EBC Climate Change Program

Protecting Boston – The Boston Harbor Barrier Study

EBC
Environmental Business Council of New England, Inc.

Welcome from the Committee Chair

Ruth Silman

Chair, EBC Climate Change & Air Committee

Member, EBC Board of Directors

Partner, Nixon Peabody, LLP

Program Introduction & Overview

Joseph Famely

Program Co-Chair and Moderator

Senior Environmental Scientist
Woods Hole Group

Preliminary Analysis for Boston Harbor

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Professor, School for the Environment

Academic Director, Sustainable Solutions Lab

University of Massachusetts Boston

Feasibility of Harborwide Barrier Systems: Preliminary Analysis for Boston Harbor

Paul Kirshen, Ph.D.

Sustainable Solutions Lab | University of Massachusetts Boston

June 22, 2018

Funded by: Barr Foundation

Sponsored by: Boston Green Ribbon Commission

Acknowledgments | Project Team

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Acknowledgments | Reviewers & Steering Committee

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GZA GeoEnvironmental, Inc. – Chad Cox, Stephen Lecco, Daniel Stapleton, Bin Wang, Wayne Cobleigh
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Steering Committee:

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Boston Planning and Development Agency
City of Boston, Environment Department
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Massachusetts Department of Environmental Protection
Massachusetts Environmental Policy Act Office
Massachusetts Executive Office of Energy and Environmental Affairs
Massachusetts Office of Coastal Zone Management
MassBays National Estuary Program
Massport
North Cambridge Consulting
National Parks Service
New England Aquarium
United States Army Corps of Engineers

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Barrier Study Guiding Principles

- Protect people and the places where they live, work, and play
- Minimize interference with Boston's maritime economy and the thousands of jobs it supports
- Protect the environmental gains made over past decades through the Boston Harbor cleanup

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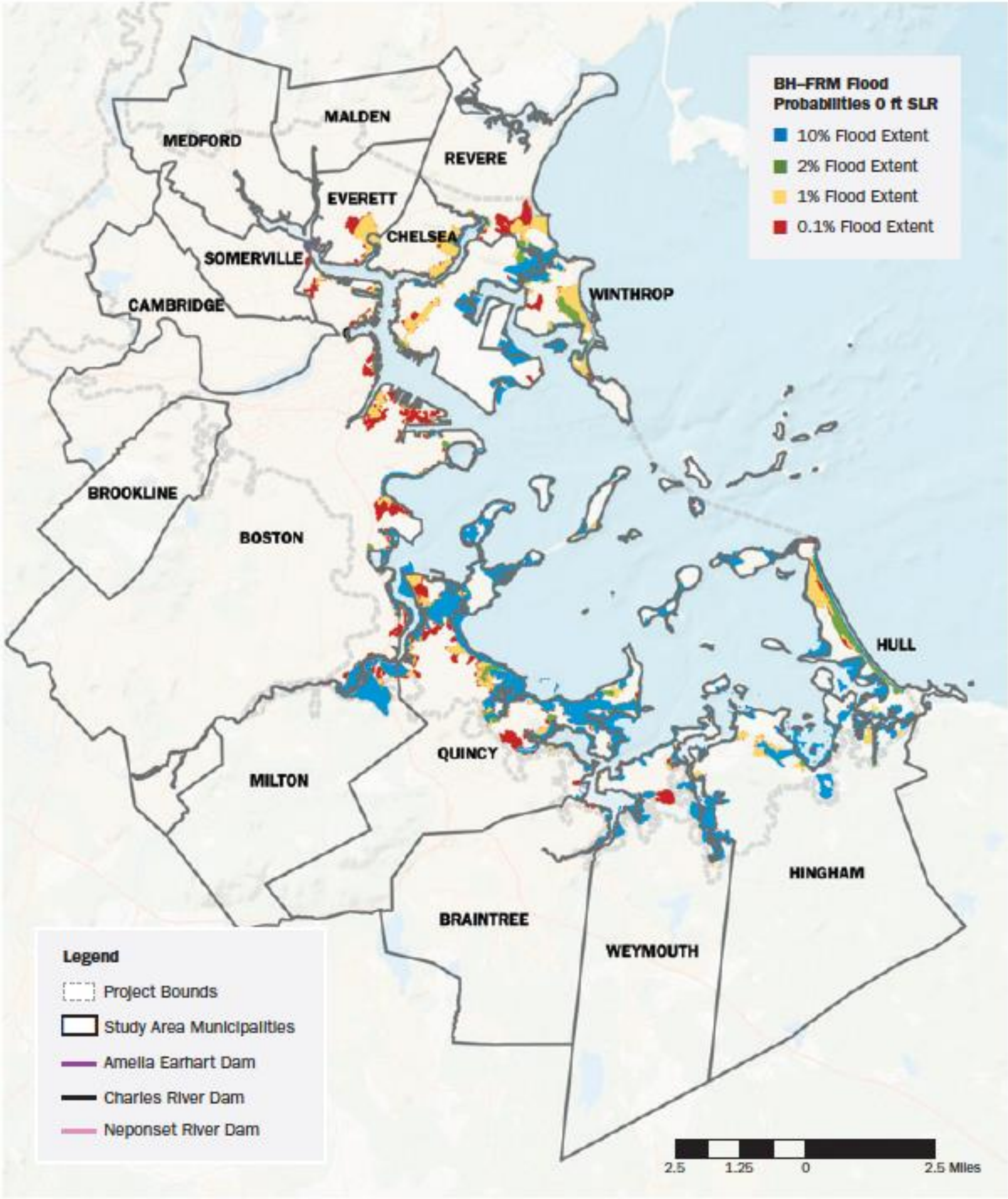
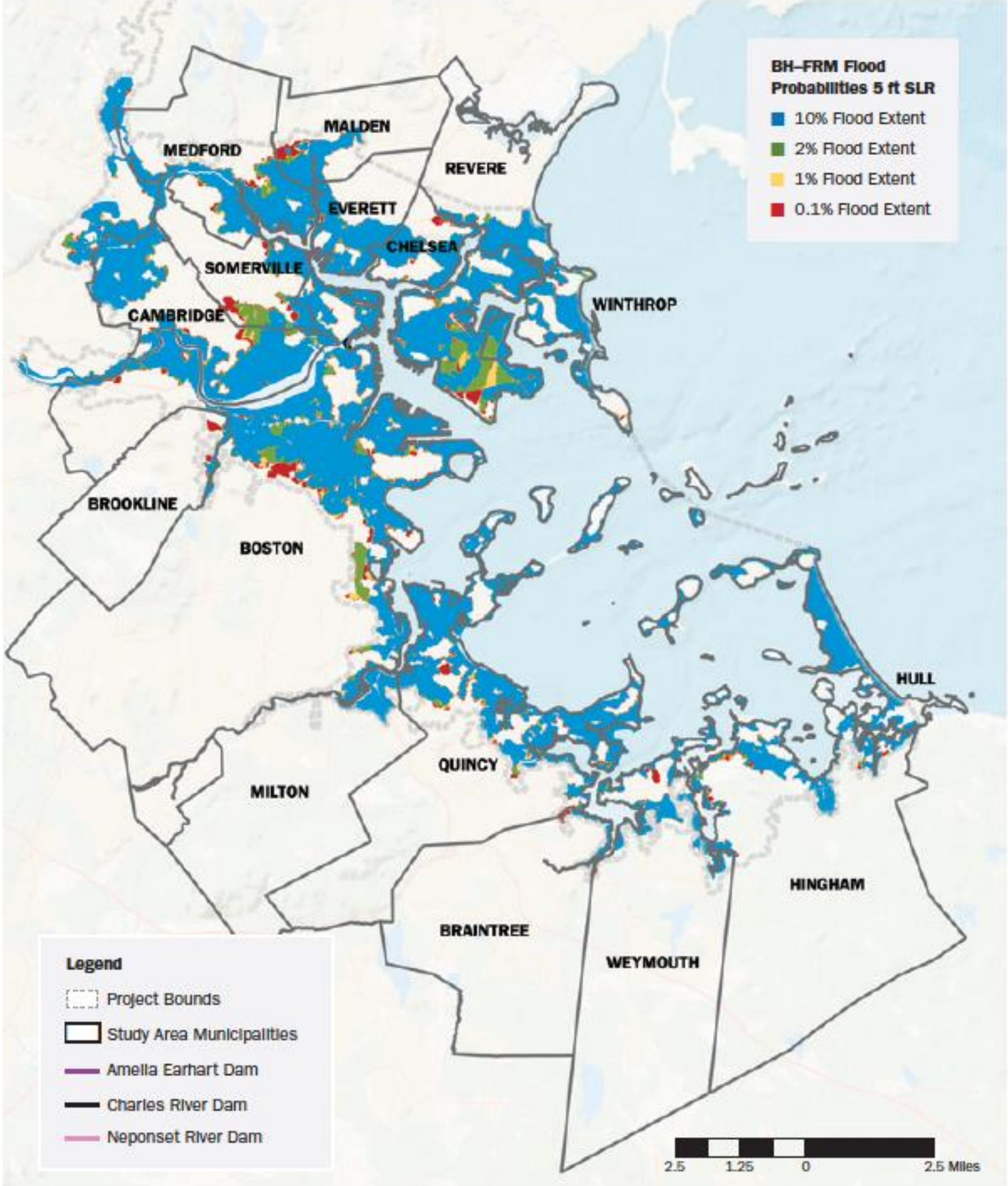
Boston Harbor Barrier—Probabilities of Flooding with 0 Feet SLR



Boston Harbor Barrier—Probabilities of Flooding with 5 Feet SLR



Introduction—Engineering & Cost

Three Proposed Alignments

- Inner-Harbor
- Outer-Harbor
- Metro Boston Dike

Sources: Arcadis, Esri World Imagery

(Very) Approximate Location of Outer Harbor Barrier

Typical Feature Assumptions—Gates

Navigation

- Floating sector gate
- 1,500 or 650-foot

Environmental Flow

- Vertical lift gate

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Cost Summary (in 2018 Dollars)

Values reported in billions of dollars	Construction	50 Years of Operations and Maintenance
Inner-Harbor	\$6B – 9B	\$1B – 1.3B
Mid-Harbor	\$8B – 12B	\$1.5B – 2B
Metro Boston Dike	\$35B – 85B	*Not analyzed*

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Hydrodynamic and Closure Analyses

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Senior Coastal Engineer / Innovation Director

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EBC
Environmental Business Council New England, Inc.

June 22, 2018

Feasibility of Harbor-wide Barrier Systems: Preliminary Analysis for Boston Harbor

Hydrodynamics and Closure Analysis

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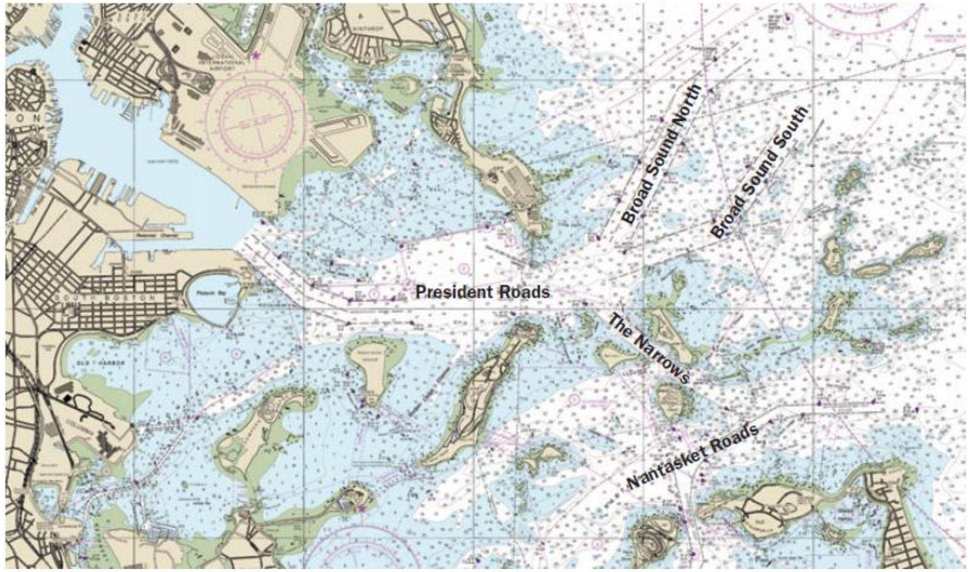
Woods Hole Group

UMASS BOSTON Sustainable Solutions Lab
ARCADIS
Woods Hole Oceanographic Institution 1930
WOODS HOLE GROUP

Funded by: Barr Foundation
Sponsored by: Boston Green Ribbon Commission

Barrier Alignments

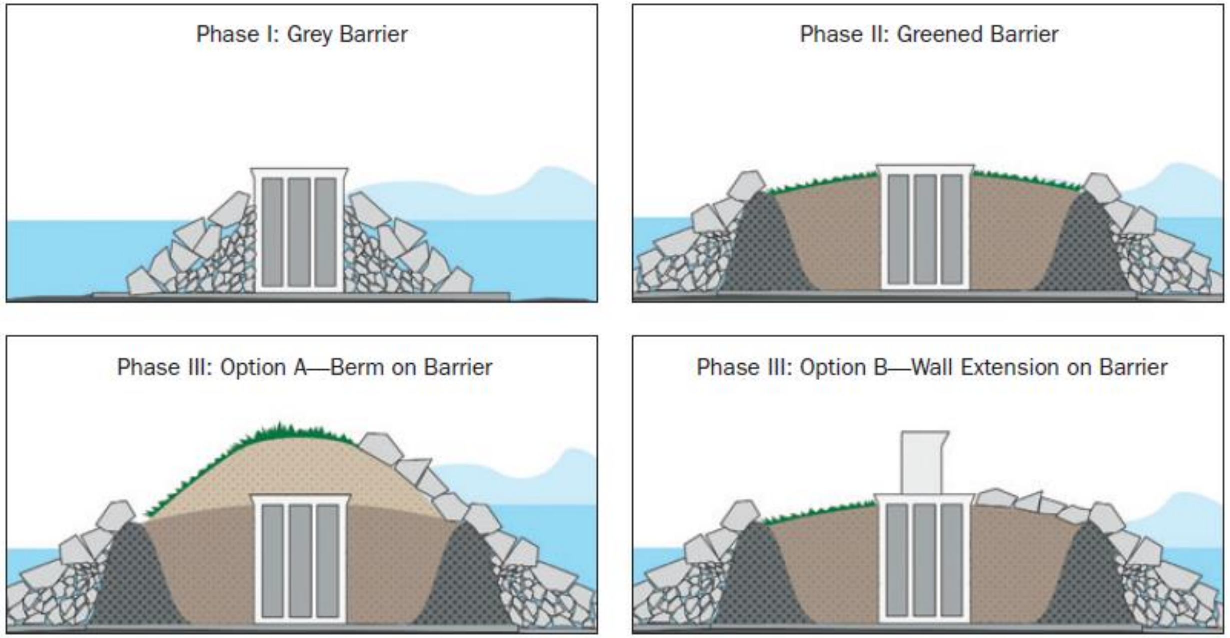
Alignment	Metro Dike	Outer Harbor	Inner Harbor
In water length	18 miles	3.8 miles	0.5 miles
Navigational Opening	Multiple Locks	Two Sector Gates	Single Sector Gate
Harbor Condition	Freshwater Lagoon	Salt water estuarine	Salt water estuarine
Flooding Control	Tides and Storm	Storm	Storm
Estimated Cost	>$80 billion	$8-11 billion	$6-9 billion



Inner Barrier

- 1 sector gate: 1,500 ft. wide
- ~95,000 feet of land based adaptations
- Pump stations required
- 83% of cost is sector gate and pump requirements

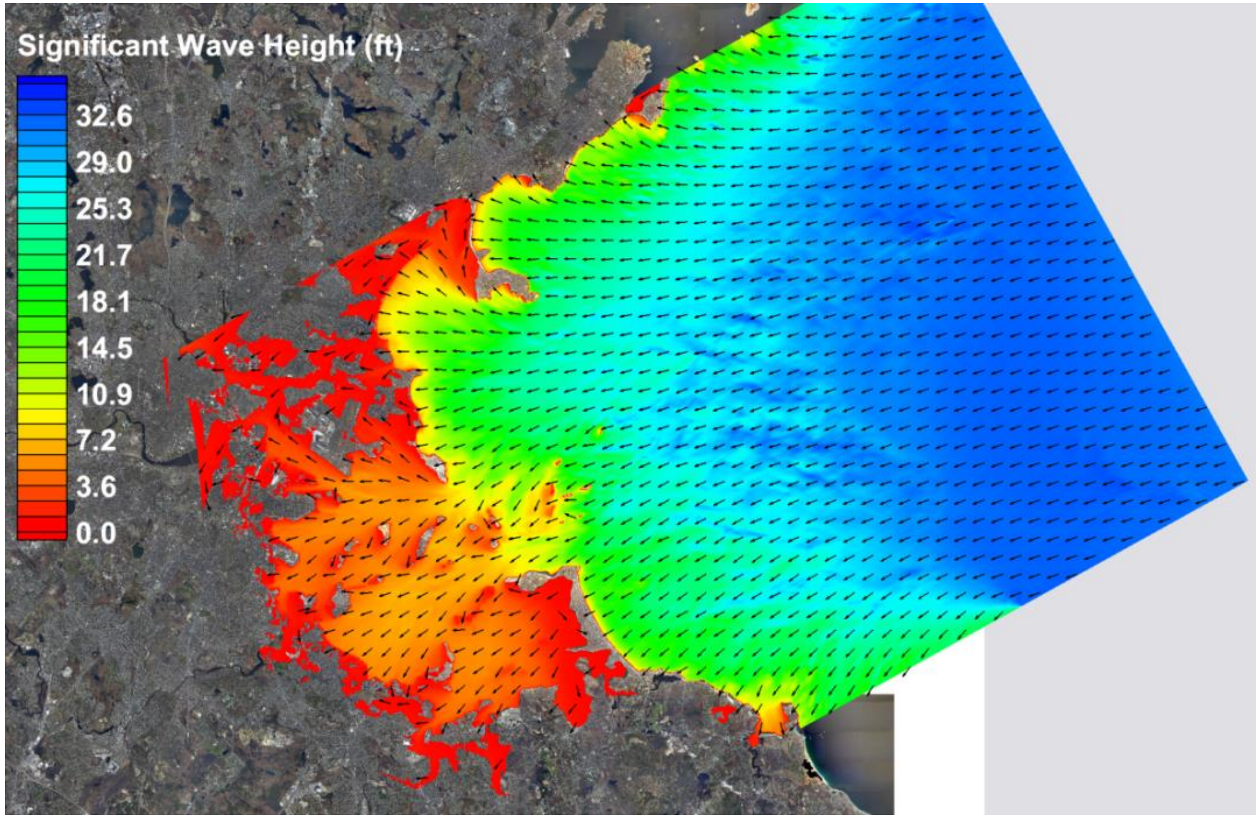
Nature based expansions as material becomes available



Outer Barrier

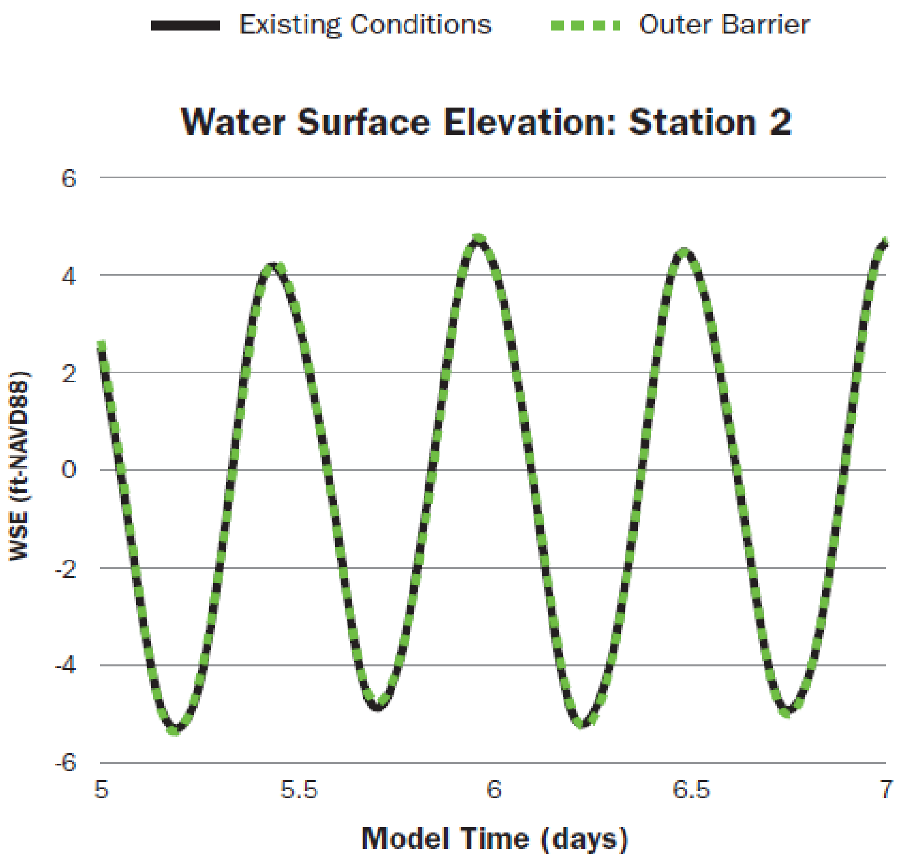
Design Elevations

- MHHW tides
- 1% surge elevation (present day)
- 2100 SLR (Kopp and DeConto, 2018) using RCP8.5 likely range (7.1 feet)
- Attenuated wave amplitude (30 ft offshore wave height)
- 2 feet of freeboard
- Overtopping allowed

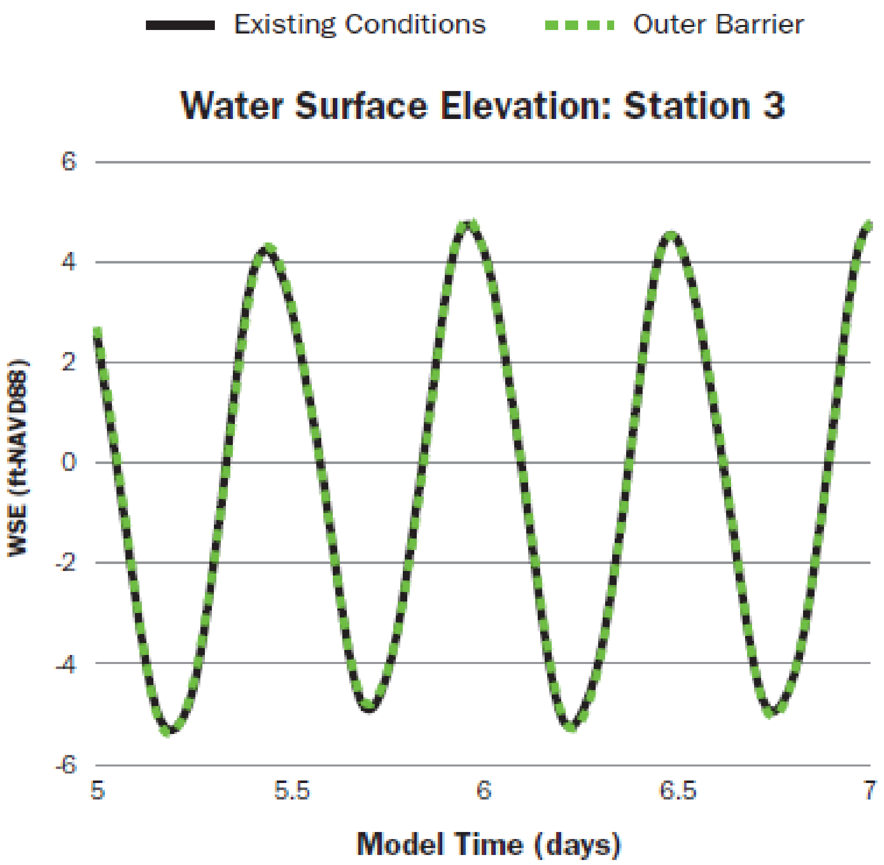


Location	Design Level (ft, NAVD88)	Design Level (ft, MLW)
Outer Barrier	27	32
Inner Barrier	22	27
Outer Shoreline (Revere) and Hull shoreline	24	29
Inner North Shoreline	20	25
Inner South Shoreline	19	24

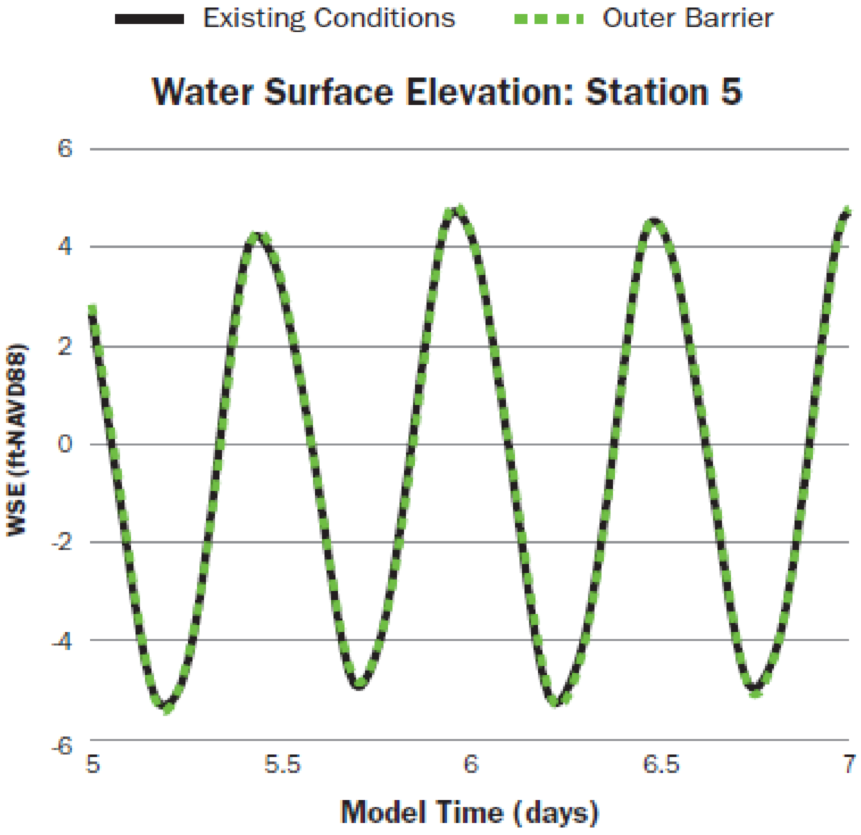
Tidal Impacts



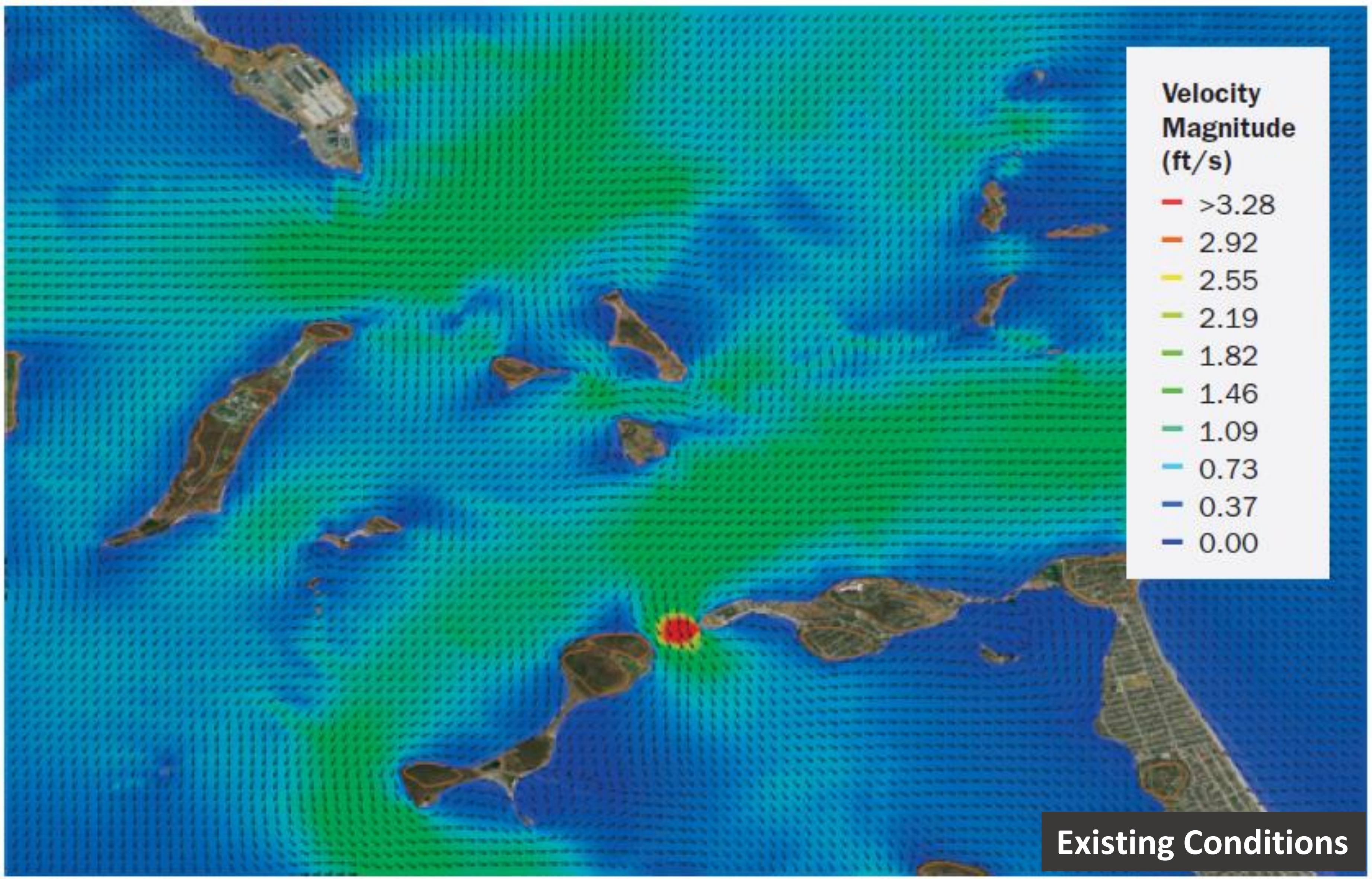
Tidal Impacts



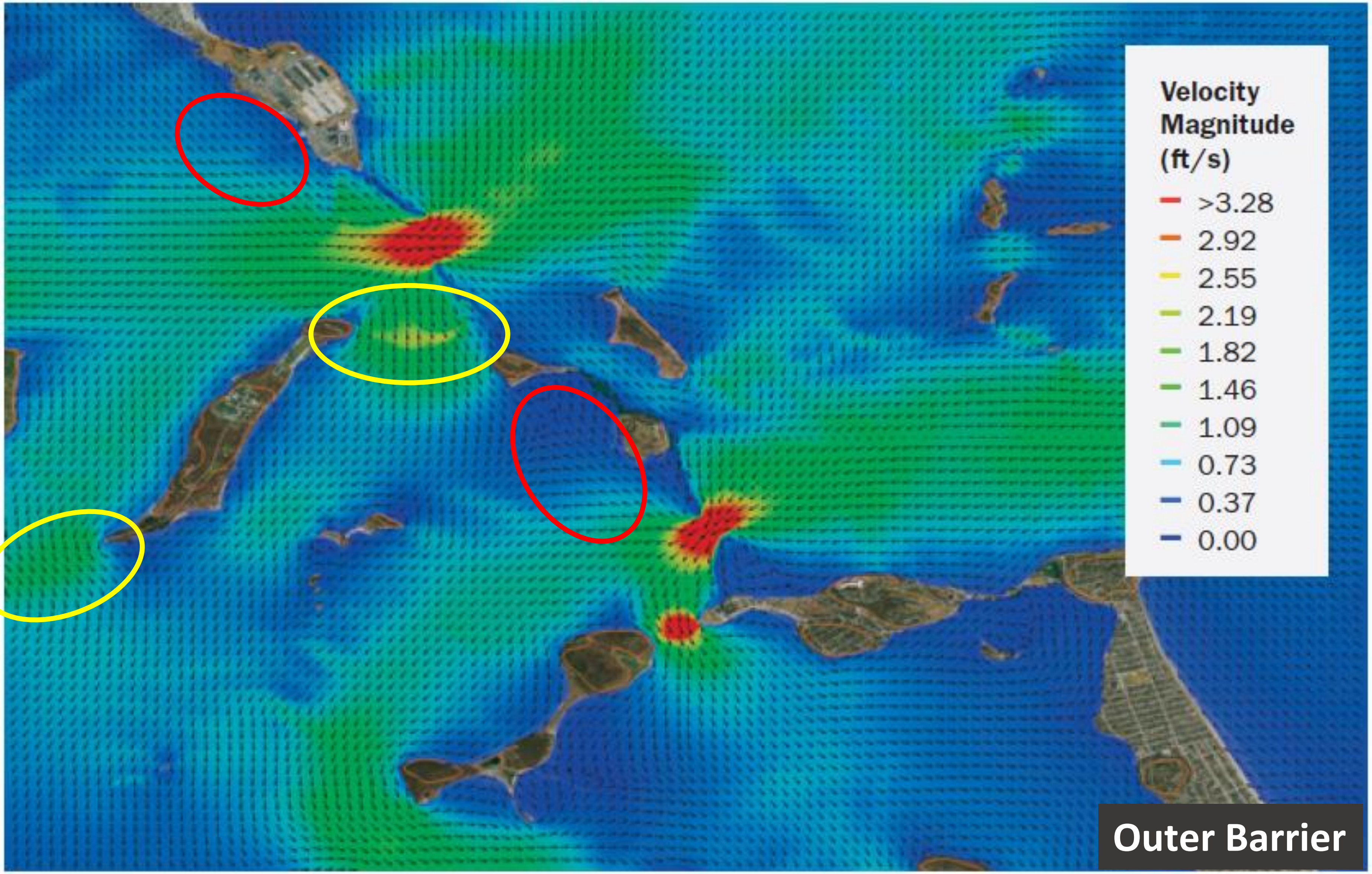
Tidal Impacts



Hydrodynamic Impacts

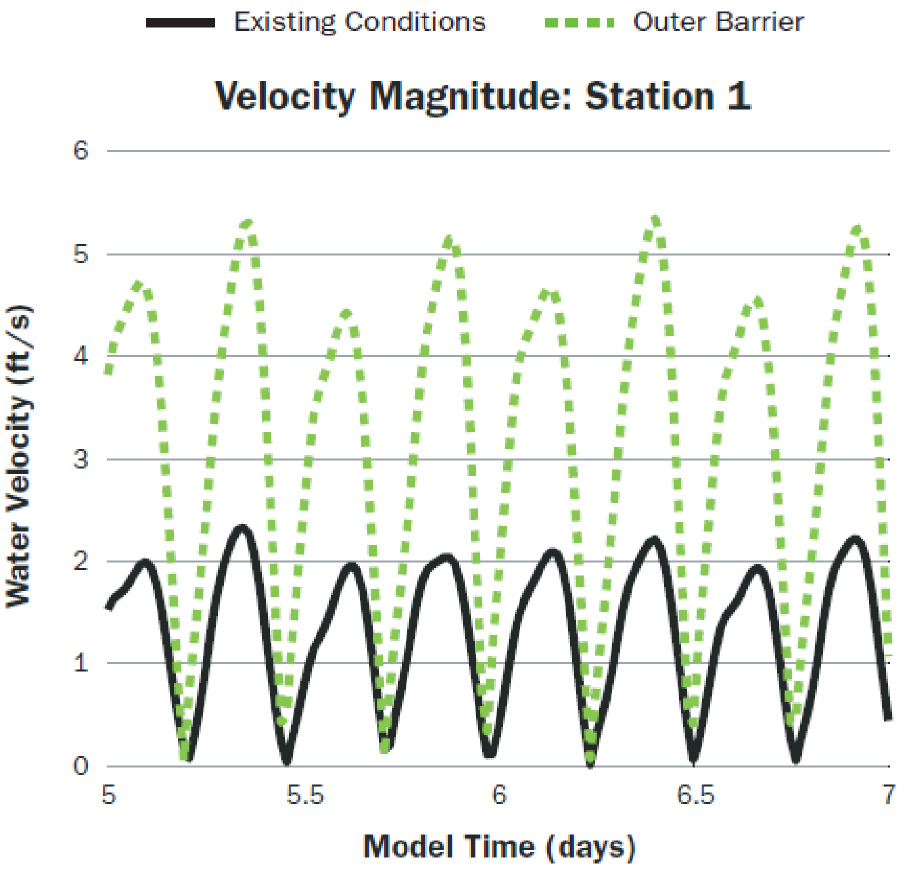


Hydrodynamic Impacts



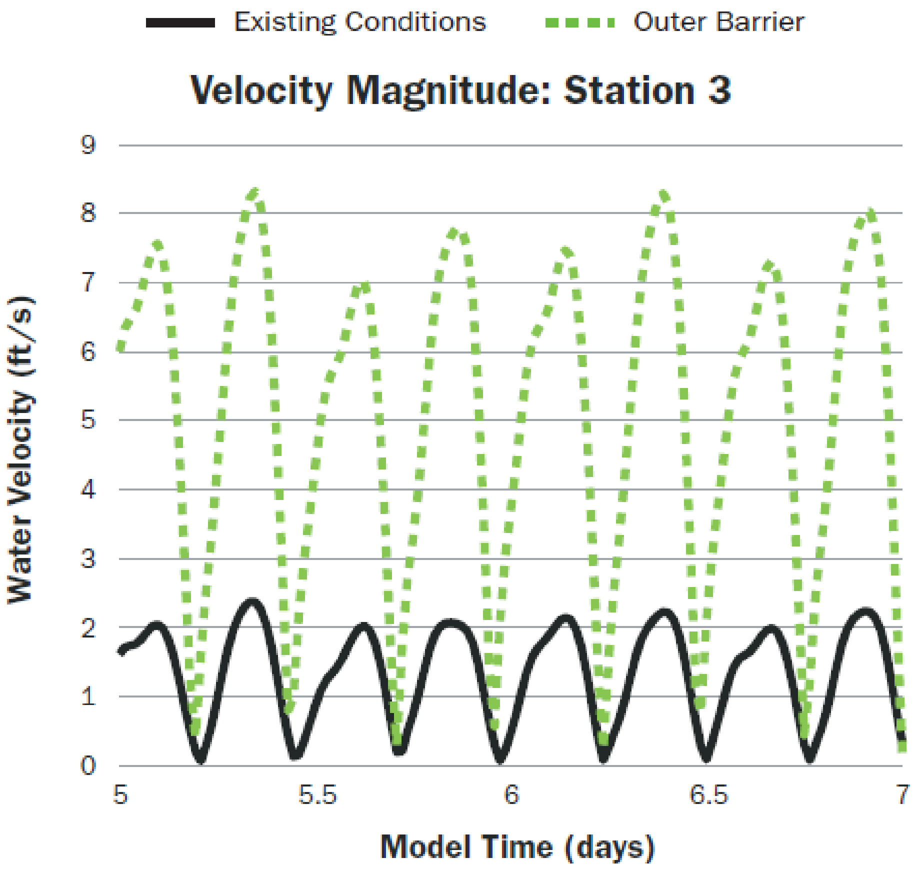
Hydrodynamic Impacts

Existing peak = 1.3 knots
Barrier peak = 3.3 knots



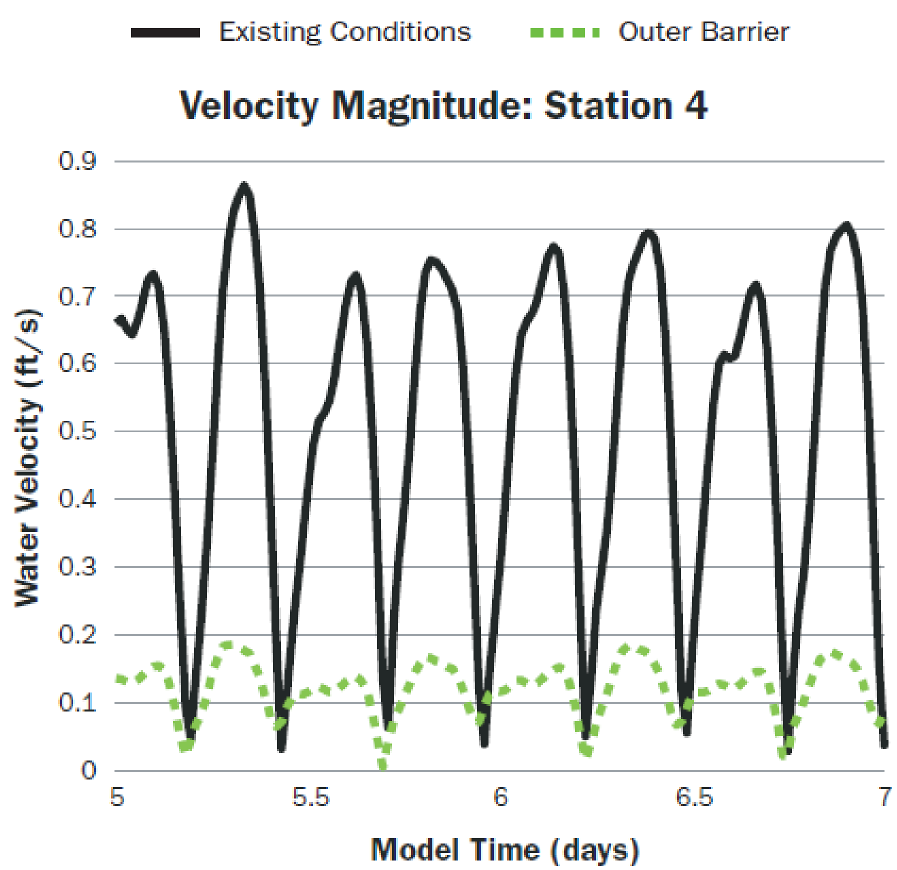
Hydrodynamic Impacts

Existing peak = 1.3 knots
Barrier peak = 5.1 knots



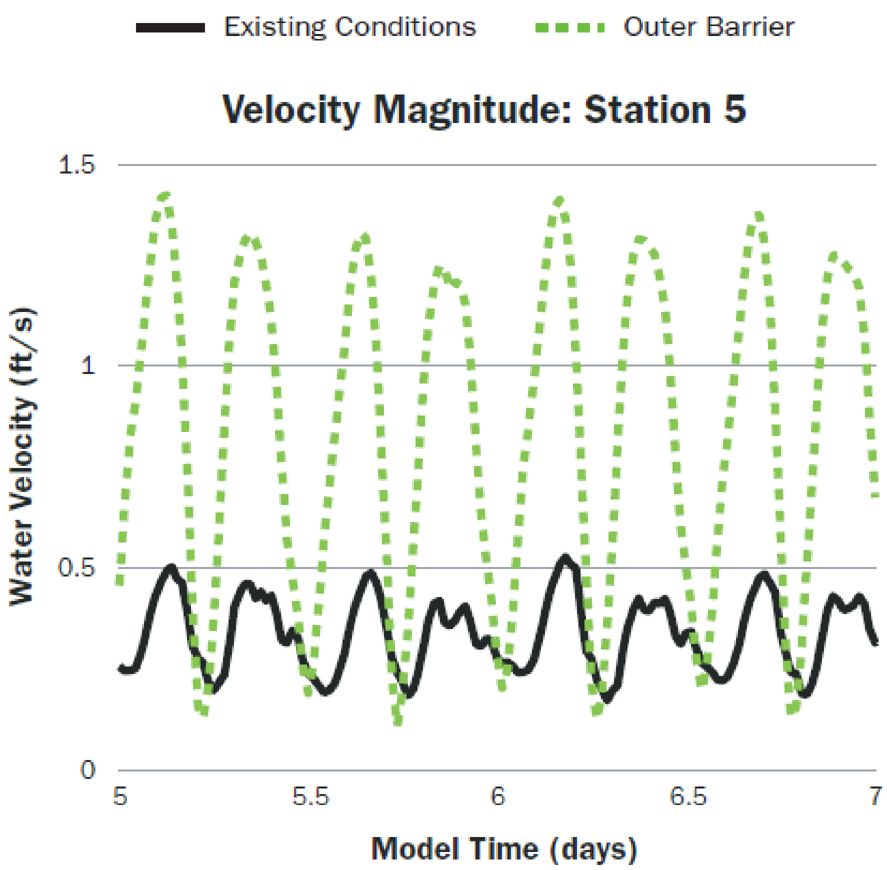
Hydrodynamic Impacts

Existing peak = 0.5 knots
Barrier peak = 0.1 knots



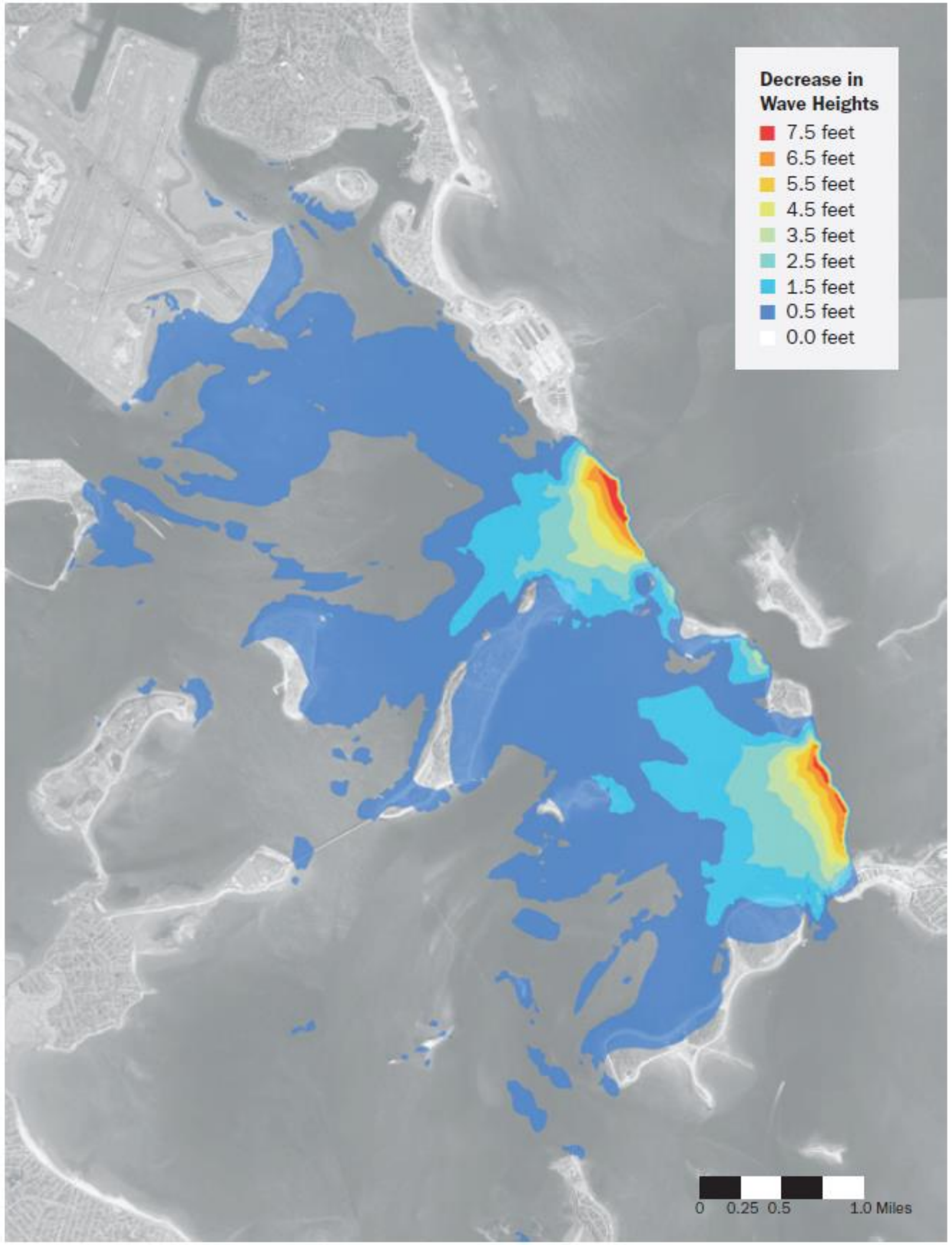
Hydrodynamic Impacts

Existing peak = 0.3 knots
Barrier peak = 0.9 knots



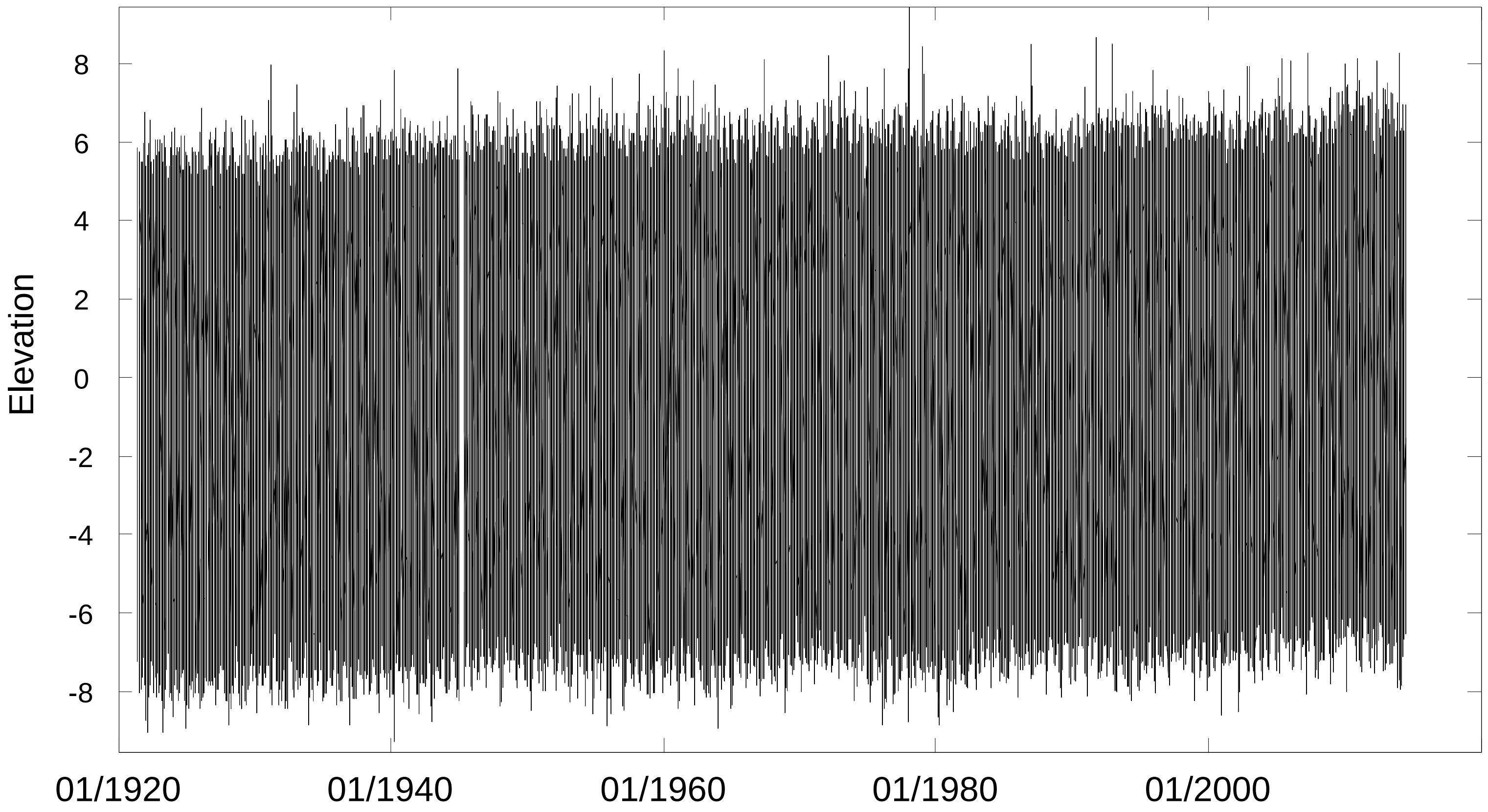
Wave Impacts

Long Wharf - March 2, 2018



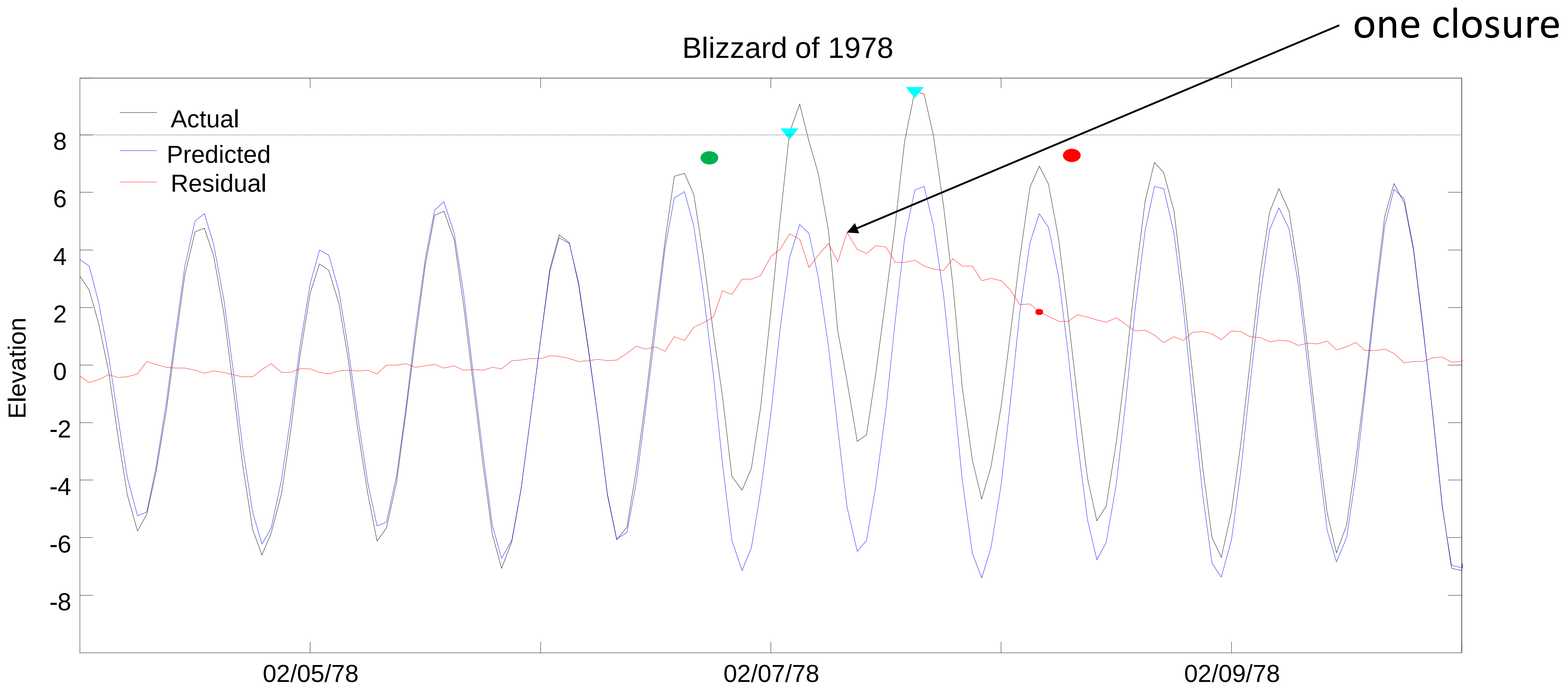
Closure Frequency

Boston NOAA tide gauge
>97 year record – one of longest water level records in country

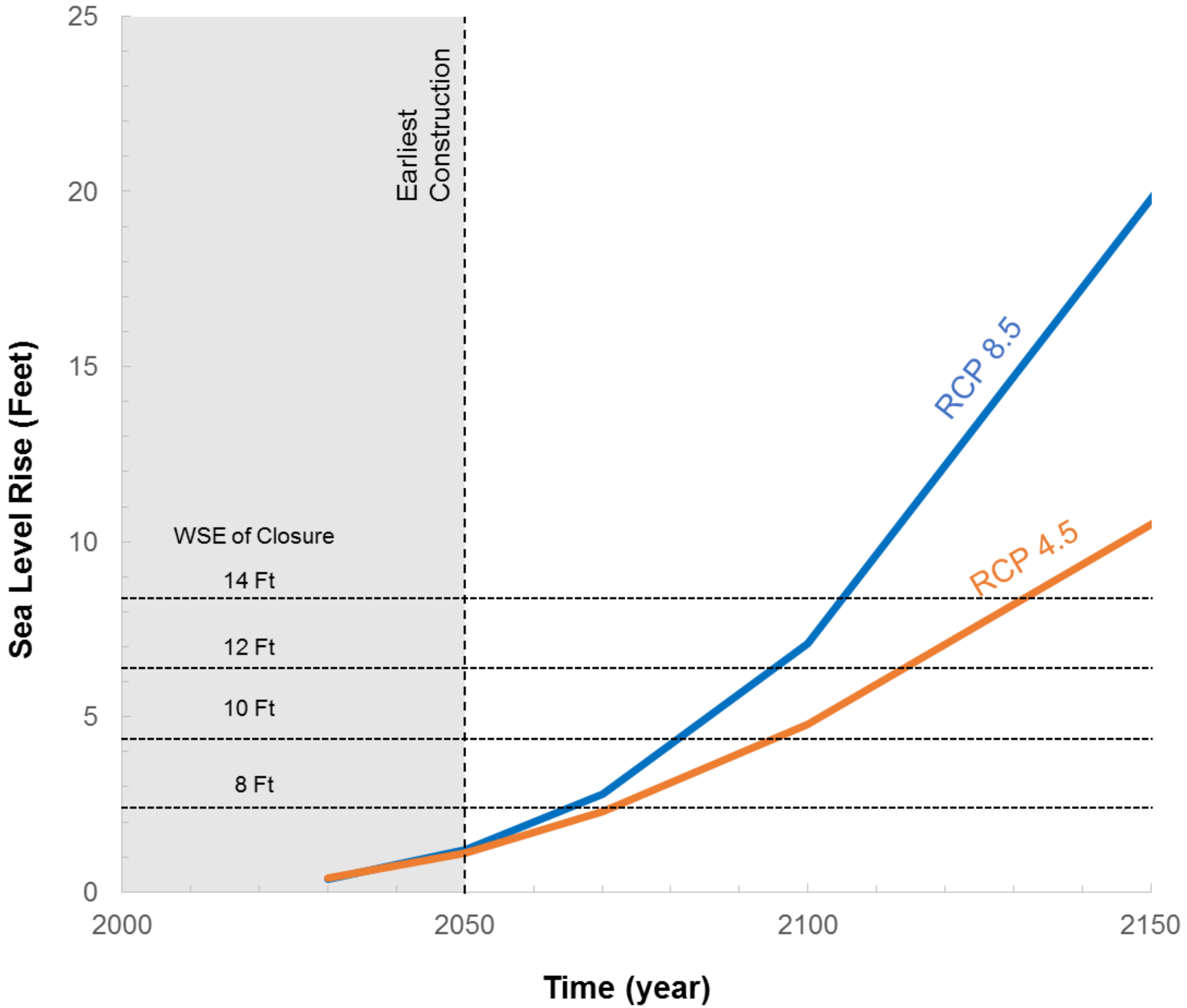


Examined barrier closure based upon the historical record

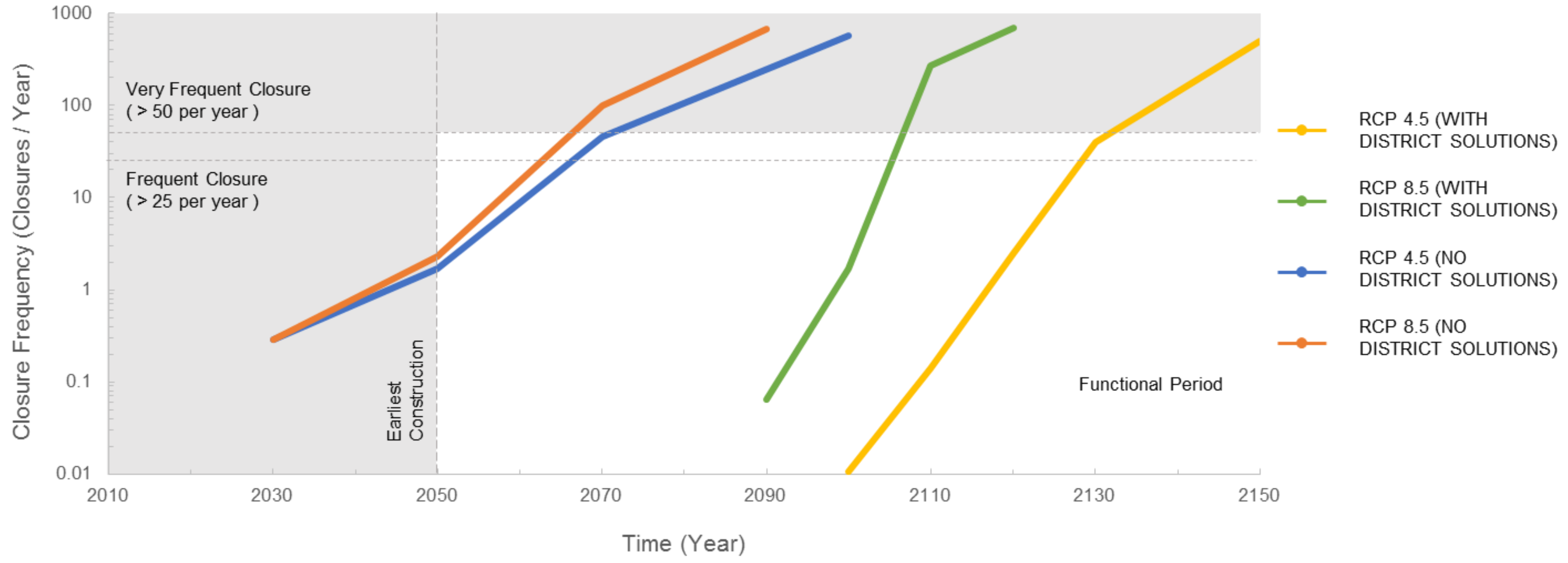
Event Identification



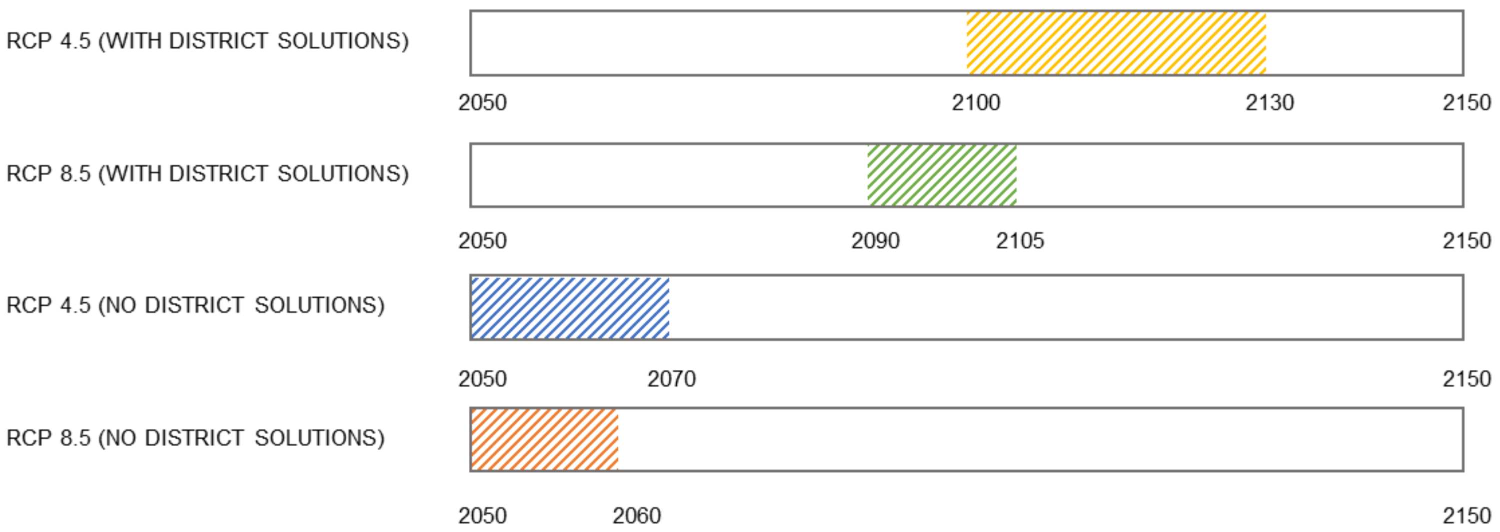
Sea Level Rise Projections vs. Closure Level

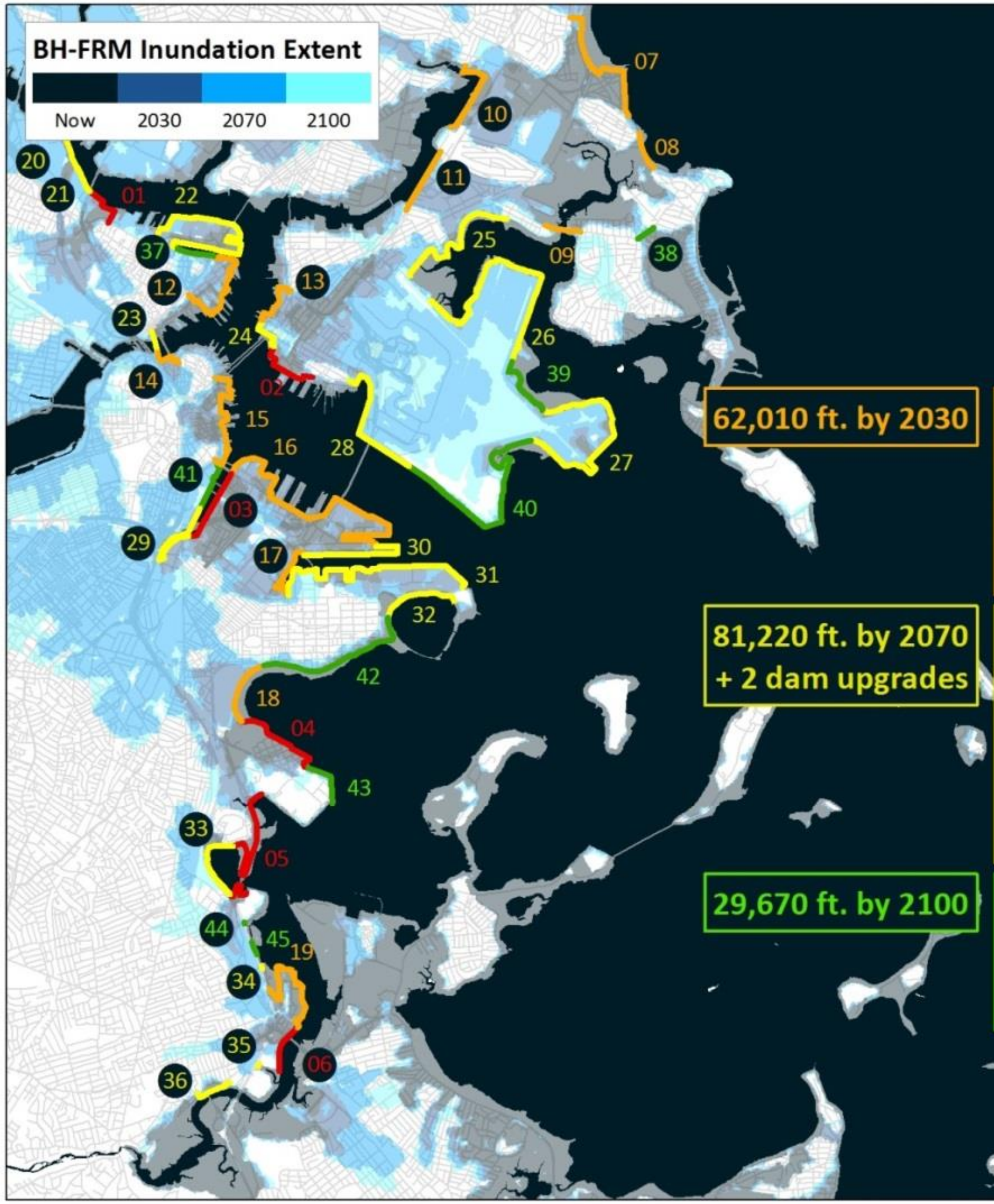


TIMELINE FOR BOSTON HARBOR BARRIER FUNCTIONALITY



Barrier Functional Period





BOSTON HARBOR BARRIER

No Harbor Barrier Concept

District-Level Solutions to Protect Boston

23,340 ft. NOW

01. Schrafft's / Ryan Playground	2,220'
02. East Boston Greenway	3,080'
03. Fort Point Channel - Lower East	3,500'
04. Bayside / Harbor Point	4,320'
05. Morrissey Boulevard	7,770'
06. Neponset Circle	2,450'

62,010 ft. by 2030

07. Revere Beach / Beachmont	6,510'	14. Lovejoy Wharf	1,540'
08. Short Beach	1,680'	15. Atlantic Avenue	6,470'
09. Belle Isle Inlet	1,620'	16. Seaport	14,960'
10. Chelsea River - Upper	4,250'	17. Reserve Channel	3,430'
11. Chelsea River - Middle	3,030'	18. Carson Beach	3,120'
12. Charlestown East	5,860'	19. Port Norfolk	6,730'
13. Border Street	2,810'		

81,220 ft. by 2070 + 2 dam upgrades

20. Amelia Earhart Dam	n/a	29. Fort Point Channel - Upper	4,990'
21. Busyard / Draw Seven Park	2,810'	30. Cruiseport	5,470'
22. Moran Terminal Auto Port	10,680'	31. Conley Terminal	11,540'
23. Charles River Dam	n/a	32. Pleasure Bay	3,510'
24. Lo Presti Park	1,780'	33. Dorchester Bay Basin	3,520'
25. Constitution Beach / Wood Island	7,000'	34. Conley Street Underpass	130'
26. Logan Airport - North	11,540'	35. Davenport Creek Culvert	140'
27. Logan Airport - East	10,090'	36. Neponset Trail	1,680'
28. Logan Airport - Southwest	6,340'		

29,670 ft. by 2100

37. Little Mystic Channel - South	1,700'	42. South Boston Harborwalk	7,200'
38. Revere Street - Winthrop	890'	43. UMass Boston	2,310'
39. Logan Airport - Northeast	3,180	44. Victory Road Underpass	90'
40. Logan Airport - South	11,380'	45. Southeast Expressway	600'
41. Fort Point Channel - Lower West	2,320'		

WOODS HOLE GROUP

Environmental Impacts

Bob Chen, Ph.D.

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University of Massachusetts Boston

Environmental Impacts

Bob Chen, Mark Borrelli, Jarrett Byrnes, Lucy Lockwood

UMassBoston

Funded by: Barr Foundation

Sponsored by: Boston Green Ribbon Commission

Wicked Problem

- Complex
  - Boston Harbor Cleanup
  - $30 B at risk
  - Boston Harbor Islands National Park Area
  - Diverse stakeholders
- Uncertain
  - Climate change
  - Economy
  - Demographics
  - Unknowns (seagrass, fish migration)
- Challenging
  - Social vulnerability
  - Historical & cultural values
  - Development demands

Building A Wall to Protect Boston

Boston is the 8th most vulnerable city in the world to financial damage due to sea-level rise (World Bank, 2013),
AND we can build a large barrier to protect the city,
BUT we don't know the environmental impacts
THEREFORE we have conducted this initial assessment

Environmental Impacts

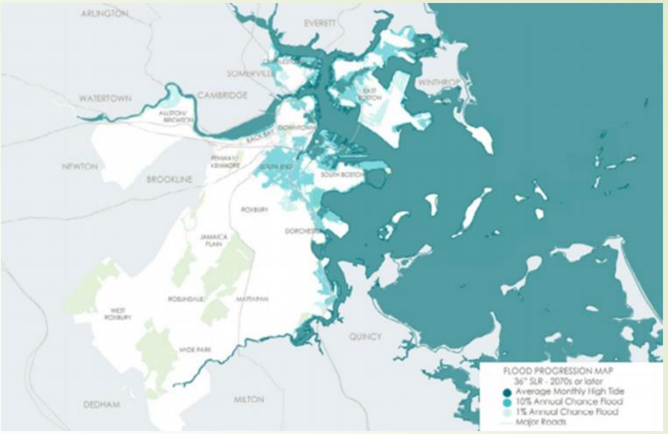
- Water Quality
- Habitats
- Ecosystems Services

- With and without an outer harbor barrier (present and with 5’ of SLR)

- Lines in the Sand
- Unknowns
- Other Considerations

Change

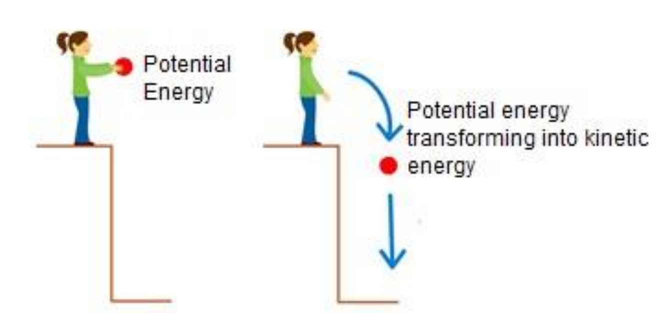
1630



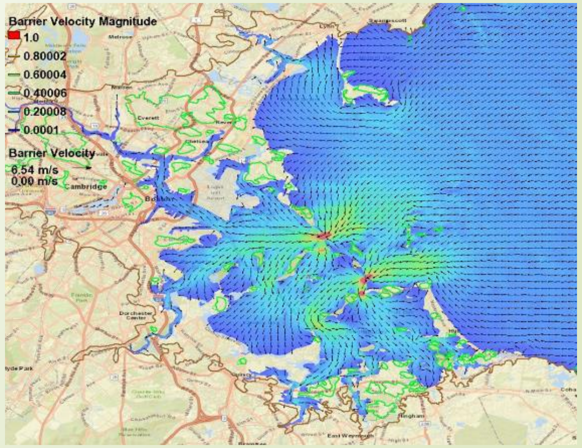
2070

- Change has already happened, change is happening, and change will continue to happen
- We predict that the installation of a barrier has less overall environmental impact than 5’ of SLR or 3.7 °C water temperature
- The scale, purposefulness, and control of the human impacts on Boston Harbor ecosystem is the issue
- There is a philosophical question of “Do we want to do this?”
- The better we understand potential impacts (science), the more informed decisions we can make

Conservation of Energy



- Tidal heights (ranges) will not be affected by the presence of a barrier.
- SLR will add volume to the Harbor so residence times will increase somewhat (with the same tidal prism).
- Restrictions that result from a barrier will increase current velocities in close proximity to the barrier (increase kinetic energy), so necessarily, current velocities (kinetic energy) in other areas will be lower than without a barrier.
- These areas are behind the barrier and in shallow backwaters.
- This means increased residence times (decreased flushing) in these areas far from the barrier.



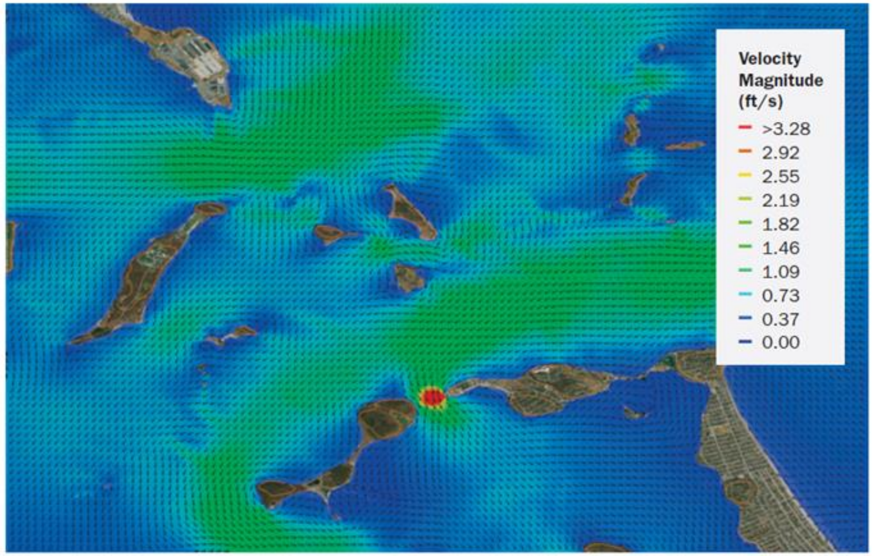
Water Quality

- *Average* flushing times of the Harbor is 10 days (Signell, 1992).
- Water parcel or particle residence times vary greatly from 6 hours to several weeks.
- SLR will increase water residence times slightly (~25%).
- Barrier w/SLR will increase some water parcel residence times significantly.
- Slightly reduced dissolved oxygen concentrations may result from increased residence times.
- Increase in water temperature could have greater adverse affect on water quality than barrier.

Water Quality

FIGURE 5.9

Simulated Existing Tidal Currents in Boston Harbor During Peak Flood Tide (1 ft/sec = 0.6 knots)



Source: Woods Hole Group

FIGURE 5.10

Simulated Existing Tidal Currents in Boston Harbor During Peak Flood Tide (1 ft/sec = 0.6 knots)

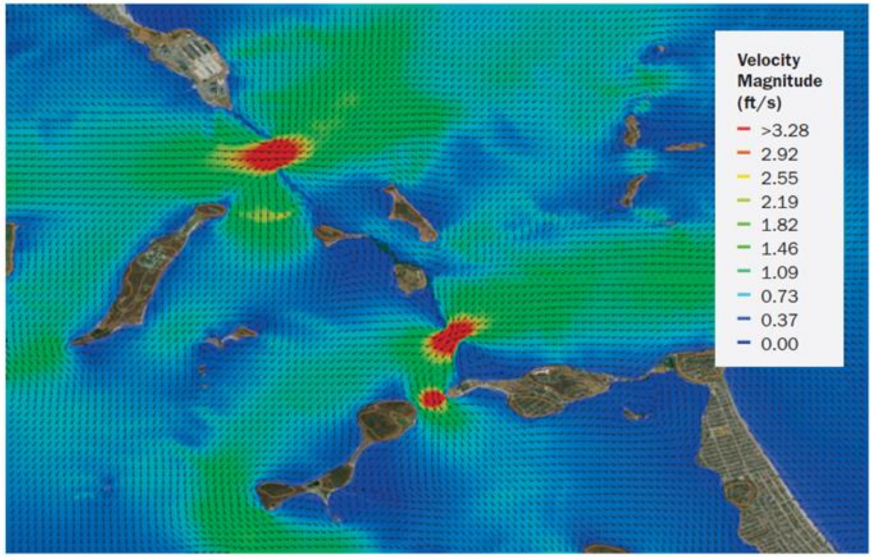
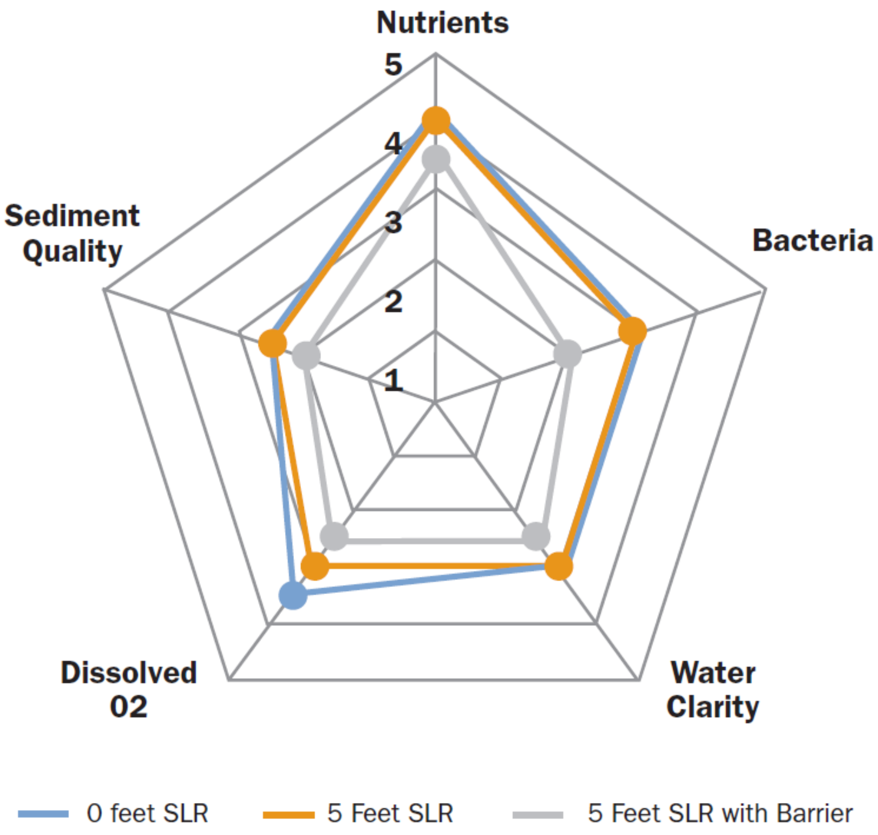


FIGURE 6.6

Boston Harbor Water Quality Ratings with SLR Scenarios



Source: UMass Boston

Habitats

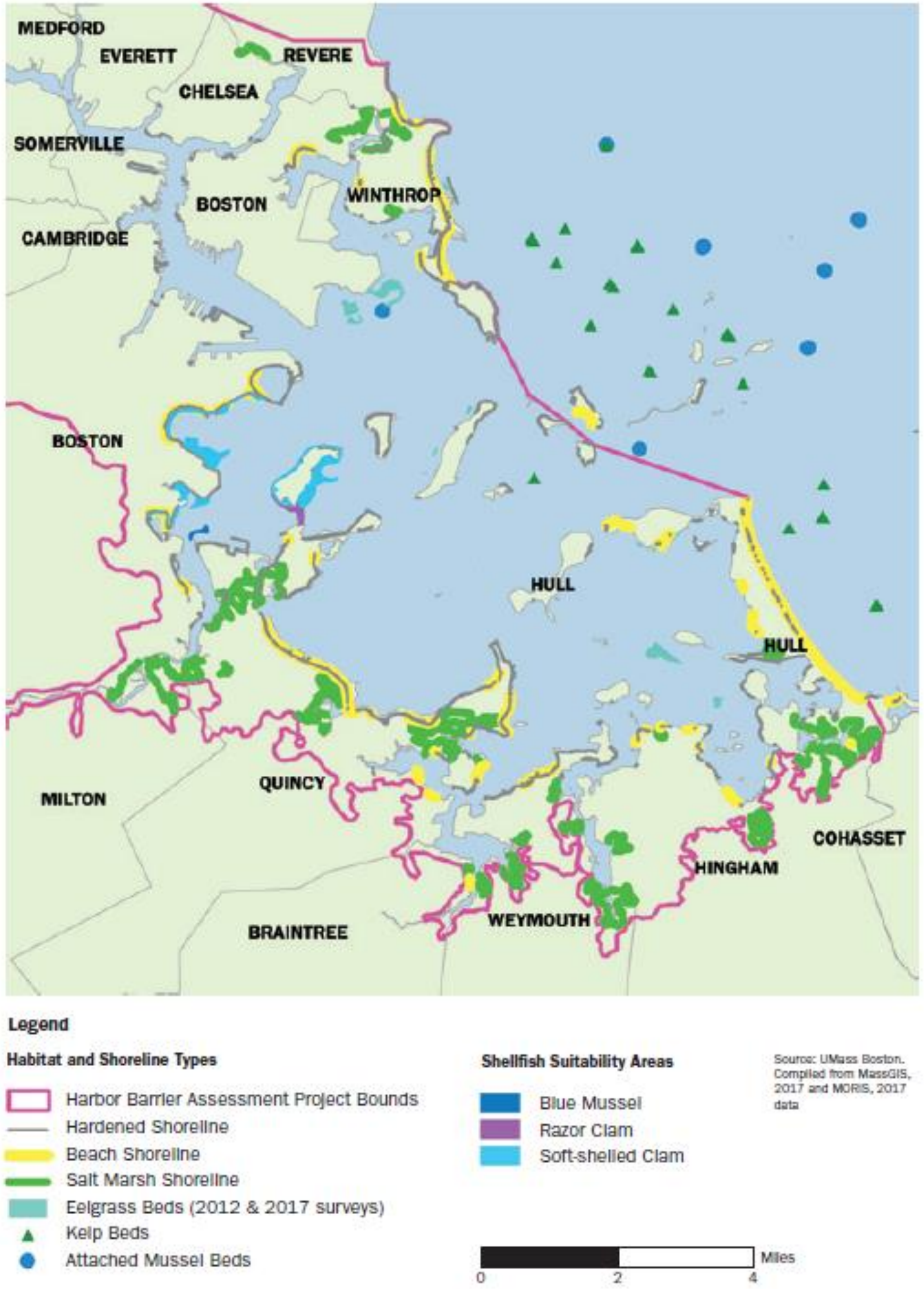
- Sandy Beach
  - SLR has greatest negative impact. Lower velocities convert some areas to mudflats. Less erosion from waves.
- Subtidal
  - Lower energy environment will increase silt/clay bottom habitat at expense of sandy and cobble habitat.
- Island-Coastal Bluff
  - SLR the greatest danger, barrier will reduce erosion for islands inside of the barrier.

Habitats

- Salt marsh
  - Drowning with SLR with or without barrier. Might be able to add sediment? Barrier reduces storm damage.
- Seagrass beds
  - Barrier may reduce or enhance water clarity, not much seagrass currently in Boston Harbor.
- Rocky Intertidal
  - Reduces flushing in some locations. Barrier adds new low quality substrate, could incorporate green design.
- Mudflats
  - Increased sedimentation in shallow back bays and behind barrier where residence times are increased.

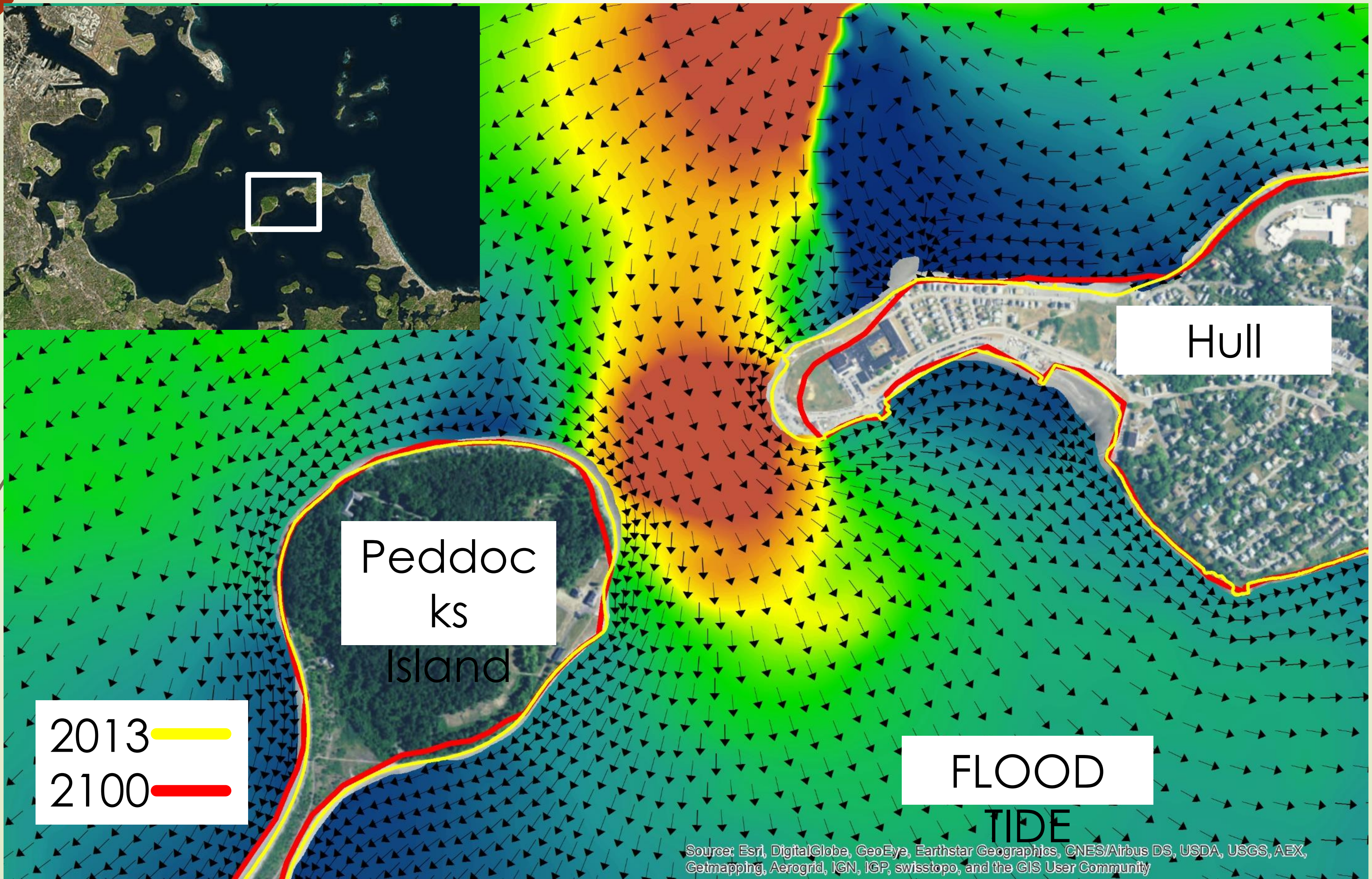
Habitats

FIGURE 6.8
Present Day Habitat Types in Boston Harbor

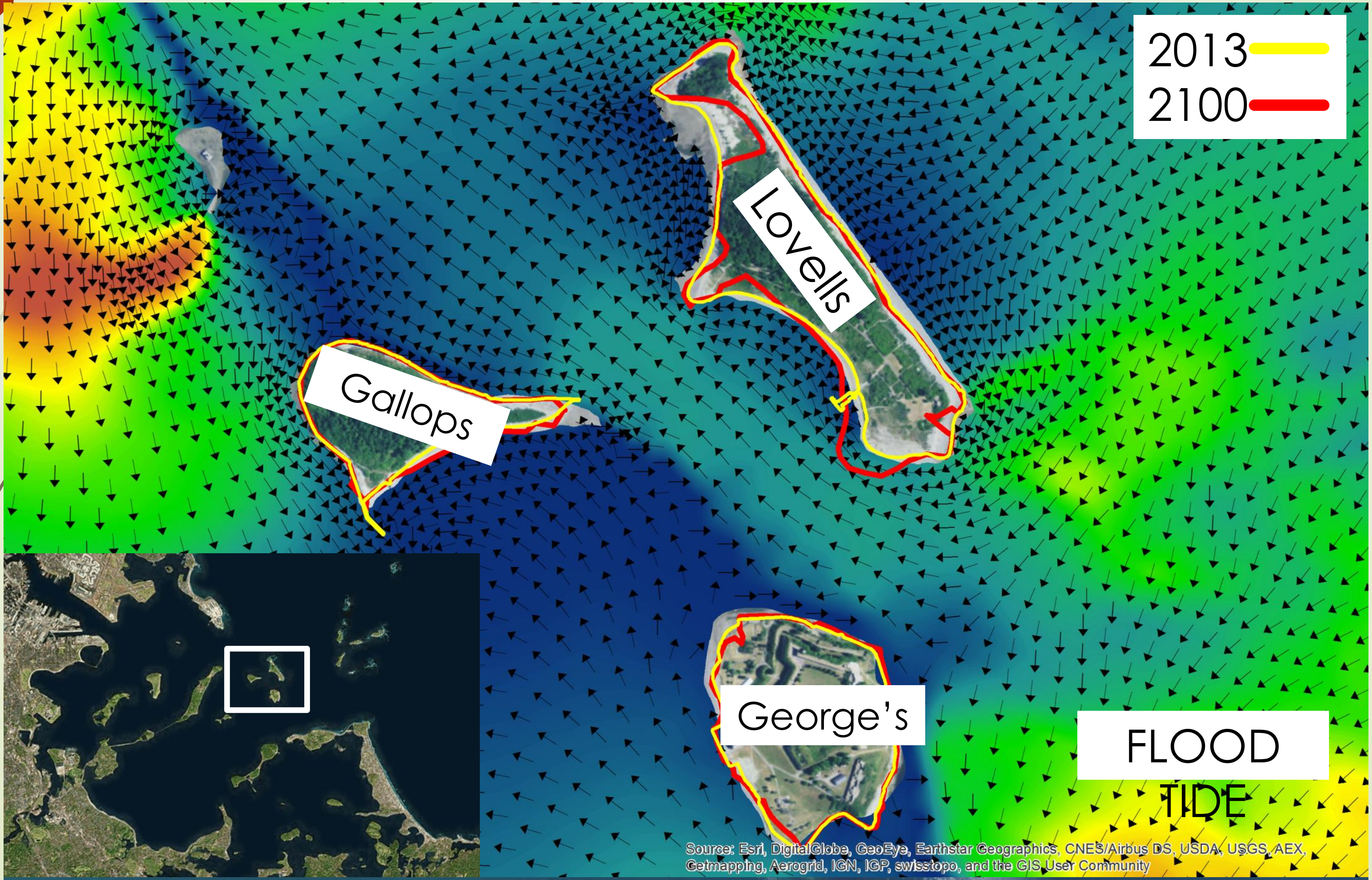


Source: UMass Boston. Compiled from MassGIS, 2017 and MORIS, 2017 data

Shoreline Change and Current Velocities



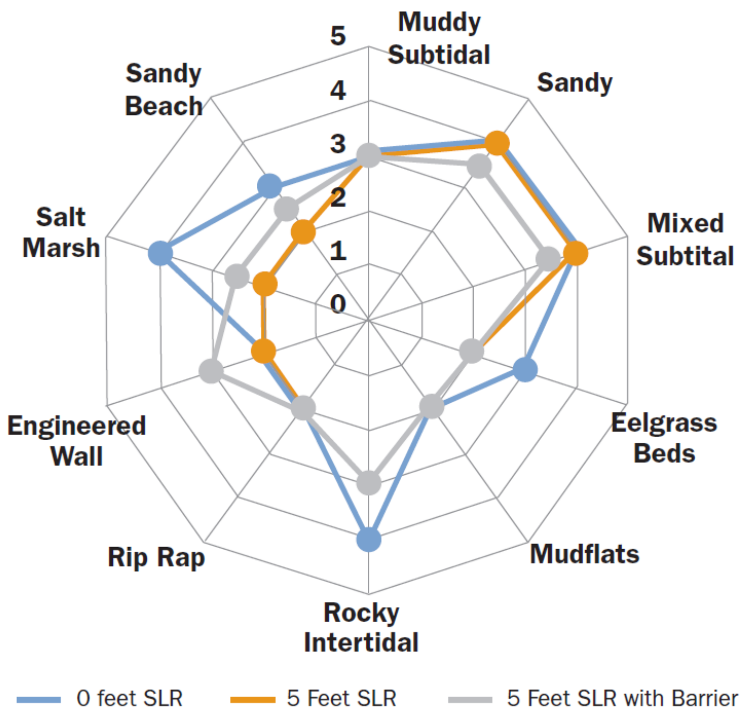
Shoreline Change and Current Velocities



Habitat

FIGURE 6.10

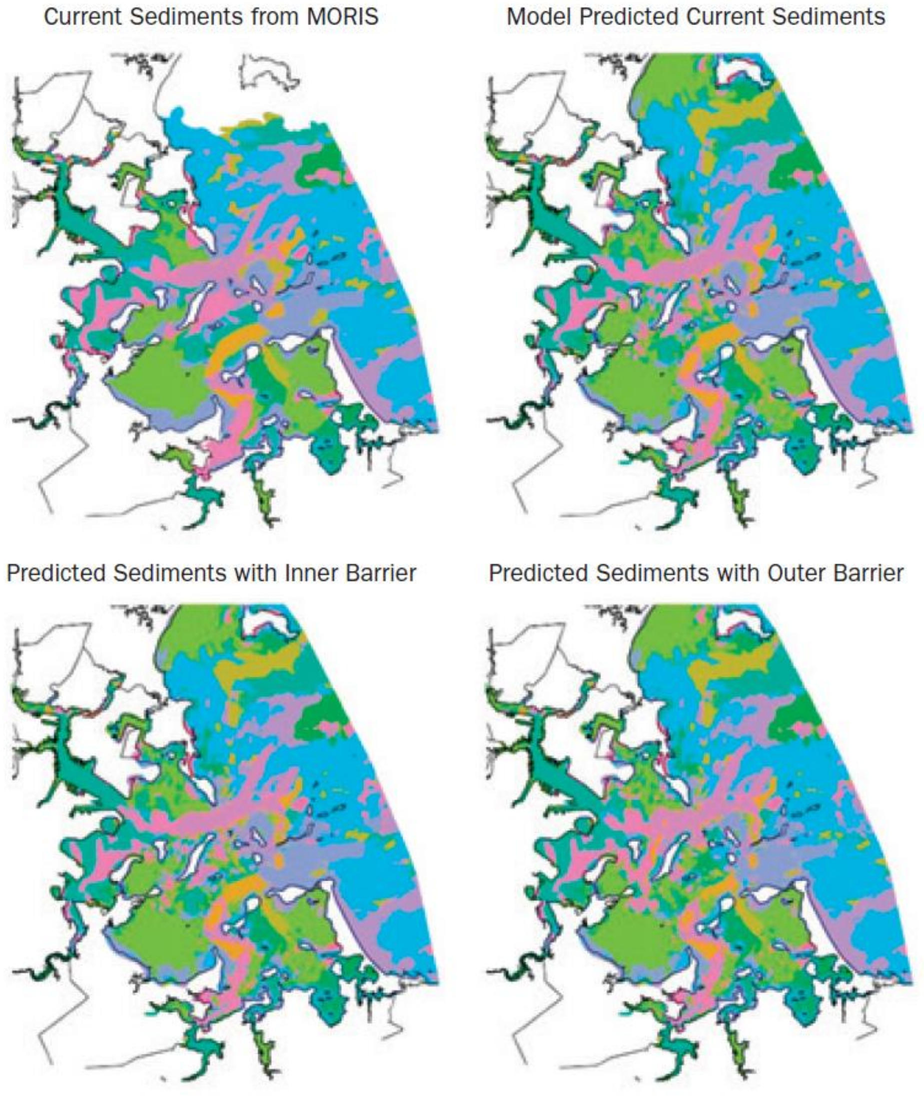
Boston Harbor Habitat Quality Ratings with SLR Scenarios



Source: UMass Boston

FIGURE 6.9

Distribution of Surficial Sediments Throughout Boston Harbor



Legend

Sediment Type

- Gravel
- Gravel with Mud
- Gravel with Rock
- Travel with Sand
- Mud
- Mud with Gravel
- Mud with Rock
- Mud with Sand
- Rock
- Rock with Gravel
- Rock with Mud
- Rock with Sand
- Sand
- Sand with Gravel
- Sand with Mud
- Sand with Rock

Source: UMass Boston

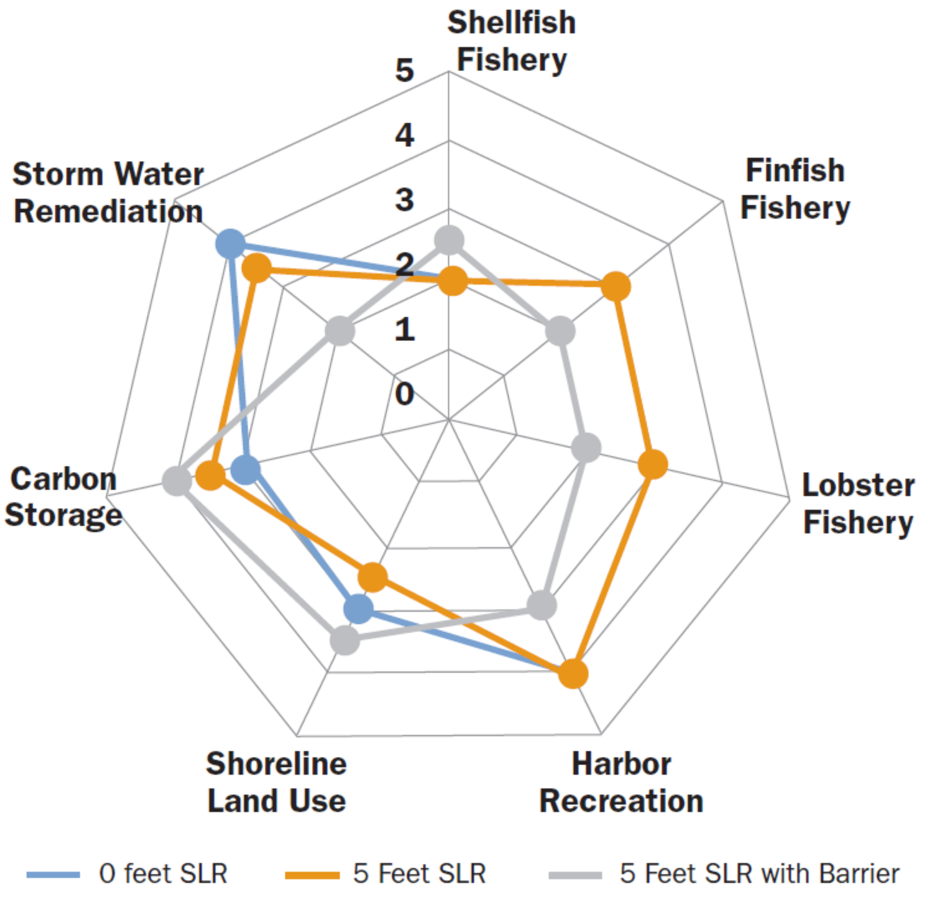
Ecosystem Services

- Carbon sequestration may be increased due to increased particle trapping with a barrier
  - could be countered if blue carbon habitats - salt marshes or sea grass beds - disrupted
  - this may happen with SLR with or without a barrier.
- Reduced flushing could lead to increased nutrients, lower DO, and higher probability of eutrophication in some areas
- Impact on fisheries is unclear but might affect migratory species
- 30’ wall changes aesthetic and historical values but also can increase access to the Harbor by the public

Ecosystem Services

FIGURE 6.11

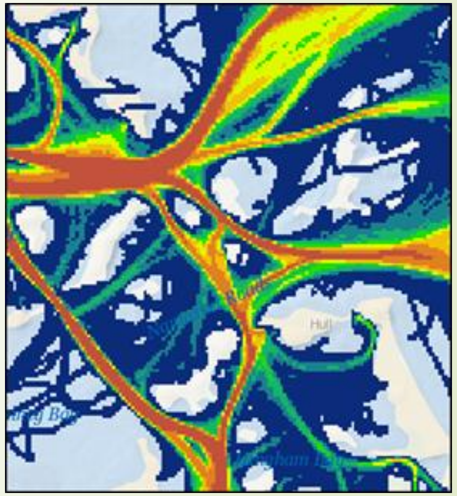
Boston Harbor Ecosystem Service Ratings with SLR Scenarios



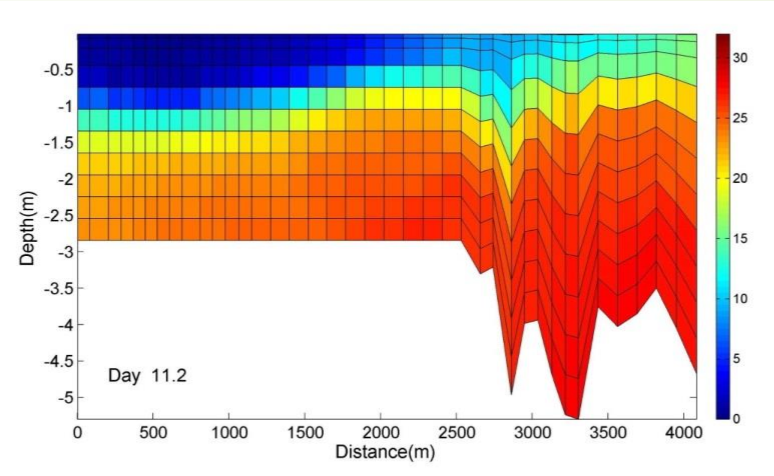
Source: UMass Boston

Unknowns

- Impacts during Construction
- Response of people and organizations
  - With or without barrier
  - Psychology
  - Timing
  - Context
- Extent of SLR and Climate Change
  - Global in nature
- Future Use of Harbor
  - Habitat, Water Quality, Ecosystem Services



Storms-River Flow



- During high flow river events (i.e. storms), there is currently a rapid (hours) sheet flow of freshwater (and first flush contaminants) at the surface into Massachusetts Bay.
- With a barrier closed for 48 or more hours, this freshwater lens (with associated contaminants) will be trapped within the Harbor (at the surface until the barrier is opened.
- We have not characterized this feature adequately to date, and potential impacts on organisms or ecosystems is unknown.

Inner Harbor Barrier

- Behind a closed barrier, freshwater runoff could increase sea level in the Inner harbor by 20-22’
- This freshwater is the most sediment and contaminant-rich of the water column
- This water would have to be pumped over the barrier and out of the Inner Harbor
- Pumps would be located near the bottom so would not help remove contaminated surface layer
- This upper layer would cut off lower layer from sunlight and atmospheric exchange until the barrier was opened

FIGURE 4.9
Inner Harbor Barrier Floating Leaf Sector Gate

Sources: Arcadis, Esri World Imagery, USACE

FIGURE 4.7
Inner Harbor Barrier Alignment

Sources: Arcadis, Esri World Imagery, USACE

TABLE 4.4
Estimated Pumping Requirements for Inner Harbor Barrier

River	Peak Discharge (cfs)	Total Discharge (cf over 72 hours)	Average Discharge (cfs)
Charles River	23,450	932 Million	3,595
Mystic River	9,380	238 Million	920
TOTAL	**32,830**	**1.17 Billion**	**4,515**

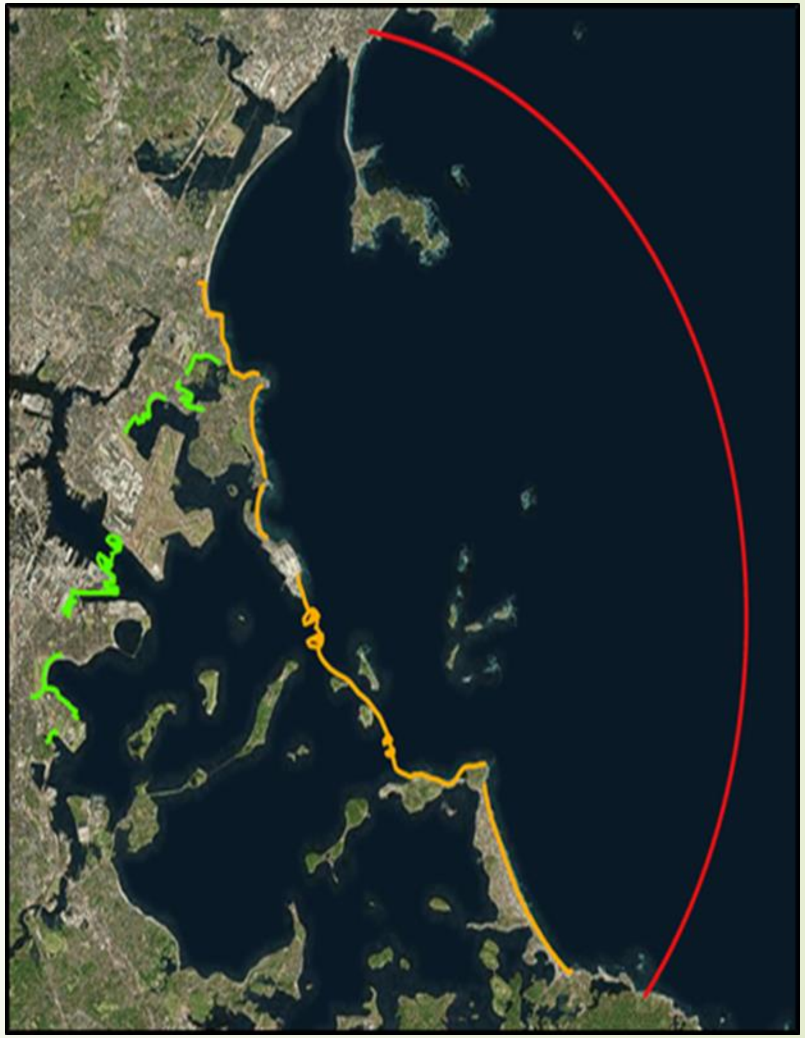
Source: Arcadis

Other Considerations

- Lines in the Sand
  - A barrier is not expected to eliminate any particular habitat or significantly decrease ecosystem function
- Unknowns
  - Impacts on fish migrations
  - Impacts on denitrification rates
  - How local responses will shift with the presence or a barrier. Local habitats might be conserved.
  - Effects of circulation pattern changes on ecosystem function.
- Perceptions
  - There will be a hurdle of peoples' perceptions of a large structure that might be overcome over time (like the idea that the Harbor Cleanup could be worth $5B).

Flexibility of Solution

- Change over time
  - Ecosystem
  - Adaptation
- Barrier lead time
  - 20 years
- Timescales
  - Match solution to expected change

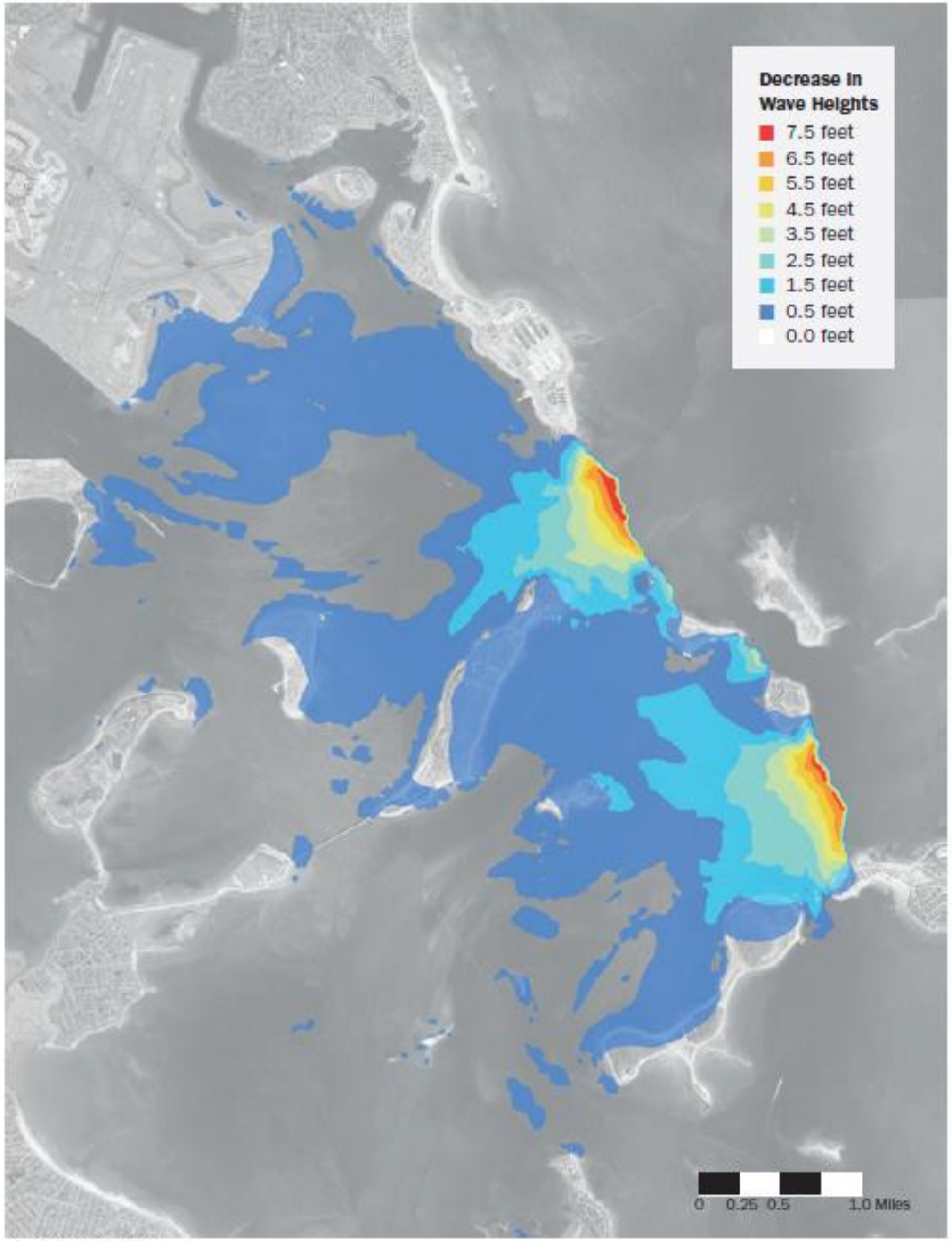


Conclusions

- There do not appear to be any clear environmental "disasters" that would result from a harbor-wide barrier.
- We have not yet assessed how ***local*** resilience strategies will affect the local ecosystem functions and services with or without a barrier as sea-level rises.
- There are still some unknown impacts, including the impacts of a barrier on fish migrations, the survivability of salt marshes and sea grass beds with SLR, the effects of circulation changes, and the impact of trapping freshwater plumes during storm events.
- Science plays a significant role, is incomplete in some areas (uncertain, unknown), but is more predictable than social science (human decisions, behavior, perspectives)

FIGURE 6.4

Wave Model Results from a Single Storm Scenario Showing the Decrease in Wave Heights in Boston Harbor Due to a Closed Harbor-wide Barrier Compared to No Barrier at All



Source: Woods Hole Group

Citation

- http://www.greenribboncommission.org/wp-content/uploads/2018/05/Feasibility-of-Harbor-wide-Barriers-Report.pdf
- Feasibility of Harbor-wide Barrier Systems:
  - Preliminary Analysis for Boston Harbor
  - Sustainable Solutions Lab, University of Massachusetts Boston, May 2018.

Ecological Economics

Di Jin

Senior Scientist

Marine Policy Center

Woods Hole Oceanographic Institution

The Boston Harbor Barrier Study:
ECOLOGICAL ECONOMICS

Di Jin, Chris Watson and Paul Kirshen

Funded by: Barr Foundation

Sponsored by: Boston Green Ribbon Commission

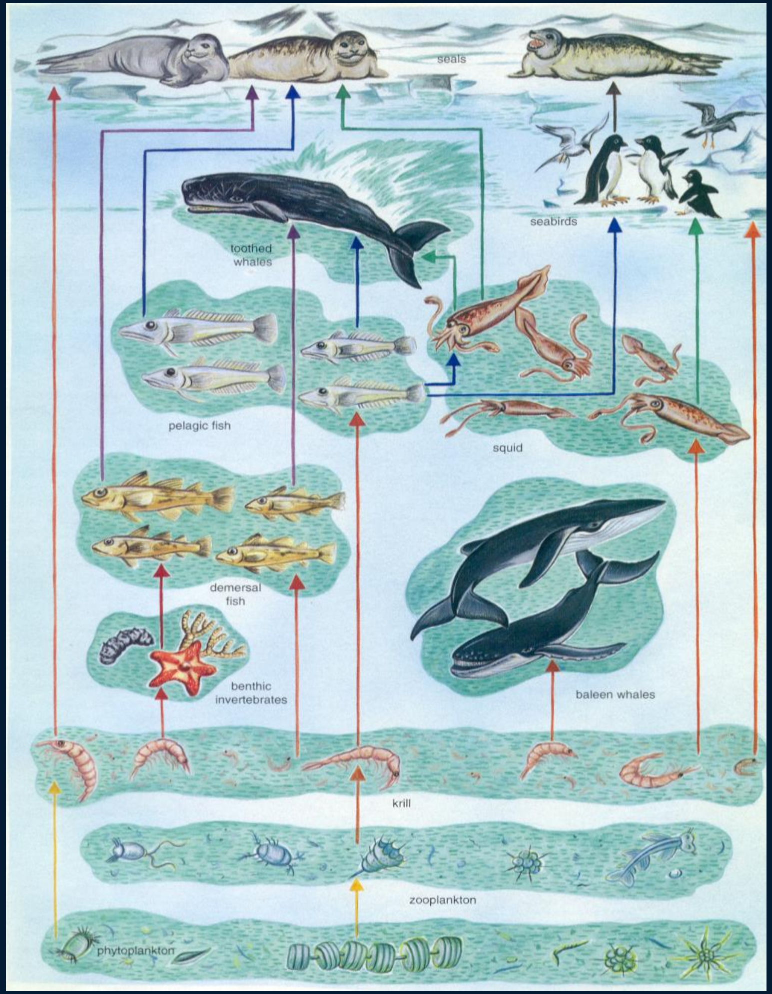
June 22, 2018

EBCNE Climate Change Program

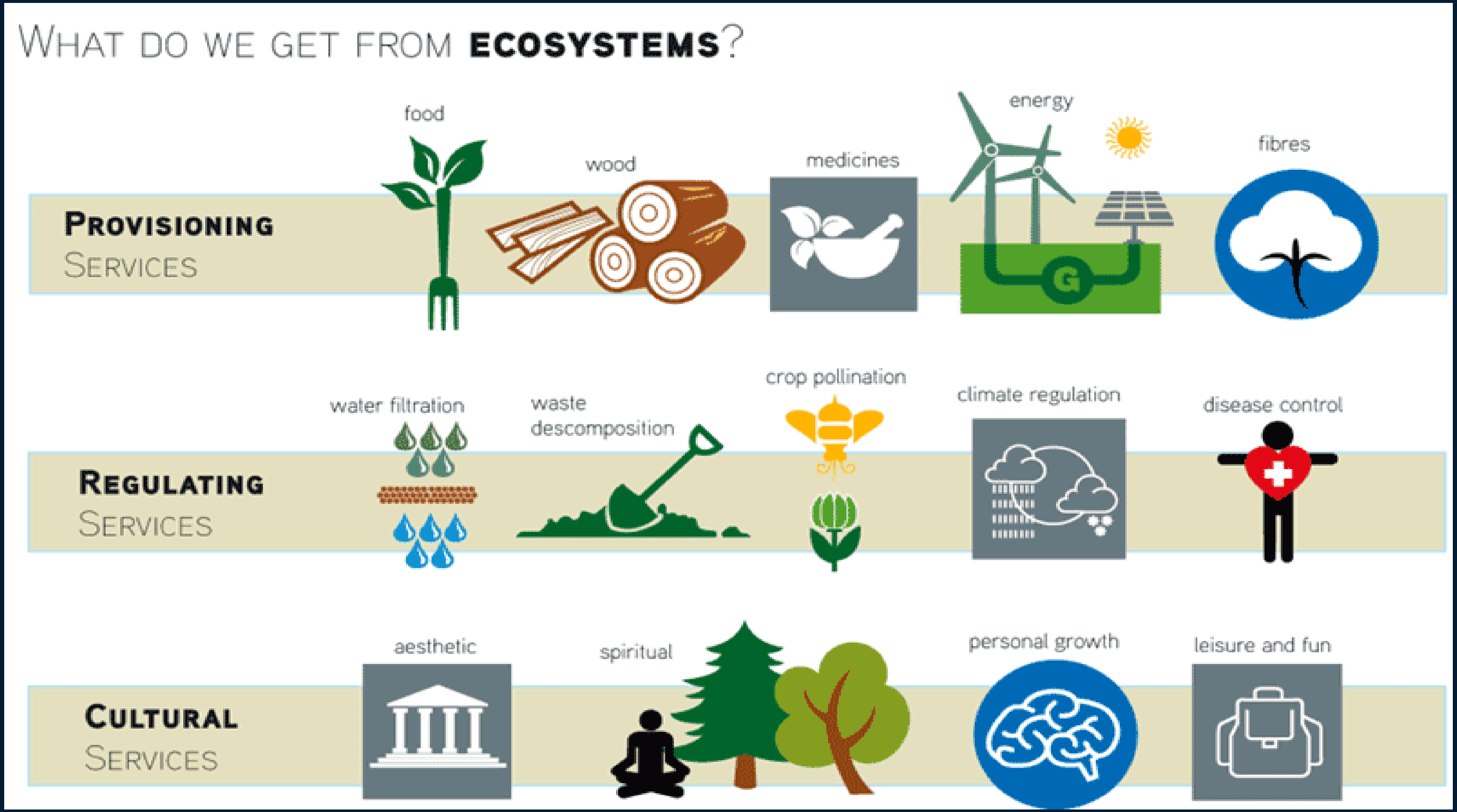
Outline

- Ecosystem Valuation
- Methods
- Results
- Summary

Ecosystem Service and Valuation

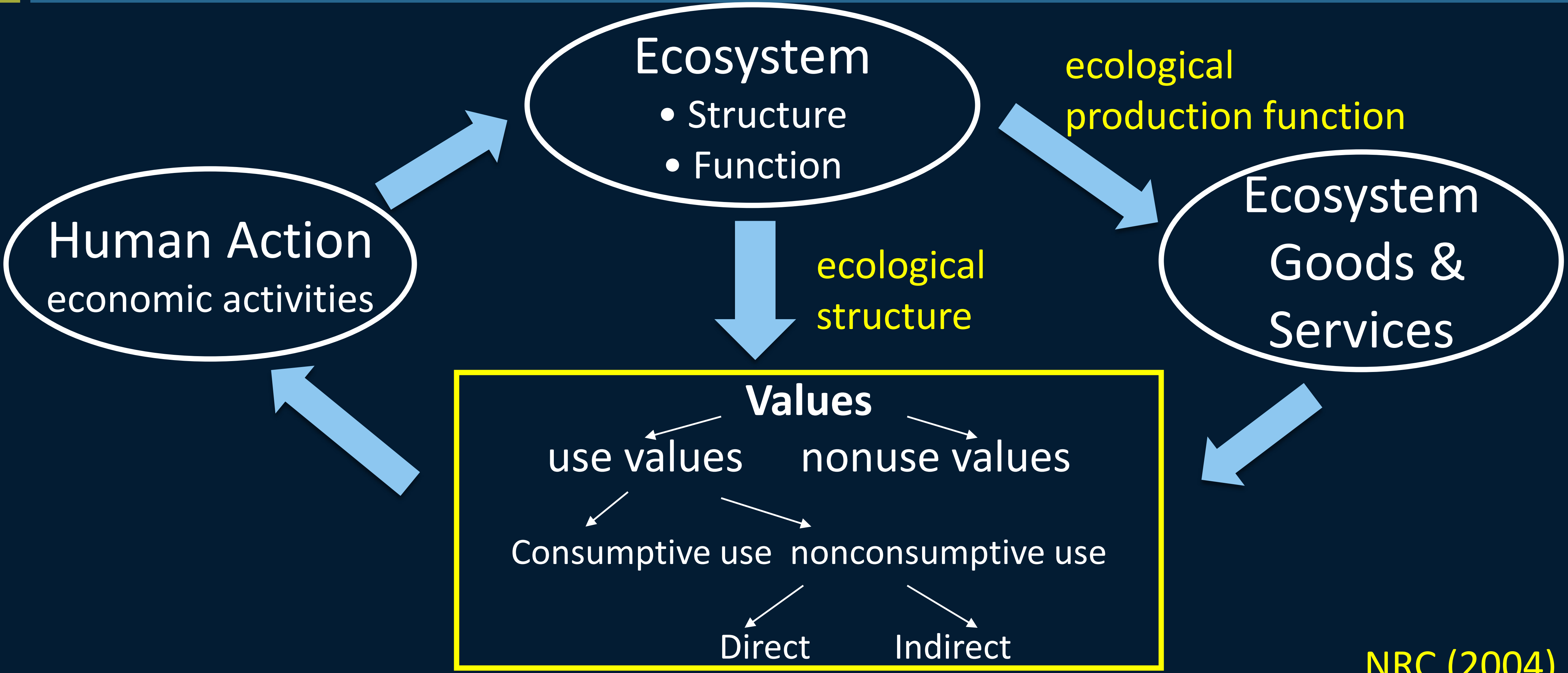


Ecosystem Services



UNESCO
http://www.ehu.eus/cdsea/web/index.php/about-us/?lang=en

Ecosystem Valuation



NRC (2004)

Methods

Ecosystem Service Value = Unit Value ($/acre/year/land cover) × Area (acre/land cover)

The study area is divided into 4 subareas:

Mystic River Watershed	Charles and Neponset Rivers Watershed
Weir River Watershed	Harbor Islands

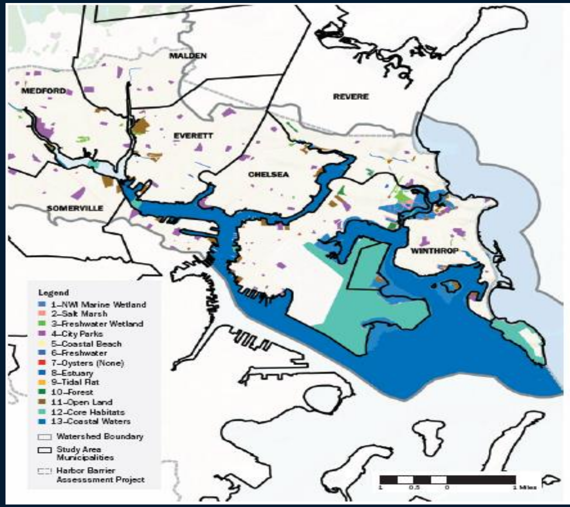
13 Land Cover Types:

Marine Wetlands	Salt Marsh	Freshwater Wetland	City Parks
Beach	Freshwater	Oyster Bed	Estuary
Tidal Flat	Forest	Grassland/Openland	Core Habitats
Coastal Waters			

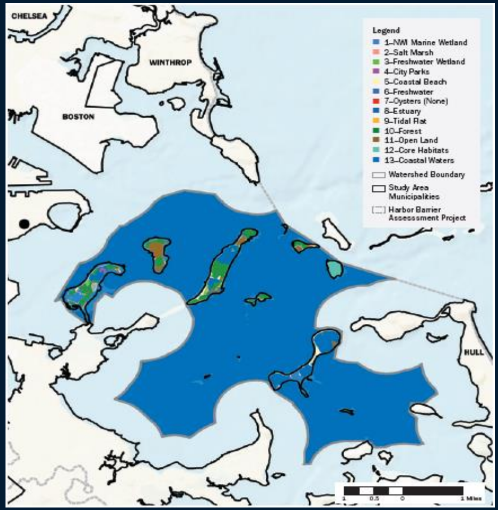
Estimate proposed barrier impacts on ecosystem asset values and NPV

Land Covers in 4 Watersheds

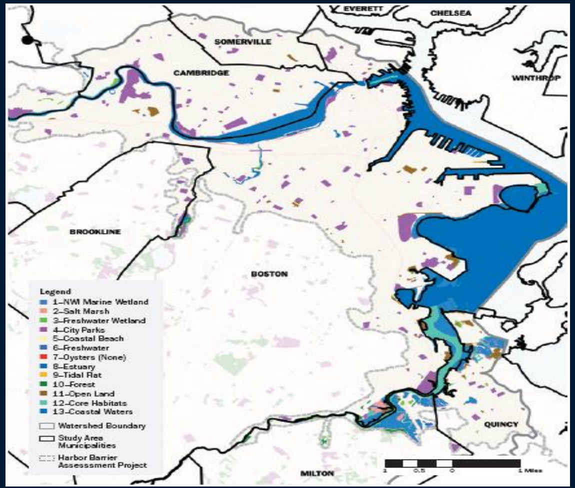
Mystic River Watershed

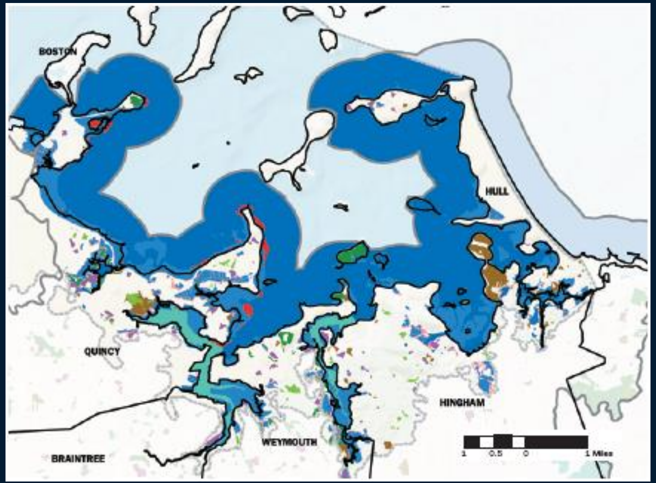


Harbor Islands



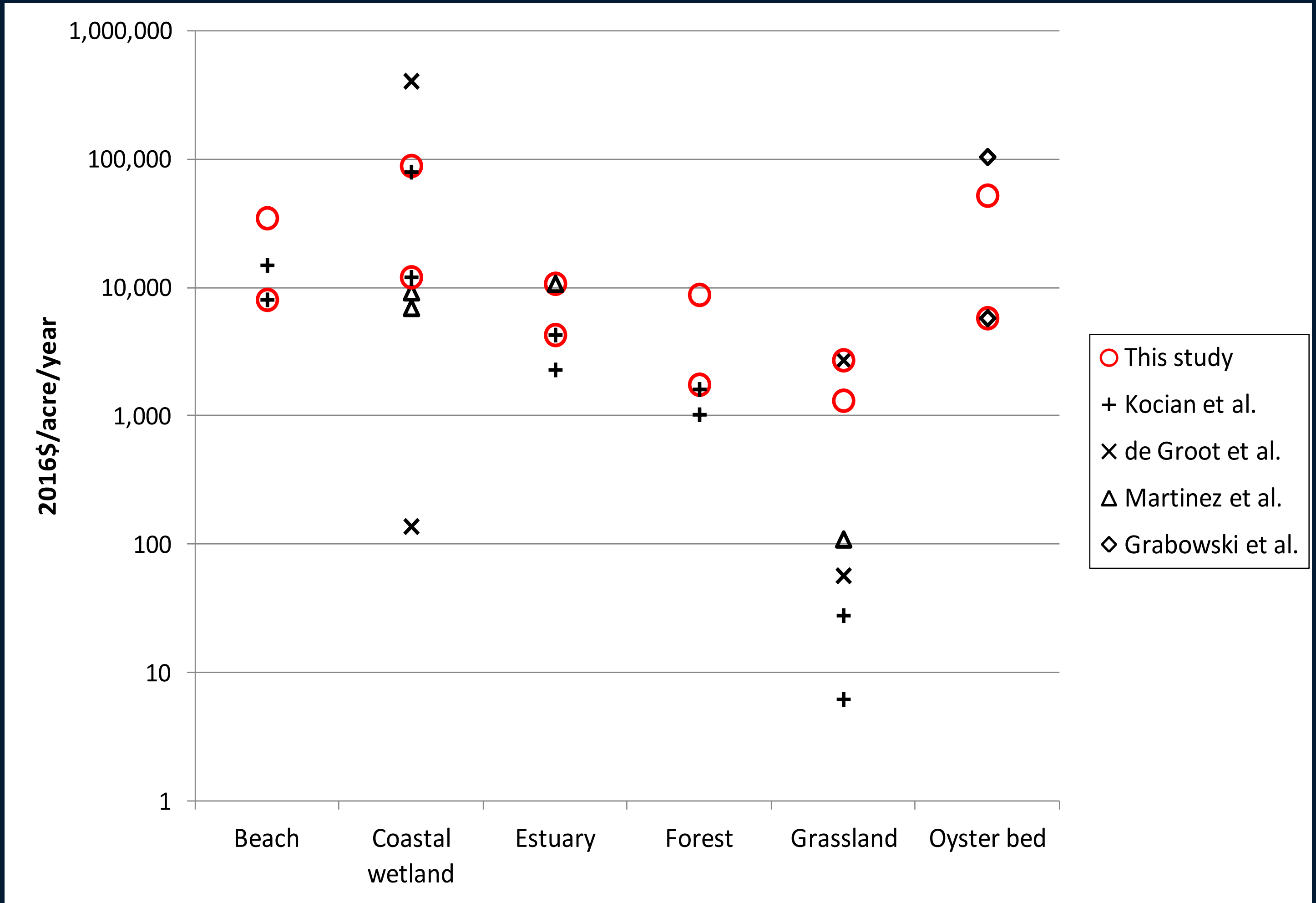
Charles and Neponset Rivers Watershed





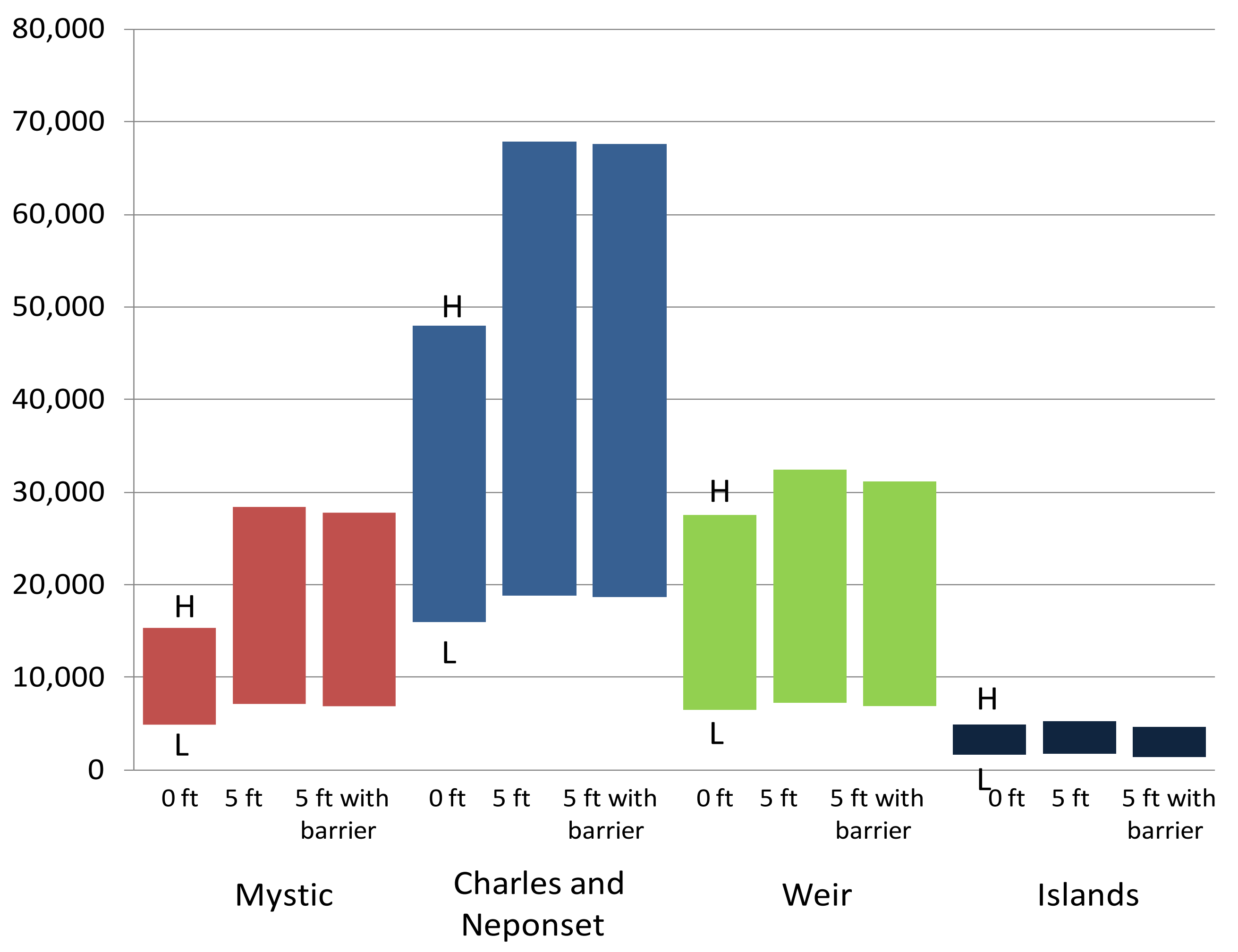
Weir River Watershed

Unit Ecosystem Service Values



Effects of SLR and Proposed Barrier on Ecosystem *Asset Values*

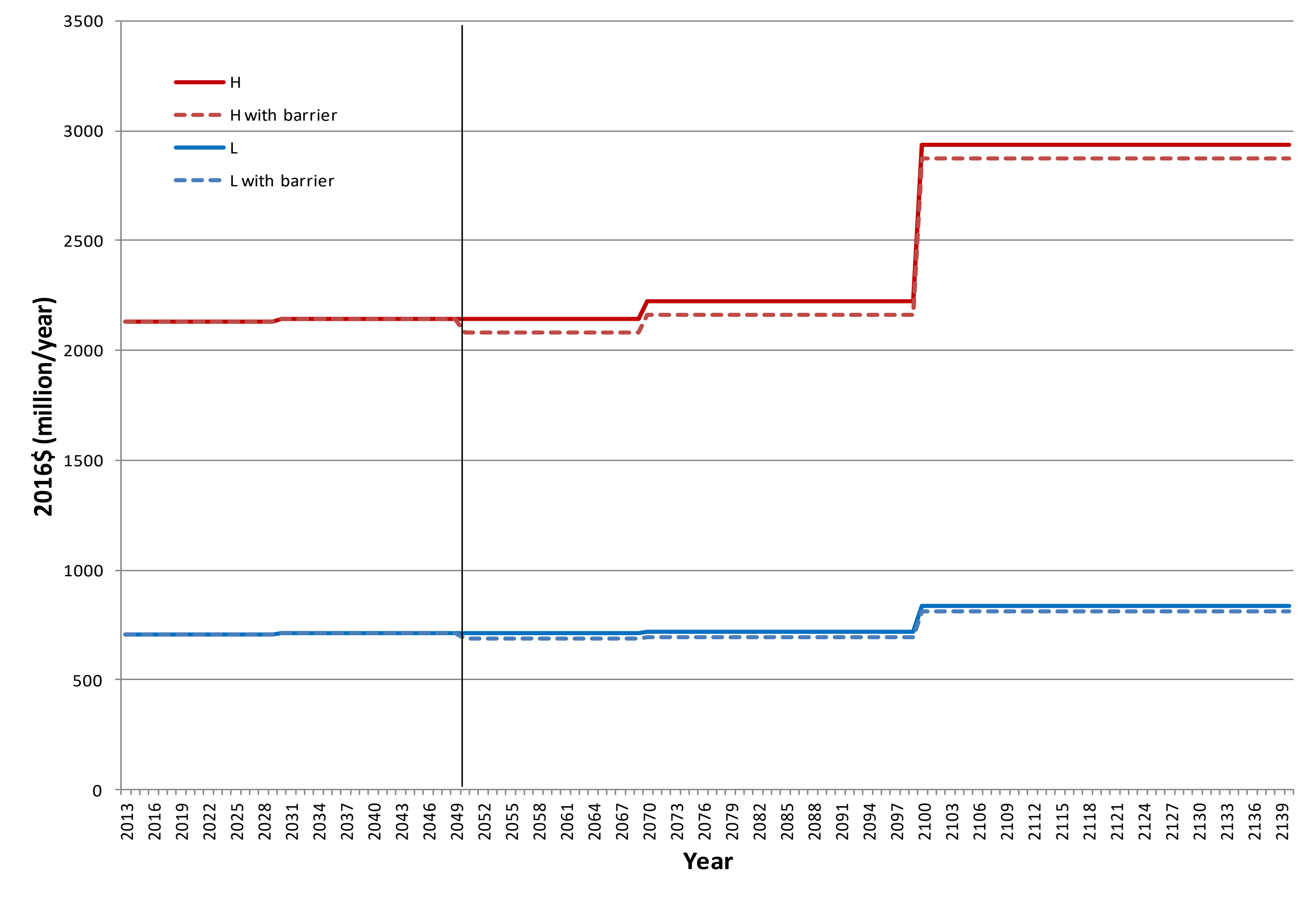
(2016$ million, sliding scale discounting)



2013 (0 ft) and 2100 (5 ft)

Effects of SLR and Proposed Barrier on *Annual Ecosystem Values*, 2013-2140

(assuming that barrier will be installed in 2050)



Summary

- Ecosystems in the study area provide multitude of services to society valued at $30-100 billion (asset value).
- Without restrictions on marsh migration, the total ecosystem asset values are expected to increase under SLR.
- Barrier impacts: the overall reductions in ecosystem asset values in the study area are small (2-3%), although local reductions in the harbor and islands sub-area may be higher (up to 16%).*
- For a barrier installed in 2050, the overall effects on NPV are small (below 2%).
- For a barrier installed in 2090, the reduction in NPV would be smaller (1.10%).

** Mainly due to reduced water quality (Chen et al. 2017).*

Recreational and Commercial Harbor Use Impacts

Kimberly Starbuck

Research Associate

Urban Harbors Institute

University of Massachusetts Boston

Feasibility of Harborwide Barrier Systems: Impacts on Recreational and Commercial Use

Kim Starbuck
Urban Harbors Institute, UMass Boston

UMASS BOSTON Sustainable Solutions Lab
ARCADIS
Woods Hole Oceanographic Institution 1930
WOODS HOLE GROUP A CLS COMPANY
Funded by: Barr Foundation
Sponsored by: Boston Green Ribbon Commission

Goal

- Determine the effect of barrier configurations on select human uses in Boston Harbor
    - Recreational boating
    - Recreational fishing
    - Commercial shipping/traffic
    - Commercial fishing
- Determine the extent to which a barrier could accommodate or disrupt continuation of uses

Methodology

- Gather baseline data on current uses of Boston Harbor
- Review literature
- Conduct interviews, focus groups, and booth engagement with industry experts and stakeholders

Source: The Boston Globe


Source: On The Water

Engaged Parties in this Analysis

- Recreational boaters
- Massachusetts Marine Trades Association
- Staff from Massport
- The Massport Port Operators Group
- The Metropolitan Area Planning Council
- United States Coast Guard
- Harbor pilots
- Commercial shipping stakeholders
- Fishing industry experts

Source: The Boston Globe


Source: On The Water

Results: Baseline Data and Potential Impacts

Recreational boating

Recreational fishing

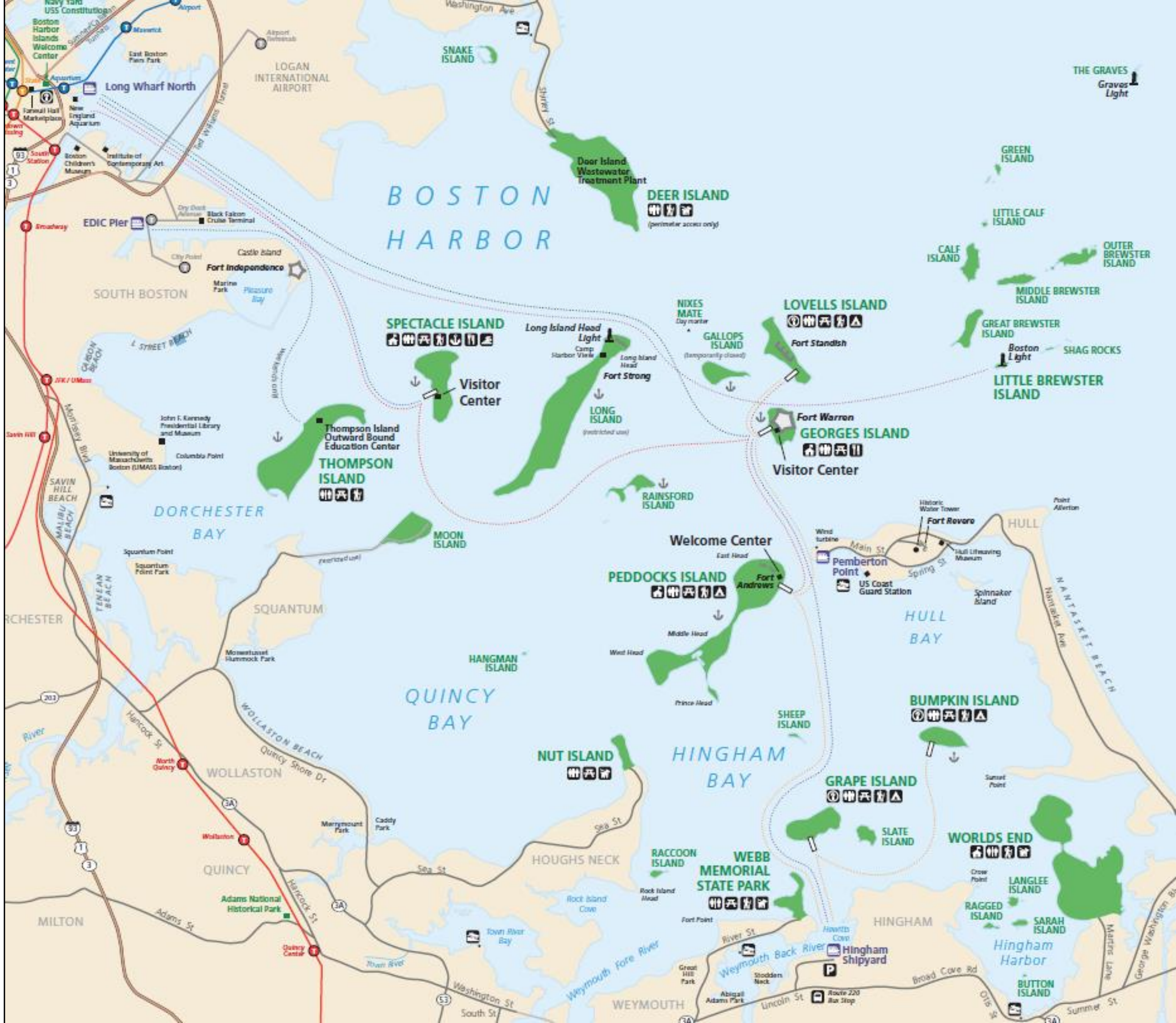
Commercial shipping/traffic

Commercial fishing

Source: Metro US

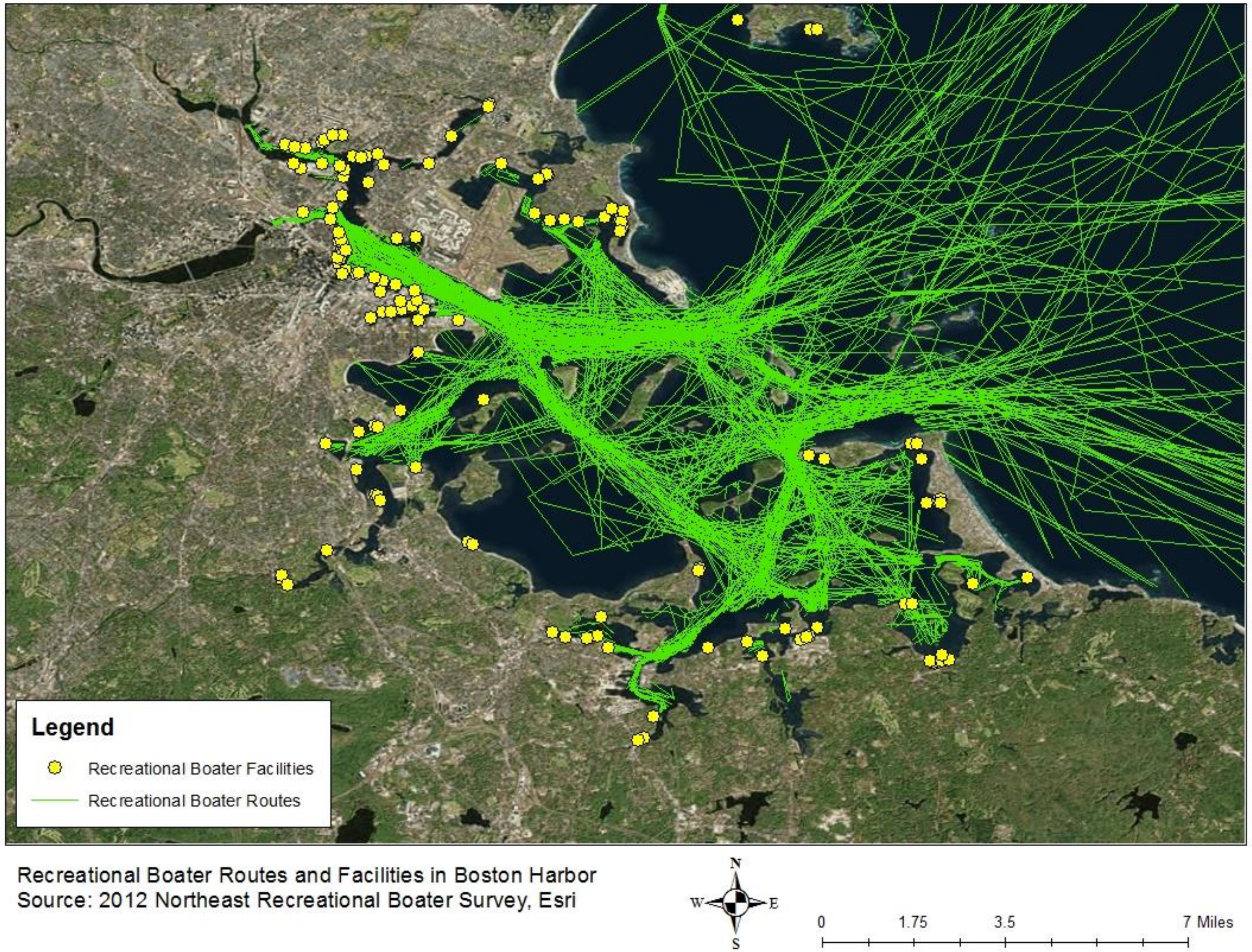
Recreational Activities

- Boating
- Fishing
- Diving
- Relaxing
- Wildlife viewing
- Swimming

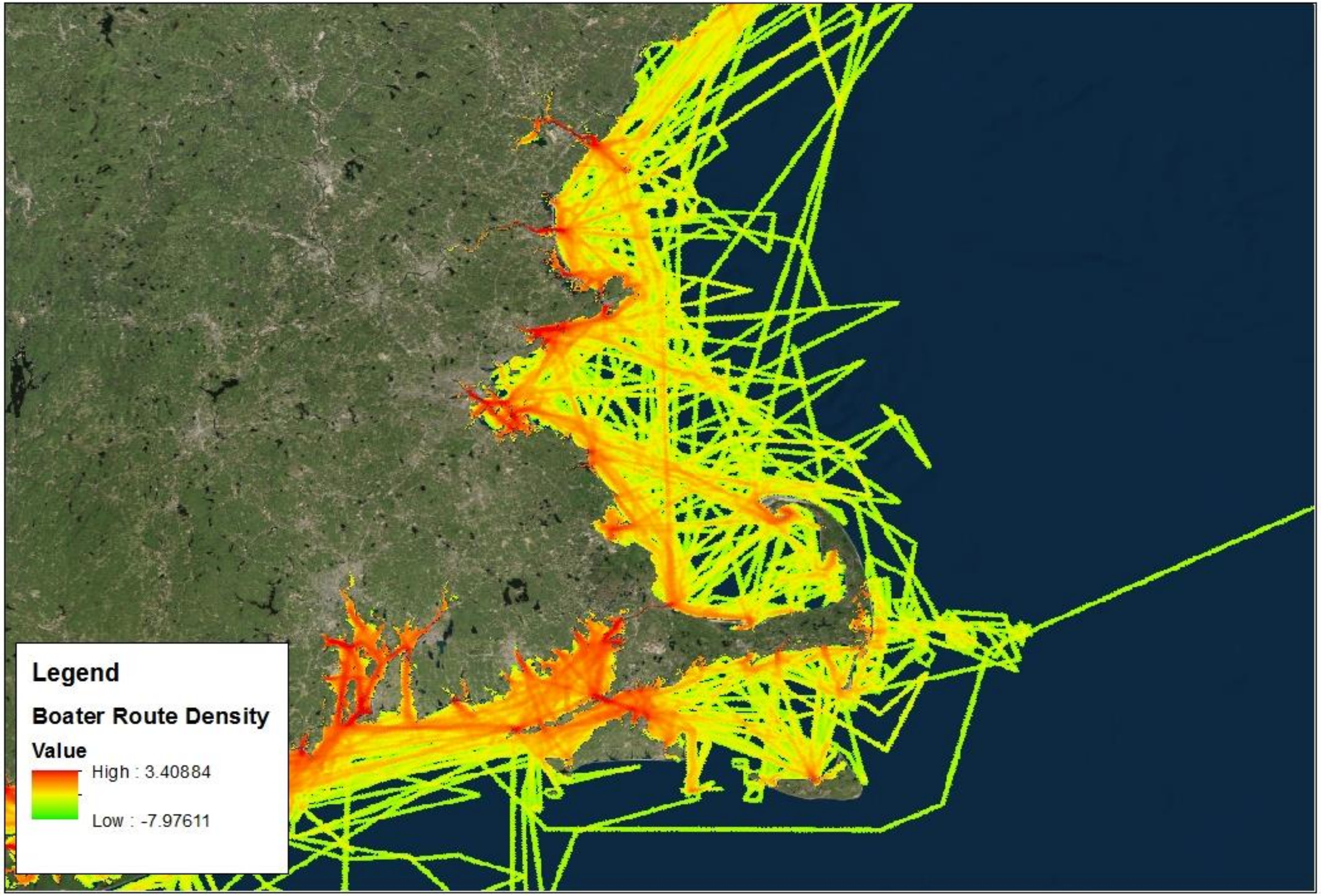


Recreational Boating

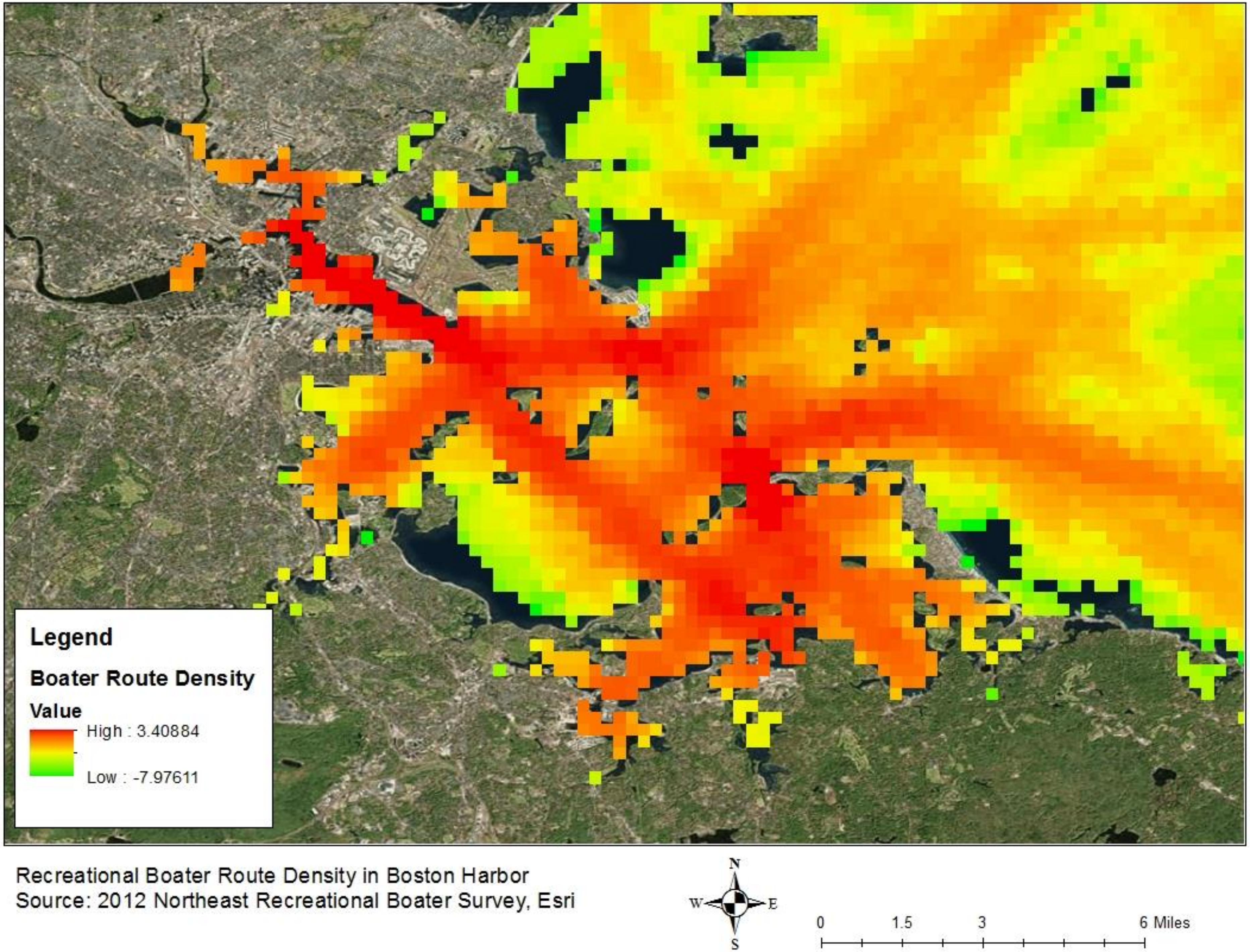
- 34 Boston Harbor Islands; many recreational activities
- Over 10,000 boats registered in communities surrounding Boston Harbor (2014)
- Impact of marine recreational boating on the entire Massachusetts economy: $840 million (2012)



Recreational Boater Routes and Facilities in Boston Harbor
Source: 2012 Northeast Recreational Boater Survey, Esri

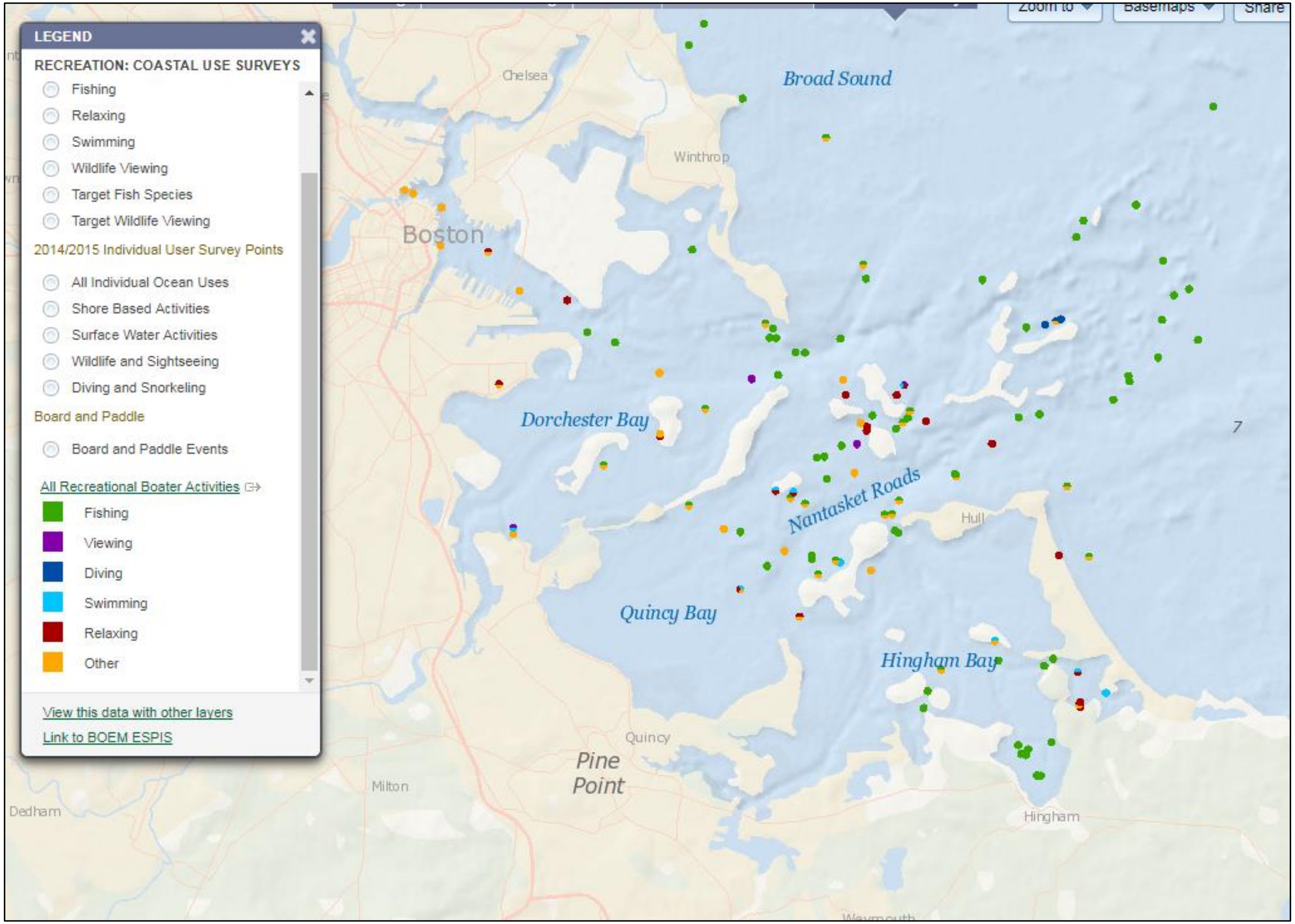


Recreational Boater Route Density in Boston Harbor
Source: 2012 Northeast Recreational Boater Survey, Esri

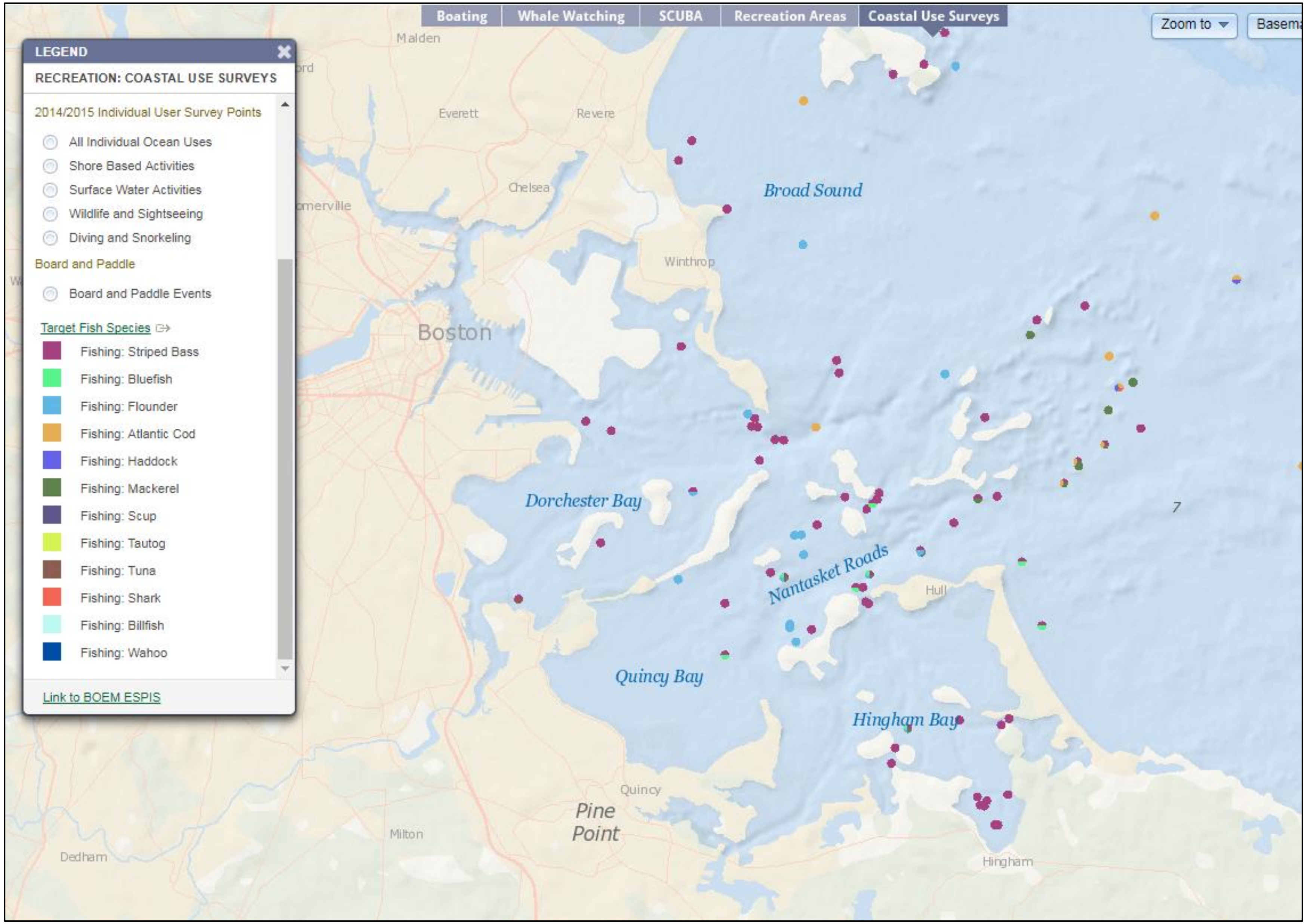


Recreational Boater Route Density in Boston Harbor
Source: 2012 Northeast Recreational Boater Survey, Esri

Recreational Activities



Recreational Fishing – Fish Targeted



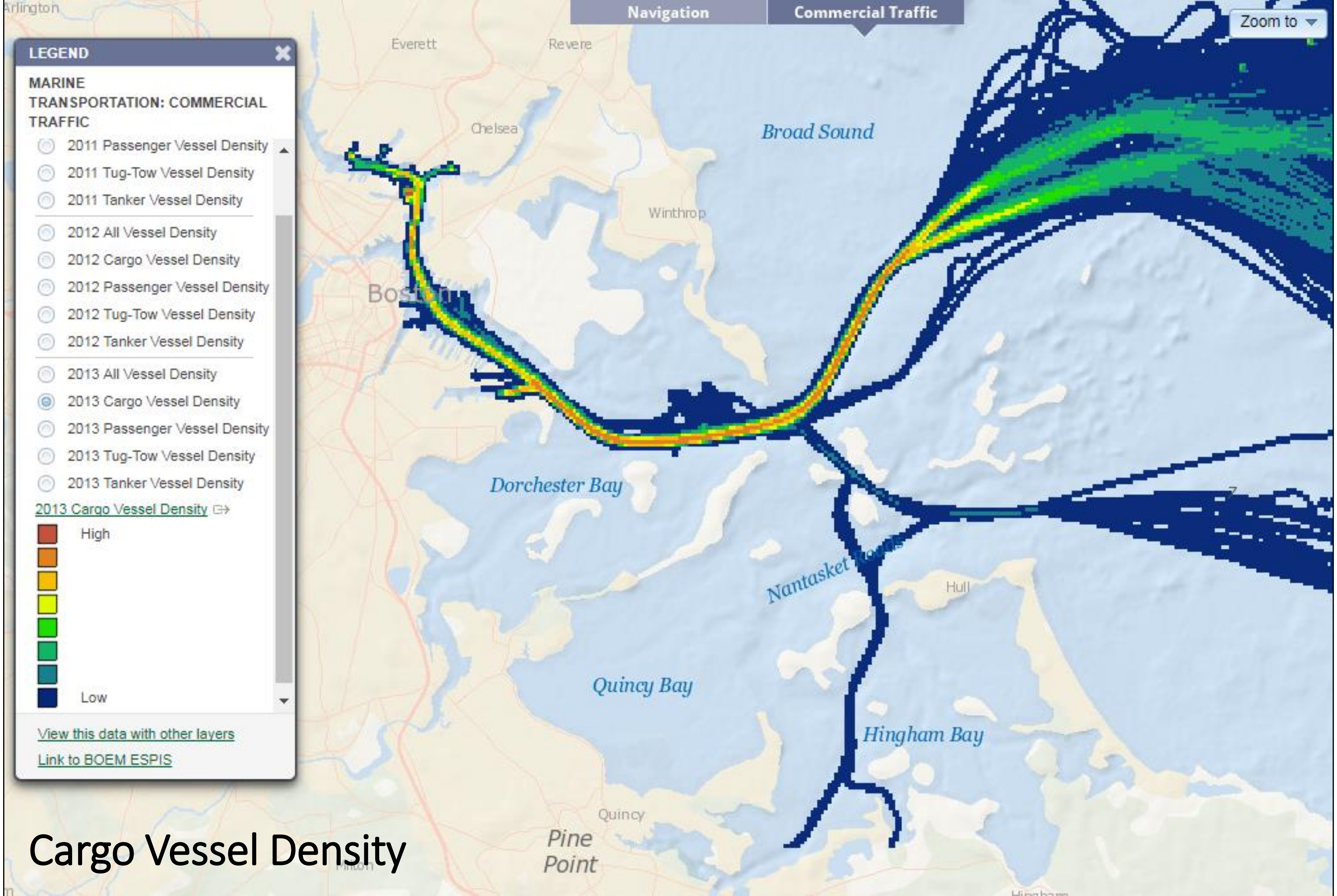
Commercial Shipping and Traffic

- Boston Harbor is region’s largest commercial port
- $4.6 billion of economic value (Martin Associates, 2012)
- 1,600+ businesses import and export
- Conley Container Terminal handled nearly 250,000 containers in 2016; 1.5 million metric tons of cargo each year
- 114 cruise vessels (2016)
- Main commercial vessels: cargos, tug-tows, tankers, and passenger vessels (e.g., ferries, cruise ships)

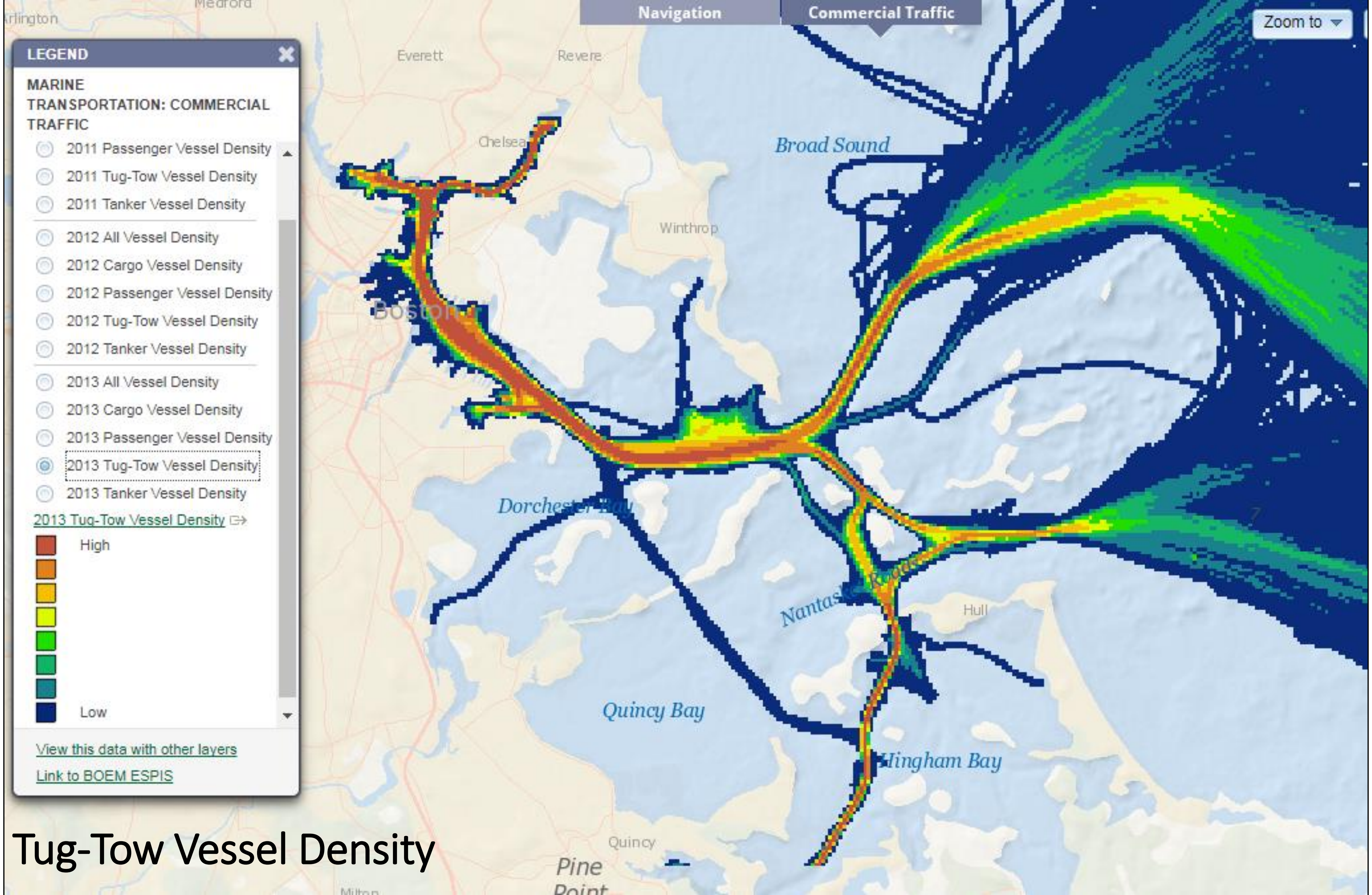
Boston Harbor Beacon

Boston Magazine

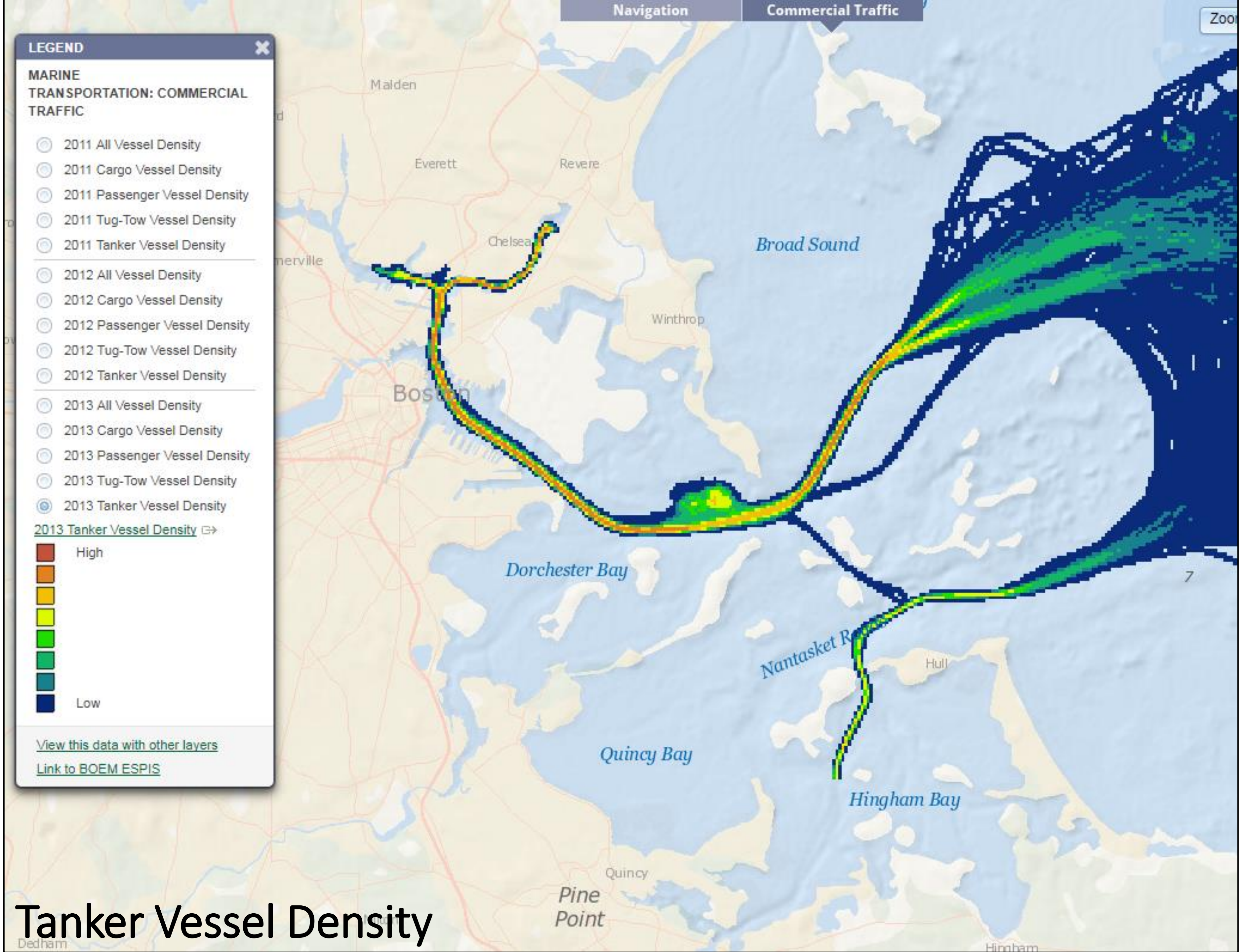
Boston Globe



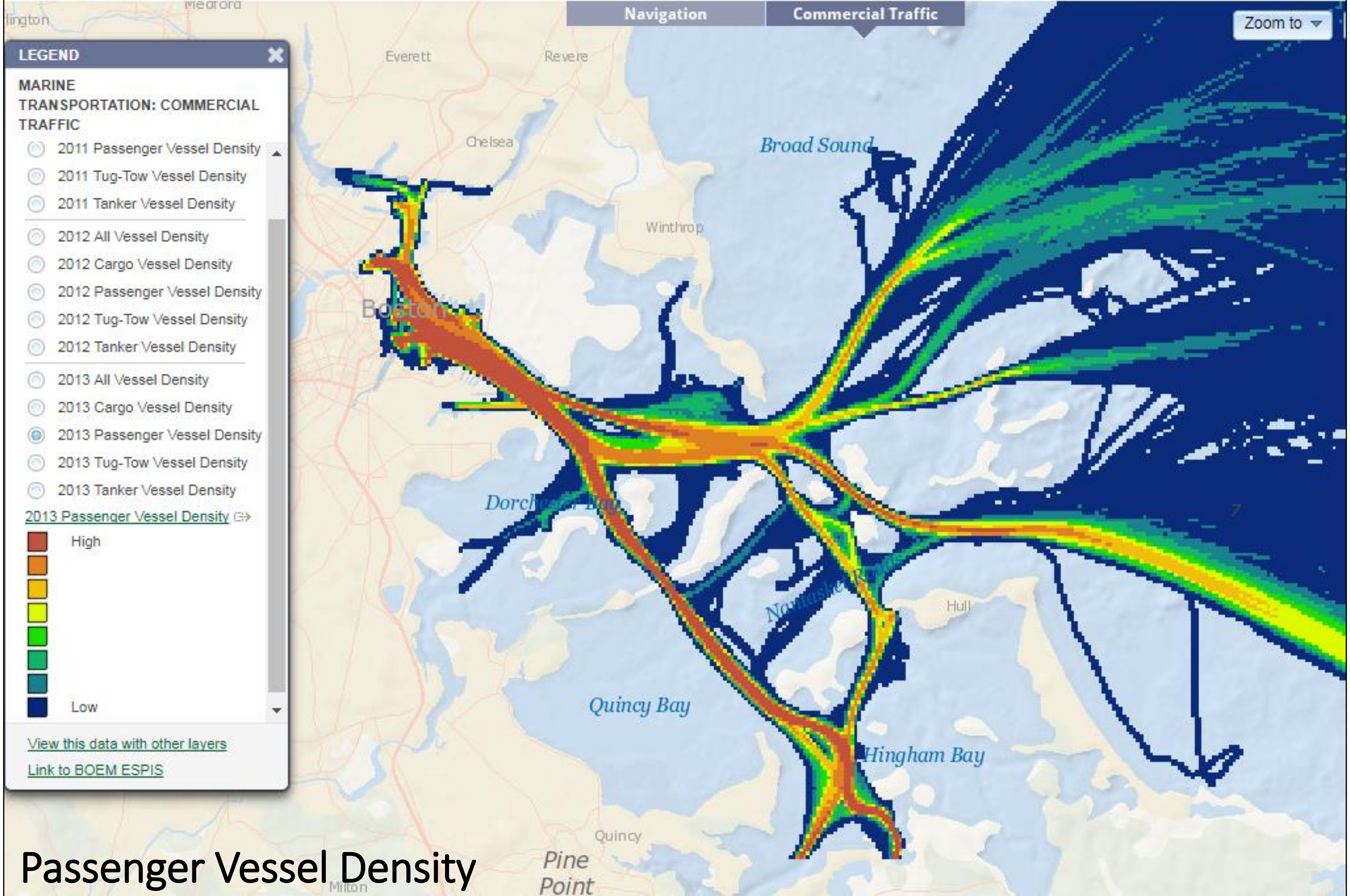
Cargo Vessel Density



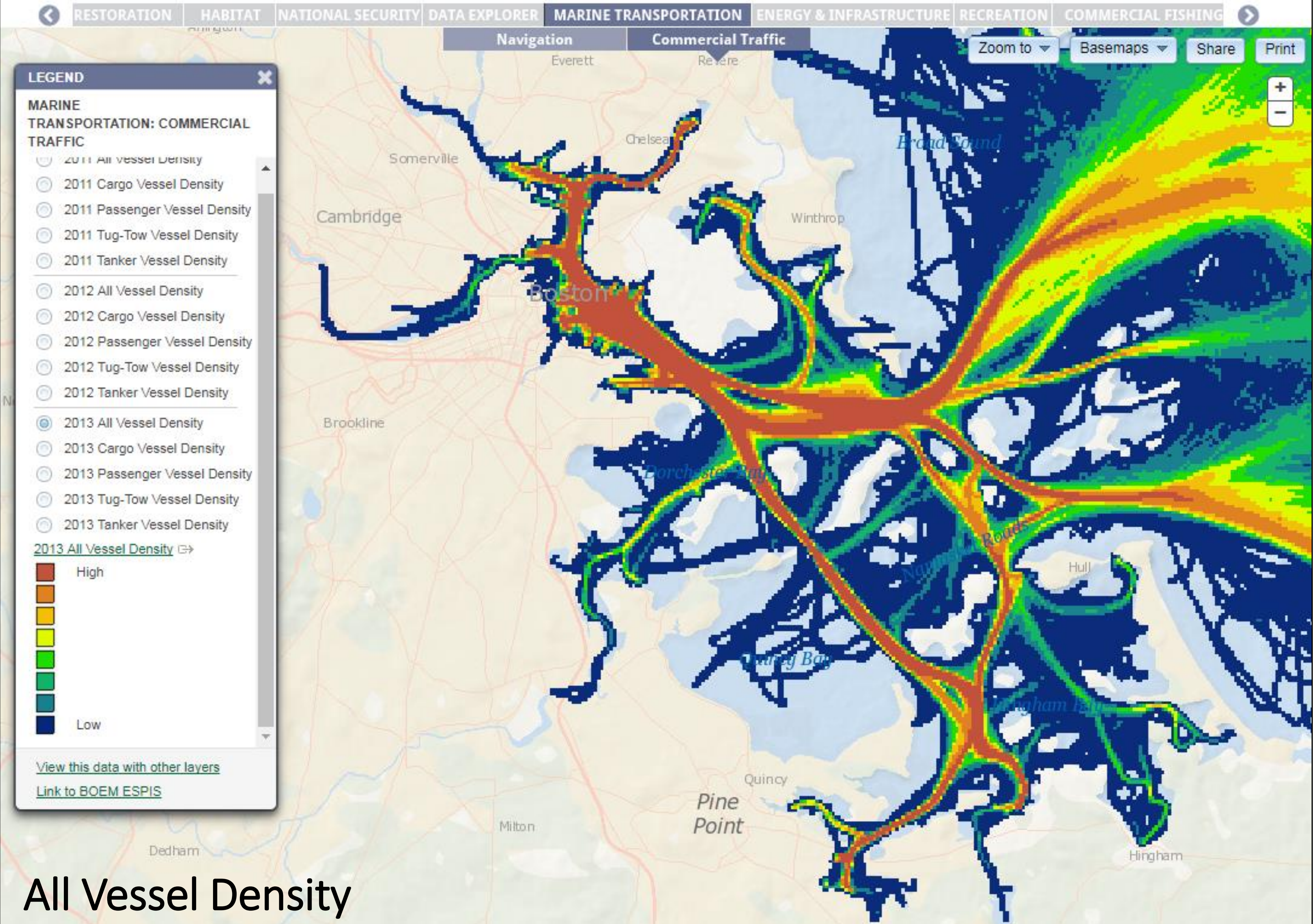
Tug-Tow Vessel Density



Tanker Vessel Density



Passenger Vessel Density

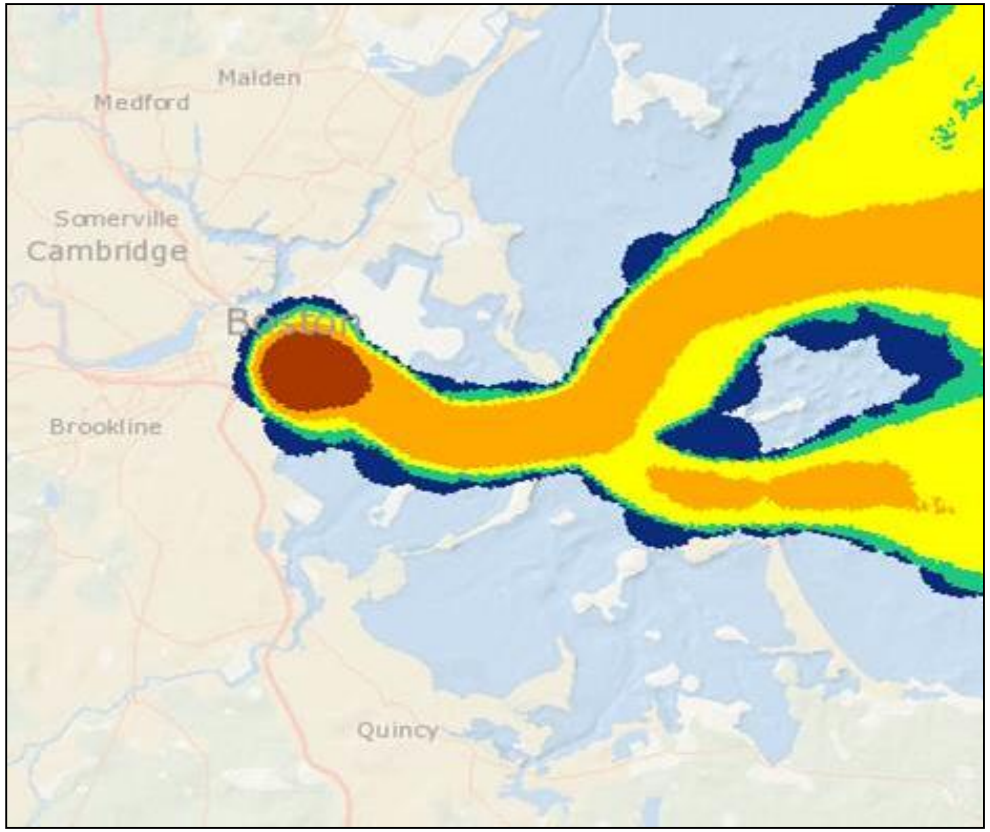


All Vessel Density

Ferry Routes

Commercial Fishing

- 14 million pounds commercial fish, worth $16.2 million, landed in 2015 in Boston Harbor
- Commercial finfishing does not generally occur within Boston Harbor due to shipping activity and shallow depths
- Lobsters are commercially fished within Boston Harbor, specifically in the Main Ship Channel, Mystic River, and Chelsea River



Potential Impacts of a Barrier to Recreational and Commercial Uses

Potential Impacts to Recreational Boating

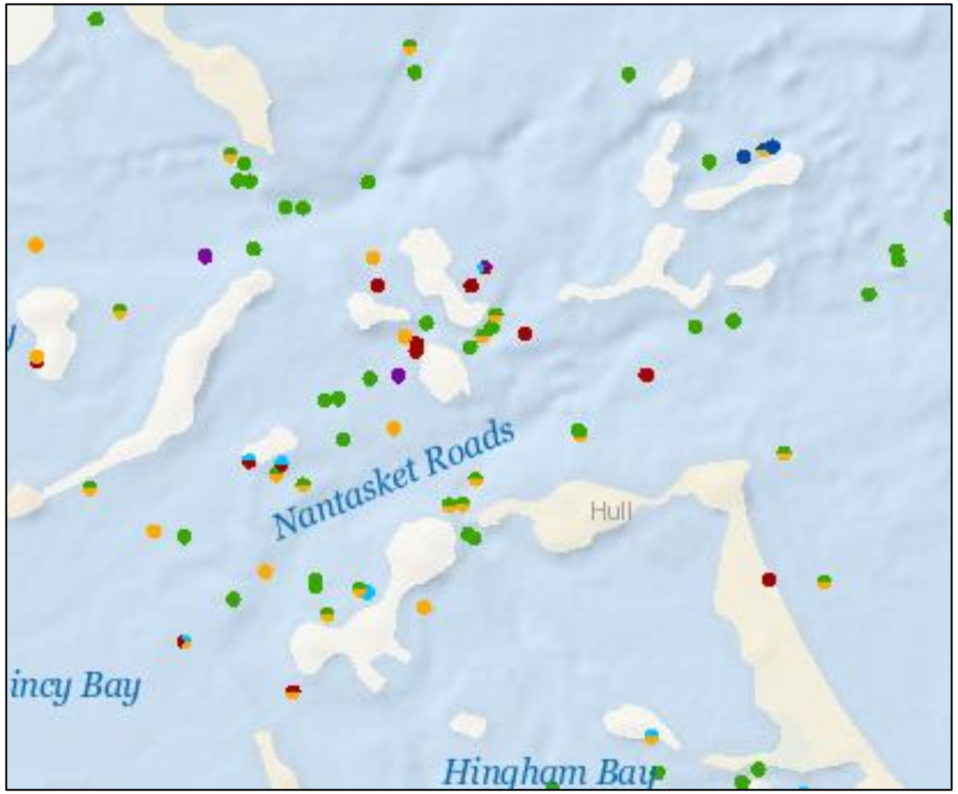
- Greater protection from storms; less turbulent conditions
- Reduce flooding and damage to docks and infrastructure
- Changes in boat routes and patterns (construction and afterwards); weaving in and out of islands
- Operational challenges: increase in water velocity
- Boating congestion (north vs. south entrance) and safety concerns
- No transit during closed barrier
- Visual impacts
- Water quality; impact to swimming/fishing

Potential Impacts to Commercial Vessels

- Greater protection from storms
- Less turbulent conditions inside harbor
- Reduce flooding and damage to docks and infrastructure
- Changes in boat routes and patterns (construction and afterwards)
- Operational challenges: increase in water velocity
- Boating congestion (north vs. south entrance) and safety concerns
- No transit during closed barrier
- Possible alteration of shipping lanes; may need guidance vessels for safe navigation
- Economic loss (traffic may select a different port during storms); changes in trade patterns
- Vessels in search of refuge may seek out barrier protection

Potential Impacts to Recreational Fishing

- Impacts to navigation
- Change in circulation and environmental conditions (water quality) in harbor could impact fish populations
- Potential fishing conflicts near barrier openings



Potential Impacts to Commercial Fishing

Navigation

Change in circulation and environmental conditions (water quality) in harbor could impact fish populations

Conclusions

Source: The Boston Globe

- Important to the economy and culture of the region
- Barrier designed to minimize impacts to users of Boston Harbor
  - Protect shoreside infrastructure and vessels from storm turbulence and flooding
  - Barrier openings accommodate traffic; slight impacts possible
  - No transit when barrier is closed
  - Possible changes to water flow velocities; may cause vessel congestion and safety issues
  - Possible changes to fish habitat and water quality

Source: On The Water

Economic Analysis and Comparison to Shore-Based Solutions

Paul Kirshen, Ph.D.

Professor, School for the Environment

Academic Director, Sustainable Solutions Lab

University of Massachusetts Boston

Expected Damage Descriptions

Losses avoided	Description
Buildings	The 2016 replacement cost of structure damage expected due to flooding. Building types include: single and multi-family residential, mixed use, commercial, industrial, government, and education.
Contents and Inventory	The dollar value of structure contents and inventory damaged due to flooding.
Displacement	Displacement is a function of direct physical damage and flood depth, and includes relocation costs associated with displacement.

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Caveats

- High-level, order of magnitude estimates of losses avoided
- Assessor data are not always up to date
- Planned or completed adaptation projects are not considered
- Riverine flooding not considered

Present Value Analysis for Shore-Based Solutions and Construction Timeline Scenario 1 and Effectiveness of Shore-Based Solutions Scenario A (2050-2100)

Barrier System	7 Percent Discount Rate					3 Percent Discount Rate			
	Cost Range	PV Costs	PV Benefits	Net PV	Benefit-Cost Ratio	PV Costs	PV Benefits	Net PV	Benefit-Cost Ratio
Outer Harbor Barrier	Low Estimate	$2.0 bil	$658 mil	–$1.4 bil	.33	$5.0 bil	$8.4 bil	$3.4 bil	1.69
	High Estimate	$3.0 bil	$658 mil	–$2.3 bil	.22	$7.3 bil	$8.4 bil	$1.1 bil	1.15
Inner Harbor Barrier	Low Estimate	$1.6 bil	$519 mil	–$1.1 bil	.32	$4.0 bil	$6.6 bil	$2.6 bil	1.65
	High Estimate	$2.2 bil	$519 mil	–$1.7 bil	.24	$5.4 bil	$6.6 bil	$1.2 bil	1.23

Note: The Present Value Analysis result for these eight planning scenarios assumes total effectiveness of shore-based solutions (incremental benefit of the Harbor Barrier) when flood elevations exceed the equivalent of 12 feet NAVD88 at the Boston Harbor tide gauge (4 flood event scenarios).

Source: Arcadis

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Present Value Analysis for Shore-Based Solutions and Construction Timeline Scenario 2 and Effectiveness of Shore-Based Solutions Scenario A (2070-2130)

		7 Percent Discount Rate				3 Percent Discount Rate			
Barrier System	Cost Range	PV Costs	PV Benefits	Net PV	Benefit-Cost Ratio	PV Costs	PV Benefits	Net PV	Benefit-Cost Ratio
Outer Harbor Barrier	Low Estimate	$521 mil	$41 mil	–$480 mil	0.08	$2.8 bil	$833 mil	–$2 bil	0.30
	High Estimate	$764 mil	$41 mil	–723 mil	0.05	$4.1 bil	$833 mil	–$3.3 bil	0.20
Inner Harbor Barrier	Low Estimate	$420 mil	$33 mil	–$387 mil	0.08	$2.3 bil	$680 mil	–$1.6 bil	0.30
	High Estimate	$566 mil	$33 mil	–$533 mil	0.06	$3.0 bil	$680 mil	–$2.3 bil	0.23

Note: The Present Value Analysis result for these eight planning scenarios assumes total effectiveness of shore-based solutions (incremental benefit of the Harbor Barrier) when flood elevations exceed the equivalent of 14 feet NAVD88 at the Boston Harbor tide gauge (4 flood event scenarios).

Source: Arcadis

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Comparison to Shoreline Adaptation Solutions

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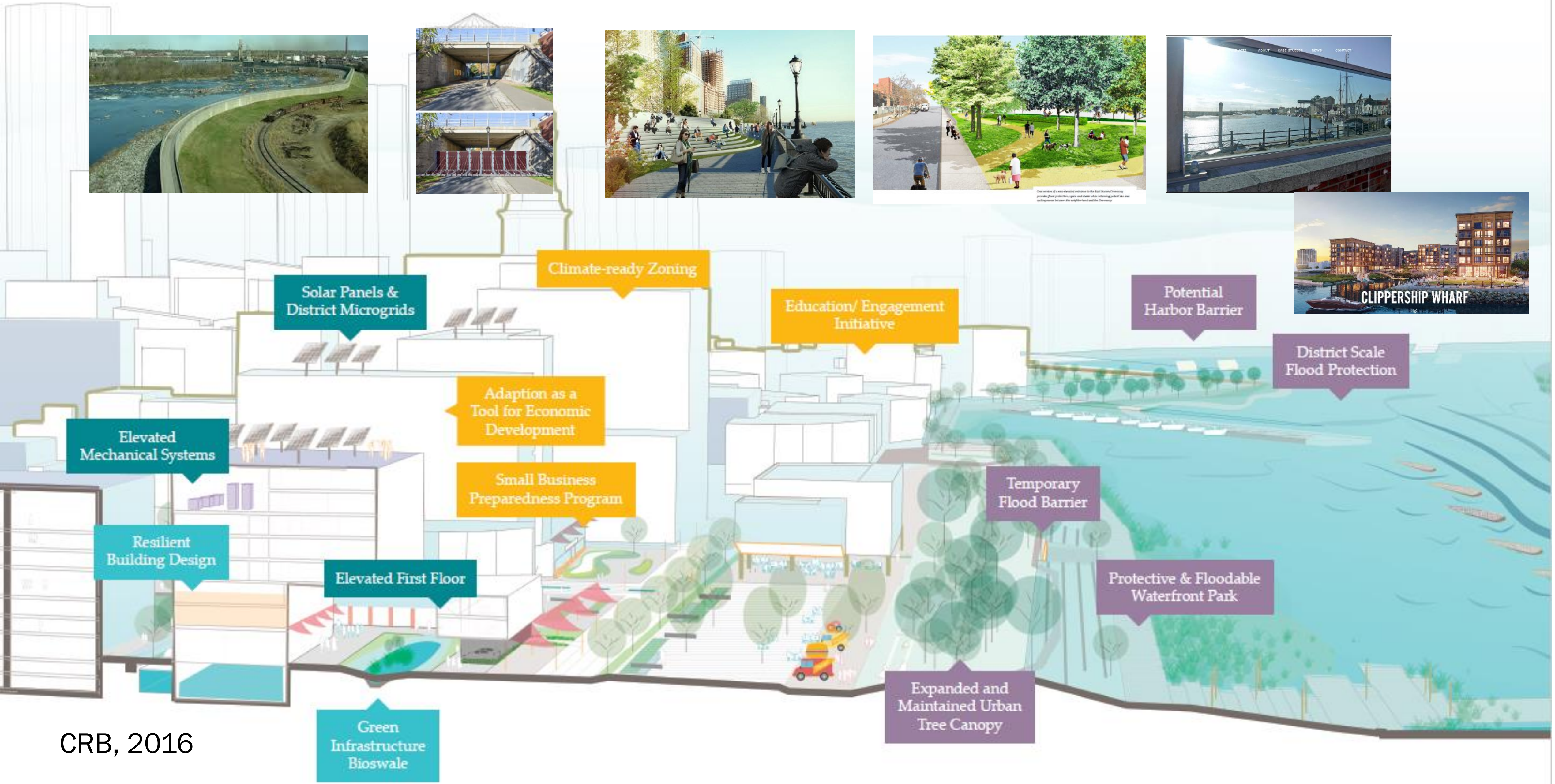
ADAPTING TO CLIMATE CHANGE

PROTECTED SHORES
PREPARED AND CONNECTED COMMUNITIES
RESILIENT INFRASTRUCTURE
ADAPTED BUILDINGS



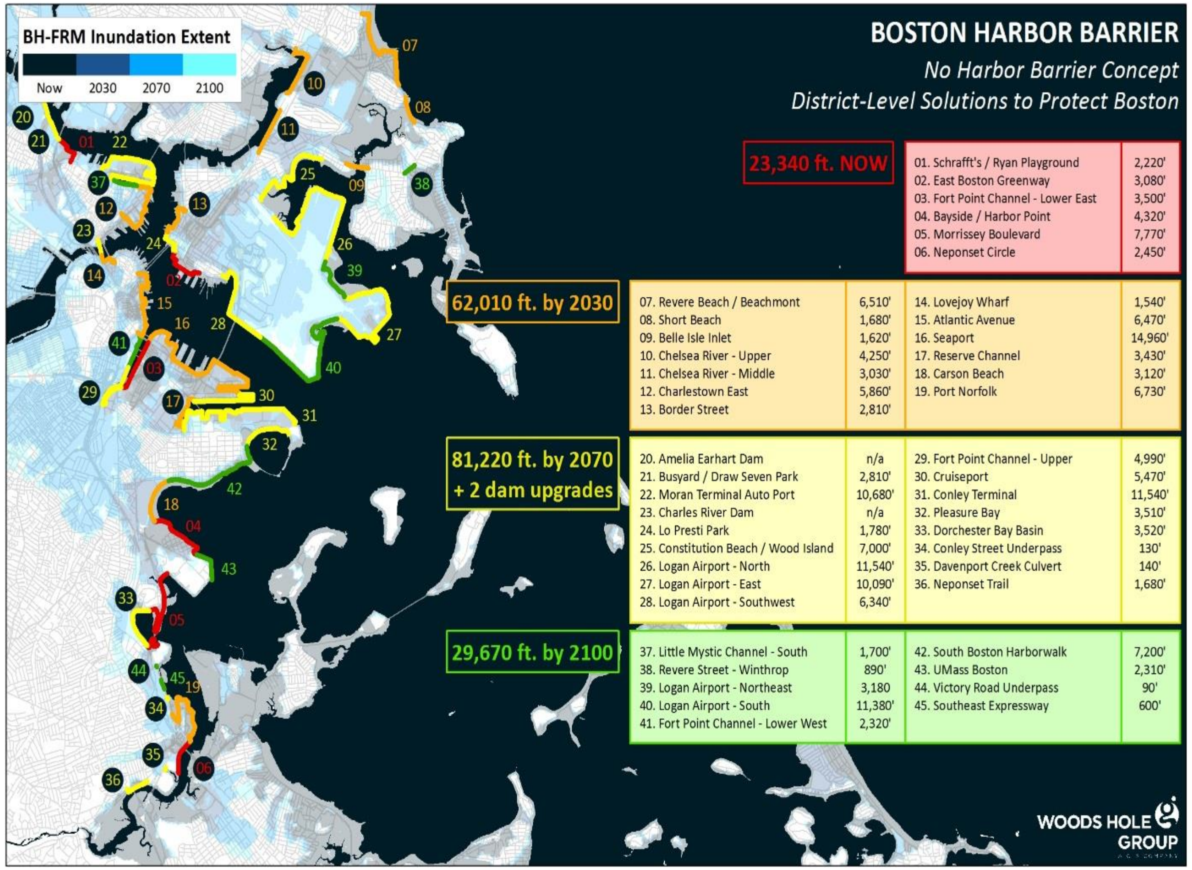
CRB, 2016

Planning Scenario

Boston develops shore-based adaption to 14 feet NAVD88 by 2070. Then either:

- Rebuilds and Expands shore-based systems to manage 2100 and beyond at cost of ~ $500 M ($2017)

- Participates in Building Outer Harbor Barrier at cost of ~$5B ($2017, half of total cost of OHB)



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Advantages of Shoreline Solutions

- Needed to manage flooding to at least 2050
- East Boston and Charlestown Shore-based Strategies
  - Benefit: Cost Ratios- 3.22-7.9 (20 years, 7 %)
- Generates Co-Benefits
- Design in Flexibility and Adaptability
- Manage Tidal or Nuisance Flooding

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Major Recommendations

“The authors recommend that the City continue to focus its climate resilience strategy for the next several decades on the shore-based multi-layered approach described in Climate Ready Boston.”

Continue to monitor climate, environmental, economic, and social changes, risk-tolerances, the continuing evolution of the technology of harbor-wide barriers, and the global experience with existing harbor-wide barrier systems to determine if the feasibility of a harbor-wide barrier should be reexamined at some point in the future.

Determine if shore-based solutions being implemented in Boston and adjacent cities can be effective for the remainder of the century and/or beyond 2100.

Undertake strong greenhouse gas mitigation actions with many others to lessen the rate of climate change.

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Moderated Discussion

Moderator: **Joe Famely,** *Woods Hole Group*

Panelists:

- **Austin Blackmon,** *City of Boston*
- **Kirk Bosma,** *Woods Hole Group*
- **Bob Chen,** *UMass Boston*
- **Di Jin,** *Woods Hole Oceanographic Institution*
- **Paul Kirshen,** *UMass Boston*
- **Kimberly Starbuck,** *UMass Boston*