TIDES TO STORMS

PREPARING FOR NEW HAMPSHIRE'S FUTURE COAST

Assessing Risk and Vulnerability of Coastal Communities to Sea Level Rise and Storm Surge

Seabrook - Hampton Falls – Hampton - North Hampton – Rye - New Castle - Portsmouth

TOWN OF RYE, NEW HAMPSHIRE

Vulnerability Assessment Report

Prepared by the
Rockingham Planning Commission

September 2015

ACKNOWLEDGEMENTS

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Cover Photo Credit: Steve Miller

Use and Applicability of this Vulnerability Assessment Report and Results:
The purpose of this vulnerability assessment report is to provide a broad overview of the potential risk and vulnerability of state, municipal and public assets as a result of projected changes in sea-levels and coastal storm surge. This report should be used for preliminary and general planning purposes only, not for parcel level or site specific analyses. The vulnerability assessment performed was limited by several factors including the vertical accuracy of elevation data (derived from LiDAR) and the static analysis applied to map coastal areas subject to future flooding which does not consider wave action and other coastal dynamics. Also, the estimated flood impacts to buildings and infrastructure are based upon the elevations of the land surrounding them, not the elevation of any structure itself.

PLANNING TO REDUCE RISK AND VULNERABILITY

New Hampshire coastal municipalities are confronted by land use and hazard management concerns that include extreme weather events, storm surges, flooding and erosion. These issues are only intensified by recent increases in the frequency and intensity of extreme storm events and increases in sea level.

New Hampshire's economy and quality of life have historically been linked to its shores, its vast expanses of productive saltmarshes and sandy beaches. Increased flooding has the potential to place coastal populations at risk, threaten infrastructure, intensify coastal hazards and ultimately impact homes, businesses, public infrastructure, recreation areas, and natural resources. Accounting for changes in sea level and coastal storms will help lead to informed decisions for public and private investments by minimizing risk and vulnerability.

What is a Vulnerability Assessment?

A vulnerability assessment identifies and measures impacts of flooding from sea level rise and storm surge on built structures, human populations and natural environments. Factors that influence vulnerability include development patterns, natural features and topography. The assessment evaluates existing and future conditions such as:

- inland extent and depth of flooding
- impacts to natural and human systems
- changes in impacts between different flood levels

How can the vulnerability assessment be used?

Information from a vulnerability assessment can help guide common sense solutions, strategies and recommendations for local governments, businesses, and citizens to enable them to adopt programs, policies, business practices and make informed decisions.

Planning for the long-term effects of sea level rise may also help communities better prepare in the short-term for periodic flooding from severe coastal storms.

How will the vulnerability assessment benefit the community?

The Tides to Storms assessment is intended to assist coastal NH communities to take actions to prepare for increase flood risk, including:

- Enhance preparedness and raise community awareness of future flood risks.
- Identify cost-effective measures to protect and adapt to changing conditions.
- Improve resiliency of infrastructure, buildings and investments.
- Protect life, property and local economies
- Protect services that natural systems provide
- Preserve unique community character

Results from a vulnerability assessment can be incorporated into various municipal planning, regulatory and management documents such as:

Master Plan	Capital Improvement Plan	Land Conservation Plan
Zoning Ordinance	Site Plan Review Regulations	Subdivision Regulations
Roadway Management Plan	Stormwater Management Plan	Facilities Management Plan

TABLE OF CONTENTS

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FEMA

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New Hampshire DOT Department of Transportation

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MAPPING AND ASSESSMENT OVERVIEW

1. VULNERABILITY ASSESSMENT: SEA LEVEL RISE AND STORM SURGE SCENARIOS

The *Tides to Storms* coastal vulnerability assessment project produced maps and statistical data about the potential impacts to New Hampshire's seven coastal municipalities from sea-level rise and storm surge to infrastructure, critical facilities transportation systems, and natural resources. Three sea-level scenarios were evaluated accounting for a range from the intermediate-low to the highest projected sea-levels at the year 2100.

Sea-Level Rise and Storm Surge Scenarios

Sea-Level Rise (SLR) Scenarios	SLR	SLR	SLR	SLR	SLR	SLR
Sea Level Rise	1.7 feet	4.0 feet	6.3 feet	--	--	--
Sea-level Rise + Storm Surge	--	--	--	1.7 feet + Storm Surge	4.0 feet + Storm Surge	6.3 feet + Storm Surge

Note: Storm surge is the area flooded by the 100-year/1% chance storm event.

Baseline: Flooding from the sea-level rise scenarios and sea-level rise plus storm surge scenarios evaluated in this study were mapped from Mean Higher High Water (MHHW) which is 4.4 feet in the coastal region of NH. ***Mean Higher High Water is the average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch. The National Tidal Datum Epoch (NTDE) refers to the specific 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken. The present NTDE is 1983 through 2001 and is considered for revision every 20-25 years (the next revision would be in the 2020-2025 timeframe).***[1]

Storm Surge: ***Storm surge is the rise of water level accompanying intense coastal storm events such a tropical storm, hurricane or Nor'easter, whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the storm event.***[2] Storm surge is mapped using the 100-year/1% chance flood events from the Preliminary Flood Insurance Rate Maps (FIRMs) released by FEMA in 2014. The preliminary FIRM's account for the limit of moderate wave action in coastal areas, however this assessment does not take into account additional flooding and impacts related to more severe wave action, wind action, erosion and other dynamic coastal processes.

Sea-Level Rise Scenarios

These sea-level rise projections used in this study are based on an earlier study completed in 2011 by Wake et al but are similar to a more recent report issued by the NH Coastal Risks and Hazards Commission's Science and Technical Advisory Panel in 2014. As shown in the graphics below, while slightly different than the scenarios cited in the 2014 report, the sea level rise scenarios used in the Tides to Storms assessment yield coverage estimates of flooding that are within the mapping margin of error for the scenarios in both the 2011 and 2014 reports.

[1] NOAA website at http://tidesandcurrents.noaa.gov/datum_options.html
[2] EPA website at http://epa.gov/climatechange/glossary.html

	Lower Emissions (B1)		Higher Emissions (A1fi)	
	2050	2100	2050	2100
Current Elevation of MHHW[a,b]	4.43	4.43	4.43	4.43
100-Year Flood Height	7.78	7.78	7.78	7.78
Subsidence	0.012	0.016	0.012	0.016
Eustatic SLR	1.0	2.5	1.7	6.3
Total Stillwater Elevation[a,c]	**13.2**	**14.7**	**13.9**	**18.5**

a - NAVD: North American Vertical Datum of 1988
b - MHHW: Mean Higher High Water at Fort Point, NH
c - Total Stillwater Elevation may not equal total of components due to rounding

Table 13. Preliminary estimates of future 100-year flood Stillwater elevations at the Fort Point Tide gauge under lower and higher emission scenarios (feet relative to NAVD[a])

Figure 2. 2011 Sea-Level Rise Scenarios (based on greenhouse gas emissions)

Source: Wake CP, E Burakowski, E Kelsey, K Hayhoe, A Stoner, C Watson, E Douglas (2011) *Climate Change in the Piscataqua/Great Bay Region: Past, Present, and Future*. Carbon Solutions New England Report for the Great Bay (New Hampshire) Stewards.

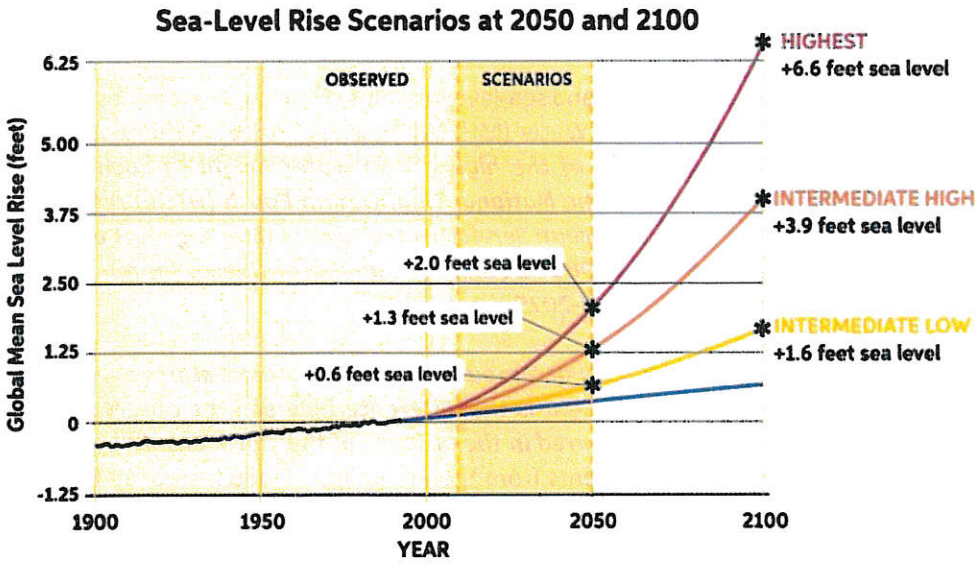


Figure 3. 2014 Sea-Level Rise Scenarios (based on greenhouse gas emissions)

Source: Wake CP, Kirshen P, Huber M, Knuuti K, and Stampone M (2014) *Sea-level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire: Analysis of Past and Projected Future Trends*, prepared by the Science and Technical Advisory Panel for the New Hampshire Coastal Risks and Hazards Commission.

2. ASSETS AND RESOURCES EVALUATED

Table 1 lists the three major categories and a detailed list of the assets and resources evaluated as part of the Tides to Storms vulnerability assessment. The assets and resources evaluated are listed in subsequent tables in this report only if they are affected by one or more of the sea-level rise and/or coastal storm surge scenarios.

CATEGORY	ASSETS AND RESOURCES
CRITICAL FACILITIES AND INFRASTRUCTURE	Municipal Critical Facilities (identified in Hazard Mitigation Plans) NHDOT Transportation Infrastructure Federal and State Historic Register Properties Other Assets: fire and police stations, graveyards, schools, dams, power stations and substations, public water supply wells, harbors, bridges NHDOT Ten-year and Long Range Plan Projects
ROADWAYS AND TRANSPORTATION ASSETS	State and Local Roadways State and Local Culverts Regional and Municipal Evacuation Routes Urban Compact Areas
NATURAL RESOURCES	Freshwater and Tidal Wetlands Aquifers and Wellhead Protection Areas Land Conservation Plan for NH's Coastal Watershed – Core Focus Areas Wildlife Action Plan – Tier 1 and Tier 2 habitats Conserved and Public Lands Agricultural Soils

3. MAP DESIGN AND ORGANIZATION

The Tides to Storms map set is comprised of two components: a map depicting the extent of projected flooding from the three sea-level rise scenarios in shades of green, and a map depicting the three sea-level rise plus storm surge scenarios in shades of pink. Each of the asset categorized evaluated are displayed on these two maps. Examples of the two scenario maps are shown on the following page.

Extent of Flooding from Sea-Level Rise and Storm Surge

Green and pink color schemes are arranged from lightest to darkest with increasing flood extent.

Figure 4.
Sea-Level Rise 1.7 feet, 4.0 feet and 6.3 feet

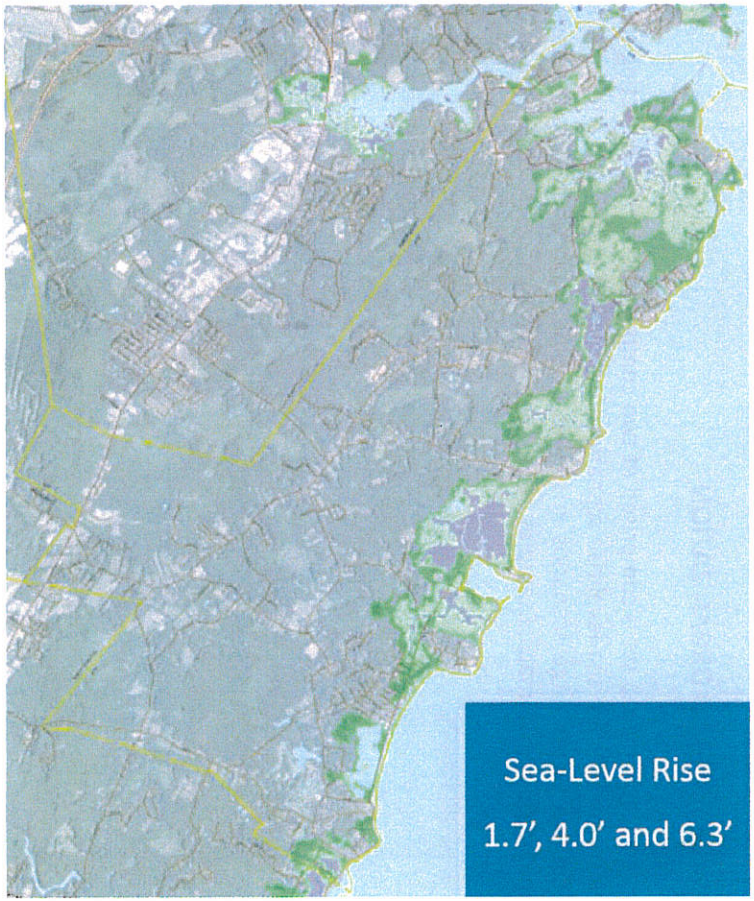
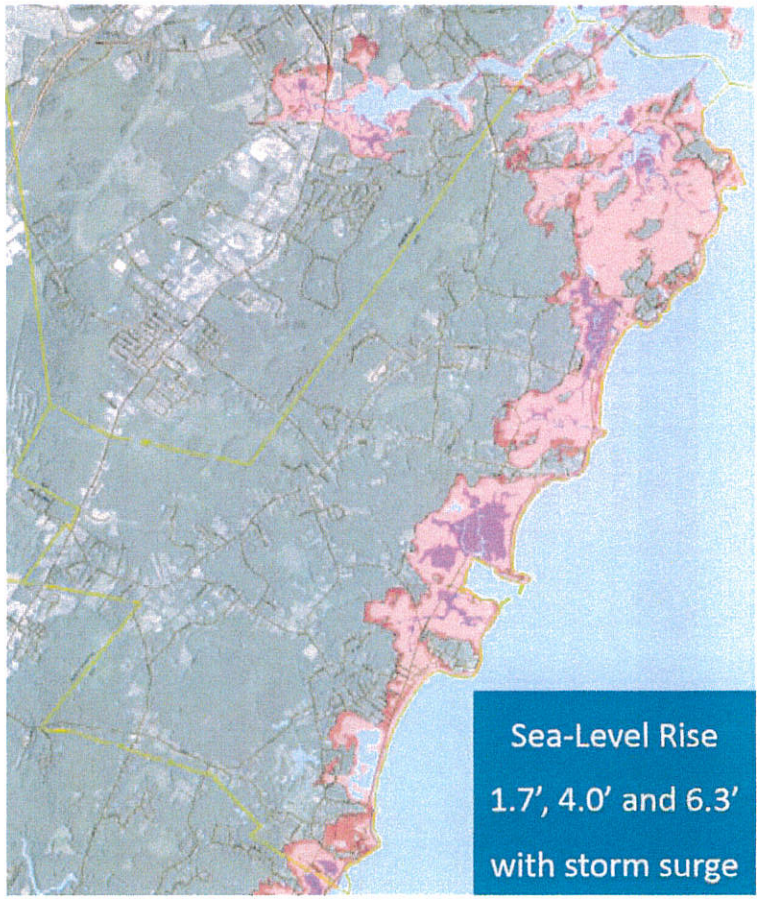


Figure 5.
Sea-Level Rise 1.7 feet, 4.0 feet and 6.3 feet with storm surge



Note: Storm surge = 100-year /1% chance flood.

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TOWN OF RYE, NEW HAMPSHIRE

OVERVIEW

The Town of Rye is located along the north coastal area of New Hampshire comprising 5,480.2 acres of upland and 2,925.7 acres of surface water, ocean and wetlands. With a population of 5,298 (2010), Rye is the fourth most populated of the seven coastal municipalities. Rye has the most coastal miles of all the seven Atlantic coastal municipalities. Rye's coastal area is diverse consisting of sandy coves and beaches, rocky shoreline, extensive freshwater wetlands and tidal marshes, and tidal waterways that extend far inland. The town has several state owned facilities, marina and state parks, and Odiorne Point State Park, and the Seacoast Science Center, a public non-profit educational facility. Rye has a coastal historic district extending from Central Avenues and Washington Avenue to Wallis Road and Washington Road. The district includes the Brackett Road massacre site.

In 2014, Rye received a grant from the Piscataqua Region Estuaries Partnership to prepare an application to FEMA's National Flood Insurance Program's (NFIP) Community Rating System (CRS). CRS is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. As a result, flood insurance premium rates are discounted to reflect the reduced flood risk resulting from the community actions meeting the three goals of the CRS:

1. Reduce flood damage to insurable property;
2. Strengthen and support the insurance aspects of the NFIP, and
3. Encourage a comprehensive approach to floodplain management.[3]

Vulnerability Assessment Results

Key findings for the Town of Rye are reported in Table 2 below based on evaluation of the 1.7 feet intermediate-low, 4.0 feet intermediate, and 6.3 feet highest sea-level rise projections at the year 2100 and the sea-level rise projections with the 100-year storm surge.

The most significant assets affected by projected sea-level rise and coastal storm surge flooding in Rye are uplands (including the 100-year and 500-year floodplains), freshwater and tidal wetlands, conserved lands, and infrastructure which are state and municipal culverts. Although a number of roads are affected by flooding, the majority are state roads including Route 1A and Route 1B.

Much of Rye's municipal facilities and infrastructure are located outside the coastal area with the exception of roads, culverts, and water and wastewater systems serving a portion of coastal residents and businesses.

Rye's local roads are more greatly affected by projected flooding than state roads at the 1.7 feet and 4.0 feet sea level rise scenarios. The state and local road miles affected by the higher sea-level rise and three

[3] From FEMA's website at http://www.fema.gov/national-flood-insurance-program-community-rating-system

storm surge scenarios are nearly equal. At the 6.3 feet sea-level rise scenarios and all three storm surge scenarios the majority of Route 1A in Rye is affected by flooding.

The land use types most impacted by both sea-level rise and coastal storm surge flooding are residential development, surface water and wetland systems. Residential areas located directly adjacent to Route 1A and developed areas adjacent to tidal drainage systems

TABLE 2. SUMMARY OF ASSESSMENT DATA

Sea-Level Rise (SLR) Scenarios	SLR 1.7 feet	SLR 4.0 feet	SLR 6.3 feet	SLR 1.7 feet + storm surge	SLR 4.0 feet + storm surge	SLR 6.3 feet + storm surge
Infrastructure (# of sites/facilities)	24	50	66	65	75	83
Critical Facilities (# of sites/facilities)	0	2	2	2	4	7
Roadways (miles)	0.2	4.5	9.5	9.9	14.2	17.1
Upland (acres)	567.7	945.8	1,223.7	1,200.6	1,465.9	1,690.6
Freshwater Wetlands (acres)	66.7	198.6	250.2	239.0	280.1	308.7
Tidal Wetlands (acres)	463.8	509.2	519.8	524.9	527.6	528.6
Conserved and Public Lands (acres)	309.0	436.2	501.0	495.7	544.3	588.3
100-year floodplain (acres)	1,227.6	1,603.9	1,707.9	1,721.7	1,786.4	1,808.1
500-year floodplain (acres)	1,228.6	1,609.1	1,763.7	1,777.1	1,842.3	1,864.1

Note: Scenarios S1, S2, S3 = sea-level rise; Scenarios S1F, S2F, S3F = sea-level rise + 100-year storm surge. Upland refers to land above mean higher high water (highest tidal extent). 500-year floodplain impacts were calculated based on flooding within the extent of the 500-year floodplain.

As reported in table 10 of this report, for Rye, there is a 42 percent increase in the number of affected parcels and nearly a $167 million increase in assessed value from the 1.7 feet to the 4.0 feet sea-level rise scenarios. There is a 28 percent increase in the number of affected parcels and approximately a $140 million increase in assessed value from the 4.0 feet to the 6.3 feet sea-level rise scenarios

The complete detailed vulnerability assessment information and recommendations are provided in the following sections of this report.

SUMMARY OF VULNERABILITY ASSESSMENT RESULTS BY ASSET TYPE

INFRASTRUCTURE AND CRITICAL FACILITIES

Maps 3 and 4 Critical Facilities and Infrastructure shows state and municipal infrastructure types affected by sea-level rise and coastal storm surge flooding. Table 3 reports when specific infrastructure types are affected by each sea-level rise and coastal storm surge scenario.

State and local culverts and five bridges are affected by projected sea-level rise and coastal storm surge flooding. The majority of the culverts are state owned supporting Route 1A and Route 1B. Rye Harbor and several marinas are also impacted by the 4.0 feet and 6.3 feet sea-level rise and the three coastal storm surge scenarios.

Many bridges, which by definition can also include large culverts, are located in areas susceptible to flooding under current seasonal high tide conditions and coastal storm surge. Even the lowest levels of projected sea-level rise may cause bridges and particularly their low-lying roadway approaches to flood. Another concern for both culverts and bridges is the introduction of tidal flood waters to freshwater drainage systems not designed to accommodate tidal hydrologic conditions.

TABLE 3. INFRASTRUCTURE (# of facilities)

Sea-Level Rise (SLR) Scenarios	SLR 1.7 feet	SLR 4.0 feet	SLR 6.3 feet	SLR 1.7 feet + storm surge	SLR 4.0 feet + storm surge	SLR 6.3 feet + storm surge
Infrastructure						
Culverts (state and local)	17	38	50	49	58	63
Dams	0	0	1	1	1	2
Historical Highway Markers	1	1	2	2	2	3
Public Water Supply, Pump Houses	0	0	1	1	1	2
Other Transportation Assets						
Bridges	5	5	5	5	5	5
Harbor/Marina/Launch	1	4	4	4	4	4
Signs, Lights, Signals, Beacons	0	2	3	3	3	3
Total - Sites	**24**	**50**	**66**	**65**	**75**	**83**

Dams. Dam locations indicted on the Tides to Storms maps are based on data maintained by NHDES Dam Bureau of all dams in the state and represent both active and inactive dams that require regular state inspections, and those dams that are in ruins or exempt from state inspections due to small size and hazard status (most of these dams impound stormwater detention ponds). Additional information in this data layer include the dam name, impounded waterbody, drainage area, impoundment acreage, dam height, dam construction type, ownership (state, municipal, or private), dam status (active, inactive, ruins, exempt), and hazard classification. Dam hazard classifications are a ranking of the potential for the loss of life of property damage if a dam were to fail; there are no dams within the focus area of this project ranks as high hazard dams. Additional information regarding dams can be found at http://des.nh.gov/organization/divisions/water/dam/index.htm.

Definition of a Bridge. Per RSA 234:2, a bridge defines a bridge as a structure, having a clear span of 10 feet or more measured along the center line of the roadway at the elevation of the bridge seats, spanning a watercourse or other opening or obstruction, on a public highway to carry the traffic across, including the substructure, superstructure and approaches to the bridge. This definition includes a combination of culverts constructed to provide drainage for a public highway with an overall combined span of 10 feet or more and a distance between culverts of half the diameter or less of the smallest culvert.

Bridges Evaluated. Bridges identified as "impacted" by sea-level rise and/or storm surge scenarios indicates that the bridge and its infrastructure are located within the extent of the scenario. There has been no analysis to determine if the bridge, or any part of its structure is impacted.

Municipal Critical Facilities

Maps 3 and 4 Critical Facilities and Infrastructure shows the municipal critical facilities affected by sea-level rise and coastal storm surge flooding. Table 4 reports when specific municipal critical facilities are affected by each sea-level rise and coastal storm surge scenario.

Rye has few identified critical facilities that are impacted by projected sea-level rise and coastal storm surge flooding. One sewage pump station and Jenness Beach State Park are affected by the 4.0 feet and 6.3 feet sea-level rise and the three coastal storm surge scenarios. Wallis Sands State Park is affected by the 4.0 feet plus storm surge scenario and 6.3feet plus storm surge scenario. Rye Harbor State Park, Odiorne State Park and St. Andrews by the Sea are affected by the 6.3 plus storm surge scenario.

TABLE 4. MUNICIPAL CRITICAL FACILITIES (# of facilities)

Sea-Level Rise (SLR) Scenarios	SLR 1.7 feet	SLR 4.0 feet	SLR 6.3 feet	SLR 1.7 feet + storm surge	SLR 4.0 feet + storm surge	SLR 6.3 feet + storm surge
Critical Facilities						
St. Andrews By the Sea	--	--	--	--	--	Flood
Rye Harbor State Park	--	--	--	--	--	Flood
Odiorne State Park	--	--	--	--	--	Flood
Sewage Pump Station	--	--	--	--	Flood	Flood
Wallis Sands State Park	--	--	--	--	Flood	Flood
Sewage Pump Station	--	Flood	Flood	Flood	Flood	Flood
Jenness Beach State Park	--	Flood	Flood	Flood	Flood	Flood
Total - Sites	**0**	**2**	**2**	**2**	**4**	**7**

In the 2015 Natural Hazards Mitigation Plan, additional municipal critical facilities will be identified including assets on the Isles of Shoals.

Historical Resources and Assets

The vulnerability assessment identified two National Historic Register properties that are affected by the sea-level rise and coastal storm surge scenarios evaluated.

TABLE 5. NATIONAL HSITORIC REGISTER PROPERTIES

Sea-Level Rise (SLR) Scenarios	SLR 1.7 feet	SLR 4.0 feet	SLR 6.3 feet	SLR 1.7 feet + storm surge	SLR 4.0 feet + storm surge	SLR 6.3 feet + storm surge
St. Andrew's By-The-Sea	0	0	0	0	0	1
Pulpit Rock Base-End Station (N. 142)*	1	1	1	1	1	1
Total - Sites	**1**	**1**	**1**	**1**	**1**	**2**

* The station structure is not affected but the surround lands are affected by flooding.

TRANSPORTATION

Maps 5 and 6 Road and Transportation Assets show the state and municipal roadways affected by sea-level rise and coastal storm surge flooding. Table 6 reports the miles of state and local roadways affected by each flood scenario.

TABLE 6. STATE AND MUNICIPAL ROADWAYS AND INFRASTRUCTURE (miles)

Sea-Level Rise (SLR) Scenarios	SLR 1.7 feet	SLR 4.0 feet	SLR 6.3 feet	SLR 1.7 feet + storm surge	SLR 4.0 feet + storm surge	SLR 6.3 feet + storm surge
Roadway Type						
Local	0.2	2.7	4.7	4.4	7.0	9.3
State	0.1	1.8	4.8	5.5	7.2	7.8
Total Road Miles	**0.2**	**4.5**	**9.5**	**9.9**	**14.2**	**17.1**
Guardrail	0.1	0.4	0.7	0.7	0.9	0.9
Bike Routes	0.3	2.3	5.0	6.1	7.6	8.2
Evacuation Routes	0.1	2.2	5.4	6.1	8.2	9.3

Rye's local roads are more greatly affected by projected flooding than state roads at the 1.7 feet and 4.0 feet sea level rise scenarios. The state and local road miles affected by the higher sea-level rise and three storm surge scenarios are nearly equal. At the 6.3 feet sea-level rise scenarios and all three storm surge scenarios the majority of Route 1A in Rye is affected by flooding.

The roads impacted, many of which connect to Route 1A, greatly affect the functionality of designated emergency evacuation routes in Rye and connections to emergency routes in adjacent municipalities. Rye recognizes the need for improved evacuation planning, particularly early notification to certain neighborhoods that may become isolated by flooding at early stages of a storm event, and installation of signage to mark evacuation routes in town. Even moderate roadway flooding can create isolated residential neighborhoods at Straws Point, Winslow Way and Fairhill.

Many of Rye's roadway improvement projects have required multi-jurisdictional approval (NHDES, USACE) whereby the town has opted to replace culverts "where is, as is" to avoid a costly and lengthy approval process. Some upgrades to culverts and roads have been difficult due to the need for expansion on private land to accommodate a new design.

NATURAL RESOURCES

Maps 7 and 8 Conservation Areas and ***Map 9 and 10 Wetlands, Aquifers, Wellhead Protection Areas*** show natural resources affected by sea-level rise and coastal storm surge flooding. Table 7 reports the number of acres for each natural resource affected by each sea-level rise and coastal storm surge scenario.

Natural coastal features such as forests, freshwater wetlands, salt marsh, sand beaches, and rocky shoreline provide protection against erosion and storm surge, and provide flood storage for both tidal flooding and stormwater runoff.

Combined, the town, the state and private property owners have conserved or hold easements on significant acreage within Rye's coastal area. Retaining these lands in a natural undeveloped state helps to reduce the town's risk and vulnerability to projected sea-level rise and coastal storm flooding. The town may consider aligning its land protection strategies by incorporating criteria in its selection process that takes into account the value and benefits to both humans and ecosystems of increasing land protection efforts in areas projected to have high flood risk in the future.

The assessment indicates potential in Rye for inland tidal marsh migration and conversation of freshwater wetlands to tidal systems. Refer to the following section of this report for a detailed description of project saltmarsh conditions from the Sea Level Affecting Marshes Model results from NH Fish & Game.

Significant acreage within the Coastal Conservation Plan Focus Areas and Wildlife Action Plan Tier 1 and Tier 2 habitats may be affected by projected sea-level rise. Refer to the new Climate Change section of the Wildlife Action Plan for information about potential impacts to Tier 1 and Tier 2 resources (http://www.wildlife.state.nh.us/wildlife/wap.html).

Although most are likely not actively farmed, agricultural soils show sensitivity to flooding under the 4.0 feet and 6.3 feet sea-level rise scenarios and the three coastal storm surge scenarios.

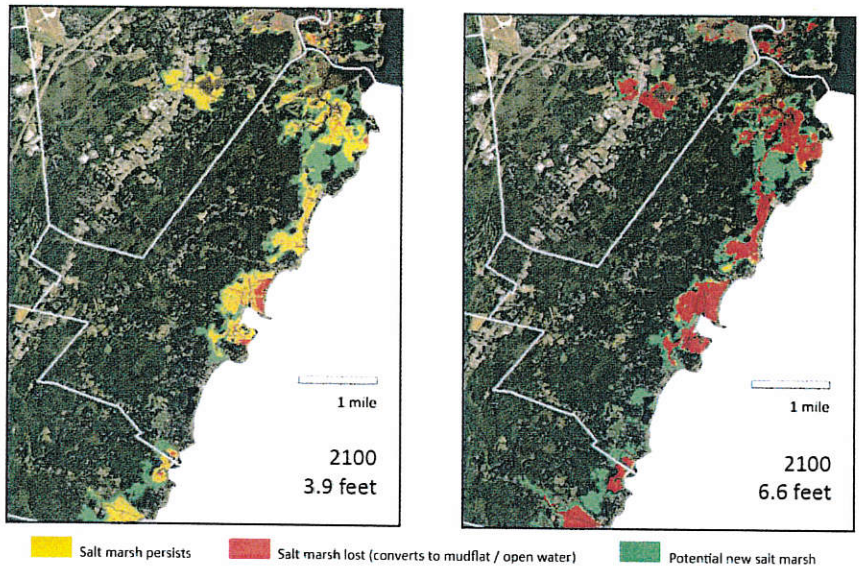
TABLE 7. NATURAL RESOURCES (acres)

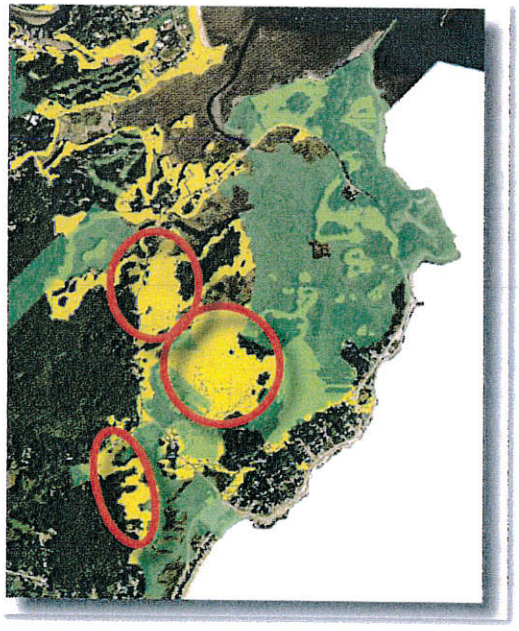
Sea-Level Rise (SLR) Scenarios	SLR 1.7 feet	SLR 4.0 feet	SLR 6.3 feet	SLR 1.7 feet + storm surge	SLR 4.0 feet + storm surge	SLR 6.3 feet + storm surge
Resource Type						
Surface Water	47.1	61.2	66.2	67.0	68.7	69.4
Stratified Drift Aquifers	0.0	0.0	0.0	0.0	0.0	0.0
Freshwater Wetlands	66.7	198.6	250.2	239.0	280.1	308.7
Tidal Wetlands	463.8	509.2	519.8	524.9	527.6	528.6
Wildlife Action Plan – Tier 1 and Tier 2 habitat	1,153.9	1,438.1	1,604.9	1,583.7	1,732.0	1,868.8
Coastal Conservation Plan Focus Areas	481.7	704.2	809.8	794.5	873.8	944.3
Conserved and Public Lands	309.0	436.2	501.0	495.7	544.3	588.3
Ag Soils (All Types)	25.0	100.6	194.6	185.3	284.2	366.8

SEA LEVEL AFFECTING MARSHES MODEL (SLAMM): TOWN OF RYE

From: A Natural Choice: Conservation and Restoration Options to Enhance Coastal Resiliency in New Hampshire (NH Fish & Game, DRAFT September 2015)

Currently, 720 acres of salt marsh lie within Rye. At the 3.9 feet sea level rise by 2100 scenario there is potential for 509 acres of new marsh to form and at the 6.6 feet scenario there is potential for 210 acres. ***Rye has the opportunity to protect the greatest number of acres of potential new salt marsh in all of NH.***





The largest and most long term tidal connection restoration opportunity in the seacoast is located in Rye. Protecting land where salt marsh can potentially migrate is a good strategy to enhance coastal resiliency. Of the opportunities available, the areas circled on the map at right are some of the priority areas for conservation as they are particularly large, currently mainly undeveloped, and are robust as they remain under the highest sea level rise scenario modeled. In terms of maximizing total acreage of salt marsh in the state, the area of forested land to the west of Oidiorne Point is the most important to conserve. Areas in green are already protected, areas in yellow have the potential to suport salt marsh as it migrates inland.

There are several opportunites to remove or modify barriers to tidal flow, although not all will be logistically feasible. Potential opportunites are show in blue on the map below. Eel Pond is one of two large tidal connection restorations in the state that are particularly robust in terms of likely duration.

LAND USE

Maps 1 and 2 Extent of Flooding show upland affected by sea-level rise and coastal storm surge flooding above mean higher high water. Table 7 reports the number of acres of upland affected by each flood scenario.

Upland impacted by flooding from sea-level rise is low to moderate and flooding from coastal storm surge is moderate. Rye has enough increase in land elevation moving from coastal and tidal areas to protect most existing developed areas and resources. As shown on ***Maps 1 and 2*** the most heavily impacted areas are located directly adjacent to Route 1A and developed areas adjacent to tidal drainage systems.

TABLE 7. UPLAND (acres)

Sea-Level Rise (SLR) Scenarios	SLR 1.7 feet	SLR 4.0 feet	SLR 6.3 feet	SLR 1.7 feet + storm surge	SLR 4.0 feet + storm surge	SLR 6.3 feet + storm surge
Acres	567.7	945.8	1,223.7	1,200.6	1,465.9	1,690.6
% Upland	7.0	11.7	15.2	14.9	18.2	20.9

Total Upland in Rye = 8,073.5 acres. Upland refers to land above mean higher high water (highest tidal extent) and excludes wetlands.

Land Use/Land Cover

Map 14 Regional Land Use shows land use/land cover types affected by sea-level rise and coastal storm surge flooding. Table 8 reports the number of acres for each land use/land cover type affected by each flood scenario.

The land use types most impacted by both sea-level rise and coastal storm surge flooding are residential development, surface water and wetland systems. Residential areas located directly adjacent to Route 1A and developed areas adjacent to tidal drainage systems

TABLE 8. LAND USE/LAND COVER (acres)

Sea-Level Rise (SLR) Scenarios	SLR 1.7 feet	SLR 4.0 feet	SLR 6.3 feet	SLR 1.7 feet + storm surge	SLR 4.0 feet + storm surge	SLR 6.3 feet + storm surge
Land Use						
Active Agricultural	0.0	0.5	1.3	1.3	4.2	6.9
Aux Transportation	0.0	1.8	3.0	3.5	3.8	3.9
Forested	23.6	100.4	176.6	161.7	232.9	300.7
Industrial/Commercial	0.9	7.1	11.2	10.9	15.5	19.6
Other/Idle	13.0	35.0	56.8	64.3	77.9	86.5
Playing fields / Recreation	3.2	29.3	58.5	57.3	79.7	98.3
Residential	9.5	56.9	124.1	120.7	200.7	278.4
Transportation	0.5	14.6	30.9	33.2	44.9	51.7
Utilities	0.0				0.4	0.4
Surface Water	79.5	84.0	85.5	85.5	86.6	87.1
Freshwater/Tidal Wetlands	489.7	677.0	740.2	726.7	784.6	823.2

Note: Auxiliary Transportation refers to small pieces of land adjacent to transportation assets.

Zoning

Map 13 Regional Zoning shows local zoning districts affected by sea-level rise and coastal storm surge flooding. Table 9 reports the acres within each zoning district affected by each flood scenario. Zoning districts are superimposed over land use and land cover.

TABLE 9. ZONING DISTRICTS (acres)

Sea-Level Rise (SLR) Scenarios	SLR 1.7 feet	SLR 4.0 feet	SLR 6.3 feet	SLR 1.7 feet + storm surge	SLR 4.0 feet + storm surge	SLR 6.3 feet + storm surge
Zoning / Land Use						
Commercial	1.7	1.7	1.9	1.9	1.9	1.9
Mixed Urban	4.3	11.9	20.2	19.0	24.9	28.7
Open Space/Conservation	308.0	415.3	437.5	434.1	447.1	455.9
Residential - High Density	47.0	100.9	141.2	142.3	171.3	195.4
Residential - Med Density	251.6	465.7	675.1	655.2	873.3	1,061.9

Parcels and Assessed Value

Table 10 reports the number of parcels affected by each of the six scenarios evaluated and the aggregated assessed value of these parcels. The degree to which the parcel and any development on the parcel is affected by sea-level rise or storm related flooding was not analyzed. Affected parcels were identified based on their location either partially or fully within the extent of the scenarios evaluated. The data may include a number of high value parcels under state and municipal ownership.

For Rye, there is a 42 percent increase in the number of affected parcels and nearly a $167 million increase in assessed value from the 1.7 feet to the 4.0 feet sea-level rise scenarios. There is a 28 percent increase in the number of affected parcels and approximately a $140 million increase in assessed value from the 4.0 feet to the 6.3 feet sea-level rise scenarios

TABLE 10. PARCELS AND ASSESSED VALUE BY SCENARIO

Sea-Level Rise (SLR) Scenarios	Number of Parcels Affected by scenario	Aggregate Value of Affected Parcels
1.7 feet SLR	462	$344,634,500
4.0 feet SLR	656	$511,326,300
6.3 feet SLR	842	$651,847,100
1.7 feet SLR + storm surge	816	$644,606,700
4.0 feet SLR + storm surge	981	$743,644,600
6.3 feet SLR + storm surge	1094	$809,845,700

FEMA Flood Hazard Areas

Maps 23 and 24 Preliminary FEMA Flood Hazard Areas show areas within the 100-year and 500-year floodplain affected by sea-level rise and coastal storm surge flooding. Table 11 reports the acreage within the current 100-year and 500-year floodplains affected by each flood scenario.

The majority of land affected by projected sea-level rise and coastal storm surge flooding is located within the current 100-year floodplain with minor extension of flooding into the 500-year floodplain. The occurrence of the three sea-level rise scenarios within the 100-year floodplain provides the rationale to implement climate adaptation strategies within the current 100-year floodplain that will create resiliency to protect against long term impacts from projected sea level rise at 2050 and 2100.

TABLE 11. FEMA FLOOD HAZARD AREAS (acres)

Sea-Level Rise (SLR) Scenarios	SLR 1.7 feet	SLR 4.0 feet	SLR 6.3 feet	SLR 1.7 feet + storm surge	SLR 4.0 feet + storm surge	SLR 6.3 feet + storm surge
100-year floodplain	**1,227.6**	**1,603.9**	**1,707.9**	**1,721.7**	**1,786.1**	**1,808.1**
Total Coastal Region Impacted	8,179.5	9,361.1	9,593.2	9,639.0	9,765.8	9,818.0
500-year floodplain						
Total Coastal Region Impacted	8,180.6	9,368.4	9,837.6	9,879.8	10,015.3	10,069.5

Total Area of the 100-year floodplain = 2,160.1 acres. Total Area of the 500-year floodplain = 2,216.1 acres. Floodplain assessment based on Preliminary Flood Insurance Rate Maps (FIRMs) released by FEMA in 2014.

ISSUES AND CONSIDERATIONS

The following issues and considerations were identified during project meetings with municipal staff and land use board and commission members.

- Improvements to the state roadway network (elevating, enlarging culvert and bridges) may affect local connector roads, driveway access points and connecting infrastructure and utilities.

- Although roadways, buildings and infrastructure can be protected by raising them above projected sea-level rise elevations, supporting land and land based uses may be impacted by daily tidal flooding from projected sea-level rise.

- Planning for long term sea-level rise can be integrated with existing regulatory and management frameworks for the current 100-year floodplain. (The three sea-level rise scenarios show future tidal flooding is contained mostly within the 100-year floodplain.)

- Ownership of transportation infrastructure and assets by multiple state agencies (roadways, culverts, state parks, parking areas) and town responsibility for management of assets (sidewalks, culverts) creates complexity in comprehensively managing these systems and implementing climate adaptation strategies. The town is concerned about the NHDOT's maintenance and improvements to several "shale piles" which serve as barriers that protect a number of homes, natural resources and roads during storm events and high tides.

- Flooding from sea-level rise and coastal storm surge impacting the state and local roadway network adjacent to the Route 1A disrupt the designated evacuation network in Rye and connections to evacuation routes in adjacent towns.

- Providing information about potential flood hazards to businesses and residents, and early notification of flood risk during a coastal storm event would enhance public safety and preparedness. Prepare a multi-tiered evacuation plan for storm events and other types of freshwater flooding.

- Long term infrastructure management, incorporating a staged and iterative approach, would benefit from an analysis of the costs necessary to improve roads and drainage infrastructure to withstand projected sea-level rise elevations at 2050 and 2100.

RECOMMENDATIONS

The following recommendations are short-term climate adaptation actions that can be included in the town's Natural Hazards Mitigation Plan, Master Plan and other planning and policy documents. These actions are focused on strengthening land use development standards, resource protection, municipal policy and plans, and public support to create more resilient development, infrastructure and natural systems. *Refer to Appendix B for an expanded list of climate adaptation strategies.*

REGULATORY

R1 - Elevate Structures 2 feet Above Base Flood Elevation. Adopt standards in floodplain zoning and/or Site Plan Review and Subdivision Regulations that require all new development and redevelopment to be elevated 2 feet above the base flood elevation. Two feet of additional elevation will ensure that structures are protected from flooding based on the highest sea-level rise projection of 2 feet by 2050.

R2 - Coastal Flood Hazard Overlay District. Adopt in the town's zoning ordinance a Coastal Flood Hazard Overlay District that includes performance based standards that protect against flood impacts from sea-level rise and coastal storm surge. Establish the overlay district boundaries based on current flood hazard areas on FEMA Flood Insurance Rate Maps and projected future high risk flood areas mapped by the Tides to Storms Vulnerability Assessment. (Also see similar recommendation in the Community Outreach and Engagement section below.)

R3 - Coastal Buffers and Tidal Marshes. Adopt buffers and setbacks that adequately separate development and infrastructure from tidal wetlands, freshwater wetlands and surface waters to sustain flood storage capacity, and allow for inland migration of tidal marsh systems and conversion of freshwater systems to tidal systems to accommodate projected changes in sea-levels.

PLANNING AND POLICY

P1 - Natural Hazards Mitigation Plan. Incorporate the vulnerability assessment information and recommendations from the Tides to Storms vulnerability assessment report in the town's 2015/2016 Natural Hazards Mitigation Plan update. Continue revising and updating the assessment information and climate adaptation recommendations in future updates of the Plan.

P2 - Master Plan Coastal Hazards Chapter. Adopt a Coastal Hazards Chapter in the town's Master Plan that incorporates information and recommendations from the Tides to Storms Vulnerability Assessment Report for Rye.

P3 - FEMA Community Rating System. Support implementation of climate adaptation actions that will qualify the town for FEMA's Community Rating System (CRS) program or increase its rating in the CRS program. Climate adaptation implementation includes planning and policy, regulatory, non-regulatory, and community outreach and engagement activities.

P4 - Capital Infrastructure and Investments. Incorporate consideration of impacts from sea-level rise and coastal storm surge flooding in current and future capital infrastructure projects. Incorporate the Tides to

Storms vulnerability assessment information into infrastructure management plans and capital improvement plans.

P5 - Land Conservation. Land conservation offers the greatest opportunities to provide for adaptation to the effects of sea-level rise and coastal storm flooding and climate change impacts.

- Adopt a targeted scoring framework or incorporate new scoring criteria into existing land conservation prioritization efforts that consider climate adaptation benefits when evaluating land for conservation purposes.
- Increase funding and resources for land conservation, land management programs, and land stewardship activities. (Note: Land conservation scores very high as an activity in the FEMA Community Rating System program.) Use land conservation as a tool for acquiring repetitive loss and highly vulnerable properties and restore them to a natural condition.

P6 - Wetlands Mitigation Site Inventory. Identify and inventory lands where protection of tidal and freshwater wetlands would provide tangible benefits to protect against flooding, and restoration opportunities to remove barriers to tidal function and marsh and migration. This inventory will allow the town to pre-identify and prioritize sites that can be permanently preserved as a mitigation strategy for wetland impacts from development in high risk coastal areas.

P7 - Evacuation Planning. Prepare evacuation plans and coordinate these plans with towns in the coastal region to implement timely and comprehensive planning and notification for coastal storm events.

COMMUNITY OUTREACH AND ENGAGEMENT

O1 – NH Coastal Adaptation Workgroup. The NH Coastal Adaptation Workgroup (CAW) is a voluntary collaborative advocacy group consisting of members from federal and state agencies, regional and non-profit organizations, municipalities, academia, and private businesses. The group's focus is to: 1) pursue activities that improve the resilience of natural systems, infrastructure and development to the impacts of climate change; and 2) facilitate communication and cooperation among stakeholders throughout the coastal watershed, especially in regard to research, programs and other efforts designed to help preserve, protect, and strengthen the Great Bay and Hampton-Seabrook Estuary. CAW can assist the city with outreach, planning and regulatory activities involving climate adaptation implementation.

- Continue supporting work of the NH Coastal Adaptation Workgroup.
- Continue the town's partnership with NH Coastal Adaptation Workgroup in climate adaptation activities that facilitate, coordinate, provide technical information, and convene public outreach events.

O2 - Implement FEMA's High Water Mark Initiative. Communities implement the High Water Mark Initiative by providing information on past floods, such as documenting high water marks in public places, and posting maps and photographs of past floods on their websites.

O3 - Coastal Flood Hazard Overlay Map. Use the Coastal Flood Hazard Overlay Map as a tool to inform property owners of existing and future risks and hazards based on projected sea-level rise and coastal storm surge flooding.

O4 - Living Shorelines and Landscaping. Maintaining natural shorelines is an effective way to preserve the functions of shoreline systems (marshes, dunes, estuaries) in providing valuable services including flood storage, recreational areas, and commercial harvesting of fish and shellfish.

- Provide information to property owners about living shorelines and the importance of retaining the functions of natural shorelines, and implementing landscaping best practices.
- Implement living shorelines projects on town lands to demonstrate best practices, and the benefits and effectiveness of living shorelines approaches.
- Dredge material could be used to replenish beaches and dunes.

Refer to Rye's Natural Hazards Mitigation Plan for additional recommendations for outreach and engagement activities.

APPENDIX A – MAP SET

Map 1 Extent of Projected Tidal Flooding - SLR 1.7', 4.0' and 6.3'
Map 2 Extent of Projected Tidal Flooding - SLR + Storm Surge
Map 3 Critical Facilities and Infrastructure - SLR 1.7', 4.0' and 6.3'
Map 4 Critical Facilities and Infrastructure - SLR + Storm Surge
Map 5 Roads and Transportation Assets - SLR 1.7', 4.0' and 6.3'
Map 6 Roads and Transportation Assets - SLR + Storm Surge
Map 7 Existing and Recommended Conservation Areas - SLR 1.7', 4.0' and 6.3'
Map 8 Existing and Recommended Conservation Areas - SLR + Storm Surge
Map 9 Wetlands, Aquifers, Wellhead Protection Area - SLR 1.7', 4.0' and 6.3'
Map 10 Wetlands, Aquifers, Wellhead Protection Area - SLR + Storm Surge
Break in map numbering.
Map 13 Zoning Districts - SLR 1.7', 4.0' and 6.3'
Map 14 Land Use/Land Cover - SLR 1.7', 4.0' and 6.3'
Break in map numbering.
Map 17 Depth of Flooding - Sea-Level Rise 1.7'
Map 18 Depth of Flooding – Sea-Level Rise 4.0'
Map 19 Depth of Flooding – Sea-Level Rise 6.3'
Map 20 Depth of Flooding – Sea-Level Rise 1.7' + Storm Surge
Map 21 Depth of Flooding - Sea-Level Rise 4.0' + Storm Surge
Map 22 Depth of Flooding – Sea-Level Rise 6.3' + Storm Surge
Map 23 Preliminary FEMA Flood Hazard Areas - SLR 1.7', 4.0' and 6.3'
Map 224 Preliminary FEMA Flood Hazard Areas - SLR + Storm Surge