MAINE STATE LEGISLATURE

PEOPLE AND NATURE

ADAPTING TO A CHANGING CLIMATE

Charting Maine's Course

A Report to
The Joint Standing Committee on Natural Resources of the
124th Maine Legislature Pursuant to Resolves 2009, ch. 16

FEBRUARY 2010

MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION
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I. INTRODUCTION:
LEGISLATIVE CHARGE AND BASIS FOR ACTION

124th Maine Legislature **LD 460, "Resolve, To Evaluate Climate Change Adaptation Options for the State"**

Sec. 1 Creation of stakeholder group; membership. Resolved: That the Department of Environmental Protection, referred to in this resolve as "the department," shall establish and convene a stakeholder group to evaluate the options and actions available to Maine people and businesses to prepare for and adapt to the most likely impacts of climate change. Convening this group to respond to climate change must not reduce continued strong state efforts to reduce greenhouse gas emissions. The department shall include in its stakeholder group and the evaluation process performed under section 2:

1. Representatives of business, industry and trade associations;

2. Representatives of nongovernmental organizations; and

3. State agencies with a current interest in these concerns and likely involvement in the implementation of recommendations.

The department must ensure that a balance of interests is represented in decision making. The department may ask the University of Maine and other higher education institutions to provide scientific and technical expertise to the stakeholder group; and be it further

Sec. 2 Evaluation. Resolved: That the department shall build upon the 2009 climate impact assessment by the University of Maine in evaluating the options available to Maine people and businesses for adapting to the likely environmental effects of climate change. That assessment concluded that climate change is already occurring in this State as a result of increased levels of greenhouse gases in the atmosphere and that, even with the greenhouse gas reduction goals set forth in the Maine Revised Statutes, Title 38, section 576, more thorough planning is necessary to identify and implement the State's responses to climate change in the areas of:

1. Ensuring sustainable opportunities for the development of greenhouse gas offset projects and low-greenhouse gas emission technologies and processes in the various sectors of Maine's economy;

2. Built infrastructure, including coastal and inland flooding effects on roads and facilities, heat effects in urban centers and beach scouring;

3. Habitat and fish and wildlife species, including the effects of invasive species, a lack of adequate conservation areas, a lack of connectivity between habitat and wildlife and inadequate wetlands protection;

4. Marine ecosystems;

5. Forests and forest management practices, including a higher incidence of pests and fires and a lack of biomass availability;

6. Agricultural and farming practices;

7. Human health, including increases in heat-related and vector-borne diseases;

8. Water supplies and drinking water; and

9. Emergency response systems and planning; and be it further

Sec. 3 Report. Resolved: That by February 27, 2010 the department shall report recommendations related to the evaluation under this resolve, along with any necessary implementing legislation, to the Joint Standing Committee on Natural Resources. The recommendations must be organized by the affected natural resource and economic sectors and may include proposals for legislation, modifications to existing rules and specific initiatives for one or more agencies to undertake in collaboration with stakeholder organizations to implement the recommendations. The Joint Standing Committee on Natural Resources is authorized to submit legislation related to the report to the Second Regular Session of the 124th Legislature; and be it further

Sec. 4 Funding of report. Resolved: That the department is authorized to accept public and private funds for the costs incurred to prepare the report under section 3. All funds received for these purposes must be deposited into the Maine Environmental Protection Fund established in the Maine Revised Statutes, Title 38, section 351 and must be used exclusively for purposes related to the preparation of this report.

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In charging the Department of Environmental Protection to convene stakeholders and produce this Report, the Legislature directed the department to "build upon the 2009 climate impact assessment by the University of Maine...." That report, *Maine's Climate Future: An Initial Assessment,* is a summary of current Maine-specific knowledge about climate change effects, and is based on both historic and recent observations and research, and on projections for Maine's future climate trends derived from mathematical climate modeling.[1]

There is abundant evidence that Earth's global, and Maine's local, climate is in the midst of significant change. As such, and regardless of disagreement over the causes of such change, there is a clear need to develop public policies that will (a) respond to measurable change that is already occurring; and (b) support planning for "the most likely impacts" of change that will occur in the future. Taken together, these actions are generally referred to as "adaptation" efforts. That is, they are "designed to reduce the vulnerability of natural and societal systems to the effects of climate change."[2]

> Adaptation refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change. An

[1] Jacobson, G.L., I.J. Fernandez, P.A. Mayewski, and C.V. Schmitt (editors). 2009. Orono, ME: University of Maine. It should be noted that stakeholders were not asked to endorse the validity of *MCF* and instead to take the information in it as a given. Not all stakeholder organizations or their memberships would necessarily agree with this.

[2] *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

> important asymmetry exists between adaptation and mitigation [actions to reduce the emissions of greenhouse gases]. Unlike mitigation, adaptation will in most cases provide local benefits, realized without long lead times. *Adaptation is the only response available for the impacts that will occur over the next several decades before mitigation measures can have an effect.*[3]

In evaluating the "options and actions available to prepare for and adapt to the most likely impacts of climate change," the Department and stakeholders were aware that their decisions and recommendations were variously based on what is known and evident; on what is very likely; and on aspects of climate about which we need to know more. The "Guiding Principles and Unifying Themes" adopted by the stakeholders and presented below begin this way:

> Although there is uncertainty as to the extent, rates and precise locations of change, we know that contemporary climate change is already affecting us, and will continue to do so. We have enough data to begin to act now, even as we gain understanding and capacity to respond more thoroughly over time. There are actions worth taking because they will benefit Maine regardless of the specific path of climate change. Society makes decisions to invest in preventive, responsive, or adaptive action based on uncertain risks all the time. The task is to balance the costs of responsive and preemptive action against the risks and potential costs of inaction.

While it is certain that there will be change, in many cases the form it takes may surprise us. Our responses may need to be novel and may not have been tested before. Therefore, Maine needs to develop planning and management approaches that are agile, responsive and that build in an adaptive management approach. Adaptive strategies and actions will vary according to the vulnerability and adaptive capacity of a resource when comparing the cost of acting to the risk of future loss. For example, a natural beach cannot adapt in-place in a condition of sea level rise (SLR)[4]. Instead, this natural resource must be allowed to migrate with the sea if it is to survive. As a community, Maine needs to establish the policies and measures needed to balance choices between the value of the migrating resource (in this example, the beach) and the value of the resources in the path of migration, such as residences or roads. In other scenarios, human-built resources and infrastructure will have such economic, cultural, historical, or functional value that significant, even heroic, efforts may be warranted to ensure their preservation and adaptation. To be successful in building a climate-resilient Maine that accounts for such considerations in the pre-

[3] http://www.eoearth.org/article/Climate_adaptation

[4] Throughout this Report, sea level rise should be considered to include the phrase, "increased storm surge," since the latter is often associated with coastal inundation.

sent and for the future, this decision making process requires a foundation of clear, well thought, and accepted policies such as those recommended below.

In contrast with actions taken to mitigate the emission of greenhouse gases, which often take place at the state or federal level of policy making and implementation, actions to *respond, adapt, and build resilience* to climate change impacts and effects occur very frequently at the local level and provide local benefits. Many recommendations aim to provide resources for Maine communities to assist their development of local responses to current and anticipated climate change impacts.[5] Municipalities in southern coastal Maine, in particular, have been jointly developing policies and plans for climate adaptation for several years, and representatives of Maine's cities, towns, and rural areas actively participated on the Coordinating Committee and each of the working groups.

This report documents the results of what many stakeholders regard as "Phase One" of a continuing climate adaptation planning and implementation effort. The stakeholders agree that, while this effort has set Maine's course, the territory has not been completely mapped. As noted below in the premier recommendation, A.1.1.1, the next critical step is for Maine to adopt an Adaptation Plan that sets forth a long-term decision-making framework and provides a more fully-developed set of recommendations based on economic analysis of benefits, costs, and opportunities; on additional data sets; and on further consultation with stakeholders.

In presenting this report, the stakeholders ask the Legislature for its affirmation of the work done to date, and its direction to continue.

[5] See, for example, A.4.1, p. 26.

II. STAKEHOLDER PROCESS

Following enactment of L.D. 460 on April 23, 2009, the Department convened an initial meeting of stakeholders (the Coordinating Committee) at the Chewonki Foundation on May 1.[6] Professor George Jacobson, University of Maine Climate Change Institute, gave an initial presentation based on the *Maine's Climate Future* report. Participants also heard from Rhett Lamb, Chief Planner, City of Keene (NH), about the adaptation planning process recently initiated by that city. The remainder of the meeting was devoted to review of the Department's proposed structure for the work ahead, culminating in a report to the Natural Resources committee by February 27, 2010.

Four working groups were then organized to review likely climate change impacts, identify areas of vulnerability, and make recommendations back to the Coordinating Committee:

- Maine's Natural Environment
- Maine's Coastal Environment
- Maine's Built Environment
- Maine's Human and Social Environment

Each group was comprised of members of the Coordinating Committee and representatives of other stakeholder organizations and agencies who were invited based on their expertise, and on recommendations from other stakeholders. Each working group met four times between June 1 and November 15.[7] The Coordinating Committee convened again on September 23 to review progress, and finally on January 25, 2010, to consider and endorse this Report.

The Department presents the report as agreed upon by the stakeholders. In almost all cases, the recommendations reflect a consensus among the stakeholders to move a particular item forward. In some cases, stakeholders representing large organizations were not necessarily opposed to a given recommendation, but could not commit their organizations to support or oppose implementation of regulatory changes and similar recommended actions. These groups would need additional and specific details as to the actual changes proposed at some future date, or further guidance from their policy committees. Any decision to take

[6] Agendas, working papers, minutes, and lists of attendees for all meetings associated with the stakeholder process can be found at http://www.maine.gov/dep/oc/adapt/ The Department also relied on the advice of an informal Steering Committee comprised of a small group representing business organizations, public interest groups, and the University of Maine.

[7] The exception was the Human/Social Environment group, which met three times.

action on a particular recommendation must weigh the potential costs and benefits. This pragmatic, careful approach to adaptation will best serve Maine as we identify the most important actions with the least risk of future regrets.

Participating Organizations

* indicates Coordinating Committee

*American Council of Engineering Companies

Associated Builders and Contractors

Associated General Contractors of Maine

Bangor Hydro

Casco Bay Estuary Partners

*Chewonki Foundation

City of Lewiston

*City of Biddeford

*City of Portland

Coastal Enterprises, Inc.

*FPL Energy / Nextera

Friends of Casco Bay

Grondin Construction

*Hannaford

Maine Aquaculture Association

Maine Association of Conservation Commissions

Maine Association of Conservation Districts

Maine Association of Insurance Companies

*Maine Association of Planners

Maine Association of Realtors

*Maine Audubon

*Maine Better Transportation Association

Maine Center for Public Health

*Maine Chamber of Commerce

Maine Coast Heritage Trust

*Maine Council of Churches

*Maine Forest Products Council

*Maine Innkeepers Association

Maine Medical Association

Maine Motor Transport Association

*Maine Municipal Association

*Maine Organic Farmers and Gardeners Association

Maine Potato Board

Maine Professional Guides Association

Maine Public Health Association

*Maine Real Estate and Development Association

Maine Rural Partners

*Maine Tourism Association

Maine Wastewater Control Association

Maine Water Utilities Association

Maine Wild Blueberry Association

*Manomet Center for Conservation Sciences

*Natural Resources Council of Maine

*The Nature Conservancy

*Portland Chamber of Commerce

*Physicians for Social Responsibility

Passamaquoddy Tribe (Sipayik)

*Small Woodlot Owners Association of Maine

*SkiMaine Association

Southern Maine Regional Planning Commission

Town of Montville

University of Maine Cooperative Extension

White Brothers Contracting

Town of York

Univ. of Maine Sea Grant

U.S. Green Building Council, Maine Chapter

Town of Edgecomb

*University of Maine Climate Change Institute

Wells National Estuary Reserve

State and Federal Agencies

Bureau of General Services

Department of Conservation

Department of Inland Fisheries and Wildlife

Land for Maine's Future

Maine Forest Service

Maine Natural Areas Program

Public Utilities Commission

Bureau of Insurance

Department of Econ. and Community Development

Department of Marine Resources

Maine Center for Disease Control

Maine Emergency Management Agency

State Planning Office

Department of Agriculture

Department of Environmental Protection

Department of Transportation

Maine Drinking Water Program

Maine Geological Survey

United States Environmental Protection Agency

The following organizations and agencies contributed funds and/or services in-kind, such as meeting facilities, to the stakeholder effort:

The Chewonki Foundation

Associated General Contractors of Maine

Maine Forest Products Council

The Nature Conservancy

Department of Transportation

St. Paul's Episcopal Church, Brunswick

Department of Agriculture

Maine Emergency Management Agency

The following organizations and agencies contributed funds toward the publication of a Summary of this report for public distribution:

The Horizon Foundation

Manomet Center for Conservation Sciences

Maine Sea Grant

Maine Department of Agriculture

The Frick Foundation

Hannaford

Maine Cooperative Extension

Maine Real Estate and Development Association

The Nature Conservancy

The Chewonki Foundation

Maine Center for Disease Control

University of Maine Climate Change Institute

III. FINDINGS

A. Guiding Principles and Unifying Themes

From the beginning of the stakeholder process, participants have sought to identify and utilize principles on which they could agree to base their decisions and recommendations. As the work has proceeded, certain common themes have emerged across the boundaries of working groups. These are combined here as the basis for the participants' efforts, and presented as guidance for further policy development.

- **Climate change affects everyone.** It is likely to have broad economic, biological and social implications for all of Maine. Although there is uncertainty as to the extent, rates and precise locations of change, we know that contemporary climate change is already affecting us, and will continue to do so. We have enough data to begin to act now, even as we gain understanding and capacity to respond more thoroughly over time. There are actions worth taking because they will benefit Maine regardless of the specific path of climate change. Society makes decisions to invest in preventive, responsive, or adaptive action based on uncertain risks all the time. The task is to balance the costs of responsive and preemptive action against the risks and potential costs of inaction.

- **Maine's adaptation planning must involve everyone**. It must include individuals, business and industry, public interest groups, land owners, and government at all levels. Policy decisions must be collaborative, transparent, and open to change as our knowledge increases and new circumstances present themselves. Planning for climate change adaptation will also benefit from the participation of Maine's state, regional, and local entities in broad-based approaches that cross political boundaries at both the local (watersheds, habitats and estuaries) and state (Gulf of Maine; New England) scales.

- **Climate change adaptation will require an on-going effort.** It will need to incorporate new information and continue to adapt and evolve. Consequently, data-gathering, monitoring, and assessment are critical tools that Maine must utilize to inform decision makers, resource managers, stakeholders, and the public. Our decisions must be founded on the best available scientific data. Thus, Maine's planning must support continuing research so we may provide the public with accurate information about the pace and extent of change. Meaningful communication of climate science and potential solutions is necessary to assist people throughout our state to take action.

- **We need to keep our natural systems resilient to likely changes.** Maintaining healthy ecosystems is essential to our long-term success in meeting the challenges of a changing climate. Natural ecosystems provide services such as clean water, food, energy, coastal protection, and carbon sequestration, but these systems are likely to be increasingly vulnerable to climate impacts. Our efforts to build resilience for Maine's communities and people must go hand-in-hand with strategies that minimize both impacts to the natural environment and losses of ecosystem services upon which we and Maine's natural resources depend.

- **Adaptation includes reducing existing stresses on natural and human systems.** Where we are unable to avoid climate-related stressors, limiting other compounding stresses that already exist is an effective form of adaptation to climate change. Our recommendations should specify which current stressors are likely to be exacerbated by climate change impacts. By taking a hard look at these, we may find ways to improve our adaptation methods and promote resilience in natural and human systems.

- **Some positive changes will occur.** A changing climate will create new economic opportunities for Maine. These will occur in many sectors and industries. Our planning must recognize and promote these opportunities, and develop incentives that will allow us to take advantage where possible. Climate change may increase Maine's competitive advantage in a number of sectors.

- **Maine must prepare for both incremental and acute impacts.** Although most climate change effects are taking place in steps over time, some will be episodic and unpredictable, such as insect outbreaks in Maine's forests or greater impacts to coastal areas from combined sea level rise and increased storm intensity. Maine's adaptation efforts must work simultaneously to address slower-arriving impacts and those that are more immediate or acute. Proactive infrastructure design, early detection, and well-developed response plans are among the steps needed to minimize future losses.

- **Maine should avoid unfairly passing the financial burden of inaction to future generations.** To the extent possible, Maine's climate planning efforts should seek to avoid passing to future generations what are likely to the potentially catastrophic costs of inaction in some areas. This report aims to alert businesses, communities, and landowners – our neighbors – to the real and often imminent impacts of climate change, and demonstrates that effective planning is possible and cost effective. While we face serious limits on our current finances, the magnitude of cumulative cost over time must be considered. At the same time, Maine's plan should avoid passing on unfunded mandates to state agencies, municipalities, and landowners, with an eye toward reducing public costs while respecting private property rights and real estate values.

- **Maine can use existing policies and programs to address climate change.** Maine should continue to use current policies (*e.g.,* laws, rules, regulations, and programs) that successfully address climate change. We should avoid creating new programs or institutions, and instead focus on enabling existing ones to function better in the service of climate change adaptation goals, consolidating functions and reevaluating policy where possible and appropriate.

- **Some communities may be more vulnerable than others.** Some of Maine's communities and people will be disproportionately affected by climate change. Our planning and implementation efforts must include their participation, and take special account of their needs.

- **Maine must maintain its commitments to reduce greenhouse gas emissions.** Adaptation should not be viewed as an alternative strategy to reducing our GHG emissions. Many of the actions to mitigate emissions go hand-in-hand with those needed to respond to climate changes we are already experiencing, and to build resilience for the expected climate future.

B. "Most Likely Impacts of Climate Change"

Based on the climate variables considered in the *Maine's Climate Future* report, and other works referenced therein, the stakeholders determined that the following impacts on Maine of a changing global climate should be used in order to plan. The word "impacts" refers to observable or foreseeable changes in a wide range of natural phenomena that can reasonably be attributed to climate change. For example, sea-level rise is one observable impact of climate change. We use effects to describe the consequences of one or more impact, such as, "greater demand for energy for cooling is a likely effect of increasing average summer temperatures and more frequent severe heat events." However, the distinction between impacts and effects is not always straightforward because the earth's climate system is complex, making it difficult to distinguish the two precisely.

These are the impacts and primary effects of climate change most often cited in this report:

- Changes in air temperature (increase/decrease)

- Changes in weather, including
  - Storm events and other weather extremes
  - Changes in timing and extent of precipitation (rain, snow)
  - Seasonal shift and variation in temperature and precipitation
  - Variability in patterns and intensity of winds

- Oceanic changes, including
  - Sea-level rise
  - Changes in oceanic circulation patterns
  - Changes in ocean temperature
  - Changes in seawater chemistry, nutrient levels

- Terrestrial fresh water changes, including
  - Changes in seasonal flow regimes and volumes
  - Changes in temperature
  - Changes in freshwater chemistry, nutrient levels

- Terrestrial ecosystem changes, including
  - Changes in the terrestrial water balance
  - Changes in carbon sequestration and/or release rates
  - Changes in the reflectivity of the land surface
  - Changes in the timing of biological processes and seasons

None of these occur in isolation, since together they make up what we call climate: "the statistical collection of average weather conditions at a given place…."[8] Further, the interactions among them can be very complex. For example, an increase in global air temperature over time causes the thermal expansion of sea-water, a contributor to sea-level rise. Similarly, a shift from snow to winter rain plus increases in winter precipitation, could result in greater runoff in Maine's watersheds. At the same time, accelerated forest growth due to warming and increased CO_2, combined with higher evapotranspiration[9] could actually reduce freshwater runoff.

The Legislature's use of the phrase "most likely" impacts recognizes that any adaptation planning must acknowledge the uncertainties inherent in determining the extent and timing of climate change. As the Nobel-laureate physicist Neils Bohr put it, "Prediction is very difficult, especially about the future."[10] *Maine's Climate Future* describes some of the limitations placed on us by the basic complexity of the earth's climate system, the current state of our knowledge, and the limitations of our models.[11] *MCF*, and thus this report, relies on the global-scale Fourth Assessment of the Intergovernmental Panel on Climate Change (IPCC Fourth Assessment 2007), as refined whenever possible by regional and Maine-specific research data.

In following the legislative mandate to "evaluate the options and actions available to Maine people and businesses," the stakeholders followed the model commonly used by scientists and policy makers, and assessed natural and human systems and structures for their *vulnerability*, *sensitivity*, and *adaptive capacity*. Here is a convenient summary of these terms:

> Climate scientists define vulnerability as the extent to which a natural or social system is susceptible to sustaining damage from climate change. Vulnerability is a function of (1) the sensitivity of a system to changes in climate (the degree to which a system will respond to a given change in climate, including beneficial and harmful effects), (2) adaptive capacity (the degree to which adjustments in practices, processes, or structures can moderate or offset the potential for damage or take advantage of opportunities created by a given change in climate), and (3) the degree of exposure of the system to climatic hazards. Resilience is a counter-weight to vulnerability–a resilient system or population may experience the disturbances caused by climate variability and change, but has the capacity to adapt.[12]

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[8] *MCF* 9.
[9] Water evaporation from the surfaces of soil and vegetation.
[10] Cited *MCF* 14.
[11] *Ibid.* In particular, all the models project a range of future variation that depends on the extent to which further emissions of climate-changing greenhouse gases are lowered in coming decades.
[12] http://www.eoearth.org/article/Climate_adaptation Emphasis added.

The result of this assessment in the working groups led to the drafting of recommendations to address those areas identified as of most immediate concern, and/or greatest long-term significance for Maine.

IV. RECOMMENDATIONS

Most of the recommendations that follow were developed in the working groups noted above. A few, indicated with an asterisk, were added by stakeholders after the working group process or by various state agency staff who distilled key ideas from working group discussions. All were reviewed by the Coordinating Committee, which agreed that they should be included. For some topic areas, the stakeholders agreed on a key strategy but were unable to identify specific recommendations for action at this time. These will need further review and development as adaptation planning continues.

You will note that very similar recommendations occur in more than one section below. While these could have been combined into several additional "All Sector Recommendations," this would have taken them out of the context of others specific to a given sector. Cross-references to related recommendations are provided.

Not all recommendations include specific implementation mechanisms or proposals for funding. The stakeholders recognize that all recommendations will require the identification and expenditure of resources in order to be implemented, and did not wish the agreed-upon *ideas* to be disregarded at this point in Maine's ongoing climate adaptation planning process solely because of cost considerations. Any decision to take action on a particular recommendation will need to weigh the potential risks, costs and benefits.

The stakeholders would note that the recommendations documented here are those that found consensus quickly given the brief time allowed, and should not be considered as constituting a complete or exhaustive list. They expect that the continuing process recommended below will identify additional vulnerabilities and needs to be addressed as our understanding increases. In the area of forest management, for example, further stakeholder assessment may be needed to identify specific actions to maintain the continuity of Maine's productive forestland.

The very process of adaptation *planning* results in enhanced adaptation *capacity* across a range of actions. Some capacity is increased without new costs through the adaptation of new approaches to "business as usual," such as including adaptation considerations into existing practices. In other cases actual costs will need to be incurred. For example, changes in regulations, tax incentives, or other policy actions aimed at minimizing the effects (and long-term costs) of climate change will often increase current costs. New resources will be required for increased monitoring and research to provide the data needed for climate adaptation decisions, the analysis of the costs of action compared with non-

action, and to identify new opportunities. Finally, the development and installation of resilient infrastructure to address likely climate impacts will come with significant costs, some of which will be paid for by redirecting existing funding streams or generating new ones, while others will certainly need to be absorbed by affected parties. As will be seen in the final section of this Report, it is important for Maine to assess the value of avoided losses as well as additional costs when calculating the risks and benefits of climate adaptation actions. There is every reason to think that real savings will arise from avoided costs due to adaptation, and that new opportunities resulting from adaptation actions will have a major positive effect on Maine's economy.

Most recommendations are presented as actions that would begin to address the broader strategies in a “no regrets” manner: that is, they are actions worth taking regardless of the specific course of likely climate change, and are intended to add value to Maine by addressing challenges that are already present, such as improving Maine’s state-wide disaster response system or wastewater treatment systems.

The stakeholders agreed that “a changing climate will create new economic opportunities for Maine. These will occur in many sectors and industries. Our planning must recognize and promote these opportunities, and develop incentives that will allow us to take advantage where possible.” A number of such opportunities were identified, although in general they have not yet been developed into specific recommendations. They are presented throughout this section in the form of call-out boxes, and will need to be evaluated further as the planning process continues to determine how to take best advantage of them.

A. All Sector Recommendations

A.1 Adaptation Planning

Responding to current and expected challenges associated with climate change in Maine, and building resilience and adaptive capacity for the future, is in many ways a connected and iterative series of planning activities. In each area of concern, individuals, interest groups, government entities, and others will need to collaborate to identify natural and human system resources that may be sensitive or vulnerable to, or at risk from, likely climate impacts and effects. Based on best available historic information, current monitoring data, and predictive models, these groups should then establish policies that form the basis for adaptation response(s); develop planned actions that respond to the anticipated challenges; identify the resources needed to implement those responses, and go on to put them into effect.

Strategy A.1.1 Develop a Maine Climate Change Adaptation Plan

Several stakeholders suggested the sub-title of this Report, "Charting Maine's Course," to indicate the importance of further and continuing action to meet the intent of the Legislature. The work of the stakeholders over the past nine months has generated substantial momentum toward building a climate-resilient Maine that needs to be recognized and continued. However, the stakeholders are also aware that we have only begun this effort. Review of already-completed climate adaptation plans in other states, most notably Washington and Maryland, demonstrates the following:

- Accurate assessment of the risks associated with climate change and the vulnerability of particular human and natural systems is fundamental to planning for a changing climate future. However, the tools, methods, and policy frameworks for such assessment still need to be developed in many cases.
- Since many of the climate change impacts for which states are preparing will occur over the course of decades, and are likely to require major resource investments, and policy and regulatory changes, careful and prudent long-term planning is necessary in all sectors and at many scales of decision-making. This is despite the fact that climate change that we are already experiencing is at the same time changing the way we live today. Thus, many of the recommended actions in these plans focus on the establishment of planning processes that will subsequently produce actionable recommendations across a range of time-scales.
- Many recommended actions will require funding mechanisms and cross-jurisdictional cooperation over long periods of time in order to be implemented. Identifying how this can be accomplished requires economic analysis and planning that may take several years to complete.
- Many of the actions needed to create climate-resilient communities and natural systems will be carried out at a local level. Adaptation planning requires that local authorities and citizens have access to accurate information about likely climate impacts specific to their location, and the tools and resources that will support them in their own planning processes, establishment of local adaptation policies, and efforts to build adaptive capacity.

Thus, the creation of an actionable state-level climate adaptation plan typically requires two to three years of work, and significant expenditure of resources, in order to assure wide-spread acceptance and implementation. While the present report identifies key

strategies and initial recommendations that Maine should adopt in order to address the most likely impacts of climate change, further effort will be needed to develop additional, and more specific, recommendations to be implemented in the years ahead.

It is highly probable that pending federal legislation will, over time, generate revenue that states may utilize for climate change-related activities, including both the mitigation of greenhouse gases, and response / adaptation to current and future climate change conditions. Separate federal funding in other related areas, such as habitat restoration, is also likely. In order to qualify for, and take effective advantage of, such funding opportunities, Maine will need to have in place a comprehensive adaptation plan that is substantially more detailed than the current report, and will need to demonstrate a coordinated capacity to administer and utilize such funds.

LD 860 specifies that "state agencies with a current interest in these concerns and likely involvement in the implementation of recommendations" be included in developing this report. Thirteen different executive branch and related agencies have actively participated in this process, and the stakeholders agree that further adaptation planning requires a high level of ongoing coordination and cooperation among these, with their federal agency counterparts, and with similar agencies in other states.

As indicated in Section IV.D [p. 67], comprehensive planning for climate change impacts must rest on sound analysis of the economic impacts of potential actions, particularly to compare the costs of "no action" against specific actions that would accomplish goals that are worthwhile for Maine under any climate scenario. The New England Environmental Finance Center at the University of Southern Maine is currently developing innovative tools for this purpose that should be evaluated for potential use by local and state planners.[13]

Finally, the active participation and leadership of private sector and public interest groups, together with the available expertise of the University of Maine, has been a key factor in bringing about this report. If further efforts are to be productive, this "coalition of partners" must be maintained.

With these considerations in mind, the stakeholders and the Department propose the following keystone recommendation:

[13] See below, D.1.1 (p. 68).

Recommendation A.1.1.1 Complete a Climate Change Adaptation Plan for Maine

The Natural Resources Committee may wish to consider several options for implementing this recommendation. The stakeholders agree that some structure should be found within Maine state government that would:

- provide a central coordinating function for the completion of a plan able to meet likely federal requirements;
- act as a "lead agency" for continuing implementation of Maine's plan; and
- maintain a coalition of partners from the public, including local government, private and public interest group sectors.

An existing statutory entity, such as the Energy Resources Council or Land and Water Resources Council, could assume responsibility for this effort. If so, it could task DEP with chairing and staffing the continuing effort, since taken as a whole, the activities associated with developing Maine's response and resilience to climate change impacts are fundamental to DEP's statutory mission and consistent with its operational functions. DEP already has statutory responsibility for implementation of 38 MRSA §§ 574-579, Maine's Climate [mitigation] Action Plan, which overlaps substantially with likely actions on adaptation. This statute could be amended specifically to direct the Department to incorporate climate change adaptation planning into its existing responsibilities. Alternatively, the Legislature could extend and expand the current authority of LD 460 by charging DEP to continue its efforts, specifying the participation of various executive agencies, and requiring the delivery of a completed plan to the 125th Maine Legislature. Such a plan should recommend a framework for Maine's continuing adaptation planning effort, and identify any enabling legislation that would be needed for implementation.

Regardless of approach, the stakeholders recommend that all state agencies be required to name a climate change liaison to the Coordinating Committee led by DEP. The stakeholders recognize that any such plan will need to be periodically updated to reflect new information about Maine's climate and the actual course of global climate change. Thus, it may be useful for the plan to combine an ongoing climate adaptation planning framework with the first of a projected series of five-year action plans containing specific recommendations.

The charge to the continuing entity between 2/27/10 and 3/31/11 (possible date for delivery of a completed Plan to the Natural Resources Committee) would include the following:

- *Development of specific implementation plans* together with estimates of cost, sources of needed funding, necessary legislative action, etc, where this report has identified actionable recommendations;
- *Development of recommendations,* together with implementation plans as above, in those areas in the present report where the stakeholders identified significant vulnerability and strategic direction, but did not propose specific recommendations;
- *Economic analysis* of the costs of implementing adaption recommendations compared with "no action" for key aspects of Maine's communities, natural resources, and overall economy;
- Identifying a mechanism by which *progress on recommendations* would be tracked; and
- *Identifying additional opportunities* that Maine could take advantage of in a changed and changing climate.

Many of the recommendations below identify a need for new or continuing multi-stakeholder groups to develop flexible strategies and management approaches. It will be up to whatever continuing entity has responsibility for overall planning to assure the integration of such groups into Maine's continuing adaptation effort.

A.2 Data, Monitoring, and Assessment

Public policy and decision making to address the likely impacts of climate change must be informed by the best scientific and technical data. This report has its origins in the language of LD 460 to "build upon the 2009 climate impact assessment by the University of Maine in evaluating the options available to Maine people and businesses for adapting to the likely environmental effects of climate change."

To assure that Maine's climate adaptation planning will continue to benefit from robust, scientifically-sound data, the stakeholders have clearly identified ongoing and enhanced environmental monitoring; data gathering (including vulnerability inventories and risk assessments in all sectors), and modeling / forecasting as a set of key strategies for Maine. As noted in the "Guiding Principles and Unifying Themes,"

> Climate change adaptation will require an on-going effort. It will need to incorporate new information and continue to adapt and evolve. Consequently, data-gathering, monitoring, and assessment are critical tools that Maine must utilize to inform decision makers, resource managers, stakeholders, and the public. Our decisions must

be founded on the best available scientific data, and Maine's planning must support continuing research.

All the stakeholder working groups, especially the Coastal and Natural environment groups, clearly noted the need to enhance and retain state-level expertise and experience in critical areas of monitoring that are needed to ensure that we have robust, Maine-specific scientific information for adaptation decision-making.[14]

Strategy A.2.1 *Integrate Current Systems for Environmental Monitoring that Support Climate Change Adaptation Activities and Address Monitoring Gaps*

We know a great deal already about climate change impacts through data gathered by direct observation over extended periods of time. Global observational records of temperature and sea level, for example, have documented change that has already occurred, and serve as key variables in the models used for climate change research. However, adaptation planning at the state and local level needs information that is specific to our geographical location. For instance, one of the key indicators for Maine is the measured increase in sea level over the past century, as recorded by the Portland tide gauge. Examples of existing monitoring programs at the federal and state levels include USGS surface and groundwater programs; the National Atmospheric Deposition Program;[15] the US Forest Service Forest Inventory and Analysis; and environmental monitoring programs in the US Environmental Protection agency and various state agencies. These programs continue to help us understand the conditions and trends of ecosystems in Maine. However, some variables that we believe could be influenced by climate change are not being systematically tracked, such as ocean acidification or peak flow patterns of small streams following more frequent and severe storms. Furthermore, there are few on-going monitoring programs designed to show us either the impacts on, or responses of, natural systems, or the trends in related human responses

Currently, we lack a program to integrate these monitoring systems in a way that yields aggregated and synthesized information to support effective climate change adaptation and opportunity planning. We also need to identify key potential research sites and ecological observatories to monitor additional indicators, such as soil moisture deficit and drought stress, that will tell us how and why Maine ecosystems are responding to climate

[14] See, for example, C.2.3, C.3.1 (pp. 56, 58).
[15] A cooperative research support program of the state Agricultural Experiment Stations, Federal and state Governments and non-governmental research organizations.

change. Because it's especially difficult to predict the impacts of climate change on large systems, long-term monitoring will continue to be essential to adaptation planning.

Recommendation A.2.1.1 Identify existing monitoring systems relevant to climate change adaptation and policy initiatives; determine the accessibility of their climate change related data; identify monitoring systems that could fill voids in critical information and implementation strategies; and improve the integration of monitoring data in support of climate change decision making.[16] Those ecosystems most vulnerable to climate change impacts, such as

- coastal salt marshes and beaches,
- cold water streams that provide habitat for critical species, or
- ecosystems that provide essential services such as wetlands, barrier beaches and shellfish harvest areas

should have a high priority for such monitoring.

Recommendation A.2.1.2 Maine's scientific community, under the leadership of the University of Maine, should identify thresholds where key natural systems are at risk of disruption. These could include thresholds of

- ocean water acidity for sensitive marine organisms;
- drought stress for crops and forest species that reduce yields or invoke declines; and
- warming that creates new opportunities for human diseases in Maine that were previously inhibited by our cold climate.

All such thresholds have the potential to cause abrupt ecosystem changes that are able to produce significant risks / hazards.

***Recommendation A.2.1.3** Maine, in cooperation with the USGS, should re-establish and expand the river stream gauging network to monitor long- and short-term trends in flow in order to improve resource allocation and emergency response preparedness. There is an additional need to build and expand monitoring of snow-pack conditions, ice conditions, lake levels, and groundwater levels. Long-term, dedicated support needs to be provided for this task.

[16] Among other possibilities, there may be a need to improve weather station coverage in Maine to assure accurate monitoring data in the different climate zones noted in *MCF* (15).

Strategy A.2.2 *Continue and Expand Efforts to Gather Data Needed to Assess Maine's Climate Vulnerability*

Although the distinction isn't rigid, if we understand "monitoring" to refer primarily to tracking the effects of climate change on ecosystems and other aspects of the natural environment, then "data gathering" can be used to describe the collection of information about the existing (primarily human) environment in order to identify at-risk systems and structures. Existing data sets, such as current flood-plain maps, will need to be periodically evaluated to determine if they are still an accurate reflection of on-the-ground conditions. All such efforts will require approaches coordinated among different agencies. If the data are subsequently to be used for regulatory purposes, the processes involved must be transparent and open to challenge.

Recommendation A.2.2.1 Improve mapping and characterization of sea level rise vulnerability for all Maine coastal areas. Specifically, obtain and process high resolution LiDAR [Light Detection and Ranging] topographic mapping data for the entire coast, and use these to create base digital elevation models to update current shoreline HAT [Highest Annual Tide] maps and 100-year floodplain maps based on updated storm frequency data. Develop projected inundation models for likely expected sea level rise and alternative SLR scenarios.[17] Evaluate the need for revisions to municipal shoreland zoning maps in the coastal zone based on better resolution. Over the longer term, develop a methodology to regularly update actual and predicted tide/storm heights, create overlays that indicate future floodplains and account for dynamic processes, and make this information available to all state and local agencies.

***Recommendation A.2.2.2** Through incentives and additional enabling structures as needed, encourage use of these data by multiple towns that share a common river (as for instance through river corridor commissions) or beach and bay system to develop regionally consistent zoning and coordinated emergency response plans.

[17] Maine Geological Survey has the GIS capability to simulate inundation where high-resolution LiDAR data are available. To date, they have simulated a 2-foot rise in HAT for beach towns in southern and mid-coast Maine. As additional LiDAR data are acquired, more scenarios can by mapped, and advanced inundation models, including sediment dynamics, developed.

Strategy A.2.3 *Use and Refine Mathematical Modeling Tools to Expand the Range of Information Available to Climate Change Adaptation Policy Makers in Maine*

The climate system can be represented by models of varying complexity. That is, for any one component or combination of components in the system, such as seasonal wind patterns, a spectrum or hierarchy of models can be identified. These may differ in such aspects as the number of spatial dimensions, the extent to which physical, chemical or biological processes are explicitly represented, or the degree to which observational data are used to develop factors in the model. Coupled Atmosphere-Ocean General Circulation Models, such as those used by the University of Maine in *Maine's Climate Future*, provide a generally comprehensive representation of the climate system as a whole. Climate models are applied as a research tool to study and simulate the climate, and for operational purposes, including monthly, seasonal and inter-annual climate predictions.[18] The development of regional and smaller-scale models is moving ahead rapidly, and will offer much better spatial resolution to support policy development based on state-level data.

Recommendation A.2.3.1 Improve mapping and characterization of likely storm and precipitation impacts to Maine's watersheds and riverine flood zones. Specifically, obtain LiDAR data for known significant riverine floodplains, and develop better models for precipitation impacts by updates to national Precipitation Frequency maps [often identified as "TP 40"] for New England.[19] Enhance existing University of Maine efforts to develop predictive models such as those for precipitation at the watershed and regional levels. Over the longer term, develop protocols for using these data to delineate resource protection areas and provide modeling for stream flow events in watersheds to assist in design of road crossings.

[18] From the IPCC Fourth Assessment: http://www.ipcc.ch/pdf/assessmentreport/ar4/syr/ar4_syr_appendix.pdf. For further information about these models and their limitations, see *MCF* 14.

[19] Currently, the Northeast Climate Research Center at Cornell University is engaged in work that will produce a similar result. TP 40 maps are based on the historic record, and are used to determine how much rainfall to account for in designing and installing stormwater management systems such as culverts and struts. The current TP 40 maps are generally regarded to be substantially out-of-date, and thus underestimate current needs without regard to likely potential increases in number and intensity of precipitation events.

A.3 Information and Awareness

The enormous amount of information on climate change at the global, national, and regional scales, and the sheer volume of new, sometimes conflicting, data and information that arrives daily in the media and on the worldwide web, makes it difficult for interested Maine people and decision makers to sort and utilize climate information specific to our state.

Strategy A.3.1 *Maine Citizens, Businesses, Public Interest Groups, and Government Entities Must Have Access to Reliable and Relevant Information about Climate Change Impacts*

There is an identified need for Maine to develop systems that encourage collection, coordination, assimilation, and dissemination of climate change data, and to produce commonly understood and consistent messages about the impacts of climate change.

Recommendation A.3.1.1 All state agencies that regulate or provide support to various economic sectors, business activities, municipal land use and land trust planning efforts, or public service infrastructure should be charged with identifying likely climate change effects specific to those groups, and then work with affected entities to develop and disseminate information that will build awareness of the need to plan for these impacts. For example, Maine DEP should develop materials specific to publically-owned wastewater treatment facilities (POTW's) that assist such facilities to consider the effects of changing precipitation and/or sea level rise on their infrastructure, and support decisions needed for capital planning, disaster mitigation, etc.

Recommendation A.3.1.2 The University of Maine should continue its effort to establish a Maine climate information and coordination office to link information and resources from the University, other climate scientists in Maine and elsewhere, and Maine DEP and other agencies. The office would coordinate information on climate initiatives being carried out by public and private research institutions; develop an inventory of existing environmental monitoring programs, and make information available to the public and decision makers at all levels of government in Maine.

Recommendation A.3.1.3 Identify a group of "leading indicators", and Maine's position along those gradients of change where known. This would offer the public

and local officials a short, concise climate change "dashboard" in ordinary language specific to Maine.[20] The foundation for this is already found in *Maine's Climate Future*, and the University of Maine, Maine DEP, and others should coordinate this effort.

A.4 Planning and Coordinating Maine's Adaptation Efforts

As previously noted, responding to current challenges associated with climate change in Maine, and building resilience and adaptive capacity for the future, is in many ways a connected series of planning activities. In each area of concern, individuals, interest groups, government entities, and others identify natural and human systems that may be sensitive or vulnerable to, or at risk from, likely climate impacts and effects. Based on best available historic information, current monitoring data, and predictive models, they then develop planned responses to the anticipated challenges, identify the resources needed to implement those responses, and, in the best case situation, go on to put them in place as monitoring and assessment of new data demonstrate their need (*i.e.,* "monitor→ plan→ adapt"). As noted above, this is particularly important at the local level where specific actions will be implemented that directly affect Maine people.

Strategy A.4.1 *Develop and Disseminate Tools that will Allow Local and Regional Planning Authorities to Initiate and Implement Their Own Adaptation Planning Processes*

Additional resources will be needed to provide support and technical assistance for climate adaptation planning in order to address the many issues outlined in this report. These include, for example, risk assessment of local infrastructure, potential changes to land use practices and regulations, protection of vulnerable habitat, or effects on local public health delivery systems. State agencies and the Southern Maine Regional Planning Commission, in cooperation with Saco Bay communities, have launched a pilot project on climate change adaptation, including compilation of examples of "best practice" that cities and towns can use to build resilience from coastal hazards.

Recommendation A.4.1.1 Maine should re-institute the provision of State Planning Office grants to municipalities and quasi-municipal entities, specific to local climate adaptation planning. Grants should emphasize inter-local collaboration in

[20] Dials on the dashboard would likely include, for instance, a sea-level indicator showing measured historic change and projected height, with a mark for most recent data; and a similar representation of temperature in Maine's different climate zones. See *MCF* 21, 13 for examples.

planning efforts. This would require legislative action to fund, or could be initiated as a pilot effort using non-state grant funding.

Recommendation A.4.1.2 The State Planning Office should partner with other organizations to develop materials such as municipal climate adaptation planning handbooks in order to build climate change awareness at the local level, and among organizations such as the Maine Association of Conservation Commissions. A key goal will be to insure that a consistent message is being delivered and that resources are being used as efficiently as possible.

Strategy A.4.2 *Foster Regulatory Approaches that Utilize Multi-agency and Public / Private Collaboration to Address Climate Change Adaptation Issues*

Existing laws and regulations govern a wide range of actions that may be taken to address existing preparedness, or to build resilience and adaptive capacity. Most were designed and written prior to the emergence of climate change concerns, and thus did not consider potentially significant effects of climate change on rare species, priority habitats, and other important natural resources. Furthermore, these laws and regulations often conflict and/or overlap. It will be important for Maine to develop ways to refine these to incorporate climate change adaptation issues without compromising their original purpose and intent.[21] At the same time, there is a need to address impediments to regulatory change that hinder long-term decision making.

Recommendation A.4.2.1 Review and assess existing statutes and rules[22] to assure their strength and applicability in the context of projected climate change effects. For example, some existing regulations may make it difficult for municipal and private interests to carry out appropriate adaptation measures. Any revisions should provide opportunities for flexibility so that municipalities can implement creative approaches that integrate state and local climate adaptation and community sustainability goals.

[21] See, for example, B.4.3.2 (p. 43).
[22] Likely regulations include the Natural Resources Protection Act, Site Location of Development Act, Maine Endangered Species Act, Sand Dune rules, Shoreland Zoning rules, and flood plain management rules.

Strategy A.4.3 *Establish and Utilize a Policy Framework at the Federal, State, and Local Level that Recognizes the Inter-connected Nature of Climate Adaptation Impacts, Effects, Research, and Planning Needs*

Recommendation A.4.3.1 Maine's federal and state legislators should advocate for federal climate change legislation and appropriations that provide Maine with resources to support the critical monitoring, research, information exchange, and adaptation planning uniquely applicable to Maine. This would both preserve the values of Maine's natural resources and economy, and provide the framework necessary to identify and develop new opportunities that should also be part of Maine's adaptation strategy.

A.5 Build Capacity in the Private Sector to Address Climate Change Adaptation

Stakeholders representing Maine's private business and commercial sector have been significantly involved in developing this report, as can be seen on pp. 8-9. However, Maine's climate adaptation planning process will need to focus in three strategic areas in order to ensure that private sector entities develop their own capacity to address these opportunities and challenges.

Climate change effects are likely to provide new opportunities for Maine businesses, such as development of innovative technologies, even as they plan for operating in a changed environment.

Strategy A.5.1 *Identify and Engage Representatives of Key Business Areas Potentially Vulnerable to Maine-specific Climate Change Effects*

Certain business areas such as property insurance, tourism, and forest products have generated strategies and recommendations found in this report.[23] As further development of a Plan occurs, policy makers will need to assure additional representation from other sectors of Maine's economy.

Strategy A.5.2 *Encourage State and Local Officials and Programs to Engage the Private Sector in Adaptation Planning and Implementation Efforts*

This will be of special importance in locations such as coastal communities where likely climate impacts would effect significant and diverse business locations. As noted below, regional planning commissions can play a major role in this sort of outreach to private land and property owners.

[23] *E.g.,* B.1.6 (p. 37); B.7.2.1 (p. 49); C.3.1.2 (p. 59).

Strategy A.5.3 *Identify Opportunities for Maine Businesses to Take Advantage of Climate Impacts that May Demand New Products and Services*

In addition to greenhouse gas mitigation efforts and development of low-emission technologies in areas such as alternative energy, Maine and the world's changing climate will generate markets for technologies and products to increase climate resilience and respond to climate challenges. For example, as noted in the agriculture section of this report there is an emerging need to develop, test, and market new crop varieties suitable to Maine's changing environment.[24] A collaboration of Maine farmers and the Cooperative Extension Service could produce a commercial opportunity.

A number of the strategies and recommendations below anticipate the need for innovative technologies, particularly in the areas of engineered materials and structures and construction techniques, in order to meet current challenges and build resilience. It will clearly be in Maine's interest to be proactive. A possible first step would be for the University of Maine, Maine Technology Institute, the Department of Economic and Community Development, and other entities expert in emerging technologies and new business development to convene a conference to explore these possibilities.

A.6 Integrate Adaptation Planning into Implementation of *A Climate Action Plan for Maine 2004* [CAPM], Maine's Existing Mitigation Plan

LD 460 specifies that "[c]onvening this group to respond to climate change must not reduce continued strong state efforts to reduce greenhouse gas emissions." As the Third Biennial Report on Progress toward Greenhouse Gas Reduction Goals to the Natural Resources Committee (2010) points out, preliminary analysis through 2008 suggests that Maine's emissions are approaching the statutory target of a return to 1990 levels. However, not all of this progress can be attributed to the implementation of policies adopted in the 2004 *Plan*. In the context of the current report, it is imperative that Maine's climate adaptation planning effort identify actions that serve both to mitigate and respond to climate change impacts and effects.

A number of the recommendations in this report meet this standard, in several different areas as follows:

[24] C.5.1, p. 64.

Energy Production and Efficiency

A primary strategy area in *CAPM* involves the more efficient use, and replacement, of greenhouse gas-emitting energy sources. In a sense, this is a strategy for adapting to climate change in a carbon-constrained world as the combustion of fossil fuels for heating and transportation is reduced. For example, improvements to infrastructure energy codes; weatherization of Maine's aging domestic housing stock, and upgrading of energy-intensive capital equipment such as sewage treatment motors all decrease the demand for fossil energy. Similarly, development of alternative and renewable energy sources such as wind and biomass can serve to increase the reliability of Maine's energy transmission grid. At the same time, such actions serve related adaptation purposes, as indicated by the following strategies:

Strategy B.1.3 *Review and Modify Design Standards to Account for Likely Climate Impacts*

Strategy B.1.5 *Strengthen Existing Municipal Water Management Programs*.

Strategy B.1.6 *Assess the Climate Change Vulnerability of Maine's Energy and Telecommunications Networks*

Strategy B.3.1 *Assure that Maine's Urban Housing Stock…is Resilient to Likely Climate Impacts*

Transportation and Land Use

Recognizing that the transportation sector accounts for approximately 40% of Maine's greenhouse gas emissions, the *CAPM* identified a number of transportation-related greenhouse gas mitigation strategies. Most mitigation efforts focus on actions such as lowering vehicle miles travelled, or increasing the proportion of low- and zero-emissions vehicles, which do not have significant adaptation implications. However, assessing and developing transportation modes that can reduce dependence on motor vehicles holds potential for reducing emissions as well as lessening Maine's dependence on road transportation fuels.

Recommendation B.2.3.1 Assess Potential Risks to, and Opportunities for, Maine's Rail System

Land use planning combines elements of both mitigation and adaptation, particularly as this involves local comprehensive planning.

Strategy B.4.1 *Develop Approaches to Encourage Planning for Resilient Communities into the Existing Comprehensive Planning Process*

Forests and Agriculture

The forestry section of Maine's mitigation plan focuses on actions to preserve and enhance Maine's forests and timberlands in the interest of carbon sequestration and the production of sustainably-grown wood for biomass energy and long-lived products. It also notes the increasing pressure from development that has converted forests to other uses in recent years. As indicated below in this report, maintenance of the forest is a key element in assuring those ecosystem services necessary to the support of wildlife and fish in a changing climate regime, and to water quality for human use. Since more than 90% of our forests are privately owned, it will be important to provide landowners with incentives and support for keeping Maine's land forested. Thus, there are explicit links to:

Strategy B.3.2 *Maintain and Enhance Urban and Community Forests*

Strategy C.3.1 *Build Maine's Knowledge Base on Potential Climate Impacts to the Forest Environment*, with recommendations on pest and pathogen management, and ongoing research on changes in species composition, etc.

Strategy C.4.1 *Include Climate Change Effects on Wildlife and Habitat in Land Conservation Planning and Decision-making*, with accompanying recommendations

Strategy C.4.2 *Expand Current Efforts to Maintain and Restore Critical Wildlife Habitat and Assure Connectivity*.

Maine's agricultural resources have an identified role in mitigating the effects of greenhouse gases, including practices to enhance carbon sequestration through different cultivation techniques, and increasing production of locally-grown food to limit emissions associated with food product transportation. This matches well with:

Strategy C.5.1 *Build Research and Cooperative Extension Capacity,*
particularly to identify and test new varieties more apt to thrive in a changed and changing agricultural climate that would also be available as locally-grown substitutes for crops from out-of-state, thus increasing Maine's food security.

B. Maine's Communities and People

B.1 Built Infrastructure

The built environment of Maine includes what we generally think of as "human infrastructure:" the things we construct to provide us with shelter, places in which to work and do business, and common services such as transportation, safe drinking water, wastewater treatment, and energy. These are critical to our society, so that climate effects that may disrupt them will have real impact on our daily lives. At the same time, they represent those sectors of our economy in which we have the greatest financial investment, such that we are already accustomed to calculating the risks associated with potential damage, and making decisions to mitigate or offset that risk. Replacing old, outworn and inadequate infrastructure is a common and ongoing state-level and municipal activity. Planners must weigh all of the risks, needs and competing projects against available resources when developing plans to improve current infrastructure and develop resilience to potential future climate change effects.

Most of the likely foreseeable climate change impacts identified above in section III.B [p. 12] would affect the built environment to a greater or lesser extent. In assessing risk and vulnerability, stakeholders were aware that Maine's adaptive capacity to respond to climate stress in this area is comparatively high: that is, our society can take actions to protect our built infrastructure, although in some cases the costs will be significant, and in certain instances, prohibitive. In other cases, particularly in the coastal zone and in riverine floodplains, property owners and government at all levels will be faced with difficult infrastructure choices, including the possibility that it may be most cost-effective in the long term to move or abandon certain structures and infrastructure at risk of severe damage due to sea-level rise and severe weather threat.

In addition to the vulnerabilities associated with the coastal zone, other concerns or areas of high risk due to climate effects are:

- The functioning of residential, institutional, and commercial structures due to heat effects and/or severe storms and flooding;
- Stability of roadways and highways from the impacts of increased intensity and volume of storm events especially on streams in built up areas;
- Saltwater intrusion into public and private coastal drinking water systems, and groundwater contamination from inundation (sea level and inland precipitation) of septic systems;

- Management of common drinking water systems due to increased seasonal variability and weather extremes;
- Stormwater and wastewater infrastructure, especially carrying capacity during extremely heavy rain events;
- Energy and telecommunications capacity due to weather extremes.

In summary, it is probably fair to say that all our structures and infrastructure, from single-family residences to state-wide energy transmission systems, will, over time, need to be assessed / evaluated within the framework of their vulnerability to the likely impacts and effects of climate change.

"Much of our infrastructure for water delivery, wastewater transport, and transportation is not designed to handle the predicted increase in intense precipitation events" (*MCF* 25*)*. In order to address these challenges, the working groups identified the following strategies and recommendations applicable to both vertical and linear infrastructure.[25]

Strategy B.1.1 Inventory and Assess Public Infrastructure Vulnerability

A recent bi-coastal survey of property owners and municipal officials regarding attitudes and barriers toward climate action identified vulnerability assessment as the highest need.[26] Maine must develop a framework for identifying and cataloging infrastructure elements at risk of likely foreseeable climate change impacts and effects. This task will include the development of risk assessment tools specific to various infrastructure categories (*e.g.,* wastewater treatment plants; stormwater systems) using a range of climate metrics and environmental scenarios. Local government involvement will be essential to a comprehensive and equitable approach, and to assure local support of suggested policies and processes.

Recommendation B.1.1.1 A state-level task force should be convened to develop and disseminate a method to inventory and map all public drinking water supply systems, waste water treatment facilities, and locations where public linear infrastructure such as roads or sewer systems intersect surface waters in order to assess vulnerability to increased flows and storm events associated with likely climate change im-

[25] Linear (or horizontal) infrastructure is comprised of systems that support water management (drinking and waste water, surface flows and stormwater); power distribution; and ground-installed telecommunications. Transportation infrastructure is considered in the next section (B.2).

[26] *Climate Variability and Coastal Community Resilience: Testing a National Model of State-based Outreach* Cone, Joseph, Oregon Sea Grant; Oregon State University and Susan White, Maine Sea Grant; University of Maine. National Oceanic and Atmospheric Administration's Climate Program Office, Sectoral Applications Research Program, Aug 09.

pacts.[27] This should include vulnerability assessment tools that could be used by local authorities.

Recommendation B.1.1.2 The State Planning Office, local partners, and other state and local agencies should identify, assess and catalogue state-owned or state-funded pier, harbor, and waterway infrastructure likely to need elevation or improvement as a result of sea level rise, more frequent severe weather, and related climate effects. Existing SHIP [Small Harbor Improvement Program], FEMA and DOT grants could potentially be leveraged to support this effort and identify priorities. Where public assets are involved, a priority list based on vulnerability should be established to direct allocation of available funds. When prioritizing infrastructure for adaptation with public funds, project funding should follow protocols established to implement climate change adaptation plans and policies. Methods used to inventory these assets could be made available to towns and private landowners for their use.

Recommendation B.1.1.3 Establish a state-level approach that brings FEMA, MEMA, MaineDOT, the State Planning Office and municipalities together to identify and prioritize public infrastructure replacement based on climate adaptation considerations. Current regulatory and permitting processes may need to be evaluated and adjusted to account for jurisdictional overlap, and to allow for preservation and adaptation of priority infrastructure.

***Recommendation B.1.1.4** The Maine Department of Education should include considerations of likely climate change impacts, particularly higher average temperatures at the beginning and end of the school year, in school design and renovation criteria and funding formulas, and work with local authorities to identify older school buildings that may need to account for warmer temperatures.

Strategy B.1.2 *Support Continuing Regional and State Efforts to Update Key Monitoring, Mapping, Assessment and Planning Tools*
[see A.2.2.1-3, pp. 23-4]

[27] A recent informal review of available data, which are likely incomplete, identified over 28,000 such intersection points.

Strategy B.1.3 *Review and Modify Infrastructure Design to Account for Likely Climate Impacts*

Portions of Maine's built infrastructure are already overdue for upgrading or replacement. Renovated and/or new structures must be designed to meet expected climate effects. Current design standards must be systematically re-evaluated to this end. Key areas include:

- Promoting overall improvements to Maine's residential housing stock that account for the likelihood of more extreme weather events, flooding, etc. Increase the adaptive capacity of buildings to be more "self sufficient" during variable climate extremes through design modifications such as passive climate control, rainwater capture, or septic and sewage control. Methods could include revisions and additions to pending state building codes, modification of land use regulations, etc.
- Review and revise design standards for significant types of infrastructure such as wastewater treatment facilities, stormwater management systems, etc. Further development of adaptation standards should strive for compatible and complementary land use and building regulations at local, state and federal levels to allow innovative technologies and approaches to better manage significant precipitation events and sea level rise.
- Add sea level rise benchmarks, siting criteria, and risk reduction guidelines to coastal facility planning.

Recommendation B.1.3.1 Engineering to Lessen Stormwater and Wastewater Nutrient Effects on Ecosystems: [see C.2.2.2, p. 56]

Recommendation B.1.3.2 Anticipate and establish protocols for preserving at-risk infrastructure that is identified for adaptation in-place.

Strategy B.1.4 *Continue to Develop Policies and Regulations that Restore, Maintain, and Improve the Resilience of Built and Natural Systems, particularly on the Coast, to Climate Change Impacts and Effects*
[see C.2.1, p. 54]

***Recommendation B.1.4.1** Review existing state building codes[28] and plumbing codes[29] to anticipate likely effects of climate change. For example, recent revisions of the plumbing code allow for less system to water table distance for certain systems, which could compromise a system if water tables become shallower.

[28] Technical Codes and Standards Board, Department of Public Safety
[29] Plumbing Board, Department of Professional and Financial Regulation

Strategy B.1.5 *Continue and Strengthen Existing Municipal Water Management Programs through Enhanced State Revolving Fund Funding and Development of Innovative Approaches*

New approaches might include identification of possibilities for, and resources needed to allow, inter-connection of neighboring utilities to increase capacity and build in redundancy. Such initiatives, if undertaken, would also have immediate benefits in any severe weather event or other emergency.

Strategy B.1.6 *Encourage the Property Insurance Industry to Consider the Maine-specific Impacts of Climate Change in Determining Underwriting Criteria*

Property insurance underwriting is primarily market-based and subject to minimal government regulation. As insurers develop an awareness of the changes to insurance exposures presented by climate change, their underwriting decisions can be expected to constitute an important component in societal decision-making relating to adaptation to, or abandonment of, particular risks or classes of risks. It will be important to encourage insurers to base decisions on sound information regarding Maine's climate change vulnerability. To the extent changing climatic conditions may cause insurers to make underwriting decisions in advance of both a general societal acceptance, and the acknowledgement of potential vulnerability by currently insured individuals or applicants, there will be a need for a public education effort. It may reasonably be anticipated that if insurers tighten underwriting criteria in response to climate change, there may be calls for publicly-developed or mandated coverage options. These will need to be carefully considered, in order to balance protection of the insurance-buying public with the maintenance of a viable property insurance market in Maine.

* * * * *

Maine's linear infrastructure also includes the energy transmission and telecommunications networks, and, as the 1998 ice-storm demonstrated, these can be extremely vulnerable to the effects of weather. Given that one of the likely foreseeable impacts of climate change is more frequent ice-storm events, as warmer early winter temperatures produce less snow and more ice, there is a clear need for Maine to assess vulnerability in this area of infrastructure. At the other extreme of the climate year, the forecast of more frequent and more acute heat events is expected to put increased demand on the electricity grid. Finally, predicted decreases in the depth of annual snow pack may have an impact on the large hy-

dro-electric generation reservoirs that produce much of Maine's renewable power, depending on the ability to adapt storage regimes and increased seasonal precipitation with demand.

Strategy B.1.6 Assess the Climate Change Vulnerability of Maine's Energy and Telecommunications Networks

This could be accomplished by a legislative request to the Public Utilities Commission to undertake a review, with stakeholder input, similar to that carried out in 2009 by MaineDOT [see p. 38]. Such an evaluation might also include an assessment of the vulnerability of the various energy generation and transmission systems current and projected for Maine, including wind and biomass, and appraisal of the usefulness of distributed generation projects to provide back-up and redundancy in view of the likelihood for more frequent severe storms. Another potential area of action would be to develop strategies to reduce the vulnerability of transmission systems, including burial of transmission lines.

B.2 Transportation

It's easy to visualize the effects on surface transportation systems of likely foreseeable climate impacts. In recent years, a number of extreme precipitation events have washed out roads and bridges that had previously been considered more than adequately engineered. Coastal storms have inundated roadways with stormwater and sediment, and have snapped street lamps. Some climate change projections for Maine predict that such extreme weather events will become more common in the future.

The key areas of transportation infrastructure that are most at risk to climate change are culverts, struts, and drainage ditches. Their vulnerability is predominantly related to precipitation and storm events and, along the coast, is overlaid on sea-level rise impacts.[30] At the same time, transportation-related infrastructure can exacerbate negative impacts of climate change effects on drinking water quality and quantity, and on natural systems, especially wetlands and streams. Unless structures are well designed and maintained they are likely to impede the resilience of natural systems and their ability to adapt. Infrastructure failure can degrade water quality, quantity, and fish and wildlife populations as sediment and blockages impact the in-stream and shoreline habitat. Extremes in weather and temperature already increase the need for fish and wildlife in and along streams and rivers to find refuge from flow and temperature extremes. Thus, the management of water has the highest prior-

[30] While bridges might be expected to occur in this list, MaineDOT has recently inspected all bridges with a span greater than 20 ft. and is currently in the midst of modifications to deal with scour. Thus, the stakeholders' assessment is that this area has lower current priority.

ity in assuring preparedness and building resilience to likely climate change effects in the transportation system.

Maine's state-level road transportation system is well-positioned to respond to current climate impacts and build resilience for the future. Maine's Department of Transportation has included considerations of climate in its long-range planning processes for several years, and recently completed a study, "Climate Change and Transportation in Maine," which addresses strategies to build adaptive capacity in the system. As the authors point out,

> Many of these projected impacts already occur with noticeable frequency. … Many of the issues associated with climate change are expected to be more intense versions of the same problems MaineDOT already deals with effectively. This will allow the department to incorporate short-term and long-term adaptation strategies on a gradual basis....[31]

However, only about one-third of Maine's public roads are within MaineDOT's span of control, not including the substantial network of private roads, particularly in the unorganized territories.[32] The majority of the roads Mainers use on a daily basis are maintained by municipalities or are privately owned. Local officials are generally aware of areas of greatest stress during severe storms, but if projections of more frequent and intense wet weather come to pass, much of this infrastructure may be at risk.

Strategy B.2.1 *Develop a Method to Inventory Roadways, Culverts, Struts, and Related Infrastructure at All Jurisdictional Levels, and Overlay This Information onto NOAA and FEMA Maps of Floodways, Coastal Inundation Zones, etc.*

Compiling this information will require substantial resources and a specific implementation plan, including development of standard assessment and inventory tools that are made available to municipalities and private road owners; determination of watershed characteristics that pose the greatest risks to transportation structures; and creation of a common repository for the information with protocols to assure continual updating and dissemination to utilities for planning purposes.

As recommended above [A.2.2.1-2, p. 23-4], acquisition of LiDAR data for Maine would be greatly beneficial to MaineDOT, and thus to the taxpayers and traveling public in

[31] Maine DOT Environmental Office, 10/14/09, pp. 2,3.
[32] Of 22,830 miles of public highway, 7472 are state-owned and maintained.

Maine.[33] LiDAR will make available high resolution elevation data over a large portion of the state, including coastal areas and the most heavily populated and developed areas. MaineDOT is responsible for countless road-waterway crossings. LiDAR data will make it possible to complete preliminary design procedures for these structures while minimizing the need for on-the-ground site visits. A critical element in waterway crossing design is assessment of high flow carrying capacity and flooding potential. LiDAR will provide additional data that is not ordinarily collected in the design process that will contribute towards improved assessments of flooding potential. MaineDOT projects crossing surface water bodies, wetlands, and coastal marshes often have the potential for imposing environmental impacts. LiDAR data will allow MaineDOT to assess these potential impacts at an earlier stage in the process while avoiding the need to collect the usual amount of project-specific data. This will result in cost savings and better project design.

Recommendation B.2.1.1 Maine DOT should initiate development and distribution of inventory/assessment tools; provide information to local jurisdictions on potential climate change impacts related to routine maintenance and repair, and capital improvement planning; and provide technical assistance to local entities for modifying existing road structures to mitigate current effects.

Strategy B.2.2 *Develop or Update Transportation Infrastructure Design Standards that Take Into Account Best-Available Calculations of Recent-Historical and Projected Storm Hydrology* [see also C.4.2.4, p. 63]

This effort may also determine methods for identifying the need, and setting priorities, to raise, retrofit, relocate, and/or consider abandonment of (where re-engineering is too costly), roadways and structures at risk of climate change effects.

Maine's rail system shares vulnerability to likely climate effects similar to the road system, and faces the challenge of greater constraints on available remedies because of less-flexible siting.

A climate-resilient rail system has the potential to lower the emissions cost of transportation, reduce the vulnerability of Maine's food and energy supply to storm-caused disruption, and enhance the capacity of the forest products industry.

Recommendation B.2.3.1 Maine DOT should conduct a comprehensive assessment of potential risks to, and opportunities for, the state's rail system associated with climate change impacts, and develop standards for upgrading to projected fu-

[33] While A.2.2.1 refers specifically to the coastal zone, and current applications for Federal funds also aim at a complete coastal record, it is noted elsewhere in the Report that LiDAR data will be equally significant in inland areas. See A.2.3.1 (p. 24).

ture conditions. Privately-owned rail companies should be invited to join this effort as stakeholders.

B.3 Urban Areas

In a rural state such as Maine, urban areas hold particular importance as the centralized locations for economic, medical, educational and transportation services. Likewise, as cultural destinations, downtowns play a vital role in the state's creative, hospitality, and tourism economies. Climate change impacts will be felt acutely in urban areas, and corresponding adaptive strategies need to accommodate the unique needs of cities and town centers. Furthermore, improvements to cities and established town centers have capacity to benefit large numbers of people, create transportation efficiencies, and combat the eroding influence of sprawl on the rural landscape. The adaptation of cities, particularly Maine's coastal cities, will be a crucial challenge in the state's climate change future. In addition to the following strategies, other areas for future strategic development include:

- Development of policies for protection of and accessibility to vital urban service centers, especially during emergency events [see B.8, p. 50];
- Protection of areas of state cultural significance such as urban and village waterfronts and historical structures of state significance.

Strategy B.3.1 Assure that Maine's Urban Housing Stock, Including Multi-Family and Public Housing Units, Is Resilient to Likely Climate Change Effects

Maine's residential housing stock is frequently identified as among the oldest in the country.[34] This is as true in urban areas that grew originally as industrial communities from which the industries have departed, as in rural areas. Such housing frequently does not meet current standards for weatherization, energy efficiency, and ventilation. It is important, especially for Maine's multi-family residential housing stock, to retrofit these structures for increased passive survivability so, in the event of an emergency, the building remains safe and habitable until services can be restored. As Maine seeks to update and improve its housing toward the recently-announced goal of 100% weatherization by 2030 - a goal that will reduce energy use and thus Maine's contribution to greenhouse gas emissions - it is vital that renovations take climate change impacts and related human health risk into account.

[34] Maine ranks 6th on the US Census Bureau's list of the states' percentage of homes built before 1940 [2008 American Community Survey].

Recommendation B.3.1.1 The Maine State Housing Authority, in collaboration with the Maine Green Building Council, the Maine Chapter of the American Council of Engineering Companies, Maine's local public housing authorities, Federal and state agencies, and other stakeholders, should be asked to develop tools to assess the climate vulnerability of older (> 30 years) public and multi-family housing, and make recommendations for renovation standards that account for this. [see also B.1.3, p. 35; B.6.2.1, p. 47]

Strategy B.3.2 Maintain and Enhance Urban and Community Forests

When most people think about the "Maine forest," the image in mind is likely to be of unbroken miles of woodland. But as population growth and development continue to transform some of this acreage for residential and commercial uses, Maine's urban and community forests will have increased importance in responding to climate change. These forests can contribute to mitigating greenhouse gas emissions by absorbing and sequestering carbon dioxide; they can play a crucial role in offsetting the "urban heat island" effect of increased summer temperatures; and they support community well-being as outdoor recreation space. Since they are also vulnerable to climate stressors such as new pests and pathogens, and damage from severe storm events, there is a clear need to assure their continued vitality.

Increasing urban tree planting not only improves "livability." It can also offset local heat effects, and sequester carbon to offset greenhouse gas emissions.

***Recommendation B.3.2.1** The Maine Forest Service in the Department of Conservation should develop a strategic plan for the maintenance and enhancement of urban and community forests in the light of anticipated climate change effects. The plan should includes recommendations for:

- Increasing financial and technical support to municipalities to improve street tree planting and maintenance, and community forest management;
- Inventorying, and developing as needed, resources for pest and pathogen early detection, outbreak planning, and response to catastrophic weather events;
- Making incremental changes in street tree species composition and diversity;
- Outreach to homeowners, municipalities, and others in support of these efforts.

B.4 Land Use and Land Use Planning

Most Maine people have a strong attachment to the land they live on and enjoy, and strong opinions about the regulation of its use. How Maine citizens, businesses, and communities account for most likely climate impacts in development and land use planning is likely to be an ongoing process of considering data and forecasts, assessing vulnerability at a local level, and developing public policy with the understanding that today's decisions will undoubtedly need to be revisited on a regular basis. An important consideration will be how to integrate planning for adaption to climate change into existing planning approaches and requirements.

Strategy B.4.1 Develop Approaches to Encourage Planning for Resilient Communities into the Existing Comprehensive Planning Process

***Recommendation B.4.1.1** SPO should include elements of planning for resilience in the face of likely climate change effects in Chapter 208, the Comprehensive Plan Rule. Until data are available to support specific analysis at the municipal level, these elements of Chapter 208 would not be used to determine consistency of a comprehensive plan but rather serve to start the conversation at the local level and help inform community planning decisions in the different regions of the state.

Local efforts to begin climate adaptation planning will allow municipalities to position themselves well to receive state and federal implementation funding in the future.

Strategy B.4.2 Develop a Series of Models for Adaptive Land Use Planning for Decision-Makers at all Jurisdictional Levels

Maine's local municipalities, land trusts, regional planning commissions, and state-level agencies such as the Land Use Regulatory Commission (DOC) and SPO Land Use Team each have a role to play in the planning necessary to meet existing climate-related challenges and build future resilience. Local conservation commissions and land trusts, where they exist, can help lead efforts to encourage towns to undertake appropriate planning, and to work directly with landowners to identify low-lying undeveloped coastal uplands and floodplain areas that have the potential to support wetland migration resulting from sea level rise and increased storm flows. Municipal and regional decisions must be based on climate change risk assessment to inform both existing development and growth management. Maine's Growth Management Act currently requires towns to address marine resources, water resources, critical natural resources, transportation, municipal facilities, and

future land use in their Comprehensive Plans. Each has a clear nexus to climate change adaptation. Models and planning tools should distinguish between existing developed areas, those that may be considered for development, and rural areas.

Recommendation B.4.2.1 Maine should develop systematic approaches and incentives for conservation and/or purchase of property that allows for ecosystem protection, landscape connectivity, natural retreat of wetlands in response to SLR, and response to inland inundation risk. These should include incentives for municipalities and landowners to develop local open space plans that protect key landscape linkages or undeveloped low-lying coast line and other vulnerable areas and habitats. Some of these will be identified at the municipal level or by local land trusts that have incorporated climate change adaptation concerns into their strategic conservation plans. Land conservation through new funding for the Land for Maine's Future program could play a key role in accomplishing this. [see also C.4.1, p. 60]

Strategy B.4.3 *Coastal Adaptation: Establish a Continuing State-Level Effort to Develop Policy, Prepare for, and Create Resilience to, the Most Likely Foreseeable Impacts of Climate Change on the Maine Coast*

The coastal zone has a unique set of challenges and opportunities associated with climate change effects that require dedicated attention. Planning for climate change effects will have to take place at all levels of government. There is a clear need for state-wide strategy and standards for land use and development, supported by regional planning to determine regional needs, with specific implementation steps developed at the local level, each level nesting into the other.

Recommendation B.4.3.1 Maine should develop a standardized set of criteria for assessing coastal communities and infrastructure for response and resilience to likely climate impacts, including a mechanism for evaluating vulnerability. These should recognize the unique ecological, social, and economic qualities of different areas of the coast, and should be used to guide investments in infrastructure repair, protection, and land conservation and restoration.

Recommendation B.4.3.2 The Maine Geological Survey should periodically evaluate the adequacy of current setback requirements for beaches and bluffs, and recommend updates to existing policies. MGS should continue to identify best management practices including promotion of "soft" solutions and methods to minimize

armoring of eroding beaches and bluffs; this will allow natural sediment transport to nourish beaches, estuaries, tidal flats, and sand bars. [see also C.2.1.3, p. 55]

Recommendation B.4.3.3 The State Planning Office and the Department of Environmental Protection, in collaboration with municipalities, landowners, and other interested parties should jointly review current state laws and regulations regarding development in coastal areas, particularly for beach/dune areas, and make recommendations for changes, if any. These may be needed to clarify that public funds may not be used to fund or support expansion or rebuilding in hazard areas unless such an expansion or rebuilding is designed, engineered and constructed to withstand climate impacts and effects, and to avoid, minimize and compensate as appropriate for undue adverse effects. Other areas for potential action would include:

- Reforming National Flood Insurance Program administration to discourage reconstruction in hazard areas;
- Establishing policies to allow significant infrastructure to be maintained with adequate standards for engineering and redevelopment;
- Development of a plan to reduce existing built infrastructure on beaches and dunes, and/or provide incentives to promote “softer” solutions to prevent destruction. Such a plan could identify resources that could be used for strategic buy-outs of at-risk property. [see also C.2.1.2, p. 55]
- Review of existing regulations and flood plain management rules toward an integrated regulatory scheme that incorporates climate change issues and emerging trends, and clarifies municipal and state responsibilities.
- Establishment of adaptation policies for state-owned properties, infrastructure and investments in the coastal zone. When such policies would be implemented in specific areas, development of methods for working with adjacent land/property owners to assist them in evaluating and responding to the situation ;
- Working with federal and industry partners to identify incentives / disincentives applicable by the financial services industry to reflect costs and benefits of coastal infrastructure investments under conditions of climate change;
- Economic development planning that allows for the natural migration of beaches;

- Review of potential protective zoning for lands likely to become coastal wetlands under projected two-foot sea level rise. (In effect, extending the concepts currently applied to beach rebuilding to the upper edge of salt marshes.)

B.5 Rural Communities and People

In recent years, as Maine's population distribution has shifted significantly toward urban and suburban areas in the south and west of the state, partially as a result of shrinkage in the traditional natural resource industry employment base, smaller towns and rural areas have seen a decline in their capacity to provide public services. In addition, planning at the local level is often not as strong in rural communities and small towns as in larger municipalities. As a result, it may be valuable to consider the particular needs of rural communities and people in the face of likely climate change impacts, in order to assure equal access to tools and resources needed to build resilience into their local structures, systems and economies. It should be noted, however, that some smaller communities may enjoy an advantage in resilience because of strong social ties and traditions of self-reliance.

Strategy B.5.1 Assess the Climate Change-Related Needs of Smaller Communities and Rural Areas of Maine, and Assure Resources and Technical Assistance to Build Adaptive Capacity

Recommendation B.5.1.1 The Maine Emergency Management Agency [MEMA] should develop assessment guidelines for local use to evaluate community all-hazards vulnerability and emergency preparedness, both current and future in light of climate change. MEMA and County Emergency Management Agencies should continue to provide technical assistance to rural communities in emergency preparedness, and build on existing social networks and relationships to optimize resilience. [see also B. 8, p. 50]

B.6 Health and Social Well-being

Climate change presents a serious threat to the public's health. According to the authors of *Maine's Climate Future*, temperature and precipitation are likely to increase across the state in the 21st century, and these changes "threaten to decrease air quality, increase the spread of animal and microbial sources of disease, and increase danger from extreme

weather events."[35] As a result, the medical, public health, and social services communities have particular responsibilities for identifying threats to Maine's people, and for leading the effort to prepare for, and adapt to, the likely consequences. To be able to plan for adaptation and prevent negative impacts on the health of Maine's residents, it will be necessary to design and develop systems to measure and monitor climate-related health effects, identify those populations which may be most vulnerable, and respond to climate-related public health emergencies effectively. The following strategies and recommendations have been developed by Maine's public health agencies and stakeholders in order to address this need.

The Maine Center for Disease Control's Environmental Public Health Tracking program is currently developing indicators for climate-change related health effects.

Strategy B.6.1 *Evaluate the Ability of Existing Public Health Surveillance and Tracking Systems to Assess Existing and Emerging Climate Change-related Health Threats*

This effort would involve enhancing existing surveillance systems to include those climate-related health threats that are insufficiently covered by existing systems, and may require additional resources. The eventual goal would be to identify highest-risk to public health emergencies likely to result from climate change effects, and develop specific state and local plans to respond

Recommendation B.6.1.1 Review existing data and current research to ensure that climate-related health concerns, such as expanding and emerging vector-borne diseases, exacerbation of respiratory symptoms due to increasing temperatures or air pollutant levels, and increasing algal blooms and water-borne disease outbreaks due to increasing temperature and precipitation, are known and understood.

Recommendation B.6.1.2 Pilot-test proposed indicators for climate change-related health effects based on existing indicators developed by the Council for State and Territorial Epidemiologists[36], as part of the Maine Center for Disease Control's (ME-CDC) Environmental Public Health Tracking program. In specific, indicators for heat-related morbidity and mortality should be constructed, and the utility of other proposed indicators of climate change-related health effects should be evaluated.

[35] *MCF* 58

[36] English, PB, AH Sinclair, Z Ross, et al. *Environmental Health Indicators of Climate Change for the United States: Findings from the State Environmental Health Indicator Collaborative.* Environmental Health Perspectives, 117(11): Nov 2009.

Strategy B.6.2 *Develop Preventive and Responsive Measures to Address Behavioral Health Issues associated with Climate Change Impacts and Stressors such as Disaster Trauma*

Recommendation B.6.2.1 Maine CDC should develop resources, and provide training, for health providers (including local health officers) on behavioral emergency preparedness. This effort should develop new models that include *curricula* to assist the establishment of guidelines and methods for introducing mental health resilience at the community level to promote successful adaptation to the effects of a changing climate.

Strategy B.6.3 *Build Awareness of Climate Change as a Health Issue among Health Providers and Maine Citizens*

As better and Maine-specific data on climate-related health impacts are gathered and assessed, information for health providers and the public will need to be revised and made available.

Strategy B.6.4 *Over the Longer Term, Adapt the Built Environment to Mitigate the Impacts of Climate Change on Human Health* [see B.1.3, p. 40]

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In addition to strategies to address the effects of climate change on public health and welfare systems in general, stakeholders noted that Maine has particular vulnerable populations and communities of special concern when viewed through the lens of climate. These include:

- Elders
- Indigenous people
- Disabled / handicapped
- Children
- Refugees and migrants
- Low income groups

Any of these may be disproportionately affected by one or more climate change impacts since they are already vulnerable due to factors unrelated to climate. For example, many of Maine's indigenous people, as pointed out in *Maine's Climate Future*, depend heavily on agriculture, forest products, and tourism, changes to any of which may put traditional Native American economies and cultural identity at risk.[37] Similarly, the elderly and very young are likely to experience health impacts more intensely because of their compromised or less-developed immune and disease-resistance systems. Many of these groups have

[37] *MCF* 35-38.

less access to information and resources that would otherwise allow them to be proactive in preparing for climate-related natural disasters and weather events, and associated health risks.

Stakeholders pointed out that any strategic response to the needs of these populations needs to be undertaken in a way that assures their integration into the wider overall scheme of planning and response, rather than being treated strictly as having "special needs."

Strategy B.6.5 *Assure that the Needs of Maine's Communities of Special Concern are Accounted for and Integrated Into Climate Adaptation Planning*

Components of such a strategy would include actions such as:

- Identifying specific groups and communities at the highest potential risk;
- Providing climate adaptation information that takes into account differences in perceptions and cultural norms about health to relevant advocacy organizations;
- Developing methods to assure that health and social service providers are aware of the special climate change-related needs of these communities / populations;
- Engaging the Governor's Office of Multi-cultural Affairs to assist in planning.

B.7 Recreation and Tourism

All of the likely changes to Maine's climate will affect recreation and tourism, a major contributor to the state's economy. The industry and outdoor users have already observed changes in seasonality (such as earlier ice-out dates on lakes and ponds, and shifts to later-season snowfall), and as overall warming increases, there is a high likelihood that Maine may become the "last refuge" in the Northeast for winter sports enthusiasts. On the other hand, as summer temperatures and heat-related air quality concerns increase, some people may be less able to take advantage of outdoor recreation opportunities.

Maine already has a multi-faceted and highly-developed approach to land conservation that allows public access for recreation in addition to other primary purposes such as habitat protection and maintenance of working forests.

Strategy B.7.1 *Assure that All State Programs Involved in Acquisition of, or Access to and Use of, Public Lands Include Climate Change Adaptation in Planning and Decision-making* [see also C.4, p. 60]

As conditions change, Maine's public lands such as parks, wildlife refuges, conservation areas, and eco-reserves may experience changes that would dictate changes in the way they are accessible and used. For instance, later onset of cold winter temperatures with resulting rain instead of snow may limit the period of motorized access to some areas. Similar conditions would likely increase the vulnerability of some areas to damage from use. The state's land managers will need to account for these changes.

***Recommendation B.7.1.1** State agencies and programs responsible for the use of public lands should collaborate in developing a long-range plan to account for likely climate change impacts.

Strategy B.7.2 *Develop and Implement Strategies to Raise Climate Change Awareness in the Recreation and Tourism Sector*

Changes in temperature and seasonality have the potential to increase demand throughout Maine's tourism industry.

Since many businesses in this sector are small and independent, they may not have access to up-to-date information about likely climate change effects on their industry.[38]

***Recommendation B.7.2.1** The Office of Tourism in the Department of Economic and Community Development should initiate an effort with representatives of the various sectors of the industry to identify and respond to their needs for information that will assist them to build business resilience to climate change.

***Recommendation B.7.2.2** Enhance the current Lodging and Hospitality Initiative in Maine's "Environment Leader" program to highlight the actions Maine's tourism industry is taking to adapt to climate change.

* * * * *

A significant share of out-of-state tourism is centered in the coastal zone, which faces the particular challenges associated with sea-level rise in addition to those likely to be experienced inland. For example, as summer heat increases, demand for ocean-front recreation may increase at the same time that some beaches lose capacity due to erosion and sea level rise, and others experience more frequent closures due to bacteria caused by stormwater run-off and wastewater overflow.

[38] For a short summary of both positive and negative impacts, see *MCF* 48-50.

Strategy B.7.3 *Utilize Existing Data, and Develop Specific Models, to Assist the Coastal Tourism Industry in Responding and Adapting To Climate Variability*

Coordination among tourism officials, industry, economists, natural resource agencies, and state and local planners will be needed to develop these approaches.

B.8 Emergency Management

Emergency management and disaster response are a fundamental responsibility of government at all levels. Response to severe weather events causing flooding or power outages, for example, is standard for local municipalities and emergency services, utilities, and for state and federal management agencies. However, given the reasonable expectation of more frequent and more intense weather events in coming years, with a corresponding increase in demand for emergency response services, the stakeholders are agreed on the need for a careful evaluation of Maine's current capacity in this area, and for planning to meet critical needs in the future.

Efforts are currently underway to address known areas for improvement in emergency planning and response. These efforts include development of regional response capacity, which encompasses facilities, equipment and trained personnel. It will be critically important to continue these and related initiatives into the future, to ensure a continuing ability to respond effectively to more, and potentially more severe, weather-related emergencies.

Strategy B.8.1 *Assist All Levels of Government Can Use to Build Resilience into Emergency Management and Response Systems*

***Recommendation B.8.1.1** Continue to monitor and influence changes to national policies and programs that have the potential to provide funding for hazard mitigation in Maine. Such programs include FEMA's pre-disaster mitigation funds. In some cases, application procedures need to be changed to make them more user-friendly.

Recommendation B.8.1.2 Develop and distribute tools to local jurisdictions and services that will allow them to evaluate the potential effects of climate change-related impacts on their emergency response capacity and critical infrastructure. Examples include:

- Hospitals and other health-care delivery facilities;

- Assessment of local road systems that may be at risk of impeding emergency or disaster response due to weather; and
- Assessment of municipal response providers' communications and delivery capacity under extreme conditions.

Strategy B.8.2 *Continue to Improve Cooperative Efforts Among Agencies at All Levels to Assure Needed Redundancy in Disaster / Severe Weather Situations*

Recommendation B.8.2.1 Continue to improve interactions among Federal, State, and local emergency services planners and providers to promote regional and statewide response and recovery capacity.[39] Specific ongoing initiatives to support this recommendation include:

- Adoption of a statewide mutual aid agreement;
- Standardized response training to support mutual aid;
- Enhancement of interoperable communications systems;
- Development of regional emergency shelter system (including the ability to serve those with disabilities, and to protect domestic pets);
- Development of mutual aid systems with other states and eastern Canadian provinces;
- Development in cooperation with FEMA of debris management, resource allocation and deployment plans;
- Supporting FEMA initiatives to build comprehensive catastrophic disaster plans in partnership with the State.

On the open ocean waters, the effects of storms and other weather extremes will affect shipping, ferry service, recreational boating, and fisheries, and will probably increase the demand for marine safety services and rescues.

Recommendation B.8.2.2 Maine's congressional delegation should be asked to work with other regional delegations to submit a request to Congress for increased funding for the Northeast Regional Coastal Ocean Observing System (NERACOOS), and to add in-shore monitoring, to maintain and enhance weather and water quality forecasting capacity.

[39] This would build on PL 2009 c. 175, calling for the creation of a statewide mutual aid/emergency assistance network, to include climate change impacts.

C. Maine's Environment and Natural Resources

C.1 The Gulf of Maine

As it is today, the Gulf of Maine has a profound effect on Maine's climate, weather, quality of life for wildlife and humans, and economy. *Maine's Climate Future* puts it this way:

> The Gulf of Maine is one of the most productive ecosystems in the world, supporting commercial and recreational fishers with a combined annual value to the US economy in excess of $1 billion and providing upwards of 26,000 jobs. The coastal zone of Maine is home to the majority of the state's population and, as the destination for millions of visitors, contributes significantly to the tourism economy (17).

In this section, the focus will be on the Gulf itself, particularly offshore, with an emphasis on marine life. Note, however, that climate impacts in this area will be mirrored in the coastal zone, the subject of the next section.

Those impacts with the likelihood of most significant impact to the ocean are:

- Changes in ocean circulation patterns, especially open ocean current changes that have an impact on the transport of deep cold waters into the Gulf from the Atlantic;
- Changes in seawater chemistry, including nutrient levels and acidification;
- Changes in amount of freshwater delivery to the Gulf from melting ice in the Arctic, which would impact stratification and in turn productivity;
- Changes in seawater temperature, which may differ between in-shore and open ocean; and
- Changes in off-shore wind patterns, a matter of importance in light of current efforts to utilize wind energy.

Given the extreme complexity of ocean chemistry, it is not yet clear just what changes such as acidification, calcification, or nutrient transport and availability will have on the marine ecosystem and the species it supports. We know that these are already stressed by other human impacts, especially stormwater runoff, which may be exacerbated by climate change. The entire marine foodweb is expected to undergo changes in both plant and animal species, including the increased risk of invasive species, with corresponding changes to Maine's ocean fishery.

Strategy C.1.1 *Develop a Monitoring Strategy for Key Marine Climate Change Indicators*

Such a strategy should include establishing a framework for coordinating the exchange of scientific knowledge, data collection protocols, regulatory issues, etc., among all interested parties in the United States and Canada. Resources are badly needed to initiate and maintain a suite of monitoring programs in the marine environment. For the estuarine and marine ecosystems, climate change affects the physical and chemical properties of Gulf of Maine waters, which in turn alters physiological processes, food webs, and distribution and migration patterns of marine organisms. Robust monitoring programs are needed to monitor atmospheric and water properties, circulation patterns, distribution and abundance of marine organisms (phytoplankton to marine mammals and sea birds, including invasive species), changes to habitats, etc.[40] The Gulf of Maine Council on the Marine Environment's recent proposal for a Gulf of Maine Restoration and Conservation Initiative could provide the multi-jurisdictional means to address region-wide monitoring needs.

Recommendation C.1.1.1 Maine's academic institutions, public interest groups, and state agencies should establish a working group of experts to catalogue and evaluate existing data / research efforts, and identify significant information gaps to which research should be directed.

Recommendation C.1.1.2 Maine should provide additional resources for the efforts of the Marine Invasive Species Working Group to improve long-term monitoring for invasive species in the Gulf of Maine.

Strategy C.1.2 *Develop and Advocate for More Adaptive / Resilient Fisheries Management*

Changes in distribution and abundance of marine species are likely. Yet current fisheries management systems present obstacles to flexibility in target species or gear on the part of any individual fisherman. This adds to the social and economic vulnerabilities of Maine coastal communities. Actions to address this strategy must be multi-jurisdictional.

[40] Programs include maintenance and expansion of the Northeast Regional Coastal Ocean Observing System (NERACOOS) buoys and CODAR systems; Maine-New Hampshire Inshore Trawl Survey; DMR's volunteer phytoplankton monitoring program for harmful algal blooms, among others.

C.2 Coastal Ecosystems

"The 4,000-plus miles of the Maine coast encompass a wide array of ecosystem types, from salt marshes and sandy beaches to steep cliffs and mountains to numerous bays, inlets, harbors and estuaries" (*MCF* 21). This section focuses on the likely climate change impacts to that morphology[41] and to the natural system populations that live there. The effects of climate change to the human and built environment in the coastal area were discussed in section B.1 [p. 32].

The anticipated rise in sea level, accelerating beyond the observed increases during the last century, is the primary concern in planning how Maine's coast could become more resilient. As noted before, the effects of higher sea surface levels will be compounded by the increase in significant storm events. In addition, increases in precipitation that result in greater stormwater runoff have a coastal impact because most of the additional runoff reaches the major rivers that flow through and into estuaries and wetlands, bringing with it sediments and pollutants.

Strategy C.2.1 Continue to Develop Policies and Regulations that Restore, Maintain, and Improve the Resilience of Natural Systems, particularly on the Coast, to Climate Change Impacts and Effects

Everywhere on the landscape, but particularly on the coast, land forms and water flows are constantly in flux. For instance, the erosion of riverbanks and coastal bluffs produces sediments that change the course of waterways and nourish fresh and saltwater wetlands over time. Since changes such as these are sometimes disadvantageous to human infrastructure and development, we have been responsible for attempting to resist or mitigate these effects through construction of seawalls, dikes, dams, hardened channels, and the like for hundreds of years. However, this effort to interfere with natural processes frequently has unintended consequences. There is strong scientific evidence that wetlands of all sorts, for example, act as buffers and sponges for the overflow of water from the increasingly impervious human environment, protecting our communities and structure from flood damage. Thus, as climate effects such as sea level rise (with a corresponding increase of "Highest Annual Tides" on Maine's coast) and severe storms drive beaches, dunes, marshes, and wetlands "inland," these protective resources may be unable to migrate to new locations. In some areas, Maine risks losing the benefits of systems that provide pro-

[41] "Morphology" refers generally to the range of landforms.

tection for our communities, as well as vital habitat for a wide range of marine and terrestrial species.

Recommendation C.2.1.1 A working group of state agencies (MGS, SPO, DEP, MR, IFW, DOC), in consultation with other stakeholders, should continue efforts to identify (1) undeveloped low-lying coastal areas for wetland migration through updated mapping and evaluation of coastal marshes, dune systems, and other wetland types having the capacity to buffer against storm events; and (2) undeveloped uplands that protect these systems and offer potential for eventual inland migration of these systems. The inventory should identify potential areas of loss and gain, including economic, ecological, and cultural value, and design and/or enhance robust monitoring systems such as the southern Maine volunteer beach profiling program to track change and vulnerability over time. Continued support should be provided for the work already underway at the Maine Natural Areas Program and Maine Geological Survey to identify landscapes to which tidal wetlands are likely to migrate in response to SLR.

Recommendation C.2.1.2 Maine should develop a state-level policy for protective zoning, conservation, and land acquisition in coastal areas that will allow for the movement of natural areas and species in response to anticipated climate effects. Such a policy should include metrics to identify priority locations based on best scientific forecasts of highest risk of loss from SLR and related impacts, and promote opportunities for state and local partnerships to develop creative approaches to respond to anticipated climate effects. [see also B.4.3.3, p. 44]

Recommendation C.2.1.3 The Maine Geological Survey, Departments of Marine Resources, IFW, and Transportation, and the State Planning Office should study and report to the Natural Resources Committee with recommendations concerning, strategies and methods to prioritize and fund removal of existing tidal restrictions where this would promote natural system maintenance, and reduce damage to associated coastal infrastructure. Such a study should also consider issues of fish and aquatic organism passage.

Strategy C.2.2 *Develop New State-level Standards for Terrestrial Non-point Source Pollution*

These will need to take into account likely increases in sea level rise and precipitation in order to diminish the risk of additional pollution, including toxic and nutrient loading in the Gulf. Runoff of both eroded sediments and human-generated pollutants increases the nutrient load in the off-shore and near-shore areas of the Gulf of Maine, disturbing the ecosystem which serves as the base of the marine foodweb, and contributing to the increased occurrence of harmful algal blooms which threaten human and marine life. For example, in the summer of 2009, a number of short-nosed sturgeon, a federal endangered species, were determined to have died as a result of eating shellfish contaminated with algal biotoxins in the Kennebec estuary.

Recommendation C.2.2.1 Maine's Department of Environmental Protection should continue the development of marine and freshwater nutrient criteria, including consideration of potential climate change effects on nutrient levels.

Recommendation C.2.2.2 Maine should improve design standards for the engineering of stormwater runoff and wastewater treatment systems to better account for higher antecedent moisture conditions and decreased interval between storm events, as well as extreme events, in order to lower overall pollutant and nutrient loads reaching the Gulf of Maine. Application of current standards should rely on updated versions of storm intensity models and rain tables. [see A.2.3.1, p. 24]

Strategy C.2.3 *Continue to Build Maine's Knowledge Base on Potential Climate Impacts to Riverine and Coastal Fisheries*

Monitoring and detection are critical to developing an understanding of climate change impacts on nearshore and riverine habitats and species which are critical to the productivity of the Gulf of Maine ecosystem. Clam flats, eel grass beds and other critical habitats are likely to suffer from impacts such as warming (air and water), acidification, and pollution associated with extreme precipitation events. While not all of these are preventable, these environments will be more likely to survive if we reduce stresses over which we do have some control, such as siltation, excessive growth of potentially harmful algae caused by too many nutrients, and overharvest.

***Recommendation C.2.3.1** Maine should maintain and develop ongoing monitoring programs to assess changes in the status of diadromous and coastal marine resources.

***Recommendation C.2.3.2** Maine should expand its capacity to monitor and assess threats to coastal marine resources and the industries that depend on them, such as harmful algal blooms and invasive species.

C.3 Forest Resources

Forested lands cover approximately 90% of Maine, and the forest products industry has been central to the Maine economy for generations. In recent years, our working forests are recovering from the effects of the spruce budworm epidemic of the 1970's -1980's and concurrent salvage and pre-salvage harvesting. Growth in Maine forests currently is balanced with or exceeds harvest in the state as a whole, and the average growth to harvest ratio is 1.15.[42] Maine's forest cover is now more extensive than at any time since 1760.[43] At the same time, since growing forests remove carbon dioxide from the atmosphere and sequester the carbon, the forest has an increasingly vital role in mitigating CO_2 emissions caused by human activity. As a result, there will be an increasing emphasis in coming decades on keeping Maine's forestlands intact, and on forest management practices that increase carbon storage while at the same time producing sustainable and renewable biomass for wood products and energy. These actions were highlighted in the 2004 *Climate Action Plan for Maine*, which also emphasized the importance of preventing loss of forestland to development.

Changes in Maine's forests will create both challenges and opportunities, as "traditional" species become less prevalent, and other valuable species take their place on the landscape.

A strong forest economy is intimately linked to the retention of forest ecosystems. As highlighted in sections C. 4 and C.6 [pp. 60, 66], in addition to fiber production and carbon sequestration, the forest environment provides essential ecosystem services such as providing wildlife habitat and biodiversity, and maintaining the supply and integrity of freshwater

[42] Laustsen, K. 2009. 2006 Mid-Cycle Report on Inventory and Growth of Maine's Forests. Maine Forest Service: Augusta, ME. http://www.maine.gov/doc/mfs/pubs/midcycle_inventory_rpt.html
[43] Table 2 from Irland, Lloyd C., Maine's Forest Area, 1600-1995: Review of Available Estimates. Maine Agricultural and Forest Experiment Station Miscellaneous Publication 736. February, 1998.

resources. This section focuses on the forest products industry, to which the effects of greatest concern are:

- Any combination of impacts that influences the migration into Maine of pests and pathogens that have not historically been present, or increases the efficacy of those that are;
- Overall changes in temperature and seasonality affecting forest composition as species currently at the southern edge of their range retreat, and those at their northern species boundary become part of Maine's forest; and
- The possibility that wood product harvesting equipment will need to be retooled to work effectively on increasingly saturated soils as the extent and duration of winter frozen ground changes.

However, it should be noted that climate impacts may also have positive impacts on Maine's forest economy. Among other possibilities

- There is some evidence that growth rates for existing trees will increase due to overall warming, and increased CO_2 and nitrogen availability[44];
- Even as spruce retreats over time, the white pine forest that feeds an important saw log market is likely to establish a greater foothold; and
- The demand for wood pellets as an alternative energy source is already increasing.

Strategy C.3.1 *Continue to Build Maine's Knowledge Base on Potential Climate Impacts to the Forest Environment*

As with other sectors, monitoring and detection will continue to play a key role in responding to climate change. Of particular importance are tracking the introduction and spread of pest and pathogens, the virulence of native and introduced pests, changes in forest condition that precede critical compositional and functional change (*e.g.,* phenology[45], growth rates, nutrient cycling), the physical climate trends of the forest (*e.g*., local temperatures, snow depths, frost penetration, soil moisture), and ultimately evidence of species shift. At the same time, there are needs for a regional monitoring network to detect and track pest and pathogen occurrences, and for increased outreach to landowners and the public on identification of, and responses to, pest/pathogen, forest growth and species migration changes. This will require enhancing Maine's scientific and resource management capacity in this area.

[44] McMahon, Sean M; Geoffrey G. Parker, and Dawn R. Miller, Evidence for a recent increase in forest growth, *Proceedings of the National Academy of Sciences* (2010) http://www.pnas.org/content/early/2010/02/02/0912376107

[45] The timing of natural phenomena such as date of blooming.

Recommendation C.3.1.1 Initiate a state-level planning process for pest and pathogen management over the long term. The planning process should include the development of "off the shelf" plans that anticipate, and allocate resources to respond quickly to, likely specific pest / pathogen outbreaks.

Recommendation C.3.1.2 The University of Maine, in partnership with industry, should expand ongoing research effort to assess the likely impacts of climate change on Maine's forest industries by (a) updating growth and yield models for current and projected forest species; (b) modeling future forest conditions and productivity for different climate scenarios; (c) identifying forest practices likely to protect forest productivity, and decrease vulnerability to climate change-related stresses; and (d) assessing the position of the Maine forest products industry in the global marketplace.

Strategy C.3.2 *Increase Maine's Capacity to Respond to Future Hydrological Change: Forest Roads and Stream Crossings* [see C.6.1, p. 66]

The road network through Maine's working forest is vital to the forest products industry. As the climate regime changes, likely increases in precipitation and runoff will make this network vulnerable to outage. At the same time, managing streamflow is critical for wildlife connectivity.

C.4 Wildlife and Biodiversity

As Maine people come to grips with the likely foreseeable impacts and effects of climate change, their focus is frequently on our neighbors, businesses, and communities. Yet the real context of adapting to climate change is the entirety of the natural world, and this challenge reminds us of the inter-connectedness of life on our planet.

When we consider the likely impacts on Maine's natural environment and the species that inhabit it, the following concerns stand out:

- Changing seasonal variation and increase in temperature will have particularly acute effects on plant and animal species that are dependent on relatively small, isolated, or distinct ecosystems, or that exist in Maine at the current boundary of their historic range;
- Human influences on the natural environment, such as land development, natural resource harvesting, and environmental pollution, both in Maine and elsewhere (for migra-

tory species that pass through Maine or spend a portion of their life cycle here) are already stressing a multitude of species independent of climate effects;[46]

- The influence on habitat and native species from new pests and pathogens, increased efficacy of existing pests/pathogens, and invasive species, will be exacerbated as the climate changes;
- Aquatic ecosystems are particularly vulnerable to shifting parameters associated with hydrologic change (extremes of high and low flows, increasing temperature) and extreme weather events resulting in erosion of sediments and nutrient loading; and
- Asynchrony in the timing of natural events (such as earlier blooming of plants to the detriment of species that depend on these for food but are not yet present)[47] is already producing changes in ecosystem function and species composition in particular ecosystems. Strategies and recommendations in this area are closely related to those in each of the other portions of this "Environment and Natural Resources" section.

Strategy C.4.1 Include Climate Change Effects on Wildlife and Habitat in Land Conservation Planning and Decision-Making

There is a clear need to incorporate the impact of climate change into conservation objectives, and to include evaluation of the potential contribution of land conservation plans to adaptation and habitat resilience efforts. Among the factors to be included are maintenance of connectivity among habitats, terrestrial and aquatic; integration of wildlife management strategies across working forest, farms, and reserve lands; and climate considerations in the design, layout, construction, and management of recreational roads and trails. Beginning with Habitat [BwH], which includes the State Planning Office, Department of Transportation, Department of Conservation, and Department of Inland Fisheries and Wildlife in partnership with Manomet Center for Conservation Sciences, is undertaking a climate change vulnerability assessment for Maine's 213 wildlife "Species of Greatest Conservation Need," Maine's listed threatened and endangered plant species, and Maine's rare natural community types. This information will be used to update Maine's State Wildlife Action Plan and will inform municipal, landowner, and land trust outreach efforts through BwH.

Recommendation C.4.1.1 Update current state-level land use plans and conservation priorities using "Beginning with Habitat" at state, regional, and local scales to

[46] For example, moose and bear have adapted well to the current management of the northern working forest while white-tailed deer have declined in the same region.
[47] Also called "phenological change."

evaluate risks of habitat loss and degradation and develop appropriate solutions to maintain terrestrial and aquatic ecosystem connectivity.

Recommendation C.4.1.2 Increase land and water conservation funding for projects that are focused on adaptation to climate change; and ensure funding for the continued coordination of inventory, prioritization, data management, outreach, and restoration project development to mitigate current and future impacts on stream connectivity. Build climate change considerations into existing criteria and scoring systems for all conservation funding.

Recommendation C.4.1.3 Assess and modify, as needed, the state's Ecological Reserves Monitoring Plan to address habitat questions related to climate change. Evaluate the vulnerability of the state's Ecological Reserves to climate change, and incorporate climate change into the criteria for selection and design of new Ecological Reserves.

Strategy C.4.2 Continue and Expand Current Efforts to Maintain and Restore Wildlife Habitat and Assure Connectivity

Various federal and state agencies and public interest groups are already active in this area. For example, Acadia National Park has submitted a number of proposals as part of their climate adaptation planning process to assess potential impacts to coldwater fisheries, wetlands, and coastal estuaries. BwH is in the final stages of a statewide habitat connectivity assessment that will inform state, regional, and local land use decisions. Additionally, BwH is partnering on a multi-state and province effort to identify strategic conservation options to maintain habitat connectivity across the northern Adirondacks from New York to New Brunswick.

Recommendation C.4.2.1 Maine's state agencies involved in this area should continue to collaborate with the University of Maine, public interest groups, federal agencies, and other interested parties, to continue development and improvement of systems to monitor, study and report the health of native wildlife systems and species, and track the spread of invasive species that may emerge in Maine as a result of climate change.

Improving stream flow through culverts not only assists habitat connectivity for wildlife, but builds resilience into stream crossing infrastructure.

Large-scale efforts to inventory stream crossings for fish passage have been underway for several years in Maine.[48] The data from these efforts is being compiled and analyzed to determine the most at-risk crossings and those that block the most and best habitat for important wildlife species, such as Atlantic salmon and Eastern brook trout. The US Fish and Wildlife Service Gulf of Maine Project is leading a multi-partner effort to assess these data and modeling the best restoration/ renovation projects.

In 2009 Governor Baldacci directed state, federal and NGO entities active in aquatic connectivity restoration to collaboratively identify the most efficient and effective way for these agencies, NGOs, the public, and others to share data and information collected through often parallel, but disparate, research efforts. This effort, the Maine Interagency Stream Connectivity Work Group, is actively developing solutions for data collection, analysis, cooperative funding, management, and outreach. There are millions of federal dollars that could be used to improve state, local, and private infrastructure if stream restoration were a concerted effort based on broadly-available scientific information. This work group hopes to improve coordination and efficiency in restoration, and assure that any public communication uses a common language.

Improving stream flow through culverts and other crossing infrastructure can increase the ability of aquatic and riparian species to move between habitats bisected by a road or other development. Improvements such as increasing flow capacity or changing the type of crossing structure can have the added benefit of making a crossing more able to withstand more frequent, extreme rainfall events and the resulting episodic storm flows. [see also B.2.2, p. 39]

Recommendation C.4.2.2 State agencies should cooperate with federal funding agencies to expand the use of restoration and hazard mitigation grant programs to creatively fund state and local infrastructure improvements that would proactively increase flow capacity and habitat connectivity. State match for such funding could be in the form of state dollars, expertise, and/or capacity building.

[48] The largest is a Maine Forest Service project with assistance from USFWS, IF&W, and The Nature Conservancy to inventory road-stream crossings in the Penobscot River Watershed. Several thousand crossings have been inventoried showing that about 50% are severe barriers to fish and wildlife movement because they are undersized, perched, damaged or unmaintained. Many of these are also clearly hazards for future transportation. Some of the other efforts are taking place for the Ossipee, Presumpscot, Royal, Sheepscot, Narraguagus, and Machias Rivers.

Recommendation C.4.2.3 Assess the effectiveness of state regulations and programs that include standards related to aquatic organism passage and natural stream flow in light of likely climate change effects

Recommendation C.4.2.4 The "Beginning with Habitat" Steering Committee should collaborate with municipalities and landowners, and the Interagency Stream Connectivity Work Group, to identify habitat connectivity priorities and efficiently distribute habitat connectivity data. Municipalities and conservation organizations can utilize this information to develop strategies to maintain, enhance or restore connectivity at the state and local levels.

C.5 Agriculture

Representatives from Maine's agricultural sector approach the likelihood of climate-change driven effects with, perhaps, a more relaxed view than some others. As they say, farmers have always needed to adapt to changing conditions, on both a year-to-year and longer term basis. Among the most likely climate change impacts, they identify seasonal shift, including warmer temperatures and changing precipitation patterns as those for which near- and long-term planning is most important. The effects of these changes with which they are most concerned are:

- The spread into Maine agriculture of pests and pathogens not traditionally considered in pest management strategies;
- Water and stormwater (erosion) management, particularly given the likelihood of both precipitation excess at some seasons, and soil moisture deficits at others;
- The potential for crop and farm infrastructure damage from storm events.

A changing climate, including longer growing seasons, will offer Maine's agricultural community opportunities to grow and market new crops, protect Maine's food security, and benefit from practices to sequester carbon and nutrients.

Maine farmers are likely to experience longer crop growing seasons although with increased risk of crop failure due to increased variability in first and last frost dates and variable patterns of water excesses and drought. Longer growing seasons have the potential to allow for:

- increased or earlier production of currently familiar crops (*i.e.g.*, spring greens);
- introduction of longer season varieties of crops, such as corn;
- introduction of new crops (*e.g.,* small grains); and

- increases in grassland production (pasture & hay/silage) and subsequent related animal production system.

It is also likely that demand for local/regional food will increase as the costs of transporting food from distant corners of the world increase and locally produced foods become more cost competitive. This potential advantage for Maine agriculture is also subject to increased risk due to more variable climate patterns. All sectors that are involved with the production, processing, storage and distribution of agricultural products will have to implement and monitor appropriate best management practices to maintain both food safety and security at the local, regional, national and international levels

Agricultural and adjacent forest systems also provide real opportunities for sequestering both carbon, and nutrients such as nitrogen and phosphorus. Most farms in Maine consist of a combination of permanent grassland, crop land and woodlots, each of which has potential to contribute to carbon and nutrient sequestration. Research is needed to quantify those agricultural and woodlot management strategies that represent net carbon and/or nutrient sequestration.

In order to build resilience, mitigate risk, and take advantage of opportunities, the stakeholders have identified the following:

Strategy C.5.1 Build Research and Cooperative Extension Capacity

New strategies for pest management, identification of new crop varieties likely to be productive under a new climate regime, and conservation and land management practices to deal with both excess and deficits of soil water, and to foster carbon and nutrient sequestration will be needed by farmers in all parts of the state. Development and deployment of these “best practices” will depend on ongoing agency efforts to identify management, market, and policy opportunities to enhance the agricultural sector, as well as funding for research and outreach (*e.g.,* Cooperative Extension) to achieve and promote these goals.

Strategy C.5.2 Increase Flexibility of Existing Federal Funds Use

Federal conservation and related funds are a cornerstone of existing programs on which Maine farmers depend. There is an identified need to re-target these programs to be more responsive to regional and state needs.

Recommendation C.5.2.1 Review and re-open the current Cooperative Working Agreement between the State of Maine and the Natural Resources Conservation Service of the Department of Agriculture, and negotiate maximum flexibility in the allocation of Federal funds and application of Federal rules, in order to address climate change adaptation challenges.

Strategy C.5.3 *Evaluate Maine's Water Management Strategies in Light of Likely Climate Change* [see C.6.1, p. 66]

Areas to be addressed include assuring support for irrigation; development of standards for water management that include environmentally sound withdrawal; availability of working capital for irrigators; and resources needed to provide technical assistance.

C.6 Water Resources

Fresh water—lakes, rivers, streams, groundwater—could be said to define the quality of Maine's inland landscape and environment just as surely as the ocean does for the coast. The significant watersheds associated with rivers flowing from mountains to sea convey snowmelt and rainwater that Mainers use for drinking, to produce electricity, and for recreation. Ground and surface waters are vital to agriculture. As noted above in section B.1, there is extensive infrastructure associated with management of water resources, including stormwater; and terrestrial freshwater and marine ecosystems are dependent on the quality of these waters.

Each of these sometimes competing uses will experience the impacts of climate change. Among the most significant challenges identified by stakeholders are:

- Potential saltwater intrusion into public and private coastal drinking water systems due to sea-level rise;
- Septic system failures from increased soil saturation following storm events, leading to ground and surface water contamination;
- Loss of coldwater habitat (streams and lakes) for key species such as brook trout;
- Increased erosion, degradation, and other effects of extremes in streams and rivers;
- Effects on hydropower storage capacity due to lessening of winter snowpack and changing flow regime affecting the timing and magnitude of hydropower supply;
- Competition for water use among different interests, particularly if agricultural irrigation needs increase due to adoption of new crops better suited to a changed climate;
- Altered water quality in certain source waters;

- Changing patterns of evaporation and recharge from rain events; and
- Increased demand by agriculture and domestic use, potentially at the time of least availability. Development of additional water storage infrastructure should be anticipated.

Strategy C.6.1 *Increase Maine's Capacity to Respond to Future Hydrological Change and Assure Water Availability for Fish, Wildlife, and Human Uses*
[see also B.1, p. 32; C.3.2, p. 59; C.4, p. 59; C.5.3, p. 65]

Understanding the changing hydrology of Maine is critical to developing responses to climate change impacts that we are already experiencing, and to building resilient infrastructure for the future.

Recommendation C.6.1.1 The Maine Geologic Survey, assisted by the University of Maine, the United States Geological Survey [USGS], and other members of the Water Resources Planning Committee, should review the current understanding of Maine's hydrological future, and identify what steps the state should take to increase forecasting and modeling of these effects in light of climate change. Such a task force could consider the establishment of a permanent state Office of Water Resources. Building on the state Drinking Water Program's existing Source Water Assessment Program, plans should be developed to address issues such as threats to road crossings and forest road networks; impacts to drinking water resources and systems; changes to water storage used for electricity generation; maintenance of base flows for fish and wildlife, and for agriculture, etc. Other activities should include review of and recommendations to modify existing regulations governing water use, stream flow, etc., including periodic review of the aquatic base flow equations used in Chapter 587 of the DEP's *Rules,* "Stream Flow and Water Level Rule," to assure their capacity to assist in building resilience.

Recommendation C.6.1.2 The Maine Geological Survey, USGS, and the Drinking Water Program [DWP] of Maine Department of Health and Human Services should be tasked with modeling aquifers and groundwater flows in the coastal zone to inventory the vulnerability of public and private water systems to saltwater intrusion under the conditions of progressive SLR. They should also develop and recommend for adoption state-level policies and priorities for state investments in drinking water infrastructure in the risk areas.

Strategy C.6.2 *Maintain and Enhance Existing Source Water Monitoring Programs*
See *****Recommendation A.2.1.3 [repeated for convenience]

Maine, in cooperation with the USGS, should reconstitute and expand the river stream gauging network to monitor long and short term trends in flow in order to improve resource allocation and emergency response preparedness. There is an additional need to build and expand monitoring of snowpack conditions, ice conditions, lake levels, and groundwater levels. Long term, dedicated support needs to be provided for this task.

D. Maine's Economy in a Changing Climate

The effects of climate change impacts on Maine's economy at both the local and state-level scales, and the costs of responding, are not yet well understood. This argues for taking action on a "no regrets" basis: for example, improving stormwater and wastewater infrastructure to protect water quality in any eventuality. Among the factors that decision-makers will need to consider going forward are:

- The extent to which forecasts of particular impacts such as sea level rise are robust enough to rely on, particularly when planning long-term capital expenditures;
- The effect of existing and proposed policies on potential economic choices. For instance, policies and regulations that limit the potential for armoring existing structures may increase the short-term costs of potential property relocation or loss from storms but decrease long-term costs of living in vulnerable areas;
- The likely costs of non-action as compared with those associated with particular adaptation responses; and
- The very real potential for economic gains in particular sectors.

The New England Environmental Finance Center [NEEFC] at the Muskie School, University of Southern Maine, is undertaking significant work in this area, focused particularly on analysis of likely climate effects on the economy of Maine's southwestern coast.[49] The Center is also developing tools that local jurisdictions will be able to apply to planning best approaches to mitigate existing climate vulnerabilities and build future resilience. These

[49] See, for example, Charles S. Colgan and Samuel B. Merrill, "The Effects of Climate Change on Economic Activity in Maine: Coastal York County Case Study," *Maine Policy Review* 17/2 (2008): 66-79.

tools will be particularly useful for comparing the costs of action to the costs, risks, and benefits of not acting.

Strategy D.1 *Continue to Refine and Make Available to Maine's Communities, Businesses, and Governments Tools to Support Economic Analysis of the Most Likely Foreseeable Effects of Climate Change*

*__Recommendation D.1.1__ NEEFC, in collaboration with the State Planning Office, the Maine Municipal Association, and other stakeholders, should continue to identify and develop additional tools that planners can use to support economic decision-making related to climate change, and make these available to local users.

*__Recommendation D.1.2__ Agencies of Maine state government involved in planning and economic analysis related to climate change should collaborate with NEEFC to avoid duplication of effort and leverage available resources.