Ecosystem Based Evaluation of Sustainable Solutions for Upper Narragansett Bay

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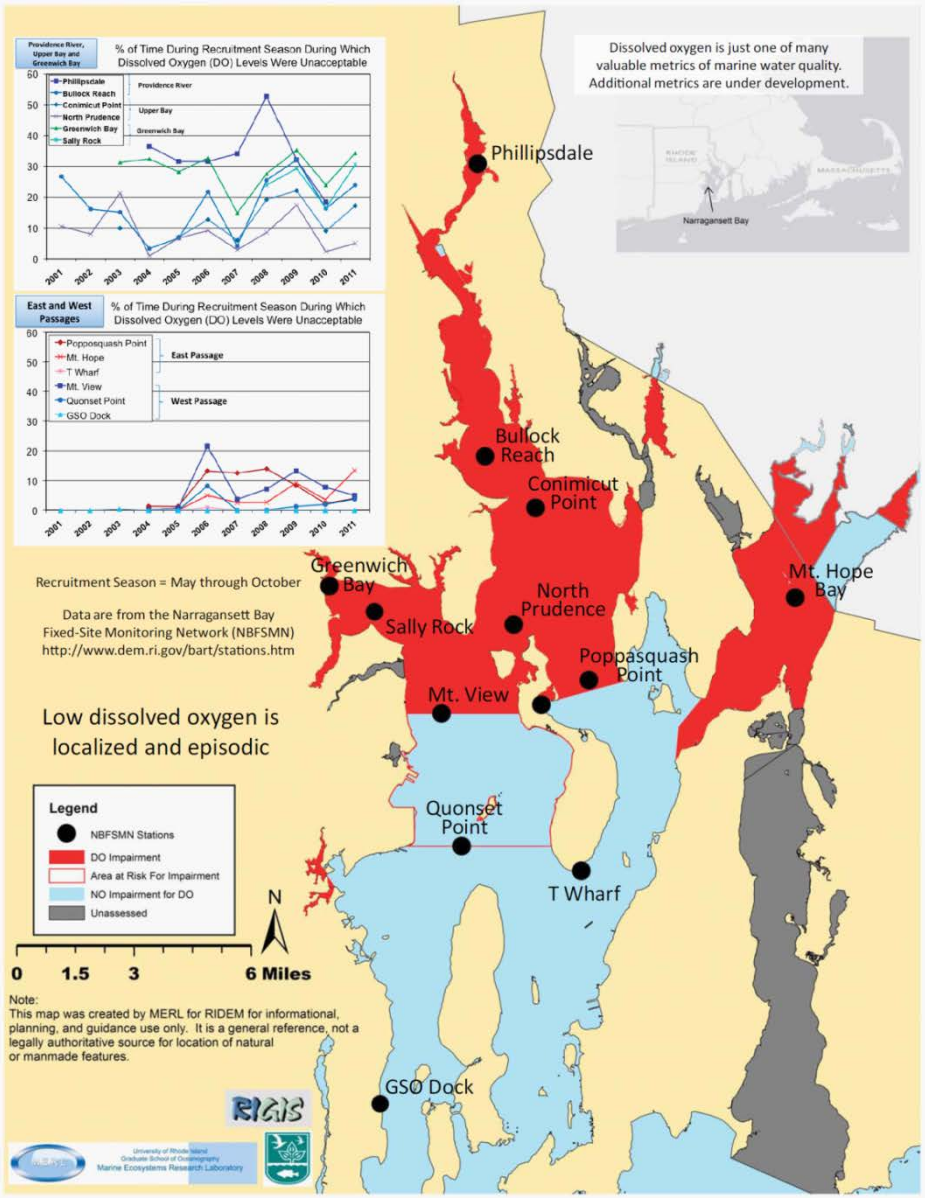
Narragansett Bay Commission

Greenwich Bay Fish Kill

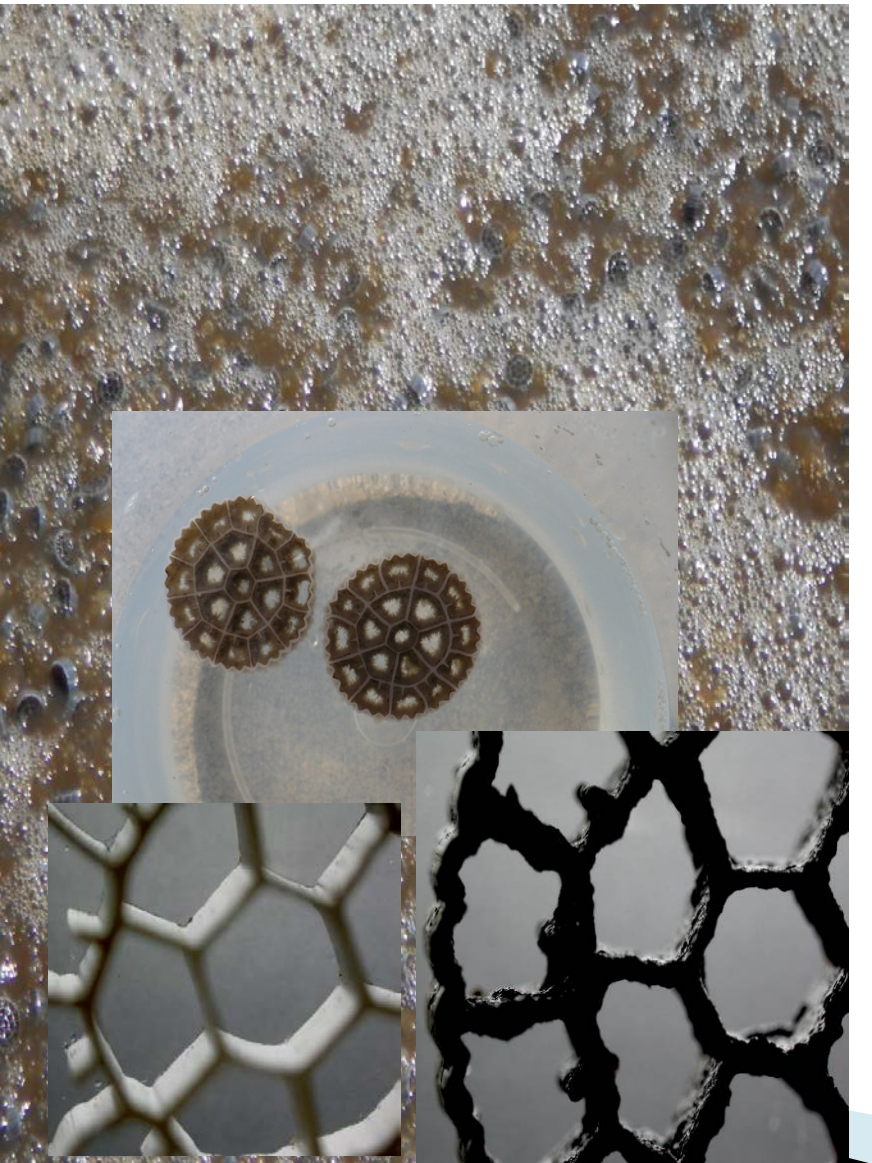
- **August 20, 2003**
  - ✓ Millions of Fish Dead, primarily menhaden
  - ✓ Crabs, eels, shrimp and blackfish also die
  - ✓ Worst Fish Kill in last 50 – 100 years
  - ✓ Dissolved Oxygen Monitoring Sondes at Greenwich Bay Marina Dock:
  - ✓ Surface Sonde: 1.1 meters deep – 0 mg/l DO
  - ✓ Bottom Sonde: ~3.8 meters deep – <0.5 mg/l DO
  - ✓ NBC Sondes in Providence River: >1.2 mg/l DO
- House and Senate held hearings into the causes of the fish kill
- Passed legislation requiring DEM to:
  - ✓ permit wastewater treatment plants by 12/31/04 to reduce nutrients
  - ✓ reduce nitrogen loads from POTWs to Bay 50% by 2008



But, many factors played a role in the fish kill and cause hypoxia in the Upper Bay:

- ✓ Low flushing or hydrodynamics
- ✓ Physical factors causing stratification of the water column
- ✓ High runoff/Fresh Water inputs (rain)
- ✓ Decreased wind mixing
- ✓ High nutrient loads in localized areas
- ✓ Warm weather & water temps

Field's Point POTW– Biological Nutrient Removal Upgrade for Total Nitrogen



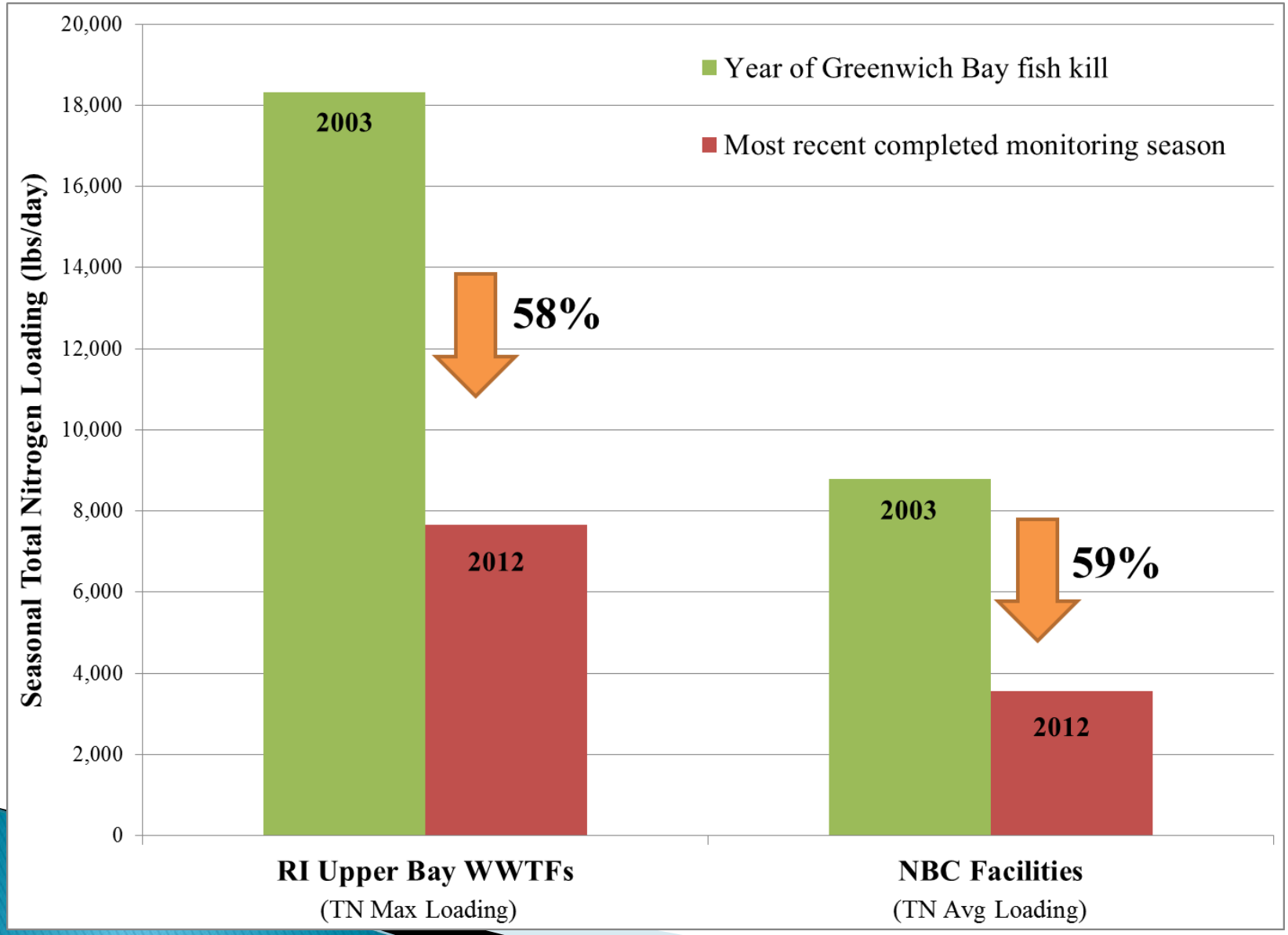
- Will use IFAS system to meet 5 ppm TN – Largest IFAS Plant in World!
- Construction complete at FP, in testing phase
- Permit Limits will be in effect for 2014 season
- Achieved 2012 seasonal average 7.6 ppm TN,4.2 ppm for Aug '12
  - 13.6 seasonal avg. 2007 – 2011
  - Already reduced 3,207 lbs TN/day at FP since fish kill based on 2012 data
- 2013 average (Jan – April) 7.0 ppm
  - April 2013 – 4.1 ppm; May – 3.9 ppm

Cost – ~$31 million

Biological Nutrient Removal Upgrades – Total Nitrogen (TN) – Bucklin Point

- Built to meet 8.5 ppm TN in 2005/2006
  - ✓$8.3 million for initial nitrogen upgrade
- 2012 seasonal average was 6.4 ppm TN
- Upgrade design to 5ppm TN ongoing
  - ✓**Estimated cost – $13 million**
  - ✓Reduction of ~158 lbs TN/day

Seasonal Total Nitrogen loading 2003 vs. 2012



NBC Nitrogen Loading to Upper Bay (May – Oct)

	Concentration (ppm)	Loading (lbs/day)	Percent Reduction (Loading)
Field's Point TN Loading			
Year of the Fish Kill (2003)	15.7	5,834	
May - Oct 2012	7.6	2,627	55%
May 2013 est.	4.0	1,255	78%
IFAS Upgrade	5.0	1,796	69%
If plant achieves 3 ppm	3.0	1,078	82%
Bucklin Point TN Loading			
Year of the Fish Kill (2003)	14.8	2,908	
May - Oct 2012	6.4	964	67%
May 2013 est.	5.8	744	74%
When achieves 5 ppm	5.0	806	72%
If plant achieves 3 ppm	3.0	484	83%
Combined NBC Facilities			
2003	BP=14.8, FP=15.7	8,741	
May - Oct 2012	BP=6.4, FP=7.6	3,591	59%
May 2013 est.	BP=5.8, FP=4.0	1,999	77%
FP&BP Upgrade to 5 ppm	BP=5.0, FP=5.0	2,573	71%
FP&BP Upgrade to 3 ppm	BP=3.0, FP=3.0	1,562	82%

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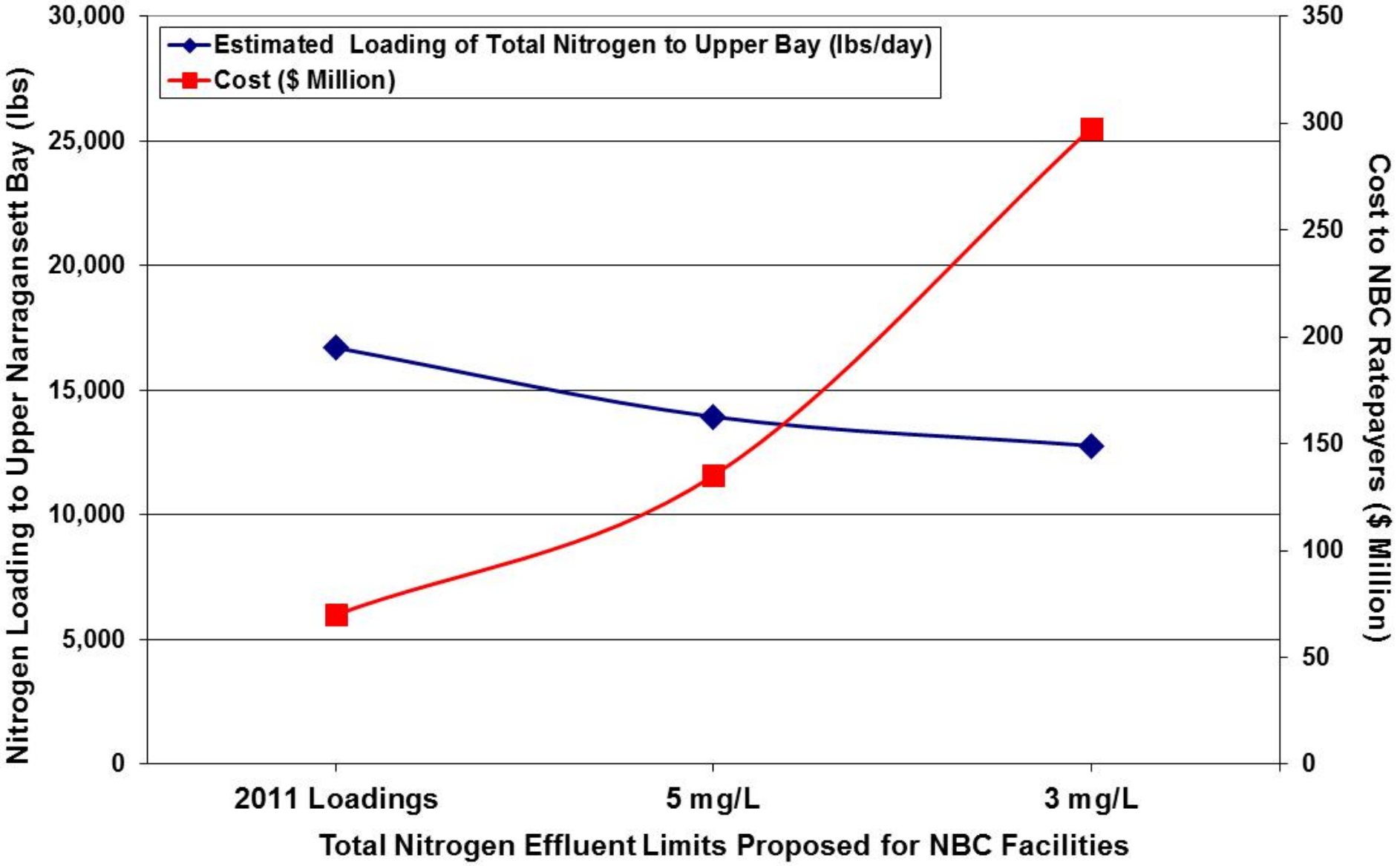
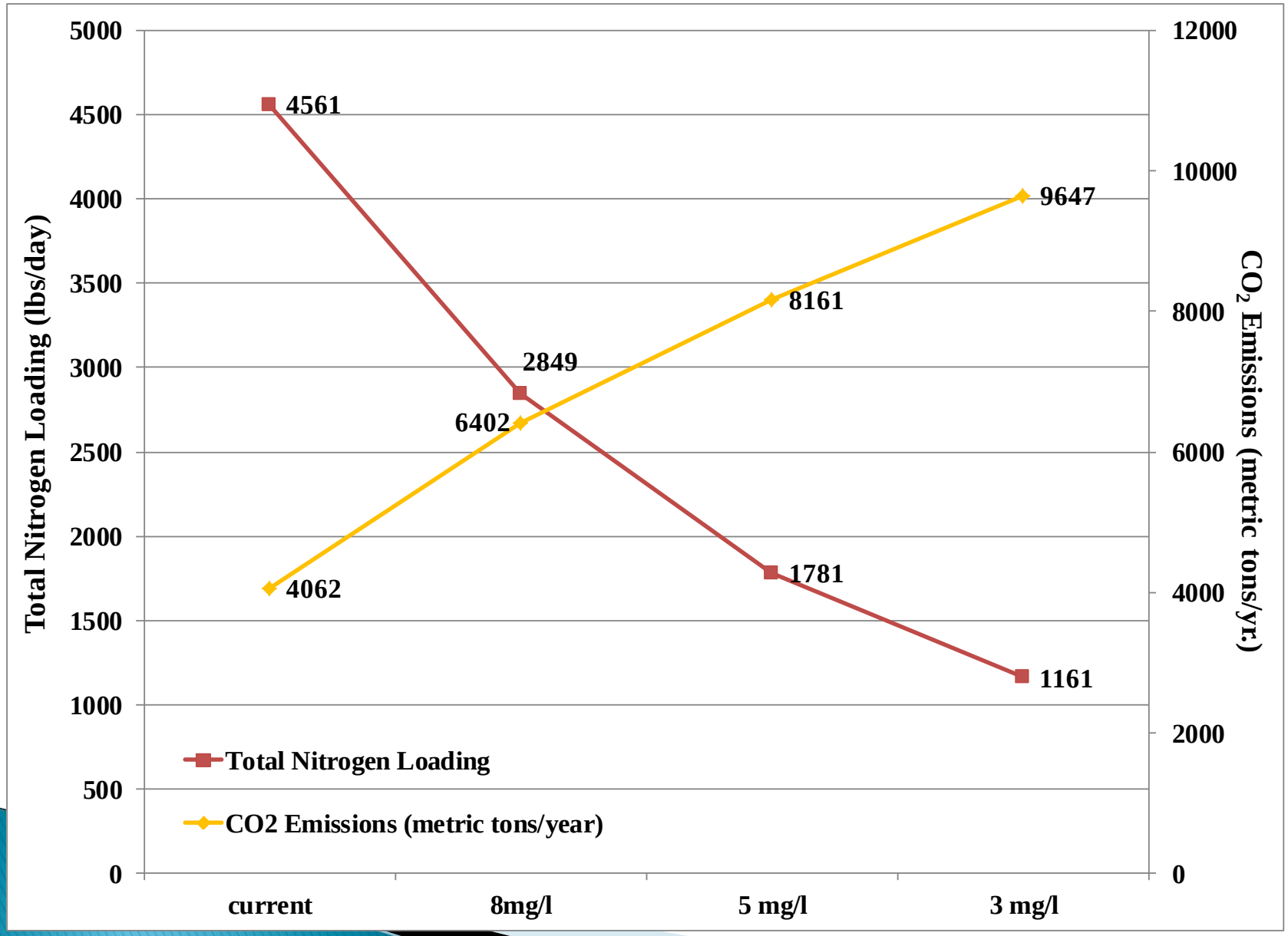
NBC Cost vs Nitrogen Reduction to Upper Bay

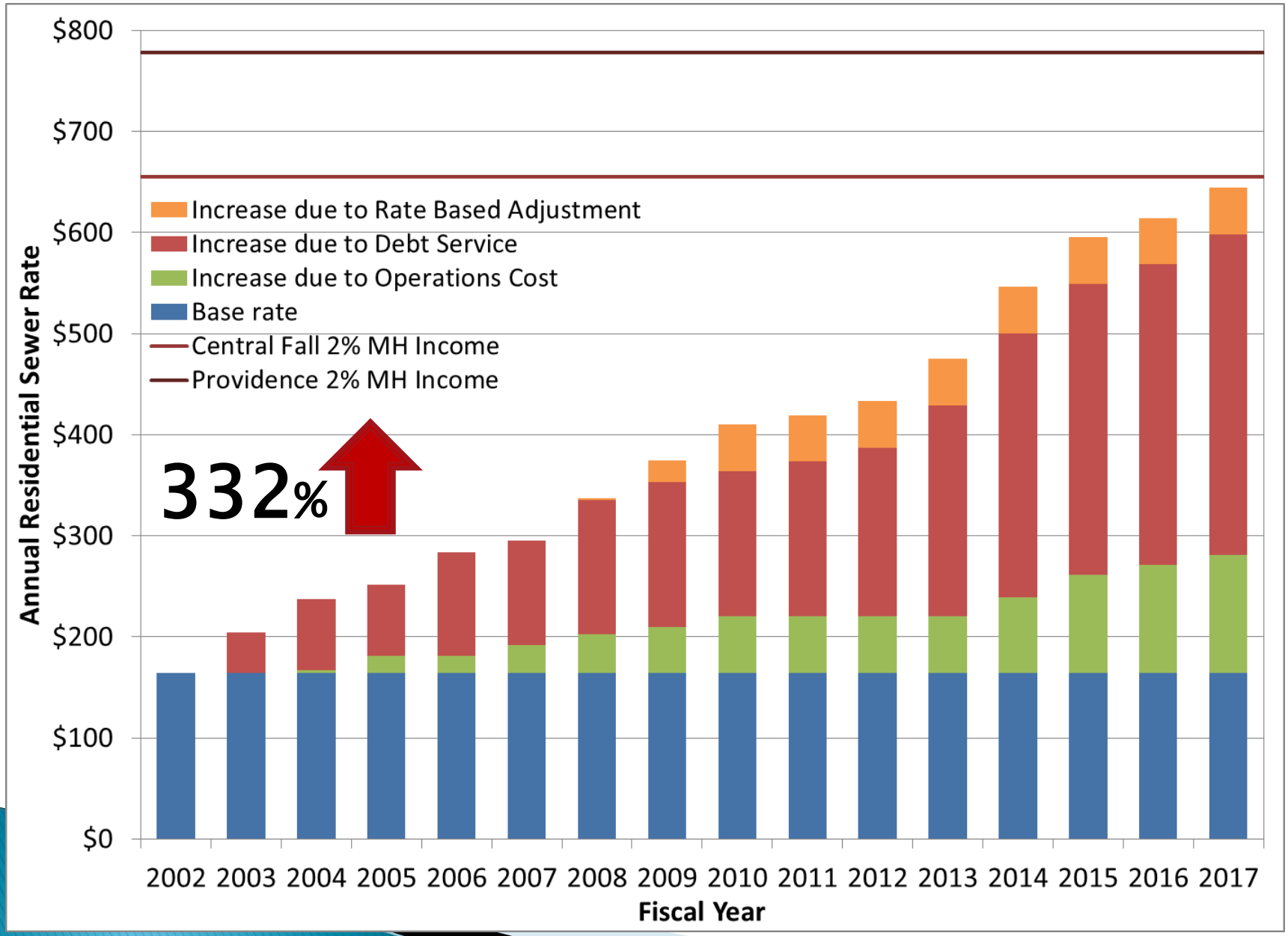


(This is input from point & nonpoint sources north of Conimicut Point)

Total Nitrogen Loading at Field's Point vs Estimated Greenhouse Gas Emissions

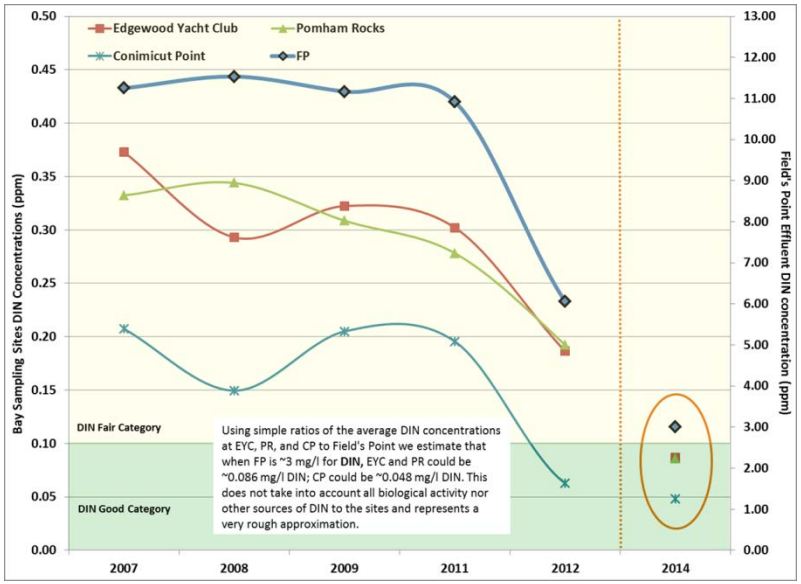


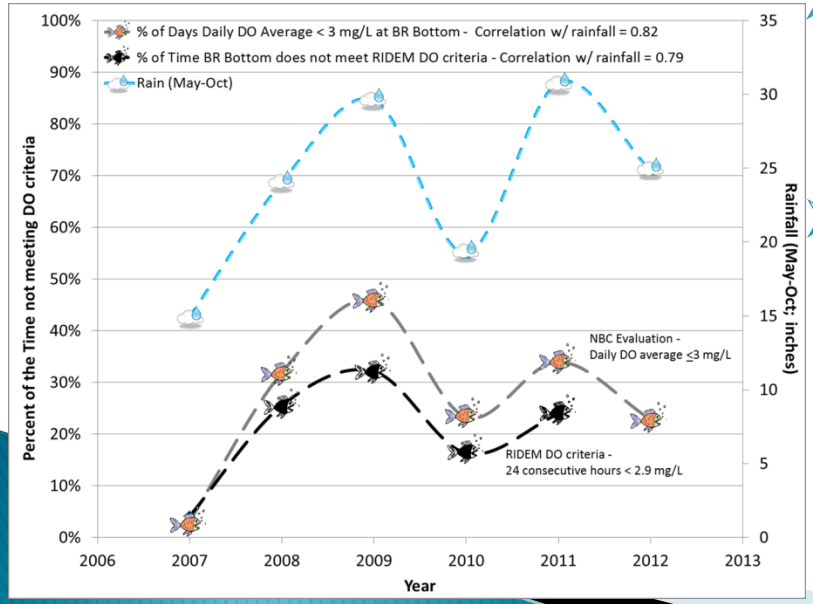
NBC Rate Increases



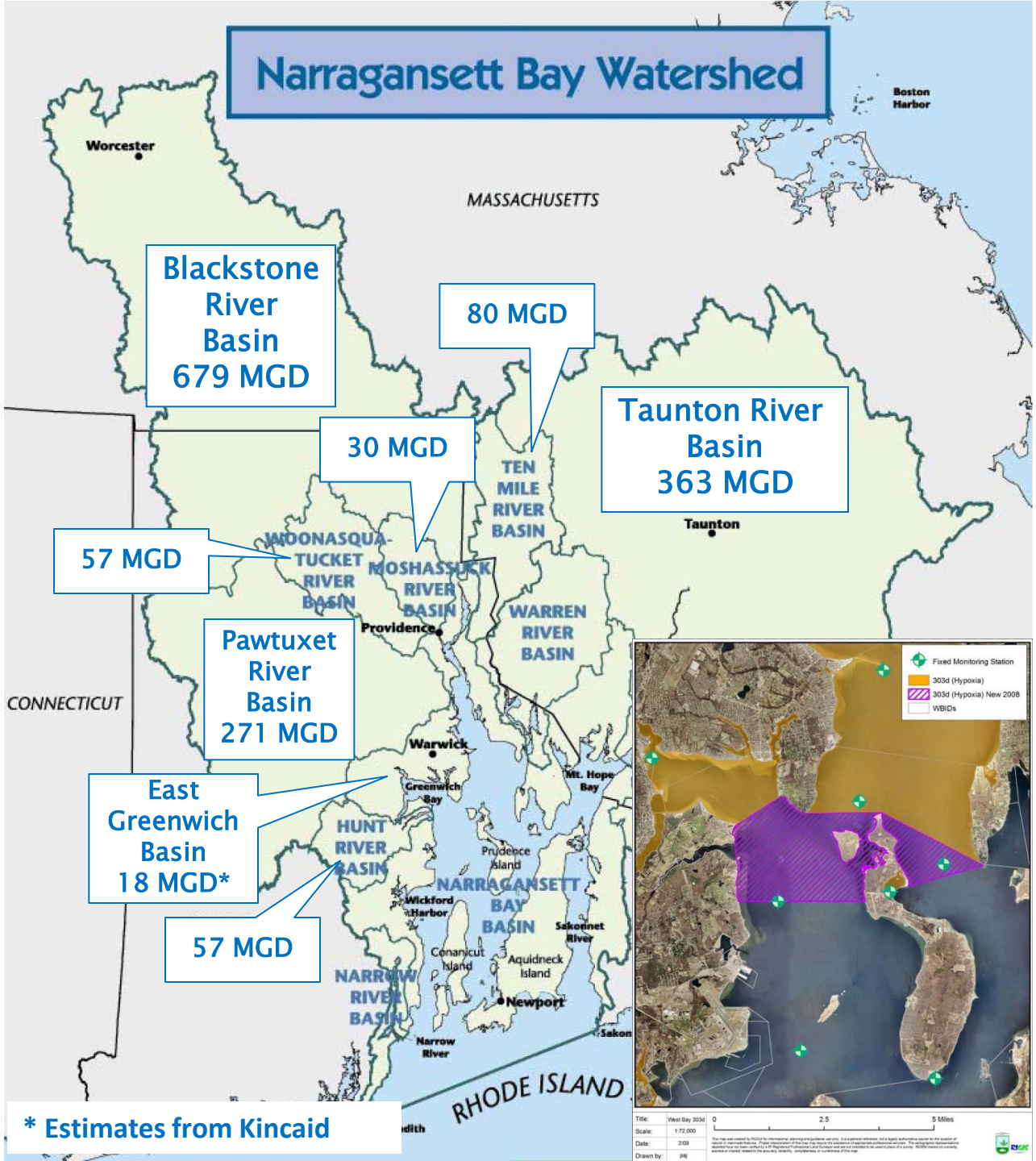
Is the Present Path a Sustainable Solution that will Achieve Water Quality Standards?

Total Nitrogen Status in the Bay





- Nitrogen concentrations already greatly reduced & will continue to decrease
- By 2014, NBC will reduced TN load by over 71%
- DIN in Prov River Projected to be <0.1 ppm by 2014
- Will nitrogen reductions alone result in decreased hypoxia in the Upper Bay?



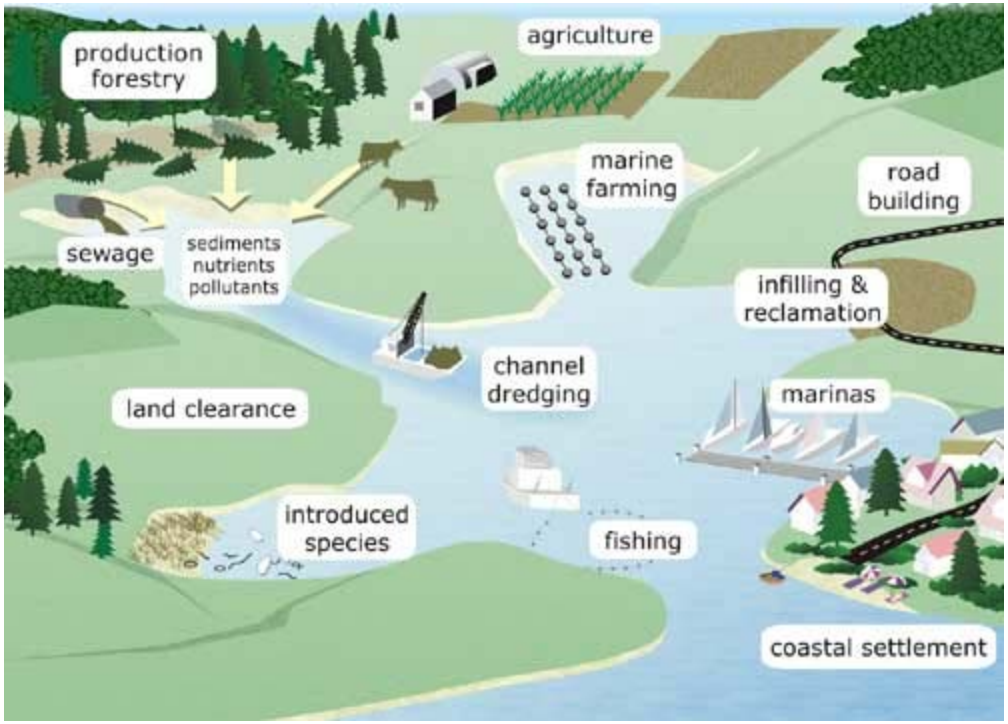
Freshwater Inputs

- Majority of NB's freshwater flow enters through the Providence River
- Approx. 1050 mi^2 Narragansett Bay watershed is gauged
- Approx. 223 mi^2 of the watershed is NOT gauged

(Info from Ullman, Brush, Kincaid)

- DO Impaired waters are where fresh waters enter bay!!!

Nutrients Are NOT the only problem responsible for hypoxia in Upper Bay…



www.waikatoregion.govt.nz

- Loss of wetlands & eelgrass
- Contaminated Sediments
- Alteration of coastline
- Change in hydrodynamics
- Climate Change
- Installed Dams & Breakwalls
- Silted up Rivers/Filled Bay
- Impervious cover/Runoff
- Stratification of the Water Column

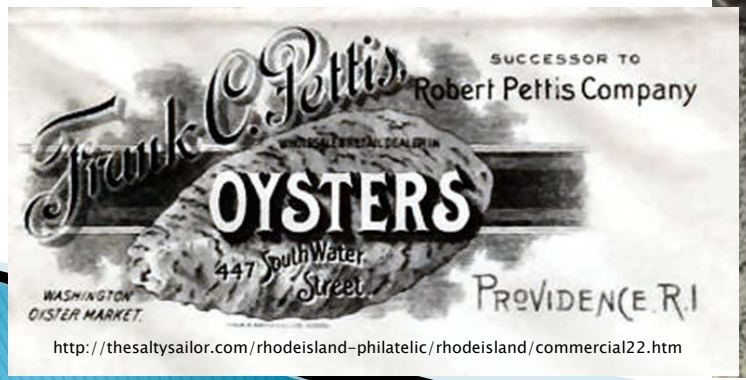
Many Ecosystem-wide problems began decades ago…

Need to look at Historical Record

The Bay's Historic Oyster Industry

- Productivity Reached its peak in 1910
- Leased oyster beds covered 5,000 acres in the Providence River & upper Bay (Fuller 1905)
- Generated $45,000 in 1903 dollars from lease fees (Fuller 1905)
- Produced ~7,000 metric tons of oysters a year (Rice et al 2000)
- People became sick from contaminated oysters, due to bacterial pollution
- Began to decline in 1911

due to anthropogenic inputs, disease & Great Hurricane of 1938



http://thesaltysailor.com/rhodeisland-philatelic/rhodeisland/commercial22.htm


Photo in 41°N (vol 4, issue 2); from 1912 annual report of the RI Shellfisheries Commission

Map of Providence Harbor in 1910

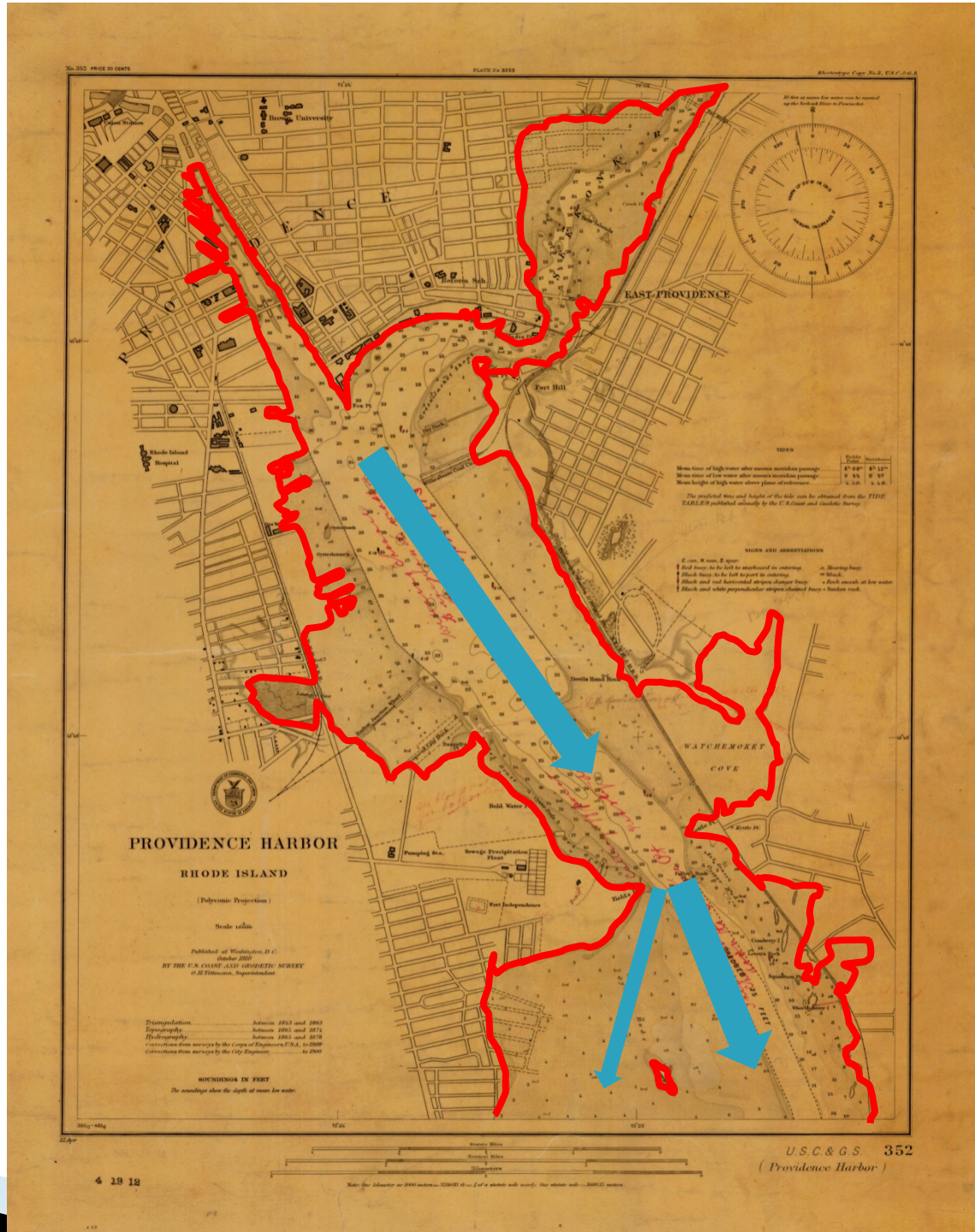
Based on 1865 – 1878 "Hydrography"

Map Clearly Shows:

- ✓ Wetlands & Eel Grass Beds
- ✓ Oyster Beds (5000 leased acres)
- ✓ Seekonk River – 37' deep
- ✓ Prov River Channel – 25' deep

Map of Providence Harbor in 1910

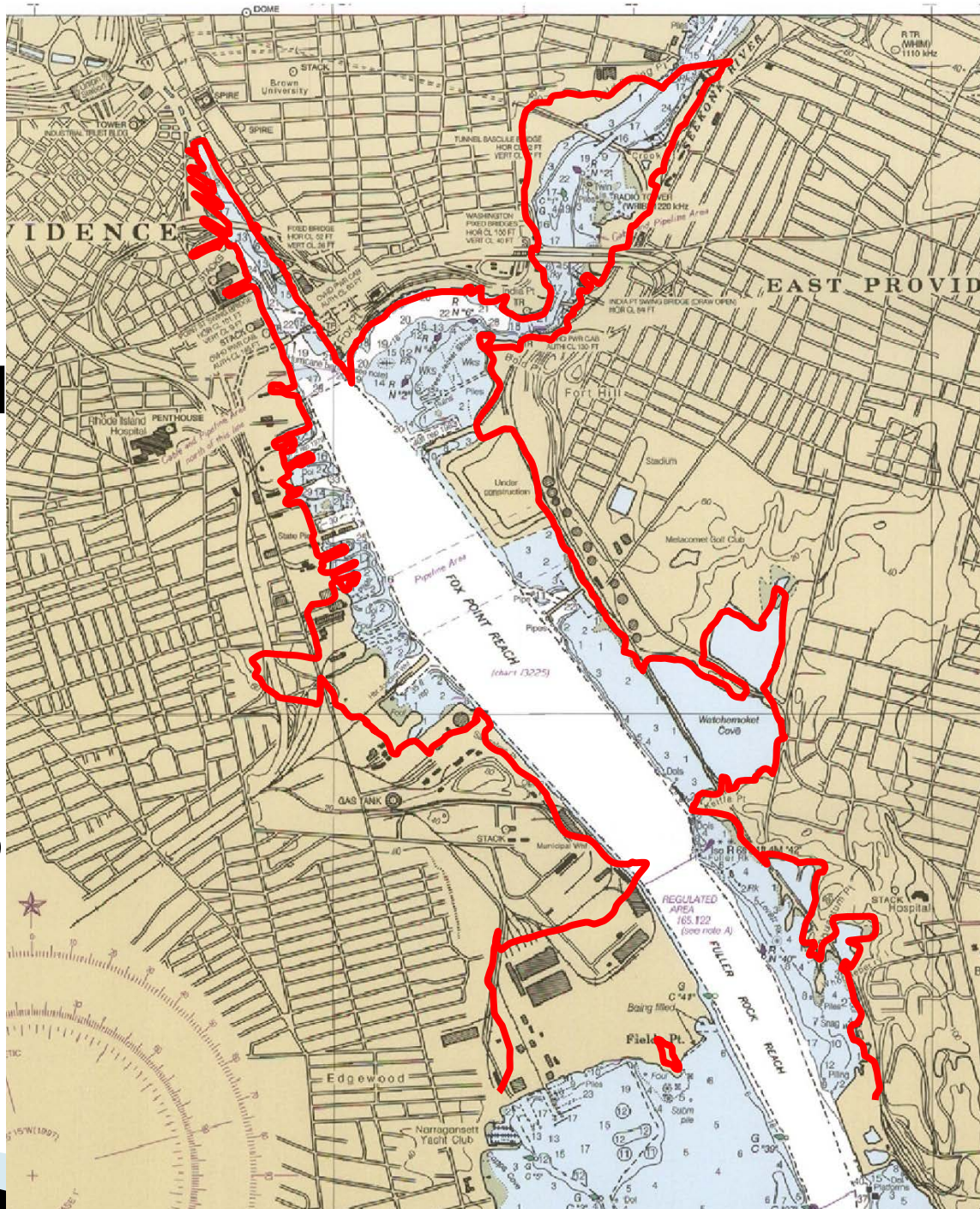
- ✓ 1910 Coast Line in Red
- ✓ City plans to Fill Bay and Build Roads
- ✓ Note:
  - ✓ Much Shallower River
  - ✓ Starved Goat Island
- ✓ What was flow circulation pattern in 1910?



Upper Providence River Today

1910 Coastline in Red

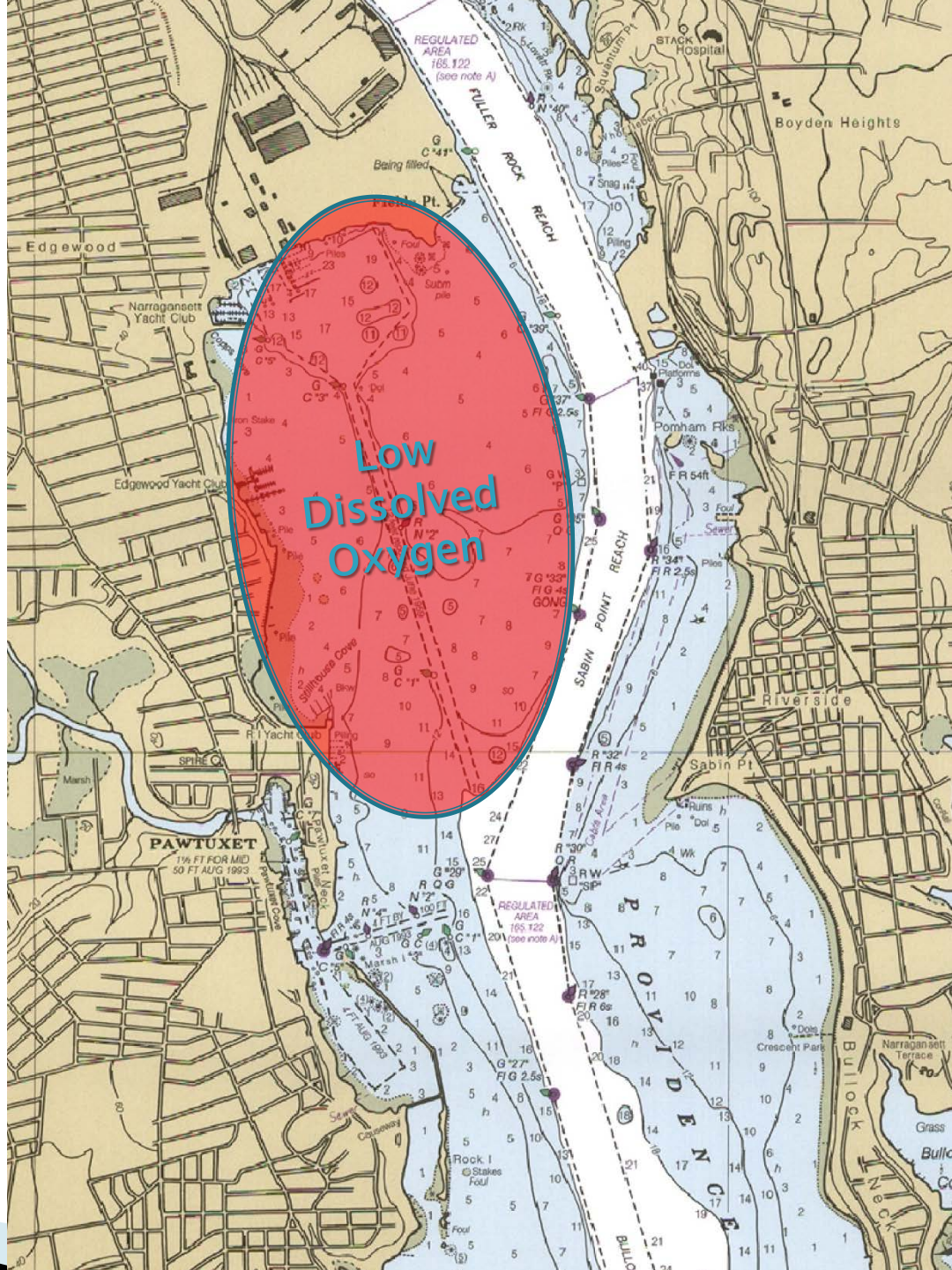
- ✓ We Filled the Bay & Wetlands
- ✓ Built the Hurricane Barrier
- ✓ Built Pawtuxet River Breakwall
- ✓ Allowed Rivers to Silt up
- ✓ Dredged Channel to 50+’



Water Quality Problems

- Edgewood Shoals area is DO impaired due to:

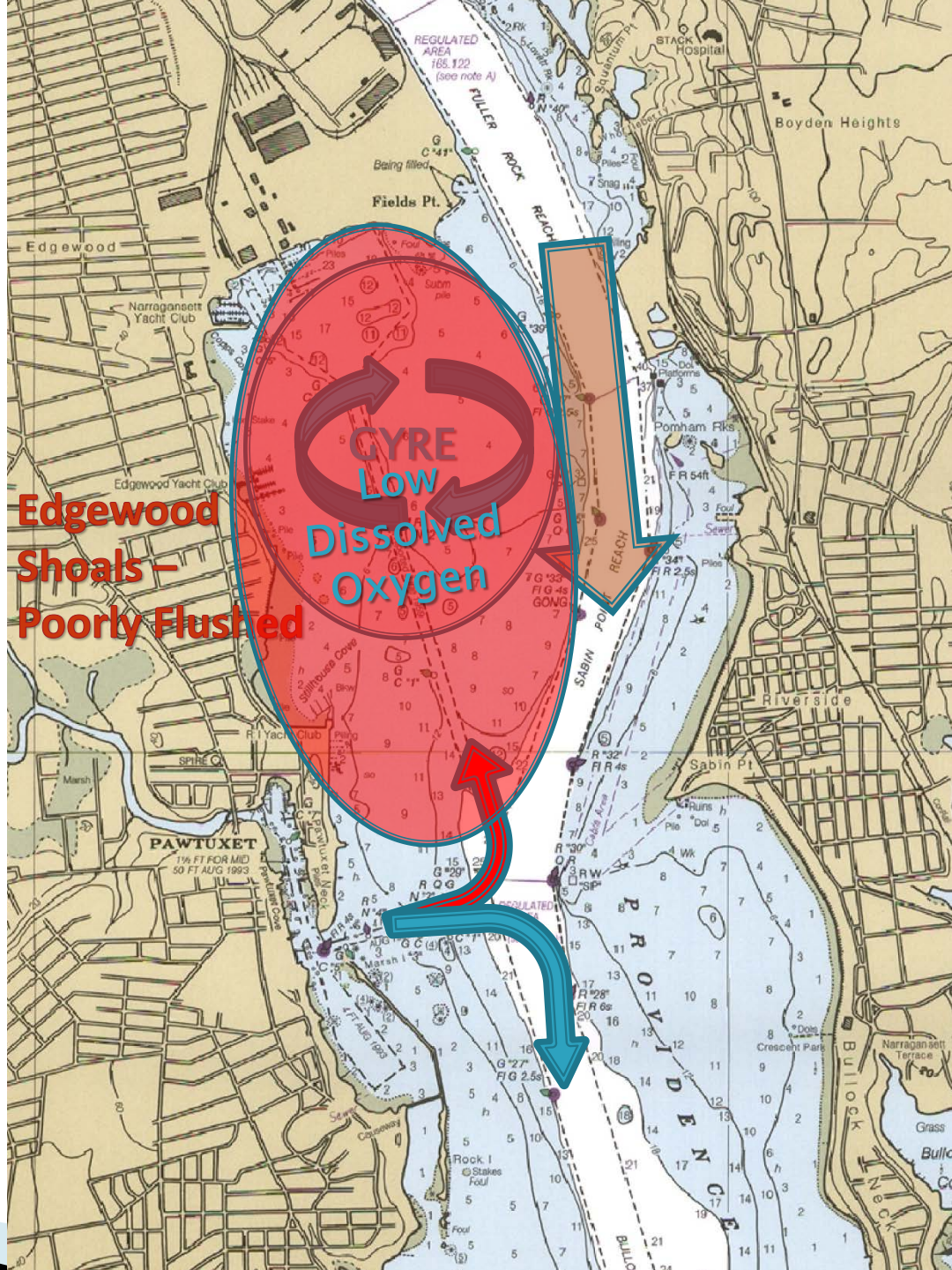
- ✓ Changed Circulation Patterns
- ✓ Poor flushing
- ✓ Nitrogen enrichment
- ✓ Stratification



Water Quality Problems

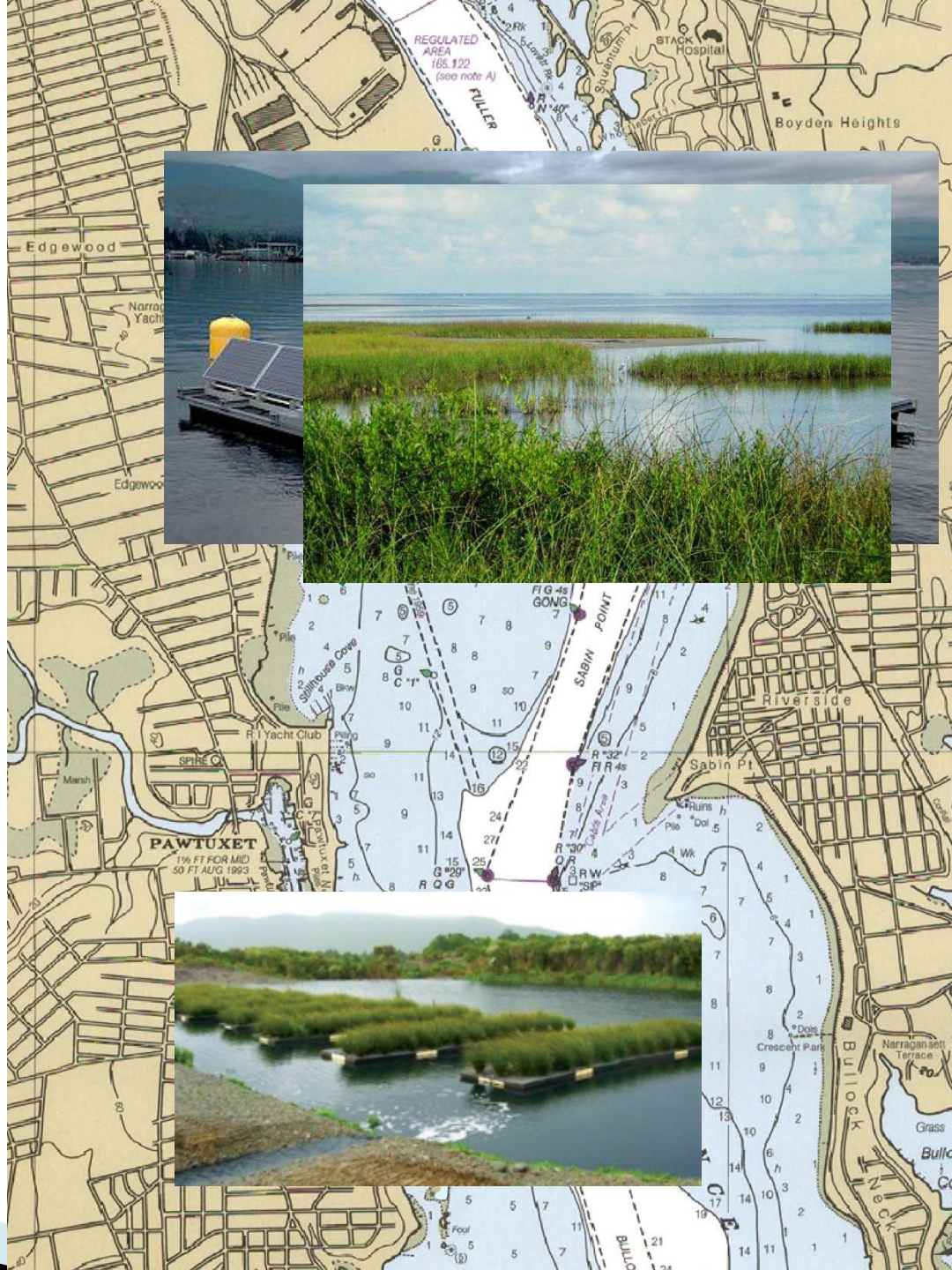
ROMS Model Indicates:

- Jet of water down the shipping channel
- Sets up a clockwise Gyre on Shoal
- Bottom waters from Pawtuxet River transport Nitrogen onto the shoal

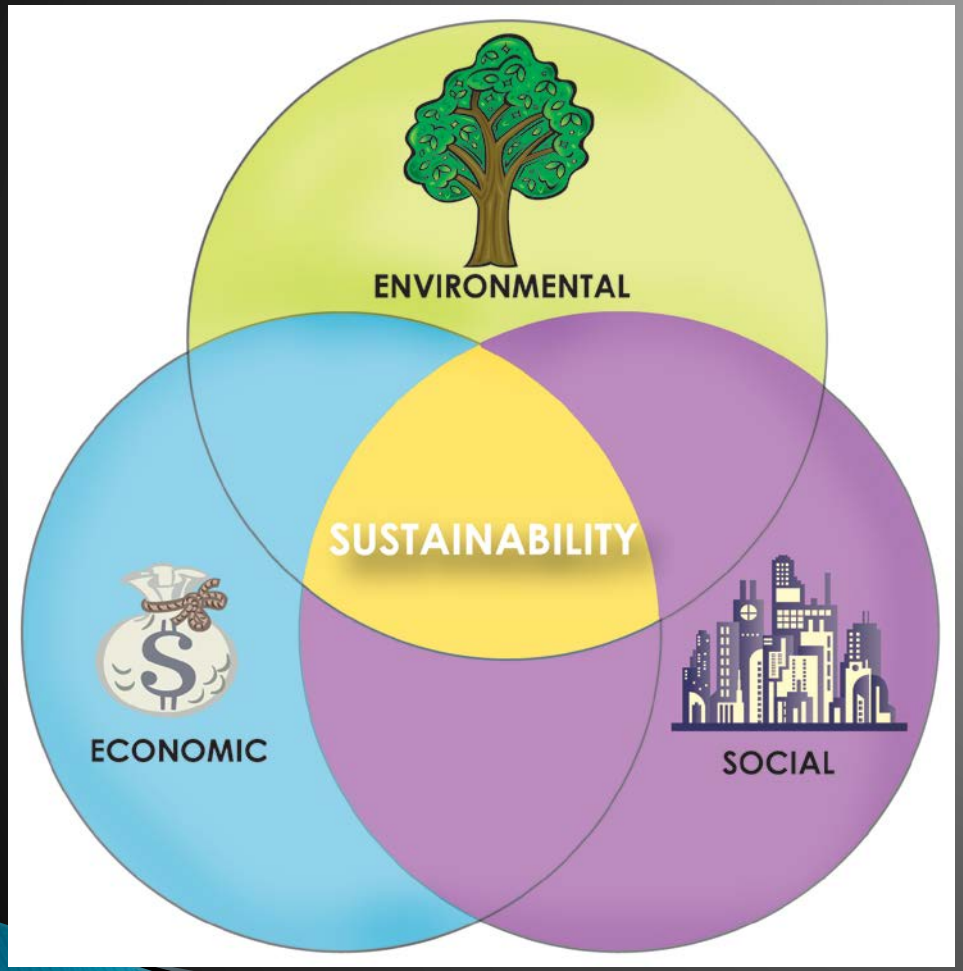


Possible Sustainable Solutions

- *Need Holistic Approach to Watershed Management*
- *Improve Water Quality By "Smart Engineering"*
  - ✓ Selective Dredging?
  - ✓ Maybe create a channel to redirect flow over shoal- improve circulation?
  - ✓ Maybe remove breakwalls to improve circulation
  - ✓ Create Island and Wetland Habitats?
  - ✓ Establish Bio-extraction or Aquaculture Projects?



Sustainable Solutions Needed!!!



- Sustainability = Achieving the "triple bottom line"
- Environmental Sustainability
- Economic Sustainability
- Social Sustainability
- Ecosystem Based Solutions
- How can we get it done?

Expert Stakeholder WQ Evaluation Process

- Goal: ***Complete Feasibility Study to Holistically Evaluate Sustainable Solutions to Improve Water Quality***

http://www.magazine.noaa.gov/stories/mag161.htm

- NBC/DEM Received $150,000 Grant from CT to begin the process
- This project will evaluate solutions to improve water quality, but more importantly, the health of entire ecosystem
- Nationally others have employed various "out of the box" solutions in TMDLs

http://www.edc.uri.edu/restoration/html/intro/salt.htm

DEM TMDL for Nitrogen and Dissolved Oxygen Let's Work Together to Give DEM a Full Toolbox

Seekonk River RI0007019E-01 Waterbody Size: 1.015 S Waterbody Classification: SB1{a}

Seekonk River from the Slater Mill Dam at Main Street in Pawtucket to India Point in Providence. Pawtucket, Providence and East Providence.

Use Description	*Use Attainment Status*	*Cause/Impairment*	*TMDL Schedule*	*TMDL Approval Date*	*Comment*
Fish and Wildlife habitat	Not Supporting	Nitrogen (Total)	2016		Determine need for TMDL post WWTF upgrades.
		Oxygen, Dissolved	2016		Determine need for TMDL post WWTF upgrades.
Fish Consumption	Fully Supporting				
Primary Contact Recreation	Not Supporting	Fecal Coliform	2022		Compliance with Consent Agreement for CSO abatement expected to negate need for TMDL.
Secondary Contact Recreation	Not Supporting	Fecal Coliform	2022		Compliance with Consent Agreement for CSO abatement expected to negate need for TMDL.

Providence River RI0007020E-01B Waterbody Size: 3.61 S Waterbody Classification: SB1{a}

Providence River from its confluence with the Moshassuck and Woonasquatucket Rivers in Providence south and south of a line from India Point to Bold Point (across the mouth of the Seekonk River), to a line extending from a point on shore due east of Naushon Avenue in Warwick to the western terminus of Beach Road in East Providence, including Watchemoket Cove. East Providence, Providence, Cranston and Warwick

Use Description	*Use Attainment Status*	*Cause/Impairment*	*TMDL Schedule*	*TMDL Approval Date*	*Comment*
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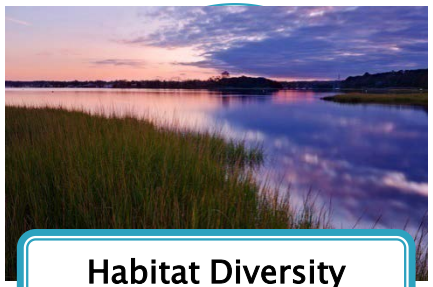
RIDEM List of Impaired Waters 2012



Habitat Diversity

Dissolved Oxygen
>4.8 mg/L

Eelgrass Beds

Navigable Rivers
(fish & people)

Sustainable

Ecosystem based management

Holistic

Harvestable Shellfish

GOAL:
Fishable
Swimmable

Viable Fisheries
(safe to eat)

Cooperation

Collaboration

Clean Sediment

Shared Vision

Compromise

Increased Water Clarity

Biological Diversity

Open Upper Bay Beaches

Remind you of Larry Quick?

Feasibility Study

- Project steering committee convened
  - ✓ Narragansett Bay Commission
  - ✓ RI Department of Environmental Management
  - ✓ Bays, Rivers and Watershed Coordination Team Chair
- Consultant hired by Steering Committee
- Development of potential sustainable solutions:

✓Beneficial use of nutrients through aquaculture
✓Bio-extraction
✓Hydro-modifications
✓Restoration of shellfish
✓Responsible WWTF upgrades
✓Restoration/creation of wetlands
✓Fertilizer controls
✓Other ideas??

The Narragansett Bay Commission

D·E·M

STATE OF RHODE ISLAND
HOPE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

?

Feasibility Study

- Expert panels convened on the following topics:
  - ✓ Shellfish
  - ✓ Aquaculture
  - ✓ Salt Marsh/Wetlands
  - ✓ Fisheries
  - ✓ Dredging
  - ✓ Hydrodynamics
  - ✓ Eelgrass
  - ✓ Geology
  - ✓ Modeling
  - ✓ Restoration
- Panel to potentially include the following:
  - ✓ USEPA
  - ✓ USDA
  - ✓ USACE
  - ✓ NOAA
  - ✓ USFWS
  - ✓ RICRMC
  - ✓ RI Sea Grant
  - ✓ RIEDC
  - ✓ RIWRB
  - ✓ RISWP
  - ✓ RIDOA
  - ✓ RIDOH
  - ✓ URI
  - ✓ UMass
  - ✓ RWU
  - ✓ STB
  - ✓ TNC
  - ✓ Brown
  - ✓ Rivers Council
  - ✓ NBNERR
  - ✓ NRCS…

Feasibility Study

- Expert panels to review & assess sustainable solutions for Environmental Improvement:
  - ✓ Scientific rational
  - ✓ Feasibility
  - ✓ Regulatory roadblocks
  - ✓ Efficacy
  - ✓ Economic Value
  - ✓ Costs
- Larger Stakeholder group will be convened to review the findings of the Expert panel
- Stakeholder groups will potentially include:
  - ✓ Save the Bay
  - ✓ Watershed Watch
  - ✓ Blackstone Coalition
  - ✓ Audubon Society
  - ✓ Nature Conservancy
  - ✓ RI Land Trust Council
  - ✓ RI Natural History Survey
  - ✓ Woonasquatucket River WC
  - ✓ Blackstone WC…
  - ✓ Friends of the Moshassuck
  - ✓ Many More…

Timeline of Study

- Year 1
  - ✓Consultant compile background research
  - ✓Expert Panel meetings to develop & assess viable topics of investigation
  - ✓Stakeholder group to review list from Expert Panel
  - ✓Draft report developed
- Year 2
  - ✓Modification of models
  - ✓Validation of priority topics
  - ✓Priority topic pilot demonstration projects
- Year 3
  - ✓Priority topic pilot demonstration projects continued

Feed Models of Narragansett Bay

- Triple Value Simulation (3VS) Model
  - ✓Include economic, societal & environmental benefits of nitrogen management strategies
- Coastal Hypoxia Research Program (CHRP)
  - ✓Nutrient loading & circulation model
  - ✓Biological aspect of model in development
- NBC Regional Oceanic Modeling System (ROMS)
  - ✓High resolution chemical transport model calibrated to specific circulation patterns of Narragansett Bay
- Blackstone River Hydrological Simulation Program – FORTRAN (HSPF)
  - ✓Evaluates nutrient & impoundment management

Typical Examples of Solutions for Evaluation

Beneficial Use of Nitrogen

- Wetlands & salt marsh restoration – remove 250 to 630 g N m^{-2} yr^{-1}
- Bio-extraction –
  - ✓ Ribbed Mussels 1.2 % N
  - ✓ Algae…
- Relay aquaculture
  - ✓ Oysters – 0.52 g N/oyster
  - ✓ Quahogs –16.2 g N/kg meat
- **Goals & Benefits:**
  - ✓ Improved Fisheries – Shellfish & Benthic species Restoration & Enhancement
  - ✓ Habitat Creation & Restoration
  - ✓ Create Green Jobs for the Future

Photos courtesy of: http://www.jaxshells.org/gdim.htm, http://viudeepbay.com/2012/02/12/design-and-construction-report-solar-flupsy-project/, algaebiodiesel.com, Cape Cod Cooperative Extension

Narragansett Bay's Oyster Industry

Restoring the Bay's harvestable oyster population to the 1910 status would:

- Increase the harvestable population by over 112.5 million oysters
- Remove an additional 130,000 lbs/year nitrogen when these oysters are harvested (Based on 60 g oyster with 0.52 g TN/oyster; Newell 2004)
- Transplant shellfish to enhance & restore various populations throughout the estuary
- Build the Rhode Island Green economy
- Create local sustainable jobs

Photo courtesy of NOAA

Shellfish Restoration

- Excess nutrients incorporated into shell & meat
  - ✓ Oysters – 0.52 g N/oyster
  - ✓ Quahogs –16.2 g N/kg meat
- Spat blocks, reef balls & cultch to provide substrate
- Shellfish utilize nutrients
- Once established:
  - ✓ Filter water
  - ✓ Protect shoreline
  - ✓ Provides habitat
  - ✓ Economic resource – leases, permits, businesses, tourism

Shellfish Restoration at work

- Falmouth, MA
  - Investigating shellfish culture to reduce nutrients
  - Incorporated into the Comprehensive Wastewater Management Plan
- White Oak, NC
  - Evaluating shellfish restoration to meet water quality standards

http://www.habitat.noaa.gov/restoration/approach...html

http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/peconic.cfm

Bio-extraction

- Nutrient bio-extraction – growing and harvesting shellfish and seaweed to remove nitrogen and other nutrients from water bodies
- Bio-extraction has been shown to be a good method to remove nitrogen once it has already entered the water and could be an excellent counterpart to source control programs

www.longislandsoundstudy.net

- Non-commercial shellfish species – Ribbed Mussel
  - Study by Woods Hole, est. 1 million ribbed mussels could remove a N load of 155 kg N/yr (~342 lbs.)
- Commercially viable Seaweed species: *Gracilaria*, *Saccharina*
  - Advantages: Fast growing, commercial demand
  - *Gracilaria* – Ammonia "sponge"– 60 µmol/g of NH_3 per hour
  - Researcher in CT (Yarish, C.) – observed uptake of up to ~145 lbs. of N in July (1 ha plot)

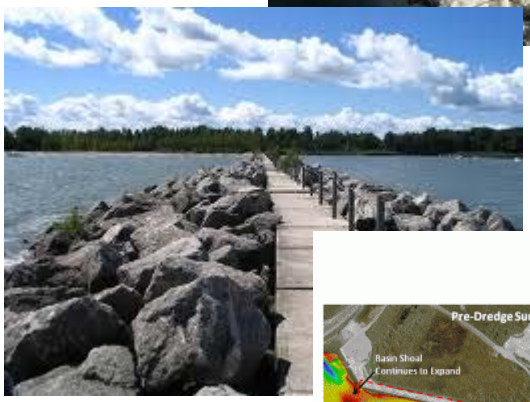
Local example of Bio-extraction assessment: Long Island Sound (LIS)

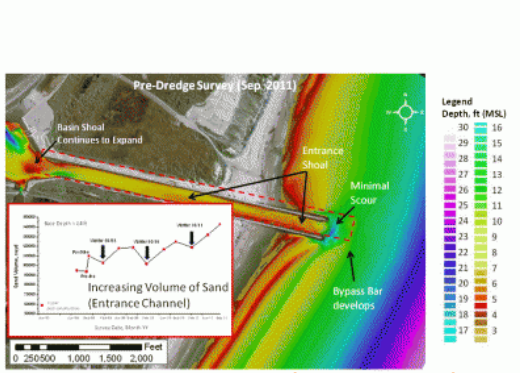
- Preliminary LIS models predict potential increase of 2 mg/l DO through the use of bio-extraction
- Discussions ongoing regarding ways to incorporate bio-extraction into the revised LIS TMDL for nitrogen
- Concept is economically promising, but substantial administrative and regulatory barriers need to be overcome
- Conducting pilot projects on Ribbed Mussels and seaweed aquaculture

Hydro-modifications

- Dam removal
  - Restores natural temp & DO
  - Allows fish passage
  - Reduces Liability
  - Allows passage & recreation
- Breakwall alteration
  - Redirect water flow
  - Retain protection barrier
- Channel creation
  - Improves flushing
  - Break up gyre/stratification
  - Restore water quality

www.tencate.com



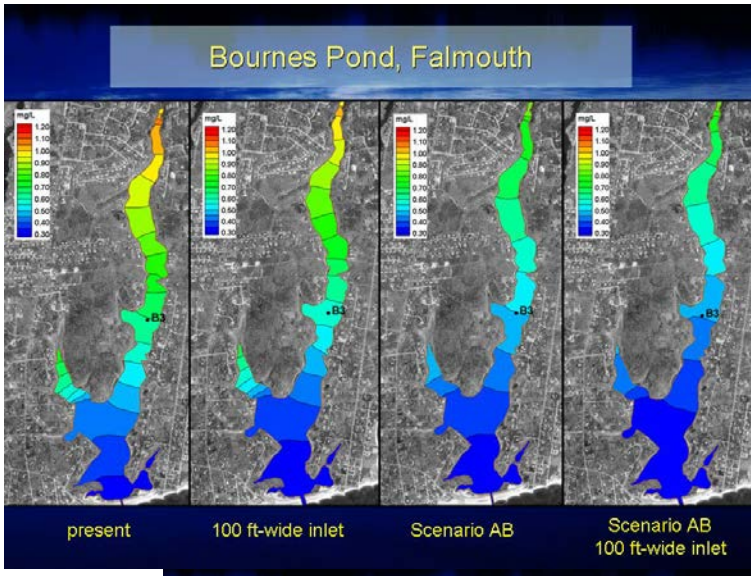


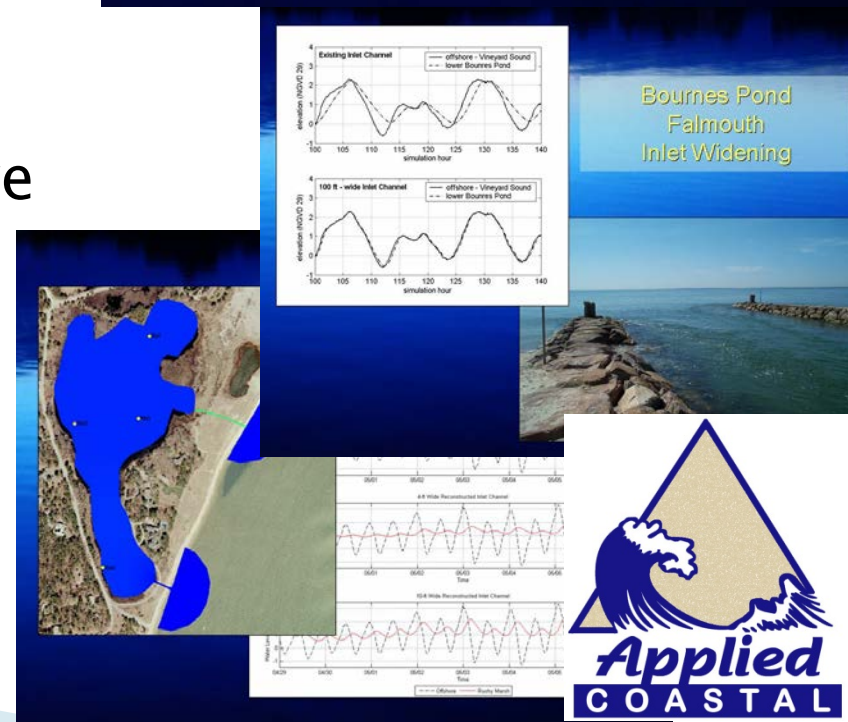
www.cbi.tamucc.edu

Examples of Hydro-modifications

Cape Cod, MA

- Bournes Pond, Falmouth
  - TN watershed reduction strategies
  - Opening of channel to improve flushing of TN
- Rushy Marsh, Cotuit
  - Opening of channel to improve flushing of TN





Applied COASTAL

Watershed Wide Fertilizer Controls

- Education on proper fertilizer uses
  - The 4 R's: Right Amount, Right Time, Right Place, Right Source
- Establish regulations for fertilizer application
  - Establish buffer zone w/ no application?
  - No application b/t Dec – April?
  - ???
- Require separate display of fertilizer types
- Specialized labeling & directions
- Certification for professionals

http://www.dec.ny.gov/chemical/74885.html

Examples of Fertilizer controls

- NY State – Fertilizer Law Jan, 2012
- FL State
  - Institute laws
  - Require licenses
  - Specialized labeling
- MD State
  - Professional certification
  - Specific labeling for de-icer
  - Particular directions for application

http://mda.maryland.gov/Pages/fertilizer.aspx

Build Wetlands from Dredge Material

- Dredged material (sand works best) incorporated into geotextile (GeoTubes) to make & protect wetlands & islands
- First successfully completed in Galveston Bay, TX in the early 1970s & many more since
- Used to protect habitats from erosion & create new habitat

http://www.gbep.state.tx.us/solutions-partners/habitat-protection-plan.asp

www.geosynthetics.com

http://www.firstcoastal.com/photos.asp?id=14&galtype=control

Create and restore wetlands to:

- Remove 250 to 630 g N m^{-2} yr^{-1}
- Provide a value of ~$75,000 as a "water treatment facility" per acre of wetland (Miller 1996)
- Provide critical habitat for biodiversity
- Enhance water quality long-term
- Provide storm protection and flood mitigation
- Contribute aesthetically to the region

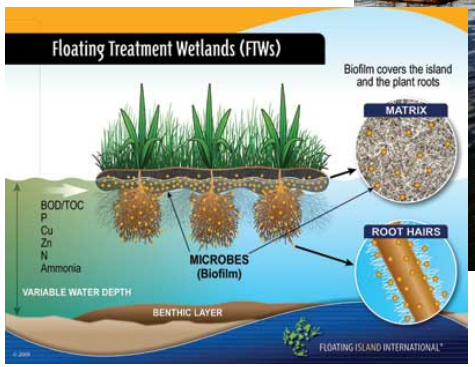
Current Use of Constructed Wetlands for Water Quality Improvements

- Virginia Institute of Marine Science Floating Wetlands Pilot Project 2012

- In August 2010, the National Aquarium assembled, planted, and launched a floating wetland island in Baltimore's Inner Harbor. In 2012, they joined other partners to launch another **2,000 square feet of floating wetlands** into Baltimore's Inner Harbor. This project is part of the Healthy Harbor Initiative, a regional effort to make the harbor swimmable and fishable by 2020. (http://www.aqua.org/care/conservation-initiatives/floating-wetland-island)

- Floating Wetlands help boost nitrogen removal in lagoons
  - Effective in substantially reducing nutrient levels in several studies involving smaller-scale lagoon treatment plants

(http://www.waterworld.com/articles/print/volume-28/issue-6/editorial-features/floating-wetlands-help-boost--nitrogen-removal-in-lagoons.html)



Outcomes of the Process

- Stakeholder developed blueprint of "sustainable" ecosystem-based management solutions to improve water quality and restore upper Narragansett Bay
- The FIRST TRUE Ecosystem Based Evaluation of an Estuary in the Nation!!!
- Ideas will feed WQ Models to assess priority topics & identify "Low Hanging Fruit"
- Initiate and Complete pilot projects to validate topics
- Provide a Robust Tool Box to DEM for TMDL development for Providence and Seekonk Rivers
- Provide a Blueprint to restore our Bay and create jobs, which will assist agencies with budget presentations at the Statehouse.
- **A Healthy Narragansett Bay, more resilient to future challenges**

Questions ???