# Using Technology and Emerging Practices to Improve Tidal Marsh Habitat Resiliency

## NROC-NALCC Science Delivery Workshop
## Marsh Models – Maine's Approach

April 4, 2017

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Maine Geological Survey
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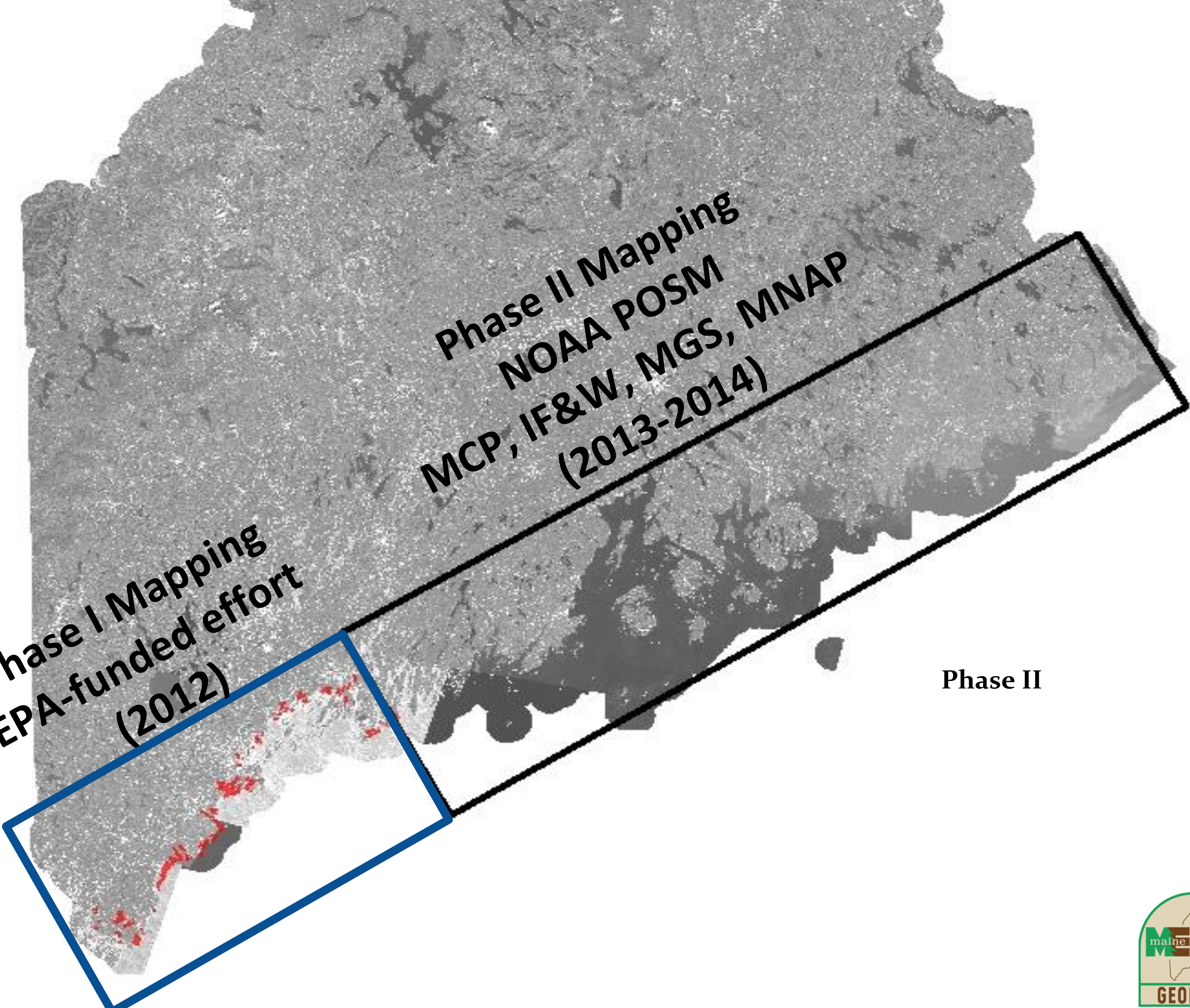
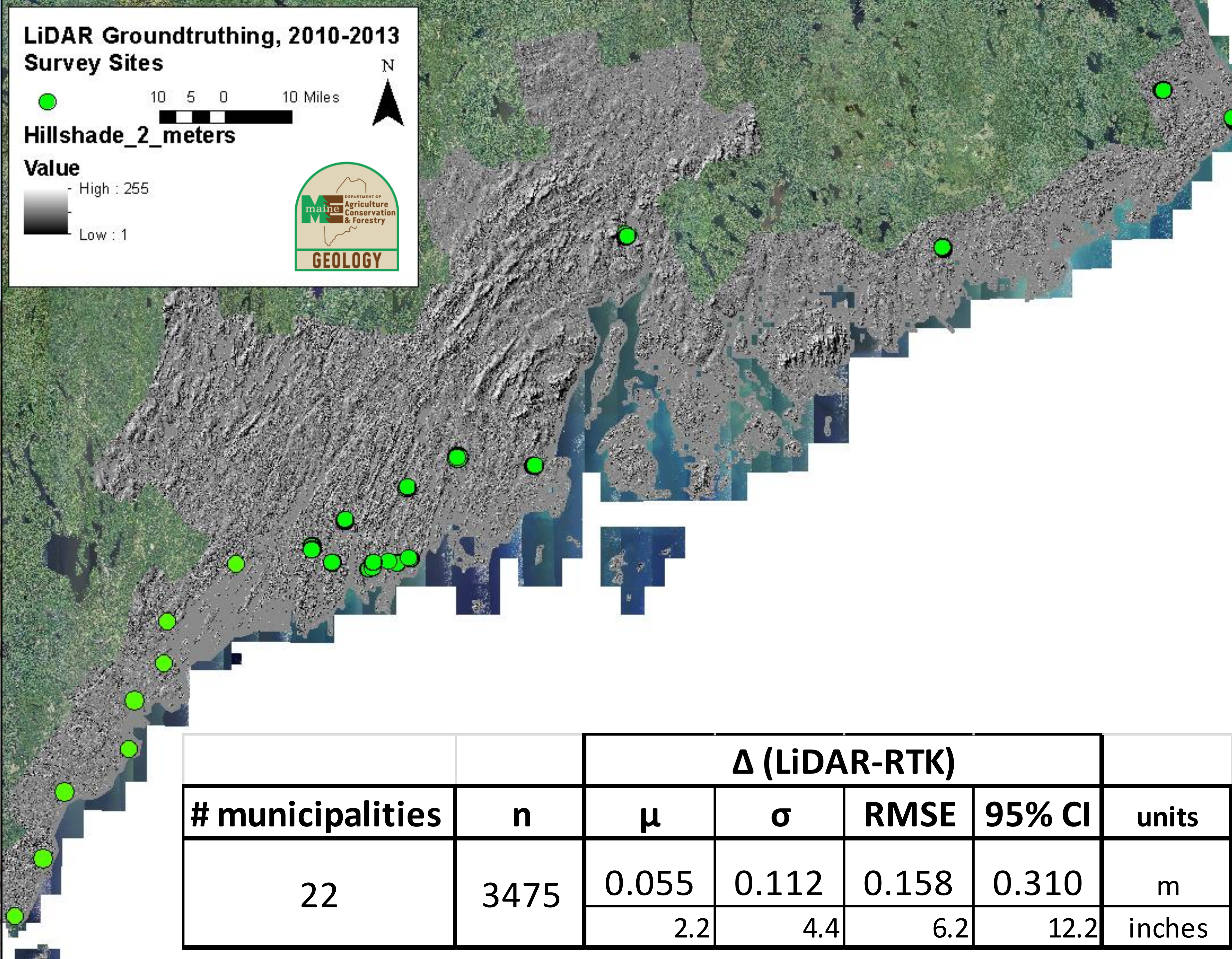
Maine Natural Areas Program

maine Department of Agriculture Conservation & Forestry


Phase II Mapping
NOAA POSM
MCP, IF&W, MGS, MNAP
(2013-2014)
Phase I Mapping
EPA-funded effort
(2012)
Phase II




| | | Δ (LiDAR-RTK) | | | | |
|---|---|---|---|---|---|---|
| **# municipalities** | **n** | **μ** | **σ** | **RMSE** | **95% CI** | **units** |
| 22 | 3475 | 0.055 | 0.112 | 0.158 | 0.310 | m |
| | | 2.2 | 4.4 | 6.2 | 12.2 | inches |

# Coastal wetlands (Maine NRPA §480-B.2.)

"Coastal wetlands" means all tidal and subtidal lands; all areas with vegetation present that is tolerant of salt water and occurs primarily in salt water or estuarine habitat; and any swamp, marsh, bog, beach, flat or other contiguous lowland that is subject to tidal action during the **highest tide level for each year** in which an activity is proposed as identified in tide tables published by the National Ocean Service. Coastal wetlands may include portions of coastal sand dunes.

***Required in Maine's Municipal Shoreland Zoning***

P.A. Slovinsky, MGS

maine Department of Agriculture Conservation & Forestry GEOLOGY

# Project Goals

- Map the limits of the Highest Annual Tide (HAT) using NOAA tidal predictions and VDATUM in support of Maine's Shoreland Zoning regulations;

- Utilize the HAT as a proxy for the upper boundary of existing coastal wetlands and map potential marsh migration areas using a scenario based approach of future sea level rise;

- Determine what types of existing land-cover types might be impacted by marsh migration MNAP)

# GIS Process Tree

- Develop VDATUM points (MLLW-NAVD)
- Determine HAT from NOAA predictions (MLLW)
- Determine “area of influence” for each tide station within HUC-10 (QC )
- Offset HAT to points using VDATUM data
- “Compare” water elevations with LiDAR DEM
- Aggregate and smooth
- Erase lower bounds using NHD ocean
- Develop SLR “marsh migration” layers
- Erase subsequent layers

# Some Assumptions and Limitations

- Our mapping uses the **Highest Annual Tide** per Shoreland Zoning regulations, not MHW. *In Maine, HAT is between 2-3 feet higher than MHW.*

- We are trying to map the limits of existing HAT for Shoreland Zoning and visualize the impacts of SLR scenarios on **potential wetland expansion**, not necessarily map the *actual limits of wetlands.*

- Our simulations use a **bathtub approach** that **doesn't account for erosion, sedimentation, or tidal restrictions.**

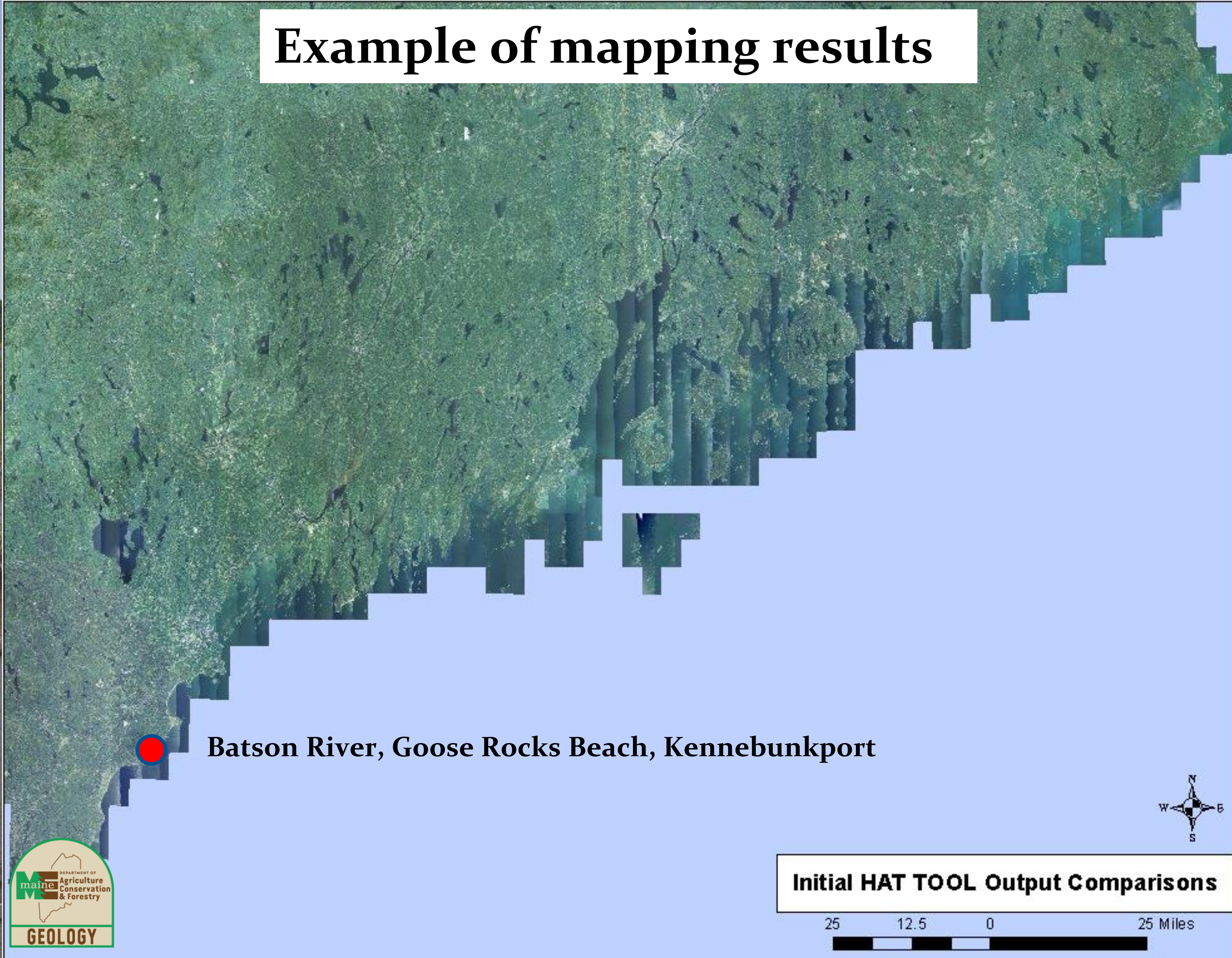
# Some Assumptions and Limitations

- LiDAR was flown at **any tide** so in some areas, LiDAR points were reflected by water (i.e., data collected at a higher tide), resulting in bad or no data in some areas.

- NOAA's VDATUM was used to convert from MLLW to NAVD88 to translate elevations across water surfaces from NOAA tide prediction data. This **adds additional vertical error** (up to a published 13.2 cm per NOAA).

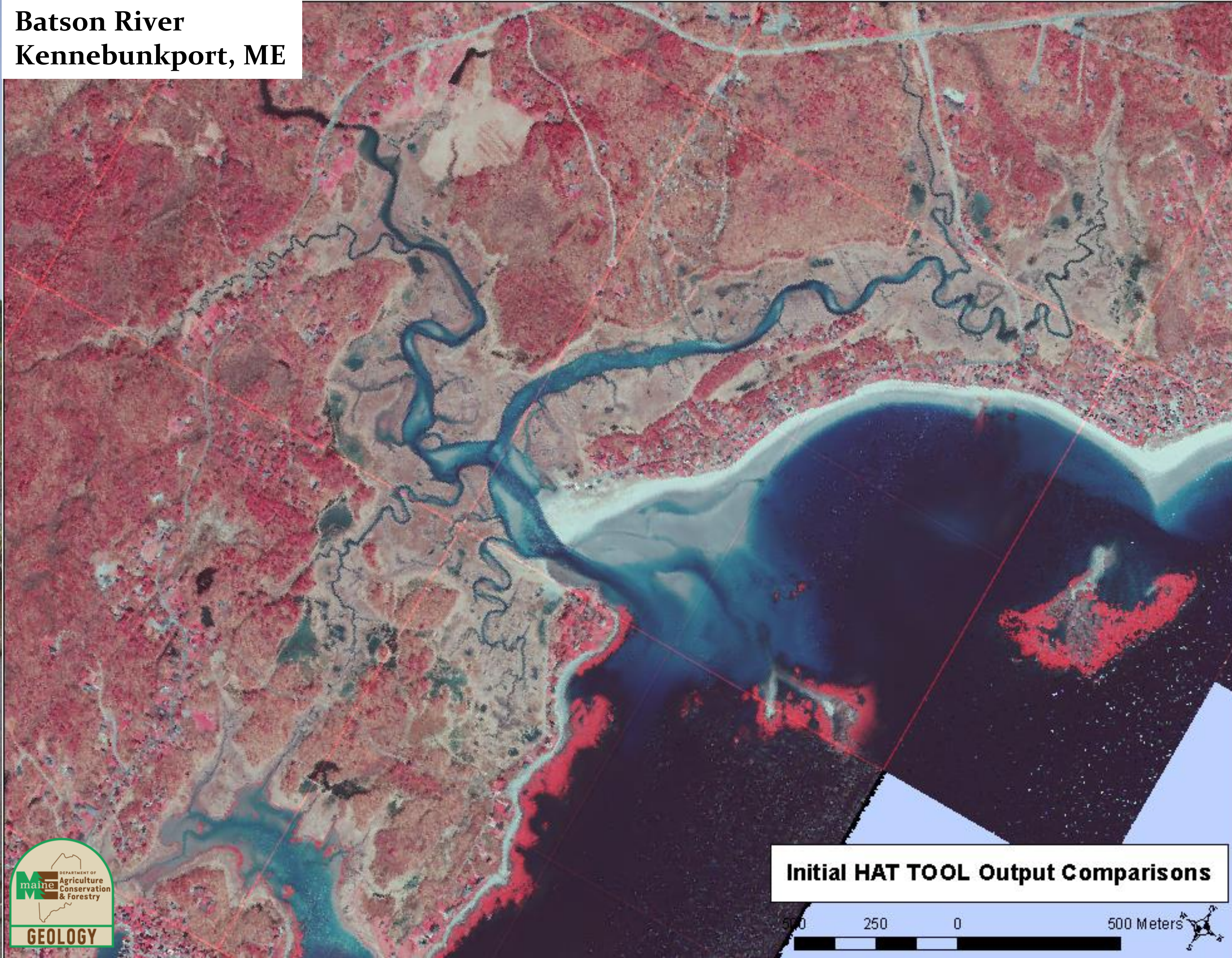
- Our analysis **doesn't look at wetland type conversion or loss** on a state-wide level.

# Example of mapping results




GEOLOGY

# Batson River
# Kennebunkport, ME



DEPARTMENT OF
maine
Agriculture
Conservation
& Forestry
GEOLOGY

# Batson River
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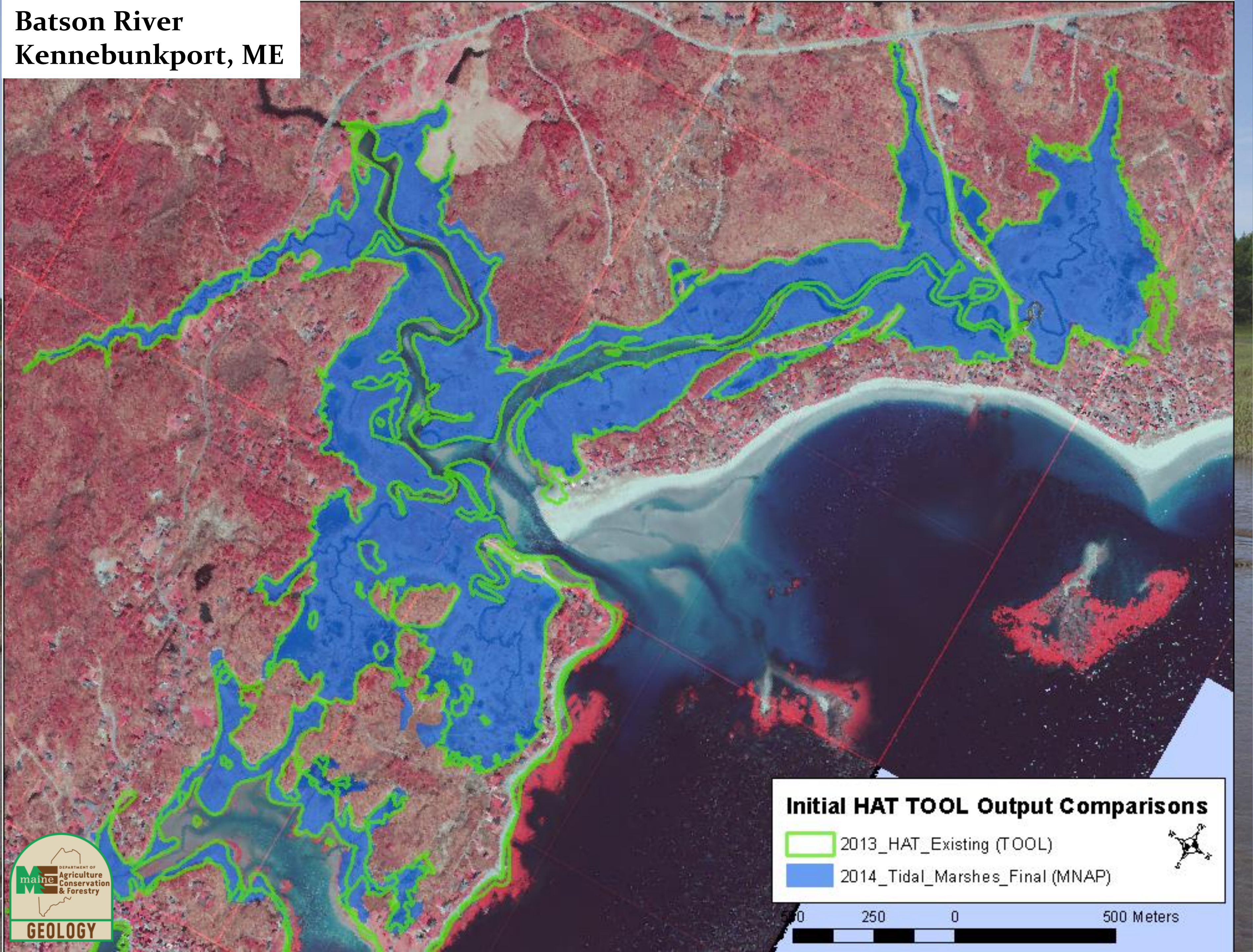
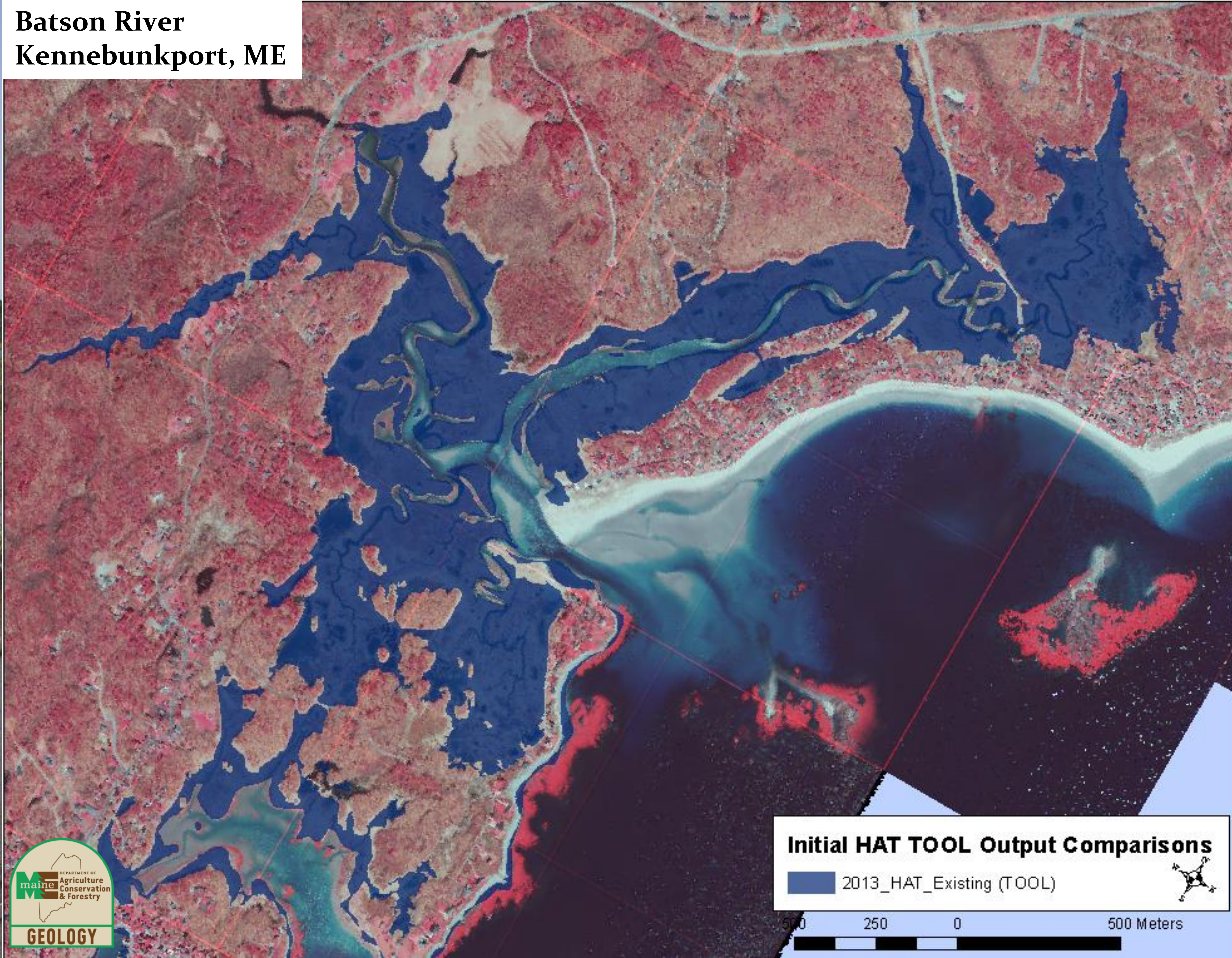
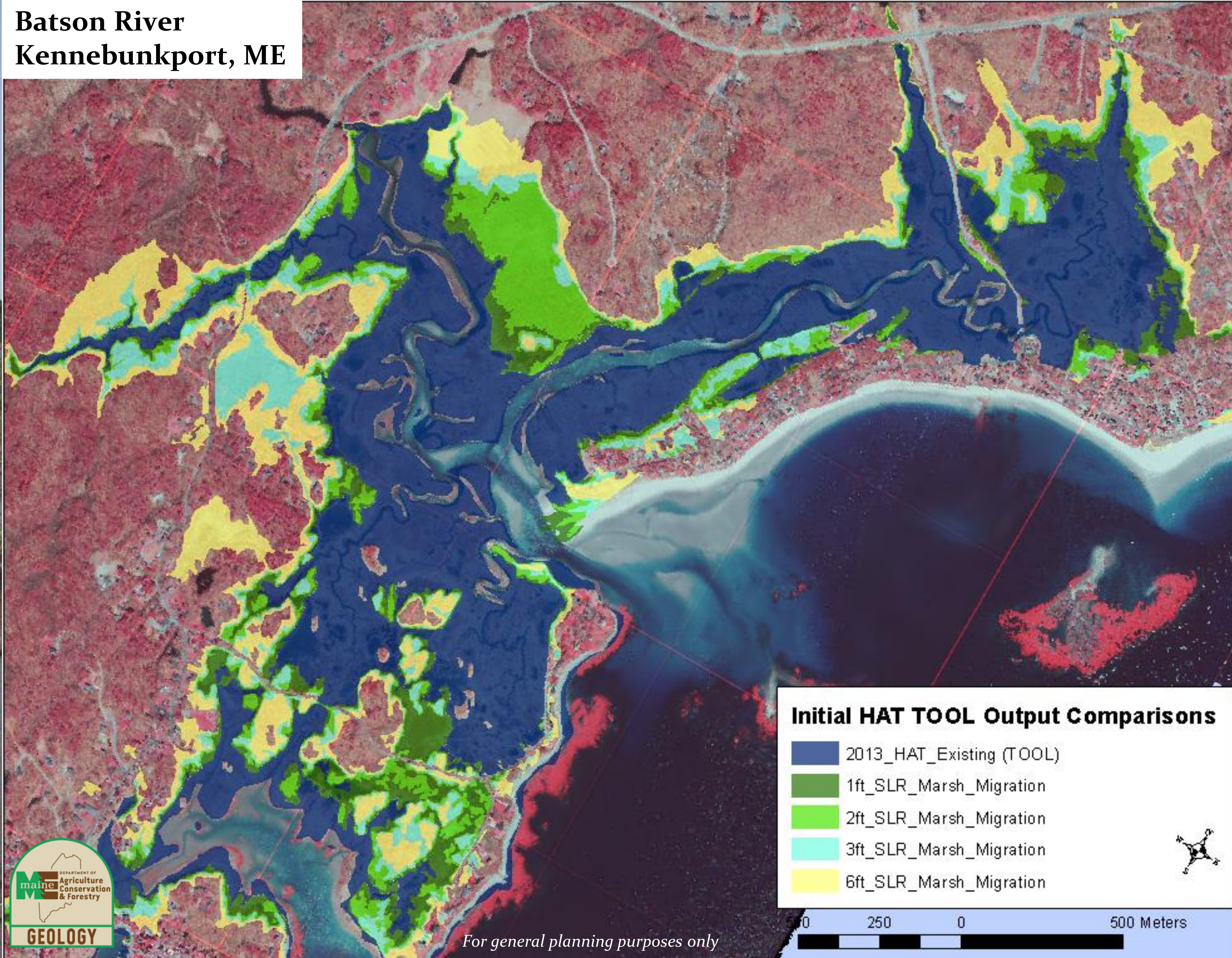


Batson River
Kennebunkport, ME



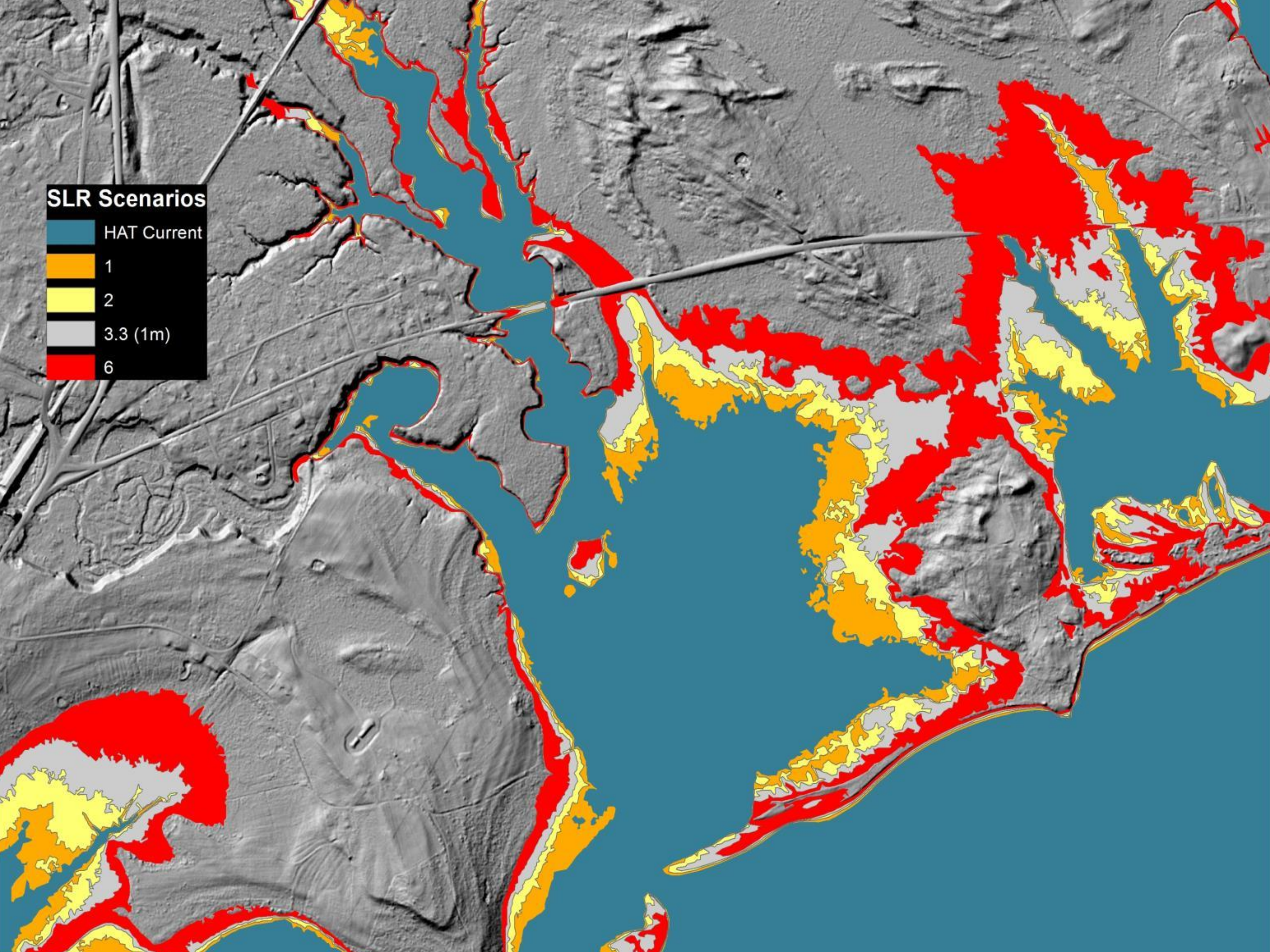
# Batson River
# Kennebunkport, ME



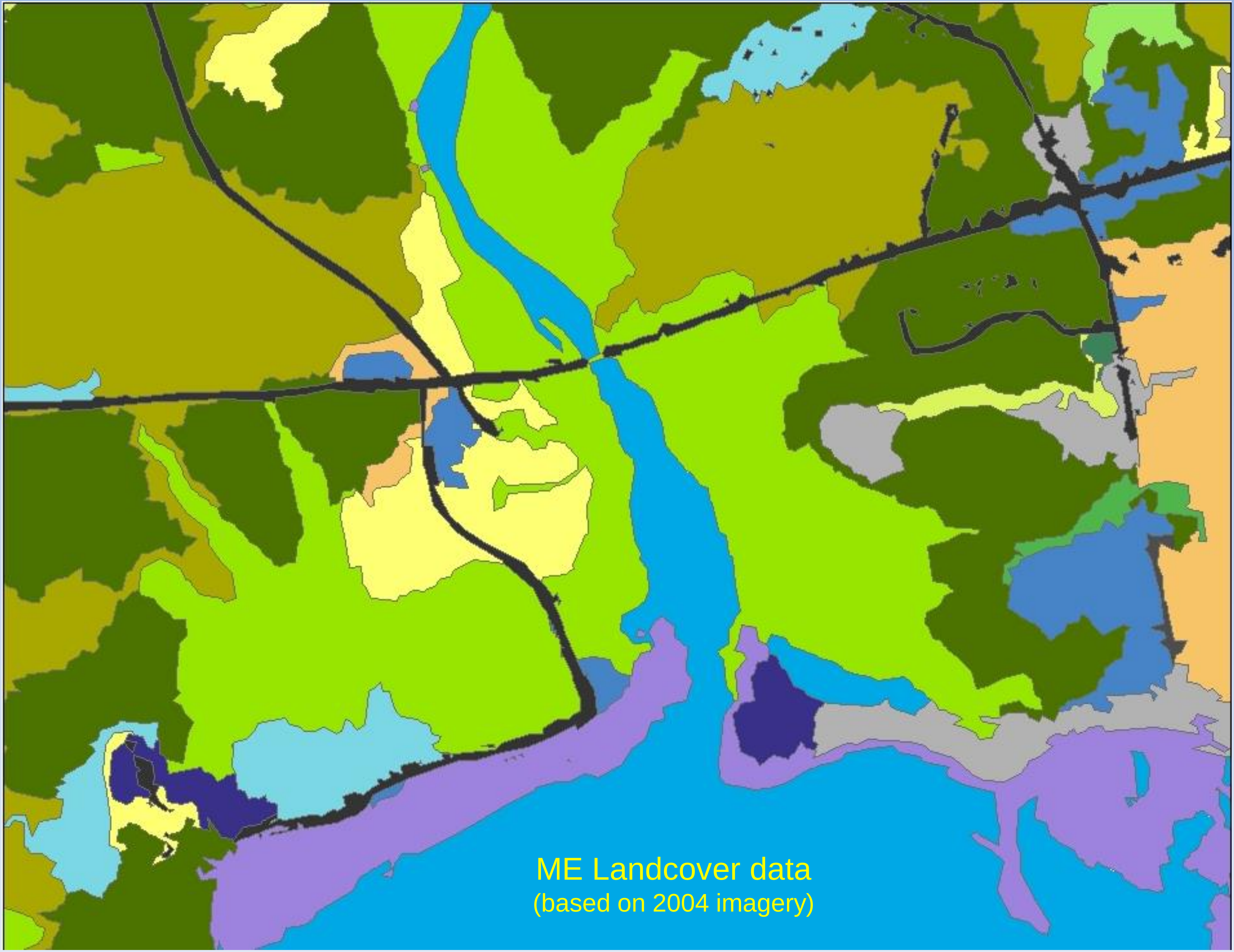

*For general planning purposes only*

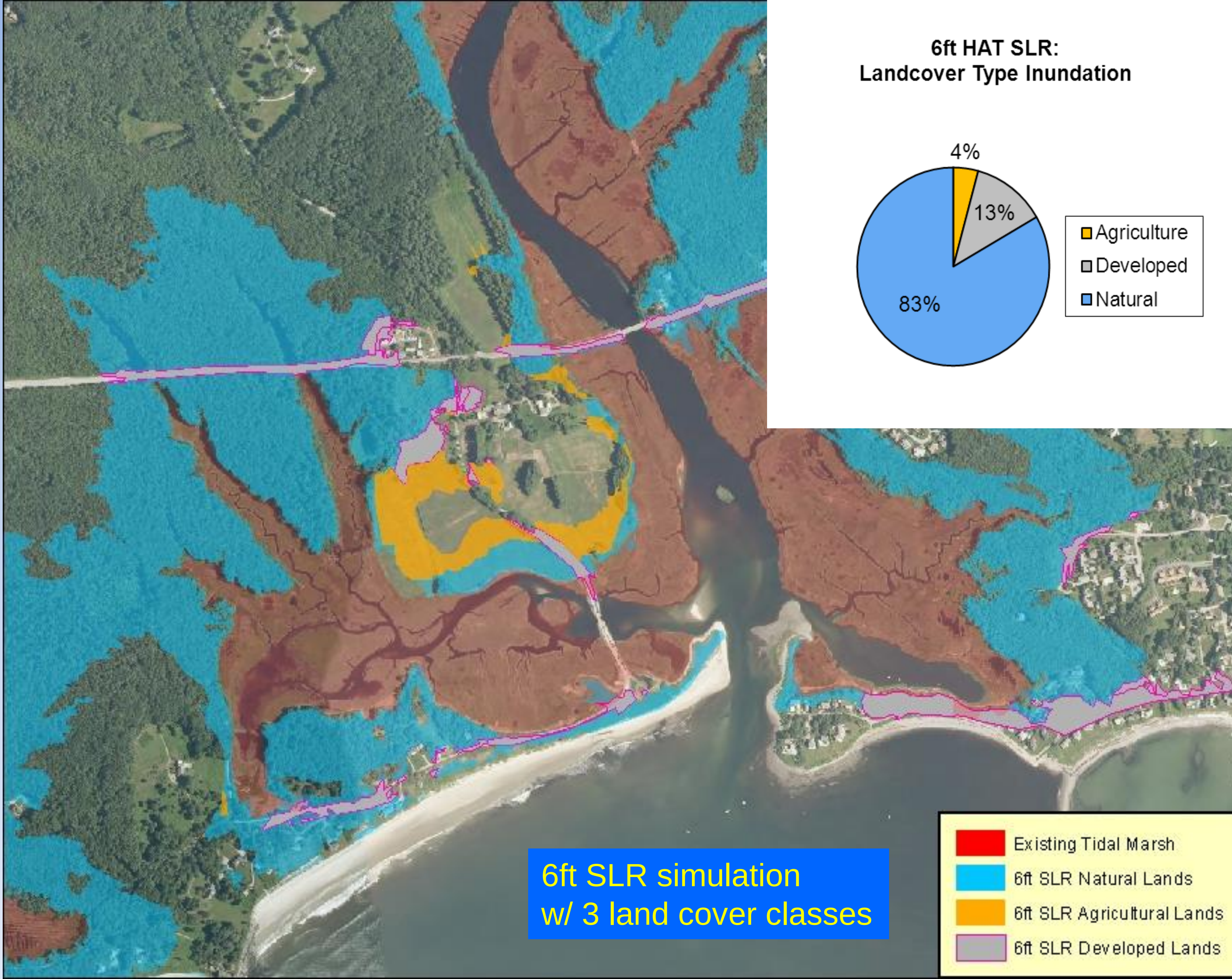
# Marsh Migration

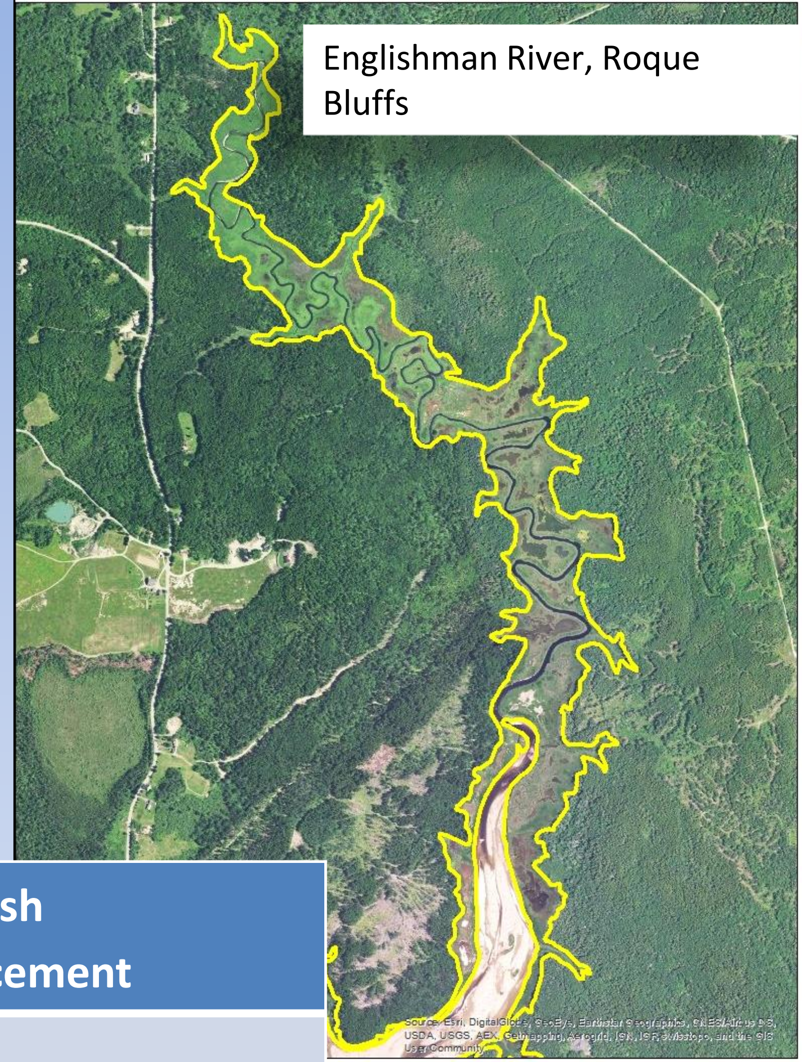
- Model development
- Applications and Outreach


SLR Scenarios
HAT Current
1
2
3.3 (1m)
6

# Marsh Migration


ME Landcover data
(based on 2004 imagery)


6ft HAT SLR:
Landcover Type Inundation
4%
13%
83%
Agriculture
Developed
Natural
6ft SLR simulation
w/ 3 land cover classes
Existing Tidal Marsh
6ft SLR Natural Lands
6ft SLR Agricultural Lands
6ft SLR Developed Lands


| SLR Simulation | % Marsh Replacement |
|---|---|
| 1 ft | 17% |
| 2 ft | 30% |
| 3.3 ft (1m) | 46% |
| 6 ft | 77% |
| *Maine Natural Areas Program, 2014* | |

# Coastal Resiliency Opportunities Work Group

*"Identify areas that have the* ***potential to accommodate the migration of coastal wetlands and supporting buffers*** *in order* ***to prioritize conservation actions and inform restoration planning*** *that will support the migration, resilience, and/or transformation of coastal wetlands under a 1m SLR scenario.*

*Output may also be used by project partners or others to guide restoration or protection of habitat connectivity, prevent inappropriate development in high risk or high vulnerability areas, or increase conservation of natural areas that can protect* ***human communities*** *from storm surge and tidal flooding."*

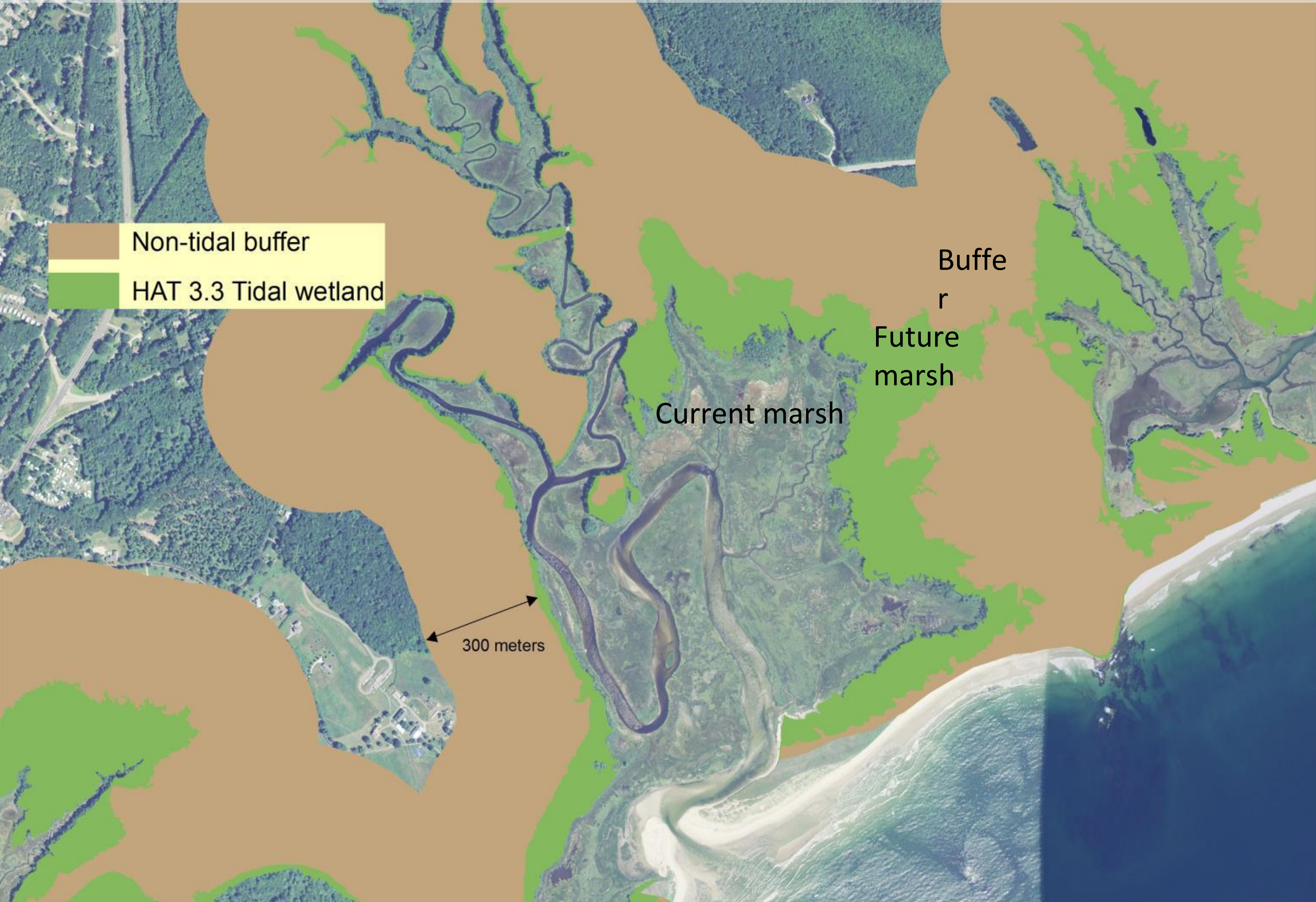
***Considerations:***

***-Ease of use and interpretation for practitioners, public, funders, landowners***

***-Easy to update/modify with new data***

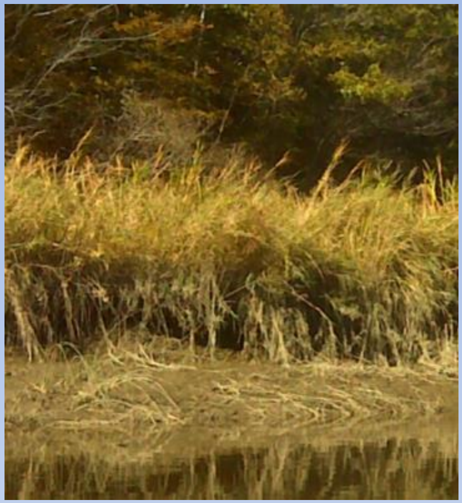
***-Limit assumptions and extrapolations***

# Coastal Undeveloped Blocks: 1m SLR



# Modeled new 1m SLR Habitats


Salt marsh


Freshwater tidal marsh


Unknown tidal wetland

**Data sources:**

**-NWI**

**-MNAP mapped marshes**

**-MNAP mapped estuaries**

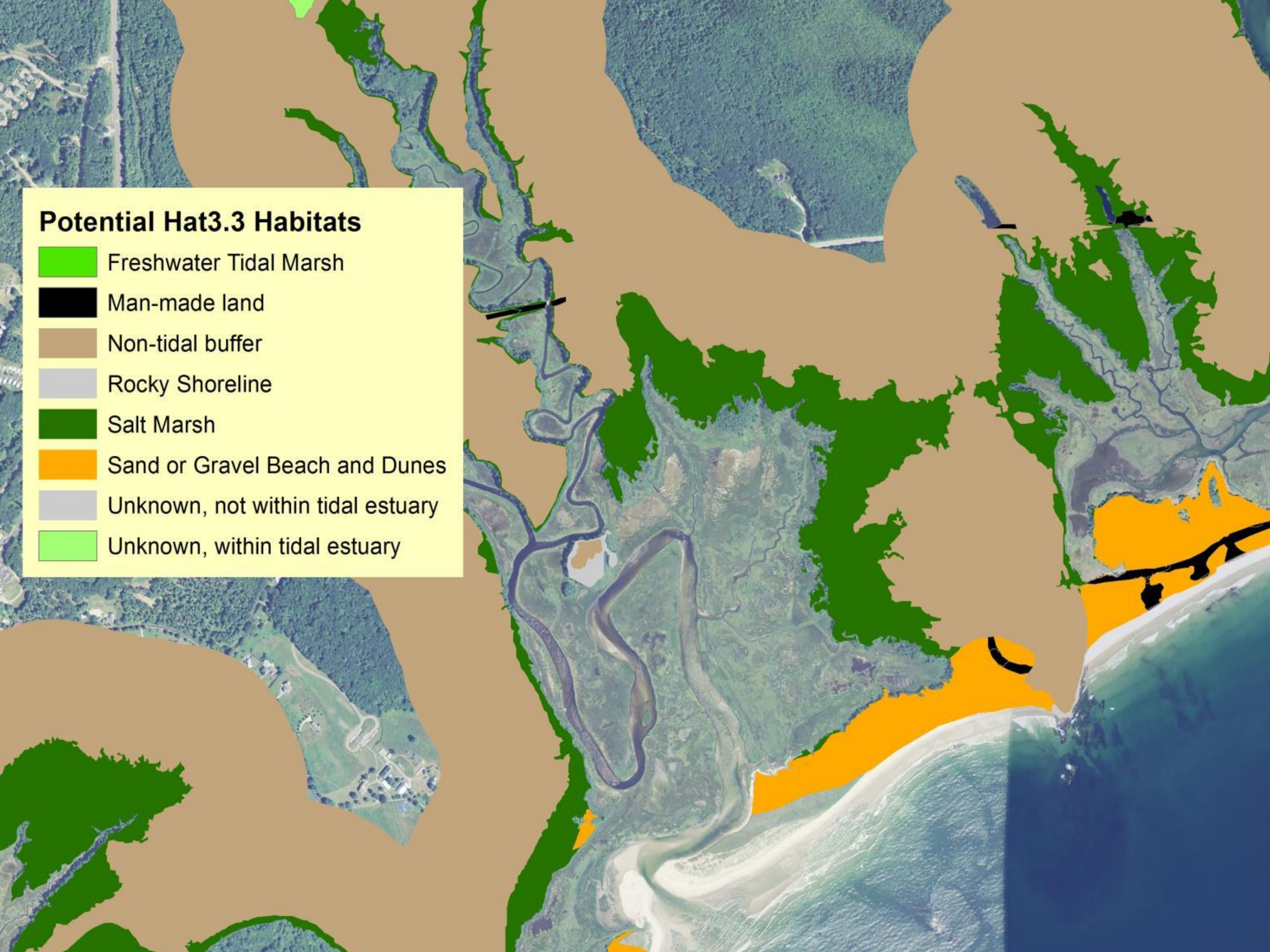
**-CMGE**

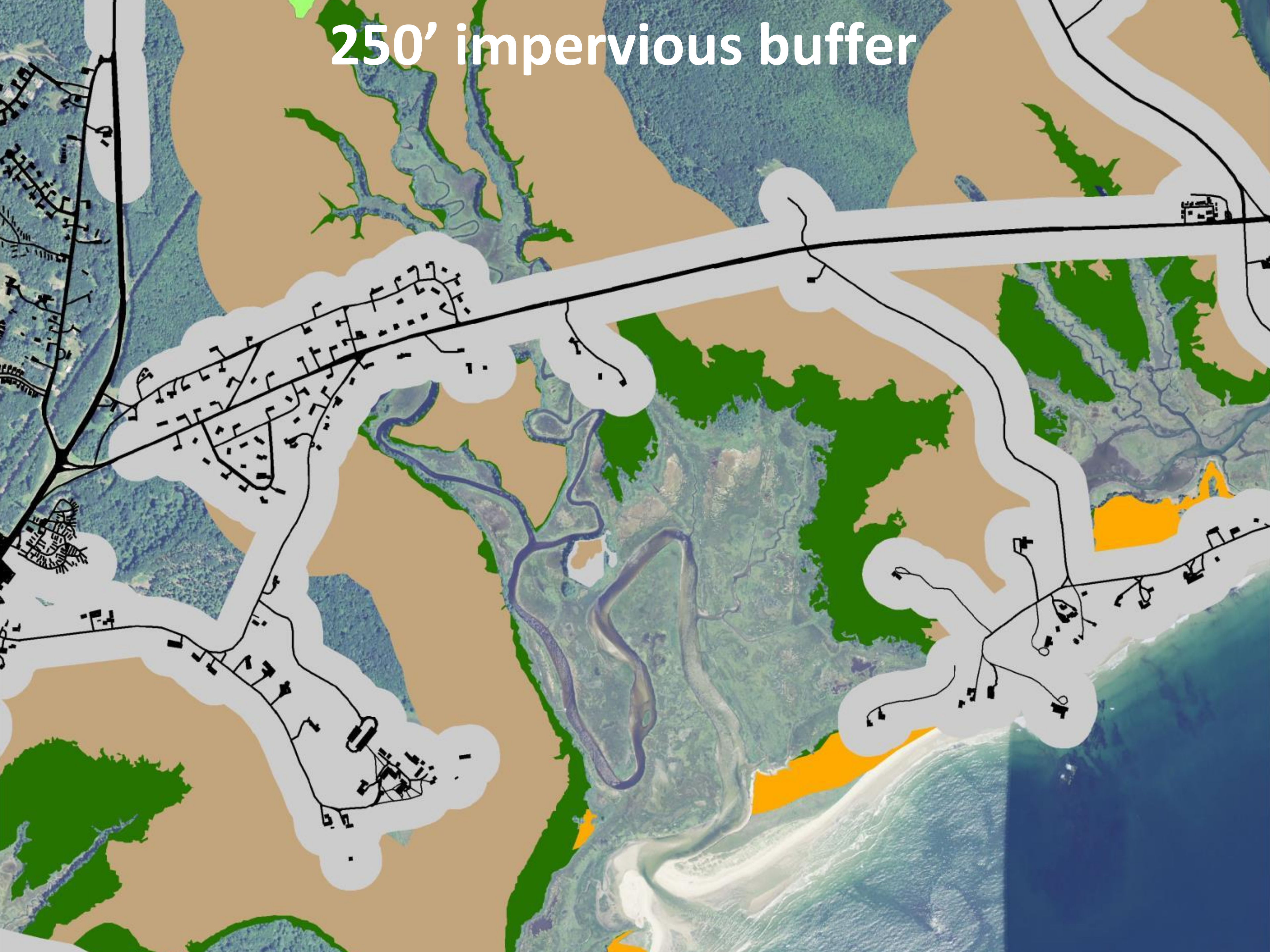

Sand or Gravel Beaches and Dunes


Rocky shoreline


Non-tidal buffer

**-CMGE**


Potential Hat3.3 Habitats
Freshwater Tidal Marsh
Man-made land
Non-tidal buffer
Rocky Shoreline
Salt Marsh
Sand or Gravel Beach and Dunes
Unknown, not within tidal estuary
Unknown, within tidal estuary


250’ impervious buffer

# Marshes in Planning

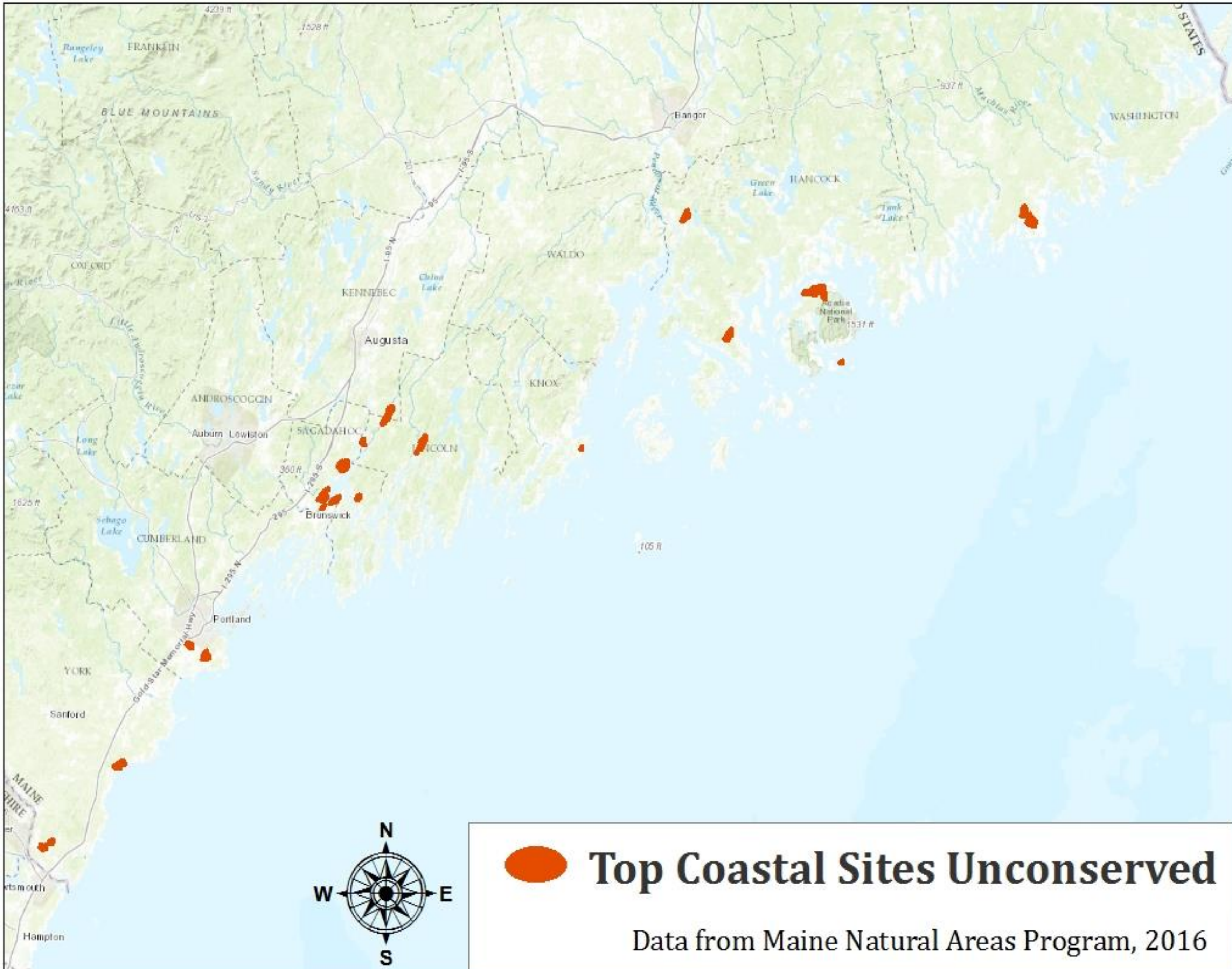
What the SLR and marsh migration models can show:

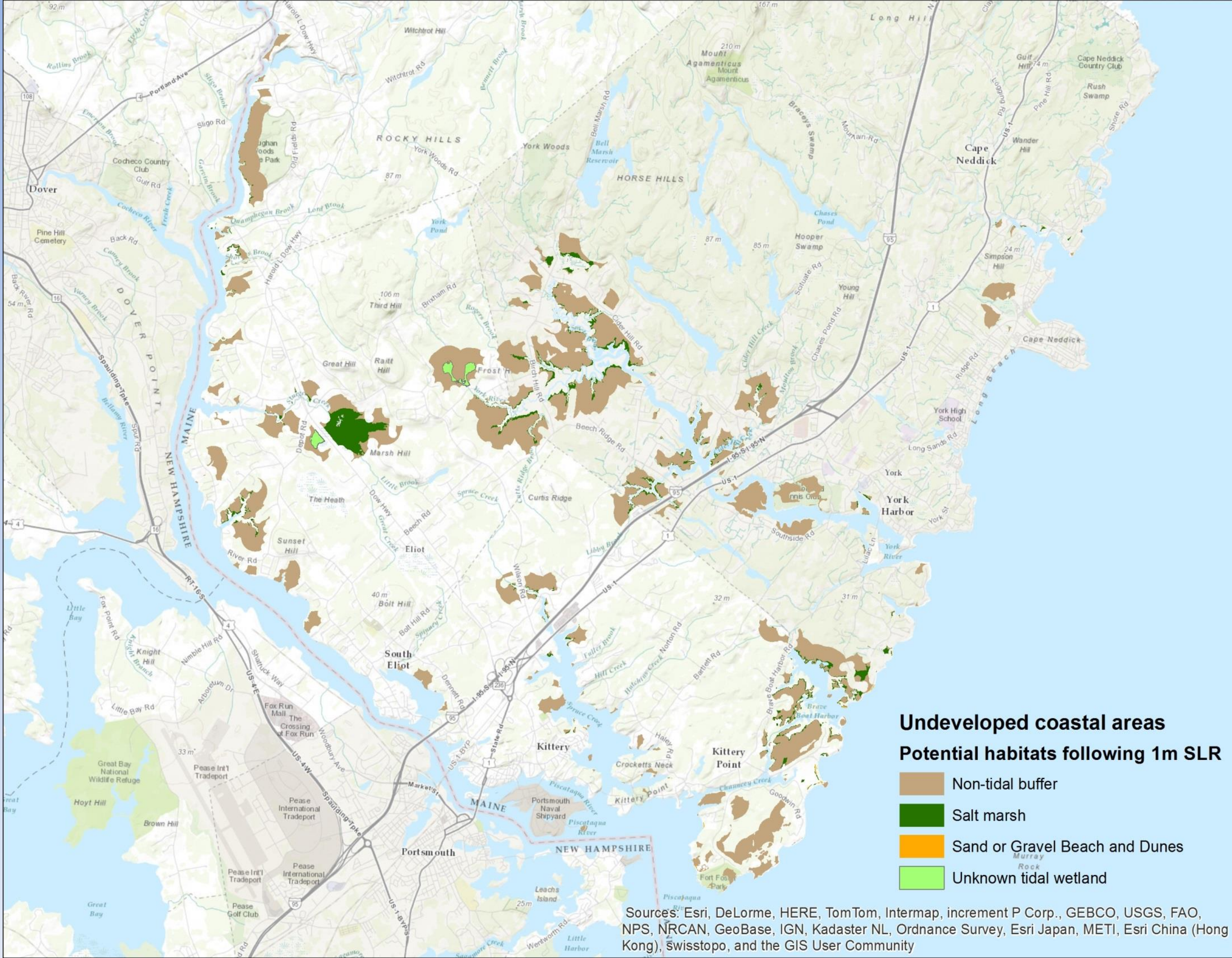
- Intersection of SLR with infrastructure (C/R nexus)
- Large, connected areas of future marsh and buffer (preventing stressors, providing habitat, ecosystem services)
- Stratification of sites statewide
- Prioritization

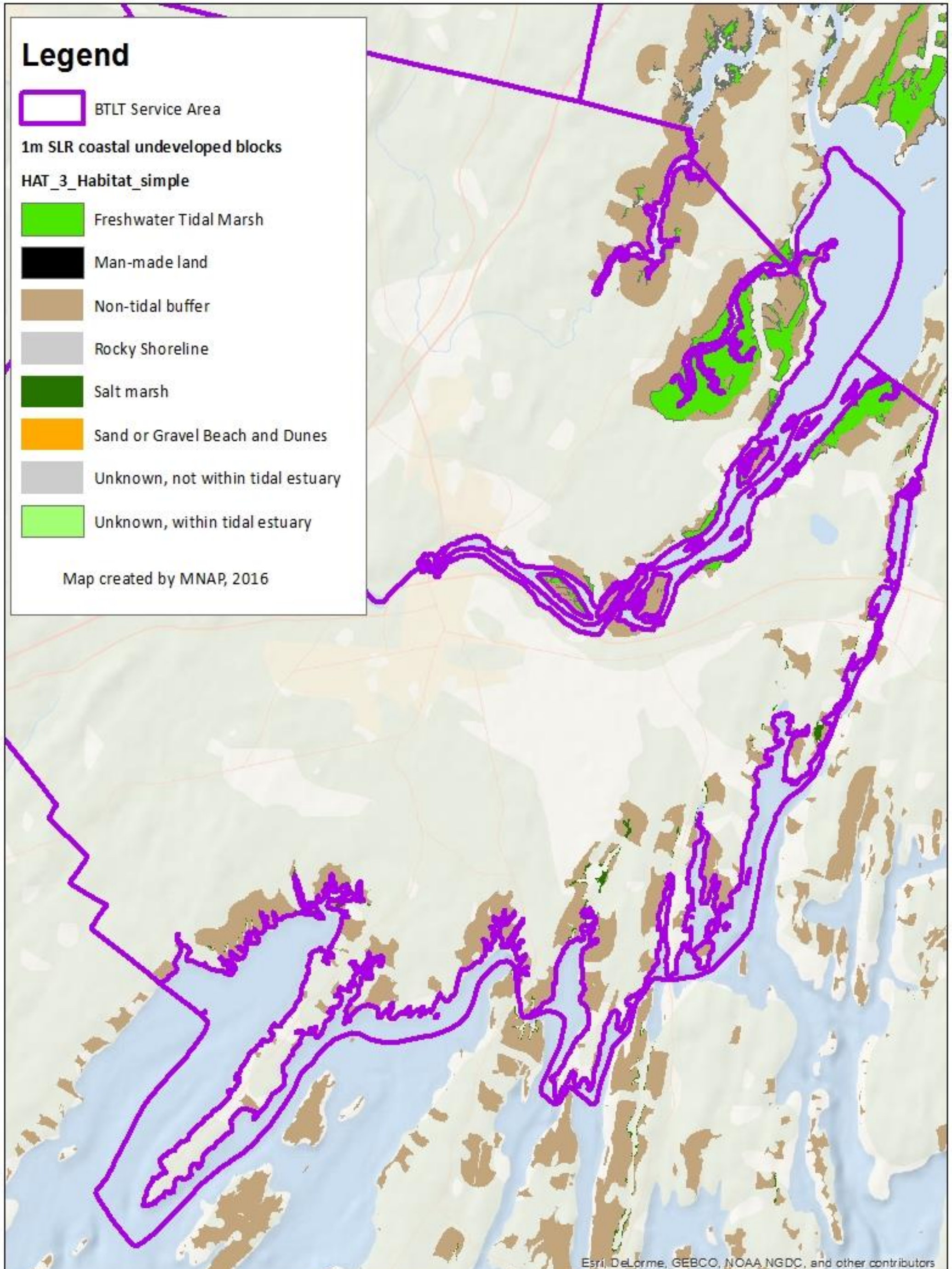
# Marshes in Planning

How the models are being used:

- ~~One size fits all~~
- Part of decision making toolkit…Planning horizon, various conservation values, funding, landowner opportunity…
- MNAP, MGS Viewer
- Maine-TNC Resiliency platform
- Application across multiple scales (examples)


Top Coastal Sites Unconserved
Data from Maine Natural Areas Program, 2016
N
W
E
S
Bangor
Augusta
Auburn Lewiston
Brunswick
Portland
Sanford
Hampton
FRANKLIN
BLUE MOUNTAINS
OXFORD
KENNEBEC
ANDROSCOGGIN
SAGADAHOC
CUMBERLAND
YORK
WALDO
KNOX
HANCOCK
WASHINGTON
Acadia National Park


Undeveloped coastal areas
Potential habitats following 1m SLR
Non-tidal buffer
Salt marsh
Sand or Gravel Beach and Dunes
Unknown tidal wetland
Sources: Esri, DeLorme, HERE, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community
Dover
ROCKY HILLS
HORSE HILLS
Mount Agamenticus
Cape Neddick
York
York Harbor
Eliot
South Eliot
Kittery
Kittery Point
Portsmouth
MAINE
NEW HAMPSHIRE
Great Bay National Wildlife Refuge
Pease International Tradeport
Portsmouth Naval Shipyard



Legend
BTLT Service Area
1m SLR coastal undeveloped blocks
HAT_3_Habitat_simple
Freshwater Tidal Marsh
Man-made land
Non-tidal buffer
Rocky Shoreline
Salt marsh
Sand or Gravel Beach and Dunes
Unknown, not within tidal estuary
Unknown, within tidal estuary
Map created by MNAP, 2016
Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors

# Marshes in Planning

Summary:

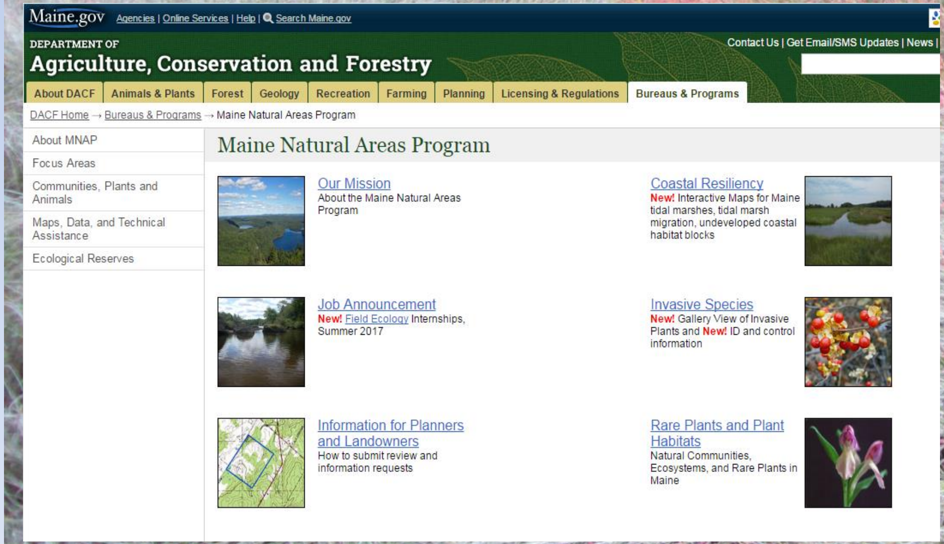
- Sea Level Rise Simulations
- Marsh Migration opportunities
- Coastal Undeveloped Blocks
- Highly Resilient Coastal Areas (*up next*….)

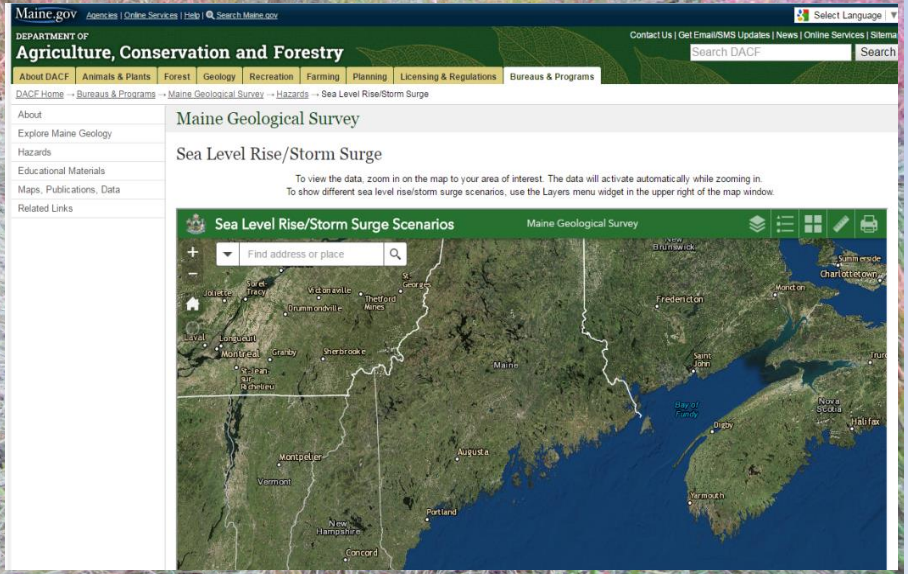
# Thank you!

With special thanks to:

Kristen.Puryear@maine.gov
Peter.A.Slovinsky@maine.gov

Additional resources:



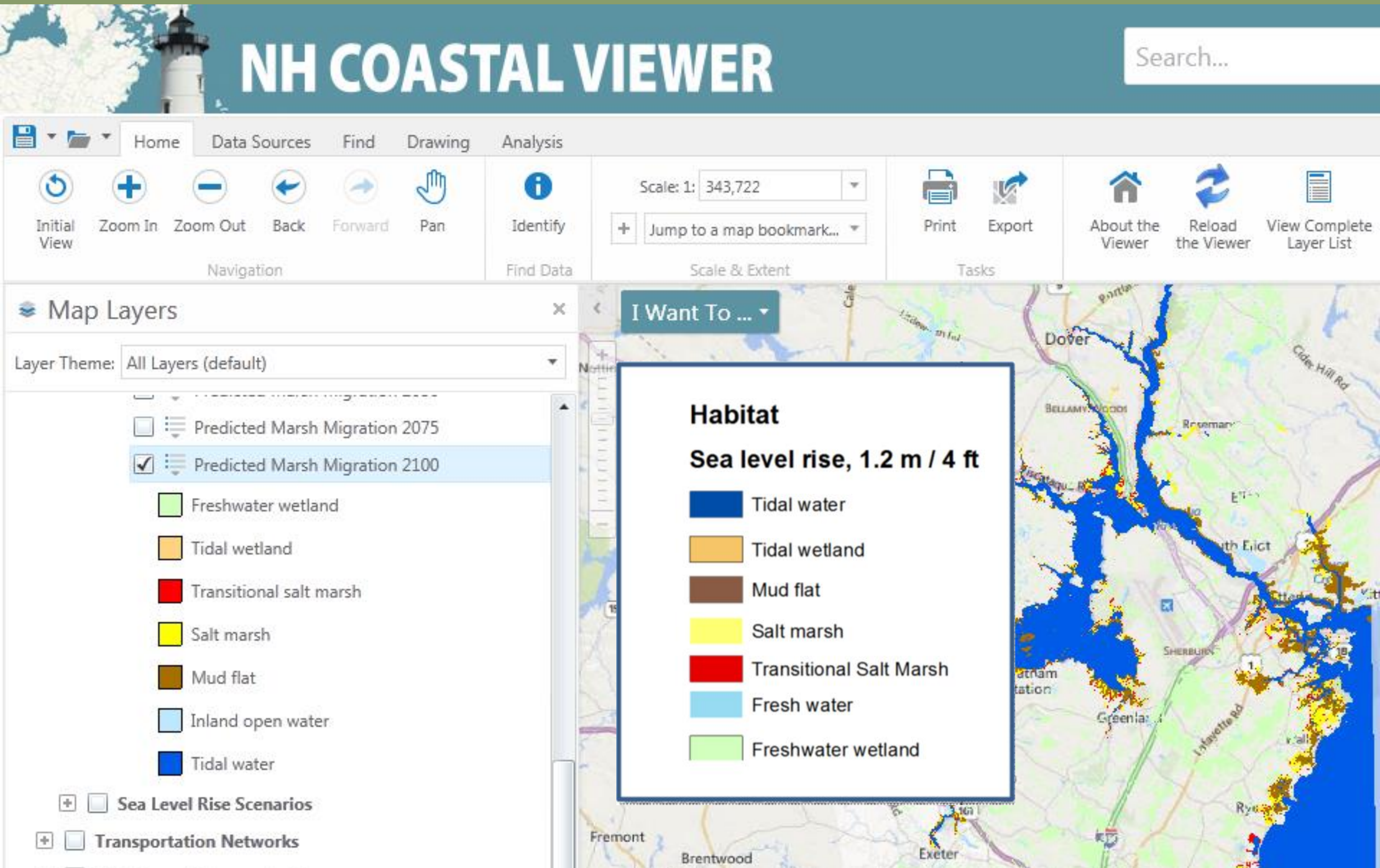



# Marsh Modeling in NH: Ecological Perspective

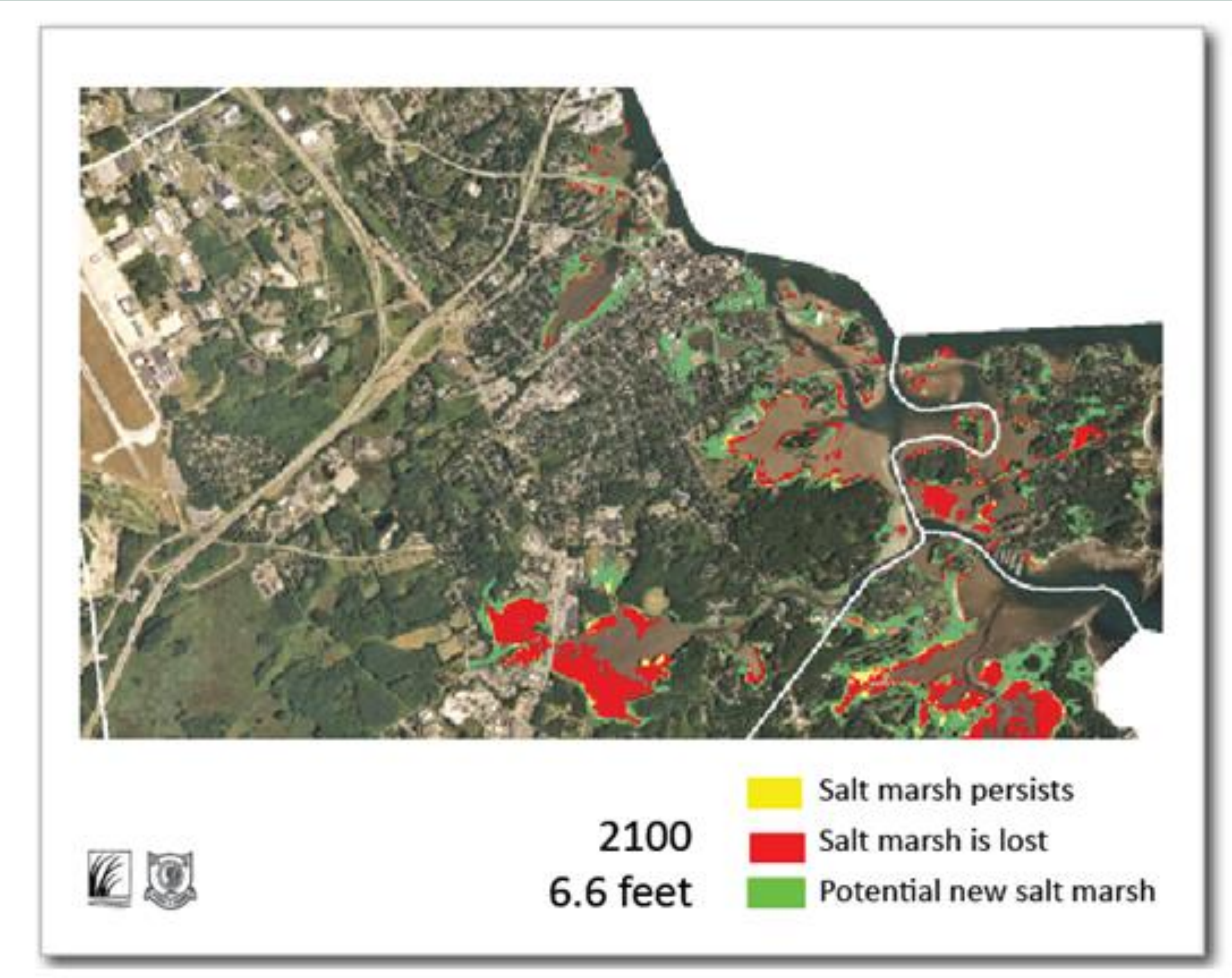
SLAMM

NOAA Office Coastal Management
High Resolution Mapping

# Simplified Data Publically Available

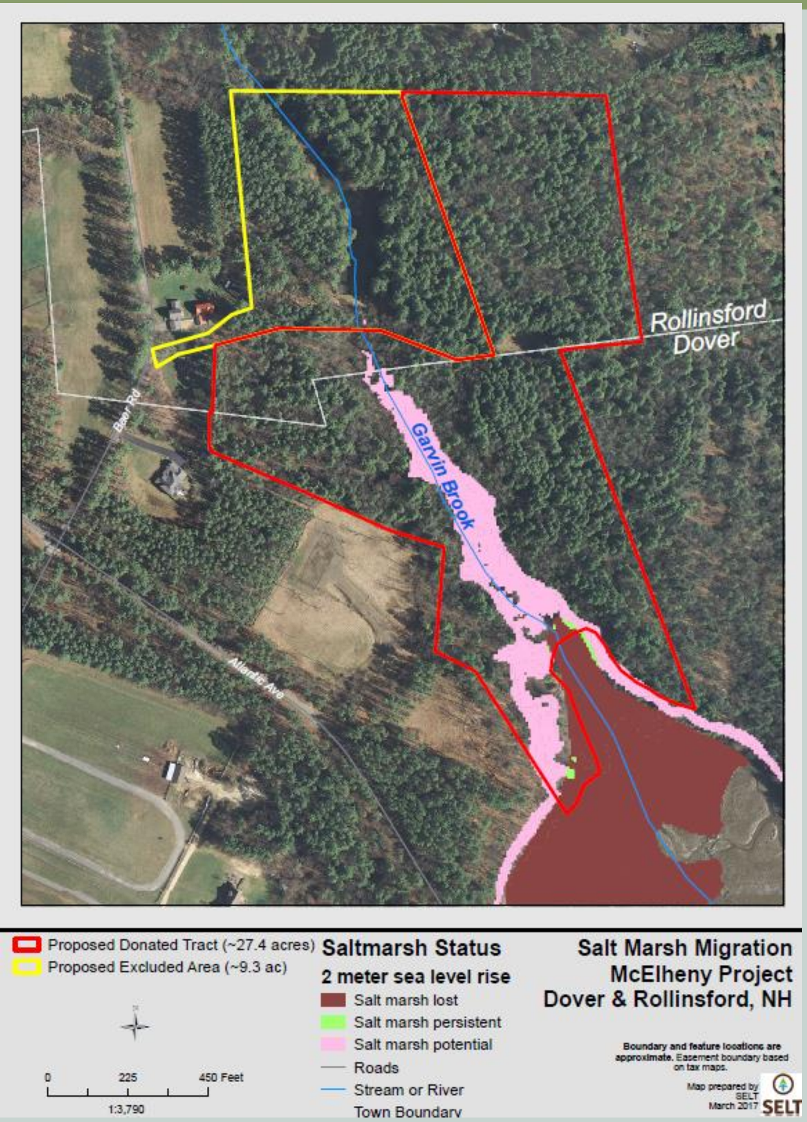


# SLAMM Supplemental Layers

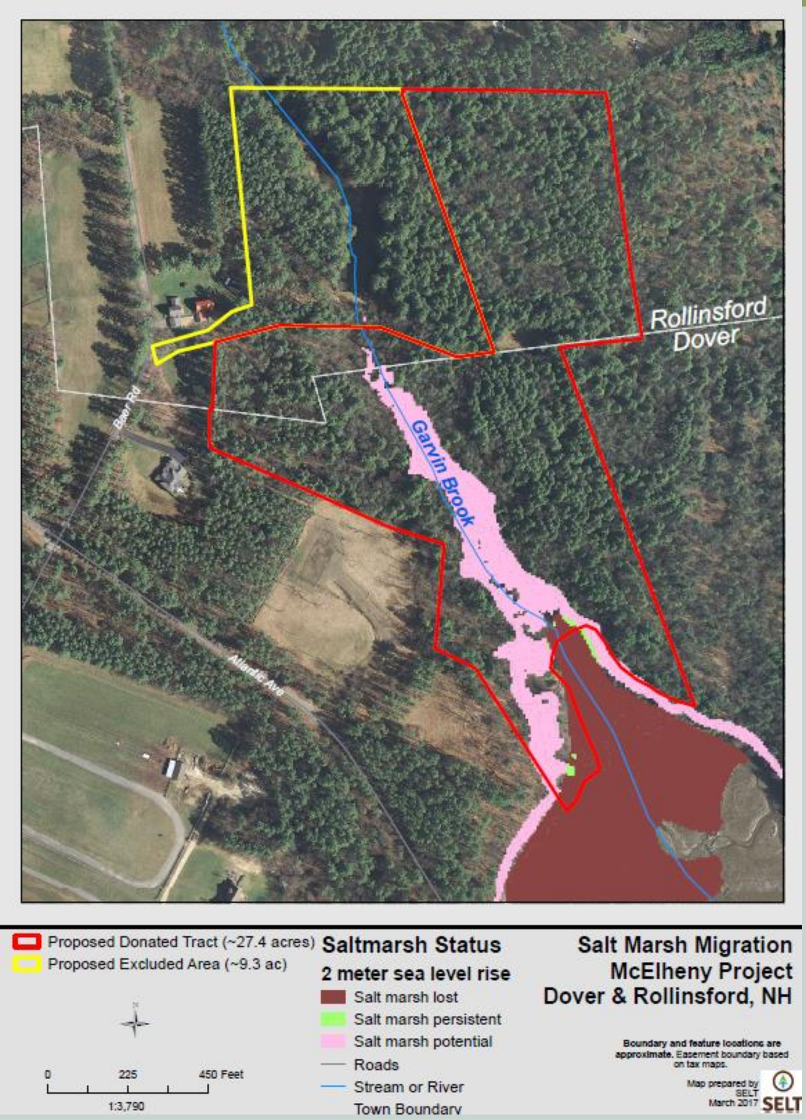



1. Migration pathways
2. Restoration of tidal flow
3. Marsh quality and resilience

# 1. SLAMM: Supporting Land Acquisition, Leveraging $



# SLAMM: Supporting Land Acquisition, Leveraging $



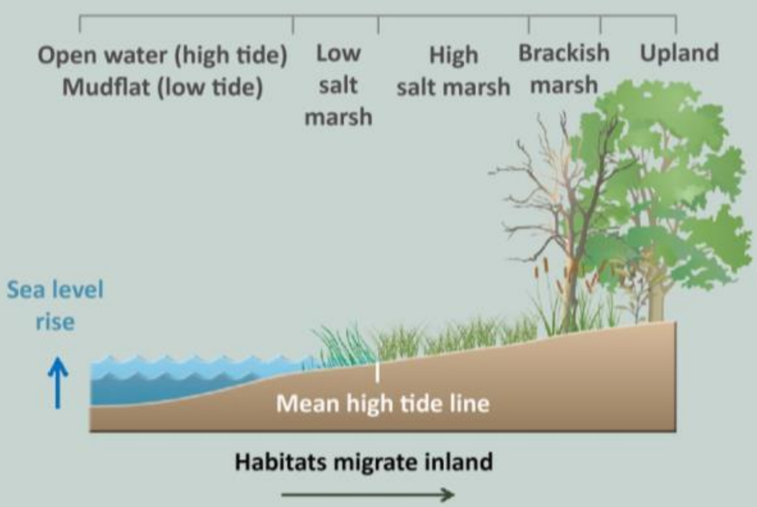

SELT
SOUTHEAST LAND TRUST of NEW HAMPSHIRE

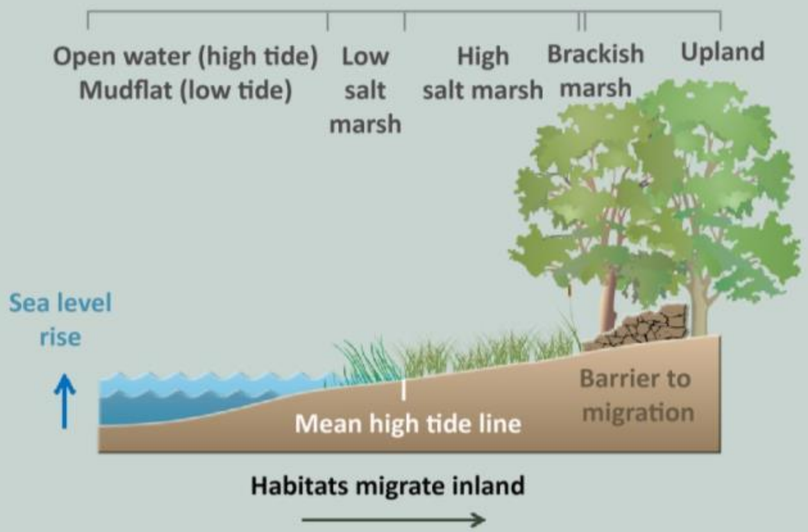
NEW HAMPSHIRE

STATE OF NEW HAMPSHIRE · LIVE FREE OR DIE · FISH AND GAME

USDA Natural Resources Conservation Service
New Hampshire

# 2. Field Verification of Migration Pathways



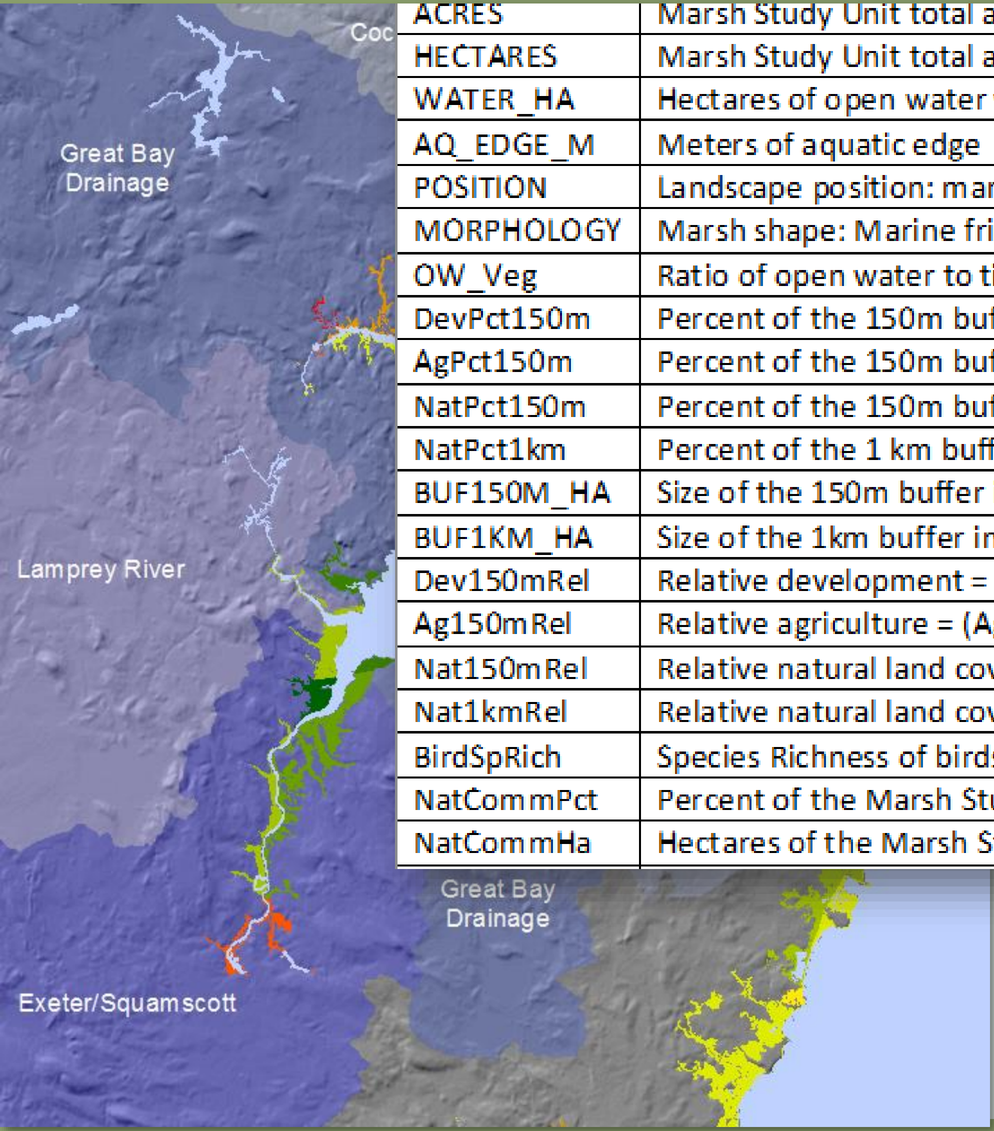




# 2. Field Verification of Migration Pathways


1 acre, n = 119

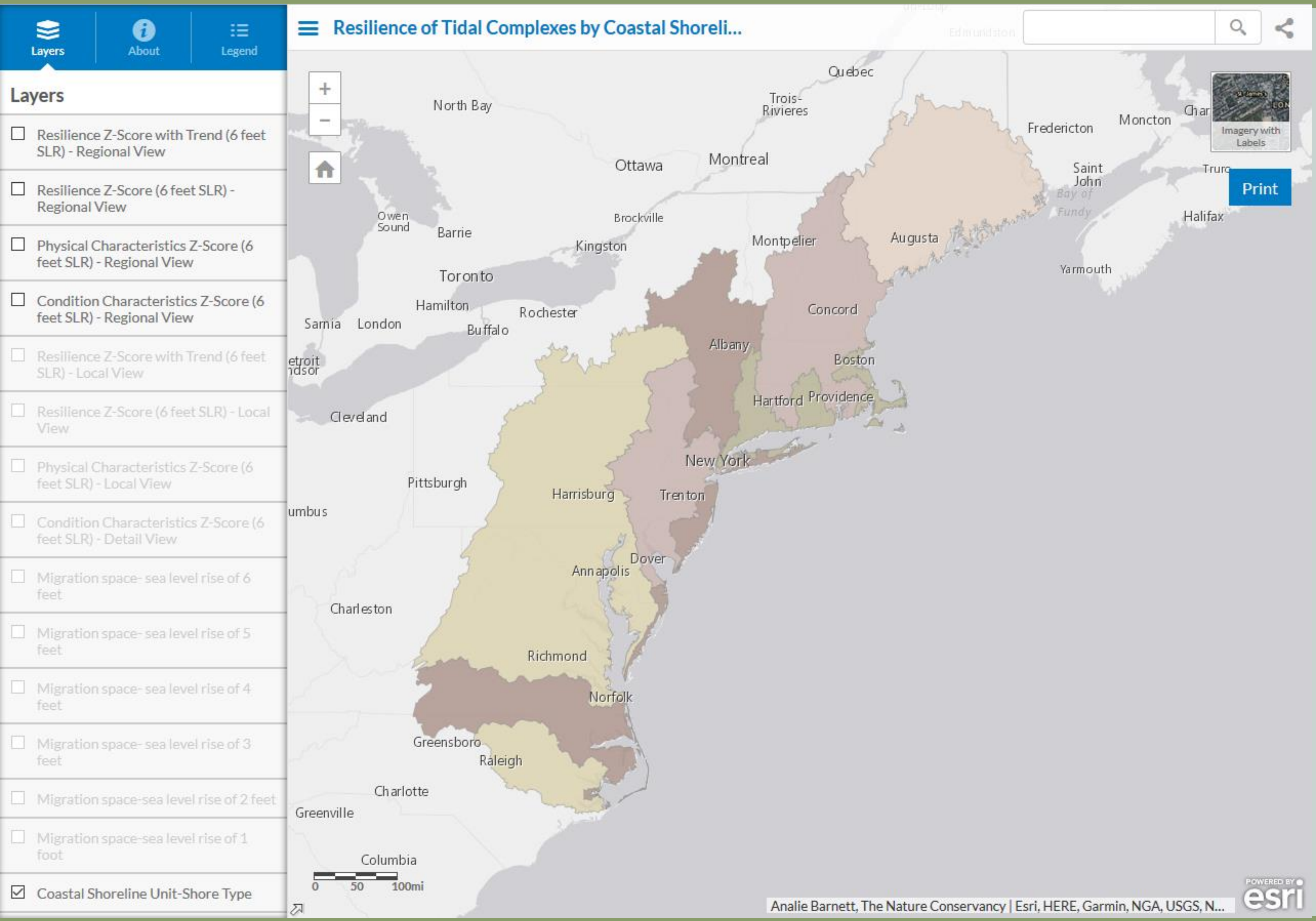
5 acres, n = 23

# 3. Habitat Quality + Migration Potential = Resilience (2013)

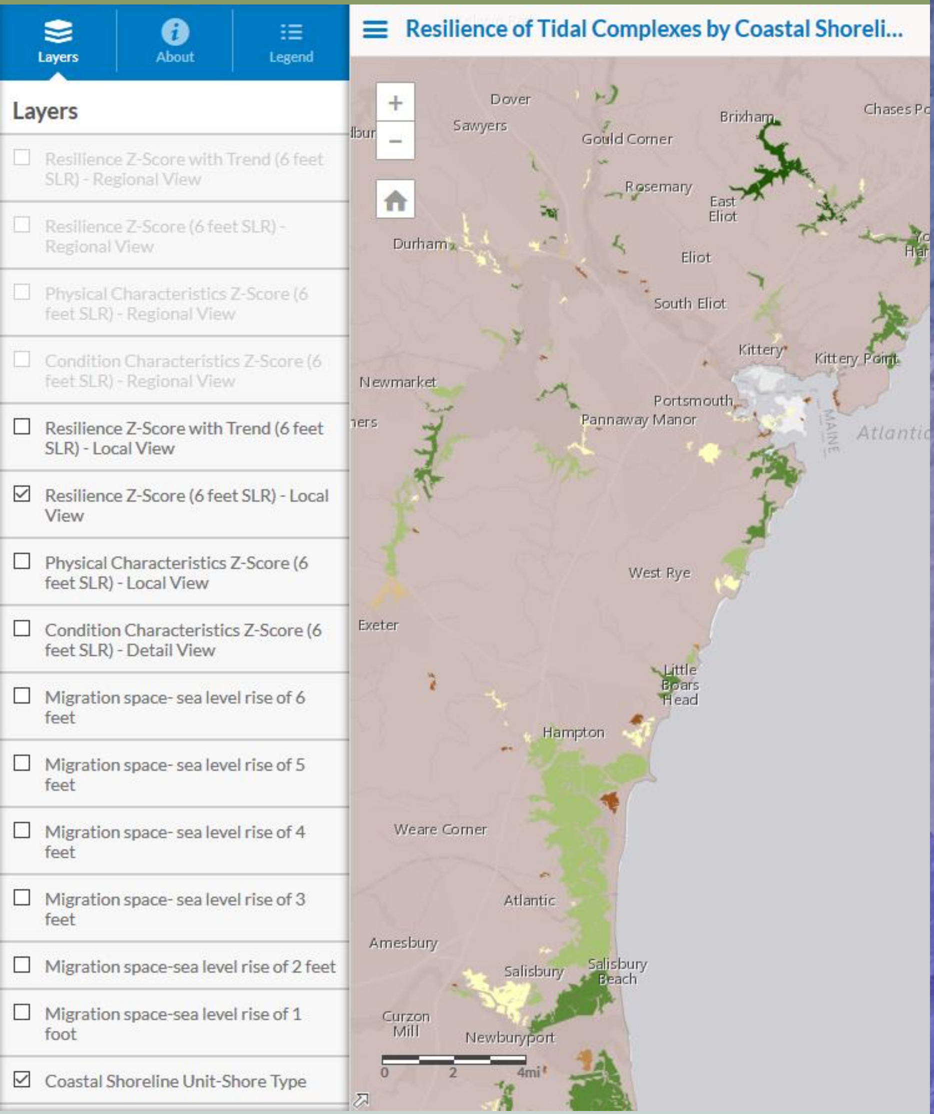


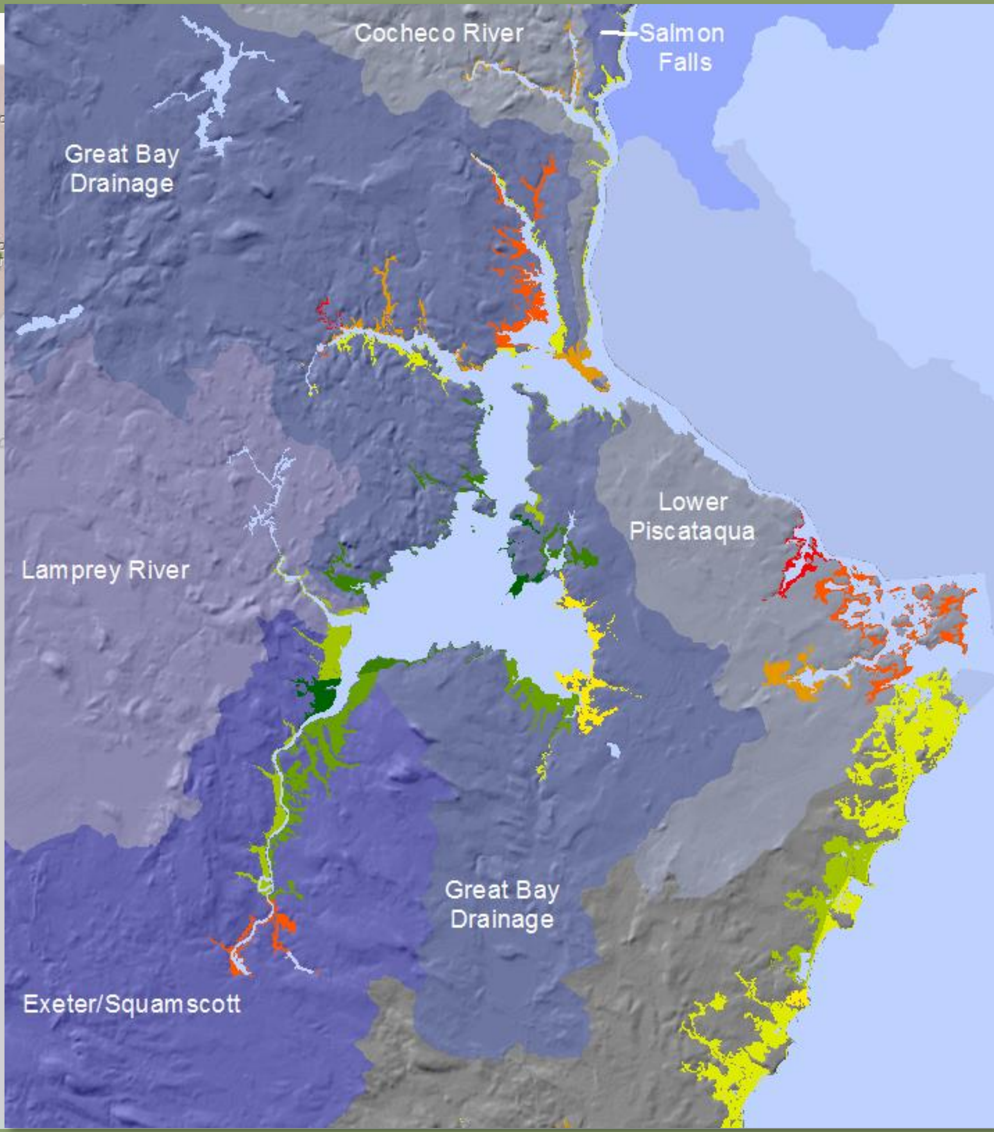

| | |
|---|---|
| ACRES | Marsh Study Unit total area (acres) |
| HECTARES | Marsh Study Unit total area (hectares) |
| WATER_HA | Hectares of open water within the MSU (NHD derived) |
| AQ_EDGE_M | Meters of aquatic edge |
| POSITION | Landscape position: marine, middle-estuary, upper-estuary |
| MORPHOLOGY | Marsh shape: Marine fringe marsh, Narrow finge marsh, Wide fringe marsh, Salt-meadow |
| OW_Veg | Ratio of open water to tidal emergent herbaceous wetland |
| DevPct150m | Percent of the 150m buffer that is developed land cover (2011 NLCD) |
| AgPct150m | Percent of the 150m buffer that is agriculture (2011 NLCD) |
| NatPct150m | Percent of the 150m buffer that is natural land cover (2011 NLCD) |
| NatPct1km | Percent of the 1 km buffer that is natural land cover (2011 NLCD) |
| BUF150M_HA | Size of the 150m buffer in hectares |
| BUF1KM_HA | Size of the 1km buffer in hectares |
| Dev150mRel | Relative development = (DevPct150m / 100) * (BUF150M_HA / HECTARES) |
| Ag150mRel | Relative agriculture = (AgPct150m / 100) * (BUF150M_HA / HECTARES) |
| Nat150mRel | Relative natural land cover = (NatPct150m / 100) * (BUF150M_HA / HECTARES) |
| Nat1kmRel | Relative natural land cover = (NatPct1km / 100) * (BUF1KM_HA / HECTARES) |
| BirdSpRich | Species Richness of birds of conservation concern |
| NatCommPct | Percent of the Marsh Study Unit that is NHB-mapped natural community |
| NatCommHa | Hectares of the Marsh Study Unit that is NHB-mapped natural community |

# Regional Model

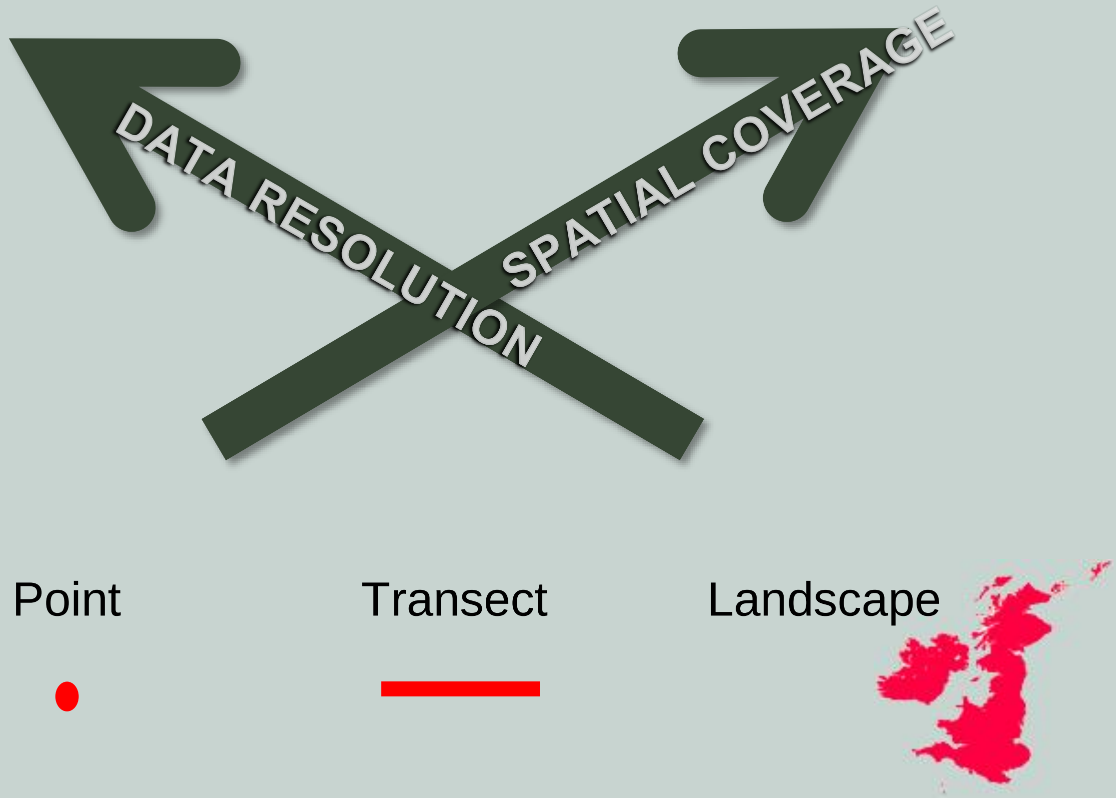


# Match Model with Management Decisions

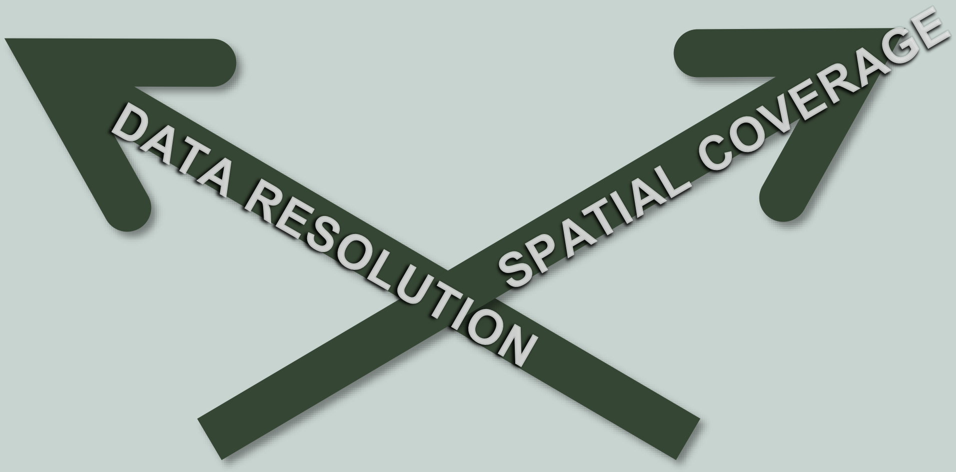


# Trade Data Resolution for Spatial Coverage



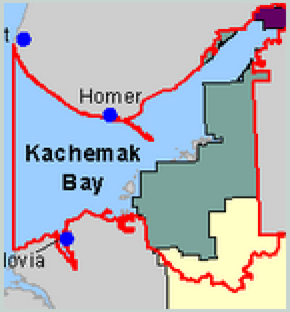
# Trade Data Resolution for Spatial Coverage




Point

Transect

Landscape



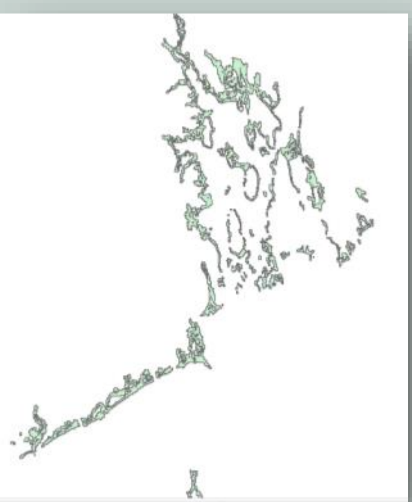

Supports site specific restoration decisions

Supports land acquisition and regional restoration decisions

# MARS: Evaluation of Site Specific Metrics

| | US State | National Estuarine Research Reserves | *Marsh Name* | Categories of indicators of marsh resilience to sea level rise | | | | | Resilience Index |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Marsh elevation | Elevation change | Sediment | Tide range | Sea-level rise | |
| East Coast | NH | Great Bay | *Great Bay Discovery Center* | | | | | | |
| East Coast | MA | Waquoit Bay | *Sage Lot Pond* | | | | | | |
| East Coast | RI | Narrangansett Bay | *Nag West* | | | | | | |
| East Coast | NY | Hudson River | *Outer Tivoli North* | | | | | | |
| East Coast | DE | Delaware | *St. Jones Reserve* | | | | | | |
| East Coast | MD | Chesapeake Bay | *Jug Bay* | | | | | | |
| East Coast | VA | Chesapeake Bay | *Goodwin Island Reserve* | | | | | | |
| East Coast | NC | North Carolina | *Masonboro Island* | | | | | | |
| East Coast | SC | NI-WB | *Crabhaul Creek* | | | | | | |
| East Coast | SC | ACE Basin | *Big Bay Creek* | | | | | | |
| Gulf | MS | Grand Bay | *Grand Bay* | | | | | | |
| West Coast | WA | Padilla Bay | *Sullivan Minor* | | | | | | |
| West Coast | OR | South Slough | *Hidden Creek* | | | | | | |
| West Coast | CA | San Francisco Bay | *China Camp State Park* | | | | | | |
| West Coast | CA | Elkhorn Slough | *Upper Slough marshes* | | | | | | |
| West Coast | CA | Tijuana River | *various marshes* | | | | | | |

# Broad Spatial Coverage: Transect or Rapid Assessment



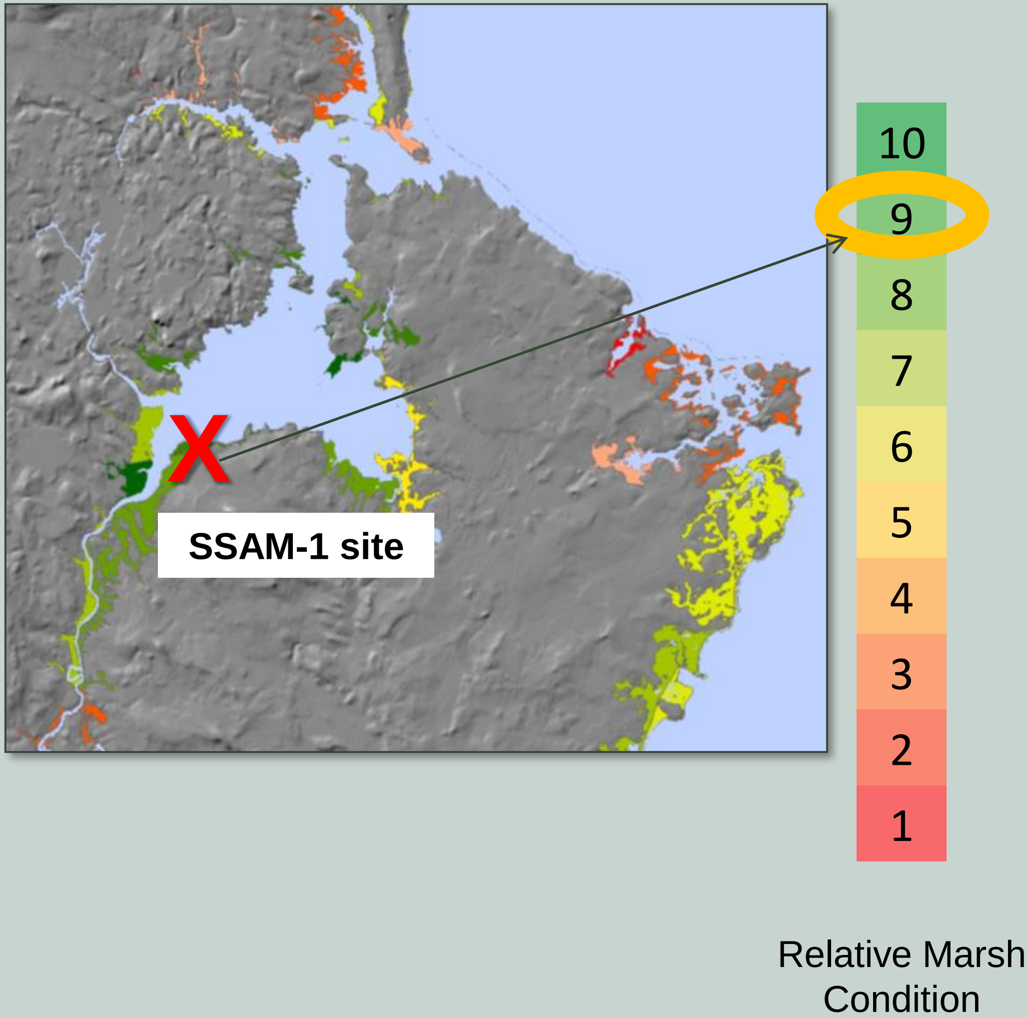
| Site | RISMA Score |
|---|---|
| Assonet | 0.91 |
| Barringt | 1.76 |
| Jacobs P | 1.90 |
| CSP | 2.11 |
| Seapowet | 2.65 |
| Coggesha | |
| Nag | 2.86 |
| Galilee | |
| ProvPt | 3.12 |
| Chase Co | 3.20 |
| Mill Cov | 3.49 |
| 100 acre | 3.82 |
| Round Hi | 3.86 |
| Smith Co | 4.15 |
| Palmer R | 4.47 |
| Satchues | 4.53 |
| Mary's C | 5.05 |
| Island R | 5.07 |
| Potowomu | 5.34 |
| Jenny | 5.72 |
| Stillhou | 6.35 |
| Narrow R | 6.54 |
| Fox Hill | 6.91 |
| Succotas | 8.09 |
| Avondale | 8.25 |
| Quonnie | 9.32 |
| Winnapau | 9.75 |
| Ninigrit | 9.83 |

Highest Quality

**SSAM-1 site**

Lowest Quality

# Allows us to set a Site in Context Within a Reserve

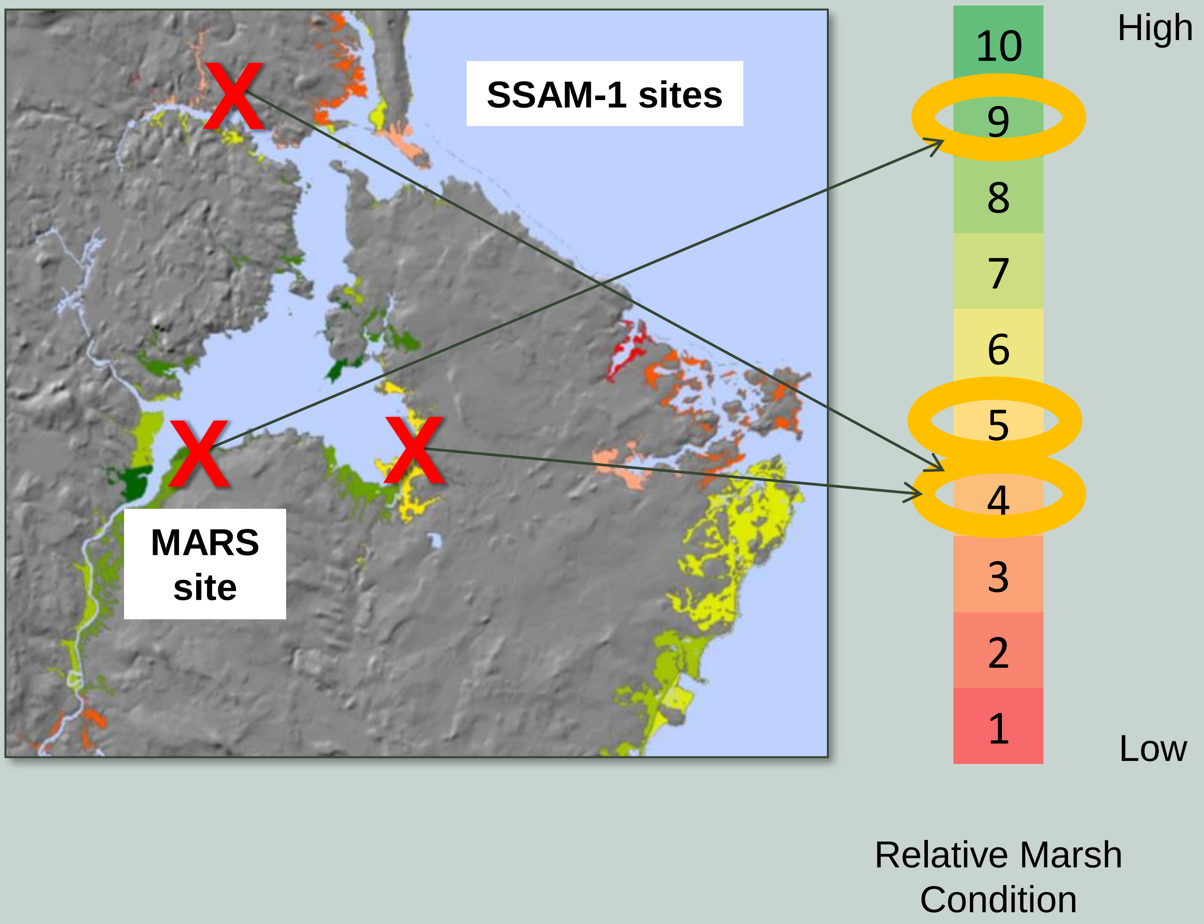



Integrate SSAM-1 monitoring with NERRS Habitat Mapping and Change

# MARS: Evaluation of Site Specific Metrics

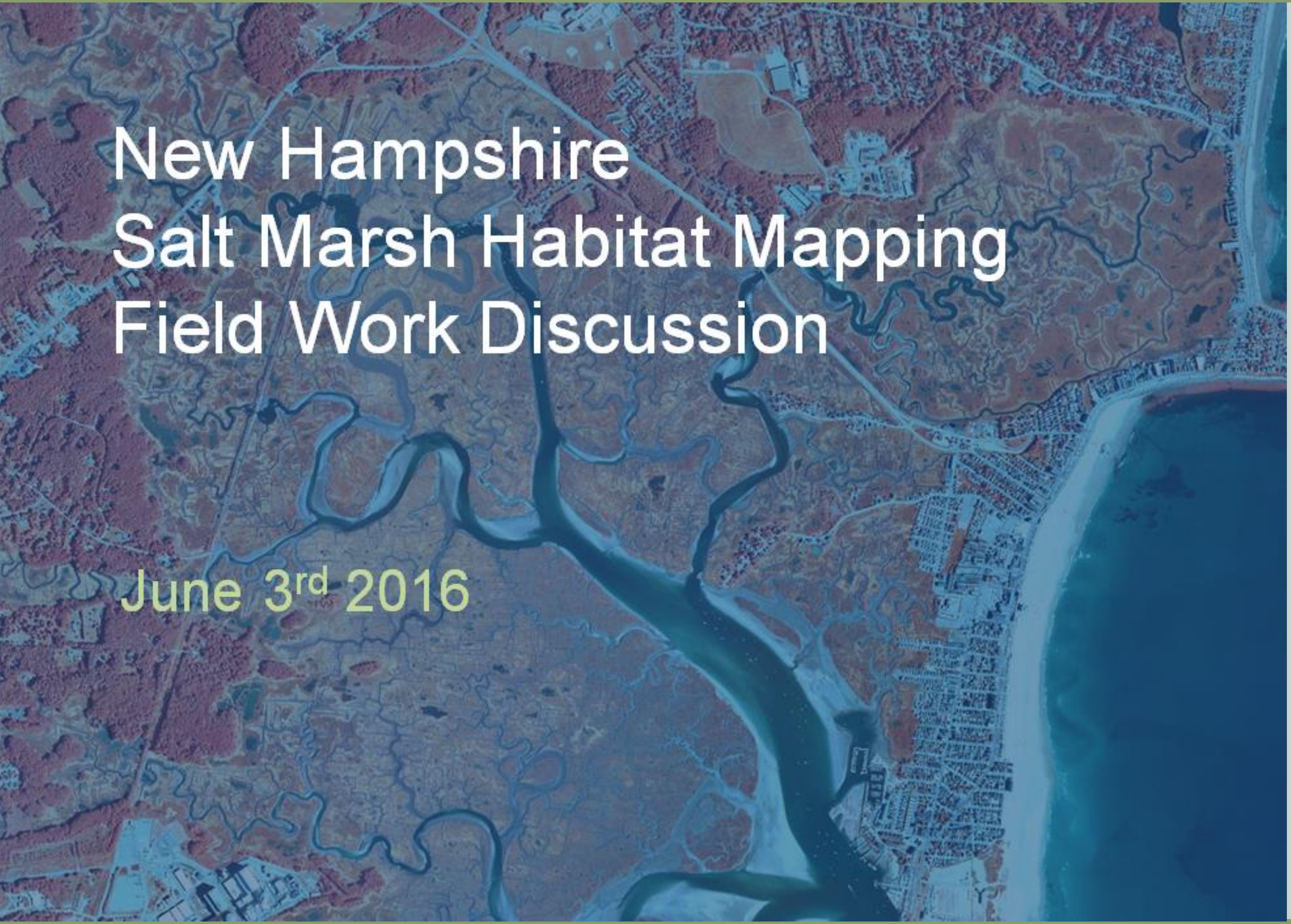
| | US State | National Estuarine Research Reserves | *Marsh Name* | Categories of indicators of marsh resilience to sea level rise | | | | | Resilience Index |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Marsh elevation | Elevation change | Sediment | Tide range | Sea-level rise | |
| **East Coast** | NH | Great Bay | *Great Bay Discovery Center* | | | | | | |
| | MA | Waquoit Bay | *Sage Lot Pond* | | | | | | |
| | RI | Narrangansett Bay | *Nag West* | | | | | | |
| | NY | Hudson River | *Outer Tivoli North* | | | | | | |
| | DE | Delaware | *St. Jones Reserve* | | | | | | |
| | MD | Chesapeake Bay | *Jug Bay* | | | | | | |
| | VA | Chesapeake Bay | *Goodwin Island Reserve* | | | | | | |
| | NC | North Carolina | *Masonboro Island* | | | | | | |
| | SC | NI-WB | *Crabhaul Creek* | | | | | | |
| | SC | ACE Basin | *Big Bay Creek* | | | | | | |
| **Gulf** | MS | Grand Bay | *Grand Bay* | | | | | | |
| **West Coast** | WA | Padilla Bay | *Sullivan Minor* | | | | | | |
| | OR | South Slough | *Hidden Creek* | | | | | | |
| | CA | San Francisco Bay | *China Camp State Park* | | | | | | |
| | CA | Elkhorn Slough | *Upper Slough marshes* | | | | | | |
| | CA | Tijuana River | *various marshes* | | | | | | |

# How Representative Is Local Site of the Reserve?



Integrating different scales help support a more comprehensive suite of decision making.

NOAA OCM High Resolution Mapping



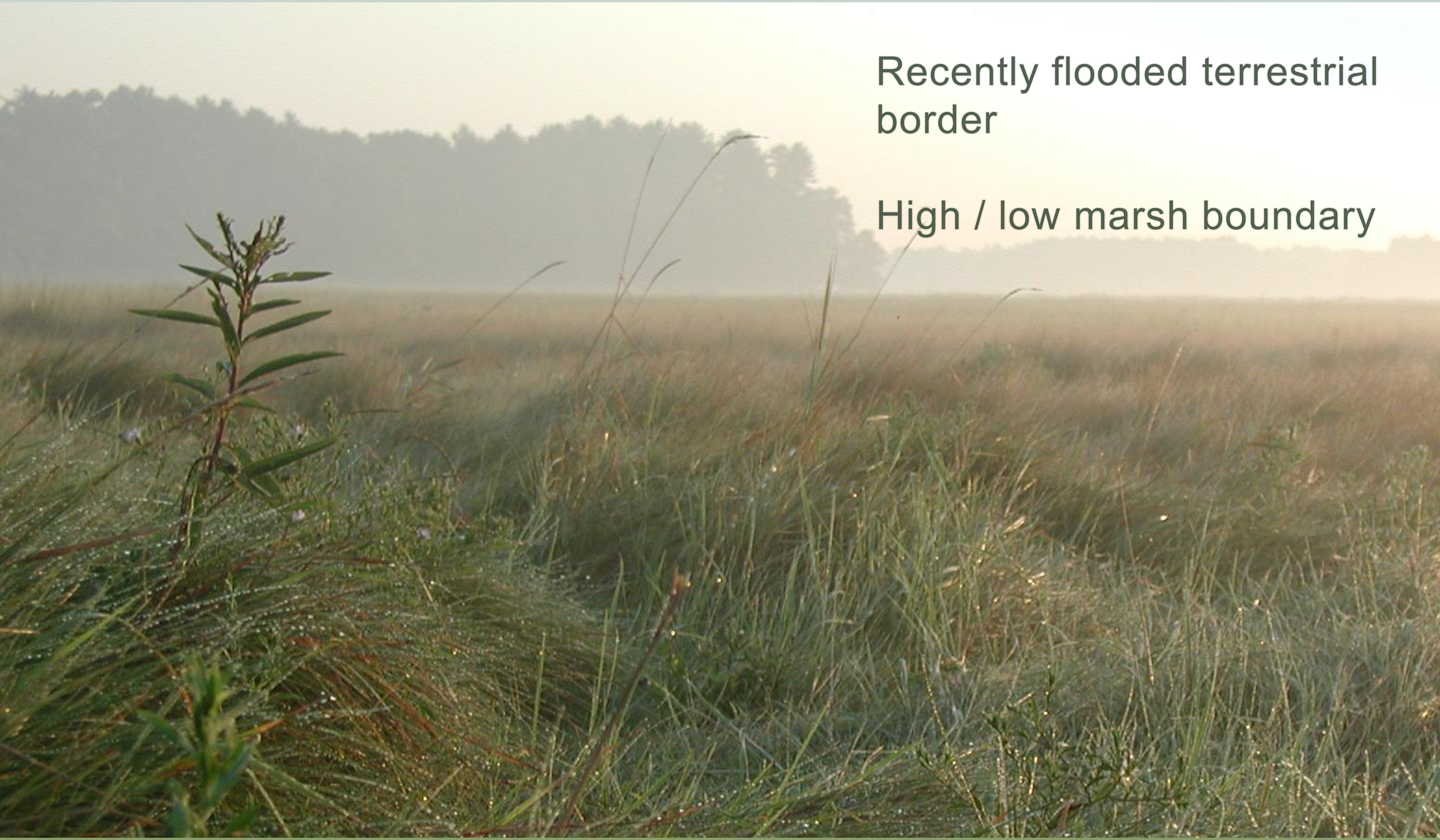
# New Hampshire Salt Marsh Habitat Mapping Field Work Discussion

June 3rd 2016

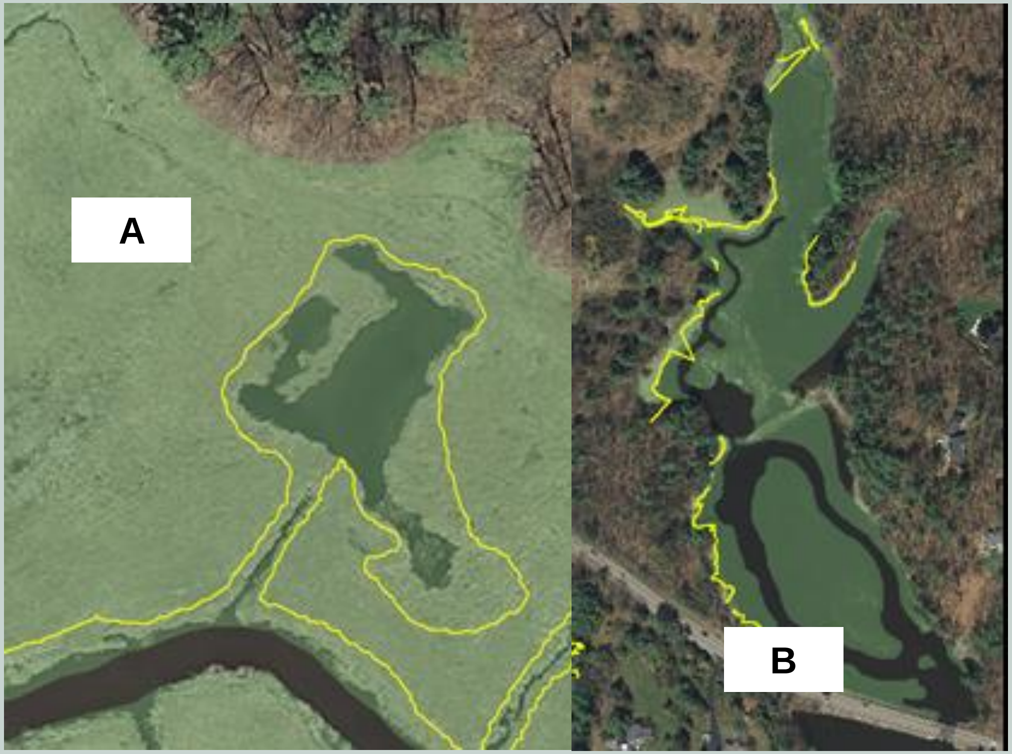
# NOAA OCM High Resolution Mapping

| Habitat Definitions | Descriptions |
|---|---|
| Creek | Natural creeks and channels. |
| Ditch | Manmade, straight ditches and associated spoils. |
| Grazed creek bank | Any area along a tidal creek where herbivores have grazed away all vegetation and exposed bare peat. |
| Invasive *Lythrum salicarnia* | Areas where the invasive plant *Lythrum salicarnia* is dominant. |
| Invasive *Phragmites australis* | Areas where the invasive plant *Phragmites australis* is dominant. |
| *Limonium* | Any area where *Limonium nashii* is the sole dominant. |
| Lower salt meadow | Any area where *Spartina patens* and *Distichlis spicata* are either sole or co-dominants. |
| Mud flat /Bare | Natural mud flat exposed at low tide, can have some sparse *S. alterniflora*. |
| Natural Panne | Very rare and dry at low tide. Species present may include *Plantago maritima*, *Sueda maritima*, *Salicornia* sp., *Juncus gerardii*, *Aster* sp. |
| Open water | Larger areas of water: bays, rivers, ponds. |
| Panne | Other unvegetated/recent die-off area (note: some die-off areas still might contain some very sparse, stunted *S. alterniflora* that is clearly dying). Shallow, wet at low tide, may have algal mat, filamentous algae or flocculent matter present. |
| Pool | Deeper than pannes, no vegetation, steep sides, Includes natural and degraded areas. |
| *Salicornia* spp. | Any area where the sole dominant species is *Salicornia* spp. No attempt was made to differentiate between annual and perennial forms. |
| Salt marsh terrestrial border | Infrequently flooded; Could include areas of higher elevation on marsh platform (commonly islands or linear patches next to excavated ditches); Most common: *Iva frutescens, Solidago sempirvirens*. |
| Short form *S. alterniflora* | Areas of short form *S. alterniflora* as a monoculture, although some *Salicornia* sp. may be present. |
| *S. alterniflora* / Lower salt meadow mixture | Any area where the dominant species include any combination of *S. alterniflora, Spartina patens*, and *D. spicata.* |
| *S. alterniflora* / *Salicornia* spp. mixture | Any area where *S. alterniflora* and *Salicornia* spp. are co-dominant. |
| S. alterniflora / Upper salt meadow mixture | Any area where *S. alterniflora* and *J. gerardii* are co-dominant or where *S. alterniflora, J. gerardii*, and *D. spicata* are co-dominant. |
| Tall form *S. alterniflora* | Regularly flooded, dominated by tall form (75 cm+) *S. alterniflora* usually found along creek or ditch edges. Other species may be present in this zone but *S. alterniflora* is the only dominant. |
| Trail | Any area of marsh that is clearly trampled by either human or animal foot traffic. |

# NOAA OCM High Resolution Mapping - Resilience



# Change Analysis: 2010




The yellow line represents the high / low marsh interface at two marshes at Great Bay. Site A is relatively healthy with an extensive high marsh plateau, but site B is becoming flooded and topology prevents migration inland.

Early warning of marsh loss.

Landscape wide validation of SET data.

# Marsh Study Unit and Point to Landscape

1. **Project Title**: A Landscape Scale Assessment of NERRS Marsh Resilience: Creating a Framework for Effective Monitoring Program and Tool Implementation.

2. **Names of Reserves:** Great Bay, Padilla Bay, Mission Aransas, Chesapeake Bay Virginia, Elkhorn Slough, Narragansett Bay.

3. **Project Lead**: Rachel Stevens; Stewardship and GIS Coordinator, Great Bay National Estuarine Research Reserve, 89 Depot Road, Greenland, NH 03824. (603) 778-0015. Rachel.stevens@wildlife.nh.gov.

4. **Additional Team Members**:

**Project Co-lead and GIS Analysis**: Suzanne Shull, GIS Specialist, Padilla Bay National Estuarine Research Reserve. (360) 428-1092. Sshull@padillabay.gov.

**Project Co-lead and GIS Analysis**: Nate Herold, Physical Scientist, NOAA Office for Coastal Management, 2234 South Hobson Avenue, Charleston, South Carolina 29405. (843) 740-1183. Nate.herold@noaa.gov.

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Katie Callahan, GIS specialist, NH Fish and Game Department and Office of Information Technology 11 Hazen Dr, Concord NH 0330. 603-271-3014. catherine.callahan@doit.nh.gov

**GIS Analysis**: David Justice, Information Technologist, Earth Systems Research Center, Morse Hall, University of New Hampshire, Durham, NH 03824. (603) 862-1792. David.justice@ unh.edu.

**Communications Specialist**: Delores Leonard, Principal, Roca Communications, 2 Oldfields Road, South Berwick, Maine, 03908. 603-289-9442. doloresjalbertleonard@gmail.com

**Advisory Committee and Project Review:**
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Eric Grossman US Geological Survey, Western Fisheries Research Center, 6505 NE 65th Street, Seattle, WA 98115. (206) 526-6282. egrossman@usgs.gov

Scott Lerberg, Watershed and Stewardship Coordinator, Chesapeake Bay VA National Estuarine Research Reserve, 7581 Spencer Rd, Gloucester Point, VA 23062. (804) 684-7129. Lerbergs@vims.
Kenny Raposa, Research Coordinator, Narragansett Bay National Estuarine Research Reserve, PO Box 151, Prudence Island, RI 02872. (401) 683-7849. Kenny@nbnerr.org.

Cory Riley, Manager, Great Bay National Estuarine Research Reserve, 225 Main Street, Durham, NH 03824. (603) 868-1095. Cory.riley@wildlife.nh.gov

Katie Swanson, Stewardship Coordinator, Mission-Aransas National Estuarine Research Reserve, The University of Texas Marine Science Institute, Estuarine Research Center, 750 Channel View Dr. Port Aransas, TX 78373. (361) 749-3106. Katie.swanson@utexas.edu.

Kerstin Wasson, Research Coordinator, Elkhorn Slough National Estuarine Research Reserve, 1700 Elkhorn Rd, Watsonville, CA 95076. (831) 728-2822. Kerstin.wasson@gmail.com.

5. **Fiscal Agent:** National Estuarine Research Reserve Association
Rebecca K. Roth, Executive Director, National Estuarine Research Reserve Association, 342 Laudholm Farm Rd.Wells, ME 04090. 202.236.4819 (office/cell). Roth@nerra.org

# Marsh Study Unit and Point to Landscape

Table 1. Example ways to link site-specific data to remotely sensed measures of "resilience".

| Category of "resilience" | Example site-specific metrics | Example landscape scale metrics | Related existing NERRS or Digital Coast product /tool. |
|---|---|---|---|
| Current condition | Biomonitoring vegetation transect data. | Connectivity, MSU size, ratio of open water to tidal emergent herbaceous wetland, percent of percent of 150m buffer that is agriculture. | Biomonitoring, Habitat Mapping and Change, C-CAP |
| Vulnerability | Percent of marsh below MHW, percent in lowest third of plant distribution, tidal range. | Percent of MSU below MHW, percent in lowest third of plant distribution, tidal range. | MARS, OCM's tidal surface and wetland modeling to and/or the SLR Viewer |
| Adaptation potential (migration inland) | Sentinel site elevation data. Ecotone monitoring. | National elevation data set, LiDAR data, landuse/landcover, soils, armoring. | OCM's tidal surface & wetland impact/migration models use in SLR viewer and SLAMM. |

# LUBBERLAND CREEK SALT MARSH

# NEWMARKET, N.H.

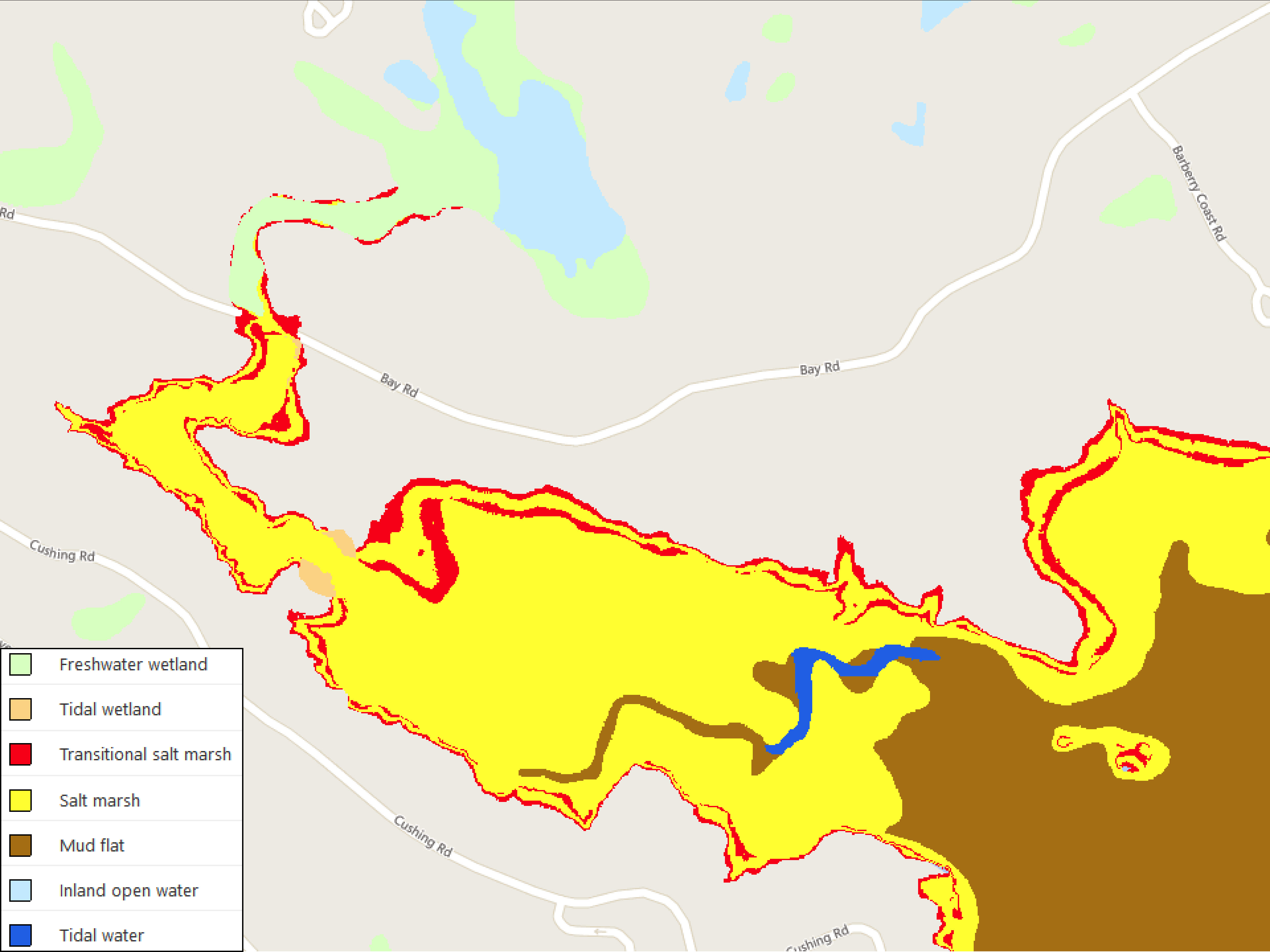
The Nature Conservancy
PROTECTING NATURE. PRESERVING LIFE.

WRIGHT-PIERCE
Engineering a Better Environment

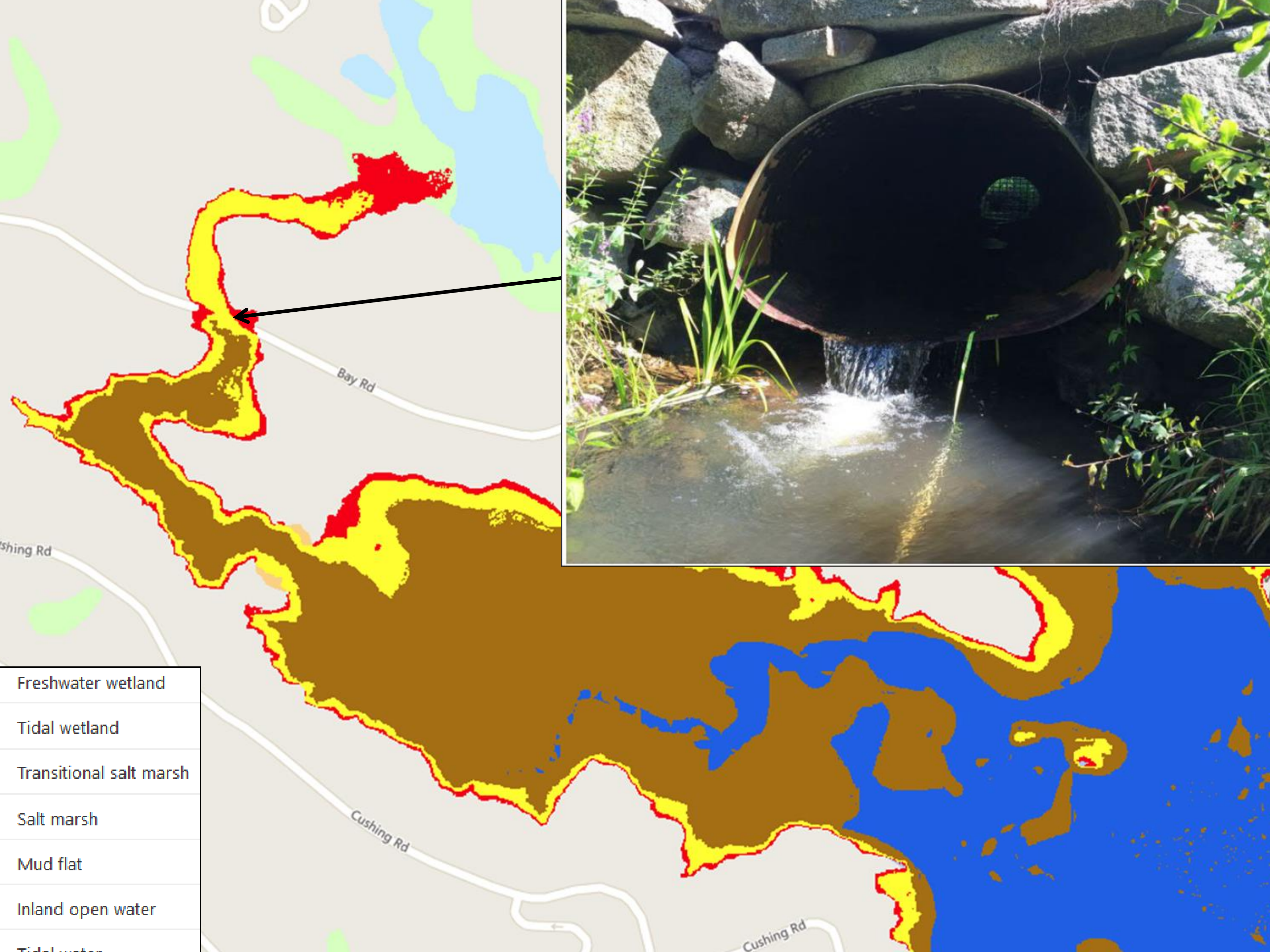
TOWN OF NEWMARKET, NH EST. DEC. 15, 1727

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

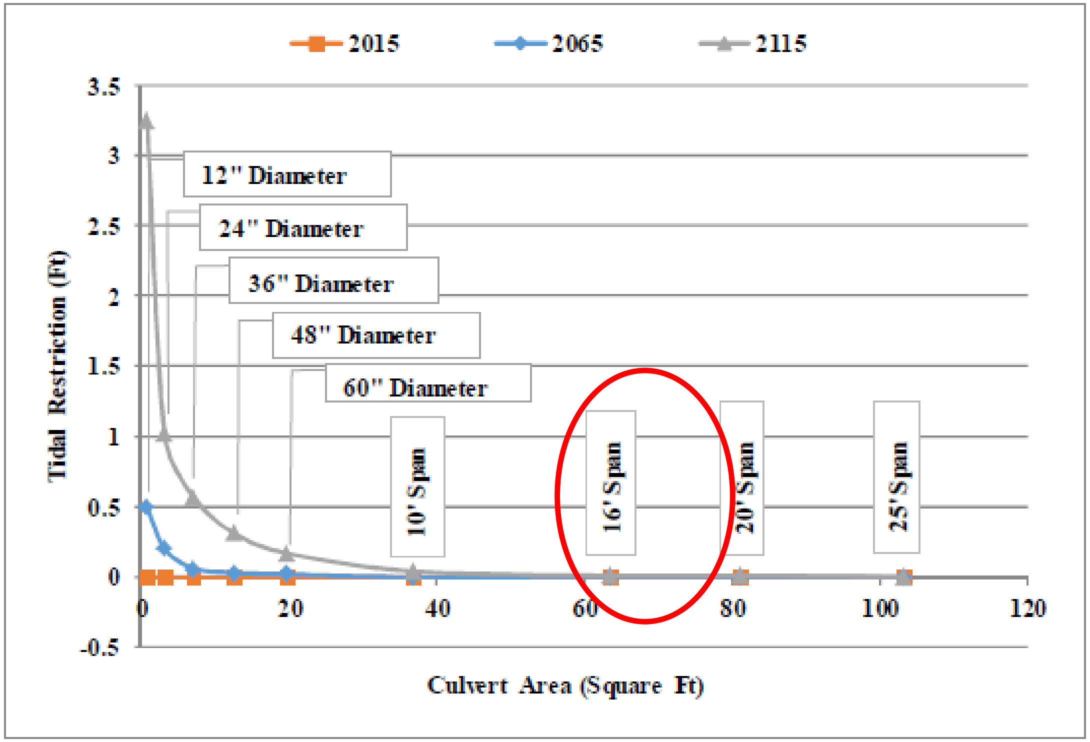
New Hampshire Coastal Program
DEPARTMENT OF ENVIRONMENTAL SERVICES



Rd
Bay Rd
Bay Rd
Barberry Coast Rd
Cushing Rd
Cushing Rd
Cushing Rd
Freshwater wetland
Tidal wetland
Transitional salt marsh
Salt marsh
Mud flat
Inland open water
Tidal water

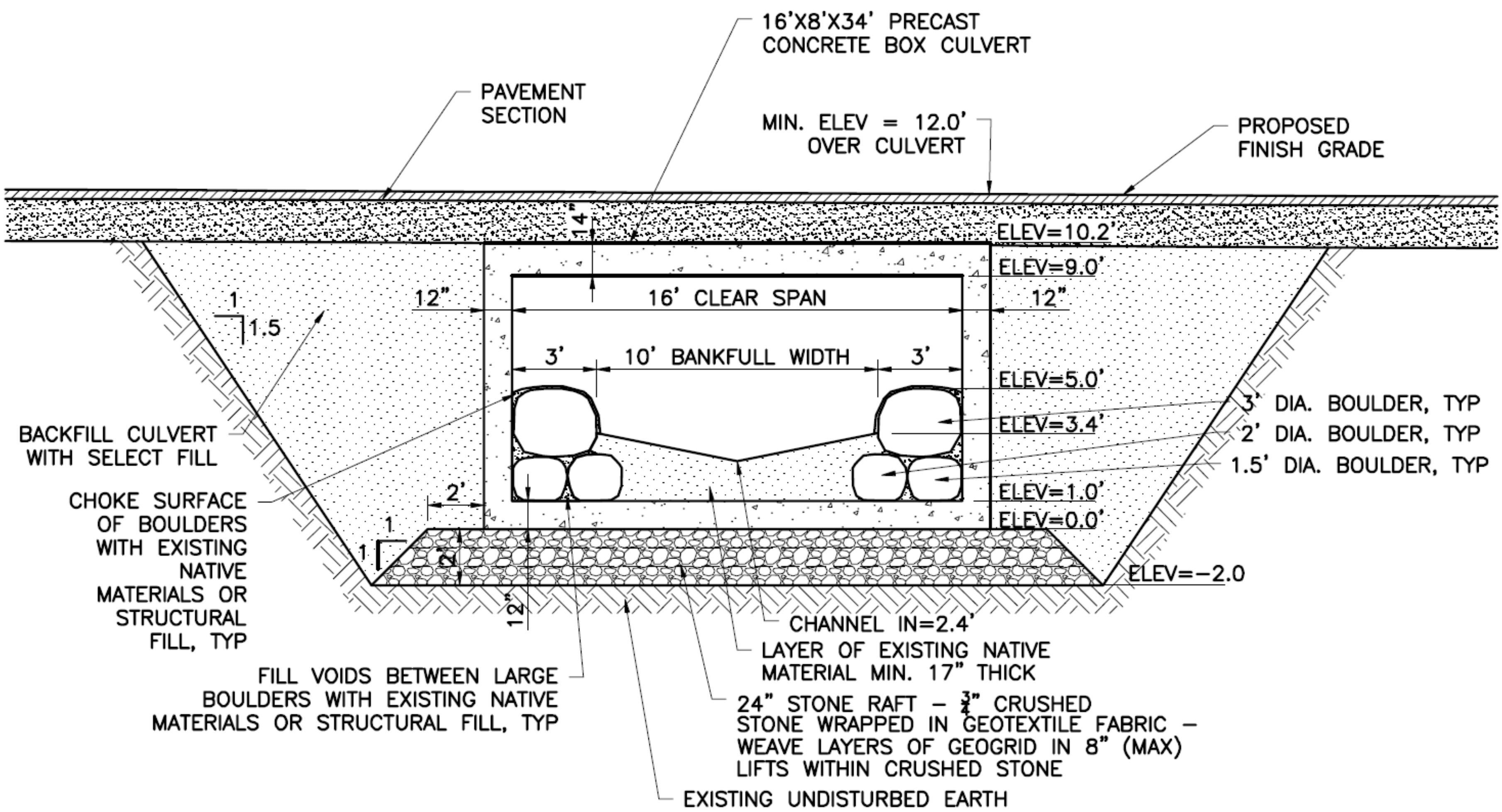

Bay Rd
Cushing Rd
Cushing Rd
Freshwater wetland
Tidal wetland
Transitional salt marsh
Salt marsh
Mud flat
Inland open water

## FIGURE 11: CULVERT OPEN AREA VS. TIDAL RESTRICTION



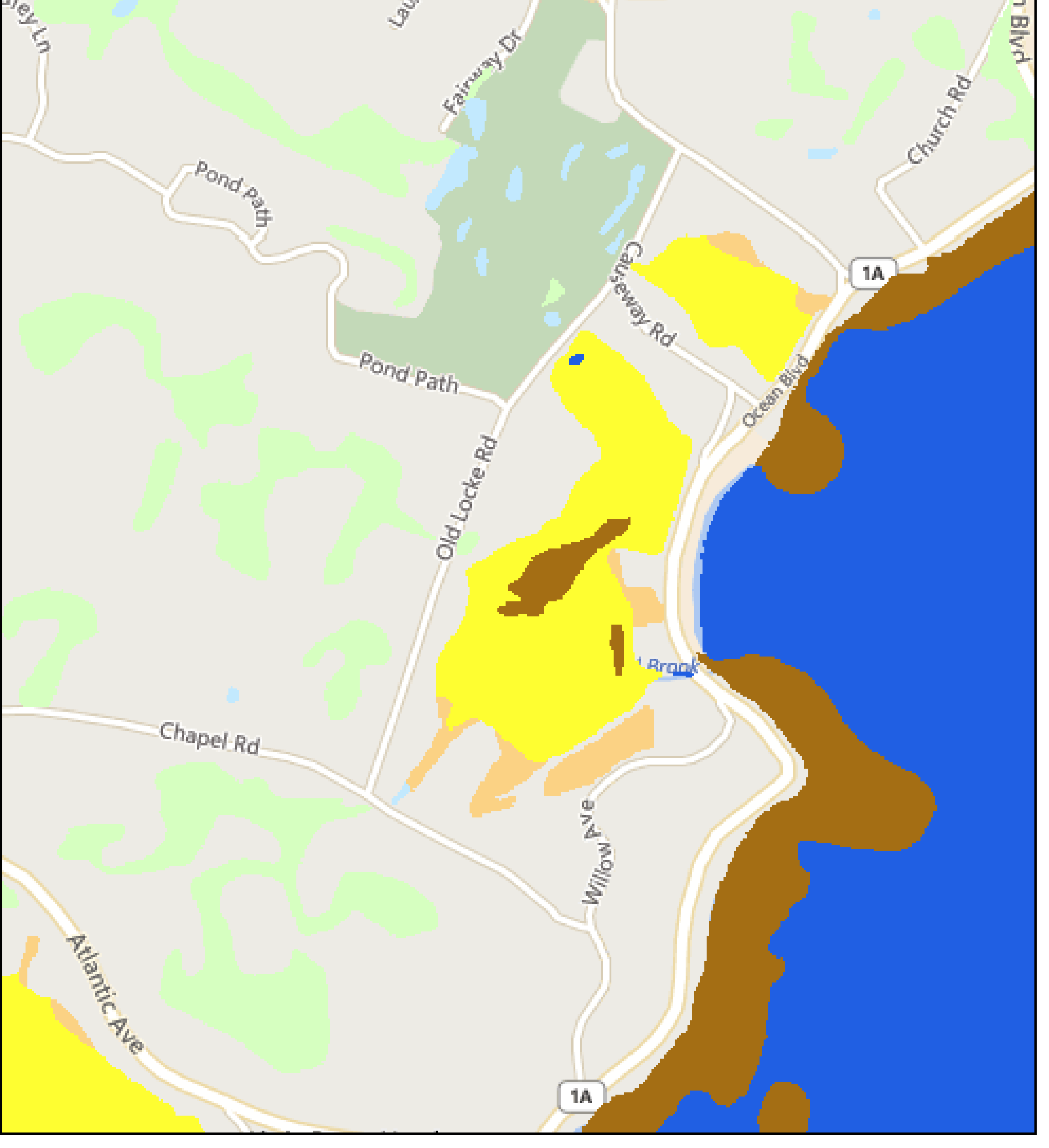

### TABLE 5.3
### CULVERT PERFORMANCE DURING 100-YEAR EVENTS

| Culvert Geometry: | Existing Structure | | | 10' Span Ceiling Elev.: 8.0' | | | 16' Span Ceiling Elev.: 8.0' | | | 16' Span Ceiling Elev.: 8.5' | | | 16' Span Ceiling Elev.: 9.0' | | | 20' Span Ceiling Elev.: 8.0' | | | 20' Span Ceiling Elev.: 9.0' | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year: | 2015 | 2065 | 2115 | 2015 | 2065 | 2115 | 2015 | 2065 | 2115 | 2015 | 2065 | 2115 | 2015 | 2065 | 2115 | 2015 | 2065 | 2115 | 2015 | 2065 | 2115 |
| W.S.E. of Tide | 5.44 | 6.77 | 9.18 | 5.44 | 6.77 | 9.18 | 5.44 | 6.77 | 9.18 | 5.44 | 6.77 | 9.18 | 5.44 | 6.77 | 9.18 | 5.44 | 6.77 | 9.18 | 5.44 | 6.77 | 9.18 |
| Peak W.S.E D/S of Culvert | 5.91 | 6.77 | 9.18 | 6.32 | 9.31 | 9.28 | 6.59 | 6.77 | 9.28 | 6.59 | 6.77 | 9.20 | 6.68 | 6.77 | 9.29 | 6.67 | 6.77 | 9.28 | 6.67 | 6.77 | 9.28 |
| Peak W.S.E U/S of Culvert | 13.21 | 13.21 | 13.44 | 10.33 | 10.33 | 10.85 | 7.66 | 7.62 | 9.77 | 7.66 | 7.62 | 9.60 | 7.73 | 7.69 | 9.44 | 7.54 | 7.47 | 9.69 | 7.52 | 7.46 | 9.34 |
| Elevation Difference (Ft) | 7.30 | 6.44 | 4.26 | 4.01 | 1.02 | 1.57 | 1.07 | 0.85 | 0.49 | 1.07 | 0.85 | 0.40 | 1.05 | 0.92 | 0.15 | 0.87 | 0.70 | 0.41 | 0.85 | 0.69 | 0.06 |

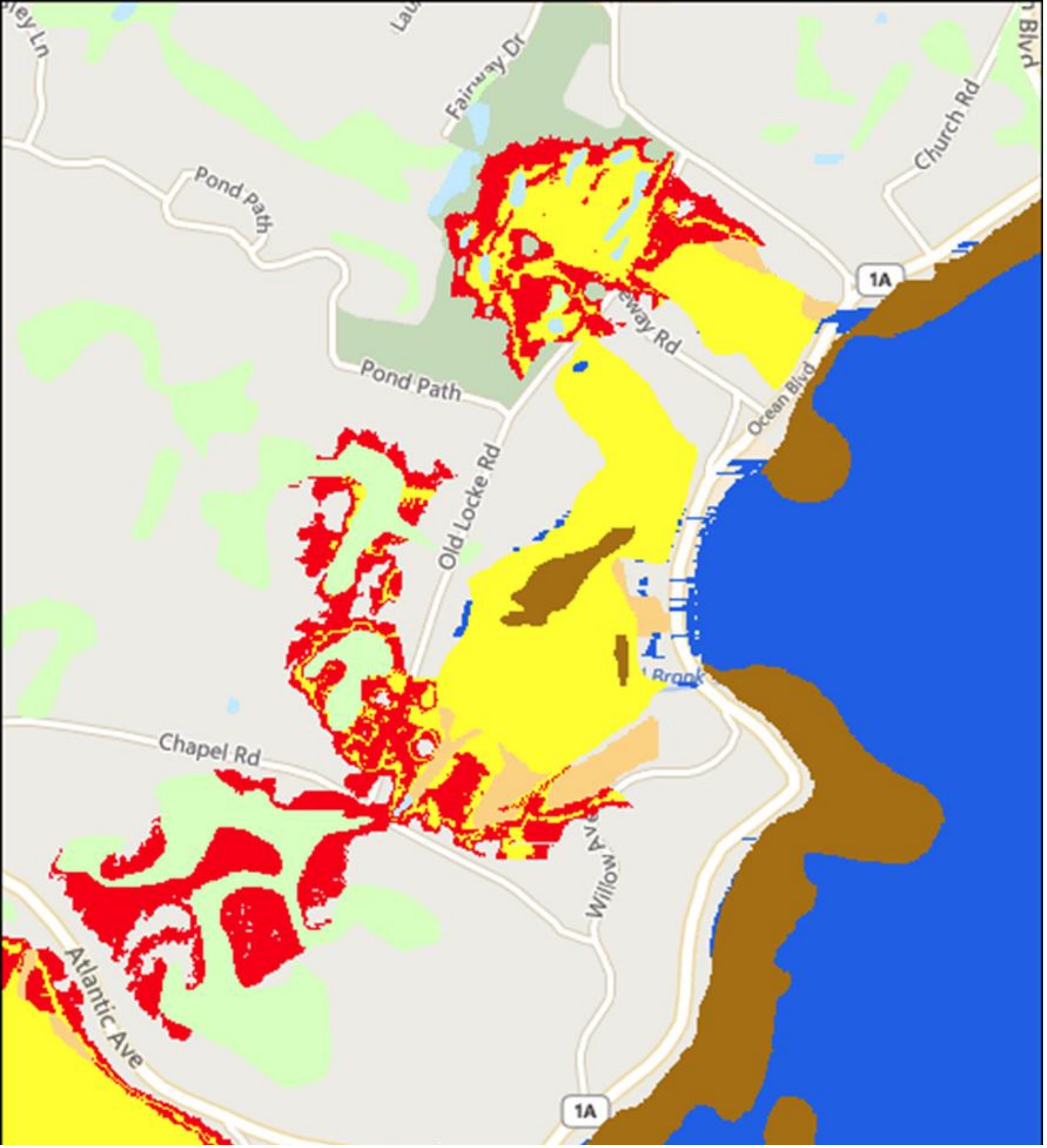

16'X8'X34' PRECAST CONCRETE BOX CULVERT
PAVEMENT SECTION
MIN. ELEV = 12.0' OVER CULVERT
PROPOSED FINISH GRADE
14"
ELEV=10.2'
ELEV=9.0'
1
1.5
12"
16' CLEAR SPAN
12"
3'
10' BANKFULL WIDTH
3'
ELEV=5.0'
3' DIA. BOULDER, TYP
ELEV=3.4'
2' DIA. BOULDER, TYP
1.5' DIA. BOULDER, TYP
BACKFILL CULVERT WITH SELECT FILL
ELEV=1.0'
2'
ELEV=0.0'
CHOKE SURFACE OF BOULDERS WITH EXISTING NATIVE MATERIALS OR STRUCTURAL FILL, TYP
1
1
2'
ELEV=-2.0
12"
CHANNEL IN=2.4'
LAYER OF EXISTING NATIVE MATERIAL MIN. 17" THICK
FILL VOIDS BETWEEN LARGE BOULDERS WITH EXISTING NATIVE MATERIALS OR STRUCTURAL FILL, TYP
24" STONE RAFT – ¾" CRUSHED STONE WRAPPED IN GEOTEXTILE FABRIC – WEAVE LAYERS OF GEOGRID IN 8" (MAX) LIFTS WITHIN CRUSHED STONE
EXISTING UNDISTURBED EARTH

# PHILBRICK POND SALT MARSH

# NORTH HAMPTON



Fairway Dr
Pond Path
Causeway Rd
1A
Church Rd
Ocean Blvd
Pond Path
Old Locke Rd
Chapel Rd
Willow Ave
Atlantic Ave
1A


Fairway Dr
Pond Path
Pond Path
Church Rd
1A
Ocean Blvd
Old Locke Rd
Chapel Rd
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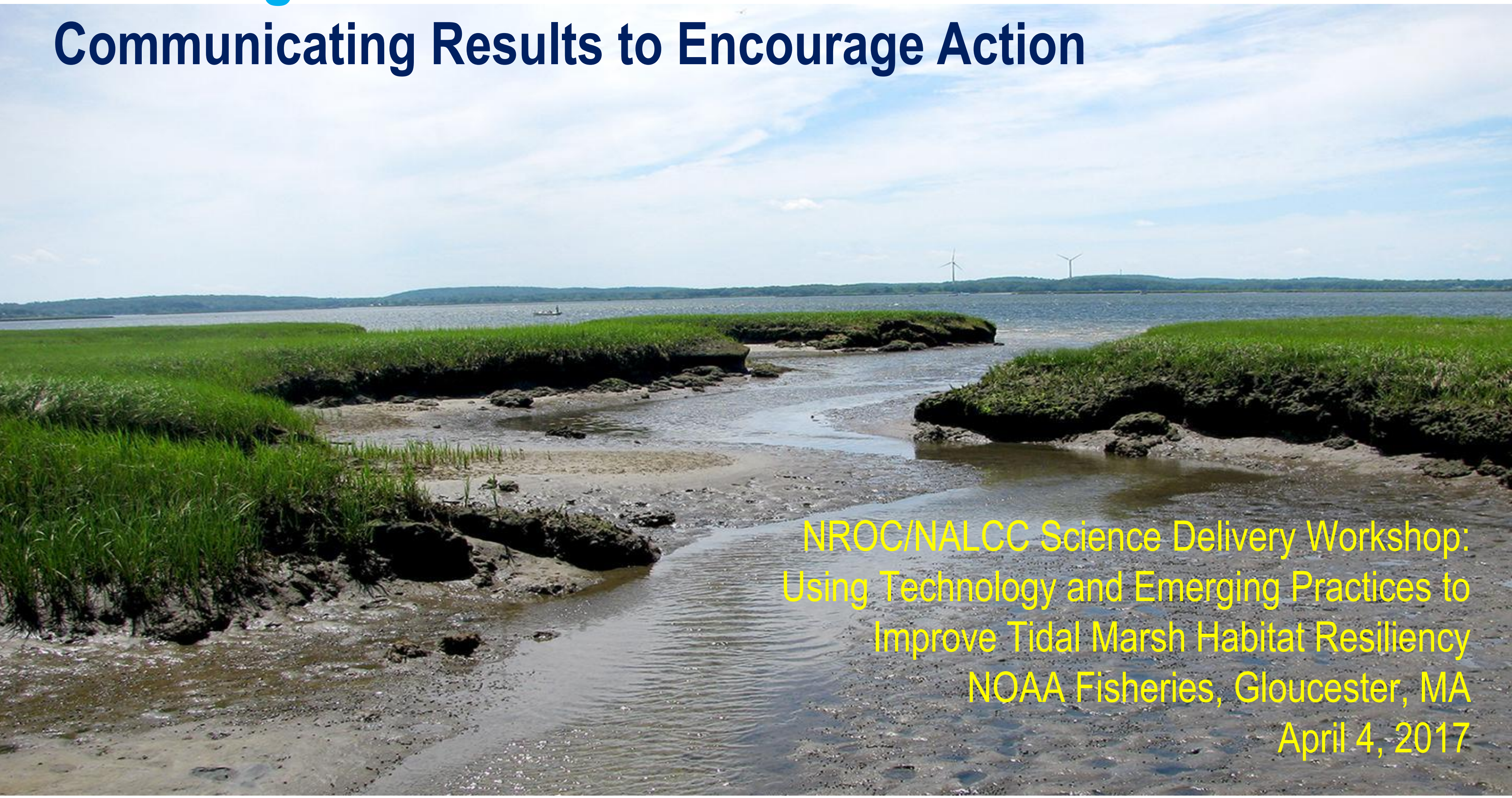
Atlantic Ave
1A

# Modeling Sea-Level Rise in Massachusetts' Wetlands

## Communicating Results to Encourage Action



NROC/NALCC Science Delivery Workshop:
Using Technology and Emerging Practices to
Improve Tidal Marsh Habitat Resiliency
NOAA Fisheries, Gloucester, MA
April 4, 2017

Marc Carullo
Massachusetts Office of
Coastal Zone Management

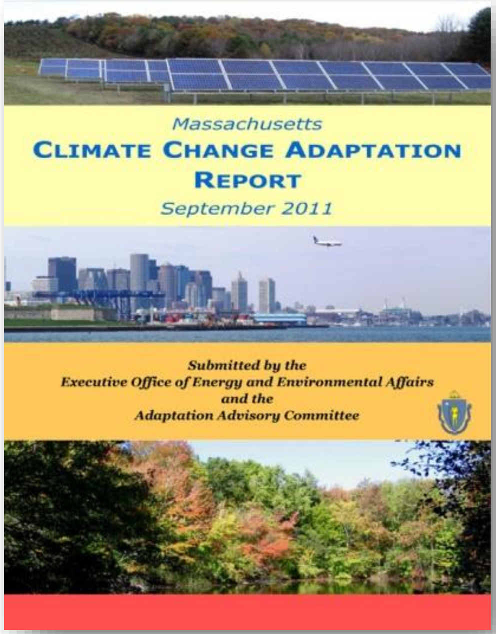
# Modeling Sea-Level Rise in Massachusetts' Wetlands

## Communicating Results to Encourage Action

- Brief project overview
- Communicating results with examples
- Modeling and data considerations
- Current applications and those to explore

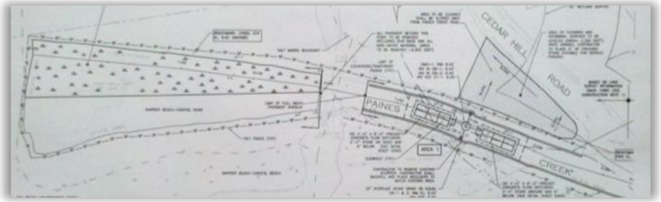
# Project Objectives

Understand potential for coastal wetland **habitat conversion/loss** under multiple scenarios of SLR




Identify and assess opportunities for and barriers to **marsh migration**

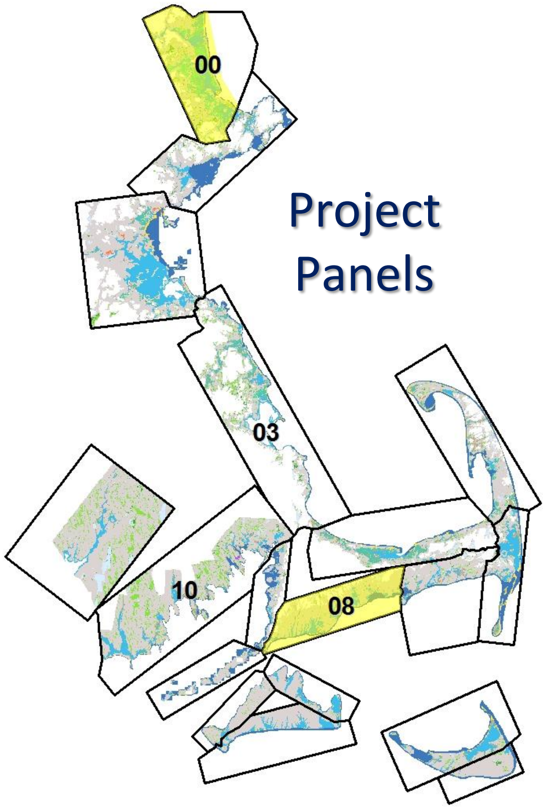
Engage stakeholders to better incorporate wetlands into **adaptation strategies** and planning efforts



# Four scenarios with estimates of SLR by 2100

*United States National Climate Assessment* (Parris et al. 2012), adjusted for local subsidence

| Projected Scenario | Total Sea Level Rise (Boston) |
|---|---|
| Lowest | 0.249 m (0.82 feet) |
| Intermediate Low | 0.706 m (2.32 feet) |
| Intermediate High | 1.385 m (4.54 feet) |
| Highest | 2.164 m (7.10 feet) |




**Project Timescale**

2011 2030 2050 2070 2100

**Models used:**

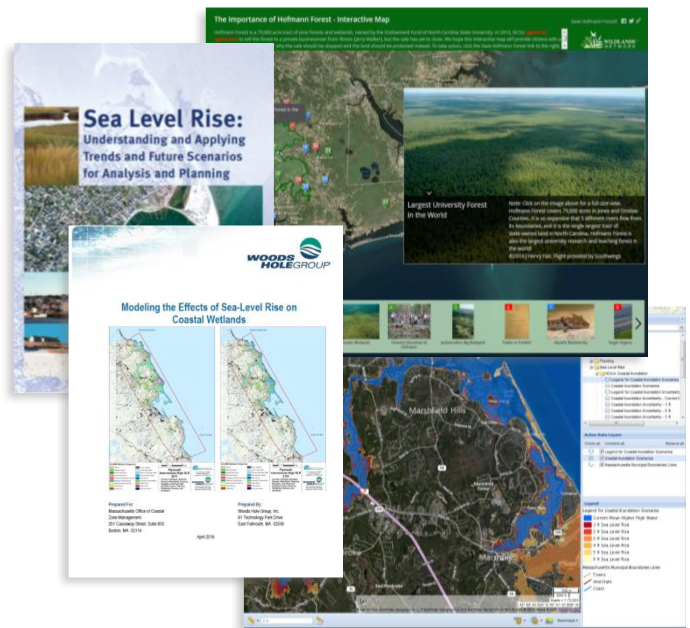
**Sea-Level Affecting Marshes Model (SLAMM)**

**Marsh Equilibrium Model (MEM)***

# Communicating Results

## Products

- Project website
- Summary and comprehensive reports
- Esri Story Map
- GIS and non-spatial data sets

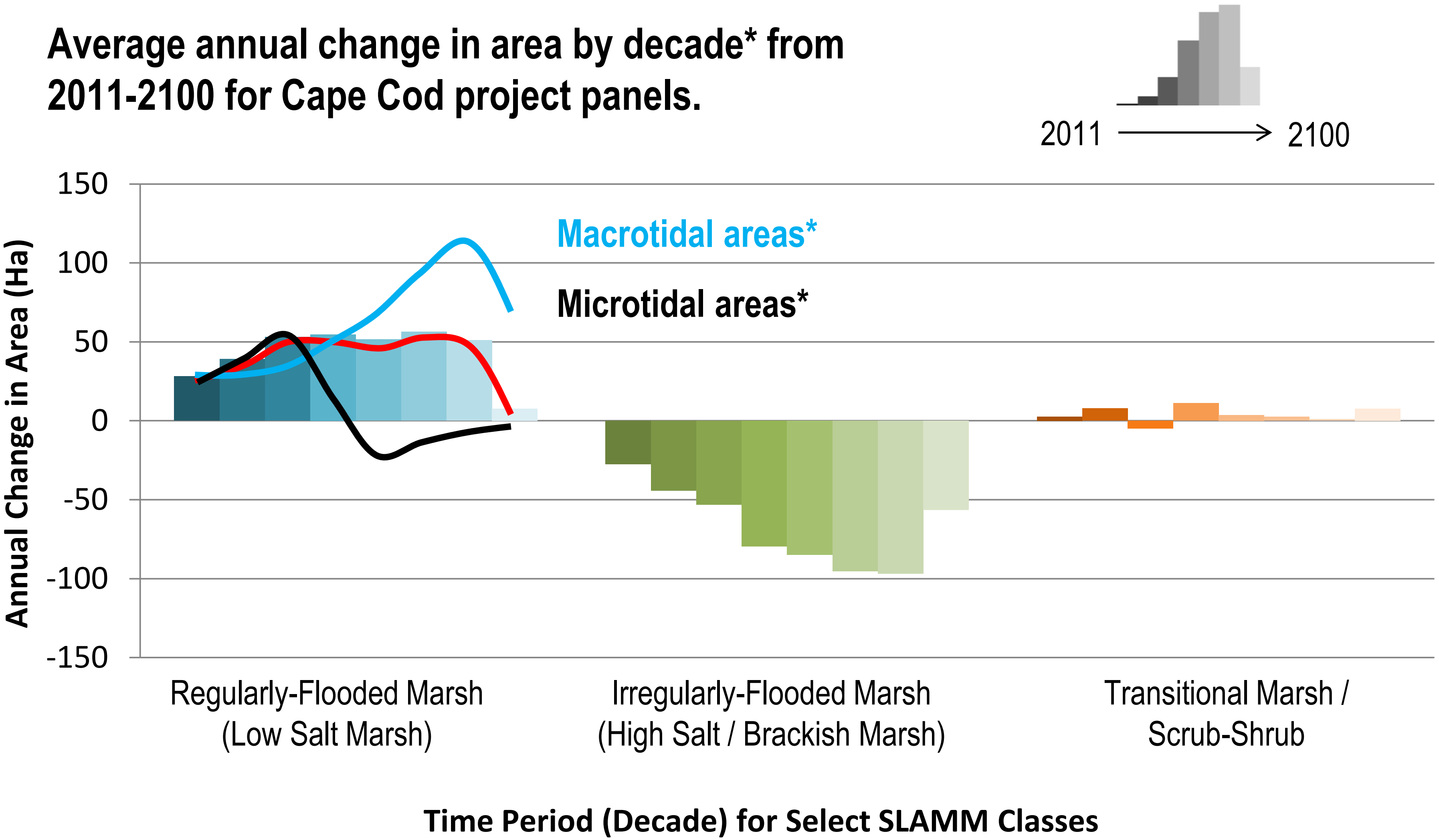


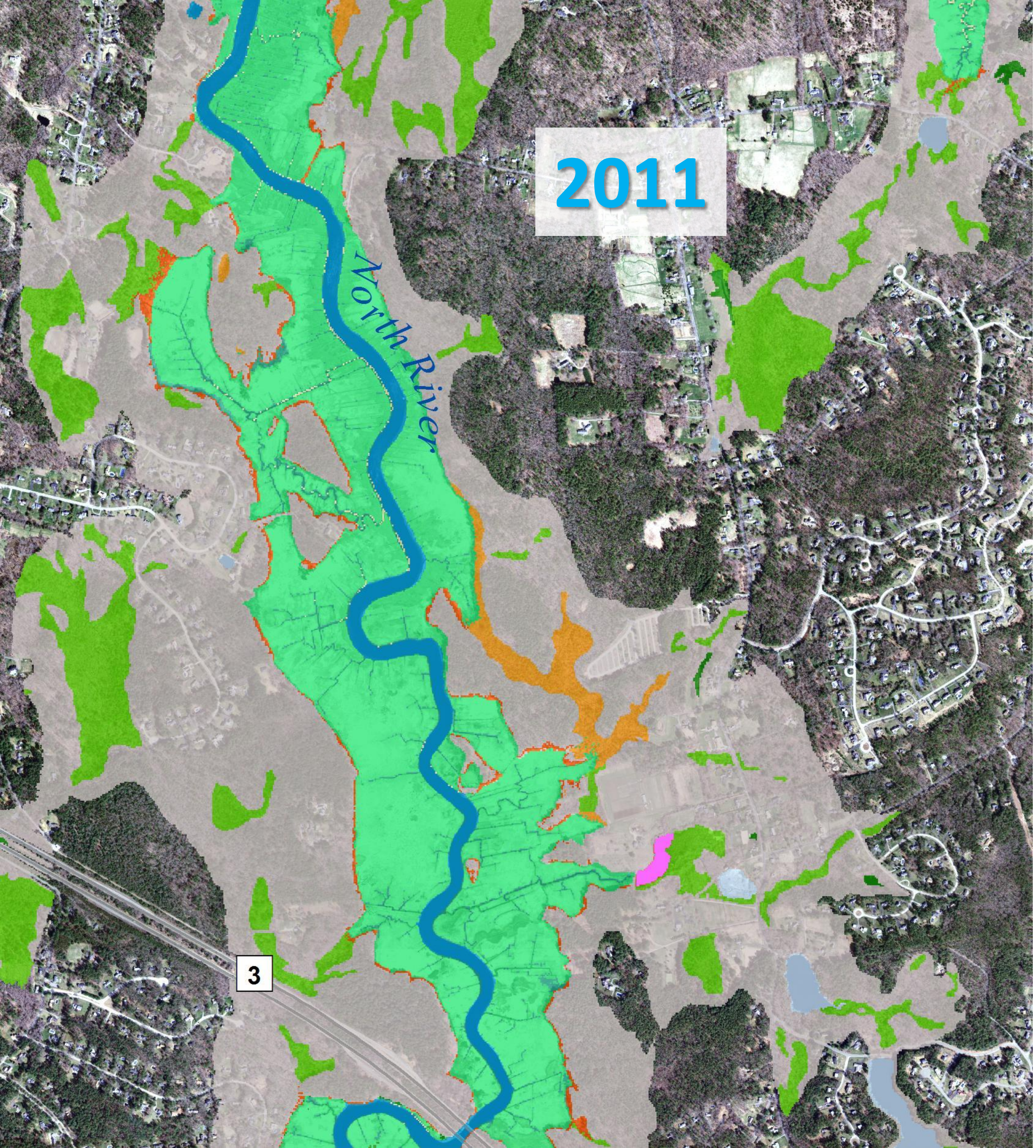

## Outreach

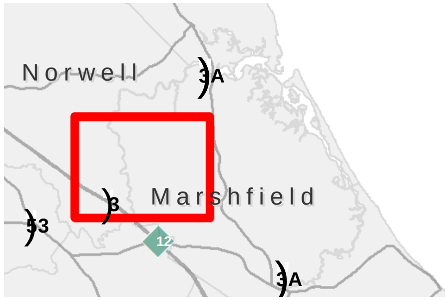
- Conferences and symposia (50-200 attendees)
- Stakeholder meetings (e.g., ConCom Network meetings; 10-50 attendees)
  - Focus on potential regional and local impacts
  - Target areas for adaptation or restoration

# Examples for Communicating Results

**Average annual change in area by decade* from 2011-2100 for Cape Cod project panels.**






**Select SLAMM Classes**

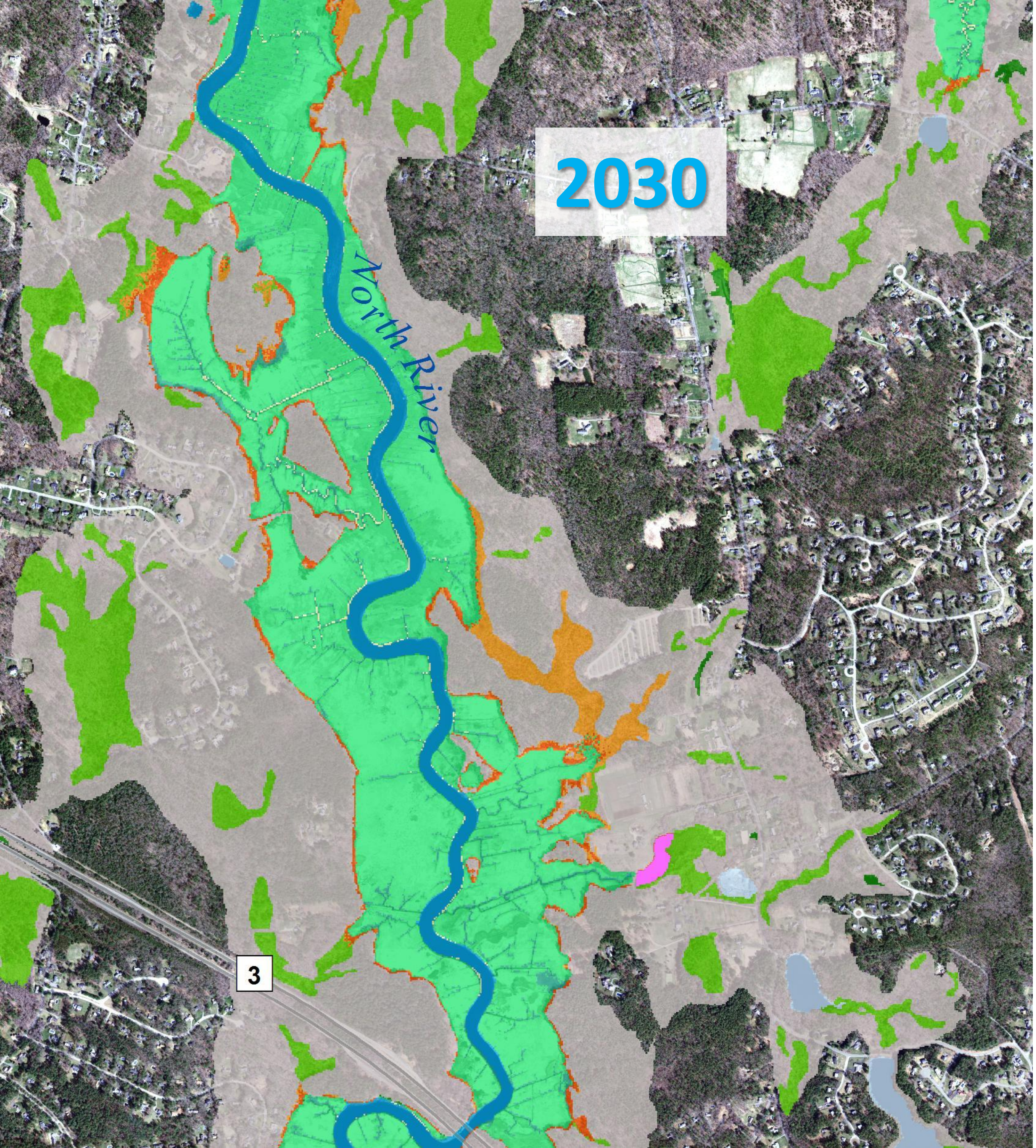
- Upland
- Transitional Marsh/Scrub-Shrub
- Regularly-Flooded Marsh
- Irregularly-Flooded Marsh
- Tidal Swamp
- Non-tidal Swamp
- Inland Fresh Marsh

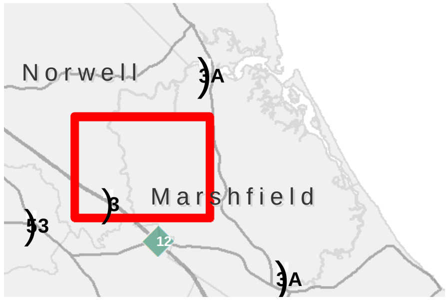
***North River***

*Marshfield*

Intermediate High SLR

Static accretion

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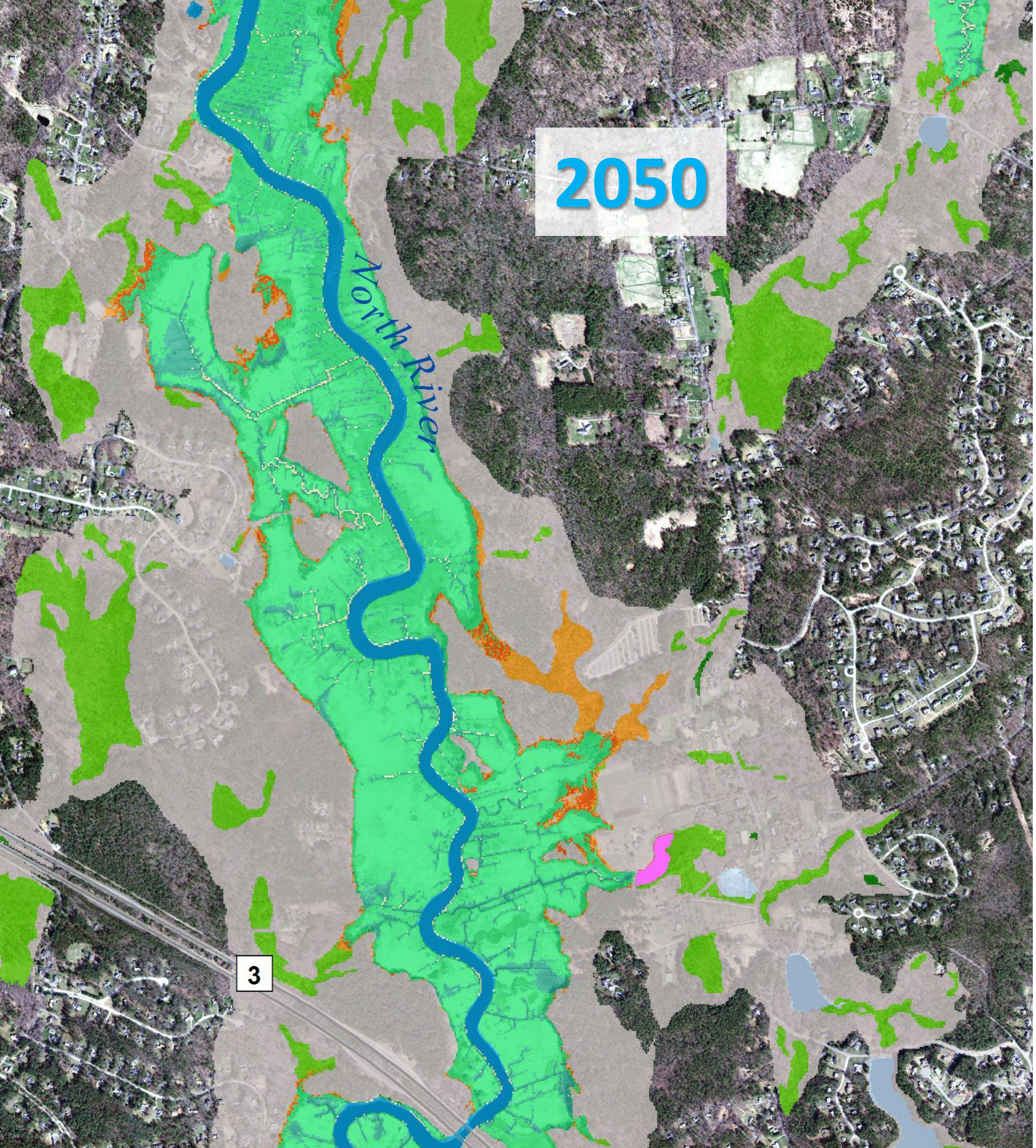
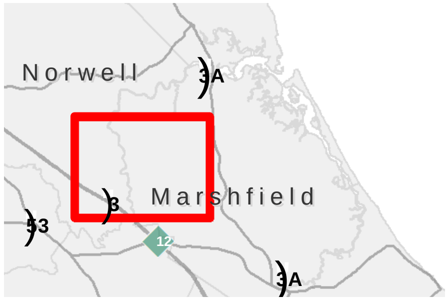
***North River***

*Marshfield*

Intermediate High SLR

Static accretion

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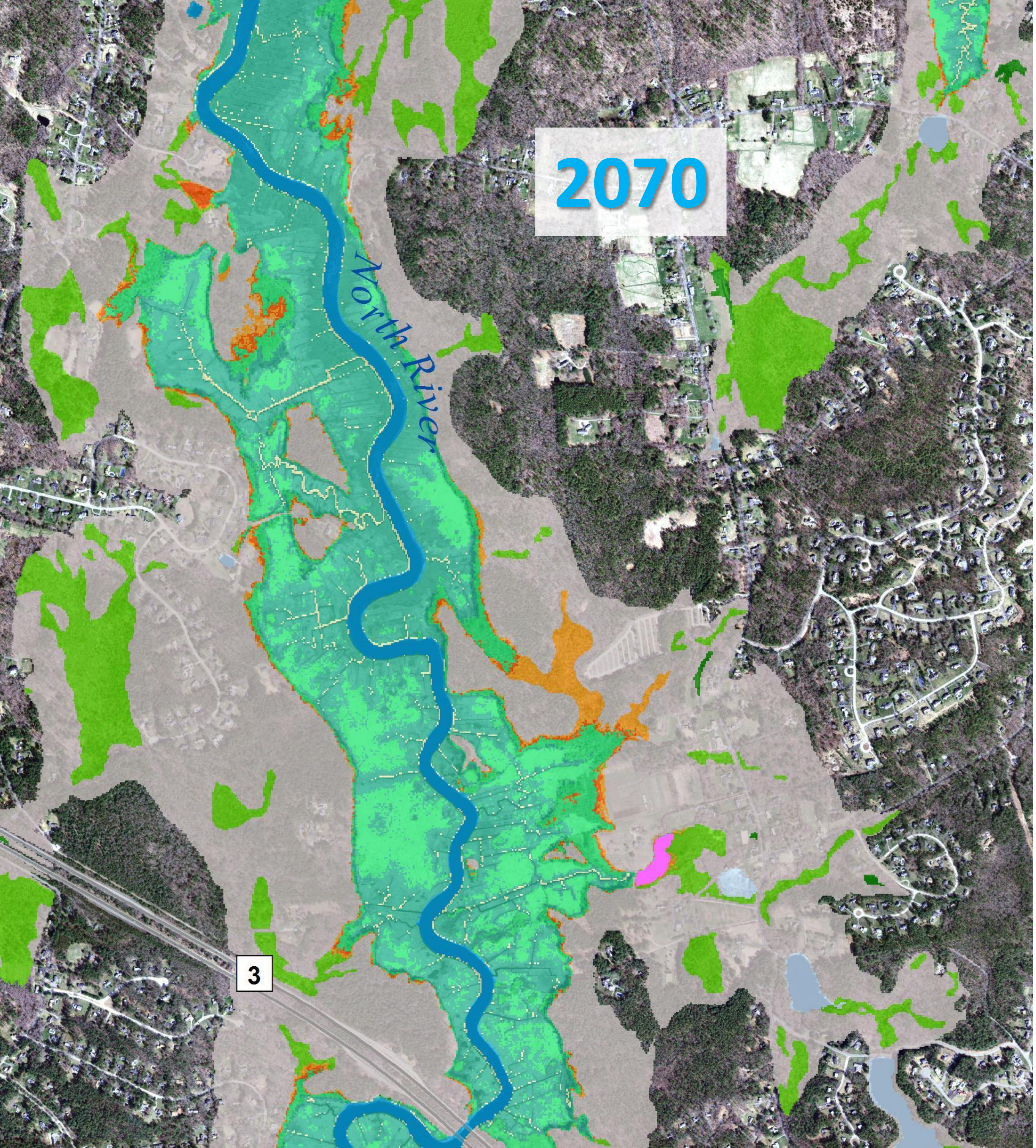
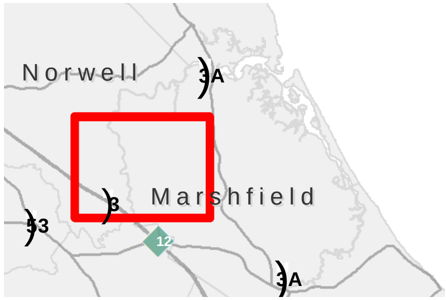
***North River***

*Marshfield*

Intermediate High SLR

Static accretion




**Select SLAMM Classes**

- Upland
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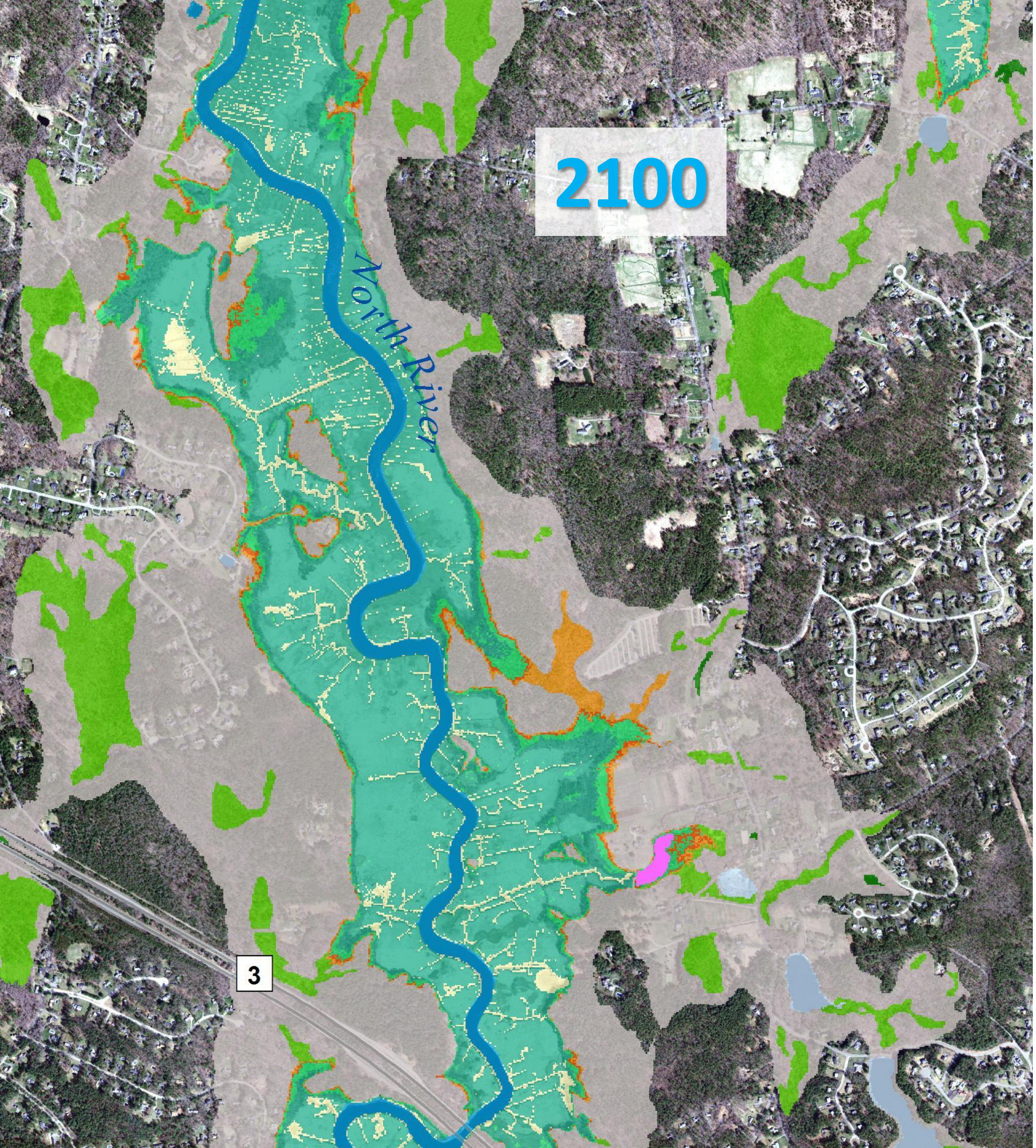
- Regularly-Flooded Marsh
- Irregularly-Flooded Marsh
- Tidal Swamp
- Non-tidal Swamp
- Inland Fresh Marsh

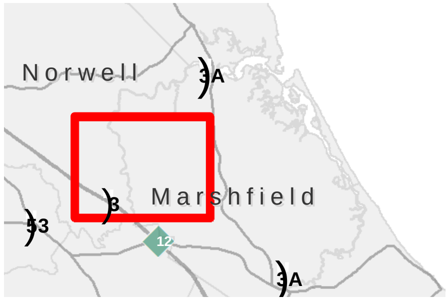
***North River***

*Marshfield*

Intermediate High SLR

Static accretion




**Select SLAMM Classes**

- Upland
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- Irregularly-Flooded Marsh
- Tidal Swamp
- Non-tidal Swamp
- Inland Fresh Marsh

***North River***

*Marshfield*

Intermediate High SLR

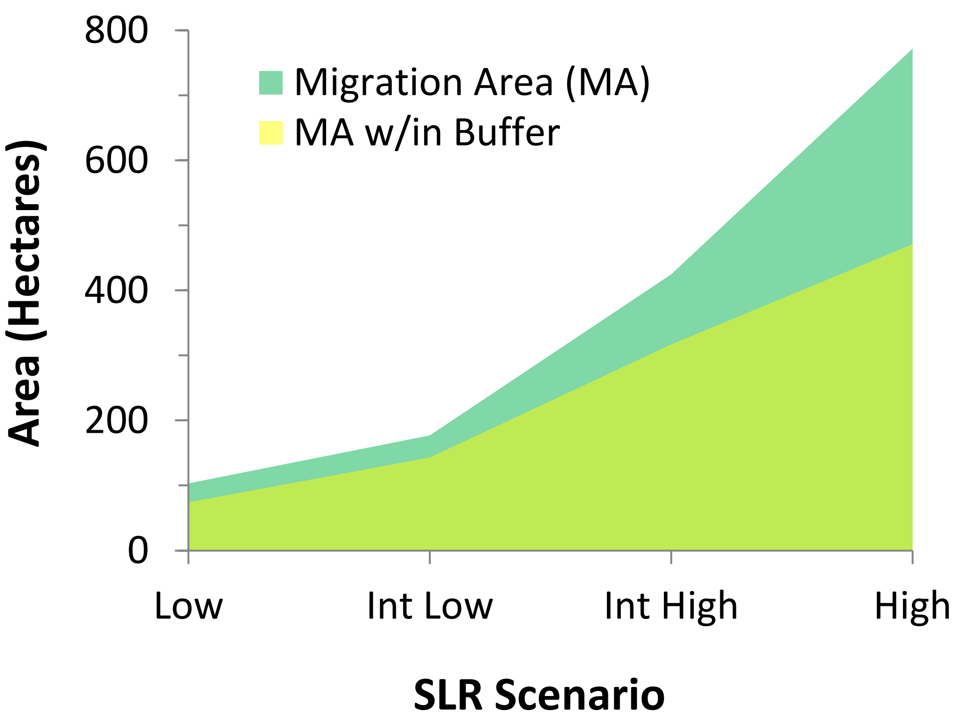
Static accretion

# Examples for Communicating Results

## Potential Upland Marsh Migration w/in 100 ft Buffer

**South Shore** | 2030-2100

Intermediate High SLR Scenario

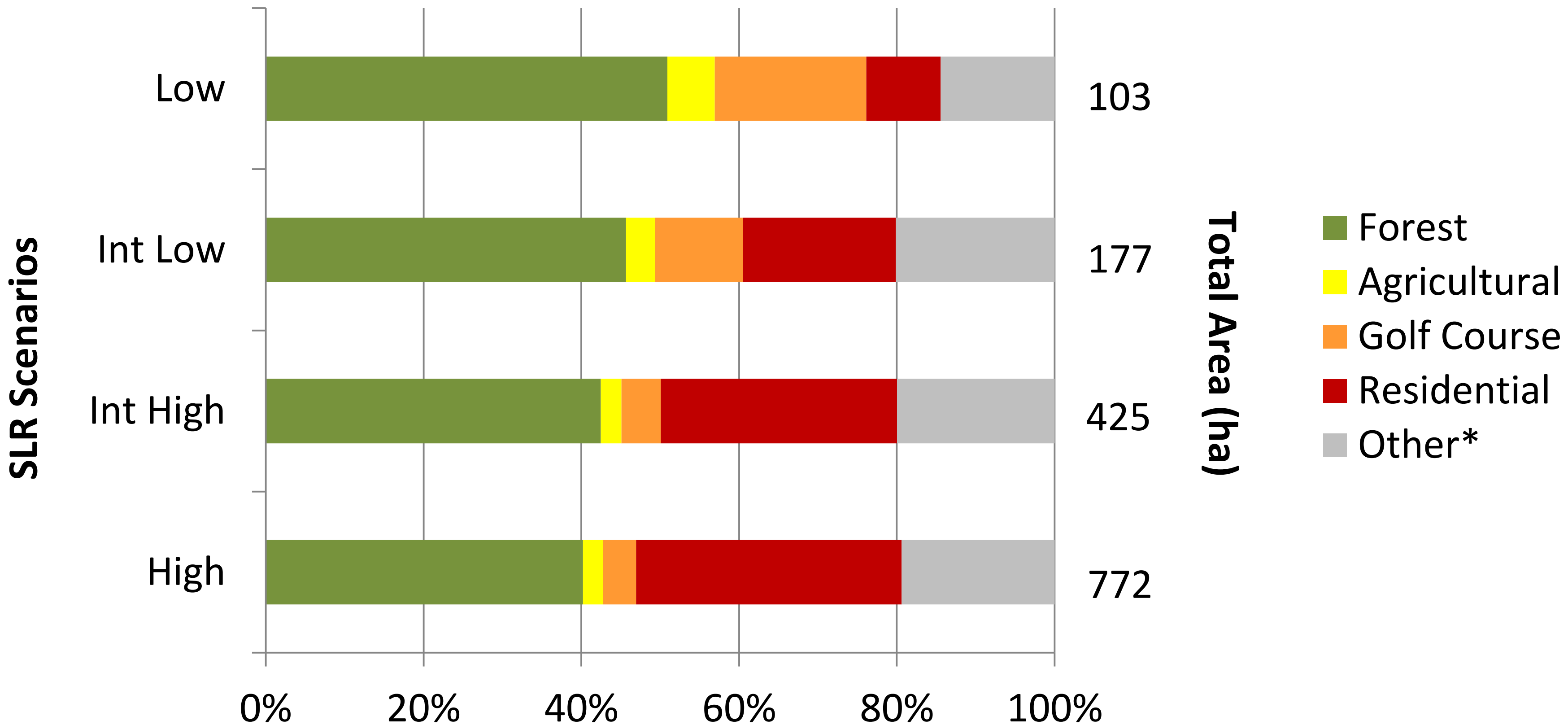



# Examples for Communicating Results

## Upland Land Use / Land Cover Distribution Within Potential Migration Areas

**South Shore** | 2030-2100

Intermediate High SLR Scenario



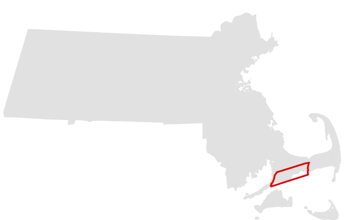

# Marsh Migration Potential

**Lidar DEM**

12 m
5 m
-2 m

**Marsh-Upland Border**

2011
2100

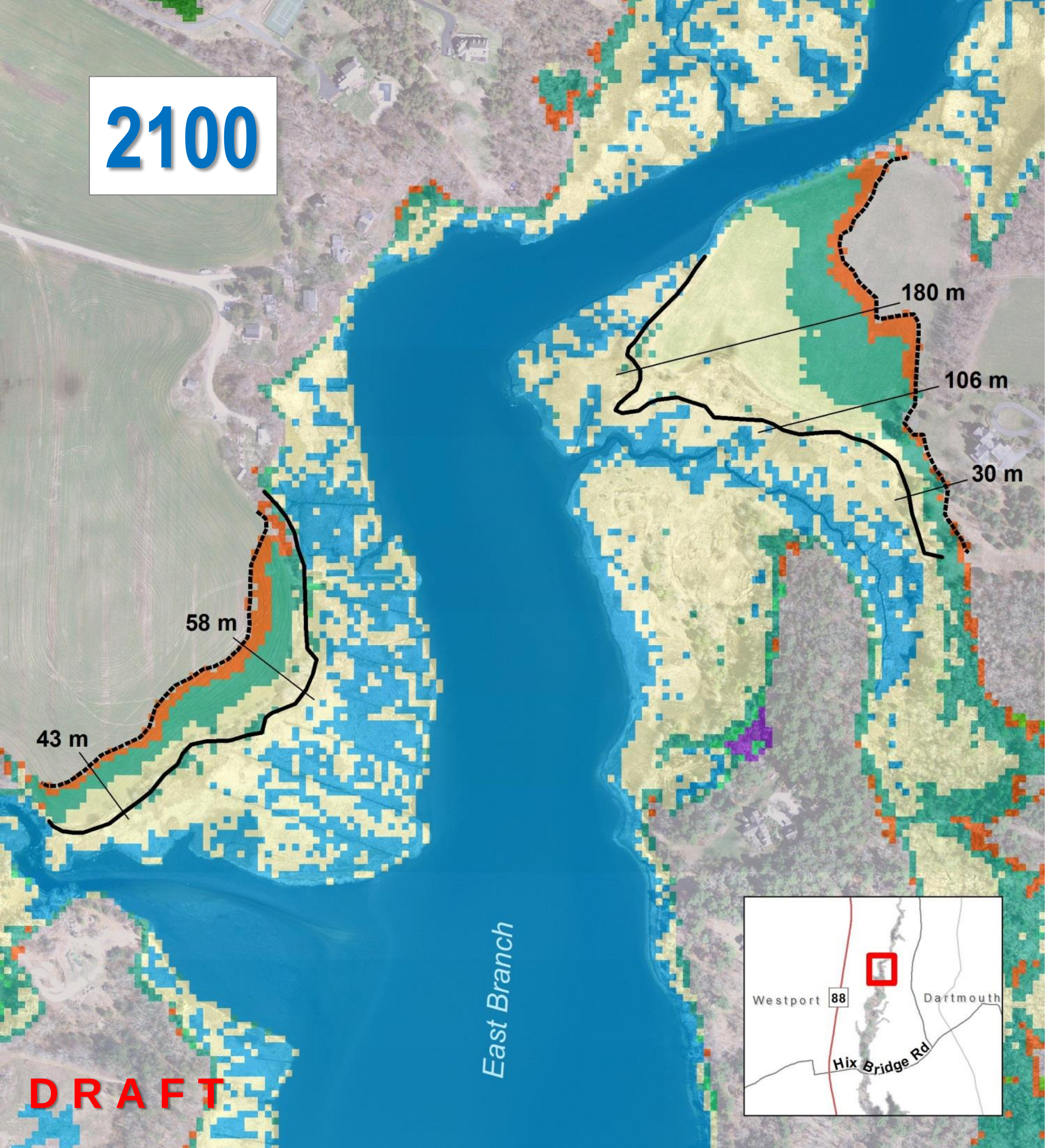


**Westport River - East**

Buzzards Bay West

Intermediate High SLR

Static accretion

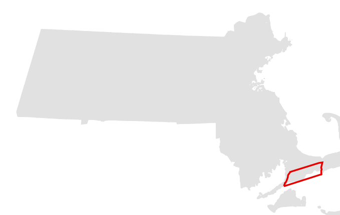



# Marsh Migration Potential

**COASTAL SQUEEZE**

**Select SLAMM Classes**

- Trans. Marsh/Scrub-Shrub
- Regularly-Flooded Marsh
- Irregularly-Flooded Marsh
- Tidal Flat



**Westport River - East**

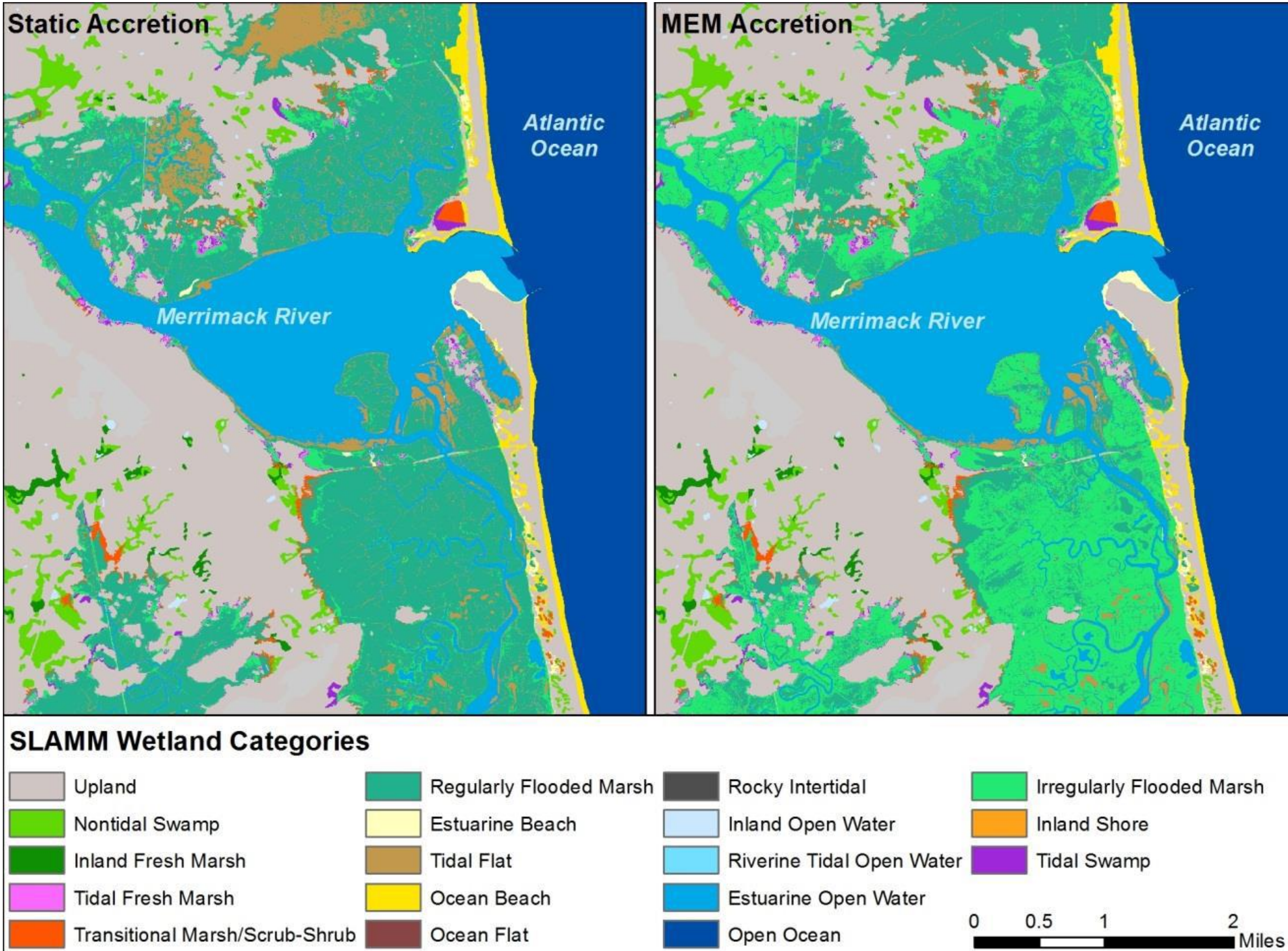
Buzzards Bay West

Intermediate High SLR

Static accretion

# Communicating Results:
# Modeling & Data Considerations

- Model inputs
  - Accretion / surface elevation change



Static Accretion
MEM Accretion
Atlantic Ocean
Merrimack River
Atlantic Ocean
Merrimack River
SLAMM Wetland Categories
Upland
Nontidal Swamp
Inland Fresh Marsh
Tidal Fresh Marsh
Transitional Marsh/Scrub-Shrub
Regularly Flooded Marsh
Estuarine Beach
Tidal Flat
Ocean Beach
Ocean Flat
Rocky Intertidal
Inland Open Water
Riverine Tidal Open Water
Estuarine Open Water
Open Ocean
Irregularly Flooded Marsh
Inland Shore
Tidal Swamp
0 0.5 1 2
Miles

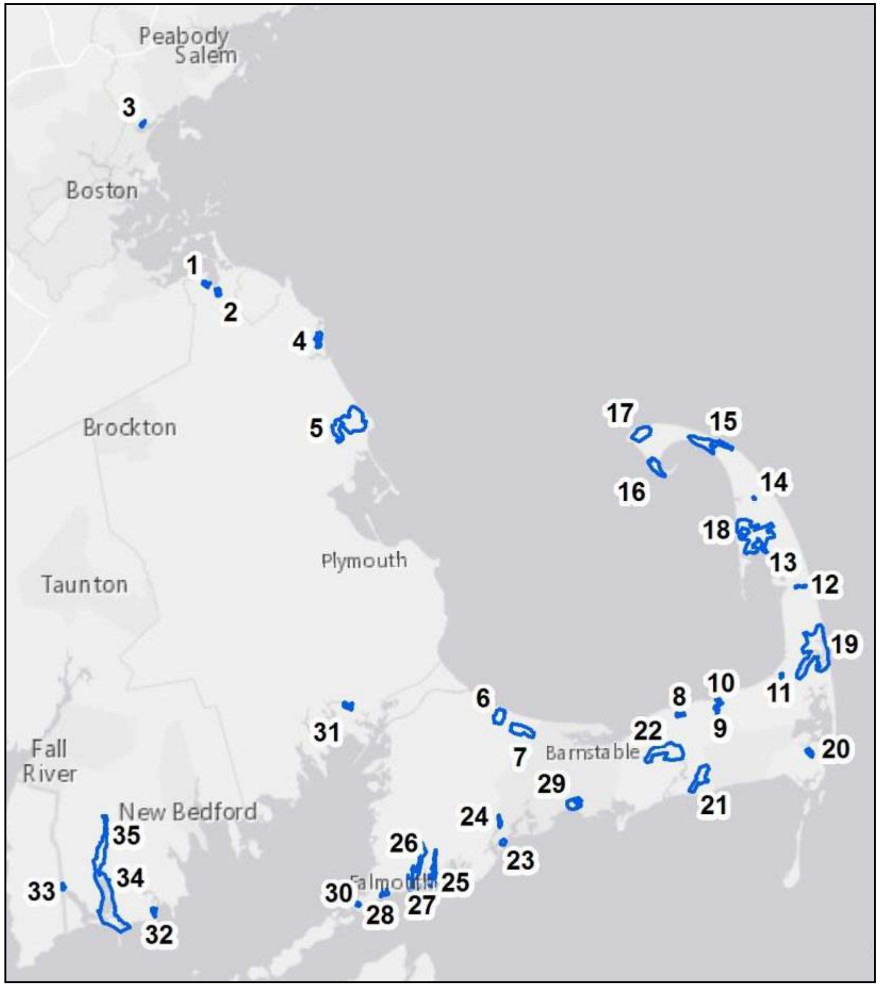
# Communicating Results:
# Modeling & Data Considerations

- Model inputs
  - Accretion / surface elevation change
  - Tidal restrictions

# Tidal restrictions could be reversed through:

- Human intervention (e.g., restoration, culvert removal)
- Natural/anthropogenic widening
- Erosion
- Change in water levels as sea-level rises (e.g., overtopping)

Set a restricted vs. unrestricted threshold at 2050 for model simulation.



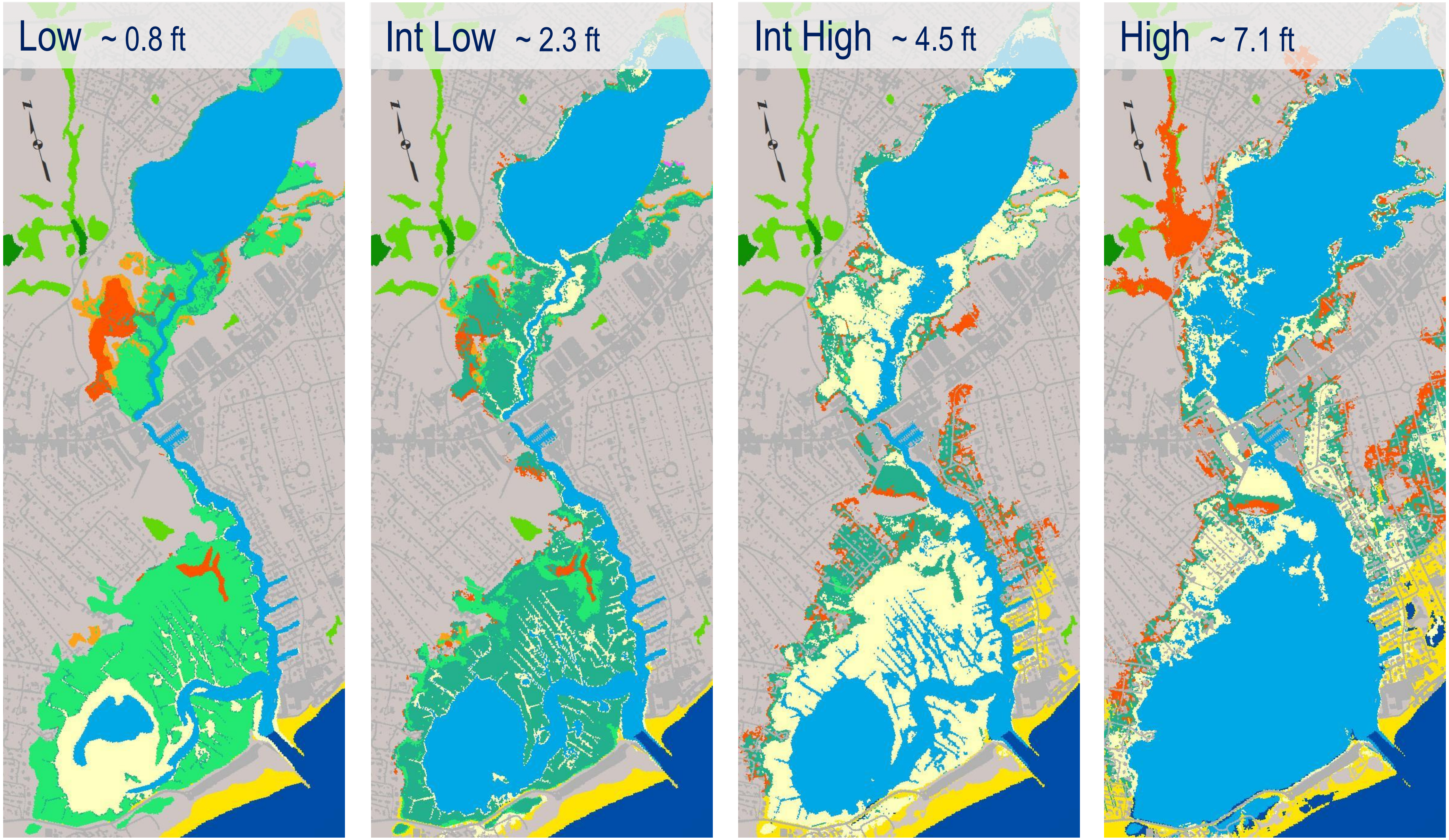

*Tidally restricted waterbodies included as subsets in SLAMM simulations.*

# Communicating Results:
# Modeling & Data Considerations

- Model inputs
  - Accretion / surface elevation change
  - Tidal restrictions
  - Sea-level rise projections

# Potential Wetland Distribution by 2100 Under Four SLR Scenarios

## Parkers River, Yarmouth

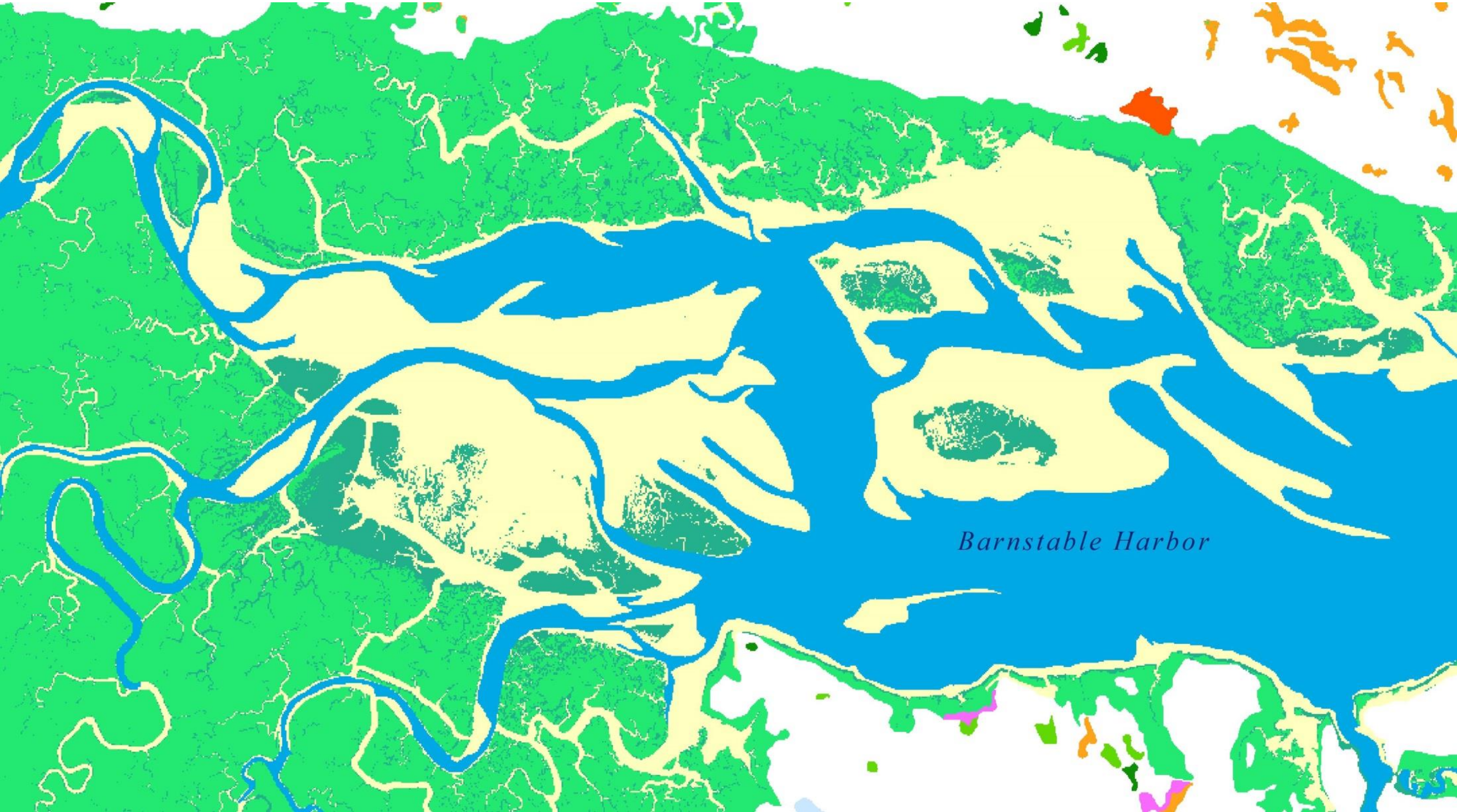


# Communicating Results:
# Modeling & Data Considerations

- Model inputs
  - Accretion / surface elevation change
  - Tidal restrictions
  - Sea-level rise projections
  - Wetland map data vs. SLAMM conceptual model

# 2011 Initial Wetlands: Pre-Calibration

# 2011 Initial Wetlands: Post-Calibration



# Applications: Monitoring and Assessment

Guide site selection for long-term monitoring of tidal marsh trends at sentinel sites; develop indices of integrity/resilience.

Field-based

- Track changes in plant community and structure, ecotones, hydroperiod and other physical parameters.

Remote sensing-based

- Satellite and drone (proof-of-concept) mapping of marsh features for resilience/vulnerability assessments; potential to move from indices of biological integrity to indices of physical integrity; pair with historical trends analysis.

# Other Applications of SLAMM Results

- The Trustees of Reservations
  - Prioritize land acquisition.
  - Outreach to benefactors and other stakeholders.
- Herring River Restoration Project
  - Inform more site-specific model runs in analyzing adaptive management scenarios.
- MassDOT hydrodynamic modeling for vulnerability of critical infrastructure
  - SLAMM results input for potential land cover change.
- Great Marsh Resiliency Planning Project
  - Educate constituents and incorporate wetland vulnerability into planning decisions.

# Potential Applications to Explore

- **Incentivize marsh migration projects** through Commonwealth grant programs (land acquisition, conservation restrictions, resilience/adaptation projects, etc.).
- **Scenario analysis** for maximizing marsh migration potential under multiple management options.
- **Prioritize restoration sites** and adaptation approaches (improved hydrology, elevation capital, marsh migration, etc.).
- Identify and pursue **policy enhancement** opportunities (CZM Program Policies).
- **Species conservation** via future updates to MA NHESP's BioMap2 coastal adaptation data set.

# Acknowledgements


## Funding

- U.S. EPA Region 1
- NOAA Office for Coastal Management

## Project Team

- MA CZM
- MA DFG - Division of Ecological Restoration (MA DER)
- Marine Biological Laboratory (MBL)

  Plum Island Ecosystems Long Term Research (PIE LTER) Project
- MassDEP
- Woods Hole Group

## Data Contributors

- MBL/PIE LTER
- USFWS – Parker River NWR
- NPS – Cape Cod NS
- MassDOT
- MassDEP
- MA DER
- Waquoit Bay NERR
- NOAA (CO-OPS)
- Woods Hole Group
- University of South Carolina

Jim Morris

Warren Pinnacle Consulting, Inc. – SLAMM 6.2

James Morris, University of South Carolina – MEM 5.4.1


Questions or comments?


marc.carullo@state.ma.us

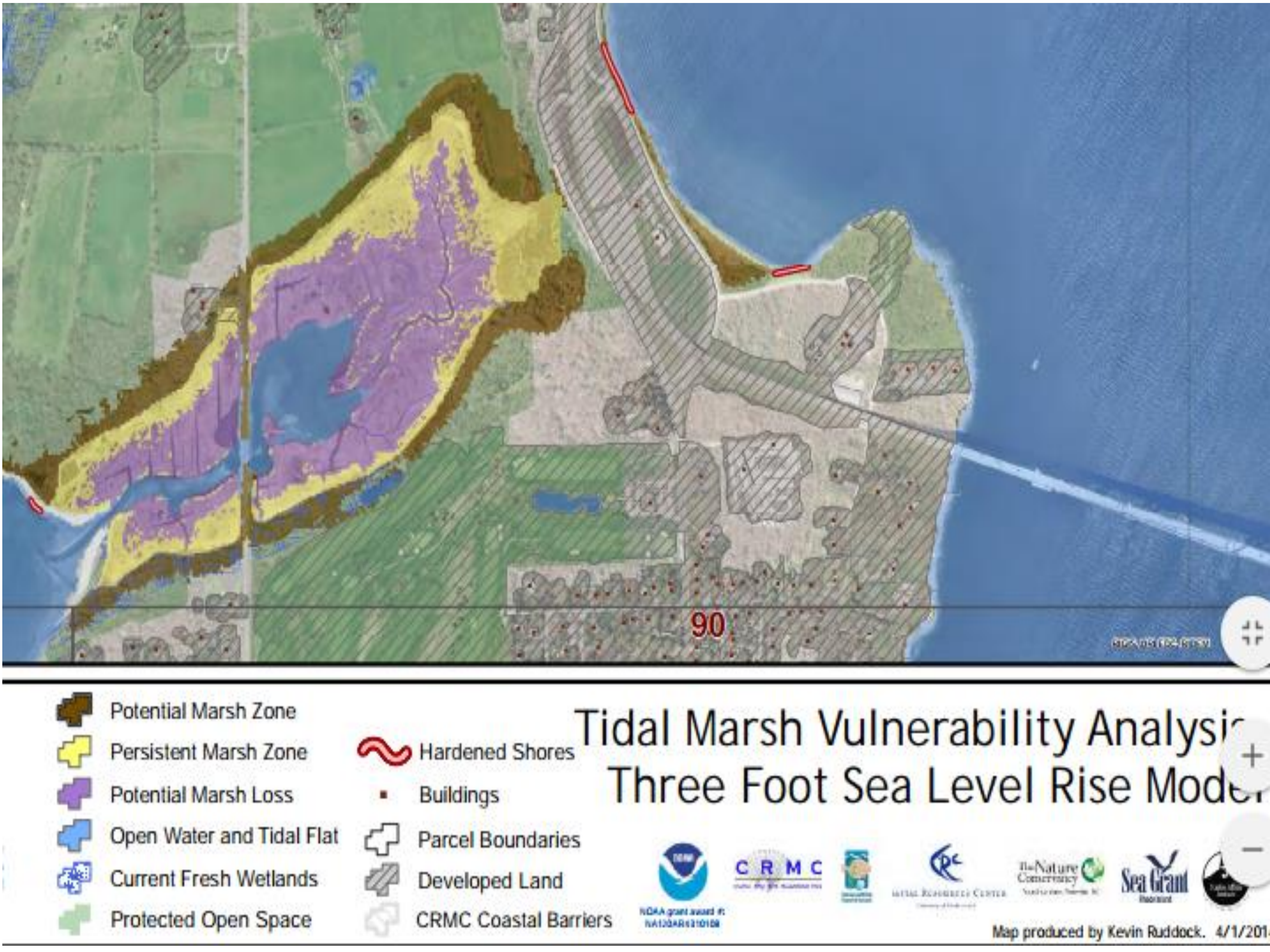
# Salt Marsh Migration Modeling in RI: Outreach, Partnerships and Next Steps

NROC / NALCC Science delivery workshop

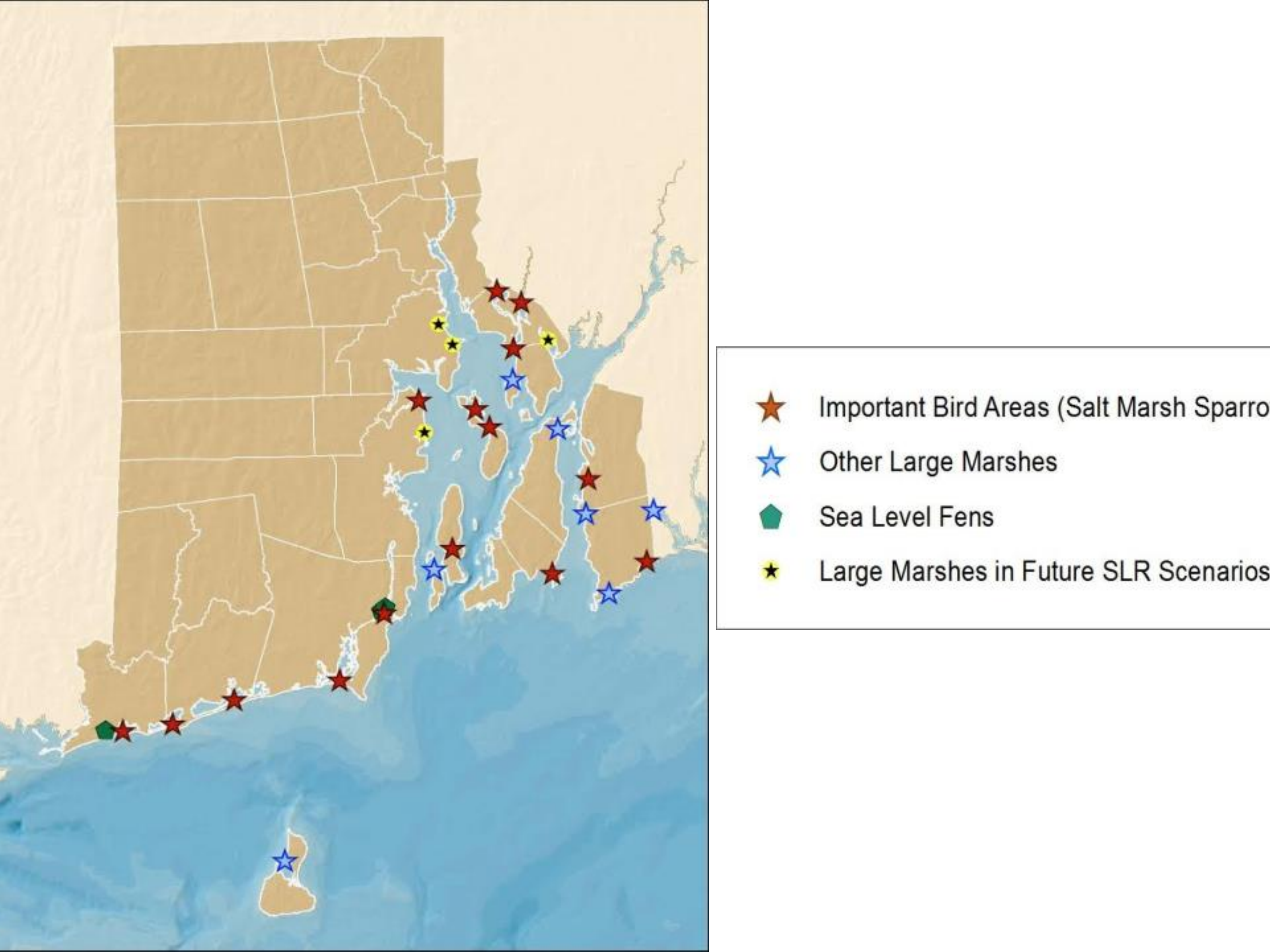
April 4, 2017



© Ayla Fox



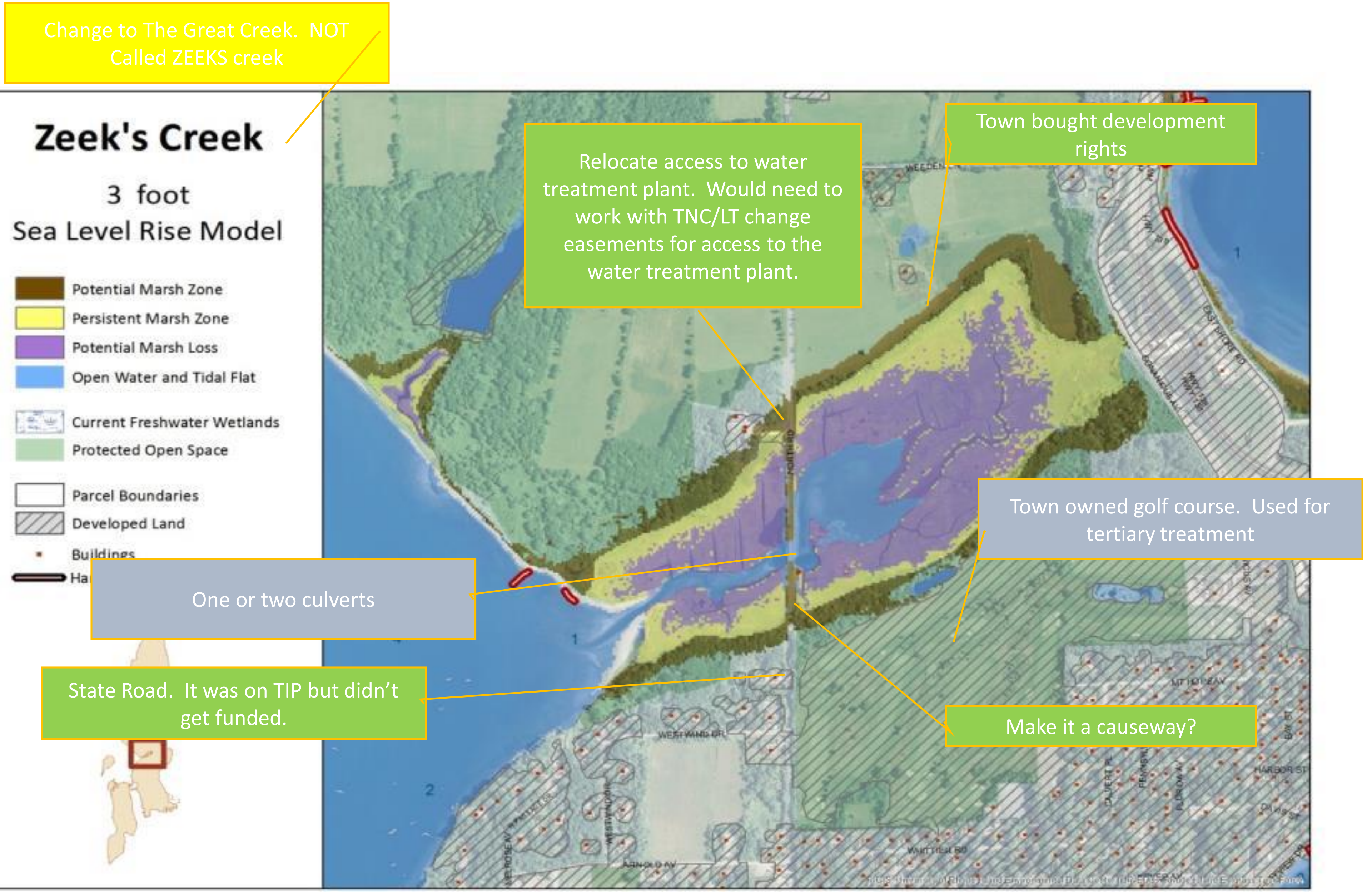
90
Potential Marsh Zone
Persistent Marsh Zone
Potential Marsh Loss
Open Water and Tidal Flat
Current Fresh Wetlands
Protected Open Space
Hardened Shores
Buildings
Parcel Boundaries
Developed Land
CRMC Coastal Barriers
Tidal Marsh Vulnerability Analysi
Three Foot Sea Level Rise Mode
CRMC
Sea Grant
Map produced by Kevin Ruddock. 4/1/201


Important Bird Areas (Salt Marsh Sparro
Other Large Marshes
Sea Level Fens
Large Marshes in Future SLR Scenarios

# Municipal Outreach

- Workshops held in 21 coastal communities during and after model development
- Attendees included municipal planners and other staff, board members, land conservation organizations
- Opportunities for coastal adaptation and land conservation identified
- Maps made available by town on CRMC website

# Jamestown: "Opportunity Map"

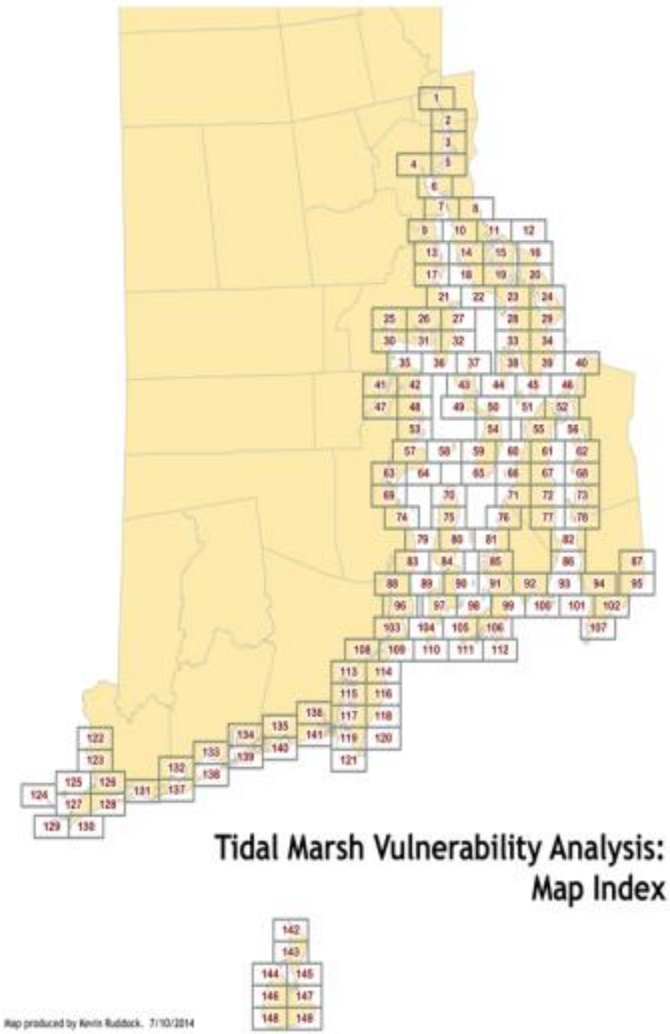


# Sea Level Affecting Marshes Model (SLAMM) Maps (adopted by the CRMC on January 13, 2015)

Rhode Island Sea Level Affecting Marshes Model (SLAMM) Project Summary Report, March 2015 (PDF)

The Rhode Island Coastal Resources Management Council (CRMC) and its partners have developed Sea Level Affecting Marshes Model (SLAMM) Maps for the coastal wetlands of all 21 Rhode Island coastal communities. The purpose of these SLAMM maps is to show how coastal wetlands will likely transition and migrate onto adjacent upland areas under projected sea level rise scenarios of 1, 3 and 5 feet in the coming decades. These maps are intended to support state and local community planning efforts and to help decision makers prepare for and adapt to future coastal wetland conditions despite the inherent uncertainties associated with future rates of sea level rise.

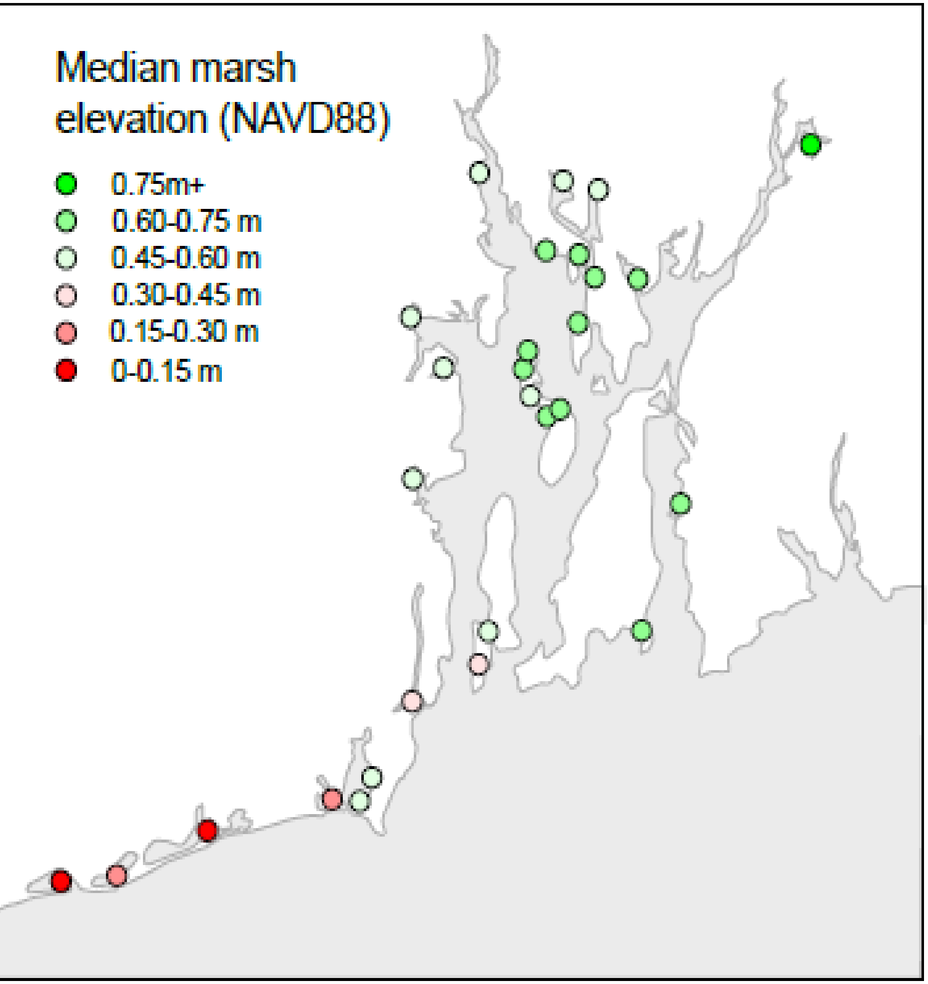
You can click on each individual panel on the map below to view a PDF of the maps for that section or click on the city or town link at the bottom of this page for maps of that entire coastal community. Be aware the files are large (approximately 5-15MB).

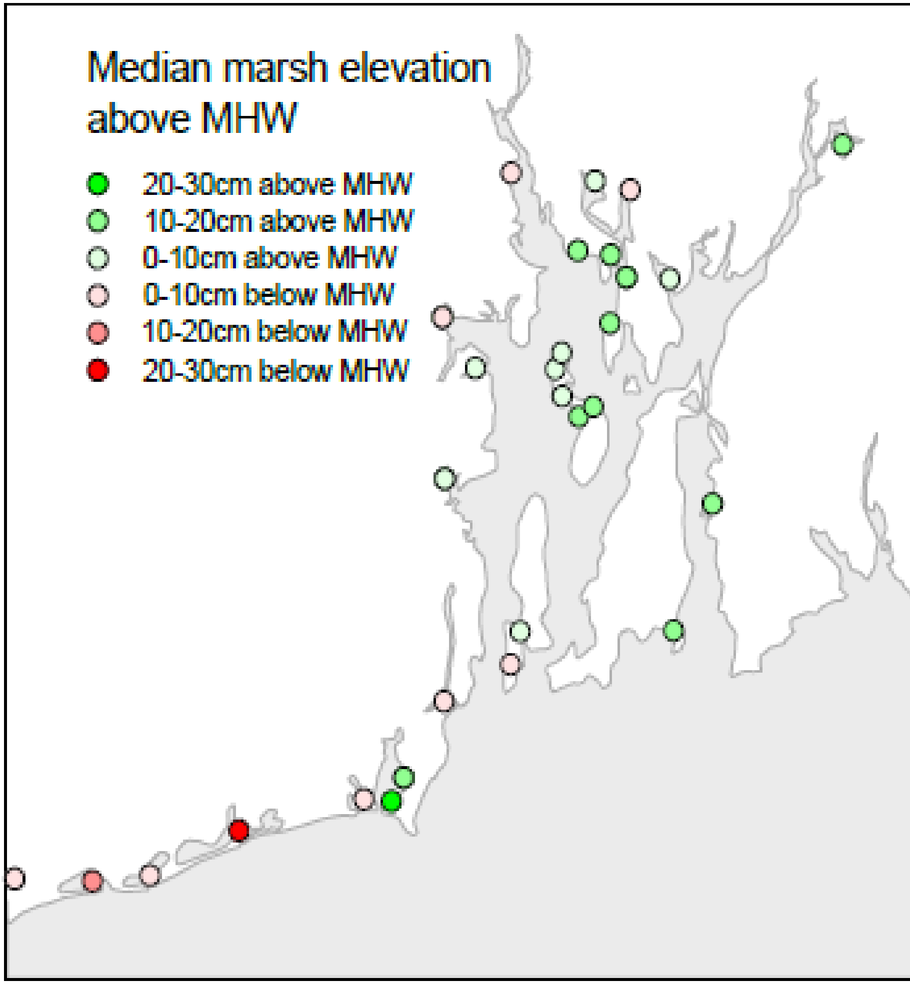



The SLAMM maps were developed using a digital wetlands coverage derived from the 2010 National Wetlands Inventory for Rhode Island. The elevation data used in the model was developed from the 2011 USGS LIDAR elevation dataset. These maps were developed using the "protection off" mode for the model simulations, thereby depicting the highest potential for marsh migration despite current limitations such as parking lots, roads or other development. In this way the maps illustrate opportunities for conservation and potential land modification to enhance wetland

# I Salt Marsh Assessment (2011-2012)

- 39 Marsh units assessed units within 29 marshes




Cole Ekberg, M.L., Raposa, K.B., Ferguson, W.S. et al. Estuaries and Coasts (2017)

# A Strategy for Developing a Salt Marsh Monitoring and Assessment Program for the State of Rhode Island

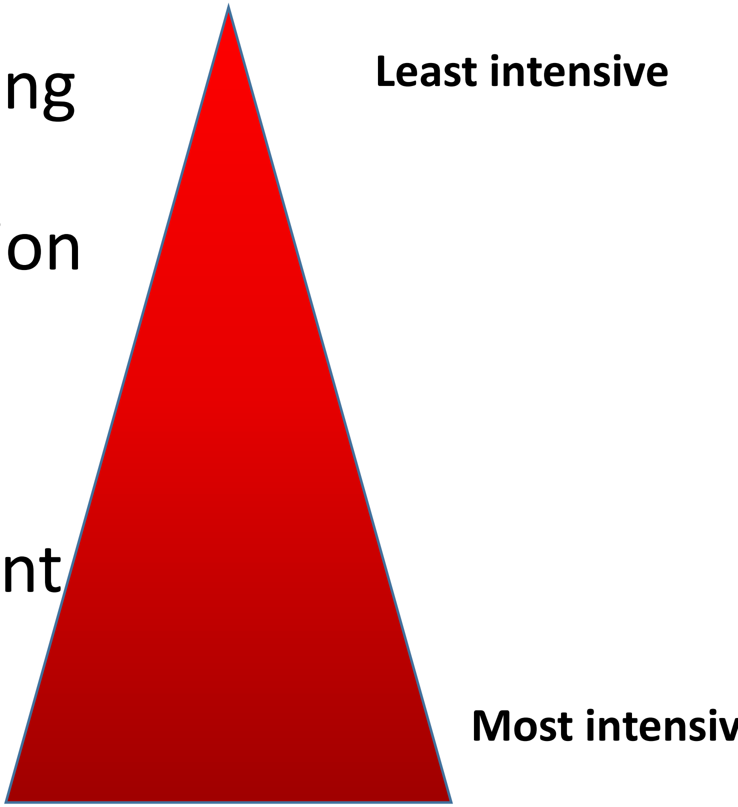
Kenneth B. Raposa, Ph.D.[1], Tom Kutcher[2], Wenley Ferguson[2], Marci Cole Ekberg, Ph.D[2]., Robin L.J. Weber[1], and Caitlin Chaffee[3]

[1]Narragansett Bay National Estuarine Research Reserve; 55 South Reserve Drive, Prudence Island RI 02872
[2]Save The Bay; 100 Save The Bay Drive, Providence RI 02905
[3]RI Coastal Resources Management Council, Wakefield RI 02879

March 1, 2016

# Tools in the Toolbox: Intervention Actions

- Land Conservation / Land Use Planning
- Removal of barriers to future migration
- Hydrologic modification
- Elevation enhancement with sediment



# Rhode Island Coastal Wetland Restoration Strategy

- Will describe current state of salt marshes, stressors and predicted impacts of climate change and sea level rise
- Will describe available management actions to address impacts and preserve functions
- Will provide guidance for prioritizing projects, use of resources for wetland restoration and conservation

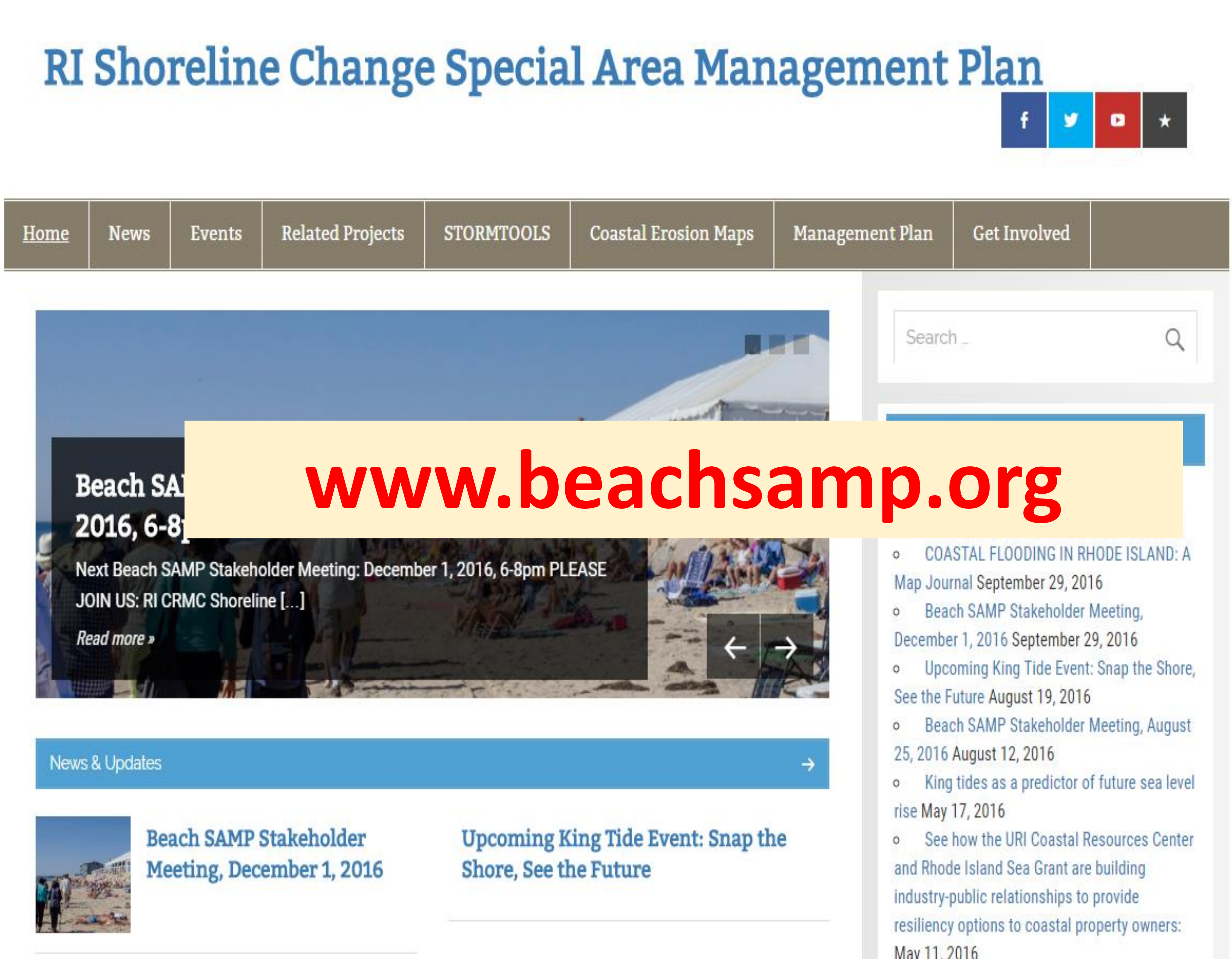
RHODE ISLAND NATURAL HISTORY SURVEY
Providing Ecosystem Science and Information

Narragansett Bay National Estuarine Research Reserve

SAVE THE BAY® NARRAGANSETT BAY

CRMC Coastal Resources Management Council

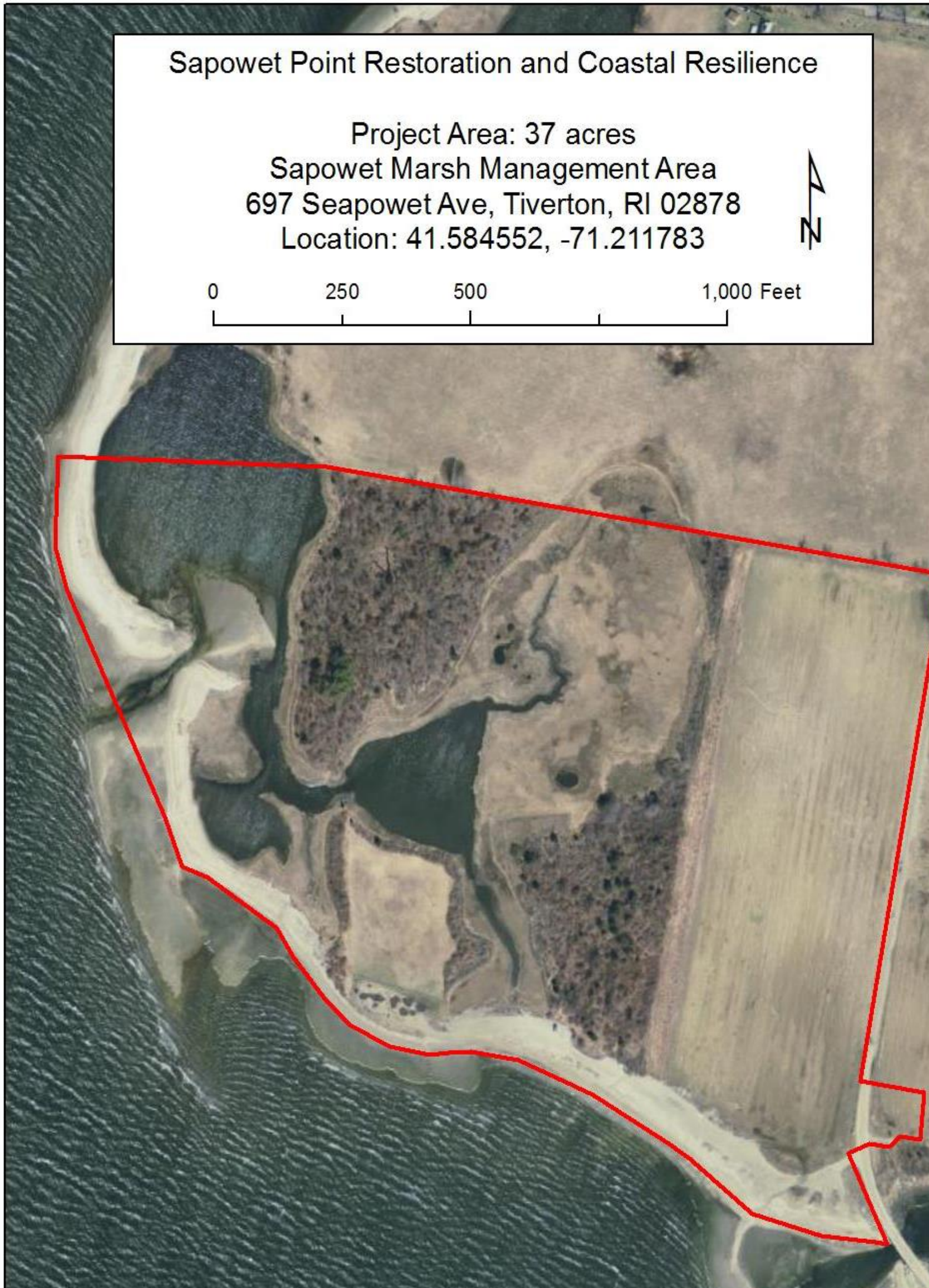
D·E·M

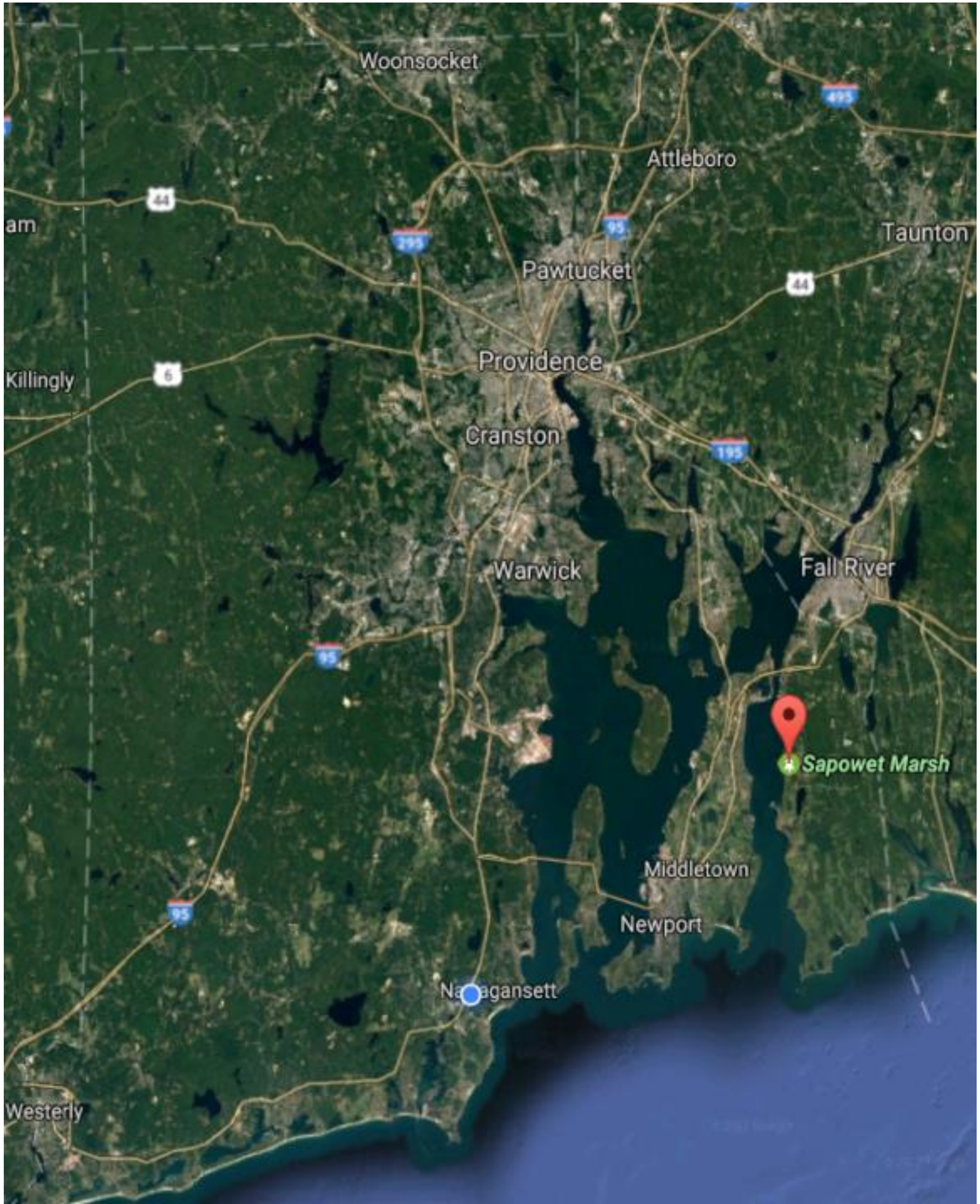



www.beachsamp.org

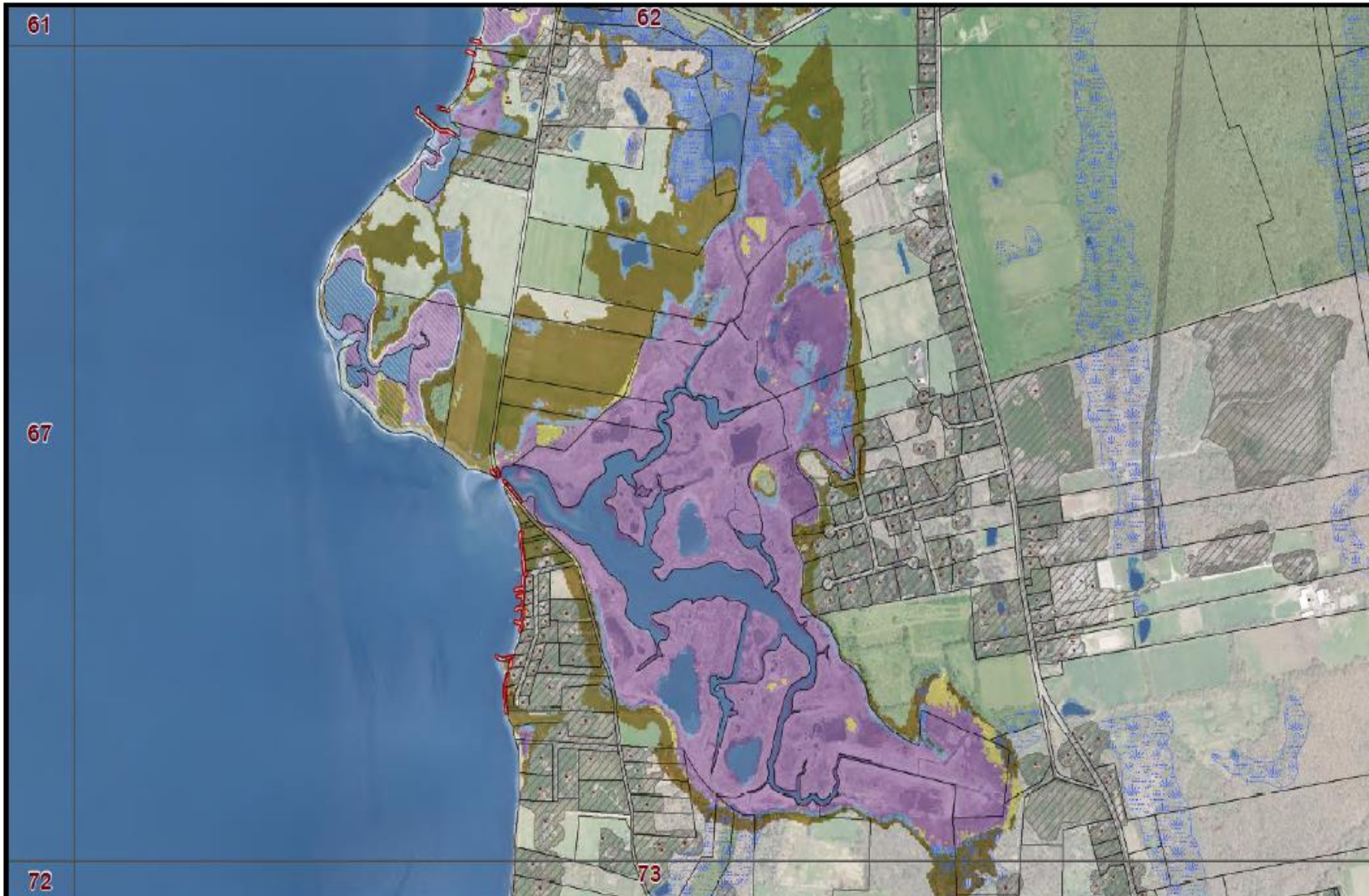
# Example Project: RIDEM Seapowet Point Restoration

Reconfiguring land use to enhance habitat and allow for migration with sea level rise




Woonsocket
Attleboro
Taunton
Pawtucket
Providence
Cranston
Warwick
Fall River
Killingly
Sapowet Marsh
Middletown
Newport
Narragansett
Westerly
44
295
95
6
195
495

vet Point
Seapowet Ave
Seapowet Ave
Sapowet Marsh
Seapowet Ave
Seapowet Ave
Seapowet Ave




Map 68

N

1:10,000

0 500 1,000 1,500 2,000 Feet

This map is not the product of a professional land survey. It was created for general reference, informational, planning, and guidance use, and is not a legally authoritative source as to the location of natural or manmade features. No warranty is expressed or implied, related to the spatial accuracy, reliability, completeness, or currentness of this map.

- Potential Marsh Zone
- Persistent Marsh Zone
- Potential Marsh Loss
- Open Water and Tidal Flat
- Current Fresh Wetlands
- Protected Open Space
- Hardened Shores
- Buildings
- Parcel Boundaries
- Developed Land
- CRMC Coastal Barriers

# Tidal Marsh Vulnerability Ar
## Five Foot Sea Level Rise

Map produced by Ke


Sapowet Point Proposal
Allow beach vegetation to recolonize area once vehicular access limited
Move parking area closer to Seapowet Ave to continue to provide access
Relocate parking area to provide room for beach and marsh migration
Limit vehicular access further east to allow for beach migration inland and buffer establishment
© 2013 Google

# Thanks!

Caitlin Chaffee
Coastal Policy Analyst
RI Coastal Resources Management Council
www.crmc.ri.gov

# Applying SLAMM to CT's Shoreline

Dave Kozak CT DEEP/ Marco Propato, Warren Pinnacle Consulting


Barn Island Wildlife Management Area, Stonington, CT

# CT's SLR - Marsh Management Goals/Questions

**Where Do We Direct Limited Conservation $ ?**

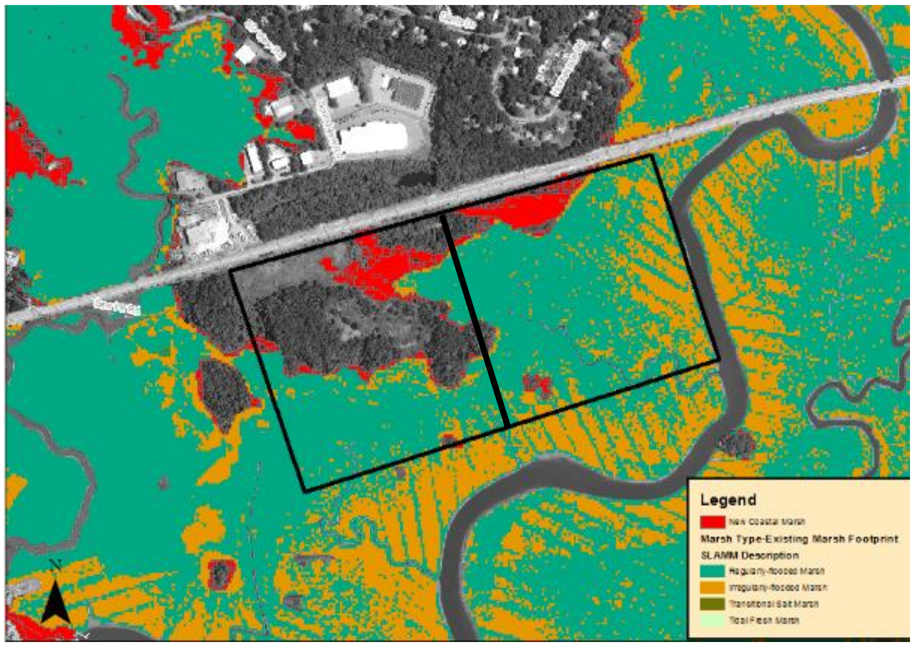
1. ID most and least resilient/sustainable marshes ?
2. Sustained by migration? → LARGEST and most likely areas?
3. Marsh composition (high v. low) change?
4. Marshes most capable of supporting high marsh?
5. Barriers to largest marsh migration areas?
6. Feasibility of modifying barriers to migration?
7. Muni's response to road flooding-a regulatory 'hook'?

# CT / LIS SLAMM Enhancements

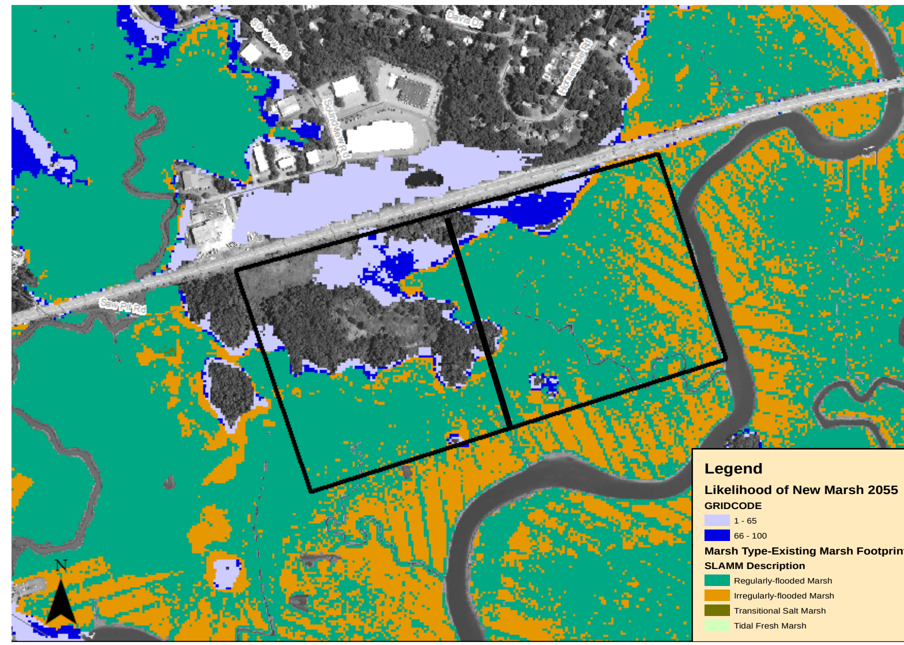
- Uncertainty analysis
- Roads and road-flooding module
- Tidal restrictions
- Additional hydro-enforcement
- Connectivity assessment

# Why Consider Uncertainty To Target Marsh Migration Areas?

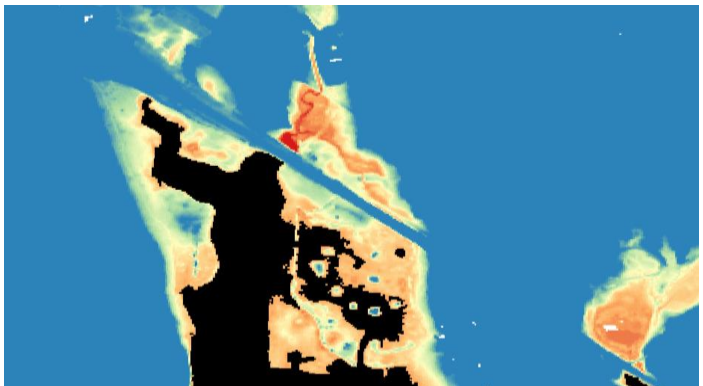
Year 2055 East River Marsh Migration (high SLR)

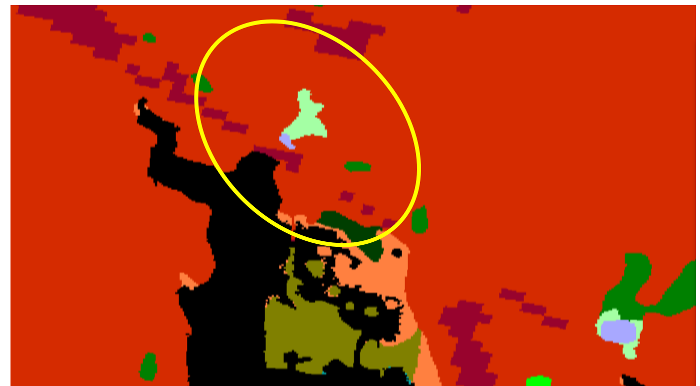


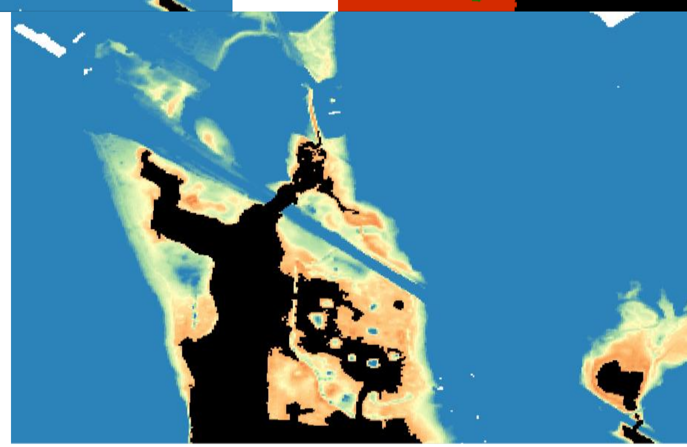

Likelihood Year 2055 East River Marsh Migration (all SLR)



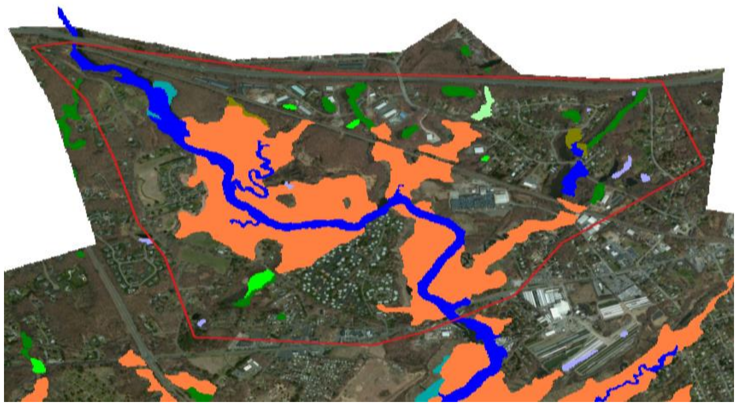
# Hydrologic enforcement

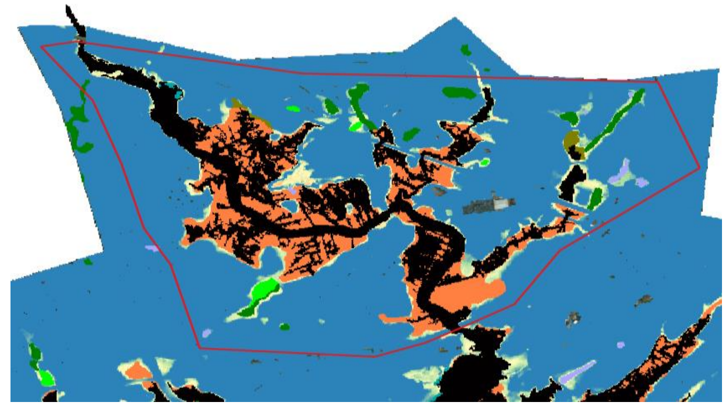


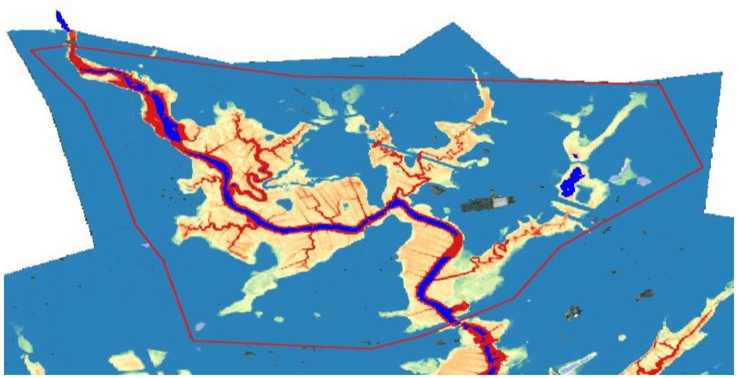




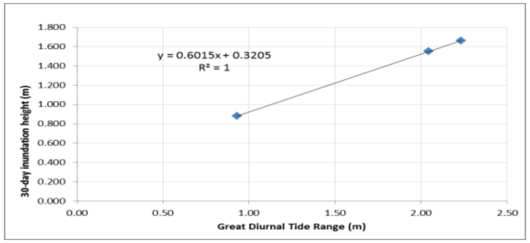
# Muted tide areas



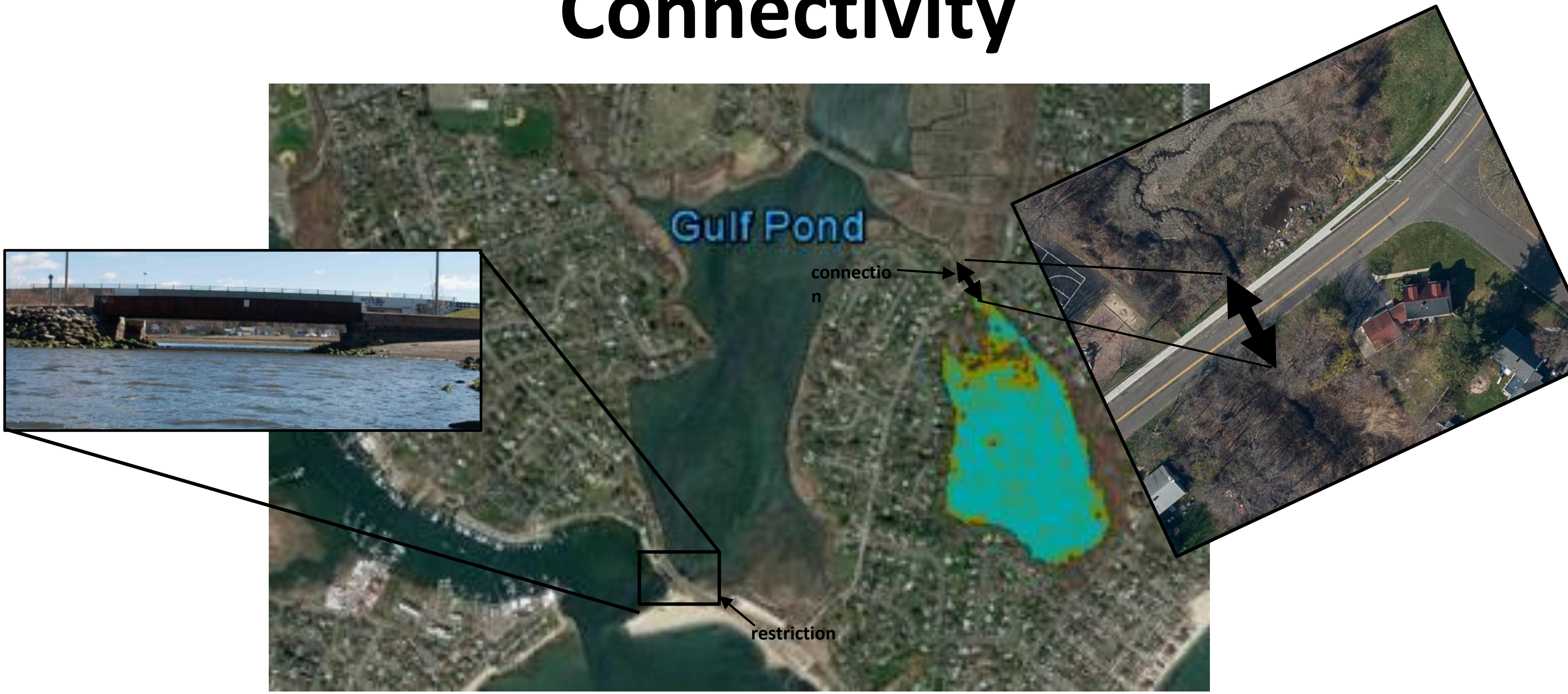




- Estimate wetland boundary elevation
- Derive GT using inverse  of GT vs WBE relationship

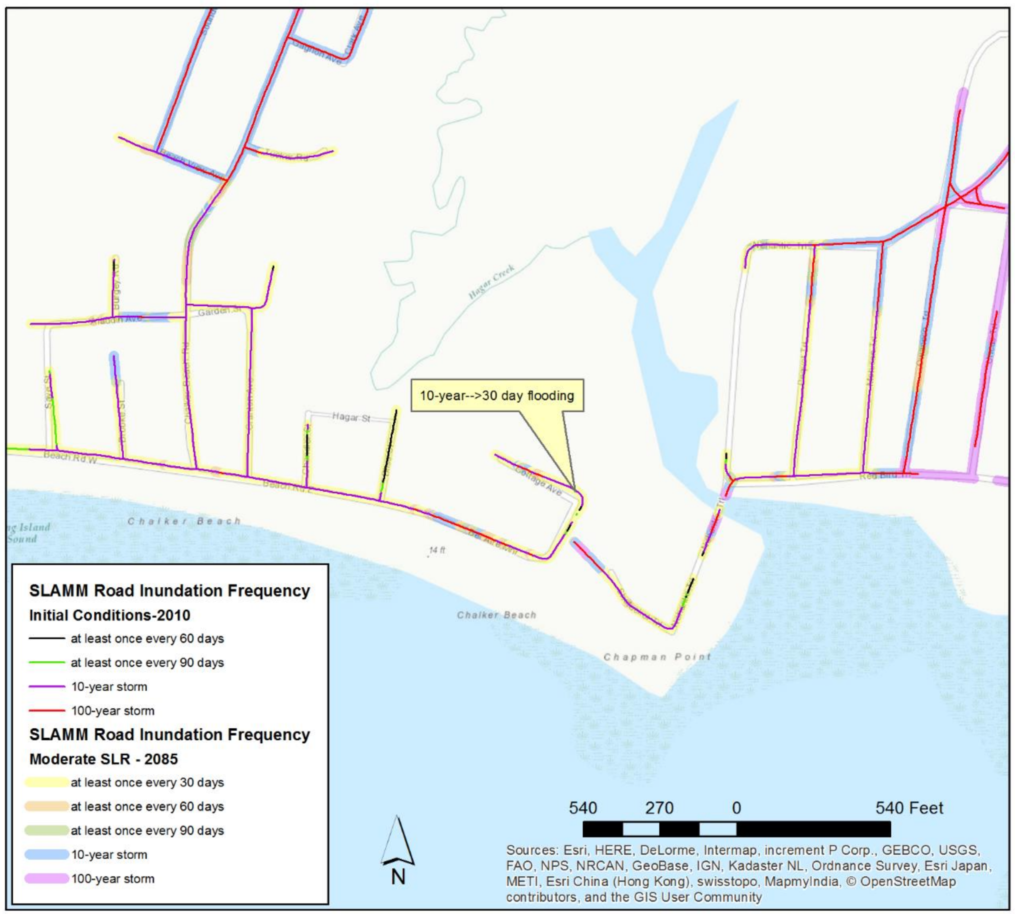


# SLAMM Tidal Muting and Connectivity



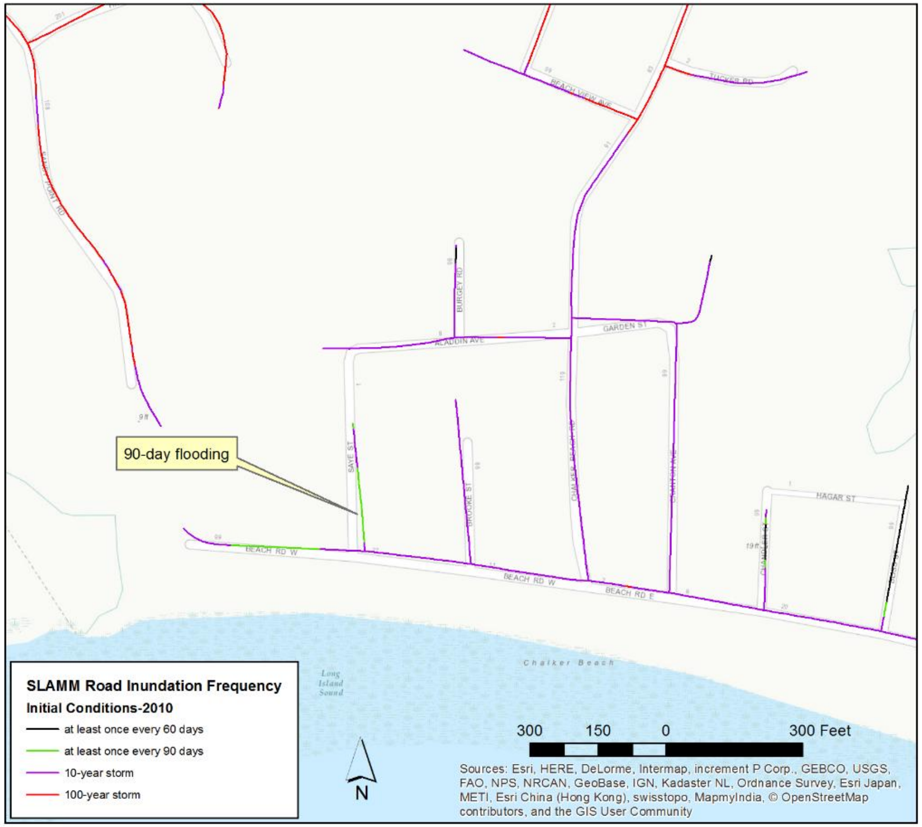
# Road Modifications and Marsh Migration

Chalker Beach Area Road Flooding 2010--> 2085 (Moderate SLR)



# SLAMM Road Flooding Verification

Existing (2010) SLAMM Road Flooding



# Road Modifications and Marsh Migration


Saye Street, Old Saybrook, CT

Global Change Biology

Global Change Biology (2016), doi: 10.1111/gcb.13398

# Upslope development of a tidal marsh as a function of upland land use

SHIMON C. ANISFELD, KATHARINE R. COOPER and ANDREW C. KEMP

*School of Forestry and Environmental Studies, Yale University, 370 Prospect St., New Haven, CT 06511, USA*

## Abstract

To thrive in a time of rapid sea-level rise, tidal marshes will need to migrate upslope into adjacent uplands. Yet little is known about the mechanics of this process, especially in urbanized estuaries, where the adjacent upland is likely to be a mowed lawn rather than a wooded natural area. We studied marsh migration in a Long Island Sound salt marsh using detailed hydrologic, edaphic, and biotic sampling along marsh-to-upland transects in both wooded and lawn environments. We found that the overall pace of marsh development was largely unaffected by whether the upland being invaded was lawn or wooded, but the marsh-edge plant communities that developed in these two environ- ments were quite different, and some indicators (soil salinity, foraminifera) appeared to migrate more easily into lawns.

In addition, we found that different aspects of marsh structure and function migrated at different rates: Wet-land vegetation appeared to be a leading indicator of marsh migration, while soil characteristics such as redox poten- tial and surface salinity developed later in the process. We defined a 'hydrologic migration zone', consisting of elevations that experience tidal inundation with frequencies ranging from 20% to 0.5% of high tides. This hydrologically defined zone which extended to an elevation higher than the highest astronomical tide datum captured the biotic and edaphic marsh-upland ecotone. Tidal inundation at the upper border of this migration zone is highly vari- able over time and may be rising more rapidly than mean sea level. Our results indicate that land management practices at the upland periphery of tidal marshes can facilitate or impede ecosystem migration in response to rising sea level. These findings are applicable to large areas of tidal marsh along the U.S. Atlantic coast and in other urbanized coastal settings.

*Keywords:* foraminifera, indicators, Long Island Sound, migration, sea-level rise, soil salinity

Correspondence: Shimon C. Anisfeld, tel. +1 617 694 8627, fax +1 203 432 9801, e-mail: shimon.anisfeld@yale.edu

NOAA Technical Report NOS CO-OPS 083

# GLOBAL AND REGIONAL SEA LEVEL RISE SCENARIOS FOR THE UNITED STATES

*Photo: Ocean City, Maryland*

**Silver Spring, Maryland**
**January 2017**

noaa National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services

# Lunch!