C-RiSe

CLIMATE RISK IN THE SEACOAST

Assessing Vulnerability of Municipal Assets and Resources to Climate Change

Rollinsford • Dover • Madbury • Durham • Newmarket • Newfields • Exeter • Stratham • Greenland • Newington

GREAT BAY REGION, NEW HAMPSHIRE

Vulnerability Assessment

of projected impacts from sea-level rise and coastal storm surge flooding

Prepared by the

Rockingham Planning Commission and Strafford Regional Planning Commission

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- New Hampshire Coastal Adaptation Workgroup
- University of New Hampshire Stormwater Center
- New Hampshire Department of Environmental Services, Coastal Program
- University of New Hampshire Complex Systems Research Center – NH GRANIT

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Notes on 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 resulting from projected changes in sea-levels and coastal storm surge. This report should be used for preliminary and general planning purposes only, not for parcel level or site specific analyses. The vulnerability assessment performed was limited by several factors including the vertical accuracy of elevation data (derived from LiDAR) and the static analysis applied to map coastal areas subject to future flooding which does not consider wave action and other coastal dynamics. Also, the estimated flood impacts to buildings and infrastructure are based upon the elevations of the land surrounding them, not the elevation of any structure itself.

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Project Partners

REPORT ACRONYMS

AOP	Aquatic Organism Passage
CAPE	Climate Adaptation Planning for Exeter
CAW	NH Coastal Adaptation Workgroup
CRHC	Coastal Risk and Hazards Commission
C-RiSe	Climate Risk in the Seacoast
FEMA	Federal Emergency Management Agency
FIRMs	FEMA Flood Insurance Rate Maps
HY-8	Federal Highway Administration's free culvert analysis software
LiDAR	Li(ght) + (ra)DAR – a mapping tool that uses infrared laser light
MHHW	Mean Higher High Water
NTDE	National Tidal Datum Epoch
SLAMM	Sea Level Affecting Marshes Model
SLR	Sea-Level Rise
STAP	Science and Technical Advisory Panel report, Coastal Risk and Hazards Commission (2015)

INTRODUCTION: PLANNING TO REDUCE RISK AND VULNERABILITY

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

New Hampshire's Great Bay municipalities are confronted by land use and hazard management concerns, including extreme weather events, storm surges, flooding and erosion. These issues are expected to intensify with increases in the frequency and intensity of extreme storm events and rising sea levels.

What is a Vulnerability Assessment?

A vulnerability assessment identifies and measures impacts of flooding from sea level rise and storm surge on built structures, human populations and natural environments. Factors that influence vulnerability include development patterns, natural features and topography. The assessment evaluates existing and future conditions such as: inland extent and depth of flooding; impacts to natural and human systems; and changes in impacts between different flood levels.

Climate Risk in the Seacoast (C-RiSe) Vulnerability Assessment

The *Climate Risk in the Seacoast* (C-RiSe) vulnerability assessment project produced maps and statistical data about the potential sea-level rise and storm surge impacts to infrastructure, critical facilities, transportation systems, and natural resources for the ten tidally-influenced municipalities surrounding New Hampshire's Great Bay Estuary. Specifically, the C-RiSe project incorporated the following assessment components:

- *Sea-Level Rise and Storm Surge Inundation Mapping* – Flood extents for six sea-level rise and sea-level rise plus storm surge scenarios were mapped for each municipality.
- *Municipal Vulnerability Assessments* – Vulnerability assessments quantified and mapped impacts to transportation systems, critical facilities and infrastructure, and natural resources was conducted for each municipality to provide a broad overview of the potential risk and vulnerability of municipal assets and resources resulting from projected increases in sea level and coastal storm surge flooding.
- *Culvert Assessment* – Modeling was developed to assess hydraulic capacity, aquatic organism passage, and geomorphic compatibility for a selection of road/stream crossings (culverts) at various storm flows. Modeling results will enable municipalities to identify and prioritize culverts for replacement that have inadequate flow capacity and/or present barriers to passage of aquatic organisms.

- *Hazard Mitigation Planning* – The project also included "next steps of hazard mitigation planning. This included outreach and technical assistance to each municipality to inform municipal leaders about future flood risks and identify ways to incorporate vulnerability assessment results and adaptation strategies into local planning efforts. The municipal vulnerability assessment reports were designed for future inclusion in local hazard mitigation plans.

How Can Vulnerability Assessments Be Used?

Information from a vulnerability assessment can help guide common sense solutions, strategies and recommendations for local governments, businesses, and citizens to enable them to adopt programs, policies, business practices and make informed decisions. Planning for the long-term effects of sea-level rise may also help communities prepare in the short-term for periodic flooding from severe coastal storms.

Results from the C-RiSe vulnerability assessment can be incorporated existing municipal plans including the Master Plan, Hazard Mitigation Plan, Road Improvement Plan, Infrastructure Management Plan, and Capital

Zoning Ordinance	Land Conservation Plan	Capital Improvement Plan
Site Plan Regulations	Master Plan	Roadway Management
Subdivision Regulations	Hazard Mitigation Plan	Facilities Management Plan

How Do Vulnerability Assessments Benefit Communities?

The C-RiSe vulnerability assessment is intended to assist New Hampshire's Great Bay municipalities in taking actions to prepare for increase flood risk, including:

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

MAPPING AND ASSESSMENT METHODS

Vulnerability Assessment: Sea Level Rise and Storm Surge Scenarios

The *Climate Risk in the Seacoast* (C-RiSe) vulnerability assessment project produced maps and statistical data about the potential sea-level rise and storm surge impacts to infrastructure, critical facilities, transportation systems, and natural resources for the ten tidally influenced municipalities surrounding New Hampshire's Great Bay Estuary. As shown in Figure 1, the C-RiSe assessment evaluated flood impacts from three sea-level rise scenarios for the year 2100 – 1.7 feet (intermediate low), 4.0 feet (intermediate high), and 6.3 feet (highest) – and three sea-level rise plus storm surge scenarios combining the static sea-level rise scenarios with the current 100-year storm surge.

FIGURE 1: Sea-Level Rise and Storm Surge Scenarios at 2100.

Sea-Level Rise (SLR) Scenarios	Intermediate Low SLR	Intermediate High SLR	Highest SLR	Intermediate Low SLR + storm surge	Intermediate High SLR + storm surge	Highest SLR + storm surge
SLR	1.7 feet	4.0 feet	6.3 feet	--	--	--
SLR + Storm Surge	--	--	--	1.7 feet + storm surge	4.0 feet + storm surge	6.3 feet + storm surge

Note: Storm surge is the area flooded by the current 100-year/1% change storm event as depicted on the Preliminary Flood Insurance Rate Maps released by FEMA in 2014.

Baseline of Mean Higher High Water

Flooding from the sea-level rise scenarios and sea-level rise plus storm surge scenarios evaluated in this study were mapped from an established baseline of Mean Higher High Water (MHHW) which is 4.4 feet in the coastal region of NH. MHHW is the average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch.[1]

Sea-Level Rise Scenarios

The three sea-level rise scenarios used in the C-RiSe assessment are based on an earlier study completed by Wake et al in 2011[3], and are similar to the more recent findings issued by the NH Coastal Risk and Hazards Commission's (CRHC) Science and Technical Advisory Panel (STAP) in 2014[4]. As shown in Figures 2 and 3 below, while slightly different than the scenarios cited in the 2014 STAP report, the sea-level rise scenarios used in this assessment yield coverage estimates of flooding that are within the mapping margin of error for

[1] The 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. See NOAA. (2013). Tidal Datums. https://goo.gl/2h7btu

[3] Wake et al. (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. https://goo.gl/PxbLLw.

[4] NH CRHC STAP. (2014). Sea-level Rise, Storm Surges, and Extreme Precipitation in Coastal NH. https://goo.gl/gvJgBD.

the scenarios in both the 2011 and 2014 reports.[5] They are essentially the same sea-level rise scenarios shown in the 2014 National Climate Assessment produced by a consortium of federal agencies and researchers that have expertise in oceans and climatology including NOAA, U.S. Army Corps of Engineers, EPA and many academic institutions.

Figure 2: 2011 Sea-Level Rise Scenarios (based on greenhouse gas emissions) at 2050 and 2100.

	2050		2100	
	Lower	Higher	Lower	Higher
Current Elevation of MHHW[a,b]	4.4	4.4	4.4	4.4
100-Year Flood Height	6.8	6.8	6.8	6.8
Subsidence	0.0	0.0	0.0	0.0
Eustatic SLR	1.0	1.7	2.5	6.3
Total Stillwater Elevation[a,c]	**12.2**	**12.9**	**13.7**	**17.5**

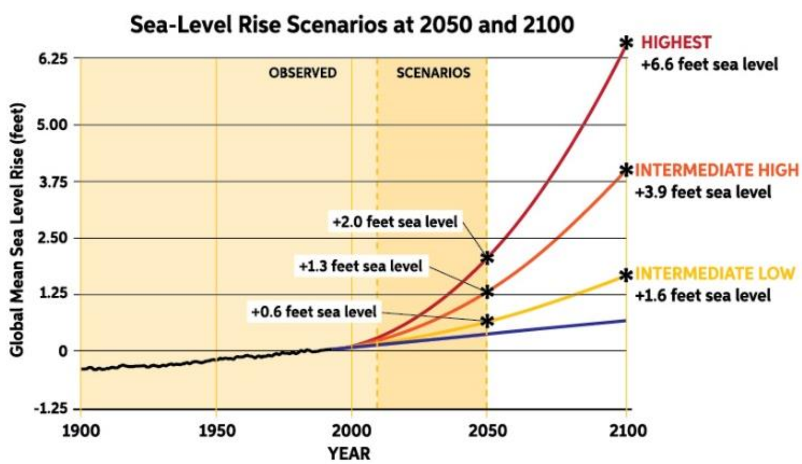
a - NAVD: North American Vertical Datum of 1988
b - MHHW: Mean Higher High Water at Fort Point, NH
c - Total Stillwater Elevation may not equal total of components due to rounding

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. https://goo.gl/PxbLLw.

Figure 3: 2014 Sea-Level Rise Scenarios (based on greenhouse gas emissions) at 2050 and 2100.

Storm

Past



Source: NH Coastal Risk and Hazards Commission Science and Technical Advisory Panel (2014). *Sea-level Rise, Surges, and Extreme Precipitation in Coastal New Hampshire: Analysis of and Projected Future Trends*. https://goo.gl/gvJgBD.

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.[7] Storm surge is caused by several factors including wind-driven waves, and increase water height from low atmospheric pressure associated

[5] For more information about how these sea-level rise scenarios were mapped, visit: https://goo.gl/btGDRV.
[7] NOAA. (2016). What is storm surge? https://goo.gl/OgQsQ2.

with intense storms. 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 account for additional flooding and impacts related to more severe wave action, wind action, erosion and other dynamic coastal processes.

Vulnerability Assessment: Assets and Resources Evaluated

A GIS analysis was conducted to determine the intersection of flood inundation areas with key assets and resources (transportation, critical facilities, infrastructure and natural resources) and quantitatively evaluate flooding impacts. Flood elevations were mapped using high-resolution topography (2-foot contour elevations acquired with LiDAR) which greatly increased the accuracy of mapping the extent of each incremental increase in flood depth. Figure 4 presents the complete list of the assets and resources evaluated as part of the C-RiSe 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.

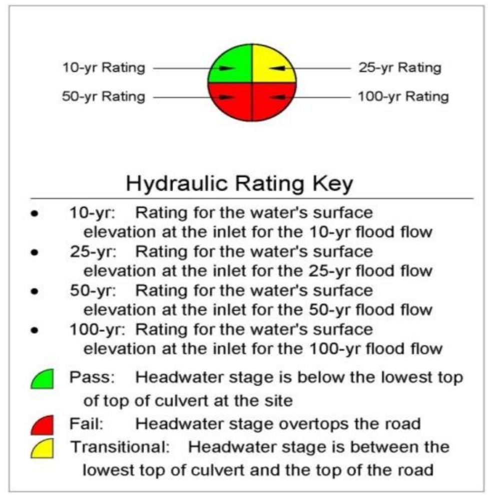
FIGURE 4: Assets and Resources Evaluated for the Vulnerability Assessment.

Category	Assets and Resources
State and Municipal Infrastructure	Municipal Culverts Federal and State Historic Register Properties Other Assets: graveyards, water access, transmission lines
Municipal Critical Facilities	Municipal Critical Facilities (e.g. Police and Fire Stations, schools, emergency shelters)
Transportation Assets & Roadways	State and Local Roadways Bridges Regional and Municipal Evacuation Routes Urban Compact Areas NHDOT Transportation Infrastructure NHDOT Ten-year and Long Range Plan Projects
Natural Resources	Freshwater and Tidal Wetlands Aquifers and Wellhead Protection Areas Wildlife Action Plan – Tier 1 and Tier 2 habitats 100-year Floodplains
Land Use	Residential Structures Assessed Value of Affected Parcels

Culvert Assessment: Hydraulic, Aquatic Organism Passage, and Geomorphic Ratings

Another significant source of flooding in the Great Bay region comes from failing or undersized culverts which can lead to localized damming or severe erosion. Many older culverts were not designed to manage the increased rainfall associated with large storm events (50-years and greater). The culvert assessment was undertaken to determine culvert capacity and ability to process stormwater. To evaluate culvert function, hydrologic and hydraulic modeling of road/stream crossings (culverts) was completed by the University of New Hampshire Stormwater Center. The C-Rise project assessed hydraulic capacity, aquatic organism passage (AOP), and geomorphic compatibility (GC) at various peak flows for a subset of culverts selected by each of the ten Great Bay coastal municipalities. The assessment was based on runoff associated with the current 10-, 25-, 50- and 100-year storm events. For each storm, each crossing was assigned a hydraulic rating, an *AOP* rating, and a GC rating; the three ratings are described in greater detail below.

FIGURE 5: Hydraulic Ratings.



Hydraulic Rating

Peak flows for the 10-, 25-, 50-, and 100-year storm events were used to determine headwater depths (water surface elevation at the inlet) for each crossing. Headwater depths were calculated using field-collected culvert and crossing data. The flood flows were calculated by one of two methods: runoff from rainfall or regression equation. For all watershed areas smaller than one square mile, the Curve Number[9] method was used; and for watersheds larger than one square mile, flows were calculated using the Regression Equations[10] published by the USGS for New Hampshire. Once the flood flows at each crossing were calculated, they were input into the Federal Highway Administration's free culvert analysis software, HY-8, along with the necessary culvert and crossing data collected at each location. Headwater depths were then calculated for each of the flood flows and compared to the lowest top of the culvert and roadway elevation in order to assign hydraulic ratings for each crossing.

The hydraulic ratings describe the headwater depth for each flood flow relative to the culvert and road elevation. The ratings for hydraulics are: Pass (green), Transitional (yellow), and Fail (red). A description of each hydraulic rating is provided in Figure 5. Figure 6 illustrates how the hydraulic rating is applied to a culvert evaluation.

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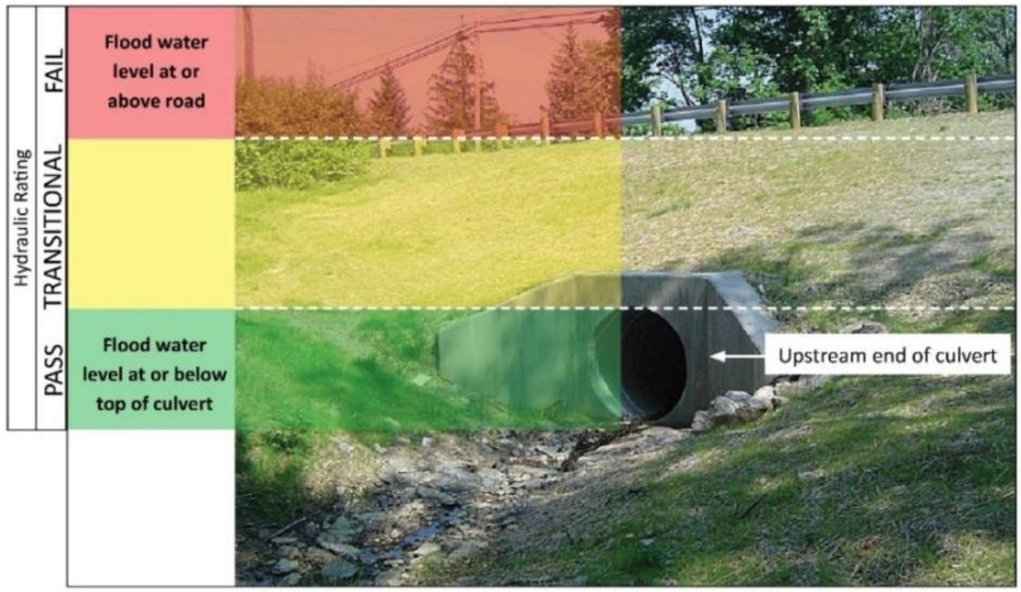
[9] A curve number is a number from zero to 100 that describes how much rainfall runs off versus how much is lost to infiltration. A high curve number implies most of the rainfall runs off.

[10] A regression equation describes a mathematical relationship between two variables in which one variable is used to predict the other.

FIGURE 6: Example of how the hydraulic rating is applied to a culvert evaluation.



Aquatic Organism Passage (AOP) Rating

The AOP ratings were developed using the New Hampshire protocol for assessment which is based directly on the Vermont Culvert Aquatic Organism Passage Screening Tool. This tool uses physical data collected at each crossing and may be used to rate each culvert at a crossing for AOP. At a crossing with multiple culverts, if one culvert is more passable than another, the more passable culvert would to be the path that organisms would utilize. Thus, the best rating for a culvert at a crossing is used as the rating for the crossing as a whole.

The AOP ratings are: Full AOP (Green), Reduced AOP (Gray), No AOP – Adult Salmonids (Orange), and No AOP (Red). A description of each AOP rating is provided in Figure 7.

FIGURE 7: Aquatic Organism Passage Ratings.

Full AOP	Crossing likely is fully passable by all aquatic organisms
Reduced AOP	Crossing likely has reduced passage capability by all aquatic organisms
No AOP - Adult Salmonids	Crossing likely is not passable by all aquatic organisms except for adult salmonids
No AOP	Crossing is likely impassable by all aquatic organisms including adult salmonids

Geomorphic Compatibility (GC) Rating

Similar to AOP, New Hampshire has a screening tool for rating crossings for their geomorphic compatibility (GC) refers to the ability of a crossing to pass sediments and debris. This rating is also adopted directly from the Vermont protocol. This method uses physical characteristics, as well as observational details, of the culvert and of the watercourse. Five categories are scored with a score of 1-5, and the sum of the five scores yields a total score, which is then used to determine the rating. GC ratings are: Fully Compatible (colored neon green), Mostly Compatible (colored pea green), Partially Compatible (colored yellow), Mostly Incompatible (colored orange), and Fully Incompatible (colored red). A description of each GC rating is provided in Figure 8.

FIGURE 8. Geomorphic Compatibility Ratings.

Fully Compatible	20 < Score ≤ 25	Structure fully compatible with natural channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. A similar structure is recommended when replacement is needed.
Mostly Compatible	15 < Score ≤ 20	Structure mostly compatible with current channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. Minor design adjustments recommended when replacement is needed to make fully compatible
Partially Compatible	10 < Score ≤ 15	Structure compatible with either current form or process, but not both. Compatibility likely short-term. There is a moderate risk of structure failure and replacement may be needed. Re-design suggested to improve geomorphic compatibility.
Mostly Incompatible	5 < Score ≤ 10	Structure mostly incompatible with current form and process with a moderate to high risk of structure failure. Re-design and replacement planning should be initiated to improve geomorphic compatibility.
Fully Incompatible	0 ≤ Score ≤ 5	Structure fully incompatible with channel and high risk of failure. Re-design and replacement should be performed as soon as possible to improve geomorphic compatibility

Map Design and Organization

The C-RiSE 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 categories evaluated are displayed on these two maps. Examples of the two scenario maps are shown in Figures 9 and 10 on the following pages.[15]

[15] The complete C-RiSe map set is available on the NHDES Coastal Program Website at: https://goo.gl/17prD6.

Figure 9: Sea Level Rise Scenarios 1.7 feet, 4.0 feet, and 6.3 feet at 2100.

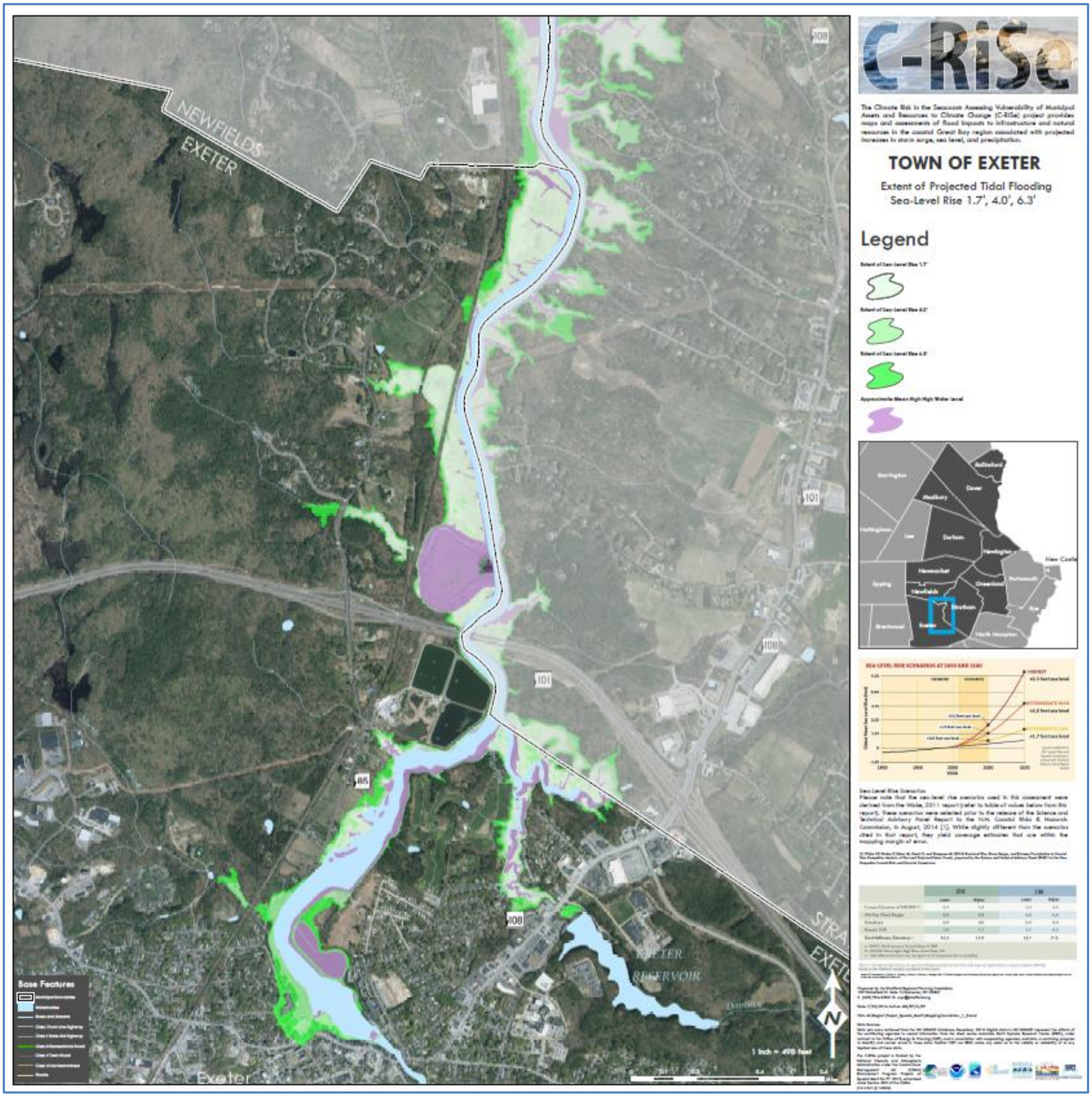
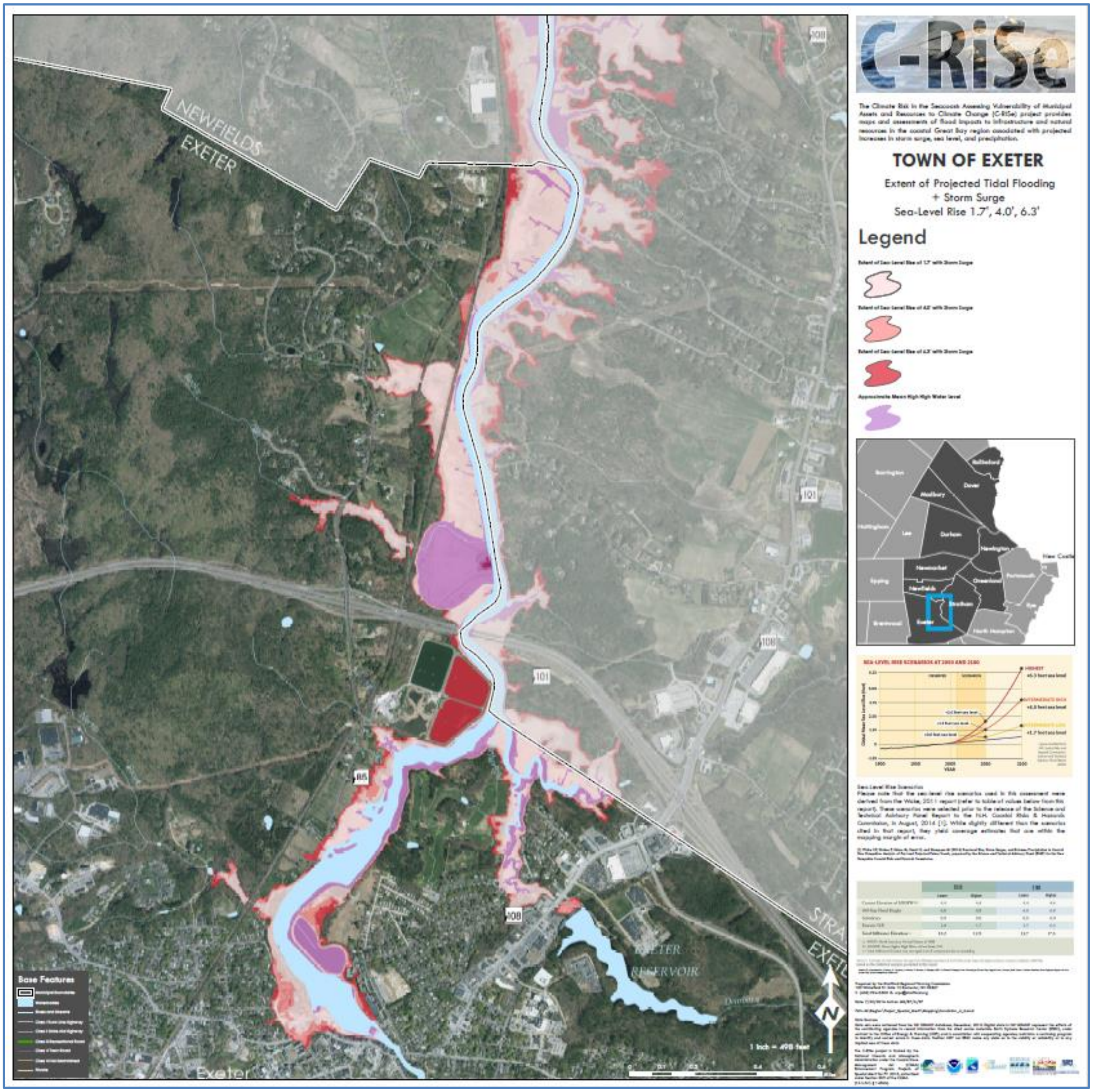


Figure 10: Sea Level Rise Scenarios 1.7 feet, 4.0 feet, and 6.3 feet sea-level rise + storm surge at 2100.
Note: Storm surge = 100-year/1% chance storm event and flood elevation.



OVERVIEW OF IMPACTS IN THE GREAT BAY COASTAL REGION

New Hampshire's Great Bay region is comprised of ten municipalities located in Strafford Regional Planning Commission and Rockingham Regional Planning Commission regions:

- *Strafford Regional Planning Commission Region:*
  - Dover, Durham, Madbury, Newmarket, and Rollinsford.
- *Rockingham Planning Commission Region:*
  - Exeter, Greenland, Newfields, Newington, and Stratham.

This section presents a brief summary of significant potential sea-level rise and storm related flooding impacts assessed in the ten Great Bay municipalities.[16]

Strafford Regional Planning Commission Region

Dover: The locations most susceptible to coastal flooding in low areas along the Bellamy River; the Piscataqua River; at the confluence of the Cochecho River and the Salmon Falls River, and along the shores of Little Bay within the coastal floodplain area. Infrastructure, aquifers, uplands, floodplains, conserved lands, freshwater wetlands, and lands identified as important habitat (Wildlife Action Plan) are the most vulnerable to flooding from sea-level rise and coastal storm surge. No impacts to residential homes reported under the first sea-level rise scenario; however, significant impacts in the intermediate high (4.0ft) and highest (6.3ft) scenarios can be expected. Nearly 3% of Dover's uplands are impacted by the highest (6.3 feet) sea-level rise plus storm surge scenario, including 476 parcels valued at roughly $235 million, and 185 homes valued at roughly $170 million.

Durham: The locations most susceptible to coastal flooding are the low areas along the Oyster River and its tributaries, at the confluence of the Oyster River and Little Bay, and along the shores of both Little and Great Bay within the coastal floodplain area. Compared to other municipalities in the region, most of Durham's key infrastructure, community assets, and natural resources are protected. Nearly 2% of Durham's uplands are impacted by the highest (6.3 feet) sea-level rise plus storm surge scenario, including 298 parcels valued at roughly $153 million, and 14 homes valued at roughly $5.6 million.

Madbury: The locations most susceptible to coastal flooding are along the Bellamy River, at the confluence of the Oyster River and Little Bay, and Johnson Creek within the coastal floodplain area. Most key infrastructure, community assets, and natural resources are protected from flooding with the exception of very minor road impacts. Freshwater wetlands, floodplains, and natural land resources identified as important habitat (Wildlife Action Plan) are the most vulnerable to flooding from sea-level rise and coastal storm surge. Less than one percent (1%) of Madbury's uplands are impacted by the highest (6.3 feet) sea-

[16] Individualized reports for each municipality are available on the NHDES Coastal Program Website at: https://goo.gl/17prD6.

level rise plus storm surge scenario, including 19 parcels valued at roughly $2.1 million. No homes are impacted by flooding.

Newmarket: The locations most susceptible to coastal flooding are south of the Mcallen Dam on the west side of the Lamprey River near the downtown; low-lying areas around Lubberland Creek, and low-lying land south of the Lamprey River along Great Bay. Significant acreage of tidal wetlands, wellhead protection areas (local drinking water supplies), conservation and public lands, and Wildlife Action Plan priority habitat are vulnerable to flooding from sea-level rise and coastal storm surge. Nearly 3.5% of Newmarket's uplands are impacted by the highest (6.3 feet) sea-level rise plus storm surge scenario, including 150 parcels valued at roughly $43.9 million, and 6 homes valued at roughly $1.76 million.

Rollinsford: Minor impacts are expected in the southeastern portion of town along Chenard Brook, Sligo Brook, Stackpole Brook, and the Salmon Falls River. Local groundwater resources (aquifers), areas surrounding local drinking water supplies (wellhead protection areas), uplands, floodplains, and lands identified as important habitat (Wildlife Action Plan) are the most vulnerable to flooding from sea-level rise and coastal storm surge. No major critical facilities impacted, but potential impacts to Sligo Road should be considered. Less than 1% of Rollinsford's uplands are impacted by the highest (6.3 feet) sea-level rise plus storm surge scenario, including 27 parcels valued at roughly $6 million, and 1 home valued at $357,177.

Rockingham Planning Commission Region

Exeter: The locations most susceptible to flooding are in the 100-year floodplain and along the upper tidal reaches of the Squamscott River. Areas of highest risk for sea-level rise and storm surge flooding include: Swazey Parkway extending west to properties on Water Street and north on Route 85; Exeter Waterfront Commercial Historic District (waterfront side of buildings on Water Street); Wheelwright Creek drainage up to Portsmouth Avenue and the Exeter Reservoir; Norris Brook, Sloans Brook, and Rocky Hill Brook. Roughly 1% of Exeter's uplands are impacted by the highest (6.3 feet) sea-level rise plus storm surge scenario, including 121 parcels valued at roughly $83.5 million and 21 residential structures valued at $32.5 million.

Greenland: The areas of highest risk for sea-level risk and storm surge flooding are adjacent to the Great Bay and tidal portion of the Winnicut River and include: properties and roadways associated with Bayshore Road, Melon Road, Fairview Terrace, Great Bay Drive West, Bayside Drive, Caswell Drive, Bruce Court; NH Route 33 between Golf and Ski Warehouse and Rizzo Warehouse/British Aisles, and Portsmouth Country Club; shoreland buffers, salt marsh, and freshwater wetlands along the Great Bay, Winnicut River, Pickering Brook, Packer Brook, Haines Brook, Shaw Brook and Foss Brook. As much as 5.9% of Greenland's uplands are impacted by the highest (6.3 feet) sea-level rise plus storm surge scenario, including 202 parcels valued at roughly $94.2 million and 26 residential structures valued at roughly $15.6 million.

Newfields: The areas of highest risk for sea-level rise and storm surge flooding occur along the Great Bay and Squamscott River include: campsites associated with Great Bay camping; Town Landing; land and docks along River Road; land abutting the Wastewater Treatment Plant, but not the Plant itself; Pan Am railroad leading to the railroad bridge crossing the Squamscott River. Nearly 3.5% of Newfields' uplands are impacted by the highest (6.3 feet) sea-level rise plus storm surge scenario, including 45 parcels valued at roughly $9.7 million and 2 residential structures valued at $513,700.

Newington: The high risk flood areas include lands currently used for commercial, industrial, residential and recreational development, and small sections of local roads and state Route 16 at the Little Bay Bridges. Specific areas most susceptible to sea-level rise and storm related flooding include: River Road/Piscataqua River waterfront commercial/industrial area; Great Bay Marine facility; Fox Point and Newington Town Park conservation lands; Shattuck Way, a designated evacuation route; and residential neighborhoods at Fabyan Point. Roughly 4.7% of Newington's uplands are impacted by the highest (6.3 feet) sea-level rise plus storm surge scenario, including 128 parcels valued at roughly $136.8 million and 8 residential structures valued at $8.4 million.

Stratham: The areas most susceptible to coastal flooding in lowlands adjacent to and within the floodplain of the Squamscott River and its tidal and freshwater tributaries. These low-lying areas, with a mix of residential and commercial development and the infrastructure that services them, are particularly vulnerable to flooding from seasonal high tides, sea-level rise and coastal storms. Other flood impacts include: Chapmans Landing water recreation access and parking lot; hay and crop fields at Stuart Farm and Scamman Farm bordering the Squamscott River; and well-head protection areas for residential developments west of Route 33. Roughly 4.7% of Stratham's uplands are impacted by the highest (6.3 feet) sea-level rise plus storm surge scenario, including 128 parcels valued at roughly $40.6 million and 6 residential structures valued at roughly $2.5 million.

KEY FINDINGS OF THE VULNERABILITY ASSESSMENT

Regional Assets and Resources

Figure 11 reports the combined impacts to assets and resources impacted sea-level rise and coastal storm surge scenario flooding in the ten municipalities. Municipalities with the largest percentage of the total regional impacts by asset type are summarized below:

- Acres of Aquifer: Dover (85%).
- Acres of Wellhead Protection Areas: Stratham (72%).
- Number of Homes: Dover (94% under 6.3 feet SLR; 64% under 6.3 feet SLR + storm surge).
- Acres of Tidal Wetlands: Exeter (27%), Stratham (22%), Greenland (15%), Newington (14%).
- Acres of Freshwater Wetlands: Durham (20%), Newington (17%), Dover (18%).
- Assessed Property Value: Dover (70% under 6.3 feet SLR; 51% under 6.3 feet SLR+ storm surge) and Exeter (13% under 6.3 feet SLR; 24% under 6.3 feet SLR + storm surge).

Overall, the Great Bay region has limited vulnerability as most major infrastructure (e.g. water and wastewater treatment plants) is located outside the 100-year floodplain. Impacts to local and state roads are also minimal; however, site specific impacts can be significant particularly if a designated evacuation route or state highway is impacted.

FIGURE 11: Summary of assets and resources impacted by sea-level rise and storm surge at 2100.

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
Upland (acres above MHHW)	289.6	775.8	1,484.7	1,100.3	1,747.4	2,429.5
State, Municipal and Private Assets						
Infrastructure (# sites)*	4	23	115	69	167	304
Critical Facilities (# sites)**	0	0	1	0	1	4
Water/Sewer/Transmission lines (miles)	0.4	1.6	4.9	3.0	6.6	10.3
Roadway-Local (miles)	0.0	0.8	2.6	1.5	3.6	5.3
Roadway-Private (miles)	0.0	0.4	1.8	1.1	2.3	3.4
Roadway-State (miles)	0.2	0.4	1.2	0.7	1.8	3.5
Roadway-Total (miles)	0.2	1.7	5.7	3.4	7.8	12.4
Transportation Assets (# sites)	46	46	49	47	52	57
Assessed Value - Parcels Impacted	$559,200	$6,806,739	$41,175,460	$24,798,028	$85,337,887	$137,832,858
Residential Structures (# of homes)	1	18	102	61	150	269
100-year Floodplain (acres)	739	1,234	1,355	1,316	1,396	1,461
Natural Resource Assets						
Freshwater Wetlands (acres)	59	182	259	222	306	413
Tidal Wetlands (acres)	754	834	851	845	855	860
Aquifers (acres)	47	142	340	244	430	595
Wellhead Protection Areas (acres)	313	511	785	623	878	1,153
Conserved and Public Lands (acres)	304	610	928	758	1,026	1,277
Focus Areas- Land Conservation Plan for NH's Coastal Watershed	625	1,040	1,474	1,244	1,610	1,978
Wildlife Action Plan (acres)	721	1,204	1,723	1,447	1,895	2,357

Notes: Storm surge is the area flooded by the 100-year/1% chance storm event. MHHW = Mean Higher High Water

* Infrastructure Assets include: the ten priority culverts assessed for each municipality (not all culverts); Federal and state historic registry properties or districts; and "Other" which includes transmission lines, water access (marinas/boat launches), graveyards, etc.

** Critical Facilities (data compiled from municipal hazard mitigation plans) include: schools, hospitals, fire stations, police stations, wastewater facilities, sewer pipes, water pipes, sewer lift stations, pump stations, power stations, recreational facilities, dams, daycare centers, and elderly housing.

Most Great Bay municipalities have conserved lands surrounding their tidal waterways and waterbodies. These riparian lands and shorelands will serve as buffers to rising seas and floodwaters, and provide transitional habitats for land and water based flora and fauna as ecosystems conditions change over time. This also includes many high value habitats and lands identified in the NH Wildlife Action Plan and Land Conservation Plan for NH's Coastal Watersheds.

The shores of the Great Bay and its tidal tributaries are fringed with saltmarsh and freshwater wetland systems. As sea levels rise, freshwater systems will transition to brackish and saltwater systems with daily tidal inundation. Saltmarsh may migrate inland with rising seas, depending on the ability of saltmarsh to keep pace with the rate of sea-level rise, the topography (gentle slopes versus steep banks), and the absence of physical barriers such as development, roads and railroad lines, hardened shoreline, and retaining walls.

Many Great Bay municipalities, primarily those not served by public water and sewer services, are concerned by rising groundwater levels resulting from rising sea levels. Rising groundwater could impact private septic systems and saltwater intrusion could contaminate private drinking water wells.

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

DETAILED VULNERABILITY ASSESSMENT RESULTS BY ASSET TYPE

Municipal Critical Facilities and Infrastructure

Maps: Critical Facilities and Infrastructure state and municipal critical facilities and infrastructure affected by sea-level rise and coastal storm surge flooding in the ten Great Bay municipalities. Figure 12 reports the total number of sites and miles of water/sewer/transmission lines affected by each flood scenario.

FIGURE 12: State and municipal critical facilities impacted by sea-level rise and storm surge at 2100.

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)*	4	23	115	69	167	304
Critical Facilities**	0	0	1	0	1	4
Water/Sewer/Transmission lines (miles)	0.4	1.6	4.9	3.0	6.6	10.3

Notes: Storm surge is the area flooded by the 100-year/1% chance storm event.
*Infrastructure Assets include: the ten culverts in each municipality assessed for this project (not all culverts in the six flood scenarios); Federal and state historic registry properties or districts; and "Other" which included transmission lines, water access (marinas/boat launches), graveyards, etc.

**Critical Facilities (data compiled from municipal hazard mitigation plans) include: schools, hospitals, fire stations, police stations, wastewater facilities, sewer pipes, water pipes, sewer lift stations, pump stations, power stations, recreational facilities, dams, daycare centers, and elderly housing.

Transportation Assets

Maps: Transportation Assets shows the state and municipal roadways and other transportation assets affected by sea-level rise and coastal storm surge flooding in the ten Great Bay municipalities. Figure 13 reports the total number of miles of state and local roadways and number of/acreage of other transportation assets affected by each flood scenario. The municipal roadway network is the asset least impacted by sea-level rise and coastal storm flooding, with minimal impacts reported under all six scenarios. However, specific sections of state roadways are impacted by flooding some of which are important regional evacuation routes. These include Route 4, Route 16, Route 85, Route 101, and Route 33.

FIGURE 13: State and local roadway miles impacted by sea-level rise and storm surge at 2100.

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						
State	0.2	0.4	1.2	0.7	1.8	3.5
Local	0.0	0.8	2.6	1.5	3.6	5.3
Private	0.0	0.4	1.8	1.1	2.3	3.4
Not Maintained	0.0	0.1	0.1	0.1	0.1	0.2
Road Miles by Municipality						
Dover	0.0	0.3	1.8	0.9	3.1	5.5
Durham	0.0	0.3	0.7	0.4	0.9	1.6
Newmarket	0.0	0.6	1.1	0.8	1.2	1.4
Madbury	0.0	0.0	0.2	0.0	0.5	0.7
Rollinsford	0.0	0.0	0.0	0.0	0.0	0.0
Exeter	0.0	0.0	0.0	0.0	0.0	0.0
Greenland	0.0	0.1	0.7	0.5	1.0	1.3
Newfields	0.0	0.1	0.4	0.2	0.4	0.7
Newington	0.0	0.1	0.2	0.1	0.2	0.3
Stratham	0.2	0.3	0.6	0.5	0.6	0.9
Total	0.2	1.7	5.7	3.4	7.8	12.4

These state roadways are primary east-west and north-south corridors during storm events requiring evacuations. This assessment did not evaluate impacts of freshwater flooding on inland local and state roads during heavy precipitation events. It is widely reported (and experience of the local population) that many local and state roads experience flooding in moderate storm conditions. Relying on local roads as alternative routes to the state roadways is risky. A more detailed flood assessment of the entire local and state road network is a necessary first step toward developing a comprehensive evacuation route plan for the Great Bay region.

The C-RiSe assessment also evaluated the hydrologic and hydraulic function of a subset of priority freshwater culverts in each of the ten municipalities. Although not evaluated, tidal culverts are supporting infrastructure for the roadway network that are highly susceptible to flooding impacts. As sea levels rise in the future, some tidal culverts may become submerged by flooding even at low tide, and freshwater culverts will be influenced by tidal flooding, creating hydrologic conditions these drainage systems were not designed for. Detailed culvert assessment results are reported below.

Culvert Assessment

Climate Ready Culverts Assessment maps were prepared for the ten Great Bay municipalities. These maps show the hydraulic and aquatic organism passage ratings of the 105 culverts assessed under existing precipitation conditions for the 10-year, 25-year, 50-year and 100-year storm event. Figure 14 reports the total number of culverts receiving Passing, Transitional, and Failing hydraulic ratings for each return period/storm event. In a 10-year storm event, roughly 30 percent of culverts fall into each of the three categories of fail, pass or transitional. In a 25-year storm event, 46 percent of culverts fail, 24 percent pass and 30 percent are transitional. In a 50-year and 100-year storm event, greater than 55 percent and 65 percent of culverts fail respectively.

FIGURE 14: Summary of culvert hydraulic ratings by return period/storm event.

Rating	10-year storm	25-year storm	50-year storm	100-year storm
Failing	34	48	56	68
Passing	39	25	23	16
Transitional	32	32	26	21
Total	105	105	105	105

Note: A rating of **Pass** means that the headwater depth is below the lowest top-of-pipe elevation of any culvert at the crossing; a rating of **Fail** means that the headwater depth is above the road surface; and a rating of **Transitional** means that the headwater depth is somewhere between these two elevations.

Refer to the *Climate Ready Culverts Assessment* maps for the location and ratings for culverts in the ten Great Bay municipalities. Figure 15 reports the total number of culverts with Failing ratings for each return period/storm event. The number of failing culverts doubles from the 1-year storm event to the 100-year storm event.

Figure 16 reports the total number and percentage of assessed crossings by Aquatic Organism Passage (AOP) rating. Of the 105 assessed culverts, roughly 12% have full AOP capacity, 69% have reduced AOP capacity, and 18% have no AOP capacity.

FIGURE 15: Summary of municipal culvert hydraulic ratings by return period/storm event

Number of Failing Road Crossings by Municipality					
Town	# Crossings	10-yr	25-yr	50-yr	100-yr
Rollinsford	6	2	2	3	4
Dover	12	3	4	5	8
Madbury	9	3	4	5	6
Durham	10	8	9	9	9
Newington	10	3	4	4	5
Newmarket	12	2	4	5	6
Newfields	*10*	1	3	4	5
Greenland	11	3	5	6	7
Stratham	10	3	3	4	7
Exeter	15	6	10	11	11
Total	105	34	48	56	68

FIGURE 16: Total number and percentage of crossings by Aquatic Organism Passage rating.

Units	Full AOP	Reduced AOP	No AOP*	No AOP**
Quantity	**13**	72	1	19
Percentage	**12.4%**	68.6%	1.0%	18.1%

Note: AOP = Aquatic Organism Passage is the degree to which aquatic organisms are able to pass through a crossing. Green = Full AOP, Gray = Reduced AOP, Orange = No AOP, for all species except Adult Salmonids, Pink = No AOP, for any species including Adult Salmonids.

Figure 17 reports the number of culverts by Aquatic Organism Passage status for each municipality. Roughly 70 percent or greater of municipal culverts show reduced AOP and 19 percent have no AOP.

FIGURE 17: Total number of crossings by Aquatic Organism Passage rating in each municipality.

Town	# Crossings	Full AOP	Reduced AOP	No AOP*	No AOP**
Rollinsford	6	1	3	0	2
Dover	12	2	8	0	2
Madbury	9	0	6	1	2
Durham	10	2	6	0	2
Newington	10	1	7	0	2
Newmarket	12	2	8	0	2
Newfields	10	2	6	0	2
Greenland	11	0	9	0	2
Stratham	10	1	7	0	2
Exeter	15	2	12	0	1
Total:	105	13	72	1	19
	* No AOP for all species except Adult Salmonids				
	** No AOP for any species, including Adult Salmonids				

Historic and Recreational Resources

Figure 18 reports historic and recreational resources impacted by sea-level rise and storm surge flooding.

FIGURE 18: Historic Resources (# sites) impacted by sea-level rise and storm surge at 2100.

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
Waterfront Commercial and Historic Districts	na	na	3	na	na	4
Water Access/Recreation Sites	na	na	4	na	na	5
Outdoor/Recreation	na	na	2	na	na	3
Total - Sites	**na**	**na**	**9**	**na**	**na**	**12**

Note: "na" = not assessed

Historic Register properties, Historic District sites, and recreational resources affected by flooding include:

- Dover – Bay View Road: Back River and Samuel Emerson Farm.
- Durham – Durham Historic District along Main Street and Newmarket Road.
- Exeter - Waterfront Commercial Historic District, Front Street Historic District, Swazey Parkway, Squamscott River water access facility.
- Stratham – Chapman's Landing boat launch.

Natural Resources

Map: Water Resources and *Map: Land Resources* show natural resources affected by sea-level rise and storm coastal storm surge flooding in the ten Great Bay municipalities. Figure 19 reports the total number of acres of natural resources affected by each flood scenario.

FIGURE 19: Natural Resources (acres) impacted by sea-level rise and storm surge at 2100.

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
Freshwater Wetlands (acres)	59	182	259	222	306	413
Tidal Wetlands (acres)	754	834	851	845	855	860
Aquifers (acres) +	47	142	340	244	430	595
Wellhead Protection Areas (acres) ++	313	511	785	623	878	1,153
Conserved and Public Lands (acres)	304	610	928	758	1,026	1,277
Coastal Conservation Plan-Focus Areas	625	1,040	1,474	1,244	1,610	1,978
Wildlife Action Plan (acres)	721	1,204	1,723	1,447	1,895	2,357

Freshwater and Tidal Wetlands

The Great Bay region has three major tidal systems – the Great Bay estuary, Lamprey River, and Squamscott River. Freshwater wetlands and tidal salt marsh in each of these river systems will be impacted by long term sea-level rise. Barriers, such as roads, natural topography and development, will prevent inland migration of saltmarsh over time. Tidal wetland systems are expected to experience the greatest impacts. Over time, low marsh may convert to mud flats and high marsh may convert to low marsh as these systems are inundated by rising seas. Based on the assessment, tidal marshes along the tidal floodplains of the Great Bay, Lamprey River, and Squamscott River may become open water as sea level rises, unless saltmarshes are able to keep pace by building upward. Additional marsh migration modeling is needed to more accurately predict the condition of tidal marshes under different sea-level rise scenarios.

Wellhead Protection Areas

The C-RiSe assessment reports the occurrence of sea-level rise and storm related flooding within designated wellhead protection areas. Significant acreage within wellhead protection areas (municipal supplies and public water systems) in Exeter, Newfields, and Stratham are within high risk flood areas. Evaluating the specific impacts of such flooding was not within the scope of this assessment. It is recommended that the municipal public works departments complete further investigation of possible flood impacts to drinking water sources. Although stratified drift aquifers are reported within the high risk flood areas identified, the C-RiSe assessment did not evaluate potential impacts to private drinking water wells from salt water intrusion as sea-level rises.

Critical Habitats

Figure 16 also reports the total acres of conservation lands and NH Wildlife Action Plan high value habitat for the ten municipalities affected by each of the sea-level rise and storm surge scenarios. Exeter has preserved substantial lands in its riparian corridors and shorelands. These lands will serve to accommodate flood waters and rising seas over time which will greatly reduce impacts to public and private assets.

Over time, coastal flooding may impact sensitive habitats identified in the Land Conservation Plan for NH's Coastal Watersheds (2006) and the NH Wildlife Action Plan (updated in 2015). Such habitats include nesting and breeding sites for shorebirds, tidal and freshwater wetlands, vernal pools, forests, scrub-shrub and meadow landscapes.

Locally Significant Natural Resources

Other locally important natural resources and environmental assets impacted by flooding include:

- Dover – Bellamy River Wildlife Sanctuary, Bellamy River, Fresh Creek, Garvin Book, at the confluence of the Lower Cochecho River and the Salmon Falls River, and the Piscataqua River.
- Durham – Wagon Hill Farm, Oyster River and its tributaries, and along the shoreline of Little and Great Bay.
- Madbury – Bellamy River, Johnson and Bunker Creeks.

- Rollinsford – Salmon Falls River, Chenard Brook, Fresh Creek, Garvin Brook, and Lower Cochecho River.
- Newmarket – Crommet Creek. Lower Lubberland Creek, and Squamscott River.
- Exeter – Squamscott River and its tidal and freshwater tributaries.
- Newington – Fox Point, Great Bay Marine, Newington Town Park, Great Bay National Wildlife Refuge, Bloody Point, and the Piscataqua River.

Refer to the municipal assessment reports for detailed information about natural resources impacts.

Upland – Land and Water

Map: Sea-Level Rise and Map: Sea-Level Rise + Storm Surge show upland affected by sea-level rise and coastal storm surge flooding in the ten Great Bay municipalities. Upland refers to land above Mean Higher High Water (MHHW – highest tidal extent). Figure 20 reports the combined number of acres of upland (land above mean higher high water) affected by each flood scenario. The degree of upland flooding is a function of topography – low lying, flat areas experience greater flood impacts such as in Stratham and Greenland on the Great Bay, and in Dover, Durham and Newmarket along the Cocheco and Lamprey Rivers and Little Great Bay. The data shows the following trends:

- a 168 percent increase in acres of upland impacted from the 1.7 feet sea-level rise to the 4.0 feet sea-level rise scenario.
- a 91 percent increase in acres of upland impacted from the 4.0 feet sea-level rise to the 6.3 feet sea-level rise scenario.

FIGURE 20: Total acreage of uplands impacted by sea-level rise and storm surge at 2100.

	Sea-Level Rise (SLR) and Storm Surge Scenarios					
Municipality	1.7 feet SLR (acres)	4.0 feet SLR (acres)	6.3 feet SLR (acres)	1.7 feet SLR + storm surge (acres)	4.0 feet SLR + storm surge (acres)	6.3 feet SLR + storm surge (acres)
Dover	25.6	100.0	261.3	181.3	337.6	476.6
Durham	23.0	79.9	168.6	120.4	198.0	304.4
Newmarket	36.4	101.7	172.9	136.0	193.9	253.5
Madbury	0.7	7.4	14.3	11.0	17.2	24.9
Rollinsford	2.7	6.4	12.8	11.2	20.1	29.0
Exeter	34.6	68.4	104.8	84.2	114.3	141.0
Greenland	51.0	119.8	224.0	162.5	261.3	375.5
Newfields	18.3	40.9	88.7	61.7	103.7	147.9
Newington	19.2	68.8	139.2	99.1	168.3	243.2
Stratham	78.1	182.5	297.9	232.9	333.2	433.6
Total	289.6	775.8	1,484.7	1,100.3	1,747.4	2,429.5

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

Figure 21 provides reports the total acres (land, water, and tidal wetlands) in each municipality affected by each sea-level rise and storm surge scenario.

FIGURE 21: Total land and water acreage impacted by sea-level rise and storm surge scenarios at 2100.

Municipality	Sea-Level Rise (SLR) and Storm Surge Scenarios					
	1.7 feet SLR (acres)	4.0 feet SLR (acres)	6.3 feet SLR (acres)	1.7 feet SLR + storm surge (acres)	4.0 feet SLR + storm surge (acres)	6.3 feet SLR + storm surge (acres)
Dover	50.97	137.77	310.74	225.16	390.66	536.53
Durham	43.85	116.82	216.27	162.00	264.09	385.81
Madbury	0.85	7.94	15.45	11.80	18.52	26.84
Newmarket	79.98	150.57	225.45	186.47	247.22	308.16
Rollinsford	10.12	16.42	24.42	22.48	32.81	42.59
Exeter	88.99	128.97	168.89	146.82	178.95	221.26
Greenland	136.07	218.66	335.80	267.74	376.01	496.38
Newfields	46.97	72.62	123.59	94.99	139.49	185.95
Newington	123.20	219.57	294.69	252.87	325.56	404.31
Stratham	191.58	325.92	452.61	382.98	489.65	593.53
Total	**772.58**	**1,395.26**	**2,167.91**	**1,753.31**	**2,462.96**	**3,201.36**

Municipalities with the largest percentage of impacts to land area based on the total regional impacts from the 6.3 feet sea-level rise plus storm surge scenario are: Stratham (19%), Dover (17%), Greenland (16%), Newington (13%), and Durham (12%).

Although the total acreage impacted under the six scenarios represents a relatively low percentage of total upland in the ten municipalities, and in most cases limited in extent, areas impacted by sea-level rise and storm related flooding include high value assets described in Figure 18 below. The location of many of these assets is dictated by development patterns established during colonial settlement of New Hampshire. Urban villages were established along the major rivers providing means for production of power for manufacturing and transport of goods to Atlantic coastal ports. Since the 1970's, primarily single-family residential development has replaced agricultural and forested lands as the dominant low-density development pattern between towns and cities, and along the regional roadway network.

Parcels and Assessed Value

Figure 22 reports the number of parcels affected by each of the sea-level rise and storm surge scenarios and the aggregated assessed value of these parcels for the ten municipalities. The number of parcels impacted and their assessed value are fairly evenly distributed across all six scenarios; comparison across scenarios is inconclusive as some impacted areas may have larger parcels rather than a large number of small parcels.[17] Comparing the combined data across all scenarios, by far Dover (30%), Durham (19%), Greenland (13%) and Newmarket (9.4%) have the highest per parcel impacts.

FIGURE 22: Parcels and assessed value impacted by sea-level rise and storm surge at 2100.

Sea Level Rise (SLR) Scenarios	Number of Parcels Affected by Scenario	Aggregate Value of Affected Parcels	Percent Total Assessed Value
1.7 feet SLR	1,118	$598,707,117	6.3
4.0 feet SLR	1,247	$674,906,378	7.1
6.3 feet SLR	1,387	$721,459,190	7.6
1.7 feet SLR + storm surge	1,310	$695,867,713	7.3
4.0 feet SLR + storm surge	1,453	$749,758,991	7.9
6.3 feet SLR + storm surge	1,594	$805,309,744	8.5
The total assessed property value of the ten Great Bay municipalities = $9,523,020,623			

Note: The degree to which a parcel and any development on a parcel is affected by sea-level rise or storm 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.

Figure 23 reports the number of parcels, homes and assessed value impacted by the highest flood scenario of 6.3 feet sea-level rise plus storm surge in the ten Great Bay municipalities. Comparing the combined data across all scenarios, by a wide margin Dover (69%) experiences the highest impacts to residential structures within the Great Bay region followed by Greenland (9.7%), Exeter (7.8%), and Durham (5.2%).

FIGURE 23: Parcels, residential structures, and assessed value impacted by 6.3ft SLR + storm surge at 2100.

Municipality-SRPC Region	# Parcels	Assessed Value	# Homes	Assessed Value
Dover	476	$235.9 million	185	$70.7 million
Durham	298	$153.9 million	14	$5.6 million
Madbury	19	$2.1 million	0	$0
Newmarket	150	$43.5 million	6	$1.8 million
Rollinsford	27	$6.0 million	1	$357,177
Municipality-RPC Region	# Parcels	Assessed Value	# Homes	Assessed Value
Exeter	121	$83.5 million	21	$32.5 million
Greenland	202	$94.2 million	26	$15.6 million
Newfields	45	$9.7 million	2	$513,700
Newington	128	$136.8 million	6	$8.4 million
Stratham	6	$2.5 million	6	$2.5 million
Total	*1,023*	*$499.5 million*	*275*	*$ Million*

[17] Detailed information about the number of parcels impacted by each scenario in each municipality is provided in each municipal report available on the NHDES Coastal Program Website at: https://goo.gl/17prD6.

FEMA Flood Hazard Areas

Figure 24 reports the combined acreage within the current 100-year and 500-year floodplains affected by sea-level rise and coastal storm surge flooding in the ten municipalities. The inundation extent of the three sea-level rise scenarios generally falls within the current 100-year floodplain, extending beyond into the 500-year floodplain in lowest lying areas (such as Dover and Newmarket). From a floodplain management perspective, creating more resilient development within the current 100-year floodplain will provide protection against flood impacts from long term sea-level rise.

From the perspective of floodplain management, creating more resilient development within the current 100-year floodplain will provide protection against flood impacts from long term sea level rise.

FIGURE 24: FEMA Special Flood Hazard Areas (acres) impacted by sea-level rise and storm surge at 2100.

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 (acres)	739	1,234	1,355	1,316	1,396	1,461

Note: Floodplain assessment based on Preliminary Flood Insurance Rate Maps (FIRMs) released by FEMA in 2014.

CLIMATE ADAPTATION AND COASTAL HAZARD ACTIVITIES IN THE GREAT BAY REGION

The following projects were completed with assistance from regional technical assistance and service providers from the academic institutions, private consultants, and agency grant funders.

Dover

In 2014, Dover engaged more than 100 participants in a mock decision-making process about how to deal with increasing stormwater flooding risk in a fictional coastal community with similar characteristics. The project findings and the City's public engagement process are summarized in the New England Climate Adaptation Project report.

In 2015, Dover adopted regulations that exceed the National Flood Insurance Program minimum standards by requiring the lowest floor of residential and non-residential structures that are new construction or substantial improvements to be elevated two feet above base flood elevation.

Durham

In 2013, Durham developed a Climate Adaption Chapter "Developing Strategies to Protect Areas at Risk from Flooding due to Climate Change and Sea-Level Rise" as an appendix to their Hazard Mitigation Plan. This chapter presented climate change and sea-level rise estimates; developed strategies that protect areas at risk from flooding; and identified various regulatory and non-regulatory options for the town's consideration.

Madbury

In 2009, Madbury adopted regulations that exceed the National Flood Insurance Program minimum standards by adopting a freeboard requirement which requires the lowest floor of new residential structures and manufactured homes to be elevated one foot above the base flood elevation, and adopted regulations that prohibit new buildings and certain other development in special flood hazard areas.

Newmarket

In 2012-2013, Newmarket participated in the Lamprey River Flood Study which mapped projected changes to the 100-year and 500-year floodplain resulting from increases in future precipitation.

In 2014 with funding from the NH Coastal Program, Newmarket updated its Master Plan Vision and Future Land Use Chapters. The Future Land Use Chapter references specific recommended actions from the Coastal Risks and Hazards Commission Report and integrates goals and recommendations that would increase resilience to climate change and protect coastal infrastructure and resources.

In 2015-2016 Newmarket implemented Phase I of the Lubberland Creek Culvert Restoration. The culvert replacement will 1) restored aquatic connectivity, 2) enhanced the resilience of the Lubberland Creek salt marsh and allow upstream salt marsh migration as sea levels rise, and 3) remediated the flood hazard of a road-stream crossing which fails during major flood events.

In 2015-2016, Newmarket completed the Moonlight Brook Watershed project to build resilience to flooding and climate change. The project resulted in two actions 1) a study of climate change related flood risk and how future development and community development may affect these risks, and 2) green infrastructure designs within the watershed to help reduce risk of flooding and reduce pollutant load.

In 2016, Newmarket began a modeling study to investigate the potential impacts of sea-level rise on groundwater and public drinking water supplies. The project will model three sea-level rise scenarios and identify areas where drinking water may be vulnerable to salt water intrusion. Results will help guide future development and future well siting away from the vulnerable areas.

Rollinsford

In 2016 received a grant from the Piscataqua Region Estuaries Partnership (PREP) to amend their existing stormwater regulations using the Southeast Watershed Alliance Model Stormwater Standards with the goals of: creating more resilient systems for groundwater infiltration by reducing non-point and stormwater pollution from existing and future development; using the best available data, including the most current precipitation data; strengthening design and performance standards for drainage, and promoting low impact development landscaping for new developments

Exeter

In 2014-2015, Exeter participated in the Climate Adaptation Plan for Exeter (CAPE) project which evaluated flood impacts from sea-level rise and storm surge to infrastructure and natural resources. The CAPE report remains in draft form and has not been formally accepted by the town.

In 2016, Exeter completed Phase I of the Lincoln Street Watershed assessment which produced an assessment of stormwater flooding and infrastructure performance. Phase II of the Lincoln Street Watershed project is underway in 2017 which will provide site-specific designs of best management practices and a public education and outreach program about local sites of stormwater flooding in the watershed.

Greenland

In 2016 with a grant from the Piscataqua Region Estuaries Partnership, Greenland adopted new stormwater management regulations, based on model standards prepared by the Southeast Watershed Alliance. The amended regulations utilize the best available precipitation data from the Northeast Region Climate Center for the sizing and design of stormwater systems, and implement Low Impact Development practices to the maximum extent practicable.

Newfields

In 2014, Newfields participated in a Preparing for Climate Change program which resulted in increased public awareness about impacts from severe weather, implementation of a bulk purchase generator program, and commitment by the Planning Board to update the town's stormwater management regulations (later adopted).

ISSUES AND CONSIDERATIONS

The following issues and considerations of local and regional importance were identified during project meetings with municipal officials, staff, and land use board and commissions.

Municipal Critical Facilities

- Extreme precipitation exacerbates coastal flooding particularly with respect to managing stormwater and combined sewer overflow (CSO) outfalls in tidally influenced areas.

State and Municipal Roadway and Transportation Infrastructure

- Roadways expected to experience the largest stretches of inundation due to flooding from sea-level rise and coastal storm surge may disrupt emergency evacuation routes, local commuting patterns, impact local businesses, and cause challenges for emergency responders.
- Flooding from sea-level rise and coastal storm surge impacts state and local roadway networks and could disrupt designated evacuation routes and connections to evacuation routes in adjacent municipalities.

- Improvements to the state roadway network (elevating, enlarging culvert and bridges) may affect local connector roads, driveway access points and connecting infrastructure and utilities.
- Long term capital improvement investments, planning at both the state and local levels should include an analysis of the design costs necessary to improve roads and drainage infrastructure to withstand projected sea-level rise at 2050 and 2100.
- Using the results of the C-RiSe Climate Ready Culvert analysis will assist municipalities in long-term planning decisions about the placement, design, and sizing of new culverts or when upgrades and repairs are being made to existing culverts.

Natural Resources

- Additional analysis is needed to identify barriers to saltmarsh migration (e.g. railroad corridor) and ways to enhance tidal flow.
- Utilizing SLAMM results from NH Fish & Game will assist municipalities in prioritizing land conservation for inland saltmarsh migration.
- Protecting both freshwater and tidal wetlands will: improve floodplain storage capacity; assist in adequately separating development and infrastructure from areas of high flood risk; and accommodate projected changes in sea-levels by allowing inland migration of tidal marsh systems and conversion of freshwater systems to tidal systems.
- Land conservation efforts can mitigate future flooding impacts by guiding development away from high risk flood areas and increasing flood storage capacity.
- As sea levels rise, saltwater intrusion is likely to change the salinity of existing fresh water sources in the coastal region. Similarly, sea-level rise causes elevation of the regional groundwater table, resulting in higher groundwater levels at significant distances from the coast. These issues need further study as it is unclear how they may impact municipalities and water resources in the coastal region.

Land Use

- Roadways, buildings and infrastructure can be protected by raising them above projected sea-level rise elevations.
- Supporting land and land based uses may be impacted by daily tidal flooding from projected sea-level rise, and may or may not be able to adapt to changes in flood conditions.
- The C-RiSe assessment shows that the inundation extent of the three sea-level rise scenarios is within the 100-year floodplain. Planning for long term sea-level rise can be integrated within existing regulatory and management frameworks for the current 100-year floodplain.
- Land conservation efforts along tidal rivers and their tributaries could prevent or help minimize future flooding impacts by guiding development away from high risk flood areas and increasing flood storage capacity.

- Open space preservation in the floodplain reduces flood risks and gains points in the FEMA Community Rating System Program.
- As sea-level and groundwater levels rise, saltwater intrusion could impact aquifers, private wells, and public water supplies, and may result in septic system failure. Productive crop-yielding agricultural fields will also be impacted.

Public Outreach

- Providing information about potential flood hazards to businesses and residents, and early notification of flood risk during a coastal storm event would enhance public safety and preparedness.
- Document flood elevations for each flood event (e.g. on a fixed structure such as a building).

RECOMMENDATIONS

The following recommendations are short-term climate adaptation actions that can be included in municipal Natural Hazards Mitigation Plans, Master Plan and other planning and policy documents. These actions are focused on strengthening land use development standards, resource protection, municipal policy and plans, and public support to create more resilient development, infrastructure and natural systems.[18]

REGULATORY

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

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

R3 - Coastal Buffers and Tidal Marshes. Adopt buffers and setbacks that adequately separate development and infrastructure from tidal wetlands, freshwater wetlands and surface waters to sustain flood storage

[18] An expanded list of climate adaptation strategies is provided in Appendix B.

capacity, and allow for inland migration of tidal marsh systems and conversion of freshwater systems to tidal systems to accommodate projected changes in sea-levels.

PLANNING AND POLICY

P1 - Natural Hazards Mitigation Plan. Incorporate the vulnerability assessment information and recommendations from the Climate Risk in the Seacoast Vulnerability Assessment report and maps into the municipal Natural Hazards Mitigation Plan updates and Emergency Operations Plans. Continue revising and updating the assessment information and climate adaptation recommendations in future updates of the Plan.

P2 - Master Plan Coastal Hazards Chapter. Adopt a Coastal Hazards Chapter in the town's Master Plan that incorporates information and recommendations from the Climate Risk in the Seacoast Vulnerability Assessment report and maps.

P4 - Capital Infrastructure and Investments. Incorporate consideration of impacts from sea-level rise and coastal storm surge flooding in current and future capital infrastructure projects. Incorporate the Climate Risk in the Seacoast vulnerability assessment information into infrastructure management plans and capital improvement plans. Evaluate the extent of sea-level rise and storm surge flooding on individual facilities (e.g. wastewater treatment plant, transfer station, high school).

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

- Adopt a targeted scoring framework or incorporate new scoring criteria into existing land conservation prioritization efforts that consider climate adaptation benefits when evaluating land for conservation purposes.
- Increase funding and resources for land conservation, land management programs, and land stewardship activities. (Note: Land conservation scores very high as an activity in the FEMA Community Rating System program.)
- Support retreat from high risk areas by buying properties and restoring them to a natural condition.

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

P7 - Evacuation Planning. Prepare evacuation plans and coordinate these plans with towns in the coastal region to implement timely and comprehensive planning and notification for coastal storm events. Mark evacuation routes with signage and communicate these routes to the public with information on the town's website and printed maps.

COMMUNITY OUTREACH AND ENGAGEMENT

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

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

O2 - Implement FEMA's High Water Mark Initiative. Consider implementing the FEMA High Water Mark Initiative (HWMI) as a public outreach activity. The HWMI provides 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.

O3 - Coastal Flood Hazard Outreach. Use information from the C-RiSe Vulnerability Assessment to inform property owners of existing and future risks and hazards based on projected sea-level rise and coastal storm surge flooding.

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

- Provide information to property owners about living shorelines and the importance of retaining the functions of natural shorelines, and implementing landscaping best practices.
- Implement living shorelines projects on town lands to demonstrate best practices, and the benefits and effectiveness of living shorelines approaches.

NH COASTAL RISK AND HAZARDS COMMISSION FINAL REPORT (2016) - RECOMMENDATIONS FOR MUNICIPALITIES

CC1. Secure new and allocate existing funding sources for state agencies and municipalities to conduct vulnerability assessments of assets at appropriate scales and to implement adaptation strategies.

ACTIONS:

e. Apply for and utilize FEMA mitigation grants and other sources of funding to implement climate adaptation and planning strategies that reduce or eliminate flooding impacts (see CC6 (a)).
f. Create and utilize a dedicated fund to acquire repetitive loss properties when structures and facilities are abandoned or destroyed (see CC6 (d)).
g. Identify mechanisms to raise matching funds for FEMA and other grant programs, such as creating a dedicated state flood mitigation fund (see CC6 (e)).
i. Utilize existing funding sources for natural resource restoration (e.g. offset measures, state Aquatic Resource Mitigation fund) (see NR2 (d)).
j. Establish dedicated funds and sources to support land preservation, restoration, acquisition of easements, and development rights to transfer vulnerable property to conservation lands

CC2. Identify vulnerable state and municipal assets at regional, municipal, and site-specific scales as appropriate.

ACTIONS:

c. Develop site-specific vulnerability assessments for public assets at risk from increased coastal flooding based on the flooding scenarios presented in the Science and Technical Advisory Panel report, as amended.
e. Disseminate and share results from coastal vulnerability assessments with relevant audiences.

CC6. Make existing structures and facilities more resilient and acquire properties in high risk areas in order to reduce or eliminate flooding impacts.

ACTIONS:

b. Elevate existing at-risk structures and implement higher freeboard standards above the Base Flood Elevation on new and substantially reconstructed structures and facilities to protect from future flood risks.

CC7. Incorporate coastal hazards, risks and vulnerability in policies, plans and investments.

ACTIONS:

a. Evaluate deficiencies and barriers in municipal regulations, plans and policies, and their implications for regional vulnerability.

b. Incorporate coastal hazards and risks assessments, including social vulnerability information, in municipal hazard mitigation plans, natural hazards and climate change adaptation Master Plan chapters, and emergency management plans.
c. Encourage municipalities to develop detailed preparation, response and recovery plans that build on existing plans and initiatives.
d. Encourage municipalities to adopt buffers and setbacks that better account for risk and vulnerability of structures, facilities, and natural resources and maintain ecosystem services (e.g. flood storage, storm surge attenuation, reduced impacts to public structures and facilities, and private property).
e. Incorporate vulnerability assessment information and adaptation strategies for structures and facilities planning and investment for long term capital projects in municipal Capital Improvement Programs (CIPs).
f. Improve connections between municipal hazard mitigation plans, master plans and capital improvement plans.
g. Identify and reduce existing inconsistencies between municipal plans and state plans, such as hazard mitigation plans, building codes, design standards, and evacuation plans.
h. Consider the concepts of uncertainty and risk in decision-making and action planning.
i. Encourage communities that conduct floodplain management activities that exceed the minimum requirements of the National Flood Insurance Program (NFIP) to consider joining and participating in the Community Rating System (CRS), which provides discounts to annual flood insurance premiums for some residents and businesses as a reward for their communities' activities.

E2. Incorporate best available climate science and vulnerability assessment information in state, regional, and municipal economic development plans.

ACTIONS:

a. Encourage private property owners and businesses to incorporate best available climate science and vulnerability assessments in their decision making and preparedness plans.
b. Consider vulnerabilities of local tax base, state economic development plan, retention or replacement of economic resources, at risk populations and population migration.
c. Improve management, coordination and delivery mechanisms to ensure continuity of services to essential facilities, people, businesses and employment centers.
e. Identify economic assets that are vulnerable to storm surge, sea-level rise, and extreme precipitation; understand the scope of that vulnerability; and evaluate existing statutes, ordinances, rules and regulations, policies, programs, and plans to determine whether changes should be made to reduce

E3. Use appropriate and available mechanisms, including but not limited to incentives and market-based tools to fund climate adaptation strategies.

ACTIONS:

a. Align land acquisition and easement programs to transfer vulnerable properties into conservation.

b. Establish stormwater utilities to fund retrofits to existing development and future improvements.
c. Develop and utilize tools to identify cost effective strategies and public investments for adapting to increased flood risk in vulnerable areas.
d. Develop special overlay districts, tax credits and revolving loan funds as mechanisms to discourage development in vulnerable areas.
e. Implement voluntary transfer of development rights programs and other economic incentives to acquire or conserve property in high risk areas.
f. Create statewide and municipal funding programs for climate adaptation strategies.
g. Adapt economic development planning approaches to respond to changing environmental conditions and leverage shifting opportunities.
h. Promote resilience and sustainability planning as economic development strategies.

E4. Improve information available to property owners and prospective buyers about coastal hazards and vulnerabilities.

ACTIONS:

a. Improve consumer protection disclosure of properties vulnerable to coastal flooding.
b. Distribute flood protection safety information to property owners in high-risk areas.
c. Encourage homeowners in moderate- to low-risk areas to purchase Preferred Risk Policy.

BL2. Implement regulatory standards and/or enact enabling legislation to ensure that the best available climate science and flood risk information are used for the siting and design of new, reconstructed, and rehabilitated state-funded structures and facilities, municipal structures and facilities, and private structures.

ACTIONS:

c. Encourage municipalities to use one of the following three approachesxiii,xiv,xv for determining a higher vertical flood elevation and expanded corresponding horizontal floodplain than the current base flood elevation and floodplain to address current and future flood risk for new construction, substantial improvement, or repairs to substantially-damaged municipal and private structures and facilities:
   i. Climate-informed Science Approach – use the best available, actionable hydrologic and hydraulic data and methods that integrate current and future changes in flooding based on climate science.xvi
   ii. Freeboard Value Approach – use the freeboard value, reached by adding an additional two (2) feet to the base flood elevation for non-critical structures and facilities and from adding an additional three (3) feet to the base flood elevation for criticalxvii structures and facilities.
   *iii. The 0.2-percent-annual-chance Flood Appro*ach – use the 0.2-percent-annual-chance flood elevation (also known as the 500-year flood elevation).

xi An acceptable source of climate science for New Hampshire includes the Coastal Risk and Hazards Commission Science and Technical Advisory Panel report, Sea-level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire: Analysis of Past and Projected Trends, as amended.

xii Any activity for which even a slight chance of flooding would be too great. For expanded description of "critical action" see Part I, Section 6 of Guidelines for Implementing Executive Order 13690.

xiii See Federal Executive Order 13690, Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Input.

xiv See Guidelines for Implementing Executive Order 13690.

xv See Appendix F for State of New Hampshire comments on Draft Guidelines for Implementing Executive Order 13690.

xvi An acceptable source of climate science for New Hampshire includes the Coastal Risk and Hazards Commission Science and Technical Advisory Panel report, Sea-level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire: Analysis of Past and Projected Trends, as amended.

xvii Any activity for which even a slight chance of flooding would be too great. For expanded description of "critical action" see Part I, Section 6 of Guidelines for Implementing Executive Order 13690.

BL4. Integrate comprehensive land use and environmental planning with floodplain management approaches that prevent and minimize impacts from coastal hazards.

ACTIONS:

c. Promote land development regulations that reduce vulnerability and protect ecosystem services (e.g. open space/cluster development).
d. Prepare watershed-based plans that address comprehensive water resource management principles focused on changes in hydrologic systems resulting from climate change.
e. Consider prohibiting development in areas destroyed by storms, experiencing repetitive loss of structures, and subject to chronic flooding and erosion. Consider adaptive reuse and/or acquisition of at-risk private properties.

NR2. Develop natural resource restoration plans that explicitly consider future coastal risk and hazards, and the ecological services that they provide.

ACTIONS:

b. Provide recommendations and incentives for removal or modification of structures and facilities, such as freshwater and tidal crossings, that create barriers to tidal flow and habitat migration, particularly those that will be impaired or severely impacted by sea-level rise, storm surge, or extreme precipitation.
c. Engage in best practices for invasive species planning and removal and incorporate climate considerations in invasive species removal plans.

d. Utilize existing funding sources for natural resource restoration (e.g. offset measures, state Aquatic Resource Mitigation fund).

NR4. Consider ecosystem services provided by natural resources in land use planning, master plans, and asset decisions.

ACTIONS:

b. Implement strategies and tools (such as land regulations, incentives, building regulations) designed to maintain or restore pervious surfaces, provide nutrient barriers, protect vegetated buffers and maintain wildlife passage.
e. Develop best management practices for shoreline buffers, including information on appropriate use of shoreline hardening, bank stabilization, vegetation restoration and agricultural practices.
f. Explore options to minimize shoreline hardening and promote natural or hybrid shoreline protection strategies.
h. Develop guidelines and provide incentives for communities to incorporate climate adaptation actions for wildlife protection in master plans, hazard mitigation plans, and zoning ordinances.

H2. Develop plans and implement strategies to prepare and adapt recreational resources based on best available climate science.

ACTIONS:

a. Conduct public information hearings to understand the impacts of proposed climate adaptation strategies.
b. Assess existing and future recreational areas for their potential to provide storage for flood waters and stormwater runoff.
c. Preserve open space and recreational areas that serve to minimize climate change impacts.
d. Integrate recreational and open space planning into climate adaptation planning and the Tidal Shoreline Management Plan.
e. Integrate protection of recreational resources into land use and management, engineering, regulatory components of state and municipal plans including the Tidal Shoreline Management Plan, hazard mitigation plans, Master Plans, and design standards.

H3. Identify and survey cultural and historic resources and assess their vulnerability to coastal risk and hazards based on best available climate science.

ACTIONS:

a. Map all currently surveyed cultural and historical resources.
b. Identify asset types that may also be cultural and historic resources.
c. Use reconnaissance level survey and vulnerability assessments to identify high priority areas for intensive survey.

H4. Develop long-term plans for protecting, adapting, or reducing risk to cultural resources affected by climate change.

ACTIONS:

a. Create or modify adaptation strategies for cultural and historic buildings affected by climate change, including plans for protecting or relocating resources.
b. Integrate protection of cultural and historical resources into land use and management, engineering, regulatory components of state and municipal plans including the Tidal Shoreline Management Plan, hazard mitigation plans, Master Plans, and design guidelines.
e. Create programmatic strategies to compensate for the loss of historic asset types that will be replaced in order to adapt to climate change impacts.

GLOSSARY

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 most communities, 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).

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.

Salmonids
Belonging or pertaining to the family of fish Salmonidae, including salmon, trout, chars, and white fish.

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]

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 – MAP SET

Map - Extent of Projected Tidal Flooding - SLR 1.7', 4.0' and 6.3'
Map - Extent of Projected Tidal Flooding - SLR + Storm Surge
Map - Infrastructure - SLR 1.7', 4.0' and 6.3'
Map - Infrastructure - SLR + Storm Surge
Map - Transportation Assets - SLR 1.7', 4.0' and 6.3'
Map - Transportation Assets - SLR + Storm Surge
Map – Water Resources 1.7', 4.0' and 6.3'
Map – Water Resources - SLR + Storm Surge
Map – Land Resources - SLR 1.7', 4.0' and 6.3'
Map – Land Resources - SLR + Storm Surge