C-RiSe

CLIMATE RISK IN THE SEACOAST

Assessing Vulnerability of Municipal Assets and Resources to Climate Change

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TOWN OF ROLLINSFORD, NEW HAMPSHIRE

Vulnerability Assessment

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

Prepared by the

Strafford Regional Planning Commission

February, 2017

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Pat McLin	Chair, Planning Board, Town of Rollinsford
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Kevin L. Hurd	Assistant Chief, Fire Department, Town of Rollinsford

Cover Photo Credit: Bob Ducharme , Police Chief

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

PLANNING TO REDUCE RISK AND VULNERABILITY

New Hampshire's economy and quality of life have historically been linked to its shores, its vast expanses of productive saltmarshes, and inland coastal rivers and estuaries. 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 risk and vulnerability.

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

What is a Vulnerability Assessment?

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

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

How can the vulnerability assessment be used?

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

Planning for the long-term effects of sea level rise may also help communities better prepare in the short-term for periodic flooding from severe coastal storms. Results from a vulnerability assessment can be incorporated into various municipal planning, regulatory and management documents.

How will the vulnerability assessment benefit the community?

The Climate Risk in the Seacoast assessment is intended to assist coastal NH communities to take actions to prepare for increase flood risk, including:

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

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

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Project Partners:

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 impacts to New Hampshire's ten inland coastal municipalities from sea-level rise and storm surge to infrastructure, critical facilities transportation systems, and natural resources. Three sea-level scenarios were evaluated accounting for a range from the intermediate-low to the highest projected sea-levels at the year 2100.

TABLE 1: Sea-Level and Storm Surge Scenarios in Rollinsford

Sea Level (SLR) Scenarios	SLR	SLR	SLR	SLR + storm surge	SLR + storm surge	SLR + storm surge
Sea Level Rise	1.7ft	4.0ft	6.3ft	--	--	--
Sea Level Rise + Storm Surge	--	--	--	1.7ft + storm surge	4.0ft + storm surge	6.3ft + storm surge

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

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

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

<u>Sea-Level Rise Scenarios</u>

The sea-level rise projections used in this study are based on an earlier study completed in 2011 by Wake et al and are similar to a more recent report issued by the NH Coastal Risks and Hazards Commission's Science and Technical Advisory Panel in 2014.[3]

[1] NOAA website at http://tidesandcurrents.noaa.gov/datum_options.html

[2] EPA website at http://epa.gov/climatechange/glossary.html

[3] For more information on how sea level rise scenarios were mapped, visit: http://granitweb.sr.unh.edu/MetadataForViewers/NHCoastalViewer/RelatedDocuments/Sea_Level_Rise_Narrative_rev20150106_FinalReport.pdf

As shown in Figures 1 and 2 and in the graphics below, while slightly different than the scenarios cited in the 2014 report, the sea level rise scenarios used in the Climate Risk in the Seacoast assessment yield coverage estimates of flooding that are within the mapping margin of error for the scenarios in both the 2011 and 2014 reports.

Figure 1: 2014 Sea Level Rise Scenarios (based on greenhouse gas emissions)

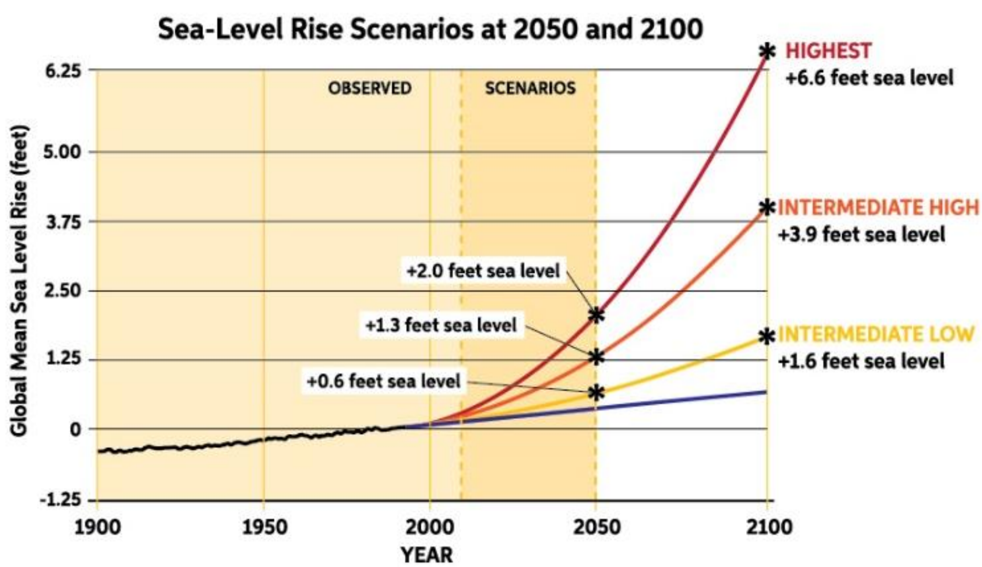
	Lower Emissions (B1)		Higher Emissions (A1fi)	
	2050	2100	2050	2100
Current Elevation of MHHW [a,b]	4.43	4.43	4.43	4.43
100-Year Flood Height	7.78	7.78	7.78	7.78
Subsidence	0.012	0.016	0.012	0.016
Eustatic SLR	1.0	2.5	1.7	6.3
Total Stillwater Elevation [a,c]	**13.2**	**14.7**	**13.9**	**18.5**

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

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

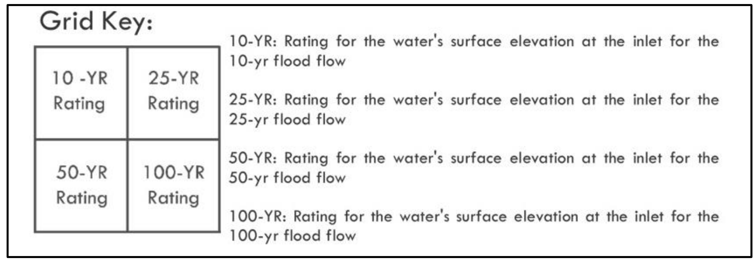
Source: Wake CP, E Burakowski, E Kelsey, K Hayhoe, A Stoner, C Watson, E Douglas (2011) *Climate Change in the Piscataqua/Great Bay Region: Past, Present, and Future*. Carbon Solutions New England Report for the Great Bay (New Hampshire) Stewards.

Figure 2: 2014 Sea Level Rise Scenarios (based on greenhouse gas emissions)

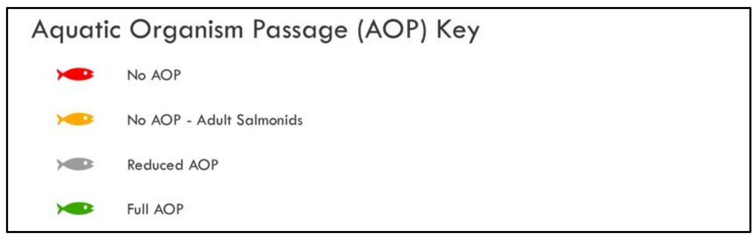


Source: Wake CP, Kirshen P, Huber M, Knuuti K, and Stampone M (2014) *Sea-level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire: Analysis of Past and Projected Future Trends*, prepared by the Science and Technical Advisory Panel for the New Hampshire Coastal Risks and Hazards Commission.

Data, Methods, Calculations, and Results of Hydrologic and Hydraulic Modeling for Road Crossings

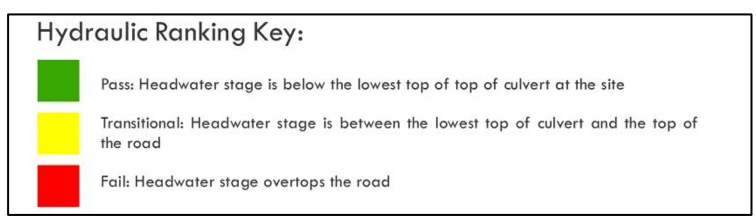


The C-Rise project assessed both aquatic organism passage capacity and hydraulic flow capacity of ten road crossings in each of the ten inland coastal municipalities. The assessment was based on runoff associated with the current 10-, 25-, 50- and 100-year storm events. For each storm, each crossing was assigned a hydraulic rating and an aquatic organism passage (AOP) rating; both ratings are described in greater detail below.



The AOP rating is labeled by color; Red, Orange, Gray, and Green. Ratings of Red and Orange mean that there is estimated to be little to no AOP at that crossing, with Red being no AOP for all species and Orange meaning no AOP for all species except for adult Salmonids. A rating of Gray means that there is reduced AOP at the crossing for all species. A rating of Green means that AOP is expected to be possible for all species.

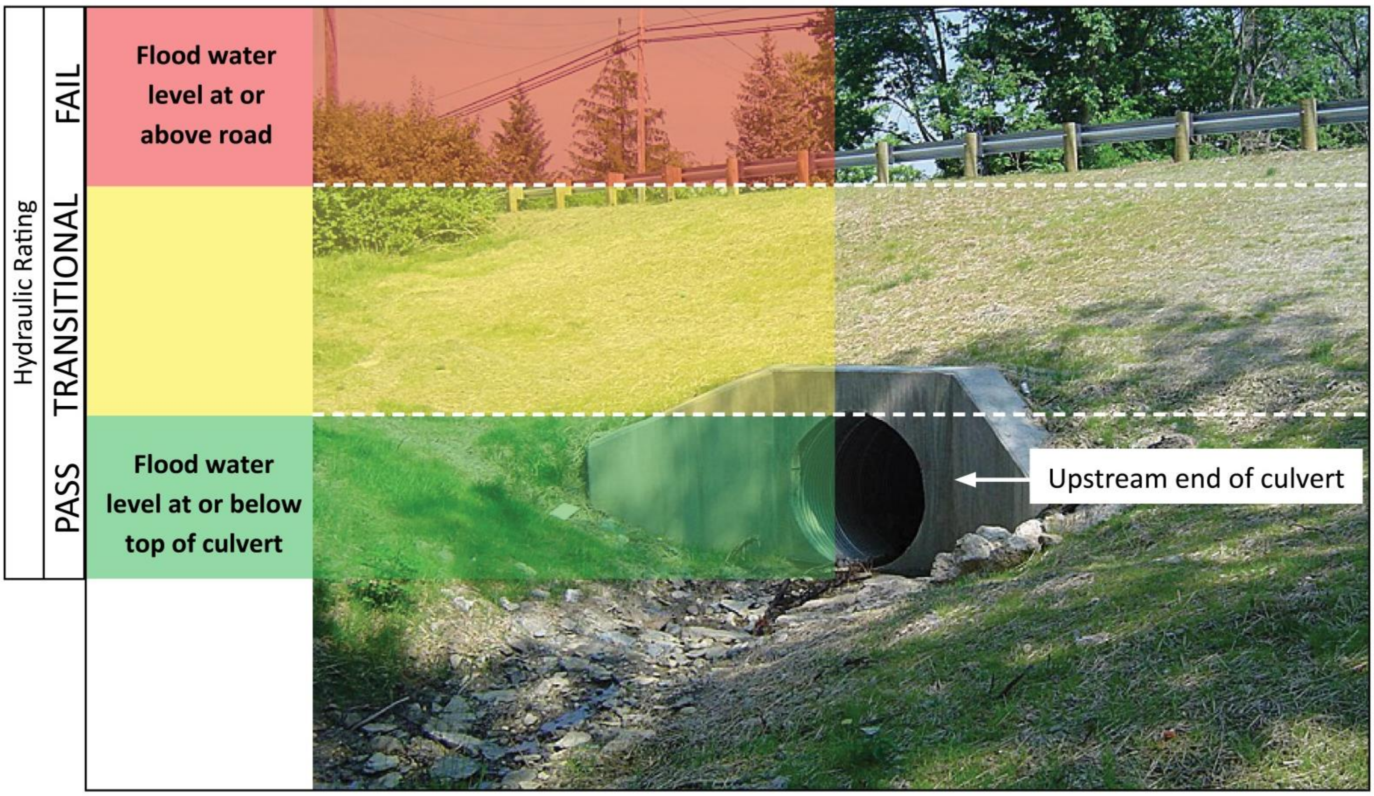
The AOP ratings were developed using the New Hampshire protocol for assessment, which was borrowed directly from the Vermont Culvert Aquatic Organism Passage Screening Tool. This tool uses physical data collected at each crossing and may be used to rate each culvert at a crossing for AOP. At a crossing with multiple culverts, if one culvert is more passable than another, then that culvert is considered 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 hydraulic rating is color-coded similar to the AOP rating. The peak flows of the 10-, 25-, 50-, and 100-year storm events were used to assess the ability of the culvert to pass the flow (measured by the depth of water upstream of the culvert – known as the headwater depth) was determined and compared to culvert and road elevations. The ratings for hydraulics are: Pass (green), Transitional (yellow), and Fail (red). These ratings describe the depth of the water at the inlet (the Headwater) for the flows for each of the selected storm events compared to culvert and road elevations. 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 (see Figure 3).

The hydraulic ratings describe the headwater depth (upstream of the culvert) for each storm event flood. The headwater depths are 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[4] method was used; and for watersheds larger than one square mile, flows were calculated using the Regression Equations[5] published by the USGS for New Hampshire. Once the 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. The program then calculated the headwater depth for each of the flows at each of the sites. This headwater depth is what is shown in the results, and are compared to the pipe crown and roadway elevations to determine the Hydraulic Ratings.

Figure 3: Hydraulic rating diagram



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

[5] An equation that describes a mathematical relationship between two variables in which one variable is used to predict the other.

Assets and Resources Evaluated

Table 2 lists the three major categories and a detailed list of the assets and resources evaluated as part of the Climate Risk in the Seacoast vulnerability assessment. The assets and resources evaluated are listed in subsequent tables in this report only if they are affected by one or more of the sea-level rise and/or coastal storm surge scenarios.

TABLE 2: Assets and Resources Evaluated for the Vulnerability Assessment

Category	Assets and Resources
State and Municipal Infrastructure	Climate Ready Culverts Federal and State Historic Register Properties Other Assets: graveyards, water access, transmission lines
Municipal Critical Facilities	Municipal Critical Facilities (as identified in Hazard Mitigation Plans)
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 Uplands Floodplains Wildlife Action Plan – Tier 1 and Tier 2 habitats Land Conservation Plan – Conservation focus areas (not mapped)
Land Use	Residential structures

Map Design and Organization

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

Extent of Flooding from Sea Level Rise and Storm Surge

The green and pink color schemes are arranged from lightest to darkest with increasing flood levels and extents.

Figure 4: Sea Level Rise Scenarios 1.7ft, 4.0ft, and 6.3ft

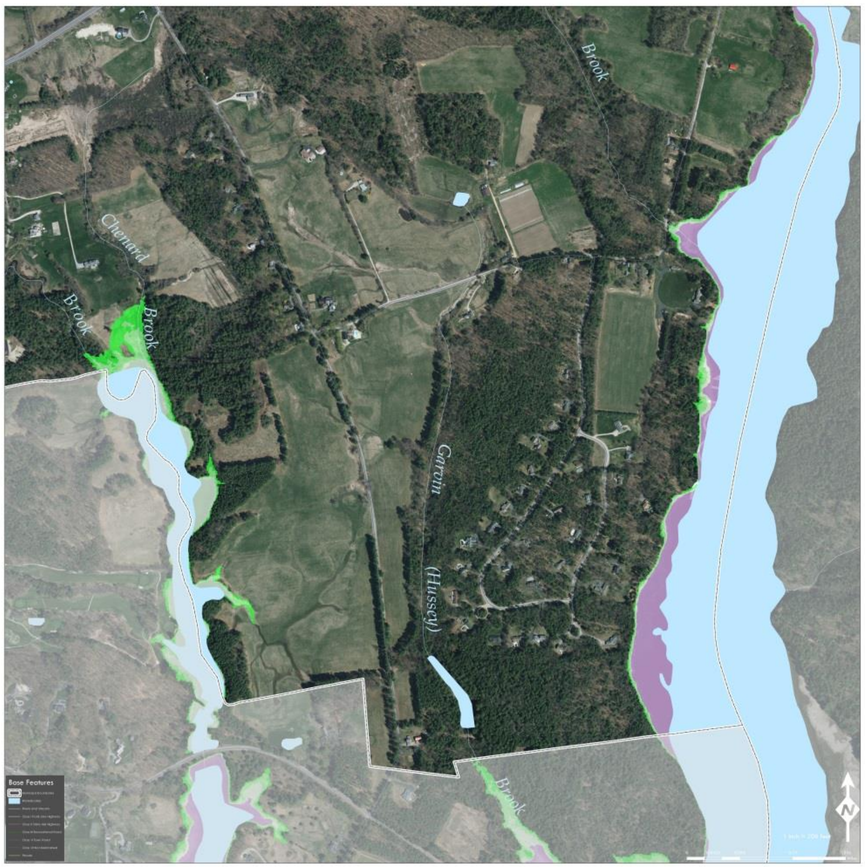
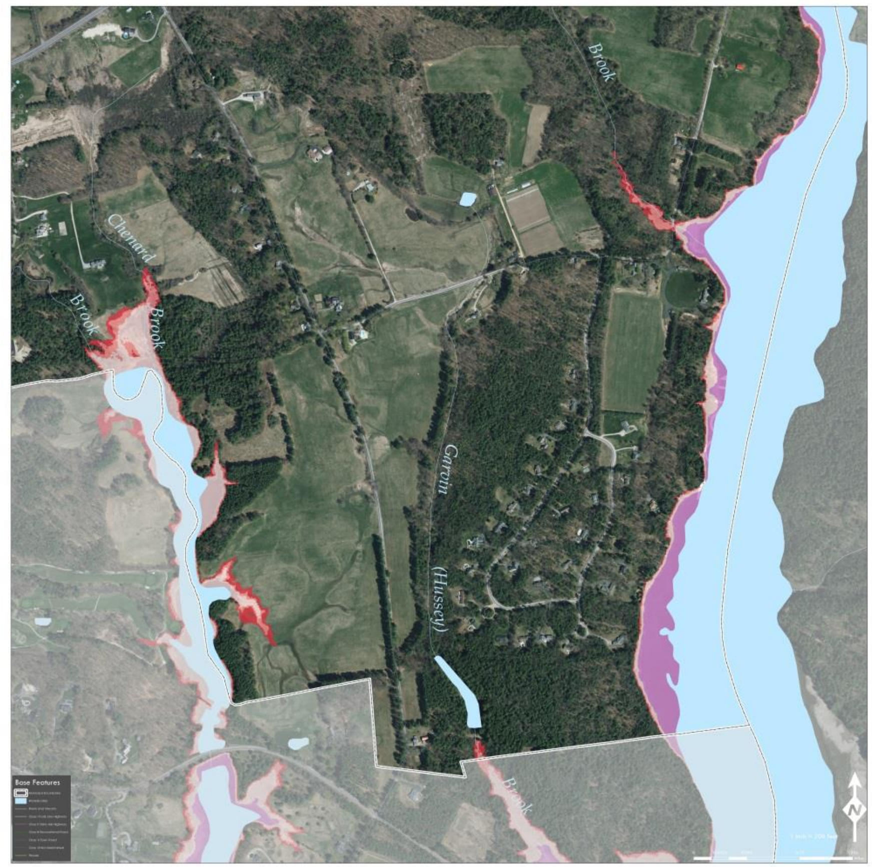


Figure 5: Sea Level Rise Scenarios 1.7ft, 4.0ft, and 6.3ft + storm surge



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

OVERVIEW

The Town of Rollinsford is located in southeastern Strafford County, New Hampshire. It sits on the border of New Hampshire and Maine, bounded by the Towns of Berwick and South Berwick (Maine), northwesterly by the City of Somersworth, and southwesterly by the City of Dover. Rollinsford's land area covers roughly 7.31 square miles, and a water area of 0.25 square miles. With an estimated population of 2,522 (2013), Rollinsford is the second least populated municipality in SRPC's coastal region – trailing only Madbury. The inland coastal portion of Rollinsford that is most susceptible to coastal flooding is located in low areas along the Salmon Falls River. Sections of Foundry Street and Sligo Road are both within the coastal floodplain area, making them particularly vulnerable to flooding from seasonal high tides, coastal storms, and sea-level rise.

Completed and Ongoing Efforts

In 2016, Rollinsford received a grant from the Piscataqua Region Estuaries Partnership (PREP) to review and update their existing stormwater regulations using the Southeast Watershed Alliance Model Stormwater Ordinance. The purpose of this project was to create more resilient systems for groundwater infiltration by reducing non-point and stormwater pollution from existing and future development. During the update the following goals were met:

1. Use the best available data, including the most current precipitation data.
2. Strengthen design and performance standards for drainage, and
3. Promote low impact development landscaping for new developments

In 2016, Rollinsford participated in a training workshop conducted by the New Hampshire Office of Energy and Planning, NH GRANIT, and the Strafford Regional Planning Commission. The purpose of this workshop was to provide an introduction to the FEMA's Flood Risk Products, present community-specific flood risk data and information, and show how the flood risk data and information can be used in planning initiatives to increase flood resiliency.

VULNERABILITY ASSESSMENT RESULTS

Key findings for the Town of Rollinsford are reported in the tables below based on evaluation of the 1.7 feet (intermediate-low), 4.0 feet (intermediate), and 6.3 feet (highest) sea-level rise projections at the year 2100, and these same sea-level rise projections with an additional 100-year storm surge. Table 3 provides data on the total acreage of each sea level rise scenario. Table 4 provides a summary of assessment data that was analyzed as part of this project.

TABLE 3: Total Acreage of Sea Level Rise Scenarios in Rollinsford

	Sea-Level Scenarios					
Community	1.7ft SLR (acres)	4.0ft SLR (acres)	6.3ft SLR (acres)	1.7ft SLR + storm surge (acres)	4.0ft SLR + storm surge (acres)	6.3ft SLR + storm surge (acres)
Rollinsford	10.12	16.42	24.42	22.48	32.81	42.59

TABLE 4: Summary of Assessment Data

Sea Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
Infrastructure (# of sites)		0			2	
Critical Facilities (# of sites)		0			0	
Transportation Assets (# of sites)		0			0	
Residential Structures (# of homes)	0	0	0	0	0	1
Uplands (acres)	2.69	6.44	12.85	11.23	20.06	28.98
Roadways (miles)	0.00	0.07	0.16	0.14	0.21	0.26
Freshwater Wetlands (acres)	8.17	10.05	10.97	10.89	11.68	15.19
Tidal Wetlands (acres)	0.37	0.99	1.30	1.26	1.45	1.54
Aquifers (acres)	3.72	8.32	15.21	13.48	22.81	32.24
Wellhead Protection Areas (acres)	1.10	4.57	9.09	7.96	15.43	21.24
Conserved and Public Lands (acres)	0.68	2.20	4.86	4.06	8.63	12.91
Wildlife Action Plan (acres)	8.32	13.40	19.56	18.09	24.17	30.84
Conservation Focus Areas (acres)	8.33	10.83	13.98	13.30	16.14	19.54
100-year Floodplain (acres)	10.12	16.42	23.78	22.12	29.15	32.54

Notes: Upland refers to land above mean higher high water (highest tidal extent). Storm surge is the area flooded by the 100-year/1% chance storm event.

The data indicates that Rollinsford's 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. In Rollinsford, floodplains are extremely sensitive to flooding from sea-level rise. Ninety-seven percent of the three sea-level rise scenarios fall within the existing FEMA 100-year floodplain. The town can expect to see further flooding impacts from sea level rise when there is a storm surge on top of the 4.0ft and 6.3ft scenarios. Even so, the 4.0ft scenario with a storm surge falls within 88 percent of the floodplain and the 6.3ft scenario with a storm surge falls with 76 percent of the floodplain. Compared to other municipalities in the region, most of Rollinsford's key infrastructure, community assets, and natural resources are protected.

As shown in *Maps 1 and 2 Extent of Projected Tidal Flooding*, Rollinsford can expect to see minor impacts in the southeastern portion of town along Chenard Brook, Sligo Brook, Stackpole Brook, and the Salmon Falls River. There are no major critical facilities impacted, but the town should consider the potential impacts to Sligo Road. In particular, there are two culverts (1) over Stackpole Brook and (2) over Sligo Brook that currently experience flooding issues. The vulnerability and risk of future failure at these two locations will increase with sea level rise projections.

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

SUMMARY OF VULNERABILITY ASSESSMENT RESULTS BY ASSET TYPE

Infrastructure

Maps 3 and 4 Critical Facilities and Infrastructure show state and municipal infrastructure types affected by sea-level rise and coastal storm surge flooding. Table 5 reports when specific infrastructure types are affected by each sea-level rise and coastal storm surge scenario.

TABLE 5: Infrastructure

Sea Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
State and Municipal Infrastructure (# of facilities)						
Climate Ready Culverts	0			2		
Total # of Sites	0			2		

Two culverts were the only impacted types of infrastructure from projected sea-level rise and coastal storm surge flooding. The culverts were chosen to be a part of the UNH's climate ready culvert analysis, and are both located on Sligo Road over Stackpole Brook and Sligo Brook. According to municipal staff, these two culverts have experienced failures in the past due to flooding, resulting in road closures and repairs.

Municipal Critical Facilities

Maps 3 and 4 Critical Facilities and Infrastructure show the municipal critical facilities affected by sea-level rise and coastal storm surge flooding. Table 6 reports when specific municipal critical facilities are affected by each sea-level rise and coastal storm surge scenario.

TABLE 6: Municipal Critical Facilities (# of facilities)

Sea Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
Municipal Critical Facilities (# of facilities)						
Total – Sites	0			0		

NOTE: Municipal Critical Facilities as identified in the Town's Hazard Mitigation Plan.

There were no municipal critical facilities identified as being vulnerable from either projected sea-level rise or coastal storm surge flooding.

Transportation

Maps 5 and 6 Road and Transportation Assets show the state and municipal roadways affected by sea-level rise and coastal storm surge flooding. Table 7 reports the miles of state and local roadways affected by each flood scenario. Table 8 provides greater detail as to which roads are impacted.

TABLE 7: State and Municipal Roadways and Infrastructure (miles)

Sea Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
Roadway Type						
State	0.00	0.00	0.00	0.00	0.00	0.00
Local	0.00	0.00	0.08	0.07	0.12	0.16
Private	0.00	0.00	0.00	0.00	0.00	0.00
Not Maintained	0.00	0.07	0.08	0.07	0.09	0.10
Total Road Miles	0.00	0.07	0.16	0.14	0.21	0.26

Rollinsford's existing municipal roadway network is not particularly sensitive to sea-level rise and coastal storm flooding, with a total of just over a quarter of mile of roadway being impacted under the 6.3ft of sea-level rise + a storm surge scenario.

TABLE 8: Rollinsford's Road Asset Impacts

Sea Level Rise (SLR) Scenarios		SLR 6.3ft	SLR 6.3ft + storm surge
Road Name	Road Class	Miles Impacted	Miles Impacted
Fresh Creek Road	Not Maintained	0.08	0.10
Sligo Road	Local	0.08	0.16
Total Road Miles	-	0.16	0.26

This analysis determined that, in Rollinsford, there are no state roads vulnerable to sea-level rise and coastal storm flooding. In fact, there are only two locations where the town may see potential future flooding along their roadways – Fresh Creek Road and Sligo Road. While the total miles impacted to Fresh Creek Road remain consistent in the sea-level rise and sea-level rise + storm surge scenarios, the total miles impacted to Sligo Road doubles. However, it is important to acknowledge that this increase totals less than two-tenths of a mile of local roadway. Maps 5 and 6 provide a visual representation of these impacts.

Natural Resources

Maps 7 and 8 Land Resources and *Map 9 and 10 Water Resources* show natural resources affected by sea-level rise and coastal storm surge flooding. Table 9 reports the number of acres for each natural land resource affected by each sea-level rise and coastal storm surge scenario. Table 10 reports the number of acres for each natural water resource.

TABLE 9: Natural Land Resources (acres)

Sea Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
Natural Land Resources (acres)						
Conservation Lands	0.68	2.20	4.86	4.06	8.63	12.91
Wildlife Action Plan	8.32	13.40	19.56	18.09	24.17	30.84
*Conservation Focus Areas	8.33	10.83	13.98	13.30	16.14	19.54
Total land resources	17.33	26.43	38.40	35.45	48.94	63.29
* As part of this analysis, conservation focus areas were calculated; however due to their overlap with data from the Wildlife Action Plan, they were not mapped.						

Rollinsford's natural land resources are moderately sensitive to sea-level rise and coastal storm flooding. Impacted natural resources include: conservation easements (3 – Aikman, Franklin, and Marian M. Aikman) along the Salmon Falls River, conservation focus areas identified in the Land Conservation Plan for NH's Coastal Watersheds (Fresh Creek and Garvin Brook & Lower Cocheco River), as well as important lands identified in the Wildlife Action Plan along the Salmon Falls River and Chenard Brook.

TABLE 10: Natural Water Resources (acres)

Sea Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
Natural Water Resources (acres)						
Wellhead Protection Areas	1.10	4.57	9.09	7.96	15.43	21.24
Estuarine and Marine Wetlands	0.37	0.99	1.30	1.26	1.45	1.54
Freshwater Wetlands	8.17	10.05	10.97	10.89	11.68	15.19
Stratified Drift Aquifers	3.72	8.32	15.21	13.48	22.81	32.24
Total water resources	13.36	23.93	36.57	33.59	51.37	70.21

In terms of spatial extent and total acreage, Rollinsford's water resources are slightly more sensitive than that of its land resources; in particular, the town's groundwater resources are subject to inundation. The total acreage (using the highest scenarios) at one of the town's wellhead protection areas, which is located in District 5, Lower Mill Road, more than doubles in size with a storm surge. Similarly, the town's stratified drift aquifers follow the same trend. While this study did not analyze the potential impacts from salt water intrusion, this may be a future challenge the town wishes to investigate. There are minor wetland impacts along the Salmon Falls River and Chenard Brook.

Land Use

Maps 1 and 2 Extent of Projected Tidal Flooding show upland affected by sea-level rise and coastal storm surge flooding above mean higher high water. Upland refers to land above mean higher high water (highest tidal extent). Table 11 reports the number of acres of upland affected by each flood scenario.

TABLE 11: Uplands (acres)

Sea Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
Uplands (acres)						
Acres	2.7	6.4	12.8	11.2	20.1	29.0
% Upland	0.06	0.14	0.28	0.24	0.43	0.62

Total Upland in Rollinsford = 4,648 acres.

Less than 1% of uplands in Rollinsford are impacted. Rollinsford's inland coastal area has some low lying areas, mainly in the eastern part of town along the Salmon Falls River, which has experienced significant riverine flooding in the past.

Parcels and Assessed Value

Table 12 reports the number of parcels affected by each of the six scenarios evaluated and the aggregated assessed value of these parcels. The degree to which the parcel and any development on the parcel are affected by sea-level rise or storm related flooding was not analyzed. Affected parcels were identified based on their location either partially or fully within the extent of the scenarios evaluated. Table 13 reports the number of residential structures affected by each of the six scenarios evaluated and the aggregated assessed value of these homes.

TABLE 12: Parcels and Assessed Value by Scenario

Sea Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
Parcels and Assessed Value						
Parcels Affected (# of parcels)	18	21	24	23	26	27
Aggregate Value of Parcels ($ value)	$3,495,897	$5,047,897	$5,999,997	$5,809,997	$6,021,925	$6,023,485

For Rollinsford, there was an incremental increase in the number of parcels impacted by each of the different scenarios. The aggregated assessed value of those parcels range from $3.5 million to $6.0 million.

TABLE 13: Residential Structures and Assessed Value

Sea Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
Residential Structures and Assessed Value						
Structures Affected (# of homes)	0	0	0	0	0	1
Assessed Value of homes ($ value)	$0	$0	$0	$0	$0	$357,177

Rollinsford has only one residential structure that is impacted by sea-level rise and coastal storm flooding with an assessed value of $357,177.

Climate Ready Culverts

Maps 11 and 12 Climate Ready Culverts Maps show areas within the 100-year floodplain affected by sea-level rise and coastal storm surge flooding. Table 14 reports the hydraulic and aquatic organism passage ratings for the six culverts chosen for this analysis.

TABLE 14: Climate Ready Culvert Analysis

Culvert Crossing ID & Location	*Precipitation Flood Flow				***Aquatic Organism Passage (AOP) Rating
	10-yr	25-yr	50-yr	100-yr	
	**Hydraulic Rating				
#1: Transfer Station Road	Transitional	Fail	Fail	Fail	No AOP
#2: Willey Street	Pass	Transitional	Transitional	Fail	No AOP
#3: Watson Lane over Warren Brook	Transitional	Transitional	Fail	Fail	Reduced AOP
#4: Sligo Road over Stackpole Brook	Fail	Fail	Fail	Fail	Reduced AOP
#5: Sligo Road over Sligo Brook	Pass	Pass	Pass	Transitional	Reduced AOP
#6: Old Mill Lane over Fresh Creek	Pass	Pass	Pass	Pass	Full AOP

NOTE: The two culverts on Sligo Road were impacted by various sea-level scenarios.

**10-YR: Rating for the water's surface elevation at the inlet for the 10-yr flood flow; 25-YR: Rating for the water's surface elevation at the inlet for the 25-yr flood flow; 50-YR: Rating for the water's surface elevation at the inlet for the 50-yr flood flow; 100-YR: Rating for the water's surface elevation at the inlet for the 100-yr flood flow*

***Pass: Headwater stage is below the lowest top of the culvert at the site; Transitional: Headwater stage is between the lowest top of culvert and the top of the road; Fail: Headwater stage overtops the road;*

**** No AOP: For all aquatic organisms including adult salmonids; No AOP – Adult Salmonids: For all aquatic organisms except adult salmonids; Reduced AOP: For all aquatic organisms; Full AOP: for all aquatic organisms*

According to the hydraulic component of the analysis, of the six culverts chosen, three culverts were able to pass the 10-yr storm event; one failed; and two were ranked transitional. For the 25-yr storm event, two culverts passed; two failed; and two were ranked transitional. For the 50-yr storm event, two culverts passed; three failed; and one was ranked transitional. For the 100-yr storm event, only one culvert passed; four failed; and one ranked transitional. The only culvert to handle all four scenarios was the crossing on Old Mill Lane over Fresh Creek. It is important to note that the two culverts located on Sligo Road are susceptible to flooding under the various sea-level rise scenarios.

According to the aquatic organism passage component of the analysis, of the six culverts chosen, one crossing was able to fully accommodate species to navigate the culvert; three were reduced; and two failed to provide the opportunity for species to successfully navigate the culvert.

FEMA Flood Hazard Areas

Maps 11 and 12 Climate Ready Culverts Maps show areas within the 100-year affected by sea-level rise and coastal storm surge flooding. The three sea-level rise scenarios generally fall within the current 100-year floodplain, extending beyond into the 500-year floodplain in certain areas.

From a floodplain management perspective, limiting development and/or strengthening existing regulations within the current 100-year floodplain will provide protection against flood impacts from long term sea level rise. Table 15 reports the acreage within the current 100-year affected by each flood scenario.

TABLE 15: FEMA Flood Hazard Areas (acres) Impacted

Sea Level Rise (SLR) Scenarios	SLR 1.7ft	SLR 4.0ft	SLR 6.3ft	SLR 1.7ft + storm surge	SLR 4.0ft + storm surge	SLR 6.3ft + storm surge
FEMA Flood Hazard Areas						
100-yr floodplain impacted (acres)	10.12	16.42	23.78	22.12	29.15	32.52
100-yr floodplain impacted (%)	100%	100%	97.4%	98.4%	88.8%	76.4%

Floodplain assessment based on Flood Insurance Rate Maps (FIRMs) released by FEMA in September, 2015.

In Rollinsford, the 100-year floodplain is highly sensitive to flooding from sea-level rise mostly along the Salmon Falls River and at the confluence of Chenard Brook and Fresh Creek. Ninety-seven percent of the three sea-level rise scenarios fall within the existing FEMA 100-year floodplain. The town can expect to see further flooding impacts from sea level rise when there is a storm surge on top of the 4.0ft and 6.3ft scenarios. Even so, the 4.0ft scenario with a storm surge falls within 88 percent of the floodplain and the 6.3ft scenario with a storm surge falls with 76 percent of the floodplain.

ISSUES AND CONSIDERATIONS

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

- Using the results of the climate ready culvert analysis will assist the town during long-term planning decisions in regard to the placement, design and size of new culverts or when upgrades and repairs are being made to existing culverts.

- There are two culverts on Sligo Road (1) over Stackpole Brook and (2) over Sligo Brook that currently experience flooding issues. The vulnerability and risk of future failure at these two locations will increase with sea-level rise projections.

- Improving the town's floodplain management by regulating development within the current 100-year floodplain will mitigate impacts from flood impacts from long term sea-level rise. The town can incorporate higher freeboard standards into existing regulatory and management frameworks within the Town's Special Floodplain Hazard Overlay District.

- Protecting both freshwater and tidal wetlands will improve floodplain storage capacity; assist to adequately separate development and infrastructure from these areas; and allow for the inland migration of tidal marsh systems and conversion of freshwater systems to tidal systems to accommodate projected changes in sea-levels.

- Flooding from sea-level rise and coastal storm surge impacting the local roadway network adjacent to the Sligo Road may disrupt local commuting patterns and cause challenges for emergency responders.

- 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.

- Land conservation efforts along Chenard Brook, Sligo Brook, Stackpole Brook, and Salmon Falls River would mitigate future flooding imapcts by guiding development away from those areas and increasing flood storage capacity.

- The Town's District 5, Lower Mill Road wellhead protection area is vulnerable to sea-level rise projections; drinking water resources may be impacted by salt water intrusion. This issue needs further study to identify how saltwater is likely to change the salinity of existing freshwater sources along the coast. Additionally, as sea levels rise, groundwater table elevations are pushed upward, resulting in higher groundwater elevations at significant distances from the coast.

RECOMMENDATIONS

The following recommendations are climate adaptation actions that can be included in Rollinsford's Hazard Mitigation Plan, Master Plan and other planning and policy documents. These actions are focused on strengthening land use development standards, resource protection, municipal policy and plans, and public support to create more resilient development, infrastructure and natural systems.

REGULATORY

R1 - Elevate Structures 2 feet Above Base Flood Elevation. Adopt standards in the town's existing floodplain hazard overlay district that require all new development and redevelopment to be elevated 2 feet above the base flood elevation. Two feet of additional elevation will ensure that structures are protected from flooding based on the highest sea-level rise projection of 2 feet by 2050.

R2 - Coastal Flood Hazard Overlay District. Adopt in the town's zoning ordinance a Coastal Flood Hazard Overlay District that includes performance based standards that protect against flood impacts from sea-level rise and coastal storm surge. Establish the overlay district boundaries based on current flood hazard areas on FEMA Flood Insurance Rate Maps and projected future high risk flood areas mapped by the Climate 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 buffer requirements for setbacks to wetlands that include consideration of climate change in order to protect land that allows coastal habitats and populations to adapt to changing conditions and also provides ecosystem services that protect people, structures, and facilities.

R4 – Culvert Maintenance and Improvement. Adopt ecosystem-friendly approaches in the placement and design of freshwater and tidal stream crossings in order to restore or maintain natural flow regimes to increase ecosystem resilience to extreme weather events and other coastal hazards.

PLANNING AND POLICY

P1 - Natural Hazards Mitigation Plan. Incorporate the vulnerability assessment information and recommendations from the C-RiSe report into the town's next Natural Hazards Mitigation Plan update. Continue revising and updating the assessment information and climate adaptation recommendations in future updates of the Plan as new data and information becomes available.

P2 - Capital Infrastructure and Investments. Incorporate consideration of impacts to the two culverts located on Sligo Road (over Stackpole Brook and Sligo Brook) from sea-level rise and coastal storm surge flooding in current and future capital infrastructure projects. These two assets were the only major infrastructure impacted in the sea-level analysis and should be considered when discussing long-term repairs and upgrades.

P3 - 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.

- Incorporate new scoring criteria into existing land conservation prioritization efforts that consider climate adaptation benefits when evaluating land for conservation purposes.
- Support funding and resources for conservation, land management programs, and land stewardship activities.

P4 - 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 routes to the public with information on the town's website and printed maps.

P5 – Drinking Water Protection. Conduct an investigation of the vulnerability of public drinking water supplies to salt water intrusion. Ongoing groundwater modeling at the University of New Hampshire is investigating the effects of climate change, including sea-level rise, precipitation and temperature, on groundwater levels and the impacts to roads in coastal New Hampshire. The groundwater modeling study will have broader applications as it can be expanded to investigate the effects of climate change on drinking water supply, base flow to streams, and the hydrology of wetlands.

COMMUNITY OUTREACH AND ENGAGEMENT

O1 - Implement FEMA's High Water Mark Initiative. Communities implement the High Water Mark Initiative by providing information on past floods, such as documenting high water marks in public places, and posting maps and photographs of past floods on their websites. High water marks can be displayed on public buildings or on permanently installed markers.

O2 - Coastal Flood Hazard Overlay District. Use the Coastal Flood Hazard Overlay District as a tool to inform property owners of existing and future risks and hazards based on projected sea-level rise and coastal storm surge flooding.

O2 - 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.

APPENDIX – MAP SET