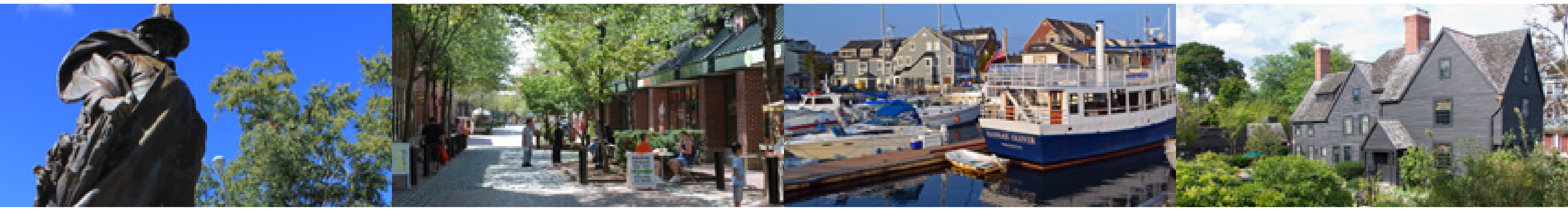
APPENDIX C



CLIMATE CHANGE ADAPTATION STRATEGIES

CDM Smith

Salem
Still making history.

Appendix B, the Climate Change Vulnerability Assessment Matrices & Priority Vulnerabilities, described the results of the vulnerability assessment and the prioritized vulnerabilities based on two methods: 1) a risk assessment and 2) evaluation criteria.

This appendix includes 43 adaptation strategies for the prioritized vulnerabilities. These include possible projects such as policies, studies, outreach, ordinances/zoning, operations, design, and construction opportunities that can address the top vulnerabilities in the City. They are high level strategies that are designed to be incorporated into existing and future plans, as appropriate. The Adaptation Strategies are organized and categorized to provide the City of Salem with a user-friendly resource for proactively addressing prioritized vulnerabilities and allowing the City to be more resilient to the effects of extreme precipitation events, sea level rise, storm surge, and extreme heat events. Each adaptation strategy contains: key context on Salem responsible party and potential partnerships, timeframe, cross-referencing notes, descriptions, recommendations and considerations, implementation case studies (where available), and links to additional references – all for the city's use in strategy implementation.

The prioritized vulnerabilities are listed in the table below.

	Prioritized Vulnerabilities	Climate Change Impacts			
		Extreme heat events	Extreme precipitation events	Sea level rise	Storm surge
A	Ineffective seawalls (CB10, CB18, SW12)			x	x
B	Ineffective tide gates (CB11, CB19) and inadequate tide gates at Lafayette Street (SW7, SW10)		x	x	x
C	Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods (SW2, SW6, SW9)		x	x	x
D	Flooding disrupts operation of pump stations (SW5, SW8)		x	x	x
E	Flooding of transportation network infrastructure from storm drain overflow and overwhelmed seawalls (T8, T12)		x		x
F	Flooding of evacuation routes (VP13, VP18, VP23)		x	x	x
G	Loss of power at critical city buildings (E1)	x			
H	Backup power failure at critical city facilities (CB5, CB12, CB20)		x	x	x
I	Downed power lines (E3)		x		
J	Critical emergency preparedness communication (VP4, VP7, VP19)	x	x		x
K	Poor air quality (VP5)	x			
L	Property damage or loss of emergency and critical city facilities (CB2, CB6, CB13, W13)		x	x	x
M	Property damage or loss at Salem State University (CB15)				x
N	Flooding of emergency response facilities (VP14, VP24)		x		x
O	Property damage or loss of historic properties (CB4, CB9, CB17)		x	x	x
P	Flooding of residential areas (VP15, VP20)			x	x
Q	Overtopping of Rosie's Pond (SW4, SW13)*		x		x

*Salem has begun a climate change adaptation project to address the flooding issues at Rosie's Pond. See the Case Study on page 24 of the Plan.

Each of the Prioritized Vulnerabilities is coded with the sector identification (below) and the number so they may be referred in more detail in the previous appendix. As a reminder, the sectors are:

- Critical Building Infrastructure (CB)
- Drinking Water and Wastewater (W)
- Energy (E)
- Stormwater (SW)
- Transportation (T)
- Vulnerable Populations (VP)

This list of adaptation strategies show the Primary City Department(s) or Staff that may be responsible for planning and implementing these strategies within existing and future projects. Each strategy will require the support from the Mayor's Office and City Council to move forward. In addition, these adaptation strategies may be most effectively implemented with additional partnerships. These partnerships are identified on each sheet, but may include: hospitals, the fire department, the police department, FEMA, MEMA, neighboring cities, EPA, DEP, DOER, MAPC, MBTA, CZM, National Grid, Salem Sound Coastwatch, North Shore Community Development Coalition, Salem Alliance for the Environment, private property owners, the Conservation Commission, and others.

		Primary City Department(s) or Staff									
Adaptation Strategy number and name		Department of Planning and Community Development	Emergency Management Department	Engineering Department	Department of Public Works	City Electrician	Inspectional Services	Housing Authority	Health Department	Recreation Department	Legal Department
1	Seawall Repair: Installation of Drainage Features			x							
2	Seawall Repair: Increase Crest/Top of Structure Height			x							
3	Seawall Repair: Installation of Structural Toe Protection			x							
4	Seawall Repair: Installation of Recurved Cap Systems			x							
5	Seawall Repair: Bulkhead Materials			x							
6	Seawall Repair: Living Shorelines			x						x	
7	Seawall Repair: Beach Nourishment			x	x					x	
8	Installation/Upgrades of Tide Gates			x							
9	Tide Gate Alternative: Duckbill/Tide Flex			x							
10	Tide Gate Alternative: Buoyant or Self-Regulating Structures			x							
11	Water Level Monitoring and Alert System				x						
12	Conduct a Drainage Study			x							
13	Enlarging and Supplementing the Drainage System			x							
14	Installation of Above Ground or Subsurface Stormwater Storage Systems			x							
15	Installation/Upgrade of Pump Stations			x	x						
16	Installation of Deployable Floodwalls			x	x						
17	Green Infrastructure - Bioretention/Street Planters	x		x							
18	Green Infrastructure - Green Roofs	x		x							
19	Green Infrastructure - Permeable Pavements			x							
20	Infrastructure Design and Materials in the Transportation Network			x							
21	Elevate or Relocate Transportation Infrastructure	x		x							
22	Increase Energy Efficiency in Critical City Buildings	x				x					
23	Install and Elevate Backup Power Sources	x				x					
24	Install Renewable Energy Backup Power Sources	x			x	x					
25	Bury the Electrical Distribution System			x		x					
26	Maintain Overhead Distribution System				x	x					
27	Improve Utility and City Communication	x	x								
28	Increase Awareness of Climate Change Risks and Safety	x	x								
29	Assist Vulnerable Populations	x	x								
30	Community Health Impact Assessment and Public Outreach during Poor Air Quality Events								x		
31	Redundancy of Evacuation Routes	x	x	x	x						
32	Review Local Public Health Care Sectors Readiness								x		
33	Promote and Expand Urban Forestry	x			x						
34	Evaluation of Buildings for Flood Proofing Opportunities	x		x			x				
35	Development of New Critical Use Facilities Outside Future Flooding Levels	x	x	x			x				
36	Re-Development Existing Facilities Outside Future Flooding Levels			x			x				
37	Elevate the Building		x	x			x				
38	Elevate a Building's Critical Uses		x	x	x		x				
39	Adopt and Enforce Updated Building Codes	x						x			x
40	Limit or Restrict Development in Future Flooding Areas	x						x			x
41	Improve Land Use Planning and Regulations			x			x				x
42	Flood Proof Buildings	x				x					
43	Perform Wharf Area Water Study			x	x						

City of Salem, Massachusetts

Adaptation Strategy 1 *Seawall Repair: Installation of Drainage Features*

Prioritized Vulnerability: **A. Ineffective seawalls (CB10, CB18, SW12)**

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☑ Sea Level Rise
- ☑ Extreme Precipitation Events
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☑ Stormwater
- ☐ Drinking Water and Wastewater
- ☐ Transportation
- ☐ Vulnerable Populations
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on installing drainage features in seawalls to prevent structural damage to seawalls from stormwater. Proper design evaluation for seawalls that have fallen into disrepair should be considered. If the area is subject to ponding caused by stormwater runoff and/or soil erosion at the top of the structure, consider improving drainage systems to alleviate hydrostatic pressure landward of the structure. At times, hydrostatic pressure may build up on the landward side of the structure and may cause damage or buckling of the structure. Weep holes and drainage systems may be appropriate. Consider installing drains at the vertical joints in the seawall panels to prevent structural damage to the wall. Consult an engineer to determine the design and construction of drainage systems in and near the shoreline structure. Future relative sea level change and elevated water levels due to storms should be considered when designing drainage improvements (i.e., water entering from the seaward side during a storm and causes upland flooding). Any modifications to the design of an existing seawall that will alter the size and location of the structure will require a permit.

Steps to implement a drainage improvements: 1. Contact local, state and/or federal regulatory officials for advice on applicable regulations before proceeding with seawall maintenance or repair (Slovinsky [Maine Sea Grant], 2011). 2. Perform a site assessment by a qualified individual to determine the current state of the seawall, regulatory requirements, site stabilization, or engineering alternatives. 3. Consider outreach or engagement with neighboring property owners to ensure they understand the potential impact to their property. 4. Share plans with local code enforcement to determine if any local ordinances apply.

Adaptation Strategy 1 ***Seawall Repair: Installation of Drainage Features***

Primary City Department(s) or Staff: Engineering Department

Project Type:
☑ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☐ Study ☐ Operations

Project Timeframe:
☐ <1 year ☐ 1-2 years ☑ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships
☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☑ MEMA ☑ Neighboring Cities
☐ EPA ☑ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☑ Private Property Owners ☑ Conservation Commission
☑ Others: MA Coastal Zone Management, MA Department of Conservation and Recreation

Adaptation Strategies with Similar Benefits

12 Conduct a Drainage Study
13 Enlarging and Supplementing the Drainage System

Technical, Implementation, and Financial Considerations:

In order to determine appropriate strategies to repair ineffective seawalls due to poor drainage, installation of drainage may involve site mobilization and excavation.

Case Studies:

San Marco Island, FL - The City provided a guide for homeowners on the construction and rehabilitation of seawalls, which includes information on drainage systems. Information available via report: http://www.cityofmarcoisland.com/modules/showdocument.aspx?documentid=15377

References:

Massachusetts Coastal Zone Management Coastal Landscaping:
http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/coastal-landscaping/coastal-bank-seawall-plan.html
http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/stormsmart-properties/fs-3-vegetation.html

Maine Coastal Hazards Guide:
http://www.seagrant.umaine.edu/coastal-hazards-guide/beaches-and-dunes/seawalls

Perfection Seawalls Bulkhead Repair:
http://perfectionseawalls.com/seawall-bulkhead-repair/

City of Salem, Massachusetts

Adaptation Strategy 2 Seawall Repair: Increase Crest/Top of Structure Height

Prioritized Vulnerability: **A. Ineffective seawalls (CB10, CB18, SW12)**

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☐ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☑ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on increasing the crest or top of seawall heights. If seawalls or revetment systems are considered "ineffective" because the crest elevation (or top) of the coastal structure is too low to resist storm surge inundation to upland areas, then increasing the crest or coastal edge elevation of those existing structures may be a viable adaptation strategy. Considerations should be made to determine the appropriate level of risk for the design and improvement of the seawall and the seawall system. A variable crest height along the seawall system may make areas with lower crest heights vulnerable to flooding. Future relative sea level change and elevated water levels due to storms should be considered when designing improvements. Any modifications to the design of an existing seawall that will alter the size and location of the structure will require a permit. In addition, a shoreline and structure monitoring and maintenance plan is recommended to ensure that projects are performing as expected.

The steps for increasing the crest height on a seawall are: 1. Contact local, state and/or federal regulatory officials for advice on applicable regulations before proceeding with seawall maintenance or repair. 2. Perform a site assessment by a qualified individual to determine the current state of the seawall, regulatory requirements, site stabilization, or engineering alternatives. 3. Consider outreach or engagement with neighboring property owners to ensure they understand the potential impact to their property. 4. Share plans with local code enforcement to determine if any local ordinances apply.

Adaptation Strategy 2 Seawall Repair: Increase Crest/Top of Structure Height

Primary City Department(s) or Staff: Engineering Department

Project Type:
☑ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☐ Study ☐ Operations

Project Timeframe:
☐ <1 year ☐ 1-2 years ☑ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships
☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☑ MEMA ☑ Neighboring Cities
☐ EPA ☑ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☑ Conservation Commission
☐ Others: MA Coastal Zone Management, MA Department of Conservation and Recreation

Adaptation Strategies with Similar Benefits

3 Seawall Repair: Installation of Structural Toe Protection
4 Seawall Repair: Installation of Recurved Cap Systems
5 Seawall Repair: Bulkhead Materials

Technical, Implementation, and Financial Considerations:

In order to determine appropriate strategies to repair ineffective seawalls, understanding why the seawalls are considered ineffective is the first step. Seawalls are expensive to replace, approximately $3,000 per linear foot. Adding height to an existing wall may have unpredictable consequences such as structural weakness at the joint, buckling, settlement, etc. Proper evaluation, design, and construction of the addition or new wall should be considered.

Case Studies:

Rockport, MA - For an approximately 0.6-mile seawall along Long Beach, the Town of Rockport provided information regarding the history, current conditions, proposed design and rehabilitation of the seawall, and the project timeline. This presentation provides potential design including a height extension for a portion of the structure. Information available at:
http://www.townofrockport.com/doc/092/Long%20Beach%20Seawall%20Public%20Info%20Mtg%20(22%20May%202012).pdf

Various Massachusetts Coastal Communities - The Dam and Seawall Repair or Removal Fund Annual Review, Fiscal Year 2014 report provides a summary of the projects that were funded in 2014 for the MA EOEEA fund for dam and seawall repair and removal. A variety of seawall projects are included, but notably, the Town of Hull was funded to increase the height of the Stoney Beach seawall, which protects the Town's wastewater treatment plant in addition to residential homes. Summary of projects available at:
http://www.mass.gov/eea/docs/eea/wrc/2014-annual-final.pdf

Adaptation Strategy 2 Seawall Repair: Increase Crest/Top of Structure Height

References:

Massachusetts Planning Commission South Shore Adaptation Planning Report:
http://www.mapc.org/sites/default/files/FINAL_South_Shore_Coastal_Adaptation_Planning_Report_12-31-11_sm.pdf

Massachusetts Coastal Zone Management Dam and Seawall Repair Funding Opportunities:
http://www.mass.gov/eea/waste-mgnt-recycling/water-resources/preserving-water-resources/water-laws-and-policies/water-laws/draft-regs-re-dam-and-sea-wall-repair-or-removal-fund.html
http://www.mass.gov/eea/docs/eea/wrc/2014-annual-final.pdf

Massachusetts Coastal Zone Management Coastal Landscaping:
http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/coastal-landscaping/coastal-bank-seawall-plan.html
http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/stormsmart-properties/fs-3-vegetation.html

City of Salem, Massachusetts

Adaptation Strategy 3 ***Seawall Repair: Installation of Structural Toe Protection***

Prioritized Vulnerability: **A. Ineffective seawalls (CB10, CB18, SW12)**

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☐ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☑ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on installing structural toe protection for seawalls and the revetments in coastal areas. Proper design evaluation for seawalls that have fallen into disrepair should be considered. The stability of a seawall depends on its total weight in cross-section, location seaward of the shoreline, cap elevation, underlying geology, and the degree to which it is used to retain the upland bluff or bank. If the area is subject to wave action and erosion, a potential rehabilitation measure is the addition of a robust toe stone and/or stone aprons to prevent sliding and sediment removal at the bottom of the structure, which may undermine the structure and cause total failure. The thickness of the armor layer is determined by the dimensions of the stone size selected for stability. The most common, and perhaps most cost effective arrangement is to specify two layers of armor stone. Consult with an engineer to determine the appropriate design for toe stone and armor layers of the structure. Any modifications to the design of an existing seawall that will alter the size and location of the structure will require a permit. In addition, a shoreline and structure monitoring and maintenance plan is recommended to ensure that projects are performing as expected.

The steps for installing structural toe protection include:
1. Contact local, state and/or federal regulatory officials for advice on applicable regulations before proceeding with seawall maintenance or repair. 2. Perform a site assessment by a qualified individual to determine the current state of the seawall, regulatory requirements, site stabilization, or engineering alternatives. 3. Consider outreach or engagement with neighboring property owners to ensure they understand the potential impact to their property. 4. Share plans with local code enforcement to determine if any local ordinances apply.

Adaptation Strategy 3 ***Seawall Repair: Installation of Structural Toe Protection***

Primary City Department(s) or Staff: Engineering Department

Project Type: ☑ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction ☐ Program ☐ Education/Outreach ☐ Study ☐ Operations

Project Timeframe: ☐ <1 year ☐ 1-2 years ☑ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships ☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☑ MEMA ☑ Neighboring Cities ☐ EPA ☑ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch ☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE) ☐ Private Property Owners ☑ Conservation Commission ☑ Others: MA Coastal Zone Management, MA Department of Conservation and Recreation

Adaptation Strategies with Similar Benefits

2 Seawall Repair: Increase Crest/Top of Structure Height
4 Seawall Repair: Installation of Recurved Cap Systems
5 Seawall Repair: Bulkhead Materials

Technical, Implementation, and Financial Considerations:

Costs associated with fortifying the toe of a structure may be high and may require a fair amount of site mobilization and coordination. Another consideration is the potential negative aesthetics associated with structures along the shoreline.

Case Studies:

Hull, MA for Natasket Beach - After performing a site-specific alternatives analysis, USACE recommends a stone revetment with geotextile fabric, toe stone, and additional repair measures for the structure. The situation in Salem is similar to the situation that the Town of Hull. A USACE study presented alternatives analysis with a potential design, which include the installation of a properly designed, engineered structure. It is available at: http://www.nae.usace.army.mil/Portals/74/docs/Topics/NantasketBeach/NantasketReport.pdf

Various Massachusetts Coastal Communities - The Dam and Seawall Repair or Removal Fund Annual Review, Fiscal Year 2014 report provides a summary of the projects that were funded in 2014 for the MA EOEEA fund for dam and seawall repair and removal. A variety of seawall projects are included, but notably, the Town of Hull was funded to increase the height of the Stoney Beach seawall, which protects the Town's wastewater treatment plant in addition to residential homes. Summary of projects available at: http://www.mass.gov/eea/docs/eea/wrc/2014-annual-final.pdf

Adaptation Strategy 3 ***Seawall Repair: Installation of Structural Toe Protection***

References:

Town of Marshfield/MA CZM Letter to USACE regarding beach nourishment:
http://www.townofmarshfield.org/Collateral/Documents/English-US/Coastal%20Advisory/USACEstudy11072012.pdf

Massachusetts Planning Commission South Shore Adaptation Planning Report:
http://www.mapc.org/sites/default/files/FINAL_South_Shore_Coastal_Adaptation_Planning_Report_12-31-11_sm.pdf

Massachusetts Coastal Zone Management Dam and Seawall Repair Funding Opportunities:
http://www.mass.gov/eea/waste-mgnt-recycling/water-resources/preserving-water-resources/water-laws-and-policies/water-laws/draft-regs-re-dam-and-sea-wall-repair-or-removal-fund.html
http://www.mass.gov/eea/docs/eea/wrc/2014-annual-final.pdf

Massachusetts Coastal Zone Management Coastal Landscaping:
http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/coastal-landscaping/coastal-bank-

City of Salem, Massachusetts

Adaptation Strategy 4 *Seawall Repair: Installation of Recurved Cap Systems*

Prioritized Vulnerability: **A. Ineffective seawalls (CB10, CB18, SW12)**

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☑ Sea Level Rise
- ☐ Extreme Precipitation Events
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☑ Stormwater
- ☐ Drinking Water and Wastewater
- ☐ Transportation
- ☐ Vulnerable Populations
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on installing recurved cap systems for seawalls and the revetments in coastal areas. Proper design evaluation for seawalls that have fallen into disrepair should be considered. A potential adaptation measure is the addition of wall extensions or a recurved cap to minimize overtopping. Proper design of the recurve portion of the seawall in addition to wave reflection causing additional scour at the toe of the structure is possible. Potential waves impacting the structure may cause an upward force on the structure and proper design of the foundation and footing is equally important. Consult an engineer to determine the appropriate design for the rehabilitation of the structure. Any modifications to the design of an existing seawall that will alter the size and location of the structure will require a permit. In addition, a shoreline and structure monitoring and maintenance plan is recommended to ensure that projects are performing as expected.

The steps for adding wall extensions or a recurved cap include: 1. Contact local, state and/or federal regulatory officials for advice on applicable regulations before proceeding with seawall maintenance or repair. 2. Perform a site assessment by a qualified individual to determine the current state of the seawall, regulatory requirements, site stabilization, or engineering alternatives. 3. Consider outreach or engagement with neighboring property owners to ensure they understand the potential impact to their property. 4. Share plans with local code enforcement to determine if any local ordinances apply.

Adaptation Strategy 4 ***Seawall Repair: Installation of Recurved Cap Systems***

Primary City Department(s) or Staff: Engineering Department

Project Type:
☑ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☐ Study ☐ Operations

Project Timeframe:
☐ <1 year ☐ 1-2 years ☑ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships
☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☑ MEMA ☑ Neighboring Cities
☐ EPA ☑ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☑ Conservation Commission
☑ Others: MA Coastal Zone Management, MA Department of Conservation and Recreation

Adaptation Strategies with Similar Benefits

2 Seawall Repair: Increase Crest/Top of Structure Height
3 Seawall Repair: Installation of Structural Toe Protection
5 Seawall Repair: Bulkhead Materials

Technical, Implementation, and Financial Considerations:

In order to determine appropriate strategies to repair ineffective seawalls, understanding why the seawalls are considered ineffective is the first step. Seawalls are expensive to replace, approximately $3,000 per linear foot. The cost of rehabilitating the seawall to include a recurved cap is likely less than complete replacement.

Case Studies:

Rockport, MA - For an approximately 0.6-mile seawall along Long Beach, the Town of Rockport provided information regarding the history, current conditions, proposed design and rehabilitation of the seawall, and timeline. This presentation provides potential design including a height extension and recurved cap for a portion of the structure:
http://www.townofrockport.com/doc/092/Long%20Beach%20Seawall%20Public%20Info%20Mtg%20(22%20May%202012).pdf

References:

Massachusetts Planning Commission South Shore Adaptation Planning Report:
http://www.mapc.org/sites/default/files/FINAL_South_Shore_Coastal_Adaptation_Planning_Report_12-31-11_sm.pdf

Massachusetts Coastal Zone Management Dam and Seawall Repair Funding Opportunities:
http://www.mass.gov/eea/waste-mgnt-recycling/water-resources/preserving-water-resources/water-laws-and-policies/water-laws/draft-regs-re-dam-and-sea-wall-repair-or-removal-fund.html
http://www.mass.gov/eea/docs/eea/wrc/2014-annual-final.pdf

Massachusetts Coastal Zone Management Coastal Landscaping:
http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/coastal-landscaping/coastal-bank-seawall-plan.html
http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/stormsmart-properties/fs-3-vegetation.html

City of Salem, Massachusetts

Adaptation Strategy 5 *Seawall Repair: Bulkhead Materials*

Prioritized Vulnerability: **A. Ineffective seawalls (CB10, CB18, SW12)**

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☐ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☑ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on repairing seawalls with bulkhead materials. Proper design evaluation for seawalls that have fallen into disrepair should be considered. Consider replacement of deteriorating/corroding bulkheads with marine-grade fiber-reinforced polymer (FRP) sheeting for steel bulkheads. Consider appropriate design of mooring piles, if necessary, as well as capping, patching, coating, or other protective measures of the bulkhead to prevent any degradation of the structure. Consult an engineer to determine the design, construction, and replacement of the bulkhead structure or sections of the bulkhead. Future relative sea level change and elevated water levels due to storms should be considered when designing the bulkhead (i.e., the height of the replacement bulkhead). Any modifications to the design of an existing seawall that will alter the size and location of the structure will require a permit. In addition, a shoreline and structure monitoring and maintenance plan is recommended to ensure that projects are performing as expected.

Steps to repair bulkheads include: 1. Contact local, state and/or federal regulatory officials for advice on applicable regulations before proceeding with seawall maintenance or repair. 2. Perform a site assessment by a qualified individual to determine the current state of the seawall, regulatory requirements, site stabilization, or engineering alternatives. 3. Consider outreach or engagement with neighboring property owners to ensure they understand the potential impact to their property. 4. Share plans with local code enforcement to determine if any local ordinances apply.

Adaptation Strategy 5 ***Seawall Repair: Bulkhead Materials***

Primary City Department(s) or Staff: Engineering Department

Project Type: ☑ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction ☐ Program ☐ Education/Outreach ☐ Study ☐ Operations

Project Timeframe: ☐ <1 year ☐ 1-2 years ☑ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships ☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☑ MEMA ☑ Neighboring Cities ☐ EPA ☑ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch ☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE) ☑ Private Property Owners ☑ Conservation Commission ☑ Others: MA Coastal Zone Management, MA Department of Conservation and Recreation

Adaptation Strategies with Similar Benefits

2 Seawall Repair: Increase Crest/Top of Structure Height
3 Seawall Repair: Installation of Structural Toe Protection
4 Seawall Repair: Installation of Recurved Cap Systems

Technical, Implementation, and Financial Considerations:

Installation and construction of the bulkhead/seawalls will require extensive site mobilization, since bulkheads are most commonly used in harbored areas.

Case Studies:

City of Newburyport, MA - The project uses fiber reinforced polymer (FRP) sheetpiles for the bulkhead repair. The website provides information and a milestone "blog" of the project progress such as information about the seawall sections that were damaged and how the construction contractor installed the new sections of seawall. Information is available at: http://www.cityofnewburyport.com/planning-development/pages/bulkhead-project

References:

Massachusetts Planning Commission South Shore Adaptation Planning Report:
http://www.mapc.org/sites/default/files/FINAL_South_Shore_Coastal_Adaptation_Planning_Report_12-31-11_sm.pdf

Massachusetts Coastal Zone Management Dam and Seawall Repair Funding Opportunities:
http://www.mass.gov/eea/waste-mgnt-recycling/water-resources/preserving-water-resources/water-laws-and-policies/water-laws/draft-regs-re-dam-and-sea-wall-repair-or-removal-fund.html
http://www.mass.gov/eea/docs/eea/wrc/2014-annual-final.pdf

Massachusetts Coastal Zone Management Coastal Landscaping:
http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/coastal-landscaping/coastal-bank-seawall-plan.html
http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/stormsmart-properties/fs-3-vegetation.html

City of Salem, Massachusetts
Adaptation Strategy 6 *Seawall Repair: Living Shorelines*

Prioritized Vulnerability: **A. Ineffective seawalls (CB10, CB18, SW12)**

Due to this/these Climate Impact(s):
- ☐ Extreme Heat Events
- ☐ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):
- ☑ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☑ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on armoring shorelines subject to wave attack, scour, undermining, and failure that may benefit from a shore stabilization technique called "living shorelines." Living shorelines use plants, sand/soil, and the limited use of hard structures to provide shoreline protection. They preserve, create, or enhance coastal habitats and improve water quality, and reduce sedimentation. Living shorelines may increase the resilience of seawalls to undermining and failure after episodes of storm surge and long-term effects of sea level rise. They are an alternative or in some cases, an enhancement, to bulkheads, seawalls, or revetments that provide for a stable shoreline resistant to erosion. As a "hybrid" or "blended" approach, living shorelines may be hardened structures that are rehabilitated to introduce a naturalized edge. Additional vegetation on or in front of the structure may help uptake water, control runoff, and buffer storm waves to prevent further erosion and to protect vulnerable areas.

A variety of living shoreline designs exist and may be divided into two general categories: 1) nonstructural and 2) hybrid/structural strategies. Nonstructural living shorelines, sometimes identified as natural or nature-based features are typically suited for low wave energy settings with minor erosion and may include vegetation management, planted marshes, fiber logs (also referred to as coir logs or bioengineering), bank grading, oyster and coral reefs, beach nourishment and dune restoration. Examples are:
- A low profile revetment placed along the edge of an existing tidal, natural marsh.
- A low profile continuous or notched revetment that is backfilled with sand to create a planted, intertidal marsh.
- An offshore breakwater, a series of rock structures strategically placed offshore to refract waves and produce stable pocket beaches.
- An oyster reef, created by oyster shells placed along a marsh edge by itself or with other containment structures.

A low-profile or submerged barrier provides calmer waters for vegetation to take hold. The submerged aquatic vegetation (SAV) is backed by coastal wetlands and marsh plantings, which aid in stabilizing the shoreline. In order to reduce the impacts of storm surge, a large expanse of SAV would be necessary. The SAV is backed by the bank face with deeper-rooted plantings and an upland buffer area. The Virginia Institute of Marine Sciences (VIMS) provides design guidance, specifications, and a helpful decision tree tool to assist in determining the type of living shoreline appropriate for the wave climate and existing conditions.

Adaptation Strategy 6 *Seawall Repair: Living Shorelines*

Primary City Department(s) or Staff: Engineering Department, Recreation Department

Project Type:
- ☑ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction
- ☐ Program ☑ Education/Outreach ☐ Study ☐ Operations

Project Timeframe: ☐ <1 year ☐ 1-2 years ☑ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships
- ☐ Hospitals ☐ Fire Department ☐ Police Department ☐ FEMA ☐ MEMA ☑ Neighboring Cities
- ☑ EPA ☑ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
- ☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
- ☑ Private Property Owners ☑ Conservation Commission
- ☑ Others: MA Coastal Zone Management, MA Department of Conservation and Recreation

Adaptation Strategies with Similar Benefits

7 Seawall Repair: Beach Nourishment

Technical, Implementation, and Financial Considerations:

Living shorelines vary greatly depending on design and site factors. Some of the common elements include: shoreline planting and wetland restoration (estimate costs $25-45/sq. ft.), geotextile grid shoreline stabilization (estimated costs $30/sq. ft.), and aquatic vegetation (estimated costs $2,000/sq. ft.). If other structural features such as breakwaters or artificial reefs are introduced, costs may increase significantly. In addition, a shoreline and structure monitoring and maintenance plan is recommended to ensure that projects are performing as expected. The Salem Sound Coast Watch have monitored Salem's coast over the long term and may be an important partner.

The steps to implement a living shorelines project include:
1. Site analysis, 2. Permit approval and legal compliance, 3. Site preparation, 4. Installation, and 5. Post-construction monitoring and maintenance.

There are Coastal Resiliency grants through the MA CZM that are available for initial feasibility, site assessment, permitting, and construction of these types of projects.

Adaptation Strategy 6 *Seawall Repair: Living Shorelines*

Case Studies:

Harlem River Park, Manhattan, NY - The NYC Department of Parks & Recreation incorporated a living shoreline design in Harlem River Park, which is a highly urbanized area. The living shoreline fronted an existing seawall structure. This was a multi-phase project during 2001-2009. Information (including lessons learned) available via fact sheet: https://www.hrnerr.org/download/HarlemRiverPark_CaseStudy.pdf

Various Massachusetts Coastal Communities - As of 2014, several coastal communities have funding from the Massachusetts Green Infrastructure for Coastal Resilience Pilot Grants. There are many different projects currently underway, that may have application in Salem: http://www.mass.gov/eea/docs/czm/stormsmart/2014-green-infrastructure-grants.pdf.

Various sites within the Chesapeake Bay - This website shows demonstration sites of living shoreline applications in a coastal or bay setting. This website also lists the project elements employed and the variety of potential applications that are considered living shorelines:
http://ccrm.vims.edu/livingshorelines/demonstration_sites.html and photo gallery:
http://ccrm.vims.edu/livingshorelines/photo_gallery/index.html

References:

New York City Urban Waterfront Adaptive Strategies:
http://www.nyc.gov/html/dcp/pdf/sustainable_communities/urban_waterfront_print.pdf

Virginia Institute of Marine Sciences Living Shorelines: http://ccrm.vims.edu/livingshorelines/

Virginia Institute of Marine Sciences Living Shorelines Design Manual:
http://web.vims.edu/physical/research/shoreline/docs/LS_Design_final_v1.2.pdf

Massachusetts Coastal Zone Management Storm Smart Coasts:
http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/

Hudson River Estuary Sustainable Shorelines:
https://www.hrnerr.org/hudson-river-sustainable-shorelines/demonstration-site-network/
https://www.hrnerr.org/wp-content/uploads/sites/9/2012/08/RellaMiller2012a_EngineeringLiteratureReview.pdf
https://www.hrnerr.org/download/HarlemRiverPark_CaseStudy.pdf

New York City Parks Department Harlem River Park:
http://www.nycgovparks.org/web/download/download.php?file=/sub_opportunities/business_ops/pdf/designing_the_edge_4-7-2010.pdf

Chesapeake Bay Foundation Living Shorelines for the Chesapeake Bay:
http://www.cbf.org/Document.Doc?id=60

National Oceanic and Atmospheric Administration Living Shoreline Implementation:
http://www.habitat.noaa.gov/restoration/techniques/lsimplementation.html

City of Salem, Massachusetts
Adaptation Strategy 7 *Seawall Repair: Beach Nourishment*

Prioritized Vulnerability: **A. Ineffective seawalls (CB10, CB18, SW12)**

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☐ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☑ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on beach nourishment and rehabilitation as a replacement for failing seawalls. A potential rehabilitation measure is for beach nourishment, depending on the location and applicability. Nourishment could be used to maintain a range of beach widths to prevent overtopping of seawalls and near shore beach erosion. Finding suitable beach nourishment borrow areas may be a limiting factor. Careful monitoring, inspection, and understanding of near shore coastal zone dynamics should be considered to ensure that beach nourishment options are appropriate. Any modifications to the design of an existing seawall that will alter the size and location of the structure will require a permit.

The situation in Salem is similar to the situation that the Town of Marshfield faces, which also has vertical concrete seawalls along a length of publicly owned shorelines. Some sections of the seawall are fronted by riprap revetments, while others are not. The coastal landform that fronts the structures is eroding and continues to undermine the structure, which in turn causes more interaction with the waves and water levels and subsequent storm damage. A multi-faceted approach, specifically beach nourishment and parcel-by-parcel recommendations, may be an option, rather than the rehabilitation of the seawall. In addition, a shoreline and structure monitoring and maintenance plan is recommended to ensure that projects are performing as expected.

Steps to implement a beach nourishment project include: 1. Contact local, state and/or federal regulatory officials for advice on applicable regulations before proceeding with seawall maintenance or repair. 2. Perform a site assessment by a qualified individual to determine the current state of the seawall, regulatory requirements, site stabilization, or engineering alternatives. 3. Consider outreach or engagement with neighboring property owners to ensure they understand the potential impact to their property. 4. Share plans with local code enforcement to determine if any local ordinances apply.

Adaptation Strategy 7 ***Seawall Repair: Beach Nourishment***

Primary City Department(s) or Staff: Engineering Department, Department Public of Works, Recreation Department

Project Type: ☑ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction ☐ Program ☐ Education/Outreach ☐ Study ☐ Operations

Project Timeframe: ☐ <1 year ☐ 1-2 years ☑ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships ☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☑ MEMA ☑ Neighboring Cities ☐ EPA ☑ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch ☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE) ☐ Private Property Owners ☑ Conservation Commission ☑ Others: MA Coastal Zone Management, MA Department of Conservation and Recreation

Adaptation Strategies with Similar Benefits

6 Seawall Repair: Living Shorelines

Technical, Implementation, and Financial Considerations:

Beach nourishment is an on-going process which is more effective with proper monitoring, maintenance, and identification of borrow areas. Costs associated with beach nourishment may be high, but benefits include ecosystem restoration, recreation possibilities, and storm damage reduction.

This City may choose to partner with a local university to execute the long-term monitoring and cut down on the costs. One example of a collaborative approach is the Coastal Research Center at Richard Stockton College of New Jersey where they have been monitoring beach profiles since 1986. This data was invaluable during post-Sandy recovery. This strategy requires equipment and commitment to continuous beach profile measurement.

There are Coastal Resiliency grants through the MA CZM that are available for initial feasibility, site assessment, permitting, and construction of these types of projects.

Case Studies:

MA Coastal Zone Management - MA CZM provided a response to an existing USACE feasibility study to changes to the structural shoreline protection near Brant Rock in Marshfield, MA. MA CZM suggests beach nourishment, erosion control vegetation, among other strategies. In addition, MA CZM encourages usage of the Historic Shoreline Change dataset and Coastal Hazards dataset. Information available from the Town of Marshfield, MA Coastal Advisory Committee website and feasibility study report at: http://www.townofmarshfield.org/Collateral/Documents/English-US/Coastal%20Advisory/USACEstudy11072012.pdf

Marshfield, Duxbury, and Scituate, MA - These towns performed a sea level rise study, which evaluated vulnerabilities within each town and as a whole. The study identifies potential adaptation strategies across multiple sectors with the projected sea level change scenarios. An adaptation strategy that they have identified, specific to the appropriate areas, is beach nourishment. More information is available at: http://www.scituatema.gov/sites/scituatema/files/file/file/south_shore_sea_level_rise_study_final.pdf

Adaptation Strategy 7 ***Seawall Repair: Beach Nourishment***

References:

Massachusetts Planning Commission South Shore Adaptation Planning Report:
http://www.mapc.org/sites/default/files/FINAL_South_Shore_Coastal_Adaptation_Planning_Report_12-31-11_sm.pdf

Massachusetts Coastal Zone Management Dam and Seawall Repair Funding Opportunities:
http://www.mass.gov/eea/waste-mgnt-recycling/water-resources/preserving-water-resources/water-laws-and-policies/water-laws/draft-regs-re-dam-and-sea-wall-repair-or-removal-fund.html

Massachusetts Coastal Zone Management Coastal Landscaping:
http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/coastal-landscaping/coastal-bank-seawall-plan.html
http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/stormsmart-properties/fs-3-vegetation.html

Maine Coastal Hazards Guide:
http://www.seagrant.umaine.edu/coastal-hazards-guide/beaches-and-dunes/seawalls

City of Salem, Massachusetts

Adaptation Strategy 8 — *Installation/Upgrades of Tide Gates*

Prioritized Vulnerabilities:

B. Ineffective tide gates (CB11, CB19) and Inadequate tide gates at Lafayette Street (SW7, SW10)
C. Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods (SW2, SW6, SW9)
D. Flooding disrupts operation of pump stations (SW5, SW8)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat
- ☑ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☑ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☑ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on installing or upgrading tide gates. Tide gates, and other backflow-prevention devices, seal a pipe at the end to prevent water from flowing backwards through the drainage system, while still allowing water to drain. Tide gates may be added to outfalls to prevent high tides, sea level rise and storm surges from entering the drainage system. The design of the tide gates is determined from the future conditions modeling performed in the drainage study. Tide gates may be used in combination with other flood mitigation measures, such as replacement of existing pipes, installation of relief pipes, above ground or subsurface storage, or pump stations. This strategy may be of particular use near the Forest River and Lafayette Road and at the South River Drainage Conduit

Adaptation Strategy 8 *Installation/Upgrades of Tide Gates*

Primary City Department(s) or Staff: Engineering Department

Project Type:
☐ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☑ Study ☐ Operations

Project Timeframe:
☐ <1 year ☐ 1-2 years ☑ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships
☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☑ MEMA ☐ Neighboring Cities
☑ EPA ☑ DEP ☐ DOER ☐ MAPC ☑ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☑ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

9 Tide Gate Alternative: Duckbill/Tide Flex

Technical, Implementation, and Financial Considerations:

Technical challenges include interference with existing utilities and designing systems to work within the existing topography. Another technical challenge is that the tide gate may impede the ability of upland area to drain stormwater (this may be evaluated in a drainage study). Implementation considerations include public acceptance of these proposed projects; push-back from property owners who may not want flood relief systems on their property; and permitting. Financially, the cost of tide gates may be high; finding funding to implement them may be challenging.

The Massachusetts Department of Transportation plans to upgrade the Bridge St. tide gate. The City may consider leveraging this process of collaboration for future tide gate repairs.

Case Studies:

Beverly, MA - Rainstorms backed up Beverly's drains in the Chase/Federal Street area and caused flooding during high tide because the water level in the Bass River blocked the discharge to the river. To address this problem, the City installed a tide gate, along with other mitigation measures, including new drains, culvert and catch basins.

References:

Giannico and Souder, Coos Watershed: Tide Gates in the Pacific Northwest
http://www.cooswatershed.org/Publications/tidegates_PACNW.pdf

USACE Galilee Tidal Marsh Restoration Fact Sheet:
http://www.nae.usace.army.mil/Portals/74/docs/Topics/Galilee/FactSheet.pdf

Tide Gate Alternatives by Juel Tide:
http://www.jueltide.com/images/New%20PDF%20files/Tide%20Gate%20Alternatives.pdf

Impact of Sea Level Rise on Tide Gate Function:
http://www.researchgate.net/publication/235399942_Impact_of_sea_level_rise_on_tide_gate_function

City of Salem, Massachusetts

Adaptation Strategy 9 *Tide Gate Alternative: Duckbill/Tide Flex*

Prioritized Vulnerabilities:

B. Ineffective tide gates (CB11, CB19) and Inadequate tide gates at Lafayette Street (SW7, SW10)
C. Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods (SW2, SW6, SW9)
D. Flooding disrupts operation of pump stations (SW5, SW8)

Due to this/these Climate Impact(s):

☐ Extreme Heat Events
☑ Sea Level Rise
☑ Extreme Precipitation Events
☑ Storm Surge

Sector(s):

☑ Critical Building Infrastructure
☑ Stormwater
☐ Drinking Water and Wastewater
☐ Transportation
☐ Vulnerable Populations
☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on duckbill or tide flex design as tide gate alternatives. The tide gates at Forest River and Lafayette Road and at the South River Drainage Conduit are structures that prevent backflow of tidal water or storm surge into creeks, rivers, and drainage systems. Tide gates close during incoming tides to prevent water from traveling into low-lying areas, but they also keep flood water from draining into the harbor or ocean. With sea level rise and elevated water levels from storm surge, higher downstream mean sea level elevations reduce the effective of tide gates by impacting the hydraulics of the system. Based on the feedback provided by the City of Salem regarding the Forest River tide gates, the manual operation and long-term reliability of the tide gates is in need of a long-term strategy. Currently, the City of Salem employs a duckbill tide gate at the Juniper Beach location.

Automatic or flow/water level-based operation of tide gates is a viable adaptation strategy. A type of tide gate solution is a duck bill technology, or tide flex. A benefit of the duckbill tide gate is that it is observed to be self-cleaning when debris is caught in the opening, and only minor inflow when debris was caught in the opening. This design is considered to be reliable and low maintenance. Consult a design professional or an engineer to determine changes in hydrodynamics associated with this type of tide control.

To ensure that a project continues to function as planned into the future it is important to develop and implement both an adaptive management plan and a monitoring plan prior to the start of the tide gate project. These plans may vary greatly depending on project goals and the expected project life. For projects that are expected to entail active management in the future, an adaptive management plan accounting for climate change may facilitate adjustments over time as sea level rises, which may involve altering the settings of a tide gate.

Adaptation Strategy 9 ***Tide Gate Alternative: Duckbill/Tide Flex***

Primary City Department(s) or Staff: Engineering Department

Project Type:

☑ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☑ Study ☑ Operations

Project Timeframe:

☐ <1 year ☐ 1-2 years ☑ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships

☐ Hospitals ☐ Fire Department ☐ Police Department ☐ FEMA ☑ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☑ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

8 Installation/Upgrades of Tide Gates

Technical, Implementation, and Financial Considerations:

Consider future storm frequency when designing tide gates and the hydraulic connections that tie into them. Ensure that the tide gate is able to be adjusted to obtain desired flow if the high tide water level increases to projected sea levels. Consider any effects of changes to tide gate operations or elevations on upland flooding and water flow, channel characteristics, water temperature, water quality, plant communities, ecological habitats and passage, or potential for estuarine restoration. Tide control may also impact the changes in water temperature, water quality, and may change the velocity, turbulence, and pattern of freshwater exchange. Costs associated with replacement of tide gates may be expensive in addition to costs associated with back up pump stations. Also, the size/opening of the current tide gate configuration may be a limiting factor to the installation of a duckbill type gate.

The Massachusetts Department of Transportation plans to upgrade the Bridge St. tide gate. The City may consider leveraging this process of collaboration for future tide gate repairs.

Case Studies:

Salem, MA - Currently, the City of Salem employs a duckbill tide gate at the Juniper Beach location. The cleaning of the outfall with the installation of the tide gate at the Juniper Beach location also provided positive water quality benefits. More information is available at:
http://salem.com/Pages/SalemMA_Engineer/southriverreport.pdf

Adaptation Strategy 9 ***Tide Gate Alternative: Duckbill/Tide Flex***

References:

Giannico and Souder, Coos Watershed: Tide Gates in the Pacific Northwest
http://www.cooswatershed.org/Publications/tidegates_PACNW.pdf

USACE Galilee Tidal Marsh Restoration Fact Sheet:
http://www.nae.usace.army.mil/Portals/74/docs/Topics/Galilee/FactSheet.pdf

Tide Gate Alternatives by Juel Tide:
http://www.jueltide.com/images/New%20PDF%20files/Tide%20Gate%20Alternatives.pdf

Impact of Sea Level Rise on Tide Gate Function:
http://www.researchgate.net/publication/235399942_Impact_of_sea_level_rise_on_tide_gate_function

City of Salem, Massachusetts

Adaptation Strategy 10 *Tide Gate Alternative: Buoyant or Self-Regulating Structures*

Prioritized Vulnerabilities:

B. Ineffective tide gates (CB11, CB19) and Inadequate tide gates at Lafayette Street (SW7, SW10)
C. Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods (SW2, SW6, SW9)
D. Flooding disrupts operation of pump stations (SW5, SW8)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☑ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☑ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on buoyant or self-regulating structures as tide gate alternatives. The tide gates at Forest River and Lafayette Road and at the South River Drainage Conduit are structures that prevent backflow of tidal water or storm surge into creeks, rivers, and drainage systems. Tide gates close during incoming tides to prevent water from traveling into low-lying areas, but they also keep flood water from draining into the harbor or ocean. With sea level rise and elevated water levels from storm surge, higher downstream mean sea level elevations reduce the effectiveness of tide gates by impacting the hydraulics of the system. Based on the feedback provided by the City of Salem regarding the Forest River tide gates, the manual operation and long-term reliability of the tide gates is in need of a long-term strategy.

Automatic or flow/water level-based operation of tide gates is a viable adaptation strategy. A type of potential tide gate is the buoyant front flap tide gate. These tide gate solutions allow for self-regulation of flow in and out of low-lying areas. The floats at the top of the self-regulating tide gate may be adjusted in height to fit site-specific conditions, which could be closed during daily tides, during extreme events, or as a managed adaptation to sea level rise.

To ensure that a project continues to function as planned into the future, it is important to develop and implement both an adaptive management plan and a monitoring plan prior to the start of the tide gate project. These plans may vary greatly depending on project goals and the expected project life. For projects that are expected to entail active management in the future, an adaptive management plan accounting for climate change may facilitate adjustments over time as sea level rises, which may involve altering the settings of a tide gate.

Adaptation Strategy 10 *Tide Gate Alternative: Buoyant or Self-Regulating Structures*

Primary City Department(s) or Staff: Engineering Department

Project Type:
☑ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☑ Study ☑ Operations

Project Timeframe:
☐ <1 year ☐ 1-2 years ☑ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships
☐ Hospitals ☐ Fire Department ☐ Police Department ☐ FEMA ☑ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☑ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

16 Installation of Deployable Floodwalls

Technical, Implementation, and Financial Considerations:

Consider design future storm frequency when designing tide gates and the hydraulic connections that tie into them. Ensure that the tide gate may be adjusted to obtain desired flow if the projected high tide water level increases to projected sea levels.

Consider any effects of changes to tide gate operations or elevations on upland flooding and water flow, channel characteristics, water temperature, water quality, plant communities, ecological habitats and passage, or potential for estuarine restoration. Costs associated with replacement of tide gates may be expensive in addition to costs associated with back up pump stations.

The Massachusetts Department of Transportation plans to upgrade the Bridge St. tide gate. The City may consider leveraging this process of collaboration for future tide gate repairs.

Case Studies:

Narragansett, RI - As part of the Galilee Salt Marsh restoration, two buoyant, self-regulating tide gates were installed. The gates assure that properties adjacent to the interior marsh are not flooded during storm tides. The State of Rhode Island funded the installation of additional culverts and tide gates on the east side of the marsh completing the restoration of the majority of the former salt marsh. Project information sheet available at: http://www.nae.usace.army.mil/Portals/74/docs/Topics/Galilee/FactSheet.pdf

Adaptation Strategy 10 Tide Gate Alternative: Buoyant or Self-Regulating Structures

References:

Giannico and Souder, Coos Watershed: Tide Gates in the Pacific Northwest
http://www.cooswatershed.org/Publications/tidegates_PACNW.pdf

Tide Gate Alternatives by Juel Tide:
http://www.jueltide.com/images/New%20PDF%20files/Tide%20Gate%20Alternatives.pdf

Impact of Sea Level Rise on Tide Gate Function:
http://www.researchgate.net/publication/235399942_Impact_of_sea_level_rise_on_tide_gate_function

City of Salem, Massachusetts

Adaptation Strategy 11 *Water Level Monitoring and Alert System*

Prioritized Vulnerability: **B. Ineffective tide gates (CB11, CB19) and Inadequate tide gates at Lafayette Street (SW7, SW10)**

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☑ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☑ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on a water level monitoring and alert system. The tide gates at Forest River and Lafayette Road and at the South River Drainage Conduit are structures that prevent backflow of tidal water or storm surge into creeks, rivers, and drainage systems. Tide gates close during incoming tides to prevent water from traveling into low-lying areas, but they also keep flood water from draining into the harbor or ocean. With sea level rise and elevated water levels from storm surge, higher downstream mean sea level elevations reduce the effectiveness of tide gates by impacting the hydraulics of the system. If the tide gates at Forest River and South River Drainage Conduit are maintained as-is, an adaptation strategy is the usage of an early warning and monitoring system associated with rising tide or water levels.

Tide-gate sensors enable real-time operations and field adjustments as needed. The tide gate sensors and tide gages provide real-time data, in the form of an early warning system for flood prediction and alert facilities, municipalities, and the public if water levels reach a certain elevation. When a low-lying area is subject to future flooding, at times, a layer of redundancy is an effective method for risk communication to communities and households. This measure is also effective in alerting engineers or the public works department to target certain areas for flood proofing measures (sand bags, etc.). In addition, consider the potential of acquiring a back-up pump station or portable pump, to alleviate floodwaters once the water level reaches a certain height.

To ensure that a project continues to function as planned into the future, it is important to develop and implement both an adaptive management plan and a monitoring plan prior to the start of the tide gate project. These plans may vary greatly depending on project goals and the expected project life. For projects that are expected to entail active management in the future, an adaptive management plan accounting for climate change may facilitate adjustments over time as sea level rises, which may involve altering the settings of a tide gate.

Adaptation Strategy 11 ***Water Level Monitoring and Alert System***

Primary City Department(s) or Staff: Department of Public Works

Project Type: ☑ Planning ☐ Ordinance/Zoning ☐ Design ☑ Construction ☐ Program ☑ Education/Outreach ☑ Study ☑ Operations

Project Timeframe: ☐ <1 year ☑ 1-2 years ☐ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships ☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☑ MEMA ☑ Neighboring Cities ☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch ☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE) ☐ Private Property Owners ☐ Conservation Commission ☐ Others:

Adaptation Strategies with Similar Benefits

Technical, Implementation, and Financial Considerations:

Consider design storm frequency when designing tide gates and the hydraulic connections that tie into them. Ensure that the tide gate may be adjusted to obtain desired flow if the high tide water level increases to projected sea levels.

Consider any effects of changes to tide gate operations or elevations on upland flooding and water flow, channel characteristics, water temperature, water quality, plant communities, ecological habitats and passage, or potential for estuarine restoration. Costs associated with replacement of tide gates may be expensive in addition to costs associated with back up pump stations.

Case Studies:

NJ Meadowlands Research Institute - The New Jersey Meadowlands Research Institute have implemented a real-time monitoring system of water levels in the nearby marsh areas. The tide gages alert local municipalities if water levels reach a certain height. In addition, the website provides inundation mapping for the communities for increasing water levels. Additional information is available at: http://meri.njmeadowlands.gov/projects/njmc-tide-gate-monitoring-system/; http://meri.njmeadowlands.gov/alerts/water-level/

References:

City of Salem, Massachusetts

Adaptation Strategy 12 *Conduct a Drainage Study*

Prioritized Vulnerabilities:

C. Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods (SW2, SW6, SW9)
D. Flooding disrupts operation of pump stations (SW5, SW8)
E. Flooding of transportation network infrastructure from storm drain overflow and overwhelmed seawalls (T8, T12)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☑ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☐ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☑ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on conducting a stormwater drainage study to address flooding that results from insufficient capacity in the drainage system and in the pumping stations. The goal of a drainage study is to assess existing and future conditions and to determine which drainage mitigation measure is the preferred solution. The model for existing drainage system would determine the current capacity of the stormwater system for extreme precipitation events, sea level rise, and storm surge conditions. A drainage study may also identify the extent and degree of flooding in these areas. Areas that may be of particular concern include: Jackson St, Jefferson Ave, the Willows neighborhood, The Point, Loring Ave, Commercial St, Bridge St, Emerton St, Forester St, Canal St, areas providing access to Rt 128, and near the railroad tracks.

Alternatives for providing additional drainage system capacity are determined for future conditions. Alternatives may include replacing the existing drainage system with larger pipes, installing relief pipe systems, installation or upgrade of tide gates to minimize backwater effects, installation or upgrade of pump stations, above ground storage, subsurface storage, the construction/modification of seawalls, and the use of green infrastructure. These alternatives may be assessed alone and in combination with one another, depending on the area prone to flooding. The alternatives may be compared with respect to cost, ease of construction, ease of implementation, functional reliability, and impact on aesthetics and landowners to determine the best alternative for the area. Each of these alternatives is further explored as individual adaptation strategies.

Adaptation Strategy 12 Conduct a Drainage Study

Primary City Department(s) or Staff: Engineering Department

Project Type: ☑ Planning ☐ Ordinance/Zoning ☑ Design ☐ Construction ☐ Program ☐ Education/Outreach ☑ Study ☐ Operations

Project Timeframe: ☐ <1 year ☑ 1-2 years ☐ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships ☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☑ MEMA ☐ Neighboring Cities ☑ EPA ☑ DEP ☐ DOER ☐ MAPC ☑ MBTA ☐ National Grid ☑ Salem Sound Coastwatch ☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE) ☐ Private Property Owners ☐ Conservation Commission ☐ Others:

Adaptation Strategies with Similar Benefits

1 Seawall Repair: Installation of Drainage Features
13 Enlarging and Supplementing the Drainage System
14 Installation of Above Ground or Subsurface Stormwater Storage Systems
15 Installation/Upgrade of Pump Stations
17 Green Infrastructure - Bioretention/Street Planters
18 Green Infrastructure - Green Roofs
19 Green Infrastructure - Permeable Pavements
20 Infrastructure Design and Materials in the Transportation Network

Technical, Implementation, and Financial Considerations:

Funding a drainage study may be challenging, but may be sourced through municipal funding, or state and federal grants. Municipal funds for a drainage study are frequently in competition with other funding needs in the municipality. Grants, such as FEMA Hazard Mitigation Grants, require a matching component from the municipality. City-wide GIS, hydrologic and hydraulic modeling provide valuable information to support a drainage study.

Case Studies:

Northampton, MA - The City of Northampton developed a Stormwater and Flood Control System Assessment and Utility Plan. The purpose of the study was to evaluate alternatives for mitigating flooding in key areas of the City. Several alternatives, such as upsizing pipes, relief pipes, and subsurface storage were considered. The alternatives were evaluated and selected to create the capital improvements plan. Overall, the study identified drainage, river erosion, and flood control improvements, provided a 20-year capital improvements plan, and considered the implementation of a new Sustainable Stormwater and Flood Control Utility. City is currently in the process of implementing new utility fee. This fee will provide a funding sources for the capital improvements projects.

References:

EPA Region I Stormwater Resources website: http://www.epa.gov/region1/topics/water/stormwater.html

City of Salem, Massachusetts

Adaptation Strategy 13 *Enlarging and Supplementing the Drainage System*

Prioritized Vulnerabilities: **C. Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods (SW2, SW6, SW9)**
E. Flooding of transportation network infrastructure from storm drain overflow and overwhelmed seawalls (T8, T12)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☑ Sea Level Rise
- ☑ Extreme Precipitation Events
- ☑ Storm Surge

Sector(s):

- ☐ Critical Building Infrastructure
- ☑ Stormwater
- ☐ Drinking Water and Wastewater
- ☐ Transportation
- ☐ Vulnerable Populations
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on enlarging and supplementing the stormwater drainage system. A possible solution to address undersized drain pipes is to replace them with pipes that have more capacity to convey flows to the discharge points or add additional pipes parallel to the existing drainage system to provide additional capacity in the system. The appropriate size of these pipes is best determined from a future conditions modeling performed in a drainage study. The capacity of the relief pipe system is the difference between the required capacity to minimize flooding and the current capacity of the existing system. Relief pipe systems or upsized drainage pipes may be used in combination with other flood mitigation measures, such as above ground or subsurface storage, pump stations or tide gates. Areas where this strategy may be most applicable to include: Jackson St, Jefferson Ave, the Willows neighborhood, The Point, Loring Ave, Commercial St, Bridge St, Emerton St, Forester St, Canal St, areas providing access to Rt 128, and near the railroad tracks.

Adaptation Strategy 13 Enlarging and Supplementing the Drainage System

Primary City Department(s) or Staff: Engineering Department

Project Type:

☐ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☑ Study ☐ Operations

Project Timeframe:

☐ <1 year ☐ 1-2 years ☑ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships

☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☑ MEMA ☐ Neighboring Cities
☑ EPA ☑ DEP ☐ DOER ☐ MAPC ☑ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☐ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

1 Seawall Repair: Installation of Drainage Features
12 Conduct a Drainage Study
14 Installation of Above Ground or Subsurface Stormwater Storage Systems
15 Installation/Upgrade of Pump Stations
17 Green Infrastructure - Bioretention/Street Planters
18 Green Infrastructure - Green Roofs
19 Green Infrastructure - Permeable Pavements
20 Infrastructure Design and Materials in the Transportation Network

Technical, Implementation, and Financial Considerations:

Technical challenges include interference with existing utilities and designing systems to work within the existing topography. Implementation considerations include: public acceptance of these proposed projects; push-back from property owners who may not want flood relief systems on their property; and permitting. Financially, the cost of replacement drains may be high and finding a funding source to implement them may be challenging.

Case Studies:

Beverly, MA - To alleviate flooding in the Lawrence Street Brook watershed, the City installed several drainage improvements, including new large-diameter drainage pipes, relief pipes, new catch basins to remove stormwater more quickly, and channel improvements. Similarly, rainstorms backed up Beverly's drains in the Chase/Federal Street area and caused flooding during high tide because the water level in the Bass River blocked the discharge to the river. To address this problem, the City installed 3,200-feet of new drains, 4-ft by 6-ft culvert, and catch basins. A similar project was done for the North Beverly Brook watershed area.

References:

EPA Region I Stormwater Resources website: http://www.epa.gov/region1/topics/water/stormwater.html

City of Salem, Massachusetts

Adaptation Strategy 14 ***Installation of Above Ground or Subsurface Stormwater Storage Systems***

Prioritized Vulnerabilities:

C. Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods (SW2, SW6, SW9)
D. Flooding disrupts operation of pump stations (SW5, SW8)
E. Flooding of transportation network infrastructure from storm drain overflow and overwhelmed seawalls (T8, T12)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat
- ☑ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☐ Critical Building
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☑ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on installing stormwater storage systems. A possible solution to address undersized drains and pump stations is to provide above ground or subsurface storage for the excess flows and then release these flows at a later point in time, when the precipitation event has passed. Flood storage areas are incorporated into the future conditions modeling in the drainage study to assess their performance within the drainage system.

Based on a review of GIS maps of the areas identified as being prone to flooding, the following areas may be considered for above ground storage (e.g., reshaping an existing park to have a bowl-shaped area to store water, while also providing an attractive park for residents) or subsurface storage:
-Willows Neighborhood: Above ground and subsurface storage in the Salem Willows Park and Fort Avenue area.
-Juniper Avenue: Subsurface storage in the athletic court area.
-Szetela Lane: Subsurface storage in the athletic fields (possible consideration of converting to artificial turf field for stormwater storage under the field).
-Collins Cove Area: Subsurface storage in Collins Cove Park. Subsurface storage in the open area between Hubron and Thorndike Streets.
-Pioneer Terrace Area: Above ground and subsurface storage in the athletic field adjacent to Leavitt Street. Subsurface storage at the Saltonstall school. Subsurface storage in the parking lot areas bounded by Congress Street, Derby Street and Peabody Street, and the in the parking lot bounded by Layfayette Street, Dow Street, Salem Street and Harbor Street.
-Commercial Street/Bridge Street: Subsurface storage in the commuter rail parking lot. Above ground and subsurface storage in the park area bounded by the North River and Bridge Street.
-Above ground and subsurface storage may be used in combination with other flood mitigation measures, such as upsizing pipes, installation of relief pipe systems, or tide gates.

Some of these areas are on private property and would require either purchase from the City or an agreement with the property owner.

Adaptation Strategy 14 ***Installation of Above Ground or Subsurface Stormwater Storage***

Primary City Department(s) or Staff: Engineering Department

Project Type:
☐ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☑ Study ☐ Operations

Project Timeframe:
☐ <1 year ☐ 1-2 years ☑ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships
☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☑ MEMA ☐ Neighboring Cities
☑ EPA ☑ DEP ☐ DOER ☐ MAPC ☑ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☑ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

12 Conduct a Drainage Study
13 Enlarging and Supplementing the Drainage System
15 Installation/Upgrade of Pump Stations
17 Green Infrastructure - Bioretention/Street Planters
18 Green Infrastructure - Green Roofs
19 Green Infrastructure - Permeable Pavements
20 Infrastructure Design and Materials in the Transportation Network

Technical, Implementation, and Financial Considerations:

Technical challenges include interference with existing utilities and designing systems to work within the existing topography. Implementation considerations include public acceptance of these proposed projects; push-back from property owners who may not want flood relief systems on their property; and permitting. Financially, the cost of flood storage may be high; finding funding to implement them may be challenging.

Case Studies:

Beverly, MA - To alleviate flooding in the Chubbs Brook watershed, the City created several flood storage areas. Some flood storage areas included use of wetlands for temporary flood storage areas, which altered the storm event hydrology of about 20 acres of wetlands by modifying, in some cases, existing wetland areas. Thus far, flooding within this watershed has been mitigated.

Worcester, MA - The City bought houses that were frequently flooded in a low-lying area and created a subsurface flood storage area in the Brightwood Avenue area to mitigate flooding in that area of the City. The project was recently completed by the City.

References:

EPA Region I Stormwater Resources website: http://www.epa.gov/region1/topics/water/stormwater.html

City of Salem, Massachusetts

Adaptation Strategy 15 *Installation/Upgrade of Pump Stations*

Prioritized Vulnerabilities:

C. Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods (SW2, SW6, SW9)
D. Flooding disrupts operation of pump stations (SW5, SW8)
E. Flooding of transportation network infrastructure from storm drain overflow and overwhelmed seawalls (T8, T12)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat
- ☑ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☐ Critical Building
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☑ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on installing or upgrading stormwater pump stations. Pump stations may be used to pump stormwater from areas where it may not be conveyed to the outfalls by gravity flow, which are generally low-lying areas. The design of pump stations would be done as part of the future conditions assessment in a drainage study. In locations where the existing conditions modeling indicates the existing pump station is insufficient to convey future stormwater flows, the pump station may be upgraded. New pump stations may be installed in low-lying areas to convey water towards the outfalls. Pump stations can be used in combination with above ground and subsurface storage, as a means of removing the water from these storage areas if it cannot be done by gravity. Pump stations may also be used in combination with other mitigation measures, such as upsizing pipes or relief pipe systems, or creating above ground and subsurface flood storage area.

Adaptation Strategy 15 ***Installation/Upgrade of Pump Stations***

Primary City Department(s) or Staff: Engineering Department, Department of Public Works

Project Type:

☐ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☑ Study ☐ Operations

Project Timeframe:

☐ <1 year ☐ 1-2 years ☑ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships

☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☑ MEMA ☐ Neighboring Cities
☑ EPA ☑ DEP ☐ DOER ☐ MAPC ☑ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☐ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

12 Conduct a Drainage Study
13 Enlarging and Supplementing the Drainage System
14 Installation of Above Ground or Subsurface Stormwater Storage Systems
17 Green Infrastructure - Bioretention/Street Planters
18 Green Infrastructure - Green Roofs
19 Green Infrastructure - Permeable Pavements
20 Infrastructure Design and Materials in the Transportation Network

Technical, Implementation, and Financial Considerations:

Technical challenges include interference with existing utilities and designing systems to work within the existing topography. Stations may need to be elevated above future flooding levels to prevent flooding and remain operational. Implementation considerations include public acceptance of these proposed projects; push-back from property owners who may not want flood relief systems on their property; and permitting. Financially, the cost of pump stations may be high; finding funding to implement them may be challenging. Once installed, pump station operation may increase the City's electricity costs.

Case Studies:

Beverly, MA - In response to the problem of high tides, the Margin Street drainage pump station, housed in a new building next to Innocenti Park, was designed to lift water from a new 4-ft by 6-ft box culvert, which is lower than the Bass River level at times of high tide, and discharge directly into the river. Four large submersible pumps were installed, each capable of moving 20,000 gallons of water per minute. The station automatically activates whenever flooding under the railroad tracks appears imminent.

References:

EPA Region I Stormwater Resources website: http://www.epa.gov/region1/topics/water/stormwater.html

City of Salem, Massachusetts

Adaptation Strategy 16 *Installation of Deployable Floodwalls*

Prioritized Vulnerabilities:

C. Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods (SW2, SW6, SW9)
D. Flooding disrupts operation of pump stations (SW5, SW8)
E. Flooding of transportation network infrastructure from storm drain overflow and overwhelmed seawalls (T8, T12)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat
- ☑ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☐ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☑ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on installing deployable floodwalls. Deployable floodwalls are temporary floodwalls that may quickly be erected at the sign of an impending storm. Deployable floodwalls consist of moveable posts and panels which are attached to permanent, in-ground foundations during storms for which flooding is a concern. Deployable floodwalls may be used in conjunction with drainage system improvements, pumping stations and tide gates to mitigate the potential for flooding in a low-lying area. Areas where this strategy may be most applicable to include: Jackson St, Jefferson Ave, the Willows neighborhood, The Point, Loring Ave, Commercial St, Bridge St, Emerton St, Forester St, Canal St, areas providing access to Rt 128, and near the railroad tracks.

Adaptation Strategy 16 ***Installation of Deployable Floodwalls***

Primary City Department(s) or Staff: Engineering Department, Department of Public Works

Project Type:

☐ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction

☐ Program ☐ Education/Outreach ☑ Study ☐ Operations

Project Timeframe:

☐ <1 year ☑ 1-2 years ☐ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships

☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☑ MEMA ☐ Neighboring Cities

☑ EPA ☑ DEP ☐ DOER ☐ MAPC ☑ MBTA ☐ National Grid ☐ Salem Sound Coastwatch

☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)

☐ Private Property Owners ☐ Conservation Commission

☐ Others:

Adaptation Strategies with Similar Benefits

10 Tide Gate Alternative: Buoyant or Self-Regulating Structures

12 Conduct a Drainage Study

Technical, Implementation, and Financial Considerations:

Technical and logistical considerations include finding a suitable location to store the floodwalls, having a workforce trained to install the floodwalls in a timely manner prior to the storm, and the need to use heavy equipment to deploy the floodwalls. Implementation considerations include public acceptance of these proposed projects, push-back from property owners who may not want flood relief systems on their property, and permitting. Financially, the cost of deployable floodwalls may be high; finding funding to implement them may be challenging.

Case Studies:

Northampton, MA - The City currently has a deployable floodwall (14-ft high stop log structure) on West Street, along the Mill River. The floodwall is erected during storm events expected to have flooding.

References:

US Army Corps of Engineers Fact Sheet on Removable/Deployable Flood Barriers:
http://www.nap.usace.army.mil/Portals/39/docs/Civil/DelComp/Removable-Deployable%20Barriers.pdf

City of Salem, Massachusetts

Adaptation Strategy 17 ***Green Infrastructure - Bioretention/Street Planters***

Prioritized Vulnerabilities: **C. Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods (SW2, SW6, SW9)**
E. Flooding of transportation network infrastructure from storm drain overflow and overwhelmed seawalls (T8, T12)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☑ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☐ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☑ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on "green infrastructure" strategies such as installing bioretention areas or street planters. "Green infrastructure" refers to the installation of stormwater management systems that mimic natural systems by absorbing and storing water. Green infrastructure may be included as a mitigation measure for any of the areas prone to flooding. They are typically designed to manage the first inch of rainfall and are therefore not a stand-alone adaptation strategy for addressing extreme precipitation events, sea level rise or storm surge.

A potential green infrastructure option could include the incorporation of street planters and bioretention areas, especially in highly impervious areas. A bioretention area is a shallow, vegetated basin that collects and absorbs runoff from rooftops, sidewalks, and streets, and may be installed in any unpaved space. A street planter box is a bioretention area with vertical walls and open or closed bottoms that collect and absorb runoff from sidewalks, parking lots, and streets. Areas where this strategy may be most applicable to include: Jackson St, Jefferson Ave, the Willows neighborhood, The Point, Loring Ave, Commercial St, Bridge St, Emerton St, Forester St, Canal St, areas providing access to Rt 128, and near the railroad tracks.

Adaptation Strategy 17 ***Green Infrastructure - Bioretention/Street Planters***

Primary City Department(s) or Staff: Engineering Department, Department of Planning and Community Development

Project Type:
☐ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☑ Study ☐ Operations

Project Timeframe:
☐ <1 year ☐ 1-2 years ☑ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships
☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☑ MEMA ☐ Neighboring Cities
☑ EPA ☑ DEP ☐ DOER ☐ MAPC ☑ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☑ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

12 Conduct a Drainage Study
13 Enlarging and Supplementing the Drainage System
14 Installation of Above Ground or Subsurface Stormwater Storage Systems
15 Installation/Upgrade of Pump Stations
18 Green Infrastructure - Green Roofs
19 Green Infrastructure - Permeable Pavements
20 Infrastructure Design and Materials in the Transportation Network
33 Promote and Expand Urban Forestry

Technical, Implementation, and Financial Considerations:

Technical challenges include interference with existing utilities and designing systems to work within the existing topography. Implementation considerations include public acceptance of these proposed projects, push-back from property owners who may not want flood relief systems on their property, and permitting. Financially, the bioretention/street planters may not be cost-effective in all locations.

Case Studies:

Philadelphia Water Department - The Green City, Clean Waters program at the Philadelphia Water Department is a 25-year plan to protect and enhance watersheds by managing stormwater with innovative green infrastructure. This program provides stormwater management and control of combined sewer overflows. Several green infrastructure best management practices are being used, including bioretention facilities. More information on this program may be found at :
http://phillywatersheds.org/what_were_doing/documents_and_data/cso_long_term_control_plan

References:

EPA's Green infrastructure website:
http://water.epa.gov/infrastructure/greeninfrastructure/gi_what.cfm

City of Salem, Massachusetts

Adaptation Strategy 18 *Green Infrastructure - Green Roofs*

Prioritized Vulnerabilities:

C. Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods (SW2, SW6, SW9)
E. Flooding of transportation network infrastructure from storm drain overflow and overwhelmed seawalls (T8, T12)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☑ Extreme Precipitation Events
- ☐ Sea Level Rise
- ☐ Storm Surge

Sector(s):

- ☐ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☑ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on "green infrastructure" strategies, such as green roofs. "Green infrastructure "refers to the installation of stormwater management systems that mimic natural systems by absorbing and storing water. Green infrastructure may be included as a mitigation measure for any of the areas prone to flooding.They are typically designed to manage the first inch of rainfall and are therefore not a stand-alone adaptation strategy for addressing extreme precipitation events, sea level rise or storm surge.

A potential green infrastructure option could include conversion of an existing roof to a green roof. Green roofs are covered with vegetation that enable rainfall infiltration and evapotranspiration of stored water. Thus, they reduce the amount of runoff that a conventional stormwater system would be required to handle.

Green roofs also have the potential to reduce energy use in a building, especially if they are replacing a dark-colored roof. This may help reduce the costs of operating the building. This strategy may be implemented throughout the City, but may be of particular use in combating stormwater flooding issues near: Jackson St, Jefferson Ave, the Willows neighborhood, The Point, Loring Ave, Commercial St, Bridge St, Emerton St, Forester St, Canal St, areas providing access to Rt 128, and near the railroad tracks.

Adaptation Strategy 18 ***Green Infrastructure - Green Roofs***

Primary City Department(s) or Staff: Engineering Department, Department of Planning and Community Development

Project Type:

☐ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☐ Study ☐ Operations

Project Timeframe:

☐ <1 year ☐ 1-2 years ☐ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships

☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☑ MEMA ☐ Neighboring Cities
☑ EPA ☑ DEP ☐ DOER ☐ MAPC ☑ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☑ Private Property Owners ☑ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

12 Conduct a Drainage Study
13 Enlarging and Supplementing the Drainage System
14 Installation of Above Ground or Subsurface Stormwater Storage Systems
15 Installation/Upgrade of Pump Stations
17 Green Infrastructure - Bioretention/Street Planters
19 Green Infrastructure - Permeable Pavements
20 Infrastructure Design and Materials in the Transportation Network

Technical, Implementation, and Financial Considerations:

Technical challenges include the ability of the existing roof to be retrofitted to a green roof. A green roof would most likely be implemented on a public building and large private properties. Financially, green roofs may be expensive, especially if the existing roof needs structural improvements to carry the additional load.

Case Studies:

New York City Parks Department - NYC Parks installed of a green roof on the Five Borough Administrative Building on Randall's Island in 2007. The roof contains multiple green roof systems and cover over 29,000 square feet. NYC Parks uses this green roof as a working laboratory for green roof design and construction. More information may be found at: http://www.nycgovparks.org/greening/sustainable-parks/green-roofs

References:

EPA's Green infrastructure website:
http://water.epa.gov/infrastructure/greeninfrastructure/gi_what.cfm

City of Salem, Massachusetts

Adaptation Strategy 19 *Green Infrastructure - Permeable Pavements*

Prioritized Vulnerabilities: **C. Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods (SW2, SW6, SW9)**
E. Flooding of transportation network infrastructure from storm drain overflow and overwhelmed seawalls (T8, T12)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☑ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☐ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☑ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on "green infrastructure" strategies such as using permeable pavement. "Green infrastructure" refers to the installation of stormwater management systems that mimic natural systems by absorbing and storing water. They are typically designed to manage the first inch of rainfall and are therefore not a stand-alone adaptation strategy for addressing extreme precipitation events, sea level rise or storm surge.

A potential green infrastructure option could include the conversion of paved areas to permeable pavements and, if possible, the elimination of paved areas. Permeable pavements are paved surfaces that infiltrate, treat, and/or store rainwater where it falls. Permeable pavements include pervious concrete, porous asphalt, and permeable interlocking pavers. Areas where this strategy may be most applicable to include: Jackson St, Jefferson Ave, the Willows neighborhood, The Point, Loring Ave, Commercial St, Bridge St, Emerton St, Forester St, Canal St, areas providing access to Rt 128, and near the railroad tracks.

Adaptation Strategy 19 Green Infrastructure - Permeable Pavements

Primary City Department(s) or Staff: Engineering Department

Project Type:
☐ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☑ Study ☐ Operations

Project Timeframe:
☐ <1 year ☐ 1-2 years ☑ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships
☐ Hospitals ☐ Fire Department ☐ Police Department ☐ FEMA ☐ MEMA ☐ Neighboring Cities
☑ EPA ☑ DEP ☐ DOER ☐ MAPC ☑ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☐ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

12 Conduct a Drainage Study
13 Enlarging and Supplementing the Drainage System
14 Installation of Above Ground or Subsurface Stormwater Storage Systems
15 Installation/Upgrade of Pump Stations
17 Green Infrastructure - Bioretention/Street Planters
18 Green Infrastructure - Green Roofs
20 Infrastructure Design and Materials in the Transportation Network

Technical, Implementation, and Financial Considerations:

Technical challenges include interference with existing utilities and designing systems to work within the existing topography and other site constraints. Implementation considerations include public acceptance of these proposed projects, push-back from property owners who may not want flood relief systems on their property, and permitting. Financially, the permeable pavements may not be cost-effective in all locations.

It is recommended that pervious pavement is inspected several times in the first few months and then annually. Traditional de-icing material such as sand and other abrasives may clog the pavement. However, ice is less likely to form on pervious pavement so de-icing materials may not be as necessary. For example the University of New Hampshire used 0 to 25% of the salt on pervious pavement as on traditional surfaces.

Case Studies:

Salem, OR - The City installed pervious pavement along a roadway in order to capture runoff. More information may be found at: http://www.lcog.org/documents/sub_action/LID_CaseStudy_PringleCreekGreenStr.pdf

References:

EPA's Green infrastructure website:
http://water.epa.gov/infrastructure/greeninfrastructure/gi_what.cfm

City of Salem, Massachusetts

Adaptation Strategy 20 — *Infrastructure Design and Materials in the Transportation Network*

Prioritized Vulnerabilities:

E. Flooding of transportation network infrastructure from storm drain overflow and overwhelmed seawalls (T8, T12)
C. Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods (SW2, SW6, SW9)
F. Flooding of Evacuation Routes (VP13, VP18, VP23)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☐ Sea Level Rise
- ☑ Extreme Precipitation Events
- ☑ Storm Surge

Sector(s):

- ☐ Critical Building Infrastructure
- ☐ Stormwater
- ☑ Drinking Water and Wastewater
- ☑ Transportation
- ☐ Vulnerable Populations
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on using nonerodible and permeable base materials in infrastructure design and construction to prevent failure or collapse. The transportation network is susceptible to considerable impacts from extreme weather events. Extreme precipitation events and storm surge saturate the soil, which compromises the structural integrity of the roadways, bridges, and railbed support structures. The incorporation of nonerodible or permeable base materials into the design, construction and maintenance of new and existing network segments would serve to improve the resiliency of the transportation system. Nonerodible materials include lean concrete base and cement treated base. Materials are more resistant to moisture damage the higher the cement content and compressive strength are. Permeable materials include porous asphalt, pervious concrete, impermeable interlocking concrete pavement, grass and gravel pavers. The use of materials with greater resistance to moisture or that naturally treat stormwater runoff could help lessen maintenance costs and disruptions to the network. Areas where this strategy may be most applicable to include: Jackson St, Jefferson Ave, the Willows neighborhood, The Point, Loring Ave, Commercial St, Bridge St, Emerton St, Forester St, Canal St, areas providing access to Rt 128, and near the railroad tracks.

Adaptation Strategy* 20** ***Infrastructure Design and Materials in the Transportation

Primary City Department(s) or Staff: Engineering Department

Project Type:

☐ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☑ Study ☐ Operations

Project Timeframe:

☐ <1 year ☐ 1-2 years ☐ 2-5 years ☐ 6-10 years ☑ 10+ years

Potential Partnerships

☐ Hospitals ☐ Fire Department ☐ Police Department ☐ FEMA ☐ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☑ MAPC ☑ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☐ Conservation Commission
☑ Others: Department of Transportation

Adaptation Strategies with Similar Benefits

19 Green Infrastructure - Permeable Pavements

Technical, Implementation, and Financial Considerations:

Porous pavement requires more extensive maintenance than other materials. Pavement materials range in cost and effectiveness in withstanding against extreme flooding events. A cost-benefit analysis may be completed in order to determine which materials would serve the City best. In addition, the service lives of network components vary - for instance, bridges are often designed for service lives of 50 to 100 years - as a result, maintenance and construction activities may vary throughout the network, potentially leading to a patchwork of flood-resistant materials within the system.

It is recommended that pervious pavement is inspected several times in the first few months and then annually. Traditional de-icing material such as sand and other abrasives may clog the pavement. However, ice is less likely to form on pervious pavement so de-icing materials may not be as necessary. For example the University of New Hampshire used 0 to 25% of the salt on pervious pavement as on traditional surfaces.

Case Studies:

Philadelphia Water Department - A Green Streets Program was implemented to incorporate stormwater and transportation infrastructure strategies in order to manage stormwater runoff. The City developed a Green Streets Design Manual, and began to implement and install pervious pavement, as appropriate, throughout the City. More information is available at:
http://www.phillywatersheds.org/what_were_doing/green_infrastructure/programs/green_streets

Adaptation Strategy 20 ***Infrastructure Design and Materials in the Transportation***

References:

Transportation Research Board. 2008. Potential Impacts of Climate Change on U.S. Transportation. TRB Special Report 290.

Climate Change Science Program. 2008. Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I. Synthesis and Assessment Product 4.7.

Meyer, M.D. and B. Weigel. 2011. Journal of Transportation Engineering, "Climate Change and Transportation Engineering: Preparing for a Sustainable Future." pp. 393-403.

U.S. Global Change Research Program. 2009. Global Climate Change Impacts in the United States.

National Asphalt Pavement Association:
http://www.asphaltpavement.org/index.php?option=com_content&view=article&id=518&Itemid=1114

Transportation Research Board. National Cooperative Highway Research Program, Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures, Part 3: Design Analysis:
http://onlinepubs.trb.org/onlinepubs/archive/mepdg/Part3_Chapter1_Subdrainage.pdf

Clemson Extension, "An Introduction to Porous Pavement":
http://www.clemson.edu/extension/hgic/water/resources_stormwater/introduction_to_porous_pavement.html

EPA, Pervious Concrete Pavement: http://water.epa.gov/polwaste/npdes/swbmp/Pervious-Concrete-Pavement.cfm

City of Salem, Massachusetts
Adaptation Strategy 21 *Elevate or Relocate Transportation Infrastructure*

Prioritized Vulnerabilities:
E. Flooding of transportation network infrastructure from storm drain overflow and overwhelmed seawalls (T8, T12)
C. Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods (SW2, SW6, SW9)
F. Flooding of Evacuation Routes (VP13, VP18, VP23)

Due to this/these Climate Impact(s):
- ☐ Extreme Heat Events
- ☑ Extreme Precipitation Events
- ☐ Sea Level Rise
- ☑ Storm Surge

Sector(s):
- ☐ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☐ Stormwater
- ☑ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on elevating transportation infrastructure. An increase in frequency and intensity of extreme precipitation events and storm surges may degrade the existing network and potentially shorten the service life of the infrastructure. Extreme precipitation events and storm surges saturate the soil, which compromises the structural integrity of the roadways, bridges, and railbed support structures. Elevating or relocating infrastructure outside of the future storm surge area would serve to protect the network from flooding events. Areas where this strategy may be most applicable to include: Rt 1A, Lafayette St, Kernwood St, Bridge St, Jackson St, Jefferson Ave, the Willows neighborhood, The Point, Loring Ave, Commercial St, Emerton St, Forester St, areas providing access to Rt 128, and near the railroad tracks.

Adaptation Strategy 21 **Elevate or Relocate Transportation Infrastructure**

Primary City Department(s) or Staff: Engineering Department, Department of Planning and Community Development

Project Type:
☑ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☑ Study ☐ Operations

Project Timeframe:
☐ <1 year ☐ 1-2 years ☐ 2-5 years ☐ 6-10 years ☑ 10+ years

Potential Partnerships
☐ Hospitals ☐ Fire Department ☐ Police Department ☐ FEMA ☐ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☑ MAPC ☑ MBTA ☐ National Grid ☐ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☐ Conservation Commission
☑ Others: Department of Transportation

Adaptation Strategies with Similar Benefits

Technical, Implementation, and Financial Considerations:

Close coordination and consultation with MBTA would be necessary in order to discuss possible elevation or relocation of bus stations, the Salem MBTA station, or the rail lines within the future storm surge area. Any changes to public transportation alignments would likely require an environmental review conforming to the requirements set forth by the National Environmental Policy Act. Roadways may be repaved to higher elevation; however, it may be necessary to also elevate those lots that drain into the roadway. The potential cost is very high - likely need state and federal partnerships depending on the magnitude of the project.

Case Studies:

San Mateo County, CA - The County found that elevating a frequently flooded road had the "longest lasting flood-reduction benefits." More information may be found at:
http://sanmateorcd.org/PescaderoFlooding/Presentation_Preliminary%20Results_Mtng_2014-06-30.pdf

References:

Transportation Research Board. 2008. Potential Impacts of Climate Change on U.S. Transportation. TRB Special Report 290.

Climate Change Science Program. 2008. Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I. Synthesis and Assessment Product 4.7.

Meyer, M.D. and B. Weigel. 2011. Journal of Transportation Engineering, “Climate Change and Transportation Engineering: Preparing for a Sustainable Future.” pp. 393-403.

U.S. Global Change Research Program. 2009. Global Climate Change Impacts in the United States.

City of Salem, Massachusetts

Adaptation Strategy 22 *Increase Energy Efficiency in Critical City Buildings*

Prioritized Vulnerability: **G. Loss of Power at Critical City Buildings (E1)**

Due to this/these Climate Impact(s):

- ☑ Extreme Heat Events
- ☐ Extreme Precipitation Events
- ☐ Sea Level Rise
- ☐ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☐ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on increasing energy efficiency in the critical city buildings to reduce the risk of power outages during events that cause grid power failure. This is particularly applicable to the Department of Public Works, Police Headquarters, Fire Headquarters and Stations 5, City Hall, South Essex Sewerage District, and schools serving as emergency shelters. Increasing energy efficiency in critical buildings may reduce the energy demand on the grid. Energy efficiency is a strategy that is obtainable through many different methods.

Examples of energy efficiency projects include:
-Updating the lighting controls to include multi-level switching (a requirement of the IECC)
-Installing day-light sensors to dim fixtures when outside light is providing adequate illumination
-Install occupancy sensors
-Replacing existing equipment with newer more efficient technologies. For example, replace window A/C units with more efficient central A/C systems
-Replacing inefficient incandescent and fluorescent fixtures with more efficient LED technologies

Studies may be conducted to determine payback periods on these modifications to illustrate exactly how much energy is being saved. The City may consider a commissioning or retrocommissioning program to optimize the performance of equipment and systems, to ensure they are working at the optimum efficiency. A computerized maintenance management system (CMMS) may also assist in alerting the City if equipment is not performing up to desired efficiency standards.

Engineering studies may be completed to assess critical city buildings to determine what methods are the most practical and critical to save the most money and energy as quickly as possible. These studies typically include findings of the existing equipment and recommended upgrades with payback periods and energy savings per year.

Adaptation Strategy 22 ***Increase Energy Efficiency in Critical City Buildings***

Primary City Department(s) or Staff: City Electrician, Department of Planning and Community Development

Project Type:
☑ Planning ☐ Ordinance/Zoning ☑ Design ☐ Construction
☐ Program ☐ Education/Outreach ☑ Study ☐ Operations

Project Timeframe:
☑ <1 year ☑ 1-2 years ☑ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships
☐ Hospitals ☑ Fire Department ☑ Police Department ☐ FEMA ☐ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☐ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☑ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☐ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

33 Promote and Expand Urban Forestry

Technical, Implementation, and Financial Considerations:

Upgrades may be evaluated based on financial considerations before implementation. Payback periods may be long for some projects, however, undertaking multiple projects at once may allow for an acceptable payback period on average. National Grid has a commissioning program to assist clients with such studies.

Case Studies:

New York Power Authority (NYPA) - In alliance with New York City DEP, NYPA undertook two separate projects aimed at energy efficiency. The first project is located at the 26th Ward Wastewater Treatment Facility in Brooklyn, NY. An engineering assessment was conducted and determined that payback periods were favorable to install LED fixtures to replace the existing less efficient technologies. In addition, the Kings County Hospital Center (KCHC) in Brooklyn, NY conducted an energy audit and to replace existing lighting with more energy efficient technologies. Existing mechanical equipment is also being assessed to increase their efficiencies.

References:

2012 International Energy Conservation Code (IECC)

City of Salem, Massachusetts

Adaptation Strategy 23 *Install and Elevate Backup Power Sources*

Prioritized Vulnerabilities: **H. Back-up Power Failure at Critical City Facilities (CB5, CB12, CB20)**
G. Loss of Power at Critical City Buildings (E1)

Due to this/these Climate Impact(s):

- ☑ Extreme Heat Events
- ☑ Sea Level Rise
- ☑ Extreme Precipitation Events
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☐ Storm water
- ☐ Drinking Water and Wastewater
- ☐ Transportation
- ☐ Vulnerable Populations
- ☑ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on installing backup generators to maintain some level of power during events that could cause grid power failure. This is particularly applicable to the Department of Public Works, Police Headquarters, Fire Headquarters and Stations 5, City Hall, South Essex Sewerage District, and schools serving as emergency shelters.

Extreme weather events including extreme precipitation events, sea level rise, storm surge and extreme heat events may cause a variety of electrical failures. A backup generator with properly rated distribution equipment and installed above future flooding elevation is recommended to maintain power at these facilities. Additionally an assessment of the current reliability of the power at these facilities may be performed to determine the priority levels for the installations.

One possible location to install the equipment, such as generators, above future flooding elevation is on the roof of these buildings. Fuel pumps could be installed to allow for easy refilling of the generators and all equipment could be properly rated for use outdoors.

This strategy may increase the overall reliability of the facilities as well eliminate their reliance on outside power sources. The facilities may be able to operate during extreme events where their operation and reliance on power will be critical. An installation of a backup generator may also bring these facilities up to the latest edition of the National Electrical Code (NEC). These critical building infrastructures likely would fall under Article 708 of the 2014 NEC which contains the requirements for Critical Operations Power Systems (COPS).

The NEC defines COPS as: *Power systems for facilities or parts of facilities that require continuous operation for the reasons of public safety, emergency management, national security, or business continuity.* Ultimately, the Authority Having Jurisdiction (AHJ) has final say on if these facilities fall under this code section, but given the functions of these facilities it would likely be necessary to design to the requirements of NEC Article 708.

Adaptation Strategy 23 Install and Elevate Backup Power Sources

Primary City Department(s) or Staff: City Electrician, Department of Planning and Community Development

Project Type:

- ☑ Planning
- ☐ Ordinance/Zoning
- ☑ Design
- ☑ Construction
- ☐ Program
- ☐ Education/Outreach
- ☑ Study
- ☐ Operations

Project Timeframe:

- ☐ <1 year
- ☐ 1-2 years
- ☑ 2-5 years
- ☐ 6-10 years
- ☐ 10+ years

Potential Partnerships

- ☐ Hospitals
- ☑ Fire Department
- ☑ Police Department
- ☑ FEMA
- ☑ MEMA
- ☐ Neighboring Cities
- ☐ EPA
- ☐ DEP
- ☐ DOER
- ☐ MAPC
- ☐ MBTA
- ☑ National Grid
- ☐ Salem Sound Coastwatch
- ☐ North Shore Community Development Coalition (CDC)
- ☐ Salem Alliance for the Environment (SAFE)
- ☐ Private Property Owners
- ☐ Conservation Commission
- ☐ Others:

Adaptation Strategies with Similar Benefits

24 Install Renewable Energy Backup Power Sources

38 Elevate a Building's Critical Uses

Technical, Implementation, and Financial Considerations:

There may be challenges when making modifications to an existing electrical infrastructure. There are many unknowns when designing for integration with older existing equipment and these factors may lead to either a greater upfront cost or change orders during construction due to unbudgeted electrical distribution equipment replacement.

Case Studies:

Federal Emergency Management Agency (FEMA) - As a result of the damage sustained to critical facilities in the New York and New Jersey area from Hurricane Sandy, FEMA assessed the damage and identified the vulnerabilities at the facilities. In many instances the critical facilities could not function due to essential electrical equipment such as transformers and transfer switches being located in areas below the 100 year flood elevation.

References:

National Electrical Code 2014 Edition - NFPA 70 - Article 708

FEMA, "Reducing Flood Effects in Critical Facilities. This is aimed at educating facility owners and operators on the importance of installing essential equipment outside of the floodplain: http://www.fema.gov/media-library-data/1381404651877-881a2cf70a90ac63b9c067100ffccace/SandyRA2CriticalFacilities_508_FINAL2.pdf

City of Salem, Massachusetts

Adaptation Strategy 24 *Install Renewable Energy Backup Power Sources*

Prioritized Vulnerabilities: **H. Back-up Power Failure at Critical City Facilities (CB5, CB12, CB20)**
G. Loss of Power at Critical City Buildings (E1)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat
- ☑ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☐ Storm water
- ☐ Transportation
- ☑ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on installing renewable energy to maintain some level of power during events that could cause grid power failure. This is particularly applicable to the Department of Public Works, Police Headquarters, Fire Headquarters and Stations 5, City Hall, South Essex Sewerage District, and schools serving as emergency shelters.

Extreme weather events including extreme precipitation events, sea level rise, storm surge, and extreme heat events may cause a variety of electrical failures. The use of renewable energy sources may be evaluated for both feasibility and practicality. In order for a renewable energy source to be a viable option as a means for back up generation, a large battery room would need to be built to store the energy from the renewable source. Additionally renewable energy sources are typically not reliable back up power and do not meet the requirements of Critical Operations Power Systems (COPS - see below).

The NEC defines COPS as: Power systems for facilities or parts of facilities that require continuous operation for the reasons of public safety, emergency management, national security, or business continuity. Ultimately, the Authority Having Jurisdiction (AHJ) has final say on if these facilities fall under this code section, but given the functions of these facilities it would likely be necessary to design to the requirements of NEC Article 708.

This strategy may increase the overall reliability of the facilities as well eliminate their reliance on outside power sources. The reliance on reliable energy may ensure the critical facilities are able to operate during extreme events.

Adaptation Strategy 24 ***Install Renewable Energy Backup Power Sources***

Primary City Department(s) or Staff: City Electrician, Department of Planning and Community Development

Project Type: ☑ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction ☐ Program ☐ Education/Outreach ☑ Study ☑ Operations

Project Timeframe: ☐ <1 year ☐ 1-2 years ☑ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships ☐ Hospitals ☑ Fire Department ☑ Police Department ☑ FEMA ☑ MEMA ☐ Neighboring Cities ☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☑ National Grid ☐ Salem Sound Coastwatch ☑ North Shore Community Development Coalition (CDC) ☑ Salem Alliance for the Environment (SAFE) ☐ Private Property Owners ☐ Conservation Commission ☑ Others: Salem's Renewable Energy Task Force

Adaptation Strategies with Similar Benefits

23 Install and Elevate Backup Power Sources

38 Elevate a Building's Critical Uses

Technical, Implementation, and Financial Considerations:

There may be challenges when making modifications to an existing electrical infrastructure. There are many unknowns when designing for integration with older existing equipment and these factors may lead to either a greater upfront cost or change orders during construction due to unbudgeted electrical distribution equipment replacement.

Distributing renewable energy directly to a building rather than through the grid may result in additional costs and ineligibility of some utility-based incentives for renewable energy. However, if this is successful, renewable energy installations may remain operable anytime, including during extreme heat events when the grid is overtaxed.

Case Studies:

US Department of Energy - The US Department of Energy compares different renewable energy backup options and the type of equipment that could be backed up in the event of an emergency. Pros and cons for the technologies and their reliability are also investigated.

References:

National Electrical Code 2014 Edition - NFPA 70 - Article 708

FEMA, "Reducing Flood Effects in Critical Facilities. This is aimed at educating facility owners and operators on the importance of installing essential equipment outside of the floodplain: http://www.fema.gov/media-library-data/1381404651877-881a2cf70a90ac63b9c067100ffccace/SandyRA2CriticalFacilities_508_FINAL2.pdf

City of Salem, Massachusetts

Adaptation Strategy 25 *Bury the Electrical Distribution System*

Prioritized Vulnerability: **I. Downed power lines (E3)**

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☑ Extreme Precipitation Events
- ☐ Sea Level Rise
- ☐ Storm Surge

Sector(s):

- ☐ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☐ Stormwater
- ☐ Transportation
- ☑ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on burying the electrical distribution system to reduce the risk of power outages during events that could cause grid power failure. Underground distribution may solve many of the problems that extreme precipitation events cause. New electrical distribution equipment rated to be submerged in water for extended periods of time have been developed and makes this type of distribution even more reliable. The underground lines are protected from high winds and downed trees, increasing the grids reliability.

This may be most applicable to the areas outside of future flooding levels that currently have overhead power lines, including Loring Ave off Rt 1A and North Salem near 114.

From an implementation standpoint, the coordination between National Grid, cable companies, Salem, and an engineering firm to come up with a plan that fits the needs of all affected parties will be a challenge. Many coordination meetings and reports may be needed to be produced to voice all sides and possible plans before a final decision is made.

Adaptation Strategy 25 Bury the Electrical Distribution System

Primary City Department(s) or Staff: City Electrician, Engineering Department

Project Type:

- ☑ Planning ☐ Ordinance/Zoning ☐ Design ☐ Construction
- ☐ Program ☐ Education/Outreach ☑ Study ☐ Operations

Project Timeframe: ☐ <1 year ☐ 1-2 years ☐ 2-5 years ☑ 6-10 years ☑ 10+ years

Potential Partnerships

- ☐ Hospitals ☐ Fire Department ☐ Police Department ☐ FEMA ☐ MEMA ☐ Neighboring Cities
- ☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☑ National Grid ☐ Salem Sound Coastwatch
- ☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
- ☐ Private Property Owners ☐ Conservation Commission
- ☐ Others:

Adaptation Strategies with Similar Benefits

Technical, Implementation, and Financial Considerations:

Completely reconstructing the existing distribution system to make it underground is extremely expensive and there are several hurdles to overcome due to the low elevation and location of Salem. In addition, contaminated areas may be uncovered which may be costly to remediate.

A complete underground distribution in Salem would be challenging because although there is equipment available that is able to be submerged in water, it is unlikely that NGRID would consider such an installation. It would be good engineering practice to install the distribution equipment above the future flood elevations and submersible rated cabling could be installed under ground.

Case Studies:

<u>Potomac Electrical Power Company (PEPCO)</u> - PEPCO implemented a reliability enhancement plan in August 2010. PEPCO provides power to customers in Washington, DC, and several counties in Maryland. The reliability enhancement plan focuses on both overhead and underground distribution systems and PEPCO's plan to maintain their system to ensure best possible performance and up-time. More information is available at: http://www.pepco.com/uploadedFiles/wwwpepcocom/PepcoPGReliabilityPlan%281%29.pdf

References:

City of Salem, Massachusetts
Adaptation Strategy 26 *Maintain Overhead Distribution System*

Prioritized Vulnerability: **I. Downed power lines (E3)**

Due to this/these Climate Impact(s):

- ☐ Extreme Heat
- ☑ Extreme Precipitation Events
- ☐ Sea Level Rise
- ☐ Storm Surge

Sector(s):

- ☐ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☐ Stormwater
- ☐ Transportation
- ☑ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on maintaining overhead power lines to prevent outages from high winds during extreme precipitation events. Upgrades and more preventative maintenance to the existing overhead distribution may increase the reliability of existing distribution. Replacing existing overhead wires with more durable cable and replacing poles that do not pass inspection are examples of upgrades that could help reliability. Working with National Grid to trim limbs that could break and fall onto power lines during extreme precipitation events could help minimize how extensive a power outage is.

This may be most applicable to areas that currently have overhead power lines, including Loring Ave off Rt 1A and North Salem near 114.

Ultimately the ability to reduce the number of outages also helps with the response time of NGRID to repair other issues.

Adaptation Strategy 26 ***Maintain Overhead Distribution System***

Primary City Department(s) or Staff: City Electrician, Department of Public Works

Project Type:
☑ Planning ☐ Ordinance/Zoning ☐ Design ☐ Construction
☐ Program ☐ Education/Outreach ☑ Study ☐ Operations

Project Timeframe:
☐ <1 year ☐ 1-2 years ☐ 2-5 years ☑ 6-10 years ☑ 10+ years

Potential Partnerships
☐ Hospitals ☐ Fire Department ☐ Police Department ☐ FEMA ☐ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☑ National Grid ☐ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☐ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

Technical, Implementation, and Financial Considerations:

Coordination between National Grid, cable companies, Salem, and an engineering firm to come up with a plan that fits the needs of all affected parties will be a challenge. Many coordination meetings and reports may be needed to be produced to voice all sides and possible plans before a final decision is made.

Case Studies:

National Grid, PPL Electric Utilities - NGRID and PPL Electric Utilities both understand that vegetation management is critical to a reliable power grid. Both utilities have existing plans for tree trimming and removing trees that pose a threat of falling and damaging a power line. More information is available at:
https://www.pplelectric.com/about-us/ppl-and-the-environment/vegetation-management/tree-trimming.aspx
https://www.nationalgridus.com/non_html/Important_Info_About_Trees_and_Electric_Service_NE.pdf

Federation of American Scientists (FAS) - Richard Campbell of the Congressional Research Service published a paper on "Weather-Related Power Outages and Electrical System Resiliency." The paper touches on various weather events and their affect on the power grid. The paper also highlights tree trimming as an important preventative measure. More information is available at: http://fas.org/sgp/crs/misc/R42696.pdf

References:

City of Salem, Massachusetts

Adaptation Strategy 27 *Improve Utility and City Communication*

Prioritized Vulnerabilities: **G. Loss of Power at Critical City Buildings (E1)**
I. Downed power lines (E3)

Due to this/these Climate Impact(s):

- ☑ Extreme Heat
- ☐ Sea Level Rise
- ☑ Extreme Precipitation Events
- ☐ Storm Surge

Sector(s):

- ☐ Critical Building
- ☐ Stormwater
- ☐ Drinking Water and
- ☐ Transportation
- ☐ Vulnerable Populations
- ☑ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on improving National Grid's and the City's communication during an event. With expected climate change, there is the possibility of more power outages in the City. In addition, working directly with the utilities may improve the efficiency of turning off electricity and natural gas supplies during emergency situations. Currently, the City speaks with multiple personnel from National Grid when there is a power outage.

The City and National Grid could benefit from having a designated individual handle all utility issues during events. Outages are stressful times for both the City and National Grid. By having a specific point person that handles and delegates all of Salem's needs on National Grid's end, efficiency would improve by reducing the need to re-explain the City's needs to multiple people and avoid confusion.

Adaptation Strategy 27 ***Improve Utility and City Communication***

Primary City Department(s) or Staff: City Electrician, Department of Planning and Community Development

Project Type:
☐ Planning ☐ Ordinance/Zoning ☐ Design ☐ Construction
☐ Program ☐ Education/Outreach ☐ Study ☑ Operations

Project Timeframe:
☐ <1 year ☑ 1-2 years ☐ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships
☐ Hospitals ☐ Fire Department ☐ Police Department ☐ FEMA ☐ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☑ National Grid ☐ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☐ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

Technical, Implementation, and Financial Considerations:

Coordination between National Grid, cable companies, Salem, and an engineering firm to come up with a plan that fits the needs of all affected parties will be a challenge. Many coordination meetings and reports may be needed to be produced to voice all sides and possible plans before a final decision is made.

Case Studies:

Utility Partnership Limited, UK - The Utility Partnership Limited (UPL) provides customers with a single point of contact for power connection and disconnection issues. They act as an intermediary between the customer and the utility company, to ensure the customer's needs are met while only needed to speak to a single individual.

References:

City of Salem, Massachusetts
Adaptation Strategy 28 *Increase Awareness of Climate Change Risks and Safety*

Prioritized Vulnerability: **J. Critical Emergency Preparedness Communication (VP4, VP7, VP19)**

Due to this/these Climate Impact(s):

- ☑ Extreme Heat
- ☐ Sea Level Rise
- ☑ Extreme Precipitation Events
- ☑ Storm Surge

Sector(s):

- ☐ Critical Building Infrastructure
- ☐ Stormwater
- ☐ Drinking Water and Wastewater
- ☐ Transportation
- ☑ Vulnerable Populations
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on preparing the public for climate change risks to protect public safety through public awareness. The impacts of extreme temperatures, extreme precipitation events (including winter storms), and associated storm surges on public health may be lessened if citizens know how to prepare and protect themselves. There are many ways to increase awareness among the citizens of Salem, including:

-Educate citizens regarding the dangers of extreme heat and cold and the steps they may take to protect themselves when extreme temperatures occur.
-Informing the public about severe winter weather impacts.
-Producing and distributing family and traveler emergency preparedness information about severe weather hazards.
-Include safety strategies for severe weather in driver education classes and materials.
-Encourage homeowners (including landlords) to install carbon monoxide monitors and alarms.
-Educate citizens that all fuel-burning equipment should be vented to the outside.

Ideas for increasing flood risk awareness in particular include the following:
-Encourage homeowners to purchase flood insurance.
-Annually distributing flood protection safety pamphlets or brochures to the owners of flood-prone property.
-Educating citizens about safety during flood conditions, including the dangers of driving on flooded roads.
-Use outreach programs to advise homeowners of risks to life, health, and safety.

Adaptation Strategy 28 ***Increase Awareness of Climate Change Risks and Safety***

Primary City Department(s) or Staff: Planning and Community Development, Department of Emergency Management

Project Type:
☑ Planning ☐ Ordinance/Zoning ☐ Design ☐ Construction
☐ Program ☑ Education/Outreach ☐ Study ☐ Operations

Project Timeframe:
☐ <1 year ☑ 1-2 years ☐ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships
☑ Hospitals ☑ Fire Department ☑ Police Department ☑ FEMA ☑ MEMA ☑ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☑ National Grid ☑ Salem Sound Coastwatch
☑ North Shore Community Development Coalition (CDC) ☑ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☐ Conservation Commission
☑ Others: Salem's Renewable Energy Task Force

Adaptation Strategies with Similar Benefits

31 Redundancy of Evacuation Routes

Technical, Implementation, and Financial Considerations:

A public education program on climate change hazard planning may include a combination of media, including press releases, mass email notifications, dedicated space in existing mailings, City website, and social media. Multi-language communication is important to reach the non-English speaking populations in Salem. Costs include the cost to develop and advertise the materials and would vary depending on the size of the program. Marketing could be handled in-house, by a non-profit, or by a consultant.

The neighborhoods around Jefferson Ave, Canal St, and Webb St have experience evacuating quickly before a storm event. Salem may consider leveraging this experience and to share evacuation knowledge among residents.

Case Studies:

StormSmart Coasts - The Massachusetts Office of Coastal Zone Management developed the StormSmart Coasts program that provides information, strategies, and tools to help communities to address the challenges of erosion, flooding, storms, sea level rise, and other climate change impacts. More information is available at: http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/stormsmart-communities/

References:

City of Salem, Massachusetts

Adaptation Strategy 29 *Assist Vulnerable Populations*

Prioritized Vulnerability: **J. Critical Emergency Preparedness Communication (VP4, VP7, VP19)**

Due to this/these Climate Impact(s):

- ☑ Extreme Heat
- ☐ Sea Level Rise
- ☑ Extreme Precipitation Events
- ☑ Storm Surge

Sector(s):

- ☐ Critical Building
- ☑ Stormwater
- ☐ Drinking Water and
- ☑ Transportation
- ☑ Vulnerable Populations
- ☑ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on ensuring vulnerable populations are prepared for climate change and remain safe during a climate change event. Measures may be taken to ensure vulnerable populations are adequately protected from the impacts of extreme temperatures, severe winter storms, and flooding, such as:
-Organize outreach to vulnerable populations, including establishing and promoting accessible heating or cooling centers in the community.
-Require minimum and maximum temperatures in housing/landlord codes.
-Create a database to track those individuals at high risk of death, such as the elderly, homeless, disabled, etc.
-Identify specific at-risk populations that may be exceptionally vulnerable in the event of long-term power outages or flooding events.
-Create social media and neighborhood apps to encourage neighbors to check on or assist vulnerable populations during climate events.

Adaptation Strategy 29 ***Assist Vulnerable Populations***

Primary City Department(s) or Staff: Department of Emergency Management, Department of Planning and Community Development

Project Type:
☑ Planning ☐ Ordinance/Zoning ☐ Design ☐ Construction
☐ Program ☑ Education/Outreach ☐ Study ☐ Operations

Project Timeframe:
☐ <1 year ☑ 1-2 years ☐ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships
☑ Hospitals ☑ Fire Department ☑ Police Department ☑ FEMA ☑ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☑ National Grid ☑ Salem Sound Coastwatch
☑ North Shore Community Development Coalition (CDC) ☑ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☐ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

30 Community Health Impact Assessment and Public Outreach during Poor Air Quality Events
32 Review Local Public Health Care Sectors Readiness

Technical, Implementation, and Financial Considerations:

The first step to assist vulnerable populations is to identify them by their age, risk factor, and place of residence. During hazard events, City officials may target emergency response efforts based on those with the highest risk factor. Communication with vulnerable populations and the neighborhood is key to implementing these strategies.

Case Studies:

Cambridge and Boston, MA - During warm months, the City of Cambridge operates a cooling center and extends the hours of its public swimming pools. The City of Boston has prepared a list of heat emergency tips and facts: http://www.cityofboston.gov/heat/tips.asp

References:

MEMA "Ready Massachusetts" website: http://www.mass.gov/eopss/agencies/mema/ready-massachusetts/

City of Salem, Massachusetts

Adaptation Strategy 30 ***Community Health Impact Assessment and Public Outreach during Poor Air Quality Events***

Prioritized Vulnerability: **K. Poor Air Quality (VP5)**

Due to this/these Climate Impact(s):

- ☑ Extreme Heat Events
- ☐ Extreme Precipitation Events
- ☐ Sea Level Rise
- ☐ Storm Surge

Sector(s):

- ☐ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☑ Vulnerable Populations
- ☐ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on a community health impact assessment and public outreach, focused on poor air quality. Poor air quality may increase the health hazards due to extreme heat events. Higher temperatures favor the formation of ground-level ozone and other secondary air pollutants created from chemical reactions with pollutants directly emitted from power plants, motor vehicles, and other sources. Poor air quality may adversely affect the health of many people, with a disproportionate disease burden among the elderly, children, and those with chronic underlying disease. With the projected increased occurrence of extreme heat events, demand for electric power generation may increase. This may contribute to further degradation of air quality despite efforts to control power plant emissions.

The City may develop a community health impact assessment specifically to understand the relationship between the health risk and poor air quality. The focus of such an assessment may be on the impacts of poor air quality and the extent of the health risk specifically to the vulnerable populations. The health impact assessment program may prepare an inventory of high risk vulnerable groups residing in Salem, MA and identify signs and symptoms of respiratory related health effects to the vulnerable groups. The public outreach program may be used to educate the vulnerable groups and their caregivers to detect these signs and symptoms. To alert the populations of the air quality risks during extreme heat events, the health department may integrate EPA's pre-existing air quality alert program (EnviroFlash). This may enable vulnerable population to take appropriate measures such as restricting outdoor exercise.

Adaptation Strategy 30 *Community Health Impact Assessment and Public Outreach*

Primary City Department(s) or Staff: Health Department

Project Type:
☐ Planning ☐ Ordinance/Zoning ☐ Design ☐ Construction
☑ Program ☑ Education/Outreach ☐ Study ☐ Operations

Project Timeframe:
☐ <1 year ☑ 1-2 years ☐ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships
☑ Hospitals ☐ Fire Department ☐ Police Department ☐ FEMA ☐ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☐ Salem Sound Coastwatch
☑ North Shore Community Development Coalition (CDC) ☑ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☐ Conservation Commission
☑ Others: MA Department of Public Health, local and regional health organizations

Adaptation Strategies with Similar Benefits

28 Increase Awareness of Climate Change Risks and Safety
32 Review Local Public Health Care Sectors Readiness

Technical, Implementation, and Financial Considerations:

Coordination between different city/state public health departments may be challenging. There may be cultural and language barriers that make communications among vulnerable groups difficult. This effort would require additional time and effort required by city officials for public outreach.

Case Studies:

Hamilton, Ontario, Canada - Air Quality and Climate Change Corporate Strategic Plan: This report discusses adaptation to smog and climate change on Page 30.
https://www.fcm.ca/Documents/reports/PCP/Hamilton_Air_Quality_and_Climate_Change_Corporate_Strategic_Plan_EN.pdf

Michigan Department of Public Health - Preparing for Public Health Impacts of Climate Change:
http://www.michigan.gov/mdch/0,1607,7-132-54783_54784_55975---,00.html

References:

EPA EnviroFlash Air Quality Alert Program: http://www.epa.gov/region1/airquality/smogalrt.html

City of Salem, Massachusetts
Adaptation Strategy 31 *Redundancy of Evacuation Routes*

Prioritized Vulnerability: **F. Flooding of Evacuation Routes (VP13, VP18, VP23)**

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☑ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☐ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☑ Vulnerable Populations
- ☐ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on a creating or expanding redundancy in the transportation network in and around Salem. Redundancy allows the transportation network to compensate for losses by ensuring the functionality remains even when network segments are damaged or destroyed. Some areas for consideration include: Rt 1A, Lafayette St, Kernwood St, Bridge St, and Canal St. Redundancy is provided through an integrated multi-modal approach. Identifying and addressing transportation bottlenecks within the system is critical. Designing and implementing redundant evacuation routes facilitates safe and secure movement out of the flooded areas caused by extreme precipitation events, sea level rise, and storm surge.

Adaptation Strategy 31 ***Redundancy of Evacuation Routes***

Primary City Department(s) or Staff: Engineering Department, Department of Public Works, Department of Planning and Community Development , Emergency Management

Project Type:
☑ Planning ☐ Ordinance/Zoning ☐ Design ☐ Construction
☐ Program ☐ Education/Outreach ☑ Study ☐ Operations

Project Timeframe:
☐ <1 year ☐ 1-2 years ☐ 2-5 years ☐ 6-10 years ☑ 10+ years

Potential Partnerships
☐ Hospitals ☑ Fire Department ☑ Police Department ☑ FEMA ☑ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☑ MAPC ☑ MBTA ☐ National Grid ☐ Salem Sound Coastwatch
☑ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☐ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

28 Increase Awareness of Climate Change Risks and Safety

Technical, Implementation, and Financial Considerations:

Capacity and connectivity constraints within the existing network may impede development of alternative evacuation routes. A study may be conducted in order to identify system failures and to develop feasible recommendations for areas where redundancy may be incorporated into the system.

Case Studies:

New York City and Washington D.C. - A redundant multi-modal network enabled thousands to evacuate areas on September 11th:
http://transportationfortomorrow.com/final_report/pdf/volume_3/technical_issue_papers/paper4e_02.pdf

References:

Battelle. 2007. National Surface Transportation Policy and Revenue Study Commission. "Commission Briefing Paper 4E-02: Evaluation of the Systems' Available Redundancy to Compensate for Loss of Transportation Assets Resulting from Natural Disasters or Terrorist Attacks." Evaluation Analysis of Future Issues and Changing Demands on the System; Part E. Security and Emergency Management

Federal Highway Administration, Using Highways for No-Notice Evacuations: Routes to Effective Evacuation Planning Primer Series: http://ops.fhwa.dot.gov/publications/evac_primer_nn/primer.pdf

City of Salem, Massachusetts
Adaptation Strategy 32 *Review Local Public Health Care Sectors Readiness*

Prioritized Vulnerability: **K. Poor Air Quality (VP5)**

Due to this/these Climate Impact(s):

- ☑ Extreme Heat Events
- ☐ Extreme Precipitation Events
- ☐ Sea Level Rise
- ☐ Storm Surge

Sector(s):

- ☐ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☑ Vulnerable Populations
- ☐ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on reviewing the capacity and available resources of local health care providers to handle poor air quality-related diseases and aliments. Poor air quality may increase the health hazards due to extreme heat events. Higher temperatures favor the formation of ground-level ozone and other secondary air pollutants created from chemical reactions with pollutants directly emitted from power plants, motor vehicles, and other sources. Poor air quality may adversely affect the health of many people, with a disproportionate disease burden among the elderly, children, and those with chronic underlying disease.

The City may consider reviewing the capacity and available resources of local health care providers to ensure there are sufficient clinics or hospitals available to care for people during poor air quality events and that the people have the ability to access them. It is also possible to integrate the emergency medical response mechanism with EPA's pre-existing air quality alert program (EnviroFlash) to provide a timely response to high risk groups.

Adaptation Strategy 32 ***Review Local Public Health Care Sectors Readiness***

Primary City Department(s) or Staff: Health Department

Project Type:

☐ Planning ☐ Ordinance/Zoning ☐ Design ☐ Construction
☑ Program ☐ Education/Outreach ☐ Study ☐ Operations

Project Timeframe:

☐ <1 year ☑ 1-2 years ☐ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships

☑ Hospitals ☑ Fire Department ☐ Police Department ☐ FEMA ☐ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☐ Salem Sound Coastwatch
☑ North Shore Community Development Coalition (CDC) ☑ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☐ Conservation Commission
☑ Others: MA Department of Public Health, local and regional health organizations

Adaptation Strategies with Similar Benefits

29 Assist Vulnerable Populations
30 Community Health Impact Assessment and Public Outreach during Poor Air Quality Events

Technical, Implementation, and Financial Considerations:

Coordination between different city/state public health departments and medical organizations may be challenging.

Case Studies:

Hamilton, Ontario, Canada - Air Quality and Climate Change Corporate Strategic Plan: This report discusses adaptation to smog and climate change.
https://www.fcm.ca/Documents/reports/PCP/Hamilton_Air_Quality_and_Climate_Change_Corporate_Strategic_Plan_EN.pdf

References:

EPA EnviroFlash Air Quality Alert Program: http://www.epa.gov/region1/airquality/smogalrt.html

City of Salem, Massachusetts

Adaptation Strategy 33 *Promote and Expand Urban Forestry*

Prioritized Vulnerability: **K. Poor Air Quality (VP5)**

Due to this/these Climate Impact(s):

- ☑ Extreme Heat Events
- ☐ Extreme Precipitation Events
- ☐ Sea Level Rise
- ☐ Storm Surge

Sector(s):

- ☐ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☑ Vulnerable Populations
- ☐ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on increasing the urban forest canopy in Salem. Urban forestry helps improve air quality. Trees have the ability to absorb air pollutants to improve local air quality. In addition, urban forests also provide economic benefits, aesthetic value, sequester carbon dioxide, improve water quality, provide health benefits and wildlife habitats. Trees may help mitigate stormwater related flooding issues and erosion. Shading from trees may reduce energy loads in the summer. The City may increase tree planning activities and consider partnership with local or regional agencies to coordinate tree planting in areas with populations sensitive to poor air quality.

A GIS layer or map of existing city trees may be a first step to understanding where the urban canopy may be improved in Salem. Another component may be a phone or online reporting system for citizens to report damage to trees, downed limbs, exposed roots, etc. This may assist the City in maintaining the health of existing trees.

Adaptation Strategy 33 ***Promote and Expand Urban Forestry***

Primary City Department(s) or Staff: Department of Public Works, Department of Planning and Community Development

Project Type:

☐ Planning ☐ Ordinance/Zoning ☐ Design ☐ Construction
☑ Program ☐ Education/Outreach ☐ Study ☐ Operations

Project Timeframe:

☑ <1 year ☐ 1-2 years ☐ 2-5 years ☐ 6-10 years ☐ 10+ years

Potential Partnerships

☐ Hospitals ☐ Fire Department ☐ Police Department ☐ FEMA ☐ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☑ North Shore Community Development Coalition (CDC) ☑ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☑ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

17 Green Infrastructure - Bioretention/Street Planters
22 Increase Energy Efficiency in Critical City Buildings

Technical, Implementation, and Financial Considerations:

The City may consider working with the school district to involve students in the planting. This would provide educational opportunities and outreach, while reducing costs. Also consider the location of newly planted trees to minimize any financial and safety issues associated with downed trees during extreme weather events.

Case Studies:

New York, NY Million Trees - New York City's urban tree planting program has found multiple environmental and health benefits http://www.milliontreesnyc.org/html/home/home.shtml

References:

Urban Forestry Network: http://urbanforestrynetwork.org/benefits/air%20quality.htm

Seattle, WA Canopy Cover website: http://www.seattle.gov/trees/canopycover.htm

City of Salem, Massachusetts

Adaptation Strategy 34 — *Evaluation of Buildings for Flood Proofing Opportunities*

Prioritized Vulnerabilities:

L. Property damage or loss of emergency and critical city facilities (CB2, CB6, CB14, W13)
O. Property damage or loss of historic properties (CB4, CB9, CB17)
M. Property damage or loss at Salem State University (CB15)
N. Flooding of emergency response facilities (VP14, VP24)
P. Flooding of residential areas (VP15, VP20)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☑ Sea Level Rise
- ☑ Extreme Precipitation Events
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☐ Stormwater
- ☐ Drinking Water and Wastewater
- ☑ Transportation
- ☐ Vulnerable Populations
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on evaluating buildings for flood proofing opportunities. This is applicable to all buildings, including:
-Emergency and critical buildings: Department of Public Works, Police Headquarters, Fire Headquarters and Stations 5, City Hall, South Essex Sewerage District, schools serving as emergency shelters
-Residential and commercial properties near: Rt 1A, The Point, the Willows neighborhood, Pioneer Terrace, Lafayette St, Kernwood St, Emerton St, Forester St, Commercial St, Canal St
-Historic areas and properties: Fort Lee, Salem Commons, Emerton St, Forester St, Derby Wharf, Bridge St, Maritime Historic District, House of Seven Gables, Custom House and Bonded Warehouse
-Institutional properties: Salem State's Central, North, and South campuses, the O'Keefe Center, Salem Academy Charter School, Carlton School, Bentley School, Salem Early Childhood School

A flood proofing evaluation may include:
-Assessing the building strength to determine if it may withstand flooding-forces.
-Understanding the likely flooding characteristics, such as the length of time a building is expected to flood.
-Determining the building location within established or future flooding areas.
-Operational and maintenance initiatives that would to ensure flood proofing options are kept in working order.
-Evaluating the utilities and critical operations in the building to see if they are at risk for flooding.

There are many codes and standards that the City may consider adopting to strengthen the ability to evaluate flood proofing opportunities. Some examples include:
-The International Building Code (IBC) and the International Residential Code (IRC).
-Incorporate higher standards for hazard resistance in localized code amendments.
-ASCE/SEI 7 Minimum Design Loads For Buildings and Other Structures.
-ASCE 24-05 Flood Resistance Design and Construction.

Adaptation Strategy 34 ***Evaluation of Buildings for Flood Proofing Opportunities***

Primary City Department(s) or Staff: Engineering Department, Department of Planning and Community Development , Inspectional Services

Project Type:
☑ Planning ☑ Ordinance/Zoning ☐ Design ☐ Construction
☐ Program ☐ Education/Outreach ☑ Study ☑ Operations

Project Timeframe:
☐ <1 year ☐ 1-2 years ☐ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships
☑ Hospitals ☑ Fire Department ☑ Police Department ☑ FEMA ☐ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☑ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

35 Development of New Critical Use Facilities Outside Future Flooding Levels
36 Re-Development Existing Facilities Outside Future Flooding Levels
37 Elevate the Building
38 Elevate a Building's Critical Uses
39 Adopt and Enforce Updated Building Codes
40 Limit or Restrict Development in Future Flooding Areas
42 Flood Proof Buildings

Technical, Implementation, and Financial Considerations:

Evaluation of the potential costs of flood proofing should be considered before moving forward. The cost of flood proofing buildings depends on many factors, such as the size of the building, the height of flood protection to be implemented, they types of materials used, and the number of openings where flood waters could enter a building.

Case Studies:

<u>Tulane Medical Center, New Orleans, LA</u> - Tulane Medical Center followed FEMA's dry flood proofing guidance to install shields, doors, and reinforced walls to protect critical assets from flooding damage.

References:

FEMA, 2013, Flood proofing Non-Residential Buildings P-936, Table 1-1.

FEMA presentation on dry flood proofing measures:
http://www.floods.org/Files/Conf2013_ppts/H4B/H4B_Ingargiola_FEMA936.pdf

City of Salem, Massachusetts

Adaptation Strategy 35 ***Development of New Critical Use Facilities Outside Future Flooding Levels***

Prioritized Vulnerabilities:

L. Property damage or loss of emergency and critical city facilities (CB2, CB6, CB14, W13)
M. Property damage or loss at Salem State University (CB15)
N. Flooding of emergency response facilities (VP14, VP24)
P. Flooding of residential areas (VP15, VP20)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☑ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☐ Stormwater
- ☑ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on locating critical use buildings outside of future flooding areas. Critical use buildings are those essential to a community's resiliency and sustainability. Critical uses within a building may include:
-Emergency response equipment- phones, supplies, back-up batteries
-Response and maintenance vehicles – DPW, Fire, Police ambulance
-Vehicle fueling stations

Retaining the function of these critical use buildings is the goal of this strategy. The proper site selection is the best solution for avoiding the devastation and costly effects of flooding. In some cases, relocating a critical public service or use into an area that is not expected to flood in the future, could be more cost effective than to design or modify such a facility located in a future flood area. The City may consider if the critical uses within a building could be relocated into another building (outside the future flood area) and serve the same function.

This may be applicable to the critical uses in buildings and properties such as:
-Emergency and critical buildings: Department of Public Works, Police Headquarters, Fire Headquarters and Stations 5, City Hall, schools serving as emergency shelters
-Residential and commercial properties near: Rt 1A, The Point, the Willows neighborhood, Pioneer Terrace, Lafayette St, Kernwood St, Emerton St, Forester St, Commercial St, Canal St
-Institutional properties: Salem State's Central, North, and South campuses, the O'Keefe Center, Salem Academy Charter School, Carlton School, Bentley School, Salem Early Childhood School

Adaptation Strategy 35 ***Development of New Critical Use Facilities Outside Future***

Primary City Department(s) or Staff: Engineering Department, Inspectional Services, Emergency Management Department, Department of Planning and Community Development

Project Type:
☑ Planning ☑ Ordinance/Zoning ☐ Design ☐ Construction
☐ Program ☐ Education/Outreach ☑ Study ☑ Operations

Project Timeframe:
☐ <1 year ☐ 1-2 years ☐ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships
☑ Hospitals ☑ Fire Department ☑ Police Department ☑ FEMA ☐ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☑ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☑ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

34 Evaluation of Buildings for Flood Proofing Opportunities
36 Re-Development Existing Facilities Outside Future Flooding Levels
37 Elevate the Building
38 Elevate a Building's Critical Uses
39 Adopt and Enforce Updated Building Codes
40 Limit or Restrict Development in Future Flooding Areas
42 Flood Proof Buildings

Technical, Implementation, and Financial Considerations:

FEMA has developed guidelines for the design and construction of utilities and buildings in flood prone locations. The manuals are written for the use of architects, engineers, builders, code officials, and property owners. These guidelines include incorporating proper site selection, elevation higher than flooding levels, ensuring that important services (electrical, communication, water and wastewater treatment) within the building are appropriate sited outside of future flood levels, and that necessary man-made flood controls are protecting the structure.

Case Studies:

References:

FEMA, 1999, Principle and Practices for the Design and Construction of Flood Resistant Building Utility Systems (FEMA 384).

FM Global, 2014, Property Loss Prevention Data Sheet 1-40, Flood. Section 2.2.4.5.

FEMA, 2013, Flood proofing Non-Residential Buildings P-936.

City of Salem, Massachusetts

Adaptation Strategy 36 *Re-Development Existing Facilities Outside Future Flooding Levels*

Prioritized Vulnerabilities:

L. Property damage or loss of emergency and critical city facilities (CB2, CB6, CB14, W13)
O. Property damage or loss of historic properties (CB4, CB9, CB17)
M. Property damage or loss at Salem State University (CB15)
N. Flooding of emergency response facilities (VP14, VP24)
P. Flooding of residential areas (VP15, VP20)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☑ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☐ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☐ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on relocating buildings outside of future flooding areas, especially small structures or historic properties. By relocating properties into future non-flood areas, the City may avoid the extreme alterations required to protect the structure, risking loss of significant historic character. Additionally, a flood protection strategy or elevation strategy could be more expensive than relocating. This strategy is to be considered for smaller structures due to the significant constraints and engineering considerations necessary to move a structure.

Properties for possible consideration include:
-Emergency and critical buildings: Department of Public Works, Police Headquarters, Fire Headquarters and Stations 5, City Hall, schools serving as emergency shelters
-Residential and commercial properties near: Rt 1A, The Point, the Willows neighborhood, Pioneer Terrace, Lafayette St, Kernwood St, Emerton St, Forester St, Commercial St, Canal St
-Historic areas and properties: Fort Lee, Salem Commons, Emerton St, Forester St, Derby Wharf, Bridge St, Maritime Historic District, House of Seven Gables, Custom House and Bonded Warehouse
-Institutional properties: Salem State's Central, North, and South campuses, the O'Keefe Center, Salem Academy Charter School, Carlton School, Bentley School, Salem Early Childhood School

Adaptation Strategy 36 Re-Development Existing Facilities Outside Future Flooding Levels

Primary City Department(s) or Staff: Engineering Department, Inspectional Services

Project Type:

☑ Planning ☑ Ordinance/Zoning ☐ Design ☐ Construction
☐ Program ☐ Education/Outreach ☑ Study ☑ Operations

Project Timeframe:

☐ <1 year ☐ 1-2 years ☐ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships

☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☑ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☑ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☑ Conservation Commission
☑ Others: Historical Commission, Salem Chamber of Commerce

Adaptation Strategies with Similar Benefits

34 Evaluation of Buildings for Flood Proofing Opportunities
35 Development of New Critical Use Facilities Outside Future Flooding Levels
37 Elevate the Building
38 Elevate a Building's Critical Uses
39 Adopt and Enforce Updated Building Codes
40 Limit or Restrict Development in Future Flooding Areas
42 Flood Proof Buildings

Technical, Implementation, and Financial Considerations:

The transportation routes to move the structure need to be considered carefully. The most important factor in moving a structure is getting it from A to B. Most movers can pick up any size structure but if there are obstaclesin the path, such as trees, street lights, utilities, curves, overpasses or narrow roads, the task may not be feasible.

Additional considerations for moving a structure:
-Acquiring the land where the structure will be placed
-Building a new foundation for the structure
-Permitting and inspection costs
-Fees for plumbers and electricians to disconnect and reconnect major utilities in the building
-Renovation costs, particularly if the City requires the structure to be brought up to all current building codes

Case Studies:

References:

FEMA, 1999, Principle and Practices for the Design and Construction of Flood Resistant Building Utility Systems (FEMA 384).

FM Global, 2014, Property Loss Prevention Data Sheet 1-40, Flood. Section 2.2.4.5.

FEMA, 2013, Flood proofing Non-Residential Buildings P-936.

City of Salem, Massachusetts
Adaptation Strategy 37 *Elevate the Building*

Prioritized Vulnerabilities:

L. Property damage or loss of emergency and critical city facilities (CB2, CB6, CB14, W13)
M. Property damage or loss at Salem State University (CB15)
N. Flooding of emergency response facilities (VP14, VP24)
P. Flooding of residential areas (VP15, VP20)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☑ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☐ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on understanding the future flood areas and designing the new structure so it is raised and out of risk. One engineering approach is to elevate the existing buildings and their critical systems. This requires understanding the future flood area and the appropriate building elevation.

Structures should be examined by a structural engineer. When necessary, modifications may be made to resist all flood-related loads and conditions, including hydrostatic loads, break wave action debris impact, and rapid rise and drawdown of water. The engineer may determine the appropriate foundation system depending on the future flood levels. These may include open foundations, fill, pilings, columns, stem wall or slabs.

Careful consideration should be given to the placement of critical building systems in both existing and new buildings. Doors, windows, and other openings below the future flooding levels may be detailed to eliminate the need for flood shields when possible. If this is not feasible through design, permanent flood shields may be incorporated. Stairs and/or ramps could ensure that the important building uses or functions are accessible.

There are many codes that the City may consider adopting to strengthen the foundation systems. Some examples for consideration include:
-Require open foundation such as piles or piers
-Require deep foundations in order to avoid erosion and scour
-Require a calculated percentage of open wall area on floors that are located in the future flooding levels

Properites at risk that may be considered for this strategy include:
-Emergency and critical buildings: Department of Public Works, Police Headquarters, Fire Headquarters and Stations 5, City Hall, schools serving as emergency shelters
-Residential and commercial properties near: Rt 1A, The Point, the Willows neighborhood, Pioneer Terrace, Lafayette St, Kernwood St, Emerton St, Forester St, Commercial St, Canal St
-Institutional properties: Salem State's Central, North, and South campuses, the O'Keefe Center, Salem Academy Charter School, Carlton School, Bentley School, Salem Early Childhood School

Adaptation Strategy 37 *Elevate the Building*

Primary City Department(s) or Staff: Engineering Department, Emergency Management Department, Inspectional Services

Project Type:
☑ Planning ☑ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☑ Study ☐ Operations

Project Timeframe:
☐ <1 year ☐ 1-2 years ☐ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships
☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☐ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☑ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☑ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☑ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

34 Evaluation of Buildings for Flood Proofing Opportunities
35 Development of New Critical Use Facilities Outside Future Flooding Levels
36 Re-Development Existing Facilities Outside Future Flooding Levels
38 Elevate a Building's Critical Uses
39 Adopt and Enforce Updated Building Codes
40 Limit or Restrict Development in Future Flooding Areas
42 Flood Proof Buildings

Technical, Implementation, and Financial Considerations:

FEMA requires that equipment and system components be above flooding levels. This may be done by putting equipment and system components on pedestals, platforms or fill, suspending systems from structural elements or moving them to upper floors or attics. Another option is to ensure equipment and system components are in watertight enclosures, protective utility shafts, or have anchoring systems. Coastal Resiliency grants and funding sources may be available.

Case Studies:

Texas Medical Center, Houston, TX - The University of Texas implemented a perimeter wall and dry flood proofing project at the Texas Medical Center after Tropical Storm Allison flooded the basement and first flood of the facility, causing $205 million in damages. As part of the project, they reinforced or replaced concrete walls, installed flood doors, and retrofitted windows with flood proof glass. More information may be found at: http://www.fema.gov/media-library-data/9a50c534fc5895799321dcdd4b6083e7/P-936_8-20-13_508r.pdf

References:

FEMA, 1999, Principle and Practices for the Design and Construction of Flood Resistant Building Utility Systems (FEMA 384).

FM Global, 2014, Property Loss Prevention Data Sheet 1-40, Flood. Section 2.2.4.5.

FEMA, 2013, Flood proofing Non-Residential Buildings P-936.

City of Salem, Massachusetts
Adaptation Strategy 38 *Elevate a Building's Critical Uses*

Prioritized Vulnerabilities:

L. Property damage or loss of emergency and critical city facilities (CB2, CB6, CB14, W13)
O. Property damage or loss of historic properties (CB4, CB9, CB17)
M. Property damage or loss at Salem State University (CB15)
N. Flooding of emergency response facilities (VP14, VP24)
P. Flooding of residential areas (VP15, VP20)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☑ Extreme Precipitation Events
- ☑ Sea Level Rise
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☐ Drinking Water and Wastewater
- ☐ Vulnerable Populations
- ☐ Stormwater
- ☐ Transportation
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on understanding the future flood level and elevating the critical uses within the building. In existing buildings, utility equipment that is critical for functionality may be relocated to higher floors or elevated additions. Most building systems may be divided into two components: 1) main equipment and 2) distribution. For example, it is recommended that HVAC systems and equipment (compressors, condensers, heat pump, furnaces, boilers, etc.) be strapped or bolted onto platforms above the future flood levels. The strapping or bolting may be designed to withstand wind and other forces. The City may also consider elevating supporting distribution systems (ducts, supply lines, and piping) within the facilities. This may be accomplished by hanging ducts from the bottom of the lowest floor or crawl space ceiling so that the bottom of the duct is less likely to flood.

Properites at risk that may be considered for this strategy include:
-Emergency and critical buildings: Department of Public Works, Police Headquarters, Fire Headquarters and Stations 5, City Hall, schools serving as emergency shelters
-Residential and commercial properties near: Rt 1A, The Point, the Willows neighborhood, Pioneer Terrace, Lafayette St, Kernwood St, Emerton St, Forester St, Commercial St, Canal St
-Institutional properties: Salem State's Central, North, and South campuses, the O'Keefe Center, Salem Academy Charter School, Carlton School, Bentley School, Salem Early Childhood School

Adaptation Strategy 38 ***Elevate a Building's Critical Uses***

Primary City Department(s) or Staff: Engineering Department, Department of Public Works, Emergency Management Department, Inspectional Services

Project Type:
☑ Planning ☑ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☑ Study ☐ Operations

Project Timeframe: ☐ <1 year ☐ 1-2 years ☐ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships
☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☐ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☐ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☐ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

23 Install and Elevate Backup Power Sources
24 Install Renewable Energy Backup Power Sources
34 Evaluation of Buildings for Flood Proofing Opportunities
35 Development of New Critical Use Facilities Outside Future Flooding Levels
36 Re-Development Existing Facilities Outside Future Flooding Levels
37 Elevate the Building
39 Adopt and Enforce Updated Building Codes
40 Limit or Restrict Development in Future Flooding Areas
42 Flood Proof Buildings

Technical, Implementation, and Financial Considerations:

FEMA requires that equipment and system components be above flooding levels. This may be done by putting equipment's and system components on pedestals, platforms or fill, suspending systems from structural elements or moving them to upper floors or attics. Another option is to ensure equipment and system components are in watertight enclosures, protective utility shafts, and anchoring systems.

Case Studies:

Spaulding Rehabilitation Hospital, Boston, MA - The Spaulding Rehabilitation Hospital designed the new facility in the Charlestown Navy Yard, to be prepared for climate change. For example, the main primary electrical services are located on the roof of the building to protect it from flooding. In addition, these electrical services are powered by a fuel pump which is secured in a flood-proof vault with a 150,000 gallon tank. These measures will allow the hospital to be functional during a flooding event. More information is available at: http://www.spauldingrehab.org/about/news-events/Spaulding-Hospital-Unveils

References:

FEMA, 1999, Principle and Practices for the Design and Construction of Flood Resistant Building Utility Systems (FEMA 384).

FM Global, 2014, Property Loss Prevention Data Sheet 1-40, Flood. Section 2.2.4.5.

FEMA, 2013, Flood proofing Non-Residential Buildings P-936.

City of Salem, Massachusetts

Adaptation Strategy 39 Adopt and Enforce Updated Building Codes

Prioritized Vulnerabilities:
L. Property damage or loss of emergency and critical city facilities (CB2, CB6, CB14, W13)
N. Flooding of emergency response facilities (VP14, VP24)
P. Flooding of residential areas (VP15, VP20)
M. Property damage or loss at Salem State University (CB15)

Due to this/these Climate Impact(s):
☐ Extreme Heat
☑ Sea Level Rise
☑ Extreme Precipitation
☑ Storm Surge

Sector(s):
☑ Critical Building
☑ Stormwater
☑ Drinking Water and
☑ Transportation
☑ Vulnerable Populations
☑ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on adopting and enforcing building codes to prevent or manage flooding. Buildings and infrastructure may be protected from the impacts of extreme precipitation, sea level rise, and storm surge with the following regulations. The City may consider any of the following actions:
-Adopt the International Building Code (IBC) and International Residential Code (IRC).
-Increase the local Building Code Effectiveness Grading Schedule (BCEGS) classification through higher building code standards and enforcement practices.
-Incorporate higher standards for hazard resistance in local application of the building code.
-Provide advanced training to local building inspectors.
-Establish “value-added” incentives for hazard-resistant construction practices beyond code requirements.
-Ensure the development and enforcement of building codes for roof snow loads.
-Discourage flat roofs in areas that experience heavy snows.
-Adopt ASCE-24-05 Flood Resistant Design and Construction.
-ASCE/SEI 7 Minimum Design Loads For Buildings and Other Structures.
-Establish design standards for buildings located in areas susceptible to storm surge.
-Adopt building requirements for higher elevation in inundation zones.
-Require open foundations (e.g., piles or piers) in coastal areas.
-Require deep foundations in order to avoid erosion and scour.
-Prohibit all first floor enclosures below base flood elevation for all structures in flood hazard areas.
-Set the design flood elevation at or above expected future flooding levels.

Stricter building codes for new construction and existing facilities may help the City protect its building stock from flooding as well as wind, and prolonged power outage. Targeted strategies include building code legislation changes, adjustments to zoning regulations, incentive programs, and best practices guides. The goal is to adopt new codes that will help to prevent flooding or allow flooded areas to bounce back from an event more quickly.

The areas where this may be most effective are generally near the coast, rivers, or canals, including: The Willows, Emerton St, Forester St, Bridge St, Canal St, and The Point.

Adaptation Strategy 39 Adopt and Enforce Updated Building Codes

Primary City Department(s) or Staff: Department of Planning and Community Development , Inspection Services Department, Legal Department

Project Type:

☑ Planning ☑ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☐ Study ☐ Operations

Project Timeframe:

☐ <1 year ☐ 1-2 years ☐ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships

☐ Hospitals ☑ Fire Department ☐ Police Department ☐ FEMA ☐ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☑ MBTA ☐ National Grid ☐ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☑ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

34 Evaluation of Buildings for Flood Proofing Opportunities
35 Development of New Critical Use Facilities Outside Future Flooding Levels
36 Re-Development Existing Facilities Outside Future Flooding Levels
37 Elevate the Building
38 Elevate a Building's Critical Uses
40 Limit or Restrict Development in Future Flooding Areas
42 Flood Proof Buildings

Technical, Implementation, and Financial Considerations:

The City may review model building codes from the International Building Code (IBC) and International Residential Code (IRC) to determine if they are appropriate to adopt the model code outright as their own or with amendments and additional rules. A working group of city staff, developers, and building inspectors may be formed to inform decisions.

Case Studies:

New York City - As part of New York City's "A Stronger, More Resilient New York," New York City is proposing targeted strategies to improve building codes for new construction and existing buildings: http://www.nyc.gov/html/planyc/html/resiliency/stronger-buildings.shtml

References:

International Code Council: http://www.iccsafe.org/Pages/default.aspx

American Society of Civil Engineers: http://ascelibrary.org/

Building Code Effectiveness Grading Schedule: http://www.isomitigation.com/bcegs/0000/bcegs0001.html

City of Salem, Massachusetts

Adaptation Strategy 40 *Limit or Restrict Development in Future Flooding Areas*

Prioritized Vulnerabilities:

L. Property damage or loss of emergency and critical city facilities (CB2, CB6, CB14, W13)
N. Flooding of emergency response facilities (VP14, VP24)
P. Flooding of residential areas (VP15, VP20)
M. Property damage or loss at Salem State University (CB15)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat
- ☑ Sea Level Rise
- ☑ Extreme Precipitation Events
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☑ Stormwater
- ☐ Drinking Water and Wastewater
- ☑ Transportation
- ☑ Vulnerable Populations
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on limiting or restricting residential development in future flooding areas.
Flooding may be mitigated by limiting or restricting how new or re-development occurs in future flooding areas through actions such as:
-Prohibit or limit future flooding area development through regulatory and/or incentive-based measures.
-Limit the density of developments in the future flooding area.
-Require that future flooding area be kept as open space.
-Limit the percentage of allowable impervious surface within developed parcels.
-Develop a stream buffer ordinance to protect water resources and limit flood impacts.
-Prohibit any fill in future flooding areas.

Coastal erosion setbacks, sea level rise, increase coastal flood and surge elevations, and building elevations are examples of what may be considered in flood-related ordinances. The first step is to review the existing regulations and zoning ordinance, review historical flood events and insurance claims, review future flooding levels, and determine implications to tax base and private property rights.

The areas where this may be most effective are generally near the coast, rivers, or canals, including: The Willows, Emerton St, Forester St, Bridge St, Canal St, and The Point.

Adaptation Strategy 40 — Limit or Restrict Development in Future Flooding Areas

Primary City Department(s) or Staff: Department of Planning and Community Development , Housing Authority, Legal Department

Project Type:
- ☑ Planning ☑ Ordinance/Zoning ☑ Design ☑ Construction
- ☐ Program ☐ Education/Outreach ☐ Study ☐ Operations

Project Timeframe: ☐ <1 year ☐ 1-2 years ☑ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships
- ☐ Hospitals ☐ Fire Department ☐ Police Department ☐ FEMA ☐ MEMA ☑ Neighboring Cities
- ☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
- ☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
- ☐ Private Property Owners ☑ Conservation Commission
- ☑ Others: MA Coastal Zone Management, Massachusetts Bays National Estuary Program

Adaptation Strategies with Similar Benefits

34 Evaluation of Buildings for Flood Proofing Opportunities
35 Development of New Critical Use Facilities Outside Future Flooding Levels
36 Re-Development Existing Facilities Outside Future Flooding Levels
37 Elevate the Building
38 Elevate a Building's Critical Uses
39 Adopt and Enforce Updated Building Codes
42 Flood Proof Buildings

Technical, Implementation, and Financial Considerations:

In developing future flooding area regulations, the City may consider the floodplain management measures required to participate in the National Flood Insurance Program (NFIP) and expand on these to account for future flooding. A robust public outreach and education campaign to solicit community feedback is important to mediate potential challenges.

Case Studies:

Model By-Law - A model bylaw for effectively managing coastal floodplain development was developed in partnership between the Woods Hole Sea Grant, Cape Cod Commission, and the University of Hawaii Sea Grant: http://nsgl.gso.uri.edu/hawau/hawaut09001.pdf

References:

WHOI Sea Grant, CCC, UH Sea Grant. 2009. Model Coastal Floodplain Development Bylaw. Available at: http://nsgl.gso.uri.edu/hawau/hawaut09001.pdf

City of Salem, Massachusetts

Adaptation Strategy 41 *Improve Land Use Planning and Regulations*

Prioritized Vulnerabilities: **L. Property damage or loss of emergency and critical city facilities (CB2, CB6, CB14, W13)**
N. Flooding of emergency response facilities (VP14, VP24)
P. Flooding of residential areas (VP15, VP20)
M. Property damage or loss at Salem State University (CB15)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat
- ☑ Sea Level Rise
- ☑ Extreme Precipitation
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building
- ☑ Stormwater
- ☑ Drinking Water and
- ☑ Transportation
- ☑ Vulnerable Populations
- ☑ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on improving land use planning and regulations to prevent or manage flooding. Land uses may be planned and regulated to minimize the impact of storm surge and mitigate future losses resulting from extreme precipitation events and sea level rise. Possible measures to implement include:

-Adopt shoreline setback regulations and establish coastal setback lines.
-Adopt coastal zone management regulations.
-Plan for future storm surge heights due to sea level rise.
-Limit or prohibit development in areas along the coast subject to inundation by the future storm surge flood event.
-Locate future critical facilities outside of areas susceptible to storm surge.
-Require that all critical facilities at least meet requirements of Executive Order 11988 and be built 1 foot above the 500-year flood elevation (considering wave action) or even higher to take into account future flooding levels.
-Use zoning, subdivision regulations, and/or a sea level rise and storm surge overlay district to designate high-risk areas and specify the conditions for the use and development of specific areas.
-Promote conservation and management of open space, wetlands, and/or sea level rise boundary zones to separate developed areas from high-hazard areas.
-Prohibit the redevelopment of areas destroyed by storms or chronic erosion in order to prevent future losses.
-Establish setbacks in high-risk areas that account for potential sea level rise.
-Acquire and use easements (e.g., conservation) to prevent development in known hazard areas.
-Incorporate low-impact development techniques.

The areas where this may be most effective are generally near the coast, rivers, or canals, including: The Willows, Emerton St, Forester St, Bridge St, Canal St, and The Point.

Adaptation Strategy 41 *Improve Land Use Planning and Regulations*

Primary City Department(s) or Staff: Department of Planning and Community Development , Legal Department

Project Type:
- ☑ Planning ☑ Ordinance/Zoning ☑ Design ☑ Construction
- ☐ Program ☐ Education/Outreach ☐ Study ☑ Operations

Project Timeframe: ☐ <1 year ☐ 1-2 ☑ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships
- ☐ Hospitals ☐ Fire Department ☐ Police Department ☐ FEMA ☐ MEMA ☑ Neighboring Cities
- ☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
- ☑ North Shore Community Development Coalition ☑ Salem Alliance for the Environment (SAFE)
- ☐ Private Property Owners ☑ Conservation Commission
- ☐ Others:

Adaptation Strategies with Similar Benefits

39 Adopt and Enforce Updated Building Codes
40 Limit or Restrict Development in Future Flooding Areas

Technical, Implementation, and Financial Considerations:

Land use planning tools and regulations vary by type (planning, regulatory, spending, or tax and market-based tool), policy objective (protection, accommodation, preservation, retreat), and type of land uses that the tool may be used to adapt (critical infrastructure, existing development, developable lands, and undevelopable lands). The City may review excising land use policies and regulations and study the legal and administrative feasibility of improving or implementing new tools.

Case Studies:

Planning Tools - The Georgetown Climate Center produced a comprehensive summary of land use planning tools available to local governments to adapt to sea-level rise. More information is available at: http://www.southernclimate.org/pages/data-tools

References:

MA Smart Growth/Smart Energy Toolkit: http://www.mass.gov/envir/smart_growth_toolkit/pages/mod-lid.html

City of Salem, Massachusetts
Adaptation Strategy 42 *Flood Proof Buildings*

Prioritized Vulnerabilities:

L. Property damage or loss of emergency and critical city facilities (CB2, CB6, CB14, W13)
O. Property damage or loss of historic properties (CB4, CB9, CB17)
M. Property damage or loss at Salem State University (CB15)
N. Flooding of emergency response facilities (VP14, VP24)
P. Flooding of residential areas (VP15, VP20)

Due to this/these Climate Impact(s):

- ☐ Extreme Heat Events
- ☑ Sea Level Rise
- ☑ Extreme Precipitation Events
- ☑ Storm Surge

Sector(s):

- ☑ Critical Building Infrastructure
- ☐ Stormwater
- ☐ Drinking Water and Wastewater
- ☐ Transportation
- ☐ Vulnerable Populations
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on flood proofing to protect the existing buildings, critical systems and equipment. There are two techniques for flood proofing a building: "dry flood proofing" and "wet flood proofing". "Dry flood proofing" is applied to building entrances, windows and surrounding equipment rooms located within the flood prone area. The goal is to seal a building to ensure that a building is watertight from floodwaters such as with flood panels for interior spaces. An effective dry flood proofing retrofit may include the following steps:

-Detailed site evaluation
-Detailed building evaluation
-Careful evaluation of all of the dry flood proofing measures, including a consideration of residual risk
-Design by a qualified registered design professional
-Verification/testing that the constructed systems provide the desired flood proofing effectiveness
-Flood proofing certificate for non-residential structures for the dry flood proofing design
-A plan for deploying any active dry flood proofing measures that require human intervention
-Sufficient warning time to deploy active dry flood proofing measures and vacate the building

"Wet flood proofing" is another method were water is allowed to enter into the structure intentionally. Wet flood proofing allows the water to equalize on both sides of the wall, reducing the risk of structural damage. This method requires that all critical utilities be raised or protected by curbs and water tight enclosures. The use of flood-damage-resistant materials and construction techniques are used to minimize the effects of flooding. The design may consider replacing building material with materials that clean-up easily and are less likely to be damaged from water.

These concepts may be considered for buildings, fueling stations, transformers, or any fixed equipment that must remain in the flood zone. Ultimately, the goal is to provide the most effective level of flood protection for all critical building systems and spaces.

Critical structures should be examined by a structural engineer. When necessary, modifications may be made to resist all flood-related loads and conditions, including hydrostatic loads, break wave action debris impact, rapid rise and drawdown of water.

(continued on next page)

Adaptation Strategy 42 ***Flood Proof Buildings***

Primary City Department(s) or Staff: Engineering Department, Inspectional Services

Project Type:
☑ Planning ☑ Ordinance/Zoning ☑ Design ☑ Construction
☑ Program ☐ Education/Outreach ☐ Study ☑ Operations

Project Timeframe:
☐ <1 year ☐ 1-2 years ☐ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships
☐ Hospitals ☐ Fire Department ☐ Police Department ☑ FEMA ☐ MEMA ☐ Neighboring Cities
☐ EPA ☐ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☑ North Shore Community Development Coalition (CDC) ☑ Salem Alliance for the Environment (SAFE)
☑ Private Property Owners ☐ Conservation Commission
☐ Others:

Adaptation Strategy Description, continued:

This is applicable to all buildings, including:
-Emergency and critical buildings: Department of Public Works, Police Headquarters, Fire Headquarters and Stations 5, City Hall, South Essex Sewerage District, schools serving as emergency shelters
-Residential and commercial properties near: Rt 1A, The Point, the Willows neighborhood, Pioneer Terrace, Lafayette St, Kernwood St, Emerton St, Forester St, Commercial St, Canal St
-Historic areas and properties: Fort Lee, Salem Commons, Emerton St, Forester St, Derby Wharf, Bridge St, Maritime Historic District, House of Seven Gables, Custom House and Bonded Warehouse
-Institutional properties: Salem State's Central, North, and South campuses, the O'Keefe Center, Salem Academy Charter School, Carlton School, Bentley School, Salem Early Childhood School

Adaptation Strategies with Similar Benefits

34 Evaluation of Buildings for Flood Proofing Opportunities
35 Development of New Critical Use Facilities Outside Future Flooding Levels
36 Re-Development Existing Facilities Outside Future Flooding Levels
37 Elevate the Building
38 Elevate a Building's Critical Uses
39 Adopt and Enforce Updated Building Codes
40 Limit or Restrict Development in Future Flooding Areas

Technical, Implementation, and Financial Considerations:

If openings exist that could allow flood water to enter the building, flood barriers may be used. These may help limit damage to the building. For example, flood protection walls may be constructed around critical interior rooms to reduce flood damage. Another example is to waterproof partitions and openings by using flood gates around mechanical equipment. The goal is to limit the amount of water that may penetrate a building to a few inches in depth.

The FEMA provides guidance for incorporating flood damage-resistance techniques as it’s related to design and construction of building utilities. FEMA requires that equipment and system components be above flooding levels. This may be done by putting equipment's and system components on pedestals, platforms or fill, suspending systems from structural elements or moving them to upper floors or attics. Another option is to ensure equipment and system components are in watertight enclosures, protective utility shafts, and anchoring systems.

Coastal Resiliency grants and funding sources may be available.

Adaptation Strategy 42 Flood Proof Buildings

Case Studies:

Fall River, MA - Flood doors and reinforcement to the exterior doors were added at the Cove Street and Central Street pump stations. This strategy also allowed for the retrofit of these pump stations to prevent the infiltration of flood water to these deep well pump stations during flooding events. The strategy included the installation of roof hatches to allow access to the building during flooding conditions.

Henrico County, VA - Upgrades were made to the pump stations and included the installation of a flood door assembly and relocation of wall openings above the flood level of the Roanoke River.

DC Water, Washington, D.C. - A deep well storm interceptor with ground level entrance was strategically located above the 500 year flood plain of the Potomac River at the Tunnel Dewatering Station/Enhanced Clarification Facility.

Narragansett Bay Commission, RI - Modifications to the protective barrier dike at the Bucklin Point wastewater treatment facility were made to raise it above the new flood plain.

References:

FEMA, 1999, Principle and Practices for the Design and Construction of Flood Resistant Building Utility Systems (FEMA 384).

FM Global, 2014, Property Loss Prevention Data Sheet 1-40, Flood. Section 2.2.4.5.

City of Salem, Massachusetts

Adaptation Strategy 43 Perform Wharf Area Water Study

Prioritized Vulnerability: **L. Property damage or loss of emergency and critical city facilities (CB2, CB6, CB14, W13)**

Due to this/these Climate Impact(s):

- ☐ Extreme Heat
- ☐ Sea Level Rise
- ☐ Extreme Precipitation
- ☑ Storm Surge

Sector(s):

- ☐ Critical Building
- ☐ Stormwater
- ☑ Drinking Water and Wastewater
- ☐ Transportation
- ☐ Vulnerable Populations
- ☐ Energy

Adaptation Strategy Description:

This adaptation strategy focuses on performing a wharf area water system study and field investigation. This study will include review of public and private water piping systems in the wharf area to update the GIS data and mapping. More accurate mapping will immediately benefit Salem by allowing Department of Public Works staff to more quickly locate and operate key valves in the system during an storm or emergency. New data will be used to evaluate the wharf area piping systems and recommend the most appropriate location for any new emergency shutdown gate valves to protect against wider spreading of distribution system failure or potential contamination, in the event of a wharf water piping failure.

Primary City Department(s) or Staff: Engineering Department, Department of Public Works

Project Type:

☐ Planning ☐ Ordinance/Zoning ☑ Design ☑ Construction
☐ Program ☐ Education/Outreach ☑ Study ☐ Operations

Project Timeframe: ☐ <1 year ☐ 1-2 years ☑ 2-5 years ☑ 6-10 years ☐ 10+ years

Potential Partnerships

☐ Hospitals ☐ Fire Department ☐ Police Department ☐ FEMA ☐ MEMA ☐ Neighboring Cities
☑ EPA ☑ DEP ☐ DOER ☐ MAPC ☐ MBTA ☐ National Grid ☑ Salem Sound Coastwatch
☐ North Shore Community Development Coalition (CDC) ☐ Salem Alliance for the Environment (SAFE)
☐ Private Property Owners ☐ Conservation Commission
☐ Others:

Adaptation Strategies with Similar Benefits

Technical, Implementation, and Financial Considerations:

Horizontal survey or GPS equipment are likely to be required to spatially show water system features or structures not currently shown included in Salem water GIS mapping. This study would benefit from the participation of and field assistance from Salem Public Works personnel to discuss potential improvements to existing emergency response procedures and to assist in the location of key water infrastructure features. Once the study is completed the city could seek funding to design and install the recommended emergency shutdown valves or repairs to any existing non-functioning valves in the wharf area.

Case Studies:

References:

MA DEP Guidelines for Public Water Systems, Handbook for Water Supply Emergencies

EPA Hurricane Preparedness Tips for Water Systems Tips: http://www.epa.gov/safewater/hurricane/pre-hurricane.html

AWWA, Public Water System Response to Loss of Pressure to All or Part of the Distribution System, Standard ANSI/AWWA C651-92 for Disinfecting Water Mains.