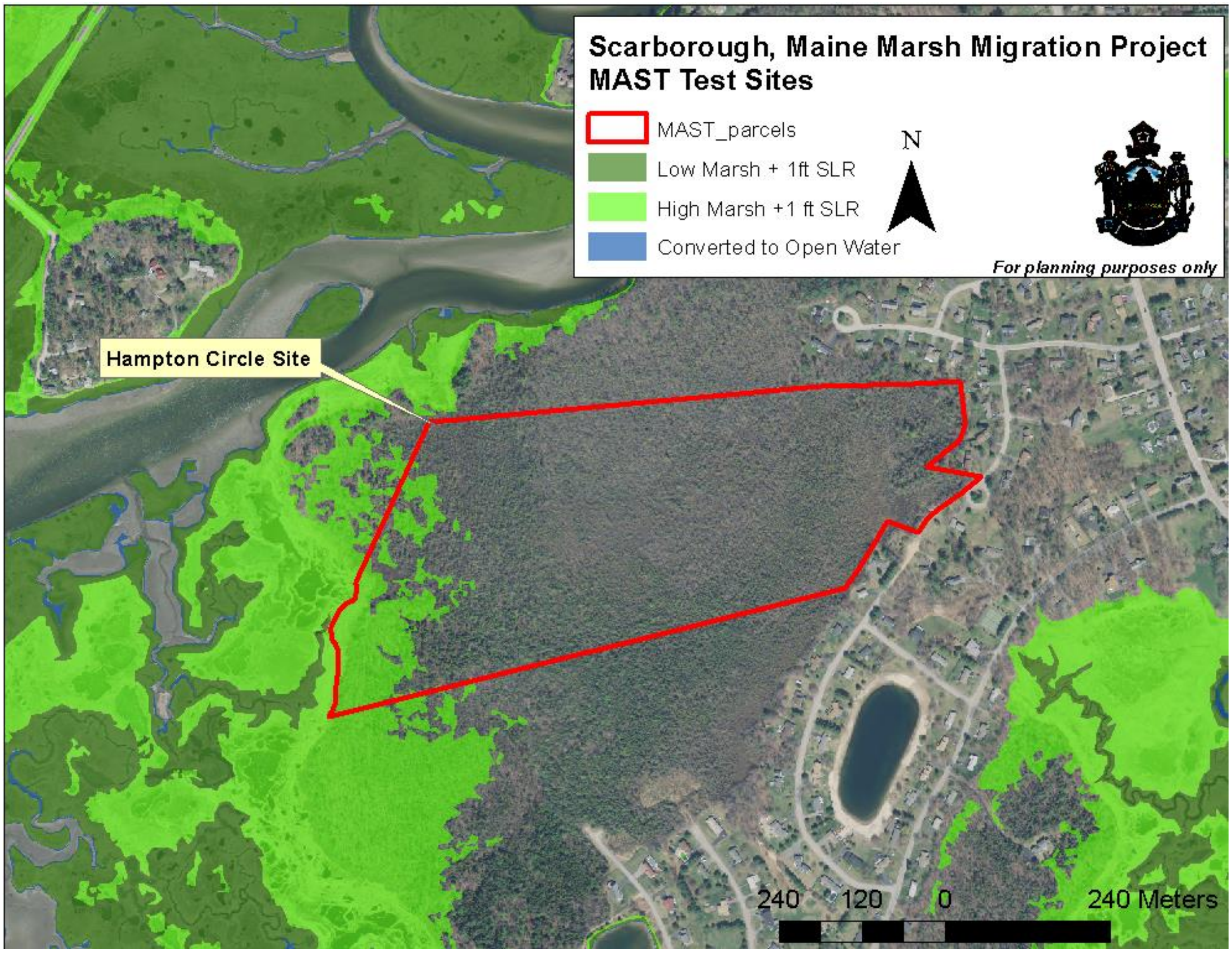
Strategic Marsh Adaptation: Creating and Testing a New Decision-support Tool.



Sample sea level rise projection used in the study, showing marsh beginning to migrate onto existing upland.

Final Report Submitted to the
Maine Department of Agriculture, Conservation, and Forestry
Catalysis Adaptation Partners, LLC
July 9, 2014

Contents

Acknowledgments

This work would not have been possible without the help of Liz Hertz of the Maine Department of Agriculture, Conservation, and Forestry (source funding from a NOAA Project of Special Merit). Bethany Atkins, Amanda Shearin, and Bob Stratton of the Maine Department of Inland Fisheries and Wildlife provided substantive input to the approach used and additional financial support. Judy Gates of the Maine Department of Transportation provided interagency coordination and administrative expertise. Pete Slovinsky of the Maine Geological Survey provided elevation data layers and created the sea level rise maps used on each study site. Jay Chace, Assistant Town Planner in Scarborough, provided critical insights and input on local site selection. Steve Walker of Maine Coast Heritage Trust provided key support in organizing a large meeting central to the project's goals. Bob Cave at Blue Marble Geographics provided superior software coding, innovation, and flexibility in creation of the tool's new capabilities. The smooth and professional way this complex project unfolded is a fine example of why great work happens in Maine – thanks to all of you.

This report may be cited as:

Merrill, S., and Colgan, C. 2014. Marsh Adaptation Strategy Tool: Creation and beta-testing in Scarborough, Maine. Catalysis Adaptation Partners, LLC, Freeport, Maine.

Abstract

In an era of rising sea levels, costal land managers including land trust representatives, municipal planners, and others contributing to decisions about whether to develop or protect coastal parcels do not have viable means of evaluating future values on wetlands that will be created when sea levels rise. This project develops and tests a software modeling approach to help address this issue. The beta test used three parcels in Scarborough, Maine: Hampton Circle, Audubon, and Pine Point. It used a group of experts to 1) allocate initial values to these parcels for a range of ecosystem services and 2) create depth-benefit curves that estimate how those values would change with increasing water depth at each site. Experts estimated that the Hampton Circle site had the highest initial values across all services. But once sea level rise and topographic diversity was accounted for via use of the software tool (MAST – Marsh Adaptation Strategy Tool), what initially appeared to be the most valuable site became the least valuable. The analysis demonstrates the importance of being able to examine interactions among a diversity of ecosystem service values, local topography, and possible sea level rise, and demonstrates the utility of a new tool to support costal land management decisions before and during upland conversion to wetland.

Introduction

With rising sea levels, coastal habitats are changing. Town managers, state resource managers, and others paying attention to health and condition of coastal assets (such as protected species of flora and fauna, beaches for tourism, and wetland capacities such as flood buffering and shorebird stopover habitat) are becoming concerned that as the coastline continues to change, some of these assets will be irrecoverably diminished or even lost completely. In response to this challenge many managers aim to become more proactive. Instead of using conventional measures of planning and policy revision, which to date have largely failed to provide a coherent framework by which natural features would migrate inland, they aim to combine the best available wetland science with new sea level rise mapping technology, to begin identifying where ecosystem service benefits are likely to emerge in evolving coastal landscapes. This would inform prioritization of land protection activities and help coastal land management be more strategic in the face of rising sea levels.

In support of this goal, in late 2013 the Maine Department of Agriculture, Conservation, and Forestry contracted Catalysis Adaptation Partners, LLC to develop and test a software tool that would use the best available scientific input, technical data layers, and spatially-referenced cumulative benefit modeling to help guide the inward migration of marsh lands. By integrating a suite of ecosystem services into the model (such as flood buffering capacity, recreation, and carbon storage), managers should be able to evaluate scenarios more proactively, including prioritizing acquisitions of uplands currently adjacent to wetlands, in ways that preserve or perhaps even enhance ecosystem function to the maximum extent possible.

The chosen approach was to enhance an existing software tool – COAST (COstal Adaptation to Sea level rise Tool) that relies on a Depth Damage Function to calculate lost value under different depths of inundation, and instead use a Depth Benefit Function to show cumulative benefits (ecosystem services and their associated value) that emerge on parcels expected to become wetlands in the coming century (see Part II for technical details). The functionality created in this project, as a subset of COAST, is called MAST (Marsh Adaptation Strategy Tool).

The specific problem MAST addresses is that even for the ambiguity faced by town planners, land trust representatives, and others at state and local levels (about how much sea level rise might happen when, what type of habitat will emerge in uplands adjacent to the sea, and many other complications of a changing land-water interface), they still must make decisions about the disposition of many parcels. A Nature Conservancy representative, for example, may have a budget to acquire several upland parcels currently adjacent to wetlands. They may know all the parcels will be underwater in 40 or 60 years, and may choose to not protect the parcels for this reason. Or, they may wish to make the purchase, and have interest in choosing parcels based on which will provide the best recreational opportunities, the best flood protection, or the best fish hatchery habitat, once they become wetlands. However it is challenging to prioritize based on any of these future possibilities, at least because nobody has a crystal ball, but also because in any location a whole suite of ecosystem services specific to that site can be expected to emerge when the parcel becomes marsh.

Nevertheless some guideposts can be created to help make this type of decision. Thus, one simplified question the MAST model is intended to help answer is, for the Nature Conservancy example, “if I have a million dollars to spend and there are three candidate upland parcels adjacent to the sea, which one should I purchase?” Using results from the beta test, this question is addressed in this report along with implications for using MAST in applied settings and consideration of issues agencies and land management organizations might think through as part of becoming more proactive about land management in an era of changing coastlines. Part II contains technical background on each project phase – survey methods used to populate MAST, geographic and other data inputs, and details about calculations used in MAST.

The MAST software was run for three parcels (Figure 1): Maine Audubon, Pine Point, and Hampton Circle. These sites were selected to represent a range of possible ecosystem service responses to rising sea levels, for example including parcels relatively near and far from existing development; having high and low connectivity with adjacent wetlands; and having high and low existing levels of recreational use. This diversity would help demonstrate the tool’s sensitivity to a range of physiographic contexts.

Timing of the project was fortuitous. It was funded as part of a six-town Project of Special Merit from NOAA. Among the concurrent sub-projects was work by the Maine Geological Survey to create new data layers in these towns for extents of the upland/marshland interface, high marsh, low marsh, and open water under different sea level rise scenarios. These data layers were complete just at the time this project needed them to conduct the software beta-test. Similarly, because the data layers represent substantial opportunity for agencies, nonprofits, and municipal land managers to ask and answer important questions about marsh migration, at about this time a day-long meeting was organized by Maine Coast Heritage Trust to explore possibilities with and implications of the new data layers. Nearly forty professionals with expertise and interest in marsh migration gathered at the Maine Arboretum (April 17 2014). At the conclusion of this session, Drs. Merrill and Colgan from Catalysis introduced the MAST model and led a 2-hour conversation to launch the expert-input portion of the project.

Part I – Tool Development and Beta Test

Results

Cumulative expected benefits through to the year 2100, in Wetland Benefit Units (WBUs; see Part II), are shown in Table 1, indicating that in all sea level rise scenarios the Audubon parcel would produce the largest value, the Pine Point parcel would produce the middle value, and the Hampton Circle parcel would produce the smallest value.

Table 1. Cumulative Wetland Benefit Units on study parcels through the year 2100.

Parcel	Sea Level Rise	Cumulative WBUs
Audubon	1'	3,899
Pine Point	1'	3,454
Hampton Circle	1'	276
Audubon	4'	4,640
Pine Point	4'	3,261
Hampton Circle	4'	1,175
Audubon	6.6'	4,803
Pine Point	6.6'	3,154
Hampton Circle	6.6'	1,410

Because of high initial values assigned to Hampton Circle by the panel of experts (Audubon = 1180, Pine Point = 750, and Hampton Circle = 1225; see Part II for more detail), it was surprising that the Hampton Circle parcel showed such low cumulative value creation over time. However this is understandable because even though the parcel is roughly 60 times larger than the other two, size differences had already been accounted for (i.e., WBUs are acre-adjusted). More importantly, the geographic analysis illustrated that topography of each site dictates the timing of partial or complete inundation and thus when benefits begin to accrue. Through 1’ of sea level rise, for example, relatively few WBUs accrue on the Hampton Circle parcel – this is consistent with Figure 4, showing that by the time sea levels have risen 1’, most of the parcel is still dry. However by the time 6.6’ of sea level rise has occurred, WBUs on the Hampton Circle parcel are substantially larger, though still smaller than on the other two parcels. If a land acquisition decision were to be made using these results, the Audubon site would clearly be the highest priority, regardless of the amount of sea level rise.

Unfortunately, because the project purpose was to develop and test a new modeling approach, and disposition of the parcels is relatively certain, these results do not provide immediate decision-making benefit for the parcels examined. Applied uses of the approach can begin at any time, however, and may provide useful guidance about parcel prioritization for land protection and other planning purposes. In general it will be a useful approach where it is important to be careful to not assume one coastal site is more important than others, or is likely to be the most important in the future – either on account of size, connectivity, or any combination of a few ecosystem services that might be evaluated.

Candidate groups that could use the approach include The Nature Conservancy, local land trusts, municipal planning offices, and others that may need to make resource allocation decisions in areas likely to convert to wetlands when sea levels rise. In using the approach in other areas, benefit allocations will need to be determined for each candidate parcel. This could occur via Delphi survey or in working groups in person. Depth Benefit Functions, however, may not need to be recreated; they could be incorporated from this study or adjusted to meet needs of the new project, either via Delphi survey or in working groups in person.

In any of these scenarios, the MAST approach represents two paradigm shifts for coastal land managers: 1) we can become more proactive in our response to sea level rise and choose to *create* value through land acquisition decisions; and 2) when new ecosystem services such as flood buffering capacity are understood to emerge in areas that will become marsh, conversations about development regulations in areas adjacent to the new marsh lands can be enhanced. This is because when wetlands migrate, regulatory boundaries will follow, creating new adjacencies to new combinations of ecosystem services. That is, in the same way that conventional efforts to prioritize lands for acquisition do more than simply help decide what to protect (they also help decide where development should go), prioritization of future wetlands in this way will have a similar range of regulatory and policy-related uses.

Part II – Methods and Technical Documentation

To assist in evaluating options for preserving and enhancing the ecosystem services values in Scarborough Marsh, a three step process was undertaken:

1. Assessing the values associated with specified wetlands parcels in their current use.
2. Identifying how those values might change over time as sea level changes.
3. Estimating the extent of inundation from possible sea level rise scenarios on the parcels under examination, and calculating value creation at each location over time.

The first two steps required use of a survey of experts to evaluate current values and probable directions of change in those values with sea level rise. The third step incorporated information from the first two steps into MAST to generate estimates of future values.

Estimating Values

Until relatively recently, coastal wetlands like Scarborough Marsh were seen as generally "useless." The historical approach to wetlands was to employ the three "D's": dyke, ditch, and drain. This process converted wetlands into dry lands that could be used for farming and building. However over the last several decades the ecological role of wetlands has become more fully understood and the role that wetlands play in serving as a key buffering component of dynamic coastal systems more fully appreciated. As ecologists have developed a better understanding of the importance of wetlands, economists have become involved in estimated the economic values associated with wetlands. The intersection of the ecological and economic assessment of wetlands takes place in the estimation of the values of ecosystem services.

These services were categorized by the assembled group of experts as:

- Attenuation or prevention of flood damages to public or private property
- Effects on land values of property adjacent to or with a view of the wetland
- Effects on water quality through filtration of pollutants
- Drinking water supply
- Recreation (active like boating and hunting or passive like sightseeing and bird watching)
- Aesthetics
- Habitat for any life stage of commercially harvested species such as groundfish or shellfish
- Habitat for any life stage of species significant for the preservation or enhancement of biodiversity, for example roosting, breeding, nesting, feeding, or wintering habitat for common and rare species
- Carbon storage
- Export of nutrients utilized by commercially harvested species
- As a research site for hydrologic, wildlife, or ecosystem studies
- Export of nutrients utilized by species critical to biodiversity
- Habitat connectivity
- Other benefits not included in any of the above

Estimating the values of these services is not easy because the values are not recognized or measured in the kinds of standard market-based transactions that would be used to estimate the value of something like land. We can determine the "value" of a piece of dry land by asking what has someone paid for the land (or a similar piece of land). But with wetlands, the values for habitat or nutrient production or flood protection of dry land simply cannot be observed in regular transactions. While we buy our food at a market where the price is set, fish do not "buy" their food at "wetlands market". To address this problem, economists use a technique called contingent valuation, which is essentially a survey that asks a sample of people "if you had to pay for this service, what is the maximum you would be willing to pay?" The principle is that someone should be willing to pay up to some maximum amount, so knowing that amount would be a good measure of what the values would be if a market in fact existed for the services being examined.

The concept of "willingness to pay" usually requires that payment be made in monetary units, e.g., dollars. Using dollars to express values is a common approach and it allows comparison of a dollar of value of a wetland to a dollar of value of anything else whose values are measured in money. But using dollars has a disadvantage: because we are so familiar with dollars it is sometimes difficult to apply this familiar concept in an unfamiliar area like "carbon sequestration" in a wetland. This is one of reasons why using "willingness to pay" approaches with wetlands valuation have proved to be difficult (for a recent comparison of several wetland valuation methods see Stelk and Christie (2014)).

Fortunately in the current assessment there is not a critical need to use dollars and perhaps create more confusion than insight. The task in Scarborough Marsh is to assess the values of different parcels *relative to one another* and not relative to all of the other possible resources. Because of this decision framework, it is possible to use a "pseudo-monetary unit," which we call a "wetland benefit unit," or WBU within a willingness to pay framework. The WBU permits a valuation process that can reflect basic economic principles of valuation in the assessment of wetlands values without having to ask for comparisons with market-based values that would be inherently difficult, particularly for the experts needed to perform the valuation process.

Another reason why wetlands valuation is inherently difficult is that most people are unfamiliar with the ecological complexity of the wetlands. The recreational values of canoeing on the Scarborough Marsh or of bird watching may be readily apparent, but the values of habitat, nutrient generation and transport, or carbon sequestration are much less likely to be familiar to most people, who will thus lack key information about the very thing they are being asked to value. For this reason, the wetlands valuation process is perhaps best started with those who know the wetlands the best: wetlands ecologists and other experts.

The challenge is to translate the ecological knowledge of the experts into the economic information needed to conduct a valuation process. To accomplish this translation, the group of experts was asked to take part in a two part "Delphi" process. The Delphi process is a well-established means of soliciting expert views by providing for input over multiple rounds (two in this case), in each of which experts are asked their views based on both their own knowledge and the collected knowledge of other experts.

In the current case, the Delphi process was carried out using an online survey. After logging into the survey through an email invitation, experts were provided with a map and description of each parcel in Scarborough Marsh and told they had a "budget" of 1000 WBU's they could use to purchase wetlands services, as listed above, for each of the parcels (the survey itself is Appendix 1). The "budget" of WBU's required that assigned values reflect scarcity (parcels could not be infinitely valuable) and tradeoffs (more of some values, like access for recreation, may diminish other values like habitat). After respondents assigned initial values, results were provided to the group, who was asked to assign values again based on their own judgment and what they had learned from the way others valued the same services. The maximum willingness to pay across all respondents for each of the services was then taken as the baseline value of the parcels. These are shown in Table 2.

Table 2. Expert allocations of Wetland Benefit Units at the three study sites.

	MAINE AUDUBON	PINE POINT	HAMPTON CIRCLE
Flood Damages	100	100	200
Land Values	20	75	100
Water Quality	100	25	100
Drinking Water	10	0	20
Recreation	500	250	100
Aesthetics	100	30	100
Commercial Habitat	50	20	50
Noncommercial Habitat	100	20	200
Carbon Storage	10	20	100
Commercial Species Nutrient	10	10	25
Biodiversity	50	50	100
Research	110	100	0
Habitat Connectivity	10	20	100
Other	10	30	30
TOTAL	1180	750	1225

Estimating Changes over Time

A second element of information was needed from the experts: how will the values change over time with sea level rise? For each of the ecosystem services listed, the experts were asked to select one of six possible change functions (Appendix 1), or "Depth Benefit Functions" (DBFs).

Table 3 shows responses of the expert respondents for each of the curve shapes, across all of the ecosystem services. The modal view of the experts was that the initial values would decline over time (curve shape b.), but there was substantial uncertainty among the expert panel, with nearly as many choosing an increasing response curve (shape a.) or a flat curve (shape f.) as chose a declining curve (38% combined flat and upward sloping v. 41% downward sloping).

Table 3. Distribution of expert opinion about benefit curve shapes across ecosystem service categories.

Response Curve	Number of Responses	Percent Distribution
a.	14	16%
b.	35	41%
c.	1	1%
d.	12	14%
e.	6	7%
f.	18	21%

A slope of 11.25% was used for the declining DBF. Although the final results could have been sensitive to the slope, running the same scenarios with five slopes ranging from -5% to -45% did not change WBU rankings at 1', 4', or 6.6' of sea level rise. Nevertheless, the question of how the rate of change in inundation interacts with the rate of change in the benefits derived from wetlands is obviously both a central and a complex problem. With no real empirical data about how wetlands have increased in value (the vast preponderance of the research addresses declines in economic values), the use of expert opinion filtered through a process like Delphi is the only currently realistic way of estimating these change functions. This project has attempted to reflect the diversity of views on the form of change in the benefit function while meeting the model's computational requirements for a single combined function. Further development will allow enhanced representation of combined benefit functions.

There are numerous additional caveats around these preliminary results. For example the benefit curves assume equivalence between parcels in the ability of ecosystem services to emerge. However some of the Pine Point and Audubon parcels are paved, for example, so this assumption will require pavement to be removed when the parcel becomes inundated. Further, meeting this assumption may create the need for additional assumptions, such as with Audubon, where the existing parking lot probably allows much of the "recreation" value captured by the benefit creation function to exist. To allow recreation benefits to continue to accrue with depth, alternative parking will need to be created when necessary.

Software

Maine-based firm Blue Marble Geographics was hired through this project to enhance the COAST software shell with the capability of running the MAST model. When this was complete, the MAST component could calculate values from ecosystem services that would emerge on the landscape through gradual change as sea levels continued to rise. The model operates by using the parcel map (asset layer, with 2014 values determined as above) in combination with an elevation layer (LiDAR imagery). For each year in a scenario, the software takes an elevation from a specified sea level rise curve and adds that elevation to the base elevation for the specific parcel. For each location in each year, a DBF is referenced that states how much benefit is created at each depths of inundation. These benefits are summed for the range of years in each scenario, producing cumulative benefit estimates for each parcel that can be compared between locations and sea level rise curves.

Geographic Data

New sea level rise data layers for Scarborough, with sea level rises of 1', 2', 3.3', and 6', were created as part of a larger Project of Special Merit, and these layers were formatted for ease of interpreting beta-test results (Figures 2 – 4). Importantly, these elevations had not been tied to particular timelines for Scarborough (or on any other Project of Special Merit sub-project), and MAST requires this association. Therefore in this study, sea level rise curves from the recent National Climate Assessment were used (Parris et al. 2012), with total sea level rise ending at 1', 4', and 6.6' by the year 2100. Reference datum was NAVD88, and subsidence used in each scenario was 0.0007' per year above NAVD88, derived from the tide gauge in Portland, Maine. Base elevation reference was 6.59', to be consistent with other Project of Special Merit sub-tasks (calculated using the 2013 predicted HAT which was 11.51' MLLW, and calculating separations between MLLW and NAVD88 using the NOAA VDATUM tool, or 4.92'; 11.51' – 4.92' = 6.59'). Additional elevation from storm surge was not included in the scenarios. Digital parcel data were provided by the Town of Scarborough. Elevation layers were LiDAR imagery obtained from the Maine Geological Survey.

Figures

Figure 1. Study sites in the Scarborough Marsh.

Maine Audubon

Pine Point

Hampton Circle

Figure 2. Inundation of the Maine Audubon parcel, showing low marsh, high marsh, and open water extents for 0', 1', 2', 3.3', and 6' of sea level rise.

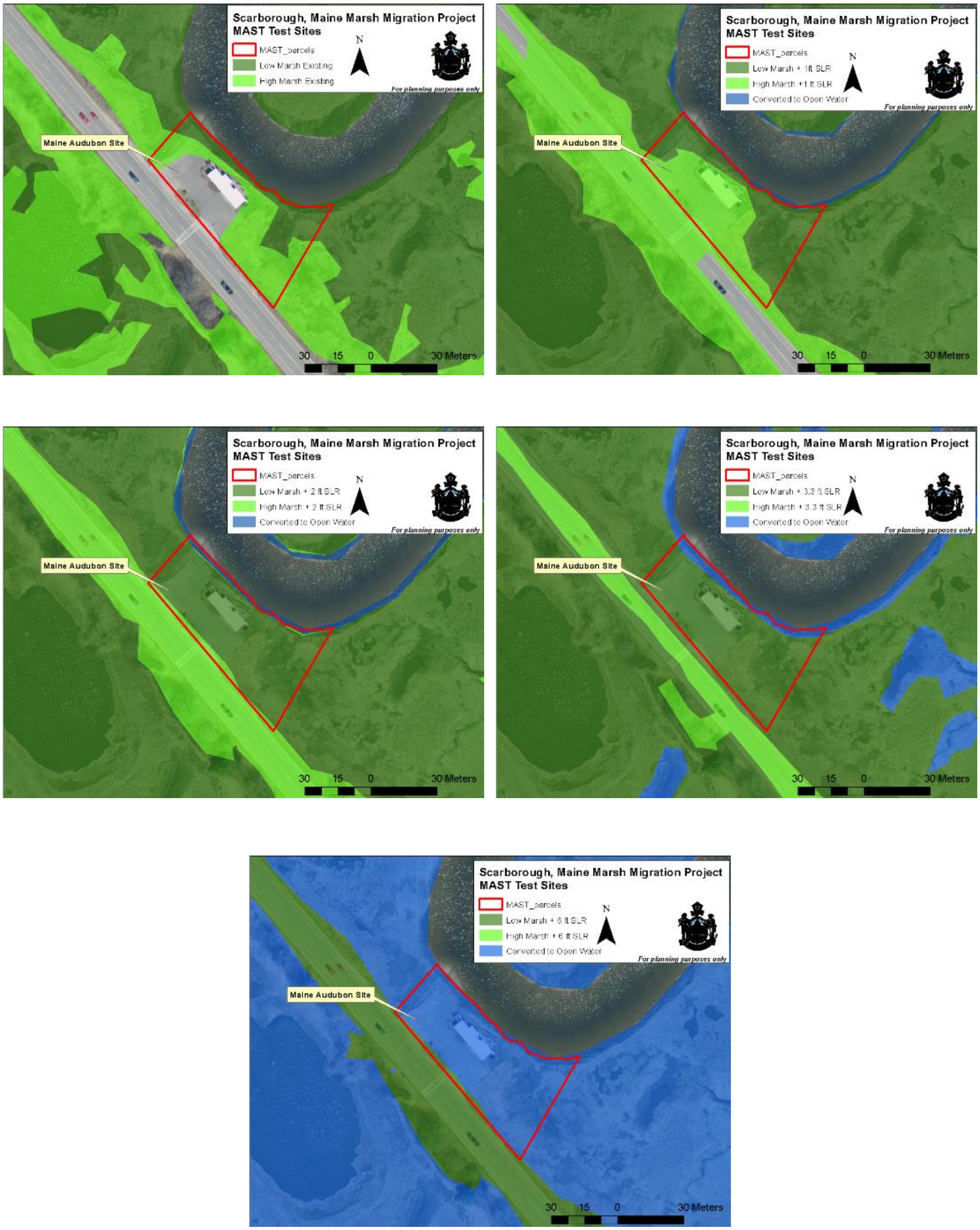


Figure 3. Inundation of the Pine Point parcel, showing low marsh, high marsh, and open water extents for 0', 1', 2', 3.3', and 6' of sea level rise.

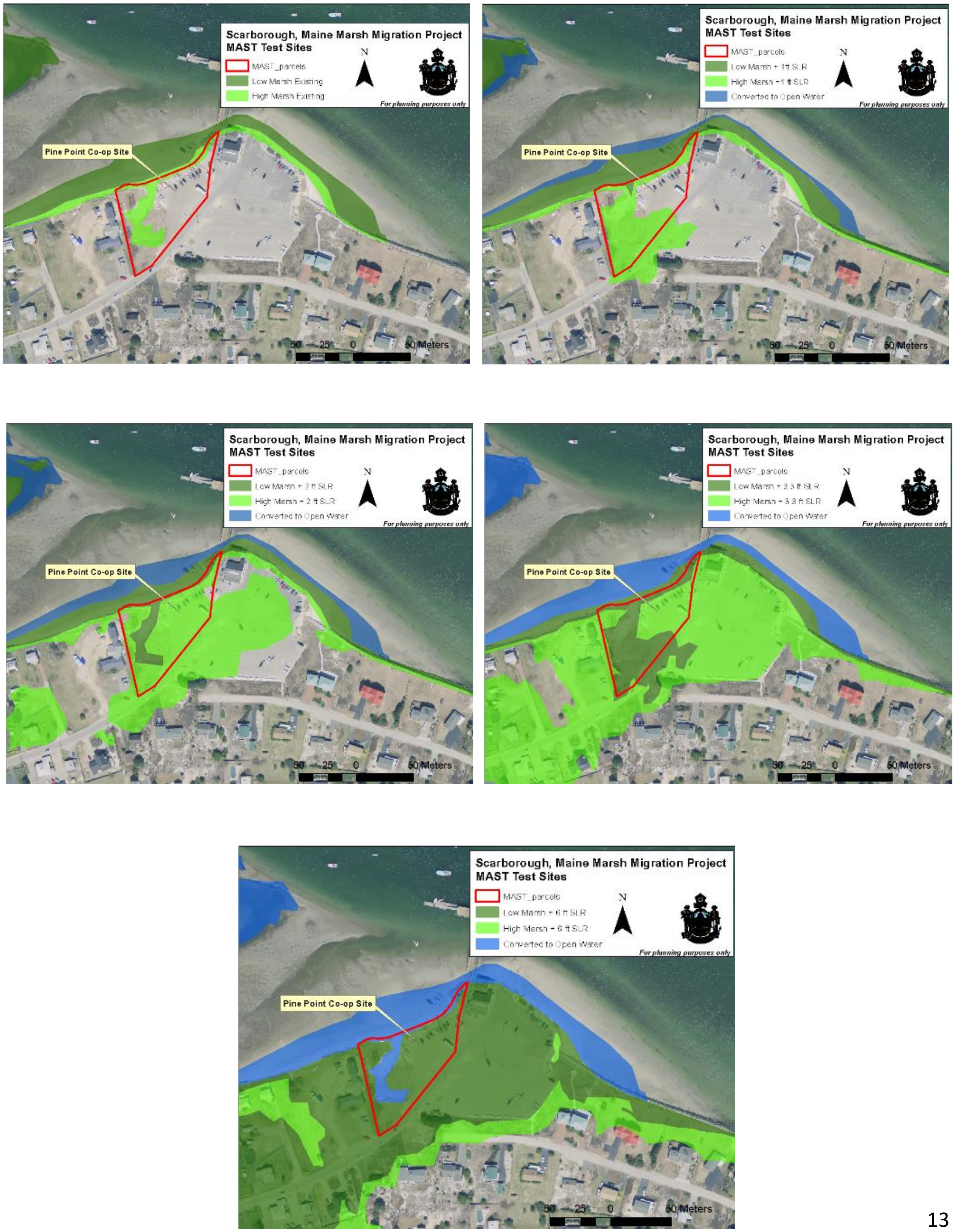
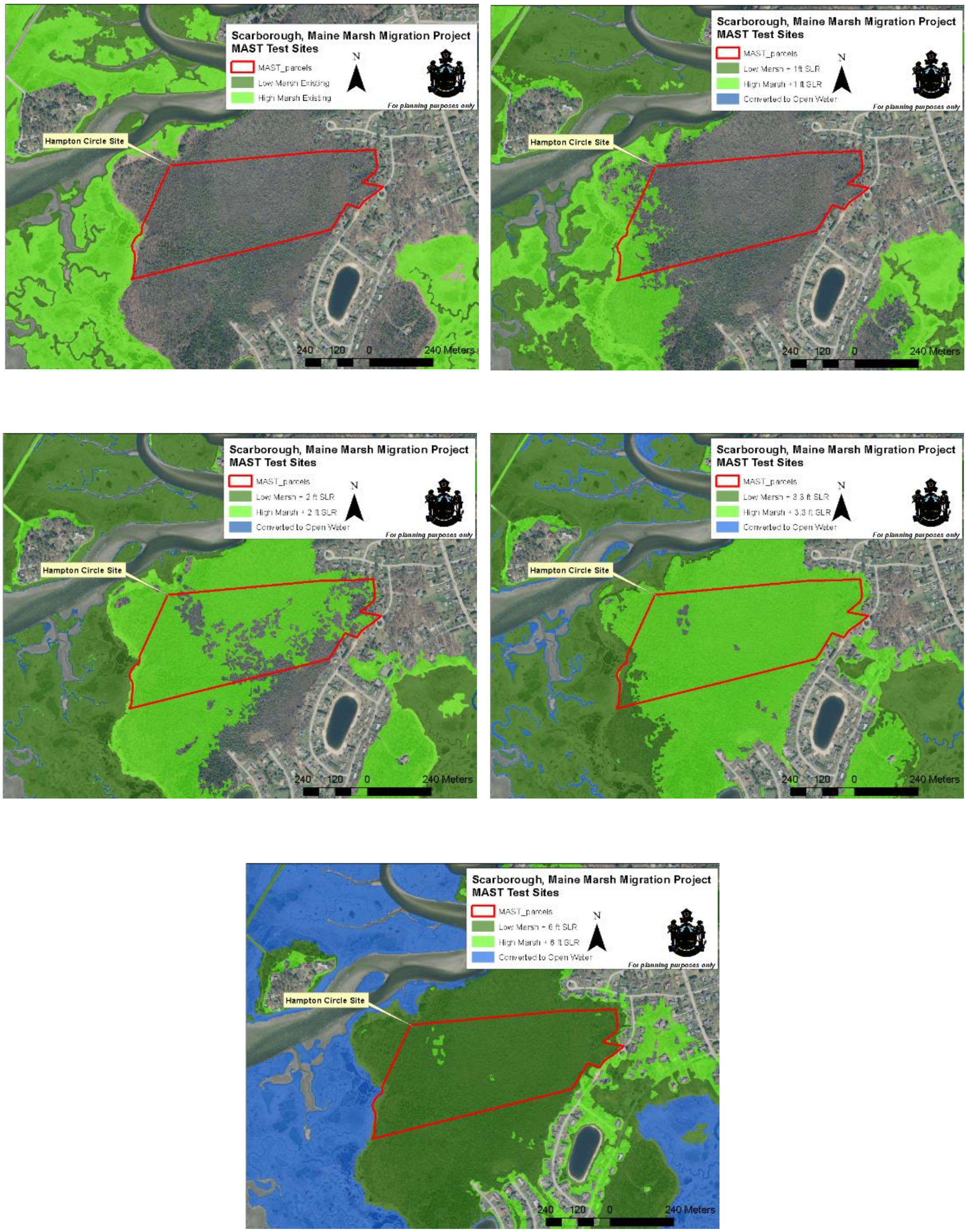


Figure 4. Inundation of the Hampton Circle parcel, showing low marsh, high marsh, and open water extents for 0', 1', 2', 3.3', and 6' of sea level rise.



Literature Cited

Stelk, M.J. & Christie, J. 2014. Ecosystem Service Valuation for Wetland Restoration: What It Is, How To Do It, and Best Practice Recommendations. Association of State Wetland Managers, Windham, Maine. <http://aswm.org/pdf_lib/ecosystem_service_valuation_for_wetland_restoration.pdf>

Parris, A., P. Bromirski, V. Burkett, D. Cayan, M. Culver, J. Hall, R. Horton, K. Knuuti, R. Moss, J. Obeysekera, A. Sallenger, and J. Weiss. 2012. Global Sea Level Rise Scenarios for the US National Climate Assessment. NOAA Tech Memo OAR CPO-1. 37 pp.

Appendix 1. Delphi Survey

Project Background for Participants

This project is developing and beta-testing technology that could be used for strategic planning of land protection in an era of sea level rise. The beta-site is Scarborough Marsh, and sites selected for this test are for exploratory purposes only. They were selected to reflect high and low anticipated ecosystem services value; are located in highly developed and less developed contexts, and have high and low connectivity with adjacent wetlands. This diversity will help show the range of anticipated ecosystem services benefits that will accrue as wetlands migrate inland. Because we are standardizing for parcel size in our methodology, we did not need to homogenize acreages between sites. Similarly, the generic Wetland Benefit Units approach allows us to not have to standardize on other parameters, providing a structure that can work with a wide range of sites. The tool will operate via a Benefit Creation Function that will be a combination of functions representing 13 ecosystem services. The shape of these curves will be determined by you, the collection of wetland experts. That is, to assess the value of parts of Scarborough Marsh that might be acquired, it is important to estimate how different parts of the marsh provide various services that people find valuable. The following questions ask you to estimate the values of parcels of land that are currently adjacent to Scarborough March has TODAY and the DIRECTION OF CHANGE in these values if sea level rise were to expand the marsh so that current land is permanently incorporated into the marsh. For this purpose you have a budget of 1000 Wetland Benefit Units (WBU's). You can distribute these benefit units across the different services of the parcels in any way you choose. The total of WBU's that you assign to each parcel will be displayed as you enter your value estimates. You can spend less than a total of 1000 units, but you cannot spend more than 1000 in total across the 3 parcels. Your estimates of value should be based on your best professional judgment about CURRENT values. The survey program keeps track of the totals you enter for each site, but not of the totals of all sites. You may find it helpful to note your totals as you proceed from one parcel to the next, so as not to exceed your budget. You may use the back button to return to previous questions. You will also be given the opportunity to change your estimates once you have completed the estimation section. This is a Delphi Survey, meaning that there will be at least one subsequent round where you can view others' responses and update your own.

The **Maine Audubon** Canoe Rental Site on Pine Point Road (Rte 9). The site is <1 acre, highly developed, and in a setting of low adjacent development. See Figure 2 for Maine Audubon parcel under existing, 1ft, 2ft, 3ft, and 6ft sea level rise conditions, showing open water, low marsh, and high marsh extents.

Q1. Please enter your allocation of Wetlands Benefits Units to the Maine Audubon site under existing conditions for each of the following services. In evaluating the allocations you may consider all available data that you wish, including published data, expert opinion, and local knowledge. You may come back to change your estimates after you enter the WBU values for the other sites.

_______ Attenuation or prevention of flood damages to public or private property
_______ Effects on land values of property adjacent to or with a view of the wetland
_______ Effects on water quality through filtration of pollutants
_______ Drinking water supply
_______ Recreation (active like boating and hunting or passive like sightseeing and bird watching)
_______ Aesthetics
_______ Habitat for any life stage of commercially harvested species such as groundfish or shellfish
_______ Habitat for any life stage of species significant for the preservation or enhancement of biodiversity, for example roosting, breeding, nesting, feeding, or wintering habitat for common and rare species
_______ Carbon storage
_______ Export of nutrients utilized by commercially harvested species
_______ Export of nutrients utilized by species critical to biodiveristy
_______ As a research site for hydrologic, wildlife, or ecosystem studies
_______ Habitat connectivity
_______ Other benefits not included in any of the above

Q2. Comments on the basis of your benefit estimates on the Maine Audubon site.

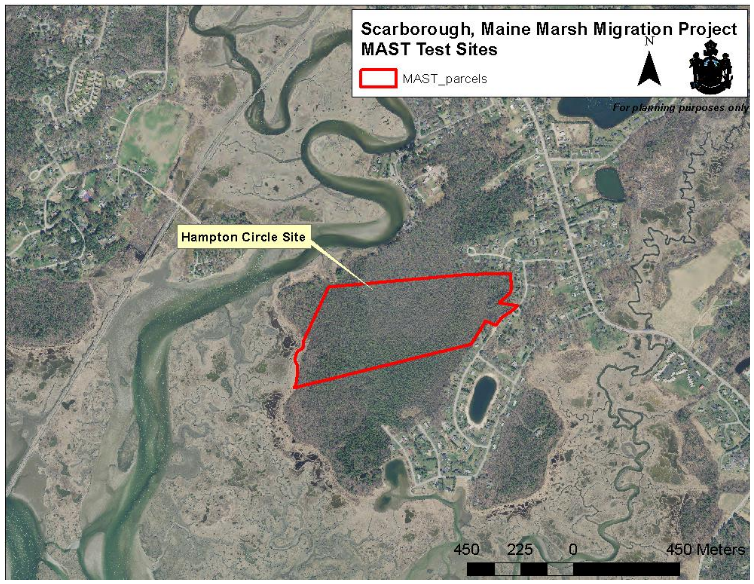
The **Pine Point** Dock and Boat Launch. The site is <1 acre, highly developed, and adjacent to substantial existing development. See Figure 3 for Pine Point lot parcel under existing, 1ft, 2ft, 3ft, and 6ft sea level rise conditions, showing open water, low marsh, and high marsh extents.

Q3. Please enter your allocation of Wetlands Benefits Units to the Pine Point site for each of the following services. In evaluating the allocations you may consider all available data that you wish, including published data, expert opinion, and local knowledge. You may come back to change your estimates after you enter the WBU values for the other sites.

_______ Attenuation or prevention of flood damages to public or private property
_______ Effects on land values of property adjacent to or with a view of the wetland
_______ Effects on water quality through filtration of pollutants
_______ Drinking water supply
_______ Recreation (active like boating and hunting or passive like sightseeing and bird watching)
_______ Aesthetics
_______ Habitat for any life stage of commercially harvested species such as groundfish or shellfish
_______ Habitat for any life stage of species significant for the preservation or enhancement of biodiversity, for example roosting, breeding, nesting, feeding, or wintering habitat for common and rare species
_______ Carbon storage
_______ Export of nutrients utilized by commercially harvested species
_______ Export of nutrients utilized by species critical to biodiveristy
_______ As a research site for hydrologic, wildlife, or ecosystem studies
_______ Habitat connectivity
_______ Other benefits not included in any of the above

Q4. Please provide any comments on the basis of your benefit estimates on the Pine Point site.

The **Hampton Circle** forest land off of Black Point Road (Rte 207). The site is 66 acres and is contiguous with existing protected wetlands and uplands. See Figure 4 for Hampton Circle parcel under existing, 1ft, 2ft, 3ft, and 6ft sea level rise conditions, showing open water, low marsh, and high marsh extents.



Q5. Please enter your allocation of Wetlands Benefits Units to the Hampton Circle site for each of the following services. In evaluating the allocations you may consider all available data that you wish, including published data, expert opinion, and local knowledge. You may come back to change your estimates after you enter the WBU values for the other sites.

_______ Attenuation or prevention of flood damages to public or private property
_______ Effects on land values of property adjacent to or with a view of the wetland
_______ Effects on water quality through filtration of pollutants
_______ Drinking water supply
_______ Recreation (active like boating and hunting or passive like sightseeing and bird watching)
_______ Aesthetics
_______ Habitat for any life stage of commercially harvested species such as groundfish or shellfish
_______ Habitat for any life stage of species significant for the preservation or enhancement of biodiversity, for example roosting, breeding, nesting, feeding, or wintering habitat for common and rare species
_______ Carbon storage
_______ Export of nutrients utilized by commercially harvested species
_______ Export of nutrients utilized by species critical to biodiveristy
_______ As a research site for hydrologic, wildlife, or ecosystem studies
_______ Habitat connectivity
_______ Other benefits not included in any of the above

Q6. Please provide any comments on the basis of your benefit estimates on the Hampton Circle site.

Q7. Do you want to alter any of your estimates of WBU's?
- Yes (This will allow you to re-enter information for each site)
- No (This will take you to the next set of questions)

Expert Familiarity with Sites

Q8. We would like to know how familiar you are with the sites in Scarborough Marsh being evaluated. The following questions let you rate your familiarity with each site and indicate the basis for your familiarity.

Q9. Please rate your familiarity with the Maine Audubon site, where 0 is "NOT FAMILIAR AT ALL" and 100 is "EXTREMELY FAMILIAR". Move the slider bar to the point that best represents your familiarity on this scale.

Q10. Is your familiarity with the Maine Audubon site based primarily on (pick one)
- Personal familiarity (I've been there but done no research there or nearby)
- Research projects I have undertaken
- Both
- Neither (only information I got for this survey)

Q10. Please rate your familiarity with the Pine Point Dock and Boat Launch site, where 0 is "NOT FAMILIAR AT ALL" and 100 is "EXTREMELY FAMILIAR". Move the slider bar to the point that best represents your familiarity on this scale.

Q11. Is your familiarity with the Pine Point site based primarily on (pick one)
- Personal familiarity (I've been there but done no research there or nearby)
- Research projects I have undertaken
- Both
- Neither (only information I got for this survey)

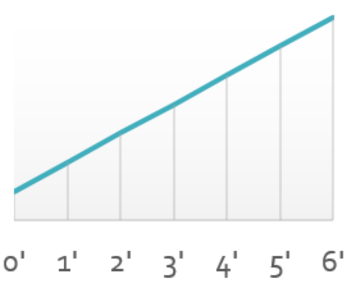
Q12. Please rate your familiarity with the Hampton Circle, where 0 is "NOT FAMILIAR AT ALL" and 100 is "EXTREMELY FAMILIAR". Move the slider bar to the point that best represents your familiarity on this scale.

Q13. Is your familiarity with the Hampton Circle site based primarily on (pick one)
- Personal familiarity (I've been there but done no research there or nearby)
- Research projects I have undertaken
- Both
- Neither (only information I got for this survey)

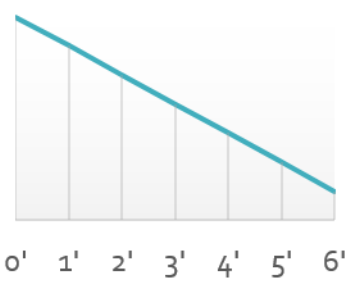
Benefit Creation Functions

Because it is not reasonable to expect marsh-related ecosystem services to increase linearly with depth, and because each ecosystem service will have its own type of response curve in relation to depth, we need to create a combined Benefit Creation Function that encompasses all ecosystem services of concern. (When the Marsh Adaptation Strategy Tool software runs for this purpose, later this month, it will use this function directly to calculate benefits created over time on each parcel). To do this we will use a combination of curve shapes determined by this survey group, based on responses to the below questions. The questions ask for your best estimates of types of changes that will occur in different values of ecosystem services in Scarborough Marsh as a result of sea level rise creating permanent inundations that transform current upland to permanent marshland. For each question please select the change shape that you think is most likely to be associated with that value as depth increases. The graphics are meant to be illustrative, not precise measurements. The X-Axis depicts depths of inundation, but is also meant to be illustrative rather than precise. "Depth" in this case references the mean high water mark, meaning that the location will be underwater at high tide most days of the year.

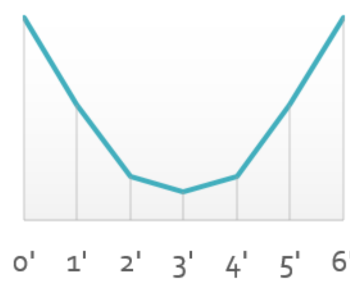
a.



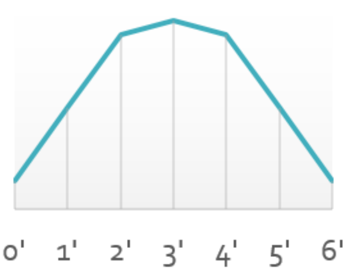
b.



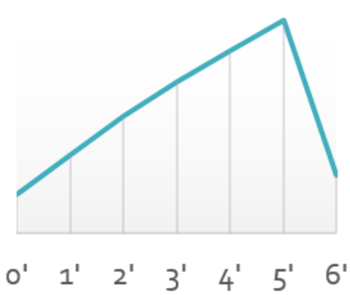
c.



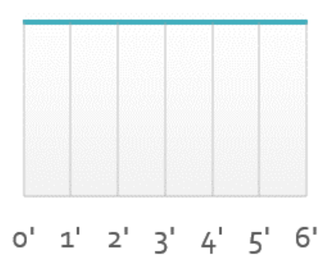
d.



e.



f.



Q14. Attenuation or prevention of flood damages to public or private property.

Q15. Effects on land values of property adjacent to or with a view of the wetland.

Q16 Effects on water quality through filtration of pollutants.

Q17. Drinking water supply.

Q18. Recreation (active like hunting and boating or passive like sightseeing and birdwatching).

Q19. Aesthetics.

Q20. Habitat for any life stage of commercially important species such as groundfish or shellfish.

Q21. Habitat for any life stage of species significant for the preservation and enhancement of biodiversity, for example roosting, breeding, nesting, feeding, or wintering habitat for common and rare species

Q22. Carbon storage.

Q23. Export of nutrients utilized by commercially important species.

Q24. Export of nutrients utilized by species critical to biodiversity.

Q25. As a research site for hydrologic, wildlife, or other ecosystem studies.

Q26. Habitat Connectivity.

Q27. Other benefits not included in any of the above.

Q28. Please enter any comments on your identification of values change functions.