Planning for Sea Level Rise and Storm Surge
to
Protect Coastal Municipalities and Ecosystems

Information Gathering Project

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Summary

This document is a synthesis of resources that are relevant to adaptation, policy and restoration strategies addressing sea level rise and storm surge planning for coastal municipalities and ecosystems. The goal was to explore regional and national adaptation, policy and restoration strategies that were proposed and/or implemented in climate change vulnerability and adaptation plans for coastal cities and towns (Gloucester, MA, Hingham, MA, East Boston and Charlestown, MA and Norfolk, VA). This document summarizes four cities and towns that have established plans moving forward to address climate change and sea level rise scenarios. There are many more cities and towns both regionally and nationally that have finished plans available and more exploration would be beneficial to better understand and draw from the suggested strategies that are out there.

Each of the summaries below include the title of the document, the link to that the document, a short description of the goals and an outline of methods and strategies. Any additional resource links are also included for further exploration and information gathering purposes.

We are in a time where we have to start thinking differently about how we respond to climate change and how we live with water. Overall, the infrastructure and governing strategies are standard across the plans presented here. However, the process and implementation of the strategies is what varies and is the most interesting to understand. The process will be unique to each focus area and making sure that the proper scale is used to best reach the overall goal is critical. Reaching out to the communities and cities that have already started the process will be central to assessing the success of the process and implementation of the suggested strategies. Cost benefit analyses will also be important to get a better sense of the budget and realistic timeline of such measures. Finally, continuous monitoring of the natural resources as well as the economic environment is crucial to bringing in the communities of the area and working together to reach the common goal of planning, preparing, mitigating and communicating.

Gloucester, MA

City of Gloucester Coastal Climate Change Vulnerability Assessment and Adaptation Plan

Project Team:
Andre Martecchini, Nasser Brahim and Indrani Ghosh – Kleinfelder
Kirk Bosma – Woods Hole Group
City of Gloucester Working Group

Resources:
1) *Public meeting slides 6/16/15 http://gloucester-ma.gov/DocumentCenter/View/3412*
2) *Adaptation Plan 6/29/15 https://gloucester-ma.gov/DocumentCenter/View/3416*

Local officials for the City of Gloucester have identified floods caused by hurricanes, nor'easters, severe rainstorms and thunderstorms to be the most serious natural hazard. The project objectives include developing appropriate sea level rise and storm surge scenarios, understanding vulnerability of municipal infrastructure and natural resources to sea level rise and storm surge, developing potential short-, mid- and long-term adaptation strategies producing high quality products that will not only move the project forward but help with public outreach and education programs. There is a phased project approach with 3 phases 1) Sea Level/Storm Surge Scenario Development, 2) Mapping Inundation Modeling Vulnerability/Risk Assessment and 3) Develop Adaptation Strategies and Public Outreach.
The recommendations and projections in this report provide guidelines based on the knowledge to date and makes decision making information based on budget. It is suggested that this data should be updated over time and a coastal flood operations plan be developed.

Sea Level/Storm Surge Scenario and Modeling:
Planning Horizons
The models were not developed as "worst case" but developed as "worst likely" scenarios for three planning horizons

- 2013 to present
- 15 years out -2030 (Total Relative SLR "Highest" – 0.66 ft)
- 55 years out –2070 (Total Relative SLR "Highest" – 3.39 ft)

These scenarios were recommended by Parris et.al (2012) and Massachusetts CZM for assessing sea level rise. The SLR scenarios that were utilized in this vulnerability assessment are listed on page 8.
The planning horizons of 2030 and 2070 were selected to provide an estimate of short-term and mid-term vulnerabilities. The 2030 planning horizon for near-term inundation modeling is comparable and consistent with other studies in Eastern Massachusetts while the 2070 planning horizon is more useful for long-term planning because the level of uncertainty of SLR projections is high and it is expected to be much closer to the true life of the infrastructure being evaluated.

Hydrodynamic models were used that were based on mathematical representations of the processes affecting coastal water levels (i.e, tides, waves, winds). The models were developed at a high resolution in order to pinpoint areas that may need adaptation alternatives.
The BH-FRM (Boston Harbor Flood Risk Model) was already developed for the MassDOT to assess flooding vulnerabilities and covers the entire coastline of Massachusetts. It is "ideally suited" to assess the vulnerability and risk of coastal flooding. ADCIRC and SWAN software were used together to provide an accurate representation of water surface elevations, winds, waves and flooding along the coast. These models include physical processes that other models don't. Other benefits of the BH-FRM model are defined on page 6. The SLAMM model was used to assess the impacts to natural resources (beaches, coves and salt marsh). Major impacts to natural resources are also outlined in this report.

A Monte Carlo approach, simulating a set of storms for each sea level rise scenario was used. Storm climatology is based on present climate for planning horizons until 2050 but for anything after that 21st century climatology is used to simulate the storms. The model was calibrated to both water surface elevation time series data and observed high water marks from the Blizzard of 1978. The model was validated to the Perfect Storm of 1991. Percent risk of flooding and depth of flooding maps were developed from the results of the model simulations.

The vulnerability assessment is based on risk and the consequence of flooding is based on several factors including area and duration of service loss, cost of damage, and impact to public safety, emergency services, economic activities, public health and impacts to the overall environment.

Adaptation Strategies:

The major approaches in developing adaptation strategies include 1) protection, 2) accommodation and 3) retreat. The strategies investigated in this study are a combination of protection and accommodation settings. Full retreat strategies (property buyouts, relocation of roads, new zoning, etc) don't appear to be needed with in the horizons presented. It does seem that the use of "rolling easements" may be the most realistic use for the future.

Before developing adaptation strategies, it is important to select a base flood elevation that will be the level to which an infrastructure asset is adapted to (Figure 20, p.32). In order for success, there is a need for both city and private participation. There is no single solution for adapting areas to future risk so flooding will need to be dealt with in a more general way. All estimates of cost are "order-of-magnitude" estimates in 2015 dollars and they "in no way" represent actual estimates. The following recommendations provide guidelines for investment decisions based on the knowledge to date. The scope of the project didn't include a full review of infrastructure so the findings include assumptions based on reasonable engineering judgement and will require verification.

Recommendations:

- Coastal Stabilization Structures (seawalls, revetments and breakwaters) and Low-Lying Roadways are at high risk and three options were proposed in this plan
    - Raise all waterfront structures, both public and private to common elevation (~$60-$175 million)
    - Install permanent flood barrier by raising the road elevation (~$4.2-$20 million)
    - Construct a hurricane barrier system (no accurate estimate but based on other existing hurricane barriers in New Bedford, MA, Stamford, CT and Providence, RI, the amounts range from ~$14.5 and $18.7 million)
- Facilities/Buildings (water pollution control facilities and pump stations)
    - A series of recommendations for specific sites are presented with cost estimates ranging from approximately $120,000 to $500,000 depending on the existing facilities.
- Roadways
    - Requires longer-term strategies for adaptation since the timelines are longer and very expensive
    - Hard to estimate cost
        - 2030 estimates - $0-$8.5 million depending on roadway
        - 2070 estimates - $330,000 - $15.86 million
- Natural Resources
    - Allow natural evolution to move forward – expansion of low marsh

        - Complex understanding of the coastal processes such as sediment transport, current, wave action, erosion rates, etc.
        - More accurate modeling
        - Better long-term recommendations for green adaptations for resiliency can be developed
        - Marsh deposition, dune and beach restoration, cobble and landscaped berms and living shoreline applications
    - Land/Resource Acquisition:
        - Consider acquiring land adjacent to coastal resource areas to accommodate changing conditions of natural resources areas such as salt marsh
        - Investigate the possibility of implementing a rolling easements program
        - Develop policies for public projects that incorporate the anticipated effects of climate change and SLR- promote sustainable practices throughout the community

Major adaptation strategy structure ideas that were suggested in this plan for the City of Gloucester include: Concrete Permanent Flood Wall, Glass Flood Wall, Self-Regulating Tide Gates, Decorative Permanent Flood Wall, Hurricane Barrier examples (from New Bedford, Stamford and Providence), Green flood-proofing with Landscape Berms.

The last chapters of the plan discussed **potential changes to the Wetlands and Zoning Ordinance** and potential changes to rules and regulations governing the subdivision of land.

Wetlands Ordinance Recommendations:

- Provide performance standards
- Provide clear definitions
- Consider allowing the ability to elevate existing structures to reduce flood hazards
- Increase the width of the buffer zone within the flood plain.

Zoning Ordinance Recommendation:

- Consider establishing a Floodplain Ordinance District – the limits would be based on FEMA FIRM maps at either the 1% or 0.2% flood level
    - List of clearly defined permitted uses and prohibited uses
      Example: Permitted – public access activities
      Prohibited – installation of basement
    - List of uses that are permitted with approval of a special permit
      Example: restoration of historic structures or any beach nourishment activities
- Provide incentives
- Allow higher maximum height restrictions
- Adopt a "freeboard incentive"
  Example stated in the document was as follows:
  "…the Town of Hull adopted a "freeboard incentive" that reduces building department application fees by $500 if an elevation certificate is provided to verify that the building is elevated a minimum of two feet above the highest federal and state requirement for the flood zone." Additional fees would be applied to any additional freeboard.
- Finally, a series of amendments for certain sections in the Zoning Ordinance encouraging preservation of land bordering salt marshes

Subdivision of Land:

- Evaluations of effects of sea level rise and climate change mitigation plans for application affecting the coastal flood plain and cost benefit analyses of the mitigation measures proposed.
- Develop an Environmental Impact Evaluation

Land/Resource Acquisition:

- Consider acquiring land adjacent to coastal resource areas - those areas can be found in this plan – acquire through easements, fee interest or purchase development rights to accommodate project effects of sea level rise.
- Consider a rolling easements program – city can purchase an easement from a property owner today in exchange for a promise to surrender the property to the City once it is substantially damaged by a flood event - "retreat policy"
- These can proved cash to a property owner today with the understanding that it would not be rebuilt after it was significantly damaged. The Gloucester Hazard Mitigation Plan Update will provide the properties are most vulnerable.

Public Projects Policies:

- Update the City's Hazard Mitigation Plan and require to build data on the impacts of coastal storms to inform future adaptation measures
- Develop a regular inventory/report of actions taken by the community to improve resilience to climate change and sea level rise.

Develop Coastal Flood Operations Plan:

- To prepare for and minimize flood damage due to coastal flooding as a result of extreme weather events and be included in the city's overall emergency response planning documents

There are many limitations that the project work group faced. There are many uncertainties in climate change science. Therefore, the projections made in this report "only reflect the professional judgement for the Project Team applying a standard of care consistent with the practice of other professionals undertaking similar work."

Other Resources:

Parris et al, 2012 https://scenarios.globalchange.gov/sites/default/files/NOAA_SLR_r3_0.pdf

MassDOT-FHWA Pilot Project Report: Climate Change and Extreme Weather Vulnerability Assessments and Adaptation Options for the Central Artery (2015) https://www.massdot.state.ma.us/Portals/8/docs/environmental/SustainabilityEMS/Pilot_Project_Report_MassDOT_FHWA.pdf

Statewide Modeling: The Effects of Sea Level Rise on Coastal Wetlands for Massachusetts Coastal Zone Management (ENV 14 CZM 08, 2015) (can't find link at this time)

Hingham, MA

Town of Hingham Climate Change Vulnerability Assessment and Adaptation Study

Project Team:
Andre Martecchini, Nasser Brahim and Indrani Ghosh – Kleinfelder
Kirk Bosma – Woods Hole Group
Hingham Town Steering Committee

Resources:

3) *Adaptation Plan 6/29/15*
   https://www.hingham-ma.gov/DocumentCenter/View/1082/Hingham-Climate-Change-Vulnerability-Risk-Assessment-and-Adaptation-Final-Report-PDF

The Town of Hingham is particularly vulnerable to sea level rise being a coastal community located on Hingham Bay and the edge of Boston Harbor. This project has four primary goals: 1) identify areas of the town that are vulnerable to the combined effects of sea level rise and storm surge from extreme storm events, 2) assess the vulnerability of municipally-owned public infrastructure and natural resources, 3) identify adaptation strategies that will help to mitigate the long-term effects of sea level rise and storm surge and 4) educate the public, town officials and state legislators about those potential impacts.
This Adaptation Plan was very similar in structure to the City of Gloucester Adaptation Plan. The main differences were an additional product of 3D renderings to better visualize the flooding impacts in certain areas. Any costs were estimates in "today's dollars". The recommended base flood elevations were unique to the Town of Hingham but were derived using the same models and validation procedures. It was also evident that the Town of Hingham is making headway and actively working on the plans put forth in this document.

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The planning horizons of 2030 and 2070 were selected to provide an estimate of short-term and mid-term vulnerabilities. The 2030 planning horizon for near-term inundation modeling is comparable and consistent with other studies in Eastern Massachusetts while the 2070 planning horizon is more useful for long-term planning because the level of uncertainty of SLR projections is high and it is expected to be much closer to the true life of the infrastructure being evaluated.

Hydrodynamic models were used that were based on mathematical representations of the processes affecting coastal water levels (i.e, tides, waves, winds). The models were developed at a high resolution in order to pinpoint areas that may need adaptation alternatives.
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The vulnerability assessment is based on risk and the consequence of flooding is based on several factors including area and duration of service loss, cost of damage, and impact to public safety, emergency services, economic activities, public health and impacts to the overall environment.

Adaptation Strategies:

The major approaches in developing adaptation strategies include 1) protection, 2) accommodation and 3) retreat. The strategies investigated in this study are a combination of protection and accommodation settings. Full retreat strategies (property buyouts, relocation of roads, new zoning, etc) don't appear to be needed with in the horizons presented. It does seem that the use of "rolling easements" may be the most realistic use for the future.

Before developing adaptation strategies, it is important to select a base flood elevation that will be the level to which an infrastructure asset is adapted to (Figure 20, p.32). In order for success, there is a need for both city and private participation. There is no single solution for adapting areas to future risk so flooding will need to be dealt with in a more general way. All estimates of cost are "order-of-magnitude" estimates in 2015 dollars and they "in no way" represent actual estimates. The following recommendations provide guidelines for investment decisions based on the knowledge to date. The scope of the project didn't include a full review of infrastructure so the findings include assumptions based on reasonable engineering judgement and will require verification.

Recommendations:

- Coastal Stabilization Structures (seawalls, revetments and breakwaters) and Low-Lying Roadways are at high risk and three options were proposed in this plan
    - Design, permit, and construct improvements to existing waterfront structures and landscape
    - Incentivize or "compel" (e.g. through betterment) private seawall owner to meet the adjoining structures at the appropriate height.
    - Design new seawalls to be modular to allow incremental construction over time to meet rising sea levels
    - Raise and repair existing seawalls (~$5-$15 million)
    - Continue monitoring structures for condition and scour, carry out regular maintenance and design for long-term design life
- Facilities/Buildings (water pollution control facilities and pump stations)
    - A series of recommendations for specific sites are presented with cost estimates up to approximately $900,000 depending on the existing facility.
- Roadways
    - Recommendations of adjustments and raising of roadways of up to $17 million
    - "Note: Extensive changes to roadway elevations or the introduction of flood control structures, such as flood walls or raised sea walls, could have a significant positive effect on the flood characteristics depicted in future FEMA Flood Insurance Rate Maps (FIRM) for the Town of Hingham which could have the positive benefit of causing a reduction in flood insurance premiums for the Town, home owners and commercial interests."

- Natural Resources
    - Increase size of culvert to increase tidal flushing
    - Leave certain areas to naturally evolve
    - Beach and dune restoration at the bathing beach and enhancement with modular seawalls
    - A construction project for improvements to the area, including the beach, is currently close to implementation. **It is unclear how future effects of climate change, including sea level rise, have been incorporated into the design.**
    - A "wait and see" approach for some natural areas
    - Green resilience design that would benefit the natural resources and fringing marsh in this area
    - Thin layer deposition projects, marsh expansion projects, and/or living shorelines.
    - Biodegradable type solutions
- Land/Resource Acquisition:
    - None

The last chapters of the plan discussed **potential changes to the Wetlands and Zoning Ordinance** and potential changes to rules and regulations governing the subdivision of land.

Wetlands Regulations Recommendations:

- Amendments to change minimum distance and requirements of applicants to provide a narrative of how effects of sea level rise are being addressed and mitigated.
- Applicant be required to submit a cost-benefit analysis of mitigation alternatives.
- Update and combine performance standards
- Consider specifying a specific sea level rise curve rather than allowing use of "at a minimum, the historic rate of relative sea level rise in Massachusetts of 1 foot per 100 years….". More definition of what will be permitted should be provided.
- Consider increasing the width of the buffer zone
- Provide clear definitions
- Increase the width of the buffer zone within the flood plain.

Zoning Ordinance Recommendation:

- Consider establishing a Coastal Management Zone (CMZ) district which would amend the Flood Plain and Watershed protection District
- Performance criteria in this zone could be developed using No Adverse Impacts principles
    - Accessibility: Allowing for wet or dry-proofing of existing buildings will help to improve their resiliency, while minimizing costly ADA modifications
    - Means of egress: Requiring that the building be unoccupied during a flood while temporary barriers are in place helps to address this building code issue.
- Provide incentives
- Allow higher maximum height restrictions
- Adopt a "freeboard incentive"
  Example stated in the document was as follows:
  "…the Town of Hull adopted a "freeboard incentive" that reduces building department application fees by $500 if an elevation certificate is provided to verify that the building is elevated a minimum of two feet above the highest federal and state requirement for the flood zone." Additional fees would be applied to any additional freeboard.

Subdivision of Land:

- Consider modifying the subdivision rules and regulations to allow for cluster development in the CMZ and other wetland protection districts which could provide a density bonus for projects that provide open space to accommodate expanding wetlands

Land/Resource Acquisition:

- Consider acquiring land adjacent to coastal resource areas - those areas can be found in this plan – acquire through easements, fee interest or purchase development rights to accommodate project effects of sea level rise.
- Consider a rolling easements program – city can purchase an easement from a property owner today in exchange for a promise to surrender the property to the City once it is substantially damaged by a flood event - "retreat policy"
- Update Open Space and Recreation Plan with priority areas identified for acquisition through easements, fee interest or purchase of development rights

Public Projects Policies:

- Assess costs and benefits of becoming a Green Community
- Evaluate the Town's Hazard Mitigation Plan
- Evaluate opportunities to relocate snow storage areas away from the Town bathing beach parking lot
- Develop a regular inventory/report of actions taken by the community to improve resilience to climate change and sea level rise.

Develop Coastal Flood Operations Plan:

- To prepare for and minimize flood damage due to coastal flooding as a result of extreme weather events and be included in the Town's overall emergency response planning documents

There are many limitations that the project work group faced. There are many uncertainties in climate change science. Therefore, the projections made in this report "only reflect the professional judgement for the Project Team applying a standard of care consistent with the practice of other professionals undertaking similar work."

Other Resources:

Parris et al, 2012 https://scenarios.globalchange.gov/sites/default/files/NOAA_SLR_r3_0.pdf

MassDOT-FHWA Pilot Project Report: Climate Change and Extreme Weather Vulnerability Assessments and Adaptation Options for the Central Artery (2015) https://www.massdot.state.ma.us/Portals/8/docs/environmental/SustainabilityEMS/Pilot_Project_Report_MassDOT_FHWA.pdf

Statewide Modeling: The Effects of Sea Level Rise on Coastal Wetlands for Massachusetts Coastal Zone Management (ENV 14 CZM 08, 2015) (can't find link at this time)

Coastal Climate Change Vulnerability Assessment and Adaptation Plan: City of Gloucester, MA (June 29, 2015) https://gloucester-ma.gov/DocumentCenter/View/3416

East Boston and Charlestown, MA

Coastal Resilience Solutions for East Boston and Charlestown

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Mat Staudt, Urban Designer

Woods Hole Group
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Resource:
1) *Coastal Resilience Solutions for East Boston and Charlestown, October 2017*
https://www.boston.gov/sites/default/files/climatereadyeastbostoncharlestown_finalreport_web.pdf

This report presents the near and long-term strategies for protecting East Boston and Charlestown from sea level rise and coastal flooding. It is part of a large Climate Ready Boston initiative that helps prepare the city for the impacts of climate change. East Boston and Charlestown are the most vulnerable areas to coastal flooding because they are currently at risk from the "1% annual chance coastal flooding". Potential flood protection strategies were identified, evaluated and developed for critical locations. Near and long-term actions that were recommended and implementation road maps were defined through on going analysis and community engagement. Costs and phasing that are indicated in this document are estimates only and should not be used in planning.

Definition: **"1% annual chance**" is defined as having a 1 in 100 chance of being equaled or exceeded in any given year and is the primary coastal flood hazard delineated in FEMA flood maps. A 1 percent annual chance event could occur multiple times in a given year, decade or century. Climate Ready Boston uses "1 percent annual chance flood" instead of "100 year flood event" due to potential misinterpretation.

Stakeholders were made up of city departments and agencies, private sector, state and regional partners, non-profit, elected officials and civic associates. Flood pathways were identified using a Flood Risk Model developed by Mass DOT. Residents shared their need for effective and lasting solutions to keep them safe from coastal flooding. Preferred solutions include protecting highway infrastructure as well as cycling and pedestrian pathways that will keep them connected to the city.

Coastal Resilience Solutions
A layered flood protection system is proposed in this report and can provide long-term protection. "Multiple priorities can be addressed by integrating coastal resilience solutions with new and existing waterfront open spaces."
The measures proposed in this report include: elevated waterfront parks, enhanced harbor walks, improved connections to the waterfront, natural wetland buffers, increased tree canopy to address higher temperatures, hardscaped seating stairs and furnishings, compatible, resilient, mixed-use redevelopment with smaller footprints and varying building heights and density.

Proposed Strategies
Open Space

- Coastal flood protection systems integrated with open space
- Increase the amount of vegetation permeable and tree-covered areas in neighborhoods and improve mobility and connectivity (addresses extreme rain and heat)
- Elevated waterfront parks and plazas
- Soft features (storm-water gardens, open lawn, etc)
- Provide space for storm-water pump stations
- Elevated waterfront pathways (berms)
- Nature based features

Infrastructure

- Elevated roadways and deployable flood walls
- Mixed use development – smaller footprints, taller buildings

Effectiveness and Adaptability

- Open space systems are adaptable to even greater sea level rise. At least 2 feet of extra flood protection is possible within their proposed footprints. Further elevation can be accomplished by adding fill, integrating structural furniture that adds height.
- Installing deployable flood walls
- Elevated parks or berms last approximately 50 years and are designed to protect up to the 1% annual chance coastal flood

Implementation
Costs were "order-of-magnitude" estimated costs for capital projects based on estimated costs per acre for typical waterfront berms, parks and shoreline protection features and scaled based on how high they need to be built above the surrounding ground. Near term actions include deployable floodwalls and elevating roadways that are shown in designs prepared in this report.

The actions were considered cost effective if the benefits were greater than or equal to the costs. Estimated costs ranged from $33-62 million in Charlestown and approximately $121-200 million in East Boston.

Zoning Code and Article 80 Development Revisions
E. Boston and Charlestown

- Establish Flood Protection Overlay District
- Establish Interim Planning Overlay District
- Transfer of priority parcels
- Increase open space requirements
- Require information on project location relative to coastal flood pathways
- Add standards for project review approval in the Flood Protection Overlay Districts

It has been recommended that this project be designed and operated to the standards set by the Army Corps of Engineers and FEMA so the project will be eligible for federal funding if there are repairs needed in the future. This way, the communities will be eligible to qualify for flood insurance. It is also suggested that the city should secure land rights or easements on several properties. The BPDA may also use established municipal harbor planning procedures to develop and update the plan in order to provide more important tools.

Other Resources:

MassDOT-FHWA Pilot Project Report: Climate Change and Extreme Weather Vulnerability Assessments and Adaptation Options for the Central Artery (2015)
https://www.massdot.state.ma.us/Portals/8/docs/environmental/SustainabilityEMS/Pilot_Project_Report_MassDOT_FHWA.pdf

Climate Ready Boston: Final Report – December 2016
https://www.boston.gov/sites/default/files/20161207_climate_ready_boston_digital2.pdf

https://www.boston.gov/departments/environment/climate-ready-boston-progress

Norfolk, VA

Coastal Resilience Strategy (City of Norfolk, VA)

Resources:

2) *Coastal Resilience Strategy (Overview 2014)* *https://www.norfolk.gov/DocumentCenter/View/16292*
3) *Norfolk's Resilience Strategy (2014) - https://www.norfolk.gov/DocumentCenter/View/27257*
4) *https://toolkit.climate.gov/case-studies/norfolk-establishes-strategy-coastal-resilience*

"But with sea level rise and increased storm intensity, we need to expand our thinking and our solutions and develop creative new infrastructure systems at both the edge and within the city. We need to think differently about how we build, how we connect, and how we live with and embrace the water." (Norfolk's Resilience Plan, pp. 28).

Plan, Prepare, Mitigate, Communicate –

In 2013 Rockefeller Foundation included Norfolk as one of the first cities that are included in the initiative supporting 100 cities across the world in their efforts to build resilience. This project will improve drainage, reduce flooding, and help prevent damage during future severe weather events. The Norfolk Flooding Strategy attempts to combine planning, preparation, mitigation and communication to reduce dangers from flooding and protecting the communities by educating them on how to handle severe storms. Norfolk has collaborated with researchers and developed community response teams that act on preparedness concepts and principles. Immediate and long-term solutions range from simple landscaping techniques allowing for storm water drainage to complex engineering projects that are designed to reroute and deflect water. Most importantly, Norfolk wants the input from residents. The City uses a variety of communication tools to better accomplish this.

http://readyhamptonroads.org/

This communication website make it easy for communities to access the information they need to connect with their local emergency management agency and find preparedness information for all of Hampton Roads in one place.

Norfolk used the Virginia Institute of Marine Science and the Center for Coastal Resource Management predictions for sea level rise in 2013. They also initiated a series of Coastal Flooding and Precipitation studies to analyze the watersheds of the City. From these studies and sea level rise predictions, building and planning codes were adapted to make the City's infrastructure less vulnerable. The typical strategies including flood walls and gates, pump stations and man-made berms are all proposed as flood protection projects.

Infrastructure/Facilities/Buildings:

The City of Norfolk's coastal features include a naval base, deep water ports, active shipyards, waterfront recreation and major maritime businesses. Like other coastal communities, Norfolk is vulnerable to sea level rise and storm surges. Public flood protection projects are similar to other coastal communities and include flood walls, flood gates, pump stations and man-made berms. Beyond the $2.4 million raised roadway elevation project, other structural projects that are planned include floodwalls, earthen berm, pumps and elevating structures. Project costs range in estimates from $10 to $306 million.

Norfolk has partnered with Army Corps of Engineers for technical guidance and funding. The Corps has completed several studies including an engineered beach and other lake and related large construction projects. Other watershed projects that have been proposed range in estimates from $21 million to $615 million.

The goal of this strategy is ultimately to protect residents and guide recovery efforts from various hazards and future threats. This document suggests that residents can reduce flooding impacts by 1) restoring wetlands and natural shorelines to preserve storm buffers, 2) planting trees, 3) installing rain barrels and finally 4) incorporating landscape techniques (i.e, rain gardens). Residents should also know the elevation of their homes and adjust the elevation of their furnace, water heater and electric panels above the expected floodwaters.

Natural Resources:
Healthy shoreline ecosystems are important for the City's resiliency. There are shoreline buffer projects that are being developed to provide the first line of defense against large storm surges and high tides. Waterway restoration projects are also identified to both improve pollutant treatments but also improve storm flow.

Communication:
Talking with experts, talking with residents and other communication tools are used to connect residents with flood information.

Norfolk Resilience Strategy (https://www.norfolk.gov/DocumentCenter/View/27257)

"Norfolk is a hub of activity for advancing next-generation thinking on living with the water. From the Dutch Dialogues to the Resilience Lab/Accelerator to the 100RC exchange and community of practitioners, Norfolk will be the leading global thinker – and doer." (page 52).

The *Norfolk Resilience Strategy* outlines the goals and strategies that could make the city more resilient. It is not only focused on environmental resiliency but also outlines the economic resiliency goals as well. The strategy was guided by the 100RC City Resilience Framework (https://www.100resilientcities.org/cities/). This document provides a list of references that may be important to look through on pages 57-58.

The strategic framework that is outlined in this document includes three major goals. The first of these goals is to design the coastal community of the future. The following strategies are outlined to complete this goal:

1) Collectively create a vision for the future for the City
2) Access, identify and implement innovative infrastructure for managing water
3) Create a place where people want to live, work and play
4) Redesign tools and regulations to achieve the above goals

Actions that are defined within each strategy are as follows:

Strategy 1: The City is developing the vision for the future using a design-based dialogues.

- Action: Launch Vision2100 (https://www.norfolk.gov/DocumentCenter/View/27768) – a citizen led discussion to identify future land use decisions for the City
- Action: Develop "next-generation" water management strategies – hosted Dutch *Dialogues* Virginia (June 2015) - https://hampton.gov/3466/Dutch-Dialogues

Dutch *Dialogues* Virginia:

The Royal Netherlands Embassy sponsored the 2nd Dutch Dialogues in the United States in June 2015. The workshop brought together Dutch urban designers, engineers, landscape architects, planners and academics and government officials to "explore creative solutions and holistic concepts to reduce flooding." The strategy developed for Norfolk combines rain gardens, cisterns, living shorelines, marshes, streams and berms to create an original water management solution that works together to manage sea level rise and precipitation in the City.

Resilience Partners:

- American Institute of Architects
- ARCADIS
- Cities of Hampton, Newport News, Norfolk
- Commonwealth of Virginia
- Elizabeth River Project
- Emerging Leaders Program
- Hampton Roads ULI
- Hampton University
- HR&A Advisors
- Old Dominion University
- Royal Netherlands Embassy
- Slover Library Foundation
- Waggonner & Ball Architects
- Wetlands Watch
- Work Program Architects

Strategy 2: Hard and soft infrastructure and creative funding solutions will be developed to implement new innovative approaches to managing water.

- Action: *RE.invest* provided new design ideas for flood control (http://www.refocuspartners.com/wp-content/uploads/pdf/RE.invest_Norfolk-City-Report.pdf
- Action: Establish a global practice on water innovation and used the 100RC network to come up with new ideas for the future of managing and living with water – Norfolk presented its innovative model of using water management to revitalize neighborhoods while Dutch cities did the same for their innovations (i.e water plazas and underground storage facilities).
- Action: Participate in Structures of Coastal Resilience (http://structuresofcoastalresilience.org/) initiative. New design concepts including "fingers of high ground" (http://structuresofcoastalresilience.org/locations/norfolk-va/) creating areas that can be developed even with the reality of sea level rise. This is included in Vision2100 planning.
- Action: Partner with the Army Corps of Engineers on flood risk study – comprehensive study that will assess the options for the City's vulnerability to flooding.

Resilience Partners:

- 100 Resilient Cities Network
- Akin Gump Strauss Hauer Feld LLP
- Bechtel
- City of Norfolk
- Re:focus Partners
- Rockefeller Foundation
- UPenn School of Design
- US Army Corps of Engineers
- Wall Street Without Wall

Strategy 3: Continue to develop protected coastline and downtown through infrastructure investment to keep it an attractive place to live and visit.

Strategy 4: Create government processes and regulatory actions that support resiliency. They must support community collaboration and public engagement.

- Action: Planning Department to re-write the zoning codes – will be the gold standard for integrating resilience into land use planning.
- Action: Incorporate lessons and technical assistance from a 100RC land use workshop to report in Leveraging Land Use Regulation to Achieve City Resilience Goals (http://www.100resilientcities.org/planning-for-resilience-innovative-land-use-policies-for-building-a-resilient-city/)
- Action: Use Better Block demos to test design ideas. These are already driving permanent improvements (http://betterblock.org/how-to-build-a-better-block/)
- Action: Update the Long-Term Recovery Plan
- Action: Develop a new rapid housing recovery model in the wake of disaster

Resilience Partners:

100 Resilient Cities network
Cities of Boulder, New Orleans, New York, Norfolk
Clarion Associates
Greehan, Taves, Pandak & Stoner
Herd Planning & Design
Miles Agency
Old Dominion University
Renaissance Planning Group

NorfolkVision2100 (https://www.norfolk.gov/DocumentCenter/View/27768)

This document creates a vision for its long-term future of the entire City and attempts to provide guidance for achieving all three of the strategy goals that are outlined in the *Norfolk Resilience Strategy*. In order to maintain the status of the City as a thriving waterfront community, it requires "a bold new set of strategies" (page 22). Realizing this vision will require implementing the strategy of how we move forward toward the vision goals. It is supplemental to plaNorfolk2030 (https://www.norfolk.gov/DocumentCenter/View/2483).

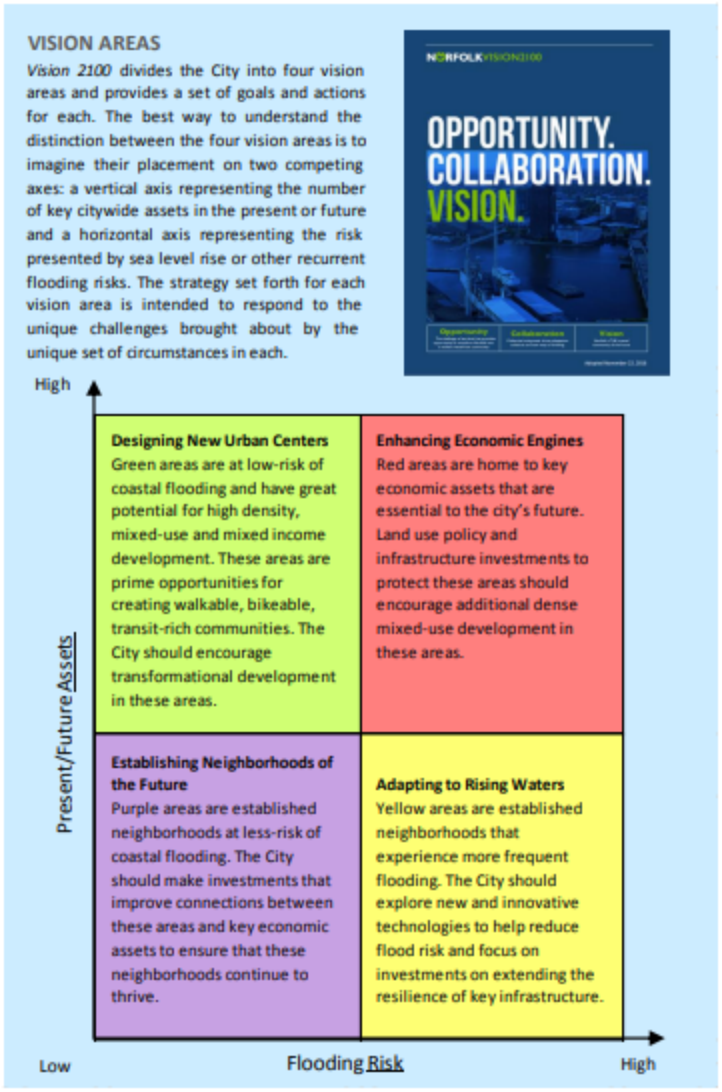
Implementation Methods for *Vision2100*:

- Land Use Decisions – land use maps
- City Work Program and Budgets
- Other City Functions and Tools
    - Future Area Plans
    - Zoning and Regulatory Tools
- Stakeholder Relationships
- Neighborhood Outreach and Strategic Planning
- Resilience

Designing the Coastal Community of the Future Action Items:

- Focus major infrastructure investments in the most resilient areas
- Improve transportation connections
- Be a model for responsibly addressing resilience
    - Green roofs, rain gardens, permeable pavements, bioswales can capture and clean rainwater when it falls, rain barrels and cisterns collect it to reduce run-off. Building construction can help avoid loss due to flooding and help withstand impacts of sea level rise by incorporating waterproof first floors and building materials that can survive water infiltration
- Create tools and incentives to develop a more resilient housing market
    - Transfer of Development Rights (TDR) is a voluntary, incentive based program allowing landowners to sell development rights from their land to the developer who can use these rights to increase the density of development at another designated location. This has not been implemented and needs significant code changes.
    - Density bonuses – zoning tool permitting developers to build more housing units and taller buildings with more floor space in exchange for defined public benefit. Zoning ordinance changes would need to be made in order to implement
    - Inclusionary zoning – a given share of new construction to be affordable by people with low to moderate incomes. Other communities in VA already have this in place as a model.
- Seize the economic opportunities of emerging resilience-based industries
    - Coastal Resilience Laboratory and Acceleration Center (2016)

Vision2100 used the method shown in the figure below dividing the City into four vision areas in order to better put forth strategies that respond to unique challenges within each separate area. Complete explanations of each designated color area can be found in this document beginning on page 39.



RE.invest: City Report Norfolk (March 2015) - http://www.refocuspartners.com/wp-content/uploads/pdf/RE.invest_Norfolk-City-Report.pdfreen

RE.invest has recognized that designing new types of projects is essential based on three major ideas:

1) Resilience is about systems, not just projects. Green resilient and sustainable infrastructure systems are not made up of a few large projects but many small pieces and parts
2) Finish new ways to align public and private interests. Coordination among sectors during design is critical.
3) Green and resilient systems aren't always successful but the benefits and savings over time requires thoughtful design and advance planning.

The need for financeable projects through a "rapid, structured, and replicable" project preparation and delivery process for integrated resilient infrastructure systems is critical. In Norfolk, the RE.invest team focused on flood management solutions to the Arts District. This document not only points to the types of infrastructure solutions, it also identifies relevant legal and financial tools to support implementation of the solutions.

Innovations:

- Integrate gray and green infrastructure solutions
- Financing options to capture real estate value increases from flood protection measures and green infrastructure upgrades
- Calculate "avoided losses" and potential financial savings due to reduced flooding
- Partner with technology companies and local businesses to quantify potential savings
- Create public programs and local competitions to encourage community based action on a series of green infrastructure possibilities

This document includes design concepts and solutions to address the resilience challenges that the City of Norfolk faces. The Downtown Arts District is impacted on a regular high tide event. The water levels in this area can rise approximately one foot due to tidal fluctuations that are impacted by precipitation and wind events. Self-raising flood barriers (SCFB) are suggested to eliminate this problem. This solution has been deployed in the Netherlands, Belgium and the United Kingdom and most recently in a small scale outside of the National Archives in Washington DC. This system uses the rising floodwater to automatically raise the flood barrier and as they recede, it automatically pulls back. A benefit to this system is that it is fairly invisible and very low maintenance. A phase approach is recommended to save on cost.

The cost estimation and benefits are intended to give a basis for how financing of the proposed systems could be achieved. The estimates include environmental review and permitting costs, engineering design costs, construction supervision and inspection costs and a 20% contingency allowance. The range of the above green infrastructure suggestions ranged from $230,000 to $2.3 million. The Flood Barrier that was discussed earlier Phase 1 = $7.6 million and Phase 2 =$17.7 million.

The 100 year based flood elevation (BFE) is defined as the elevation that water is anticipated to rise to during a 100 year flood. Norfolk's BFE is 7.6 feet. The hydraulic model that was created was missing bathymetric data and therefore was not used. A GIS method was used to determine the number of flooded building structures with and without the SCFB. The volume of water was also determined using GIS. The team also investigated green stormwater strategies to solve some of the overtopping of water of the rim of the wall around the inlets.

The Initiative worked to identify green infrastructure practices that would serve to retain stormwater onsite during storm events with storm drains are strained. The following were suggested:

- Blue Roofs –
    - Non-vegetated point source controls that detain stormwater that can reduce the urban heat island effect and are inexpensive options (implemented by New York City - http://www.nyc.gov/html/dep/pdf/green_infrastructure/gi_annual_report_update_supplement_2012.pdf)
    - Estimated millions of cubic feet of water would be delayed into the storm water sewer system and reduce the magnitude and frequency of flooding (of 63 buildings in Arts District, volume of water captured = over 200,000 cubic feet).
- Raised Planter Boxes –
    - Flow-through stormwater treatment facilities adjacent to buildings and disconnected downspouts – provide temporary retention during storm events
    - For every 100 linear feet of raised planter box, 7,800 gallons of stormwater will be delayed into the storm drain system
- Green Alleys
    - Alleys designed in order to help manage stormwater, reduce urban heat island effects and conserve energy
    - Replacement of asphalt to permeable pavement and a PVC pipe near the bottom of the storage media could create additional storage within the watershed to delay entry into the system.
- Permeable Pavement
    - Non-traditional pavement surfaces that allow stormwater runoff to filter through voids in the surface into a stone reservoir below where this water can either be retained or allow to replenish the groundwater
    - Pervious concrete, porous asphalt and interlocking pavers
    - The use of this potential solution could delay millions of gallons of water into the system
- Stormwater Tree Trench
    - Subsurface trench with a stone reservoir for stormwater runoff retention and conveyance along with sections of engineered soil for growth of trees
    - Collects surface runoff vis inlets and overland flow and conveys surface flow to subsurface trench and is stored temporarily in the voids and provides water to the trees
    - Approximately 37,000 gallons of stormwater could be captured and delayed
- Surface Depression Storage
    - Medians and grassy areas should be excavated to a 6 inch depth in order for stormwater runoff to pond temporarily in medians and grassy areas
    - Approximated 75,000 cubic feet can be delayed

The RE.invest team also presented a series of partnerships that the City of Norfolk could pursue to increase the likelihood of attaining private funding for flood management projects by collecting data and continuing private participation. They also suggest that creating innovative financing options would be beneficial.

Dutch *Dialogues* Virginia: Life at Sea Level *(https://wparch.com/dutch-dialogues-va-life-at-sea-level/)*

Key Partcipiants:

- Christine Morris – Chief Resilience Officer – City of Norfolk
- Dale Morris – Senior Economist – Royal Netherlands Embassy
- David Waggonner – Architect - Waggonner&Ball

The Dutch *Dialogues* Virginia was a 5 day workshop in June 2015. Norfolk is considered a "globally important region" as defined by the Dutch. It ranks second to New Orleans in the size of the population that will be affected by water. It is a region that needs to rise to resiliency. The Dutch *Dialogues* are acollaborative effort of Dutch technical experts, the Netherlands Embassy in Washington, D.C., local and state governments and other stakeholders. The first Dutch *Dialogues* were held in New Orleans, and other workshops were held in New York, Bridgeport, St. Louis, Tampa Bay, and Los Angeles. The goal is to improve the region's approach to water management through learning about the Dutch perspective on "living with water."

Goal:
How do you preserve areas for the next 50-100 years and reduce flooding?

Looking at both temporal and geographic scales, the Dutch suggested some solutions to the rising sea levels and how to protect the City. A phasing approach should be considered and a coalition or compact should be developed for the communities that will be most impacted. It is important to retain, restore and drain the water. Some design ideas that were presented included the following:

- *Architectural embankment*
    - Combine architectural and urban development to protect areas behind the embankment
- *Folding the ground level*
    - Higher berm to protect behind industrial areas
- *Landscaping the shorelines*
    - Picking up the quality of existing shoreline and trying to design beautiful shoreline that will be ready for the threats that are coming
    - Work with green and grayscapes for berm development
    - Water storage is critical. Systems that are developed to create an intervention with water are key to the design for the future. Norfolk is competing for funding through the National Disaster Resilience Competition

Water storage is critical. Systems that are developed to create an intervention with water are key to the design for the future. Norfolk is competing for funding through the National Disaster Resilience Competition ($1 billion).

Other ideas for coastal defense:

- Green berms (priority)
- Floodwalls
- Living shorelines
- Increasing stormwater pipe sizes
- Increasing storage capacity of wetlands
- Curb retention areas at intersections
- Rain gardens
- Pervious pavement on parking alleys

The following are other links that may be informative regarding the workshops and strategies that are recommended for the Norfolk, Hampton, Hampton Roads municipalities.

Other Dutch *Dialogues* Virginia links:
http://plus.usgbc.org/dutch-dialogues/
http://orf.maps.arcgis.com/apps/MapJournal/index.html?appid=5887c8fa1c754366bed999eb0c9b9f8a
https://wparch.com/national-disaster-resilience-competition/
https://hampton.gov/3466/Dutch-Dialogues
https://wbae.com/projects/dutch_dialogues_virginia
http://wetlandswatch.org/dutch-dialogues/

Videos of Sessions and Recaps of Workshop:
https://youtu.be/36umjKvxtPA - recap 6/23/15

https://youtu.be/x9Zx0Qp8CKA

https://youtu.be/KuHOwTVYHQA -video opening sessions

https://www.youtube.com/watch?v=A5Gh51we4fM