

# Nuisance flooding in New England and effects on groundwater salinity

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What is nuisance flooding?

# Nuisance flooding

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**Tidal flooding/sunny day flooding/nuisance flooding** is the inundation of coastal areas during exceptionally high tides, without the aid of winds or precipitation.



What is nuisance flooding?

# Nuisance flooding: Known and unknown impacts

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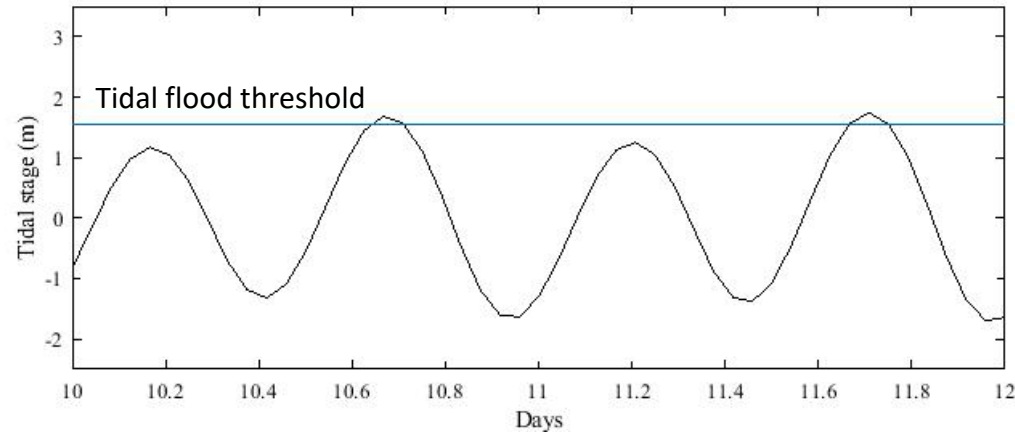
What causes nuisance flooding?

# Background: The importance of tides

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2 days

Tidal stage in Boston, MA

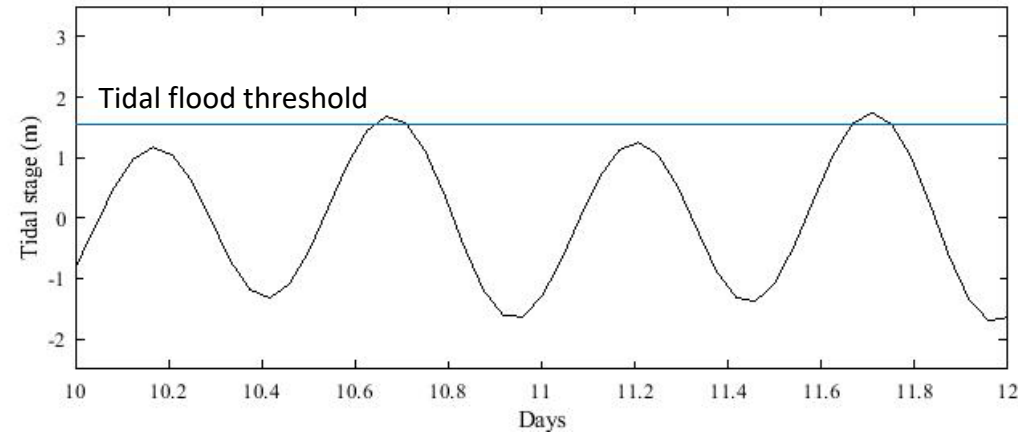


What causes nuisance flooding?

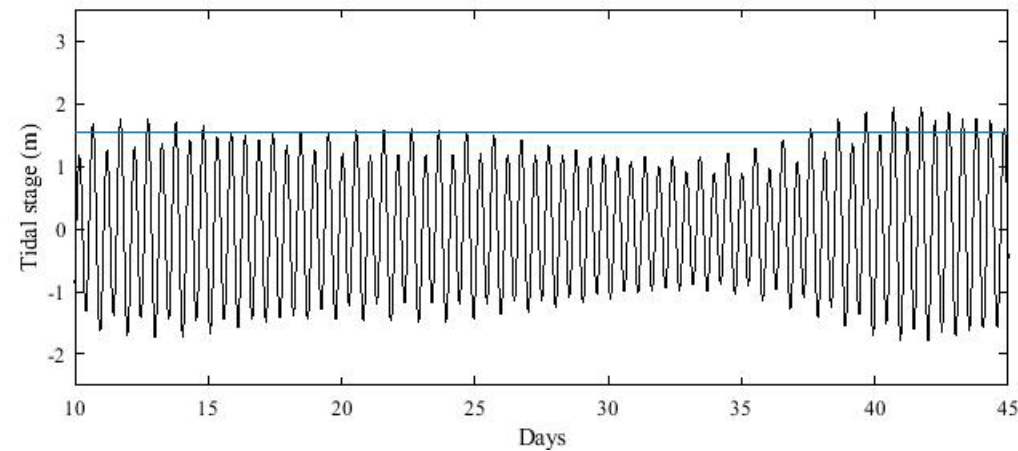
# Background: The importance of tides

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Tidal stage in Boston, MA



2 days



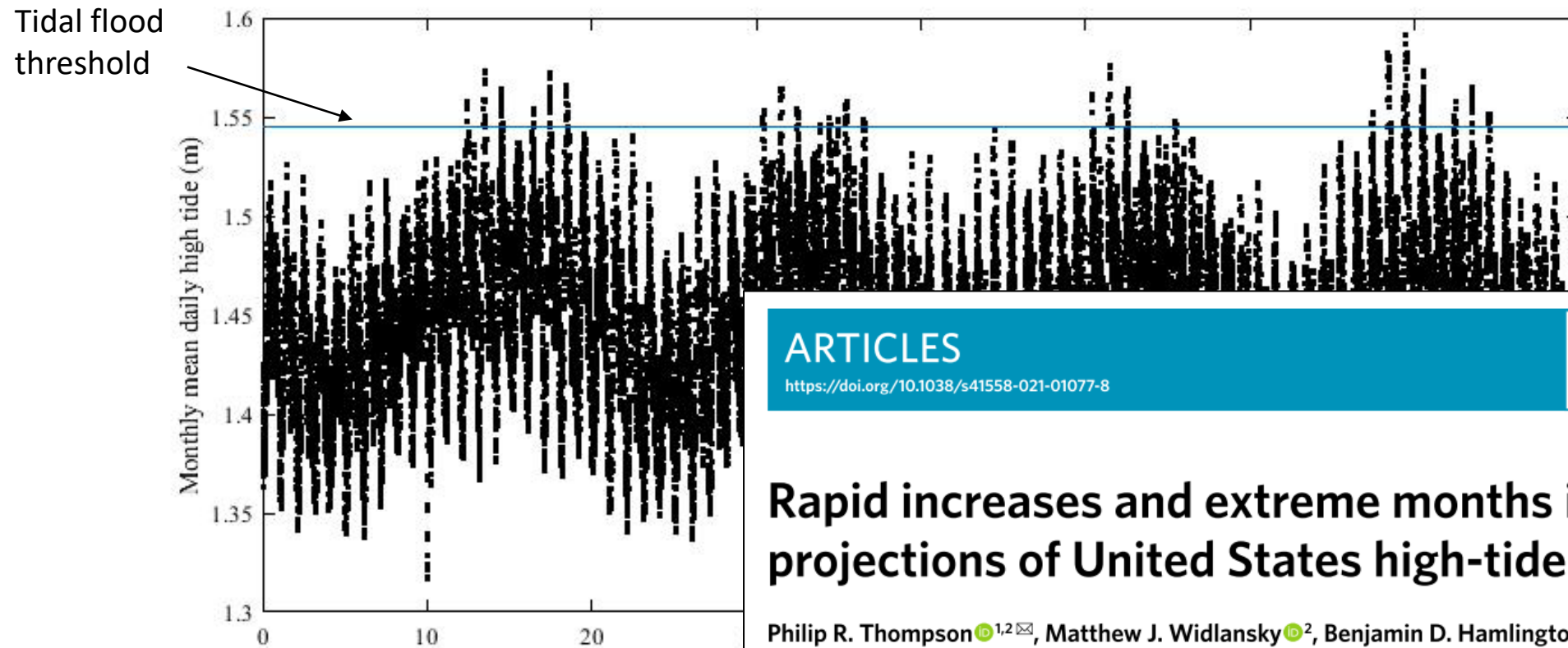
35 days



What causes nuisance flooding?

# Background: The importance of tides

Monthly mean high tide level: Boston, MA



ARTICLES

<https://doi.org/10.1038/s41558-021-01077-8>

nature  
climate change

Check for updates

## Rapid increases and extreme months in projections of United States high-tide flooding

Philip R. Thompson<sup>1,2</sup>, Matthew J. Widlansky<sup>2</sup>, Benjamin D. Hamlington<sup>3</sup>, Mark A. Merrifield<sup>4</sup>, John J. Marra<sup>5</sup>, Gary T. Mitchum<sup>6</sup> and William Sweet<sup>7</sup>

Coastal locations around the United States, particularly along the Atlantic coast, are experiencing recurrent flooding at high

What causes nuisance flooding?

## Background: Tidal Harmonics

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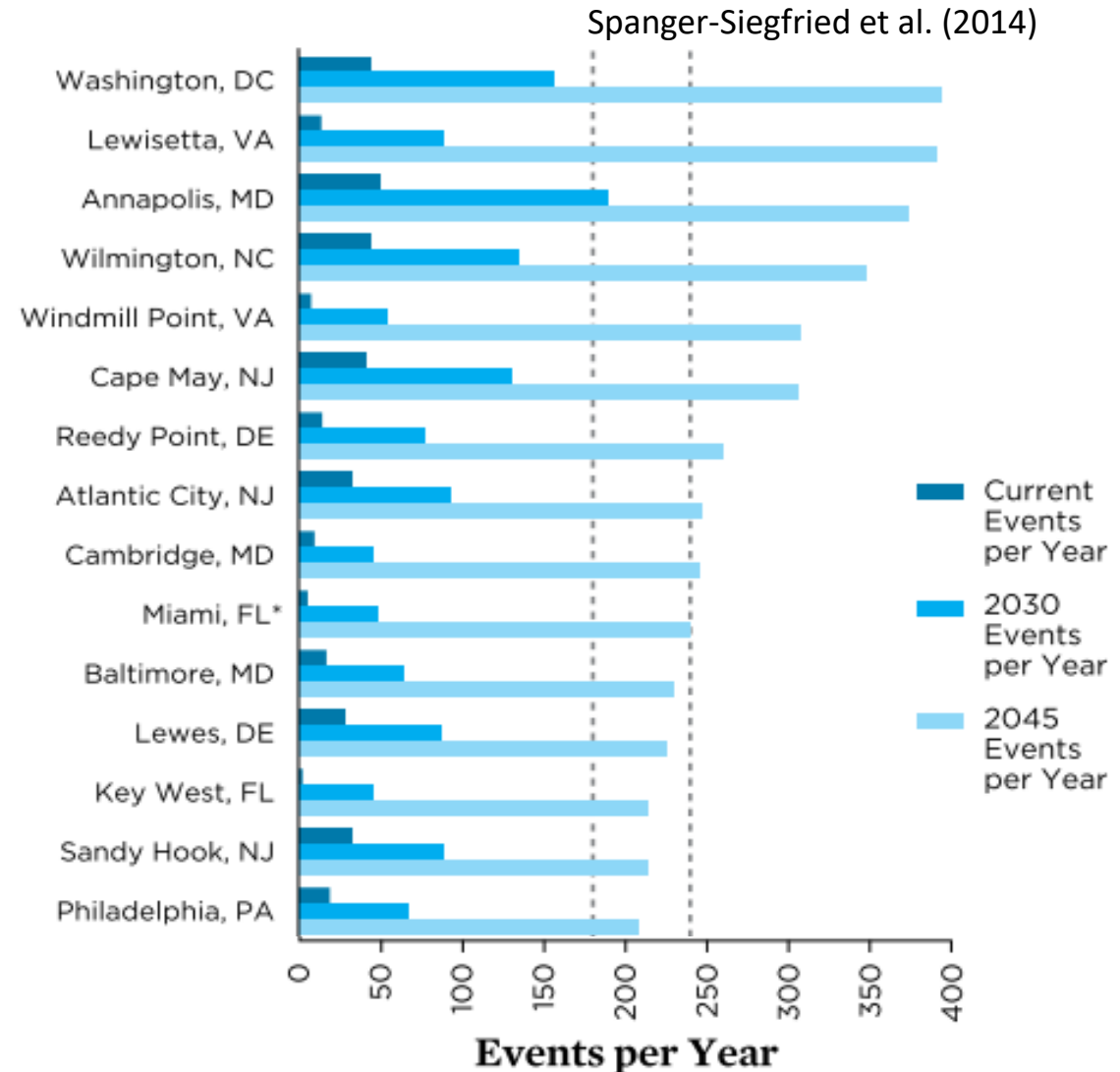
- In tidal predictions, the long and short period tides are represented by tidal constituents
- The tidal constituents represent motion of the Earth, Moon, and Sun system

# Background: Future nuisance flooding

City-by-city tidal flooding frequencies (events per year) from present day (dark blue) to 2045 (light blue)

Across board there is going to be a large increase in the frequency of these events.

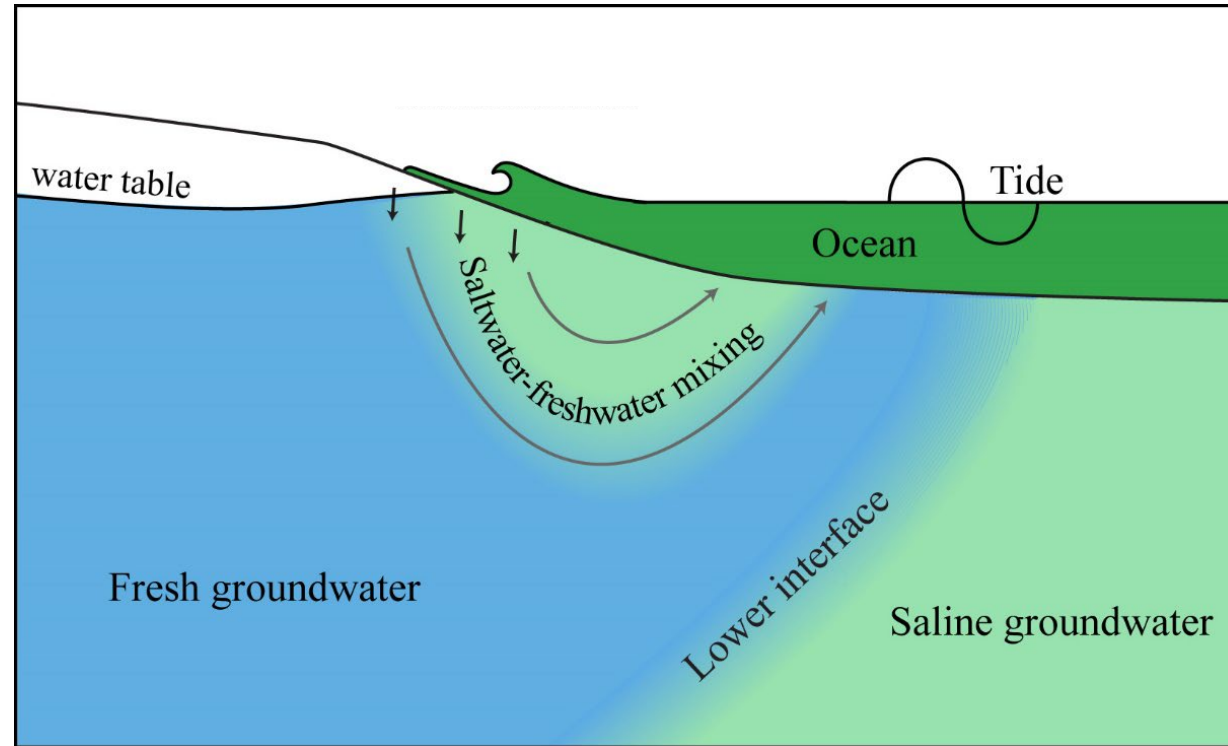
We anticipate that groundwater salinity will be strongly affected by these future events



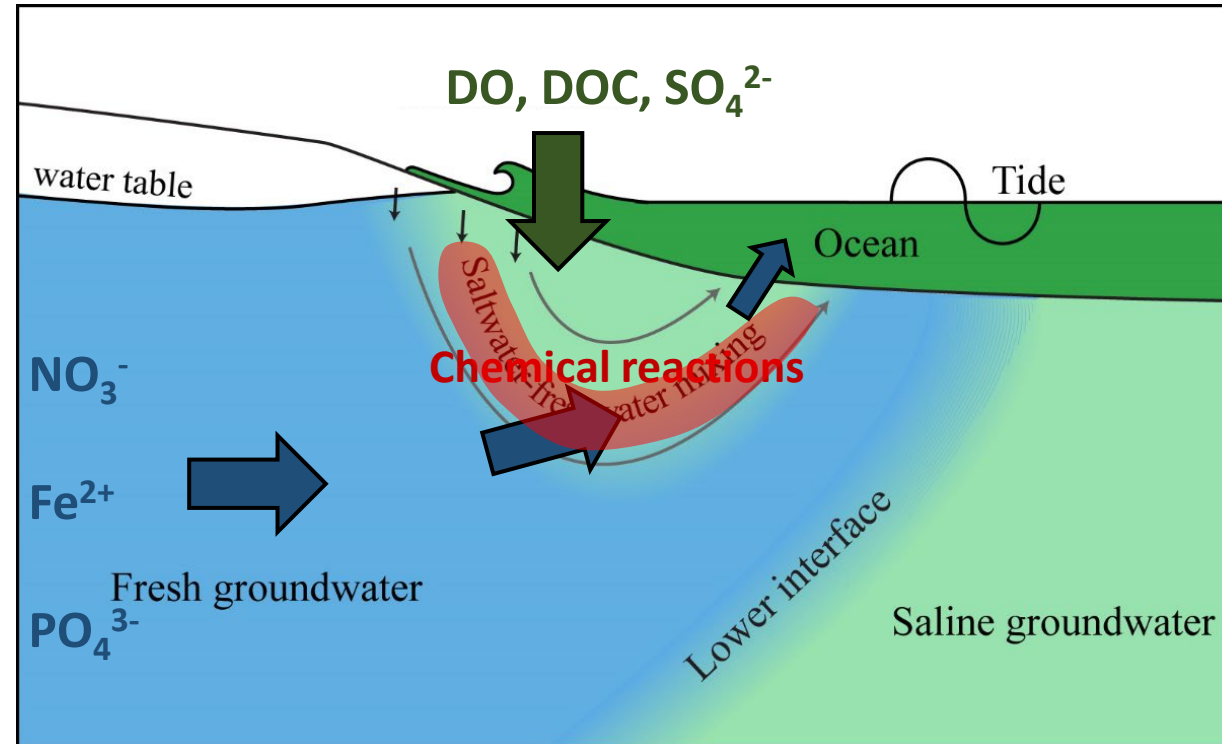


# Coastal groundwater systems

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# Coastal groundwater systems



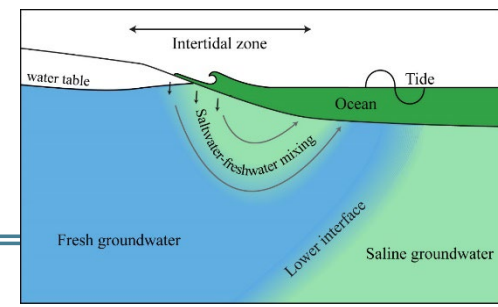
Objective: Understand aquifer responses to increases in tidal flooding frequency

# Driving research question

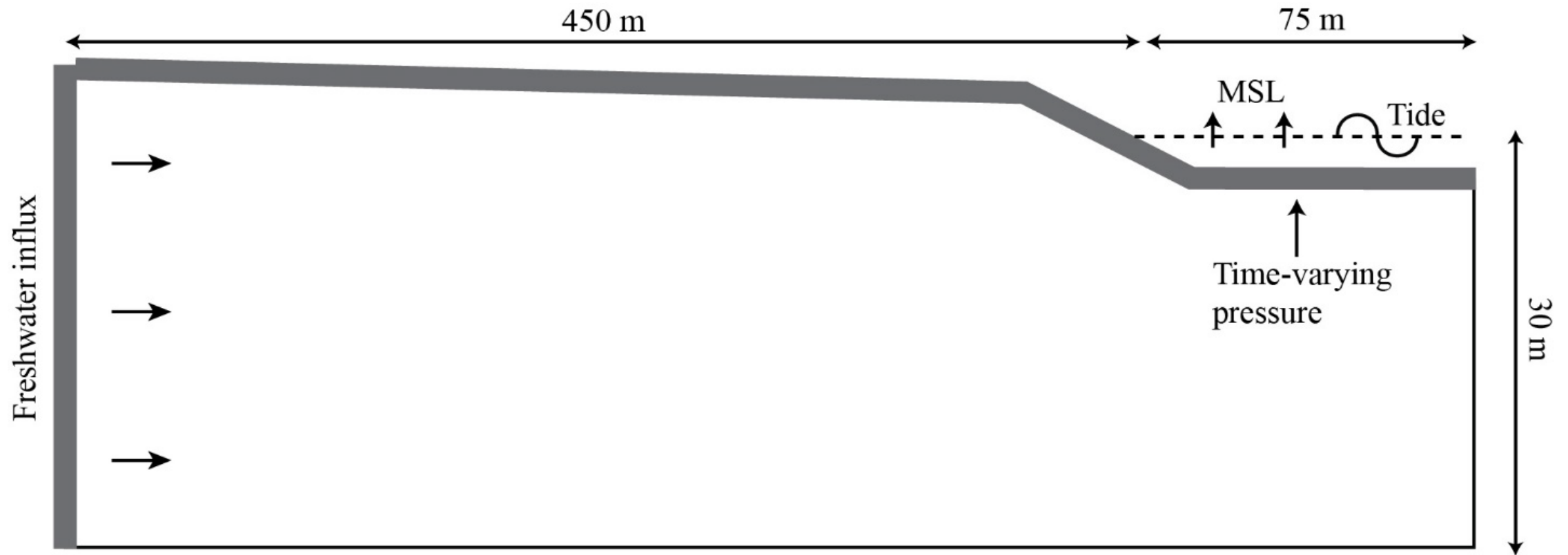
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How will salinity in coastal aquifers respond to increases in tidal flooding due to rising sea level? How sensitive are intertidal salinities to sea level rise projections?

# Groundwater flow and transport model

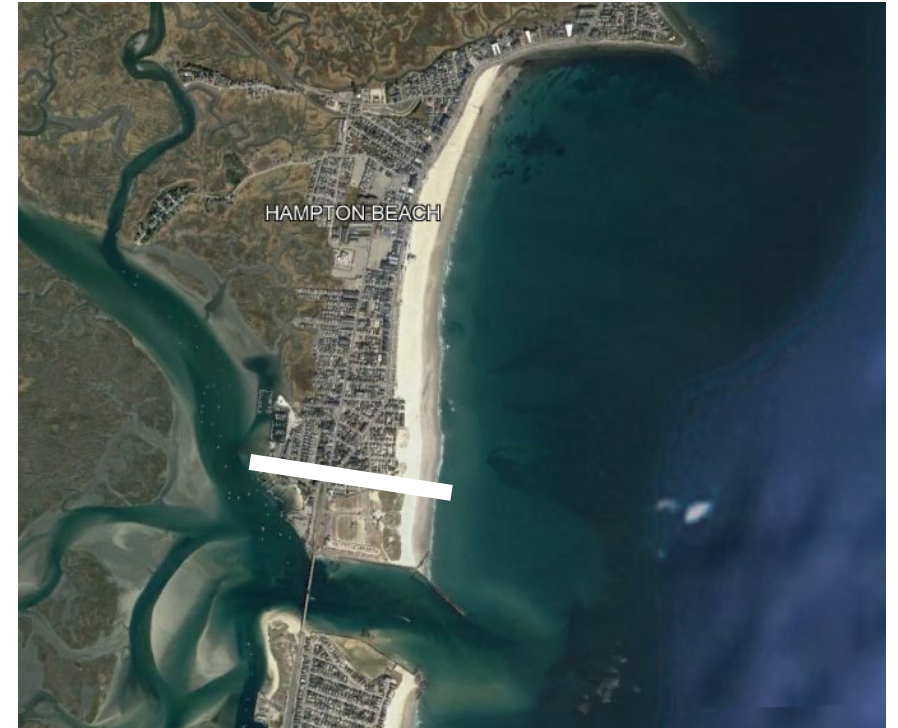


USGS SUTRA code for variably-saturated variable-density groundwater flow and salt transport



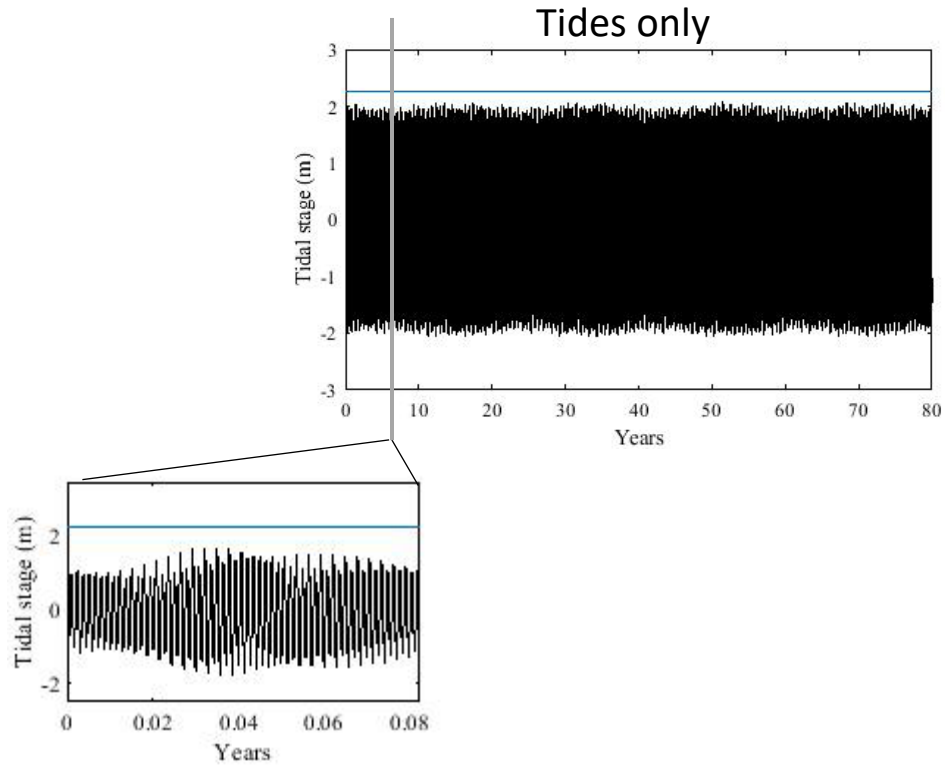
# Hampton Beach, NH topographic slope

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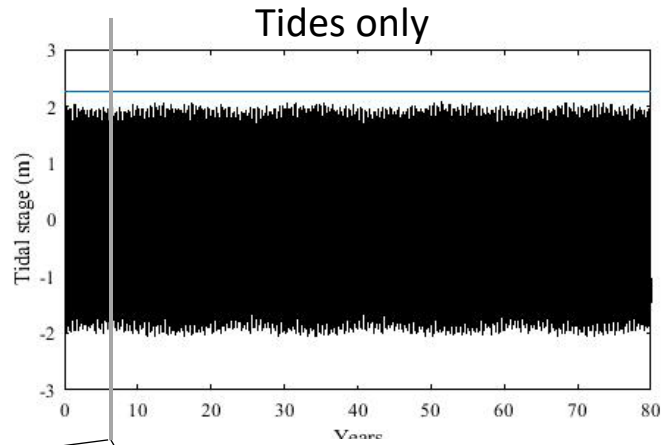


# Hampton Beach, NH; Tide+SLR

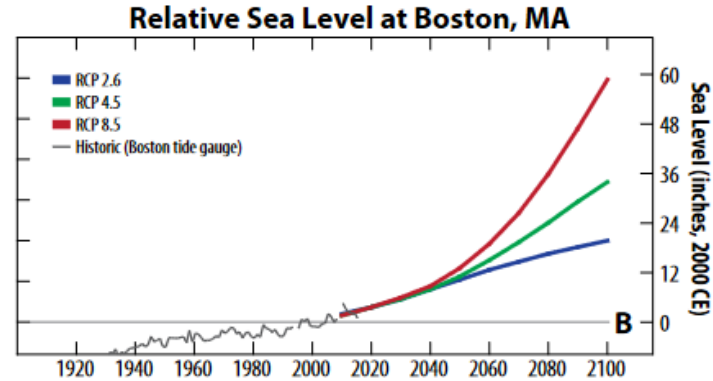
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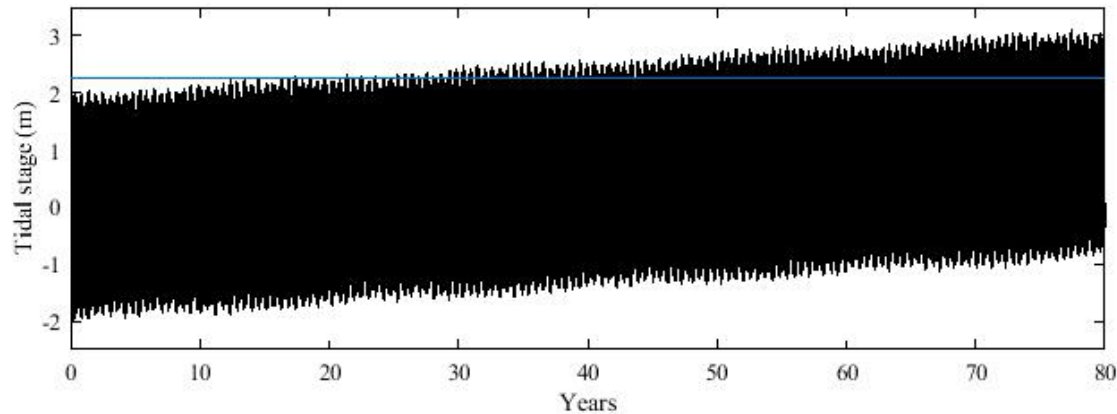
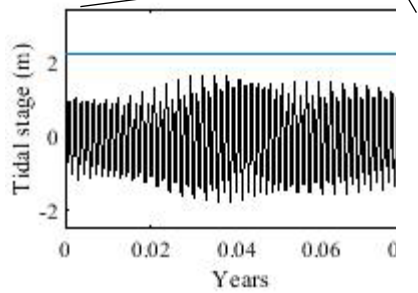
# Hampton Beach, NH; Tide+SLR



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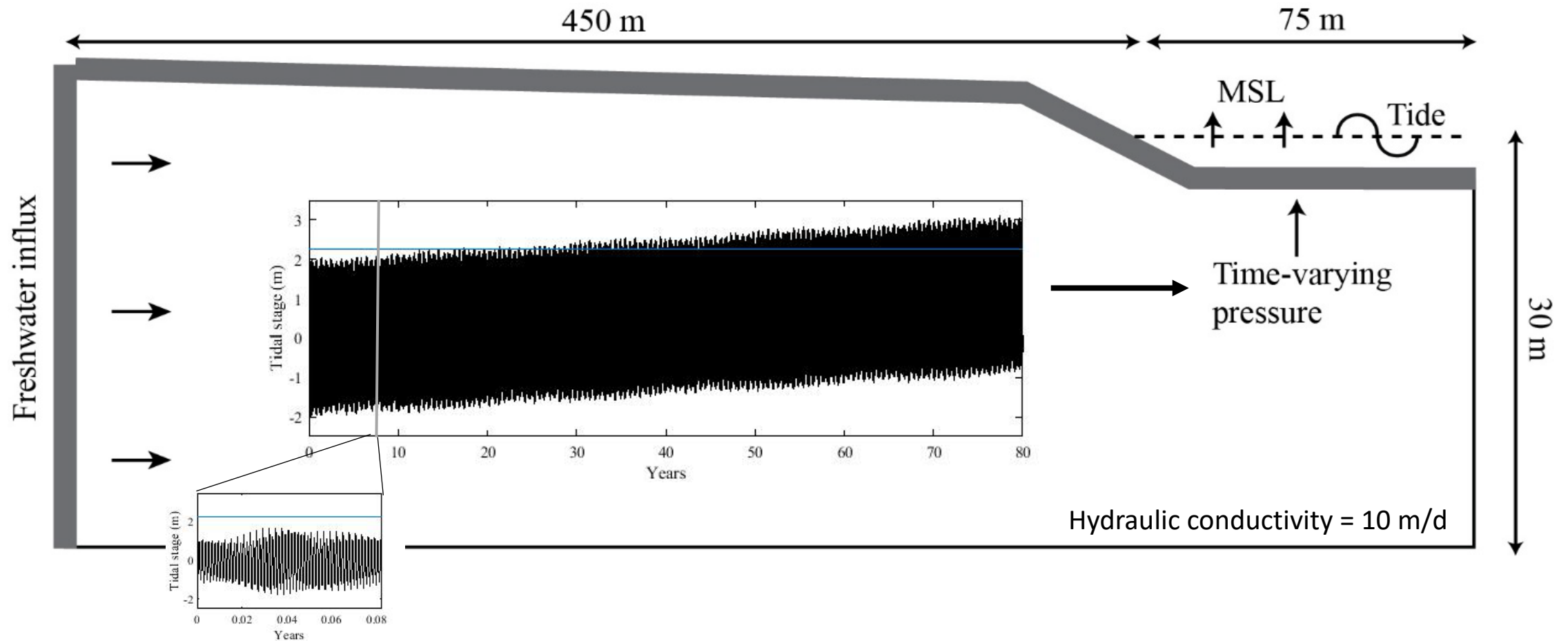
## Model scenarios:

- No SLR
- RCP 2.6 (0.85 m)
- RCP 4.5 (1.10 m)
- RCP 8.5 (1.49 m)

# Groundwater flow and transport model

**4 Model scenarios:** No SLR, RCP 2.6 (0.85 m), RCP 4.5 (1.10 m), RCP 8.5 (1.49 m)

**Temporal discretization:** 5 minute time steps to 2100

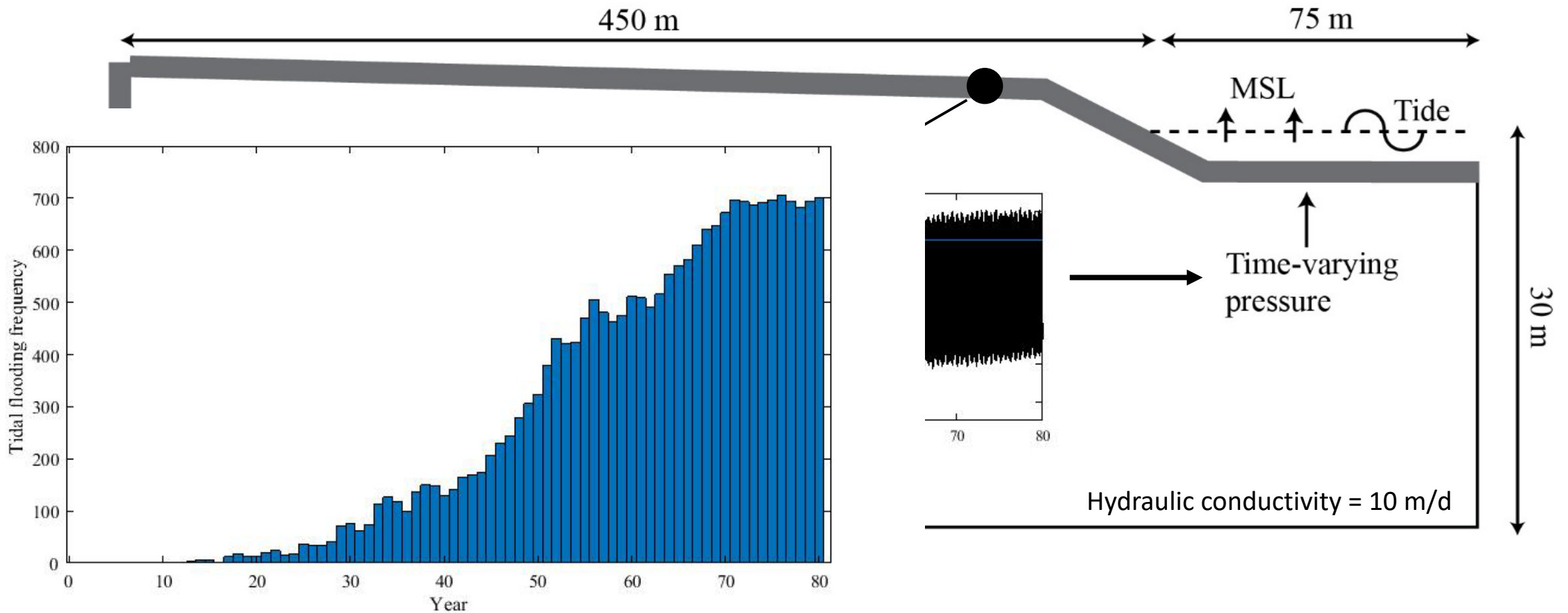




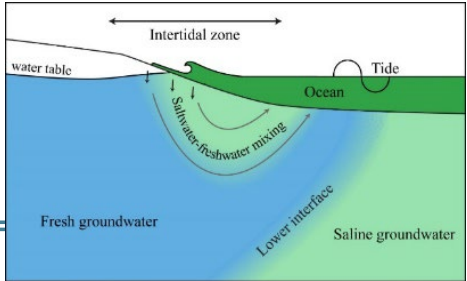
# Groundwater flow and transport model

**4 Model scenarios:** No SLR, RCP 2.6 (0.85 m), RCP 4.5 (1.10 m), RCP 8.5 (1.49 m)

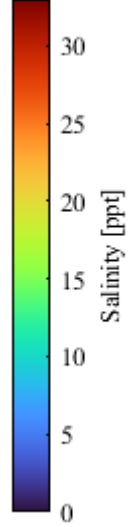
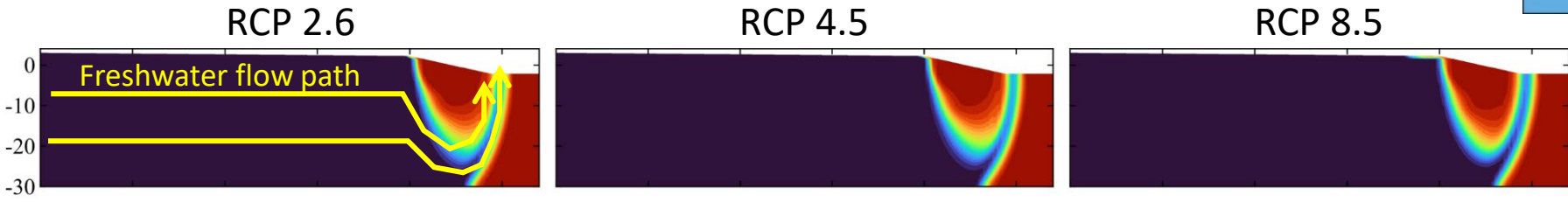
**Temporal discretization:** 5 minute time steps to 2100



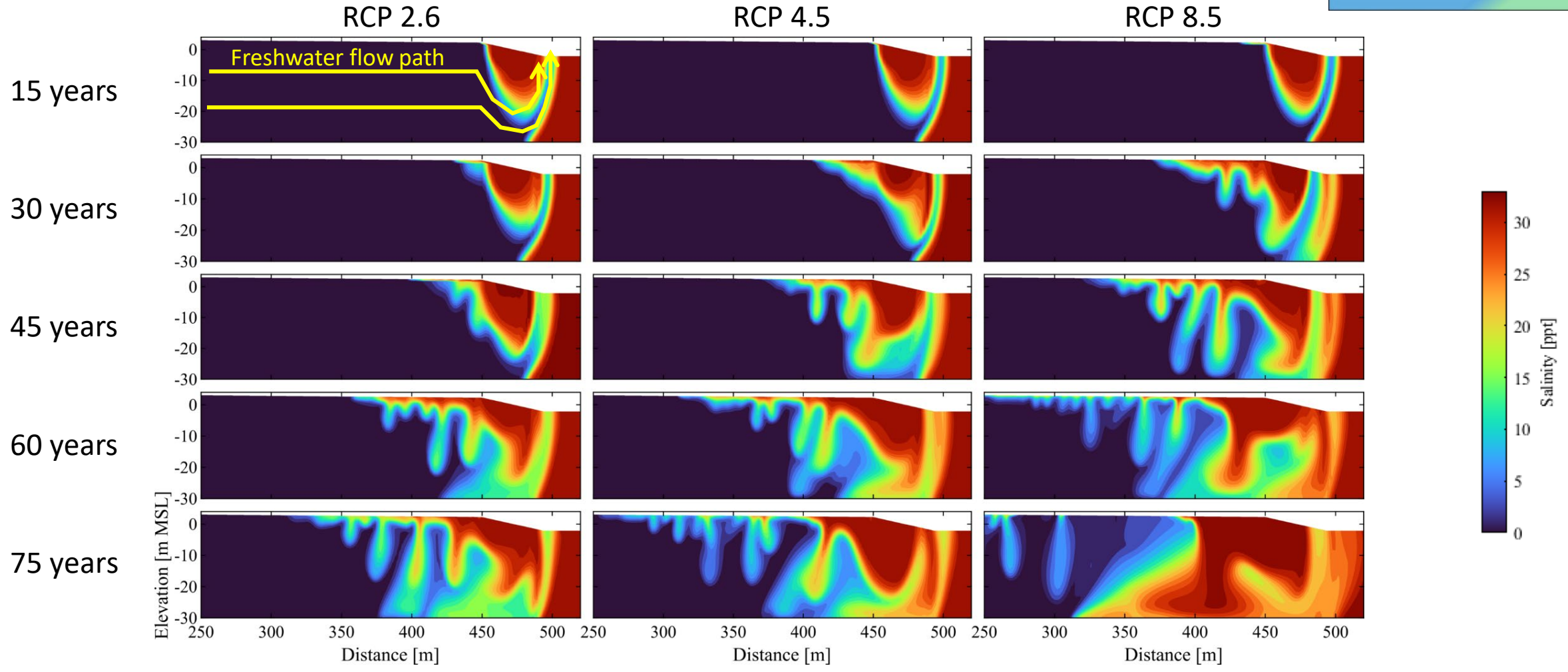
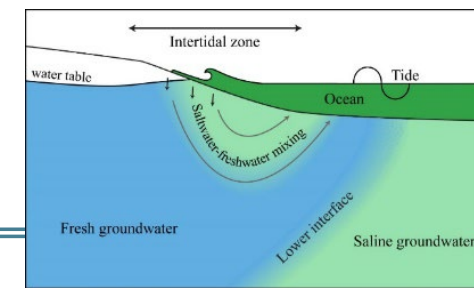
# Pore water salinity dynamics



15 years

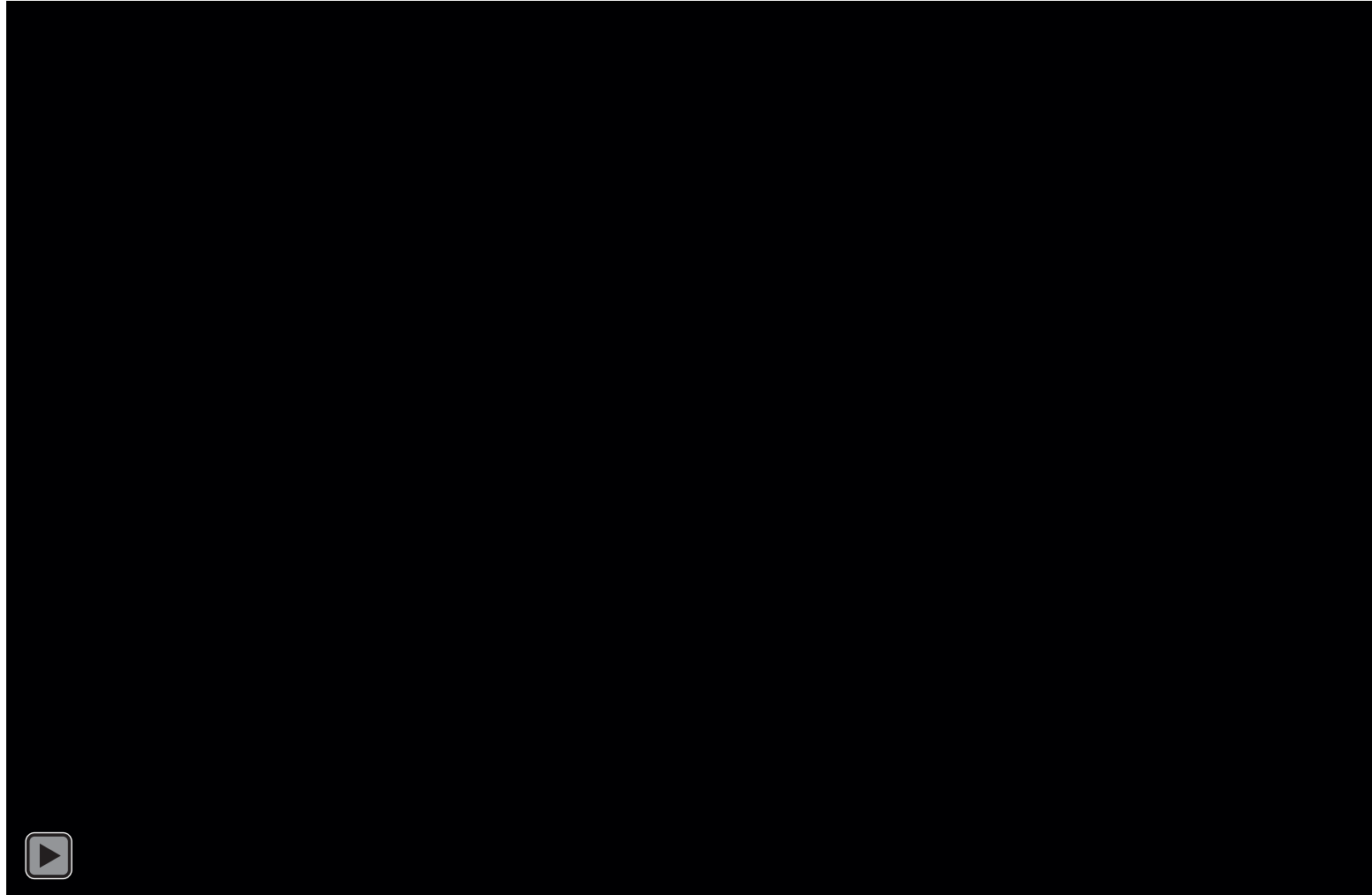


# Pore water salinity dynamics



# Pore water salinity dynamics

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RCP 4.5

Start: 2045

End: 2070

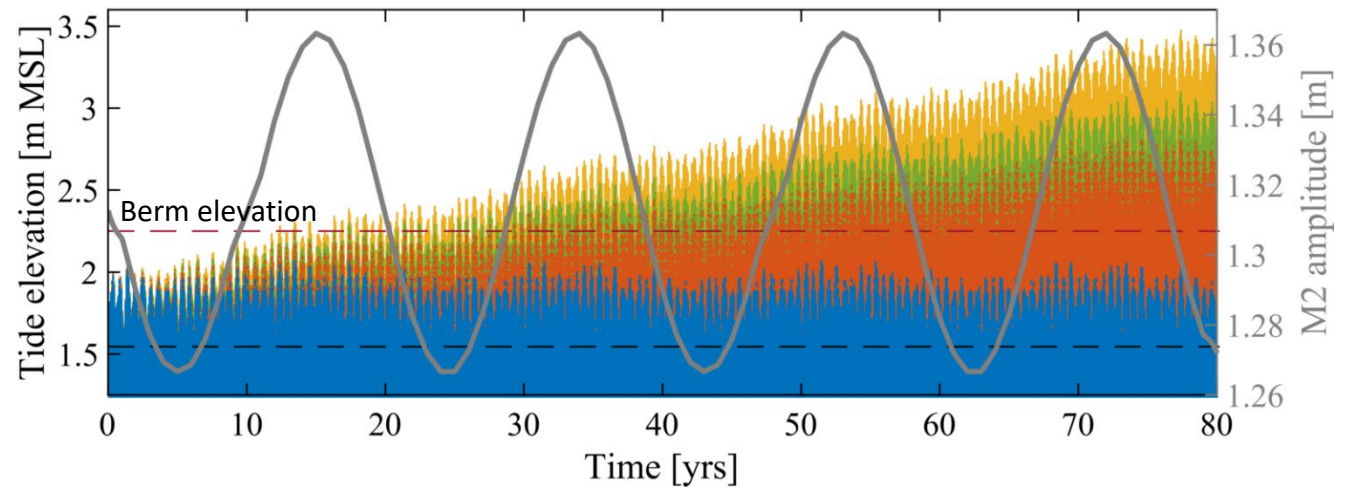
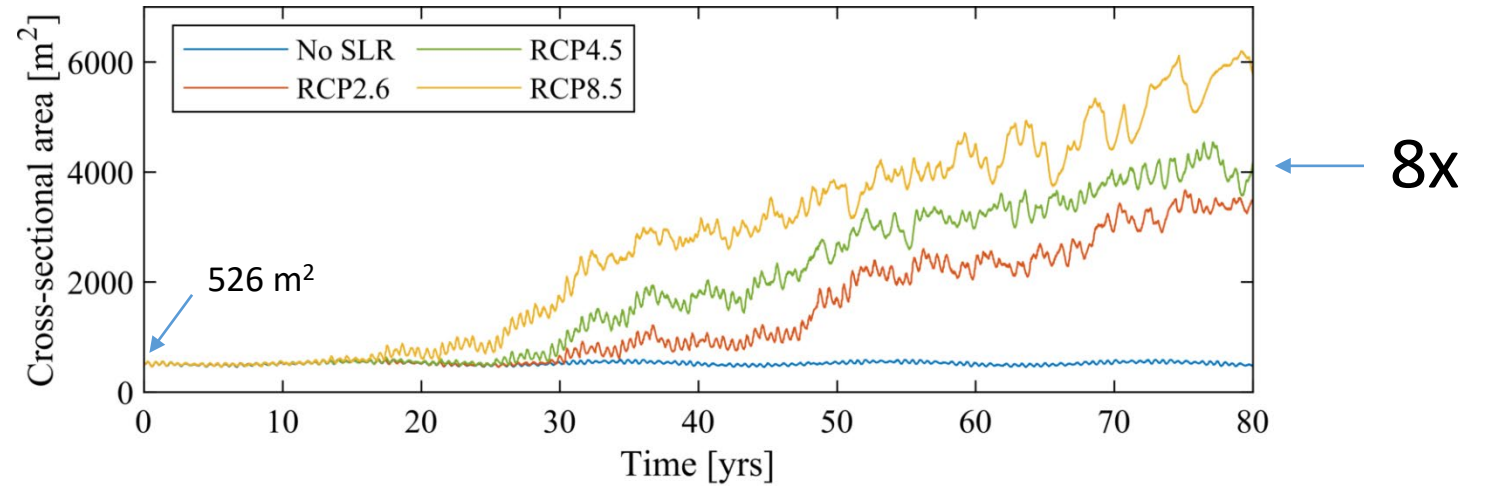
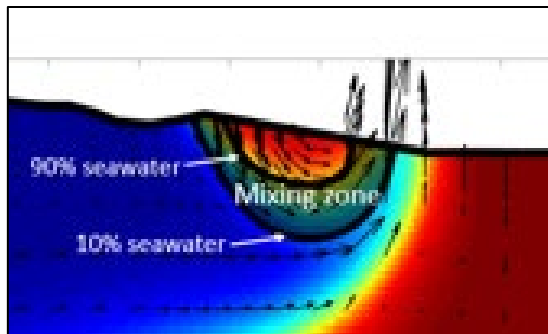
erm elevation

lean high tide

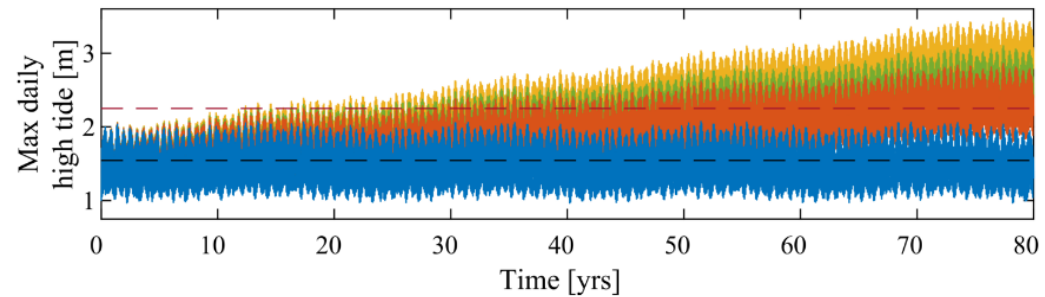
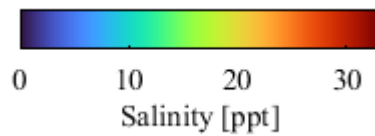
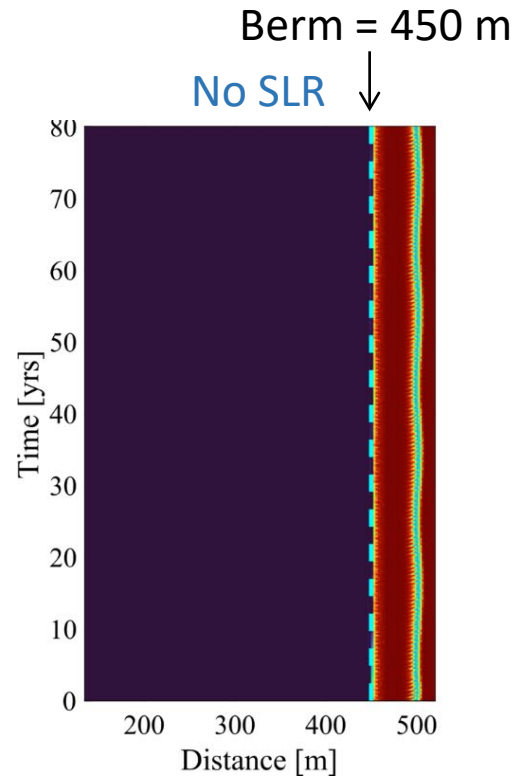
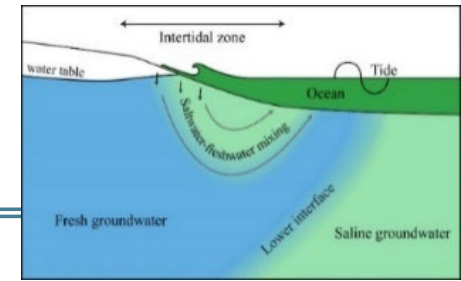
# Intertidal mixing zone size

Mixing zone growth rates:

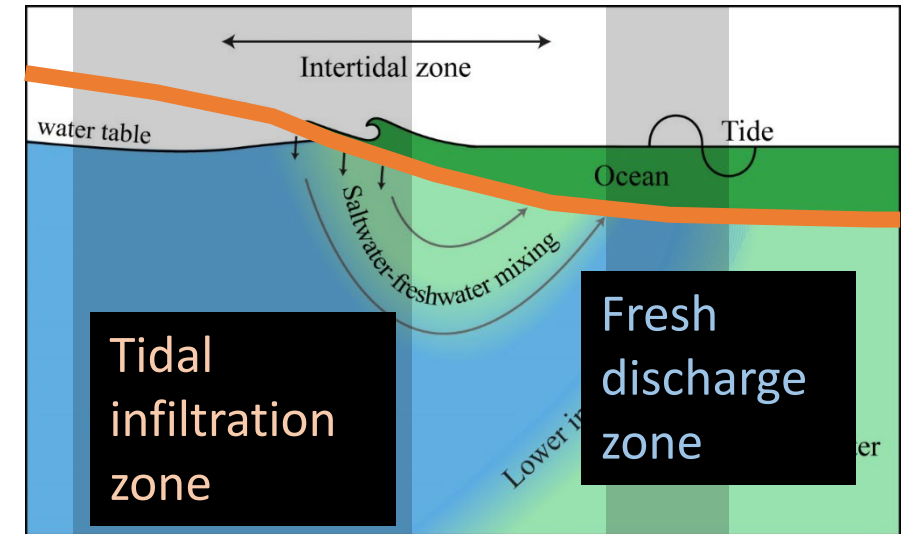
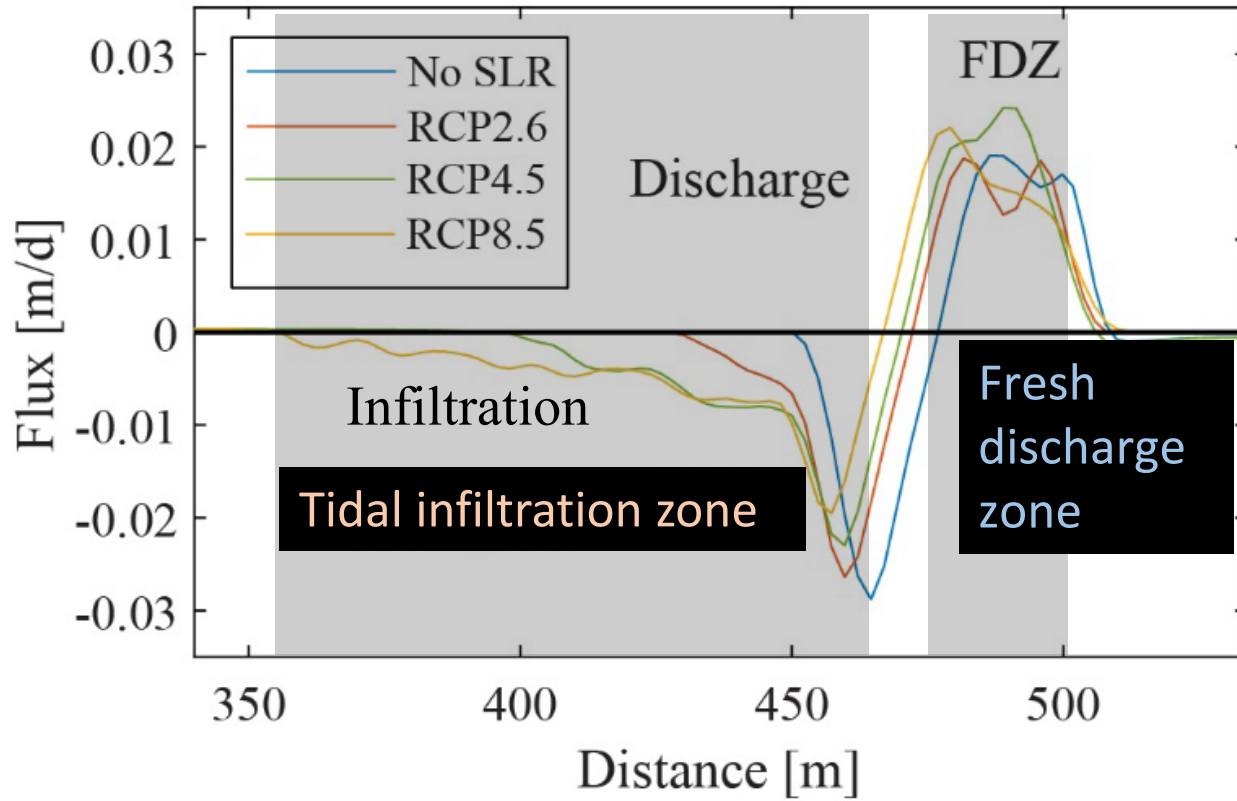
- RCP 2.6: 58 m<sup>2</sup>/yr
- RCP 4.5: 63 m<sup>2</sup>/yr
- RCP 8.5: 87 m<sup>2</sup>/yr



# Water table salinity through time

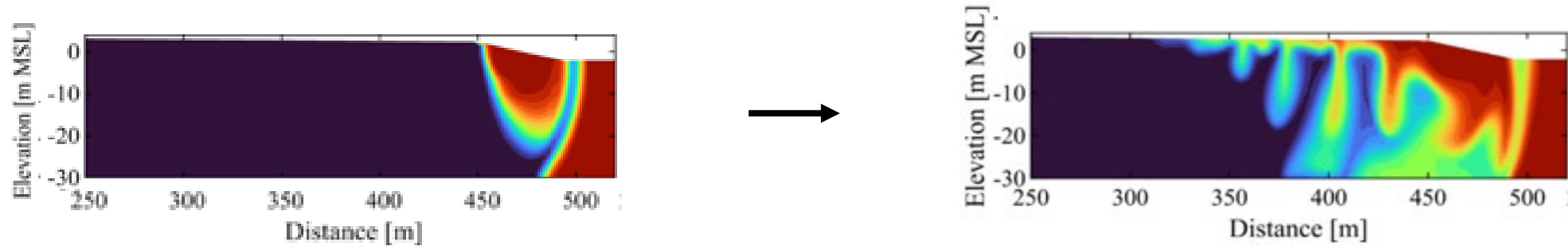


# Vertical fluid exchange



# Summary

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Model results show: Increased tidal flooding due to sea level rise disrupts intertidal mixing patterns over decadal time scales and leads to an 8 fold increase in the size of the saltwater-freshwater mixing zone.

Implications for biogeochemical processes and material fluxes to coastal ecosystems



# Moving forward

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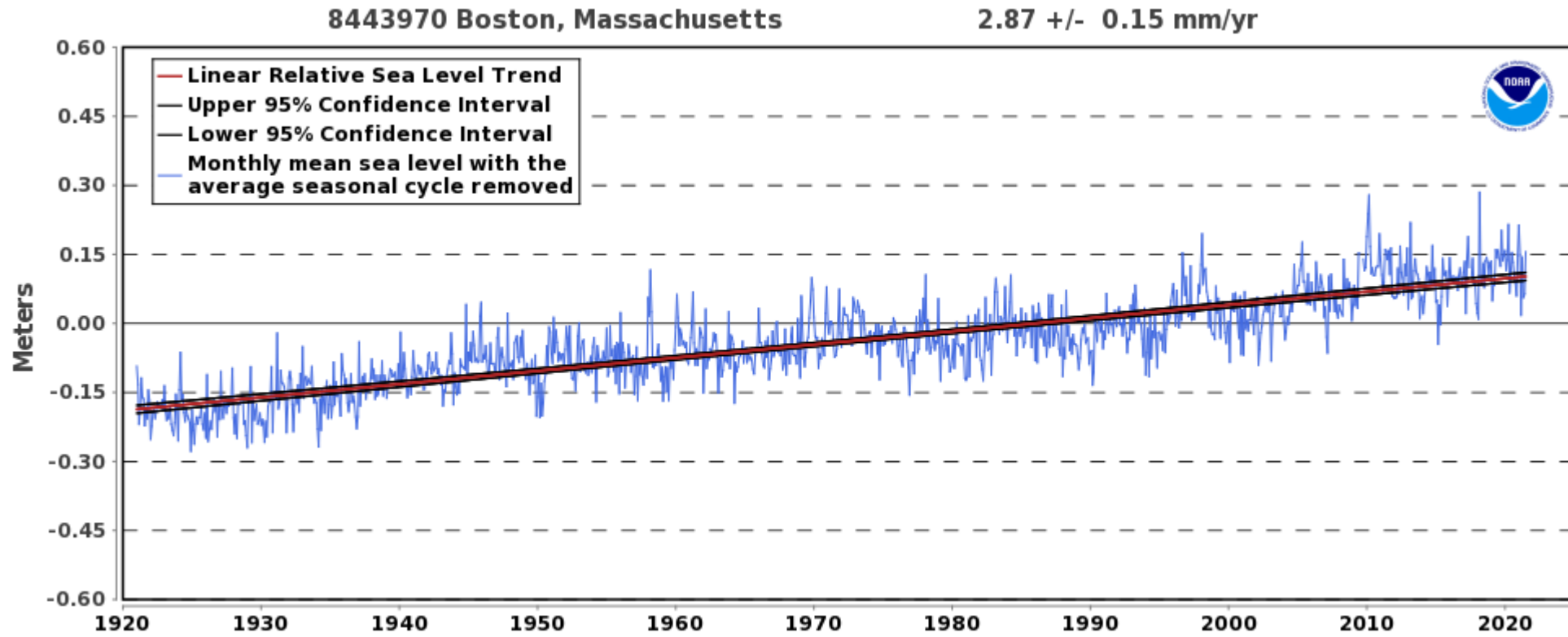
- These results are based on models that simplify the real-world
- Observe aquifer responses in the field



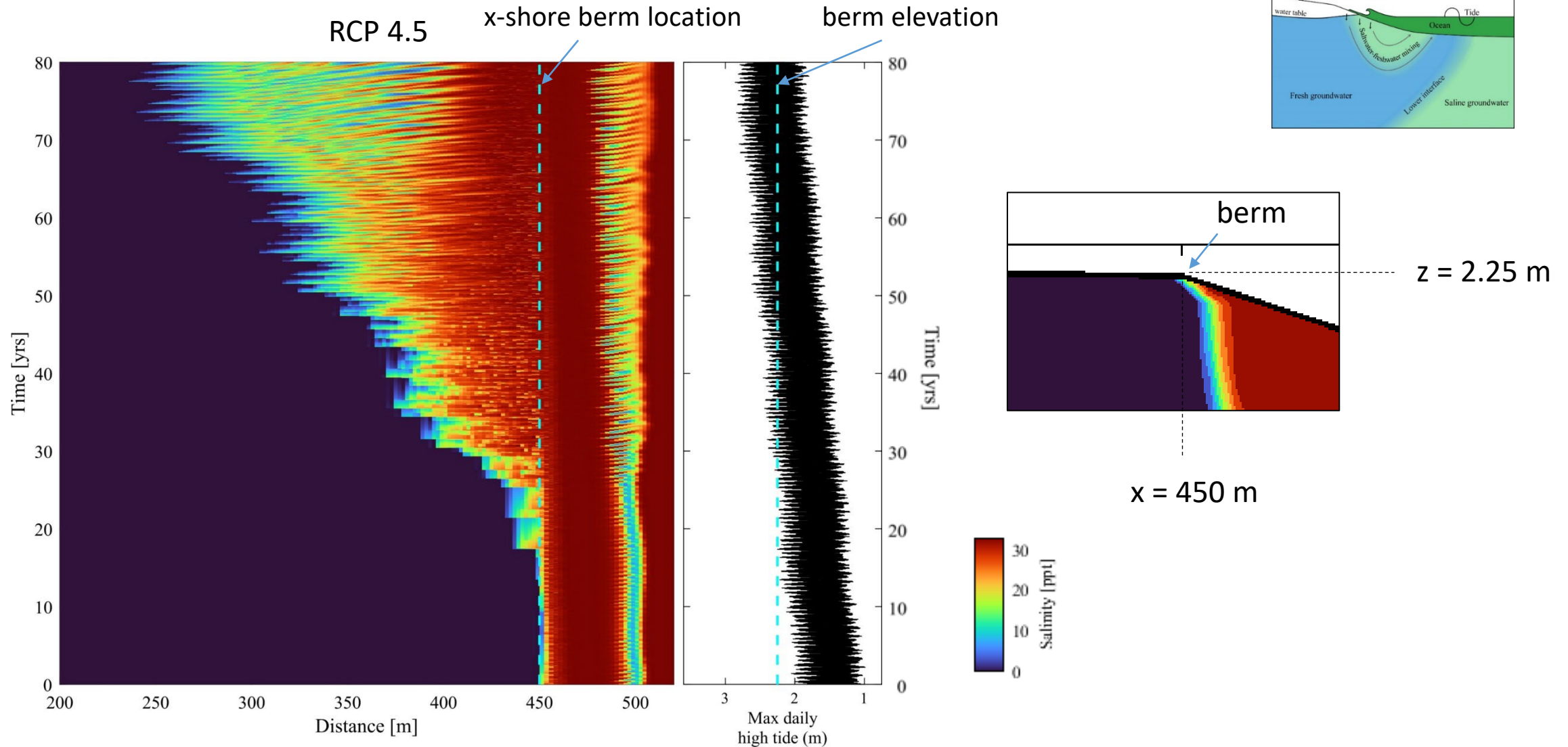
What causes tidal flooding?

# Boston, MA Sea Level Rise

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# Water table salinity through time





# A Watershed Approach to Environmental Restoration and Preservation on a Changing Coast

SNEP 2022

Elisabeth Cianciola

# What is an In-Lieu Fee Program (ILFP)?

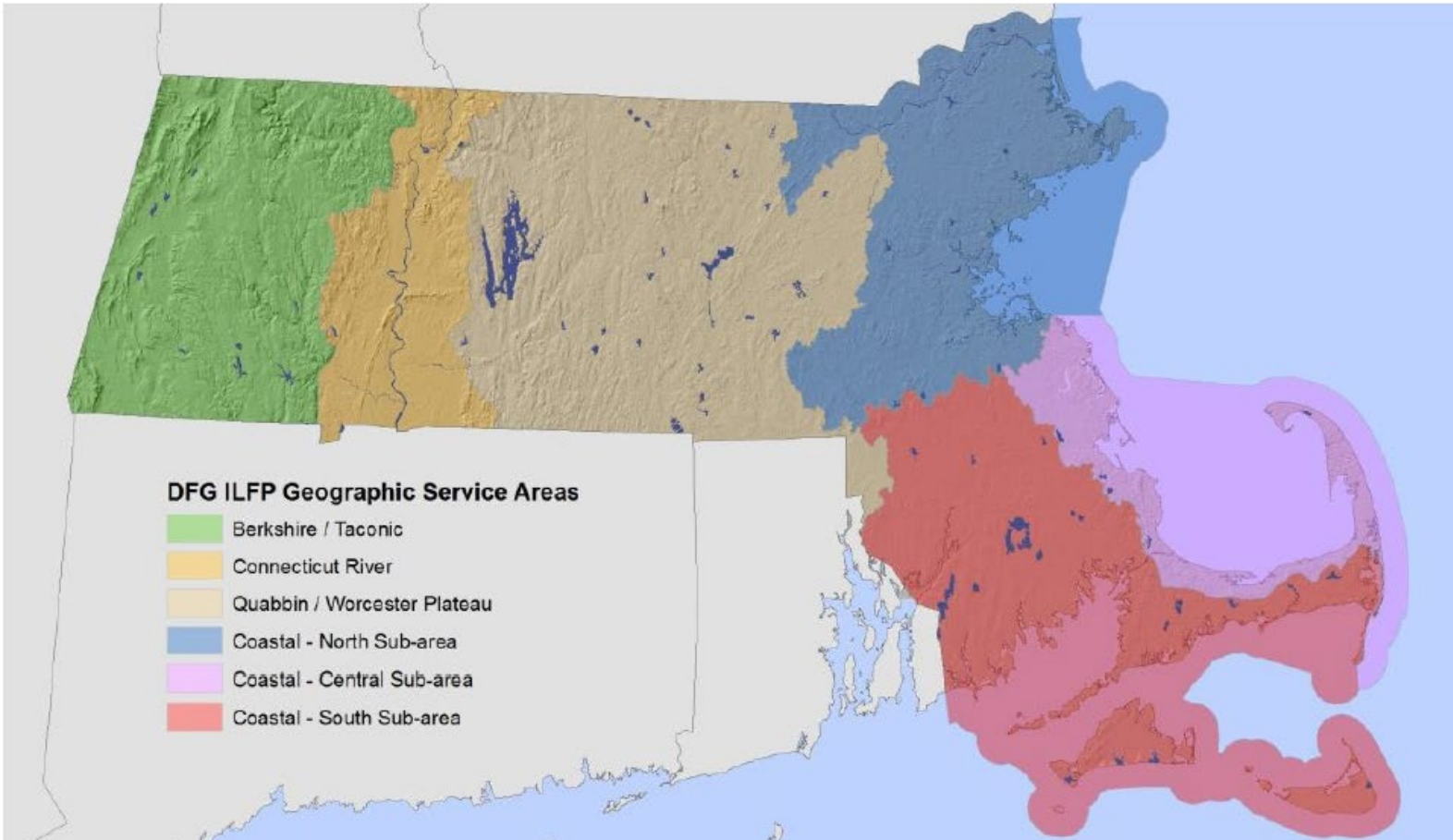
- Under Section 404 of the Clean Water Act, the Army Corps of Engineers requires compensatory mitigation for unavoidable impacts to aquatic resources
- ILFP allows Corps permittees to make payment rather than mitigate onsite
  - Payment only allowed for impacts remaining after avoidance and minimization
  - Corps decides whether onsite or in-lieu fee mitigation is appropriate
  - ILFP Sponsor uses payments to fund mitigation projects
    - *Can take the form of preservation, enhancement, rehabilitation and restoration projects*

**TABLE C1 – RECOMMENDED COMPENSATORY MITIGATION RATIOS  
FOR DIRECT PERMANENT IMPACTS TO WETLANDS<sup>1</sup>**

<b>Mitigation</b> <b>Impacts</b>	<b>Restoration<sup>2</sup></b> <b>(re-establishment)</b>	<b>Creation</b> <b>(establishment)</b>	<b>Rehabilitation<sup>3</sup></b>	<b>Preservation</b> <b>(protection/ management)</b>
<b>Emergent Wetlands</b>	1:2 <sup>4</sup>	1:3	1:5 if hydrology 1:10 if vegetation	1:20
<b>Scrub-shrub Wetlands</b>	1:2	1:3	1:5 if hydrology 1:10 if vegetation	1:20
<b>Forested Wetlands</b>	1:2	1:4	1:5 if hydrology 1:10 if vegetation	1:20
<b>Vernal Pools</b>	Use the same ratios as above for the pool itself <b>plus</b> , when pool is to be eliminated: high rated VP: PRM = preservation of 5 pools and their life zone moderate rated VP: PRM = preservation of 3 pools and their life zone low rated VP: PRM = preservation of 1 pool and their life zone			
<b>Upland<sup>5</sup></b>	≥10 <sup>6</sup>	N/A	project specific	1:15 <sup>7</sup>

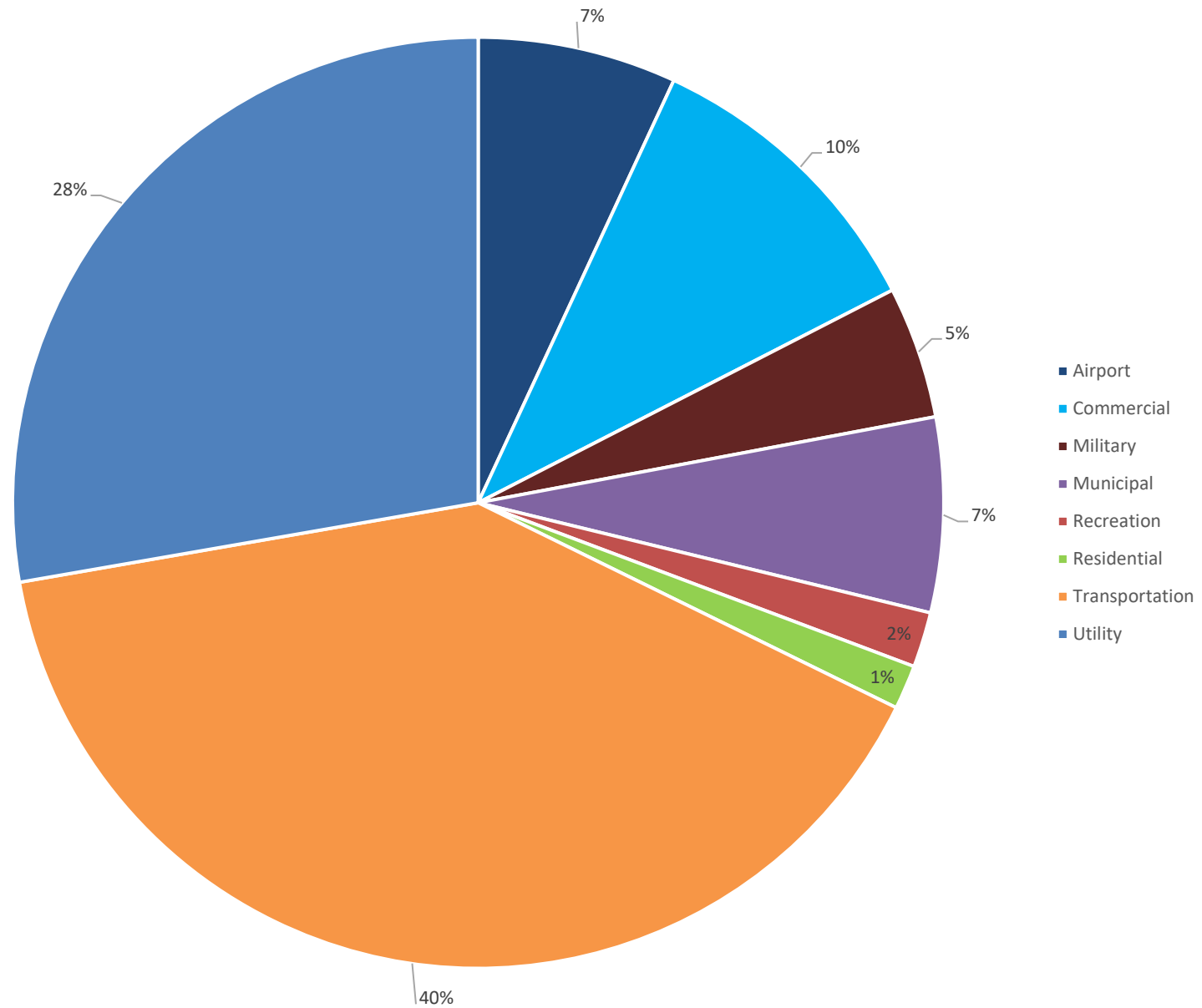
# About the MA ILFP

- Established in 2014
- Sponsor = Department of Fish and Game (DFG)
- Four service areas
  - Berkshire/Taconic
  - CT River
  - Quabbin/Worcester
  - Coastal
    - *North*
    - *Central*
    - *South*





# MA ILFP Revenue by Permittee Type



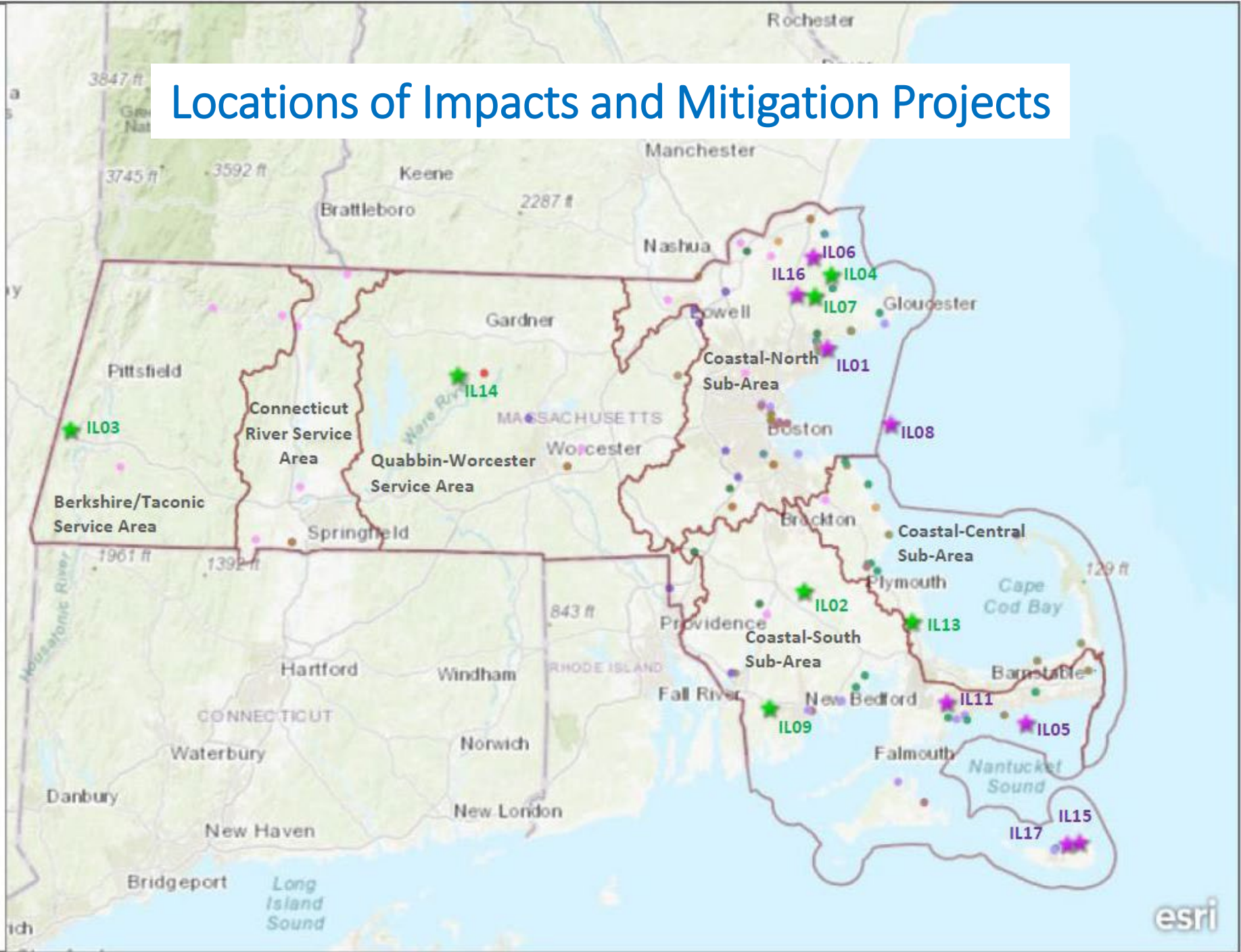
# Locations of Impacts and Mitigation Projects

## ILFP Funded Projects

- ★ Preservation
- ★ Restoration

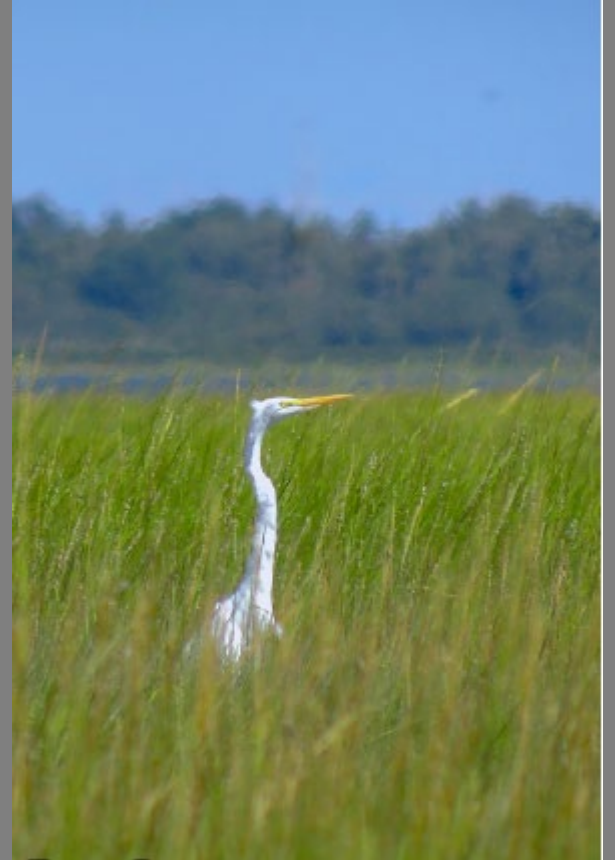
## ILF Permitted Impacts

- Estuarine
- Estuarine Intertidal
- Estuarine Subtidal
- Marine Intertidal
- Marine Subtidal
- Marine Tidal
- Palustrine
- Palustrine Emergent
- Palustrine Forested
- Palustrine Freshwater
- Palustrine Scrub-Shrub
- Riverine Freshwater
- Riverine Intertidal
- Riverine Tidal
- Other



# PROGRAM GOALS

- Protect high-quality aquatic resources under threat of loss or adverse change
- Restore degraded wetlands connected to high-quality wetlands
- Restore riparian buffers on agricultural lands
- Restore habitat continuity in coldwater streams and along the coast
- Facilitate coastal wetland migration to adapt to sea level rise



Google Images, 2019

# ILF in the SNEP Region

## Conservation projects

- Nemasket River
- Lyons Brook

## Tidal restoration projects

- Yarmouth reef
- Nantucket reef

## Restoration projects in planning

- Nantucket eelgrass restoration
- Chop Chaque Bogs restoration

# Yarmouth Reef



Deployment on January 6, 2020.

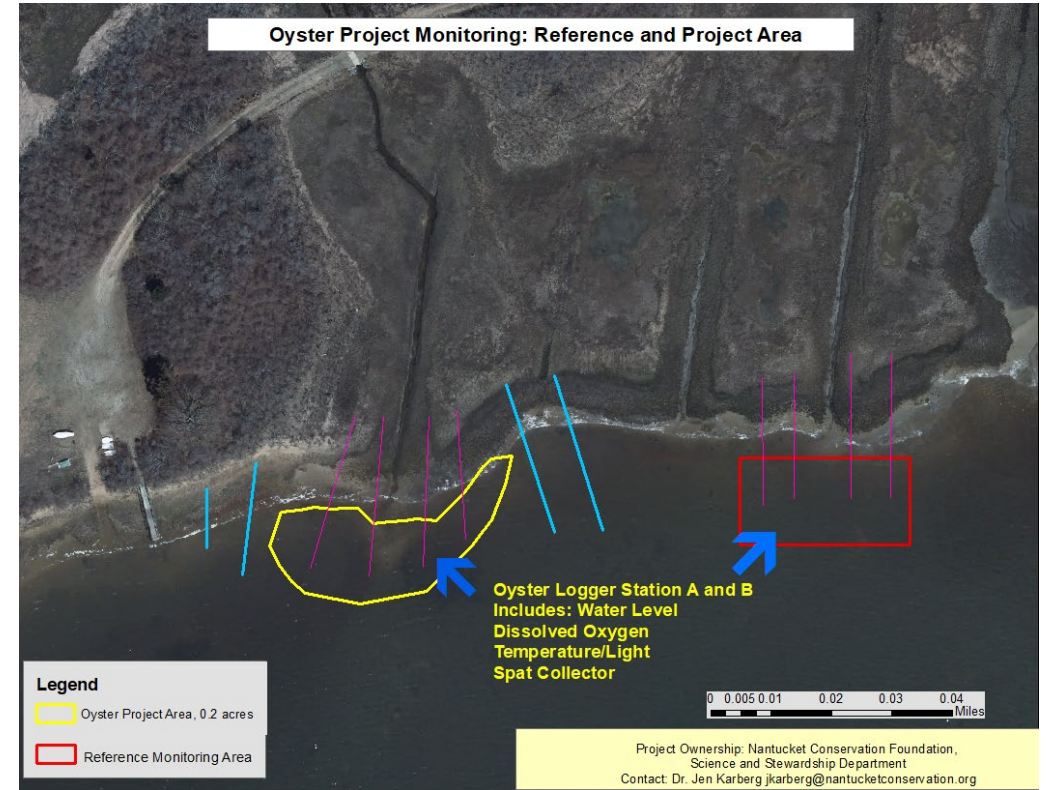
- Deployed 2,000 CY of material over 2.1 acres
- Cost of over-land transportation, weight of granite vs. concrete
- Site marking & relationship to equipment size
- Broad dispersal off barge effective

# Project Results

- Meets construction specifications open vs. structured
- Pre and post side-scan sonar
- 5-yr monitoring 2021-2025 ecological diversity & production



<https://www.youtube.com/watch?v=0Jt7sWsBqGA>



## Nantucket Reef

- NCF installed 0.17 acre reef November 2021
  - 500 oyster castles
  - 30 shell bags with 1,093,675 spat
- Purple crab trapping and native cordgrass planting in 1.1-acre salt marsh dieback area

# Project Results

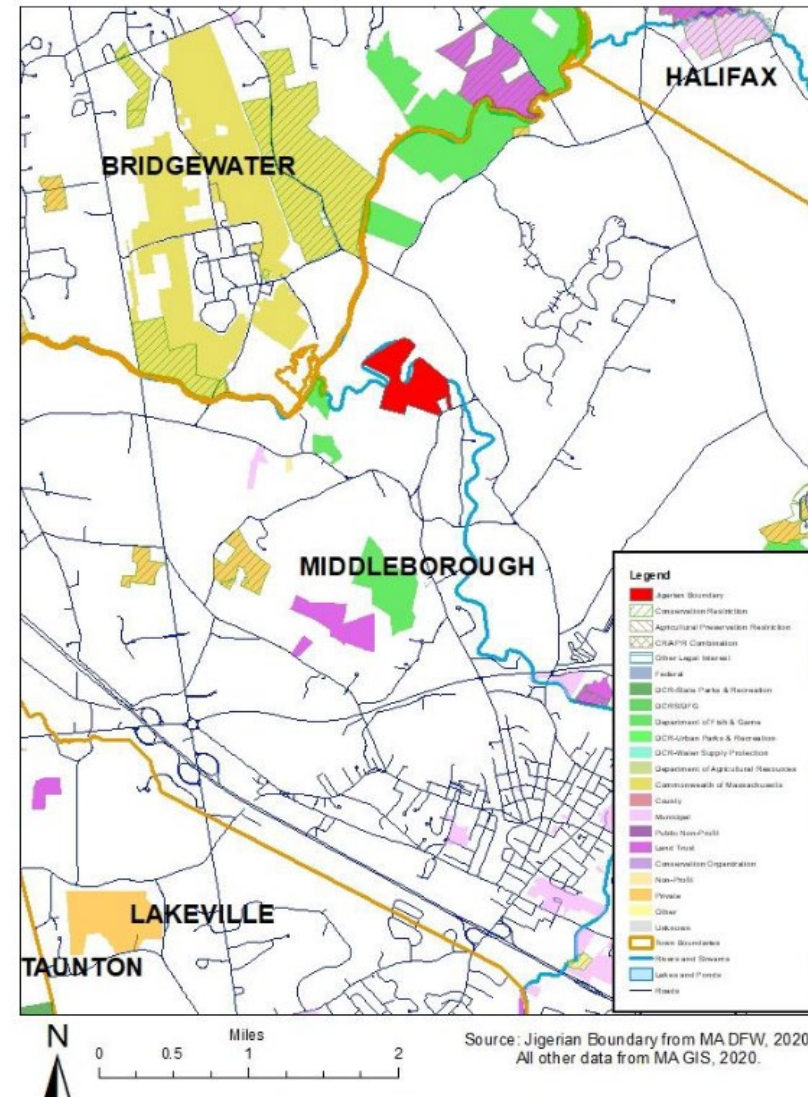
- Secure permits prior to purchasing supplies or setting oyster spat
- Practice building on dry, flat land
- Plan installation during lowest tides

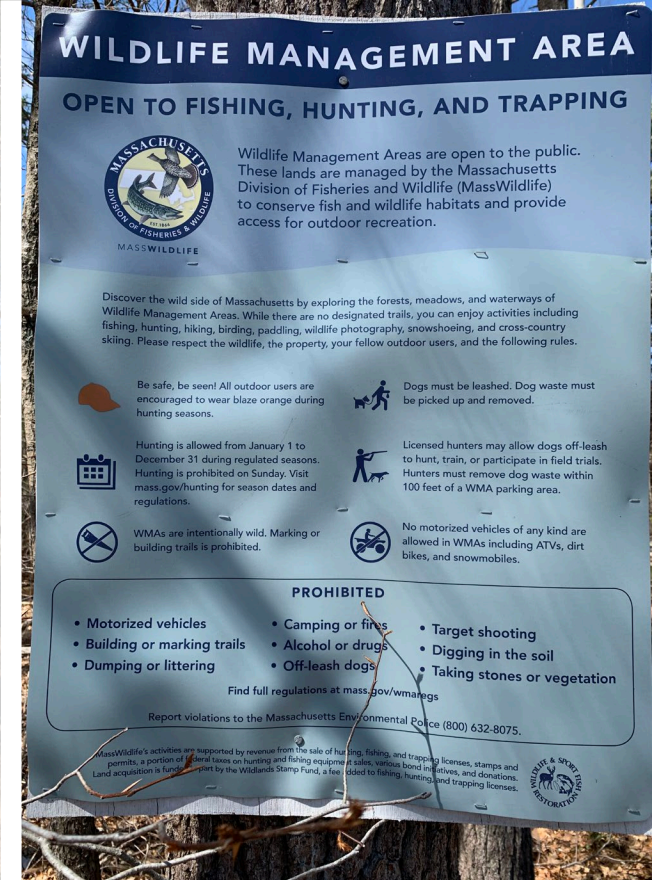




# Nemasket River

- 8.10 acres marsh
- 6.64 acres forested wetland
- River
  - One bank only, 5,070'
  - Both banks and channel, 1,220'
- 70.0 acres Pine-hardwood upland

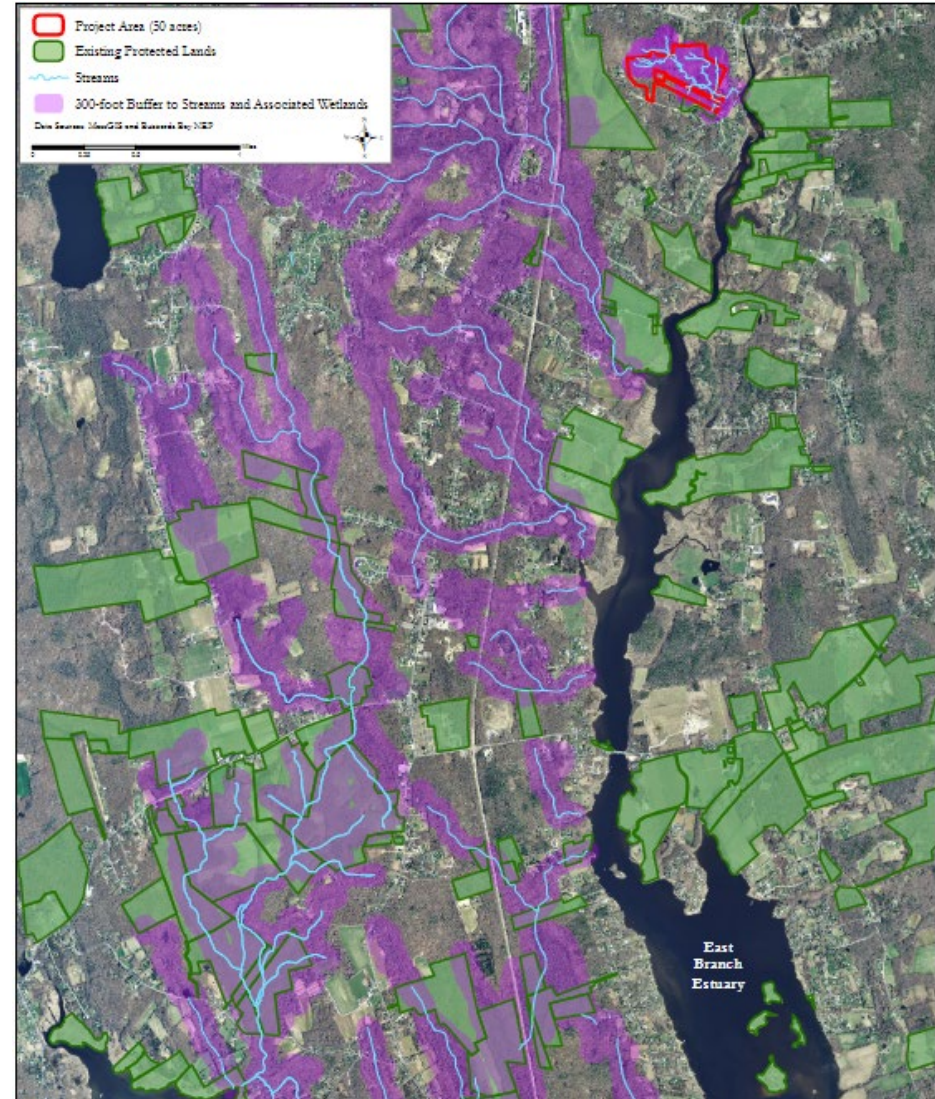




# Project Results

# Lyons Brook, Westport

- 3.6 acres forested wetland
- 46.1 acres oak/beech forested upland
- 3,600' river
  - Both banks, stream channel, & 100' buffer





**Welcome!**

This Lyons Brook Reserve land is open to the public from dawn until dusk. Please stay on the marked trails and respect the land and other users. Leave no trace of your visit.

**Permitted Activities:**

- Walking/Hiking
- Biking/Skiing
- Wildlife Observation
- Dog Walking (Dogs must be under your control at all times. Please pick up pet waste.)

**Prohibited Activities:**

- No motorized vehicles
- No dumping/littering
- No camping or fires
- No digging or defacement
- No cutting or removal of wood or vegetation



For more information, contact (508) 999-6363  
[www.savebuzzardsbay.org](http://www.savebuzzardsbay.org)

**Lyons Brook Reserve**

**Land protected by Buzzards Bay Coalition with a conservation restriction held by the Westport Land Conservation Trust with support from a Massachusetts Conservation Partnership Grant and the Massachusetts Department of Fish and Game In-Lieu Fee Program**



**Project Results**

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# Nantucket Eelgrass

- Restoration site A near Monomoy ( $41^{\circ} 17'9.06''$ ,  $-70^{\circ} 4'39.78''$ )
- Restoration site B near Coatue ( $41^{\circ}19'37.12''$ ,  $-70^{\circ} 2'6.46''$ )
- Both sites previously supported eelgrass
- Environmental data suggest sites are suitable for eelgrass
- Reference site on Hussey Shoal ( $41^{\circ} 17.205'$ ,  $70^{\circ} 4.936''$ )
- Plant 1/3 acre annually 2022-2024

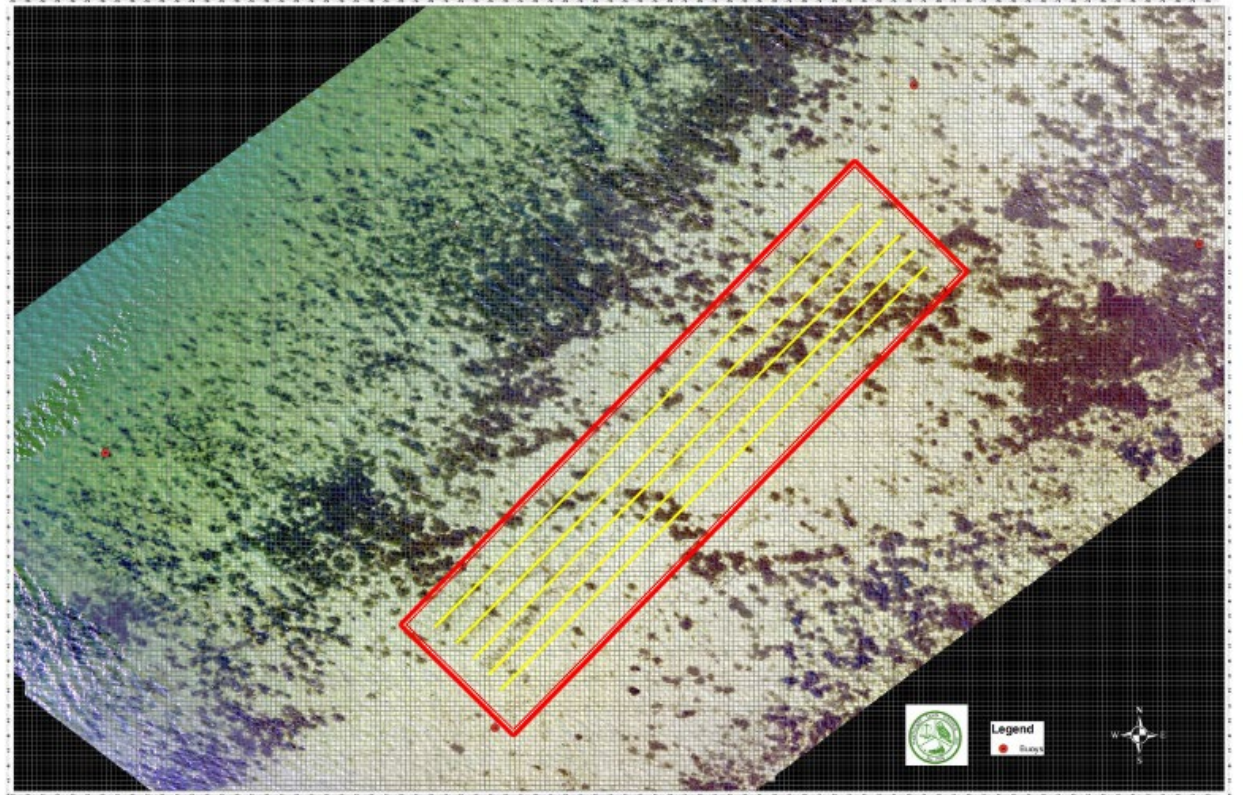


Figure 1. Map showing Restoration Site A (0.5 acres) at Monomoy with 1 m grid overlay. The boundary of the restoration site is denoted by the red polygon and transect lines are denoted in yellow. A rectangular area > 5 acres has been closed to shell-fishing and boating since 2017 (corners denoted by red dots) and eelgrass is now recruiting into the area. Please note the entire area shown on this map (inside and outside the restoration site) was completely devoid of eelgrass prior to 2017.

# Chop Chaque Bogs



- Restore ~6 acres of retired cranberry bogs
  - Remove water control structures
  - Move sand out of wetlands
  - Plug ditches
  - Roughen bog surface
- Owned by Town of Mashpee
  - Conservation restriction to be held by Native Land Conservancy

# Additional Resources



## MA In-Lieu Fee Program

<https://www.mass.gov/in-lieu-fee-program>

- Annual program reports & Instrument
- Project reports & factsheets
- Funding announcements



WOONASQUATUCKET RIVER  
WATERSHED COUNCIL

**SNEP**  
Symposium 2022  
May 18, 2022  
8:30a – 5:00p  
Virtual via Microsoft Teams

# Greening the Woonasquatucket River Greenway

Alicia Lehrer, Woonasquatucket River Watershed Council (WRWC) Executive Director

Understanding Regional Climate Change Impacts

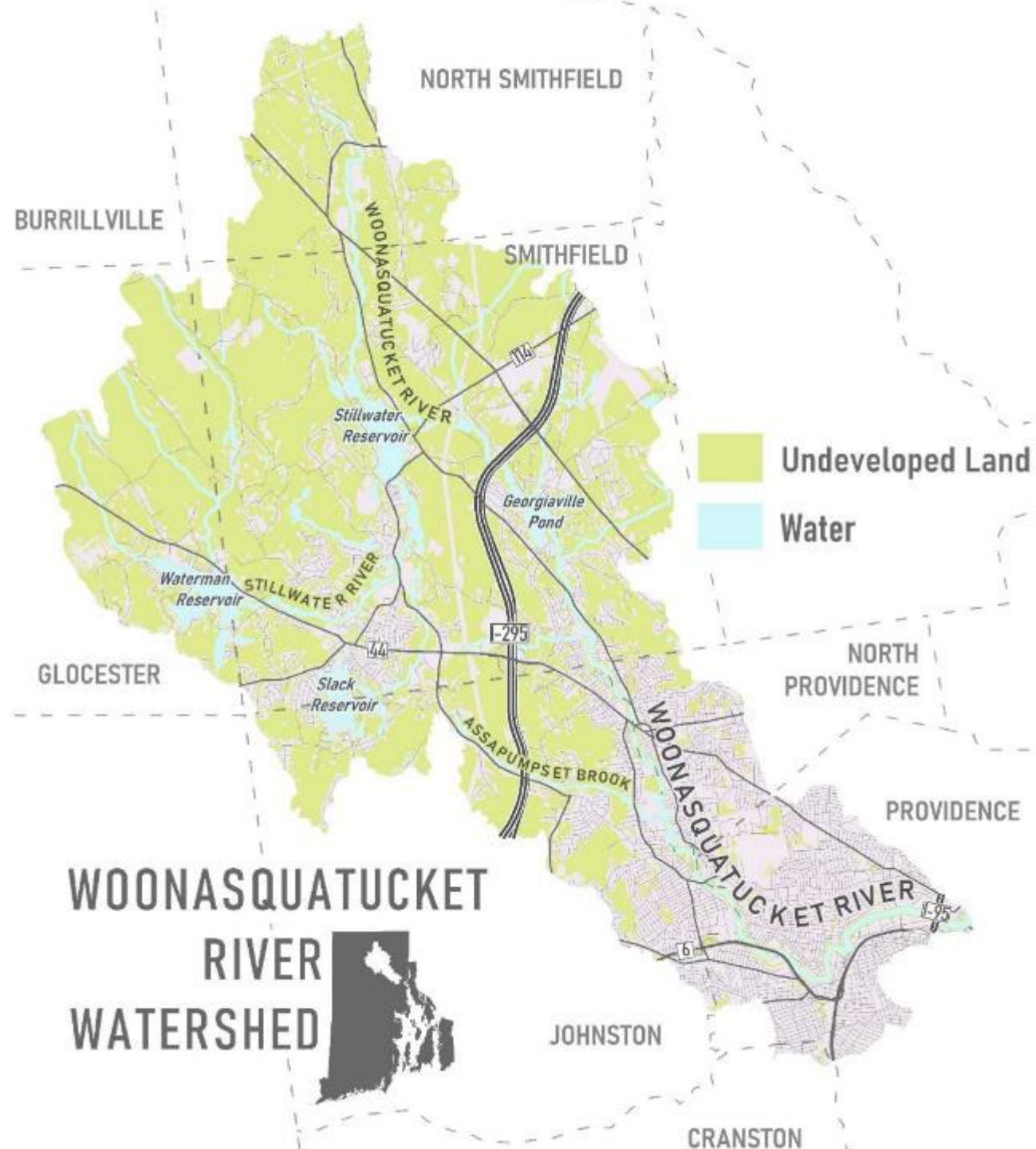




WOONASQUATUCKET RIVER  
WATERSHED COUNCIL

*WRWC Mission: Create positive environmental, social  
and economic change by revitalizing the  
Woonasquatucket River, its Greenway and its  
communities.*

**283,757 total  
population  
(27% of RI)**



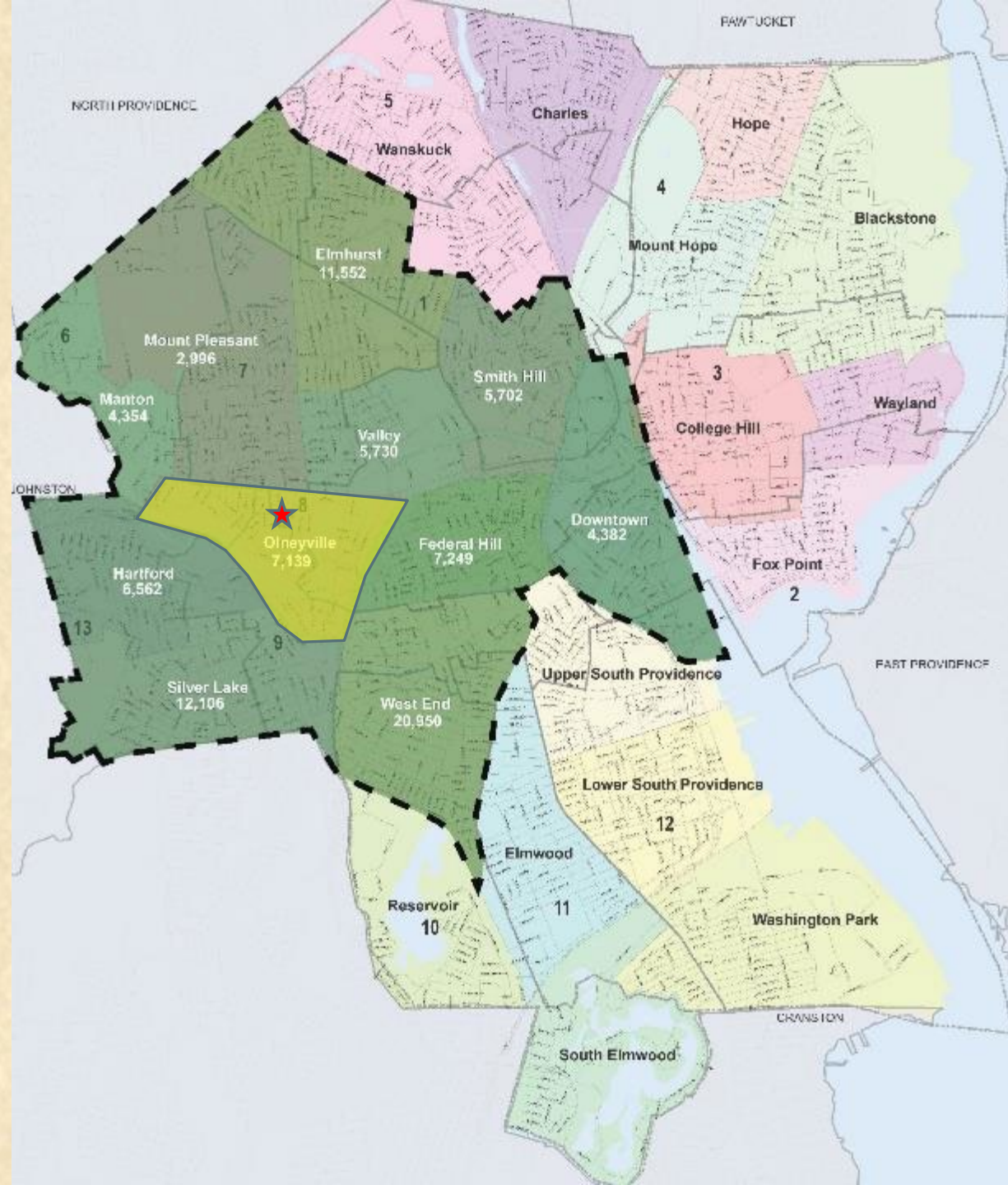
**More Than 7,000**  
people live in Olneyville

In EPA Region 1 – Northeast

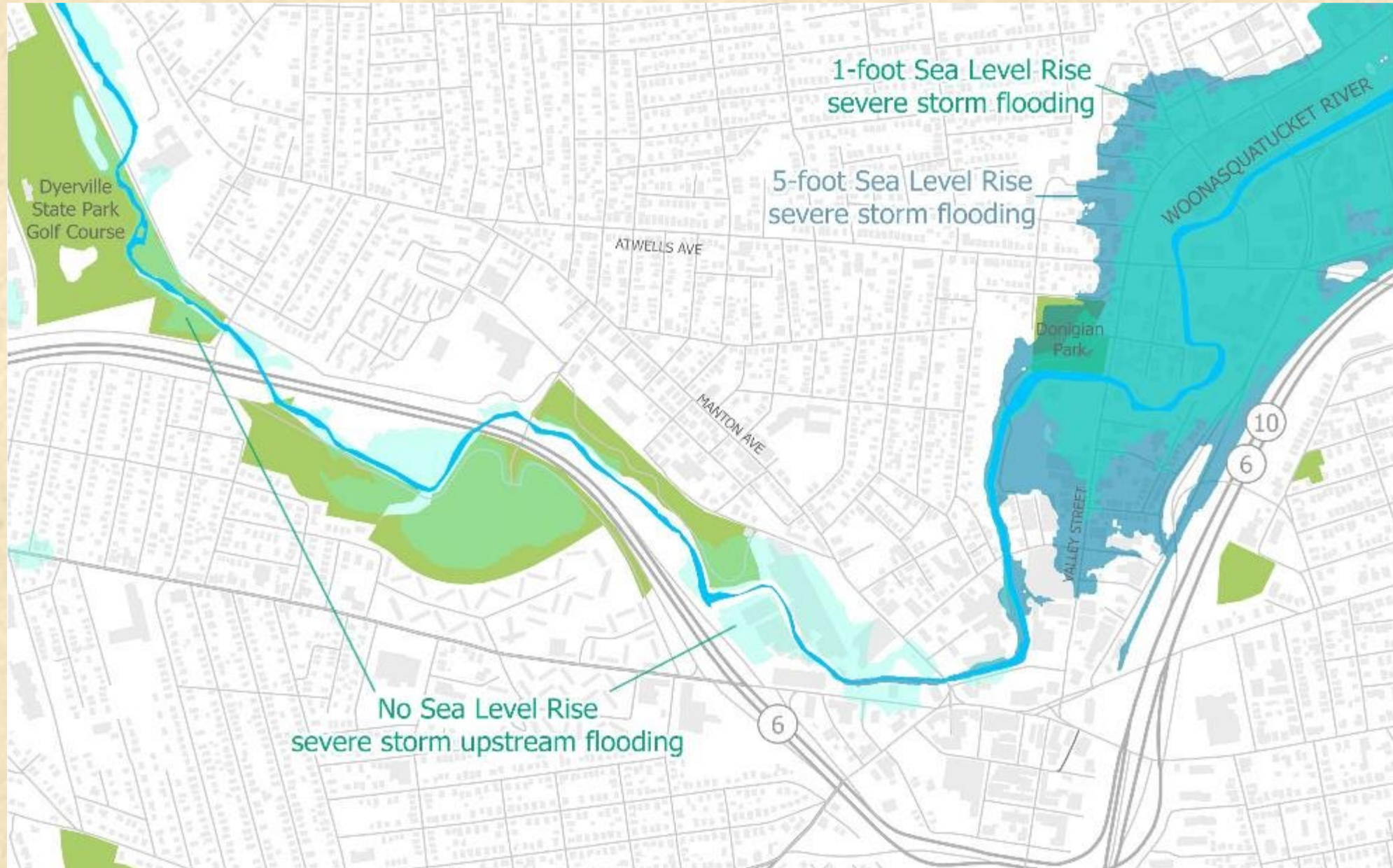
- 92% all EJ Indexes
- 96% wastewater discharge

For the state of RI, Olneyville

- 94% minority population
- 94% low-income population
- 86% linguistically isolated population
- 95% population < high school education
- Highest density native Spanish speaking population in Providence.



# 100 Year Flood Zone



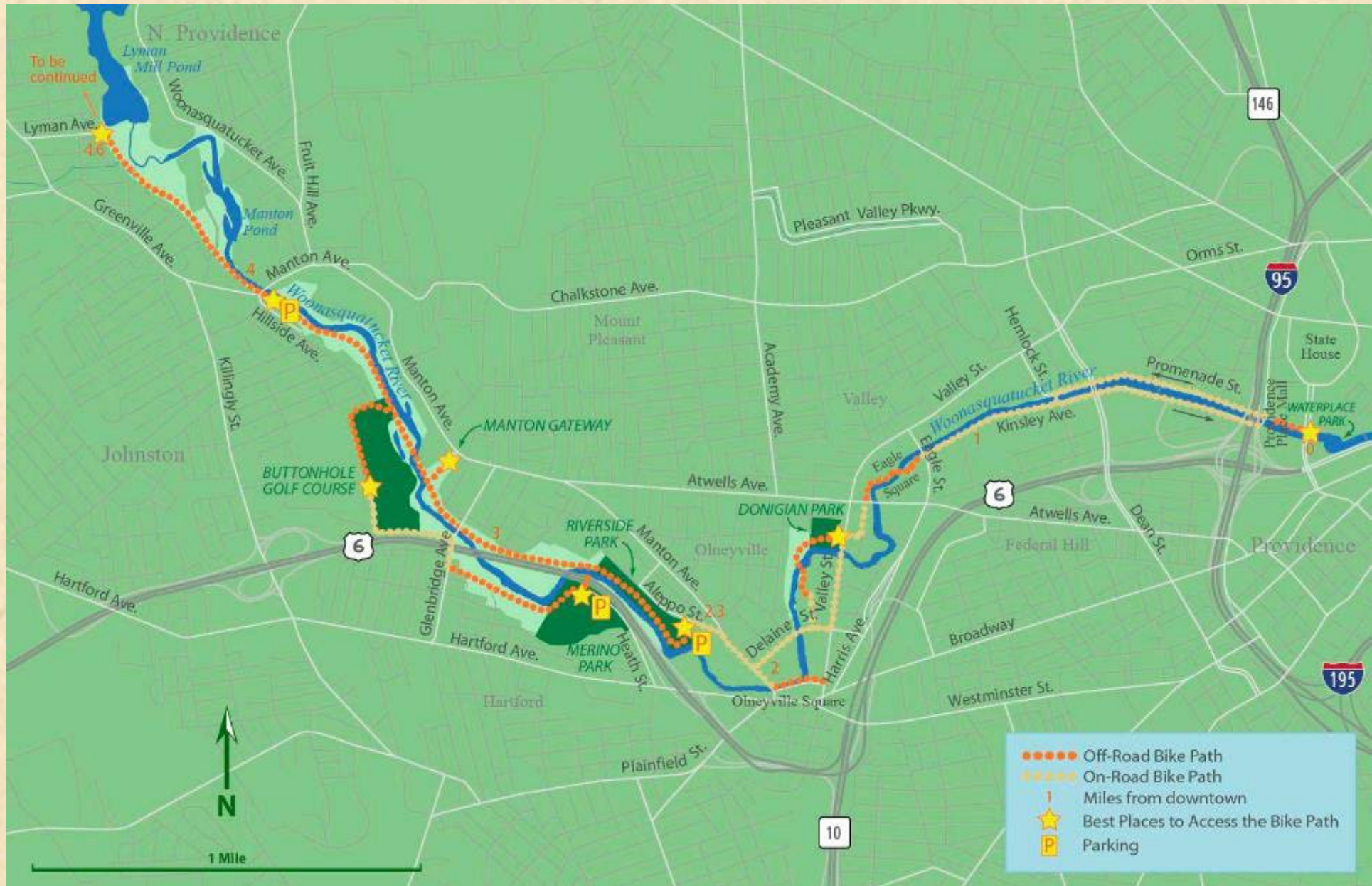


**March 2010  
Flood**

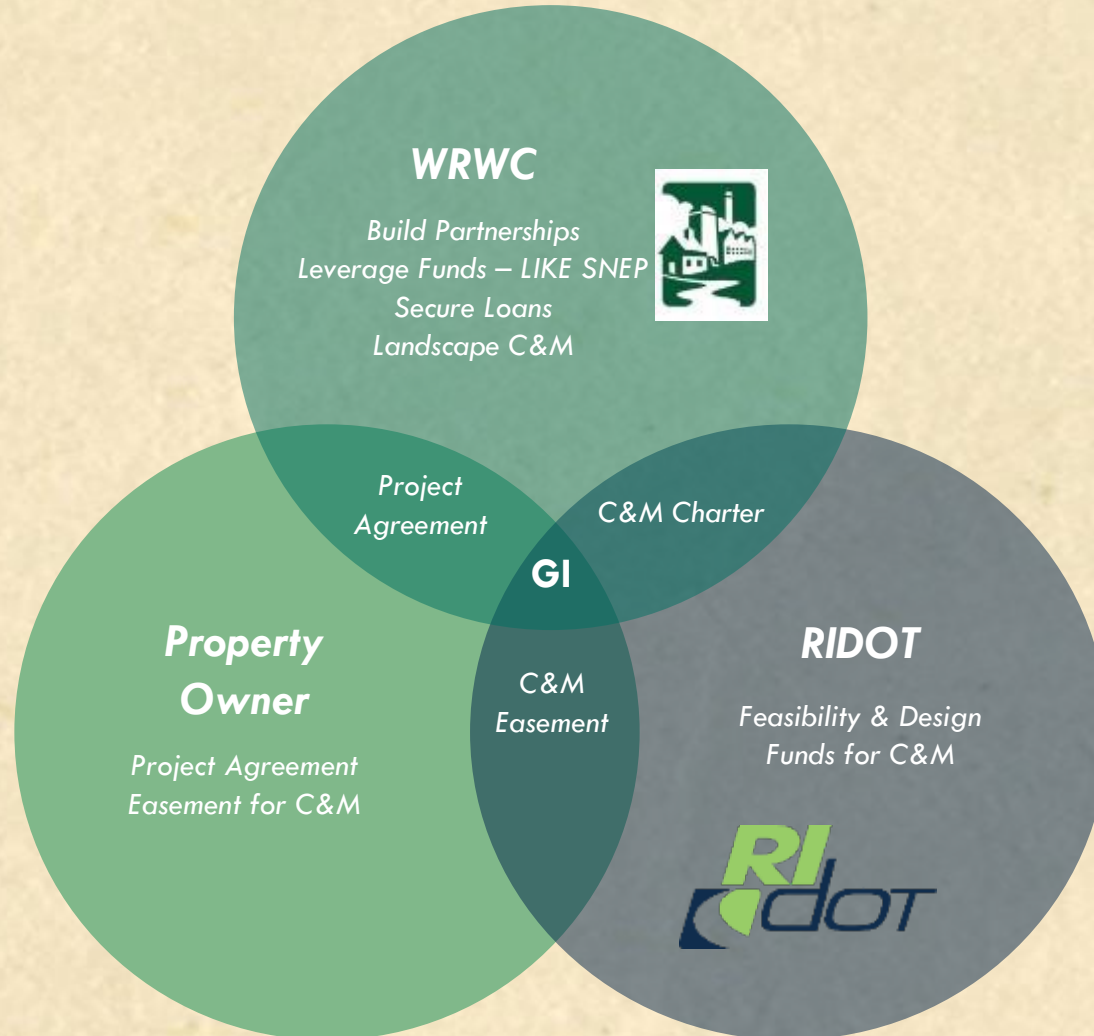


**Frontline Resident Cohort  
NRCS Flood Resilience Project**

# The Woonasquattucket River Greenway



# Using A Successful Public/Private Partnership To Green the Greenway



# Greening the Greenway Pilot Project



90% Impervious

42 Parking Spaces

Entrances & Exits

- *Westminster Street (x1)*
- *San Souci Drive (x2)*

 Catch Basin



# Greening the Greenway Pilot Project



6,000 SF of impervious surface removed

38 Parking Spaces

Entrances & Exits

- Westminster Street (x1)
- San Souci Drive (x1)

Bioretention Basin

Volume: 1,450 CF

Treats runoff from 17,400 SF of impervious surface

# GTG Pilot Construction Concurrent w/ New Greenway Spur



# Citizens Bank – Post Construction



# GTG Pilot – Post Construction



# WRWC River Rangers Install GTG GI Job Training



Signage in English & Spanish  
Engages Community

# Building on the Pilot: Prioritizing Projects - Highest Possible Score = 100

Woonasquatucket River Watershed Plan Matrix Greening the Greenway Opportunities													
Opportunity	Description	Location	City	Owner	Status	Drainage System			Visibility, Connection to Greenway (Points 0-20)	Education Opportunity (Points 0-10)	Additional Benefits Notes	Bonus Points	Total
						Drains from:	To River?	Points (3-25)					
Citizen's Bank	Parking Lot Retrofit	1917 Westminister St Manton Ave between	Providence	Citizen's Bank	Completed	Private Property (3)	Yes (10)	13	20	5			78
Manton Ave	Tree Filters	Tanyard Ln and Julian St Greenville Ave &	Providence	City of Providence	In Progress	State Road (15)	Yes (10)	25	20	5			77
Greenville Ave Outfall	Streambank Restoration	Greenway	Johnston	RIDOT	In Progress	State Road (15)	Yes (10)	25	20	3			68
Woonasquatucket River Streambank Stabilization (Manton Ave Dam to Manton Ave)	Streambank Restoration	Manton Ave Dam to Manton Ave	Johnston	Public ROW	Potential Site	State Road (15)	Yes (10)	25	20	5			65
Pleasant Valley Parkway	Tree Filters	Pleasant Valley Pkwy and	Providence	City of Providence	Completed	Local City/Town (3)	Yes (10)	13	5	5			60
Farm Fresh RI Food Hub	Parking Lot & Green Space	498 Kinsley Ave	Providence	Farm Fresh RI	In Progress	Private Property (3)	Yes (10)	13	20	9			59
Cathedral Art Metal Co	Parking Lot Retrofit	25 Manton Ave Near Rising Sun Mill	Providence	Leo Tracey	Potential Site	Private Property (3)	Yes (10)	13	20	5			58
Woonasquatucket River Streambank Stabilization (Delaine St to Rising Sun Mill Dam)	Streambank Restoration	166 Valley St	Providence	Public ROW	Potential Site	State Road (15)	Yes (10)	25	15	3			58
Greystone Social Club	Parking Lot Retrofit	3 Greystone Ave	North Providence	Robert Varin	In Progress	Private Property (3)	Yes (10)	13	20	5			55
Atlantic Mills (Wolfe Myrow)	Parking Lot Retrofit	118 Manton Ave	Providence	Paige Plum	Potential Site	Private Property (3)	Yes (10)	13	20	8			54
O'Reilly Auto Parts/old Price Rite	Parking Lot Retrofit & Pot	80 Manton Ave	Providence	Grasso Management	Potential Site	Private Property (3)	Yes (10)	13	20	7	Potential to add Greenway	5	53
Lyman Ave Greenway Entrance	Streambank Restoration	Lyman Ave where Greenway	North Providence	Public ROW	Potential Site	Local City/Town (3)	Yes (10)	13	20	5			50
Stop & Shop	Parking Lot Retrofit	850 Manton Ave	Providence	Calvi Realty Co Inc	Potential Site	Private Property (3)	Yes (10)	13	20	6			44
Preferred Equipment Resource	Parking Lot Retrofit	1 Goldsmith St	Johnston	Ken Bent	Potential Site	Private Property (3)	Yes (10)	13	10	5			43
Contech Medical	Parking Lot Retrofit & Pot	99 Hartford Ave	Providence	RCFL, LLC (Raymond Byrne)	Potential Site	Private Property (3)	Yes (10)	13	10	5	Potential to add Greenway	5	38
Puerta de Refugio	Parking Lot Retrofit	274 Valley St	Providence	Door of Refuge Pentecostal Church	Potential Site	Private Property (3)	Yes (10)	13	12	5			35
Providence Journal Bulletin	Parking Lot Retrofit	210 Kinsley Ave	Providence	Rhode Island Holdings Inc	Potential Site	Drains from:	To River?						0
Bath St property	Parking Lot Retrofit	373 Promenade St	Providence	Williams Communications Inc	Potential Site	Drains from:	To River?						0
	Parking Lot Retrofit	100 Manton Ave	Providence	Furniture Depot	Potential Site								
	Parking Lot Retrofit	46 Aleppo St	Providence	Anthony & Robin Antonelli	Potential Site								

## Points For:

- Drainage System (drains from & to) – 3 to 25
- Visibility, Connection to Greenway – 0 to 20
- Matching Funding Opportunity – 0 to 5
- Existing Partnership – 0 to 10

- Educational Opportunity – 0 to 10
- RIDOT Stormwater Credits – 0 to 25
- Bonus Points (e.g. potential new section of Greenway)
- Site Restrictions Negative Points

# GTG Potential Projects

5 DRAFT

Title  
**Lower Woonasquatucket Focus Sites 5-13**

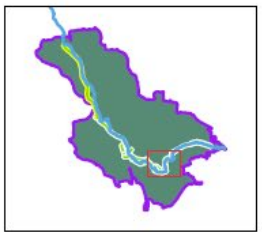
Client/Project  
Client Woonasquatucket Watershed Plan  
Project Greening the Greenway  
Report

Project Location  
Prepared by DW on 2020-02-20  
Lower Woonasquatucket TR by JD on 2020-02-20  
Watershed, RI IR Review by CF on 2020-02-20



- Legend**
- Lower Woonasquatucket Watershed
  - 10D CSO Area
  - RIDOT State Roads
  - Existing Greenway Bike Path
  - Proposed Greenway Bike Path

Completed	Id	Name
<span style="background-color: #f08080; width: 10px; height: 10px;"></span>	1	Bath St Property
<span style="background-color: #ffa500; width: 10px; height: 10px;"></span>	2	Providence Journal Bulletin
<span style="background-color: #90ee90; width: 10px; height: 10px;"></span>	3	Farm Fresh RI Food Hub
<span style="background-color: #90ee90; width: 10px; height: 10px;"></span>	4	Pleasant Valley Parkway
<span style="background-color: #90ee90; width: 10px; height: 10px;"></span>	5	Puerta de Refugio
<span style="background-color: #90ee90; width: 10px; height: 10px;"></span>	6	Delaine St Streambank Restoration
<span style="background-color: #90ee90; width: 10px; height: 10px;"></span>	7	Cathedral Arts
<span style="background-color: #90ee90; width: 10px; height: 10px;"></span>	8	Citizen's Bank
<span style="background-color: #90ee90; width: 10px; height: 10px;"></span>	9	O'Reilly Auto Parts
<span style="background-color: #90ee90; width: 10px; height: 10px;"></span>	10	Manton Ave Tree Filters
<span style="background-color: #90ee90; width: 10px; height: 10px;"></span>	11	Atlantic Mills
<span style="background-color: #90ee90; width: 10px; height: 10px;"></span>	12	Wolfe Myrow
<span style="background-color: #90ee90; width: 10px; height: 10px;"></span>	13	Contech Medical



**Notes**  
 1. Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere  
 2. Data Source:  
 3. Background URI: EDC, RIGIS



# Project 1

## Greening & Cleaning Manton Ave

### Goals

1. Employ “Nature at Work” green infrastructure techniques along Manton Avenue to capture and treat stormwater runoff from the neighborhood, starting at Olneyville Square and moving northwest up Manton Avenue.
  - A. Install Tree Filters – 4 Tree Filters w/ attached catch basins installed
  - B. Install other green landscape elements – 8 sidewalk inset planting areas installed



# After Pilot: Site 1 – Manton Avenue, Olneyville



Before

# After Pilot: Site 1 – Manton Avenue, Olneyville



After

## Site 2 – Farm Fresh RI Food Hub



# Site 2 – Farm Fresh RI Food Hub – Ranger Install



The Market Now! Photo Credit: Farm Fresh RI

# Site 3a – Iglesia Puerta De Refugio - Before



# Site 3a – Iglesia Puerta De Refugio - After



# Site 3a – Iglesia Puerta De Refugio – Ranger Install



# Site 3b – Iglesia Puerta De Refugio - Before





## Site 3b – Iglesia Puerta De Refugio - After



# In Design – GTG Phase II -Downtown Greenway



# In Design – GTG Phase II -Downtown Greenway 2023



# The Impact



GTG Stormwater Capture – 1” Design Storm

San Souci Pilot: 539 cubic feet, 4,032 gallons

Manton Tree Filters: 315 cubic feet, 2,356 gallons

Pleasant Valley Tree Filters: 1,250 cubic feet, 9,351 gallons

Greystone Social: 2,495 cubic feet, 18,664 gallons

Farm Fresh: 5,510 cubic feet, 41,150 gallons

**TOTAL CAPTURE 1” Storm: 10,109 cubic feet, 75,553 total gallons**

**The Bad News: 5 sq mi capture needed to impact flooding = 600 Pilot Projects**

# The Good News: Education, New Stewards, Support



Tours



Art Highlights Projects



Young Stewards

# Greening the Woonasquatucket River Greenway

Clean Water, Environmental Justice, Community Engagement and Resilience

**Alicia Lehrer**

Executive Director



WOONASQUATUCKET RIVER  
WATERSHED COUNCIL

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You



WOONASQUATUCKET RIVER  
WATERSHED COUNCIL