Chapter Seven

PRELIMINARY ADAPTIVE RESPONSE STRATEGY: CONCLUSIONS AND RECOMMENDATIONS

This study evaluated whether Maine should develop an adaptive response strategy to prepare for the possibility of accelerated sea-level rise as a result of global climate change. It concludes that Maine should begin to prepare itself for the possible consequences given:

- the significant possibility of global warming,
- the magnitude of the negative impacts if global warming theories are correct, and
- the potential for anticipatory measures to reduce adverse impacts if sea-level rises as projected, without imposing substantial costs if the projections are not realized.

A. VULNERABILITY ASSESSMENT AND ANALYSIS OF EXISTING LAWS

Researchers determined that the developable portion of the study area within 100 meters of the shoreline is, for the most part, already built up. There is little usable, vacant land zoned for development. The shoreline development that has occurred over the last several years has been typified by seasonal conversion, infill development in grandfathered subdivisions or on grandfathered lots, and renovation or expansion of existing single family homes.

However, Maine has experienced a relatively depressed real estate market since approximately 1987. If development pressure increases in the future, coastal areas may face attempts to subdivide or redevelop larger estates, to consolidate and redevelop marginal seasonal homes and marginal commercial structures, and to redevelop cottage areas for multifamily residential units. Additional development pressure might also prompt individuals to attempt to develop land which is not currently zoned for development nor currently thought of as being suitable for development, specifically including eroding bluffs and land in or adjacent to coastal wetlands.

Any strategy to minimize damage from future sea-level rise should not only control the location of new development, but also consider the impacts of the strategy on existing development, and the impacts of existing development on natural coastal processes as shoreline position changes.

The mapping and vulnerability assessment for specific sites determined that the components of Maine's "soft coast" (coastal sand dune system, coastal wetlands, coastal eroding bluffs) face the

prospect of significant coastal erosion and inundation even without accelerated sea-level rise, based on historic rates of change. And for beaches and coastal wetlands, that erosion and inundation will be exacerbated by an accelerated rate of sea-level rise.

1. Beaches

The most profound changes will be experienced on and adjacent to the beaches. Not only is the projected landward movement of shoreline position along beaches three to six times greater than the projected movement along salt marshes or bluffs. A change in shoreline position along a beach is likely to affect relatively intensely developed areas immediately adjacent to the beach. At the same time, any interference with the natural migration of the sand dune system could reduce or eliminate the dry sand portion of the beach and have a very significant impact on coastal tourism, recreation, and the local economy.

However, the analysis of Maine's laws and regulations concludes that Maine already has strong laws and regulations in place to regulate development in or adjacent to sand dune systems. Maine's Natural Resources Protection Act and the accompanying Sand Dune Rules already prohibit large, new development unless the applicant can show that the site will remain stable assuming a 3 foot rise in sea level over 100 years. While smaller, new development is evaluated based on historic, rather than accelerated sea-level rise, all new development is subject to retreat requirements. There are also limits on expansion of existing development and those structures essentially cannot be rebuilt if they are destroyed by 50% or more of their value by coastal erosion or storms.

While some minor amendments would strengthen the law (e.g., adequate protection for unstable back dune sites, clarification of the standards for site stability for smaller development), the Sand Dune Rules are essentially a sound and exemplary set of far-sighted regulations. As part of the anticipatory strategy for possible sea-level rise, it is critical to ensure that NRPA and the related Sand Dune Rules are not weakened through amendments, site specific exceptions, or permissive permit-by-rule regulations for back dune sites.

2. Coastal Wetlands

To date, Maine has not been equally attentive to the potential impact of sea-level rise on coastal wetlands. Any anticipatory sea-level rise strategy should correct this omission.

It is beyond question that coastal wetlands play a critical role in maintaining landscape-level ecosystem functioning. For example, they minimize damage from coastal storms and flooding, help maintain water quality, and in serve as critical habitat for juvenile fish and waterfowl. Even though them represent only 5% of the total land area of the United States, they contain 35% of all federally listed rare and endangered animal species, and fully one-half of all listed animals rely on wetlands habitats to some degree.[1] The influence of wetland loss or disruption is likely to be felt well beyond the wetland itself, in the waterways, flyways, and the fisheries to which they are functionally linked.[2] Any disruption of this critical coastal ecosystem could have serious economic impacts, particularly on the commercial fishing industry.

A rise in sea level will result in the conversion of areas that were formerly just above mean low water to open water. Some researchers have concluded that healthy coastal marshes with an adequate supply of sediment will be able to build coastal marshland as fast as the sea rises to

inundate it up to a rate almost equivalent to a 200 cm rise over 100 years.[3] This means that, given the right conditions, wetlands could migrate landward in equilibrium. But there are significant limitations: the marsh must be healthy, there must be adequate sediment, and it must not run into upland barriers, either natural (steep slopes, bedrock) or human-made (bulkhead, levee or other hardened edge).

A national vulnerability study projected that in New England, if there were no artificial interference with natural migration, a sea-level rise of .5 m to 2.0 m would result a maximum of a 5% loss in wetland area. In similar circumstances, if all shores were protected with bulkheads or similar structures, 15 - 17% of the remaining coastal wetlands could be lost. If only already developed areas were protected, the wetland loss could be reduced to 6 - 10% of remaining coastal wetlands.[4] Further study might conclude that these regional projections substantially understate the wetland loss that might occur in Maine due to its steeper slope and bedrock-dominated characteristics.

Thus, under current conditions, with a significant rise in sea level, Maine is likely to suffer a substantial reduction in wetland area for a combination of reasons. First, there are no laws designed to protect the ability of wetlands to migrate inland by precluding the artificial hardening of the upland edge. NRPA wetland regulations were formulated primarily to maintain an adequate buffer to maintain wetland habitat value, assuming a static position. They do not preclude the construction of artificial barriers to upland migration just outside the wetland.

Second, natural upland barriers will contribute to wetland loss even without human interference. The steepness of the coastal region and the fact that it is bedrock-dominated will result in a much smaller area of new marsh creation than would occur in non-rocky regions.

Finally, unless current trends are reversed, multiple stressors not directly related to sea-level rise may contribute to the death of wetland vegetation which is critical to the process of vertical accretion. For example, dredge and fill projects, nonpoint source pollution, and reductions in the supply of sediment and nutrients may tax the health of wetland vegetation.

Given that some reduction in wetland area will be inevitable due to its topography alone, Maine should focus with renewed resolve on that portion of wetland loss which is within human control. Policy-makers need to decide how much of the existing wetland shoreline should remain in a natural, unarmored condition. They could decide that all of it should be kept free from further human interference with natural inland migration. Or they could decide that in specified circumstances, existing investment justifies allowing the upland edge of a wetland to be hardened, for instance to protect already intensely developed areas. Once the decision is made, appropriate regulations patterned after the setback and retreat policy of the Sand Dune Rules should be adopted to implement this policy in coastal wetlands.

3. Eroding Bluffs

Maine's laws also fail to do a complete job of regulating the third element of the soft coast, eroding coastal bluffs. While not likely to be affected by a change in the rate of sea-level rise, it is anticipated that this erosion will continue at a significant pace into the future, threatening individual structures. Any unified State coastal erosion/inundation policy should address bluff erosion to prevent interference with the process through hard erosion control strategies. Eroding bluffs can play

an important role in the sediment budget for sand dunes and coastal wetlands. Thus, it is important to sand dunes and coastal wetlands that armoring structures not be allowed to unreasonably interfere with the transfer of soil from the terrestrial to the marine environment.

4. Urban Engineered Shorefronts

This study determined that Portland's central waterfront is already lined with engineered structures which will essentially keep shoreline position constant even given a 2 meter rise in sea level over the next century. However, it is probable that this area will experience negative impacts associated with flooding and storm surges with greater frequency, particularly in areas that already experience flooding during a 100-year storm event.

The study concluded that existing laws, particularly State enabling legislation for zoning for maritime activities and commercial fishing, the Coastal Management Policies Act and local waterfront zoning ordinances, all make an important contribution to damage mitigation by reserving this type of engineered waterfront site for water dependent uses.

5. Rocky Shores

It is not expected that Maine's rocky shoreline will be adversely affected by inundation or erosion as a result of sea-level rise associated with global climate change. There may be very minimal inland movement of the shoreline position, depending upon the adjacent slope. It was concluded that no regulatory changes are required along the hard coastline to address possible impacts of accelerated sea-level rise.

B. Developing an Anticipatory Response Strategy

1. Maine's Advantages

Maine has three advantages which should help it as it makes policy decisions about an anticipatory response strategy. First, even though Maine is substantially built up along its developable shoreline, it is not saddled with the intense, multi-unit recreational shoreline development characteristic of states to its south.[5] Maine is still in a position to decide *whether to allow* further intensification of shoreline development. In most other states, the decision about sea-level rise response options will be skewed by extensive investments already sunk into vulnerable but immovable structures.

Second, some analysts have characterized response strategies as a choice between *maintaining economic activities in a shorefront location* (e.g., making substantial environmental changes such as dredging sand for beach nourishment, construction of bulkheads to protect houses from migrating wetlands) or *preserving the environment* (e.g., removing structures to allow beach and wetland migration).[6] While this economy vs. the environment dichotomy may be true in other coastal states, the choices in Maine are not that stark. Maine is much more heavily dependent on its natural resources than many other coastal states. Its commercial fishing industry, other marine resource harvesting industries, coastal recreation and coastal tourism industries are of critical importance to the State's economy. These key industries depend upon maintaining the quality and ecological functioning of Maine's coastal wetlands, marine waters and sand beaches. Thus, it is not a matter of

economic activity or the environment; there are substantial economic benefits associated with maintaining the environmental quality of the coastal ecosystem.

Finally, Maine should be in a good position to develop an anticipatory sea-level response strategy because it has already successfully confronted very similar issues in regulating sand dune systems. NRPA and the associated Sand Dune Rules already establish a clear policy of retreat from advancing seas, whether at historic or accelerated rates, and impose reasonable limitations on the development expectations of owners of land within or adjacent to sand dune systems. This provides a valuable model to follow in developing policies for other areas of the soft coast.

As a means of bringing more information to bear on the complex choices to be made in developing a formal sea-level rise response strategy, researchers conducted a cost/benefit analysis of alternative response options for one site and analyzed constitutional limitations on regulatory options. The findings are summarized below.

2. Economic Cost/Benefit Analysis

The cost-benefit analysis of four options for one specific sand beach site concluded that, subject to the conditions and assumptions articulated in Chapter Four, it was more cost-effective to adopt a strategy of retreat from the shoreline as sea level rises. The benefits of a retreat strategy outweighed costs for the 50, 100 and 200 cm rise scenarios. In contrast, the analysis found that attempts to protect most of the development or to maintain the shoreline in its current position were not justified by a cost-benefit analysis. The costs of these reactive protection strategies (assuming beach nourishment, bulkheads and in one strategy a selective buy-out of threatened structures) exceeded benefits for the 50, 100 and 200 cm rise scenarios.

Specifically, that analysis concluded that for the currently eroding beach at Camp Ellis, with a sea-level rise of 50 to 200 cm by 2100, from a quantitative standpoint, the preferable option is to allow new development within the area projected to be inundated, but to require retreat of both new and existing development as the shoreline position changes (Option 4). The second most favorable response of the options evaluated was to ban all new development within the area projected to be inundated under the particular scenarios and to require existing development to retreat as it suffers major damage from coastal erosion or coastal storms (Option 3).

The major factors making the retreat strategies preferable to the reactive protection strategies were the cost of sand and the expense of ongoing beach nourishment. As noted in Chapter Four, this analysis is still very rough. The results are highly dependent upon the particular assumptions used and the analysis is very simplified. Each strategy has different costs associated with it if sea level actually rises either more or less than projected under the particular scenario; this uncertainty would need to be considered when selecting a strategy. Moreover, there are other foreseeable costs or risks, such as political feasibility, which are not addressed through this cost-benefit analysis. For example, a community might initially select Option 4 (allow construction in vulnerable areas, but with retreat requirements) but then lose the political will to enforce the retreat requirement when faced with the actual need for abandonment. If the community then decides to protect that development, the strategy would then become one of reactive protection, with all of those associated costs.

Despite these admitted constraints, the results of this simplified cost/benefit analysis lend general support to the type of response strategy which is already embodied in the Sand Dune Rules. To implement a retreat strategy, those Rules:

1) ban all new development in a band of land which extends from the water upland to the projected shoreline 100 years hence, based on projections of a continuation of historic rate of erosion over the next 100 years;

2) allow modest continued development in the next band of land, which consists of land between the projected 100 year shoreline based on historic rates and the projected 100 year shoreline based on a 1.0 m rise in sea level.

3) allow development up to the maximum allowed by local zoning ordinances in the furthest upland band of land in the sand dune system, from the projected 100 year shoreline based on a 1.0 m rise in sea level to the upland edge of the sand dune system, subject only to the retreat requirements outlined below;

4) throughout the sand dune system, require all rebuilding or repair of existing structures to meet the requirements for new construction if the structure is damaged by 50% or more of its value; and

5) condition all new development upon the requirement that the owner remove the structure and return the site to its unaltered condition if the shoreline position changes so that the structure is on part of the active dune system for six or more months.

The existing sand dune policies are not completely reflected in either Option 3 or Option 4 of the cost-benefit analysis, but rather take a middle position between those retreat strategies. The Sand Dune Rules allow modest new development in the area described in #2, above, thus avoid the high opportunity costs otherwise incurred if all development were banned in the area threatened by accelerated sea-level rise (as in cost-benefit Option 3). There are, of course, still some opportunity costs associated with limiting the development to modest intensity rather than allowing high-intensity development, but these cost are justified by environmental, hazard mitigation, and visual access considerations which would support keeping high intensity development from locating on the shoreline even assuming no change in shoreline position.

3. Legal Considerations for Maine's Policy Response

Researchers also analyzed several legal issues to determine if they might constrain the State's ability to adopt a retreat strategy. The primary purpose of the analysis was to determine if the retreat strategies being supported in the analysis of existing laws and in the cost-benefit analysis suffered from substantial vulnerability to successful legal challenge.

The legal analysis concluded that Maine is at somewhat of a disadvantage in comparison to the majority of coastal states due to the weakness of its public trust doctrine. However, it concluded that with careful attention to drafting, U.S. constitutional law and State constitutional law give adequate room to develop, adopt and enforce regulations on coastal development to restrict new development in areas threatened by accelerated sea-level rise, to require removal of new development upon a change in shoreline position, and to prohibit the rebuilding of existing structures which are substantially damaged by coastal storms or erosion. The analysis also concluded that existing laws

give adequate opportunity to adopt some non-regulatory responses, but that other non-regulatory strategies would require statutory or constitutional amendments.

C. RECOMMENDATIONS FOR MAINE'S ANTICIPATORY RESPONSE STRATEGY

The remainder of this chapter summarizes the recommendations developed based on the analysis in the preceding chapters. It is not intended as an exhaustive list of recommendations; individual chapters should be consulted for full details.

Clearly, these recommendations are not the formal policy of any agency of the State of Maine; they are the recommendations of the members of the research team, and are presented for further consideration by appropriate state and local agencies.

These recommendations have been developed as part of a "no regrets" response based on the best available technical information at this time. Any anticipatory strategy formulated based on these recommendations will need to be reviewed periodically (e.g., every 5 to 10 years) to incorporate new information available at that time.

1. Underlying Recommendations

The key recommendation of this report, underlying all of the others, is that **the State should protect and strengthen the ability of natural systems to adjust to changes in shoreline position.** There should be a strong presumption in favor of non-interference with "soft" coastal processes including the natural inland migration of beaches and salt marshes and the natural movement of material from the terrestrial to the marine environment. The correlative recommendation is that **the State should prevent new development which is likely to interfere with the ability of natural systems to adjust to changes in shoreline position.**

2. Specific Strategies

Within these general premises, more specific strategies should be articulated. There are at least four types of responses to climate change:

1) **"No action today"/action when problem emerges,** where least-cost solutions are well-defined and can be implemented quickly at the appropriate time using existing technology and information. There is little reason to take action before the problem emerges.

2) **Anticipatory action,** where concrete measures are justified today despite uncertainties due to the minor additional cost of incorporating the measures today being outweighed by large potential gains and possible benefits even without global climate change.

3) **Planning,** where no physical changes are needed immediately, but the "rules of the game" need to be announced or changed so that people can make their decisions with advanced notice of how the government intends to respond to climate change and sea-level rise.

4) **Strategic assessments, research and education,** where it will take long periods of time to determine the type and timing of responses to global warming, where we need to develop a much better scientific understanding of natural processes and how to apply that knowledge to mitigate impacts, and where enlightened professionals and citizens are critical to support required changes.[7]

The following sections summarize the recommendations for each type of action.

a. Action When the Problem Emerges

This report does not identify any actions in this category to be taken now, or in the near term. Concrete problems specifically attributable to global climate change induced sea-level rise have not yet emerged to the point where it is necessary to take specific physical actions to implement solutions. Altered resource management practices (e.g., reservoir water release schedules, shifting crops) and engineered solutions specifically in response to rising sea level (e.g., raising piers and wharfs, redesigning existing coastal drainage systems, bulkheading, etc.) should be undertaken, if at all, only if there is an actual rise.

The State should continue to monitor Maine-specific sea-level rise data, global sea-level rise projections, and local conditions on a periodic basis to determine if a problem has emerged which requires specific action. It is also likely that if individuals begin to feel the effects of rising sea level, they will take certain adaptive actions on their own, without governmental incentives or mandates. For example, water-dependent uses reinforcing or maintaining their piers and wharves may build to withstand higher water level based on their own observations about reduced protection from coastal storms. Public education (discussed below) will help individuals place these actions into a larger context.

b. Anticipatory Action

Maine should encourage anticipatory tangible responses to sea-level rise if the proposed action meets the "no regrets" test. Such response options include the following:

1) Review design standards and similar specifications for every new coastal public works project to determine whether it is cost-effective to make minor alterations in the design to accommodate a changed shoreline position (e.g., slightly increasing the setback to provide a protective buffer) or to design it to accommodate a more frequent storm event (e.g., designing for a 15- to 20-year storm rather than a 100-year storm);

2) Develop a written capital investment policy to discourage an irreversible commitment of public resources for new infrastructure or structures in areas likely to be affected by accelerated sea-level rise, except to the extent necessary to support continued economic viability and efficient functioning of water-dependent uses. The policy should also provide specific guidance on avoiding coastal infrastructure investments that would encourage residential development on the shore (e.g., extension of water systems, sewer systems and roads to shoreline areas). It should also provide guidelines to help balance when shoreline capital investments might be appropriate, such as in the case of strengthening the viability of water-dependent industries or securing public waterfront access. Except for water-dependent use infrastructure, all new and substantially modified

public structures and facilities should be adequately setback to protect them from erosion for 100 years assuming a rise in sea level of 100 cm by 2100. Even if shoreline position does not change, these policies are consistent with sound coastal management practices.

3) Increase the amount of upland area owned or controlled by public or quasi-public entities (e.g., State, municipality, land trust) adjacent to low-lying facilities intended to provide public waterfront access (e.g., beaches, shoreline walkways, boat ramps, waterfront parks, public docks, etc.) so that these facilities would still be available even with a change in shoreline position. Until needed for shoreline access, the additional upland could be used for beneficial purposes such as open space, parking or storage.

4) Expand coastal nature preserves, acquire key undeveloped coastal wetlands and similar conservation areas to preserve areas important to the public and to provide sufficient upland buffer areas for wetland migration in the event of a change in shoreline position. This would increase protection of threatened ecosystems now, and would enhance the prospects of wetlands being able to migrate in equilibrium with a change in sea level. In conjunction with this, review funding options and financial incentives to determine if they can be made more attractive. Mechanisms reviewed should include preferential open space tax treatment, conservation easements coupled with required property tax reassessment to reflect the decrease in value due to the encumbrance, preference for purchase of this type of land under a bond-supported public purchase program, and a real estate transfer tax surcharge on the transfer of coastal property or an income tax checkoff system to fund property acquisition. Acquisition would not have to be in fee simple. Conservation easements could protect the land in its undeveloped condition. Similarly, it may be possible to acquire a contingent "flooding" easement which would not encumber the land unless erosion or inundation changed the applicable shoreline position or upland/marsh boundary.

c. Planning and Regulatory Policy

The State should "change the rules of the game" by adopting land use restrictions which will guide the bulk of the development away from potential hazard areas and will protect the ability of coastal ecosystems to migrate. While the following policy options are generally phrased in terms of what the State of Maine should do, in some cases the State may decide it is more desirable to delegate that responsibility to local governments with retained State oversight. Summary recommendations include:

5) Halt attempts to stabilize the shoreline within or adjacent to the soft coast; maintain/restore the ability for coastal sand dune systems, coastal wetlands and eroding bluffs to migrate inland. This has already been accomplished to a great extent within the frontal dune system. Maine needs to hold the line on existing sand dune restrictions and not allow additional exceptions. Similar sorts of protections need to be extended to back dunes, coastal wetlands and eroding bluffs. For example, amend NRPA to prohibit edge-hardening structures (e.g., bulkheads, levees, etc.) adjacent to the upland edge of a coastal wetland if any part of the structure is projected to interfere with the inland migration of the wetland assuming an accelerated sea-level rise of 100 cm by 2100.

6) Along all soft coasts, establish building setbacks to protect the natural systems. Prohibit all new structures on or adjacent to sand dunes or coastal marshes if the site is projected to be affected by sea-level rise within 100 years, assuming a rise in sea level of 100 cm by 2100 (except as provided in 7, below). Similarly, for eroding bluffs, if not included within a district allowing only non-intensive use, adopt setbacks for structures and septic systems which require them to be set back from the area likely to experience erosion over the next 100 years assuming a continuation of the historic rate of erosion or, if greater, set back 75 feet plus the average annual rescission rate times the structure's assumed life span.

7) As a limited exception to 6, above, allow construction of new, small, easily-movable structures built at low densities (e.g. walkways, small single family residences on reasonably large lots, temporary/reversible structures) adjacent to sand beaches or marshes if, and only if, the site is expected to remain stable over the next 100 years assuming a continuation of the historic rate of erosion. This exception should only be allowed if the State has the political will to require removal of these structures if erosion exceeds historic rates. In cases where small, new, movable development is allowed, extend the Sand Dune Rule's "presumed mobility" policy to all areas of the soft coast (beach, marsh and bluff) by making all new building permits conditional. As a condition of approval, require the owner to agree to remove any structure permitted after adoption of the policy if the shoreline position changes so that the structure interferes with the ability of the natural systems to adjust to changes in shoreline position. Require that the condition be recorded at the appropriate registry of deeds so that all subsequent purchasers are put on notice of the risk of being in a hazard area and their obligations in the event of a change in shoreline position.

8) Notwithstanding 6, above, allow new structures for functionally water- dependent uses which meet certain performance standards designed to minimize the impact on natural systems, regardless of whether the area is likely to be affected by either historic or accelerated sea-level rise.

9) Treat existing development located within the area which is threatened by erosion or inundation from a sea-level rise of 100 cm over the next century as a non-conforming structure if it can not meet the new setback standards; prohibit expansion of the structure or intensification of use, but allow ordinary maintenance and repair so long as it is not damaged by more than 50% of its value. To the extent legally feasible without constituting a taking, extend the "presumed mobility" policy to existing structures as well to require the owner to remove any structure if the shoreline position changes so that any portion of the structure is located on public land or becomes a public nuisance (even if the structure has not sustained damage of 50% or more of its value).

10) On any site which is unlikely to be affected by accelerated sea-level rise assuming a 100 cm rise over 100 years but which is projected to be affected by a 200 cm rise over 100 years, allow new development only if it meets perfor-

mance standards for cluster development designed to minimize the costs of protection should the 100 cm sea-level rise estimate be too low.

11) Supplement the State regulatory procedures by encouraging or requiring other State agencies and individual municipalities to consider a high probability of future increased rates of sea-level rise in making daily investment, development and permitting decisions. For example, consider mandating incorporation of a sea-level rise standard into shoreland zoning and subdivision review standards.

d. Strategic Assessments, Research and Education

Given scientific uncertainty and rapidly evolving scientific knowledge, coastal managers are not in a position to make decisions now about a definitive adaptive response strategy for the next century. Policy decisions will have to be made now based on the best available knowledge, with the express intent of reviewing these policies periodically as scientists refine their predictions. Continuing research will be required to revise and refine anticipatory strategies and policies as scientific knowledge increases. The State of Maine should participate in increasing the understanding of global warming and its projected impacts, particularly as applied to the State, in the following ways:

12) The State should designate one State agency as the lead agency for monitoring issues associated with global climate change and sea-level rise. This agency should keep abreast of scientific progress and policy responses of other entities. It should also work with related State agencies and with municipalities in formalizing an anticipatory response strategy and seeing that it is implemented. Since it appears that a major part of the implementation strategy will involve strengthening the core laws of the coastal management program, it would be logical to designate the State Planning Office as this lead agency. This lead agency would need to work closely with the Maine Geological Survey and other State agencies with coastal and marine responsibilities.

13) The lead State agency and cooperating State agencies should undertake additional research to document coastal erosion in Maine and to determine how global or regional projections concerning particular impacts might affect Maine. For example, the ability to regulate coastal development will be improved if Maine Geological Survey receives funding to complete its work on historic coastal erosion rates for all beach, marsh and bluff segments. In addition, the State's anticipatory plan will be strengthened if municipalities adopt complementary comprehensive plans and implementing regulations. To facilitate this, the State should increase technical assistance to municipalities to help them identify areas threatened by coastal erosion and to modify their comprehensive plans accordingly.

14) As part of a related effort, to enhance the likelihood that regulatory policies will be accepted and supported, the State should undertake a substantial educational effort aimed at local officials, code enforcement officers, other State agencies, and the general public. The focus of this effort should be to educate the target

audience about the hazards of coastal erosion and inundation, including the possible impacts of an accelerated rate of sea-level rise, the fragility of the coastal ecosystem, the benefits of conserving (or restoring) it as a resilient natural system, and the costs (both financial and environmental) of hard structures, beach nourishment and similar engineered "solutions."

15) Finally, as additional funding is available, the State should undertake supplemental studies on different aspects of sea-level rise to compliment this study. The possible impacts with highest priority for further study are coastal flooding/storm surges and salinization/saltwater intrusion. These are discussed in additional detail immediately below.

D. RECOMMENDATIONS FOR ADDITIONAL RESEARCH

Additional research is recommended to complete the picture of probable impacts of accelerated sea-level rise as a result of global climate change. While flooding and storm surges are closely related to inundation and erosion, developing a flood model and conducting detailed surveys of elevations and types of structures were outside of the scope of this study.

National studies suggest that sea-level rise will bring with it additional damage from flooding and storm surges because of the loss of protective wetlands, the erosion of the shoreline, the higher base for the surge to build on, a higher water table and reduced coastal drainage. Depending upon the tides, winds and waves at the time the storm hits, there can be a substantial temporary increase in water level.[8] For example, Hurricane Hugo in 1989 caused a 6.5 meter storm surge.[9]

Low barriers can be overcome, either by overtopping or undermining, resulting in storm damage. It has been estimated that with moderate sea-level rise, today's 100-year flood could essentially become a 15-year flood (a storm with a severity averaging a 15 year recurrence interval).[10]

It is particularly important to undertake a flooding/storm surge analysis for Portland's central waterfront, particularly in the Commercial Street area. While this study concluded that there would probably be no change in shoreline position in this area due to the engineered structures (which were observed to be built approximately 2 meters above mean high water), it did not rule out damage from storm events. This area contains new residential condominiums, multi-story office buildings, retail shops, restaurants, intermodal transportation facilities, a recreational marina, the municipal fish pier and municipal fish display auction, a major ship repair facility, many other commercial fishing or other water-related enterprises, and various public or institutional uses. These structures are built on piers, wharves, and formerly filled land. Additional study is needed to assess the vulnerability of the public investments and private infrastructure along this engineered waterfront to flooding and storm surges.

Another potential impact that should have high priority for additional analysis is salinization. A rise in sea level will move the salt water/fresh water boundary landward. Saltwater intrusion may significantly impact coastal towns or residents that use a river or well as their source of drinking water.[11] Additional analysis is required to determine which coastal towns or residents may be at risk from this impact.

The problem may be particularly acute for coastal islands that rely on ground water for their drinking water. As sea level rises and decreases the island size, the fresh water lens overlying the salt water will shrink and its ability to sustain island residents will decrease.[12] Several Maine islands have based their comprehensive plans and implementing ordinances on island carrying capacity concepts based on ground water studies. Those studies should be reviewed to determine the adequacy of any sea-level rise assumptions.

Finally, some studies suggest that a change in the fresh water/salt water boundary may impact the abundance of marine resources, particularly shellfish.[13] Additional research would be required to determine probable impacts on Maine's fisheries. While the State may not be able to take any action to prevent this change, the possible impact should be factored into decisions concerning management of the State's marine resources.

E. ENDNOTES

1. Curtis Bohlen, *Wetlands Politics from a Landscape Perspective,* MARYLAND JOURNAL OF LAW AND CONTEMPORARY PROBLEMS,

2. *Id*. at

3. Robert Costanza, et al., *Modeling Coastal Landscape Dynamics*, 40 BIOSCIENCE, Feb. 1990, at 91.

4. T.V. Armentano, R.A. Park, and C.L. Cloonan, *Impacts on coastal wetlands throughout the United States, in* GREENHOUSE EFFECT, SEA-LEVEL RISE AND COASTAL WETLANDS 87-128 (J.G. Titus, ed., Wash., DC: EPA, 1988).

5. This may be attributable to the rocky, highly irregular coastline, the relative scarcity of sand beaches, and the temperature of the coastal water. This high density, highly engineered shoreside development has been referred to as "New Jerseyization." In 1989, one observer of the Maine coast cautioned that "there are beach communities with the first growing pains of New Jerseyization already apparent." JOSEPH T. KELLEY, ET AL., LIVING WITH THE COAST OF MAINE 3 (National Audubon Society and Maine Geological Survey, Duke University Press, 1989)

6. James G. Titus, *Strategies for Adapting to the Greenhouse Effect,* APA JOURNAL, Summer 1990, at 311, 313.

7. Adapted from *id.* at 315-321.

8. Fletcher, Charles H. III, *Sea-Level Trends and Physical Consequences: Applications to the U.S. Shore,* 33 EARTH SCIENCE REVIEWS, 1992, at 94.

9. *Id*.

10. THE POTENTIAL EFFECTS OF GLOBAL CLIMATE CHANGE ON THE UNITED STATES 328 (J.B. Smith & D.A. Tirpak, eds., Wash., DC: Hemisphere Publishing Corporation, 1990).

11. Fletcher, *supra* note 8, at 91.

12. *Id*. at 92.

13. James G. Titus, et al., *Greenhouse Effect and Sea Level Rise: The Cost of Holding Back the Sea*, 19 COASTAL MANAGEMENT 179 (1991).