Effects of Sea-level Rise in North Carolina

JP Walsh

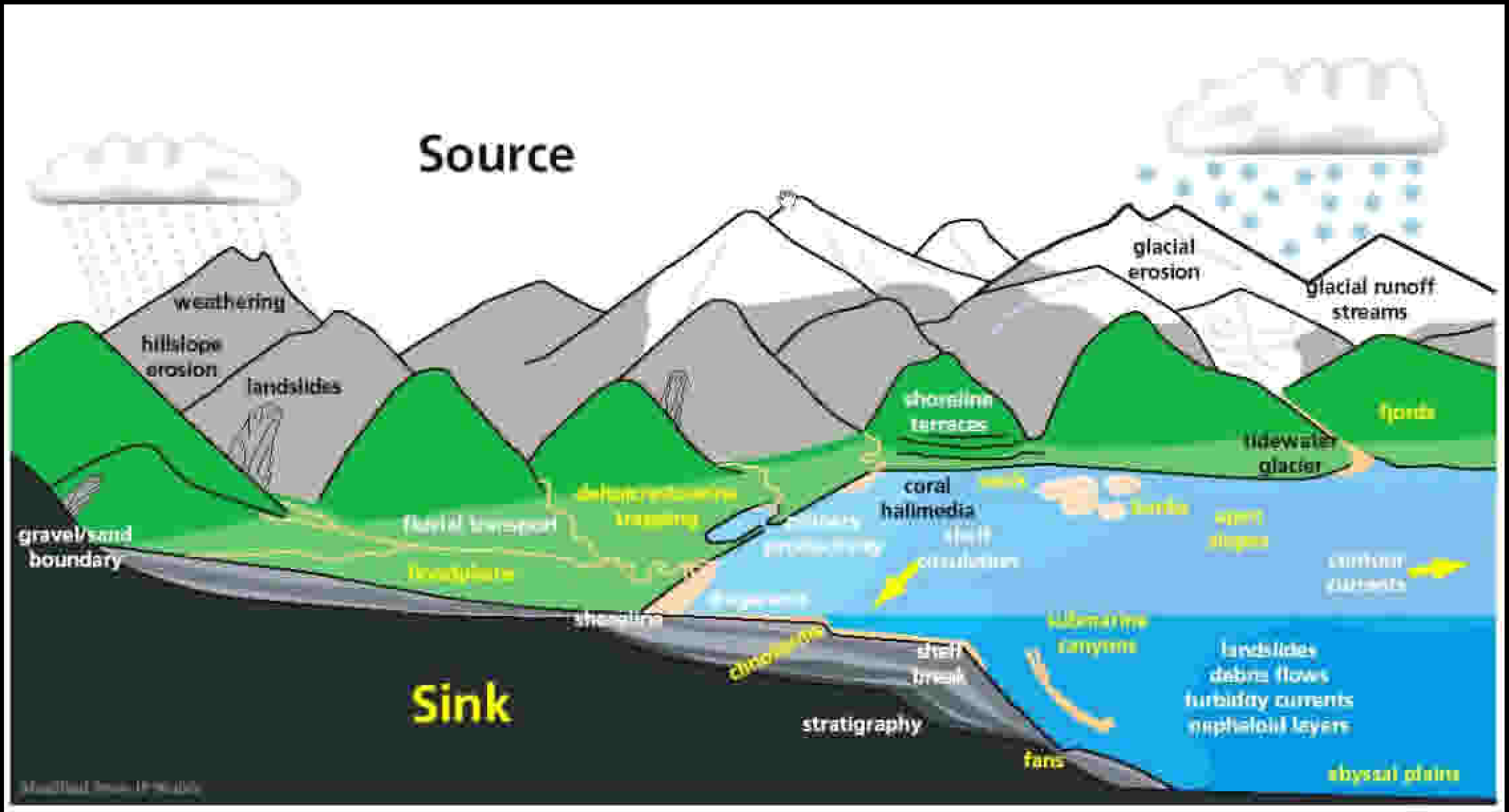
Geological Sciences and Institute for Coastal Sciences and Policy

East Carolina University

Acknowledgements: Reide Corbett, Lisa Cowart, David Kunz, Mark Brinson, Bob Christian, Ben Horton, and Stan Riggs. Also, Steve Culver, Dave Mallinson, and many others.

My Background

- Joint-appointed Assistant Professor at ECU.
- Interested in land-sea interactions and coastal hazards.
- Use variety of tools (e.g., geophysical, sedimentological, GIS) to map, analyze, visualize and understand sediment dynamics and associated impacts.
- Shorezone to deep seafloor.
- Cape Hatteras to Cape York, Australia.



NOAA Ecological Effects of Sea-level Rise and Related Research at East Carolina University

The Big Picture

- **Generally interested in impacts of coastal hazards (e.g., erosion, SLR, storm surge) on the coastal ecosystem and human resources.**

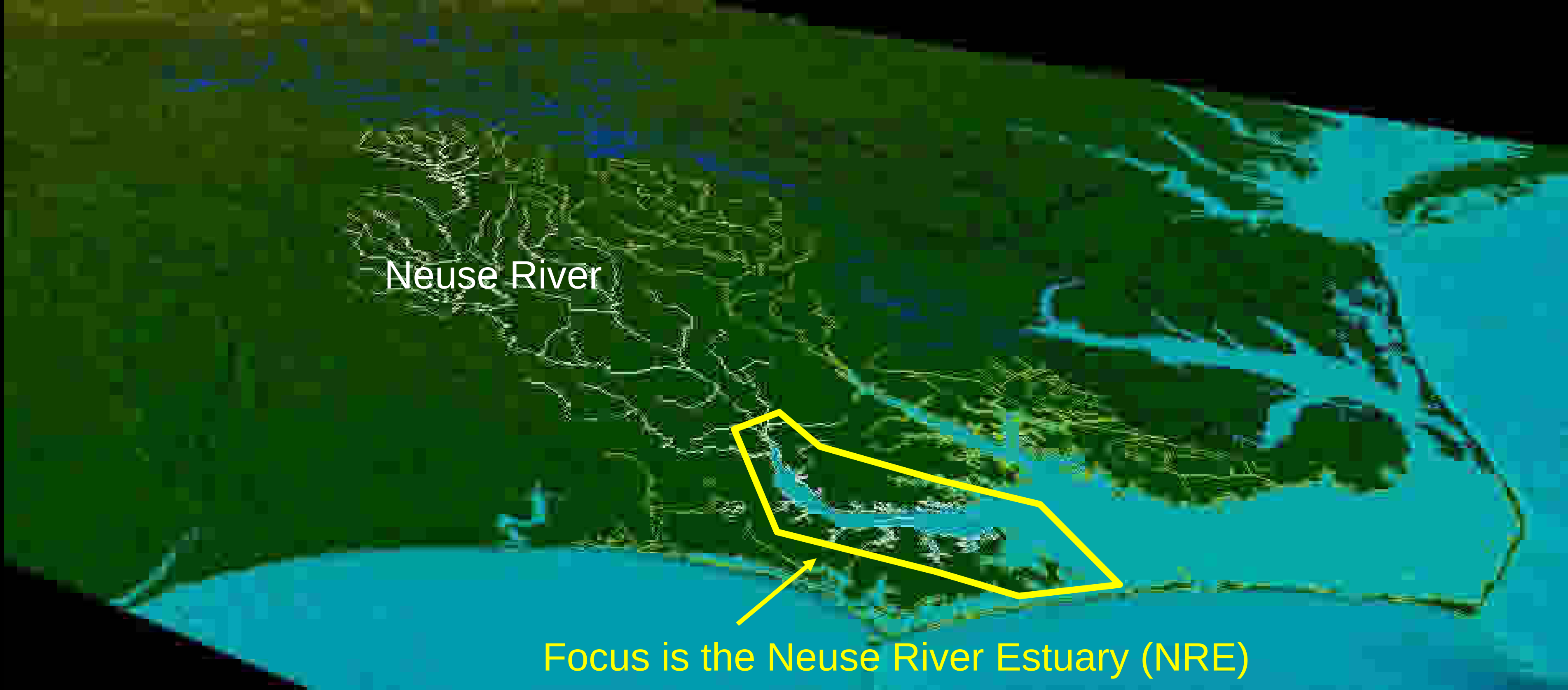
- **Specifically, involved in two separate but related parts of NOAA-SLR:**

1) **Looking at past: decadal response to SLR (Corbett, Walsh, Brinson, Christian, Riggs, Horton (from UPenn))**

2) **Evaluating the future through modeling (Reyes working with Corbett et al. and other SLR researchers)**

Why study eastern NC?

- **Eastern NC has a massive area <2-m.**
- **Much of the Eastern and Gulf coastal states have a similar geomorphology and are similarly vulnerable.**



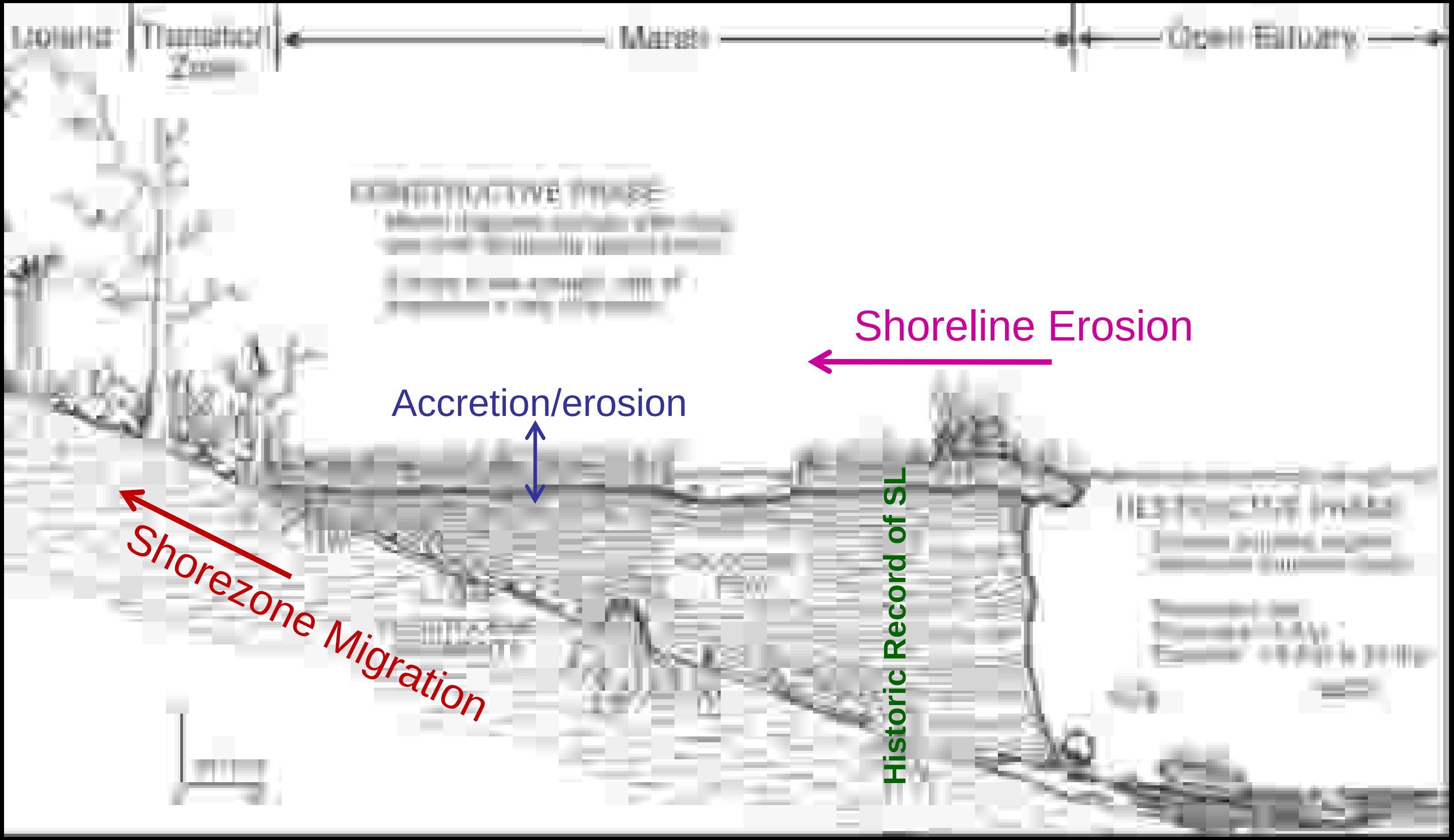
More specifically, what are Corbett et al. doing?

The shorezone is defined as the area of the coast from the coastline to the upland boundary of regular flooding.

The ECU-UPenn effort is documenting change in the shorezone over the last century including:

1) How has sea-level risen over the last century?
2) How, where, and why has the shoreline position changed?
3) How does land-cover vary in the NRE region and has the shorezone changed (e.g., wetland loss) over this period.

Influence of Sea Level Rise in Coastal NC



This research has important ecosystem-functioning and human-resource implications including:

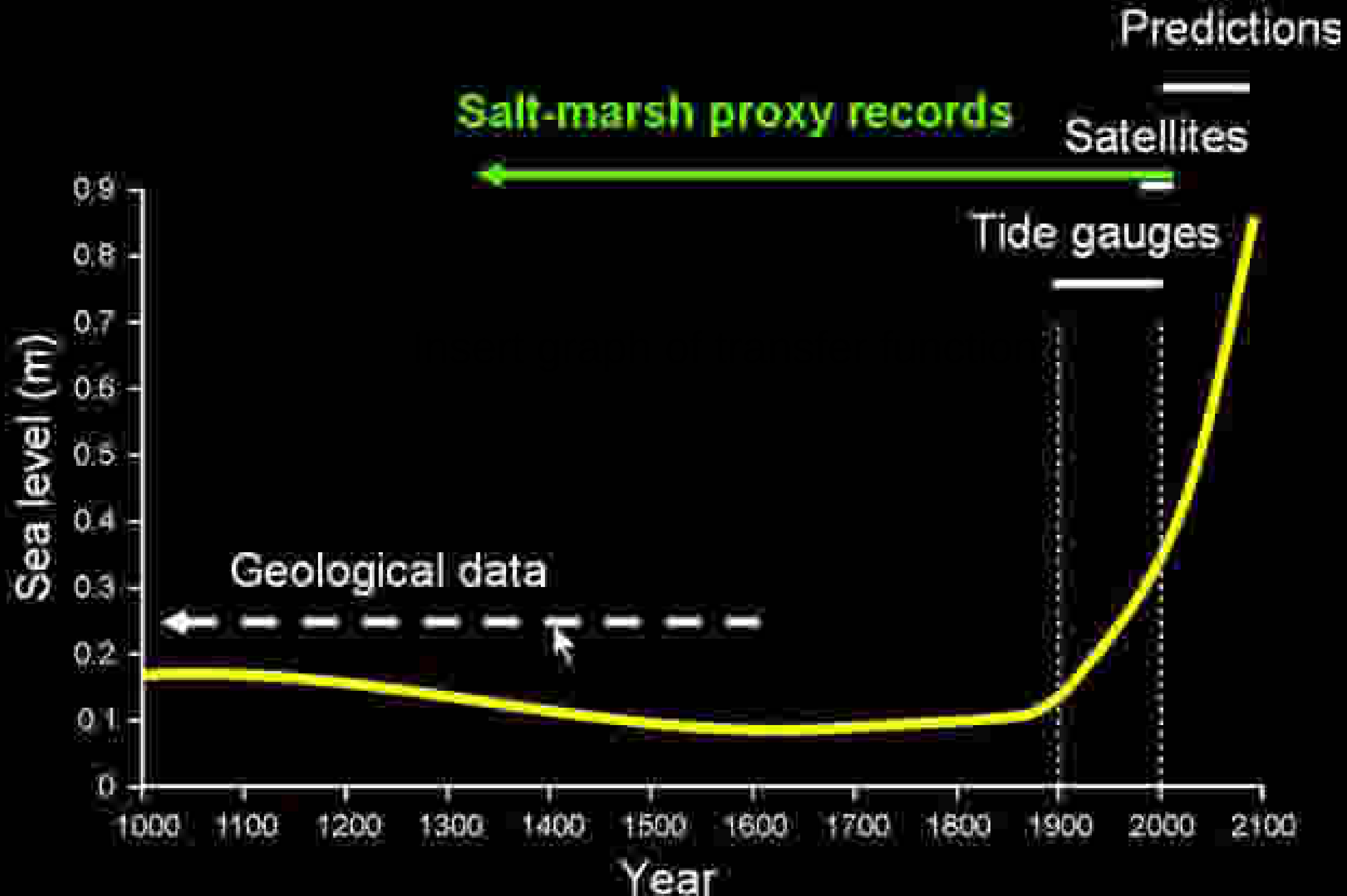
- Loss of wetland habitat.
  - Natural filter improving water quality
  - Critical fisheries habitat
  - Storm flooding protection

- Loss of expensive coastal property.

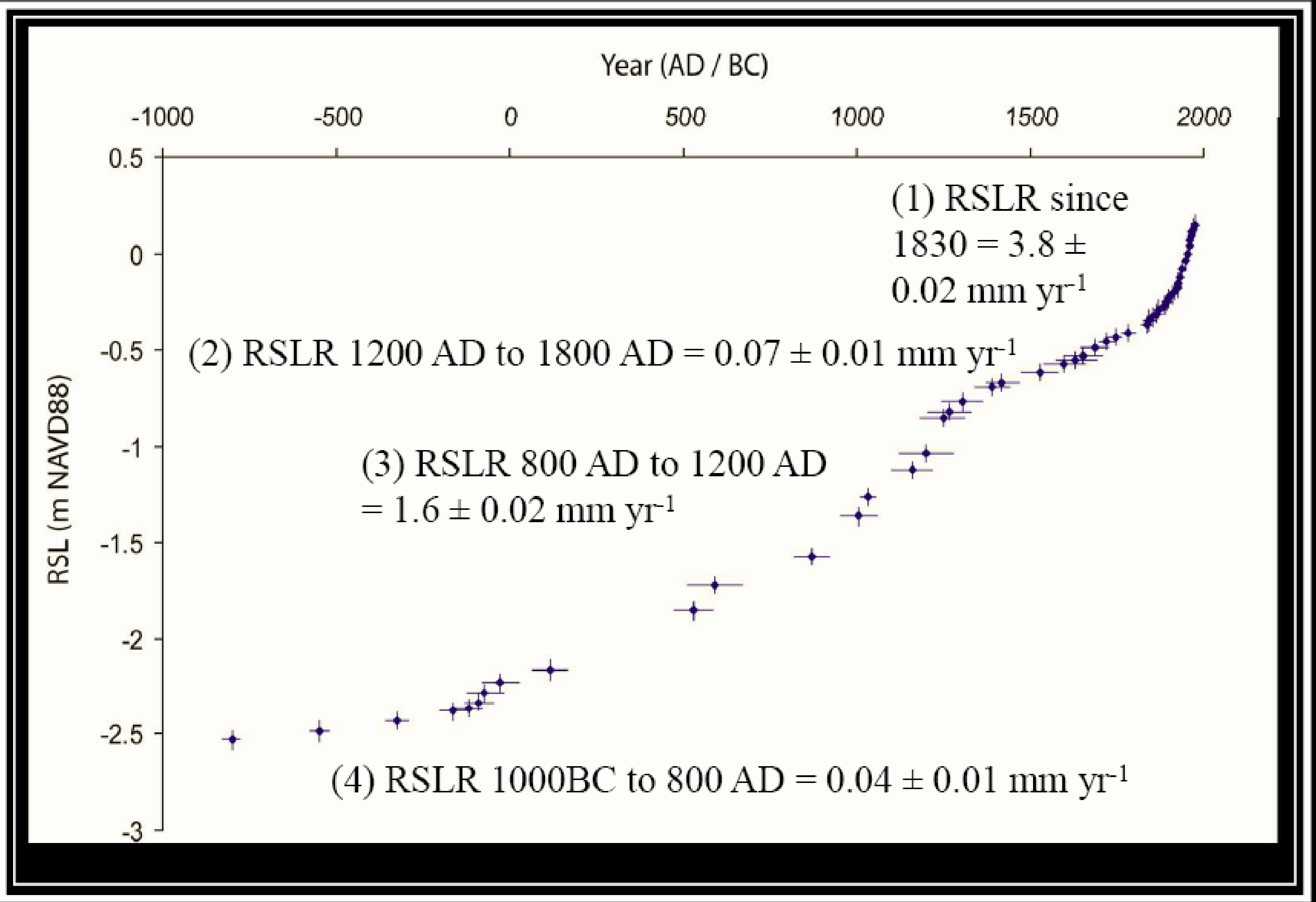
- Damage and Destruction to coastal infrastructure.

Has SLR changed with time?

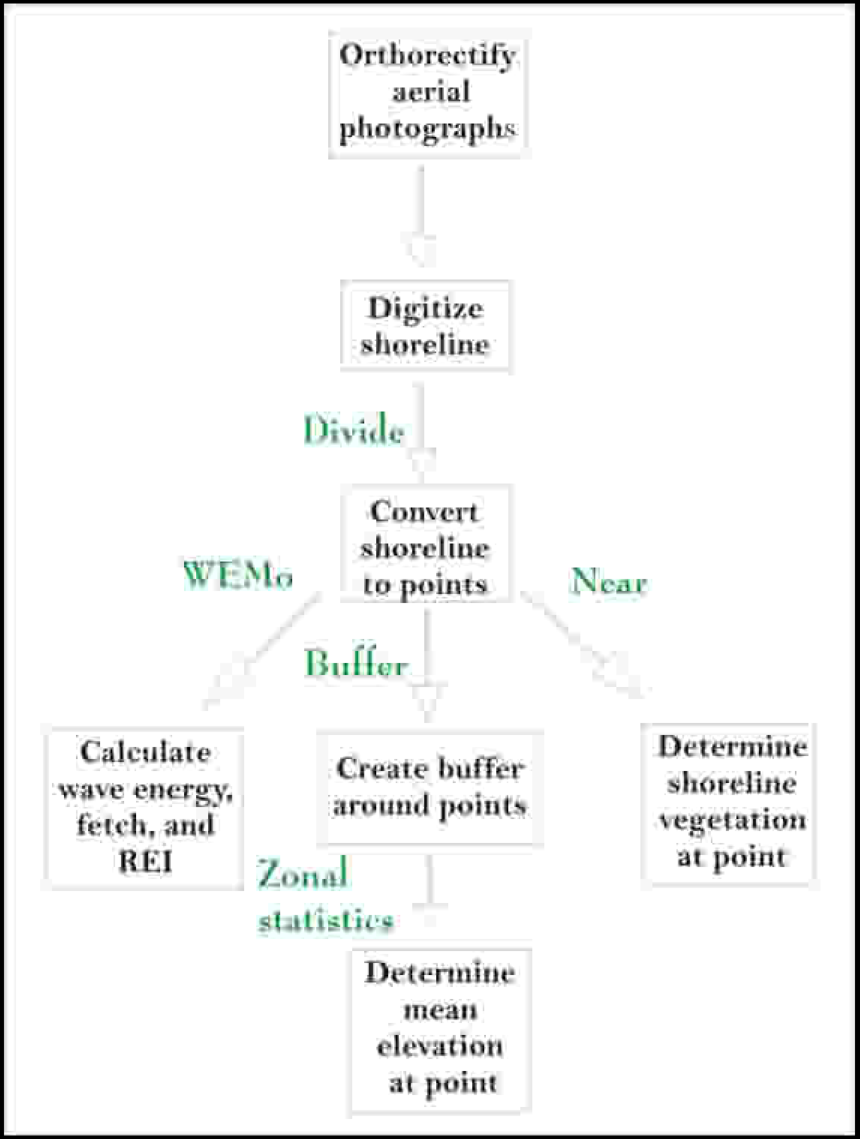
- Unfortunately our tide gauge records are only as good as their length and their locations.
- We must use the geological record to look farther back and in areas without gauge data.

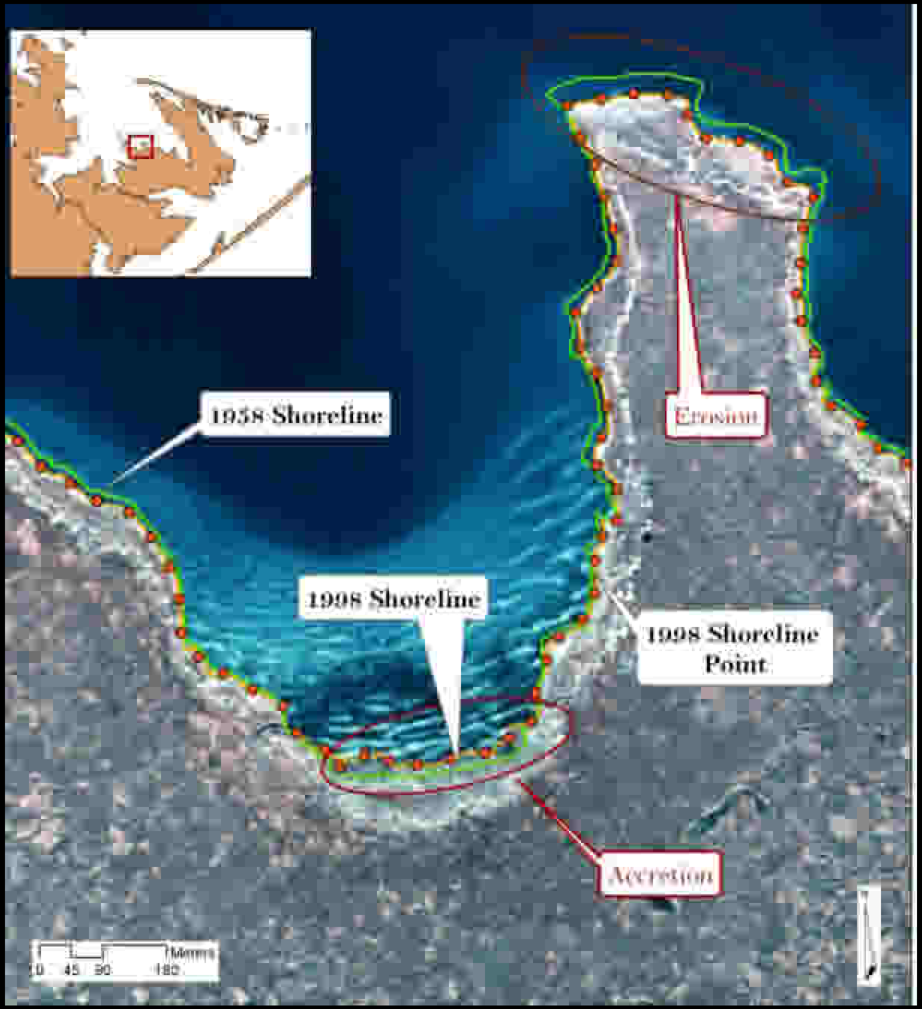


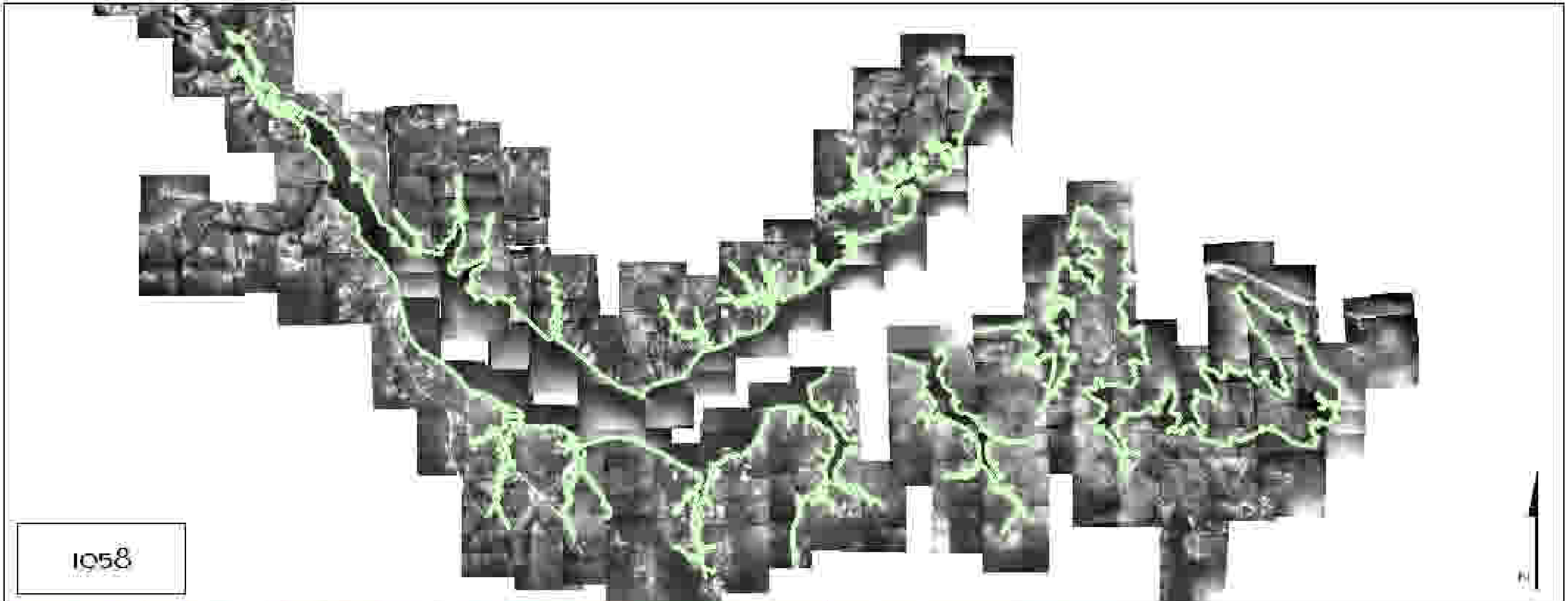
Microfossil and radionuclide data suggest a pronounced change in the rate of SLR.



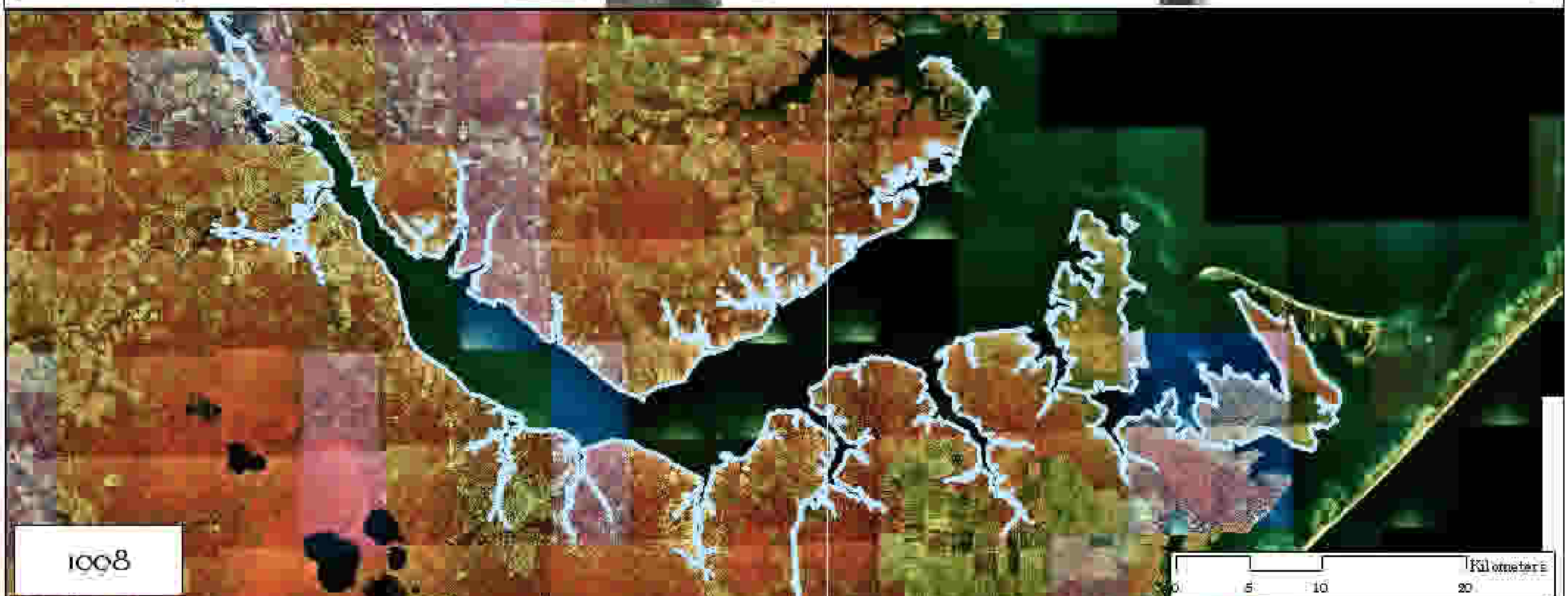
Quantifying Shoreline Change





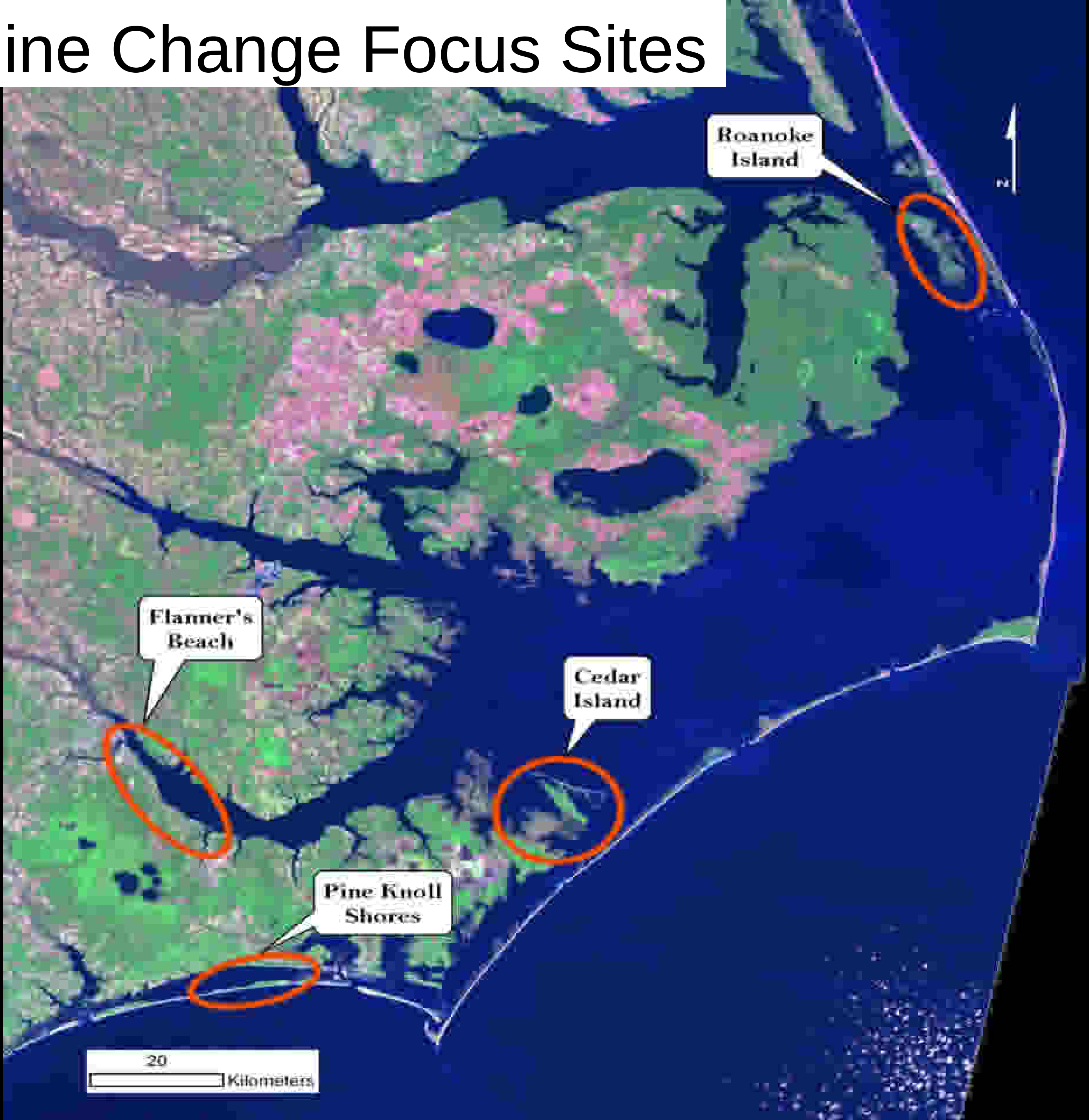


1958
N

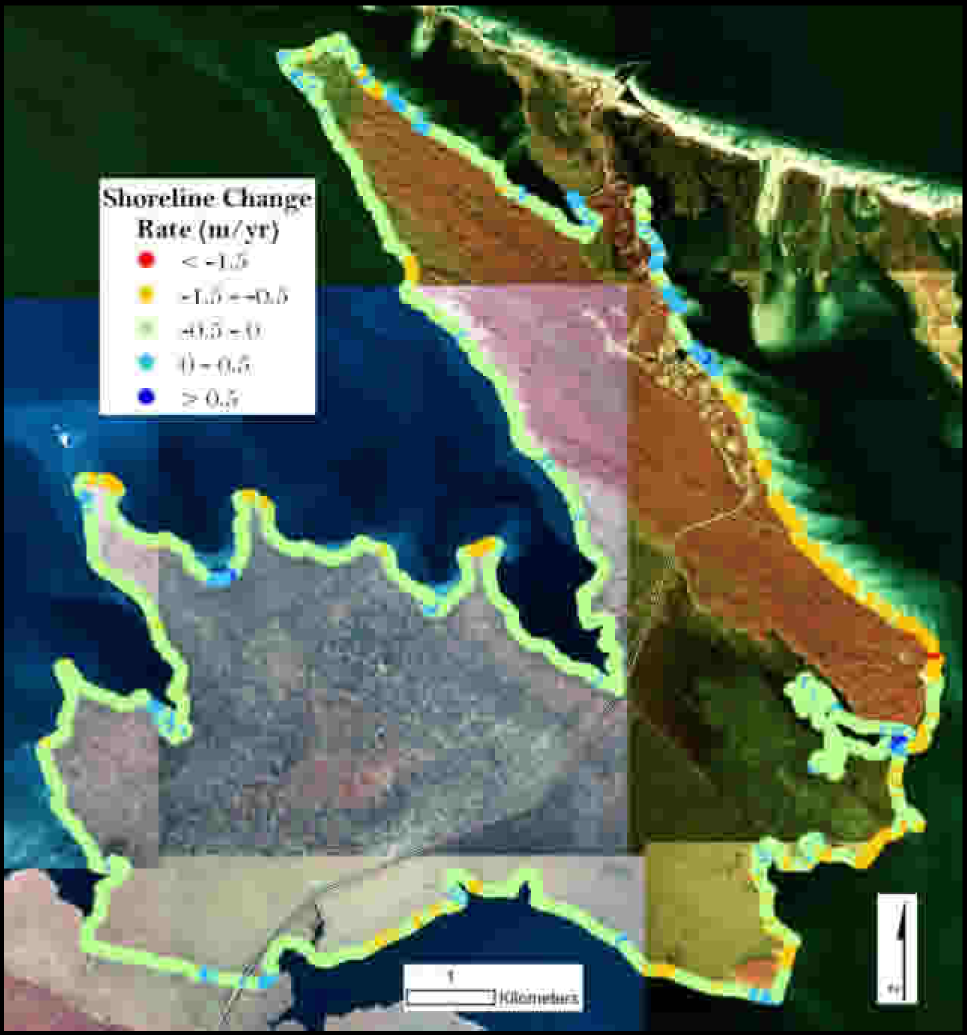


1998
0 5 10 20
Kilometers

Shoreline Change Focus Sites



Cedar Island

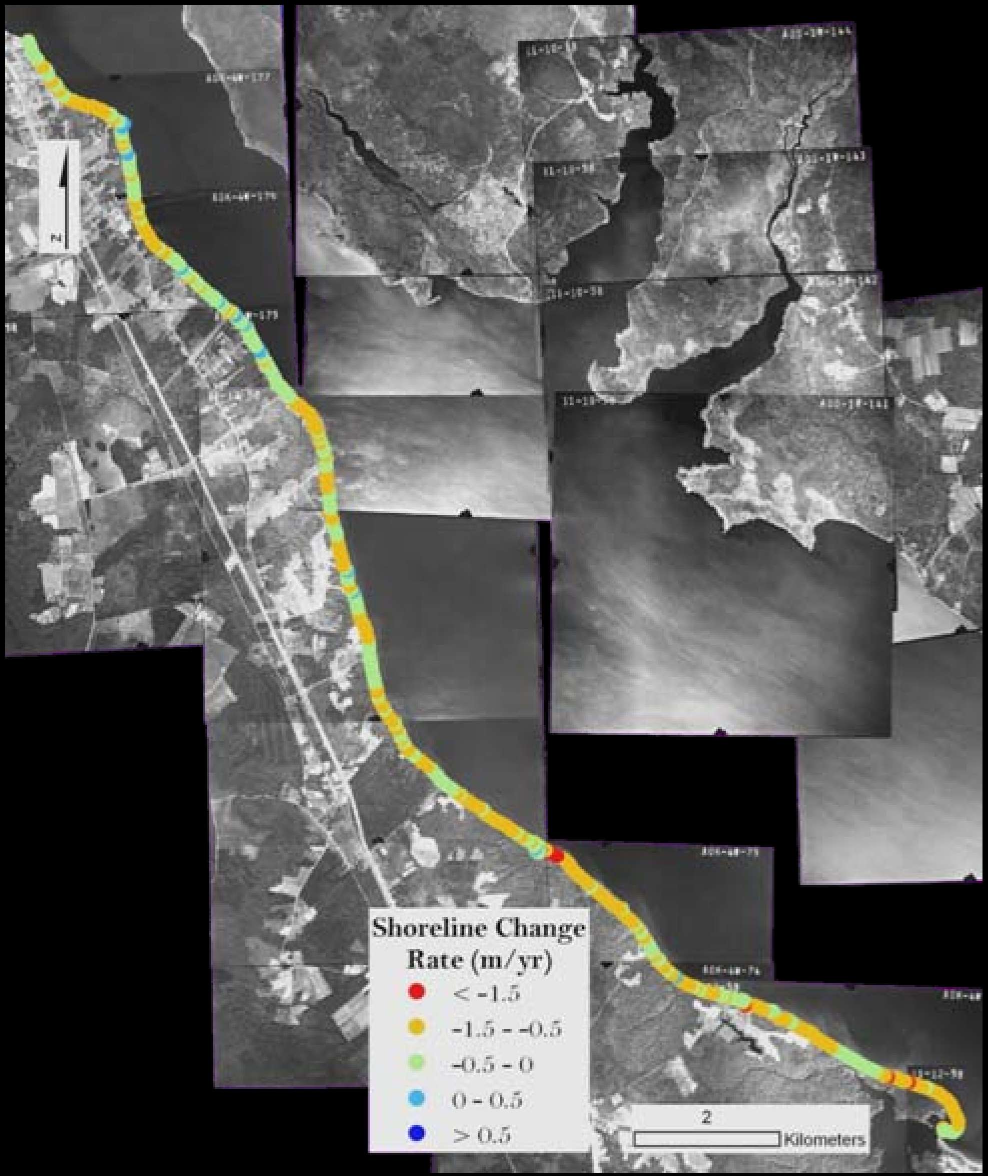


- 78.4 km of shoreline digitized
- Mean SCR of -0.24 m yr^{-1} with 88% eroding.
- Mean fetch values ranged from 0 to 9.3 km, with the average fetch of the study area being 1.5 km
- Mean REI value of the shoreline of 318.
- Dominant LULC type is estuarine emergent wetland (79%), with scrub/shrub and evergreen forest being the second and third most abundant. Together, these three LULC types compose 92% of the shoreline analyzed

Pine Knoll Shores

- 12.6 km of shoreline digitized
- Mean SCR of the area was 0 m yr^{-1} with a range from –0.9 to 1.8 m yr^{-1}
- Mean elevation values ranged from 0 to 2.9 m and the average elevation of the shoreline was 0.7 m
- Mean REI of 66 and fetch of 2 km
- Estuarine emergent wetland is most abundant, composing 43% of the shoreline

Flanner's Beach

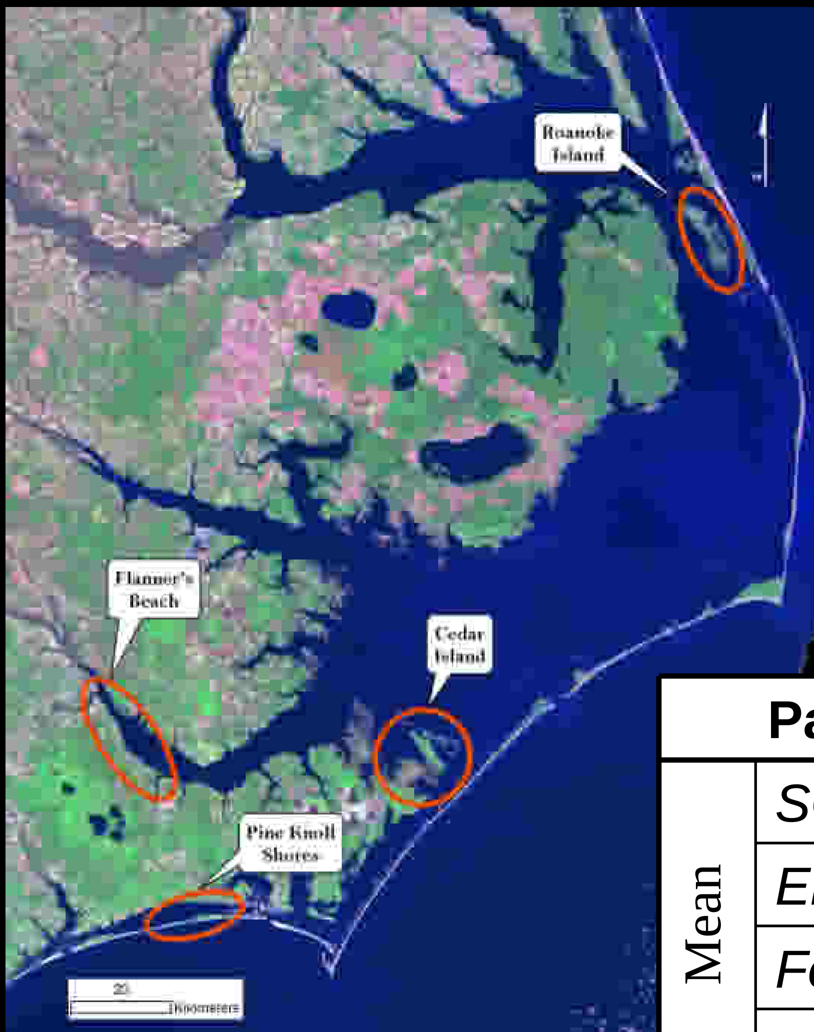


- 24.0 km of shoreline digitized.
- Mean SCR of -0.57 m/yr
- Mean elevation ranged from 0 m to 8.4 m with an average of 1.8 m for the shoreline analyzed.
- Mean fetch of shoreline was 3.0 km with a range of 4.9 km
- Largest mean fetch was from the eastern direction (7.3 km) and the smallest was from the southwestern direction.
- LULC type distribution was more evenly distributed.

Roanoke Island

- 46.3 km of shoreline digitized.
- 26.3 km on the east side and 20.0 km on the west side.
- Average SCR of the study area was -0.58 m/yr.
- Eastern side -0.16 m/yr mean SCR and western side -1.13 m/yr
- More estuarine emergent wetland on the eastern shoreline (73%) than on the western side (63%)

Site Summary

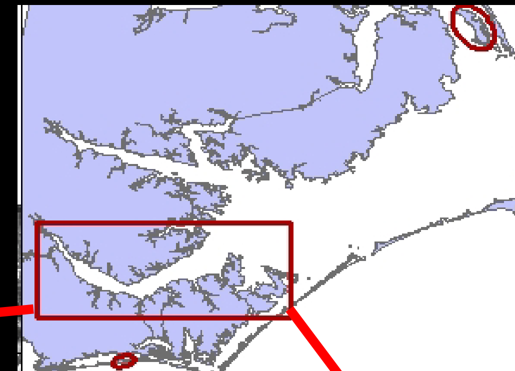


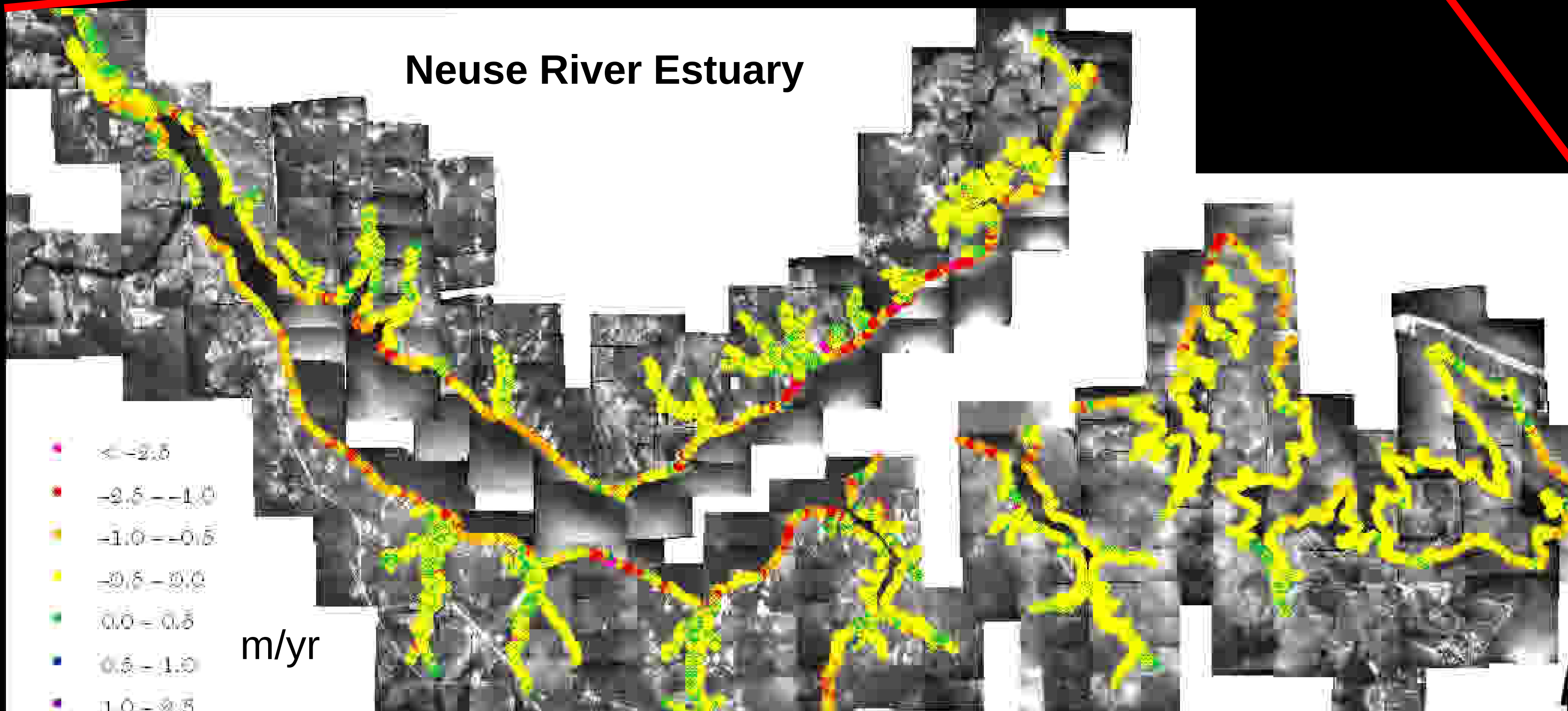
- **Significant variation in SCR throughout the APES**
- **Relationship between elevation/fetch and SCR (erosion), but not a simple linear function.**

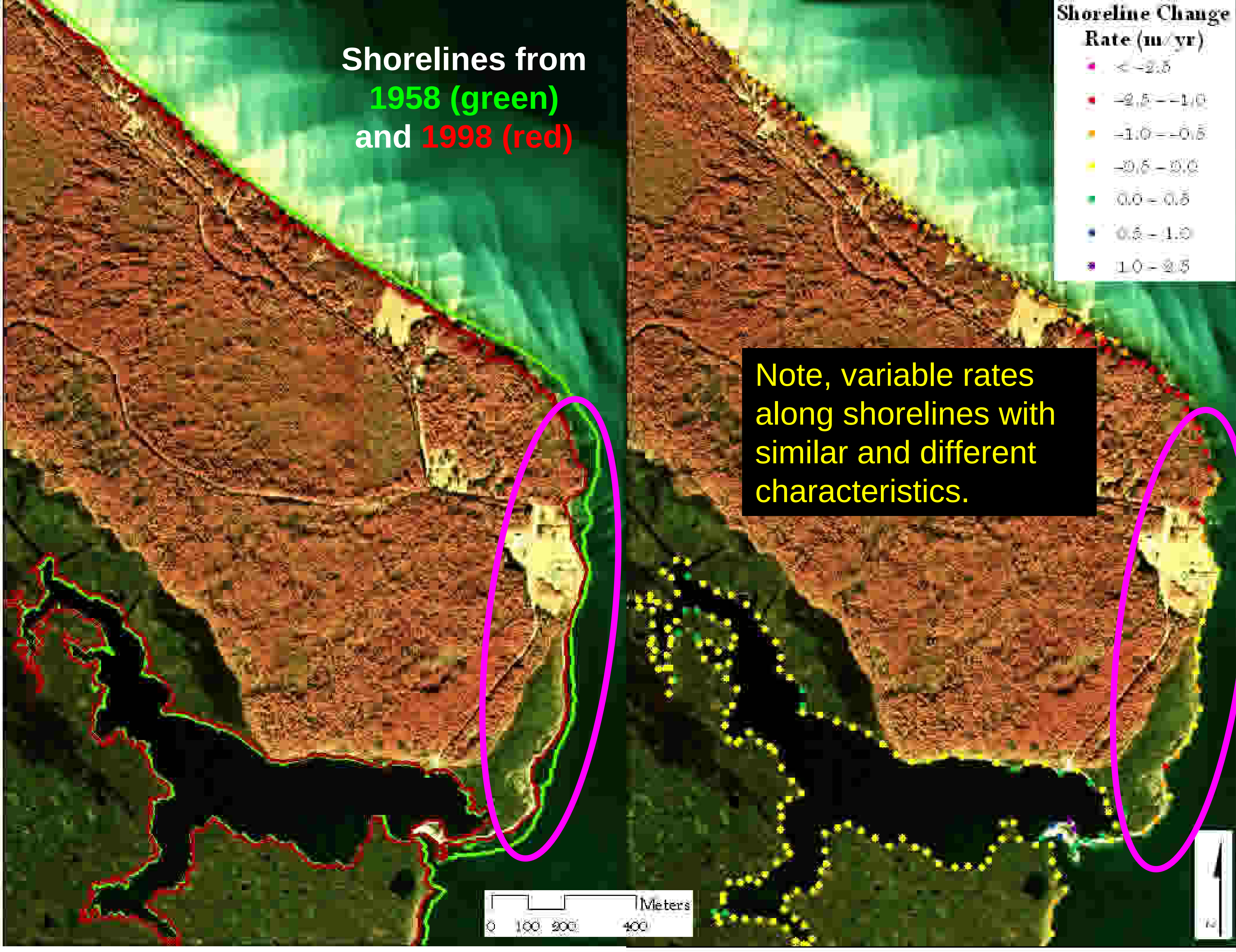
	Parameter	FB	RI	CI	PKS
Mean	*SCR (m/yr)*	-0.57	-0.36	-0.24	0.00
	Elevation (m)	1.8	1.3	0.6	0.7
	Fetch (km)	3.0	N/A	1.5	2.0
	REI	273	N/A	318	66

Estuarine Shoreline Erosion Rates

- **Erosion rates show great variability; however, they are large (>2 m/yr) in some locations.**
- **Prediction cannot easily be accomplished as many factors (e.g., fetch, hardening) are important.**

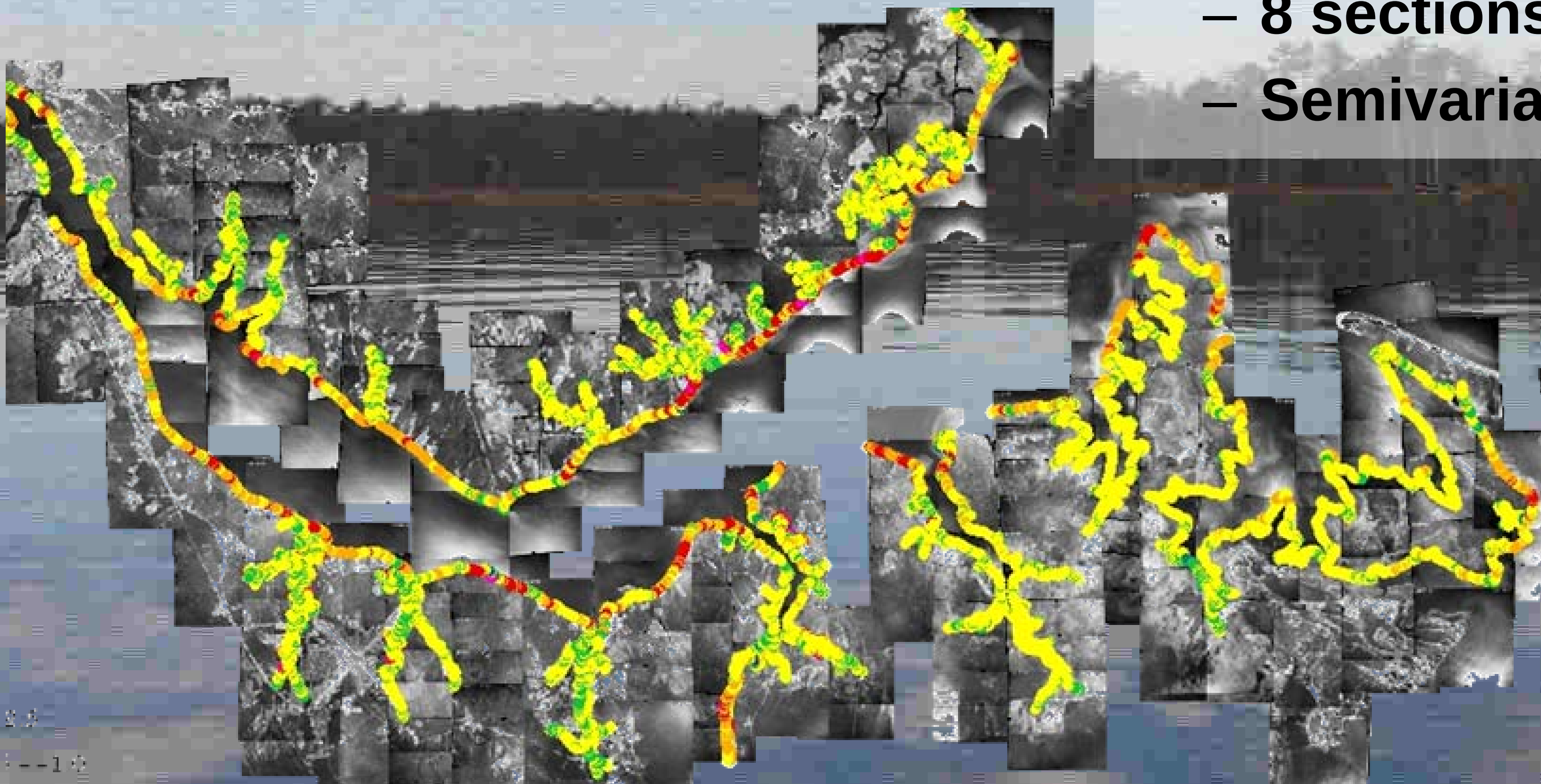


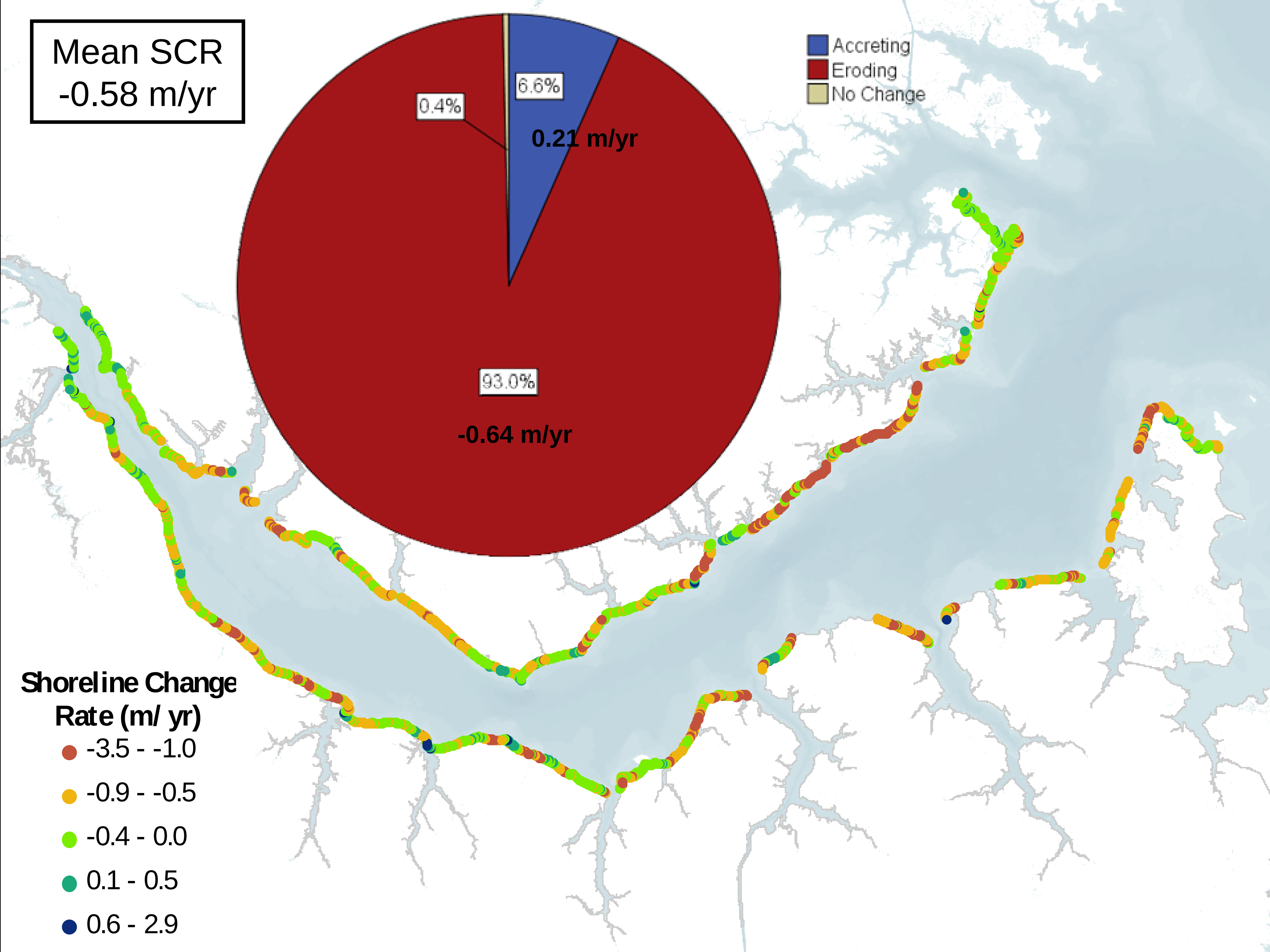



Shorelines from
1958 (green)
and 1998 (red)
Shoreline Change
Rate (m/yr)
< -2.5
-2.5 - -1.0
-1.0 - -0.5
-0.5 - 0.0
0.0 - 0.5
0.5 - 1.0
1.0 - 2.5
Note, variable rates along shorelines with similar and different characteristics.
Meters
0 100 200 400

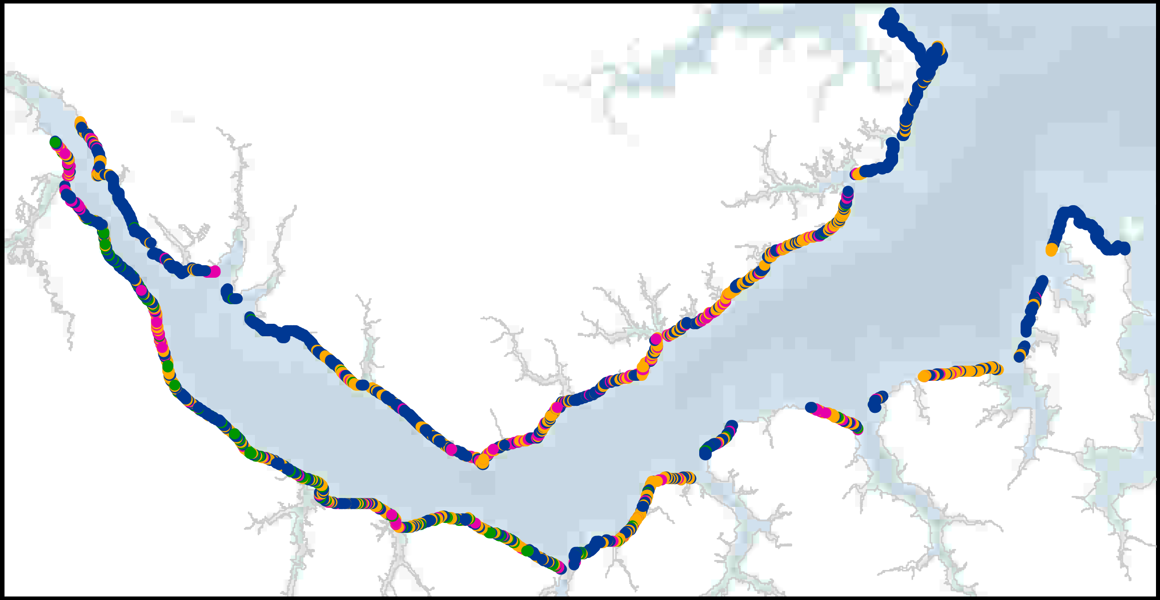
Work in Progress

- Focusing on scale
  - Trunk
  - 4 sections
  - 8 sections
  - Semivariance



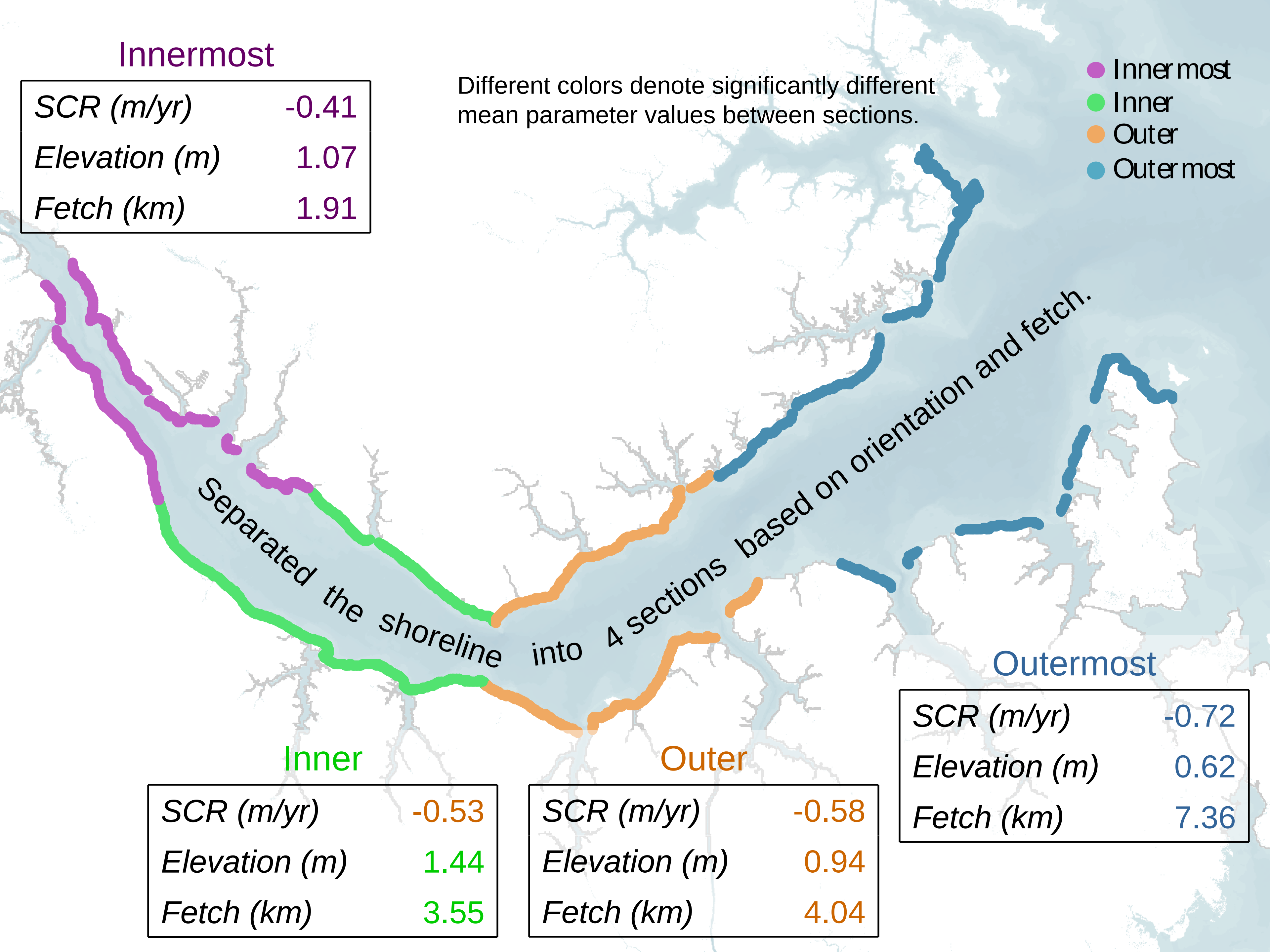

Mean SCR
-0.58 m/yr
Accreting
Eroding
No Change
6.6%
0.4%
0.21 m/yr
93.0%
-0.64 m/yr
Shoreline Change Rate (m/ yr)
-3.5 - -1.0
-0.9 - -0.5
-0.4 - 0.0
0.1 - 0.5
0.6 - 2.9

Shoreline Vegetation Type

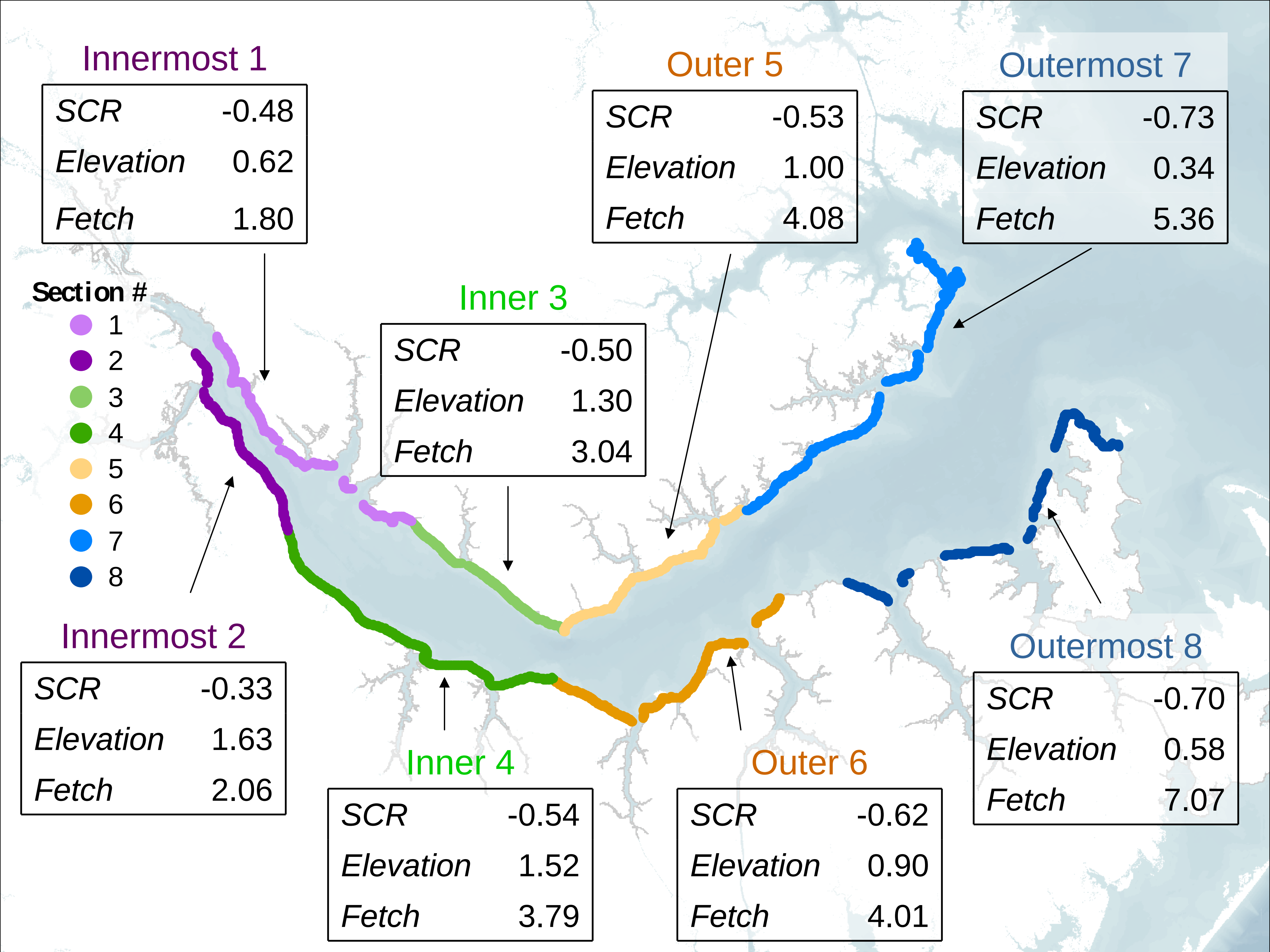


Parameter	LULC Type			
	Wetland	Forest	Sediment Bank	Other
Shoreline Change Rate (m/yr)	-0.53	-0.57	-0.70	-0.56
Elevation (m)	0.85	1.40	1.09	1.09
Fetch (km)	4.9	3.5	4.6	3.7

Note: Different colors denote significantly different mean parameter values



Innermost
SCR (m/yr) -0.41
Elevation (m) 1.07
Fetch (km) 1.91
Different colors denote significantly different mean parameter values between sections.
Innermost
Inner
Outer
Outermost
Separated the shoreline into 4 sections based on orientation and fetch.
Outermost
SCR (m/yr) -0.72
Elevation (m) 0.62
Fetch (km) 7.36
Inner
SCR (m/yr) -0.53
Elevation (m) 1.44
Fetch (km) 3.55
Outer
SCR (m/yr) -0.58
Elevation (m) 0.94
Fetch (km) 4.04

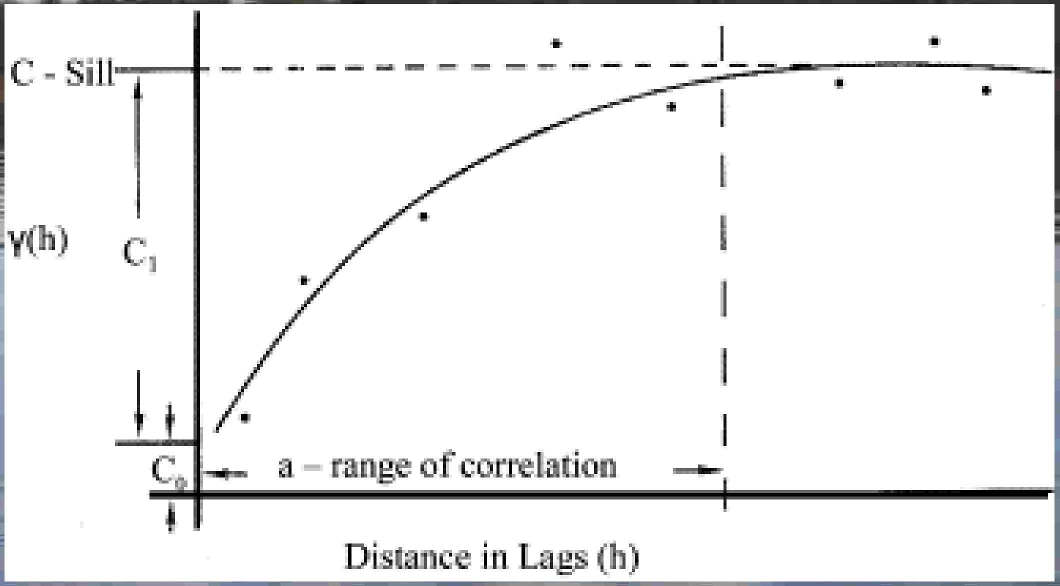


Innermost 1
SCR -0.48
Elevation 0.62
Fetch 1.80
Outer 5
SCR -0.53
Elevation 1.00
Fetch 4.08
Outermost 7
SCR -0.73
Elevation 0.34
Fetch 5.36
Section #
1
2
3
4
5
6
7
8
Inner 3
SCR -0.50
Elevation 1.30
Fetch 3.04
Innermost 2
SCR -0.33
Elevation 1.63
Fetch 2.06
Inner 4
SCR -0.54
Elevation 1.52
Fetch 3.79
Outer 6
SCR -0.62
Elevation 0.90
Fetch 4.01
Outermost 8
SCR -0.70
Elevation 0.58
Fetch 7.07

Using Geostatistics

$$\gamma(h) = \frac{1}{2N(h)} \sum_{\alpha=1}^{N(h)} \left[z(u_\alpha) - z(u_\alpha + h) \right]^2$$

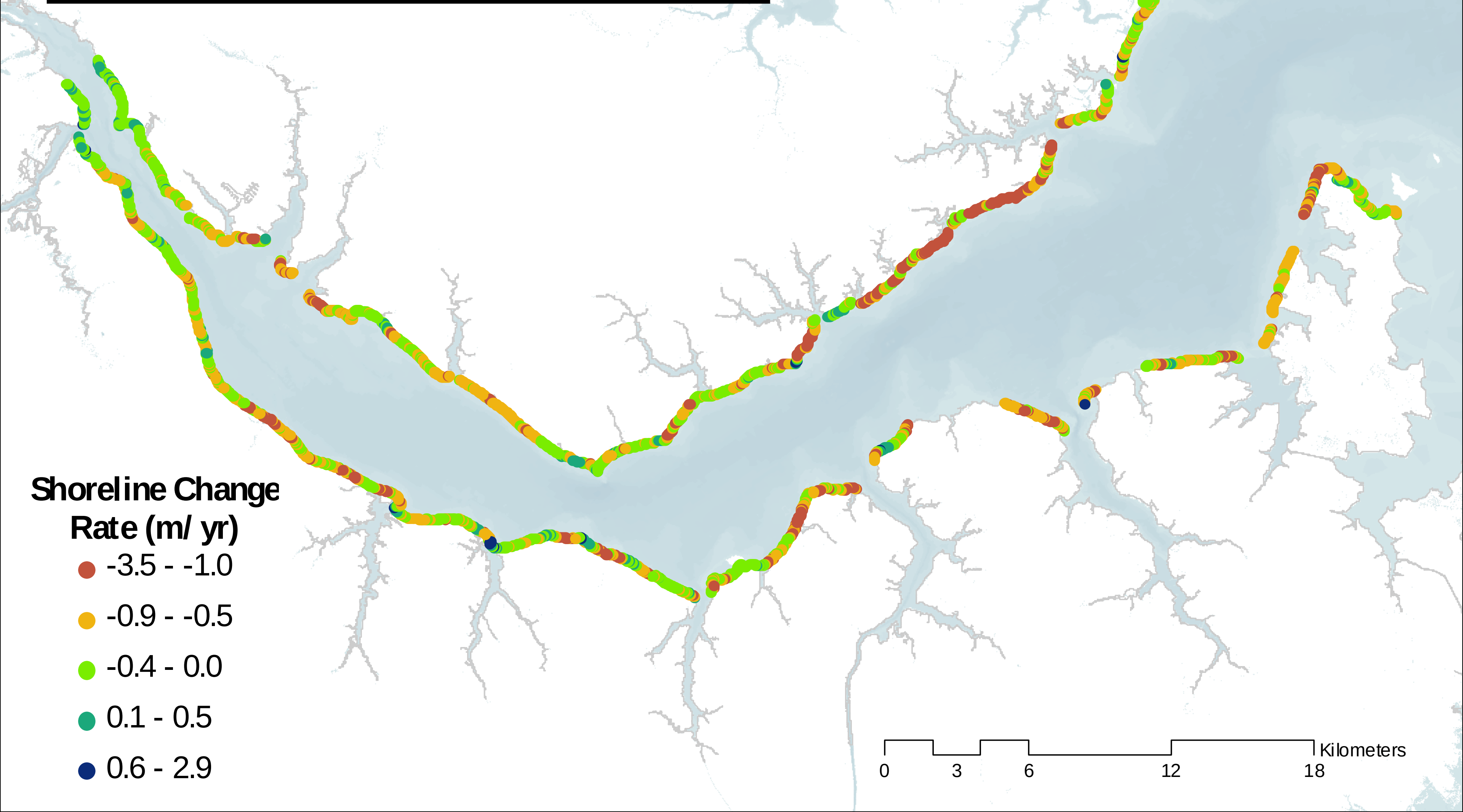
Through calculating the semivariance, the distance at which shoreline change rates are spatially independent can be determined (range)



Idealized semivariogram plot taken from Caeiro, S. *et al.* 2003 Spatial sampling design for sediment quality assessment in estuaries. Environmental Modeling & Software 18: 853-859

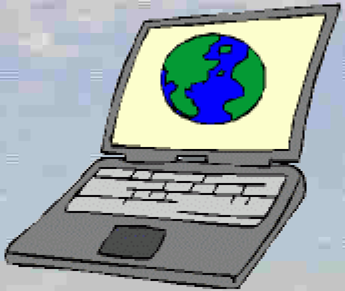
Semivariance

- Variance tends to be greater on northern shoreline
- Range of correlation - ~0.7 – 1.2 km



Shoreline Modification

+



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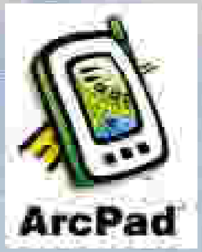
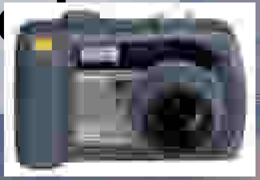
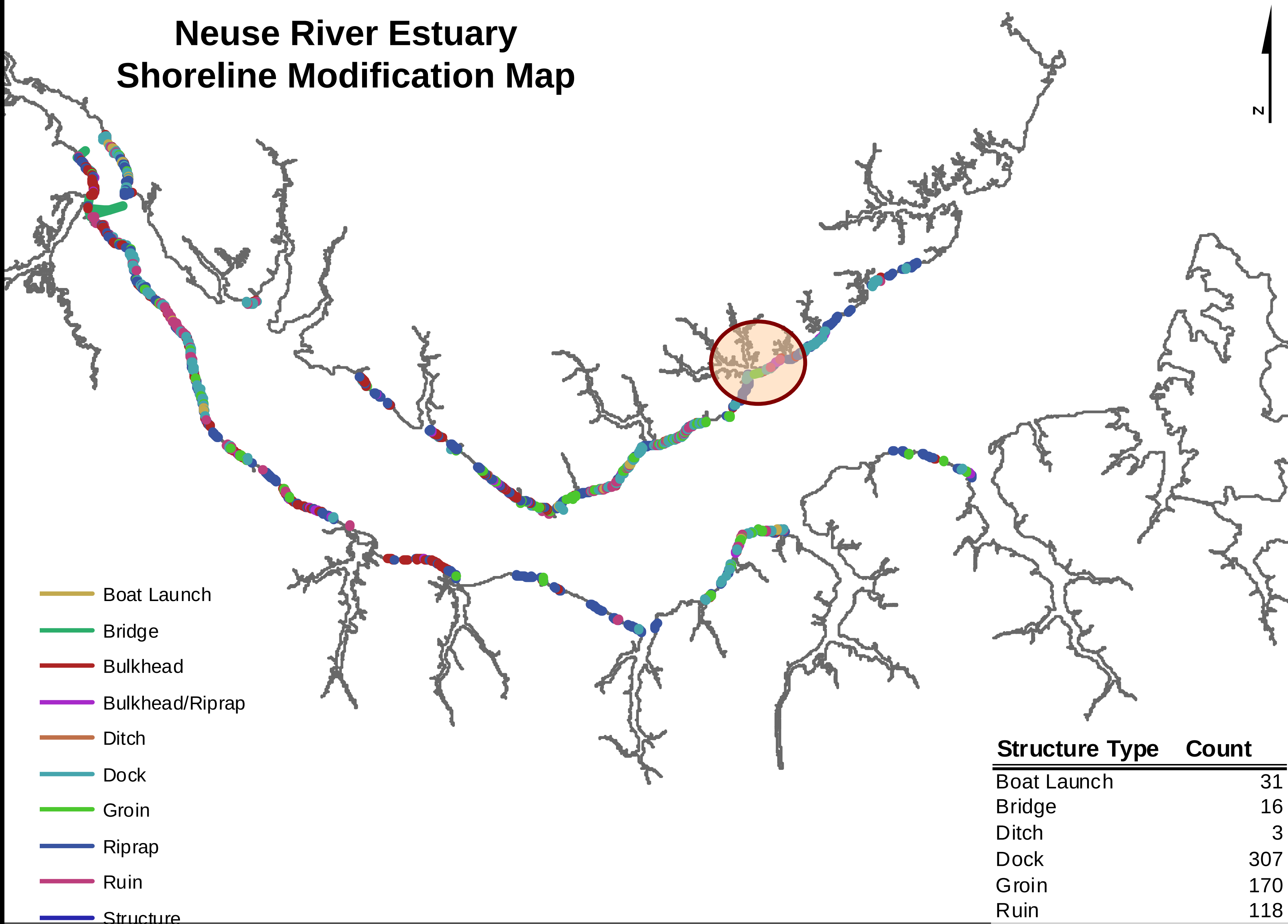


- Used ArcPad software, laptops, in conjunction with GPS units
- Structures were heads-up digitized as the boat motored perpendicular to shore
- GPS camera documente i modified structures

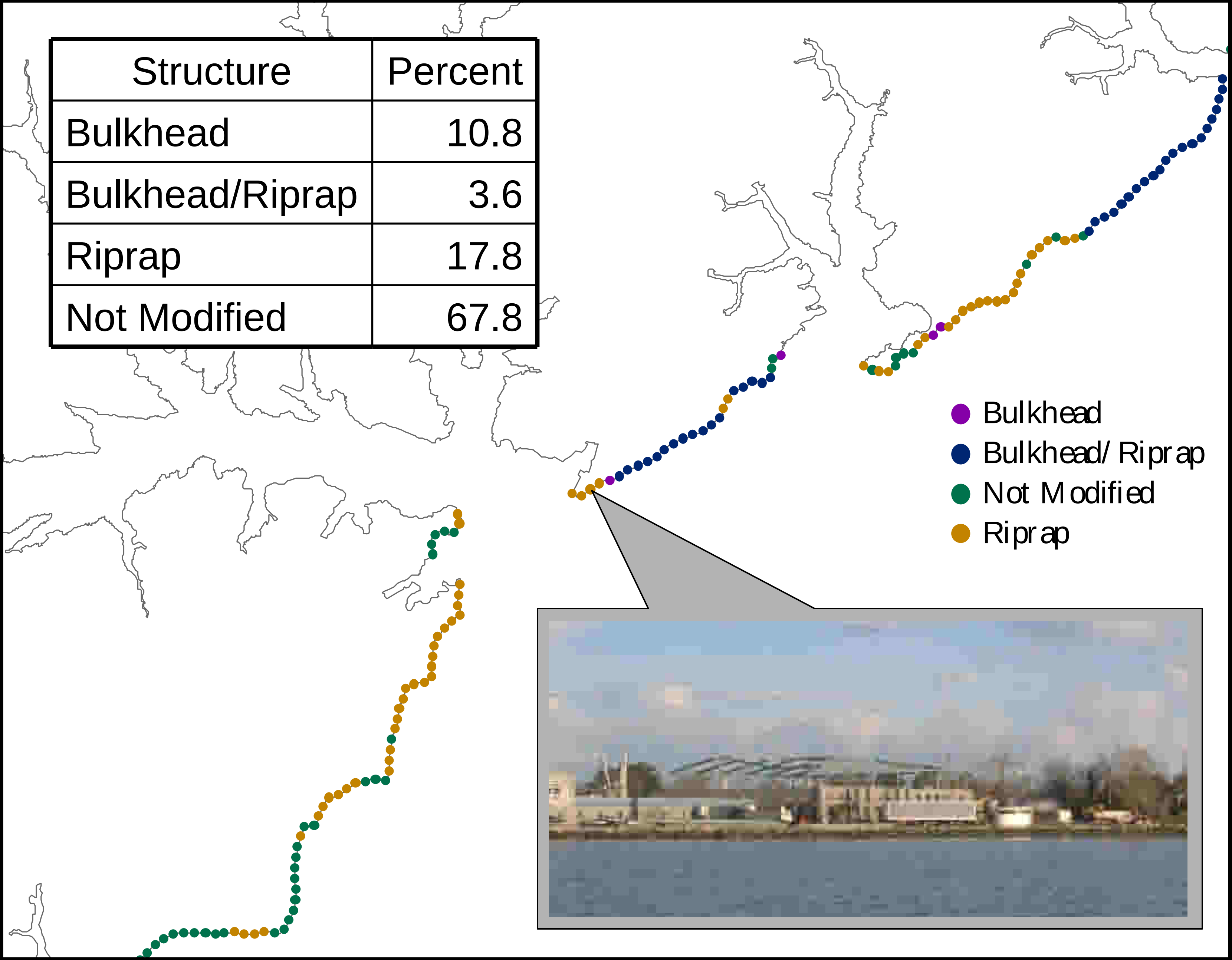


Neuse River Estuary
Shoreline Modification Map



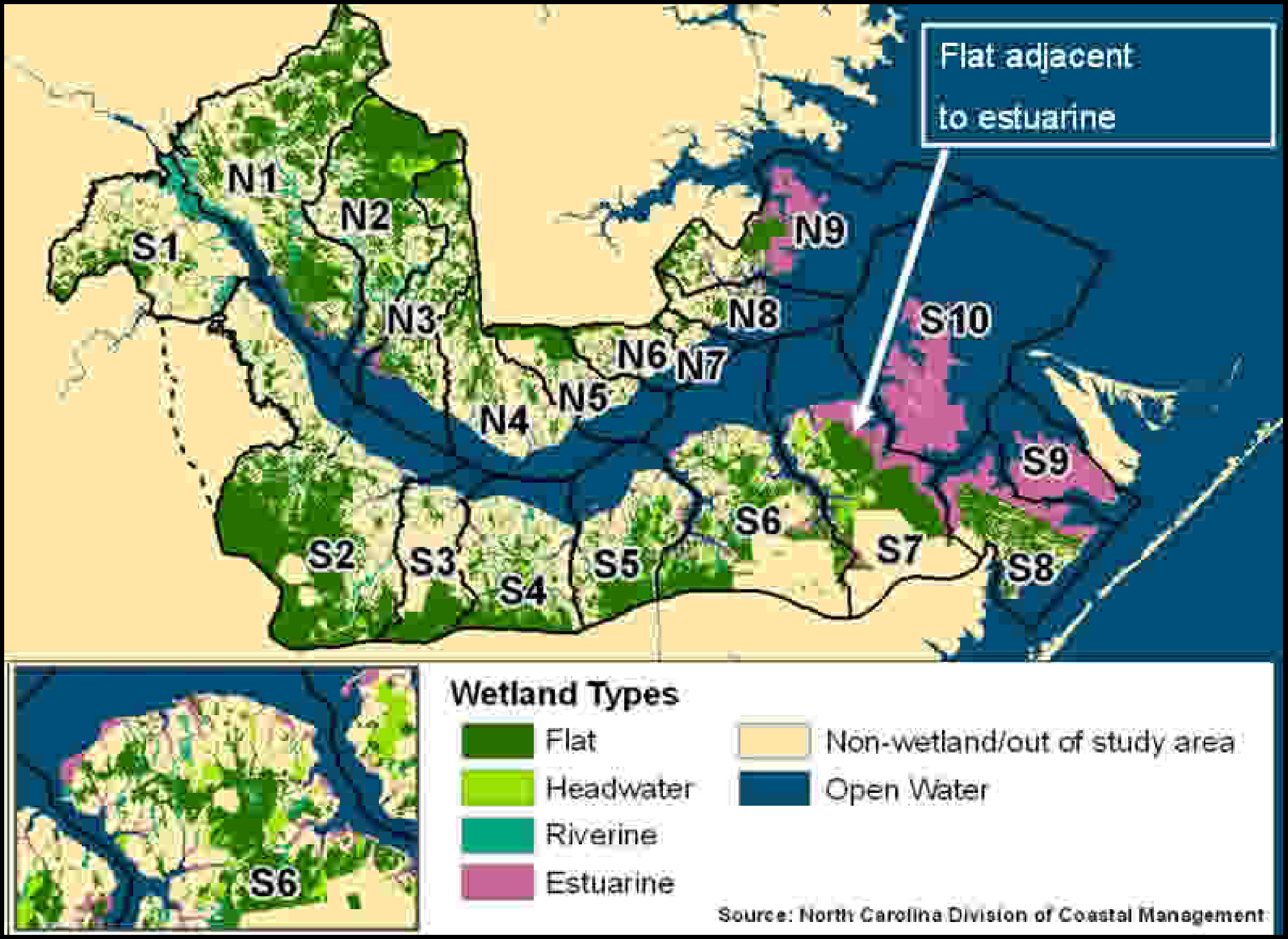
Structure Type	Count
Boat Launch	31
Bridge	16
Ditch	3
Dock	307
Groin	170
Ruin	118
Structure	2

Structure	Percent
Bulkhead	10.8
Bulkhead/Riprap	3.6
Riprap	17.8
Not Modified	67.8



Land-Cover Change along the NRE

- Variations are anticipated over relatively long (millennial) and short (decadal) timescales.
- The former, which is anticipated to impact the latter, can be evaluated using a space-for-time approach as shown:

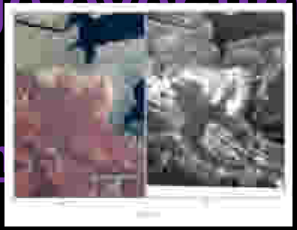


Hierarchical Landscape Study Design
(Urban et al. 1987)

1. How does the shorezone change across the estuary? Landscape/Estua

   – Space for time substitution

2. How does the shorezone change over time? Shorezone Scale

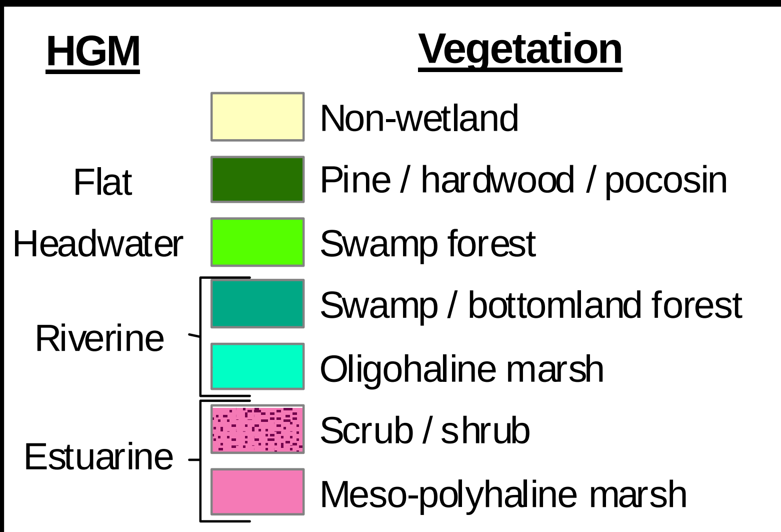


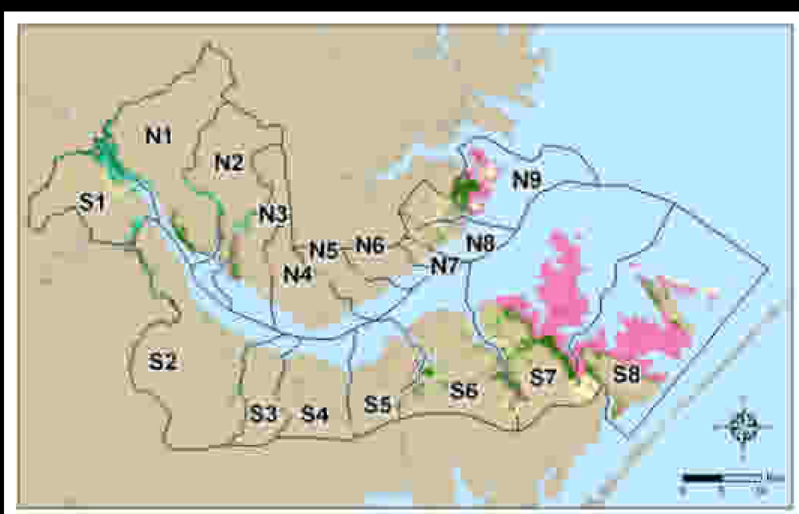
   – Change in shorezone position over tim

3. How does vegetation, soil, and elevation change across the shorezone? Plant Community Scale

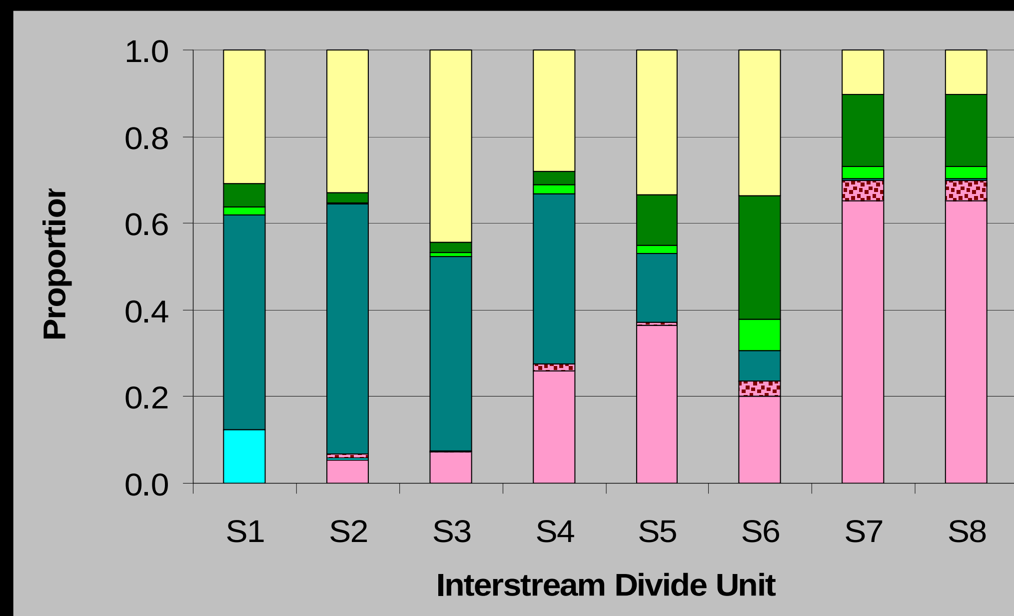
   – Change across shorezone

Distribution of wetlands in the shorezone



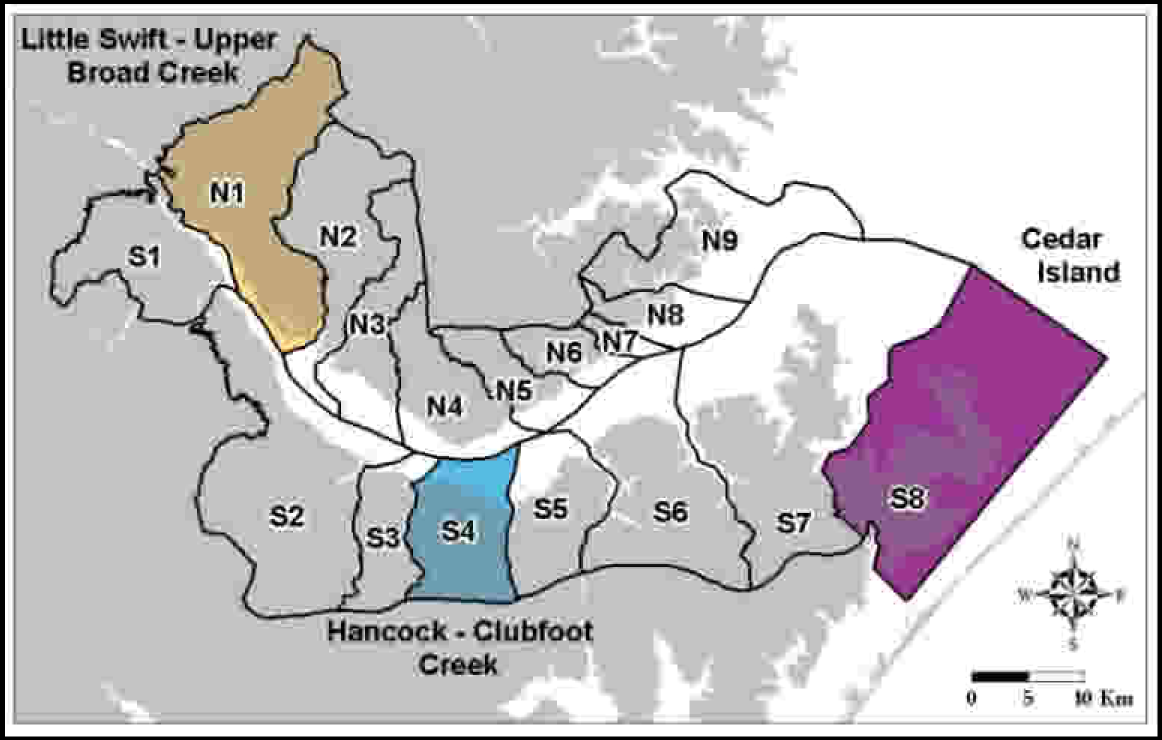


Note, the modern land-cover distribution along the NRE changes down the system reflecting the varying degree of flooding.



Shorezone Scale

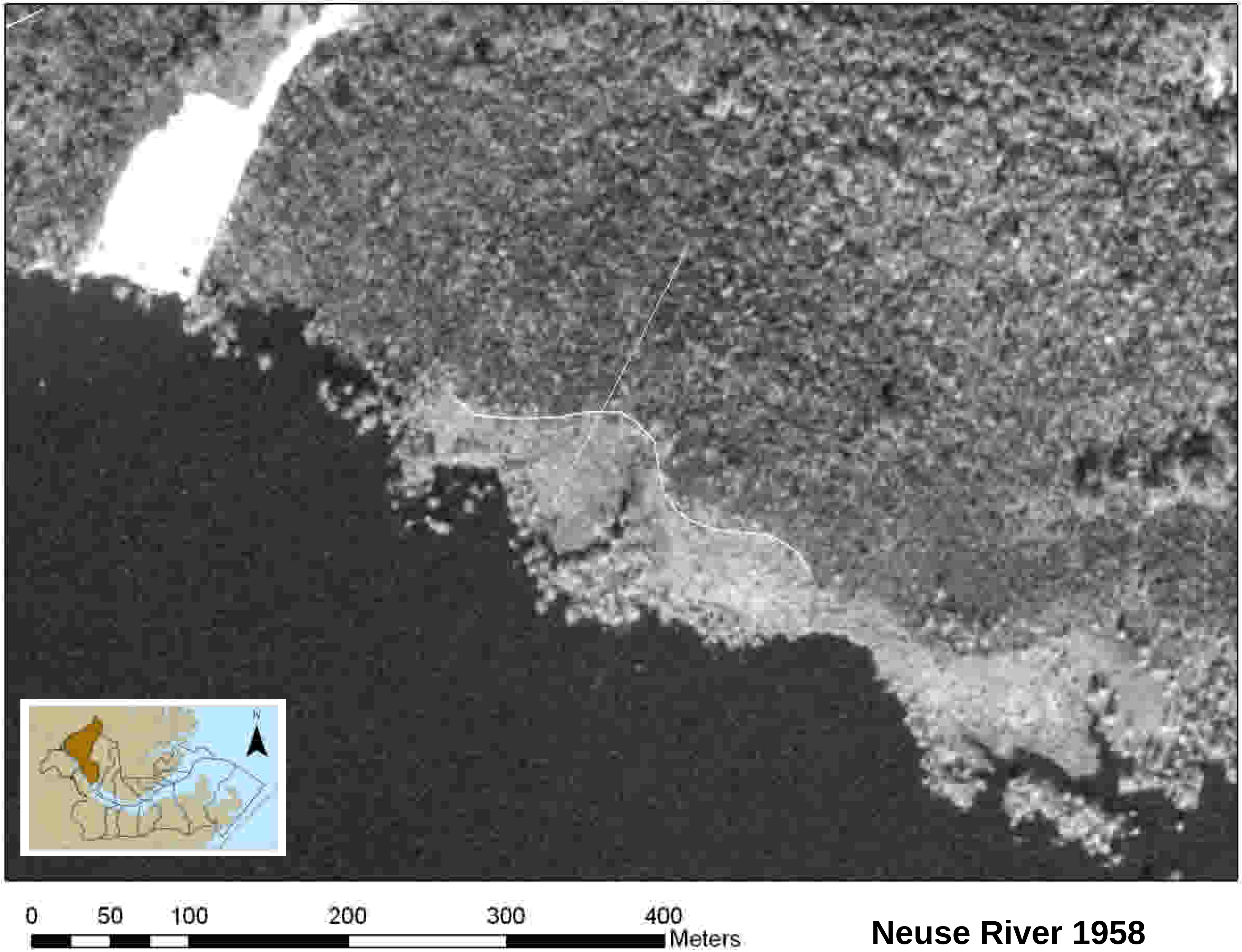
- Investigating vegetation boundary changes between the 1958 and 1998 at select study sites.



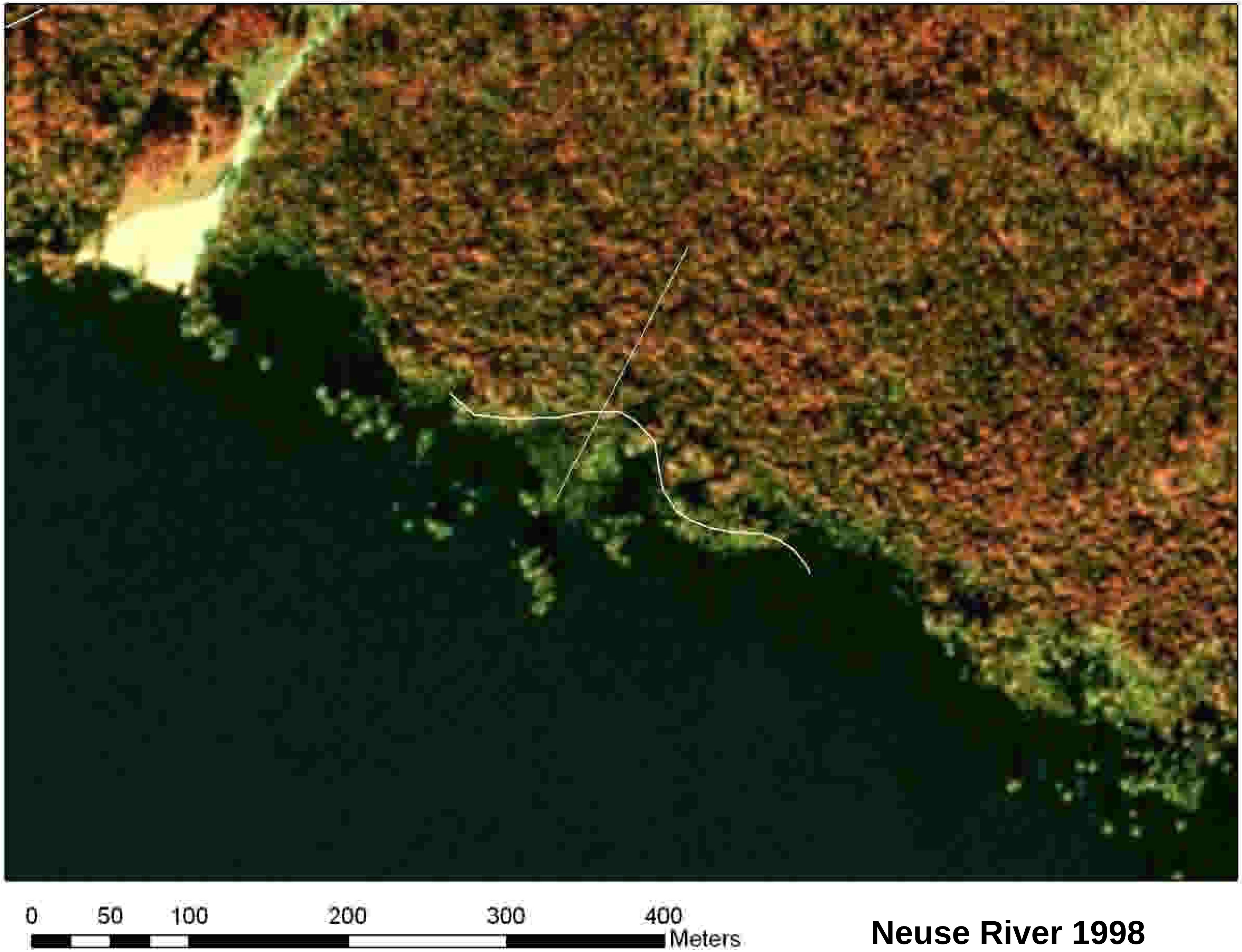

Lola Road
1958
0
50
100
200
300
400
Meters


Lola Road
1998
0
50
100
200
300
400
Meters


Lola Road
2008



Neuse River 1958

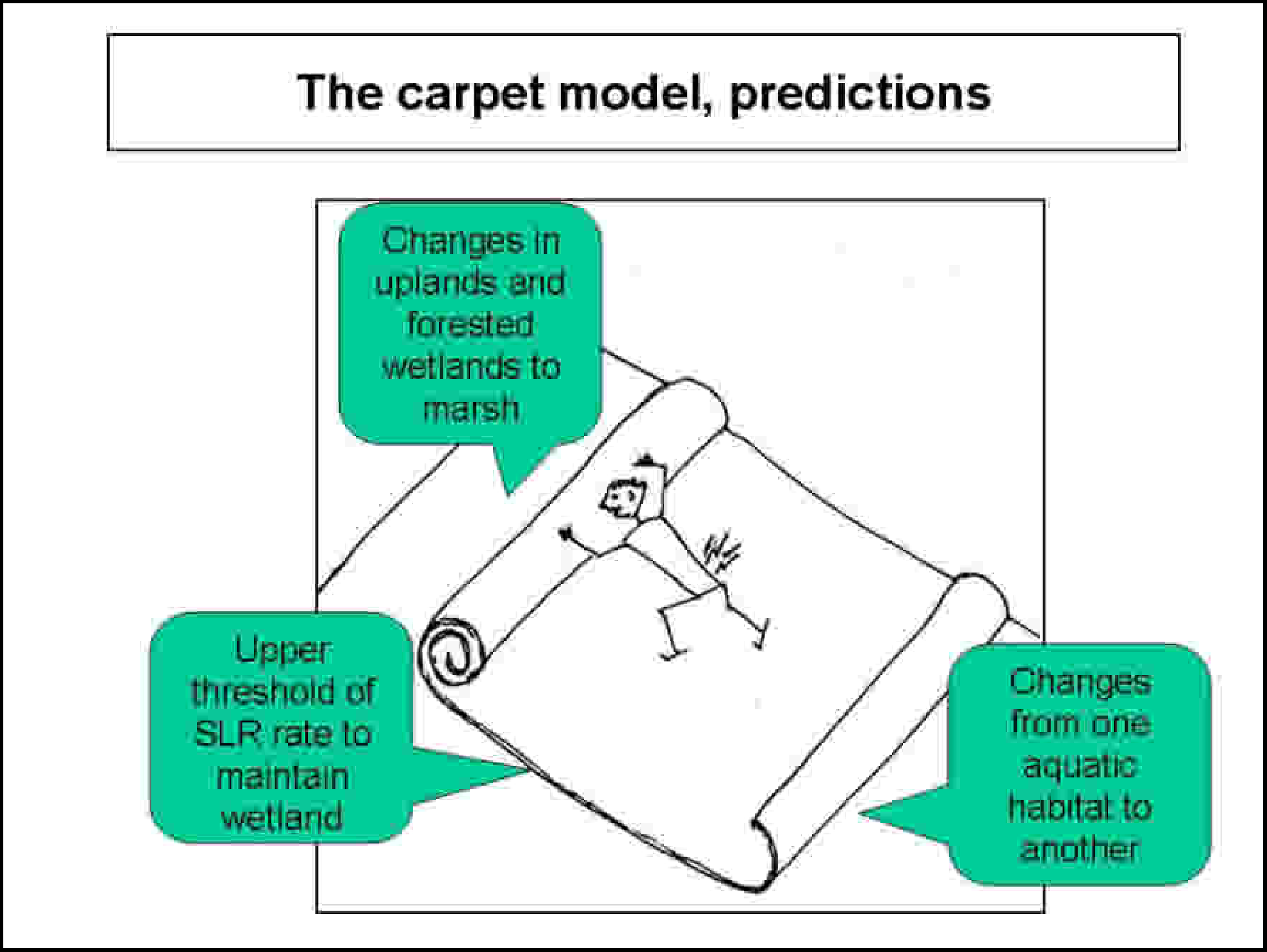


Neuse River 1998

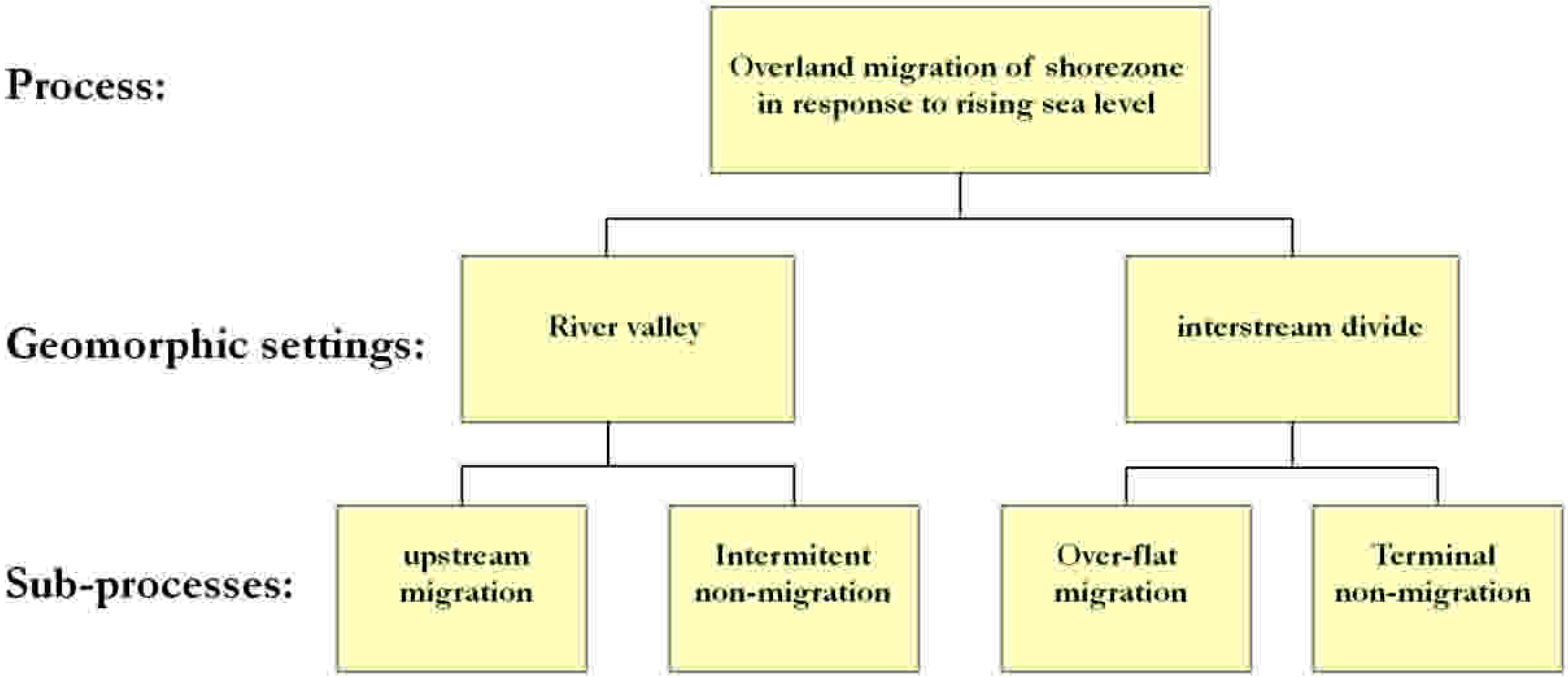

Neuse River 2008

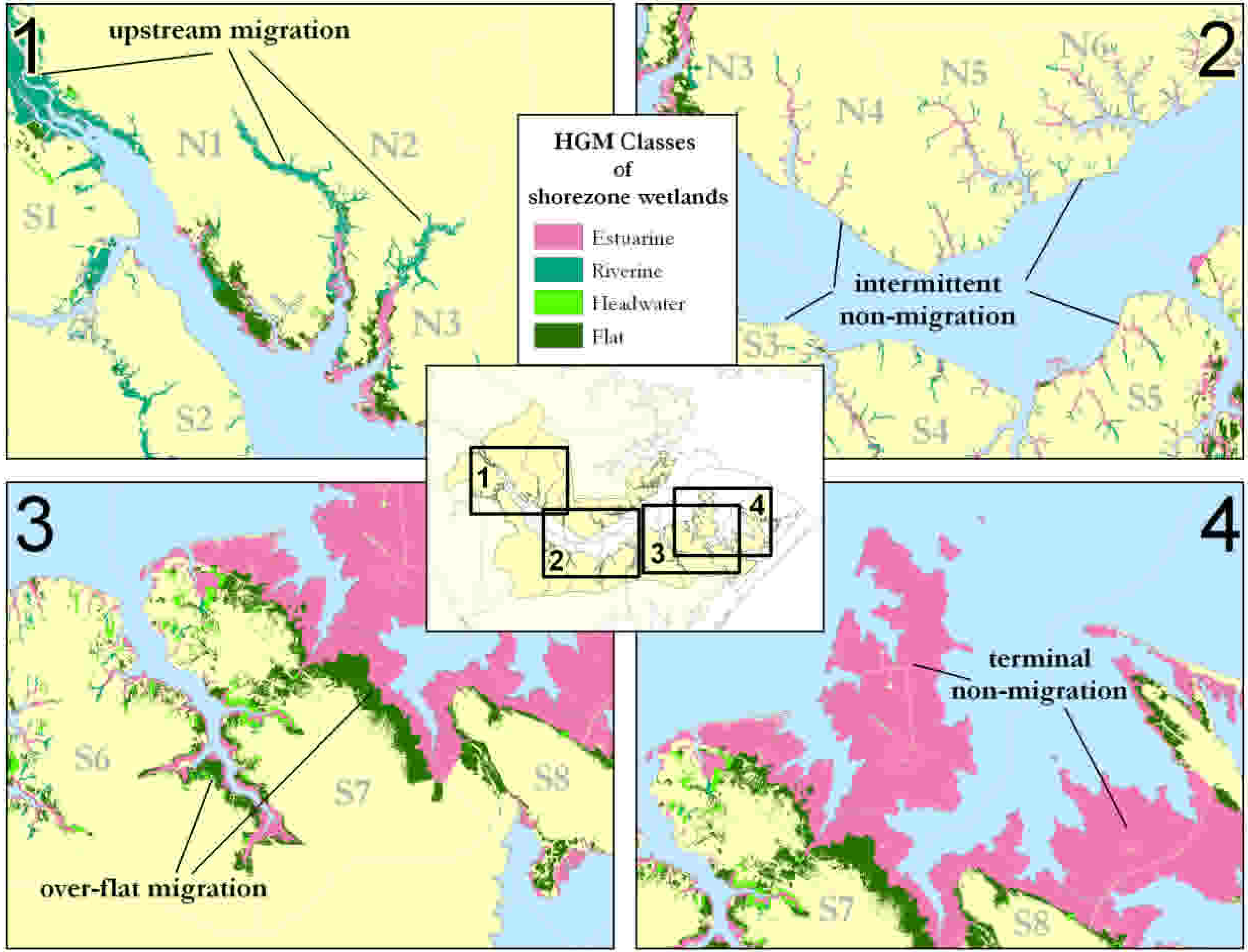
Analysis of the ecological shorezone change over the
st century at sites along the NRE continues...stay tuned

An initial, important insight: It's not as simple as the "Bathtub" or "Carpet Model"!



Landscape modeling is key… see Reyes work.


Process:
Overland migration of shorezone in response to rising sea level
Geomorphic settings:
River valley
interstream divide
Sub-processes:
upstream migration
Intermitent non-migration
Over-flat migration
Terminal non-migration



1
upstream migration
N1
N2
N3
S1
S2
2
N3
N4
N5
N6
intermittent
non-migration
S3
S4
S5
HGM Classes
of
shorezone wetlands
Estuarine
Riverine
Headwater
Flat
1
2
3
4
3
S6
S7
S8
over-flat migration
4
terminal
non-migration
S7
S8

Working with products…

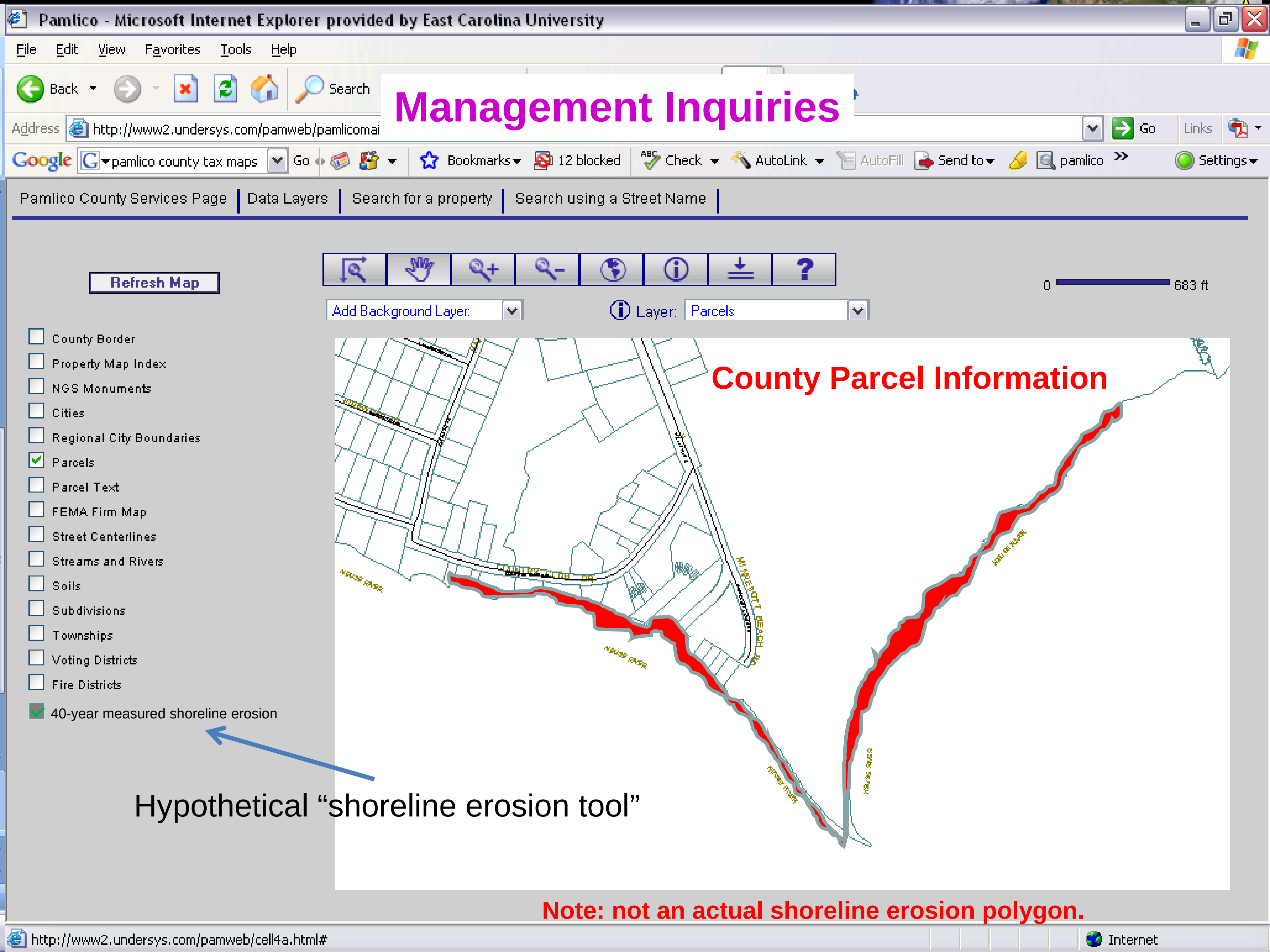
- Shoreline change observations.
- Digital shoreline including structure distribution
- Examples of shorezone change.
- Understanding of geologic evolution.

Focus is the Neuse River Estuary (NRE)

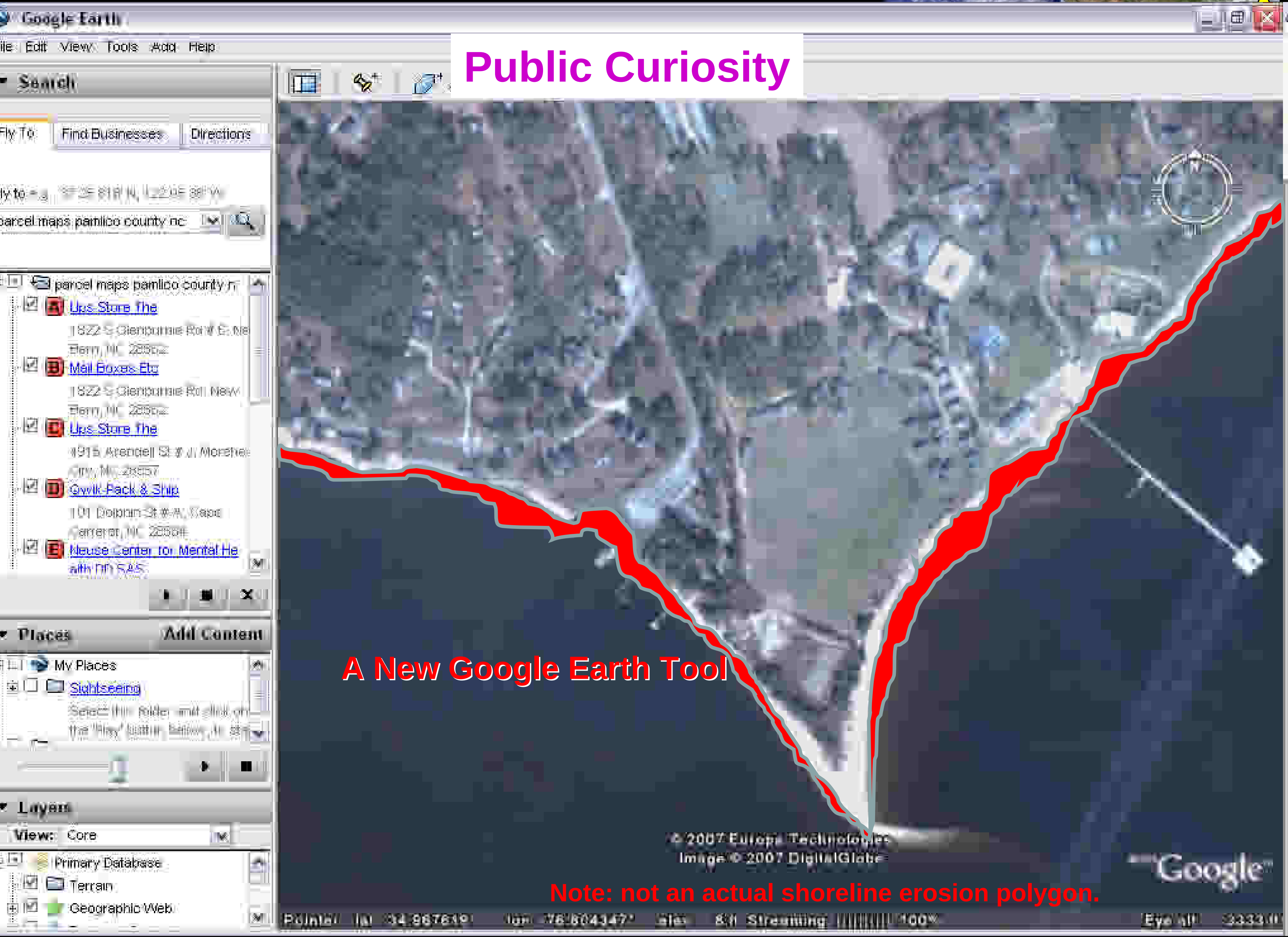
Theoretical Product Examples

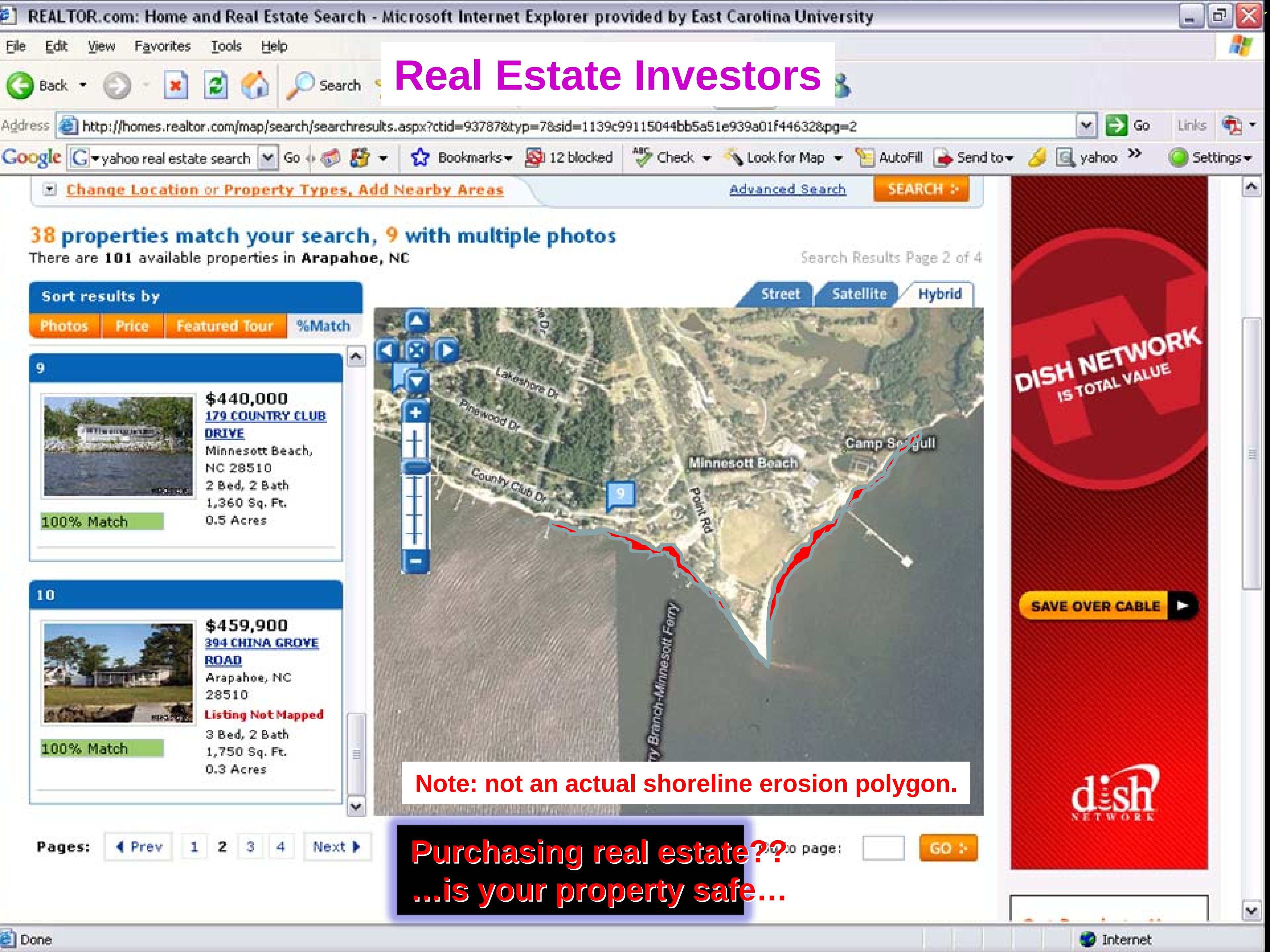
- Shown below is an image with a 1998 aerial photograph along with the 1958 (green) and 1998 (red) digitized shorelines.

The following slides provide some theoretical examples of how these data may be developed into useful products.


Management Inquiries
Pamlico - Microsoft Internet Explorer provided by East Carolina University
File Edit View Favorites Tools Help
Back Search
Address http://www2.undersys.com/pamweb/pamlicomai
Go Links
pamlico county tax maps
Bookmarks 12 blocked Check AutoLink AutoFill Send to pamlico Settings
Pamlico County Services Page | Data Layers | Search for a property | Search using a Street Name
Refresh Map
0 683 ft
Add Background Layer:
Layer: Parcels
County Border
Property Map Index
NGS Monuments
Cities
Regional City Boundaries
Parcels
Parcel Text
FEMA Firm Map
Street Centerlines
Streams and Rivers
Soils
Subdivisions
Townships
Voting Districts
Fire Districts
40-year measured shoreline erosion
County Parcel Information
Hypothetical "shoreline erosion tool"
Note: not an actual shoreline erosion polygon.
http://www2.undersys.com/pamweb/cell4a.html#
Internet

Public Curiosity





Real Estate Investors
REALTOR.com: Home and Real Estate Search - Microsoft Internet Explorer provided by East Carolina University
http://homes.realtor.com/map/search/searchresults.aspx?ctid=93787&typ=7&sid=1139c99115044bb5a51e939a01f44632&pg=2
Change Location or Property Types, Add Nearby Areas
Advanced Search
SEARCH
38 properties match your search, 9 with multiple photos
There are 101 available properties in Arapahoe, NC
Search Results Page 2 of 4
Sort results by
Photos
Price
Featured Tour
%Match
Street
Satellite
Hybrid
9
$440,000
179 COUNTRY CLUB DRIVE
Minnesott Beach, NC 28510
2 Bed, 2 Bath
1,360 Sq. Ft.
0.5 Acres
100% Match
10
$459,900
394 CHINA GROVE ROAD
Arapahoe, NC 28510
Listing Not Mapped
3 Bed, 2 Bath
1,750 Sq. Ft.
0.3 Acres
100% Match
Lakeshore Dr
Pinewood Dr
County Club Dr
Minnesott Beach
Camp Seagull
Point Rd
Note: not an actual shoreline erosion polygon.
Pages: Prev 1 2 3 4 Next
Go to page:
GO
Purchasing real estate??
…is your property safe…
DISH NETWORK IS TOTAL VALUE
SAVE OVER CABLE
dish NETWORK
Done
Internet

North Carolina COastal HAZards Decision Portal

NC COHAZ

- UNC Competitiveness
- Building coastal hazards database
- Including Google Maps viz tools

www.coastal.geology.ecu.edu/NCCOHAZ

NCCOHAZ: Inlet-Opening Potential

Inlet-Opening Potential along the Outer Banks, NC

Shown at left is the standard Google Maps "Satellite" view overlain by a transparent layer of inlet-opening potential along the Outer Banks (OBX) of North Carolina. See the key for the classification levels. Note, the transparency of the inlet-opening-potential layer can be adjusted using the sliding bar at the bottom of the view. The data, where available, highlight the areas with greatest potential for the opening of an inlet during a major storm. Because the opening of an inlet will sever the major transportation route (i.e., Highway 12) along the OBX, such an event is expected to have complicating effects along the OBX as occurred during Hurricane Isabel in 2003. Although many factors are hypothesized to affect inlet opening, the approach used to quantify the hazard is accurate, simple and straightforward, using cross-section measurements of the island volume above sea level (Perkins et al., 2007, Walsh et al., submitted).

Directions for use:

-Use the zoom tool to adjust the focus area.
-Use arrows or click and drag mouse to pan the view.
-Adjust layer transparency with slide bar below map.

NOTE: Page best viewed using **Mozila Fire Fox 2.0.**

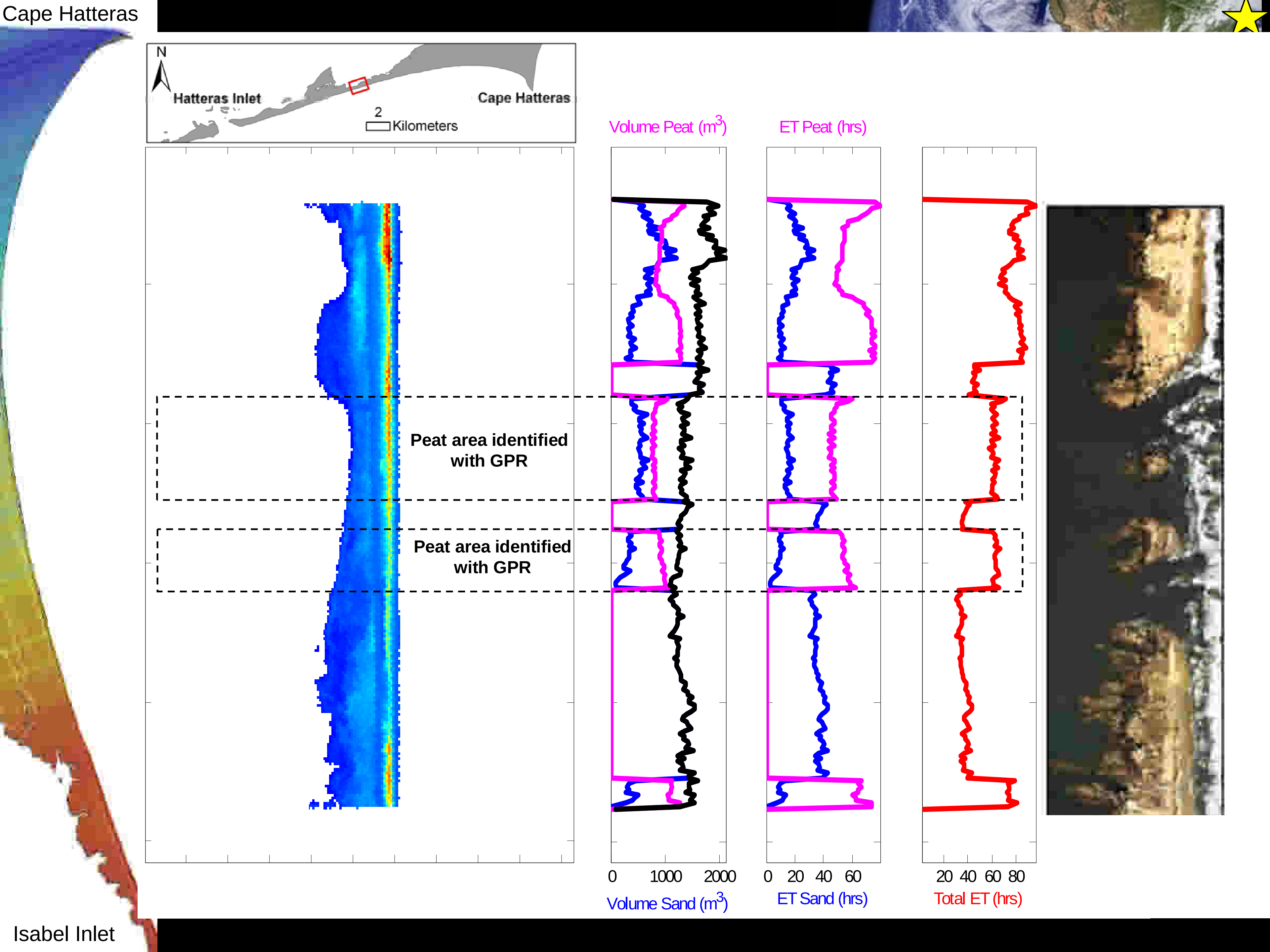
Click a link below to navigate to a specific town

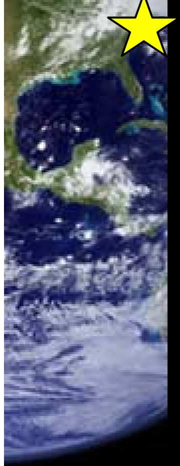
Avon	Nags Head
Buxton	Rodanthe
Frisco	Salvo
Hatteras Village	Southern Shores
Kill Devil Hills	Waves
Kitty Hawk	

EAST CAROLINA UNIVERSITY

Built using the new Google Maps API

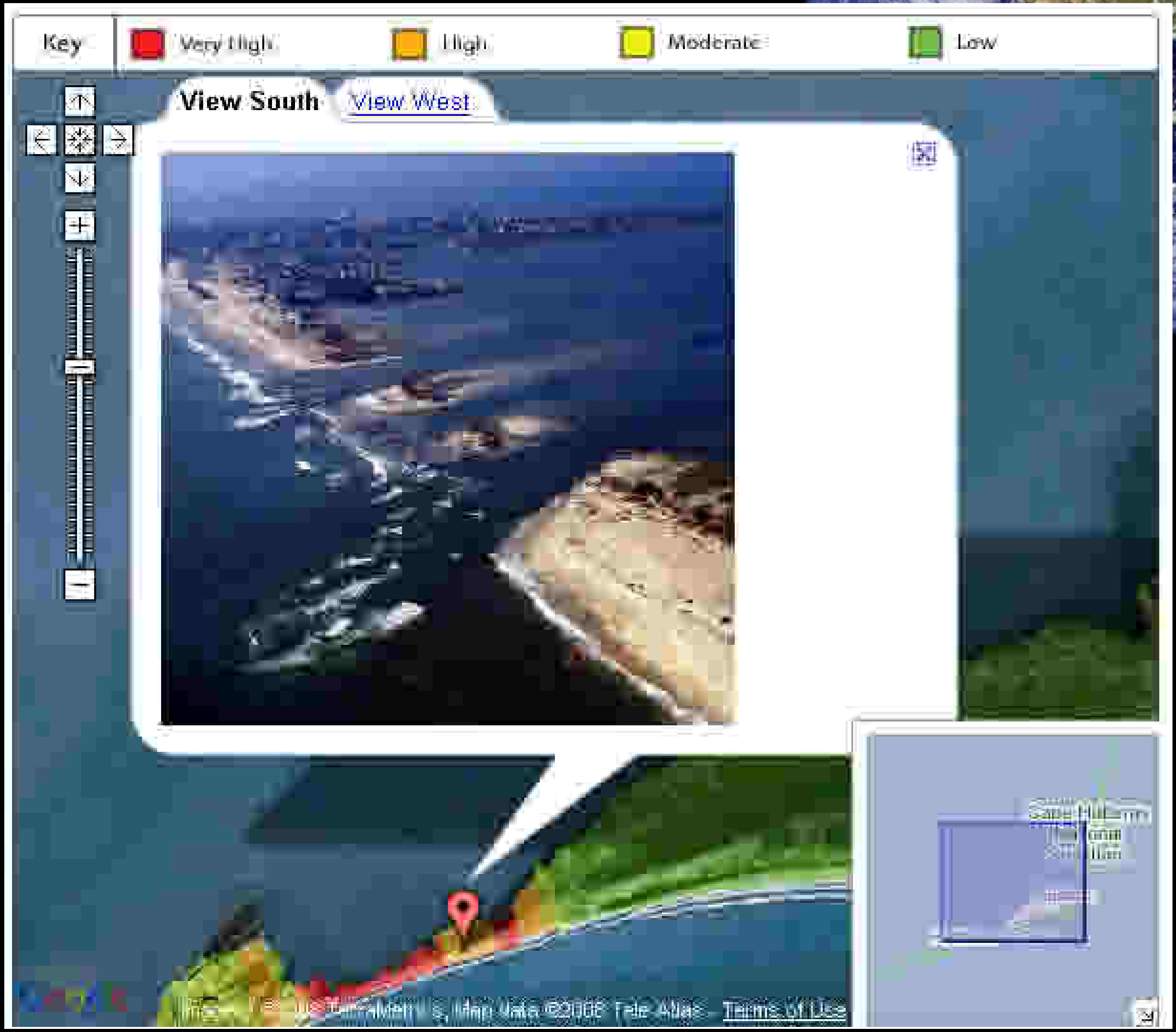
Question, Comments, Concerns? Contact Us


Cape Hatteras
N
Hatteras Inlet
Cape Hatteras
2
Kilometers
Peat area identified with GPR
Peat area identified with GPR
Volume Peat (m3)
ET Peat (hrs)
0
1000
2000
Volume Sand (m3)
0
20
40
60
ET Sand (hrs)
20
40
60
80
Total ET (hrs)
Isabel Inlet



lets in last century.

Cape Hatteras



Isabel Inlet

NCCOHAZ: Real-time Coastal Hazards in northeastern North Carolina

Shown at left are active (or very recent) coastal hazards in the region, including river flooding, potentially dangerous winds, low dissolved oxygen (cause of fish kills), high coastal water levels, and large waves (a risk for rip currents, boaters and erosion). Measurements or warnings of hazardous conditions are shown in hot colors (yellow to red).

Click on any station to query latest data

Click on the "+" at left to add or remove layers (e.g., Doppler radar)

Warning and Observation Layers

- NWS Severe Thunderstorm warning
- NWS Flash Flood warning
- NWS Tornado warning
- NWS Special Marine warning
- River Gauge Level
  - Normal, Action, Flood
  - Moderate Flood, Major Flood
- Water Quality station
- low Dissolved Oxygen warning

- Waves (height @ period), Hazard (> 5m)
- Wind, Hazard (>22kts), Calm
- Water Level low, at MSL, high

Legend: Warnings & Observations | Background

This mapping tool for NCCOHAZ was created by researchers at UNC Chapel Hill (Jesse Cleary and Harvey Seim) in collaboration with J.P. Walsh and Reide Corbett (ECU).