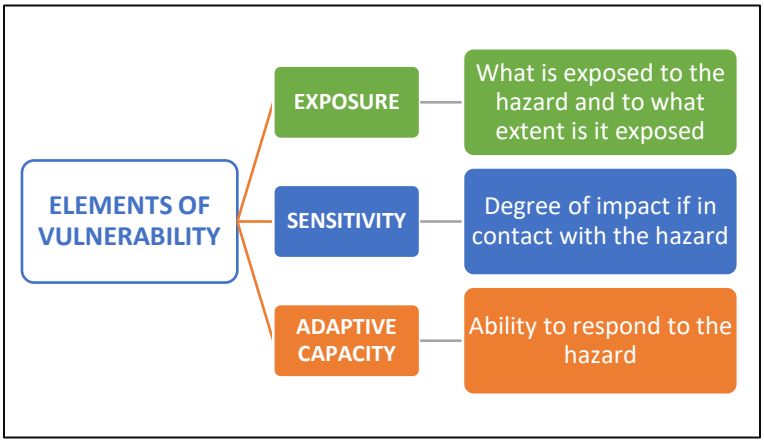
Climate Change Vulnerability Assessment Summary

KITTERY

Introduction

One of the first steps to understanding how communities can plan for and address climate change impacts is to assess climate hazards that are projected to impact an area as well as the things, people, and places that are vulnerable to those hazards. **Climate vulnerability is commonly defined** as the product of **exposure** to climate hazards, **sensitivity** of the built, social, and natural systems to those hazards, and the **adaptive capacity** of those systems for responding to change and stressors. The more sensitive something or someone is to a hazard and the lower their adaptive capacity to respond to the hazard, the greater their vulnerability. Vulnerability also increases as exposure to the hazard does. Evaluating vulnerabilities, including what will be impacted by climate hazards, and to what extent those impacts will occur, provides a baseline for developing targeted strategies, measures, and solutions for reducing vulnerabilities.



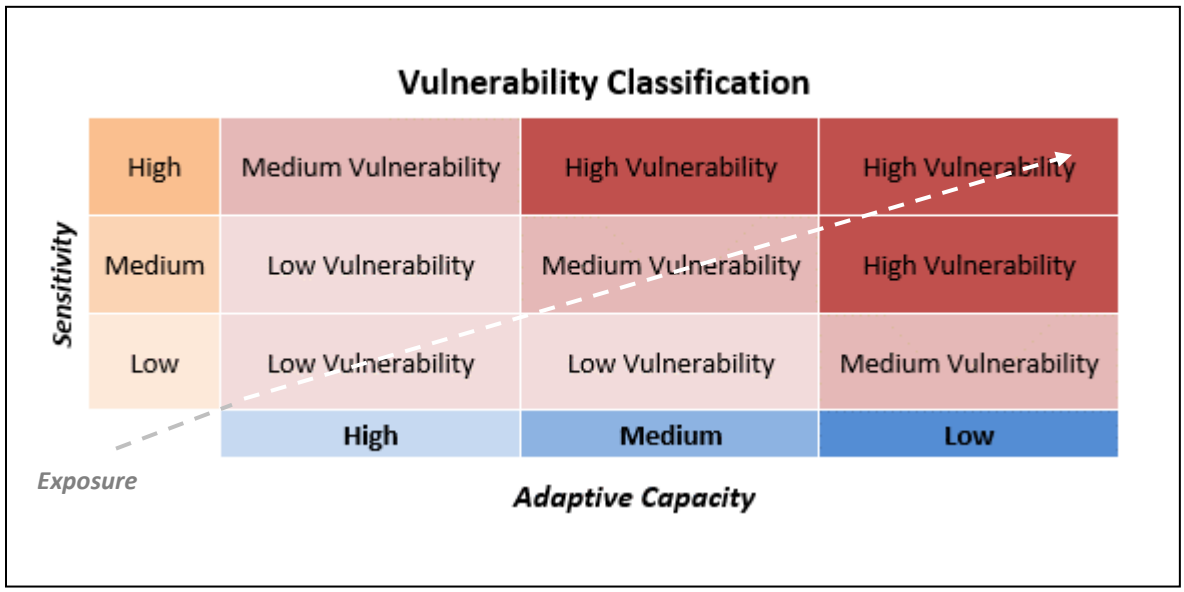


Figure adapted from NOAA. 2022. Implementing the Steps to Resilience: a Practitioner's Guide.

This draft vulnerability assessment summary presents an overview of climate hazards and associated impacts and vulnerabilities for the community of Biddeford. The assessment uses local, regional, state, and national data pertaining to climate hazards, historical conditions, trends, and future projections to assess impacts of and local vulnerabilities associated with the following:

- Flooding from sea level rise and storm surge
- Precipitation and extreme storms
- Extreme temperatures
- Drought
- Changing marine conditions

The assessment evaluates impacts of those hazards to the built, social, and natural environment; public health; and the economy. The 'desktop' vulnerability assessment generated quantitative-based information about climate hazard exposure within each Cohort community. Information about adaptive capacity and sensitivity, which is usually more qualitative in nature and not readily captured by state or national datasets or numeric data, as well as information about what/where/who is of greatest concern to the community, will be added to this document over the next several months. The project team will support the gathering of that information through input and feedback from the community Task Force and the broader community through engagement activities. **This assessment will be updated and refined by the project team throughout the CAP process.**

Key Takeaways

- Coastal areas of Kittery are extremely vulnerable to the increasing impacts of coastal flooding and storm surge. In these areas, community members are more likely to be older and live alone, making them more sensitive to these climate hazards. Admiralty Village is particularly vulnerable based on its relatively high social vulnerability, exposure to flooding and sea level rise, and its infrastructure that is located in flood prone areas.
- Kittery's roads and transportation infrastructure are also extremely vulnerable to flooding risks.
- Increasing temperatures are likely to create more extreme heat hazards for Kittery's densely developed areas, including the outlet malls and Foreside neighborhood.
  Drought is becoming a hazard of increasing concern and can negatively impact public and private drinking water supplies, natural resources, and agriculture, and could lead to increased wildfire risk.

Social Vulnerability

The impact of climate change will not be felt evenly across the community and will not be uniformly distributed among population groups. Individuals who already have increased social vulnerability will be disproportionately affected by climate hazards, as they generally have lower capacity to prepare for, respond to, and recover from hazard events and disruptions. Demographic information can help determine local populations' adaptive capacity, or the ability to adapt and respond to a disaster.

The following demographic information summarizes indicators of social vulnerability and adaptive capacity at the community level and US Census-designated block group level, which is the smallest geographic unit at which this demographic data is available. Information about the community's social

vulnerability will be supplemented and contextualized with information gathered from the Task Force and community members through engagement approaches.

Demographic Profile

Table 1 outlines 17 demographic indicators of social vulnerability at the community-wide and block group levels, which align closely with those used in the Maine Social Vulnerability Index.[1] These data are from the 2021 American Community Survey (ACS), which is conducted by the U.S. Census Bureau. The 2021 ACS is the most current demographic data available because the results of the 2020 Decennial Census have not been released yet. Block groups are the small geographic unit for which the U.S. Census provides demographic data. Block groups are delineated based on population and contain between 600 to 3,000 people. There are a total of 8 block groups in Kittery (Map 1).

The ACS is conducted annually on an ongoing basis throughout the year to collect information about changing socioeconomic characteristics in communities. Unlike the Decennial Census which surveys every household, the ACS only surveys a portion of households in the community and uses the results to estimate demographic characteristics across the community. In small communities, like many along the coast of Maine, that accuracy of ACS estimates may be imperfect due to the small sample size. In larger communities the estimates tend to be more accurate because the sample size is more statistically robust. The ACS also surveys seasonal residents which can make it difficult to understand the characteristics of the year-round population in seasonal communities. The Task Force can use the 17 demographic indicators to begin thinking about which parts of the community may be more socially vulnerable to the impacts of climate change. However, qualitative and anecdotal information from the Task Force and Town staff can improve the accuracy of this information.[2]

Demographic data are presented at the population and household level. The U.S. Census Bureau defines a household as a group of people who live within the same housing unit regardless of whether or not they are related. A housing unit is a room or group of rooms that is designed to be separate living quarters such as a house, apartment, or condo.[3]

There are three income thresholds referenced in the table. These thresholds were selected because they approximate the U.S. Environmental Protection Agency (EPA) climate change and social vulnerability income threshold ($51,500), the State median income ($64,767), and the York County median income ($73,856).

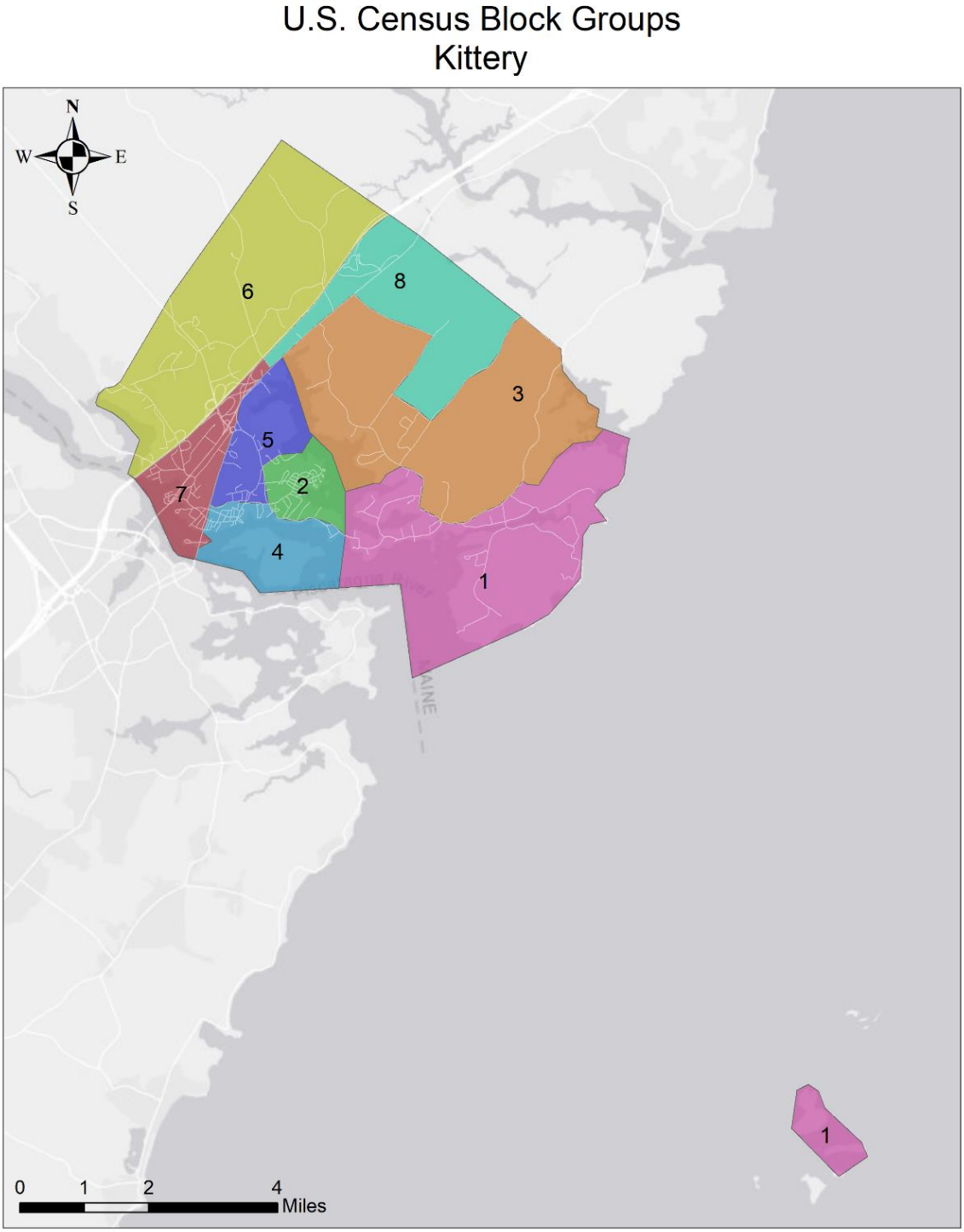
Key Takeaways

- The neighborhoods near the Kittery Historic and Naval Museum and Orchard Gove Cemetery (block group 5) have the highest percentage of the population within the block group that are 65 years or older, minorities, below the EPA climate change and social vulnerability low-income threshold, below the County and State median incomes, have no internet access, no vehicle, and are age 65+ and living alone. This area also has an elevated percentage of the population within

[1] Johnson et al., 2018, A lifeline and social vulnerability analysis of sea level rise impacts on rural coastal communities
[2] Johnson et al., 2018, A lifeline and social vulnerability analysis of sea level rise impacts on rural coastal communities
[3] U.S. Census Bureau, Subject Definitions: https://www.census.gov/programs-surveys/cps/technical-documentation/subject-definitions.html#household

the block group that is below the national poverty level and living alone compared to the rest of the community.

- Admiralty Village and surrounding neighborhoods are within block group 2, which is the most populated area in the community and has elevated social vulnerability due to the relative percentage of the population and households within the block group that are 17 years or younger, minorities, speak English less than well, have no high school diploma, have a person in the house with a disability, are unemployed, below the EPA climate change and social vulnerability low-income threshold, below the County and State median incomes, have no vehicle, are a single parent households, and are age 65+ and living alone.
- The neighborhoods to the east of the Kittery outlets and west of the Rachel Carson National Wildlife Refuge (block group 3) have the highest percentage of households within the block group that have at least one person with a disability.
- Seavey Island (block group 4) has the highest percentage of the population within the block group that has no high school diploma and is living alone.
- The neighborhoods northwest of I-95 (block group 6) have the highest percentage of the population within the block group that are unemployed and are single parent households.
- The neighborhoods along Route 1, between I-95 and State Road (block group 7) have the highest percentage of the population within the block group that are 17 years old or younger, and are below the national poverty level.
- Across the entire community 35% of households have at least one person with a disability, 14% of households have no vehicle, and 18% of the population is living alone. Additionally, 37% of households are below the EPA climate change and social vulnerability income threshold, 41% are below the State median income, and 50% are below the County median income.



Map 1 US Census-Designated Block Groups in Kittery (2020 Decennial Census)

Table 1 Demographic profile summary (2020 Decennial Census)

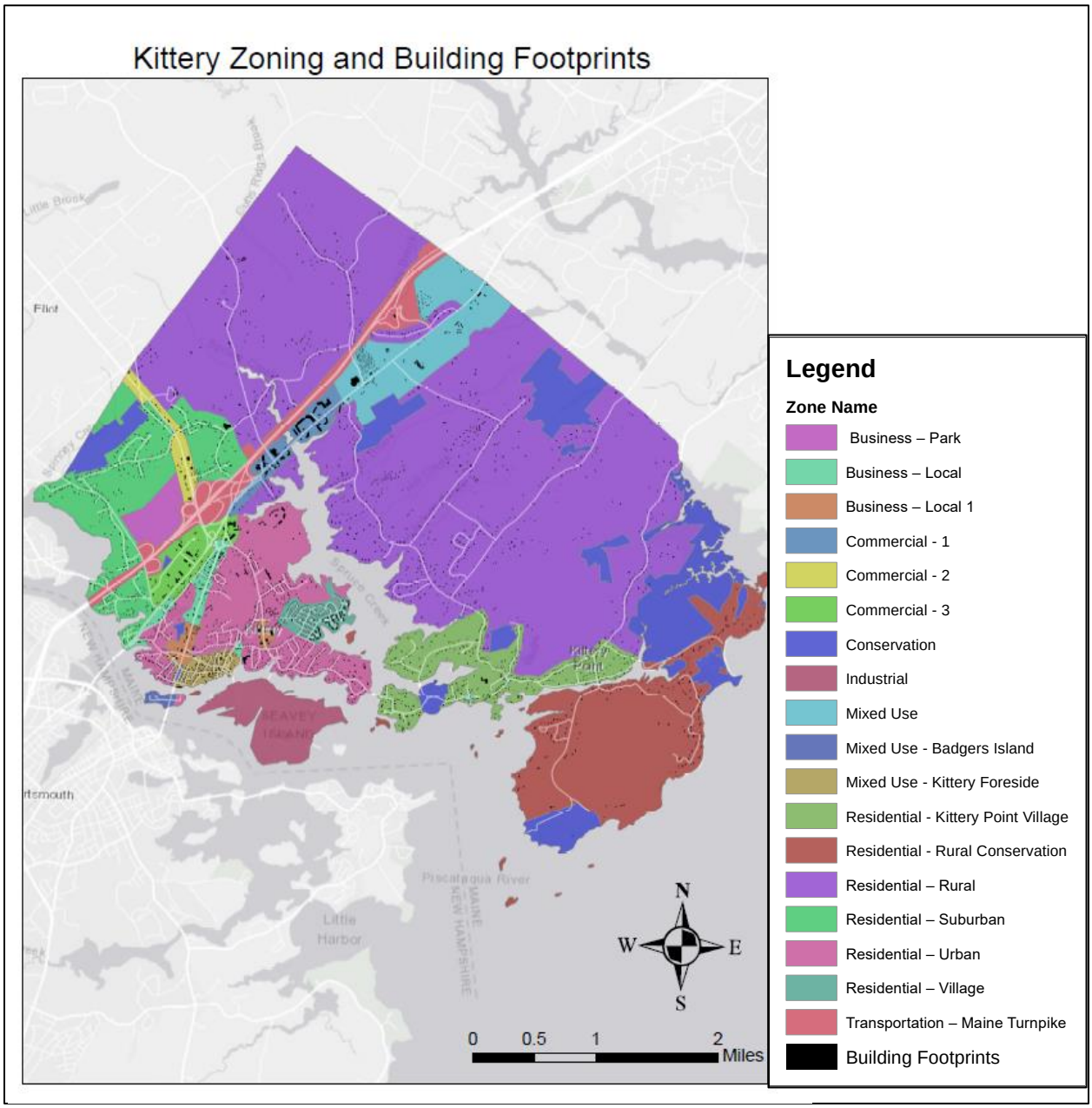
	Community wide	Block Groups							
		1	2	3	4	5	6	7	8
Total Population	10,006	745	2,217	1,414	853	1,497	1,542	887	851
Total Households	4,962	370	1,122	659	442	927	714	345	383
Age <18	1,279	13	405	84	127	129	242	195	84
% total population	13%	2%	18%	6%	15%	9%	16%	22%	10%
Age 65+	2,766	260	449	463	185	740	286	157	226
% total population	28%	35%	20%	33%	22%	49%	19%	18%	27%
Minority	975	48	276	63	54	244	106	100	84
% total population	10%	6%	12%	4%	6%	16%	7%	11%	10%
Speaks English "Less than well"	35	0	34	0	0	1	0	0	0
% population age 5+	0%	0%	2%	0%	0.0%	0%	0%	0%	0.0%
No HS Diploma	195	20	68	20	36	8	8	0	35
% population age 25+	2%	3%	4%	2%	5%	1%	1%	0%	5%
1+ Persons with a Disability	1,721	50	436	380	105	348	201	43	158
% households	35%	14%	39%	58%	24%	38%	28%	12%	41%
Below Poverty Level	417	42	93	14	0	124	55	62	27
% households	8%	11%	8%	2%	0%	13%	8%	18%	7%
Unemployment	131	24	51	0	0	0	47	9	0
% population age 16+	1%	3%	3%	0%	0%	0%	4%	1%	0%
Income <$50k	1,812	94	527	123	127	533	218	105	85
% households	37%	25%	47%	19%	29%	57%	31%	30%	22%
Income <$60k	2,046	94	589	149	156	562	264	116	116
% households	41%	25%	52%	23%	35%	61%	37%	34%	30%
Income <$75k	2,495	131	666	187	175	625	378	130	203
% households	50%	35%	59%	28%	40%	67%	53%	38%	53%
No Internet	396	16	15	83	0	218	36	9	19
% households	8%	4%	1%	13%	0%	24%	5%	3%	5%
No Vehicle	690	0	281	18	0	372	0	0	19
% households	14%	0%	25%	3%	0%	40%	0%	0%	5%
Single Parent	198	0	86	0	9	14	80	5	4
% households	4%	0%	8%	0%	2%	2%	11%	1%	1%
Living Alone	1,811	134	414	163	237	473	187	61	142
% total population	18%	36%	37%	25%	54%	51%	26%	18%	37%
65+ Living Alone	990	119	294	106	71	300	46	16	38
% total population	10%	16%	13%	7%	8%	20%	3%	2%	4%

Lowest Value *Highest Value*

Supplemental Community Information

Zoning

Local zoning will impact where in the community (*i.e.* particular geographic areas) certain types of development-related climate mitigation and adaptation strategies would likely have more impact due to where different types of development are allowed and what the standards are for those types of development. The zoning map below (Map 2) is provided for reference to show where areas zoned for commercial, industrial, and residential uses are located.



Map 2 Kittery zoning map

Land Cover and Carbon Sequestration

Forests, wetlands, and grasslands store high amounts of organic carbon. Coastal wetlands are among the largest natural carbon sinks of all terrestrial ecosystems, particularly on a per unit area basis. Undisturbed forest soils also store substantial amounts of carbon. Certain land use activities can enhance carbon storage, such as soil health and conservation practices, whereas others can be a source of carbon release [4]. In built environments, carbon is stored in trees, grassy areas, gardens, and in wooden structures and are increasingly important for reducing carbon in the atmosphere. Changes in land cover, such as conversion of forest to developed land, impacts not only the health of the natural environment, but the carbon sequestration potential of land. The image below shows the change in forested land coverage in Kittery from 1996 to 2016. During that time period, there was smattering of forest distributed across the northwestern areas of town and a larger area west of Spruce Creek. There was minimal forest gains.

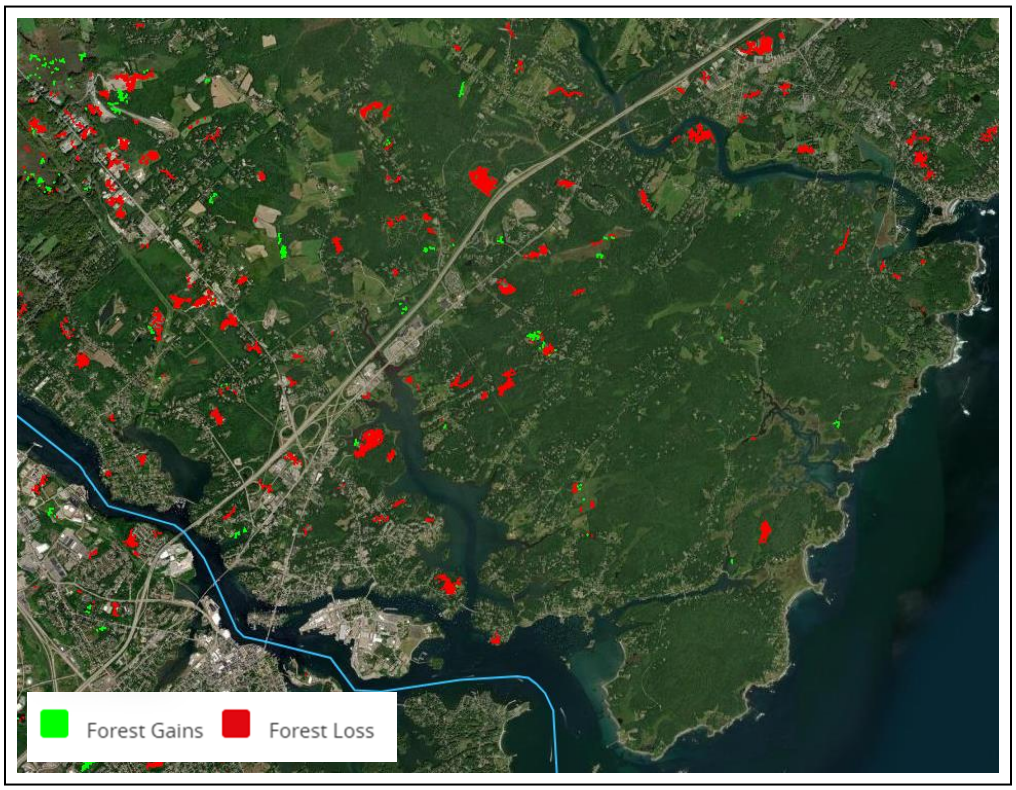


Figure. Changes in forested land cover from 1996 to 2016. Green areas indicate a transition of non-forested land to forested, while red areas indicate a transition from forested land to a different type of land cover (e.g., impervious, grassland, wetland, shrub-scrub habitat, etc.). Source: NOAA Coastal Change Analysis Program (C-CAP) Land Cover Atlas.

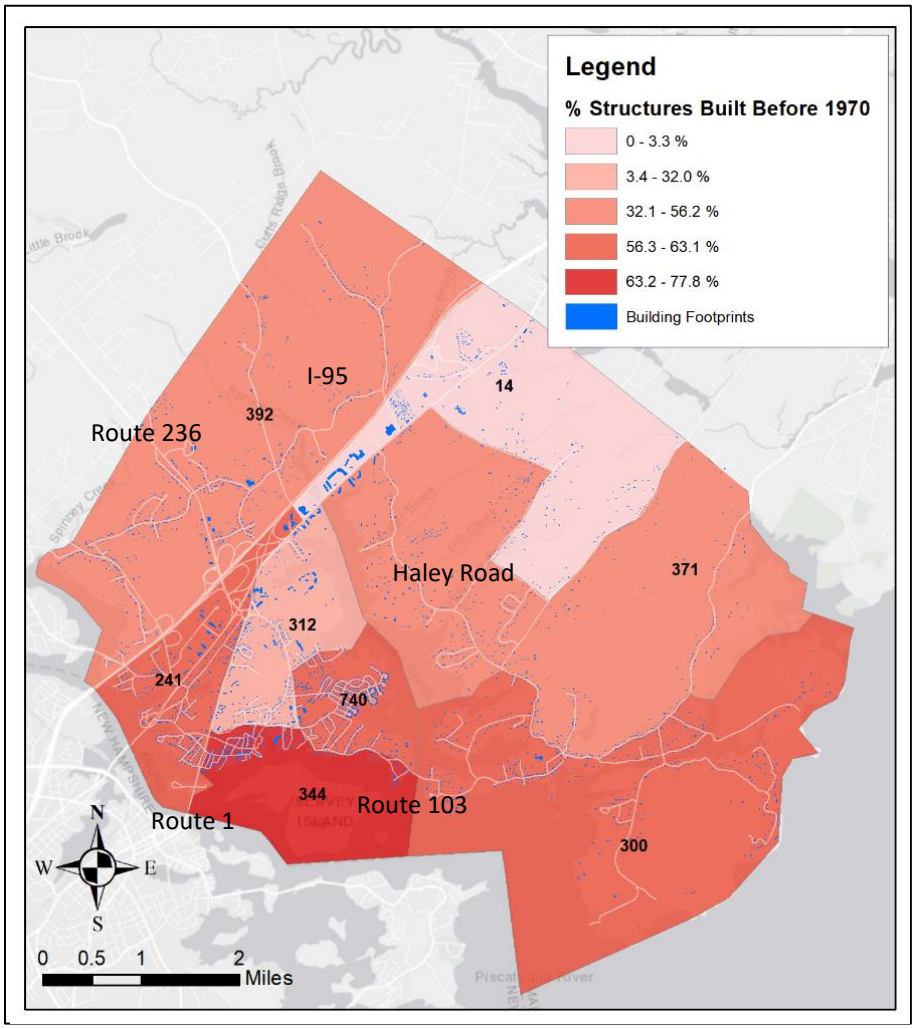
Age of Buildings

Maine has one of the oldest housing stocks in the country. Older buildings tend to be less energy efficient, which is especially problematic during the winter and summer months when outdoor

[4] State of Maine. 2022. Maine Soil Carbon Incentives Study Policy Recommendations.

temperatures are at their extremes. Further, houses constructed before 1970 were built prior to the adoption of modern building codes and significant federal and state/local risk-reduction policies (National Flood Insurance Program (1968), Maine Shoreland Zoning (1971)). Older buildings are ideal targets for weatherization, energy efficiency upgrades, and resilience retrofits.

Error! Reference source not found.3 shows the percentage of structures, at the block group level, built before 1970. In Kittery, areas with the highest concentration of buildings constructed before 1970 are located in the Foreside neighborhood and along the coastline. These areas also have elevated social vulnerability based on demographic characteristics and are vulnerable to hazards, including flooding, sea level rise, and urban heat islands. The concentration of older buildings in flood prone areas means that it is likely those structures are not built to modern codes and are not elevated above projected future flood levels, or even current flood levels.



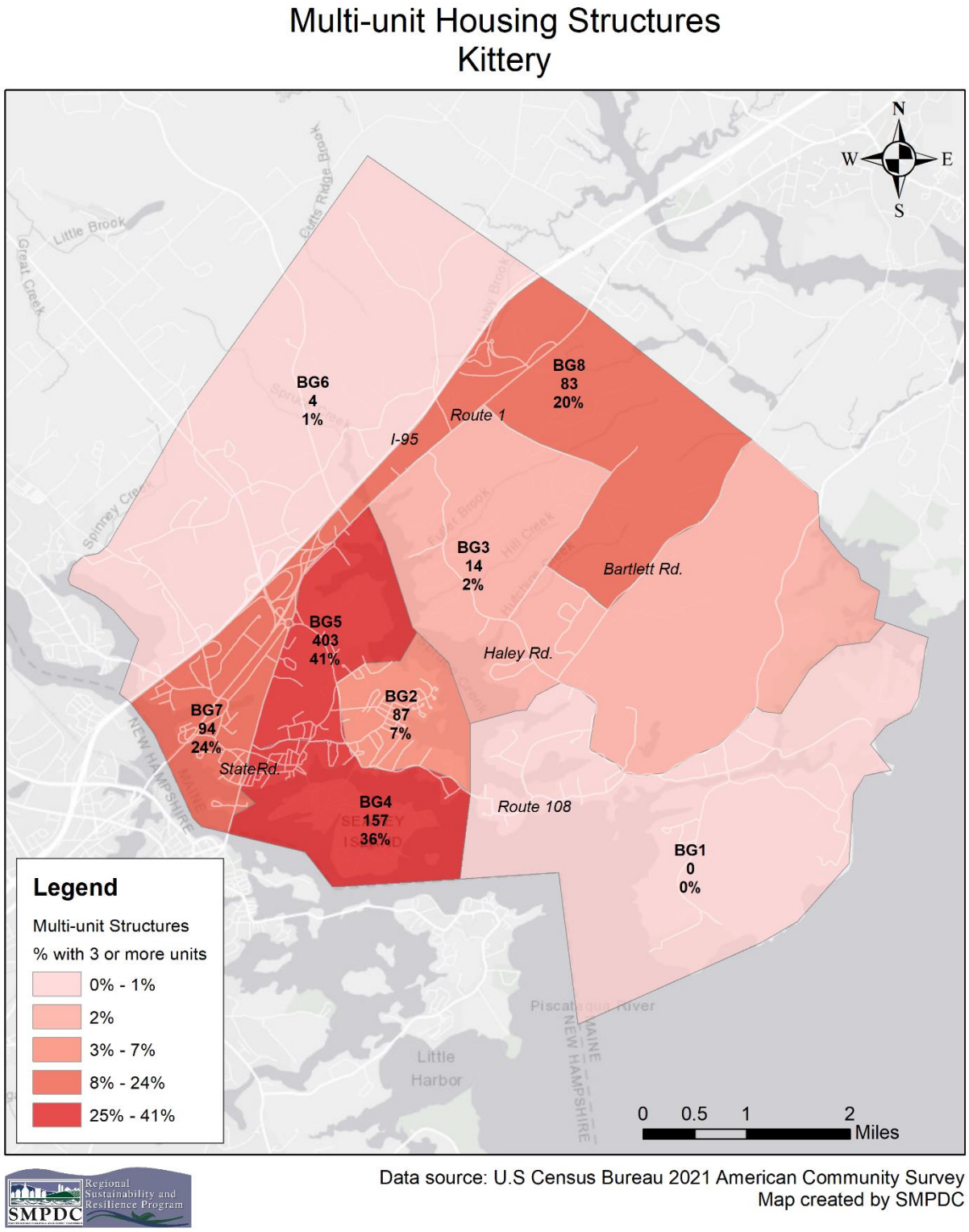
Map 3 Percent and actual number of structures built before 1970 presented at the block group level. The block groups are color-coded by the percentage of structures built before 1970 and are labelled with the number of structures built before 1970. (Data source: year structures built: US Census American Community Survey; building footprints: Microsoft)

Housing Characteristics

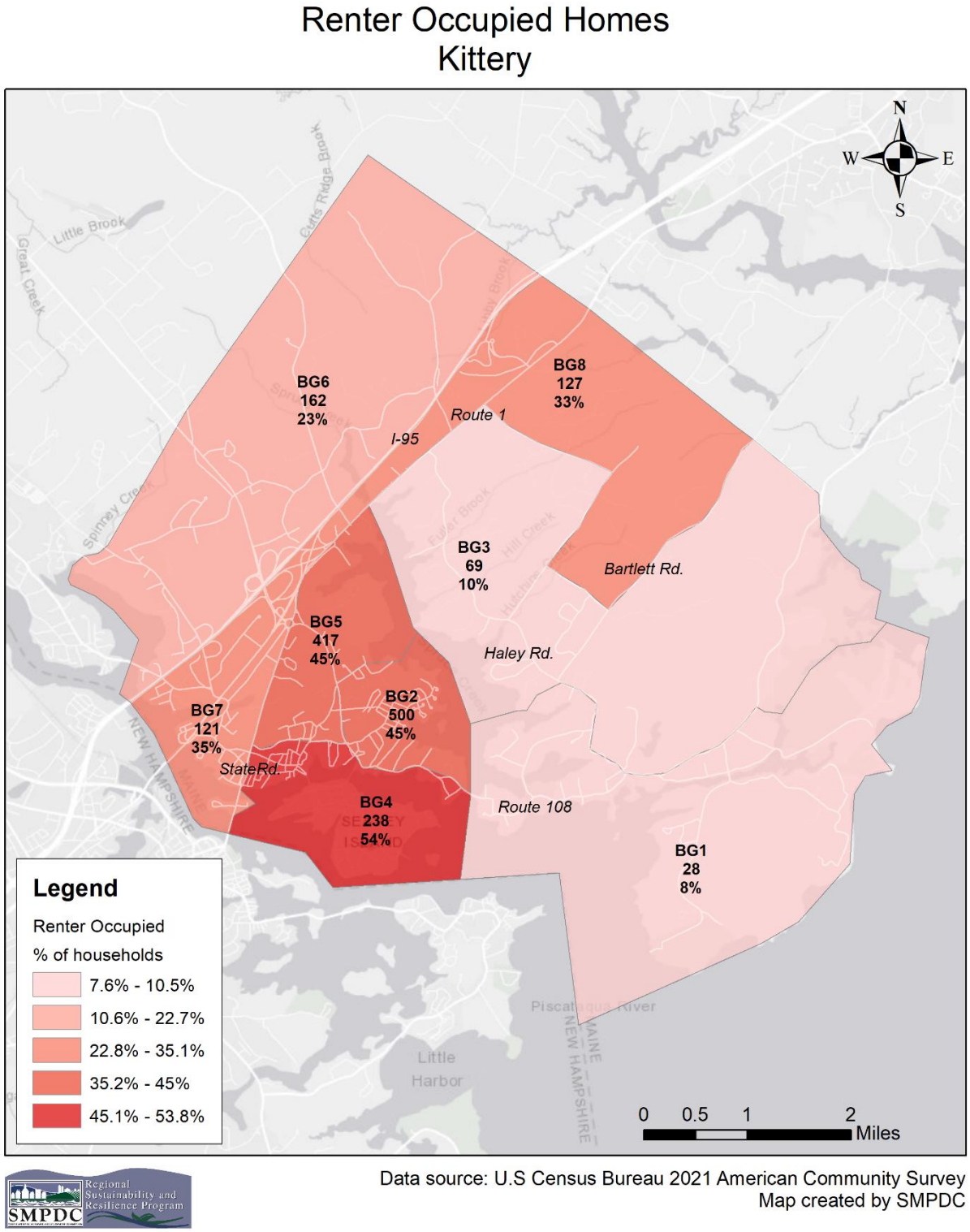
Renter occupied households, multi-unit homes, and mobile homes tend to be associated with socially vulnerable populations and/or reduced adaptive capacity. For example, renters and multi-unit households generally have less adaptive capacity than single family homeowners because they tend to have lower incomes and fewer financial resources and therefore, have less ability to make property improvements. Additionally, landlords have little incentive to improve energy efficiency because energy costs are borne by tenants. Mobile homes have a higher energy cost per square foot than site-built homes and are generally more vulnerable to the impacts of climate hazards. Data shown in Table 2 and Map 4 are from the 2021 American Community Survey (see Demographic Profile for a description of ACS data).

Key Takeaways

- Across the entire community nearly a third of households (32%) are renter occupied.
- The neighborhood around Seavey Island (block group 4) has the highest percentage of renter occupied households, followed by the neighborhoods east of State Road, north of Haley Road and west of Spruce Creek (block groups 2 and 5). These block groups also have greater social vulnerability.
- The neighborhoods near the Kittery Historic and Naval Museum and Orchard Gove Cemetery (block group 5) have the highest percentage of multi-unit (3+) housing structures, followed by Seavey Island (block group 4).
- The area along the Kittery-York border between I-95 and Bartlett Road (block group 8) has the highest percentage of mobile homes, though mobile homes only make up 1% of housing units in the community overall.



Map 4A Breakdown of multi-unit (3 or more units) housing units in Kittery by block group. Housing units include occupied households as well as vacant units and represent the total housing stock in Kittery. The block group is labeled (BG#) as well as the total number of multi-unit housing units in the block group and the percent of total housing units within the block group that are multi-unit. Data source: U.S. Census Bureau 2021 American Community Survey



Map 4B Breakdown of renter occupied households in Kittery by block group. Households do not include vacant housing units, so this data is representative of occupied housing units in Kittery. The block group is labeled (BG#) as well as the total number of renter occupied households in the block group and the percent of renter occupied households within the block group. Data source: U.S. Census Bureau 2021 American Community Survey

Table 2 Community wide and block group level housing characteristics in Kittery. Housing units include occupied households as well as vacant units and represent the total housing stock in Kittery. Data source: U.S. Census Bureau 2021 American Community Survey

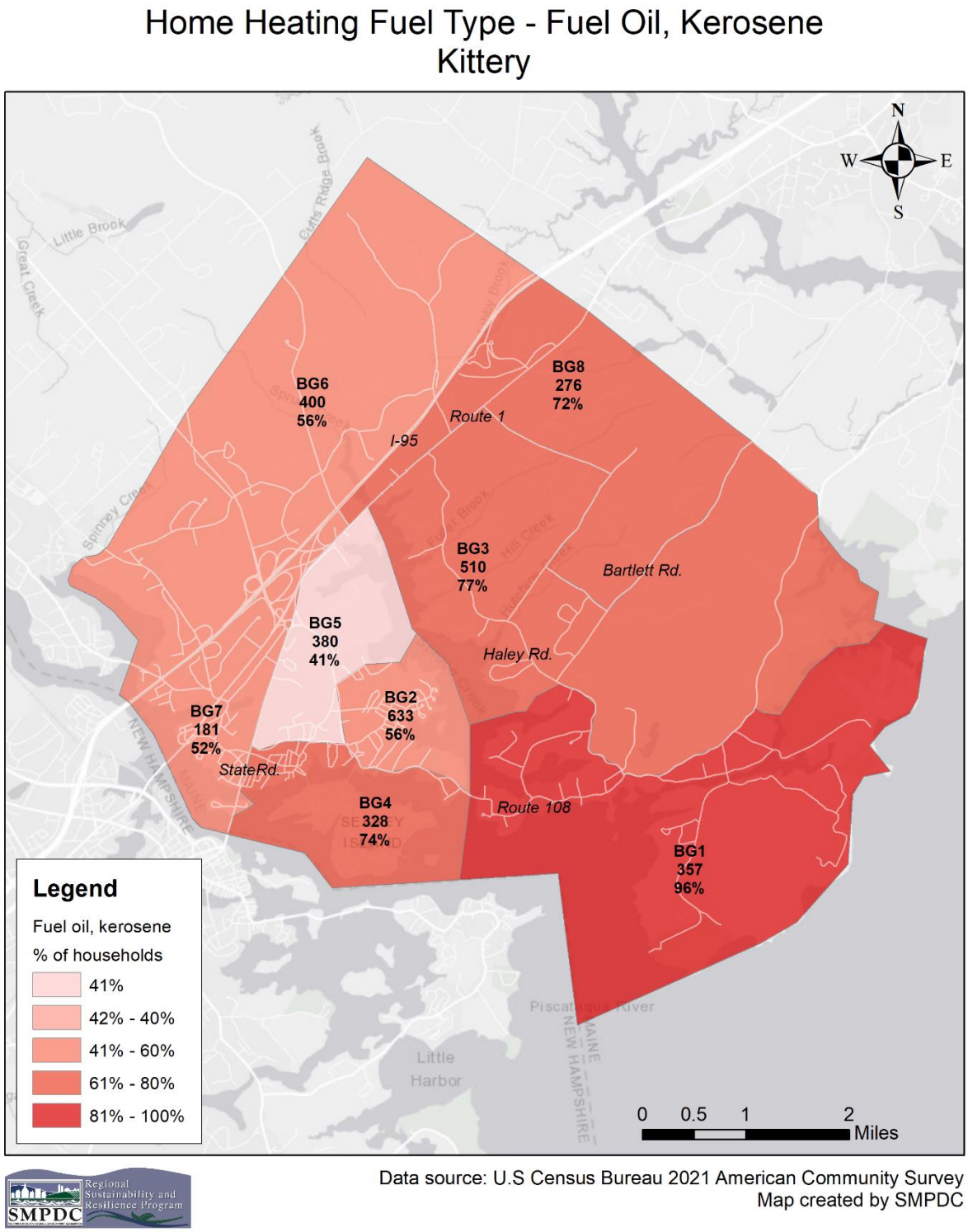
	Community wide	Block Groups							
		1	2	3	4	5	6	7	8
Total Housing Units	2,828	475	1,252	659	442	974	763	386	416
Total Households	2,593	370	1,122	659	442	927	714	345	383
Renter Occupied	835	28	500	69	238	417	162	121	127
% households	32%	8%	45%	10%	54%	45%	23%	35%	33%
Multi-unit	258	0	87	14	157	403	4	94	83
% total with 3+ units	10%	0%	7%	2%	36%	41%	1%	24%	20%
Mobile Homes	20	0	0	20	0	14	54	0	204
% total units	1%	0%	0%	3%	0%	1%	7%	0%	49%

Lowest Value *Highest Value*

Household Heating Fuel Types

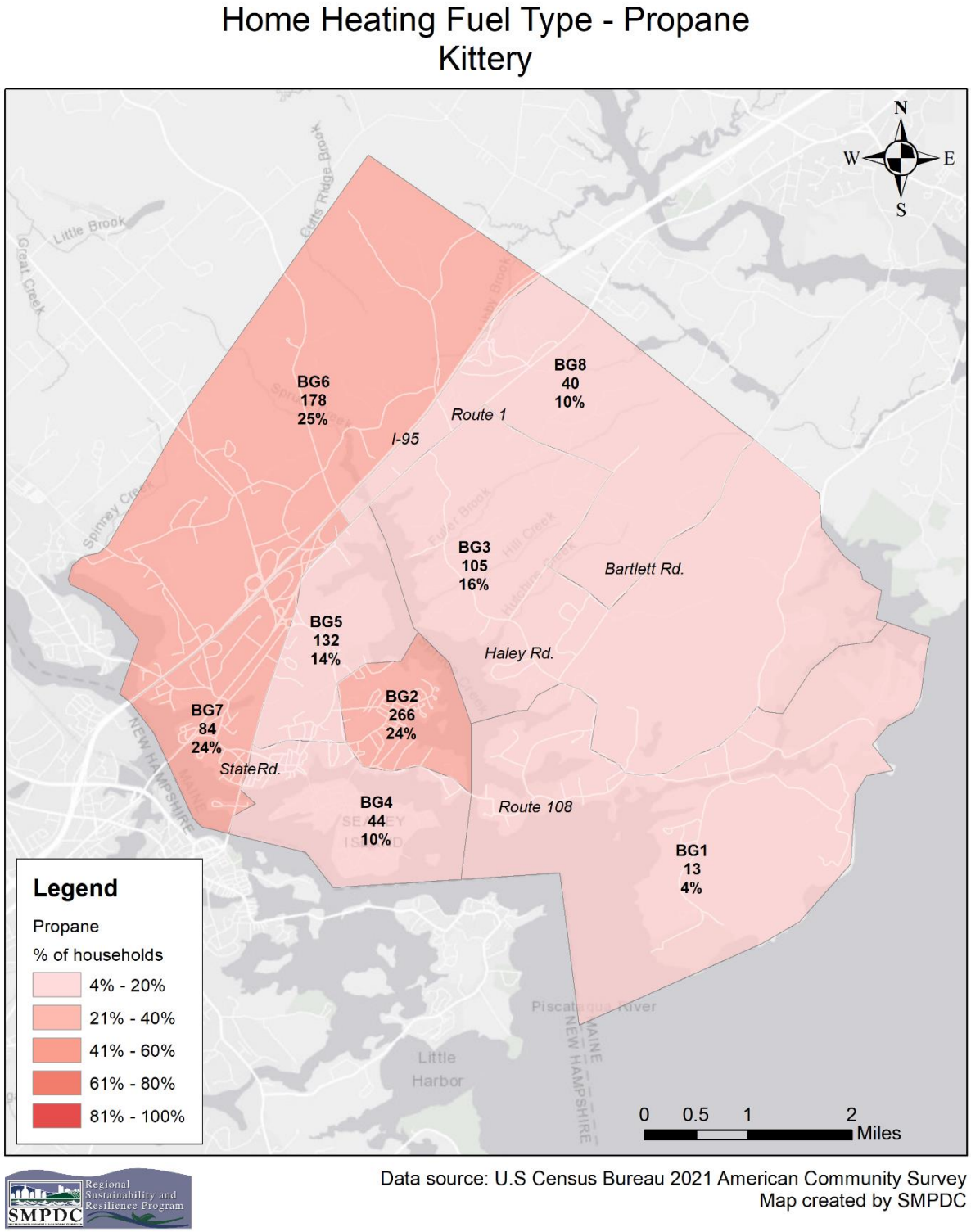
Key Takeaways

- The vast majority (70%) of households in the community are primarily heated using fuel oil or kerosene followed by propane, natural gas, and electricity.
- Kittery Point (block group 1) has the highest percentage of households that use fuel oil and kerosene, followed by the area from the Kittery-York boundary between Haley Road and I-95 (block groups 3 and 8) and Seavey Island (block group 4).
- The western part of Kittery, downtown neighborhood, and Eagle Point (block groups 2, 6, and 7) have the highest percentage of households that use propane, ranging from 24% to 25% of households within the block group.
- The neighborhoods near the Kittery Historic and Naval Museum and Orchard Gove Cemetery (block group 5) have the highest percentage of households that use natural gas or electricity.



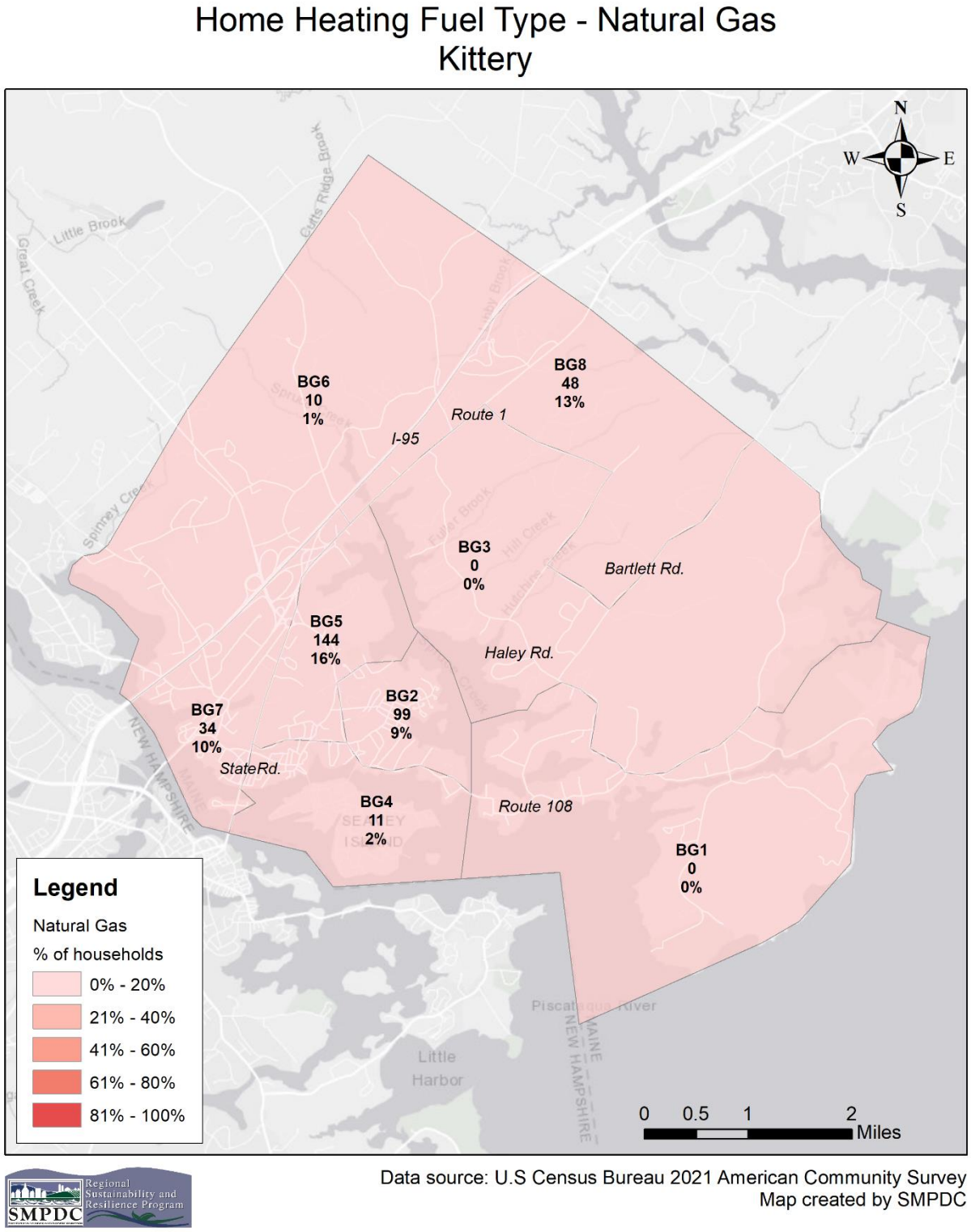
Data source: U.S Census Bureau 2021 American Community Survey
Map created by SMPDC

Figure 5A. Breakdown of households in Kittery that use fuel oil or kerosene for heating by block group. Households do not include vacant housing units, so this data is representative of occupied housing units in Kittery. The block group is labeled (BG#) as well as the total number of households within the block group that use fuel oil or kerosene for heating and the percent of households within the block group that use fuel oil or kerosene for heating. Data source: U.S. Census Bureau 2021 American Community Survey



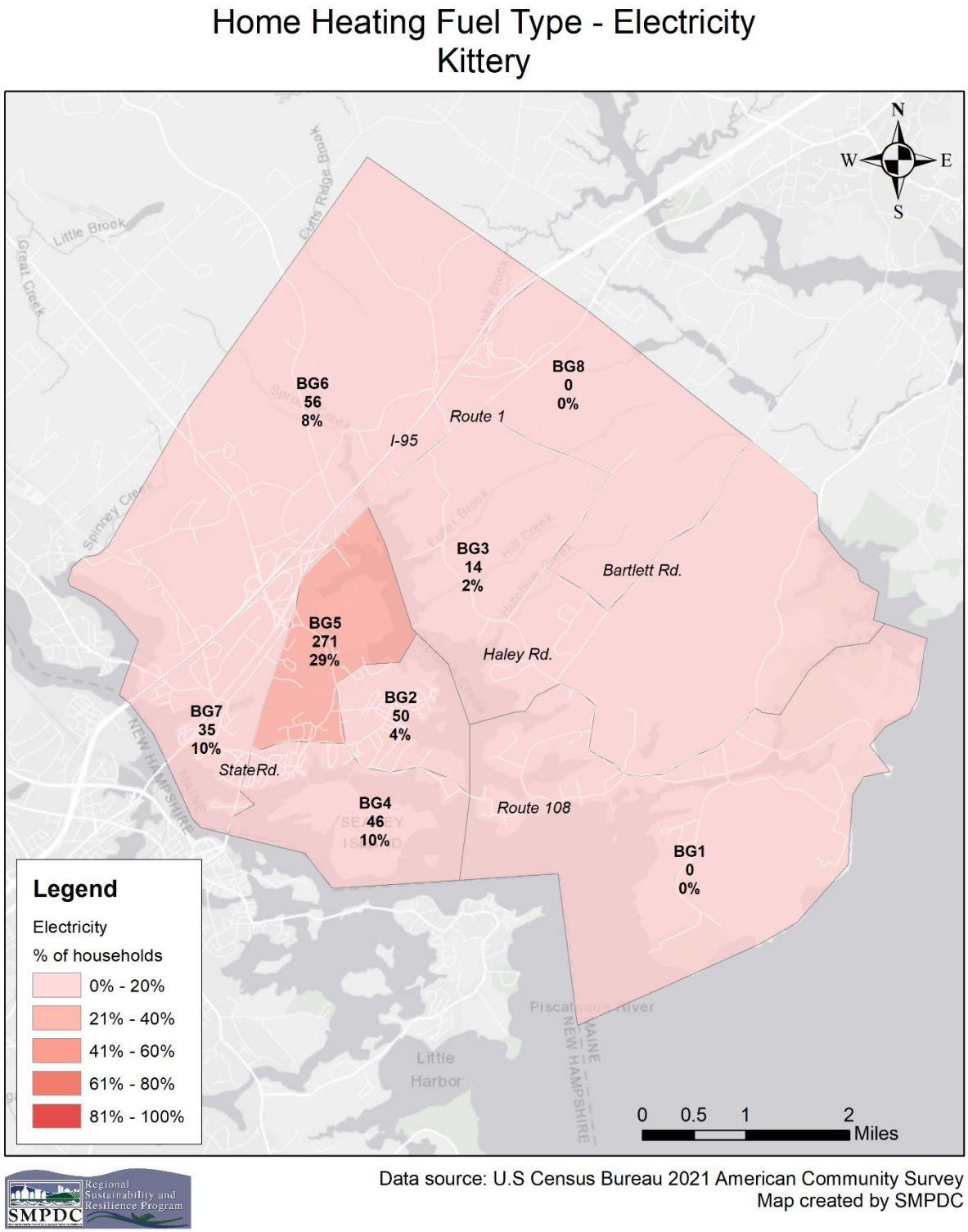
Data source: U.S Census Bureau 2021 American Community Survey
Map created by SMPDC

Figure 5B. Breakdown of households in Kittery that use propane for heating by block group. Households do not include vacant housing units, so this data is representative of occupied housing units in Kittery. The block group is labeled (BG#) as well as the total number of households within the block group that use propane for heating and the percent of households within the block group that use propane for heating. Data source: U.S. Census Bureau 2021 American Community Survey



Data source: U.S Census Bureau 2021 American Community Survey
Map created by SMPDC

Figure 5C. Breakdown of households in Kittery that use natural gas for heating by block group. Households do not include vacant housing units, so this data is representative of occupied housing units in Kittery. The block group is labeled (BG#) as well as the total number of households within the block group that use natural gas for heating and the percent of households within the block group that use natural gas for heating. Data source: U.S. Census Bureau 2021 American Community Survey



Data source: U.S Census Bureau 2021 American Community Survey
Map created by SMPDC

Figure 5D. Breakdown of households in Kittery that use electricity for heating by block group. Households do not include vacant housing units, so this data is representative of occupied housing units in Kittery. The block group is labeled (BG#) as well as the total number of households within the block group that use electricity for heating and the percent of households within the block group that use electricity for heating. Data source: U.S. Census Bureau 2021 American Community Survey

Table 3. Community wide and block group level household heating fuel types in Kittery. Households do not include vacant housing units, so this data is representative of occupied housing units in Kittery. Data source: U.S. Census Bureau 2021 American Community Survey

	Community wide	Block Groups							
		1	2	3	4	5	6	7	8
Total Households	2,593	370	1,122	659	442	927	714	345	383
Fuel oil, kerosene	1,828	357	633	510	328	380	400	181	276
% households	70%	96%	56%	77%	74%	41%	56%	52%	72%
Propane	428	13	266	105	44	132	178	84	40
% households	17%	4%	24%	16%	10%	14%	25%	24%	10%
Natural gas	110	0	99	0	11	144	10	34	48
% households	4%	0%	9%	0%	2%	16%	1%	10%	13%
Electricity	110	0	50	14	46	271	56	35	0
% households	4%	0%	4%	2%	10%	29%	8%	10%	0%

Lowest Value *Highest Value*

Extreme Storms & Precipitation

Key Takeaways

- Since 1895 annual precipitation in York County has increased 6.9 inches, and extreme precipitation events (greater than 2 inches in a day) have become more frequent. Future projections indicate that annual precipitation will likely continue to increase and extreme precipitation events will become even more frequent.
    - Flooding events are the most common type of disaster in York County and the most destructive. In the last quarter century, flooding events have caused nearly $45 million in property damage across coastal York County, and coastal floods alone have caused about $22 million in property damage.
    - There is a high degree of impervious surfaces in and around Kittery's downtown and along the I-95 and Route 1 corridors which increases the vulnerability of these areas to flooding and stormwater overflow during extreme precipitation events. Areas along the Piscataqua River are more vulnerable to the combined impacts of extreme precipitation and coastal flooding during severe storms.
    - Increases in extreme storms are likely to cause more frequent and longer duration power outages in Kittery. Additionally, access to the CMP substation on Picott Road could be blocked during flooding due to extreme precipitation or coastal storms.

Background Info, Trends, & Projections

Storms and heavy rainfall are becoming more frequent and intense with climate change. From 1895 to 2022 total annual precipitation in York County has increased 6.9 inches (Figure 8), which is slightly higher than the statewide trend of about 6 inches. Shifting weather patterns are causing more precipitation to fall as rain rather than snow,[5] and extreme precipitation events (greater than 2 inches in a day) are becoming even more frequent. Coastal communities like Biddeford are experiencing even more frequent extreme storms and precipitation events because of the influence of Atlantic storm tracks.[6] Hurricanes and tropical storms are tracking further northward and there is a high increase in the probability of lower category storms impacting the East Coast. A recent national study found that the Northeast is expected to see the largest increases in the annual probability of at least tropical storm wind conditions or higher, as hurricanes are expected to move further up the Atlantic coast in the future. This may have a significant impact on buildings not built to a code that considers the wind speeds they will likely face over the next 30 years.[7]

[5] ME Climate Council, Scientific Assessment of Climate Change and Its Effects in Maine, 2020: http://climatecouncil.maine.gov/reports

[6] University of Maine, Maine's Climate Future, 2020: https://climatechange.umaine.edu/climate-matters/maines-climate-future/

[7] First Street Foundation. 2023. Embargoed: The 7th National Risk Assessment: Worsening Winds

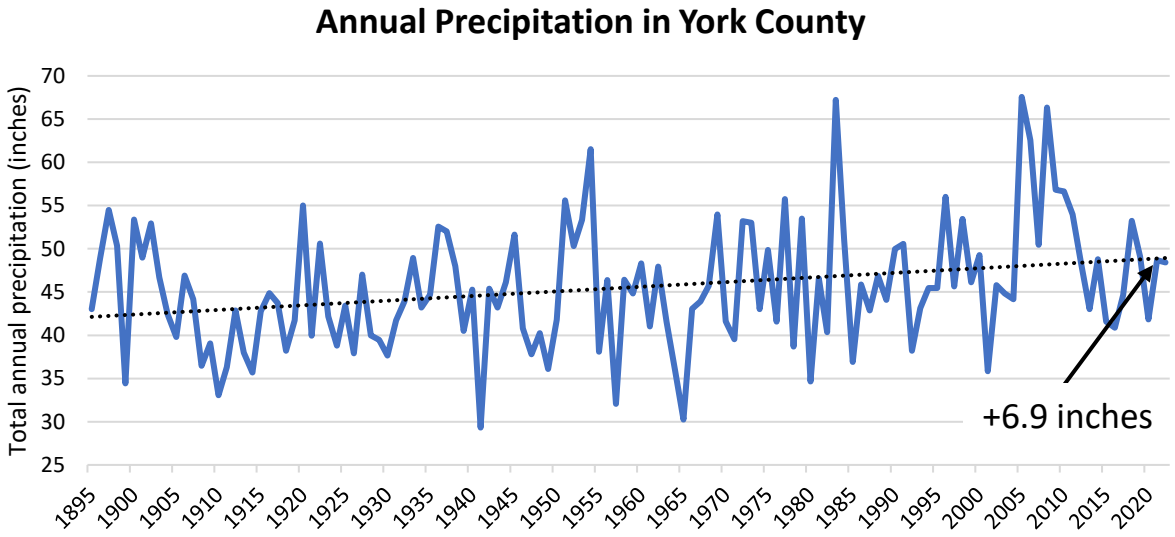


Figure 1 Total annual precipitation in York County from 1895 to 2022 based on monthly data from the [NOAA National Centers for Environmental Information](). Over this time period total annual precipitation has increased by 6.9 inches.

Since 1970 there have been 34 federally declared disasters in York County related to storm events. Severe storms with heavy rains, strong winds, and coastal flooding have been the most common type of event and have occurred most frequently during the months of February and March followed by October.[8] NOAA maintains a database of all reported storm events, including storms that did not qualify for a disaster declaration. Since 1996 there have been a total of 361 storm events in coastal York County, and 122 events that caused significant property damage totaling about $54 million (Table 4). Flooding events alone, including coastal flooding, have caused nearly $45 million in damage across the region.[9]

Table 4 Cumulative storm events and property damage in coastal York County from 1996 to 2022 based on data from the [NOAA Storm Events Database]().

Storm Events in Coastal York Co. from 1996-2022		
Event Type	**Number**	**Property Damage**
Coastal Flood	58	$21,659,000
Flash Flood	8	$12,625,000
Flood	10	$10,653,500
Ice Storm	2	$7,930,000
High/Strong Wind	28	$537,500
High Surf	8	$229,000
Lightning	8	$145,000
TOTAL	**122**	**$53,779,000**

[8] FEMA Disaster Declarations Summary, as of 2022: https://www.fema.gov/openfema-data-page/disaster-declarations-summaries-v1

[9] NOAA Storm Events Database, as of 2022: https://www.ncdc.noaa.gov/stormevents/

Recent notable storms include:

- December 23rd Storm 2022 – The highest water level recorded at the Portland tide gauge was 13.72 ft MLLW, the third highest ever recorded. Heavy rainfall, high winds, and storm surge caused extensive power outages, coastal flooding, and property damage along the coast of Maine. Governor Mills requested a disaster declaration in February, but FEMA has not made a determination yet.
- Flash floods, October 2021 – (Federally declared disaster) 4 to 6.5 inches of rain fell over coastal York County in a 6-hour period, which caused widespread power outages and flooded roads. [10]
- Nor'easters, March 2018 – (Federally declared disaster) Two nor'easters, only days apart, brought heavy rainfall, high storm surge, and high winds which caused severe coastal flooding and damage.[11]
- Patriot's Day Storm, April 2007 – (Federally declared disaster) High winds, waves, and coastal flooding caused severe damage to roads, bridges, and wastewater treatment plants as well as private homes and businesses. Extensive power outages left residents without electricity for days. The most extensive damage occurred along coastline and was caused by flooding and storm surge.[12]
- Mother's Day Storm, May 2006 – Southern Maine received up to 16 inches of rain, exceeding precipitation amounts associated with the 100-year storm event and resulting in extensive flooding and damage.[13]

In the future, as sea level rises and storms become more frequent and intense, Kittery can expect to see more damage from coastal flooding, high winds, and heavy rainfall. With 1.6 feet of sea level rise by 2050, it's estimated that cumulative damage costs caused by coastal flooding could be $16.9-$18.2 billion statewide.[14]

Historically, flooding has been the most common type of disaster in York County, particularly coastal flooding caused by nor'easters.[15] Storm tides cause extensive coastal flooding and occur when a storm surge coincides with an astronomical high tide. The highest water level recorded at the Portland tide gauge (the closest gauge to Kittery) occurred during the Blizzard of 1978 and exceeded 14 feet MLLW (Figure 9). The 2018 nor'easter and 2007 Patriot's Day Storm also caused storm tides within the top 20 water levels recorded at the Portland tide gauge. During the recent December 23rd storm (which is not displayed on the graph) a water level of 13.72 feet MLLW was recorded in Portland, about an inch lower than the 2018 nor'easter storm tide.[16]

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[10] York County Emergency Management Agency, Hazard Mitigation Plan, 2022: https://www.yorkcountymaine.gov/emergency-management
[11] SMPDC, Economic Resilience Planning for Coastal York County, 2022: https://smpdc.org/coastal
[12] York County Emergency Management Agency, Hazard Mitigation Plan, 2022: https://www.yorkcountymaine.gov/emergency-management
[13] SMPDC, Tides, Taxes, and New Tactics, 2021: https://smpdc.org/coastal
[14] ME Climate Council, Assessing the Impacts Climate Change May Have on the State's Economy, Revenues, and Investment Decisions, Summary Report, 2020: http://climatecouncil.maine.gov/reports
[15] York County Emergency Management Agency, Hazard Mitigation Plan, 2022: https://www.yorkcountymaine.gov/emergency-management
[16] Tides and Currents https://tidesandcurrents.noaa.gov/waterlevels.html?id=8418150

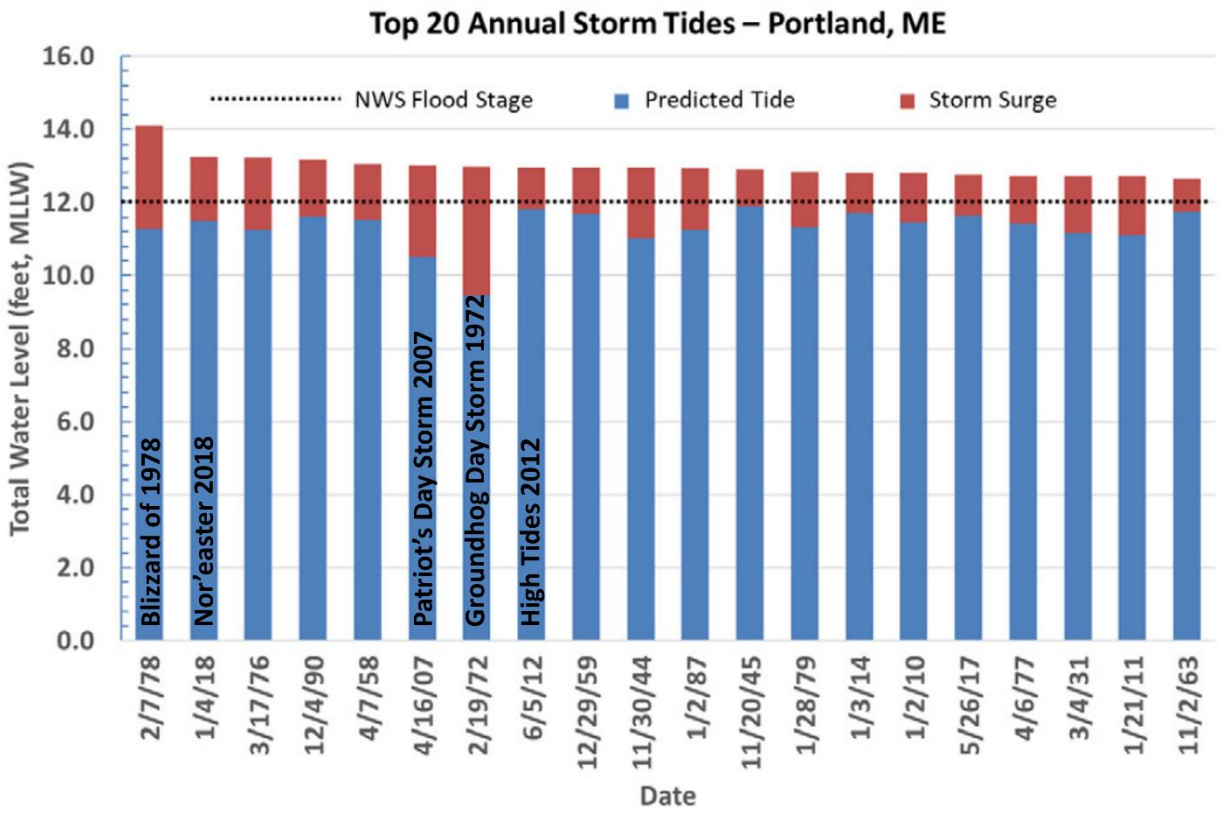


Figure 2 Major storm events and top 20 annual storm tides recorded at the Portland, ME tide gauge from 1912-2019. The National Weather Service Flood Stage of 12 feet MLLW is shown as a dashed line. This threshold indicates when elevated water levels begin to create a hazard to public safety, property, and infrastructure. Graph was created by Pete Slovinsky at the Maine Geological Survey for the ME Climate Council, Scientific Assessment of Climate Change and Its Effects in Maine, 2020.

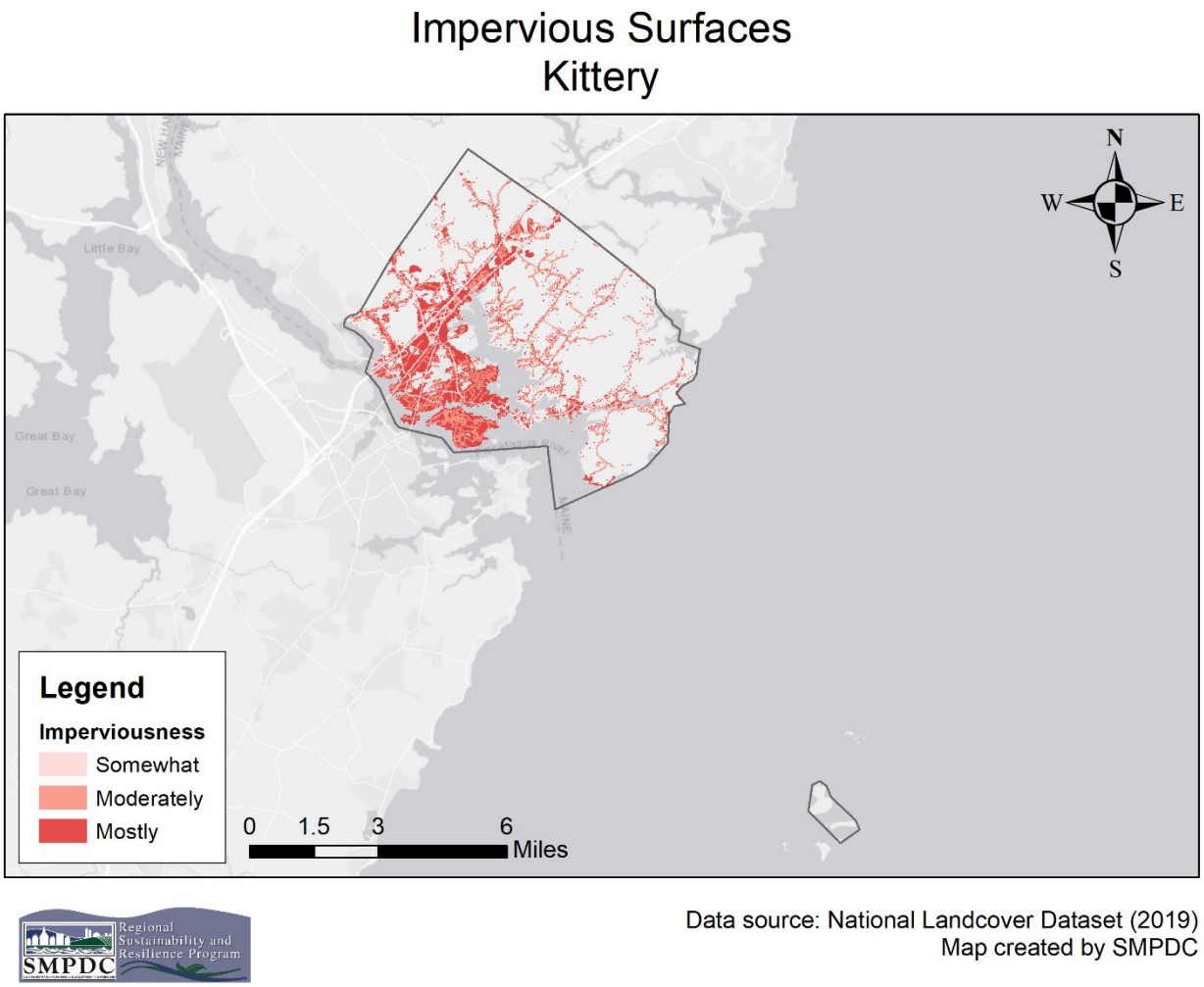
Intense storms and heavy precipitation can cause inland flooding along rivers and streams and exacerbate coastal flooding. Developed areas with lots of impervious surfaces such as roads, parking lots, sidewalks and buildings experience more flooding during heavy rainfall because the water has nowhere to go. Stormwater systems can overflow because of limited capacity to handle high water volumes, causing runoff into lakes and rivers. Inland and urban flooding poses a threat to public safety, infrastructure, and property. Runoff also increases the risk of contaminated drinking water supplies and degraded water quality in coastal areas making it unsafe to swim.[17] (*Note: Local information about beach closures due to poor water quality is forthcoming and will be included in the final version of the assessment)*

Like coastal flooding, inland and urban flooding may occur during winter nor'easters, but also occur during summer and fall tropical storms or intense thunderstorms. Flash floods are historically uncommon in Maine, but in October 2021 a flash flood dropped 4-6.5 inches of rain over coastal York County in 6 hours, causing extensive damage. Inland flooding is difficult to predict but changing weather

[17] York County Emergency Management Agency, Hazard Mitigation Plan, 2022: https://www.yorkcountymaine.gov/emergency-management

patterns and more frequent and intense hurricanes in the southern U.S. have the potential to cause more inland and urban flood events in coastal communities like Kittery. [18]

Kittery's location at the mouth of the Piscataqua River increases the community's risk of inland flooding. Additionally, there is a high degree of impervious surfaces in and around Kittery's downtown and along the I-95 and Route 1 corridors (Map 5). There is an elevated risk of flooding from extreme precipitation and stormwater overflow in these areas. Heavy rainfall coupled with a high degree of impervious surfaces can also exacerbate the impacts of coastal flooding. In the future, with more intense storms and extreme precipitation events these areas will be at a higher risk of flooding.



Map 5 Impervious surfaces in Kittery based on their level of imperviousness (somewhat, moderately or mostly impervious). Data is from the [2019 National Landcover Dataset](#).

[18] York County Emergency Management Agency, Hazard Mitigation Plan, 2022: https://www.yorkcountymaine.gov/emergency-management

Power Outages

Power outages due to extreme weather can have significant impacts and hazards for a community. Power outages can jeopardize essential public safety services. Downed wires during power outages can make roads impassable or dangerous. Lack of heating and electricity during power outages puts vulnerable community members at risk. Homes and businesses also face significant costs due to power outages.

Maine has some of the worst power outages in the country. From 2015-2019 Maine had the highest average annual frequency of power outages per customer of any state (3.9 outages per year). Maine also had the second longest average duration of power outages per customer annually (14.1 hours), only behind Florida (14.6 hours).

Major events and storms significantly impact the duration of power outages, greatly impacting the number of hours Mainers spend without power. In 2020, a greater number of severe weather events meant that CMP customers experienced an average of 29.5 hours without power. However, in 2021 CMP customers experienced only an average of 5.25 hours of power outages.[19]

In Kittery, the leading cause of power outages is tree limbs falling on power lines due to high winds or heavy ice or snow loads on trees. Tree limbs can cause outages by leaning on conductor lines, pulling lines down completely, or by damaging utility poles. In Kittery, tree impacts caused 70% of all customer hours without power in 2021(Data supplied by CMP). On the circuits serving Kittery, CMP customers experienced an average of 3.83 power outages with an average outage duration of 2.14 hours in 2021.[20]

In addition to downing lines, extreme storms can put other power system infrastructure at substations at risk. Substations are a key part of electrical power generation, transmission and distribution systems and often serve circuits that span multiple municipal jurisdictions. Flooding can damage substation components, leading to power outages and even fires. During extreme storms, damages to roads and other infrastructure can prevent utility services from reaching and repairing sub-stations, prolonging power outages. The Town of Kittery is served by two substations. One is located in Eliot on Bolt Hill Road and the other is located in Kittery off of Picott Road near Spruce Creek. While neither substation itself is likely vulnerable to extreme flooding, access to the substation off Picott road could be blocked due to flooding of Spruce Creek during extreme precipitation or storm surge.

Flooding: Sea Level Rise & Storm surge

Key Takeaways

- Kittery's coastal infrastructure, properties, and natural resources are vulnerable to flooding.
- Approximately $140.9 million in assessed value (FY21 assessment) are at risk from the 1% annual chance event storm surge plus 1.6 feet of sea level rise.
- **Admiralty Village** is vulnerable to flooding from the 1.6 ft scenario and is an area of elevated social vulnerability due to a relatively high percentage of the population having annual

[19] Annual Electric Power Industry Report, Form EIA-861 detailed data files, https://www.eia.gov/electricity/data/eia861/
[20] Data supplied by Central Maine Power

household incomes lower than the county and state median incomes, and less than the US EPA climate change and social vulnerability income threshold.

- The **Town Pier at Frisbee's Wharf/Pepperrell Cove** and **Harbormaster's Office building** are vulnerable to sea level rise and are important for tourism, economic activity, cultural significance, and community wellbeing.
- Key transportation routes and access roads are vulnerable to flooding and storm surge, which could potentially cut off access to the shipyard, residential the Kittery Outlets, Kittery public facilities, and neighborhoods.
- **Route 1** near the outlet malls over Spruce Creek is also a significant route for local and regional traffic and is vulnerable to flooding. The bridge is inundated by 1.6 ft scenario, and some outlet parking is vulnerable to the 3.0 ft scenario. Additionally, some of the area adjacent to the Creek is mapped as being able to potentially support future marsh migration as long as there are no physical barriers impeding that migration.
- With 1.6 ft of sea level rise, Kittery's dry beach width (distance from the mean high water to seawall or dune edge) is projected to decrease by 4.1 acres, or by 47%, leading to loss of habitat, recreation opportunities, and perhaps even cultural identity.
- Many engineered coastal structures (e.g., seawalls, bulkheads, etc.) in Kittery are vulnerable to being overtopped by flood waters from the 1% annual chance event storm, placing adjacent properties and roads at risk of flooding.

Background Info, Trends, & Projections

Sea level in Maine has been rising in the long-term, but over the past few decades the rate of rise has accelerated. That rise is increasing the frequency of nuisance or high tide flooding, with southern Maine seeing 4 times as many nuisance flooding events over the last decade compared with the average of the past 100-years. According to a recent State assessment, there is a 67% probability that sea level will rise between 1.1 and 1.8 feet by 2050, and between 3.0 and 4.6 feet by the year 2100 under intermediate global greenhouse gas emissions scenarios, with higher sea level rise amounts possible. With that rate of sea level rise, not accounting for increased intensity and frequency of storms, Maine will see a 15-fold increase in coastal flooding by 2050. Those scenarios do not account for more intense rainfall that climate change is bringing to the region, which will exacerbate flood risk.

As sea level rises in the future, normal high tides will be higher and storms, and accompanying storm surge, will be more impactful, causing extensive coastal flooding to roads, homes, and businesses. Storm surge is the abnormal rise in ocean water level during a storm event, measured as the height of the water above the normal predicted astronomical tide. This rise in water level can cause extreme flooding in coastal areas, especially when storm surge coincides with normal high tide. While future sea level rise will occur gradually over time, extreme storm events can cause damaging flooding episodically in the short-term.

In addition to rising seas, storm surge, and more nuisance flooding events, southern Maine's coastal areas are seeing more frequent and intense precipitation events. Further, the intensity and frequency of precipitation is expected to increase in the future with climate change. Stormwater runoff from rainfall events combined with surge and future sea level rise will lead to more extensive flooding in coastal areas.

Coastal flooding threatens public health and safety by putting transportation corridors, evacuation routes and provision of emergency services at risk; disrupts economic activity through lost business and reductions in tourism; reduces property values; and imperils municipal revenue and budgets. In southern Maine, future sea level rise will cause regular inundation of low-lying coastal areas during high tide, contamination of groundwater aquifers and wells from saltwater intrusion, and increased erosion of the region's sandy beaches, dunes, and salt marshes.

To plan for sea level rise and associated impacts, the Maine Climate recommends an approach of committing to manage for a higher probability, lower risk scenario, but also preparing to manage for a lower probability, higher risk scenario. That concept involves building flexibility into designs and decisions so that adjustments can be made to address more extreme sea level rise. It accounts for some of the variability and uncertainty regarding global emissions reductions efforts and evolving science about potential future melting of land-based ice. The State recommends that Maine commit to manage for 1.5 feet of relative sea level rise by 2050, and 3.9 feet of sea level rise by the year 2100, but prepare to manage for 3.0 feet by 2050, and 8.8 feet by 2100, all in relation to 2000 local sea level. When planning for sea level rise, consideration should be given to the risk tolerance of different kinds of infrastructure. In other words, the intended lifespan, criticality, and exposure of infrastructure and assets to flood hazards should be considered when evaluating what sea level rise scenarios and planning horizons to account for in design and maintenance decisions.

Individuals who already have increased social vulnerability will be disproportionately affected by sea level rise and climate change as they have less capacity to prepare for, respond to, and recover from coastal hazard events.

This section presents assessment results of the impacts of modeled flooding from storm surge combined with sea level rise to represent what flooding from storm events could look like in the future. The two flooding scenarios, listed below, align with the Maine Climate Council's planning recommendation of committing to manage 1.5 feet of rise by 2050 and preparing to manage 3.0 feet by 2050.

Flooding scenarios used for assessment[21]:

- **Storm surge from 1% annual chance event (i.e. 100-year storm) + 1.6 feet of sea level rise**
- **Storm surge from 1% annual chance event + 3.0 feet of sea level rise**

The assessment results presented below use the terms 'vulnerable', 'impacted', and 'at-risk' to describe impacts. All three terms mean that the subject parcels, asset, or area is touched by water under the given inundation scenario. It is important to note that the modeled flood scenarios show inundation at high tide, so not every area or thing that is directly impacted by the flood scenarios will be permanently inundated.

[21] The sea level rise scenarios were developed by the Maine Geological Survey and do not account for wave action or precipitation. The storm surge values were provided by Ransom Consulting, LLC, and consist of storm surge and static wave set-up, without additional wave action due to crests or wave runup.

Property Impacts

Where and how we choose to develop land profoundly impacts the resilience of our community. Buildings located in areas exposed to natural hazards like flooding are at greater risk of climate change impacts. Kittery's municipal budget, like most southern Maine coastal communities, is highly dependent on revenue from local property taxes and coastal development provides a substantial portion of the municipal tax base, generating vital funds that sustain community operations, services, and programs. However, it is that same development that is most susceptible to coastal flooding, placing residents, visitors, and municipal fiscal health at risk. Studies have shown that coastal hazards and climate change diminish the value of impacted properties[22]. Municipal fiscal health could be negatively impacted if coastal properties, which generate a large portion of local tax revenue, are exposed to flooding and if development in vulnerable areas continues. In addition, the coastal areas and resources, especially sandy beaches, that serve as the economic engine for towns, the region, and state are particularly vulnerable to storms and rising seas as increasing water levels reduce the area of dry beach available.

The map below (Map 6) shows the locations of buildings and facilities that are critical for community safety, function, and well-being, and the location of historic properties. It also shows parcels that are vulnerable to, or 'impacted' by, projected flooding from the 1%-annual chance event (*e.g.*, the FEMA regulatory floodplain), 1.6 feet of sea level rise, and/or 3.9 feet of sea level rise.

- Approximately $140.9 million in assessed value (FY21 assessment) are at risk from the 1% annual chance event storm surge + 1.6 ft SLR scenario. The assessed value of impacted parcels increases to $186.6 million from the 1% annual chance event storm surge + 3.0 ft SLR scenario (Table 5).
- Access to 201 parcels that aren't directly at-risk of flooding is cutoff due to road flooding from storm surge plus 1.6 feet of sea level rise. Most of the cut-off parcels are in the Kittery Point area.
    - Access to 185 parcels that aren't directly at-risk of flooding is cutoff due to road flooding from storm surge plus 3.0 feet of sea level rise (note that this number decreases from flooding from storm surge plus 1.6 feet of sea level rise because more parcels become directly impacted by flooding with 3.0 feet of sea level rise).
- Access to **Fort McCleary State** Park via Crockett's Neck Road bridge over Barters Creek, and small portions of the park are vulnerable to flooding from both scenarios.
- Large portions of **Gerrish Island**, namely low-lying parts **of Fort Foster**, are vulnerable to flooding from both scenarios. Access via Pocahontas Road is cutoff by a small portion of inundation in 3.0 ft scenario only. Fort Foster beaches and walking paths, critical recreational and tourism resources, are also vulnerable.
- The **Town Pier at Frisbee's Wharf/Pepperrell Cove** and **Harbormaster's Office building** are vulnerable to flooding from both scenarios. Areas of the parking lot are inundated in the 1.6 ft scenario and adjacent commercial buildings are vulnerable to the 3.0 ft scenario.
- The **Government Street Wharf** and public **Traip Launch** are both vulnerable to flooding from 1.6 ft and 3.0 ft of sea level rise.
- **Admiralty Village** is vulnerable to flooding from the 1.6 ft scenario. The residential neighborhood is an area of elevated social vulnerability due to a relatively high percentage of the population having annual household incomes lower than the county and state median

[22] Shi, L., Varuzzo, A. M. (2020). *Surging seas, rising fiscal stress: Exploring municipal fiscal vulnerability to climate change*. Cities 100 (2020) 102658.

incomes, and less than the US EPA climate change and social vulnerability income threshold. Additionally, it is the area of town where the most water and sewer infrastructure in areas vulnerable to flooding are located.

	Assessed Value: Land Only Impacted	**Assessed Value: Buildings & Land Impacted**	**Total Assessed Value Impacted**	**Total Municipal Tax Impact (impacted property value x FY '22 tax rate of 0.013)**	**% of Town-Wide Assessed Value (2022)**
Storm surge + 1.6 ft sea level rise	$63,045,228	$77,873,600	$140,918,828	$1,831,945	5%
Storm surge + 3.0 ft sea level rise	$81,574,068	$115,086,800	$186,660,868	$2,426,591	7%

Table 5 Assessed property value of parcels directly impacted by flooding from storm surge and sea level rise, the total property tax those values generate for the Town, and impacted values as a percentage of the community-wide assessed value (2022 values) and (Source: SMPDC. 2022. Economic Resilience Assessment and Plan for Coastal York County.)

Infrastructure Impacts

- Kittery has a total of 5.01 miles of road vulnerable to flooding from storm surge plus 1.6 feet of sea level rise, and 6.52 miles vulnerable to flooding from storm surge plus 3.0 feet of sea level rise (Table 6) (Map 7a). Vulnerable roadway include both public and private roads, with slightly more miles of private roads impacted than public roads.
- Roads that are particularly vulnerable due to the amount of local and regional travel they support and access they provide to important areas include:
    - **Route 103/Whipple Road**, which is a critical route for commuting, local travel, and access to the Portsmouth Naval Shipyard, is vulnerable to flooding from 1.6 feet of sea level rise along several segments, namely the Main Street bridge over Spinney Creek, a critical section near Gate 2 of the Shipyard, and large portions at the York border near Brave Boat Harbor.
    - **Route 1** near the outlet malls over Spruce Creek is also a significant route and is vulnerable to flooding. The bridge is inundated by 1.6 ft scenario, and some outlet parking is vulnerable to the 3.0 ft scenario.
    - **Seapoint Road** over Chauncey Creek, near its intersection with Chuancey Creek Road and Cutts Island Lane, is also vulnerable and is the only access road to Seapoint Beach and Cutts Island.
    - **Payne Road and Brave Boat Harbor Road** near the York border are also vulnerable to flooding and are important routes for local travel and to York Hospital.
    - While they are not inundated directly, the **Horace Mitchell Primary School and Kittery Police Department may have access issues due to road flooding**. Access to the school via Route 103 is cut off a short distance east of the school, and the Kittery Police Department is located about a mile from the inundation over the Route 1 bridge.
- There are 12 tidal road crossings (culverts) that are located in areas vulnerable to the 1.6 ft scenario.
- 10% (2,273 ft of 20,819 total ft) of Kittery's storm and sewer pressure mains and 3% (3,718 ft of 126,705 total ft) of gravity mains are located in areas vulnerable to flooding from the 1.6 ft

scenario (Map 7b). Most storm and sewer infrastructure located in vulnerable areas is in the Foreside and Route 1 areas.

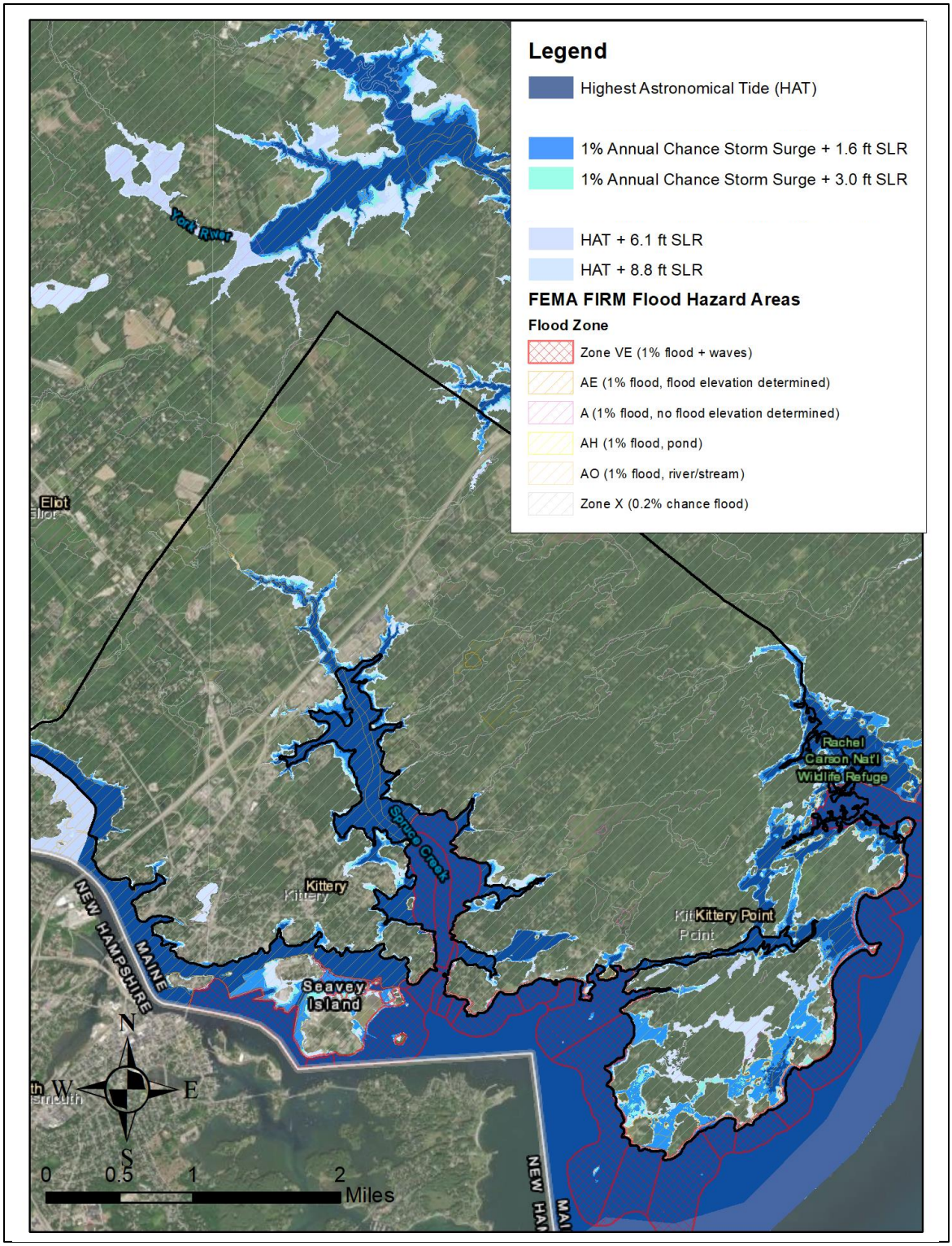
- Based on an assessment by the Maine Geological Survey, coastal engineered structures (e.g., seawalls, bulkheads, jetties, etc.) in the following areas are vulnerable to overtopping by flooding from the modeled current 1% annual chance storm event, not including sea level rise.
    - Most engineered structures around Badgers Island
    - Most structures along the river shoreline in the Foreside area
    - Most rip-rap and bulkhead structures along private properties off Whipple Road across from the Shipyard and off Old Ferry Lane, Bowen Road, and along Pepperrell Cove.
    - Most rip along private residential properties at Crescent Beach and north of Sapoint Beach.

	Road Length (Miles) and Classification Impacted
Storm surge + 1.6 ft SLR	**5.01** *Local: 2.27* *Private: 2.37* *Secondary: 0.37*
Storm surge + 3.0 ft SLR	**6.52** *Local: 2.89* *Private: 3.16* *Secondary: 0.46*

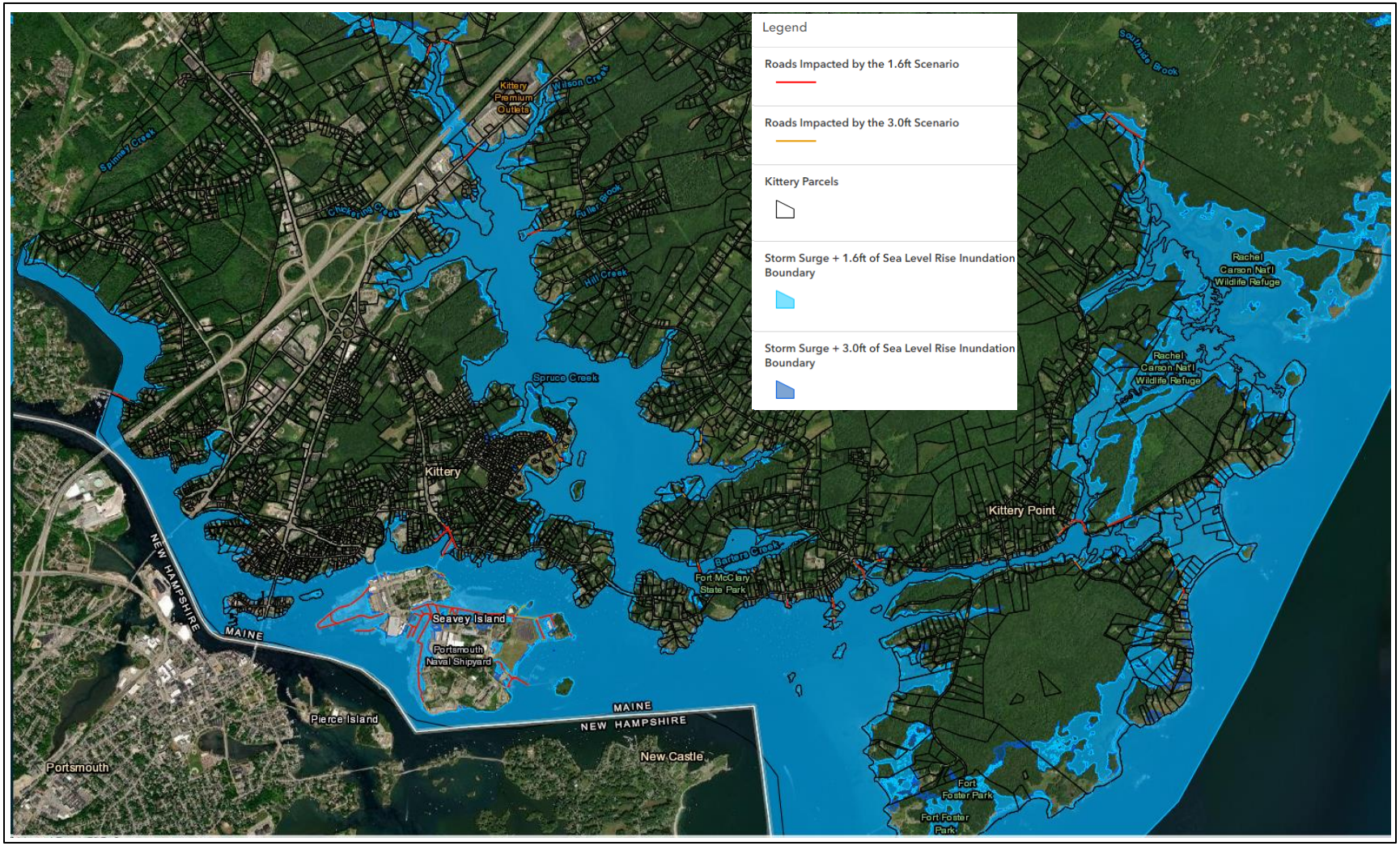
Table 6 Road length and classification impacted by storm surge from the 1% annual chance event plus 1.6 feet and 3.0 feet of sea level rise. (Source: SMPDC. 2022. Economic Resilience Assessment and Plan for Coastal York County)

Economic Impacts

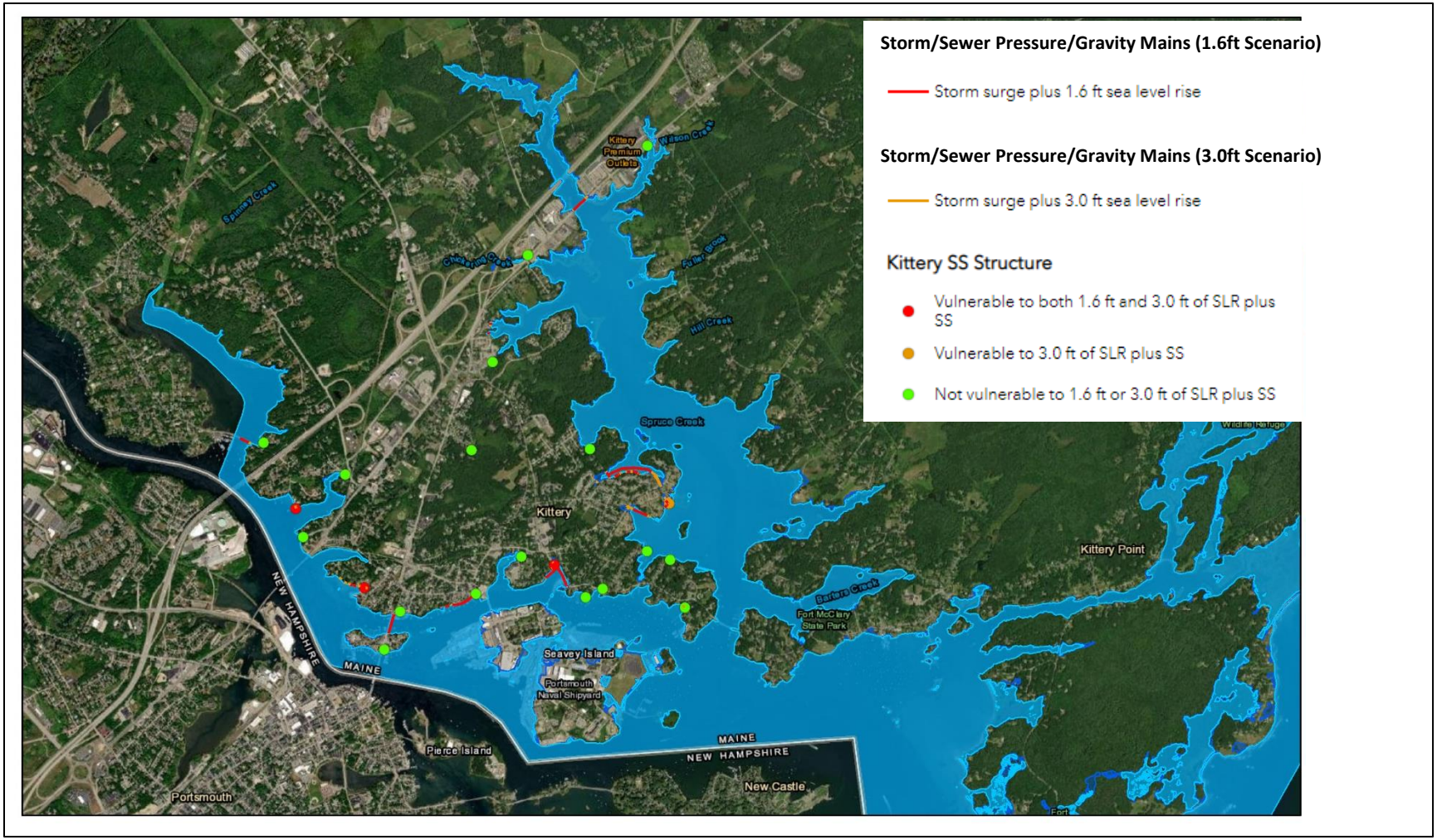
- More than 200 jobs, more than $4 million in labor income, nearly $7 million in area gross domestic product, and over $11 million in revenue in Kittery may be affected in some way by the two scenarios of storm surge and sea level rise. Approximately 10% of the employment in the local restaurant industry is projected to be impacted, which is important because generally, individuals employed in the restaurant sector have increased social vulnerability.



Map. Modeled inundation from sea level rise (SLR), storm surge, and the 1% annual chance storm event (Special Flood Hazard Area depicted on the FEMA-Issued Flood Insurance Rate Map).



Map 7a Roads that are projected to be flooded from storm surge combined with 1.6 feet and 3.0 feet of sea level rise. (Source: SMPDC. 2022. Economic Resilience Assessment and Plan for Coastal York County)

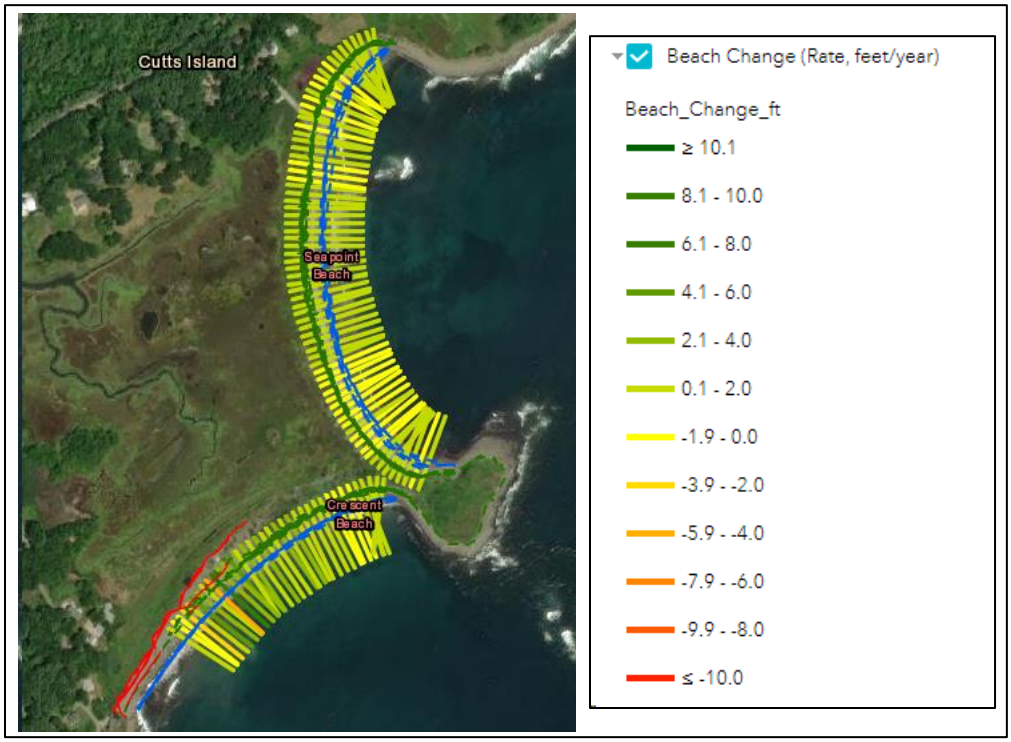


Map 7b. Storm and sewer infrastructure that are projected to be flooded from storm surge combined with 1.6 feet and 3.0 feet of sea level rise. (Source: SMPDC. 2022. Economic Resilience Assessment and Plan for Coastal York County

Impacts to the Natural Environment

Rising seas and coastal storms threaten local beaches and dune systems through erosion and flooding. Hardened coastal structures, like seawalls, roads, and homes, prevent beach systems from migrating inland as ocean levels increase. Additionally, how beaches will fare with increase sea level is related to sediment supply, both sources and volumes of the supply. Sand and gravel for beaches can come from rivers, eroding bluffs, the offshore seafloor, or marine shells. Shorelines that have been engineered to prevent erosion, protect property, and stabilize the shoreline offer reduced sediment supply to beaches.

- With 1.6 ft of sea level rise, Kittery's dry beach width (distance from the mean high water to seawall or dune edge) is projected to decrease by 4.1 acres, or by 47%. With 3.9 feet of sea level rise, the dry beach width is projected to decrease by nearly 83%[23].
- Sea level rise is expected to lead to loss of coastal habitat. Along Kittery's coast, loss of dry beach will impact local species, including piping plovers and other shorebirds that use the beach for nesting.
- Monitoring data from the Maine Geological Survey conducted as part of the Maine Beach Mapping Program show that Seapoint and Crescent Beaches have been relatively stable in terms of their width over the past several years (2016 – 2020) (Map 8).

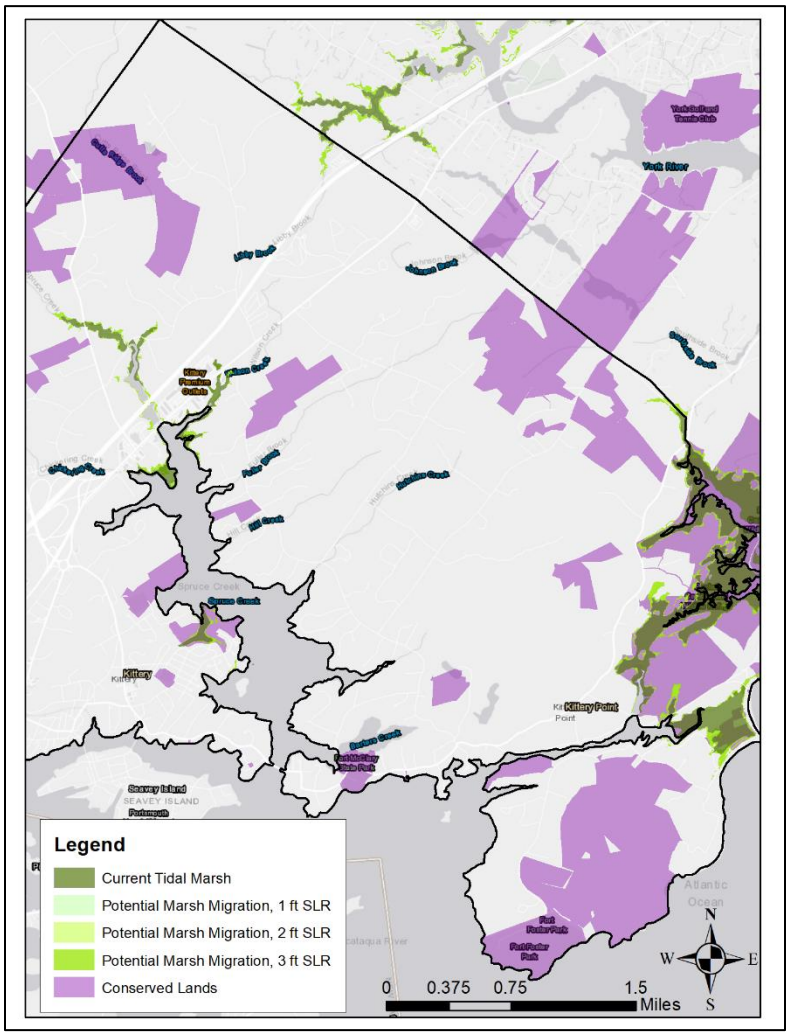


Map 8 Mapped shoreline change along Goose Rocks Beach. This map shows the rate of beach change, in feet per year, from data collected from 2016 through 2020. A positive value (green lines) represents a rate of beach growth, while a negative value (yellow/orange/red lines) represents a rate of beach loss. (Source: Maine Geological Survey. Maine Beach Mapping Program. Maine Beach Mapping viewer)

[23] Maine Geological survey. 2021. Unpublished analysis of the impact of sea level rise on dry beach width of Maine's sandy beaches.

While sea level rise threatens inundation of the beach system, it also has the potential to facilitate the landward expansion, or migration, of tidal marshes. However, this landward migration can only occur if saltmarshes are healthy and there are not physical barriers, such as stonewalls, roads, or buildings, that inhibit marsh movement. The Maine Natural Areas Program (MNAP) has mapped areas that could support marsh migration with future sea level rise (Map 9). Protecting these areas will be crucial for ensuring the long-term viability of local tidal marshes, which provide tremendous natural benefits and services including wildlife habitat, flood control, and water quality protection.

- Areas along Spruce Creek near its origin and near the Route 1 crossing have been identified as being able to support future marsh migration. This migration will likely be inhibited by impervious surfaces and structures in the outlet mall area.
- Areas around Brave Boat Harbor and Seapoint Beach are also identified as being able to support future marsh migration. The majority of this area is already conserved, which will help to ensure that future development won't impact migrating marshes in those areas.



Map 9 Existing conserved lands (purple) and areas that could support future migration of existing tidal marshes with future sea level rise. The areas are non-tidal lands within existing tidal estuaries that could be inundated and facilitate the development of new areas of tidal marsh if sea level rises by 1, 2, or 3.3 feet above current highest annual tide (HAT). (Source: Maine Natural Areas Program. Sea level rise scenarios are from the Maine Geological Survey.)

Extreme Temperatures & Air Quality

Key Takeaways

- Maine's average annual temperature has increased by 3.2°F since 1895 and could warm an additional 2-4°F by 2050.
- Southern Maine is expected to experience roughly 4.5 times more 'extreme heat' days by the 2050s.
- Exposure to extreme heat is a significant public health concern and can be especially dangerous for older adults, infants, people with existing health conditions, and those who have limited access to air conditioning.
- Extreme heat will exacerbate the impacts of urban 'heat islands', the locations of which overlap with areas of socially vulnerable populations in Kittery, such as in the foreside area and along the Route 1 corridor.
- There are fewer days with below-freezing temperatures and snow cover, leading to an increase in pest outbreaks and prevalence vector-borne diseases like Lyme disease.

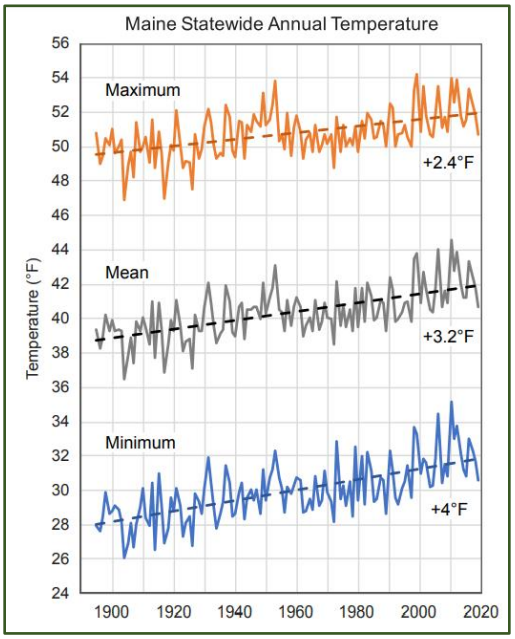


Figure 4 Maximum, mean, and minimum statewide annual temperatures from 1895 to 2019. (Source: MCC STS. 2020.)

Background Information, Trends, & Projections

Climate change is causing increased temperatures and more frequent extreme temperature occurrences. In Maine, the average annual statewide temperature has increased by 3.2°F since 1895[24] (Figure 4). Winters are warming faster than other seasons, and coastal areas have warmed more than the interior of the State. Climate models project that Maine could warm an additional 2 to 4°F by 2050 and up to 10 °F by 2100 depending on global greenhouse gas emissions. Extreme heat days are expected to be 2 - 4 times more frequent in Maine by 2050, increasing the likelihood of heatwaves. Southern Maine is expected to experience roughly 4.5 times more 'extreme heat' days, where the heat index (a combination of temperature and relative humidity that approximates the 'felt' temperature) exceeds 95°F (Figure 5)[25].

Eight of the ten warmest years for which monthly temperature exists for the Cape Neddick site have occurred within the past ten years, based on average annual temperatures from National Weather Service (NWS) data collected between 2000 and January of 2023 in Cape Neddick, the NWS data collection station closest to Kittery (**Error! Reference source not found.**7). The warmest average

[24] MCC STS. 2020. Scientific Assessment of Climate Change and Its Effects in Maine. A Report by the Scientific and Technical Subcommittee (STS) of the Maine Climate Council (MCC). Augusta, Maine. 370 pp.
[25] Fernandez, I.J., Schmitt, C.V., Birkel, S.D., Stancioff, E., Pershing, A.J., Kelley, J.T., Runge, J.A., Jacobson, G.L. & Mayewski, P.A. (2015). Maine's Climate Future: 2015 Update. Orono, ME: University of Maine.

monthly temperatures for the summer months (June, July, and August) have been 2.1 – 4.5°F warmer than the monthly mean temperature. (**Error! Reference source not found.**8). 2023 was the warmest January on record, with an average temperature of 32.6°, which is 9.2° warmer than the January mean temperature.

	Year	Average Annual Temperature (°F)
1	2010	49.0°
2	2012	48.9°
3	2021	48.3°
4	2020	48.2°
5	2018	48.1°
6	2016	47.9°
7	2022	47.9°
8	2011	47.4°
9	2017	47.4°
10	2013	46.5°

Table 7 The top ten warmest years based on average annual air temperatures measured in Cape Neddick, 2000 – January 2023. (Source: National Weather Service).

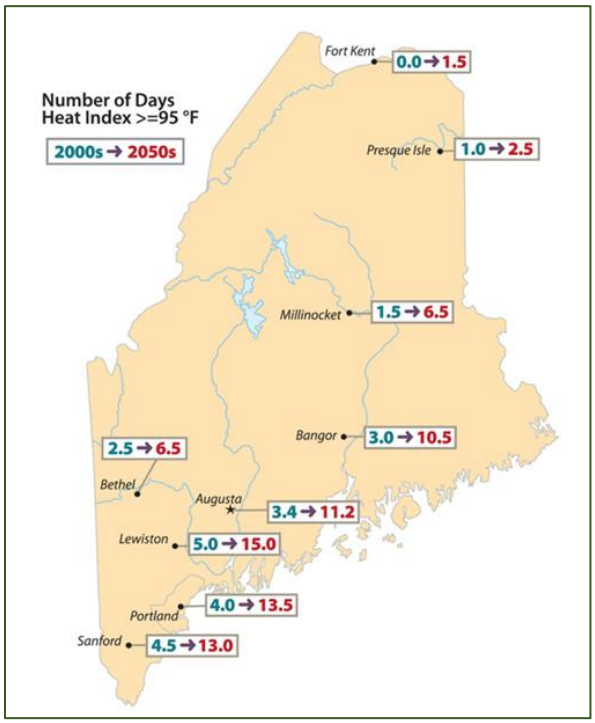


Figure 5 Average number of days when the heat index is greater than or equal to 95°F at selected sites for 2000 - 2004 and 2050 – 2054. Predicted values derived from a 48-km downscale simulation of one ensemble member of the CCSM3 model for the IPCC A2 emissions scenario. Source: Fernandez et al. (2015). (Figure from MCC STS. 2020.)

Month	Year	Average Temperature (°F)	Mean Temperature (°F), 1989 - 2022	Difference Between Mean and Average of Warmest Month
June	2021	67.9°	63.4°	+4.5°
July	2010	72.3°	70.0°	+2.3°
August	2022	71.3°	69.2°	+2.1°

Table 8 The warmest average monthly temperatures of the three summer months and years in which they occurred compared with the mean monthly temperatures for those months measured in Cape Neddick, 2000 – January 2023. (Source: National Weather Service.)

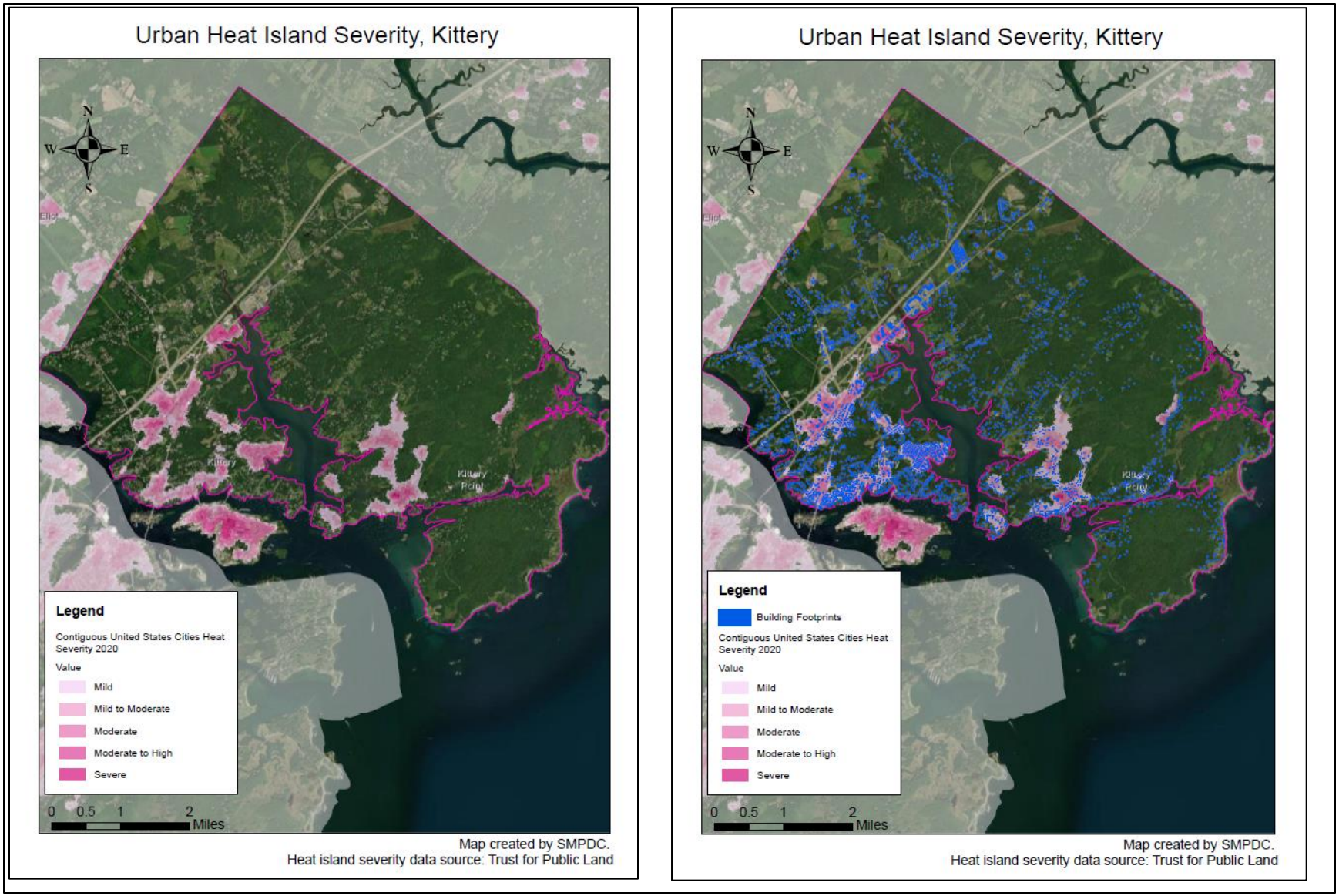
Urban Heat Islands

Extreme heat days in Maine will exacerbate the severity and impacts of "heat islands", or areas with a lot of impervious surfaces, such as buildings and pavement, that absorb and re-emit heat. The Trust for Public Land notes that extreme heat exacerbated by urban heat islands can lead to increased respiratory difficulties, heat exhaustion, and heat stroke.

Map 10 shows areas in Kittery that are hotter than the average temperature for the community as a whole. The map on the right shows the location of building footprints in relation to heat islands. The

maps show the relative heat severity measured on a scale of 1 to 5, with 1 being a relatively mild heat area (slightly above the mean for the city), and 5 being a severe heat area (significantly above the mean for the city). (*Heat island temperature data: 30-meter resolution based on data derived from Landsat 8 imagery band 10 (ground-level thermal sensor) from the summers of 2019 and 2020*.)

In Kittery, areas along Route 1 in the western portion of town and near the outlet malls, State Road, the Foreside, Naval Shipyard, Admiralty Village, and near the intersection of Route 103 and Haley Road have elevated ground temperatures in relation to the rest of the community. The Route 1 corridor through the outlet malls and in the western portion of town, the area where Route 103 and Haley Road intersect, and Admiralty Village neighborhood are mapped as having moderate to severe heat severity also have elevated social vulnerability and vulnerabilities to flood hazards. The map also illustrates that the presence of a high concentration of buildings in an area does not necessarily mean the area has elevated ground temperatures. Knowing where areas of high heat are located can inform mitigation and adaptation strategies.



Map 10 Urban heat island severity (left) overlaid with building footprints (right). (Data source: heat island severity data, Trust for Public Land; building footprints, Microsoft)

Public Health Impacts

Extreme heat is one of the most significant impacts of climate change on human health and is the leading cause of weather-related deaths across the United States. Exposure to extreme heat has been linked with a wide range of health issues, including heatstroke, heat exhaustion, impacts on kidney function, dehydration, fetal health, mental health, and exacerbation of pre-existing health conditions (24). Extreme heat is also linked with increased deaths and emergency department visits. From 2011 to 2015 and 2017 to 2019, York County had the second highest number of annual emergency department visits for heat-related illness across Maine, with Cumberland County seeing the highest numbers[26]. **Error! Reference source not found.**6 shows peak emergency department visits for heat-related illnesses to hospitals in York County between 2018 and 2023, the years for which monthly data is available.

Residents of cooler climates, like Maine, are less physiologically adapted to extreme heat exposure, and experience disproportionate health effects on hot days when compared to residents of warmer climates. Additionally, the prevalence of air conditioning, one of the most effective tools for preventing heat illness, is significantly lower in Maine than in the rest of the region and the country [27]. Certain populations, including older adults, infants, pregnant women, and people who have chronic diseases or who are sick already may feel much worse or have serious problems in extreme heat. Further, people with limited access to air conditioning, outdoor laborers, and unhoused populations are also more vulnerable to the impacts of extreme heat. A survey conducted by the Maine Behavior Risk Factor Surveillance System found that in 2014, 70.8% of homes in York County had some form of air conditioning, the highest percentage of all Maine counties. However, as noted above, York County also had the second highest number of heat illness emergency department visits.

[26] Maine Health Data Organization (MHDO). Data analyzed and display prepared by the Environmental Public Health Tracking Program. Data updated: 06/2021.

[27] MCC STS. 2020. Scientific Assessment of Climate Change and Its Effects in Maine. A Report by the Scientific and Technical Subcommittee (STS) of the Maine Climate Council (MCC). Augusta, Maine. 370 pp.

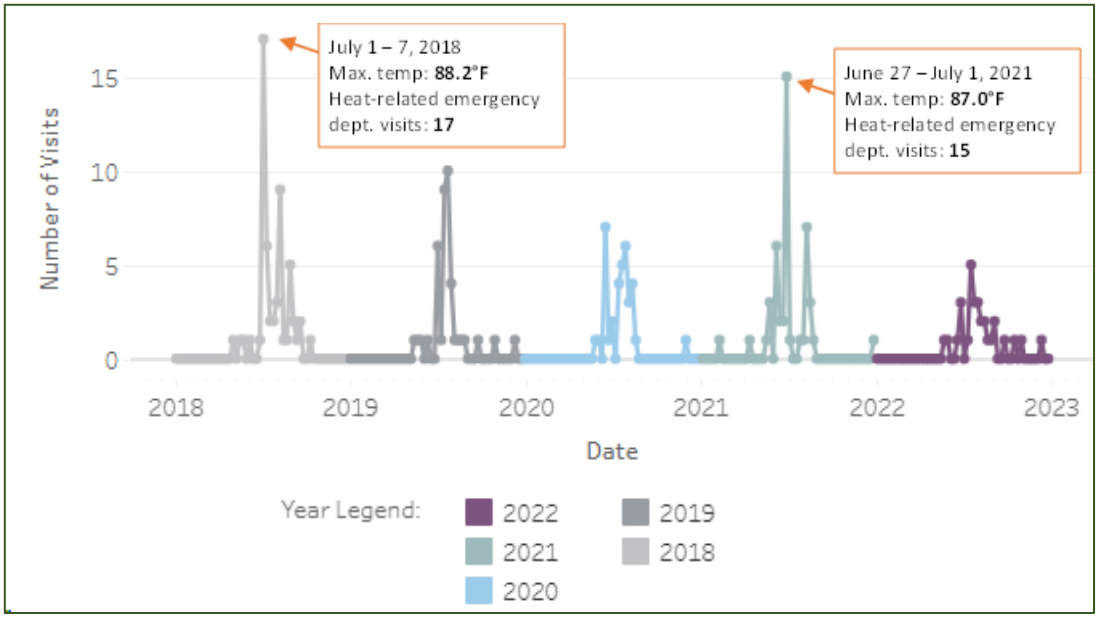


Figure 6 Number of heat illness visits to emergency departments in York County from 2018 to 2023. (Source: Maine Center for Disease Control and Prevention, Maine Tracking Network.)

Climate change can impact air quality and lead to worsening air pollution. Atmospheric warming associated with climate change has the potential to increase ground-level ozone in many regions, which may cause public health issues and present challenges for compliance with the ozone standards in the future. The impact of climate change on other air pollutants, such as particulate matter, is less certain, but research is underway to address these uncertainties.[28] Figure 7 shows the number of days in York County with an 8-hour average ozone concentration that exceeded the National Ambient Air Quality Standard of 0.070 ppm, established December 28, 2015. Previous standards were set at .075 ppm from 2008-2015 and .080 prior to 2008. Research for this assessment could find no cause of the relatively high number of exceedances between 2001 and 2007. An analysis by the Maine Department of Environmental Protection affirmatively demonstrates that Maine emissions are insignificant contributors to non-attainment of ozone for the 8-hour ozone air quality standards[29]. Regardless of the cause, individuals with existing health conditions, older populations, and children are especially vulnerable to poor air quality.

[28] US Environmental Protection Agency. Air Quality and Climate Change Research webpage.
[29] State of Maine Clean Air Act Section 176A(a)(2) Petition. 2020.

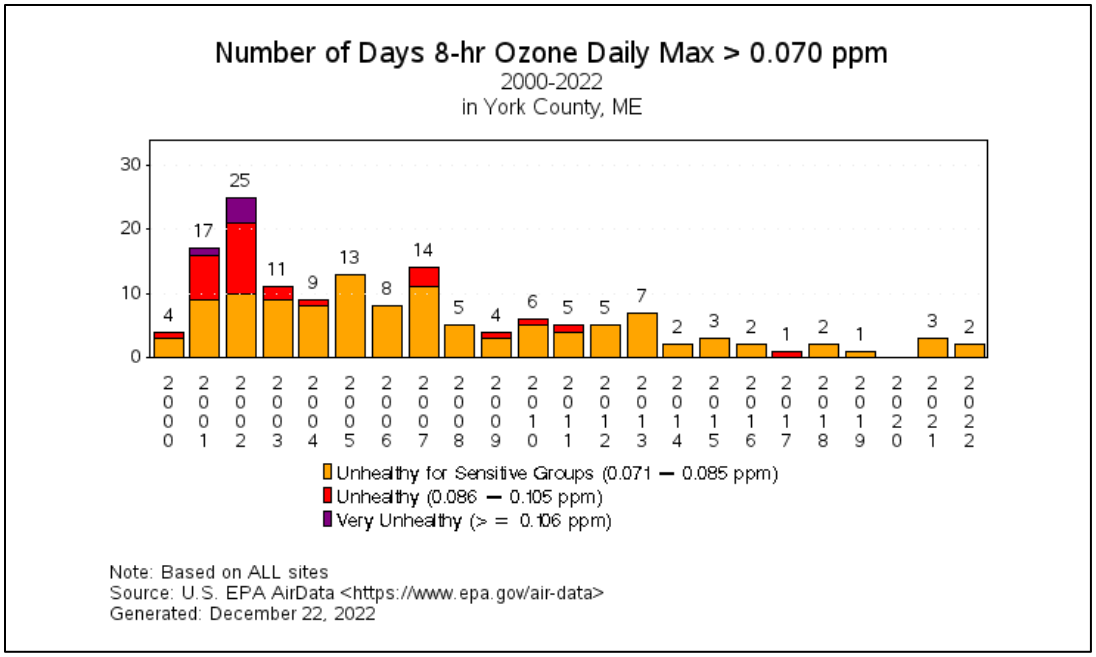


Figure 7 Number of days during which the 8-hour average ozone concentration exceeded national air quality standards. (Source: US EPA AirData portal)

The prevalence of tickborne diseases, including Lyme, anaplasmosis, and babesiosis, has increased in York County in recent years. Figure 8**Error! Reference source not found.** shows that rates of all three diseases have increased since 2001. Table 9 shows the incidence rate (per 100,000 people) of confirmed and probable cases of tickborne disease in Kittery. Between 2016 and 2020, Kittery had the second highest rate of babesiosis and ninth highest rate of Lyme of all York County communities.

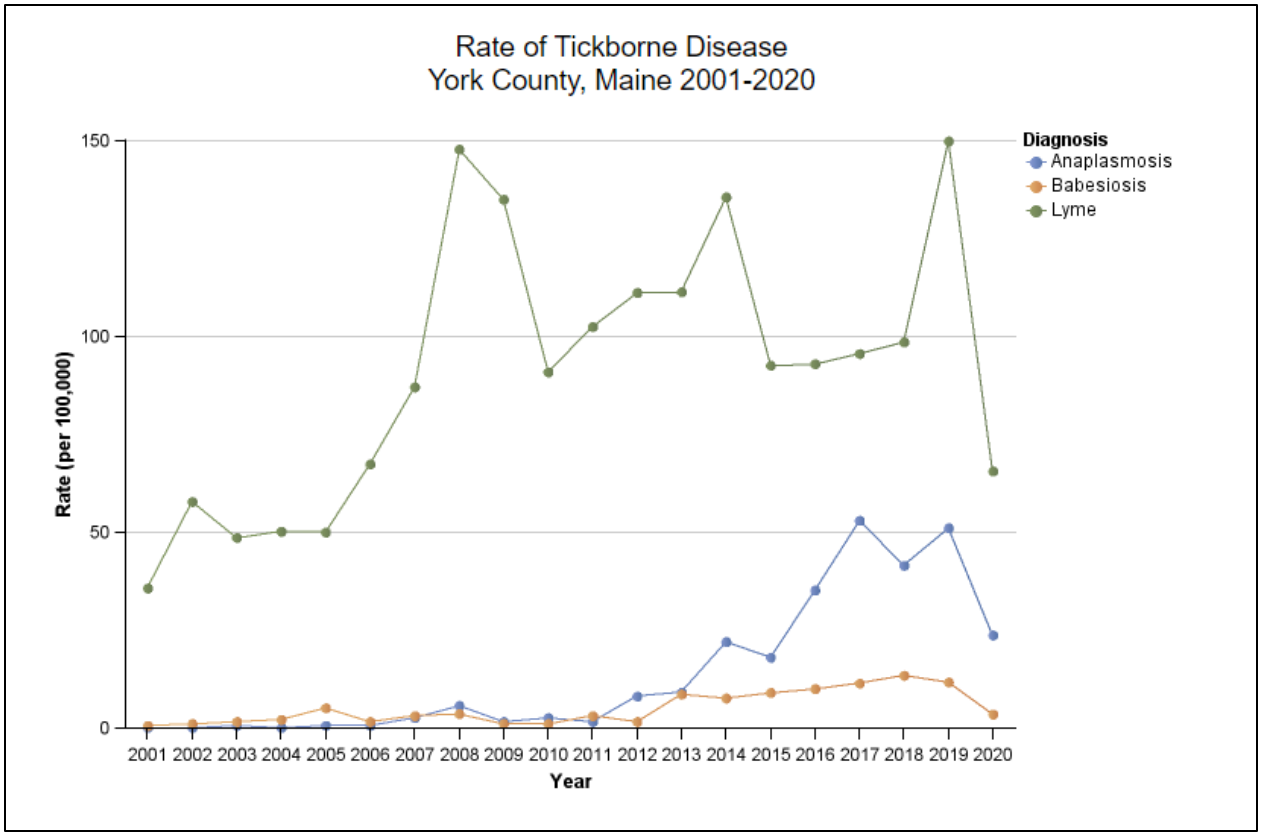


Figure 8 Annual incidence rate (per 100,000 people) of confirmed and probable cases of tickborne diseases of the population in York County. Maine CDC's Infectious Disease Program obtained these data through notifiable conditions surveillance based upon reports from healthcare providers, laboratories, and other healthcare partners. (Data Source: Maine CDC's Infectious Disease Program collected and analyzed population data from the U.S. Census Bureau to calculate state and county rates of tickborne disease. Maine CDC used population data from Maine CDC Data, Research, and Vital Statistics (DRVS) to calculate town-level rates of tickborne disease. The Maine Environmental Public Health Tracking Program prepared the data display. Data updated: 05/2021. Display updated: 05/2021.

Rate and Number of Tickborne Diseases in Kittery, 2016 - 2020			
	Anaplasmosis	Babesiosis	Lyme
Confirmed and probably cases	20	17	69
Rate (per 100,000 people)	41.4	35.2	142.7

Table 9 Rate and number of confirmed and probable cases of tick-borne disease in Kittery, 2016 -2020. (Source: Maine Center for Disease Control and Prevention. Infection Disease Program. Maine Tracking Network Data Portal.)

Impacts to the Natural Environment

Increasing and shifting temperatures will impact the natural environment and Maine's wildlife and vegetation. Shorter winters, less snow, a rapid expansion of pests (e.g., winter ticks), presence of parasites previously only found further south, heat stress, more frequent and higher flooding of tidal marshes, invasive species, and changes in available prey species all threaten local species and natural areas. Increasing temperatures impact biodiversity and affect ranges where species can live. Scientists

predict that 34%–58% of species will go extinct given current climate change scenarios if they are unable to disperse to new locations, while 11–33% will still go extinct even if they can disperse to future areas that are within their current climatic niche (24).

While Maine's growing season has lengthened overall due to warming temperatures, some years have seen killing frosts in late spring and early fall. It is uncertain whether such events will become more or less frequent in the future, but the trend of longer growing seasons and warmer falls is expected to continue. Climate model projections indicate that in the future, it is likely that increased evaporation will dry surface soil layers, particularly in the warm season[30]. These changes will impact local agricultural activities as well as home gardeners.

Drought

Key Takeaways

- Despite wetter conditions overall, changing precipitation patterns caused by climate change have contributed to the emergence of drought conditions in southern Maine in recent years.
    - There have been four periods of severe to extreme drought in York County since 2000, 3 of which have occurred in the last 7 years.
- Average annual snowfall across the state has decreased about 2 inches since 1895 because more precipitation is falling as rain rather than snow. Lower spring snowpack reduces aquifer recharge, contributing to the emergence of drought.
    - Maximum monthly recorded snow depths at a survey site in South Berwick have fallen substantially since 2000.
- Communities supplied by groundwater wells, rivers, or smaller lakes are at greater risk of water quantity and quality impacts from drought.
    - To date, it does not appear that Kittery Water District has experienced significant water quality issues because of drought. In the future, more frequent, prolonged, or intense droughts have the potential to exacerbate existing regional water quantity issues and increase the risk of water quality issues.
    - There are 295 private wells in Kittery. Groundwater levels were historically low during the recent droughts and in 2020 and 2022, 45 and 15 dry wells were reported in York County respectively.
- Wildfire risk may increase with more frequent, severe, and intense droughts, and though the likelihood of wildfires may remain low such an event could have major impacts on the community.
    - In Kittery, wildfire occurrences over the last several decades have been slightly higher than the rest of the county. In the future, more frequent, prolonged, or intense droughts have the potential to increase wildfire risk in Kittery threatening public safety and the natural environment.

[30] MCC STS. 2020. Scientific Assessment of Climate Change and Its Effects in Maine. A Report by the Scientific and Technical Subcommittee (STS) of the Maine Climate Council (MCC). Augusta, Maine. 370 pp.

Background Info, Trends, & Projections

Annual precipitation in York County has increased 6.9 inches since 1895 (see Extreme Storms & Precipitation) and is expected to continue to increase with climate change. Despite wetter conditions overall, changing precipitation patterns caused by climate change have contributed to the emergence of drought conditions in southern Maine in recent years.[31] During the winter, more precipitation is falling as rain rather than snow. Average annual snowfall across the state has decreased about 2 inches since 1895, and reduced snowpack depth has been even more pronounced in southern, coastal areas.[32] Spring snowmelt recharges freshwater aquifers, so less snowpack in the spring diminishes spring recharge and results in a lower water table. Low rainfall during the spring and summer, along with higher-than-average temperatures can further deplete the water table, increasing the risk of summer and fall droughts.[33]

In the last few years Maine has experienced some of the driest periods in over a century. The driest May to September period since 1895 occurred during the 2020 drought, and September 2020 was the driest month since 1895.[34] In York County there have been four periods of severe to extreme drought since 2000, which occurred during the summer and fall months of 2001-2002, 2016, 2020, and 2022 (Figure 9). There was also an extended period of moderate drought in 2015.

- 2001-2002: 73%-100% of the county was in a severe drought for 28 weeks from the end of October to May 2002
- 2016: 67%-100% of the county was in a severe for 22 weeks from August to December, and 95% of the county was in an extreme drought for 4 weeks from the end of September to mid October
- 2020: 74%-100% of the county was in a severe drought for 12 weeks from September to December, and 70%-76% of the county was in an extreme drought for 6 weeks from late September to the end of October
- 2022: 66% of the county was in a severe drought for 4 weeks in August

[31] ME Drought Task Force Report, 10/6/2022: https://www.maine.gov/mema/hazards/drought-task-force
[32] University of Maine, Maine's Climate Future, 2020: https://climatechange.umaine.edu/climate-matters/maines-climate-future/
[33] ME Drought Task Force Report, 10/6/2022: https://www.maine.gov/mema/hazards/drought-task-force
[34] ME Climate Council, Maine Climate Science Update 2021: http://climatecouncil.maine.gov/reports

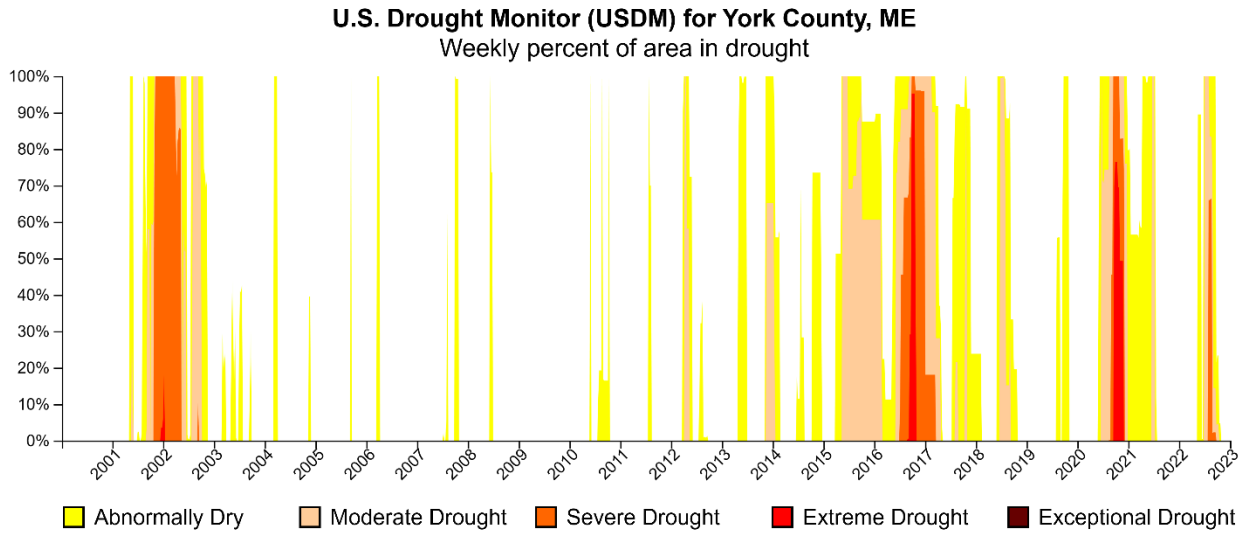


Figure 9 Drought conditions in York County from 2000 to 2022. Four severe to extreme droughts have occurred over the last 20 years and have been more frequent in the past decade. Data source: [U.S Drought Monitor](#).

As part of the Maine Cooperative Snow Survey, snowpack depth data have been collected at a survey site in South Berwick since 2001 and reported to the Maine Geological Survey (Figure 10). In the past 20 years, March has generally been the snowiest month in the region. The greatest maximum monthly snow depths were recorded in the early 2000s and maximum monthly snowfall amounts have fallen substantially since then.

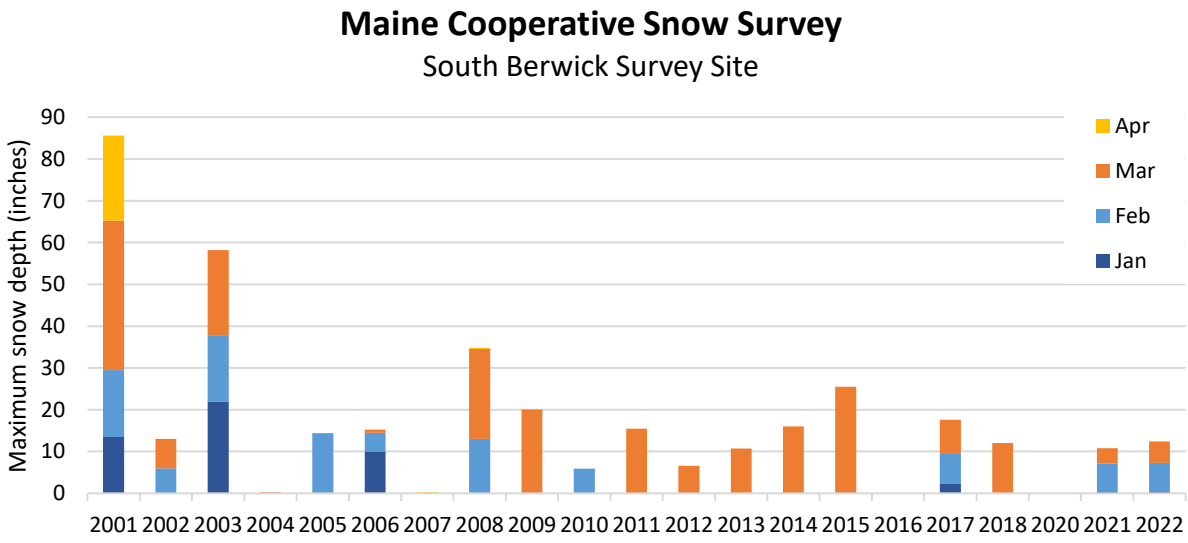


Figure 10 Maximum snow depth at South Berwick Survey Site, 2001-2022. Data source: Maine Geological Survey Cooperative Snow Survey

Combined snowfall amounts in Kittery during the winters of 2020-21 and 2021-22 were about 5-6 feet less than the previous 30 years, based on data from the Maine Drought Task Force. The snowfall deficit over the last two winters resulted in reduced spring snowpack depth and aquifer recharge and

contributed to the emergence of a summer and fall drought in 2022.[35] As future precipitation patterns in Southern Maine continue to shift towards more rain and less snow, the risk of drought will likely increase.

Water Supply Impacts

Public Water Supply

Intense and prolonged droughts have the potential to diminish surface and groundwater supplies and degrade water quality.[36] Communities supplied by groundwater wells, rivers, or smaller lakes are at greater risk of water quantity and quality impacts from drought.[37] The Town of Kittery is serviced by the Kittery Water District and four man-made ponds serve as the main source of district's public water supply.[38]

There is no local surface water monitoring data available in Kittery. In southern Maine generally though, the four most recent droughts have been associated with historically low streamflows which impacts the volume of water in surface water bodies like ponds and lakes. It appears that the Kittery Water District has not experienced water quantity issues related to drought in recent years. However, in 2020 the neighboring York Water District (YWD) had insufficient water supply to serve their customers, so the Kittery Water District along with the Kennebunk, Kennebunkport, and Wells Water District pipped approximately 50 million gallons into YWD's reservoir.[39]

To date, it does not appear that Kittery Water District has experienced significant water quality issues because of drought.[40] However, water utilities in York County that rely on small surface water supplies have had drought related water quality issues. In the summer of 2022, the public water supply in Berwick, which is sourced by the Salmon Falls River, contained elevated levels of manganese due to low water levels making it unsafe for children to drink.[41] In the future, more frequent, prolonged, or intense droughts have the potential to exacerbate existing regional water quantity issues and increase the risk of associated water quality issues.

Private Wells

Groundwater supplies can also be impacted by drought. The USGS monitors groundwater levels in York County at an index well in Sandford. Since 2000, the lowest recorded ground water levels occurred in November 2002, October 2015, and October 2016 coinciding with the 2002 and 2016 droughts (Figure 11). Groundwater levels were also low in October 2020, coinciding with the 2020 drought, though not as low as the previous two droughts.

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[35] ME Drought Task Force Report, 10/6/2022: https://www.maine.gov/mema/hazards/drought-task-force
[36] ME Climate Council, Maine Climate Science Update 2021: http://climatecouncil.maine.gov/reports
[37] Casco Bay Estuary Partnership, Climate Trends in Casco Bay, 2015: https://www.cascobayestuary.org/publication/climate-trends-in-the-casco-bay-region/
[38] Kittery Water District: https://kitterywater.org/faq/
[39] https://www.seacoastonline.com/story/news/2020/08/25/york-siphoning-millions-of-gallons-of-water-to-quench-drought-thirst/42413493/
[40] EPA Safe Drinking Water Information System: https://ordspub.epa.gov/ords/sfdw_pub/r/sfdw/sdwis_fed_reports_public/11?clear=RP,RIR
[41] Maine Public, 8/4/2022: https://www.mainepublic.org/environment-and-outdoors/2022-08-04/berwick-issues-drinking-water-advisory-due-to-ongoing-drought-conditions

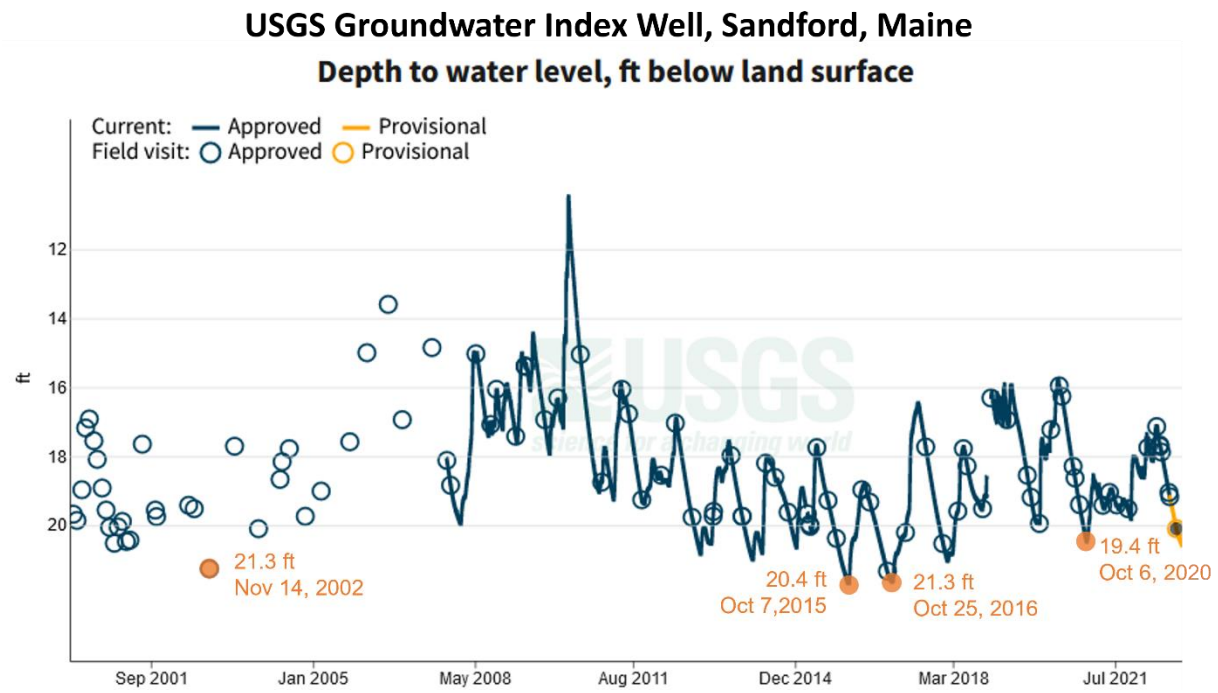


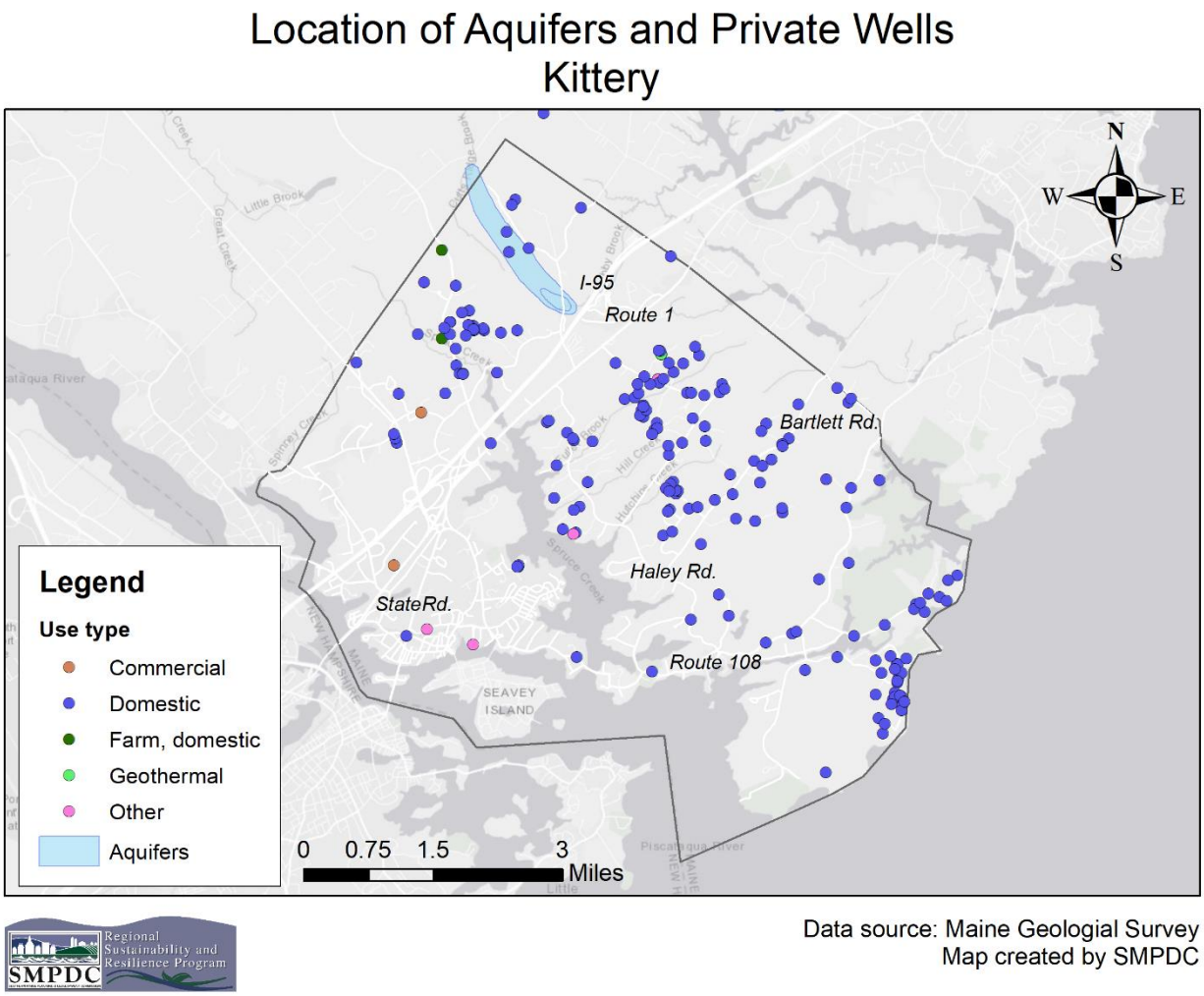
Figure 11 Groundwater levels in York County measured at an index well in Sandford, 2001-2021

Since 2020, the Maine Drought Task Force has collected data about wells that run dry due to drought. In 2020, 45 wells in York County ran dry compared to 2 in 2021, and 15 in 2022 (Table 10). Though these data are limited, they correlate with the intensity of the 2020 drought compared to the 2022 drought.

Table 10 Number of dry wells in York County in 2020, 2021, and 2022. Data source: Maine Emergency Management Agency

Maine Dry Well Survey			
Year	**2020**	**2021**	**2022**
York County	45	2	15

There are a total of 295 private wells in Kittery (196 wells have location data and are displayed on Map 11), and 96% of these wells are for domestic use. In the future, more frequent, prolonged, or intense droughts could pose a risk to the hundreds of homeowners and businesses in Kittery who rely on groundwater wells as their water source.



Map 11 Location of aquifers and private wells in Kittery as well as well use type. Data source: Maine Geological Survey

Impacts to the Natural Environment

The environmental impacts of drought include:

Damage to animal species	Damage to plant communities
• lack of feed and drinking water • disease • loss of biodiversity • migration or concentration • degradation of fish and wildlife habitats	• loss of biodiversity • loss of trees from urban landscapes and wooded conservation areas • Increased number and severity of fires • Reduced soil quality

Data source: 2018 York County Hazard Mitigation Plan, Pennsylvania

Although wildfire risk may seem small in Maine compared to the western U.S., wildfires do occur and are often associated with periods of drought. In 1947, drought induced wildfires burned over 200,000

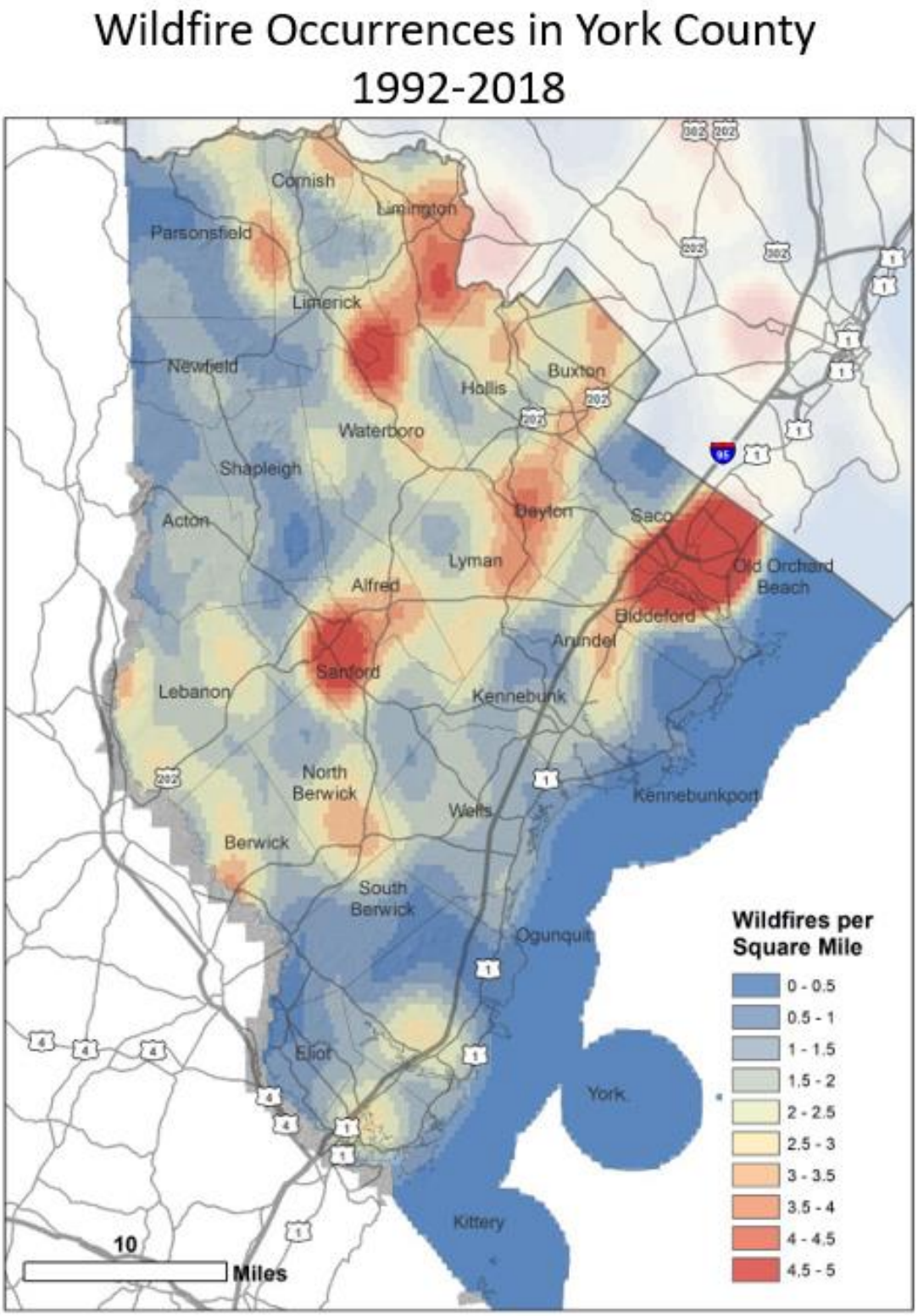
acres across the state.[42] The Maine Drought Task Force reported a higher number of wildfires in 2020, compared to 2021 and 2022, coinciding with the long, intense drought that summer and fall (Table 11).[43] In Kittery, wildfire occurrences over the last several decades have been slightly higher than the rest of the county (Map 12). In the future, more frequent, prolonged, or intense droughts have the potential to increase wildfire risk in Kittery threatening public safety and the natural environment.

Table 11 Wildfire occurrences in Maine in 2020, 2021, and 2022. Data source: Maine Drought Task Force 10/6/2022 Report

Maine Wildfire Occurrences			
Year	**2020**	**2021**	**2022**
Annual total	1,154	650	624

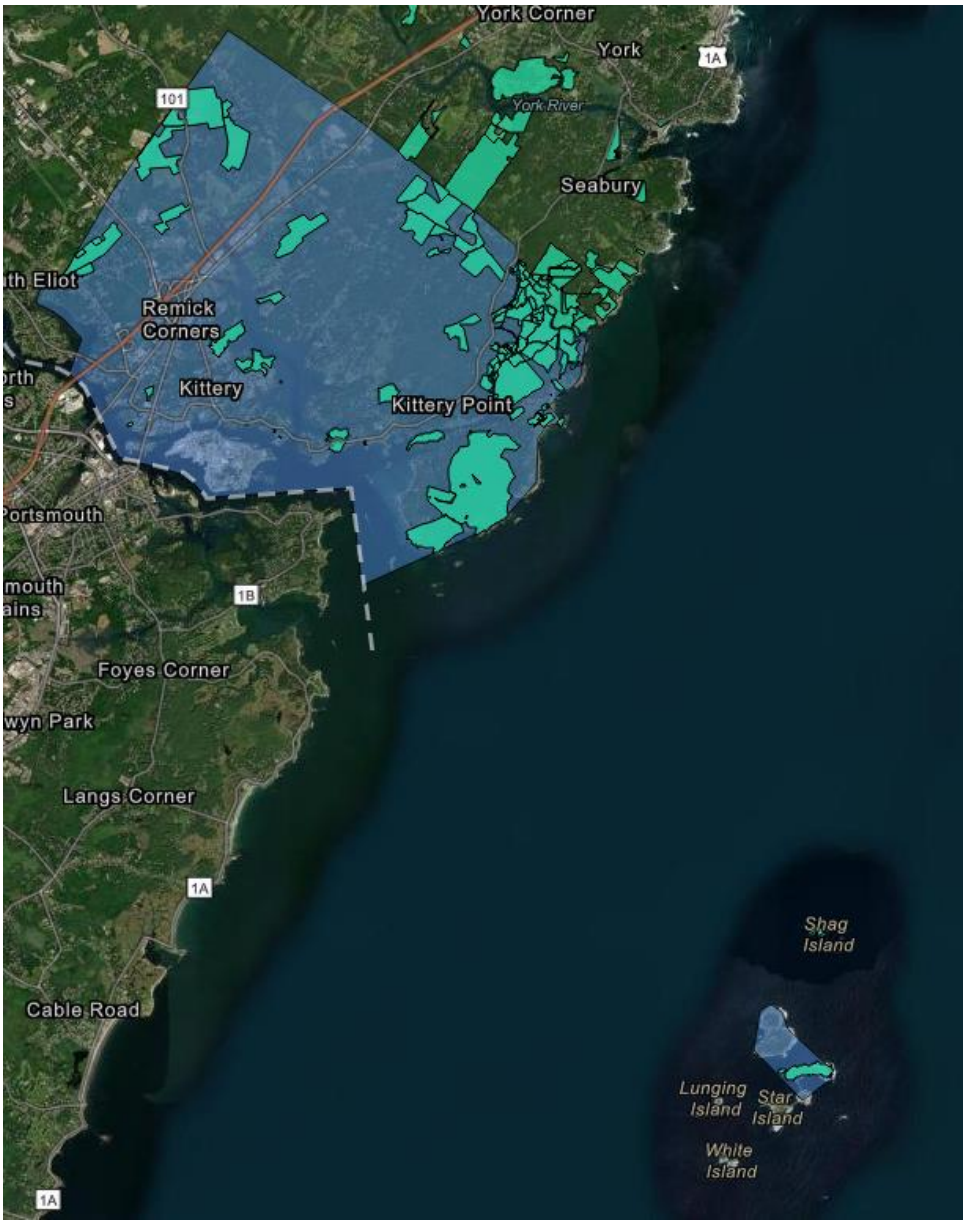
[42] York County Emergency Management Agency, Hazard Mitigation Plan, 2022: https://www.yorkcountymaine.gov/emergency-management

[43] ME Drought Task Force Report, 10/6/2022: https://www.maine.gov/mema/hazards/drought-task-force



Map 12 Wildfire occurrences in York County per square mile, 1992-2018. York County Emergency Management Agency, Hazard Mitigation Plan, 2022: https://www.yorkcountymaine.gov/emergency-management

Much of Kittery's eastern coastline is zoned for conservation (Map 13). Most of Gerrish Island is conserved by Maine Coast Heritage Trust, and a the tip Fort Foster Park is conserved by the Town. The Rachel Carson National Wildlife Refuge straddles the Kittery-York town boundary and stretches from Brave Boat Harbor to Crescent Beach. Inland, there are smaller pockets of land conserved by the Kittery Land Trust. Fort Foster Park and Gerrish Island have both forest and coastal habitat that supports shellfish, waterfowl, and deer as well as rare and endangered species. There is also important river habitat and freshwater wetlands. The National Wildlife Refuge is primarily marsh habitat that supports shellfish, waterfowl, sea and shore birds, and rare and endangered species. The Kittery Land Trust conserved areas are generally forested habitats including freshwater wetlands and rivers, as well as deer winter areas. These habitats can also support rare and endangered species. In the future, more frequent, prolonged, or intense droughts have the potential to damage these critical habitat areas.



Map 13 Conserved lands in Kittery are indicated by the green polygons. Data source: Maine Natural Areas Program. Map source: Climate Ready Coast Southern Maine

Agricultural Impacts

Drought can impact agricultural operations due to shifts in the growing season, crop losses, and increased costs associated with irrigation. During the 2022 drought, the Maine Drought Task Force reported that farmers had to irrigate their crops, which increased their operational costs.[44] In both 2020 and 2022 the Farm Services Administration issued emergency declarations for York County as a result of prolonged, severe drought conditions.[45] Even if farmers have irrigation systems, water supply can still be an issue. The Maine Department of Environmental Protection restricts irrigation withdrawals when stream and river levels fall below a certain threshold.[46]

Kittery is known as a center for shipbuilding and trade. Today the local economy is driven by tourism, retail, and the Portsmouth Naval Shipyard. Agriculture is not a significant part of Kittery's economy. However, Agriculture has been historically important in the neighboring towns of Eliot and the Berwicks as well as Durham and Dover NH. There are a number of operating farms in these areas that grow a variety of products including fruits and vegetables, honey, and alpacas. In the future, more frequent, prolonged, or intense droughts have the potential to reduce local farmers' production, increase their costs, and disrupt local food systems Kittery.

Changing Marine Conditions

Key Takeaways

- In the last 40 years, ocean temperatures have risen faster in the Gulf of Maine than almost anywhere else in the world and will likely rise 1.5°F. Maines marine ecosystem will resemble present day conditions in southern New England.
    - There are 52 commercial fishing licenses in Kittery. Individuals who rely on fishing for their livelihood are vulnerable to the economic impacts of changing marine conditions.
- Ocean and coastal acidification are expected to worsen due to higher amounts of carbon dioxide in the atmosphere and more frequent precipitation events.
- The dynamics of harmful algal blooms (HABs) in Maine have shifted in recent years and could continue to change in the future, posing new threats to public health.
- Eelgrass is an important nursery habitat for commercially important species and is an indicator species for overall ecosystem health.
    - Eelgrass habitat loss in the Piscataqua River estuary between 1997 and 2010 suggests that water quality worsened over this time period, possibly due to higher amounts of stormwater runoff or upstream watershed degradation.
    - In the future, more frequent and intense precipitation and increasing invasive species have the potential to decimate eelgrass habitat, reducing the carbon sink and coastal resilience benefits this habitat provides.

[44] ME Drought Task Force Report, 8/4/2022: https://www.maine.gov/mema/hazards/drought-task-force
[45] Cumberland County Emergency Management Agency, Hazard Mitigation Plan, 2022: https://www.cumberlandcounty.org/231/Hazard-Mitigation
[46] Maine DEP Press Release: https://www.maine.gov/dep/news/news.html?id=8535391

Background Info, Trends, & Projections

Southern Maine is located in the Gulf of Maine which stretches from Cape Cod to Nova Scotia. Since 1982, ocean temperatures in the Gulf of Maine have risen 96% faster than the rest of the world's oceans due to rising air temperatures and shifting ocean currents caused by climate change.[47] Marine species ranges are shifting northward following colder ocean temperatures. Lobster stocks in Long Island Sound and southern New England have collapsed, and as ocean temperatures continue to warm Maine's lobster resource could be facing a similar future. Invasive species like European green crabs, Asian shore crabs, tunicates have proliferate in warmer waters. Future projections indicate that by 2050 ocean temperatures in Maine will likely rise 1.5°F, and the marine ecosystem will resemble present day conditions in southern New England.[48]

The oceans are also becoming more acidic. As carbon dioxide builds up in the atmosphere from the burning of fossil fuels, some of that carbon dioxide is absorbed into the ocean. Dissolved carbon dioxide changes the chemical composition of the water making it more acidic. In coastal areas, ocean acidification is exacerbated by nutrient rich runoff which can trigger agal blooms. As the blooms die off and decay, the water becomes more acidic. Ocean and coastal acidification primarily impact shellfish species like scallops, oysters, clams, and mussels all of which are commercially harvested in Maine. Both ocean and coastal acidification are expected to worsen in the future with increasing fossil fuel emissions and more frequent and intense rainfall events.[49]

It is also hypothesized that warming waters and shifting currents due to climate change are changing the dynamics of harmful algal blooms (HABs) in Maine. Every summer Maine experiences a "red tide" when a toxin producing phytoplankton species blooms. Shellfish become contaminated with the toxin and, when eaten, can cause Paralytic Shellfish Poisoning. In recent years Maine has experienced blooms of new HAB species that have different impacts on human health and the ecosystem. Currently it is unclear how HAB dynamics may shift with climate change, but coastal Maine communities are facing an uncertain future regarding the public health, economic, and ecosystem impacts of HABs.

Habitat Shifts and Carbon Sinks

Eelgrass beds are critical marine habitat for commercially important species such as fish and shellfish. It is also vital to estuarine ecosystem functioning because it provides nursey habitat for many species. Eelgrass is sensitive to sediment loading and pollutants often caused by poor stormwater and wastewater management. Invasive species including the European green crab and various tunicate species can also destroy eelgrass habitat, uprooting plants and smothering growth. As a result, eelgrass habitat loss is generally indicative of poor watershed management practices and declining ecosystem health.[50]

DMR surveyed eelgrass distribution in Kittery in 1997 and again in 2010 (Map 14). The greatest distribution and highest density of eelgrass habitat was located off the southern tip of Gerrish Island

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[47] https://www.gmri.org/stories/gulf-of-maine-warming-update-summer-2021/

[48] University of Maine, Maine's Climate Future, 2020: https://climatechange.umaine.edu/climate-matters/maines-climate-future/

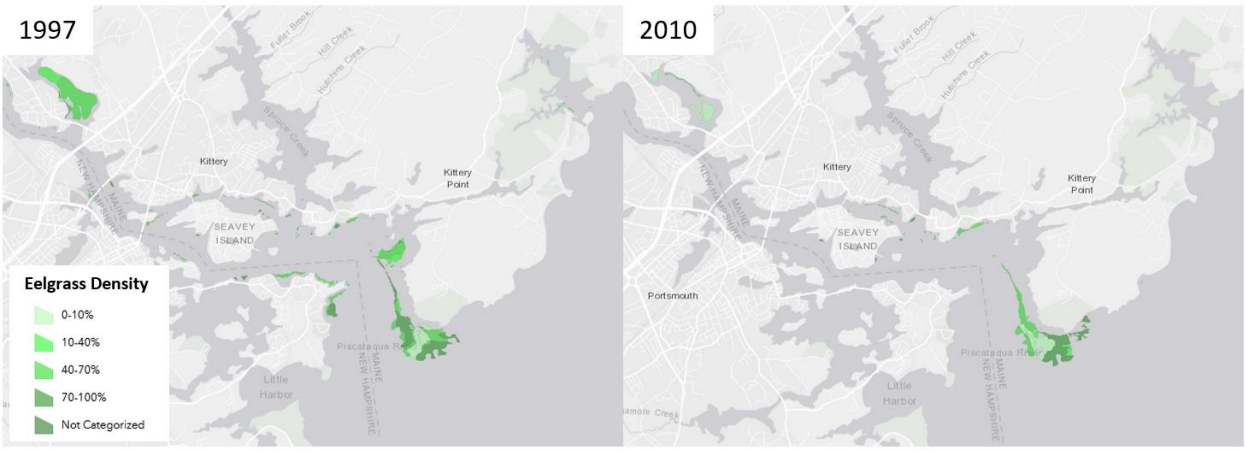
[49] ME Climate Council, Scientific Assessment of Climate Change and Its Effects in Maine, 2020: http://climatecouncil.maine.gov/reports

[50] Piscataqua Region Estuaries Partnership: https://prepestuaries.org/eelgrass/

near Fort Foster Park. In 1997 there was also an extensive eelgrass bed in Spinney Creek and along the shores of New Castle Island in Portsmouth. Between 1997 and 2010, the extent of the eelgrass bed off of Gerrish Island remained largely unchanged though the density decreased on the eastern side of the bed. Eelgrass coverage disappeared or was greatly diminished in Spinney Creek, along New Castle Island, and around Gooseberry Island. The loss of eelgrass habitat suggests that water quality worsened over this time period, possibly due to higher amounts of stormwater runoff or upstream watershed degradation.

In the decade since DMR's 2010 eelgrass survey, distribution and coverage may have shifted. Substantial eelgrass habitat losses were observed in Casco Bay between 2012 and 2013 coinciding with a rapid increase in the green crab population.[51] Kittery may have experienced similar losses, but there is not data available for current eelgrass habitat distribution. Regardless, the 1997 and 2010 survey data show where critical eelgrass habitat existed historically and suggest how the ecosystem has been impacted by watershed management practices.

Eelgrass Distribution and Coverage
Kittery



Map 14 Distribution and coverage of eelgrass habitat in Kittery in 1997 and 2010 based on the Department of Marine Resources eelgrass survey. Exact distribution ranges may have shifted in the last decade, but these data indicate the presence of historic eelgrass habitat and potential carbon sinks.

In the future, extreme precipitation events are expected to become more frequent and intense which will likely present new and increasing stormwater and wastewater management challenges, potentially threatening the health of Kittery's eelgrass beds. There is a high degree of impervious surfaces in and around Kittery's downtown and along the I-95 and Route 1 corridors (see Extreme Storms & Precipitation), which increases runoff during heavy rainfall events, further stressing eelgrass habitat. Additionally, warming ocean temperatures favor green crab population growth which may contribute to future eelgrass habitat loss.[52]

[51] Casco Bay Estuary Partnership, Eelgrass Beds Decline as Green Crab Numbers Explode, 2015: https://www.cascobayestuary.org/wp-content/uploads/2015/10/Indicator_Eelgrass.pdf
[52] ME Climate Council, Scientific Assessment of Climate Change and Its Effects in Maine, 2020: http://climatecouncil.maine.gov/reports

There is evidence that eelgrass beds can serve as carbon sinks, absorbing carbon dioxide from the water and locally reducing the influence of ocean and coastal acidification. The vegetation also stabilizes sediments and reduces wave action which has the potential to buffer coastlines against intense coastal storms. For these reasons, eelgrass habitat is not only important for the role it plays in ecosystem functioning, but also for the climate mitigation and resilience benefits it provides. These ecosystem services emphasize the importance of protecting this vulnerable habitat.[53]

Economic Impacts

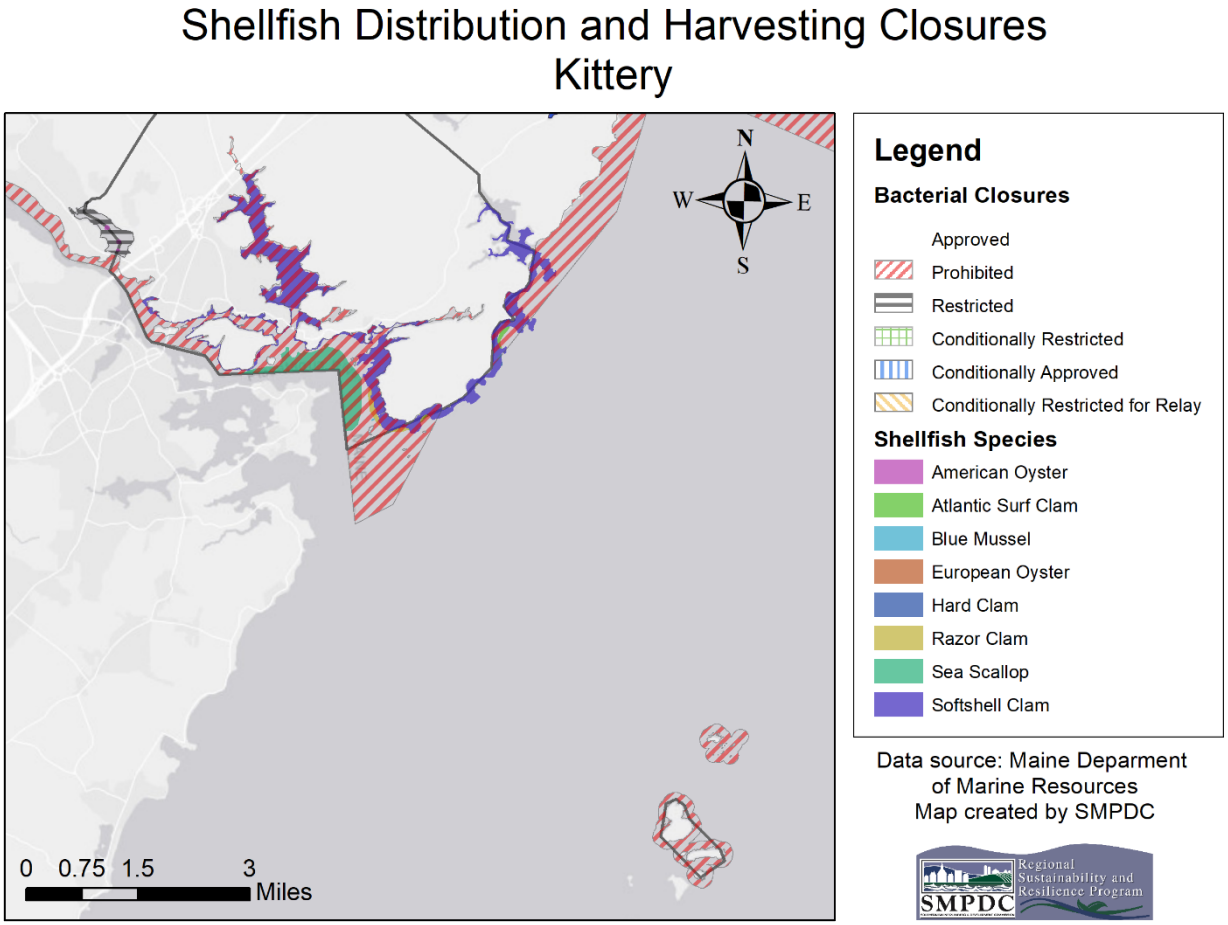
There are a total of 52 commercial fishing licenses held in Kittery and 91 non-commercial licenses (Table 12). The majority of commercial licenses are for harvesting lobster and crab. Individuals who rely on these fisheries for their livelihoods, especially lobster, may experience economic impacts as species' ranges shift with climate change. Recreational fishing opportunities for non-commercial license holders may also be impacted representing a significant cultural loss for the community's identity..

Table 12 Commercial and non-commercial fishing licenses in Kittery from the Maine Department of Marine Resources.

Commercial and Non-Commercial Fishing Licenses	
Commercial	**Number of Licenses**
Lobster/crab	37
Fishing	9
Sea urchin	2
Menhaden	1
Shellfish	1
Elver	1
Scallop	1
Total	*52*
Non-Commercial	
Lobster/crab	48
Saltwater fishing	43
Total	*91*

In 2010, the Maine Department of Marine Resources (DMR) conducted a survey of shellfish habitat across the state (Map 15). Based on that survey, there was substantial scallop and softshell clams habitat in Kittery as well as smaller pockets of razor clams and surf clams. However, shellfish harvesting is largely prohibited or restricted along Kittery's coastline because of poor water quality. The eastern side of Gerrish Island and Brave Boat Harbor are the areas open to unrestricted shellfish harvesting. As a result, wild shellfish harvesting is limited in Kittery and there is only 1 commercial shellfish license holder. The community is therefore less economically vulnerable to the impacts of climate change on shellfish species. However, warmer waters and ocean acidification have the potential to impact these species which are a critical part of the marine ecosystem.

[53] ME Climate Council, Scientific Assessment of Climate Change and Its Effects in Maine, 2020: http://climatecouncil.maine.gov/reports



Map 15 Distribution of shellfish species based on a survey conducted by the Maine Department of Marine Resources in 2010. Areas that are prohibited for shellfish harvesting based on poor water quality from bacterial contamination are also indicated. Data from the Maine Department of Marine Resources.

In the last decade aquaculture has exploded in Maine, particularly in southern Maine where the impacts of the declining lobster fishery have been felt more acutely. Aquaculture is viewed as a more climate resilient alternative to wild harvest fisheries like lobster. Currently, aquaculture activity is sparse in Kittery. There are three Limited Purpose Application Licenses for growing kelp off the eastern tip of Gerrish Island. Spinney Creek Shellfish is based in Eliot and has a lease to grow oysters in Spinney Creek. Changing marine conditions have the potential to impact the emerging aquaculture industry in Kittery.