Hydrodynamic Modeling for Marsh Restoration and Optimization

Prime Hook National Wildlife Refuge Milton, DE

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Prime Hook NWR

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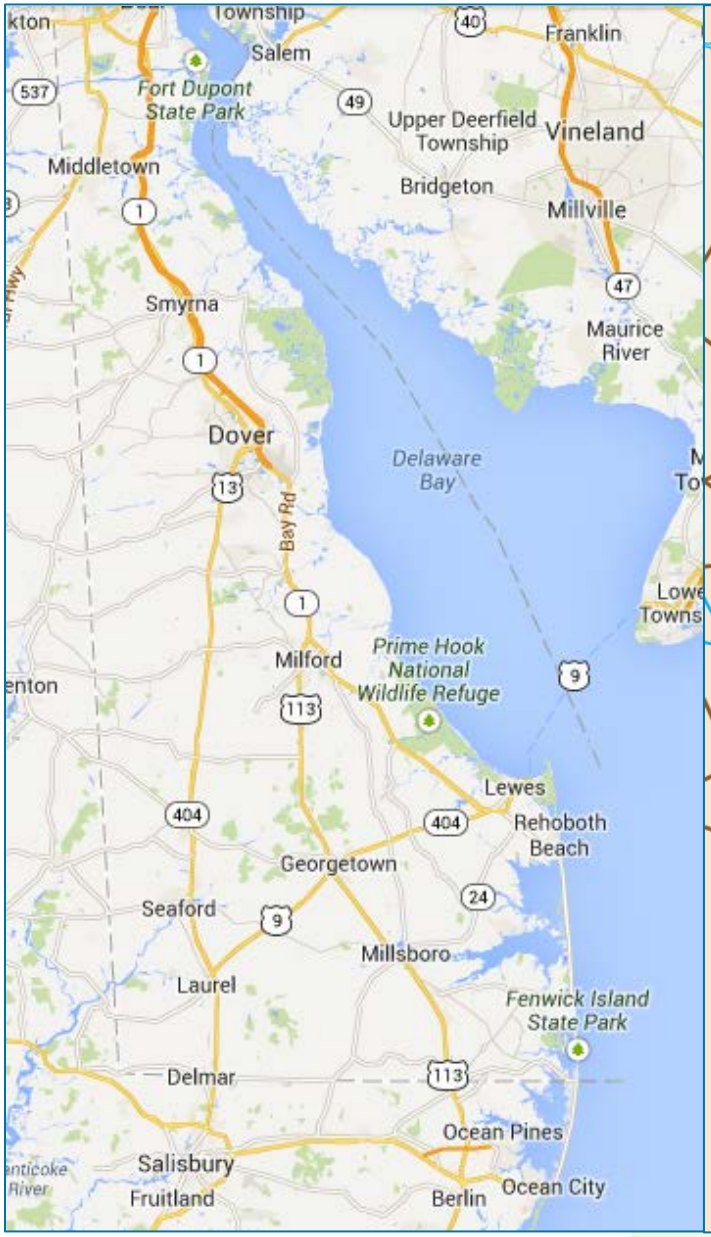
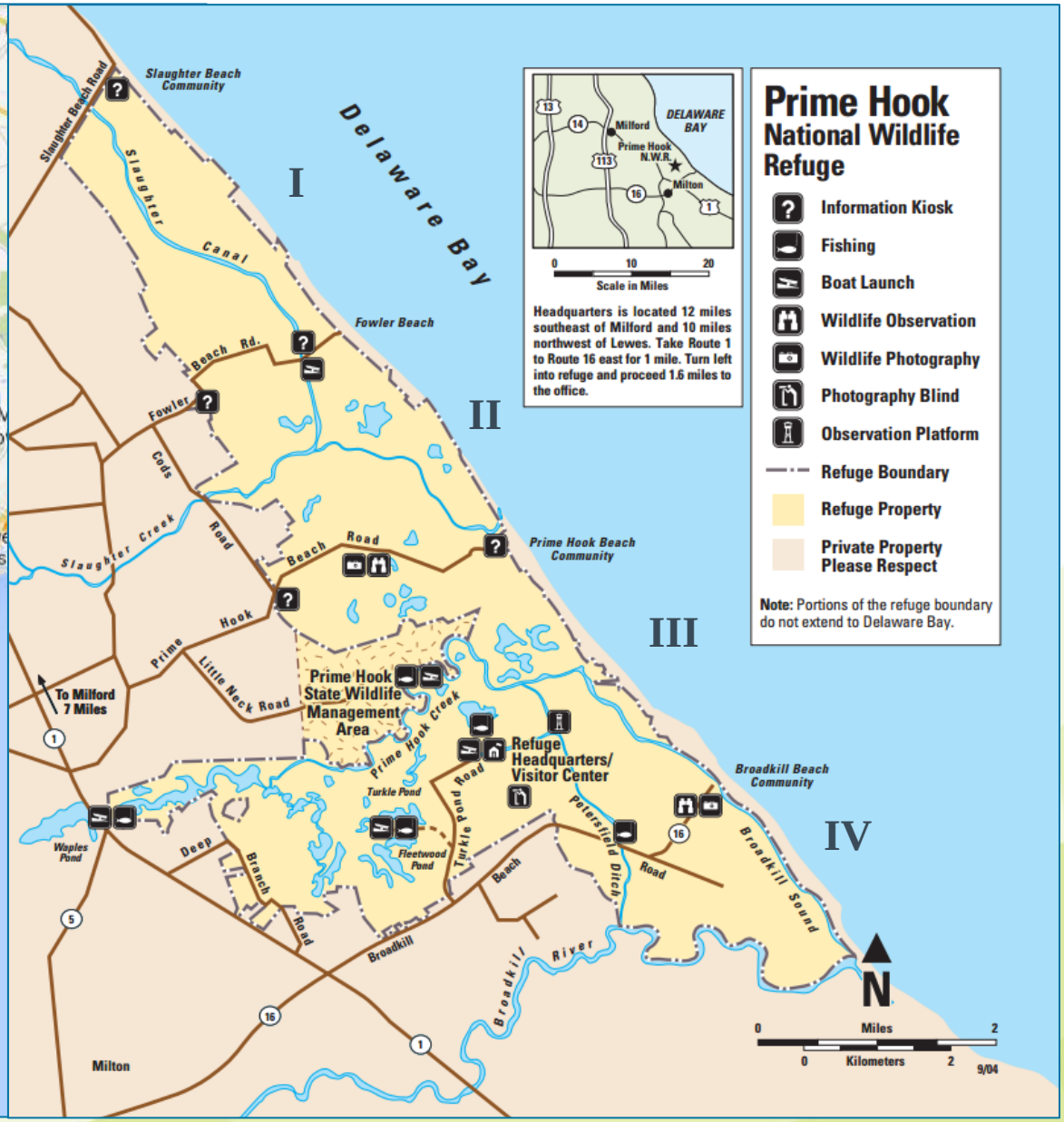




Circulation Model Study

ATKINS

- June 2012 – Executed Task Order
- 8 Month Schedule
- Hurricane Sandy and Delays in Data Acquisition
- Objectives
  1. Analyze available data
  2. Develop circulation & water quality model
  3. Develop restoration alternatives
  4. Model water circulation & salinity
  5. Analyze results and evaluate alternatives
  6. Prepare final report & recommendations

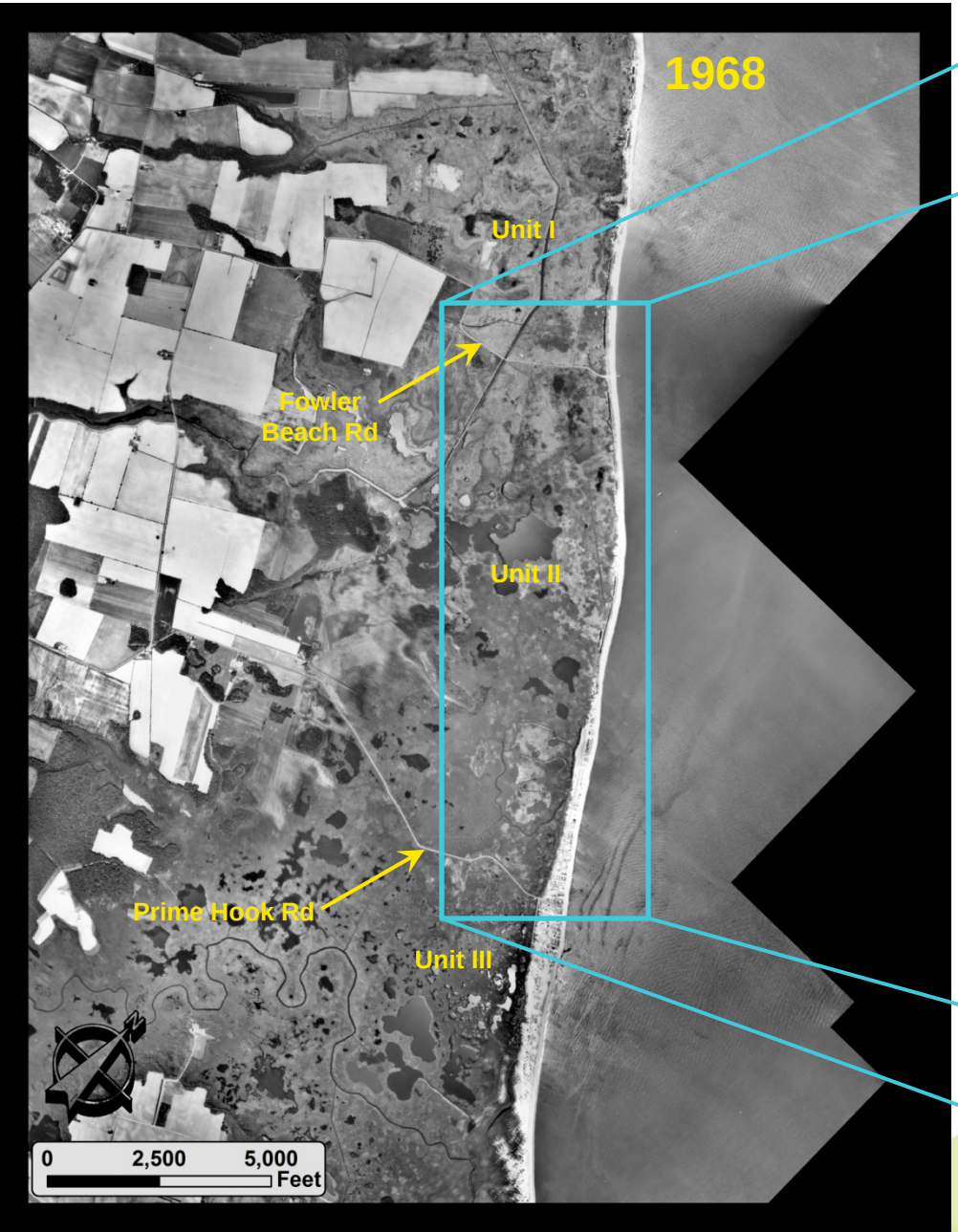
Project Background

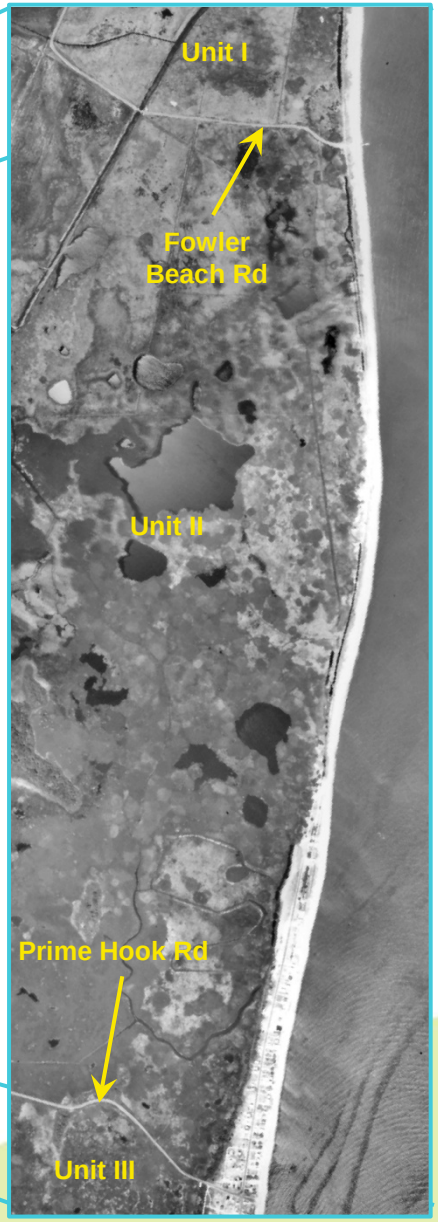
- Breaches along Units I & II
  - Initial breach in Unit I in 2006
  - Fall Nor'easter 2009
  - Hurricane Irene 2011
  - Hurricane Sandy 2012
- Units II & III
  - "Abrupt" shift to saline conditions
  - Loss of substrate & vegetation
  - Largely open saltwater system

Project Background

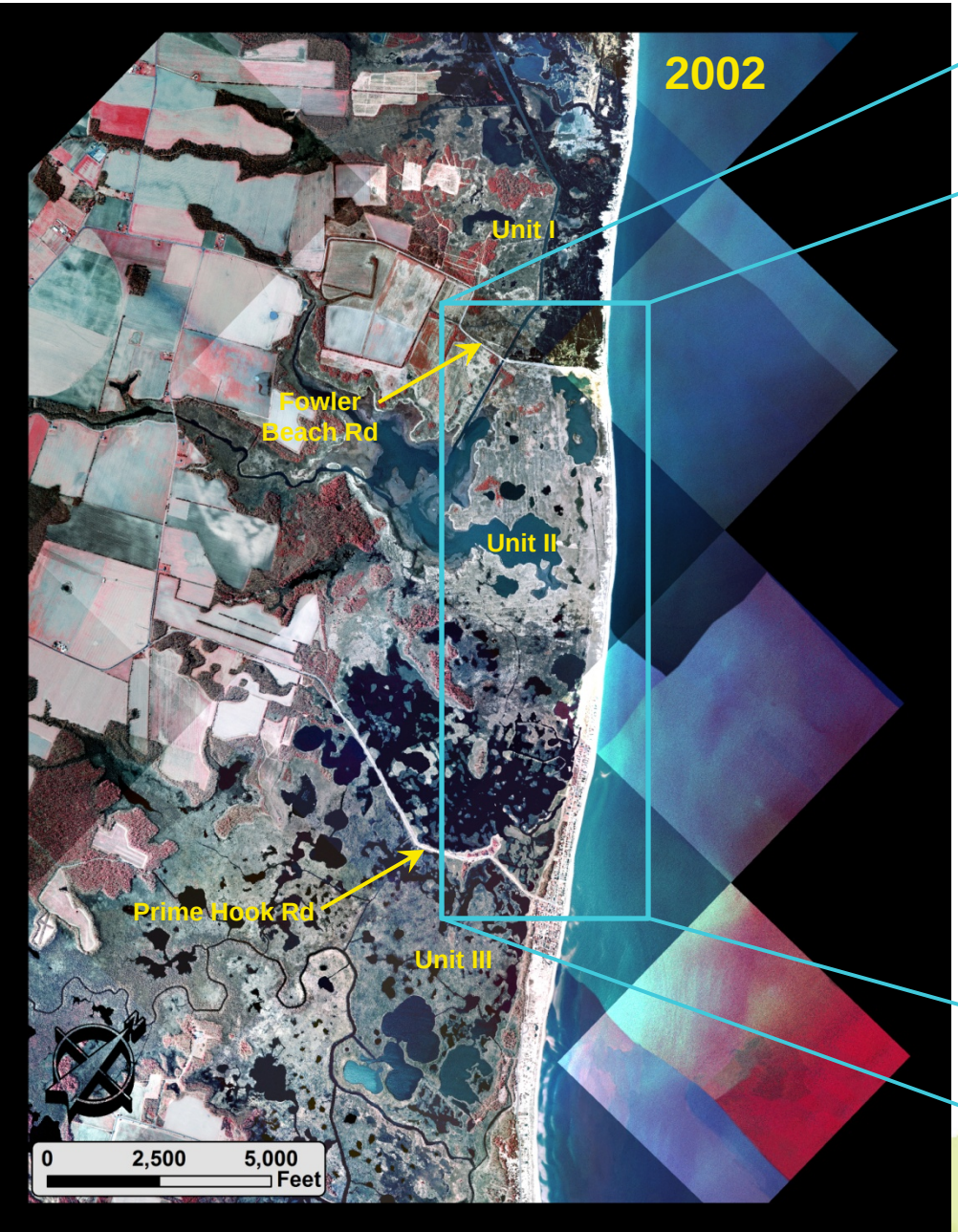
- Topographic & hydrographic survey
- Evaluation of breach fill alternatives
  - Development of multiple alternatives
  - Estimated sand volume needed
  - Preliminary cost estimates
  - Potential borrow sites

Historical Aerials: 1968

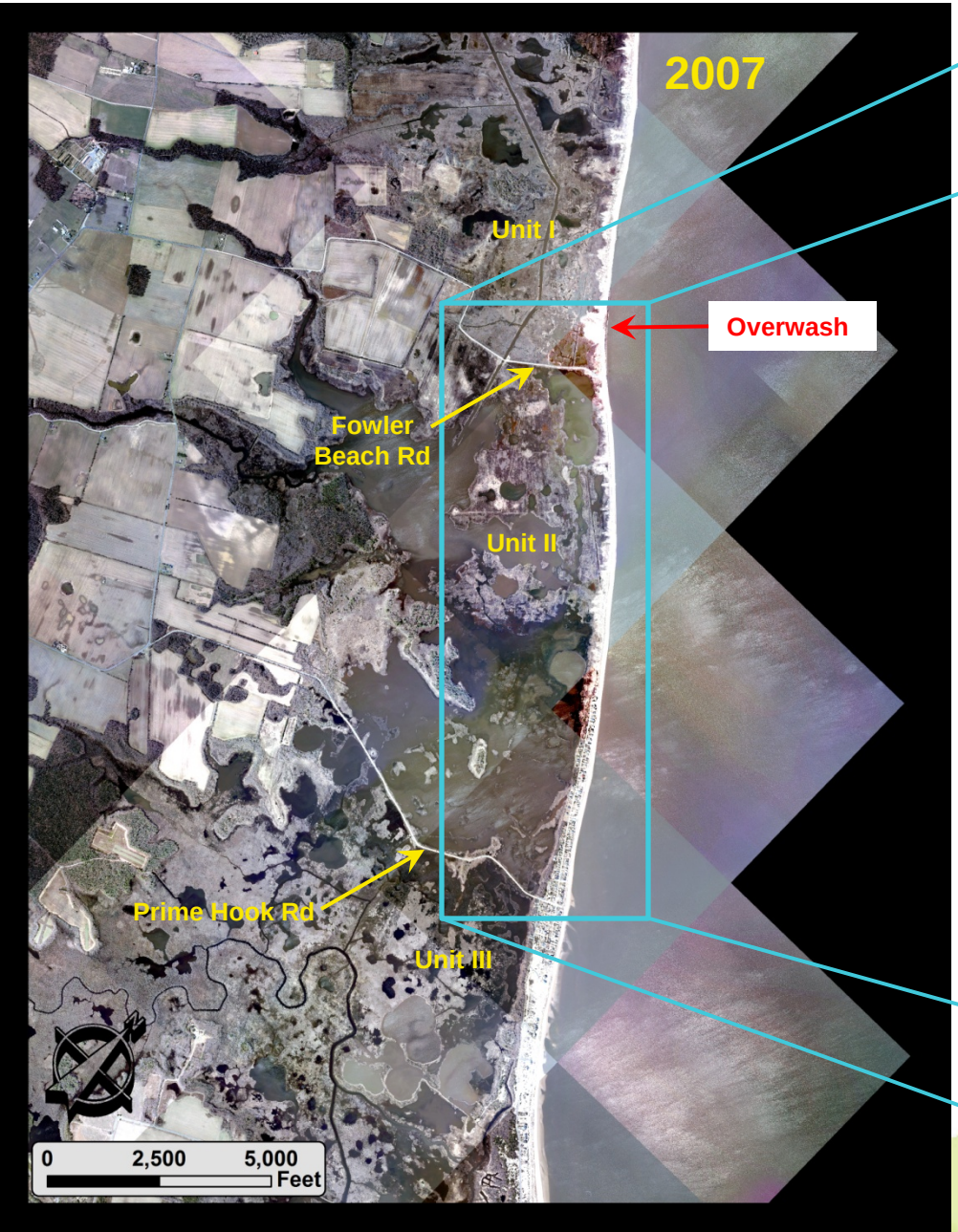




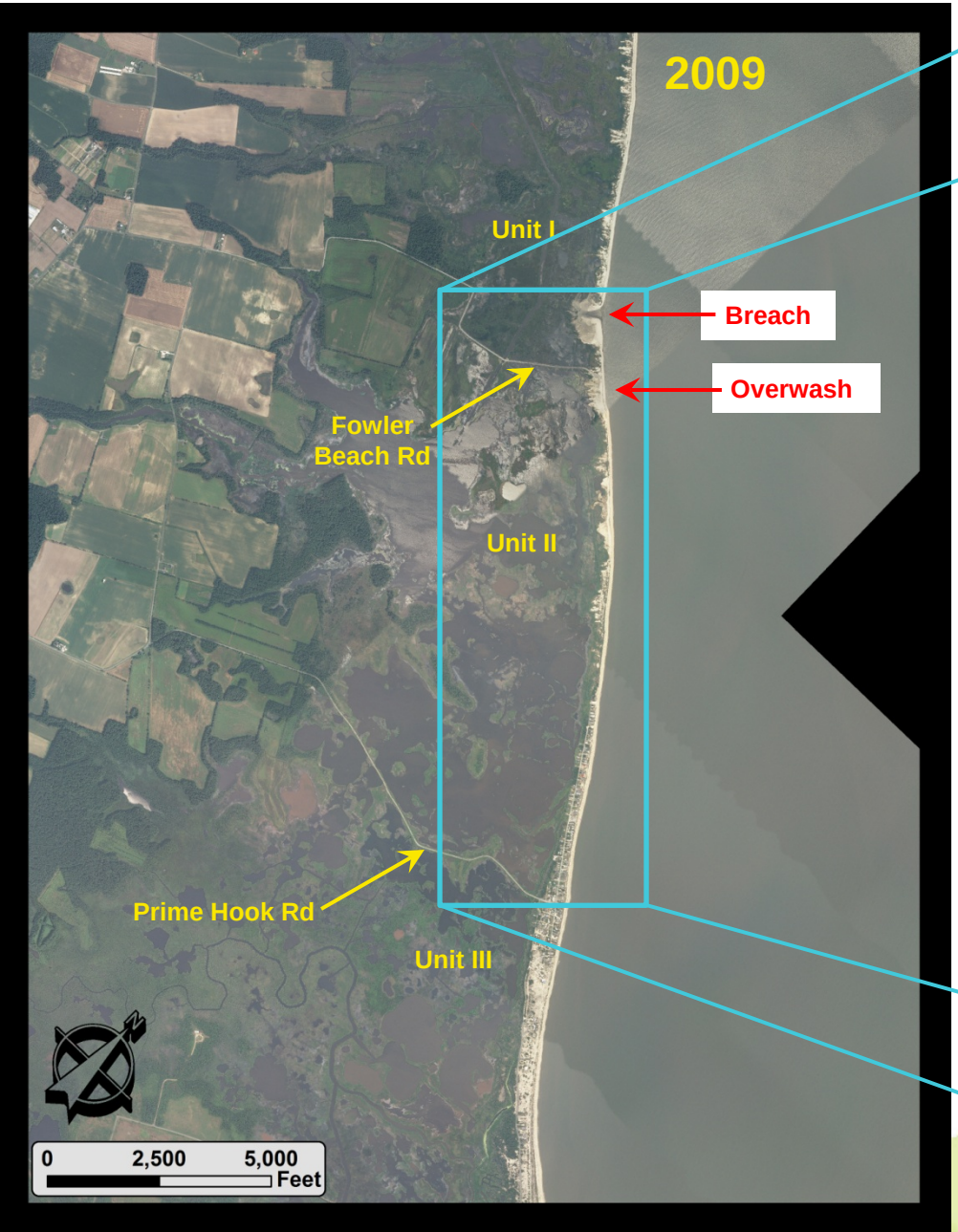
Historical Aerials: 2002



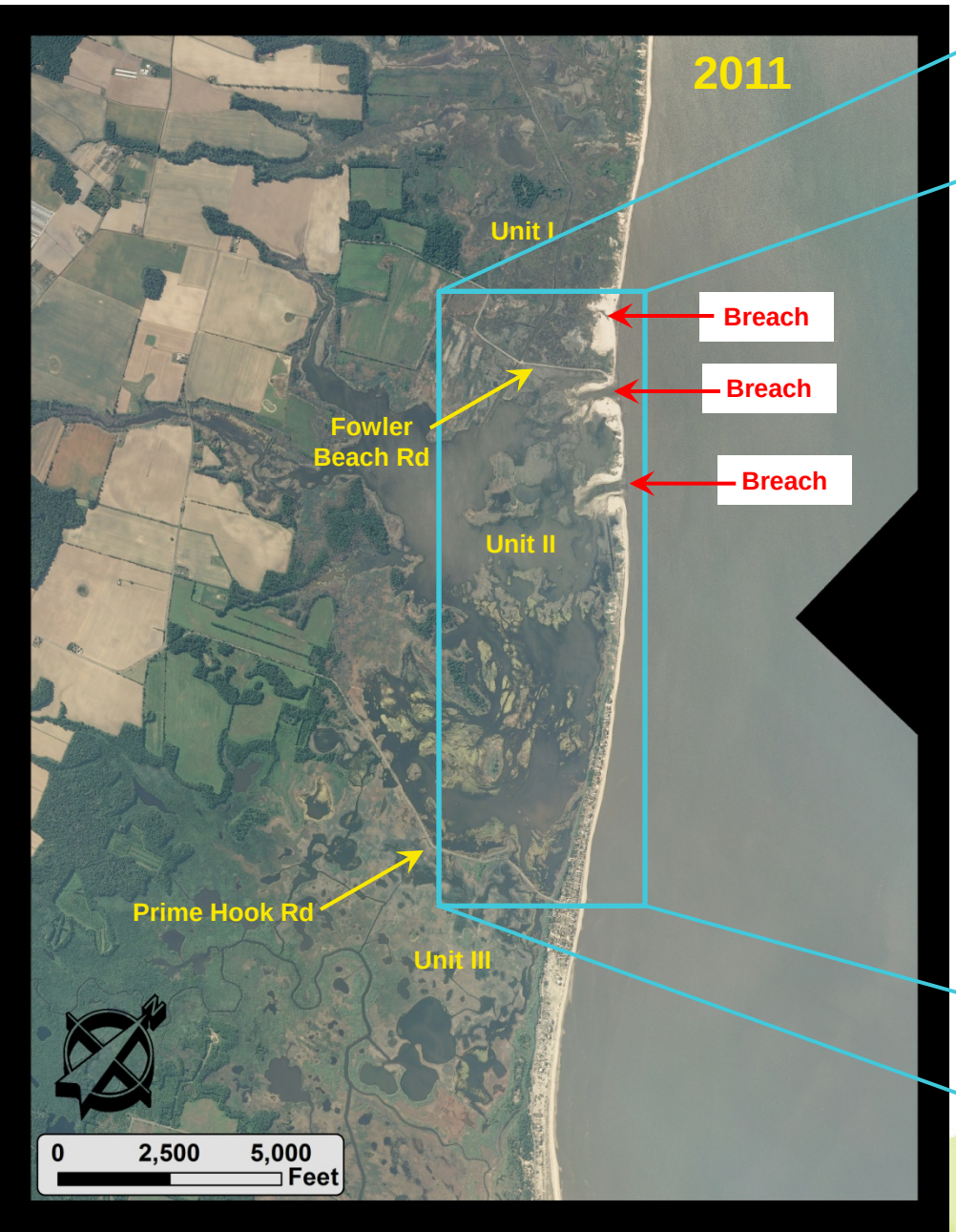
Historical Aerials: 2007



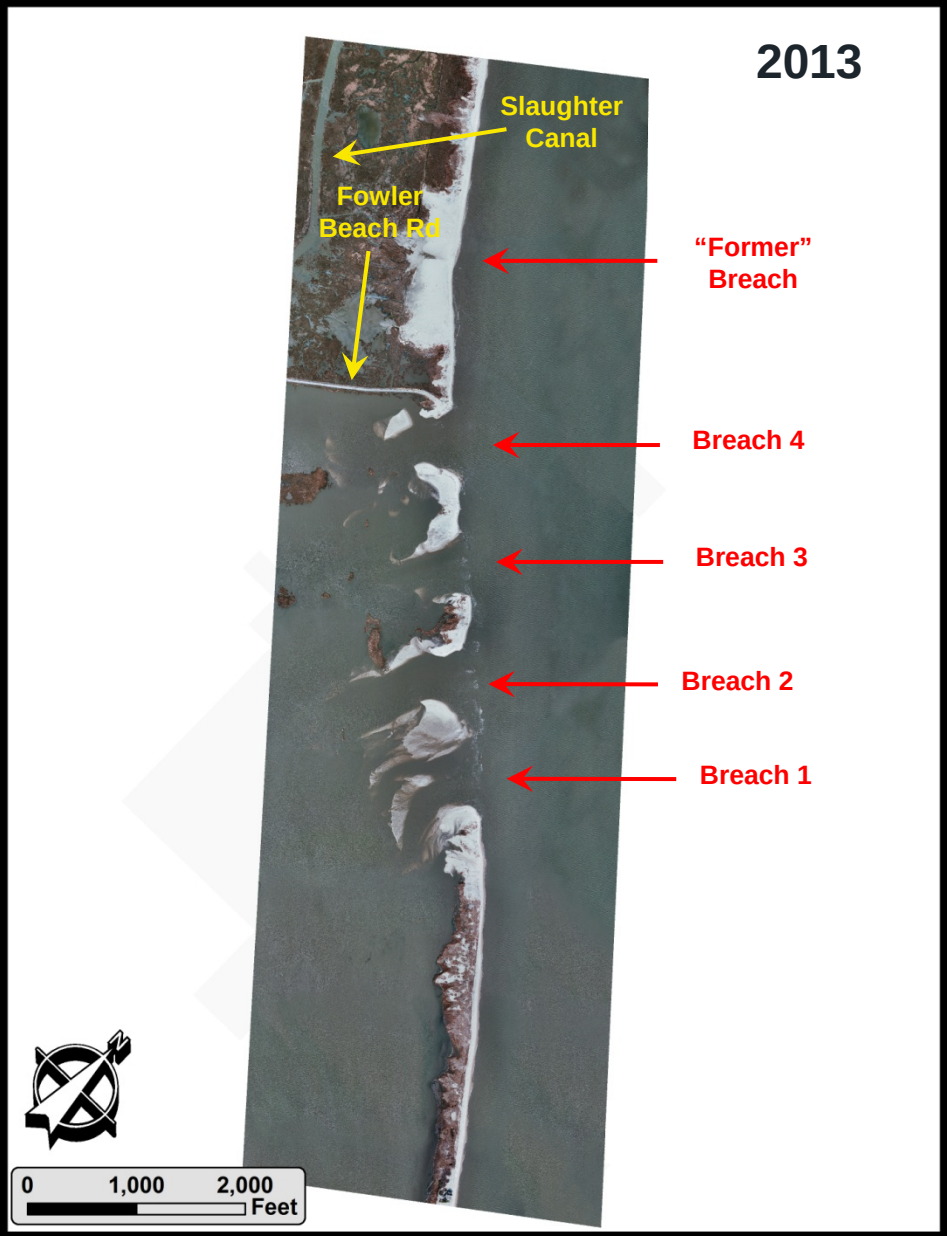
Historical Aerials: 2009



Historical Aerials: 2011



Historical Aerials: 2013



Numerical Modeling Overview

ATKINS

- Delft3D 2D/3D hydrodynamic model
- Curvilinear grid with domain-linking capability for complex geometry
- Inputs:
  - Bathymetry/topography
  - Bottom friction
  - Tidal, inflow, and wind forcing
  - Subdomain flow structures (weirs, barriers)
- Outputs (global and/or specific locations):
  - Water levels, currents, salinity

Modeling Approach: Testing

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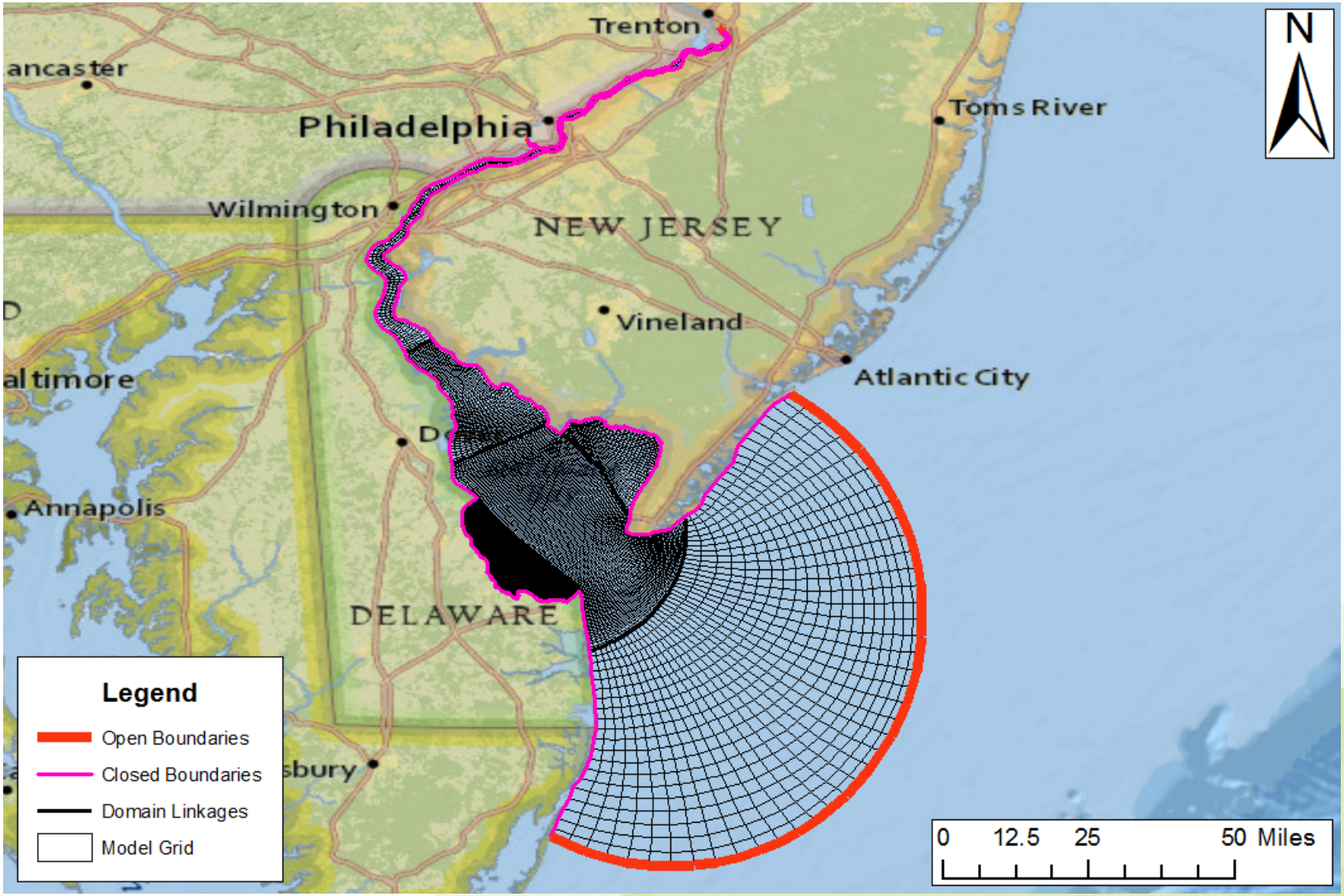
- Calibrate/refine grid and input parameters (bottom friction, formulations, etc). for existing topographic conditions (to the extent data are available)
- Model existing conditions with available data for operational (“normal”) and extreme (Hurricane Sandy) conditions
- Refine parameters within acceptable ranges to best duplicate water level fluctuations in the Refuge and Delaware Bay close to shore for extreme conditions
- Model parameters with operational conditions to verify applicability of parameters to varied forcings

Model Grid Setup

- **Domain**:
  - Delaware Bay from Trenton, NJ to Atlantic Ocean
  - Bounded by +4 m NAVD88 elevation in PHNWR (shoreline elsewhere)
  - 7 subdomains of varying resolution (~4 km to 10 m)
  - Approximately 2 million elements

- **Bathymetry**:
  - FEMA Region III ADCIRC DEM (2011)
  - Sussex County LiDAR (DE Coastal Program, 2005)
  - PHNWR Surface Elevation Survey (DNREC)
  - Post-Sandy survey and LiDAR (2013)

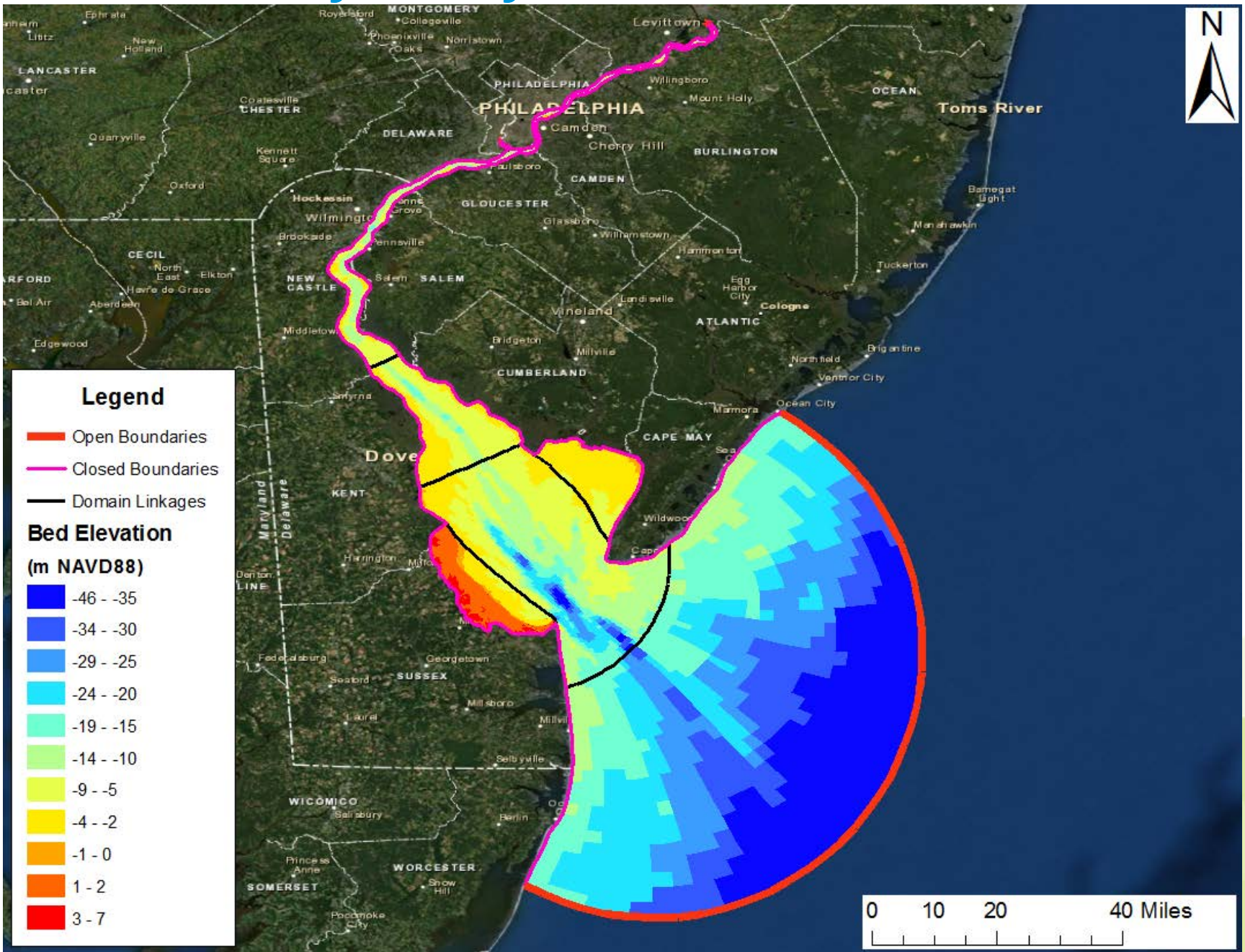
Model Grid


Trenton
ancaster
Philadelphia
Toms River
Wilmington
NEW JERSEY
Vineland
Atlantic City
altimore
Annapolis
DELAWARE
sbury
N
Legend
Open Boundaries
Closed Boundaries
Domain Linkages
Model Grid
0 12.5 25 50 Miles

Model Grid

Model Bathymetry

ATKINS



Calibration Locations

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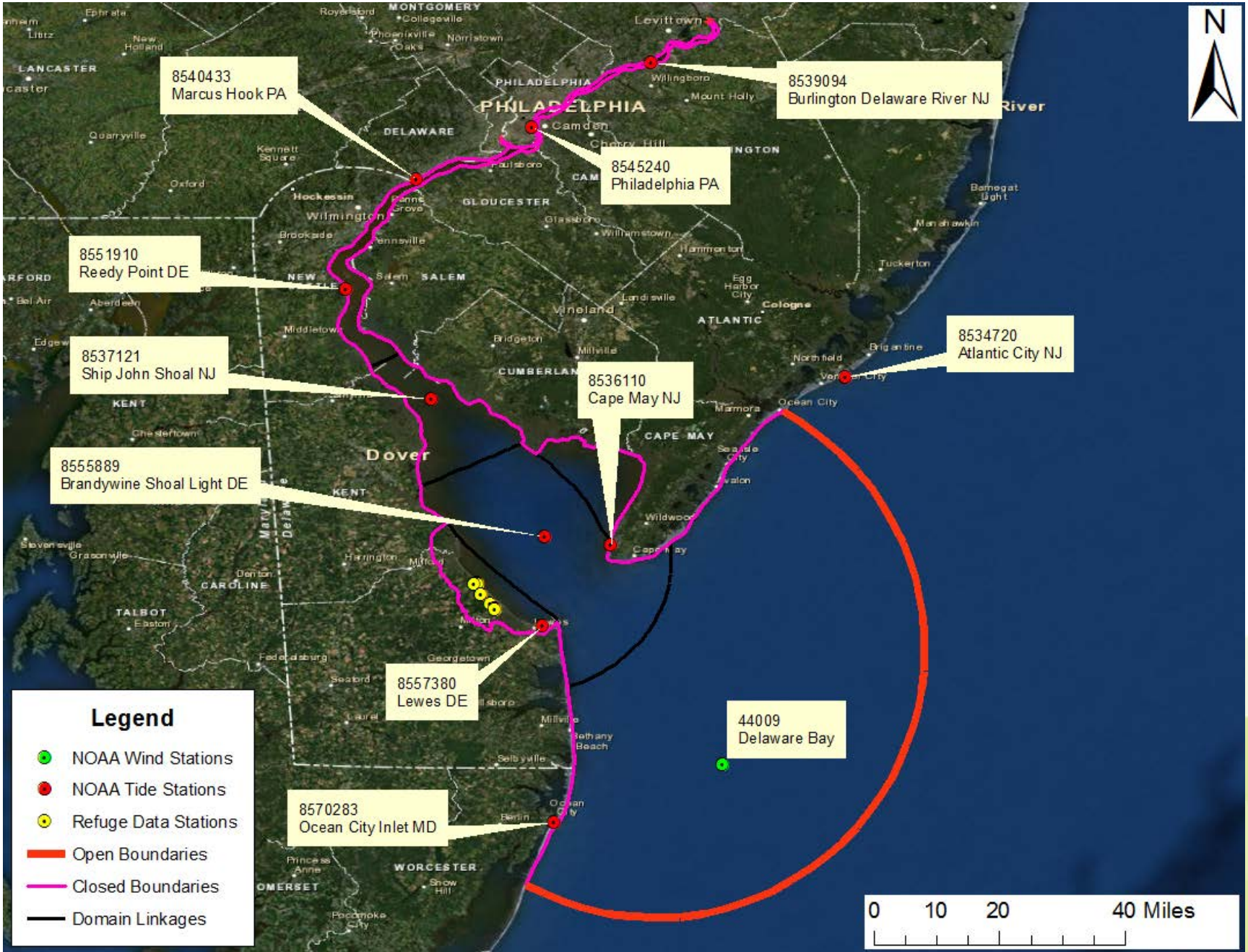

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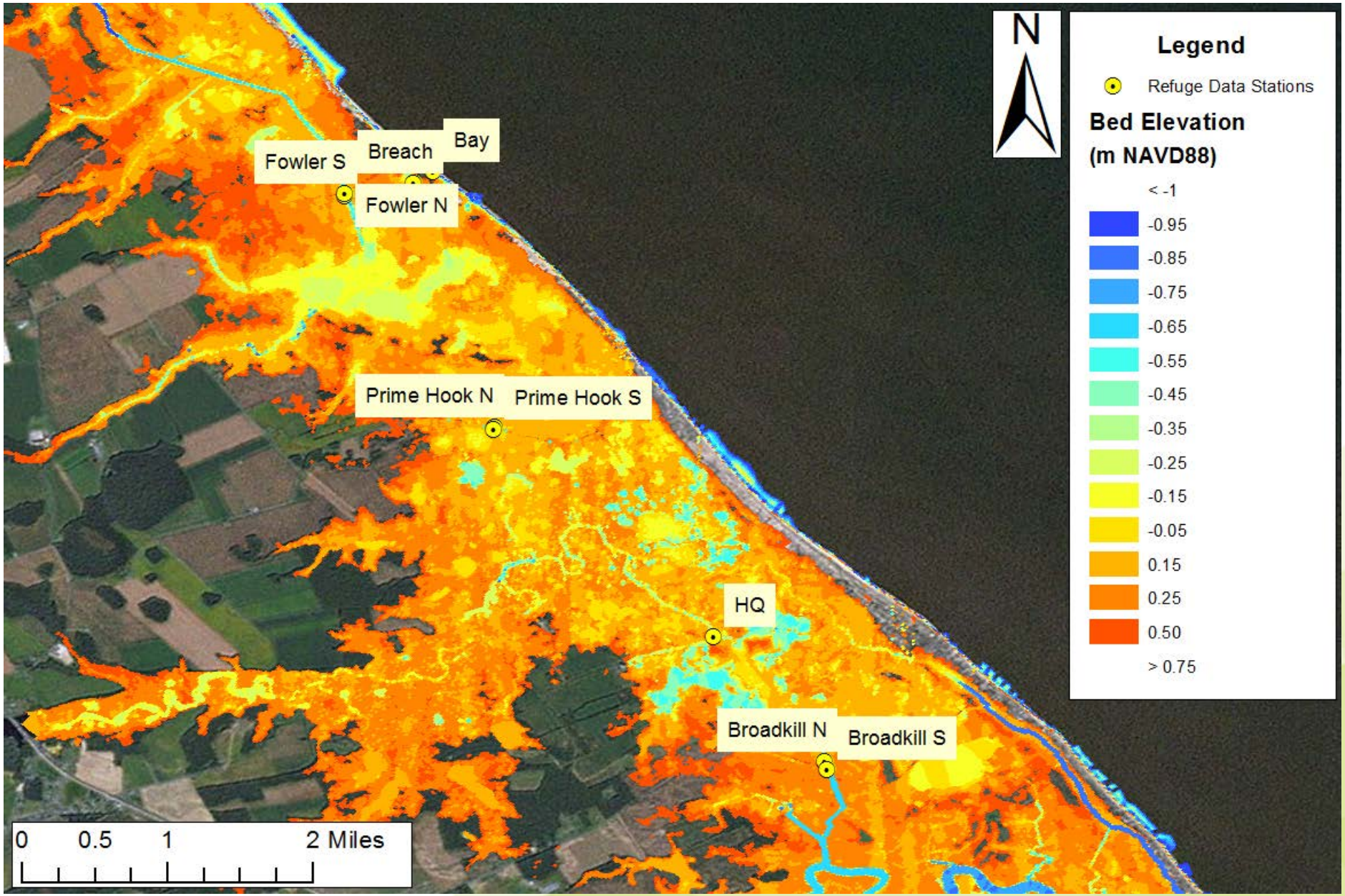
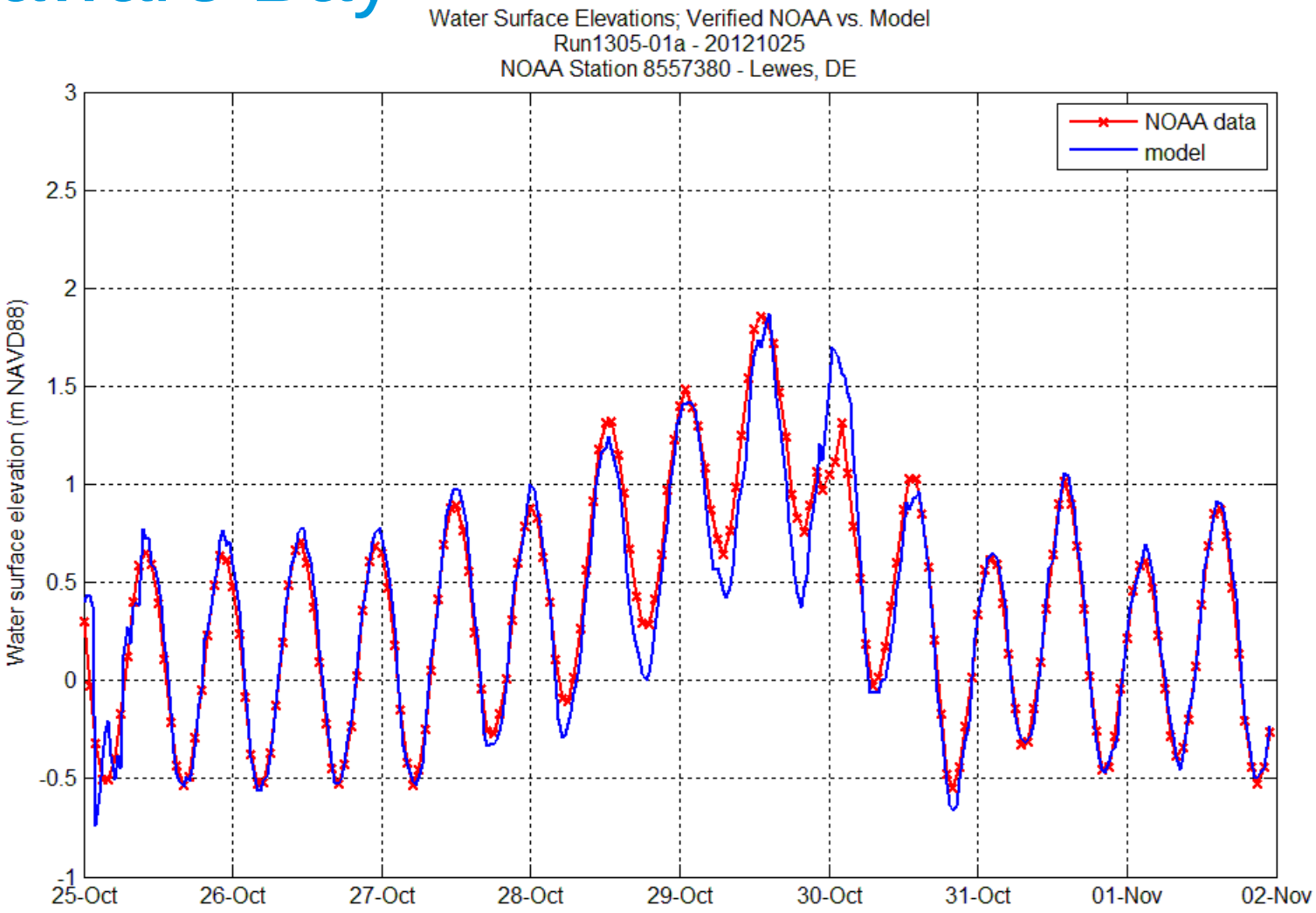
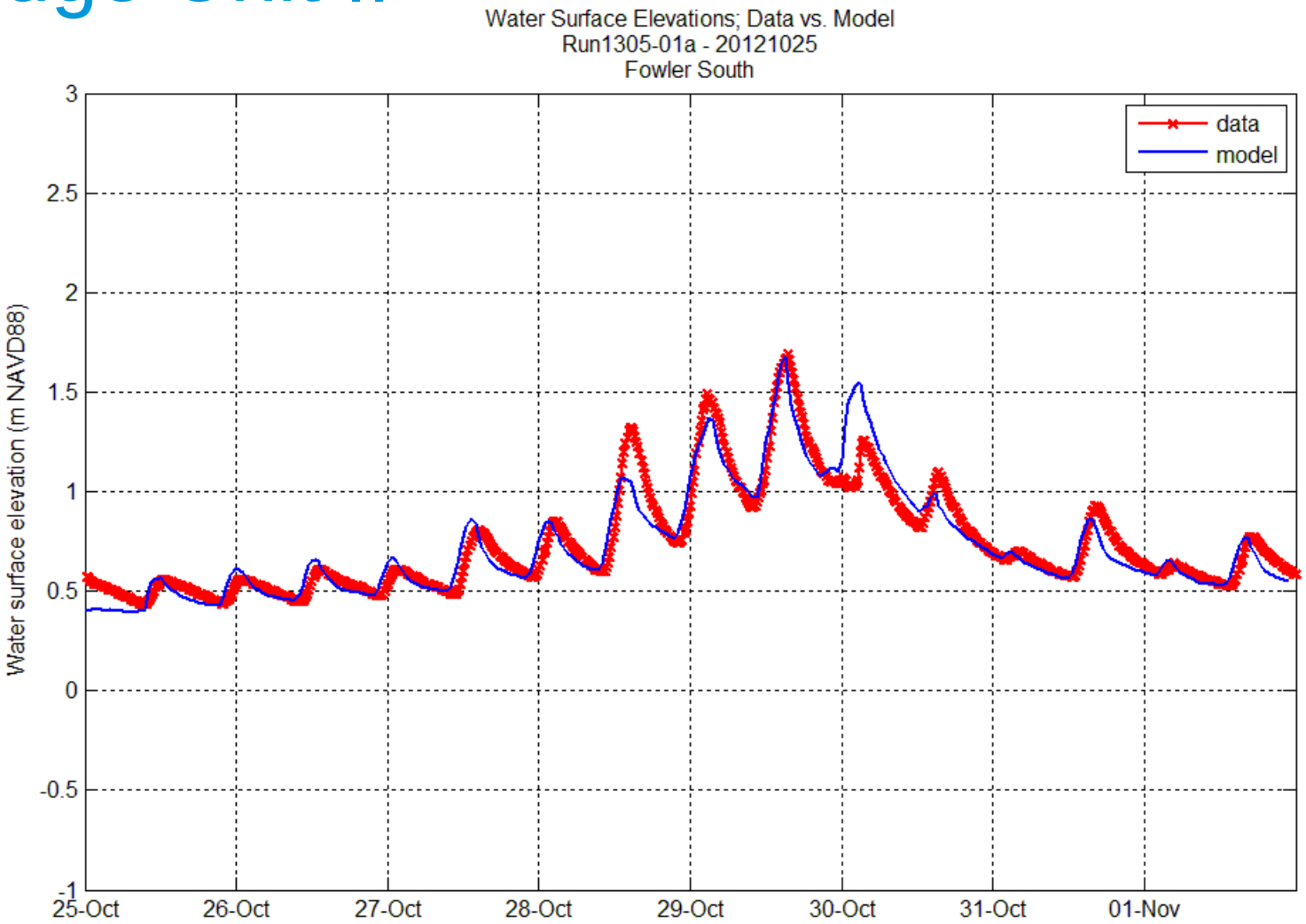


Hurricane Sandy Water Level: Delaware Bay



Hurricane Sandy Water Level: Refuge Unit II



Model Calibration: Conclusions

ATKINS

- Model reproduces water level and salinity fluctuations very well in Delaware Bay and Refuge close to the breach and within Unit II (best coverage of bathymetry and topography)

- Throughout Refuge, results within range suitable to examine differences in water levels and salinities between alternatives

Modeling Approach: Analysis

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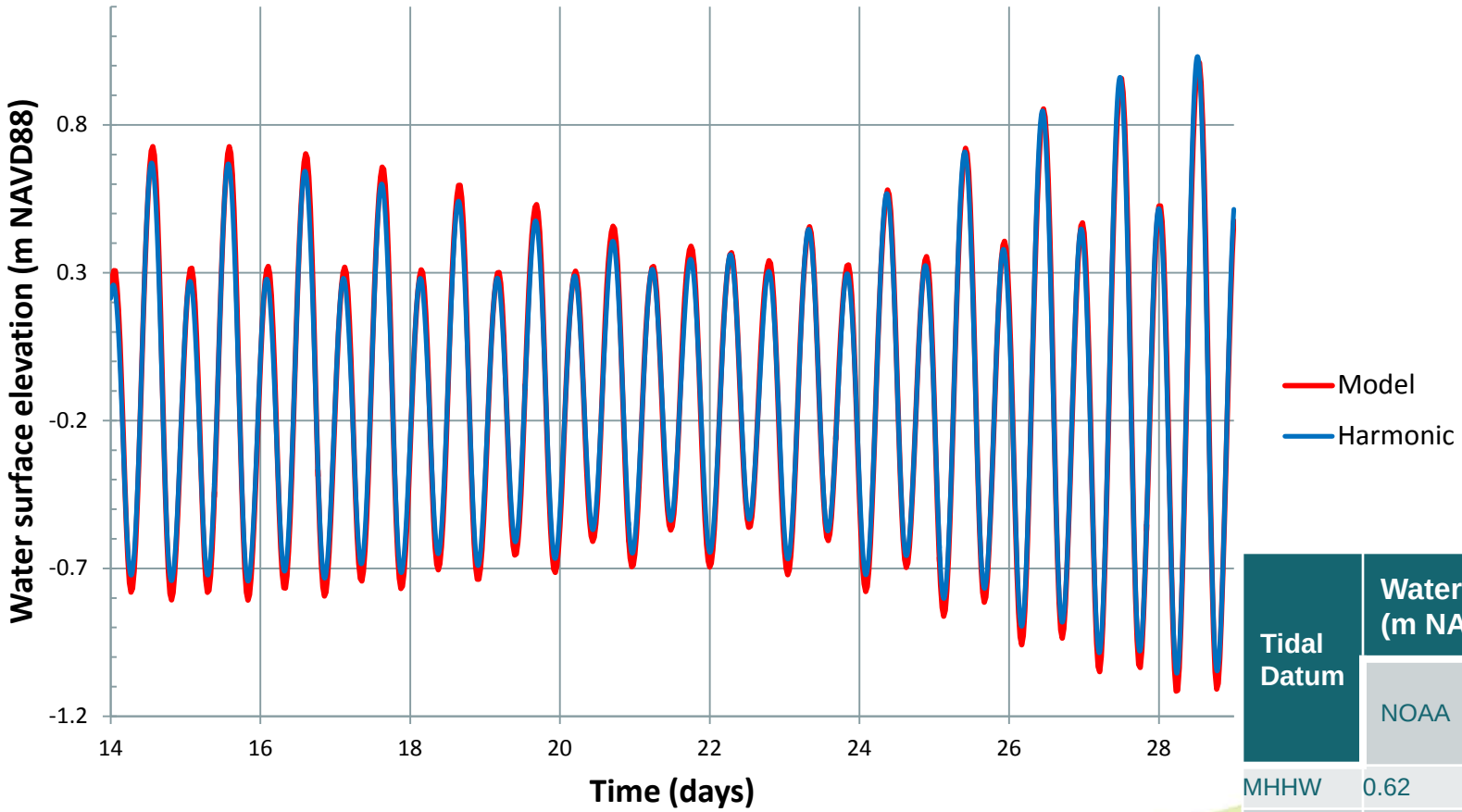
- Reconstruct theoretical tidal time series at model boundary using NOAA harmonic tidal constituents
- Model tidal forcing alone, check results at Lewes with reconstructed constituents (verify time series as well as MHW, MLW, etc.)
- Add base flow rates (constant, from USGS Streamstats) at Slaughter Creek and Prime Hook Creek (within Refuge)
- Model theoretical tide and base freshwater inflow with existing and proposed conditions

Harmonic Tide vs. Model: Lewes, DE



Tidal Datum	Water level (m NAVD88)		
	NOAA	Model	Harmonic
MHHW	0.62	0.65	0.62
MHW	0.49	0.51	0.48
MSL	-0.12	-0.12	-0.12
MLW	-0.75	-0.79	-0.73
MLLW	-0.80	-0.82	-0.78

Modeling Approach: Analysis

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- Examine/map high/low water, tide range, salinity range
- Ensure tidal exchange is sufficient to sustain saline conditions within Refuge
- Examined range of 0-31 ppt and look for development of regular salinity pattern
- Preliminary results show modeled Refuge settles into regular cycle after 5-6 months; use results of these months to inform restoration decisions

Initial Alternatives

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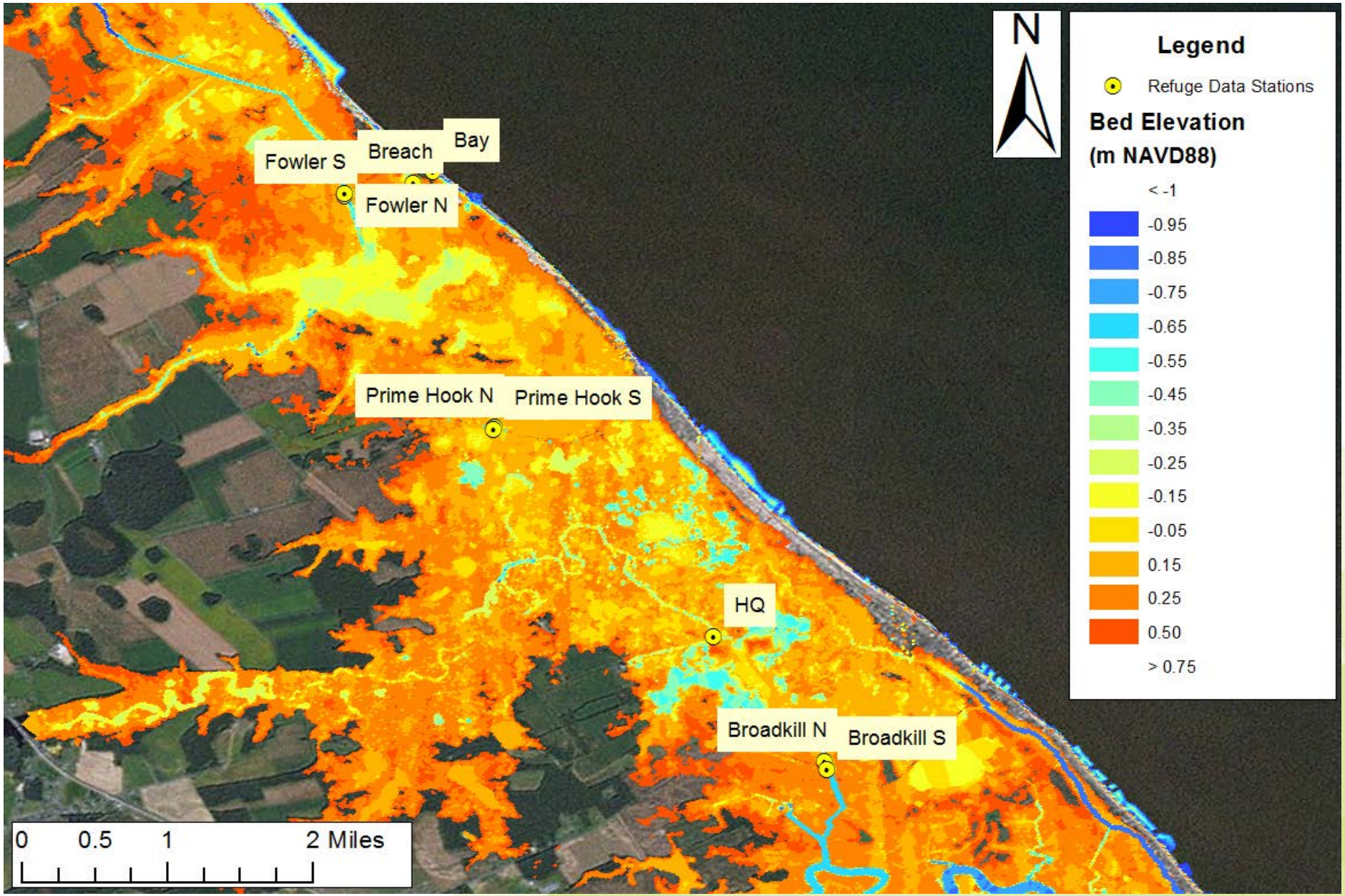
- Existing marsh elevations
  - All breaches closed
    - With existing WCS
    - WCS removed
    - Fowler Beach Rd removed
  - Breach 4 “controlled inlet”
    - With existing WCS
    - WCS removed
    - Fowler Beach Rd removed

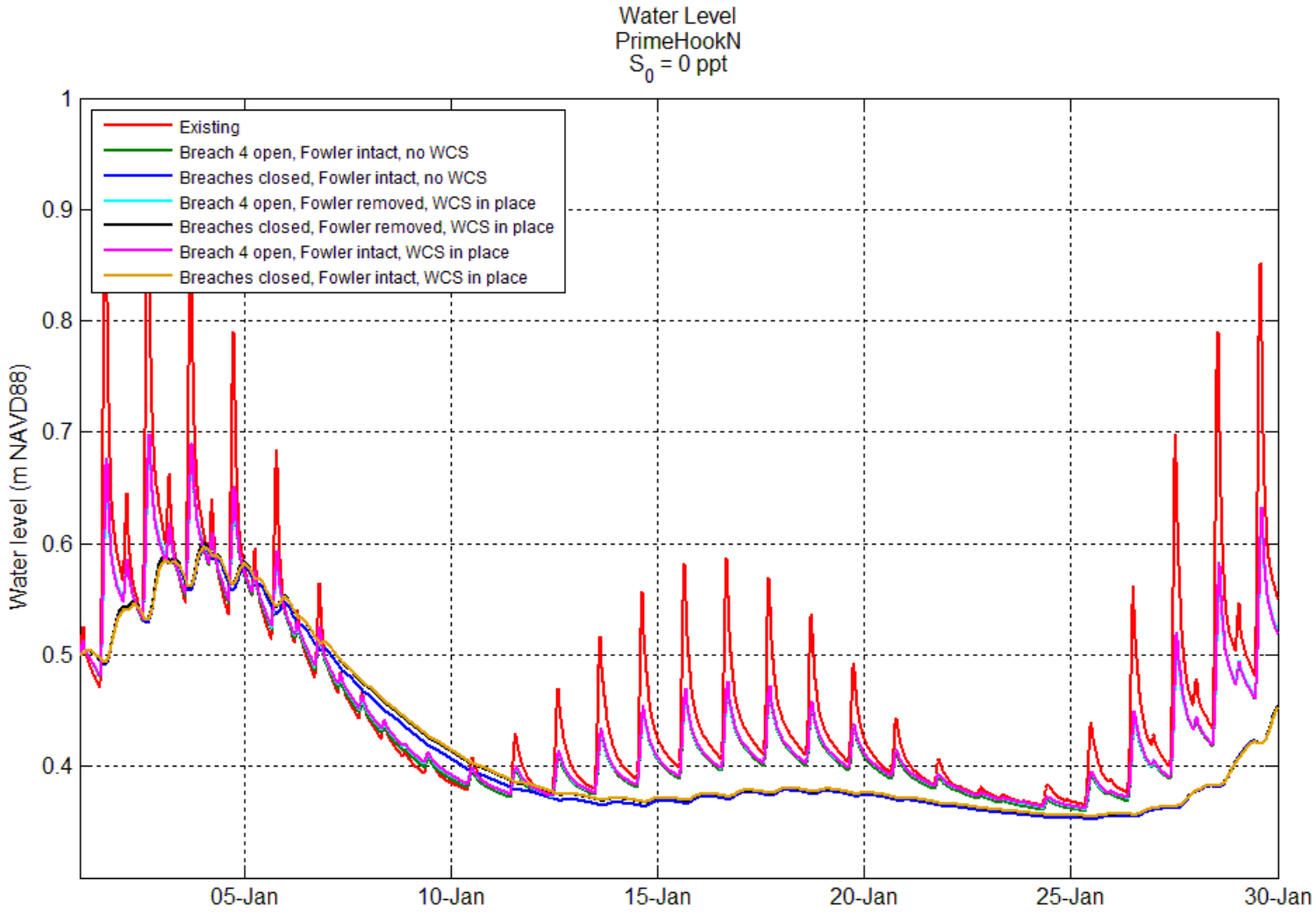
- Variations in breach openings shown to be most important factor
- Brackish habitat possible with breaches closed

Calibration Locations

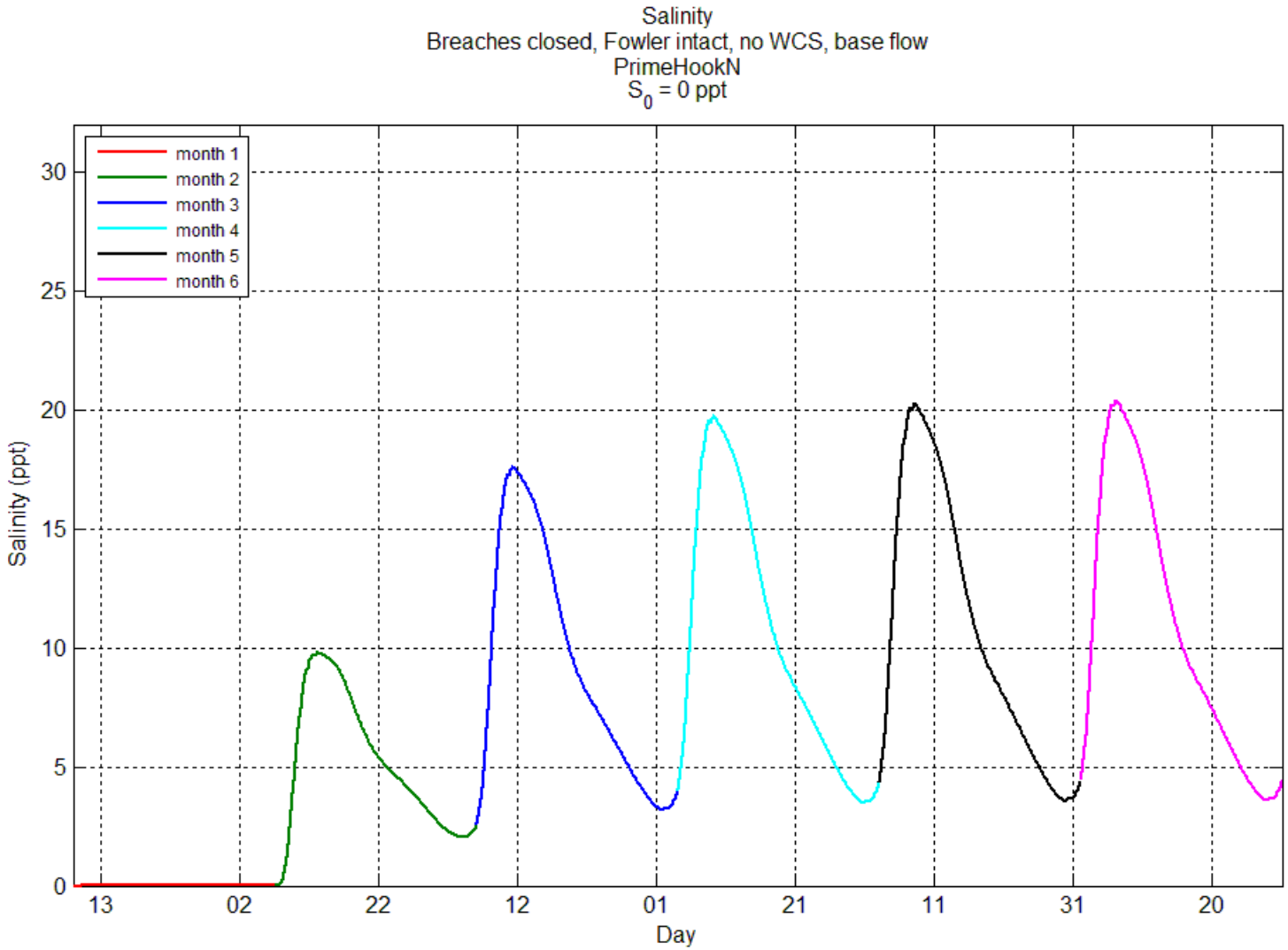
ATKINS



Initial Alternatives: Water Level



Long Term Salinity: Breaches Closed



Primary Alternatives

ATKINS

- For all scenarios:
  - Breaches closed
  - No WCS
  - Fowler Beach Rd removed
  - Base inflow
  - Initial salinity of 0 ppt within Refuge

- Varying parameters:
  1. Existing marsh elevations
  2. Addition of main conveyance channel between Slaughter Canal and Prime Hook Creek
     - 1 model cell (~30 ft) in width and depth of -2.3 ft NAVD88
  3. Main conveyance channel plus additional distribution ‘branches’

Prime Hook NWR Proposed Channel Locations*

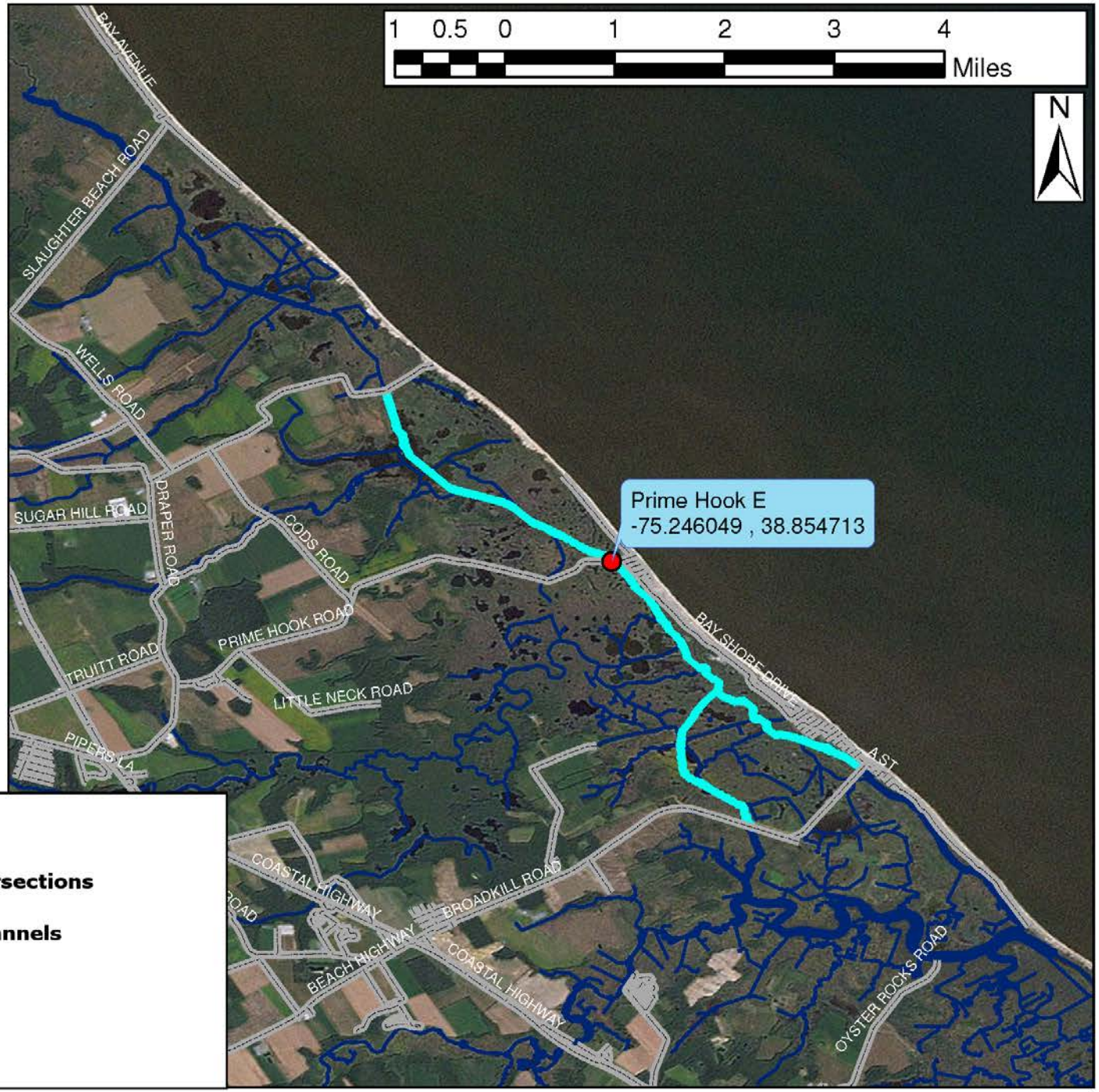
*subject to change during design phase

Legend

- **Existing & historical channels**

Prime Hook NWR Proposed Channel Locations*

*subject to change during design phase

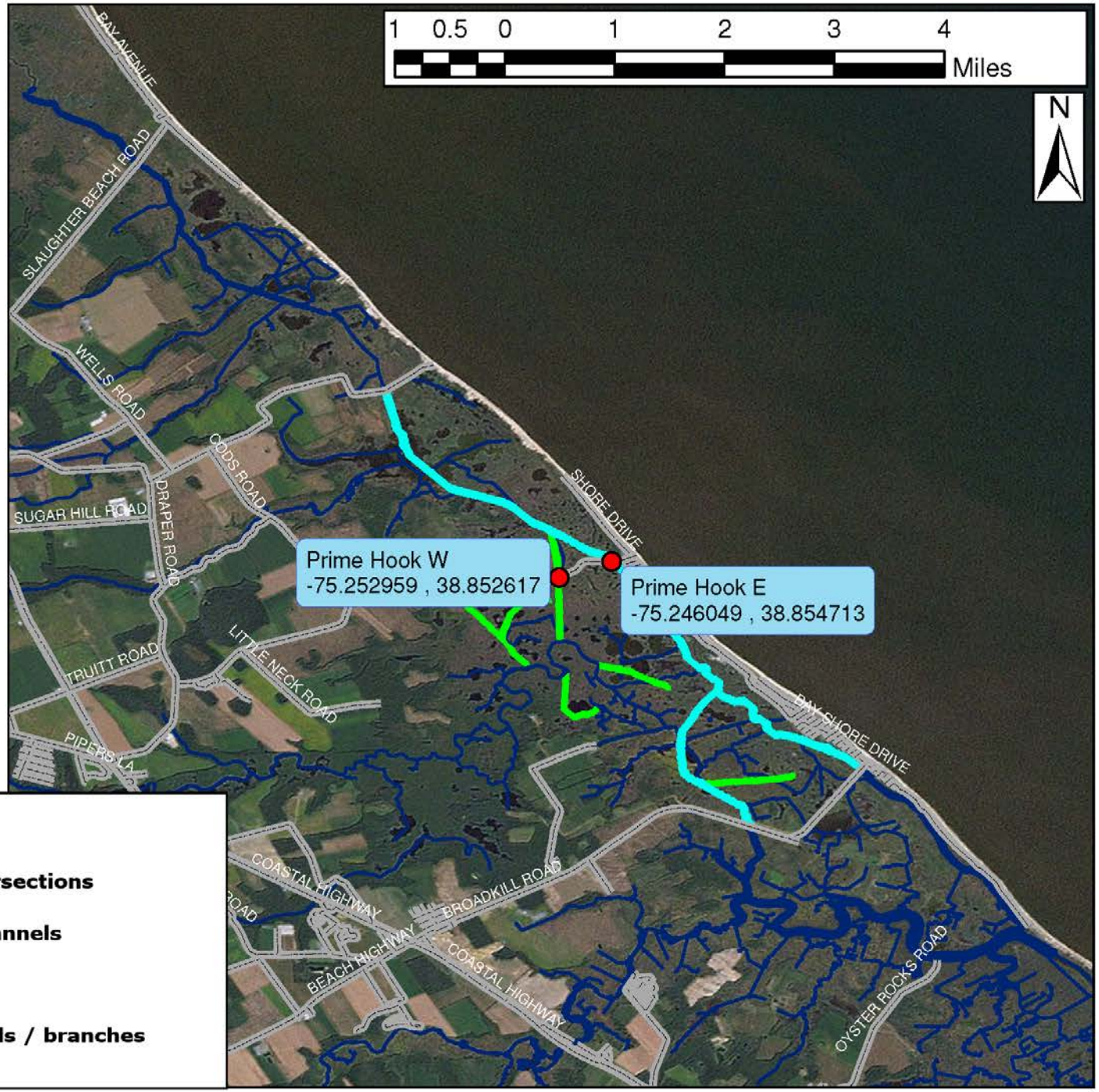


Legend

- **Proposed roadway intersections**
- **Existing & historical channels**
- **Proposed main channel**

Prime Hook NWR Proposed Channel Locations*

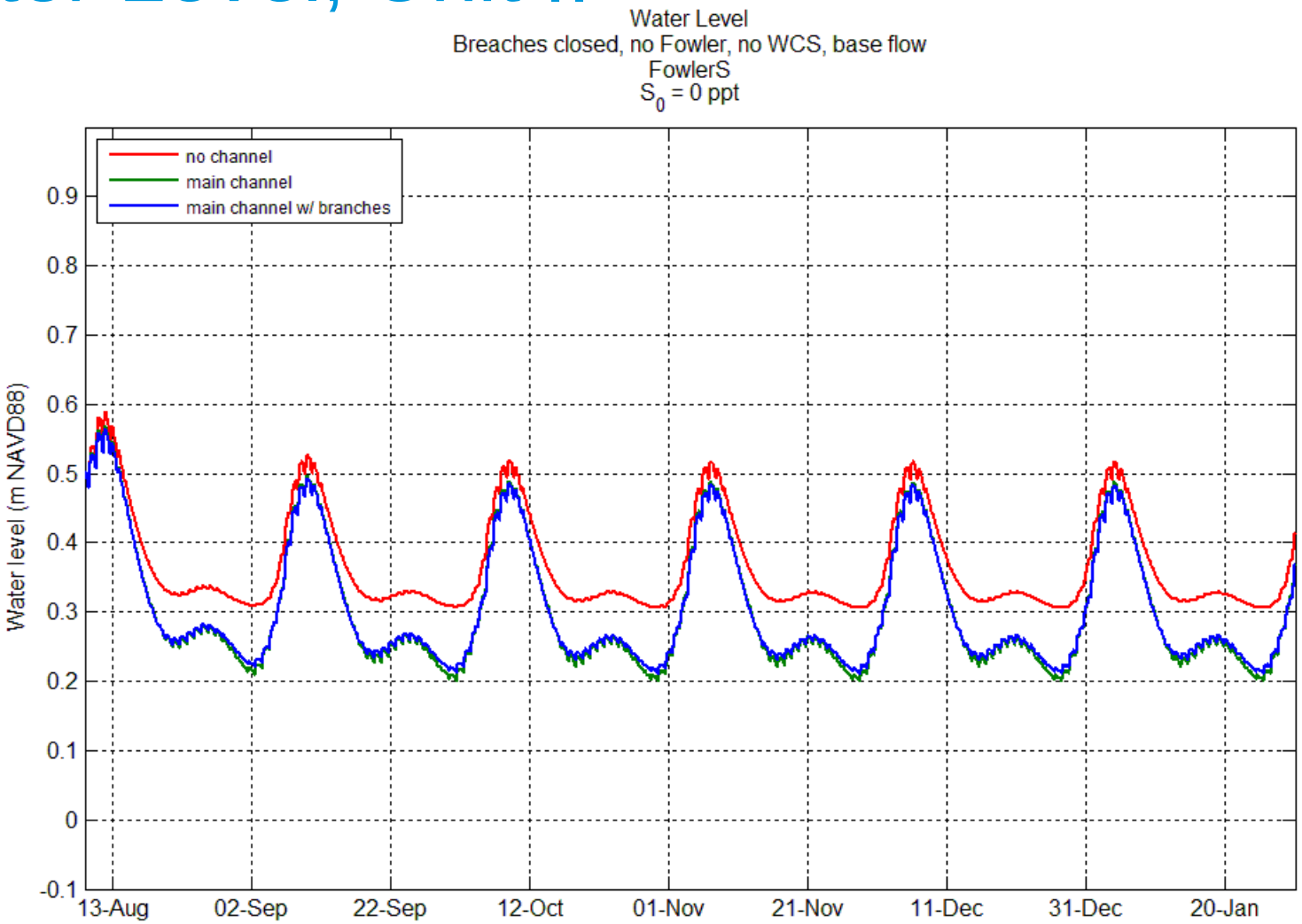
*subject to change during design phase



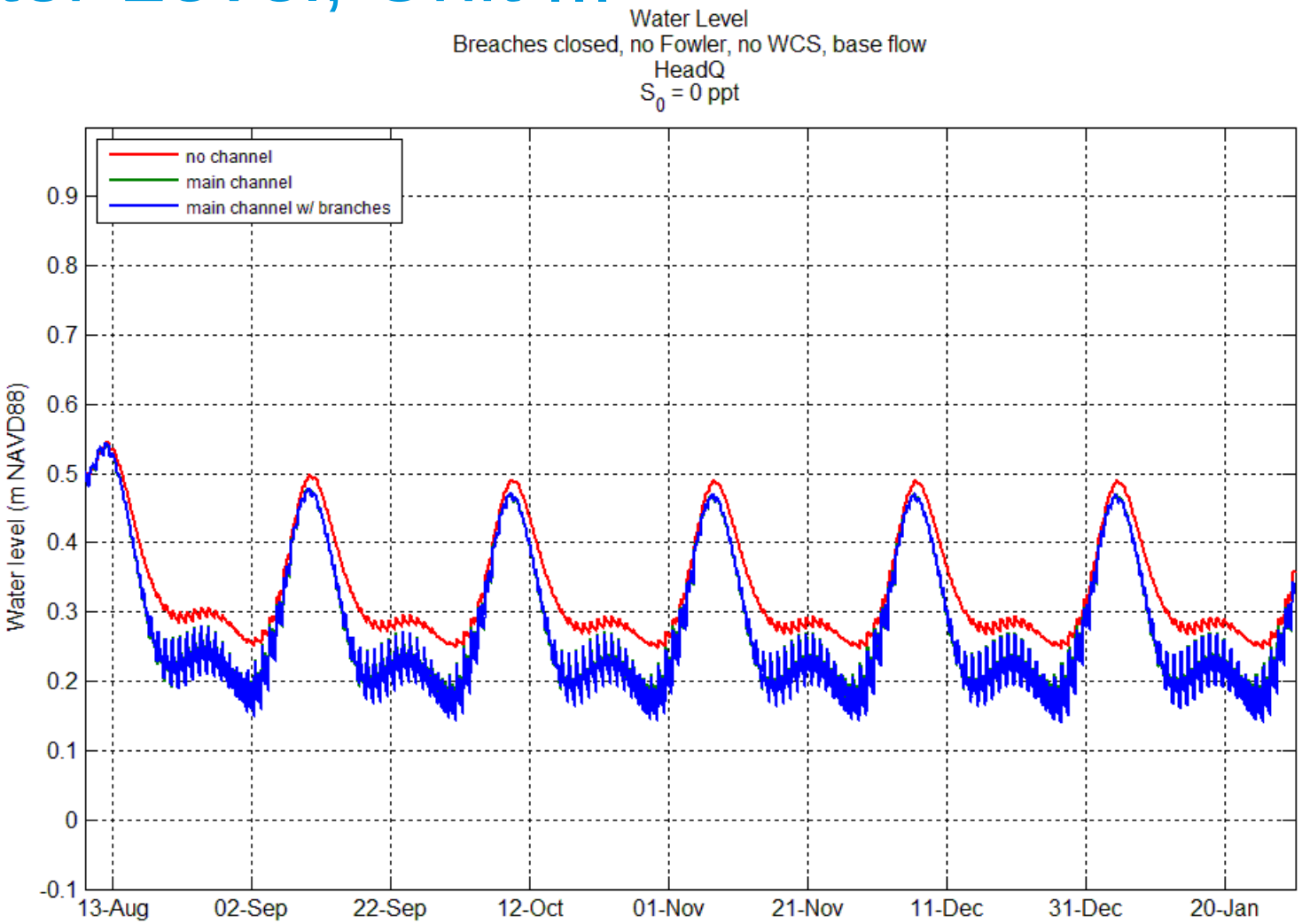
Legend

- **Proposed roadway intersections**
- **Existing & historical channels**
- **Proposed main channel**
- **Proposed finger channels / branches**

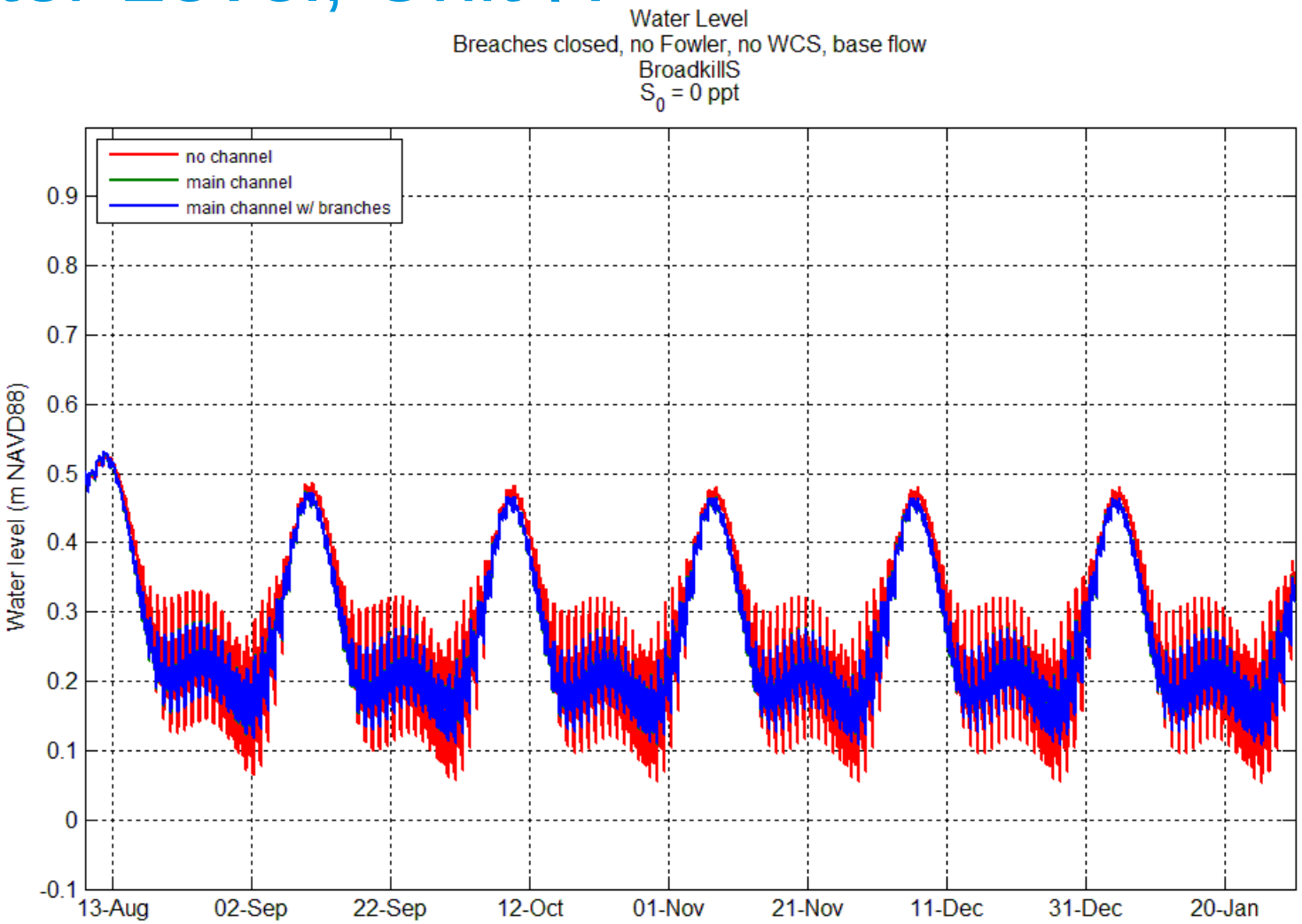
Primary Alternatives: Water Level, Unit II



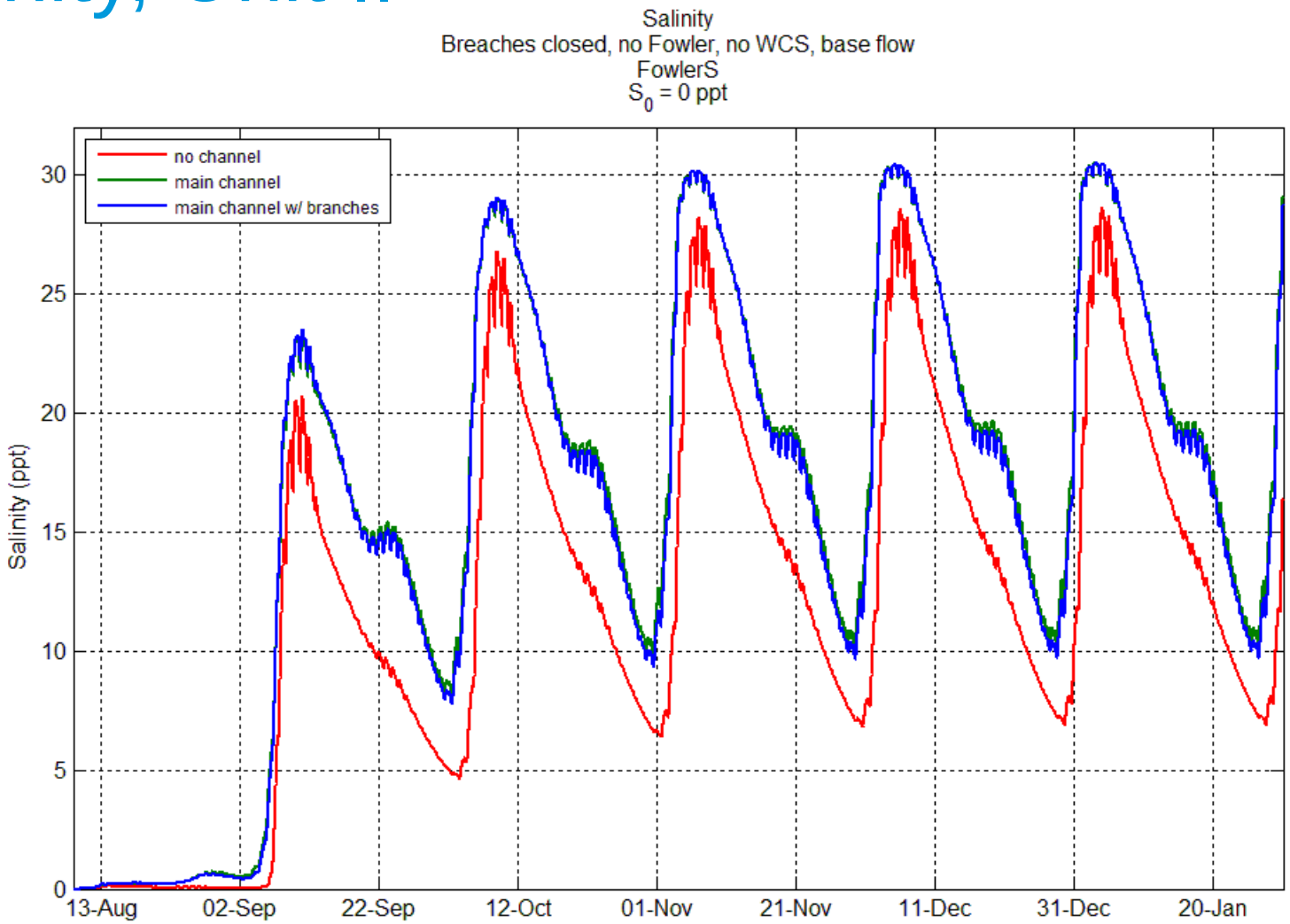
Primary Alternatives: Water Level, Unit III



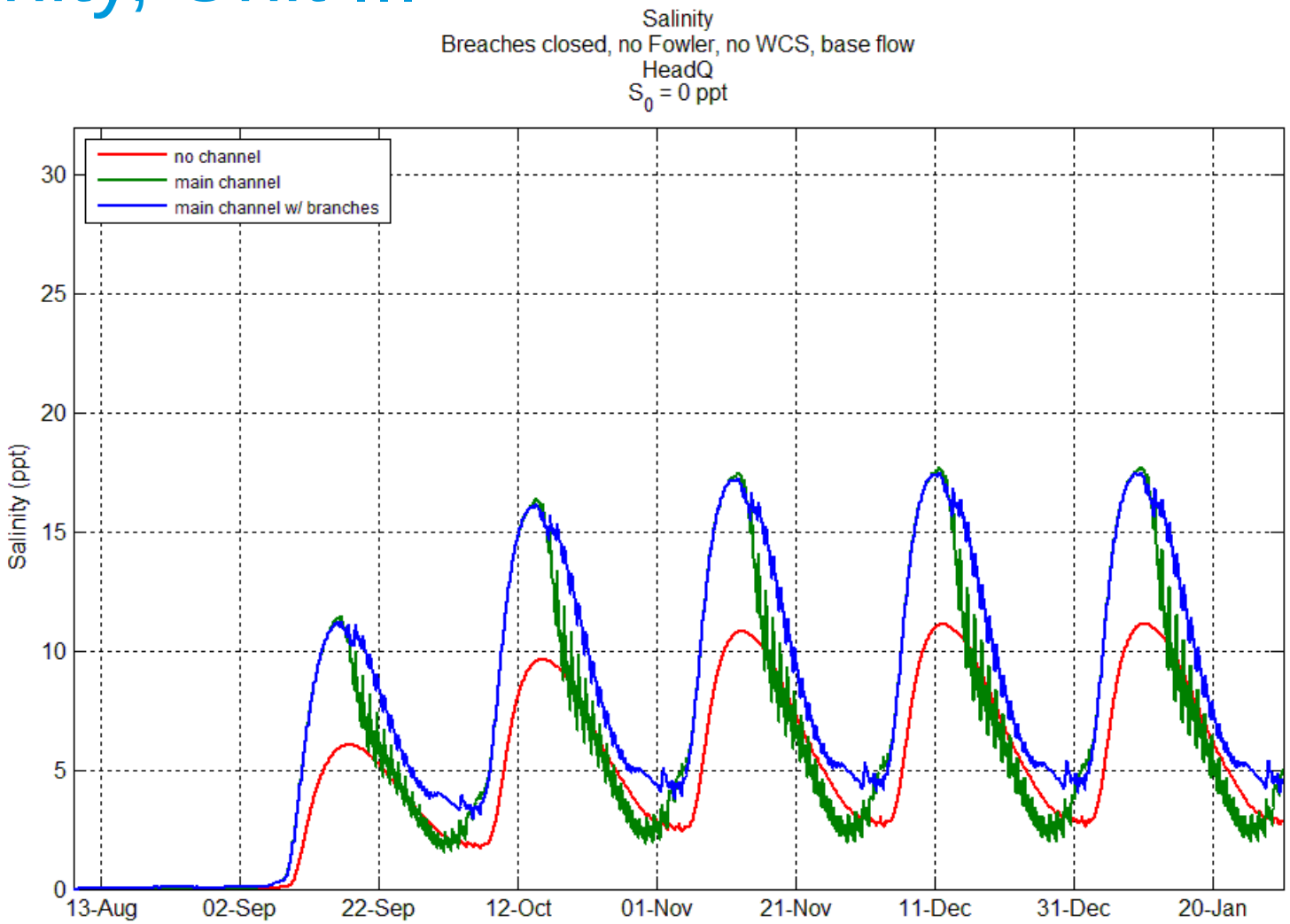
Primary Alternatives: Water Level, Unit IV



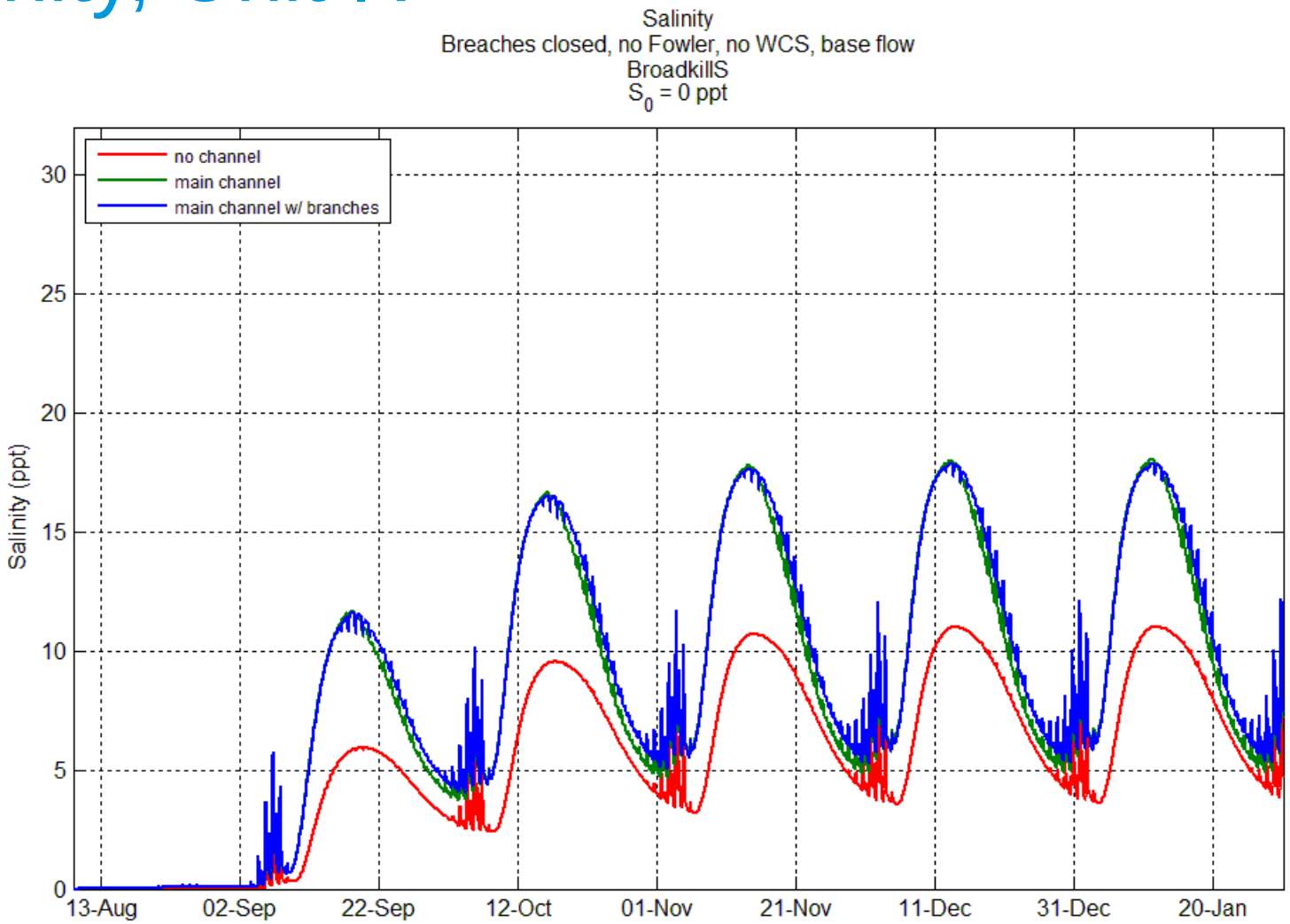
Primary Alternatives: Salinity, Unit II



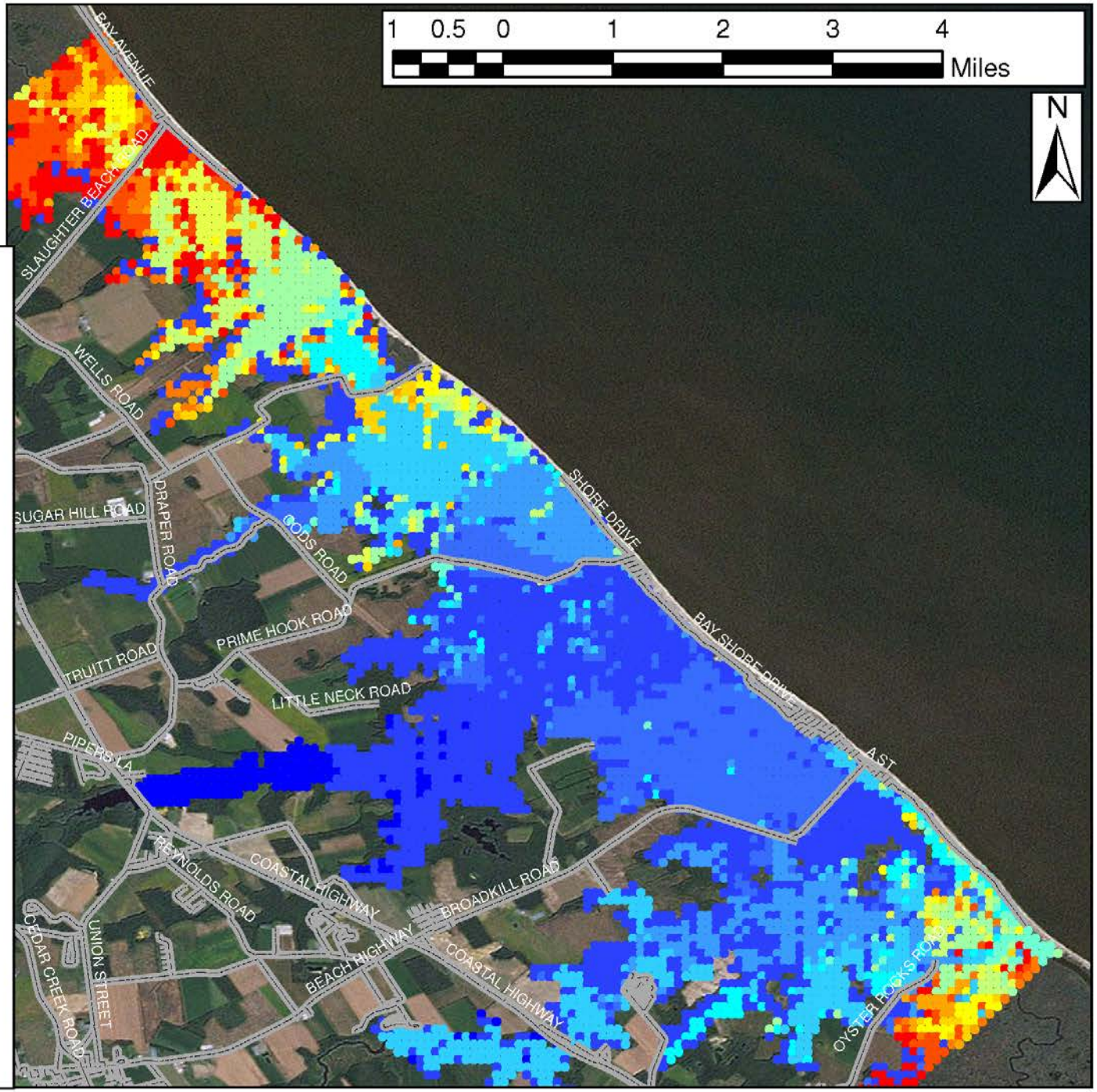
Primary Alternatives: Salinity, Unit III



Primary Alternatives: Salinity, Unit IV



Prime Hook NWR Modeling Results Typical Tidal Cycle



Legend

Min Salinity - No Mods (ppt)

- 0
- 1 - 2
- 3 - 4
- 5 - 6
- 7 - 8
- 9 - 10
- 11 - 12
- 13 - 14
- 15 - 16
- 17 - 18
- 19 - 20
- 21 - 22
- 23 - 24
- 25 - 26
- 27 - 28
- 29 - 31

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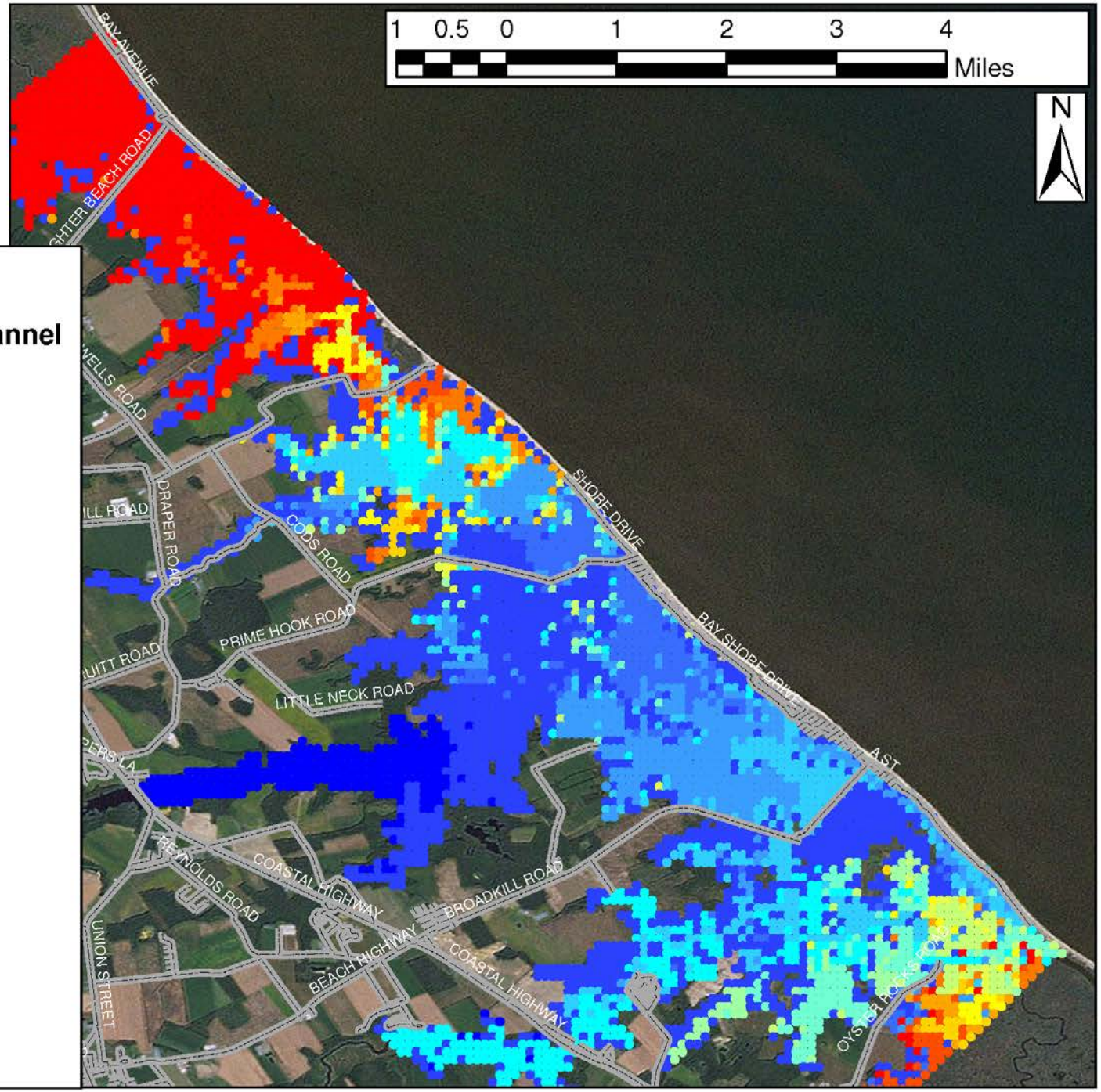

Legend

Min Salinity - Main Channel (ppt)

- 0
- 1 - 2
- 3 - 4
- 5 - 6
- 7 - 8
- 9 - 10
- 11 - 12
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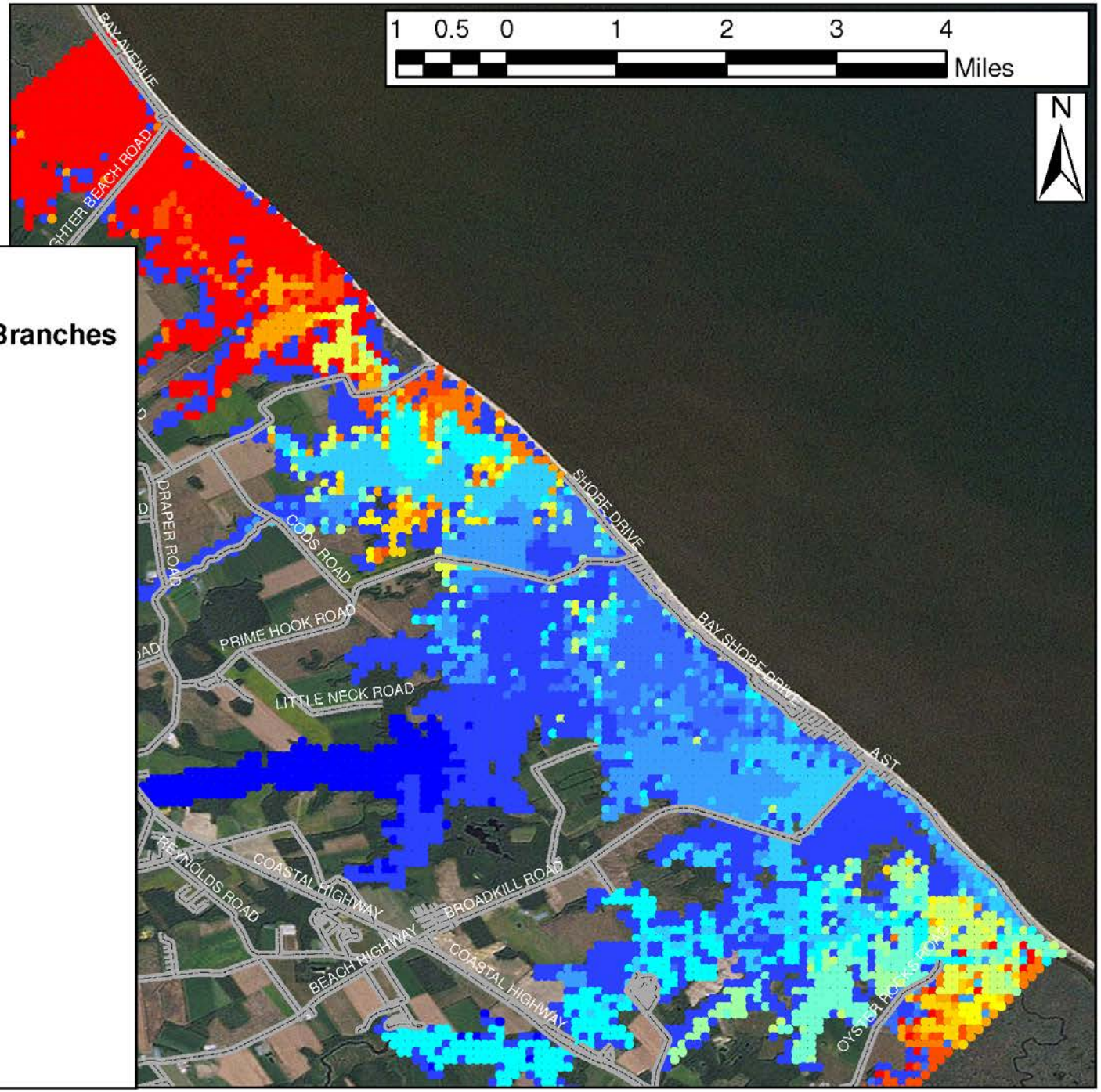

Legend

Min Salinity - Main w/ Branches (ppt)

- 0
- 1 - 2
- 3 - 4
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- 7 - 8
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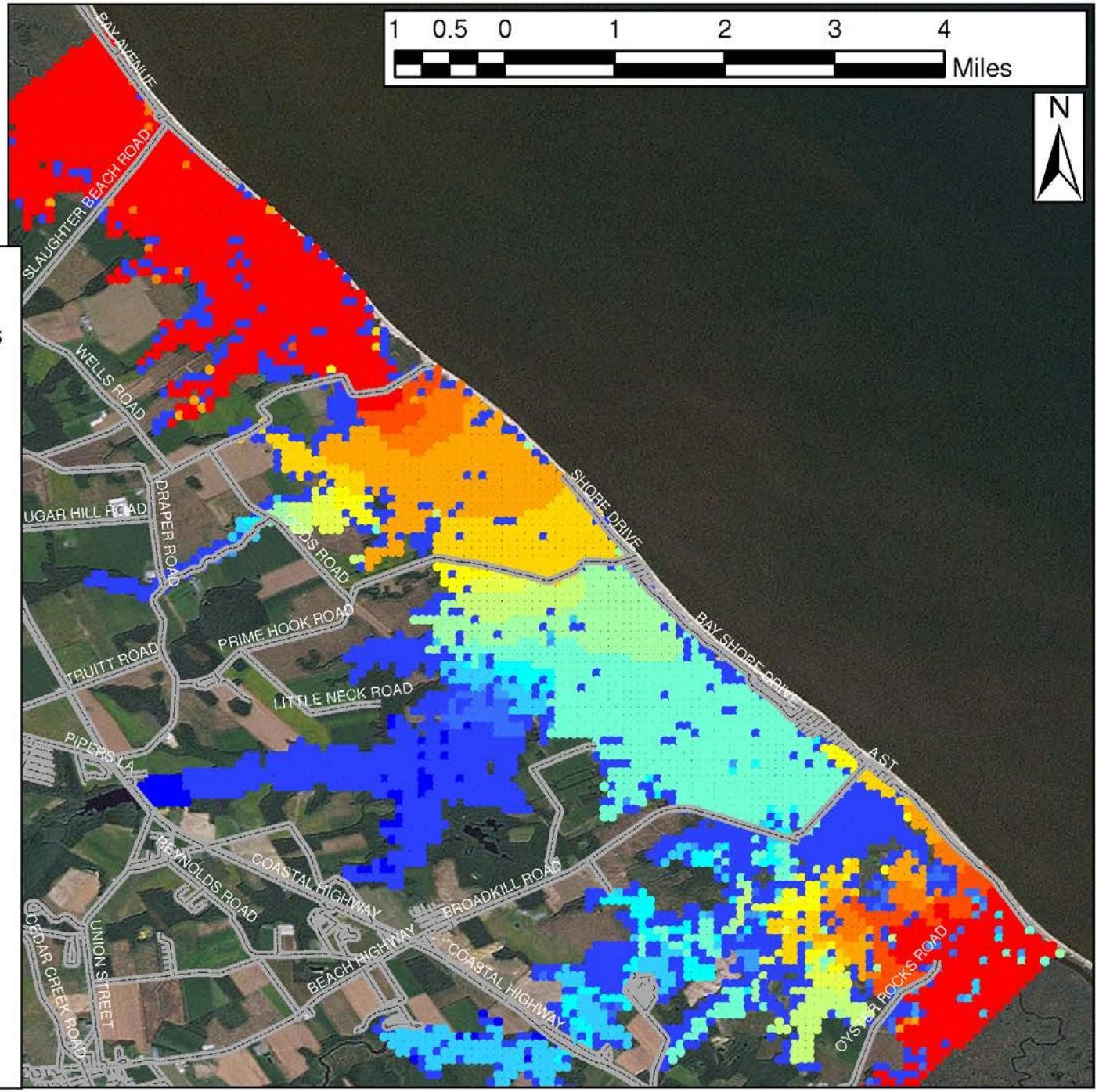

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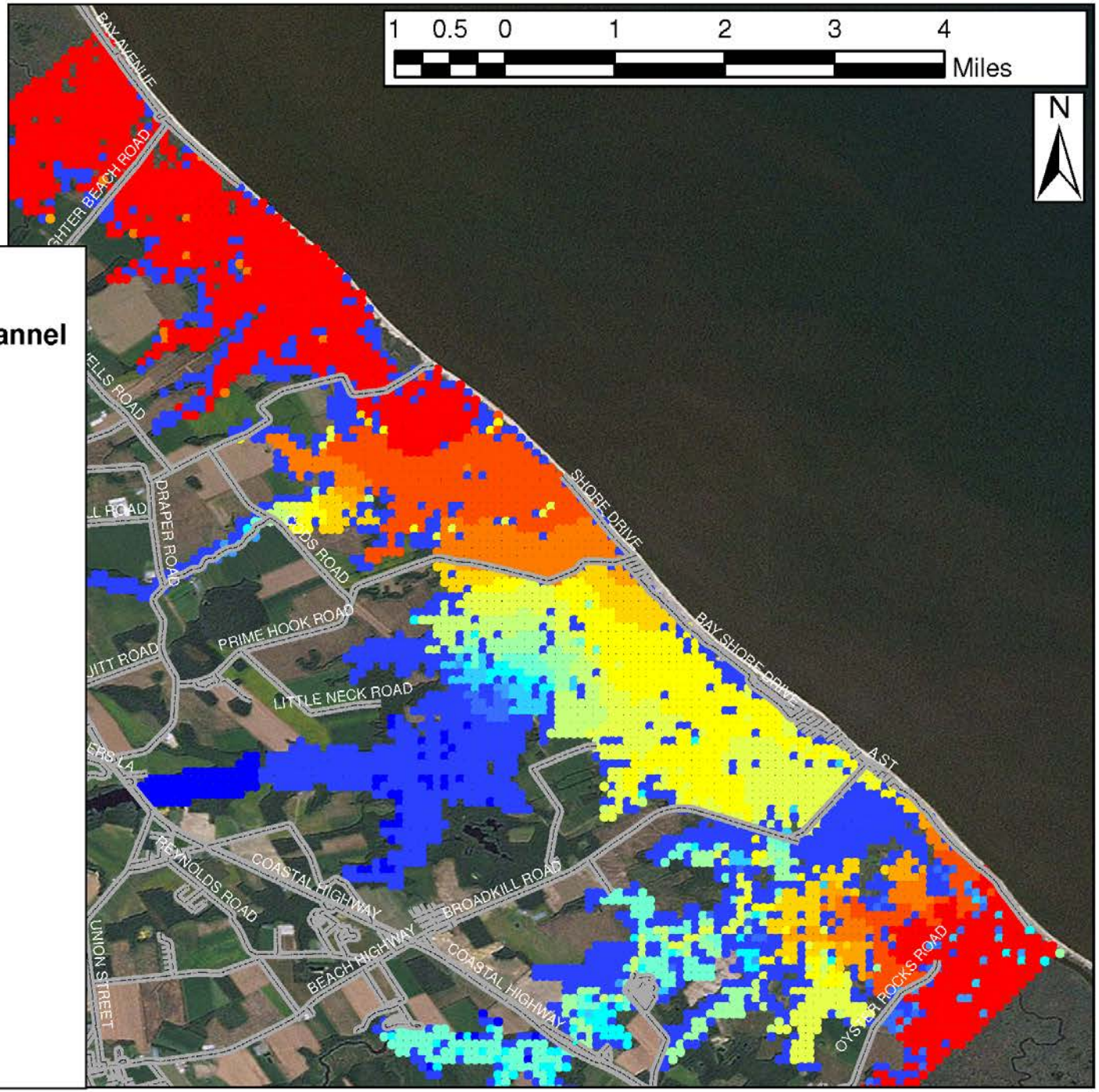
Prime Hook NWR Modeling Results Typical Tidal Cycle



Legend

Max Salinity - Main Channel (ppt)

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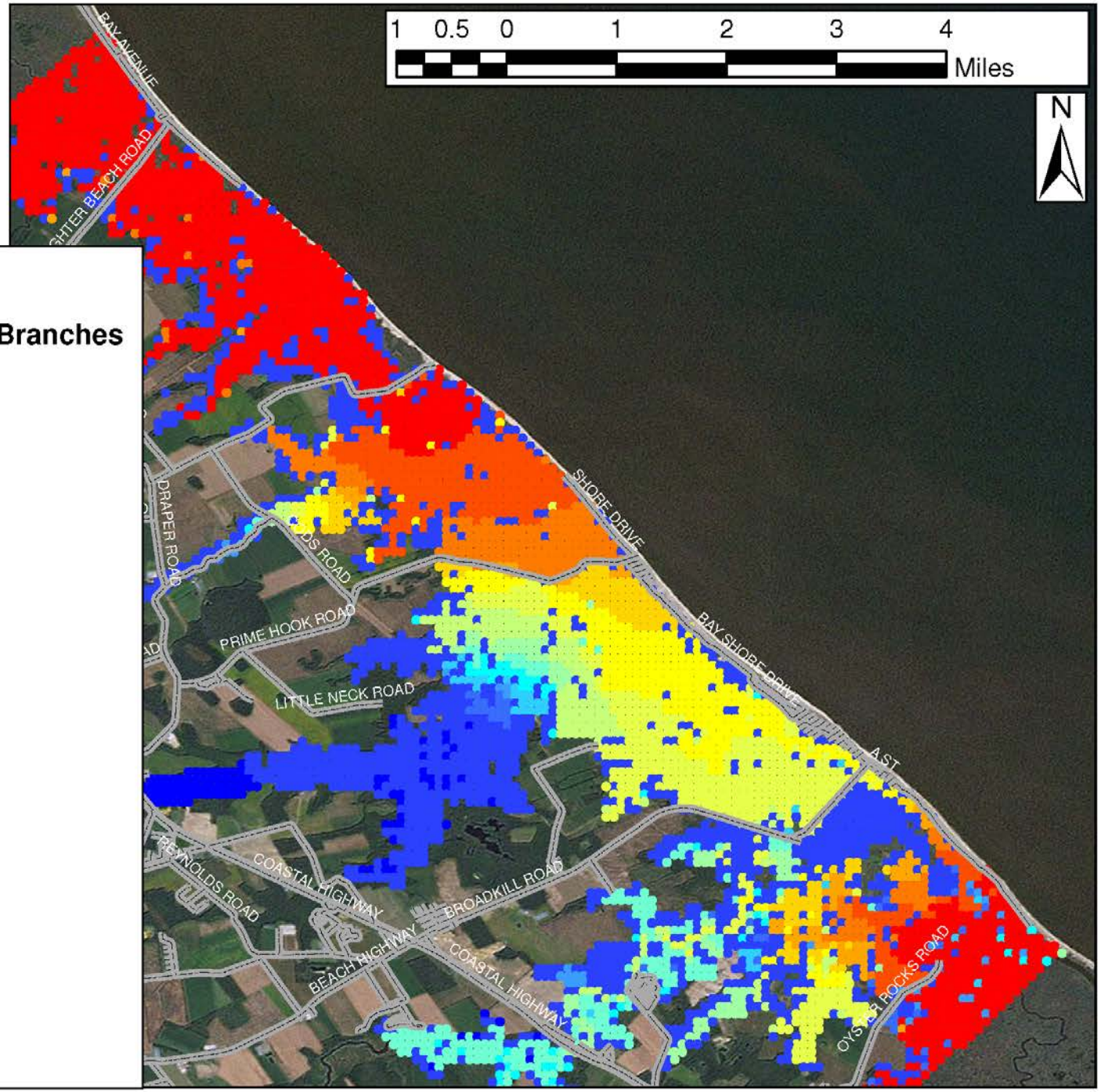

Legend

Max Salinity - Main w/ Branches (ppt)

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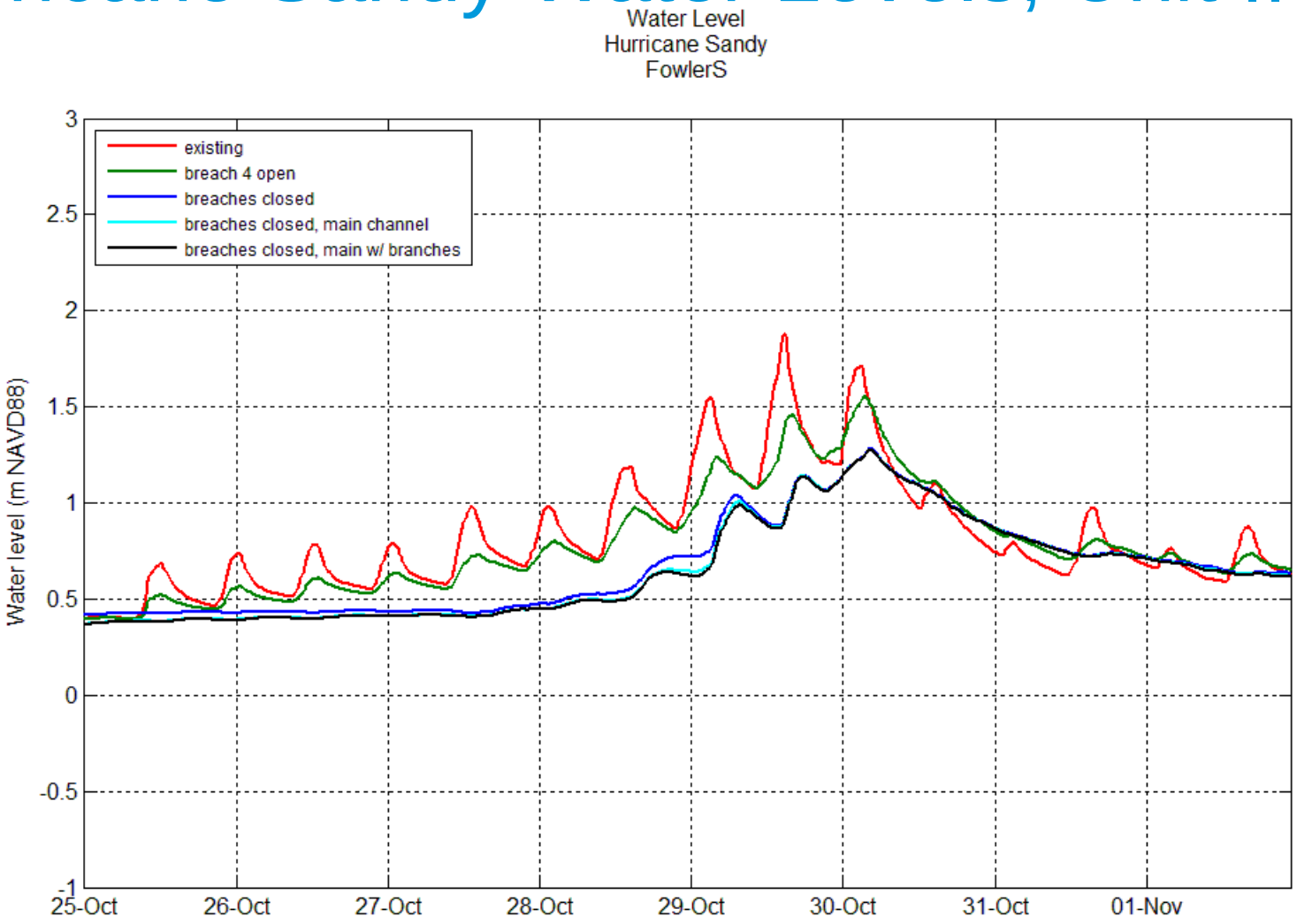
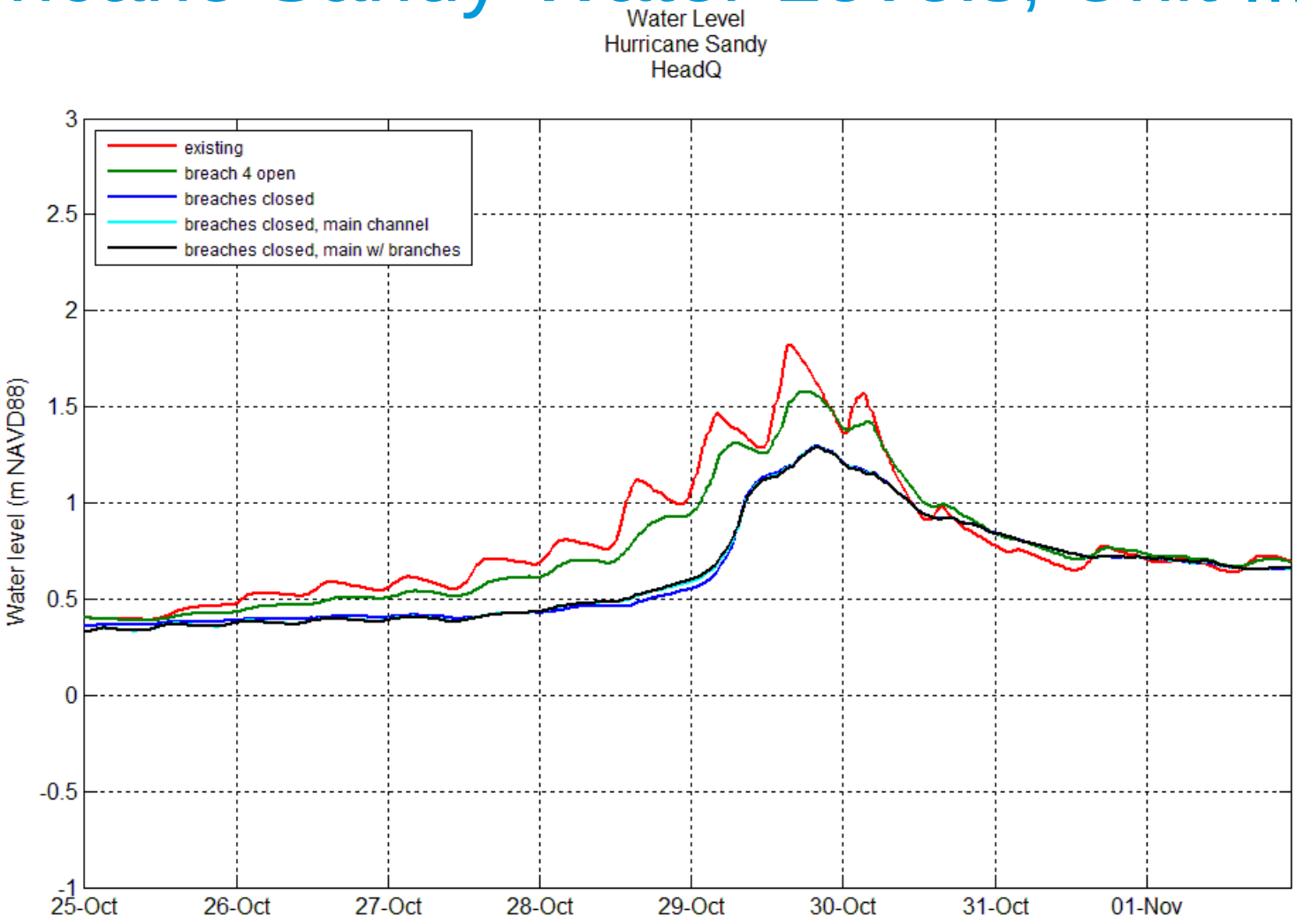
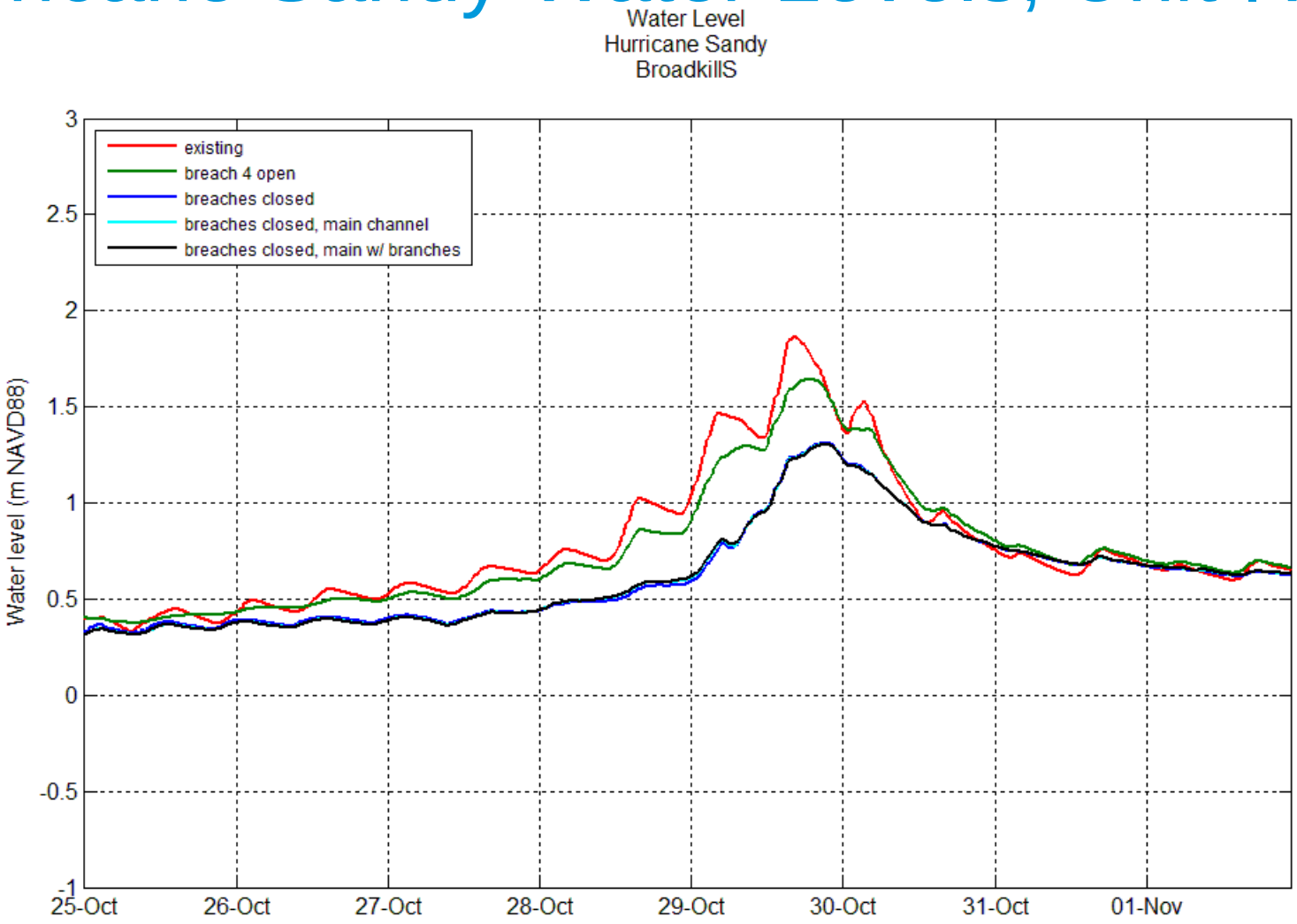
Primary Alternatives: Hurricane Sandy Water Levels, Unit II



Primary Alternatives: Hurricane Sandy Water Levels, Unit III



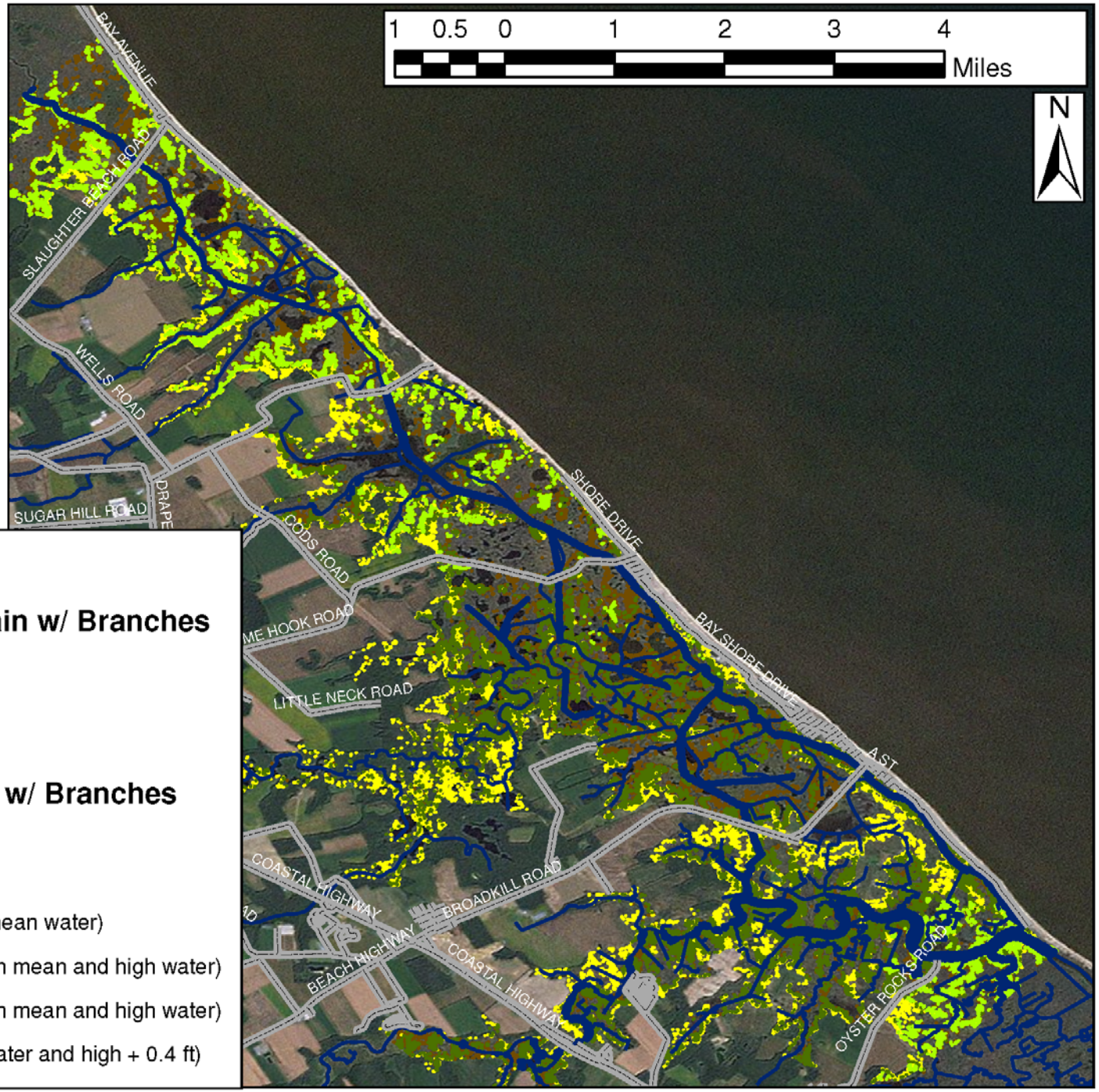
Primary Alternatives: Hurricane Sandy Water Levels, Unit IV



Further Efforts Utilizing Model Results

- Delineation of potential marsh areas based on modeled bottom elevations, water levels, and salinity
- Develop restoration plan based on physical and biological parameters
- Refinement of restoration parameters

Prime Hook NWR Modeling Results Typical Tidal Cycle



Legend

Bottom Elevation - Main w/ Branches

elevation (ft NAVD88)

- below -2.0

Channel centerlines

Land Coverage - Main w/ Branches

Type

- Open water (< low water)
- Tidal flat (between low and mean water)
- Low marsh > 18 ppt (between mean and high water)
- Low marsh < 18 ppt (between mean and high water)
- High marsh (between high water and high + 0.4 ft)

Thank you!

Questions?