Geospatial Infrastructure for Change Monitoring within Coastal Sentinel Sites

NERRS Training Session April 2012

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Objectives (1)

- To effectively combine spatially discrete ecosystem observations to assess the impacts of sea level change on coastal marshes

- To ensure consistent results across a national network of Sentinel Sites

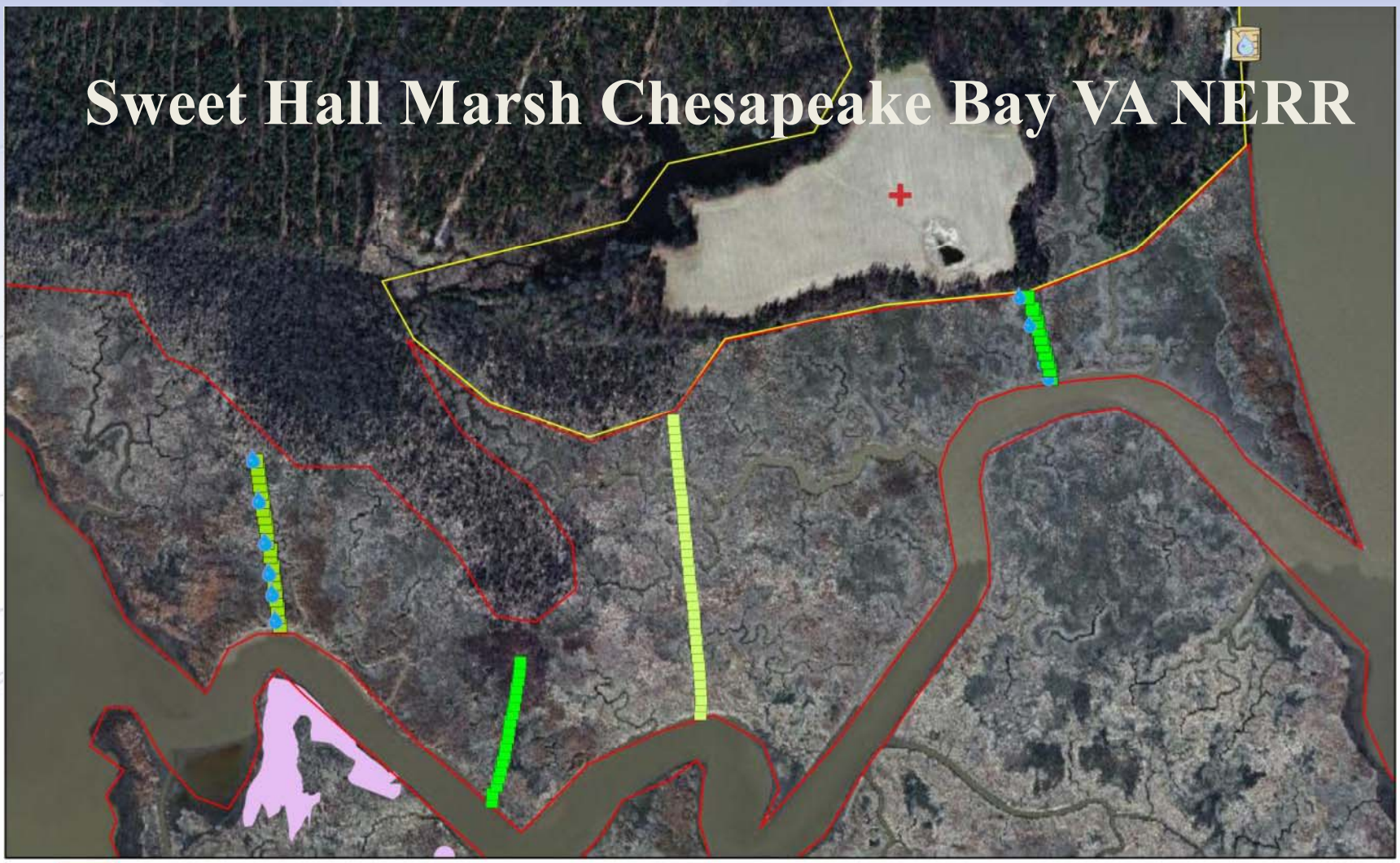
Objectives (2)

- To relate patterns/changes in vegetation over time to wetland elevation and changes in local water levels/inundation
- To document changes in the inundation and tidal range at a given site
- To understand the relationship between marsh surface elevation change and local water levels

The Challenges

- Sea level rise/impact is locally expressed
- Different rates of motion among sea level, uplands, and coastal wetlands
- Multiple Datums – Multiple sensors each with own "zero point"
- Spatial scale – Millimeters of change per year over thousands of kilometers of shorelines
  - Local vs. Network Accuracy
- Time Scale – Need for ongoing observations for decades into the future.

Sweet Hall Marsh Chesapeake Bay VA NERR




Four Components of Chesapeake Bay Virginia NERR
Sweet Hall
Taskinas Creek
Catlett Island
Goodwin Islands
King and Queen
Lancaster
Middlesex
New Kent
Mathews
James City
Williamsburg
York
Northampton
Poquoson
Surry
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2009 Europa Technologies
Image © 2009 Commonwealth of Virginia
© 2009 Google
Imagery Date: Feb 1, 2007
37°25'52.55" N 76°33'10.66" W elev 72 ft
Eye alt 59.15 mi
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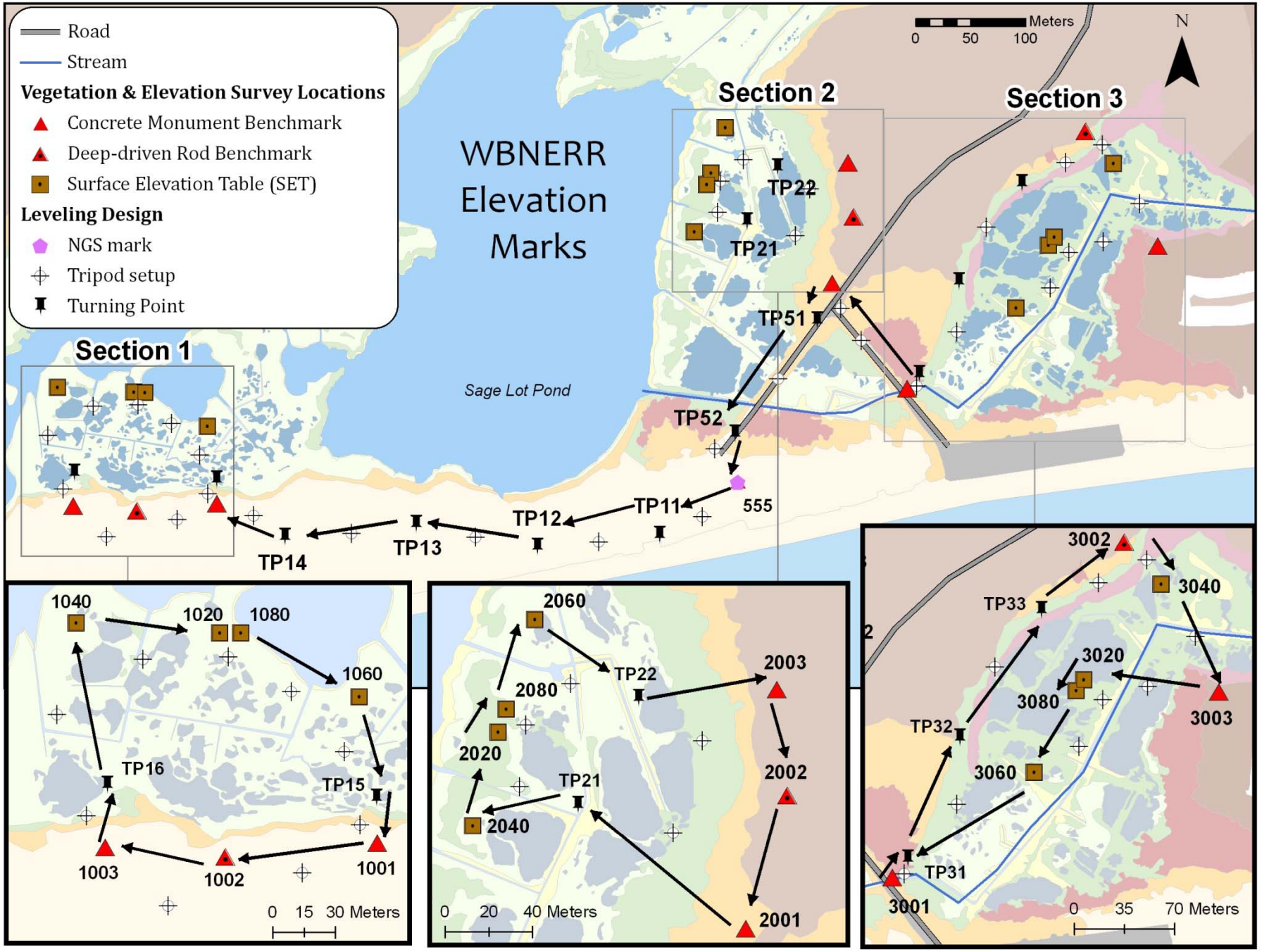
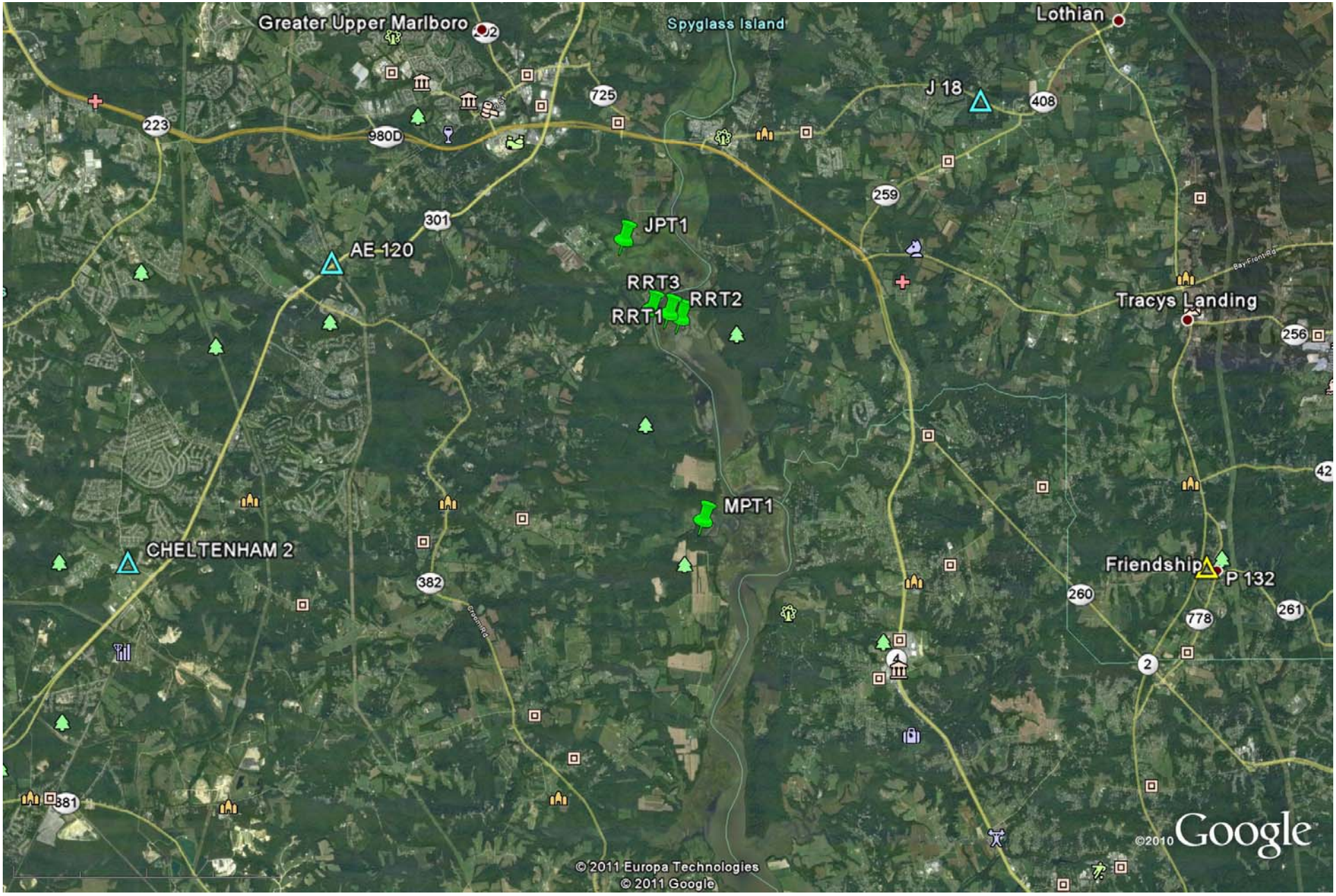
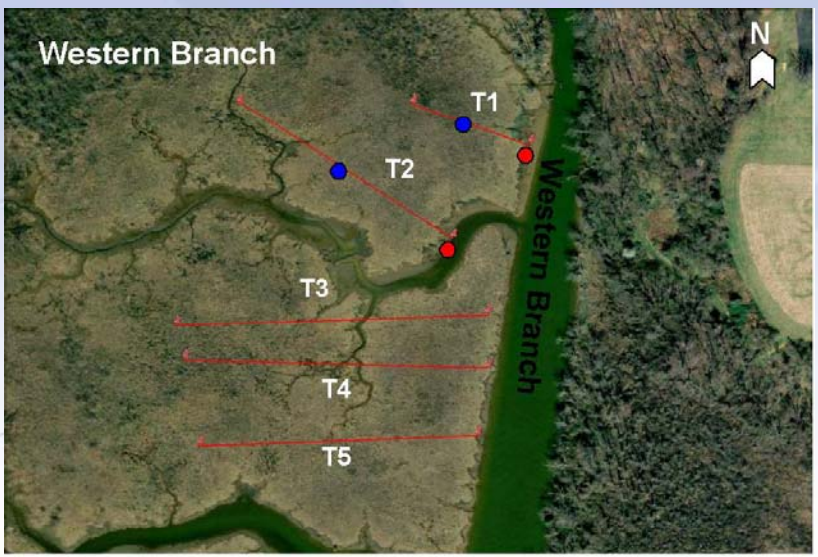
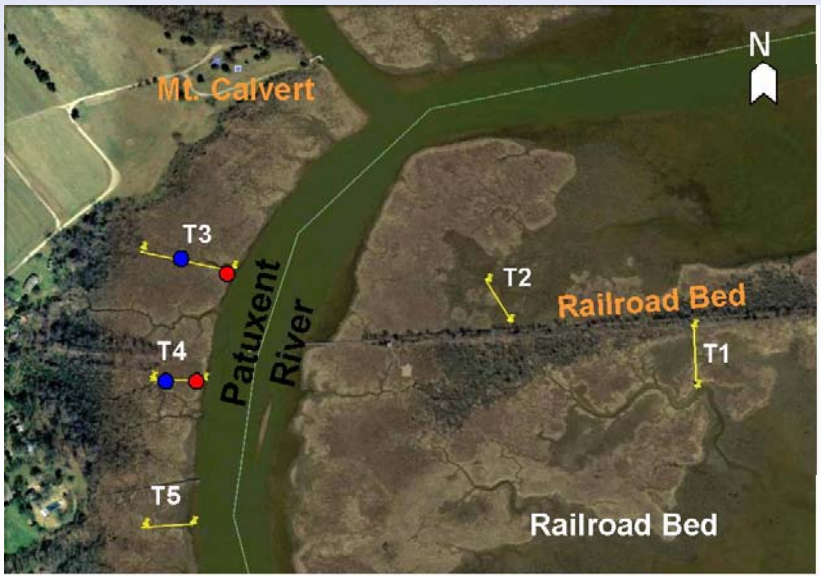
J. Mora ~ Dec 2011

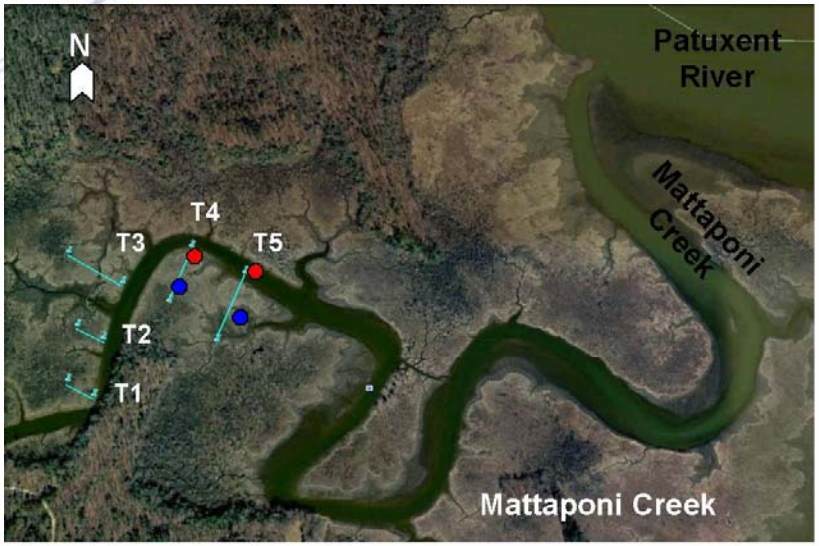




Vertical control marks at the Jug Bay component of the CBNERR-MD







Chesapeake Bay MD:
Jug Bay Component

Geospatial Infrastructure Components

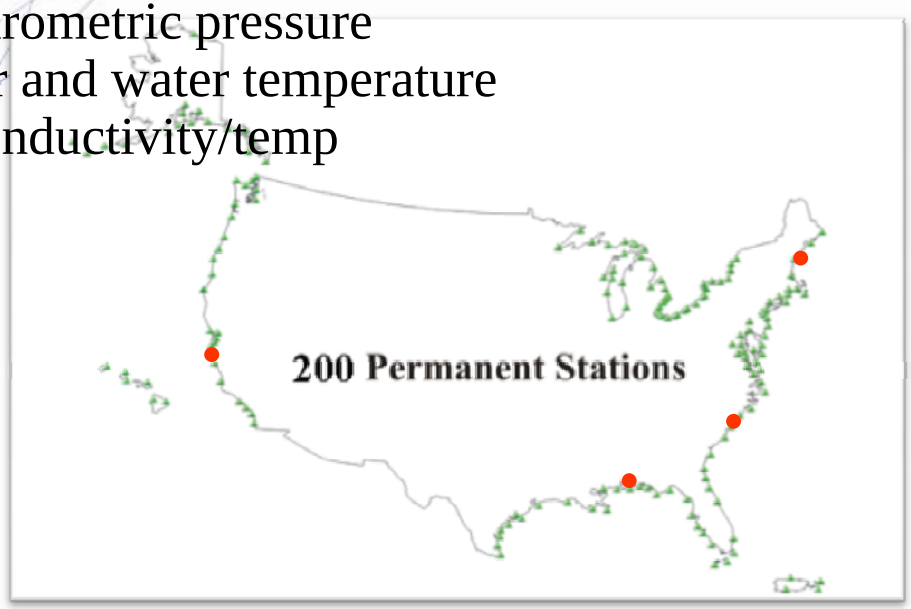
- Local Geodetic Control Network
  - A network of permanent survey control points are required to accurately measure the relative movements of these observing systems and to compare their data trends over time.
- Tide Stations
  - NWLON, temporary tide stations, local SWMP stations
- Ecological monitoring infrastructure and data
  - SETs
  - Vegetation transects
  - Groundwater wells
  - Marsh DEMs
  - Lidar
  - Shallow water bathymetry
  - Multispectral imagery, etc.

NWLON

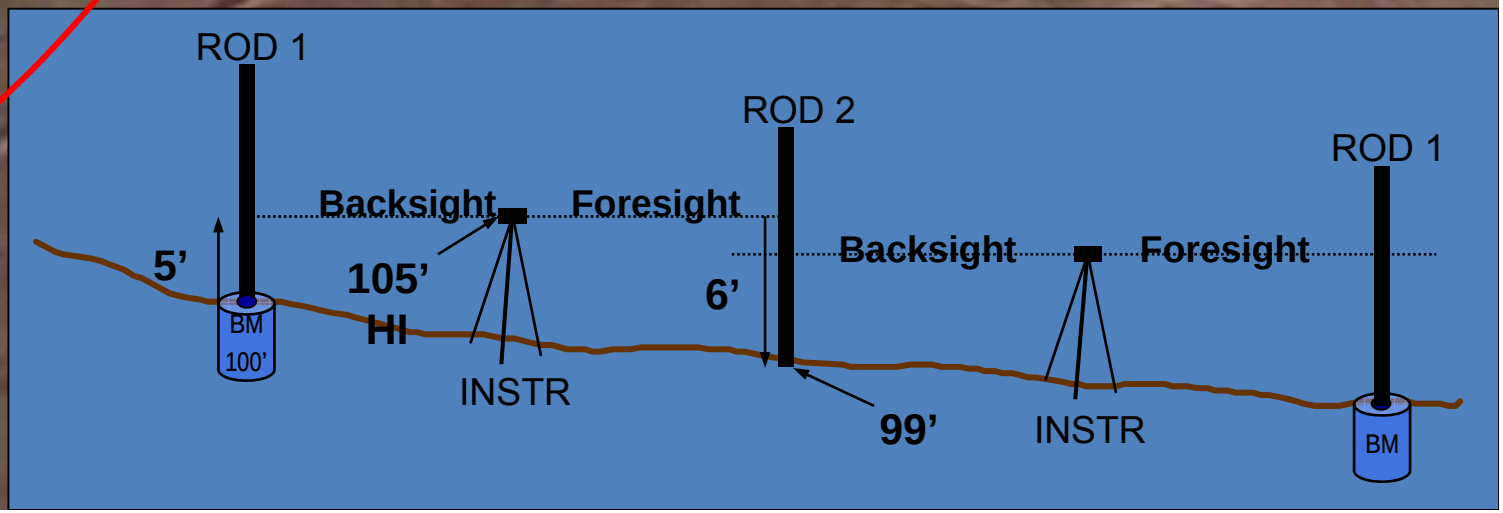
National Water Level Observation Network (NWLON)

A network of continuously operating tide stations that are the foundation for NOAA's tide prediction products

The network provides:
- water level
- wind speed and direction
- barometric pressure
- air and water temperature
- conductivity/temp

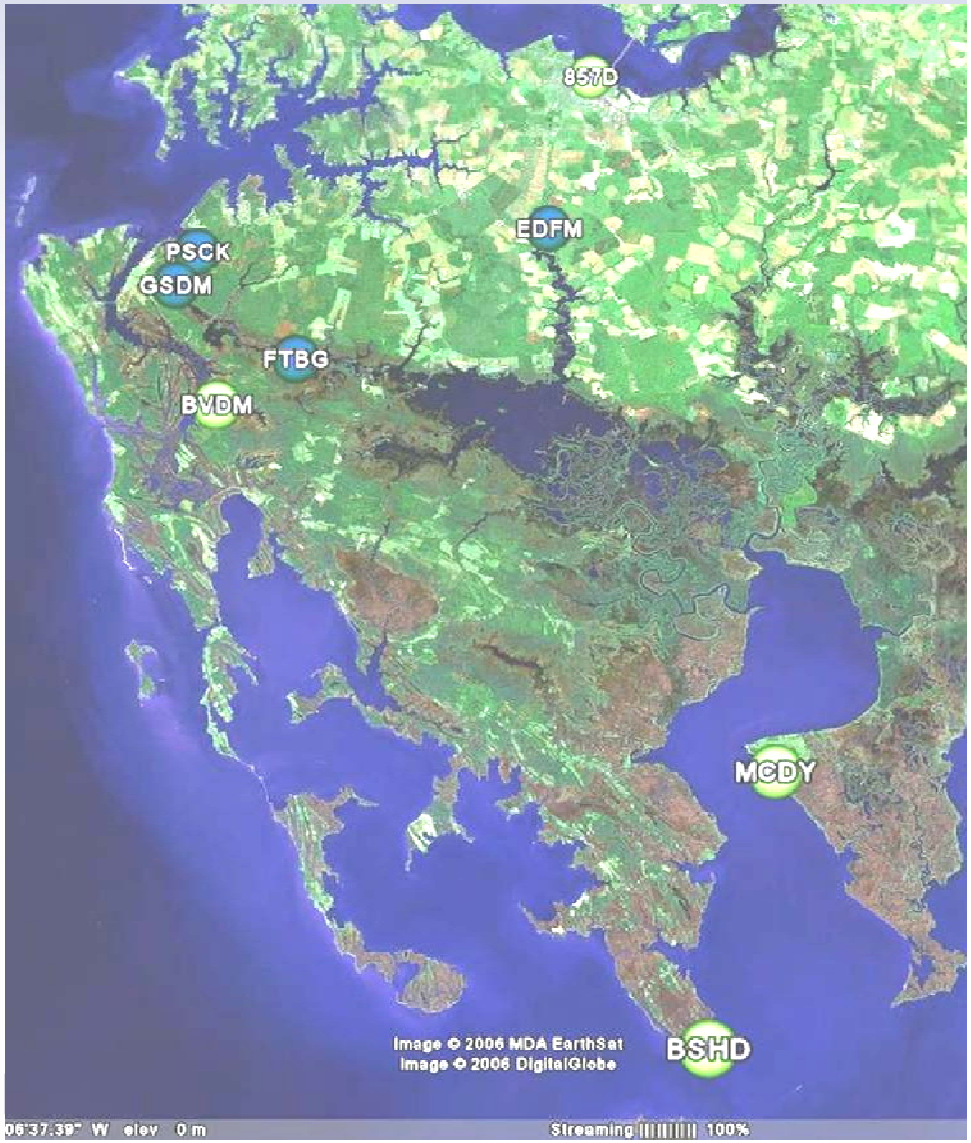


McCready's Creek Tide Station and Tidal Benchmarks



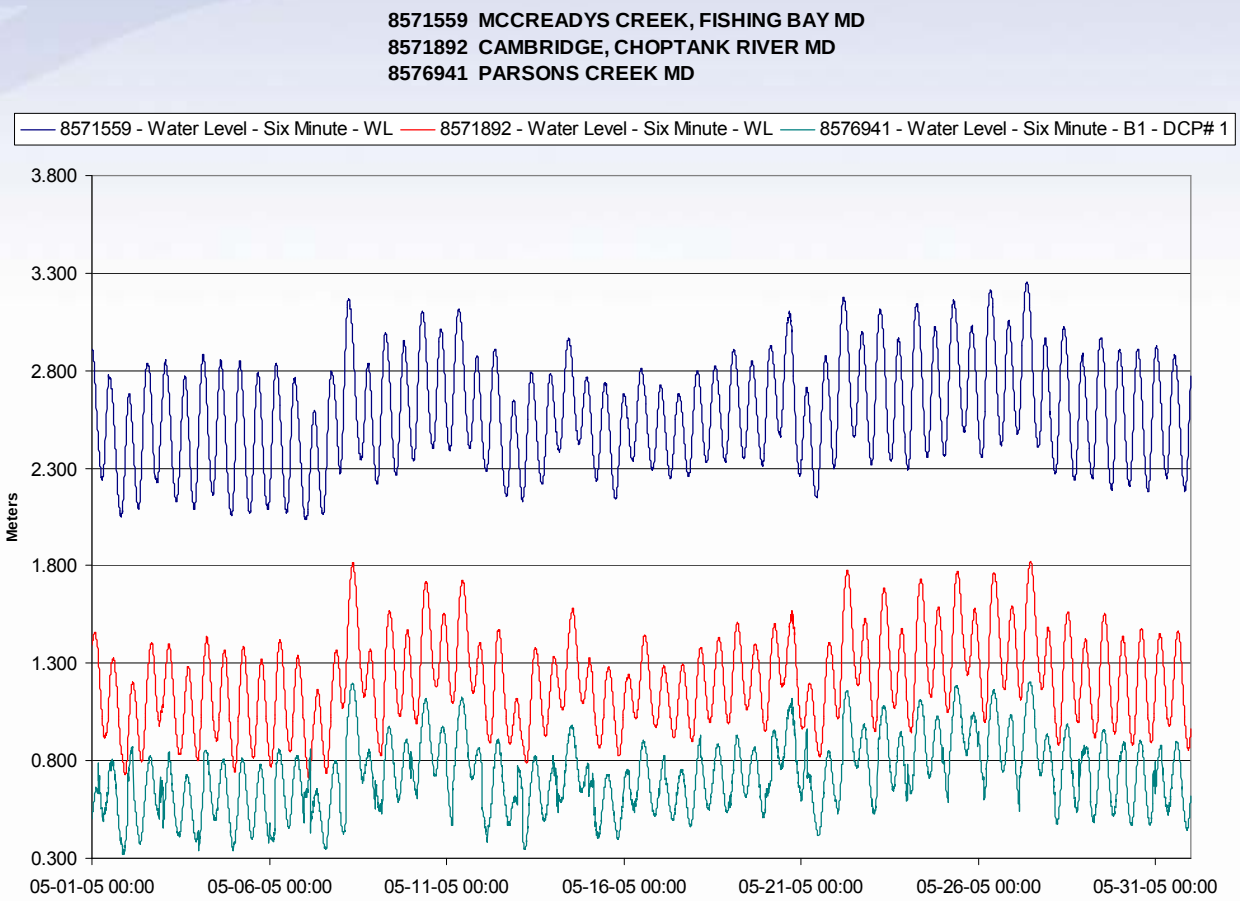
The Case for a Common Vertical Reference Frame

- Have water level observations from eight points in and around Blackwater.
  - •4 NOAA Tide guages
  - •4 USGS water-level gages
- Each is on a local datum, with water levels referenced to nearby points on the ground



The Case for a Common Vertical Reference Frame

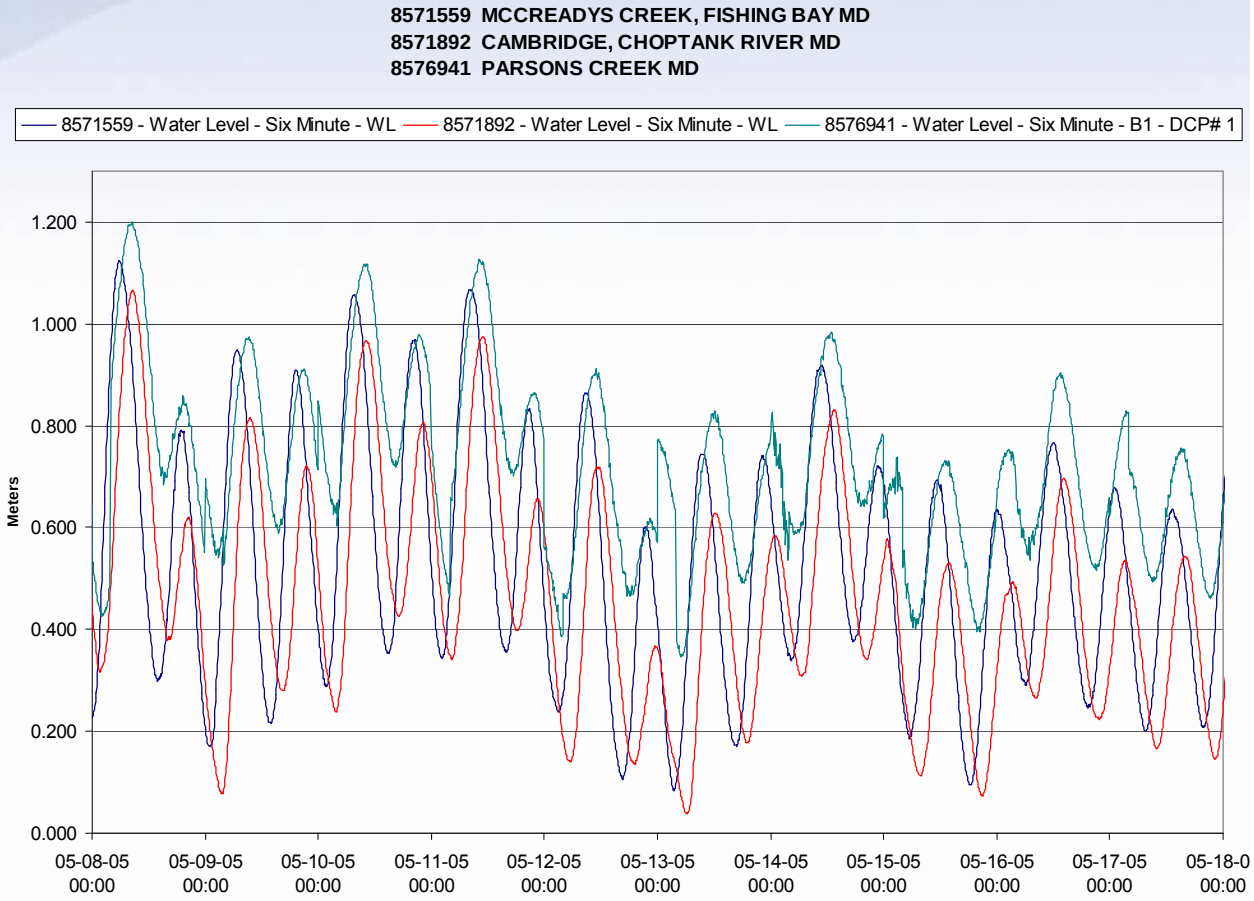
Observing systems such as tide stations, water level gages, and SETs require a "Zero Point" to compare to each other.



Each gage referenced to its own local "island" datum

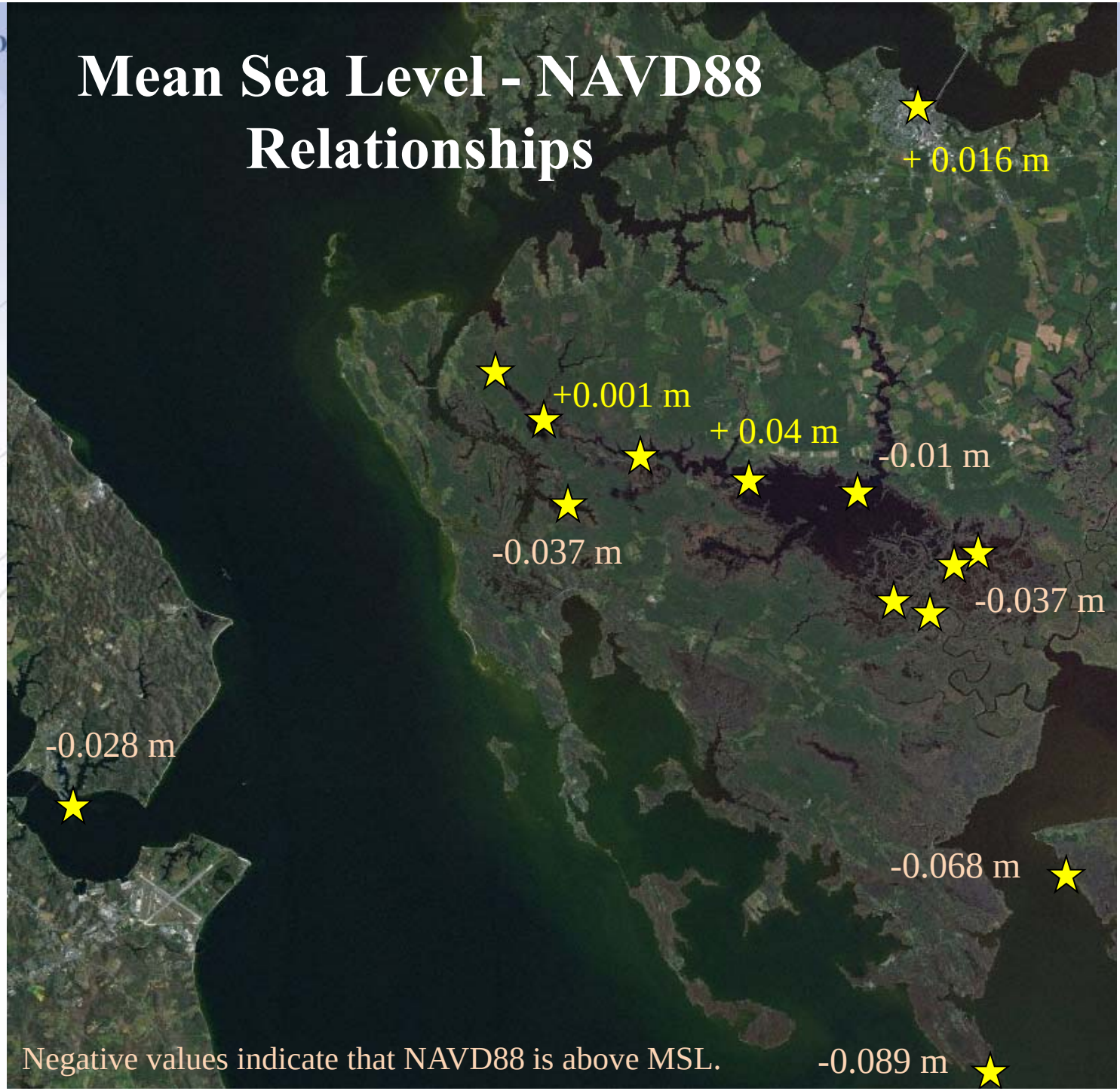
The Case for a Common Vertical Reference Frame

NAVD88 can serve as the common vertical reference system, to enable comparison of observations.



Each gage referenced to NAVD88

Mean Sea Level - NAVD88 Relationships



CORS Network

Continuously Operating Reference Stations (CORS)

A multi-purpose cooperative network providing 3-dimensional positioning

- Continually desnifying network
- Will incorporate results from GRAV-D for increased accuracy of vertical positioning
- Co-locating with other instruments increases overall knowledge
- Not specifically designed to measure vertical velocity of land

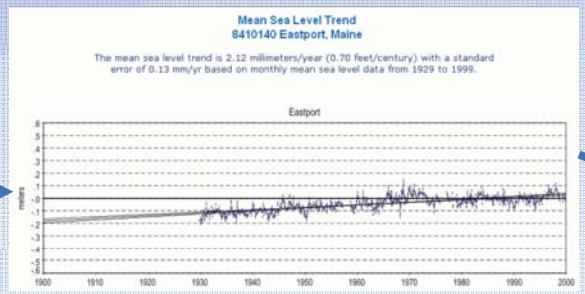
Coordinating Technology for Sea-Level Rise

Observing Systems

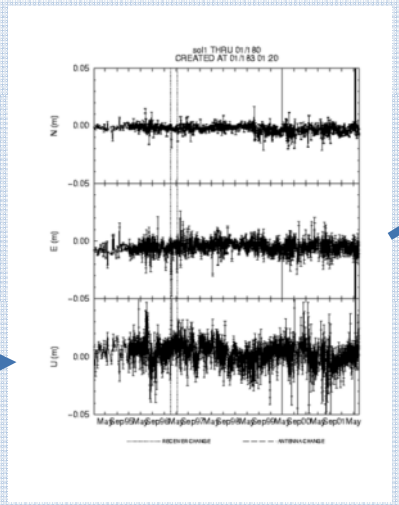
NWLON

CORS

Local Predictions

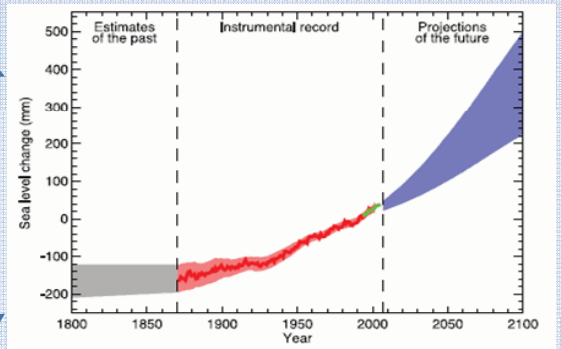


Local Relative Sea Level Trends



Vertical and Horizontal Land Movement

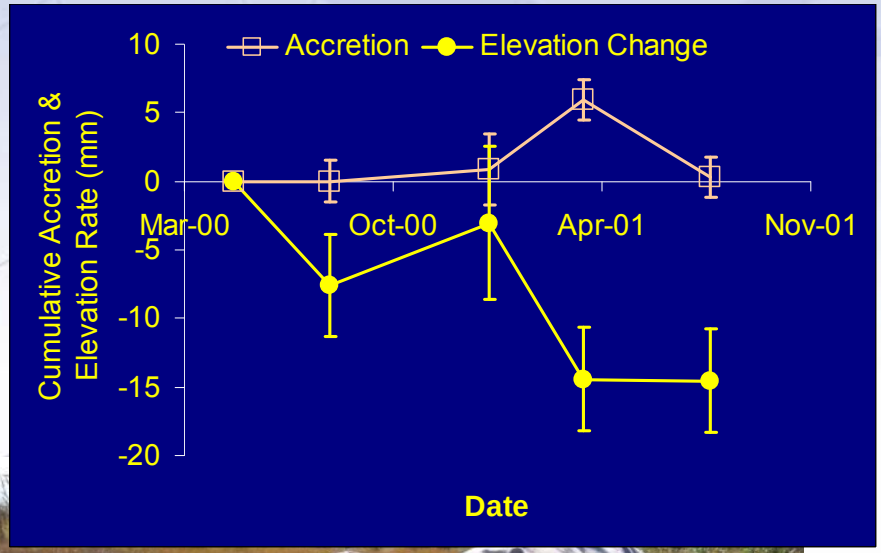
Global Predictions



FAQ 5.1, Figure 1. *Time series of global mean sea level (deviation from the 1980-1999 mean) in the past and as projected for the future. For the period before 1870, global measurements of sea level are not available. The grey shading shows the uncertainty in the estimated long-term rate of sea level change (Section 6.4.3). The red line is a reconstruction of global mean sea level from tide gauges (Section 5.5.2.1), and the red shading denotes the range of variations from a smooth curve. The green line shows global mean sea level observed from satellite altimetry. The blue shading represents the range of model projections for the SRES A1B scenario for the 21st century, relative to the 1980 to 1999 mean, and has been calculated independently from the observations. Beyond 2100, the projections are increasingly dependent on the emissions scenario (see Chapter 10 for a discussion of sea level rise projections for other scenarios considered in this report). Over many centuries or millennia, sea level could rise by several metres (Section 10.7.4).*

Global Mean Sea Level

SET Technology



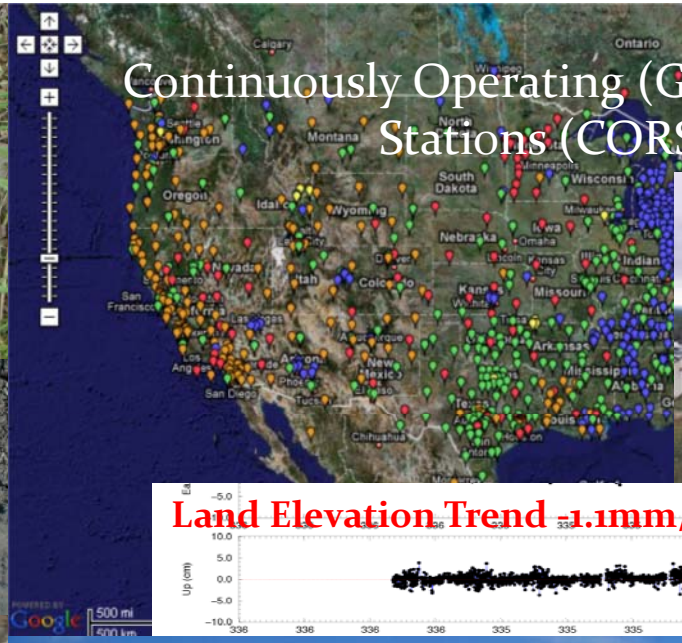
Surface Elevation Tables (SETs)

Portable leveling device to measure relative elevation of wetland sediments.

- SETs monitor coastal land elevation relative to local sea level rise
- Provides further understanding to processes leading to the formulation and maintenance of coastal elevation

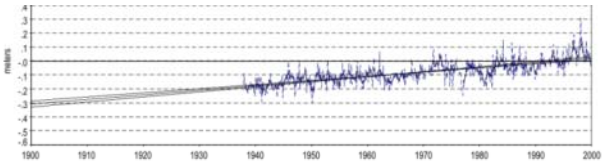
Survey Control Monuments

Continuously Operating (GPS) Reference Stations (CORS)



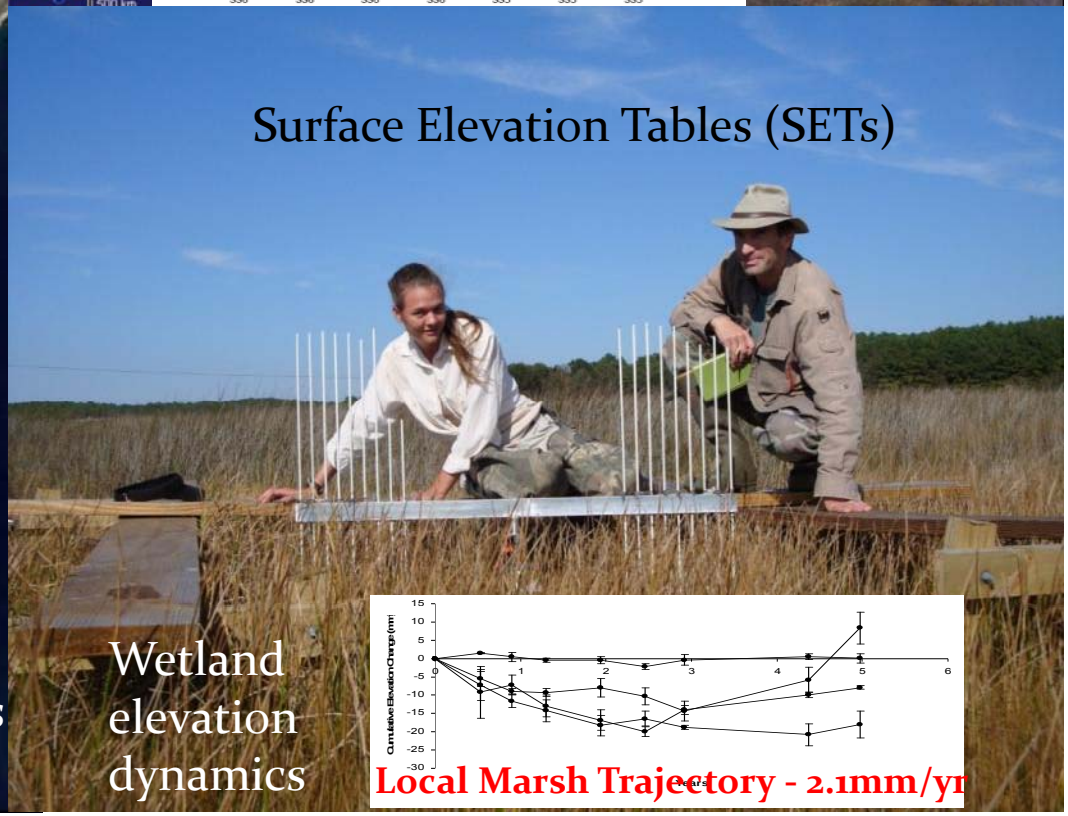
Land Elevation Trend -1.1mm/yr

Local Sea-Level Rise 3.29 mm/yr



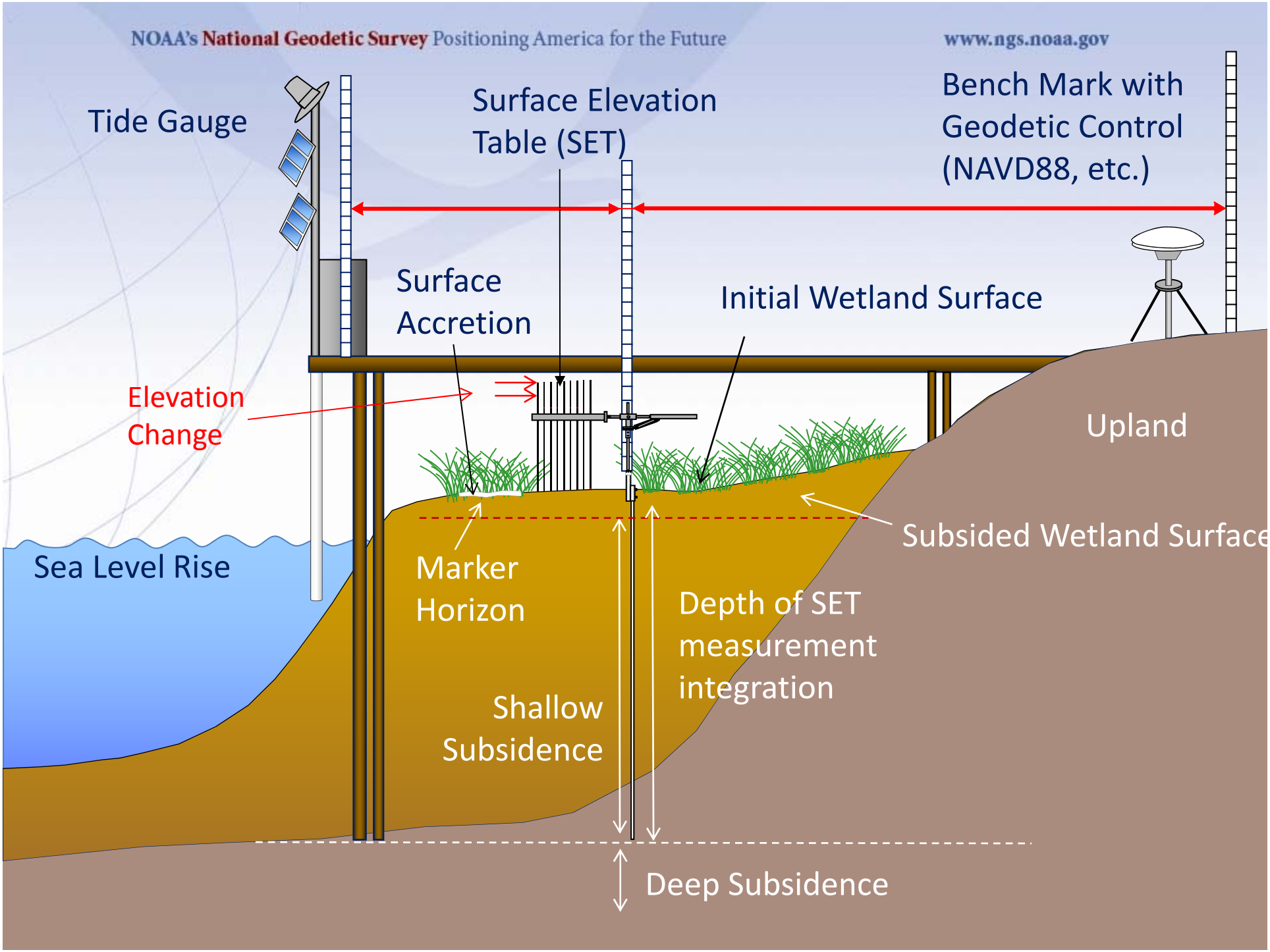
Long Term Tide Stations

Surface Elevation Tables (SETs)



Wetland elevation dynamics

Local Marsh Trajectory - 2.1mm/yr


NOAA's National Geodetic Survey Positioning America for the Future
www.ngs.noaa.gov
Tide Gauge
Surface Elevation Table (SET)
Bench Mark with Geodetic Control (NAVD88, etc.)
Surface Accretion
Initial Wetland Surface
Elevation Change
Upland
Subsided Wetland Surface
Sea Level Rise
Marker Horizon
Depth of SET measurement integration
Shallow Subsidence
Deep Subsidence

Surveying Protocols

Surveying Methods for Establishing and Monitoring Vertical Control Networks

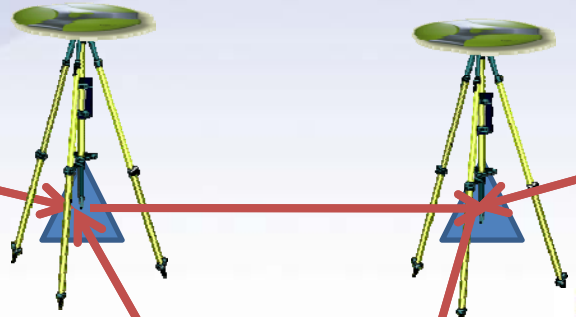
- **Static GPS** – For Establishing control networks and monitoring stability of networks over time (subsidence)
  - 2 – 5 cm Accuracy (relative to NSRS)
  - Long occupation times (5 hours per point)
  - Relatively low technical expertise required

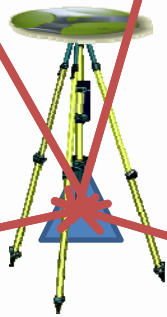
- **RTK GPS** – For creating Digital Elevation Models and positioning remote or hard to reach points.
  - 1 to 5 cm accuracy (relative to local network)
  - Short occupation times (1 second to 6 minutes)
  - High technical expertise required

- **Leveling** – Highest accuracy method for local network connections and monitoring of network and sensor stability.
  - Sub-Centimeter accuracy (local and NSRS)
  - Time commitment depends on distance of connections
  - Moderate to High Technical expertise required

Establishing a Local Geodetic Network at Each Reserve
Tool: Static GPS

Result: Sub-decimeter accuracy to the National CORS network.





- **Minimum of three geodetic control marks at each reserve component**
- **Simultaneous observations of all 3 markers, during two separate GPS constellations**
- **Observe for as long as practicable, 5 – 48 hour sessions recommended**

CORS

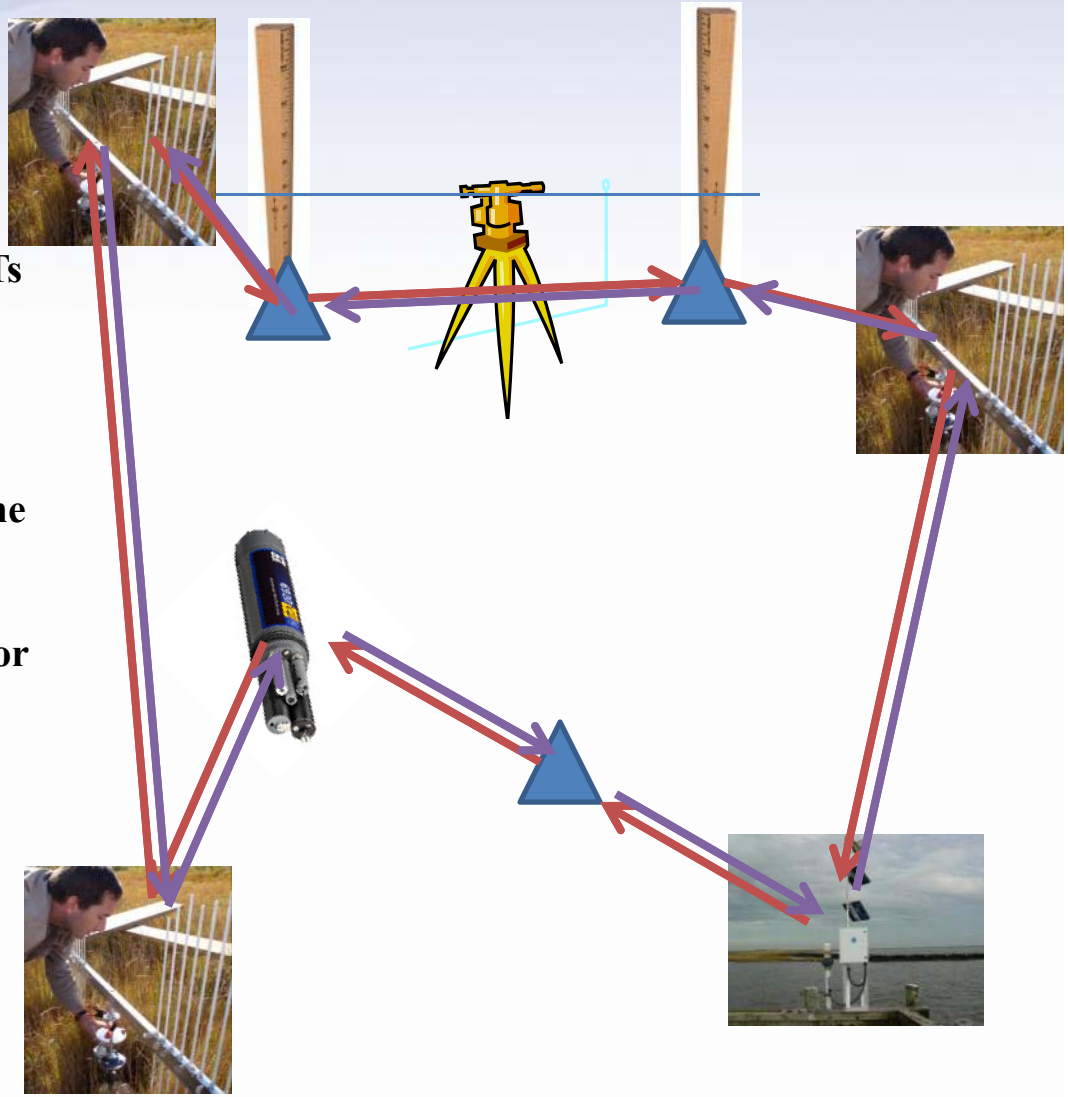
Control Monument

- **Use OPUS to reduce GPS data and select option to "submit to database".**
- **Final positions are the average of the two independent solutions.**

Connecting NERRS sensors to the Local Geodetic Network
Tool: Geodetic Leveling

Result: Sub-Centimeter relative accuracy to the local network

- **Double run level loop (per NGS guidelines) through all Control Monuments, SWMP Station, or NWLON station if available, and as many SETs or other sensors as can be leveled to.**
- **Elevation differences hand computed**
- **Averaged OPUS GPS Derived Heights held at one Control Monument.**
- **OPUS results from other monuments archived for future comparison.**



Control Monument

SET

SWMP Station

Connecting SET sites and water level gauges to NAVD88

Digital (laser) barcode leveling

Second order class 2 leveling (8 mm km^{-1})

Reference: height modernized vertical marks (NGS or SET BM's)

Connecting SET sites and water level gauges to NAVD88

NAVD88 height transferred to SET reference plane (deployed arm)

NAVD88 height transferred to pins of known lengths to sediment surface

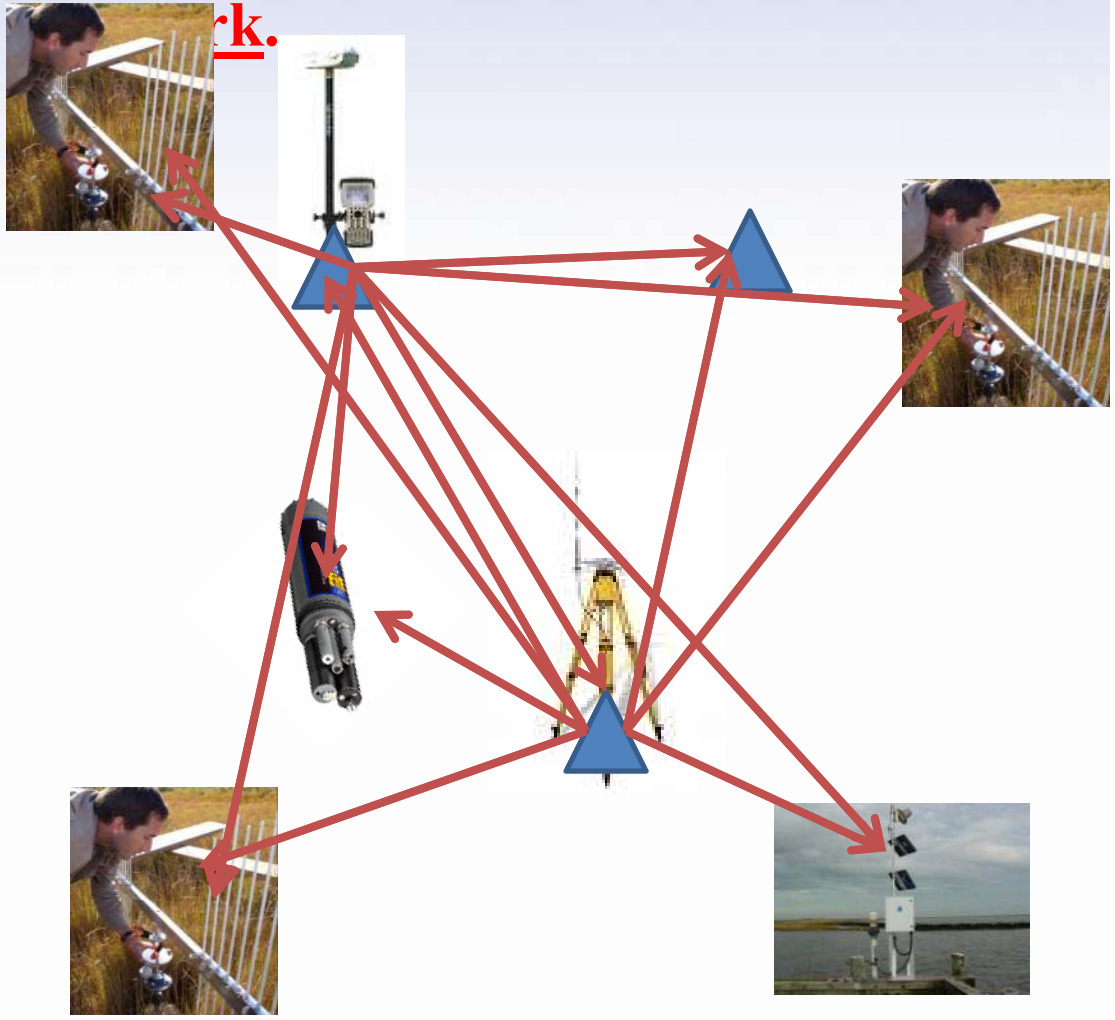
Photo courtesy of Don Cahoon, USGS

Connecting NERRS sensors to the Local Geodetic Network
Tool: Kinematic GPS

Result: Centimeter level relative accuracy to the local rk.

- **Following NGS RTK Guidelines, use RTK to determine position information for all sensors and other measurements not accessible by geodetic leveling.**

- **All RTK observations are conducted with the base station set up at one of the 3 local control marks.**



Control Monument

SET

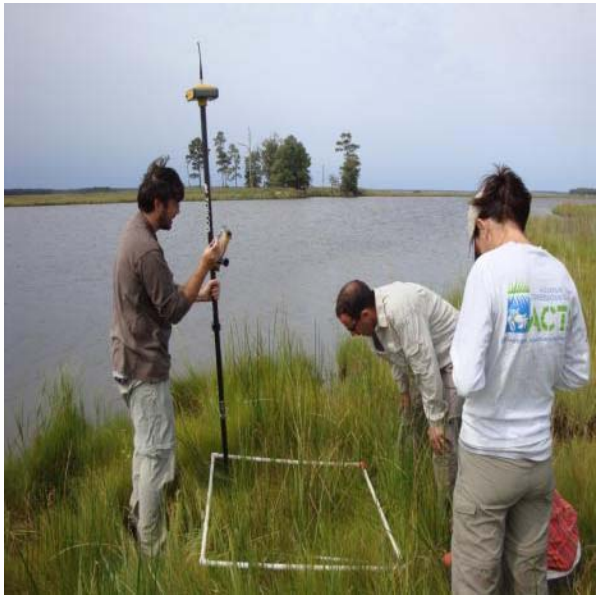
Water level Station

RTK elevations in a field of SET bench marks

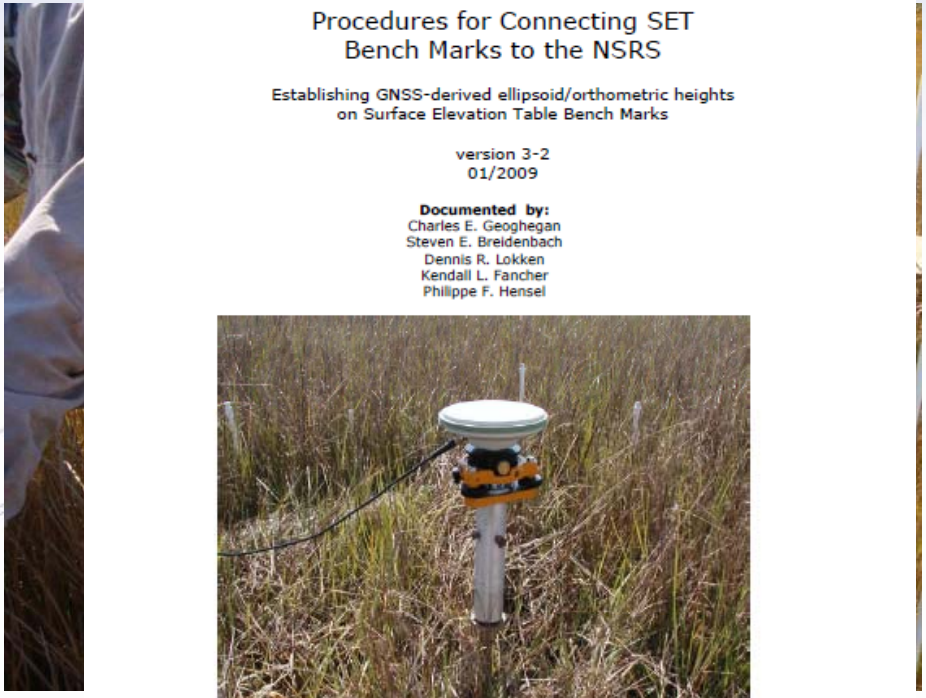
The Need for Ongoing Monitoring of Geospatial Infrastructure

Developing Surveying Protocols for Tying Sensors to Common Datums

NGS, CO-OPS and CBVANERR working on Guidelines Documents



Establishing Heights on Surface Elevation Tables (SET)



Procedures for Connecting SET Bench Marks to the NSRS

Establishing GNSS-derived ellipsoid/orthometric heights on Surface Elevation Table Bench Marks

version 3-2
01/2009

Documented by:
Charles E. Geoghegan
Steven E. Breidenbach
Dennis R. Lokken
Kendall L. Fancher
Philippe F. Hensel

DRAFT Document
Please submit comments to Philippe Hensel

- *New* Fixed Dimension SET based on error analysis of previous instrument designs
- NGS Approved Guidelines for establishing Orthometric Heights on SET foundations
- Statistical framework for SET experimental design and data analysis
- Technical Assistance for SET deployment design and data analysis protocols

Geospatial Infrastructure Installation Process Steps

Geospatial Infrastructure Installation Step 1

- **Design customized geodetic and tidal control network plan** to support sea level sentinel site monitoring infrastructure on a case by case basis, based on the individual scientific and management requirements at each Site.

Geospatial Infrastructure Installation Step 2

- **What do we already have in the ground?**
  - Conduct an inventory of existing control/marks within proximity of the proposed local control network
  - DSWorld, Datasheets
  - USmart – USACE recon tool
  - Compare "ideal" plan to what is already available.

Geospatial Infrastructure Installation Step 3

- **Conduct reconnaissance** to find existing marks but also, to document descriptions of proposed local control network locations.
  - Prioritize marks by stability and mark type to create an initial plan and organize according to what is necessary for the accuracy of the survey.
  - Recover marks in the field using the station descriptions on the NGS datasheets and CO-OPS station descriptions
  - Note of the condition of the existing or proposed marks, any new landmarks or disturbances in the area, or any change to the station description.

Geospatial Infrastructure Installation Step 4

- **Submit preliminary survey plan to NGS ECO**
  - Maps and shape files with locations of local geodetic control network marks and monitoring elements
  - Brief description of recovered marks, proposed marks (including construction and assumed stability type), any bench mark recovery sheets, photos, as well as proposed techniques to obtain elevations on marks and for transferring marks to monitoring elements

Geospatial Infrastructure Installation Step 5

- **Install survey control monuments according to network designs.** This includes both geodetic control points needed to bring accurate heights into sites as well as tidal marks required as control for water level stations

Geospatial Infrastructure Installation Step 6

- Conduct Static GPS Campaign to tie local network to NSRS
  - Simultaneous (if possible) 5^{+} hour occupations over different days.

Geospatial Infrastructure Installation Step 7

- **Submit GPS data** to NGS via Online Positioning Users Service (OPUS)
  - Use OPUS to reduce GPS data and select option to "submit to database"
  - Final positions are the average of the 2 independent solutions.

Geospatial Infrastructure Installation Step 8

- **Level among control marks if possible**
  - To the maximum extent practicable, use second order techniques using a digital barcode level.
  - Hold one geodetic control point constant.
  - Archive all raw level data as well as calculated height differences.

Geospatial Infrastructure Installation Step 9

- **Transfer elevations from local control network to monitoring infrastructure.**
  - Surface and Ground water level sensors
  - Vegetation transects
  - SETs

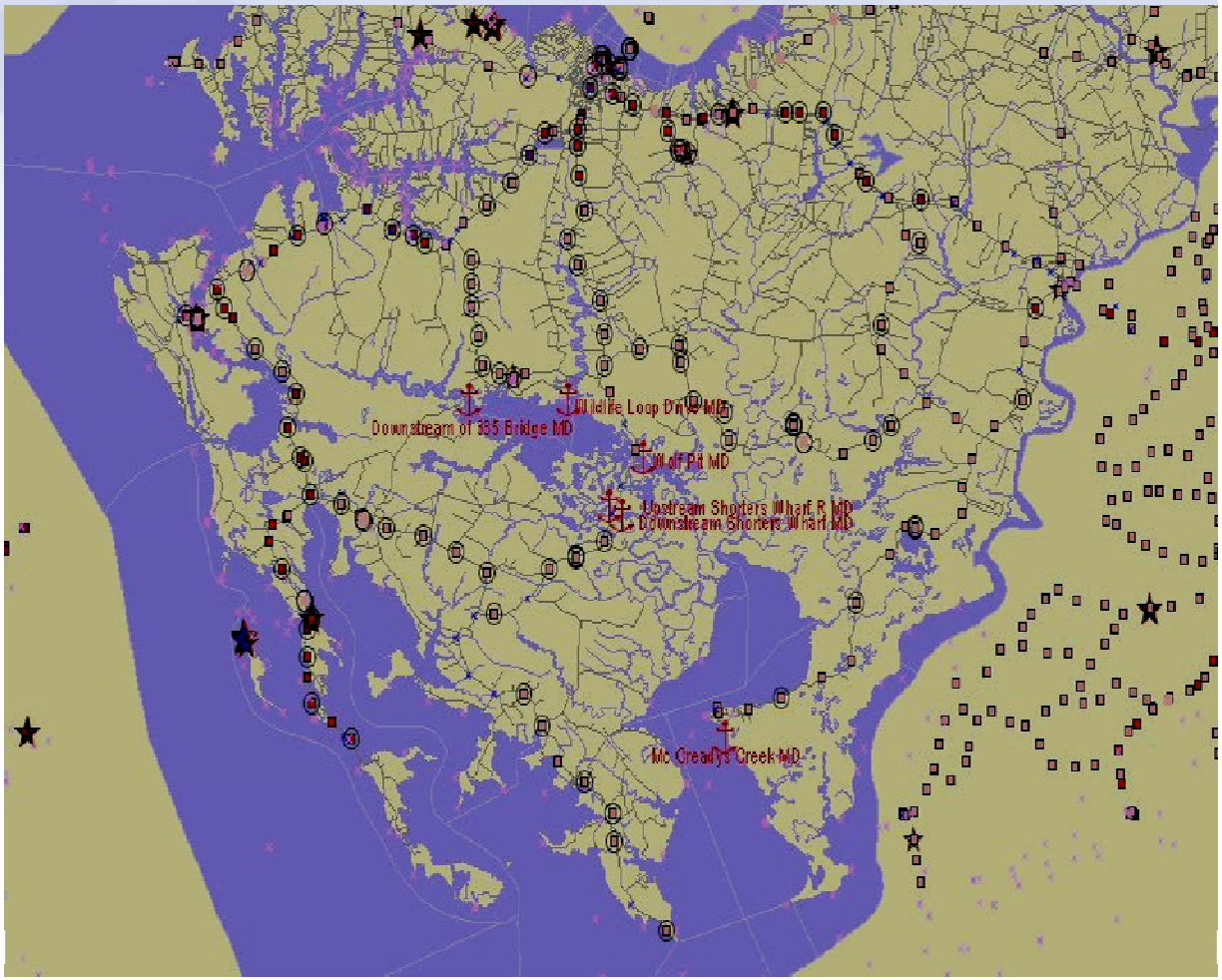
Geospatial Infrastructure Installation Step 10

- **Compute tidal datums from local observations**
  - Calculate elevation capital
  - Compute frequency and duration of inundation
  - Conduct seasonal analysis
  - Observe long term sea level trends

Blackwater Height Mod Example

Reconnaissance

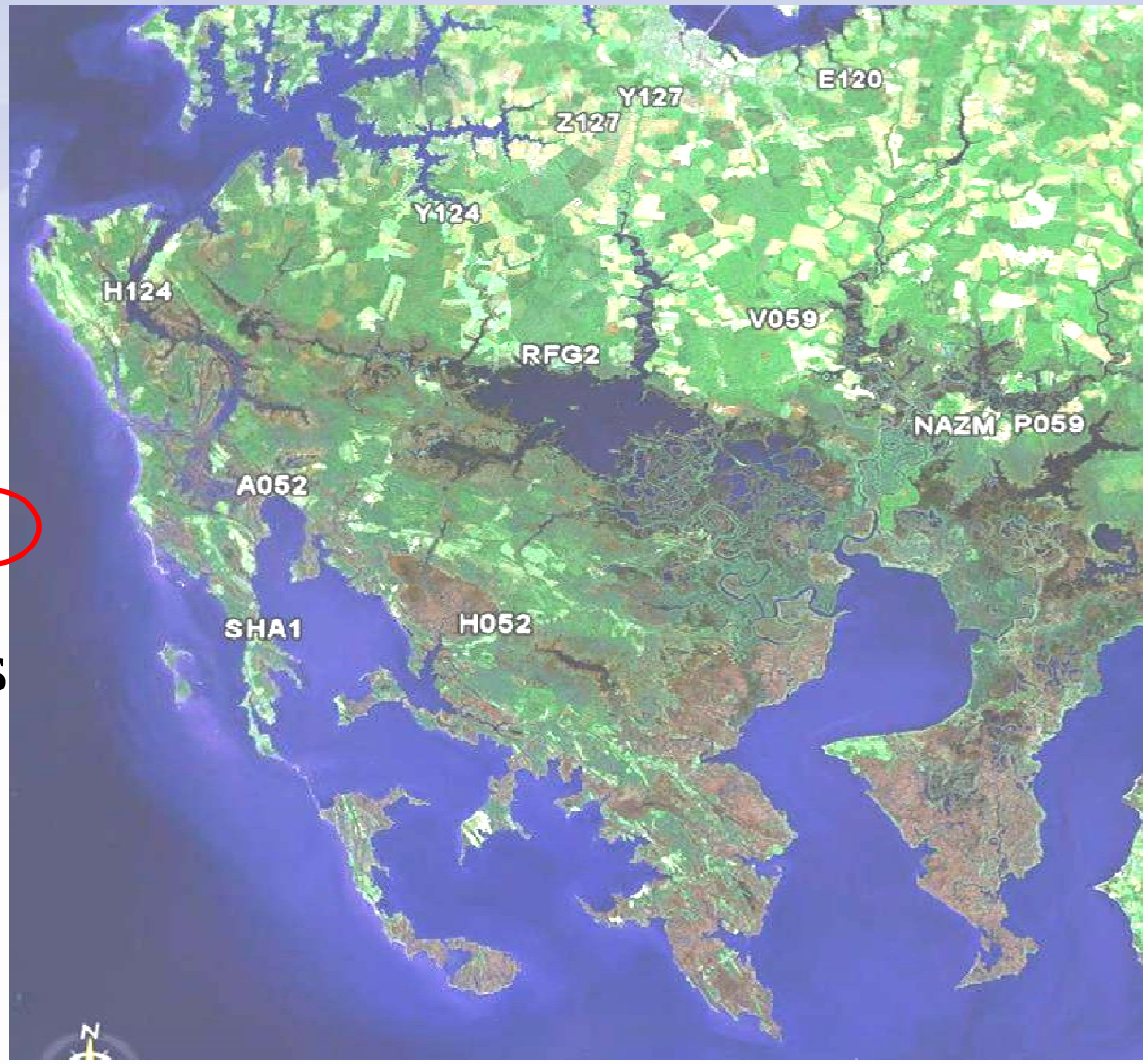
Reviewed ~ 100 existing control stations primarily from USC&GS leveling projects in 1942 & 1971



Reconnaissance

Selected 12 marks to serve as geodetic control stations.

Includes 3 high accuracy GPS stations

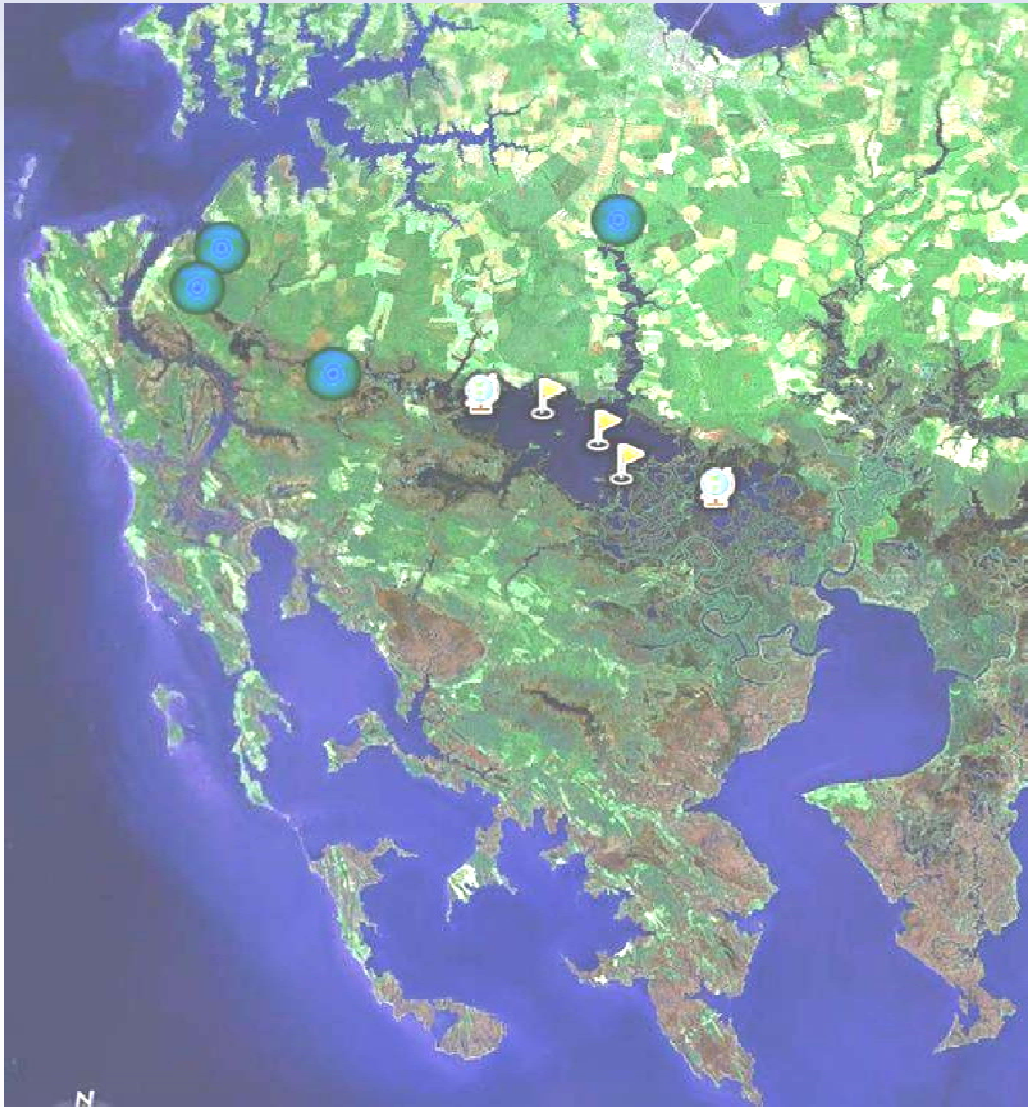


Install Deep-Rod SET Foundations & NGS 3-D Rod Marks

Nine SET Foundations in 3 SET fields

Six new 3-D Rod Marks for SET & gage reference:

- Parson's Creek
- Goose Dam
- Footbridge
- Edgar's Farm
- Boat Ramp
- Wolf Pit



Install Deep-Rod SET Foundations and NGS 3-D Rod Marks

- Steel rods driven to refusal with a jackhammer.
- 15 sites each 60 to 100 feet deep

Photo Credits Copyright ©2005 Mary Konchar

Survey Planning & Coordination

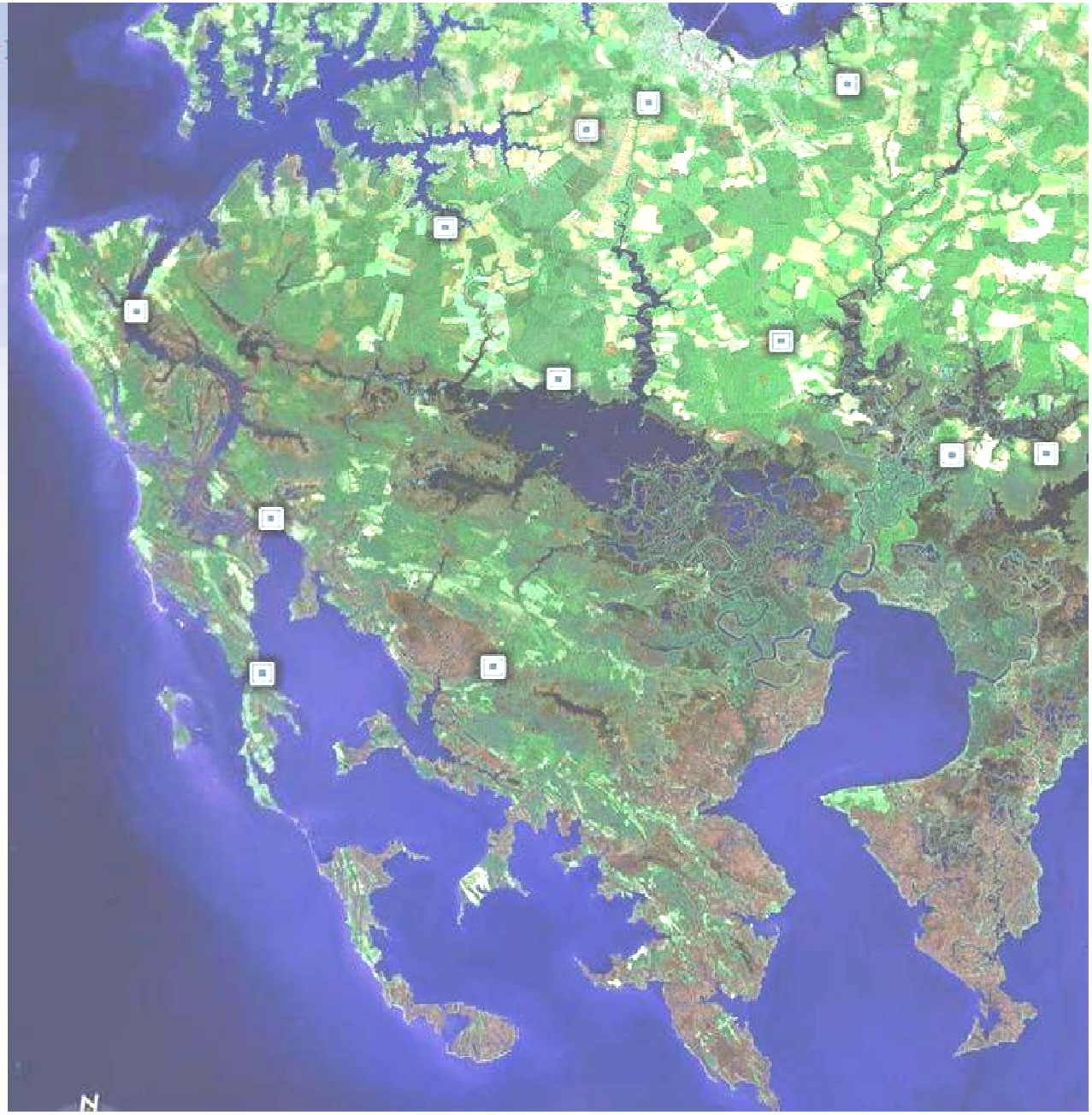
Assembled 30+ survey grade GPS units from 5 different sources. (>$250K in equip)

Deployed ~23 people across 450 mi^2 in cars, trucks, and boats.

Survey Overview

29 Survey Points

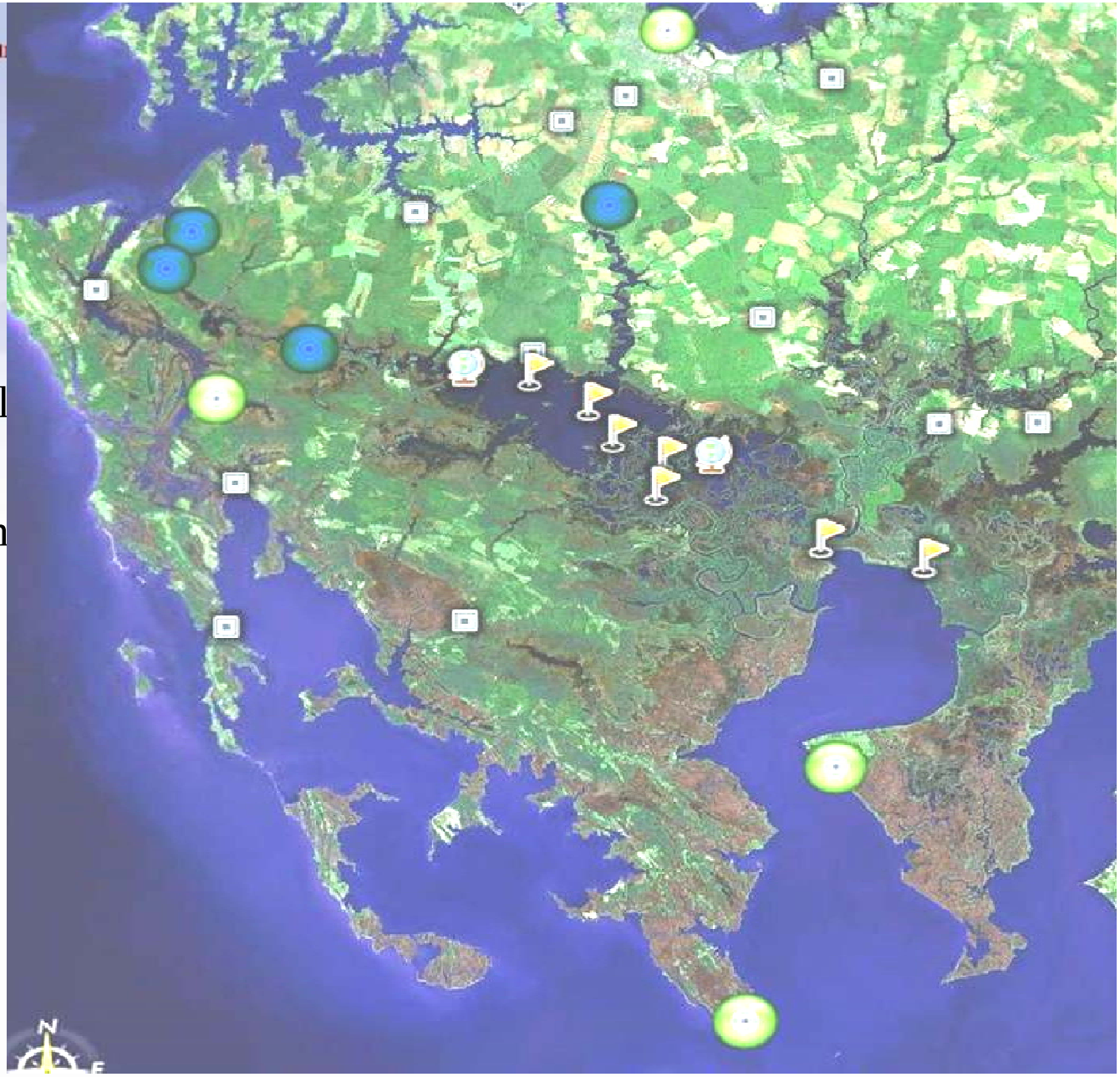
- 12 Existing Control Stations



Survey Overview

29 Survey Points

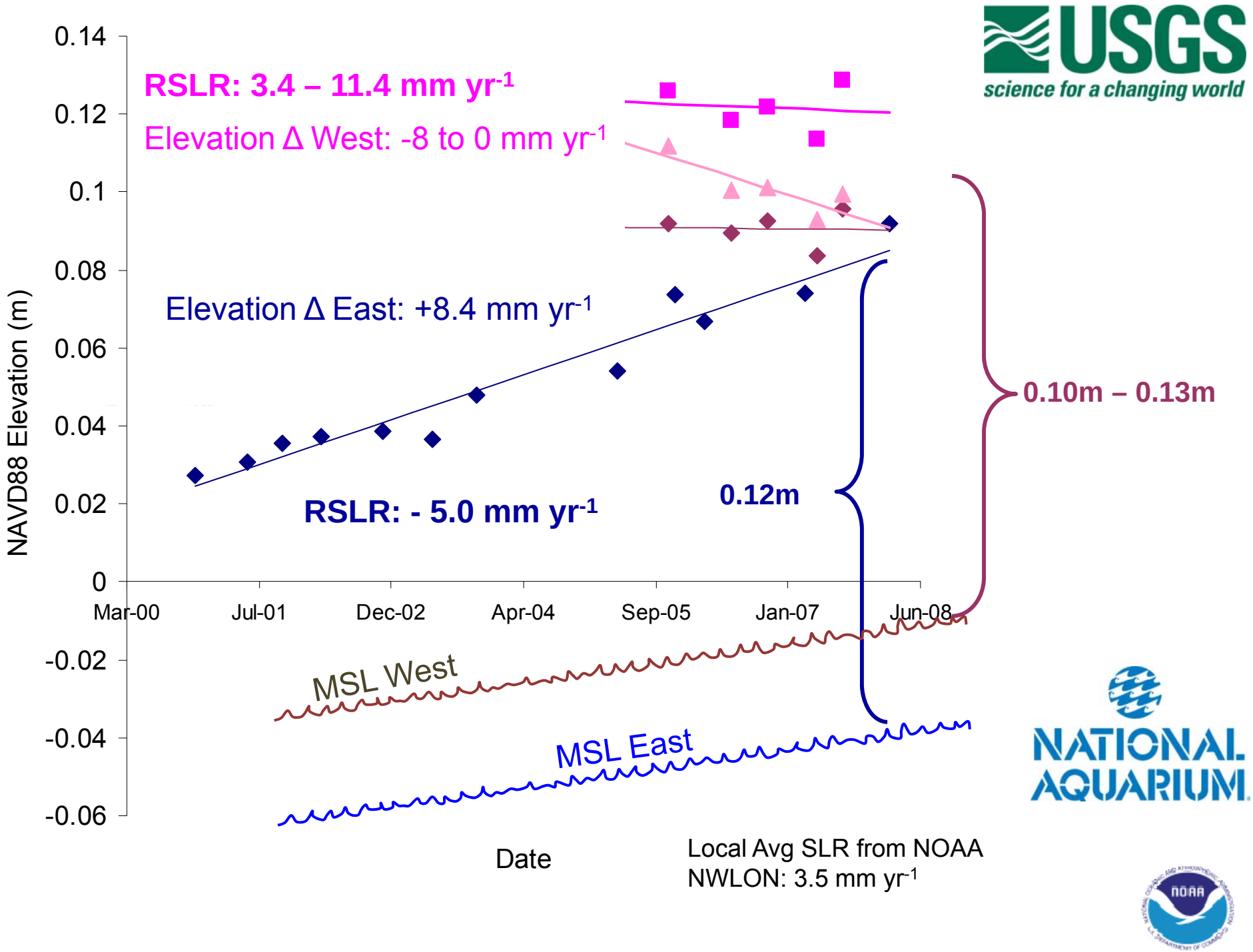
- 12 Existing Control Stations
- 4 NOS Tidal Bench Marks
- 6 USGS Gage & SET Marks
- 7 SET Foundations



Survey Overview

- Occupied 29 stations simultaneously with survey grade GPS receivers.

- Observed three four-hour sessions over 2 days.

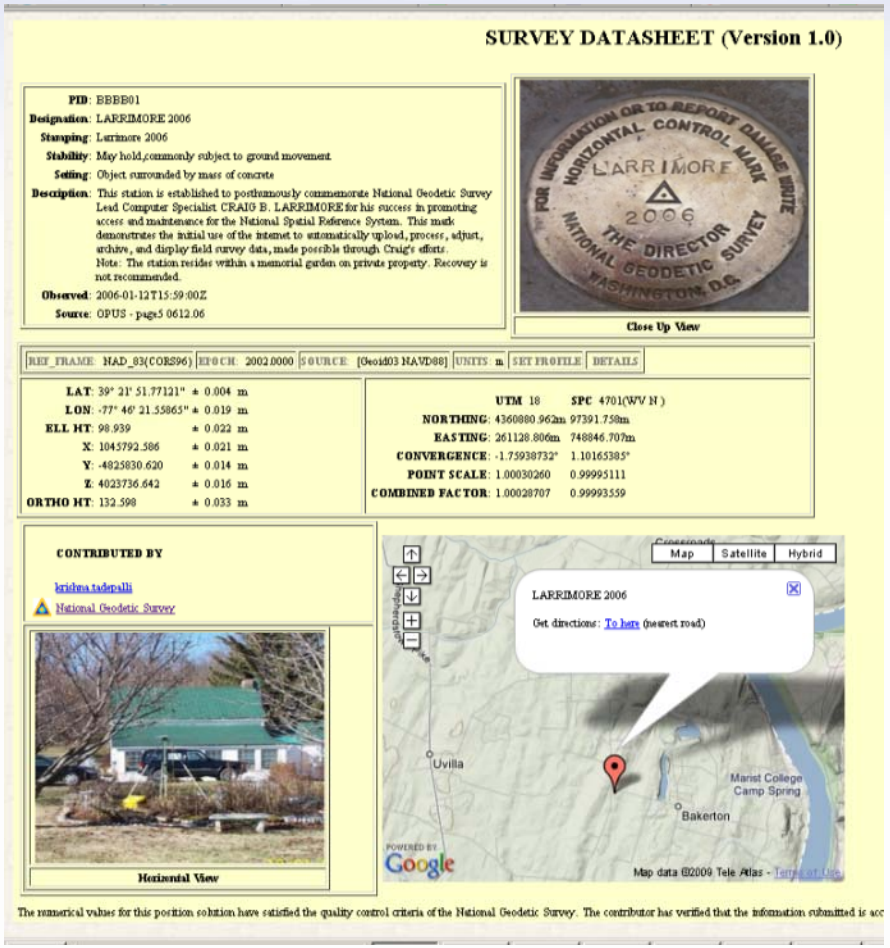

RSLR: 3.4 – 11.4 mm yr-1
Elevation Δ West: -8 to 0 mm yr-1
Elevation Δ East: +8.4 mm yr-1
RSLR: - 5.0 mm yr-1
0.12m
0.10m – 0.13m
MSL West
MSL East
NAVD88 Elevation (m)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
Mar-00
Jul-01
Dec-02
Apr-04
Sep-05
Jan-07
Jun-08
Date
Local Avg SLR from NOAA
NWLON: 3.5 mm yr-1

NOAA Resources

OPUS-DB: GPS Data Sharing

NGS Online Positioning Users Service (OPUS) – Processes static GPS observations with nearby CORS data to provide accurate positions.

OPUS users will be provided, in addition to their standard position report, an option to **publish their position in the NGS database**



LOCUS – Leveling Online Calculation Service

Provides tools for users to submit vertical control data, either from an optical or digital instrument, perform the necessary reductions, apply the needed constraints, and compute elevations through a standard least squares adjustment process.

NGS Corbin Training Center

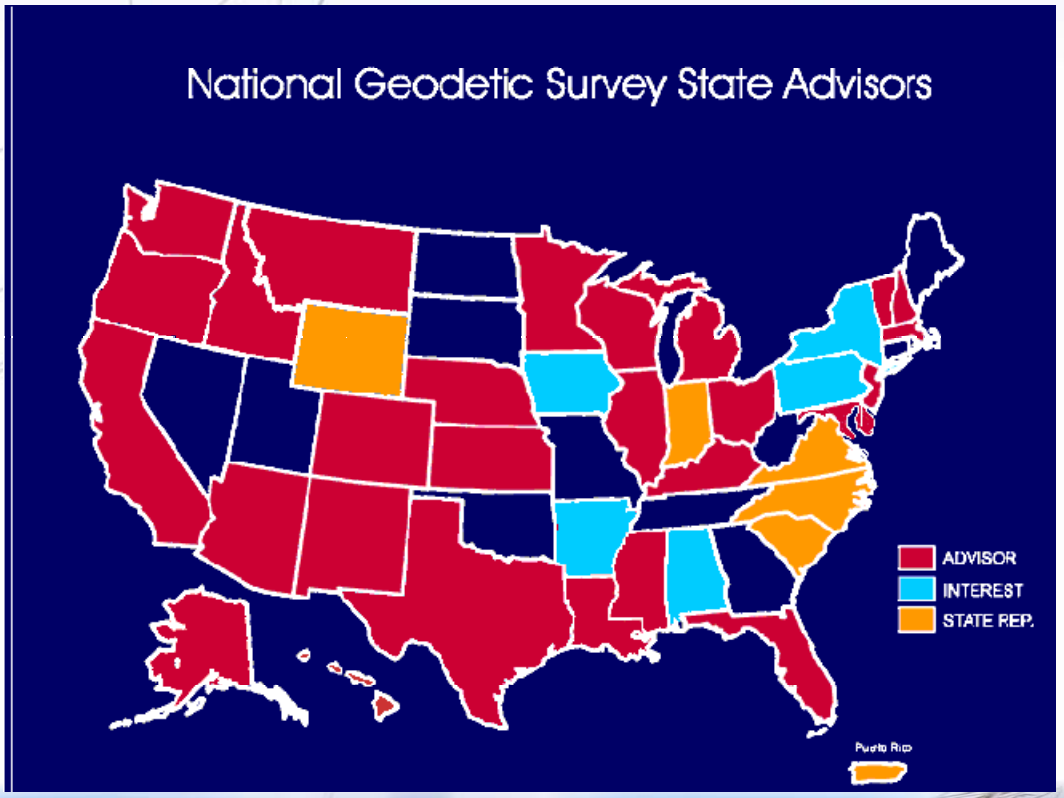
www.ngs.noaa.gov/corbin

Your training resource for:

- Geodetic and Tidal Datums
- GPS (Static & RTK)
- Leveling
- Surface Elevation Tables

NGS State Geodetic Advisors

www.ngs.noaa.gov/ADVISORS



Local, free technical support on datums and coordinates, and all your high accuracy surveying questions.

Integrated Ocean and Coastal Mapping (IOCM):
Map Once, Use Many Times

- International Working Group on Ocean and Coastal Mapping (IWG-OCM)
- Coordination of ocean and coastal mapping data and activities
- Partnerships for resource synergies
- Integrated products and services

Goal: Increase efficiency and improve coordination of many Federal mapping agencies.

Conclusion

By concentrating geospatial infrastructure within and around biomonitoring stations and linking that infrastructure to a common reference frame through robust surveying methodology, we can **enhance capacity to assess change** and **increase our confidence** in our understanding of complex spatial relationships.