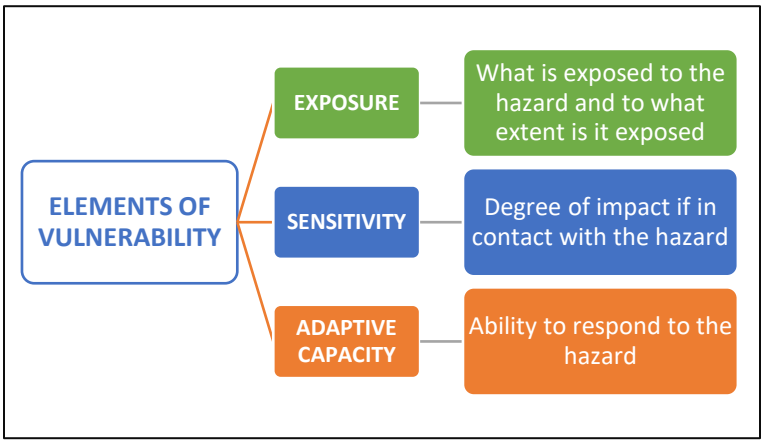
Climate Change Vulnerability Assessment Summary

KENNEBUNKPORT

Contents

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.



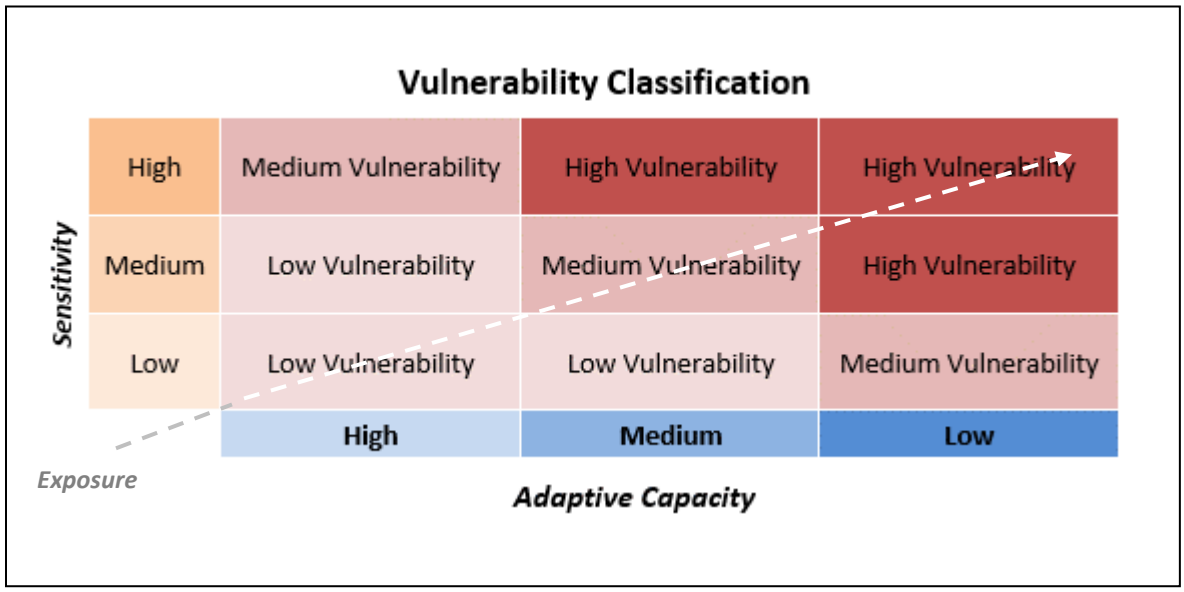


Figure adapted from NOAA. 2022. Implementing the Steps to Resilience: a Practitioner's Guide.

This draft vulnerability assessment summary presents an overview of climate hazards and associated impacts and vulnerabilities for the community of Kennebunkport. 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 and wildfires
- 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, was gathered through Task Force input and community engagement.

Key Takeaways

- Climate change will impact all facets of the community and compounding climate change vulnerabilities will impact all areas of life, including public health, natural areas, the local economy, municipal fiscal health, and community well-being.
- The impacts of climate change will not be felt evenly across the community and will not be uniformly distributed among population groups. Socially vulnerable and marginalized populations will be disproportionally affected by climate change as they generally have less capacity to prepare for, respond to, and recover from climate-related hazards and effects.
- Coastal areas of Kennebunkport, including Dock Square, Cape Porpoise, and the Goose Rocks area, are extremely vulnerable to the increasing impacts of coastal flooding and storm surge, putting the local economy, tourism, and municipal tax base at risk.
- Drought is becoming a hazard of increasing concern, particularly in the more rural regions where there could be negative impacts to public and private drinking water supplies, natural resources, and agriculture, and could lead to increased wildfire risk.
- Kennebunkport's older population (30% is 65 or older) puts the community at greater risk from extreme storms, as older community members tend to be more sensitive to extended power outages, rely more heavily on public services that could be closed, and often have fixed incomes that limit their ability to build back resiliently after storm damage.
- Kennebunkport's power systems are increasingly vulnerable to extreme storms and flooding, both of which will be exacerbated by climate change.
- Increasing rates of vector borne diseases and incidents of extreme heat will negatively impact public health.

Social Vulnerability

The impact of climate change will not be felt evenly across the community and will not be uniformly distributed among population groups. The ability to adapt and respond to climate change varies widely based on individual and household resources and characteristics, as well as existing social inequities. Individuals who already have increased social vulnerability are at greatest risk of climate change and 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. Socially vulnerable groups include children; older adults; people with existing health conditions; disabled individuals; households with lower or

moderate incomes; those with less formal education; people of color; and those who have limited connectivity, either physically and/or digitally, to others and resources. Demographic information can help determine local populations' adaptive capacity, or the ability to adapt and respond to a disaster.

Age can be correlated with decreased adaptive capacity, in the case of the very young, or older populations. Generally, families with children require more time and space to evacuate, and people who are 17 or younger are more dependent on family or other networks than other age brackets. Some people who are 65 and older may also be dependent on family, friends, or organizations, and may face challenges anticipating the event or finding information on how and when to evacuate or adapt. The unique physical and psychosocial challenges of the population ages 65 and over may impact their ability to prepare for, respond to, and recover from storms events.[1]

Maine is known to be one of the least diverse states in the country and demographic data collected from the 2021 American Community Survey supports that statistic. This highlights the need to pay specific attention to the minority populations that do live throughout the state, who may have cultural or language barriers to accessing information, resources, or accommodations. Gaps in resources, and access to those resources, leave many minority groups vulnerable to exclusion from adaptation based on economic factors.[2]

The coastal York County towns are among the wealthiest in the state, but they are not without low-moderate income households. Income is a significant indicator of social vulnerability with respect to natural hazards such as flooding. Households with lower income levels generally have a lower adaptive capacity to respond and adapt to natural hazards since someone with limited or no disposable income would have fewer resources to pay for evacuation, transportation, accommodation, and repair activities.

The following demographic information summarizes indicators of social vulnerability and adaptive capacity at the community level and U.S. 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 is supplemented and contextualized with information gathered from the Task Force and community members through project engagement efforts

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 for the Maine Social Vulnerability Index.[3] 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 smallest 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 4 block groups in Kennebunkport (Map 1).

[1] EPA. 2021. Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts. U.S. Environmental Protection Agency, EPA 430-R-21-003. www.epa.gov/cira/social-vulnerability-report

[2] EPA. 2021. Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts. U.S. Environmental Protection Agency, EPA 430-R-21-003. www.epa.gov/cira/social-vulnerability-report

[3] Johnson et al., 2018, A lifeline and social vulnerability analysis of sea level rise impacts on rural coastal communities

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, the 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 17 demographic indicators can inform the development of strategic climate actions by providing important information about areas of the community that may be more socially vulnerable to the impacts of climate change. However, qualitative anecdotal information about the community gathered from the Task Force, community members, and City staff helps to refine demographic data and aid with interpretation of local social vulnerability information.[4]

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.[5]

There are three income thresholds referenced in Table 1. These thresholds were selected because they approximate the U.S. Environmental Protection Agency (EPA) climate change and social vulnerability income threshold ($51,500), the 2021 State median income ($64,767), and the 2021 York County median income ($73,856).

Key Takeaways

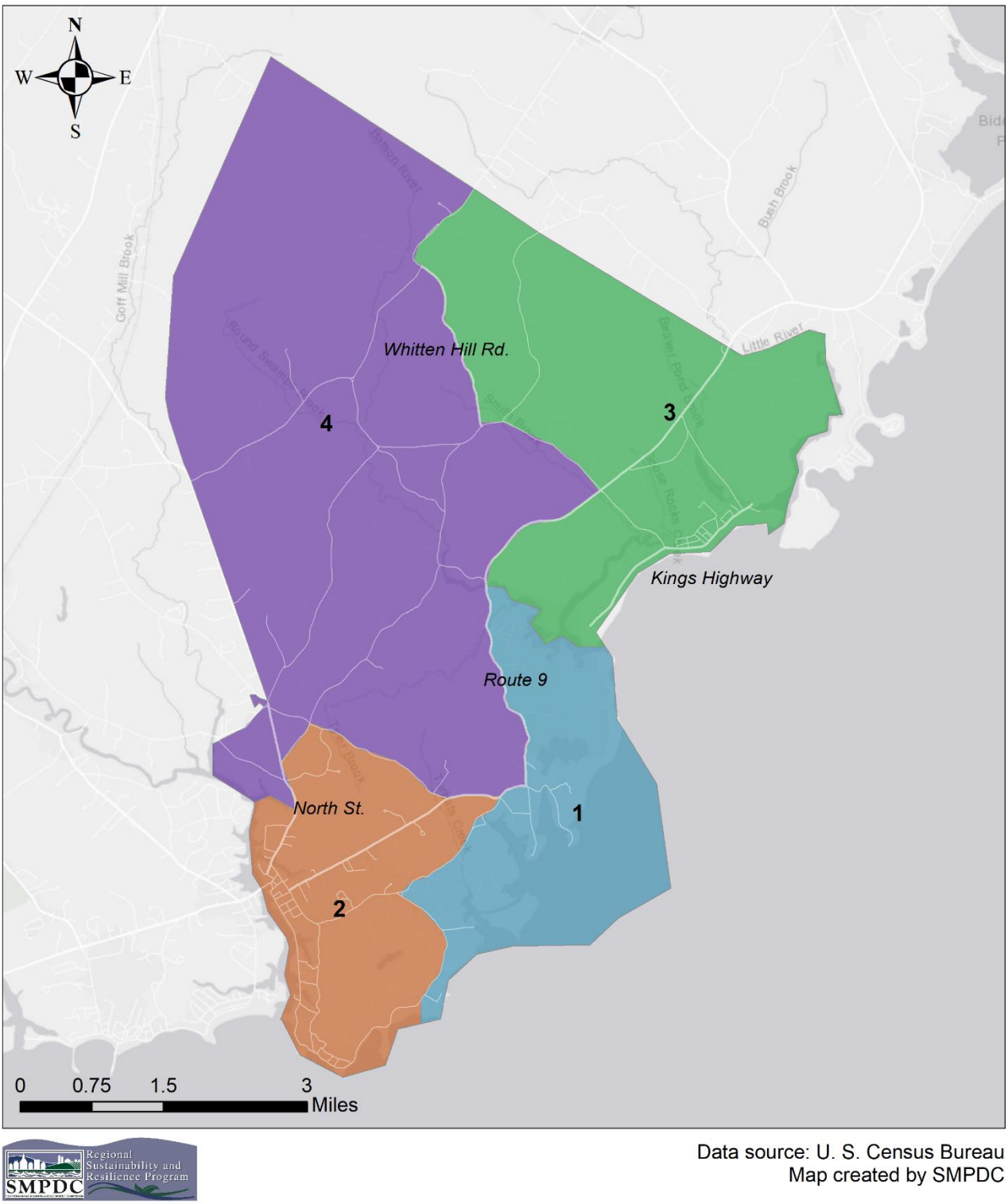
- Cape Porpoise and the surrounding neighborhoods (block group 1) have the highest percentage of the population within the block group that are 65 years or older, have a disability, are below the national poverty level, are below the EPA climate change and social vulnerability low-income threshold, are below the County and State median incomes, have no internet access, and have no vehicle.
    - *Note that some individuals choose not to have internet, so lack of internet access at the household level does not necessarily indicate that internet is not available to the household.*
- The northwestern part of Kennebunkport, west of Whitten Hill Road and Route 9 (block group 4) is the most populated part of the community and has the highest percentage of the population within the block group that are 17 years or younger, are living alone, and are 65 plus and living alone. This area also has an elevated percentage of the population within the block group that are unemployed, are below the County and State median incomes, and are single parent households compared to the rest of the community.
- The northwestern part of Kennebunkport, west of Whitten Hill Road and Route 9 (block group 4) also has the highest percentage of the population within the block group that speak English less

[4] Johnson et al., 2018, A lifeline and social vulnerability analysis of sea level rise impacts on rural coastal communities

[5] U.S. Census Bureau, Subject Definitions: https://www.census.gov/programs-surveys/cps/technical-documentation/subject-definitions.html#household

than well and that do not have a high school diploma, but both indicators represent a small proportion of the block group population.

- Dock Square and the surrounding neighborhoods (block group 2) have the highest percentage of the population within the block group that are unemployed and that are single parent households, as well as an elevated percentage of the population that is 65 years or older and living alone compared to the rest of the community.
- The northeastern corner of the community, including Goose Rocks Beach (block group 3), has the highest percentage of the population within the block group that are minorities.
- Across the entire community, 30% of the population is 65 years or older and 30% of households have at least one person with a disability.
- Additionally, about a third of households (34%) are below the EPA climate change and social vulnerability income threshold, 37% are below the State median income, and 43% are below the County median income.



Map 1. Census block groups in Kennebunkport. Data source: U.S. Census Bureau 2021 American Community Survey

Table 1. Demographic profile summary by block group. Data source: U.S. Census Bureau 2021 American Community Survey

	Community wide	Block Groups			
		1	2	3	4
Total Population	3,607	607	1,087	624	1,289
Total Households	1,663	291	505	269	598
Age <18	474	19	158	93	204
% total population	13%	3%	15%	15%	16%
Age 65+	1,092	279	349	220	244
% total population	30%	46%	32%	35%	19%
Minority	110	17	37	56	0
% total population	3%	3%	3%	9%	0%
Speaks English "Less than well"	5	0	0	0	5
% population age 5+	0%	0%	0%	0%	0.4%
No HS Diploma	24	0	0	0	24
% population age 25+	1%	0%	0%	0%	2%
1+ Persons with a Disability	496	124	118	41	213
% households	30%	43%	23%	15%	36%
Below Poverty Level	98	83	0	7	8
% households	6%	29%	0%	3%	1%
Unemployment	57	0	29	0	28
% population age 16+	2%	0%	3%	0%	3%
Income <$50k	559	149	79	76	255
% households	34%	51%	16%	28%	43%
Income <$60k	616	156	92	96	272
% households	37%	54%	18%	36%	45%
Income <$75k	723	164	132	130	297
% households	43%	56%	26%	48%	50%
No Internet	74	67	0	0	7
% households	4%	23%	0%	0%	1%
No Vehicle	67	60	0	0	7
% households	4%	21%	0%	0%	1%
Single Parent	52	0	26	0	26
% households	3%	0%	5%	0%	4%
Living Alone	457	67	134	52	204
% total population	13%	23%	27%	19%	34%
65+ Living Alone	276	31	68	13	164
% total population	8%	5%	6%	2%	13%

Lowest Value *Highest Value*

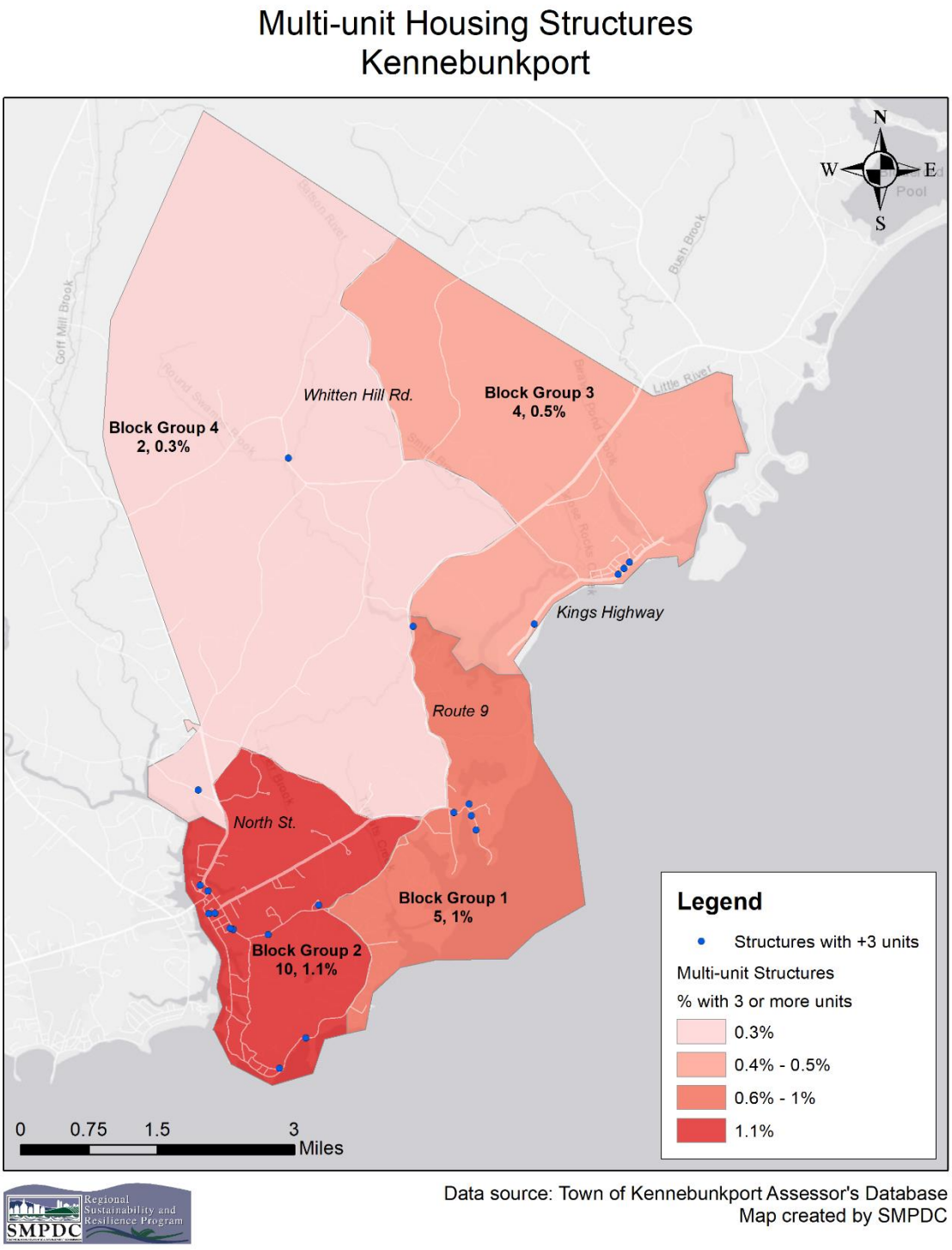
Supplemental Community Information

Housing Characteristics

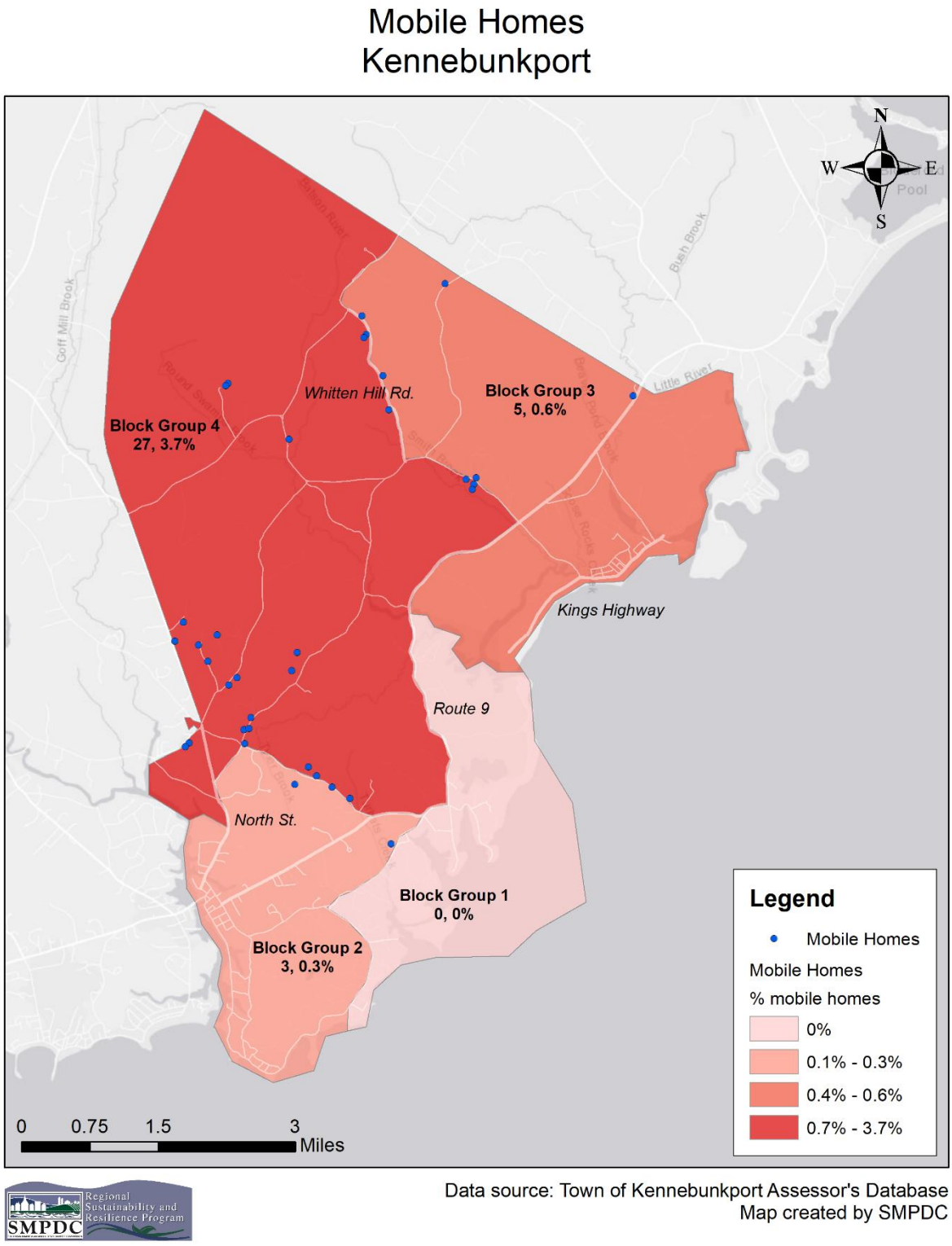
Map 2, Map 3, and Table 2 show data about housing characteristics including multi-unit housing structures, mobile homes, and renter occupied homes. Multi-unit homes and mobile homes are associated with elevated social vulnerability and/or reduced adaptive capacity. For example, multi-unit households generally have less adaptive capacity than single family homeowners because they tend to have lower incomes/financial resources and have less ability to make property improvements. Additionally, multi-unit households are often occupied by renters, and landlords have little incentive to improve energy efficiency because energy costs are commonly 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. Multi-unit and mobiles homes also tend to be associated with socially vulnerable populations. Data are from the Town of Kennebunkport Assessor's Database.

Key Takeaways

- Community-wide there are 21 multi-unit structures in Kennebunkport representing less than 1% of all homes in the community.
    - About half of all multi-unit structures (10) in Kennebunkport are located in and around Dock Square and Cape Arundel (block group 2) representing 1.1% of all housing units in the block group.
    - There is a cluster of 4 multi-unit structures located on Cape Porpoise (block group 1), and a cluster of 3 multi-unit structures located near Goose Rocks Beach (block group 3).
- Community-wide there are 35 mobile homes in Kennebunkport representing just over 1% of all homes in the community.
    - The majority of mobile homes (27) in Kennebunkport are located in the northwestern part of the community (block group 4) representing 3.7% of all housing units in the block group.
    - There are clusters of mobile homes along Whitten Hill Road, Goose Rocks Road, Old Cape Road, Beachwood Avenue, and Arundel Road.



Map 2. Breakdown of multi-unit (3 or more units) housing structures in Kennebunkport by block group. Housing units include condos, mobile homes, multi-unit structures, and single-family homes and may be year-round or seasonal properties. The block group is labeled as well as the total number of multi-unit housing structures in the block group and the percent of total housing units within the block group that are multi-unit. Data source: Town of Kennebunkport Assessor's Database



Map 3. Breakdown of mobile home units in Kennebunkport by block group. The block group is labeled as well as the total number of mobile homes in the block group and the percent of total housing units within the block group that are mobile homes. Housing units include condos, mobile homes, multi-unit structures, and single-family homes and may be year-round or seasonal properties. Data source: Town of Kennebunkport Assessor's Database

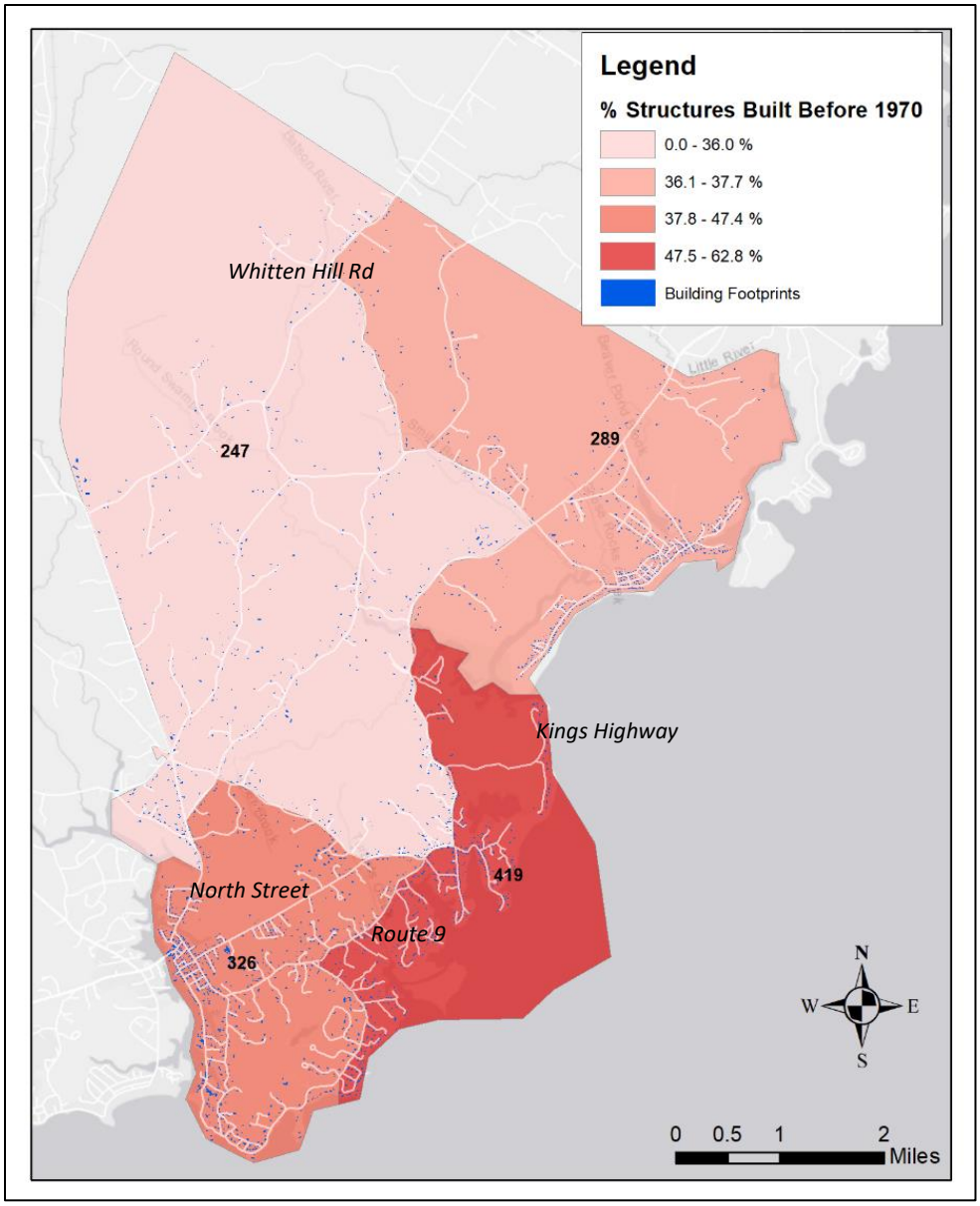
Table 2. Community wide and block group level housing characteristics in Kennebunkport. Homes include all housing unit types (condos, mobile homes, multi-unit structures, and single-family homes) and may be year-round or season properties. Data source: Town of Kennebunkport Assessor's Database

	Community wide	Block Groups			
		1	2	3	4
Total homes	2,941	519	912	789	721
Multi-unit	21	5	10	4	2
% of total homes with 3+ units	0.7%	1.0%	1.1%	0.5%	0.3%
Mobile Homes	35	0	3	5	27
% of total homes	1.2%	0.0%	0.3%	0.6%	3.7%

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 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.

Map 4 shows the percentage of structures, at the block group level, built before 1970. In Kennebunkport, areas with the highest concentration of buildings constructed before 1970 are located along the coastline near Cape Porpoise. These areas also have elevated social vulnerability based on demographic characteristics and are vulnerable to hazards, including coastal and riverine flooding, sea level rise, and urban heat islands.



Map 4. 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).

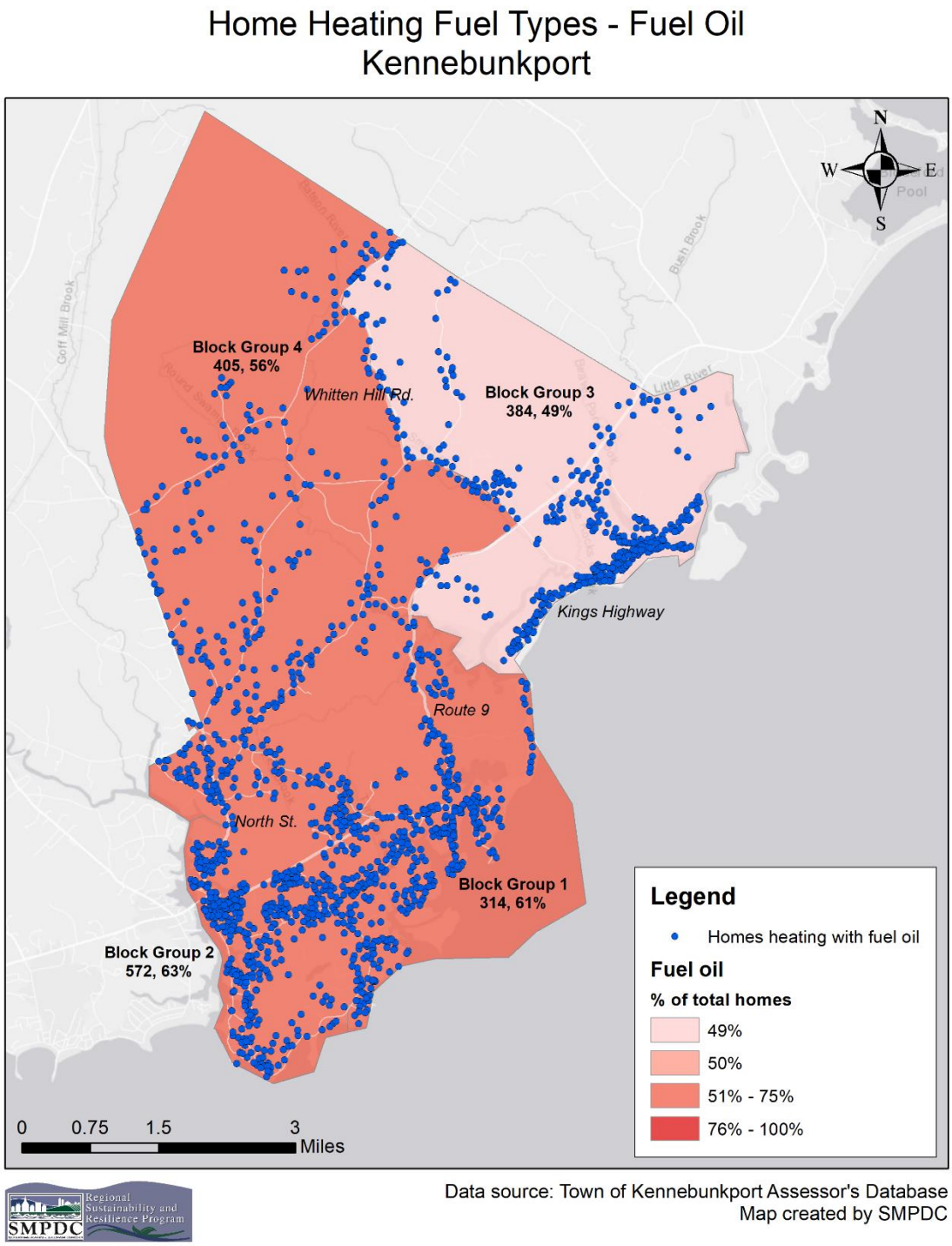
Home Heating Fuel Types

Understanding heating fuel trends is important for evaluating the potential impacts of electrifying the heating sector to reduce greenhouse gas emissions. Electrification must be paired with electricity grid resilience measures to ensure that the grid can withstand increased electricity consumption as well as climate hazards such as flooding, high winds, high temperatures, and wildfires (see Extreme Storms & Precipitation: Power Outages for more information about these impacts). Map 5, Map 6, Map 7, Map 8, and Table 3 show data about primary heating fuel types across Kennebunkport, which provides context about where fossil fuels are used most heavily and therefore where electricity consumption for heating is expected to increase.

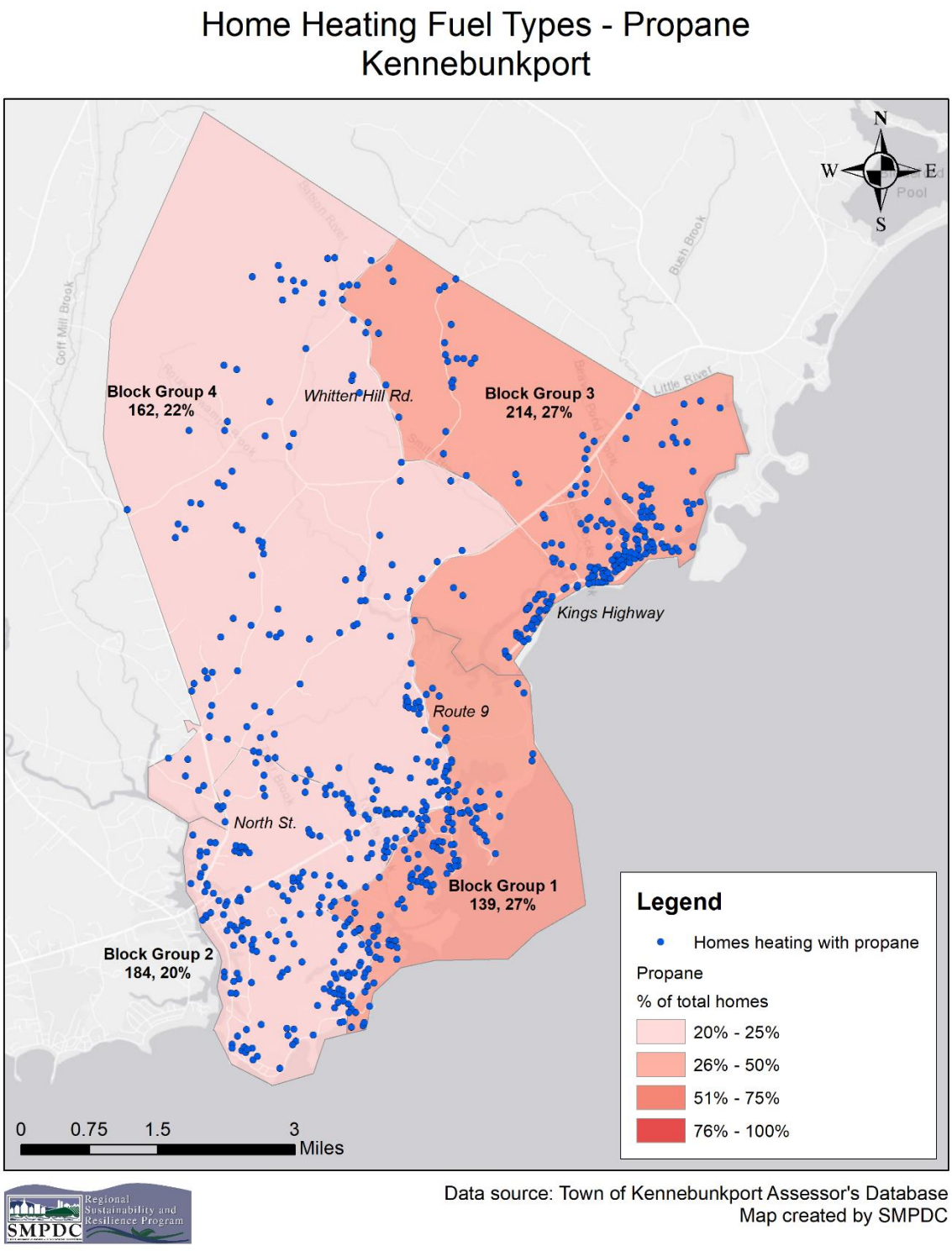
Homes include all housing unit types (condos, mobile homes, multi-unit structures, and single-family homes) and may be year-round or seasonal properties. Data are from the Town of Kennebunkport Assessor's Database.

Key Takeaways

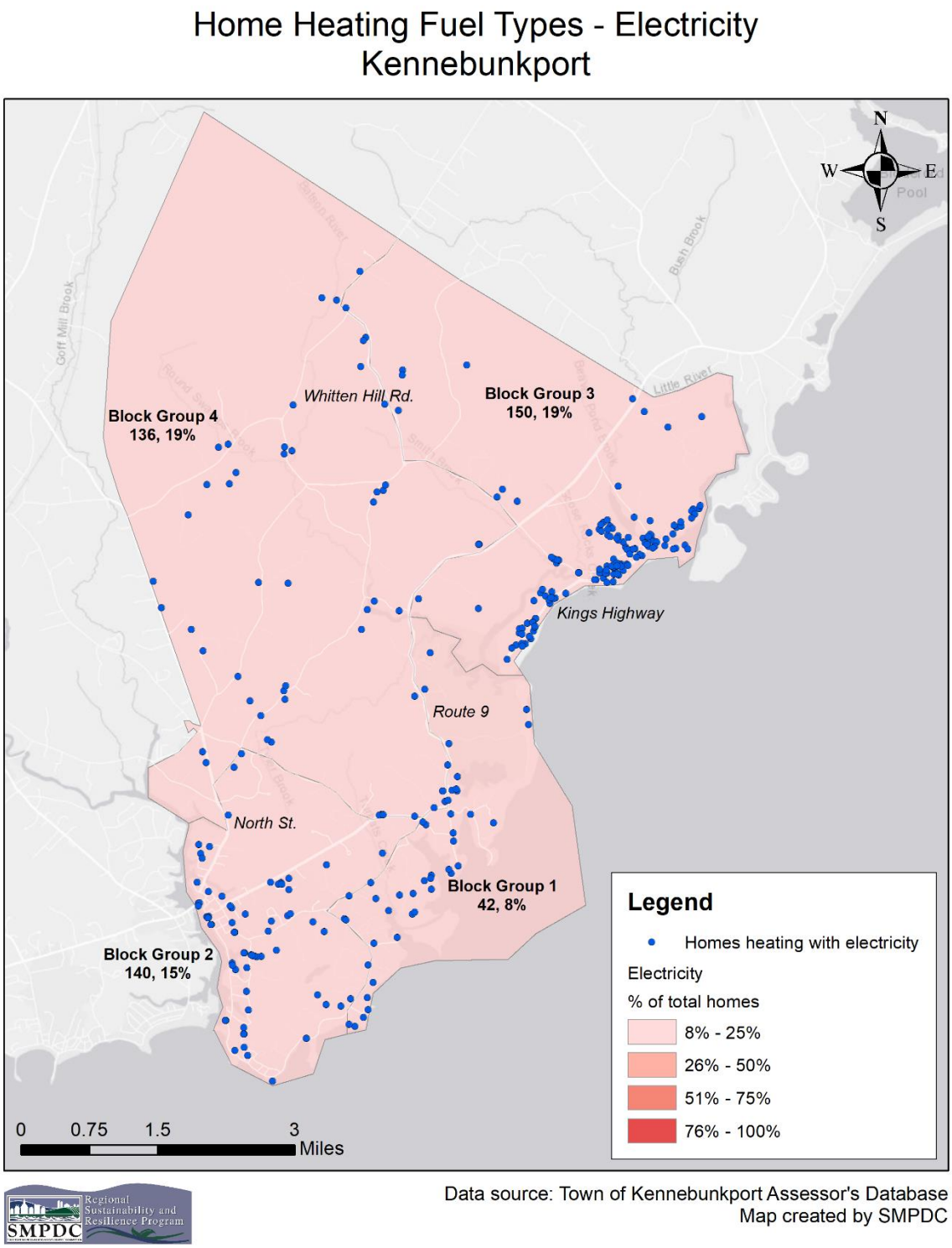
- Community-wide the majority of homes (57%) are heated using fuel oil.
    - The greatest number of homes (572) that are heated with fuel oil are located in and around Dock Square and Cape Arundel (block group 2) representing 63% of all homes in this block group.
    - The neighborhoods in the northeastern part of the community near Goose Rocks Beach and along the Biddeford town boarder (block group 3) have the lowest proportion of homes (49%) within the block group that are heated with fuel oil.
- Community-wide about a quarter of homes (24%) are heated using propane.
    - The greatest number of homes (214) that are heated with propane are located in the northeastern part of the community near Goose Rock's Beach and along the Biddeford town boarder (block group 3), representing 27% of all homes in the block group.
    - The neighborhoods in and around Dock Square and Cape Arundel (block group 2) have the lowest proportion of homes within the block group (20%) that are heated with propane.
- Community-wide 16% of homes are heated using electricity.
    - The greatest number of homes (150) that are heated with electricity are located in the northeastern part of the community (block group 3) and are clustered near Goose Rock's Beach along Kings Highway, representing 19% of all homes in the block group.
    - The neighborhoods in and around Cape Porpoise and Marshall Point (block group 1) have the lowest proportion of homes within the block group (8%) that are heated with electricity. There is also a higher concentration of older buildings in this area.
- Community-wide 3% of homes are heated using wood.
    - The greatest number of homes (36) that are heated with wood are located in the northeastern part of the community (block group 3) and are clustered near Goose Rock's Beach along Kings Highway, representing 5% of all homes in the block group.
    - In Kennebunkport, homes heated with wood are generally located near the coast and are clustered near Cape Arundel, Turbats Creek, Cape Porpoise, and Goose Rocks Beach.



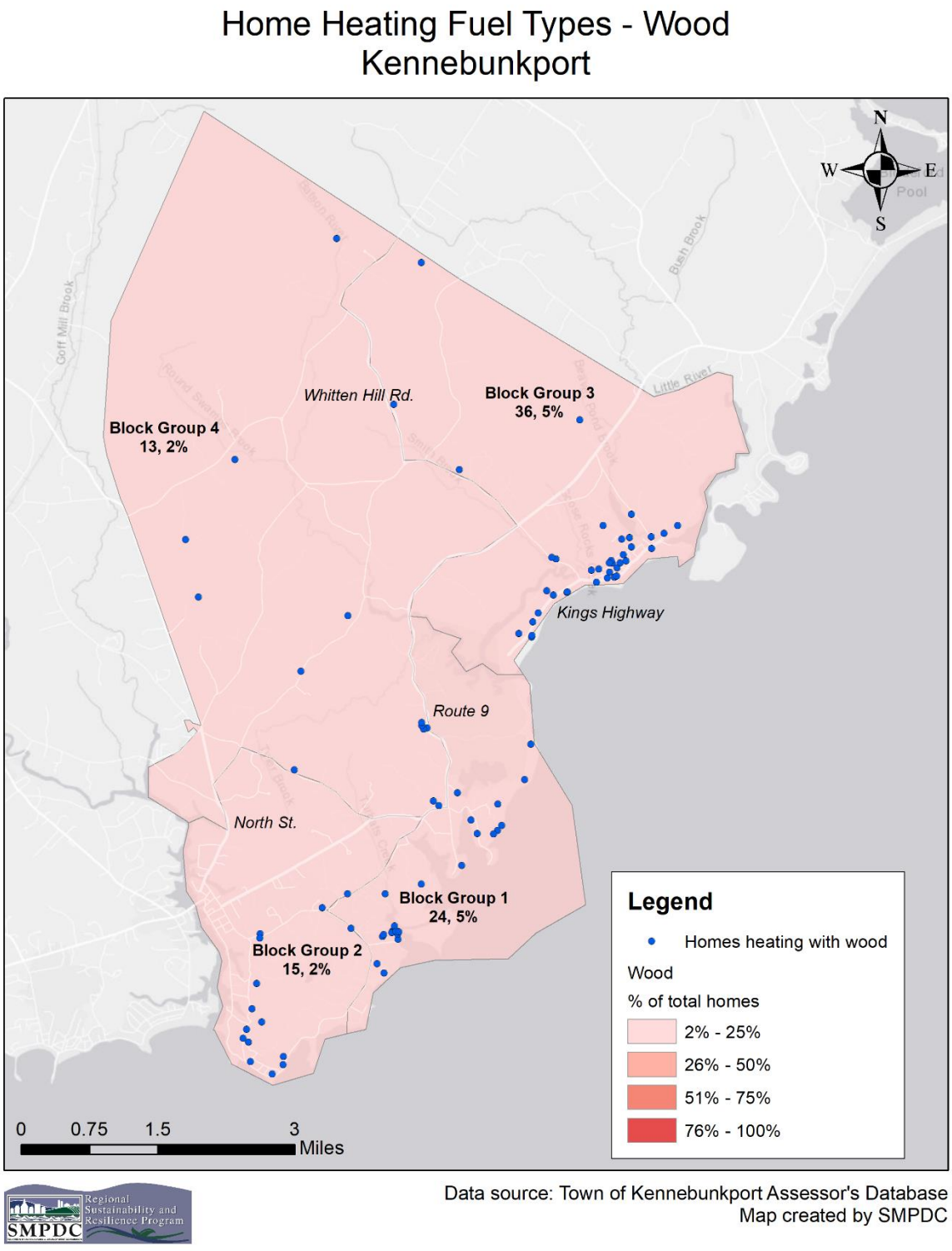
Map 5. Breakdown of homes in Kennebunkport, by block group, that are heated with fuel oil. Homes include all housing unit types (condos, mobile homes, multi-unit structures, and single-family homes) and may be year-round or seasonal properties. The block group is labeled as well as the total number of households within the block group that are heated with fuel oil and the percent of households within the block group that are heated with fuel oil. Data source: Town of Kennebunkport Assessor's Database



Map 6. Breakdown of homes in Kennebunkport, by block group, that are heated with propane. Homes include all housing unit types (condos, mobile homes, multi-unit structures, and single-family homes) and may be year-round or seasonal properties. The block group is labeled as well as the total number of households within the block group that are heated with propane and the percent of households within the block group that are heated with propane. Data source: Town of Kennebunkport Assessor's Database



Map 7. Breakdown of homes in Kennebunkport, by block group, that are heated with electricity. Homes include all housing unit types (condos, mobile homes, multi-unit structures, and single-family homes) and may be year-round or seasonal properties. The block group is labeled as well as the total number of households within the block group that are heated with electricity and the percent of households within the block group that are heated with electricity. Data source: Town of Kennebunkport Assessor's Database



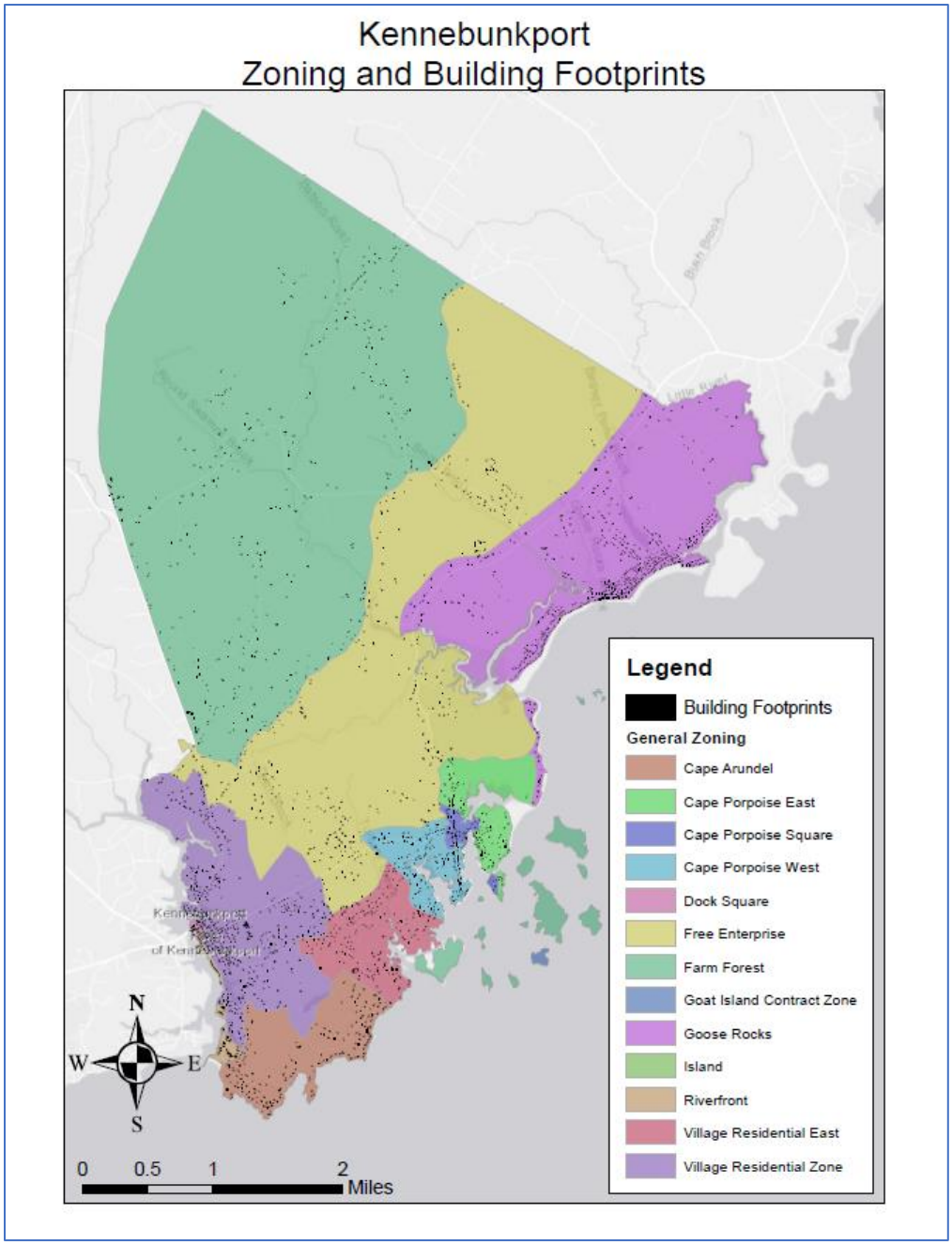
Map 8. Breakdown of homes in Kennebunkport, by block group, that are heated with wood. Homes include all housing unit types (condos, mobile homes, multi-unit structures, and single-family homes) and may be year-round or seasonal properties. The block group is labeled as well as the total number of households within the block group that are heated with wood and the percent of households within the block group that are heated with wood. Data source: Town of Kennebunkport Assessor's Database

Table 3. Community wide and block group level home heating fuel types in Kennebunkport. Homes include all housing unit types (condos, mobile homes, multi-unit structures, and single-family homes) and may be year-round or seasonal properties. Data source: Town of Kennebunkport Assessor's Database

	Community wide	Block Groups			
		1	2	3	4
Total homes	2,941	519	912	789	721
Fuel oil	1,675	314	572	384	405
% of total homes	57%	61%	63%	49%	56%
Propane	699	139	184	214	162
% of total homes	24%	27%	20%	27%	22%
Electricity	468	42	140	150	136
% of total homes	16%	8%	15%	19%	19%
Wood	88	24	15	36	13
% of total homes	3%	5%	2%	5%	2%

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 9) is provided for reference to show where areas zoned for commercial, industrial, and residential uses are located.



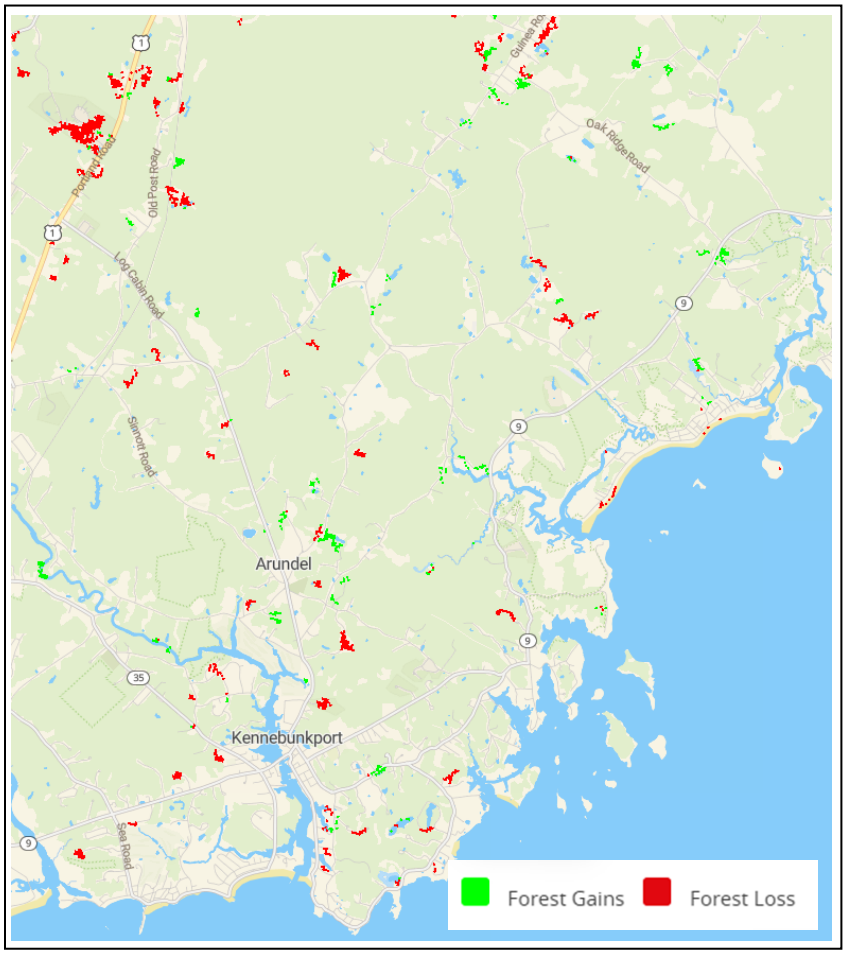
Map 9. Kennebunkport's adopted zoning map.

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 [6]. In built environments, carbon is stored in trees, grassy areas, gardens, and in

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

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. Map 10 shows the change in forested land coverage in Kennebunkport from 1996 to 2016. Overall, there was little change in forest cover in town during that time period.



Map 10. 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.

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.
    - The highest concentrations of impervious surfaces in Kennebunkport are located along the Kennebunk River, Ocean Avenue, and Goose Rocks Beach. There is an elevated risk of flooding from extreme precipitation and stormwater overflow in these areas, which can also exacerbate the impacts of coastal flooding.
    - Kennebunkport's aging electric grid is increasingly vulnerable to several climate impacts, including extreme storms and precipitation as well as increasing temperatures. This will likely result in more frequent and longer duration power outages in Kennebunkport that can pose serious risks for public health and safety.

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 increased 6.9 inches (Figure 1), 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,[7] and extreme precipitation events (greater than 2 inches in a day) are becoming even more frequent. Coastal communities like Kennebunkport are experiencing even more frequent extreme storms and precipitation events because of the influence of Atlantic storm tracks.[8] 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.[9]

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

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

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

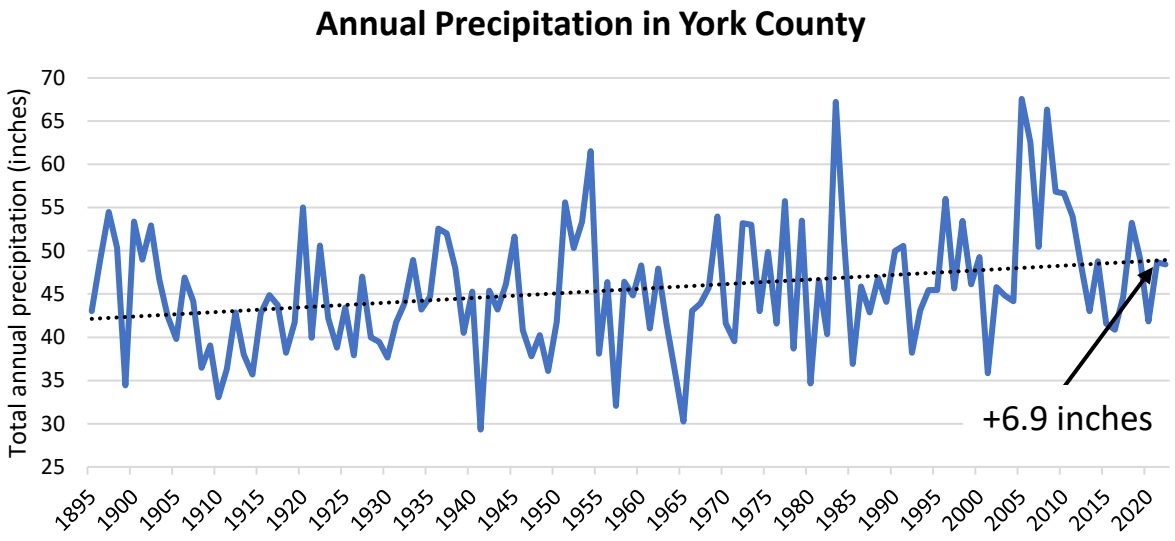


Figure 1. Total annual precipitation in York County from 1895 to 2022 based on monthly data from the NOAA National Centers for Environmental Information. Over this time period total annual precipitation increased by 6.9 inches

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.[10] 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. Flooding events, including coastal flooding, have caused nearly $45 million in damage across the region and coastal flooding events alone have caused approximately $22 million in damage (Table 4).[11]

Table 4. Cumulative storm events and property damage in coastal York County from 1996 to 2022. Data source: 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**

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

[11] 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 2023, 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. [12]
- 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.[13]
- 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 the coastline and was caused by flooding and storm surge.[14]
- 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.[15]

In the future, as sea level rises and storms become more frequent and intense, Kennebunkport 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.[16]

Historically, flooding has been the most common type of disaster in York County, particularly coastal flooding caused by nor'easters.[17] 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 official NOAA tide gauge to Kennebunkport) occurred during the Blizzard of 1978 and exceeded 14 feet MLLW (Figure 2). 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 included in Figure 2) a water level of 13.72 feet MLLW was recorded in Portland, about an inch lower than the 2018 nor'easter storm tide.[18]

[12] York County Emergency Management Agency, Hazard Mitigation Plan, 2022: https://www.yorkcountymaine.gov/emergency-management
[13] SMPDC, Economic Resilience Planning for Coastal York County, 2022: https://smpdc.org/coastal
[14] York County Emergency Management Agency, Hazard Mitigation Plan, 2022: https://www.yorkcountymaine.gov/emergency-management
[15] SMPDC, Tides, Taxes, and New Tactics, 2021: https://smpdc.org/coastal
[16] 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
[17] York County Emergency Management Agency, Hazard Mitigation Plan, 2022: https://www.yorkcountymaine.gov/emergency-management
[18] NOAA Tides and Currents: https://tidesandcurrents.noaa.gov/waterlevels.html?id=8418150

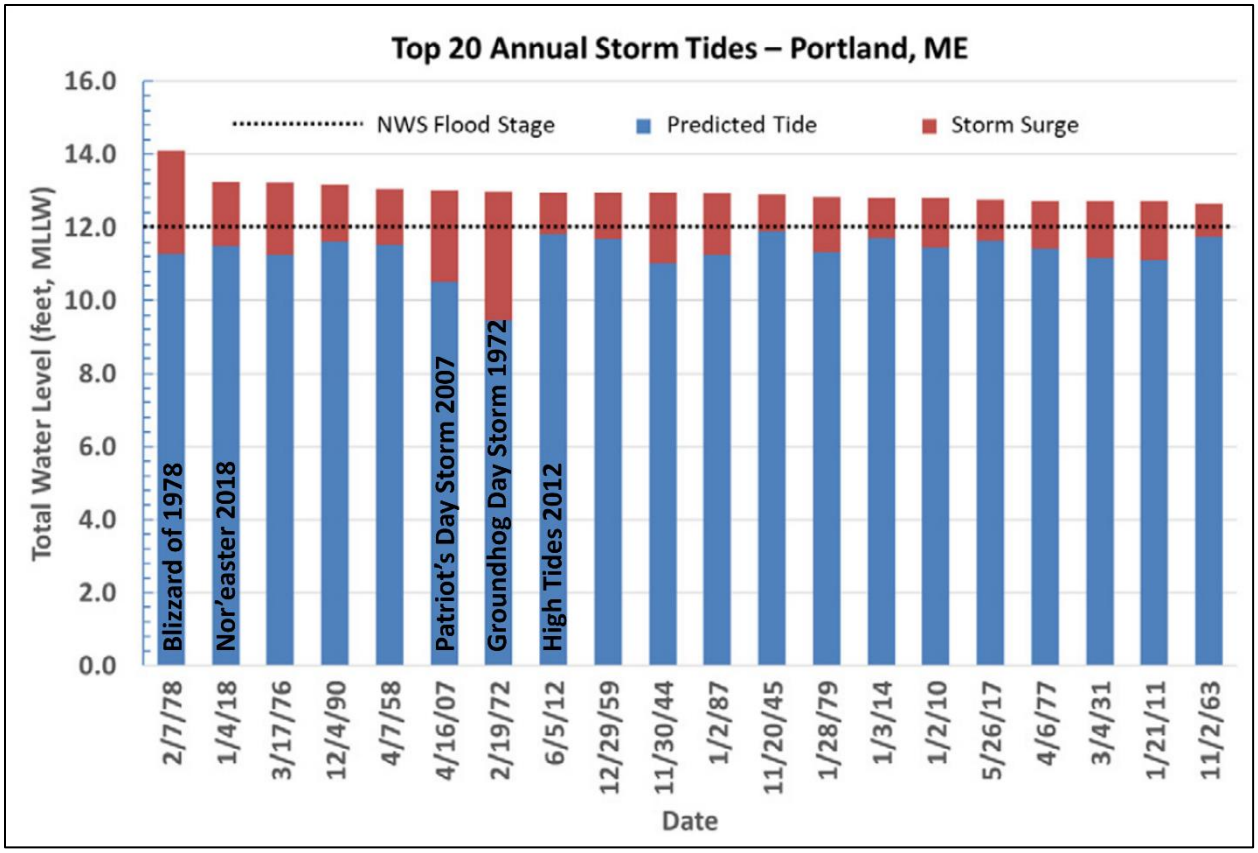


Figure 2. Major storm events and top 20 annual storm tides recorded at the Portland, ME tide gauge from 1912-2019. The National Weather Service Flood Stage of 12 feet MLLW is shown as a dashed line. This threshold indicates when elevated water levels begin to create a hazard to public safety, property, 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 pose 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.[19]

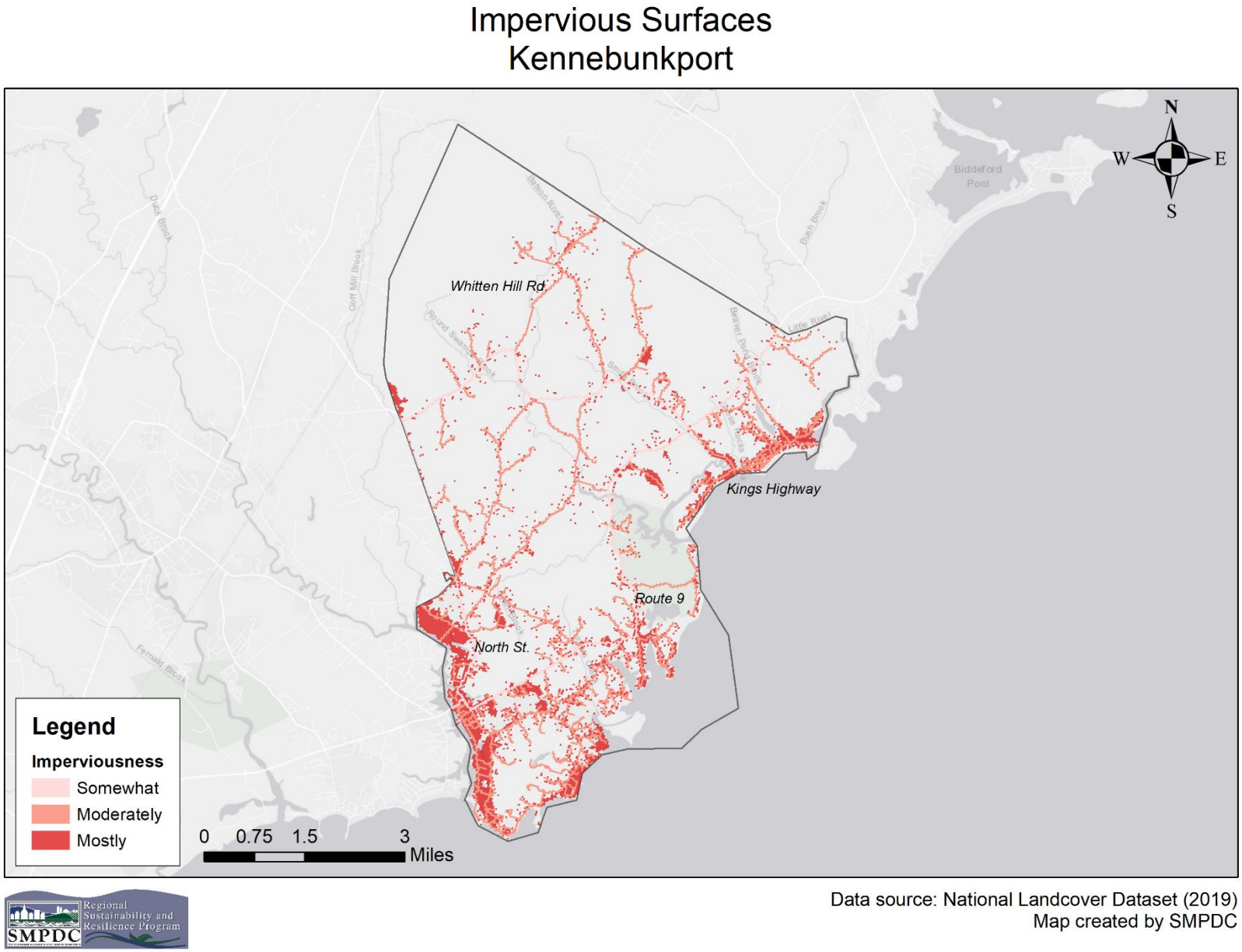
Like coastal flooding, inland and urban flooding may occur during winter nor'easters, but it also occurs during summer and fall tropical storms or intense thunderstorms. Flash floods are historically uncommon in Maine, but in October 2021 a flash flood dropped nearly 7 inches of rain in Kennebunkport in 6 hours, causing extensive power outages and damage. Inland flooding is difficult to predict due to the complex interaction of factors that contribute to precipitation-based flooding conditions, but changing weather patterns and more frequent and intense hurricanes in the southern

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

U.S. have the potential to cause more inland and urban flood events in coastal communities like Kennebunkport. [20]

Kennebunkport's proximity to the Kennebunk and Batson Rivers increases the community's risk of inland flooding. Additionally, the highest concentrations of impervious surfaces are along the Kennebunk River, Ocean Avenue, and Goose Rocks Beach (Map 11). There is an elevated risk of flooding from extreme precipitation and stormwater overflow in these areas, which 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.

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



Map 11. Impervious surfaces in Kennebunkport based on their level of imperviousness (somewhat, moderately or mostly impervious). Data is from the 2019 National Landcover Dataset.

Power Outages and Electric Grid Resilience

The reliability of the electric grid is vital to the day-to-day well-being and quality of life of Kennebunkport's community members, the Town's operations, and local economic activities. Breakdowns in grid operations and infrastructure result in power outages that can have significant impacts and hazards for a community. Power outages can jeopardize essential public safety services as well as drinking water and wastewater systems. Downed wires during power outages can make roads impassable or dangerous. Lack of heating/cooling and electricity during power outages puts vulnerable community members at risk. Homes and businesses also face significant costs due to power outages.

Kennebunkport is served by the ISO-New England Electric Grid, which oversees the day-to-day operation of New England's electricity grid. Grid components, including substations, transmission lines, and distribution lines, are owned by energy delivery service companies. In Kennebunkport the delivery service company is Central Maine Power, who provides Kennebunkport with electricity on several circuits that link Kennebunkport with the surrounding communities of Arundel, Biddeford, and Kennebunk.

The New England electricity grid is aging and is characterized by an extensive network of older, lower-capacity transmission lines serving as feeder lines to transformers and other critical system components. It is also increasingly vulnerable to several climate impacts, including extreme storms and precipitation as well as increasing temperatures.

Currently, the greatest source of power outages in Kennebunkport and the broader region is storm events, including nor'easters, ice storms, snowstorms, and high wind events. A combination of high storm frequency, aging electric grid infrastructure, and an abundance of trees results in Maine having 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).[21]

In Kennebunkport, 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 Kennebunkport, tree impacts caused 91% of all customer hours without power. On the circuits serving Kennebunkport, CMP customers experienced an average of 4.63 power outages with an average outage duration of 1.24 hours in 2021 (Data supplied by CMP).[22]

In the future, increases in extreme storm frequency and duration will likely result in more power outages from downed lines, blown transformers, and other damage to regional grid infrastructure. Additional climate impacts will also strain grid infrastructure and cause power outages in the following ways:

- Increased likelihood of equipment breakdown from flooding of coastal and inland grid infrastructure from increases in storm surge and extreme precipitation events. In particular,

[21] Annual Electric Power Industry Report, Form EIA-861 detailed data files, https://www.eia.gov/electricity/data/eia861/

[22] Data supplied by Central Maine Power.

substations can be significantly damaged by flooding. 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. Also, during extreme storms, damage to roads and other infrastructure can prevent utility services from reaching and repairing sub-stations, prolonging power outages. The Town of Kennebunkport is served by one substation located on School Street. This substation also serves portions of Kennebunk's lower village, Arundel, and coastal Biddeford. Road access to this substation could be potentially vulnerable due to extreme flooding of Grist Mill Pond from extreme precipitation, storm surge, or sea level rise.

- Reduction in the grid transmission capacity and increase in the risk of damage to transformers due to higher average temperatures and nighttime temperatures.
- Increased risk of physical deformation of powerlines, damage to transformers, and disruptions to service due to extreme high temperatures.
- Increased demand for electricity, due to both the electrification of other energy systems as well as increased average and peak cooling demand during warmer temperatures and longer, more frequent, and more severe heat waves.

Taken together, these impacts mean that the regional electric grid is extremely vulnerable to climate change, while at the same time electrification and electricity demand are going up. These vulnerabilities are exacerbated by aging grid infrastructure that has an increasingly limited capacity to take on more electricity transmission. At the same time, increases in average and extreme temperatures lead to greater health risks for Kennebunkport's vulnerable community members, which in turn amplifies the need for reliably electrified and conditioned spaces to ensure their safety.

Flooding: Sea Level Rise & Storm Surge

Key Takeaways

- Kennebunkport's coastal infrastructure, properties, and natural resources are vulnerable to flooding.
- Dock Square, Cape Porpoise, and the beaches are significant drivers of tourism, key to the local economy, and are important cultural resources that are particularly vulnerable to flooding.
- More than $634.5 million in assessed property value (FY21 assessing data) in Kennebunkport is at risk of flooding from the 1% annual chance event storm surge plus 1.6 feet of sea level rise, corresponding to 23.3% of the town-wide assessed property value and representing 26% of the Town's FY21 municipal budget.
- Several coastal neighborhoods are vulnerable to flooding from coastal storms, including Cape Porpoise, Goose Rocks Beach, the Langsford Road peninsula and Marshall Point Road.
- Significant transportation routes for local traffic and tourists already experience flooding during storms, including Route 9 and Ocean Avenue.
- Almost all engineered coastal structures (e.g., seawalls, bulkheads, etc.) 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[23]. 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[23]. 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[23]. Those scenarios do not account for more intense rainfall that climate change is bringing to the region, which will exacerbate flood risk. With just 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[24].

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.

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

[24] Eastern Research Group. 2020. Assessing the Impacts Climate Change May Have on the State's Economy, Revenues, and Investment Decisions: Volume 2, Cost of Doing Nothing Analysis. Prepared for the State of Maine. Governor's Office of Policy Innovation and the Future.

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 Council recommends a 'risk tolerance' 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[25]. 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[26]. 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[27]:

- **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**

[25] Maine Climate Council. 2020. Maine Won't Wait: A Four-Year Plan for Climate Action.

[26] Southern Maine Planning and Development Commission. 2020. Economic Resilience Assessment and Plan for Coastal York County: Towns of Kennebunk, Kennebunkport, Kittery, Ogunquit, Wells, and York.

[27] 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.

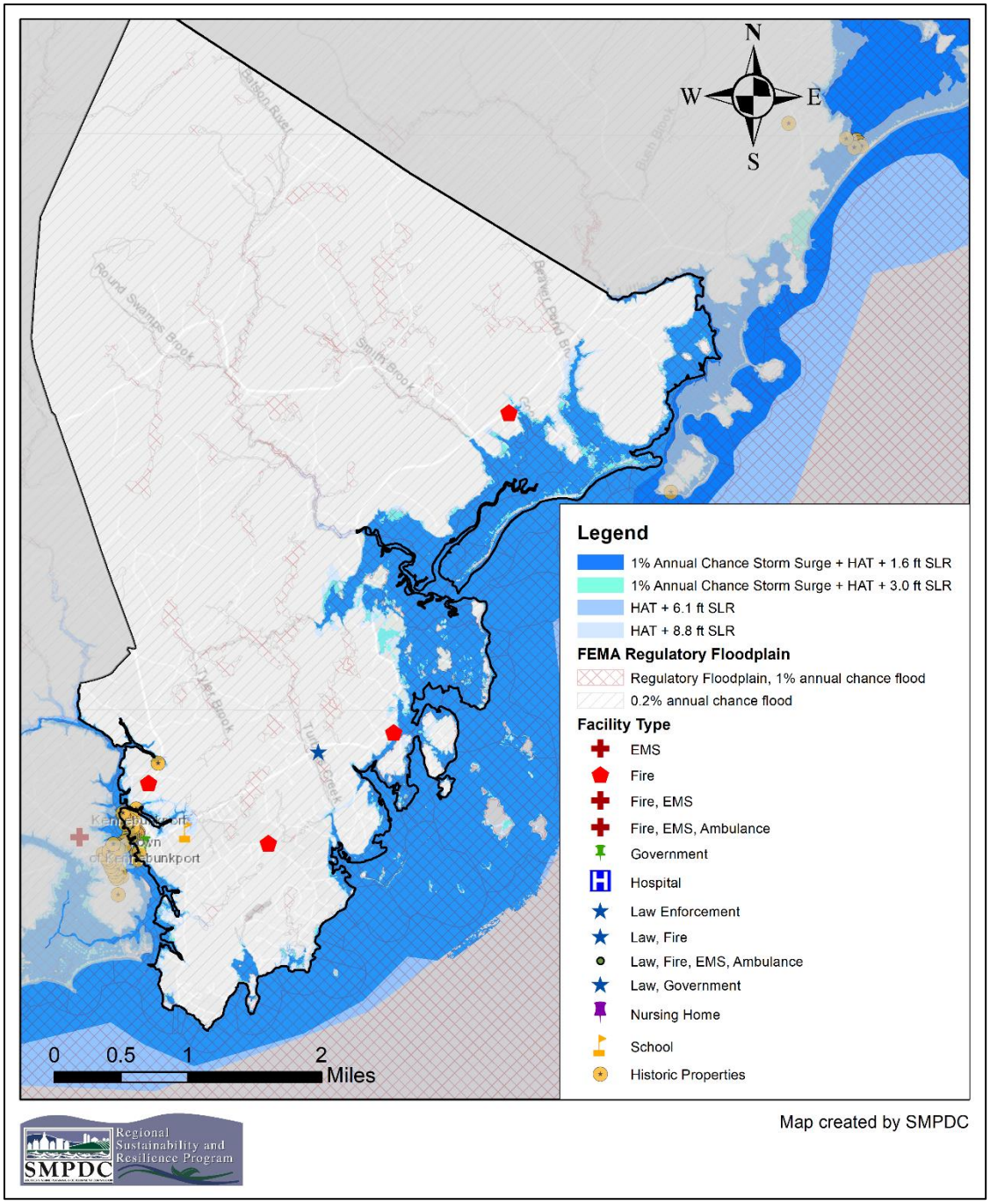
The assessment results presented below use the terms 'vulnerable', 'impacted', and 'at-risk' to describe impacts. All three terms mean that the subject parcels, asset, or area is touched by water under the given inundation scenario. It is important to note that the modeled flood scenarios show inundation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

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. Kennebunkport'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[28]. 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 (*Map #)* below 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 areas vulnerable to projected flooding from the 1%-annual chance event (*e.g*., the FEMA regulatory floodplain), projected flooding from the 1%-annual chance event (*e.g*., the FEMA regulatory floodplain), storm surge from the 1% annual chance event plus 1.6 feet and 3.0 feet of sea level rise, 6.1 feet of sea level rise, and 8.8 feet of sea level rise. There is a concentration of mapped historical properties that are vulnerable to flooding in the Dock Square area. Notably, the Kennebunkport Fire Station near Cape Porpoise and Goose Rocks Beach Fire Station are located in areas that are projected to be impacted by future sea level rise.

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



Map #: Critical facilities and buildings for public safety and well-being, historic properties, and parcels projected to be directly impacted by flooding from storm surge plus 1.6 feet of sea level rise and plus 3.0 feet of sea level rise, 6.1 feet of sea level rise, 8.8 feet of sea level rise, and the 1% annual chance event.

Table 5. Assessed value of parcels (FY21 values) 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)

	Land Only	**Buildings + Land**	**Total**	**Total Municipal Tax Impact** *(impacted assessed property value x '21/'22 tax rate of 0.0096)*	**% of Town-Wide Assessed Value ('21)**	**% of FY21 Municipal Budget**
Storm surge + 1.6 ft SLR	$ 76,475,801	$ 558,006,300	$ 634,482,101	$ 6,091,028	23.3%	26%
Storm surge + 3.0 ft SLR	$ 79,534,008	$ 679,596,200	$ 759,130,208	$ 7,287,650	27.9%	31%

- $634.5 million in assessed property value (FY21 assessing data) is vulnerable to the 1.6 ft scenario. Under this scenario, $76.5 million in assessed value is from properties where only the land is impacted, while $558.0 million in assessed value is from properties where both building and land are impacted. $759.1 million in assessed property value is vulnerable with the 3.0 ft scenario (Table 5).
    - Those values correspond to 23.3% and 27.9% of the town-wide assessed property value, respectively, and represent 26% and 31% of the Town's FY21 municipal budget.
    - Single-family residential homes make up the majority of the assessed property impacted by flooding, followed by multi-family residential homes.
- Dock Square is a key economic and tourism hub for the community and is vulnerable to flooding from both modeled scenarios. There are a number of historic properties located in the area that are also vulnerable to flooding.
- Many of the structures in Kennebunkport built before 1970 are located along the coast flood in prone areas. 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, making those areas especially vulnerable to flooding.
- Road access to 175 parcels that aren't directly at-risk of flooding is cutoff by flooding with the 1.6 ft scenario; 145 parcels are cutoff from the 3.0 ft scenario (the number decreases because with the higher sea level rise scenario, more of the parcels cutoff by the 1.6 ft scenario become directly impacted by flooding).
- **Residential properties along Turbats Creek** are vulnerable to flooding from both scenarios.
- Almost all **properties on the Langsford Road peninsula** are vulnerable to flooding from both scenarios.
- The **coastal neighborhood off of Marshall Point Road** is vulnerable to flooding under both scenarios.
- **Cape Porpoise** is a particularly vulnerable area of town, as several residential properties, businesses, and the Town pier are vulnerable to flooding from both modeled flood scenarios.

- The **Goose Rocks Beach** neighborhood, including residential properties, vacation rentals, hotels, and other businesses are vulnerable to both the 1.6 ft and 3.0 ft scenarios.
- **Goose Rocks and Colony Beaches**, **Vaughn Island**, and **Rachel Carson National Wildlife Refuge lands along the Batson River** are all significant areas for outdoor recreation and tourism and are vulnerable to flooding from both scenarios.
- Some coastal properties are served by private drinking water wells and are at risk of saltwater intrusion from rising seas, placing drinking water supplies for those homes at risk.

Infrastructure Impacts

Sea level rise threatens surface and subsurface infrastructure. Inundation of surface infrastructure can cause short-term disruptions due to road closures and limited access to infrastructure. It can also cause substantial damage to infrastructure, including pavement, culverts, stormwater infrastructure, and utility infrastructure. Higher water levels can reverse or reduce efficiency of stormwater drainage and wastewater outfall operations.

Along the coast, groundwater and saltwater are naturally separated by the seaward movement of groundwater. As seas rise, landward intrusion of seawater pushes groundwater levels up and shifts the interface of fresh groundwater and saltwater inland. Studies conducted in coastal New Hampshire show that sea level rise induced groundwater rise is projected to extend up to three to four times further inland than surface tidal water inundation from sea level rise[29].

Low-lying coastal communities and important infrastructure are at risk of impacts including intrusion of saltwater into groundwater and drinking water resources, increased flooding from higher coastal water tables, and water damage to roadways and other infrastructure from below. Researchers are working to model and assess this phenomenon in New England to better understand coastal hazards stemming from sea level rise. No assessment has yet been completed for Kennebunkport, however, subsurface stormwater, transportation, and utility infrastructure; contaminated sites; septic systems; and drinking water wells in coastal areas will likely be negatively impacted by rising groundwater and saltwater intrusion. Rising groundwater can impede the ability of septic systems to function properly as the vertical separation between the groundwater table and leachfield is reduced. This can result in contamination from septics into groundwater and nearby surface waters. The U.S. Geological Survey (USGS) notes that if too much freshwater is pumped from an aquifer system, saltwater can migrate landward[30]. Wells located near the landward migrating freshwater/saltwater interface, saltwater could be contaminated from saltwater entering the well, threatening drinking water supplies. However, the USGS also notes that this is less likely to happen with residential wells and is a larger concern for municipal or community-size wells where pumping rates are much higher.

In Kennebunkport, most coastal areas in town are served by public sewer and have access to public water from Kennebunk, Kennebunkport, and Wells Water District, limiting vulnerability of septic systems and private drinking water wells from groundwater rise and saltwater intrusion, respectively. However, neighborhoods directly inland from Vaugn Island, those along Ocean Avenue and Shore Road

[29] Knott, J.F.; Jacobs, J.M.; Daniel, J.S., and Kirshen, P., 2019. Modeling groundwater rise caused by sea-level rise in coastal New Hampshire. *Journal of Coastal Research*, 35(1), 143–157. Coconut Creek (Florida), ISSN0749-0208.
[30] U.S. Geological Survey. 2019. https://www.usgs.gov/mission-areas/water-resources/science/saltwater-intrusion

east of Walker's Point to Turbats Creek Road, and most parcels in fairly densely developed neighborhoods along Little River and Batson River do not appear to be served by public water. Those areas could experience saltwater intrusion into wells, making them vulnerable. Those same areas are also not served by public sewer are likely on private septic systems that could be at risk of failure due to rising groundwater.

- Roughly 9.9 miles of road are vulnerable to flooding by the 1.6 ft scenario and almost 12.3 miles are impacted by the 3.0 ft scenario (Table 6). A complete list of roads impacted by both flooding scenarios can be found at the end of this section.

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)

	Road Length (ft) Impacted	Road Length (Miles) and Classification Impacted
Storm surge + 1.6 ft SLR	52,399	**9.92** *Local: 5.56* *Private: 4.02* *Secondary/paper street: 0.36*
Storm surge + 3.0 ft SLR	64,841	**12.28** *Local: 6.65* *Private: 5.09* *Secondary/paper street: 0.54*

- **Route 9** is vulnerable to flooding at the Kennebunk River. Flooding cuts off access to several businesses in the 1.6 ft scenario, and the bridge is entirely inundated under the 3.0 ft scenario. Route 9 will also be impacted in Cape Porpoise and at the crossing of Tyler Brook.
- **Dyke Road and New Biddeford Road** are vulnerable to flooding from both the 1.6 feet and 3.0 feet scenarios, threatening road access to the Goose Rocks Beach area.
- **Ocean Avenue** is a significant transportation route for local traffic and tourists. It already experiences flooding during coastal storms and high tides and is vulnerable to both the 1.6 ft and 3.0 ft scenarios.
- **Marshall Point Road** is vulnerable to flooding from both scenarios.
- **North Street** and its associated culvert at the Gristmill Pond outlet are vulnerable to flooding under both scenarios.
- 12% and 17% of local sidewalks, paved shoulders, and crosswalks are vulnerable from the 1.6 ft and 3.0 ft scenarios, respectively.
- There are no critical facilities directly at risk from either 1.6 ft or 3.0 ft scenarios.
- Of the 1,392 sewer users in Kennebunkport, 763 (or 55%) of them have properties in areas at risk from the 1.6 ft scenario and an additional 44 are in areas at risk from the 3.0 ft scenario. The other coastal properties vulnerable to flooding are on private septic systems, which are vulnerable to failure from sea level induced groundwater rise which could lead to contamination of nearby surface waters and groundwater. Areas on septic systems include parcels along Ocean Avenue and Shore Road east of Walker's Point to Turbats Creek Road, neighborhoods just inland from Vaughn Island, most areas around Batson River and Little River, and areas just inland from Goose Rocks Beach around Smith Brook. Many of those same areas are also not served by public water, placing them at risk of saltwater intrusion into drinking water wells.

- 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.
    - Almost all of the engineered structures (rip-rap, bulkhead, etc.) along the Kennebunk River.
    - Various sections of rip-rap and bulkhead along segments of Ocean Avenue on the open coast.
    - Segments of rip-rap and bulkhead in front of private properties along Cleaves Cove.
    - All segments of engineered structures along the western side of the Turbats Creek outlet.
    - Almost all sections of engineered structures in the Cape Porpoise area.
    - Most structures along Goosefare Bay and Goose Rocks Beach.

Road Name	Road Classification	Impacted by Storm Surge + 1.6 ft Sea Level Rise	Impacted by Storm Surge + 3.0 ft Sea Level Rise
Agamenticus Ave	Private	✓	✓
Bartlett Ave	Local	✓	✓
Beach Rose Ln	Private	✓	✓
Beaver Pond Rd	Private	✓	✓
Beech St	Private	✓	✓
Belair Ave	Local	✓	✓
Belleglade Ave	Private	✓	✓
Bellevue Ave	Local	✓	✓
Bellewood Ave	Private	✓	✓
Bellewood Ave	Local	✓	✓
Belvidere Ave	Local	✓	✓
Binnacle Ln	Private	✓	✓
Broadway	Local	✓	✓
Brooks St	Private	✓	✓
Buzzys Way	Private	✓	✓
Chestnut St	Local		✓
Clark Rd	Private	✓	✓
Cleaves Ave	Local	✓	✓
Coffin Ln	Private		✓
Community House Rd	Local		✓
Cottage Ave	Private	✓	✓
Crescent Ave	Local	✓	✓
Crescent Ave	Private	✓	✓
Dock Sq - Route 9	Secondary	✓	✓
Dorrance Rd	Local	✓	✓
Dyke Rd	Local	✓	✓
Edgewood Ave	Local	✓	✓

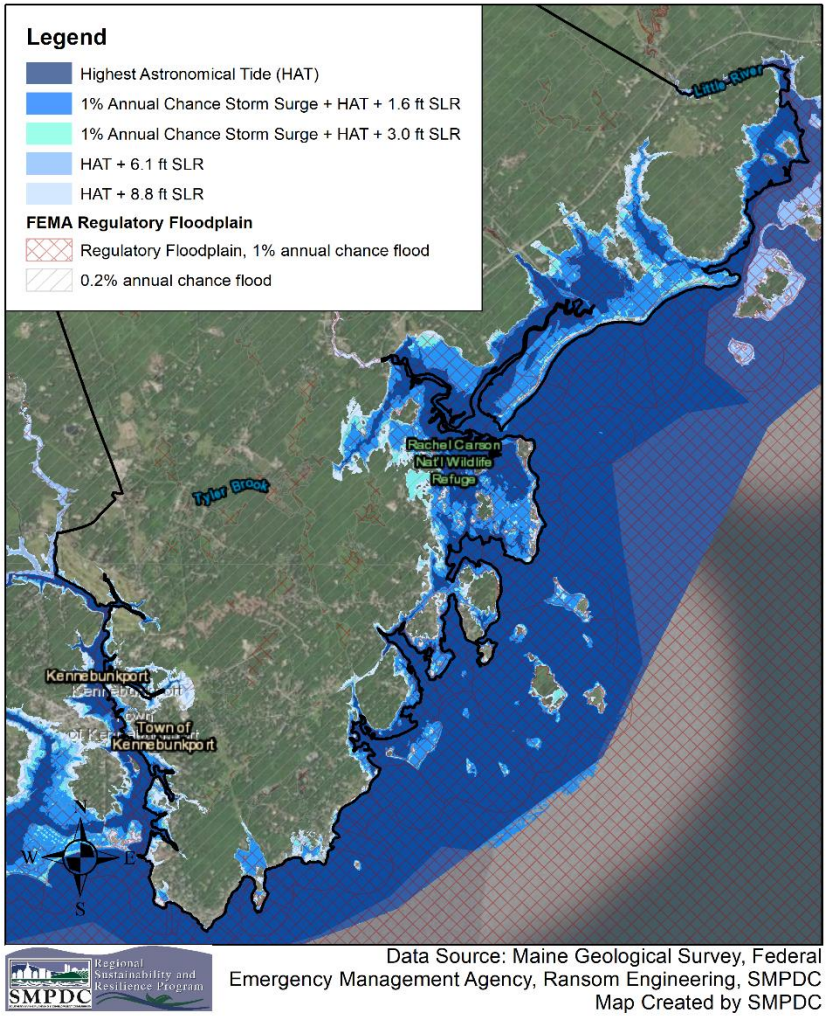
Eel Bridge Ln	Local	✓	✓
Elm St	Local		✓
Elwyn Ln	Private	✓	✓
Fishers Ln	Private	✓	✓
Fishers Ln	Local	✓	✓
Glazier Ln	Private	✓	✓
Goosefair	Private	✓	✓
Grandview Ave	Local	✓	✓
Greene St	Local	✓	✓
Grier Rd	Private	✓	✓
Harrison Ln	Private	✓	✓
Harwood Dr	Private	✓	✓
Hayward Ave	Local	✓	✓
Hayward Ave	Private	✓	✓
Henchey Way	Private	✓	✓
Jefferys Way	Local	✓	✓
Josiah Curtis Ln	Local	✓	✓
Kings Hwy	Local	✓	✓
Kings Hwy	Private	✓	✓
Kings Ln	Private	✓	✓
Lands End Rd	Private	✓	✓
Langsford Rd	Local	✓	✓
Main St - Route 9	Secondary	✓	✓
Marleys Way	Private		✓
Marsh Madness Ln	Private	✓	✓
Marshall Point Rd	Private	✓	✓
Mill Ln	Local	✓	✓
Mills Rd - Route 9	Secondary	✓	✓
Mitchell Way	Private	✓	✓
Nehoc Ln	Private	✓	✓
New Biddeford Rd	Local	✓	✓
North St	Local	✓	✓
Norwood Ln	Private	✓	✓
Ocean Ave	Local	✓	✓
Ocean View Ave	Private		✓
Paddy Creek Rd	Private	✓	✓
Paddy Creek Rd	Local	✓	✓
Pegs Way	Private	✓	✓
Perkins Ln	Private		✓
Pier Rd	Local	✓	✓
Prescott Dr	Private	✓	✓

Proctor Ave	Local	✓	✓
Rugosa Way	Private	✓	✓
Rush Pond Ln	Private	✓	✓
Salt Air	Private		✓
Sand Point Rd	Private	✓	✓
Sand Point Rd	Local	✓	✓
Sandy Cove Rd	Private		✓
Sea Ln	Private	✓	✓
Seagrass Ln	Private	✓	✓
Seaview Ave	Private	✓	✓
Skipper Joes Point Rd	Private	✓	✓
Skyline Dr	Private	✓	✓
Stage Rd	Private	✓	✓
Summer Breeze Ln	Private		✓
Sunset Ln	Private	✓	✓
Tidal Shore Dr	Private	✓	✓
Turbats Creek Rd	Local	✓	✓
Turbats Creek Rd	Private	✓	✓
Tyler Brook Rd	Private	✓	✓
Union St	Local	✓	✓
Ward Rd	Local	✓	✓
Ward Road Ext	Private	✓	✓
Waterside Ln	Private	✓	✓
Wharf Ln	Private	✓	✓
Whittemore Ln	Private	✓	✓
Wild Horse Run	Private	✓	✓
Wildes District Rd	Local	✓	✓
Wildwood Ave	Local	✓	✓
Wildwood Ave	Private	✓	✓
Winter Harbor Rd	Local		✓
Wood Rd	Private	✓	✓

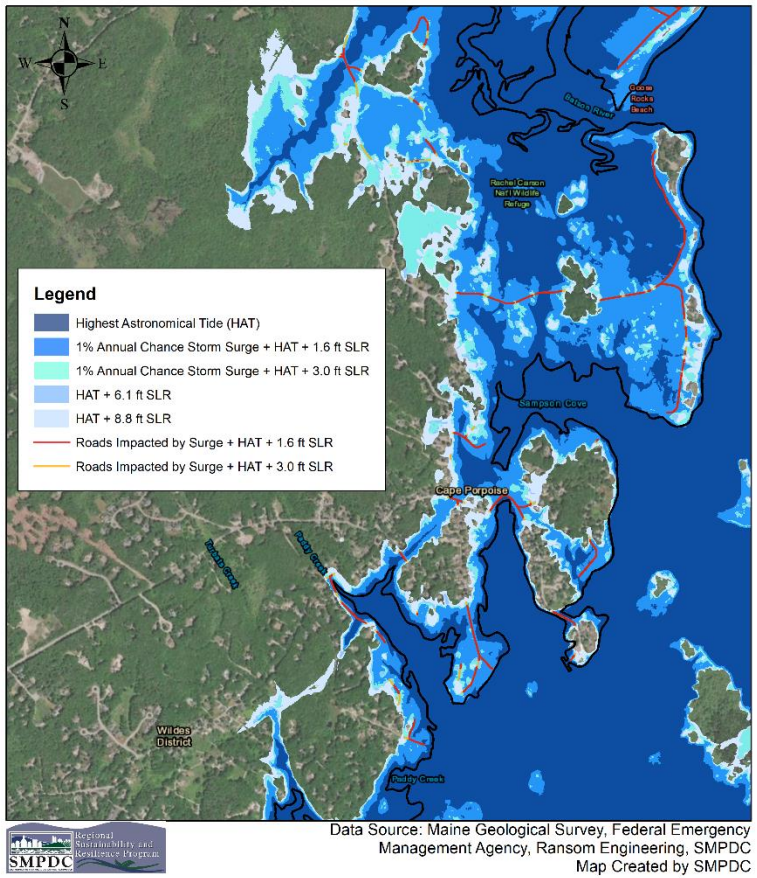
Economic Impacts

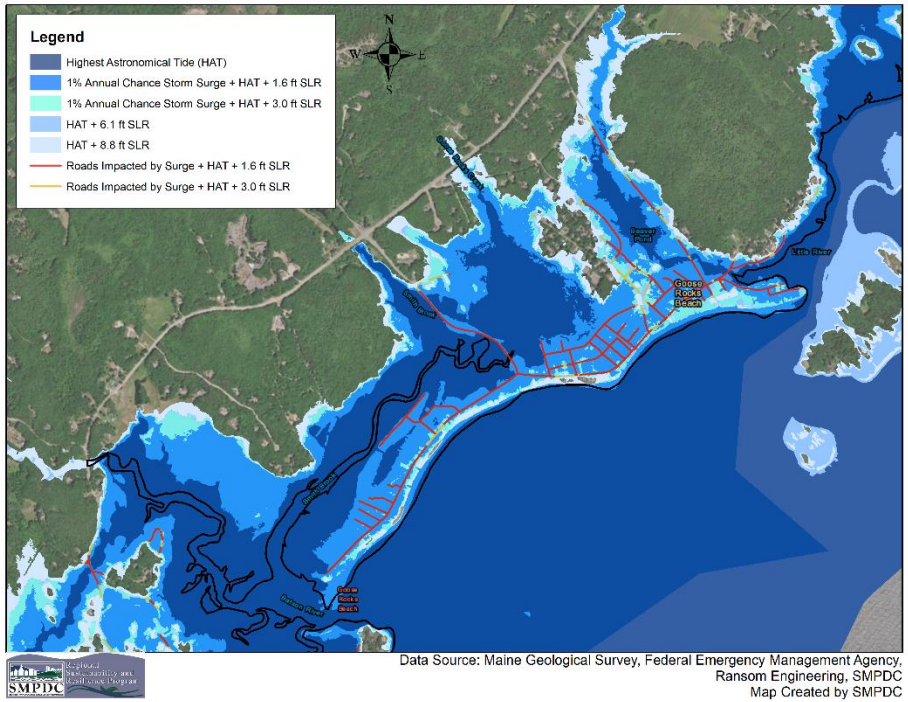
- More than 600 jobs, more than $17 million in labor income, nearly $30 million in area gross domestic product, and over $45 million in revenue in Kennebunkport may be affected in some way by sea level rise and storm surge.
- 1 out of every 6 jobs in Kennebunkport is vulnerable under the 3.0 ft scenario, and nearly $1 out of every $10 generated in town is connected to a business that is directly impacted by flooding.
- Under the 3.0 feet scenario, over 60% of the sales revenue in the hotel industry and over 50% of the sales revenue from the restaurant industry are at risk. From an employment perspective,

over 80% of the employment in both the restaurant and hotel industries are vulnerable. Employees at those types of businesses are particularly vulnerable, as their jobs rely on tourism activity. Additionally, people employed in restaurant and hotel industries tend to have lower adaptive capacity to respond to disruptions to employment activity linked to things like temporary business closures and decreased tourism activity caused by flooding.

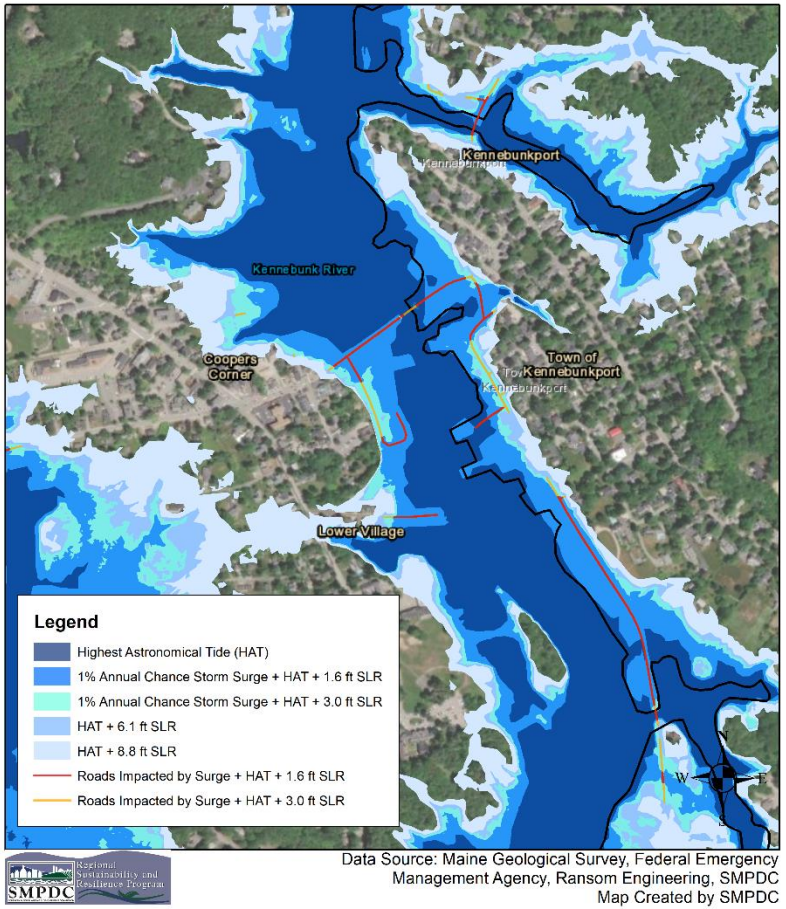


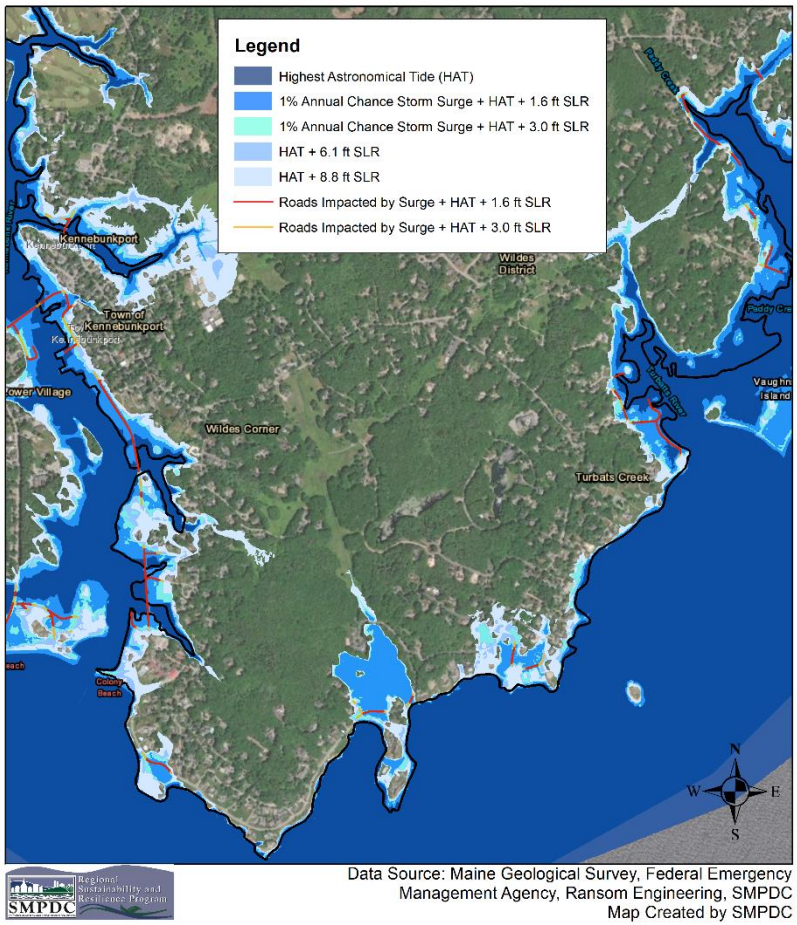
Map 12. Modeled inundation from sea level rise (SLR), storm surge, and the 1% annual chance storm event (Special Flood Hazard Area depicted on the FEMA-Issued Flood Insurance Rate Map).





Map 13. Roads impacted by storm surge from the 1% annual chance (i.e. 100-year) event plus 1.6 feet and 3.0 feet of sea level rise. Road impacts account for bridge elevation, as LiDAR was used to confirm whether a bridge would be overtopped based on bridge deck elevations and the water surface elevations of the inundation scenario. So, even if the inundation boundary appears to 'cover' a bridge, the bridge is only projected to be inundated by water if it is shown as red or orange on the map. (Source: SMPDC. 2022. Economic Resilience Assessment and Plan for Coastal York County).





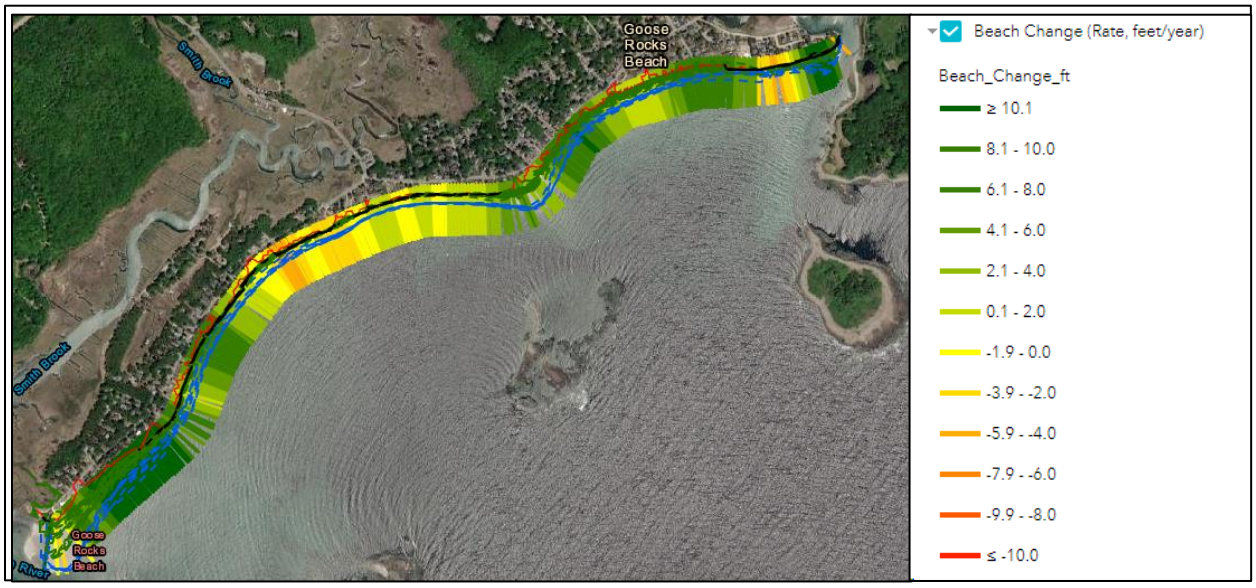
Map 14. Roads impacted by storm surge from the 1% annual chance (i.e. 100-year) event plus 1.6 feet and 3.0 feet of sea level rise. Road impacts account for bridge elevation, as LiDAR was used to confirm whether a bridge would be overtopped based on bridge deck elevations and the water surface elevations of the inundation scenario. So, even if the inundation boundary appears to 'cover' a bridge, the bridge is only projected to be inundated by water if it is shown as red or orange on the map. (Source: SMPDC. 2022. Economic Resilience Assessment and Plan for Coastal York County).

Impacts to the Natural Environment

Beach Erosion

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, Kennebunkport's dry beach width (distance from the mean high water to seawall or dune edge) is projected to decrease by 9.7 acres, or by roughly 73%. With 3.9 feet of sea level rise, the dry beach width is projected to decrease by 13 acres, more than 97%[31].
- Sea level rise is expected to lead to loss of coastal habitat. Along Kennebunkport'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 show that Goose Rocks Beach has been relatively stable in terms of measured beach width over the past several years (2016 – 2020) with mostly growth (accretion) at the southern and northern ends of the beach and some relatively minor loss (erosion) in the middle portion of Goosefare Bay. Sea level rise will likely exacerbate erosion in areas already experiencing it and lead to additional erosion along all beach areas.



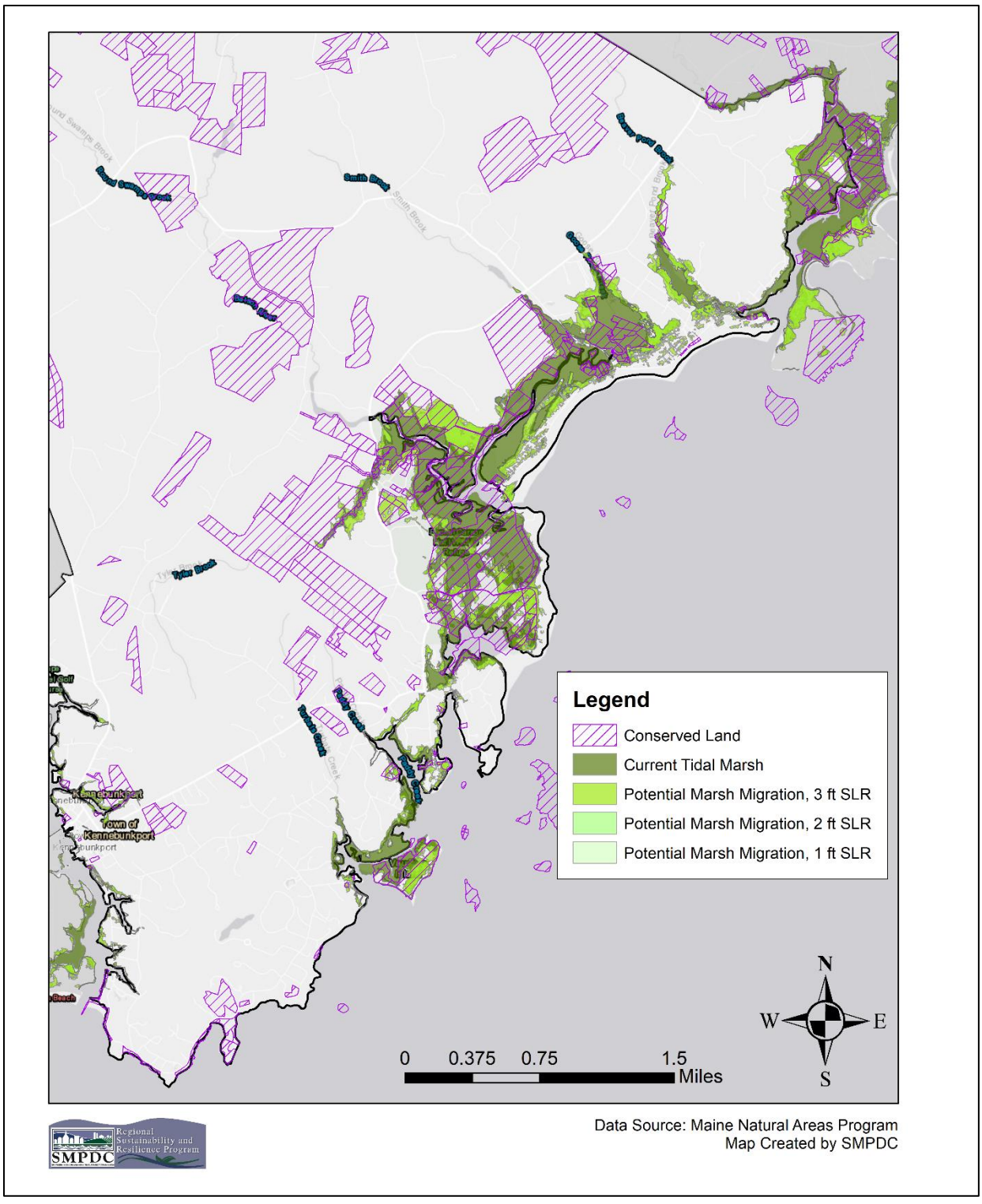
Map 15. Mapped shoreline change along Goose Rocks Beach. This map shows the rate of beach change, in feet per year, from data collected from 2016 through 2020. A positive value (green lines) represents a rate of beach growth, while a negative value (yellow/orange/red lines) represents a rate of beach loss. (Source: Maine Geological Survey. Maine Beach Mapping Program. Maine Beach Mapping viewer)

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

Marsh Migration

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 16). 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 around Batson River and the Goose Rocks are identified as being able to potentially support future marsh migration. Some of these areas are either conserved or adjacent to conserved lands, which can help to ensure that future development won't impact migrating marshes in those areas.
- Areas around Vaughn Island are also identified as being able to support future marsh migration.



Map 16. 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 Kennebunkport, such as in the downtown area of Dock Square.
- 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.

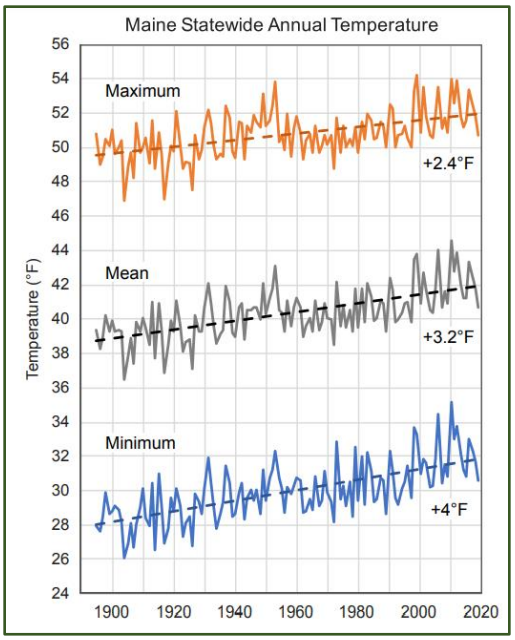


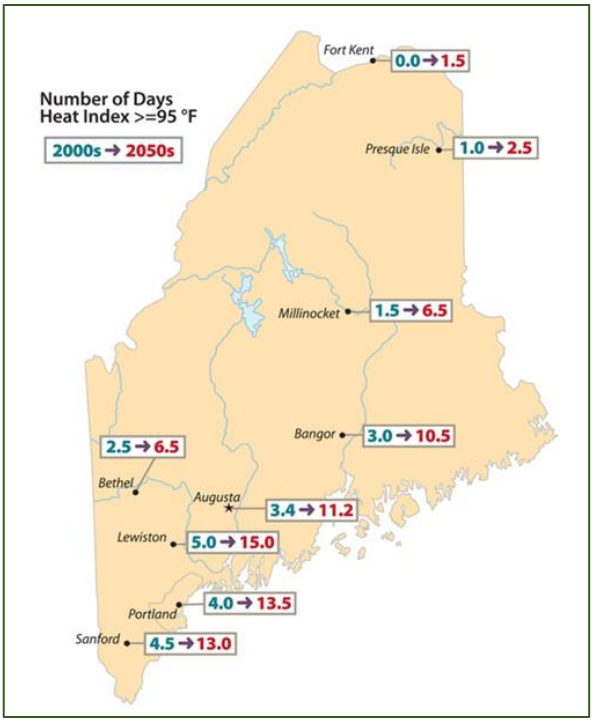
Figure 3. Maximum, mean, and minimum statewide annual temperatures from 1895 to 2019. (Source: MCC STS. 2020.)

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[32] (Figure 3). 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 almost 3 times more 'extreme heat' days, where the heat index (a combination of temperature and relative humidity that approximates the 'felt' temperature) exceeds 95°F, as the early 2000s (Map 18)[33]. In addition to extreme heat, there is research showing that more short-term temperature variability and volatility may be happening as a result of climate change.

[32] 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.
[33] 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.

Five of the ten warmest years on record have occurred within the past ten years, based on average annual temperatures from National Weather Service (NWS) data collected between 1989 and January of 2023 in Kennebunkport (Table 7). The warmest average monthly temperatures for the summer months (June, July, and August) have also occurred within the past ten years and have been 3.1 – 4.3°F warmer than the monthly mean temperature (Table 8). Based on the Kennebunkport data, January 2023 was the warmest January on record, with an average temperature of 31.9°, which is 8.5° warmer than the January mean temperature.



Map 17. 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.)

Table 7. The top ten warmest years based on average annual air temperatures measured in Kennebunkport, 1989 – January 2023. (Source: National Weather Service).

	Year	Average Annual Temperature (°F)
1	1989	49.9°
2	1998	49.0°
3	2021	47.8°
4	2010	47.7°
5	2012	47.6°
6	2020	47.2°
7	1999	47.0°
8	2006	47.0°
9	2022	46.8°
10	2016	46.7°
1989-2023 Average		45.3°

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 Kennebunkport, 1989 – January 2023. (Source: National Weather Service.)

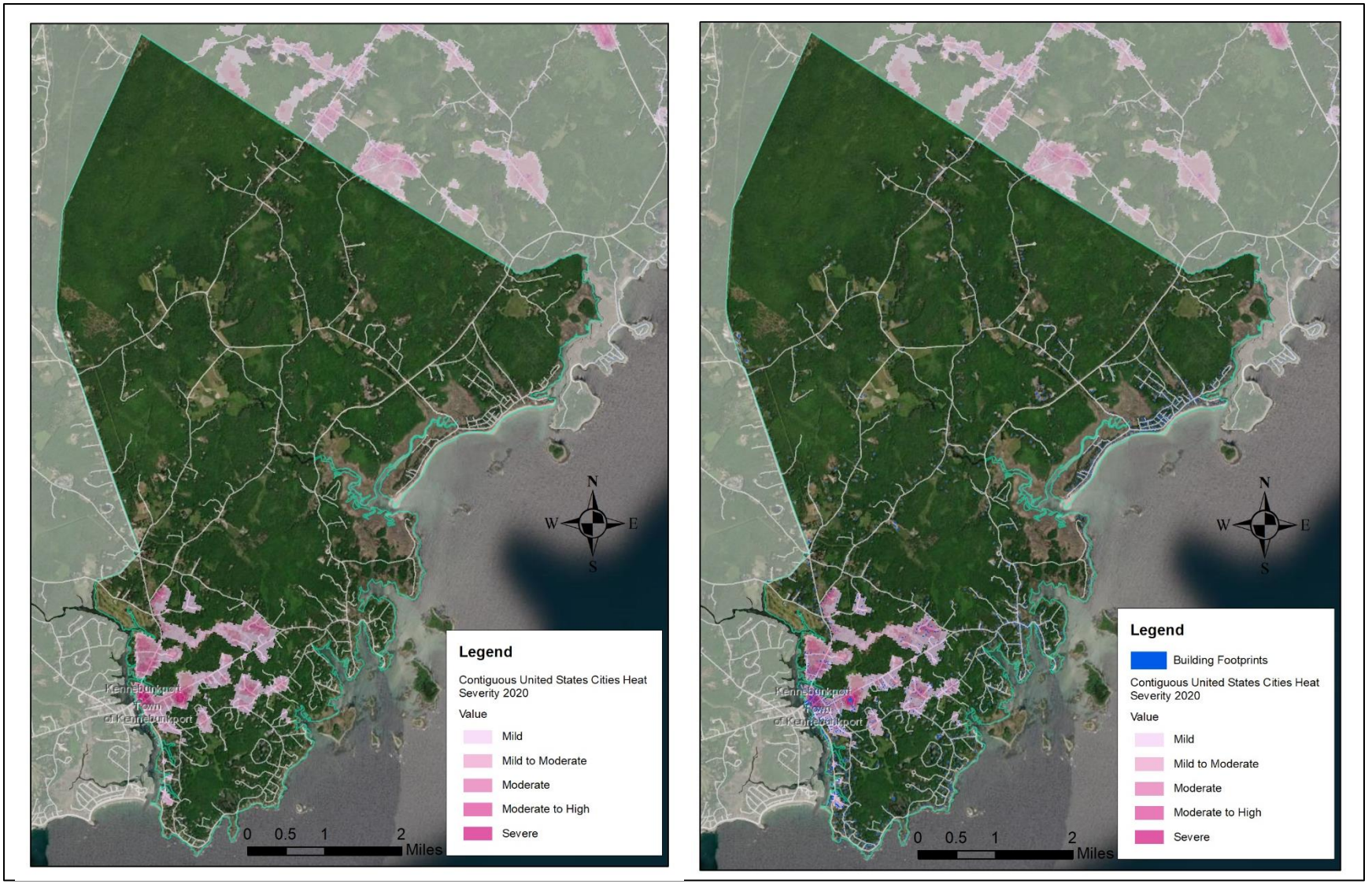
Month	Year	Average Temperature (°F)	Mean Temperature (°F), 1989 - 2022	Difference Between Mean and Average of Warmest Month
June	2021	65.7°	61.6°	+4.1°
July	2013	70.5°	67.4°	+3.1°
August	2018	70.4°	66.1°	+4.3°

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 18 shows areas in town 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 town), and 5 being a severe heat area (significantly above the mean for the town). (*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 Kennebunkport, the Dock Square area in the southwestern portion of town, along the western portion of Route 9, and the area around the Kennebunkport Fire Station are mapped as having elevated ground temperatures in relation to the rest of the community. The Dock Square and western portion of Route 9 areas are mapped as moderate to severe heat severity and are popular areas with pedestrians and tourists. The map illustrates that the presence of a high concentration of buildings in an area, such as in the Goose Rocks neighborhood, 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 18. 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. 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[34]. Figure 4 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 [35]. 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.

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

[35] 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.

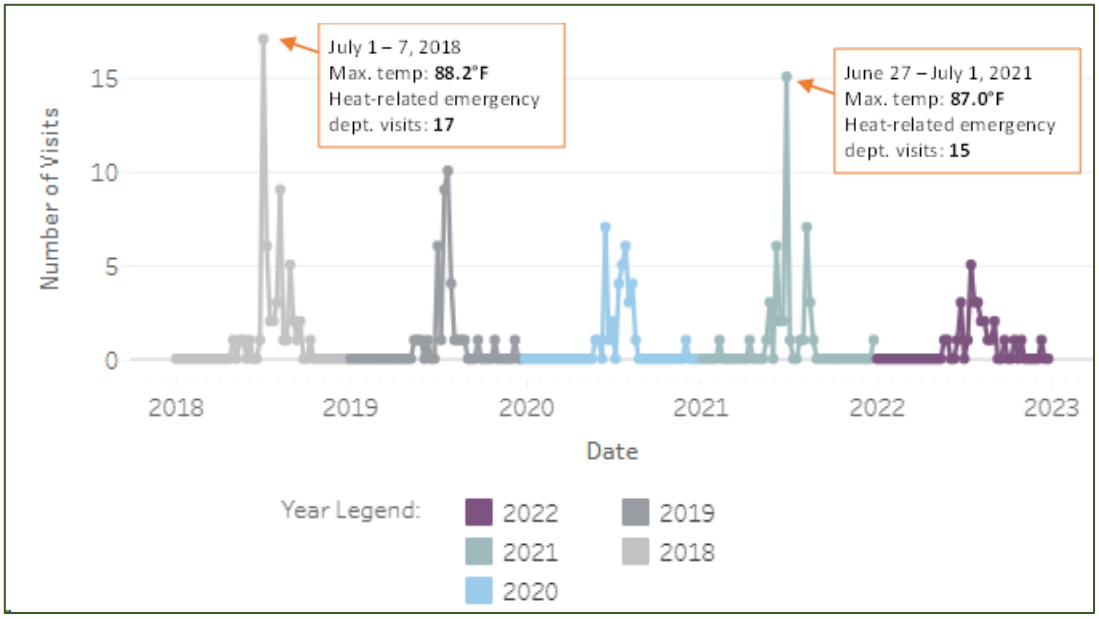


Figure 4. Number of heat illness visits to emergency departments in York County from 2018 to 2023. (Source: Maine Center for Disease Control and Prevention, Maine Tracking Network.)

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.[36] Figure 5 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[37]. Regardless of the cause, individuals with existing health conditions, older populations, and children are especially vulnerable to poor air quality.

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

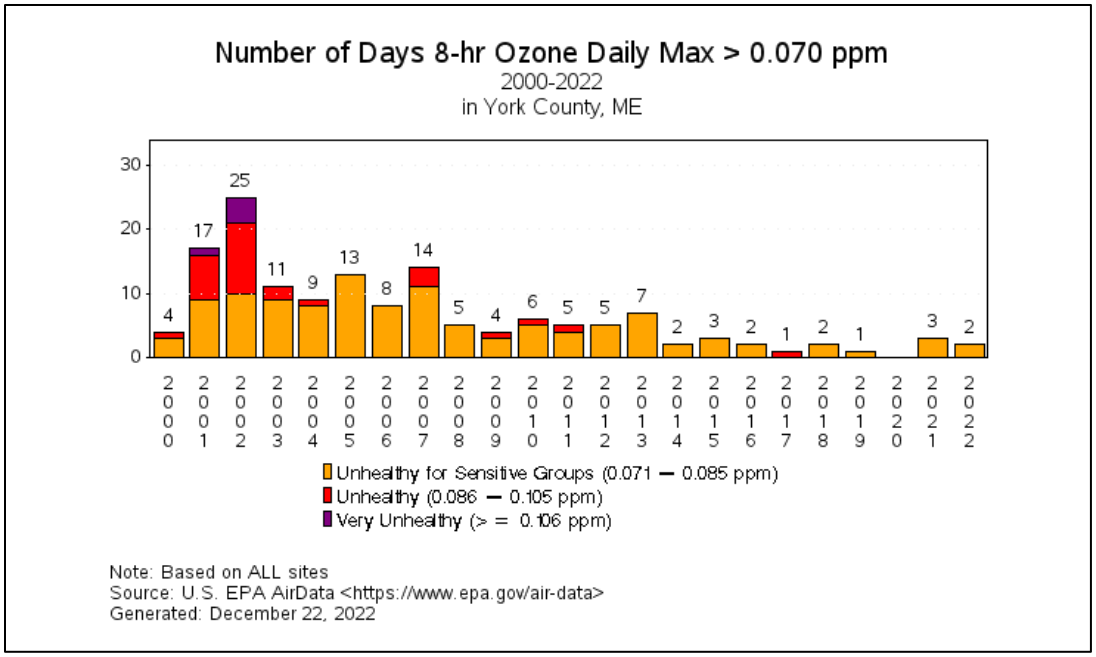


Figure 5. Number of days during which the 8-hour average ozone concentration exceeded national air quality standards. (Source: US EPA AirData portal)

The prevalence of tickborne diseases, including Lyme, anaplasmosis, and babesiosis, has increased in York County in recent years. Figure 6 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 Kennebunkport. Between 2016 and 2020, Kennebunkport had the fourth highest rate of babesiosis of all York County communities.

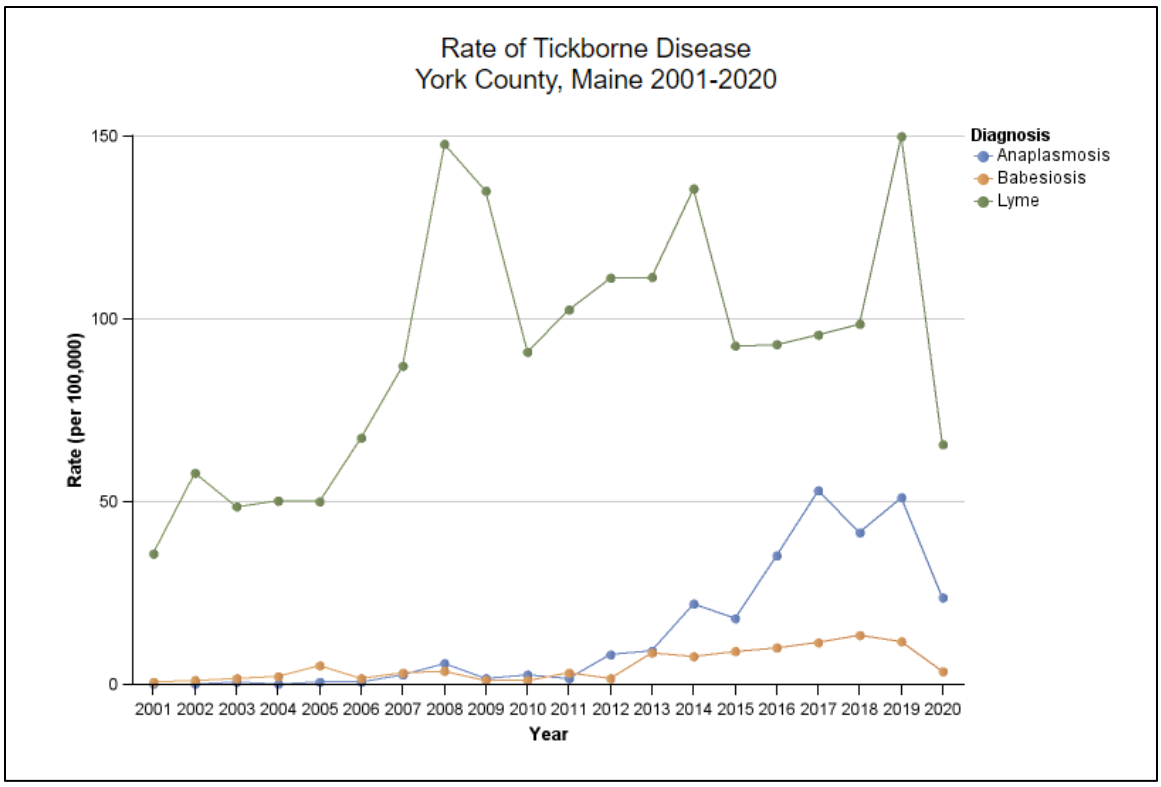


Figure 6. Annual incidence rate (per 100,000 people) of confirmed and probable cases of tickborne diseases of the population in York County. Maine CDC's Infectious Disease Program obtained these data through notifiable conditions surveillance based upon reports from healthcare providers, laboratories, 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.

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

Rate and Number of Tickborne Diseases in Kennebunkport, 2016 - 2020			
	Anaplasmosis	Babesiosis	Lyme
Confirmed and probably cases	2	3	20
Rate (per 100,000 people)	11.5	17.2	115.0

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 (32).

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[38]. These changes will impact local agricultural activities as well as home gardeners.

Drought & Wildfires

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 4 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.
    - Since 2017 maximum monthly snowfall amounts recorded in West Kennebunk have declined steadily compared to the previous 2 decades.
- Communities supplied by groundwater wells, rivers, or smaller lakes are at greater risk of water quantity and quality impacts from drought.
    - In the last decade the Kennebunk, Kennebunkport, and Wells Water District (KKWWD), which manages Kennebunkport's public water supply, has experienced water quantity challenges due to increasing customer demand.
    - KKWWD now supplements the primary Branch Brook supply with several groundwater wells. These past challenges indicate potential vulnerability to lower water quantities during more frequent, prolonged, or intense droughts in the future.
    - There are 543 private wells in Kennebunkport and groundwater levels were historically low during the recent droughts.
    - During the 2020 and 2022 droughts, 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.

[38] 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.

- During the intense 1947 statewide drought, Kennebunkport suffered a devastating wildfire that burned over 200 homes and became known as the “Kennebunkport Fire”.
- Wildfire occurrences over the last several decades have been relatively low compared to the rest of the county, however more frequent, prolonged, or intense droughts in the future have the potential to increase wildfire risk in Kennebunkport, threatening public safety and the natural environment.

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.[39] 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.[40] 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.[41]

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.[42] 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 7). 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

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

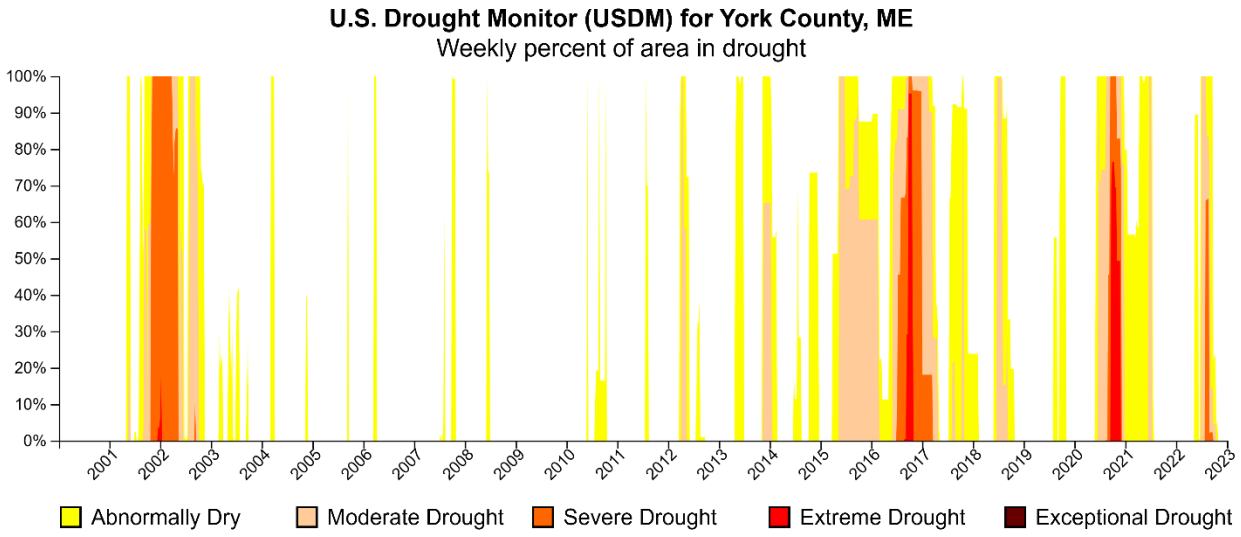


Figure 7. Drought conditions in York County from 2000 to 2022. Four severe to extreme droughts have occurred over the last 20 years and have been more frequent in the past decade. Data source: U.S Drought Monitor

As part of the Maine Cooperative Snow Survey, snowpack depth data have been collected at a survey site in West Kennebunk since 1950 and reported to the Maine Geological Survey. Due to a 14-year gap between 1975 and 1990, we have focused on data from 1990 to the present (Figure 8). In the past 30 years, March has generally been the snowiest month in this region. Between 1990 and 2000, snow depths were relatively low. Recorded snow depths were deepest between 2001 and 2008, and to a lesser extent between 2014 and 2017. In the last 5 years recorded snow depths have declined steadily compared to the previous 2 decades.

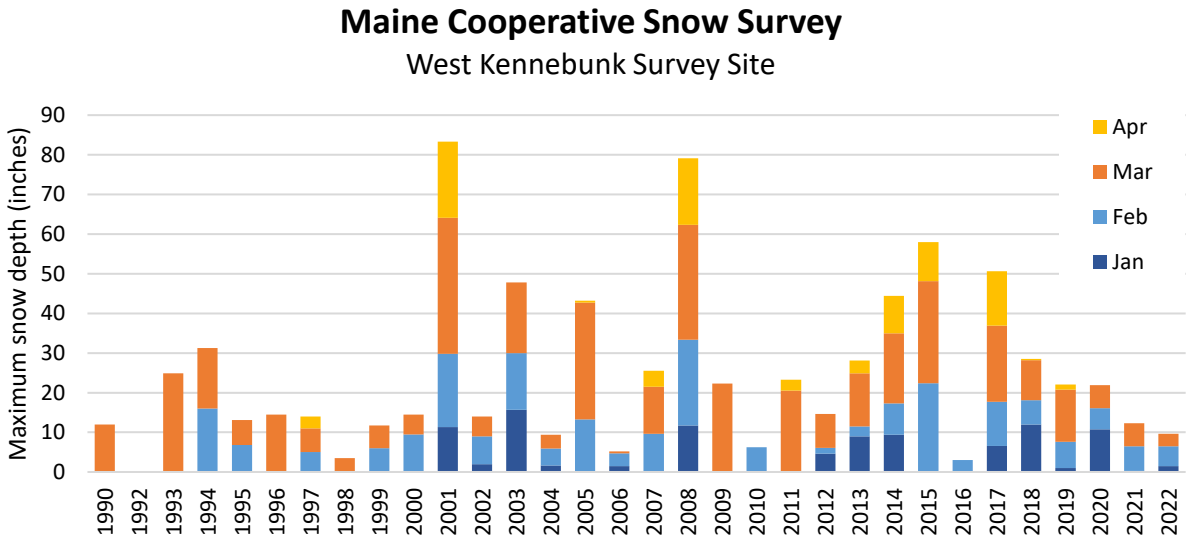


Figure 8. Maximum snow depth at West Kennebunk Survey Site, 1990-2022. Data source: Maine Geological Survey Cooperative Snow Survey

Combined snowfall amounts in Kennebunkport during the winters of 2020-21 and 2021-22 were about 2-4 feet less than the previous 30 years, based on data from the Maine Drought Task Force. The snowfall deficit over these two winters resulted in reduced spring snowpack depth and aquifer recharge and contributed to the emergence of a summer and fall drought in 2022.[43] 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

Intense and prolonged droughts have the potential to diminish surface and groundwater supplies and degrade water quality.[44] Communities supplied by groundwater wells, rivers, or smaller lakes are at greater risk of water quantity and quality impacts from drought.[45] The Town of Kennebunkport is serviced by the Kennebunk, Kennebunkport, and Wells Water District (KKWWD) and Brank Brook is the primary source of Kennebunkport's public water supply.

Water Quantity

Over the last couple of decades KKWWD has seen a substantial increase in customers' water demands, partly because of a large influx of seasonal residents in the summertime. Brank Brook alone cannot meet peak summer demand, so KKWWD supplements the Branch Brook supply using several ground water wells. The district also has an agreement with neighboring water utilities in Biddeford and York to purchases additional water supplies if necessary. In the future, more frequent, prolonged, or intense droughts have the potential to exacerbate KKWWD's existing water quantity issues. [46]

The United States Geological Survey (USGS) monitors daily streamflow conditions in Branch Brook. Since 2008, the lowest streamflows were recorded in September 2016, September 2020, and August 2022 coinciding with the three most prolonged and intense droughts in the region since 2008.

Groundwater supplies can also be impacted by drought. The USGS monitors groundwater levels in York County at an index well in Sanford (Figure 9). Since 2000, the lowest recorded ground water levels occurred in November 2002, October 2015, and October 2016 coinciding with the 2002 and 2016 severe droughts and the 2015 moderate drought. Groundwater levels were also low in October 2020, coinciding with the 2020 drought.

[43] ME Drought Task Force Report, 10/6/2022: https://www.maine.gov/mema/hazards/drought-task-force
[44] ME Climate Council, Maine Climate Science Update 2021: http://climatecouncil.maine.gov/reports
[45] Casco Bay Estuary Partnership, Climate Trends in Casco Bay, 2015: https://www.cascobayestuary.org/publication/climate-trends-in-the-casco-bay-region/
[46] Kennebunk, Kennebunkport, and Wells Water District: https://www.kkw.org/about-us-2

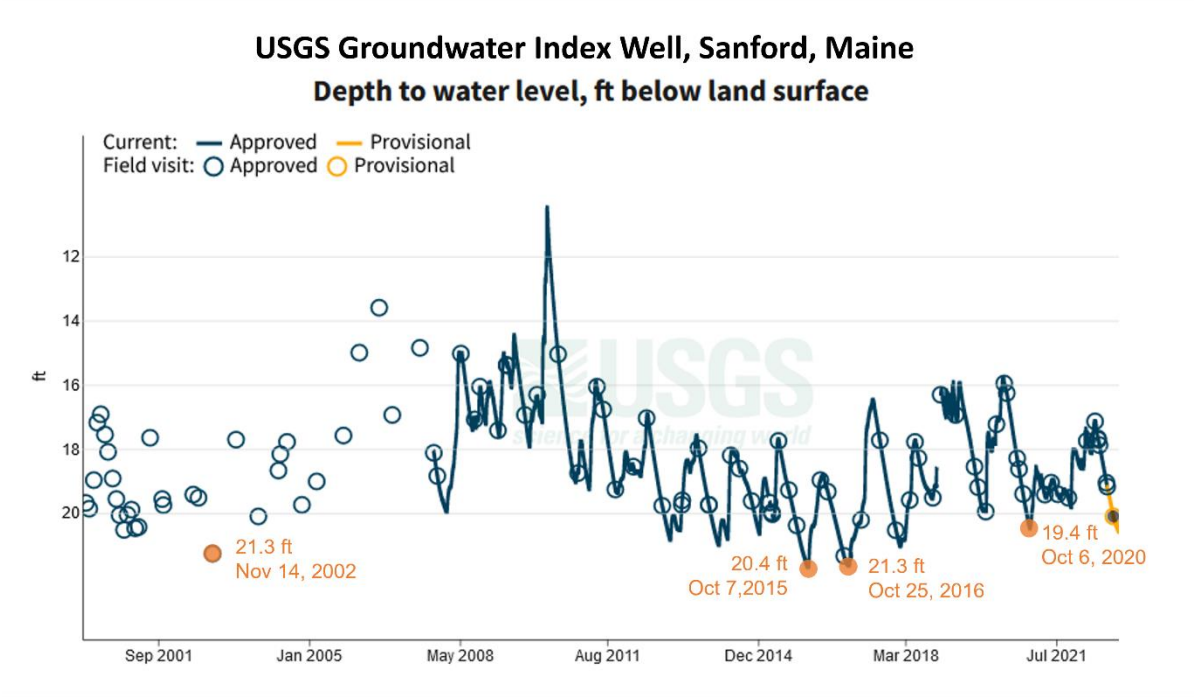


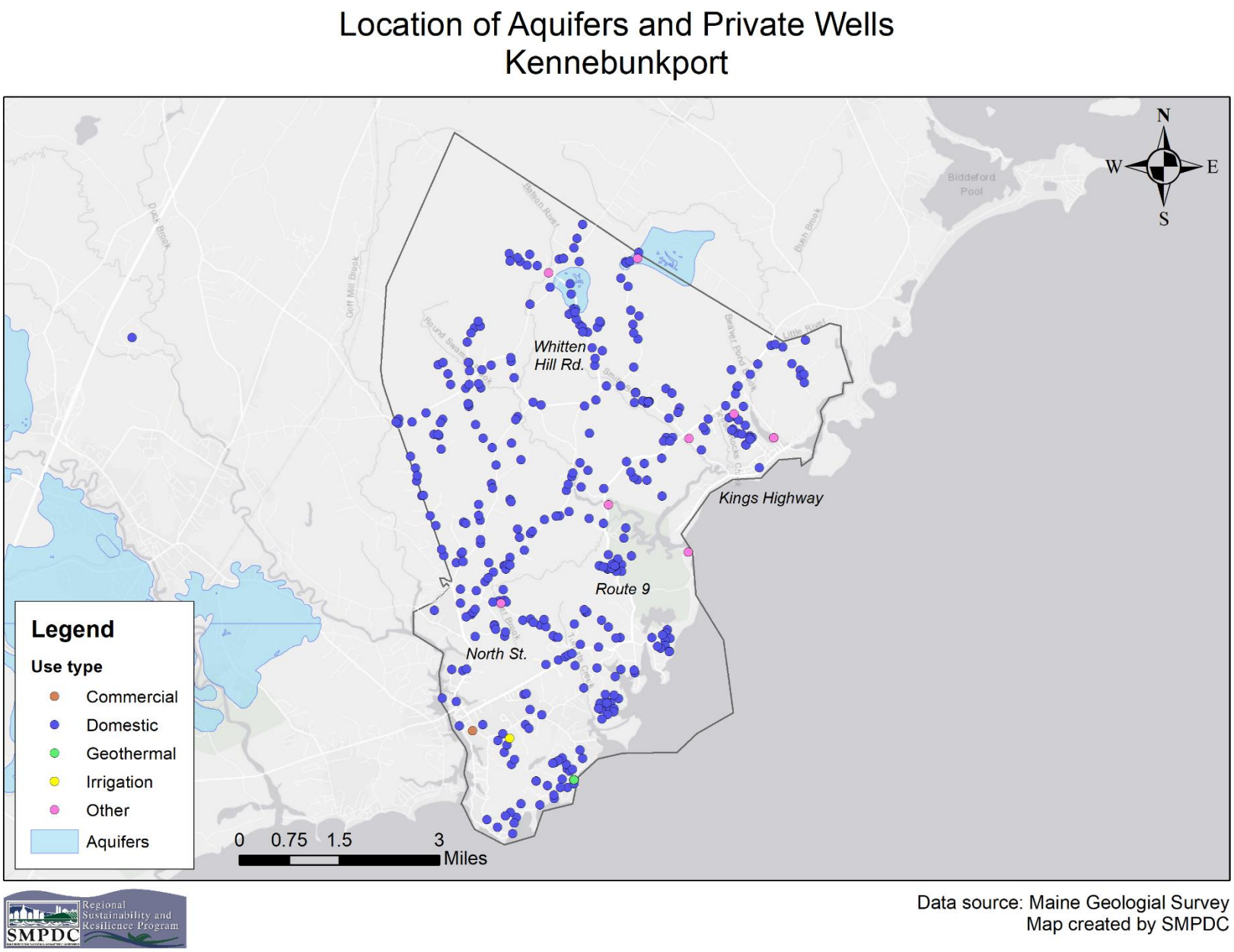
Figure 9. Groundwater levels in York County measured at an index well in Sanford, 2001-2021. Data source: United States Geological Survey

In addition to the groundwater wells that KKWWD uses to supplement surface water supplies from Branch Brook, there are a total of 543 private wells in Kennebunkport (385 wells have location data and are displayed in Map 19), and 83% of these wells are for domestic use.

Since 2020, the Maine Drought Task Force has collected data about wells that run dry due to drought (Table 10). In 2020, 45 wells in York County ran dry compared to 2 in 2021, and 15 in 2022. Though these data are limited, they correlate with the intensity of the 2020 drought compared to the 2022 drought. In the future, more frequent, prolonged, or intense droughts could pose a risk to KKWWD and the hundreds of homeowners and businesses in Kennebunkport who rely on groundwater wells as their water source.

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



Map 19. Location of aquifers and private wells in Kennebunkport, and well use type. Data source: Maine Geological Survey

Water Quality

To date, it does not appear that KKWWD has experienced significant water quality issues because of drought.[47] 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.[48] In the future, more frequent, prolonged, or intense droughts have the potential to cause similar types of issues in Branch Brook.

Impacts to the Natural Environment

The environmental impacts of drought include:

Table 11. Environmental impacts of drought. Data source: 2018 York County Hazard Mitigation Plan, Pennsylvania

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

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.[49] Kennebunkport suffered a devastating wildfire that burned over 200 homes and became known as the "Kennebunkport Fire".[50] 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 12).[51]

Table 12. Number of wildfires statewide 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

In Kennebunkport, wildfire occurrences over the last several decades have been relatively low compared to the rest of the county (Map 20), however more frequent, prolonged, or intense droughts in the future have the potential to increase wildfire risk in Kennebunkport, threatening public safety and the natural environment.

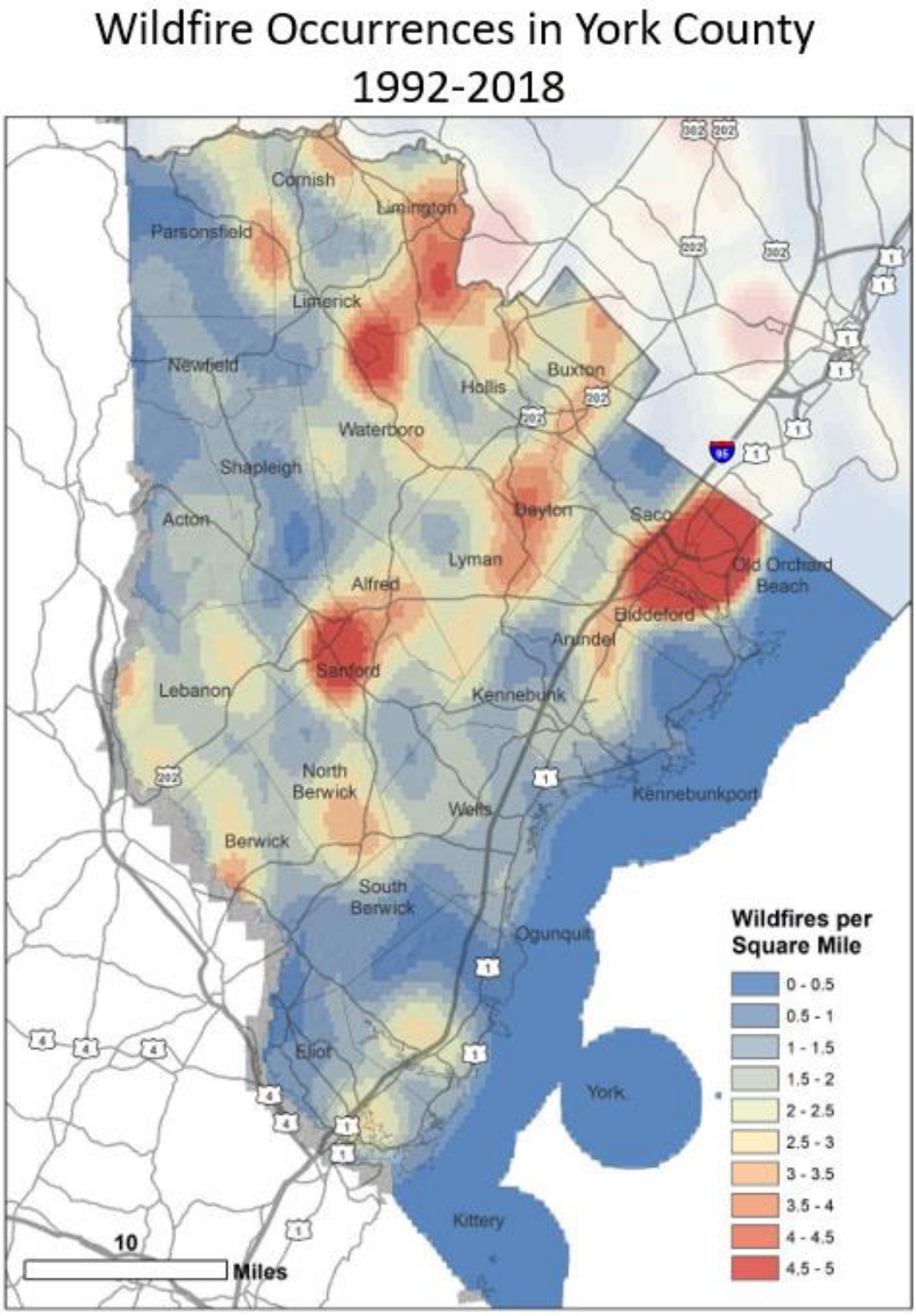
[47] EPA Safe Drinking Water Information System: https://ordspub.epa.gov/ords/sfdw_pub/r/sfdw/sdwis_fed_reports_public/11?ireq_pwsid=ME0090760&clear=11,RIR

[48] 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

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

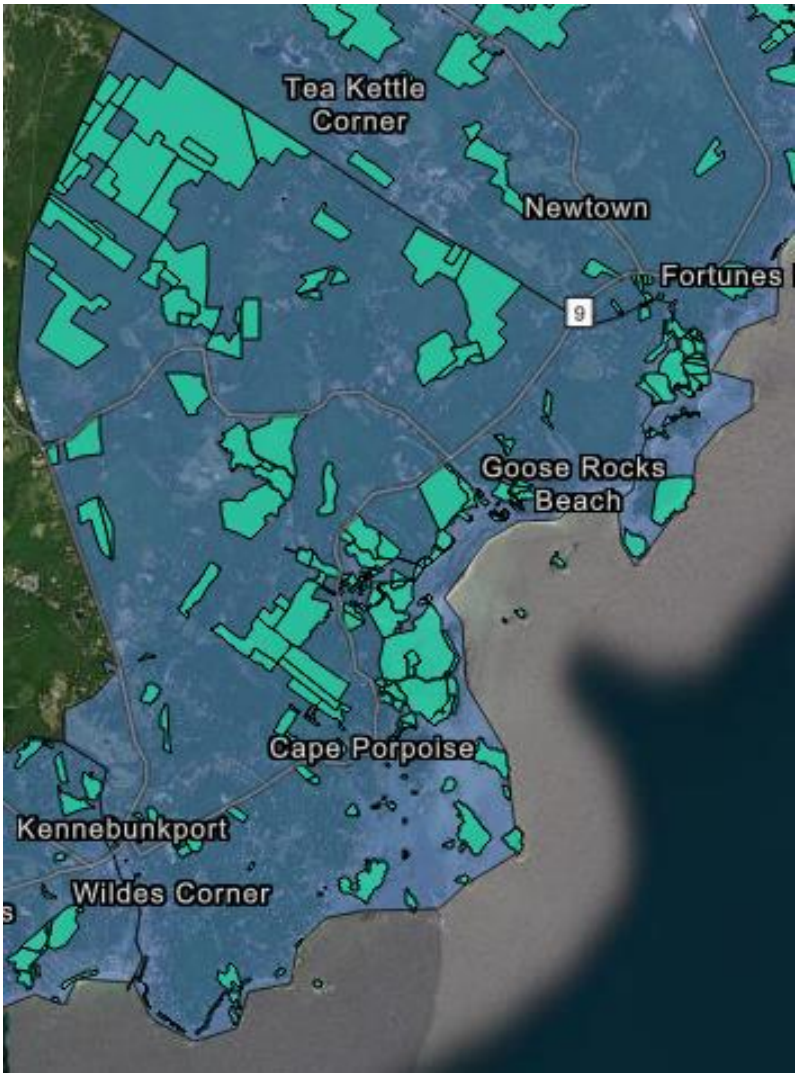
[50] Town of Kennebunkport: https://www.kennebunkportme.gov/fire-department/pages/1947-fire

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



Map 20. Wildfire occurrence in York County per square mile, 1992-2018. Data source: York County Emergency Management Agency, Hazard Mitigation Plan, 2022: https://www.yorkcountymaine.gov/emergency-management

The Maine Natural Areas Program inventories land parcels owned by federal, state, municipal, and non-profit entities that have conservation easements. Considering the small geographic size of Kennebunkport, there is a fair amount of conserved land within the town (Map 21). These conservation areas are primarily managed by the USFWS Racheal Carson National Wildlife Refuge, or the Kennebunkport Conservation Trust. The richest habitat areas are located in the National Wildlife Refuge and around Goose Rocks Beach. These habitats include tidal marshes, rare and endangered species habitat, sea and shorebird nesting areas, and tidal waterfowl habitat. Inland, the forest areas in the northwestern corner of Kennebunkport are conserved by the Kennebunkport Conservation Trust and have valuable rare and endangered species habitat and freshwater wetlands. In the future, more frequent, prolonged, or intense droughts have the potential to damage these critical habitat areas.



Map 21. Conserved lands in Kennebunkport 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.[52] In both 2020 and 2022 the Farm Services Administration issued emergency declarations for York County as a result of prolonged, severe drought conditions.[53] 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.[54]

Kennebunkport is known for its shipbuilding industry and the iconic Dock Square village, but the town has a rich agricultural heritage as well. A large portion of the northwestern corner of Kennebunkport is zoned for farm and forest (see Supplemental Community Information: Zoning Map 9). There are a handful of operating farms that grow fruits and vegetables, Christmas trees, and raise sheep. Neighboring Arundel has even more operating farms including dairy producers, organic fruit and vegetable growers, and more. 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 in Kennebunkport.

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. Ocean temperatures will likely rise 1.5°F by 2050, and Maine's marine ecosystem will resemble present day conditions in southern New England.
    - There are 53 commercial fishing licenses in Kennebunkport. 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.
    - The largest eelgrass beds in Kennebunkport are located off Goose Rocks Beach, Vaughn Island, and in Cleaves Cove.
    - Between 2010 and 2021, the extent and density of eelgrass habitat in Kennebunkport expanded and increased, potentially because of improved water quality due to better stormwater and wastewater management practices or a lack of invasive European green crabs.
    - 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.

[52] ME Drought Task Force Report, 8/4/2022: https://www.maine.gov/mema/hazards/drought-task-force
[53] Cumberland County Emergency Management Agency, Hazard Mitigation Plan, 2022: https://www.cumberlandcounty.org/231/Hazard-Mitigation
[54] 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.[55] 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, and tunicates have also proliferated 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.[56]

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.[57]

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 face 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 functions 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.[58]

Eelgrass habitat in southern Maine was most recently surveyed in 2021 by the Maine Department of Environmental Protection and was previously surveyed in 2010 by the Maine Department of Marine Resources. Based on these two surveys, there is eelgrass habitat along most of the Kennebunkport

[55] https://www.gmri.org/stories/gulf-of-maine-warming-update-summer-2021/
[56] University of Maine, Maine's Climate Future, 2020: https://climatechange.umaine.edu/climate-matters/maines-climate-future/
[57] ME Climate Council, Scientific Assessment of Climate Change and Its Effects in Maine, 2020: http://climatecouncil.maine.gov/reports
[58] Piscataqua Region Estuaries Partnership: https://prepestuaries.org/eelgrass/

coastline (Map 22). The largest eelgrass beds are located off Goose Rocks Beach, Vaughn Island, and in Cleaves Cove. Between 2010 and 2021, the extent and density of eelgrass habitat in Kennebunkport expanded and increased, especially along the southeastern coastline off Vaughn Island and in Cleaves Cove. These habitat shifts suggest that water quality may have improved over this time period, possibly as a result of better stormwater and wastewater management practices.

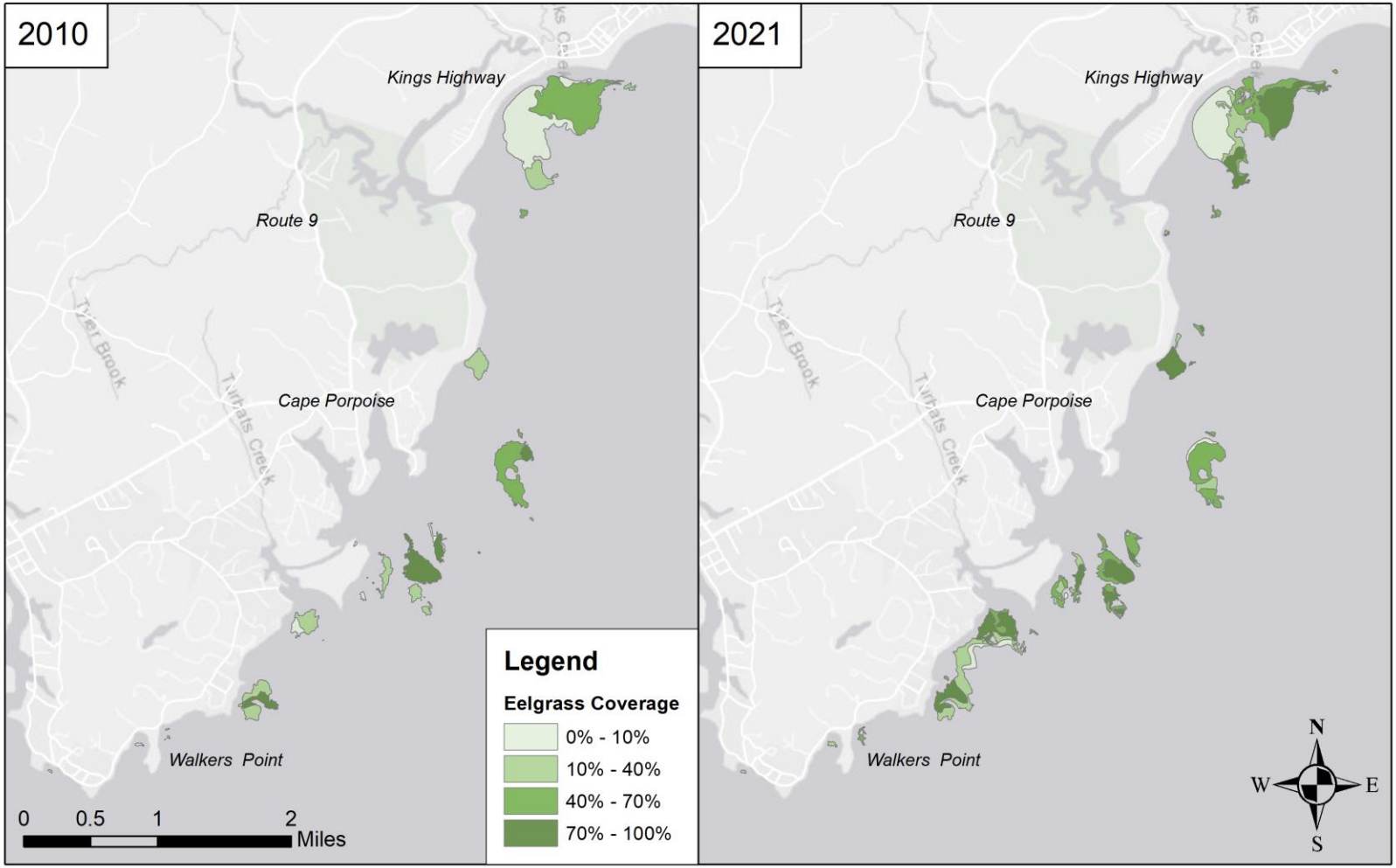
In addition to poor water quality, invasive European green crabs can destroy eelgrass habitat. Substantial eelgrass habitat losses were observed in Casco Bay between 2012 and 2013 coinciding with a rapid increase in the green crab population.[59] The status of the green crab population in southern Maine is not as well understood but these data suggest that green crabs may not have been as much of a problem in Kennebunkport as they have been in Casco Bay.

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 Kennebunkport's eelgrass beds. There is a high degree of impervious surfaces along the Goose Rocks Beach and Cleaves Cove (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.[60]

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 functions, but also for the climate mitigation and resilience benefits it provides. These ecosystem services emphasize the importance of protecting this vulnerable habitat.[61]

[59] 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
[60] ME Climate Council, Scientific Assessment of Climate Change and Its Effects in Maine, 2020: http://climatecouncil.maine.gov/reports
[61] ME Climate Council, Scientific Assessment of Climate Change and Its Effects in Maine, 2020: http://climatecouncil.maine.gov/reports

Eelgrass Coverage and Extent, 2010 and 2021
Kennebunkport



Regional Sustainability and Resilience Program
SMPDC

Data source: Maine Department of Marine Resources (2010),
Maine Department of Environmental Protection (2021)
Map created by SMPDC

Map 22. Distribution and coverage of eelgrass habitat in Kennebunkport in 2010 and 2021 based on surveys conducted by the Maine Department of Marine Resources and the Maine Department of Environmental Protection. These data indicate the location of potential carbon sinks as well as marine ecosystem shifts over time.

Economic Impacts

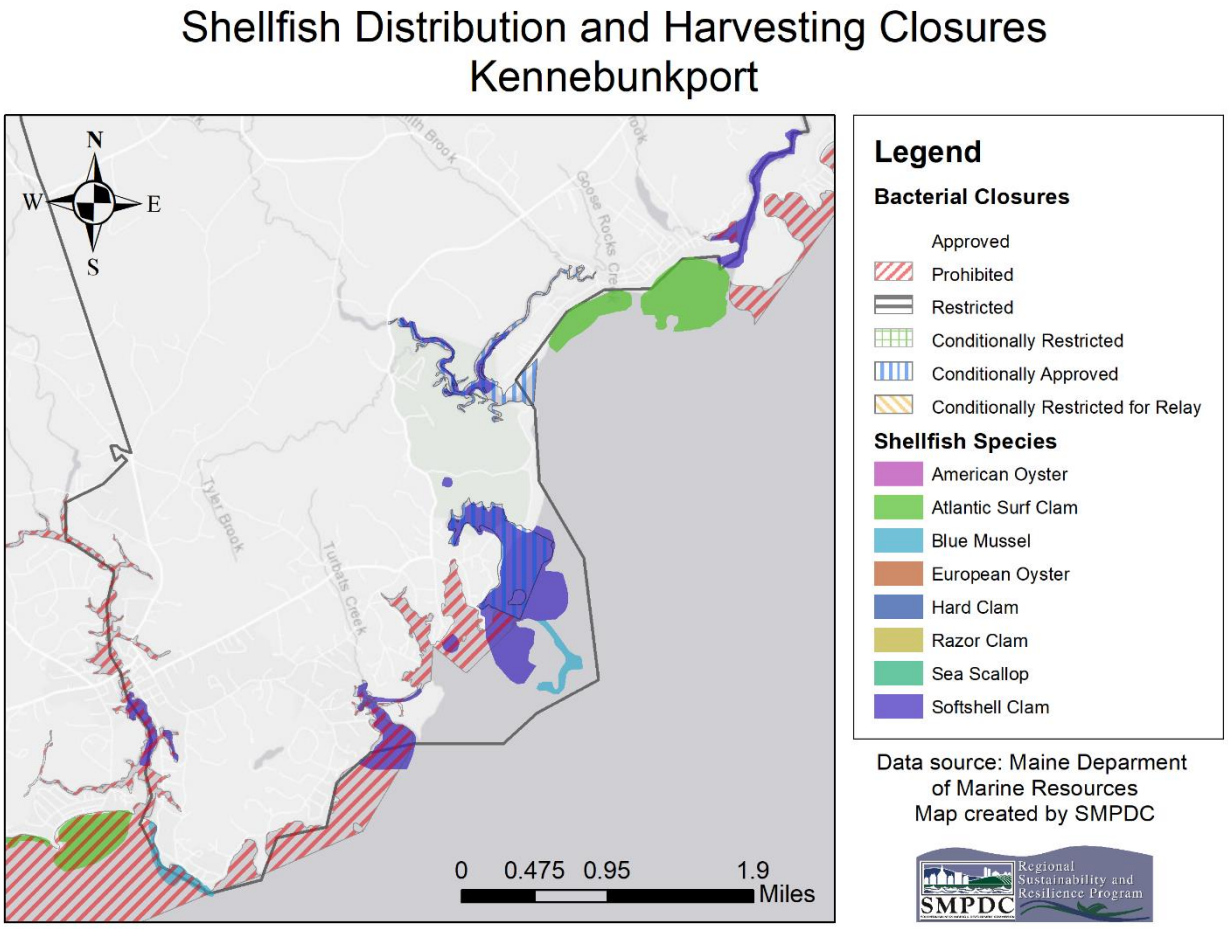
In 2022, there were a total of 53 commercial fishing licenses in Kennebunkport and 44 non-commercial licenses[62] (Table 13). The majority of these licenses are for harvesting lobster and crab, or fish. Individuals who rely on these fisheries for their livelihoods, especially lobster, may experience 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.

Table 13. Commercial and non-commercial fishing licenses in Kennebunkport. Data source: Maine Department of Marine Resources.

Commercial and Non-Commercial Fishing Licenses	
Commercial	**Number of Licenses**
Lobster/crab	30
Fishing	17
Menhaden	3
Shellfish	2
Sea urchin	1
Total	*53*
Non-Commercial	
Lobster/crab	24
Saltwater fishing	19
Menhaden	1
Total	*44*

In 2010, the Maine Department of Marine Resources (DMR) conducted a survey of shellfish habitat across the state (Map 23). Based on that survey, there are several pockets of softshell clams, blue mussels, and surf clams in Kennebunkport. Shellfish harvesting is prohibited along Kennebunkport's southern coastline because of poor water quality. Goose Rocks Beach is open for harvesting and Batson River and Sampson Cove are conditionally approved, which means DMR will allow harvesting under certain conditions. As a result, wild shellfish harvesting is limited in Kennebunkport and there are only 2 commercial license holders. 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.

[62] Maine Department of Marine Resources. 2022 fishing license data.



Map 23. Distribution of shellfish species based on a survey conducted by the Maine Department of Marine Resources in 2010. Areas that are prohibited or restricted for shellfish harvesting based on poor water quality from bacterial contamination are also indicated. Data source: 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 Kennebunkport with only one Limited Purpose Application License for growing oysters off Vaughn Island. There is one pending experimental lease application for a kelp farm approximately 3 miles offshore. Changing marine conditions have the potential to impact Kennebunkport's nascent aquaculture industry.