C-RiSe

CLIMATE RISK IN THE SEACOAST

Assessing Vulnerability of Municipal Assets and Resources to Climate Change

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TOWN OF GREENLAND, NEW HAMPSHIRE

Vulnerability Assessment

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

Prepared by the
Rockingham Planning Commission

March 31, 2017

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Cover Photo: Winnicut River
Photo Credit: Jean Eno

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 only intensified by recent increases in the frequency and intensity of extreme storm events and

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
Hazard Mitigation Plan	Stormwater Management Plan	Facilities Management Plan

TABLE OF CONTENTS

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.

FIGURE 1: Sea-Level and Storm Surge Scenarios in Greenland (year 2100)

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

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

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

Storm Surge: ***Storm surge is the rise of water level accompanying intense coastal storm events such 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. The preliminary FIRM's account for the limit of moderate wave action in coastal areas, however this assessment does not take into account additional flooding and impacts related to more severe wave action, wind action, erosion and other dynamic coastal processes.

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

<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]

As shown in Figures 12 and 3 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 2: 2014 Sea Level Rise Scenarios (based on greenhouse gas emissions)

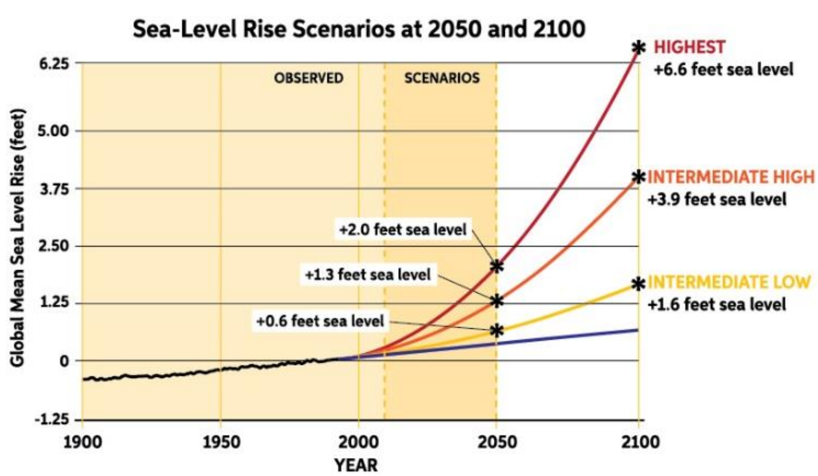
	Lower Emissions (B1)		Higher Emissions (A1fi)	
	2050	2100	2050	2100
Current Elevation of MHHW [a,b]	4.43	4.43	4.43	4.43
100-Year Flood Height	7.78	7.78	7.78	7.78
Subsidence	0.012	0.016	0.012	0.016
Eustatic SLR	1.0	2.5	1.7	6.3
Total Stillwater Elevation [a,c]	**13.2**	**14.7**	**13.9**	**18.5**

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 3: 2014 Sea Level Rise Scenarios (based on greenhouse gas emissions)



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

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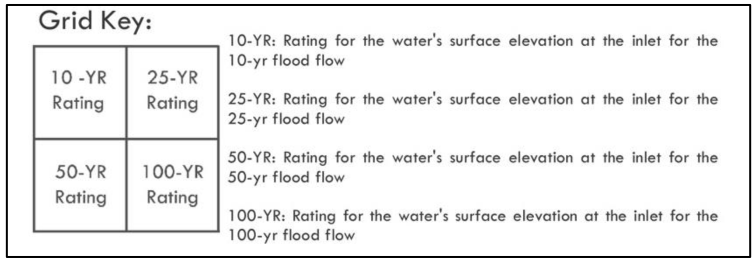
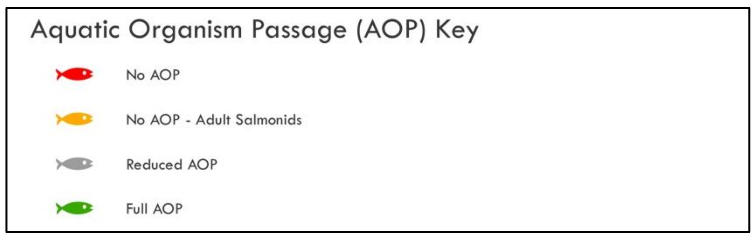
[3] For more information on how sea level rise scenarios were mapped, visit http://granitweb.sr.unh.edu/MetadataForViewers/NHCoastalViewer/RelatedDocuments/Sea_Level_Rise_Narrative_rev20150106_FinalReport.pdf

Data, Methods and Results of Hydrologic and Hydraulic Modeling for RoadCrossings Analyzed

The C-Rise project assessed both aquatic organism passage capacity and hydraulic flow capacity of twelve 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.

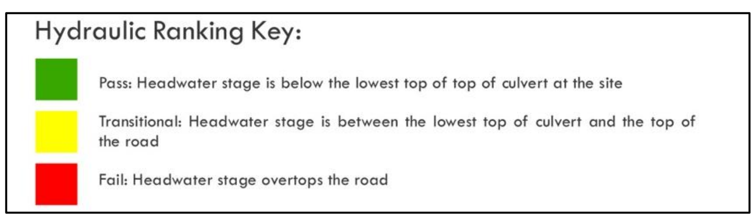


The AOP rating is labeled by color; Red, Orange, Gray, and Green. Ratings of Red and Orange mean that there is estimated to be little to no AOP at that crossing, with Red being no AOP for all species and Orange meaning no AOP for all species except for adult Salmonids. A rating of Gray means that there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

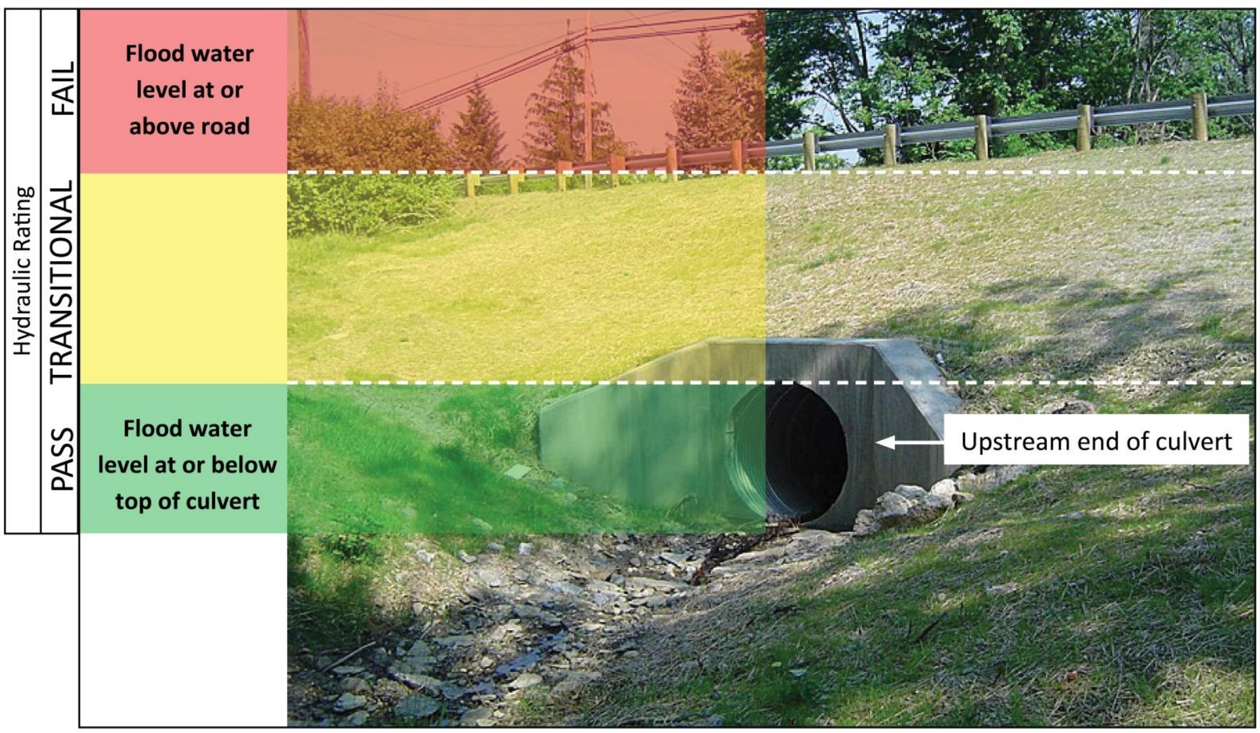
The hydraulic rating is color-coded similar to the AOP rating. The peak flows of the 10-, 25-, 50-, and 100-year storm events were used to assess the ability of the culvert to pass the flow (measured by the depth of water upstream of the culvert – known as the headwater depth) was determined and compared 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, below.

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 4: 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

Figure 5 lists 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.

FIGURE 5: 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. Examples of the two scenario maps are shown on the following page.

Extent of Flooding from Sea Level Rise and Storm Surge

In Figures 5 and 6, the green and pink color schemes are arranged from lightest to darkest with increasing flood levels and extents. The complete C-RiSe map set for Greenland is available on the Rockingham Planning Commission website at http://www.rpc-nh.org/regional-community-planning/climate-change/resources.

FIGURE 5: Sea Level Rise Scenarios 1.7ft, 4.0ft, and 6.3ft

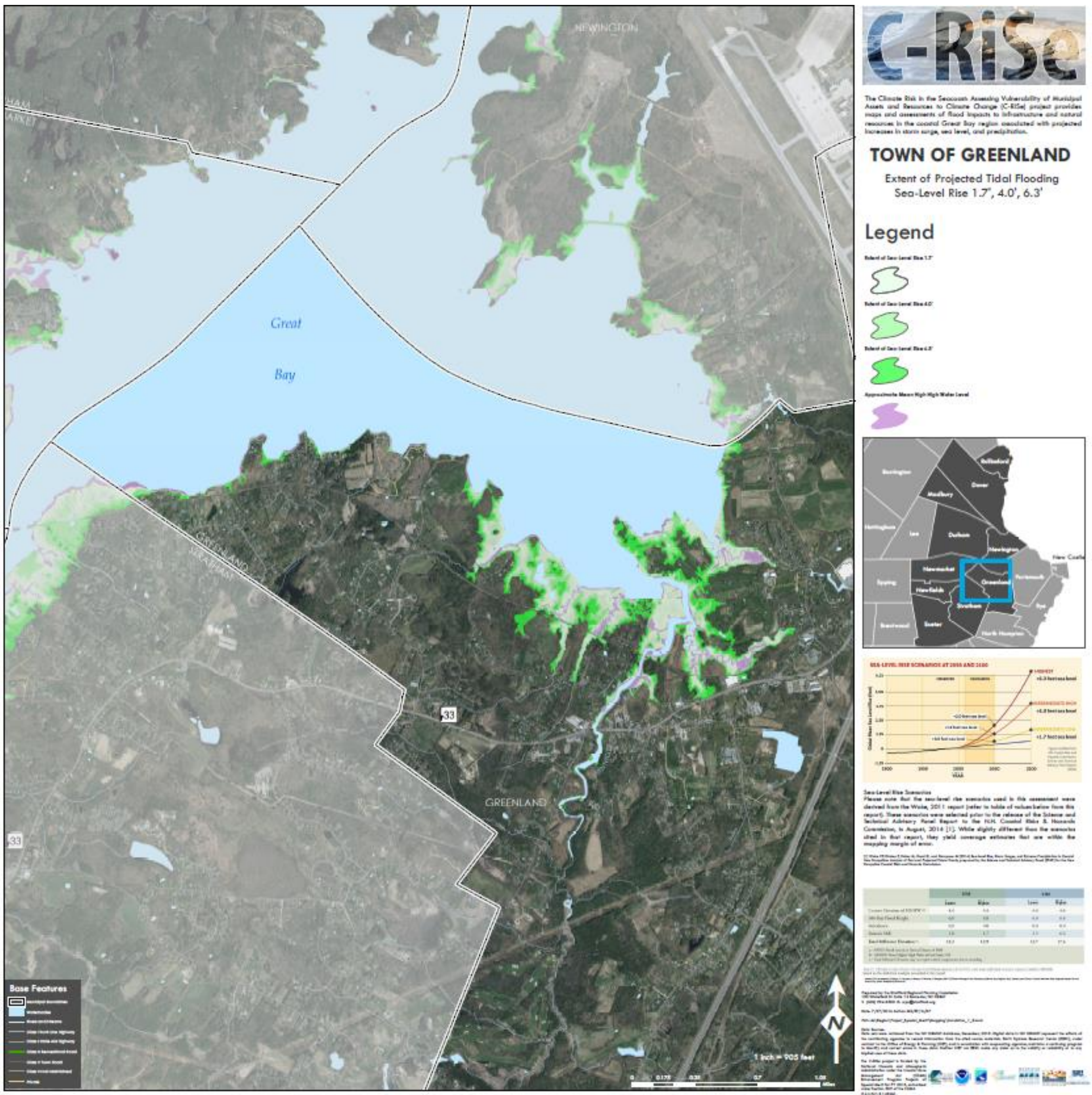
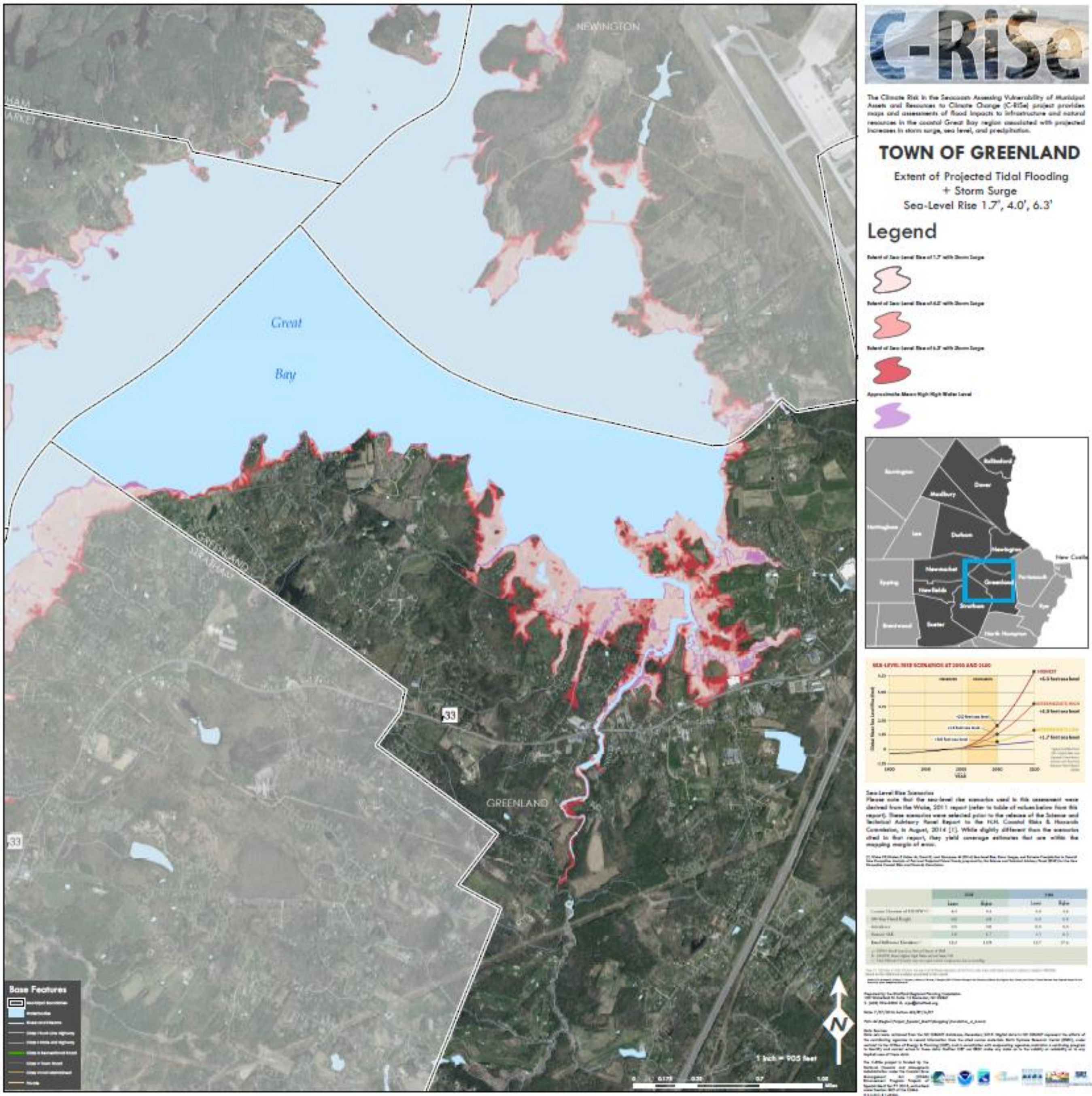


FIGURE 6: Sea Level Rise Scenarios 1.7ft, 4.0ft, and 6.3ft + storm surge

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



Report Acronyms

AOP	Aquatic Organism Passage
CAPE	Climate Adaptation Planning for Exeter
CAW	NH Coastal Adaptation Workgroup
C-RiSe	Climate Risk in the Seacoast
FEMA	Federal Emergency Management Agency
FIRMs	FEMA Flood Insurance Rate Maps
HY-8	Federal Highway Administration's fre 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
Salmonids	family of fish including salmon, trout, chars and white fish
SLAMM	Sea Level Affecting Marshes Model

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.

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]

PURPOSE AND APPLICATIONS OF THE VULNERABILITY ASSESSMENT

The *Climate Risk in the Seacoast* (C-RiSe) vulnerability assessment project produced maps and statistical data about the potential impacts from sea-level rise and storm related flooding to state and municipal infrastructure, critical facilities, transportation systems, and natural resources in New Hampshire's 10 Great Bay coastal municipalities. As shown in Figure 8, the assessment evaluated flood impacts from six sea-level rise and storm surge scenarios - 1.7 feet (intermediate-low), 4.0 feet (intermediate), and 6.3 feet (highest) sea-level rise projections at the year 2100 and these sea-level rise projections with the 100-year storm surge. These scenarios capture a range of plausible projections of sea levels at 2100, from the intermediate-low to the highest scenarios.

FIGURE 8: Sea-Level and Storm Surge Scenarios at year 2100.

Sea Level (SLR) Scenarios	SLR Intermediate Low 2100	SLR Intermediate High 2100	SLR High 2100	SLR + storm surge 2100	SLR + storm surge 2100	SLR + storm surge 2100
Sea Level Rise	1.7 feet	4.0 feet	6.3 feet	--	--	--
Sea Level Rise + Storm Surge	--	--	--	1.7 feet + storm surge	4.0 feet + storm surge	6.3 feet + storm surge

Note: Storm surge is the area flooded by the current 100-year/1% chance storm event as depicted on the FEMA Flood Insurance Rate Maps (preliminary maps, 2014).

The results of this vulnerability assessment can be incorporated into existing municipal plans including the Master Plan, Hazard Mitigation Plan, Road Improvement Plan, Infrastructure Management Plan, and Capital Improvement Plan. These results can also inform zoning amendments such as floodplain development standards and natural resource protection, and land development standards in site plan review regulations and subdivision regulations.

OVERVIEW

The Town of Greenland is located on the eastern edge of Rockingham County, New Hampshire, along Great Bay. The Winnicut River, a tidal tributary to Great Bay flows through town. Municipal buildings and the town center are located along NH Rt. 33 and NH Rt. 151. The town's center is removed from the shoreland of Great Bay, away from the impacts associated with rising sea levels and coastal storm surge. Greenland has a total area of approximately 13.3 square miles of which 10.5 square miles is land and 2.8 square miles is water. The population of the Town was estimated to be 3,668 in 2014.[6]

The Town worked closely with the NH Department of Environmental Services for several years to complete the removal of the Winnicut Dam across the Winnicut River in 2009. The Winnicut Dam was owned by NH Fish

[6] US Census Bureau. American Community Survey, 5-year estimate.

and Game and was situated at the head-of-tide on the river. The dam restricted fish movement within the Winnicut River, which in turn affected other ecological systems dependent upon the fish populations. The dam removal improved upstream and downstream migration for fish, including river herring, American eel, and rainbow smelt, and enabled flood waters to move unrestricted downstream.

It is recommended to the Town that this Vulnerability Assessment be included in updates to the Town's Master Plan and the Town's Hazard Mitigation Plan.

VULNERABILITY ASSESSMENT RESULTS

In Greenland, the areas of highest risk for sea-level risk and storm surge flooding are:

- Tidal wetlands (15% of Greenland's tidal wetlands are impacted by sea-level rise and storm surge)
- Properties and roadways associated with Bayshore Road, Meloon Road, Fairview Terrace, Great Bay Drive West, Bayside Drive, Caswell Drive, Bruce Court
- Rising sea-levels will result in rising groundwater tables near the shoreline, resulting in saltwater intrusion into drinking water wells and increasing the risk of septic system failure
- NH Route 33 between Golf and Ski Warehouse and Rizzo Warehouse/British Aisles
- Shoreland buffers and salt marsh along Great Bay
- Shoreland buffers, salt marsh, and freshwater wetlands along the Winnicut River, Pickering Brook, Packer Brook, Haines Brook, Shaw Brook and Foss Brook
- Natural resources associated with conserved lands, including shoreland, wetlands, marshes, and farmland
- Agricultural land along Great Bay
- Land associated with the Portsmouth Country Club
- Railway line and associated culverts and river crossings
- 202 parcels valued at $94,173,900 and 26 residential structures valued at $15,626,708

Key findings for the Town of Greenland 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 sea-level rise projections with the 100-year storm surge. Figure 7 provides data on the total acreage of each sea level rise scenario.

FIGURE 7: Total Acreage of Sea Level Rise Scenarios in Greenland (year 2100)

	Sea-Level Scenarios					
Community	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)
Greenland	136.1	218.7	335.8	267.7	376.0	496.4

Figure 8 provides a summary of assessment data that was analyzed as part of this project.

FIGURE 8: Summary of Assessment Data (year 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)	0			2 Outdoor Recreation Sites: Great Bay Discovery Center and Portsmouth Country Club		
Critical Facilities (# of sites)	0			2 - Biospray and dam at Country Club Pond		
Transportation Assets (# of sites)	1 Railroad			1 Railroad		
Residential Structures (# of homes)	0	0	3	4	9	26
Uplands (acres)	51.0	119.8	224.0	162.5	261.3	375.5
Roadways (miles)	0	0	0.2	0.8	1.2	1.4
Historic/Recreation Sites	na	na	1	na	na	2
Natural Resources						
Freshwater Wetlands (acres)	2.8	9.5	18.8	14.0	23.4	33.8
Tidal Wetlands (acres)	115.6	123.7	124.9	124.3	125.2	125.9
Aquifers (acres)	0	0	0.1	0.01	0.3	1.2
Wellhead Protection Areas (acres)	11.0	16.2	29.2	20.9	34.3	54.1
Conserved and Public Lands (acres)	59.7	112.2	178.1	142.1	198.8	253.1
Wildlife Action Plan (acres)	129.5	199.6	285.6	236.2	313.3	389.4
Conservation Focus Areas (acres)	130.2	190.3	248.9	218.2	265.9	312.2
100-year Floodplain (acres)	136.1	202.2	210.8	207.1	212.5	222.5
Assessed Value of Parcel Impacted	$72,300,700	$74,659,700	$77,676,500	$81,371,600	$83,017,300	$93,990,000

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. This data does not reflect the fact that some structures may be elevated.

The data indicates that homes and properties along Bayshore Drive, Meloon Road, Bayside Road, Fairview Terrace, Great Bay Drive West, Bruce Court, and Caswell Drive, shoreland associated with the Great Bay Discovery Center and shoreland and upland associated wtih Portsmouth Country Club, tidal wetlands and saltmarsh, uplands above and land identified in the NH Wildlife Action Plan and NH Coastal Watershed Conservation Plan are most vulnerable to flooding from sea-level rise and coastal storm surge in Greenland.

Approximately 75% of the highest sea-level rise scenario (6.3 ft.) falls within the existing FEMA 100-year floodplain. Compared to many municipalities in the region, most of the key infrastructure and community assets are protected from flooding due to their location away from Great Bay and its tributaries.

As shown in *Maps 1 and 2 Extent of Projected Tidal Flooding*, Greenland can expect to see impacts from sea-level rise along the shoreline of Great Bay, the Winnicut River, Pickering Brook, Packer Brook, Shaw Brook, Foss Brook, Haines Brook, as well as smaller tributaries. Unlike other towns in the coastal watershed, the impacts of sea-level rise are not as great in Greenland, due to the rapidly rising slope of land adjacent to the shoreline as well as the relatively undeveloped nature of riverfront land. The active railway line near the River has acted as a dam against land development. The regions of the town most susceptible to coastal flooding are the campsites associated with Great Bay Camping and property and docks along River Road.

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. Figure 9 reports when specific infrastructure types are affected by each sea-level rise and coastal storm surge scenario.

FIGURE 9: Municipal Infrastructure (at year 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
State and Municipal Infrastructure (# of facilities)						
Climate Ready Culverts	na	na	0	na	na	0
Water Access	na	na	1	na	na	1
Dams	na	na	1	na	na	1
Total # of Sites	na	na	2	na	na	2

“na” = not assessed

The boat ramp at Great Bay Discovery Center is considered water access infrastructure. The dam listed in Table 5 is located at Country Club Pond.

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. Figure 10 reports when specific municipal critical facilities are affected by each sea-level rise and coastal storm surge scenario.

FIGURE 10: Municipal Critical Facilities (at year 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
Municipal Critical Facilities						
Sewer Pipes (miles)	0.00	0.00	0.00	0.00	0.00	0.00
Water Pipes (miles)	0.00	0.00	0.00	0.00	0.00	0.00
Total (miles)	0.00	0.00	0.00	0.00	0.00	0.00
Pump Station (# of facilities)	na	na	0	na	na	0
Outdoor Recreation (# of facilities)	na	na	0	na	na	0
Total (# of facilities)	**0**	**0**	**0**	**0**	**0**	**0**

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

None of the Municipal Critical Facilities identified in the Town's Hazard Mitigation Plan are impacted by sea-level rise or storm surge. Note that the Great Bay Discovery Center is an outdoor recreation facility, but, because it provides water borne access into and out of town, it is accounted for under Table 5.

Culvert Assessment - 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. Figure 11 reports the hydraulic and aquatic organism passage ratings for the ten culverts chosen for this analysis.

According to the hydraulic component of the analysis, of the eleven culverts assessed, four culverts were able to pass the 10-yr storm event; three failed; and four were ranked transitional. For the 25-yr storm event, three culverts passed, four failed, and three were ranked transitional. For the 50-yr storm event, three culverts passed, six failed, and two were ranked transitional. For the 100-yr storm event, two culverts passed, seven failed, and two ranked transitional. Two culverts handle all four scenarios, #75, located along Winnicut Road at Thompson Brook, and #77, located along Portsmouth Avenue (NH Rt. 33) on the western edge of the bridge over the Winnicut River.

According to the aquatic organism passage component of the analysis, of the eleven culverts studied, none of the crossings were able to fully accommodate species to navigate the culvert; nine offered reduced passage, and two failed to provide the opportunity for species to successfully navigate the culvert.

FIGURE 11: Culvert Assessment - Climate Ready Culverts

Crossing #	Location	Hydraulic Rating				AOP Rating	
		10-yr	25-yr	50-yr	100-yr	Color	Rating
71	Nantucket Place at Thompson Brool	Transitional	Transitional	Fail	Fail	RED	No AOP
72	Great Bay Road at Foss Brook	Fail	Fail	Fail	Fail	GRAY	Reduced AOP
73	Coastal Way at Shaw Brook	Fail	Fail	Fail	Fail	GRAY	Reduced AOP
74	Coastal Way at Rt. 33	Transitional	Transitional	Transitional	Fail	GRAY	Reduced AOP
75	Winnicut Road at Thompson Brook	Pass	Pass	Pass	Pass	RED	No AOP
76	Caswell Drive at Shaw's Brook	Fail	Fail	Fail	Fail	GRAY	Reduced AOP
77	Rt. 33 at Winnicut River bridge	Pass	Pass	Pass	Pass	GRAY	Reduced AOP
78	Rt. 33 at Winnicut River near Country View Restaurant	Transitional	Fail	Fail	Fail	GRAY	Reduced AOP
79	Rt. 33 at Packer Brook	Pass	Pass	Pass	Transitional	GRAY	Reduced AOP
80	Post Road at Norton Brook	Transitional	Transitional	Transitional	Transitional	GRAY	Reduced AOP
81	Breakfast Hill Road at Railroad tracks	Transitional	Fail	Fail	Fail	GRAY	Reduced AOP

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.

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

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. Figure 12 reports the miles of state and local roadways affected by each flood scenario.

Impacts from sea-level rise and storm surge to both state and local roadways are absent or quite low under all scenarios. However, a stretch of Portsmouth Avenue-Route 33 is impacted under the three storm surge scenarios. As a major part of the town and regional transportation network, the impacted portion of Portsmouth Avenue-Route 33 should be addressed as a near term strategy to improve resilience for public safety, business continuity, employment access and emergency services.

FIGURE 12: State and Municipal Roadways and Infrastructure (miles) (year 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
Roadway Type						
State	0.00	0.00	0.00	0.24	0.54	0.72
Local	0.00	0.00	0.23	0.52	0.62	0.98
Private	0.00	0.00	0.00	0.00	0.00	0.00
Not Maintained	0.00	0.00	0.00	0.00	0.00	0.00
Total Road Miles	**0.00**	**0.00**	**0.22**	**0.76**	**1.16**	**1.70**

Figure 13 provides greater detail as to which roads are impacted.

FIGURE 13: Greenland's Road Asset Impacts (year 2100)

Sea Level Rise (SLR) Scenarios		SLR 6.3 feet	SLR 6.3 feet + storm surge
Road Name	Road Class	Miles Impacted	Miles Impacted
Bayshore Drive	Local	0.03	0.30
Bayview Terrace	Local	0.06	0.07
Caswell Drive	Local	0	0.04
Fairview Terrace	Local	0.04	0.12
Great Bay Drive West	Local	0.09	0.12
Private Road – No Name	Private	0	0.33
Portsmouth Avenue (Rt. 33)	State	0	0.72
Total Road Miles		0.22	1.70

This analysis determined there are four roads that are vulnerable to the high sea-level rise and an additional three roads that are vulnerable to sea-level rise with storm surge in Greenland. The road with the greatest impact is Portsmouth Avenue (NH Rt. 33), with 0.72 miles projected to be impacted by flooding under a 6.3ft sea-level rise scenario with storm surge. Maps 5 and 6 provide a visual representation of the impacts to roads in Greenland. It is important to consider that although less than one mile of a roadway may be projected to be impacted by the high sea-level rise scenario, the effect of flooding on these segments may result in closure of an evacuation route, reduced or loss of access to other roads, infrastructure, critical facilities, homes, and other assets and resources.

The transportation asset identified in Figure 14 is a NH DOT project along Portsmouth Avenue (NH Rt. 33) at Winnicut Road.

FIGURE 14: Greenland's Other Transportation Asset Impacts (year 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
Roadway Type						
NHDOT Projects (# of sites)	na	na	1	na	na	1

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. Figure 15 reports the number of acres for each natural land resource affected by each sea-level rise and coastal storm surge scenario. Table 11 reports the number of acres for each natural water resource.

FIGURE 15: Natural Land Resources (acres) (year 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
Natural Land Resources (acres)						
Conservation Lands	59.7	112.2	178.1	142.1	198.8	253.1
Wildlife Action Plan (Total for Tiers 1, 2 and 3)	129.5	199.6	285.6	236.2	313.3	389.4
Conservation Focus Areas	130.2	190.3	248.9	218.2	265.9	312.2
Total land resources	**319.4**	**502.0**	**712.7**	**596.5**	**777.9**	**954.7**

There are ten conservation properties impacted by rising sea-levels and storm surge: Emery, GCNE Easement, Great Bay Shoreline South, Great Bay WMA, Hughes #1, Leonard Weeks and Descendents, Portsmouth Country Club, Sandy Point, Smith Tract, and the Town of Greenland parcel.

The acres of Tier 1, 2, and 3 Wildlife Action Plan habitat impacted by sea-level rise and coastal storm surge are another indication of the sensitivity of wildlife habitat to rising water levels. Tier 1 habitat, deemed the most critical habitat for wildlife, is by far the most impacted of the three habitat types, with up to 333.25 acres vulnerable to flooding and storm surge under the highest sea-level rise scenario (6.3 ft.) with storm surge.

As depicted in Figure 16, water resources including wetlands, aquifers, and drinking water protection areas are vulnerable to sea-level rise. Estuarine and marine wetlands are the most impacted water resource in Greenland, with approximately 126 acres impacted under the highest sea-level rise scenario (6.3 ft.) with storm surge. Over 15% of Greenland's tidal wetlands are projected to be impacted by sea-level rise and storm surge.

FIGURE 16: Natural Water Resources (acres) (year 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
Natural Water Resources (acres)						
Wellhead Protection Areas	11.0	16.2	29.2	20.9	34.3	54.1
Estuarine and Marine Wetlands	115.6	123.7	124.9	124.3	125.2	125.9
Freshwater Wetlands	2.8	9.5	18.8	14.0	23.4	33.8
Stratified Drift Aquifers	0.00	0.00	0.1	0.01	0.3	1.2
Total water resources	**129.4**	**149.5**	**173.0**	**159.2**	**183.2**	**215.1**

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). Figure 17 reports the number of acres of upland affected by each flood scenario.

FIGURE 17: Uplands (acres) (year 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
Uplands (acres)						
Acres	51.0	119.8	224.0	162.5	261.3	375.5
% Upland	0.08%	1.88%	3.52%	2.55%	4.11%	5.90%

Total Upland in Greenland = 6,357 acres.

The upland areas surrounding the Winnicut River, Pickering Brook, Packers Brook, Shaw Brook and Foss Brook are the portions of Greenland most impacted by sea-level rise and storm surge. Smaller pockets of impacted uplands lay along the shoreline of the Winnicut River. Under the high sea-level rise scenario (6.3 ft.) with storm surge as much as 5.90% of the upland area of the town is vulnerable to sea-level rise and storm surge.

Parcels and Assessed Value

Figure 18 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.

In Greenland, the number of impacted parcels ranges from 135 to 202, and values of $72,502,100 to $94,173,900, respectively.

FIGURE 18: Parcels and 2016 Assessed Value by Scenario (year 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
Parcels and Assessed Value						
Parcels Affected (# of parcels)	135	141	160	149	170	202
Aggregate Value of Parcels ($ value)	$72,502,100	$74,861,100	$81,573,000	$78,556,200	$83,218,700	$94,173,900

Note: This data does not reflect the fact that some structures may be elevated. Data source: NH Department of Revenue Administration Property Appraisal Division CAMA.

Figure 19 reports the number of residential structures affected by each of the six scenarios evaluated and the aggregated assessed value of these homes.

FIGURE 19: Residential Structures and 2016 Assessed Value (year 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
Residential Structures and Assessed Value						
Structures Affected (# of homes)	0	0	4	1	9	26
Assessed Value of homes ($ value)	0	0	$2,739, 700	$625,000	$5,844,800	$15,626,709

Data source: NH Department of Revenue Administration Property Appraisal Division CAMA. Data digitized by SRPC.

Greenland does not experience any impacts to homes under the first two sea-level rise scenarios. However, there is a significant increase in the number of residential parcels impacted by the high sea-level rise scenario (6.3 ft.) with storm surge, 26 parcels in total, as compared to no parcels under the low level sea-rise scenario (1.7 ft.). These 26 residential parcels have an assessed value of $15,626,709.

FEMA Flood Hazard Areas

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

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. Figure 20 reports the acreage within the current 100-year floodplain affected by each flood scenario.

FIGURE 20: FEMA Flood Hazard Areas (acres) Impacted

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
FEMA Flood Hazard Areas						
100-yr floodplain impacted (acres)	136.1	202.2	210.8	207.1	212.5	222.5
Percentage of SLR within the floodplain	100%	92.5%	62.8%	77.4%	56.5%	44.8%

Floodplain assessment based on FEMA Flood Insurance Rate Maps (FIRMs) dated May 17, 2005.

In Greenland, the 100-year floodplain is highly sensitive to flooding from sea-level rise along Great Bay, Winnicut River, Pickering Brook, Packer Brook and other creeks and brooks flowing into Great Bay. According to this analysis, 100% of the lowest level sea-level rise (1.7 ft.) occurs within the floodplain. As storm surge is integrated into the sea-level rise analysis, roughly 44.82% of the highest sea-level rise scenario (6.3 ft.) falls within the existing FEMA 100-year floodplain. Note that the percentage of flooding that occurs in the floodplain decreases as the sea-level rise and associated storm surge increase because more flooding is occurring within and beyond the boundaries 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 members.

- Using the results of the climate ready culvert analysis will assist the Town with 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.

- According to the hydraulic component of the analysis, of the eleven culverts chosen, four were able to pass the 10-yr storm event, three failed, and four ranked transitional. The vulnerability and risk of future failure at these locations will become greater with an expected increase in the frequency of extreme precipitation events.

- Several town roads were identified as vulnerable to either projected sea-level rise or coastal storm surge. These roads include Great Bay Drive West, Bayshore Drive, Meloon Road, Caswell Drive, Bayside Road, and Fairview Terrace. A portion of one state road was identified as vulnerable; Portsmouth Avenue (NH Rt. 33) near Golf and Ski Warehouse. The railroad tracks and railroad bridge crossing the Winnicut River are impacted by sea-level rise and storm surge.

- As sea-levels rise in Great Bay and its tributaries, septic systems located in inundation areas are at risk of failure, posing a threat to groundwater and drinking water supplies. Groundwater tables located near the shoreline will rise, impacting leachfields and reducing the ability of the system to treat bacteria and pathogens in wastewater. Review of the Town's septic system regulations and consultation with NH DES is recommended to identify changes need in regulations to address failure of existing and proposed septic systems.

- 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.

- Ten parcels of conservation land are vulnerable to sea-level rise and coastal storm flooding. The impacts of flooding and salt water on conservation land will vary greatly depending on the types of natural communities present.

- Land conservation efforts and land use planning efforts along Great Bay, the Winnicut River, and other tributaries in Greenland may mitigate future flooding impacts by guiding development away from those areas and increasing flood storage capacity. Additional conservation land along Great Bay River will increase capacity to mitigate future flooding.

- While the land above groundwater resources is vulnerable to sea level rise and storm surge, it is unclear what the impact of saltwater intrusion due to sea level rise and storm surge on aquifers and groundwater may be in the town. A preliminary study modeling the impacts of sea level rise on drinking water is currently ongoing. 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-level rises, groundwater table elevations are pushed upward, resulting in higher groundwater elevations at significant distances from the coast.

- 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.

RECOMMENDATIONS

The following recommendations are short-term climate adaptation actions that can be included in the Town'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 - 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 Vulnerability Assessment. (Also see similar recommendation in the Community Outreach and Engagement section below.)

R2 - 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.

R3 – 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.

R4 – Siting and Design of Structures, Including Septic Systems. Ensure that the best available climate science and flood risk information are used for the siting and design of new, reconstructed, and rehabilitated municipal structures and facilities and private structures, including homes and their associated septic systems and drinking water wells.

PLANNING AND POLICY

P1 – Municipal Hazard Mitigation Plan. Incorporate the vulnerability assessment information and recommendations from the C-RiSe report into the Town's Hazard 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 municipal infrastructure such as roadways, bridges and culverts into current and future capital infrastructure projects. Evaluate the extent of sea-level rise and storm surge flooding on outfalls along shorelines.

P3 - 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.

P4 - Land Conservation. Land conservation offers an opportunity to adapt 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, including migration for tidal wetlands and salt marsh.
- Support funding and resources for conservation, land management programs, and land stewardship activities.

P5 – Drinking Water Protection. Incorporate findings of the University of New Hampshire's investigation of impacts of sea level rise on groundwater into Hazard Mitigation Plans and long term drinking water protection planning. Other 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.

P7 – Road Maintenance. Evaluate the extent of sea-level rise and storm surge flooding to sections of roadway serving the Great Bay Campground. Ensure that all existing and future transportation related projects within identified vulnerable areas take projected sea-level rise scenarios into account.

P8 – Model Ordinance. Collaborate with NHDES, NHOEP, RPCs, and technical experts to create a model ordinance for climate change.

COMMUNITY OUTREACH AND ENGAGEMENT

O1 - Implement FEMA's High Water Mark Initiative. This initiative is a community-based awareness program that increases local communities'' awareness of flood risk and encourages action to mitigate that risk. 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. For more information visit: https://www.fema.gov/about-high-water-mark-initiative.

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.

Example of a living shoreline (Photo Credit: Vance Miller, from Living Shorelines Academy)

APPENDIX – MAP SET

Map 1: Extent of Projected Tidal Flooding - SLR 1.7', 4.0' and 6.3'
Map 2: Extent of Projected Tidal Flooding - SLR + Storm Surge
Map 3: Critical Facilities and Infrastructure - SLR 1.7', 4.0' and 6.3'
Map 4: Critical Facilities and Infrastructure - SLR + Storm Surge
Map 5: Roads and Transportation Assets - SLR 1.7', 4.0' and 6.3'
Map 6: Roads and Transportation Assets - SLR + Storm Surge
Map 7: Land Resources - SLR 1.7', 4.0' and 6.3'
Map 8: Land Resources - SLR + Storm Surge
Map 9: Water Resources - SLR 1.7', 4.0' and 6.3'
Map 10: Water Resources - SLR + Storm Surge
Map 11: Climate Ready Culverts - SLR 1.7', 4.0' and 6.3'
Map 12: Climate Ready Culverts - SLR + Storm Surge