ADAPTING TO CLIMATE CHANGE IN THE OCEAN STATE: A STARTING POINT

RHODE ISLAND CLIMATE CHANGE COMMISSION
2012 PROGRESS REPORT

May, 2012

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Cover Photos: Sappowet Marsh, R. Hancock; Central Bridge 182, RIDOT; Coalition for Water Security

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Working Group Co-Chair Natural Resources and Habitat

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INTRODUCTION

The Rhode Island Climate Risk Reduction Act of 2010 (RIGL 23-84) established the Rhode Island Climate Change Commission, a standing, independent Commission comprised of twenty-eight representatives from the General Assembly, Rhode Island executive agencies, business organizations, environmental organizations, and community groups. The Commission's mandate is to "study the projected impacts of climate change on Rhode Island, to identify and report methods of adapting to these climate change impacts in order to reduce likely harm and increase economic and ecosystem sustainability, and to identify potential mechanisms to mainstream climate adaptation into existing state and municipal programs including, but not limited to, policies plans, infrastructure development and maintenance." (RIGL 23-84-3(b)) The Commission serves to review and advance legislative recommendations, coordinate and foster climate adaptation planning and programs across Rhode Island, facilitate the "mainstreaming" of climate change and adaptation policies in existing state and local law and policy, and increase the capacity of decision-makers and citizens to prepare for and proactively adapt to the consequences of climate change.

This 2012 progress report of the Rhode Island Climate Change Commission summarizes its work since its inaugural meeting in December 2011. Specifically, this report:

- Reviews key climate risks and social, economic, and environmental vulnerabilities to them, as well as current and projected impacts upon human health and welfare, public and private infrastructure, and the natural environment;

- Identifies current private and public climate change initiatives and their contributions to climate change adaptation;

- Highlights adaptation needs yet to be addressed; and

- Outlines the Rhode Island Climate Change Commission's next steps in the coming year as it prepares to issue the next report to the RI General Assembly and Rhode Islanders in the spring of 2013.

At the December 2011 meeting the Commission established three working groups: 1) Key Infrastructure and the Built Environment, 2) Natural Resources and Habitat, and 3) Human Health and Welfare. Building upon the efforts of similar climate risk assessments in Massachusetts and Connecticut, these Working Groups have begun to review and summarize the key climate risks and vulnerabilities that will increasingly affect Rhode Island and southern New England, and adaptation efforts already in underway at the local, state and regional level. The working group summaries included in this report detail the results of their efforts since January 2012. Each working group brought significant expertise to their issue through active participation by Commission members and the input of scientists, government officials and public and private interest representatives. The Commission and its working groups must continue to seek such external inputs to support its work and advance its mission.

The initial work of the working groups has also helped to acquaint Commission members about climate change risks and adaptation strategies. This in turn will help the Commission communicate about the emerging climate imperatives to all Rhode Islanders and their elected leadership.

Climate Change Commission Milestones

2011	
November 21	Organizational Session to plan Commission's First Meeting
December 6	Inaugural Meeting of RI Climate Change Commission
December 14	Next Steps Meeting with Organizers
2012	
January 6	Meetings of each of the three Working Group Co-chairs
February 8	Human Health Working Group Meeting
February 17	Key Infrastructure and Built Environment co-chairs Meeting
February 24	Natural Resources and Habitat Working Group Meeting
March 16	Key Infrastructure and Built Environment Working Group meeting
April 3	Co-Chair joint meeting
April 25	Full RI Climate Commission Meeting, Presentation of Draft Progress Report
May 30	Submittal of 2012 Progress Report

The following section briefly summarizes observed and projected climate change impacts upon Rhode Island and New England. Subsequent sections summarize the findings to date of the Commission's working groups, followed by Appendix A identifying existing initiatives relative to climate change in Rhode Island.

CLIMATE CHANGE IN RHODE ISLAND

The impacts of climate change upon Rhode Island's built and natural environments are wide-ranging, discernible and documented, and, in many instances are growing in severity. The climatological sciences with increasing temporal and spatial accuracies are projecting substantial future impacts upon Rhode Island from more severe hurricanes and Nor'easters, greater frequency of other extreme weather events such as heat waves, and fundamental, rapid transformations of terrestrial and aquatic ecosystems, their structures and functions, and natural resource values they generate and sustain.

Rhode Island is already beginning to feel the impacts of a shifting local climate (Heffner et al. 2012[1]), and the changes are speeding up sharply. Average air temperatures have increased 1.7°F from 1905 to 2006, and Narragansett Bay temperatures have risen four degrees at the surface just since the 1960s (Table 1).

Table 1. A summary of observed and documented climate change trends described at the global, regional, and state levels. The trends and impacts are compiled in a more detailed science summary for Rhode Island. (URI Coastal Resources Center/RI Sea Grant, 2012)

CLIMATE CHANGE VARIABLE	**OBSERVATIONS OF RECENT CHANGE**		
	Global	**US Northeast**	**Rhode Island**
Increase in mean air temperature	0.74°C (1.33°F) in last 100 years	0.83°C (1.5° F) since 1900	0.94° C (1.7°F) from 1905 to 2006
Increase in average annual ocean temperature	Consistent increase since the 1960's, with 2007 as the warmest year on record	Average annual increase of 1.2°C (2.2°F) since the 1970's	2.2 C (4°F) at surface of Narragansett Bay since the 1960's
Sea Level Rise	• average rate of increase of 1.8 mm (0.07 in) per year during the 20th century - a rate greater than that of the preceding eight centuries. • The rate almost doubled to 3.4 mm (0.13 in) per year from 1993-2003	-	• 2.6 mm (0.1 in) rise per year since 1930 at Newport's tide gauge • Between 1990 and 2009 this rate increased to 3.6 mm (0.14 in) per year
Increased Storminess	Increased Severity of tropical cyclones since the 1970s.	Increased severity of tropical cyclones in the North Atlantic	-
Changing Precipitation and Weather	Rainfall increased in mid-latitudes and decreased in the subtropics of the Northern Hemisphere over the last 50 years	5-17 percent increase in regional precipitation over the last century	• Increased 3 mm (0.12 in) per year (rain and snow) • Annual mean wind speed at T.F. Green Airport has significantly declined since at least the 1960s
Ocean acidification	Surface pH is 0.1 units lower than pre-industrial levels	-	-

[1] Heffner, L., Williams, R., Lee, V., Rubinoff, P., and Lord, C. 2012. Climate Change & Rhode Island's Coasts: Past, Present, and Future. Coastal Resources Center and Rhode Island Sea Grant, University of Rhode Island, Narragansett, R.I.

Since 1962, the number of days with temperatures over 90°F in the Northeastern U.S. has nearly doubled (Frumhoff et al. 2007[2]). Currently, southern and inland regions of the Northeast experience up to 20 days of temperatures above 90°F each year.These regions now experience about 2 days above 100°F in cities. More frequent extreme heat events will increase the vulnerability of many elderly and poor Rhode Islanders to heat-related illnesses. Air quality plummets during periods of extreme heat, driving increased asthma, heat-related illnesses and even deaths.

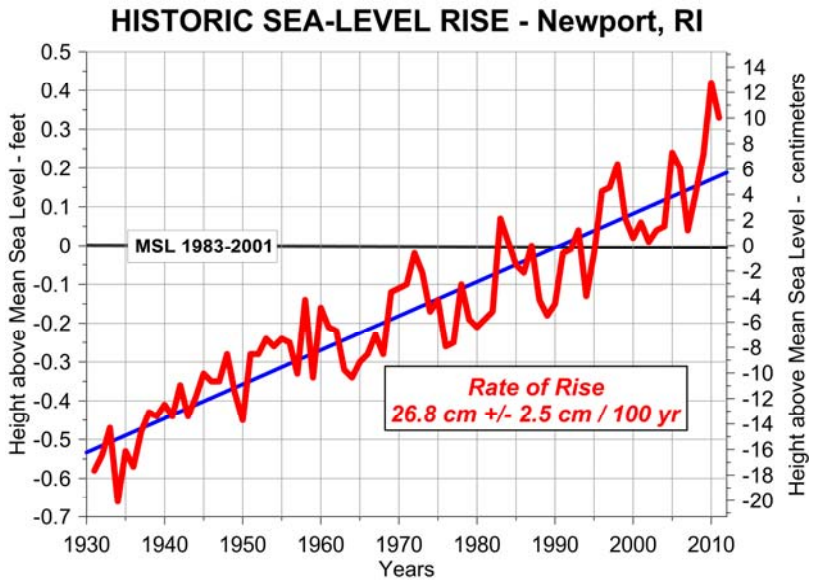

Figure 1: This graph shows the difference between average sea level at Newport, R.I., from 1983 to 2001 and mean annual sea level plotted for each year between 1930 and 2011. The blue trend line shows a 10.6 inch (26.8cm) increase in sea level per century. *Graph courtesy of Jon Boothroyd, 2012. Data from: http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8452660%20Newport,%20RI*

Average sea level has risen ten inches since the 1930's, and the rate of sea level rise is accelerating (Figure 1). The frequency of intense rainfall events is increasing, while hot and dry spells are lengthening.

We are beginning to see the impacts of climate change on Rhode Island's economy. Rhode Island's farmers are experiencing lengthened seasons but less predictable rainfall patterns. Predominant fish species in Narragansett Bay are shifting from cold-water, bottom dwelling species to warm-water, water-column habitat species. An increase in jellyfish populations and algae blooms are posing threats to the quality of Rhode Island's water recreation assets upon which much of the state's substantial tourism industry relies.

Many of these climatological, oceanographic, and ecological changes and transformations are occurring more rapidly than originally anticipated by scientists, who have historically been cautious and conservative about predicting future manifestations of global warming, climate change, and biospheric responses to them.

Climate change indisputably may produce relatively benign impacts as well. For example, warm weather tourism in Rhode Island may increase in the spring and fall and new recreational and commercial fisheries may as warm water tolerant finfish populations grow in our coastal and

[2] Frumhoff, P. C., J. J. McCarthy, J. M. Melillo, S. C. Moser, and D. J. Wuebbles. 2007. Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Rhode Island report of the Northeast Climate Impacts Assessment (NECIA). Cambridge, MA: Union of Concerned Scientists (UCS).

adjacent marine waters. But these positives will be overwhelmed by the many deleterious impacts that can as well be expected to interact synergistically.

In sum, Rhode Island will experience warmer air and water temperatures, more extreme weather events such as droughts, intense precipitation, severe storms and flooding, increasing rates of sea level rise, shorter winters and longer summers, and less snowfall and ice coverage. Finally, ocean acidification has more recently emerged as a very significant risk posed by unchecked (and still increasing) global $C0_2$ emissions.

Climate change poses significant risks for Rhode Island's water, wastewater, surface transportation, and energy infrastructures and utilities, our natural environment, and our health, welfare, and economic well-being. The Commission's three working groups have begun to catalogue and further specify these risks upon our environment, infrastructure and economy, and to describe what's being done to address and adapt to these risks. Many of these initial adaptation actions were initiated for other reasons, but climate change provides additional justification to advance and expand these actions.

KEY VULNERABILITIES AND RISKS

Sea level rise, warming air and water and increased storminess have distinct and multiple consequences depending upon which facet of society, environment, and economy one looks at. The working group reports outline these in more detail. Nevertheless, the Commission has initially identified two risk categories that stand out as top concerns for Rhode Island: wastewater infrastructure vulnerability to sea-level rise and impacts upon our drinking water supplies and related freshwater resources.

Flooding in 2010 closed this wastewater treatment facility and sewage discharged into the Pawtuxet River.

Our state's wastewater treatment systems are highly vulnerable to severe storms and accompanying storm surges, flooding, and sea level rise. Sewer pipes and sewage treatment plants often are located within river and coastal floodplains and situated directly upon coastal and riverine shorelines. Wastewater treatment processes thus may be quickly flooded out, releasing untreated sewage directly into our natural waters and communities. As experienced along the Pawtucket River in the March 2010 floods, such massive, abrupt releases of sewage can have devastating impacts on aquatic ecosystems and resources and generate major threats to public health by widespread exposure to water-borne diseases.

More frequent and longer periods of drought will diminish water supplies, leading to severe shortages in drinking water, inadequate fire suppression ability, decreased agricultural production and reductions in water quality and aquatic habitat quality.

EXISTING EFFORTS ADDRESSING CLIMATE CHANGE AND ADAPTATION

The Commission's Working Groups identified existing initiatives that are beginning to invest in climate change assessment and adaptation. These include impact assessments; adaptation planning; revision of infrastructure design and construction standards; interagency and inter-government planning and coordination; public education and outreach; and of course research and monitoring. A goal of the Commission is to foster the continuance of these activities and identify additional collaboration opportunities essential for climate change adaptation and resilience in Rhode Island.

Central Bridge 182 in Barrington will be rebuilt with sea level rise in mind.

The following efforts either been completed, are currently underway (*), or are planned (**). Further project details can be found in Appendix A.

Assessments

- Lessons Learned From Tropical Storm Irene, January 2012 (Senate Commission on Housing and Municipal Government)
- Statewide Substation Flooding Assessment (National Grid)
- Stormwater extraneous flow assessments and mitigation (Town of Bristol)
- Assessment and support of shoreline adaptation actions (Save the Bay)*
- Assessing dams for catastrophic failure* (RIDEM)
- Dead end road stormwater assessments; Culvert Assessments (Save the Bay)*
- Transportation network sea level rise vulnerability assessments (RIDOA Statewide Planning, RIDOT)*
- Water Supply and Quality Study with Climate Change (RIDOH)*
- Coastal Wetland Migration Study (CRMC, TNC, RI SEA GRANT, NBNERR) Town of *North Kingstown pilot complete (2011); statewide assessment to initiate in August 2012* **
- Wastewater treatment infrastructure climate change vulnerability assessment (RIDEM) **

Adaptation Plans

- Asthma State Plan 2009-2014 (DOH, RIACC)
- Central Landfill Disaster Preparedness Plan (RIRRC)
- RI Aquatic Invasive Species Management Plan (CRMC, URI, RINHS)
- Strategic planning initiative for potable water supply (RIWRB)

- Community vulnerability assessments (USEPA)*
- Comprehensive Wildlife Conservation Strategy update with climate change (RIDEM)*
- Hazard Mitigation Plan updates (RIEMA, municipalities)*
- Health Impacts of Climate Change: Implications for Resilient Communities (City of Providence)*
- Hurricane and Flooding Evacuation Study (USACE, FEMA, RIEMA)*
- Stream depletion methods for water allocation (RIDEM)*
- Structural Concept and Contingency Plan to Inundation of the Ferry Terminals and Island Roadway Systems (New Shoreham, Interstate Navigation, CRMC, CRC)*
- North Kingstown Sea Level Rise Pilot Study and plan (RISPP, NK, RISG, URI, CRMC, TNC)* *phase 1 completed, phase 2 underway ***

Design and Construction Standards

- Updated State Building Code requirements (RIBCC)
- Updated (2010) Stormwater Design Manual with low impact development methods (RIDEM, CRMC)
- Transportation infrastructure projects incorporate adaptation strategies (RIDOT) *

Executive Management Programs/Policies

- Adoption of Climate Change Policy - Section 145 (CRMC)
- RI Ocean Special Area Management Plan, with climate change, research and monitoring (CRMC)
- Updated (2011) Comprehensive Planning and Land Use Act with sea level rise element (RISPP)
- Addressing Climate Change through Habitat Protection and Land Trusts (URICRC/EDC, TNC, SKLT, CRMC)*
- Bills introduced - Enabling Authority for Municipal Stormwater Management (RI General Assembly)*
- Climate Ready Estuaries study of climate change vulnerabilities in the Pawtuxet watershed (NBEP)*
- Combined Sewer Overflow Abatement Project (NBC)*
- Stormwater Mitigation Program (NBC)*
- Sustainable Energy Management Program: wastewater treatment facilities (RIDEM, NBC, National Grid, URI, USEPA, RI Manufacturers Extension Service)*
- Trees 2020 (Groundwork Providence, City of Providence)*
- RI Erosion and Inundation Special Area Management Plan (CRMC)**

Inter-Agency Coordination and Outreach

- Coastal Training Program Workshops related to climate change (NBNERR, RIDEM)
- Exploring climate change resilience strategies in Rhode Island urban under-served communities (ECRI, funded by National Wildlife Federation and RI Foundation)
- Reverse 9-1-1 (various municipalities)
- RI Flood Awareness and Climate Change Task Force – RIFACCT (RISG, CRMC, RIBCC, RIEMA, RIFMA)
- Sea level rise mapping and visualizations (RI Sea Grant, URI, CRMC, RISPP, TNC)
- Shoreline Change Maps (CRMC)
- Stormsmart Coasts RI web portal on flood preparedness (RISG, CRMC, RIBCC, RIEMA)

- Flood Mitigation Working Group (RIEMA)*
- RI Climate Change Portal web site development (RI Sea Grant, URI Coastal Institute, Brown CES)*
- Stormwater Solutions Project (RIDEM)*
- Updated coastal Flood Insurance Rate Maps (FEMA)*

Research and Monitoring

- Monthly monitoring of coastal and bay waters (NBEP, NOAA)*
- RI Ocean Special Area Management Plan Research and Monitoring (CRMC)*
- System Wide Monitoring; saltmarsh Sentinel Site Monitoring (NBNERR)*
- URI Climate Change Collaborative (URI, RISG)*
- Vector surveillance for mosquito-borne and tick-borne diseases (RIDOH)*
- Watershed Counts climate change indicators (NBEP, URI)*

CLIMATE CHANGE COMMISSION NEXT STEPS

The Commission will take the following proposed actions to advance our goals and prepare for the next report to the General Assembly in 2013.

- **Assess risks and vulnerabilities** for priority sectors. Identify an approach to determine and prioritize risks. Once completed, the Working Groups can recommend adaptation strategies, link to appropriate existing initiatives and assist advancing work of the Commission and it's member organizations.

- **Track climate change activities and update members** on assessments, programs and planning efforts that are currently being implemented in various state agencies, municipalities, private and non-government organizations, and academic institutions.

- **Identify legislative priorities** to support climate change adaptation. As the Working Groups advance in their assessment and planning, they may begin to identify elements that may be supported by legislation. The Commission will review and prioritize the legislative recommendations.

- **Build upon and support existing initiatives** related to implementing state policies and standards. The Working Groups bring together various stakeholders, providing a forum to support ongoing agency initiatives that can integrate adaptation actions, such as the development of Guidelines for building in areas exposed to sea level rise, or future revisions to the State Building Code.

- **Support efforts** to build understanding of climate change adaptation among state and local government decision makers, legislators, business and NGO leaders, and the general public. The Commission and its working groups will identify complementary efforts to engage the public and local climate change expertise.

- **Develop an annual work plan** outlining milestones, activities, and support/resources for the Commission.

KEY INFRASTRUCTURE & BUILT ENVIRONMENT WORKING GROUP

PROGRESS REPORT

INTRODUCTION

ABOUT THE WORKING GROUP

The Key Infrastructure and Built Environment Working Group of the Climate Change Commission consists of representatives from several sectors, including community planning, transportation, energy, buildings and structures, water supply and emergency management. The Working Group is co-chaired by Representative Arthur Handy, the Associate Director of the Division of Planning, Kevin Flynn, and the Chief of the Statewide Planning Program, Jared Rhodes. Other members include:

James Boyd, Coastal Resources Management Council
Kenneth Burke, RI Water Resources Board
Michelle Burnett, RI Emergency Management Agency
John Carter, RI Builder's Association
Paul Fournier, Greater Providence Chamber of Commerce
Janet Freedman, Coastal Resources Management Council
Grover Fugate, Coastal Resources Management Council
Michael Lewis, RI Department of Transportation
John Leyden, State Building Code Commission
Jon Reiner, Town of North Kingstown
Alexander Taft, National Grid
Arthur Yatsko, RI Realtors Association
Jen Zolkos, American Institute of Architects, Rhode Island Chapter

PROCESS FOR IDENTIFYING VULNERABILITIES

To identify the general vulnerabilities to climate change of the state's key infrastructure and built environment, staff of the Division of Planning's Statewide Planning Program held interviews with representatives from several key sectors. The interviews sought to determine the threats facing the sector given the predicted climate changes and to identify existing projects, resources and data that may assist in the further assessment of actual vulnerabilities. From the interviews, a full Vulnerability Assessment was compiled, a summary of which is presented in this report. Interviews were conducted with:

Kenneth Burke and Kathleen Crawley, RI Water Resources Board
Michelle Burnett and Jessica Stimson, RI Emergency Management Agency
Janet Freedman and James Boyd, RI Coastal Resources Management Council
Peter Healey and Courtney Danella, RI Department of Transportation
Jane Kenney Austin, Save the Bay
Sarah Kite, Krystal Noiseux and Mike McGonagle, RI Resource Recovery Corporation
John Leyden, State Building Code Commission
William Patenaude, RI Department of Environmental Management
Jon Reiner, Town of North Kingstown
Pam Rubinoff, Coastal Resources Center, RI Sea Grant
Alexander Taft and John Stavrakas, National Grid
Tom Uva and Pamela Reitsma, Narragansett Bay Commission

RHODE ISLAND'S GENERAL VULNERABILITIES

BUILDINGS AND STRUCTURES

Sea level rise may put a number of coastal structures at risk for permanent inundation. Structures that have been raised above the flood plain may remain intact, but access to such structures will be limited.

Increased storm surge levels and stronger, more frequent storm events and heavier precipitation may increase the frequency of storm related flood damage and may extend flood damage to structures lying outside of the existing flood zones, in both coastal and riverine areas. This could result in the loss of a greater number of structures, especially considering that structures outside of current flood zones have not been built to the same level of flood protection as those within flood zones. In addition to the loss and/or damage of structures, building related illnesses may increase due to mold build-up cause by untreated or poorly treated water damage. Additional information on the associated public health risks can be found in the section on Public Health and Safety.

Historically, most of Rhode Island's development has occurred along the coast and rivers, therefore the potential for the damage of a large number of homes and structures is substantial. A recent study determined that there are 2705 housing units less than 1 meter (3.28 feet) above the Mean High Water (MHW) elevation along the Rhode Island shoreline (Strauss et al., 2012[3]). Rhode Island's historic coastal and riverine villages, such as Wickford and Pawtuxet, are at particular risk, consisting of older buildings and being located in vulnerable areas. Sea level rise and storm-related flooding have the potential to displace a significant number of residents and cause the closing of a number of businesses and institutions, either permanently or for significant periods of time.

TRANSPORTATION NETWORKS AND INFRASTRUCTURE

Sea level rise may cause the permanent inundation of some transportation infrastructure, including the state's port facilities, access roads, bridges, railroad tracks, airports, bike paths, ferry terminals and drainage systems. Such permanent breaks in the transportation network may lead to isolated communities that are disconnected from the rest of society and have no access to goods, services and employment. Permanent inundation of the state's ports, airports and railroads will reduce interstate access, affecting economic viability and potentially limiting imports and exports. Sea level rise may also reduce the navigational clearances of the state's bridges, additionally limiting access.

Road damage in Hopkinton from the 2010 floods.

Stronger, more frequent storm events will cause the damage and destruction of transportation infrastructure due to erosion caused by stronger precipitation that overwhelms stormwater infrastructure, storm surges and wave activity or heavy snow accumulation. As an example of erosion, Matunuck Beach Road in South Kingstown, which provides the sole access and emergency evacuation routes for 240 residences, is in escalating threat of collapse due to the ongoing erosion of the beach and the coastal bluff that fronts the roadway because of storms and sea level rise.

[3] Strauss, B., R. Ziemlinski, J. Weiss and J. Overpeck. 2012. Tidally adjusted estimates of topographic vulnerability to sea level rise and flooding for the contiguous United States. Environmental Research Letters 7 (2012) 014033 12pp.

Heavier precipitation may overwhelm the capacity of rivers, dams and the stormwater system, causing flash flooding in neighborhoods and potential large-scale flooding of riverine areas, making local roadways and portions of I-95 temporarily impassable, as was experienced in the floods of March 2010. Flooding of this type can limit neighborhood access to emergency responders and reduce resident's evacuation capabilities. Transportation rights-of-way are also some of the primary utility corridors in the state, carrying gas, electric, telecommunications and sewer infrastructure above and beneath the road surface. Any effect to the transportation network, including the undermining of rights of way due to coastal erosion, may have a ripple effect for utilities.

ENERGY INFRASTRUCTURE

Sea level rise may cause the permanent inundation of coastal gas and electricity infrastructure, including distribution and transmission stations and customer equipment. Permanent inundation may require the relocation of infrastructure systems, including transfer stations and gas pipelines. Stronger and more frequent storm events and heavier precipitation could result in the temporary flooding of infrastructure, as well as the overturning of utility poles and towers, causing service disruptions.

Flooding of customer basements, due to storm surges, sea level rise or increasing groundwater levels, may occur prior to the flooding of a building's occupied space and can affect gas service to an entire community. Flooding at customer premises may cause long-term, neighborhood wide gas service disruptions, as bringing flooded areas back into service requires that each building be reconnected to the system one at a time. Unprotected electrical equipment, including transformers and the equipment located at natural gas transmission and distribution stations, may become damaged if flooding occurs.

The permanent inundation of the state's ports could have a substantial impact on the availability of coal and petroleum products, including oil, diesel and gasoline, throughout the state as these products are mainly transported via ships. Also, warmer temperatures, longer periods of intense heat and increased heat island effects will increase building cooling demands and may place a strain on the capacity of the state's energy system.

WATER SUPPLY

Sea level rise may cause the permanent saltwater intrusion of some public and a number of private drinking supplies, especially in the southern portion of the state and on Aquidneck Island. The availability of potable water may be severely limited and relocation of infrastructure may be necessary. Additionally, increased storm surge levels and more frequent strong storm events may cause the temporary inundation of drinking supplies, causing temporary saltwater intrusion that will require mitigation. The reservoirs located in Newport may be highly susceptible due to their location on the coast and within the urban land use pattern. Southern and Eastern Rhode Island have a high number of coastal wells, saltwater intrusion of which will require mitigation to maintain water quality, including the removal of biological contaminants in areas with combined systems. Increases in snowfall may also increase the use of road salt during the winter, which could lead to drinking water contamination in both inland and coastal areas.

Longer periods of drought may also deplete groundwater supplies, which affect both the availability of potable water and fire suppression capabilities. Additionally, loss of pressure in the water supply system may heighten the level of contaminants. Additional information on the public health risks related to water supply can be found in the section on Public Health and Safety.

FLOOD CONTROL AND STORMWATER INFRASTRUCTURE

More frequent storm events and heavier precipitation may overwhelm the capacity of rivers, dams and the stormwater system, causing flash flooding in neighborhoods and potential large-scale flooding of riverine areas, straining flood control and stormwater infrastructure. Pre-1975 development was not required to include stormwater infrastructure and therefore communities with a high concentration of this type of development may be more vulnerable.

The state's dams may be subject to greater stresses on a more regular basis, due to rising and falling water levels, and therefore may require additional maintenance and upkeep. The Rhode Island Department of Environmental Management (RIDEM) maintains an inventory of the state's 669 dams, which includes an assessment of the potential damage that could be caused by a sudden release of water from behind the dam. Currently, 97 dams have been classified by RIDEM as "high hazard," meaning that failure or improper operation of these dams would result in a probable loss of human life. RIDEM has classified 81 dams as "significant hazard," meaning that failure or improper operation would not result in probable loss of human life but could cause major economic loss, disruption of lifeline facilities or would be otherwise detrimental to the public's health, safety or welfare. RIDEM also completes a visual, technical evaluation of the physical conditions of a dam that affect performance of the structure and based on the inspection, rates the dam's safety. Alarmingly, 19 "high hazard" dams and 3 "significant hazard" dams have been deemed "unsafe," meaning that the condition is such that an unreasonable risk of failure exists. Given the potential increase in dam stressors related to climate change, it is likely that the conditions of "high hazard" and "significant hazard" dams may deteriorate more quickly, causing them to become "unsafe," and that additional resources may be necessary to protect human life and to prevent economic losses. Recognizing the need for increased dam upkeep, in 2011 the Rhode Island House of Representatives has passed a resolution in support of federal legislation to eliminate the Federal Energy Regulatory Commission's regulation of hydroelectric installations of less than two megawatts, which would leave regulation to RIDEM, in order to make dam operation more economically viable and therefore self-supporting.

WASTEWATER INFRASTRUCTURE

Sewage treatment plants and pump stations are typically sited in the lowest parts of the state, which puts them at increased risk for permanent and/or temporary inundation. Most of the state's wastewater infrastructure cannot be easily or inexpensively relocated, and therefore wastewater treatment facilities routinely incorporate many redundancies in their systems to mitigate impacts and ensure continuous compliance with stringent permit conditions. RI Department of Environmental Management regulations require sewage treatment facilities to mitigate potential flooding effects by designing facilities to withstand flooding at the 100-year level. Other regulations have been set federally to minimize the impact of combined sewage overflows, which are prevalent throughout RI and New England. However, even given these precautions and redundancies, inundation can occur.

Sea level rise and stronger, more frequent precipitation events may cause the permanent inundation of sewage treatment facilities, pump stations and sanitary sewer systems in low-lying, coastal and riverine areas. Increased storm surges, more frequent storm events and heavier precipitation may lead to higher flows within and the temporary inundation of these systems, both in coastal and riverine areas, as occurred in Warwick, West Warwick and Cranston during the storms in March of 2010. The heavy rains associated with that storm system caused the complete inundation of the Warwick and West Warwick wastewater treatment facilities, resulting in total shutdown of the wastewater system and the expenditure of millions of dollars to return the damaged infrastructure to operation.

Severe storms that require the closing of the Providence Hurricane Barrier may become more frequent due to climate change, posing an additional threat to the wastewater system. During these situations, valves that transport sewage from the city to the treatment facility must be closed to prevent Providence from being back-flooded through the sewer collection system. This would result in untreated sewage being discharged into the Providence River, primarily causing a human health risk.

Onsite Wastewater Treatment Systems (OWTS) serve about one-third of the State's population, primarily in suburban and rural areas where municipal wastewater infrastructure is impracticable and too costly. It has been estimated that about 6,000 OWTS are located in close proximity to the coast and may be vulnerable to the impacts of sea level rise inundation and rising groundwater. Rising groundwater from increased precipitation may also pose a contamination threat to areas with combined well and septic systems. The New England Onsite Wastewater Training Center, located at URI, is in the process of launching a research initiative to address OWTS adaptation methods to climate change.

High groundwater can also infiltrate community wastewater systems, causing pumps to operate more heavily and generating greater costs and maintenance needs. Water quality issues and more frequent equipment replacement can be handled by upgrades to the system but will result in environmental impacts and rate increases for customers. Low flow, caused by drought conditions, can also create operational issues for the wastewater system.

SOLID AND HAZARDOUS WASTE

Sea level rise, stronger storm surges, more frequent storm events and heavier precipitation could cause the permanent and/or temporary inundation of solid waste transfer stations. Loss of transfer stations would necessitate more direct hauls until the transfer station could reopen or be relocated, which would increase fleet maintenance and energy costs and possibly require additional vehicles and staff. Additionally, stronger storm surges and more frequent storm events may increase coastal erosion. Many of the state's capped landfills are located in coastal areas, making them particularly vulnerable to the effects of erosion.

Loss of ground transportation to communities due to flooding may require local waste storage areas until links can be repaired or the use of other means of transport. These climate change phenomenon could also cause the temporary and/or permanent inundation of businesses that generate or store potentially hazardous waste, including the industrial uses located in the state's ports, as well as closed landfills and superfund sites.

Warmer temperatures could result in an increase of leaf and yard waste, and a greater number of strong storms could result in more storm-related debris, requiring additional transport vehicles and possibly straining the processing system. Additional handling of this type of waste by municipalities may be required.

TELECOMMUNICATIONS

Sea level rise, increased storm surge levels, more frequent storm events and heavier precipitation may cause the permanent and/or temporary inundation of telecommunications infrastructure. Much of this infrastructure is connected to the transportation networks and energy infrastructure, and would be subject to many of the same vulnerabilities. Prolonged disconnections from telecommunications service will impact the states businesses, especially those in high-tech industries.

EXISTING EFFORTS ADDRESSING CLIMATE CHANGE ADAPTATION

A full list of the existing efforts addressing the adaptation of key infrastructure and the built environment can be found in Appendix A of this report. As seen from the list, many efforts currently underway throughout the state address climate change adaptation related to the key infrastructure and build environment. However, a few key areas still need to be addressed.

First, there is a need for updated data related to the effect of increased precipitation and more frequent storm events on the state's riverine areas. As seen during the March 2010 storms, the state's riverine areas are susceptible to sizable damages in the event of a strong storm. In order to properly assess the potential impacts to key infrastructure and the built environment in riverine areas, updated flood maps are essential. One type of data that could assist in properly planning for strong precipitation events are location specific hydrographs for the rivers throughout the state. Point specific hydrographs for key locations would provide a way to predict when and to what elevation floodwater would be expected at a particular point in time. Such a tool could, for example, help us determine when to close, and then predict when we will reopen a particular road during river flooding conditions.

Second, examining ways to support the Senate's Housing and Municipal Government Committee's recommendations related to the state's telecommunications infrastructure should be examined. By looking at ways to implement these recommendations for future

storm events, it may help mitigate the impacts of telecommunication breakdowns for a substantial numbers of residents and businesses.

Third, the wastewater system throughout Rhode Island is primarily run by municipalities and/or private companies. While the Narragansett Bay Commission, who is responsible for a large portion of the system, has been assessing their system's vulnerabilities, exploring the opportunity to convene municipalities state wide to conduct assessments would be beneficial in long term planning.,

Finally, it seems that a great need exists to discuss, at a statewide level, the options for coastal and riverine communities that are located in highly vulnerable areas. We need to explore opportunities to convene cities and towns in collaboration with state agencies to examine vulnerable areas and discuss policies for future adaptation projects.

LOOKING AHEAD: KEY INFRASTRUCTURE AND BUILT ENVIRONMENT WORKING GROUP

SETTING PRIORITIES FOR THE WORKING GROUP

Moving forward, the Key Infrastructure and Built Environment Working Group of the Climate Change Commission (the Working Group) would like to begin to make headway towards the identification of potential adaptation strategies. According to the International Council for Local Environmental Initiatives (ICLEI), a national leader in climate change adaptation, prioritized strategies should be based on risk and vulnerability, with those sectors and resources with the highest vulnerability and highest risk taking the first priority.

Being tasked with looking at many sectors and many vulnerable resources, as described above, it is clear to the Working Group that it will not be possible, at least in the short-term, to complete full vulnerability and risk assessments for all of the vulnerable resources in all of the sectors. With this in mind, the Working Group will conduct a quick, qualitative prioritization exercise, based on the knowledge and expertise of our members, to determine which vulnerability and risk assessments should be tackled first.

Our initial, qualitative prioritization will look at the potential extent of the climate change related impacts, including the certainty and immediacy of the potential climate change phenomena, how many people may be impacted, the suspected societal implications of the impacts, the potential economic impacts, and whether there is likely to be a disproportionate impact on specific populations, among other things. The intended result of this qualitative prioritization will be to identify those vulnerable resources that, when impacted by climate change, have the potential to cause the most harm to Rhode Island. It is anticipated that this prioritization effort will be completed by Fall of 2012.

Then, once the vulnerable resources have been prioritized, the Working Group will look at the potential that exists for moving the highest priority vulnerability and risk assessments forward. Things to be considered will include whether any similar assessments are currently being done, the availability of funds for completing the assessments, existing data availability, political will, which agency (or agencies) can champion the work, and whether the effort could consider and/or address multiple vulnerabilities.

From there, using the ICLEI vulnerability and risk assessment process as a model, the Working Group will assist lead agencies in determining the methodology, data sources, and available resources for completing the assessments. In order to be effective and actionable, the adaptation strategies that the Working Group recommends must have a foundation in data, especially when determining exposure. To this end, the Working Group will establish methodologies for determining exposure to each of the climate change phenomena that can be used in the priority vulnerability assessments. These methodologies are likely to utilize some of the mapping processes refined in the North Kingstown pilot study.

Once the actual vulnerability and risk are determined for each priority sector and/or resource, the Working Group will brainstorm, discuss and prioritize climate change adaptation strategies and then will make recommendations to implement the strategies.

SUPPORTING EXISTING EFFORTS

As outlined in the Existing Efforts section, many of the Key Infrastructure and Built Environment Working Group members' agencies are already involved in ongoing efforts targeted at addressing and adapting to climate change. Several of these initiatives cross multiple sectors and affect a variety of stakeholders and thus would benefit from the additional support and involvement of the Working Group membership.

In some cases, data-based assessments are already in process or are certain to begin in the near term. These projects include the North Kingstown and Coastal Resources Center's *Sea Level Rise Pilot Study* and the Division of Planning and RI Department of Transportation's *Transportation Network Vulnerability Assessment*. As these projects have already been identified as priorities, the preliminary qualitative assessment outlined above is not necessary and the agencies can delve in to the data-driven vulnerability and risk assessments. To support these efforts, the Working Group can assist in determining some of the necessary inputs into the assessments, such as projected changes in stresses and any barriers to adaptation, and at the end of the assessments, can assist in brainstorming strategies and building constituent support.

In other cases, agencies have identified priorities or actions to be taken in support of adaptation, but have not yet begun assessments of risk and vulnerability. For example, the Coastal Resources Management Council (CRMC) has adopted a policy to review its internal policies, plans and regulations to proactively plan for and adapt to climate change and sea level rise, and the State Building Code Commission is looking at further revisions to the State Building Code to adapt to climate change. While CRMC and the Building Code Commission should be responsible for conducting risk and vulnerability assessments to inform their policy decisions, the Working Group can step in, where necessary, to support and assist their efforts.

NATURAL RESOURCES AND HABITATS WORKING GROUP

PROGRESS REPORT

INTRODUCTION

ABOUT THE WORKING GROUP

The Natural Resources and Habitat Working Group of the Climate Change Commission consists of representatives from environmental agencies and organizations, non-profits, and universities. The Working Group is co-chaired by Senator Susan Sosnowski, Ames Colt of RI Bays, Rivers, and Watershed Coordination Team, and Jane Austin of Save the Bay. Other members include Scott Millar and Janet Coit from RI Department of Environmental Management, Meg Kerr of ECRI- Narragansett Bay Estuary Program, Richard Hittinger of Alliance Environmental Group, Judith Swift and Q Kellogg of URI Coastal Institute, Grover Fugate, Janet Freedman, and James Boyd of Coastal Resource Management Council, and Michelle Burnett of RI Emergency Management Agency.

ISSUE OVERVIEW

Climate change and coastal and marine acidification pose substantial and diverse risks to the productivity and sustainability of Rhode Island's natural resources and habitats. The primary drivers of these risks across terrestrial and aquatic environments are:

- Increasing air and water temperatures,
- Alterations to precipitation patterns and hydrologic cycles
- Sea level rise and coastal inundation
- Ocean acidification

These drivers affect the native plant, animal, and insect populations and ecosystems directly as well as affecting the ways in which they interconnect.

One mandate of the Rhode Island Climate Change Commission is to identify and characterize the immediate and long-term consequences of Climate Change and ocean acidification to our natural environment, economy, infrastructure, and public health and welfare. This initial report from the Natural Resources and Habitats Workgroup surveys briefly the environmental consequences of climate change and coastal and marine acidification. It also catalogues initiatives underway in Rhode Island to respond to a warming climate, altered weather patterns, rising seas, and an acidifying ocean.

Salt marshes provide habitat for many animals, as well as protect coastal waters from pollution and limit erosion. R. Hancock

Climate Change and marine and coastal acidification impacts are spatial and temporal, and range from local to global spatial scales, are readily observed currently, and are expected to accelerate in the coming decades. We need to assess both local impacts, as well as regional and global impacts that will indirectly affect Rhode Island's and southern New England's natural environment. Also of critical concern should be how socio-economic responses and environmental feedbacks resulting from climate change and ocean acidification themselves may alter our natural environment in ways that are difficult to foresee currently.

Finally, Rhode Island should seek to characterize potential risks and risk mitigation strategies over significant time-scales of thirty, fifty, and one hundred years.

ECOSYSTEM IMPACTS

TERRESTRIAL ENVIRONMENTS

Rising air and water temperatures change the way plants and animals grow and behave; additionally, these changes are experienced differently by different plants and animals. Of fundamental concern is the alteration of "relationships between climate and the regular seasonal progression of biological events, such as the migration of animals, the flowering of plants," or the blooming of phytoplankton (Nixon et al. 2009)[4]. As these phenological relationships are transformed, they will in turn modify other fundamental ecological relationships such as predator/prey relationships and food web dynamics.

As temperatures increase, species assemblages, or communities, and habitat will be disrupted. For example, Rhode Island may lose some species of trees, like apple and maple trees, which prefer colder climates. However, individual species will shift in different ways and at different rates of geographic spread. Communities of plants and animals and insects that depend on or interact with each other will be disrupted or disappear.

New and different plants, animals, and insects will thrive in a warming Rhode Island climate. For example, the productivity and geographic spread of invasive plants and insects such as Black–swallow Wort and Hemlock Wooly Adelgid have historically been inhibited by winter die off. [5] As winter temperatures increase, these and additional terrestrial and aquatic invasive species will expand in population and geographic range. Invasive plant species such as Norway Maple, Garlic Mustard, and Mile-a-Minute Vine are becoming established or expanding. Response and eradication of invasives should be considered an important priority for climate adaptation efforts. For example, efforts are underway in the City of Providence's Blackstone Park to eradicate invasive Norway Maples, which will over time replace native plant and tree species.

FRESHWATER ENVIRONMENTS

Rivers, lakes, ponds, and streams provide essential habitat values and many recreational uses and benefits to Rhode Islanders. They provide transport of fresh water, as well as a multitude of recreational uses for Rhode Islanders.

We should anticipate that Rhode Island will experience a significant increase in intense rain events and decreasing ice coverage and snowfall. As a consequence, Rhode Island's rivers, lakes, ponds, and streams will be subjected to more intense and frequent droughts and floods. Increased flooding may degrade water quality and result in lowered dissolved oxygen (DO) concentrations or aggravated eutrophication. Additional stormwater runoff may increase water column stratification and pollutant loadings. Coupled with warmer water temperatures, increased stormwater runoff may trigger harmful algal blooms (HABs).

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[4] Nixon, S.W., Fulweiler, R.W., Buckley, B.A., Granger, S.L., Nowicki B.L. and Henry, K.M. 2009. The impact of changing climate on phenology, productivity, and benthic-pelagic coupling in Narragansett Bay. Estuarine, Coastal and Shelf Science 18:1-18.

[5] The Black-swallow Wort, a member of the milkweed family, once introduced quickly overtakes native plants and floral habitats. It out-competes other milkweed species that provide food for for insects such as the Monarch Butterfly, boosting mortality rates among insect larvae. The spread of the Black-Swallow Wort will poses substantial risks to regional Monarch Butterfly populations, an important pollinator in Rhode Island. The Hemlock Wooly Adelgid weakens and kills the eastern hemlock (*Tsuga Canadensis*), an important staple to New England forests.

Invasive species are already widespread in Rhode Island's freshwater environments, including wetlands. 59% of recently surveyed waterbodies were inhabited by one or more invasive species (RI DEM, 2012[6]; RI Aquatic Nuisance Species Task Force, 2007[7]).

For example, the Asian Clam is a freshwater clam species found in some Rhode Island lakes and ponds and the Pawtuxet River. This invasive bivalve thrives in waterbodies with degraded water quality and crowds out native bivalves. If the Asian Clam comes to dominate RI's freshwater systems, even with concerted attempts at eradication, some waterbodies may end up less suited for the restoration of native freshwater species.

ESTUARINE & COASTAL ENVIRONMENTS

Rhode Island's coastal ecosystems are experiencing increased water temperatures, alterations in storm and wind patterns, sea level rise and coastal inundation, and marine and coastal acidification (Heffner et al., 2012)[8]. Estuarine and coastal species may be particularly vulnerable to climate change. Shallower water depths will result in more rapid declines in coastal and estuarine water column temperature refuges. Coastal and estuarine large-scale flushing rates could slow due to diminished wind speeds and changes in prevailing wind directions.

SPECIES RANGE AND COMMUNITY IMPACTS

Many commercially and ecologically important cold-water marine species found in Narragansett Bay and adjacent ocean waters live within the southern extent of their habitat ranges, such as the Atlantic Cod and Winter Flounder. Over the last 40 years in Narragansett Bay, many cold-water and demersal species appear to have declined in population, and pelagic and warm-water species populations appear to have increased (Collie et al., 2008)[9]. These changes in species ranges and populations can be statistically linked to rising water temperatures and climatically-driven changes to predation/prey relationships, phytoplankton phenology, and planktonic biomass productivity (Nixon et al., 2008)[10].

Cold-water marine species could be locally extirpated due to temperate range shifts, increased disease mortality and facilitated introductions of invasive species. Ecological changes may include declines in adaptive fitness to existing habitat areas, reproductive fitness, alterations to biomass productivity, and propagation rates.

There is the additional difficulty and importance of gaining insight into how individual species and ecological communities will adapt to climate change and coastal and marine acidification. We should expect to see declines in the overall viability and productivity of many of Narragansett Bay's natural resources. However, climatic and acidification consequences may also be benign, such as the emergence of commercial and recreational fisheries based upon warm-water tolerant species.

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[6] Rhode Island Department of Environmental Management. 2012. RI Freshwater Lakes and Ponds: Aquatic Invasive Plants and Water Quality Concerns Report.

[7] Aquatic Nuisance Species Task Force. 2007. Rhode Island Aquatic Invasive Species Management Plan.

[8] Heffner, L., Williams, R., Lee, V., Rubinoff, P., and Lord, C. 2012. Climate Change & Rhode Island's Coasts: Past, Present, and Future. Coastal Resources Center and Rhode Island Sea Grant, University of Rhode Island, Narragansett, R.I.

[9] Collie, J.S., Wood, A.D. and Jeffries, H.P.. 2008. Long-term shifts in the species composition of a coastal fish community. Canadian Journal of Fisheries and Aquatic Sciences 65:1352-1365.

[10] Nixon, S.W., Fulweiler, R.W., Buckley, B.A., Granger, S.L., Nowicki, B.L. & Henry, K.M. (2008). The impact of changing climate on phenology, productivity and benthic-pelagic coupling in Narragansett Bay. *Estuarine, Coastal and Shelf Science*. Volume 82, Issue 1, 20 March 2009, Pages 1–18

FISHERIES IMPACTS: THE AMERICAN LOBSTER

Climate change is driving disease onset and spread in many coastal and marine species that we value directly in Narragansett Bay, through increased temperature stress, changes in salinity regimes, and facilitated introduction and growth of invasive parasites and competitors. Since the 1980's, growing incidences of invertebrate diseases in Narragansett Bay have been observed. But the appearance and rapid spread of lobster shell disease in southern New England lobster populations may be most sobering example of how climatic changes to physical and chemical habitat parameters deleteriously affect a marine species of leading human importance.

First observed in Long Island Sound in the 1980's, lobster shell disease has been observed in lobster populations in Narragansett Bay since the 1990's, with severe outbreaks documented in 2000-2005 (Cobb & Castro, 2006)[11]. Today, lobster shell disease is prevalent among lobster populations in Narragansett Bay and directly offshore, most notably in females. Lobster shell disease diminishes lobster growth and reproduction and increases susceptibility to or infectious diseases. The etiology (causes) of lobster shell disease is complex. Lobster shell disease is primarily caused by a bacterium becoming established in the pores of the outer lobster carapace shell and causing lesions to form through the consumption or dissolution of the shell. These lesions may penetrate the shell and cause it to rot away completely. The responsible bacterium has been present historically in New England coastal and marine waters, so scientists are studying the physical and chemical conditions that trigger the onset of lobster shell disease. Research strongly suggests that elevated water temperatures, hypoxia, and toxic substances are important drivers for lobster shell disease (Cobb and Castro, 2006[12]; Glenn and Pugh, 2006[13]). Additionally, shell disease has not been observed in lobsters from the colder waters of the Gulf of Maine.

By 2100, coastal and estuarine water temperatures are projected to be 3-8 °F higher than present. Such elevated temperatures will significantly increase the risk of economic extinction of the American Lobster in Rhode Island waters. NOAA data has already shown the decreasing value of the American Lobster harvest in Rhode Island. from just over $23 million in 2005 to $11.5 million in 2009 (NOAA, 2011[14]). Further climate stressors could increase this devaluing.

COASTAL AND OCEAN ACIDIFICATION

The world's oceans are becoming more acidic. Declining pH levels indicate have led to an overall decrease in ocean acidity of about 30%. By 2100, ocean pH levels may decline an additional 0.4 units from present levels, a 150% increase in ocean acidity. Current pH declines remain too small to be observed in coastal and estuarine environments because pH variability in these waters is much greater than in ocean waters. It is clear nevertheless that acidification will eventually be observed in Rhode Island coastal and estuarine waters and the rate of overall acidity increase will accelerate. Increased acidity in marine and coastal waters will promote the erosion of calcium carbonate shells and skeletons, impede neurotransmitter functions in fish, and reduce species growth and reproduction. Increased acidity will exert synergistic impacts in coastal embayments such as Greenwich Bay that are characterized by complex flow regimes, high levels of stormwater runoff, pollution, and eutrophication.

11 Cobb, J.S. and Castro, K.M.. 2006 Shell Disease in Lobsters: A Synthesis. Prepared for the New England Lobster Research Initiative.

[12] Cobb, J.S. and Castro, K.M.. 2006 Shell Disease in Lobsters: A Synthesis. Prepared for the New England Lobster Research Initiative.

[13] Glenn, R. P. and T. L. Pugh. 2005. Observations on the chronology and distribution of lobster shell disease in Massachusetts coastal waters. pp. 141-155. In, M. F. Tlusty, H. O. Halvorson, R. Smolowitz, and U. Sharma (eds.), Lobster Shell Disease Workshop. Aquatic Forum Series 05-1. New England Aquarium, Boston, Massachusetts, U.S.A.

[14] National Marine Fisheries Service, National Oceanic and Atmospheric Administration. 2011. Fisheries Economics of the U.S. , 2009.

WETLAND ENVIRONMENTS

Marshes, fens, bogs, and swamps are critically important habitat areas that serve as transition zones between land and water areas or salt and fresh water systems. Wetlands cover over 18% of Rhode Island. Wetland habitats will be degraded by water temperature increases, sea-level rise and coastal inundation, and shifting hydrological regimes (including water depth, hydroperiods, and flow dynamics).

Inundation of coastal marshes poses one of the most significant risks to Rhode Island's natural environment. Rising sea level will amplify coastal groundwater salinization, which will in turn degrade brackish wetlands. Wetlands salinization will alter vegetative communities and their capacities as nursery and juvenile habitats. Coastal wetlands will migrate inland with sea level rise and inundation over the next fifty years. But such landward shifts will be constrained by hardened shorelines and coastal development. Some coastal wetlands will simply shrink and disappear, along with their values as storm buffer zones and habitats.

LOOKING AHEAD: NATURAL RESOURCES AND HABITATS WORKING GROUP

The three working groups will work with Commission co-chairs to determine an appropriate Vulnerability Assessment approach to be used for each to prioritize and focus actions. There are many groups that depend directly on Rhode Island's natural resources for their livelihood, including those involved in outdoor recreation, farming, aquaculture, commercial fishing and recreational fishing. Future work of the Working Group will include identification of those groups most likely to be affected and creation of activities that can disseminate information and help those groups to prepare for the impacts they are likely to experience. Once these priorities are identified, the Working Group can then address specific actions. In the meantime, a series of immediate steps such as supporting existing efforts can be taken at various levels to avoid some of the worst risks to Rhode Islanders' natural environments.

HUMAN HEALTH AND WELFARE WORKING GROUP

PROGRESS REPORT

INTRODUCTION

ABOUT THE WORKING GROUP

The Human Health and Welfare Working Group of the Climate Change Commission consists of representatives from public health, universities, and Water Resources Board. The Working Group is co-chaired by Representative David Bennett, Robert Vanderslice of the RI Department of Health and Timmons Roberts, Director of the Center for Environmental Studies at Brown University. Other members include: Ken Burke and Kathleen Crawley of the RI Water Resources Board.

THREE MAIN ISSUES FOR RHODE ISLAND'S HUMAN HEALTH AND WELFARE IN A CHANGING CLIMATE

ISSUE #1: INCREASED HEAT AND DROUGHT

While climate change projections show that average temperatures may increase, the greatest risks to Rhode Islanders' health, safety and welfare will likely be during the predicted more frequent, more intense, and longer heat waves (Frumhoff et al 2007)[15].

HEALTH RISKS

Increased average temperatures, with later frosts and weaker winter freezes may extend the season and geographic range of disease vectors, such as ticks and mosquitoes, which may lead to an increase in cases of Encephalitis, West Nile Virus, Lyme Disease and the emerging Dengue Fever and increased exposure to pesticides. Such increases in temperature may also promote pollen, algae and pathogen growth, which could increase exposure to toxic algae blooms and pathogens, as well as occurrences of hay fever and asthma. Warmer ocean temperatures, caused by increased average temperatures, may increase exposure to waterborne pathogens while also increasing jellyfish populations, and decreases in water- and beach-based recreation.

Coalition for Water Security

Drought will impact surface water and groundwater quality. The degree of this effect is a function of many factors, drought severity being one. When reservoir levels are depleted (depending on the severity of

[15] Frumhoff, P. C., J. J. McCarthy, J. M. Melillo, S. C. Moser, and D. J. Wuebbles. 2007. Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Rhode Island report of the Northeast Climate Impacts Assessment (NECIA). Cambridge, MA: Union of Concerned Scientists.

the drought), you may expect increasing water temperatures, changing water chemistry, a re-suspension of dissolved solids (turbidity) depending on how low the water levels are and the mechanical configuration of influent systems, and an increased possibility of bacteria and algae growth that will require additional treatment. For groundwater systems, the wells are at a fixed elevation. During drought (or short term dry spells), these systems are subject to drawing down on a water column that is closer to their intake screens, increasing the susceptibility of these systems to "running dry", or the pumps getting air bound due to the groundwater cone of influence being lower (and closer to the screens). Depending on the surrounding soils, this could have impacts on the amount of iron and manganese that are "stripped" across the gravel wells, impacting quality.

Similarly, self-supplied users (residential) may experience conditions where their pumps are air bound (or close to it). In many instances where residential self-supplied users also have septic systems in relative close proximity to their drinking water wells, there is an increased likelihood that (treated) effluent has a shorter path to travel (vertically) to get to the screen in the drinking water well because of the drop in the ground water table.

SAFETY RISKS

More days of extreme heat is likely to cause an increase in air quality and heat emergency alert days. Extreme heat may restrict the healthful activities of Rhode Island residents, such as walking and outdoor recreation. Worsening of the "heat island" effect may have an adverse impact on air quality in urban and heavily built out environments, which can negatively affect populations that are most vulnerable to heat-illness and heat-related death. These most vulnerable groups include infants, elderly, invalids, and socially isolated people who have been seen in other cities to stay in overheated apartments. More air quality alert days and increased heat island effect may provoke asthma episodes, increase hospital visits and mortality for those with heart and/or lung disease and cause more heat-related disorders for people who work outside. These people include construction workers, landscape and maintenance workers, public works and park employees, and police.

Frequent and/or longer periods of drought may decrease water availability, which could lead to shortages in drinking water in parts on the state. Droughts lead to inadequate fire suppression ability and decreased agricultural production. Drought may also have a negative impact on water quality, which could increase exposure to water contaminants.

It should also be noted that public safety can degrade rapidly in heat emergencies. During heat waves and air quality alerts most employers and sports programs are unprepared for protecting the safety and health of their workers and participants. Sharp increases in power demands due to use of air conditioning units can cause electrical brownouts and/or blackouts, which can create multiple and cascading disasters, including health services interruptions and communication breakdowns.

WELFARE RISKS

The likely economic impacts of heat and drought are many. Warmer ocean temperatures and drought may cause changes in fisheries and agricultural production due to changes in species distribution and water shortages. Commercial fisherman may need to go further out to find their catch or they may need to change gear to target different species, both of which will increase operating and/or capital costs. Clinics and public health infrastructure, businesses, hotels and hospitality facilities and other public service buildings that are without air conditioning may have to close, stressing other facilities or sending ill patients home. While there may be an increase in some waterfront related activities and industries in the summer, there may also be a decrease in tourism due to jellyfish populations and a decrease in winter activities due to warmer temperatures. Summer athletic activities and recreation may suffer with prolonged heat and insect pests. With increased drought conditions, Rhode Island may be unable to attract businesses that require a steady water supply.

ISSUE #2: LIKELY IMPACTS OF INCREASED PRECIPITATION AND FLOODING

More intense rainstorms are expected, as are extreme snowfall events; both are expected to drive upland flooding in the state, especially in river valleys that have been heavily developed. The following table summarizes Health, Safety and Welfare impacts of more severe precipitation and flooding events we can expect in Rhode Island as the climate shifts here:

<table>
<tr><td>H
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H</td><td>More severe precipitation events and flooding can cause:

• Extended season (later die-off, not greater populations) and geographic range of disease vectors (i.e. mosquitoes which breed in standing water)
• Increased moisture damage to buildings causing increasing problems with mold growth, decay, rodent and insect infestations, impacts on indoor air quality in homes, schools and businesses
• Increased exposures to chemical disinfectants and biocides, pesticides and other products used to address moisture-related building damage.
• Increased surface water runoff

Possible outcomes:

• Increased Encephalitis, and emerging Dengue Fever
• Increased exposure to toxic algae blooms
• Increased exposure to chemical agents used to address flood damage, mold and pest problems.
• Exacerbation of asthma and other respiratory disease due to decreased indoor air quality.
• Increased potential for water-borne disease outbreaks during and after floods
• Increased exposure to water contaminants in marine recreation areas</td></tr>
<tr><td rowspan="2">S
A
F
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Y</td><td>Heavier precipitation events cause:

• Increased nutrients entering the freshwater and saltwater systems
• Stress on water treatment and sewer systems
• Less efficient/effective replenishment of natural water storage systems

Possible outcomes:

• Increased chance for drinking water contamination
• Potential for sewer system failure, people unable to remove waste from homes
• May increase stored water supplies used during high demand
• Damaged crops, livestock, spoiled perishable food due to power outages</td></tr>
<tr><td>Public safety can degrade rapidly in flood emergencies

Possible outcomes:

• Roads and facilities become inaccessible (PRIORITY)
• Sewage treatment plants can release untreated sewage
• People may be stranded in their homes
• Emergency management capabilities may be stressed</td></tr>
</table>

WELFARE	Likely economic impacts of more **severe precipitation events and flooding** include: • Increase overflow from combined storm and wastewater treatment systems, impacting recreational beach water quality- loss of tourism revenue • More frequent closure of conditional shellfish areas due to contamination • More precipitation could mean longer growing season or flooding of crops, depending on intensity and timing. • Loss of damaged crops and livestock

ISSUE #3: LIKELY IMPACTS OF INCREASED STORMINESS AND SEA LEVEL RISE

Hurricanes and Nor'easters can bring tidal surge; hurricanes can bring substantial damages of several types all at once—high wind after soaking rains. This table summarizes the likely impacts of storm intensity and sea level rise on Rhode Islanders' health, safety, and welfare.

HEALTH	Increase in **storm intensity** can cause: • Flash floods • Increased surface water runoff • Building damage, debris *Possible outcomes:* • Increased potential for water-borne disease outbreaks during and after floods • Increased exposure to water contaminants in marine recreation areas • Mental health effects such as anxiety resulting from displacement under emergency circumstances, and physical trauma from flooding
SAFETY	Accelerated **sea level rise** can cause: • Coastal flooding and increased nutrients entering the freshwater and saltwater systems • Compromised integrity of coastal water treatment and sewer systems *Possible outcomes:* • Increased chance for drinking water contamination both from surface runoff and saltwater intrusion of reservoirs • Potential for sewer system failure, people unable to remove waste from homes • Medical care infrastructure in coastal floodplains may be at risk • Contaminated drinking wells as saltwater moves landward

SAFETY	Public safety can degrade rapidly in **storm** emergencies *Possible outcomes:* • Downed trees make roads and facilities inaccessible (PRIORITY) • Fallen tree limbs can knock out power • Flooded sewage treatment plants can release untreated sewage • People may be stranded in their homes if roads are blocked with debris • Emergency management capabilities may be stressed
WELFARE	Likely economic impacts of more **severe storms and sea level rise** include: • Increase overflow from combined storm and wastewater treatment systems, impacting recreational beach water quality and causing closures- loss of tourism revenue • Storm damage threats to shellfish aquaculture operations • Coastal tourism areas may be threatened by increase in sea level rise

Together, prudent planning is needed for Rhode Island to prepare for these three sets of risks. Fortunately, the state's next steps can build upon a series of already ongoing efforts.

LOOKING AHEAD: HUMAN HEALTH AND WELFARE WORKING GROUP

The three working groups will work with Commission co-chairs to determine an appropriate Vulnerability Assessment approach to be used for each to prioritize and focus actions. Once these most vulnerable areas are identified, the Working Group can start to prioritize actions. In the meantime, a series of immediate steps including supporting existing efforts can be taken at various levels to avoid some of the worst risks to Rhode Islanders' health, safety and welfare.

State agencies can review their activities to consider climate risks, including floods greater than the "100 year" normal, long heat waves, and coastal storm surge that will come from hurricanes on top of gradual sea level rise. The state can support local programs to identify and reach out to especially vulnerable populations, especially the elderly, infirm, homeless, non-English speaking, and shut-in isolated individuals. Local registries of individuals needing help in case of evacuation could serve as a model. Working with churches and community organizations is crucial to reach many of these individuals. Municipal authorities and public service workers have a special role to play, as do utilities and other major institutions such as schools, charities, and universities. Common actions adopted around the country are emergency alert systems to warn the sick and elderly of coming disasters (including heat, flooding, hurricanes, Nor'easters), emergency cooling centers during heat waves, prohibiting utilities from turning off service during heat and cold emergencies, and supporting poor citizens in purchasing fans and air conditioners. These interventions have been shown to save lives.

Regarding droughts, current local ordinances and policies are inadequate to reduce water consumption during dangerous dry spells. The state and municipalities need to work together to identify and implement better policies. Relatedly but in the category of longer-term solution, current incentives in Rhode Island are inadequate to promote water saving devices such as low flush toilets and showerheads. One next step would be to explore the possibility of state-instituted policies for incentivizing their installation

For adapting to increased flooding and severe weather events, it will be critical to focus upon reducing stormwater runoff. Incentives for property owners and municipalities to reduce impervious surfaces (roofs and paved areas) will create immediate and long-term

public benefits, as will tree planting and the installation of rain gardens and other technologies to reduce the number and severity of flooding events. Since many are poorly maintained and filling with sediment, Rhode Island's over 400 dams are part of the stormwater problem, rather than part of a solution. For public safety, progress is needed to remove or maintain existing dams.

On storms and sea level rise, Matunuck beach road provides a dramatic example of a problem we will face over and over again in coming years. Choosing to harden shoreline to provide relief to homeowners provides an easy short-term solution to a problem that will grow worse with sea level rise. Emergency response workers' lives and expensive equipment will be put at risk to rescue homeowners along isolated shorelines during storm events. Long term solutions to these problems are needed.

APPENDIX A: EXISTING ACTIVITIES RELATED TO CLIMATE CHANGE

ARMY CORPS OF ENGINEERS, FEDERAL EMERGENCY MANAGEMENT AGENCY AND RHODE ISLAND EMERGENCY MANAGEMENT AGENCY: **HURRICANE AND FLOODING EVACUATION STUDY**

The Army Corps of Engineers New England District in coordination with the Federal Emergency Management Agency and the Rhode Island Emergency Management Agency are beginning a multistate Hurricane Evacuation Study (HES). The project, titled the New England Multistate HES, includes all 21 of the coastal communities in RI. While this study is focused on hurricane evacuation, all of the products of this study will assist Rhode Island communities in preparing for climate change impacts. Storm surge inundation mapping for RI was completed in July 2009 using the Boston Bay/Buzzards Bay 2 (PV2, 2009) Sea, Lake and Overland Surges from Hurricanes (SLOSH) basin. All of the twenty-one coastal communities in Rhode Island were contacted and were asked to examine their current evacuation zones and identify any areas that they felt could be enlarged or decreased based on the most recent SLOSH modeling. This product will be digitized and incorporated into new evacuation zones for all coastal communities. The project will also consist of multiple components including a Vulnerability Analysis, a Behavioral Analysis and a Transportation Analysis for CT, RI, and MA.

BRISTOL, RI: **STORMWATER EXTRANEOUS FLOW ASSESSMENTS AND MITIGATION**

Starting in 2006, the Town of Bristol has been implementing a program to inspect buildings for sump pump connections to the sewer system for extraneous flow. To date, approximately 350 properties have been identified Town-wide as having at least one source (i.e. sump pump, roof drainage, etc.) of extraneous flow connected to the Town's sewer collection system. Given these figures, the Town has begun implementation of an extraneous flow source removal program in select pilot study areas of the collection system. The effort will focus on removal and relocation of approximately 30 sources of inflow (sump pumps, roof drainage, yard drainage) from the sanitary sewer collection system to alternate discharge locations.

The efforts aimed at reducing levels of extraneous flow within the Town's sanitary sewer collection system will increase the hydraulic capacity of the system and its ability to convey wet-weather flow produced by storm events of varying magnitude, without the occurrence of sanitary sewer overflows and/or the disruption of conveyance and treatment equipment and processes. The continued implementation of these measures can help to curtail impacts on the Town's collection system from potential rises in sea levels and groundwater tables, as well as from increases in rainfall frequencies and intensities, due to climate change.

COASTAL RESOURCES MANAGEMENT COUNCIL

- **ADOPTION OF CLIMATE CHANGE POLICY – SECTION 145**: In 2008 the Coastal Resources Management Council (CRMC) developed and adopted findings and a policy concerning climate change and sea level rise impacts to the State's coastal areas. CRMC is currently incorporating revisions to the coastal program to implement the Council's climate change and sea level rise policy. http://www.crmc.ri.gov/climatechange/RICRMP_145.pdf

- **SHORELINE CHANGE MAPS:** Shoreline change maps for the entire coastline of Rhode Island have been developed. These maps are used for determining the CRMC erosion setbacks for development and can also be used to identify hazard areas with high erosion rates. Combining the shoreline change maps with the coastal inundation maps gives a clearer picture of resources at risk, i.e. abandoned landfills that were capped but are now eroding. http://www.crmc.ri.gov/maps.html

- **RI OCEAN SPECIAL AREA MANAGEMENT PLAN (SAMP) WITH CLIMATE CHANGE, RESEARCH, AND MONITORING:** The Ocean SAMP lays out enforceable policies and recommendations to guide CRMC in promoting a balanced and comprehensive ecosystem-based management approach to the development and protection of Rhode Island's ocean-based

resources within the Ocean SAMP study. Scientific research and stakeholder involvement lead to the zoning of offshore waters for diverse current activities and future activities including renewable energy development. The SAMP document provides information and policies to protect current uses and habitats. Chapter 3: Climate Change outlines existing research and potential issues concerning changing climate on coastal and marine resources and activities of the SAMP area. A Research and Monitoring program is being developed for implementation by CRMC and other institutions. http://www.crmc.ri.gov/samp_ocean.html

- **RHODE ISLAND EROSION AND INUNDATION SPECIAL AREA MANAGEMENT PLAN**: On May 4, 2012, CRMC proposed to develop a Special Area Management Plan (SAMP) for the state's coastline to address coastal erosion and inundation along the southern shore.

COASTAL RESOURCES MANAGEMENT COUNCIL, THE NATURE CONSERVANCY, RI SEA GRANT, NARRAGANSETT BAY NATIONAL ESTUARINE RESEARCH RESERVE: **COASTAL WETLAND MIGRATION STUDY**

Project to assess the migration of coastal wetlands for all RI coastal communities (except North Kingstown, completed in 2011 as a pilot project) using the Sea Level Affecting Marshes Model (SLAMM) and protocol developed with North Kingstown project. Results will inform policy makers and stakeholders to develop new coastal policies and standards and identify upland areas for increased protection. The project start date is August 1, 2012. http://seagrant.gso.uri.edu/climate/slr_tools.html

COASTAL RESOURCES MANAGEMENT COUNCIL (CRMC), UNIVERSITY OF RHODE ISLAND, RI NATURAL HISTORY SURVEY: **RI AQUATIC INVASIVE SPECIES MANAGEMENT PLAN**

Working in collaboration with an inter-institutional Working Group, the plan assesses the impacts and threats of aquatic invasive species in Rhode Island, and outlines prevention and management techniques.

http://www.anstaskforce.gov/State%20Plans/RI_SMP_Approved.pdf

ENVIRONMENTAL COUNCIL OF RHODE ISLAND (ECRI), NATIONAL WILDLIFE FEDERATION AND RIFOUNDATION: **EXPLORING CLIMATE CHANGE RESILIENCE STRATEGIES IN RI URBAN UNDERSERVED COMMUNITIES**

The ECRI partnered with community organizations in Providence to explore resident's familiarity with climate change issues and develop recommendations to improve urban resilience. Report recommendations look at education, infrastructure, green space and permeable surfaces, food scarcity and access, toxics, cooling centers and adaptation for extreme heat events, energy and displacement. The work was funded by grants from the RI Foundation and the National Wildlife Federation.
http://www.environmentcouncilri.org/index.html

FEDERAL EMERGENCY MANAGEMENT AGENCY: **UPDATED COASTAL FLOOD INSURANCE RATE MAPS**

New coastal Federal Emergency Management Agency (FEMA) Digital Flood Insurance Rate Maps for Washington, Kent, Newport and Providence Counties were rolled out in Spring 2012, with Bristol County to follow in summer 2012. These new digital maps corresponded to only the coastal communities in these counties. These communities have six months to adopt both the new maps and corresponding ordinances which will result in new effective maps in the fall and winter 2012 respectively. While the updated FEMA maps do not account for sea level rise or other climate change phenomena, they serve as a starting point from which municipalities and the state can plan for adaptation.

http://www.starr-team.com/starr/RegionalWorkspaces/RegionI/Pages/default.aspx

NARRAGANSETT BAY COMMISSION

- **COMBINED SEWER OVERFLOW ABATEMENT PROJECT:** The Combined Sewer Overflow (CSO) Abatement Project is a three phase program designed to significantly reduce the discharge of sewage contaminated stormwater to the urban rivers of upper Narragansett Bay. The Project is designed to capture flows from a three month storm event; however, and, if deemed necessary, to deal with the effects of climate change, the system can be managed to optimize the capture of sewage contaminated stormwater and at a minimum be modified to deal with the effects of climate change by collecting and treating the first flush of a storm event, which is thought to be the most contaminated. In Phase I, a 26 foot diameter, 3 mile long tunnel was built 300 feet under the city of Providence to capture sewage contaminated stormwater flow from 12 CSOs in the Field's Point service district, which services Providence, North Providence, Johnston and portions of Cranston and Smithfield. During intense rain events, excess flow travels from sanitary and stormwater pipes to interceptor pipes then into the 65 million gallon CSO tunnel. As flows decrease at the Field's Point facility after a storm event, the volume of wastewater and stormwater collected in the CSO tunnel is pumped to the facility and receives full secondary treatment. Since the tunnel was put into operation in November 2008, the CSO tunnel has captured 3.88 billion gallons of sewage contaminated stormwater that would have otherwise been discharged through CSOs directly into local rivers and the Bay. Phase II of the Project is currently underway and consists of constructing two major sewer interceptor pipes located along the Woonasquatucket and Seekonk Rivers, connecting 14 more CSOs in the Field's Point service area into the CSO tunnel. Also included in Phase II is the separation of storm and sewer lines to eliminate two CSOs and the construction of a wetlands treatment facility. Once Phase II has been completed and evaluated, NBC anticipates beginning Phase III of the CSO Abatement Project, which will include the design and construction of another deep rock tunnel to capture flow from CSOs in the Bucklin Point district which serves Pawtucket, Central Falls, Lincoln Cumberland and portions of East Providence. http://www.narrabay.com/en/About%20Us/Facilities/MajorInitiatives/CSO.aspx

- **STORMWATER MITIGATION PROGRAM:** The Narragansett Bay Commission (NBC) instituted a Stormwater Mitigation Program in 2003 with the ultimate goal of reducing stormwater flows into the NBC wastewater collection treatment facilities. The Program requires developers and building contractors in the NBC district to develop Stormwater Management Plans, evaluating on-site opportunities to eliminate discharges that otherwise would have been diverted into the wastewater collection system. Eliminating or reducing stormwater is accomplished by incorporating green infrastructure into the project design plans, utilizing Low Impact Design technologies, Best Management Practices and other environmentally friendly mitigation practices.

  http://www.narrabay.com/ProgramsAndProjects/Stormwater%20Mitigation%20Program.aspx

NARRAGANSETT BAY ESTUARY PROGRAM: CLIMATE READY ESTUARIES STUDY OF CLIMATE CHANGE VULNERABILITIES IN THE PAWTUXET WATERSHED

Focus on restoring dammed rivers to ease future climate change impacts, such as flooding due to increased precipitation. Narragansett Bay Estuary Program will develop an appropriate action plan and initiate a pilot program. http://www.nbep.org/

NARRAGANSETT BAY ESTUARY PROGRAM, NOAA OFFICE OF MARINE ECOSYSTEM STUDIES: MONTHLY MONITORING OF COASTAL AND BAY WATERS

Monthly monitoring system measures physical, chemical, and biological characteristics of the waters in Rhode Island Sound and Narragansett Bay, including East and West Passages, Mt. Hope Bay, and the Providence River. http://www.nbep.org/index.html

NARRAGANSETT BAY ESTUARY PROGRAM, URI COASTAL INSTITUTE: WATERSHED COUNTS CLIMATE CHANGE INDICATORS

Watershed Counts is a broad coalition of agencies and organizations that have committed to work together to examine and report regularly on the condition of the land and water resources of the Narragansett Bay Watershed Region. Watershed Counts is facilitated by the URI Coastal Institute and the Narragansett Bay Estuary Program. The coalition's focal indicators reported in 2011 were climate change, impervious cover, beach closures, fresh water flow, invasive species. In 2012, marine water quality, freshwater quality, open space and resource economics were added. These indicators will be used to describe the condition of the watershed region and then to communicate this information to the public and decision makers in order to inform and guide future management and development of the watershed. The indicators consider the region's interwoven economic and environmental assets http://www.watershedcounts.org/

NARRAGANSETT BAY NATIONAL ESTUARINE RESEARCH RESERVE

- **COASTAL TRAINING PROGRAM WORKSHOPS:** Climate change-related workshops have been delivered, including "Wastewater Treatment in the Face of a Changing Climate", in partnership with RI DEM and the Narragansett Water Pollution Control Association; "Planning for Community Climate Change Adaptation", in partnership with RI CRMC, RI Sea Grant, and ICLEI- Local Governments for Sustainability; and "Climate Literacy and NOAA in Rhode Island", in partnership with RI Sea Grant and NOAA's Regional Climate Services Office. The CTP, in partnership with RI DEM has also delivered several "Low Impact Development Site Planning and Design" workshops, which make the connection between land use planning and climate change by presenting how LID can be used to mitigate increases of runoff from more intense storm events by decreasing impervious cover. The CTP will continue to coordinate with the organizations mentioned above, as well as new partners, to develop and deliver additional climate change-related workshops to decision-makers based on their needs as indicated through workshop evaluations and more formal needs assessments.

- **SALTMARSH SENTINEL SITE MONITORING:** The Sentinel sites program is a nationally coordinated effort to establish monitoring infrastructure within selected salt marshes in the 28 National Estuarine Research Reserves. They goal is to quantify marsh responses to sea level rise and climate change. Primary parameters include vegetation, hydrology, soils, and elevation. At NBNERR, the development of the Nag and Coggeshall salt marshes into NERR Sentinel Sites began in 2008 and both sites will be fully functional Sentinel Sites in 2012.

- **SYSTEM WIDE MONITORING PROGRAM:** The Narragansett Bay National Estuarine Research Reserve (NBNERR) has been regularly monitoring water quality, meteorology, and nutrient and chlorophyll concentrations at four locations around Prudence Island since 1995. NBNERR also has a biological monitoring component that focuses on macroalgae, submersed aquatic vegetation, salt marshes, invasive crabs, benthic infauna, and seals. Long-term monitoring of these biological resources will complement the abiotic component of SWMP to provide a more comprehensive understanding of how resources are changing in the Reserve and in Narragansett Bay in response to climate change. http://www.nbnerr.org/research.htm

NATIONAL GRID: **STATEWIDE SUBSTATION FLOODING ASSESSMENT**

National Grid has undertaken a comprehensive flooding assessment of all of its electric transmission and distribution substations. The most vulnerable locations have been identified and prioritized for the necessary actions to address the threat. In some instances this entails raising control house buildings and/or certain electrical control boxes within a substation to a height above

design flood elevation. In other instances it might entail raising the actual foundation of the structure or being moved altogether. In addition, since recent flooding events, certain gas infrastructure assets are being reinforced or moved.

NEW SHOREHAM: **STRUCTURAL CONCEPT AND CONTINGENCY PLAN TO INUNDATION OF THE FERRY TERMINALS AND ISLAND ROADWAY SYSTEMS**

The Town of New Shoreham is developing a plan to respond to the potential inundation of the ferry terminals that serve to connect the island to the mainland. The plan will also examine climate change impacts to the roadway system which links the harbors, commercial and residential areas of the island. The plan incorporates the sea level rise scenarios developed by the RI Sea Grant and others. This project, when completed, will serve as a model for other island communities.

PROVIDENCE: **HEALTH IMPACTS OF CLIMATE CHANGE- IMPLICATIONS FOR RESILIENT COMMUNITIES IN PROVIDENCE**

The purpose of this project is to create a forum for city departments to engage with academic institutions, community leaders and state health officials in exchanging ideas and developing recommended priority actions for addressing the health implications of climate change. The approach includes mapping out what agencies are already doing and comparing that to what other cities of similar size and capacity are doing. The project will then recommend a process for collaboration among city agencies to communicate, monitor, mitigate and adapt to the public health impacts of climate change. Funding was provided by the Association of State and Territorial Health Organizations to the Rhode Island Public Health Institute and the City Office of Sustainability. http://www.nbep.org/

RI DEPARTMENT OF HEALTH

- **ASTHMA STATE PLAN 2009-2014:** Department of Health collaborated with Rhode Island Asthma Control Coalition (RIACC) to create this plan which provides a road map on how to best improve asthma control among those in Rhode Island with asthma, reduce asthma-related hospitalizations and emergency department visits, and reduce disparities among priority populations. http://www.health.ri.gov/publications/plans/2009-2014AsthmaStatePlan.pdf

- **VECTOR SURVEILLANCE FOR MOSQUITO-BORNE AND TICK-BORNE DISEASES:** A surveillance system is in place to track and monitor these diseases throughout Rhode Island.

- **WATER SUPPLY AND QUALITY STUDY WITH CLIMATE CHANGE:** The Rhode Island Department of Health Office of Drinking Water Quality, has launched a new effort called "SafeWater RI: Ensuring Safe Water for Rhode Island's Future" to help address the issue. The objective of the project is to assess changing environmental conditions (including temperature, precipitation patterns, sea level rise, and storm surge) and their potential impacts on drinking water utilities in Rhode Island, and to develop strategies to address these changing conditions.

RI DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

- **ASSESSING DAMS FOR CATASTROPHIC FAILURE:** The RIDEM has classified all dams in the state based on the probable damage caused by catastrophic failure. Those dams that would be expected to cause loss of human life or significant property or infrastructure damage are routinely visually inspected in accordance with the Dam Safety Regulations, and their conditions are rated. Regulatory priority is given to those dams that would cause loss of life upon failure and are in the worst condition. The RIDEM has classified all dams in the state based on the probable damage caused by catastrophic failure. Those dams that would be expected to cause loss of human life or significant property or infrastructure damage are

routinely visually inspected in accordance with the Dam Safety Regulations, and their conditions are rated. Regulatory priority is given to those dams that would cause loss of life upon failure and are in the worst condition.

- **COMPREHENSIVE WILDLIFE CONSERVATION STRATEGY UPDATE WITH CLIMATE CHANGE:** Provides an overview of current impacts on wildlife due to climate change, direct human impact, and other stressors. It outlines species and habitats under greatest threat and addresses statewide monitoring and management techniques. RIDEM and Fish and Wildlife are preparing to issue an updated and expanded RI Wildlife Strategy in 2012. A major new addition to the strategy will be to address climate change adaptation. http://www.dem.ri.gov/programs/bnatres/fishwild/pdf/swgplan.pdf

- **STREAM DEPLETION METHODS FOR WATER ALLCOATION**: RIDEM is developing methods for allocating water during dry periods.

- **STORMWATER SOLUTIONS PROJECT:** This RIDEM project provides training and support for municipal wastewater and stormwater managers, decision-makers, etc. related to short-term and long-term climate/precipitation issues, as well as planning for variations in sea level.

- **WASTEWATER TREATMENT INFRASTRUCTURE CLIMATE CHANGE VULNERABILITY ASSESSMENT:** The Rhode Island Department of Environmental Management (RIDEM) is currently considering the implementation of a vulnerability assessment of the state's wastewater treatment infrastructure. The assessment would include the state's nineteen (19) major wastewater treatment facilities, as well as the Narragansett Bay Commission's Combined Sewer Overflow Abatement Project (described above); the major pump stations in Providence, Cranston, Westerly, West Warwick, Warwick, Bristol, Narragansett and South Kingstown; and the two combined sewer overflow facilities in Newport. The assessment would include watershed modeling analysis, a risk assessment and the development of associated adaptation strategies. RIDEM is currently seeking funding for this important project, which is estimated to cost between $40,000 and $60,000. If the project were to move forward, it would be one of the earliest, if not the first, assessments of its kind in the country.

RI DEPARTMENT OF ENVIRONMENTAL MANAGEMENT AND COASTAL RESOURCES MANAGEMENT COUNCIL: **UPDATED STORMWATER MANUAL WITH LOW IMPACT DEVELOPMENT METHODS**

In 2010, the Department of Environmental Management and the Coastal Resources Management Council have developed and adopted a revised State of Rhode Island stormwater manual that requires low impact development methods to manage stormwater on new construction and redevelopment projects. The manual was developed to implement the Cleaner Bay Act of 2007, to ensure a higher level of stormwater treatment and to reduce overland runoff and recharge groundwater by requiring a greater percentage of stormwater infiltration. The new stormwater manual design requirements account for recent climatic changes in precipitation and will help new projects and redevelopment projects adapt to climate change.

http://www.dem.ri.gov/programs/benviron/water/permits/ripdes/stwater/pdfs/desgnmnl.pdf

RI DEPARTMENT OF ENVIRONMENTAL MANAGEMENT, NARRAGANSETT BAY COMMISSION, NATIONAL GRID, UNIVERSITY OF RHODE ISLAND, US ENVIRONMENTAL PROTECTION AGENCY & RHODE ISLAND MANUFACTURERS EXTENSION SERVICE: **SUSTAINABLE ENERGY MANAGEMENT PROGRAM FOR WASTEWATER TREATMENT FACILITIES**

In 2008 the Rhode Island Department of Environmental Management (RIDEM), the Narragansett Bay Commission (NBC), the University of Rhode Island (URI), EPA Region I, the Rhode Island Manufacturers Extension Service (RIMES), and National Grid (the Project Team) initiated a Sustainable Energy Management Program for Rhode Island Wastewater Treatment Facilities (WWTF). Using a combination of EPA and ARRA grant funds the Project Team has worked with all 19 Rhode Island WWTFs to identify and

implement Energy Management and Renewable Energy Projects to help make these facilities become more resilient to the energy related impacts of climate change. These efforts have resulted in the identification and assessment of more than 125 individual energy improvement opportunities. In addition to the cost savings associated with less energy use, these efforts also help to reduce the generation of greenhouse gases. http://www.narrabay.com/en/programsandprojects/nbc%20energy%20projects/

RI DEPARTMENT OF TRANSPORTATION: **INFRASTRUCTURE PROJECTS INCORPORATE ADAPTATION STRATEGIES**

- **ROUTE 138 RECONSTRUCTION:** The Rhode Island Department of Transportation (RIDOT) is currently designing roadway improvements on Route 138 from Route 2 to Route 108 in the Town of South Kingstown, which covers a distance of 3.2 miles. The design calls for the replacement of the existing storm drain system in its entirety. By utilizing the design requirements of the 2010 Rhode Island Stormwater Design and Installation Standards Manual, the new system will be able to accommodate a 25-year storm event based on the updated rainfall totals provided by the Northeast Regional Climate Center. The new system will also be designed to maintain runoff in each of the four watersheds within the project corridor, rather than conveying stormwater to adjacent watersheds. Overall, the project will infiltrate stormwater runoff from approximately 16.6 acres of existing impervious roadway surface. This represents roughly one half of the existing roadway surface area. Roughly 3.3 acres of new impervious surface will also be infiltrated into the ground, thus significantly reducing stormwater runoff from the project.

- **REPLACEMENT OF CENTRAL BRIDGE NO. 182:** This is one of two bridges crossing the Barrington River. Originally constructed in 1939, the concrete structure now requires full replacement due to its deteriorated condition. Clearance under existing conditions is approximately 6.2 feet at mean high water (MHW). Due both to past sea-level rise and in anticipation of additional sea-level rise due to climate change, the Town of Barrington has requested that RIDOT increase the bridge clearance by approximately 2 feet, to which RIDOT has agreed. The proposed bridge clearance will be approximately 8.5 feet at MHW. The raised structure will facilitate the passage of Town emergency vessels that are partially restricted by the existing bridge. Other elements of this project that seek to address the effects of climate change include reducing stormwater runoff volumes by removing excess pavement from a nearby roadway; providing offsite infiltration for stormwater runoff; and armoring the proposed bridge causeways to protect them from erosion and scour from higher tides due to sea level rise.

RI DIVISION OF PLANNING: **UPDATED COMPREHENSIVE PLANNING AND LAND USE ACT WITH NATURAL HAZARDS AND SEA LEVEL RISE REQUIREMENT**

Adopted in 2011, the updated Comprehensive Planning and Land Use Act requires cities and towns to include as part of their comprehensive plans, an identification of areas that could be vulnerable to the effects of sea-level rise, flooding, storm damage, drought, or other natural hazards as well as goals, policies, and implementation techniques that would help to avoid or minimize the effects that natural hazards pose to lives, infrastructure, and property.

RI DIVISION OF PLANNING, NORTH KINGSTOWN, UNIVERSITY OF RHODE ISLAND, CRMC, THE NATURE CONSERVANCY: **NORTH KINGSTOWN SEA LEVEL RISE PILOT STUDY AND PLAN**

The Town of North Kingstown was selected as a pilot community to assess the effects of sea level rise on coastal communities. Phase 1 of the study identified critical assets impacted by various sea level rise scenarios, using sea level rise map overlays created by the University of Rhode Island, and looked for opportunities to incorporate actions into the hazard mitigation plan and local comprehensive plan. The Coastal Resources Center has also been selected as a recipient of a 2012 Planning Challenge Grant to develop, in collaboration with the Town of North Kingstown, for Phase 2 to develop a comprehensive plan element addressing

climate change adaptation in relation to transportation and land use issues. A training session on incorporating climate change adaptation into comprehensive plans will be developed to assist other Rhode Island communities and a communications strategy to assist in educating residents. http://seagrant.gso.uri.edu/climate/slr_tools.html

RI DIVISION OF PLANNING AND RI DEPARTMENT OF: **TRANSPORTATION NETWORK SEA LEVEL RISE VULNERABILITY ASSESSMENTS**

The Rhode Island Division of Planning and the Department of Transportation are working together to refine the initial sea level rise inundation mapping contained in Transportation 2030 and to identify specific bridges, roads, rail segments, airports and other intermodal facilities that may be impacted throughout the state. To inform this process, the State of Rhode Island was awarded funding from the United States Geologic Survey to obtain coastal LiDAR data and State funds were used to upgrade the project to a statewide LiDAR data set. This information will be used to develop a strategy for working with stakeholders to identify prioritized mitigation needs.

RI EMERGENCY MANAGEMENT AGENCY

- **HAZARD MITIGATION PLAN UPDATES**: State and local mitigation plans form the foundation for a community's long-term strategy to reduce disaster losses and break the cycle of disaster damage, reconstruction, and repeated damage. Mitigation plans create a framework for risk-based decision making to reduce damages to lives, property, and the economy from future disasters. State, Indian Tribal, and local governments are required to develop a hazard mitigation plan as a condition for receiving certain types of non-emergency disaster assistance. The State of Rhode Island Hazard Mitigation Plan was most recently updated and approved in April 2011. Local Hazard Mitigation Plans are required to be updated every five years and the State Plan every three years. There is an effort underway by the Rhode Island Emergency Management Agency to incorporate climate change adaptation planning into community- and state-level hazard mitigation plans. http://www.riema.ri.gov/documents/preparedness/RI_State_HM_Plan%20Final.pdf

- **FLOOD MITIGATION WORKING GROUPS:** Since the March, 2010 event, the Flood Mitigation Working Group, convened by RI Emergency Management Agency, meets quarterly to address planning and actions to reduce flooding.

RI GENERAL ASSEMBLY

- **BILLS INTRODUCED - ENABLING AUTHORITY FOR MUNICIPAL STORMWATER MANAGEMENT:** Senator Miller and Representative Handy introduced legislation in 2012 that will give municipalities additional tools to address stormwater management. S2445 and H7803 will provide municipalities with enabling authority, in collaboration with state agencies, to establish uniform standards to reduce long term flooding impacts and protect water resources in order to restore water quality conditions where needed.

- **LESSONS LEARNED FROM TROPICAL STORM IRENE, JANUARY 2012:** The Senate Committee on Housing and Municipal Government report on Tropical Storm recommends the following actions as they relate to telecommunications. 1. All appropriate entities should have a presence at the state command headquarters during a classified storm event. 2. Utility companies and telecommunication companies should operate a municipality room twenty-four hours a day with a dedicated customer service representative to assist local leaders. 3. Utility companies and telecommunication companies should maintain up-to-date lists of critical facilities. While these recommendations were initially meant to address hazard mitigation, they can help reduce post-storm damage and hardship as we experience impacts from climate change such as increased storminess. http://www.rilin.state.ri.us/Documents/Tropical%20Storm%20Irene%20Report.pdf

RI RESOURCE RECOVERY CORPORATION: **CENTRAL LANDFILL DISASTER PREPAREDNESS PLAN**

The design of the Rhode Island Resource Recovery Corporation (RIRRC) Central Landfill facility takes into account large storm events and the ability to manage localized flooding on site. The base designs use a 25-year storm event, as a minimum, for all surface water control structures. These facilities also include emergency overflows to the nearby waterways to minimize overtopping and inundation of the structures. During the March 2010 storm event, all structures functioned as designed, with no erosion, failure or loss of operations.

Further, RIRRC maintains a fleet of equipment on site, and therefore will be able to quickly return the site to full operations after storm events. RIRRC also maintains two fuel trucks with a combined capacity of 8,000 gallons of diesel fuel, which provides RIRRC a buffer of about three days of fuel supply while vital infrastructure is restored, or other fuel deliveries are resumed.

RI SEA GRANT, URI COASTAL INSTITUTE, BROWN CENTER FOR ENVIRONMENTAL STUDIES: **RI CLIMATE CHANGE PORTAL WEB SITE DEVELOPMENT**

The overall goal of the website is to provide information on the impacts of climate change on Rhode Island's people, economy, landscape, and plant and animal life. The site should empower people to plan for and prepare for these impacts. The target audience includes a broad range of people including concerned members of the general public as well as community leaders and decision makers.

RI SEA GRANT, URI COASTAL INSTITUTE, CANCER PREVENTION RESEARCH CENTER, GRADUATE SCHOOL OF OCEANOGRAPHY, URI COMMUNICATIONS DEPARTMENT: **URI CLIMATE CHANGE COLLABORATIVE**

An interdisciplinary project draws on communication and behavioral science, as well as climate change research to understand how to help increase capacity of individuals and advance the application of climate change adaptation. The team works to 1) develop a synthesis of climate change research relevant to coasts that is credible, current, and accessible; 2) apply a behavior change model from the public health arena to coastal communities coping with environmental and socio-economic impacts of climate change; 3) build the capability of academics, extension staff, and decision-makers to effectively communicate the science and implications of climate change to citizens and motivate them toward proactive behavior change; and 4) use Rhode Island as a living laboratory to start communities on the path to becoming more aware of the implications of climate change and thus more confident of, and ultimately capable of, incorporating adaptation in community planning. http://seagrant.gso.uri.edu/climate/index.html

RI SEA GRANT, URI ENVIRONMENTAL DATA CENTER, COASTAL RESOURCES MANAGEMENT COUNCIL, THE NATURE CONSERVANCY, STATEWIDE PLANNING: **SEA LEVEL RISE MAPPING AND VISUALIZATIONS**

Rhode Island Sea Grant collaborated with partners to developed statewide GIS overlay maps that depict sea level rise (1, 3, 5 foot) scenarios, as well as the 1938 hurricane inundation, that can assist communities in planning for climate change adaptation. Using a patchwork of existing LiDAR data available in the state prior to 2011, the maps use a "bathtub" model, which assumes even rise of sea level, similar to what happens when a bathtub is filled. This model, which was created by combining accurate high resolution maps, represents a conservative estimate of the extent of inundation. North Kingstown, in collaboration with university, state, and NGO organizations, piloted an effort in 2011 to use the maps to estimate potential impact to buildings and transportation infrastructure, as described below. Also available are visualizations (using photographic simulation) of the potential impact of sea level rise at key locations along Rhode Island's shores developed by the Coastal Resources Center. http://seagrant.gso.uri.edu/climate/index.html

RI SEA GRANT, COASTAL RESOURCES MANAGEMENT COUNCIL, RI BUILDING COMMISSION, RI EMERGENCY MANAGEMENT: **STORMSMART COASTS RI WEB PORTAL ON FLOOD PREPAREDNESS**

StormSmart Coasts is a national resource for coastal decision makers looking for the latest and best information on how to protect their communities from weather and climate hazards, both on State and Federal levels, before, during and after a storm. Rhode Island was the 7th state to complete the StormSmart Coast website specific to Rhode Island regulations, with assistance from the Rhode Island Flood Awareness and Climate Change Task Force. The site has links for the City Council or Town managers; the building departments: public works; and the planning boards. http://ri.stormsmart.org/

RI STATE BUILDING CODE COMMISSION: **UPDATED STATE BUILDING CODE REQUIREMENTS**

The State Building Code (2011) requires a one (1) foot freeboard in all V and Coastal A-Zones. In addition, new construction (or substantially-improved structures) in Coastal A- Zones must be built to V- Zone standards. www.ribcc.ri.gov

RI STATE BUILDING CODE COMMISSION, RHODE ISLAND EMERGENCY MANAGEMENT AGENCY, RI SEA GRANT, RHODE ISLAND COASTAL RESOURCES MANAGEMENT COUNCIL, AND RHODE ISLAND FLOOD MITIGATION ASSOCIATION**: RHODE ISLAND FLOOD AWARENESS AND CLIMATE CHANGE TASK FORCE (RIFACCT)**

RIFACCT is a cooperative effort between state agencies, educational facilities and non-government organizations (Rhode Island State Building Code Commission, Rhode Island Emergency Management Agency, RI Sea Grant, Rhode Island Coastal Resources Management Council, and the Rhode Island Flood Mitigation Association) to inform the public on hazard issues and the process required for rebuilding after a major disaster. The first FACCT sheet is designed to familiarize property owners with state and local permitting procedures for repair or rebuilding structures and septic systems after a storm to ensure that reconstruction is done in a safe and timely fashion, and is compliant with local ordinances and state regulations. RIFACCT will be reconvened to update the State Building Code to develop the safest redevelopment regulations considering sea level rise. http://www.riema.ri.gov/prevention/floods/FACCT.php

SAVE THE BAY

- ASSESSMENT AND SUPPORT OF SHORELINE ADAPTATION ACTIONS: Assess and map areas most vulnerable to sea level rise, such as areas of the watershed with low lying infrastructure, undersized culverts, at-risk salt marshes, and coastal erosion. In these areas, Save The Bay advocates for adaptation techniques such as buffer enhancement, shoreline grading and planting, bioengineering erosion control, rebuilding intertidal shellfish reefs, and hybrid techniques (such as living shorelines). Save The Bay is collaborating with municipalities on coastal adaptation projects in Warwick, India Point Park in Providence, Narragansett, Newport and Bristol County. www.savebay.org

- CULVERT ASSESSMENTS: Save The Bay is assessing culverts and bridges in coastal areas for their ability to handle high flows due to tidal surge and floods and their impact on wildlife passage and water quality. Many of the culverts and bridge spans located in tidal areas are undersized and contribute to road flooding and damage. As sea level has already risen, some culverts are now under water at high tide. Maps and photographs are being shared with municipalities to make them aware of these problem areas.

- DEAD END ROAD STORMWATER ASSESSMENT: Save The Bay is conducting in-house assessments of roads that dead-end on the coastline and is identifying areas where the pavement can be removed and stormwater can be infiltrated before it enters coastal waters throughout the Narragansett Bay watershed and the south coast. Many of these road ends have been washed out by erosion, are flooding at high tide and are causing erosion of salt marshes adjacent to the road end. . Conceptual designs are being developed for swales and other bio-retention solutions in these areas.

TREES 2020, GROUNDWORK PROVIDENCE & CITY OF PROVIDENCE

Trees 2020 is an initiative to increase Providence's tree cover to 30% by the year 2020. The initiative strongly encourages homeowners, land-owning institutions, and city-sponsored tree planting programs to plant over 40,000 trees by providing low-cost, resilient tree options. http://www.trees2020.org/

URI COASTAL RESOURCES CENTER, URI ENVIRONMENTAL DATA CENTER, THE NATURE CONSERVNACY, SOUTH KINGSTOWN LAND TRUST, AND THE COASTAL RESOURCES MANAGEMENT COUNCIL: **ADDRESSING CLIMATE CHANGE THROUGH HABITAT PROTECTION AND LAND TRUSTS**

This pilot project works with the South Kingstown Land Trust to identify and test tools that incorporate climate change considerations into conservation programs for land acquisition and management. Important tools used in conducting sensitivity analysis and developing management actions include habitat vulnerability assessment, Ecological Land Unit (ELU) evaluation, and sea level rise mapping. http://seagrant.gso.uri.edu/climate/habitat.html

WATER RESOURCES BOARD: **STRATEGIC PLANNING INITIATIVE FOR POTABLE WATER SUPPLY**

The WRB's recently approved Strategic Planning Initiative analyzed the State's water resources with a focus on potable water supply. WRB aggregated similar water supply systems into four different regions of the State. These regions allow WRB to assess current and future demands for both sustainable potable water supply and environmental requirements (developed jointly with RIDEM). The regions acknowledge the capacity of both the environment and the water supply infrastructure to mitigate various demand scenarios, including the effects we are experiencing from climate change. The WRB strategic plan identified a palette of initiatives that address short term and long term water supply needs, with a focus on critical water resources and vulnerable water supplies in both coastal and upland areas. The effects of climate change will be addressed through our water availability estimating and system vulnerability initiatives. http://www.wrb.ri.gov/policy_statutes_planning/WRB_StrategicPlan_031612.pdf

OTHER LOCAL EFFORTS

COMMUNITY VULNERABILITY ASSESSMENTS: U.S. Environmental Protection Agency's Safe Drinking Water, Clean Water Act, and Community Right to Know (toxic release inventory) have required community vulnerability assessments.

REVERSE 9-1-1: Many localities have "reverse 9-1-1" systems in place that could be mobilized to warn residents about heat emergencies, floods or other immediate events.