in 2030.

The primary and secondary roads like Derby Street and Webb Street are likely to see greater annual flooding probabilities in the near future, including an increase to 100% in 2030 for a portion of Debry Street—meaning this portion of Derby Street could be flooded by coastal waters at least once a year in the 2030s. Flooding of these routes could result in an emergency if the Salem Neck, Willows, and Winter Island cannot be accessed by traditional methods of transportation by residents and emergency responders. Furthermore, as ground elevations decrease moving southwest along the Neck, the likelihood of flooding along transportation routes increases. The low point along Derby Street occurs at elevation 5.5 feet (NAVD88). According to water depth data retrieved from MC-FRM, predicted water depths at the lower elevations on Derby Street for a 1% annual frequency storm (i.e., 100-year storm event) are predicted to see depths up to 1.0 feet for present day (Figure 5), and increase further in 2030 up to 2.5 feet (Figure 6).

A hydrologic and hydraulic (H&H) model developed for the City of Salem as part of the Collins Cove to Willows Coastal Resilience Study was used to identify flooding from rainfall events. Model scenarios are shown in Figure 7 and Figure 8 for present day and 2030 respectively to evaluate the impacts from multiple types of flooding events for each planning horizon. As shown in Figure 7 and Figure 8, the extent and depth of flooding progressively increases from present day to 2030. The flooding reflects similar inundation locations to what is shown by the MC-FRM flood depths (Figure 5 and Figure 6), with major flooding occurring along Szetela Lane, Webb Street and Derby Street.

Figure 2: Massachusetts Hurricane Evacuation Zones in the Study Area. The Letters Are Dependent on Predicted Inundation (i.e., Zone A Floods Before Zone B) (MEMA, 2023).

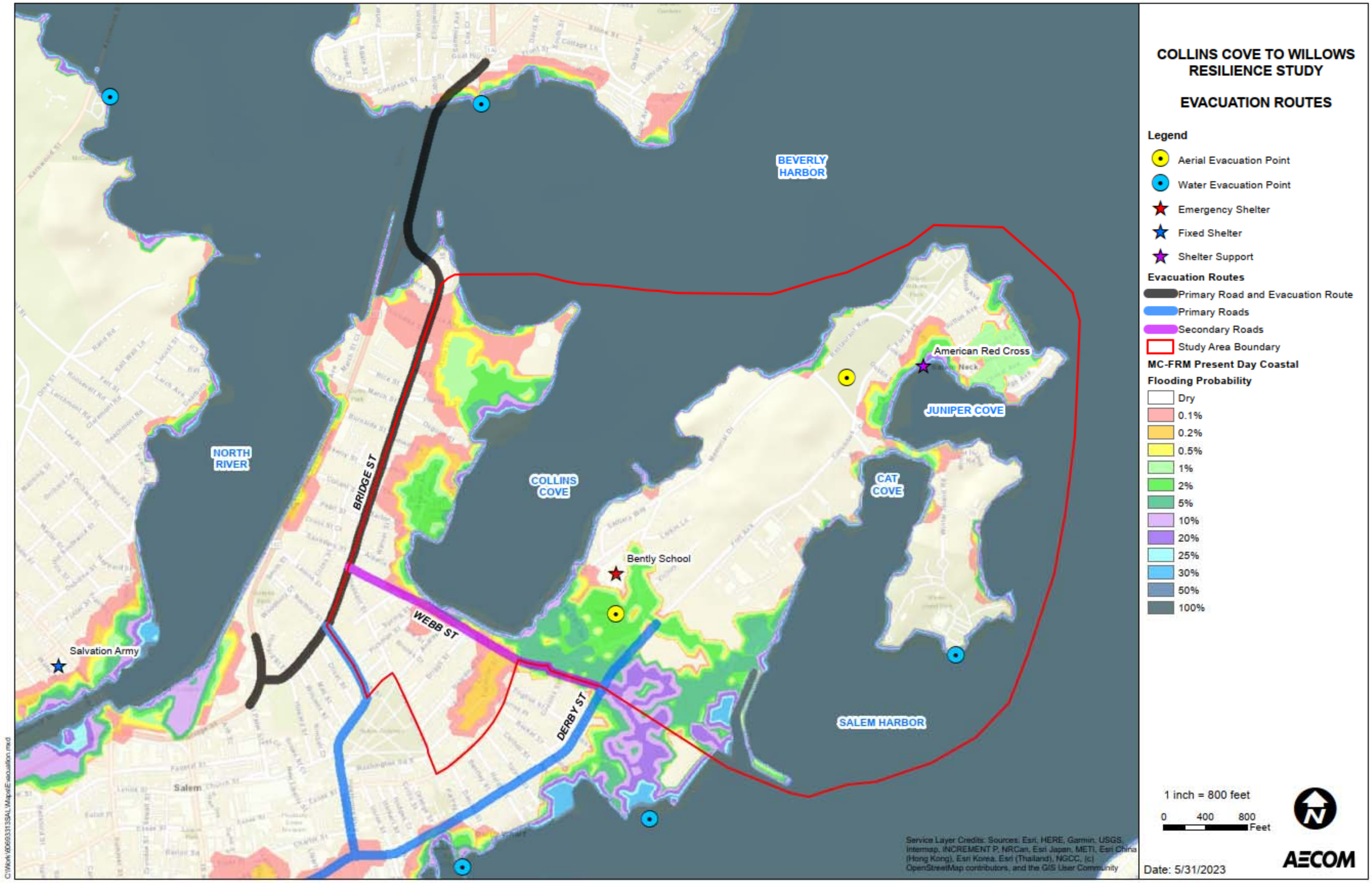


Figure 3: Critical Infrastructure and Present-Day MC-FRM Annual Probability of Flooding

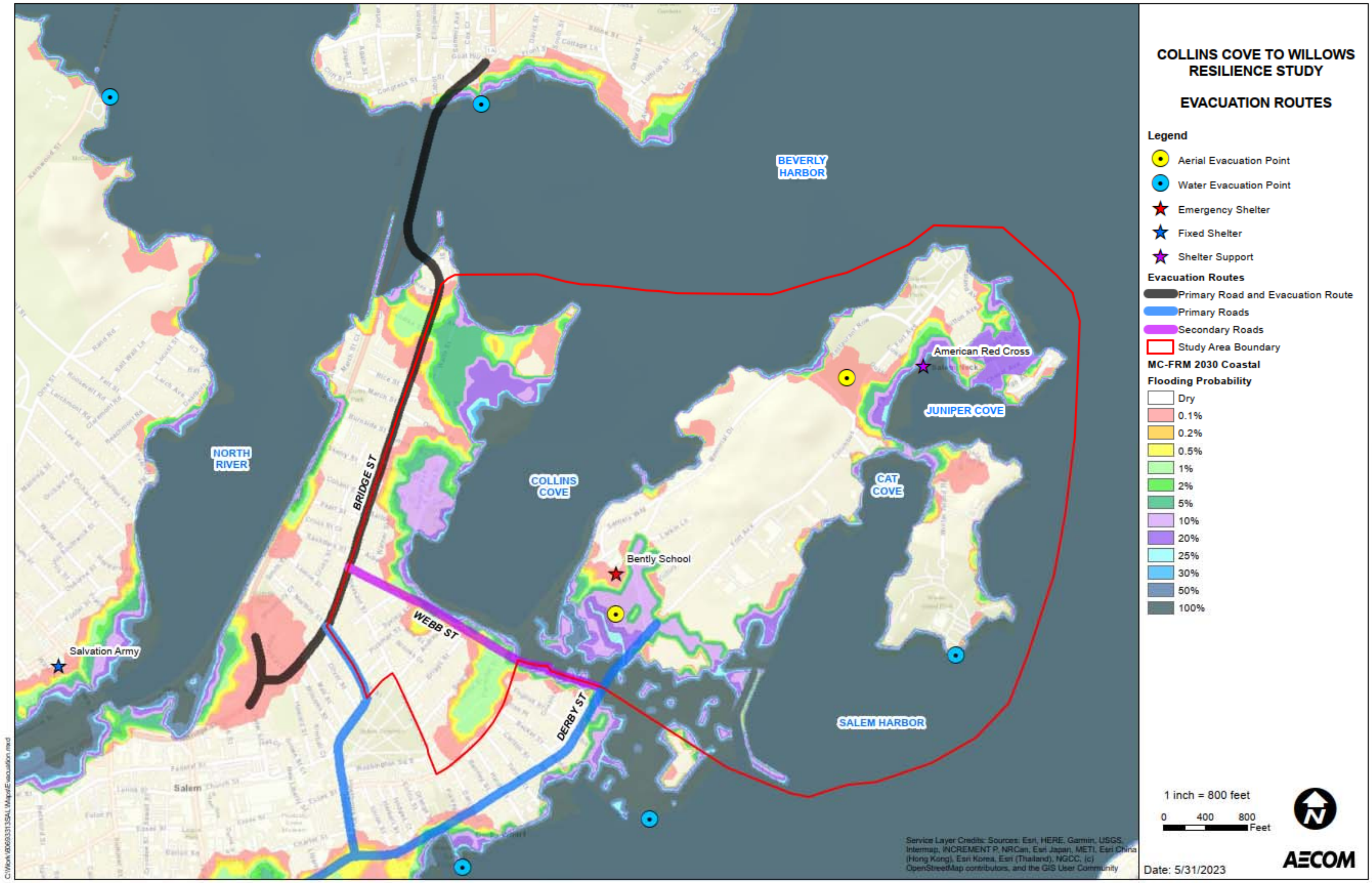


Figure 4: Critical Infrastructure and 2030 MC-FRM Annual Probability of Flooding

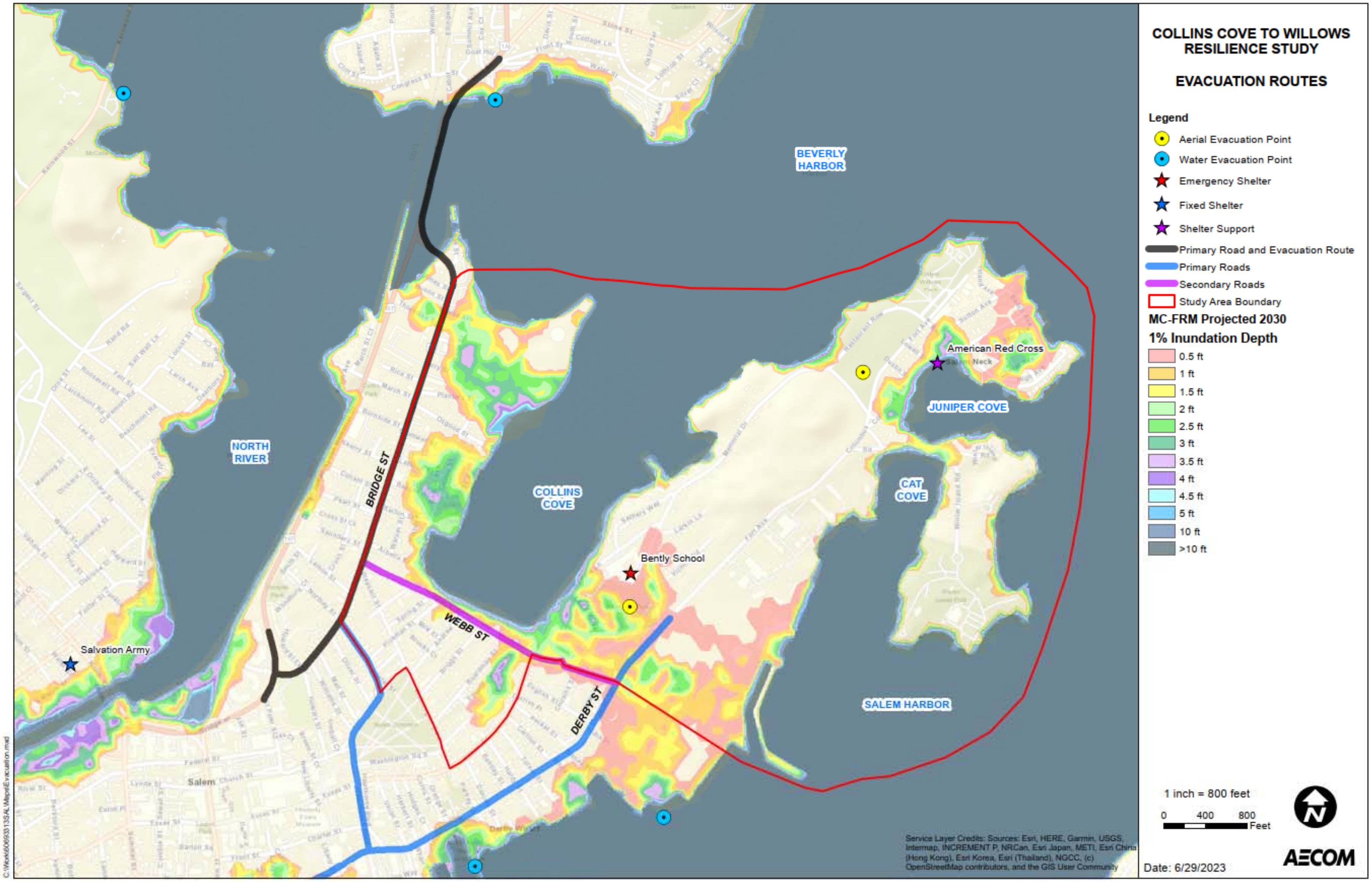


Figure 5. Critical Infrastructure and Present-Day MC-FRM Inundation Depth of the 1% ACFEP Flood Event

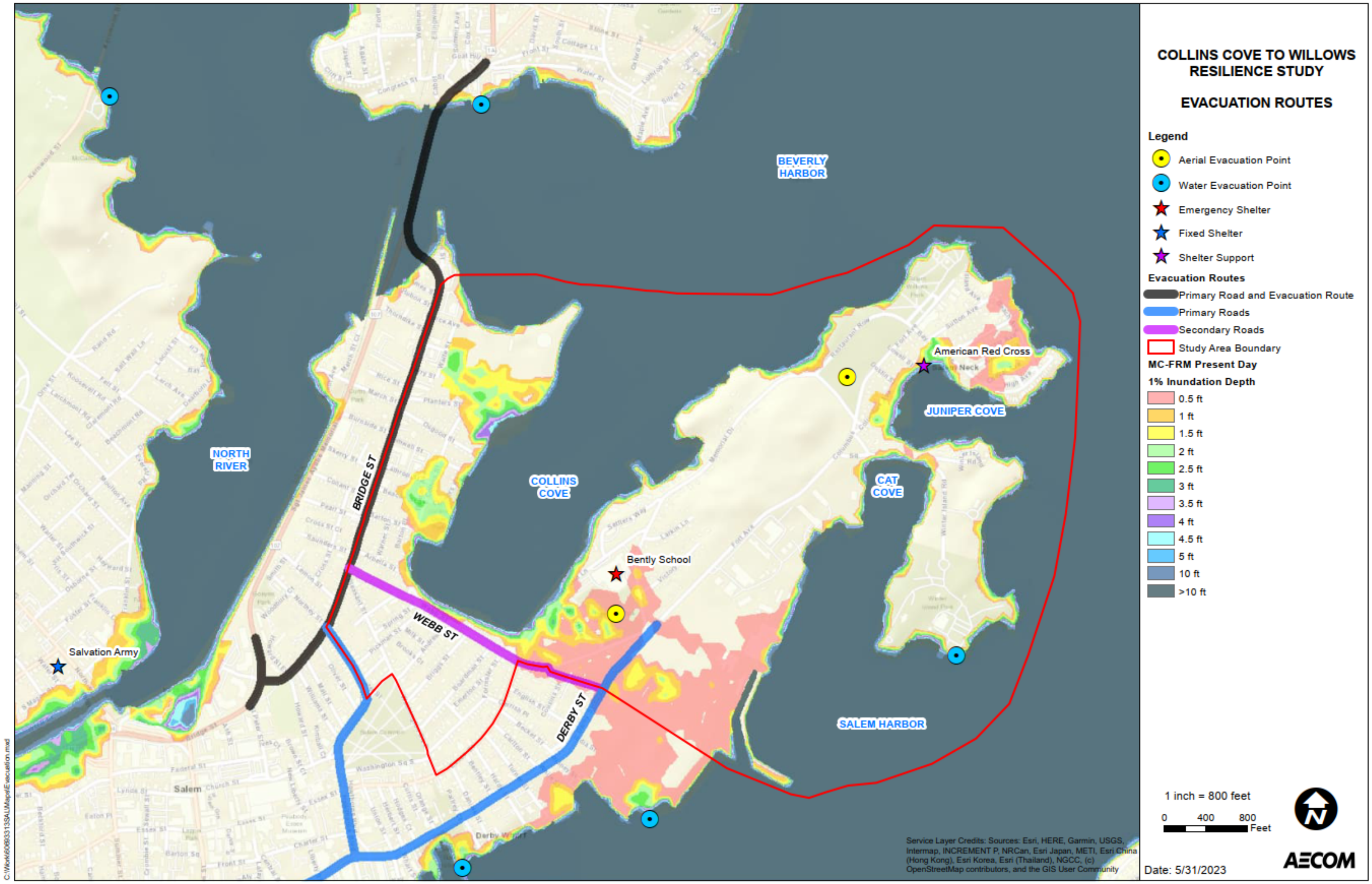


Figure 6. Critical Infrastructure and 2030 MC-FRM Inundation Depth of the 1% ACFEP Flood Event

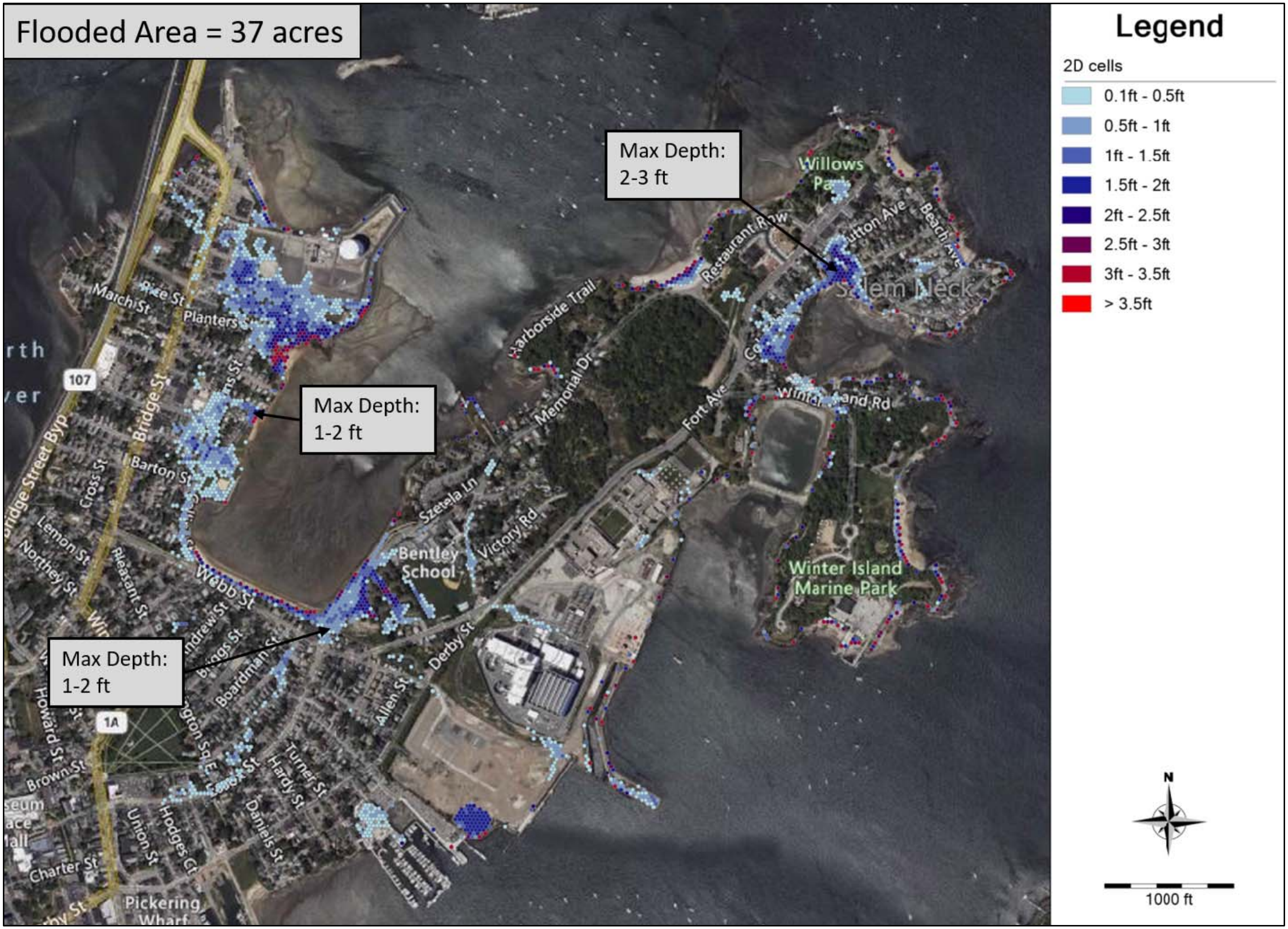


Figure 7. Present Day (2008) 1% Storm Surge with Present Day 5-Year 24-Hour Precipitation Event

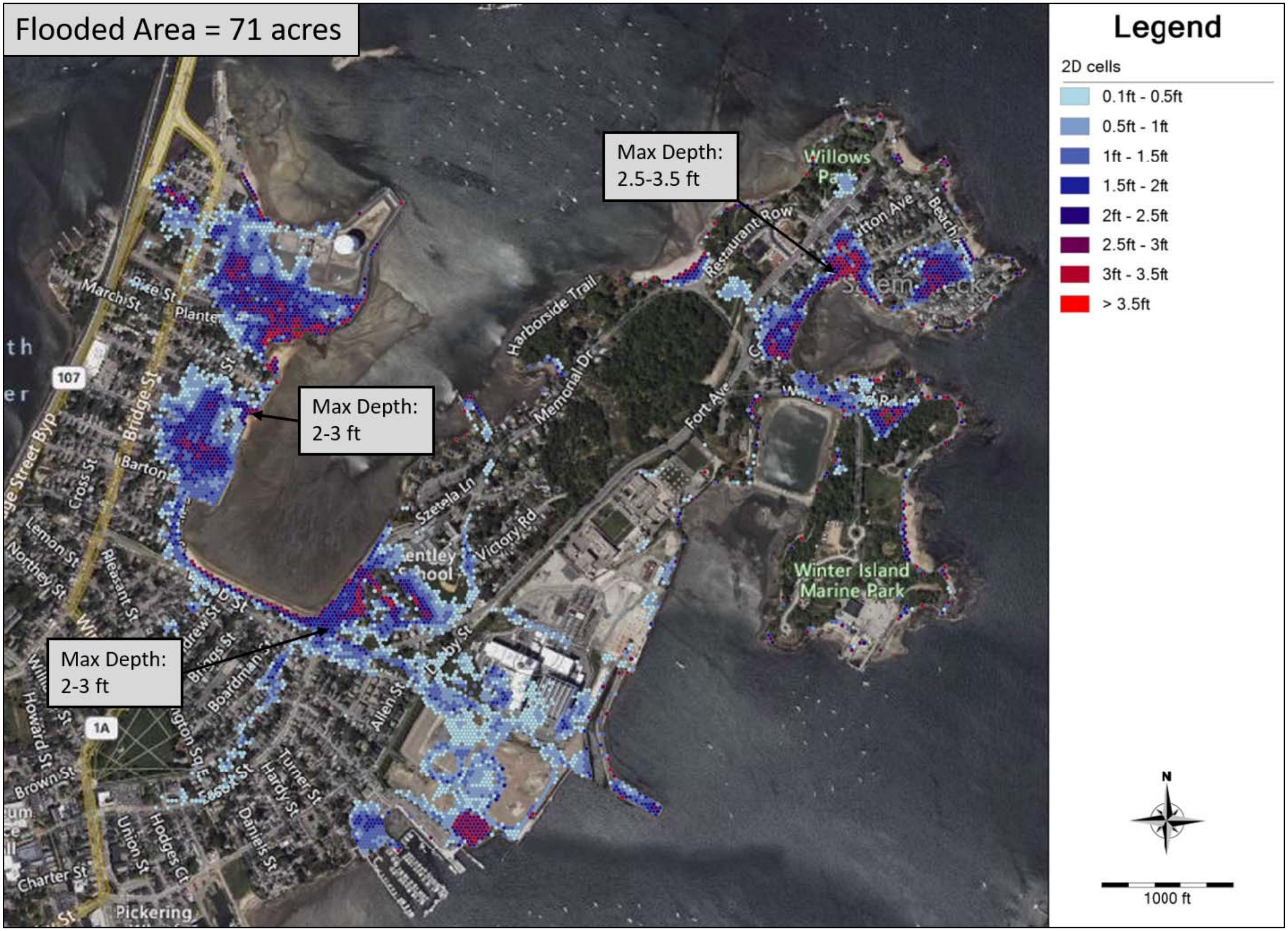


Figure 8. 2030 1% Storm Surge with 2030 5-Year 24-Hour Precipitation Event

4. Recommendations

In coordination with the current feasibility study addressing natural hazards resulting from future climate change, recommendations to include in the CEMP focus on addressing impacts of future sea level rise and flooding in the Collins Cove to Willows study area. Sea level rise and flooding can affect evacuation routes, emergency support to the area, and shelter-in-place effectiveness.

There are currently six evacuation shelters in Salem (Table 1 and Figure 9) as well as designated evacuation route networks (Figure 10). As shown in Figure 3 through Figure 5 and discussed in Section 3, the primary and secondary routes leaving Salem Neck (Derby Street and Webb Street; Figure 3) would be severely impacted by a flooding event. Bridge street would also see some inundation, especially in 2030. While additional air and water transportation measures are in place, these options are not always possible during a storm event and might not be sufficient for the population at risk. Other contingency language could be included in the CEMP to detail alternative routes if roads are impassable. It is recommended that the City review and revise the CEMP to include flood maps (e.g., Figure 3 through Figure 5) to provide insight into what parts of the study area are projected to flood now and in the future.

Also, the CEMP includes descriptions of natural hazards that would prompt an evacuation (e.g., winter storms, coastal flooding, hurricanes) with some decision-making guidance for the Department of Public Works. However, the document does not provide detail as to what measures should be taken during a specific type or classification of storm or flooding event. It is recommended the City consider adding a decision point or language in both documents that would classify an upcoming storm event and based on the classification and communicate specific shelter-in-place or evacuation decisions to parts of the city and study area.

An example of a flood classification system is that of Valley Water in Santa Clara County, CA (Figure 11). Although the language is catered towards river flooding, a similar classification system can provide guidance for precipitation and coastal flooding, with specific condition levels defined for observed or anticipated flood depths. These condition levels can be coupled with severity descriptions (Figure 12), which are also utilized by the National Weather Service, to trigger specific action by City officials. It is recommended that an appropriate classification system be incorporated into the CEMP, to properly define winds and water levels of a forecasted storm.

Finally, it is recommended that the City add language regarding how and when shelter-in-place or evacuation directives will be communicated to the residents in the Collins Cove to Willows study area. The information could be communicated via a reverse 911 alert in advance of a forecasted storm event to allow residents ample time to prepare for either shelter-in-place or evacuation conditions, as is done currently in some parts of Salem. The populations in these areas will need to be informed of a flooding event with as much buffer time as possible as it will impact their ability to leave the area.

Table 1: Evacuation Shelters

Emergency Shelter Locations	Ward	Address	Availability
Bentley Charter School	1	25 Memorial Drive Salem, MA. 01970	Emergency
Bates Elementary School	2, 6	53 Liberty Hill Avenue Salem, MA. 01970	Emergency
Saltonstall School	5, 7	211 Lafayette Street Salem, MA. 01970	Emergency
Salem High School	3, 4	77 Wilson Street Salem, MA. 01970	Emergency
Salvation Army	NA	93 North Street Salem, MA. 01970	Fixed Year Round
Lifebridge	NA	56 Margin Street Salem, MA. 01970	Fixed Year Round

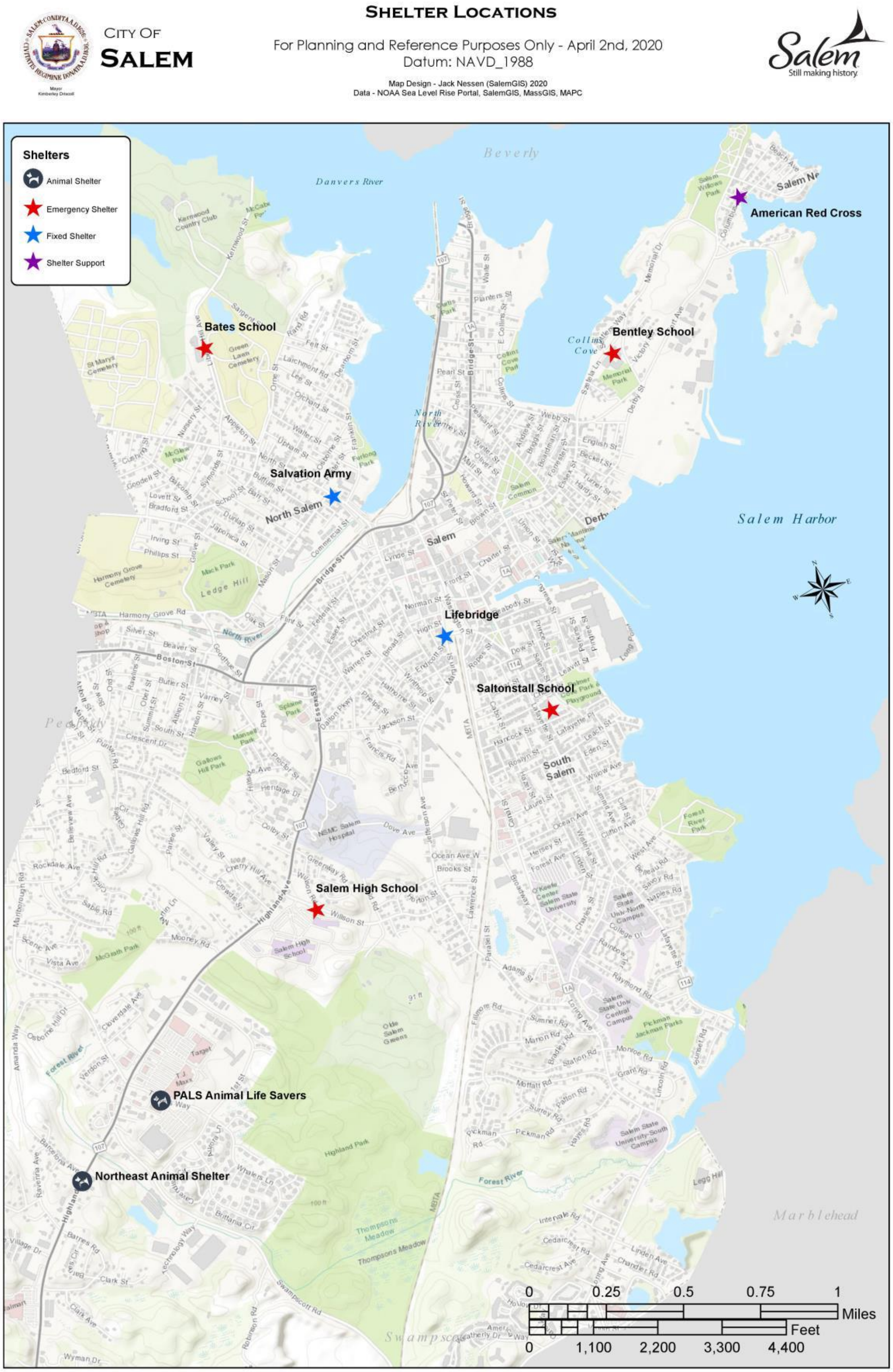


Figure 9: Shelter Locations (City of Salem, 2022).

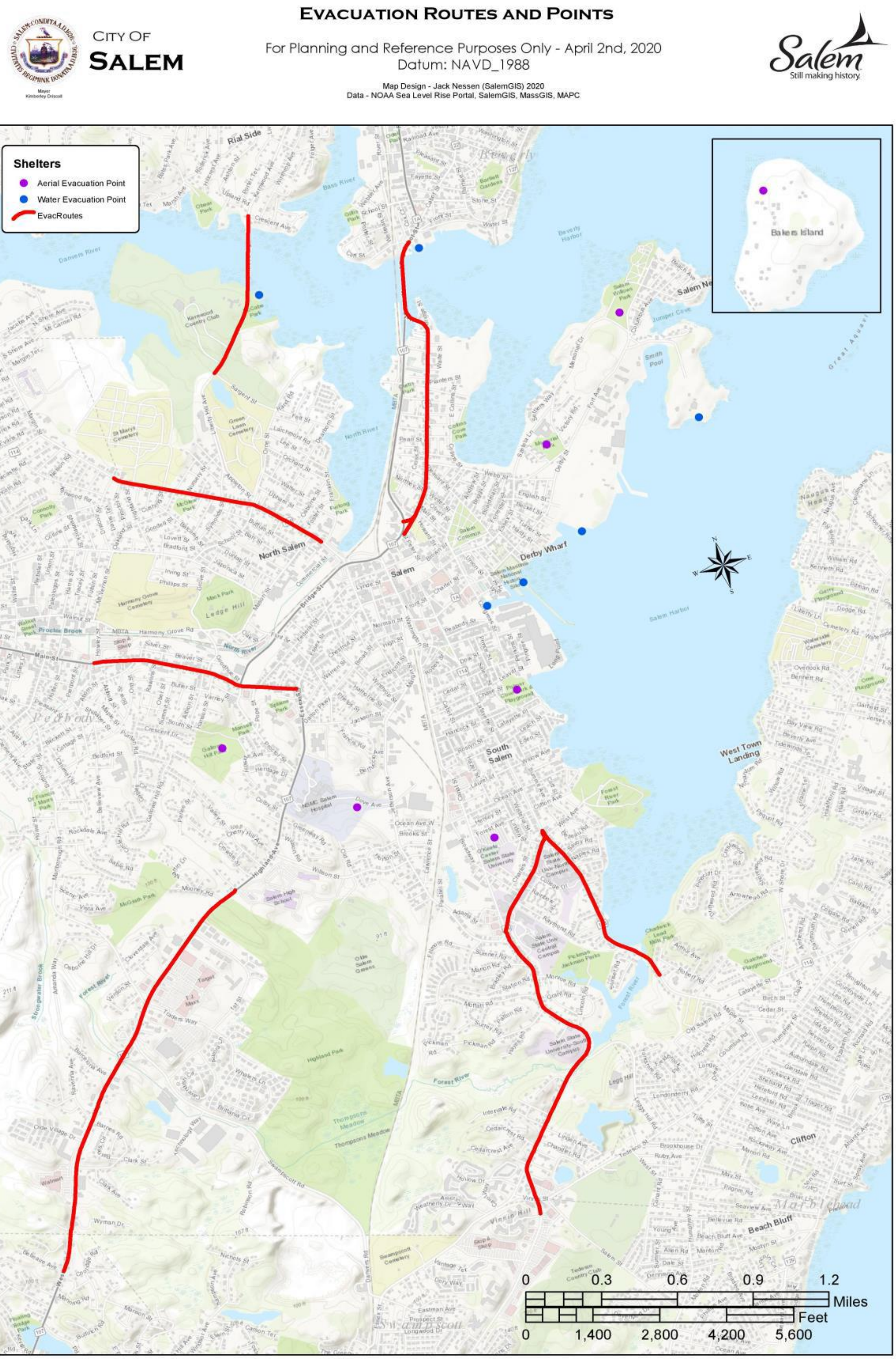


Figure 10: Evacuation Route Network (City of Salem, 2022).

Classification System Before and during events the level of risk for flooding		
Color	**Condition Level**	**Defined as**
Green	**Preparedness**—This stage is the base stage of readiness that will be the typical condition throughout most of the year.	• Flood stage (Minor Flooding or greater) or 90% to 100% of Design stage is not estimated within the next 72 hours or • Measured stream depth is below 70% of Flood stage or Design stage.
Yellow	**Monitoring**—This condition is variable and requires more intense monitoring and heightened level of alertness. Minimal staff in each Stakeholder's Emergency Operations Center (EOC) may be activated. A virtual MAC could be activcated. An informal EOC Action Plan (AP) could be initiated if activated.	• Stream depth is estimated to reach Flood stage or 90% to 100% of Design stage in 72 hours or more or, • Measured stream depth is at 50% to 70% of Flood stage or 70% to 90% of Design stage or, • For areas that are controlled purely by storm drain runoff (flashy systems), the stream depth is estimated to reach Flood stage or near Design Stage within 24 hours.
Orange	**Watch**—The Stakeholders' would increase staff in their EOCs, if they had been activated, and a MAC facility could also be established. If activated, a formal EOC AP will be drafted.	• Stream depth is estimated to reach Flood stage or greater than Design stage within 24 to 72 hours or, • Measured stream depths are at 70% to 100% of Flood stage, or • Measured stream depths are at 90% to 100% of Design stage, or • For areas that are controlled purely by storm drain runoff (flashy systems), the stream depth is estimated to reach flood stage or greater than Design stage within 6 to 12 hours.
Red	**Warning**—This is a more urgent situation. The Stakeholders' EOC may be activated along with a MAC that would monitor the situation, providing notifications and responding according to a written AP. Often for smaller watersheds with flashy creeks, an EOC or MAC will not be opened until the storm event is occurring.	• Flood stage or greater than Design stage or is occuring or is estimated to occur within 24 hours, or • Measured stream depths are 100% or greater than Flood stage, or • Measured stream depths are greater than Design stage, or • For areas that are controlled purely by storm drain runoff (flashy systems), the stream depth is estimated to reach flood stage or greater than Design stage within minutes/hours or is occurring.

Figure 11: Example Flood Risk Classification System (Valley Water, 2023).

Classification System Flood severity descriptions used by both agencies		
Color	**Flood Severity**	**Defined as**
Yellow	**Action**	An established gauge height which when reached by a rising stream, lake, or reservoir represents the level where action is taken in preparation for possible significant hydrologic activity.
Orange	**Minor Flooding**	Minimal or no property damage, but possibly some public threat (e.g., inundation of roads).
Red	**Moderate Flooding**	Some inundation of structures and roads near stream, evacuations of people and/or transfer of property to higher elevations.
Purple	**Major Flooding**	Extensive inundation of structures and roads, significant evacuations of people and/or transfer of property to higher elevations.

Figure 12: Flood Severity Descriptions (Valley Water, 2023).

5. Conclusion

The City of Salem's CEMP acts as a comprehensive guide and decision support tool during an emergency event. This review provided additional considerations related to future climate change affecting the Collins Cove to Willows study area that could be incorporated into the plan to increase resilience and readiness. Recommendations are based on MC-FRM predicted sea level rise/coastal flooding and H&H modeled flooding and include:

1. Reviewing the impact that future flooding will have on access to transportation routes, public transportation, and evacuation centers.
2. Including flood maps detailing what evacuation routes and shelters will be impacted by storms of pre-defined classifications.
3. Adding language to the CEMP specific to flooding so that it is considered early in the emergency response process.

Flooding could increase risk to the study area population if either the area becomes isolated and no longer has access to emergency services in a shelter-in-place scenario, or evacuation cannot proceed in an evacuation scenario. These considerations should be reviewed to help promote resilience in an emergency event caused or exacerbated by future climate change conditions.

6. References

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Woods Hole Group, 2021. Massachusetts Coast Flood Risk Model.

Appendix C: Vulnerability Assessment and Modeling Results Memo

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250 Apollo Drive
Chelmsford, MA 01824
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Project name:
Collins Cove to Willows Resilience Study

Project ref:
60693313

To:
Deb Duhamel, City of Salem

From:
AECOM

CC:
File

Date:
June 29, 2023

Task 3: Vulnerability Assessment and Modeling Results Memorandum

Table of Contents

Table of Figures

Table of Tables

1. Introduction

As a coastal city with a rich maritime history, Salem, Massachusetts is likely to experience the impacts of climate change. Rising sea levels, more frequent and intense storms, and coastal erosion can all have significant impacts on Salem's infrastructure, economy, and community. To prepare for these challenges and maintain a resilient coastal community, assessing the city's vulnerabilities to coastal hazards and identifying opportunities to improve resilience are important. This Memorandum is part of the third task in a five-task resilience study that will provide the City of Salem with an overview of historic, present, and future vulnerability and risk due to sea level rise (SLR), storm surge, and precipitation-based (stormwater) flooding in the Collins Cove to Willows area, which will be referred to as the Study Area. This is the second of three technical memoranda that will be provided as part of the resilience study. The findings from the three technical memoranda as well as three stakeholder meetings will be summarized in a final report which will also include an implementation plan identifying prioritized action items, responsibilities, potential funding sources, and implementation challenges to address coastal vulnerabilities in the Study Area. This Memorandum provides an overview of the most recent projections for future climate conditions followed by a discussion of existing and future climate hazard vulnerability as well as their potential impacts to the Study Area.

2. Summary of Study Area and Identification of Key Resources

The project Study Area is located along Beverly Harbor and Salem Harbor within Salem Sound, roughly 15 miles north of Boston, which is within the larger Massachusetts Bay (Figure 1). Salem Sound opens to the Atlantic Ocean, facing eastward, with Cape Ann to the north and Boston Harbor to the South. The Danvers, North, and Bass Rivers all empty into the Beverly Channel which runs along the northern end of the site. The Sound itself is a mixed drowned river estuary with a semi-diurnal tide (8.5 feet range; Figure 2). The Sound is relatively shallow with a mean depth of 30 feet mean high water (MHW) (Jerome et al., 1967).

Figure 1. Map of Salem Sound and the Study Area

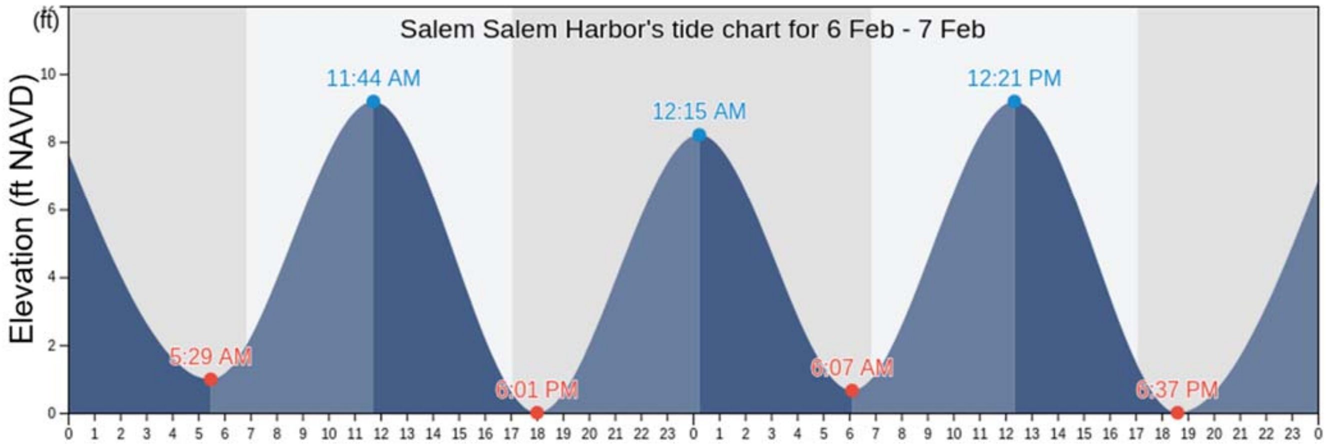

Figure 2. Tidal Range of Salem Harbor (tideforecast.com; Accessed 2/6/2023)

The hydrodynamics in Salem Sound are tidally dominated, which exchanges approximately 70% of its water over the course a tidal cycle (Jerome et al., 1967). Depths in the sound are relatively shallow, with the largest depths offshore exceeding 40 feet NAVD88. In the Study Area, many of the coves are relatively shallow, with Collins Cove averaging 3 to 6 feet NAVD88, and even shallower for most of the southeastern portion. The opening of Collins Cove to the Atlantic Ocean is rather narrow (0.9 miles across). There are no fresh water flows directly into the coves included in the Study Area, with all the water coming from the larger Salem Sound.

Most of the coves on the western side of the Willows do not often experience major wave action, due to the narrow opening to Salem Sound and shallow waters. Only occasionally do the shores of the cove experience erosion, due to exceptionally high tides and extreme storms, especially hurricanes and nor'easters (Figure 3). However, some of the coves along the eastern side of the WIllows are more exposed to ocean swell. For example, Winter Island is relatively exposed to easterly swell from the Atlantic Ocean. An example of a unique storm which had significant impacts to the Study Area shoreline occurred on October 17, 2019 when a "bomb cyclone" struck Salem with northeasterly winds and waves that propagated into Collins Cove. Increased sea levels will exacerbate the impacts of these storms to these coves which historically did not see significant impacts from waves.

Figure 3. Wave Breaking on Juniper Beach Seawall During a 2013 Nor'easter (Swin, 2013)

In Salem Sound, much of the coast is characterized by rocky shorelines with pocket beaches such as Dead Horse Beach (Figure 4). The shoreline can be classified at the surface as either bedrock or a mixture of sand and gravel locations (Figure 5). The existing geology of Salem consists of glacial deposits and underlying rock outcrops, characterized by pocket beaches flanked by headlands. Sub-bottom geophysical surveys of Salem Sound reveal glaciomarine sediments overlying bedrock (Boglione and Hubeny, 2014). The bottom of some of the coves, such as Collins Cove and Dead Horse Beach (Figure 6), are primarily composed of mud flats. While not currently present, this area historically had salt marshes (Figure 7).

The headlands of Salem Neck are often composed of boulder and cobble deposits left after the finer clays, silts, and sands have been washed away. These erosion-resistant deposits act as natural armor, thereby reducing or in some cases eliminating the landform as a sediment source to down-drift beaches. In addition, extensive shoreline reinforcement (e.g., sea walls, revetments) has eliminated many sources of sediment supply. Although the sections of rocky shoreline found in the Sound are often at a higher elevation and less vulnerable to erosion than other parts of the coast, the small pocket beaches and coastal marshlands can present areas of localized vulnerability to shoreline change (Burkett et al., 2001). Understanding of these qualitative aspects of the geologic evolution of the coastal system and anthropogenic impacts can define boundaries of the littoral system and aid management efforts.

Figure 4. Dead Horse Beach with Rocky Ledge and Adjacent Sandy Beach (Compass, 2021)

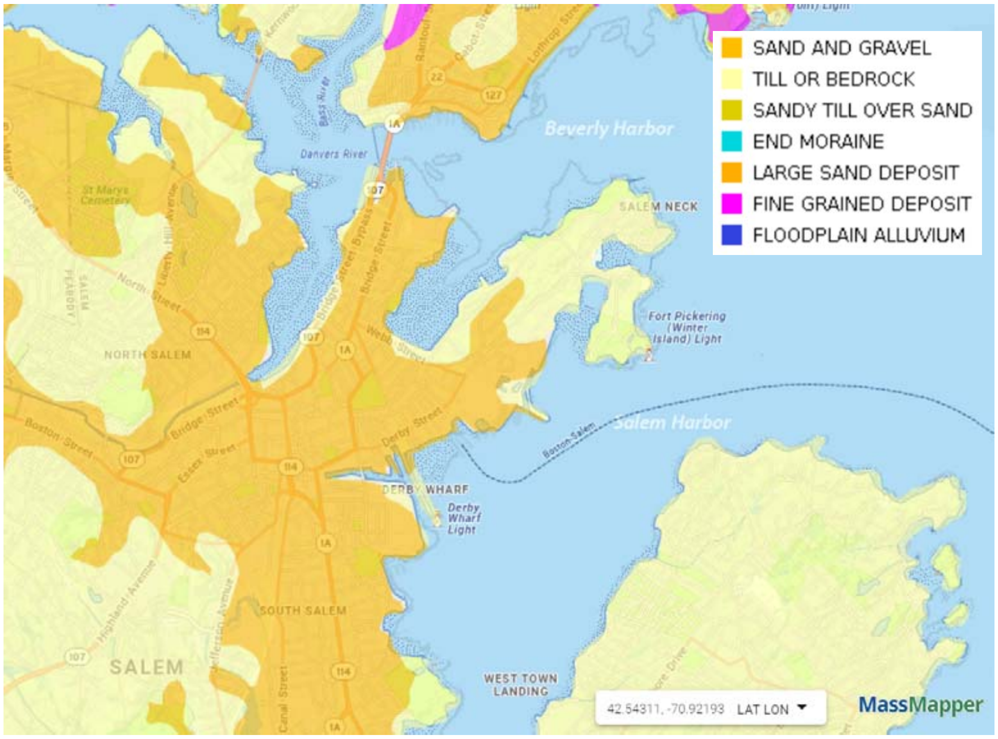

Figure 5. Surficial Geology Composition of Study Area (MORIS GIS, Accessed 2/6/2023)

Figure 6. Mud Flats of Dead Horse Beach at Low Tide (Foursquare City Guide, 2019)

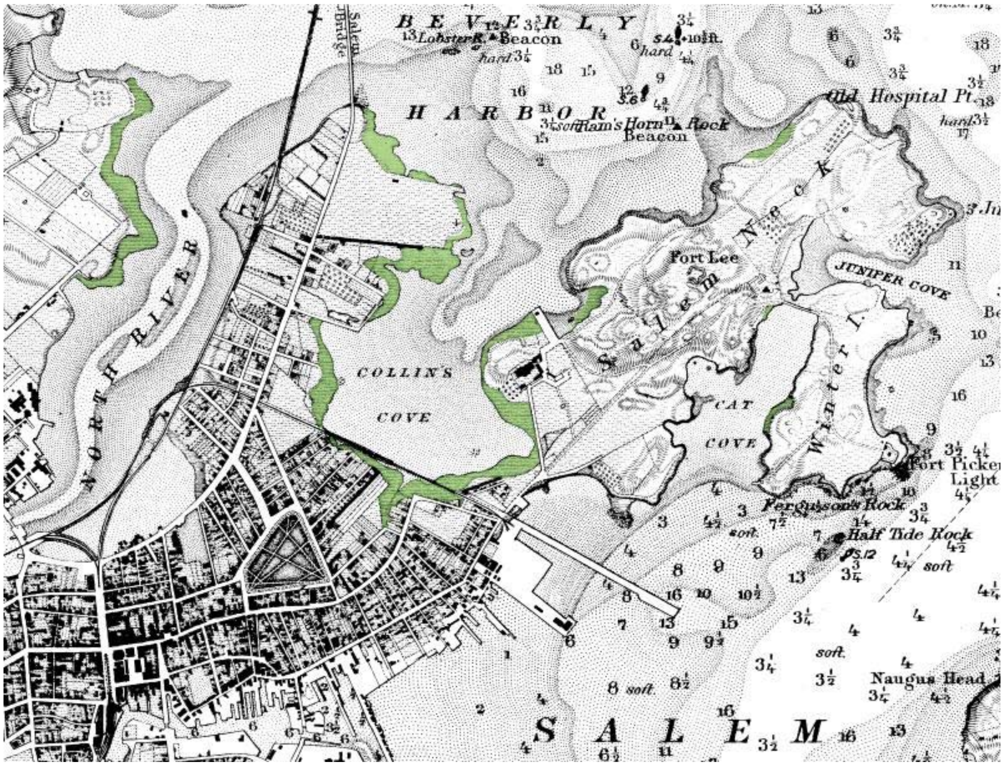

Figure 7. 19th Century Map of Salem with Historical Salt Marsh identified in Green (Salem Sound Coastwatch, 2021)

In addition to the environmental conditions of the Study Area, highlighting the key resources in the Study Area, including both infrastructural and societal assets is important. Several previous studies, notably the City of Salem's 2020 Community Resilience Building Workshop and the Hazard Mitigation Plan 2020 Update identified and prioritized some of the key resources. Based on the evaluation of these past reports, some of the vulnerable key assets of the Study Area that may require action in the short- and/or long-term can be summarized into the following groups:

- Emergency/First Responder Facilities and Vehicles/Equipment (i.e., fire department)
- Transportation Infrastructure (Roads/Bridges/MBTA)
- Private Utilities/Infrastructure including Facilities (gas, electric, telecommunications)
- Public Utilities and Associated Facilities/Infrastructure (water, sewer, drainage)
- Recreation and Conservation Land
- Schools
- Shoreline Protection Structures
- Historical Resources

Specific features and assets were prioritized in the 2020 Community Resilience Building Workshop and identified by the individuals that live in the community. Also, the Hazard Mitigation Plan 2020 Update identified 180 pieces of critical infrastructure located in hazard areas in Salem. According to the 2020 Update, critical infrastructure includes facilities that are important for disaster response and evacuation (such as emergency operations centers, fire stations, pump stations, etc.) and facilities where additional assistance might be needed during an emergency (such as nursing homes, elderly housing, daycare centers, etc.). Recreational resources including municipally owned parks and beaches were also identified as critical infrastructure. Of these 180 Critical Infrastructure located in Hazard Areas identified by the plan,15 are located in the Study Area. Table 1 lists the critical facilities located in the Study Area categorized by use type. The critical facilities identified in

Figure 8 correspond to the numbered items included in Figure 9. The list has been amended per input from the City for the purposes of this study, including the addition of two facilities: Memorial Park and the Salem Harbormaster.

The 2009 Massachusetts Coastal Infrastructure Inventory and Assessment Project catalogued coastal structures to better understand the state's vulnerability to coastal hazards. Twenty-four structures from that inventory are in the Study Area and are listed in Table 2 and included in Figure 8. There are also seventy-two structures located on private property in the Study Area. These private property structures are not included in Figure 8 due to this project's focus on city or state-owned property and infrastructure (e.g., the living shoreline in Collins Cove as shown in Figure 9). The impact of natural hazards and climate stressors on these critical infrastructure and coastal structures is discussed in Sections 5 and 6.

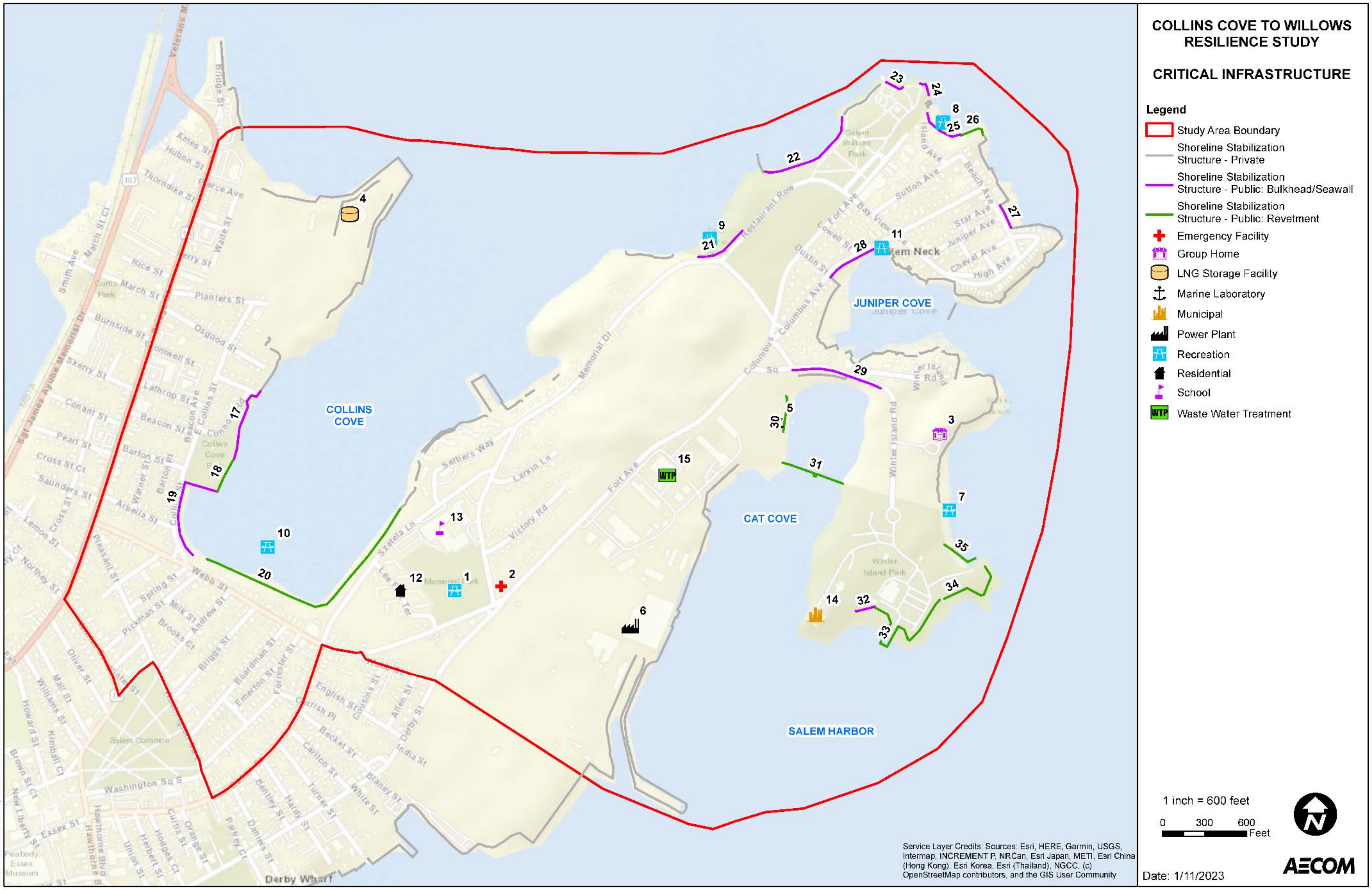

Figure 8. Critical Infrastructure and Shoreline Stabilization Structures

Table 1. Critical Infrastructure in Hazard Areas located in the Study Area (adapted in 2022 from the Hazard Mitigation Plan 2020 Update)

ID*	Name	Type	Address
1	Memorial Park	Recreation / Municipal	25 Memorial Dr
2	Salem Fire Department	Emergency Facility	29 Fort Ave.
3	Plummer Youth Promise	Group Home	37 Winter Island Rd.
4	National Grid Energy Delivery	LNG Storage Facility	20 Pierce Ave
5	Division of Marine Fisheries Cat Cove Marine Lab	Marine Laboratory	92 Fort Ave.
6	Salem Harbor Station	Power Plant	24 Fort Ave
7	Waikiki Beach	Recreation / Municipal	Winter Island Rd
8	Willows Pier Beach	Recreation / Municipal	Restaurant Row
9	Dead Horse Beach	Recreation / Municipal	Salem Willows Park
10	Collins Cove Beach	Recreation / Municipal	Webb Street
11	Steps Beach	Recreation / Municipal	Columbus Ave
12	Leefort Terrace	Residential / Municipal	Essex St.
13	Bentley Academy Innovation School and Salem Early Childhood School	School	25 Memorial Dr
14	Salem Harbormaster	Municipal	51 Winter Island Rd
15	South Essex Sewage District	Waste Water Treatment	50 Fort Ave.

*The ID numbers in this column correspond to the numbering in Figure 8.

Figure 9. Example of a Natural Shore Protection Structure in the Study Area (December 2022)

Table 2. Inventory of Publicly Owned Major Coastal Structures and Elevations (MA Coastal Infrastructure Inventory, Accessed 2/6/2023)

ID*	Location #	Structure Type	Geographic Location	Elevation (ft NAVD88)	Height Above Beach (ft)
17	064-036-000-473-400	Bulkhead/Seawall	8 Conners Rd, Collins Cove Park	13	2
17	064-036-000-473-300	Revetment/Seawall	Collins St at Conners Rd, Collins Cove Park	13	6
18	064-036-000-473-200	Revetment	Collins St at Barton St, Collins Cove Park	13	8
19	064-036-000-473-100	Bulkhead/Seawall	Collins St at Barton St, Collins Cove Park	13	9
19	064-036-000-474-100	Bulkhead/Seawall	Collins Street at Arbella St	13	7
20	064-042-000-003-100	Revetment	Szetela Lane at Collins St	13	3
21	064-045-000-089-100	Bulkhead/ Seawall	Memorial Dr at Restaurant Row, Willows Park, Dead Horse Beach	12	1
22	064-045-000-089-200	Bulkhead/ Seawall	Restaurant Row at Fort Ave, Willows Park	12	6
23	064-045-000-089-300	Bulkhead/ Seawall	Restaurant Row at Fort Ave, Willows Park near Yacht Club	12	4
24	064-045-000-089-400	Bulkhead/ Seawall	Restaurant Row at Fort Ave, Willows Park near pier	15	5
24	064-045-000-089-500	Bulkhead/ Seawall	Restaurant Row at Fort Ave, Willows Park near pier	15	8
25	064-045-000-089-600	Bulkhead/ Seawall	Restaurant Row at Fort Ave, Willows Park Front Beach	15	10
26	064-045-000-089-700	Revetment	Restaurant Row at Fort Ave, Willows Park	15	10
27	064-045-000-079-100	Bulkhead/ Seawall	Beach Avenue at Juniper Ave	15	3
28	064-044-000-146-100	Bulkhead/ Seawall	61 Columbus Avenue	10	5
30	064-044-000-037-400	Revetment	Fort Ave at Winter Is Rd, Cat Cove	10	15
29	064-044-000-037-300	Bulkhead/Seawall	4 Winter Is Rd, Cat Cove	10	5
29	064-044-000-037-200	Bulkhead/Seawall	4 Winter Is Rd, Cat Cove	10	12
31	064-044-000-037-100	Groin/Jetty	Fort Ave at Winter Is Rd, Salem State College Marine La	11	10
35	064-043-000-001-500	Revetment	Winter Island Rd end	18	8

34	064-043-000-001-400	Revetment	Winter Island Rd end	18	6
33	064-043-000-001-300	Revetment	Winter Island Rd end	14	10
32	064-043-000-001-100	Bulkhead/Seawall	Winter Island Rd end	13	5
33	064-043-000-001-200	Revetment	Winter Island Rd end	13	5

*The ID numbers in this column correspond to the numbering in Figure 8.

3. Identification of Data Sources and Relevant Climate Projections

3.1 Coastal Flooding

The primary data source used to evaluate existing and future coastal flood vulnerability is the Massachusetts Coast Flood Risk Model (MC-FRM)—developed through a collaboration between the Woods Hole Group, the Massachusetts Department of Transportation (MassDOT), and the University of Massachusetts Boston. The MC-FRM Level 1 data, which was released in late 2020, include annual coastal flood exceedance probability (ACFEP) rasters for four time horizons (present day (2008), 2030, 2050, and 2070) and depth of flooding at three ACFEP levels (1%, 0.5%, and 0.1%). Additionally Level 2 data, released in late 2021/early 2022, consists of water surface elevations (WSE), maximum wave heights (H_{max}), and design flood elevations (DFE) for six ACFEP levels (1%, 2%, 5%, 0.5%, 0.2%, and 0.1%) and three time horizons (2030, 2050, and 2070).[1] WSEs are provided in units of feet relative to the vertical datum NAVD88 as rasters in floating-point format rounded to the nearest tenth of a foot. H_{max} values are statistically calculated based upon the significant wave height (H_s) outputs from the MC-FRM and are provided in units of feet as rasters in floating-point format rounded to the nearest tenth of a foot. DFEs were calculated based on the WSE and H_{max} rasters calculated for each ACFEP and are provided in units of feet referenced to the NAVD88 datum as rasters in floating-point format rounded to the nearest tenth of a foot. While these DFEs include wave effects, they do not directly account for freeboard and other possible design considerations and thus should not be used directly in design despite what the product name may imply. Tidal benchmarks were also developed for 2030, 2050, and 2070 and include mean higher high water (MHHW), mean high water (MHW), mean tide level (MTL), mean low water (MLW), and mean lower low water (MLLW) (Woods Hole Group, 2021).

3.2 Sea Level Rise

The latest SLR projections were released by NOAA in 2022. The NOAA 2022 projections build upon the NOAA 2017 projections to provide updated timing and exceedance probabilities based on different levels of climate change. The 2022 report is based on the latest generation of general circulation models and the Intergovernmental Panel on Climate Change's Sixth Assessment Report (AR6) and uses a longer observational record as well as an improved understanding of ice-sheet dynamical processes. The NOAA 2022 projections include the 17^{th}, 50^{th}, and 83^{rd} percentile levels for each of five scenarios: low, intermediate-low, intermediate, intermediate-high, and high. Each scenario describes future potential conditions to support decision-making under conditions of uncertainty. Table 3 shows the 50^{th} percentile relative SLR values for Boston.

Table 3. 50^{th} Percentile Relative Sea Level Rise Values for Boston (NOAA, 2022)

Year	SLR Scenario (50^{th} Percentile)				
	Low (ft)	Intermediate-Low (ft)	Intermediate (ft)	Intermediate-High (ft)	High (ft)
2030	0.52	0.56	0.59	0.62	0.62
2050	0.95	1.08	1.21	1.38	1.48
2070	1.25	1.57	1.97	2.49	3.05
2100	1.57	2.20	3.71	4.86	6.23

[1] Note that Level 2 did not revise the datasets of Level 1, but provided additional datasets related to SLR and storm surge for the coast of MA.

The scientific community is continually improving its understanding of how sea level change is occurring, and accordingly, estimates periodically change as new and improved projections are developed. The FEMA Region I Coastal Erosion Study (Compass, 2021) uses the NOAA 2017 projections Table 4 which differ somewhat from the most recent projections presented in Table 3. NOAA 2022 SLR curves for Boston (Gauge 8443970) are shown in Figure 10 along with the sea level change values used by the Woods Hole Group for the Massachusetts Coast Flood Risk Model (MC-FRM).

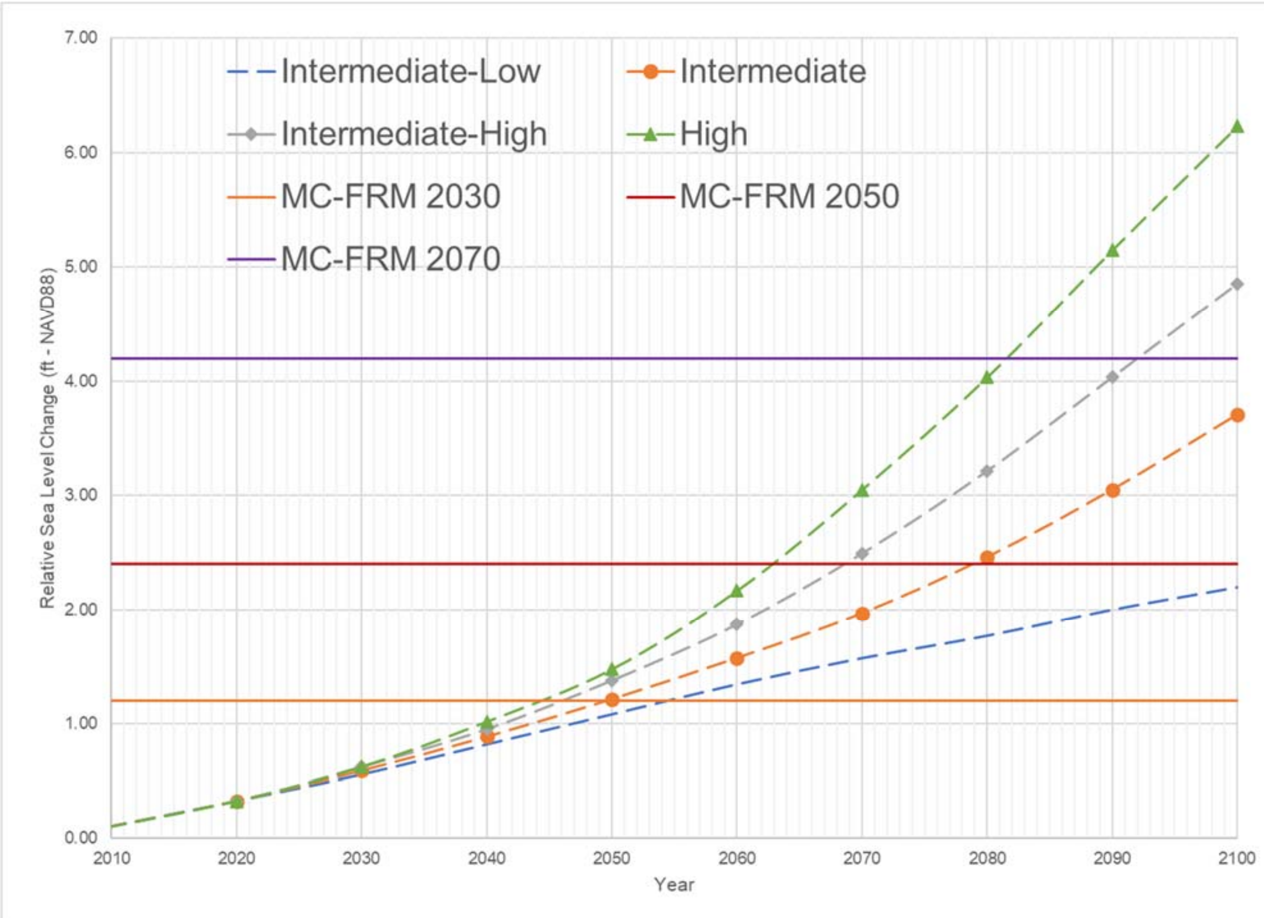

Figure 10. Relative Sea Level Rise (Boston – NOAA 2022) for the 50th Percentile

3.3 Precipitation

While the MC-FRM data set establishes a projected coastal boundary condition, it does not account for projected precipitation events. The Resilient Massachusetts Action Team (RMAT) has developed the Climate Resilience Design Standards and Guidance (RMAT, 2022) which provides guidelines for which design storm event to use for the established planning horizons of 2030, 2050, and 2070 for flood mitigation and critical infrastructure. Figure 11 shows the RMAT recommended design storm return period based on useful life and the intent of the infrastructure. Green boxes show the return periods that qualify for flood control structures such as sea walls with a useful life of greater than 50 years. With the vulnerability assessment focusing on flood mitigation and critical infrastructure, a 100-year precipitation event is recommended to be utilized. The 100-year rainfall event was selected due to the higher probability of the storm occurring than the 500-year rainfall event. Additionally, stormwater system deficiencies would be more clearly shown by the smaller rainfall event rather than extreme flooding in the study area with the 500-year rainfall event. Multiple options are presented as feasible options to project precipitation depth. However, the methodology developed by Cornell University (Steinschneider & Najibi, 2022) was selected as the best data source to use for this project. The RMAT technical document states “Cornell University generated a database of updated IDF curves across different temperature changes using regionalized scaling rates” which make the projected precipitation specific to the Northeast. Figure 12 presents the Cornell 100-year storm event precipitation depths for 2030, 2050, and 2070 planning horizons. The precipitation depths shown in Figure 12, 9.5-inches, 10.5-inches, 11.3-inches, will be applied by the modeling team to an SCS Type III 24-hour distribution which possesses a conservative hyetograph shape with a high peak intensity. These will be used as the projected precipitation events.

Table 4.11. Recommended Return Periods Provided by the Tool for the Extreme Precipitation Climate Parameter

EXTREME PRECIPITATION				INFRASTRUCTURE				
Criticality	Useful Life	BUILDINGS / FACILITIES	Transportation	Dams & Flood Control Structures	Utilities	Green Infrastructure[1]	Solid / Hazardous Waste
		Return Period (Annual Probability)					
High	51-100 years	100-yr (1%)	100-yr (1%)	500-yr (0.2%)	100-yr (1%)	N/A	100-yr (1%)
Medium	51-100 years	50-yr (2%)	50-yr (2%)	100-yr (1%)	50-yr (2%)	N/A	50-yr (2%)
Low	51-100 years	25-yr (4%)	25-yr (4%)	50-yr (2%)	25-yr (4%)	N/A	25-yr (4%)
High	11-50 years	50-yr (2%)	50-yr (2%)	100-yr (1%)	50-yr (2%)	5-yr (20%)	50-yr (2%)
Medium	11-50 years	25-yr (4%)	25-yr (4%)	50-yr (2%)	25-yr (4%)	5-yr (20%)	25-yr (4%)
Low	11-50 years	10-yr (10%)	10-yr (10%)	25-yr (4%)	10-yr (10%)	5-yr (20%)	10-yr (10%)
High	10 years or less	25-yr (4%)	25-yr (4%)	50-yr (2%)	25-yr (4%)	5-yr (20%)	25-yr (4%)
Medium	10 years or less	10-yr (10%)	10-yr (10%)	25-yr (4%)	10-yr (10%)	5-yr (20%)	10-yr (10%)
Low	10 years or less	5-yr (20%)	5-yr (20%)	10-yr (10%)	5-yr (20%)	5-yr (20%)	5-yr (20%)

1. Green infrastructure assets will not receive a recommended return period for assets with a useful life of greater than 50 years since green infrastructure assets typically need significant reconstruction/renovation or replacement before then.
2. Natural Resource assets will receive projected values associated with a 25-yr (4%) return period from the Tool, but this is not a recommended Standard.

Figure 11: Recommended Return Periods for the Extreme Precipitation Climate Parameter Based on Infrastructure Type (RMAT, 2022)

NEWBURYPORT

Projected Total Precipitation Depths for 24-hr Design Storms (inches)

Return period	Potential Tier Designation for Assets from the Tool	NOAA Atlas 14 Present Day Baseline[1]	NOAA+[2]	2030 Cornell Projections	2030 NCHRP 15-61[3]	2050 Cornell Projections	2050 NCHRP 15-61[3]	2070 Cornell Projections	2070 NCHRP 15-61[3]
2-yr	Tier 1	3.3	3.6	3.8	3.5	4.2	3.7	4.5	3.8
5-yr	Tier 1	4.4	4.8	5.0	4.5	5.6	4.8	5.9	4.9
10-yr	Tier 1/Tier 2	5.3	5.8	6.0	5.3	6.7	5.7	7.1	5.8
25-yr	Tier 1/Tier 2/Tier 3	6.5	7.5	7.4	6.4	8.2	6.9	8.8	7.0
50-yr	Tier 1/Tier 2/Tier 3	7.4	8.7	8.4	7.4	9.3	7.7	10	7.8
100-yr	Tier 2/Tier 3	8.3	10.3	9.5	8.4	10.5	8.7	11.3	8.7
500-yr	Tier 3	11.4	14.6	13.1	12.3	14.5	12.0	15.5	11.9

1. Baseline: Median values from NOAA Atlas14 total precipitation depth
2. NOAA+: 90% of the upper bound of the 90% Confidence Interval of NOAA Atlas 14 total precipitation depth; for Tier 1 projects only
3. NCHRP 15-61: Site specific analysis for dams and flood control structures; For Tier 3 projects only

The Tool (V1.2) does not give the highlighted return periods for any asset that receives a Tier 1 designation and/or a "Dams and Flood Control Structures" asset type that receives a Tier 3 designation.

Figure 12: Projected Cornell Precipitation Depth (RMAT, 2022)

3.4 Erosion and Shoreline Change

Net changes to shoreline position can vary at different time scales, switching from negative (erosion) to positive (accretion) and vice versa. Shoreline evolution on the order of days or seasons is mostly determined by localized wind and wave patterns. Beaches remain relatively stable under these short-term patterns. However, longer term shoreline evolution on the order of years, decades, or more is predominately determined by changing sea levels, which generate the greatest net changes in shoreline position.

Historical short- and long-term change rates were derived for the Massachusetts Office of Coastal Zone Management (MA CZM) shoreline study that was initiated in 1989 to identify erosion-prone areas of the Massachusetts coast by compiling a database of historical shoreline positions (Thieler, 2013). The study includes both historical shorelines and topographic light detection and ranging (LiDAR) derived shorelines from mean high water and looked at both short term and long-term erosion rates. A 2021 data release includes rates that incorporate one new shoreline, extracted from 2018 lidar data collected by the U.S. Army Corps of Engineers Joint Airborne Lidar Bathymetry Technical Center of Expertise, added to the existing database of all historical shorelines (1844-2014). The derived shoreline change rates to assess existing conditions are further discussed in Section 5. There are some more localized shoreline change assessments along the Salem coast such as Young et al. (2021). Continuing to maintain these more localized monitoring projects will be important to understand how coastal processes continue to shape the shoreline, and ultimately make predictions for planning purposes.

In addition to looking at historical trends and existing conditions, consideration of future erosion predictions incorporating SLR is critical. An initiative by the Federal Emergency Management Agency (FEMA) resulted in a Region I Coastal Erosion Study (Compass, 2021) to investigate future coastal erosion due to SLR and produce future coastal erosion hazard maps. The study implemented a one-dimensional (1-D) transect-based approach, with transects spaced approximately 50 meters and oriented perpendicular to the shoreline. At each site, 2018 topographic LiDAR data sets were downloaded and processed to determine the state of the shoreline and provide a baseline for future erosion projections. Historical shoreline position data were collected by MA CZM on beaches, marshes, and dunes. These historical shoreline data points were used to calculate the historical shoreline rate of change linear regression rate for each transect. Shoreline cross sections were extracted from the bathymetric data to determine the shoreline cross section slope used to predict future erosion from SLR (Figure 13). Global SLR predictions developed by National Oceanic and Atmospheric Administration (NOAA) in 2017 (Sweet et al., 2017) were adjusted using local SLR observed at nearby tide stations used for the adjustment. Table 4 shows the relative SLR values used for the northern coastline of Essex County. The relative rates of local SLR and predicted future SLR were then used to adjust the linear regression rate and predict future shoreline change. Finally, future erosion risk areas were mapped based on low, intermediate-low, intermediate, intermediate-high, and high NOAA SLR scenarios at three-time frames (2030, 2050, and 2100[2]). These mapped risk areas are important tools for community planning and hazard mitigation.

It is important to note that the FEMA Region I Coastal Erosion Study will adjust in area based on the difference of elevation between the 2017 and 2022 NOAA projections. For example, the 2030 flood level projected in 2017 (Table 4) will now be reached by 2046 based on the 2022 projections. Similarly, the 2050 level will be reached by 2070, and the 2070 level will be reached by 2120. Therefore, the erosion region for 2030 is more reflective of the 2050, and the 2050 erosion area is reflective of 2070. The 2030 erosion area will be smaller than what was presented in the FEMA study. While these maps are still important planning tools and should not be discounted, projections are continuously updated, and therefore products such as erosion hazard areas will adjust as well.

The FEMA study also has a limitation related to the incorporation of structures into the change rate. Existing structures play a prominent role in shoreline change, and therefore are necessary to consider when making predictions. In many cases, erosion protection structures were installed in specific areas of high erosion in the middle of the recorded historical period. Therefore, the actual high erosion environment is not reflected in the calculated rate, as the structure often will maintain a low erosion rate for some time following construction. Changing sea levels can also leave a structure incapable of performing at what it was designed for. For the structures to be accurately included in the study, the contributors would need to have knowledge of future sedimentation and the structure's performance during maintenance, which was unknown. Therefore, the assumption was made to remove any identified structures that impacted historical erosion patterns and interpolate the hazard area from abutting transects across the structured area. The interpolation process creates a risk area that reflects the future unprotected scenario and assumes that the future performance of the structure is uncertain or unknown. An assumption was

[2] As the year 2070 was not included in the FEMA study, the 2100 erosion risk will be considered in its place.

also made that the future erosion hazard area would be the same as the adjacent unprotected portion of the beach with similar exposure and topography.

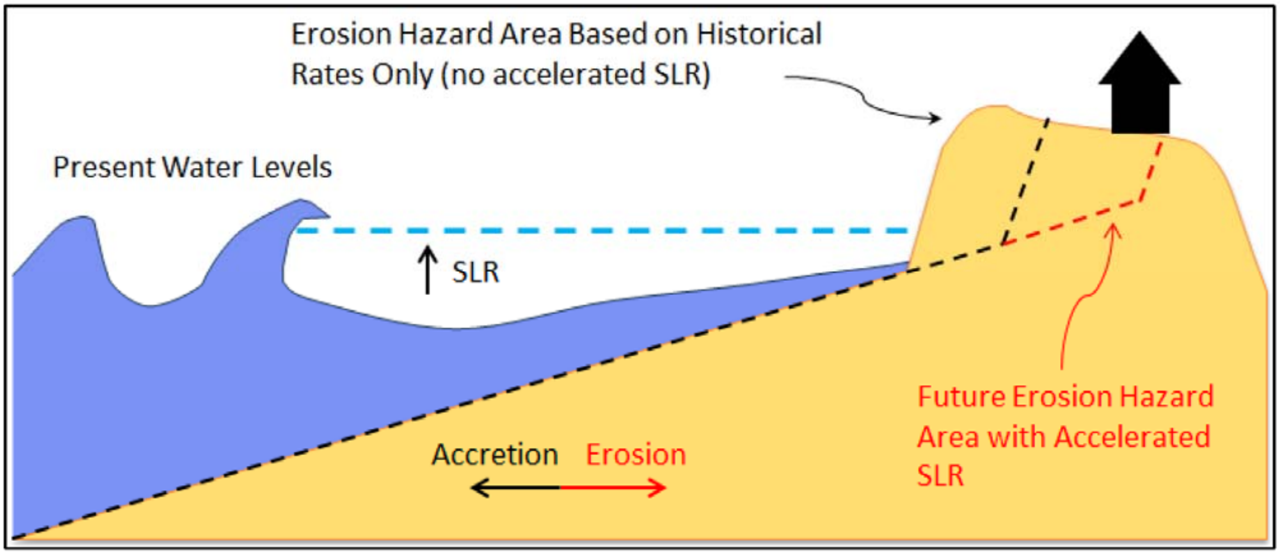

Figure 13. Conceptual Sketch of Predicted Sandy Dune and Beach Erosion Response (Compass, 2021)

Table 4. NOAA 2017 Predicted Relative Future SLR for Essex County North (Compass, 2021)

Year	NOAA 2017 Low (ft)	NOAA 2017 Intermediate-Low (ft)	NOAA 2017 Intermediate (ft)	NOAA 2017 High (ft)
2030	0.3	0.3	0.7	1.3
2050	0.7	0.7	1.3	3.0
2100	1.0	1.3	3.6	8.5

4. Hydrologic/Hydraulic Modeling

4.1 Model Development

As part of the vulnerability assessment, a Hydrologic/Hydraulic (H&H) model was developed using PCSWMM to simulate the impacts of both rainfall and coastal events on the Study Area through the software's 2D capabilities. The model was developed using data provided by the City and publicly available data and then verified using observed flooding compared to predicted flooding, observed flooding was based on community feedback and a storm event that occurred during the study. Once verified, MC-FRM model projected coastal conditions and Cornell projected precipitation depth in the form of an SCS Type III design storm for the 2030, 2050, and 2070 planning horizons were simulated through the model. The model was then used to evaluate location specific alternatives to increase the Study Area's resiliency.

Existing stormwater infrastructure in the Collins Cove to Willows Study Area, such as manholes and pipes, were imported into the model using GIS shapefiles provided by the City of Salem. The Study Area's infrastructure is comprised of separated stormwater and sewer conveyance systems. Therefore, the sewer system was not modeled. Shapefile data was used to delineate stormwater systems which were hydraulically connected to the Study Area, resulting in the model network as shown in Figure 14. The GIS data contained information such as manhole depth, pipe length, pipe slope, pipe size and pipe material. In locations of hydraulic importance where information was missing, field investigations and available record drawings were utilized to verify that the model represented the existing drainage network. However, where other data gaps were present, assumptions were made with regard to the stormwater system such as pipe inverts, pipe sizes, pipe roughness, etc. As indicated by the City of Salem, none of the stormwater outfalls had functioning tide gates. LiDAR data was used to estimate manhole and catch basin rim elevations.

Figure 14: Existing Conditions Model Network

The GIS data included catch basin locations within the Study Area. To simplify the model network, catch basins in close proximity to one another that discharge to the same pipe were modeled as one catch basin. This allows for a simpler model network and subcatchment delineation. As shown in Figure 15, the catch basins near the intersection of Szetela Lane and Webb Street along the southwest corner of Collins Cove were simplified from four catch basins to one. However, the inlet capacity of the catch basins was accounted for through an orifice and grate capacity calculations using the open area of a standard catch basin grate, as shown in Figure 16, multiplied by the number of catch basins. The standard catch basin open area was calculated based on dimensions from General Foundries (http://www.generalfoundries.com/) which indicate that one catch basin has a grate opening of approximately two square feet.

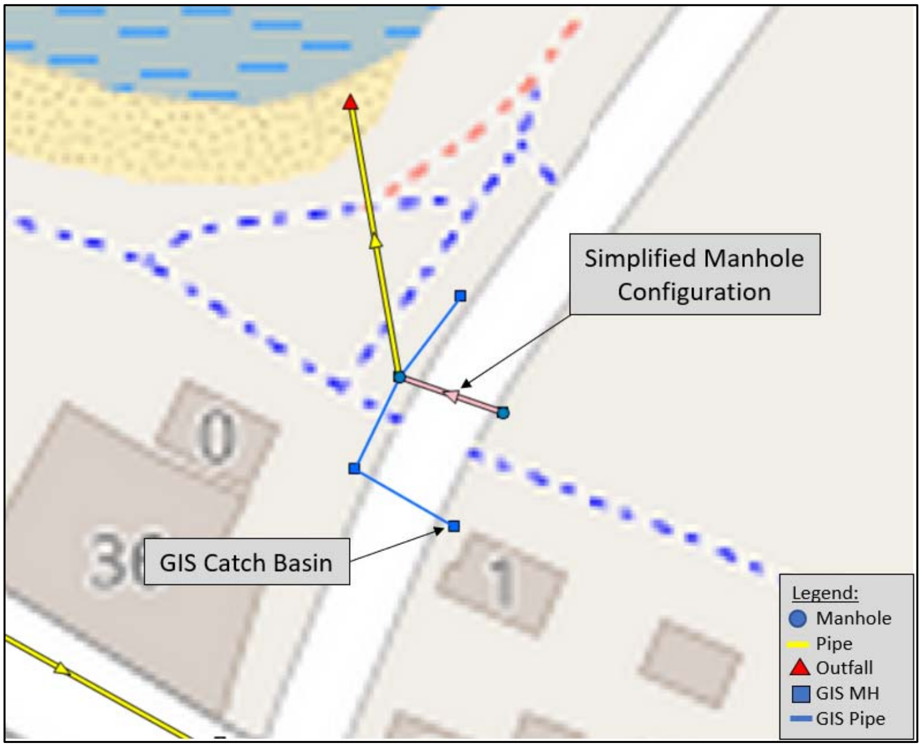

Figure 15: Simplified Catch Basin Configuration

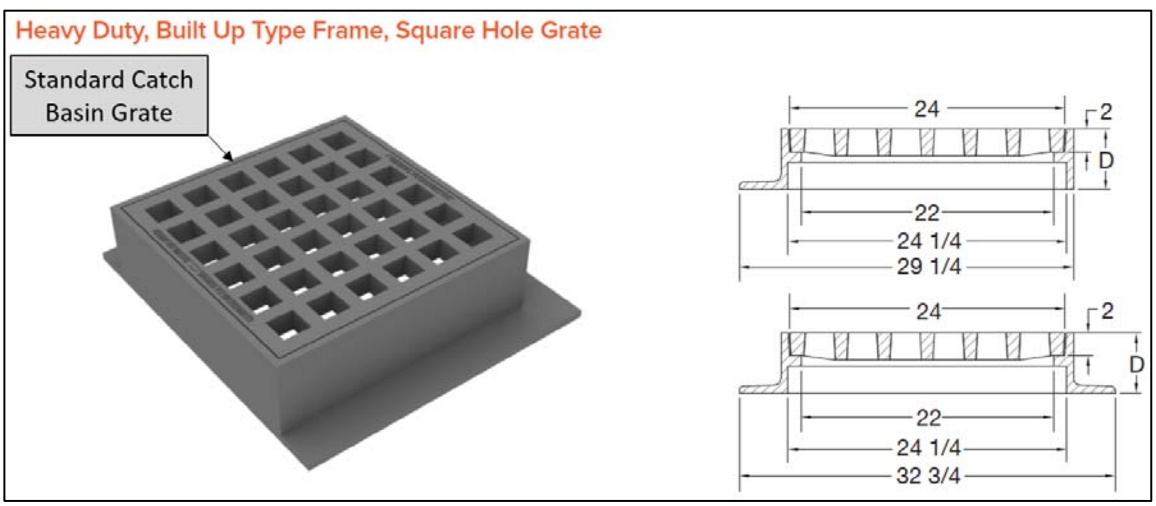

Figure 16: Standard Catch Basin Grate Open Area (http://www.generalfoundries.com/)

Modeling catch basin inlet restrictions results in the potential for roadway ponding and overland flow. PCSWMM accounts for roadway ponding and overland flow down a curbed roadway through the dual drainage creation tool. This allows for water that is unable to enter the catch basin or backs up through a catch basin due to the drainage pipes being over capacity, to be accounted for by the model. The tool creates a roadway transect as shown in Figure 17, which is connected to the drainage system by orifices at the catch basin rim elevations. This results in a primary flow path through the pipes and a secondary flow path along the roadway as shown in Figure 18.

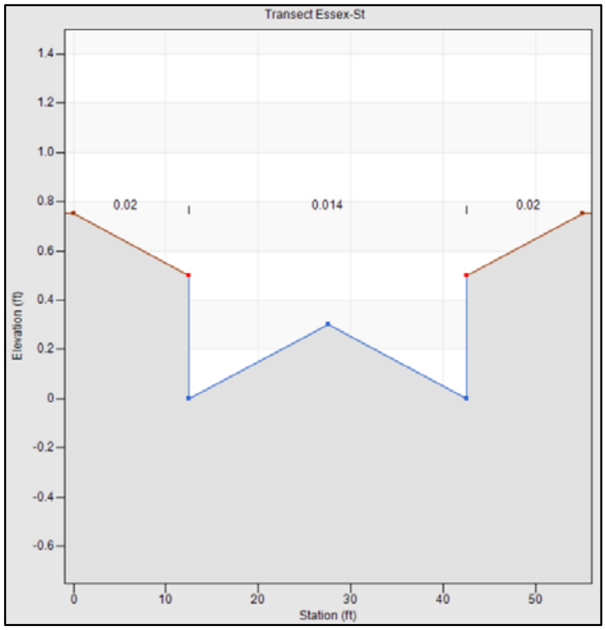

Figure 17: Overland Flow – Roadway Transect Section

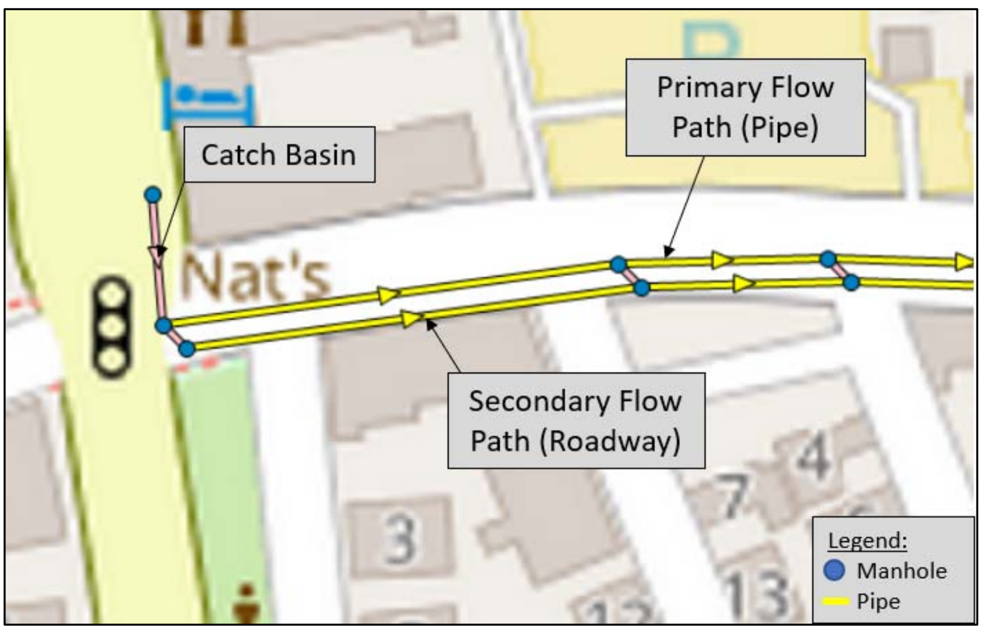

Figure 18: Dual Drainage Flow Paths

Subcatchment delineation was completed using LiDAR data in coordination with PCSWMM's watershed delineation tool. The tool uses the LiDAR topography information to delineate watersheds based on ground slope. The model's delineation does not account for roadway overland flow interception or the existing drainage infrastructure and as a result, the baseline model output needed to be adjusted. Where the baseline subcatchment crossed over a roadway or existing drainage structure, the subcatchment was trimmed to account for the existing flow barriers. Along Hawthorn Boulevard, at the upstream end of the Study Area's hydraulically connected drainage system, the stormwater GIS was utilized to determine how the slope derived subcatchments should be adjusted. Area within the slope derived subcatchment was removed if the GIS indicated that stormwater pipes that are not connected to the Study Area directs stormwater away from the Study Area. Conducting this analysis avoided the overestimation of the area that enters the upstream drainage system. Following the subcatchment analysis factoring in overland flow barriers, the model contained 171 subcatchments as shown in Figure 19. Each subcatchment's parameters such as percent impervious, catchment width, slope, etc. was calculated based on Mass GIS information and mathematical calculations. For other subcatchment parameter values such as soil parameters, soil mapping tools were utilized to populate the model's soil parameters for the Modified Green-Ampt infiltration method. Due to the Study Area consisting of highly residential neighborhoods with an abundance of lawn space, standard loam values for soil hydraulic conductivity, suction head, and initial deficit were used throughout the model.

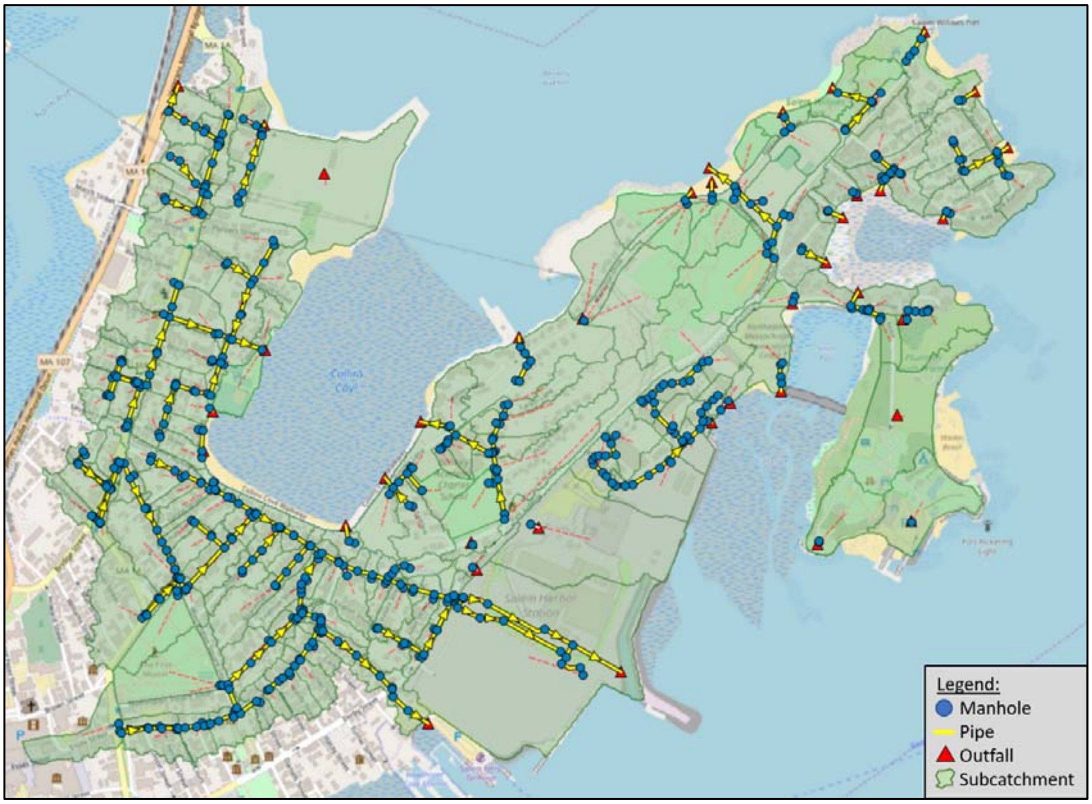

Figure 19: Model Network Subcatchment Delineation

The 2D modeling capabilities of PCSWMM allow for both coastal and precipitation-based flooding to be characterized in terms of flooded area and flood depth within the model for different scenarios. The 2D mesh used to visually display flooding is a series of junctions and conduits connected to the 1D model where flooding can escape at the junctions and catch basins. When water floods from the 1D system, it flows through the 2D mesh and is then rendered to display flooded area and depth at any timestep throughout the model simulation. The 2D mesh is bound to the 1D model by the previously discussed LiDAR data that accounts for the Study Area's topography. As shown in Figure 20, a majority of the Study Area is covered by the 2D mesh. Locations at high elevation which are not predicted to be inundated during a 2070 storm surge event were excluded from the 2D mesh. The LiDAR data accounts for ground elevation differences between the tidal zone bathymetry and habitable land including the sea walls. To model the tidal and storm surge conditions, dummy outfalls with tidal time series data were attached to the 2D mesh in the tidal zone as shown in Figure 21. This allows for the coastal conditions to be modeled by filling the 2D mesh in the tidal zone and abut the higher ground elevation along the shoreline.

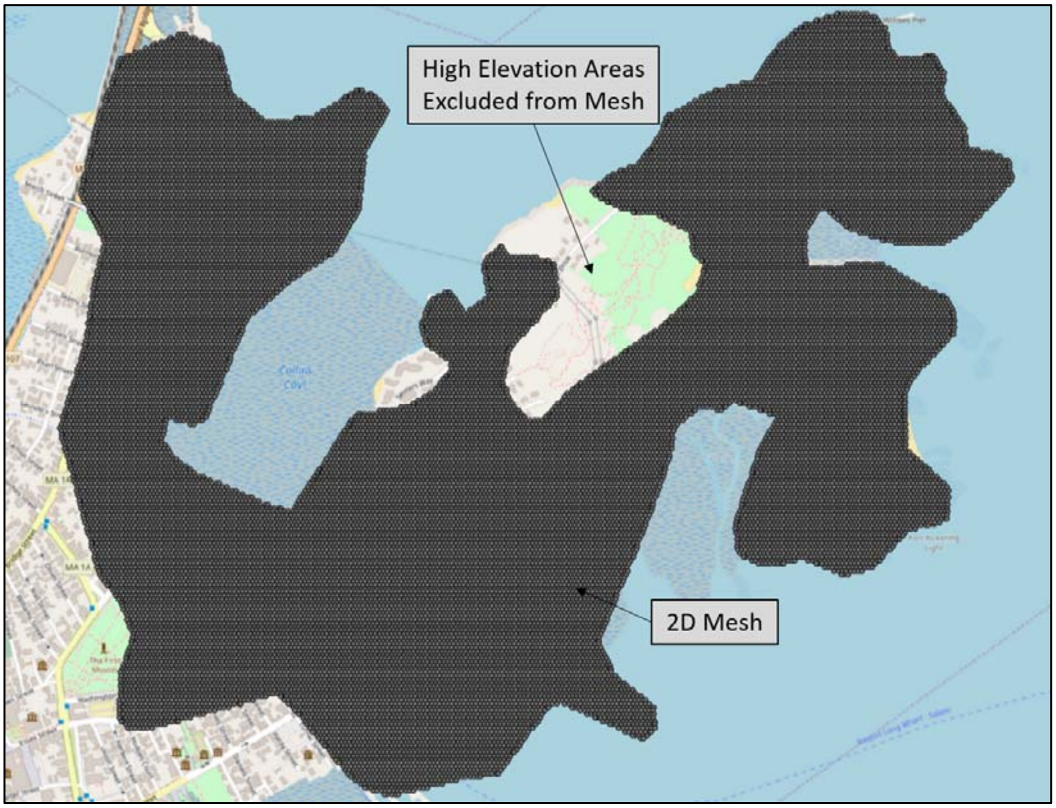

Figure 20: 2D Mesh Coverage

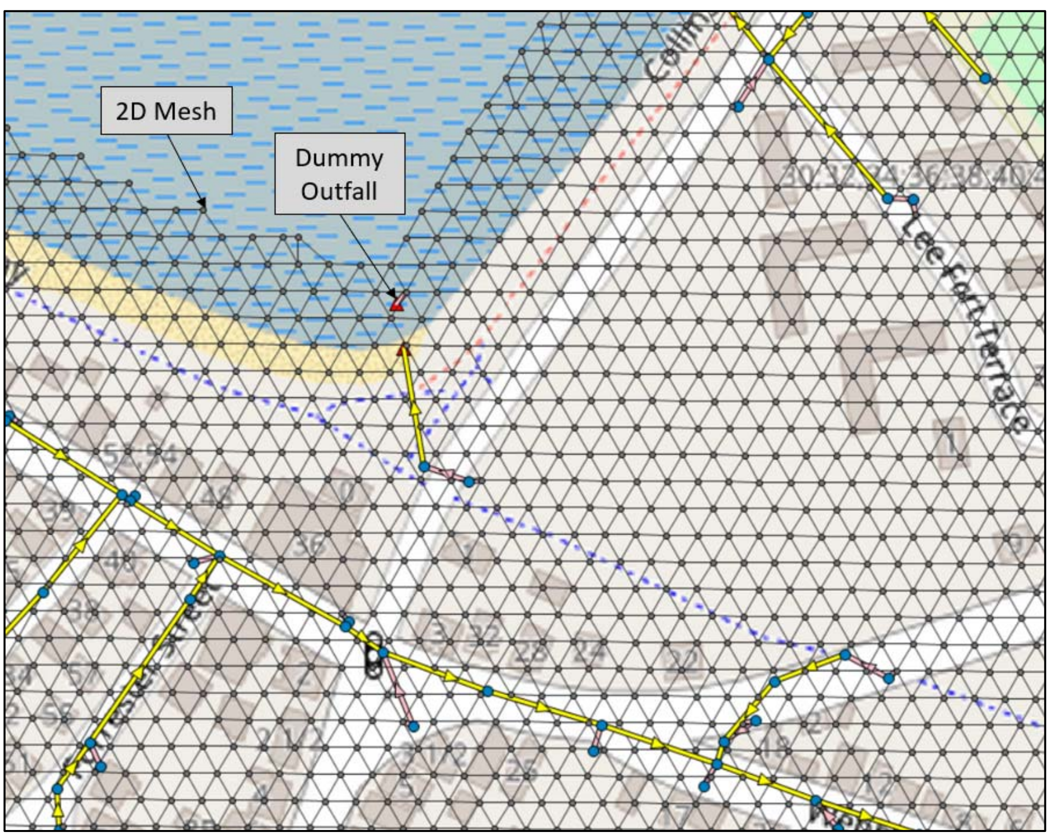

Figure 21: 2D Mesh – Tidal Zone

5. Existing Conditions Vulnerability Assessment

As the impacts of climate change continue to be felt around the world, communities need to assess vulnerabilities and prepare for potential risks. In particular, coastal communities are facing a range of challenges associated with sea level rise, coastal erosion, and extreme weather events. To develop a complete vulnerability assessment, assess existing conditions first is required as these present the most immediate vulnerabilities. This section includes a review of existing conditions as they pertain to coastal flooding, SLR, stormwater and coastal flooding, erosion, and shoreline change results.

5.1 Coastal Flooding and Sea Level Rise

Coastal flooding is one of the most significant existing hazards for the Study Area. Coastal flooding can occur at any time that water levels are elevated sufficiently above the normal tide levels, such as during a King Tide or storm surge event. Tidal datums for Salem Harbor as reported by NOAA (Gauge #8442645) are shown in Table 5.

Table 5. Salem Harbor Tidal Datums (NOAA Gauge #8442645)

Tidal Datum	Elevation (feet NAVD88)
Mean Higher High Water (MHHW)	4.54
Mean High Water (MHW)	4.10
Mean Sea Level (MSL)	-0.31
Mean Low Water (MLW)	-4.83
Mean Lower Low Water (MLLW)	-5.16

A number of areas have been identified as particularly vulnerable to coastal flooding in the City's Comprehensive Emergency Management Plan (2022) as well as the Hazard Mitigation Plan 2020 Update, including the following:

Daniels Street, Ocean Avenue and Willows Park neighborhood

Columbus Avenue

North River

Bridge Street

Commercial Street

Canal Street

Brooks Road/Jefferson Avenue/Rosie's Pond neighborhood

Derby Wharf

Figure 22 shows the FEMA effective national flood hazard map overlaid on the critical infrastructure and coastal structures. A significant portion of the Study Area is located within the floodplain of the 1% annual chance exceedance (ACE) event—a term used to define a flood event having a 1-percent chance of being equaled or exceeded in any given year. The 1% ACE event is often referred to as the 100-year flood event, which refers to the average recurrence interval associated with the flood event (1 in 100 annual chance in this case). For example, the 10-year flood event has an average recurrence interval of 10 years and an annual probability of occurrence equal to 10%.

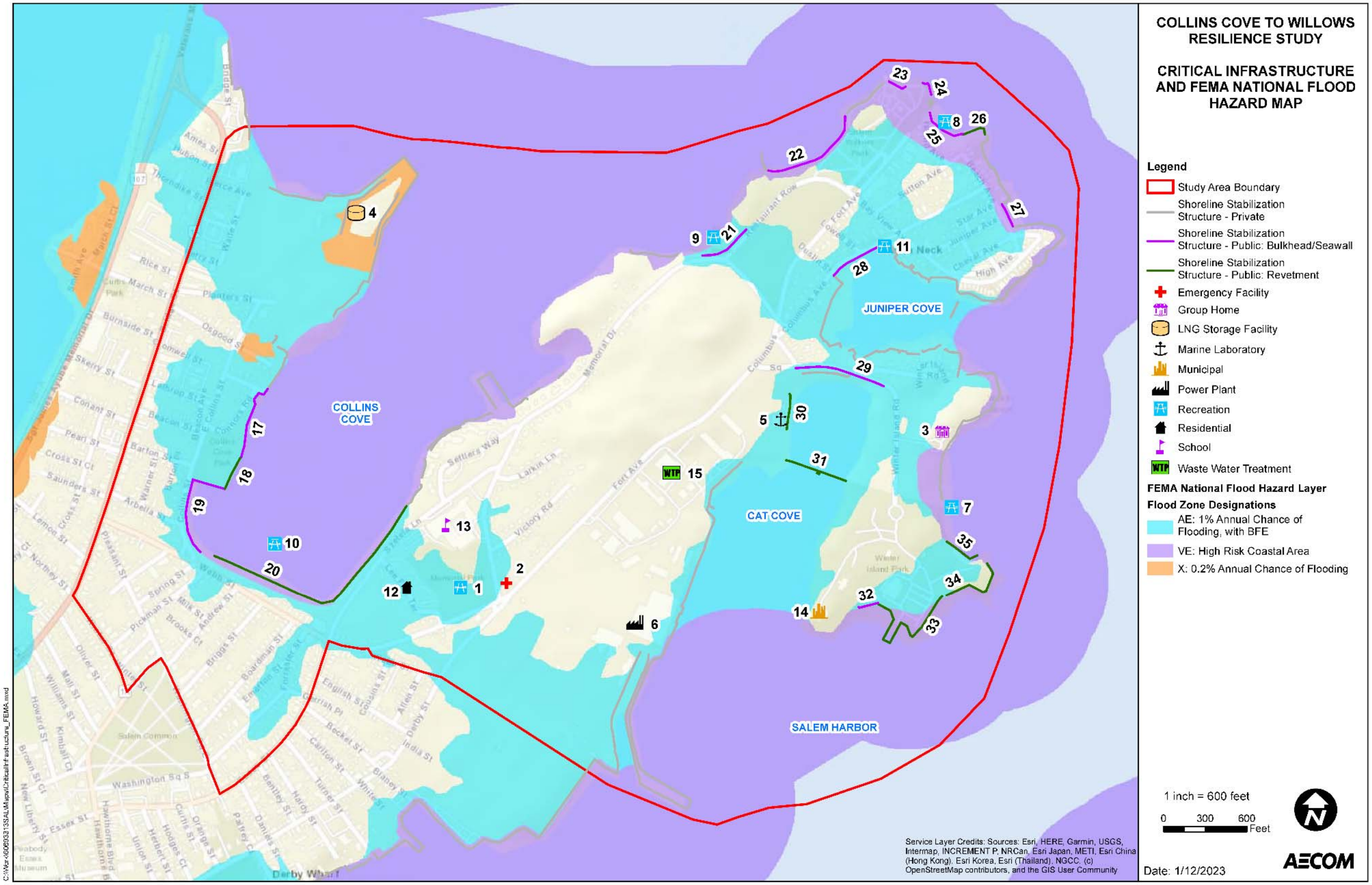

Figure 22. Critical Infrastructure and FEMA National Flood Hazard Map

Figure 23 presents the present day (2008) estimated annual probability of coastal flooding for the Study Area as evaluated by the MC-FRM. The depth of coastal flooding is not quantified as this is a purely probabilistic analysis. The probabilities can be understood to correspond to a flood event of the same annual chance or recurrence interval. A 100% probability of flooding implies that the location is likely to be flooded at least once a year. Notably, an extensive area along the southern edge of the Study Area from Collins Cove to Salem Harbor including Leefort Terrace and the Salem Harbor Station Power Plant is estimated to have approximately a 5% annual probability of flooding. Depending on the depth, flooding in this area could restrict or prohibit evacuation from Salem Neck to the mainland as all connecting roads are shown to be impacted by flooding.

Additionally, Memorial Park and the Salem Fire Department are located in this area and are impacted by the 1% event. Residential areas along Juniper Cove and Juniper Point including Columbus Avenue and Bay View Avenue are estimated to have approximately a 30% annual probability of flooding in the areas closest to the shoreline including Steps Beach and approximately 1% annual probability of flooding for most of the lower lying areas to the northwest of Juniper Point. Northwest of Collins Cove is another area of high vulnerability with annual probabilities ranging from approximately 20% in limited areas along the shoreline to approximately 5% in more extensive residential areas.

The 0.1% annual probability floodplain inundates large areas all along Collins Cove including evacuation routes to the north including the National Grid Energy Delivery LNG Storage Facility and Collins Cove Beach. The Bentley Academy Innovation School and Salem Early Childhood School, South Essex Sewage District Wastewater Treatment Facility, Division of Marine Fisheries Cat Cove Marine Lab, and Plummer Youth Promise group home are estimated to have essentially no present day annual probability of coastal flooding.

The depth of inundation associated with the present day (2008) MC-FRM 1% ACFEP event is shown in Figure 24. Most inundation is around 0.5 feet or less though there are low-lying areas along Collins Cove and north of Juniper Cove and where inundation depths reach 1.5 to 2.5 feet based on model results.

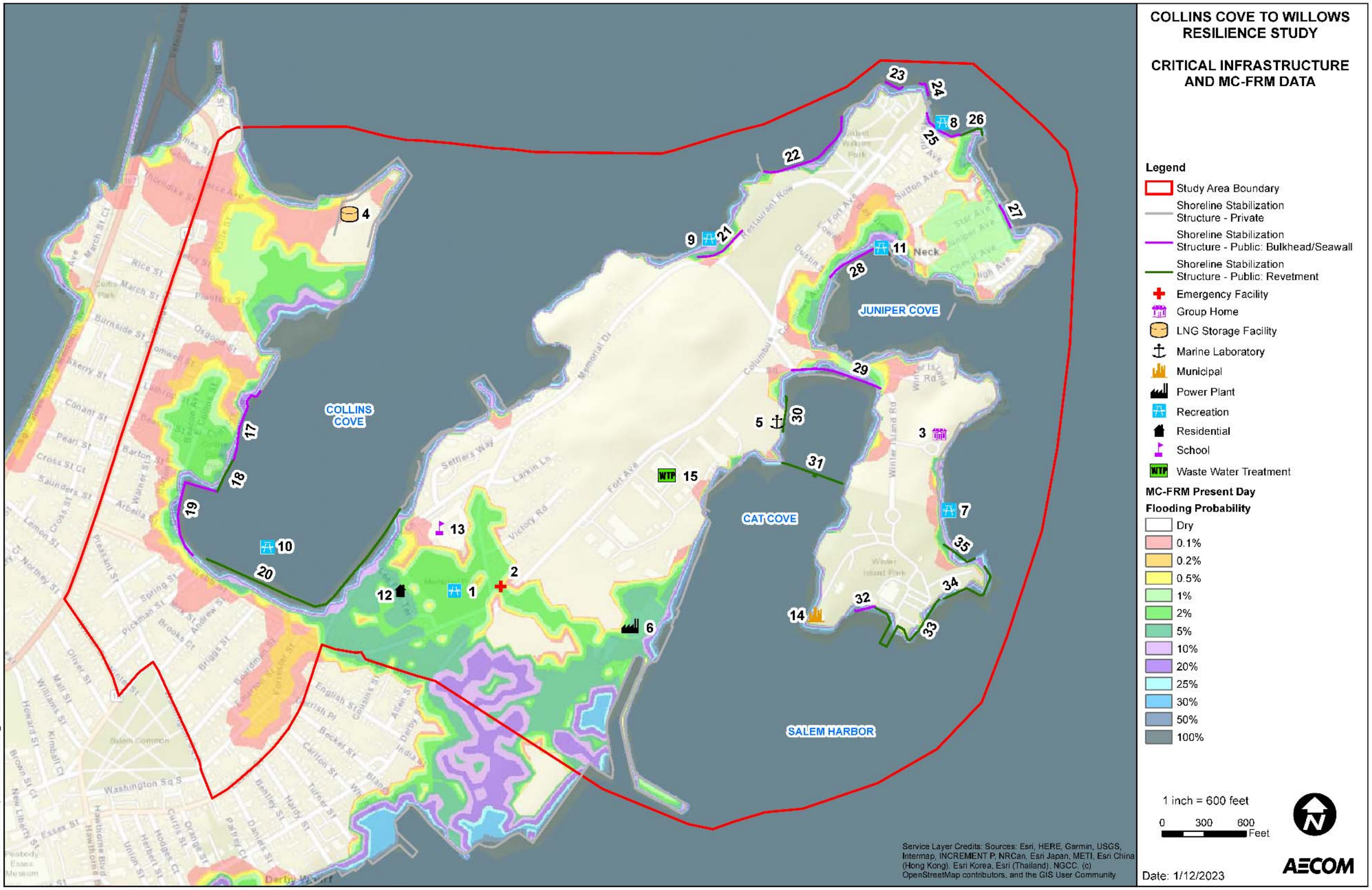

Figure 23. Critical Infrastructure and Present Day (2008) MC-FRM Annual Probability of Flooding

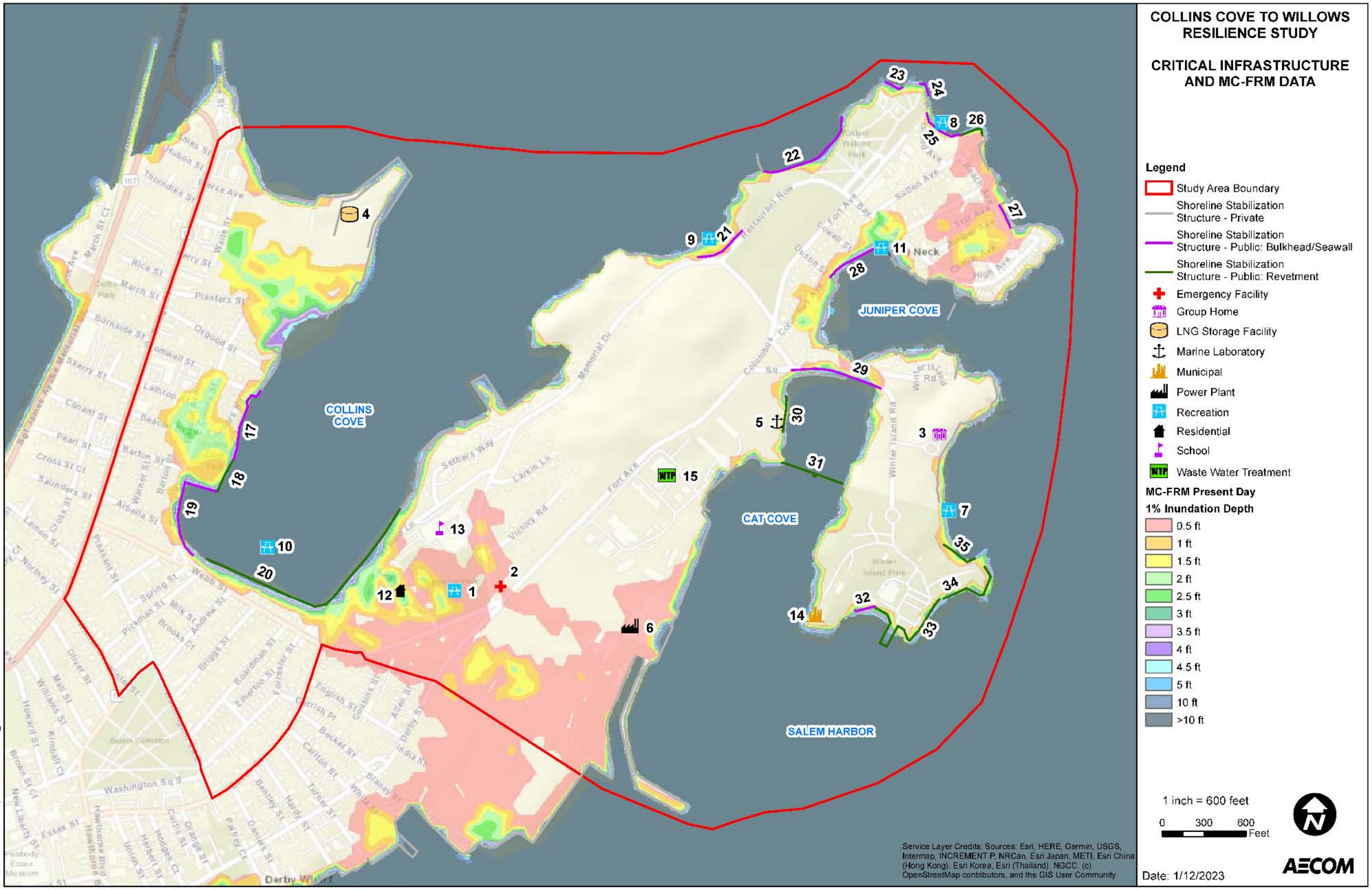

Figure 24. Critical Infrastructure and Present Day (2008) Inundation Depth of the 1% ACFEP Flood Event

5.2 Model Predicted Flooding for Existing Conditions

As previously discussed, the H&H model network was developed to represent the existing drainage network and topography in the Study Area. With the absence of flow meter data for calibrating the model, the model was verified to be representing existing field conditions based on observations and measurements from the December 23, 2022 storm event and an Atlas-14 1-year depth 24-hour duration storm event under average tidal conditions.

Firsthand field observations were conducted by the project team during the December 23, 2022 event in the Study Area. As shown in Figure 25, the observed event was comprised of both precipitation and storm surge. However, the rainfall component was less than a 3-month storm event with a total depth of 1.35-inches and a peak intensity of 0.28 in/hr recorded at the nearby USGS rain gauge in Peabody, MA. Additionally, the majority of the rainfall occurred before the storm surge caused coastal flooding during high tide at 10:30 AM. It was concluded that the observed flooding for this event was due to the storm surge overtopping seawalls and backing up through the stormwater outfalls, not the precipitation aspect of this event. The tidal data was derived from NOAA's nearest active tide gauge in Boston Harbor and translated to Salem, which was done by using the predicted tides from both Salem and Boston in coordination with the verified recorded tides from the event. This resulted in a coastal boundary that accounted for the geographical and timing differences that occur between Boston and Salem.

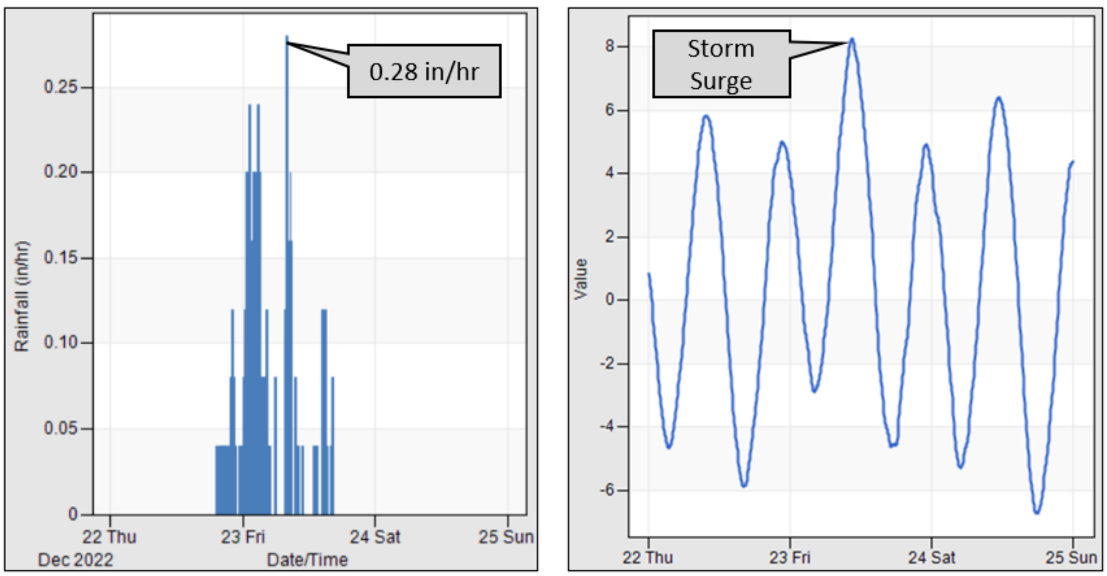

Figure 25: December 23, 2022, Rainfall and Tidal/Surge Conditions

During the field observations, multiple pictures and flood depth measurements throughout the Study Area were gathered by the project team and from residents. This data was used to verify that the model was representative of flooding due to storm surge events. While in the field it was confirmed that storm surge conditions in Collins Cove differ from the conditions on Juniper Beach. The geographic location of Collins Cove protects the inner portions of the cove from storm surge events that come from the south as shown in Figure 26. When using the model for future projected storm events, the tidal boundary condition from the MC-FRM will account for these differences.

Figure 26: December 23, 2022, Storm Surge Differences Based on Location

To model this event, the tidal boundary condition and precipitation were used as inputs to the model network. When initially run, the model was able to reproduce the observed flooding in some locations more accurately than in others. As a result, the model's 2D mesh, which is based on LiDAR data that has an elevation tolerance of seven inches, was slightly adjusted to reflect observed flooding. The 2D mesh is also refined to a 30-foot threshold between the next node which allows for the mesh to be adjusted when necessary to account for flooding in areas in between nodes. Model verification for the December 23, 2022, event can be seen in the following three figures (Figure 27 through Figure 29) which highlight three locations within the Study Area that are subject to a higher susceptibility to flooding.

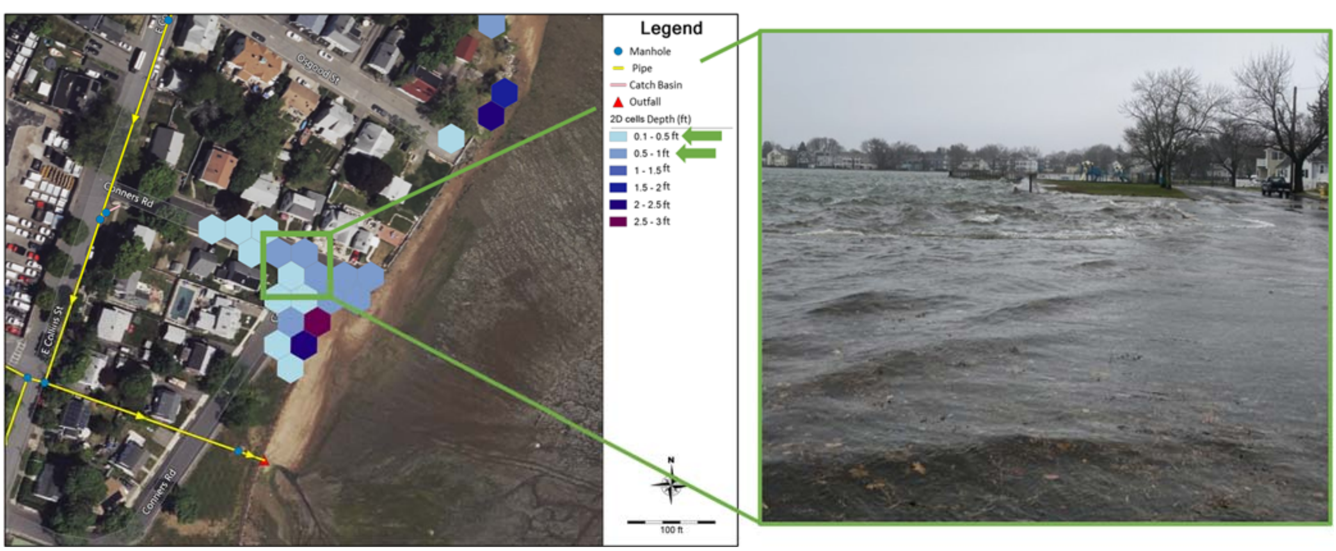

Figure 27: Conners Road – December 23, 2022, Model vs. Observed Flooding

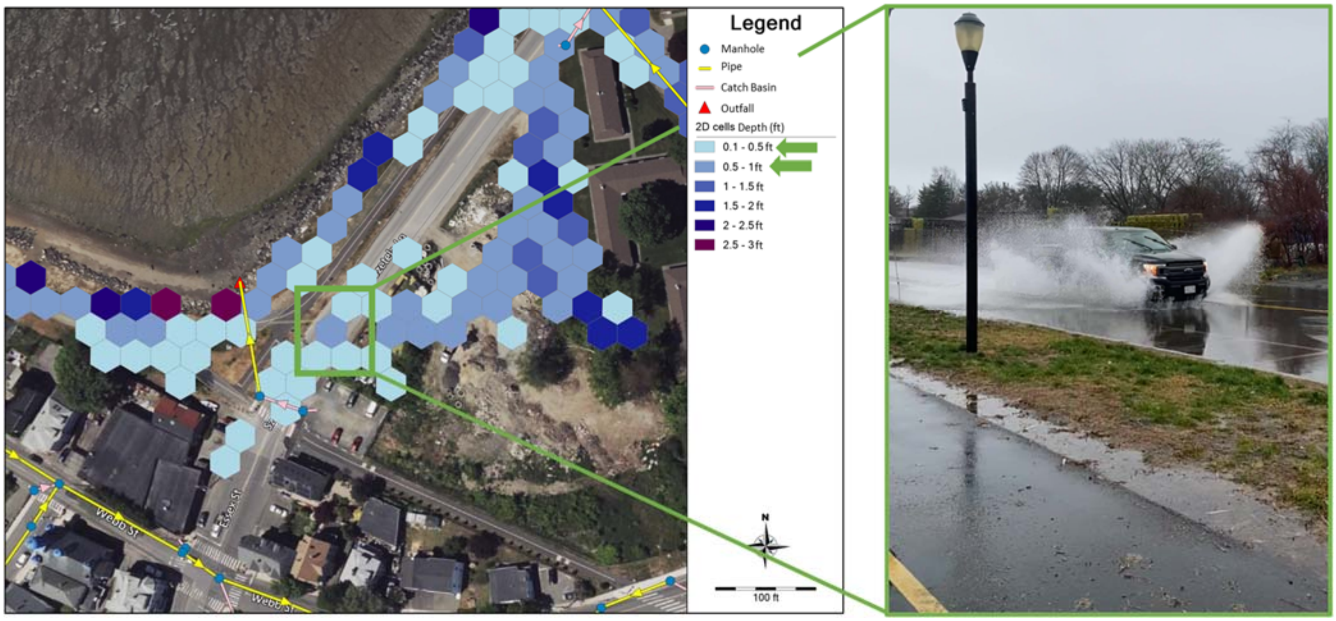

Figure 28: Webb Street & Szetela Lane – December 23, 2022, Model vs. Observed Flooding

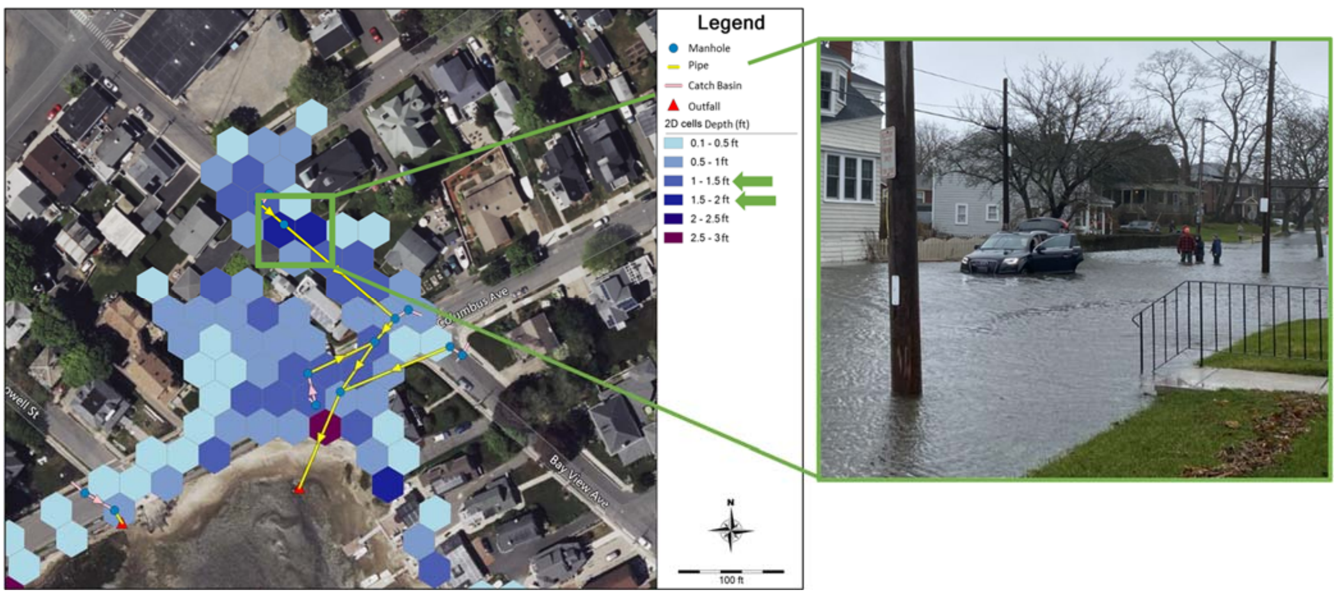

Figure 29: Bay View Avenue & Columbus Avenue – December 23, 2022, Model vs. Observed Flooding

As previously discussed, the December 23, 2022 flooding event was primarily due to storm surge, not precipitation. As a result, the model's hydrologic response was tested using an Atlas-14 1-year depth 24-hour storm event with 2.55 inches of rainfall in the form of an SCS Type III design storm resulting in a peak intensity of 2.14 in/hr. The peak of the rainfall intensity coincides with a tidal boundary condition that would not restrict stormwater discharging from the outfalls. By simulating the rainfall with a lower tide condition, the model's ability to predict flooding based on only the hydrologic response can be evaluated. The rainfall and tidal conditions are shown in Figure 30.

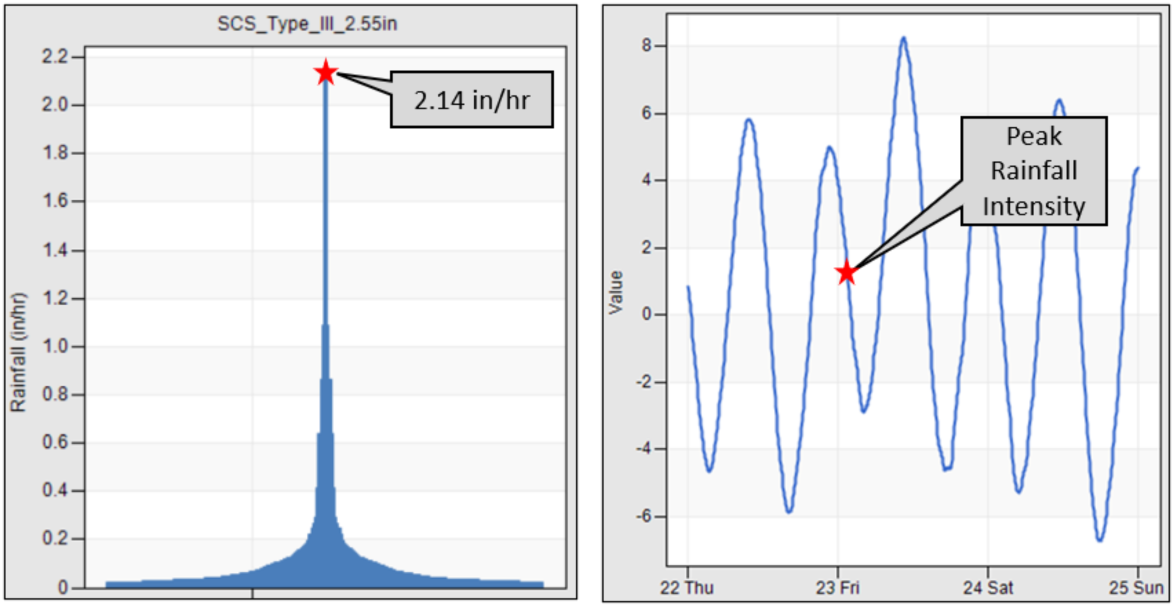

Figure 30: Existing Condition Model Inputs to Test Hydrologic Response

The model's hydrologic response to the storm event shows street flooding in multiple areas throughout the Study Area. Flooding predicted by the model for high intensity rainfall is a shorter duration of flooding compared to the December 23, 2022, coastal flooding event. The street flooding can be caused by either catch basin inlet restrictions or the stormwater pipes being overwhelmed by the volume of water entering the system. For this particular event, the model shows that the flooding was due to the system being over capacity, indicating that the stormwater pipes may be undersized for a 1-year recurrence interval sized storm event and larger. To verify that the flooding predicted by the model is consistent with observed conditions, resident input from the first public meeting was considered in addition to public feedback during the second public meeting. The public indicated that the flooding in the three representative areas of Forrester Street, Bridge Street, and at Bay View and Columbus Avenue was representative of the observed flooding during high intensity rainfall events (Figure 31 through Figure 33).

Figure 31: Forrester Street Model Predicted Flooding – 1 Year Rainfall – SCS Type III Distribution

Figure 32: Bay View Avenue & Columbus Avenue Model Predicted Flooding – 1 Year Rainfall – SCS Type III Distribution

Figure 33: Bridge Street Model Predicted Flooding – 1 Year Rainfall – SCS Type III Distribution

5.3 Erosion and Shoreline Change

Erosion is an important hazard to consider in coastal environments where development is near shorelines. The stability of these shorelines is influenced by a number of factors, including human activities (e.g., beach nourishments, sea wall construction) and endlessly shifts in response to waves, water levels, and currents.

The Massachusetts Coastal Zone Management shoreline study quantified historical shoreline change rates with historical shorelines dating back to the 19th century (Thieler, 2013). Historical shorelines from this study were downloaded within the Study Area (Figure 34) for shoreline change analysis. The study included both long-term (~150 years) and short term (~30 years) rates. Overall, the study found long term rates in the Study Area to be mostly stable (Figure 35), with a few pockets of erosion and accretion. The most severe long-term erosion was found in Collins Cove (approximately -1.3 ft/year), along the southeastern end. This section of shoreline consisted of salt marsh historically (Figure 7), until it was filled in for railroad construction in the late 19th century.

The short-term shoreline changes rates show conditions with no statistically significant change (characteristic of cyclical change) along most of the Study Area shoreline (Table 6), with one distinct area of erosion in Collins Cove (Figure 36). This stretch of beach at the end of Planters Street (approximately -3.0 ft/year), shows heavy short-term erosion as it is the only stretch of shoreline on the northwestern side of Collins Cove that is not protected by rock or manmade structure. This northwestern section of the cove is also particularly vulnerable to storms, as there is some exposure to storm waves out of the northeast. While the historical trends show relatively stable existing conditions along most of the Study Area shoreline, the vulnerability of the shoreline is increasing as sea levels rise, structures continue to degrade, and weather patterns change.

Despite the abundance of coastal property owned by the City which provides the city some jurisdiction over shore protection design, some challenge exists due to privately owned coast in Salem. Privately owned coastline does not guarantee (and often actively prevents) jurisdiction to maintain these coastal areas. Regardless, some public and private shoreline protection measures have been established over time along these pocket beaches, typically in the form of sea walls. These structures are all designed at different elevations and are of varying structural integrity. Other protection measures include beach nourishments, which can influence historical shoreline change rates. There is evidence of historical nourishment of beaches in the Study Area based on an evaluation of beach nourishments by Perdikis (1962). Nourishments can influence the estimates of change rates. However, for the purposes of this study, any nourishments that occur were not relevant for this evaluation. Despite measures implemented to prevent erosion and maintain a fixed shoreline position, shorelines change over time and are influenced by localized wind and wave patterns. During the winter of 2022/2023, several factors led to accelerated erosion at Salem's south and southeastern facing coastal banks: lack of snow or frozen ground, increased rain events, and storms coming from the south and southeast rather than traditional nor'easters. In particular, the erosion at Winter Island Park was quite dramatic. With climate change, these patterns are expected to continue.

Table 6. CZM Shoreline Change Data for Select Beaches in the Study Area

	Number of transects	Average of Long-term shoreline change rate (ft/yr)*	Max of Long-term shoreline change rate (ft/yr)	Average of Short-term shoreline change rate (ft/yr)	Max of Short-term shoreline change rate (ft/yr)
Collins Cove Park	7	1.66	3.97	-0.22	0.10
Columbus Avenue, Juniper Cove	6	0.27	0.79	-0.47	0.23
Dead Horse Beach	6	0.20	0.66	-0.64	0.52
Fort Pickering Beach	8	0.03	0.20	-0.56	-0.10
Juniper Beach 1	5	-0.15	0.26	-0.81	-0.26
Juniper Beach 2	2	-0.44	-0.16	-0.51	-0.30
Szetela Lane, Collins Cove	7	1.45	4.10	-0.32	0.03
Webb Street, Collins Cove	8	-0.01	0.36	-0.51	-0.16
Winter Island	8	-0.05	0.13	-0.49	0.00

*Many of these values are low due to the coastline being filled to make more land. See the maps of Bridge Street and Webb Street in Appendix A of the Past Studies and Available Data Memo and the drastic shoreline change between 1844-1897 and 1943-1969.

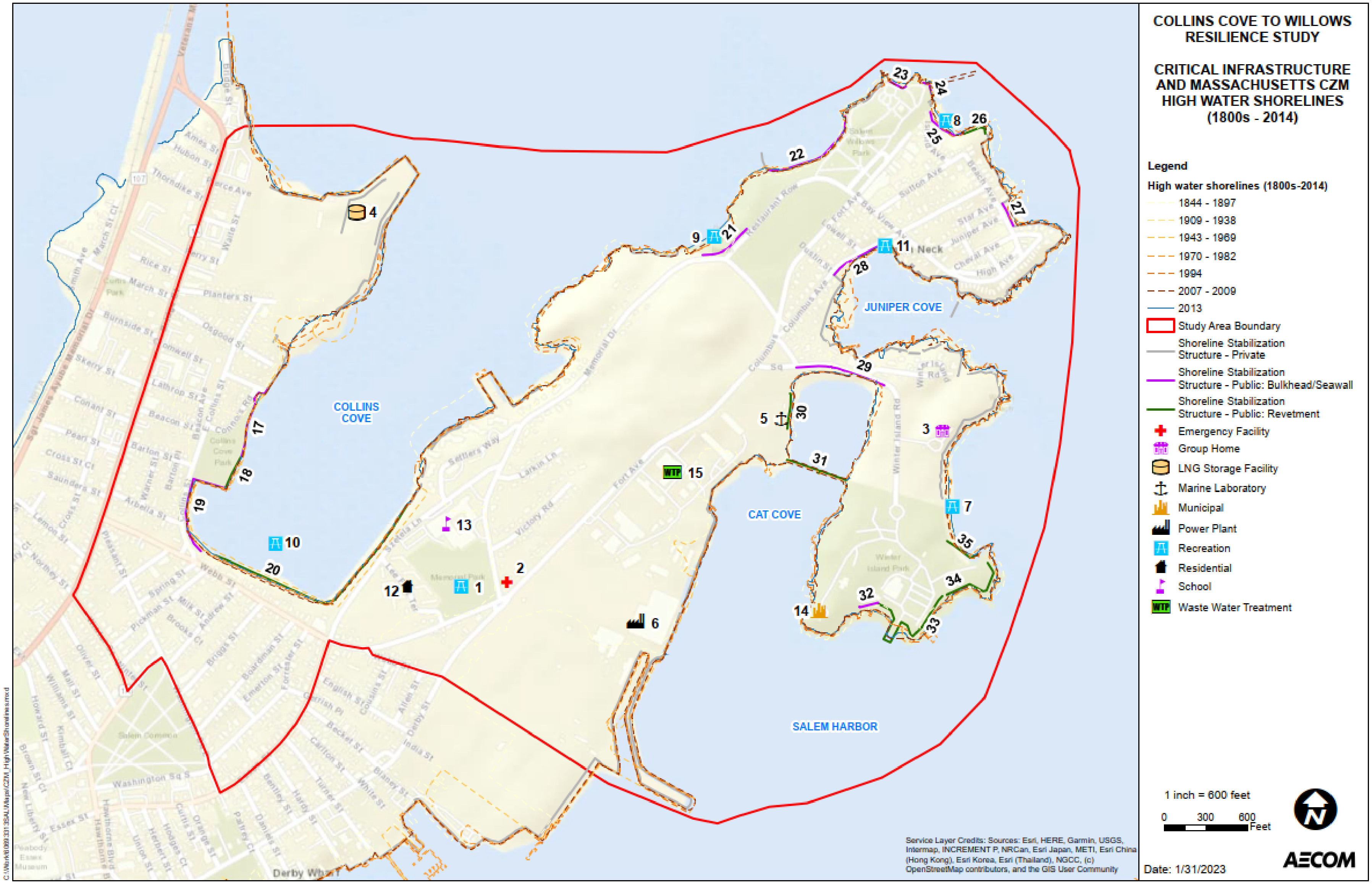

Figure 34. MA CZM Shoreline Change Shorelines

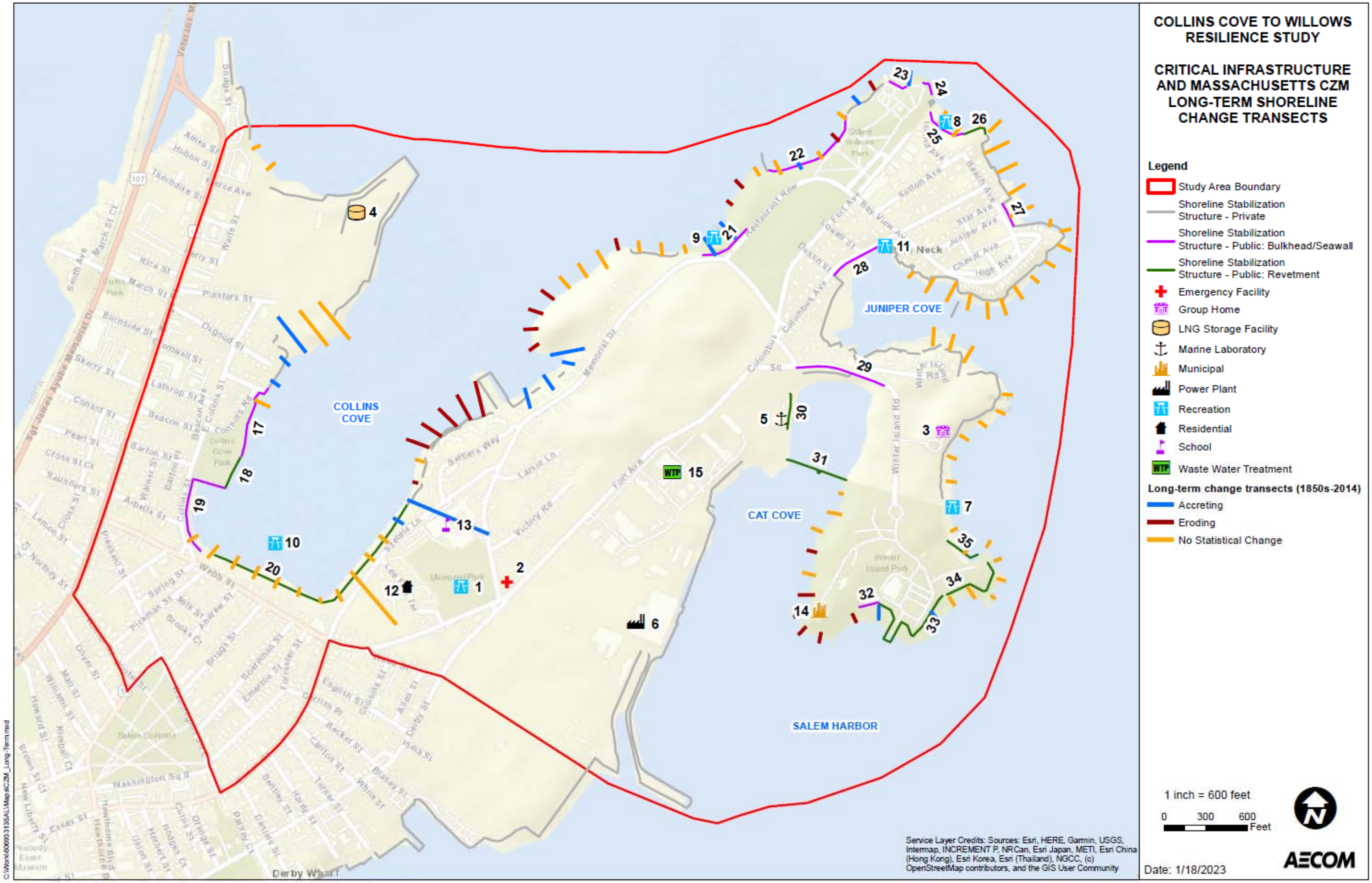

Figure 35. MA CZM Long Term Shoreline Change

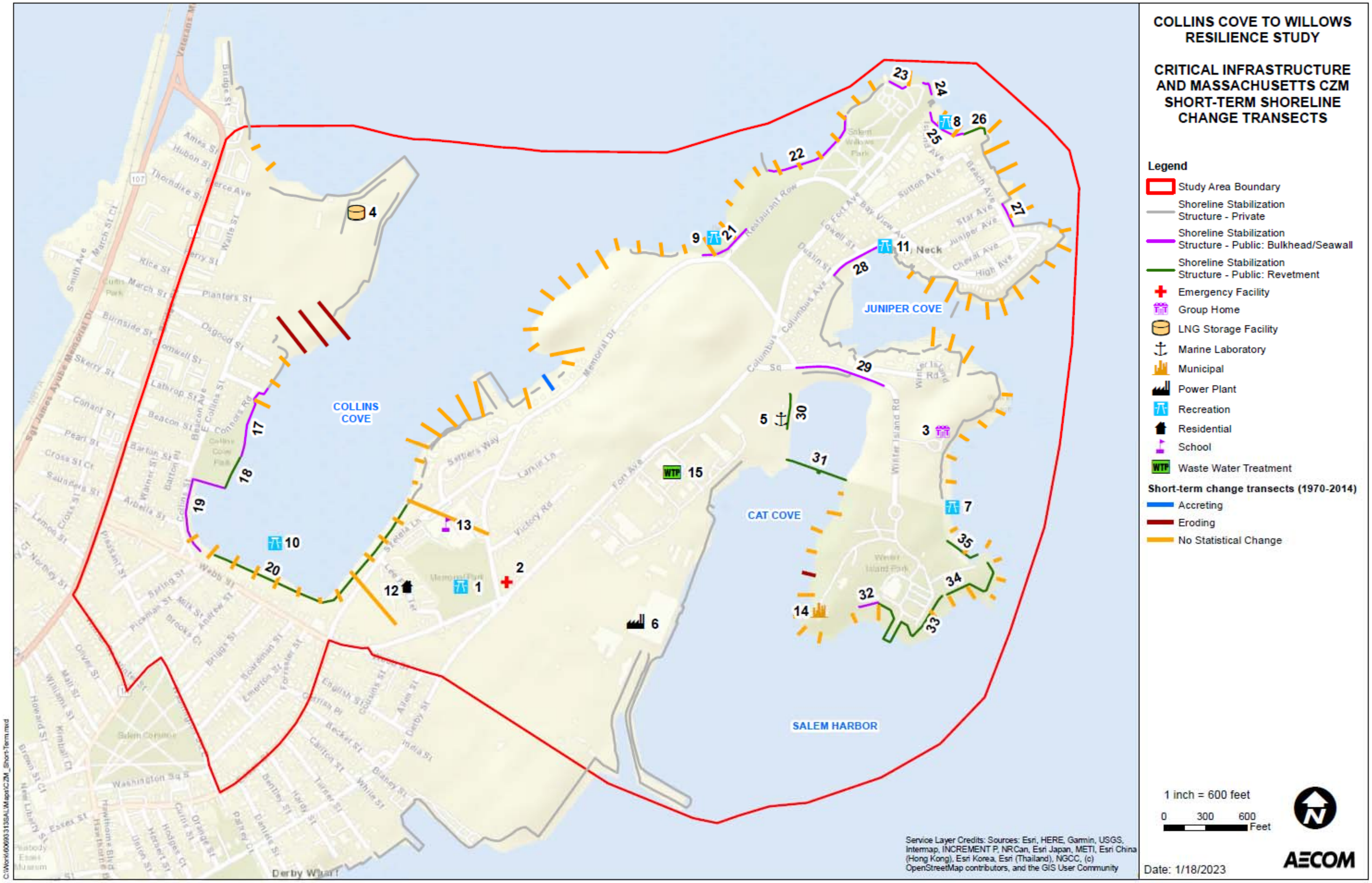

Figure 36. MA CZM Short Term Shoreline Change

6. Future Conditions Vulnerability Assessment

6.1 Coastal Flooding and Sea Level Rise

SLR can result in increases to coastal flooding and can also create areas of permanent inundation. Permanent inundation occurs when daily high tides inundate a given area, rendering it effectively part of the ocean and no longer part of the inhabitable landmass. Mean Higher High Water is the average highest daily tide level and is used in Figure 37 to represent permanent inundation due to one-foot increments of SLR up to 6 feet. One foot and 2 feet of SLR result in relatively small changes to the permanently inundated shoreline. Three feet of SLR results in permanent inundation of residential areas along Juniper Cove and some areas along Collins Cove. Four feet of SLR significantly increases permanently inundated areas along Collins Cove. Comparing Figure 10 and Figure 37, it is possible to develop approximate timing associated with different levels of inundation based on NOAA's 2022 projections for Boston. Table 7 shows the possible timing of permanent inundation associated with 1 to 4.2 feet of SLR. This table also provides an updated understanding of the timing associated with the different MC-FRM scenarios. The MC-FRM 2030 scenario can be expected to occur between 2044 and 2055; the MC-FRM 2050 scenario can be expected to occur between 2063 and approximately 2110; while the MC-FRM 2070 scenario is projected to occur as early as 2082 or beyond 2150.

As sea levels rise, the probability of coastal flooding for any given location within the Study Area increases. Figure 38, Figure 39, and Figure 40 show the annual probability of coastal flooding predicted by the MC-FRM, for the planning horizons of 2030 (1.2 feet of SLR), 2050 (2.4 feet of SLR), and 2070 (4.2 feet of SLR), respectively. With just 1.2 feet of SLR (2030 planning horizon) the southern edge of the Study Area from Collins Cove to Salem Harbor including Leefort Terrace and the Salem Harbor Station Power Plant increases from a 5% annual chance of flooding to between approximately 50% and 75% annual chance. Similarly, the lower lying areas to the northwest of Juniper Point increase from 1% annual chance to approximately 15% annual chance of flooding. Extensive residential areas along the western bank of Collins Cove are projected to have annual probabilities of flooding from 10% to 20%. With 4.2 feet of SLR (2070 planning horizon) the areas of approximately 75% annual chance of flooding dominate the Study Area, and all key resources have a non-zero annual chance of flooding. The depth of inundation associated with the 2030 (1.2 feet of SLR) MC-FRM 1% ACFEP event is shown in Figure 41. Most inundation is around 0.5 feet to 1.5 feet though there are low-lying areas along Collins Cove and north of Juniper Cove where inundation depths are projected to reach 2.5 to 3.5 feet.

Table 7. Timing of Permanent Inundation due to Sea Level Rise (Boston – NOAA 2022)

Sea Level Change	Approximate Sea Level Change Projection Timing (Based on NOAA 2022)		
	Earliest	*Intermediate*	*Latest*
+1 Foot	2025	2044	2047
MC-FRM 2030 (+ 1.2 Feet)	2044	2050	2055
+2 Feet	2058	2070	2090
MC-FRM 2050 (+ 2.4 Feet)	2063	2079	>2100
+3 Feet	2070	2090	>2100
MC-FRM 2070 (+ 4.2 Feet)	2082	>2100	>2100

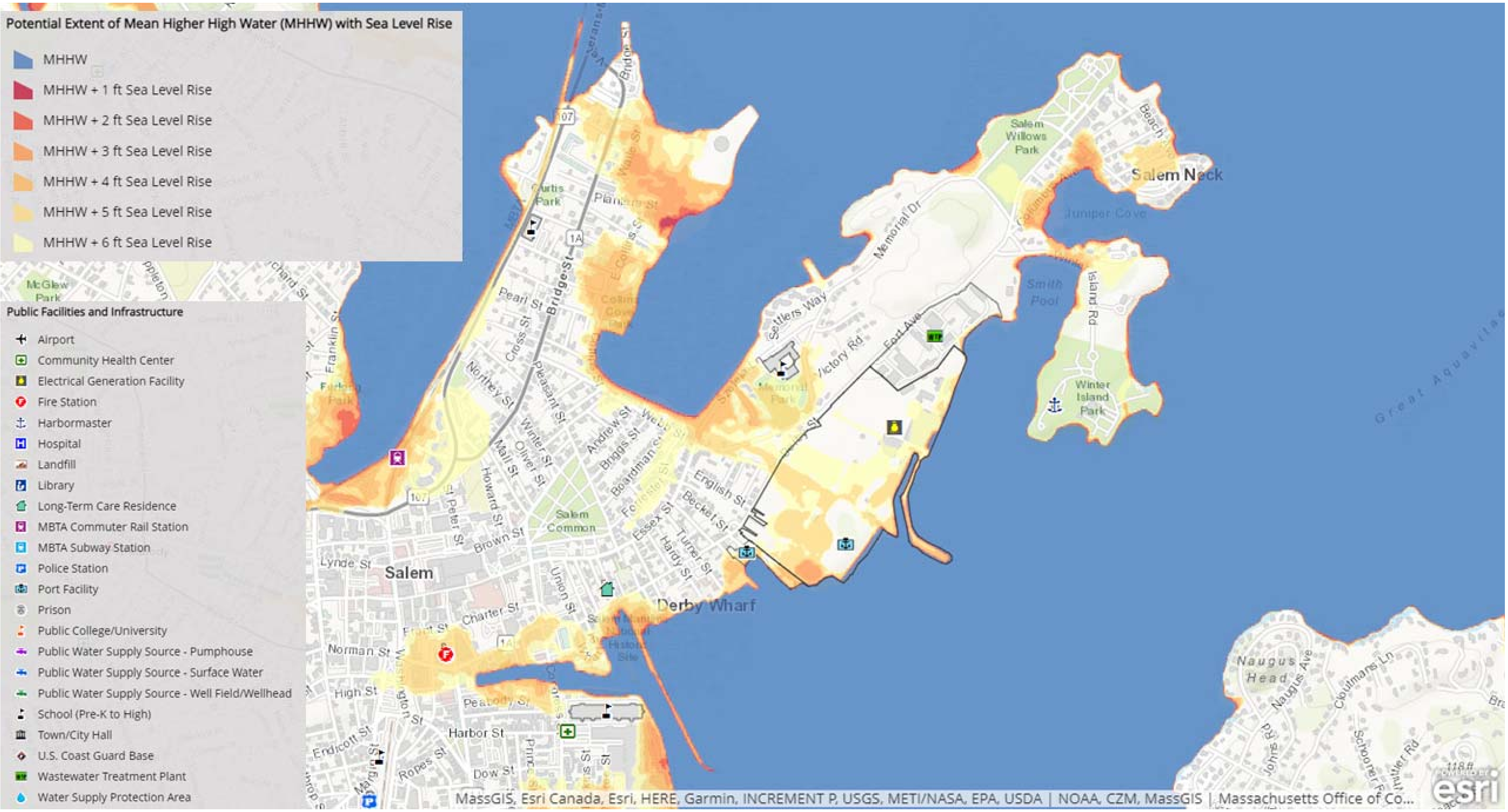

Figure 37. Salem Sea Level Rise (Massachusetts Sea Level Rise and Coastal Flooding Viewer)

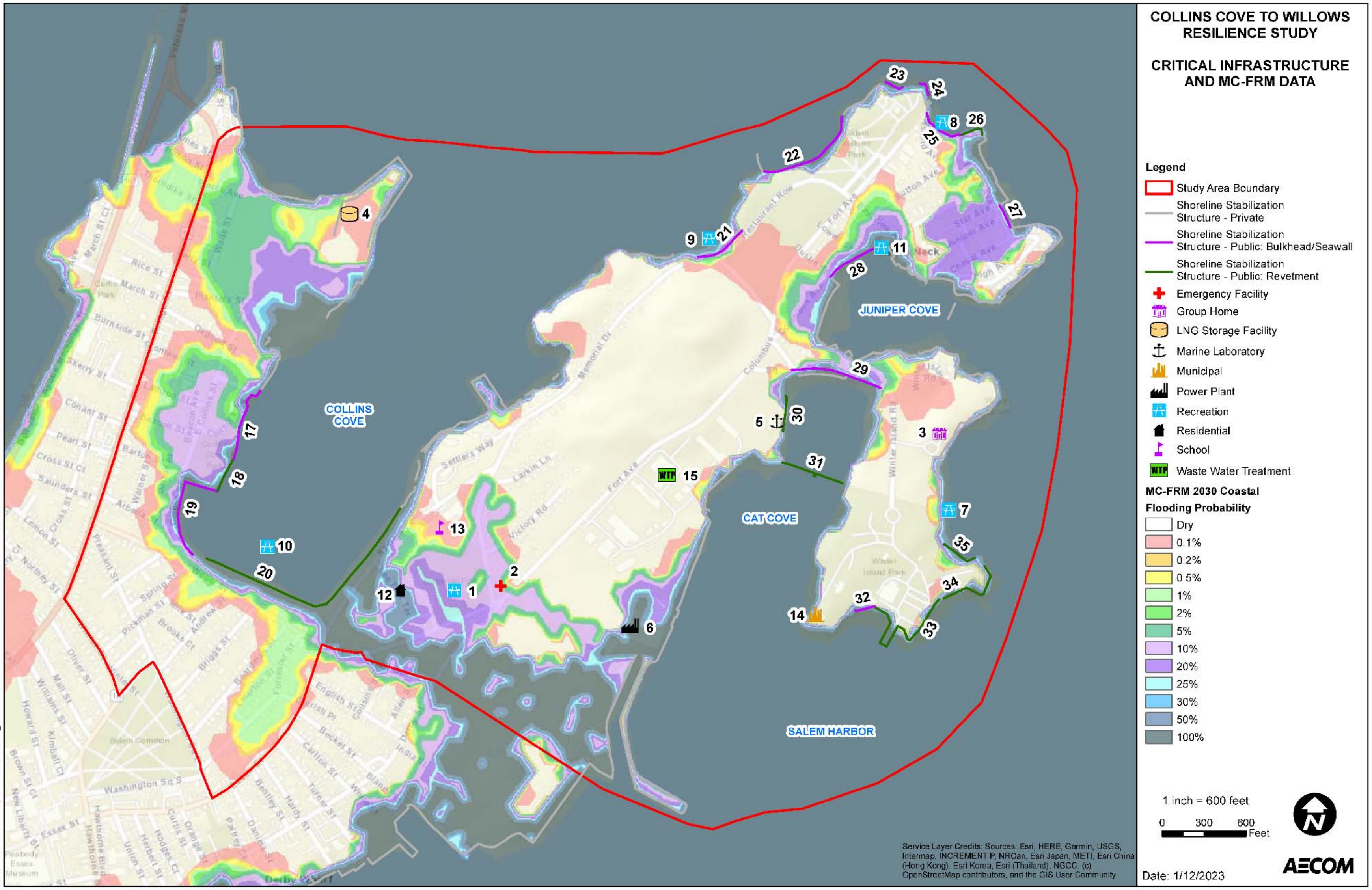

Figure 38. Critical Infrastructure and 2030 (1.2 feet of SLR) MC-FRM Annual Probability of Flooding

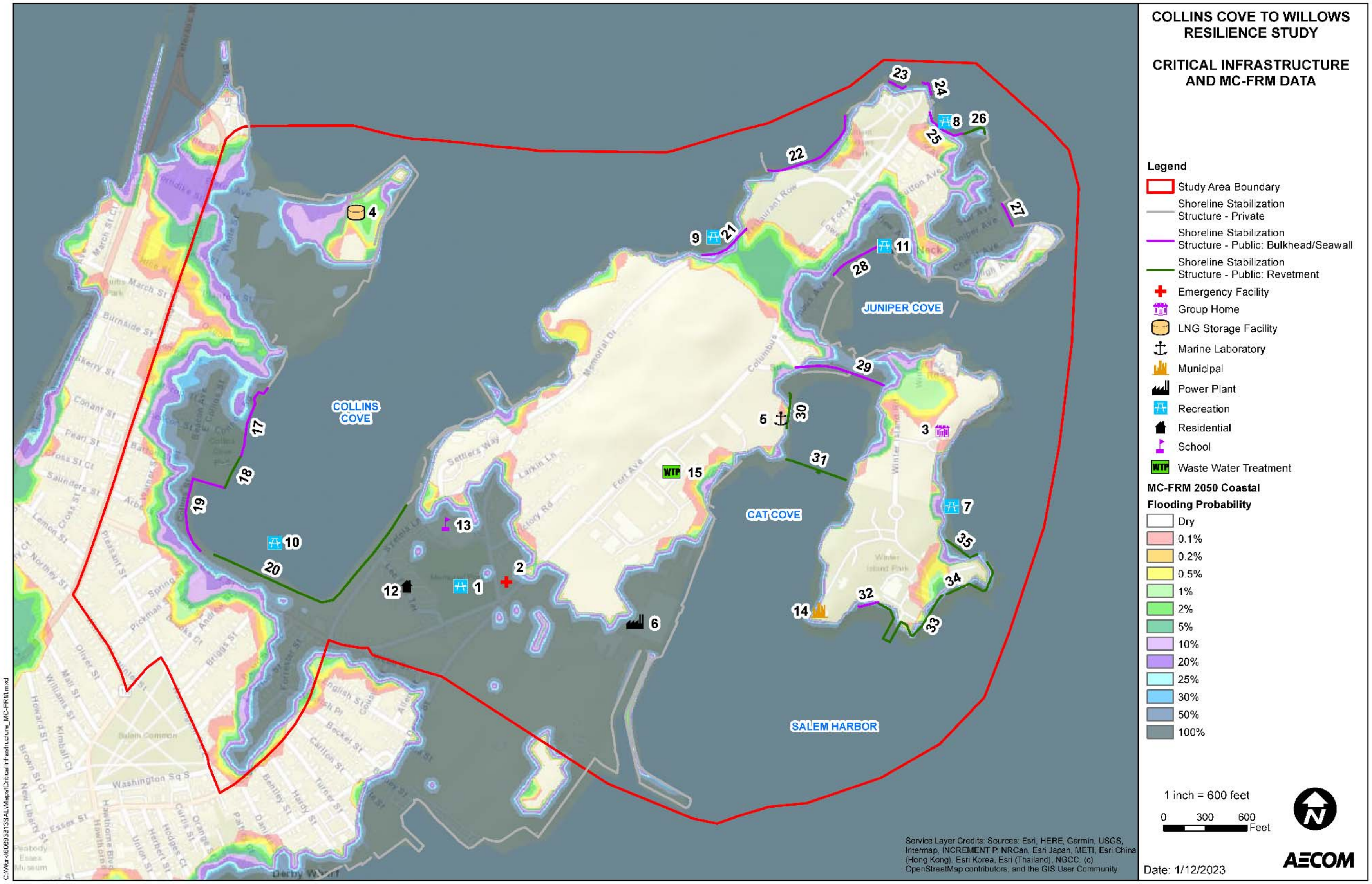

Figure 39. Critical Infrastructure and 2050 (2.4 feet of SLR) MC-FRM Annual Probability of Flooding

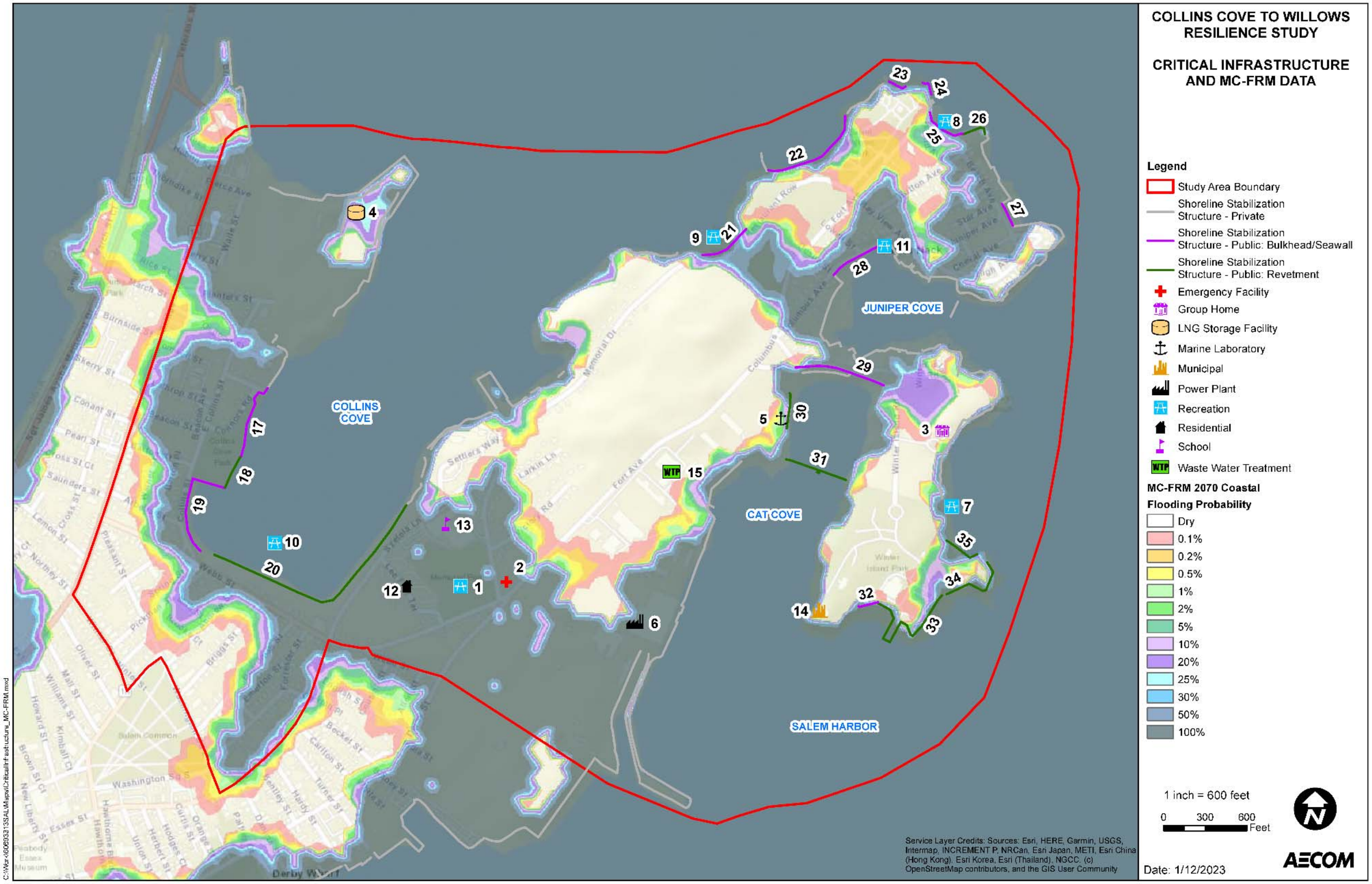

Figure 40. Critical Infrastructure and 2070 (4.2 feet of SLR) MC-FRM Annual Probability of Flooding

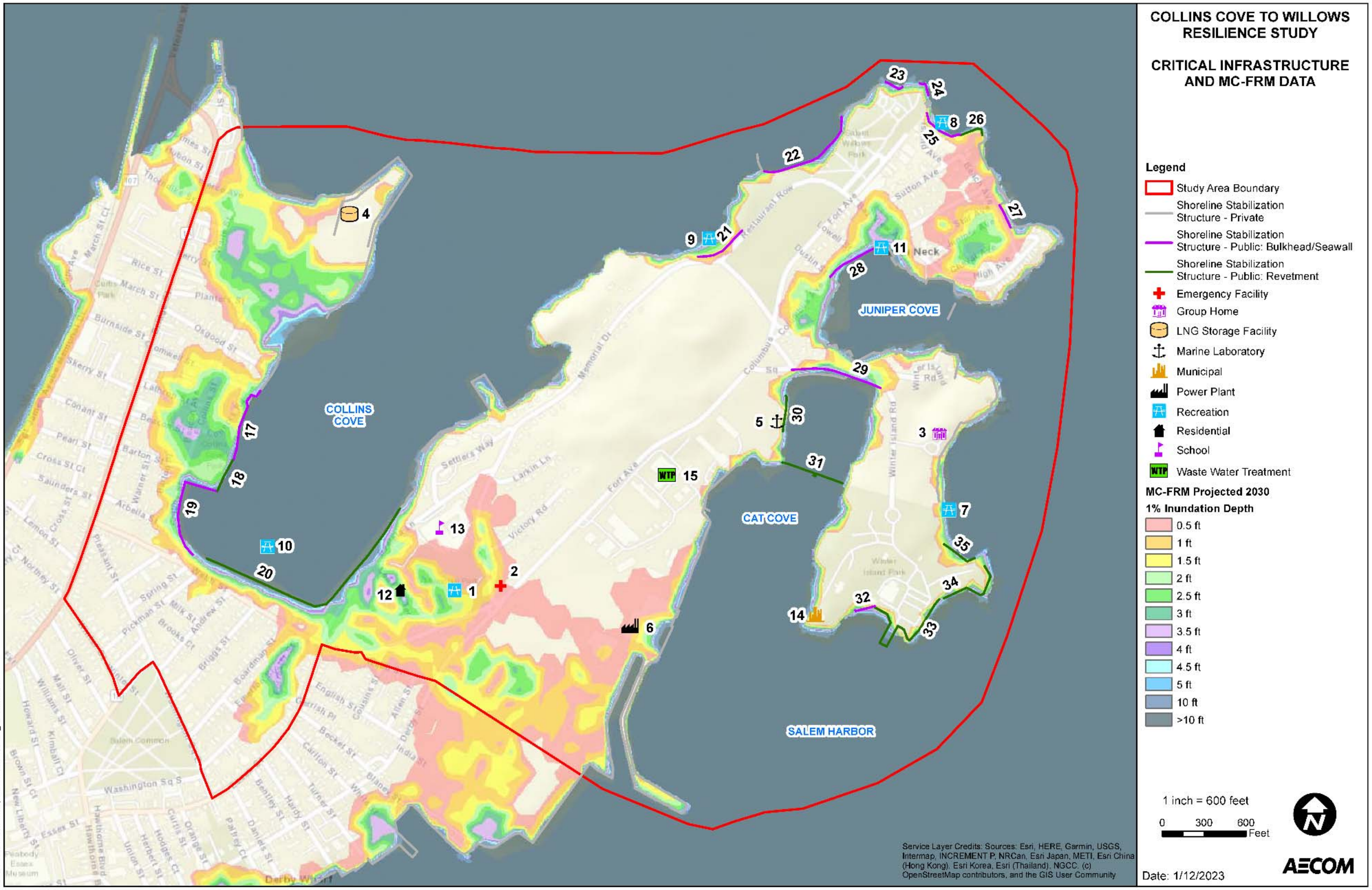

Figure 41. Critical Infrastructure and 2030 (1.2 feet of SLR) Inundation Depth of the 1% ACFEP Flood Event

6.2 Model Predicted Flooding for Future Conditions

As discussed in Section 5.2, the H&H model's ability to reproduce existing flooding based on the December 23, 2022, and a high intensity rainfall event was validated based on field measurements and community feedback received during the second public meeting. With the model able to represent existing conditions, projected conditions such as tidal, storm surge, and precipitation-based storm events were applied to the model. Three locations were selected to apply the MC-FRM data including Salem Harbor, Juniper Beach, and Collins Cove. These locations were selected based on the difference in coastal conditions observed during the December 23, 2022, storm event as discussed in Section 5.2. As previously discussed, the present day, 2030, 2050, and 2070 planning horizons were evaluated using MC-FRM spring tide and 1% storm surge time series data in addition to Cornell projected 5-year and 100-year 24-hour storm depths in an SCS Type III distribution.

Model scenarios for the three planning horizons and present day were determined based on model outputs that would be useful for the City of Salem to evaluate the impacts from multiple types of flooding events for each planning horizon. Model simulations included:

The MC-FRM 1% storm surge event with a 5-year 24-hour precipitation event in which the peak of the storm surge and the highest intensity rainfall occur simultaneously.

The MC-FRM Spring tide without precipitation.

The Cornell projected 5-year and 100-year 24-hours storm depths applied to an SCS Type III storm distribution.

The MC-FRM 1% storm surge event with a 5-year 24-hour precipitation event in which the peak of the storm surge and the highest intensity rainfall occur simultaneously results in a worst-case scenario condition in which high intensity rainfall is occurring during the highest water elevation of the storm surge event. Modeling both the coastal and precipitation conditions expand upon the capabilities of the MC-FRM, as that did not account for precipitation-based flooding. As shown in Figure 42, Figure 43, Figure 44 and Figure 45, the extent and depth of flooding progressively increases, and the time horizon projects further into the future. The model predicted flooding as a result of the 2070 storm surge and 5-year precipitation events indicate that inundation is possible in multiple locations throughout the study area resulting in temporary islands forming during similar storm events with a total flooded depth of up to 7 feet. Table 8 summarizes the flooded area and duration of flooding within the Study Area for each planning horizon for the Spring tide scenario.

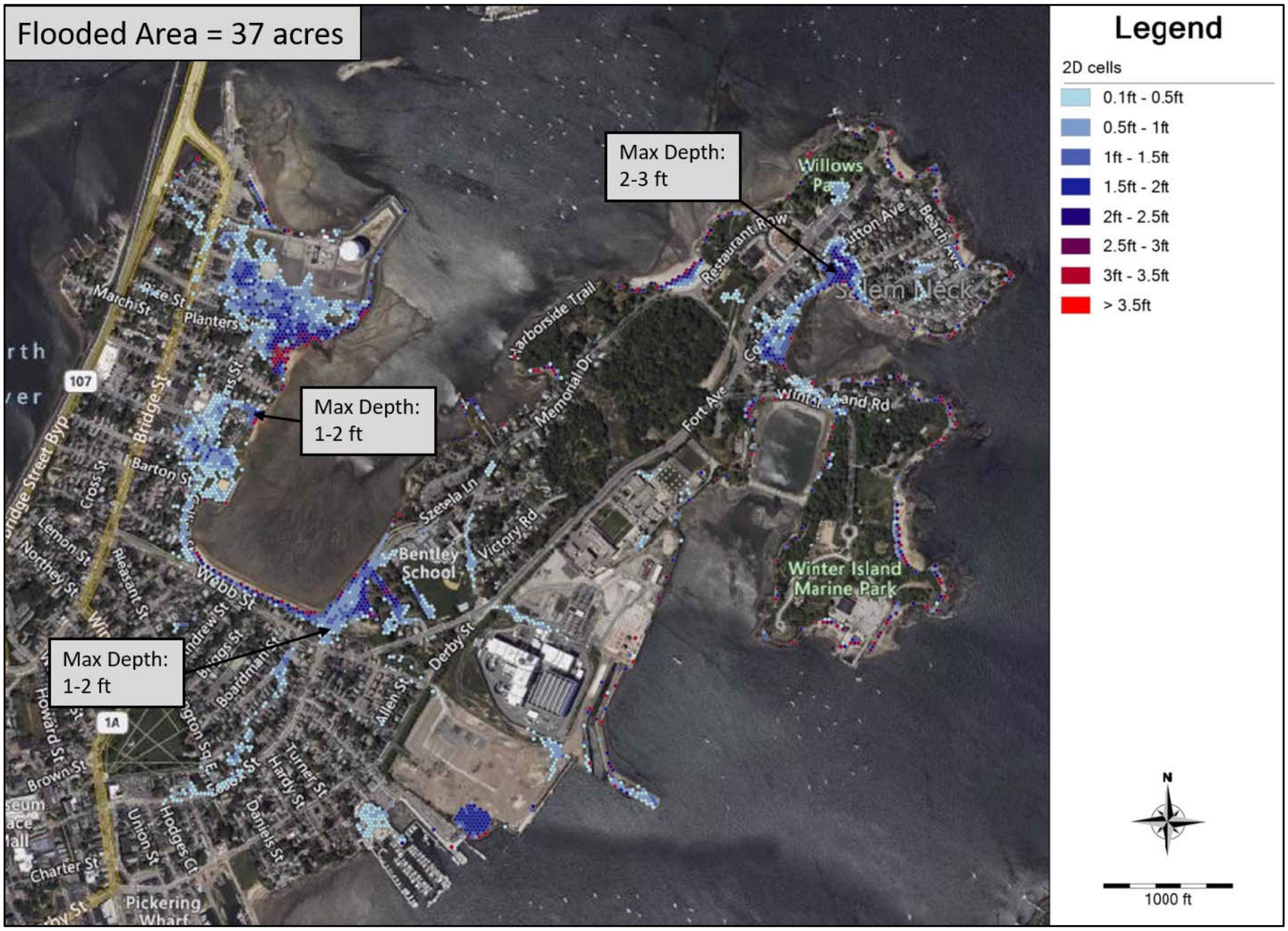

Figure 42. Present Day (2008) 1% Storm Surge with Present Day 5-Year 24-Hour Precipitation Event

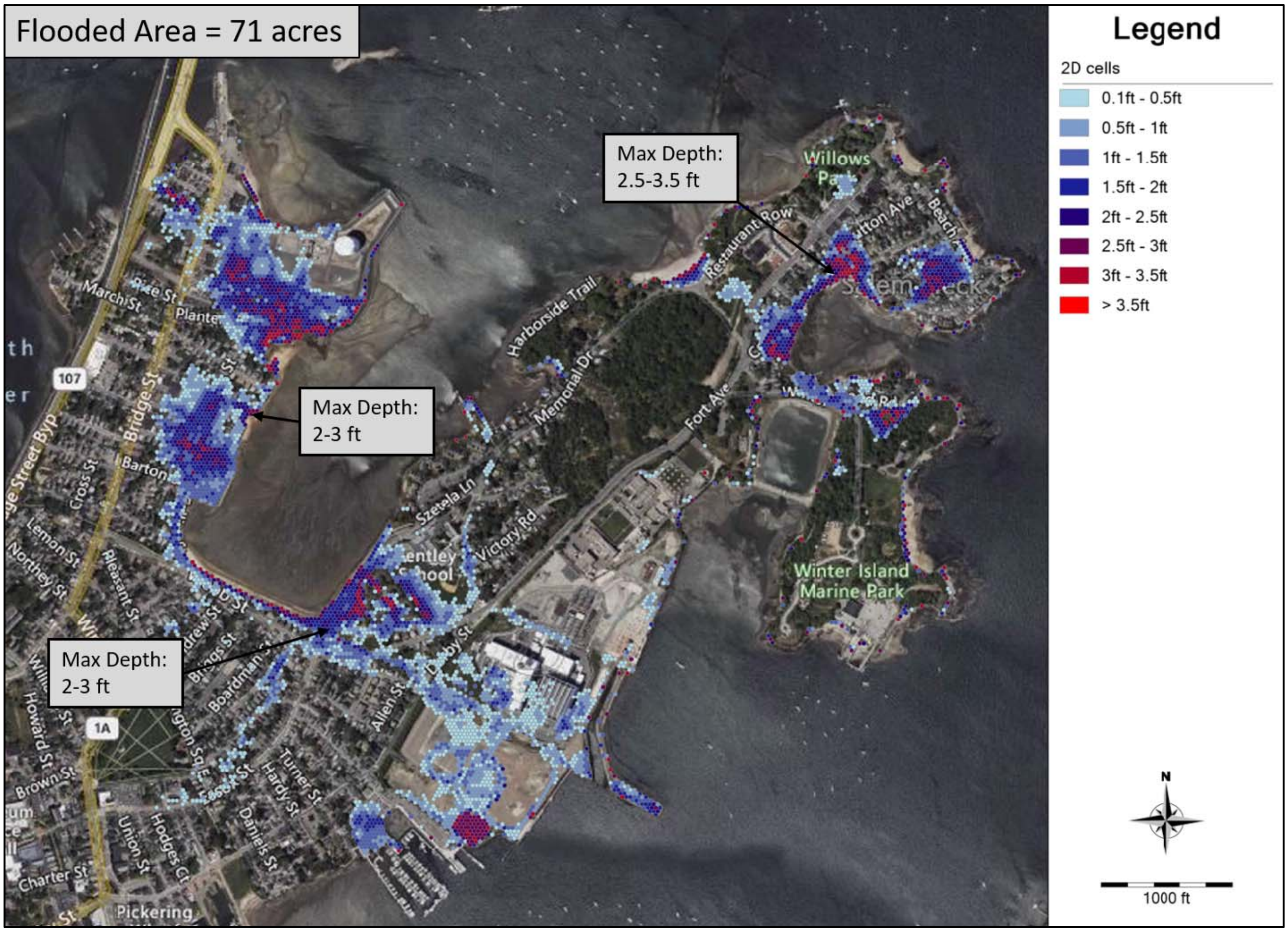

Figure 43. 2030 1% Storm Surge with 2030 5-Year 24-Hour Precipitation Event

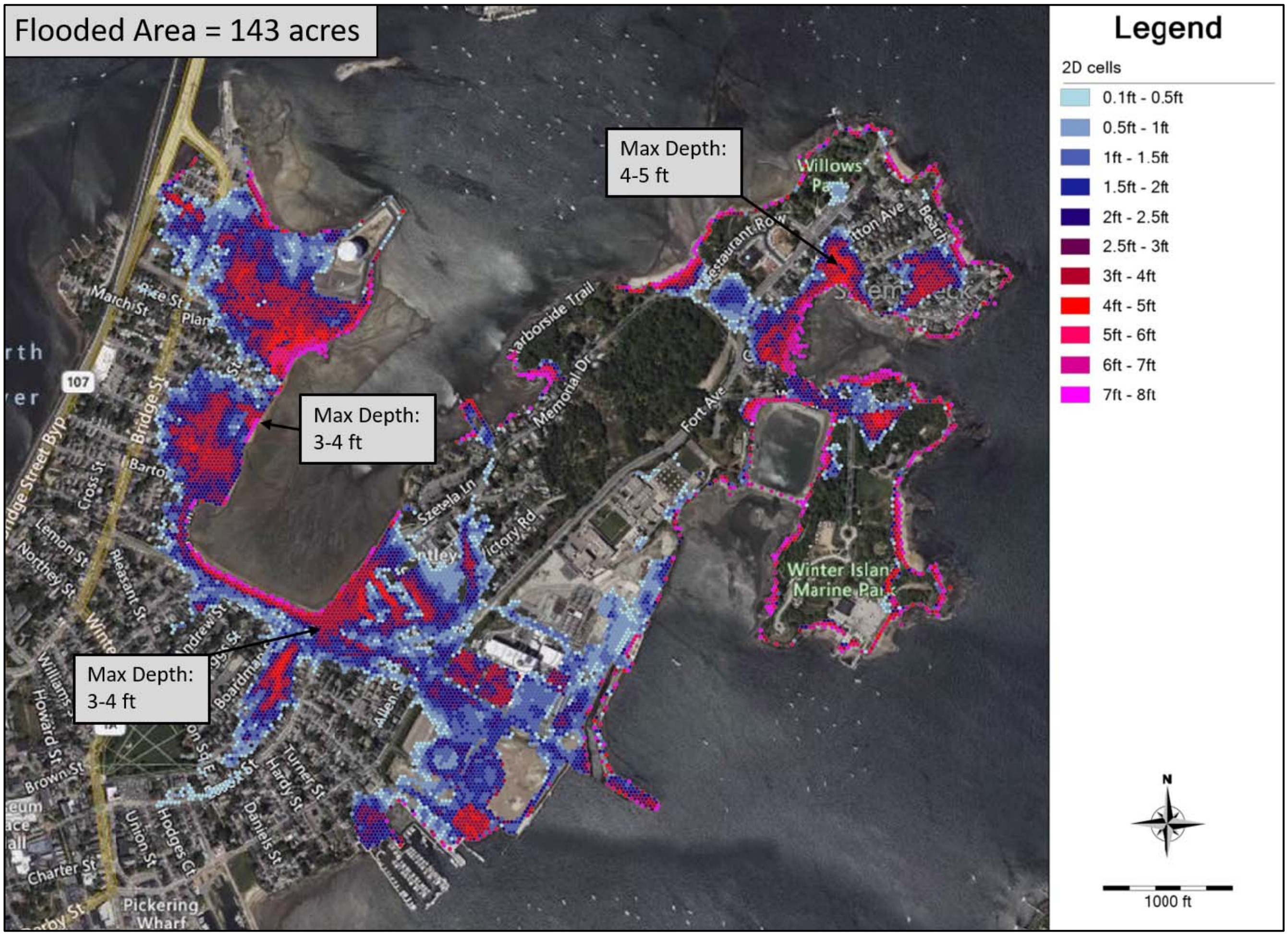

Figure 44. 2050 1% Storm Surge with 2050 5-Year 24-Hour Precipitation Event

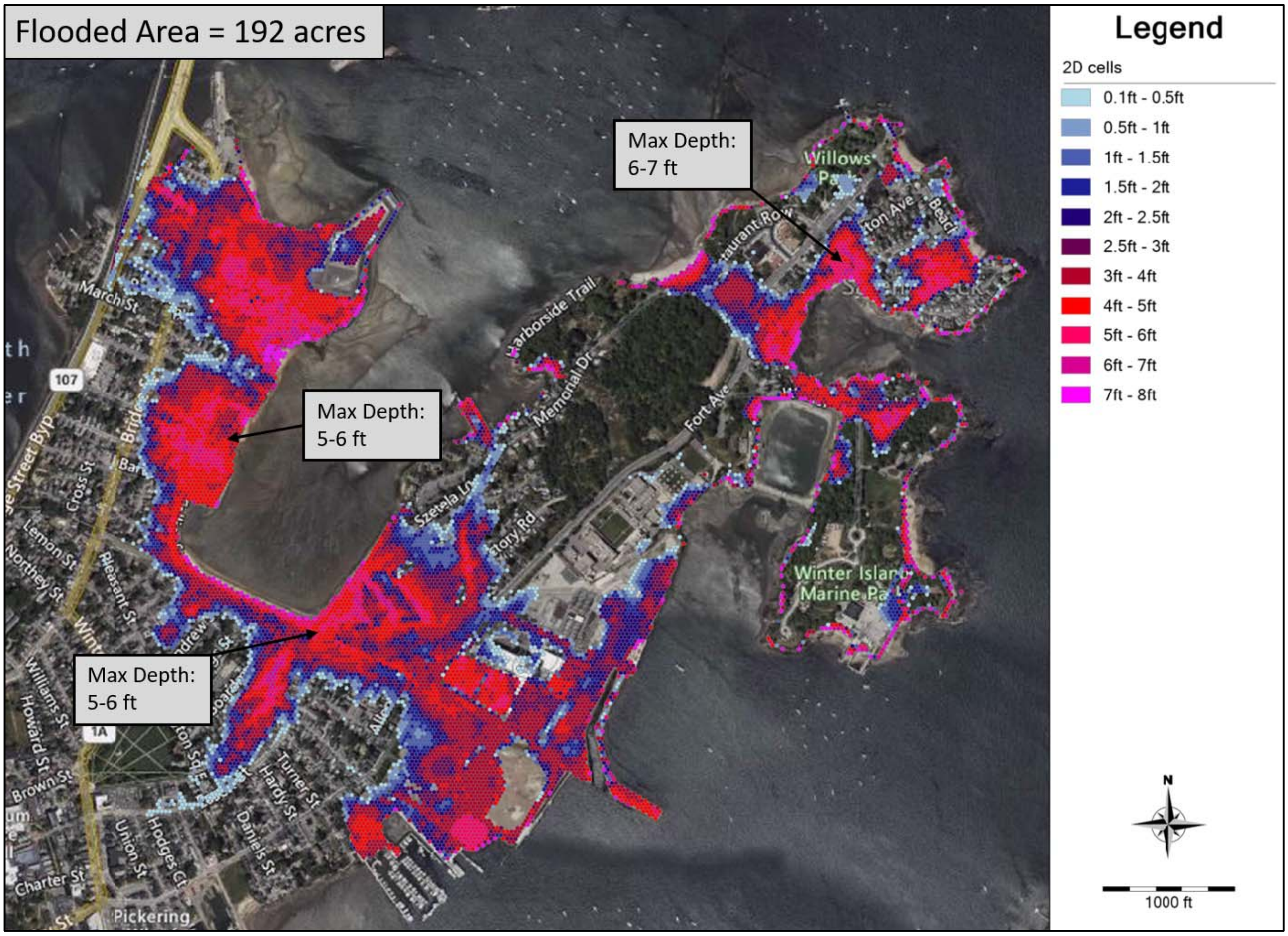

Figure 45. 2070 1% Storm Surge with 2070 5-Year 24-Hour Precipitation Event

The MC-FRM Spring tide was applied as the model's coastal boundary condition without precipitation to account for a higher frequency of coastal flooding that could occur approximately once per month. This scenario focuses on coastal flooding at a less severe basis compared to the storm surge scenarios. Model results indicate that the Spring tide does not currently cause calculable flooding in the study area. However, by 2070, approximately 93 acres could be flooded approximately once per month based on the Spring tide. Areas susceptible to Spring tide flooding include Conners Road, Webb Street, Szetela Lane, and Bay View – Columbus Ave. Table 8 summarizes the flooded area and duration of flooding within the Study Area for each planning horizon for the Spring tide scenario.

As previously discussed, Cornell projected 24-hour rainfall depths were assigned to an SCS Type III design storm distribution and applied to the model to evaluate the Study Area's vulnerability to precipitation-based flooding. To evaluate the stormwater system independent of a tidal boundary condition, the peak of the rainfall occurred at low tide. This allowed for an unrestricted discharge to the receiving water and identified areas where the stormwater infrastructure was unable to convey the runoff which resulted in flooding. Model results indicate that the locations susceptible to precipitation flooding include Osgood – Arbella Road, Szetela Lane, Forrester Street, Bridge Street, Memorial Drive, Juniper – Beach Ave, and Bay View Ave. Table 8 summarizes the flooded area and duration of flooding within the Study Area for each planning horizon for the Spring tide scenario.

Table 8. Model Predicted Future Condition Flooded Area and Duration

Scenario	Planning Horizon	Max. Flooded Area (ac)	Max. Duration of Flooding (hr)
Storm Surge + 5yr Rainfall	2070	192	9
	2050	143	8
	2030	71	7
	Present Day	37	5.5
Spring Tide (no rainfall)	2070	93	6.5
	2050	22	4
	2030	3	3.5
	Present Day	<1	<0.5
100yr Rainfall	2070	33	5.5
	2050	28	5
	2030	26	4.5
	Present Day	21	3.5
5yr Rainfall	2070	14	3
	2050	12	2.5
	2030	11	2
	Present Day	9	2

6.3 Erosion and Shoreline Change

The inclusion of non-static sea levels in any long-term shoreline change projections are critical to planning. As discussed in Section 1, the FEMA Region I Erosion Study incorporated NOAA SLR projections in their analysis of erosion risk areas, making it an important planning tool for identifying vulnerable sections of coast along the Study Area (Compass, 2021). The erosion risk area envelope varied greatly along the Study Area shoreline. Based on analysis of the FEMA study, sections of pocket beach were identified as having a higher erosion risk (Figure 46, Figure 47, Figure 48). Some of these more vulnerable areas include:

- Bridge Street Beach (Between Bill and Bob's Roast Beef and National Grid)
- Collins Cove
- Dead Horse Beach
- Fort Pickering Beach
- Juniper Cove
- Juniper Beach 1 and 2
- Waikiki Beach

These beaches all are projected to erode a minimum of 150 feet by the year 2100 under the NOAA high SLR projection (Figure 46). As discussed, these predictions operate under the assumption that there will be no rehabilitation to any existing shoreline protection structures. Any rehabilitation or construction of shoreline protection structures should be incorporated in future analysis. It is important to recognize that SLR will be the predominant forcing of net erosion on the system. This shoreline position adjustment initiated by SLR induced erosion is represented in Figure 46 through Figure 48. As discussed in

Young et al. (2021), as sea levels rise, storms will have a greater impact on the shorelines as higher water levels allow larger waves to propagate into the coves and erode the pocket beaches. Modeling of changing storm impacts should be considered in future studies, in addition to monitoring at regular intervals.

Currently, there is still uncertainty and a large range in future climate change scenarios and SLR projections. In future decades, additional monitoring of coastal processes and shoreline positions will allow these SLR projections to be refined and improve map accuracy. Also, other considerations for future shoreline change studies would be to incorporate other SLR datasets, such as the MC-FRM, to provide alternative projections that will influence erosion on Salem's shoreline.

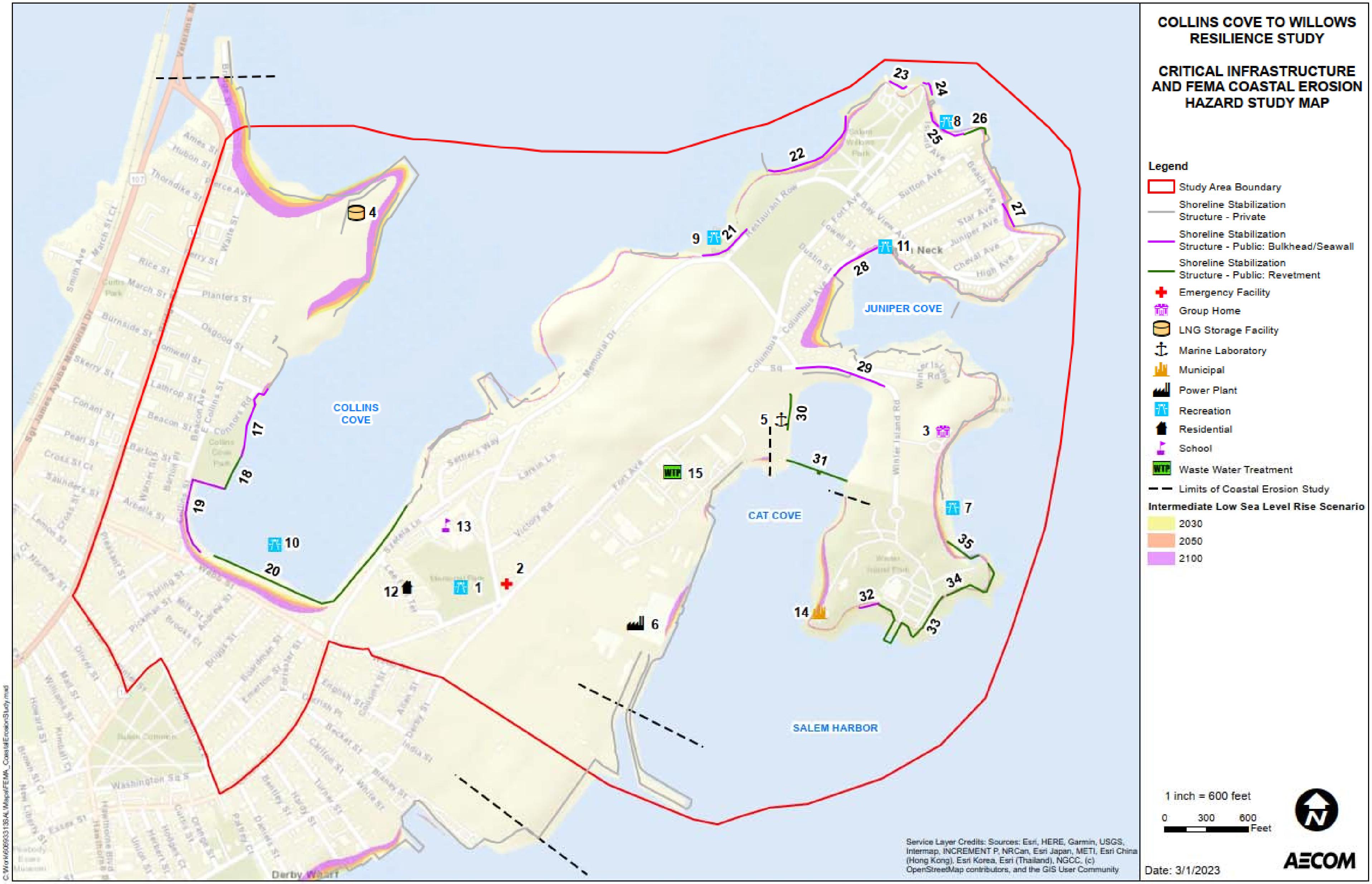

Figure 46. FEMA Future Conditions (Intermediate-Low Sea Level Rise Scenario)

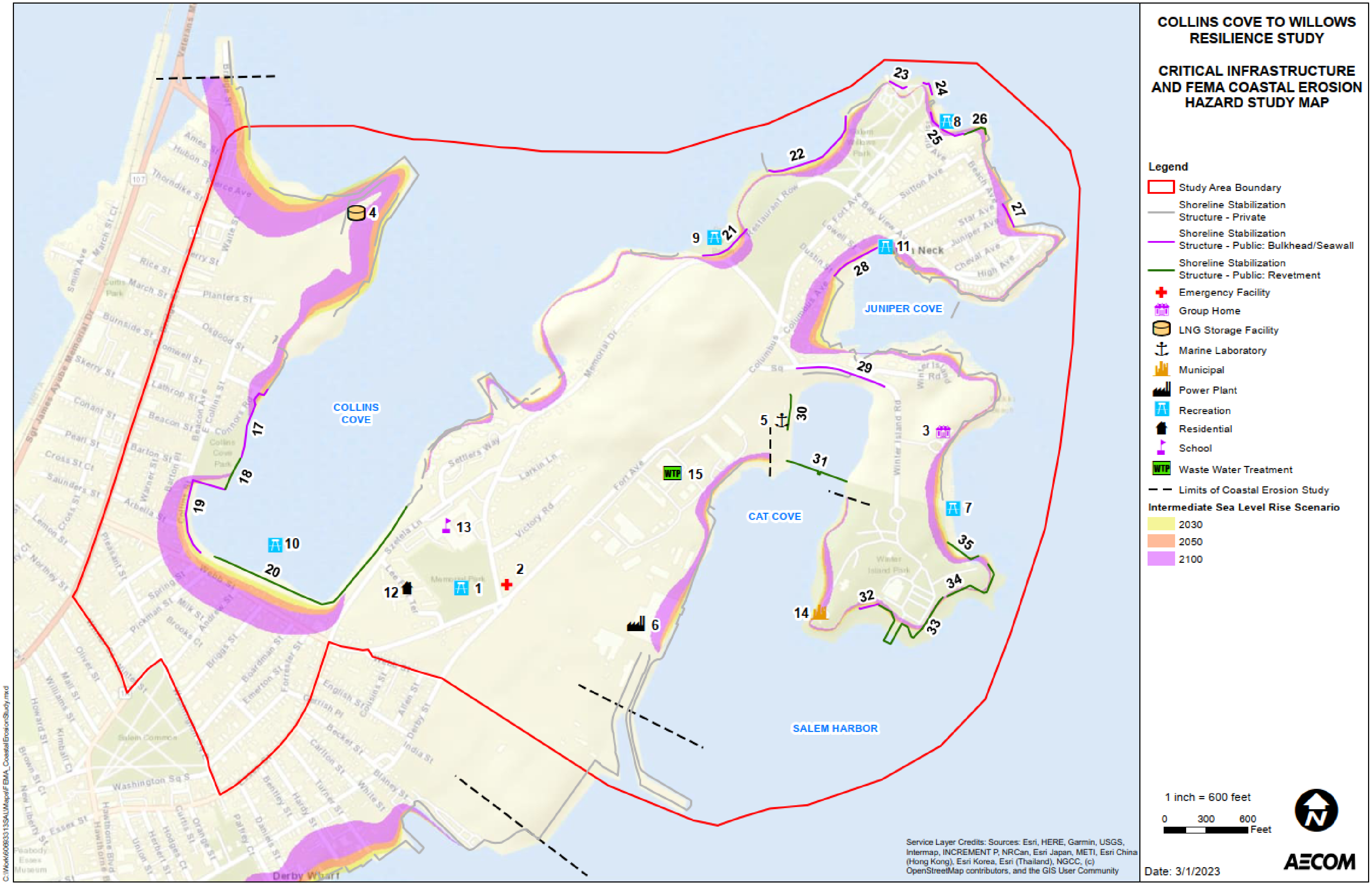

Figure 47. FEMA Future Conditions (Intermediate Sea Level Rise Scenario)

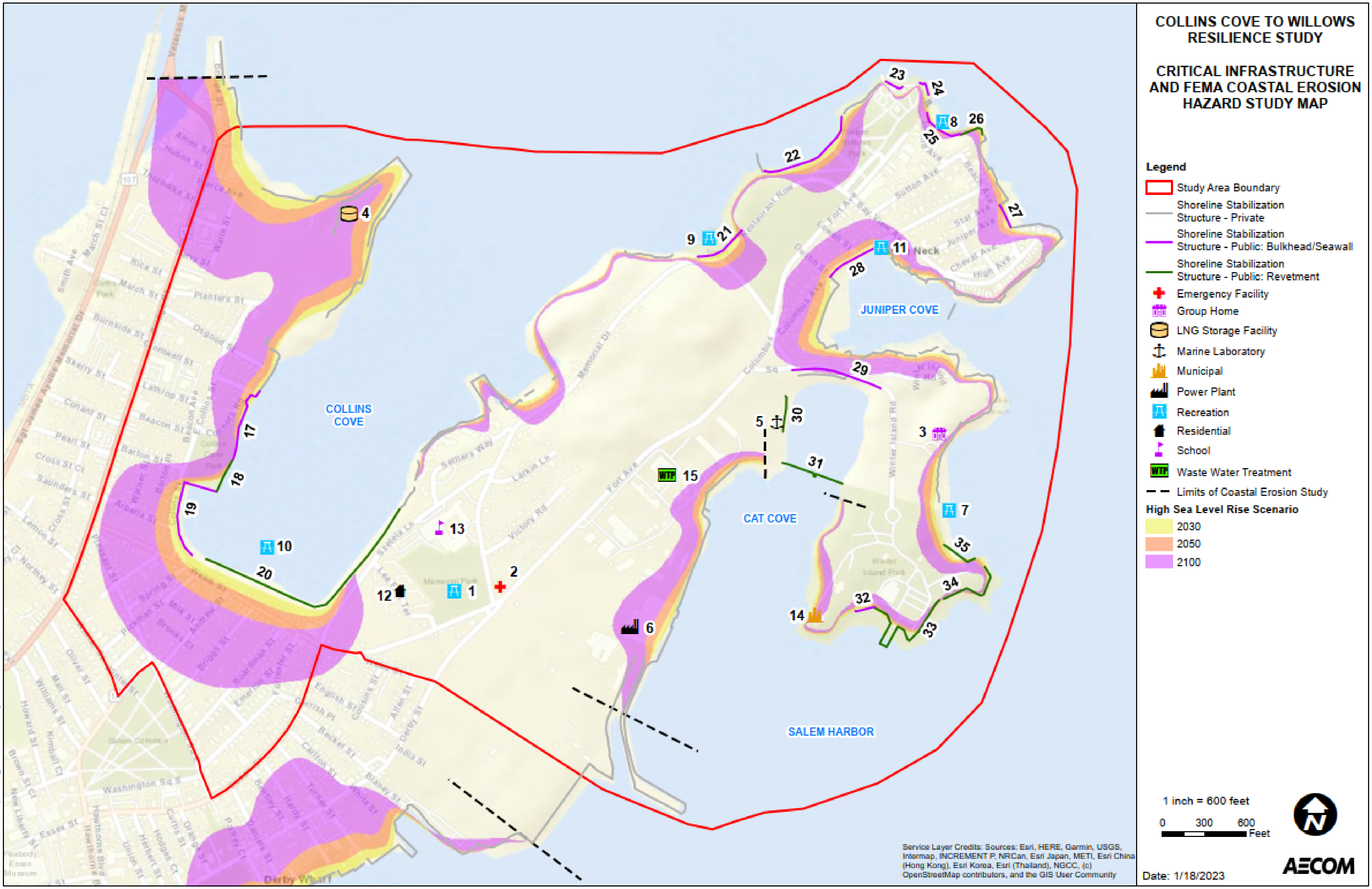

Figure 48. FEMA Future Conditions (High Sea Level Rise Scenario)

7. Priority Area Selection

H

7.1 Vulnerable Area Identification

The most vulnerable areas were identified based primarily on the severity of pluvial/stormwater and coastal flooding from the MC-FRM and H&H modeling results for the 2050-time horizon. Areas where both hazards were present were prioritized while also considering predominantly residential areas and the presence of critical infrastructure or major roads. The 2050-time horizon was selected as it balances relatively near-term vulnerability with a feasible implementation timeline for resiliency solutions. The following areas were identified as shown in Figure 49 alongside the Study Area boundary and city-owned parcels:

Forrester – Essex St

Webb St

Szetela Lane – Lee Fort Terrace

Bay View – Columbus Ave

Bridge St (North)

Osgood – Arbella – Bridge St

Juniper Ave

Memorial Drive

Planters St

Winter Island Rd

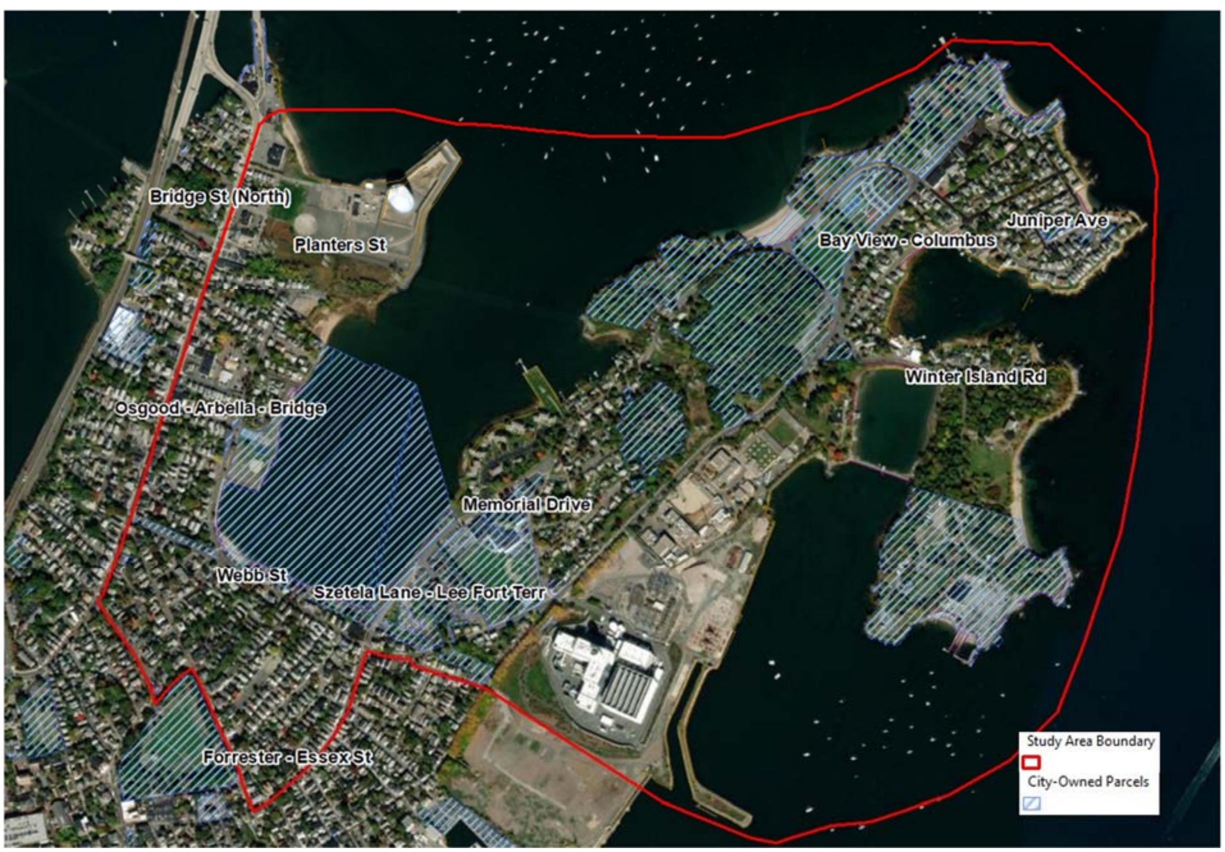

Figure 49. Most Vulnerable Areas

7.2 Priority Area Selection Criteria and Methodology

The most vulnerable areas were scored based on four major categories of vulnerability: stormwater/pluvial flood, coastal flood, erosion, and community. Seven selection criteria were developed to quantify the vulnerability for each category by assigning a score of 0 to 3 where a higher numerical value represents greater vulnerability. Flood-related criteria were binned according to severity (1, 2, or 3) while erosion and community vulnerability criteria were scored on a binary (0 or 3). The following bullets show the selection criteria and scoring for each underlined category:

<u>Stormwater/Pluvial Flood Vulnerability</u>

1. *2050 5-year Storm Floodplain Area*

   3 = > 1 acre

   2 = 0.5 – 1 acre

   1 = < 0.5 acre

2. *2050 5-year Storm Flood Depth*

   3 = > 2 feet

   2 = 0.5 – 2 feet

   1 = 0 – 0.5 feet

<u>Coastal Flood Vulnerability</u>

1. *2050 MC-FRM Coastal Flood Probability*

   3 = 0.5 – 1 annual exceedance probability

   2 = 0.1 – 0.5 annual exceedance probability

   1 = 0 – 0.1 annual exceedance probability

2. *2050 Spring Tide Floodplain Area*

   3 = > 3 acres

   2 = 1 – 3 acres

   1 = < 1 acre

<u>Erosion Vulnerability</u>

1. *FEMA Coastal Erosion Hazard Layer*

   3 = in 2050 Intermediate Erosion Area

   0 = not in 2050 Intermediate Erosion Area

<u>Community Vulnerability</u>

1. *Evacuation Route/Major Road*

   3 = Evacuation route or major road present

   0 = No evacuation route or major road present

2. *Environmental Justice (EJ)*

   3 = EJ population present

   0 = No EJ population present

Stormwater/pluvial flood vulnerability was represented using results from the H&H model 2050 5-year, 24-hour storm. Flooded area and depth of flooding were scored as separate selection criteria. Coastal flood vulnerability was represented using first, the MC-FRM 2050 annual coastal flood exceedance probability, and second, the flooded area simulated by the H&H model using a typical 2050 spring tide boundary condition provided by Woods Hole Group as used in their development of future conditions tidal benchmarks. Erosion vulnerability was scored on a binary (0 or 3) according to whether the vulnerable area was impacted by the FEMA Region I 2050 Intermediate Coastal Erosion layer. Community vulnerability was represented using the presence or absence of an impacted major road or evacuation route and was scored on a binary (0 or 3). Additionally, the 2020 Environmental Justice (EJ) Populations layer as developed by the state's Executive Office of Energy and Environmental Affairs (EEA) was used to evaluate the social vulnerability of each area and scored on a binary (0 or 3) as a part of the community vulnerability category.

Selection criteria scores were summed for each of the identified vulnerable areas to generate an overall vulnerability score. Scores are shown in Table 9. The top 5 overall vulnerability scores were selected for prioritization in the development of resiliency solutions in the next phase of this study. The selected areas and their overall scores listed below are shown in Figure 50 alongside the Study Area boundary and city-owned parcels:

1. Bridge St (North): 18
2. Osgood – Arbella – Bridge St: 16
3. Bay View – Columbus Ave: 16
4. Webb St: 15
5. Planters St: 15

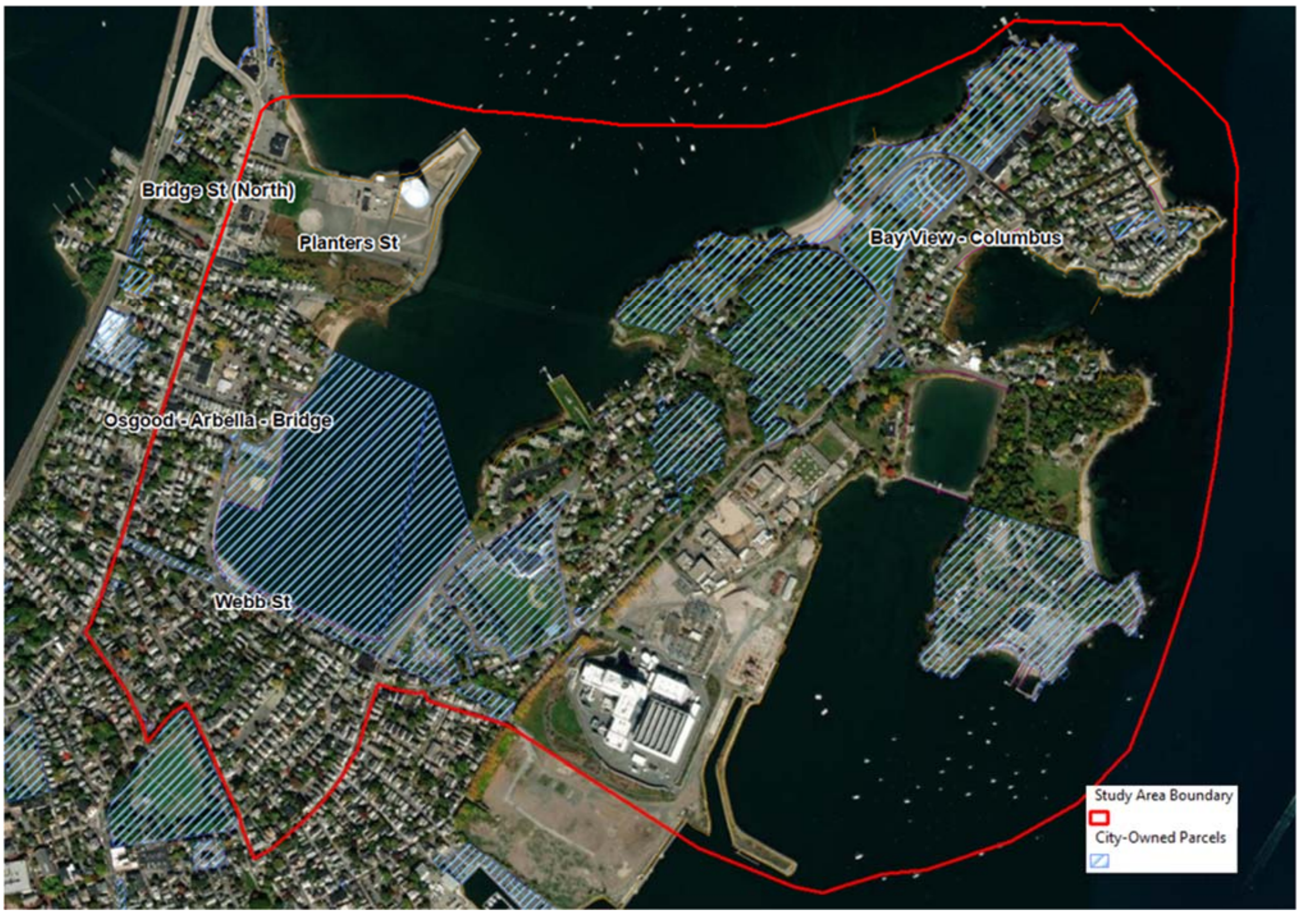

Figure 50. Selected Priority Areas

Table 9. Priority Area Selection Criteria Scores

Impacted Areas	Pluvial Flood Vulnerability		Coastal Flood Vulnerability		Erosion Vulnerability	Community Vulnerability		Score
	Stormwater Flooded Area (2050 5-yr)	*Stormwater Flood Depth (2050 5-yr)*	*MC-FRM Annual Coastal Flood Probability (2050)*	*Spring Tide Coastal Flooded Area (2050)*	*2050 Intermediate Erosion*	*Evacuation Route / Major Road*	*Environmental Justice*	
Bridge St (North)	3	2	2	2	3	3	3	18
Bay View - Columbus	2	2	3	3	3	3	0	16
Osgood - Arbella - Bridge	3	2	3	2	3	0	3	16
Webb St	1	1	3	1	3	3	3	15
Planters St	1	2	3	3	3	0	3	15
Szetela Lane - Lee Fort Terr	2	2	3	3	0	0	3	13
Winter Island Rd	1	2	3	1	3	3	0	13
Juniper Ave	2	2	3	1	3	0	0	11
Forrester - Essex St	3	2	3	1	0	0	0	9
Memorial Drive	2	2	3	1	0	0	0	8

8. Conclusions

This vulnerability assessment and modeling results memo for the City of Salem aims to provide a comprehensive understanding of Salem's vulnerability to coastal hazards and stormwater management challenges. By analyzing key factors such as the city's topography, infrastructure systems, and natural resources, we can identify critical areas of focus for resilience planning and develop effective strategies for reducing risks and improving resilience.

An extensive area along the southern edge of the Study Area from Collins Cove to Salem Harbor including Leefort Terrace and the Salem Harbor Station Power Plant, as well as low-lying areas surrounding Juniper Cove and Collins Cove, were identified as having high coastal flood risk in existing conditions and will become increasingly vulnerable as sea levels rise. All major roads connecting Juniper Point, Winter Island, and Salem Neck to the mainland (Derby Street, Szetala Lane/Essex Street, and Webb Street/Fort Avenue) are vulnerable to coastal flooding in present day and with 1.2 feet of SLR have over 50% annual probability of flooding.

In general, erosion and coastal flooding will most severely impact pocket beaches and the low-lying areas adjacent to the shoreline. The highest risk due to the combined impacts of these hazards exists along the southeast and western/northwestern portions of Collins Cove as well as the northern and western portions of Juniper Cove. Long-term erosion rates were greatest along the southeastern end of Collins Cove (approximately -1.3 ft/year) while the stretch of beach at the end of Planters Street shows heavy short-term erosion (approximately -3.0 ft/year) and is not protected by rock or manmade structures. It is important to recognize that while manmade structures can provide protection for their designed life, long term planning that is continually updated with new predictions is critical. Shoreline stabilization structures are typically designed to a particular flood elevation, and degrade over time eventually undermining the effectiveness. If proper action in the form of maintenance and planning are not taken, the impacts of storms and flooding both present day and under future conditions will prove devastating for the surrounding residential areas.

Based on public feedback with regards to the H&H model's ability to replicate observed flooding during a high intensity storm event, the H&H model is believed to be representative of field conditions. Although stormwater flooding occurs throughout the study area, three locations—Forrester Street, Bridge Street, and at Bay View and Columbus Avenue—were identified as areas of high vulnerability to existing conditions stormwater flooding. Model results show that the existing stormwater infrastructure in the Study Area exceeds capacity during a present day 1-year storm event, which suggests that improvements to the stormwater infrastructure will be essential for the long-term resiliency of the City.

Stormwater flooding for future conditions was evaluated for the 2030, 2050, and 2070 5-year and 100-year 24-hour storm event. In addition to the three locations identified by the existing conditions evaluation, Osgood – Arbella Road, Szetela Lane, Memorial Drive, and Juniper – Beach Ave are predicted by the model to be susceptible to stormwater flooding for both storm events. The stormwater flooding is caused by both catch basin inlet capacity restrictions and pipe capacity deficiencies in the existing system. Stormwater management solutions will be necessary to mitigate stormwater flooding today and in the future.

A selection process was developed and implemented in order to identify and prioritize the most vulnerable areas within the Study Area. The selection process considered vulnerability to stormwater/pluvial flooding, coastal flooding, erosion, and community vulnerability. The following five priority areas were identified through the selection process as described in Section 7:

1. Bridge St (North)
2. Osgood - Arbella – Bridge St
3. Bay View – Columbus Ave
4. Webb St
5. Planters St

These areas will guide the development of resiliency solutions in the next phase of this study.

9. Acronyms

ACFEP	Annual Coastal Flood Exceedance Probability
ACE	Annual Chance Exceedance
Atlas-14	Atlas of rainfall depths and durations for the United States, version 14
CZM	Coastal Zone Management
DFE	Design Flood Elevation
FEMA	Federal Emergency Management Agency
H&H	Hydrologic and Hydraulic
H_{max}	Maximum Wave Height
LiDAR	Light Detection and Ranging
MA	Massachusetts
MC-FRM	Massachusetts Coastal Flood Risk Model
MHHW	Mean Higher High Water
MHW	Mean High Water
MLLW	Mean Lower Low Water
MLW	Mean Low Water
MSL	Mean Sea Level
MTL	Mean Tide Level
NAV88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PCSWMM	Personal Computer Storm Water Management Model
SCS	Soil Conservation Service
SLR	Sea Level Rise
USGS	United States Geological Survey
WSE	Water Surface Elevation

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Appendix D: Past Studies and Available Data Memo

AECOM

AECOM
250 Apollo Drive
Chelmsford, MA 01824
aecom.com

Project name:
Collins Cove to Willows Resilience Study

Project ref:
60693313

To:
Deb Duhamel, City of Salem

CC:
File

From:
AECOM

Date:
March 8, 2023

Task 3: Past Studies and Historical Data Memorandum

1. Introduction

Adapting to the increasingly severe and highly variable challenges presented by the climate crisis remains a high priority for the City of Salem. There are few locations along the coast that are spared from the threats of sea level rise, coastal surge, and erosion. The Collins Cove to Willows area ("Study Area"), a highly residential coastal community, has experienced a particularly large number of flooding events (both coastal and overland) in recent years. The purpose of this Memorandum is to provide an overview of the many studies, both previous and ongoing, seeking to address this issue in the Study Area. The Memorandum also summarizes historical natural hazard and climate information, property ownership, and critical resources and infrastructure within the Study Area. This Memorandum is part of the third task in a five-task resiliency study that will provide the City with an overview of historical, present, and projected future threats that necessitate further resiliency measures to be undertaken in this area. The material summarized in this Memorandum will be used to inform the vulnerability assessment that is being performed for the study.

2. Past Studies Relevant to the Collins Cove to Willows Study Area

For decades, residents, businesses, and visitors within the Study Area have experienced hazards due to extreme weather events, including flooding and coastal storms. Numerous studies have been conducted by the City and local planning organizations to better understand and prioritize the needs of Salem as related to climate resilience. The City received a Municipal Vulnerability Preparedness (MVP) Community designation in 2017 following the publication of the City's first Climate Change Vulnerability Assessment and Adaptation Plan (CDM Smith, 2014). This designation allows access to additional resources and grant funding to initiate capital improvement projects and data-gathering projects, including the MVP Action grant that funded this Collins Cove to Willows Resilience Study. This section summarizes studies conducted and their relevance to the Collins Cove to Willows Study Area. Several studies examine the entire City, in which case only the findings and recommendations related to the Collins Cove to Willows Study Area are communicated here. Key points are provided in Table 1, starting with the most recent source, followed by a source overview and summary of recommendations. Several studies have relevant tables and figures, which are provided in Section 2.1.

Table 1. Summary of Past Studies and Reports for the Collins Cove to Willows Area

Title	Author(s)	Date of Source	Definition of Study Area	Source Overview	Recommendations (if applicable)
Reimagining Community Engagement to Increase Resilience to Climate Change in El Punto Neighborhood, Salem, Massachusetts	Elizabeth L. Sweet, PhD; Fabián Torres-Ardila, PhD; Daniela Bravo, B.A.; Leandra Jara, B.A. (UMass Boston)	Sep-22	The Point/Palmer Cove	This report compiles the key findings and recommendations that resulted from conducting a qualitative study with residents and other individuals who play important roles in advocating for and supporting the El Punto [The Point] community.	Promote a positive perception of what El Punto and its residents are. Facilitate processes of community empowerment. Support and strengthen local community-based organizations. Consider specific interventions that link the interests of the residents and the City.
Resilient Together: The Point	Woods Hole Group	Jul-22	The Point/Palmer Cove	This project seeks to address present and future climate risks in one of Salem's most socio-economically and physically vulnerable neighborhoods (The Point or "El Punto"). Public engagement activities were undertaken to understand existing conditions. A vulnerability assessment of The Point was carried out, and strategies and priorities were developed.	Other recommendations are included in the original document. The most relevant excerpts are summarized here. - Modify the existing Stormwater Management Ordinance to include projects with less than 1-acre disturbance. See Somerville, MA ordinance and regulations as an example. - Use the new flood model developed for The Point to evaluate engineering alternatives and develop a prioritized capital plan to reduce rain flooding and its impacts on transportation infrastructure and mobility. Design long-term coastal flood protection infrastructure across the waterfront between Peabody St and the South River.
The City of Salem Comprehensive Emergency Management Plan	City of Salem	Mar-22	City of Salem	Intended for use during non-emergency conditions, this plan documents hazard mitigation measures and strategies. It is an updated version of the original CEMP (2012). Potential impacts from flooding, high winds, winter storms, extreme temperatures, etc., are considered. Existing strategies from the 2012 plan are also detailed to the extent they were completed, in progress, or deferred.	Salem would like to complete work on seawall infrastructure, complete work begun to mitigate coastal flooding in the Canal Street, Brooks Road/ Jefferson Avenue/Rosie's Pond neighborhoods, mitigate flooding along Bridge Street, continue to acquire priority vacant flood-prone land, and complete its upgrading of backup generating capacity at all its fire stations.

Title	Author(s)	Date of Source	Definition of Study Area	Source Overview	Recommendations (if applicable)
Beverly & Salem Resilient Together: Climate Action and Resilience Plan	Kim Lundgren Associates, Inc, Nitsch Engineering, Inc., Utile	Jul-21	Cities of Beverly and Salem	This plan was developed in partnership with the cities of Salem and Beverly to identify specific, climate-resiliency-related actions based on the needs of community members as identified by the Climate Action Advisory Committee. Classifies these proposed projects based on their type, duration (short/medium/long), and cost.	Additional recommendations are provided on pages 56 and 57. The most relevant excerpts are summarized here. **Capital Improvement**: Implement resilience upgrades for critical infrastructure assets vulnerable to coastal flooding. **Research/Assessment**: Analyze all infrastructure for vulnerability, evaluate for criticality, rank for priority upgrades, and incorporate into asset management and capital planning. **Policy**: Explore financing strategies like stormwater fees to generate needed revenue for infrastructure financing. **Technology/Software**: Implement a computerized maintenance management system to assess public asset conditions, streamline data collection, and estimate asset replacement values, considering, as appropriate, life cycle assessment. **Policy**: Establish a long-term strategy for public shoreline stabilization structures with an emphasis on nature-based solutions and naturalizing the coastline.
Hazard Mitigation Plan 2020 Update	Metropolitan Area Planning Council	Feb-20	City of Salem	Following the 2012 Salem Hazard Mitigation Plan, this update reviews previously identified measures and decides whether to continue prioritizing these measures.	The original document includes a list of 180 "Critical Infrastructure in Hazard Areas." Table 2 lists the committee's recommendations on whether to include the various mitigation measures in the 2020 plan and with what priority. A revised mitigation measure prioritization table is included in the original document. The most relevant actions are listed here: - Identify resources to maintain City drainage and climate resilience infrastructure on an ongoing basis. - Complete upgrades to finish Daniels Street, Ocean Avenue, and Willows Park sea walls. - Assess which pump stations can handle flooding - examine backup power and the need for flood barriers. Update codes for seawalls being rebuilt to take future flooding into account Palmer/Point, Juniper Cove, Collins, and others.

Title	Author(s)	Date of Source	Definition of Study Area	Source Overview	Recommendations (if applicable)
Community Resilience Building Workshop: Summary of Findings	Barbara Warren, Salem Sound Coastwatch	Mar-20	City of Salem	Following the City's first Climate Change Vulnerability and Adaptation Plan (2014), a community-based resilience workshop was held to better engage the MVP community. While there is some overlap with the Hazard Mitigation Plan (2020), this summary includes long-term assessments and planning for changing climate hazards.	Recommendations in the areas of (1) Emergency Planning and Response, (2) Long-term Climate Resiliency, (3) Roadway Continuity, (4) Green Infrastructure and Low Impact Design (LID), and (5) Community Outreach and Education are included in the original document. The recommendations most relevant to this work are listed here: - Evaluate current and future flood pathways on the watershed level and possible resilience actions for the City, residents, and community partners - Conduct immediate flood-proofing at critical city-owned infrastructure, which may mean moving important items (i.e., documents, generators, etc.) to higher ground and/or actual flood-proofing buildings Explore and implement opportunities to restore and protect natural systems within existing parks or near seawalls.
Salem Willows Existing Conditions Report: Historic Resources	Pamela Hartford, Landscape History, Design, and Preservation	Jan-19	Willows Park	This document reviews the historic resources in the Salem Willows historic District and historical elements of vehicle and pedestrian circulation.	Figure 1 depicts existing seawalls as of 2018. The original document contains qualitative descriptions of the walls' materials and history. In 2002, the park underwent improvements to its amenities and safety.
Salem Flood Map Revisions	Sean W. Kelley, Applied Coastal Research and Engineering	Sep-16	City of Salem	Using a wave analysis, SWAN Model of Salem Sound, and simulation of 1% East Conditions, the author used transects to delineate flood zones and proposed adjustments to the FEMA Flood Insurance Rate Maps (FIRM).	The following changes are recommended to the FEMA Flood Map: Juniper Point & Winter Island - Lower VE zone* elev. (21 ft reduced to 16 ft NAVD) - Reduce VE zone* extent - Lower AE zone** elev. (14 ft reduced to 11 ft NAVD) - Expanded zone X*** (out of 1% floodplain) *VE zone: Coastal flood zone with waves component less than 3 feet **AE zone: Coastal flood zone with waves component less than 3 feet ***Zone X is shown on maps in the original document

Title	Author(s)	Date of Source	Definition of Study Area	Source Overview	Recommendations (if applicable)
Massachusetts Coastal Infrastructure Inventory and Assessment Report Update	Bourne Consulting Engineering	Jul-15	Manchester, Beverly, Salem (Statewide)	The assessment report focused on the state's vulnerability to coastal hazards and is the most recent update to this study. This iteration expanded the scope to include: • Federally owned and maintained coastal structures • Identification of probable cost to improve coastal structures to meet current estimated coastal storm exposure levels, including sea level rise impacts. • Incorporation of structures missed in the original studies and corrections to the previous structure assessments as identified in the current structure assessments.	Section IV: Salem. Within the City of Salem, 43 structures had public or unknown ownership which provide significant coastal protection. Table 3 details these structures of unknown ownership by condition rating. Table 4 provides estimates of replacement costs by type of structure. Profiles detailing the individual coastal structures and their condition are provided in the original document.
The City of Salem Open Space and Recreation Update 2015-2022	Gale Associates, Inc.	Jul-15	City of Salem	The plan proposes goals and objectives for open space and recreation within the city, along with a seven-year action plan.	Former industrial or mill properties in Salem may provide the City with the greatest potential for improvements. While almost all these properties are currently privately owned, some occupy key waterfront or gateway sites in the city and would offer great potential to open the city's waterfront.
The City of Salem Climate Change Vulnerability Assessment & Adaptation Plan	CDM Smith	Dec-14	City of Salem	The plan was created by assessing vulnerability using institutional knowledge, flood mapping, and consulting with technical experts. Forty-three adaptation strategies are described.	A "List of Prioritized Vulnerabilities" is provided in Table 5. The original text includes tables with adaptation strategies and what prioritized vulnerabilities they address. Seawall repair is at the top of the list of prioritized vulnerabilities.
Mapping and Analysis of Privately-Owned Coastal Structures along the Massachusetts Shoreline	RPS Group	Mar-13	Massachusetts Coastline (Statewide)	This report is the first of two updates to the Massachusetts Coastal Infrastructure Inventory and Assessment Project. The scope was expanded to include privately-owned structures.	There are 124 privately-owned shoreline stabilization structures within the City of Salem. Many of these structures were built prior to modern coastal management policies and regulations, and until recently, no centralized database of coastal structures existed. Considering both private and publicly-owned structures, nearly 27% of Massachusetts' ocean-facing shoreline is armored with some form of coastal protection.

Title	Author(s)	Date of Source	Definition of Study Area	Source Overview	Recommendations (if applicable)
Massachusetts Coastal Infrastructure Inventory and Assessment Project	Bourne Consulting Engineering	Jul-09	Manchester, Beverly, Salem (Statewide)	The project was initiated to identify all the coastal structures the state either owns or has a responsibility to maintain for the four regions included in the study. Structures were then assessed for likely rehab or repair costs to withstand major coastal storms without damage. Structures were also rated based on perceived immediacy of action and the presence of potential risk to inshore structures if not corrected.	Within the City of Salem, 42 structures had public or unknown ownership which provide significant coastal protection. Section 4 of the original document details these structures, some of which are in Collins Cove and Willows.

2.1. Tables and Figures from Past Studies and Reports

This section includes summary tables and figures from the past studies and reports identified in the preceding section. The content has not been updated or modified from the original sources and is provided for reference purposes.

Table 2. 2020 Status of Mitigation Measures from the 2012 Hazard Mitigation Plan (from the City of Salem Hazard Mitigation Plan 2020 Update)

Mitigation Measure	Priority	Lead Implementation	Current Status	Include in 2020 Plan? Priority
South River Drainage and Flood Mitigation Study: Finish Canal Street drainage project design and construction.	High	Engineering	Not complete - Project has been started and will complete by 2022	Yes - High
South River Drainage and Flood Mitigation Study: Brooks Road/Jefferson Design and Construction	High	Engineering	Not complete - Plan to have under construction winter of 2020 and finish by end of 2020.	Yes - High
Storm surge/precipitation flooding mitigation: Forrester Street/Collins Cove neighborhood	High	Engineering	Complete: Living Shoreline project completed in 2018	No
Identify resources to maintain City drainage infrastructure on an ongoing basis.	High	Engineering	Not complete.	Yes - carry over as medium priority for 2020 plan as ongoing climate resilience issue for the City.
Complete repairs to finish Daniels Street, Ocean Avenue and Willows Park seawall repairs	High	Engineering	Not completed	Yes - Ocean Avenue piece is partially complete
Install new tide gates at mouth of North River.	High	Engineering	Not completed-MA DOT issue	Yes - High
Acquisition of Vacant Flood Prone Lands	High	Planning/ Conservation Commission	Partially completed: Lead Mills property acquired but this is an ongoing management issue.	Yes - Medium
Install Fixed Generators at DPW and Fire Stations	High	DPW/Fire Dept.	Mostly complete: Station 2 Completed and Station 5 in process. DPW complete.	No
Survey all coastal infrastructure, buildings, and land impacted by Massachusetts General Law Chapter 91.	Medium	Conservation/ Engineering	Not completed	Yes - Medium
Assess the earthquake vulnerability of all public buildings. Investigate options to make all public buildings earthquake resistant.	Medium	Fire Department	Not completed	Yes - Medium

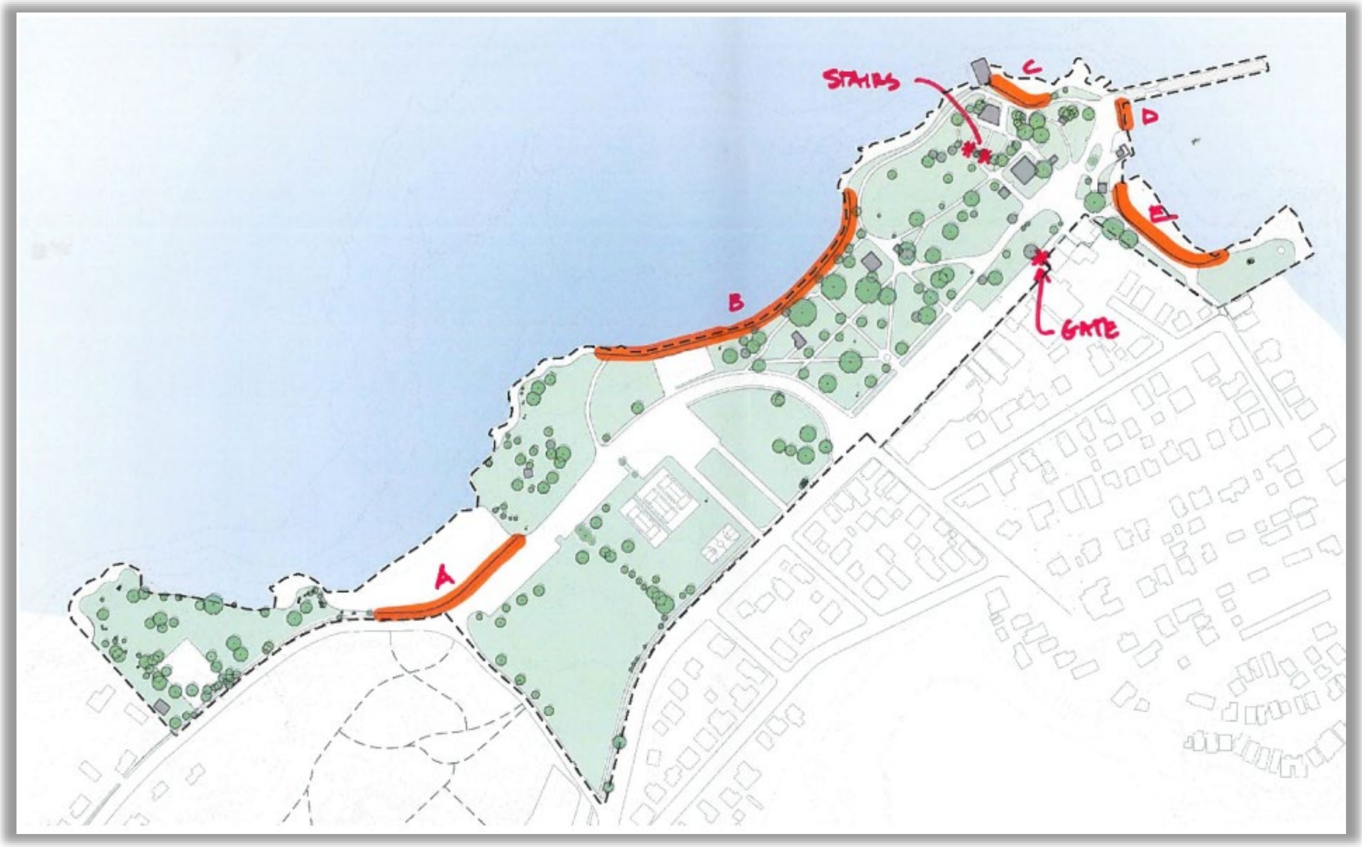

Figure 1. Sketch of Existing Seawalls Near Willows Park (HATCH, 2019)

Table 3. City of Salem Structure Type and Quantity (from the Massachusetts Coastal Infrastructure Inventory Assessment Report Update, 2015)

Primary Structure (1)	Total Structures	Structure Condition Rating A	B	C	D	F	Total Length
Bulkhead / Seawall	27	3	11	10	3		6154
Revetment / Seawall	1			1			397
Revetment	14	2	7	4	1		8078
Breakwater							
Groin / Jetty	1			1			491
Coastal Dune							
Coastal Beach							
	43	5	18	16	4		15120

Table 4. Structure Repair/Reconstruction Costs of Existing Coastal Infrastructure to Bring Them to Their Original Design Condition (from the Massachusetts Coastal Infrastructure Inventory Assessment Report Update, 2015)

Primary Structure (1)	Total Structures	Structure Condition Rating A	B	C	D	F	Total Cost
Bulkhead / Seawall	27		$476,339	$2,593,730	$2,672,884		$ 5,742,953
Revetment / Seawall	1			$74,636			$ 74,636
Revetment	14		$1,021,157	$2,767,714	$4,258,375		$ 8,047,246
Breakwater							$ -
Groin / Jetty	1			$1,043,375			$ 1,043,375
Coastal Dune							$ -
Coastal Beach							$ -
	43	$ -	$ 1,497,496	$ 6,479,455	$ 6,931,259	$ -	$ 14,908,210

Table 5. List of Prioritized Vulnerabilities (from The City of Salem Climate Change Vulnerability Assessment & Adaptation Plan, 2014)

Critical Building Infrastructure | Transportation | Water | Stormwater | Vulnerable Populations | Energy

VULNERABLE, STRESSED COMPONENTS	CLIMATE CHANGE IMPACTS				SECTOR IMPACTED
A: Ineffective seawalls			✓	✓	Critical Building Infrastructure
B: Ineffective tide gates, inadequate tide gates at Lafayette Street		✓	✓	✓	Critical Building Infrastructure, Stormwater
C: Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods		✓	✓	✓	Stormwater
D: Flooding and disrupted operation of pump stations		✓	✓	✓	Stormwater
E: Flooding of the transportation network infrastructure from storm drain overflow and overwhelmed seawalls		✓		✓	Transportation
F: Flooding of evacuation routes		✓	✓	✓	Vulnerable Populations
G: Loss of power at critical City buildings	✓				Energy
H: Backup (emergency) power failure at critical City facilities		✓	✓	✓	Critical Building Infrastructure
I: Downed power lines		✓			Energy
J: Critical emergency preparedness communication	✓	✓		✓	Vulnerable Populations
K: Poor air quality	✓				Vulnerable Populations
L: Property damage or loss of emergency and critical City facilities		✓	✓	✓	Critical Building Infrastructure
M: Property damage or loss at Salem State University				✓	Critical Building Infrastructure
N: Flooding of emergency response facilities		✓		✓	Critical Building Infrastructure
O: Property damage or loss of historic properties		✓	✓	✓	Critical Building Infrastructure
P: Flooding of residential areas			✓	✓	Vulnerable Populations
Q: Overtopping of Rosie's Pond[a]		✓		✓	Stormwater

3. Ongoing Relevant Projects and Plans

This section includes a summary of ongoing projects and plans in the City of Salem that are relevant to the Collins Cove to Willows Resilience Study. The approximate location of each item discussed in this section is identified in Figure 2.

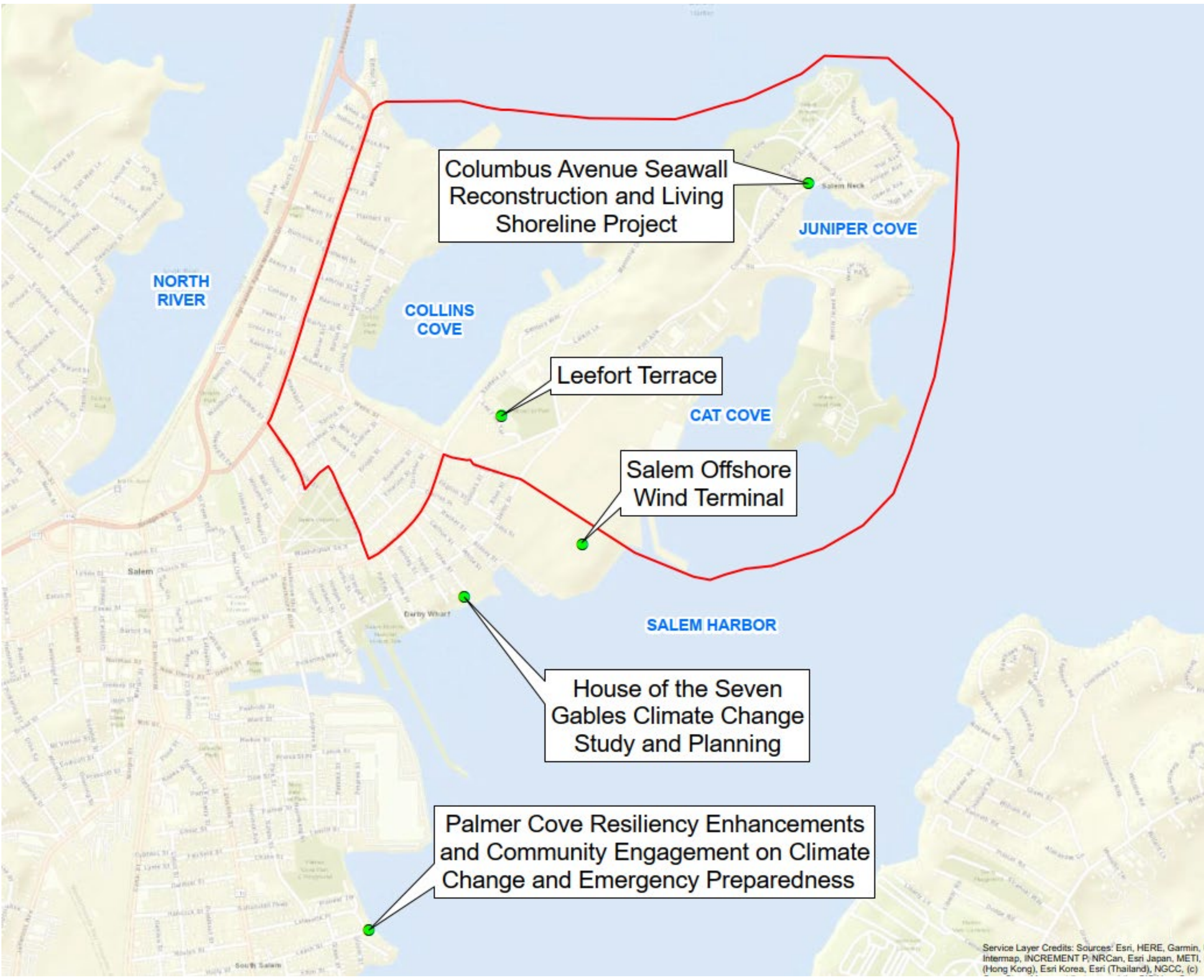

Figure 2. Ongoing Projects and Plans in or Adjacent to the Study Area

3.1. Salem Offshore Wind Terminal

The Salem Offshore Wind Terminal is the proposed construction of a terminal providing services for offshore wind operations. The facility will be a staging area for wind turbine components for offshore installation, with no turbines being installed in the immediate vicinity of Salem. The proposed facility and its proximity to the Study Area can be seen in Figure 3. Previously a coal plant and currently vacant industrial land, the project site is 42 acres and is within the Study Area, located southeast of Collins Cove and southwest of Salem Willows in Salem Harbor. An access road off Derby Street north of India Street is the proposed entrance road to the facility. The relatively flat Project Site is located off of the Salem Neck peninsula and on filled tidelands and borders properties on the south and west sides that are also low and subject to storm tidal flooding. Resilience measures account for sea level rise and coastal storms by designing marine structures to withstand 100-year storm conditions and elevating the project site more than two feet above the current 100-year base flood elevation. Additionally, the project intends to improve the existing wharf infrastructure to better withstand storm surge flooding and install landscape berms on the project site to reduce the risk of flooding into the abutting neighborhoods along Derby Street. The project is anticipated to be developed over the course of two to three years, with a projected completion date of Winter 2024/2025.

Figure 3. Conceptual Layout of Offshore Wind Terminal Facility (salemoffshorewind.com). Note Collins Cove in the background and Willows/Winter Island to the right.

3.2. Leefort Terrace

Leefort Terrace is a State Public Housing development for elderly and disabled households and is adjacent to Collins Cove (along the street named Leefort Terrace, between Szetela Lane and Fort Avenue). The original development was built in 1958, and due to its location in the coastal floodplain, renovating the buildings under current State and Federal regulations is not feasible. Therefore, the proposed project is a redevelopment to demolish the existing buildings and replace them with a single multistory climate-resilience, affordable housing development. The new construction will increase the number of units from 50 to 124 while also reducing the impervious surface of the site by 5,800 square feet. Apartments in the new building will be elevated 21 feet above sea level, above both the current or FEMA 100-year floodplain and the projected 2070 sea level. The shore-facing side of the project will feature a publicly accessible, passive park with bioswales, rain gardens, and improved soil retention. This park and the footprint of the development can be seen in Figure 4. The bioretention system has been designed to capture, hold, and infiltrate a volume of water equivalent to 1.6 inches of rainfall over the development's impervious area. In November 2022, the Salem Conservation Commission approved the redevelopment project. Construction is anticipated to begin in August 2023 and be completed in February 2025. Whereas Leefort Terrace (the road) currently connects Szetela Lane and Fort Avenue, the proposed redevelopment would disconnect these two streets. The apartment building's parking lot only has one point of vehicular ingress/egress to Fort Avenue. Because Fort Avenue would ostensibly serve as an emergency or evacuation route for the residents of this housing development, measures to reduce flood risk to the road require consideration, such as elevating the road.

Figure 4. Leefort Terrace Project Site Plan (leefortterrace.com). Collins Cove is in the upper lefthand corner across from Szetela Lane.

3.3. House of the Seven Gables Climate Change Study and Planning

The House of the Seven Gables is a 17th-century historical landmark located along Salem Harbor at 115 Derby Street. With support from Horsley Witten, Union Studio, Collins Engineers, and Salem Sound Coastwatch, the organization is preparing an adaptation plan to improve the resiliency of the estate's campus. This two-year project is in the planning phase and is funded by a Coastal Zone Management (CZM) Coastal Resilience Grant FY23-FY24. The two-acre campus consists of seaside colonial revival gardens and seven historic buildings, three of which are important First Period Houses. First Period Houses are those that were built in the 1600s, and there are only four hundred such houses left in the country. The property has been experiencing several ongoing issues related to sea level rise, including more frequent seawall failure and maintenance needs, seawall inadequacy and flooding during storms, and sinkholes developing in the lawn. The campus lies at the bottom of a gradual decline with a densely populated neighborhood to the north. The property is flanked by two city streets, Hardy Street and Turner Street. Both Hardy Street and Turner Street end in city-owned seawalls. While the Seven Gables does not intend to perform upgrades to the city walls, it is likely the findings of their study will help with City define needed upgrades.

3.4. Columbus Avenue Seawall Reconstruction and Living Shoreline

This design summary focuses on the Columbus Avenue seawall abutting Juniper Cove. The study aims to design a replacement of the existing seawall with consideration to raise the height of the wall for greater protection and resilience to wave surge and flooding conditions. See Figure 5 for a rendering of this project. The project is motivated by extensive damage from a winter storm-related flood in 2018. The seawall provides foreshore protection to Columbus Avenue, the public sidewalk, utilities, and residential buildings. It is fronted by the publicly accessible "Steps Beach" and an area of salt marsh vegetation along the southwest portion of the beach area. A model was created, and analyses were performed for coastal flood elevations, wave effects, and relative sea level rise to inform the recommended design for the proposed reconstructed seawall and living shoreline marsh restoration (as outlined in the 2020 Preliminary Design Study Letter). Among the environmental conditions considered in this model analysis were combined tides, storm surge, and waves. According to the Massachusetts Coastal Infrastructure Inventory and Assessment Project, in 2009, the seawall was graded as being in good condition. By 2019, the seawall's condition declined to overall fair or poor. The salt marsh area at that time was observed to be partly desiccated and degraded. Improvements and enhancement of the salt marsh area are anticipated to help stabilize the shoreline, reduce erosion, attenuate waves, and provide habitat for plant and animal species. As of 2022, a secondary wave deflection analysis is being considered.

Figure 5. Living Shoreline Salt Marsh Enhancement Rendering by Chester Engineers (Columbus Avenue Seawall Reconstruction Project Preliminary Design, 2020)

3.5. Palmer Cove Resiliency Enhancements and Community Engagement on Climate Change and Emergency Preparedness

Following the plan developed in the 2022 Resilient Together: The Point project, the City is seeking a consultant to design a recommended adaptation strategy or set of strategies for the El Punto neighborhood before initiating similar climate change planning studies in other vulnerable neighborhoods in Salem. This next phase of the project will focus on expanding resiliency and adaptation efforts (design, permitting, and construction) for the Palmer Cove Park area and continue engagement efforts with the community focusing on climate change disaster preparedness. The Palmer Cove Park renovations are in Phase II, having secured permitting and conducted various community input presentations. This adaptation strategy will include short-term resiliency measures that will be incorporated into the park renovations.

3.6. Salem Open Space and Recreation Plan Update

The City of Salem contracted with the Metropolitan Area Planning Council in the summer of 2022 to lead the update of the 2015 Open Space and Recreation Plan. A community advisory group has been convened on the topic with the intent to hold two public forums, issue an online survey, and conduct multiple focus groups. The new plan is anticipated to be completed in the spring of 2023 and will include an updated land inventory and a 7-year action plan. The Plan is not a specific capital program linked to a funding source but rather a means to engage the public and set goals to guide the allocation of local funds or make competitive proposals for outside funding. As the Plan is at an intermediate stage, no details regarding action items for specific parks exist. It is anticipated that the City will continue its substantial focus on climate resiliency, as seen in the 2015 Plan.

4. Property Ownership

Ten City-owned coastal parcels are located within the Study Area with a combined area of 131 acres. These parcels are identified in Figure 6. Many of these properties could be used to incorporate resilience measures against coastal flooding and storm surge. City-owned properties are ideal for implementing adaptation measures in these locations wherein state and federal funding, such as grants, can be obtained and used by the City without the need to obtain easements or conservation restrictions from private property owners. Listed below are some instances of coastal parcels and their uses.

- 85 Memorial Drive is owned by the Department of Conservation and Recreation Division of Urban Parks and Recreation and is used as a seasonal campground. It has been proposed that the site will be redeveloped to host a museum.
- 200 Fort Avenue is Salem Willows Park and has two small beaches. Several sea walls at this location date back to the 19th century.
- 31 Collins Street is a playground and has existing sea walls at varying heights.
- 96 Webb Street is the location of the Collins Cove Living Shoreline project that was completed in 2019.

Notably, Juniper Cove (a location in the Study Area identified as particularly susceptible to flooding) does not have any City-owned parcels.

Figure 6. City-Owned Parcels (outlined in yellow) within the Study Area

5. Critical Facilities and Infrastructure

5.1. Critical Facilities

As summarized in Table 1, the Hazard Mitigation Plan 2020 Update developed by the Metropolitan Area Planning Council (MAPC) identified 180 pieces of “Critical Infrastructure Located in Hazard Areas” in Salem. Critical infrastructure includes facilities important for disaster response and evacuation (such as emergency operations centers, fire stations, pump stations, etc.) and facilities where additional assistance might be needed during an emergency (such as nursing homes, elderly housing, daycare centers, etc.). Of these 180 pieces of Critical Infrastructure in Hazard Areas,15 are located in the Study Area. This list was revisited and updated in 2022 during the data-gathering phase of this Resilience Study. Table 6 lists the critical infrastructure located in the Study Area categorized by use type. The ID numbers in this table correspond to what is shown in Figure 7. The list has been amended per input from the City for this study, including the addition of two facilities: Memorial Park and the Salem Harbormaster.

Table 6. Critical Infrastructure located in the Study Area (adapted in 2022 from the Hazard Mitigation Plan: 2020 Update)

ID*	Name	Type	Address
1	Memorial Park	Recreation	25 Memorial Dr
2	Salem Fire Department	Emergency Facility	29 Fort Ave.
3	Plumber Youth Promise	Group Home	37 Winter Island Rd.
4	National Grid Energy Delivery	LNG Storage Facility	20 Pierce Ave
5	Division of Marine Fisheries Cat Cove Marine Lab	Marine Laboratory	92 Fort Ave.
6	Salem Harbor Station	Power Plant	24 Fort Ave
7	Waikiki Beach	Recreation	Winter Island Rd
8	Willows Pier Beach	Recreation	Restaurant Row
9	Dead Horse Beach	Recreation	Salem Willows Park
10	Collins Cove Beach	Recreation	Webb Street
11	Steps Beach	Recreation	Columbus Ave
12	Leefort Terrace	Residential	Essex St.
13	Bentley Academy Innovation School and Salem Early Childhood School	School	25 Memorial Dr
14	Salem Harbormaster	Municipal	51 Winter Island Rd
15	South Essex Sewage District	Waste Water Treatment	50 Fort Ave.

*The ID numbers in this column correspond to the numbering in Figure 7.

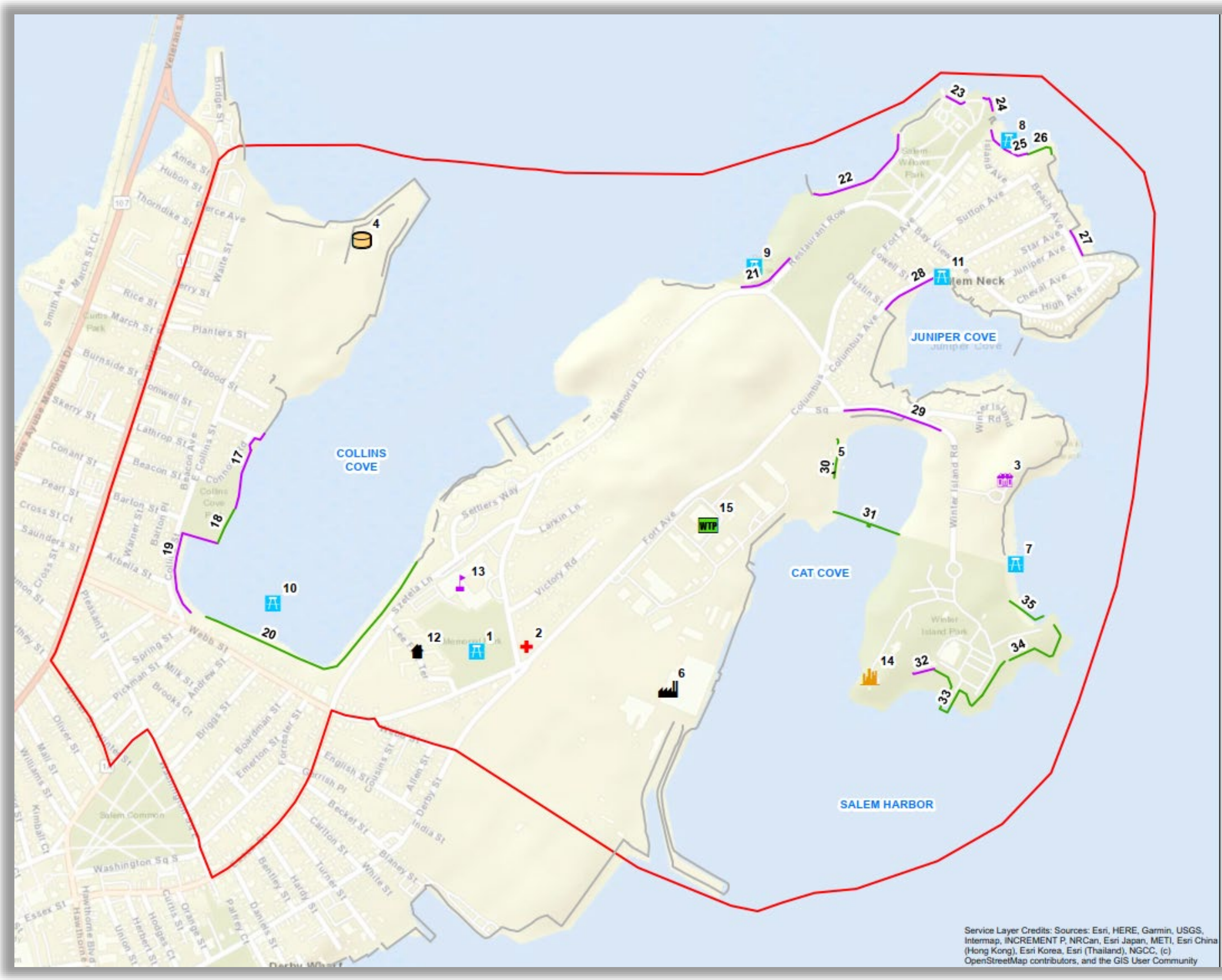

Figure 7. Critical Infrastructure and Shoreline Stabilization Structures in Study Area (adapted in 2022 from the Hazard Mitigation Plan: 2020 Update)

5.2. Critical Infrastructure

As summarized in Table 1, the 2009 Massachusetts Coastal Infrastructure Inventory and Assessment Project cataloged coastal structures to better understand the state's vulnerability to coastal hazards. Twenty-four structures from that inventory are in the Study Area and are listed in Table 7. These structures are also represented in Figure 7. There are also seventy-two structures located on private property in the Study Area. These private property structures are not included in Table 7 due to this project's focus on city or state-owned property and infrastructure.

Table 7. Inventory of Publicly Owned Major Coastal Structures and Elevations (MA Coastal Infrastructure Inventory)

ID*	Location #	Structure Type	Geographic Location	Elevation (ft NAVD88)	Height Above Beach (ft)
17	064-036-000-473-400	Bulkhead/Seawall	8 Conners Rd, Collins Cove Park	13	2
17	064-036-000-473-300	Revetment/Seawall	Collins St at Conners Rd, Collins Cove Park	13	6
18	064-036-000-473-200	Revetment	Collins St at Barton St, Collins Cove Park	13	8
19	064-036-000-473-100	Bulkhead/Seawall	Collins St at Barton St, Collins Cove Park	13	9
19	064-036-000-474-100	Bulkhead/Seawall	Collins Street at Arbella St	13	7
20	064-042-000-003-100	Revetment	Szetela Lane at Collins St	13	3
21	064-045-000-089-100	Bulkhead/ Seawall	Memorial Dr at Restaurant Row, Willows Park, Dead Horse Beach	12	1
22	064-045-000-089-200	Bulkhead/ Seawall	Restaurant Row at Fort Ave, Willows Park	12	6
23	064-045-000-089-300	Bulkhead/ Seawall	Restaurant Row at Fort Ave, Willows Park near Yacht Club	12	4
24	064-045-000-089-400	Bulkhead/ Seawall	Restaurant Row at Fort Ave, Willows Park near pier	15	5
24	064-045-000-089-500	Bulkhead/ Seawall	Restaurant Row at Fort Ave, Willows Park near pier	15	8
25	064-045-000-089-600	Bulkhead/ Seawall	Restaurant Row at Fort Ave, Willows Park Front Beach	15	10
26	064-045-000-089-700	Revetment	Restaurant Row at Fort Ave, Willows Park	15	10
27	064-045-000-079-100	Bulkhead/ Seawall	Beach Avenue at Juniper Ave	15	3
28	064-044-000-146-100	Bulkhead/ Seawall	61 Columbus Avenue	10	5
30	064-044-000-037-400	Revetment	Fort Ave at Winter Is Rd, Cat Cove	10	15
29	064-044-000-037-300	Bulkhead/Seawall	4 Winter Is Rd, Cat Cove	10	5
29	064-044-000-037-200	Bulkhead/Seawall	4 Winter Is Rd, Cat Cove	10	12
31	064-044-000-037-100	Groin/Jetty	Fort Ave at Winter Is Rd, Salem State College Marine La	11	10
35	064-043-000-001-500	Revetment	Winter Island Rd end	18	8
34	064-043-000-001-400	Revetment	Winter Island Rd end	18	6
33	064-043-000-001-300	Revetment	Winter Island Rd end	14	10
32	064-043-000-001-100	Bulkhead/Seawall	Winter Island Rd end	13	5
33	064-043-000-001-200	Revetment	Winter Island Rd end	13	5

*The ID numbers in this column correspond to the numbering in Figure 7.

6. Historical Natural Hazards and Climate Information

Resilience strategies must be guided by a strong understanding of an area's geography and observed climate hazards. This section includes brief summaries of available resources that provide details on historical natural hazards and climate information for the City of Salem. Unless noted, the content is taken directly from the source documents and has not been updated or checked for accuracy.

6.1. City of Salem Hazard Mitigation Plan: 2020 Update

Salem's average annual precipitation is 47 inches. While total annual precipitation has not significantly increased with climate change, intense rainstorms and snowstorms have become more frequent and severe over the last half century in the Northeast. The most severe flooding event in Essex County in the last ten years occurred in March 2010, when the National Weather Service recorded a total of 14.83 inches of rainfall accumulation.

Salem has experienced many significant weather events, a great deal of which resulted in coastal and/or inland flooding. The most significant winter storm in recent history was the "Blizzard of 1978," which resulted in over 3 feet of snowfall and multiple day closures of roadways, businesses, and schools. Because the City of Salem does not keep a historical record of winter storm events, it is difficult to ascertain whether these closures were due to flooding or snowfall. However, other historical records show that during this event, coastal flooding did occur in other coastal municipalities. More recently, in both 2015 and 2018, the neighborhoods around Columbus Avenue, Collins Cove, Juniper Cove, and Willows Park experienced power loss and coastal flooding associated with severe winter storms, which resulted in significant property damage.

6.2. Community Resilience Building Workshop Summary of Findings, 2020

Extreme precipitation and storm surge are driven by severe storms, which may take the form of nor'easters, blizzards, hurricanes, thunderstorms, and tornadoes. Salem experiences flooding from both storm surges and king tides (exceptionally high tides that occur during a new or full moon). Heavy precipitation events coupled with storm surge or a high tide increase the occurrences and severity of such flood events. Table 8 contains a list of historical flooding events and their impacts on the City.

Table 8. Historic Flooding Events (Salem Community Resilience Building Workshop Summary of Findings, 2019)

Date	Type of Event	Local Impacts
September 21, 1938	The Great New England Hurricane - Cat 3	10-17" of rainfall and up to 20-foot storm surge.
September 15, 1944	The Great Atlantic Hurricane - Cat 1	11" of rain and up to 70-foot waves reported.
August 31, 1954	Hurricane Carol - Cat 2, followed by Edna	2 hurricanes struck within 12 days with 7 inches of rain causes stream flooding and streets washed out.
September 12, 1960	Hurricane Donna - Cat 2	10-20" of rain and 5-10-foot storm surge; wettest tropical cyclone to hit New England.
March 1972	Severe Storms and Flooding	No information available.
February 1978	The Blizzard of '78	Nor'easter set an all-time high water mark of 15.1 feet above Mean Higher High Water (MHHW) in Boston Harbor, 30" snowfall.
September 27, 1985	Hurricane Gloria - Cat 3	Arrival at low tide resulted in moderate storm surge.
March 31-April 7, 1987	Severe Storms and Flooding	Spring storms added 7" to already high river conditions to produce major flooding.
August 19-21, 1991	Hurricane Bob - Cat 3	4-7 inches of rain and storm surge impacts.
October 15-18, 1991	"'The No-Name Storm' or 'Perfect Storm'"	25-foot waves on top of 4-foot high tide washed out many coastal roads.
December 11-13, 1992	Nor'easter	Highest water levels 1-foot below record of 1978 (25 ft. dunes wiped out in Ipswich) and 6 inches of rain.
October 20-21, 1996	Severe storms and flooding	13" of rainfall in Essex County (7.89" in Boston).
June 13-18, 1998	Heavy rain and flooding	Flash flooding from June 12-14, over 8" in 12 hours.
March 21-22, 2001	Nor'easter	High tides 2-3 feet above normal along east facing shore.
February 2003	Presidents Day Storm	Astronomical high tide coincided with 15-foot seas to cause flooding along most of eastern Massachusetts.
March 31-April 2, 2004	Flooding	6-inches over several days, flooding closed many roads.
May 9-16, 2006	"Mother's Day Flood"	Extreme rainfall >12 inches.
April 15-20, 2007	"Patriot's Day Storm" Nor'easter	Worst coastal flooding coincided with evening high tide on April 17 (3.6" recorded at Logan Airport).
December 11-12, 2008	Severe winter storm	8-12" of snow fell accompanied by 30-40 mph winds resulting in coastal flooding and structural damage.
March 12-16, 2010	Nor'easter	Record-breaking rainfall (7.06" Logan), 70 mph winds.
January 11-12, 2011	Nor'easter	Snow, high winds, and coastal flooding.
October 29-30, 2012	Nor'easter	Rare October snow storm, icing, high winds.

Date	Type of Event	Local Impacts
February 8-10, 2013	Winter Storm - Nemo - Nor'easter	24.9" of snow in Boston, hurricane-force winds, and 4.2 feet of storm surge.
January 26-28, 2015	Winter Storm - Juno	24" of snow in Boston with 4-foot storm surge, high winds.
January 4, 2018	Winter Storm - Grayson	15.16' high water level, with storm surge topping 4.88' MHHW, +12" of snow.
March 1-3, 6-8, 12-14, 2018	3 - Nor'easters - Riley, Quinn, Skyla	Unusually high tides and storm surges, hurricane-force winds, downed trees, heavy snow, severe coastal flooding.
October 17, 2019	Bomb Cyclone	Central pressure plummeted 30 millibars in only 15 hours, 4" of rain and 90 mph winds.

6.3. Coastal Zone Management's Shoreline Change Project

The Coastal Zone Management's (CZM's) Shoreline Change Project was developed to track shoreline trends, including erosion and accretion rates, along the Massachusetts oceanfront. The project illustrated how the shoreline of Massachusetts has shifted between the mid-1800s and 2009. Data from historical and modern sources were used to generate the local high-water line with transects at approximately 50-meter intervals. Maps depicting shoreline change at select sites from the Study Area is provided in Appendix A. A summary of the shoreline change data is provided in Table 9.

Table 9. CZM Shoreline Change Data for Select Beaches in the Study Area

	Number of transects	Average of Long-term shoreline change rate (ft/yr)*	Max of Long-term shoreline change rate (ft/yr)	Average of Short-term shoreline change rate (ft/yr)	Max of Short-term shoreline change rate (ft/yr)
Collins Cove Park	7	1.66	3.97	-0.22	0.10
Columbus Avenue, Juniper Cove	6	0.27	0.79	-0.47	0.23
Dead Horse Beach	6	0.20	0.66	-0.64	0.52
Fort Pickering Beach	8	0.03	0.20	-0.56	-0.10
Juniper Beach 1	5	-0.15	0.26	-0.81	-0.26
Juniper Beach 2	2	-0.44	-0.16	-0.51	-0.30
Szetela Lane, Collins Cove	7	1.45	4.10	-0.32	0.03
Webb Street, Collins Cove	8	-0.01	0.36	-0.51	-0.16
Winter Island	8	-0.05	0.13	-0.49	0.00

*Many of these values are low due to the coastline being filled to make more land. See the maps of Bridge Street and Webb Street in Appendix A and the drastic shoreline change between 1844-1897 and 1943-1969.

6.4. FEMA Region I's Coastal Erosion Hazard Map

The FEMA Coastal Erosion Hazard Map was developed to explore the potential extent of coastal erosion hazards by the years 2030, 2050, and 2100. These extents are estimated from both the long-term historical erosion rate and the acceleration of coastal erosion due to increasing sea level rise. While storm impacts are not considered in this analysis, they are predicted to exacerbate rates of coastal erosion. Each of the four sea level rise scenarios used in Essex County (high, intermediate, intermediate low, and low) were developed by NOAA. Figure 8 depicts the projected coastal erosion hazard advancement under a High Sea Level Rise Scenario.

Figure 8. Coastal Erosion Hazard Projections, High Sea Level Rise Scenario

6.5. Community Mapping

In a workshop on November 29, 2022, community members gathered in a public meeting for the Collins Cove to Willows Resilience Study. Over sixty-five people attended to hear an introductory presentation to the project and discuss six maps of the Study Area. Participants were invited to mark places on the map where they have observed flooding or other climate-related impacts and provide a brief description, including approximate frequency of occurrence, depth, conditions, etc. Data generated via this mapping will be used to spot-check coastal flooding models, help identify the areas where adaptation measures are needed, and inform the types of measures that might be implemented for the various impacts observed. The annotated maps are provided in Appendix B. Selected excerpts are listed here (edited only for clarity).

Willows Area

- At the Columbus Avenue seawall, there is flooding over the wall and undermining the wall. Sand has built up in the corners of Juniper Cove.
- Dead Horse Beach: Sand erosion.
- Juniper Beach 2: Waves crash over the seawall causing flooding on Star, Juniper, and Cheval Avenues.
- Cheval Avenue flooded on January 17, 2021.
- The intersection of Columbus Avenue and Bay View Avenue: Floods yearly and blocks egress. Major floods in 2015 and on January 4, 2018.

Winter Island

- The [Smith Pool] dam overtops during high tide.
- Tidal action creating erosion and changing the coastline along the eastern side of Cat Cove.
- Erosion at the beach on the south of Winter Island, the steps have a much higher step. The old seaplane pier is more usable at low tide.
- Erosion and deterioration of walkway and structures at the beach on the eastern side of Winter Island.
- Rocks to block erosion at the north of Winter Island are beginning to have erosion behind them.
- Guard shack has no drainage structures and puddles every time it rains.

Szetela Lane

- The southeast corner of the cove is increasingly carved out, creating a ‘head of the cove’ depository.
- Area parallel to the bike path is subject to erosion.
- The intersection of Szetela and Leefort Terrace floods during a storm.
- Szetela, just north of Leefort Terrace, floods during rain events and high tide.

- A few times in 2021 and a few years ago, the area outside of the Salem Early Childhood Center on Memorial Drive flooded during a storm.
- The backyard across Memorial Drive from the [Salem Early Childhood School] floods during large rain events.

Webb Street/Common Area

- Floods up to the house's fence at the southeast corner of Collins Cove from storm surge and some high tides. Water has not reached the street in front of the house since mid-2018.
- The path along Collins Cove floods at least 4 times a year due to high tides and/or small storm surges.
- Water came across the City's grass strip all the way into the house across from Webb Street's garden during the November 2018 storm. During an 18-year period (2004 – 2022), there have been three winters when the water has come across the walking path onto the City's grass strip about 1/3 of the way toward the house's garden.
- The intersection of Emerton St and Forrester St floods several times per year from high-intensity precipitation events which coincide with high tides.
- Concerns for the new housing development at Leefort Terrace about potential flood risk and displacement.
- The intersection of Szetela and Leefort Terrace flooded during the January 2018 storm. Water surpassed the top of a car tire. Police officers were necessary to direct traffic.

Bridge Street

- On January 2, 2022, there was high tide flooding on Conners Road cul-de-sac caused by the lower seawall. January 17, storm flooding: water over the seawall filling the street and into the park.

7. Conclusions

The review of historical weather conditions, studies, reports, and assessments in the Collins Cove to Willows Study Area reaffirms the area's vulnerability to the impending threats of climate change-related hazards. Coastal flooding, caused by both extreme weather events and high tides, and as exacerbated by sea level rise, has been present in Collins Cove and Salem Willows for decades. Occurrences of this nature are only becoming more frequent and severe. A summary of past and ongoing studies within the Study Area offers an overview of the various strategies and plans currently in place regarding coastal resilience. The historical data contained in this literature review will be used to inform the next steps in this study, which will ultimately be used to identify coastal resiliency strategies for the Study Area.

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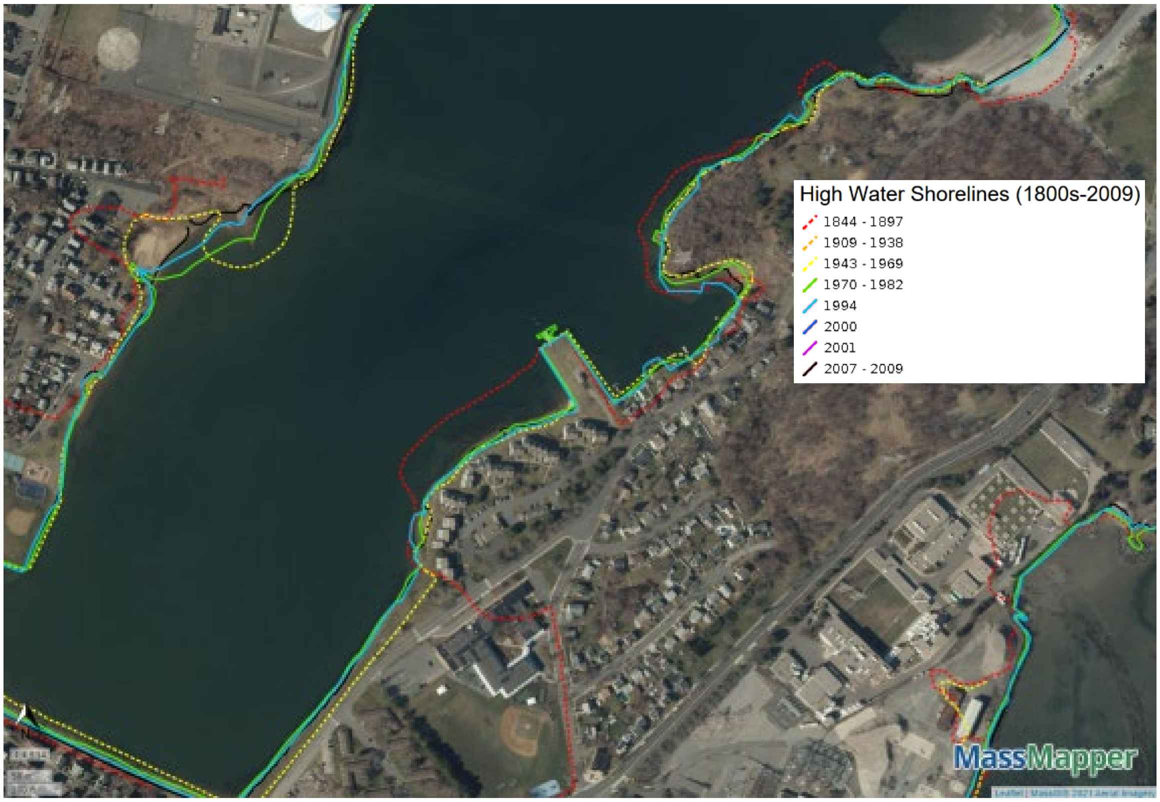
Appendix A CZM Projected Coastal Erosion Hazards

B01 Bridge Street, Collins Cove

B02 Webb Street, Collins Cove



B03 Szetela Land, Collins Cove

B04 Dead Horse Beach, Willows

B05 Juniper Beach 1

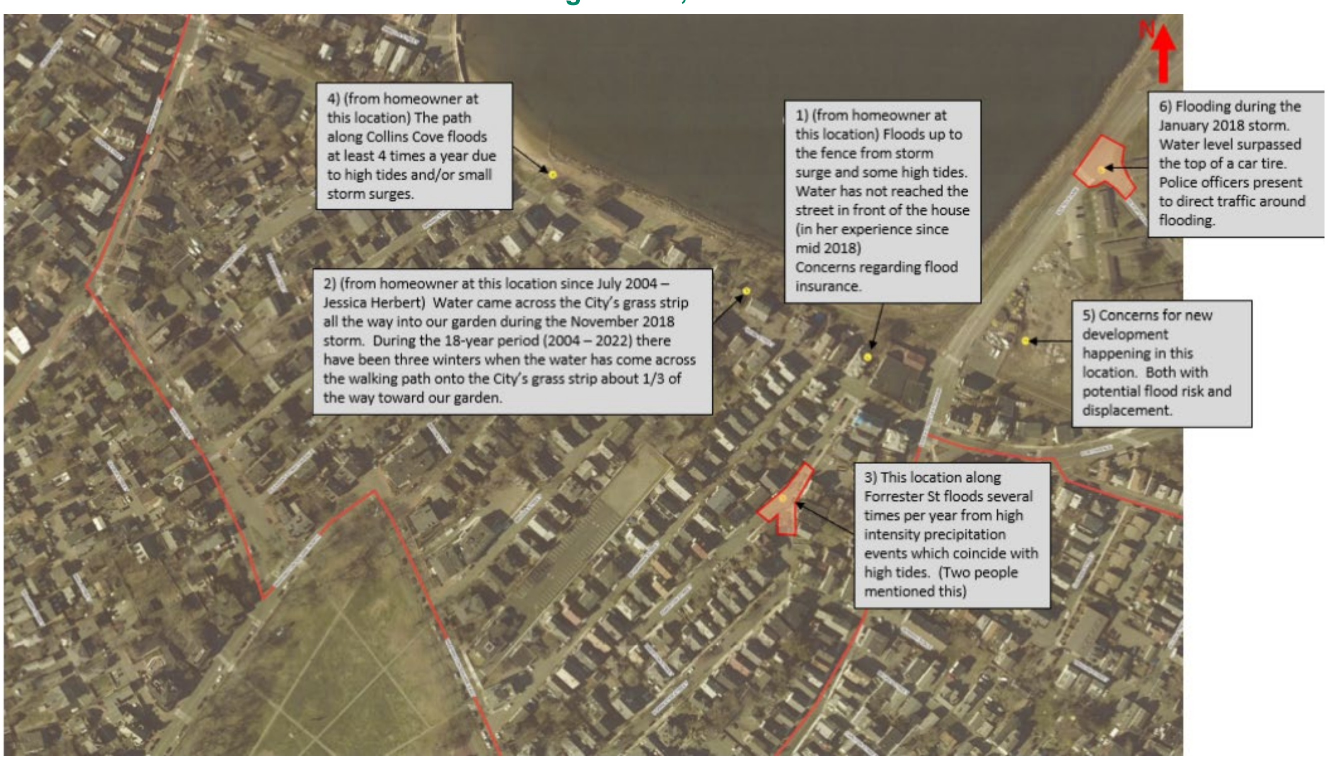
B06 Juniper Beach 2

B07 Juniper Cove, Willows

B08 Winter Island

Appendix B Community-Based Flood Event Mapping of the Study Area

C01 Bridge Street, Collins Cove



C02 Webb Street, Collins Cove

C03 Szetela Lane, Collins Cove

C04 Willows Area

General Comments:
1) Trees that survive saltwater inundation.
2) Please label the maps with specific information "rain garden" "enhancement"…

C05 Winter Island

Appendix E: Resilient Coastal Parks Toolkit

AECOM
250 Apollo Drive
Chelmsford, Massachusetts 01824
aecom.com

Project name:
Collins Cove to Willows Resilience Study

Project ref:
60646341

To:
Deb Duhamel, City of Salem

From:
AECOM

Date:
May 3, 2023

CC:
File

Task 4: Resilient Coastal Parks Toolkit

1. Introduction

The Collins Cove to Willows Resilience Study for the City of Salem, Massachusetts, was conceived as an integrated coastal protection initiative. The complete study includes an examination of coastal flood projections and overland flooding (both current and future conditions), conducting stakeholder engagement, developing resilient options for the city parks and road networks, developing an emergency response and evacuation plan, and developing a resilient coastal parks toolkit. This memo focuses on the resilient coastal parks toolkit, which is part of Task 4 of the study.

Coastal parks have the potential to be particularly significant in improving coastal resiliency. As these public spaces are typically owned by either municipalities or the State of Massachusetts Department of Conservation and Recreation, state grants can be used for structural and non-structural improvements. Some of the many public services that parks provide include protecting groundwater, improving air quality, and providing habitats for wildlife (National Recreation and Park Association, n.d.). Additionally, as physical “third places” (non-commercial spaces where people spend time between home and work), parks are places where people can connect with one another (Oldenburg, 1989). The City of Salem has a long history of encouraging recreation in coastal parks. In the contemporary era, these coastal parks remain essential community resources and front-line buffers against coastal flooding hazards. The City of Salem’s open space and park system is highly valued by the community, which feels that this resource needs to be protected and preserved (Gale Associates, Inc., 2015).

The study area is shown in Figure 1 and includes five parks (Collins Cove Playground and Park, Camp Naumkeag, Salem Willows Park, Fort Pickering, and Winter Island Park) and six beaches (Collins Cove Beach, Dead Horse Beach, Salem Willows Beach, Juniper Beach, Steps Beach, and Winter Island/Waikiki Beach)

Figure 1. Coastal Public Spaces within the Study Area Boundary

Attached to this memorandum in Appendix A is a coastal parks resilience toolkit graphic that summarizes the coastal protection options discussed in this memo and may act as a resource for future climate resilience projects. This toolkit may be used not only for the City of Salem's Collins Cove to Willows Resilience Study but also for other coastal municipalities in the Commonwealth.

2. Vulnerability to Flooding

The project study area is located along Beverly Harbor and Salem Harbor within Salem Sound, roughly fifteen miles north of Boston, which is within the larger Massachusetts Bay. Salem Sound opens eastward to the Atlantic Ocean, with Cape Ann to the north and Boston Harbor to the South. The Danvers, North, and Bass Rivers all empty into the Beverly Channel, which runs along the northern end of the site. The Sound is a mixed drowned river estuary with a semi-diurnal tide (~8.5 feet range). The Sound is relatively shallow, with a mean depth of 30 feet mean high water (MHW) (Jerome et al., 1967). Figure 2, Figure 3, and Figure 4 show the annual probability of coastal flooding predicted by the Massachusetts Coast Flood Risk Model (MC-FRM, which is being used to inform the vulnerability assessment for this project) for the planning horizons of 2030 (1.2 feet of sea level rise), 2050 (2.4 feet of sea level rise), and 2070 (4.2 feet of sea level rise), respectively. These maps also depict the pieces of critical infrastructure identified in the City's 2020 Hazard Mitigation Plan (amended with input from the City) and coastal structures cataloged in the 2009 Massachusetts Coastal Infrastructure Inventory and Assessment Project.

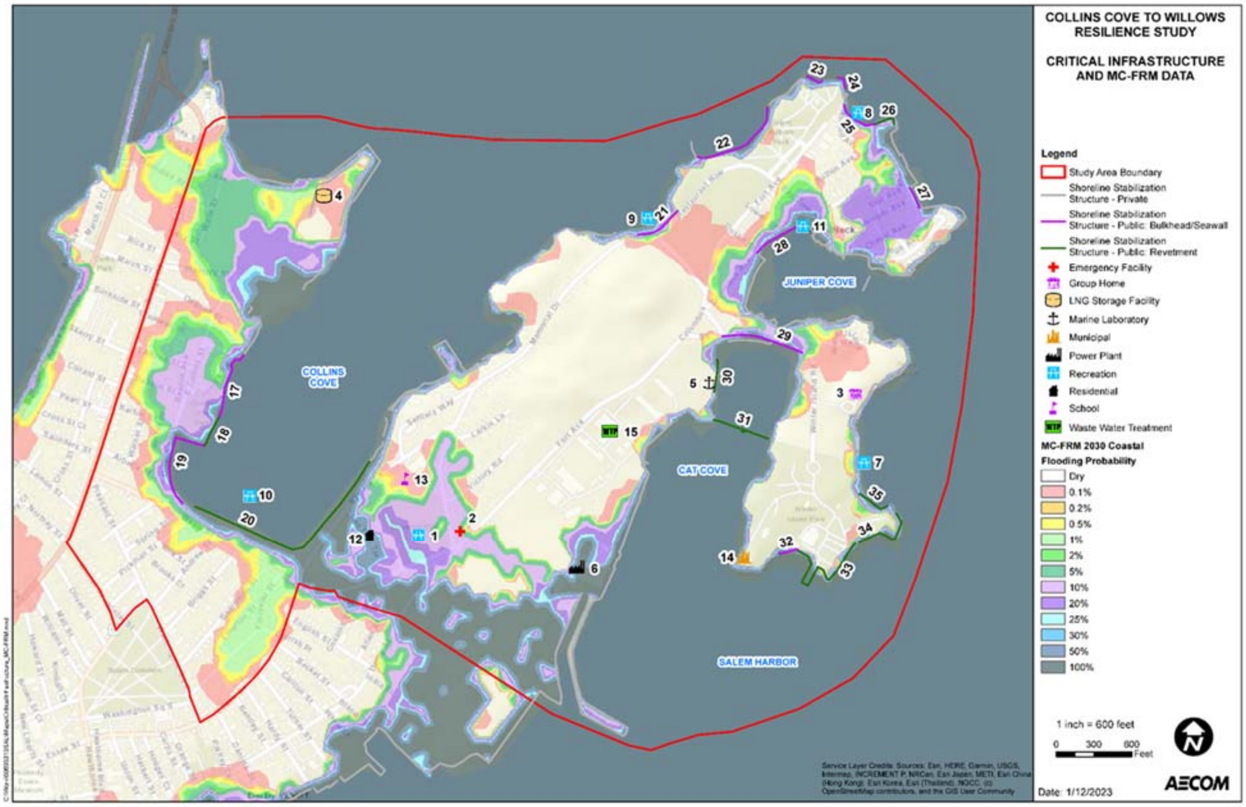


Figure 2. Critical Infrastructure and 2030 (1.2 feet of SLR) MC-FRM Annual Probability of Flooding

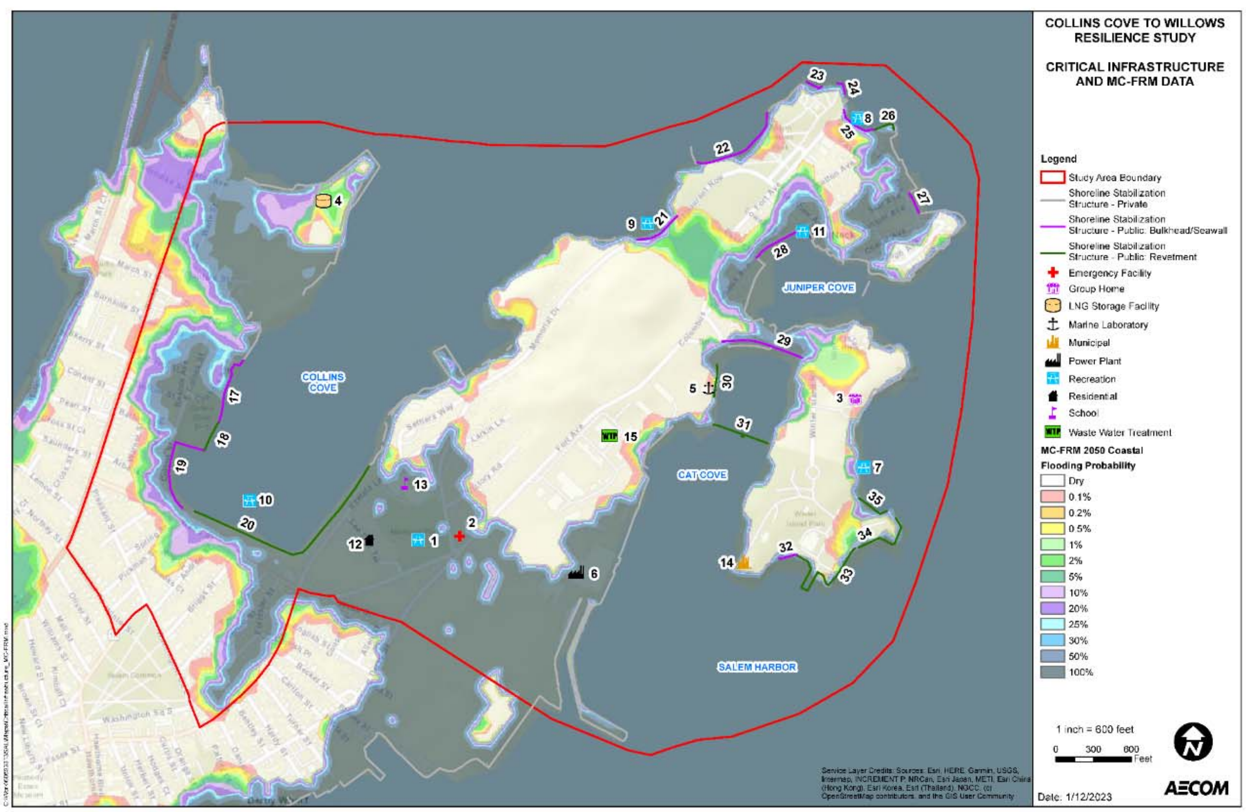


Figure 3. Critical Infrastructure and 2050 (2.4 feet of SLR) MC-FRM Annual Probability of Flooding

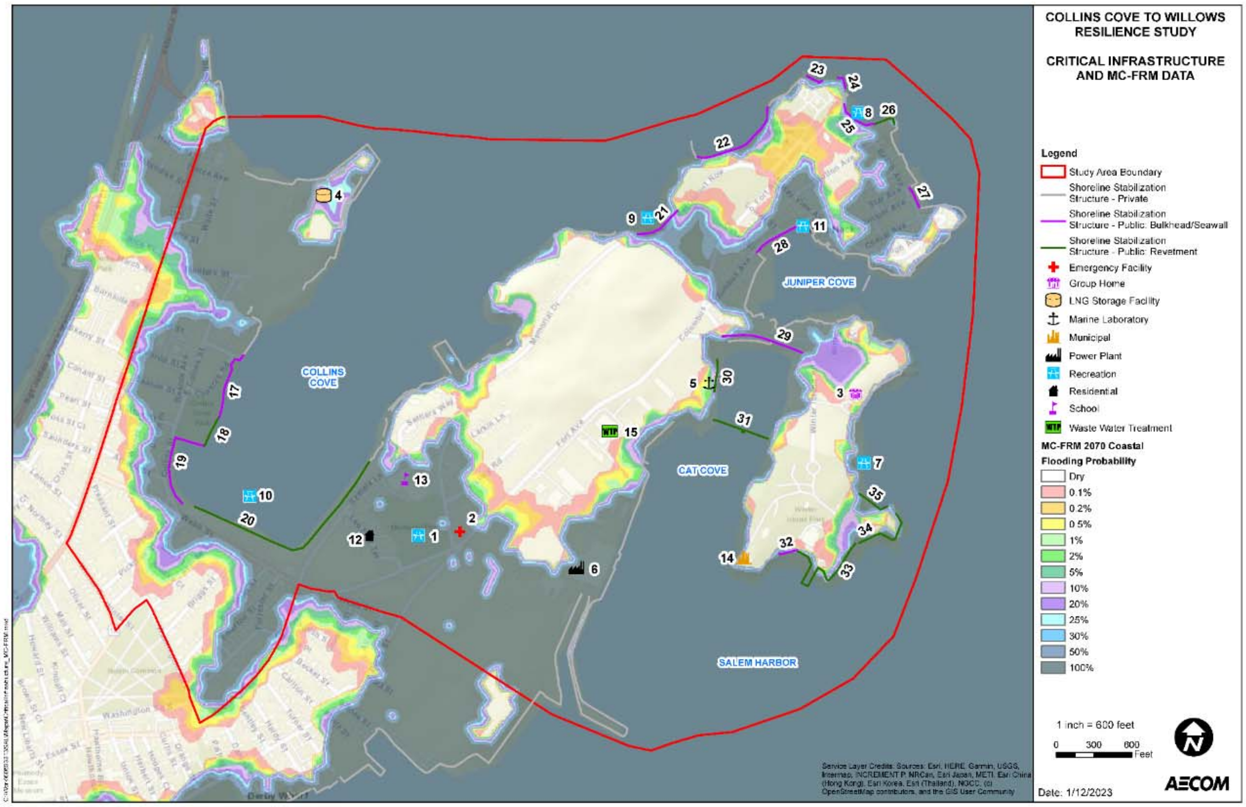


Figure 4. Critical Infrastructure and 2070 (4.2 feet of SLR) MC-FRM Annual Probability of Flooding

3. Coastal Resilience Toolkit

Coastal resilience is determined by both structural and less visible, non-structural measures. Whereas structural flood mitigation strategies, such as flood control dams, detention basins, and flood diversion channels, modify a community's risk to flooding, non-structural flood mitigation strategies, such as public education, land acquisition, and open space preservation, modify a community's exposure and vulnerability to flooding. It is only through a combination of these strategies that a coastal resilience plan can mitigate risk, reduce exposure, and ameliorate vulnerability. Coastal parks are community resources that, as many of the following case studies prove, have a significant potential to boost resiliency in the surrounding areas. This Toolkit is divided into four sections: non-structural measures, stormwater management, nature-based shoreline protection, and structural flood risk reduction measures. A case study is included for each section. Case studies were selected based on proximity to the Study Area, with a preference given to projects in Massachusetts; applicability (i.e., is it a coastal resilience project and is the project located in a park or other public property); and scale, with preference given to projects at a scale feasible for the Study Area. Some additional case studies are included that are located outside of New England. Because the options presented herein are so diverse, not every Toolkit strategy can be applied in the City of Salem.

3.1 Non-Structural Measures

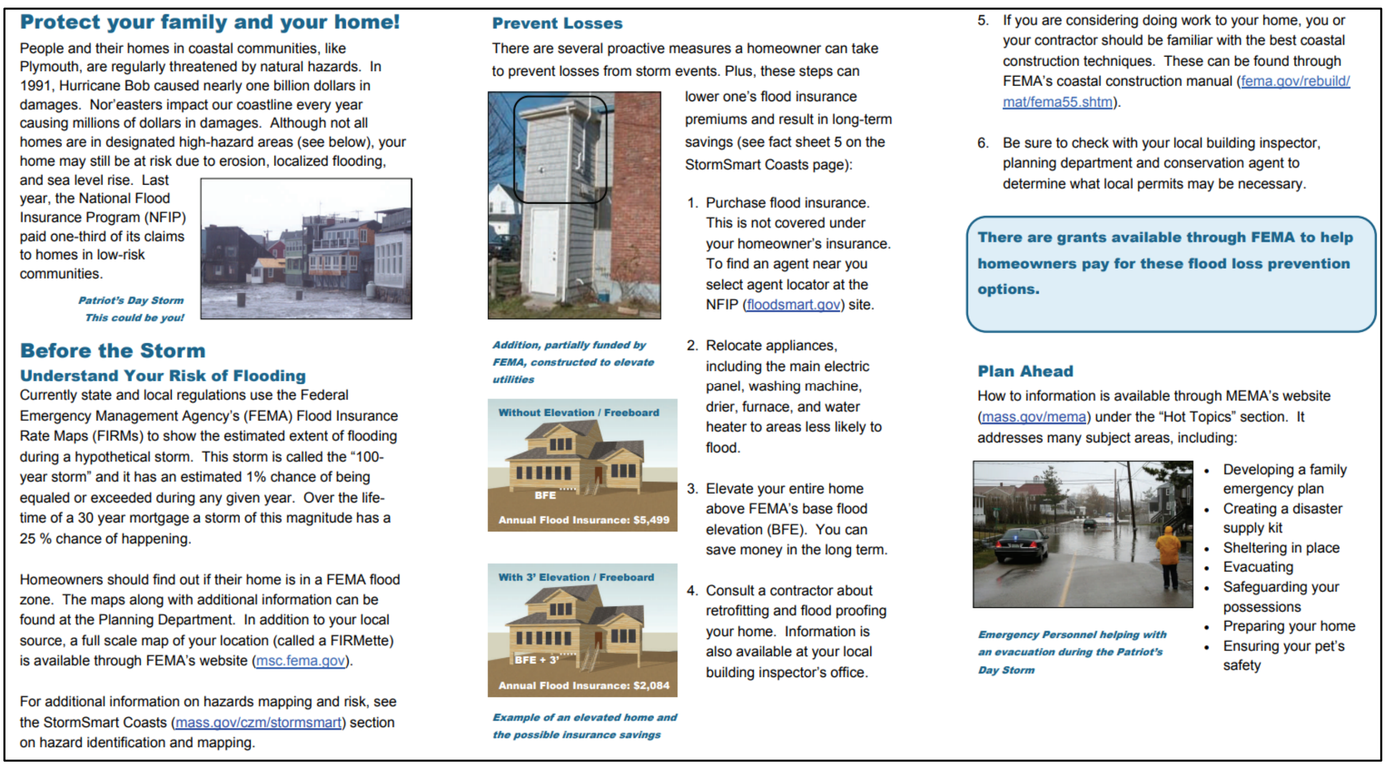
Non-structural climate adaptation measures are essential components of coastal resiliency planning. Non-structural measures are "measures not involving physical construction which use knowledge, practice or agreement to reduce disaster risks and impacts, in particular through policies and laws, public awareness raising, training, and education" (United Nations Office for Disaster Risk Reduction, n.d.). These strategies are unique in their adaptability. If something constructed (like a seawall) proved inadequate by design, it would take another round of construction to either retrofit or replace that structure. In contrast, a non-structural measure like a public education plan can be more flexible in addressing community needs and changing conditions.

3.1.1 Public Education

Public outreach and education are indispensable components of coastal resiliency planning. Parks are unique resources for public education due to their high visibility and relative accessibility. Public education in coastal parks may reinforce the community's awareness of and ability to respond to flooding events. Outreach and education efforts can take many forms, including written materials (signs at the parks, mailings, etc.), videos, public presentations, and training courses/workshops.

Case Study

The Massachusetts Office of Coastal Zone Management (CZM) launched a pilot program for coastal hazard awareness for three coastal towns in Massachusetts: Duxbury, Kingston, and Plymouth. Similar to many other coastal towns in Massachusetts, coastal resources such as coastal beaches, coastal banks, barrier beaches, salt marshes, salt ponds, and tidal flats in these towns experience coastal storm impacts, including high winds and waves. The main goal of the project for these three towns was to improve future coastal floodplain development trends through targeted education and outreach (CZM, n.d.). CZM helped these towns achieve this goal through the development of a public information brochure regarding flood hazards and through targeted workshops (see Figure 5). The brochure focused on concise descriptions of flood risk, preventing losses from flooding events, and proper planning for future flooding events. Workshops were targeted toward local officials and builders and included topics such as "no adverse impact" approaches to ensure development would not worsen flooding, low-impact development techniques to reduce inundation impacts, construction site erosion control, stormwater management, and floodplain building techniques.



Protect your family and your home!

People and their homes in coastal communities, like Plymouth, are regularly threatened by natural hazards. In 1991, Hurricane Bob caused nearly one billion dollars in damages. Nor'easters impact our coastline every year causing millions of dollars in damages. Although not all homes are in designated high-hazard areas (see below), your home may still be at risk due to erosion, localized flooding, and sea level rise. Last year, the National Flood Insurance Program (NFIP) paid one-third of its claims to homes in low-risk communities.

Patriot's Day Storm
This could be you!

Before the Storm

Understand Your Risk of Flooding

Currently state and local regulations use the Federal Emergency Management Agency's (FEMA) Flood Insurance Rate Maps (FIRMs) to show the estimated extent of flooding during a hypothetical storm. This storm is called the "100-year storm" and it has an estimated 1% chance of being equaled or exceeded during any given year. Over the life-time of a 30 year mortgage a storm of this magnitude has a 25 % chance of happening.

Homeowners should find out if their home is in a FEMA flood zone. The maps along with additional information can be found at the Planning Department. In addition to your local source, a full scale map of your location (called a FIRMette) is available through FEMA's website (msc.fema.gov).

For additional information on hazards mapping and risk, see the StormSmart Coasts (mass.gov/czm/stormsmart) section on hazard identification and mapping.

Prevent Losses

There are several proactive measures a homeowner can take to prevent losses from storm events. Plus, these steps can lower one's flood insurance premiums and result in long-term savings (see fact sheet 5 on the StormSmart Coasts page):

Addition, partially funded by FEMA, constructed to elevate utilities

1. Purchase flood insurance. This is not covered under your homeowner's insurance. To find an agent near you select agent locator at the NFIP (floodsmart.gov) site.
2. Relocate appliances, including the main electric panel, washing machine, drier, furnace, and water heater to areas less likely to flood.
3. Elevate your entire home above FEMA's base flood elevation (BFE). You can save money in the long term.
4. Consult a contractor about retrofitting and flood proofing your home. Information is also available at your local building inspector's office.

Example of an elevated home and the possible insurance savings

5. If you are considering doing work to your home, you or your contractor should be familiar with the best coastal construction techniques. These can be found through FEMA's coastal construction manual (fema.gov/rebuild/mat/fema55.shtm).
6. Be sure to check with your local building inspector, planning department and conservation agent to determine what local permits may be necessary.

There are grants available through FEMA to help homeowners pay for these flood loss prevention options.

Plan Ahead

How to information is available through MEMA's website (mass.gov/mema) under the "Hot Topics" section. It addresses many subject areas, including:

- Developing a family emergency plan
- Creating a disaster supply kit
- Sheltering in place
- Evacuating
- Safeguarding your possessions
- Preparing your home
- Ensuring your pet's safety

Emergency Personnel helping with an evacuation during the Patriot's Day Storm

Figure 5. Flood Hazard Brochure for Plymouth, Massachusetts. Image Source: Plymouth-ma.gov.

3.1.2 Open Space Preservation

Compared to other urban communities in the region, the City of Salem has exceptional open space resources, both in size and quantity (Gale Associates, Inc., 2015). Open spaces contribute to flood risk management by increasing rainwater interception, storage, and infiltration, reducing the quantity of water requiring management (CIRIA Open Green Space, 2023). Vegetated open spaces function like storage reservoirs and reduce peak flows of runoff during rain events. Conserving land in floodplains helps avoid property damages associated with coastal flooding by preventing development in these flood-prone areas where damage is most likely to occur (The Trust for Public Land, 2013). Parks that are mostly or entirely open spaces with minimal permanent structures are more resilient and can act as a first defense against coastal flooding. Open space preservation is compatible with coastal parks as newly acquired land can be incorporated into existing parklands and used with wetland and other habitat preservation and restoration. In Massachusetts, several state and federal programs exist to improve resilience through measures including land acquisition. Among them are the Municipal Vulnerability Preparedness (MVP) Program and FEMA's Hazard Mitigation Assistance grant programs.

Case Study
In partnership with Mattapoisett Land Trust and the Buzzards Bay Coalition, the Town of Mattapoisett, Massachusetts, purchased 120 acres of forest, streams, freshwater wetlands, and coastal salt marsh to safeguard the natural resources therein. The acreage is located within the Pine Island Watershed and abuts land owned by the Mattapoisett Land Trust. An MVP Action grant provided $960,000 to help pay for a conservation restriction with the understanding that the thirty acres of salt marsh would provide protection from storm surges (Ismay, 2021). A portion of the funds came from over one hundred individuals and families donating to the cause, many citing the potential of development in this land as threatening to the environmental quality and scenic character of the surrounding neighborhoods and the town overall (Sippican Week Today, 2019). The acquisition was finalized in 2019, bringing the Land Trust's contiguous holdings to over four hundred acres (as shown in Figure 6).

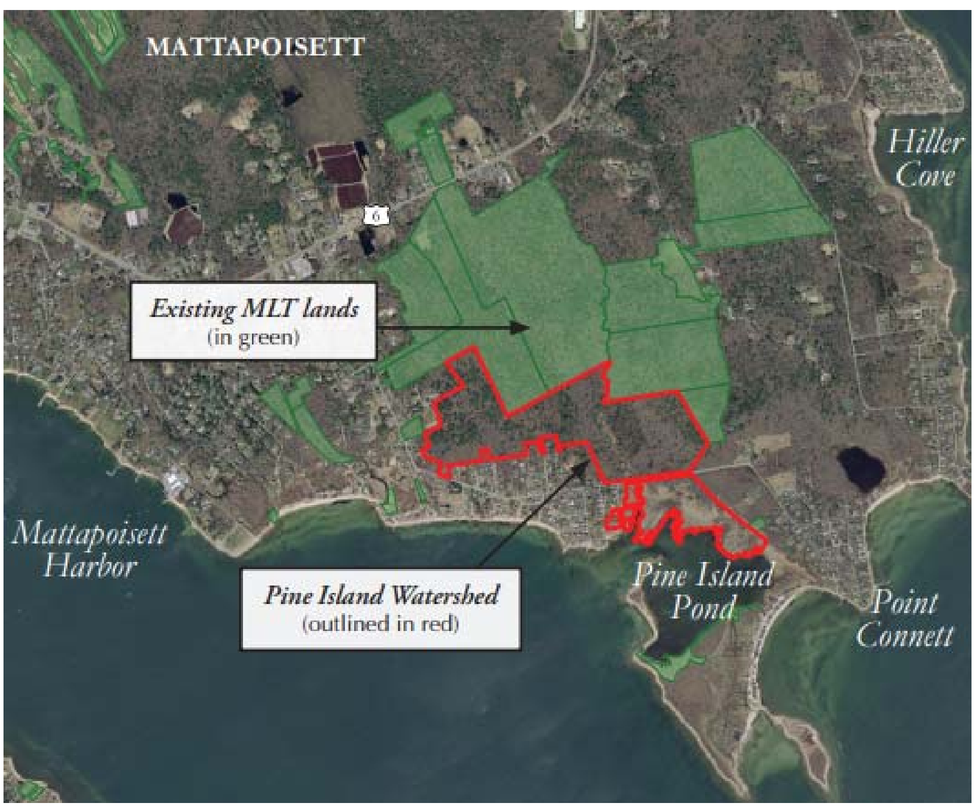


Figure 6. Land Acquired and Held in Trust by the Town of Mattapoisett, Massachusetts. Image Source: Mattapoisett Land Trust.

3.1.3 Land Acquisition

Targeted land acquisition can be used to enhance coastal resilience within and around coastal parks by purchasing strategically important or highly vulnerable privately-owned property by public entities. This strategy is also known as a property buyout. Targeted acquisition or a property buyout aims to reduce and/or prevent repeated storm-related property damage and associated public expenditures. Some consider this strategy a sustainable climate adaptation and floodplain management strategy. Under a planned and well-coordinated buyout program, the residents relocate away from a flood-prone area, the home is removed, and the land is permanently conserved. This one-time investment eliminates the risks and costs associated with flooding and rebuilding while restoring floodplains, salt marshes, dunes, and beaches (The Trustees, 2021). After an acquisition, existing structures are demolished or relocated, and no additional permanent structures are built (other than public access or public amenities, depending on the property involved and the ultimate plan for the property). Acquisitions are supported by cost/benefit analyses and other assessments and are entirely voluntary programs. In some cases, they can be the only solution for low-income homeowners and Environmental Justice populations who face extensive flood insurance premiums and have a cost barrier to relocating. Massachusetts does not currently have a statewide buyout program, and advocates cite the success of programs in other parts of the country (such as New Jersey, North Carolina, and Texas) to advance the cause (Daley, 2015). Many of the coastal parks in the study area are adjacent to private property that is equally vulnerable to coastal flooding.

Case Study
The City of Newport News, Virginia, bought out approximately a dozen homes bordering Salter's Creek, a tidal estuary known to flood at king tides (Figure 7). The marshland bordering the creek used to be in backyards and homes, and following the acquisition, it has been converted to wetlands and greenspace. As of 2021, the town has acquired over eighty flood-prone homes in their voluntary buyout project to prevent future losses to floods. Officials set aside about $200,000 annually to fund the program (Turken, 2021).

Figure 7. Salter's Creek During a King Tide in Newport News, Virginia. Image Source: WHRO.org.

3.2 Stormwater Management

3.2.1 Onsite Flood Storage (Above Ground)

The purpose of a flood storage area is to help reduce peak flows in a body of water, therefore reducing flooding. During heavy rain, the flood storage area structure fills with water, temporarily holding back flood water and reducing the flood risk to properties nearby. Once the flood has passed, the water in the storage area will subside. Much of the remaining undeveloped land in the City of Salem is marked by the presence of ledge (bedrock at or near the surface), steep slopes, or wetlands (Gale Associates, Inc., 2015), which motivates consideration of above ground flood management.

Case Study
Above ground flood storage projects are frequently most beneficial when working within existing features of the site. One such example is the onsite flood storage system incorporated into the Ballard Street marsh system restoration. The Ballard Street marsh is located northeast of Boston in Saugus, along the Saugus River estuary. Before the restoration project and due to the construction of an adjacent highway berm in the 1960s, the marsh system lacked adequate storage capacity and had poor drainage from the nearby ditch network (Woods Hole Group, Inc., 2014). Eighty thousand (80,000) cubic yards of sediment were dredged from the marsh, lowering the ground elevation to a level that allows tidal flushing (Figure 8). The resulting marsh system offers flood control to the surrounding neighborhood while providing a habitat for various native wildlife (Massachusetts Department of Conservation and Recreation, 2015).

Figure 8. Ballard Street Marsh Flood Storage Area. Image Source: USDA Natural Resources Conservation Service.

3.2.2 Onsite Flood Storage (Below Ground)

This method of flood storage requires that a structural component (such as a water tank or cistern) be buried underground. In contrast to above ground flood storage, below ground flood storage requires no surface area to be flooded. For this reason, below ground flood storage should be considered in parks without an existing flood storage area (like a wetland) and in parks where a substantial above ground storage area would disrupt public use. In some cases, rainwater can be stored underground for future use for purposes including irrigation.

Case Study
The City of Peabody, Massachusetts, is pursuing a subsurface stormwater storage project to ameliorate flooding in the Lawrence Brook watershed. The proposed storage tank is sized to hold approximately 50,000 cubic feet of water (equivalent to the stormwater flow predicted for the 2-year design storm). It would be sited in the centrally located Connolly Park. This park currently has several soccer fields, and the installation of this storage tank (beyond the construction and restoration stage) would not otherwise impact the recreational aspects of the park. The storage tank would receive flow during storm events and then discharge the flow back to the storm drain system after the peak of the flow. The storage tank consists of corrugated plastic halfpipes buried inside a 42-inch-tall envelope of porous crushed stone (see Figure 9). The proposed system consists of 650 halfpipe

chambers arranged in a 220-foot by 110-foot area and was designed to avoid tennis courts and sanitary sewer infrastructure.

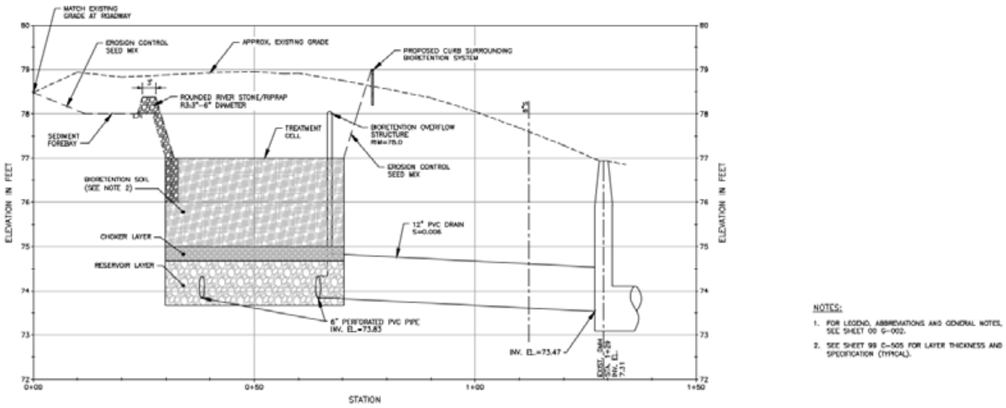


Figure 9. Subsurface Stormwater Holding Volume System Profile Proposed for Connolly Park, Peabody, Massachusetts. Image Source: AECOM.

3.2.3 Bioretention Basins

Green infrastructure is generally defined as systems of stormwater management that filter and absorb stormwater where it falls. Compared to gray infrastructure (systems of gutters, pipes, and tunnels), green infrastructure can offer co-benefits, including providing cleaner air and water, increase exposure to the natural environment, and an opportunity for recreation (EPA, n.d.). These stormwater management techniques are increasingly favored in communities where existing gray infrastructure is aging and needs repair or replacement. Green infrastructure tends to be highly adaptable and can be employed at both small and large scales.

A bioretention basin is one example of green infrastructure. These are landscaped depressions or shallow basins that slow and treat on-site stormwater runoff. Stormwater is directed to the basin and then percolates through the system where it is treated by several physical, chemical, and biological processes. The slowed, cleaned water is allowed to infiltrate native soils or directed to nearby stormwater drains or receiving waters.

Case Study
The City of Salem's Phase 1 of Salem Willows Park Improvements, initiated in June 2021, included the addition of bioretention basins (Figure 10). These basins were built on either side of the park's parking lot entrance off Restaurant Row. Their location serves to catch runoff from the adjacent tennis courts.

Figure 10. Bioretention basin at Salem Willows, Salem, Massachusetts. Image Source: AECOM.

3.2.4 Permeable Surfaces

Removal of impermeable surface materials, when combined with permeable pavement or vegetation establishment, is intended to reduce stormwater runoff rate and volume and associated pollutants transported from the site by stormwater runoff. Rain or runoff water re-enters the ground naturally and can flow back to the stream system (Virginia Association of Soil and Water Conservation Districts, n.d.). Pavilions, walkways, parking areas, and driveways in coastal parks can all be converted to pervious areas that increase infiltration to groundwater. Gardens, lawns, and permeable pavers all can be used in place of the impervious area removed.

Case Study
The Salem Willows Park Improvements included retrofitting the parking lot with permeable pavers (Figure 11). The area had been used for informal parking, leading to a loss of green space, inefficient parking utilization, and fatal damage to mature trees. These permeable pavers mediate runoff from the adjacent tennis courts and enable infiltration (City of Salem, 2021).

Figure 11. A Reconstructed Parking Lot in Salem, Massachusetts, designed with Permeable Pavers. Image Source: AECOM.

3.2.5 Increased Stormwater Pipe Capacity

Compared to on-site above and below ground flood storage, stormwater pipes are part of a more extensive, city-wide system designed to convey stormwater from streets. Stormwater drainage networks should minimize flooding from stormwater runoff, but sea level rise reduces the efficacy of coastal stormwater networks (Virginia Association of Soil and Water Conservation Districts, n.d.). Increasing the stormwater pipe capacity at places that experience flooding during heavy rain may increase the system's efficacy.

Case Study
The City of Peabody is pursuing a stormwater system upgrade project wherein the existing stormwater system would be supplemented with additional capacity by installing a new drainage pipe and outfall. Currently, the entire 199-acre watershed drains to one stormwater outfall that conveys water to the North River, which is shown in Figure 12). During short, intense rain events such as thunderstorms, the lower reaches of the watershed experience flooding along streets and adjacent properties. This situation impedes safe access for residents, businesses, and safety personnel while stressing stormwater infrastructure. The additional drainage pipe will increase the drainage system's capacity and reduce storm-related flooding.

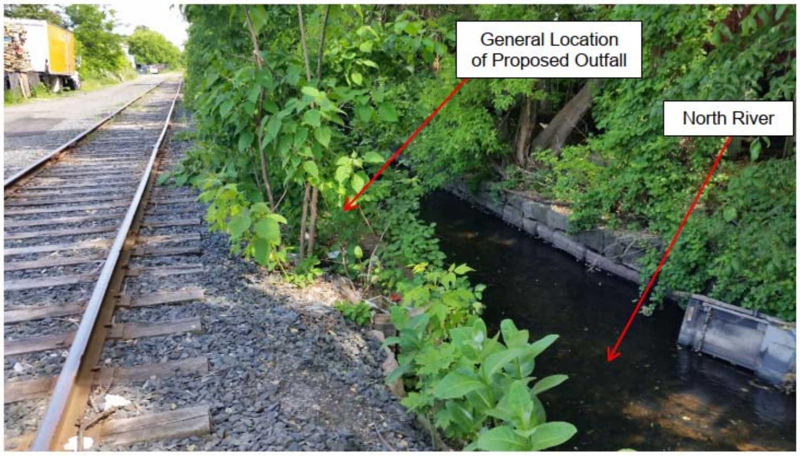


Figure 12. The North River, to which Stormwater will be Discharged via the New Drainage Pipe (Shown Above). Stormwater is collected by a series of catch basins and drains to the north river via one existing outfall. Image Source: AECOM.

3.2.6 Backflow Prevention Definition/Design Components

Backflow prevention devices are stormwater control devices that are either attached to the discharge end of a stormwater outfall pipe or structure or installed within the pipe to prevent stormwater network inundation. Backflow prevention devices may include flap gates/valves, duckbills, inline check valves, self-regulating tide gates, and other designs.

Case Study
The Town of Framingham, Massachusetts, experienced repeated flooding along a specific street, causing repetitive damages to town-owned and private properties. It was determined that the flooding was a result of the Sudbury River backing up at two locations into the town's stormwater drainage system (Town of Framingham, 2017). To mitigate this problem, the town installed "duckbill" style check valves that only allow liquid flow in a single direction. In future events where the river water level surpasses the height of the stormwater release valve, water would be unable to reverse itself. Also, the City of Salem, Massachusetts has installed duckbill check valves on some coastal stormwater outfalls that discharge into the ocean to prevent water from backing up into the outfalls during high tides and coastal storms (see Figure 13).

Figure 13. Example of a Duckbill Backflow Prevention Device at Juniper Beach in Salem, Massachusetts. Image Source: Barbara Warren, Salem Sound Coastwatch.

3.2.7 Rain Gardens

A rain garden (another example of green infrastructure) is a shallow area in the landscape designed to collect rainwater. Vegetation in the garden helps facilitate infiltration and reduce the amount of water running offsite. They can also filter out nonpoint source pollution and protect groundwater. Generally, at least two feet of soil are needed between the bottom of the rain garden and the water table to filter out pollutants effectively (CZM, n.d.-b). This method of stormwater management can be naturally integrated into a park's landscape.

Case Study
In 2019, the City of Salem, Massachusetts, constructed a half-dozen rain gardens. These gardens are designed to filter the "first flush," or the initial surface runoff of a rainstorm. It is understood that this first flush has higher concentrations of water pollutants than subsequent runoff. One such garden on Winter Island is positioned downslope from an adjacent parking lot to filter stormwater runoff before it reaches Salem Sound (Luca, 2021). The system also has an overflow dome to temporarily contain excess stormwater. The outer layer of rocks (see Figure 14) collects trash like cigarette butts, while a mulched area allows water to infiltrate into the sublayer of pollutant-absorbing media. Plant roots help the water percolate through the ground.

Figure 14. Rain Garden in Salem, Massachusetts. Image Source: Barbara Warren, Salem Sound Coastwatch.

3.3 Nature-Based Shoreline Projection

3.3.1 Vegetated Living Shorelines

A living shoreline is a bioengineered natural infrastructure solution designed to stabilize a shoreline. It often consists of natural fiber products such as coir logs (coconut husk fiber) or natural fiber blankets planted with live native plants adapted to conditions at the site. Living shorelines can also include strategically placed sand, stone fill, or other structural and organic materials to stabilize a shoreline (Fuss & O'Neill, 2022). Living shorelines are a natural alternative to hard infrastructure such as concrete seawalls. Living shorelines can provide additional benefits by providing wildlife habitat and carbon sequestration services.

Case Study
The City of Salem, Massachusetts, recently completed a three-quarter-acre salt marsh restoration along an 800-linear foot section of Collins Cove (rendering in Figure 15). The project was designed to restore the salt marsh and its associated interests, specifically the protection of wildlife habitat, protection of fisheries, and storm damage protection (Executive Office of Energy and Environmental Affairs, n.d.). Volunteers planted native marsh grasses to prevent erosion and encourage the accumulation of sand. The marsh is designed to keep rising due to the accumulation of biomatter and accreting sediment. It will offer protection to the adjacent walking/bike path and residential area along Webb Street. A CZM grant is supporting the maintenance of this project.

Figure 15. Salt Marsh Planting along Collins Cove Bike/Walking Path. Image Source: Barbara Warren, Salem Sound Coastwatch.

3.3.2 Oyster Reef Enhancement

An oyster reef is the accumulation of many individual oysters which tend to coalesce on hard substrates. A full-size reef contains thousands, even millions of oysters and can be as tall as a few meters (Massachusetts Oyster Project, n.d.). Such reefs can be found in lower energy environments along the Atlantic coast (Naturally Resilient Communities, n.d.-c). Shoreline protection is one of several ecosystem services that oyster reefs can provide. Oyster reefs can reduce the speed of waves and storm surges, reducing shoreline erosion. In the long term, oyster reefs near salt marshes can help the marsh migrate outwards. Additionally, oysters are particularly adept at filtering bacteria and pathogens, making them suitable for many littoral clean-up applications. Oyster reef enhancement is not allowed in the City of Salem specifically, as all waterbodies are closed for shellfish harvesting and aquaculture. This resilience option remains applicable for other coastal parks in municipalities where shellfish harvesting and aquaculture are permitted.

Case Study

The island of Nantucket, Massachusetts, undertook a two-year-long restoration project to create a new oyster reef in Polpis Harbor (Figure 16). The project is the first of its kind in Massachusetts and is designed to reduce wave and tide impacts on the existing salt marsh, preventing shoreline erosion (Karberg, 2021). The reef was constructed using Oyster Castles®, concrete building blocks that oyster spats can attach to. The project area has an average water depth of 1.3 feet, which allowed these concrete blocks to be installed by hand. While this “soft” barrier is not anticipated to slow sea level rise at the site, this and similar projects have decreased wave velocity (EEA, 2021).

Figure 16. Oyster Reef Enhancement in Polpis Harbor. Image Source: Nantucket Conservation Foundation.

3.3.3 Beach/Dune Restoration

Beaches are defined as stretches of sand or smaller loose particles (such as pebbles, shells, or gravel) that exist between the water and the land. Dunes are landforms that occur when there is a sufficient supply of sand or sediment and strong enough wind to promote sediment transport and, often, some type of an obstacle– vegetation being the most common– that allows the blown sand to accumulate. Beaches and dunes are naturally dynamic environments and will fluctuate in size and shape year to year based on the effect of wind, waves, tides, and storm events. These processes are essential to the ongoing maintenance of the natural system and, if interrupted or suspended, can have great negative impacts on the size and shape of the coastline and the ability of the system to provide flooding and erosion control benefits. A beach's size, width, slope, shape, and sand volume help determine how well the beach can protect a developed area during a storm. Beaches can reduce impacts from coastal storms by acting like a buffer along the coastal edge and absorbing and dissipating the energy of breaking waves, either seaward or on the beach itself (Naturally Resilient Communities, n.d.-a). Dunes serve as more of a barrier between the water's edge and inland areas, taking the brunt of larger storm surges. The wider a beach or dune system is, and the more space between the sea and any developed or populated areas, the more effective and efficient the system will be at reducing the impacts of coastal hazards.

As erosion occurs, the ability of these structures to provide shoreline protection is reduced. Restoring beaches and dunes through managed sand deposits and construction can provide multiple benefits, including shoreline protection as well as public recreation spaces. Salem does not have any sand dunes, although the beaches in the study area may be considered for this strategy.

Case Study
Town Neck Beach in Sandwich, Massachusetts, has experienced an erosion problem for decades. While many beaches along the Cape are being eroded, this case is especially severe due to sand starvation (Figure 17). Adjacent to the beach is an inlet to the Cape Cod Canal. A rock jetty blocks sediment from moving into the canal and has the related consequence of preventing said sediment from reaching Town Neck Beach (just down drift of the Canal). Scusset Beach, just up drift of the canal, is accreting sand. The Town of Sandwich will dredge that extra sand from Scusset Beach and transport it to Town Neck, artificially creating the same movement of sediments that would otherwise have occurred if not for the rock jetty (Treffeisen, 2021).

Figure 17. Town Neck Beach undergoing Sand Renourishment. Image Source: Cape Cod Times.

3.4 Structural Flood Risk Reduction Measures

3.4.1 Deployable Barriers

Deployable flood barriers are designed to maintain pedestrian and vehicle access during typical conditions and are only deployed before an extreme weather event begins. Examples of deployable structures include flip-up, swing, and sliding gates. These deployable measures can be activated by a push button, automatically triggered by sensors, or operated manually. Flip-up gates are stowed on-site in situ and can also be deployed using hydraulics. Seepage barriers are often used in conjunction with deployable structures to provide flood protection. As a supplement to the above ground mobile barrier, a permanent sub-surface component can prevent the flow of water beneath the ground.

Case Study
The South Battery Park City Resiliency Project in New York City aims to construct a continuous flood barrier from the Museum of Jewish Heritage, through Wagner Park, across Pier A Plaza, and along the northern border of Historic Battery Park. In Pier A Plaza, flip-up gates will be used to protect Battery Place and other roads located behind the Plaza (Flood Control International, 2023). There are usually permanent posts, two of which are shown in Figure 18, and into which the gates will lock to form a continuous barrier.

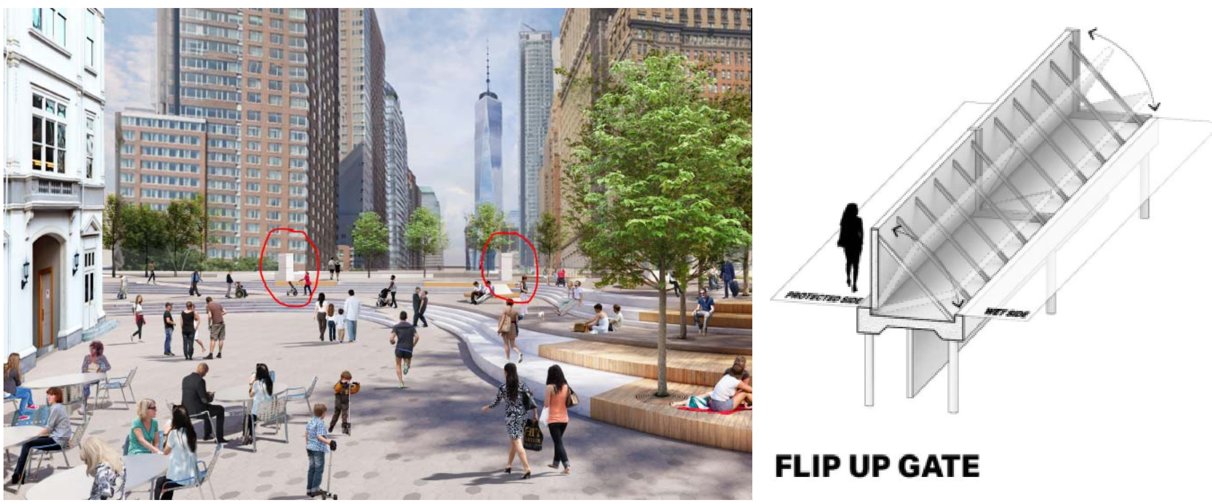


Figure 18. Flip Up Deployable Gate used in Pier A Plaza of South Battery Park City. Image Source: Flood Control International.

3.4.2 Bulkhead or Seawall: Construction or Raising

Coastal structures are built along the shoreline to protect coastal areas from erosion caused by wave action, currents, and flooding during heavy seas. Bulkheads and seawalls are constructed of various materials, including rubble mounds, granite masonry, or reinforced concrete. They are usually supplemented by steel or concrete sheet pile-driven into the soil and are strengthened by wales and brace-type piles. Seawalls can result in the erosion and disappearance of nearby sediment beaches while providing inland soil stabilization. Note that construction of new bulkheads or seawalls can be challenging to permit as new structures.

Case Study
The Matunuck Beach Road Seawall in South Kingstown, Rhode Island, is a 350-foot sheet metal wall along the street for which it is named. The seawall was built in 2022 and is an extension of a 202-foot wall that was completed in 2018. While the project faced controversy, engineers testified that there was no room to relocate the road. It was affirmed that the road is the only thoroughfare to an isolated neighborhood of 240 homes and several businesses. Additionally, beneath the road is a buried water main. It was for these reasons that a seawall (a “hardening” of the coastline) was determined as the only viable option (Faulkner, 2019). The sheet-pile wall stands four feet above ground, with a concrete cap and a stone wall at its base. The piles are driven about forty feet into the ground (as shown in Figure 19). A 20-foot-wide gap in the wall will allow flood waters to return to open waters in the Block Island Sound.

Figure 19. The Matunuck Beach Road Seawall under construction. Image Source: The Boston Globe.

3.4.3 Levee

Like bulkheads and seawalls, a levee is an embankment that runs parallel to the coastline and reduces the risk of flooding on the landward side. Unlike floodwalls, which are typically made from concrete and/or steel, levees are typically earthen. Wherever possible, an artificial levee should be aligned with the existing topography to take advantage of naturally occurring protective features (Naturally Resilient Communities, n.d.-b).

Case Study

Foster City, a coastal city in California, recently undertook a major levee improvements project following a 2014 FEMA determination that the levee system (surrounding most of the outer-bay front perimeter of the City) was inadequate (Foster City Levee Improvements Project, n.d.). An earthen levee is being built near the San Mateo Border Wall (Figure 20). The levee blends into the surrounding park area and will be planted with native vegetation. In conjunction with the other structures, the levee system will keep Foster City properties out of the FEMA-mapped flood zone.

Figure 20. Proposed Earthen Levee in Foster City, California. Image Source: Levee Improvements Project.

3.4.4 Revetment

Revetments are structures typically constructed out of stone parallel to the bank to stabilize or protect the bank from erosion. These structures prevent landward migration of beaches in response to sea level rise (National Park Service, n.d.-b). While holding in place the soils behind the structure, in some cases, revetments result in the erosion and disappearance of adjacent beaches. Note that construction of new revetments can be challenging to permit as new structures.

Case Study

The Nahant Beach Reservation is a protected metropolitan beach covering 67 acres in Nahant, Massachusetts. The Nahant Causeway, the only road that connects the town of Nahant to the mainland, runs parallel to the beach (see Figure 21). This 1.5-mile causeway was reconstructed in 2010 as part of the Nahant Beach Reservation Restoration. Central to this reconstruction was an armor stone revetment designed to attenuate the impact of incident waves and prevent damage to the causeway (Rattigan, 2010).

Figure 21. Revetment in Nahant, Massachusetts. Image Source: TenCate Geosynthetics.

4. Conclusion

The coastal park resilience measures discussed in this memorandum and the attached toolkit graphic are intended to act as a resource for future climate resiliency projects not only for the City of Salem but also for other coastal municipalities in the Commonwealth. Potential permanent risk reduction measures were grouped into the following categories: non-structural measures, stormwater management, nature-based shoreline protection, and structural flood risk reduction measure. Each of these measures has a particular way of performing, addressing a need, and relating to other components. For this reason, a range of solutions and combinations will likely be used to protect the Collins Cove to Willows study area. Identifying and assessing resilience options to address vulnerabilities and risks identified in the study area will be summarized under a separate deliverable for the Collins Cove to Willows Resilience Study.

5. Acronyms

CZM	Coastal Zone Management, or Office of Coastal Zone Management
EEA	Executive Office of Energy and Environmental Affairs
FEMA	Federal Emergency Management Agency
Ft. or ft	feet
In. or in	inches
MC-FRM	Massachusetts Coastal Flood Risk Model
MVP	Municipal Vulnerability Preparedness
NGVD	National Geodetic Vertical Datum
SLR	sea level rise

USACE United States Army Corps of Engineers

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Appendix A – Coastal Parks Resiliency Toolkit Graphic

COASTAL PARKS RESILIENCE TOOLKIT

NON-STRUCTURAL MEASURES

PUBLIC EDUCATION

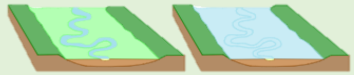
OPEN SPACE PRESERVATION

LAND ACQUISITION

DEVELOPING A TOOLKIT:

No single solution will address the many needs and issues of coastal parks located throughout the Collins Cove to Willows study area. To enable a sustainable, resilient future for these spaces, a multitude of approaches is necessary. This toolkit is a resource for future adaptation measures within the City of Salem's coastal parks. Due to the general nature of these strategies, this toolkit also has the potential to be applied in coastal parks in other communities. Potential non-structural measures, stormwater management strategies, nature-based shoreline protection, and flood risk reduction measures are provided herein and discussed in the accompanying memorandum. Although there are some buildings and roads within and adjacent to the coastal parks in the study area, adaptation measures for these structures are not included in the Coastal Parks Resilience Toolkit since the focus of the toolkit is on open spaces and coastal resources. However, adaptation measures for buildings and roads will be discussed in the project report. Each of the measures included in this toolkit has a particular way of performing, addressing a need, and relating to other components, and thus deserve site-specific considerations. For this reason, a range of solutions and combinations will likely be used to protect these parks.

STORMWATER MANAGEMENT



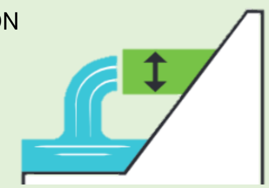
ONSITE FLOOD STORAGE (ABOVE GROUND)

CULTEC, Inc.

ONSITE FLOOD STORAGE (BELOW GROUND)

PERMEABLE SURFACES

BIORETENTION BASIN



INCREASED STORMWATER PIPE CAPACITY

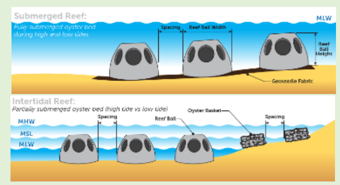
Red Valve Company, Inc.

BACKFLOW PREVENTION

RAIN GARDENS

NATURE-BASED SHORELINE PROTECTION

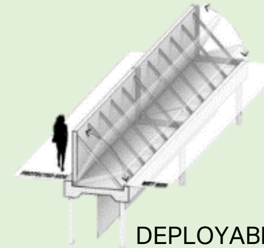
VEGETATED LIVING SHORELINES



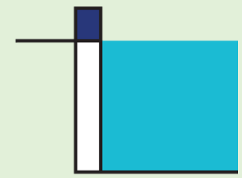
OYSTER REEF ENHANCEMENT

BEACH/DUNE RESTORATION

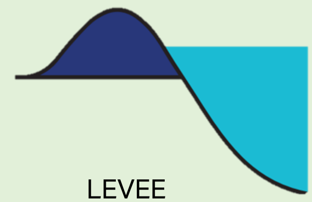
STRUCTURAL FLOOD RISK REDUCTION MEASURES



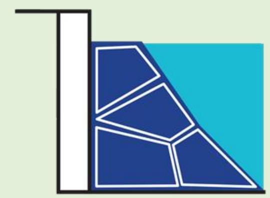
DEPLOYABLE BARRIERS



BULKHEAD OR SEAWALL: CONSTRUCTION OR RAISING



LEVEE



REVETMENT

Appendix F: Resilience Options Memo

AECOM
250 Apollo Drive
Chelmsford, Massachusetts 01824
aecom.com

Project name:
Collins Cove to Willows Resilience Study

Project ref:
60646341

To:
Deb Duhamel, City of Salem

From:
AECOM

Date:
June 29, 2023

CC:
File

Task 4: Resilience Options Memo

1. Introduction

The Collins Cove to Willows Resilience Study for the City of Salem, Massachusetts, was conceived as an integrated coastal protection initiative. The complete study includes an examination of coastal flood projections and overland flooding (both current and future conditions), conducting stakeholder engagement, developing resilient options for the city parks and road networks, developing an emergency response and evacuation plan, and developing a resilient coastal parks toolkit.

In the Task 3 Vulnerability Assessment and Modeling Results memorandum, key areas in the study area were selected based on vulnerabilities and risks that were identified and application of priority area selection criteria (see Figure 1). In the Task 4 Resilient Coastal Parks Toolkit memorandum, potential non-structural, stormwater management, nature-based shoreline protection, and structural flood risk reduction measures were identified.

This memorandum evaluates the feasibility of the resiliency options identified in the Task 4 Resilient Coastal Parks Toolkit memorandum as well as some additional resiliency options identified herein, regarding their ability to protect priority areas within the Collins Cove to Willows study area.

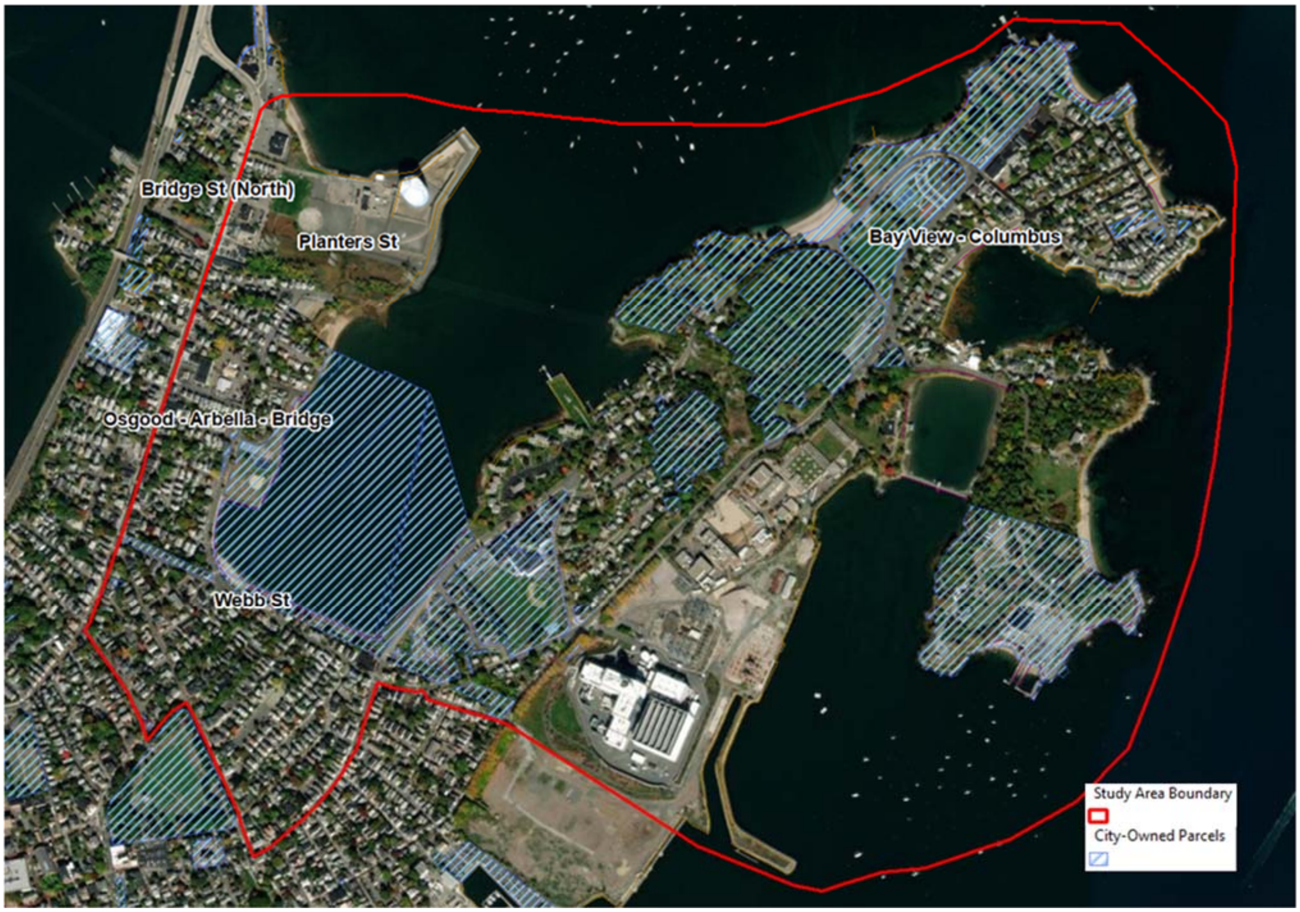


Figure 1. Selected Priority Areas

2. Resilience Options

As described in the Task 4 Resilient Coastal Parks Toolkit memorandum, there are a variety of measures that can be used to increase resilience. The resilience options described in the Resilient Coastal Parks Toolkit fall into the following categories: non-structural measures, stormwater management, nature-based shoreline protection, and structural flood risk reduction measures. The options provide a range of protection and are described in more detail in that memo.

Many of the options in the Resilient Coastal Parks Toolkit are applicable for the wider Collins Cove to Willows study area beyond just the coastal parks. Several additional resilience options were also added that are more applicable to areas outside of the coastal parks. The resilience options included in this memo include structural and nature-based solutions that provide protection against different types of flood hazards including tides and storm surge coming from the coastal waters as well as overland flooding from rainwater and stormwater systems. The options are listed below and if they are also included in the Resilient Coastal Parks Toolkit, this is noted. There is not a “one fits all” solution, and different resilience options may be more applicable and feasible in certain applications within the study area.

2.1 Stormwater Outfall Backflow Prevention

Backflow prevention devices are stormwater control devices that are either attached to the discharge end of a stormwater outfall pipe or structure or installed within the pipe to prevent stormwater network inundation from downstream hydraulic grade line influences. Backflow prevention devices may include flap gates/valves, duckbills, inline check valves, self-regulating tide gates, and other designs. The City of Salem has already implemented some stormwater outfall backflow prevention devices.

Preliminary modeling was conducted to consider the effectiveness of stormwater outfall backflow prevention devices throughout the study area. The modeling results showed the backflow preventers were effective in reducing the impacts of high tide waters from backflowing through the stormwater system. However, these devices should be combined with an increased shoreline elevation (through the elevation of existing seawalls or new levee/berms), otherwise high tide could overtop the shoreline and the stormwater outfall backflow prevention measures will not be enough on their own to reduce coastal flooding.

This resilience option is included in the Resilient Coastal Parks Toolkit, which includes a case study.

2.2 Impervious Surface Removal / Reduction

Removal of impermeable surface materials, when combined with permeable pavement or vegetation establishment, is intended to reduce stormwater runoff rate and volume and associated pollutants transported from the site by stormwater runoff. The City of Salem has already implemented several projects to reduce impervious surfaces throughout the city by replacing them with pervious surfaces such as permeable pavers or vegetated areas. For example, the recent Salem Willows Park Improvements included retrofitting the parking lot with permeable pavers which mediate runoff from the adjacent tennis courts and enable infiltration.

Permeable pavers and similar materials can complicate winter weather treatment as salt is not recommended and snow plowing can be difficult and can cause possible damage. Therefore, the use of these materials should be undertaken with consideration for these winter weather accommodations.

This resilience option is included in the Resilient Coastal Parks Toolkit, which includes a case study.

2.3 Bioretention Basin / Rain Garden

Green infrastructure is generally defined as systems of stormwater management techniques that filter and absorb stormwater where it falls. Compared to gray infrastructure (systems of gutters, pipes, and tunnels), green infrastructure can offer co-benefits, including providing cleaner air and water, increased exposure to the natural environment, and an opportunity for recreation (EPA, n.d.). These stormwater management techniques are increasingly favored in communities where existing gray infrastructure is aging and needs repair or replacement. Green infrastructure tends to be highly adaptable and can be employed at both small and large scales.

A bioretention basin is one example of green infrastructure. These are landscaped depressions or shallow basins that slow and treat on-site stormwater runoff. Stormwater is directed to the basin and then percolates through the system where it is treated by several physical, chemical, and biological processes. The retained, treated water infiltrates into native soils or is directed to nearby stormwater drains or receiving waters.

Another example of green infrastructure with a similar purpose is a rain garden. A rain garden is a shallow area in the landscape designed to collect rainwater. Vegetation in the garden helps facilitate infiltration and reduce the amount of water running offsite. They can also filter out nonpoint source pollution and protect groundwater. Generally, at least two feet of soil are needed between the bottom of the rain garden and the water table to filter out pollutants effectively (MA CZM, n.d.-b).

The City of Salem constructed several rain gardens throughout the city in 2019. The gardens are designed to filter the “first flush,” or the initial surface runoff of a rainstorm. The first flush has higher concentrations of water pollutants than subsequent runoff. One such garden on Winter Island is positioned downslope from an adjacent parking lot to filter stormwater runoff before it reaches Salem Sound (Luca, 2021). The system also has an overflow dome to temporarily contain excess stormwater. The outer layer collects trash like cigarette butts, while a mulched area allows water to infiltrate into the sublayer of pollutant-absorbing media. Plant roots help the water percolate through the ground.

These resilience options are included in the Resilient Coastal Parks Toolkit, which includes a case study.

2.4 Stormwater System Improvements

The stormwater system in the City of Salem is designed to convey surface runoff caused by rainfall events away from streets and parking lots to prevent localized flooding. However, localized flooding can still occur due to increasing tide elevations, which result in the stormwater not being able to discharge to the receiving water. The solution to that problem is covered in Section 2.1 (stormwater outfall backflow prevention). Other stormwater system improvements can include increasing catch basin inlet capacity in which the surface level stormwater runoff can enter the stormwater pipe network with fewer restrictions by increasing the number of catch basins. If the stormwater system's catch basin inlet capacity is sufficient, increasing conveyance capacity through enlarging pipes and/or removing hydraulic restrictions within the system can be effective in reducing street flooding during more intense or larger rainfall events.

Increased stormwater pipe capacity is included in the Resilient Coastal Parks Toolkit, which includes a case study.

2.5 Alternative Access Route

An alternative access route (e.g., extension of Island Avenue) can be used by emergency responders and residents during emergencies or when primary or secondary access roads become inaccessible due to natural hazard events. The designation of an alternative access route involves creating a new roadway that connects key areas and provides an alternative route for residents, emergency services, and essential goods and services. An alternative access route can improve the accessibility to critical services and evacuation routes, reducing the impact on residents' safety and well-being. Implementing an alternative access route such as an extension of Island Avenue will require collaboration between various stakeholders, including the City, engineers, and community members. Including an extension of Island Avenue as an alternative access route in this resilience options memo demonstrates proactive and forward-thinking approaches to address the challenges posed by natural hazards and climate change. By diversifying transportation options and improving connectivity, the City of Salem can improve the overall resilience and adaptability in the study area.

2.6 Additional Temporary Stormwater Storage

Temporary stormwater storage can be used to reduce the potential flooding caused by high intensity/large volume rainfall events. By storing a portion of the surface runoff that enters the stormwater collection system, there is more available capacity in the collection system during the rainfall event. Additionally, the volume of water that is stored does not contribute to surface flooding. In a below ground storage system, no surface level area is required to be utilized and includes a structural component such as a water tank or cistern buried underground. After the rainfall event is over and the stormwater system's hydraulic grade line has subsided, the stored water is discharged to the stormwater system and conveyed to the receiving water body. Alternatively, depending on the peak water table elevation and soil characteristics, stored stormwater could be infiltrated into the ground. Above ground storage can include retention and detention ponds and wetlands where surface runoff is infiltrated.

The purpose of a flood storage area is to help reduce peak flows in a body of water, therefore reducing flooding. During heavy rain, the flood storage area structure fills with water, temporarily holding back flood water and reducing the flood risk to properties nearby. Once the flood has passed, the water in the storage area will subside. These stormwater storage areas can occur above ground or below ground. Above ground storage can include retention and detention ponds and wetlands. Below ground storage requires no surface area to be flooded and includes a structural component such as a water tank or cistern buried underground.

These resilience options are included in the Resilient Coastal Parks Toolkit, which includes several case studies.

2.7 Living Shorelines

A living shoreline is a bioengineered natural infrastructure solution designed to stabilize a shoreline. It often consists of natural fiber products such as coir logs (coconut husk fiber) or natural fiber blankets planted with live native plants adapted to conditions at the site. Living shorelines can also include strategically placed sand, stone fill, or other structural and organic materials to stabilize a shoreline (Fuss & O'Neill, 2022). These features are a natural alternative to hard infrastructure such as concrete seawalls and can provide additional benefits by providing wildlife habitat and carbon sequestration services.

The City of Salem recently completed a three-quarter-acre salt marsh restoration along an 800-linear foot section of Collins Cove. The project was designed to restore the salt marsh and provide additional co-benefits such as the protection of wildlife habitat, protection of fisheries, and storm damage protection (Executive Office of Energy and Environmental Affairs, n.d.). Volunteers planted native marsh grasses to establish the living shoreline which helps prevent erosion and encourage the accumulation of sand. The marsh is designed to keep rising due to the accumulation of biomatter and accreting sediment. It will offer protection to the adjacent walking/bike path and residential area along Webb Street. A Coastal Zone Management grant is supporting the maintenance of this project.

This resilience option is included in the Resilience Coastal Parks Toolkit and includes the case study listed above.

2.8 Elevation Existing Seawall / Shoreline Height Increase

Coastal structures along the shoreline are designed to protect coastal areas from erosion caused by wave action, currents, and flooding during heavy seas. Within the study area, existing seawalls are located along multiple shorelines (shown in Figure 2 as gray, green, and purple lines). While adding new seawalls may be a permitting challenge, an option to increase the height of existing seawalls is possible.

This resilience option is included in the Resilient Coastal Parks Toolkit, which includes a case study.

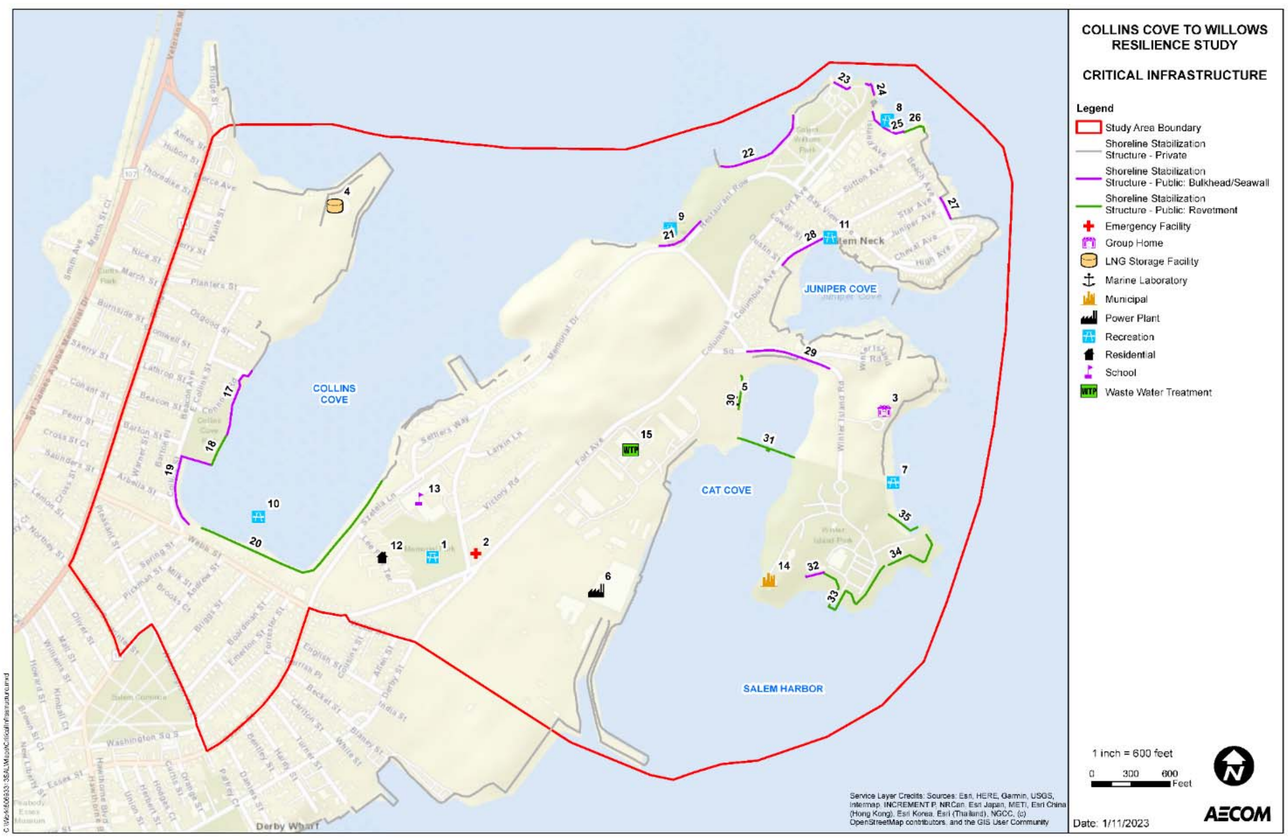


Figure 2: Critical Infrastructure

2.9 New Levee / Berm

Like bulkheads and seawalls, a levee is an embankment that runs parallel to the coastline and reduces the risk of flooding on the landward side. Unlike floodwalls, which are typically made from concrete and/or steel, levees are typically earthen. Levees and berms require a larger footprint for construction due to the side slopes necessary to support the earthen materials.

This resilience option is included in the Resilient Coastal Parks Toolkit, which includes a case study.

2.10 Building Elevation

Elevating a building above predicted flood levels reduces the risk of flood damage to the structure. The process of elevating an existing building typically includes lifting the structure, reinforcing its foundation, and creating a new elevated platform. This elevation allows floodwaters to flow beneath the building without causing significant damage. By elevating buildings, communities can maintain critical functions during and after flood events, minimize disruption, and protect valuable assets. Building elevation can significantly reduce flood-related losses including property damage and business interruptions.

Implementing building elevation requires careful planning, engineering expertise, and coordination between stakeholders such as homeowners, architects, and local authorities. It is essential to consider factors like building codes, aesthetics, and community acceptance. Financial assistance programs and incentives may be available to support property owners in undertaking elevation projects (see Section 3.2).

2.11 Building Acquisition

Building acquisition involves the strategic purchase and removal of properties located in high-risk areas, such as floodplains or coastal zones, where the potential for damage and loss is significant. Building acquisition allows communities to proactively manage their exposure to hazards by removing structures from harm's way. This approach reduces the potential for property damage, infrastructure disruption, and human casualties during extreme events. Also, it provides an opportunity to restore natural floodplains or coastal ecosystems, which can provide valuable ecosystem services, including floodwater storage and habitat preservation.

Building acquisition programs typically involve collaboration between government agencies, non-profit organizations, and local communities. These programs may offer financial incentives to property owners to voluntarily participate in the acquisition process. The acquired properties are then carefully managed to ensure their long-term ecological benefits and prevent future development in hazardous areas. Implementing building acquisition as part of a resilience toolkit requires careful planning, coordination, and community engagement. It is essential to consider social equity aspects and provide support to affected property owners throughout the process.

2.12 Green Roofs

Green roofs, also known as vegetated roofs or eco-roofs, offer a sustainable solution for stormwater management. They are designed to utilize the natural properties of plants and soil to mitigate the effects of heavy rain and reduce the risk of flooding. Green roofs consist of a layered system that includes a waterproofing membrane, a drainage layer, a lightweight growing medium, and vegetation. The vegetation acts as a natural sponge, absorbing rainfall and reducing the volume of stormwater runoff that would otherwise overwhelm drainage systems. This helps to alleviate the strain on urban stormwater infrastructure.

The design and construction of green roofs vary depending on the specific requirements of the building and its location. They can be installed on various types of structures, including residential, commercial, and industrial buildings. Green roofs offer numerous benefits beyond stormwater management, such as improving air quality, reducing energy consumption by providing insulation, creating habitats for wildlife, and enhancing the aesthetic appeal of urban areas. By incorporating green roofs into urban landscapes, the City of Salem can mitigate some of the impacts of intense rainfall events.

2.13 Harbor Barrier

Flood protection barrier structures are major infrastructure projects designed to provide protection during significant hurricane and coastal storm events. As an example, the New Bedford Hurricane Protection Barrier is located approximately 50 miles south of Boston and protects the communities of New Bedford, Fairhaven, and Acushnet from coastal flooding caused by hurricanes and Nor'easters. The barrier, which extends across New Bedford and Fairhaven Harbor, is operated and maintained by the U.S. Army Corps of Engineers. The structure consists of a long earthen dike with stone slope protection. There is a gate to provide access for commercial and recreational vessels, which can be closed before coastal storm surge events (USACE, 2015).

A harbor barrier could be an option to protect Collins Cove from extreme coastal conditions. The structure would be limited by the need to tie into high ground in the Planters Street / Bridge Street North area, which has a lower ground elevation than across the cove along Memorial Dr. The high cost of constructing and maintaining a harbor barrier in Collins Cove as well as complex permitting requirements may make this solution less feasible than other resiliency options.

2.14 Floodproofing Buildings

Floodproofing buildings involves implementing a range of strategies and techniques to minimize flood damage and protect the occupants and contents of buildings. Floodproofing measures can include both structural and non-structural solutions. There are two types of floodproofing: wet floodproofing and dry floodproofing.

Wet floodproofing allows floodwaters to enter a structure or area but includes actions to minimize the damage. This includes techniques such as elevation of mechanical and utility equipment and the use of openings or breakaway walls. The application of wet floodproofing as a flood protection technique under the National Flood Insurance Program is limited to enclosures below elevated residential and non-residential structures.

Dry floodproofing is only allowed in areas where the depth of water under flooded conditions is projected to be less than 3 feet and base flood velocities are less than 5 feet per second. Dry floodproofing includes: coverings on doors and windows designed to be watertight; paints, membranes, gaskets, or other sealants that reduce water seepage; electrical equipment and circuits that are protected to the flood level; and other similar measures. Dry floodproofing is intended for only commercial (i.e. non-residential) structures.

2.15 Road Elevation

Road elevation increases the top of the road above existing or projected flood hazards. Road elevation is best suited to address nuisance-level flooding such as tides or smaller rainfall events. The challenge is that the road needs to be able to tie into existing roads at higher elevations. Additionally, while the elevated road may stay above floodwaters, the project can increase localized flooding around the elevated road leading to unintended consequences for neighboring low-lying areas. If assessments indicate that neighboring low-lying areas could be negatively affected, the feasibility of this resiliency alternative could be impacted. Alternatively, further infrastructure improvements would be necessary to mitigate an increased flooding risk in the low-lying areas.

2.16 Breakwater (Juniper Ave.)

Juniper Cove is a natural harbor on the northeast peninsula area of the City of Salem within the study area. Remnants of an existing breakwater exist at the narrow section of the cove entrance. Local community members support a proposal to rebuild this breakwater to help limit wave action and erosion along the shoreline inside the cove. However, according to recent correspondence with the City's Assessor's Office, the breakwater is not owned by the City of Salem. Preliminary discussions about restoring this breakwater have been conducted with residents, the City, and the Massachusetts Office of Coastal Zone Management.

3. Feasibility Criteria

To evaluate the various resilience options, the following criteria were identified to assess the feasibility and value of implementation of the options: relative cost, funding opportunities, ownership, community acceptance, and effectiveness in providing protection against future predicted flooding conditions. Each criterion is described below.

3.1 Relative Cost

The costs of the project options were not given an absolute cost but rated on a relative cost scale that ranged from *low, medium, high*, to *very high*. *Low* costs were considered a priority and are shown as green in Table 2 in Section 4. *Medium* costs are shown as yellow, and *high* and *very high* costs are shown as red.

3.2 Funding Opportunities

Funding opportunities for projects are predominantly determined by two key factors: the ownership of the project site and the nature of the proposed activity. Projects located on privately owned land are ineligible for most government funding. However, projects owned by state or municipal entities may be eligible for a range of grant programs. When it comes to MVP Action Grants, it is important to note that feasibility studies may explore potential projects on privately held land, but the grant funding is specifically allocated for projects executed on lands owned by municipal, state, or federal agencies, non-profit conservation organizations, or private lands with the consent of the owners. For applications proposing projects on privately owned property, eligibility requires a letter from the property owner(s) affirming their commitment to pursuing the project's restoration goals and actions. Alternatively, evidence can be provided to demonstrate that the property will be transferred to an entity committed to the project's goals.

It is important to note that to qualify for an MVP Action Grant, the City must have legal access to the project area before project execution. This criterion also applies to most other state or federal funding opportunities, which generally require projects to take place on publicly owned or accessible land. To assist in identifying potential funding sources for resiliency tools, Table 1 presents an overview of grant funding opportunities that may be available. This table provides valuable information to support the City's efforts in securing the necessary financial resources for implementing resilience projects. By understanding the requirements and constraints associated with funding opportunities, the City can strategically plan and seek appropriate grants that align with its objectives for enhancing resilience in the study area.

Funding opportunities were based on the following ranking system: *Few, Average*, or *Many*. If a project type had several (>2) potential funding sources identified, it was given a *Many* rating and shown as green in Table 2 in Section 4. If a project type had 1 - 2 funding sources identified, then the project was given an *Average* rating and is shown in yellow. If no known funding sources were available for a particular project type, then a *Few* rating was assigned and shown in red.

Table 1. Representative Funding Opportunities for Resilience Tools

Funding Opportunities	Source	Categories	Approximate Submission Month	Other Notes
Coastal Zone Management (CZM) Coastal Resilience Grant Program	State	Infrastructure, Stormwater Management, Environmental, Land Acquisition, Education, Emergency	June	Local match encouraged, but not required
Federal Emergency Management Agency (FEMA) Hazard Mitigation Assistance Grant Program	Federal	Infrastructure, Emergency, Land Acquisition	Varies	Funding available following a major federal disaster declaration
National Fish and Wildlife Foundation (NFWF) National Coastal Resiliency Fund	Federal	Infrastructure, Environmental, Emergency, Education	June	No maximum award
Flood Mitigation Assistance Grant Program (FEMA)	Federal	Infrastructure, Environmental, Education	January	Match requirements
Federal Emergency Management Agency (FEMA) Building Resilient Infrastructure and Communities (BRIC)	Federal	Infrastructure	January	Maximum grant award amount: $2,000,000
Department of Environmental Protection (DEP) State Revolving Fund Loan (SRF) Clean Water Program	State	Infrastructure, Environmental, Stormwater	Revolving Fund	The standard terms are 2% interest for 20 years
Division of Conservation Services Local Acquisitions for Natural Diversity (LAND) Grant	State	Land Acquisition	July	Maximum grant award amount: $500,000
Parkland Acquisitions and Renovations for Communities (PARC) Grant Program	State	Land Acquisition	July	Maximum grant award amount: $500,000
EEA Municipal Vulnerability Preparedness Municipal Vulnerability Preparedness (MVP) Action Grant	State	Infrastructure, Stormwater, Environmental, Education	May	Maximum grant award amount: $3,000,000
EEA Dams and Seawall Repair or Removal Program Grants	State	Infrastructure, Environmental, Emergency	February	Maximum grant award amount: $2,000,000
MassDEP 319 Grants	State	Education	November	-

3.3 Ownership

The City of Salem has more control over designing and implementing projects on properties that they have ownership of. This feasibility criterion has the following rating options: *City Ownership* or *Other Ownership.* The ability to implement projects on city-owned property is anticipated to be easier and this is indicated with a green box in Table 2 in Section 4 indicating *City Ownership*. For projects that are owned privately or by a State or National entity, these projects are rated as less feasible and given a red box indicating *Other Ownership.*

3.4 Community Acceptance

Community acceptance of resilience options is a high priority for the City of Salem. This criterion is subjective and evaluates whether the implementation of a resilience option would have a negative or positive effect on the area's aesthetics and whether it would conflict with the existing uses of the area. Feasibility ratings of *low, medium,* or *high* are available. In Table 2 (see Section 4), projects with *low* community acceptance are shown in red; projects with *medium* community acceptance are shown in yellow; and projects with *high* community acceptance are shown in green.

3.5 Permitting Complexity

The resilience options presented herein entail permitting complexity ranging from *low, medium,* to *high* based on the amount and location of ground disturbance (both temporary and permanent). If the permitting for a resilience option was determined to be straight-forward the project was given a *low* rating and shown as green in Table 2 in Section 4. Projects with some permitting complexity were given a rating of *medium* and are shown in yellow Table 2 in Section 4. For projects requiring complex permitting, the projects were given a *high* rating and are shown in red in Table 2 Section.

The type of option selected influences the amount of ground disturbance required, while the location of the planned intervention determines which regulations the project is subject to. Planning and procedural tools such as building acquisition might not require permits or approvals from any environmental resource agencies such as the Salem Conservation Commission, MassDEP, or the MA Division of Fisheries and Wildlife (MassDFW). Most of the study area includes a resource area which, when work is proposed within it, would trigger the need for approval under the Massachusetts Wetlands Protection Act (WPA) at a minimum. The City of Salem also has a Wetlands Protection Ordinance (Sections 50-1 through 50-18 of Part III of the City of Salem Code). Maintenance of pre-existing structures without further alteration or expansion (such as some stormwater system improvements) are generally exempt from the WPA, while other projects that require direct alterations to protected resource areas are subject to a greater degree of scrutiny.

Much of the study area is mapped as FEMA 100-year floodplain, which is regulated under the WPA as Bordering Land Subject to Flooding (BLSF) or Land Subject to Coastal Storm Flowage (LSCSF). This classification triggers the need to file a Request for Determination of Applicability (RDA) or Notice of Intent (NOI) with the Salem Conservation Commission and MassDEP. In addition to the areas jurisdictional under the WPA, the Salem Conservation Commission regulates a 25-foot No Disturbance Zone (in which no alterations are allowed, other than activities that improve the character of the Zone) and a 50-foot Mitigation Zone (in which disturbance is prohibited without adequate mitigation provided as determined by the Conservation Commission). At their discretion, the Commission may exclude improvements to existing seawalls from mitigation requirements in the Mitigation Zone. Various beaches in the study area include wetland resource areas regulated under the WPA, including Salt Marsh, Coastal Dune, Coastal Bank, Barrier Beach, Coastal Beach, and Rocky Intertidal Shore. Any alteration of these resource areas triggers the need to file an Environmental Notification Form (ENF) with the Massachusetts Environmental Policy Act (MEPA) office for review, public/agency comments, and identification of whether an Environmental Impact Report (EIR) must be prepared for further MEPA and agency review.

Several locations along the perimeter of the study area (including much of Salem Willows) are regulated under Chapter 91 (the Massachusetts Public Waterfront Act) as filled or flowing tideland. Installation of permanent structures in Chapter 91 jurisdictional area requires either obtaining a Chapter 91 License or amending a previously issued License if one exists. Resilience options that would be in Chapter 91 jurisdictional area were deemed to have a moderate degree of permitting complexity.

The southern half of Winter Island, a portion of the northeast shore of Salem Willows, and Collins Cove Park are mapped as Massachusetts Department of Conservation and Recreation (DCR) Article 97 Protected and Recreational OpenSpace. Article 97 exists to protect land acquired by the Commonwealth for conservation and to prevent the conversion of said land for inconsistent uses. Land protected under Article 97 requires a 2/3 vote of the Massachusetts General Court before it can be altered from its intended use. A project that is proposed in Article 97 land must at a minimum be approved by DCR and likely seek approval from the General Court. Projects located in Article 97 have a moderate to high degree of complexity.

3.6 Effectiveness in Providing Protection Against Future Predicted Flooding Conditions

Determining the effectiveness in providing protection against future predicting flooding conditions relied on a mix of modeling and engineering judgement. For some resilience options, modeling of future conditions was conducted and is discussed in Section 2. For the other resilience options, engineering judgement and expertise was used to estimate the effectiveness of the option for the City of Salem. The effectiveness was rated *high, medium,* or *low.* Projects that were determined to provide a low level of flood protection are shown in red Table 2 in Section 4 and are listed as *low.* Projects that were determined to provide a moderate level of flood protection are shown in yellow and are listed as *medium.* Projects that were determined to provide a high level of flood protection are shown in green and are listed as *high.*

4. Feasibility Assessment Results

Table 2 provides the results of applying the feasibility criteria to the resilience options and includes a summary regarding the relative feasibility and suitability for implementation in the priority areas. The options are listed from most feasible at the top to least feasible at the bottom.

Table 2. Feasibility Criteria and Ranking for Resilience Options

Resilience Option	Feasibility Criteria					
	Relative Cost	Funding Opportunities	Ownership	Community Acceptance	Permitting Complexity*	Effectiveness
Stormwater Outfall Backflow Prevention	*Low*	*Many*	*City*	*High*	*Low*	*Medium*
Impervious Surface Removal/Reduction	*Low*	*Many*	*City*	*High*	*Low*	*Medium*
Bioretention Basin/Rain Garden	*Low*	*Many*	*City*	*Medium*	*Low*	*Medium*
Stormwater System Improvements	*Medium*	*Many*	*City*	*Medium*	*Low*	*High*
Additional Temporary Stormwater Storage/Subsurface Infiltration Basin	*Medium*	*Many*	*City*	*Medium*	*Moderate*	*High*
Living Shorelines	*Low*	*Many*	*City*	*Medium*	*Moderate*	*Medium*
Alternative Access Route	*High*	*Few*	*City*	*High*	*Low*	*High*
Elevate Existing Seawall/Shoreline Height Increase	*Medium*	*Few*	*City*	*Medium*	*Moderate*	*High*
Building Elevation	*Medium*	*Average*	*Other*	*Low*	*Moderate*	*High*
Building Acquisition	*Medium*	*Average*	*Other*	*Low*	*Moderate*	*High*
New Levee/Berm	*High*	*Few*	*City*	*Medium*	*High*	*High*
Green Roofs	*Low*	*Average*	*Other*	*Medium*	*Low*	*Low*
Harbor Barrier	*Very High*	*Few*	*City*	*Medium*	*High*	*High*
Floodproofing Buildings	*Low*	*Few*	*Other*	*Medium*	*Low*	*Medium*
Road Elevation	*High*	*Few*	*City*	*Medium*	*Moderate*	*Medium*
Juniper Ave Breakwater	*Medium*	*Average*	*Other*	*High*	*High*	*Medium*

*Other permitting variables will likely arise based on the location of proposed options.

5. Potential Resilience Options by Priority Area

The following sections provide a discussion of the resilience options that were determined to be most feasible and suitable for addressing the coastal and inland flooding vulnerabilities identified in each priority area within the study area. In some cases, hydrologic/hydraulic modeling has been conducted to better understand the effectiveness of a resilience option. Modeling results are incorporated as appropriate.

Table 3 shows which resilience options are applicable for each priority area with an “x” in the green box. More information on each priority area’s applicable resilience options is provided in the following sub-sections.

5.1 Bridge Street (North)

The Bridge Street (North) area is vulnerable to a variety of flooding impacts as discussed in the Task 3 Vulnerability Assessment and Modeling Results Memo including pluvial, coastal, and erosion. The highest risks are from stormwater flooding (2050, 5-year event) and erosion (2050 intermediate erosion).

Resilience strategies that are applicable to this area and would provide improved protection from **stormwater flooding** include:

- Stormwater outfall backflow prevention
- Impervious surface removal/reduction
- Bioretention basins and rain gardens
- Stormwater system improvements
- Green roofs

Although **erosion** is a risk for this area, typical erosion control measures such as living shorelines are not applicable for this region and new hardened shorelines are unlikely to be permitted in this area.

Resilience strategies that are applicable to this area and would provide improved protection from **coastal flooding** include:

- New levee or berm
- Floodproofing Buildings
- Road elevation

5.2 Planters Street

The Planters Street area is vulnerable to a variety of flooding impacts as discussed in the Task 3 Vulnerability Assessment and Modeling Results Memo including pluvial, coastal, and erosion. The highest risks are from coastal flooding (2050 tides and surge) and erosion (2050 intermediate erosion).

Resilience strategies that are applicable to this area and would provide improved protection from **coastal flooding** include:

- New levee or berm
- Flood gates
- Floodproofing Buildings

Resilience strategies that are applicable to this area and would provide improved protection from **erosion** include:

- Living shorelines

Although **stormwater flooding** is not the highest risk hazard, some risk from stormwater flooding is present. Resilience strategies that are applicable to this area and would provide improved protection from stormwater flooding include:

- Impervious surface removal/reduction
- Green roofs

Table 3. Resilience Options as Applicable to Priority Areas

Resilience Option	Type of Hazard Protection	Priority Area				
		Bridge Street North	Planters Street	Osgood-Arbella-Bridge	Webb Street	Bay View - Columbus
Stormwater Outfall Backflow Prevention	Coastal	x		x	x	x
Impervious Surface Removal/Reduction	Stormwater	x	x	x	x	x
Bioretention Basin/Rain Garden	Stormwater	x				x
Stormwater System Improvements	Stormwater	x		x	x	x
Alternative Access Route (Island Ave)	Coastal / Stormwater					x
Additional Temporary Stormwater Storage/Subsurface Infiltration Basin	Stormwater				x	x
Living Shorelines	Erosion		x		x	x
Elevate Existing Seawall/Shoreline Height Increase	Coastal			x		x
Building Elevation	Coastal / Stormwater			x	x	
Building Acquisition	Coastal / Stormwater			x	x	
New Levee/Berm	Coastal	x	x	x	x	
Green Roofs	Stormwater	x	x	x	x	x
Harbor Barrier	Coastal		x	x	x	
Floodproofing Buildings	Coastal / Stormwater	x	x	x	x	x
Road Elevation	Coastal / Stormwater	x			x	x
Juniper Ave Breakwater	Erosion					x

5.3 Osgood - Arbella - Bridge

The Osgood - Arbella - Bridge area is vulnerable to a variety of flooding impacts as discussed in the Task 3 Vulnerability Assessment and Modeling Results Memo including pluvial, coastal, and erosion. This area has a high risk from all three hazard types: stormwater flooding (2050, 5-yr event), coastal flooding (2050 tides and surge), and erosion (2050 intermediate erosion).

Resilience strategies that are applicable to this area and would provide improved protection from **stormwater flooding** include:

- Stormwater outfall backflow prevention
- Impervious surface removal/reduction
- Stormwater system improvements
- Green roofs

Resilience strategies that are applicable to this area and would provide improved protection from **coastal flooding** include:

- New levee or berm
- Harbor barrier
- Elevate existing seawall / shoreline height increase
- Building elevation
- Building acquisition
- Floodproofing buildings

Although **erosion** is a risk for this area, typical erosion control measures such as living shorelines are not applicable for this region and new hardened shorelines are unlikely to be permitted in this area.

5.4 Webb Street

The Webb Street area is vulnerable to a variety of flooding impacts as discussed in the Task 3 Vulnerability Assessment and Modeling Results Memo including pluvial, coastal, and erosion. This area has a high risk from two hazard types: coastal flooding (2050 tides and surge) and erosion (2050 intermediate erosion).

Resilience strategies that are applicable to this area and would provide improved protection from **coastal flooding** include:

- New levee or berm
- Harbor barrier
- Building elevation
- Building acquisition
- Floodproofing buildings
- Road elevation

Resilience strategies that are applicable to this area and would provide improved protection from **erosion** include:

- Living shorelines

Although stormwater flooding is not the highest risk hazard, some risk from stormwater flooding is present. Resilience strategies that are applicable to this area and would provide improved protection from **stormwater flooding** include:

- Stormwater outfall backflow prevention
- Stormwater system improvements
- Impervious surface removal/reduction
- Additional temporary stormwater storage / subsurface infiltration basin
- Green roofs

5.5 Bay View - Columbus

The Bay View - Columbus area is vulnerable to a variety of flooding impacts as discussed in the Task 3 Vulnerability Assessment and Modeling Results Memo including pluvial, coastal, and erosion. This area has a high risk from two hazard types: coastal flooding (2050 tides and surge) and erosion (2050 intermediate erosion).

Resilience strategies that are applicable to this area and would provide improved protection from **coastal flooding** include:

- Elevate existing seawall / shoreline height increase
- Floodproofing buildings
- Road elevation
- Alternative access route

Resilience strategies that are applicable to this area and would provide improved protection from **erosion** include:

- Living shorelines
- Juniper Avenue breakwater

Although stormwater flooding is not the highest risk hazard, some risk from stormwater flooding is present. Resilience strategies that are applicable to this area and would provide improved protection from **stormwater flooding** include:

- Stormwater outfall backflow prevention
- Impervious surface removal / reduction
- Bioretention basin / rain garden
- Stormwater system improvements
- Additional temporary stormwater storage / subsurface infiltration basin
- Green roofs

6. Conclusion

This memo presented the results of an initial evaluation of resilience options identified as most feasible and suitable for protecting priority areas identified in the study area from coastal and inland flooding and shoreline erosion. The resilience options range from projects that would impact a single building such as a green roof to large scale-projects such as increasing the elevation of existing seawalls or constructing a harbor barrier.

The feasibility of these resilience projects was rated based on relative cost, funding opportunities, ownership, community acceptability, permitting complexity, and the effectiveness in providing protection against future flooding. The resilience options were also evaluated for the applicability to stormwater, coastal, and erosion hazards for each priority area.

This evaluation will be refined as part of the Task 5 Collins Cove to Willows Resilience Study Report, based on discussion and input from the City of Salem as well as stakeholder feedback.

8. Acronyms

BLSF	Bordering Land Subject to Flooding
BRIC	Building Resilient Infrastructure and Communities
CZM	Coastal Zone Management, or Office of Coastal Zone Management
DCR	Department of Conservation and Recreation
EEA	Executive Office of Energy and Environmental Affairs
EIR	Environmental Impact Report
ENF	Environmental Notification Form
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
Ft. or ft	feet
In. or in	inches
LAND	Local Acquisitions for Natural Diversity
LSCSF	Land Subject to Coastal Storm Flowage
MassDEP	Massachusetts Department of Environmental Protection
MC-FRM	Massachusetts Coastal Flood Risk Model
MEMA	Massachusetts Emergency Management Agency
MVP	Municipal Vulnerability Preparedness
NFWF	National Coastal Resiliency Fund
NGVD	National Geodetic Vertical Datum
NHESP	Natural Heritage and Endangered Species Program
NOI	Notice of Intent
RDA	Request for Determination of Applicability
SLR	sea level rise
SRF	State Revolving Fund
USACE	United States Army Corps of Engineers
WPA	Wetland Protection Act

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