City of Portsmouth, New Hampshire

COASTAL RESILIENCE INITIATIVE

Climate Change Vulnerability Assessment and Adaptation Plan

March 29, 2013

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City of Portsmouth, New Hampshire

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Note: The purpose of this report is to provide a broad overview of spatial and temporal risk and vulnerability of public and private assets as a result of projected changes in climate. This report should be used for preliminary and general planning purposes only, not for parcel-level or site-specific analyses. The vulnerability assessment performed was limited by several factors including the vertical accuracy of elevation data and the static analysis applied to map coastal areas subject to future flooding which does not consider wave action and other coastal dynamics. Also, the estimated damages to buildings and infrastructure are based upon the elevations of the land surrounding them, not the structure itself.

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FLOOD ELEVATION SCENARIO MAPS

Individual maps from the complete map set list below are referenced throughout this report using the numbering system listed below for the corresponding asset or indicator and mapped flood elevation.

Map Number	Flood Elevation Scenarios
Buildings (8 maps)	
B-1.1	7.5-foot flood elevation (full extent)
B-1.2	11.5-foot flood elevation (full extent)
B-1.3	13.5-foot flood elevation (full extent)
B-1.4	18.0-foot flood elevation (full extent)
B-2.1	7.5-foot flood elevation (downtown)
B-2.2	11.5-foot flood elevation (downtown)
B-2.3	13.5-foot flood elevation (downtown)
B-2.4	18.0-foot flood elevation (downtown)
Freshwater Flooding (1 map)	
FF-1.1	18.0-foot flood elevation (full extent)
Infrastructure and Critical Facilities (4 maps)	
I-1.1	7.5-foot flood elevation (full extent)
I-1.2	11.5-foot flood elevation (full extent)
I-1.3	13.5-foot flood elevation (full extent)
I-1.4	18.0 foot flood elevation (full extent)
Wetlands/Environmental Resources (4 maps)	
WE-1.1	7.5-foot flood elevation (full extent)
WE-1.2	11.5-foot flood elevation (full extent)
WE-1.3	13.5-foot flood elevation (full extent)
WE-1.4	18.0 foot flood elevation (full extent)

Details of Maps B-2.1 through B-2.2 are presented in Figure 2 and Figure 3.

PART 1. INTRODUCTION

Research shows how the climate of New Hampshire and the Seacoast region has changed over the past century, and predicts that the future climate of the region will be affected by human activities that are warming the planet. The most current climate report for New Hampshire (Wake et al, 2011) describes historic trends over the past century and likely changes in New Hampshire's climate over the next century and is designed to help residents and communities plan and prepare for changing climate conditions.[1]

Overall, New England has been getting warmer and wetter over the last century, and the rate of change has increased over the last four decades according to detailed analysis of data collected at four meteorological stations (Durham and Concord NH; Lawrence, MA; and Portland, ME).

- Since 1970, mean annual temperatures have warmed, with the greatest warming occurring in winter.
- Average minimum and maximum temperatures have also increased over the same time period, with minimum temperatures warming faster than mean temperatures.
- Both the coldest winter nights and the warmest summer nights are getting measurably warmer.

The Coastal Resilience Initiative (CRI) is the City of Portsmouth's first look at the potential impact from a changing climate. Coastal communities like Portsmouth are most vulnerable to impacts of sea level rise and coastal storm surge.

The objectives of the Coastal Resilience Initiative were to:

- Describe the range of climate change and sea level rise scenarios that researchers have identified for the New Hampshire Seacoast region;
- Map four sea level elevations to show how these scenarios would impact the City of Portsmouth in the next 40 to 90 years;
- Using these maps, identify physical assets (buildings and infrastructure) and natural resources that are vulnerable to sea level rise and coastal storm surge;
- Develop preliminary strategies for adapting to future conditions, and estimates of the costs of these adaptation actions;
- Provide recommendations to guide adaptation planning, including policies and regulations.

The study products include a set of flood elevation maps, a vulnerability assessment, a preliminary outline of potential adaptation strategies, and recommendations for future planning, regulation and policies. This report represents a starting point for the City to identify avenues to implement adaptation measures that impart resiliency in the built environmental and protect natural systems.

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[1] *Climate Change in the Piscataqua/Great Bay Region: Past, Present, and Future*, Wake, C., E. Burkowski, E. Kelsey, K.Hayhoe, A.Stoner, C. Watson, E. Douglas, Earth Systems Research Center, University of New Hampshire (2011) available online by Carbon Solutions New England at http://www.carbonsolutionsne.org/.

Study Purpose and Limitations

The purpose of this report is to provide a broad overview of spatial and temporal risk and vulnerability of public and private assets as a result of projected changes in climate. This report should be used for preliminary and general planning purposes only, not for parcel-level or site-specific analyses.

The best available predictive information about future climatic conditions specific to sea level rise were utilized in the preparation of this report which with LiDAR (Light Detection and Ranging) data collected by aircraft in 2011 serves as the primary source information for this project. That said, the vulnerability assessment performed for the project was limited by several factors including the vertical accuracy of elevation data (derived from LiDAR) and the static analysis applied to map coastal areas subject to future flooding which does not consider wave action and other coastal dynamics. Also, the estimated damages to buildings and infrastructure listed in Table 4 of the report are based upon the elevations of the land surrounding them, not the structure itself.

The modeled information in this report is based on the best understanding of the current and predicted future climate for this region. As model results and climate based projections are improved this report and reports of this type will need to be updated to reflect that new information, which could change the predicted amount of sea level rise and future climate impacts.

PART 2. SEA LEVEL ELEVATION SCENARIOS

To evaluate the impacts of flooding from sea level rise and coastal storms, the CRI project began with two known baseline conditions for present-day water elevations:

- Mean Higher High Water (MHHW);[2] and
- Mean Higher High Water with a 100-year coastal storm surge (MHHW Flood).[3]

The baseline elevations for these two conditions are presented in Table 1, in the columns headed "Present Day Elevations."

Using a regional model that predicts changes in climate and sea level over time based on various estimates of greenhouse gas emissions, a lower probable emissions scenario and a higher probable emissions scenario were modeled and mapped for the City of Portsmouth for the future dates of 2050 and 2100. The 2050 and 2100 sea level projections provided in Table 1 include both a lower emissions (low) and higher emissions (high) scenario. All elevation predictions are stillwater sea level rise elevations: that is, they do not include wave effects or freshwater floods, both of which can be significant.

Table 1: Reference Elevations

Water Level	Elevations Relative to NAVD (North American Vertical Datum)				
	Present Day Elevations (feet)	*Future Scenarios (feet)			
		2050 Low	2050 High	2100 Low	2100 High
Projected SLR	--	+1.0	+1.7	+2.5	+6.3
MHHW	4.4	5.4	6.1	6.9	10.7
MHHW Flood	11.2	12.2	12.9	13.7	17.5

* Future Scenarios represent projected low and high Greenhouse Gas Emissions at 2050 and 2100

Mapping

From the 10 elevations in Table 1, four discrete flood elevations were selected to represent the probable range of lower and higher flood elevations: 7.5 feet, 11.5 feet, 13.5 feet and 18.0 feet.[4] The column titled "Mapped Elevation" in Table 2 below shows how these selected elevations relate to a range of present and future sea level elevations.

- The 7.5-foot modeled elevation correlates closest to the predicted MHHW in 2100 given a low greenhouse gas emission scenario (6.9 ft. above NAVD).

[2] Every day there are two high tides, one of which is higher than the others. MHHW is defined as the average of the elevations of these higher high tides averaged over a defined 19-year period.
[3] A 100-year coastal storm surge has a one-percent chance of occurring in any given year.
[4] For detailed explanation of mapping methods, refer to Appendix C – Mapping Methods and Metadata.

- The 11.5-foot elevation correlates to the present-day 100-year coastal flood elevation (11.2 ft.) and to two future conditions: the 2050, 100-year coastal flood elevation at MHHW under a low greenhouse gas emission scenario (12.2 ft.), and the MHHW in 2100 given a high greenhouse gas emission scenario (10.7 ft.).
- The 13.5-foot elevation maps correlate to the 100-year coastal flood elevation at MHHW given the 2050 high greenhouse gas emission scenario (12.9 ft.) as well as the 100-year coastal flood elevation at MHHW with the 2100 low emission scenario (13.7 ft.).
- Finally, the 18-foot modeled elevation corresponds to the 100-year coastal flood at MHHW given the 2100 high emission scenario (17.5 ft.).

Table 2: Mapped sea level and storm surge elevations

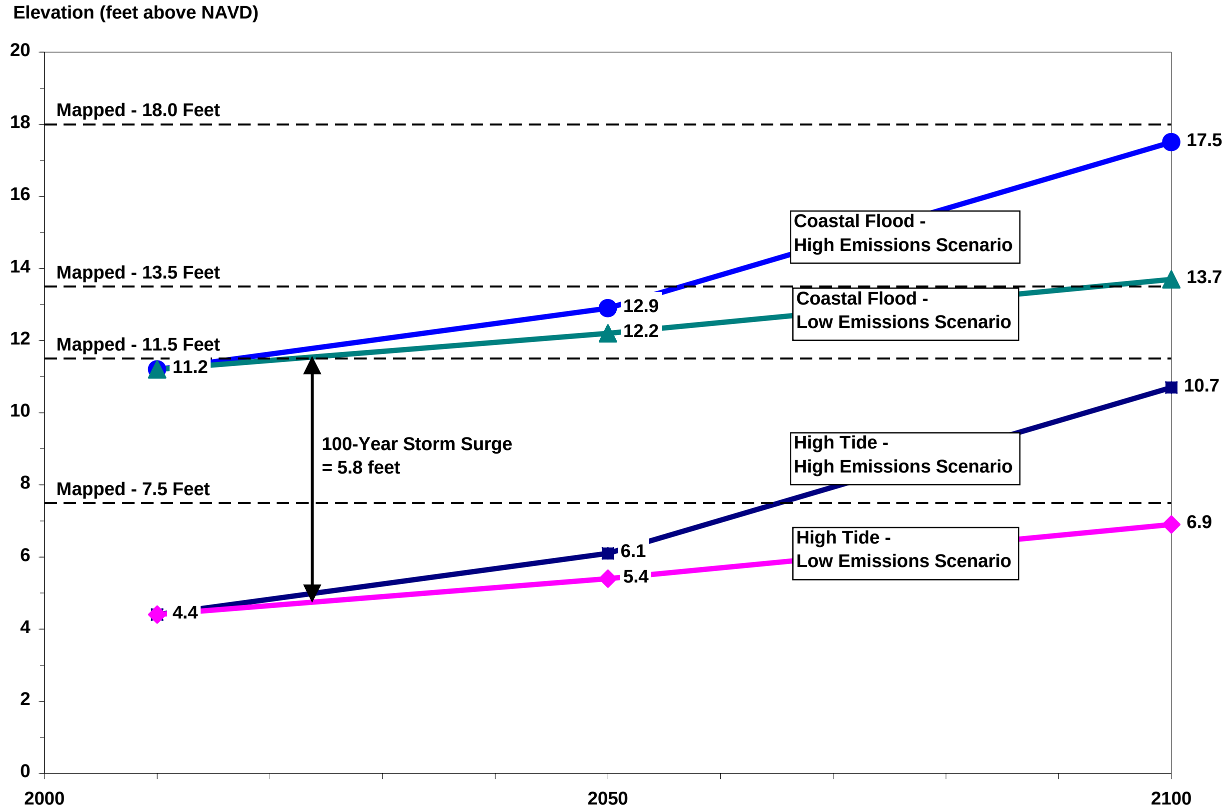
<table>
<tr><th colspan="4">Flooding Scenarios Modeled
(ordered by increasing elevation below)</th><th colspan="3">Mapped Elevations (feet)[5]</th></tr>
<tr><th>Scenario</th><th>Water Level</th><th>Water level (ft)</th><th>Change (ft)</th><th>Mapped Elevation</th><th>lower bound</th><th>upper bound</th></tr>
<tr><td>Present Day</td><td>MHHW</td><td>4.4</td><td>n/a</td><td colspan="3">n/a - reference elevation only</td></tr>
<tr><td>2100 Low Emission</td><td>MHHW</td><td>6.9</td><td>2.5</td><td>7.5</td><td>6.5</td><td>8.5</td></tr>
<tr><td>2100 High Emission</td><td>MHHW</td><td>10.7</td><td>3.8</td><td rowspan="3">11.5</td><td rowspan="3">10.5</td><td rowspan="3">12.5</td></tr>
<tr><td>Present Day</td><td>MHHW Flood</td><td>11.2</td><td>0.5</td></tr>
<tr><td>2050 Low Emission</td><td>MHHW Flood</td><td>12.2</td><td>1.0</td></tr>
<tr><td>2050 High Emission</td><td>MHHW Flood</td><td>12.9</td><td>0.7</td><td rowspan="2">13.5</td><td rowspan="2">12.5</td><td rowspan="2">14.5</td></tr>
<tr><td>2100 Low Emission</td><td>MHHW Flood</td><td>13.7</td><td>0.8</td></tr>
<tr><td>2100 High Emission</td><td>MHHW Flood</td><td>17.5</td><td>3.8</td><td>18.0</td><td>17.0</td><td>19.0</td></tr>
</table>

The base maps used for this study were produced using Google imagery and high resolution elevation data or LiDAR (Light Detection and Ranging) data that was collected during the spring of 2011. Note that the maps are provided for planning level analysis and application only. It is not appropriate to use the maps for detailed analysis (e.g. at the parcel specific level). Data layers were sourced from the City of Portsmouth, NH GRANIT, and Rockingham Planning Commission.

The elevations presented in Table 1 are also plotted in Figure 1 on the following page. In the Figure, the solid lines that increase from left to right connect the modeled sea level rise elevation scenarios from the left side of Table 2. The horizontal dashed lines represent the mapped elevations on the right side of the Table 2.

[5] Mapping methods are described in Appendix C.

Figure 1: Reference Elevations and Mapped Elevations



The four flood elevations 7.5, 11.5, 13.5 and 18 feet were used to create maps for the assets and resources selected for evaluation: buildings, critical infrastructure, roads and saltmarsh (tidal wetlands). A total of 17 maps accompany this report, as follows:

- Eight Building maps show inundation of water at each of the 7.5-foot, 11.5-foot, 13.5-foot and 18-foot elevations described above. Four of these maps show the entire project area (B-1.1 through B-1.4) and four enlarged maps (B-2.1 through B-2.4) show the flood impact of just the downtown area. These maps show the level of inundation up to and around buildings in the City.
- One Freshwater Flooding map (FF-1.1) shows tidal inundation to the 18-foot elevation which shows low areas of potential flooding.
- Four Infrastructure and Critical Facilities Maps (I-1.1 through I-1.4) show infrastructure such as wastewater pump stations, waste water treatment plant, combined sewer overflows, culverts, storm drain outfalls, bridges, and roads.
- Four Wetlands/Environmental Resources maps show areas of wetlands and conservation land that will be impacted by coastal flooding at each of the four water level elevations.

Figure 2 and Figure 3 on the following pages present details of the four scenarios for the Northern Tier and South End/Pleasant Point areas, respectively. The colored areas on the maps represent the estimated depth of flood water or inundation at each flooding elevation, as follows:

- Amber represents areas with up to three feet of standing water at the given flood elevation;
- Orange represents a water depth of three to six feet;
- Pink represents a water depth of six to nine feet;
- Light blue represents a water depth of nine to twelve feet; and
- Dark blue represents areas with more than twelve feet of standing water (including areas that are currently open water).

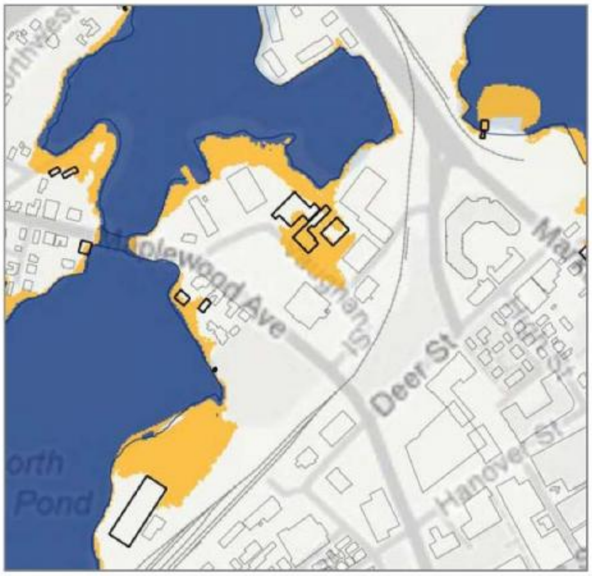
On the maps showing impacts to buildings, buildings with flooding impacts are shown in black. This mapping effort assumes buildings are impacted when any portion of the building is flooded. As this is a planning exercise the actual impacts to buildings would need to be confirmed with an on-site survey of potentially affected properties.

The maps in Figure 2 illustrate the estimated flooding impacts in the area of the downtown between North Mill Pond and Hanover Street,[6] and those in Figure 3 depict the estimated impacts in the South End and Pleasant Point areas.

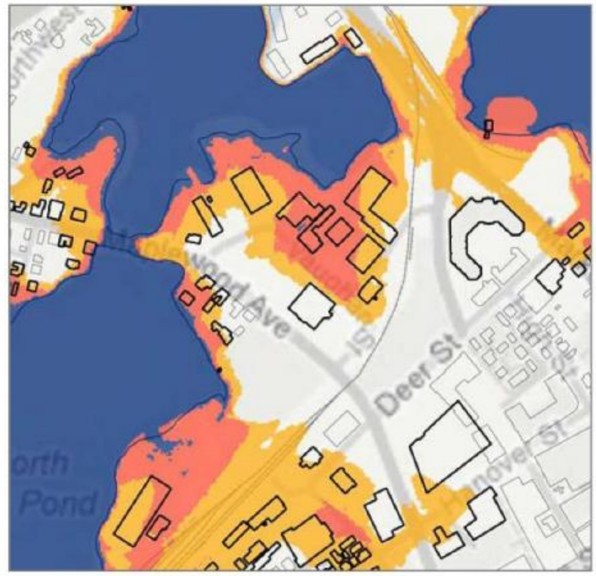
Figure 3 shows large areas of the South End, Prescott Park, Strawbery Bank, Peirce Island, and Pleasant point experiencing extensive impacts as sea level rises. However, it is important to note that this study did not use a dynamic model, so it is not able to capture the effect of the tidal restriction on the South and North Mill Ponds. In particular, the impact of the tide gate on the South Mill Pond has not been accounted for by this study and would need additional study to determine specific impacts to areas adjacent to the pond and nearby which may be protected or impacted differently due to existing tidal restrictions.

[6] Note that the maps were created using data which shows the former Parade Mall building between Deer and Hanover Streets. Although the specific configuration of buildings has changed with the development of the Portwalk project, the impacts to buildings in this area would be similar to the mapped scenarios.

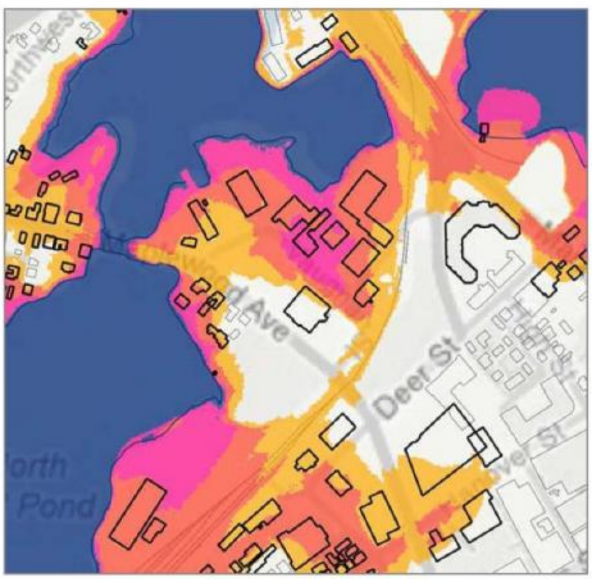
Figure 2: Sea Level Rise Scenarios – Northern Tier



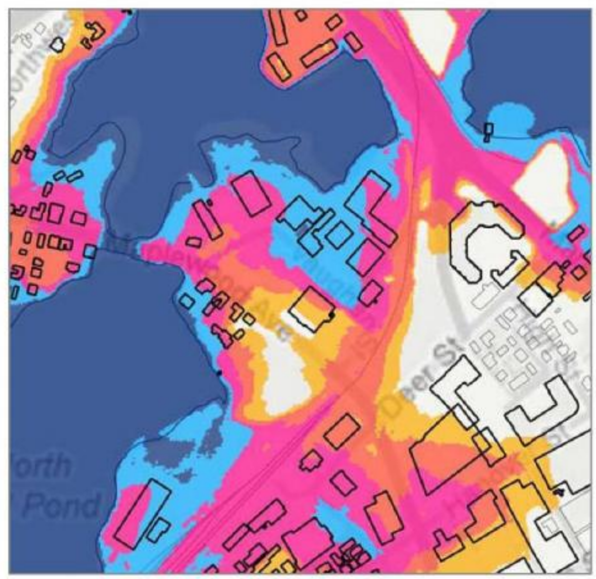
Stillwater Elevation 7.5 Feet NAVD



Stillwater Elevation 11.5 Feet NAVD



Stillwater Elevation 13.5 Feet NAVD



Stillwater Elevation 18.5 Feet NAVD

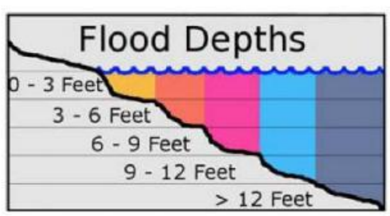
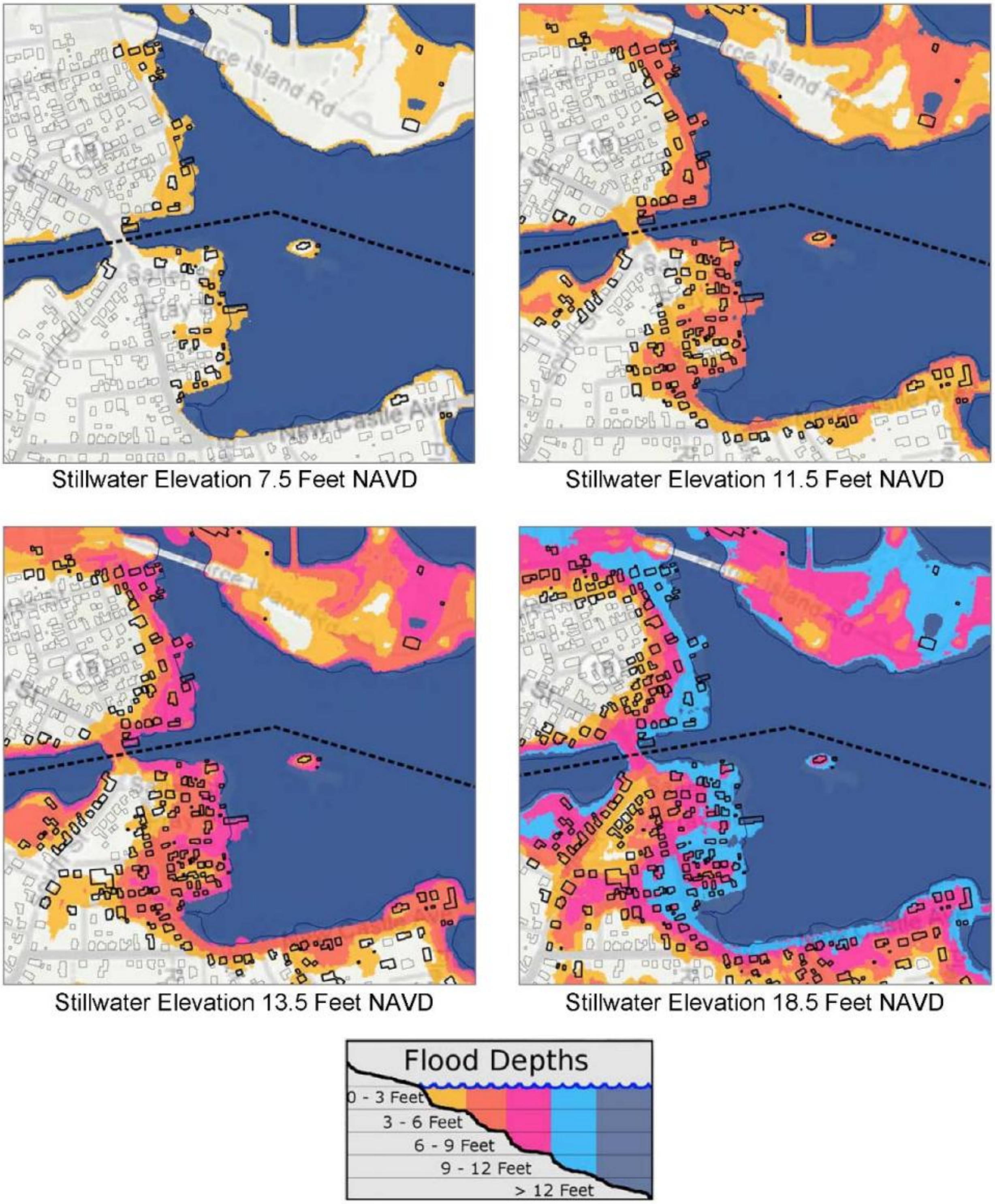


Figure 3: Sea Level Rise Scenarios – South End and Pleasant Point



Stillwater Elevation 7.5 Feet NAVD

Stillwater Elevation 11.5 Feet NAVD

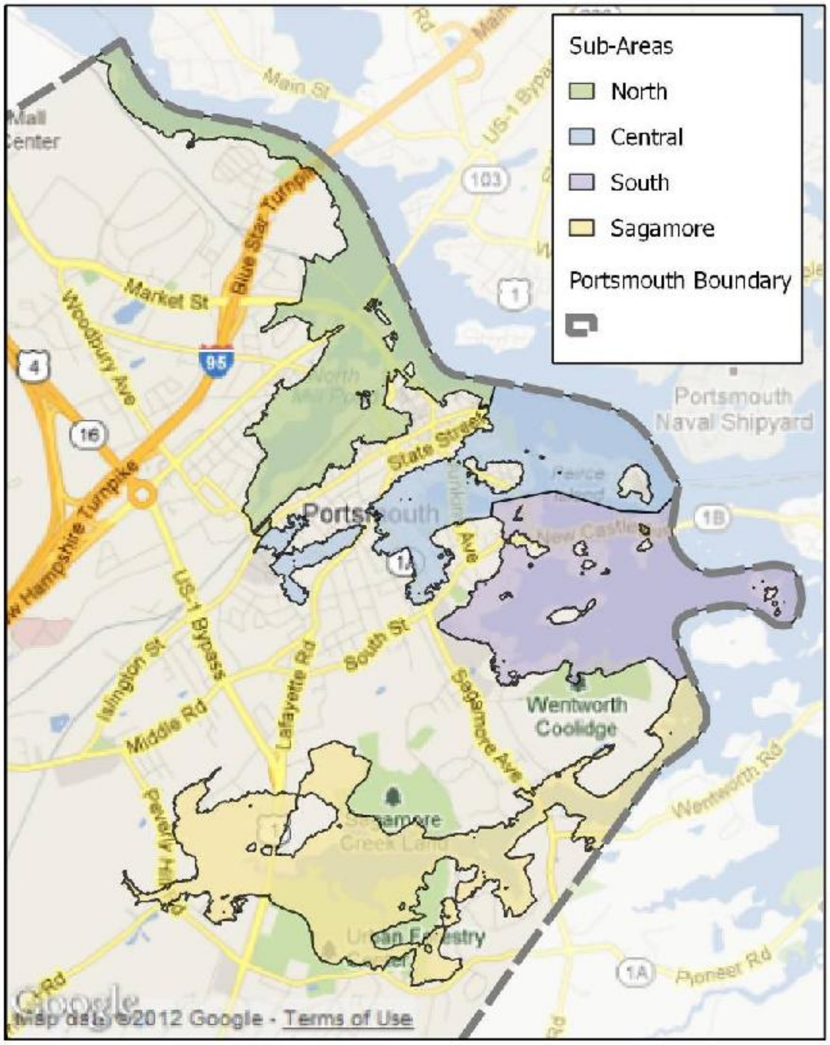
Stillwater Elevation 13.5 Feet NAVD

Stillwater Elevation 18.5 Feet NAVD

Analysis Subareas

To orient the reader and coordinate the various narrative descriptions in the vulnerability assessment, four Subareas were delineated within the primary areas of coastal flood impact identified in this study: North, Central, South and Sagamore Subareas (see Figure 4). These Subareas were delineated using the spatial extent of the 18-foot flood elevation.

Figure 4: Four Subareas Comprising the Area of Coastal Flood Impact



<u>North Subarea</u>
Areas north of Islington Street and State Street

<u>Central Subarea</u>
Bounded on the north by Islington and State Streets and south to South Street and encompassing South Mill Pond and Peirce Island

<u>South Subarea</u>
Areas north and south of New Castle Avenue; and Little Harbor west to South Street

<u>Sagamore Subarea</u>
Areas within the Sagamore Creek drainage area inland westward to Peverly Hill Road and south to Elwyn Road and east of the Town of Rye border

PART 3. BUILDINGS AND INFRASTRUCTURE: VULNERABILITY ASSESSMENT AND ADAPTATION STRATEGIES

A. Vulnerability Assessment

This section of the report presents an assessment of the vulnerability to climate change and flooding of buildings, critical infrastructure and facilities, public health and coastal wetlands. Table 3 lists the correspondences between the vulnerability indicators described in this section and the 17 maps prepared for this project.

Table 3: List of indicators and description of map presentation

Indicator	***Description of map presentation***
Buildings (8 maps)	Shown as building footprints; 4 full extent maps and 4 downtown maps
Infrastructure and Critical Facilities (4 maps)	Shown as symbols (wastewater pump station, waste water treatment plant, combined sewer overflows, culverts, storm drain outfalls, bridges, roads); shown by number at facility location and summarized in a table
Freshwater Flooding (1 map)	Shown as green and blue circles depicting areas subject to flooding today and the 18.0 foot flood depth (maximum scenario)
Wetlands and Environmental Resources (4 maps)	Labeled by NWI[7] wetland type and/or code and shown by green cross-hatching if impacted under the mapped scenario; eelgrass, Hodgson Brook Watershed, conservation land, wellhead protection areas

As discussed in Part 2, the maps display four elevations representing a range of coastal flooding scenarios: 7.5 feet, 11.5 feet, 13.5 feet and 18.0 feet above NAVD. Because detailed hydrologic analysis of upland freshwater flooding was not performed for this project, the 18-foot flood elevation was depicted on the Freshwater Flooding map to show the maximum extent of influence that coastal flooding (from sea level rise and coastal storm influences) would have on freshwater systems.

Vulnerability of Buildings

Current and Future Flooding at Mean High Higher Water

From observations by City staff from the Department of Public Works, it is known that the following areas can flood at high tide: areas adjacent to Route 1 at Sagamore Creek, playing fields and grounds behind Portsmouth High School, intersection of Peverly Hill Road and Banfield Road, uplands adjacent to South Mill Pond above Junkins Avenue (Leary Field and District Court), and uplands adjacent to North Mill Pond at Bartlett Street.

By 2100 under the lower sea level rise scenario, the daily tidal flooding at mean higher high water will be similar to Maps B-1.1 and B-2.1 (showing elevation 7.5 feet). Under the higher sea

[7] National Wetland Inventory wetland type is also know as the Cowardin Classification, used as a system for describing and classifying different wetland types

level rise scenario by 2100, daily tidal flooding at mean higher high water could resemble the present 100-year coastal flood or storm surge (Map B-1.2 and B-2.2 showing elevation 11.5 feet).

Flooding for the Lower Sea Level Rise Scenario

Maps B-1.2 and B-2.2 show the present flooding of the 100-year storm surge at approximately 11.5 feet (NAVD). The most extensive flooding of buildings is predicted in the Central and North Subareas. Because of higher terrain and less development, uplands in the South Subarea and Sagamore Subarea would be less impacted. By mid-century, under a lower sea level rise scenario, there would not be a significant change in extent of flooding due to the minor flood elevation change of less than one foot. By 2100, however, under the lower sea level rise scenario (Maps B-1.3 and B-2.3 showing elevation 13.5 feet), in all Subareas except Sagamore, the coastal floodplains are generally the same but deeper causing greater damage to infrastructure, buildings and other assets.

By 2100, under the lower sea level rise scenario (Maps B-1.3 and B-2.3 showing elevation 13.5 feet), the Sagamore Subarea coastal floodplain is larger and deeper, but still only a few additional buildings are flooded due to limited development there. Areas of flooding include non-residential development north and south of the Route 1 bridge over Sagamore Creek (for example, the Bratskellar and businesses on Mirona Road), the upper tidal limits across Greenleaf Avenue, several building west and east of Route 1A, and commercial buildings on Route 1B-Wentworth Road at the Rye border.

Flooding Under the Higher Sea Level Rise Scenario

Under the higher sea level rise scenario by 2050 (Maps B-1.3 and B-2.3 showing elevation 13.5 feet), there is increased flooding of buildings compared to the present 100-year storm surge particularly in the heavily developed North and Central Subareas. By 2100, under the higher sea level rise scenario (Maps B-1.4 and B-2.4 showing elevation 18.0 feet), the coastal floodplains are larger compared to projections for 2050. The greatest increase in impact occurs in the Central Subarea, where flooding extends to densely developed areas.

Assessment of Property Impacted by Flooding

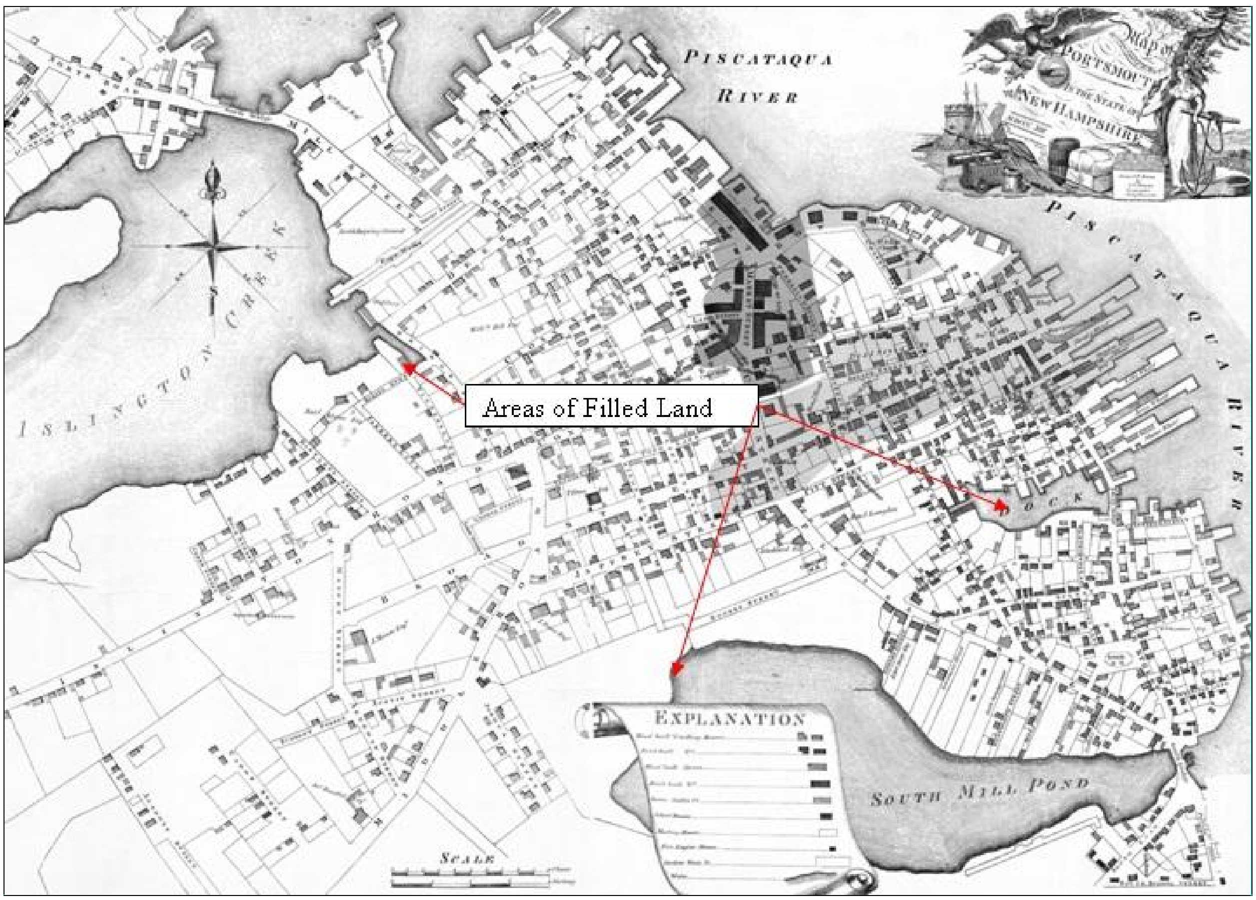
Table 4 presents estimates of the potential impact to buildings from future flooding based on monetary value of damages under each of the four mapped flood scenarios. The impact estimates were calculated using data from the City's GIS and Assessor's database. The numbers have been approximated by including the total value of all buildings associated with a lot in the Assessor's database, when at least a portion of one building on the lot is identified as flooded. As the flood elevation increases the number of buildings impacted increases.

Table 4: Summary of flood impacts based on assessed value per building.

Subarea	7.5 feet	11.5 feet	13.5 feet	18.0 feet
North	$22,667,533	$162,790,228	$180,273,596	$307,903,360
Central	$3,175,938	$61,599,338	$84,880,151	$178,798,579
South	$5,907,856	$26,393,580	$36,711,040	$58,196,538
Sagamore	$484,939	$5,134,649	$7,615,214	$54,830,986
Total	$32,236,266	$255,917,795	$309,480,001	$599,729,464

Table 4 indicates that the greatest change in the estimated monetary impact from one flood elevation level to the next is between the 7.5-foot and 11.5-foot levels. Comparing the flood elevation maps to historic maps of the City helps in understanding why this is so. Figure 5 is a map of the downtown area in 1813, indicating areas that were water then but have since been filled. These include the area on the south shore of North Mill Pond (then called "Islington Creek") which is now the site of the railroad tracks; the inlet at Puddle Dock (now Strawbery Banke); and the north and west shores of South Mill Pond. These areas correspond closely with the predicted flooding shown on Map B-1.2. These areas of previously filled land in the City tend to be low in elevation, and are thus likely to be the first to see significant impacts from increased tidal flooding.

Figure 5: 1813 Hale Map of Portsmouth



Vulnerability of Infrastructure and Critical Facilities

Where infrastructure is present the assumption is that it will be impacted; however, on the ground some infrastructure may be above floodwaters. These impacts can be verified with a more detailed field inventory.

Map I-1.2 shows the present infrastructure and critical facilities in the present 100-year floodplain. As expected, most of the flooded facilities are in the heavily developed North Mill Pond and Central Subareas. Most of these are pump stations and culverts but also Strawbery Banke the Library and Middle School in the Central Subarea.[8] The Schiller Station power plant may also be impacted if a storm surge travels that far upstream on the river. While not many local roads are flooded, some sections of key roadways over water bodies such as Market Street and Maplewood Avenue in the North Subarea, Pierce Island Road, Junkins Avenue, New Castle Avenue, and Marcy Street in the Central Subarea, and Routes 1 in the Sagamore Subarea.

Under the low SLR scenario, by 2050, there are no major changes in the floodplain. However, by 2100, under the low SLR scenario (Map I-1.3), the floodplains in the developed areas of North Mill Pond and Central Subarea are generally the same but deeper causing more damage.

By 2050 under the high SLR scenario, there would be relatively deep flooding of many pump stations and culverts in the North and Central subareas (Map I-1.3). The Schiller Station power plant shows more impact if a storm surge travels that far upstream. While not many local roads are flooded, some sections of key roadways over water bodies are such as: Market Street and Maplewood Avenue in the North Subarea; Peirce Island Road, Junkins Avenue, and Marcy Street in the Central Subarea; New Castle Avenue in the South Subarea; and Routes 1 in the Sagamore Subarea.

Under the high SLR scenario, by 2100 (Map I-1.4) there is considerably more flooding of infrastructure than in 2050. Added to the list are the Margeson Apartments in the Central Subarea. Under the high SLR scenario by 2100, additional local roads become flooded and the extent of the roads flooded under previous elevations is increased as well.

Table 5, Table 6 and Table 7 summarize the impacts to critical facilities and infrastructure as they become impacted by the increasing flood elevations.

[8] The analysis did not model the level of protection provided by the tide gate at the mouth of South Mill Pond. Therefore, flood impacts to buildings around the Pond, including the Library and Middle School will likely be lower than estimated based the mapping in this report.

Table 5: Critical facilities impacted under the four flood scenarios.

Impact by Flood Scenario				Map ID#	Critical Facility	Address
7.5 feet	11.5 feet	13.5 feet	18.0 feet			
n/i	n/i	n/i	X	1	WHEB Radio	815 Lafayette Road
n/i	n/i	X	X	2	Clough Drive Pump Station	210 Clough Road
n/i	X	X	X	3	Deer Street Pump Station	2 Deer Street
n/i	n/i	n/i	X	4	Margeson Apartments	245 Middle Street
n/i	n/i	X	X	5	Jackson Hill Sub-Station	Jackson Hill Street
n/i	n/i	X	X	6	Lafayette Road Pump Station	630 Lafayette Road
n/i	X	X	X	7	Leslie Drive Pump Station	590 Market Street
n/i	X	X	X	8	Marcy Street Pump Station	535 Marcy Street
n/i	X	X	X	9	Strawbery Banke Museum	14 Hancock Street
n/i	X	X	X	10	Mechanic Street Pump Station	113 Mechanic Street
n/i	X	X	X	11	Mill Pond Way Pump Station	131 Mill Pond Way
n/i	X	X	X	12	New Hampshire Port Authority	555 Market Street
n/i	n/i	n/i	X	13	PSNH Schiller Station Power Plant	Gosling Road
n/i	X	X	X	14	Northwest Street Pump Station	221 Northwest Street
n/i	X	X	X	15	Portsmouth Middle School	155 Parrott Avenue
n/i	X	X	X	16	Portsmouth Library	175 Parrott Avenue
n/i	X	X	X	17	Rail Yard	Brewster Street

n/i = No impact identified. X = Land and/or structures impacted

Table 6: Bridges impacted under the four flood scenarios.

Impact by Flood Scenario				Bridges
7.5 feet	11.5 feet	13.5 feet	18.0 feet	
n/i	n/i	n/i	n/i	I-95 at Piscataqua River
n/i	n/i	n/i	X	Market Street Extension at North Mill Pond
n/i	n/i	n/i	n/i	Sarah Mildred Long Bridge at Piscataqua River
n/i	n/i	n/i	n/i	Memorial Bridge at Piscataqua River (approaches of former structure only)
n/i	n/i	X	X	Maplewood Avenue bridge at North Mill Pond
n/i	n/i	n/i	n/i	Peirce Island Bridge
n/i	n/i	X	X	Marcy Street Bridge at South Mill Pond
n/i	X	X	X	Junkins Avenue bridge (culverts) over South Mill Pond
n/i	n/i	n/i	X	New Castle Avenue Bridge to Shapleigh Island
n/i	n/i	X	X	Belle Isle Road Bridge at Little Harbor (approaches only)
n/i	n/i	n/i	n/i	Route 1A at Sagamore Creek (approaches only)
n/i	X	X	X	Route 1/Lafayette Road at Sagamore Creek

n/i = No impact identified. X = Land and/or structures impacted

Table 7: Culverts and combined sewer overflows (CSOs) impacted under the four flood scenarios.

Impact by Flood Scenario				Drainage Infrastructure	Address
7.5 feet	11.5 feet	13.5 feet	18.0 feet		
X	X	X	X	CSO (1)	Upper North Mill Pond
X	X	X	X	CSO (2)	South Mill Pond
X	X	X	X	CSO (1)	Near Peirce Island
n/i	n/i	n/i	X	Culvert	Off Alumni Circle/Summit Avenue
n/i	X	X	X	Culvert	Upper Little Harbor
X	X	X	X	Culvert	Northwest of Route 1 over Sagamore Creek
n/i	X	X	X	Culvert	Peverly Hill Road
n/i	X	X	X	Culvert	Wentworth Road

n/i = No impact identified. X = Land and/or structures impacted

Note: Storm outfalls are not listed in this table due to the large number affected. Refer to the Infrastructure map set for locations.

Flood Impacts to Roads, Trails/Paths, Recreational Areas and Municipal Properties

Table 8 presents a summary of flood impacts to roads based on the Infrastructure and Critical Facilities map set for the four flood elevations.

Table 8: Flood impacts to roads, trails/paths, recreation areas and municipal properties for the four selected flood elevations

Water Elevation (NAVD)	Description of Impact
7.5 feet	▪ Impact to large portion of Leary Field, South Street Cemetery, Sagamore Creek Land, and Urban Forestry Center
11.5 feet	▪ Fringe neighborhoods of North Mill Pond below Dennett Street McDonough Street, Vaughan Street, State Pier ▪ Flooding on Market Street at both sides of Mill Pond crossing ▪ Impact to Prescott Park, Marcy Street and Strawbery Banke ▪ Impact to Marcy Street crossing at South Mill Pond, New Castle Avenue, and fringe areas on Pleasant Pond Drive ▪ Flooding on Richards Avenue, Rockland Street, Lincoln Avenue and Junkins Avenue, and fringe areas ▪ Flooding of neighborhood at end of Brackett Road ▪ Flooding of fringe areas along Little Harbor and Sagamore Creek ▪ Increase flooding at Peirce Island
13.5 feet	▪ Flooding at Islington and Bartlett Streets ▪ Increased flooding at Bracket Road and Clough Drive ▪ Flooding at Richard's Avenue and vicinity extends to Miller Avenue ▪ Flooding across Route 1B Wentworth Avenue ▪ Increased inland flooding throughout Little Harbor and Sagamore Creek drainage ▪ Flooding along Maplewood Avenue and Hanover Street vicinity ▪ Increased flooding at District Court, Strawbery Banke and Urban Forestry Center
18.0 feet	▪ Flooding on Route 1 in Central and Sagamore Creek Subareas ▪ Flooding in Central District extends from upper North Mill Pond across Bartlett Street into areas between Islington Street and Route 1 ▪ Increased flooding of Rockland Street and Millers Avenue area ▪ Substantial flooding on Route 1B and surrounding neighborhoods (peninsula) ▪ Interior flooding between Elwyn Road-Gosport Road and Walker Bungalow Road-Martine Cottage Road in Sagamore Creek Subarea

B. Adaptation Strategies

There are three broad categories of strategies for adapting to climate change and sea level rise: *protection*, *accommodation* and *retreat*:

- *Protection* measures typically focus on hard-engineered solutions to prevent impacts for flooding, storm surge and erosion. Protection may include preservation strategies such as restoration and/or maintenance of natural shorelines and dune systems.

- *Accommodation* measures manage risk by requiring development to be built and retrofitted to be more resilient to impacts and by limiting development in highest risk areas, favoring adaptive uses (i.e., passive uses such as recreation), and gradual modification of structures and uses as conditions change over time.

- *Retreat* involves planning for the eventual relocation of structures to upland areas as properties become threatened or directly impacted by rising sea level, erosion and coastal storms. Such measures may include rolling setbacks and buffers, transfer of development rights, and property acquisition/buyout programs. Retreat is often the last action before abandonment.

The choice of strategy for any facility or resource will depend on its location with respect to the potential threat and the time period for taking action:

- *Protection* strategies are recommended under current conditions through 2100 conditions as coastal flooding moves further inland and freshwater flooding increases, resulting in impacts to more properties and at greater levels over time.
- *Accommodation* will be recommended under 2050 and beyond conditions depending upon risk and vulnerability.
- *Retreat* is a “last resort” action, typically at 2100 conditions or earlier depending upon risk and vulnerability.

Adaptation Strategies and Estimated Costs by Location

Table 9 presents a possible set of time-sequenced actions that the City of Portsmouth could implement to address or mitigate the impacts of sea level rise and coastal storms that will increase over the next century.

The adaptation actions and costs presented in Table 9 are intended simply as a starting point, as a way to begin consideration of the potential responses available to the community. These actions are neither proposed nor recommended by the City of Portsmouth, but are provided more as a proxy for determining what activities may be necessary to consider and what range of possibilities the City might investigate. As the City moves forward in refining its adaptation approach, a greater level of effort will be needed to explore options and understand the feasibility of various strategies.

The Cost Estimates in Table 9 were determined based on the following estimates of unit costs:

1. Coastal floodproofing capital costs
   - Residential properties and parks: $40 per lineal foot per foot of height of the berm or floodwall.
   - Business properties: $90 per lineal foot per foot of height.
   - O&M for these structures estimated at 1% of capital cost.

2. Building costs are unique to each site. For estimation purposes, moving or raising buildings estimated at $3 per square foot of building per foot of raising.

3. Raising road costs set at $30 per lineal foot per foot of height.

4. Raising railroad costs set at $20 per lineal foot per foot of height.

Table 9: Adaptation actions and costs to protect assets under various flood scenarios.
[Note: "Operating Cost" = increase in annual operating cost over what is paid now.]

NORTH SUBAREA			
1 BUSINESS AT NORTHERN END BY RAILROAD TRACKS			
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan for floodwall and floodproofing the property ▪ Plan on infilling some of property for future building relocation	$3,000	$0
11.5 feet	▪ Consider moving east buildings to filled land in center of property ▪ Floodwall	$380,000 (floodwall)	$4,000
13.5 feet	▪ Elevate infrastructure ▪ Abandon ▪ Floodwall ▪ Relocate on same properties to filled ground	$660,000 (floodwall)	$7,000
18.0 feet	▪ Elevate infrastructure ▪ Abandon ▪ Floodwall ▪ Relocate on same properties to filled ground	$1,000,000 (floodwall)	$10,000
Note: If floodwall is constructed, moving/raising buildings may be unnecessary but basement would need attention.			

2	PORT OF NEW HAMPSHIRE		
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan on filling areas for future relocation of buildings.	$3,000	$0
11.5 feet	▪ Consider moving east building to filled land in center of property	$100,000	$1,000
13.5 feet	▪ Abandon eastern building ▪ Retreat facilities to filled higher ground	$250,000 (floodwall) plus $300,000 (building)	$3,000
18.0 feet	▪ Abandon eastern building ▪ Retreat facilities to filled higher ground	$600,000 (floodwall) plus $630,000 (2 buildings)	$6,000
Note: Floodwall may be more expensive than fill and moving buildings.			

3	RAILROAD EAST OF NORTH MILL POND		
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan on elevating	$40,000	$0
11.5 feet	▪ Elevate	$250,000	$0
13.5 feet	▪ Elevate	$730,000	$0
18.0 feet	▪ Elevate	$3,000	$0
Note: Unnecessary if North Mill Pond has a tide barrier and subsurface drainage does not back up.			

4 NORTH MILL POND			
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Some buildings require floodproofing now ▪ Plan for future tide gate/tide barrier (easements, rights of way, etc.) ▪ Thorough assessment of all subsurface infrastructure, especially drains and where they daylight	$150,000 (floodwall) plus $150,000 (tide barrier planning) plus $20,000 (assessment)	$2,000
11.5 feet	▪ Need a tide gate/tide barrier at US 1 Bypass plan for 18 feet elevation eventually ▪ Ensure stormwater drains have flap gates plan for 18 feet elevation eventually ▪ Small watersheds, may need to investigate the need for pumping water to estuary ▪ Consider filling ground or elevating buildings at lower ground, or their abandonment	$12,000,000 (just tide barrier)	$120,000
13.5 feet	▪ Expand a tide gate/tide barrier at US 1 Bypass ▪ Ensure stormwater drains have flap gates ▪ Small watersheds, but may need to investigate the need for pumping water to estuary ▪ Abandon structures at lower elevations	$16,000,000	$160,000
18.0 feet	▪ Expand a tide gate/tide barrier at US 1 Bypass ▪ Ensure stormwater drains have flap gates ▪ Small watersheds, may need to investigate the need for pumping water to estuary	$25,000,000	$250,000
Note: Building floodproofing may be unnecessary if North Mill Pond tide barrier is constructed; however, any basements will require attention such as sump pumps and drainage improvements.			

5	MARKET STREET ON BOTH SIDES OF NORTH MILL POND		
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan on elevating road – eventually to 18 feet and beyond	$60,000 (planning)	$0
11.5 feet	▪ Elevate road	$350,000	$0
13.5 feet	▪ Elevate road	$800,000	$0
18.0 feet	▪ Elevate road	$1,800,000	$0
Note: Unnecessary if North Mill Pond has a tide barrier and subsurface drainage does not back up.			

6	MAPLEWOOD AVENUE BETWEEN DEER STREET AND CONGRESS STREET		
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan on elevating road	$20,000	$0
11.5 feet	▪ Elevate road	$40,000	$0
13.5 feet	▪ Elevate road	$90,000	$0
18.0 feet	▪ Elevate road	$820,000	$0

CENTRAL SUBAREA			
7 CERES STREET AND BUILDINGS			
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan on flood protection of some buildings on east side or ultimate abandonment	$20,000 (raise buildings) Plus $20,000 (road planning)	$0
11.5 feet	▪ Implement flood protection for all structures on east side or abandon ▪ Elevate road	$100,000	$0
13.5 feet	▪ Implement flood protection for all structures or abandon ▪ Plan on flood protection on west side of street ▪ Elevate road	$360,000	$0
18.0 feet	▪ Implement flood protection for all structures along the road or abandon ▪ Elevate road	$1,200,000	$0
Note: If access to Ceres Street is not critical, no real need to raise it.			

8 PRESCOTT PARK AND STRAWBERY BANKE			
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan for fill at higher ground for ultimate building relocation or tide barrier ▪ Raise one building	$3,000 (planning) plus $100,000 building OR $3,000,000 (tide barrier)	$30,000 (tide barrier)
11.5 feet	▪ Tide gate (costly) tied in to a Floodwall (will block view unless adaptable) ▪ Relocate structures to filled land onsite (gardens)	$1,700,000 (raising buildings) OR $5,600,000 (tide barrier and floodwall)	$56,000
13.5 feet	▪ Tide gate (costly) tied in to a Floodwall (will block view unless adaptable) ▪ Relocate structures to filled land onsite (gardens)	$2,200,000 (raising buildings) OR $6,900,000 (tide barrier and floodwall)	$69,000
18.0 feet	▪ Tide gate (costly) tied in to a Floodwall (will block view unless adaptable) ▪ Relocate structures to filled land onsite (gardens)	$2,400,000 (raising buildings) OR $11,200,000 (tide barrier and floodwall)	$112,000

9 PEIRCE ISLAND			
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Some road locations need to be elevated ▪ Plan for elevating road or water access ▪ Plan for filling portions for future relocation of buildings and recreational activities	$15,000 (planning) plus $17,000 (road)	$0
11.5 feet	▪ Elevate access road or plan for water access facilities ▪ Relocate swimming pool	$250,000 (road) plus $2,600,000 (recreation)	$0
13.5 feet	▪ Elevate access road or plan for water access facilities ▪ Abandon facilities or fill western island for building relocation	$540,000 (road) plus $4,000,000 (recreation)	$0
18.0 feet	▪ Elevate access road or plan for water access facilities ▪ Abandon facilities or fill western island for building relocation	$1,000,000 (road) plus $8,000,000 (recreation)	$0
Note: Four Tree Island may need to be abandoned because at 11.5 feet, most of island and causeway is under 3 feet of water.			

10 SOUTH MILL POND			
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan for future tide gate/tide barrier (easements, rights of way, etc.) ▪ Some buildings need floodproofing ▪ Understand subsurface drainage infrastructure that can short-circuit future floodproofing strategies, especially along Pleasant Street ▪ Elevate Junkins Ave.	$36,000 (buildings) plus $200,000 other planning and assessment) plus $22,000 raise Junkins Ave. plus $250,000 (tide barrier planning)	$0
11.5 feet	▪ Tide gate/tide barrier at mouth ▪ Pumping for fresh and storm water ▪ Ensure all coastal drainage infrastructure has tide gat/valve ▪ Elevate Jenkins Avenue	$330,000 (elevate Junkins) plus $100,000 (drainage backflow) $6,000,000 (raise buildings) plus $700,000 (pumping station) and $6,000,000 (tide barrier)	$70,000 (pumping and tide barrier)
13.5 feet	▪ Tide gate/tide barrier at mouth ▪ Pumping for fresh and storm water ▪ Pleasant Street could have existing stormwater drainage that allows flooding into a protected South Mill Pond. Therefore, inspect for such short circuits and remedy. ▪ Elevate Pleasant Street ▪ Investigate any subsurface (drainage) connections to Strawbery Banke	$430,000 (elevate Junkins) plus $100,000 (drainage backflow) plus $11,800,000 (raise buildings) plus $1,200,000 (pumping station) and $8,000,000 (tide barrier)	$100,000 (pumping and tide barrier)

18.0 feet	▪ Tide gate/tide barrier at mouth ▪ Pumping for fresh and storm water ▪ Pleasant Street could have existing stormwater drainage that allows flooding into a protected South Mill Pond. Therefore, inspect for such short circuits and remedy. ▪ Elevate Pleasant Street ▪ Investigate any subsurface (drainage) connections to Strawbery Banke	$600,000 (elevate Junkins) plus $150,000 (drainage backflow) plus $17,000,000 (raise buildings) plus $2,000,000 (pumping station) and $12,000,000 (tide barrier)	$140,000 (pumping and tide barrier)
Note: Floodproofing buildings and raising roads are less expensive short term measure.			
11 RICHARDS AVENUE			
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan on elevating road	$25,000 (planning)	$0
11.5 feet	▪ Elevate road	$270,000	$0
13.5 feet	▪ Elevate road	$700,000	$0
18.0 feet	▪ Elevate road	$1,400,000	$0
(Note: adaptation actions unnecessary if tide barrier in place for South Mill Pond)			
SOUTH SUBAREA			
12 ROUTE 1B			
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan on elevating road	$800,000 (planning)	$0
11.5 feet	▪ Raise above flood elevation	$12,000,000	$0
13.5 feet	▪ Raise above flood elevation	$15,000,000	$0
18.0 feet	▪ Raise above flood elevation	$20,000,000	$0
Note: Costs higher than just road elevation since bridge to Newcastle will require significant modification.			

13 COASTAL PROPERTIES EAST OF PLEASANT AND MARCY STREETS			
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Some buildings need floodproofing now ▪ East of Marcy Street, properties need to plan on floodproofing	$800,000 (buildings) plus $90,000 (planning)	$0
11.5 feet	▪ May have to abandon ▪ Floodwall (costly plus will block view) ▪ Elevate infrastructure ▪ Plan on floodproofing for properties west of Marcy Street	$3,000,000 (floodproofing)	$0
13.5 feet	▪ May have to abandon ▪ Floodwall (costly plus will block view) ▪ Elevate infrastructure ▪ Properties west of Marcy Street require floodproofing or abandonment	$5,800,000 (floodproofing)	$0
18.0 feet	▪ Extends to South Street and almost all properties east of Baycliff Road on Route 1B ▪ May have to abandon ▪ Floodwall (costly plus will block view) ▪ Elevate infrastructure ▪ Properties west of Marcy Street require floodproofing or abandonment	$10,000,000 (floodproofing)	$0

14 LITTLE HARBOUR SCHOOL			
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan for moving Clough Drive or infilling Clough field for future building relocation	$10,000	$0
11.5 feet	▪ Major site redevelopment planning ▪ Floodproof Little Harbour School ▪ If there is need to expand, consider higher elevation or move new facilities to Clough Field and Clough Field land use to site of present-day school.	$60,000 (planning) plus $45,000 (floodproofing)	$500
13.5 feet	▪ Move Clough Drive north to expand to higher elevation or move new facilities to Clough field and Clough field land use to site of existing school.	$80,000 (floodproofing)	$800
18.0 feet	▪ Flooding extends to properties on Brackett Road	$20,000,000 (move school to higher ground)	$0

15 SOUTH OF SOUTH STREET AT THE COAST			
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan on floodproofing properties	$10,000	$0
11.5 feet	▪ Implement floodproofing properties	$45,000	$0
13.5 feet	▪ Floodwall at coast ▪ Abandon	$720,000	$0
18.0 feet	▪ Floodwall at coast ▪ Abandon	$1,800,000	$0
Note: Floodwall expensive and will impede views.			

16 CURRIERS COVE			
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan for floodproofing properties	$10,000	$0
11.5 feet	▪ Implement floodproofing properties	$30,000 (buildings)	$0
13.5 feet	▪ Implement floodproofing properties	$150,000 (buildings)	$0
18.0 feet	▪ Implement floodproofing properties	$300,000 (buildings)	$0
Note: Floodwall expensive and will impede views.			
17 BELLE ISLE			
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan on floodproofing strategy for buildings on east end	$10,000	$0
11.5 feet	▪ Floodproofing strategy for buildings on east end – raise	$120,000 (floodproofing)	$0
13.5 feet	▪ Elevate buildings ▪ Abandon	$200,000 (floodproofing)	$0
18.0 feet	▪ Elevate buildings ▪ Abandon	$420,000 (floodproofing)	$0

SAGAMORE SUBAREA			
18 SAGAMORE CREEK			
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan for future tide gate/tide barrier (easements, rights of way, etc.)	$1,200,000	$0
11.5 feet	▪ Tide gate/tide barrier at Route 1 ▪ Pumping station for fresh water	$8,000,000 (tide barrier) plus $1,000,000 (pumping station)	$90,000
13.5 feet	▪ Tide gate/tide barrier at Harborview ▪ Pumping station for fresh water	$11,000,000 (tide barrier) plus $2,000,000 (pumping station)	$130,000
18.0 feet	▪ Tide gate/tide barrier at Harborview ▪ Pumping station for fresh water	$18,000,000 (tide barrier) plus $4,000,000 (pumping station)	$220,000
19 LAFAYETTE ROAD AT SAGAMORE CREEK (BRIDGE DESIGN)			
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan on elevating or consider alternative routes	$250,000 (bridge and road)	$0
11.5 feet	▪ Elevate road	$7,000,000 (bridge and road)	$0
13.5 feet	▪ Elevate road	$10,000,000 (bridge and road)	$0
18.0 feet	▪ Elevate road	$14,000,000 (bridge and road)	$0
Note: Unnecessary if a tide barrier is constructed on Sagamore Creek.			

20	PEVERLY HILL ROAD AT SAGAMORE CREEK (CULVERT DESIGN)		
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan on elevating or consider alternative routes	$0	$0
11.5 feet	▪ Plan on elevating or consider alternative routes	$50,000	$0
13.5 feet	▪ Elevate road	$300,000 (culvert and road)	$0
18.0 feet	▪ Elevate road	$5000,000 (culvert and road)	$0

21	GREENLEAF AVENUE AT SAGAMORE CREEK (CULVERT DESIGN)		
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Plan on elevating	$20,000 (planning)	$0
11.5 feet	▪ Plan on elevating	$25,000 (planning)	$0
13.5 feet	▪ Elevate road	$43,000 (planning)	$0
18.0 feet	▪ Elevate road	$84,000 (planning)	$0

22 BUILDINGS ALONG ROUTE 1B EAST OF ROUTE 1A			
Scenario	**Adaptation Actions**	**Capital Cost**	**Operating Cost**
7.5 feet	▪ Abandon ▪ Floodwall (costly) ▪ Elevate infrastructure	$36,000 (floodproofing)	$400
11.5 feet	▪ Abandon ▪ Floodwall (costly) ▪ Elevate infrastructure	$150,000 (floodproofing)	$1,500
13.5 feet	▪ Abandon ▪ Floodwall (costly) ▪ Elevate infrastructure	$240,000 (floodproofing)	$2,400
18.0 feet	▪ Abandon ▪ Floodwall (costly) ▪ Elevate infrastructure	$324,000 (floodproofing)	$4,000
Note for #20-22: Unnecessary if Sagamore Creek floodwall is east of these properties			

Total Estimated Adaptation Costs and Approximate Timing

Table 10 summarizes the total capital costs and operating costs for the adaptations actions corresponding with the four mapped flood elevations of 7.5 feet, 11.5 feet, 13.5 feet and 18.0 feet as recommended in Table 9.

Table 10: Summary of adaptation actions and costs reported in Table 9.

Scenario	Total Capital Costs – Low	Total Capital Costs – High	Total Operating Costs (low)	Total Operating Costs (range)
7.5 feet	$4,370,000	$7,287,000	$0	$2,000 ($30,00 Prescott Park tide barrier)
11.5 feet	$62,670,000	$66,595,000	$0	$4,000-$70,000 ($120,000 North Mill Pond)
13.5 feet	$93,650,000	$98,393,000	$0	$7,000-$100,000 ($160,000 North Mill Pond)
18.0 feet	$169,447,000	$178,247,000	$0	$10,000-$140,000 ($250,000 North Mill Pond)

Note: “Operating Cost” = increase in annual operating cost over what is paid now.

Table 11 identifies the approximate time periods when action should be taken based upon the change in the elevation of the 100-year flood. Eventually, near the end of the century, some locations will have challenges with high tidal flooding every day.

Table 11: Flood elevation scenarios and time of tidal flooding and 100-year flood.

Scenarios	Time to Tidal Flooding	Time to 100-year Flood
7.5 feet	2070 to 2100	In Present 100-year floodplain
11.5 feet	Beyond 2100	Present to 2050
13.5 feet	Beyond 2100	2050 to 2100
18.0 feet	Beyond 2100	2100

Adaptation Costs in Relation to Potential Flood Impacts

The adaptation actions outlined in Table 9 and summarized in Table 10 are approximate and help to begin the process of planning for the potential impacts from sea level rise. To put the estimated costs of adaptation into perspective, it is illustrative to compare these costs to the estimated monetary impacts of flooding as presented in Table 4 (see page 11). While both sets of cost figures are rough estimates, a comparison citywide at each mapped elevation shows that the cost of just the impacts to buildings (that is, not including any infrastructure or road costs) would be substantially more than the cost of putting in place the corresponding adaptation actions. In fact the report shows that the potential flooding impact to buildings alone would be 3 to 4 times as great as the cost of putting in place adaptation actions.

As a next step in planning for climate change it will be helpful to refine the set of adaptation actions, making them more realistic and have a strong basis of community support. Then, a feasibility study and realistic cost accounting can be done to determine the benefit of implementing specific adaptation strategies.

PART 4. WETLANDS AND FRESHWATER FLOODING

A. Freshwater Drainage Flooding

Shown in Map F-1.1 are the areas identified by the City of Portsmouth that flood during rain storms, highest tides and coastal storms. The areas subject to freshwater flooding in the study area are mainly in the North, South and Sagamore Creek Subareas.

The green and blue circles are areas with direct coastal connection thus their vulnerability is compounded. These areas flood above elevations 11.5 feet NAVD and 7.5 feet NAVD respectively, which means that they can be impacted by the full range of flood scenarios mapped for this study (MHHW and MHHW Flood at present day, 2050 and 2100).

The black circled areas on Map F-1.1 are subject primarily to freshwater flooding. Although not connected directly to tidal waters or the Piscataqua River, some of these areas may have drainage networks that are; thus, they may become flooded with tidal and/or river water under sea level rise conditions even without precipitation. Given the increases in precipitation intensity existing freshwater drainage flooding will likely increase in the future. It is important to note that, due to their low topography and isolated location, the black circled areas serve as important freshwater flood storage areas.

B. Coastal Wetlands Impacts

1. Portsmouth's Current Wetlands and Their Distribution

The coastal wetlands of Portsmouth are comprised of both tidal and non-tidal wetlands. The non-tidal wetlands include freshwater wetlands of forested swamp, shrub scrub swamp, and emergent marsh. Some emergent marshes are dominated by invasive species like common reed and purple loosestrife. Tidal wetlands include subtidal eelgrass meadows and intertidal emergent marshes. Intertidal salt marshes are composed of low marsh (dominated by smooth cordgrass), and high marsh (dominated by a mixture of salt hay, spike grass and black grass). Along most shorelines the salt marshes grade into uplands, but where they border freshwater tributaries to the estuary, these marshes grade into brackish and fresh marshes.

As shown in Figure 1 Sub-Area Map, the shoreline of Portsmouth extends from the Schiller Power Station on the main stem of the Piscataqua River at the Newington border south to, and including, Sagamore Creek. Interpretation of impacts to wetlands from climate change associated with sea level rise and flooding from the 100-year storm surge is presented by Sub-Area, with a focus on the South and Sagamore Creek Sub-areas. Descriptions of specific marsh locations, conditions and projected impacts are referenced from the Wetlands and Environmental Resources map set, WE-1.1, WE-1.2, WE-1.3 and WE-1.4.

Several small subtidal eelgrass meadows are located just north of the Port of New Hampshire, near the inlet to North Mill Pond. Traveling south, no eelgrass is found until the northern shore of Peirce Island. More substantial eelgrass meadows extend around the northwest corner of Shapleigh Island and the southern end of Shapleigh Island. The only other eelgrass meadows in

Portsmouth are several small beds found in Sagamore Creek, just south of the inlet to Little Harbor.

Rising sea level will impact seagrass meadows through light reduction as waters get deeper. Beds may also be impacted from greater tidal currents, as more water will be forced through existing waterways. Eelgrass may be able to expand at higher elevations around the islands of Little Harbor as adjacent mudflats submerge. However, eelgrass beds are somewhat ephemeral and their health and survival is largely dependent upon water quality, with predictions beyond this project's scope.

Responses of tidal salt marshes were examined for the Sagamore Creek and Little Harbor Sub-areas. Under low rates of sea level rise by mid-century, most of our current low marsh may survive if it can accrete (build in elevation) at rates of 0.2 inches per year, or about half that of the sea level rise (0.34 inches per year). At higher rates of sea level rise (0.86 inches per year) and by the end of the century under either scenario, most, if not all of the low marsh will have submerged and converted to mudflat or subtidal bay. The current high marsh will convert to low marsh even under conditions of slow SLR, and high marsh will migrate upslope several feet (3.1 feet in elevation), where possible (along shorelines without barriers).

Losses in ecosystem services from submerged tidal wetlands can be mitigated by allowing the high marsh to migrate into adjacent uplands and non-tidal wetlands. Barriers will need to be removed and provision for tidal waters and suspended sediments to nourish the marshes will be needed, specifically for large culverts and bridges where transportation paths cross wetlands. Losses of tidal wetlands in highly developed areas are unlikely to be replaced by migration, so extra planning efforts and negotiations need to be made on less developed and protected lands to ensure these critical habitats can be maintained.

The major impacts to freshwater and non-tidal wetlands will include expansion of wetlands into adjacent uplands due to rising sea level and ground water tables, as well as salinity intrusion associated with storms. For freshwater wetlands that occur within 10 feet elevation of the current MHHW mark (see yellow and pink bands on Map WE-1.4), rising sea levels will raise groundwater levels by similar amounts. Storm surges that punctuate rapid sea level rise rates will convert large portions of non-tidal freshwater wetlands (marsh, shrub scrub and forested) into tidal brackish and salt marshes due to salinity intrusion.

Please see appendix A for a more indepth discussion of impacts to Coastal Wetlands

PART 5. PUBLIC HEALTH IMPACTS

The basis for this report is resilience to climate change in Portsmouth, NH. However this report gives much more in-depth treatment to the impacts from predicted sea level rise and coastal storm surge based on work that has been done at the regional level and based on mapping which was conducted specific to this study. As a result the brief section below is just a starting point for discussions of public health impact related to climate change.

The Centers for Disease Control and Prevention (CDC) and the National Environmental Health Association (NEHA) identify several health impacts of climate change and offer recommendations for action.

Heat Impacts

Heat stress has a range of health impacts and exacerbates several chronic conditions such as respiratory and cardiovascular disease.

Vector Borne Disease

There are a number of diseases that will be able to prevail in new environments when the natural barriers of inhospitable environments to the vectors of such diseases are diminished in a warming climate. Strong storms displace animals and insects and change migration routes as their ecosystems change. Disease will migrate with them.

Extreme Weather Events

Tornados, floods, hurricanes, and blizzards have numerous immediate to long-term physical and emotional health impacts. Immediate impacts include injury, drowning and death from structural collapses. More long-term impacts such as infectious and chronic disease, displacement, and socioeconomic disruption often follow extreme weather events.

Air Quality

Increased ground-level pollutants and extended growing seasons could result in heightened levels of allergies and respiratory disease.

Waterborne Diseases

Pathogens and pollutants from runoff and flooding will enter water supplies, increased temperatures will support pathogen growth, and concentration of these agents under drought conditions will increase the threat of waterborne disease, including communicable disease as well as neurological disorders and cancers. Urbanization of coastal regions may lead to additional chemical, pathogen and nutrient runoff and changes in pH.

Food

Pressure on agricultural productivity, crop failure, and agricultural diseases of crops may lead to malnutrition and starvation which contribute to social instability and human susceptibility to disease and birth defects. Increased pathogens and pesticides in soil could impact the food supply.

PART 6. POLICY, PLANNING AND REGULATORY RECOMMENDATIONS

A. Zoning Ordinances and Land Development Regulations

The following recommendations for managing and regulating land use and development in the coastal zone can be adopted separately or in combination as amendments to the zoning ordinance, site plan development regulations, subdivision regulations and building codes.

1. Zoning Districts and Overlays

Recommendation ZLU-1: Evaluate the benefits and costs of adopting an Extended Flood Hazard Overlay District utilizing the flood elevation scenarios identified in the CRI Report. An extended Flood Hazard Overlay District would regulate these vulnerable areas by imposing special regulations aimed at:

- Incorporating phased adaptation actions for new development, redevelopment, and expansion of existing development;
- Protecting municipal infrastructure and private investments;
- Implementing sustainable and resilient development practices and infrastructure; and
- Protecting critical environmental resources.

The regulatory standards for this District would seek to reduce the amount of damage and threats to health and safety caused by highest tide events and moderate to major storm events, while sustaining beneficial functions of coastal and estuarine systems (storm and flood damage reduction, wildlife and habitat, fishery and shellfish industry, recreation, tourism and aesthetics) and protecting coastal landforms such as salt marshes and coastal banks.

Recommendation ZLU-2: Evaluate regulatory strategies that achieve reduction of risk and vulnerability to life and property, and reduction in municipal expenditures to support development in highly vulnerable areas.
Structural fortification of buildings to withstand flooding impacts reinforces expectations of security and safety, and incentivizes further development. Strategies that reduce development density over time in the most vulnerable areas is highly recommended because it reduce risk and loss and can result in the creation of flood storage areas. In areas where structural fortification or elevation of structures is not warranted, retreat or relocation should be considered as the most cost effective option.

Recommendation ZLU-3: Consider initiating a coastal flood monitoring program to measure and document changes in coastal and shoreland conditions over time (i.e. erosion rates, areas of increased or new flooding, landward extent of specific coastal storm events).
A coastal flood monitoring program would serve to track on the ground changes so the City can be more responsive to measured changes over time. Additionally, a system could be utilized as an early warning system for residents of upcoming storms and likely areas of impact so precautionary measures and evacuations can be more accurately implemented.

Recommendation ZLU-4: Consult with the Portsmouth Historic District Commission to evaluate options for protecting, preserving and managing historic resources within areas impacted by current and projected flooding as identified in this report.
Portsmouth's Historic District contains cultural and historical resources and assets which give the City's waterfront a distinct and unique character. It is important to consider the best and most practical measures to protect and sustain the Historic District recognizing that there is no "perfect solution" to prevent the potential impacts resulting for projected changes in climate.

Recommendation ZLU-5: Prepare an inventory of historic assets and resources within the affected study area (land areas affected by flood elevation 18.00 feet NAVD), including basement and first floor elevations and location and type of utilities, essential mechanical components, and opportunity to elevate or relocate structures on the parcel.
This approach would evaluate what can be done now to protect assets in the Historic District and identify a phased approach to managing its resources over the long term.

Recommendation ZLU-6: Prepare a Historic District Flood Hazard Adaptation Plan which utilizes the results of an inventory to provide a long-term framework for floodproofing of structures, and opportunities for protection or relocation of structures.
The bulletin FEMA P-467-2 *Floodplain Management Bulletin Historic Structures (May 2008)* by the National Flood Insurance Program (NFIP) provides comprehensive guidance on how to minimize impacts to historic structures, and explains how the NFIP defines historic structure and gives relief to historic structures from floodplain management requirements (44 CFR §60.3).

2. Floodplain Standards

Recommendation ZLU-7: Based on the flood scenarios presented in this report, determine if higher floodplain standards that require elevation, relocation, or floodproofing that exceed the minimum FEMA standards are necessary to protect citizens, property and critical infrastructure and other municipal and private investments.
The National flood Insurance Program (NFIP) requires participating communities to adopt and implement minimum standards to protect development in the 100-year floodplain (both upland and coastal).

Recommendation ZLU-8: Establish new road and street grade and building first floor elevation and infrastructure requirements covering the life-cycle of such construction based on the flood elevations projected in this study to 2050 and 2100 (i.e. preferably an elevation that exceeds current town, state and FEMA standards).
Communities are allowed to adopt stricter standards than NFIP minimum standards such as: Require that new, renovated or expanded buildings and structures be elevated and strengthened to withstand increase flood depths and storm impacts (surge and high winds) based on regional or local mapping of coastal storm surge and projected flood and environmental conditions due to climate change. Based on the current FEMA FIRM mapped flood zones, areas mapped as Zones A and AE correspond fairly well with areas identified in this report as being impacted by sea level rise and coastal storm surge for the mapped 11.5-foot elevation, equivalent to the present day MHHW flood, MHHW flood for low. The concurrence of existing FEMA FIRM flood zones

and future scenarios lends support to adopting stricter building and infrastructure standards within these areas of projected high vulnerability.

Recommendation ZLU-9: Prepare strategic plan toward qualification for FEMA's Community Rating System program.
The FEMA Community Rating System (CRS) is a voluntary incentive program for communities participating in the NFIP that recognizes and encourages floodplain management activities that exceed the minimum NFIP requirements. Communities can earn points for adopting and enforcing certain floodplain management regulations and activities. The number of points a community accumulates will determine the percent discount their residents will receive on their flood insurance premiums. The discounted flood insurance premium rates reflect the reduced flood risk resulting from actions by the community to meet the three goals of the CRS:

1. Reduce flood damage to insurable property;
2. Strengthen and support the insurance aspects of the NFIP; and
3. Encourage a comprehensive approach to floodplain management.

3. Setbacks and Buffers

Recommendation ZLU-10: Consider adopting more stringent structural setbacks for lands within the South Subarea and Sagamore Subarea.
Setbacks are not a particularly effective adaptation strategy in densely developed areas such as the North Subarea, and Central Subarea. However setbacks are beneficial in areas that are currently undeveloped or sparsely developed. Some areas of the South Subarea and the Sagamore Subarea are either sparsely developed or have larger lots with room for shoreline setbacks.

Recommendation ZLU-11: Consider adopting stricter standards for the reference line in determining the landward extent of 100-foot coastal wetlands buffer – for example, one that captures the landward extent of the Highest Astronomical Tide (annual event) and preferably the 100-year coastal storm flood elevation identified in the CRI Report (alternatively, as determined by FEMA for revision of the FIRMs in process).
Setbacks can be applied as a static line based on a mapped flood elevation, or as a rolling setback, where flood elevations are measured from mean high water at the time of development approval. Any future improvements to buildings or structures would be subject to this "rolling setback" regardless of where the setback location previously.

By adopting a stricter standard for definition of the reference line applied in determining the landward extent of 100-foot coastal wetlands buffer, critical areas can be protected to allow natural migration of saltmarsh landward where topography permits.

4. Redevelopment Standards

Recommendation ZLU-12: [As stated in a previous recommendation and based on the range of flood scenarios presented in this report] The City should determine if higher development standards and best practices that require elevation, relocation, or floodproofing that exceed the minimum standards required by local, state and NFIP requirements are necessary to protect citizens, property and critical infrastructure and other municipal and private investments.

The goal of such restrictions is to limit redevelopment in areas where impacts and/or damages from coastal flooding have occurred, are ongoing today, or highly probable in the near future. Rebuilding in highly vulnerable areas places life, property and public welfare at risk, including provision of emergency services, maintenance of supporting infrastructure (roads, utilities, water, sewer), increased financial burden to taxpayers, and economic impacts to public and private investments. Development on grandfathered and new undeveloped lots of record may be limited within highly vulnerable areas identified by studies of projected changes in sea level and coastal flooding (see Extended Flood Hazard Overlay District).

Recommendation ZLU-13: Consider initiating a cost/benefit study to determine the expected costs of maintenance and reinforcement of critical infrastructure and roads within highly vulnerable areas and to evaluate additional funding needs and sources.

Municipalities may require additional fees from property owners and developers to pay for the costs of infrastructure services and maintenance, and emergency response in highly vulnerable areas. For example, only those property owners and developments located in an Extended Flood Hazard Area Overlay District would be assessed such fees. Fees may be structured to apply immediately to address ongoing impacts or phased in over time as specific flood elevation benchmarks occur in developed upland areas.

5. Resilient Design and Construction of Buildings and Infrastructure

Recommendation ZLU-14: Prepare an inventory of roads, bridges, culverts and drainage infrastructure on local roads and streets, identifying appropriate improvements based on predicted future flood elevations from this report, and incorporate into the City's Hazard Mitigation Plan and Capital Improvement Plan.

To assist with capital planning of anticipated sea level rise, impact inventory information can be utilized to raise capital funds and to assist when requesting additional funding where eligible from the FHWA and FEMA.

Recommendation ZLU-15: Engage in collaborative discussions with the FHWA NH Division Office, NHDOT and the Rockingham Planning Commission MPO about ways to incorporate findings from this report into the State's and RPC-MPO Long Range Transportation Plan.

Recommendation ZLU-16: Consider incorporating or providing incentives for new development and (significant) redevelopment to integrate adaptive management and reuse strategies into design plans for structures located or sited in highly vulnerable areas.

Adapting existing buildings to mitigate climate change impacts is a viable alternative to demolition and replacement. Thus, designing for future buildings with embedded adaptive reuse potential is a defensible goal toward sustainability. Building adaptive reuse entails less energy and waste, protects a buildings' historic and cultural values- its socio-cultural and historic meanings embedded in the community - while giving them a renewed lifespan and purpose.[9]

Adaptive reuse has long been applied effectively as a method of historic preservation. Commercial buildings – often mills and manufacturing here in New England – have been converted to residential uses, cultural spaces, and businesses of all sizes.

6. Shoreland Protection Options

Recommendation ZLU-17: Engage in discussion with the Conservation Commission and property owners about ways to improve procedures and criteria for the siting and design of both hard armoring and soft armoring coastal protection projects.

Adopt requirements for regulating the construction of hardened, engineered structures that provide flood and erosion control along the immediate coastal shoreland and adjacent upland areas at risk for storm surge and future projected flooding. Shoreline hardening may be necessary in the North Subarea and South Subarea to protect densely developed areas.

Sometimes referred to as "living shorelines", soft armoring employs natural approaches to protection and restoration of shorelines and coastal lands, particularly where natural ecosystems have been damaged by erosion. Marsh restoration and creation, low profile breakwaters are common forms of soft armoring. Soft shoreland practices protect exiting saltmarsh and habitat and are most appropriate in the South Subarea and Sagamore Creek Subarea to allow for upland migration.

B. Master Plan

As the City of Portsmouth prepares to update the Master Plan, information from the Portsmouth Coastal Resilience Initiative Report (Report) should be reviewed and shared to inform residents about the types of events associated with climate change and the challenges and opportunities impacting the City's land use decisions. The Master Planning process is also a place where input from residents should be requested and used to guide how adaptation measures are incorporated into the document.

Because the Master Plan discusses key issues the City should address in the coming years, the Rockingham Planning Commission (RPC) reviewed the 2005 Master Plan to better understand the process the City uses to develop Master Plan themes, goals and objectives and to identify opportunities for introducing both the concepts of adaptation, climate change and resiliency and opportunities for incorporating recommendations from the Report into the Master Plan. http://www.cityofportsmouth.com/masterplan/MasterPlanFinalComplete-Aug2005.pdf

Portsmouth's Master Plan presents a set of goals, objectives and strategies that together describe a direction for the City over the next ten years. Development of the Master Plan involves

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[9] *Designing for Future Building: Adaptive Reuse as a Strategy for Carbon Neutral Cities*, Sheila Conejos, Craig Langston and Jim Smith. *The International Journal of Climate Change: Impacts and Responses*, Volume 3, Issue 2, pp.33-52.

extensive participation by City residents and public officials, providing a unique opportunity to explain the findings of the CRI Report and to brainstorm as a community about adaptation strategies.

Recommendations for ways in which the City can use the CRI Report to update the Master Plan are described below.

Recommendation MP-1. *A Vision for Portsmouth* – Establish a Study Circle on climate change and adaptation planning. Have the participants review this CRI Report's findings and recommendations collect information on what changes members have seen in the community and discuss what can be done to prepare for these changes. *(Short-Term Recommendation*)

Recommendation MP-2. *Priorities for Action* – Portsmouth's land use priorities are grouped into themes that reflect resident interests and concerns. Themes in the 2005 Master Plan are *Downtown Vitality*, *Corridor Areas*, *Supporting a Diverse Community* and *Resource Protection and Sustainability*. Needs and projects expressed for each of these themes will be impacted by climate change and will require the City to adapt Master Plan recommendations. For example, a core element identified under Downtown Vitality is a "renewed support for a working waterfront and improved visual and physical connections to the water's edge." As the Planning Board and Planning Department develop the 2015 Master Plan, projects related to this goal (Themes in the 2005 Master Plan) need to be planned for keeping sea level rise and coastal flooding in mind. (*Medium-Term Recommendation*)

Recommendation MP-3. *Goals, Objective and Strategies* – Portsmouth's Master Plan is organized into ten functional elements – Land Use; Housing; Economic Development; Transportation; Community Facilities and Services; Natural Resources and Open Space; Natural Hazards, Emergency Management, and Recovery Planning; Recreation; Cultural and Historic Resources and the Arts; and Social Services. The City should consider adding a new functional element, Community Resiliency to Climate Change, to discuss the CRI Report, call attention to areas of the City most impacted by sea level rise and storm events, and recommend changes to land use regulations and City policies and programs. Adaptation planning and resiliency should become recurrent themes found in each of the Master Plan's functional elements. *(Medium-Term Recommendation)*

- Land Use – Incorporate the findings and recommendations of the CRI Report into all future land use decisions in impacted areas. The Future Land Use map needs to be amended to incorporate data from the CRI Report relative to subareas, coastal flooding, overlay districts, etc.
- Housing – Discuss the need for building codes to be amended to require resilient design; add a goal that promotes adaptive building and reuse.
- Economic Development – Sustaining the City's working waterfront is a primary goal in this section of the Master Plan. Add a goal to work with the many stakeholders involved with the working waterfront, such as the Fishermen's Coop, Pease Development Authority's Division of Ports and Harbors, PSNH, etc., to review the CRI Report's findings and recommendations.

- Transportation – The CRI Report finds that Portsmouth's transportation infrastructure will be strongly impacted by climate change and coastal flooding. Planning for bridges, culverts, roads, boat ramps and sidewalks must take potential sea level rise impacts into consideration.
- Community Facilities and Services – Community facilities and services will also be strongly impacted by climate change. Water and sewer services, City owned buildings, parking lots, parks and recreation facilities, and schools have detailed and complex projects and budgets that will need to be reviewed in light of CRI Report findings.
- Natural Resources and Open Space – The City and its residents have made a clear commitment to protecting natural resources and open space for a wide variety of reasons, including protection of wildlife habitat, drinking water, and human health. The CRI Report's maps highlight the role conservation land plays in helping to protect Portsmouth from sea level rise, coastal flooding, and extreme storm events. This role needs to be added and discussed in the Master Plan. In addition, climate change will impact the habitat of plants of animals, requiring a greater understanding of the impacts of human activities on the capacity of ecosystems to adapt.
- Natural Hazards, Emergency Management, and Recovery Planning – Amend the City's Natural Hazard Mitigation Plan to include the specific disaster planning recommendations found in the CRI Report.
- Recreation – Review the City's recreational resources to identify areas impacted by climate change. Waterfront resources are most vulnerable but the increased frequency of severe storm events may also require management changes to recreation areas.
- Cultural and Historic Resources and the Arts – Cultural and historic resources such as buildings, landmarks, and scenic roads and landscapers are all defining components of Portsmouth and many are vulnerable to the impacts of climate change. Enabling these resources to become more structurally resilient or enabling the resource to be relocated will allow the City to plan for protection. The RPC's recommendations for incorporating climate change adaptation into the City's zoning ordinance and land development regulations provide specific recommendations that could protect cultural and historic resources.
- Social Services – Public and private agencies provide a wide variety of services in Portsmouth. All the agencies involved in providing these services need to be made aware of the impacts of climate change on their ability to plan for and provide services.

Recommendation MP-4. *Implementation Plan* – The City's Master Plan outlines an ambitious agenda for the future. This agenda becomes even more ambitious with the addition of climate change adaptation. The action plan and priorities developed during the Master Plan update will need to reflect the many recommendations made in the CRI Report for regulating land use and development.

C. Coastal Wetlands

Recommendation CW-1. Inventory public and private lands and work with landowners and managers to establish migration areas for tidal marsh.

Recommendation CW-2. Strengthen 100 foot buffer width along all tidal wetlands through enforcement of a strict no-build policy in this buffer. All non-tidal wetlands that are subject to flooding by present day storm surges as shown on Map WE-1.2 should be inventoried and additional protection considered.

Recommendation CW-3. Future construction projects should include provisions for allowing tidal flow which does not interrupt the transport of suspended sediment to nourish existing marshes and not impede landward migration.

Recommendation CW-4. Highway departments should be provided inventory maps of areas vulnerable to flooding risk from storms and efforts to protect and allow for the expansion of existing wetlands.

Recommendation CW-5. An inventory should be conducted to understand the capacity of tidal flow to move beyond Greenleaf Avenue and the Peverly Hill Road culvert.

Recommendation CW-6. An inventory should be conducted to determine available pathways for marsh migration onto low-lying uplands for Currier Cove Road, Belle Isle Road, the South Cemetery, Clough Drive, and Brackett Road.

Recommendation CW-7. An inventory should be conducted to better understand the impacts to the drainage that passes through the athletic fields at the High School and empties into Sagamore Creek.

Recommendation CW-8. A study of Peirce Island should be conducted to determine how it will be able to adapt to potential future flooding and whether space is available for marsh migration.

Recommendation CW-9. Develop inventory and initiate discussions with managers of the Urban Forestry Center, South Cemetery, Creek Farm and other protected lands to determine areas appropriate for marsh migration over uplands.

Recommendation CW-10. To extend the lifetime of existing saltmarshes, inventories should be conducted to determine the efficacy of sediment amendments (called nourishment) that could be made to the surface of saltmarsh areas to maintain marsh elevations as sea level rises.

Recommendation CW-11. Given that losses of tidal wetlands in highly developed areas are unlikely to be replaced by migration inventory and planning efforts should be conducted to ensure these critical habitats can be maintained.

D. Public Health

This report provides much more in-depth treatment of predicted impacts associated directly with sea level rise and coastal storm surge than on public health impacts. Below are some recommendations which serve as a starting point when looking at public health measures which should be considered in response to climate change.

Recommendation PH-1. Identify specific locations and population groups at greatest risk for each threat identified.

Recommendation PH-2. Develop and implement preparedness and response plans for each threat identified.

Recommendation PH-3. Communicate the health-related aspects of climate change, including risks and ways to reduce them, to the public, decision makers, and healthcare providers. Emphasize personal responsibility and preparedness

Recommendation PH-4. Develop and disseminate public education on affecting change, such as consumption, and travel choices, sustainable practices for the home and work environment and reducing chemicals in the environment.

Recommendation PH-5. Support legislation to mitigate source emissions, and address issues related to climate change and secondary factors affecting human health and the environment.

Recommendation PH-6. Support research of environmental pollution/contaminants on the climate and environment by participating and cooperating with universities, and public health and environmental groups that wish to study these issues.

Recommendation PH-7. Support existing technologies and policies that result in cleaner and more sustainable resources.

Recommendation PH-8. Strictly enforce current environmental controls.

Recommendation PH-9. Educate the public and key public health and policy groups and institutions on the issue of climate change and secondary public health issues.

Recommendation PH-10. Ensure City staff have well-rounded training in hazard mitigation, environmental and health outcomes of their particular expertise

E. Emergency Management and Hazard Mitigation Planning

The information found within this section is based upon a review of the City of Portsmouth's Natural Hazard Mitigation Plan (updated November 2011). The following recommendations could be used to incorporate climate adaptation planning information and strategies into the City's Hazard Mitigation Plan.

Recommendation EM-1. Work with the Rockingham Planning Commission to develop a Climate Change Coastal Flood Vulnerability Chapter within the Hazard Mitigation Plan.

- The model chapter will include information found within the report including but not limited to the inundation maps, critical facilities impacted from flood inundation, potential adaptation/mitigation strategies for minimizing the impacts of sea level rise and storm surge, etc.
- As part of a FEMA required Hazard Mitigation Plan update (every 5 years) incorporate this new chapter as well as the recommendations found within the CRI Report.

Recommendation EM-2 . Modify and or add a goal within the Hazard Mitigation Plan that specifically addresses reducing vulnerability to current as well as future coastal flood events due to sea level rise.

- This may be achieved through education and outreach of staff and City boards as well as by continuing to evaluate solutions for the protection of public and private infrastructure that falls within current and future coastal inundation areas.

Recommendation EM-3 Continue to enable emergency management to serve on the Technical Advisory Committee (TAC) in order to obtain emergency management review comment on development proposals.

- This will allow emergency management to evaluate risks associated with emergency response to buildings that are being developed within areas of flood inundation, or on local evacuation routes.

Recommendation EM-4 Utilize the Portsmouth Coastal Resilience Initiative Report and the Hazard Mitigation Plan update to educate city staff, land use boards, and the City Council about the science and terminology of climate change and how the City of Portsmouth may be impacted in the future by climate change, particularly sea level rise and coastal storm surge.

- Hold work sessions and retreats with City boards to educate and inform them about the science of climate change and sea level rise and potential impacts the City may have to withstand due to a changing climate.

Recommendation EM-5 Continue to assess the impacts of sea level rise on local population evacuation within the City limits and Route 1.

- As part of an annual FEMA required 5 year Hazard Mitigation Plan update evaluate evacuation and response route impact based on the CRI Report. Investigate and include secondary evacuation and response routes as part of that update.

Recommendation EM-6 Evaluate Emergency Response to the sewer treatment plant as flood inundation on access roadways to the plant will likely be more frequent due to sea level rise.

- Emergency management planning should ensure that accessibility to the Pierce Island treatment plant is maintained and includes the proper equipment for disaster response.

CLIMATE ADAPTATION GLOSSARY

Following is a glossary of terms used in this report that describes the various scientific elements and actions associated with assessing and describing climate change, and ways communities can respond to changing conditions by identifying their vulnerability and implementing proactive adaptation and planning.

100-year Coastal Floodplain
Includes flood hazard areas subject to tidal flooding and storm surge and identified on the FIRMs as a Special Flood Hazard Area (SFHA). SFHA are defined as the area that will be inundated by the flood event having a 1-percent chance of being equaled or exceeded in any given year. The 1-percent annual chance flood is also referred to as the base flood or 100-year flood. In coastal areas, these SFHAs are defined as specific zones on the FIRM's: In Portsmouth there are two coastal flood zones areas within the SFHA:

- The A zone – an area subject to a 1 percent annual chance of a flood event but does not have a mapped elevation and;
- The AE zone – an area that has the same 1 percent annual chance of a flood event and a corresponding mapped flood elevation of 9 feet.

Accommodate
Measures that manage risk by requiring development to be built and retrofitted to be more resilient to impacts and by limiting certain types or all development in highest risk areas, favoring adaptive uses (i.e. passive uses such as recreation) and gradual modification of structures and uses as conditions change over time.

Adaptation
The deliberate and considered actions taken to avoid, manage or reduce the consequences of a changing climate and to take advantage of the opportunities that such changes may generate.
[http://www.vcccar.org.au/content/pages/what-climate-change-adaptation].

Climate Change
Climate change refers to any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among others, that occur over several decades or longer.
[EPA http://epa.gov/climatechange/glossary.html]

Coastal Flooding
Upland areas inundated by tides, storm surge, and projected sea level rise.

Protect
Measures focused typically on hard-engineered solutions to prevent impacts for flooding, storm surge and erosion. Protection may include preservation strategies such as restoration and/or maintenance of natural dune systems and "living shorelines", and beach nourishment.

Resilience
A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment.
[EPA http://epa.gov/climatechange/glossary.html]

Retreat
Often the last action before abandonment, retreat follows an incremental path of planning for the eventual relocation of structures to upland areas as properties become threatened or directly impacted by rising sea level, erosion and coastal storms. Such measures may include rolling setbacks and buffers, transfer of development rights, and property acquisition/buyout programs.

Riverine (and Freshwater) Flooding
Areas inundated adjacent to freshwater drainage systems not affected by coastal flooding, including the 100-year floodplain and other areas subject to flooding from precipitation and snow melt.

Sea Level Rise
Sea level is measured in various ways. ***Relative Sea Level*** refers to the measurement of sea level at a local tide gauge station which is referenced relative to a specific point on land. These measurements at any given local tide gauge station include both measurements of global sea level rise and local vertical land movement, such as subsidence, glacial rebound, or large-scale tectonic motion. Because the heights of both the land and the water are changing, the land-water interface can vary spatially and temporally and must be defined over time. The term ***Mean Sea Level*** (MSL) refers to a tidal datum defined by the average tide over a specific period of time. ***Global Sea Level Rise*** (or eustatic sea level rise) refers to the increase currently observed in the average ***Global Sea Level Trend***, which is primarily attributed to changes in ocean volume due to two factors: ice melt and thermal expansion.
[NOAA http://www.tidesandcurrents.noaa.gov/est/faq]

Storm Surge
An abnormal rise in sea level accompanying intense events such a tropical storm, hurricane or Nor'easter, whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the storm event.
[EPA http://epa.gov/climatechange/glossary.html]

Sustainability
Sustainability is based on the principle that everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment. Sustainability creates and maintains the conditions under which humans and nature can exist to permit fulfilling the social, economic and other requirements of present and future generations.
[EPA http://www.epa.gov/sustainability/basicinfo.htm].

Vulnerability Assessment
An evaluation of the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. [www.ipcc.ch/pub/syrgloss.pdf]

Appendices

Appendix A

Coastal Wetlands

1. Portsmouth's Current Wetlands and Their Distribution

The coastal wetlands of Portsmouth are comprised of both tidal and non-tidal wetlands. The non-tidal wetlands include freshwater wetlands of forested swamp, shrub scrub swamp, and emergent marsh. Some emergent marshes are dominated by invasive species like common reed and purple loosestrife. Tidal wetlands include subtidal eelgrass meadows and intertidal emergent marshes. Intertidal salt marshes are composed of low marsh (dominated by smooth cordgrass), and high marsh (dominated by a mixture of salt hay, spike grass and black grass). Along most shorelines the salt marshes grade into uplands, but where they border freshwater tributaries to the estuary, these marshes grade into brackish and fresh marshes.

As shown in Figure 1 Sub-Area Map, the shoreline of Portsmouth extends from the Schiller Power Station on the main stem of the Piscataqua River at the Newington border south to, and including, Sagamore Creek. Interpretation of impacts to wetlands from climate change associated with sea level rise and flooding from the 100-year storm surge is presented by Sub-Area, with a focus on the South and Sagamore Creek Sub-areas. Descriptions of specific marsh locations, conditions and projected impacts are referenced from the Wetlands and Environmental Resources map set, WE-1.1, WE-1.2, WE-1.3 and WE-1.4.

Several small subtidal eelgrass meadows are located just north of the Port of New Hampshire, near the inlet to North Mill Pond. Traveling south, no eelgrass is found until the northern shore of Peirce Island. More substantial eelgrass meadows extend around the northwest corner of Shapleigh Island and the southern end of Shapleigh Island. The only other eelgrass meadows in Portsmouth are several small beds found in Sagamore Creek, just south of the inlet to Little Harbor.

North and Central Sub-Areas

The two northern Sub-Areas of Portsmouth - North and Central - are either steeply sloped or largely developed and protected by seawalls, except for Peirce Island, and as a result will have minor wetland impacts from sea level rise and storm surges.

South and east of the City boundary with Newington at the Schiller Power Plant, the shoreline extends along the Piscataqua River until the inlet to North Mill Pond. Here the shoreline is typically very steep with rocky outcrops and little to no vegetated wetlands. The North Mill Pond has been filled extensively, yet most areas are unarmored and the Pond still possesses significant intertidal salt marsh fringing most shorelines. The shoreline surrounding the Port of New Hampshire, extending to downtown Portsmouth and the South End, has been developed where intertidal marshes were filled and armored with riprap and seawalls. Some areas still support narrow fringing marshes, but most armored shores are without vegetated wetlands. To the east of downtown Portsmouth lies Peirce Island, which has a mix of unvegetated shorelines, natural rock outcrop, fringing salt marshes where some marshes were filled and armored with riprap.

South Sub-Area

South of Peirce Island lies the inlet to South Mill Pond, which has a mechanical tidal gate and was the site of a former gristmill and dam. The tide gate is currently maintained in the open position following a shellfish and tidal-marsh restoration project in 2000. The shoreline of South Mill Pond, though previously filled for development, supports a fringe of salt marsh.

Southward, Pleasant Point forms the northern boundary to Little Harbor, which has substantial intertidal wetlands including areas of broad marshlands as well as narrow fringing marshes. The western portion of Little Harbor by the South Cemetery and elementary school has a significant intertidal salt marsh grading into freshwater marsh and forested wetland.

Sagamore Sub-Area

The western portion of Sagamore Creek supports substantial intertidal wetlands grading into brackish and fresh water wetlands along several small freshwater tributaries. However, from where the Creek narrows to Little Harbor, intertidal marshes are best described as fringing marshes between steep bedrock outcrops.

2. <u>Impacts of Climate Change</u>

General Impacts. Negative impacts to subtidal eelgrass habitats will depend most upon water clarity as depths increase with sea level rise. Eelgrass beds develop and maintain themselves along a narrow range of water depths between the lowest of low tides (above this elevation they are subject to exposure where they dry out and die) and the depth where they cannot obtain enough light to grow and survive throughout the year. Choices in land use, nutrient release, and storm water treatment may directly and indirectly affect water clarity and ability of subtidal areas to support meadows. As sea levels rise, deeper beds may not be able to survive, but beds may expand landwards and, if able to establish, new subtidal areas may be able to support eelgrass meadows. In addition, the persistence and establishment of eelgrass beds may be somewhat limited by strong tidal currents that can pull and tear plants. Eelgrass beds may be subject to stronger currents with rising sea levels. Because the volume of water driven by tides will increase with submergence, stronger currents may erode and expand tidal channels to accommodate more water.

Table 10 reports water elevations that define the boundaries of high marsh and low marsh systems.

Table 10. Present sea level datums that correspond with salt marsh elevations.

Datum	NAVD
Mean Lower Low Water (MLLW)	-4.99
Mean Sea level (MSL/ Low Edge of Low Marsh)	-0.3
Mean High Water (MHW/transition to High Marsh	3.98
Mean Higher High Water (MHHW/Upper Marsh Edge)	4.41

[from Table 6; McKee and Patrick 1988, Fuller et al. 2011]

Intertidal wetlands form within an elevation band along shorelines that is controlled by water levels, with the upper edge of high marsh at MHHW (+4.41 feet NAVD) and the lower edge of low marsh, where it becomes mudflat, usually found around MSL (-0.3 feet NAVD). As sea level rises, there may be losses of tidal marsh at the deeper edge, primarily what is currently low marsh populated by smooth cordgrass. However, marsh grasses interact with flooding tides to build in elevation, so the extent of loss will depend upon the ability of the marsh to collect and build sediments (referred to as the rate of accretion). If plants can facilitate accretion at a rate of 0.2 inches per year (Morris et al. 2002, Kirwan et al. 2010), in 50 years the marsh elevation could reach 10 inches in height and in 2100 could reach up to 18 inches in height.

Similarly, the high marsh, dominated by salt hay, has a lower edge that is controlled by tides and is typically found at Mean High Water (+3.98 feet NAVD), where it transitions from low marsh. High marsh then extends about a foot in elevation until the upland edge is reached. Although it has a narrow elevation range, high marsh makes up most of the area of tidal marshes in New England. Under all the flood scenarios examined here, it is likely that all of the existing high marsh will be impacted or lost to rising seas. If conditions are favorable, drowned high marshes may be replaced by low marsh, but some period of adjustment is likely necessary and a portion of the high marsh may be unvegetated for several years (as found on Cape Cod by Smith in 2006). Indeed, local observations show loss of high marsh is underway in some Portsmouth marshes (Figure 2). .

Figure 2. High marsh dieback observed in Portsmouth marshes. (A) Marsh hay develops hummocks and dies off, to be replaced by green algae and glasswort (B) on Pleasant Point in 2011. (C) Hummocks developing in marsh hay in marsh on Peirce Island, May 2012 (photos: D. Burdick).

If there are no physical barriers, new high marsh is expected to migrate onto adjacent low-lying inland areas. Both low and high marsh will continue to accrete and build in elevation, but rapid rates of accretion (0.20 inches per year) will likely be lower than the rate of sea level rise in both scenarios (low SLR rate equal to 0.34 inches per year average; high SLR rate equal to 0.86 inches per year average), so tidal marshes will continue to submerge into tidal flats and open water.

During the current century, the 100-year coastal storm surge flooding may range from 11.5 feet NAVD by 2050 under the lower sea level rise scenario to as much as 18 feet NAVD by 2100 under the higher sea level rise scenario (refer to Map series WE-1.2 – WE-1.4). A surge will actually have less effect upon tidal wetlands than the increased tidal level because most of the flooding will drain from the tidal wetlands in several days. Tidal wetlands are fairly resilient to storm surge flooding unless they are destroyed by storm waves and/or debris. The major impacts from storm surge flooding will be salinity intrusion into adjacent freshwater/non-tidal wetlands.

As an example of the possible impacts of climate change upon the wetlands, following is a detailed examination of possible impacts in the Sagamore Creek and South Sub-Areas over time and adaptation options that may be considered. The major areas of concern are along the Sagamore Creek and Little Harbor shorelines simply because most other coastal/tidal wetlands in the North and Central Sub-Areas of the City were previously been filled for development.

3. South Sub-Area - Little Harbor and Islands, including Peirce Island

Present Day: MHHW 4.4 feet above NAVD with 6.8 foot storm surge (11.2 feet above NAVD)

Little Harbor extends from Sagamore Creek northward to Pleasant Point. Flooding from a 100-year storm surge at present day sea level is shown as an 11.5 foot flood event on Map WE-1.2. Because tidal wetlands are resilient to storm surge flooding unless under direct physical attack from waves or debris, the storm surge will have minor effects upon tidal wetlands. Floodwaters will drain from the tidal wetlands quickly and the major wetland impacts from storm surge flooding will be salinity intrusion into adjacent freshwater/non-tidal wetlands.

Along the shoreline of Little Harbor and its associated islands (Pest, Shapleigh and Lady Isle), the storm surge will flood adjacent uplands and freshwater wetlands. If the storm occurs within the growing season (April to October), floodwaters can kill the salt-intolerant vegetation in these freshwater wetlands, including herbaceous vegetation as well as trees. The result will be the formation of several new, isolated forested uplands surrounded by marshlands along the southern shore of Little Harbor and the southeastern corner of Pleasant Point (Map WE-1.2). Adjacent freshwater marshes, shrub scrub and forested swamps will flood, especially along the southern shoreline, the South Cemetery and low-lying lands between the Elementary School and Ridges Court (Map WE-1.2). Large areas of Peirce Island will flood including the center and western portions (but not the Waste Water Treatment Plant), producing a series of isolated uplands. The Little Harbor Islands do not support non-tidal fresh wetlands, so impacts will be limited to the replacement of upland freshwater vegetation and with intertidal marshes. Finally, several waterfront homes and a small section of the South Cemetery are likely to flood where they have been built on low-lying uplands.

2050 to 2100: Scenario of MHHW 5.4-10.7 feet above NAVD (1.0-6.3 foot increase).
Forty to ninety years from now sea level is projected to rise by several feet. Furthermore, a 100-year storm surge, which is likely to occur within this period, may flood elevations ranging from 12.2 feet to17.5 feet.

Several large eelgrass beds are mapped around Shapleigh and Peirce Islands. These beds will likely experience losses along their deeper edges as sea level increases by 3 feet (Map WE-1.1) and perhaps by 6 feet (Map WE-1.2) above current conditions. Eelgrass may be able to expand at higher elevations around these and other islands near the Little Harbor inlet as adjacent mudflats submerge. However, the health and survival of eelgrass beds is largely dependent upon water quality, with predictions beyond the scope of this project.

The tidal marshes in the area are mostly fringing marsh, generally less than 100 feet in width, with low marsh grading into high marsh and high marsh becoming upland above MHHW. Notable exceptions are the two larger marshes east of South Cemetery. Without considering storm surge, moderate rates of sea level rise will submerge a portion of the low marsh as shown by the blue areas expanding into high marshes (Map WE-1.1). If sea level increases modestly at no more than 3.1 feet above current levels and the low marsh can accrete rapidly (0.2 inches/year), then only about half the existing low marsh will be lost by 2100. If the marshes cannot accrete appreciably or the rate of SLR is rapid (for example, 6.3 feet above current levels by 2100 under the high emissions scenario), then the entire low marsh will be lost by the latter part of the century (tidal marshes shaded blue on Map WE-1.2). The few broad areas of high marsh will gradually be replaced by low marsh. Tidal marsh will migrate upwards into the upland (3-6 feet in elevation, depending on SLR rate). Because the upland edge bordering the marsh is typically much steeper than the existing high marsh, high marsh will be reduced to a narrow band along most Little Harbor shorelines (within, but narrower than, the yellow band on Map WE-1.2). Along the southern and western shores of Little Harbor, however, broader areas of high marsh may establish in the freshwater wetlands and connect the mainland to the forested islands newly created as described previously.

When storm surge is considered along with moderate to high rates of sea level rise, we can expect significant flooding within the period 2060 to 2100, as shown on Maps WE-1.3 and WE-1.4. The impacts to tidal wetlands may be similar to those described in the previous paragraphs. Along with Pleasant Point, Pest, Shapleigh and Peirce Island have only small portions remaining above the waves and the New Castle Avenue causeway is under as much as 9 feet of water. Nearly all the freshwater/non-tidal wetlands in the area, including a small skating pond in the Cemetery, will be impacted by the floodwaters.

4. <u>Sagamore Creek Sub-Area</u>

Present Day: MHHW 4.4 feet above NAVD with 6.8 foot storm surge (11.2 feet above NAVD)

Flooding from a present day storm surge is shown as an 11.5’ flood event in WE-1.2. This 100-year storm surge will have minor effects upon tidal wetlands because tidal wetlands are resilient to storm surge flooding unless under direct physical attack. Floodwaters will drain from the tidal wetlands quickly and the storm may deposit significant amounts of sediment to help build the marsh (Turner et al. 2006). The major impacts from storm surge flooding will be salinity intrusion into adjacent fresh water non-tidal wetlands.

In the Sagamore Creek watershed, the storm surge will flood adjacent uplands and freshwater wetlands along the minor tributaries and salt water will kill some of the fresh vegetation, especially if the storm occurs within the growing season (April to October). This includes herbaceous vegetation as well as trees. The largest areas to be affected are in the creek south of the High School athletic fields (loss of vegetation in shrub scrub and fresh marsh), the southern shoreline of the Urban Forestry Center and the cove to the east (loss of trees in forested wetlands), the two areas currently occupied by businesses along the west side of Route 1 (by the bridge and further north by the traffic light at Greenleaf Woods Drive), and the creeks and shoreline west of Route 1 (loss of vegetation in forested and shrub scrub swamps as well as fresh marsh). An indirect effect of the flooding will likely be expansion of invasive species that is salt tolerant and is currently found along the shoreline (invasive common reed - *Phragmites australis*).

2050 to 2100: Scenario of MHHW 5.4-10.7 feet above NAVD (1.0-6.3 foot increase). Forty to ninety years from now sea level is projected to rise by several feet. Furthermore, a 100-year storm surge, which is likely to occur within this period, will flood elevations of 12.2 to17.5 feet. Therefore the mapped scenario for moderate rates of SLR without storm surge is shown in WE-1.1 (7.5 feet), and with a storm surge is shown in WE-1.2 (11.5 feet) under low SLR rates, in WE-1.3 (13.5 feet) under moderate rates and in WE-1.4 (18.0 feet) under high rates of SLR.

Several eelgrass beds are found in the northeastern reach of Sagamore Creek, close to Little Harbor. These beds will likely contract along their deeper edges as sea level increases 3 to 6 feet (Maps WE-1.1 and WE-1.2) above current conditions. Eelgrass may be able to expand at higher elevations as adjacent mudflats submerge, especially around the small islands, but the health and survival of eelgrass habitat is largely dependent upon water quality, as expressed previously.

Broad areas of high marsh lined with low marsh along its lower borders and tidal creeks cover a substantial portion of Sagamore Creek. Without considering storm surge, much of the low marsh will become submerged and replaced by mudflat as shown by the blue areas expanding along tidal creeks and into high marshes (Map E-1.1). If sea level increases 3.1 feet above current levels and the low marsh can accrete rapidly (0.2 inches/year), then about half the existing low marsh will be lost by 2100. If the marshes cannot accrete appreciably or the rate of SLR is rapid (6.3 feet above current levels by 2100), then the entire low marsh will be lost by the latter part of the century (tidal marshes colored blue on Map WE-1.2). The broad areas of high marsh will gradually be replaced by low marsh. Tidal marsh will migrate upwards into the upland (3-6 feet in elevation, depending on SLR rate). Because the upland edge bordering the marsh is typically much steeper than the existing high marsh, high marsh will be reduced to a narrow band along most areas of the Creek (within, but narrower than, the yellow band on Map WE-1.2).

Exceptions where high marsh may be wider than several feet can be seen in the western portion of the creek, west of Route 1, showing wide yellow bands (Map WE-1.2). Locations include an undeveloped peninsula that will become an island surrounded by tidal marsh flooded on a regular basis. Tidal marshes will expand to Peverly Hill Road at the southwest corner of Sagamore Creek and northward beyond Greenleaf Avenue in the northwest corner (Map WE-1.2). The freshwater wetlands of forested and scrub-shrub swamps and emergent marshes will convert to tidal high marsh. An area currently occupied by several businesses on the western side of Route 1 by the bridge over the Creek, including a restaurant (refer to Map B-1.2), appears to be at an elevation suitable for high marsh before mid-century (yellow on Map WE-1.1), and suitable for low marsh after mid-century (shaded pink on Map WE-1.2), if buildings and pavement are removed. Similarly, several businesses along Route 1 (720-750 Lafayette Road) and Route 1 itself at Greenleaf Woods Drive will begin to flood on a regular basis (shaded yellow on Map

WE-1.2). To the east of Route 1, high marsh expansion into freshwater marsh and scrub shrub swamp south of the High School athletic fields will potentially occur. The Urban Forestry Center protects a large area of southern shoreline along Sagamore Creek where the high marsh may expand into several forested wetlands and onto relatively flat upland areas.

When storm surge is considered along with moderate to high rates of sea level rise, we can expect significant flooding events to occur in the period from 2050 to 2100 (and beyond), as shown on Maps WE-1.3 and WE-1.4. The impacts to tidal wetlands are described above, but the storm surge impacts to non-tidal freshwater wetlands and the developed areas increase dramatically. West of Route 1, storm waters flood over Mirona Road, under the culvert at Peverly Hill Road and into the forested wetlands, all along the western shore and far up into the Greenleaf Avenue drainage, across Greenleaf Woods Drive and across Route 1 into the shopping plaza and extending south to the bridge. East of Route 1, floodwaters will cover the athletic fields at the High School, extensive areas of the Urban Forestry lands, and reaching into the residential development to the east. East of Sagamore Road, forested wetlands and fresh marshes will be flooded across Walker Bungalow Road, with floodwaters extending across Wentworth Road. In the wetland drainage area between Creek Farm Road and Little Harbor Road the forested swamp will flood.

5. Adaptation Responses

Tidal marshes are valuable habitats that provide a wide range of ecosystem services, from support of fisheries to nitrogen cycling. Over the near term, several actions can be taken by the City to protect wetlands now and improve adaptability for the future. The City of Portsmouth could chart a path for providing migration areas for tidal marsh. Fortifying infrastructure and development that results in erecting barriers landward of tidal marshes without providing for marsh migration would result in a variety of negative impacts. Barriers would result in greater flooding of unprotected areas, loss in ability of intertidal systems to take up and denitrify nitrogen, and significantly greater marsh loss that will impact threatened and endangered species as well as wildlife as a whole (NH Wildlife Action Plan, 2010).

The City of Portsmouth should continue to recognize 100 feet as the minimum buffer width along all tidal wetlands and enforce a strict no-build policy in this buffer. In addition, 100 foot buffers should remain in place for all non-tidal wetlands that are subject to flooding by present day storm surges as shown on Map WE-1.2. These wetlands are not only expected to expand laterally as sea level rises, but they will also provide migration paths for tidal wetlands. Provisions for allowing tidal flow should also be designed to carry as much suspended sediment as possible to promote the accretion of tidal marshes. The City should examine public and private lands and work with landowners and managers to establish migration areas for tidal marsh.

City and State highway departments need to be contacted about the flooding risk from storms and provided with specific information about intentions to protect current wetlands and the expected expansion of wetlands, especially at low-lying elevations.

Roads can be raised on pilings or elevated by filling to elevations above 11.5 feet above NAVD, culverts will need to be expanded or replaced by bridges and bridges will need to be replaced by larger structures to accommodate flood waters.

Specifically for Sagamore Creek, current threats to roads from flooding by a 100-year storm surge are evident on Map WE-2 (Route 1, Greenleaf Avenue, Greenleaf Woods Drive, and Wentworth Road). Also, several businesses will begin to flood on a regular basis in the short term (west side of Route 1 at and north of bridge, Mirona Road and~~,~~ Witch Cove Marina; Map WE-1.2). Over the long term, a bridge is needed for Greenleaf Avenue and a tidal culvert designed for two-way flow is needed for Peverly Hill Road.

Specifically for Little Harbor and the islands, including Peirce Island, sea level rise and storm surges will impact roads. A 100-year present day storm will flood significant portions of New Castle Avenue, Marcy Street, Pleasant Point Drive, Peirce Island Road and the private roadways of the Cemetery, Currier Cove Road and Belle Isle Road. Pathways for marsh migration onto low-lying uplands and freshwater waters should be planned for Currier Cove Road, Belle Isle Road, the South Cemetery, Clough Drive, and Brackett Road.

Decisions will need to be made regarding the drainage that passes through the athletic fields at the High School and empties into Sagamore Creek. Some fields can be filled, but filling all the fields or creating a barrier to tidal flooding will exacerbate problems with expanding wetlands up gradient of the playing fields. Similarly, the South Cemetery in Little Harbor could provide a large area for marsh migration, but, as in the past, it could also be filled without regard for replacing our valuable tidal wetlands. Peirce Island will need to be fortified if the State Fishing Pier and swimming pool are to be maintained. A compromise might allow tidal marshes to migrate and occupy the remainder of the low-lying portions of the Island.

Discussion with managers of the Urban Forestry Center, South Cemetery, and Creek Farm as well as other protected lands managed by the City (e.g. Peirce Island) should seek to promote marsh migration over uplands. To extend the lifetime of the current marsh areas, sediment amendments (also called nourishment) could be made to the surface of the marsh. Marsh nourishment would have to be done in small increments to avoid negative impacts to the marsh, but could be a useful method to protect specific areas that serve as habitat for listed species.

6. Summary

Rising sea level will impact seagrass meadows through light reduction as waters get deeper. Beds may also be impacted from greater tidal currents, as more water will be forced through existing waterways. Eelgrass may be able to expand at higher elevations around the islands of Little Harbor as adjacent mudflats submerge. However, eelgrass beds are somewhat ephemeral and their health and survival is largely dependent upon water quality, with predictions beyond this project’s scope.

Responses of tidal salt marshes were examined for the Sagamore Creek and Little Harbor Sub-areas. Under low rates of sea level rise by mid-century, most of our current low marsh may survive if it can accrete (build in elevation) at rates of 0.2 inches per year, or about half that of the sea level rise (0.34 inches per year). At higher rates of sea level rise (0.86 inches per year) and by the end of the century under either scenario, most, if not all of the low marsh will have submerged and converted to mudflat or subtidal bay. The current high marsh will convert to low marsh even under conditions of slow SLR, and high marsh will migrate upslope several feet (3.1 feet in elevation), where possible (along shorelines without barriers).

Losses in ecosystem services from submerged tidal wetlands can be mitigated by allowing the high marsh to migrate into adjacent uplands and non-tidal wetlands. Barriers will need to be removed and provision for tidal waters and suspended sediments to nourish the marshes will be needed, specifically for large culverts and bridges where transportation paths cross wetlands. Losses of tidal wetlands in highly developed areas are unlikely to be replaced by migration, so extra planning efforts and negotiations need to be made on less developed and protected lands to ensure these critical habitats can be maintained.

The major impacts to freshwater and non-tidal wetlands will be expansion of wetlands into adjacent uplands due to rising sea level and ground water tables, as well as salinity intrusion associated with storms. For freshwater wetlands that occur within 10 feet elevation of the current MHHW mark (see yellow and pink bands on Map WE-1.4), rising sea levels will raise groundwater levels by similar amounts. Storm surges that punctuate rapid sea level rise rates will convert large portions of non-tidal freshwater wetlands (marsh, shrub scrub and forested) into tidal brackish and salt marshes due to salinity intrusion.

Recommendations

1. If saltmarsh preservation is a priority, the City should chart a path for providing upland migration of tidal marsh. The City or Conservation Commission should examine public and private lands and work with landowners and managers to establish migration areas for tidal marsh. Losses in ecosystem services from submerged tidal wetlands can be mitigated by allowing the high marsh to migrate into adjacent uplands and non-tidal wetlands.
2. The City should continue to recognize 100 feet as the minimum buffer width along all tidal wetlands and enforce a strict no-build policy in this buffer. In addition, 100 foot buffers should remain in place for all non-tidal wetlands that are subject to flooding by present day storm surges as shown on Map WE-1.2.
3. Municipal and private construction should include provisions for allowing tidal flow should also be designed to carry as much suspended sediment as possible to promote the accretion of tidal marshes. Barriers will need to be removed and provision for tidal waters and suspended sediments to nourish the marshes will be needed, specifically for large culverts and bridges where transportation paths cross wetlands.

4. City and State highway departments need to be contacted about the flooding risk from storms and provided with specific information about intentions to protect existing wetlands and the expected expansion of wetlands, especially at low-lying elevations.
5. Over the long term, a bridge is needed for Greenleaf Avenue and a tidal culvert designed for two-way flow is needed for Peverly Hill Road.
6. Pathways for marsh migration onto low-lying uplands and freshwater waters should be planned for Currier Cove Road, Belle Isle Road, the South Cemetery, Clough Drive, and Brackett Road.
7. Decisions will need to be made regarding the drainage that passes through the athletic fields at the High School and empties into Sagamore Creek.
8. Peirce Island will need to be fortified if the State Fishing Pier and swimming pool are to be maintained. A compromise might allow tidal marshes to migrate and occupy the remainder of the low-lying portions of the Island.
9. Discussion with managers of the Urban Forestry Center, South Cemetery, and Creek Farm as well as other protected lands managed by the City (e.g. Peirce Island) should seek to promote marsh migration over uplands
10. To extend the lifetime of existing saltmarshes, sediment amendments (called nourishment) could be made to the surface of the marsh to maintain elevations as sea level rises.
11. Losses of tidal wetlands in highly developed areas are unlikely to be replaced by migration, so extra planning efforts and negotiations need to be made on less developed and protected lands to ensure these critical habitats can be maintained.

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Appendix B

Planning and Technical Resources

I. Additional Considerations for Community Based Climate Adaptation Planning

A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC), *Chapter 5: Managing the Risks from Climate Extremes at the Local Level (2012)* provides an thorough overview of the considerations in preparing comprehensive community-based climate adaptation plans. The report states that in fostering sustainable and disaster-resilient areas, local response to climate extremes will require disaster risk management that acknowledges the role of climate variability and change and the associated uncertainties that will contribute to long-term adaptation. In order to anticipate the risks and uncertainties associated with climate change there are a number of widely emerging approaches and responses being applied [and tested in the U.S. and internationally]. These types of disaster risk management strategies protect and enhance natural resources at the local scale, improve local capacities to adapt to future climate, and may also address immediate development challenges and needs. Following is a synthesis of the Executive summary from this Chapter.[1]

Developing strategies for disaster risk management in the context of climate change requires a range of approaches, informed by and customized to specific local circumstances. These differences and the context (national to global, urban to rural) in which they are situated shape local vulnerability and local impacts.

The impacts of climate extremes and weather events may threaten human security at the local level. Vulnerability at the local level is attributed to social, political, and economic conditions and drivers including localized environmental degradation and climate change. Addressing disaster risk and climate extremes at the local level requires attention to much wider issues relating to sustainable development.

While structural measures provide some protection from disasters, they may also create a false sense of safety. Such measures – often providing temporary and/or limited protection - result in increased property development, heightened population density, and more disaster exposure. Current regulations and design levels for structural measures may be inadequate under conditions of climate change.

Sustainable land management is an effective disaster risk reduction tool.

Land management includes land use, planning, zoning, conservation zones, buffer zones, or land acquisition. Often it is difficult for local jurisdictions to implement

[1] Cutter, S., B. Osman-Elasha, J. Campbell, S.-M. Cheong, S. McCormick, R. Pulwarty, S. Supratid, and G. Ziervogel, 2012: Managing the risks from climate extremes at the local level. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 291-338.

such measures as a result of political and economic pressures for development. However, such measures are often less disruptive to the environment and more sustainable at the local level than structural measures.

Post-disaster recovery and reconstruction provide an opportunity for reducing weather- and climate-related disaster risk and for improving adaptive. An emphasis on rapidly rebuilding houses, reconstructing infrastructure, and rehabilitating livelihoods often leads to recovering in ways that recreate or even increase existing vulnerabilities, and that preclude longer-term planning and policy changes for enhancing resilience and sustainable development. Including local actors benefits the recovery process.

Disasters associated with climate extremes influence population mobility and relocation affecting host and origin communities. Most people return and participate in the post-disaster recovery in their local areas. If disasters occur more frequently and/or with greater magnitude, some local areas will become increasingly marginal as places to live or in which to maintain livelihoods. In such cases, migration and displacement could become permanent and could introduce new pressures in areas of relocation. For locations such as atolls, in some cases it is possible that many residents will have to relocate. In other cases, migration is an adaptation to climate change, with remittances supporting community members who remain at home.

Integration of local knowledge with additional scientific and technical knowledge can improve disaster risk reduction and climate change adaptation. Local populations document their experiences with the changing climate, particularly extreme weather events, in many different ways, and this type of self-generated knowledge induces discussions of proactive adaptation strategies and can uncover existing capacity within the community and important current shortcomings.

Ecosystem management and restoration activities that focus on addressing deteriorating environmental conditions are essential to protecting and sustaining people's livelihoods in the face of climate extremes. Such activities include, among others, watershed rehabilitation, agro-ecology, and forest landscape restoration. Moreover, provision of better access to and control of resources will improve people's livelihoods, and build long-term adaptive capacity. Such approaches have been recommended in the past, but have not been incorporated into capacity building to date.

Local-level institutions and self-organization are critical for social learning, innovations, and action; all are essential elements for local risk management and. Adaptive capacities are not created in a vacuum – local institutions provide the enabling environment for community-based adaptation planning and implementation. Local participation (community-based organizations, development committees) contributes to empowering the most vulnerable and strengthening innovations. Addressing political and cultural issues at the local levels are fundamental to the development of any strategy aiming at sustained disaster risk management and adaptation.

Local participation supports community-based adaptation to benefit management of disaster risk and climate extremes. However, improvements in the availability of human and financial capital and of disaster risk and climate information customized for local stakeholders can enhance community-based adaptation.

- **Mainstreaming disaster risk management into policies and practices provides key lessons that apply to climate change adaptation at the local level.** Addressing social welfare, quality of life, infrastructure, and livelihoods, and incorporating a multi-hazards approach into planning and action for disasters in the short term, facilitates adaptation to climate extremes in the longer term.

Note: The report's Executive Summary also includes statements not included in this report relating to the importance of effectively communicating scientific information, engaging community residents and stakeholders, and ensuring equitable access to information and services.

II. Federal and State References/Resources

1. State Support and Guidance for Implementation of Climate Adaptation

a) NH Natural Hazard Mitigation Plan 2010

Chapter III Hazard Analysis provides an overview of severe storm event, flood history, and hurricane occurrence in NH. According to National Flood Insurance Claims data (NHOEP July 2010), the number of NFIP policies, insurance dollars in force, total paid losses, total paid amount, and total repetitive loss properties in Rockingham County exceed all other counties in the state. The Summary section of this chapter describes the rationale and need for further analysis and comprehensive planning efforts in the seacoast area to improve adaptation and mitigation measures that address the impacts of sea level rise, storm surge and severe storm events.

The Portsmouth Coastal Resilience Initiative project will directly address or directly support nearly all of the Objectives and Actions in Chapter IV Risk Assessment, Chapter VI Coordination of Local Mitigation Planning, and Chapter VII Mitigation Measures and Action Plan.

b) NH Coastal Program, 2010 Section 309 Assessment and Strategy

The NH Coastal Program, 2010 Section 309 Assessment and Strategy identifies sea level rise as natural hazard that poses a long term risk to NH's coastal zone. It is the Coastal Program's opinion that if appropriate actions are taken now (in the short term) to plan for sea level rise, much of the risk associated with projected long term impacts can be reduced. Overall, the report supports improvements to policies and programs related to coastal hazards, recognizes that changes in the current climate conditions are already being experienced, and identifies the need to implement appropriate measures now to improve preparedness, such as development of a comprehensive Coastal Adaptation Plan.

The Portsmouth Coastal Resilience Initiative project will directly address or directly support the development of detailed local information to enable proactive planning, and address gaps and needs identified by this report.

c) NH Climate Action Plan

In 2009, the Governor's Climate Change Policy Task Force released the NH Climate Action Plan, containing 10 overarching strategies necessary to meet the states greenhouse gas reduction and climate change related goals. Goal 9 states "Plan for how to address existing and potential climate change impacts". *The Portsmouth Coastal Resilience Initiative project will directly address this stated goal of the NH Climate Action Plan.*

d) NH Coastal Adaptation Workgroup

Formed in December 2009, the New Hampshire Coastal Adaptation Workgroup (NH CAW) is a voluntary group of 19 organizations, agencies and non-profit groups, and 27 individual members, working to help communities in New Hampshire's coastal watershed and seacoast area prepare for the effects of extreme weather events and potential long term impacts of changes in climate. NH CAW provides communities with education, facilitation and guidance through public workshops, their NH Stormsmart website (www.nh.stormsmartcoast.org) and through direct engagement and assistance.

NH CAW's unique strength is its capacity for collaboration among not only its members but also with other researchers and practitioners at all levels within the state and throughout New England. This collaboration focuses on two important goals - improving access to science and information, and developing actions and strategies that build resiliency in human systems and the natural environment. NH CAW provides a coordinated, strategic approach to educate and provide technical assistance to improve the resilience of coastal communities. CAW developed and offers workshops to provide a "community of learning" where participants share stories and insights around the issues and tools that can assist with implementation of adaptation strategies. The results of the coordinated efforts of NH CAW are many and widespread; municipalities know who to turn to for assistance; a network and community of climate leaders who know and understand the critical nature and growing concerns about changing climate; and the organizations and agencies researching climate and climate responses, and who provide technical assistance work together.

Implementation and use of products and data from the Portsmouth Coastal Resilience Initiative project will help support activities and collaboration with the NH Coastal Adaptation Workgroup.

a. New Hampshire Division of Historical Resources, State Historic Preservation Office

The New Hampshire Division of Historical Resources, State Historic Preservation Office is a valuable resource for information and guidance on protecting, preserving and managing historic resources within areas impacted by current and projected flooding.

Contact information: 19 Pillsbury Street - 2nd floor, Concord, NH 03301-3570

Email: preservation@dcr.nh.gov. Phone: 603-271-3483 / Fax: 603-271-3433

2. Federal Support and Guidance for Implementation of Climate Adaptation

a) U.S. Department of Transportation – Federal Highway Administration

In a Memorandum of September 2012, *Eligibility of Activities To Adapt To Climate Change and Extreme Weather Events Under the Federal-Aid and Federal Lands Highway, the Federal Highway Administration Programs*, the Federal Highway Administration states that activities to plan, design, and construct highways to adapt to current and future climate change and extreme weather events are eligible for reimbursement under these programs. These adaptation activities can be applied to existing and planned facilities to protect and extend the useful life of Federal highway investments and conserve funding resources. Examples of eligible activities include:

- Vulnerability and risk assessments of Federal aid-eligible highways related to climate change and extreme weather events.

- Consideration of climate change and extreme weather events in highway project development, environmental review and design work.
- Construction projects or features to protect existing eligible assets from impacts and damages associated with climate change and extreme weather events.
- Evaluation of potential impacts of climate change and extreme weather events on asset management cycles, life cycle costs, etc.

The Memo states that creating a more resilient transportation system is a priority of FHWA and is consistent with a U.S. Department of Transportation policy statement in June 2011 on climate change adaptation. The statement noted DOT's intention to integrate consideration of climate adaptation into its planning, operations, policies and programs, and also described some of the guiding principles of its policy.

b) <u>Federal Emergency Management Agency</u>

The Federal Emergency Management Agency (FEMA) recently released an Administrative Policy Directive 2011-OPPA-01 FEMA Climate Change Adaptation Policy Statement (2011). The statement outlines the purpose, scope, policy and procedures, and responsibilities of FEMA in carrying out comprehensive climate adaptation planning and implementation. The purpose statement states "this policy statement is to establish an Agency-wide directive to integrate climate change adaptation planning and actions into Agency programs, policies and operations." The statement applies to all Agency activities and is intended to guide FEMA personnel responsible for oversight and implementation of organizations plans, policies and procedures. I also states that "The challenges posed by climate change - such as more intense storms, frequent heavy precipitation, heat waves, drought, extreme flooding, and high sea levels – could affect the Agency's ability to fulfill its mission."

The Policy Directive identifies seven initial actions the Agency will take to help integrate climate change adaptation considerations into programs and operations. These actions also "align with the Agency's vision of a Whole Community approach to emergency management, as it is expected that extensive collaboration with the public, at all levels of government. The private sector, non-governmental organizations, and community organizations will be required. ***The scope of this Policy Directive offers strong support for local actions and planning with respect to climate change adaptation.***

Historic Structures

The bulletin FEMA P-467-2 *Floodplain Management Bulletin Historic Structures (May 2008)* by the National Flood Insurance Program (NFIP) provides comprehensive guidance on how to minimize impacts to historic structures, and explains how the NFIP defines historic structure and gives relief to historic structures from floodplain management requirements (44 CFR §60.3). This bulletin also provides guidance on mitigation measures that can be taken to minimize the devastating effects of flooding to historic structures. The following is an excerpt from the Introduction of this publication which explains the incentives against and benefits in favor of implementing proactive measures to protect historic structures in highly vulnerable floodplains and coastal areas.

> The National Flood Insurance Program (NFIP) gives special consideration to the unique value of one of our Nation's most significant resources – its historic buildings, landmarks, and sites. It does so in two ways.
>
> First, the NFIP floodplain management regulations provide significant relief to historic structures. Historic structures do not have to meet the floodplain management requirements of the program as long as they maintain their historic structure designation. They do not have to meet the new construction, substantial improvement, or substantial damage requirements of the program. This exclusion from these requirements serves as an incentive for property owners to maintain the historic character of the designated structure (44 CFR §60.3). It may also serve as an incentive for an owner to obtain historic designation of a structure.
>
> Secondly, a designated historic structure can obtain the benefit of subsidized flood insurance through the NFIP even if it has been substantially improved or substantially damaged so long as the building maintains its historic designation. The amount of insurance premium charged the historic structure may be considerably less than what the NFIP would charge a new non-elevated structure built at the same level. Congress requires that the NFIP charge actuarial rates for all new construction and substantially improved structures (National Flood Insurance Act of 1968, 42 U.S.C. 4015).
>
> Although the NFIP provides relief to historic structures from having to comply with NFIP floodplain management requirements for new construction, communities and owners of historic structures should give consideration to mitigation measures that can reduce the impacts of flooding on historic structures located in Special Flood Hazard Areas (44 CFR §60.3). Mitigation measures to minimize future flood damages should be considered when historic structures are rehabilitated or are repaired following a flood or other hazard event. Qualified professionals such as architects, historic architects, and engineers who have experience in flood mitigation techniques can help identify measures that can be taken to minimize the impacts of flooding on a historic structure while maintaining the structure's historic designation.

A highly informative publication - *Disaster Mitigation for Historic Structures: Protection Strategies (August 2008)* by the 1000 Friends of Florida on behalf of the Florida Department of State, Division of Historical and Cultural Resources and the Florida Department of Emergency Management - details construction methods and materials, mitigation and rehabilitation measures, and case studies of mitigation actions implemented for historic structures. Refer specifically to Section 2 for a guide to evaluating appropriate mitigation options for historic structures. The publication is available at http://www.1000friendsofflorida.org/building-better-communities/historic-preservation/.

c) Association of State Floodplain Managers

The Association of State Floodplain Managers is a national non-profit organization of 15,000 professionals involved in floodplain and flood risk management, flood hazard mitigation, the National Flood Insurance Program, and flood preparedness, warning, and recovery. Information about flooding and flood mitigation issues can be found on the ASFPM website www.floods.org or from Executive Director Chad Berginnis at cberginnis@floods.org, 608-828-3000.

Recently, the Association of State Floodplain Managers released a report *Hurricane Sandy Recovery: Using Mitigation to Rebuild Safer and More Sustainable Communities* (Release date 12/13/2012). The report outlines some of the actions that communities, individuals, businesses, and state and federal officials can take to reduce the catastrophic damage and risks from events like Hurricane Sandy in the future.

The history of our nation and the world provide ample evidence that large natural disasters can occur frequently, and with a vengeance. This region of the east coast experienced another event, Irene, just a year ago. These storms had similar paths and strength, but resulted in totally different impacts.
While the Hurricane Sandy damage throughout the Atlantic Region, New York, and New Jersey coasts and cities is one of the worst the region has suffered, similar large events – and the increasing likelihood of similar future events – should teach us valuable lessons that we must consider in the days, weeks, and months ahead. There is a need to take this disaster and use it as an opportunity to avoid the next one, not to rebuild in a way that will ensure another disaster or just have less damage and disruption next time. We should react to this disaster in a different way than in the past. The rules need to change or we will keep repeating our mistakes, proving, yet again, that we have not learned the lessons of the past.

The report outlines a series of proactive strategies aimed at increasing resilience in the built environment, protection communities from harm and risk, and maintaining critical natural and coastal systems. The ASFPM recognizes that: 1) there will be pressure to roll back existing standards, to rebuild quickly and to not incorporate higher standards to create safer communities; and 2) that right now is the best window of opportunity to incorporate actions to make those communities impacted by Hurricane Sandy more resilient from future flood events. Following are their major recommendations:

- Rebuilding in Damaged Areas—Do It Smarter and Safer!
- Mitigate Wherever Possible
- Provide Resources and New Authority/Flexibility for Mitigation Programs
- Protect and Restore Natural Floodplain and Coastal Systems

1. Legal Concerns for Regulating Floodplains and Coastal Areas

In several states, court cases have upheld the rights of municipalities to restrict where and what can be constructed in highly vulnerable coastal areas. Legal challenges to coastal zone regulations are described in detail in the publication *No Adverse Impact Status Report: Helping Communities Implement NAI*, Association of State Floodplain Managers (June, 2002). This report explains how to incorporate NAI into ongoing, everyday community activities and provides detailed information on five community efforts, showing how they incorporated No Adverse Impact regulations and policies. This report is available on the ASFPM website at http://www.floods.org/index.asp?menuid=745&firstlevelmenuid=188&siteid=1.

Another useful publication by the ASFPM is the Coastal No Adverse Impact Handbook (2007) available at http://www.floods.org/index.asp?menuid=340. This handbook describes NAI is an approach by which the action of any community or property owner, public or private, is not allowed to adversely affect coastal resources or the property or rights of others. NAI can help establish a strong foundation that reduces community legal vulnerability to “takings” and negligence claims.

Additional ASFPM publications about No Adverse Impacts include: Common Legal Questions about Floodplain Regulations in the Courts; Legal Questions: Government Liability and No Adverse Impact Floodplain Management; No Adverse Impact: A Toolkit for Common Sense Floodplain Management (2003); No Adverse Impact: Community Liability and Property Rights: As Mayor or County Commissioner, should you worry about your liability in the event of a flood?; Property Rights and Community Liability: The Legal Framework for Managing Watershed Development (2007); and No Adverse Impact: A Common Sense Strategy for Protecting your Property (2001).

2. Vermont Law School Legal Opinion for the Lamprey River Flood Study

Assessing the Risk of 100-year Freshwater Floods in the Lamprey River Watershed of New Hampshire Resulting from Changes in Climate and Land Use (2012), Vermont Law School Land Use Clinic Report

Following is an excerpt from the Executive Summary: <u>New Floodplain Maps for a Coastal New Hampshire Watershed and Questions of Legal Authority, Measures and Consequences</u>

This report assesses various types of legal risks communities in the Lamprey River Watershed may be concerned about as a result of adopting new flood management regulations and policies. To assess these risks we identified four potential legal challenges related to: (1)
municipal liability, (2) enabling authority, (3) the use of climate maps as evidence, and (4) takings. In general, the risk of municipal liability is low, so long as municipalities follow sound planning principles. Not only is the level of risk low, the federal government *encourages* communities to enact certain types of regulations designed to reduce flood hazards. This encouragement provides states and municipalities an additional layer of assurance with respect to adopting and defending revised or new flood regulations. Under federal floodplain guidelines, states and municipalities are encouraged to establish more stringent regulations above and beyond minimum federal requirements. For example, the Federal Emergency Management Agency (FEMA) advises communities to enact stricter regulations through its Community Rating System Program. This document also provides a list of additional regulatory and non-regulatory tools communities can use to both help reduce risk of flood hazards and avoid legal quandary.

With emphasis on New Hampshire, we provide examples, case studies, and legal review of relevant judicial precedents to help communities in the Lamprey River Watershed reduce risk as follows.

Municipal Liability: Municipalities are very unlikely to be held liable for failure to adopt new floodplain maps. This rule is based on several rulings by the courts that defer to decisions (or non-decisions) made by government employees. The most likely way for a town to ever be found liable is under the law of negligence, where a municipality has a legal duty to an individual or group and fails to perform that duty. Municipalities owe no duty to the general public. This rule is based on the fact that the government would not provide services at all (particularly fire and police) if it were held liable when those services failed to protect citizens. Even if a municipality was found negligent, it would very likely be immune from liability. Towns are generally immune from liability based on actions involving discretionary judgment. It is very unlikely that a municipality could be held liable for a planning activity, such as the policy choice to reference or adopt floodplain maps.

Recommendations: There is no need for municipalities to take action related to municipal liability for failing to adopt floodplain maps. Note that it is possible – though extremely unlikely – that the New Hampshire legislature may reverse municipal liability protections. A method for adoption of stricter floodplain standards and maps could be through participation in the Community Rating System. a voluntary incentive program which recognizes a community's efforts to go above and beyond the minimum NFIP requirements. Exceeding the minimum standards gives a community discounts on insurance premiums.

Enabling Authority: In New Hampshire, towns cannot enact regulations unless they are authorized to do so under enabling statutes. There are many potential sources of enabling authority for regulations based on floodplain maps. We provide a list of statutes in section 4. Courts almost always find that New Hampshire municipalities soundly act within their enabling authority. Unless a statute specifically describes the limits of the authority and the municipality exceeds an express limit, the regulation will be upheld.

Recommendations: Clearly identify the enabling statute or statutes authorizing municipal floodplain ordinances. Check the language of the statute to make sure specific authorizations are not being exceeded. When enacting new ordinances related to or referencing new floodplain maps, use the list of potential enabling statutes from this document as a resource.

The Use of Projected Future Climate Conditions: Climate science may be challenged in court and during administrative hearings as being unreliable. The municipalities within the Lamprey River Watershed may rely in part on new climate data or climate projections based on model output to justify the enactment of new regulations. Given the susceptibility of climate data and model output in court, it is important to know whether climate science could be questioned if an ordinance based on current or future climate conditions is challenged. In New Hampshire, scientific data is very rarely needed to justify the enactment of ordinances.

Recommendations: To ensure the use of future climate conditions and related floodplain maps stands up in court, identify in the ordinance the reason you are adopting or referencing the maps. As long as you have a reasonable justification for using the maps, the maps will be upheld. Examples of a reasonable basis for an ordinance include protecting the health and welfare of the community from the dangers of flood hazards.

Takings: A municipality can be subject to takings claims when a regulation deprives a landowner of all economically viable uses of his land or when the regulation goes "too far" and infringes on private property rights.

Recommendations: Regulatory mechanisms should be enacted in a way that preserves some economically viable use of the land. For example, do not create distance requirements for setbacks that cover an entire parcel and thereby prohibit the landowner from being able to build on any part of the property. Indicate that the purpose of the regulation is to promote hazard mitigation. Make the basis for floodplain regulation clear in the master plan. If necessary, amend your plan to include goals and policies for floodplain management and indicate that the purpose includes the health, safety, and welfare of citizens in the community.

Appendix C

Mapping Methods and Metadata

LiDAR (Light Detection And Ranging data)

The final NH Coastal LiDAR data set, collected in 2010, is now available. The distribution includes the unclassified .LAS files, the classified .LAS files, and the 2-meter Digital Elevation Model (DEM). Supporting documentation is also included. Total size of the distributed data: 270 GB. Due to the size of the data set, distribution is by external drive only. To preview the LiDAR data set as either a DEM or a shaded relief map, please visit the GRANIT website, select "GRANITView" and open the "Topography" folder.
[LiDAR information eferenced from the NH GRANIT Website at http://www.granit.unh.edu/Calendar/ViewEvent?EVENT_ID=1418&NAV=NO]

SELECTION OF ELEVATIONS MODELED AND MAPPED

Flood maps showing the spatial extent of these estimates of future coastal flooding elevations for the New Hampshire seacoast were developed using the new digital elevation model generated from the recently acquired LiDAR (Light Detection And Ranging) data.

Sea level rise modeling using LiDAR (Light Detection and Ranging) data at increments (change in feet) less than 1.9 feet does not meet National Map Accuracy Standards (Gesch et. al, 2009). Therefore, combining scenarios to capture a range of elevations is recommended. Additionally, modeling elevations at or below MHHW is not recommended due to lack of tidal constraints on the LiDAR data collection (i.e. data collected at various tidal stages). Therefore, using 3-foot depth intervals, the minimum elevation that can be modeled is MHHW + 3 feet, or approximately 7.5 feet NAVD, which will be the lowest proposed mapped elevation. Also shown above are the upper and lower bounds at the 95% confidence interval for the LiDAR data (+/- 0.96 feet) for each mapped elevation. As indicated by these bounds, the proposed mapped elevations (7.5, 11.5, 13.5, and 18 feet in brown shading) collectively capture all of the selected scenarios.

METADATA

Summary
Feature classes representing the analysis performed for the Portsmouth Climate Resilience Initiative (CRI) project are provided as Esri-format shapefiles within a single compressed file (**portsmouth_cri_p11fld_20121008.7z)**. This file can be uncompressed using various programs, including the free open-source program 7-zip (http://www.7-zip.org).

Within the main folder (**/shp**) are several subfolders, each containing both intermediate and final analysis results. The phrase “flooding” refers to “coastal flooding” unless prefaced by the adjective “freshwater.”

The folder names and files they contain are listed in the table below.

Folder name	***Contents***	***Comments***
p11fld	Raw elevation analysis polygons based on 2011 NH GRANT Digital Elevation Model	Four coastal flood scenarios
p11fld_230	Analysis of flooding at 2.3 meters relative to the North American Vertical Datum of 1988 (NAVD)	6.0 feet NAVD
p11fld_350	Analysis of flooding at 3.5 meters NAVD	11.5 feet NAVD
p11fld_410	Analysis of flooding at 4.1 meters NAVD	13.5 feet NAVD
p11fld_550	Analysis of flooding at 5.5 meters NAVD	18.0 feet NAVD
p11fld_freshwater	Freshwater flooding	Incorrectly named as p11fld, should be ports_cri_freshwater
ports_cri	Source datasets	Sources: Portsmouth, GRANIT, RPC

Flood polygons (p11fld)

DRAFT: Detailed discussion to follow. Key points:

- For all feature classes provided, **p11fld** represents analysis performed using the 2011 two-meter digital elevation model (DEM) provided by GRANIT
    - Horizontal Coordinate System: UTM Zone 19N meters (WGS84)
    - Horizontal Bounds of Raster Analysis: City of Portsmouth Boundary plus one mile
    - Vertical Coordinate System: NAVD meters
- DEM raster analysis was performed in the native coordinate system (UTM19N). Resulting flood polygons were then re-projected to NH State Plane meters for indicator analysis
- Four polygon feature classes (**pfld11_MMM_fc**) are provided in the **p11fld** folder, each representing the areas in Portsmouth that are located at elevations at or below MMM, where
    - MMM is the elevation in centimeters NAVD
    - fc indicates raw analysis results, which includes ponds and other topographic depression areas not necessarily hydraulically connected to the ocean under flood conditions

Freshwater Flooding (p11fld_freshwater)

One polygon feature class (freshwater_flooding) is provided representing digitization of hand-drawn polygons provided on a paper map during a meeting with Portsmouth Department of Public Works (DPW). These polygons delineate the approximate

boundaries of known areas of freshwater flooding that have been observed by DPW personnel during rain events.
DRAFT: This folder is incorrectly named with a p11fld prefix, which incorrectly implies that it was developed with the DEM. This folder should be named ports_cri_freshwater.

Source Datasets (ports_cri)
Three subfolders are provided that contain various feature classes derived from the three primary source datasets provided for this project. Naming conventions include the folder name representing the source of the original datasets, and the feature class name. With the exception of the RPC folder, the feature classes are named using the following naming convention: **SourceFC_metric_Portsmouth**, where:

- SourceFC is the name of the source feature class
- Metric indicates that the feature class has be reprojected to NH State Plane meters
- Portsmouth indicates that the horizontal boundaries of the feature class have been clipped to match the horizontal boundaries of the City of Portsmouth
    - Some feature classes did not require clipping

The RPC folder contains two original feature classes provided by RPC, copies of these two feature classes re-projected to metric, and a final feature class that contains a combination of the two feature classes with duplicates features removed.

Flood Impacts Analysis
Each of the remaining four subfolders contains the results of the analyses performed for each flooding scenario. The naming convention is p11fld_MMM, where MMM is the flood elevation in centimeters NAVD.
Within each folder are three subfolders and a collection of feature classes:

- The folder named **utm19** contains two feature classes named using the following naming convention:
    - **p11fld_MMM_ocean** represents the pfld11_MMM_fc polygon without ponds and other topographic depression areas not necessarily hydraulically connected to the ocean under flood conditions
    - **p11fld_MMM_depth** represents the same horizontal boundaries as p11fld_MMM_ocean with individual polygon features representing the depth of flooding
- The folder named **nh_metric** contains two feature classes that represent these same two (utm19) feature classes reprojected to NH State Plane meters
- The folder named **pfldMMM_buildings** represents the results of flooding impact analysis on buildings, discussed in more detail below
- The feature classes are named using the following naming convention: **p11fld_MMM_indicator**, where indicator indicates the indicator analyzed, discussed in more detail below, and directly or generally indicates the source dataset (see ports_cri above) that was analyzed.

All flood impact analysis was performed in NH State Plane metric coordinate system. The horizontal coordinate system for all feature classes representing impact analysis results is NH State Plane meters.

Flood Impact Indicators

Indicators feature classes analyzed are listed below. Indicators feature classes included points, lines and polygons, and each type of class was generally analyzed using the methodology described below.

Point feature analysis was performed by identifying all indicator features that were located within the flood polygon for the specified scenario (p11fld_MMM_ocean). Point feature classes for each indicator (p11fld_MMM_indicator) were then generated that represent all point features impacted.

Polyline feature analysis was performed by clipping indicator features such that the horizontal boundaries of the resulting polyline were within the horizontal boundaries of the flood polygon for the specified scenario (p11fld_MMM_ocean). Polyline feature classes for each indicator (p11fld_MMM_indicator) were then generated that represent the impacted portions of the indicator polyline features.

Polygon feature analysis, with the exception of building analysis (discussed below), was performed by clipping indicator features such that the horizontal boundaries of the resulting polygon were within the horizontal boundaries of the flood polygon for the specified scenario (p11fld_MMM_ocean). Polygon feature classes for each indicator (p11fld_MMM_indicator) were then generated that represent the impacted portions of the indicator polyline features.

Infrastructure indicators included the features listed below. Feature class names for the analysis results (provided in the **p11fld_MMM** folders) are also listed below:

- Point features
    - Critical Facilities (p11fld_MMM_CritFac)
        - Includes Sewer Facilities
    - Culverts (p11fld_MMM_culverts)
    - CSOs (p11fld_MMM_sewer_cso)
    - Stormdrain Outfalls (p11fld_MMM_stormdrain_outfalls)
    - Waste Water Treatment Plant
        - Single point feature flooded under all scenarios
            - SewerDrainEnd_WWTP_metric_Portsmouth
                - found in the **ports_cri** folder
- Polyline features
    - Road Centerlines (p11fld_MMM_road_centerlines)
    - Bridges (p11fld_MMM_bridges)

Environmental / Ecological indicators included the polygon features listed below. Flood impact analysis was performed on these features for only the 18 foot NAVD flood scenario. Feature classes names for the analysis results (provided in the **p11fld_550** folder) are also listed below:

- Eel Grass (p11fld_550_Eelgrass)
- Conservations Lands (p11fld_550_d-conservation_consnh)
- Wellhead Protection Areas (p11fld_550_WellheadProtectionAreas)
- Hodgson Brook Watershed (p11fld_550_watersheds_hodgson)
- No Impacts
    - Freshwater Flood Storage

New Hampshire Wildlife Action Plan (NH WAP) indicators included the aggregated polygon features listed below. Flood impact analysis was performed on these aggregated features for only the 18 foot NAVD flood scenario. Feature classes names for the analysis results (provided in the **p11fld_550** folder) are also listed below:

- Forests (p11fld_550_d-wap_forests)
- Grasslands (p11fld_550_d-wap_grasslands)
- Salt Marsh (p11fld_550_d-wap_saltmarsh)
- Unfragmented Habitat Blocks (p11fld_550_d-wap_unfrag)
- No Impacts