Upper Narragansett Bay Water Quality

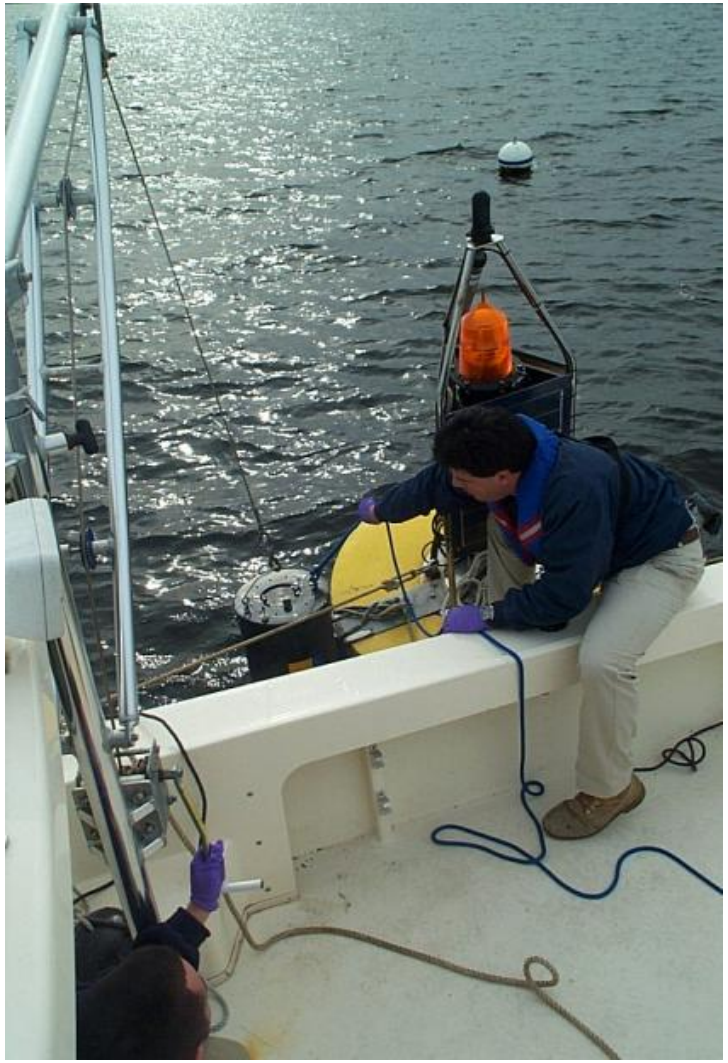
Sins of the Past, Present Day Efforts & Future Opportunities

Thomas Uva
Director of Planning, Policy & Regulation
Narragansett Bay Commission

NBC Water Quality Monitoring Initiatives

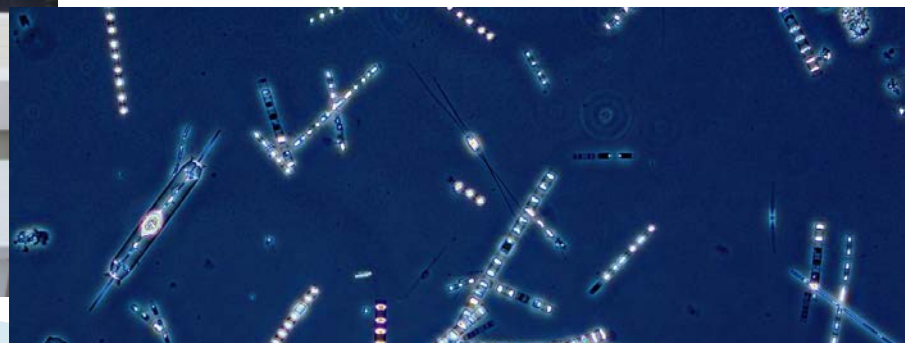
NBC Monitoring Initiatives

- Operate 2 Fixed Site Monitoring Stations
- Upper Bay and Tributary River Nutrients Monitoring
- State Border Nutrients Monitoring
- Bay Bacteria Monitoring
- River Bacteria Monitoring



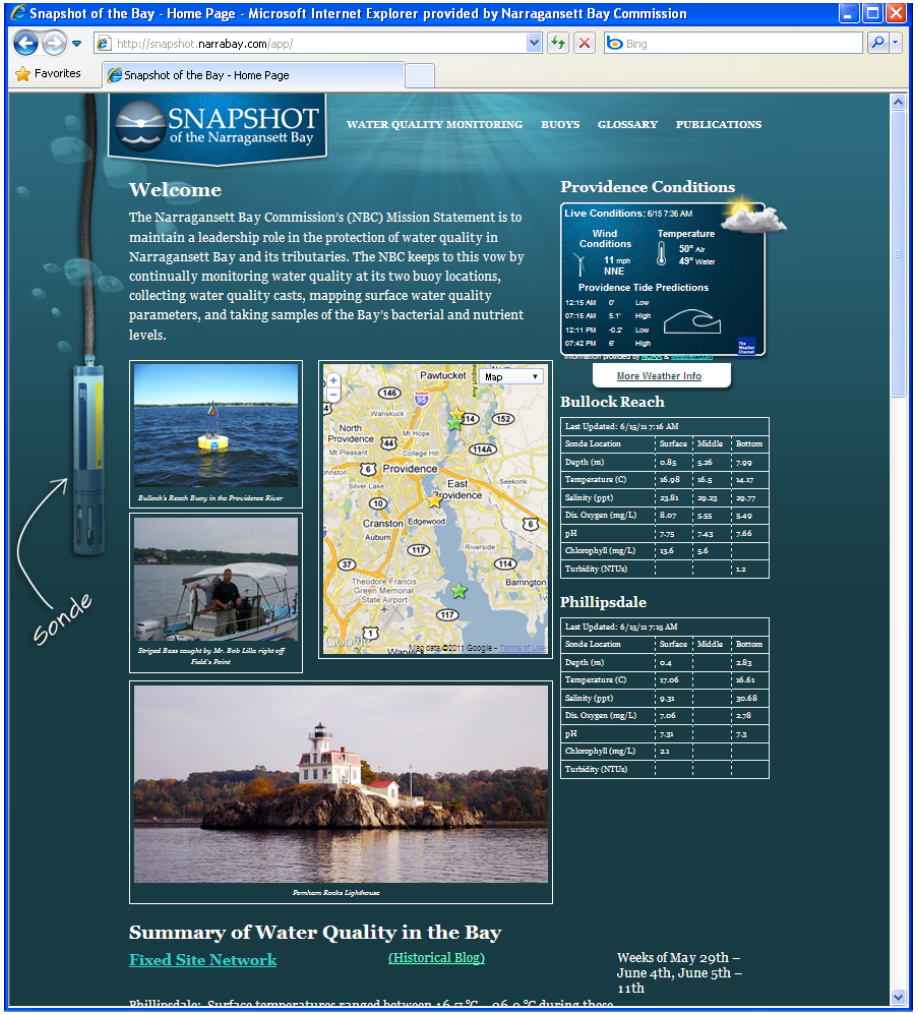
NBC Monitoring Initiatives

- Seabird Water Quality Profiles
- Water Clarity Monitoring
- Real-Time Mapping of Surface Water Quality
- Benthos Monitoring
- Plankton Monitoring



“Snapshot of Upper Narragansett Bay”

- NBC Water Quality Webpage
- Data available promptly for Stakeholders, Regulators, Universities & General Public
- New information & functionality will be added to the site
- National Association of Clean Water Agencies (NACWA) Award for excellence in e-media education
- *Visit www.narrabay.com*



Upper Bay Water Quality Impairments

Upper Bay Issues & Impairments

- Bacterial Contamination
- Dissolved Oxygen Impairments – Hypoxic and Anoxic conditions
- Excessive nutrient loads
- Contaminated Sediments
- Loss of Wetlands, Habitat & Eel Grass

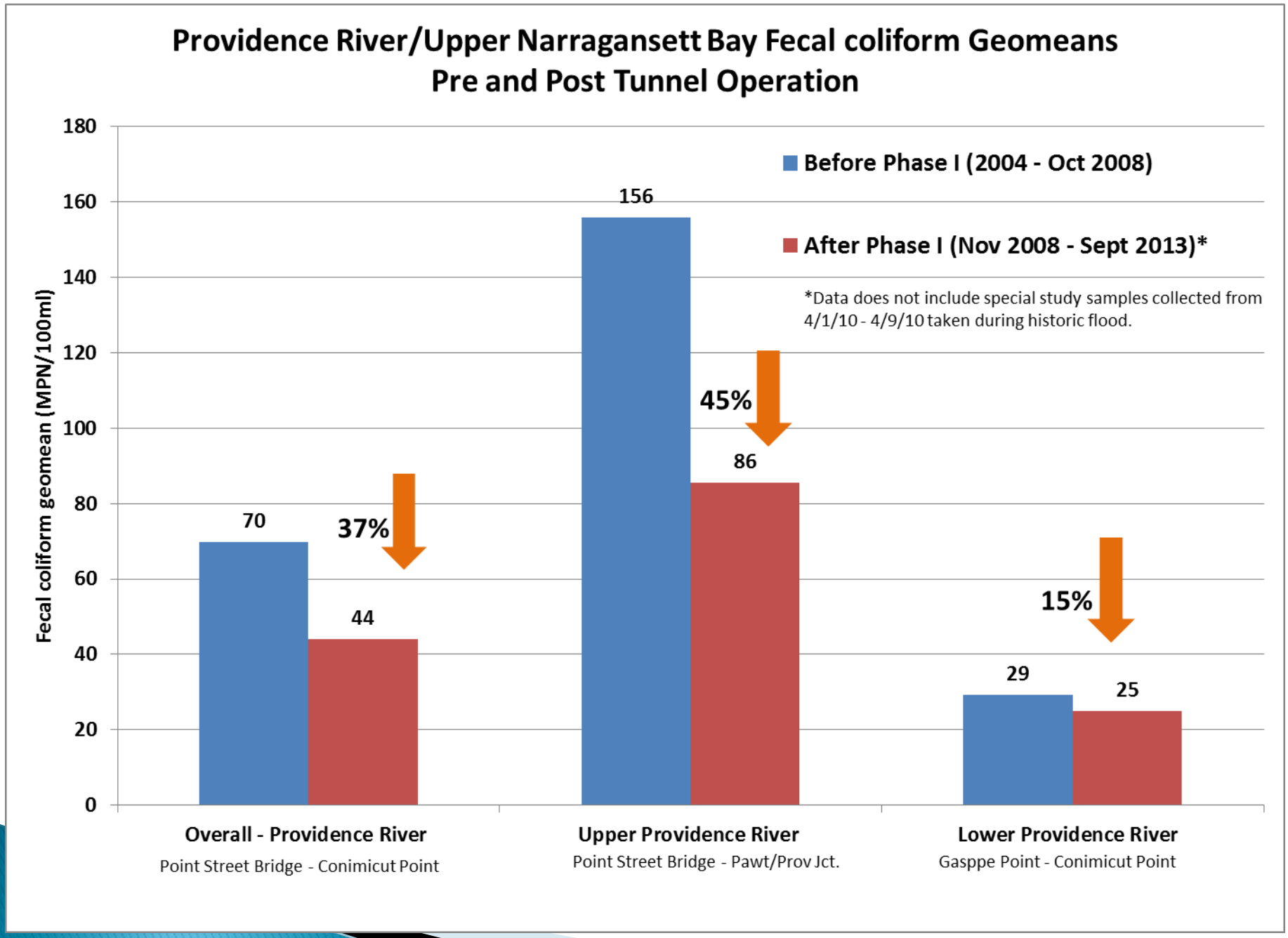
Water Quality Monitoring Findings

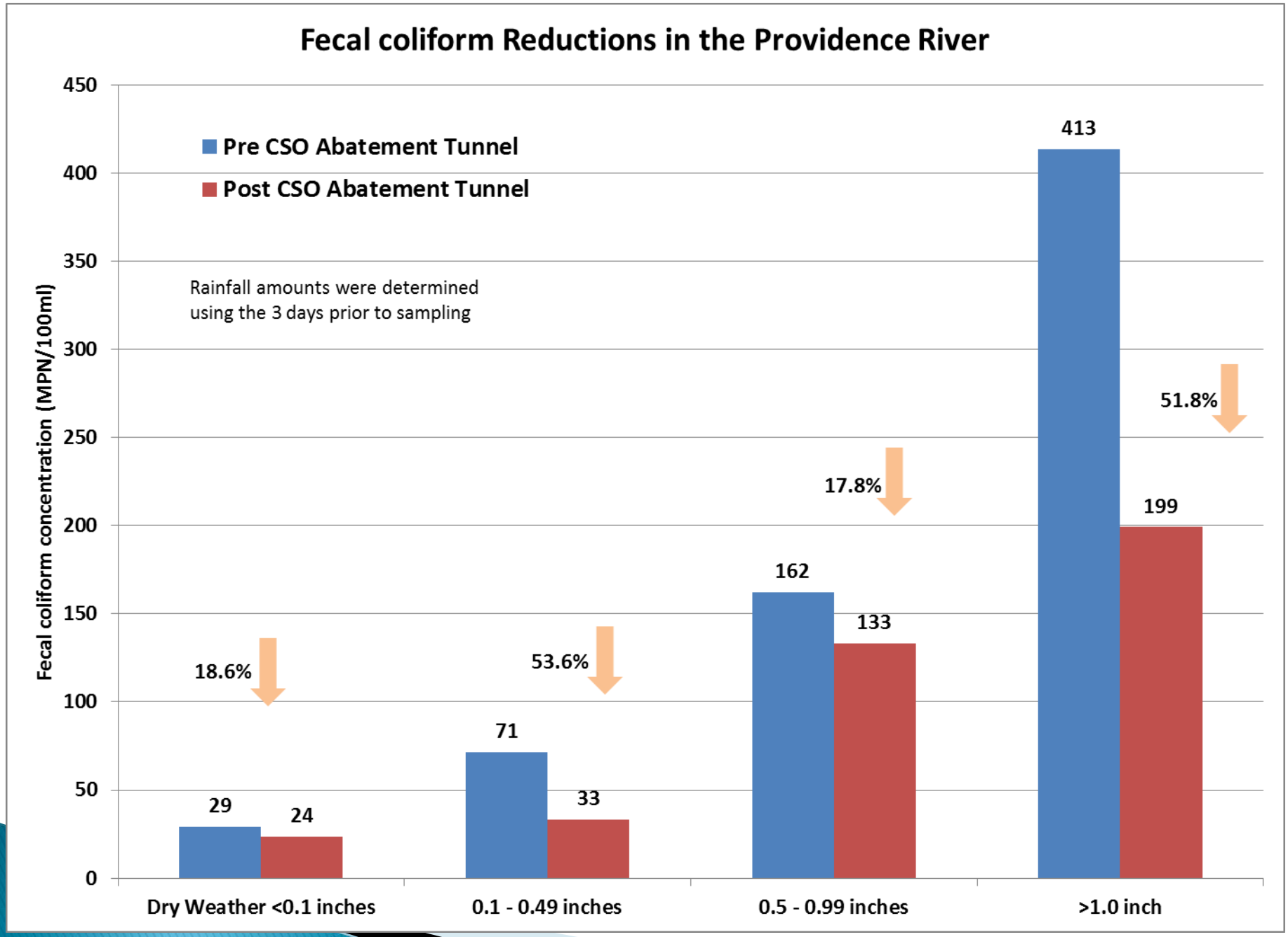
NBC CSO Abatement Project

- $1.3 Billion Project
- 3 Phases
- 98% volume reduction
- 80% reduction in shellfish bed closures
- Designed for a 3 month storm, 1.65” rain in 6 hour period
- Overflows will still occur for big storms!!!

CSO Phase I Achievements

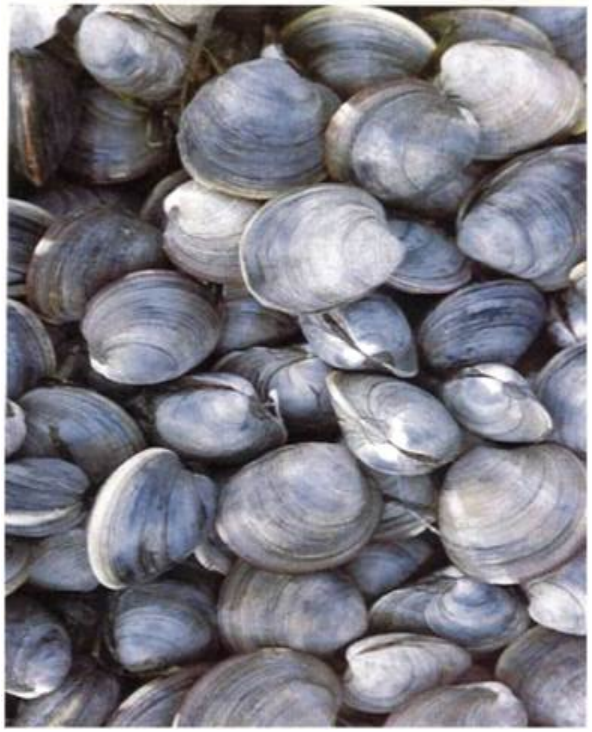
- Model estimates 2.2 Billion Gallons of CSO Flow annually
- Phase I CSO Tunnel Capturing 1.1 Billion Gallons annually (50%)
- 5.3 Billion Gallons Captured and Treated since 11/2008
- Significant Reduction in Bacteria Contamination has been realized


Providence River/Upper Narragansett Bay Fecal coliform Geomeans
Pre and Post Tunnel Operation
Fecal coliform geomean (MPN/100ml)
180
160
140
120
100
80
60
40
20
0
Before Phase I (2004 - Oct 2008)
After Phase I (Nov 2008 - Sept 2013)*
*Data does not include special study samples collected from 4/1/10 - 4/9/10 taken during historic flood.
70
44
37%
156
86
45%
29
25
15%
Overall - Providence River
Point Street Bridge - Conimicut Point
Upper Providence River
Point Street Bridge - Pawt/Prov Jct.
Lower Providence River
Gasppe Point - Conimicut Point


Fecal coliform Reductions in the Providence River
Pre CSO Abatement Tunnel
Post CSO Abatement Tunnel
Rainfall amounts were determined using the 3 days prior to sampling
Fecal coliform concentration (MPN/100ml)
450
400
350
300
250
200
150
100
50
0
29
24
18.6%
71
33
53.6%
162
133
17.8%
413
199
51.8%
Dry Weather <0.1 inches
0.1 - 0.49 inches
0.5 - 0.99 inches
>1.0 inch

Shellfish Closure Criteria Changes

- Historically, RIDEM closed Conditional Shellfishing Area A with rain of ≥0.5 inches rainfall (24 hr. period).
- Both Areas A &B were closed with ≥1.0 inches of rainfall
- On May 26th, 2011 DEM announced that Conditional Area A would now close with ≥0.8 inches of rain and Conditional Area B with ≥1.5 inches of rain
- On average Area A is expected to be open 65 more days/year Area B is projected to be open 45 more days/year
- *"the changes are a result of water quality improvements associated with the completion of Phase I of the three-phase Narragansett Bay Commission (NBC) combined sewer overflow (CSO) program in 2008*"…DEM Statement

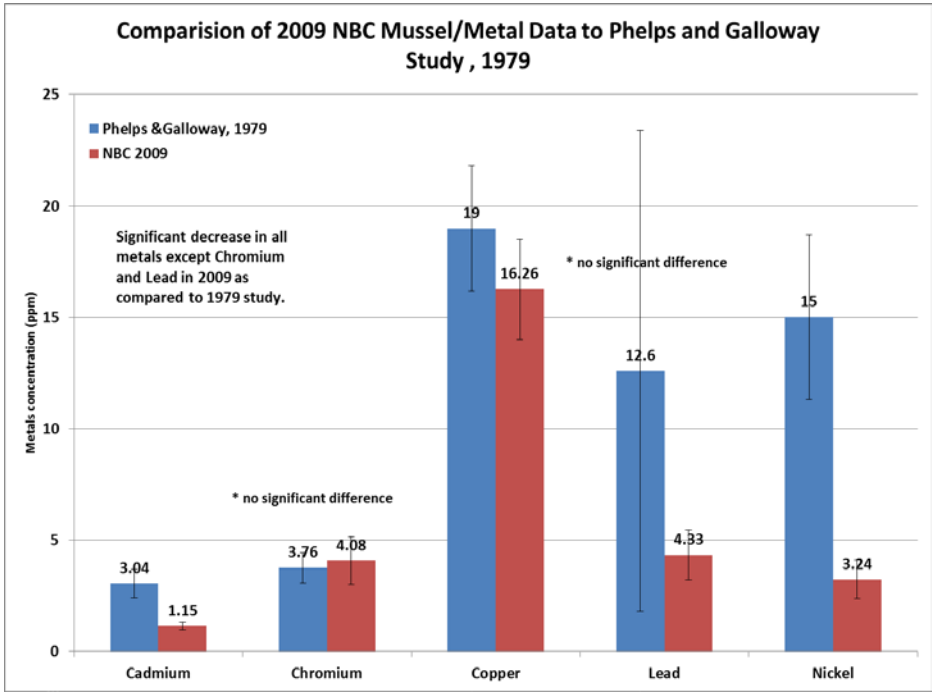


Heavy Metals Contamination in Blue Mussels, *Mytilus edulis*

- NBC evaluated toxic metals concentrations in mussels in Upper Bay in 2008, 2009 & 2012
- Replicated study design from 1979 EPA experiment by Phelps and Galloway
- Replicated: Equipment design, deployment location, metals tested
- Differences: original mussel collection location, control design
- Control Mussels collected from Ft. Getty, Jamestown
- Tested for: cadmium, chromium, copper, lead, nickel, and zinc

Mussel Toxics Study Conclusions

- All NBC study year results were below concentrations from P&G 1979 study
- All 6 metals tested were significantly lower than 1979 concentrations except for Chromium in 2009 and 2012, which there was no sig. difference.
- All years, including 1979, were below National Shellfish Sanitation Standards for metals levels (Cd, Cr, Ni), **except for Pb which was above the standard in all 4 years**!!!
- Control Samples from Jamestown also exceeded Pb Standard!!!
- Providence & Seekonk Rivers were removed from EPA 303d List for toxic pollutants in 2004



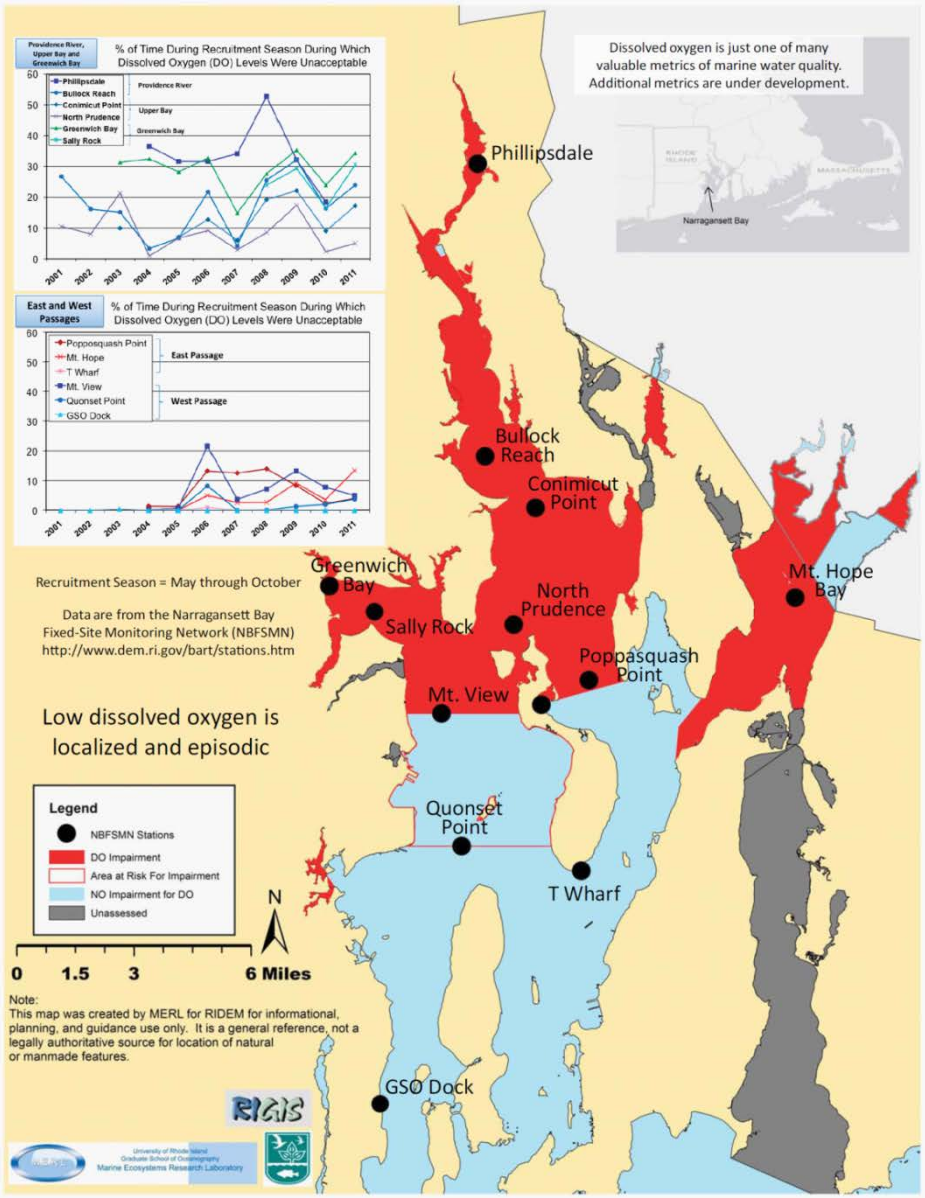
Video Benthos Monitoring

- NBC performs Quad & Transect Videos of upper Bay
- Extensive Amphipod Mats observed
- Also observed many burrows – Mantis Shrimp?
- Vast areas of upper Bay lack structure for fish habitat

Edgewood Shoal Transect Video – 2013

Greenwich Bay Fish Kill

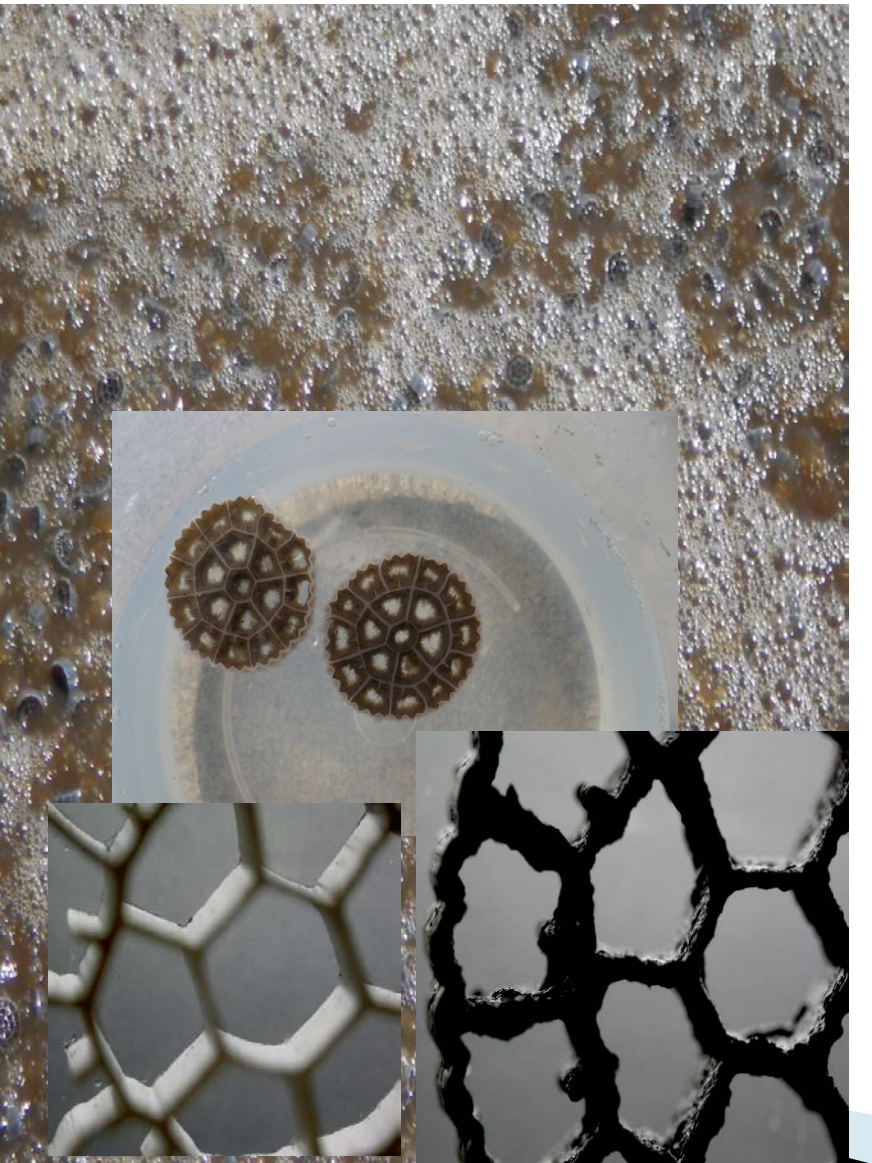
- **August 20, 2003**
  - ✓ Millions of Fish Dead, primarily menhaden
  - ✓ Crabs, eels, shrimp and blackfish also die
  - ✓ Worst Fish Kill in last 50 – 100 years
  - ✓ Dissolved Oxygen Monitoring Sondes at Greenwich Bay Marina Dock:
  - ✓ Surface Sonde: 1.1 meters deep – 0 mg/l DO
  - ✓ Bottom Sonde: ~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

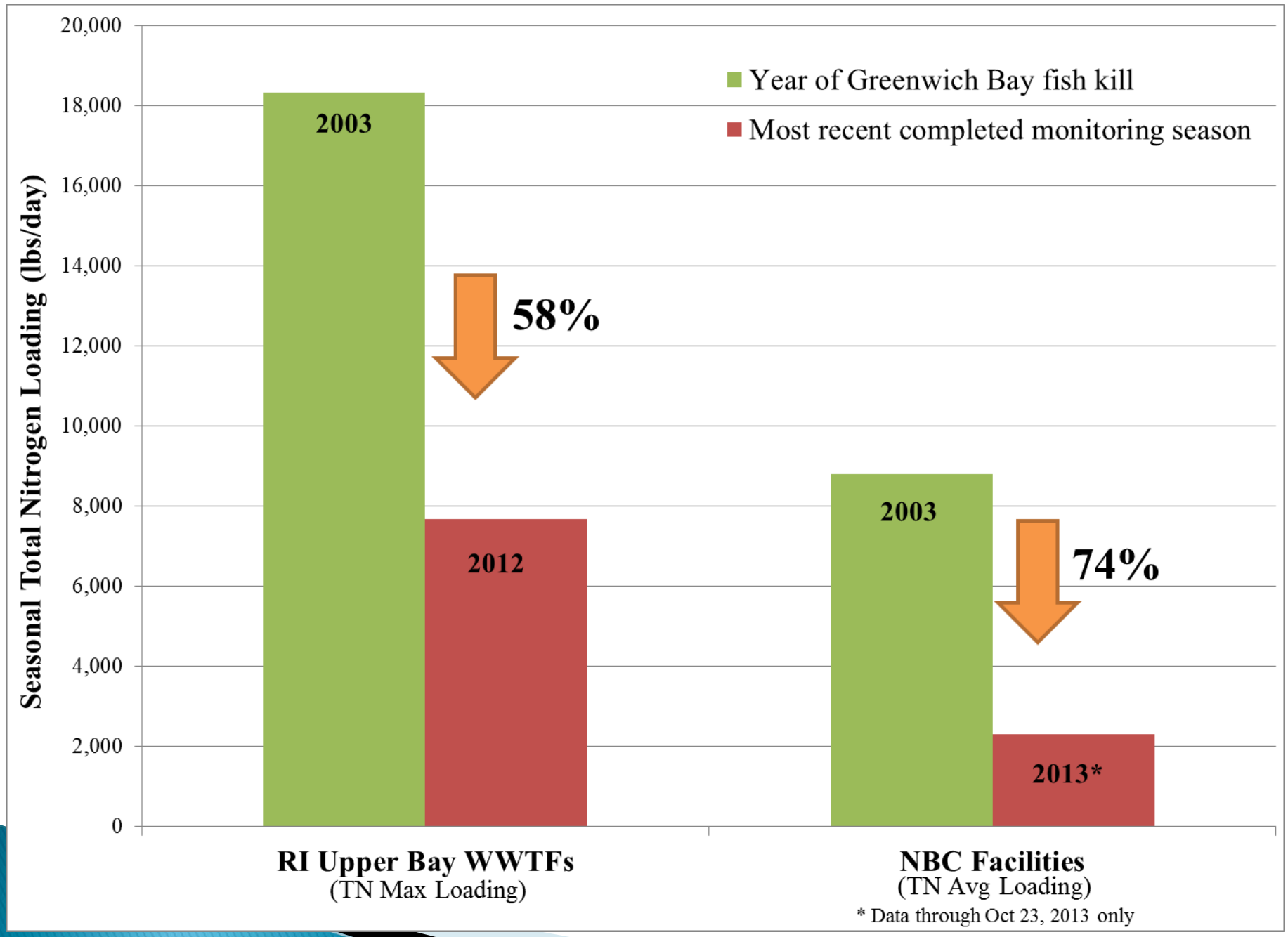
Field's Point POTW– Biological Nutrient Removal Upgrade for Total Nitrogen



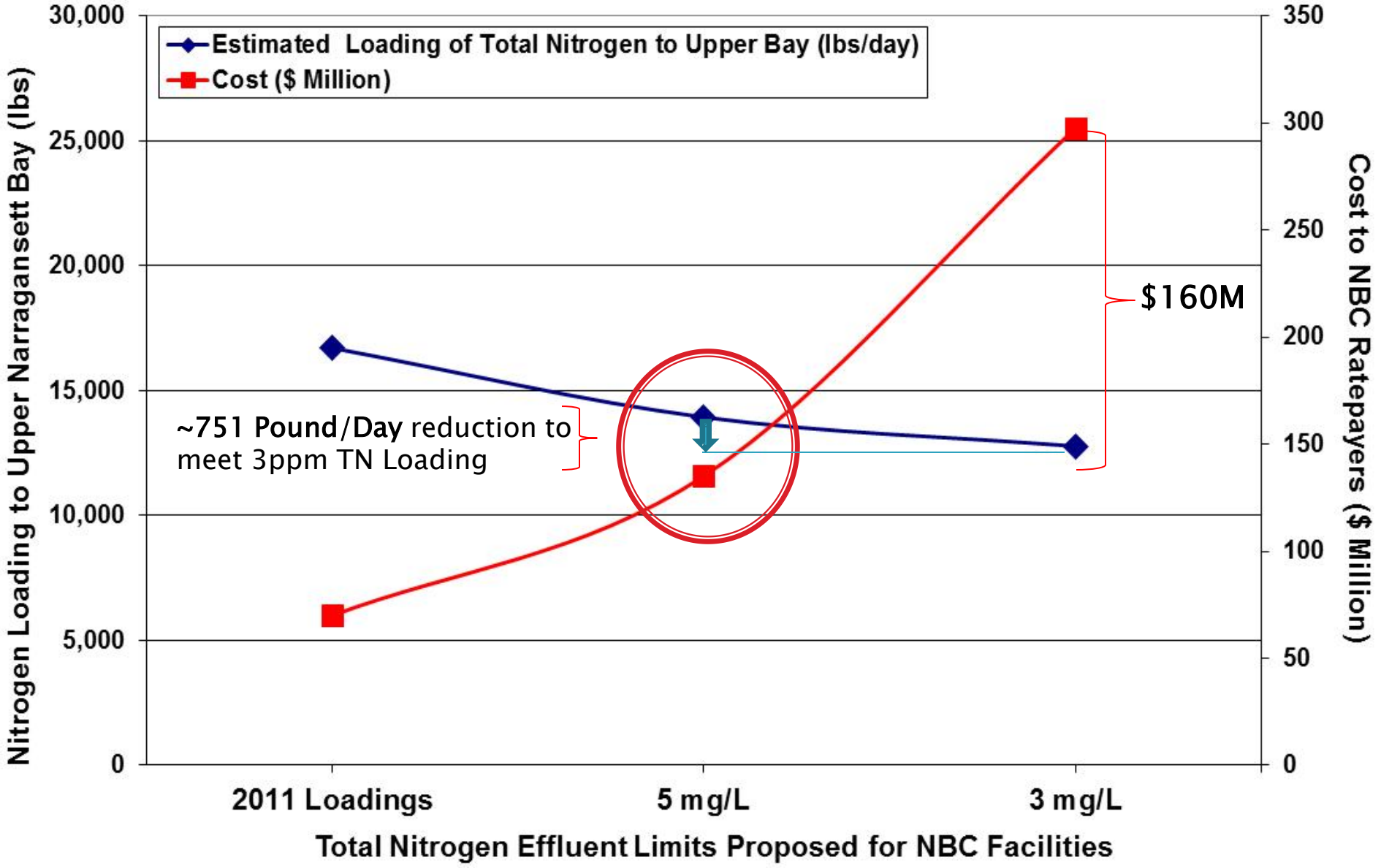
- Will use IFAS system to meet 5 ppm TN – Largest IFAS Plant in World!
- Construction complete at FP, in testing phase
- Permit Limits will be in effect for 2014 season
- Achieved 2013 seasonal average 3.6 ppm!!!!
  - Already reduced 3,541 lbs TN/day at FP since fish kill based on 2013 data (-78%)
- **Upgrade Cost – ~$31 million**

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

- Built to meet 8.5 ppm TN in 2005/2006
  - ✓$8.3M of $70M project for initial nitrogen upgrade
- 2013 seasonal average was 5.9 ppm TN (-66% since 2003)
- Upgrade design to 5ppm TN ongoing
  - ✓**Upgrade cost to hit 5ppm TN -$13 M**
  - ✓Reduction of ~158 lbs TN/day

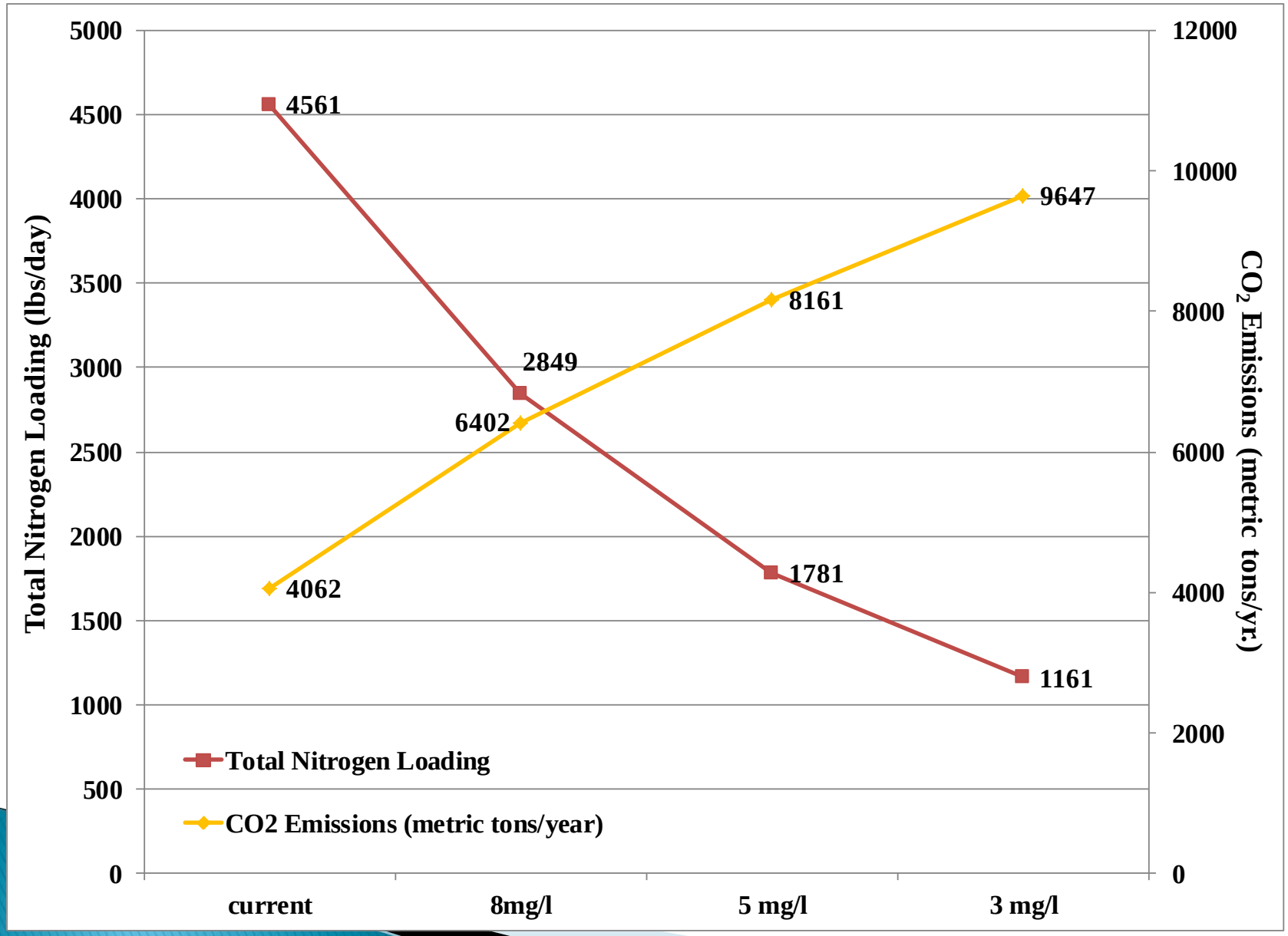

Seasonal Total Nitrogen Loading (lbs/day)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Year of Greenwich Bay fish kill
Most recent completed monitoring season
2003
2012
58%
2003
2013*
74%
RI Upper Bay WWTFs
(TN Max Loading)
NBC Facilities
(TN Avg Loading)
* Data through Oct 23, 2013 only

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



United States Environmental Protection Agency
Office of Research and Development/Office of Water
Washington, DC 20460

EPA/842-R-08-002
December 2008
http://www.epa.gov/nccr

National Coastal Condition Report III

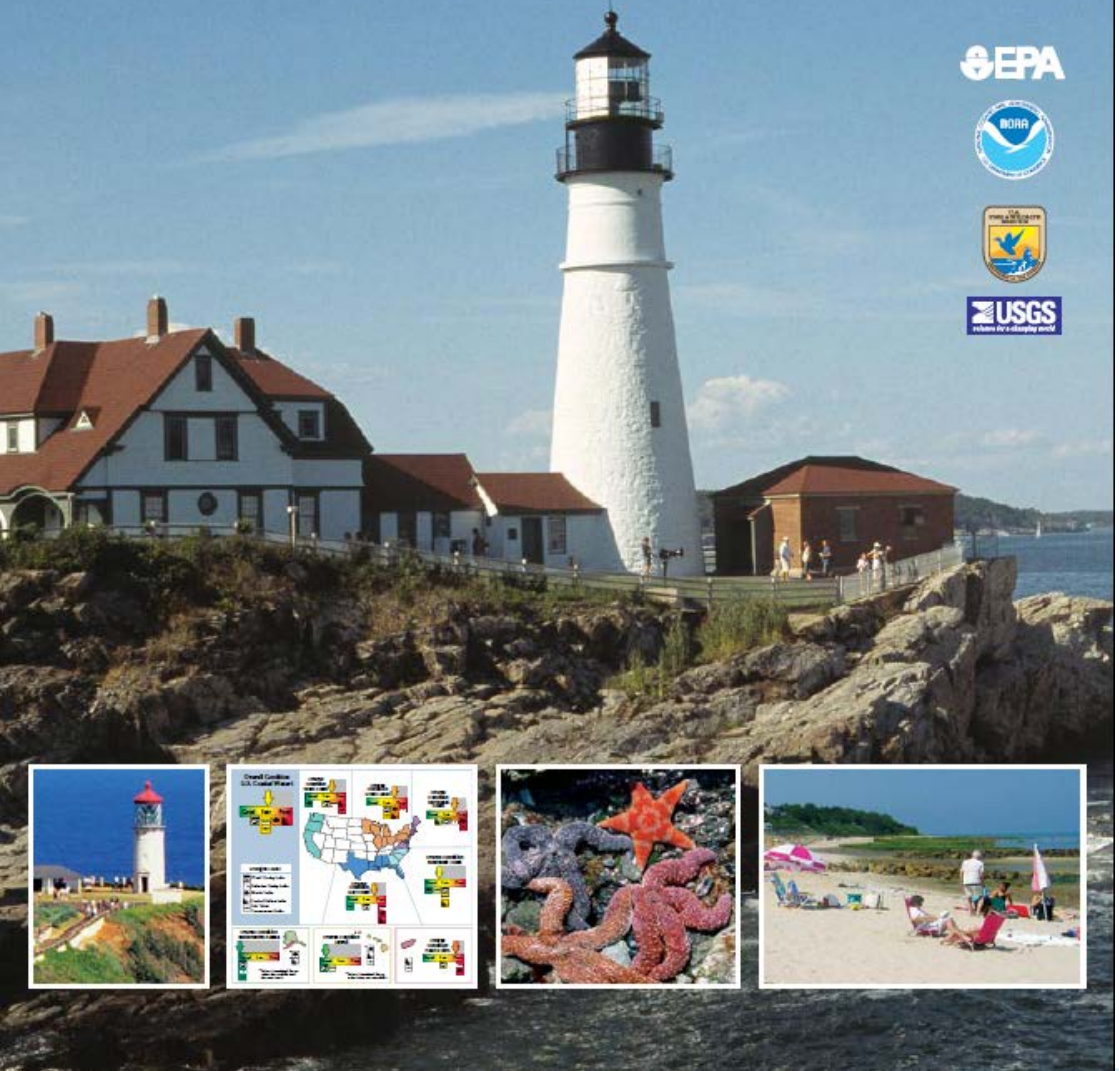
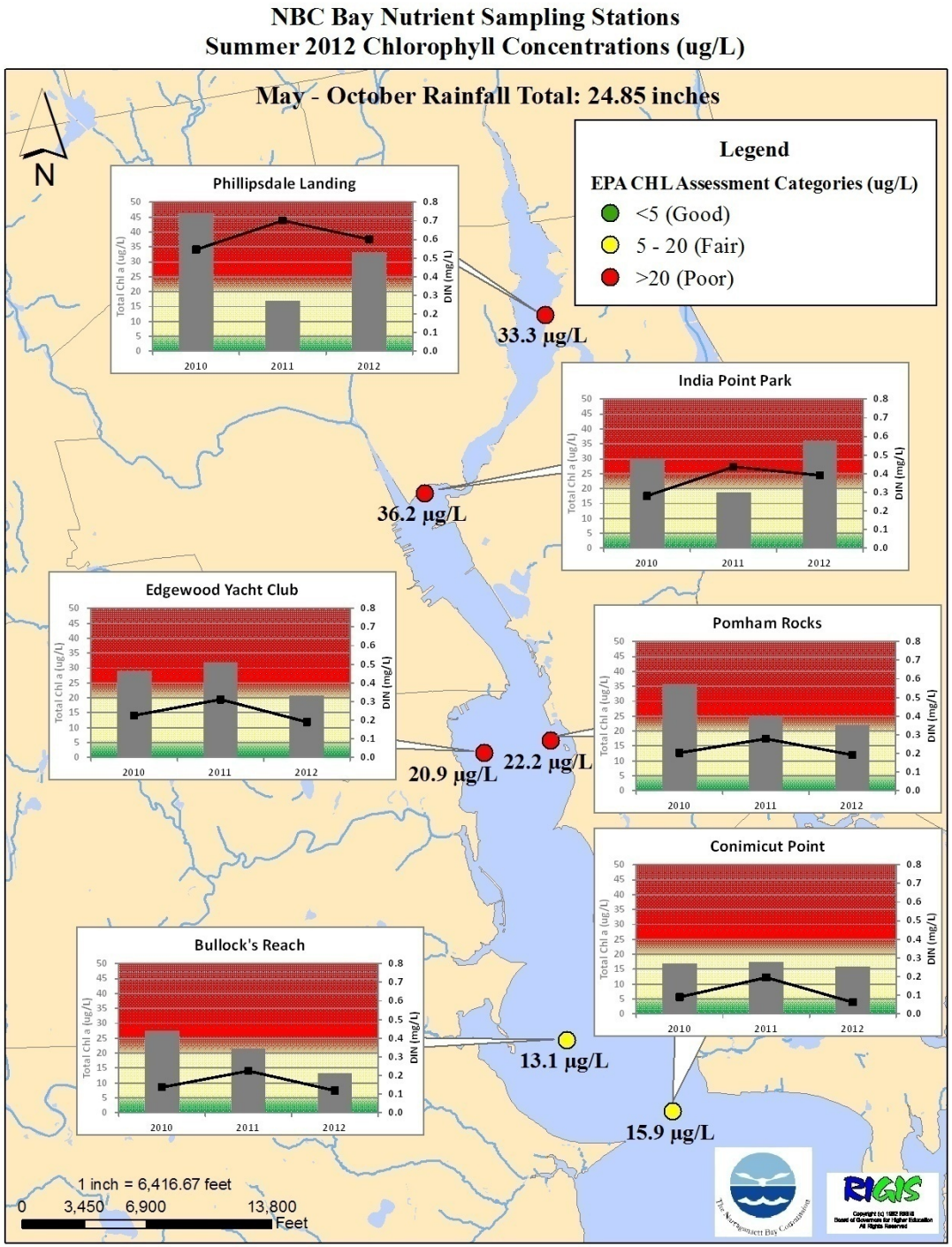


Table 1-2. Criteria for Assessing Dissolved Inorganic Nitrogen (DIN)

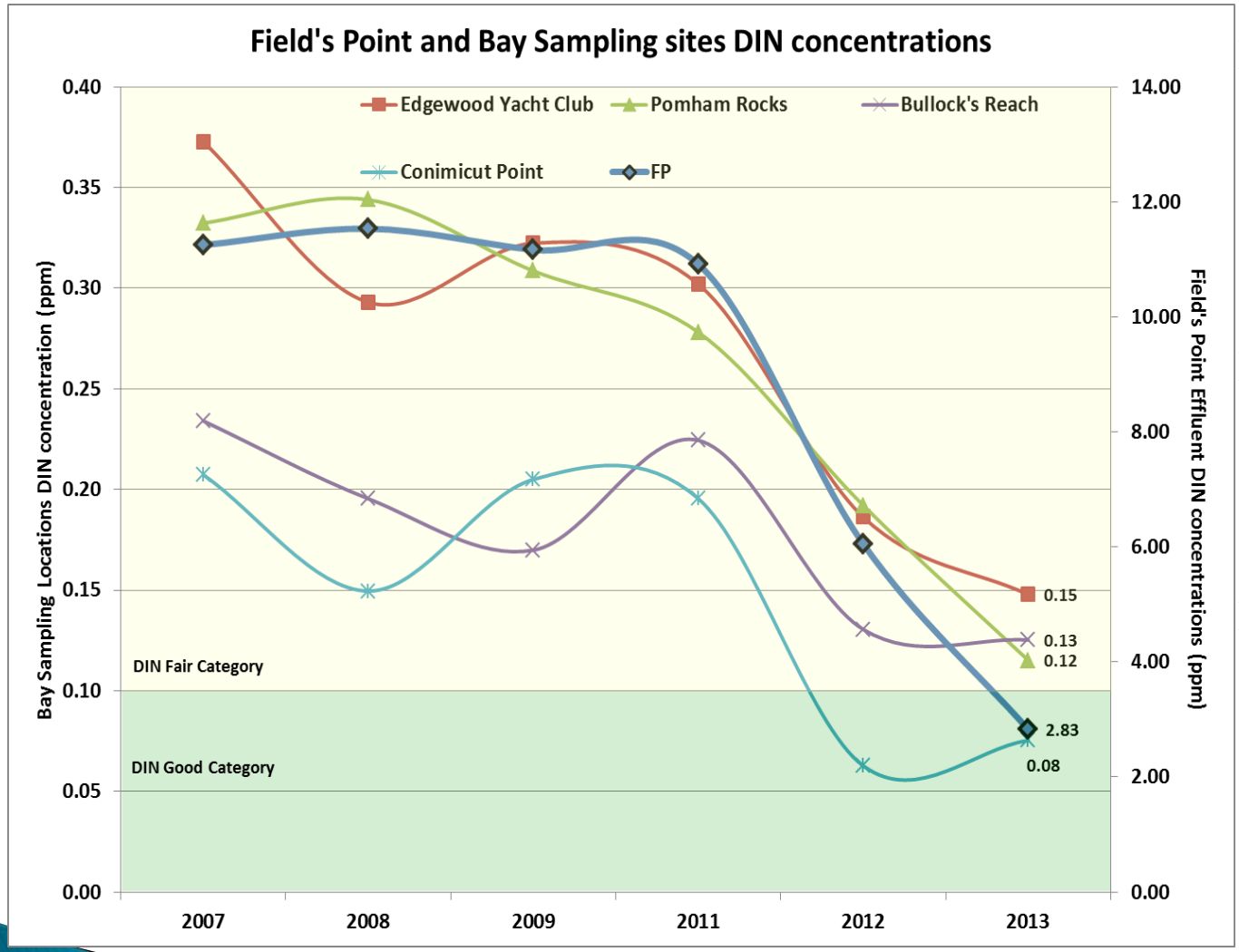
Area	Good	Fair	Poor
Northeast, Southeast, and Gulf Coast sites	< 0.1 mg/L	0.1–0.5 mg/L	> 0.5 mg/L
West Coast and Alaska sites	< 0.5 mg/L	0.5–1.0 mg/L	> 1 mg/L
Hawaii, Puerto Rico, and Florida Bay sites	< 0.05 mg/L	0.05–0.1 mg/L	> 0.1 mg/L
Regions	Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.	10% to 25% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.	More than 25% of the coastal area is in poor condition.



Chlorophyll

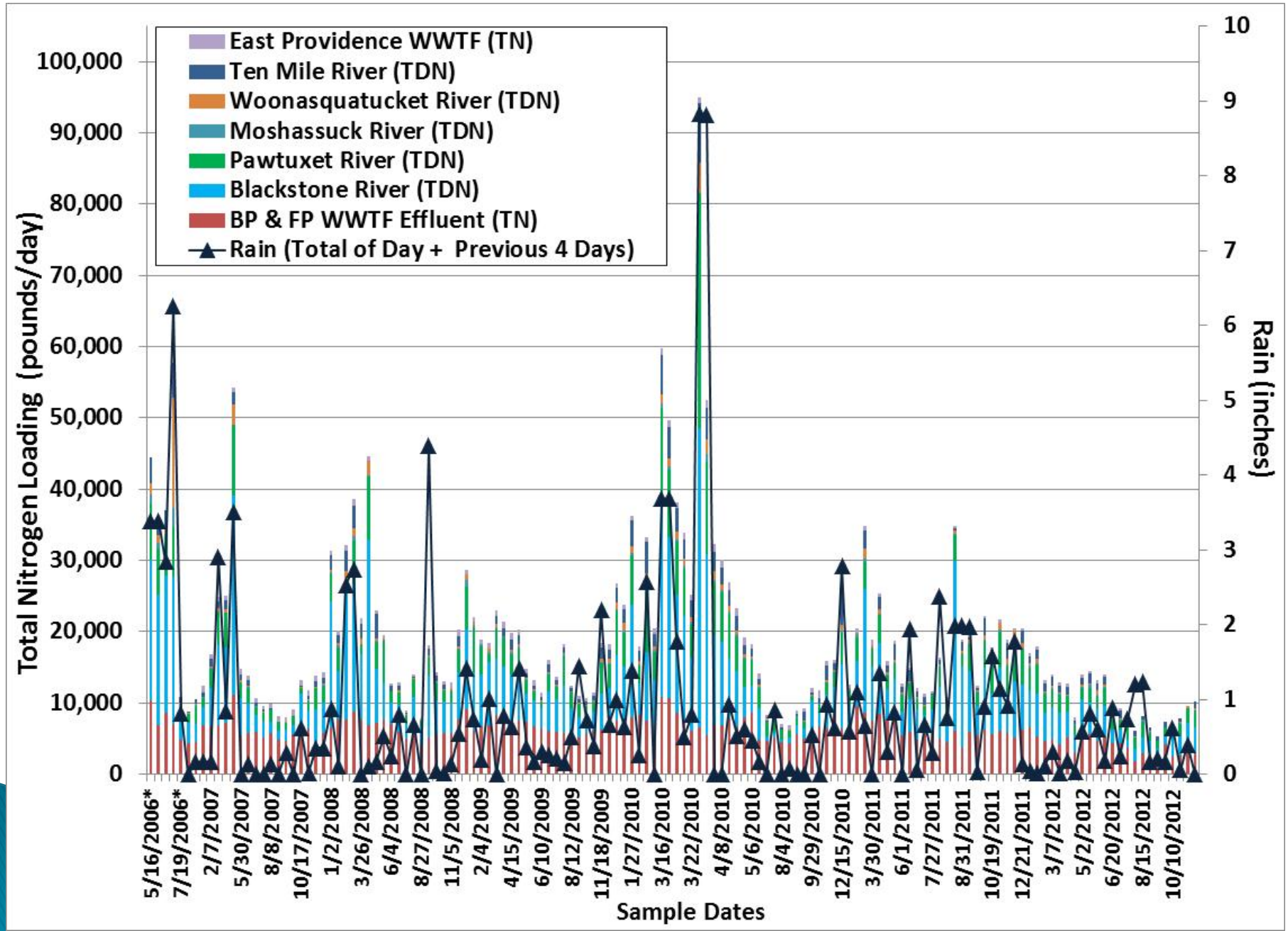
- Coastal Condition report recommends <=5µg/L Chlorophyll
- Data starting 2010
- Varies annually (46 – 13 µg/L)
- Not all years show the expected down bay gradient (2011 EYC is highest)
- Conimicut Point is constantly 16-17 µg/L
- GSO Mid-Bay station averages 4 µg/L

Total Nitrogen Status in the Bay



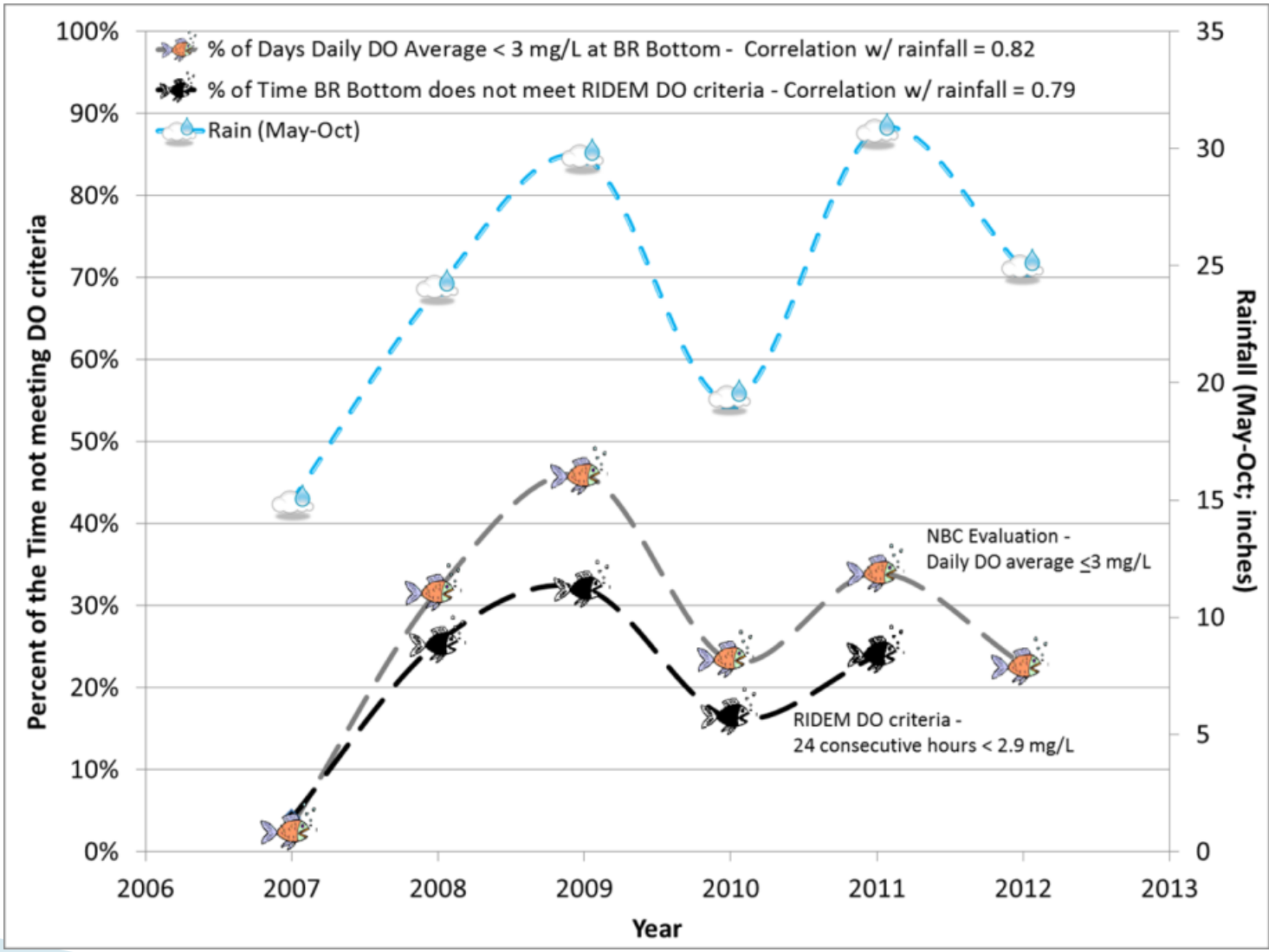
- TN Loads to Upper Bay greatly reduced
- DIN conc. in Providence River dropping
- Conimicut Pt <0.1 ppm DIN for past 2 years – Good Category!!!!!

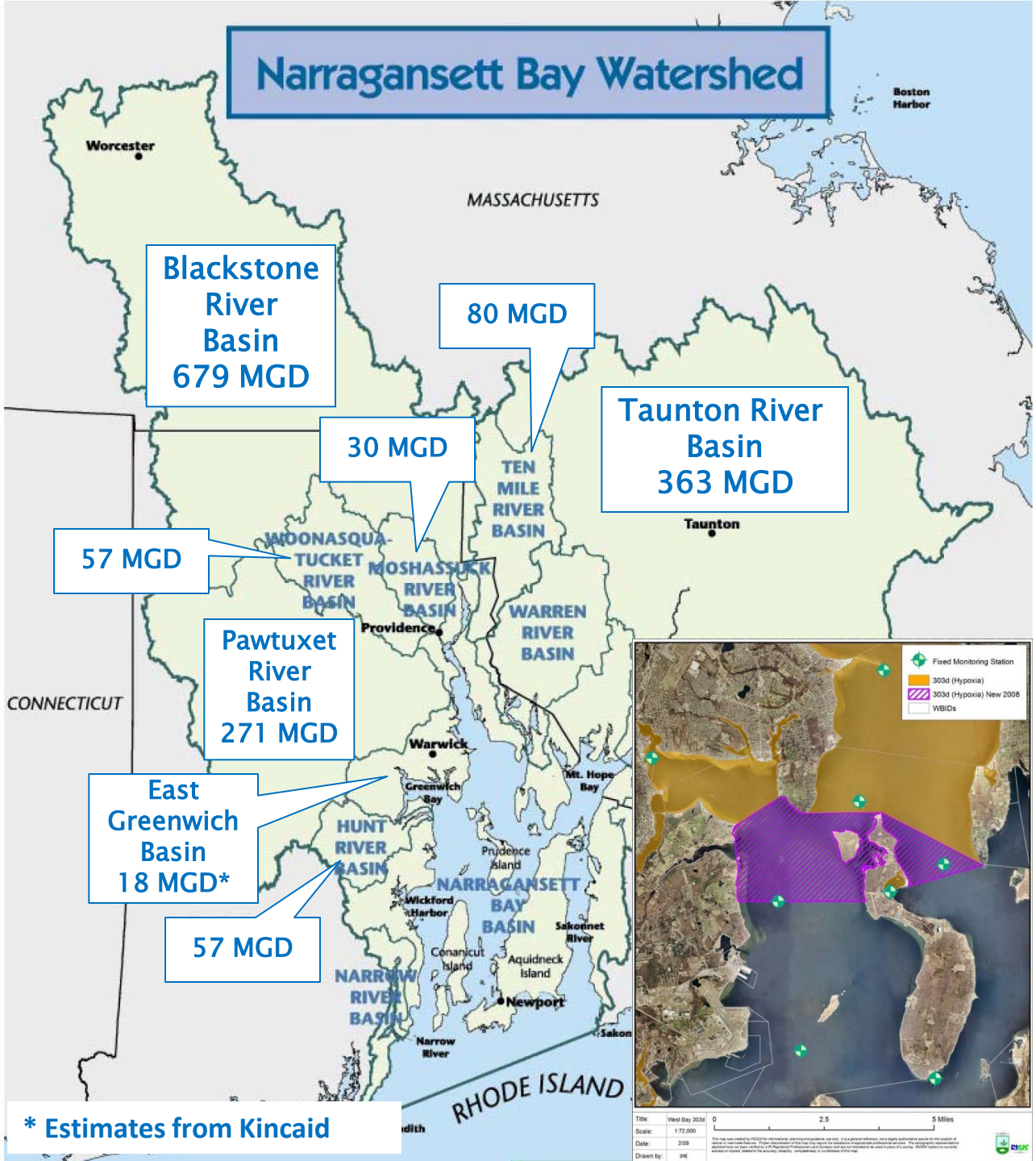
Upper Bay Total Nitrogen Loading & Rainfall



Strong DO Impairment Correlation

- Strong correlation between rainfall and DO Impairment Time
- Will further TN reductions eliminate DO impairments?
- Is Rainfall and Stormwater a major cause?





Freshwater Inputs

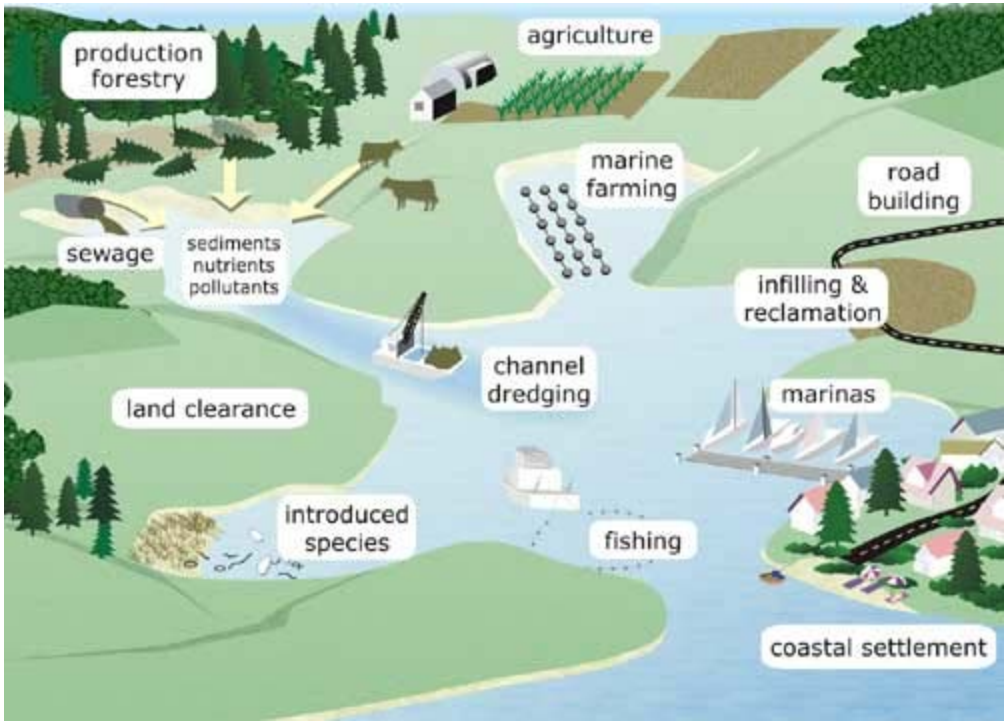
- Majority of NB's freshwater flow enters through the Providence River
- Approx. 1050 mi^2 Narragansett Bay watershed is gauged
- Approx. 223 mi^2 of the watershed is NOT gauged

(Info from Ullman, Brush, Kincaid)

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

The Sins of the Past!
.....and Future Opportunities?

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

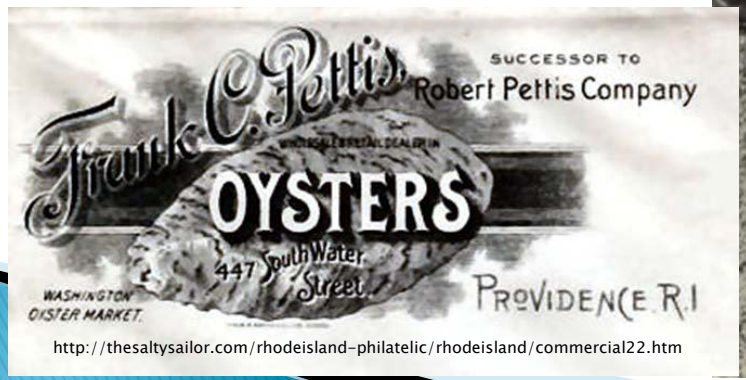
Many Ecosystem-wide problems began decades ago…

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

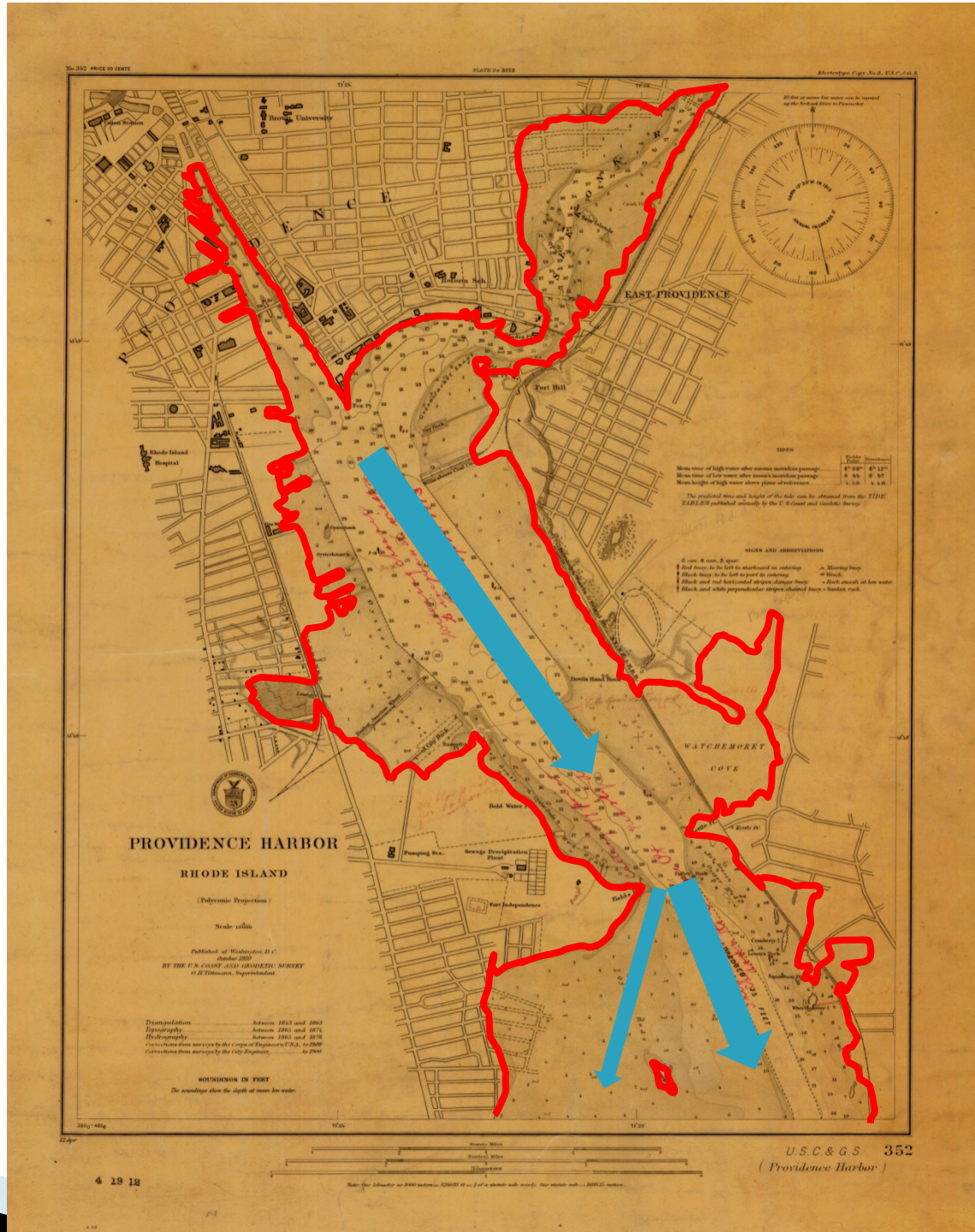
Based on 1865 – 1878 "Hydrography"

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

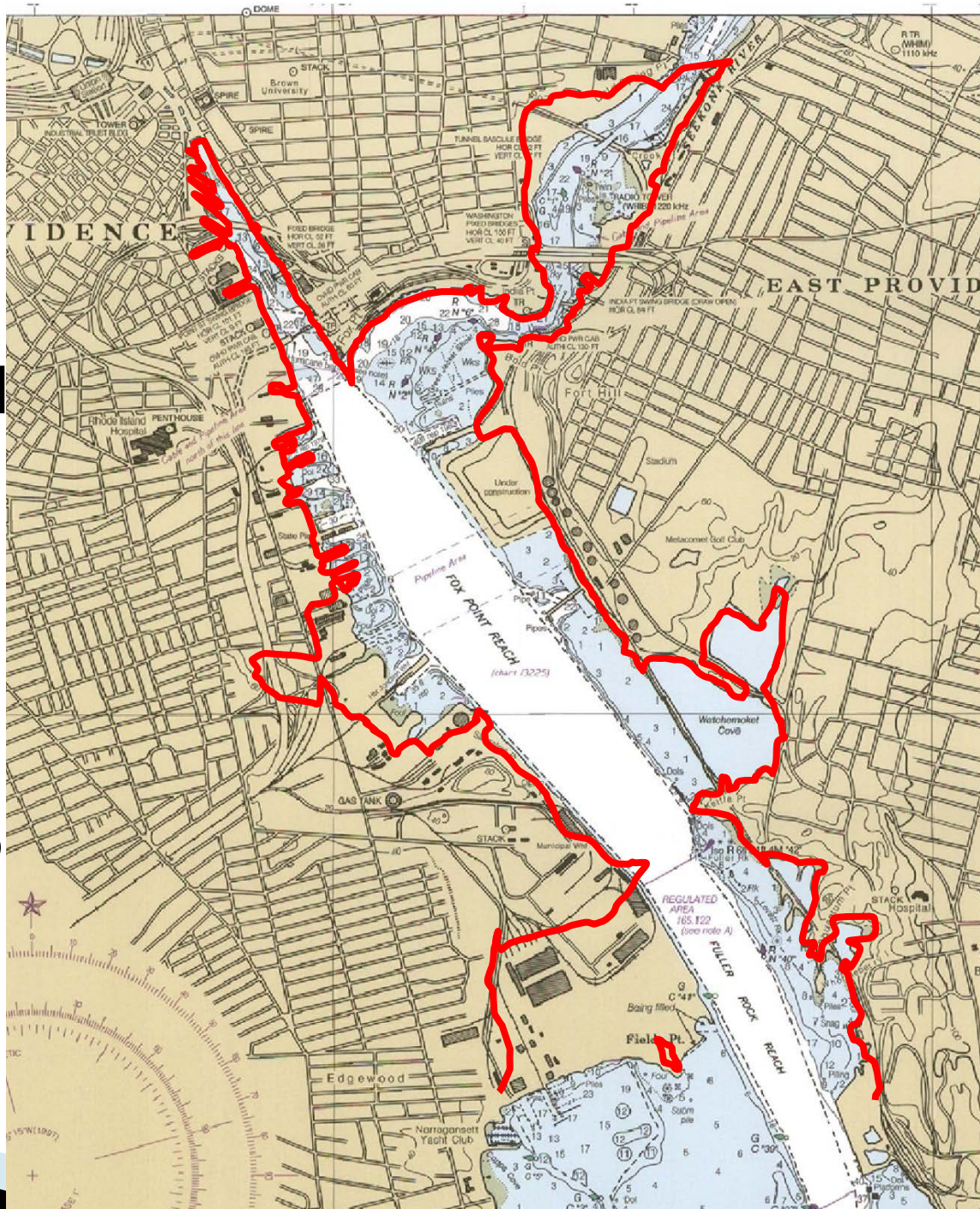
- ✓ 1910 Coast Line in Red
- ✓ City plans to Fill Bay and Build Roads
- ✓ Note:
  - ✓ Much Shallower River
  - ✓ Starved Goat Island
- ✓ What was flow circulation pattern in 1910?



Upper Providence River Today

1910 Coastline in Red

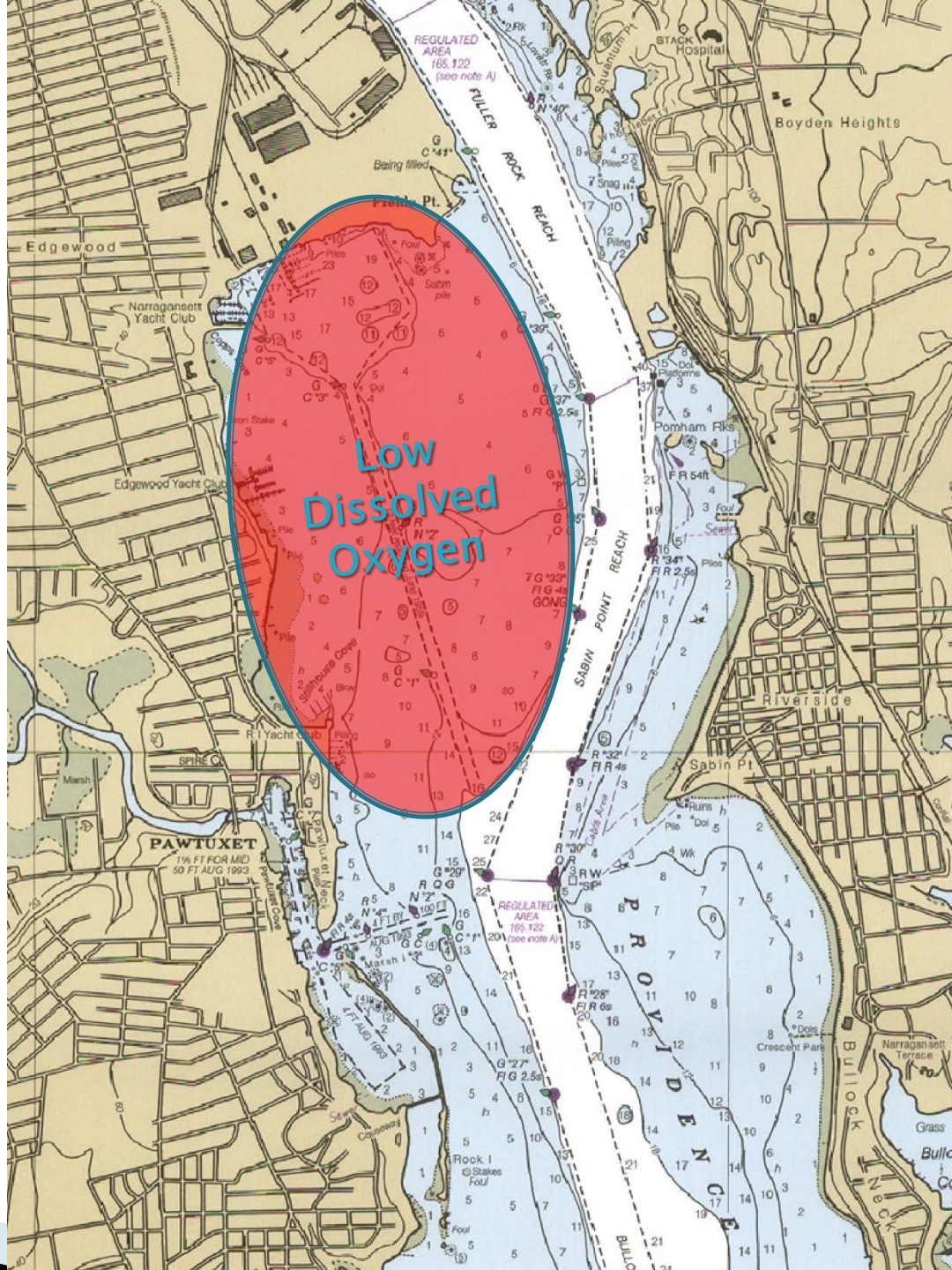
- ✓ We Filled the Bay & Wetlands
- ✓ Built the Hurricane Barrier
- ✓ Built Pawtuxet River Breakwall
- ✓ Allowed Rivers to Silt up
- ✓ Dredged Channel to 50+’



Water Quality Problems

- Edgewood Shoals area is DO impaired:

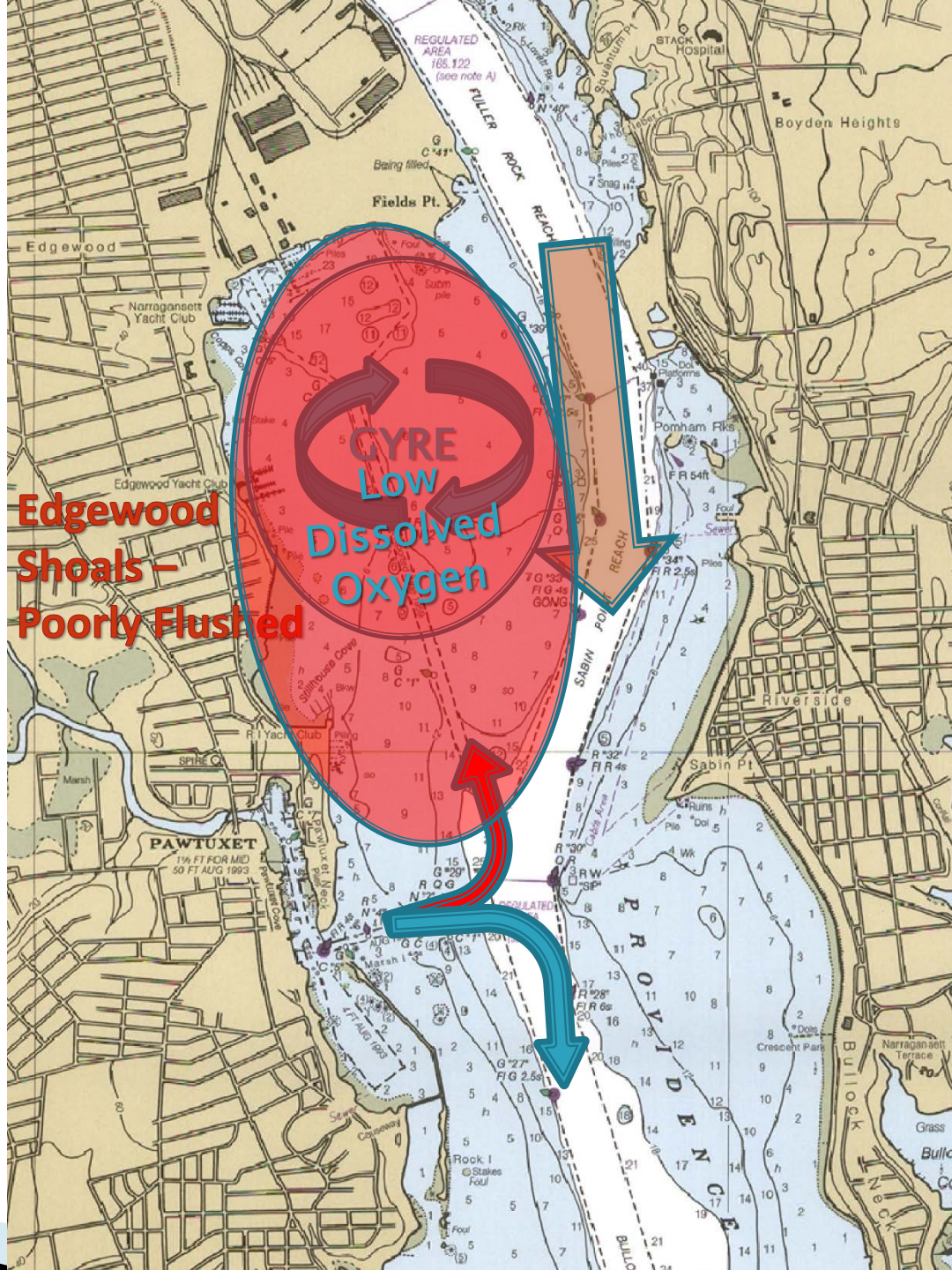
- ✓ We Changed Flow Circulation Patterns
- ✓ Poor flushing
- ✓ Nitrogen enrichment
- ✓ Stratification



Water Quality Problems

ROMS Model Indicates:

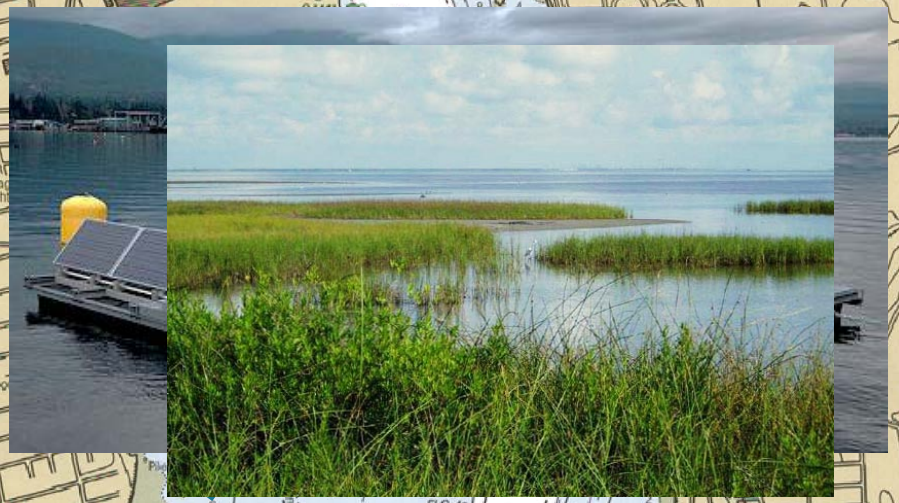
- Jet of water down the shipping channel
- Sets up a clockwise Gyre on Shoal
- Bottom waters from Pawtuxet River transport Nitrogen onto the shoal



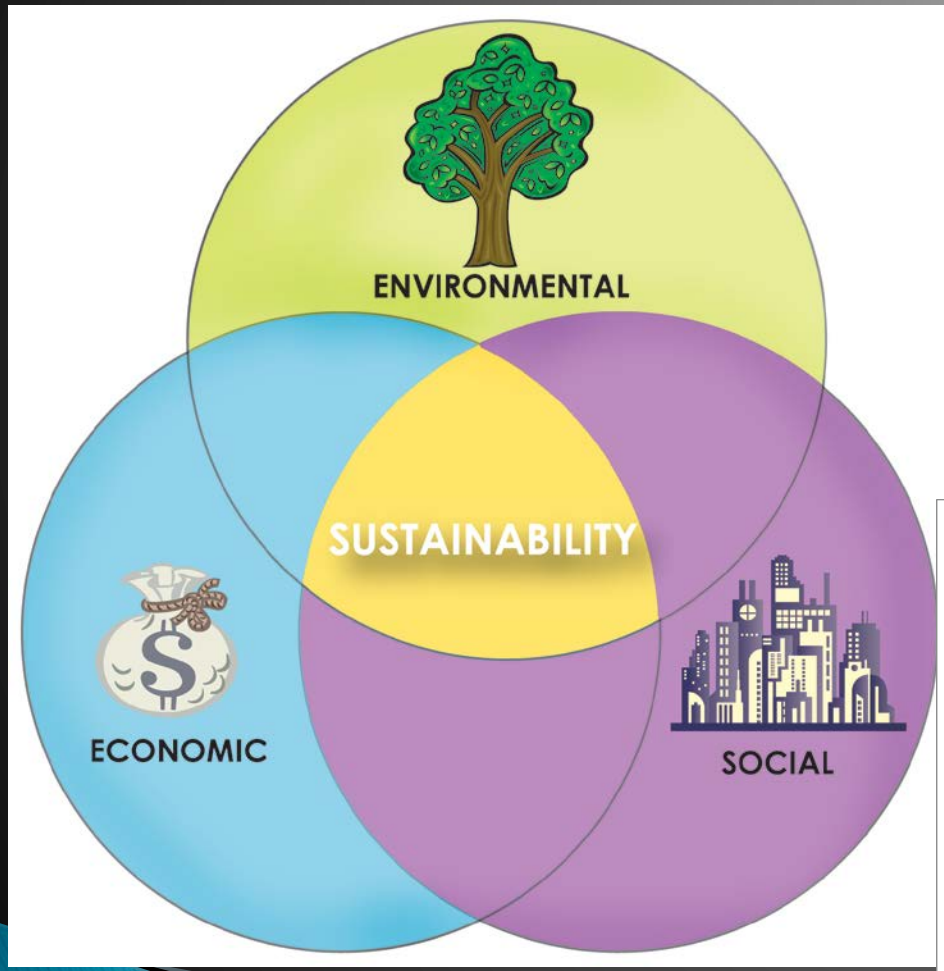
Possible Sustainable Solutions

- *Lets take a Holistic Approach to Watershed Management*
- *Can we Improve Bay WQ By "Smart Engineering"?*

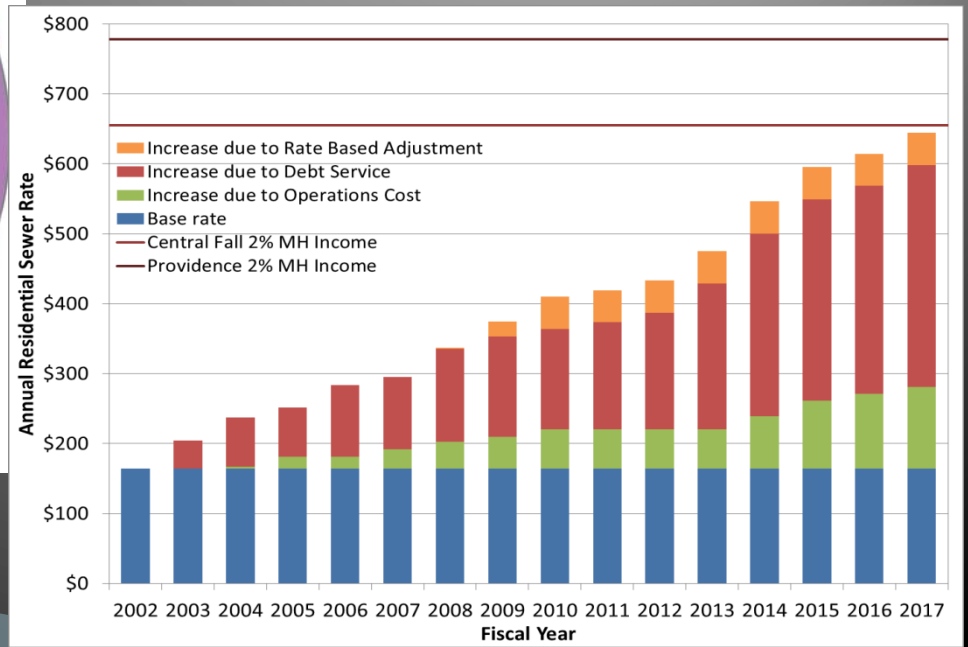
- ✓ Selective Dredging?
- ✓ Maybe create a channel to redirect flow over shoal- improve circulation?
- ✓ Remove or open breakwalls to improve circulation?
- ✓ Create Islands, Wetland Habitats, natural buffers?
- ✓ Establish Bio-extraction or Aquaculture Projects?

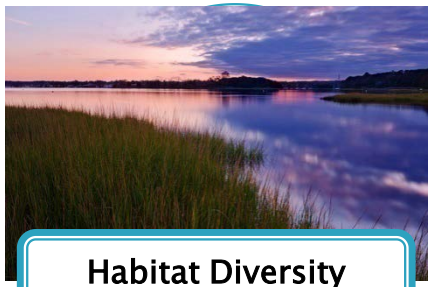


Sustainable Solutions Needed!!!



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





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

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 DO water quality, by looking at 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

RIDEM List of Impaired Waters 2012

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
Fish and Wildlife habitat	Not Supporting	Nitrogen (Total)	2016		Determine need for TMDL post WWTF upgrades.
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Let's Work Together to Give DEM a Full Toolbox for TMDL Development!

Beneficial Use of Excess 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

Feasibility Study

- Project steering committee convened
  - ✓ Narragansett Bay Commission
  - ✓ RI Department of Environmental Management
  - ✓ Bays, Rivers and Watershed Coordination Team Chair
- Consultant to be 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??

Feasibility Study

- Convene Expert Panels on:
  - ✓ Shellfish
  - ✓ Aquaculture
  - ✓ Salt Marsh/Wetlands
  - ✓ Fisheries
  - ✓ Dredging
  - ✓ Hydrodynamics
  - ✓ Eelgrass
  - ✓ Geology
  - ✓ Modeling
  - ✓ Habitat Restoration
- Expert panels to review & assess sustainable solutions for Environmental Improvement:
  - ✓ Scientific rational
  - ✓ Feasibility
  - ✓ Regulatory roadblocks
  - ✓ Efficacy
  - ✓ Economic Value
  - ✓ Costs & Benefits
- Larger Stakeholder group will be convened to review the findings of the Expert panels

Timeline of Study

- Year 1 – 2014
  - ✓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
- Years 2 & 3 – 2015/2016
  - ✓Modification of water quality models
  - ✓Validation of priority topics
  - ✓Priority topic pilot demonstration projects
  - ✓Identify “Low Hanging Fruit”

Outcomes of the Process

- Developed a blueprint of "sustainable" ecosystem-based management solutions to improve water quality and ultimately restore upper Narragansett Bay
- Complete the FIRST TRUE Ecosystem Based Evaluation of an Estuary in the Nation!!!
- Provide a Robust Tool Box to DEM for TMDL development for Providence and Seekonk Rivers
- Identify opportunities to create sustainable jobs as we restore our Bay
- **A Healthy Sustainable Narragansett Bay, more resilient to future challenges**

Questions ???

Typical Examples of Solutions for Evaluation

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)

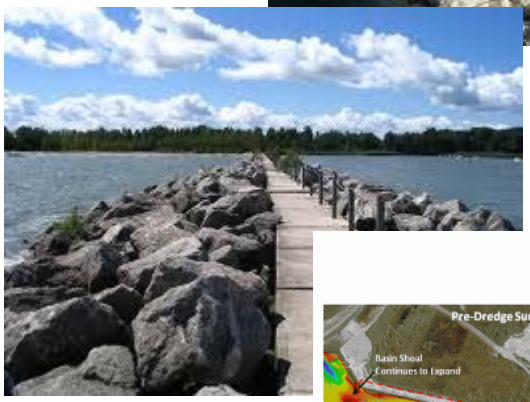
Local example of Bio-extraction assessment: Long Island Sound (LIS)

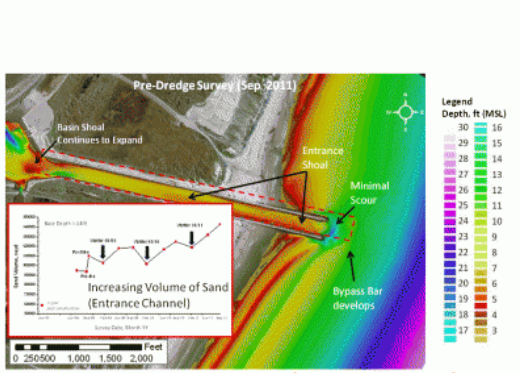
- Preliminary LIS models predict potential increase of 2 mg/l DO through the use of bio-extraction
- Discussions ongoing regarding ways to incorporate bio-extraction into the revised LIS TMDL for nitrogen
- Concept is economically promising, but substantial administrative and regulatory barriers need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



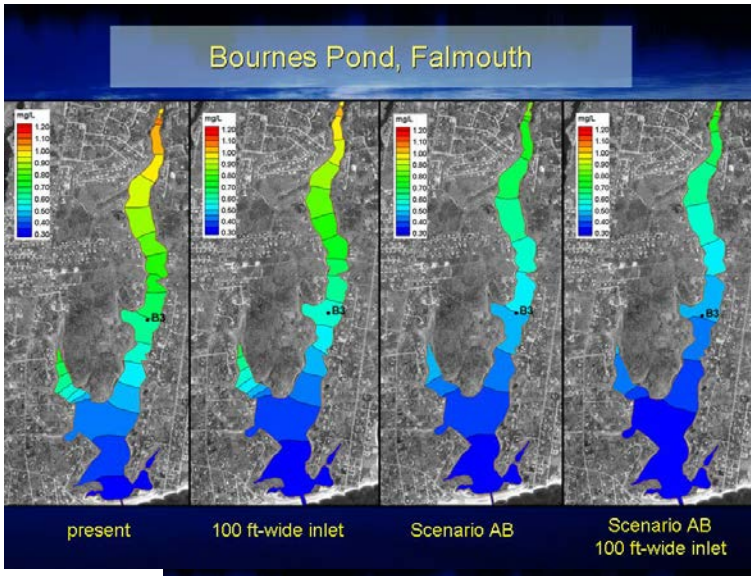


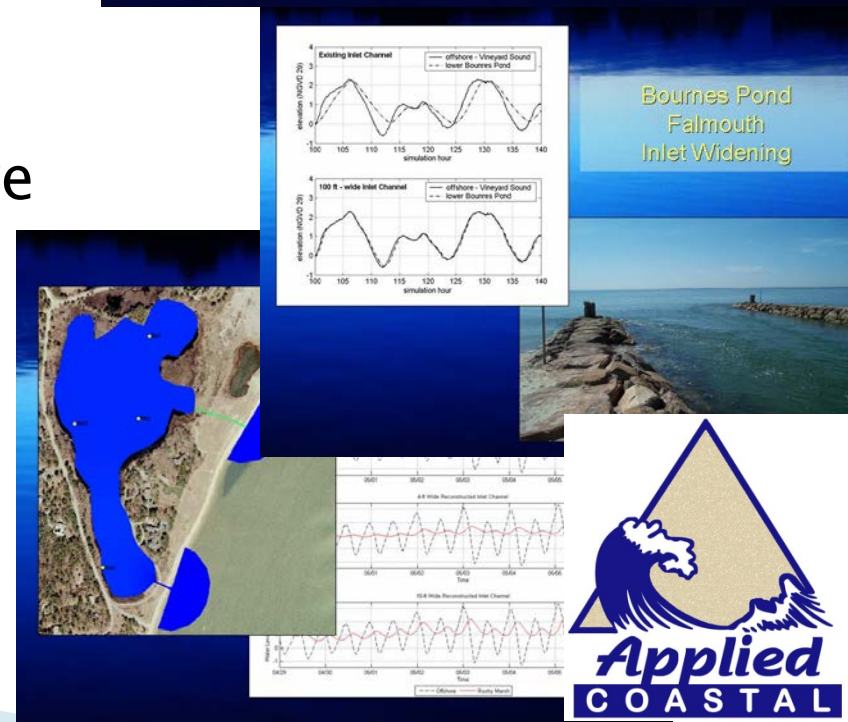
www.cbi.tamucc.edu

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

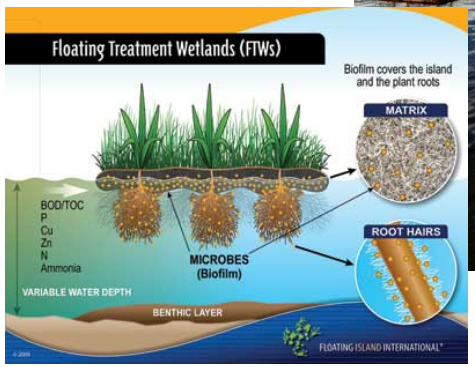
Current Use of Constructed Wetlands for Water Quality Improvements

- Virginia Institute of Marine Science Floating Wetlands Pilot Project 2012

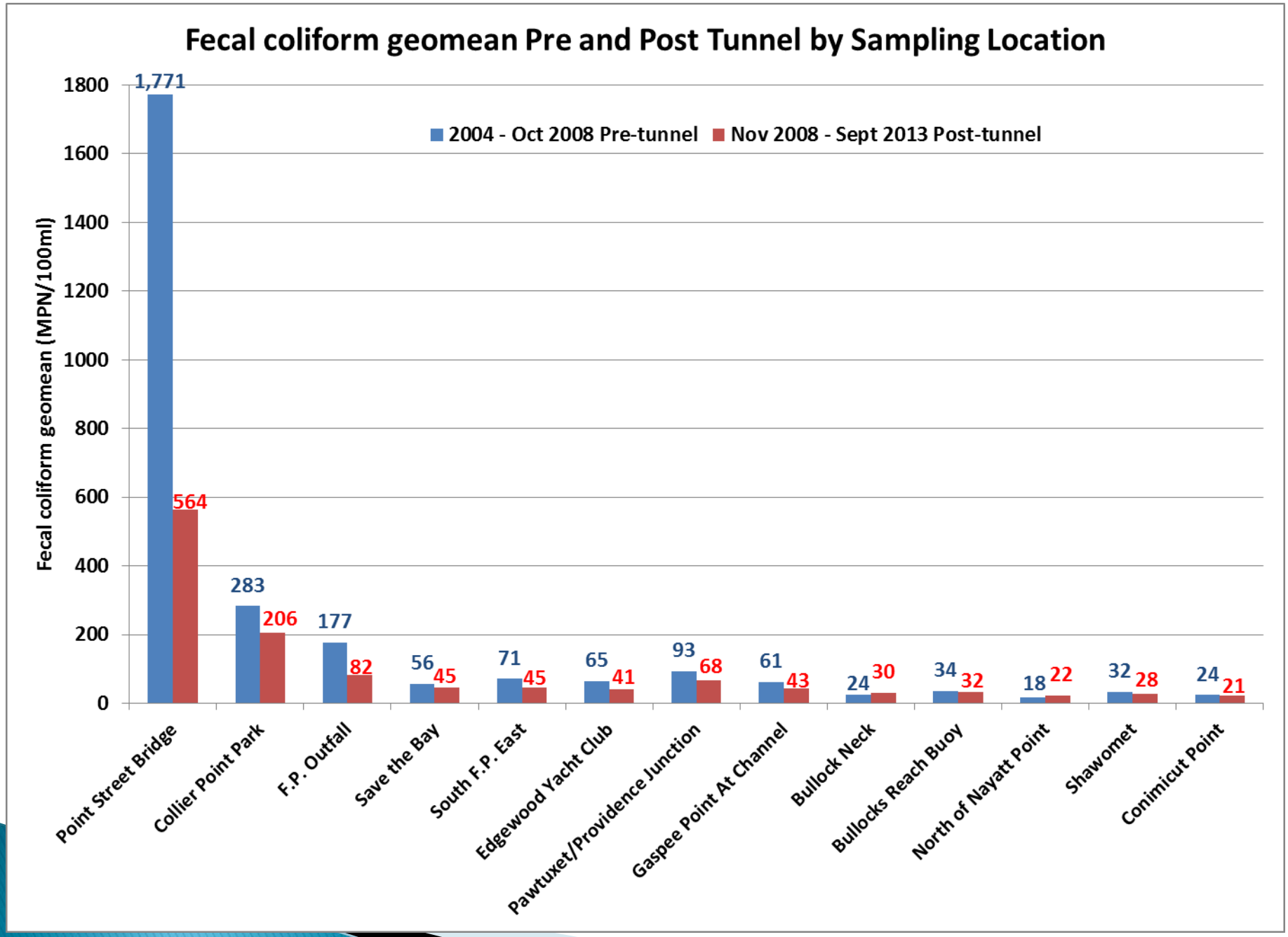
- In August 2010, the National Aquarium assembled, planted, and launched a floating wetland island in Baltimore's Inner Harbor. In 2012, they joined other partners to launch another **2,000 square feet of floating wetlands** into Baltimore's Inner Harbor. This project is part of the Healthy Harbor Initiative,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

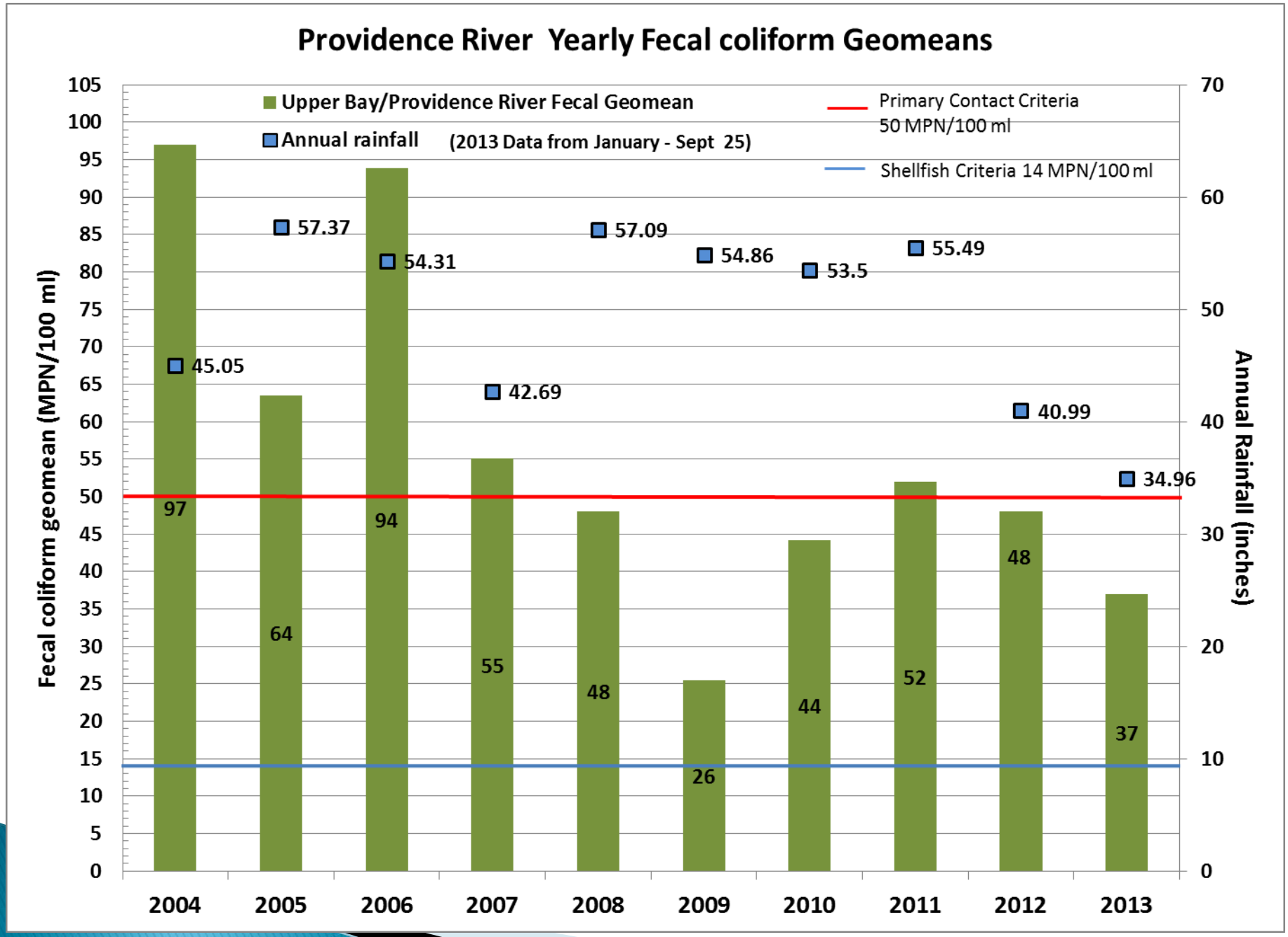
- Floating Wetlands help boost nitrogen removal in lagoons
  - Effective in substantially reducing nutrient levels in several studies involving smaller-scale lagoon treatment plants

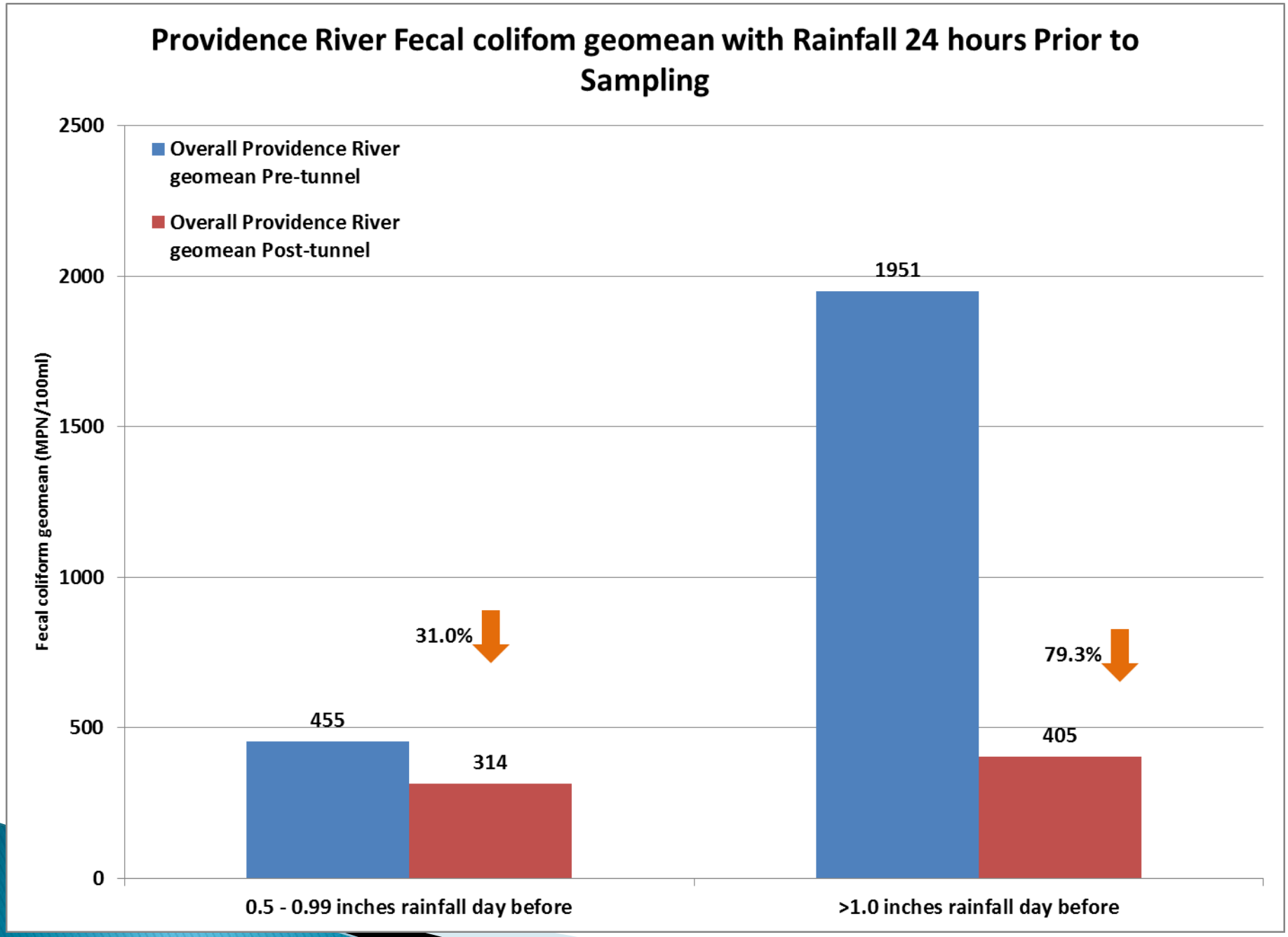
(http://www.waterworld.com/articles/print/volume-28/issue-6/editorial-features/floating-wetlands-help-boost--nitrogen-removal-in-lagoons.html)

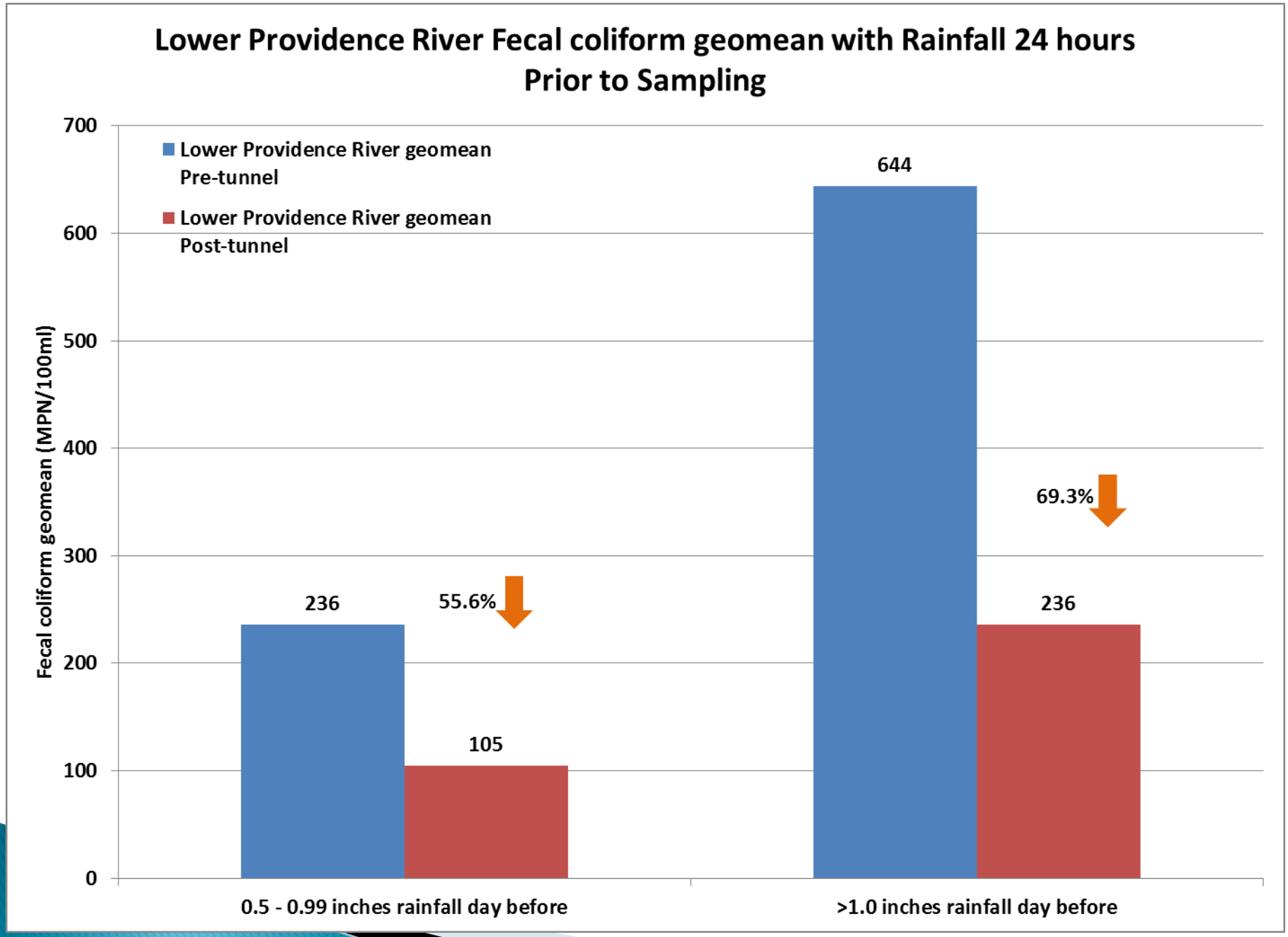


Additional Bacteria Data Analysis

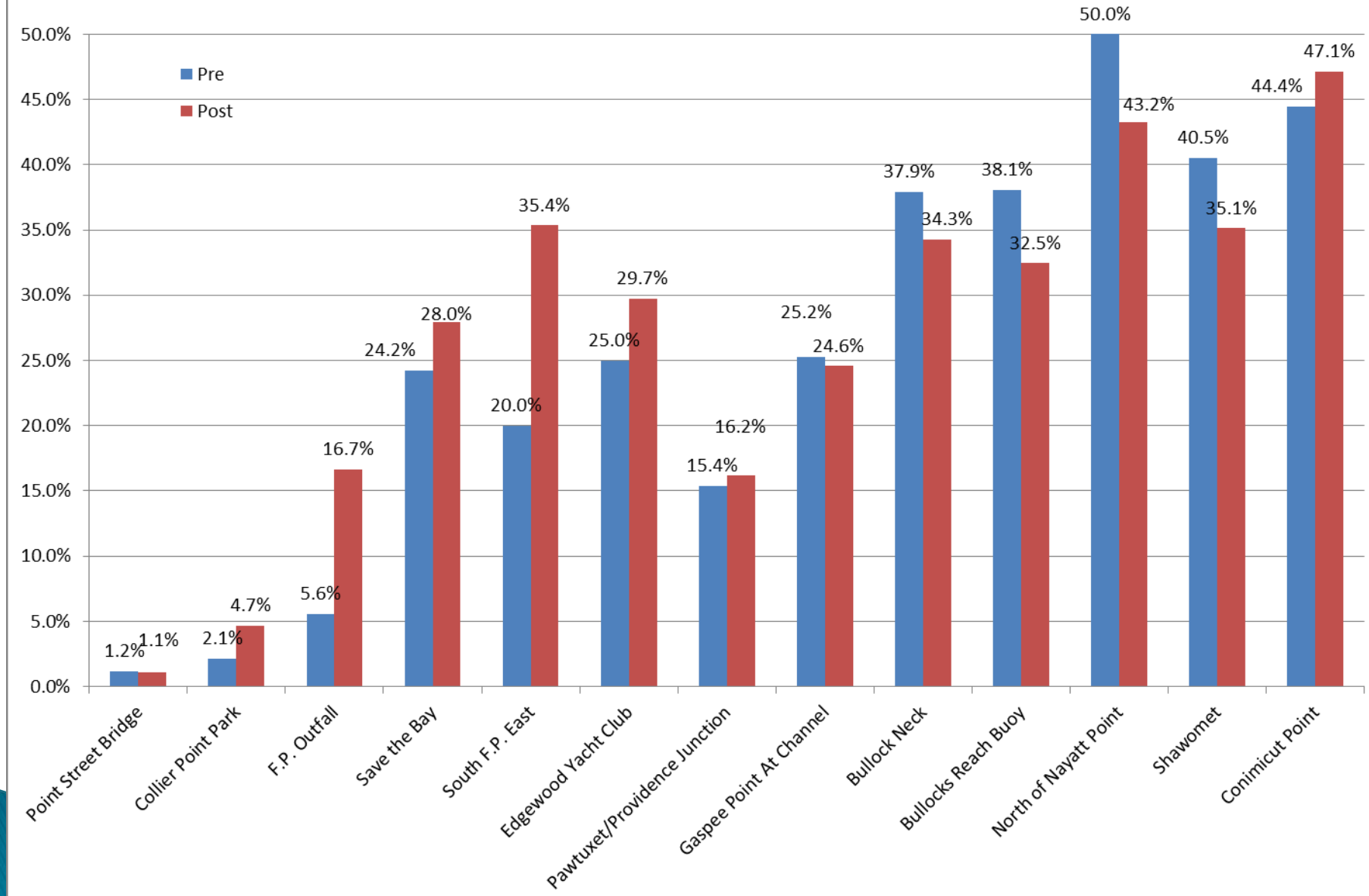

Fecal coliform geomean Pre and Post Tunnel by Sampling Location
2004 - Oct 2008 Pre-tunnel
Nov 2008 - Sept 2013 Post-tunnel
Fecal coliform geomean (MPN/100ml)
1800
1600
1400
1200
1000
800
600
400
200
0
1,771
564
283
206
177
82
56
45
71
45
65
41
93
68
61
43
24
30
34
32
18
22
32
28
24
21
Point Street Bridge
Collier Point Park
F.P. Outfall
Save the Bay
South F.P. East
Edgewood Yacht Club
Pawtuxet/Providence Junction
Gaspee Point At Channel
Bullock Neck
Bullocks Reach Buoy
North of Nayatt Point
Shawomet
Conimicut Point


Providence River Yearly Fecal coliform Geomeans
Upper Bay/Providence River Fecal Geomean
Annual rainfall
(2013 Data from January - Sept 25)
Primary Contact Criteria
50 MPN/100 ml
Shellfish Criteria 14 MPN/100 ml
Fecal coliform geomean (MPN/100 ml)
Annual Rainfall (inches)
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
70
60
50
40
30
20
10
0
45.05
57.37
54.31
42.69
57.09
54.86
53.5
55.49
40.99
34.96
97
64
94
55
48
26
44
52
48
37
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013


Providence River Fecal colifom geomean with Rainfall 24 hours Prior to Sampling
Overall Providence River geomean Pre-tunnel
Overall Providence River geomean Post-tunnel
Fecal coliform geomean (MPN/100ml)
2500
2000
1500
1000
500
0
455
314
1951
405
31.0%
79.3%
0.5 - 0.99 inches rainfall day before
>1.0 inches rainfall day before


Lower Providence River Fecal coliform geomean with Rainfall 24 hours Prior to Sampling
Lower Providence River geomean Pre-tunnel
Lower Providence River geomean Post-tunnel
Fecal coliform geomean (MPN/100ml)
700
600
500
400
300
200
100
0
236
55.6%
105
644
69.3%
236
0.5 - 0.99 inches rainfall day before
>1.0 inches rainfall day before

Percent of Samples Below 14 MPN/100ml Shellfish WQ standards Pre and Post Tunnel



NBC Nitrogen Loading to Upper Bay (May – Oct)

	Concentration (ppm)	Loading (lbs/day)	Percent Reduction (Loading)
Field's Point TN Loading			
Year of Fish Kill (2003)	15.7	5,834	
May - Oct* 2013	3.6	1,297	78%
IFAS Upgrade (5 ppm)	5.0	1,778	70%
If plant achieves 3 ppm	3.0	1,067	82%
Bucklin Point TN Loading			
Year of Fish Kill (2003)	14.8	2,908	
May - Oct* 2013	5.9	997	66%
Upgrade (5 ppm)	5.0	793	73%
If plant achieves 3 ppm	3.0	476	84%
Combined NBC Facilities			
2003	BP=14.8, FP=15.7	8,741	
May - Oct* 2013	BP=5.9, FP=3.6	2,293	74%
FP&BP Upgrade to 5 ppm	BP=5.0, FP=5.0	2,571	71%
FP&BP Upgrade to 3 ppm	BP=3.0, FP=3.0	1,542	82%

All calculations use May - Oct seasonal data.

*Data for 2013 is updated through October 23, 2013

NBC Rate Increases