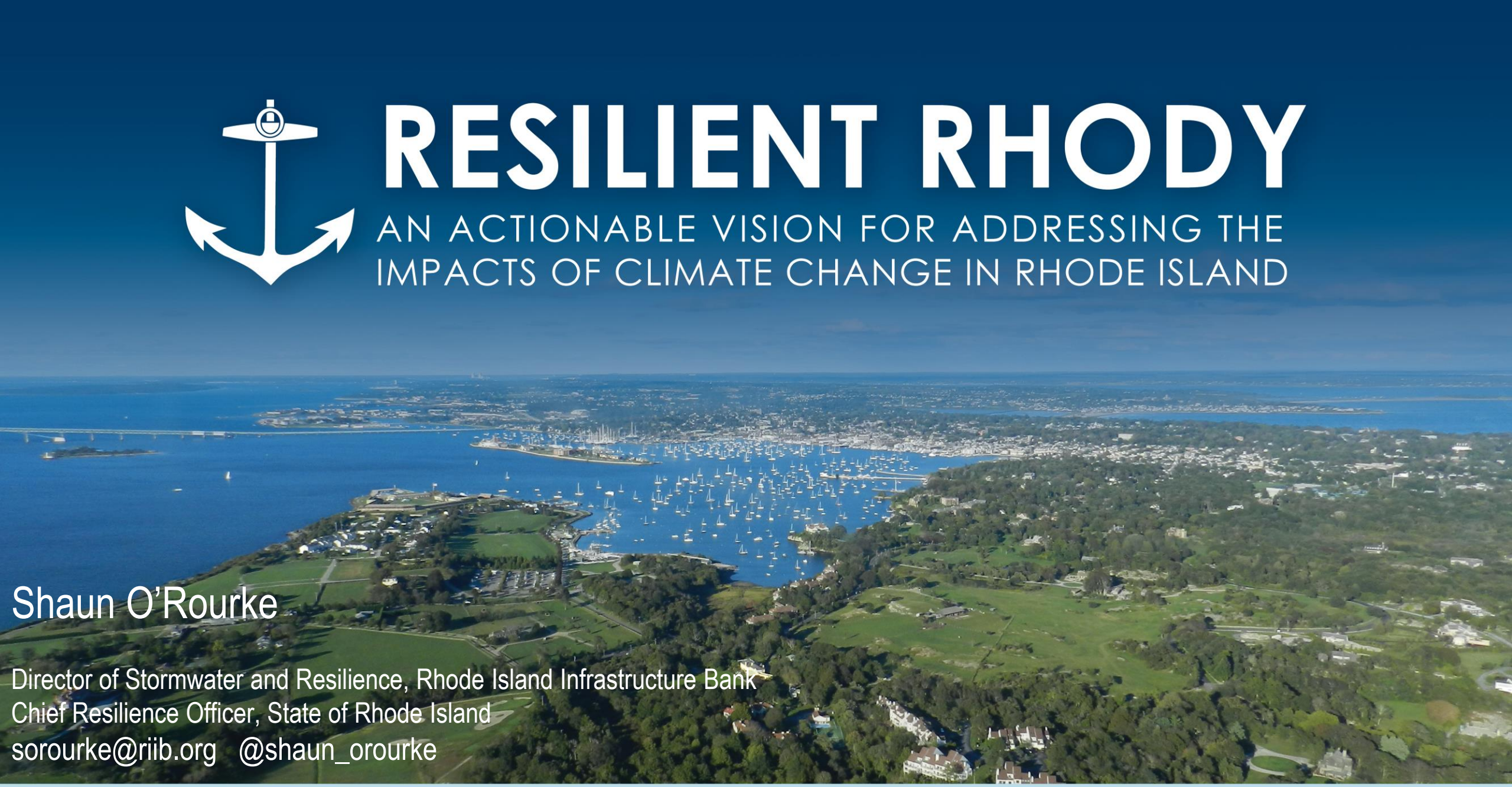
RESILIENT RHODY

AN ACTIONABLE VISION FOR ADDRESSING THE IMPACTS OF CLIMATE CHANGE IN RHODE ISLAND



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Aerial view of Newport and Narragansett Bay, photo from Robinson R44 Helicopter by Michael Kagdis, courtesy of Wikimedia Commons

Rhode Island: the fun-sized state

- With over 400 miles of coastline and more than 100 beaches, Rhode Island's shores and coastal waters are central to the state's cultural, environmental, and economic interests.
- Narragansett Bay is an estuary of "national significance" and a focus of water quality restoration and climate change resilience projects.
- Tourism is one of Rhode Island's most important economic sectors and the state is increasingly a foodie destination.

South Kingstown Town Beach: 2005

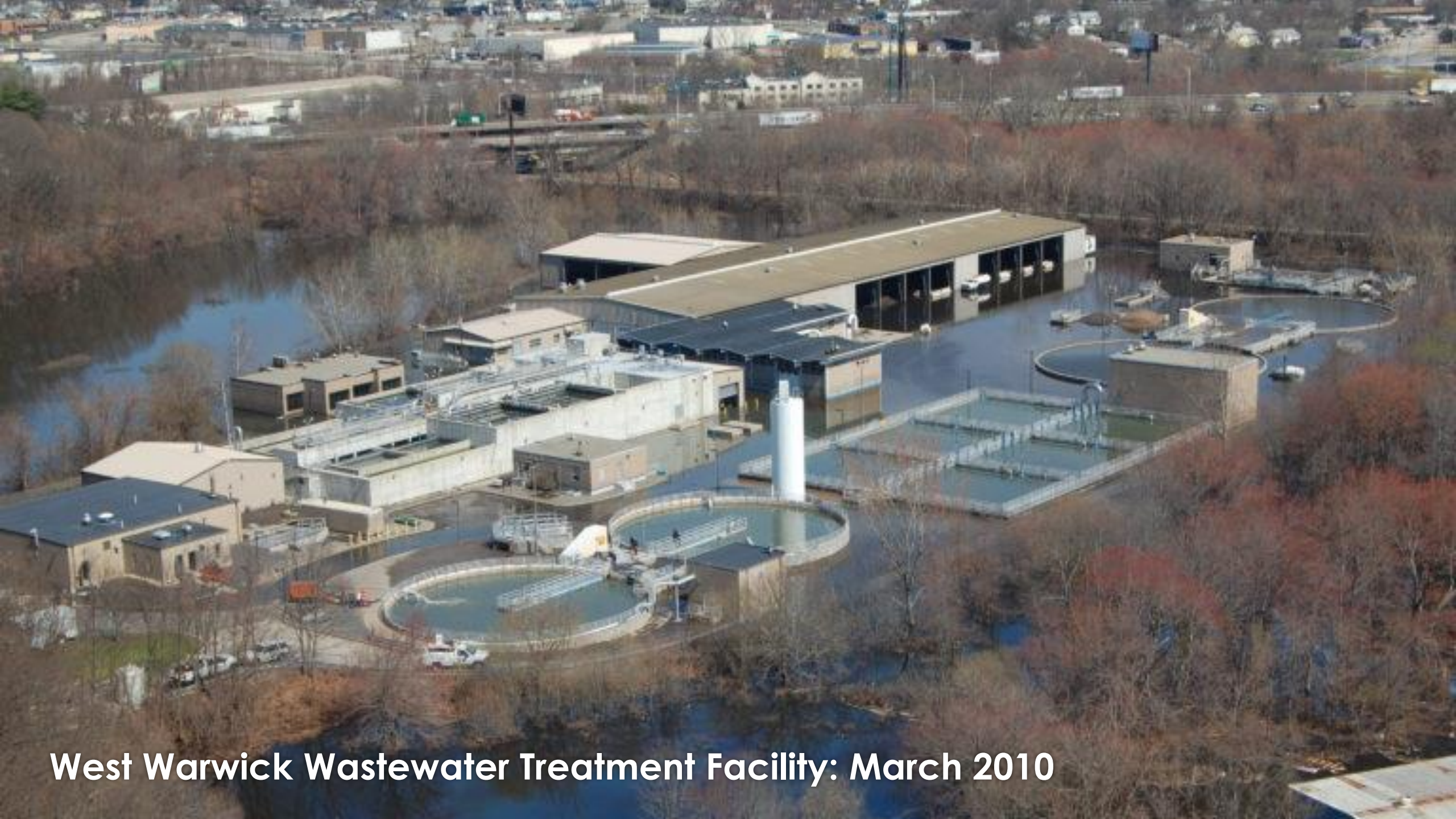

South Kingstown Town Beach: Today

Narrow River in Narragansett

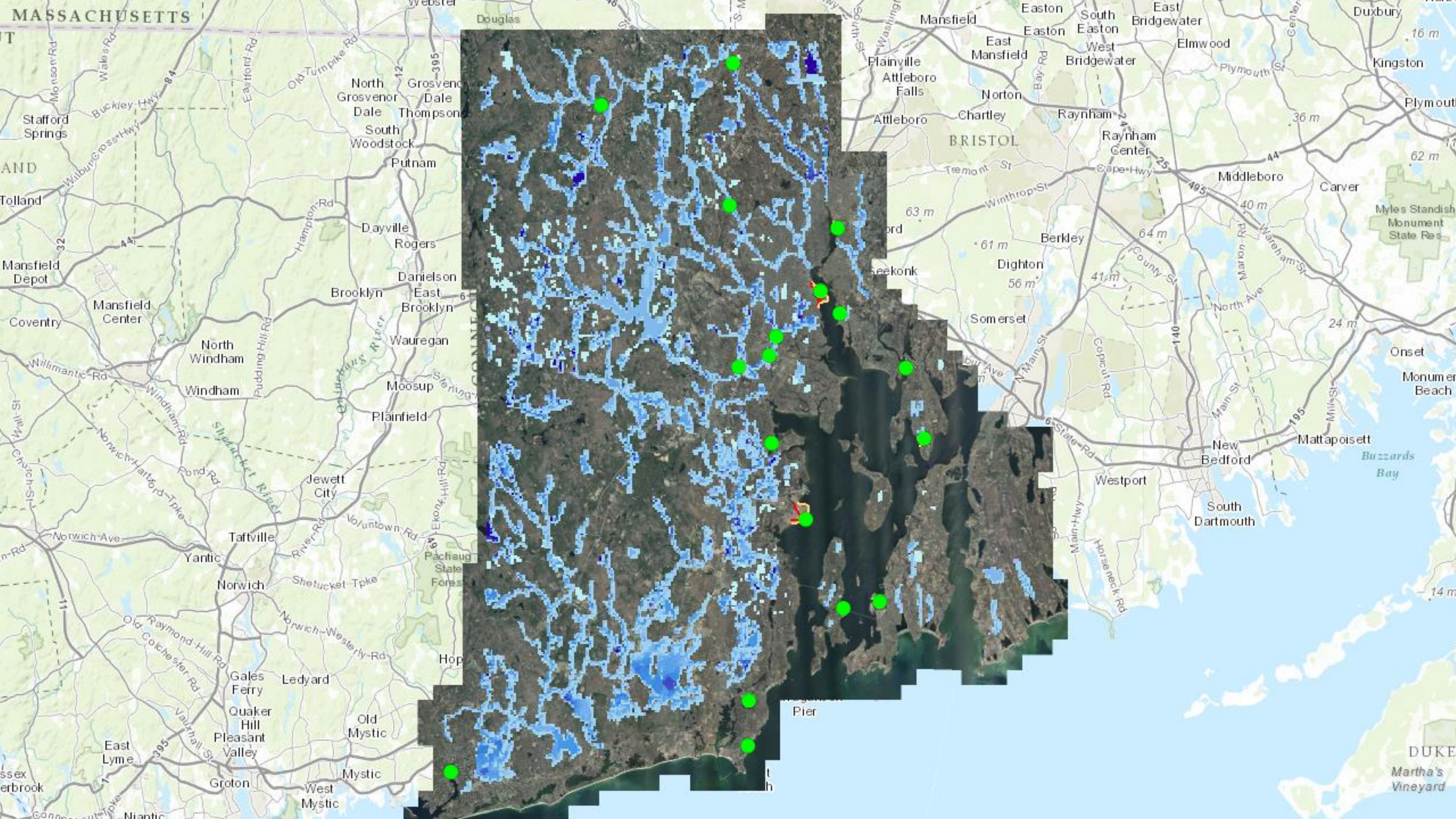
Narrow River in Narragansett: After Superstorm Sandy

Johnston RI: Repetitive inland flooding

West Warwick Wastewater Treatment Facility



West Warwick Wastewater Treatment Facility: March 2010


MASSACHUSETTS
Webster
Douglas
Mansfield
Easton
South Easton
East Bridgewater
Duxbury
East Mansfield
West Bridgewater
Elmwood
Kingston
Plainville
Attleboro Falls
Norton
Plymouth
North Grosvenor Dale
Grosvenor Dale
Thompson
Stafford Springs
South Woodstock
Attleboro
Chartley
Raynham
Raynham Center
BRISTOL
Putnam
Tolland
Middleboro
Carver
Dayville
Rogers
Myles Standish Monument State Res
Berkley
Mansfield Depot
Danielson
Dighton
Seekonk
Brooklyn
East Brooklyn
Mansfield Center
Coventry
Somerset
North Windham
Wauregan
Onset
Windham
Moosup
Monument Beach
Plainfield
New Bedford
Mattapoisett
Buzzards Bay
Westport
Jewett City
South Dartmouth
Taftville
Yantic
Norwich
Pachaug State Forest
Gales Ferry
Ledyard
Quaker Hill
Old Mystic
Pleasant Valley
East Lyme
Mystic
Groton
West Mystic
Niantic
Pier
DUKES
Martha's Vineyard
16 m
36 m
62 m
63 m
61 m
64 m
40 m
41 m
56 m
24 m
14 m

THE UNIVERSITY OF RHODE ISLAND

Development of an Integrated Watershed/River Model for Flood Management: Assessment of a Record Breaking Event in March 2010 in the Pawtuxet River, RI.

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EWRI ASCE

Introduction

A record-breaking flood event (about 500-yr return period) that occurred in March 2010 in Rhode Island (Figure 1), initiated several studies to understand and develop mitigation strategies to address flooding impacts along the Pawtuxet River. We have developed a spatially distributed hydrological/hydraulic modeling system for the entire watershed and river using the state of the art GIS-based numerical models, and the most recent watershed and river data.

Figure 1: Warwick Mall [1] (left) , Warwick Sewer Treatment Facility [2] (right) during March 2010 Flood.

Objectives

- Developing a web/GIS-Based watershed/river model for the Pawtuxet watershed to predict flooding along the river flood plains.
- Assessment of the watershed issues using the developed model: impact of the Scituate Reservoir on flooding, effect of historical dams on flooding, dam removals, debris, and levee heights.
- Paving the way for a real-time forecasting system for this river, and other rivers in RI.

Study Area

The Pawtuxet River is located on the western side of Narragansett Bay in RI. The geographical focus area in this study is the Pawtuxet River watershed, encompassing the Main, North, and South Branches Pawtuxet River. Inside the watershed are two major reservoirs: the Scituate and the Flat River Reservoirs, as well as several structures (historical dams and bridges) along the river (Figure 2).

Table 1 shows an overview of the drainage areas of subbasins in this watershed. Figure 3 shows the peak discharges for 10-yr, 50-yr, 100-yr, and 500-yr return periods in the Main, North, and South branches of the Pawtuxet River [11]. The drainage area ratio is higher for the North Branch than for the South Branch. It is interesting to note that the ratio of flow peaks are very close to the ratio of drainage areas.

Model

Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) and River Analysis System (HEC-RAS) are implemented to calculate runoff and river flooding in this study, respectively. Figure 4 represents the steps applied in the modeling. Spatial distributed data are pre-processed in ArcGIS and HEC-GeoHMS to produce the drainage network model, acting as an input to the rain-runoff model in HEC-HMS. The HEC-HMS model also takes distributed basin data, meteorological data, soil/landuse data, baseflow, and modeling control specifications to compute the timeseries of discharge. From the HEC-HMS model, timeseries of flow at upstream of rivers are used as input into the river hydraulic model (HEC-RAS), along with river cross sections, channel geometry, river structures, and roughness. Finally, from the hydraulic model, the water elevations are computed. These elevations are superimposed in DEM to compute flood maps in HEC-GeoRAS.

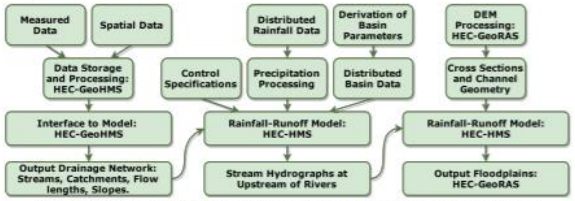


Figure 4: Flowchart of the distributed hydrologic and hydraulic modeling system for flood maping [4].

Simulation Methods

The methods used in the rainfall-runoff calculations in HEC-HMS were SCS for surface runoff calculation, monthly constant method for the baseflow calculation, SCS unit hydrograph for subbasin flow routing, and lag time method for reach routing calculations. Selections are mostly based on the similar studies in the United States and other countries. Other choices may also lead to similar results by proper calibration, but it is better to use the most appropriate method based on a watershed characteristics. Infiltration or runoff rates are predicted from the empirical loss rate parameter Curve Number (CN). CN is based on the area's soil type, land use, hydrologic condition, and depth of high water table. The runoff equation is expressed as

$$P_e = \frac{(P - 0.2S)^2}{P + 0.8S}, \quad (1)$$

where P_e is excess rainfall (runoff), P is precipitation, and S is potential maximum soil moisture which in SI units is

$$S = \frac{25400 - 254CN}{CN}. \quad (2)$$

where $30 <= CN <= 100$. The soil type data, land cover and resulting CN map of the Pawtuxet River watershed are shown in Figure 5.

Uncertainty Analysis – Continued

Figure 8(left) shows the timeseries of the flow discharge(computed by HEC-HMS) corresponding to various precipitation datasets. Figure 8(right) shows the 90% confidence interval for the flood discharge. Note that the observed discharge is within this uncertainty interval.

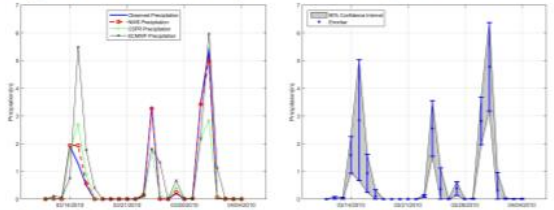


Figure 7: Daily precipitation data based on various data sources (left), and 90% confidence intervals (right) for mid-March to early April, 2010. See Table 2 for sources of precipitation data.

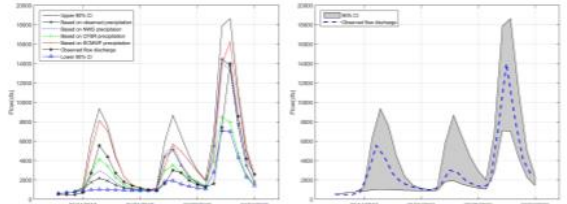


Figure 8: Computed HEC-HMS flow discharge based on various daily precipitation data (left), and the confidence interval of the flow discharge prediction (right).

The Effect of Scituate Reservoir on Flooding

The Scituate Reservoir is located in the middle of the northern part of the Pawtuxet River watershed. The Scituate Reservoir provides over 60% of the Rhode Island drinking water. The specifications of the spillway in the Scituate Reservoir are summarized in Table 3. Figure 9 shows the relationship between the discharge and water elevation for the spillway. The Scituate Reservoir has the capability to retain runoff during high flow periods as it has a very large reservoir (150 MCM). Figure 10 plots the modeled inflow and outflow to the ogee spillway in the Scituate Reservoir when the reservoir is at full capacity (left), and also when the reservoir water elevation is 4 ft below the crest elevation (right). During March 28 – April 4, 2010 the reservoir was almost full, but if the Scituate reservoir was just 4 ft below the spillway crest elevation, the peak flood discharge would decrease 60%. Adding this flood capacity could be potentially

Effect of Debris on Flooding

Debris such as tree limbs and accumulations of trash may contribute significantly to blockage of flow under bridges. In particular, in extreme storms and weather emergencies, tree trunks or branches may be broken off into rivers, without chance for removal. During the site visits, we observed a lot of broken trees and wooden debris in the river stream or floodplains, one example of which is shown in Figure 13(left). Figure 13(right) shows the Pawtuxet Village Bridge. The pier has a width of 7.5 ft. Lagasse et al. 2010[5] suggests the average width of debris to be 15 times a pier width and the height of the debris to be 0.33–0.5 of the water depth; based on this assumption, a block of debris with the dimension of 80 ft width and 6 ft height was simulated.

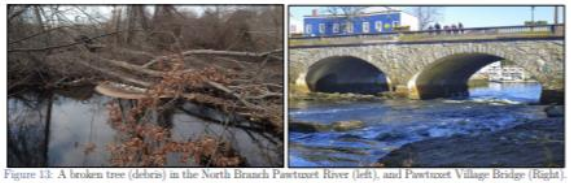


Figure 13: A broken tree (debris) in the North Branch Pawtuxet River (left), and Pawtuxet Village Bridge (Right).

Figure 14 shows the water depth after adding debris to the piers of the Pawtuxet Village bridge for a 100-yr event. As it can be seen, debris can significantly increase the flooding extent of an event, and should be modeled for more accurate flood risk assessments.

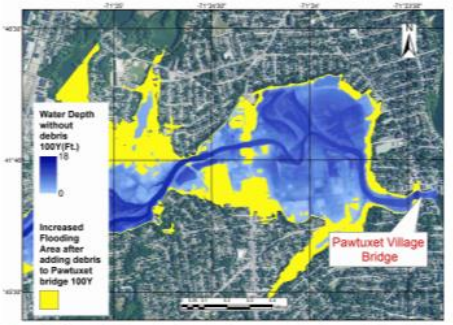


Figure 14: Effect of debris on the 100-yr flooding extent at the Pawtuxet Village bridge.

Online GIS-Based Tool to Access Flooding Maps: STORMTOOLS

Wake Up With Al

STORM TEARS THROUGH NEIGHBORHOOD

Westerly inundated with flood waters in 2010

RHODE ISLAND MANIFESTATIONS OF CLIMATE CHANGE

1. Sea Level Rise
2. Warming Air Temperatures
3. Warming Water Temperatures
4. Storm Frequency And Intensity
5. Changing Biodiversity
6. Precipitation and Inland Flooding

Resilient Rhody what's at risk

- 100% of **state drinking water supply** – 85% surface water

- 337 miles of **state and municipal roadway** are vulnerable to flooding in a 100 yr. storm surge event

- The state's 360,000 acres of **forest land** are being impacted by drought and invasive pests

- **Providence County has the worst air quality** in the Boston-Worcester-Providence metro area and received an F for high ozone days (American Lung Foundation)

In September 2017, Governor Gina M. Raimondo signed an Executive Order appointing a Chief Resilience Officer to drive climate resilience efforts across the state with the mission to develop a statewide action strategy by July 2018.

Resilient Rhody leadership structure

- The Resilient Rhode Island Act established the **Executive Climate Change Coordinating Council (EC4)** in 2014.
- It also sets specific greenhouse gas reduction targets; establishes **two advisory bodies, the EC4 Advisory Board and the EC4 Science and Technical Advisory Board**, to assist the Council.

Resilient Rhody

Strategy Goals

- Catalyze the planning and vulnerability studies already developed and move towards implementation
- Identify and prioritize resiliency actions the State can control to demonstrate progress and implementation
- Prioritize actions that promote cross-agency collaboration and support municipalities in resilience planning and project implementation

Timeline of natural disasters and select state agency reports and tools

Resilient Rhody framework

Making the Case for Climate Resilience

RESILIENCE THEME:

Emergency Preparedness

RESILIENCE THEME:

Natural Systems

RESILIENCE THEME:

Critical Infrastructure and Utilities

RESILIENCE THEME:

Community Health and Resilience

Financing Climate Resilience Projects

RESILIENCE THEME:

Financing Climate Resilience Projects

Groundbreaking of the Warren Wastewater Treatment Facility

- Communities across Rhode Island face an urgent need to build climate resilient infrastructure that will survive extreme weather events.
- There are several existing loan, bond, and grant programs for addressing climate resilience, and many new financing mechanisms currently under development by state and local agencies based on successful programs around the country.

Existing climate financing mechanisms

CRITICAL INFRASTRUCTURE AND UTILITIES

FINANCE TOOL	WATER	POWER	TRANSPORTATION
CLEAN WATER STATE REVOLVING FUND	X	X	
DRINKING WATER STATE REVOLVING FUND	X	X	
USDA RURAL DEVELPMENT LOAN PROGRAM	X	X	
BONDS	X	X	X
RIIB STORMWATER ACCELRATOR	X		
EFFICIENT BUILDINGS FUND		X	
WATER INFRASTRUCTURE FINANCE AND INNOVATION FUND	X		
ELECTRIC/GAS RATEPAYER FUNDS		X	
ENERGY SAVINGS PERFORMANCE CONTRACTS		X	
POWER PURCHASE AGREEMENTS		X	
PROPERTY ASSESSED CLEAN ENERGY	X	X	
MUNICPAL ROAD AND BRIDGE REVOLVING FUND			X
TAX INCREMENT FINANCING	X	X	X

NATURAL SYSTEMS

FINANCE TOOL	COASTAL	INLAND
MITIGATION BANKING	X	X
LAND TRUST	X	X
CLEAN WATER STATE REVOLVING FUND	X	X
DRINKING WATER STATE REVOLVING FUND		X
BONDS	X	X

EMERGENCY PREPAREDNESS

FINANCE TOOL	COASTAL	INLAND
EFFICIENT BUILDINGS FUND	X	X
PROPERTY ASSESSED CLEAN ENERGY	X	X
MUNICIPLE ROAD AND BRIDGE REVOLVING FUND	X	
BONDS	X	X

COMMUNITY RESILIENCE

FINANCE TOOL	COASTAL	INLAND
EFFICIENT BUILDINGS FUND	X	
PROPERTY ASSESSED CLEAN ENERGY	X	X
BONDS	X	X
TAX CREDITS		X
FHA MORTGAGES		X

Rhode Island Infrastructure Bank

Groundbreaking of the Warren Wastewater Treatment Facility

- Centralized hub of local infrastructure investment in Rhode Island
- Our mission is to support and finance investments in the State's infrastructure. Through its activities the Bank fosters infrastructure improvements that enhance the environment, create jobs, and promote economic development.

RHODE ISLAND
INFRASTRUCTURE BANK

Resilient Rhody Implementation

Town of Warren Wastewater Treatment Facility Upgrade

2011- Consent Agreement

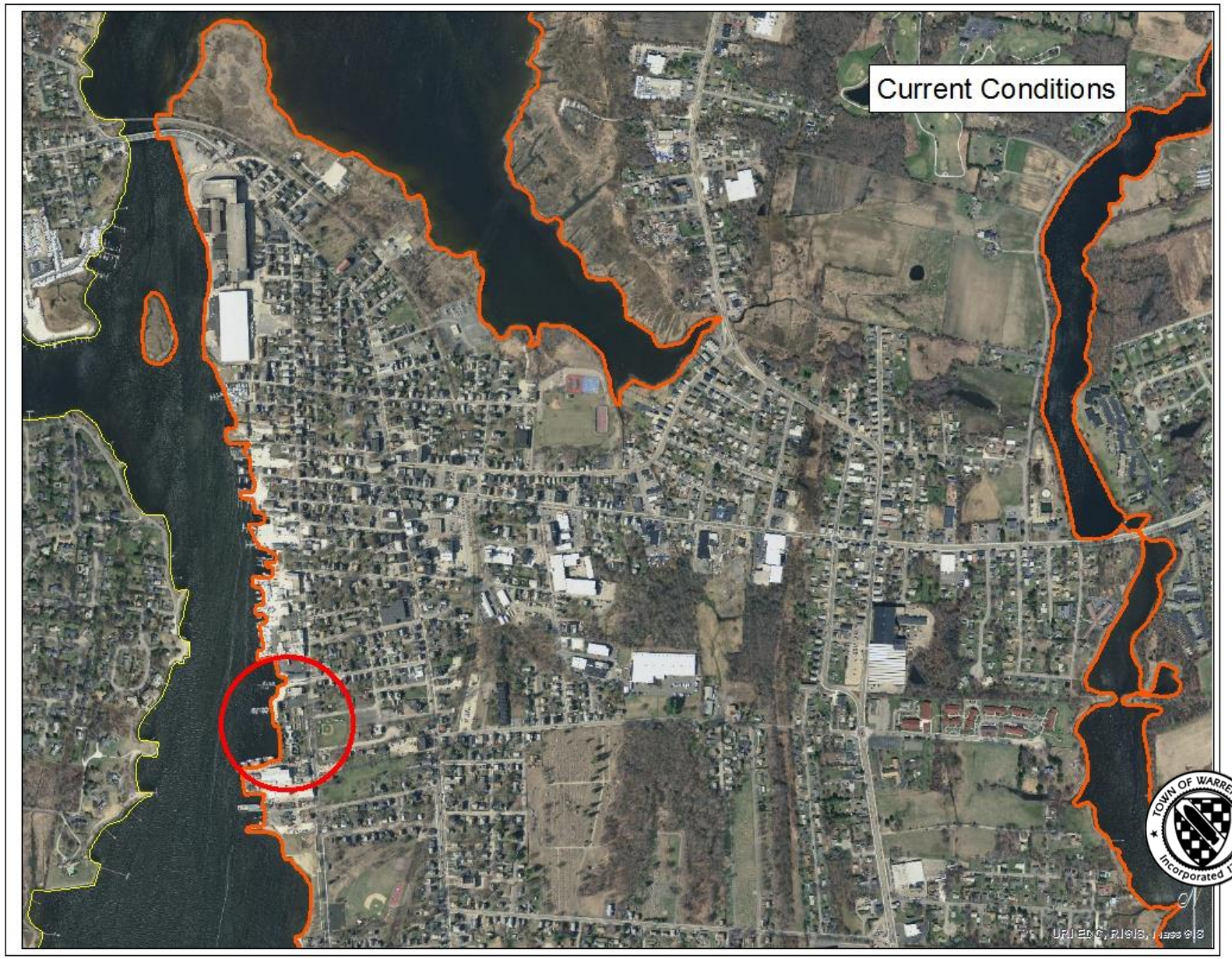
2015 – Design Basis Report
FEMA Flood – 11.4’

2016
Stormtools Analysis
12’ projected Stillwater
3’ SLR (NOAA 2065)
1’ wave based on STWAVE

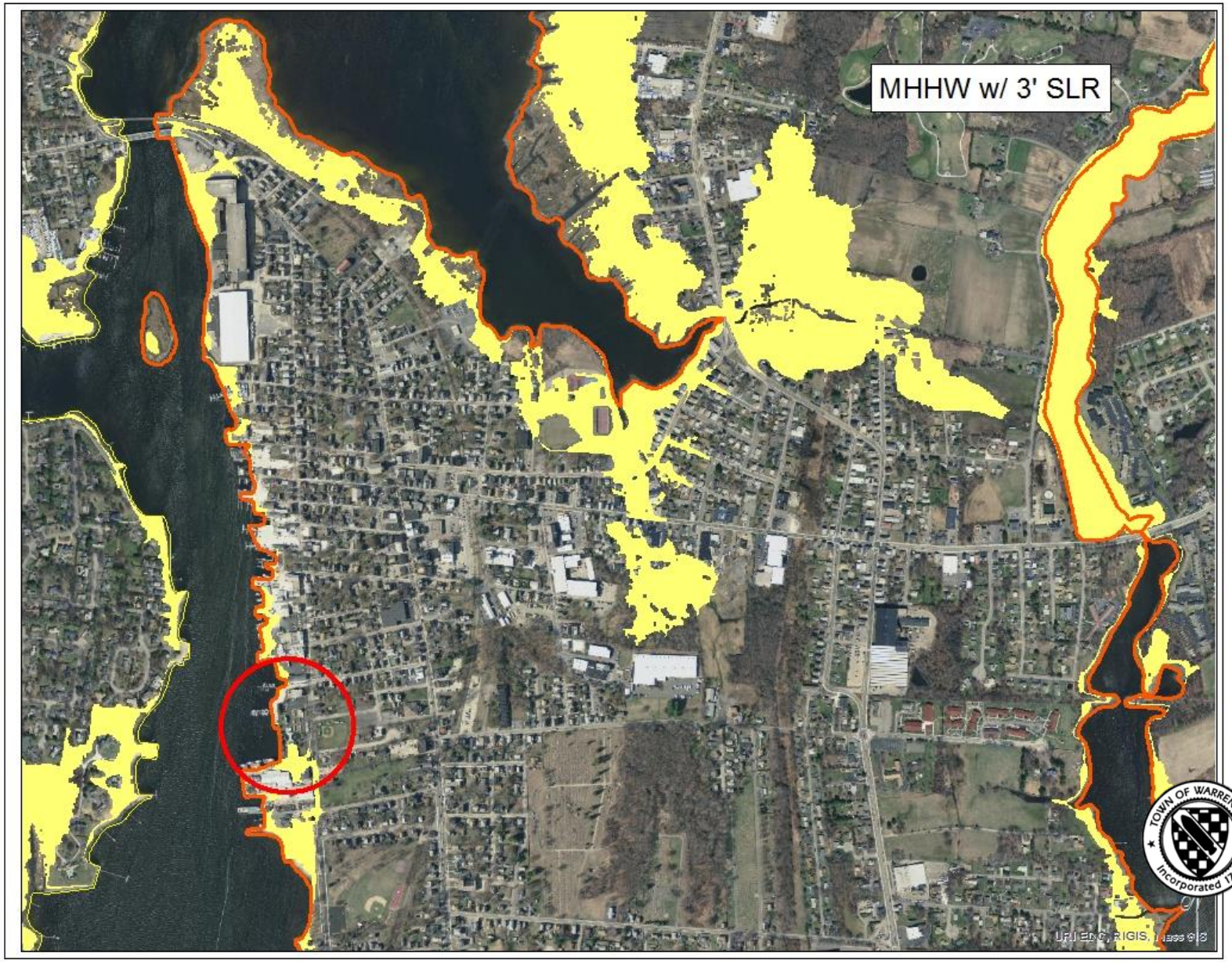
2017
Final Design
Permitting
Bid Process
-$20mm total
-$450 PF from RIIB

May 2018
Groundbreaking
-First WWTF to integrate DEM study recommendations

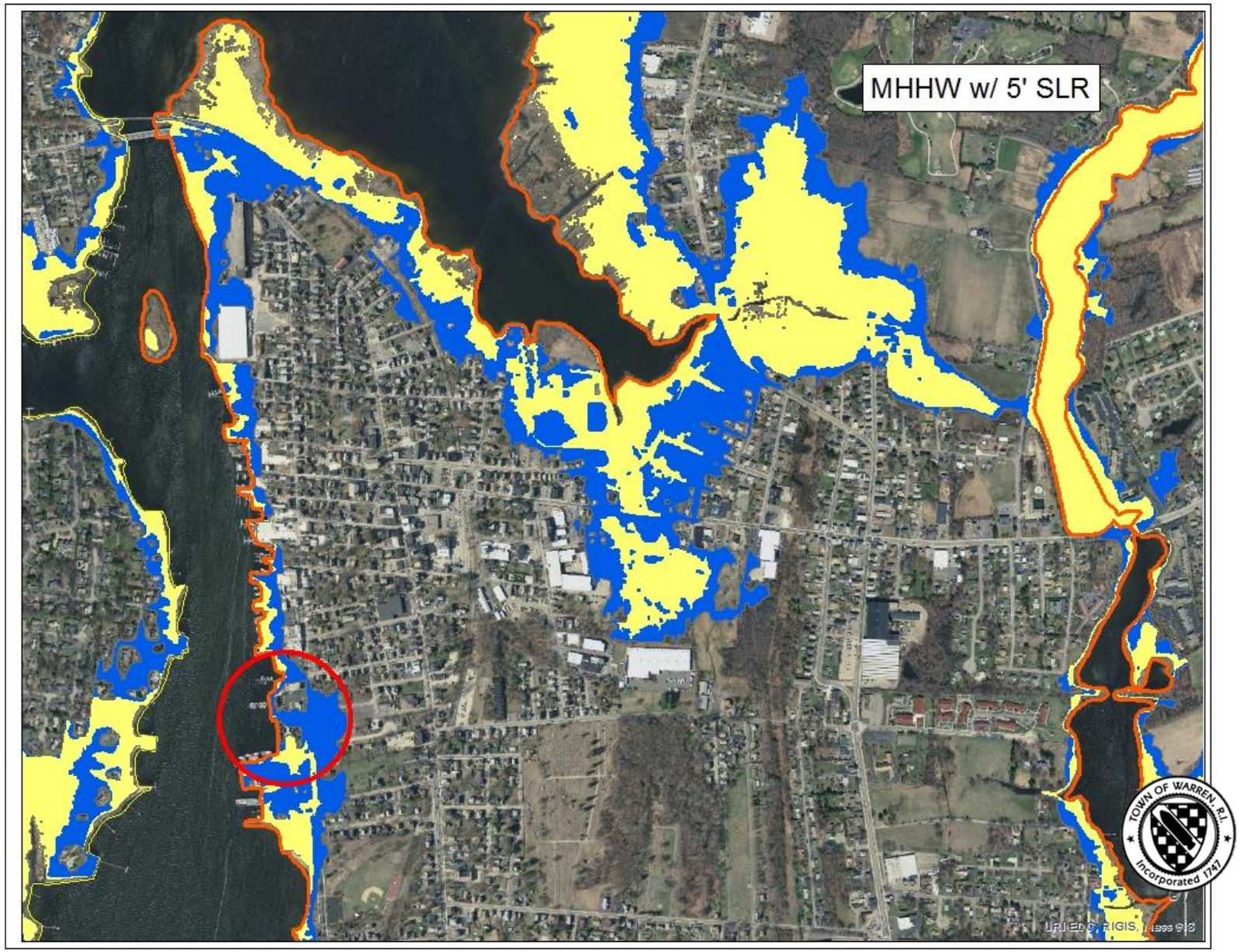
Current Conditions



MHHW with 3’ Sea Level Rise

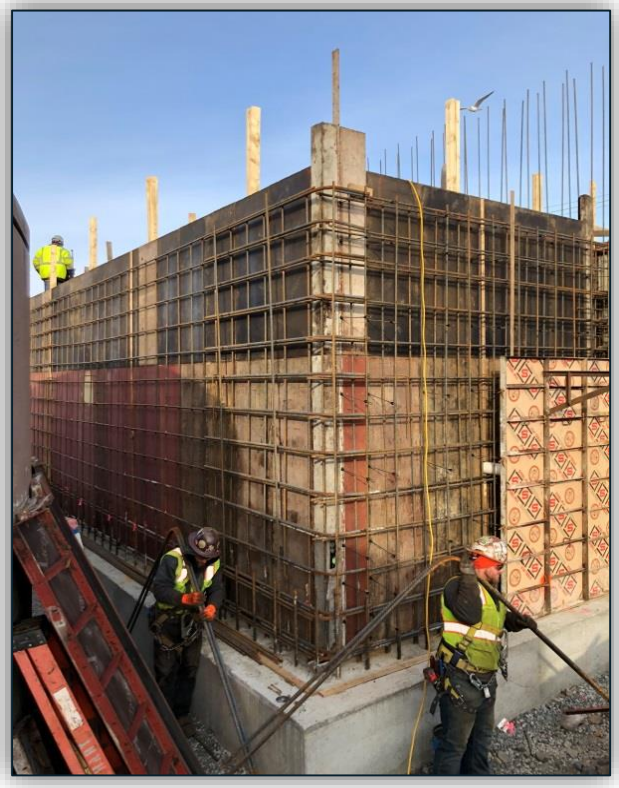


MHHW with 5’ Sea Level Rise



Resilience Improvements

SUBMERSIBLE PUMPS



COLLECTOR DRIVES

MOTOR CONTROLS & SWITCH GEAR

BACKUP GENERATOR

Resilient Rhody Implementation Priorities

- Assigned leadership across EC4 agencies
- Ownership of all 61 actions and aligning achievable1,3,5 year goals
- Establish and accelerate funding and financing for resilience
  - Resilient Rhody has been a catalyst for $13mm in new climate resilience funding
- Evaluate sustainable revenue streams for climate resilience

Resilient Rhody Municipal Resilience Program

- Developed in partnership between Rhode Island Infrastructure Bank and The Nature Conservancy
- The MRP is **open to all 39 municipalities** in Rhode Island
- The MRP provides technical assistance to **selected municipalities** to complete the "Community Resilience Building" process
- Municipalities will identify priority climate resilience projects and action grant funding is available

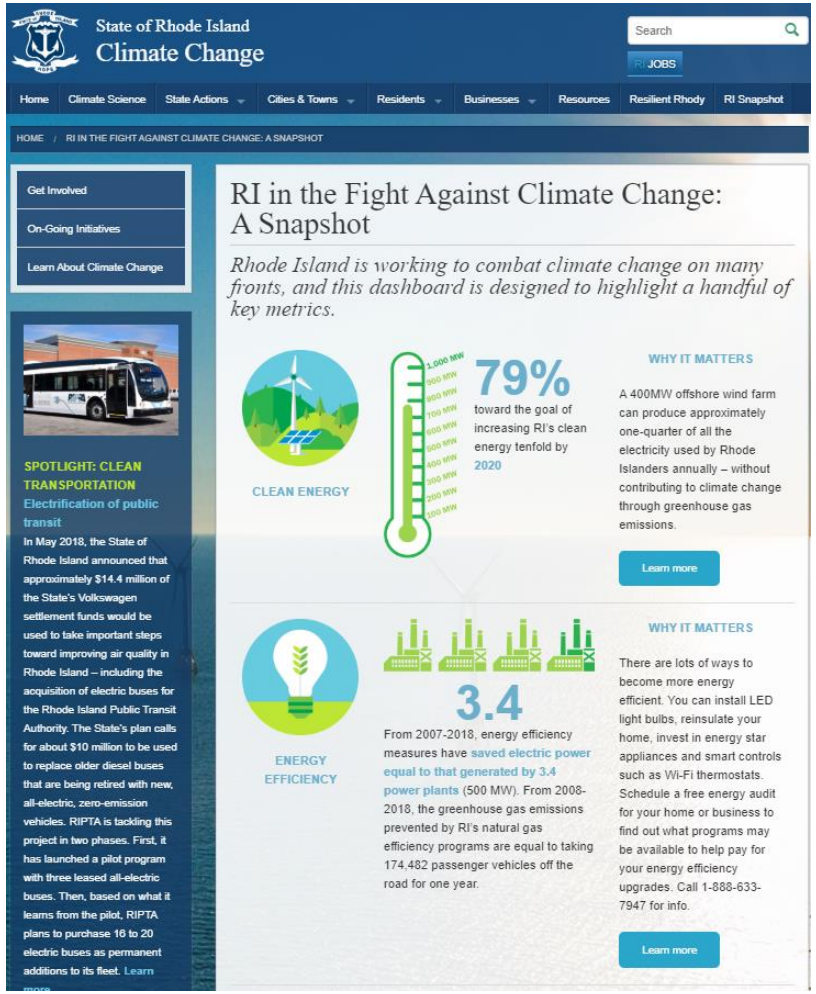
$47.3 MILLION 2018 green economy and clean water bond

Rhode Island's **vibrant green economy** accounts for more than **15,000 jobs** and adds **$2.5 billion** to the economy each year.

- 2016 URI study

This bond invests in water quality, land cleanup, farmland, recreational facilities, and open space to ensure Rhode Island remains a wonderful place to live, visit, and raise a family.

Rhode Island Climate Action snapshot



www.climatechange.ri.gov

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