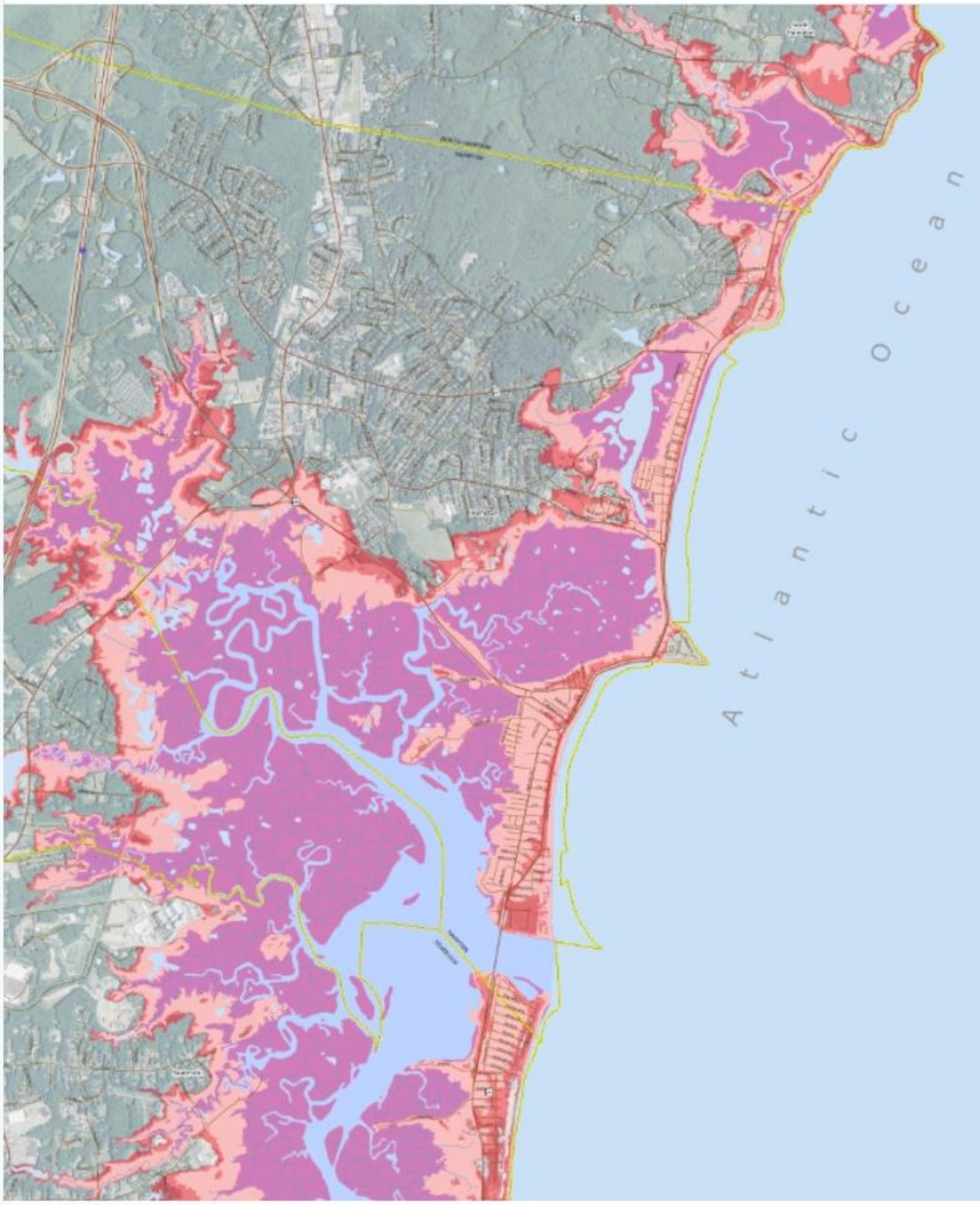
FROM TIDES TO STORMS: PREPARING FOR NEW HAMPSHIRE'S FUTURE COAST

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

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



ROCKINGHAM PLANNING COMMISSION

Prepared by Rockingham Planning Commission

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The Rockingham Planning Commission gratefully acknowledges the participation of coastal New Hampshire municipalities in the preparation of this report:

City of Portsmouth
Town of New Castle
Town of Rye
Town of North Hampton
Town of Hampton
Town of Hampton Falls
Town of Seabrook

The Tides to Storms project was enhanced by the willingness of these municipalities to support preparation of a coastal vulnerability assessment for New Hampshire. These municipalities contributed a great deal of staff hours to support this effort and their elected officials, land use boards and commissions, and volunteers participated in roundtable discussions to review maps and assessment data, and share their perspectives about how coastal hazards impact their community. We thank each municipality and their representatives for their contributions to this project.

Sincerely,

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Use and Applicability of this 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 identification of flood impacts to buildings and infrastructure are based upon the elevations of the land surrounding them, not the elevation of any structure itself. The changes in sea-level used as the basis of the vulnerability assessment are based on a plausible range of sea-level scenarios as depicted in the 2014 National Climate Assessment and New Hampshire Coastal Risks and Hazards Commission Science and Technical Advisory Committee 2014 report, and are not projections or estimates. The assumptions that underlie the sea-level scenarios should be reviewed on a regular basis.

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List of Maps

Assessing Risk and Vulnerability to Sea-level rise and Storm Surge: A Vulnerability Assessment of Coastal New Hampshire

I. Executive Summary

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

New Hampshire coastal communities have a distinct and pressing need to address the existing and future impacts relating to climate change, particularly relating to coastal flooding from storm surge and sea-level rise. Without proactive solutions to address the expected impacts of climate change, coastal communities face a multitude of challenges to ensure the security, health and welfare of their citizens and provide for a stable and viable economic future.

In September 2015 the Rockingham Planning Commission (RPC) completed the Tides to Storms project to assess the vulnerability of coastal municipalities and public infrastructure to flooding from expected increases in storm surge and rates of sea-level rise. The project's purpose was to develop a regional scale understanding of what and where impacts from sea-level rise and storm surge will occur on New Hampshire's coast. The geographic extent of the project includes the following municipalities: Portsmouth, New Castle, Rye, North Hampton, Hampton, Hampton Falls and Seabrook. The study did not include an assessment of the specific degree of damage nor estimate monetary losses to specific sites or properties. Further depth-damage analyses of affected assets using the flood depth maps may yield some of this information in follow-up work. The data generated from this project will enable individual communities, agencies and researchers to undertake this work in the future.

In addition to the regional vulnerability assessment, an assessment report and map set were prepared for each of the seven coastal municipalities. Municipalities were provided maps and an assessment of risks to roadways and supporting transportation infrastructure, critical facilities and infrastructure, and natural resources. Flooding scenario maps were based on the 2014 National Climate Assessment, 2015 (Preliminary) Flood Insurance Rates Maps released by the Federal Emergency Management Agency (FEMA), and high resolution digital elevation data. This information was supplemented with a series of recommended actions that municipalities can take to help adapt and improve resiliency to changing conditions caused by storm surge and sea-level rise. The information and recommendations from this project should be considered for incorporation into local hazard mitigation plans. The information can also be incorporated into other state and municipal plans, policies, practices and regulatory standards.

Data sources and assumptions that underlie the flood scenarios used in this assessment are explained more fully in Section IV of this report.

SUMMARY OF VULNERABILITY ASSESSMENT RESULTS

Key findings of the coastal assessment are based on evaluation of the extent of inundation that would result under three scenarios of static sea-level rise: 1.7 feet (“intermediate-low”), 4.0 feet (“intermediate high”), and 6.3 feet (“highest”) for the year 2100 and three additional scenarios that combine the static sea-level rise combined with the 100-year storm surge. In addition separate regional maps were prepared which mapped the depth of flooding associated with each scenario. An analysis was conducted to determine the intersection of inundation areas with key assets, including transportation, critical facilities (community defined) infrastructure and natural resources to evaluate the quantitative impacts of the flooding.

Table 1 provides a statistical overview of the flood impacts to specific assets and resource types from the sea-level rise and storm surge scenarios evaluated. A few of the findings discussed in more detail in the body of the report are these:

- In most instances, the greatest increase in flood impacts occurs from the transition from the intermediate low (1.7 feet) to the intermediate high (4.0) feet sea-level rise scenarios.
- The miles of local roadways impacted by flooding is at least double the miles of state roadways affected under all six flood scenarios in all seven coastal municipalities.

TABLE 1. SUMMARY OF FLOOD IMPACTS FROM SEA-LEVEL RISE AND STORM SURGE

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)	37	90	135	137	162	190
Critical Facilities (# of sites)	13	33	48	44	64	98
Roadways – Local (miles)	3.5	17.0	29.4	32.8	38.8	50.5
Roadways - State (miles)	1.6	6.6	14.1	18.7	21.8	25.6
Transportation Assets (# of sites)	35	50	68	65	78	90
Upland (acres)	1,484.6	2,602.2	3,613.5	3,473.5	4,439.0	5,298.4
Freshwater Wetlands (acres)	184.1	396.2	518.7	488.8	592.5	660.6
Tidal Wetlands (acres)	235.3	257.3	264.2	266.5	268.4	268.6
Conserved and Public Lands (acres)	492.7	717.0	873.0	882.6	1,007.0	1,131.0
Conservation Focus Areas (acres)	4,021.7	4,851.1	5,468.8	5,385.4	5,947.5	6,458.3
Wildlife Action Plan Tier I+II (acres) Tier 1 and Tier 2 habitats (acres)	1,080.7	1,600.4	1,914.7	1,864.9	2,112.0	2,309.9
100-year floodplain (acres)	8,179.5	9,361.1	9,593.2	9,639.0	9,765.8	9,818.0
500-year floodplain (acres)	8,180.6	9,368.4	9,837.6	9,879.8	10,015.3	10,069.5

Note: Upland refers to land above mean higher high water (highest tidal extent). The seven coastal region municipalities have approximately 52,751.8 acres of upland. Storm surge = 100-year / 1% chance flood event.

- The seven coastal municipalities combined have 49,266 acres of upland (land above mean higher-high water). At the lowest SLR scenario, about 3% (1484 acres) of this upland will be inundated by tides on a regular basis; at the intermediate high scenario, 5.3% (2602 acres) of upland would be affected and at the highest SLR scenario, 7.3% or 3613 acres would be affected. Upland impacts are greater in Rye than in other communities because of the extensive low-lying areas around the marshes west of Odiorne Point.

- Over500 acres of current freshwater wetlands would be subject tidal inflows under the highest (6.3 feet) SLR scenario (non-storm surge).
- Portsmouth, Rye, Hampton and Seabrook have the greatest number of acres of conserved lands and public lands within the coastal floodplain. Although impacted by sea-level rise and coastal storm surge flooding, these undeveloped lands serve as important flood storage areas and allow space for future habitat conversation and salt marsh migration.
- Projected sea-level rise and coastal storm surge flooding are largely contained within the current 100-year floodplain with minor incursions within the 500-year floodplain in lowest lying areas.

Roadways and Transportation Assets

Route 1-A provides the vital transportation link on the immediate coast and is essential to coastal communities for access, safety, livability, recreation and for the continued viability of coastal tourist economy. With its immediate shoreline exposure, it comes as no surprise that Route 1-A is the transportation asset most vulnerable coastal flooding and disruption from sea-level rise scenarios. As shown in the project maps, the route and any connecting streets and roads are significantly affected by sea-level rise in the intermediate high and high scenarios. I-A is the backbone of the road network on the immediate coast for all of the communities (except Hampton Falls) and is essential for maintaining a function roadway system. To a great extent local responses on municipal roads will depend on State plans for improving the resilience of Route 1A and will require extensive regional coordination.

Critical Facilities and Infrastructure

Communities recognize the critical importance ensuring that emergency facilities and shelters be located in places that are secure and accessible. With existing coastal flood hazards in mind, relatively few although critical facilities are located in vulnerable locations including the Hampton Police Station and Fire Station, and the Hampton and Seabrook wastewater treatment facilities. Given the cost of making certain infrastructure and critical facilities more resilient, it is important that upgrades be budgeted as part of a long term capital improvement and included in cost estimates for new projects and facilities.

Land Use

As stated in section VI.2 General Considerations, the best way to limit the region's property and infrastructure exposure to future sea-level rise is to ensure that future development is limited in those vulnerable areas. Future land use polices that discourage further development in areas that will become vulnerable in a future 100-year storm will extend that protection and limit future losses. The adjacent upland areas that would be protected with this approach will also serve as critical flood storage in future storms and support marsh migration. Implementation strategies include land conservation/property acquisition, conservation subdivision, transfer of development rights, restoration of natural vegetation and adaptive repurpose/reuse.

Natural Resources and Environment

The coastal region is home to a wide variety of natural resources and ecosystems, including tidal and freshwater wetlands, salt marsh systems, estuarine systems, beaches, dunes, freshwater aquifers, and farm and forest land. Many of these natural areas provide significant economic value to the state and critical ecosystem services that protect assets and infrastructure, however many of these resources are also highly vulnerable to impacts from sea-level rise and storm surge. Salt marshes are particularly sensitive to changes in sea level. If marsh elevations can't keep pace with water elevations their capacity to store flood water during coastal storm events may be diminished. Many tools can be applied to protect these critical services including land conservation and acquisition, land development regulations, zoning standards, and municipal policies and plans.

Assessed Value of Parcels

Tables 2 and 17 report the number of parcels affected by each of the six scenarios evaluated and shows the aggregated assessed value of these parcels. The extent to which the parcel and any structure or development on the parcel is affected by sea-level rise or storm related flooding was not analyzed. Affected parcels were identified based on whether the parcel was either partially or fully within the extent of the scenarios evaluated. *The data includes a number of high value parcels under state and municipal ownership.*

Between 2,800 to 5,700 parcels will be partially or wholly effected by tidal flooding, depending on the scenario, and up to 7,200 affected when storm surge is added. The data shows a 55 percent increase in the number of parcels and a $651 million dollar increase in the assessed value of parcels when comparing the 1.7 feet to the 4.0 feet sea-level rise scenario. This compares to a 32 percent increase in the number of parcels and a $659 million increase in the assessed value of parcels when comparing the 4.0 feet to the 6.3 feet sea-level rise scenario.

TABLE 2. SUMMARY OF PARCELS AND ASSESSED VALUE BY SCENARIO

Sea-Level Rise (SLR) Scenarios	Number of Parcels Affected by scenario	Aggregate Value of Effected Parcels
1.7 feet SLR	2,789	$1,298,033,374
4.0 feet SLR	4,334	$1,949,171,074
6.3 feet SLR	5,740	$2,608,930,224
1.7 feet SLR + storm surge	5,555	$2,555,831,824
4.0 feet SLR + storm surge	6,468	$2,988,594,674
6.3 feet SLR + storm surge	7,165	$3,258,843,274

Mapping shows that the three sea-level rise scenarios are for the most part contained within the current 100-year floodplain. To qualify for federal disaster relief and the National Flood Insurance Program, FEMA requires municipalities to regulate development within the 100-year floodplain. These floodplain standards are considered minimum requirements. FEMA encourages municipalities to adopt stricter floodplain standards and offers incentive programs such as the Community Rating System (CRS) which qualifies property owners to pay lower insurance premiums. CRS is a voluntary program that requires municipalities to adopt protective standards within highly vulnerable areas and take proactive actions that reduce flood risks. Creating more flood resiliency within the current 100-year floodplain may also provide flood protection against impacts from sea-level rise in the long term.

Planning Considerations

In order to effectively adapt in short-term and long–term, municipalities need help developing and implementing policies and regulations to plan for and minimize the impacts of climate induced changes. Planning for climate change can result in positive actions that improve preparedness and reduce impacts from current coastal hazards and address long-term changes that may result from climate change including sea-level rise. Communities that implement climate adaptation planning may see benefits such as:

- Enhancing preparedness and community awareness of future flood risks.
- Identifying cost-effective measures to protect and adapt to changing conditions.
- Improving resiliency of infrastructure, buildings and other community investments.
- Protecting life, property and local economies.
- Protecting coastal natural resources and the critical services they provide.
- Preserving historical assets and unique community character.

The Tides to Storms Coastal Vulnerability Assessment is a snapshot of existing conditions in coastal New Hampshire based on the current distribution of developed lands and natural landscapes and resources for the year 2015. As the developed and natural landscapes in the coastal region change, and climate parameters change, so will the degree and extent of impact from sea-level rise and coastal storm surge flooding. In order to use the latest science-based information to guide decision making, it is highly recommended that vulnerability assessments be updated as new information about emerging trends and revised projections of climate change are published.

From state and regional perspectives, the increased risk of exposure to coastal flooding from changing sea level raises a number of important issues that should be considered and addressed in state, regional and local responses to increased coastal flood risks. There are both general considerations that apply to our collective response as well as considerations that apply to the specific asset classes affected (e.g. roads, infrastructure, natural resources). These considerations are listed below and discussed in detail in Section VI.2 Regional Considerations.

Acting in uncertainty and the value of an incremental response: The most difficult circumstance under which to take action in response to a future threat is when there is uncertainty about the degree of risk from that threat. This is especially true when the threat is distant in time and the cost of responding is high. Each situation needs to be evaluated individually taking into consideration many factors.

The value of time and of acting now: Acting today may result in long term cost savings by anticipating sea level change and ensuring all current and future infrastructure investments in vulnerable areas are resilient to at least moderate sea-level rise expected over their design life.

State and regional economic considerations: Coastal New Hampshire is highly important to the region's and the state's economy. Statewide, tourism ranks as the state's second largest economic sector, and, for several communities in the coastal region, it is the largest. Much of that tourism activity is driven by access to coastal assets including beaches and the ocean.

State and municipal collaboration, coordination and planning: The state and municipalities share assets and infrastructure on the coast and as such need to align their policies, assumptions and responses to existing and future coastal flood hazards to the greatest extent possible. Failure to coordinate such actions will increase the cost and decrease the effectiveness of planning and preparation for increased flood risk.

Creative financing mechanisms for infrastructure projects: Creating more resilient buildings and infrastructure will cost more in the short term and may accelerate the need for certain improvements. This may necessitate innovative financing approaches to make such investments workable. For example, establishing a hazard mitigation fund to enable state agencies or municipalities to purchase developed properties in high hazard locations, or in undeveloped areas.

Comprehensive shoreline management planning: A comprehensive shoreline management plan would identify both general priorities and policies for shoreline management, but also examine specific sections of coast to recommend where specific management approaches are necessary. Given the complexity of coastal property ownership, any successful shoreline management plan must be undertaken as a collaborative effort between the state, municipalities and other stakeholders.

Consistency in land development standards: Local and state land use standards should be adapted to anticipate increased flood risks associated with storm surge and sea-level rise as soon as possible so that new development will be resilient to these conditions based on comparable levels of protective standards.

Identify priority areas for restoration, protection and retreat: Developing a comprehensive shoreline management plan may me the best approach for determining priority areas for restoration, protection and retreat. It should be acknowledged that some of these priorities will likely change as future sea-level rise scenarios are refined and as conditions change as projected or altogether differently. A priority to protect some areas for the intermediate low sea-level rise scenario may prove infeasible in a higher scenario.

Continued evaluation of science based climate change projections: Over time both the range and rate of expected sea-level rise will presumably narrow as climate change projections become more certain. This in turn will allow estimates of vulnerability to become more refined. It will be important for local and state officials to periodically revisit these projections and assumptions and adjust responses accordingly.

II. Introduction

Coastal New Hampshire is Vulnerable Today

New Hampshire coastal municipalities are confronted by a challenging set of land use and hazard management concerns that include exposure to extreme weather events, storm surges, flooding, coastal erosion and loss of key coastal habitats. These issues are exacerbated by changes in climate that result in a probable increase in the frequency and intensity of storms and an increasing rate of sea-level rise. These effects are compounded by increasing stormwater runoff and flooding caused by additional development and impervious surfaces in the coastal watershed.

Sea-level rise has the potential to displace coastal populations, threaten infrastructure, intensify coastal flooding and ultimately lead to the loss of homes, businesses, public infrastructure, recreation areas, public space, and coastal wetlands and salt marsh. Residential and commercial structures, roads, and bridges may be more prone to flood damage. Sea-level rise may also reduce the effectiveness and integrity of existing seawalls, which have been designed for historically lower water levels.

Effective preparedness and proactive land use management will allow coastal communities to reduce future exposure and improve resilience to the increased flood risk, and thus minimize economic, social and environmental impacts. This report is intent to assist municipalities and other stakeholders to become more proactive by providing information about potential vulnerabilities to flooding based on a range of se level rise scenarios.

First Steps

Completing a coastal vulnerability assessment is the first step in gaining a better understanding of the potential future impacts of sea-level rise and storm related coastal flooding. Municipalities need sound science and data to develop and implement policies and regulations to plan for and minimize the impacts of climate induced changes. Important first steps for coastal municipalities include:

1. Identifying areas at most risk from flooding due to sea-level rise and coastal storms.
2. Incorporating climate change adaptation and mitigation strategies in local hazard mitigation plans; putting regulations in place that decrease the vulnerability of buildings and infrastructure in these areas subject to higher risk of flooding, particularly in the next 30 to 50 years (or within the life cycle of most existing facilities).
3. Leveraging existing institutional practices - such as master plans, and capital improvement plans – to maximize use of available funds and implement comprehensive strategies to adapt to changing conditions, prevent or minimize impacts and protect public and private investments.

Evaluating Costs and Risks and Planning for the Future

Reducing risk and vulnerability requires long-range planning and investment, evaluation of costs associated with improving infrastructure and facilities under a range of flood levels (e.g. sea-level rise scenarios), and continually reevaluating conditions and current climate scenarios on a periodic basis to determine if coastal flooding is occurring as projected by climate models. Recommended actions to address coastal flood impacts should be focused on adaptation strategies that are both multi-sector and sector specific. Adaptation will be most likely iterative and incremental, and will necessitate a great deal of coordination among elected officials, municipal staff, land use boards and commissions as well as federal, state and regional partners.

III. Climate Change in New Hampshire

1. PROJECTED FUTURE CONDITIONS REGARDING COASTAL FLOODING

Coastal Risks and Hazards Commission – Science and Technical Advisory Panel Report (2014)

This Vulnerability Assessment of Coastal New Hampshire uses assumptions regarding sea-level rise and storm surge that are consistent with the National Climate Assessment and the NH Coastal Risks and Hazards Commission (see Section IV Mapping and Assessment Methods). The NH Coastal Risks and Hazards Commission established a Science and Technical Advisory Panel (STAP) to review and advise them on scientific findings, reports and assessments on climate change specifically relating to sea-level rise, storm surge and extreme precipitation. The purpose was to aid the Commission in identifying likely conditions New Hampshire should plan for by 2050 and 2100, and to further advise them of scientifically supportable assumptions that should be used in formulating recommendations. The STAP's report (July 2014) offers the following projections of future climatic conditions for the region. Key findings of this report are summarized in Table 3..

TABLE 3. KEY FINDINGS FROM THE NH COASTAL RISKS AND HAZARDS COMMISSION SCIENCE AND TECHNICAL ADVISORY PANEL REPORT

CONDITIONS	PROJECTIONS
Sea-level rise	The range that best covers plausible sea-level rise increases to 2050 and 2100 are those prepared for the US National Climate Assessment and include the "Highest". "Intermediate High", "Intermediate Low" and "Lowest" scenarios based on varying greenhouse gas emissions and other climate responses: (see nested table below) Source: Table ES.1. Sea-Level Rise (in feet) provided for the National Climate Assessment, 2014. (Parris, et al., 2012)
Storm Surge	Given the uncertainties associated with future storm surge changes, recommend that projects continue to use the present frequency distributions for 100-year and 500-year storms (as depicted in the 2014 FEMA Flood Insurance Rate Maps for Rockingham and Strafford Counties).
Precipitation	Projected increases in annual precipitation are uncertain but could be as high as 20% in the period 2071-2099 compared to 1970-1999, with most of the increases in winter and spring with less increase in the fall and perhaps none in the summer.

Time Period*	Lowest	Intermediate Low	Intermediate High"	Highest
2050	0.3 feet	0.6 feet	1.3 feet	2.0 feet
2100	0.7 feet	1.6 feet	3.9 feet	6.6 feet

*using mean sea level in 1992 as a reference (Parris et al., 2012)

Extreme Precipitation	While unable at present to assign with confidence future changes in extreme precipitation events, recommend at a minimum that all related infrastructure be designed with storm volumes based on the current Northeast Regional Climate Center (Cornell) precipitation atlas to represent current conditions and be designed to manage a 15% increase in extreme precipitation events after 2050 and that a review of these projections be continued.

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.

Precipitation Trends

The impacts of flooding from future increases precipitation and freshwater flooding were not evaluated as part of this vulnerability assessment. However, it is important to acknowledge recent trends in increased precipitation in the coastal region and to incorporate them into existing stormwater management and design standards. The Northeast Region Climate Center (NRCC) at Cornell University published new extreme precipitation data for New Hampshire which shows the southeastern and coastal region of the state have substantial increases in the amount of rain associated with large precipitation events (i.e. the 25-, 50-, and 100-year storms). The NRCC online database is available online at: http://precip.eas.cornell.edu/. Table 4 show a comparisons of the old TP40 and the new NRCC rainfall data for the seven coastal municipalities. Increases across all locations range from 2 inches to 2.5 inches of additional precipitation associated with the 24-hour 100-year storm event.

TABLE 4. CHANGES IN PRECIPITATION FROM A 100-YEAR/1% CHANCE STORM BY MUNICIPALITIES

Municipality	TP40 Rainfall Data (inches in a 24-hour period)	NRCC Data (inches in a 24-hour period)
Portsmouth	6.5	8.85
New Castle	6.5	8.83
Rye	6.5	8.99
North Hampton	6.5	9.08
Hampton	6.5	9.12
Hampton Falls	6.5	9.15
Seabrook	6.5	9.19

Rainfall data is interpolated from Technical Paper No. 40 (TP40) Rainfall Frequency Atlas of the Eastern United States; the data is reported as a single value for each municipality (from New Hampshire Stormwater Manual: Volume 2 Post-Construction Best Management Practices Selection & Design, December 2008). NRCC extreme precipitation atlas was updated in 2011. Data reported are the locations of the town halls for each municipality.

2. FEDERAL GUIDANCE ON CLIMATE CHANGE

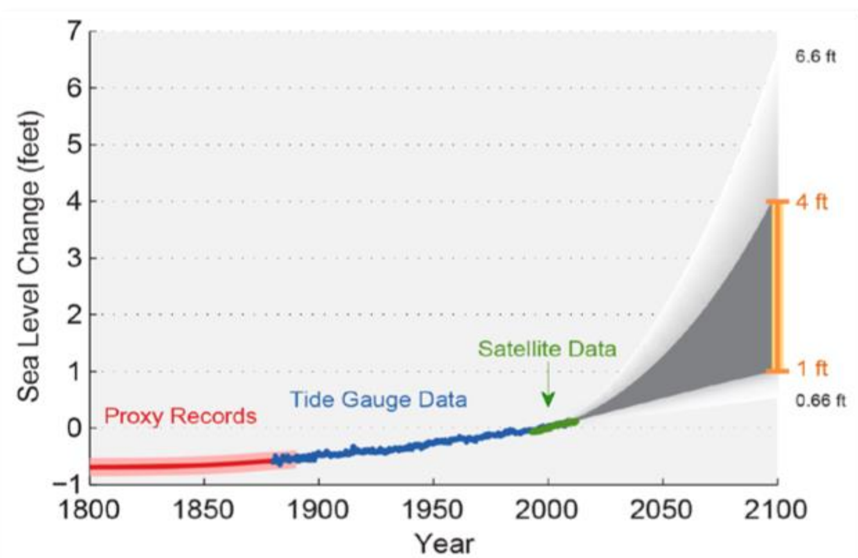
U.S. Global Change Research Program (USGCRP) and the National Climate Assessment

The U.S. Global Change Research Program (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to "assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change." The GCRA requires that the USGCRP produce a National Climate Assessment every four years. The most recent assessment was released in 2014 and has been a key source of information for the sea-level rise scenarios used in this vulnerability assessment.

The National Climate Assessment represents a synthesis of the current science and understanding about what climate changes are occurring, what future conditions are expected and how they may affect the nation. There have been two previous assessments prior to 2014, the first released in 2001 and the second in 2009. The assessments cover a full range of climate change information and impacts. This report has focused on the assessment's content pertaining to sea-level rise.

Prior to the 2014 Assessment, no coordinated, interagency resource existed in the US to identify global mean sea-level rise. States and localities were left to identify global or regional SLR estimates through their own interpretation of the scientific literature, the advice of experts, or on an ad-hoc basis. The 2014 Assessment addresses this need by providing sea-level rise scenarios, rather than predict a specific future condition, describe a range of future plausible future conditions which can be compared and evaluated with regard to vulnerability, and impact. This is a more appropriate approach given the large range in the plausible change in sea level over the next century. The large projected range reflects uncertainty about how glaciers and ice sheets will react to the warming ocean, the warming atmosphere, and changing winds and currents. The scenarios range from 0.66 feet to 6.6 feet in 2100 as shown above in Table 3. The scenarios are not based on climate model simulations, but rather reflect the range of possible scenarios based on other scientific studies. The most plausible range of sea-level rise is stated in the report to be between one to four feet by 2100, which falls within the larger risk-based scenario range. The three inundation scenarios mapped in this report closely coincide with the scenarios in the 2014 Assessment.

FIGURE 1. Estimated, observed, and possible future amounts of global sea-level rise from 1800 to 2100 (relative to the year 2000) Figure source: 2014 National Climate Assessment Adapted from Parris et al.



The "key message" statement in the 2014 NCA with respect to sea-level rise is this:

"Global sea level has risen by about 8 inches since reliable record keeping began in 1880. It is projected to rise another 1 to 4 feet by 2100." The National Climate Assessment (2014) report by the U.S. Global Research Change Program is available at http://ncadac.globalchange.gov.

Executive Order 13690

On January 30, 2015 President Obama issued an Executive Order (EO 13690) establishing new management guidelines for federal investments and programs that involve exposure to future flood risk. The new standard, known as the Federal Flood Risk Management Standard (FFRMS) amends the previous floodplain management Executive Order (EO 11988) issued in 1977. Once finalized, these guidelines are to be used by affected federal agencies to develop or update their own rules and policies regarding flood risk management. In broad summary, the Executive Order declares that it is the policy of the United States to improve the resilience of communities and Federal assets against the impacts of flooding; that these impacts are anticipated to increase over time due to the effects of climate change and other threats, and establishes new criteria for determining future flood risks.

The FFRMS was developed through an interagency effort within the federal government, and also considered the views of governors, mayors and other stakeholders. The resulting policy establishes a new forward looking flood risk reduction standard applicable to federally funded projects.

The key provision of the new policy is a change in the way federal agencies will determine whether or not a proposed federal "actions" (e.g. federally funded and/or permitted projects) would be located within a flood hazard area. Previously this determination was made based on whether the action occurred within the HUD/FEMA defined 100 year (1% annual flood risk percent) floodplain. Under the new policy, that determination is to be made using one of three methods:

1. The elevation and flood hazard area that result from using a climate-informed science approach that uses the best-available, actionable hydrologic and hydraulic data and methods that integrate current and future changes in flooding based on climate science. This approach will also include an emphasis on whether the action is a critical action as one of the factors to be considered when conducting the analysis.
2. The elevation and flood hazard area that result from using the freeboard value, reached by adding an additional 2 feet to the base flood elevation for non-critical actions and by adding an additional 3 feet to the base flood elevation for critical actions.
3. The area subject to flooding by the 0.2 percent annual chance flood (500 year floodplain).

The practical effect of this change is that federally funded projects and other actions will have to be designed to anticipate future expected flood conditions rather than only existing flood hazards. In the absence of more refined or localized information, this will result in adding either two or three feet (depending on function and design life of the facility being constructed) to the base flood elevation of construction within existing flood hazard areas or in using the 500 year floodplain rather than the 100 year floodplain in determining flood risk. Exception to the new standard are permitted where it application makes no sense (is "demonstrably inappropriate") or where the action is for national security or in response to an emergency.

Federal Agency Actions and Policies

FEMA Climate Change Adaptation Policy

In January 2012, the Federal Emergency Management Administration (FEMA) issued a policy statement that established an agency-wide directive to integrate climate change considerations, adaptation planning and actions into FEMA's programs and policies. The policy explicitly recognizes that the potential impacts from climate change (including more intense storms, frequent heavy precipitation, extreme flooding, heat waves, drought, and higher sea levels) may effect FEMA's ability to effectively manage emergencies. The key policy elements included in the statement are summarized as follows:

1. Enhance climate research, monitoring and adaptation capabilities.
2. Study the specific impacts of climate change on the National Flood Insurance Program (NFIP) and incorporate climate change considerations in future NFIP reform.
3. Evaluate how climate change considerations can be incorporated into grant programs and strategies, and especially on infrastructure.
4. Engage local communities in addressing and supporting climate change efforts.

5. Promote updated building standards and practices that consider the future impacts of climate change.

FEMA Requirements for State Hazard Mitigation Plans

In March 2015, FEMA issued new guidance for the minimum required content of State Hazard Mitigation Plans. State plans must now consider the projected effects of climate change on natural hazards such as more intense storms, frequent heavy precipitation, heat waves, drought, extreme flooding, and higher sea levels because of their potential to significantly alter the types and magnitudes of hazards impacting states in the future.

Specifically, the new guidance requires state plans to include climate projections and data, and to consider climate change effects in evaluating the probability of future hazard events.

FHWA Guidance

To date, the Federal Highway Administration (FHWA) has not established specific highway and bridge design standards or guidelines that require projected acceleration of sea-level rise to be taken into account in highway and bridge design. However, they have been active in developing planning tools to facilitate the consideration of climate change impacts in transportation systems design, including consideration of heat, precipitation, sea-level rise and storm surge.

Climate Change and Extreme Weather Vulnerability Assessment Framework (2012): This is a voluntary process to guide transportation agencies in assessing transportation asset vulnerability to climate change and extreme weather events. It recommends key steps to be followed in conducting vulnerability assessments and incorporating results into decision-making and provides modules and tools to aid in the assessment process. The framework stresses that climate change and extreme weather vulnerability in the transportation context are a function of a transportation asset or system's *sensitivity* to climate effects, *exposure* to climate effects, and *adaptive capacity*. The framework encourages incorporating the results of the vulnerability assessment into the agency's decision-making process to ensure that the information is used in practice. An agency encouraged to use the results of the assessment in its asset management programs, hazard mitigation plans, transportation planning project selection criteria, and in the development of specific adaptation strategies for assets identified as highly vulnerable to climate change. **Highways in the Coastal Environment Highways in the Coastal Environment, Second Edition (FHWA Publication No. FHWA-NHI-07-096 June 2008)**: This publication extensively reviews special factors that should be considering the design of transportation facilities in coastal areas, including areas prone to coastal flooding. Net sea-level rise is discussed as an important factor to consider in facility design. The historical eustatic SLR rise rate of 2mm/year is reviewed as well as the possibility that these rates will accelerate as a consequence of ocean warming, however no recommended eustatic SLR levels or scenarios for design purposes are provided.

U.S. Army Corp. of Engineers

Sea-Level Change Considerations for Civil Works Programs (US Army Corps. of Engineers Circular No. 1165-2-212, October 2011 USACE has a large coastal program that supports inland and maritime transportation, hurricane and coastal risk reduction, and ecosystem restoration. USACE requirements are far-reaching in that Section 404 wetlands permits are required for many actions proposed by other entities and agencies. The Circular referenced here is a guidance document originally released in 2009 and updated in 2011. Interagency Performance Evaluation (IPET) findings after Hurricane Katrina led USACE to update and expand policies and guidance to incorporate new and changing conditions in project planning and engineering.

The 2009 (and 2011) scenario-based sea-level change guidance was developed with the aid of other agency experts from the National Oceanic and Atmospheric Administration (NOAA) and U.S. Geological Survey (USGS) guidance. It expanded 1986 planning guidance on sea-level change to consider the whole project life cycle. As its key elements the Circular requires the following:

- Relative sea level change must be considered in all USACE coastal activities within the extent of tidal influence.
- Base level SLR is to be considered from the history of recorded changes for a specific site.
- Project planning and design must consider how sensitive and adaptable natural and managed ecosystem, and human engineered systems are to predicted climate change.
- Project development must include consideration of a multiple scenario approach to deal with future condition uncertainty when no credible probabilities can be established.
- Project alternatives are to be formulated and evaluated for the entire range of future rates of sea level change scenarios using low, medium and high scenario ranges, based on National Research Council's sea-level rise scenario curves.

3. NEW HAMPSHIRE PREPARATIONS FOR CLIMATE CHANGE

Department of Homeland Security and Emergency Management

The N.H. Department of Homeland Security and Emergency Management (HSEM) is responsible for preparing the state's hazard mitigation plan and coordinating the state's response to natural disasters including hurricanes, floods and severe winter storms. The NH HSEM Planning Section administers the Hazard Mitigation Assistance programs, assisting in the development of comprehensive hazard mitigation plans and projects to protect citizens, and their property from exposure to all hazards including: natural, human caused, and technological. The Planning Section is also responsible for management of the FEMA Public Assistance grant program and the Emergency Management Performance Grant. HSEM also prepares the State Hazard Mitigation Plan (last updated in 2013) which lays out goals and recommendations to protect the state, municipalities and residents from impacts from natural and human caused hazards. For more information about programs and assistance refer to the Homeland Security and Emergency Management website at http://www.nh.gov/safety/divisions/hsem/.

> The United States Congress, in 2000, adopted the Disaster Mitigation Act of 2000, providing federal funding for the development of state and local hazard mitigation plans and projects.
>
> States and municipalities must adopt hazard mitigation plans in order to be eligible for federal hazard mitigation project funding and disaster relief. These plans are reviewed and approved by the Federal Emergency Management Agency (FEMA).

New Hampshire Multi-Hazard Mitigation Plan

The 2009 update of the New Hampshire Multi-Hazard Mitigation Plan (last updated in 2013) incorporated for the first time goals about addressing climate change including technical support, planning, assessment of risk and vulnerability, and adaptation statewide. RPC staff in collaboration with NH CAW members and the Coastal Program assisted with preparation of climate change goals and recommendations for the Plan update. Below are key goals and objectives from the NH Multi-Hazard Mitigation Plan relating to climate change.

Goal #2. Reduce the potential impact of natural and human caused disasters on New Hampshire's Critical Support Services, Critical Facilities and Infrastructure.

Objective H: Develop strategies to address coastal flooding and protection of infrastructure against storm surge.

Action 1. Sustain the NHDES Coastal Program's participation and support of the Coastal Adaptation Workgroup to address hazard and mitigation needs relative to state and community infrastructure.

Goal #7. Address the challenges posed by climate change as they pertain to increasing risk to the State's infrastructure and natural environment.

Objective A. Support efforts to characterize and identify risks posed by climate change especially as it relates to changing precipitation patterns, storm event frequency, and sea level rise.

Objective B. Support strategies for adaptation to climate change.

Objective C. Encourage coastal communities to incorporate mitigation planning in master plans, zoning, land use and resource regulations and other planning studies and initiatives that address the existing and potential future threats related to climate change and sea level rise.

NH Climate Action Plan

In 2009, the Governor's Climate Change Policy Task Force released the NH Climate Action Plan, containing 10 overarching strategies necessary to meet the states greenhouse gas reduction and climate change related goals. Goal 9 states "Plan for how to address existing and potential climate change impacts". Chapter 3 Adapting to Climate Change describes in greater detail the benefits of planning for and adapting to climate change and how this may be achieved to minimize impacts to the economy, human health, natural systems, and infrastructure. The plan was intended to act as a broad guide to examine projected future conditions and needs, and adjust our actions as needed to maintain a high quality of life in our state.

The NH Climate Action Plan has helped guide many research and planning initiatives, policy decisions, and audits of the existing regulatory standards and procedures by state agencies to address climate change. Currently, there is limited funding and staff at the state level to assist with implementing the recommendations of the plan. The plan envisions that all stakeholders throughout the state would contribute to implementation of its recommendations. Organizations like the NH Coastal Adaptation Workgroup and others have made progress toward implementing recommendations from the Climate Adaptation Chapter of the Plan.

NH Coastal Risks and Hazards Commission (RSA 483E)

The Coastal Risks and Hazards Commission was established under RSA 483-E by the New Hampshire Legislature in 2013.The Commission is charged with recommending legislation, rules and other actions to prepare for projected sea-level rise and other coastal and coastal watershed hazards such as storms, increased river flooding, and storm water runoff, and the risks such hazards pose to municipalities and state assets in New Hampshire. The Commission was charged to review National Oceanic and Atmospheric Administration (NOAA) and other scientific agency projections of coastal storm inundation, and flood risk to determine the appropriate information, data and understanding of risk to use in its recommendations. The Commission established a Science and Technical Advisory Panel to advise them on what assumptions can be supported in science with respect to sea-level rise, storm surges, and extreme precipitation.

The Commission's membership includes representatives from the New Hampshire House of Representatives, state agencies, regional planning commissions, all coastal and tidally influenced municipalities, University of New Hampshire and other private sector and non-profit stakeholders from the coastal watershed. The Commission has been informed about the preliminary findings of this Vulnerability Assessment and has used some of the information to help inform the findings and recommendations that it is currently developing.

With respect to sea-level rise, the Advisory Panel determined that the global SLR scenarios developed by the National Climate Assessment are applicable to the New Hampshire coast since relative sea-level rise here is essentially the same as the global (eustatic) level. These SLR scenarios were included in the Panel's report to the Commission that was subsequently adopted and referenced in Table 3 of this report.

For more information on the Commission refer to the CRHC website hosted by the NH Coastal Adaptation Workgroup website on the Storm Smart Coast network at http://nhcrhc.stormsmart.org/.

NH Coastal Adaptation Workgroup

The New Hampshire Coastal Adaptation Workgroup (NHCAW) is a collaboration of 20 partners and organizations working to help communities in southeastern New Hampshire prepare for the effects of extreme weather events and other effects of long term climate change. Since inception in 2010, CAW has led numerous projects and events that have elevated discussions about climate preparedness at municipal, state, and regional levels. CAW partners have received 18 grants totaling over $2.75 million dollars to conduct research, analyses, develop tools and implement outreach in the coastal watershed including municipalities, decision makers and practitioners. CAW projects are typically multi-faceted, incorporating science-based research, development of tools and guidance, and stakeholder outreach and engagement. NHCAW helps communities learn about and utilize existing resources and locate additional assistance to better prepare for the effects of a changing climate in order to protect their social, economic, human and environmental health. NHCAW provides communities with education, facilitation and guidance. NHCAW's yearly workshop series *Water, Weather, Climate and Community* focus on information to help communities acquire technical knowledge, gain access to resources, and learn from each other's experiences in order to prepare for the impacts of climate change.

RPC has been a participating member of NH CAW for over five years, providing staff time, technical resources and regional collaboration. RPC has collaborated with member agencies and organizations to implement workshops, apply for funding, prepare advisory and guidance documents, and give presentations at national, state, regional and local events. For more information, refer to CAW's website on the Storm Smart Coasts network at http://nh.stormsmart.org/.

IV. Mapping and Assessment Methods

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

Sources

The *Tides to Storms* vulnerability assessment project was designed to produce detailed maps and statistical data about the potential impacts to New Hampshire's seven coastal municipalities that would arise as a consequence of sea-level rise. This is the first such analysis for New Hampshire based on the high resolution LiDAR imagery which became available for the New Hampshire Seacoast in 2012. The LiDAR maps provide much more accurate topographic resolution than has been available for prior regional analyses and provided a basis for a more accurate assessment of the potential impacts from coastal flooding associated with changes in sea level.

Critical to this analysis was the selection of sea-level rise assumptions. A number of prior studies and reports relating to sea-level rise have been conducted in New Hampshire in recent years, including the 2011 report *Climate Change in the Piscataqua/Great Bay Region: Past, Present, and Future*. (Wake, et al, 2011), the 2013 Portsmouth Coastal Resilience Initiative Report, the PREP 2011 Climate Ready Estuaries Project *Coastal Adaptation to Sea-level rise Tool (COAST)* project, and RPC's 2009 Study *Adaptation Strategies to Protect Areas of Increased Risk From Coastal Flooding Due to Climate Change* for Seabrook, NH. In addition, RPC staff reviewed other sources, including reports from the International Panel on Climate Change (IPCC – 2013 report), Vermeer & Rahmstorf (2009), the National Research Council (2012) and NOAA Technical Report *Global Sea-level rise Scenarios For The United States* OAR CPO-1 (Parris, et al; prepared for the 2014 National Climate Assessment.) Based on this review and preference to maintain comparability with other contemporary studies in New Hampshire, three sea-level rise scenarios were chosen as shown in Table 5.

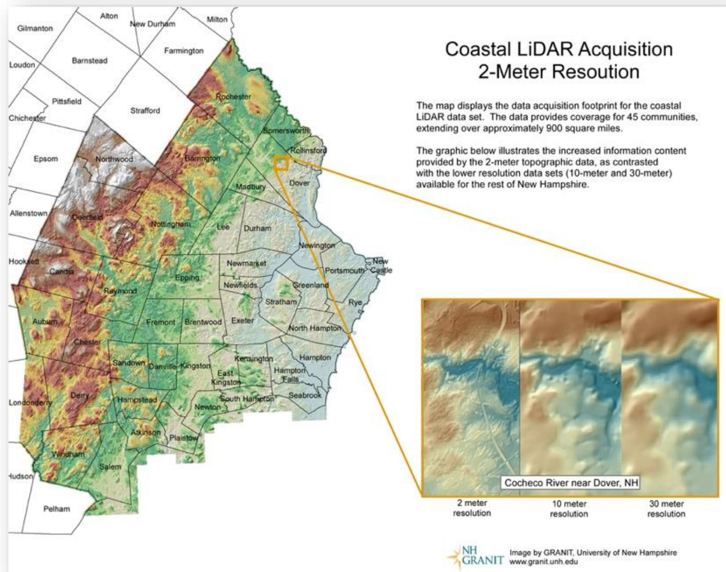


FIGURE 2. EXAMPLE OF LIDAR RESOLUTION PAST AND PRESENT.

TABLE 5. 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 represents is the area flooded by the 100-year/1% chance storm event.

Through NH GRANIT (Earth Systems Research Center, University of New Hampshire LiDAR data for the New Hampshire coast was processed to derive elevation contours which correspond to the three elevations defined in the three scenarios. For the 100 year flood/storm surge scenarios, RPC coordinated with NH GRANIT to develop the storm surge elevation data based on the new FEMA digital FIRM flood model and maps then being developed as a component of the FEMA Coastal Floodplain Mapping Project.

Subsequent to the start of our analyses, the Science and Technical Advisory Panel (STAP) of Coastal Risks and Hazards Commission (CRHC) issued its synthesis report recommending the CRHC use the National Climate Assessment scenarios for formulating its findings and recommendations about sea-level rise. As shown in Figures 2 and 3, while slightly different than the scenarios cited in the 2014 STAP 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.

FIGURE 3. 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.

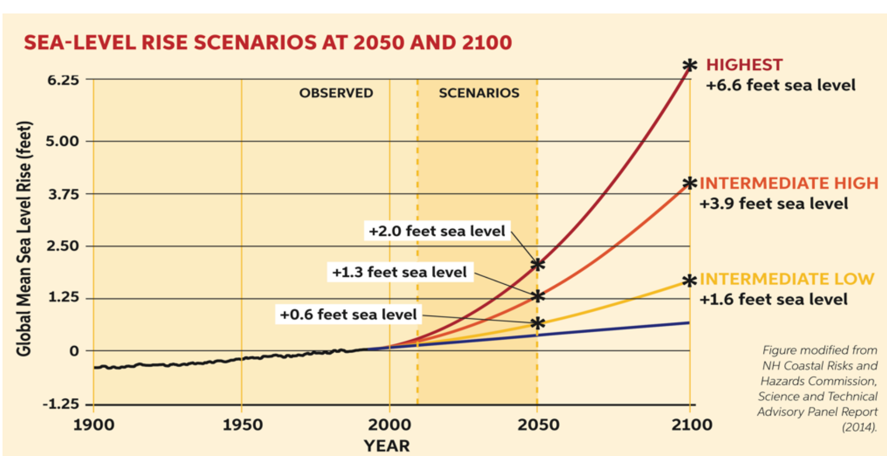
	Lower Emissions (B1)		Higher Emissions (A1fi)	
	2050	2100	2050	2100
Current Elevation of MHHW [a,b]	4.43	4.43	4.43	4.43
100-Year Flood Height	7.78	7.78	7.78	7.78
Subsidence	0.012	0.016	0.012	0.016
Eustatic SLR	1.0	2.5	1.7	6.3
Total Stillwater Elevation [a,c]	**13.2**	**14.7**	**13.9**	**18.5**

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 4. STAP REPORT SEA-LEVEL RISE SCENARIOS (BASED ON NATIONAL CLIMATE ASSESSMENT)

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.



Sea-Level Rise Scenarios

Key findings of the coastal assessment are based on evaluation of the extent of inundation that would result under three scenarios of static sea-level rise: 1.7 feet ("intermediate-low"), 4.0 feet ("intermediate high"), and 6.3 feet ("highest") for the year 2100 and three additional scenarios that combine the static sea-level rise with the 100-year storm surge. In addition, separate regional maps were prepared which map the depth of flooding associated with each scenario. A GIS analysis was conducted of the intersection of inundation areas with key assets (transportation, critical facilities, infrastructure and natural resources) to evaluate the quantitative impacts of the flooding. The concept of this study was to generate a regional scale understanding of what and where impacts from sea-level rise and storm surge will occur on New Hampshire's coast. The study did not include an assessment of the specific extent of damage nor estimate monetary losses for specific sites or properties. Further depth-damage analyses of affected assets using the flood depth maps may yield some of this information in future work and the data generated from this project will enable individual communities or other agencies to undertake this in depth analysis work independently.

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.

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

2. ASSETS AND RESOURCES EVALUATED

Table 6 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.

TABLE 6. ASSETS AND RESOURCES EVALUATED

CATEGORY	ASSETS AND RESOURCES
ROADWAYS AND TRANSPORTATION ASSETS	State and Local Roadways State and Local Culverts Regional and Municipal Evacuation Routes Urban Compact Areas
CRITICAL FACILITIES AND INFRASTRUCTURE AND	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
NATURAL RESOURCES	Freshwater and Tidal Wetlands Aquifers and Wellhead Protection Areas Conserved and Public Lands Land Conservation Plan for NH's Coastal Watershed – Core Focus Areas Wildlife Action Plan – Tier 1 and Tier 2 habitats FEMA Flood Hazard Areas

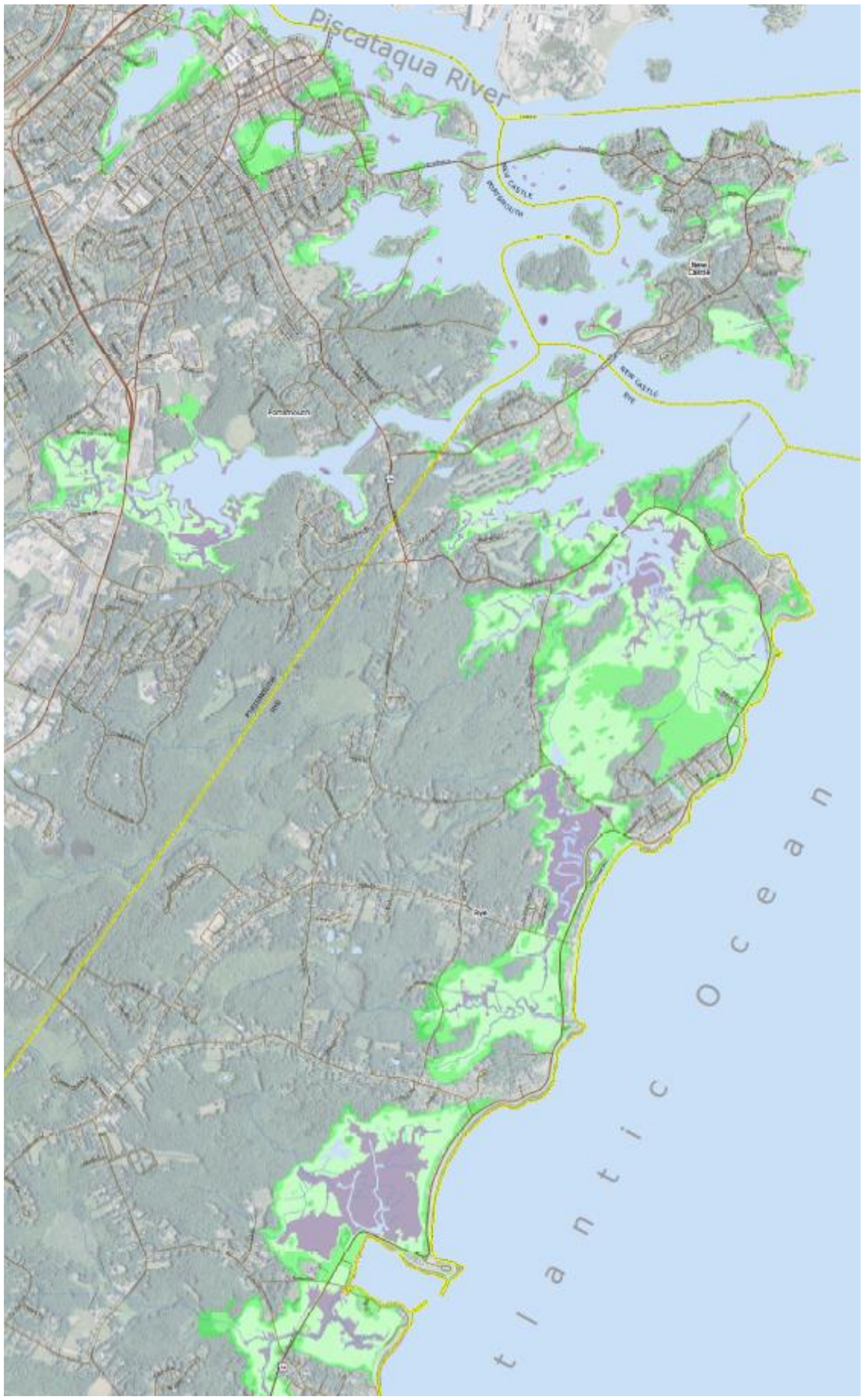
3. MAP DESIGN AND ORGANIZATION

The Tides to Storms map set is comprised of two components: maps depicting the extent of projected flooding from the three sea-level rise scenarios in shades of green, and maps 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 sea-level rise and storm surge maps are shown on the following page.

Example: Extent of Flooding from Sea-Level Rise – North Coast

The green toned color scheme is arranged from lightest to darkest with increasing flood extent.

FIGURE 5. SEA-LEVEL RISE 1.7 FEET, 4.0 FEET AND 6.3

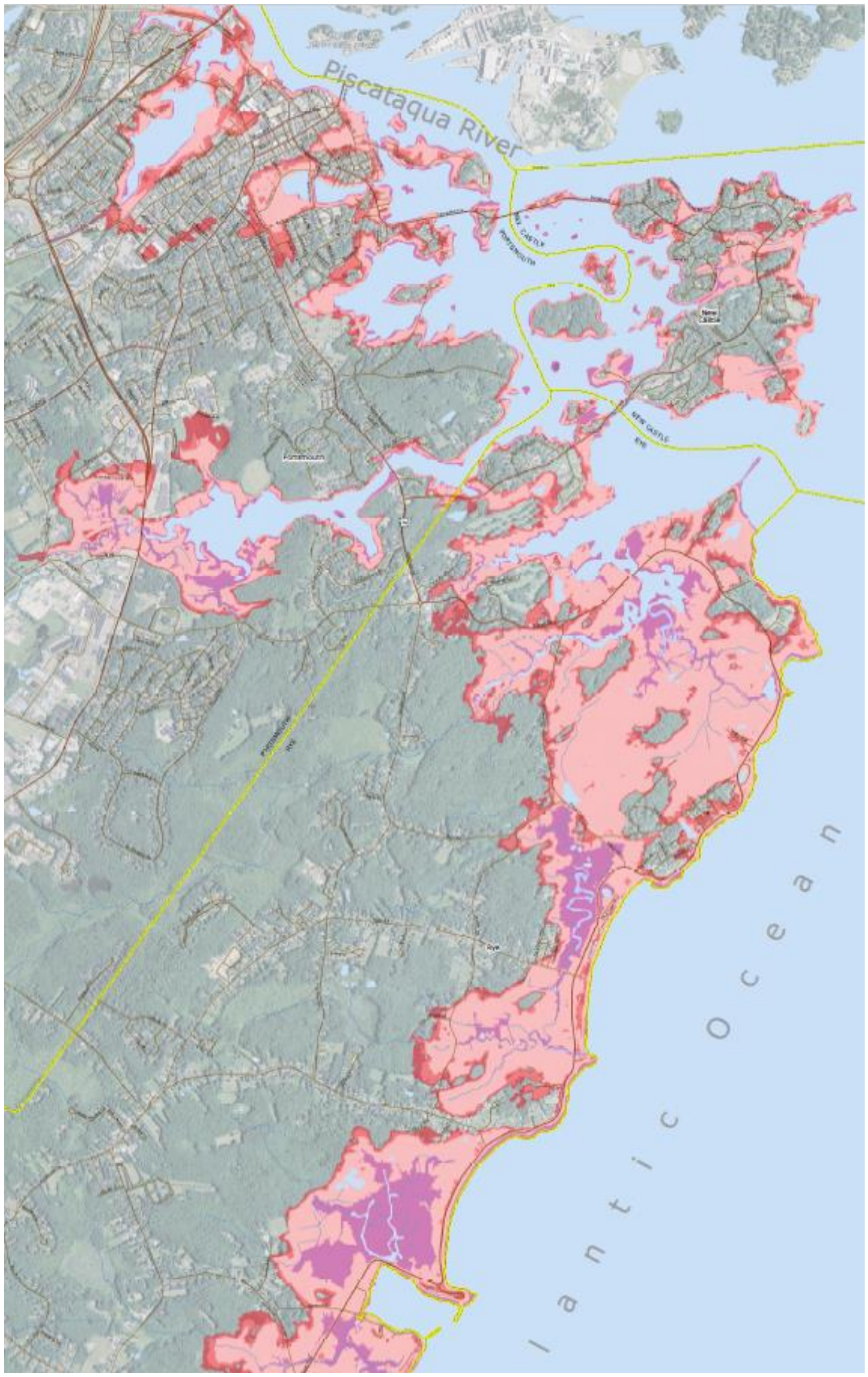


Note: Storm surge = flood extent from a 100-year /1% chance storm event.

Example: Extent of Flooding from Sea-Level Rise Plus Storm Surge – North Coast

The pink toned color scheme is arranged from lightest to darkest with increasing flood extent.

FIGURE 6. SEA-LEVEL RISE 1.7 FEET, 4.0 FEET AND 6.3 FEET STORM SURGE.



Note: Storm surge = flood extent from a 100-year /1% chance storm event.

V. Vulnerability Assessment Results

1. INFRASTRUCTURE AND CRITICAL FACILITIES

Critical Facilities

Maps 3N, 3S, 4N and 4S Critical Facilities and Infrastructure shows state and municipal infrastructure types affected by sea-level rise and coastal storm surge flooding. Table 7 reports the number of specific infrastructure types affected by each sea-level rise and coastal storm surge scenario.

Municipal critical facilities are highly susceptible to impacts from coastal flooding. Critical facilities – such as wastewater treatment plants, stormwater outfalls, and pump stations – are by design located close to tidal waters and low-lying coastal areas. Municipalities are actively flood-proofing and evaluating projected flood levels on the performance and sustainability of these facilities.

TABLE 7. CRITICAL FACILITIES (# of sites/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
Fire Stations	0	1	1	1	1	1
Graveyards	2	6	8	6	13	25
Hospitals	0	0	0	0	0	0
Municipal Critical Facilities	11	25	37	35	46	66
Nursing Homes	0	0	0	0	2	2
Police Stations	0	1	1	1	1	1
Schools	0	0	1	1	1	3
Total Sites/Facilities	**13**	**33**	**48**	**44**	**64**	**98**

Municipal Critical Facilities identified in Natural hazard Mitigation Plans are reported in the municipal Vulnerability Assessments.

Infrastructure

Maps 3N, 3S, 4N and 4S Critical Facilities and Infrastructure shows state and municipal infrastructure types affected by sea-level rise and coastal storm surge flooding. Table 8 reports the number of specific infrastructure types affected by each sea-level rise and coastal storm surge scenario.

By far culverts are the most infrastructure type most highly impacted by coastal flooding. Dams and water infrastructure (public water supply, pump houses, wellhead protection areas) are also susceptible to coastal flooding.

TABLE 8. INFRASTRUCTURE (# of sites/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
Culverts	37	90	135	137	162	190
Dams	6	10	13	13	15	22
Historical Highway Markers	1	1	3	3	3	4
Powerstations and Substations	0	1	2	2	2	3
Public Water Supply, Pump Houses, Wells	4	4	7	7	10	19
Wastewaster Treatment	0	0	0	0	0	1
Total Sites	**49**	**112**	**167**	**169**	**202**	**254**

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.

Maps 3N, 3S, 4N and 4S Critical Facilities and Infrastructure shows state and municipal transportation infrastructure types affected by sea-level rise and coastal storm surge flooding. Table 9 reports the number of transportation infrastructure affected by each sea-level rise and coastal storm surge scenario.

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 9. TRANSPORTATION 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
Bridges	21	25	31	29	36	42
Harbor/Marina	4	9	9	9	10	10
Public Transportation Facility	1	1	1	1	1	1
Signs, Lights, Signals, Beacons	1	5	16	15	18	22
Stormwater Structures	1	1	1	1	1	1
Ten Year Plan/Long Range Plan Projects	7	9	10	10	12	14
Total Sites/Facilities	**35**	**50**	**68**	**65**	**78**	**90**

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.

Historical Resources and Assets

Maps 3N, 3S, 4N and 4S Critical Facilities and Infrastructure shows National Historic Register and New Hampshire Historic Register properties affected by sea-level rise and coastal storm surge flooding. Table 10 reports when historic resources are affected by each sea-level rise and coastal storm surge scenario.

The City of Portsmouth has the greatest number of historic resources impacted by flooding, including Strawberry Banke and their historic district, however most resources are impacted only at the highest flood scenarios of 4.0 feet and 6.3 feet sea-level rise plus storm surge.

TABLE 10. 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
National Historic Register	**1**	**2**	**3**	**3**	**5**	**10**
NH Historic Register	**0**	**4**	**4**	**4**	**5**	**5**
City of Portsmouth						
Strawberry Banke Historic District	0	1	1	1	1	1
Richard Jackson House	1	1	1	1	1	1
Old North Cemetery	0	0	0	0	0	1
George Rogers House	0	0	0	0	0	1
Gov. John Wentworth House	0	0	0	0	1	1
General Porter House	0	0	0	0	0	1
Haven-White House	0	0	0	0	0	1
Wentworth-Coolidge Mansion*	0	0	0	0	0	0
Wentworth-Gardner House*	0	0	0	0	0	0
Wentworth-Gardner and Tobias Lear Houses*	0	0	0	0	1	1
Town of New Castle						
Portsmouth Harbor Light	0	0	1	1	1	1
Town of Rye						
St. Andrew's By-The-Sea	0	0	0	0	0	1
Pulpit Rock Base-End Station*	1	1	1	1	1	1

* The structures are not affected but the surround lands are affected by flooding.

2. TRANSPORTATION ASSETS

Maps 5N, 5S, 6N and 6S Road and Transportation Assets show the state and municipal roadways affected by sea-level rise and coastal storm surge flooding. Table 11 reports the miles of state and local roadways affected by each flood scenario for the region and by municipality.

In all seven coastal municipalities and for all six flood scenarios, more miles of local roadway are impacted by flooding than state roadways. Of the seven coastal municipalities, the Town of Hampton has the greatest number of total roadway miles impacted by flooding, the majority of which are local roadways.

TABLE 11. STATE AND MUNICIPAL ROADWAYS (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
Road Type						
Local	**3.5**	**17.0**	**29.4**	**32.8**	**38.8**	**50.5**
State	**1.6**	**6.6**	**14.1**	**18.7**	**21.8**	**25.6**
Interstate	0.1	0.1	0.1	0.1	0.1	0.1
State	1.0	5.6	12.5	17.3	19.6	23.0
US Route	0.5	0.9	1.5	1.3	2.1	2.5
Total Miles	**5.1**	**23.6**	**43.6**	**51.5**	**60.6**	**76.1**
Portsmouth	1.1	2.2	4.9	4.2	7.5	11.0
New Castle	0.1	0.5	1.4	1.5	1.8	2.8
Rye	0.2	4.5	9.5	10.6	14.1	17.1
North Hampton	0.0	0.7	1.3	1.4	2.6	3.0
Hampton	3.4	13.2	20.6	25.8	26.7	31.3
Hampton Falls	0.0	0.1	0.3	0.2	0.4	0.7
Seabrook	0.4	2.4	5.7	7.8	7.5	10.3

3. LAND USE AND ZONING

New Hampshire coastal municipalities are confronted by a particularly challenging set of land use and hazard management concerns that include extreme weather events, storm surges, flooding, coastal erosion and loss of key coastal habitats. These issues are exacerbated by changes in climate that result in an increase in the frequency and intensity of storms and an increasing rate of sea-level rise. These effects are compounded by growth and development through increasing storm water runoff and flooding. Sea-level rise has the potential to displace coastal populations, threaten infrastructure, recreation areas, public space, coastal wetlands and salt marsh. Existing and future residential and commercial structures, roads and bridges may be more prone to flooding. Sea-level rise may also reduce the effectiveness and integrity of existing seawalls, which have been designed for historically lower water levels.

Upland

Maps 1N, 1S, 2N and 2S Extent of Flooding show upland affected by sea-level rise and coastal storm surge flooding above mean higher high water. Table 12 reports the number of acres of upland affected by each flood scenario. Upland refers to land above mean higher high water (highest average tidal extent) excluding wetlands.

The seven coastal region municipalities have approximately 52,752 acres of total land area. At the regional scale, over 49,266 acres of upland are expected to have flood impacts from sea-level rise. This equates to total regional upland impacted by each scenario of:

- 1,484 acres or 3.0 percent at 1.7 feet SLR
- 2,602.2 acres or 4.9 percent at 4.0 feet SLR
- 3,613.5 acres or 7.3 percent at 6.3 feet SLR
- 3,473.5 acres or 7.0 percent at 1.7 feet SLR plus storm surge
- 4,439.0 acres or 9.0 percent at 4.0 feet SLR plus storm surge
- 5,298.4 acres or 10.8 percent at the 6.3 feet SLR plus storm surge.

When predicted storm surge is added, flood impacts increase significantly, to 3,474 feet under the 1.7 feet SLR plus storm surge scenario (134% increase), 4,439 feet under the 4.0 feet SLR plus storm surge scenario (70% increase), and 5,298 feet under the 6.3 feet SLR plus storm surge scenario (47% increase). Upland impacted by flood is highest in New Castle and Rye due to their high freshwater and tidal wetlands acreage and relatively low-lying topography adjacent to tidal areas.

TABLE 12. UPLAND (acres)

Sea-Level Rise (SLR) Scenarios	Total upland acres	SLR + 1.7 feet	% of total upland	SLR + 4.0 feet	% of total upland	SLR + 6.3 feet	% of total upland
Coastal Region	**49,266.3**	**1,484.6**	**3.0**	**2,602.2**	**5.3**	**3,613.5**	**7.3**
Portsmouth	10,763.4	104.5	1.0	197.3	2.0	313.9	3.1
New Castle	1,347.6	33.6	6.4	64.5	12.2	96.4	18.3
Rye	8,405.9	567.7	7.0	945.8	11.7	1,223.7	15.2
North Hampton	8,922.8	67.8	0.8	135.3	1.5	215.9	2.4
Hampton	9,072.8	319.4	3.9	632.3	7.7	897.8	10.9
Hampton Falls	8,078.0	121.3	1.6	187.4	2.4	252.3	3.2
Seabrook	6,161.3	270.4	4.7	439.7	7.7	613.6	10.8
Sea-Level Rise (SLR) + Storm Surge Scenarios	**Total upland acres**	**SLR 1.7 feet + storm surge**	**% of total upland**	**SLR 4.0 feet + storm surge**	**% of total upland**	**SLR 6.3 feet + storm surge**	**% of total upland**
Coastal Region	**49,266.3**	**3,473.5**	**7.0**	**4,439.0**	**9.0**	**5,298.4**	**10.8**
Portsmouth	10,763.4	287.7	2.9	406.6	4.1	534.6	5.3
New Castle	1,347.6	94.7	17.9	126.0	23.9	159.7	30.2
Rye	8,405.9	1,200.6	14.9	1,465.9	18.2	1,690.6	20.9
North Hampton	8,922.8	193.5	2.2	283.9	3.2	358.6	4.0
Hampton	9,072.8	879.7	10.7	1,123.5	13.6	1,321.1	16.0
Hampton Falls	8,078.0	237.4	3.0	305.6	3.9	383.7	4.9
Seabrook	6,161.3	580.0	10.2	727.6	12.8	850.1	14.9

Note: Upland refers to land above mean higher high water (highest average tidal extent) excluding wetlands.

Land Use and Land Cover

Map 14 Regional Land Use shows land use/land cover types affected by sea-level rise and coastal storm surge flooding. Table 13 reports the number of acres for each land use/land cover type affected by each flood scenario.

Regional land use categories most impacted by sea-level rise under all scenarios are Wetlands, Residential, and Forested, highlighting not only the impacts of sea-level rise and storm surge on property but also on natural ecosystems and the ability of these systems to function as flood storage, erosion control, and wildlife habitat.

TABLE 13. 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
Active Agricultural	2.6	10.9	20.9	18.5	34.5	50.7
Aux Transportation	0.9	8.9	14.4	20.4	27.8	36.9
Farmsteads	0.0	0.0	0.0	0.0	0.0	0.2
Forested	75.8	316.8	565.9	513.5	761.4	993.7
Industrial/Commercial	11.8	66.7	140.2	126.3	192.9	247.9
Mixed Urban	0.4	3.5	6.4	5.8	8.9	11.7
Other/Idle	50.9	139.7	232.5	254.8	319.4	370.7
Playing Fields/Recreation	17.9	76.7	131.8	128.5	169.5	224.0
Railroad	0.1	0.6	2.1	1.7	3.6	6.1
Residential	83.3	343.9	637.9	591.1	895.9	1179.5
Transportation	7.5	63.4	127.1	128.6	185.1	232.4
Utilities	6.1	22.6	44.4	39.4	59.3	75.4
Water	87.9	157.3	161.5	160.3	167.3	171.8
Wetlands	1240.2	1570.4	1731.3	1691.8	1828.0	1918.5

Note: Auxiliary Transportation refers to small pieces of land adjacent to transportation assets. Other/Idle refers to disturbed, undeveloped and non-classified lands.

Municipal Zoning Districts

Map 13 Regional Zoning shows local zoning districts affected by sea-level rise and coastal storm surge flooding. Table 14 reports the acres within each zoning district affected by each flood scenario. Zoning districts are superimposed over land use and land cover.

Zoning Districts in the coastal region most impacted be sea-level rise and storm surge are Residential –Low Density, Public/Institutional, and Residential – Medium Density. There is a critical need in the region to educate homeowners about the threats posed by climate change to their property and ways in which they can assist in mitigating impacts.

TABLE 14. MUNICIPAL 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
Commercial	54.8	151.9	230.2	238.0	284.5	307.2
General/Single Zone	54.8	151.9	230.2	238.0	284.5	307.2
Industrial	83.7	172.9	226.5	216.3	268.7	331.8
Mixed Urban	26.2	47.3	89.1	79.3	129.9	182.1
Open Space/Conservation	28.7	51.6	86.7	79.1	114.0	147.8
Public/Institutional	572.2	794.1	913.2	895.4	978.8	1,049.1
Residential - High Density	47.0	100.9	141.2	142.3	171.3	195.4
Residential - Med Density	217.9	404.2	573.6	557.6	716.1	838.8
Residential - Low Density	518.4	996.7	1,470.5	1,385.2	1,883.6	2,338.7

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 15 reports the acreage within the current 100-year and 500-year floodplains affected by each flood scenario.

The 100-year and 500-year FEMA Flood Hazard Areas increase under all sea-level rise and storm surge scenarios, with the 100-year floodplain for the coastal region ranging from 8,179 acres under the 1.7 feet sea-level rise scenario to 9,818 acres under the 6.3 feet sea-level rise plus storm surge scenario. The 500-year FEMA Flood Hazard Areas increase from 8,180 under the 1.7 feet sea-level rise scenario to 10,068 acres under the 6.3 feet sea-level rise plus storm surge Scenario.

Projected sea-level rise and coastal storm surge flooding are largely contained within the current 100-year floodplain with minor incursions within the 500-year floodplain in lowest lying areas. The greatest extent of impacts from sea-level flooding (the projected daily tidal condition) within the 100-year floodplain are in Hampton, Seabrook, Rye and Hampton Falls.

TABLE 15. 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 in Coastal Region	**8,179.5**	**9,361.1**	**9,593.2**	**9,639.0**	**9,765.8**	**9,818.0**
Portsmouth	927.3	1,017.8	1,023.1	1,022.8	1,023.9	1,023.8
New Castle	539.0	570.9	589.4	589.9	600.3	601.2
Rye	1,227.6	1,603.9	1,707.9	1,721.7	1,786.4	1,808.1
North Hampton	256.9	324.4	334.3	337.2	348.3	357.6
Hampton	2,393.0	2,738.3	2,810.9	2,836.2	2,865.8	2,872.9
Hampton Falls	1,105.7	1,203.3	1,207.8	1,207.4	1.208.2	1,208.6
Seabrook	1,730.1	1,902.5	1,919.7	1,923.8	1,932.9	1,945.8
500-year floodplain in Coastal Region	**8,180.6**	**9,368.4**	**9,837.6**	**9,879.8**	**10,015.3**	**10,069.5**
Portsmouth	927.3	1,017.9	1,028.8	1,028.0	1,030.8	1,031.3
New Castle	539.0	570.9	589.4	589.9	600.3	601.2
Rye	1,228.6	1,609.1	1,763.7	1,777.1	1,842.3	1,864.1
North Hampton	256.9	324.6	356.1	358.9	370.3	379.8
Hampton	2,393.0	2,739.1	2,886.0	2,910.4	2,941.7	2,948.9
Hampton Falls	1,105.7	1,203.7	1,234.0	1,232.7	1,236.0	1,237.1
Seabrook	1,730.1	1,903.1	1,979.5	1,982.7	1,993.9	2,007.1

Area of the 100-year floodplain in coastal region = 12,358.8 acres. Area of the 500-year floodplain in coastal region= 12,950.2 acres.

Parcels and Assessed Value

Table 16 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.

A range of 2,800 to 5,700 parcels will be partially or wholly affected by tidal flooding under the scenarios used, and up to 7200 effected when storm surge is added. The data shows a 55 %increase in the number of parcels and a $651 million dollar increase in the assessed value of parcels when comparing the 1.7 feet to the 4.0 feet sea-level rise scenario, and a 32 %increase in the number of parcels and a $659 million increase in the assessed value of parcels when comparing the 4.0 feet to the 6.3 feet sea-level rise scenario.

TABLE 16. PARCELS AND ASSESSED VALUE BY SCENARIO

Sea-Level Rise (SLR) Scenarios	Number of Parcels Affected by scenario	Aggregate Value of Effected Parcels
1.7 feet SLR	2,789	$1,298,033,374
4.0 feet SLR	4,334	$1,949,171,074
6.3 feet SLR	5,740	$2,608,930,224
1.7 feet SLR + storm surge	5,555	$2,555,831,824
4.0 feet SLR + storm surge	6,468	$2,988,594,674
6.3 feet SLR + storm surge	7,165	$3,258,843,274

4. NATURAL RESOURCES AND ENVIRONMENT

Maps 7 and 8 Conservation Areas, Map 9 and 10 Wetlands, Aquifers, Wellhead Protection Areas, and Map11 and 12 Agricultural Soils show natural resources affected by sea-level rise and coastal storm surge flooding. Table 17 reports the number of acres for each natural resource affected by each sea-level rise and coastal storm surge scenario.

The Coastal Region is home to a wide variety of natural resources and ecosystems, including tidal and freshwater wetlands, salt marsh systems, estuarine systems, beaches, dunes, freshwater aquifers, and farm and forest land. Many of these critical natural areas are vulnerable to sea-level rise and storm surge. Impacts include:

- Aquifers and surface water systems – saltwater intrusion into aquifers, municipal and privately owned water systems located in the coastal region are vulnerable to salt water intrusion and damage to infrastructure;
- Freshwater wetlands – transition of freshwater wetlands to saltwater and tidal wetlands;
- Tidal wetlands – inland migration of coastal and tidal wetlands and loss of these systems as this migration comes up against developed land;
- Wildlife habitat – many types of habitats, as identified in the NH Fish and Game Wildlife Action Plan and the NH Coastal Conservation Plan, are located within the Coastal Region and habitat compositions will change as a result of sea-level rise and storm surge. Some habitat types may expand and others may retreat;
- Conservation and public lands – Seal-level rise and storm surge will impact land conserved from development and public lands, including beaches. Dunes will need opportunities to migrate inland;
- Agricultural soils and farmland – storm surge has a profound impact on agricultural soils in the coastal region, with an increase of 913% acres impacted under the S3F scenario.

TABLE 17. 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
Surface Water	48.8	133.8	143.9	143.6	151.7	156.2
Stratified Drift Aquifers	8.0	23.8	55.9	48.0	86.7	122.0
Freshwater Wetlands	184.1	396.2	518.7	488.8	592.5	660.6
Tidal Water Wetlands	235.3	257.3	264.2	266.5	268.4	268.6
Wildlife Action Plan – Tier 1 and Tier 2 habitats	4,021.7	4,851.1	5,468.8	5,385.4	5,947.5	6,458.3
Coastal Conservation Plan - Focus Areas	1,080.7	1,600.4	1,914.7	1,864.9	2,112.0	2,309.9
Conserved/Public Lands	492.7	717.0	873.0	882.6	1,007.0	1,131.0
Ag Soils (All Types)	122.7	378.1	677.6	620.4	937.0	1,237.5

Major freshwater river systems impacted by sea-level rise and coastal storm surge flooding include Cains Brook in Seabrook, Taylor River in Hampton, Little River in North Hampton, and Eel Pond in Rye.

In the assessment of flood impacts to tidal wetland systems (identified from the National Wetland Inventory), only estuarine and marine wetland types above mean higher high water were evaluated. The data indicates greater acres of freshwater wetlands are flooded from sea-level rise and coastal storm surge than these estuarine and marine wetland types above mean higher high water.

Portsmouth, Rye, Hampton and Seabrook have the greatest amount of conserved and public land within the coastal floodplain. Although impacted by sea-level rise and coastal storm surge flooding, these undeveloped serve as important flood storage areas and allow space for future habitat conversation and salt marsh migration.

Sea Level Affecting Marshes Model (SLAMM): A Regional and Community Analysis

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

Introduction

Salt marsh is an important habitat that exists within only 17 communities in all of New Hampshire. This coastal wetland type has been identified as one of the most valuable habitats in the state and has been designated "Tier 1", meaning of statewide importance, in the NH Wildlife Action Plan. In addition to wildlife habitat, salt marshes provide multiple human benefits including long term carbon storage, healthy fisheries, storm protection, and flood mitigation. These ecosystem services are provided at no, or low, financial cost.

Rising sea level is likely the biggest threat to salt marsh. Fortunately, salt marshes have the potential to keep up with sea-level rise by migrating inland and forming new marsh when they are adjacent to low lying undeveloped areas of land and no physical barriers block their movement (see figure below).

Statewide Change In Marshes

There are currently 6, 039 acres of salt marsh in New Hampshire. If sea-level rises at a rate of 6.6 feet by 2100 SLAMM projects we are likely to lose 240 of the 6040 acres of salt marsh we see today in just the next decade, and by 2100 we are likely to reach a statewide "tipping point" where less than 300 acres of currently existing salt marsh remains.

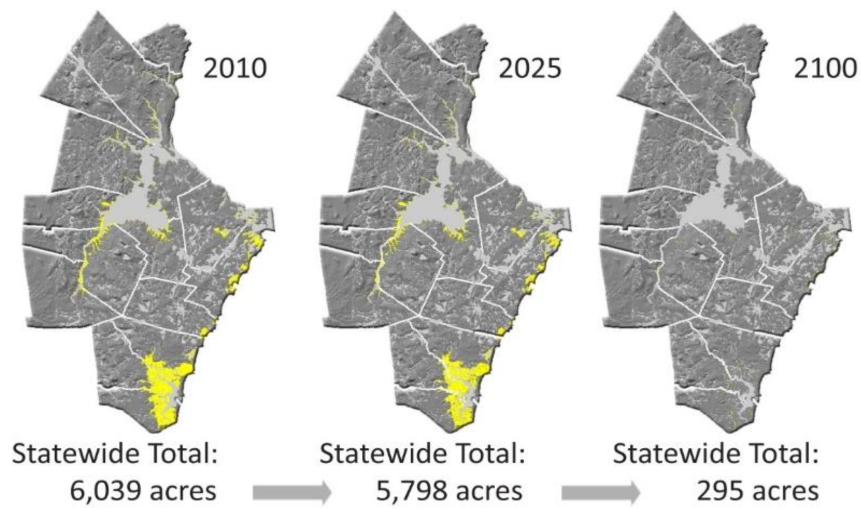


FIGURE 7. STATEWIDE ACRES AT 2010, 2025 AND 2100

Where Can New Salt Marsh Form?

Although the largest acreage of salt marsh is currently found in Hampton, Seabrook and Hampton Falls respectively, Rye is the community in which there is potential for the most new salt marsh to be created.

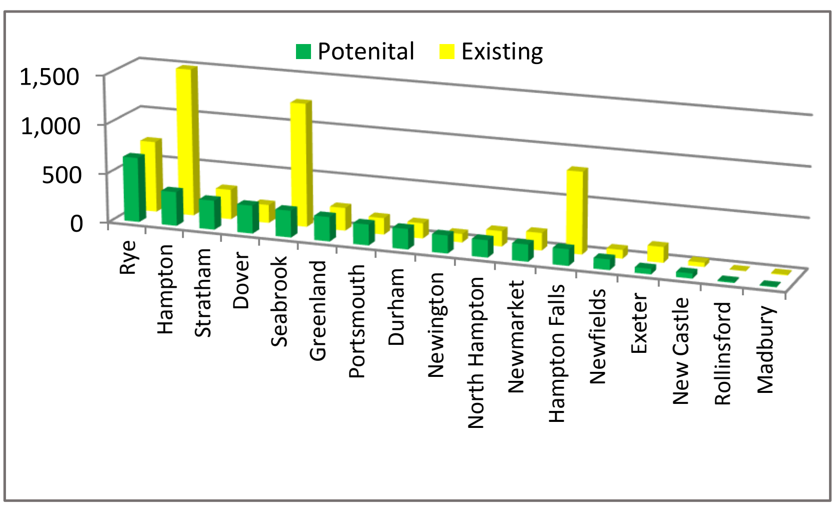


FIGURE 8. EXISTING AND POTENTIAL ACRES BY MUNICIPALITY

The figure shows conditions of existing and potential salt marsh under 6.6 feet of sea-level rise by the year 2100. At the 3.9 feet rate, Rye is once again the community that has the potential for most salt marsh to be created. Some of the communities with relatively extensive areas of potential new marsh, and so the greatest number of conservation opportunities, are not traditionally thought of as expansive salt marsh towns. For example, Stratham and Dover have slightly more potential new marsh than Seabrook**.**

Focusing land protection in areas where salt marsh has the potential to migrate is a key strategy in enhancing coastal resiliency.

What Has the Potential to Convert to Salt Marsh?

Statewide, the majority (43%) of areas that have potential to convert to salt marsh are currently forested land. The next major category of potential conversion is freshwater wetland at 21%. The residential category is comprised of single family or duplex homes. Of the 3, 438 total potential acres of new marsh, 34% is currently developed land and 66% is undeveloped.

In all of New Hampshire, there are currently 548 potential restrictions that if removed, or modified, could restore tidal flow. However, the majority of these are small at less than 1 acre. There are only 38 opportunities over 1 acre and just 6 of these that are 5 acres or more in size (shown in yellow on the map). Of the three regions highlighted, the Hamptons-Seabrook estuary is expected to experience greatest loss of salt marsh.

Areas in Rye and North Hampton have the potential to support the greatest amount of new marsh, primarily due to conversion of an area of forested land to the west of Odiorne Point that is circled in red on the map below. This conversion is particularly robust as it is likely to remain salt marsh in 2100 even under the highest projected sea-level rise scenario.

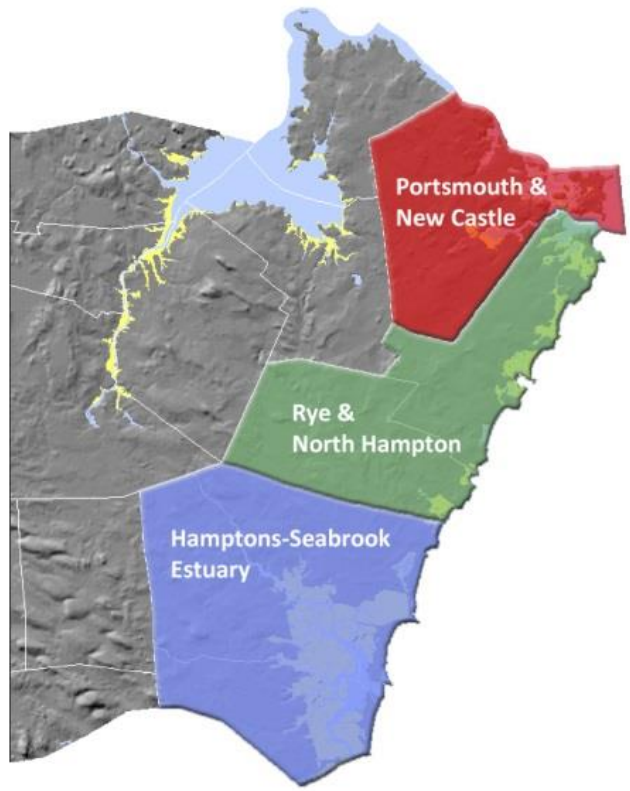


FIGURE 9. AREAS OF EVALUATION IN COASTAL NEW HAMPSHIRE.

Sea-Level Rise and Salt Marshes

Even at the 3.9 feet sea-level rise scenario, all three regions are likely to experience some loss of salt marsh in the next decade but the loss is not likely to be extensive. The Hamptons-Seabrook estuary will lose most at around 127 acres. However, in each region, if land is protected and salt marsh is allowed to migrate inland in all possible areas, there could be a potential net gain. Statewide, this net gain could be over 800 acres.

TABLE 18. SALTMARSH ACRES AT 2025 WITH 3.9 FEET SEA-LEVEL RISE

3.9 feel sea-level rise at 2025 (acres)				
Municipality	**Current**	**Persist**	**Loss**	**Potential Gain**
Portsmouth & New Castle	210	203	7	84
Rye & North Hampton	875	862	13	325
Hamptons-Seabrook Estuary	3,570	3,443	127	223
State	**6,039**	**5,821**	**218**	**1,082**

By 2100, at the same rate of sea-level rise, the loss of currently existing salt marsh will increase in each region, but the overall potential net gain will also increase.

TABLE 19. SALTMARSH ACRES AT 2100 WITH 3.9 FEET SEA-LEVEL RISE

3.9 feel sea-level rise at 2100 (acres)				
Municipality	**Current**	**Persist**	**Loss**	**Potential Gain**
Portsmouth & New Castle	210	173	37	209
Rye & North Hampton	875	779	95	656
Hamptons-Seabrook Estuary	3,570	3,060	510	627
State	**6,039**	**5,013**	**1,026**	**2,666**

By 2100, at the 6.6 feet sea level scenario, each region reaches a "tipping point" and is likely to experience significant loss of salt marsh.

TABLE 20. SALTMARSH ACRES AT 2100 WITH 6.6 FEET SEA-LEVEL RISE

6.6 feel sea-level rise at 2100 (acres)				
Municipality	**Current**	**Persist**	**Loss**	**Potential Gain**
Portsmouth & New Castle	210	19	190	261
Rye & North Hampton	875	84	790	828
Hamptons-Seabrook Estuary	3,570	83	3,488	780
State	**6,039**	**295**	**5,744**	**3,429**

Community Summaries

Community-based summaries of the SLAMM model results for Portsmouth, New Castle, Rye, North Hampton, Hampton, Hampton Falls and Seabrook are included in their respective Tides to Storms Vulnerability Assessment Reports.

5. DEPTH OF FLOODING FROM SEA-LEVEL RISE AND STORM SURGE

Maps 17-22 display depth of flooding across the coastal region for each of the six scenarios (three sea-level rise and three sea-level rise plus storm surge) evaluated as part of this assessment. Depth of flooding is displayed in shades of orange in the following increments: < 2 feet, 2-4 feet, 4-6 feet, 6-8 feet, 8-10 feet, and > 10 feet.

VI. Regional Planning Recommendations

1. PLANNING FOR CLIMATE CHANGE

In order to effectively adapt in short-term and long–term, municipalities need help developing and implementing policies and regulations to plan for and minimize the impacts of climate induced changes. Important first steps for coastal communities include identifying areas at most risk from flooding due to sea-level rise and coastal storms; incorporating climate change adaptation and mitigation strategies in local hazard mitigation plans; putting regulations in place that decrease the vulnerability of buildings and infrastructure in these areas subject to higher risk of flooding, particularly in the next 30 to 50 years (or within the life cycle of most existing facilities); and leveraging existing institutional practices - such as master plans, and capital improvement plans – to maximize use of available funds and implement comprehensive strategies to adapt to changing conditions, prevent or minimize impacts and protect public and private investments.

Planning for climate change can result in positive actions that improve preparedness and reduce impacts from current coastal hazards and address long-term changes that may result from climate change including sea-level rise. Communities that implement climate adaptation planning may see benefits such as:

- Enhancing preparedness and community awareness of future flood risks.
- Identifying cost-effective measures to protect and adapt to changing conditions.
- Improving resiliency of infrastructure, buildings and other community investments.
- Protecting life, property and local economies.
- Protecting coastal natural resources and the critical services they provide.
- Preserving historical assets and unique community character.

Climate Adaptation

Climate adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic change and their effects or impacts. It refers to changes in processes, practices and infrastructures to moderate potential damages or to benefit from opportunities associated with climate change. [3]. Climate adaptation is often described as actions that fall in three main categories.

Accommodate

Measures that manage risk by requiring development to be built and retrofitted to be more resilient to impacts and by limiting certain types or all development in highest risk areas, favoring adaptive uses (i.e. passive uses such as recreation) and gradual modification of structures and uses as conditions change over time.

Protect

Measures focused typically on hard-engineered solutions to prevent impacts for flooding, storm surge and erosion. Protection may include preservation strategies such as restoration and/or maintenance of natural dune systems and “living shorelines”, and beach nourishment.

Retreat

Often the last action before abandonment, retreat follows an incremental path of planning for the eventual relocation of structures to upland areas as properties become threatened or directly impacted

[3] United Nations Framework Conference on Climate Change at http://unfccc.int/focus/adaptation/items/6999.php

by rising sea level, erosion and coastal storms. Such measures may include rolling setbacks and buffers, transfer of development rights, and property acquisition and/or buyout programs.

Coastal Climate Resilience

To be climate resilient is the capability of communities to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment. Natural systems that can respond to and accommodate changing environmental conditions while remaining stable, healthy and productive are climate resilient.[4]

Adding resilience to human and natural systems can be an integral component of current and future decisions by the state, municipalities and resources managers about the placement and design of new infrastructure and buildings, redevelopment of the landscape, and restoration and protection of natural systems that provide economic and societal benefits. Resilience can also guide post-disaster response planning and how we in coastal New Hampshire decide to rebuild in the event of a catastrophic event.

The Tides to Storms Coastal Vulnerability Assessment is a snapshot based on existing conditions in coastal New Hampshire based on the current distribution of developed lands and natural landscapes and resources for the year 2015. As the developed and natural landscapes in the coastal region change, and climate parameters change, so will the degree and extent of impact from sea-level rise and coastal storm surge flooding. In order to use the latest science-based information to guide decision making, it is highly recommended that vulnerability assessments be updated as new information about emerging trends and revised projections of climate change are published.

2. REGIONAL CONSIDERATIONS

From state and regional perspectives, the increased risk of exposure to coastal flooding from changing sea level raises a number of important issues that should be considered and addressed in state, regional and local responses to increase coastal flood risk. There are both general considerations that apply to our collective response as well as considerations that apply to the specific asset classes affected. These are summarized below.

General

Acting in uncertainty: the value of an incremental response: The most difficult circumstance under which to take action in response to a future threat is when there is uncertainty about the degree of risk from that threat. This is the case with projections of coastal flooding caused by sea-level rise. The risk of catastrophic damage, especially from the highest sea-level rise scenarios is very high, but so too is the uncertainty about whether and when those conditions will arise. This combination can lead to a paralysis of action if it seems safer to wait to act until there is better information and more certainty. This is especially true when the threat is distant in time and the cost of responding is high. In the case of sea-level rise, given that certainty will improve over time and that change will be gradual, it may prove most advantageous to respond incrementally. Roads and other infrastructure, for example, can be raised in increments and raised again as needed/warranted based on refined projections. This approach can help reduce disruption and the cost of responding and allow for action rather than paralysis. There are also cases, however, based on the expect design life or critical nature of a facility, where an incremental approach could be wasteful or dangerous. Each situation needs to be evaluated individually taking into consideration many factors.

[4] Adapted from EPA glossary http://epa.gov/climatechange/glossary.html

The value of time and of acting now: Incremental responses can be effective against sea-level rise because of the length of time over which the sea levels are expected to change. It is likely that many, if not most, roads, bridges and other infrastructure will be replaced or extensively rehabilitated before the year 2100 due to age, capacity or deficiencies. This renewal cycle provides an opportunity to incorporate resiliency to higher sea levels into infrastructure designs and as they are replaced. If this approach is adopted early, then the cost of responding to sea level change may be largely absorbed within the normal expected investments in those facilities. Conversely if we fail to do this then the cost of radical retrofits and replacement from flood losses are likely to be much greater. This points to the need and long term cost savings of anticipating sea level change now, as well as the need to make all future infrastructure investments in vulnerable areas resilient to at least moderate sea-level rise expected over the facility design life.

State and regional economic considerations: Coastal New Hampshire is highly important to the region's and the state's economy. Statewide, tourism ranks as the state's second largest economic sector, and, for several communities in the coastal region, it is the largest. Much of that tourism activity is driven by access to coastal assets including beaches and the ocean. In terms of building and property assets, the analysis in this study shows, not unexpectedly, a disproportionate amount of property value is clustered in coastal communities: About 35% of the property valuation of Rockingham County's 37 communities is concentrated in the seven ocean-fronting communities, which account for only 22% of the county population. Within those communities about one-third of their property values is associated with parcels wholly or partially within the areas potentially affected by sea-level rise. A similar pattern is apparent with room and meals taxes. Rockingham County collects 32% of the rooms and meals taxes in the state annually (2014 DRA data), while representing only 22% of the State's population. With an important part of the region's economy at stake, it is the state's and the town's interest to be proactive about this threat and take action beginning now to minimize risk.

State and municipal collaboration, coordination and planning: The state and municipalities share assets and infrastructure on the coast and as such need to align their policies, assumptions and responses to existing and future coastal flood hazards to the greatest extent possible. Examples where this approach is essential are shoreline management, land use policy and infrastructure. For example, NHDOT, NHDES and municipalities need to agree about areas where hardened shoreline should be maintained, where future building should be prohibited and were and how critical infrastructure like road and utilities should be moved or raised to become more flood resilient. Failure to coordinate such actions will increase the cost and decrease the effectiveness of planning and preparation for increased flood risk.

Creative financing mechanisms for infrastructure projects: As described above, by acting sooner rather than later, by phasing-in higher standards over time and by timing reconstruction and renovation with facility lifecycles, the costs of building more resilient communities and infrastructure can be minimized. Nevertheless, more resilient buildings and infrastructure will cost more in the short term and may accelerate the need for certain improvements. This may necessitate innovative financing approaches to make such investments workable. For example the period of construction bonds may need to be lengthened for facilities built to higher standards, supported by the rationale they will have a longer useful life. Another area where creative financing may be called for is in establishing a hazard mitigation fund to enable state agencies or communities to purchase developed properties in high hazard locations, or in undeveloped areas that could provide space for marsh migration. A few states, for example, have pre-funded buy-out programs enabling them to acquire repetitive-loss properties after a coastal flooding event to enable owners to move to non-flood prone area rather rebuild in the same high hazard locations. The acquired property can become part of the living shoreline and serve as flood protection. Such financing alternatives will likely need active state and federal support.

Comprehensive Shoreline Management Planning: The extent of damage to shorelines possible under the "intermediate high" (4.0 feet) and "high" (6.3 feet) sea-level rise scenarios mapped in this study demonstrate the clear need for a comprehensive shoreline management plan for the New Hampshire coast. Such a plan would identify both general priorities and policies for shoreline management, but also examine specific sections of coast to recommend where specific management approaches are necessary. For example, in some locations shoreline hardening will be needed to protect critical assets and populations; in others retreat or abandonment will be more appropriate given risk exposure or cost. In still other locations, assets can be made more resilient or adapted to periodic flooding, and living shorelines can created or enhanced to provide improved flood protection. Given multiple stakeholders, any successful shoreline management plan must be undertaken as a collaborative effort between the state, municipalities and other stakeholders.

Consistency in land development standards: The best way to limit the region's property and infrastructure exposure in future flood prone areas is to ensure that future development does not add to that exposure. Local and state land use standards should be adapted to anticipate increased flood risks associated with storm surge and sea-level rise as soon as possible so that new development will be resilient to these conditions. Measures that can be adopted quickly and relatively easily include adding 2 to4 feet of freeboard from the existing base flood elevations to create a buffer for higher flood levels in the future. For municipalities this can be incorporated into existing flood hazard regulations; for state agencies will be incorporated into minimum design standards required for federally funded project as part of the FFRMS (see Chapter III, Section 2, above).

Identify priority areas for restoration, protection and retreat: Effectively preparing for increased coastal flooding from storm surge and sea-level rise will require a section by section examination of our shoreline to determine the best management approach for each. Places with high concentrations of population and assets, for example will call for flood protection; others, such as isolated development in area difficult to make resilient may call for retreat, and still other sections may need restoration of natural living shoreline to enhance natural systems protect us from coastal erosion and help maintain coastal ecosystems. As described above, developing a comprehensive shoreline management plan may me the best approach for determining these priorities and its development should be pursued. It should be acknowledged that some of these priorities will change under different sea-level rise scenarios. A priority to protect some areas in the intermediate low (1.7 feet) sea-level rise scenario may prove infeasible in a higher scenario.

Continued evaluation of science based climate change projections: The basis for recommending an incremental approach in responding to sea level change is the lack of certainty about the timing and extent of this change. As explained in the CRHC Science and Technical Advisory Panel report, there are several major global drivers of sea-level rise. The size and level of certainty for these components differs. The largest single driver, the warming of oceans, is relatively certain, assuming atmospheric warming continues along a given projection. Other drivers, including the response of the land ice sheets in Greenland and

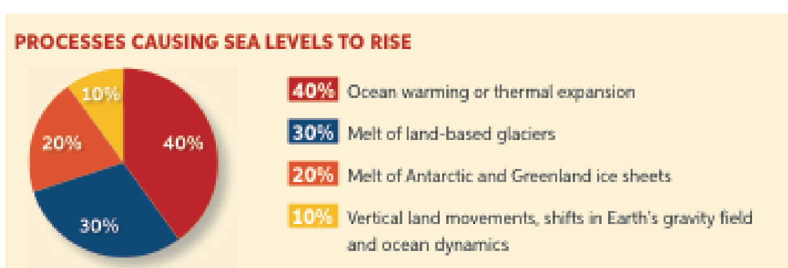


FIGURE 10. RELATIVE PERCENT CONTRIBUTIONS TO SEA-LEVEL RISE. (Source: CHRC/STAP Report Summary)

the West Antarctic to ocean warming are much less certain. This is the reason for the wide gap in the sea-level rise scenarios for 2100 used in the National Climate Assessment, and hence in the mapping completed for this project. Over time both the range and rate of expected sea level rise will presumably narrow as climate change projections become more certain. This in turn will allow estimates of vulnerability to become more refined. It will be important for local and state officials in New Hampshire to periodically revisit these projections and assumptions and adjust responses accordingly.

Roadways and Transportation Assets

Responses to impacts from coastal flooding to roads and other transportation assets will commonly include raising road beds and bridges and culverts to accommodate changes sea level and tidal ranges. Changing linear infrastructure like a roadway is particularly challenging and requires careful transitions and sequencing when approached in segments. An important consideration for these actions is coordinating changes to match connections to local roads and driveways which will also need to be raised.

Route 1-A provides the vital transportation link on the immediate coast and is essential to coastal communities for access, safety, livability, recreation and for the continued viability of coastal tourist economy. With its immediate shoreline exposure, it comes as no surprise that Route 1-A is the transportation asset most vulnerable coastal flooding and disruption from sea-level rise scenarios. As shown in the project maps, the route and any connecting streets and roads are significantly affected by sea-level rise in the intermediate high and high scenarios. I-A is the backbone of the road network on the immediate coast for all of the communities (except Hampton Falls) and is essential for maintaining a function roadway system. To a great extent local responses on municipal roads will depend on State plans for improving the resilience of Route 1A and will require extensive regional coordination.

In addition, the east to west evacuation routes (see Maps 15 and 16) from the immediate coast nearly all depend to some degree on I-A to move traffic to these routes. This must also be considered in prioritizing efforts to address vulnerability of this critical link.

A number of existing state Ten Year Plan projects hare identified in this study as being potentially effected by future coastal flooding. These include the Ocean Boulevard reconstruction in Hampton, the Rye/New Castle lift bridge, the Portsmouth-New Castle Causeway and others. It will be important for the engineering and design for these projects to account for a reasonable degree of sea-level rise, such as that called for the Federal Flood Risk Management Standard (FFRMS).

Critical Facilities and Infrastructure

As with roads, water and wastewater conveyance utilities cannot be addressed effectively in small segments and likewise require careful (and costly) sequencing and matching to the existing system. Since utilities areey are often embedded within roadway rights of way, they are best addressed at the same time, requiring extensive project coordination. Gravity type sewers may need to be converted to pressure designs in vulnerable areas than cannot be sufficiently raised. Utility point facilities, such as pump stations, telecommunication switches, and electrical substations in a few locations will need to be raised but are easier to secure. However, the continued function of these systems will be affected by the connected, dependent infrastructure. Communities recognize the critical importance ensuring that emergency facilities and shelters be located in places that are secure and accessible. With existing coastal flood hazards in mind, relatively few although critical facilities are located in vulnerable locations including the Hampton Police Station and Fire Station, and the Hampton and Seabrook wastewater treatment facilities.

Given the cost of making certain infrastructure and critical facilities more resilient, it is important that upgrades be budgeted as part of a long term capital improvement and included in cost estimates for new projects and facilities.

Land Use

Direct land use impacts to buildings from the sea-level rise scenarios alone were found to be comparatively limited in most of the study are because the sea-level rise bounds are almost all within the existing 100-year flood hazard areas. To the extent that development has been discouraged or limited in the current 100-year floodplain, they have been protected from impacts from increases in sea level. This does not, of course, protect them from storm surge impacts that are added to future increases in sea level.

As stated earlier in the “General” considerations, the best way to limit the region’s property and infrastructure exposure to future sea-level rise is to ensure that future development is limited in those vulnerable areas. Future land use polices that discourage further development in areas that will become vulnerable in a future 100-year storm will extend that protection and limit future losses. The adjacent upland areas that would be protected with this approach will also serve as critical flood storage in future storms and support marsh migration. Implementation strategies include land conservation/property acquisition, conservation subdivision, transfer of development rights, restoration of natural vegetation and adaptive repurpose/reuse.

For development or redevelopment that does occur in vulnerable areas, communities can readily make use of existing standards, such as local Floodplain Management standards, by building in higher standards. Measures that can be adopted quickly and relatively easily include adding two to four feet of freeboard from the existing base flood elevations to create a buffer for higher levels in the future. The amount of buffer called for can be variable based on the expected useful life and/or critical nature of the facility and the extent of projected future flooding. This approach is becoming increasingly common in states along the eastern seaboard and is consistent with Federal Flood Risk Management Standard (FFRMS).

3. POLICY AND CAPACITY BUILDING RECOMMENDATIONS (STATE, REGIONAL, MUNICIPAL)

P1 - Strengthen state, regional and municipal capacity to understand risks and vulnerability to potential future impacts of climate change.

Actions

- Assist municipalities with application of assessments, data and technical guidance about climate change planning and climate adaptation strategies.
- Partner with federal and state agencies, regional partners and local organizations to apply for funding and technical support.
- Partner with federal and state agencies, regional partners and local organizations to expand resources and improve coordination.
- Support implementation of state, regional and local research, assessments and initiatives that fill gaps in climate change data, resources and tools.
- State agencies and municipalities commit resources and capacity to plan for climate change.

P2 - Integrate protection of natural and constructed systems, social services, and historic and cultural resources into engineering and regulatory frameworks of shoreline management.

Actions

- Improve shoreline management to address the intensifying challenges posed by climate change, including management of development in high risk areas.
- Improve shoreline management to include measures that minimize coastal and floodplain erosion, and loss of natural resources that protect against flooding.
- Retain and expand dunes, beaches, wetlands, forests and natural vegetation to protect against coastal and riverine flooding.
- Discourage hardening of shorelines in favor of protecting existing natural shorelines and restoring them when feasible.
- Apply hard and engineered shoreline techniques only to protect essential infrastructure and evaluate the benefit to cost of maintaining these techniques in the future.

P3 - Integrate climate mitigation actions across all sectors of planning, transportation, land development and infrastructure projects.

Actions

- Attain reduction in vehicle miles travelled and overall greenhouse gas emissions in the region.
- Protect areas that serve as carbon storage such as forests, wetlands and other natural landscapes.
- Facilitate increase in use of low-carbon energy sources and installation and use of renewable energy sources.

With respect to climate change, ***mitigation*** is the reduction of greenhouse gas (GHG) emissions achieved through energy efficiency and conservation, use of renewable and alternative energy sources, and CO_2 storage in forests and biomass.

P4 - Provide guidance and recommendations to incorporate climate adaptation strategies and actions in state and regional policy, planning and regulatory sectors.

Actions

- Utilize existing funds and seek additional funding sources to support integration of climate change in RPC work program.
- Incorporate climate adaptation strategies and actions in RPC projects and plans.
- Work with municipalities to incorporate climate change strategies in hazard mitigations plans, open space and land conservation plans, zoning ordinances and land development regulations.

- Assist municipalities to implement climate change actions and adaptation strategies including adoption of policy, planning and regulatory measures.
- Encourage comprehensive land use planning, environmental planning and floodplain management that prevents and minimizes impacts.

4. MUNICIPAL PLANNING RECOMMENDATIONS

M1 - Natural Hazards Mitigation Plan. Incorporate the vulnerability assessment information and recommendations from the Tides to Storms vulnerability assessment report in municipal Natural Hazards Mitigation Plan updates. Continue revising and updating the assessment information and climate adaptation recommendations in future updates of the Plan.

M2 - 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.

M3 - 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.

M4 - 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. Evaluate the extent of sea-level rise and storm surge flooding on individual municipal facilities (e.g. wastewater treatment plant, transfer station, high school, drinking water systems).

M5 - 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.)
- Support retreat from high risk areas by buying properties and restoring them to a natural condition.

M6 - 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.

M7 - 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. Mark evacuation routes with signage and communicate these routes to the public with information on the town's website and printed maps.

5. REGULATORY RECOMMENDATIONS - MUNICIPAL

RM1 - Elevate Structures Above Base Flood Elevation. Adopt standards in floodplain zoning and/or Site Plan Review and Subdivision Regulations that require all new habitable development and redevelopment to be elevated a minimum of 2 feet above the base flood elevation (100-year/1% chance event). 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. For critical facilities or high cost infrastructure projects with long lifecycles, require up to 4 feet elevation above base flood elevation and encourage the facility design to be adaptable to even higher elevations.

RM2 - 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.)

RM3 - 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.

6. OUTREACH AND ENGAGEMENT RECOMMENDATIONS

State and Regional

OE1 - Implement outreach and engagement measures to raise regional and community-based awareness about climate change.

Actions

- Work with regional partners to promote and encourage land and resource conservation in high risk areas such as coastal and riverine floodplains and to protect surface and groundwater resources.
- State, regional and municipal decision-makers work together to protect critical services and the health and safety of the public.
- Disseminate climate change informational resources through RPC staff and circuit riders, website, Commission meetings and other partners.
- Educate municipalities and property owners regarding options for protecting properties from flooding and erosion.

OE2 - Support the NH Coastal Adaptation Workgroup and other regional and statewide climate adaptation initiatives. 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.

Actions

- Assist the NH Coastal Adaptation Workgroup and its members to apply for funding and technical support for climate change initiatives.
- Support of collaborative partnerships and networks of professionals, practitioners, and researches that provide technical assistance and build capacity for municipal actions.
- Continue the partnerships with NH Coastal Adaptation Workgroup in climate adaptation activities that facilitate, coordinate, provide technical information, and convene public outreach events.

Municipal

OM1 - Seabrook-Hamptons Estuaries Alliance. The Seabrook-Hamptons Estuaries Alliance (SHEA) is a voluntary collaborative advocacy group consisting of members from Hampton, Hampton Falls and Seabrook. 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 the three towns, especially in regard to research, programs and other efforts designed to help preserve, protect, and strengthen the Estuary. SHEA can assist the town with outreach, planning and regulatory activities involving climate adaptation implementation.

- Continue participating in and supporting the Seabrook-Hamptons Estuaries Alliance.
- Continue SHEA's and the town's partnership with NH Coastal Adaptation Workgroup in climate adaptation activities that facilitate, coordinate, provide technical information, and convene public outreach events for the Estuary towns.

OM3 - 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. High water marks can be displayed on public buildings or on permanently installed markers.

OM4 - Coastal Flood Hazard Overlay Maps. Use the Coastal Flood Hazard Overlay Maps 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.

OM5 - 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.

VII. Glossary of Climate Adaptation Terms

Following is a glossary of terms used in this report that describe the various scientific elements and actions associated with assessing and describing climate change, and ways communities can respond to changing conditions by identifying their vulnerability and implementing adaptation and planning.

100-year Coastal Floodplain
Includes flood hazard areas subject to tidal flooding and storm surge and identified on the FIRMs as a Special Flood Hazard Area (SFHA). SFHA are defined as the area that will be inundated by the flood event having a 1-percent chance of being equaled or exceeded in any given year. The 1-percent annual chance flood is also referred to as the base flood or 100-year flood. In coastal areas, these SFHAs are defined as specific zones on the FIRM's: In Portsmouth there are two areas or flood zones within the SFHA:

- A zone – an area subject to a 1 percent annual chance of a flood event but does not have a mapped elevation and;
- AE zone – an area that has the same 1 percent annual chance of a flood event and a corresponding mapped flood elevation of 9 feet.

Accommodate
Measures that manage risk by requiring development to be built and retrofitted to be more resilient to impacts and by limiting certain types or all development in highest risk areas, favoring adaptive uses (i.e. passive uses such as recreation) and gradual modification of structures and uses as conditions change over time.

Adaptation
Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic change and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change. [http://unfccc.int/focus/adaptation/items/6999.php]

Climate Change
Climate change refers to any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among others, that occur over several decades or longer.
[EPA http://epa.gov/climatechange/glossary.html]

Coastal Flooding
Upland areas inundated by tides, storm surge, and projected sea-level rise.

Mean Higher High Water (MHHW)
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).

Protect
Measures focused typically on hard-engineered solutions to prevent impacts for flooding, storm surge and erosion. Protection may include preservation strategies such as restoration and/or maintenance of natural dune systems and "living shorelines", and beach nourishment.

Resilience
A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment.
[EPA http://epa.gov/climatechange/glossary.html]

Retreat
Often the last action before abandonment, retreat follows an incremental path of planning for the eventual relocation of structures to upland areas as properties become threatened or directly impacted by rising sea level, erosion and coastal storms. Such measures may include rolling setbacks and buffers, transfer of development rights, and property acquisition/buyout programs.

Riverine (and Freshwater) Flooding
Areas inundated adjacent to freshwater drainage systems not affected by coastal flooding, including the 100-year flood plain and other areas subject to flooding from precipitation and snow melt.

Sea-level rise
Sea level is measured in various ways. *Relative Sea Level* refers the measurement of sea level at a local tide gauge station which is referenced relative to a specific point on land. These measurements at any given local tide gauge station include both measurements of global sea-level rise and local vertical land movement, such as subsidence, glacial rebound, or large-scale tectonic motion. Because the heights of both the land and the water are changing, the land-water interface can vary spatially and temporally and must be defined over time. The term *Mean Sea Level* (MSL) refers to a tidal datum (which a frame of vertical reference) defined by the average tide over a specific period of time. *Global Sea-level rise* (or eustatic sea-level rise) refers to the increase currently observed in the average *Global Sea Level Trend*, which is primarily attributed to changes in ocean volume due to two factors: ice melt and thermal expansion.
[NOAA http://www.tidesandcurrents.noaa.gov/est/faq]

Storm Surge
Storm surge is the rise of water level accompanying intense 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.
[EPA http://epa.gov/climatechange/glossary.html]

Sustainability
Sustainability is based on the principle that everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment. Sustainability creates and maintains the conditions under which humans and nature can exist to permit fulfilling the social, economic and other requirements of present and future generations. [EPA http://www.epa.gov/sustainability/basicinfo.htm].

Vulnerability Assessment
An evaluation of the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. [www.ipcc.ch/pub/syrgloss.pdf]

APPENDIX A – REGIONAL MAP SET

The regional map set is provided in a separate PDF file titled "Appendix A-Regional Map set." The following maps are included:

List of Maps

APPENDIX B – OUTREACH MATERIALS

The following Tides to Storms outreach materials are provided in a separate document titled "Appendix B-Outreach Materials". The following materials are included:

- **Tides to Storms Project Flyer**
- **Tides to Storms Vulnerability Assessment Flyer**
- **Powerpoint Presentations:**
  - Tides to Storms Kick-Off meeting on November 6, 2013
  - Rockingham Planning Commission-MPO-Commission meeting on July 29, 2015
  - Coastal Risks and Hazards Commission meeting on July 17, 2015