Sagadahoc Region, Maine

Climate Change Adaptation Plan

Manomet Center for Conservation Sciences

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May 2013

Cover photo by Steve Walker

Contents

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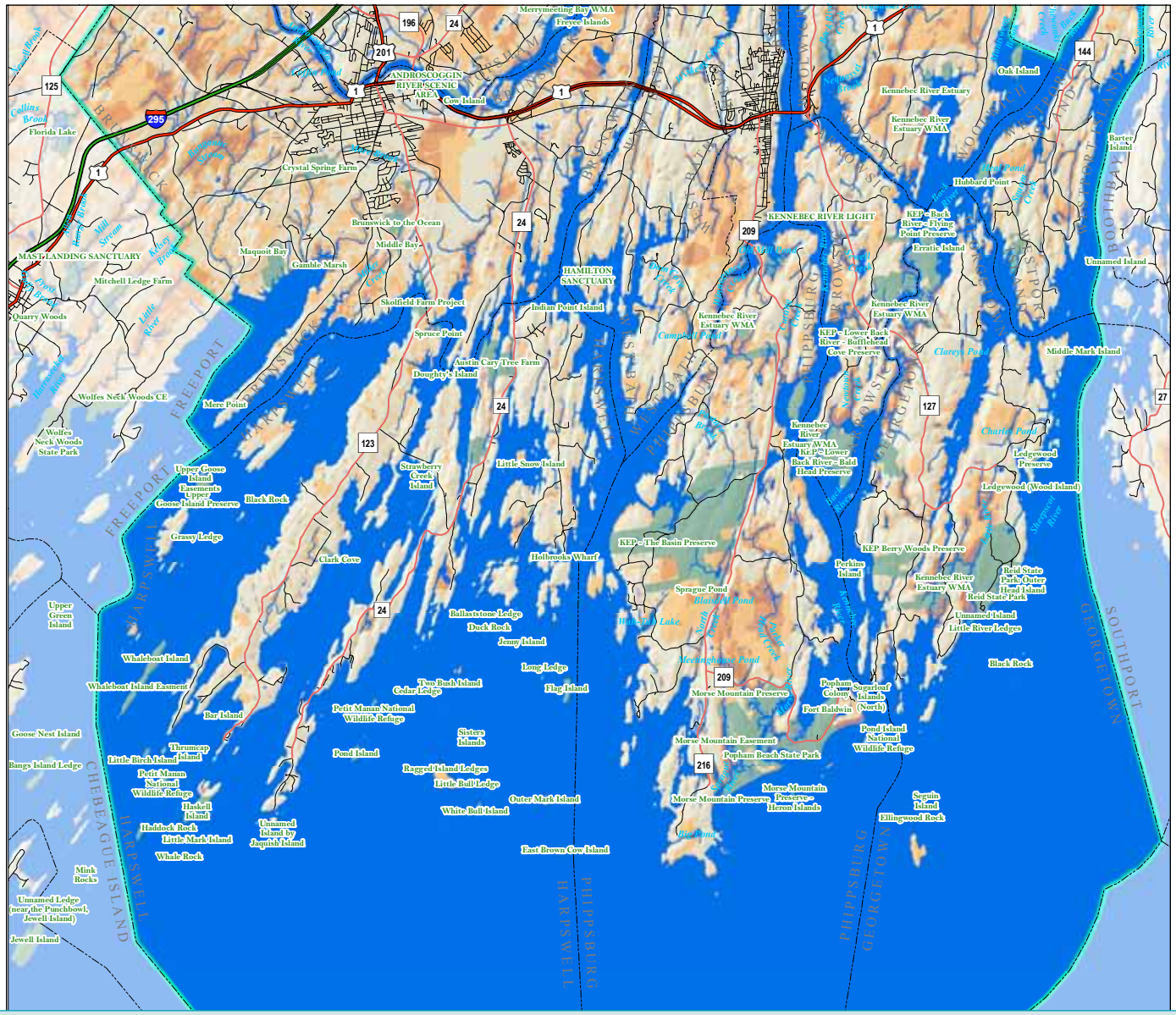
Executive Summary

Adapting to climate change in the Sagadahoc region will be a multifaceted endeavor with planning and implementation required at both the local and regional scales. At the regional scale, a shared vision of a resilient landscape will be essential to informing local planning and development decisions. In an effort to build on previous regional planning initiatives and add climate change considerations to the analysis, Manomet Center for Conservation Sciences analyzed riparian resources, important habitat areas and prime farm land to identify the regional green infrastructure network depicted in Maps 1-4. The green infrastructure network for the Sagadahoc region is a starting point for local and regional decisions on adapting to climate change. Refining development controls to protect high priority conservation lands will support resiliency to freshwater flooding and nonpoint source pollution, minimize exposure of new development to sea level rise, enhance biodiversity and support food security for the region. The Sagadahoc region has a significant opportunity for climate smart planning in that the relatively intact natural landscape provides valuable adaptation services at little or no cost. Health and safety benefits and minimization of tax burden are available to the communities of the region if they work together to protect a functional green infrastructure network as future development takes place.

- High priority for protection from development
- Moderate-high priority for protection from development
- Moderate priority for protection from development

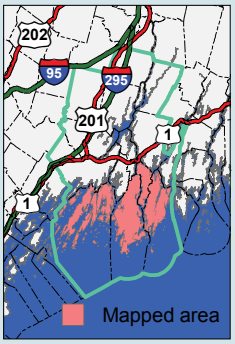


MAP 1

- Town boundary

Roads

- Interstate
- U.S. route
- State route
- Local road
- Sagadahoc area boundary
- Lakes/ponds/wetlands
- Streams
- Wetlands
- Conserved land



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MAP 1

Components

	THEME/SUBTHEME WEIGHT
COMPONENT 1	
Riparian areas NWI Wetlands including all wetland types, not buffered, *(all equally weighted, combined using a Boolean OR with* NHDFlowlines, Area, and Waterbody including all types, not buffered, *(combined using a Boolean OR with)* TNC's Active River Area (ARA) consisting of non-source water cells	1
COMPONENT 2	
Unfragmented habitat & forest Undeveloped habitat blocks, unfragmented forest blocks *(all equally weighted, combined with simple linear sum)*	1
COMPONENT 3	
Significant wildlife habitats Inland wadingbird waterfowl habitats, tidal wadingbird waterfowl habitats, seabird nesting islands, deer wintering areas, significant vernal pools, shorebird roosting areas, shorebird feeding areas, brook trout habitat *(all equally weighted, combined with simple linear sum)*	1
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Rare/exemplary communities Critically imperiled natural community, imperiled natural community, rare natural community, A/B rank exemplary community *(all equally weighted, combined with simple linear sum)*	1
COMPONENT 4	
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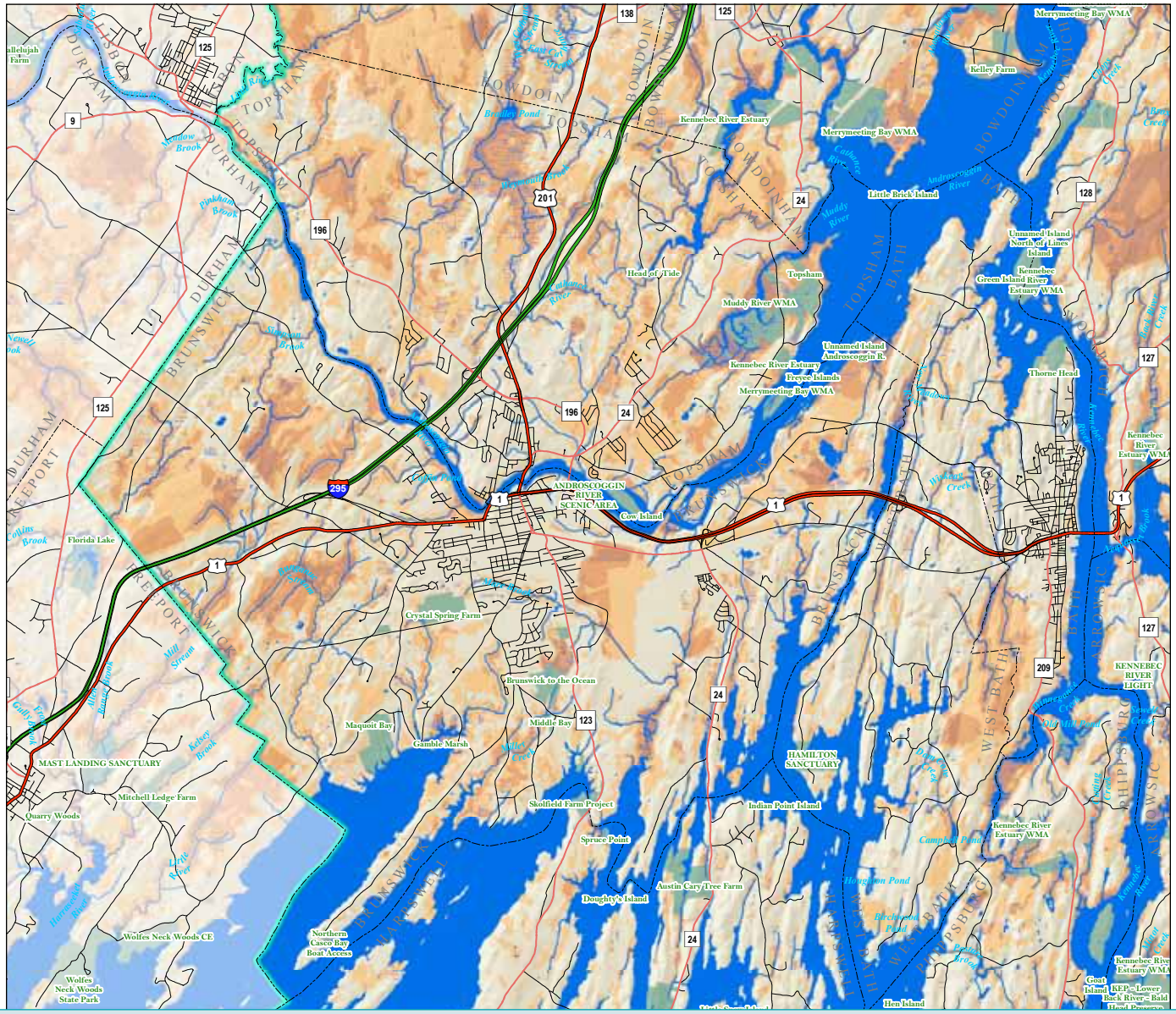
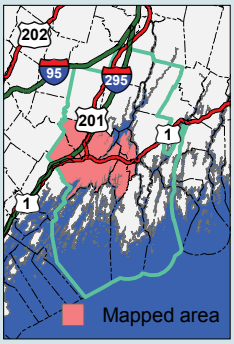


MAP 2

- Town boundary

Roads

- Interstate
- U.S. route
- State route
- Local road
- Sagadahoc area boundary
- Lakes/ponds/wetlands
- Streams
- Wetlands
- Conserved land



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Map 3: Sagadahoc Region Green Infrastructure for Bowdoin, Bowdoinham, Dresden, and Richmond

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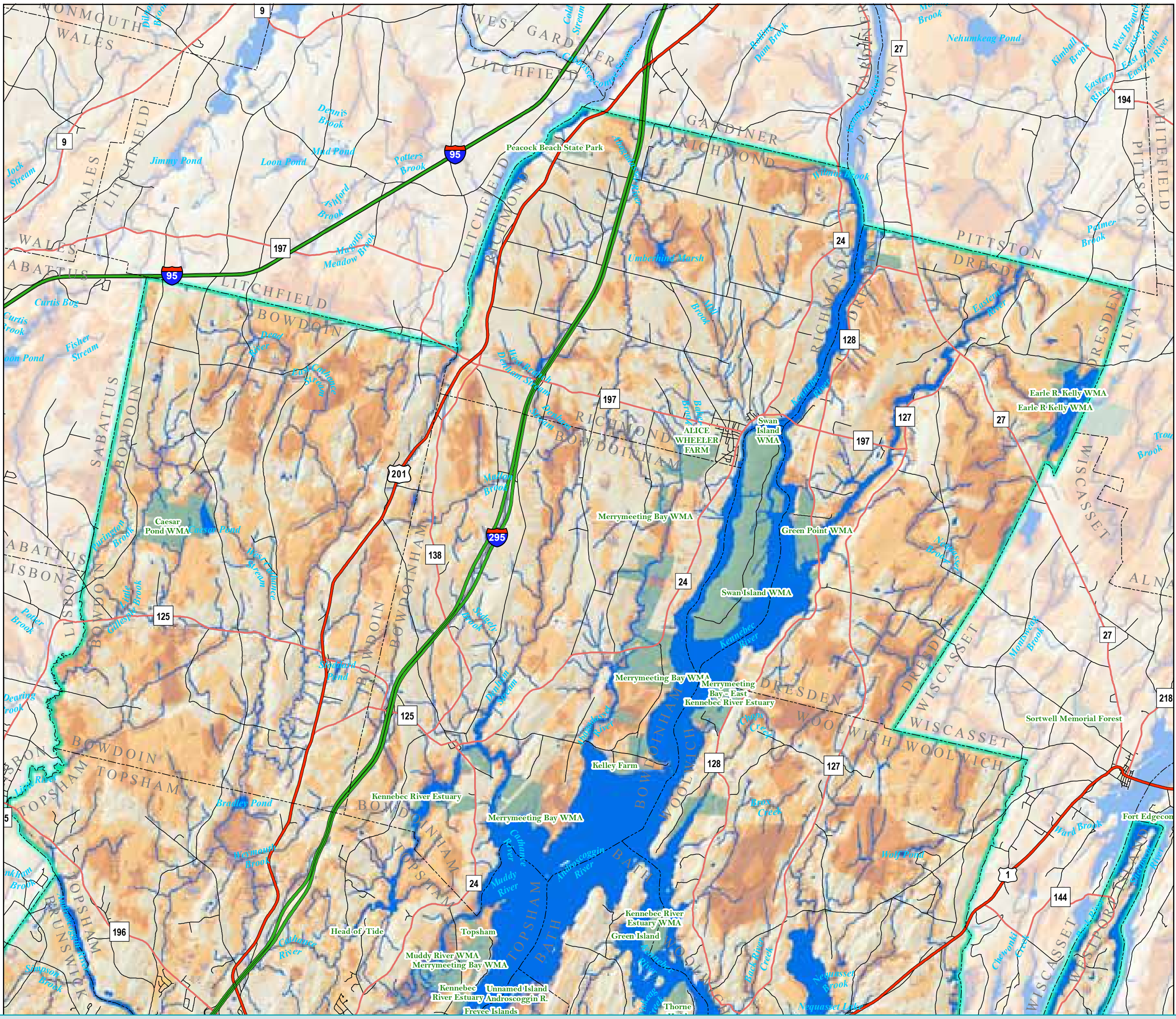
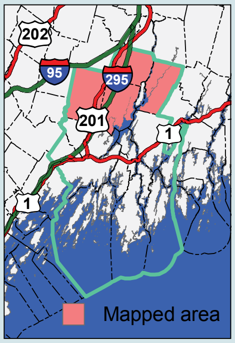


MAP 3

- Town boundary

Roads

- Interstate
- U.S. route
- State route
- Local road
- Sagadahoc area boundary
- Lakes/ponds/wetlands
- Streams
- Wetlands
- Conserved land



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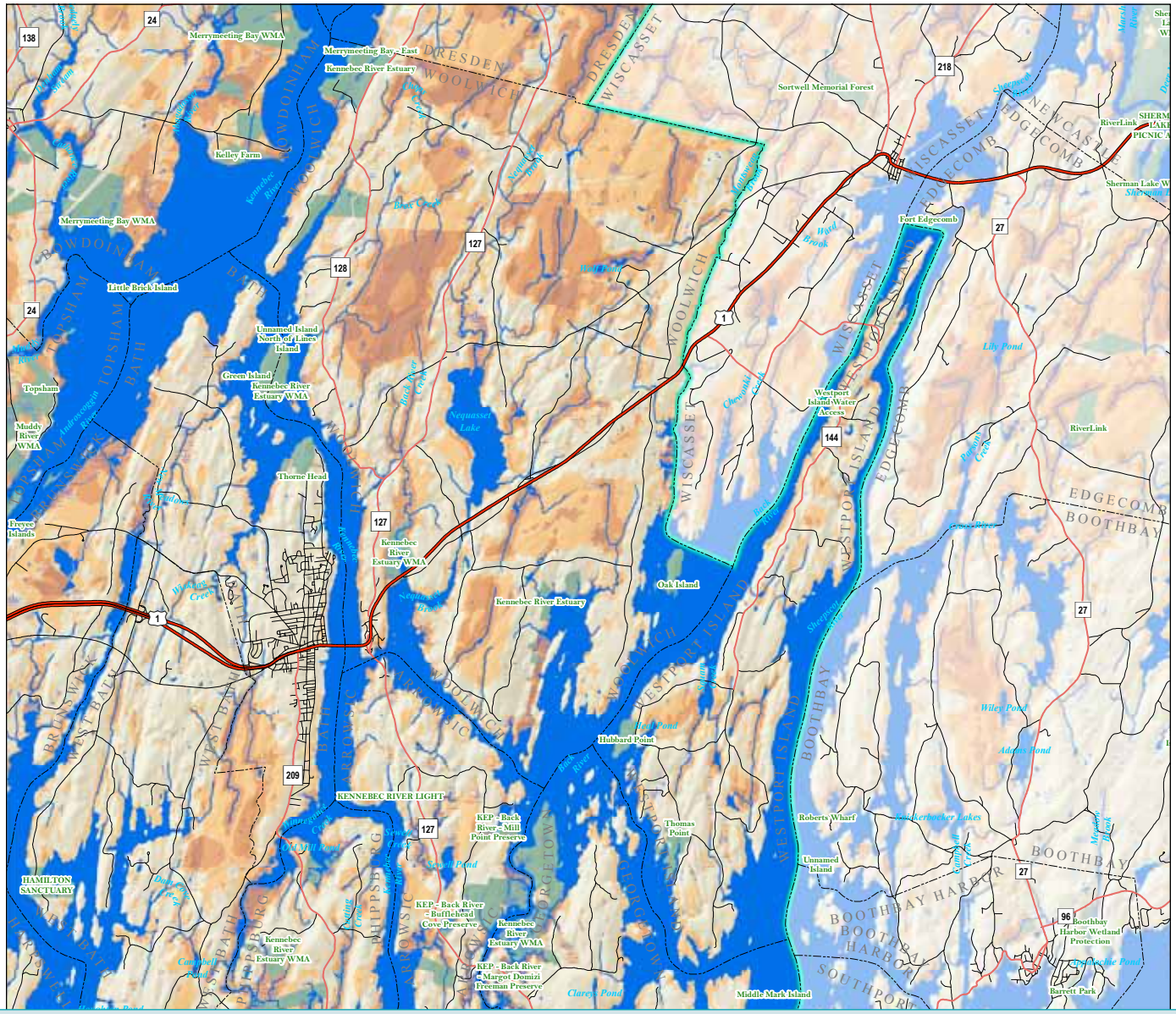


MAP 4

Town boundary

Roads

- Interstate
- U.S. route
- State route
- Local road

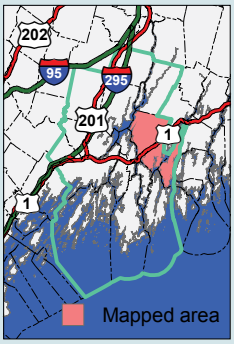
Sagadahoc area boundary

Lakes/ponds/wetlands

Streams

Wetlands

Conserved land



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MAP 4

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Introduction

The Sagadahoc Region of Maine

THE GREATER SAGADAHOC REGION: AN ABUNDANCE OF NATURAL DIVERSITY

The name "Sagadahoc" comes from the native Abenaki, meaning, "mouth of the big river." The natural landscape of the greater Sagadahoc region (Map 5) is defined by its water, freshwater and tidal, and features two of Maine's largest rivers, the Androscoggin and the Kennebec. These meet with four smaller rivers, the Cathance, Muddy, Eastern, and Abagadasset, and form the vast, unusual, and biologically diverse inland freshwater delta of Merrymeeting Bay. Merrymeeting Bay teems with biological diversity, supporting significant habitat for migratory fish and birds. Merrymeeting Bay drains south through the narrow, fast-moving Chops, down the Lower Kennebec River and to the ocean.

In part because of its extensive and varied waterways, connections to the sea, and relatively limited development, the region is host to an unusually high concentration of rare, threatened, and endangered species and habitat types. The region is laced with freshwater wetlands, largely untapped groundwater, and hundreds of streams. The southern portion of the greater Sagadahoc area boasts hundreds of miles of dramatic rocky coast, innumerable coastal islands, salt marshes, and two long, sandy beaches, a rarity along Maine's rocky coast. The extensive mudflats of the region are home to abundant shellfish, the near coastal waters evidence a thriving lobster population with thousands of colorful lobster buoys, and the sparkling Gulf of Maine with its rich fishing heritage stretches beyond. The greater Sagadahoc region includes two Focus Areas of Statewide Ecological Significance.[1]

The Sagadahoc region's diversity continues in settlement patterns as well as governance. From dense downtowns, to big box commercial sectors, to wooded and rural, to sprawling residential communities, the region's built environment is is very diverse. To the north, Richmond's historic downtown enjoys a growing connection to its Kennebec waterfront. Outside of Dresden's quaint main street, organic farm fields nestle between the Kennebec and Eastern Rivers. Bohemian Bowdoinham with its eclectic town center and organic farms sits atop the rich alluvial soils of Merrymeeting Bay, south of which bustles the shopping malls and multi-lane roads of Topsham. Over the Androscoggin is the region's largest community, the commuter and college town of Brunswick, then southeast and down the peninsulas to the waterfront views and homes of Harpswell. To the east, sparsely inhabited West Bath lacks a town center, while just to its east the City of Bath is home to the most densely populated downtown district in the region and the largest employer, Bath Iron Works. Over the Kennebec lies Woolwich, another largely rural residential town with a small historic center. The southern coastal fingers of Phippsburg, Georgetown, Arrowsic and Westport Island stretch into the sea, sparsely settled around areas of historic trade.

A proud tradition of local governance: Maine towns have broad decision-making authority and are responsible to set their own future goals and zoning under Maine law. The Sagadahoc region illustrates diversity here as well. The more populous municipalities of Topsham, Bath and Brunswick have adopted a Town Council form of government, with numerous town services and professional staff. The majority of towns in Maine and in the Sagadahoc region have the traditional New England town meeting form of government.

Development Patterns and Conserved Lands

The two main population centers of the region are Brunswick and Bath. Map 6 shows the population distribution in 2010. Housing density increase during the period of 1990 – 2010 was concentrated along the Route 1 corridor as shown in Map 7. Significant new housing development also occurred in the Harpswell area along Routes 100 and 24. Map 8 highlights local growth areas as designated in the region's comprehensive plans. Finally, Map 9 shows the conserved lands in the Sagadahoc region.

Stakeholder Involvement

Manomet hosted an initial stakeholder workshop on May 17, 2011 in Brunswick to initiate discussion of climate change adaptation priorities. Approximately 60 people participated in the workshop and break-out discussions. Presentations covered a wide range of topics including regional conservation priorities, climate variability and Maine's landscape, impacts of sea level rise, and infrastructure and climate change. Over lunch, in six small working groups, participants identified future development, increased precipitation, and sea level rise as their priority areas for adaptation planning, with one group also noting that projected future water scarcity outside of Maine should make water policy a priority as well. A second stakeholder workshop was held in Brunswick in November of 2012 to review the results of the local government survey and discuss the preliminary findings from the adaptation planning process.

Local Government Survey

Assessing local trends: Manomet conducted a series of in-depth interviews with the 14 towns' planning and/or codes enforcement staff, many Town Managers, and some Selectmen and Planning Board members to gain insight on planning capacity and local development controls. The interviews utilized a questionnaire with a broad range of questions on community resources, planning initiatives, zoning ordinances and voluntary mechanisms that will help shape future landscapes. The results of the survey showed a significant disparity in the planning capacity of the region's localities. The surveys were conducted between November 2011 and June 2012.

PLANNING:

- All fourteen towns have adopted or are in the process of adopting Comprehensive Plans.
- Five towns have professional full-time or part-time Planners on staff.
- Two towns assess development impact fees.
- Numerous other local plans (Open Space, downtown, area master plans) have been completed, but with limited implementation.

ZONING:

- Nine towns have a zoning map that is consistent with their Comprehensive Plan, but only three towns have a zoning map with a designated growth area. Most towns have adopted zoning that is consistent with the existing pattern of development, rather than an attempt to create a more densely developed center or extending the development pattern of their existing town center;
- Three towns have mandatory conservation subdivision requirements for larger subdivisions;
- Two towns offer bonus density to encourage greater open space set aside during development.

STORMWATER AND SEA LEVEL RISE:

- The majority of towns employ only state standards for storm water and phosphorous control. Only one town requires storm water or erosion control measures for individual residences.
- No town regulations require Low Impact Development techniques.
- No town has a storm water utility fee or fund. Two towns require third party review to ensure that storm water control requirements are properly constructed;
- Ten towns experienced flooding from storms over the past several years, with some experience with coastal flooding. Some towns were aware that a regional land trust is exploring challenges to stream and storm flow through culverts, but no town has a program in place to systematically address blockage or inadequate flows caused by culverts;
- Only three towns review shoreline stabilization proposals, although they are not certain whether they can or ever would deny them. No town limits development or redevelopment in floodzones at the local level.
- Of the ten towns with coastal frontage, only one town has discussed the potential impacts of Sea Level Rise. No town has begun to plan for these impacts.

INTACT HABITATS AND UNFRAGMENTED FOREST LANDS:

- Four towns have created Open Space Plans
- Only two towns have adopted fees or other novel approaches to fund land conservation, and neither town has actually implemented their approach;
- Only two towns have adopted zoning overlays to effect some habitat protection outside of areas required by state-mandated Shoreland Zoning;
- Two towns have mandatory Conservation Subdivision zoning, and those same two towns give bonus densities to encourage additional conservation;

ENERGY CONSERVATION:

- Eight towns had adopted the PACE program to enable town residents to participate in the state energy savings low cost loan program;
- No town offered any local incentives for energy efficiency;
- Two towns had either sustainability or energy conservation committees, although no implementation had yet occurred;
- One town had some preliminary planning focused on climate change.

The results of the survey underscore the diversity in both levels of staffing and planning approaches among the localities of the Sagadahoc region. Unfortunately, the Sagadahoc Region Rural Resource Initiative, which was intended to develop a cohesive regional approach to natural resource protection, is no longer active. Reestablishment of a regional planning process is a needed next step in moving towards protection of the attributes that make the region special.

Related Planning Efforts

Manomet Urban Forestry Initiative

Manomet is working with local communities in Sagadahoc County, Maine to develop and evaluate strategies for using urban forests to adapt to climate change and evaluate opportunities for generating non-harvesting revenue through ecosystem service markets. Manomet is partnering with the city of Bath, local land trusts (Brunswick-Topsham Land Trust and Kennebec Estuary Land Trust), the New England Forestry Foundation, and private land owners to quantify how much urban forests help safeguard communities from climate change impacts, identify and evaluate "climate-smart" management strategies that can reduce risk of climate change impacts to urban forests and communities, and explore the feasibility of ecosystem service markets to fund climate change adaptation projects.

There is currently little research assessing the role that urban forests can play in reducing risks associated with climate change. The project goal is to help communities use their urban forest resources to safeguard against climate change impacts. Manomet has three strategies for achieving this goal: (1) use existing tools to assess how urban forests can help safeguard communities from impacts of climate change; (2) build and disseminate guidance information that can reduce risk of climate change impacts to urban forests and communities; and (3) explore ways of using ecosystem service markets to help financially support climate change adaptation of urban forests.

The project area includes the City of Bath and nearby communities in Sagadahoc County, Maine. The area is well positioned to advance urban forestry as a municipal-level tool for adapting to climate change. Bath is a small city of about 10,000 people ranging from high-density housing and retail units in its core to small farms and forestlands at its periphery. The city employs an urban forester and has a forestry committee, an active forest outreach program, and a sustainability manager. It maintains an inventory of 6,000 street-side trees and 14,000 public trees and has completed a STRATUM analysis. Bath citizens have demonstrated a commitment to climate change issues by forming an energy committee, conducting a greenhouse gas (GHG) emission inventory, and approving a Climate Action Plan.

Core activities include:

- Conducting a Threats Assessment: Identify, assess, and summarize threats posed by climate change and other stressors to City of Bath and the region's urban forests, community forests, and green infrastructure.
- Summarize urban forest and green infrastructure strategies to improve the capacity of urban forests to reduce impacts of climate change.
- Work with land trusts and the City of Bath to revise their management plans to include climate-smart management strategies for safeguarding urban and community forests
- Create a how-to document titled: Creating climate-smart management plans for northern urban forests, A case study from Bath, Maine
- Determine options for using carbon markets to pay for urban and community forest conservation

Bath, Maine Climate Change Adaptation Plan

A climate change adaptation plan was developed for Bath, Maine in 2011.[2] The risk assessment identified a projected increase in pests and invasive species, ocean acidification, and an increasing water pollution threat associated with changing precipitation patterns as important issues for Bath. Recommended adaptation actions include development of an action plan for invasive species, enhancement of urban forest management and further evaluation of sea level rise impacts on downtown infrastructure.

Management Goals

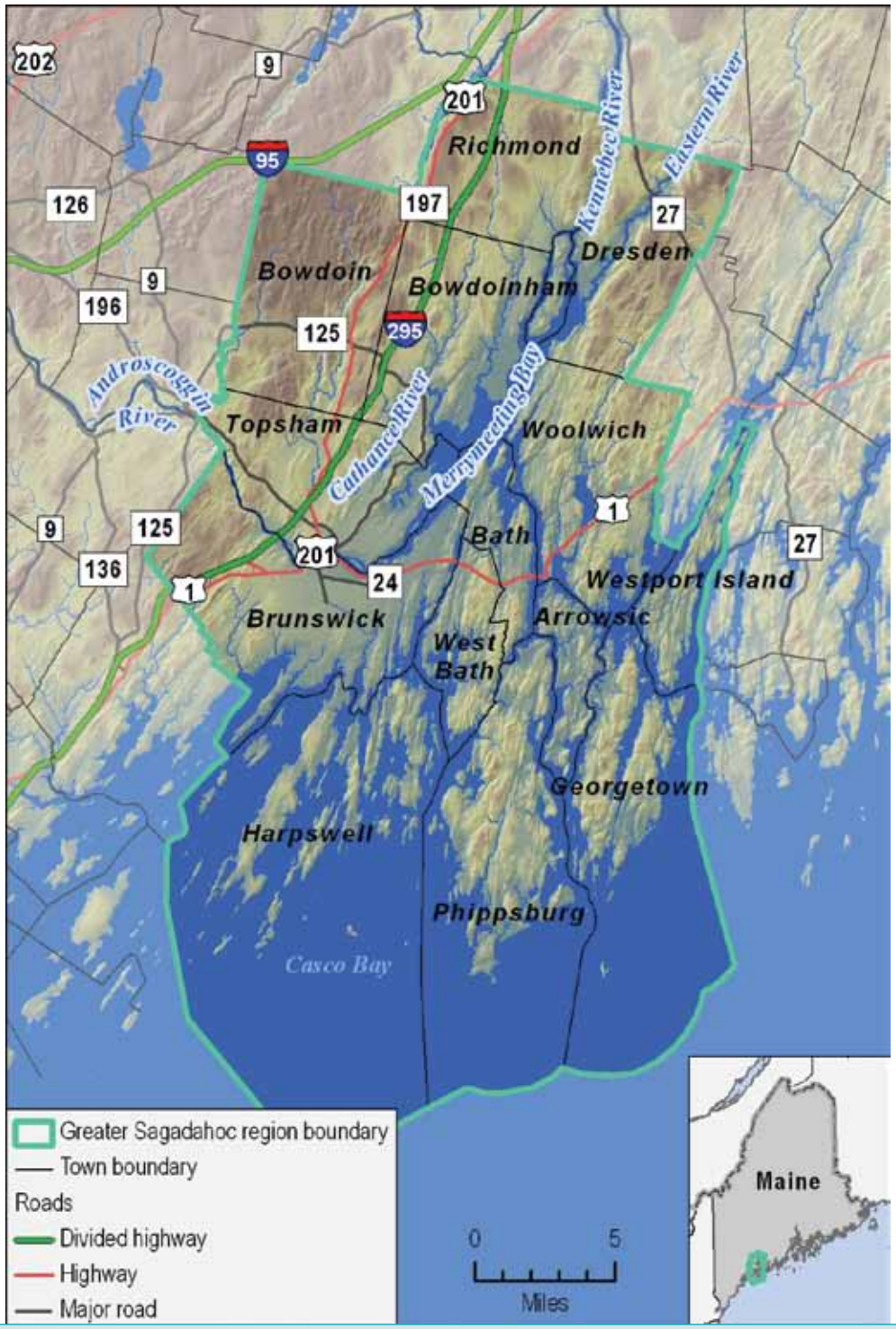
While no single set of management goals exists for the Sagadahoc region, the recommended priorities identified by the steering committee of the Sagadahoc Region Rural Resource Initiative (SRRRI) mesh well with the protection of ecosystem service delivery under climate change.[3] The SRRRI recommended priorities for local action are:

1. Protect water resources and riparian areas
2. Maintain large unfragmented blocks
3. Maintain connections between core habitat areas
4. Protect habitat for rare species and rare and exemplary natural communities
5. Protect farmland and support farmers
6. Protect, develop and maintain trails

The SRRRI blueprint for the region does not explicitly address climate change but it does provide important background information for thinking about resiliency to climate change and appropriate adaptation actions. In particular, the recommendations to protect water resources and riparian areas through enhanced buffering and maintaining riparian forest will have multiple benefits. The recommendations to maintain blocks of undeveloped land and connections between habitat areas will support the reorganization of species and habitats that climate change will drive.

As previously mentioned, the working groups at the initial Manomet stakeholder workshop identified the impacts of future development, increased precipitation, and sea level rise as priority areas for adaptation planning. These topics were taken up as major themes in the subsequent analysis of climate change impacts and formulation of adaptation recommendations.

Map 5: Sagadahoc Location



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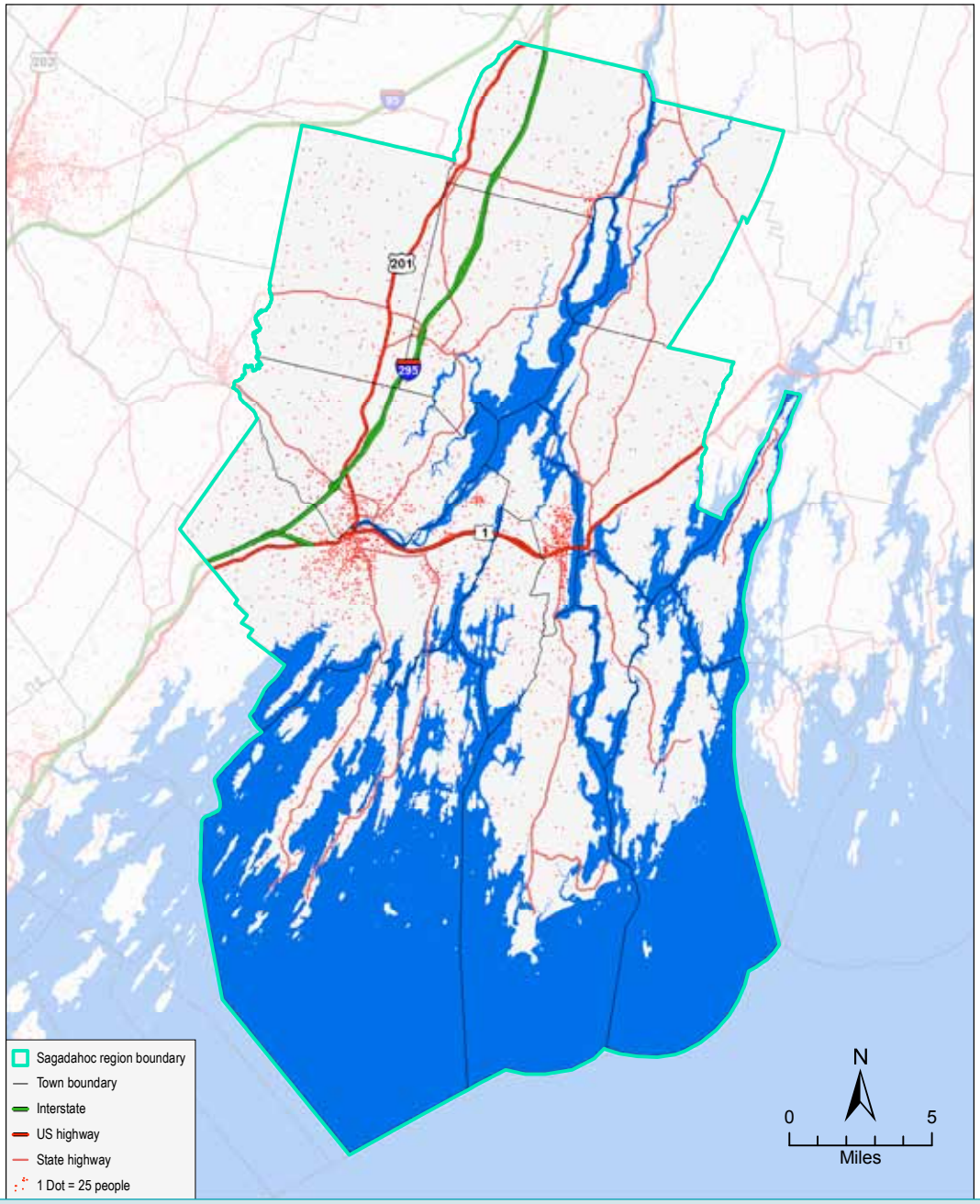
MAP 5



MAP 6

Map showing 2010 population density in and around the Sagadahoc region. Map based on 2010 Tiger/LINE shapefiles of census blocks using 2010 SF-1 total population 100% count data. Town and state boundaries and road data from MaineGIS. Hydrography data from the National Hydrography Dataset.

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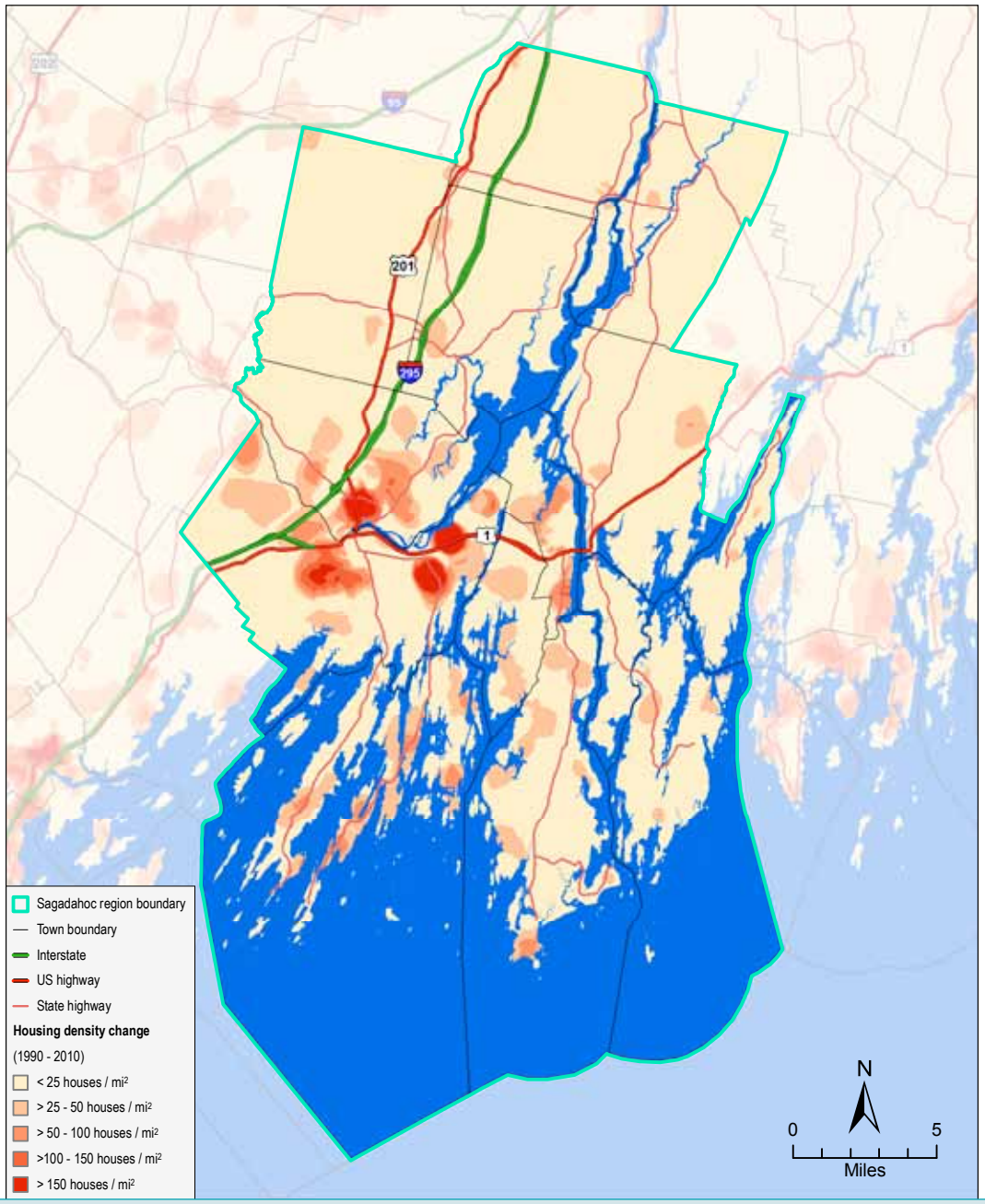
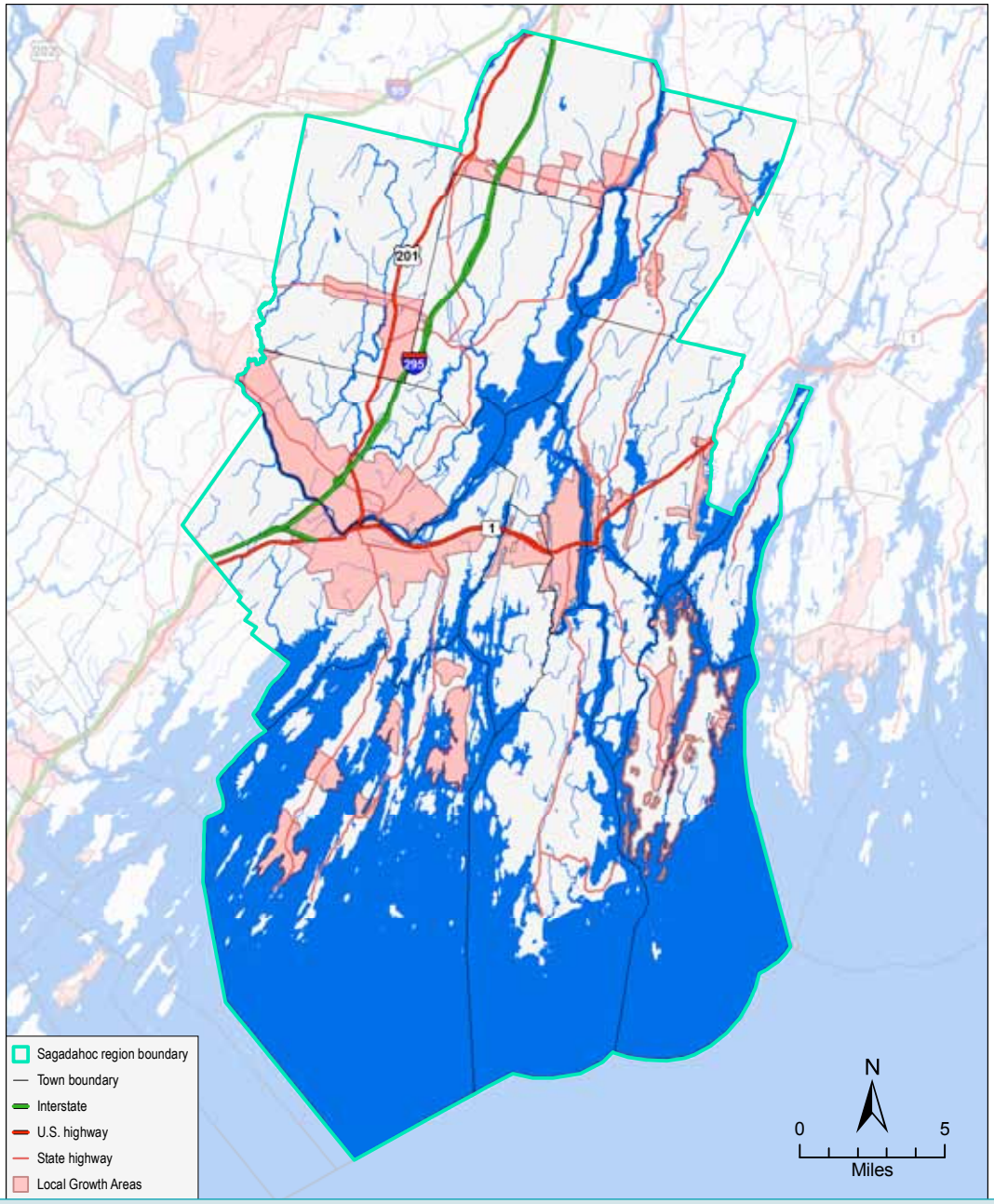


Map showing change in total housing density from 1990 - 2010 in and around the Sagadahoc region. Map based on 1990 and 2010 Tiger/LINE shapefiles of census blocks using SF-1 housing unit 100% count data, and verified using data from National Historical Geographic Information System. The housing units were distributed evenly over the block area because of changes in census block lines and converted to a density surface. Town and state boundaries and road data from MaineGIS. Hydrography data from the National Hydrography Dataset.

MAP 7



MAP 8

Map showing Local Growth Areas in and around the Sagadahoc region. This data was acquired from the Maine DEP GIS unit. Local Growth Areas are designated by a community's adopted comprehensive plan. These are areas identified by the community into which most development projected over the ten years following adoption of the areas is directed. Town and state boundaries and road data from MaineGIS. Hydrography data from the National Hydrography Dataset.

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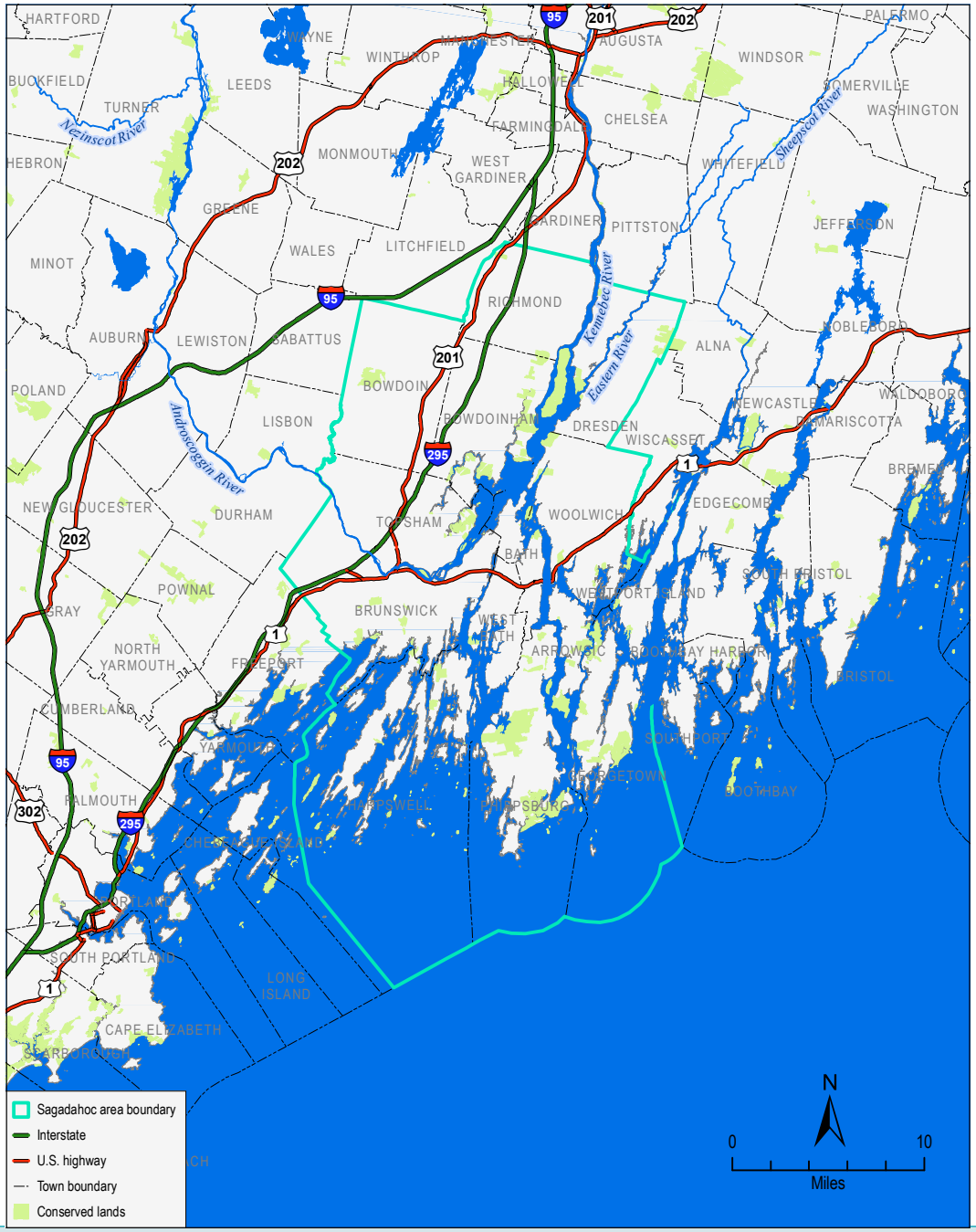


Map showing conserved lands in and around the Sagadahoc area. Conservation status from MaineGIS (2012). Town and state boundaries from MaineGIS. Hydrologic data from the National Hydrography Dataset (1:100k). Road data from the National Highway Planning Network.

MAP 9

Recent and Projected Climate Change in New England

Climate has changed significantly in New England during the period 1900 through 1999. Average annual temperatures have increased by 0.08 degrees Celsius per decade and average winter temperatures have increased by 0.12. The rate of average temperature increase accelerated significantly during the period of 1970-2000 with average annual temperatures increasing by 0.25 degrees Celsius per decade and average winter temperatures increasing by 0.70. Driven by these changes growing seasons have lengthened, the number of days with snow on the ground has decreased for many locations and the timing of peak spring stream flow has shifted to earlier in the year.[4]

The continued increase in atmospheric greenhouse gas levels is also driving associated increases in extreme weather events. In 2008 the U.S. Climate Change Science Program found that:

- "Human-induced warming has likely caused much of the average temperature increase in North America over the past 50 years and in turn causing changes in temperature extremes.
- Heavy precipitation events in North America have increased over the past 50 years in conjunction with observed increases in atmospheric water vapor.
- Increasing greenhouse gas concentrations have contributed to the increase in sea surface temperatures in the hurricane formation regions. Over the past 50 years there has been a strong statistical connection between tropical Atlantic sea surface temperatures and Atlantic hurricane activity as measured by the Power Dissipation Index."[5]

The change in frequency and intensity of extreme precipitation events differs regionally within North America with the most pronounced increase taking place in New England. A recent study of the period of 1948-2007 found significant increases in both the occurrence and intensity of extreme precipitation with the most significant increases occurring most recently.[6]

Projections of future climate change indicate a likely acceleration of the changes that have occurred during the last 100 years. Due to significant unknowns such as future greenhouse gas emission rates, the influence of various feedback loops and the likely existence of climate tipping points it is impossible to predict the exact timing and extent of climate change. However, over time climate modeling tools are becoming more sophisticated and for the most part different modeling approaches are yielding increasingly similar results. A 2006 study downscaled output from several global climate models and produced output specific to New England for three different possible future emission scenarios.[7] Nine atmosphere-ocean general circulation models were utilized in creating the projections that were downscaled. The three emission scenarios were the B1, A2 and A1FI scenarios developed by the IPCC. The B1 scenario assumes a stabilizing of atmospheric CO_2 levels at or above 550 ppm by year 2100. The A2 scenario assumes atmospheric CO_2 levels of 830 ppm by 2100 and the A1FI scenario assumes CO_2 levels of 970 ppm by 2100. Results for the B1 and A1FI scenarios for two of the modeled variables, temperature and precipitation are shown in the following table.

Table 1. Temperature and Precipitation Projections for New England

	UNITS	2035-2064		2070-2099	
Temperature	Degrees C	B1	A1FI	B1	A1FI
Annual		+2.1	+2.9	+2.9	+5.3
Winter		+1.1	+3.1	+1.7	+5.4
Summer		+1.6	+3.1	+2.4	+5.9
Precipitation	% change				
Annual		+5%	+8%	+7%	+14%
Winter		+6%	+16%	+12%	+30%
Summer		-1%	+3%	-1%	0%

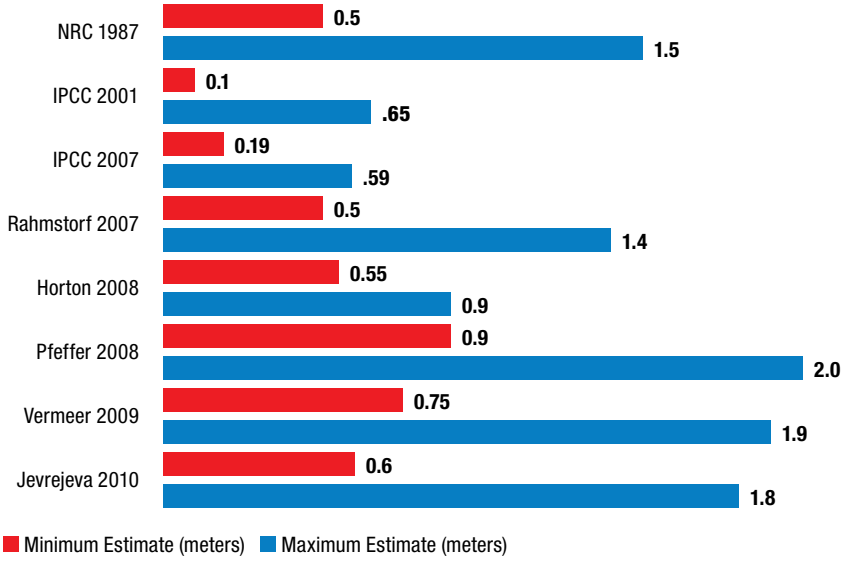
Source: (Reference number 4, Hayhoe)

Several other variables were modeled including stream flow and drought frequency. The projected changes in stream flow are mixed with low flow periods decreasing slightly for all but the A1FI scenario for the period 2070-2099, where the number of low flow days per year is projected to increase by 22 days. Drought is projected to increase for both scenarios and both time periods with the most significant increases for the A1FI scenario in the latter time period.[8]

Sea Level Rise

Sea level rise (SLR) projections through the year 2100 cover a broad range due to several factors including an uncertain trajectory for future greenhouse gas emissions and an incomplete understanding of future ice melt rates. Figure 1 provides a synopsis of sea level rise projections based on several different modeling approaches.[9]

Figure 1. Projected Sea Level Rise by 2100

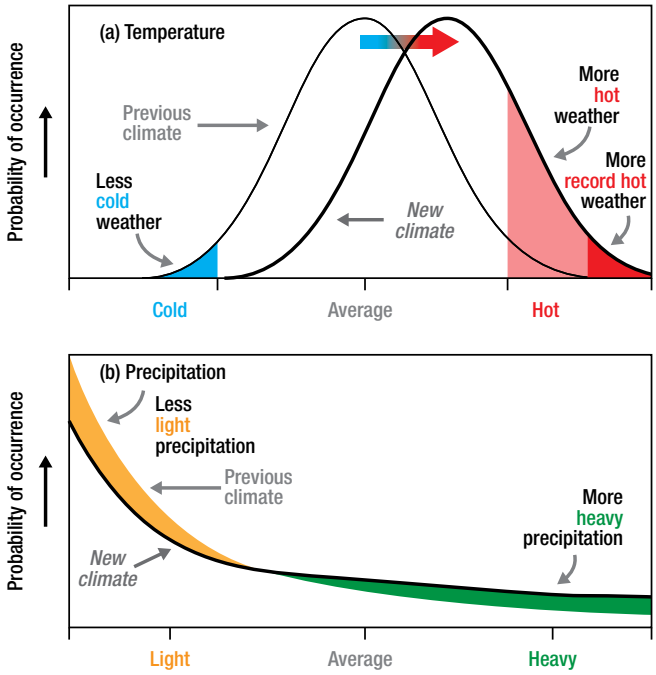


Source: (Reference number 9, U.S. Army Corps of Engineers)

The most recent U.S. Army Corps of Engineers guidance indicates that two meters is the likely upper bound of SLR through 2100 but does not rule out higher maximum levels.[10] A recent study by the United States Geological Survey indicates that the section of the Atlantic coast from Cape Hatteras to Maine is subject an additional increment of sea level rise associated with a slowing of the Atlantic Meridional Overturning Current.[11]

Sea level rise will increase the severity of storm surge flooding. A recent study estimated the change in frequency in occurrence of today's 100-year flooding event through the year 2050. The projected changes include a recurrence frequency of every 5 years for Portland, ME, a 30 year return frequency for Boston, MA and a 10 year return frequency for Providence, RI.[12]

Figure 2. Projected Changes in Extreme Weather and Climate



Source: (Reference number 5, Karl)

As average temperature and precipitation continue to increase in North America the projections indicate related changes in extreme weather and climate. The U.S. Climate Science Program projects that:

- "Future changes in extreme temperatures will generally follow changes in average temperature: Abnormally hot days and nights and heat waves are very likely to become more frequent. Cold days and cold nights are very likely to become much less frequent. The number of days with frost is very likely to decrease."[13] (See Figure 2 [14])
- "Over most regions, precipitation is likely to be less frequent but more intense, and precipitation extremes are very likely to increase."[15]
- "It is likely that hurricane/typhoon wind speeds and core rainfall rates will increase in response to human-caused warming. Analyses of model simulations suggest that for each 1 degree C increase in tropical sea surface temperatures, hurricane surface wind speeds will increase by 1 to 8% and core rainfall rates by 6 to 18%."[16]
- "Storm surge levels are likely to increase due to projected sea level rise, though the degree of projected increase has not been adequately studied."[17]
- "There are likely to be more frequent deep low-pressure systems (strong storms) outside the tropics, with stronger winds and more extreme wave heights".[18]

Climate Change Vulnerabilities

Climate change will impact many of the highly valued natural systems that characterize the Sagadahoc region. Sea level rise will alter ocean and bay shorelines and move tidal wetlands inland. Warming ocean temperatures and ocean acidification will change the species mix in the ocean, bays and rivers and will threaten the viability of the shellfish in the region. Increasing total precipitation and increasing heavy precipitation events will increase the threat of freshwater flooding and nonpoint source pollution.

These changes will also impact the infrastructure of the region. Low lying coastal areas will suffer increased storm surge flooding and over time upgrades will be required to maintain the viability of the transportation network, utilities, homes and businesses located in vulnerable areas.

1. Changing threat of freshwater flooding

The projected increase in total annual precipitation, coupled with the projected continued increase in the prevalence and severity of heavy precipitation events, will change design standards for storm water infrastructure in New England. Combined with continued urbanization of the Sagadahoc region and the associated increase in impervious surface cover, climate change will increase the frequency and severity of fresh water flooding in the absence of best management practices.

2. Sea level rise

Many towns in the Sagadahoc region have significant coastal frontage and associated exposure to sea level rise and increasing threat of storm surge flooding. Due to variations in the topography of the region's coastal zone sharp differences exist between areas that are vulnerable and those that are not. For those areas at low elevation, the road network, utilities, and septic systems are all at risk and will require periodic evaluation and upgrade to avoid failure. From a natural systems perspective, sea level rise will cause tidal wetlands to move upslope and inland where the topography and infrastructure allow movement to occur.

3. Ocean acidification

The world's oceans absorb approximately 25% of the carbon dioxide emitted from the burning of fossil fuels. This input is changing ocean chemistry and over time is reducing the pH of ocean water. The biological impacts of ocean acidification are complex and not yet fully understood. Experiments show that marine organisms react differently to acidification. Oysters, clams, some snails and urchins lose the ability to form shells in highly acid conditions while lobsters, crabs and prawns appear to increase shell building.[19] Ocean acidification will have direct adverse impacts on shellfish populations in the Sagadahoc region and may have indirect effects on the lobster fishery by impacting the marine environment and the food chain.

4. Agriculture

Climate change will stress global agricultural production. In particular, the projected increase in extreme hot weather will limit the ability to increase global food production in response to increasing demand. Agricultural production in New England will remain viable as compared to some regions of the United States with projected continued water availability and a lengthening growing season. While climate change will present new agricultural opportunities in New England, it will also present impediments. Increase in heat stress on livestock and projected increase in summer drought will present management challenges.

5. Water Supply

In a general sense, climate change is projected to make wet regions of the United States wetter and dry regions dryer. As these changes occur the water supply in New England will become an increasingly valuable resource. Maine does not currently have effective regulations in place to control the withdrawal and export of drinking water.

Adaptation Recommendations

The following climate change adaptation recommendations were identified based on stakeholder input, the local government survey, and the analysis of regional resources and vulnerabilities. All of the recommendations are "no regrets" strategies in that they will provide benefit regardless of the rate and extent of climate change.

Identification and Protection of a Regional Green Infrastructure Network

Adapting to climate change in the Sagadahoc region will be a multifaceted endeavor with planning and implementation required at both the local and regional scales. At the regional scale, a shared vision of a resilient landscape will be essential to informing local planning and development decisions. The green infrastructure network for the Sagadahoc region depicted in Maps 1 – 4 emphasizes protection of riparian corridors and wetlands, important habitat areas and agricultural lands.

The network is intended as input to regional and local planning efforts to better prepare for both new development and the effects of climate change. Refinement of the network will be required to accommodate evolving local comprehensive plans and detailed analysis of changing flood threat under climate change. In particular, modeling of storm surge inundation areas under different increments of sea level rise is needed to identify areas where new development should be minimized. Detailed storm surge modeling was not available as an input to the green infrastructure analysis.

Refining development controls to protect the green infrastructure network will support resiliency to freshwater flooding and nonpoint source pollution, minimize exposure of new development to sea level rise, enhance biodiversity and support food security for the region. The Sagadahoc region has a significant opportunity for climate smart planning in that the relatively intact natural landscape provides valuable adaptation services at little or no cost. Health and safety benefits and minimization of tax burden are available to the communities of the region if they work together to protect a functional green infrastructure network as population growth and new development takes place.

Adoption of Low Impact Development Standards

Low impact development standards are typically focused on minimizing the adverse storm water and nonpoint source pollution impacts associated with new development. Site design elements include minimizing new impervious surface area, infiltrating storm water on site and utilizing small-scale green infrastructure features such as rain gardens and grassed swales to minimize the direct linkage between impervious surfaces and receiving waters. In conjunction with a regional green infrastructure approach, LID standards provide significant cost savings as compared to traditional engineered storm water management systems.

Responding to Sea Level Rise and Maintaining Opportunities for Upslope Migration of Tidal Wetlands

Responding to sea level rise in the Sagadahoc region will involve addressing interrelated infrastructure and natural system concerns. The road network, utilities, homes and businesses in low-lying sections of the coastal zone will be increasingly impacted by storm surge flooding as sea levels continue to rise. Elevation of roads and bridges, enlargement of culverts, relocation of utilities and elevation of buildings will all be required in those areas that are most vulnerable to flooding. From a natural systems perspective, allowing the shoreline to move and tidal wetlands to migrate will contribute to maintain healthy marine ecosystems in response to climate change.

The Casco Bay Estuary Partnership recently completed an analysis of the impacts of sea level rise on tidal wetlands in Casco Bay.[20] The study found that in many locations sea level rise will not result in significant wetland loss if opportunities of upslope migration are preserved. In some locations dams, road crossings or shoreline hardening will limit marsh migration opportunities. While the primary objective of the study was to analyze the marsh migration questions, the mapping of one-foot, two-foot and three-foot sea level rise should be of use to the localities of the region in assessing the broader questions of changing vulnerability of infrastructure to storm surge flooding.

Implementation Options

Land trusts in the Sagadahoc region have made significant progress in protecting open space for natural resource protection, recreational use and agricultural preservation. However, it is not possible for land trusts to singlehandedly address regional resiliency to climate change. Two planning approaches could be used to foster climate smart land use decisions without the need to buy conservation easements on all of the land that should be protected. The first approach is linking the local development approval process to a green infrastructure plan. One of the best examples of this approach is found in Prince George's County, Maryland.[21] This program requires that local development projects consider the green infrastructure plan during the site design process. Modifications to lot layout and building placement may be required to avoid encroachment into the green infrastructure network. A second approach is the establishment of local or regional transfer of development rights programs (TDR). TDR programs support the establishment of a framework to allow land owners to sell development rights in conservation areas and purchase additional development rights in designated development areas. One of the best examples of a regional TDR program focused on natural resource protection is the Pinelands Development Credit Program in New Jersey. The program is an implementation mechanism for the Pinelands Comprehensive Management Plan and has resulted in conservation of thousands of acres of environmentally sensitive and priority agricultural lands. A similar program in the Sagadahoc region would provide a market-based approach protecting the natural features that provide resiliency to climate change.

Endnotes

1 http://www.maine.gov/doc/nrimc/mnap/focusarea/kennebec_estuary_focus_area.pdf

2 Samantha Ricker, *Forest and Water Climate Adaptation: A Plan for Bath*, Maine (Sagle, ID: Model Forest Policy Program, Cumberland River Compact, 2011).

3 Steve Walker, *Conservation Blueprint: A Guidebook for Protecting Place and Prosperity* (Sagadahoc Region Rural Resources Initiative, March 2010), http://www.maine.gov/doc/commissioner/landuse/docs/ConservationBlueprint_March2010.pdf.

4 Katharine Hayhoe et al., "Past and Future Changes in Climate and Hydrological Indicators in the U.S. Northeast," *Climate Dynamics* (2007), http://www.northeastclimateimpacts.org/pdf/tech/hayhoe_et_al_climate_dynamics_2006.pdf.

5 Thomas Karl et al., *Weather and climate extremes in a changing climate, Regions of focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands*, 2008, http://purl.access.gpo.gov/GPO/LPS110676.

6 Susan Spierre and Camron Wake, *Trends in Extreme Precipitation Events for the Northeastern United States 1948-2007* (Carbon Solutions New England, 2010), http://www.cleanair- coolplanet.org/cpc/documents/2010neprecip.pdf.

7 Hayhoe et al., "Past and Future Changes in Climate and Hydrological Indicators in the U.S. Northeast."

8 Ibid.

9 *Sea-Level Change Considerations for Civil Works Programs* (U.S Army Corps of Engineers, October 2011).

10 Ibid.

11 Asbury Sallenger, Kara S. Doran, and Peter A. Howd, "Hotspot of Accelerated Sea-level Rise on the Atlantic Coast of North America," *Nature Climate Change* (2012), doi:10.1038/nclimate1597.

12 Tebaldi C, Strauss B.H, and Zervas C.E, "Modelling sea level rise impacts on storm surges along US coasts," *Environ.Res.Lett. Environmental Research Letters 7*, no. 1 (2012).

13 Karl et al., *Weather and climate extremes in a changing climate regions of focus*.

14 Ibid.

15 Ibid.

16 Ibid.

17 Ibid.

18 Ibid.

19 Kate Madin, *Ocean Acidification: A Risky Shell Game* (Woods Hole Oceanographic Institution, 2009), https://www.whoi.edu/oceanus/viewArticle.do?id=52990.

20 Curtis Bohlen et al., Geomorphology and the Effects of Sea Level Rise on Tidal Marshes in Casco Bay (Casco Bay Esturay Partnership, 2012).

21 *Countywide Green Infrastructure Plan* (The Maryland-National Capital Park and Planning Commission, June 2005), http://www.pgplanning.org/Resources/Publications/Green_Infrastructure_Publication.htm.

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