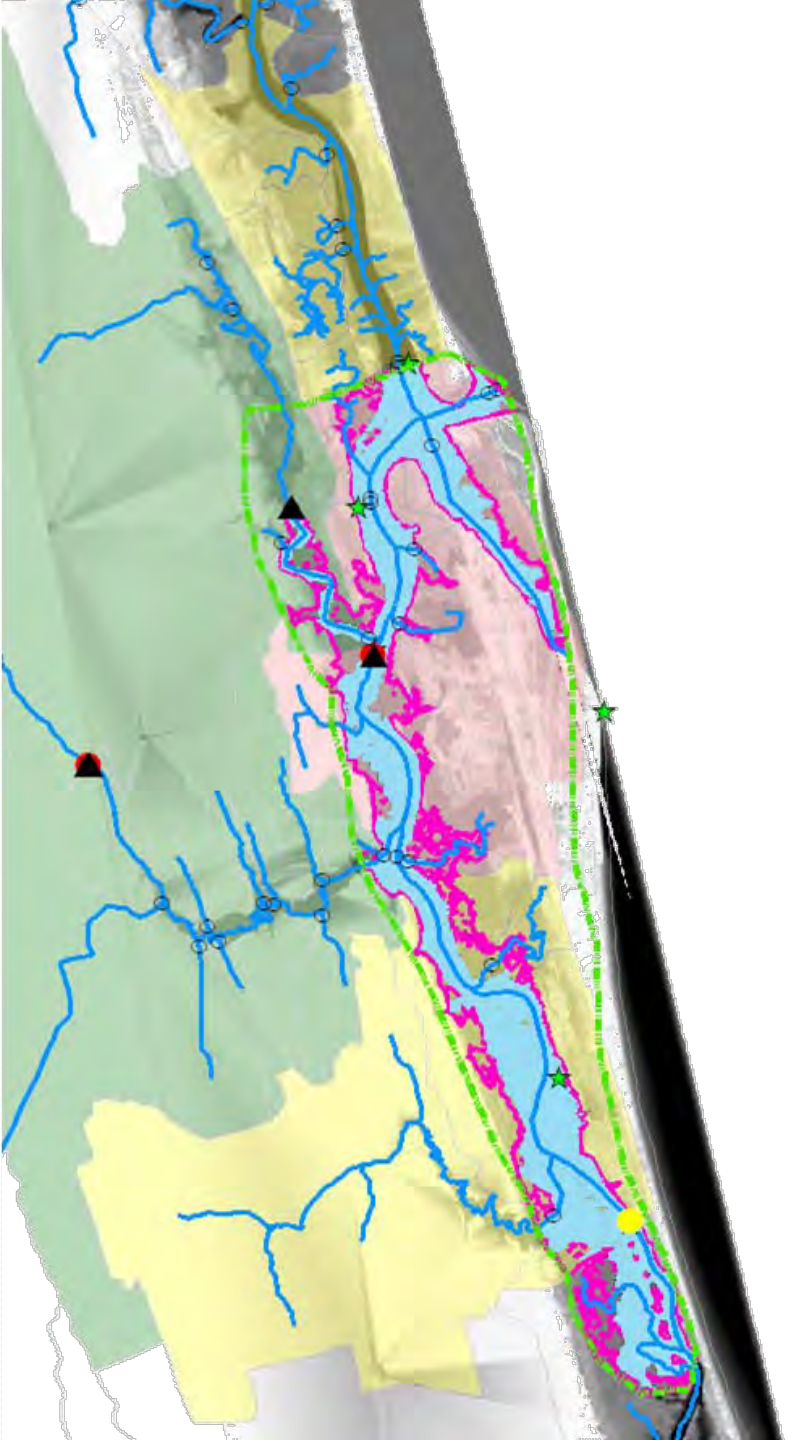


Building a GIS-Based Analytical Framework for Coastal and Estuarine Study

Sandra Fox – *St. Johns River Water Management District, Palatka, FL*

Steve Bourne – *Post, Buckley, Schuh and Jernigan, Atlanta, GA*

Clay Montague – *University of Florida, Gainesville, FL*

Palmer Kinser – *St. Johns River Water Management District, Palatka, FL*

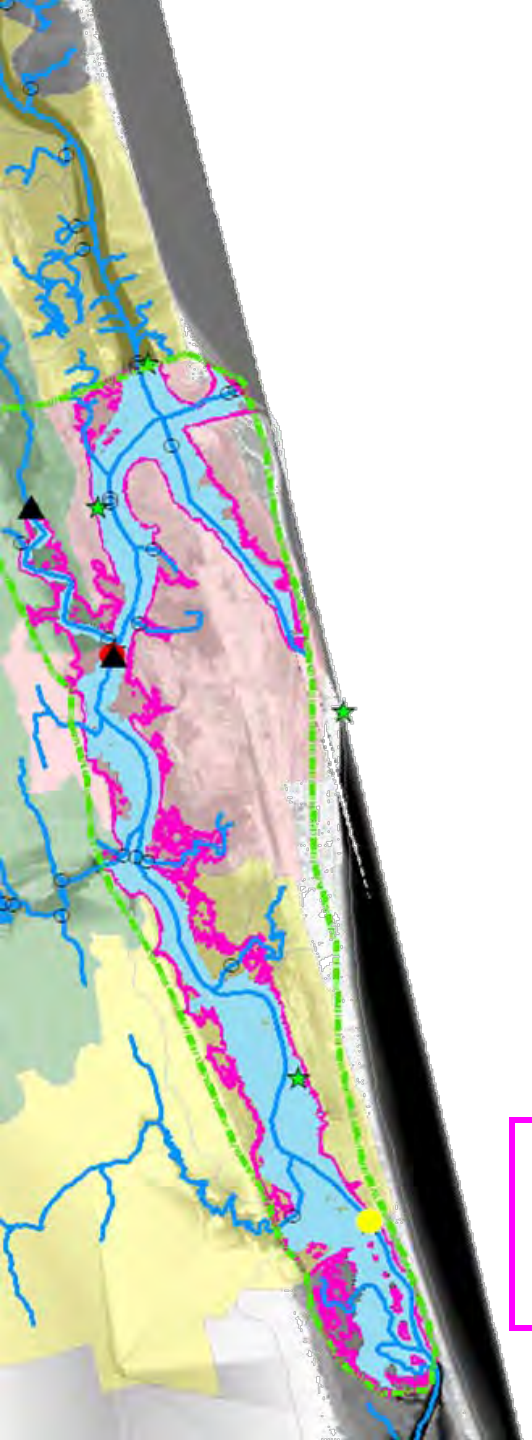
Coastal Geotools 2009

A Conference Objective

Participants learn about emerging tools and techniques and their benefits and applicability

Outline

- Background
- Function
- Demo
- Applicability
- Benefits



Background

Tool and schema were designed:

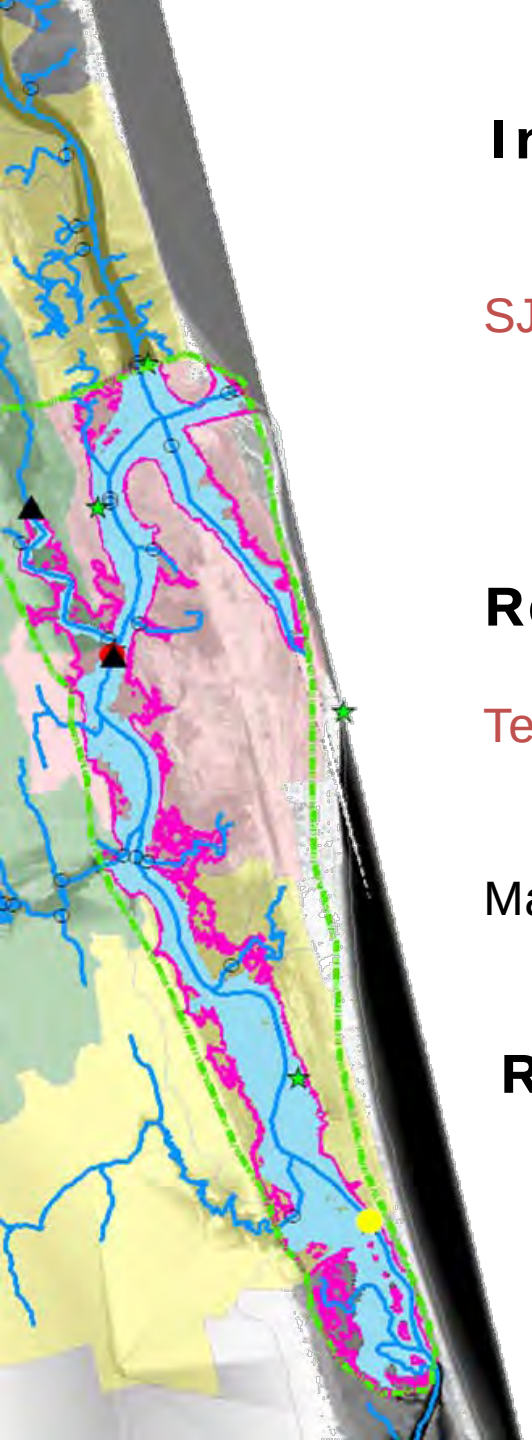
- As a collaborative effort by a team of scientists, engineers, GIS experts, software (GIS) programmers

- Then reviewed by an additional team of experts

- To assist in better understanding of estuarine systems, and to assist in the development of estuarine and coastal decision support systems *"C - 08" - NOAA Coastal GeoTools 2009 Tom Singleton et al.*

- To take advantage of advances in GIS technology, including Arc Hydro (GIS for Water Resources)

- To take a different approach in the determination of the "area of influence" for water quality monitoring sites



Initial design team:

- Steve Bourne – PBS&J
- Sandra Fox, Palmer Kinser, Pete Sucsy, Aisa Ceric – SJRWMD
- Clay Montague, Ashish Mehta – University of Florida
- Michael McManus – The Nature Conservancy
- Michael Turtora – USGS

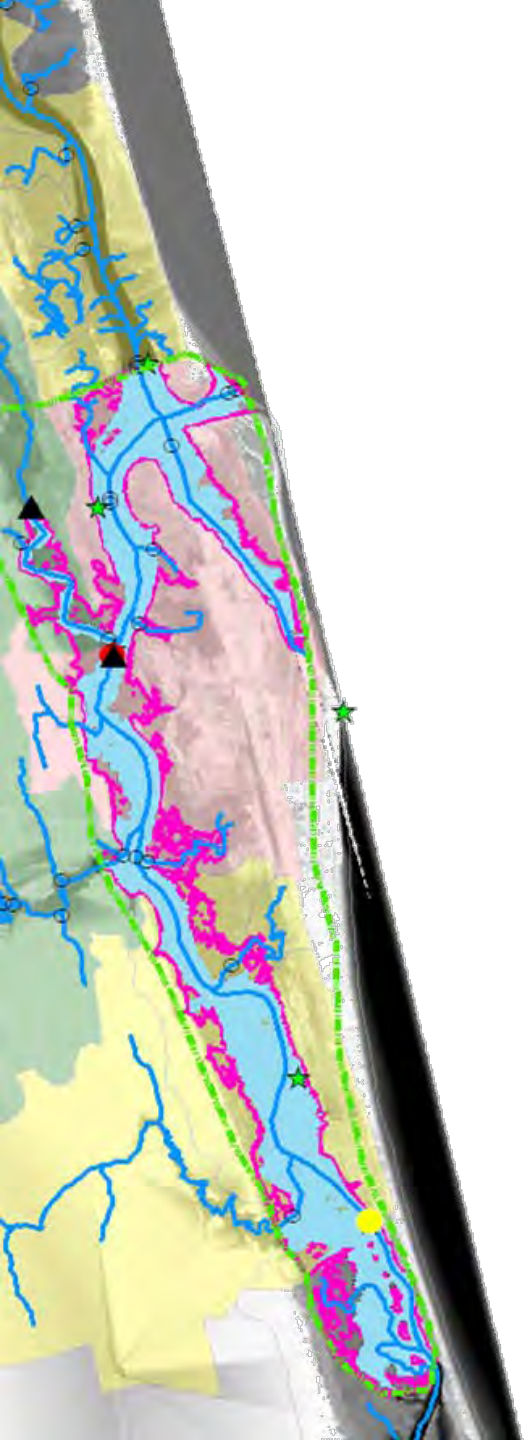
Review team:

- David Maidment, Tim Whiteaker – University of Texas, Center for Research in Water Resources
- Rob Wallace – USACE, Vicksburg
- Joel Steward, Whit Green, Steve Winkler, Nathan Martin, Adrian Lin – SJRWMD
- Jack Hampson – PBS&J

Recent review:

- Naomi Detenbeck – EPA

"D - 07" - NOAA Coastal GeoTools 2009



The tool and schema were designed:

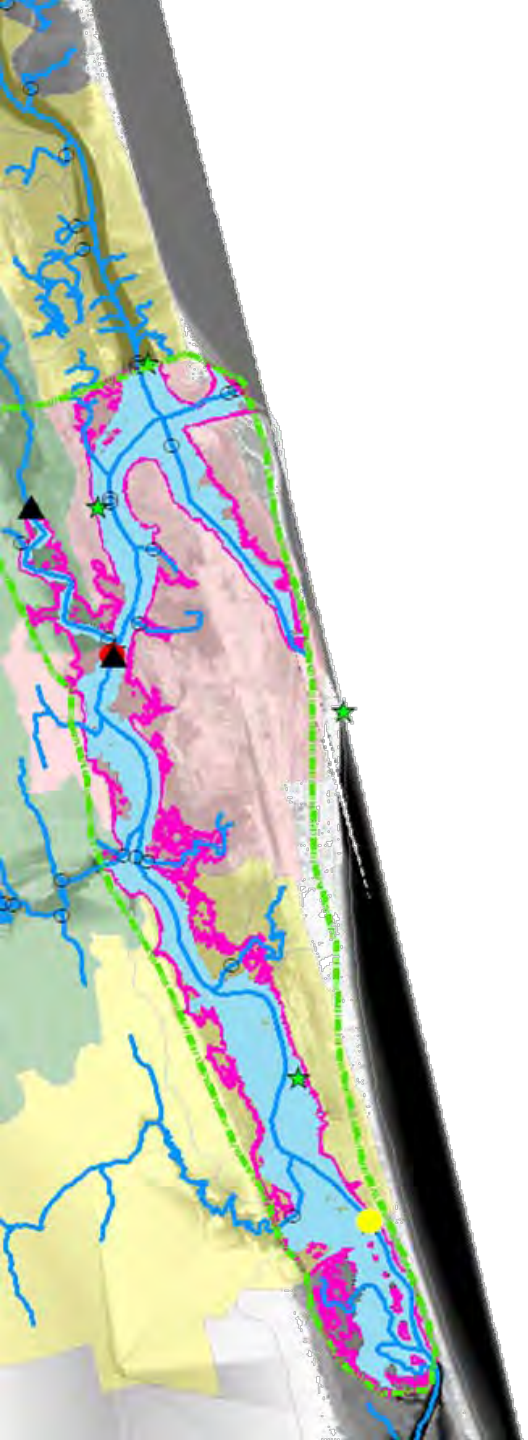
To assist in better understanding of estuarine systems:

- complex geomorphology, hydrodynamics and biogeochemistry

- traditionally tackled with commensurately complex supercomputer-based modeling techniques

- computational, intellectual and financial expense renders them unavailable to most coastal professionals

- Focus on “First-Principles-Analysis” of Estuary

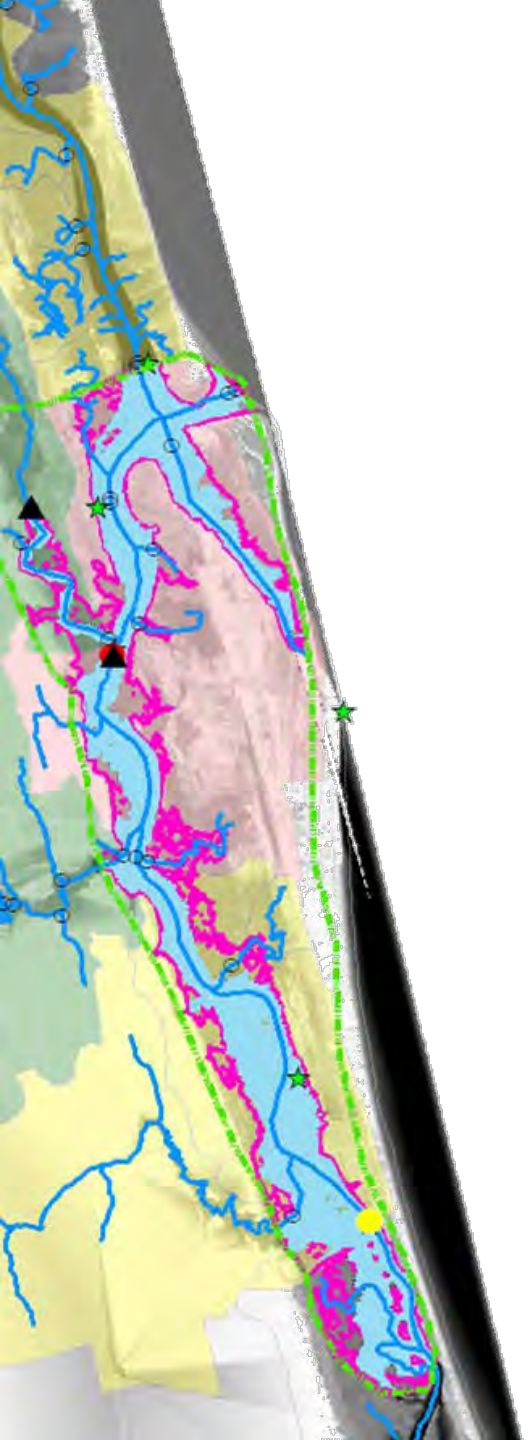


The tool and schema were designed:

To take advantage of advances in GIS technology, including Arc Hydro:

- Arc Hydro is a template system (geodatabase & tools) designed specifically for water resources

- ESRI, CRWR (UT – Dr. David Maidment) and CUASHI (Consortium of Universities for the Advancement of Hydrologic Sciences, inc.)



The tool and schema were designed:

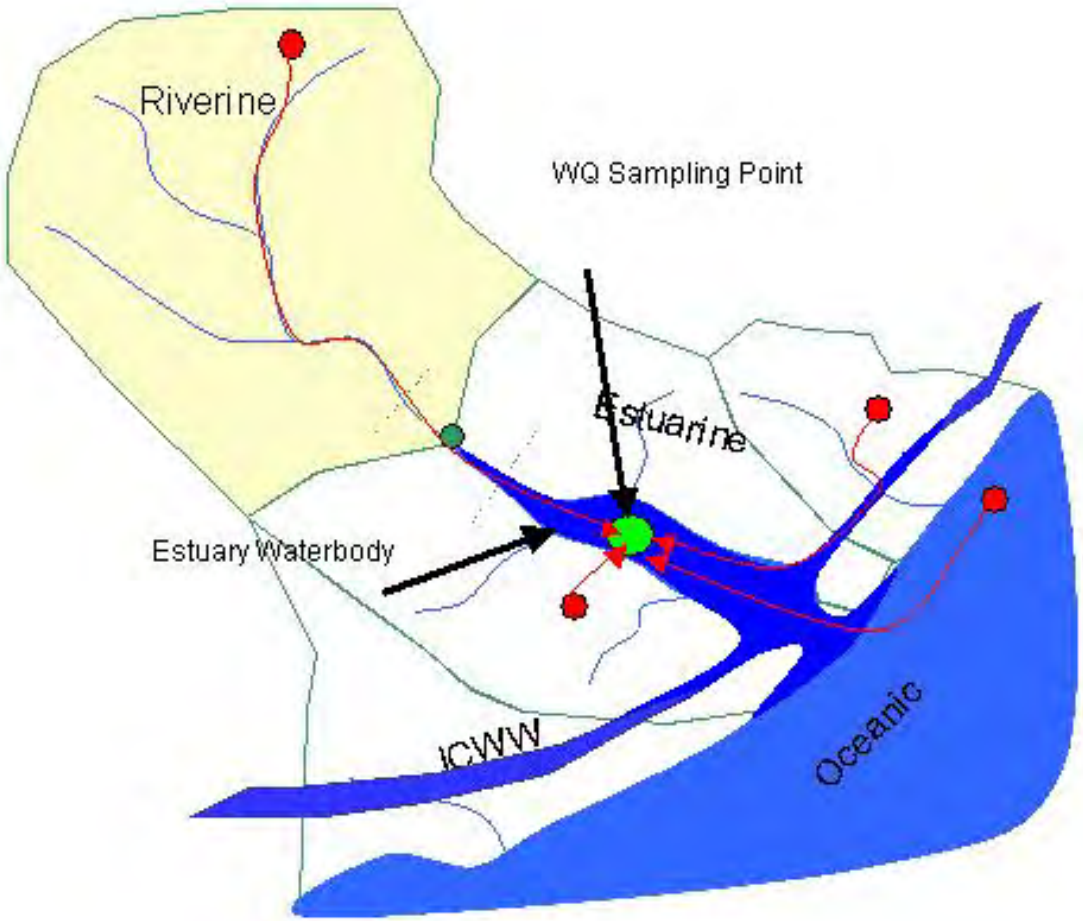
To take advantage of advances in GIS technology, including Arc Hydro: ***But.....***

- Arc Hydro falters at the coast

- No method to account for or simulate tidal influence

- Developed some “work-arounds” for Arc Hydro to “work” at the coast, but they were not satisfying from either a scientific or GIS perspective

Enhancement / modifications to Arc Hydro for Coastal and Estuarine areas



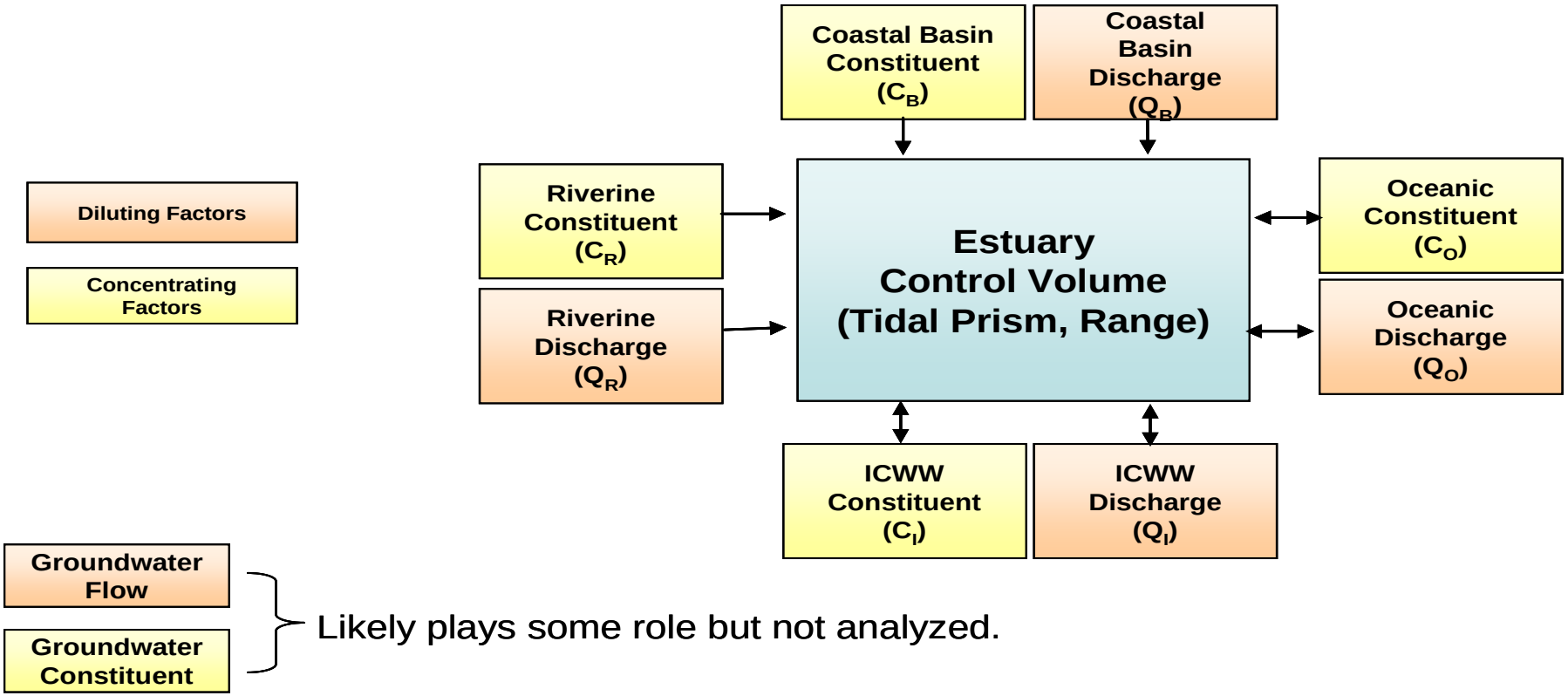
Estuary conceptual model

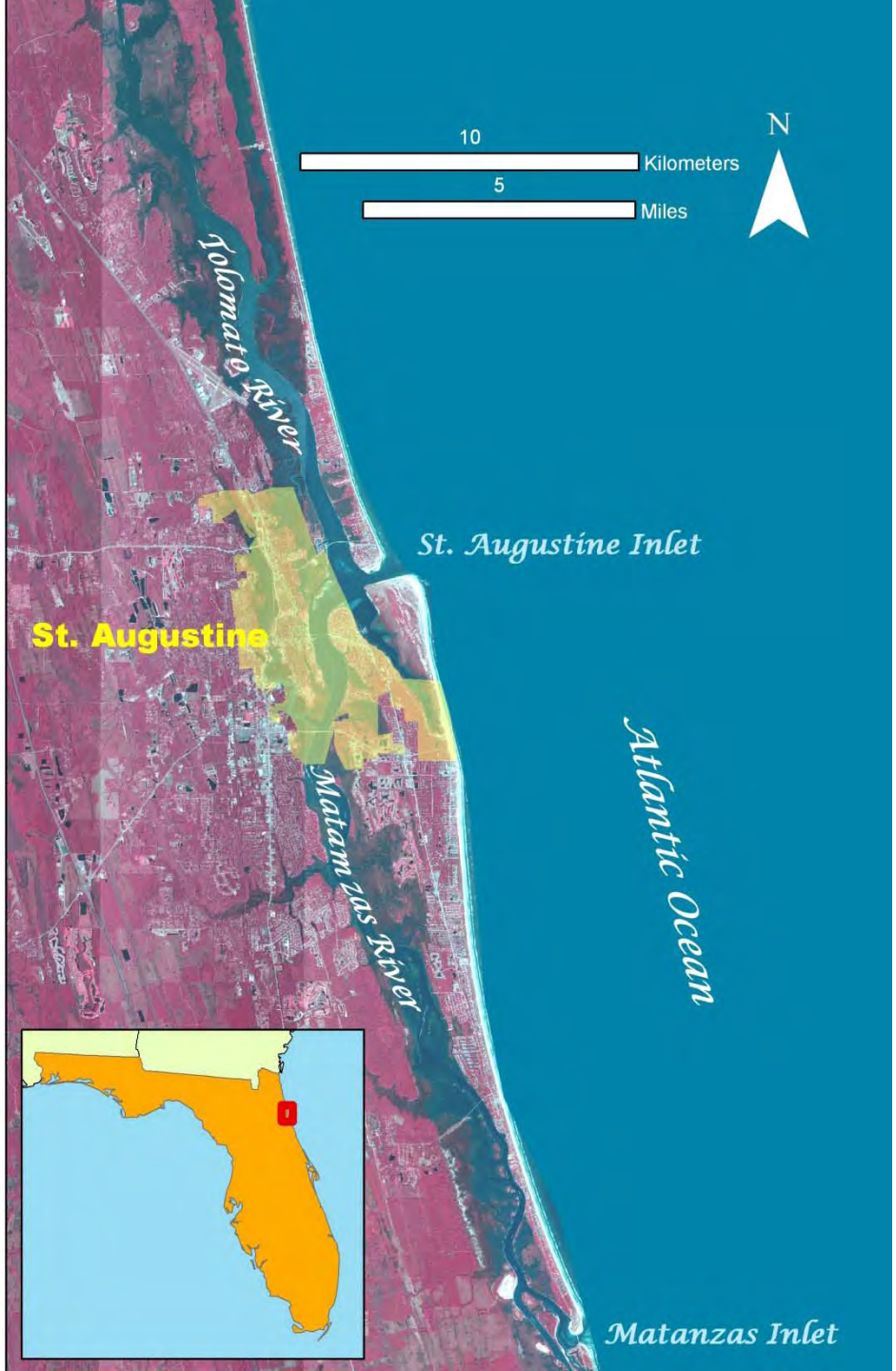
"C-08" - NOAA Coastal GeoTools 2009

Singleton et al., DSS

Focus on "First-Principles-Analysis" of Estuary"

Control Volume Approach to estuarine water quality analysis





Initial study site:

St. Augustine Inlet

Why here?

Best available dataset

REQUIREMENTS FOR PROTOTYPE TOOL OPERATION:

1. **The Tool installed** as an extension to ESRI ArcMap.
2. **ArcMap** at full ArcInfo license level, Spatial Analyst and 3D Analyst.
3. **An enhanced Arc Hydro geodatabase**, an extended version of the SJRWMD Arc Hydro geodatabase, with the following Arc Hydro feature classes populated:
   a. "QuadBasin" (Catchment) – vector landscape representation
   b. Monitoring_Point_HDS – discharge data
   c. Water Quality Monitoring Points
   d. HydroEdge (Arc Hydro flowlines)
   e. TidalNullPoint (approx. point flow diverges on an outgoing tide) optional
4. **A populated TidePoint feature class,** part of the **Coastal Feature Dataset** of the enhanced Arc Hydro geodatabase (schema). The TidePoint feature class should have the attribute fields "Hi Tide Ht" and "Lo Tide Ht" populated, from **NOAA.**
5. **An Estuary feature class.** The Estuary feature class is part of the Coastal Feature Dataset of the enhanced Arc Hydro geodatabase. (Because the tool generates the information necessary to fill in the attribute information in this feature class, the feature class does not have to be populated in order to get started.)
6. **Time series data.** The enhanced Arc Hydro geodatabase has new "DataCube table couplets" (*explained in the Requirements & Specifications document, Part 2 of the documentation* that contain time series data. These time series DataCubes are related (by virtue of ESRI ArcMap relationship classes) to the water quality monitoring points, the QuadBasins, and the HDS monitoring points. You can populate these DataCubes with time series of observations measured at these locations or with derived data. (*There is a short tutorial in documentation on one method for how to populate the DataCube tables*.)
7. **A Bathymetry/Terrain layer (DEM).** This should be a single, floating point, raster that has merged bathymetry and terrain data.
8. **An ArcMap mxd** that contains all the data listed above.

Steps (work flow):

1. Introduction to the Tool Interface (Workbench) and Creation of the Virtual Estuary.

2. Associating Bathymetry and Terrain with the Estuary.

3. Associating TidePoints with the Estuary

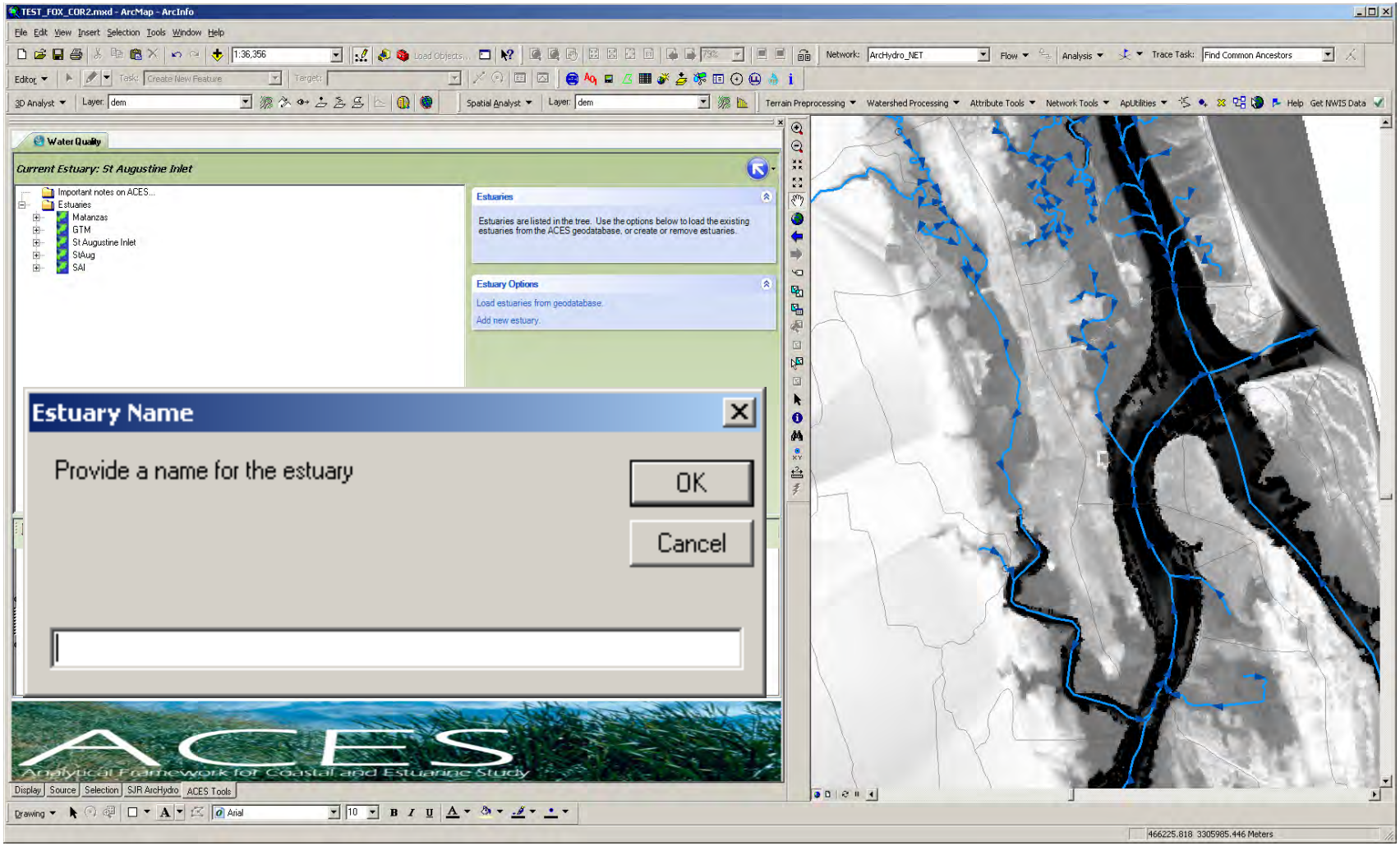
4. Creating the Estuary boundary or boundaries.

5. Associating other features with the Estuary

6. Calculating Bulk Parameters

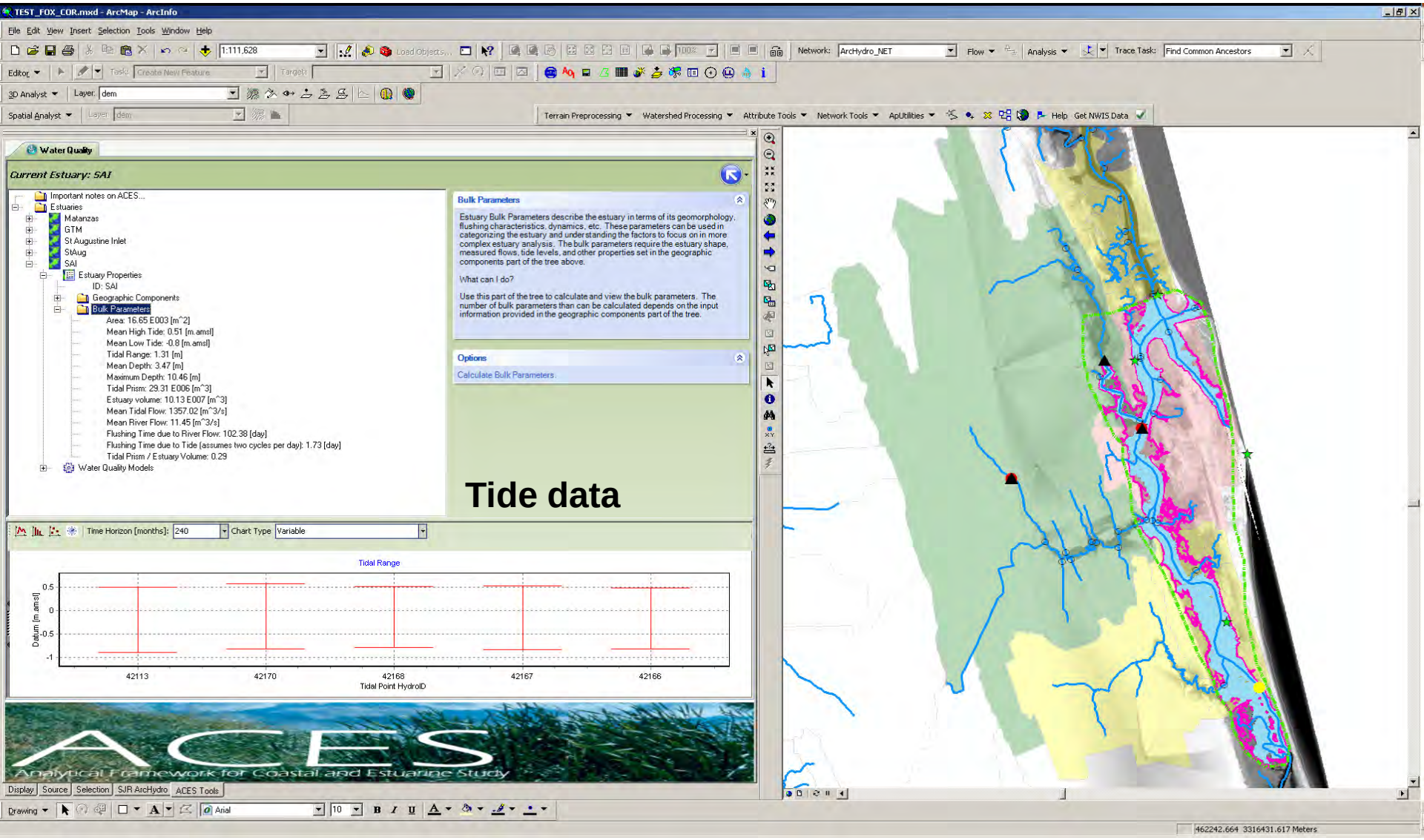
7. Building a linear regression or other model. *(This needs work!)*

1. Introduction to the Tool Interface and Creation of the Virtual Estuary

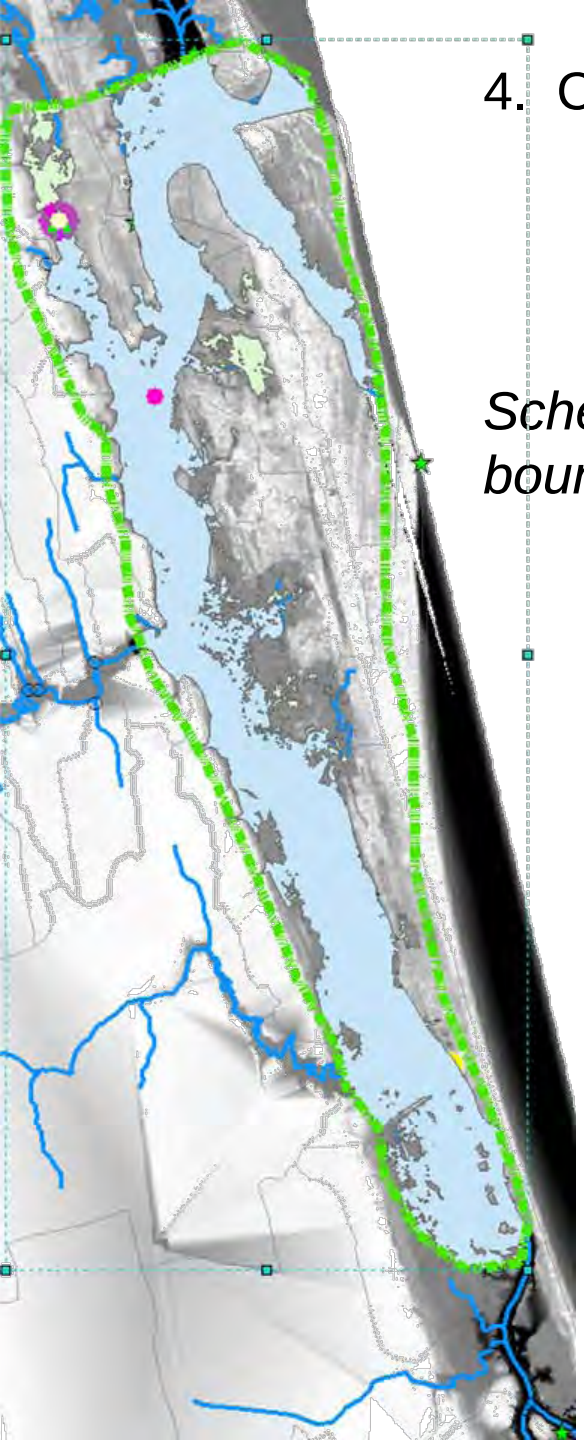


2. Associating DEM to the virtual estuary

3. Associating features with the Estuary - - - - viewing attribute data

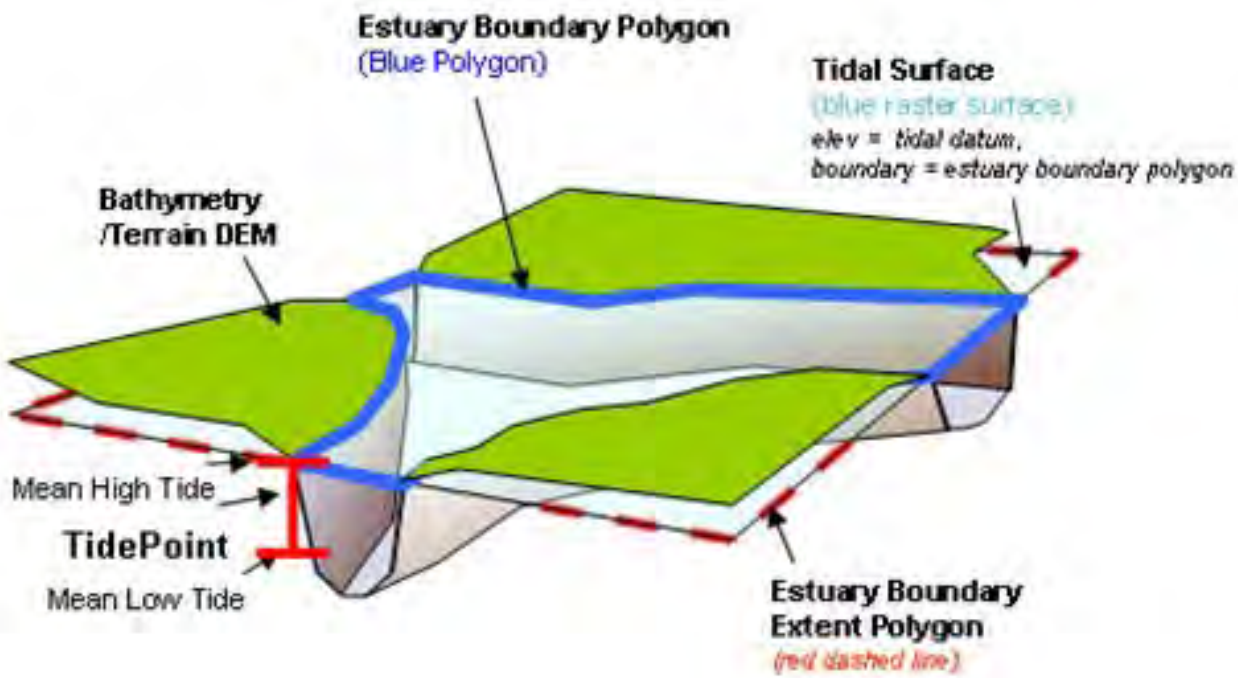


By virtue of relationship classes in geodatabase schema



4. Creating the Estuary boundary or boundaries

Schematic of the process for creating the Estuary boundary polygon

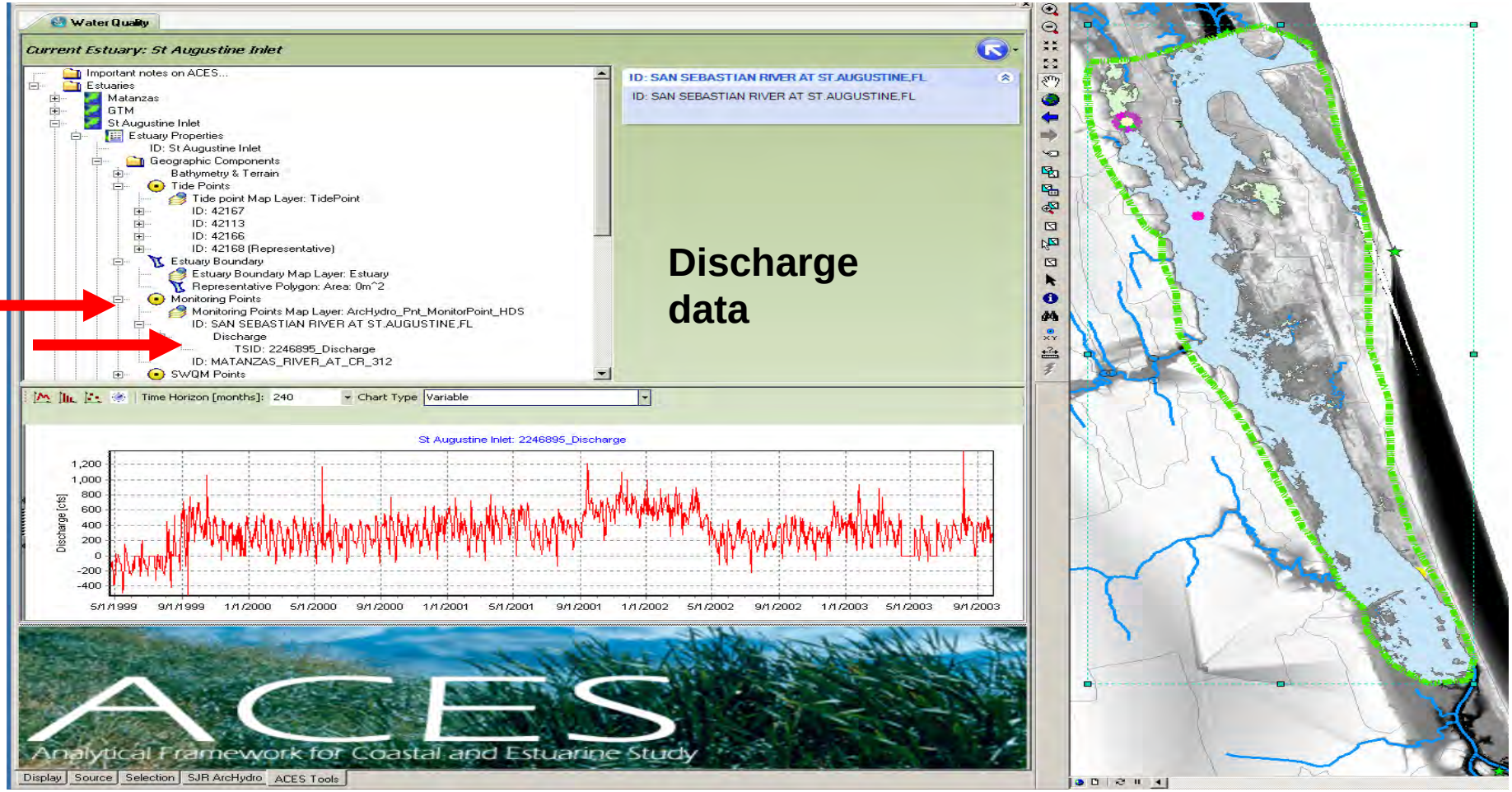


Creating the Estuary boundary or boundaries

Green = Low Tide

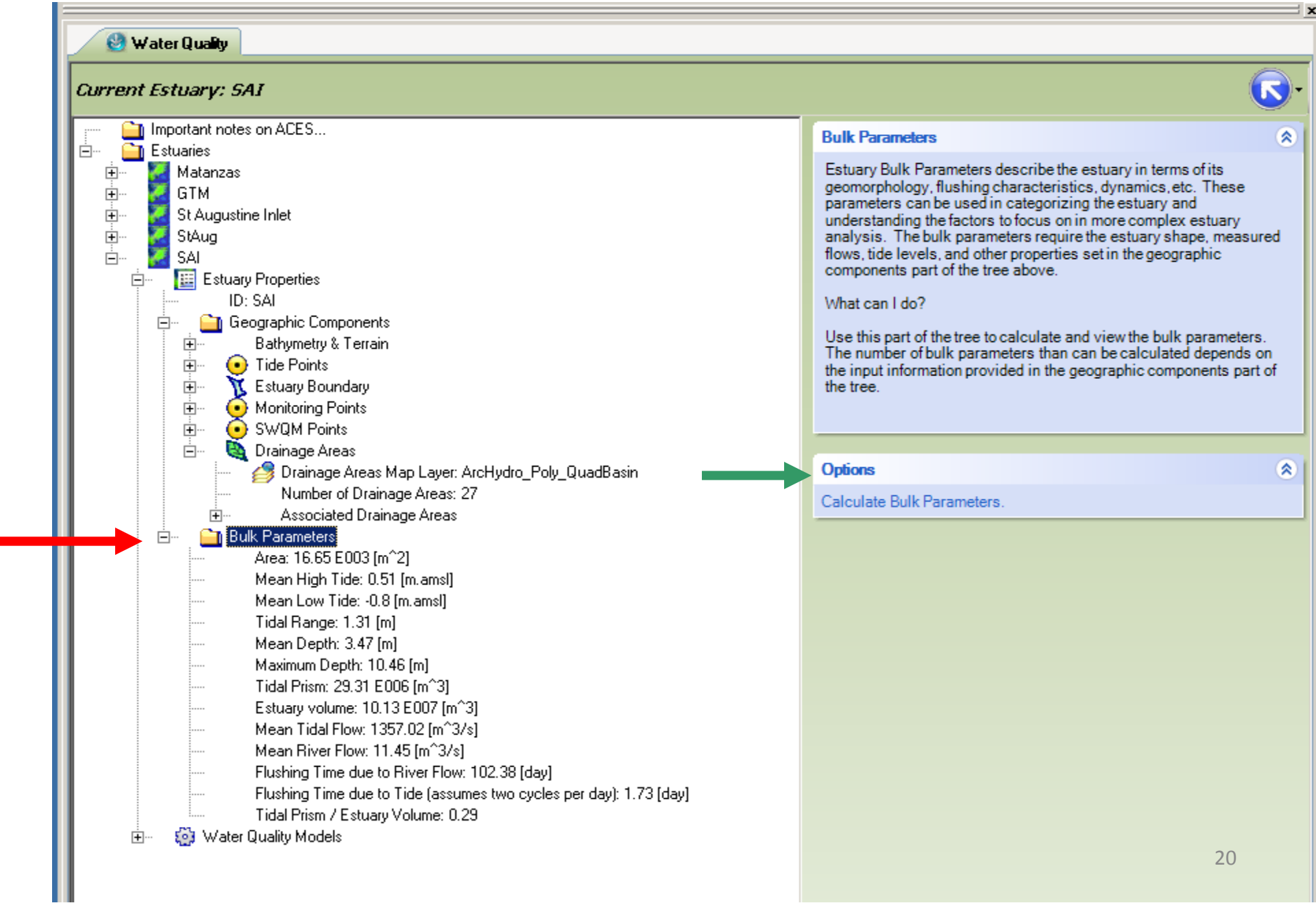
Purple = High Tide

5. Associating other features with the Estuary - - - - *time series data*



Demo

6. Calculating Bulk Parameters

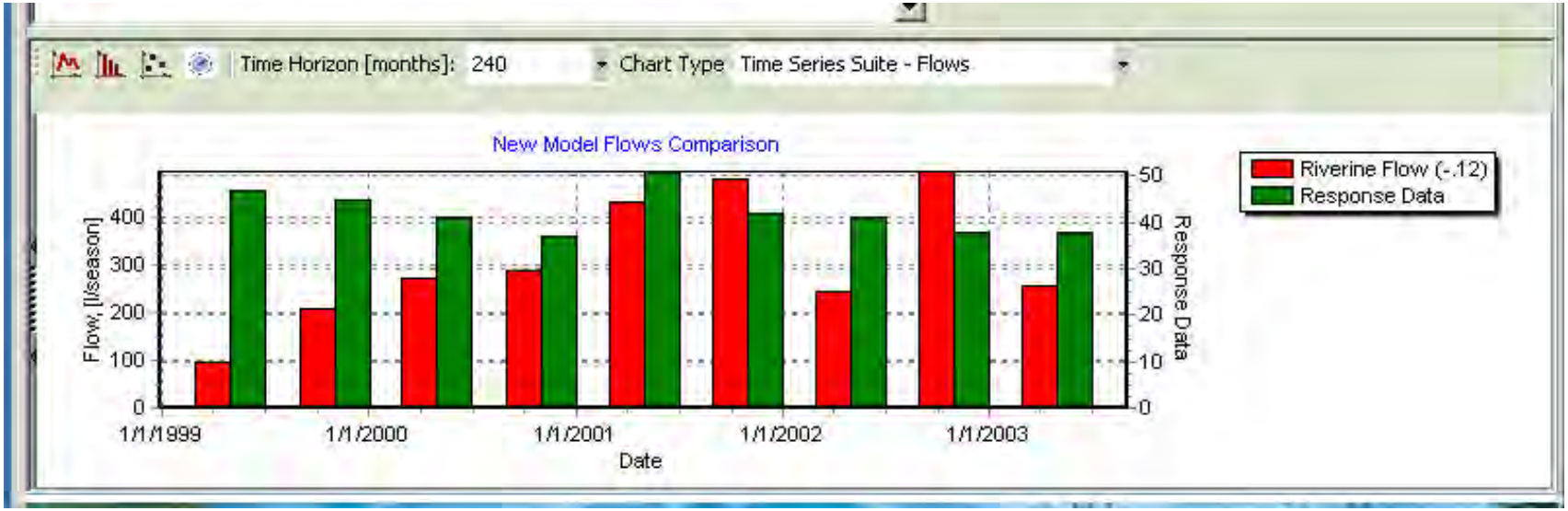


Calculating Bulk Parameters

Bulk Parameters

- Area: 16.65 E003 [m^2]
- Mean High Tide: 0.51 [m.amsl]
- Mean Low Tide: -0.8 [m.amsl]
- Tidal Range: 1.31 [m]
- Mean Depth: 3.47 [m]
- Maximum Depth: 10.46 [m]
- Tidal Prism: 29.31 E006 [m^3]
- Estuary volume: 10.13 E007 [m^3]
- Mean Tidal Flow: 1357.02 [m^3/s]
- Mean River Flow: 11.45 [m^3/s]
- Flushing Time due to River Flow: 102.38 [day]
- Flushing Time due to Tide (assumes two cycles per day): 1.73 [day]
- Tidal Prism / Estuary Volume: 0.29

7. Building a linear regression model



Water Quality Models

- San Sebastian Water Quality
  - Model Start Date: 5/1/1999
  - Model End Date: 9/1/2003
  - Model Aggregation Period: SWQM Wet+Dry Season
  - Influential Factors (Predictors)
  - Calibration Data
  - Regression Analysis
    - R2 = 0.273656390816748
    - R2adj = 0.182863439668842
    - B0 = 24.6096466460373
    - Predictor Parameters
      - Riverine Flow: Coefficient = 0.0445986872193934, P-Value = 0.1207564441127

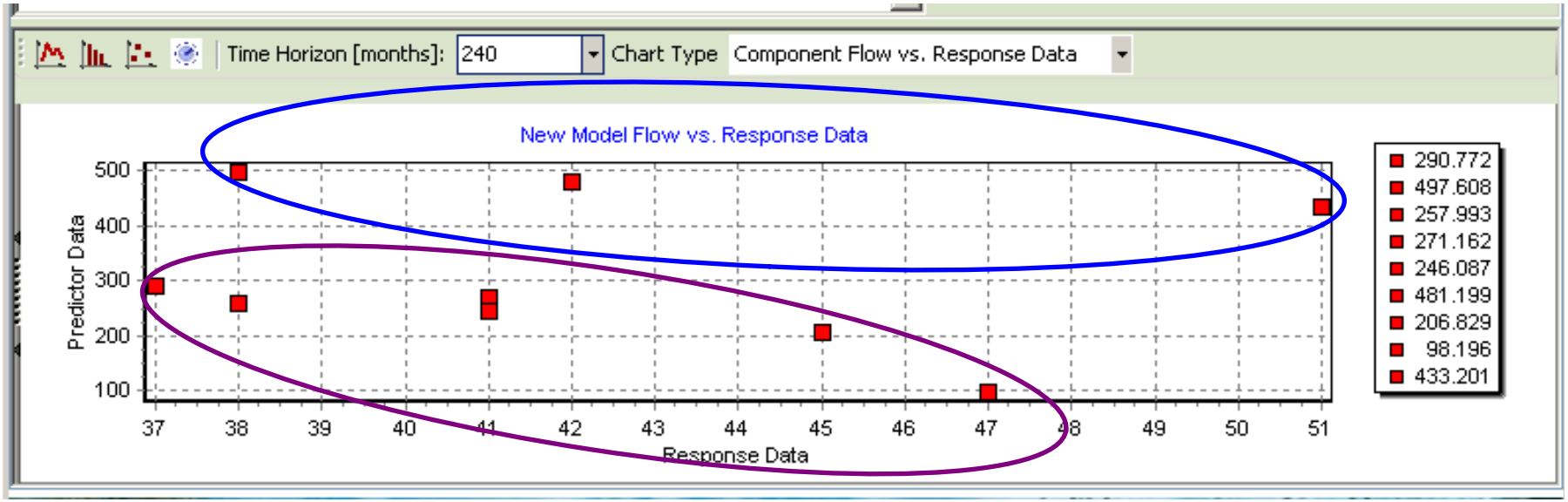
EXAMPLE: Building a linear regression model

Remove outliers?

Suggestion of 2 patterns?

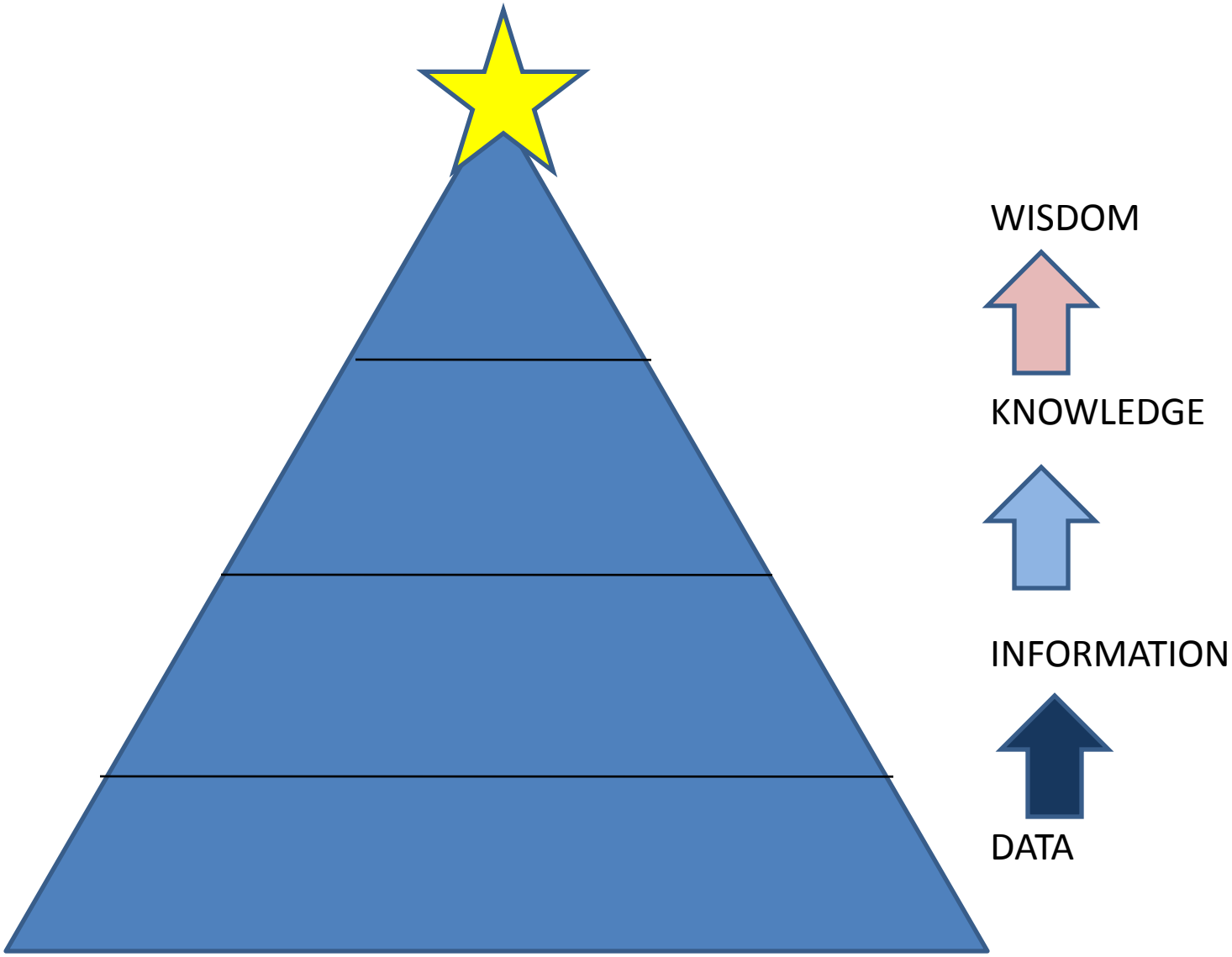
High flow or storm events and “normal” flow

Don’t really have enough data points…..



This is as far as we got with this…..

I would like to pick up where we left off…..



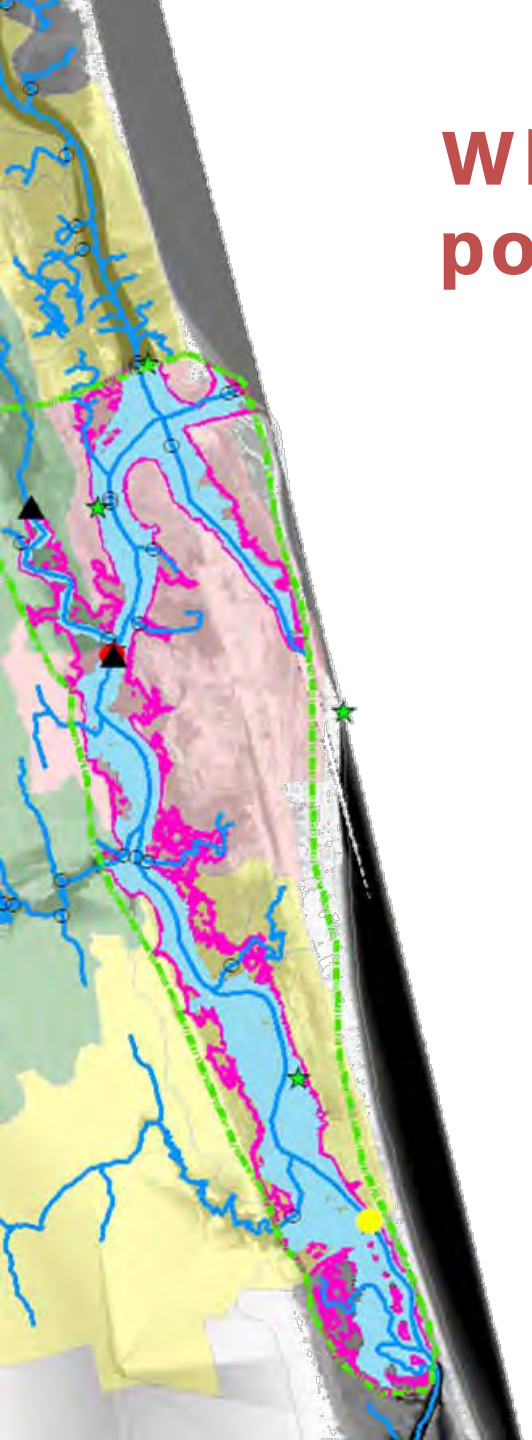
"C - 08" - NOAA Coastal GeoTools 2009 Tom Singleton et al.

Applications

- Estuary polygon delineation*
- Contour creation for wetlands inventory*
- Data viewing (attribute and time series)*
- e-Estuary program (D-07 *NOAA Coastal GeoTools 2009)*
- *"P-35" - NOAA Coastal GeoTools 2009*
- Estuary classification using bulk parameters

Based upon:

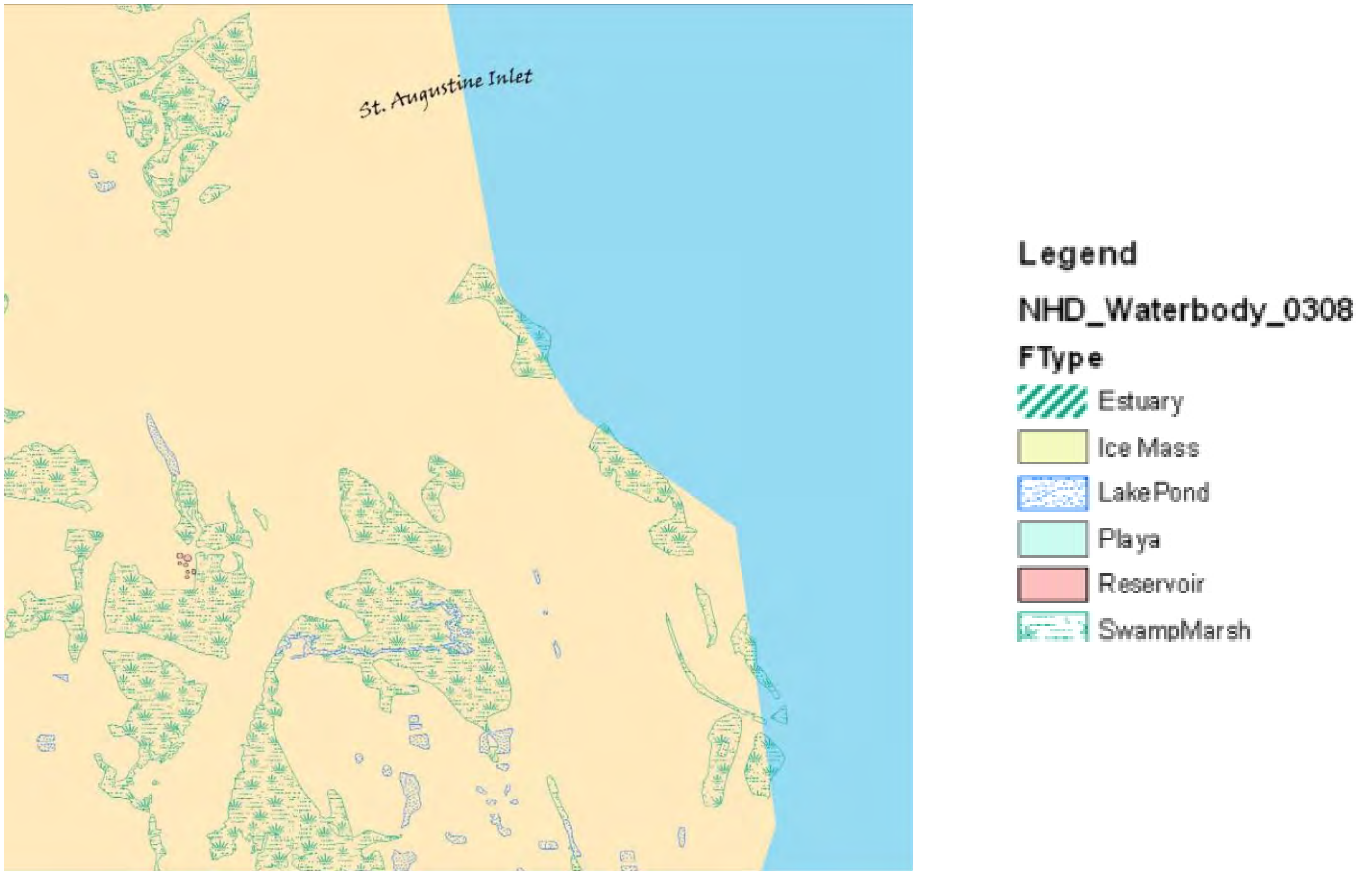
- Physical "virtual estuary" framework
- Modules for different purposes / approaches
- Example of water quality modeling – multiple modules



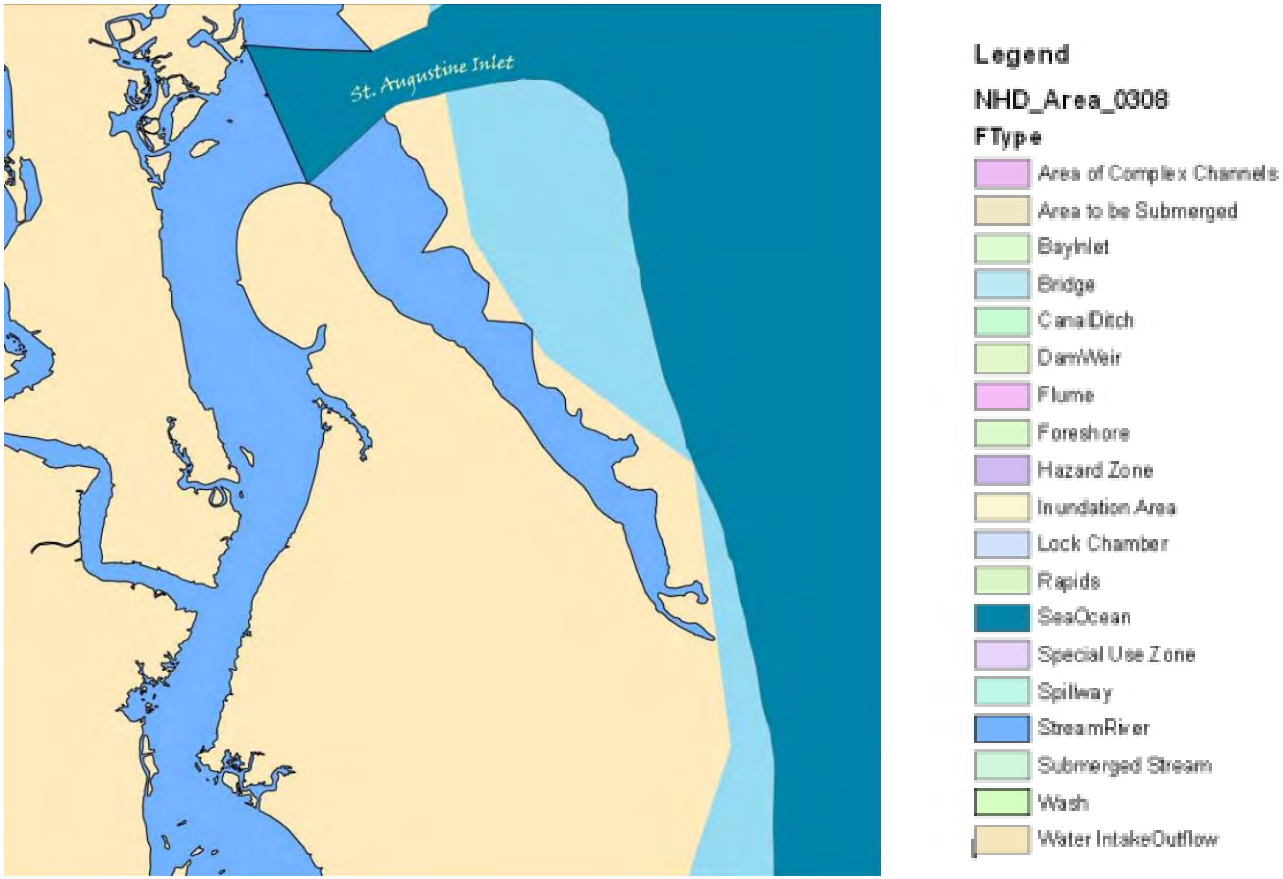
Where do we need estuary polygons?

- National Hydrography Dataset!

The NHD Waterbody features for the St Augustine Inlet. The tan and blue are representation of the land and ocean respectively. Note that Estuary is not populated.



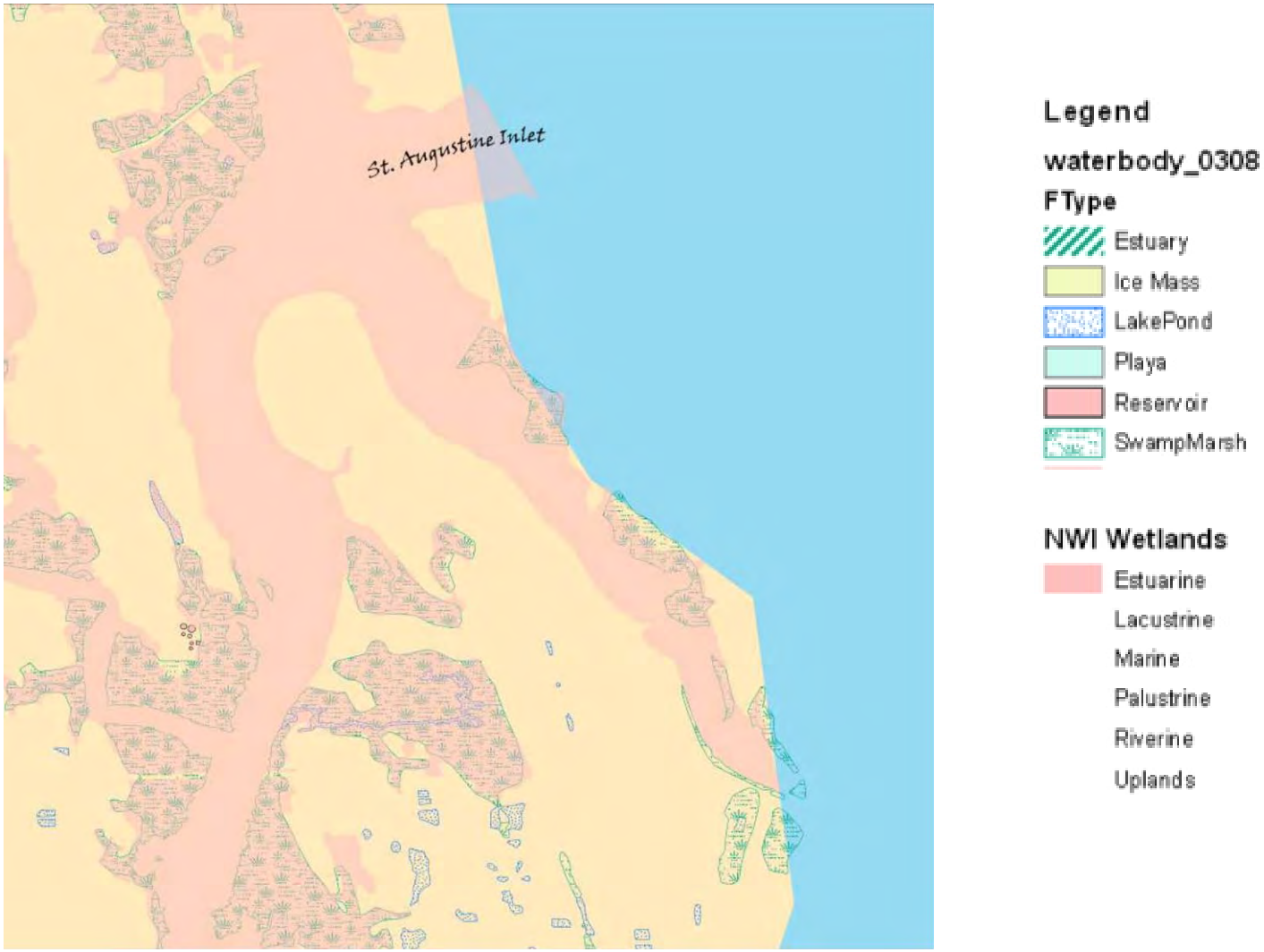
The NHD Area features for the St. Augustine Inlet area. The tan and blue are representation of the land and ocean respectively. Note that SeaOcean and StreamRiver features are located in the area that would commonly be identified as estuarine.

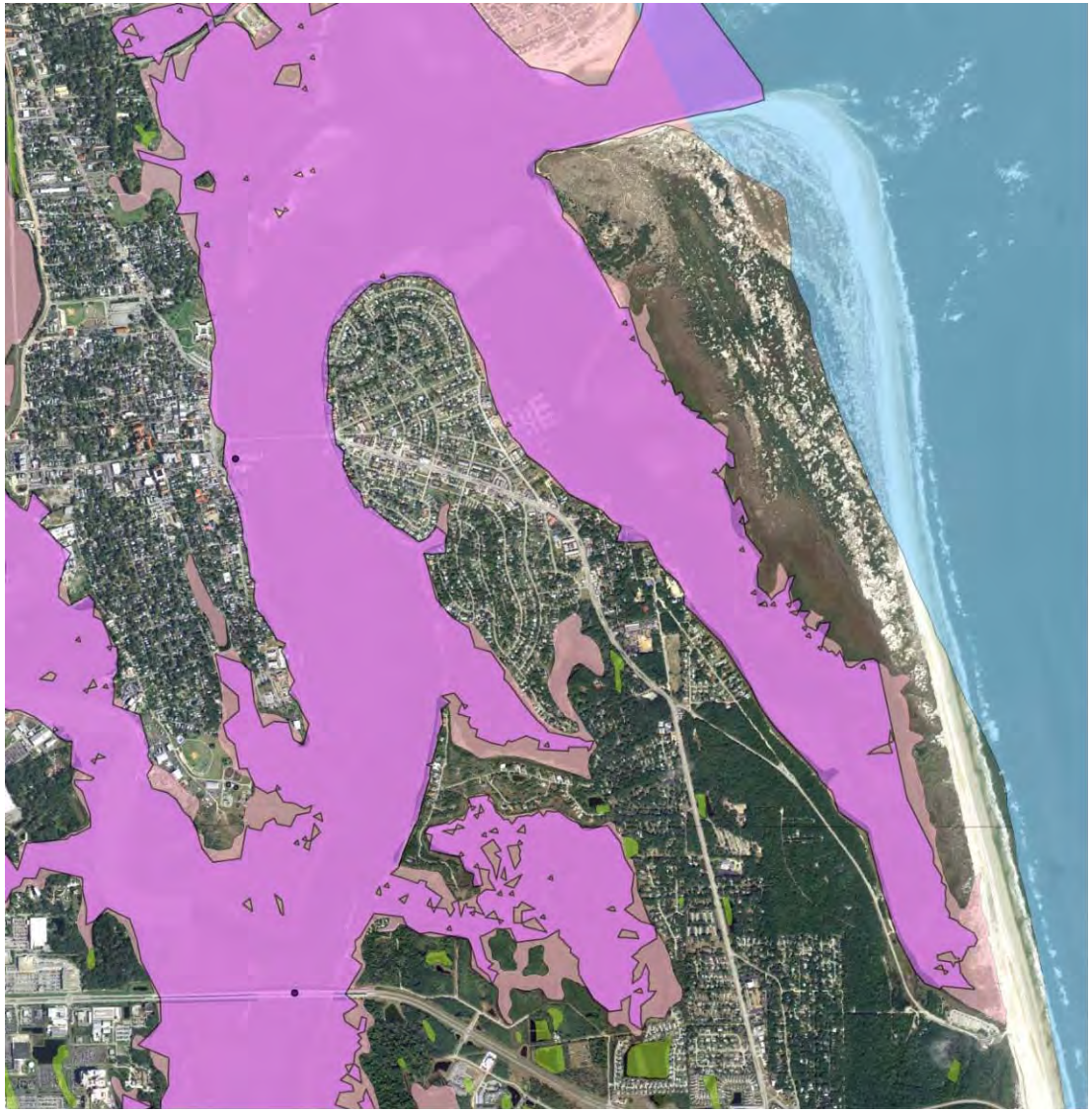


Populate Estuary Feature Type

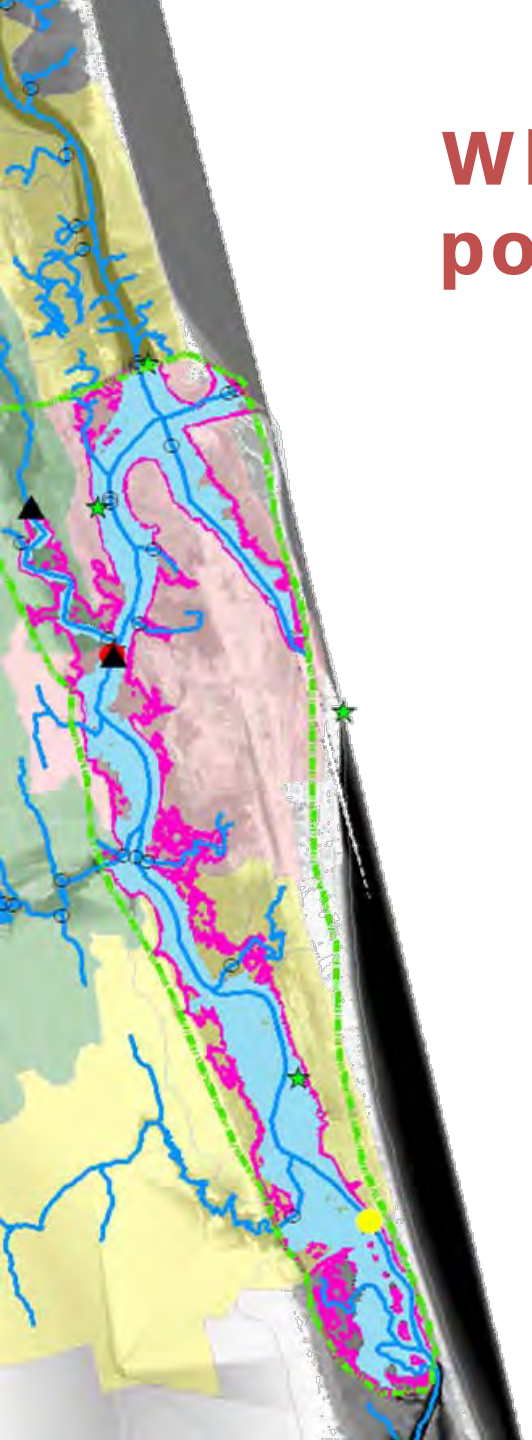
- *If Estuary has been identified as an Estuarine area by the National Wetland Inventory (NWI), then capture.*
  - NHD Standards (USGS, 1999)

The NWI estuary feature(s) with NHD Waterbody features for the St. Augustine Inlet area. The NWI features are a possible representation of what the NHD Estuary feature type (Waterbody feature class) might look like. Note that the non-estuarine NWI features have been excluded from the image. The tan and blue are representation of the land and ocean respectively.



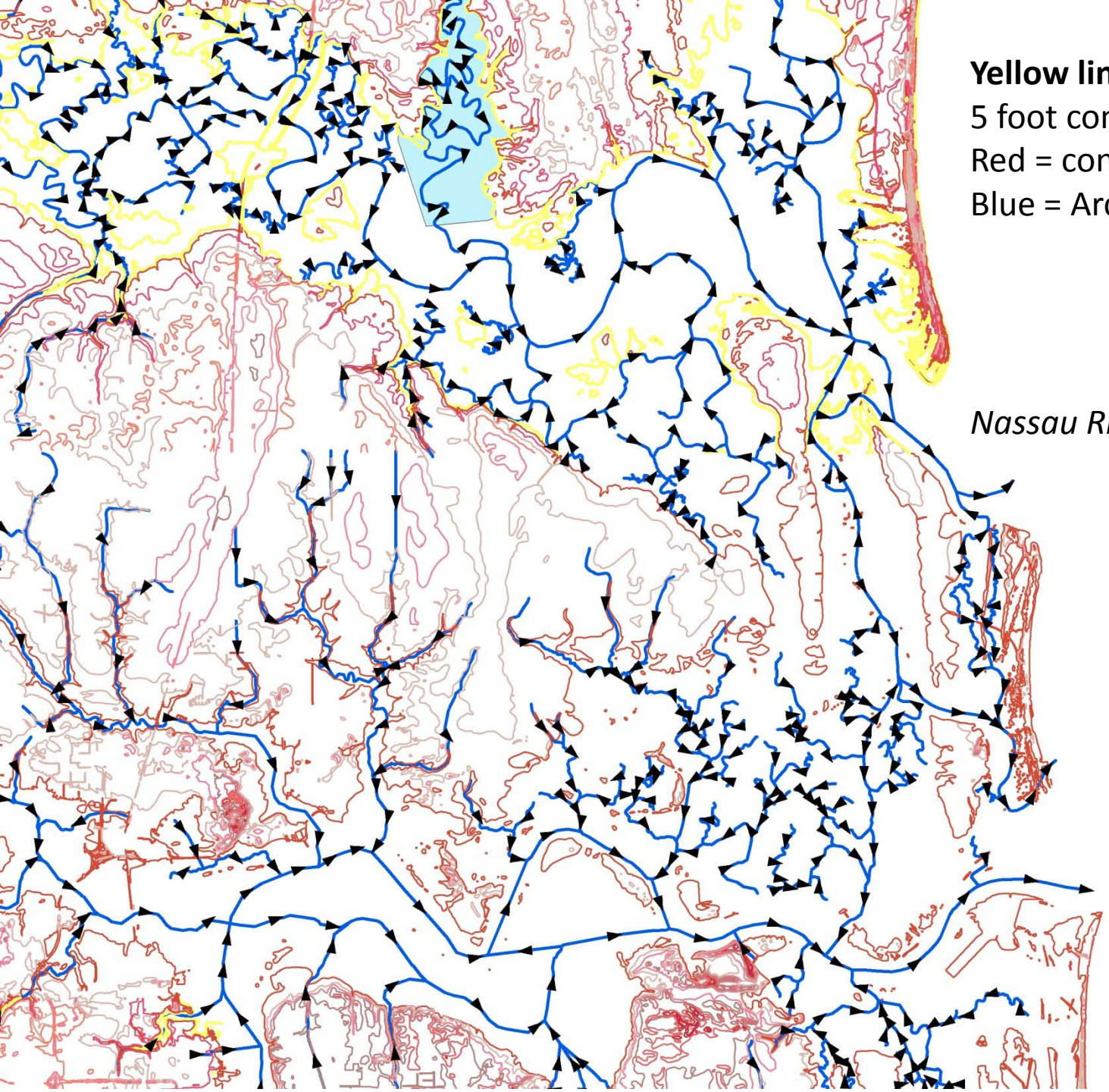


The ACES Estuary polygon (bright pink) and the NWI estuary features (pale pink) over the aerial photography for the St. Augustine Inlet area. Note that the ACES polygon boundary reflects the elevation of the mean high tide or mean high water on the terrain, while the NWI polygon was derived from photointerpretation.



Where do we need estuary polygons?

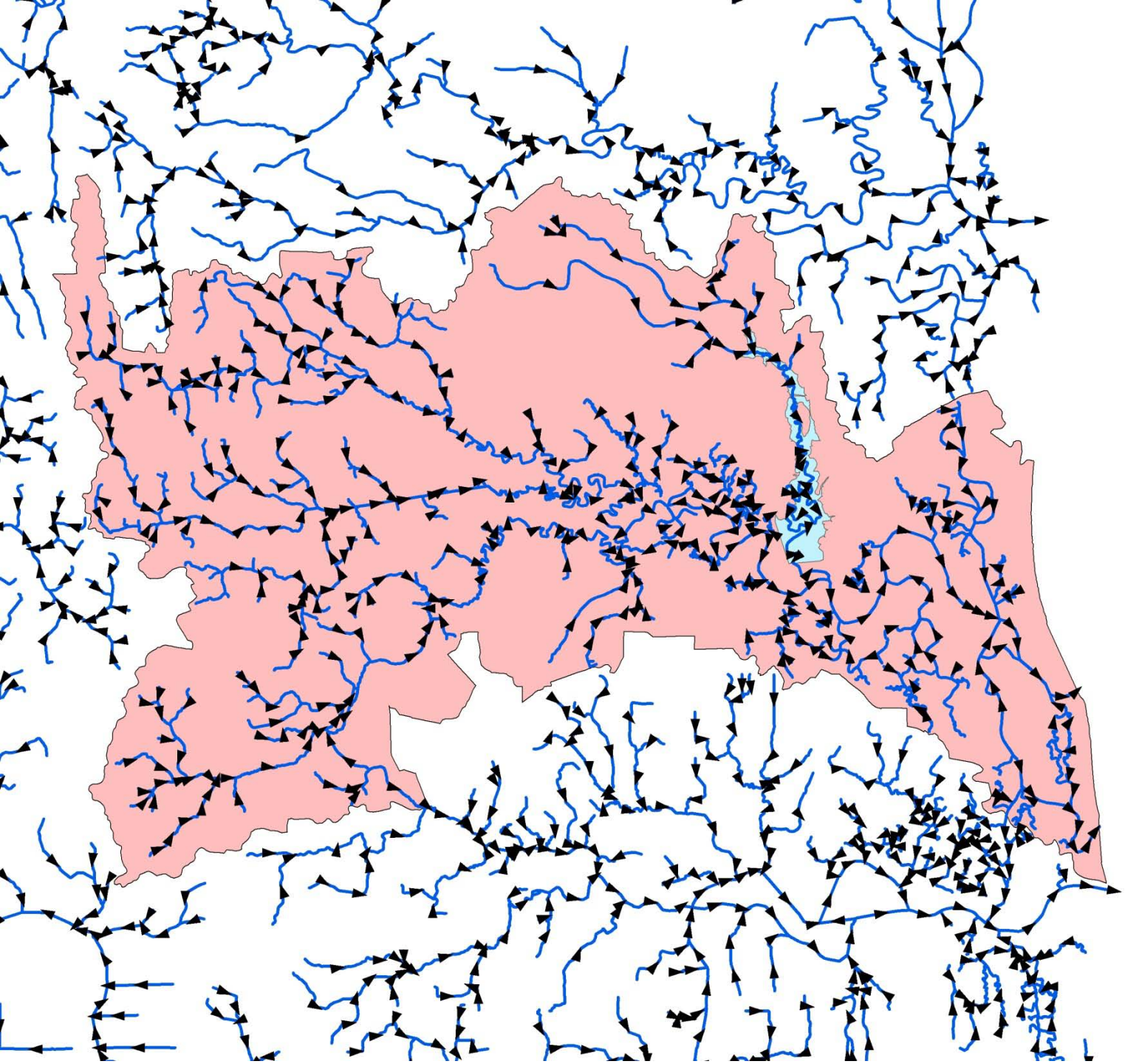
- National Hydrography Dataset
- 5 foot contour line – St. Johns River / Timucuan Ecological and Historical Preserve (wetlands inventory for SJRWMD “Alternative Water Supply” project)



Yellow lines = USGS
5 foot contour line
Red = contours
Blue = Arc Hydro HydroEdges

Nassau River mouth

SJR mouth

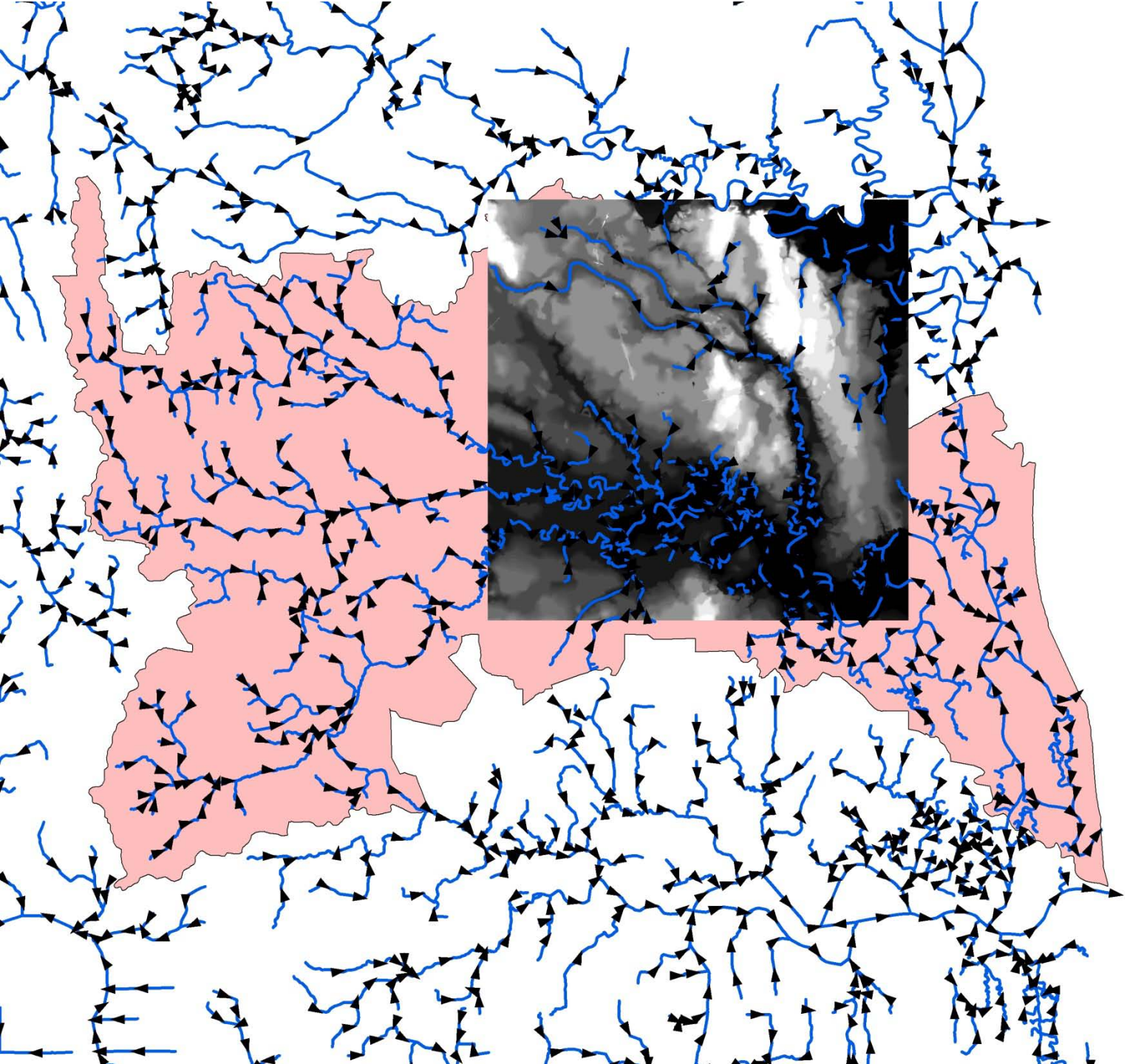


QAQC –

How well do the tool-created 5 foot contours match the USGS contours?

Pink polygon = Nassau River drainage basin

Blue lines = Arc Hydro HydroEdges

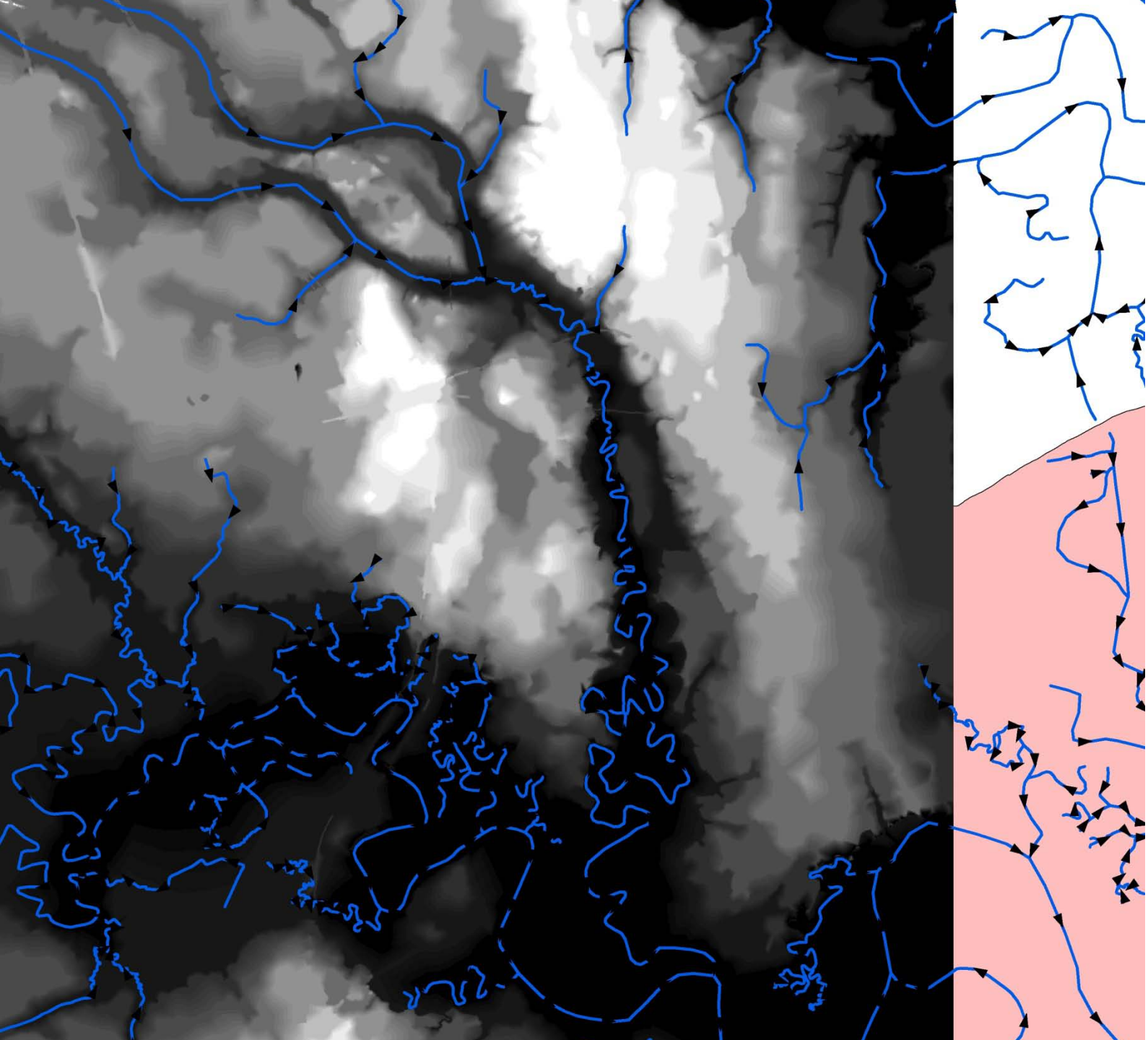


QAQC –

How well do the tool-created 5 foot contours match the USGS contours?

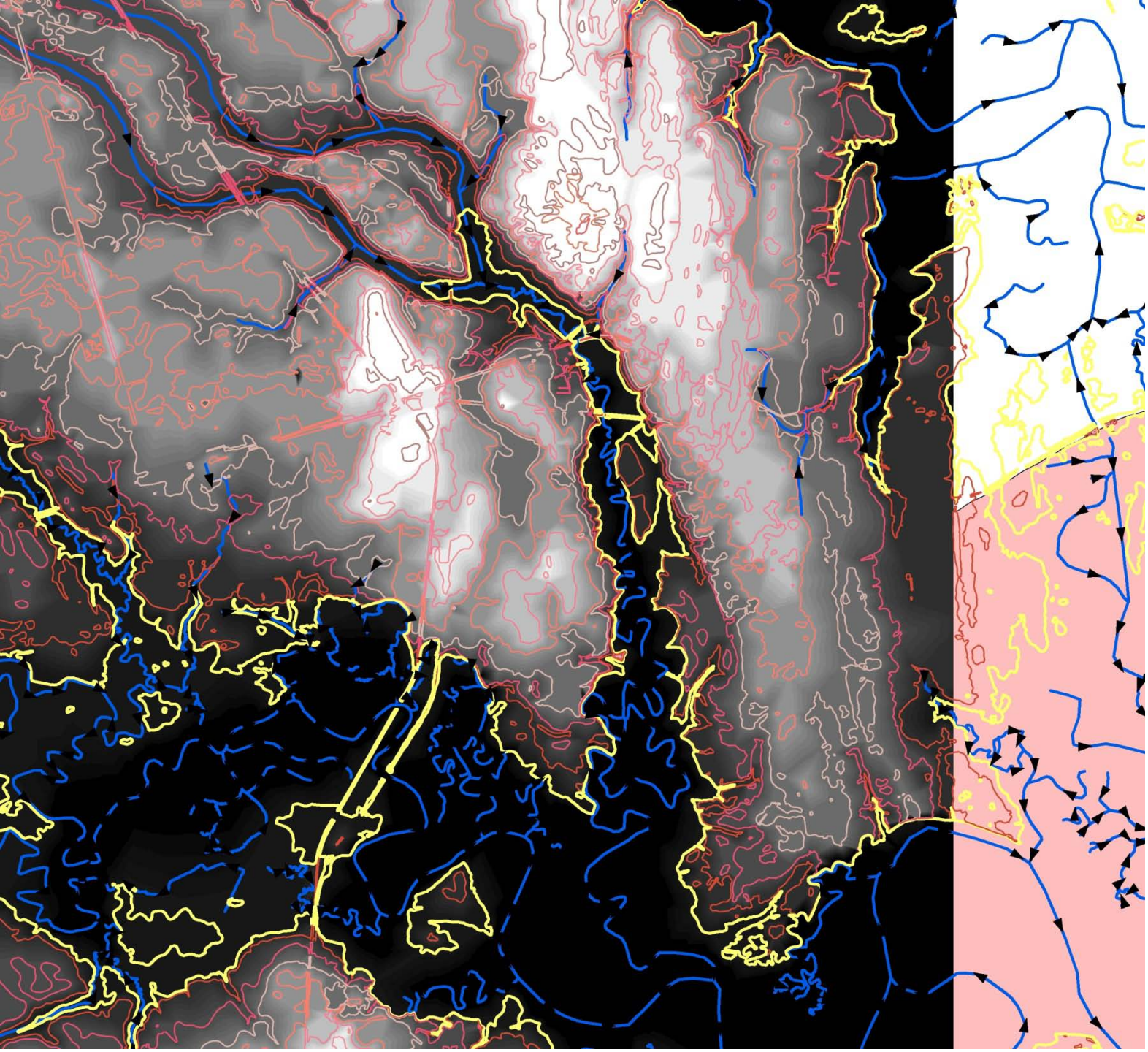
Added source DEM

(no tide points added – manually set elevation to 5 feet)



QAQC –

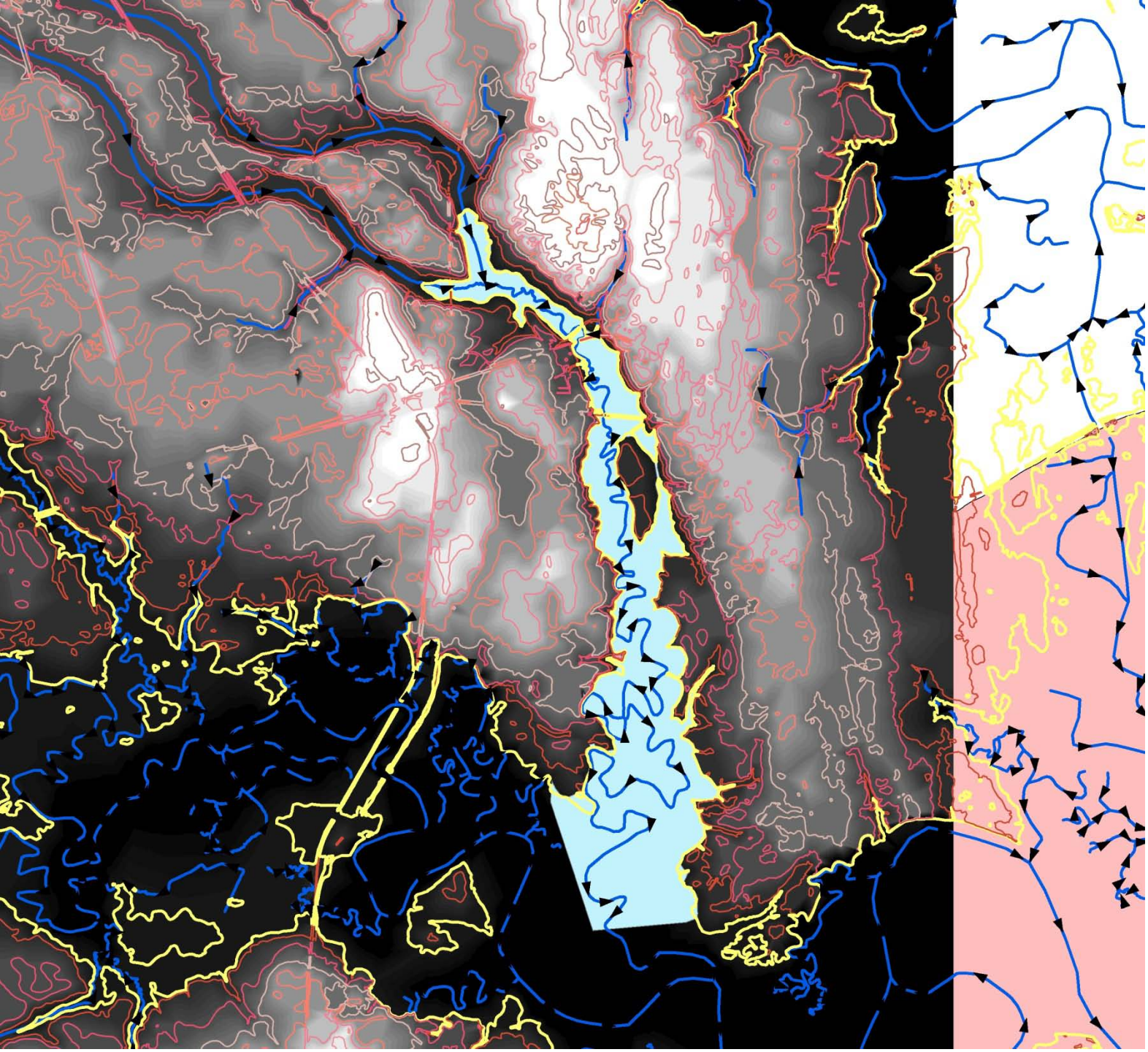
Close up of area



QAQC –

Close up of area

Added USGS contour lines



QAQC –

Close up of area

Added USGS contour lines

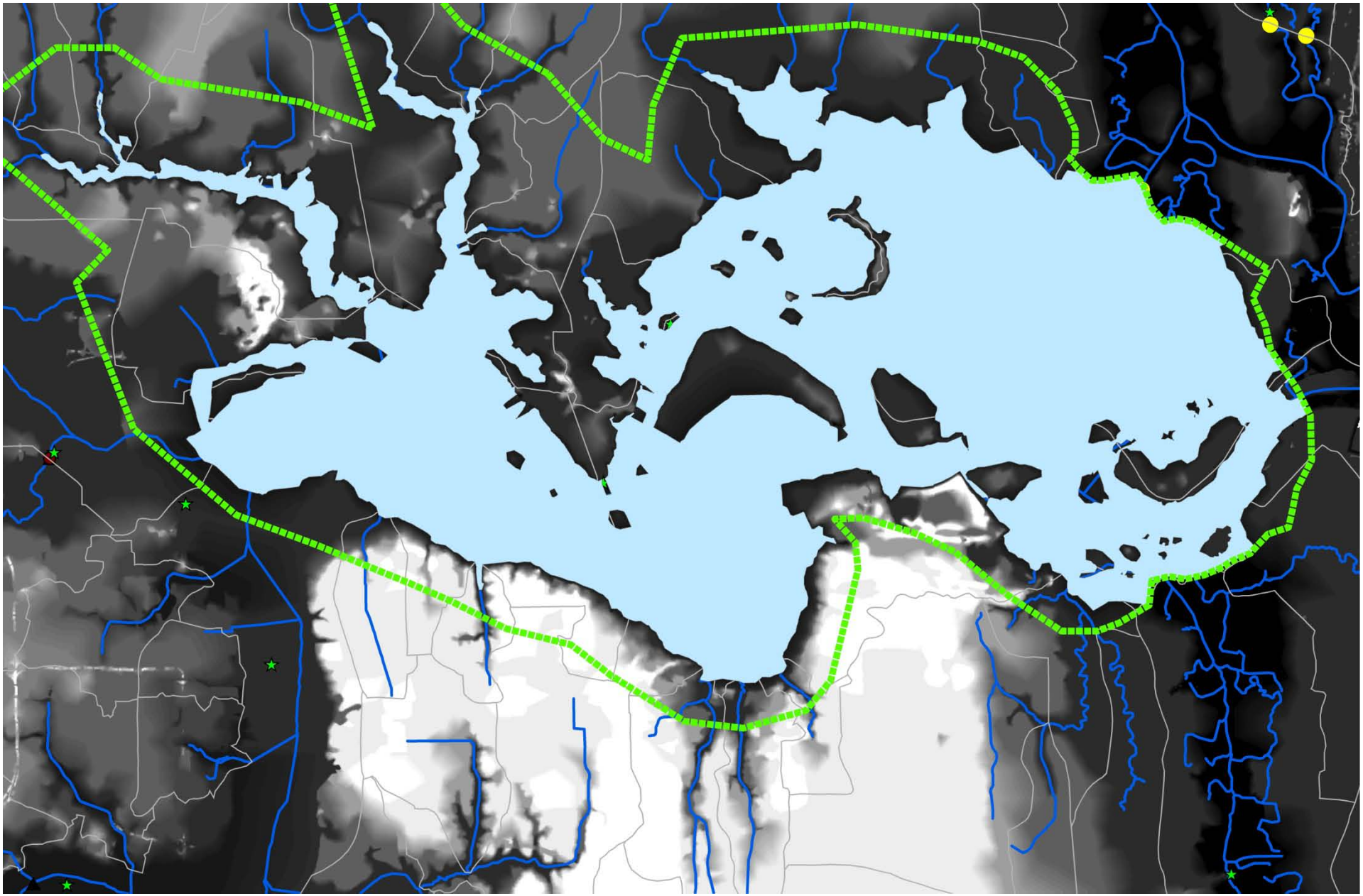
And light blue polygon = tool created Polygon at 5 foot

GOOD MATCH!

Area without USGS 5 foot contour lines

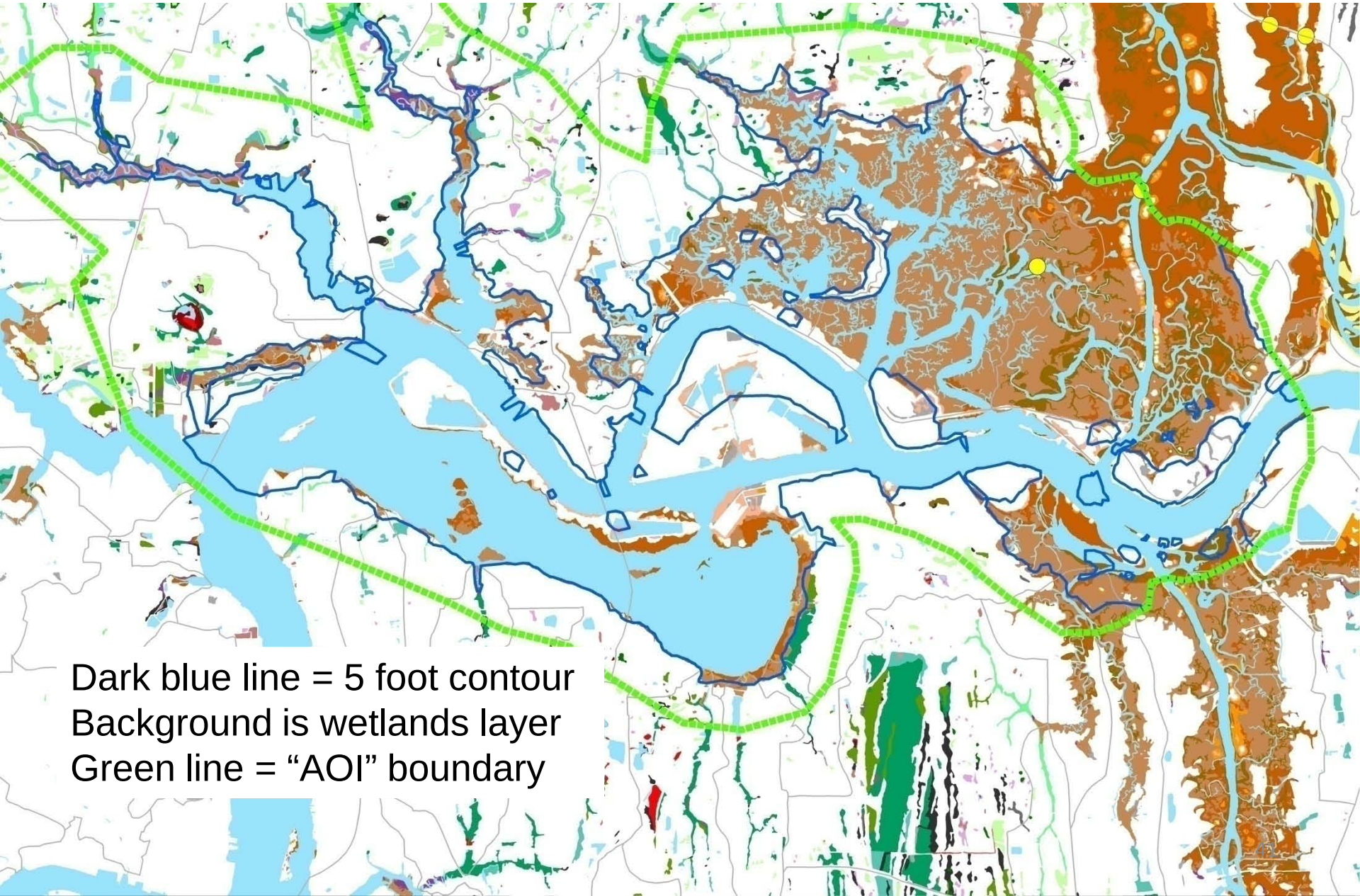
St. Johns River mouth

Red = contours
Blue = Arc Hydro HydroEdges



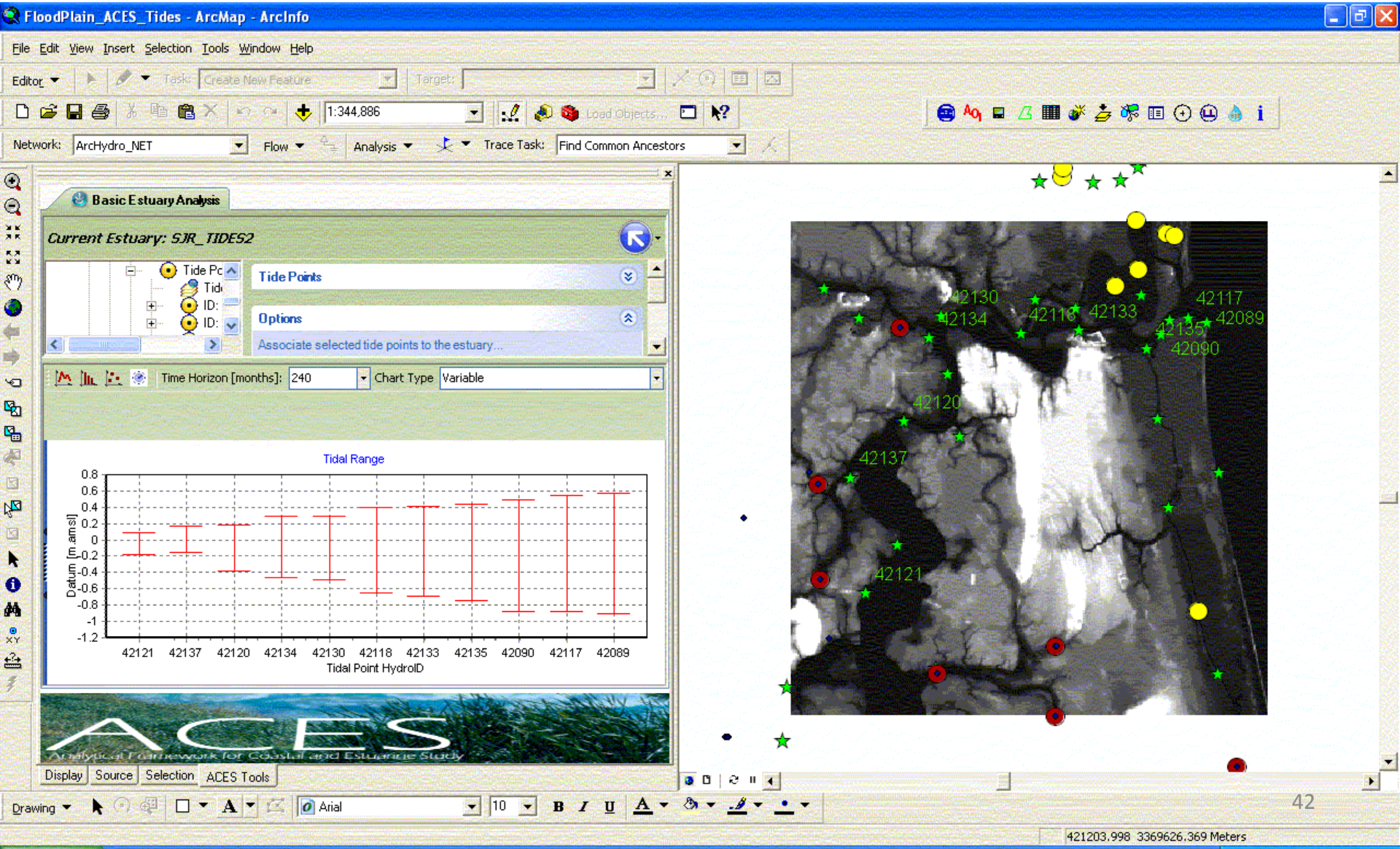
Green dashed line = Estuary AOI; blue polygon edge = 5 foot contour
Background = DEM used as input to create the polygon; blue lines = Arc Hydro

Wetlands inventory within “created” 5 foot contour



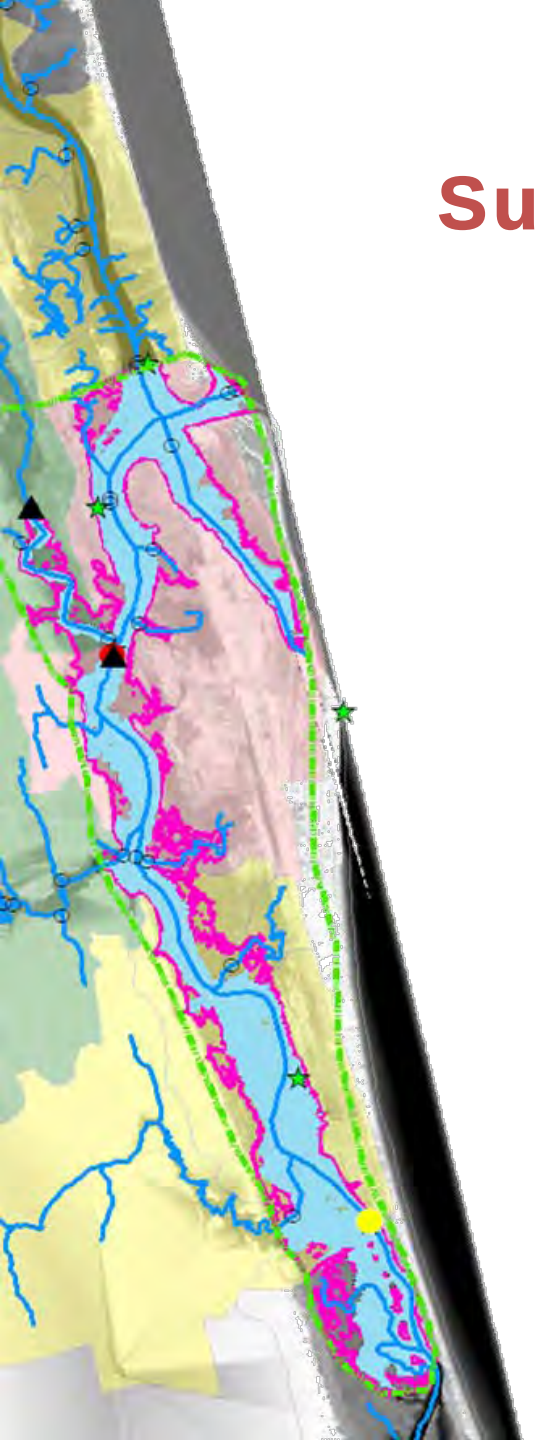
Data viewing within GIS – attribute and time series data

in this case – NOAA Tide data associated with TidePoint feature class



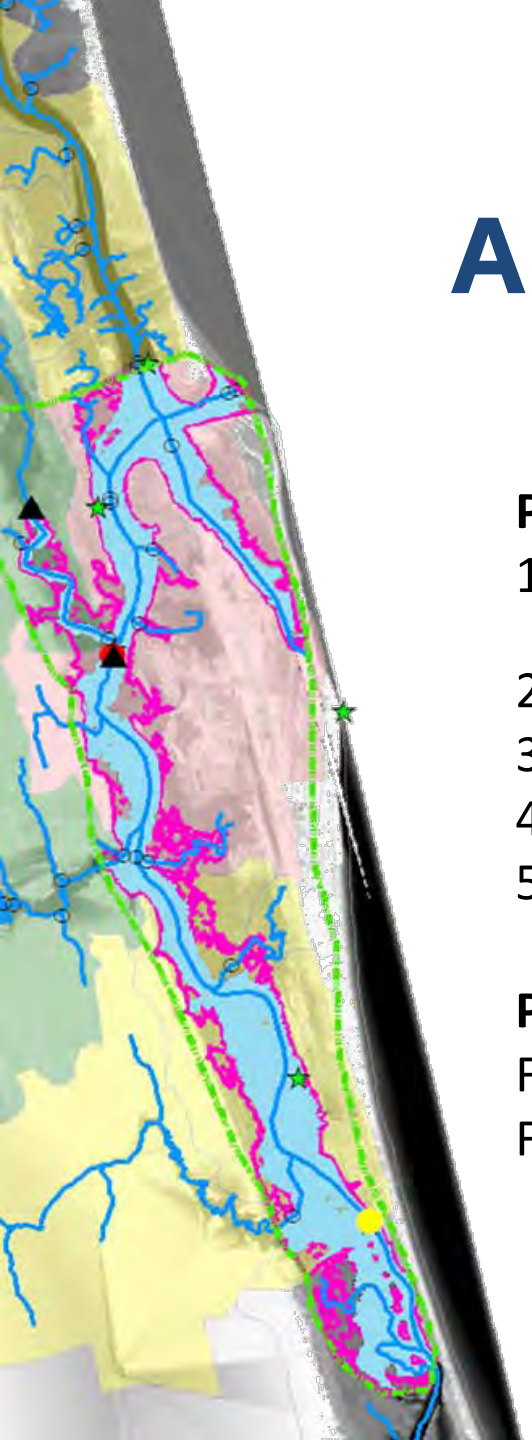
Benefits

- Existing “proof of concept” tool and schema
- More easily attainable for coastal professionals than traditional modeling approaches
- Modular concept amenable to development of additional applications



Summary

- Demonstrated an existing “proof of concept” tool using a GIS approach to integration and analysis of estuarine data
- Workbench / work flow design
- First principles – control volume and bulk parameters
- Creation of estuary polygons, boundaries
- Calculation of bulk parameters
- Additional applications
- Benefits based on versatile modular concept



Additional information

Project documentation:

1) Conceptual Approach *(includes extensive literature review)*
2) Requirements and Specifications
3) User Manual with exercise
4) NHD Estuary feature class population
5) Schema poster

Proceedings papers:

Fox et al, 2008 AWRA GIS and WR

Fox and Bourne, 2008 ESRI International User Conference

Questions?

CONTACT INFORMATION

Sandra Fox
sfox@sjrwmd.com

Steve Bourne –
sfbourne@pbsj.com

REQUIREMENTS FOR PROTOTYPE TOOL OPERATION:

1. **The Tool installed** as an extension to ESRI ArcMap.
2. **ArcMap** at full ArcInfo license level, Spatial Analyst and 3D Analyst.
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