C-RiSe

CLIMATE RISK IN THE SEACOAST

Assessing Vulnerability of Municipal Assets and Resources to Climate Change

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

TOWN OF NEWMARKET, NEW HAMPSHIRE

Vulnerability Assessment

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




Prepared by the
Strafford Regional Planning Commission

January 2017

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Diane Hardy	Town Planner, Town of Newmarket
Rick Malasky	Public Works Director, Fire Chief, Town of Newmarket
Bill Arcieri	Resident

Cover Photo Credit: Newmarket Fire and Rescue Department

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 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 Newmarket (year 2100)

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

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.

Sea-Level Rise Scenarios: 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)

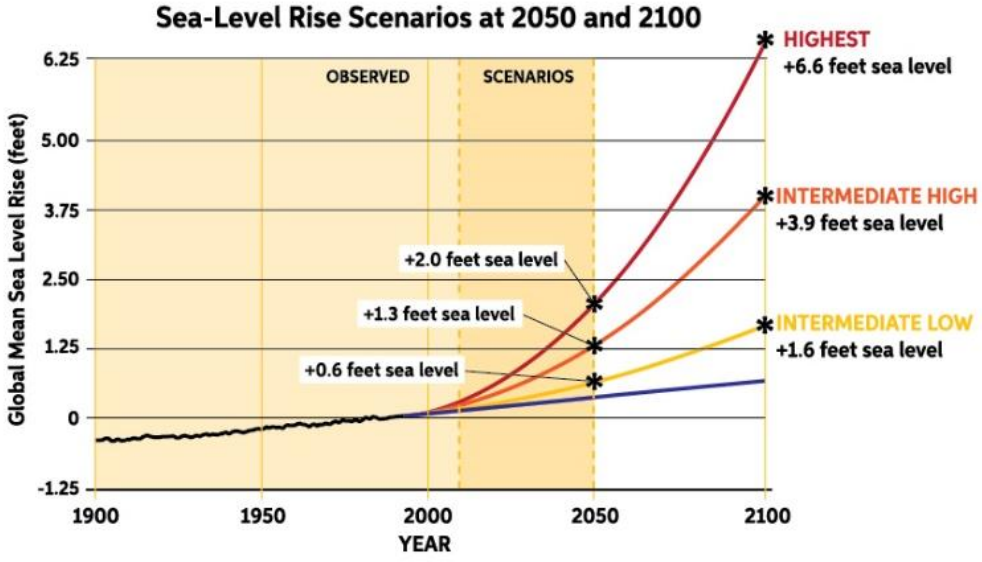
	Lower Emissions (B1)		Higher Emissions (A1fi)	
	2050	2100	2050	2100
Current Elevation of MHHW [a,b]	4.43	4.43	4.43	4.43
100-Year Flood Height	7.78	7.78	7.78	7.78
Subsidence	0.012	0.016	0.012	0.016
Eustatic SLR	1.0	2.5	1.7	6.3
Total Stillwater Elevation [a,c]	**13.2**	**14.7**	**13.9**	**18.5**

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.

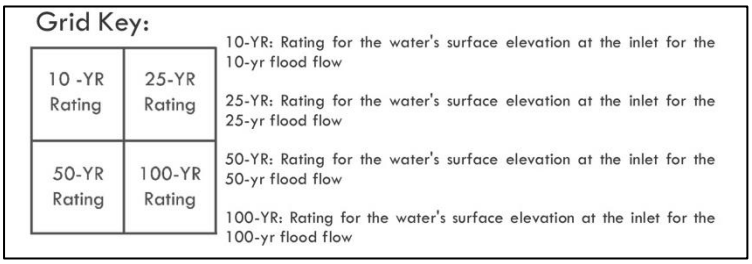
Figure 2: 2014 Sea Level Rise Scenarios (based on greenhouse gas emissions)



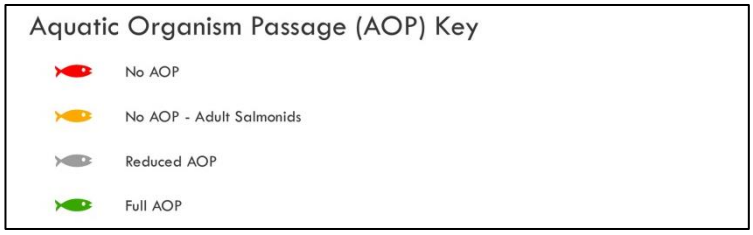
Source: Wake CP, Kirshen P, Huber M, Knuuti K, and Stampone M (2014) *Sea-level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire: Analysis of Past and Projected Future Trends*, prepared by the Science and Technical Advisory Panel for the New Hampshire Coastal Risks and Hazards Commission.

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

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.

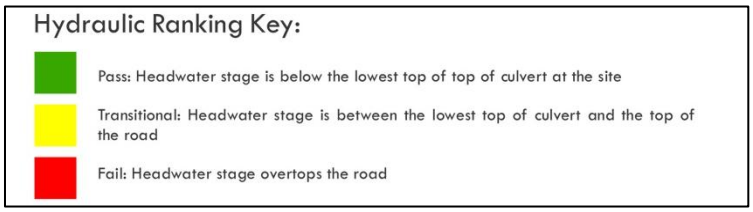


The AOP rating is labeled by color; Red, Orange, Gray, and Green. Ratings of Red and Orange mean that there is estimated to be little to no AOP at that crossing, with Red being no AOP for all species and Orange meaning no AOP for all species except for adult Salmonids. A rating of Gray means that there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

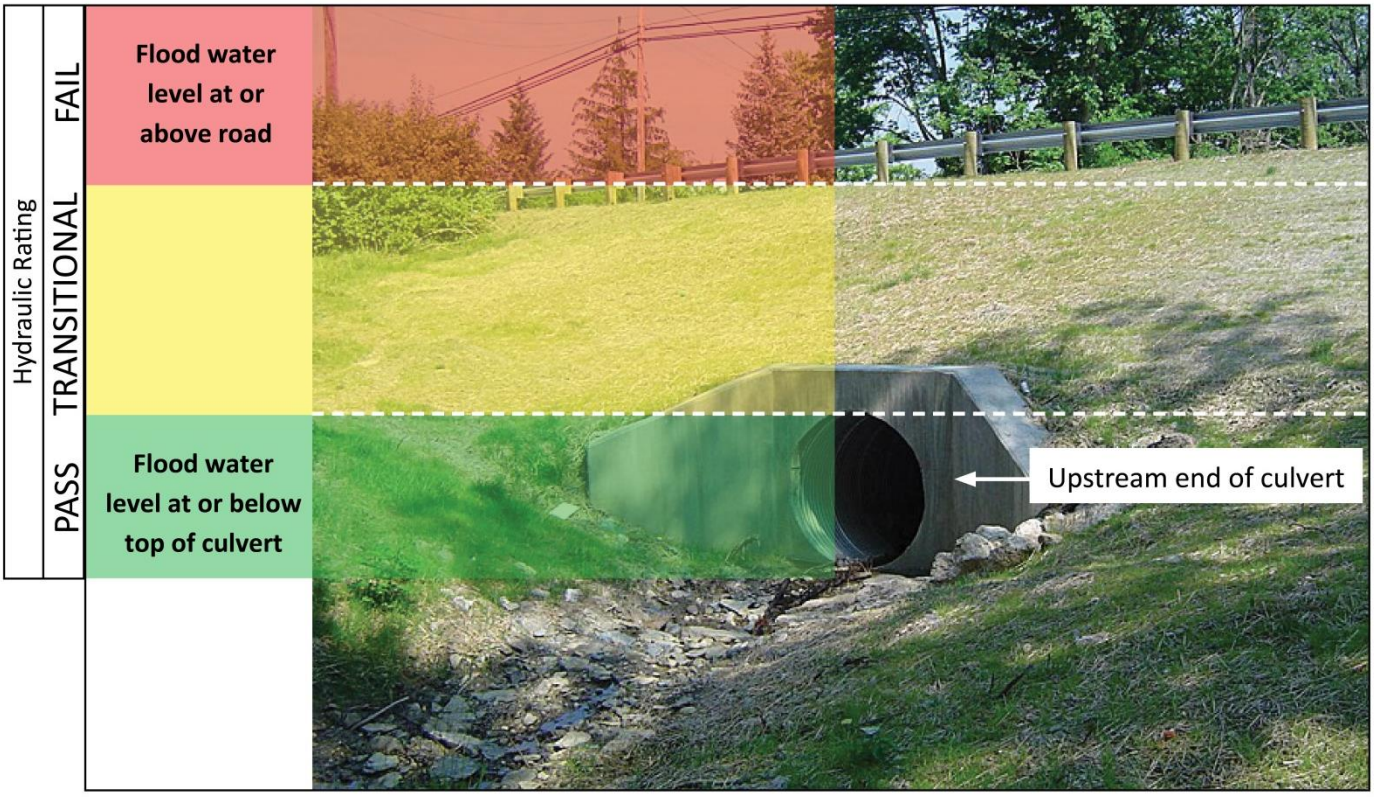
The hydraulic rating is color-coded similar to the AOP rating. The peak flows of the 10-, 25-, 50-, and 100-year storm events were used to assess the ability of the culvert to pass the flow (measured by the depth of water upstream of the culvert – known as the headwater depth) was determined and compared 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 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 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. Examples of the 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. To zoom in and view the full map and key, see the large format maps.

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

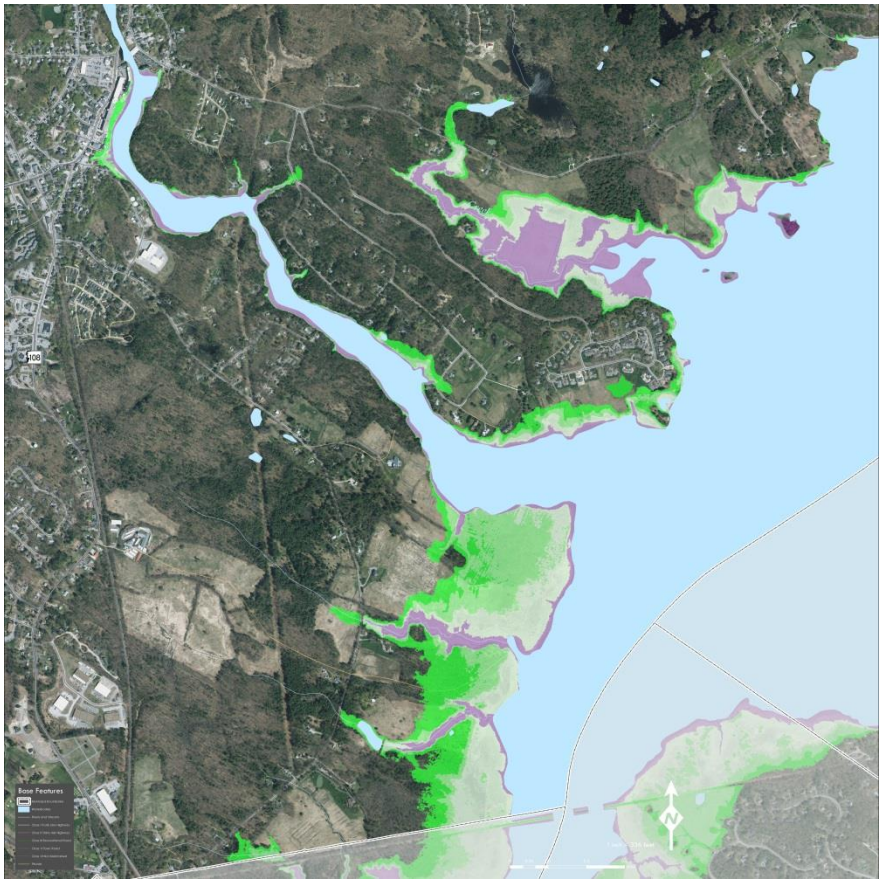
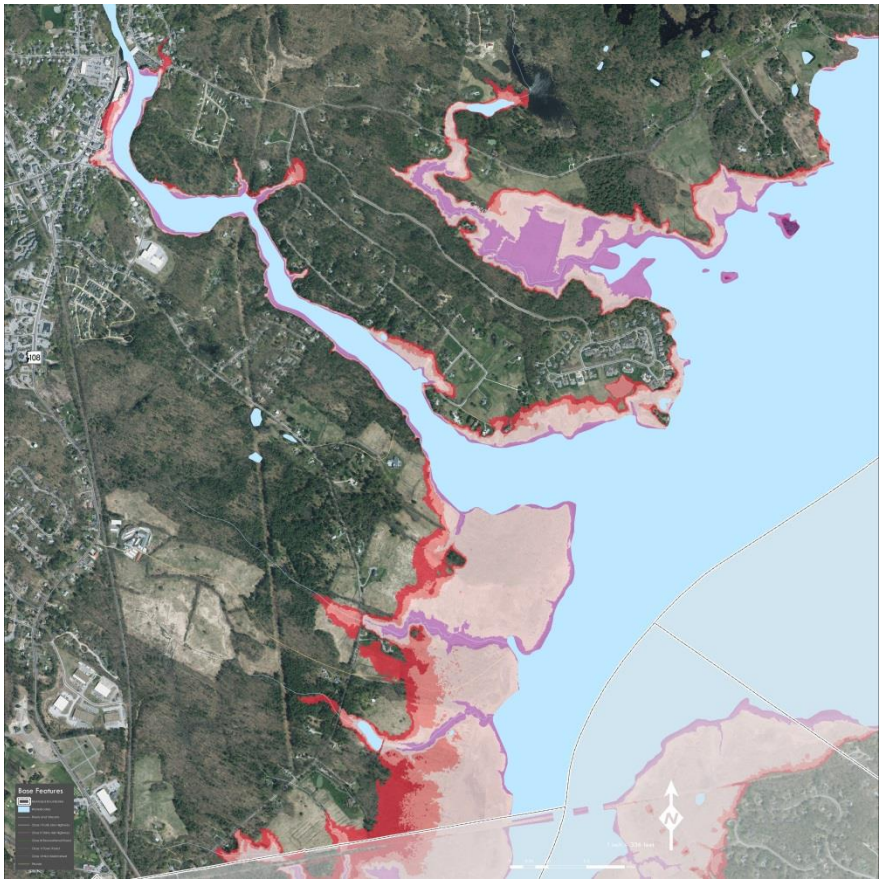


Figure 5: Sea Level Rise Scenarios 1.7ft, 4.0ft, and 6.3ft + storm surge



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

OVERVIEW

The Town of Newmarket is located in southeastern Rockingham County, New Hampshire. Newmarket is located along the Lamprey River and Great Bay. The center of the town is located at the junction of NH Route 108 and NH Route 152. Newmarket has a land area of approximately 12.5 square miles. Water accounts for approximately 1.6 square miles or 12.8% of the total area of the Town. The population of the Town was estimated at 8,928 in 2014.[6]

Completed and Ongoing Efforts

The Strafford Regional Planning Commission (SRPC) received 2014 funding from the NH Coastal Program to provide technical assistance to the Town in preparing an update of its Master Plan Vision and Future Land Use Chapters. The Future Land Use Chapter also references specific recommended actions from the Coastal Risks and Hazards Commission Report. Specifically, SRPC and the Town sought to integrate goals and recommendations in this planning document that would increase resilience to climate change and protect coastal infrastructure and resources. This is reflected in the following statements:

- *The community is more resilient against coastal and riverine flooding in large part due to local land use policies and regulations that reduce risk and vulnerability* (Vision Chapter, Vision Statement)
- *The integration of climate adaptation measures into municipal programs, policies, and operations reflect Newmarket's commitment to reduce community risk. Smart development has led to a greater resilience against adverse impacts and infrastructure vulnerability associated with climate changes, such as sea level rise and increased flooding* (Vision Chapter, Newmarket's Vision for the Future).

The Nature Conservancy implemented Phase I of the Lubberland Creek Culvert Restoration in Newmarket in 2015 and 2016. The culvert replacement will 1) restore aquatic connectivity, 2) enhance the resilience of the Lubberland Creek salt marsh and allow upstream salt marsh migration as sea levels continue to rise, and 3) remediate the flood hazard of the road-stream crossing which overtops during major flood events.

With Horsley Witten Group, Inc., the Town completed a project in 2015 and 2016 to build resilience to flooding and climate change in the Moonlight Brook Watershed. Moonlight Brook is a tributary to the Lamprey River. The project team conducted a two-part effort to 1) study flood risk associated with climate change and how future development and build out of the community affect these risks, and 2) design robust green infrastructure practices within the watershed to help reduce risk of flooding while reducing pollutant load.

In 2016, SRPC and the University of New Hampshire, with guidance from a technical advisory committee, initiated a modeling study to investigate the potential impacts of sea-level rise on groundwater and public drinking water supplies. The project will model three sea-level rise scenarios and identify areas where drinking water may be vulnerable to salt water intrusion. It will also help guide future development and future well siting away from the vulnerable areas of the town.

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

VULNERABILITY ASSESSMENT RESULTS

Key findings for the Town of Newmarket 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. 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 Newmarket (year 2100)

	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)
Newmarket	79.98	150.57	225.45	186.47	247.22	308.16

TABLE 4: Summary of Assessment Data (year 2100)

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)	2			3		
Critical Facilities (# of sites)	4			4		
Transportation Assets (# of sites)	2			2		
Residential Structures (# of homes)	0	1	2	2	2	6
Uplands (acres)	36.4	101.7	172.9	136.0	193.9	253.5
Roadways (miles)	0.00	0.12	0.37	0.24	0.44	0.66
Freshwater Wetlands (acres)	7.04	23.39	34.32	30.52	37.14	45.48
Tidal Wetlands (acres)	66.28	72.36	73.20	72.90	73.27	73.42
Aquifers (acres)	0	0	0	0	0	0
Wellhead Protection Areas (acres)	47.92	67.86	96.80	79.58	103.43	123.08
Conserved and Public Lands (acres)	35.17	70.42	94.67	82.90	100.67	115.92
Wildlife Action Plan (acres)	78.55	142.77	203.40	174.09	220.52	266.00
Conservation Focus Areas (acres)	73.63	133.05	187.22	160.46	203.48	244.26
100-year Floodplain (acres)	50.78	66.33	82.69	74.16	86.66	96.9

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.

Summary of Findings: The data indicates that significant acreage of tidal wetlands, wellhead protection areas (local drinking water supplies), conservation and public lands, and Wildlife Action Plan priority habitat are vulnerable to flooding from sea-level rise and coastal storm surge in Newmarket. Between 36.68% and 63.49% of sea-level rise occurs within the 100-year floodplain in the three sea-level rise scenarios. When storm surge is added, the percent of sea-level rise that occurs within the floodplain is 31.44%-39.77%, depending on the sea-level rise scenario, indicating

that with storm surge, even more of the flooding that is projected to occur will occur outside of the 100-year floodplain. Higher sea-level rise scenarios and the addition of storm surge significantly increases the amount of upland land that is vulnerable to sea level rise; as much as 253.5 acres of upland are vulnerable to a 6.3 foot sea-level rise with storm surge scenario. Two to three types of infrastructure are impacted by sea-level rise and sea-level rise with storm surge depending on the scenario. Four critical facilities and two transportation assets are impacted by all sea-level rise and storm surge scenarios considered in this vulnerability assessment. As much as 0.66 miles of roadway may be directly impacted by a high sea-level rise scenario with storm surge; this drops to 0.12 miles with moderate sea-level rise and no storm surge, and 0 miles under the low sea level rise with no storm surge scenario. The following sections include more details about vulnerable assets and structures.

As shown in *Maps 1 and 2 Extent of Projected Tidal Flooding*, Newmarket can expect to see impacts from sea-level rise in several areas of town. The regions of the town that are most susceptible to coastal flooding are those located south of the Macallen Dam on the west side of the Lamprey River near the downtown, low-lying areas around Lubberland Creek, and low-lying land south of the Lamprey River along Great Bay. In addition, small sections of 10 different roads in the Town are vulnerable to low, moderate, and high sea-level rise scenarios (with and without storm surge).

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 (year 2100)

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	1			1		
Water Access	1			1		
Dams	0			1		
Total # of Sites	2			3		

One culvert on Lubberland Creek, a water access site on the Lamprey River, and one dam on the Lamprey River were the only impacted infrastructure from projected sea-level rise and/or sea-level rise and coastal storm surge flooding.

The culvert, located on Bay Road, was chosen to be a part of the UNH's climate ready culvert analysis. According to municipal staff, this culvert has experienced failures in the past due to flooding. The Nature Conservancy completed Phase 1 of a culvert upgrade project at this location in 2016. Phase 2 includes the development of a tidal culvert assessment protocol review of best practices for tidal culverts.

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 (year 2100)

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						
Sewer Pipes (miles)	0.00	0.02	0.03	0.03	0.04	0.08
Water Pipes (miles)	0.00	0.00	0.00	0.00	0.00	0.00
Total (miles)	0.00	0.02	0.03	0.03	0.04	0.08
Pump Station (# of facilities)	1			1		
Outdoor Recreation (# of facilities)	1			1		
Total (# of facilities)	2			2		

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

Short segments of the municipal sewer pipes are impacted by flooding from moderate and high sea level rise scenarios. These segments are located at located at the end of Water Street and Creighton Road and at Lamprey Street and the intersection with Bay Road. A total of 0.03 miles (158ft) are vulnerable to a high sea-level rise scenario. When storm surge is added, this increased with 0.08 miles (422.4ft). Additional vulnerable infrastructure includes a pump station and water access site near Schanda Park on the Lamprey River. Flooding associated with these sea-level rise scenarios is not projected to occur over water pipes.

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) (year 2100)

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	0.02	0.09	0.04	0.14	0.28
Private	0.00	0.10	0.28	0.20	0.30	0.38
Not Maintained	0.00	0.00	0.00	0.00	0.00	0.00
Total Road Miles	0.00	0.12	0.37	0.24	0.44	0.66

The total number miles impacted under the 6.3ft of sea-level rise with storm surge scenario are 0.66 miles. No roadways in Town are projected to be impacted under a low sea-level rise scenario; when storm surge is added, about one quarter of a mile of roadway will be impacted under the 1.7ft sea-level rise scenario. Private roads are the most sensitive to sea-level rise and coastal storm flooding in Newmarket.

TABLE 8: Newmarket's Road Asset Impacts (year 2100)

Sea Level Rise (SLR) Scenarios		SLR 6.3ft	SLR 6.3ft + storm surge
Road Name	Road Class	Miles Impacted	Miles Impacted
Bay Road	Local	0.03	0.07
Bayview Road	Private	0.03	0.04
Lamprey Street	Local	-	0.03
Moody Point Drive	Local	0.02	0.05
New Road	Local	-	0.02
Private Road (off New Road)	Private	0.25	0.33
Smith Garrison Road	Local	0.01	0.05
Stevens Drive	Local	-	0.01
Young Lane	Local	0.03	0.04
Water Street	Local	0.01	0.01
Total Road Miles		0.38	0.65

This analysis determined that there are seven 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 Newmarket. There are no state roads impacted. The road with the greatest impact is a private road off New Road, 0.25 miles of which are projected to be impacted by flooding under a 6.3ft sea-level rise scenario and 0.33 miles impacted under this scenario plus storm surge. The total number of miles impacted by 6.3ft sea-level rise scenario increased by approximately 70% when storm surge is added. Maps 5 and 6 provide a visual representation of these impacts. It is important to consider that although less than one mile of roadway is projected to be impacted by the high sea-level rise scenario, the effect of flooding on these segments may result in reduced or loss of access to other roads, infrastructure, critical facilities, homes, and other assets and resources.

Table 9: Newmarket's Other Transportation Asset Impacts (year 2100)

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						
NHDOT Projects (# of sites)	1			1		

The following are other transportation related assets that are vulnerable to sea-level rise and coastal storm flooding, including: one NHDOT Bay Road repair in 2016 associated with the May 2006 flood event.

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 10 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.

TABLE 10: Natural Land Resources (acres) (year 2100)

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	35.17	70.42	94.67	82.90	100.67	115.92
Wildlife Action Plan	78.55	142.77	203.40	174.09	220.52	266.00
Conservation Focus Areas	73.63	133.05	187.22	160.46	203.48	244.26
Total land resources	187.35	346.24	485.29	417.45	524.67	626.18

A significant number (14 properties) of conservation lands are sensitive to sea-level rise and coastal storm flooding, however the acres of impacted land vary significantly by property and range from less than one acre to as much as 38.88 acres. A total of 115.92 acres of conservation land are impacted by flooding associated with sea-level rise and storm surge. The impacts of flooding and salt water on conservation lands will also vary greatly depending on the types of natural communities present.

The acres of Tier 1, 2, and 3 Wildlife Action Plan habitat impacted by sea-level rise and coastal storm surge is another indicator of how sensitive wildlife habitat is to changes in water levels. Tier 1 habitat is by far the most impacted of the three habitat types, with up to 226.55 acres that are vulnerable to flooding. There are also three Conservation Focus Areas identified as vulnerable including Crommet Creek, Lower Lubberland Creek, and Squamscott River.

TABLE 11: Natural Water Resources (acres) (year 2100)

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

Water resources including wetland, aquifers, and drinking water protection areas are vulnerable to sea-level rise. Under a low sea-level rise scenario, 1.10 acres of land within the wellhead protection area for the Moody Point well are flooded by sea-level rise. This acreage increases to 7.96 acres under a low sea-level rise scenario with storm surge, and as many as 21.24 acres of land are flooded under a high sea-level rise scenario with storm surge. Slightly more acres of stratified drift aquifer are impacted by each sea-level rise scenario than the acres of land within wellhead protection areas. Up to 15.19 acres of freshwater wetlands are vulnerable to flooding from sea-level rise and storm surge in Newmarket.

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 12 reports the number of acres of upland affected by each flood scenario.

TABLE 12: Uplands (acres) (year 2100)

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	36.4	101.7	172.9	136.0	193.9	253.5
% Upland	0.50%	1.39%	2.36%	1.86%	2.65%	3.47%

Total Upland in Newmarket = 7,312 acres.

Newmarket's inland coastal area has some low lying areas that are vulnerable to flooding. Most of these areas are located along Great Bay south of the mouth of the Lamprey River, as well as around Lubberland Creek. As much as 3.47% of the upland area of the town is vulnerable to sea-level rise and storm surge.

Parcels and Assessed Value

Table 13 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 14 reports the number of residential structures affected by each of the six scenarios evaluated and the aggregated assessed value of these homes.

TABLE 13: Parcels and 2016 Assessed Value by Scenario (year 2100)

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)	97	111	123	130	131	150
Aggregate Value of Parcels ($ value)	$33,931,174	$37,476,074	$39,236,159	$40,755,159	$41,195,359	$43,972,259

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.

In Newmarket, 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 $33.9 million to $43.9 million.

TABLE 14: Residential Structures and 2016 Assessed Value (year 2100)

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	1	2	2	2	6
Assessed Value of homes ($ value)	$0	$448,200	$678,700	$678,700	$678,700	$1,760,700

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

According to the analysis done for this vulnerability assessment, there are six residential structures impacted by sea-level rise and coastal storm flooding with an assessed value of $1,760,700.

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 15 reports the hydraulic and aquatic organism passage ratings for the six culverts chosen for this analysis.

TABLE 15: 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				
#48: Ash Swamp Rd near Lee Rd over unnamed stream	Fail	Fail	Fail	Fail	Reduced AOP
#49: Grant Rd over unnamed stream	Pass	Transitional	Transitional	Transitional	Reduced AOP
#50: Grant Rd over Piscassic River	Pass	Transitional	Transitional	Transitional	Reduced AOP
#51: Grant Rd over unnamed stream	Fail	Fail	Fail	Fail	Reduced AOP
#52: Grant Rd near Neal Mill Rd over unnamed stream	Transitional	Fail	Fail	Fail	Reduced AOP
#53: Lang's Ln over unnamed stream	Pass	Transitional	Transitional	Fail	No AOP
#54: Grant Rd near Ash Swamp Rd over unnamed stream	Pass	Transitional	Transitional	Transitional	Reduced AOP
#55: Grant Rd near Lang Rd over unnamed stream	Pass	Pass	Pass	Pass	Full AOP
#56: Private Rd over Moonlight Brook	Transitional	Transitional	Transitional	Fail	Reduced AOP
#57: Maple St over Moonlight Brook	Transitional	Transitional	Transitional	Transitional	Reduced AOP
#58 Railroad crossing near end of Railroad St over Moonlight Brook	Transitional	Transitional	Transitional	Fail	Full AOP
#59: Bay Rd over Lubberland Creek	Fail	Fail	Fail	Fail	No AOP

NOTE: The culverts on Bay Road at Lubberland Creek 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 twelve culverts chosen, five culverts were able to pass the 10-yr storm event; three failed; and four ranked transitional. For the 25-yr storm event, one culvert passed; four failed; and seven were ranked transitional. For the 50-yr storm event, one culvert passed; four failed; and seven ranked transitional. For the 100-yr storm event, one culvert passed; seven failed; and four ranked transitional. The only culvert to handle all four scenarios was the #55 - Grant Rd near Lang Rd over unnamed stream. It is important to note that the culverts located on Bay Road at Lubberland Creek were susceptible to flooding under the various sea-level rise scenarios.

According to the aquatic organism passage component of the analysis, of the twelve culverts chosen, two crossings were able to fully accommodate species to navigate the culvert; eight 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 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. Table 16 reports the acreage within the current 100-year floodplain affected by each flood scenario.

TABLE 16: 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)	50.78	66.33	82.69	74.16	86.66	96.9
Percentage of SLR within the floodplain	63.49%	44.05%	36.68%	39.77%	35.05%	31.44%

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

In Newmarket, the 100-year floodplain is highly sensitive to flooding from sea-level rise along tidal areas of the Lamprey River, Great Bay, and Lubberland Creek. The analysis shows that as sea-level rise increases and as storm surge is integrated into the sea-level rise analysis, the percentage of flooding that occurs in the flooding that occurs in floodplain decreases because more flooding is occurring within and beyond the boundaries of the floodplain. Under the low sea-level rise scenario, only 63.69% of flooding occurs within the floodplain, and the remaining 36.5% occurs outside of the floodplain. Under the high sea-level rise with storm surge scenario, less than one-third of the flooding that is projected to occur will occur within 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 twelve culverts chosen, five 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.

- Municipal infrastructure identified as vulnerable to either projected sea-level rise or coastal storm surge includes a water access site at Shanda Park on the Lamprey River, the dam on the Lamprey River, and the culvert on Bay Road over Lubberland Creek, which is currently being replaced.

- Municipal critical facilities identified as vulnerable to either projected sea-level rise or coastal storm surge include impacts to sewer pipes located at the end of Water Street and Creighton Road and at Lamprey Street and the intersection of Bay Road; a pump station at Creighton Road; and Schanda Park on the Lamprey River.

- Roadways that can expect to experience the greatest of inundation due to flooding from sea-level rise and coastal storm surge include sections of the unnamed private road off New Road, Bay Road, and segments of other local and private roads. Flooding along even short segments of roads may impact access, commuting patterns, and emergency response.

- 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.

- Fourteen properties 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 the Lamprey River, Lubberland Creek, and Great Bay may mitigate future flooding impacts by guiding development away from those areas and increasing flood storage capacity. Additional conservation along the Lamprey River, Lubberland Creek, and shores of the Bay 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 Newmarket'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. 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.

PLANNING AND POLICY

P1 - Natural Hazards Mitigation Plan. Incorporate the vulnerability assessment information and recommendations from the C-RiSe report into Newmarket'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, including water access at Schanda Park, pump station at Creighton Road, and flooding on critical roads such as Treatment Plant Road in current and future capital infrastructure projects. Evaluate the extent of sea-level rise and storm surge flooding on individual facilities, including sewer pipes located at the end of Water Street and Creighton Road and at Lamprey Street and the intersection of Bay Road. Discussions about the future of the Macallen Dam should take into account vulnerability from sea level rise and storm surge.

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.
- 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 and Strafford Regional Planning Commission'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 on sections of the unnamed private road off Bay Road, Bayview Road, Lamprey Street, Moody Point Drive, New Road, Smith Garrison Road, Stevens Drive, Young Lane, Water Street, and segments of other private roads. 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