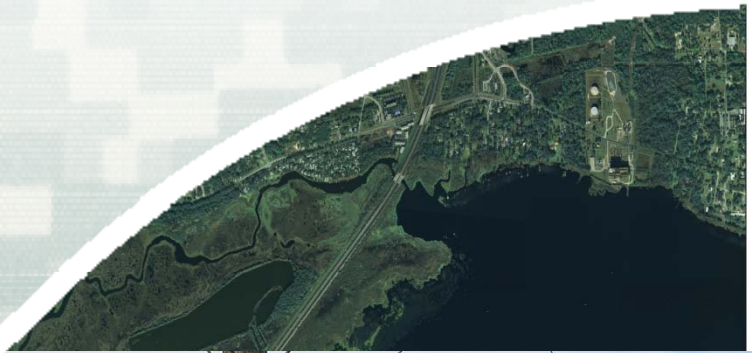
Geomorphic, Hydrologic and Hydraulic Surveys



Sarah J. Miller

Research Ecologist, Fluvial Geomorphologist

ERDC Environmental Laboratory

7 November 2013

Presentation Roadmap

- Brief review of Monitoring and Adaptive Management Framework
- What's important to consider in the data you collect and analyze to maximize its utility
- Basic definitions and what we might care about in terms of parameters and processes
- General organizational schemes that lead to selecting a different parameter or approach
- Methodological categories to consider
- Lots of examples of direct, indirect and remote sensing data collection and analysis

Adaptive Management and Monitoring Framework

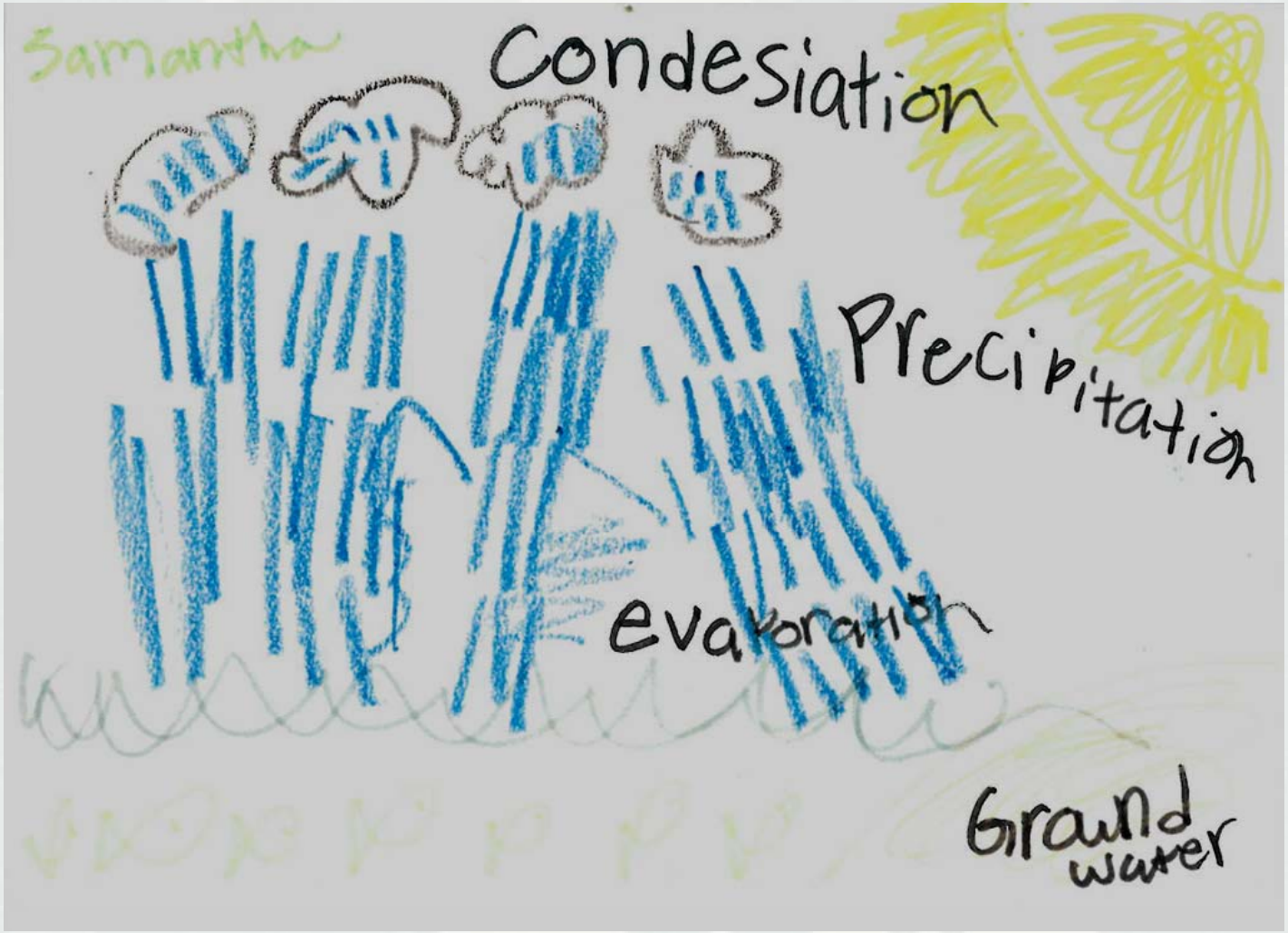
- What are the project goals and objectives?
- What are the expected project benefits and/or project outcomes? What would you regard as success?
- What are the key metrics, indicators and measures?
- How would you assess progress toward goals?
- What are the key constraints?
- What are the sources of significant uncertainty? How would you address these (monitoring, research, AM)?
- Can you anticipate any unintended consequences? Are there alternative project trajectories or project outcomes?
- Do all parties agree on the most effective design and operation to achieve project goals and objectives?
- What would you do if (fill in blank)?

Optimal Monitoring Plan

- Clear monitoring program goals and objectives – tied directly to project objectives
- Appropriate scaling (temporal and spatial) and resource allocation for data collection, management, interpretations, and analyses
- Standardized QA/QC procedures
- Programmatic and procedural flexibility
- Reasonable costs
- High implementation efficiency
- Reportability to diverse audiences

Clear and Explicit Documentation

- Foster trust in information as the foundation for decision-making
  - Derive metrics from objective statements
  - Relevant measures that relate to specific elements or processes
  - Methods that capture variability and range as needed
  - Specify sampling design and protocols – spatial limits, periodicity, frequency, duration, sample number
  - Data custody, storage, entry, processing, QA/QC roles



Hydrology: The study of the properties, distribution (spatial and temporal), movement and behavior of water on the land surface, underground and in the earth's oceans.

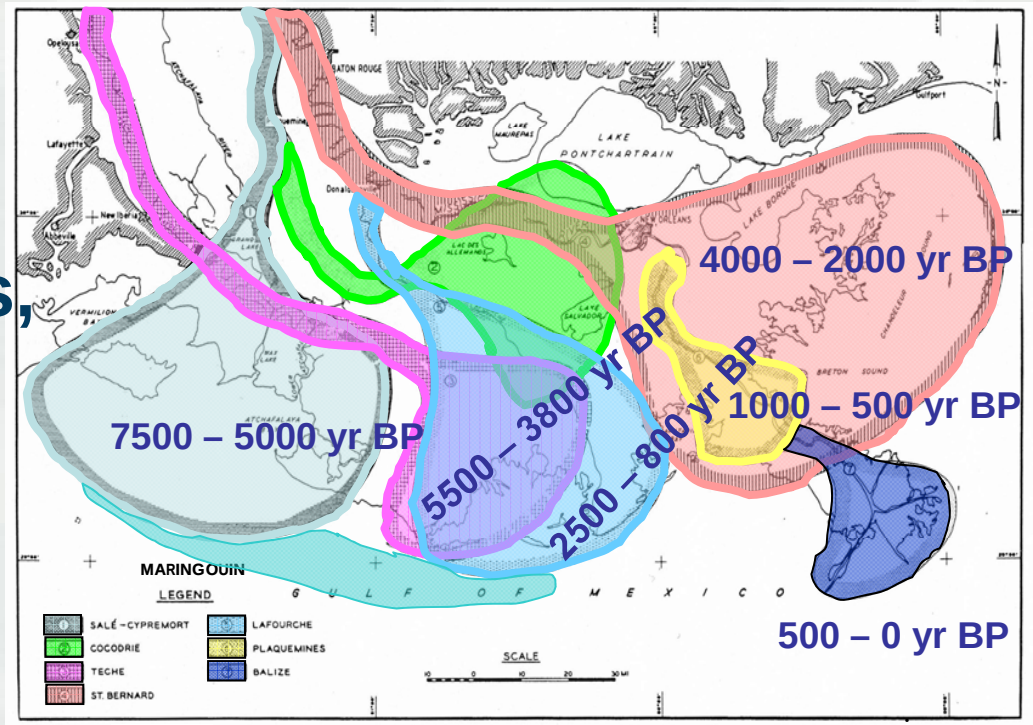
What we might care about: Ecohydrology, Limnology, Hydrogeology, Meteorology – some reasonable characterization of the amount, location and trajectory of water in various forms

- Groundwater
- surface water (runoff)
- stream flow
- storage
- soil moisture
- regional climate
- snow pack / snow melt
- ice dynamics
- drought
- floods
- precipitation dynamics, storms
- other seasonal cycles

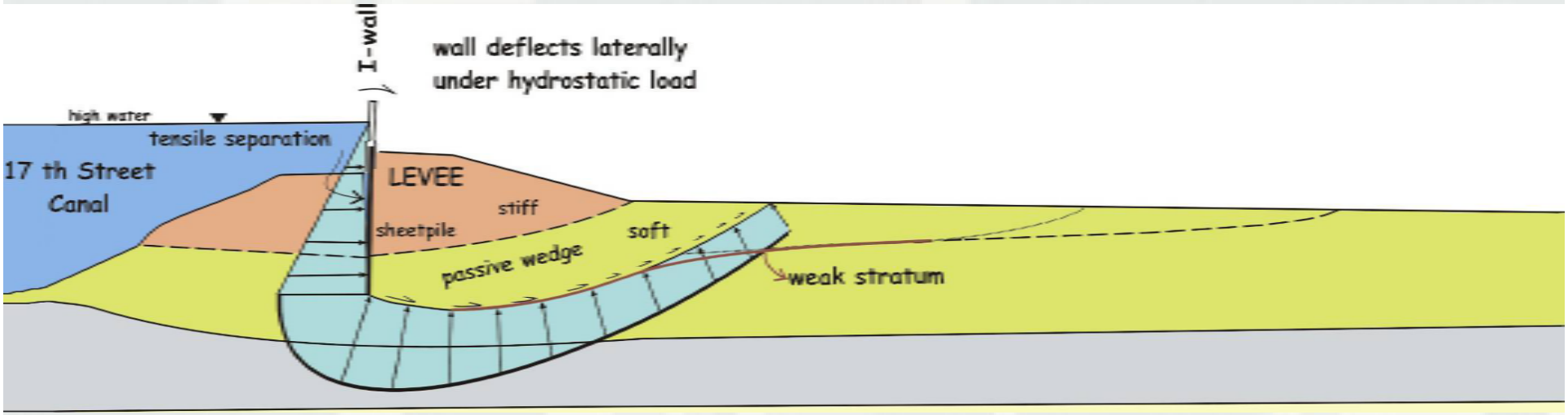
Hydraulics: Relating to the mechanical properties of fluids; free surface hydraulics pertains to properties associated with the conveyance of water through a channel or water body (lakes, oceans, wetlands, etc.). Hydraulic engineering deals with flow and fluid conveyance, primarily water, and interactions related to flowing water such as sediment transport and storage dynamics, erosion processes and inundation – all of which have anthropogenically-determined beneficial and detrimental components.

- *What we might care about:* Some reasonable characterization of the properties of water through a management timescale as it impacts or is impacted by construction or management of structural features – dams, bridges, canals, levee systems, sea walls, tide gates, locks, etc. – and aquatic ecosystems or restoration projects
  - Usage
  - Evaporative loss
  - Storage capacity
  - Currents and velocity
  - Energy surface, slope
  - Seepage, piping
  - Wave dynamics
  - Wind, fetch
  - Interflow
  - Inundation
  - Tidal influence
  - Sea level rise

Geomorphology: The branch of geology that pertains to the nature and origin of land forms, forces that shape landforms including water, ice, wind, gravity and biological agents acting over time.



Chronologic sequence of Holocene Mississippi Delta lobes (from Kolb and Van Lopik, 1966 Fraiser, 1967).



Headwaters trout stream
Catskill Mountains, NY

What we might care about:

- Form – shape of the landscape, topography, bathymetry, hydrography, depositional features
- Constituents – what is the geomorphic feature made of and how is it arranged – lithology, geology, soils, transported sediments
- Function – physical processes, materials transport, changes in elevation through materials cycling, climate impacts
- Trends – timescale of functional impacts

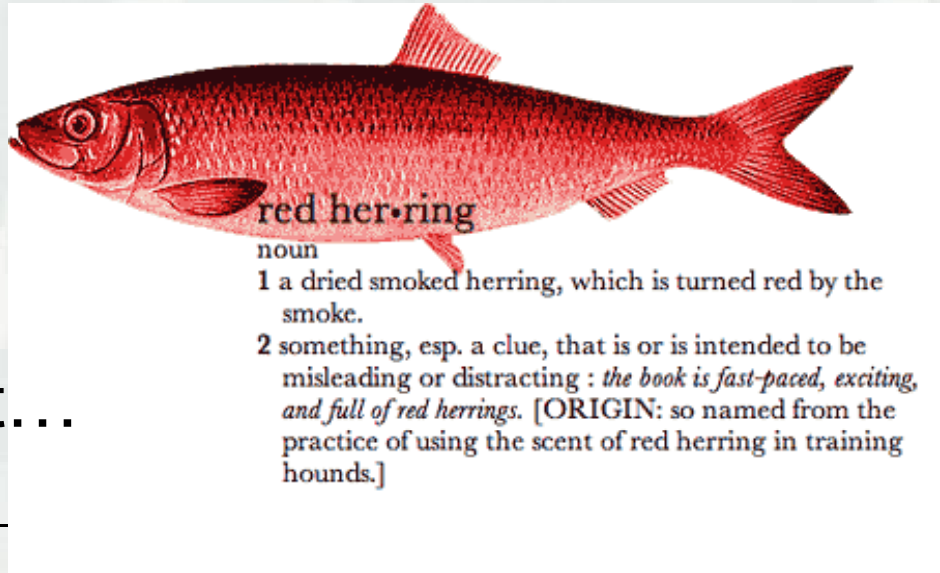
Categorical Components That Generally Apply…

- Constituent materials, energy source or expression
- Magnitude
- Functions, processes and linkages
- Temporal aspects
- Spatial aspects

- What, How Much, How Does it Work, When, and Where

Geomorpholgy, Hydrology and Hydraulics Data

- Several ways to compartmentalize data collection: for each category that applies to our project, we need *only the type and amount of data required to make decisions or determinations*
- The point is not that we know all the terms, roles and formative processes of each feature in any landscape we manage, but that we understand there are parameters we can monitor that directly pertain to our goals and objectives, and others that may not…



Different Types of Projects or Overarching Goals

Eight business lines covered by Corps Civil Works

- Environment; includes Ecosystem Restoration, FUSRAP, Stewardship
- Flood Risk Management; includes Dam Safety, Levee Safety, Bridges
- Hydropower
- Navigation
- Recreation
- Water Supply

Different Aquatic Environments

- Freshwater wetlands, marshes, swamps
- Streams and rivers, emphemeral and perrenial
- Lakes and reservoirs
- Subtidal estuaries
- Coastal wetlands
- Open coastline and near coastal waters
- Many sub-classes…

Regional Considerations

- Arid regions – evapotranspiration, drought, groundwater storage
- Cold regions – ice formation processes, frost depth, snow pack hydrology
- Mountainous regions – flood flashiness, sediment size and quantity, rain shadow
- Plains – wind, storms
- Coastal areas – wave impacts, coastal storms, tide flux

Methodological Categories

- Direct field measurement – in person or by in-situ sensors or other instruments
- “Indirect” field measurement – accessing field databases maintained by others
- “Assumptive” measurement – surrogates, proxies, indexes, representative sampling and extrapolation; modeling of a huge range of complexity
- Remote sensing – also a huge range of complexity and source types

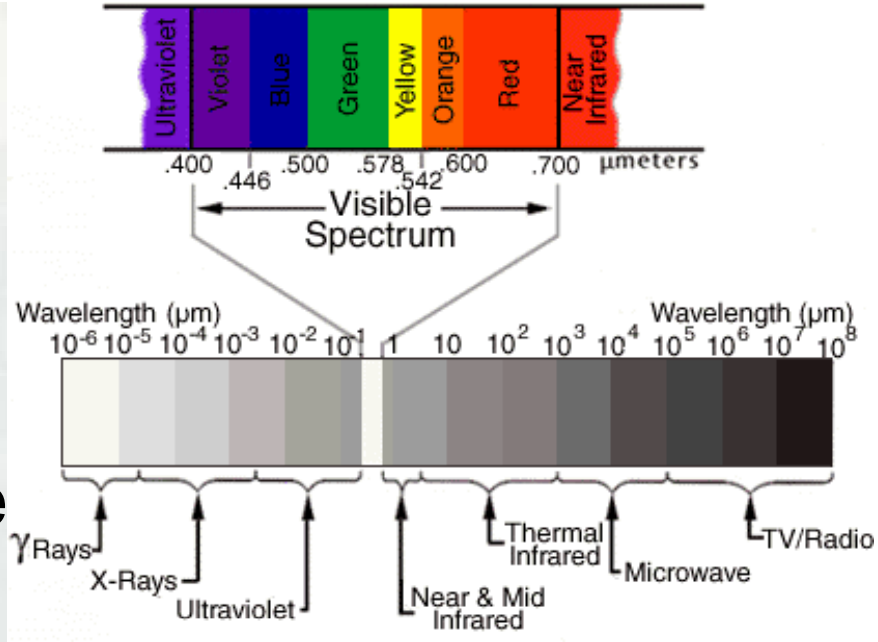
Field Data Collection Considerations

- Plan Ahead – SOP, QAPP including your sampling design, complete field equipment list, well-trained consistent staff with the right gear
- Plan B – you *will* end up with dead batteries for your GPS unit, laser level sensor or datalogger, no satellites due to bad scheduling, deep valley or heavy cloud cover, broken _____, or missing _____
- Know the difference between accuracy and precision, which one you really need to get the job done, which one is superfluous, when you need both

Indirect and Representative Database Considerations

- All the things you plan for in your own field data collection should be readily determinable for others' data sources, models or indices
  - SOPs, QAPP, other QA/QC
  - Locations, conditions, other considerations for data – e.g., USGS Q wading measurements are not necessarily always taken at the same station depending on stage
  - Changes in methodology, precision, frequency
  - Hidden things – e.g., USGS stream gage stations that have recorded many rating curve shifts, know the % that triggers a rating shift

Remotely Sensed Data Considerations



Similarly, various elements should be readily determinable for remotely sensed data

- Know your source and the type of imagery: Aerial Photography, Multispectral, Active and Passive Microwave and LIDAR
- Under what conditions were data acquired – time of day, season, atmospheric conditions
- Resolution – Spatial, Spectral, Temporal, Radiometric
- Just like other data – SOPs, QA/QC, metadata
- Interpretation – shape, shadow, tone and color, texture, pattern, relative height and depth,

Subsurface Flow

- Groundwater – stilling wells, piezometers, ground-penetrating radar “radargram”, time series to show subsurface fluid flow
- Infiltration rates, soil moisture, interflow
- Seepage, piping, stratification
- Wetlands – hydric soils, obligate veg…

Dowser Otto Edler von Graeve, 1913

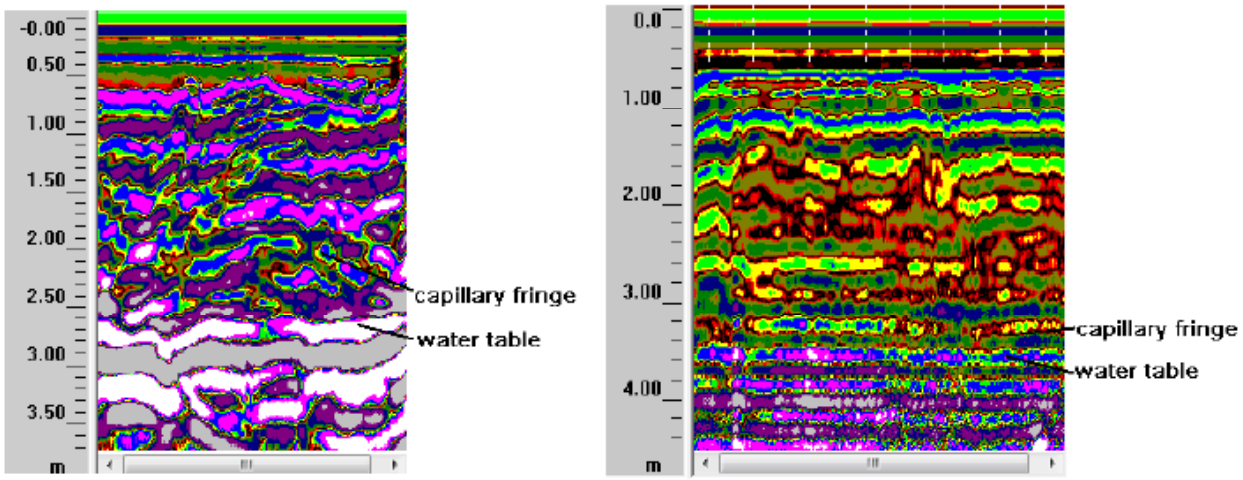
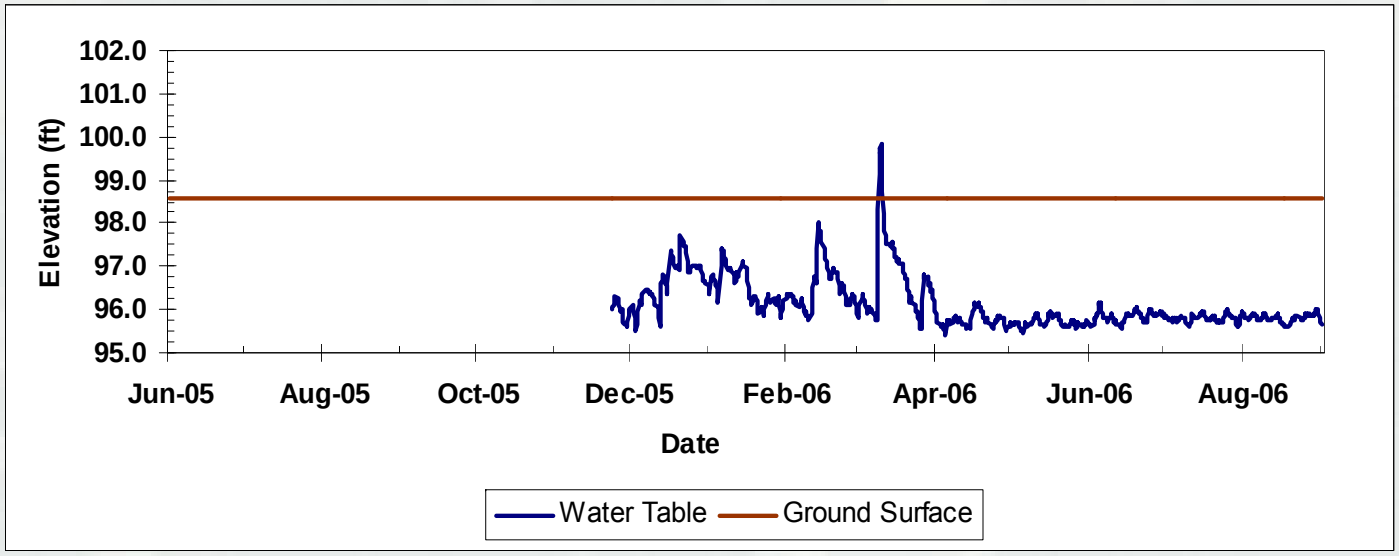


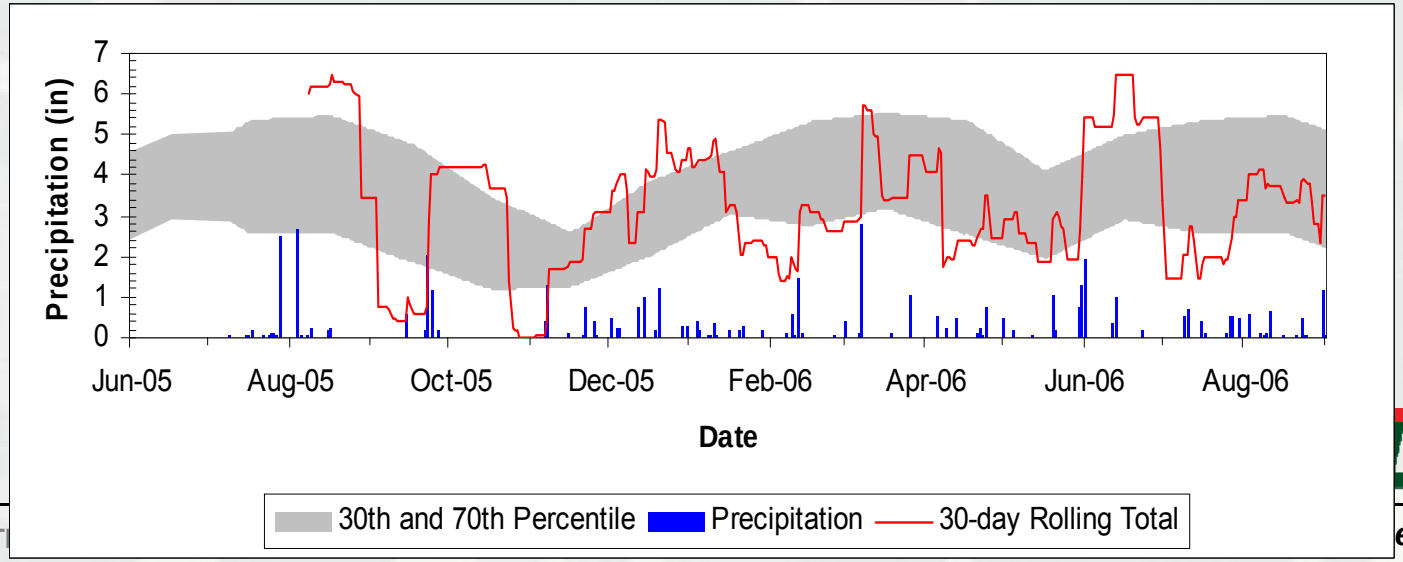
Figure 3: GPR sections at profile show changes in the electromagnetic signal during the exploration. Antenna frequency is centered in 400 MHz.

Wetland Delineation Methods: Wetland Hydrology

(Bruce A. Pruitt, PhD, PH, PWS)

Shallow Groundwater Well Data

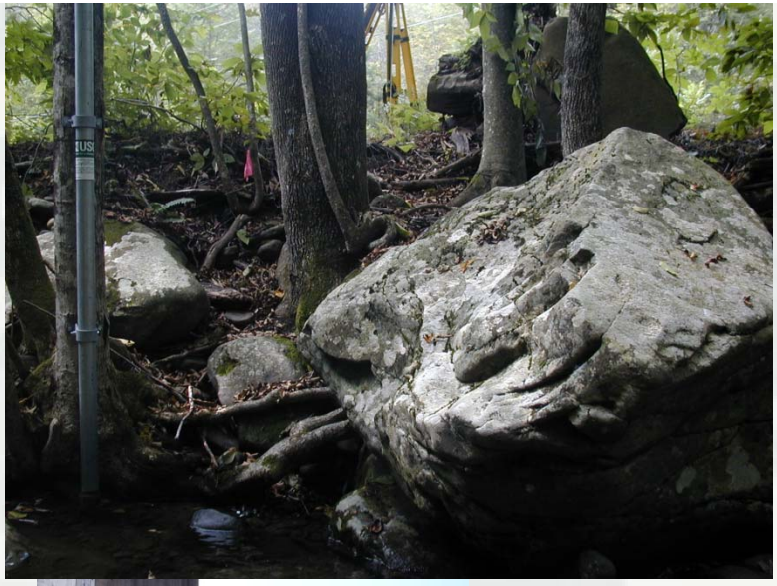




Surface Water

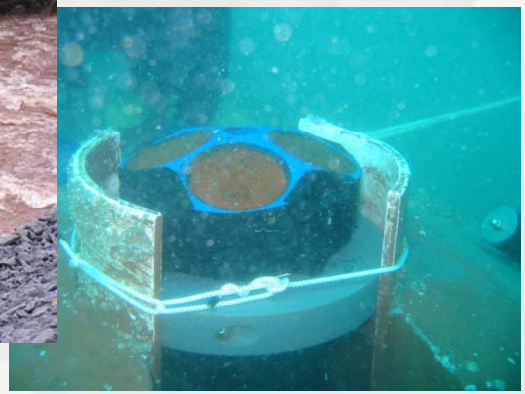
Water surface elevation/level, stage, slope (energy surface)

- Continuous stage recording gages (USGS other agencies, commissioned installation)
- crest or maximum stage recording gages (high tech, low tech)
- field survey at the time or by flood marks
- wetland: similar methods, though may require greater precision since slopes tend to be lower



Wetland Hydrology:
Primary Indicators

- Visual observation of inundation or saturation to within 12” of surface
- Water marks
- Drift lines
- Sediment deposition
- Drainage patterns
- Stream gage data



Velocity – highly situation dependent – many methods from very low tech to high tech. streams –

- can use the cableway system as Bruce showed with a current meter or velocity meter, used to have a car to ride across in… scary…
- other sites are wadable – current meter (e.g., Price Pygmy up to 3 fps or AA up to 8 fps), Acoustic Doppler, electromagnetic, other…

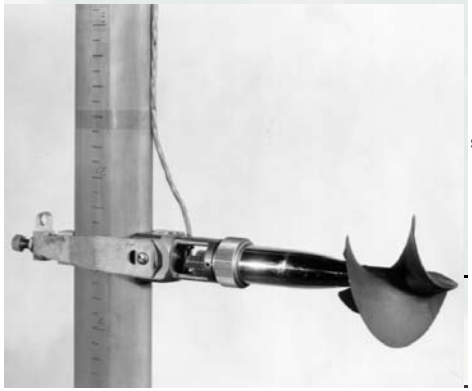
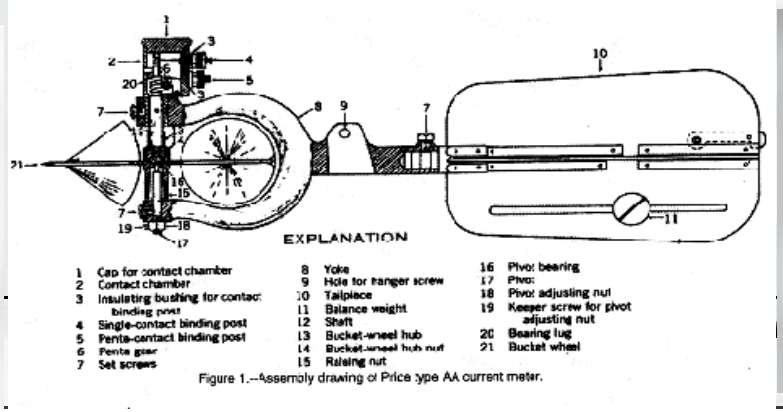



Figure 1.--Assembly drawing of Price type AA current meter.

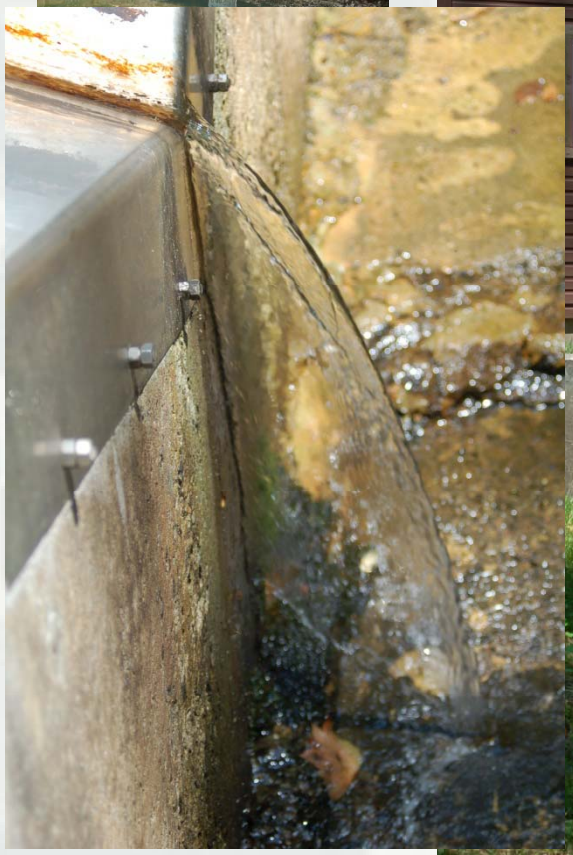
12/17/2012 13:28

12/17/2012 13:27

Flow Magnitude, Duration, Frequency

- Discharge magnitude –
  - for very small settings, construct a weir and create a stage/discharge rating curve
  - for larger settings, can also create a rating curve by measuring velocity, multiply by XS area (Q=AV) – USGS
  - Take advantage of culverts, bridge openings, etc.
- Duration – hydrograph plotting, sampling density to get enough but not too much info – 15 min, hourly, daily, monthly, annual… >> flow duration, inundation duration
- Frequency – influential occurrences such as floods, baseflow, some threshold of inundation or recession – this is primarily a sampling design and statistical or analytical exercise to manipulate field or other data you already have

Monitoring Weirs



Geomorphic Field Methods

Elevation, topography, bathymetry surveys can be done on foot or vehicle, by land or water

- longitudinal profiles, cross sections or transects – many specific geomorphic features that distinguish slope breaks or reflect a change in process like wetted areas, vegetation shifts, constituent materials shifts, thalweg, water surface (current, bankfull, flood) floodplain, bank or terrace, edge of standing water, dune crest, toe of slope, etc.
- Specific feature topo or site topo – design, layout, as-built, other goal-specific monitoring
- hand level and cable and folding rule, range-finder, Survey level and tapes, transit and stadia rod, total station, handheld LiDAR

Variables

1. Stream type
2. Drainage area, mi^2
3. Bankfull width (W_{bkf}), ft
4. Bankfull mean depth (d_{bkf}), ft
5. Width/depth ratio (W_{bkf}/d_{bkf})
6. Bankfull cross-sect. area (A_{bkf}), ft^2
7. Bankfull mean velocity (V_{bkf}), fps
8. Bankfull discharge (Q_{bkf}), cfs
9. Bankfull maximum depth (d_{max}), ft
10. Floodprone width (W_{fpa}), ft
11. Entrenchment ratio (W_{fpa}/W_{bkf})
12. Meander length (L_m), ft
13. Meander length ratio (L_m/W_{bkf})
14. Radius of curvature (R_c), ft
15. Ratio of radius of curvature to bankfull width (R_c/W_{bkf})
16. Belt width (W_{blt}), ft
17. Meander width ratio (W_{blt}/W_{bkf})
18. Sinuosity (k), (stream length/valley distance)
19. Valley slope (S_{val})
20. Average slope (S_{bkf})

Feature Data

27. Maximum pool depth (d_{pool}), ft
28. Ratio of pool depth to average bankfull depth ($_{ool}/d_{bkf}$)
30. Pool width (W_{pool}), ft
31. Ratio of pool width to bankfull width (W_{pool}/W_{bkf})
32. Pool/pool spacing (p-p), ft
33. Ratio of pool/pool spacing to bankfull width (p-p/W_{bkf})
34. Run slope (S_{run})
35. Ratio of run slope to average slope (S_{run}/S_{bkf})
36. Maximum run depth (d_{run}), ft
37. Ratio of run depth to average bankfull depth (d_{run}/d_{bkf})
38. Run width (W_{run}), ft
39. Ratio of run width to bankfull width (W_{run}/W_{bkf})
40. Glide slope (S_{gld})
41. Ratio of glide slope to average slope (S_{gld}/S_{bkf})
42. Maximum glide depth (d_{gld}), ft
43. Ratio of glide depth to average bankfull depth (d_{gld}/d_{bkf})
44. Glide width (W_{gld}), ft
45. Ratio of glide width to bankfull width (W_{gld}/W_{bkf})

Selected morphological characteristics of existing, proposed, gage station and reference reach. Adapted from Rosgen, 1998 unpublished short course materials, River Restoration and Natural Channel Design

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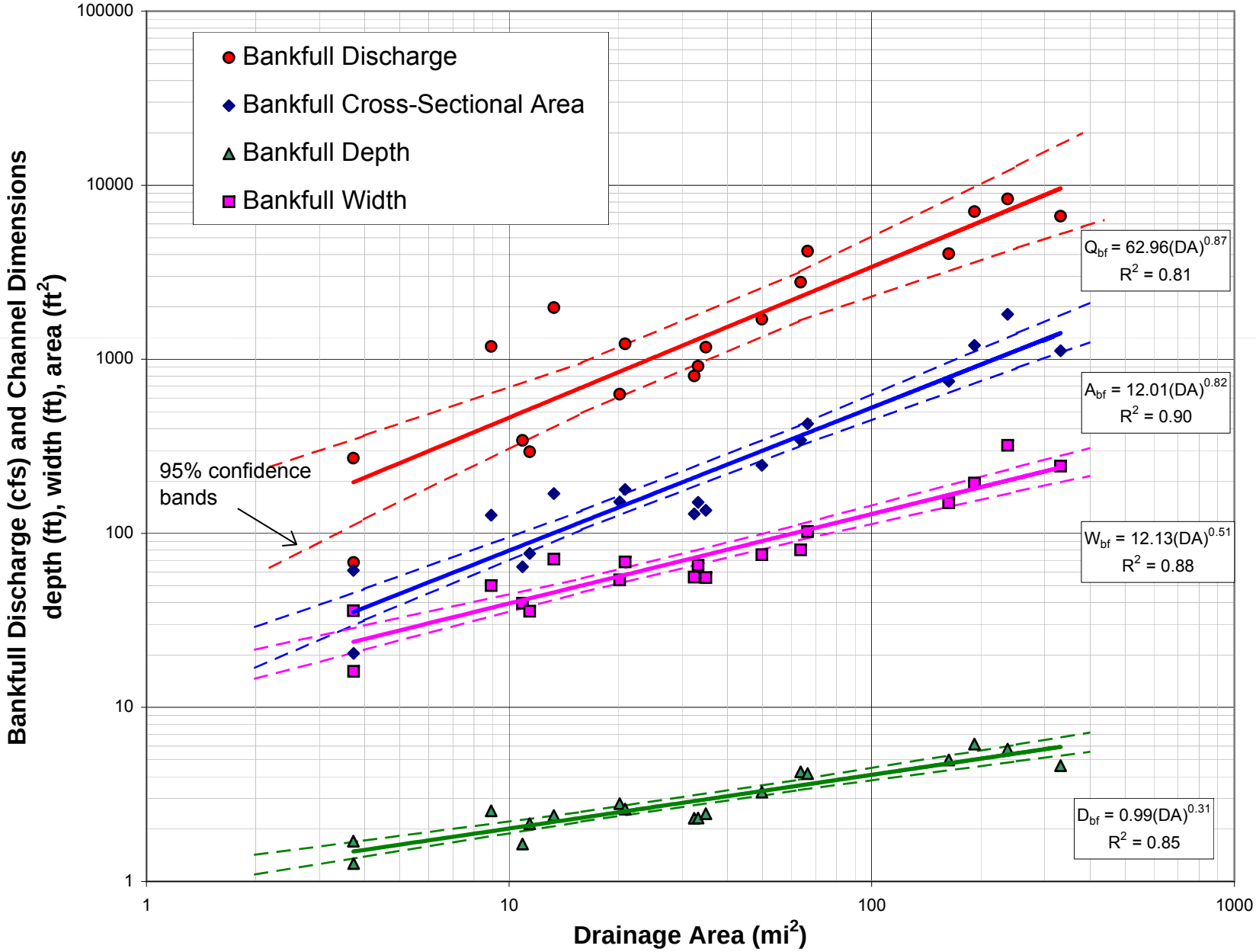
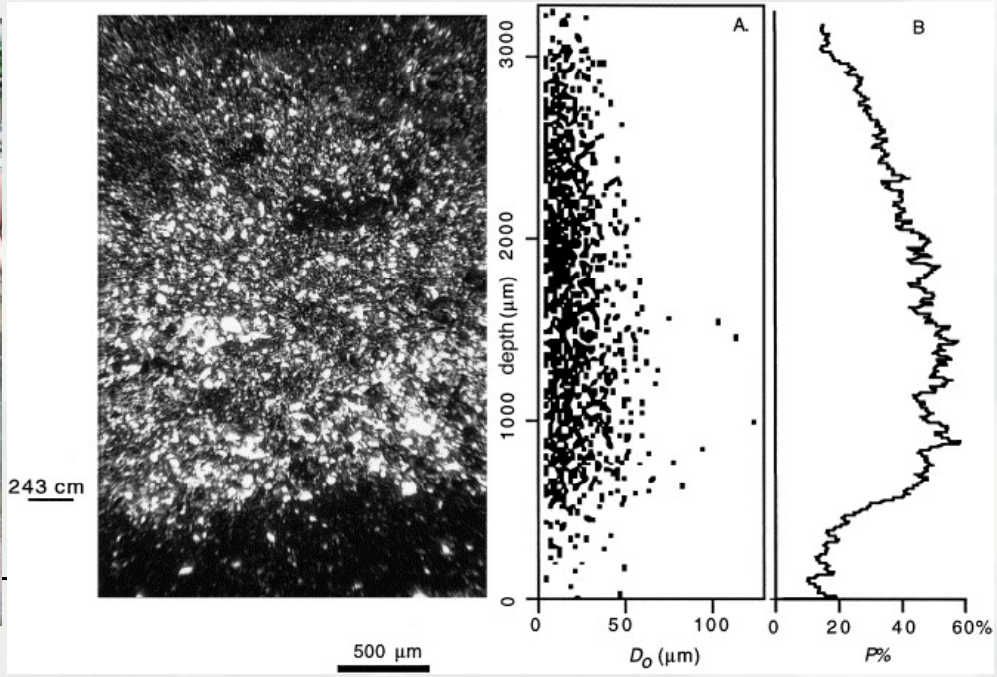
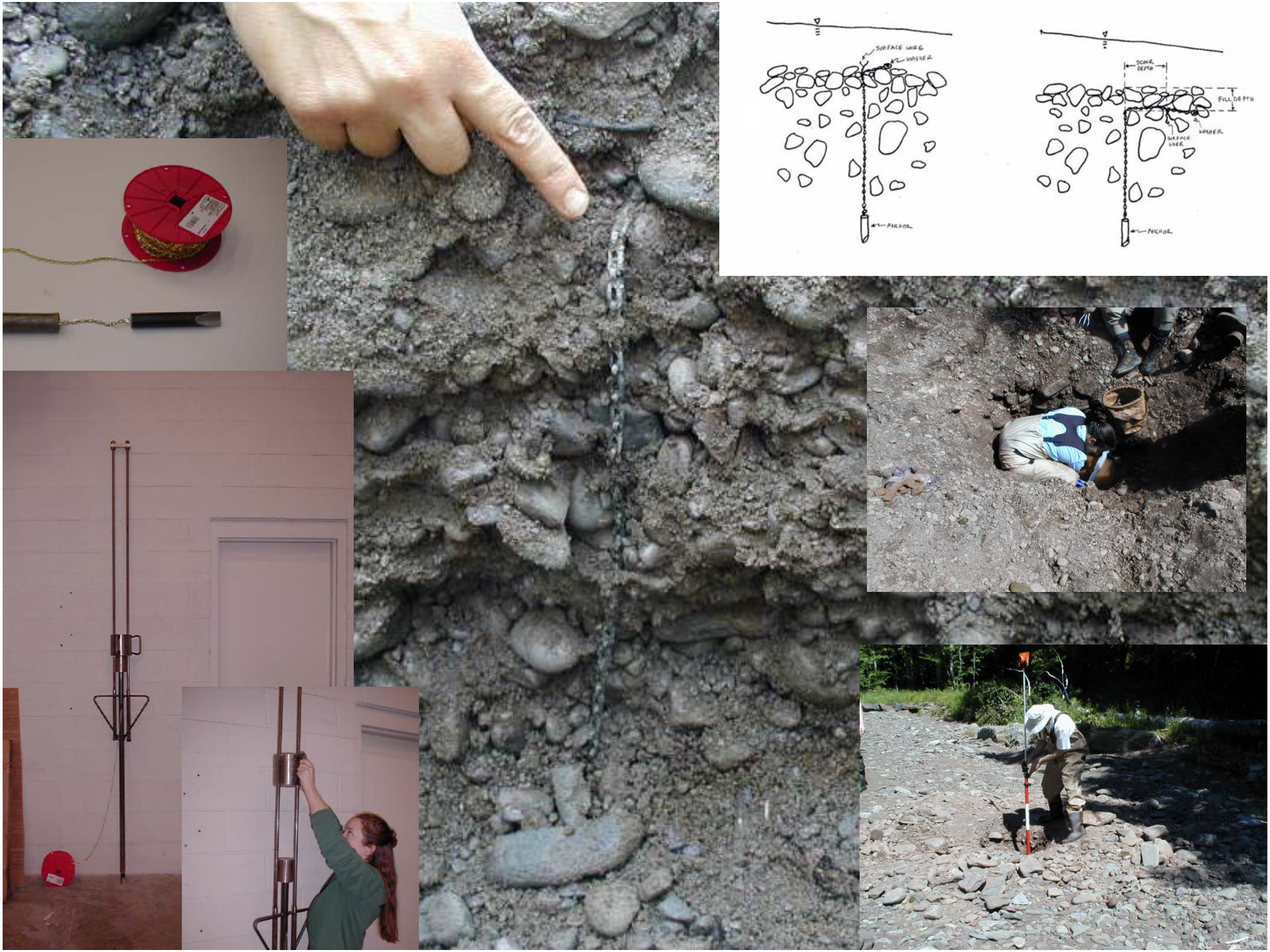
Bankfull Discharge and Hydraulic Geometry Relationships for 18 USGS Stream Gages, Catskill Mountains, NY



►Constituent materials characteristics and transport dynamics

- Soil properties – various field methods
- geotechnical properties – levees, dams etc – seepage, piping, burrowing, failure scarps
- ground penetrating radar
- Surface or bulk substrate sampling also in-situ sampling methods – many of these… pebble counts, sieve analysis, image analysis, freeze cores
- scour chain analysis, scour sand
- tracers, painted / drilled and bolted

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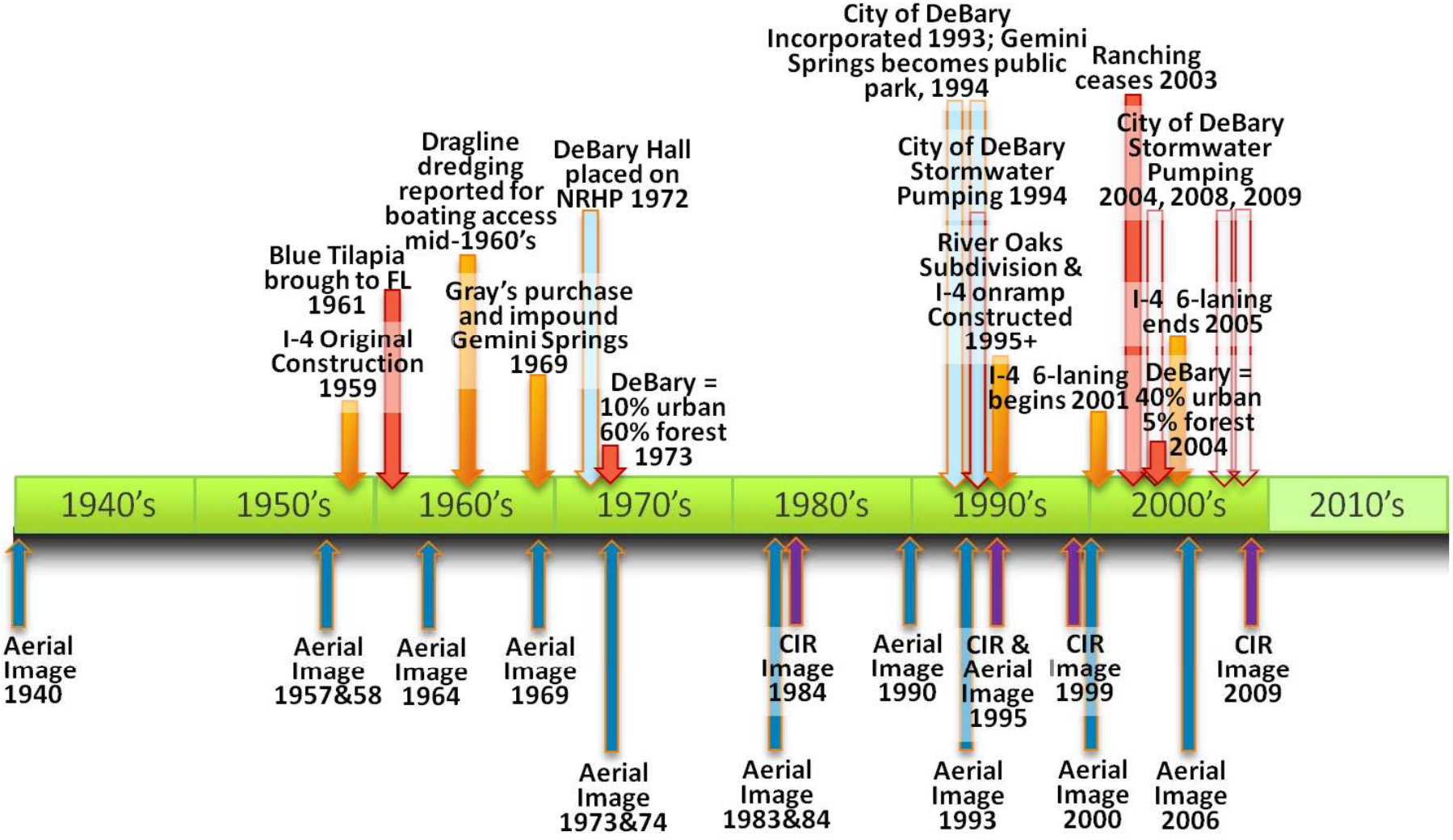
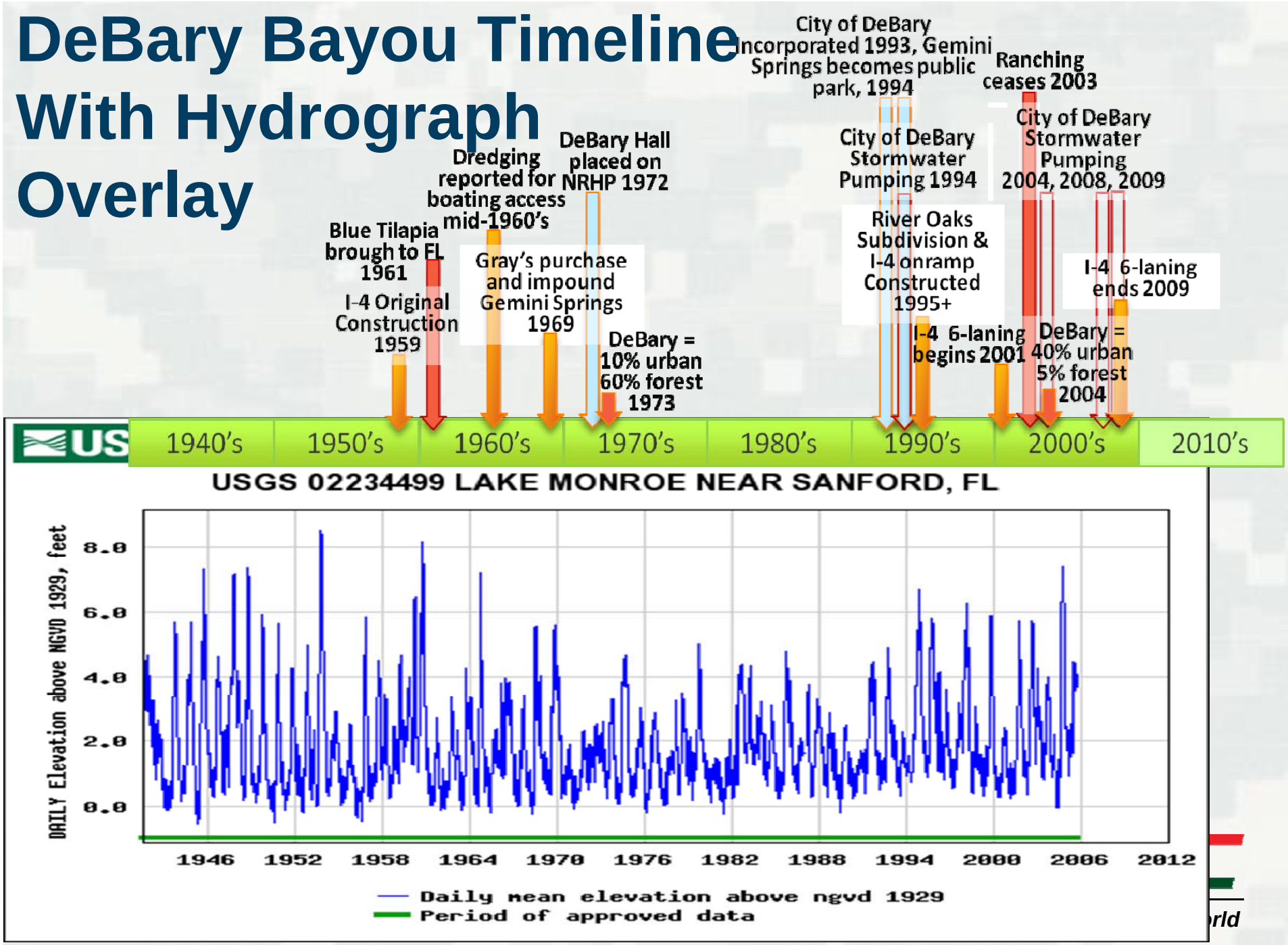
Change Over Time – DeBary Bayou, DeBary, FL Case Study

DeBary Bayou Timeline



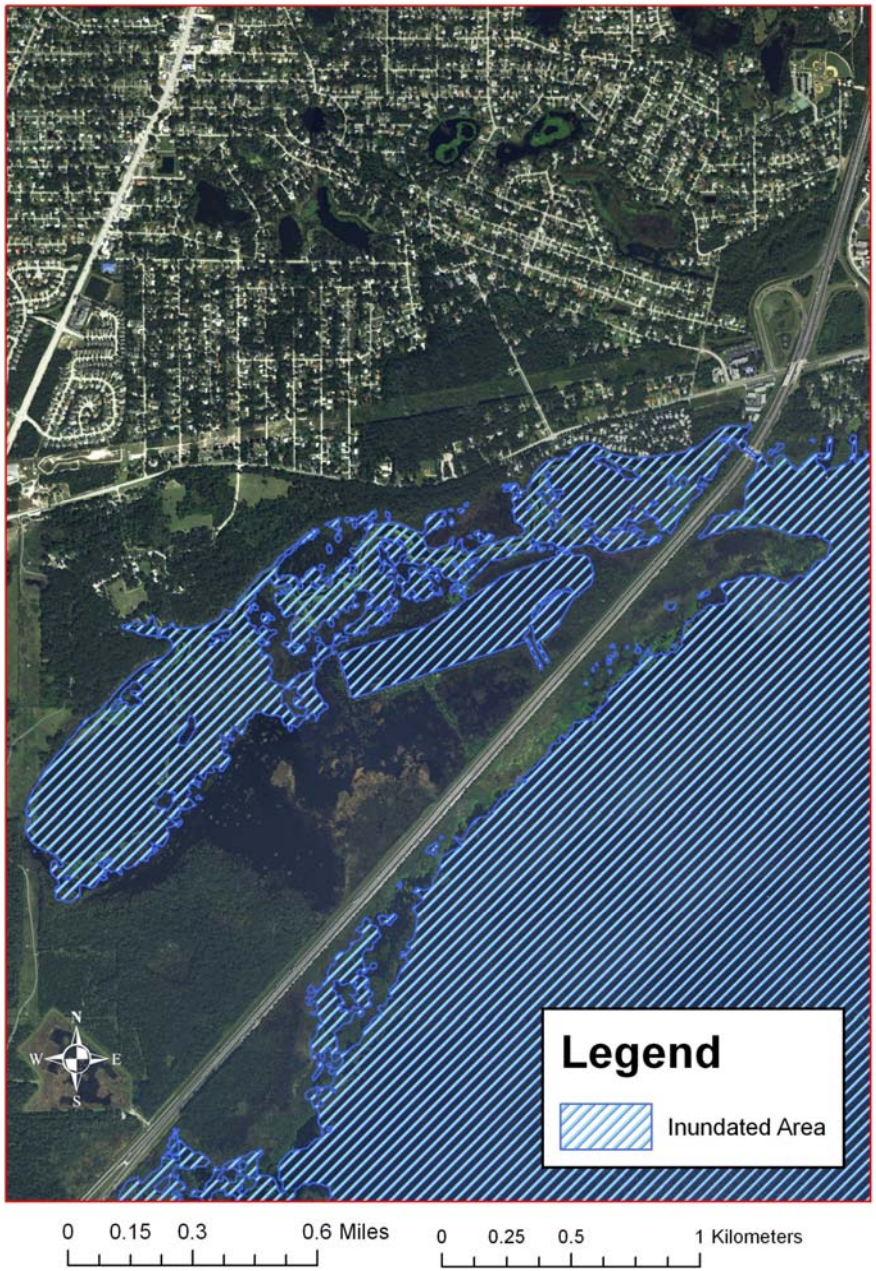
DeBary Bayou timeline of selected construction or development events in light orange, historic dates in light blue, landuse- or resource-related dates in dark orange, stormwater pumping dates outlined in red, and remotely sensed data available in dark blue and purple depending on type of imagery.

DeBary Bayou Timeline With Hydrograph Overlay



DeBary Bayou 1940 to 2006

Change over time – georeferenced aerial photo series, satellite images



DeBary Bayou, FL stage = 1.0 ft

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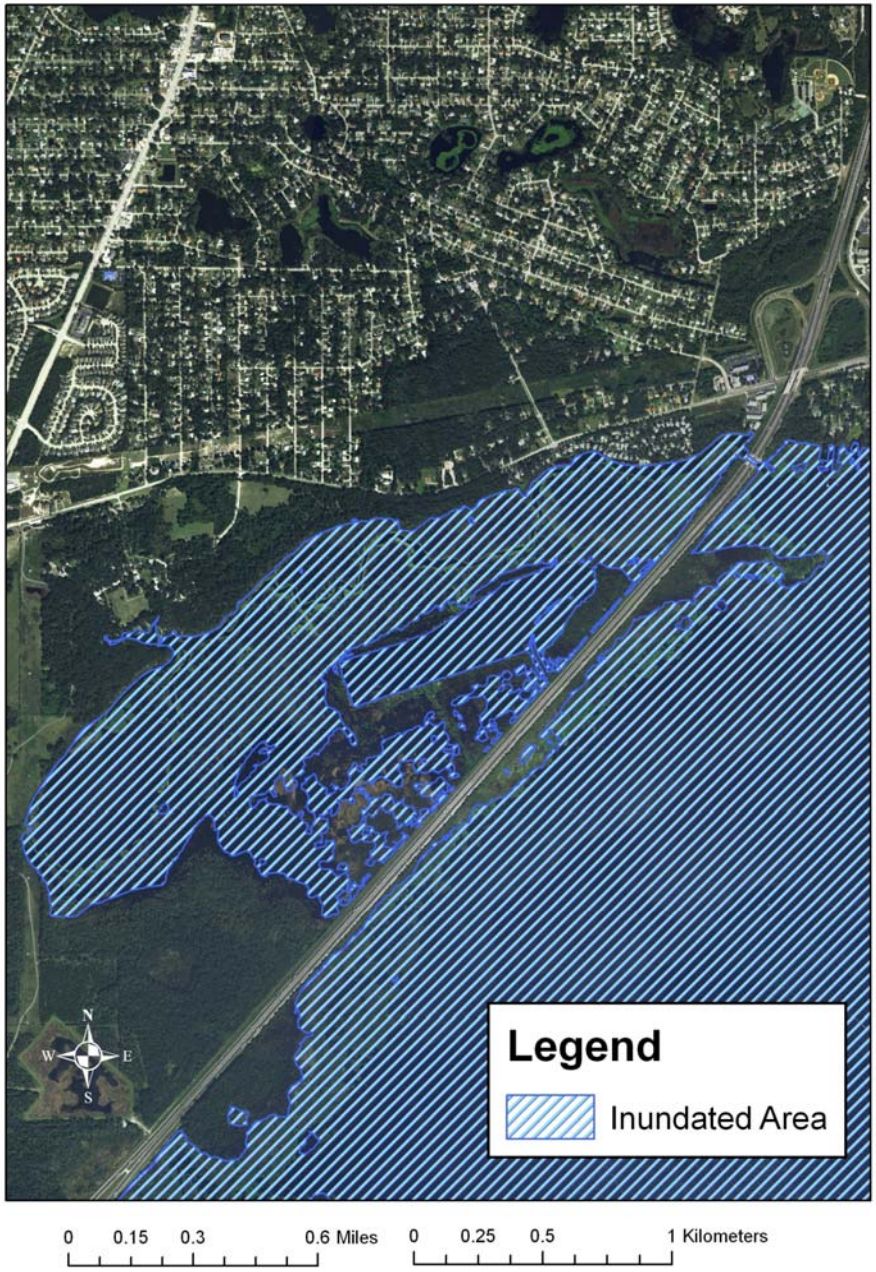

DeBary Bayou, FL stage = 2.0 ft

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DeBary Bayou, FL stage = 3.0 ft

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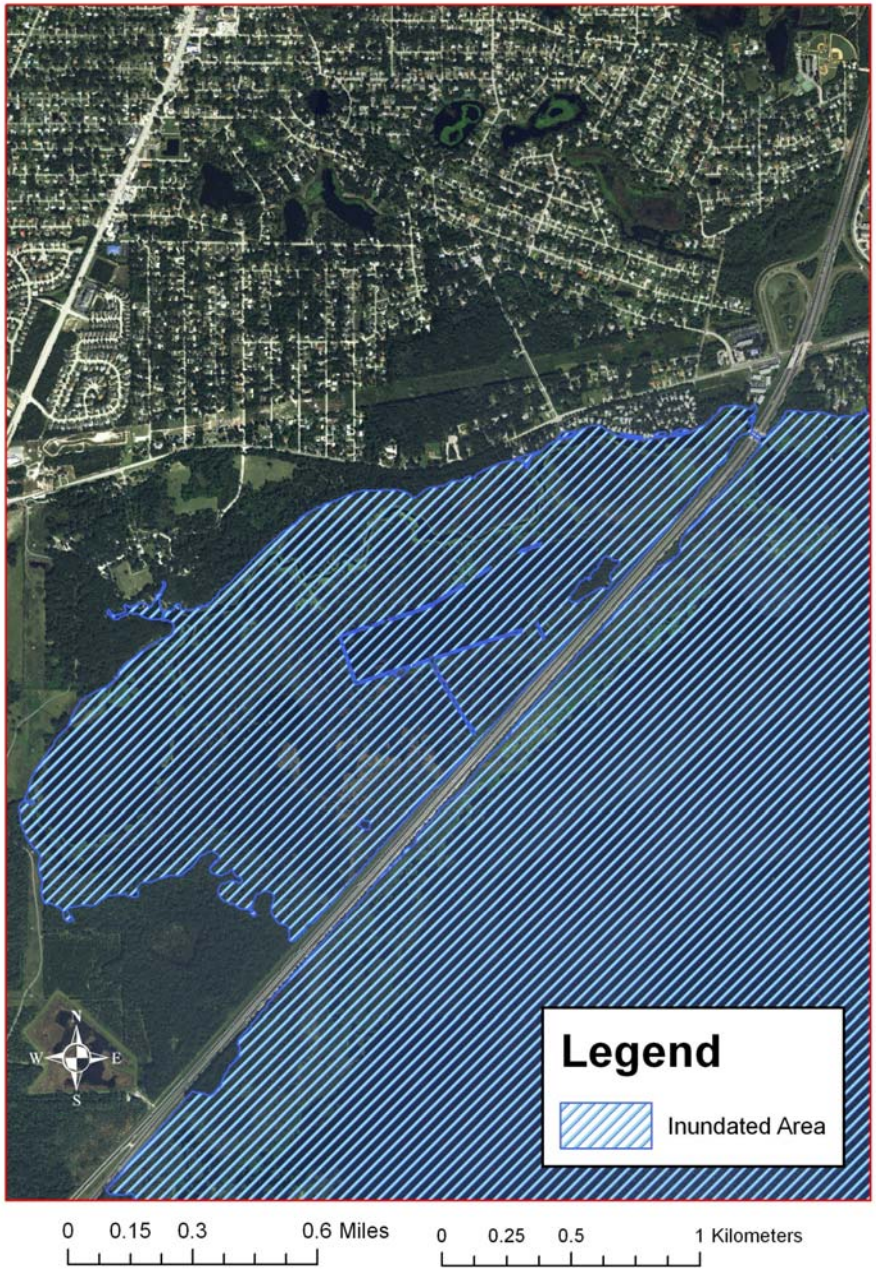

DeBary Bayou, FL stage = 4.0 ft

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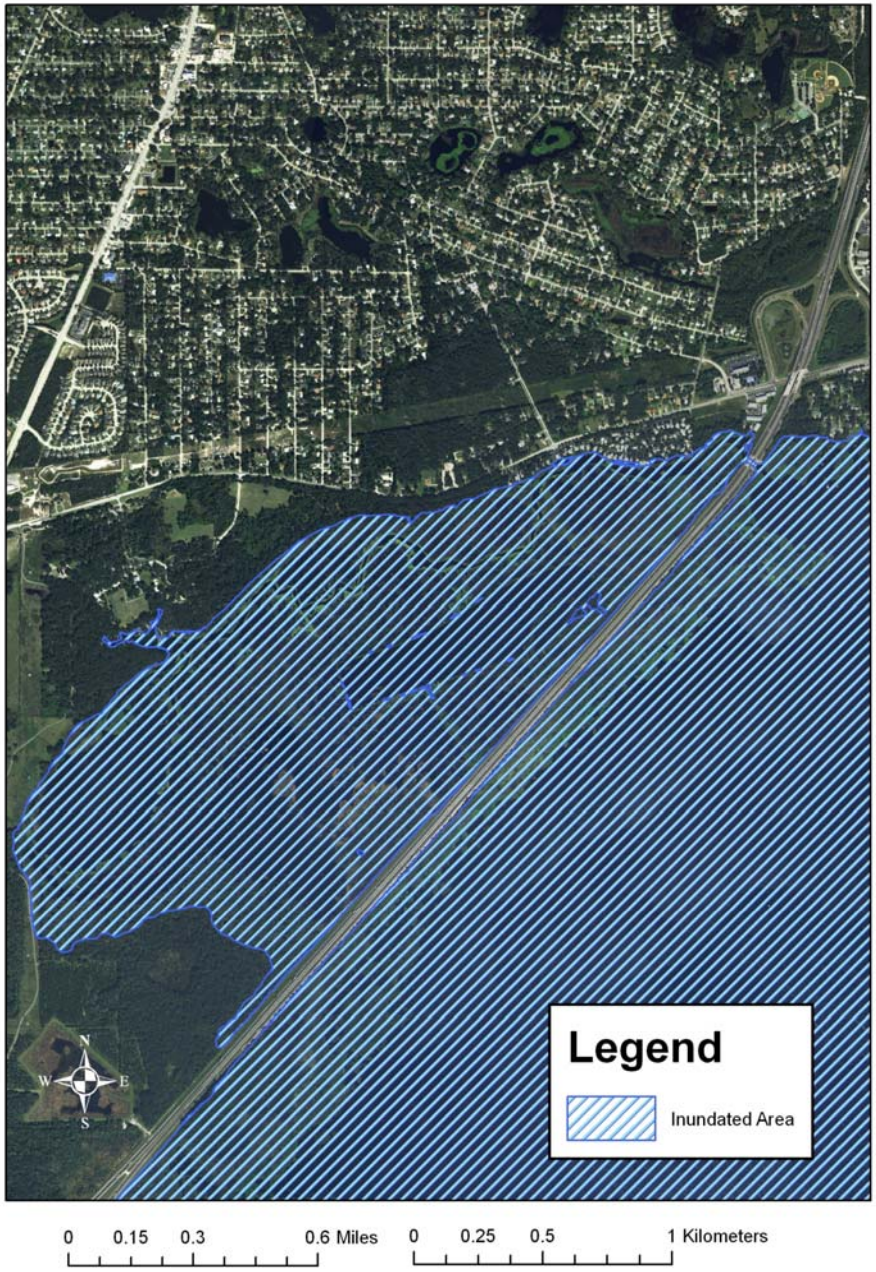

DeBary Bayou, FL stage = 5.0 ft

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Photo Points

Bryant's Brook 1997, following flood of record, 1996

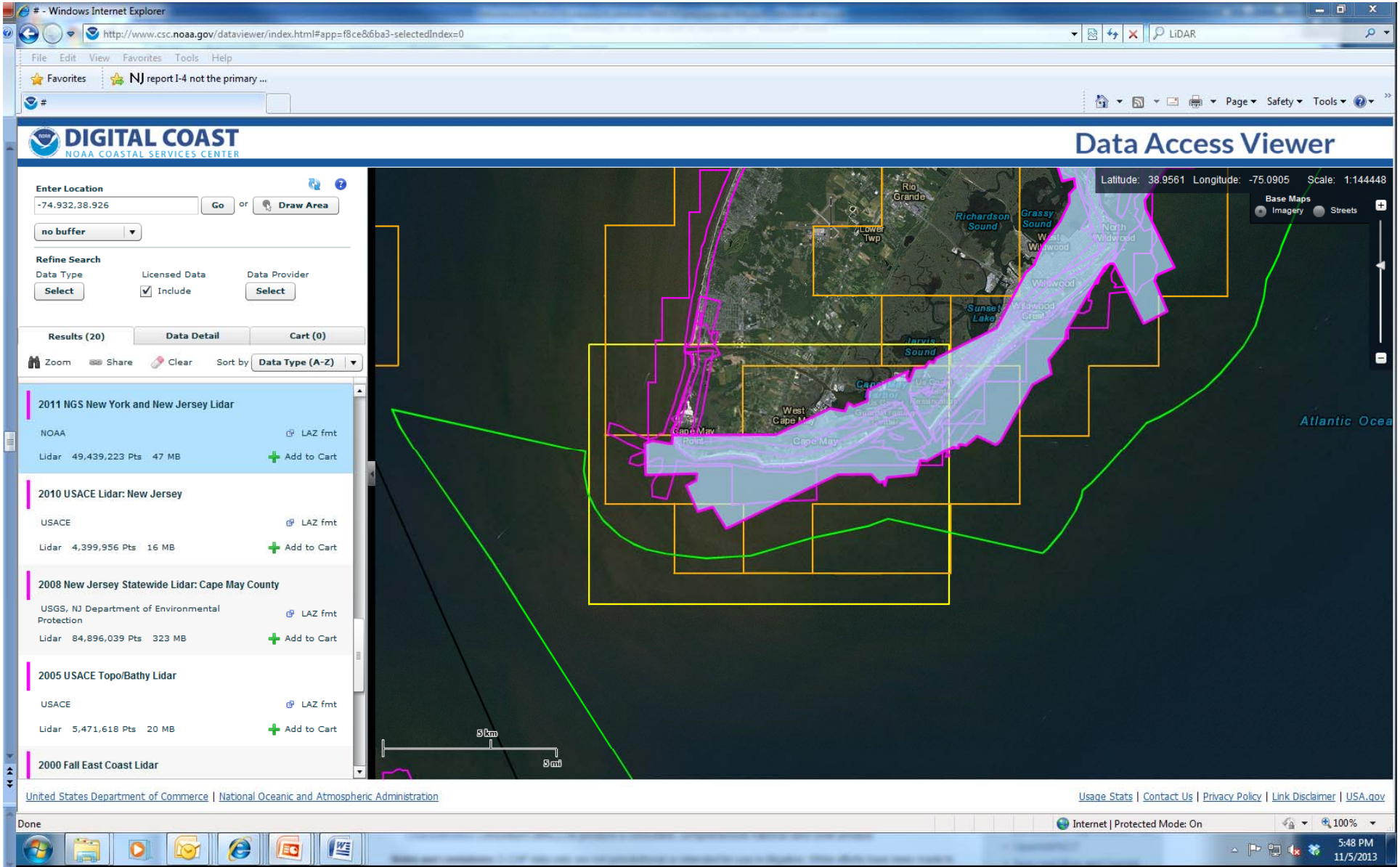
Bryant's Brook 2007

Light Detection and Ranging, LiDAR

- Terrestrial LiDAR
- Bathymetric LiDAR
- USACE NCMP / JALBTCX Joint Airborne Lidar Bathymetry Technical Center of Expertise (see webinar 29 Nov 2011 http://cw-environment.usace.army.mil/exchange.cfm?Option=Webinar&Type=Past&CoP=Env&Id=59&ICS=No)
- NOAA uses LiDAR data to model storm surge, inundation extents, hydrodynamic modeling, shoreline mapping, hydrographic surveys, and coastal vulnerability analysis.

NOAA Digital Coast

- http://www.csc.noaa.gov/dataviewer/index.html#
- Cape May, NJ – 20 data layer results
- LiDAR from USACE, USGS, NJDEP, DE Coastal Program, NASA, from 1996 Fall East Coast NOAA and NASA LiDAR to 2012 post-Sandy USGS LiDAR
- Imagery from NOAA, 2013 and 2011 Delaware Bay and Cape May, NJ
- 2001, 2006 Coastal Change Analysis Program (C-CAP) Land Cover
- http://www.csc.noaa.gov/digitalcoast/tools/slrviewer/



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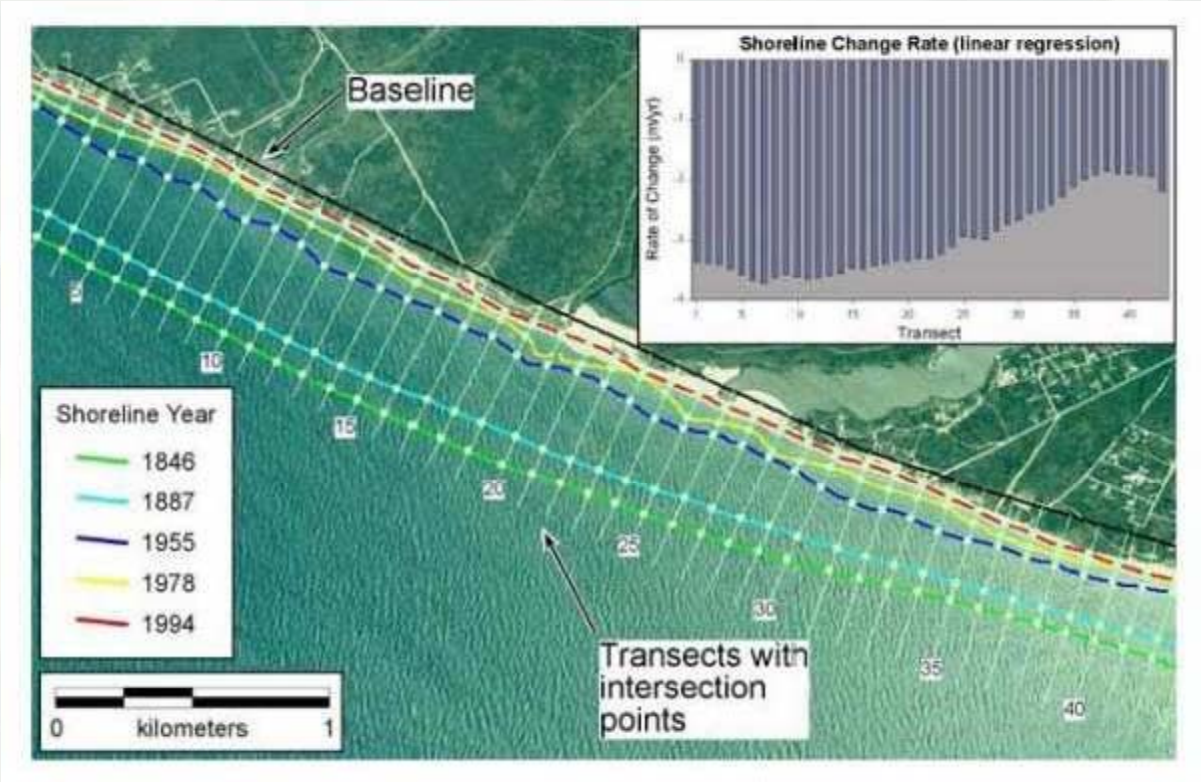
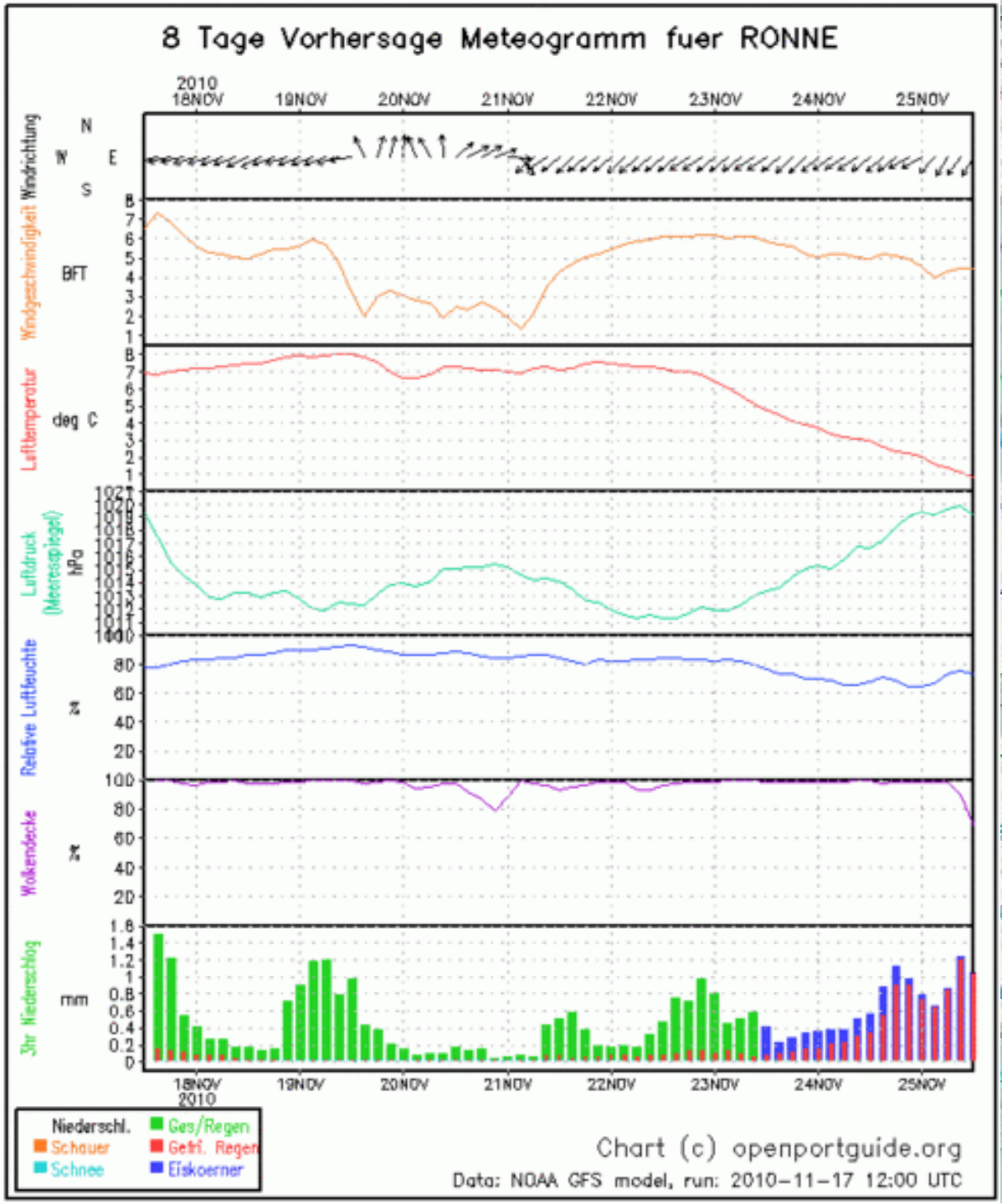
Digital Shoreline Analysis System

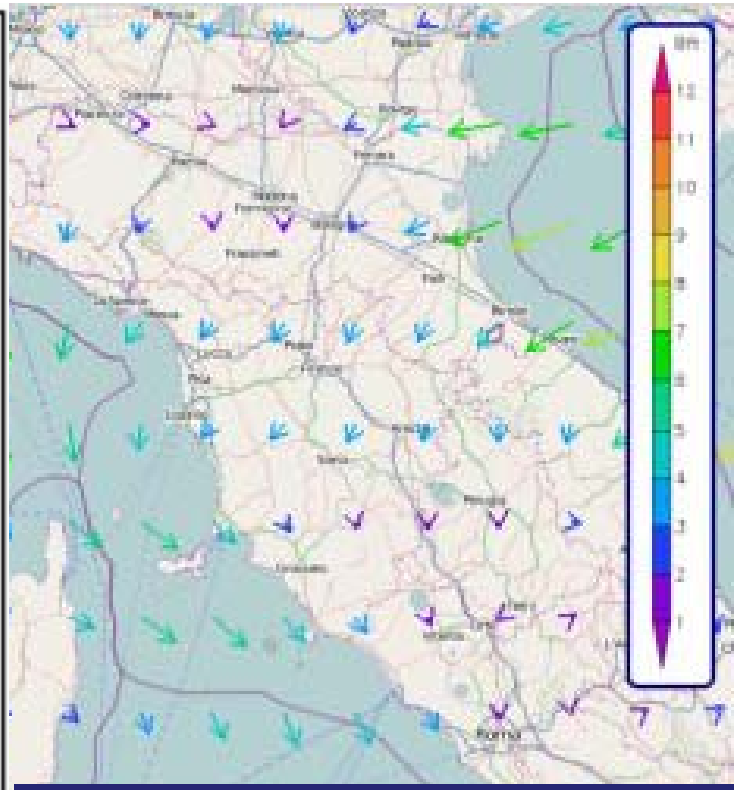
- ESRI ArcGIS v.10 extension for calculating shoreline change using multiple historic positionsthe authors and other DSAS users.



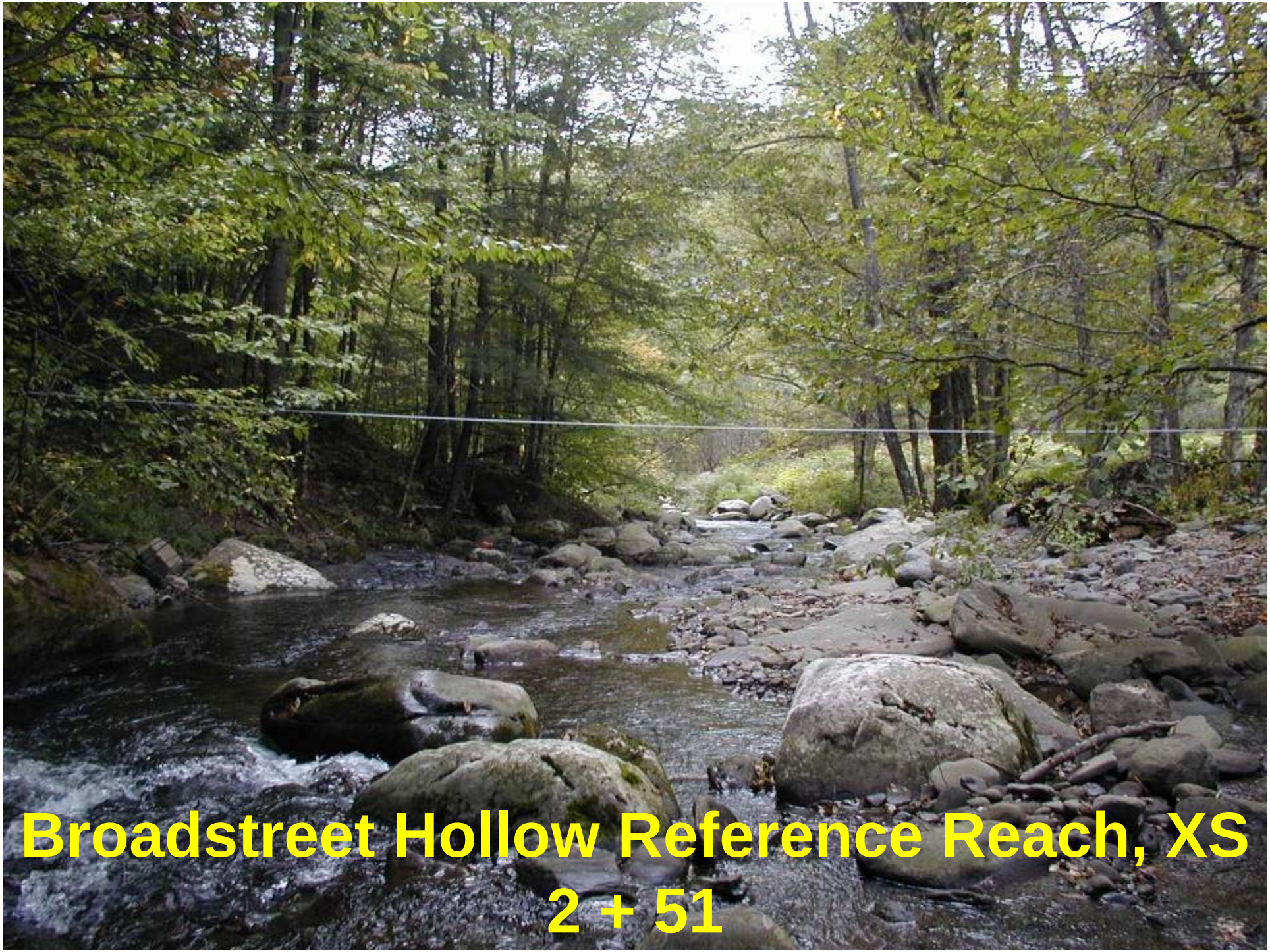
Historic shorelines and DSAS-generated transects at 100-meter spacing with histogram showing rates of shoreline change computed using simple linear regression.

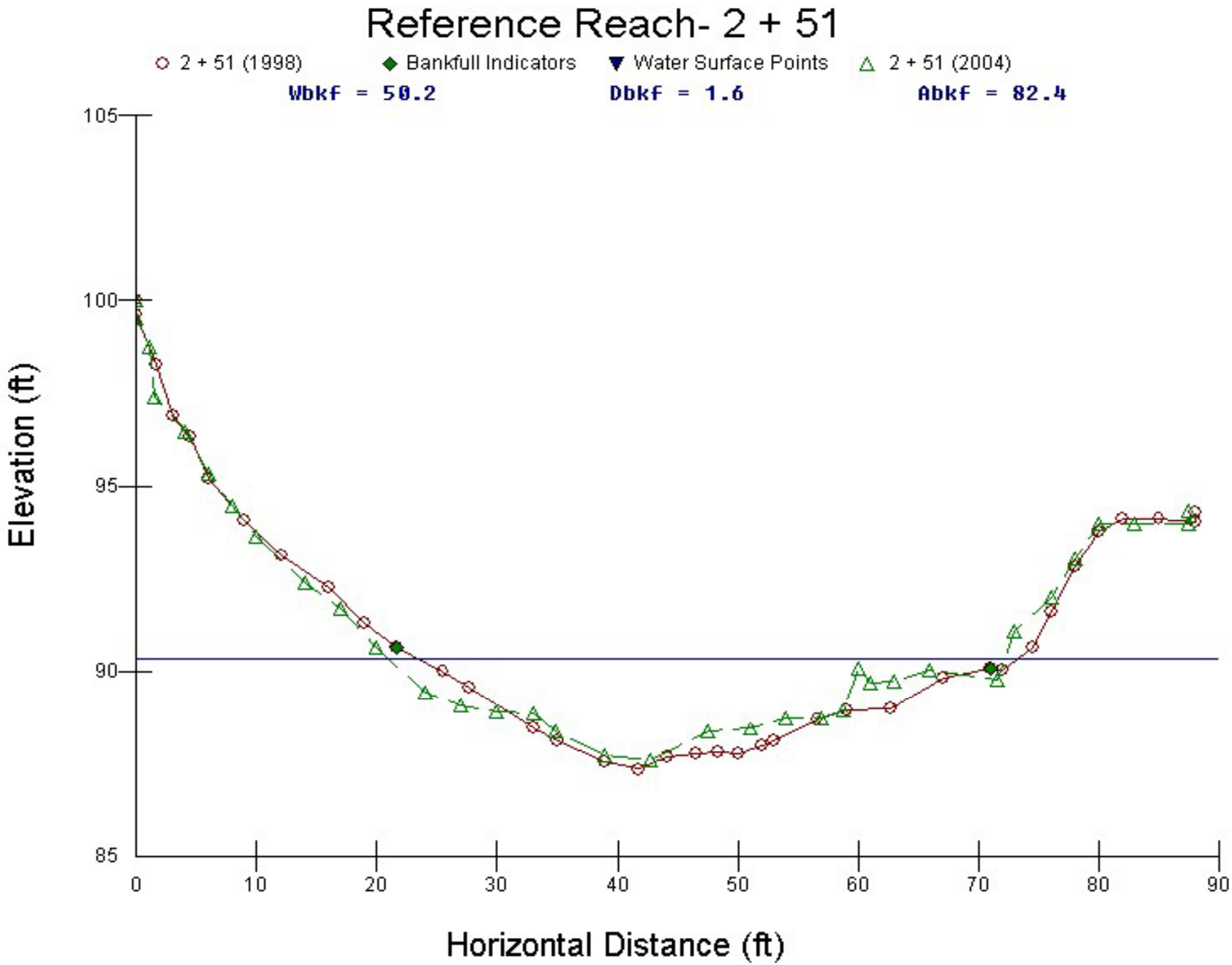
http://woodshole.er.usgs.gov/project-pages/DSAS/version4/index.html

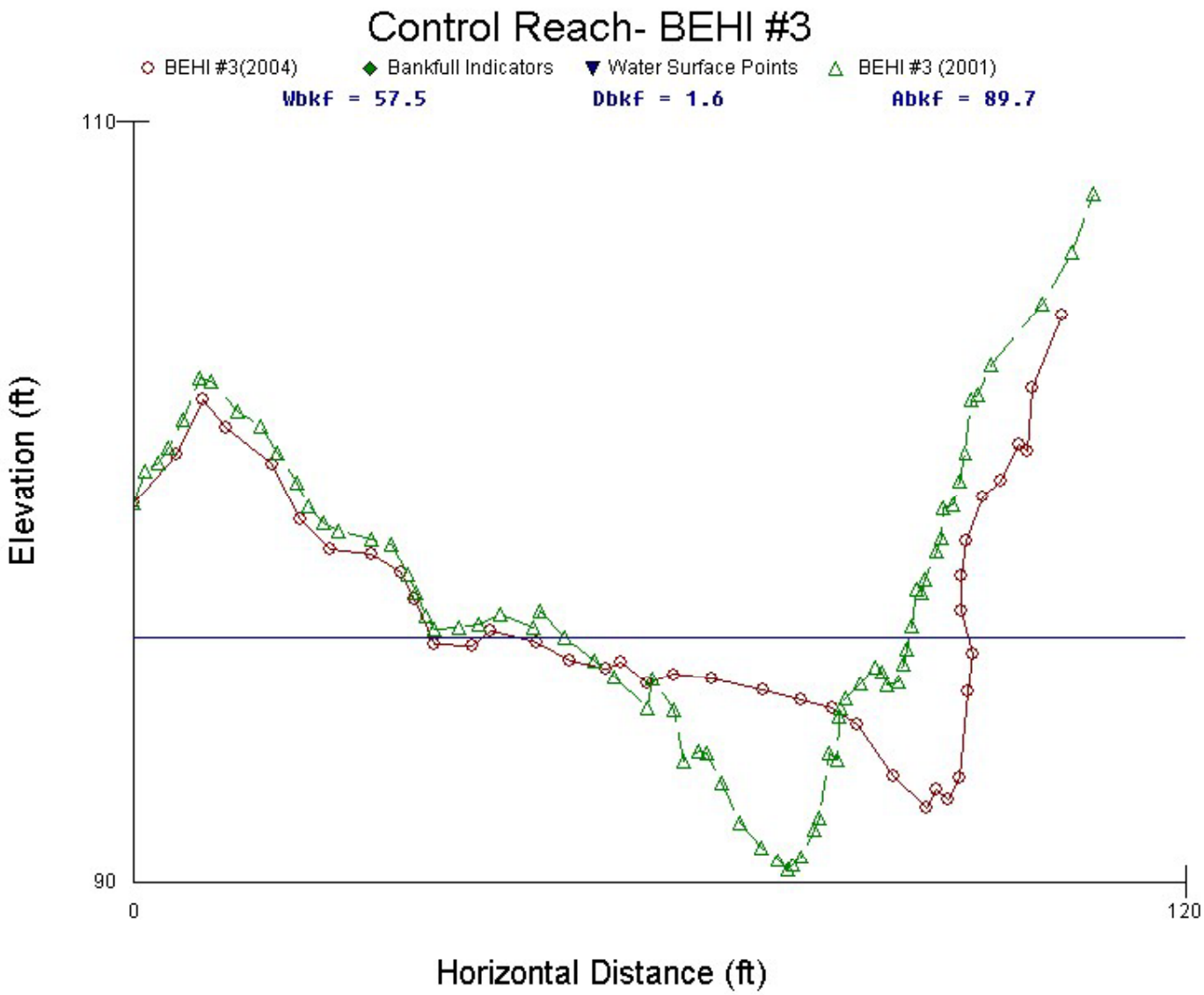




OpenSeaMap – geospatial nautical charts with worldwide bathymetry, other resources like Meteogram that gives an 8 day forecast including direction of wind, wind force, barometric pressure, relative humidity, air temperature, precipitation, wave height for 5000 harbors worldwide.
http://www.openseamap.org/


Broadstreet Hollow Reference Reach, XS
2 + 51


Reference Reach- 2 + 51
2 + 51 (1998)
Bankfull Indicators
Water Surface Points
2 + 51 (2004)
Wbkf = 50.2
Dbkf = 1.6
Abkf = 82.4
Elevation (ft)
105
100
95
90
85
0
10
20
30
40
50
60
70
80
90
Horizontal Distance (ft)


Control Reach- BEHI #3
BEHI #3(2004)
Bankfull Indicators
Water Surface Points
BEHI #3 (2001)
Wbkf = 57.5
Dbkf = 1.6
Abkf = 89.7
110
90
0
120
Elevation (ft)
Horizontal Distance (ft)

Batavia Kill, Catskill Mountains, NY. Photo by Sarah J. Miller

Batavia Kill, Catskill Mountains, NY. Photo by Sarah J. Miller

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- Countless student interns

Questions and Feedback

Presentation recording:
http://el.erdc.usace.army.mil/wots/wots.html

Next Presentation: 14 November 2013: Aquatic Communities Monitoring, Jock Conyngham, ERDC-EL

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