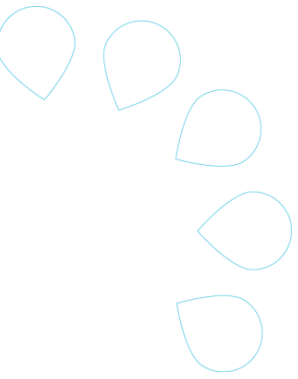




# Regional Climate Vulnerability Assessment

December 2022



# Table of Contents

<b>1. Executive Summary .....</b>	<b>4</b>	<b>5. Infrastructural Impacts and Vulnerabilities.....</b>	<b>42</b>
What’s Changing? Climate Projections.....	6	Transportation System .....	42
What’s at Risk? Key Vulnerabilities .....	7	Energy System .....	45
Foundation for Building Regional Resilience .....	11	Water and Wastewater Systems .....	48
<b>2. Methodology &amp; Tools .....</b>	<b>12</b>	Communications System .....	51
Assessment Methodology .....	12	Other Critical Facilities .....	53
Interactive Regional Map & Data Viewer.....	15	<b>6. Socioeconomic Impacts and Vulnerabilities.....</b>	<b>55</b>
<b>3. Climate Hazards .....</b>	<b>17</b>	Local Economy/Livelihoods .....	55
Future Climate Scenario.....	17	Education, Community, & Culture .....	58
Temperature.....	18	Health.....	60
Precipitation .....	21	Housing.....	64
Extreme Weather Events .....	25	Food Security .....	67
Sea Level Rise.....	27	<b>7. Additional Considerations .....</b>	<b>69</b>
Consideration of Disproportionate Impacts .....	28	Social Vulnerability .....	69
<b>4. Environmental Impacts and Vulnerabilities .....</b>	<b>30</b>	Land Cover.....	70
Waterbodies and Waterways .....	30	Resilient and Connected Lands.....	71
Wetlands .....	32	<b>Acknowledgements .....</b>	<b>72</b>
Forests and Trees .....	34	<b>Appendices .....</b>	<b>73</b>
Conservation Lands, Parks, Trails, and Recreation .....	37	Appendix A: GIS-based Asset Exposure Scores .....	73
Agriculture .....	39	Appendix B: Regional Map Data Layer Index.....	74
		Appendix C: Regional Stakeholder Interviews Summary ..	75



# 1. Executive Summary

Weather patterns and climate trends are changing, and they are predicted to continue to change through the end of the century and beyond. The impacts are being felt differently across Maine, prompting a need to understand how these changes in climate are affecting specific regions to inform local and regional decision making. This Climate Vulnerability Assessment was prepared for the communities of: Bangor, Orono, Brewer, Penobscot Indian Island, Veazie, Bradley, Hampden, Hermon, Milford, Old Town, and Orrington, as well as the University of Maine – the collective region spanned by these communities is referred to as the *Penobscot Climate Action Region* in this Assessment.

This Climate Vulnerability Assessment presents the current and future climate risks to the Penobscot Climate Action Region, and how those risks will affect the natural environment, infrastructure, and the community – livelihoods and wellbeing – including the most essential assets and systems. Additionally, this Assessment considers how climate risks will affect various populations with special attention to the most vulnerable people, such as older adults. The methods for this assessment included GIS-based mapping to screen for climate hazard exposures, a review of relevant reports and studies related to the region, its people, and assets, and use of local expertise and lived experience through a series of workshops and stakeholder interviews involving more than 50 people.

The information this report provides, along with a regional GHG inventory, forms the baseline assessment for the Region to conduct climate action and adaptation planning. Planning and action are vitally important for strengthening the Region and protecting lives and livelihoods – both in the short term and the long term. This information also allows the Region to take

advantage of opportunities, such as grants, that can bring about new strategies, initiatives, and programs to build resilience.

<b>Purpose of this Climate Vulnerability Assessment</b>	
<b>Identify</b>	<ul style="list-style-type: none"><li>• The most vulnerable people, assets, and systems in the region.</li></ul>
<b>Inform</b>	<ul style="list-style-type: none"><li>• Strategies in the Region’s Climate Action and Adaptation Plan.</li><li>• Prioritization of projects funded under federal and state infrastructure and resilience programs.</li><li>• Other local or regional policies, zoning, and plans.</li></ul>
<b>Educate</b>	<ul style="list-style-type: none"><li>• The community about regional vulnerabilities, especially social vulnerabilities, and environmental impacts related to climate change.</li></ul>





**Figure 1.1: Penobscot Climate Action Region**

This Climate Vulnerability Assessment was prepared for the communities of: Bangor, Orono, Brewer, Penobscot Indian Island, Veazie, Bradley, Hampden, Hermon, Milford, Old Town, and Orrington, as well as the University of Maine – the collective region spanned by these communities is referred to as the *Penobscot Climate Action Region*.

## What's Changing? Climate Projections



### Rising Temperatures

- Central Maine has warmed by over 3°F over the last century and the rate of warming has accelerated in recent decades. The northeast is warming faster than any other region in the U.S.
- Extreme heat is increasing. By late century, the Penobscot Climate Action Region could experience 3 weeks per year with days over 100°F. Developed areas, with lots of buildings and pavement, become “heat islands” and experience even higher temperatures.
- Warming causes seasonal shifts such as earlier ice out on lakes, warming waterbodies, less snow and more rain and ice in winter, and an expanded growing season.



### Extreme Precipitation and Inland Flooding

- Maine is receiving more rain, especially in the summer and early fall. Heavy storms of 2-4 inches are becoming more frequent. Since 2000, there have been 10-15 additional heavy rainstorms per year compared to the previous century.
- There is uncertainty around whether there will be more drought in Maine’s future; however, future droughts will be amplified by warmer temperatures and increased evaporation.
- Increases in intense, short-duration precipitation events create risk for more surface flooding or flash flooding events, especially in developed areas where infrastructure is not designed for these events or on dry soil which absorbs less water.



### More Frequent and Intense Storms

- Since the 1950’s, storm frequency and intensity has been increasing across the Northern Hemisphere, with changes observed mostly during the cold season. The trend is expected to continue for most extreme weather events, including nor’easters.



### Sea Level Rise

- As the earth warms and causes ocean expansion and glacier melt, Maine is projected to experience 3.9 to 8.8 feet of sea level rise by the year 2100. The Penobscot River is tidally influenced up to Bangor exposing parts of the region adjacent to the river to rising sea levels and corresponding storm surge.

## What's at Risk? Key Vulnerabilities

The following key vulnerabilities were identified across the multiple community systems assessed:

- Effects of flooding and extreme weather on transportation infrastructure and services
- Effects of heat on vulnerable groups, especially seniors
- Effects of heat and extreme weather on energy infrastructure
- Small business vulnerability and preparedness
- Threat of development pressure and climate migration on natural resources
- Effect of rising temperature on natural resources, especially trees and forests
- Cost of adaptation competing with other community needs



Low-lying road on Penobscot Indian Island. Photo: Matthew DeWitt

## Effects of Flooding and Extreme Weather on Transportation Infrastructure and Services

The Region's transportation infrastructure is aging and carrying significant deferred maintenance. Extreme precipitation events already cause detours and road and culvert washouts multiple times per year. Extreme weather events – including heavy rain, snow, and ice events - disrupt operations for Public, ADA, and medical transportation providers, including the Community Connector and Penquis.

Underlying some of these challenges is workforce capacity and the ability of small workforces to carryout planned transportation improvement projects and respond to significant fluctuations in demand whether that involves storm response or accommodating rescheduled trips when public transit operations resume. The transportation infrastructure underlies the rest of the Region's critical services including emergency response, access to jobs, school, and medical services, and the ability for businesses and farmers to receive supplies and deliver their goods to market.

As the intensity and frequency of extreme precipitation events and other storms increases, and the floodplain expands, this existing problem is going to get worse. There is a disproportionate impact on more vulnerable populations as lower income workers tend to hold jobs that cannot be done remotely. Seniors, people with disabilities, and people without access to a personal vehicle are more severely impacted when public transportation services become unavailable.

## Effects of Extreme Heat on Vulnerable Groups, Especially Seniors

Rising temperatures and extreme heat will be one of the most significant changes and challenges for residents of the region. Extreme heat increases incidents of heat-related illness and death, but also has numerous indirect effects such as lowering air quality on high heat days which exacerbates symptoms of asthma and other respiratory illnesses. Over the last 30 years, heat has been more deadly than any other weather-related event, including hurricanes, floods, and tornadoes.<sup>1</sup>

Individuals who work outdoors, people engaging in outdoor sports and recreation, and those who travel by public transit, biking, or walking are among those who will have greater exposure. Though not true for all, seniors tend to have multiple risk factors that contribute to heat vulnerability. Older people have less capacity to adapt to heat stress and may have underlying health conditions that are exacerbated by heat.<sup>2</sup> Residents may shelter-in-place on extreme heat days when being outside poses a health hazard; this could increase social isolation. On the other hand, seniors may need cooling centers if the temperatures in their homes become unsafe. Homes in New England (especially older homes) are designed to keep residents warm - not cool - with techniques that promote trapping heat, such as dark and steep roofs. Living on a fixed income can be prohibitive to completing energy retrofits or adding air conditioning to their homes (only about half of homes in Maine have air conditioning). They may not be physically able to install air conditioners alone. Even with air conditioning, electric bills for cooling in the summer can put a strain on one's ability to afford other essentials.

---

<sup>1</sup> Weather Related Fatality and Injury Statistics. National Weather Service. Retrieved October 27, 2022, from <https://www.weather.gov/hazstat/>.

## Effects of Heat and Extreme Weather on Energy Infrastructure

Gradual increases in temperature and an extended warm season are transforming energy demand in the Region. Buildings that once didn't require air conditioning, such as the Region's schools and older buildings across the UMaine campus, now require it. Residents, especially those most vulnerable to heat including the elderly, the very young, and individuals with chronic or mental illnesses, are finding they need air conditioning at home as well. Some parts of the region's grid, including in Orono, are already at capacity, which will pose challenges with increased loads and a societal shift to electrify buildings and transportation.

The increasing frequency and intensity of extreme storms exacerbates this vulnerability. A robust tree canopy is one of the region's assets, especially as it relates to protecting people and the environment in the face of rising temperatures; however, it is also a liability when located in the vicinity of vulnerable infrastructure.

<sup>2</sup> Heat Health Prevention Measures and Adaptation in Older Populations – A Systematic Review. Int J Environ Res Public Health. Retrieved December 6, 2022, from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6888447/>.



## Small Business Vulnerability and Preparedness

The majority of businesses in the region are considered small businesses and provide employment, goods, and services. Local small businesses are still recovering from the impacts of the COVID-19 pandemic including revenue loss from lower demand and increased operating expenses to implement public health and safety measures. Presently, businesses are responding to inflation and numerous supply chain disruptions, some of which can be tied to climate-related disasters in other parts of the world. These strains on human and financial resources can compete with small businesses' ability to prepare for climate change. The most commercially developed part of the area, downtown Bangor, is also one of the most vulnerable areas to flooding. And all parts of the region are vulnerable to localized flooding, short-term, long-term, or permanent closures from extreme storm events, rising operating costs as the global economy responds to climate-related disruptions, and gradual impacts – such as changes to the recreational economy.

## Potential Increase in Development Pressure and Climate Migration on Natural Resources

The Bangor metro area experienced a population decline of approximately 0.9% between 2010 and 2020.<sup>3</sup> However, Penobscot County and the state overall are expected to experience a net increase in population in the coming years.<sup>4</sup>

Further, inland Maine is often considered a likely destination for climate migration as people from other parts of the country experiencing sea-level rise, drought, and wildfires come and

<sup>3</sup> Bangor Metro Area Population (2022). <https://worldpopulationreview.com/us-cities/bangor-me-population>

<sup>4</sup> Maine State Economist (2018). Maine Population Outlook 2016-2026. <https://www.maine.gov/dafs/economist/sites/maine.gov.dafs.economist/file/s/inline-files/Maine%20Population%20Outlook%20to%202026.pdf>



Downtown Bangor business district. Photo: Matthew DeWitt

take advantage of a locale with robust natural resources, and since Maine's bitter cold winters will subside with rising temperatures.<sup>5</sup>

In addition to population growth and potential climate migration, housing affordability is a significant challenge in the region with more than 50% and sometimes more than 70% of households in a given community unable to afford the average

<sup>5</sup> UMaine School of Marine Sciences (2017).

<https://umaine.edu/marine/2017/09/18/climate-refugees-see-safety-maine-can-prepare-migration-triggered-extreme-weather/>; NPR (2022).

<https://www.mainepublic.org/environment-and-outdoors/2022-05-17/for-all-its-perils-climate-change-could-make-maines-frigid-interior-more-hospitable>

2-bedroom rent. Multiple regional stakeholders described homelessness as a growing issue in the region.<sup>6</sup>

Pressures to add housing to address both these trends could place a strain on the region's natural resources which provide substantial ecosystem service benefits (e.g. carbon sequestration, cooling, flood mitigation, and habitats) that support humans as well as biodiversity. Strategic and coordinated planning makes it possible to turn this threat into an opportunity for new development with multiple co-benefits including affordability, climate resilience, social connectedness, and minimal environmental impacts to preserve ecosystem services.

### Effect of Rising Temperatures on Natural Resources, especially Trees and Forests

Natural environments provide essential resources and services, such as habitats for native species, shade for residents, ambient cooling (especially on hot days), air filtration, water purification, water storage (flooding prevention), and carbon storage. Of particular concern are the effects of rising temperatures on trees and forests. About 50% of the Region's land cover is forest.<sup>7</sup>

Rising temperatures lead to decreased plant, tree, and animal health, resulting in a loss of – in both amount and quality – the services that trees and forests provide.

As such, the Region will have to contend with decreased canopy cover, increased erosion, flooding and runoff, heat, pollution in air and waters, and pests (such as bacteria, insects, and ticks) that harm the species that are intrinsically associated with Central and Northern Maine.

---

<sup>6</sup> Maine Housing (2020). Housing Facts and Affordability Index. [https://www.mainehousing.org/docs/default-source/policy-research/housing-facts/2020/rental/bangorlmental2020.pdf?sfvrsn=3a2b8e15\\_3](https://www.mainehousing.org/docs/default-source/policy-research/housing-facts/2020/rental/bangorlmental2020.pdf?sfvrsn=3a2b8e15_3)



DeMeritt Forest, University of Maine. Photo: University of Maine

These negative consequences will have both gradual and sudden impacts on economic sectors such as agriculture and recreation, and residents' ability to enjoy the benefits trees and forests provide. Stakeholder interviews revealed that the Region is known for outdoor recreation, and that the Bangor International Airport is *the* launch point for recreation in more northern parts of the state and continent. So, impacts to ecosystems in those areas will affect the Region, and vice

<sup>7</sup> Resolution Land Characteristics Consortium. (2019). NLCD Land Cover 2019 CONUS Land Cover. <https://www.mrlc.gov/viewer/>

versa. Lastly, rising winter temperatures can lead to a loss of snow cover and snowpack, with negative impacts for those who are associated with winter recreational activities, such as cross-county skiing.

### **Cost of Adaptation Competing with Other Community Needs**

Based on the key vulnerabilities described above, the Penobscot Climate Action Region's adaptation will include

- Public and private infrastructure investments as well as more frequent maintenance and replacement following damage or destruction left by an extreme weather event.
- Enhanced government planning, policy review, and coordination to prepare for and plan more resilient communities and infrastructure, and enhance the capacity to provide public safety, health, and other services to individuals vulnerable to weather extremes and damages; and
- Engagement, education, training, and coordination from a variety of regional stakeholders including businesses, non-profits, community-based organizations, and others to prepare for personal and community resilience, among others.

At the same time, the region is focused on needs to increase public transportation, support a growing senior population, address issues of housing affordability and homelessness, and more.

Throughout regional stakeholder interviews, community members expressed a concern that disaster response and increased recovery costs from more frequent extreme weather would detract from the Region's capacity – in both time and money – to achieve other priorities. A strategic and coordinated approach, that focuses on achieving multiple co-benefits, will be critical for enhancing regional resilience.

### **Foundation for Building Regional Resilience**

While the purpose of this assessment was to identify regional vulnerabilities, engagement with regional stakeholders provided insight into a strong foundation upon which the Penobscot Climate Action Region can further build resilience.

Recent weather extremes are creating an existing level of awareness of changing weather patterns and climate trends within the Region. Individuals, businesses, community organizations, and municipalities all discussed noticing changes such as more frequent heavy rainstorms and heatwaves, and a shift from snow to more ice and were able to describe how these changes impacted lives and livelihoods in the region. The Region's infrastructure is very old, more than 100 years old in many cases, and requires significant upgrades or replacement. Personal experiences of recent weather extremes help infrastructure owners understand what the impacts could be and how systems need to change and also create an understanding and urgency within the Region's population that change is necessary to protect lives and livelihoods.

Increasingly robust data and projections, from Maine's Climate Council, the Office of the State Climatologist, and other sources provide useful information and tools to support local and regional actions. These groups have also identified additional data and modeling priorities to develop in the coming years.

On an individual and collective level, planning and adaptation are already underway. For example, Northern Light Health, Bangor International Airport, the Bangor and Orono Land Trusts, and Eastern Maine Development Corporation are just some of the local stakeholders planning for resilience to extreme weather. These efforts, coupled with regional conveners like BACTS, and local expertise from the University of Maine, the Penobscot Indian Nation, and many others with lived experience, create a foundation for building resilience in the Penobscot Climate Action region.

## 2. Methodology & Tools

### Assessment Methodology

Climate Change Vulnerability is the propensity of a species, system or resource to be adversely impacted by climate change and other stressors.<sup>8</sup> Vulnerability is a combination of three factors:

- **Exposure:** the amount and rate of change that a system experiences from the impacts of climate change;
- **Sensitivity:** the degree to which a system will likely be affected by climate change; and
- **Adaptive capacity:** the ability to cope and persist under changing conditions.

This assessment utilized a hybrid quantitative and qualitative methodology that included the following steps:

#### 1. Identification of Hazards Likely to Impact the Region

Section 3 of this report “Climate Hazards” describes historical trends and future climate projections for changes in temperature, precipitation, extreme weather events, and sea level rise. Most commonly, climate change projections were available at 2050 (mid-century) and 2100 (late century), though some data sources provided projections at different or additional time horizons. To align with statewide efforts of the Maine Climate Council, *Maine’s Climate Future*<sup>9</sup> and the

<sup>8</sup> IPCC. (2022). Summary for Policymakers, p. 5.  
[https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC\\_AR6\\_WGII\\_SummaryForPolicymakers.pdf](https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryForPolicymakers.pdf)

<sup>9</sup> The University of Maine. (2020 & 2021). *Maine’s Climate Future*.  
<https://climatechange.umaine.edu/climate-matters/maines-climate-future/>

*Scientific Assessment of Climate Change and its Effects in Maine*<sup>10</sup> were the primary sources of information though additional local, state, national, and international sources were utilized to complement any gaps in available information. When sources were conflicting, the Maine sources were utilized.

#### 2. Selection of Assets and Systems

This assessment took a broad view of the Penobscot Climate Action Region’s environmental, infrastructural, and socioeconomic systems and their vulnerability to climate change. Each of these systems is detailed in Sections 4, 5, and 6 of this report.

To efficiently screen for vulnerability across this multi-jurisdictional, multi-system project, emphasis was placed on utilizing publicly available, geospatial asset information, to screen for climate hazard exposure. This included information on public roads and bridges, land cover types, schools, cellular towers, demographic information, and more. Asset and system GIS data were obtained primarily from project communities, the Maine GeoLibrary, and US Department of Homeland Security Cybersecurity and Infrastructure Agency. All GIS data was imported to the interactive regional map and data viewer available at: [www.penobscotclimateaction.org/regionalmap](http://www.penobscotclimateaction.org/regionalmap).

Some asset and system information does not lend itself to GIS mapping or was not readily available in a digital format. Plans, reports, and regional key stakeholder interviews provided supplemental information. This information is not included in the regional map but is included in the discussion in Sections 4, 5, and 6 and information sources are cited throughout the report.

<sup>10</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). *Scientific Assessment of Climate Change and its Effects in Maine*, [http://climatecouncil.maine.gov/future/sites/maine.gov.future/files/inline-files/GOPIF\\_STS\\_REPORT\\_092320.pdf](http://climatecouncil.maine.gov/future/sites/maine.gov.future/files/inline-files/GOPIF_STS_REPORT_092320.pdf)

### 3. Assessment of Exposure to Specific Hazards

Some hazard exposures are assumed to be experienced consistently throughout the Region and, in those cases, all assets in the region are considered “exposed.” For example, the entire Region is assumed to be exposed to extreme precipitation events and rising air temperature. In other cases, geospatial hazard data is available at sufficient resolution to identify differences in exposure among assets in the region.

Figure 2.1 describes which exposure variables were mapped and the corresponding scoring. All scores are available in Appendix A. Exposure can also be explored visually in the regional map and data viewer available at: [www.penobscotclimateaction.org/regionalmap](http://www.penobscotclimateaction.org/regionalmap).

**Figure 2.1: Mapped Exposures and Scoring**

Exposure & Data Source	Description
<p><b>Sea Level Rise/Storm Surge</b> Maine Geological Survey Sea Level Rise/Storm Surge Scenarios (2018)</p>	<p>Identifies assets that are in the approximate extent of inundation on the Maine coast after scenarios of 1.2, 1.6, 3.9, and 8.8 feet of potential sea level rise, or storm surge, on top of the Highest Astronomical Tide.</p> <p>Maine's Climate Council has recommended the following actions for Sea Level Rise</p> <ul style="list-style-type: none"> <li>• "Commit to Manage": 1.5 ft of SLR by 2050; 3.9 ft by 2100</li> <li>• "Prepare to Manage": 3.0 ft of SLR by 2050; 8.8 ft by 2100</li> </ul>
<p><b>Flooding</b> FEMA National Flood Hazard Layer <i>*includes preliminary data where effective FEMA FIRMS were not available digitally. More information at: <a href="https://www.fema.gov/flood-maps/national-flood-hazard-layer">https://www.fema.gov/flood-maps/national-flood-hazard-layer</a></i></p>	<p>Identifies assets in the 100 and 500 year flood plains. FEMA uses historical data to predict current flood risk and does not include future flood projections.</p> <p>This also identifies the asset's Flood Hazard Zone, if any. Zone definitions: <a href="https://www.fema.gov/glossary/flood-zones">https://www.fema.gov/glossary/flood-zones</a></p>
<p><b>Urban Heat Island</b> The Trust for Public Land (2019)</p>	<p>This shows where certain areas of cities are hotter than the average temperature for that same city as a whole. Severity is measured on a scale of 1 to 5, with 1 being a relatively mild heat area (slightly above the mean for the city), and 5 being a severe heat area (significantly above the mean for the city).</p>
<p><b>Land Cover Type</b> National Land Cover Database (2016)</p>	<p>Provides land cover type of each asset at a 30 meter resolution. All cover type definitions can be found at: <a href="https://www.mrlc.gov/data/legends/national-land-cover-database-class-legend-and-description">https://www.mrlc.gov/data/legends/national-land-cover-database-class-legend-and-description</a></p>
<p><b>Social Vulnerability</b> CDC Social Vulnerability Index (2020)</p>	<p>The CDC/ATSDR Social Vulnerability Index (CDC/ATSDR SVI) uses 15 U.S. census variables to help local officials identify communities that may need support before, during, or after disasters.</p> <p>Social vulnerability is scored from 0 to 1. A social vulnerability score of .5 is the US average. Those scoring 0 to .49 are considered to have less vulnerability (i.e., more resilient) than the US average. Those scoring above .5 are more vulnerable than the US average.</p>

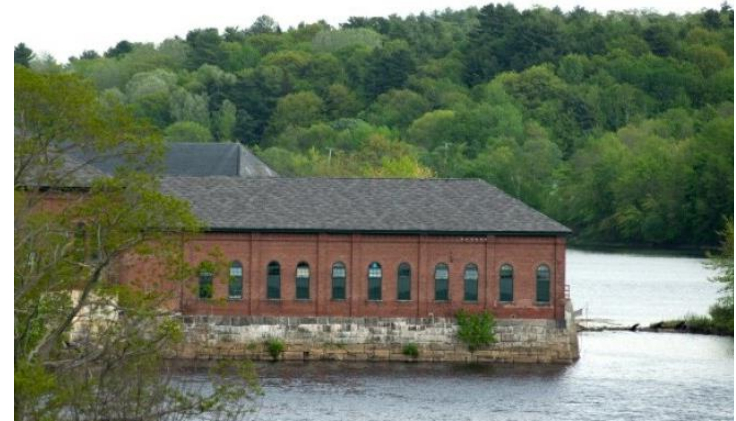
#### 4. Assess Sensitivity and Adaptive Capacity

Exposure alone doesn't signify vulnerability; the degree to which the asset or system is adversely affected by the hazard (sensitivity) and whether it is able to cope with or bounce back (adaptive capacity) are important to understand. Sensitivity and adaptive capacity were informed by reports, such as the *Scientific Assessment of Climate Change and its Effects in Maine (2020)* and the *Penobscot County Multijurisdictional Hazard Mitigation Plan (2021)* as well as local expertise and institutional knowledge provided through regional key stakeholder interviews. 16 interviews and one workshop, involving more than 50 people, were conducted for this assessment and included community residents, businesses, large landowners, public safety officials, infrastructure operators, municipal staff, and more. Interviewers presented preliminary climate projections and hazard exposures then sought to understand the most important assets (tangible or intangible) within an interviewees area of knowledge. Appendix C includes an example of an interview presentation and a summary of key takeaways from each interview.

#### 5. Screen for Vulnerability and Risk

To determine the top regional vulnerabilities and themes, exposure, sensitivity, and adaptive capacity were considered through the following lenses:

- Extent: Does the impact have a broad geographic or lengthy impact?
- Urgency: Is the impact already being felt or is the impact expected mid-century or sooner?
- Disproportionality: Is the impact greater on vulnerable populations?
- Existing Resilience: Is there existing resilience to withstand the impact?
- Community Priority: Have community members identified the system/asset/issue/impact a priority?



Bangor Waterworks Apartments on State Street on the edge of the Penobscot River. Photo: Linda Coan O'Kresik, BDN



Brewer Riverwalk. Photo: Matthew DeWitt

## Interactive Regional Map & Data Viewer

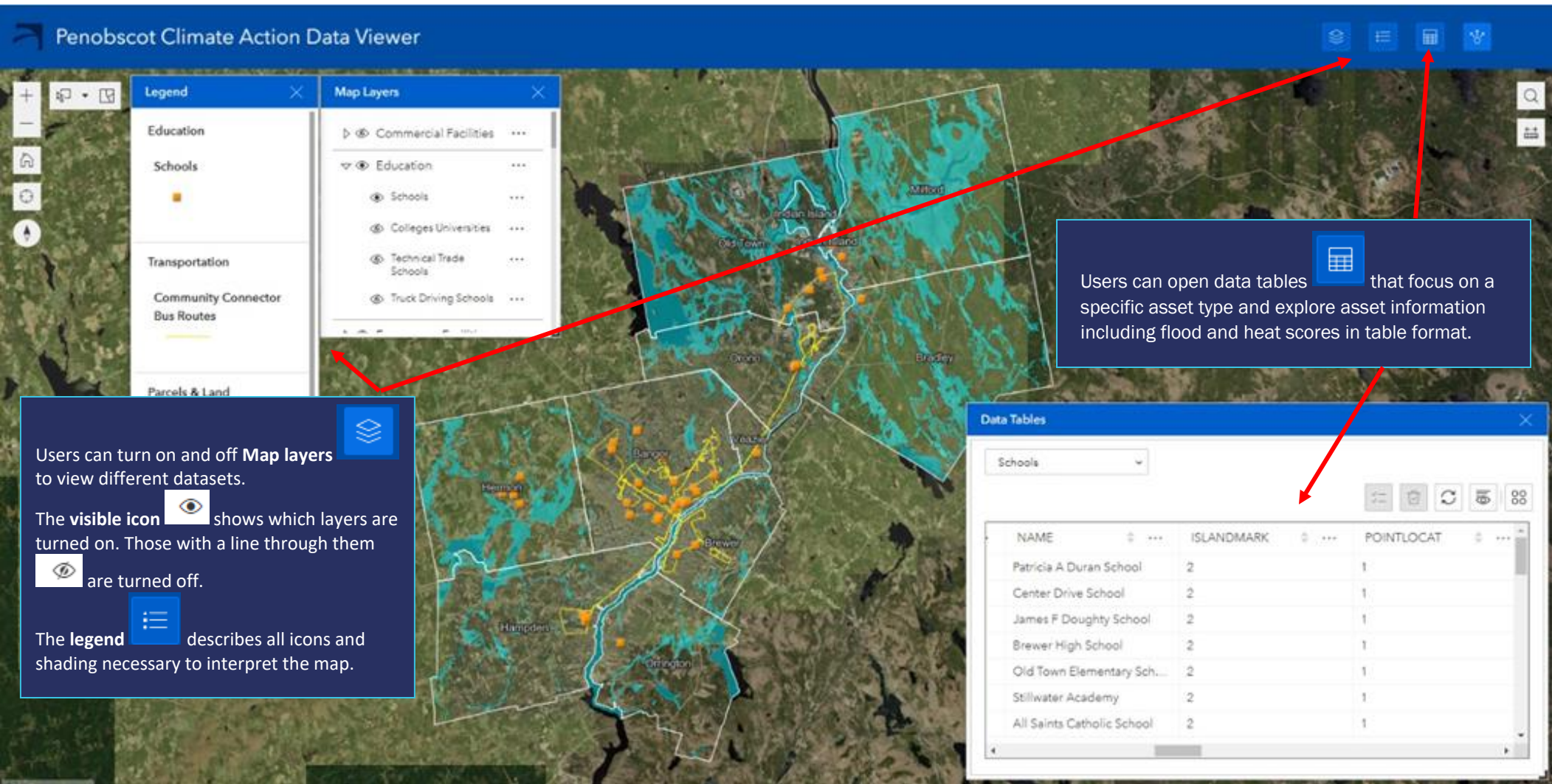
Sections 4, 5, and 6 discuss environmental, infrastructural, and socioeconomic impacts and vulnerabilities throughout the region. To keep this report focused and succinct, these sections discuss the most notable impacts, assets, people, and issues. While this report identifies top vulnerabilities and themes, the publicly accessible map and data viewer (see Figure 2.2) is an important, complementary tool that allows regional stakeholders to explore a variety of systems, climate hazards, and complementary data, such as social vulnerability or land resilience. It is the intent that this tool will allow a more granular exploration of the identified themes and also support future planning and assessments. The summaries of impacts and vulnerabilities throughout Sections 4, 5, and 6 include suggested map layers to further explore the topics being discussed.

The regional map and data viewer can be accessed at:

[www.penobscotclimateaction.org/regionalmap](http://www.penobscotclimateaction.org/regionalmap)

A video tutorial on using the key features of the map is available at: <https://www.penobscotclimateaction.org/data-viewer-tutorial>

Appendix B includes an index of all data layers available in the regional map.



Users can turn on and off **Map layers** to view different datasets.

The **visible icon** shows which layers are turned on. Those with a line through them are turned off.

The **legend** describes all icons and shading necessary to interpret the map.

Users can open data tables that focus on a specific asset type and explore asset information including flood and heat scores in table format.

**Figure 2.2: Regional Map and Data Viewer**

Image of the regional map showing public bus routes, schools, and the FEMA floodplain. The data viewer feature allows asset data to be viewed in table format which includes flood and heat exposure scores.



## 3. Climate Hazards

### Future Climate Scenario

Over the last century, Maine's average annual temperature has risen by 3.2°F and precipitation events of 4 inches or more occur three times as often. In 2020 and 2021, Maine recorded no less than nine records related to drought and heat. Supporting healthy communities and ecosystems and strengthening our infrastructure and economy requires that we anticipate and plan for these continued changes. While there is a high-level of confidence that changes in temperature, as well as more frequent extreme weather events and anomalies, will continue throughout this century and beyond,<sup>11</sup> there is more uncertainty about the specific projections due to the complexities of climate modeling and the amount of greenhouse gas humans will emit in the future.

Given this uncertainty, this report provides projections for both low and high-emission future climate scenarios to identify the range of likely future conditions. When thinking about how best to act upon this uncertainty, the Penobscot Climate Action Region can consider the approach at the state level where Maine's Climate Council recommends committing to manage for a low-emission scenario (higher probability/lower risk scenario) but also preparing to manage for the high-emission scenario (lower probability/higher risk scenario).<sup>12</sup>

<sup>11</sup> The University of Maine. (2020). Maine's Climate Future, p. 22



**Figure 3.1: Recent Climate Records for Maine**

Source: Maine Climate Science Update 2021

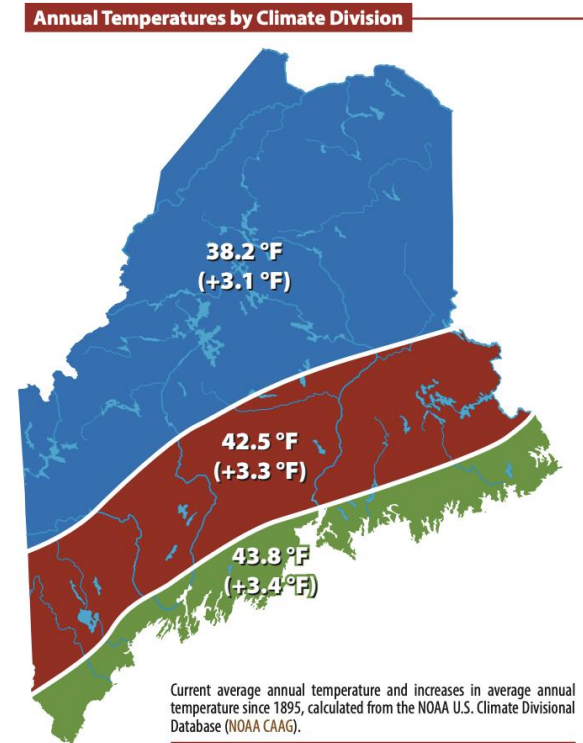
<sup>12</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 11

## Temperature

### Gradually Rising Temperatures and Extreme Heat

Maine's air temperature is warming, and the rate of warming has accelerated in the last few decades. Annual average (figure 3.2 in red) has increased by about 3.3 °F (1.8 °C) since 1895.<sup>13</sup> Continued warming is projected through the remainder of the century including an increase in more high heat days. By 2050, the Bangor area is projected to have more than 10 days per year with a heat index greater than 95 °F compared to 3 days at the beginning of this century.<sup>14</sup> **By late century (2085), if greenhouse gas emissions continue “business as usual,” the region could experience 3 weeks per year with temperatures 100 °F or greater and 11 days per year with temperatures 105 °F or greater (Figure 3.4).**<sup>15</sup>

People will experience even higher temperatures in heat islands, developed areas where buildings, roads, and other infrastructure absorb and re-emit heat more than naturalized landscapes like forests. Downtown Bangor and Brewer, as well as part of Hampden, Milford, Orono, and Old Town are identified as heat islands.



**Figure 3.2 - Average Annual Temperature Increases, Since 1895, by Climate Division**

Source: Maine Climate Science Update 2021

<sup>13</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 8

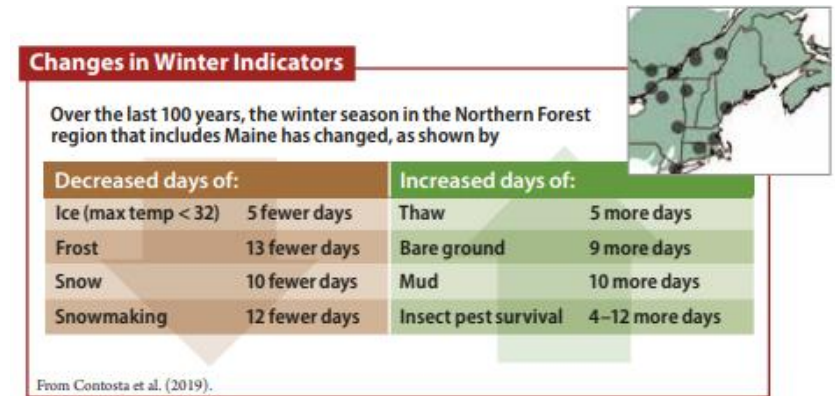
<sup>14</sup> The University of Maine. (2020). Maine's Climate Future, p. 25

<sup>15</sup> Climate Toolbox. (n.d.) Future Climate Dashboard. Retrieved October 20, 2022, from <https://climatetoolbox.org/tool/Future-Climate-Dashboard>

### Seasonal Shifts in Temperature

Winter is the fastest warming season in Maine.<sup>16</sup> By 2090, Penobscot County’s average winter high temperature is projected to be 31-35 °F compared to 24.7 °F historically (1961-1990) and winter average lows are expected to rise to 14.2-18 °F compared to 3.7 °F historically.<sup>17</sup>

Looking ahead, as the region becomes more likely to experience winter days above freezing, it may experience more winter precipitation as rain or mixed precipitation. **Maine’s Climate Future describes “winter weather whiplash” which references a trend of more rapid shifts from freezing to thawing conditions, heat waves and rain in the depths of winter, and cold or snow in the spring and fall when leaves are still on the trees.**<sup>18</sup>



**Figure 3.3 – Changes In Winter Indicators**

Source: Maine’s Climate Future – 2020 Update

**Figure 3.4 – Projected Heat Indices for Bangor, ME**

Days Heat Index	Historical Average	Projected		
	1990s	2025s	2055s	2085s
≥ 90 °F	5	12-14	21-31	27-54
≥ 100 °F	0	1	3-7	5-21
≥ 105 °F	0	0	1-3	2-11

Source: U.S. Federal Government, 2021: U.S. Climate Resilience Toolkit Climate Explorer

<sup>16</sup> The University of Maine. (2020). Maine’s Climate Future, p. 12

<sup>17</sup> U.S. Federal Government. (2021). U.S. Climate Resilience Toolkit Climate Explorer. Retrieved September 27, 2022 <https://crt-climate-explorer.nemac.org/>

<sup>18</sup> The University of Maine. (2020). Maine’s Climate Future, p. 9

## Cascading Effects of Rising Temperatures

- **More Intense Storms.** Warmer air holds more moisture. Higher moisture content in storms may be contributing to a slower decay of storms over land and slower movement over land. When storms travel over land further and slower, this increases their geographic impact and the amount of rain they can drop in a given region.<sup>19</sup>
- **Variability in Snowfall and Earlier Snowmelt.** Warming temperatures have led to more days of rain rather than snow, although there is much regional variability. Northern Maine has had some of the snowiest months on record in the past few years as a result of warmer air providing increased moisture for precipitation in the form of snow.<sup>20</sup>
- **Longer Growing Season.** As a result of warming, the growing season - which spans the period between the last frost and first frost - has increased by 16 days since 1950.<sup>21</sup> The growing season is expected to further increase by 2–3 days per decade.<sup>22</sup>
- **Warming Waterbodies.** Much like Maine’s air temperatures, the water temperatures of rivers, streams and lakes have been increasing over the last several decades. Maine lake surface temperatures have warmed on average by nearly 5.5°F (3°C) since the 1980s - with smaller lakes warming more rapidly than larger lakes.

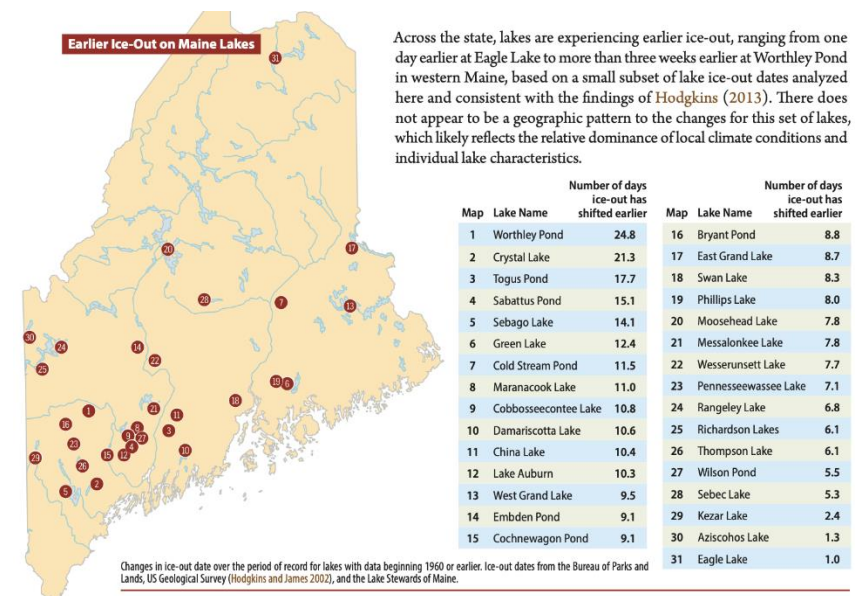
<sup>19</sup> Global Warming and Hurricanes: An Overview of Current Research Results. (2022, July 12). <https://www.gfdl.noaa.gov/global-warming-and-hurricanes/>

<sup>20</sup> The University of Maine. (2020). Maine’s Climate Future, p. 12

<sup>21</sup> The University of Maine. (2020). Maine’s Climate Future, p. 4

<sup>22</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 288

- **Less Ice.** Winter ice thickness in lakes and streams has been decreasing. Ice thickness is important to the water cycle, biodiversity, agriculture, recreation, and tourism.<sup>23</sup> Winter ice thickness of the Piscataquis River, a major tributary of the Penobscot River, has decreased by over 9 inches since 1912 (as measured around February 28 of each year).<sup>24</sup> Similarly, ice-out is occurring on Maine lakes 1-2 weeks earlier on average compared to around 1960.<sup>25</sup>



**Figure 3.5 – Earlier Ice-Out on Maine Lakes**

Source: Maine’s Climate Future – 2020 Update

<sup>23</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 40

<sup>24</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 40

<sup>25</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 25

## Precipitation

### More Precipitation and More Extreme Precipitation

Warming is causing Maine to become wetter overall, with statewide annual precipitation (rainfall and snowfall) increasing by 6 inches (15%) since 1895. Precipitation surpluses are mostly the result of increased rainfall in the summer and early fall.<sup>26</sup>

As temperatures rise, more water evaporates into the air; this moisture-laden air can produce more intense precipitation. Heavy precipitation in the northeastern U.S. has increased at a higher rate than any other region in the U.S.<sup>27</sup>

Heavy storms of 2 to 4 inches of precipitation are becoming more frequent in Maine, increasing the probability of floods that will erode infrastructure and degrade water quality in ponds, lakes, streams, rivers, and coastal areas.<sup>28</sup> **An analysis of daily precipitation data from Farmington, ME shows an increase in the overall frequency of extreme precipitation events since 2000, with 10-15 more events occurring per year compared to the previous century.**

Precipitation at Farmington, Maine

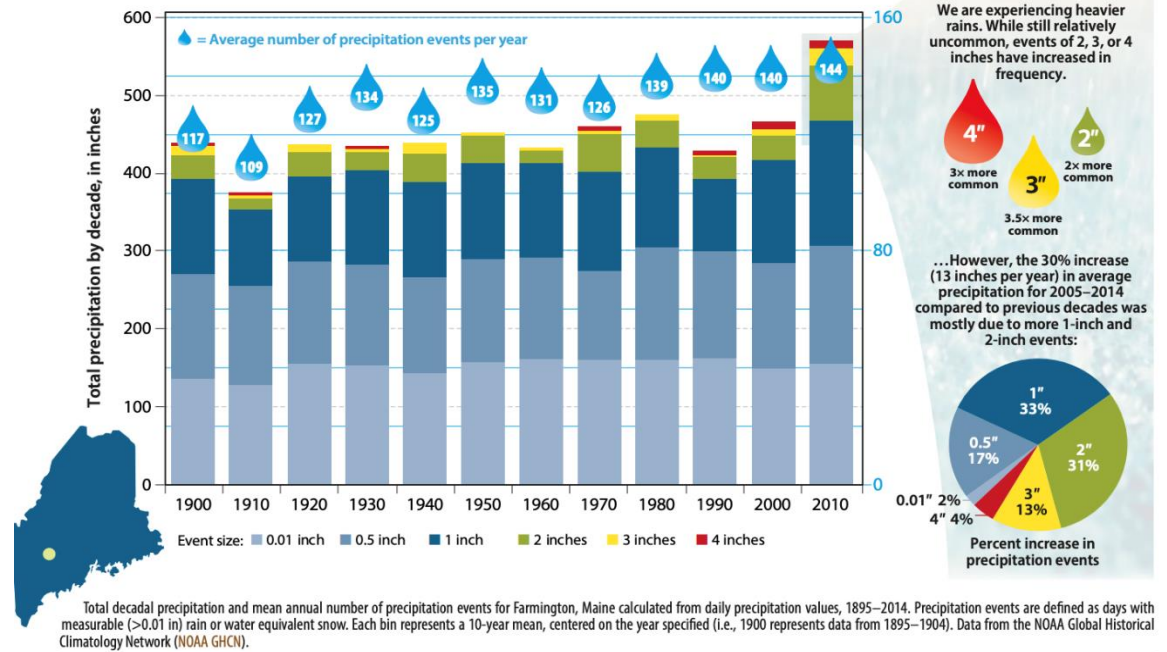


Figure 3.6 – Historical Precipitation Trends

Source: Maine's Climate Future – 2020 Update

Extreme rainfall increases the risk of flooding as it will likely result in greater runoff rather than an increase in soil moisture and groundwater recharge. However, much of the increase in precipitation has occurred in seasons outside of the primary flood season, when streamflow tends to be lower.

<sup>26</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 9

<sup>27</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 24

<sup>28</sup> Maine Climate Council. (2021). Maine Won't Wait, p. 8

## Riverine and Surface Water Flooding

Annual floods have increased in volume in Maine's rivers and streams during the last century with increases in precipitation. Decreases in winter snowpack, and seasonality of increased precipitation create uncertainty around future flooding and even suggest a potential decline in larger, less frequent floods, such as the 100-year (1% annual chance) flood.<sup>29</sup> However, increases in intense, short-duration precipitation events create risk for more surface flooding or flash flooding events, especially in developed areas where infrastructure is not designed for these events or on dry soil which absorbs less water.

### Flood Maps

FEMA Flood Insurance Rate Maps (FIRM) are the current standard for comparison of flood risk among properties. They designate flood hazard zones based on projected inundation from the 100-year (1% annual chance) and 500-year (0.2% annual chance) flooding events as predictors of current flood risks and do not incorporate future climatological changes. However, one assessment commissioned by FEMA reported that, in riverine environments, by the year 2100, the relative increase in the median estimates of the 1% annual chance floodplain depth and area is projected to average about 45% across the nation, though regional variability is expected.<sup>30</sup>

FIRMs also identify areas that are deemed moderate or low flood risk (Zones X, B, and C). While properties in these zones are not required to obtain flood insurance, historically, 20% of

flood insurance claims have been made from flood insurance holders within these lower risk areas.<sup>31</sup>

Detailed flood models and inundation maps for areas of recurring riverine flooding are not available in most parts of Maine; however, the Maine Climate Council's Scientific and Technical Subcommittee has identified their development as a priority need for the State.

First Street Foundation, a non-profit research and technology group, has modeled future flood risk and projections of the cost of annual flood damage for residential properties nationwide. First Street analyzed expected average annual loss for residential properties due to flooding in the years 2021 and 2051. **Three of the top ten municipalities in Maine with the greatest estimated increase in residential property loss were located in the Penobscot Climate Action Region (Old Town: 39.1% increase; Brewer: 9.8%; Bangor: 9.8%).**<sup>32</sup>

<sup>29</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 38

<sup>30</sup> Federal Insurance and Mitigation Administration and Federal Emergency Management Agency. (2013, June). The Impact of Climate Change and Population Growth on the National Flood Insurance Program. Climate Change Report, p. 6

<sup>31</sup> First Street Foundation. (2021). The cost of Climate Change: America's Growing Flood Risk, p. 25.

[https://assets.firststreet.org/uploads/2021/02/The\\_Cost\\_of\\_Climate\\_FSF20210219-1.pdf](https://assets.firststreet.org/uploads/2021/02/The_Cost_of_Climate_FSF20210219-1.pdf)

<sup>32</sup> First Street Foundation. (2021). The cost of Climate Change: America's Growing Flood Risk, p. 56.

[https://assets.firststreet.org/uploads/2021/02/The\\_Cost\\_of\\_Climate\\_FSF20210219-1.pdf](https://assets.firststreet.org/uploads/2021/02/The_Cost_of_Climate_FSF20210219-1.pdf)

## Drought

There has not been an observed increase in meteorological drought occurrence across Maine over the past century and there is notable uncertainty around whether there will be more drought in Maine's future;<sup>33</sup> however, Maine's States at Risk report projects a 70% increase in the risk of widespread drought by 2050.<sup>34</sup>

What is known is that future periods of decreased moisture (including droughts) will be amplified by increased average temperatures since increased evaporation will dry surface soil layers, particularly in the warm season.<sup>35</sup>

One climate modeling study assessed the 1960s Northeastern US drought, the most severe in the last century, under a future high-emissions scenario. **The simulations also showed an increase in extremes: wet months become wetter and dry months become drier, with increasingly rapid transitions from wet to dry conditions posing water management challenges.**<sup>36</sup>

## NOTABLE MAINE DROUGHTS

- **1940s** – This drought was the main contributor to wildfires in 1947 that burned over 250,000 acres of forest and destroyed over 850 homes across nine Maine communities (Maine Historical Society).
- **1960s** - A protracted drought that stands as the drought of record in Maine (and the northeastern U.S. generally) in terms of its overall duration and accumulated precipitation deficits (Seager et al. 2012; Lyon et al. 2005; Leathers et al. 2000).
- **1999 – 2002** – This protracted drought brought major impacts to the agriculture, water resources, and forestry (Kasson and Livingston 2012) sectors.
- **2016** - Above-average temperatures played a role in the development and severity of this short-lived but high impact drought in Maine. Across the Northeast winter snowpack was reduced, spring runoff peaked earlier than average and high summer temperatures likely contributed to increased evaporative water loss (Sweet et al. 2017).

<sup>33</sup> The University of Maine. (2020). Maine's Climate Future, p. 11

<sup>34</sup> States of Risk. (2016, October 27). Maine's Drought Threat. Maine Drought. Retrieved October 20, 2022, from <https://statesatrisk.org/maine/drought>

<sup>35</sup> Penobscot County Emergency Management Agency. (2021). Penobscot County Multi-Jurisdictional Hazard Mitigation Plan Section IV-Risk Assessment, p. 11

<sup>36</sup> Xue, Z., & Ullrich, P. (2021). A Retrospective and Prospective Examination of the 1960s U.S. Northeast Drought. *Earth's Future*, p. 1. <https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020EF001930>



Wildfire in Island Falls  
(Aroostook County), ME.  
Photo: Maine Forest Rangers

## Wildfires

Wildfires are historically rare in Maine.<sup>37</sup> According to the Maine Forest Service, more than 90% of wildfires in Maine are started by human activity (burn piles, campfires, sparks from machinery, etc.). While numerous factors contribute to fire risk, higher temperatures – which support drought and lightning strikes – suggest overall increased fire risk.<sup>38</sup> Warmer temperatures will also more quickly dry out fuels and increase fire risk probabilities.

Historically, wildfires in Penobscot County have been relatively small in size and have not spread over significant acreage. From 2011-2014, for example, 258 forest fires occurred county-wide but burned only 161.7 acres of forest.<sup>39</sup> **Despite the uncertainty of future wildfire occurrence, attention should be paid to the risks wildfires present due to the large number of homes in Maine in close proximity to forests, a lack of firefighting infrastructure to respond to wildfires compared to more fire prone states, and the potential effects on air quality and carbon emissions associated with wildfires.**<sup>40</sup>

<sup>37</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 304

<sup>38</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 237

<sup>39</sup> Penobscot County Emergency Management Agency. (2021). Penobscot County Multi-Jurisdictional Hazard Mitigation Plan Section IV-Risk Assessment, p. 36

<sup>40</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, pp. 237-238



## Extreme Weather Events

*"Children born in 2020 will experience a two- to seven-fold increase in exposure to extreme events and heat waves in the world they will live in compared to people born in 1960, even accounting for current climate pledges for reductions in greenhouse gas emissions."*

*Maine Climate Science Update 2021*

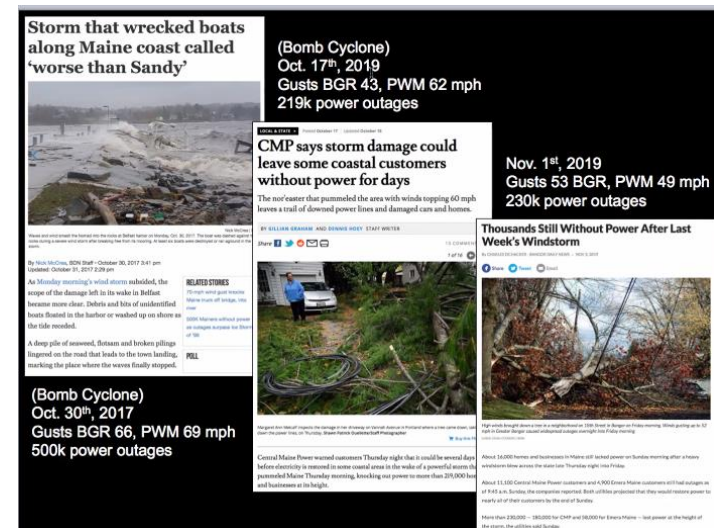
Since the 1950's, storm frequency and intensity have been increasing across the Northern Hemisphere, with changes observed mostly during the cold season. The trend is expected to continue for most extreme weather events, including nor'easters. Some events, such as ice storms and windstorms, are more difficult to predict, but may also become more frequent and intense as a result of warming conditions.<sup>41</sup>

<sup>41</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 12

## Severe Wind and Summer Storms

Maine has experienced some significant windstorms in recent years, most notably in October 2017, October 2019, and November 2019: events which produced hurricane-strength winds (over 70 mph in some places during the 2017 storm) and left hundreds of thousands of Mainers without power.

Historical records suggest that Penobscot County should expect severe thunderstorms every summer, some of which will include damaging wind gusts and hail.



News coverage of recent severe windstorm events in Maine.  
Courtesy of Dr. Sean Birkell, University of Maine

## Severe Winter Storms

All of Penobscot County is subject to periodic winter storms which are known to damage roadways and utilities in particular: areas north of Howland usually receive heavier snowfall during winter storm events, while the southern zone is more likely to receive mixed precipitation including freezing rain and sleet. Each year, there is a high probability that the County will experience storms between November and April.<sup>42</sup>

Historically, nor'easters – coastal storms associated with extreme precipitation, strong winds, and flooding, that occur between September and April – have caused more harm and damage than any other type of extreme event in Maine.<sup>43</sup> When nor'easters move inland and are fueled by southeasterly winds, they can be referred to as southeasters.<sup>44</sup>

Bangor is susceptible to storm surges resulting from southeasters, which pile water up into the enclosed Penobscot Bay and up the Penobscot River. This was especially evidenced by the Groundhog Day Storm of February 2, 1976, which led to significant flooding in areas of downtown Bangor.<sup>45</sup> Tidal surge up the Penobscot River can be significant in comparison to other locations because of local geographic conditions.

Other types of storms have also caused significant harm and damage in recent years include ice storms. Ice storms in 1998, 2008, and 2013 caused significant damage in Maine. The 1998 storm left over half of Mainers without power - some for two to three weeks - and resulted in at least five fatalities from falling trees or ice, hypothermia, or carbon monoxide exposure (as well as more than 200 carbon monoxide poisonings).

<sup>42</sup> Penobscot County Emergency Management Agency. (2021). Penobscot County Multi-Jurisdictional Hazard Mitigation Plan Section IV-Risk Assessment, p 32

<sup>43</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 34

<sup>44</sup> Epstein, D. (2022, January 14). A bitterly cold and windy weekend is ahead. Boston.com. Retrieved October 19, 2022, from



FIGURE 8.—Floodwaters at highest point, Kerdushong Plaza, Bangor, Maine. This photograph (Bangor Daily News, 1976) shows the depth and area of the downtown flood. The normal channel of the Kerdushong is between the two light poles on the left, and footbridge guardrails are shown insulated near the center of the photograph. The normal flow is from right to left. Photograph courtesy of Bangor Daily News.



FIGURE 9.—Strong currents hampering rescue attempts, Kerdushong Plaza, Bangor, Maine (Bangor Daily News, 1976). In the center of this photograph, a young woman stranded in her car is being rescued. At this location Kerdushong Stream is channeled between parking areas on both banks. The stream normally flows between the guardrails in a left-to-right direction. Photograph courtesy of Bangor Daily News.

Photos of Groundhog Day Storm of 1976 in Downtown Bangor. Source: National Weather Service

<https://www.boston.com/news/weather/2022/01/14/a-bitterly-cold-and-windy-weekend-is-ahead/>

<sup>45</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 84

## Sea Level Rise

### Historical Trends

The Gulf of Maine is especially susceptible to changes in sea level because of changes in the strength of the Gulf Stream, which carries warm water from the Gulf of Mexico to the Gulf of Maine. In fact, from 2004 to 2016, the Gulf of Maine warmed faster than 99% of the global ocean. Sea level has risen 0.07 in. per year in the past century, but the rate has increased to about 0.12 in. per year since 1990.<sup>46</sup>

### Projections

Under a high-emission scenario, Maine is projected to experience 2-3 feet of sea level rise by 2050 and 8-11 feet by 2100. Under a moderate-emission scenario, Maine experiences at least 1 foot of sea level rise by 2050 and between 3.6 and 6.5 feet by 2100.<sup>47</sup> Given these scenarios, the Scientific and Technical Subcommittee has advised the State’s Climate Council to consider “committing 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... [and] consider preparing to manage for 3.0 feet of relative sea level rise by 2050, and 8.8 feet of sea level rise by the year 2100.” Figure 3.7 estimates static inundation of the existing land surface at higher sea and tide levels in each Maine county. For every foot of sea level rise, approximately 7,400 acres (11.6 square miles) of upland become tidal.<sup>48</sup>

### Tidal Surge

Tidal surge up the Penobscot River can be relatively significant because of local geography, bathymetry, and tide-surge-river interaction in the Penobscot Bay estuary. The section of the

<sup>46</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 12

<sup>47</sup> The University of Maine. (2020). Maine’s Climate Future, p. 29

Penobscot River which is downstream of Bangor is influenced by ocean tides.

### Nuisance Flooding

Flooding resulting from high tides rather than precipitation or storms is known as “sunny day” flooding or “nuisance” flooding. Each 1-foot increase in sea level is predicted to lead to a 5-fold increase in the frequency of “nuisance” flooding. A 1-foot increase in sea level, which could occur by 2050, would cause a “100-year storm” flood level to have a probability of occurring once in every 10 years. Not accounting for changes in storm intensity or frequency, this would result in a 10-fold increase in coastal flooding in Maine in the next 30 years.<sup>49</sup>

**Figure 3.7: Estimated Future Inundation Area due to Sea Level Rise**

County	Sea Level Rise Scenario*					
	1.2 ft	1.6 ft	3.9 ft	6.1 ft	8.8 ft	10.9 ft
York	1,195	1,604	4,011	6,097	8,627	10,821
Cumberland	1,127	1,501	3,758	5,917	8,255	10,889
Sagadahoc	1,435	1,870	4,286	5,874	7,425	8,979
Kennebec	112	202	611	848	1,115	1,290
Lincoln	621	854	2,122	3,403	4,911	6,508
Knox	754	1,018	2,788	4,764	6,841	9,242
Waldo	317	375	669	974	1,253	1,819
Penobscot	27	36	103	181	281	364
Hancock	1,517	2,002	5,152	8,127	11,687	15,721
Washington	1,390	1,933	5,191	8,529	12,764	16,948
<b>Maine Total</b>	<b>8,494</b>	<b>11,394</b>	<b>28,690</b>	<b>44,715</b>	<b>63,157</b>	<b>82,580</b>

*Scenarios are 50% Probability Estimates from Sweet et al. (2017) for low to extreme scenarios*

*Inundation area rounded to nearest acre*

Table 10. This table shows the area of current upland (in acres) that may become inundated during the highest tides under different sea-level rise scenarios in each of the 10 coastal counties in Maine. For reference, there are 640 acres per square mile. Analysis by H. Corney, MGS and rounded to the nearest acre.

<sup>48</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 91

<sup>49</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 12

## Consideration of Disproportionate Impacts

Climate change is an inherently social issue. Extreme weather, rising temperatures, and increased flooding will disrupt everyone's lives. However, the impact of climate change will not be felt by everyone the same way. Socially vulnerable groups – particularly low-income communities, people of color (POC), Indigenous people, people with disabilities, physically isolated communities, and the elderly – are less able to prepare for, withstand, and recover from a climate related disaster.

It is important to note that socially vulnerable groups are not inherently victims of climate disaster. Systemic inequities shape vulnerability to climate change. Vulnerability is a result of historic and current patterns of systemic discrimination and marginalization that shape certain people's access to opportunity, power, and resources. Further, just as systemic inequities shape vulnerability to climate change, climate change impacts exacerbate social inequity. Equitable mitigation and adaptation efforts reduce the vulnerability that people experience because of systematic social or economic marginalization. Climate vulnerabilities are impacted by:

- **Economic disparities:** Low-income people and people living in poverty are less able to prepare for, respond to, or recover from extreme weather events. Residents with limited disposable income are unable to spend money on mitigation efforts like flood insurance and building retrofits. In the event of a storm that causes power loss, people who can't afford hotels, generators, or additional utility costs will be more impacted. Additionally, people facing financial barriers to recovery might also face racial or socio-economic discrimination if they need to find alternative accommodations or relocate during or after a

storm.

Mainers who live in rural areas, are working class, are Black, people of color, Indigenous, recent immigrants, or have a disability, are more likely to live in poverty or lack access to necessary resources. Mainers who have racialized identities, are Indigenous, or represent tribal populations typically experience unemployment and poverty twice the rate of white Mainers. Additionally, 14.8% of Mainers live in poverty, including 1 in every 5 children; 50% of black and African Americans; and one-third of Maine's Native Americans.<sup>50</sup>

- **Environmental disparities:** Rural areas tend to have less access to food, education, quality infrastructure, transportation, internet, and employment opportunities. Lower municipal tax base and staff capacity in rural areas also pose challenges from an adaptation perspective. The vulnerability of people who already lack access to food, medicine, healthcare, and economic opportunities will be heightened as the region deals with the impacts of climate change. Additionally, people may struggle to evacuate in anticipation of a storm, and it will be even harder to access food, medicine, and other essential services if transportation infrastructure is impacted by severe weather.

Black and POC, Indigenous, low-income, and elderly, as well as recent immigrants, are more likely to live in areas that are more vulnerable, such as areas that are rural, socially or linguistically isolated, are proximate to coastal or tidal flooding, have inadequate housing, are more dependent on natural resources, or are food deserts. Lack of access to food, health care, and other essential services leads to disproportionate impacts specifically

---

<sup>50</sup> Walsh, P., Gimlet, C., & Berry, A. (2015). (rep.). Maine Insights Report. Brunswick, ME: Maine Initiatives.

related to health, which then further exacerbates vulnerability to climate change, as outlined below.

- **Health disparities:** Older adults, young children, people with chronic illnesses, and people with disabilities, are all more vulnerable to extreme weather. Because of an underlying health issue, they may not be able to regulate their body temperature as well during cases of extreme heat or cold. People who don't have underlying conditions, but work in outdoor industries, such as construction and landscaping, also face disproportionate health risks due to high heat. Low-income households and people on fixed-incomes are forced to make tradeoffs with health impacts: on high heat days, they are forced to choose between paying for cooling, food, or housing, and could therefore risk heat-related illness since cooling would likely be deemed less of a necessity than food or housing. People living with disabilities are more likely to have greater healthcare needs and costs and face more challenges getting around, which poses a greater barrier to evacuating and recovering from extreme weather or flooding events. Additionally, people with chronic illnesses, older adults, or others who depend on energy-powered medical devices will suffer medical issues in cases of power outages.
- **Native peoples:** Lack of access to their ancestral homeland has a significant impact on vulnerability and resilience for Native tribes in the Penobscot Climate Action Region. Lack of access to land means lack of ability to practice cultural, religious, and land stewardship practices that are essential to health and wellbeing (from a cultural identity standpoint, and from an environmental justice standpoint), food access (fishing and hunting), and ability to practice sustainable environmental stewardship that will ultimately help all of us mitigate and adapt to impacts of climate change.

# 4. Environmental Impacts and Vulnerabilities

## Waterbodies and Waterways

Lakes, ponds, and rivers are an integral part of the Penobscot Climate Action Region’s culture and are vital to the overall wellbeing of the people, economy, and environment. The major source of Maine’s freshwater comes from the Penobscot River. Major tributaries of the Penobscot River include Kenduskeag Stream, Felts Brook, and Stillwater River, all of which flow directly through cities and towns within the region. The Penobscot River is tidally influenced by the Atlantic Ocean up through Bangor. Major lakes and ponds that are significant due to also being dams within the Region include Swett’s Pond Dam and Brewer Lake Dam. Although outside the Region, Floods Pond (in Otis) and Hatcase Pond (in Eddington) are the drinking water sources for the Bangor and Brewer Water Districts.

### Notable Impacts and Vulnerabilities

**Map It** ([Explore Online](#))

#### Rising Temperature

- Increased surface water temperatures reduce the amount of dissolved oxygen creating uninhabitable freshwater resource areas. This results in potential threats to biodiversity, recreation, and associated economic impacts.
- Increased potential for toxic algae growth in lakes and ponds as water surface temperatures continue to rise.
- Fishermen may have to travel further to new fishing locations as aquatic species, particularly game fish shift their home ranges to colder waters.<sup>51</sup>
- Non-game fish and invasive species may begin to populate Maine’s rivers, streams, and lakes.

Environmental Features (multiple), Urban Heat Island Severity

#### Precipitation & Extreme Weather Events

- Vernal pools, cold-water holding pools, and spawning bed habitats may be reduced or disappear during periods of low rainfall posing a threat to game fish nursery grounds.<sup>52</sup>
- Although not a problem in the Region historically, the risk of harmful algal blooms (HABs) increases with rising temperatures and increased runoff from extreme precipitation events. HAB events sometimes require freshwater remediation. For example, restoration of East Pond in the Belgrade Lakes region cost over \$1 million.<sup>53</sup>
- Poor water quality affects lake shoreline real estate values. It is estimated that lakes generate an annual revenue of

Environmental Features (multiple), FEMA Floodplain layers, and National Inventory of Dams

<sup>51</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 50

<sup>52</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 208

<sup>53</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 10

approximately \$4 billion statewide.<sup>54</sup>

- Recreational activities around lakes and ponds affected with HABs can produce skin rashes, liver damage, and nervous system damage in humans and pets.<sup>55</sup>
- Extreme precipitation events cause flooding upstream of dams and within low-lying areas and wetlands. When the Penobscot River floods, so do connected freshwater resources.<sup>56</sup>
- Penobscot Indian Island is located in the Penobscot River; more frequent flooding will make tribal lands more difficult to access as well as impact plant and animal habitats.

### Sea Level Rise & Tidal Flooding

- Runoff from tidal flooding within highly developed communities introduces contaminants into the Penobscot River. This will reduce the Penobscot River's overall water quality.<sup>57</sup>

Environmental  
Features  
(multiple), Maine  
Sea Level Rise  
Storm Surge  
Scenarios

<sup>54</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 10

<sup>55</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 54

<sup>56</sup> Regional Stakeholder Interview

<sup>57</sup> Regional Stakeholder Interview

## Wetlands

Conservation of wetlands is important because of the pivotal role wetlands play in flood and heat mitigation. Further, wetlands act as a natural carbon and greenhouse gas sink. Wetlands are located throughout the Penobscot Climate Action Region, with higher concentrations of wetlands located within the less developed northeastern and northwestern regions. These regions are also where the Penobscot River significantly branches out into major tributaries. The FEMA maps place much of the northeastern and northwestern parts of the region within the 100-year and 500-year floodplain. Many of the wetlands in this area have been designated as conserved lands, meaning that no further development can occur in these areas. All wetlands in Maine, whether designated as conserved lands or not, are protected under Maine’s Natural Resources Protection Act (NRPA), which aims for no net loss of wetland functions and values.<sup>58</sup> If wetlands in the northeastern and northwestern region were to be removed, the area would experience significantly more flood events. The southern part of the region is highly developed, specifically around the main stem of the Penobscot River, the wetlands in this area are noticeably fewer and more spread out. Natural ecosystems, such as wetlands, that are disconnected from each other are not as effective at flood mitigation or as habitats for amphibians and mammals. See Section 7: Additional Considerations, or the interactive regional map, for the region’s overall land resilience and connectedness.

### PROTECTING THE PENJAJAWOC MARSH

The Bangor Land Trust has identified the Penjajawoc Marsh, located to the northwest of the Bangor Mall, as the most important area for the Trust to preserve because the marsh provides essential habitat for nesting birds and other animals. Currently, the land north of Penjajawoc Marsh is vulnerable to further development, which would divide this important natural environment and reduce its capacity to provide vital ecosystem services. The Bangor Land Trust is trying to permanently protect the land around Penjajawoc Marsh so the ecosystem can remain as a connected system.

## Notable Impacts and Vulnerabilities

Map It ([Explore Online](#))

### Rising Temperature

- Isolated wetlands near highly developed infrastructure are at risk of experiencing higher than average surface water temperatures, as opposed to well-connected wetlands located within lower developed areas.
- Warming surface water temperatures in wetlands will influence cold-water aquatic species. Cold-water species will not be able to tolerate increased surface water temperatures.<sup>59</sup>
- Wetlands support biodiversity. It is predicted that native animal species that rely on wetlands for nesting, breeding, and hunting will have to relocate due to reduced wetlands.<sup>60</sup>
- Rising temperatures increase evaporation rates. During periods of high temperatures, small, isolated wetlands can potentially disappear.

Urban Heat Island Severity, Wetland Characterization, and Land Cover/Resiliency Datasets layers

<sup>58</sup> National Association of Wetland Managers. (n.d). Maine State Wetland Program Summary, p. 2. [https://nawm.org/pdf\\_lib/state\\_summaries/maine\\_state\\_wetland\\_program\\_summary\\_111615.pdf](https://nawm.org/pdf_lib/state_summaries/maine_state_wetland_program_summary_111615.pdf)

<sup>59</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 47

<sup>60</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 192



<ul style="list-style-type: none"> <li>Isolated wetlands present migration challenges to native species such as turtles, fish, invertebrates, and salamanders.<sup>61</sup></li> </ul>	
--	--

**Precipitation & Extreme Weather Events**

<ul style="list-style-type: none"> <li>If the region experienced an extended drought, wetlands and swamps could dry out and release stored carbon and other GHGs.<sup>62</sup></li> <li>Increases in precipitation increase runoff into wetlands. This can contaminate wetlands with pollution and excess soil, which will reduce wetland surface area.</li> </ul>	<p>Significant Vernal Pools, Maine Wetland Characterization, FEMA Floodplain layers</p>
--	---

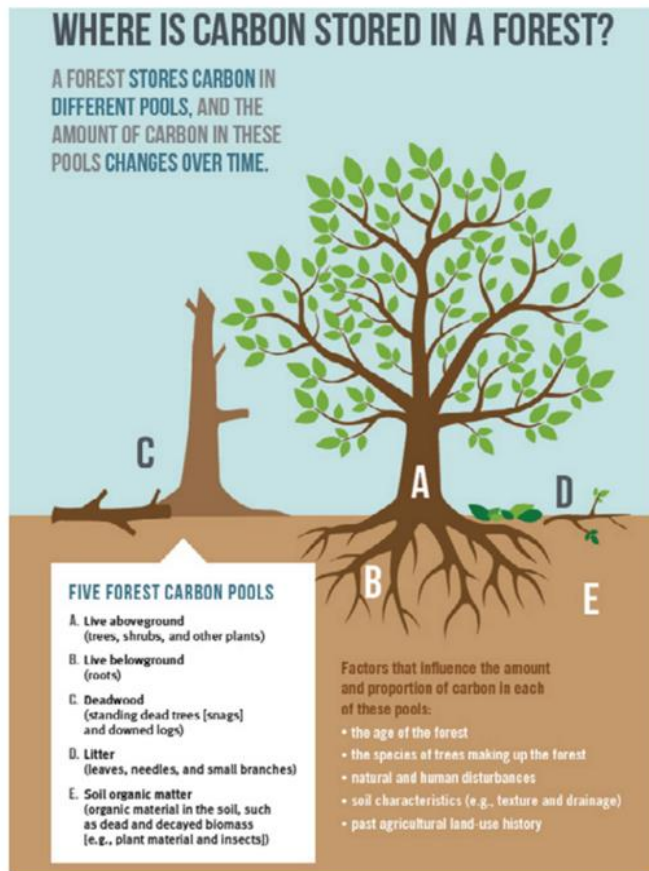
**Sea Level Rise & Tidal Flooding**

<ul style="list-style-type: none"> <li>Sea level rise will increase the likelihood of flooding along the Penobscot River. This could potentially introduce salt water to nearby freshwater resources, which would negatively impact aquatic freshwater species within wetlands and vernal pools.</li> </ul>	<p>Significant Vernal Pools, Maine Wetland Characterization, and Maine Sea Level Rise Storm Surge Scenarios</p>
---	---

<sup>61</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 191

<sup>62</sup> Town of York. (2022). York Climate Action Plan, p. 48

## Forests and Trees



**Figure 4.1 – Forest Carbon Pools**

Source: Maine Scientific and Technical Subcommittee Report – 2020

Forests provide crucial ecosystem services for the Penobscot Climate Action Region and are the second largest global storage of carbon dioxide. Approximately 50% of the region is covered in forest, primarily evergreen and mixed forest.<sup>63</sup>

There is a noticeable decline in tree canopy cover in Bangor, Brewer, and Old Town, especially in areas close to the Penobscot River. Trees along rivers slow runoff from rain, reduce erosion, flooding, and pollution and serve as habitats. Stakeholder interview participants observed that trees located within developed areas are often cut down because of the risk fallen trees pose to infrastructure and private property during extreme weather events.<sup>64</sup> This leads to further habitat fragmentation and reduces the stormwater, cooling, and air quality benefits trees provide. Well-connected forests and natural habitats support resilient environments and biodiversity. As urbanization continues to expand and encroach on forests, the county will experience further deforestation and fragmentation of once connected forests.

### CONSIDERING DISPROPORTIONATE IMPACTS

#### Effects of the Emerald Ash Borer

For Wabanaki people in the region, basket-making is not only an important means of economic income, but also a significant cultural practice that plays a role in maintaining native languages and familial structures. The Emerald Ash Borer's increased presence threatens brown ash trees, on which this basket-making practice relies.

<sup>63</sup> Multi-Resolution Land Characteristics Consortium. (2019). NLCD Land Cover 2019 CONUS Land Cover. <https://www.mrlc.gov/viewer/>

<sup>64</sup> Regional Stakeholder Interview

## Notable Impacts and Vulnerabilities

Map It ([Explore Online](#))

### Rising Temperature

- Warmer temperatures in the winter months will result in less snow cover, which is important for growth of Sugar Maples. This will result in stunted growth and increased vulnerability to pests like the Southern Pine Beetle.<sup>65</sup>
- Threats to important and iconic trees are expected to increase as invasive pests take advantage of a warming climate. For example, Southern Pine Beetle is projected to reach the pitch pine forests of southern Maine by 2050, and the red and jack pines of northern Maine by 2100.<sup>66</sup> The southern pine beetle tunnels under tree bark, effectively killing the tree.<sup>67</sup> The Town of Orono monitors for the presence of the Brown Tail Moth (BTM) and has been experiencing an outbreak of BTM since 2015. Increased abundance of BTM is correlated to higher temperatures in the spring and late summer/early fall the previous year; the exact warming trend that is expected with climate change.<sup>68</sup>
- Rising temperatures increase the presence of earth worms, invasive plants, and animal herbivory, which will lead to forest fragmentation and disease.<sup>69</sup> Unhealthy forests typically result in land use changes, which can lead to further deforestation.
- Maple, spruce, and fir trees have begun to migrate due to warming temperatures.
- Pests such as the Hemlock Woolly Adelgid, Emerald Ash Borer, Spruce Budworm, and Butternut Canker are expected to damage or destroy native trees.<sup>70</sup>
- As heat waves become more predominate during summer months cities and suburbs are less resilient to the urban heat island effect due to lack of tree shading. Very young children and older adults are most vulnerable to extreme temperatures.

National Land Cover Datasets (NLCD), Canopy Cover, and Urban Head Island Severity

### Precipitation & Extreme Weather Events

- Extreme rain events will result in the decline of Sugar Maples, Red Maples, and Birch Trees.
- Drought is a major stressor on forest ecosystems and will often lead to insect and disease outbreaks on stressed trees.<sup>71</sup>
- As a possible result of droughts and humidity, small wildfires (<100 acres) in rural areas are expected to be more challenging for firefighters to stop due to difficult accessibility.<sup>72</sup>
- Disturbances such as flooding, ice storms, and wildfire can open forest canopies, expose mineral soil, and reduce tree

National Land Cover Datasets (NLCD), Canopy

<sup>65</sup> The University of Maine. (2020). Maine's Climate Future, p. 19

<sup>66</sup> The University of Maine. (2020). Maine's Climate Future, p. 30

<sup>67</sup> University of Florida. (n.d.). Southern Pine Beetle. Southern Pine beetle - dendroctonus Frontalis Zimmermann. Retrieved October 20, 2022, From [https://entnemdept.ufl.edu/creatures/trees/southern\\_pine\\_beetle.htm#:~:text=Southern%20pine%20beetle%20females%20colonize,its%20death%20\(Hain%20et%20a](https://entnemdept.ufl.edu/creatures/trees/southern_pine_beetle.htm#:~:text=Southern%20pine%20beetle%20females%20colonize,its%20death%20(Hain%20et%20a)

<sup>68</sup> Town of Orono. (n.d.) Browntail Moth Monitoring. <https://storymaps.arcgis.com/stories/f070b4dd6a0545a39cf72aafa0bc32f5>

<sup>69</sup> The University of Maine. (2020). Maine's Climate Future, p. 19

<sup>70</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 215

<sup>71</sup> The University of Maine. (2020). Maine's Climate Future, p. 19

<sup>72</sup> Penobscot County Emergency Management Agency. (2021). Penobscot County Multi-Jurisdictional Hazard Mitigation Plan Section IV-Risk Assessment, p 10

cover, providing greater opportunities for pest invasion.<sup>73</sup>

Cover, and FEMA  
Floodplain layers

### Sea Level Rise & Tidal Flooding

Sea level rise and tidal flooding are not expected to have significant impacts to forests in this region.

---

<sup>73</sup> The University of Maine. (2020). Maine's Climate Future, p. 30

## Conservation Lands, Parks, Trails, and Recreation

Large sections of Bradley, Milford, Old Town, and Orono, and smaller portions of the region's remaining communities are conserved lands meaning they are designated as wild and development and agricultural uses are restricted in the area. The majority of the conserved lands are located outside the cities and provide the region resiliency from flooding, heat, and extreme weather events. The conserved lands located in the northern region are large and moderately well-connected. Well-connected lands are important for animal migration. In contrast, south of Orono there are fewer areas that are designated as conserved lands. The conserved lands that do exist in the southern region are smaller and spread apart from one another. This is primarily due to larger communities, like in Bangor and Brewer, dominating the area with denser development. Small, segregated conserved lands do not provide as much resiliency and ecological benefits as large, well-connected lands. The conserved lands that do exist in the southern Penobscot Climate Action Region are primarily designated as parks and hiking trails. For example, the City of Bangor has 900 park acres and 39 miles of trail. A resident survey highlighted the City Forest as the most visited park. Green spaces provide visitors relief from rising temperatures due to tree shading and other unique features, such as outdoor pools/splashpads, which are among the top priorities for funding in the city because both assets support cooling amidst high temperatures.<sup>74</sup> However, these kinds of assets can be challenged by overuse; heavy foot traffic on trails is a contributor to soil erosion, damaged vegetation, and altered hydrology among other impacts.

Seasonal recreation, including fishing, hunting, boating and skiing, are a significant part of the culture of Maine – they are what Maine is known for, what tourists come to Maine for, and what Mainers are proud of. Bangor International Airport is an important entry point for visitors coming to Central and Northern Maine for recreation. This is all at risk of being lost due to gradual changes that might impact snow cover, fish habitats, and similar changes described in earlier sections, as well as extreme weather events that can damage natural and built recreational amenities.



Old Town Park. Photo: Matthew DeWitt

<sup>74</sup> City of Bangor. (2021). Parks & Recreation Master Plan

## Notable Impacts and Vulnerabilities

Map It ([Explore Online](#))

### Rising Temperature

- In rivers, changes in stream flows and temperature will affect habitat and fishing opportunities for cold-water species like trout and salmon. It is possible that salmon and trout are likely to disappear from all but a few streams in the White Mountains in western Maine.<sup>75</sup>
- Delays in winter onset have lengthened the fall tourist season. This will increase visitors to conservation lands and parks, which will increase stress and disturbance in these areas.<sup>76</sup>
- Due to shortening winter months, snowmelt and lake-ice thaw will occur earlier. This will impact winter recreation tourism such as cross-country skiing, ice fishing, and snowshoeing.<sup>77</sup>
- Rising temperatures may result in closure or cancellation of recreational activities due to the health risks posed by extreme heat days or outbreaks of vector-borne illness from longer tick and mosquito seasons.
- Impacts to biodiversity are expected as native cold-loving animals and plants are unable to tolerate warming weather.
- Reduced stream/river flows due to accelerated snowpack melts impacting paddling and fishing activities.<sup>78</sup>

Conserved Lands, Bangor Trails, Bangor Open Space, and Urban Heat Island Severity

### Precipitation & Extreme Weather Events

- Reduced snow amounts and more rain events will make winter recreational activities, such as ice fishing, become more dangerous. “Winter whiplash” as described in the climate projections, can create variability in conditions that can negatively impact recreational activities and economy.
- Heavy rain events will lead to hiking trails and park access road closures because trails and roads will become eroded and washed out.<sup>79</sup>
- During flash flood events runoff from nearby development runs into streams located within parks. The runoff contains contaminants that pollute the park’s water resource.<sup>80</sup>

Conserved Lands, Bangor Trails, Bangor Open Space, and FEMA Floodplain layers

### Sea Level Rise & Tidal Flooding

- Sea level rise could increase occurrences of flooding in parks and recreational areas along the Penobscot River. Portions of the Penobscot River Walkway (Bangor) and Brewer Riverwalk are vulnerable to near-term sea level rise (1.2 ft. SLR) and the trails become fully exposed at 3.9 ft of SLR.

Conserved Lands, Bangor Trails & Open Space, and Maine Sea Level Rise Storm Surge Scenarios

<sup>75</sup> The University of Maine. (2020). Maine’s Climate Future, p. 30

<sup>76</sup> The University of Maine. (2020). Maine’s Climate Future, p. 30

<sup>77</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 41

<sup>78</sup> Regional Stakeholder Interview

<sup>79</sup> Regional Stakeholder Interview

<sup>80</sup> Regional Stakeholder Interview

## Agriculture

---

*“[The growing season] has already shifted from about 100 days to about 110 days...some farmers are experimenting with different varieties, and are starting to grow okra, watermelon, and peaches.” –Stakeholder Interview, Penobscot County Cooperative Extension*

---

The State of Maine’s agricultural economy is the basis of over 1.2 billion dollars of food and fiber products annually and employs 22,000 workers.<sup>81</sup> In 2017, the United State Agricultural Census reported that a total of 105,452 acres of cropland were harvested in Penobscot County, with \$50,915,000 in commodity sales.<sup>82</sup>

Per the Penobscot County Hazard Mitigation Plan, approximately 23% of the land area of Penobscot County is agricultural or open space.<sup>83</sup> While the Penobscot Climate Action region is more developed than the County as a whole, residents of the region may travel outside of the region for work in the agriculture sector, and they may also rely on nearby agricultural lands for food and other products.

A visual analysis of the USA Cropland map layer shows that there is a substantial amount of land dedicated to crops in Orrington, Hampden, Brewer, Bangor, and Hermon, and less cropland in Bradley, Orono, Old Town, and Milford. Commonly grown crops in the region are Hay<sup>84</sup> (9251 acres), Corn (419 acres) and Blueberries (185 acres). Hay is the most common cropland designation for all 11 communities in the region, which may necessitate research on the part of growers and Extension specialists on how climate change will impact the growth of non-alfalfa hay crops, such as clover and oats. Additionally, stakeholder interviews revealed that pasture farming (livestock) is also present in the area. In fact, livestock accounts for approximately \$33M in sales each year, while crop farming accounts for approximately \$18M in sales each year.<sup>85</sup> Additional important agricultural land in the region are small mixed vegetable farms that supply farmers markets, CSAs, and farm stands.

Farms will experience different climate impacts based on their location and the varieties grown. For example, stakeholder interviews also revealed that farms adjacent to the river are vulnerable to flooding, while upland farms experience significant drought - “they’re all in their own pockets...you can’t paint with a broad brush.”<sup>86</sup> Nevertheless, drought has been identified as the number one climate hazard threatening Maine’s agricultural economy, which could be as extreme as a \$50M sales loss. Droughts resulting in less widespread loss of crops would result in smaller losses.<sup>87</sup> Most abnormally dry conditions and drought conditions impact the agricultural areas north of Bangor.<sup>88</sup>

---

<sup>81</sup> Penobscot County Emergency Management Agency. (2021). Penobscot County Multi-Jurisdictional Hazard Mitigation Plan Section IV-Risk Assessment, p 45

<sup>82</sup> Penobscot County Emergency Management Agency. (2021). Penobscot County Multi-Jurisdictional Hazard Mitigation Plan Section IV-Risk Assessment, p. 88

<sup>83</sup> Penobscot County Emergency Management Agency. (2021). Penobscot County Multi-Jurisdictional Hazard Mitigation Plan Section IV-Risk Assessment, p. 35

<sup>84</sup> Identified in the National Land Cover Datasets Cropland layer as “Other Hay/Non-Alfalfa”

<sup>85</sup> [https://www.nass.usda.gov/Publications/AgCensus/2017/Online\\_Resources/County\\_Profiles/Maine/cp23019.pdf](https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/County_Profiles/Maine/cp23019.pdf)

<sup>86</sup> Stakeholder interviews

<sup>87</sup> Penobscot County Emergency Management Agency. (2021). Penobscot County Multi-Jurisdictional Hazard Mitigation Plan Section IV-Risk Assessment, p. 88

<sup>88</sup> Penobscot County Emergency Management Agency. (2021). Penobscot County Multi-Jurisdictional Hazard Mitigation Plan Section IV-Risk Assessment, p. 42

Some of the vulnerabilities the agricultural sector will experience, beyond drought, include prolonged spring rains, extended spring frost risk, and summer water deficits; alternatively, some growers may benefit from longer growing seasons and new crop options as a result of the warmer temperatures.<sup>89</sup> The map below demonstrates how warmer temperatures are shifting what are known as “plant hardiness zones” or 10-degree Fahrenheit zones that determine which crops will thrive in a given region based on the local climate. Finally, growers must contend with weather patterns that are less predictable as the climate shifts, and include more extremes in both temperature and precipitation, making planning significantly more challenging.

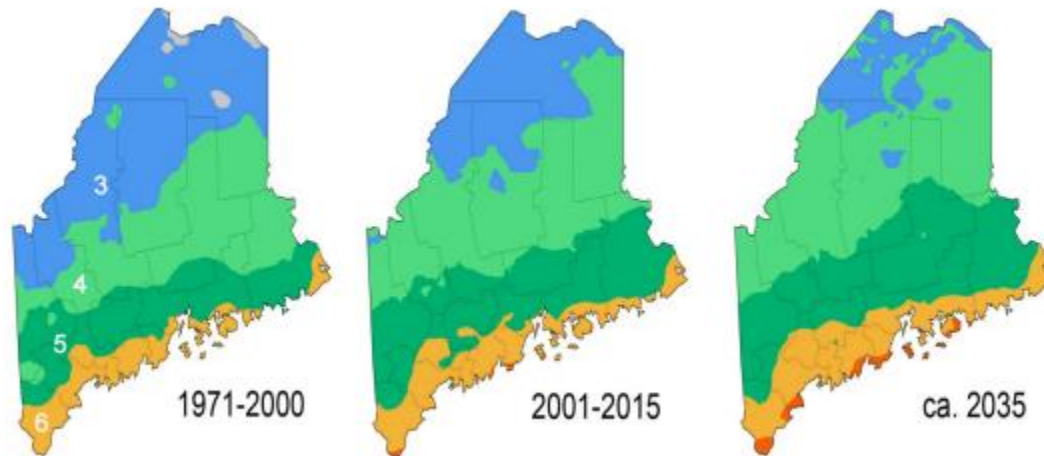


Figure 4.2: Recent, current, and future projected plant hardiness zones, which are shifting northward in Maine due to warmer temperatures. Zones are labeled in the left map. Source: University of Maine, Maine Climate and Agriculture Network. Data from PRISM Climate Group, Oregon State University.

Many of the growers in the region, not unlike the State at large, are older adults who prefer print communication to electronic communication, which makes dissemination of information related to weather more difficult. The large number of older adults in agriculture also raises concerns about food supply when they retire. According to the USDA, only 136 of the 1090 producers in Penobscot County are under 35. 363 are over 65.<sup>90</sup>

## Notable Impacts and Vulnerabilities

[Map It \(Explore Online\)](#)

### Rising Temperature

- Winter minimum temperatures are increasing faster than other daily highs, and winter minimums define plant hardiness zones. Growers will need to consider planting new crop varieties in response to the shifts.
- More frequent and intense heat waves will require extreme caution on the part of growers and outdoor workers, especially when the Heat Index exceeds 90 degrees.
- High temperatures negatively affect the health of livestock such as dairy cows.
- Drought is of high concern to farmers, according to stakeholder interviews. Water issues generally create irrigation issues.

Crop Layers, Urban Heat Island Severity

<sup>89</sup> The University of Maine. (2020). Maine’s Climate Future, p. 30

<sup>90</sup> [https://www.nass.usda.gov/Publications/AgCensus/2017/Online\\_Resources/County\\_Profiles/Maine/cp23019.pdf](https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/County_Profiles/Maine/cp23019.pdf)



<p>Longer dry periods in recent years have corresponded with a need for more irrigation, especially for strawberry, potato, blueberry, mixed vegetable, hay, and pasture farmers. In fact, Extension recently hired an irrigation specialist.</p> <ul style="list-style-type: none"> <li>• “Water scarcity is the primary risk factor driving risk of crop failures. By 2050 the risk of yield failures for individual production areas (US, China, India) increases up to 25x, with a 50% chance of a failure per year.”<sup>91</sup></li> </ul>	
---	--

**Precipitation & Extreme Weather Events**

<ul style="list-style-type: none"> <li>• Stakeholder interviews revealed that drought is more of a concern than flooding for farmers.</li> <li>• Road infrastructure (more than rail and air) is essential for farmers in getting their products to the market in the region – storms and flooding may damage roads and disrupt transportation routes.</li> <li>• Power outages, which are common during storms, are especially challenging for dairy farmers.</li> </ul>	<p>Crop Layers, FEMA Floodplain layers</p>
---	--

**Sea Level Rise & Tidal Flooding**

<ul style="list-style-type: none"> <li>• Road infrastructure (more than rail and air) is essential for farmers in getting their products to the market in the region – SLR and tidal flooding may damage roads and disrupt transportation routes, depending on the farms’ and roads’ proximity to the Penobscot River.</li> </ul>	<p>Crop Layers, Maine Sea Level Rise Storm Surge Scenarios</p>
---	--

<sup>91</sup> Maine Climate Council. (2021). Maine Won’t Wait, p. 16

---

## 5. Infrastructural Impacts and Vulnerabilities

---

### Transportation System

Key assets in the region's transportation system include:

- Roads and bridges – I-95, I-395, Route 9, Route 178, Route 2, Stillwater Avenue, Veterans Remembrance Bridge, Joshua Chamberlain Bridge, Down St. Bridge, among many others
- Public transportation - Community Connector Bus, Black Bear Orono Express Bus, and multiple transit providers for medical transport
- Air - Bangor International Airport, Dewitt Field (Old Town)
- Rail – Rail yards in Bangor, Old Town, and Hermon; and the PanAm freight main line that travels along the west bank of the Penobscot from Bangor to Old Town then crosses to east of the river just south of Indian Island
- Bike – East Coast Greenway travels through Orrington, Brewer, Bangor, and Hermon on road except for paved trail sections along the Penobscot River in Bangor and Brewer

Driving is the primary mode of transportation in the region and detours from road closures and construction have major impacts on commutes to school and work, response time for health and public safety trips, and the economy. Regional stakeholders consistently emphasized the need for a resilient transportation system including well maintained roads, culverts that are sized for heavy precipitation, and more public transportation. Local infrastructure managers noted revised design standards that account for future increases in precipitation would help them justify building beyond current standards and code.



#### CONSIDERING DISPROPORTIONATE IMPACTS

##### Unequal Impacts of Transportation Disruptions

Residents in the region already face transportation access challenges. It's likely that low population numbers make it difficult to support a robust transit network. This has negative impacts on those who don't have cars or can't drive, as relying on public transportation significantly limits one's options to access food, medicine, and economic opportunities. Approximately 7.1% of households in the Penobscot County do not own a vehicle.

Extreme weather events that block road systems or damage public transit infrastructure heighten this vulnerability. Interruptions in road systems or public transportation routes can lead to increased instances of loss of income and employment, as well as making food and medicine even more inaccessible. Additionally, those who don't own cars are less able to evacuate before a storm, or access necessary supplies in the wake of an extreme weather event.

If only 5% of bus stops are covered in the region, and 88% of proposed Community Connector bus stops are within an identified heat island, individuals with underlying health conditions, young children, and older adults will be disproportionately impacted, as they are more vulnerable to extreme heat, and are at heightened risk of heat related illness when waiting for public transit at unsheltered bus stops.

For Indigenous folks in the region, an increase in extreme precipitation events can block road systems that are normally used for opening tribal lands for management and harvesting activities, delaying important seasonal practices.

[Michelle, N., Ranco, D., & Willis, T. \(2017\). \(rep.\). BIA Tribal Comprehensive Adaption](#)

## Notable Impacts and Vulnerabilities

Map It ([Explore Online](#))

### Rising Temperature

- Bangor International Airport is in a moderate heat island (3) and is already experiencing the effects of alkalinized silica reaction (ASR) which causes an expansion of concrete in high heat or rapid temperature changes<sup>92</sup>.
- Rapid temperature fluctuations and extreme heat can decrease pavement life and increase bridge fatigue leading to increased maintenance and replacement costs for roads and vehicles.
- Bus passengers are vulnerable to high heat days. Bus routes are concentrated in developed areas of the region. 88% of proposed Community Connector bus stops are within an identified heat island with more than a third of all bus stops in moderate to high (level 3-5) heat islands. 5% of bus stops are sheltered.

CDC Social Vulnerability Index and Public Roads, Runways, Proposed Bus Stops, and Community Connector Bus Routes, Urban Heat Island Severity

### Precipitation & Extreme Weather Events

- Of the 721 miles of roads in the region, 85 miles (~12%) intersect the 100-year floodplain and 74 miles (~10%) intersect the 500-year floodplain. Impacted roads include areas of I-95 and I-395 throughout the region, areas of downtown Bangor where the Kenduskeag River branches from the Penobscot River, and many of the region's rural roads, especially in the north and south of the region. Over 1/3 of the region's culverts are in fair to critical condition.
- All areas along the Penobscot are also susceptible to spring ice jams which may cause the river to overflow its banks and may cause road closures, damaged bridges and stranded residents. Many of the rural area's road systems are not built to appropriate roadway drainage standards and are subject to flooding during heavy rains.<sup>93</sup>
- High wind events knock down trees and the (aging) mast arms of traffic signals, disrupting transportation and placing increased demands on the public safety and public works workforce. This is occurring presently and the impact is likely to increase with increasing storm frequency and intensity.
- Bus routes and stops have moderate exposure to flooding. 5 Community Connector proposed bus stops are located in the 100-year FEMA floodplain and 8 additional are in the 500-year floodplain.
- More frequent and changing storm events cause transportation disruptions with numerous cascading effects that impact access to jobs, education, healthcare, and other services. Specifically,
  - Regional stakeholders noted relatively small local workforces have less ability to meet higher demand for clearing roads and storm drains before, during, and after severe weather.
  - Storms result in cancelled paratransit trips followed by an influx of trip requests when appointments are rescheduled; the transit workforce is challenged to meet these fluctuations in demand which impacts access to medical and other important services.
  - Throughout the region, but especially in rural areas, heavy precipitation events damage roads and culverts

Public Roads, Bridges, Culverts, Runways, Proposed Bus Stops, and Community Connector Bus Routes, and FEMA Floodplain

<sup>92</sup> Regional Stakeholder Interview

<sup>93</sup> Penobscot County Emergency Management Agency. (2021). Penobscot County Multi-Jurisdictional Hazard Mitigation Plan Section IV-Risk Assessment, p. 44

resulting in lengthy detours. Regional stakeholders already report road and culvert washouts, and this trend is expected to increase.

- Regional stakeholders noted a transition from snow to more frequent ice and freezing rain events affecting safety for vehicles, pedestrians, and at the airport.
- For Indigenous folks in the region, an increase in extreme precipitation events can block road systems that are normally used for opening tribal lands for management and harvesting activities, delaying important seasonal practices.<sup>94</sup>

### Sea Level Rise & Tidal Flooding<sup>95</sup>

- Approximately 3.5 miles of road are projected to experience flooding from sea level rise by mid-century (1.6 ft of sea level rise); this increases to 6 miles of road by late century (8.8 ft of sea level rise). Multiple roads in areas of downtown Bangor where the Kenduskeag River branches from the Penobscot River are vulnerable to near-term sea level rise/storm surge flooding.
- Of the 356 proposed Community Connector bus stops, only 9, all in Bangor, are exposed to end of century sea level rise (8.8 ft. of sea level rise).

Public Roads, Bridges, Culverts, Runways, Proposed Bus Stops, and Community Connector Bus Routes, Maine Sea Level Rise Storm Surge Scenarios

<sup>94</sup> Michelle, N., Ranco, D., & Willis, T. (2017). (rep.). BIA Tribal Comprehensive Adaptation Planning.

<sup>95</sup> Maine DOT is currently engaged in a statewide transportation vulnerability analysis and is developing an updated sea-level rise/storm surge flood model. It is recommended that the Penobscot Climate Action region incorporate this information when available.

## Energy System

Maine has the highest energy use and energy expenditure per-capita in New England; the greatest expenditure is in petroleum products for transportation and heating. Approximately 2/3's of Maine's households are reliant on fuel oil for home heating.<sup>96</sup> This makes Maine subject to the volatility of oil and gas prices nationally and globally.

Versant Power is the primary electric provider in the region which generates and distributes power through the Bangor Hydro District. Additionally, Bangor Natural Gas provides natural gas to 7 of the region's 11 communities.

In May 2022, Maine's governor signed into law *An Act Regarding Utility Accountability and Grid Planning for Maine's Clean Energy Future*. The act requires utilities to submit every three years a 10-year outlook that indicates how they plan to respond to and mitigate climate change.<sup>97</sup> In August 2022, Versant power announced that it was seeking an increase in distribution rates to fund several activities including work to improve reliability in Old Town/Orono and activities to reduce tree-related outages.<sup>98</sup>

### CONSIDERING DISPROPORTIONATE IMPACTS

#### Cost Burden and Energy Access

Low-income individuals, people of color, renters, people living in rural areas, and the elderly, all experience high energy burdens. In Maine, “the median energy burden of rural elderly households is 44% higher than that of non-elderly households, [and] rural renters experience a median energy burden 29% higher than that of owners.” Those already struggling to pay their utilities are at higher risk of injury, illness or death in cases of extreme weather.

During periods of extreme heat, those without reliable air conditioning are at higher risk of heat related illness or death. In cases of extreme weather or heavy storms, power outages can disrupt energy that provides heat in the winter, or electricity for critical medical devices, which can also have serious health implications. Power outages can disrupt transportation, which means those who rely on hourly wages will lose income if they can't get to work. Additionally, small businesses will be impacted if customers can't reach the business itself.

Lastly, natural gas pipelines do not reach many rural communities in Maine. Natural gas pipelines are not the solution if we're trying to move away from using fossil fuels. However, as we build out renewable electric energy systems and move away from fossil fuels, it will be important to consider access and geographic equity. Increasing access to affordable, sustainable, and resilient heating systems is a critical piece of alleviating energy burdens and ensuring that those whose health is at risk during an outage are not in danger.

Silka, L., Keleman, S., & Hart, D (2020). *Assessing the Potential Equity Outcomes of Maine's Climate Action Plan: Framework, Analysis and Recommendations*.

<sup>96</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). *Scientific Assessment of Climate Change and its Effects in Maine*, pp. 349-356

<sup>97</sup> Runyon, J. (2022, August 2). Maine PUC sets minimum service standards for utilities. Powergrid International. <https://www.power-grid.com/policy-regulation/maine-puc-sets-minimum-service-standards-for-utilities/>

<sup>98</sup> Versant Power. (2022, August 4). Versant Power will seek distribution rate change in summer '23. <https://www.versantpower.com/about-us/news-and-press-releases/news-detail/?id=8633>

## Notable Impacts and Vulnerabilities

Map It [\(Explore Online\)](#)

### Rising Temperature

- Regional power plants, substations, and transmission infrastructure are all in low to moderate heat islands (0-3); however, high heat events will be felt throughout the region.
- Rising temperatures have multiple impacts on electric transmission and distribution including<sup>99</sup>:
  - lower generation efficiency,
  - decreased solar PV efficiency,
  - reduced carrying capacity, and increased losses in lines and transformers, and
  - increased demand for cooling
- Demand for electricity will increase throughout the region as cooling demand rises. Currently, 56% of homes in the county have air conditioning. Stakeholders note that facilities that traditionally didn't need air conditioning, such as the region's schools and UMaine's dormitories, now need it. Stakeholders commented that some substations are already operating at capacity and now face this added load.

All energy layers and Urban Heat Island Severity

### Precipitation & Extreme Weather Events

- 3 power plants (Brookfield Black Bear Hydro plants in Milford, Old Town, and Orono), 1 substation (Stillwater B in Orono), and 3 fuel terminals (Bangor, Brewer, and Hampden) are located in the 100-year floodplain. Many substations are in close proximity to the current FEMA floodplain and could become exposed if the floodplain expands, as projected, with increases in heavy precipitation.
- Transmission and distribution infrastructure are vulnerable to higher winds and more ice events. In rural parts of the region with high tree coverage, this risk is exacerbated as tree limbs knock out power lines.
- UMaine's Central Steam Plant is not in, but is adjacent to, the floodplain. The steam plant provides heat to the entire campus and is designed to run without electricity. The University is planning an addition to the steam plant that will allow vulnerable equipment to be moved to a higher elevation.
- Regional stakeholders note that severe storms result in multiple power outages per year and the trend seems to be increasing. They report backup power generation is not adequate throughout the region. Some cascading impacts of power outages were noted to include:
  - Reliance on private wells disrupts the drinking water supply. Community stakeholders noted they are not well prepared for mass distribution of water during extended outages.
  - Loss of internet which disrupts remote work and schooling as well as increases isolation for vulnerable populations who, due to poor cellular service, rely on internet for outside information and connection

All energy layers and FEMA Floodplain layers

<sup>99</sup> One Climate Future. (2019). Climate Change Vulnerability Assessment: Cities of Portland and South Portland, p. 37

- Sensitive research equipment and frozen or refrigerated specimens at UMaine are highly sensitive to power outages and can result in economic impacts as well as lost scientific advancement.

### Sea Level Rise & Tidal Flooding

- 1 electric substation (Stillwater B in Old Town) and 3 fuel terminals (Bangor, Brewer, and Hampden) are exposed to late century sea level rise/storm surge flooding (8.8 ft. of SLR). This includes the Cold Brook Energy fuel terminal which supplies jet fuel to the airport.
- 29 electrical transmission line segments were evaluated. Of those, 7 segments (24%) are exposed to mid-century sea level rise/storm surge flooding under a low emissions scenario (1.2 ft. of SLR) creating vulnerabilities for damaged towers due to erosion and other flood damage to low-lying infrastructure.<sup>100</sup>

All energy layers and Maine Sea Level Rise Storm Surge Scenarios

<sup>100</sup> One Climate Future. (2019). Climate Change Vulnerability Assessment: Cities of Portland and South Portland, p. 37



## Water and Wastewater Systems

---

*“Currently the stormwater infrastructure is barely sufficient to handle even current precipitation; much of it is very old, as old as the turn of the 20th century.” - Town of Orono Stakeholder Interview*

---

Water treatment systems and wastewater treatment systems are critical for safe consumption of clean water and safe transport and treatment of contaminated wastewater. Per the Penobscot County Hazard Mitigation Report, water treatment facilities and wastewater treatment plants are considered “critical facilities.”<sup>101</sup>

More than 50% of Mainers rely on a private well for their drinking water.<sup>102</sup> Public water is supplied to the region through four water districts:

- The **Bangor Water District** serves Bangor, Hampden, Hermon, and parts of Veazie, as well as communities outside the Penobscot Climate Action Region. The main source is Flood’s Pond in Otis. The water district owns 99% of the land in the watershed. Boating and swimming are prohibited and there is no industry or agriculture in the watershed, which mitigates the risk of invasive species and runoff from fertilizers and other contaminants that might otherwise be of concern with rising temperatures and increased precipitation and flooding.<sup>103</sup>
- The **Orono/Veazie Water District** serves a population of 8,125. Water is treated at a facility at 116 Bennoch Road and is sourced from four drilled wells north of the treatment plant.<sup>104</sup>
- The **Old Town Water District** serves Old Town, Milford, Bradley, parts of Orono, and the Penobscot Indian Nation on Indian Island. Water comes from five gravel packed wells: three on Spring Street and two on Bennoch Road. All the district’s water is treated at the Spring Street filter plant.<sup>105</sup>
- The **Brewer Water Department** provides water to Brewer, parts of Orrington, and communities outside the Penobscot Climate Action Region. Water is sourced from Hatcase Pond and is treated at Hayes Treatment Plant; the water source is protected by limiting nearby activity through land purchases.

Seven of the region’s eleven communities (Bangor, Brewer, Hampden, Milford, Old Town, Orono, and Veazie) have Municipal Separate Storm Sewer System (MS4) permits which requires them to implement minimum control measures to reduce pollution from stormwater runoff. In stakeholder interviews, communities noted that underground stormwater infrastructure, in general, is aging and at capacity. Hampden notes aging stormwater infrastructure is a challenge to economic development as inadequate infrastructure deters businesses from establishing operations in the town. In other parts of the region, drainage ditches and other forms of above ground stormwater management are employed. Bangor International Airport is working to mitigate storm runoff

---

<sup>101</sup> Penobscot County Emergency Management Agency. (2021). Penobscot County Multi-Jurisdictional Hazard Mitigation Plan Section IV-Risk Assessment, p. 43

<sup>102</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 303

<sup>103</sup> Frequently asked questions: Bangor water: Bangor, me. Bangor Water. (2021, September 21). Retrieved October 20, 2022, from <https://www.bangorwater.org/faq/>

<sup>104</sup> 2016 Annual Drinking Water Quality Report. Orono-Veazie Water District. (2016). Retrieved October 20, 2022, from [https://ovwd.weebly.com/uploads/5/0/9/1/50914273/2016\\_ccr\\_report.pdf](https://ovwd.weebly.com/uploads/5/0/9/1/50914273/2016_ccr_report.pdf)

<sup>105</sup> Old Town Water District’s Annual Drinking Water Quality Report for 2021. Old Town Water. (2021). Retrieved October 20, 2022, from [https://ovwd.weebly.com/uploads/5/0/9/1/50914273/2016\\_ccr\\_report.pdf](https://ovwd.weebly.com/uploads/5/0/9/1/50914273/2016_ccr_report.pdf)



using a bio-retention system around the airport. The City of Bangor has plans to add an 8.6-million-gallon storage tank for sewage control during heavy precipitation events.<sup>106</sup>

## Notable Impacts and Vulnerabilities

Map It ([Explore Online](#))

### Rising Temperature

- As discussed in the “Waterbodies and Waterways” section; rising temperatures can negatively affect water quality.
- High heat days cause chlorine in water distribution systems to decay and can contribute to the release of pathogens. Future increases in temperature will pose an economic and technical challenge for water utilities to maintain disinfectant residual concentrations throughout the entire distribution network without compromising the health of consumers.<sup>107</sup>

Water System Layers, and Urban Heat Island Severity

### Precipitation & Extreme Weather Events

- All three wastewater treatment facilities in the region (Bangor, Brewer, and Orono) are within the 100-year floodplain.<sup>108</sup>
- Bangor, Orono, and Hampden noted the age and relative capacity of their stormwater systems as vulnerabilities. The systems are presently overwhelmed by heavy precipitation events and this issue will be further exacerbated as precipitation intensifies in the coming decades. Overwhelmed systems impact nearby infrastructure, release contaminated water into the environment, and can be damaged themselves. Stakeholders reported that during flash flooding events, wastewater treatments facilities are overwhelmed and overflow drains directly into the river.
- More heavy rainfall will increase the likelihood and frequency of infiltration of stormwater into sewer pipes through cracks and poorly constructed or corroded manholes, which can lead to overflows, blockages, and infrastructure damage.<sup>109</sup>
- Data on pump stations was not available throughout the whole region; of those available, only 1 (Bangor Kenduskeag) was exposed to flooding. More extreme and frequent storms may put the structural and mechanical systems of pump stations at greater risk of damage and power loss, resulting in backups and potential overflows into buildings and homes.<sup>110</sup>
- Increased flooding in areas served by private wells will likely lead to an increase in the incidence of waterborne diseases among those served by private wells, in addition to the added burden of cleaning and disinfecting affected wells.<sup>111</sup>
- Drought can negatively affect water availability; however, stakeholders commented that water supply has not been impacted by recent droughts. In fact, water conservation measures in response to droughts would have adverse effects on

Water System Layers, and FEMA Floodplain layers

<sup>106</sup> Regional Stakeholder Interviews

<sup>107</sup> Calero Preciado, et. al. (2021). Implications of Climate Change: How Does Increased Water Temperature Influence Biofilm and Water Quality of Chlorinated Drinking Water Distribution Systems? <https://www.frontiersin.org/articles/10.3389/fmicb.2021.658927/full>

<sup>108</sup> This assessment’s GIS analysis did not identify the Bangor and Orono facilities as located in a floodplain due to specifics of the GIS data available. However visual inspection of the regional GIS map showed that portions of each facility intersect with the floodplain.

<sup>109</sup> York, ME Climate Action Plan (2022) citing Ministry for the Environment. (2008). [www.sciencedirect.com/science/article/pii/S2212096320300528](http://www.sciencedirect.com/science/article/pii/S2212096320300528)

<sup>110</sup> York, ME Climate Action Plan (2022).

<sup>111</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 303

drinking water as too little flow in water pipes can negatively impact water quality.<sup>112</sup>

- Emergencies resulting in the shutdown of drinking water treatment plants, such as flooding or loss of power from storms, can have implications on the delivery of water across the system.

--

### Sea Level Rise & Tidal Flooding

- The Bangor and Brewer wastewater treatment facilities are exposed to near-term (1.2 ft) and late century (8.8 ft. of SLR) sea level rise/storm surge flooding, respectively.
- Conserved lands in the Orono-Veazie water district are exposed to near-term sea level rise/storm surge flooding (1.2 ft. of SLR)
- Data on pump stations was not available throughout the whole region; of those available, only 1 (Bangor Kenduskeag) was exposed to late century sea level rise/storm surge flooding (8.8ft SLR).

Water System Layers, and Maine Sea Level Rise Storm Surge Scenarios 2018
--

<sup>112</sup> Regional Stakeholder Interviews

## Communications System

Information technology and communications systems in the region include cell towers and facilities, radio and TV broadcast towers, fiber lines, data centers, telephone networks, and related infrastructure. There are at least two data centers in the region, one at Neville Hall on the UMaine campus in Orono and the FirstLight Bangor Data Center located at 60 Summer St. in Bangor. Penobscot County Regional Communications Center, the Public Safety Answering Point for Penobscot and Aroostook County, is located at 97 Hammond St. in Bangor. GIS data was available to assess cell towers, AM & FM towers, mobile broadcast towers, radio and paging transmissions towers, and analog TV station towers for exposure to high heat and flooding.

The importance of connectedness has only increased in recent years. The COVID-19 pandemic resulted in a shift to more remote work and remote schooling. While this allows continuity in some respects, it creates vulnerabilities in others. Despite cellular carrier coverage maps, regional stakeholders identified poor cellular reception and dead zones as a concern in the region. Residential internet is a critical resource; however, it is dependent upon a resilient electric grid in addition to its own vulnerabilities. Disruptions to cell service and internet are even more impactful for socially and geographically isolated people, including seniors. While broadband service is generally available in town centers, “last mile” connectivity is a challenge. Eastern Maine Development Corporation identified broadband expansion as one of the region’s five economic development goals and recently received a grant for broadband planning.<sup>113</sup>

### CONSIDERING DISPROPORTIONATE IMPACTS

#### Broadband Access

Inequitable access to digital resources creates a significant barrier to one’s ability to access education, employment, essential services (such as telemedicine), and opportunities to participate in civic life. The COVID-19 pandemic recently illuminated the disproportionate impact that digital inequity has on vulnerable communities across the U.S. In Maine in particular, rural communities, communities of color, immigrant communities, older adults, individuals with disabilities, and low-income families were most affected by inequitable digital access during the pandemic.<sup>1</sup> On a more local level, in 2017, one in five Penobscot County residents did not have reliable broadband access.<sup>2</sup>

Rural communities, communities of color, immigrant communities, older adults, individuals with disabilities, and low-income families in the region will experience disproportionate vulnerability to climate change, as lack of access to digital resources will make them less able to access important information, including the ability to prepare for or hear about an emergency, ability to apply for aid or access recovery resources after an emergency.

<sup>1</sup>Maine Advisory Committee to the U.S. Commission on Civil Rights. (2022). Digital Equity as a Civil Right in Maine.

<sup>2</sup>Maine Shared CNA (2022) Penobscot County Community Health Needs Assessment Report, p.16

<sup>113</sup> Regional Stakeholder Interview

## Notable Impacts and Vulnerabilities

Map It ([Explore Online](#))

### Rising Temperature

- The Bangor and Orono data centers are located in high (level 4 and 5) urban heat islands. As temperatures rise, the risk of data center overheating increases as does demand and costs for air-conditioning.<sup>114</sup>
- Wireless signal transmission can experience a decreased range in high temperatures resulting in the location/density of wireless masts becoming sub-optimal.<sup>115</sup>

Communication Infrastructure layers, Urban Heat Island Severity

### Precipitation & Extreme Weather Events

- There is limited exposure of communications infrastructure to flooding. Neither data center, nor the Penobscot County Regional Communications Center, nor any of the region's cell towers are located in the FEMA Floodplain.
- Flooding may damage low-lying or underground infrastructure and access points. Further, erosion or damage to transportation infrastructure may expose cables and trunk routes.<sup>116</sup>
- Heavy precipitation reduces the quality and strength of wireless service.<sup>117</sup>
- Strong storms, wind, and fallen trees may increase fallen cell towers or telephone poles.<sup>118</sup>
- Changes in humidity change requirements to maintain internal environments for data centers and other buildings housing communications equipment.<sup>119</sup>

Communication Infrastructure layers, FEMA Floodplain layers

### Sea Level Rise & Tidal Flooding

- Neither data center nor the Penobscot County Regional Communications Center nor any of the region's cell towers are exposed to sea level rise/storm surge flooding per the MGS model.
- Corrosion from saltwater exposure is a risk for communications infrastructure that experiences sea level rise/storm surge.<sup>120</sup>

Communication Infrastructure layers, and Maine Sea Level Rise Storm Surge Scenarios 2018

<sup>114</sup> USAID. (2013). Addressing Climate Change Impacts on Infrastructure, p. 10. <https://www.climatelinks.org/resources/addressing-climate-change-impacts-infrastructure-preparing-change>

<sup>115</sup> USAID. (2013). Addressing Climate Change Impacts on Infrastructure, p. 30.

<sup>116</sup> USAID. (2013). Addressing Climate Change Impacts on Infrastructure, p. 30.

<sup>117</sup> USAID. (2013). Addressing Climate Change Impacts on Infrastructure, p. 29.

<sup>118</sup> USAID. (2013). Addressing Climate Change Impacts on Infrastructure, p. 30.

<sup>119</sup> USAID. (2013). Addressing Climate Change Impacts on Infrastructure, p. 30.

<sup>120</sup> USAID. (2013). Addressing Climate Change Impacts on Infrastructure, p. 11.

## Other Critical Facilities

"Critical facilities" are defined as those structures from which essential services and functions for victim survival, continuation of public safety actions, and disaster recovery are performed or provided.<sup>121</sup> For the purposes of this assessment, critical facilities include EMS Stations (3), Fire Stations (12), Hospitals (7), Emergency Operations Center (1), Designated Emergency Shelters (16), Nursing Homes (6), Pharmacies (27), Public Health Office (1), Urgent Care Centers (3), and Veterans' Centers (2)<sup>122</sup>. Some critical facilities, such as airports and water infrastructure, are discussed elsewhere in this assessment. More extreme weather events will make the availability of public health and safety facilities, and the services they enable, even more important.

As a collective, these facilities tend to have moderate to minimal exposure to the mappable climate hazards; usually this is considered when siting these kinds of facilities. However, what might be even more important is the resilience of the infrastructure they rely on – roads and bridges, energy, communications, water. Loss of water to a hospital, if it persists long enough, may result in an evacuation while flooded roads may slow the response time for first responders to reach victims and certain extreme conditions, such as high wind speeds, are unsafe for large response vehicles to operate at all.<sup>123</sup> Often, public safety buildings, hospitals, and nursing homes are required to have emergency power, backup communications, and other redundant systems to minimize impacts.

### Notable Impacts and Vulnerabilities

[Map It \(Explore Online\)](#)

#### Rising Temperature

- 11 of 16 emergency shelters in the region are in heat islands. The availability of air conditioning at emergency shelter locations and identified cooling stations is becoming more important at the confluence of higher temperatures, in general, and more frequent and intense storms that may require the opening of emergency shelters. Designated cooling centers are of additional importance during extreme heat days and possible brown outs.
- Stakeholders note that air conditioning has traditionally not been available at nursing homes in the region but that is changing now. Seniors are among the groups most vulnerable to extreme heat.

Select Emergency Facilities layers and Urban Heat Island Severity

#### Precipitation & Extreme Weather Events

- There is moderate to minimal flood exposure for critical facilities in the region. 3 Fire Stations (all Bangor) and 8 emergency shelters (Bangor, Old Town, Brewer, Veazie, Milford, Indian Island, Hermon, Orono) are located in moderate/minimal flood hazard areas (Zone "X") but still outside the 100-year floodplain.
- Disruptions to power supply could affect climate control in healthcare facilities, which is necessary to maintain a safe environment for people as well as supplies. Excess humidity in surgical settings, for example, can affect instrument

Select Emergency Facilities layers and FEMA Floodplain layers

<sup>121</sup> FEMA. <https://emilms.fema.gov/IS0815/groups/11.html>

<sup>122</sup> Number in parenthesis denotes the number of each facility that were available for GIS exposure scoring

<sup>123</sup> Pennsylvania Department of Health Bureau of EMS (2011). EMS Info Bulletin 2011-12: Wind effects on ambulance vehicles. [https://pehsc.org/wp-content/uploads/2014/05/EMSIB-2011-012\\_Wind-Effects-on-Amb.pdf](https://pehsc.org/wp-content/uploads/2014/05/EMSIB-2011-012_Wind-Effects-on-Amb.pdf)

sterility.<sup>124</sup> If generators are not available for refrigeration at hospitals, pharmacies, nursing homes, and public health offices, temperature sensitive pharmaceuticals, samples, and other supplies could be compromised, causing adverse effects to patients.

### Sea Level Rise & Tidal Flooding

- The public health and safety facilities had no direct exposure to sea level rise/storm surge. However, flooded transportation and other infrastructure is likely to have indirect effects on these facilities and services.

Select Emergency  
Facilities layers and  
Maine Sea Level  
Rise Storm Surge  
Scenarios

<sup>124</sup> Consulting Specifying Engineer Magazine (2019). The Fine Line of Humidity and Healthcare: 4 MEP Engineering Considerations. <https://www.csemag.com/articles/the-fine-line-of-humidity-and-healthcare-4-mep-engineering-considerations/>

---

## 6. Socioeconomic Impacts and Vulnerabilities

---

### Local Economy/Livelihoods

Key demographics and economic indicators for Penobscot County include the following:

- Approximately 150,000 residents in approximately 75,000 housing units
- Median age of 42.2 years
- 19.4% persons aged 65 years and over (vs. 16.9% of the U.S. population)
- 60% of residents aged 16+ in the labor force
- Median household income of \$52,128 (median U.S. income is about \$31,000; median Maine income is about \$57,918)
- Lower-than-average income inequality (0.434 Gini index)
- 13.4% of population below the poverty line

The economy of Penobscot County employs about 74,000 people. The leading industries in Penobscot County are Educational Services (13.4%); Retail Trade (14.5%); and Health Care and Social Assistance (21.6%),<sup>125</sup> representing a shift away from the forest products industry. As such, some of the larger employers are Northern Light Health, St. Joseph Hospital, Penobscot Community Health Care, Husson University (Bangor), and the University of Maine (Orono).<sup>126</sup> However, these organizations employ on the order of several hundred rather than several thousand – most businesses in the area are considered small businesses.<sup>127</sup> Regional stakeholders noted small businesses having a lack of capital to stay open, so costs associated with preparing for climate impacts as well as responding to damage from climate impacts would be significant.<sup>128</sup> The Eastern Maine Development Corporation (EMDC) has many resources for small business owners, such as the Economic Opportunity Response Program, which has trained EMDC point people who facilitate connections between businesses facing challenges and experts who can help. EMDC is very focused on collaboration and partnerships.

Climate change also poses challenges to the region's economy in the form of lost profits and lost wages due to closures and disturbances from climate impacts, as well as supply chain disruptions. These impacts will be most felt in parts of the Penobscot Climate Action Region with less redundancy (e.g., the

---

<sup>125</sup> Penobscot County Emergency Management Agency. (2016). Penobscot County Multi-Jurisdictional Hazard Mitigation Plan, p. 14

<sup>126</sup> Top Private Employers in Maine by Average Monthly Employment 1<sup>st</sup> Quarter 2022. (2022). Maine Labor Department. Retrieved October 19, 2022, from <https://www.maine.gov/labor/cwri/publications/pdf/MaineCountyTop25Employers.pdf>

<sup>127</sup> Regional Stakeholder Interviews

<sup>128</sup> Regional Stakeholder Interviews

only nearby grocery store closes due to air conditioning/food storage issues). Simultaneously, the region faces challenges from an aging population – when the owner of the only pharmacy in the neighborhood retires, the neighborhood is left without access to the services and products the business provided.<sup>129</sup>

## Notable Impacts and Vulnerabilities

Map It ([Explore Online](#))

### Rising Temperature

- Reduced number of winter tourists and seasonal residents as a result of decreased snowpack, leading to losses by businesses and lost tax revenue
- Increased water temperatures and low summer water levels in local streams and rivers negatively impact businesses and lead to lost tax revenue – such as for fishing guides, people working in habitat restoration, and summer tourism.
- Business closures because of extreme heat and lack of air conditioning may lead to losses by businesses and lost wages.
- Owners of both residential and commercial properties may need to invest in air conditioning.
- Outdoor workers may face lost wages because of cancellations due to extreme heat (e.g., Construction, Landscaping).
- Natural resource-based industries may face losses because of temperature increases (e.g., Forestry, Agriculture).
- Food and economic security for members of the Penobscot Nation is impacted by loss of moose, Atlantic salmon, brook trout, and brown ash trees.

Commercial Facilities,  
 Government Facilities,  
 Demographic Datasets,  
 Urban Heat Severity

### Precipitation & Extreme Weather Events

- Business closures because of flooding and storms may lead to losses by businesses and lost wages.
- Downtown Bangor has flooding issues during particularly bad storms. During a stakeholder interview, an interviewee noted that the parking garage in downtown Bangor had flooded right before the interview.
- Hampden is having difficulties in attracting businesses downtown because of the insufficient stormwater system and flooding issues that result.
- Owners of both residential and commercial properties may need to invest in costly repairs before and after flooding/storms - stakeholder interviews revealed that small businesses barely have enough capital to stay open in some instances, and COVID only made that more difficult in the past few years.
- Natural resource-based industries may face losses because of flooding, drought, and storms (e.g., Forestry, Agriculture).
- Power outages as well as losses in internet connectivity have profound effects on many businesses, as can be common during storms.
- Many businesses do not have enough staff members/backups to deal with people calling out of work, say because of

Commercial Facilities,  
 Government Facilities,  
 Demographic Datasets,  
 NLCD Impervious  
 Surface, FEMA  
 Floodplain

<sup>129</sup> Regional Stakeholder Interviews



storms or transportation disruptions.

- Extreme weather events (such as hurricanes, floods, heavy rainfall, and freezes) in other parts of the world cause supply chain disruptions. For example, the Texas freeze of 2021 forced the closure of three major semiconductor plants, which produce essential components of electronic devices used in computing, healthcare, transportation, and clean energy.

### Sea Level Rise & Tidal Flooding

- Some businesses may be impacted by SLR and Tidal Flooding based on their proximity to the Penobscot River, leading to damage and losses by businesses; some businesses may even need to relocate.
- Sea level rise inundates ports and other coastal infrastructure across the globe, causing supply chain disruptions that cause price increases and delays for many goods that get passed on to consumers.

Commercial Facilities,  
Government Facilities,  
Demographic Datasets,  
Maine Sea Level Rise  
Storm Surge Scenarios



## Education, Community, & Culture

Engaging in meaningful activities that align with one's identity and values is essential to overall wellbeing. Stakeholder interviews revealed key values for the Penobscot Climate Action Region, including the following: compassion, cooperation, being neighborly, and appreciating the outdoors through recreation and conservation.<sup>130</sup> (See Section 4. Environmental Vulnerability: Conserved Lands, Parks, Trails, and Recreation for information on outdoor recreation and climate impacts.) This assessment considered the K-12 Schools, Colleges and Universities, Trade Schools, Childcare Centers, Places of Worship, Cross Insurance Center (multi-purpose arena), and Bangor State Fairgrounds. Exposure to high heat, flooding, and extreme weather events threatens community members' ability to access and enjoy the services provided by these sites.

The Penobscot Climate Action Region is home to the state's public research university (with R1 designation) and land-grant university – The University of Maine – in Orono. It enrolls approximately 12,000 students, some of whom participate in Division I athletics. Other large institutions include Husson University, which enrolls about 3,000 students, and Eastern Maine Community College, which enrolls approximately 2,500 students. All contain critical facilities in a range of research areas including aquaculture, biochemistry, biomedical engineering, and environmental policy. The Colleges and Universities have played a large, collaborative role in the state's climate change planning, such as how local professors and researchers are members of the Maine Climate Council and its various subcommittees. Younger students in the region likely attend one of the 43 K-12 schools that were analyzed in this assessment. Schools' and institutions' exposure to high heat will pose a challenge for facilities without cooling systems, may result in school cancellations on extreme heat days, and may drive up costs for facilities that need to be temperature controlled. Athletes engaged in outdoor sports will be more at risk for heat stress during the warm seasons and may face interruptions in winter sports schedules due to decreased snowpack.

All educational institutions, alongside organizations that provide community benefits such as places of worship, will need to prepare for the ramifications of extreme weather events, such as capital improvement costs, communication and power system interruptions, and supply chain disruptions.

### CONSIDERING DISPROPORTIONATE IMPACTS

#### Penobscot Nation and the Cascading Impacts of Climate Change

Within tribal communities in Maine, ecosystems are deeply intertwined with economy, culture, food security, and general well-being. Climate change's impact on biodiversity and water quality in the region has significant implications for Native access to food sources, physical and mental health, and economic and recreational opportunities. When local ecosystems are impacted, tribal communities lose access to food through hunting, fishing, and gathering; shelter materials for dwellings; opportunities for education through the transfer of ecological knowledge; economic opportunities through using natural goods for sale; spiritual support; and much more

According to a recent study conducted in partnership with Maine tribes and the University of Maine, a major concern for the Penobscot Nation is the impact of increased tick infestations on the moose population in the region. The decrease in moose population has negatively impacted economic opportunities for tribal guides and threatens a major food source for families in Native tribes across the state. Similarly, increased water temperature and reduction of overall water quality in the Penobscot River threatens Atlantic Salmon and Brook Trout, both of which are culturally relevant species, and important food sources, to tribes in the region.

Michelle, N., Ranco, D., & Willis, T. (2017). (rep.). BIA Tribal Comprehensive Adaption Planning.

<sup>130</sup> Regional Stakeholder Interviews

## Notable Impacts and Vulnerabilities

Map It ([Explore Online](#))

### Rising Temperature

- Nearly half of the K-12 schools (20/42) are located in urban heat islands (based on a UHI index score of 3 or higher). Capital and operating expenses associated with cooling facilities could strain tight school budgets and compete with other pressing needs.
- 8/40 Childcare Centers are located in urban heat islands (based on a UHI index score of 3 or higher). The very young, like seniors, are more susceptible to heat stress than the population as a whole and air conditioning may not be universally available at centers.
- The Cross Insurance Center is located in an area with a UHI index score of 4, which denotes relatively high urban heat island effect.
- 17/43 Places of Worship are located in urban heat islands (based on a UHI index score of 3 or higher). Places of worship without air conditioning could choose to cancel services on days of extreme heat, out of concern for public health and safety.

All Education layers/Childcare Center layer/Places of Worship layer/Major Sports Venues layer/Convention Centers layer and Urban Heat Island Severity

### Precipitation & Extreme Weather Events

- Educational Institutions do not have significant exposure to flooding, but participants and their caretakers may face flooding-related challenges with regard to their commutes. The Bangor School District educates students from around the region and a functioning transportation system is essential.
- As with Educational Institutions, Places of Worship do not have significant exposure to flooding; however, regional impacts will affect their congregations.

All Education layers/Childcare Center layer/Places of Worship layer/Major Sports Venues layer/Convention Centers layer and FEMA Floodplain layers

### Sea Level Rise & Tidal Flooding

- This vulnerability assessment did not identify any significant community/cultural assets as especially vulnerable to sea level rise and/or tidal flooding.

All Education layers/Childcare Center layer/Places of Worship layer/Major Sports Venues layer/Convention Centers layer and Maine Sea Level Rise Storm Surge Scenarios

## Health

Climate impacts pose a number of serious health risks: high heat/extreme heat, air pollution, aeroallergens, reduced water quality and quantity, water-borne diseases, vector-borne diseases, foodborne diseases, and injury risk. For example, days of extreme heat (considered 90 °F or above) are becoming more common. Bangor is projected to experience 10.5 days per year over 95 °F in the 2050s as compared to its current rate of 3 days per year over 95 °F. Extreme heat causes heat illness (symptoms include fatigue, nausea, cramps, weakness, fainting, and stroke). Increased heat is especially of note for the following populations that are more at risk of experiencing a heat illness: older adults; those with existing health conditions including chronic disease(s); those living in older homes; those without air conditioning; pregnant women; young children; those who are socially isolated; outdoor athletes; those in outdoor work, including agriculture, forestry, outdoor recreation and tourism, landscaping, and construction.

As such, this assessment considered assets necessary to maintaining health and wellbeing, as well as assets necessary for emergency response. Existing health inequities are often furthered by climate change, so special attention was given to populations that may face compounded vulnerability, including: older adults, people with disabilities, people with limited digital connectivity, those living in rural areas, people with existing chronic health conditions, and those with lower or moderate incomes.

According to the Maine Shared Community Health Needs Assessment Report of 2019, some of the top health priorities for Penobscot County are social determinants of health (how socioeconomic factors such as education and access to food affect health); mental health; access to care; physical activity, nutrition, and weight; and older adult health/healthy aging.<sup>131</sup> All are impacted by climate change to some degree, such as how older adults are more vulnerable to heat stroke.<sup>132</sup>

Income is a powerful determinant of health: access to health care, food, and shelter are all dependent on income. Many Mainers do not earn enough to meet their basic health needs, and Mainers with lower incomes have higher rates of chronic disease, such as asthma, diabetes, and cancer.<sup>133</sup> Low-income individuals, people who are geographically isolated, and people with

### CONSIDERING DISPROPORTIONATE IMPACTS

#### Elderly Populations

A significant proportion of Penobscot County's population – almost 20% – is 65 years or older. Seniors face heightened health challenges, including increased fall related injuries, higher rates of chronic illnesses such as cardiovascular disease and diabetes, and increased instances of physical and mental disabilities. Many of these challenges intersect with, and are exacerbated by, experiences of poverty, isolation, and lack of access to adequate transportation or other important services. Because they are less likely to have access to a cell phone or digital resources, and are more likely to be socially isolated, making it more difficult to reach older citizens in case of an emergency. They are at higher risk of illness or death related to extreme temperatures, loss of power after a storm, or loss of access to medication and medical care during and after extreme weather events. Additionally, limited physical mobility or access to financial resources makes it much harder for seniors to relocate during an emergency or afford the cost of recovery. All of these factors make seniors exceptionally vulnerable to the impacts of climate change.

<sup>131</sup>Maine CHNA. (2019). Penobscot County 2019 Maine Shared Community Health Needs Assessment Report, pp. 4-10. <https://www.maine.gov/dhhs/mecdc/phdata/MaineCHNA/documents/county-reports/2019/Penobscot-Report-Web.pdf>

<sup>132</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, pp. 297-321

<sup>133</sup> Pizzonia C, Lichter EL, Teach F, Birkhimer N, Morian-Lozano E. The Way Health Should Be: Social Determinants of Health in Maine 2019. Augusta, Maine: Maine Center for Disease Control and Prevention

disabilities or mobility issues, will also be disproportionately impacted by health risks posed by climate change, as they are at higher risk of not being able to physically access health care centers or afford health care costs.

Penobscot County residents in particular face high barriers to health care access. The 2022 Maine Shared Community Health Needs Assessment for Penobscot County found that, in one 12-month period, 12.3% of adults reported that they could not see a doctor when they needed to. Similarly, 8.8% of individuals were uninsured, and 14.5% of residents needed to travel 30 miles or more to be seen by a primary care provider.<sup>134</sup> Other environmental factors, like exposure to lead, mold, and other toxins, compound the health risks that tens of thousands of Mainers already face due to living in poor housing conditions or in geographic areas with higher levels of contamination.<sup>135</sup> Additionally, people experiencing housing insecurity or homelessness have overlapping health issues that could make them less mobile (in the case of evacuation) and less able to access resources for safety in extreme temperatures (access to the ability to stay cool during extreme heat days) and put them at higher risk of injury or illness in extreme weather events.

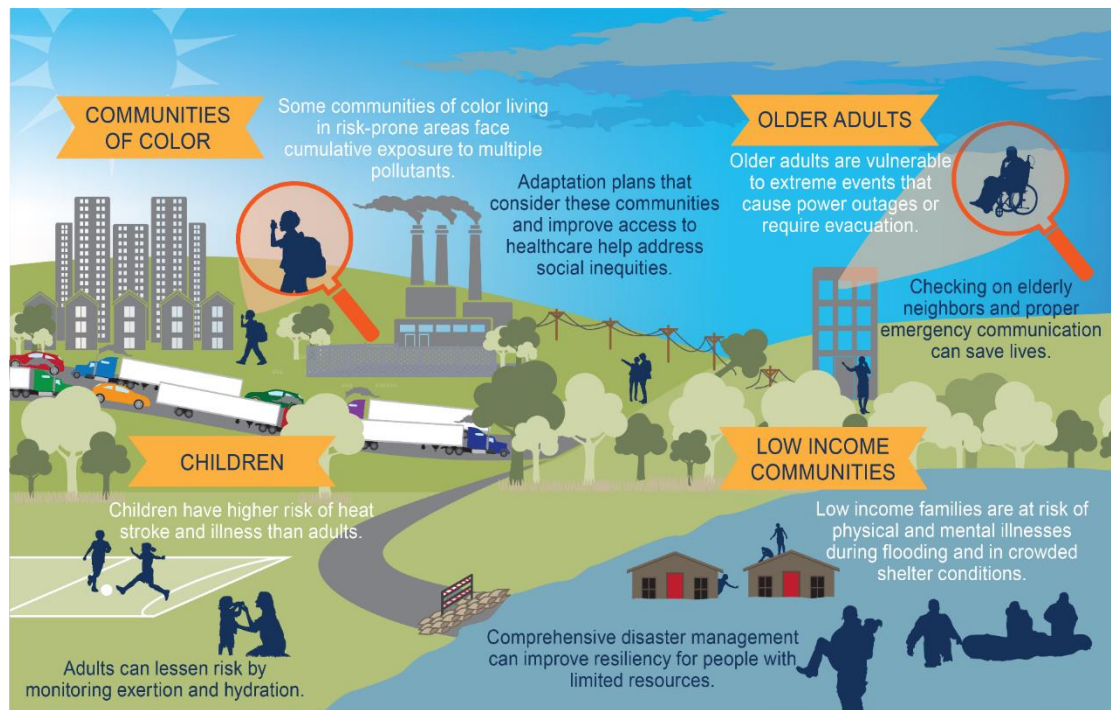


Figure 6.1: Examples of populations at higher risk of exposure to adverse climate-related health threats are shown along with adaptation measures that can help address disproportionate impacts.

Source: National Climate Assessment (2018).

134 Maine Shared CNA (2022) Penobscot County Community Health Needs Assessment Report, p. 13

135 Pizzonia C, Lichter EL, Teach F, Birkhimer N, Morian-Lozano E. The Way Health Should Be: Social Determinants of Health in Maine 2019. Augusta, Maine: Maine Center for Disease Control and Prevention

## Notable Impacts and Vulnerabilities

Map It ([Explore Online](#))

### Rising Temperature

- Many healthcare facilities, including St. Joseph Hospital, Acadia Hospital, and Eastern Maine Medical Center in Bangor, as well as Northern Light Hospital in Brewer, are situated within urban heat islands (UHI levels 3 and 4), which increases electrical demand on these facilities for cooling.
- 6/27 Pharmacies face notable urban heat effect (UHI 4 or above), which could have serious consequences for medication storage in the event of a power outage as well as challenges for those who access those pharmacies by walking or public transit.
- 3/6 Nursing homes face some urban heat effect (UHI 3), which could lead to heat stroke/heat illness concerns for older residents on days of extreme heat.
- Both Veterans' Centers face some urban heat effect (UHI 3).
- There are approximately 10% more all-cause emergency department visits and all-cause deaths on extremely hot days (95 °F), as compared to moderate days (75 °F).<sup>136</sup>
- Exposure to extreme heat has been associated with decreased well-being, reduced cognitive performance, aggression, violence, and suicidality.
- For unhoused residents in the region, lack of access to water is especially dangerous on high heat days.
- While the burden of cold-related illness in Maine is currently higher than the burden of heat-related illness, modeling of heat- and cold-related illness projections for Portland, Bangor, and 207 other US cities suggest that reductions in cold-related impacts will be more than offset by increases in heat-related impacts. For example, one of the projected scenarios shows an annual reduction in Bangor of 12 cold-related deaths, against an increase of 29 heat-related deaths, by 2100.<sup>137</sup>
- Earlier spring arrival and warmer temperatures can increase the duration of the pollen season and can increase the amount of pollen produced by plants, prompting more allergic responses – especially of note for those with preexisting respiratory conditions.
  - Maine lacks a publicly accessible, statewide mechanism for reporting pollen information.
- Rising temperatures are associated with more case numbers and a larger geographic extent of tick-borne diseases such as Lyme disease, anaplasmosis, babesiosis, and Powassan encephalitis virus.
- Warmer surface waters may be associated with outbreaks of waterborne diseases, including vibrio bacteria and harmful algal blooms (HABS), both of which decrease water quality and increase exposure to waterborne illnesses.

Select Emergency Facilities layers, Demographic Datasets, and Urban Heat Island Severity

### Precipitation & Extreme Weather Events

<sup>136</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 297

<sup>137</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 300

<ul style="list-style-type: none"> <li>• 15/27 Pharmacies face low flood risk (FEMA Hazard Zone X).</li> <li>• Extreme weather events, especially extreme precipitation events like coastal storms and nor'easters, are likely to increase in frequency and intensity, leading to increases in storm-related injuries and deaths. Extreme weather events can cause power outages, which are associated with carbon monoxide poisonings and foodborne illnesses.</li> <li>• Increased precipitation (as well as an increased growing season) is associated with larger mosquito populations and increased viral amplification within mosquitoes during spring and summer. This could lead to greater incidence of mosquito-borne diseases such as West Nile virus, Eastern Equine Encephalitis, and Jamestown Canyon virus.</li> <li>• Anxiety, depression, post-traumatic stress disorder, and suicidality have been documented in communities that have been displaced or severely impacted by storms or flooding.<sup>138</sup></li> </ul>	<p>Select Emergency Facilities layers and, Demographic Datasets, FEMA Floodplain layers</p>
--	---

**Sea Level Rise & Tidal Flooding**

<ul style="list-style-type: none"> <li>• This vulnerability assessment did not identify any health assets to be significantly vulnerable to sea level rise impacts and/or tidal flooding impacts.</li> </ul>	<p>Select Parcels and Land Information layers, Demographic Datasets, and Maine Sea Level Rise Storm Surge Scenarios</p>
--	---

<sup>138</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 299

## Housing

Penobscot County is home to approximately 150,000 residents in approximately 75,000 housing units. 70% of housing units are owner-occupied, and the median value of those units is about \$148,000.<sup>139</sup> For renters, the gross rent is \$823.<sup>140</sup> Roughly 85% of residents are living in the same house as the year before. 4% of households speak a language in the home other than English, 91% of households have a computer, 83% of households have an internet subscription, and the average number of cars per household is 2.<sup>141</sup>

When considering the vulnerabilities caused to the housing sector by climate change, major considerations include the ability of homes to withstand climatic changes and the costs associated with improvements that decrease vulnerability, such as waterproofing. Some residents, including those in poverty, those experiencing housing insecurity, and those with lower incomes, often face higher risk of flooding as well as higher exposure to urban heat island effect, alongside the possibility of high costs associated with improvements, damages, and repairs. In this way, climate change affects housing stock, housing affordability, and housing costs such as heating and cooling costs. Additionally, stakeholder interviews revealed that residents of the Penobscot Climate Action Region prefer to endure storms and extreme weather events in their homes rather than shelters, information which only supports increased attention to resilient housing in the region.<sup>142</sup>

Cooling will be of particular importance in the region in light of increasing occurrence of high heat days, as homes in New England (especially older homes) are designed to keep residents warm - not cool - with techniques that promote trapping heat,

---

<sup>139-140</sup> U.S. Census Bureau (2021). QuickFacts: Penobscot County, Maine. Retrieved from <https://www.census.gov/quickfacts/penobscotcountymaine>

<sup>142</sup> Stakeholder interviews

## CONSIDERING DISPROPORTIONATE IMPACTS

### Housing Burden

Stakeholder interviews emphasized that housing – particularly affordability for seniors, low-income families, and people with disabilities - is already a pressing issue in the region. Stakeholders also noted concern about the lack of safe and affordable housing options for the rising number of people experiencing homelessness.

In Bangor, 65.2% of households are unable to afford the average rent for a 2-bedroom apartment.<sup>1</sup> Low-income individuals, people on fixed incomes (like seniors and people with disabilities), and renters are less likely to be able to afford energy retrofits or other upgrades that will make their housing more resilient to climate change impacts before a storm or reduce energy burdens for heating and cooling. Those who lack financial resources to afford repairs, hotels, or relocation costs are at particularly high risk after a storm. Elevating housing to address flooding can reduce accessibility for those with disabilities, but people living in housing with chronic flooding could see increased instances of mold, which can lead to adverse health impacts. As temperatures get more extreme, increases in heating or cooling bills put strain on one's ability to afford rent or mortgage payments. Renters will likely carry a disproportionate burden as, nationally, energy use per square foot is 10% greater for rentals than owner-occupied homes for buildings built after 1980 (35% for buildings built before 1940).<sup>2</sup>

Affordable housing, including mobile homes and public housing, tend to be in areas that are physically more vulnerable to climate impacts, further exacerbating the strain on affordable options that the region is already feeling. A recent report by Climate Central estimates that nearly 50 affordable housing units in Penobscot County will be vulnerable to annual coastal flooding by 2030, with that number projected to quadruple by 2100.<sup>3</sup> The Bangor Waterworks Apartments (a 35-unit affordable housing community) are among the affordable housing units most at risk of being affected by increased instances of flooding. All of these vulnerabilities will be exacerbated by climate change, which overall, leads to greater housing insecurity, risk of displacement, and houselessness.

<sup>1</sup>Maine Housing (2020). Housing Facts and Affordability Index

<sup>2</sup>Carliner, M. (2013). Reducing Energy Costs in Rental Housing: The Need and the Potential. Joint Center for Housing Studies, Harvard University. Research Brief: 13-2.

<sup>3</sup>Climate Central (2020). Struggling Against a Rising Tide: Sea Level Rise and Coastal Flooding Threaten Affordable Housing.



such as dark and steep roofs. Over one-fifth of owned Maine homes were built before 1940, and nearly one-third of rented Maine units were built before 1940 – it wasn’t until the late 1960s that new homes were being built with central air conditioning in the United States.<sup>143</sup> While the national average for air conditioning in homes is 88%<sup>144</sup>, only 56.3% of homes in Penobscot County have air conditioning (as of 2014).<sup>145</sup> On days of high heat, Mainers with air conditioning will likely need to contend with the high costs associated with cooling their homes, while Mainers without air conditioning will face increased risk of heat illness. Hot weather also causes mold issues, foundation and roof deterioration, and warping of floors, especially hardwood. The Maine Climate Council’s Scientific and Technical Subcommittee has identified, “a better understanding of key facilities...such as long-term care facilities without air conditioning around the state as a priority information need.”<sup>146</sup> However, a need for residential improvements and upgrades can coincide with both climate-friendly solutions and low-cost technologies, such as passive cooling techniques alongside energy efficient appliances and systems.

Additionally, attention should be given to climate migration - both in the region and to the region. While this assessment records the climate impacts faced by Mainers living in the Penobscot Climate Action Region, it will experience relatively fewer impacts from sea level rise, flooding, heat, and extreme weather events than some parts of New England and other parts of the United States. As such, this climate-driven movement of people to, and within, the Penobscot Climate Action Region could increase housing and living costs for current residents.

## Notable Impacts and Vulnerabilities

Map It ([Explore Online](#))

### Rising Temperature

- The Maine Housing Authority does not have specific requirements for climate adaptation for some facilities – it can be cost prohibitive to add features such as heat pumps to facilities after the fact.
- 2 Mobile Home Parks are in areas experiencing urban heat island (UHI 3).
- High utility costs are common in older homes, which are more common among low-income owners and renters. Stakeholder interviews revealed that low-income residents (especially older adults on fixed incomes) are not purchasing air conditioning units because of the cost, even though they are becoming essential. Additionally, older adults and those with limited mobility may have an especially difficult time installing the heavy air conditioning units – these groups are faced with either costs after finding someone to install the units or risk of injury from attempting to do it by themselves. The same is true of installing generators.
- Extreme temperatures pose severe threats to people in the region experiencing homelessness. Compounding issues such as substance misuse disorders, mental health, and a preference to be alone make using group shelters and emergency cooling centers a challenge. Providing alternatives that are outdoors and or allow for privacy will better support residents. For example, interviewees mentioned ensuring access to water through fountains or misters and providing private cooled spaces. Further, high utility costs, especially in rental units, make it even more difficult to transition to independent housing.

Select Parcels and Land Information layers, Demographic Datasets, and Urban Heat Island Severity

<sup>143</sup> U.S. Census Bureau (2017). American Community Survey, 5-Year Estimates, via [https://www.mainehousing.org/docs/default-source/policy-research/research-reports/housing-profiles/characteristics-of-housing-in-maine---january-2019.pdf?sfvrsn=5a63a815\\_10](https://www.mainehousing.org/docs/default-source/policy-research/research-reports/housing-profiles/characteristics-of-housing-in-maine---january-2019.pdf?sfvrsn=5a63a815_10)

<sup>144</sup> Barrone, Emily (2022), These 5 Charts Show Just How Much the U.S. Relies on Air Conditioning, Time Magazine. Retrieved from <https://time.com/6209442/air-conditioning-america-reliance/>

<sup>145</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 300

<sup>146</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 316

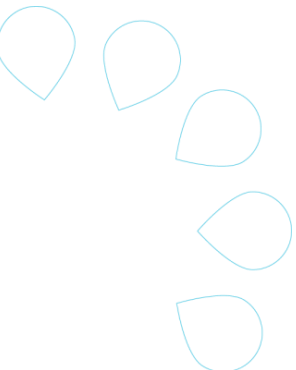
<ul style="list-style-type: none"> <li>Stakeholder interviews revealed that it has become more common to cut down trees to prevent any damage from falling trees during storms. However, a lack of shade trees leads to more urban heat.</li> <li>Heat can damage properties, resulting in costly financial losses for homeowners.</li> </ul>	
---	--

**Precipitation & Extreme Weather Events**

<ul style="list-style-type: none"> <li>The cost of flood insurance will continue to rise.</li> <li>Flooding can cause significant damage to personal property, resulting in costly financial losses for homeowners. Stakeholder interviews revealed that Northern light has noticed more damage from flooding to patients’ homes as well as facilities.</li> <li>1 Mobile Home Park is in the 100-Year Floodplain, and 2 are in the 500-Year Floodplain.</li> <li>Extreme weather events (especially windstorms) cause power outages and internet/broadband outages, which stakeholder interviews revealed are common in some communities, even on days without apparent weather concerns.</li> <li>Unhoused residents of the region noted that many people experiencing homelessness have multiple overlapping vulnerabilities (e.g., health, disability, mental health, substance misuse disorders) that make it particularly hard for them to be in group shelters, and hard for them to get around during extreme weather. Both are challenges that will increase for this portion of the population.</li> </ul>	<p>Select Parcels and Land Information layers, Demographic Datasets, and FEMA Floodplain layers</p>
--	---

**Sea Level Rise & Tidal Flooding**

<ul style="list-style-type: none"> <li>Those located near the tidal portions of the Penobscot River system may experience tidal flooding, which can cause significant damage to personal property, resulting in costly financial losses for homeowners.</li> </ul>	<p>Select Parcels and Land Information layers, Demographic Datasets, and Maine Sea Level Rise Storm Surge Scenarios</p>
--	---



## Food Security

Mainers consume primarily imported food – approximately 90% of Maine food is brought in from out of state.<sup>147</sup> As such, Mainers are especially vulnerable to global supply chain disruptions caused by climate change, as they are more reliant on imports than local food economies for personal food consumption.

Of all the New England states, Maine ranks 1<sup>st</sup> in food insecurity, meaning that many Maine households find themselves with a lack of financial resources to consistently purchase the food needed for an active, healthy life.<sup>148</sup> Food insecurity is often not the result of limited available food, but rather uneven distribution of resources. Of the Mainers facing food insecurity, one-third live in Cumberland and Penobscot Counties.

Within the Penobscot Climate Action Region, many low-income or food insecure residents rely on gardening, hunting, fishing and foraging to supplement their food supply. All of those activities increased during and post-COVID19 pandemic. However, all of these activities are at risk of lower yields/take-home from both gradual climatic changes and extreme events.<sup>149</sup>

Per the Penobscot County Hazard Mitigation Plan, the major threats to food security are severe winter storms, specifically snowstorms. Snowstorms make it difficult for residents (especially remote and isolated residents) to access food and fuel for themselves, and feed, water, and shelter for their livestock.<sup>150</sup> Some of the worst winter storm damages came from an ice storm – the Great Ice Storm of 1998 – leading to massive power loss and food spoilage.<sup>151</sup> Ice storms are another type of winter storm where rain freezes on impact, creating a coating at least one-fourth inch in thickness, leading to damaged trees and overheard wires, alongside other issues. Extreme rainfall events are also associated with power outages - which make it difficult to access food and cause food spoilage. Alongside more extreme weather events of all types, more days of extreme heat will also make it more difficult to access food stores and food banks – especially for those who walk. Extreme heat can also lead to power outages and disruptions, affecting safe storage of food.

---

<sup>147</sup> Maine Climate Council Scientific and Technical Subcommittee. (2020). Scientific Assessment of Climate Change and its Effects in Maine, p. 16

<sup>148</sup> What is food insecurity in America? Hunger and Health. (2022, May 5). Retrieved October 19, 2022, from <https://hungerandhealth.feedingamerica.org/understand-food-insecurity/>

<sup>149</sup> National Food Access and COVID Research Team (2021). Home Food Production and Food Security Since the COVID-19 Pandemic.

<sup>150</sup> Penobscot County Emergency Management Agency. (2016). Penobscot County Multi-Jurisdictional Hazard Mitigation Plan, p. 105

<sup>151</sup> Penobscot County Emergency Management Agency. (2016). Penobscot County Multi-Jurisdictional Hazard Mitigation Plan, p. 120

## Notable Impacts and Vulnerabilities

Map It ([Explore Online](#))

### Rising Temperature

- More frequent high heat days will increase cooling costs for food access points such as grocery stores.
- More frequent high heat days will also make it more difficult for people to get to food access points if they use public transportation or walk to those destinations.
- Increased heat can lead to higher occurrence of food spoilage and food-borne pathogens.
- Increased temperatures lead to new pests, water scarcity, and decreased crop yields. Then, global supply chain disruptions can cause limited availability of certain goods as well as rising food prices.
  - Stakeholder interviews revealed that affording food is already difficult for older adults in the region. Food prices are already rising. There are resources in the region to support those who are food insecure, but the resources appear to be insufficient for the number of people needing assistance.

Public Refrigerated Warehouses, Demographic Datasets, Urban Heat Island Severity

### Precipitation & Extreme Weather Events

- Regional food distribution could be disrupted by road closures during extreme weather events/emergencies as well as disruptions after said events because of damages.
- Supply chain disruptions can cause food costs to rise, which could increase food insecurity among lower-income residents in the region.

Public Refrigerated Warehouses, Demographic Datasets, NLCD Impervious Surface, FEMA Floodplain

### Sea Level Rise & Tidal Flooding

- Sea level rise inundates ports and other coastal infrastructure across the globe, causing supply chain disruptions that cause price increases and delays for many goods that get passed on to consumers.
- Food access points located close to the tidal regions of the Penobscot River system may be affected by sea level rise and tidal flooding.

Public Refrigerated Warehouses, Demographic Datasets, Maine Sea Level Rise Storm Surge Scenarios

## 7. Additional Considerations

### Social Vulnerability

The CDC's Social Vulnerability Index (SVI) is an important indicator of Penobscot Climate Action Region citizens' vulnerability to disease, natural disasters, and economic health.

The SVI indicates how prepared a community is to prevent human suffering and financial loss in the event of a disaster.<sup>152</sup>

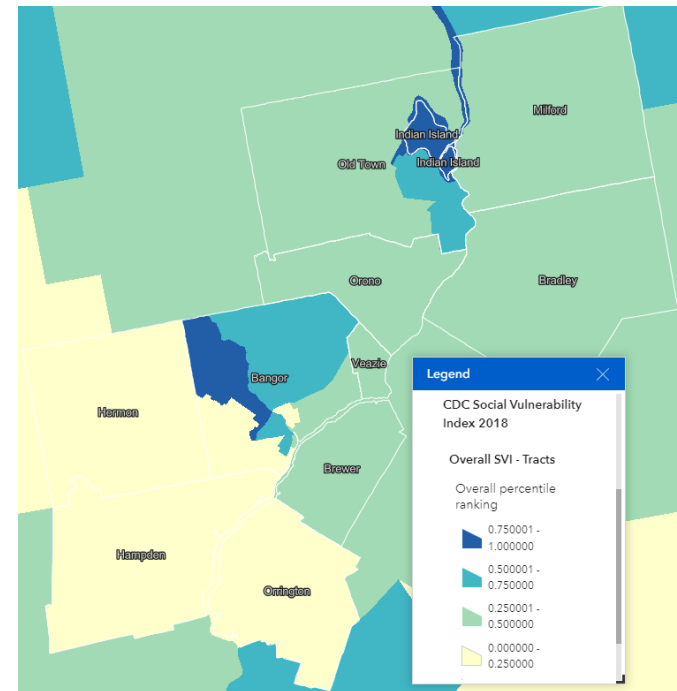
The SVI scores range from 0 (lowest vulnerability) to 1 (highest vulnerability). As of 2018, Penobscot County's SVI score was 0.4532, which indicates a low to moderate level of vulnerability.

The main driver of social vulnerability in Penobscot County is Housing Type and Transportation.

<sup>152</sup> CDC SVI 2018 Documentation. (2020, January 31). CDC's Social Vulnerability Index (SVI). (n.d.). Retrieved August 25, 2022, from [https://svi.cdc.gov/Documents/Data/2018\\_SVI\\_Data/SVI2018Documentation.pdf](https://svi.cdc.gov/Documents/Data/2018_SVI_Data/SVI2018Documentation.pdf)

### CDC Social Vulnerability by Census Tract

**Social vulnerability** refers to the potential negative effects on communities caused by external stresses on human health. Such stresses include natural or human-caused disasters, or disease outbreaks. Reducing social vulnerability can decrease both human suffering and economic loss. Darker blue areas represent census tracts that are more likely than the national average to require support before, during, or after a disaster.



## Land Cover

The National Land Cover Datasets shows the overview of the composition of the Penobscot Climate Action Region. The majority of the region is covered by evergreen and mixed forests. Open space, wetlands, farm fields, and forests provide the region a valuable service of storing carbon.

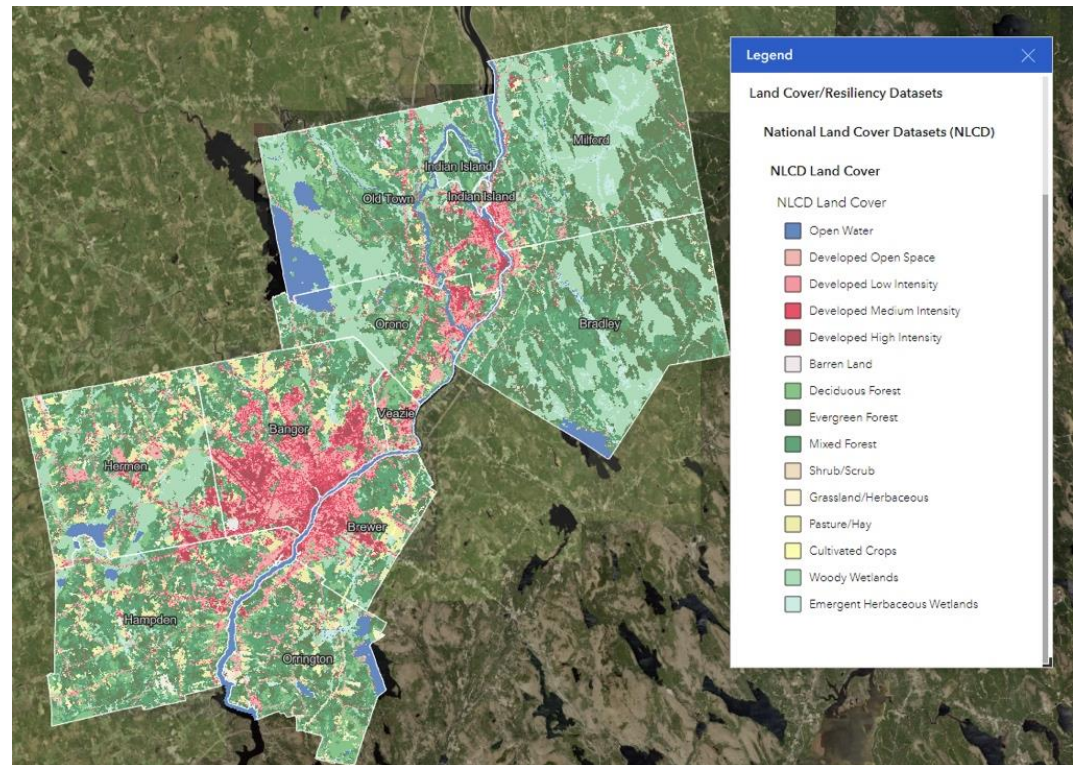
Densely developed areas around the Bangor, Brewer, Orono, and Old Town area has led to deforestation in those communities. The loss of open space in these cities means a loss of carbon storage as well. Therefore, the region is not able to offset their carbon emissions as effectively.

More developed communities' often correspond with urban heat islands. In addition to the human health impacts caused by excess heat, continued warming prompts a need for more energy to keep buildings cool.

Areas that are more developed also have a larger relative portion of impervious surfaces, which makes them more vulnerable to flooding associated with runoff from heavy precipitation events.

## National Land Cover Datasets (NLCD)

The National Land Cover Datasets provide nationwide data on land cover and land cover change at a 30m resolution with a 16-class legend.<sup>153</sup> The green shading on the map shows the different forested areas in the region. Red shading indicates developed area.



<sup>153</sup> Multi-Resolution Land Characteristics Consortium. (2019). NLCD Land Cover 2019 CONUS Land Cover. <https://www.mrlc.gov/viewer/>

## Resilient and Connected Lands

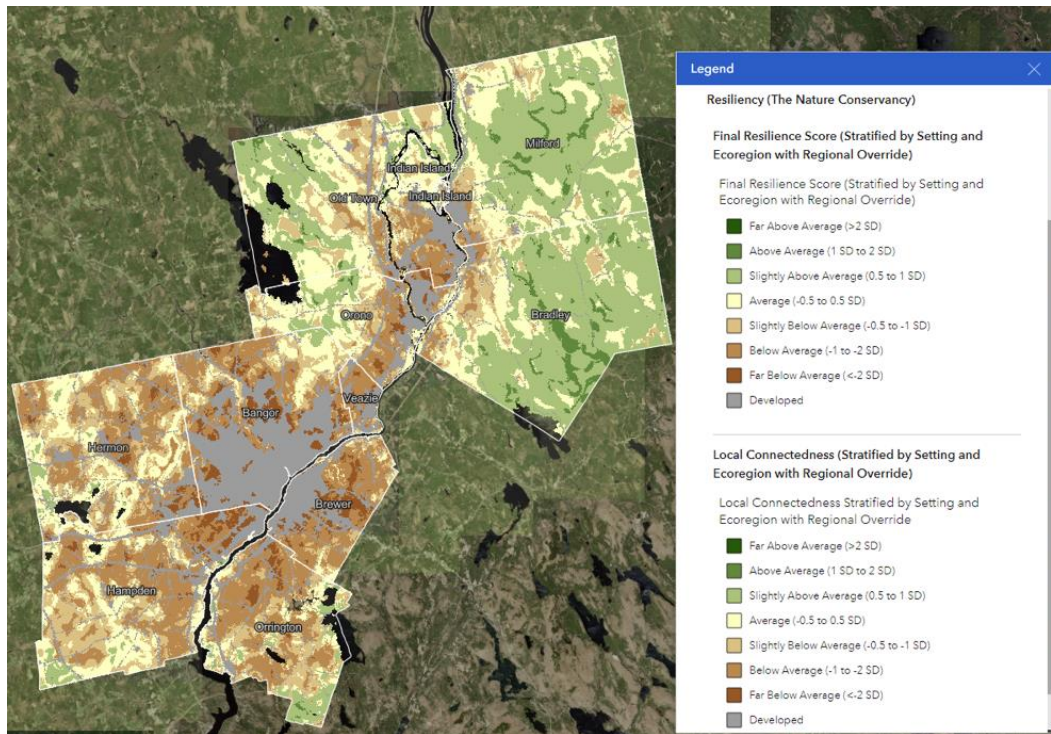
The Nature Conservancy's Resilient and Connected Landscapes project, which led to the Resilient and Connected Lands Mapping Tool, allows users to view an area's most resilient sites and most significant climate corridors.

The Penobscot Climate Action Region interactive map viewer contains data from the project on two dimensions for any specific area or "ecoregion": one score that represents the area's resilience, and one that represents local connectedness.

As such, it is an important tool to assess the region's environments' resiliency to impacts from climate change, and it illuminates where to protect land to maintain connected habitats.

## The Nature Conservancy's Resilient and Connected Land Mapping Tool

The Nature Conservancy's Resilient and Connected Land Mapping Tool allows users to pinpoint climate-resilient environments and confirm biodiversity locations and species movement. Dark brown areas indicate where there is low resiliency – typically, these areas are located within the more densely developed communities. These areas also often score very low for connectedness because of barriers, such as roads and large buildings. Green areas indicate high resiliency and connectedness. This is because there is more open space, and natural habitats are not fragmented by development and infrastructure. These areas provide many services against climate change, such as ambient cooling, and habitat for native species which outcompete invasive species.



---

# Acknowledgements

---

This Penobscot Climate Action baseline assessment project was managed by the Bangor Area Comprehensive Transportation System (BACTS) in partnership with the City of Bangor and Town of Orono.

## **Project Management Team**

Anja Collette, City of Bangor  
Sara Devlin, BACTS  
Dan Dixon, University of Maine  
Meghan Hess, Town of Orono  
Madeline Jensen, BACTS  
Courtney O'Donnell, City of Bangor  
Belle Ryder, Town of Orono

## **Project Interns**

Mary O'Flaherty, University of Maine/BACTS  
Sara Delaney, University of Maine/BSC Group  
Robert Cade King, University of Maine/BSC Group  
Gabriella Wiegman, University of Maine/BSC Group

## **Consultant Team**

BSC Group, Inc. (Climate Vulnerability Assessment Lead)  
Linnean Solutions (Community Engagement Lead)  
Integral Group (Greenhouse Gas Inventory Lead)  
Scouter Design (Design Lead)

**Special thanks** to the following individuals and organizations who participated in interviews or otherwise provided valuable time, data, and information that informed this assessment:

## **Penobscot Climate Action Communities**

City of Bangor: Laurie Linscott, Anne Krieg, Steve Bolduc, John Theriault, Josh Saucier, Rich May, Amanda Smith, Patty Hamilton, Jenny Doyle  
Town of Orono: Sophie Wilson, Kyle Dexler, Rob Yerxa, Kevin Sirois  
Town of Bradley: Melissa Doan  
City of Brewer: Linda Johns, Jeremy Caron  
Town of Hampden: Amy Ryder  
Town of Hermon: Scott Perkins  
Town of Milford: Sarah Commeau  
City of Old Town: EJ Roach, Karoline Bass  
Town of Orrington: Chris Backman, Benjamin Birch  
Town of Veazie: Mark Leonard, Chuck Applebee  
Penobscot Indian Nation: David Pardilla, Darren Ranco

## **Additional Partners and Contributors**

University of Maine: Sean Birkell, Mike Schwartz, Stewart Harvey, Kenneth Doiron, Donna Coffin  
Bangor Area Comprehensive Transportation System: Evan King  
BACTS Policy Committee Members  
Bangor Land Trust: Lucy Quimby  
Bangor School District: Ray Phinney  
Community Residents: Dominick Rizzo, Harris Madson, Steven Morin  
Eastern Area Agency on Aging: Tabatha Caso  
Eastern Maine Development Corporation: Vicki Rusbult  
Maine Department of Transportation: Taylor LaBrequé, John Devin  
Maine Emergency Management Agency: Samuel Roy  
Northern Light: Kathy Knight, Tim Doak, Paul Howe, Melissa Stuart  
Orono Land Trust: Adam Toothaker  
Penobscot County Emergency Management: Bradley Nuding  
Penquis: Steve Richard  
US Cybersecurity and Infrastructure Agency: Thomas "TJ" Swensen, Jr.  
Erik DaSilva, Bicycle Coalition of Maine  
Residents, Community Housing of Maine<sup>154</sup>

---

<sup>154</sup> Residents did not wish to provide names



---

# Appendices

---

## Appendix A: GIS-based Asset Exposure Scores

Exposure scores are available in an Excel workbook at: <https://www.penobscotclimateaction.org/reportsandresources>

## Appendix B: Regional Map Data Layer Index

The following is a list of data layers, by group, in the regional map viewer to assist users with navigating the layers menu.

Layer Name	Layer Name	Layer Name	Layer Name
<b>Bangor/Orono Features</b> <ul style="list-style-type: none"> <li>Bangor Trails</li> <li>Bangor Open Space</li> <li>Critical Assets</li> <li>Bangor Utilities: Stormwater/Sewer</li> <li>Orono/Veazie Water District Features</li> </ul>	<b>Communications</b> <ul style="list-style-type: none"> <li>AM/FM Transmission Towers</li> <li>Cellular Towers</li> <li>Paging Towers</li> <li>Land Mobile Broadcast Towers</li> <li>TV Analog Station Transmitters</li> </ul>	<b>Government Facilities</b> <ul style="list-style-type: none"> <li>Courthouses</li> <li>Department of Defense Facilities</li> <li>Correctional Facilities</li> </ul>	<b>Environmental Features (con't)</b> <ul style="list-style-type: none"> <li>Maine High Value Plant and Animal Habitats</li> <li>Maine Wetlands Characterization</li> </ul>
<b>Commercial Facilities</b> <ul style="list-style-type: none"> <li>Banks</li> <li>Industrial/Manufacturing</li> <li>Child Care Centers</li> <li>Shipping Facilities</li> <li>Places of Worship</li> <li>Major Sports Venues</li> <li>Convention Centers and Fairgrounds</li> </ul>	<b>Energy</b> <ul style="list-style-type: none"> <li>Electrical Substations</li> <li>Power Plants in the US</li> <li>Petroleum Terminals</li> <li>Petroleum, Oil, and Lubricants Terminals</li> <li>Natural Gas Receipt Delivery Points</li> <li>Natural Gas Compressor Stations</li> <li>Non-Gasoline Alternative Fueling Stations</li> <li>EPA Facility Interests</li> <li>National Inventory of Dams</li> <li>Dam Lines</li> <li>Electric Power Transmission Lines</li> <li>Natural Gas Liquid Pipelines</li> </ul>	<b>HazMat, Wastewater, &amp; Chemicals</b> <ul style="list-style-type: none"> <li>Wastewater Treatment Plants</li> <li>Solid Waste Landfill Facilities</li> <li>EPA Sites/Facilities</li> </ul>	<b>Parcels and Land Information</b> <ul style="list-style-type: none"> <li>BACTS Town Boundaries</li> <li>Oher Town Boundaries</li> <li>Parcels</li> <li>Conserved Lands</li> <li>Native Lands</li> </ul>
<b>Education</b> <ul style="list-style-type: none"> <li>Schools</li> <li>Colleges and Universities</li> <li>Technical/Trade Schools</li> <li>Truck Driving Schools</li> </ul>	<b>Food and Agriculture</b> <ul style="list-style-type: none"> <li>Public Refrigerated Warehouses</li> <li>Poultry Processing Facilities</li> </ul>	<b>Transportation</b> <ul style="list-style-type: none"> <li>Proposed Bus Stops</li> <li>Airports</li> <li>Bridges</li> <li>Boat Launches</li> <li>Large Culverts</li> <li>Cross Culverts</li> <li>Amtrak Stations</li> <li>Community Connector Bus Routes</li> <li>Intermodal Freight Facilities Pipeline</li> <li>Railroads</li> <li>Runways</li> <li>Public Roads</li> </ul>	<b>FEMA Floodplain</b> <ul style="list-style-type: none"> <li>100-year</li> <li>500-year</li> </ul>
<b>Emergency Facilities</b> <ul style="list-style-type: none"> <li>Hospitals</li> <li>EMS Stations</li> <li>Urgent Care Facilities</li> <li>Pharmacies</li> <li>Veterans' Health Facilities</li> <li>Nursing Homes</li> <li>Public Health Offices</li> <li>Fire Stations</li> <li>Local Emergency Operations Centers</li> <li>National Shelter System Facilities</li> </ul>		<b>Mobile Home Parks</b>	<b>Coastal Tidal Data</b> <ul style="list-style-type: none"> <li>Coastal Undeveloped Blocks – 1m SLR</li> <li>Current Tidal Marshes</li> <li>Tidal Marsh Potential Migration</li> <li>Maine Sea Level Rise Storm Surge Scenarios</li> </ul>
		<b>Environmental Features</b> <ul style="list-style-type: none"> <li>Vernal Pool Centerpoints</li> <li>Significant Vernal Pools</li> <li>Tidal Waterfowl and Wading Bird Habitat</li> <li>Endangered Threatened and Special Concern</li> </ul>	<b>Urban Heat Island Severity for US Cities</b>
			<b>Land Cover/Resiliency Datasets</b> <ul style="list-style-type: none"> <li>National Land Cover Dataset – Land Cover, Canopy, Impervious Surface, Cropland</li> </ul>
			<b>Demographic Datasets</b> <ul style="list-style-type: none"> <li>CDC Social Vulnerability</li> <li>ACS – Income, Language, Disability</li> </ul>

## Appendix C: Regional Stakeholder Interviews Summary

A sample interview presentation is available at:

<https://www.penobscotclimateaction.org/reportsandresources>

### Eastern Maine Development Corporation (9/15/22)

- Vulnerable assets – roads, housing stock, last mile broadband, see notes
- Majority of businesses in the area are small or medium.
- This means that they don't have bigger staffing resources to draw from, if someone is out sick, quits, etc. → Vulnerability
- Smaller businesses may be struggling to stay open, hard to invest in long-term planning unless get additional support
- People want to hear about climate projections from local partners rather than outsiders
- EMDC is visiting communities and talking about 'what they can do now'
- EMDC has climate resiliency in its 5-yr plan, and now has a climate change question in its business needs assessment. Other relevant projects mentioned.

### Transportation System Managers (9/16/22)

- Vulnerable assets – older and already damaged roads, bridges
- The goal of the transportation services is to get people

where they need to go safely and efficiently. Public transportation is working to remove barriers in people's lives.

- More frequent or more intense storms can make it harder for these services to achieve those goals – with more detours, schedule changes, inability to clear ice/snow quickly enough, power outages
- The bus/paratransit workforce is small and can't adjust to big swings in demand from cancellations and rescheduling
- Concern about capital needed to make adjustments and improvements
- Intertown coordination for adaptation and mitigation strategies will be important

### City of Bangor (9/19/2022)

- Economy – working to create employment opportunities
- Vulnerable assets – only enough money and supplies to keep up with current infrastructure needs, operating more reactively than preventatively. Upgrading critical infrastructure over-time.
- Need more redundancy and flexibility in the infrastructure
- High heat days and drought lead to issues in the water systems – chloramines break down, and not enough water flow in pipes
- Maine is very water rich, so will not want to follow the same trend in water regulations as much of the rest of the country – can be an issue since appliances and

other infrastructure now being designed for water-saving

- Regulations – Bangor area has stricter environmental/safety regulations for industry than some other areas, and businesses have chosen to relocate because of this, will continue to do so

### **BACTS Policy Committee Workshop (9/20/22)**

#### **Breakout Group 1:**

- Highlighting vulnerability of infrastructure to flooding, in particular bridges and culverts, and need to upsize
- Hampden has particularly old stormwater infrastructure and it has prevented some business from wanting to locate in the area, which is hard given they want to attract more business
- Orono highlighted issue with residents not wanting change or too much development and need to align their priorities with development plans
- DOT rep highlighted need for better coordination between DOT and municipalities, in particular when it comes to stormwater

#### **Breakout Group 2:**

- Similar conversation about need to update infrastructure to deal with future rain events, and update older roads
- Some projects have had maintenance deferred, for example in Orrington, which is an issue
- Suggestion that town need to have the DOT and DEP engineering standards updated to align with the needed design changes

- Town planners have a bigger challenge because they are used to making 5-yr plans based on expected challenges vs budget, and now there is more variability

#### **Breakout Group 3:**

- It was suggested that Bangor needs to upgrade aging or insufficient infrastructure and ensure that essential services and systems have a high level of redundancy.
- Traffic signals, roads, and drainage infrastructure are all vulnerable to more damages in a future climate more extreme than today's.
- More interruptions to the public transportation schedule could cause issues for people who rely on it to access essential goods and services.
- Emphasis was placed on being able to prioritize which assets & vulnerabilities should be addressed first.
- Traffic and transportation infrastructure needs more redundancy
- Bangor has no designated location for emergencies capable of housing and caring for large quantities of people. This may be something to address in the event of a crisis in the future.
- Maine may see an influx of heat refugees or simply people seeking a moderate climate and less natural hazards (climate refugees). It may be wise to develop a plan so that the City is prepared if such a population boom were to occur.
- Also, it was suggested that changes should be systemic, addressing vulnerabilities and issues at their root. For example, minimizing motor vehicle traffic by

implementing new alternative transportation infrastructure and making Bangor more walkable. This could reduce traffic, road wear and tear, and emissions simultaneously.

- One of the biggest concerns was simply that it is difficult to predict how long new infrastructure will last. There is a sense that everything must be almost overbuilt to accommodate more extreme weather and ensure infrastructure lasts as long as it used to.

#### **Bangor Public Health Department (9/23/22)**

- Vulnerable people they work with include low-income, uninsured, house-bound, unhoused
- Increase in new diseases such as Lyme disease can hit uninsured since they don't go to regular preventative care visits and just visit the clinics
- Power outages and high heat days – public health department DOES set up shelters and cooling areas, but are designed for 1-2 days and not more
- Power outages leave some vulnerable, including those in apartments in Bangor. Sometimes landlords register as one address/bill with Versant so the power companies don't know it has many residents and don't see the building as a priority unless the PH team alerts them
- Suggest that public health needs to work with the city to incentive landlords to add cooling as well as better insulate houses/apartment buildings
- Bangor is the only public health department in the area, so they do get calls from all over, but can't

support much outside of the city unless they have a special grant

#### **Bangor and Orono Land Trusts (9/23/22)**

- The Land Trusts have conservation as their primary objective, however the public often views the areas as recreational. This works fine as it is a way for the public to connect with conservation through recreation.
- Risks mentioned include flooding, wind downing trees and invasive species.
- They are starting to plan for the future with flood plans, as well as working to conserve more contiguous land
- Both presidents see the land trusts as a potential launching point for climate change communication and conversation with the community, and they would like to be involved in this.

#### **Agriculture/UMaine Extension (9/26/22)**

- Biggest change she has seen is longer dry periods and more drought. More farmers are needing to add irrigation, and more will need to do so.
- You can't 'paint the region with a broad brush' when looking at climate impacts to farms, there are too many microclimates and variation in topography. So each farm needs to consider the risks of their site, and work with advisors to plan.
- Farmers have also adapted, and those that want to continue farming will continue to do so.

### **Northern Light Health (9/27/22)**

- Northern Light is a very large healthcare network, the 2<sup>nd</sup> largest in the state. We tried to focus on their facilities in the Bangor region.
- They strive to provide a continuum of care and have a very integrated system with many parts.
- They have a working group on Climate Change/Resilience which is made up of interested/volunteer staff people from across the organization. Everyone in the interview is a member of this group
- The hospitals depend on the infrastructure of the surrounding area – including roads, power, telecommunications, public transport
- Hospital needs to have complete redundancy in their systems, and they are continuing to work on building and maintaining that
- They think of their assets in three categories – space, staff and stuff
- Need the time and money to prepare for changing climate challenges
- They have observed some changes, including increase in homelessness, behavioral health issues, increased flooding on riverbanks affecting the homeless, vector-borne diseases, high-heat related admissions

### **Community Members/ Focus on Aging (9/28/22)**

- Elderly community members may also be disproportionately affected by increasingly extreme weather events.

- They are more vulnerable to health complications associated with high heat days, icy conditions, etc.
- They may be isolated in their homes for longer periods of time or more frequently if they have concerns about going outside because of the weather.
- They are also at greater risk of experiencing emergencies or health issues during power outages caused by more frequent extreme storms
- They may struggle to afford and install air conditioners and generators on their own
- Many elderly Mainers will often refuse assistance or resources because they feel that somebody else needs aid more than they do.
- Also, because most communication is digital now, many seniors are unaware of the assistance available to them. Print media is still essential to communication with elderly people.
- Lack of community involvement and interaction can decrease public visibility of the struggles faced by elderly people.
- Fostering a sense of community encourages neighborly deeds and inter-reliance between community members. This can be especially helpful to seniors in need and can make a municipality more resilient overall.
- There were many concerns over the lack of affordable housing in the region for both seniors and the public

more broadly.

- The interviewees suggested encouraging intra-neighborhood communication through simple measures like building front porches.
- Additionally, they suggested minimizing exposure to the elements for all community members by ensuring that there are adequate street trees for shade.

### **County Emergency Management (9/30/22)**

- Although most communication is faster now than ever, there is increasingly less time to prepare for weather events because storm systems are more erratic and more difficult to predict (in terms of both severity and trajectory). This is a problem that is especially prevalent for Maine because of the way the jet stream behaves at this latitude.
- However, climate projections are better than ever. Communities need to continue developing comprehensive plans to address climate change and severe weather events based on the best available data.
- Facilities and buildings are often old, out of date, or inefficient. Such assets must be updated so that they are no longer vulnerabilities.
- In order minimize impacts during emergencies, it is essential that communities increase redundancy of all basic systems. Everything either needs to have a backup or a failsafe.
- Access to capital is the biggest obstacle that practically every community must overcome in order to adapt to

climate change.

- Climate hazards, risks, and challenges must be properly communicated to the public so that they can prepare for emergencies on an individual level too.

### **Town of Orono (10/5/22)**

- The largest concern is aging drainage & stormwater infrastructure. Even if climate change weren't occurring, the current infrastructure would struggle to manage stormwater during heavy precipitation events.
- The town of Orono relies heavily on sub-terraneous stormwater systems that are quite old (turn of the 20<sup>th</sup> century.) In contrast, more rural municipalities tend to rely on ditches and above ground systems.
- With more intense and frequent precipitation on the horizon, this infrastructure must be replaced to prevent damage to assets and safety issues.
- Stormwater infrastructure that cannot manage the amount of water that it receives can not only result in damage to other assets, but the stormwater infrastructure itself can be damaged.
- There are also concerns about how drought may affect the town's response to emergencies. When a drought does occur, the Penobscot River is swiftly affected. The lower water levels during a drought can lead to issues with launching boats and obstacles for the swift water rescue team during emergencies.
- Power outages are increasingly becoming an issue. When a storm downs powerlines or trees, the

emergency department is quickly overwhelmed because they must ensure that all of the fallen trees and power lines are managed properly to prevent further injury.

- The emergency department is not equipped to handle live wires. So, they can only block off areas around them and wait for the electricity provider to fix it.
- Flooding is less common in Orono now than it once was (prior to the removal of the Veazie dam), but it still does occur on some roads and poses safety concerns.
- There is also no designated emergency shelter location in Orono, which may be an issue in the event of a crisis in the future. However, Orono emergency management has set up heating and cooling centers previously on the UMaine campus.

### University of Maine (10/5/22)

- Aging utility infrastructure seemed to be the primary concern of all of the interviewees.
- More than 50% of UMaine's infrastructure has a renovation age of 50+ years old. It is not well-equipped for climatic changes.
- Some specific vulnerabilities are:
  - The steam plant which supplies ~90% of the campus' buildings with heat is at risk of flooding. There is a plan to expand the steam plant and move vulnerable components out of harm's way
  - The Orono substation is essentially at its maximum capacity. There is a plan to

replace it. However, there is other electrical infrastructure in need of being upgraded

- The campus electricity supply is via on two different electrical substations. 1/3 of the campus is fed power via the Orono substation. So, if Orono loses power, 1/3 of the UMaine campus also does.
- Some campus fuel is delivered via truck. Because the campus is on an island, there are limited points of entry: 3 bridges to be exact. One of which is load limited and cannot handle the weight of large fuel trucks.
- At any given time on campus millions, if not billions of dollars of research are occurring. UMaine also houses countless pieces of highly specialized and sensitive equipment, volumes of data, and priceless resources (such as sediment cores and Antarctic ice cores) which are all at risk of being damaged during power outages.
- Some assets have their own backup systems. These are not necessarily widespread.
- Although new buildings and housing are needed, they place even more strain on the campus electrical grid and other utility systems.
- So, the campus' utility infrastructure must be upgraded all around to accommodate the growth.
- The biggest barrier to adaptation is access to capital, time, and staff.



### **Unhoused Residents / Community Housing of Maine (10/6/22)**

- We spoke with two adults who are living in a transitional subsidized apartment building owned by Community Housing of Maine, and who have been homeless for significant periods of time
- Many people who are unhoused or in and out of housing have overlapping issues including health problems, being overweight, being old, and not being very mobile. Many also have some mental health challenge – sometimes exacerbated by drug use or addiction. This makes them particularly vulnerable.
- Indoor and group shelter set-ups are a challenge for many homeless, given the above. Many do not want to be around others for any long period of time.
- Suggestions included more outdoor or private heating and cooling when possible.
- Also more outdoor drinking water
- Increases in cost of living and cost of housing/building materials are hitting both the low-income/homeless, as well as the agencies trying to support them.

### **Outdoor Recreation (10/7/22)**

- Warming temperatures have a big impact on fish species and fish health. In particular as river waters warm, and changes in snow melt influences river flow.
- Both Atlantic Salmon and Brook Trout are unique to Maine, are vulnerable to changing climate, and are a very important aspect of Maine’s outdoor recreation

economy

- Interviewees shared that they think the MDIFW needs to do more with habitat conservation if we are going to be successful in saving these fish species, citing some other models and partnership ideas.
- Other important recreation includes paddling, and cross-country skiing, both of which are also vulnerable to changing climate.
- Bangor airport and the city of Bangor are the key launch point for all recreation in northern Maine, as well as the northern coast (Acadia NP and surrounding area). This means that any decline in this tourism will hit the whole economy here.

### **Bangor School District (10/14/22)**

- Bangor schools are strong in many areas, including STEM, and made some improvements to student tech during/post pandemic.
- Heat - Many older buildings that don’t have AC; Holding summer practices in early morning/late evening to avoid heat.
- Schools are also vulnerable to power outages.
- Transportation – construction on roads within Bangor increases travel time, and some students travel from further away to attend Bangor schools so need roads to be in good condition
- Provide free meals for all students – can’t rely on consistent supply chain; have to change menus
- Cost of construction is going up and contractors are in demand so time to complete projects is getting longer