Mapping Fundamentals and Creating Inundation Maps

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Inundation Mapping Fundamentals

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DIGITAL COAST

Home Data Tools Training In Action

Inundation

Inundation mapping can be viewed as a 4 step process.

Obtain and Prepare Elevation Data

Elevation (including bathymetry) serves as the base data layer upon which coastal inundation mapping relies.

Prepare Water Levels

In order to map inundation, a water surface is generated. That surface can be based upon model output or a single value.

Map Inundation

With the prepared DEM and water level information, GIS processes can be used to create layers that represent inundation extent and depth.

Visualize Inundation

Visualizing the data is important for assessing exposure and impacts, and serves as a powerful tool for education and awareness.

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Obtain and Prepare Elevation Data

Elevation (including bathymetry) serves as the base data layer upon which coastal inundation mapping relies. The primary steps toward generation of a suitable elevation layer(s) are provided below.

Define Needs/Data type

What type and quality of data do I need?

Find data

Where can I find elevation data?

Specify data/Review data

Is the data I have appropriate?

Create and Review elevation products

How do I create an elevation surface?

Long Island, NY Case Study

The Nature Conservancy obtained a 5-meter lidar based DEM from Suffolk County, NY.

Prepare Water Levels

In order to map inundation, a water surface is generated. That surface can be based upon model output (i.e. ADCIRC, SLOSH, etc) or a single value applied consistently over the entire study area (i.e. bathtub mapping of sea level rise).

Single Value Surfaces
(aka. flood the bathtub)

- Select values (IPCC, published studies, etc).
- Determine vertical reference level (examples: MHW for sea level rise, MLLW for shallow coastal flooding).
- Compute vertical datum shift.

Modeled Surfaces

- Obtain model output.
- Note vertical reference level of model output (example: NGVD29 or NAVD88 for SLOSH).
- Compute vertical datum shift.

Long Island, NY Case Study

The Nature Conservancy worked with NASA Goddard to determine local sea level change based on various climate model runs and emission scenarios.

Map Inundation

With the prepared DEM and water level information (model or single value), GIS processes can be used to create layers that represent inundation extent and depth.

Single Value Surfaces
(aka. flood the bathtub)

- Use ESRI ArcMap Spatial Analyst Tools (map algebra, con statement) to create inundation depth rasters.
- Use ESRI ArcMap Tools to convert depth rasters to polygons representing inundation extent only.

Modeled Surfaces

- Use ESRI ArcMap Tools to extract points from gridded model output.
- Use ESRI ArcMap Spatial Analyst Tools to create a water surface by interpolating points.
- Use ESRI ArcMap Spatial Analyst Tools to subtract the DEM from the water surface to create the inundation depth raster.
- Use ESRI ArcMap Tools to convert depth rasters to polygons representing inundation extent only.

Long Island, NY Case Study

The Nature Conservancy used SLOSH model output with a lidar based DEM to show potential category 1 through 4 storm surge inundation.

Visualize Inundation

Visualizing the data is important for assessing exposure and impacts, and serves as a powerful tool for education and awareness.

Static Maps

A picture is worth a thousand words. Use GIS to create 2-D maps of inundation.

Animations

Animations are useful to show time series of data.

Google Maps API Viewer

This offers the ability to interact with data in a framework that is very user friendly. Also, other data layers (infrastructure, land cover, census, etc.) can be included.

ArcIMS Viewer

Internet mapping with the ability to use more complex functionality.

Elevation Data

Integrating Elevation Data: What to Consider?

Spatial Framework

- Coordinate system: projection, datum, ellipsoid
- Vertical datum used to reference height and depth values

Purpose

- What do you intend to do with the results?
- What are your accuracy requirements?

Resolution

- Cell size that will be used to represent elevation data
- Scale of application/analysis
- Topographic data are usually available at a higher resolution than bathymetric data

Processing the data

- Converting data into a consistent format
- What tools are available to help you do this?

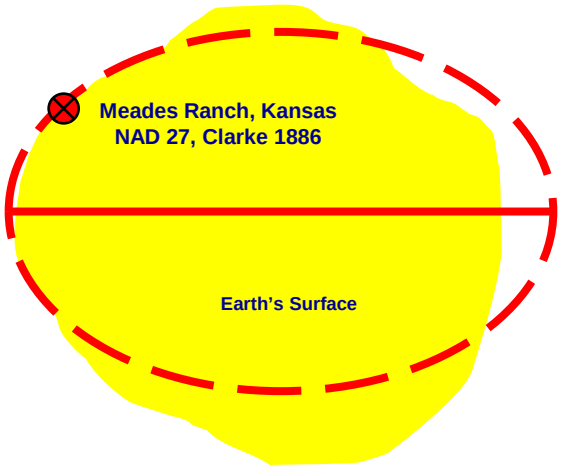
Mapping Fundamentals

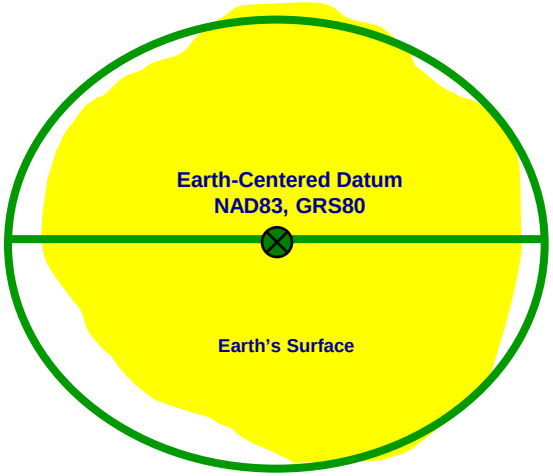
Datums

- A datum serves as a reference point for calculating surface locations, heights, and depths

- A datum can be geocentric (Earth-centered) or locally established

- Types of Datums:
  - Horizontal datum: defines the position of the ellipsoid relative to the Earth, and is used for measuring X,Y locations on the Earth's surface
  - Vertical datum: references a modeled surface for calculating height or depth at a particular location on the Earth's surface.





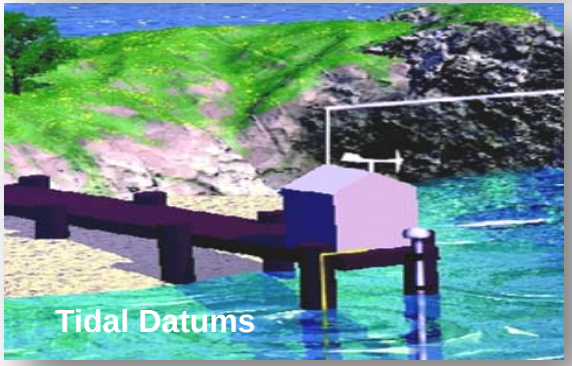
Mapping Fundamentals

Vertical Datums

- To create a continuous grid of the Earth's surface, data sets must reference the same datum so that the height and depth values are consistent

- Types of vertical datums:
  - Ellipsoidal: geometric model
  - Orthometric: physical model of mean sea level
  - Tidal: water levels derived from tidal stages

- Topographic data usually reference an orthometric datum, while bathymetry data reference a tidal datum (mean lower low water, or MLLW)



Mapping Fundamentals

Vertical Datums

Vertical Datums Commonly Used in the U.S.

Datum	Model Type	Examples
North American Vertical Datum of 1988 (NAVD 88)	Orthometric	USGS NED Digital Elevation Models
National Geodetic Vertical Datum of 1929 (NGVD 29)	Orthometric	Older FEMA Flood Maps
Mean Lower Low Water (MLLW)	Tidal	Hydrographic Surveys
Mean High Water (MHW)	Tidal	Shoreline Data
WGS84, NAD83	Ellipsoidal	Lidar-derived topographic data

Mapping Fundamentals

Ellipsoidal Datums

- An ellipsoid is a simplified representation of the Earth's shape and size
- Primary means of horizontal reference, but can also be used as a vertical reference
- Height is the distance between a point on the Earth's surface to the ellipsoid
- This is referred to as height above the ellipsoid, or as the geodetic height

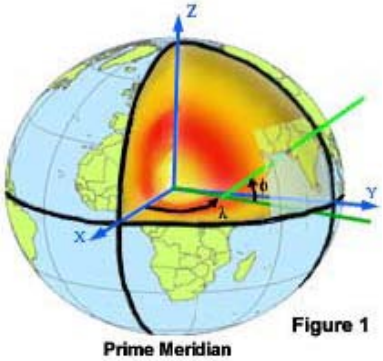


Figure 1

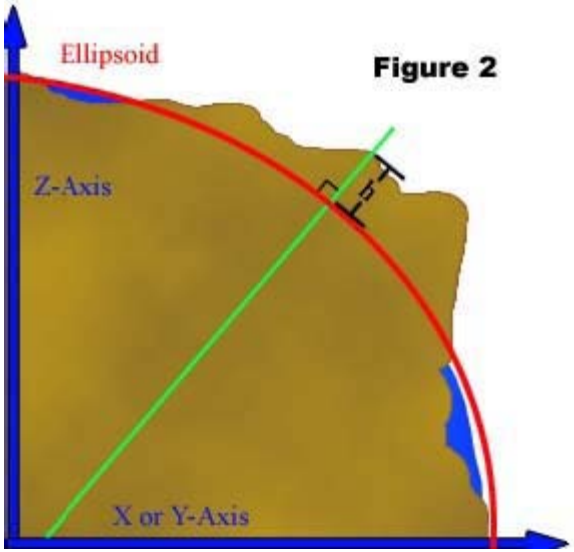
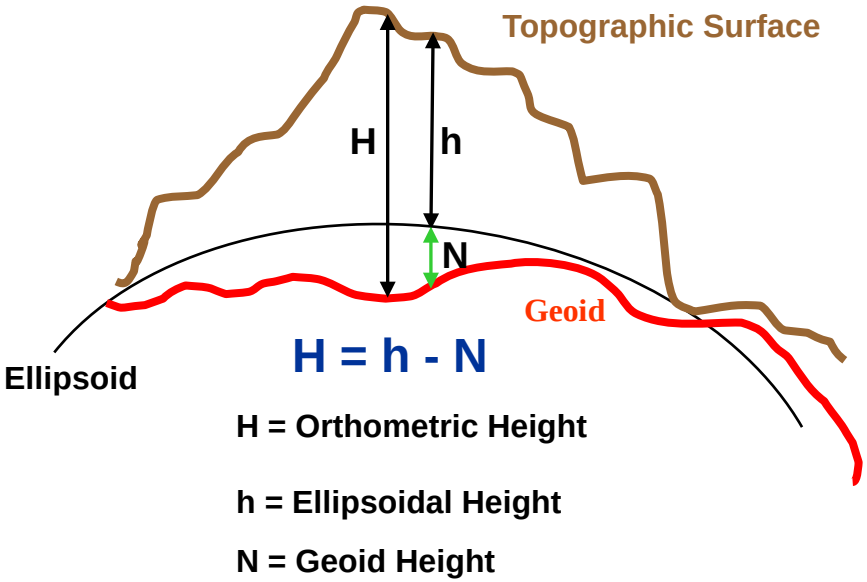


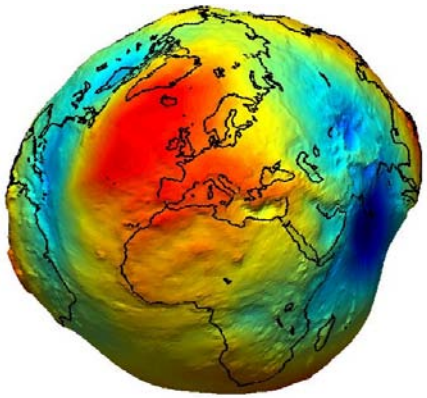
Figure 2

Mapping Fundamentals

Orthometric Datums

- The orthometric height is the elevation above the geoid
- A **geoid** is “the equipotential (level) surface of the Earth’s gravity field that, on average, coincides with mean sea level in the open undisturbed ocean” *(NDEP, Guidelines for Digital Elevation Data)*
- Geoid Models: GEOID03 and GEOID99
- The **geoid height** can be above or below the ellipsoid, therefore can be either positive or negative value





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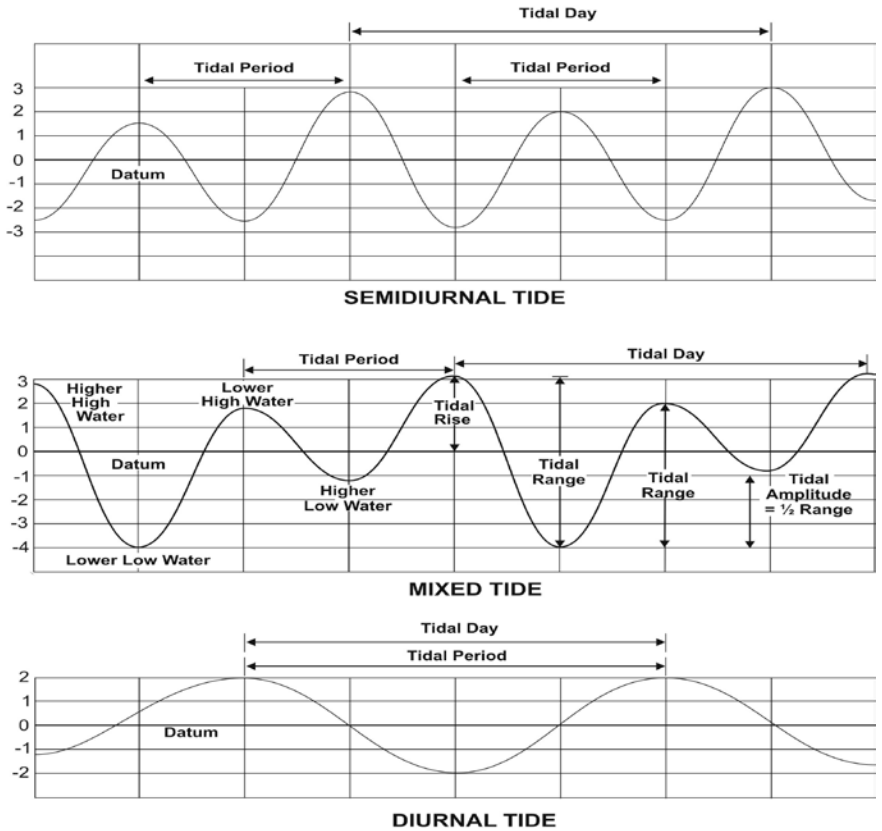
Tidal Datums

- These are local datums
- Tidal epoch is derived using an averaging technique for a specific time period of 19 years. The current epoch is 1983-2001.
- Most tidal datums are referenced to fixed points called benchmarks.



Source: Tidal Datums and Their Applications

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Transformations

Vertical Datum Transformations

- Topographic data are commonly referenced to an orthometric datum
- Bathymetric data commonly reference a tidal datum (ex.MLLW)
- Merging these into a single data set requires the user to define a common vertical datum so that the elevation values are consistent
- Tools are available to perform these transformations

Mapping Fundamentals

Datum Transformation Tools

Conversions need to be done separately for horizontal datums and vertical datums

NADCON

- The North American Datum Conversion tool
- Converts between NAD27 and NAD83
- *www.ngs.noaa.gov/TOOLS/Nadcon/Nadcon.shtml*

VERTCON

- Vertical conversion tool
- Converts between NGVD29 and NAVD88
- *www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html*

VDATUM

- Vertical Datum Transformation tool
- Converts between ellipsoidal, orthometric, and tidal vertical datums
- *http://vdatum.noaa.gov/*

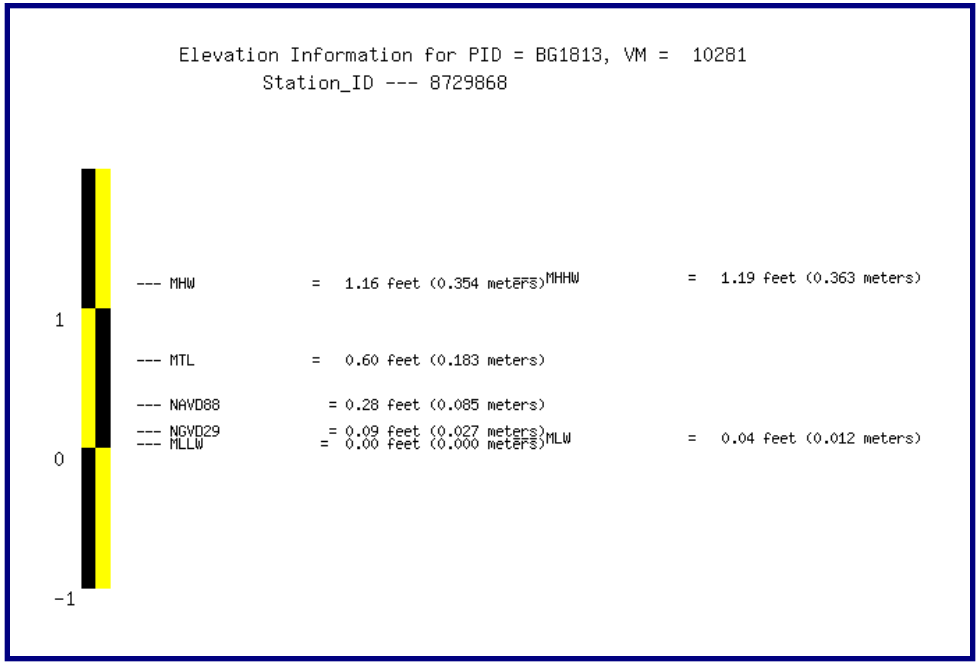
CORPSCON

- Converts between horizontal and vertical (orthometric) datums
- *http://crunch.tec.army.mil/software/corpscon/corpscon.html*

Transformations

National Geodetic Survey (NGS) Tidal and Orthometric Elevations Tool Kit

- Will display tidal and orthometric elevations of a specific survey control mark
- Displayed will be the differences between the published NGS's NAVD88 and NGVD29, and the CO-OPS' MLLW datums
- User can enter "PID" (control mark identifier) or latitude and longitude
- Entering lat/long coordinates will generate a list of PIDs within a 25 mile radius



NGS Geodetic Tool Kit: Tidal and Orthometric Elevations – www.ngs.noaa.gov/TOOLS/

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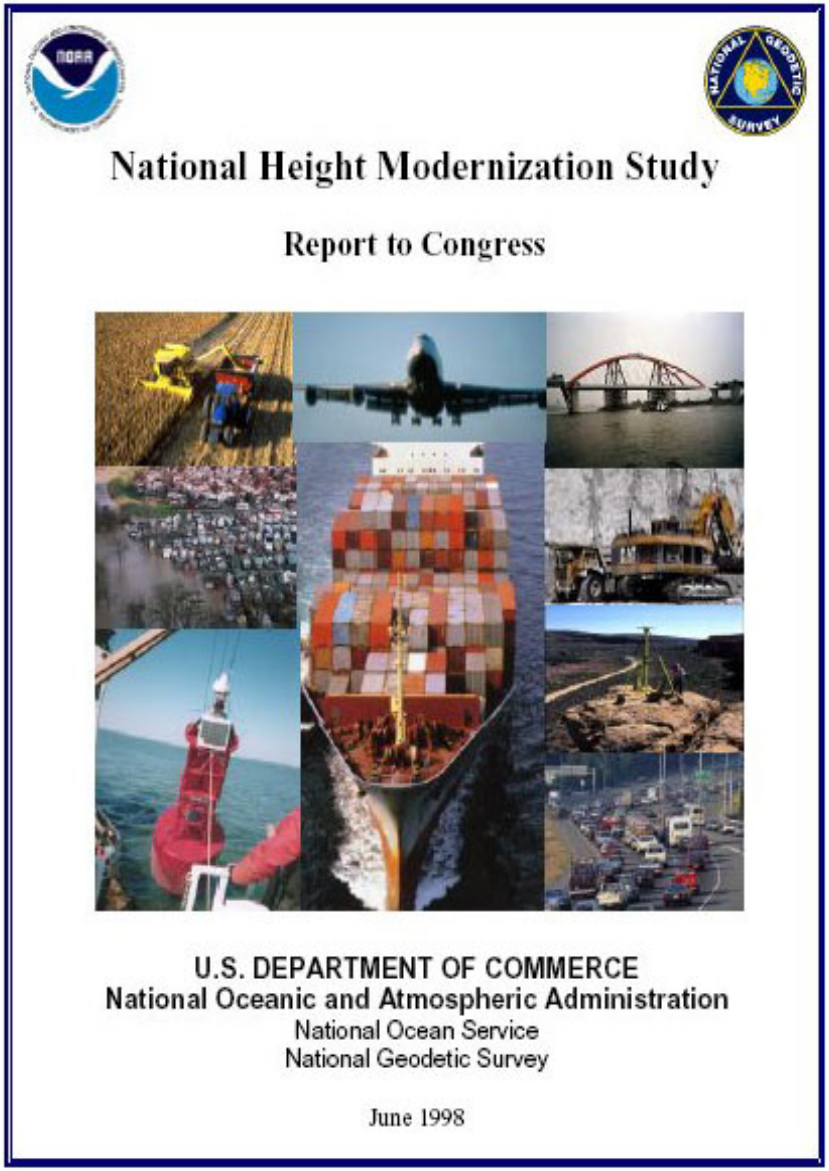
National Height Modernization

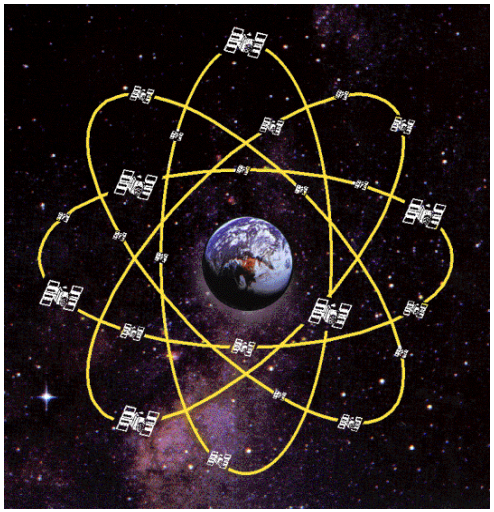


National Height Modernization Study

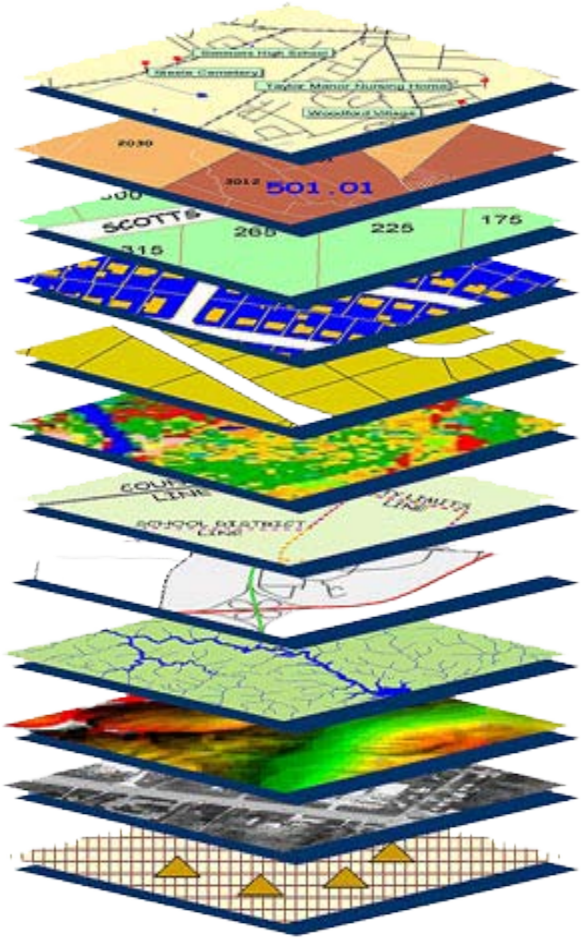
Report to Congress

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service
National Geodetic Survey

June 1998



National Height Modernization



- **Program in NOAA's National Geodetic Survey using Global Position System (GPS) and other new technologies to increase accuracy of elevation measurements that make up the vertical portion of the National Spatial Reference System (NSRS).**

- **NSRS's survey marks provide the foundation for positioning and navigation activities for the U.S.**

Geodetic Control is the **Critical Layer** for GIS Applications

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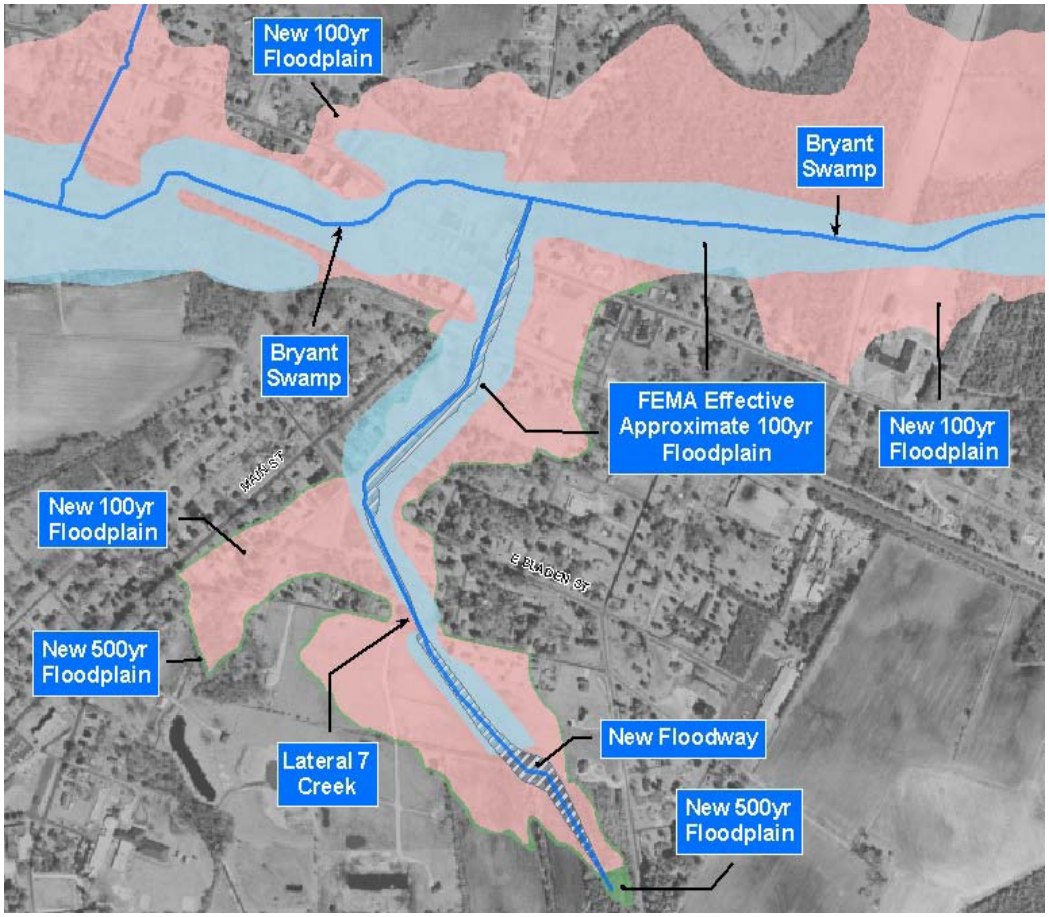
Accurate Heights Are Critical for Floodplain Mapping

Help Determine Who Needs Flood Insurance:

- **Make sure that those who need it, have it.**

and

- **Those who don't need it, don't have to pay for it.**



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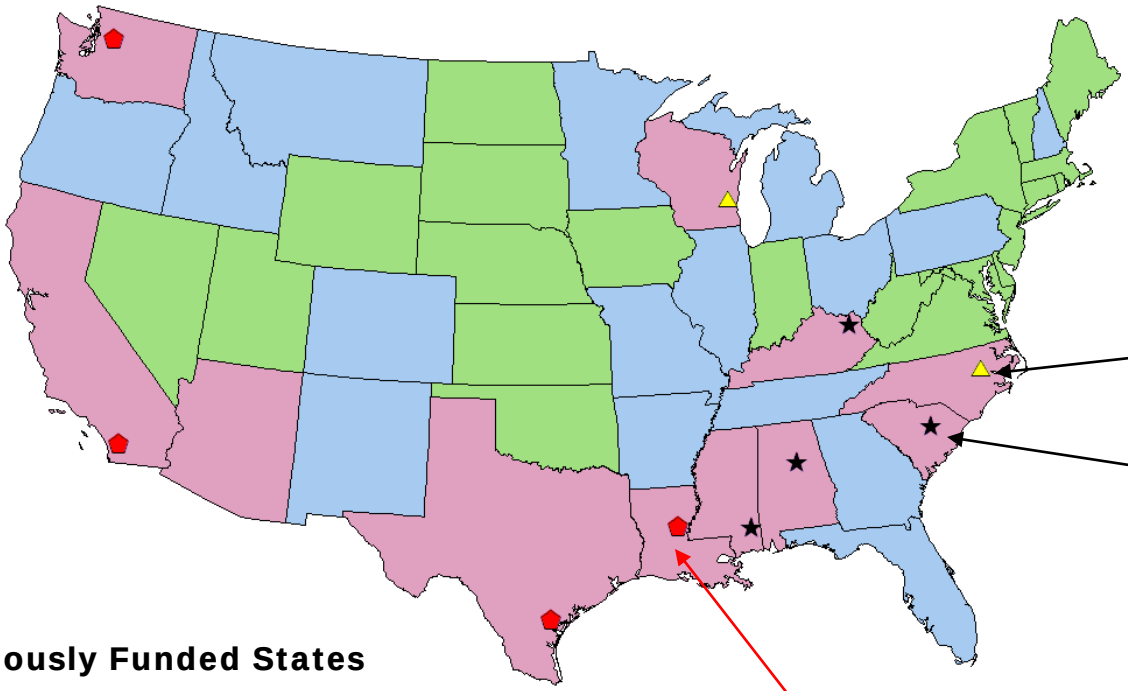
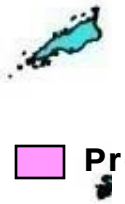
Height Modernization: Where Are We Today?





Regional Ht Mod Leaders

State Ht Mod Leaders

Spatial Reference Centers

Previously Funded States

States that Have Shown an Interest

Inactive States

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Creating Inundation Polygons

(Sea Level Rise Example)

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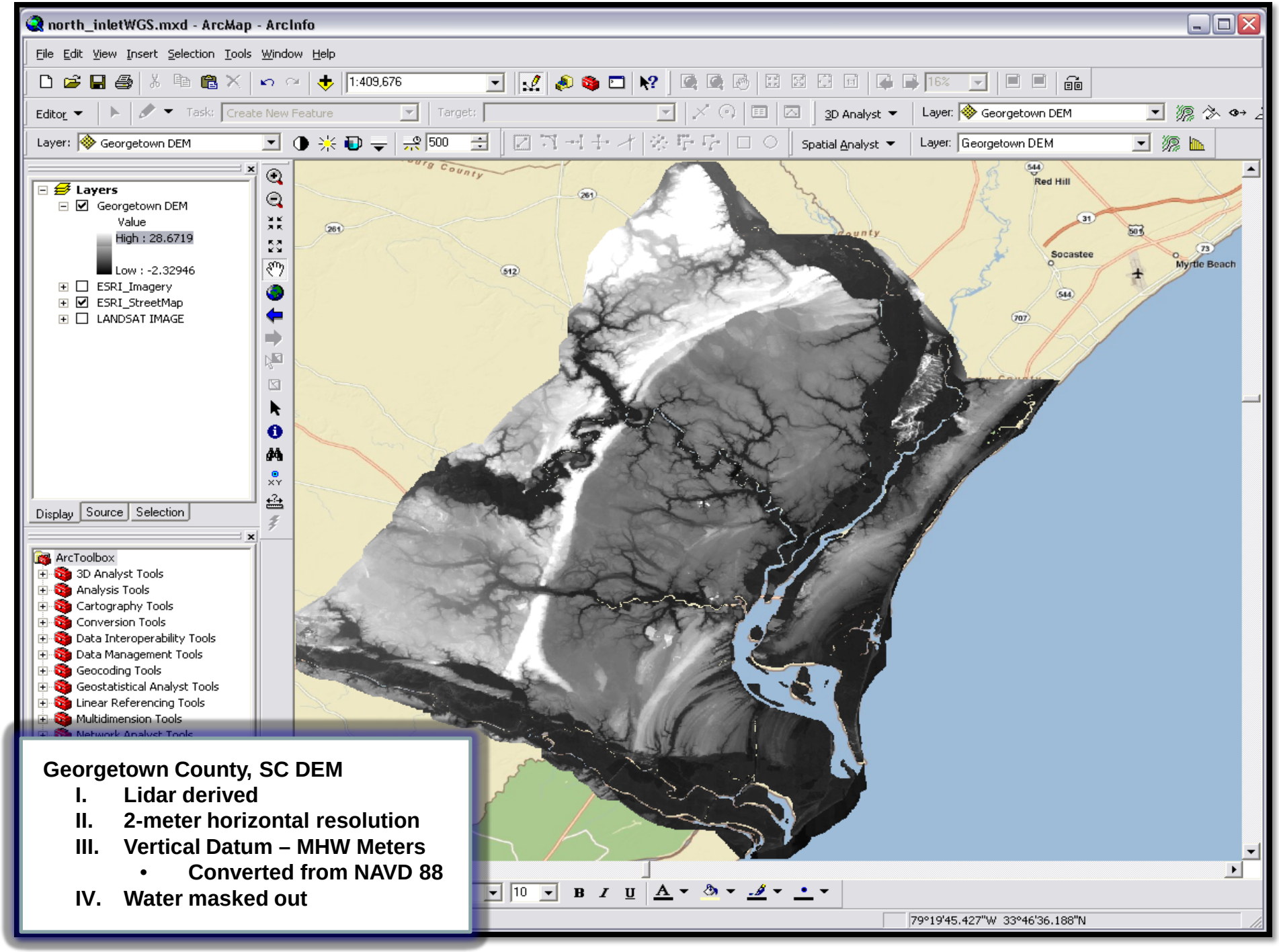
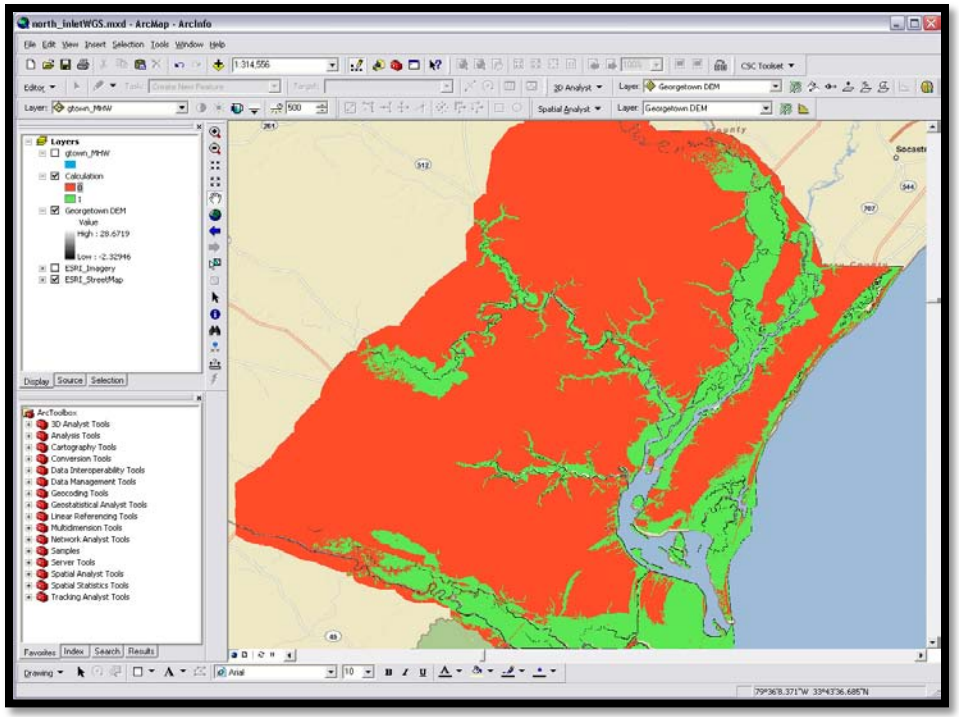
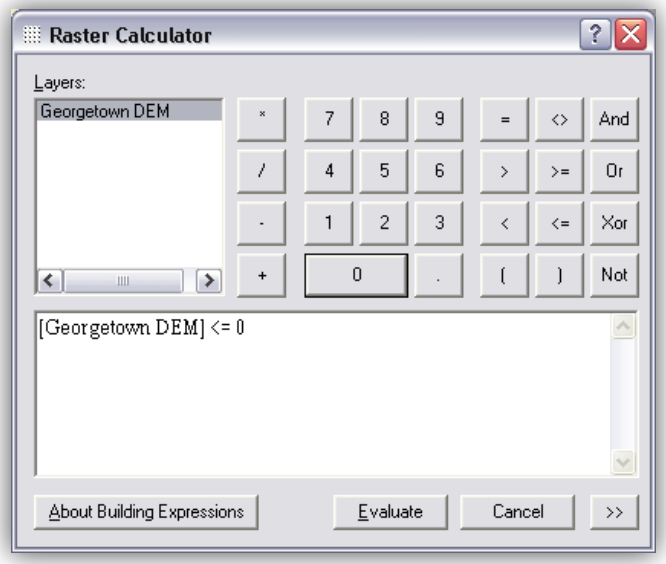


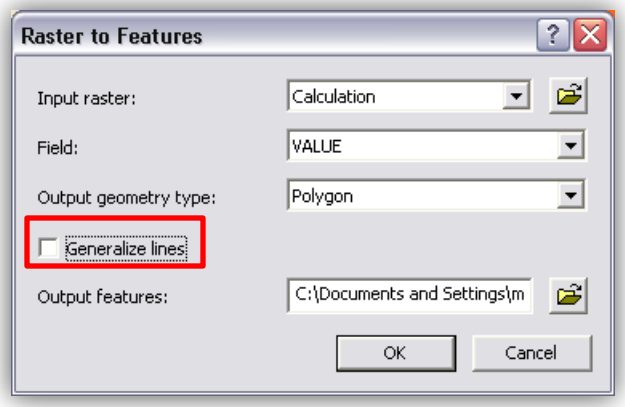
Georgetown County, SC DEM

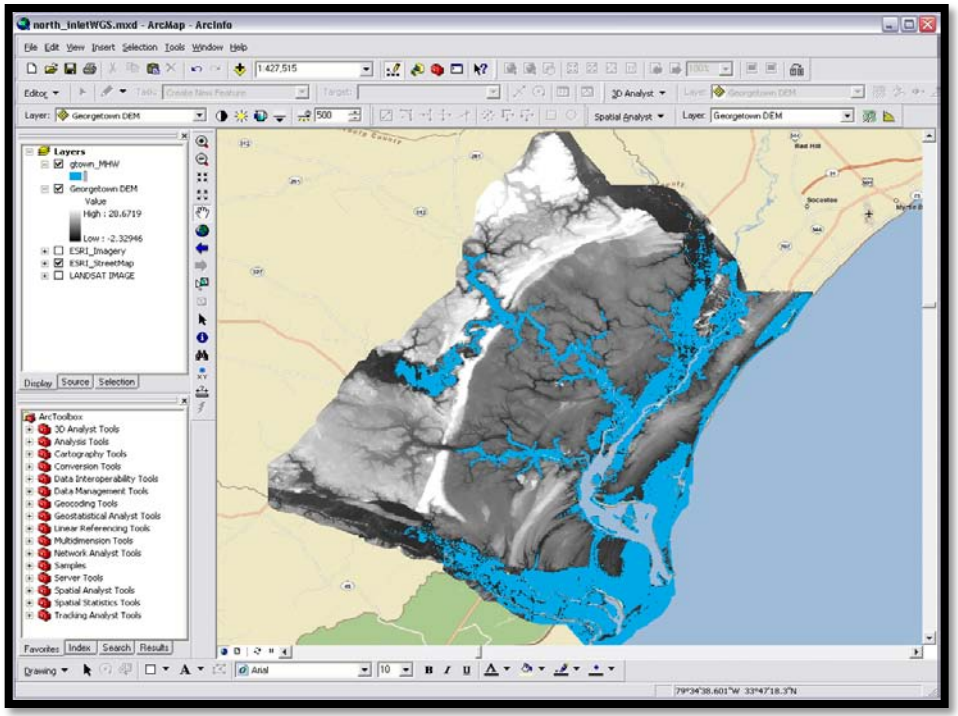
I. Lidar derived
II. 2-meter horizontal resolution
III. Vertical Datum – MHW Meters
    - Converted from NAVD 88
IV. Water masked out

Mapping Current MHW





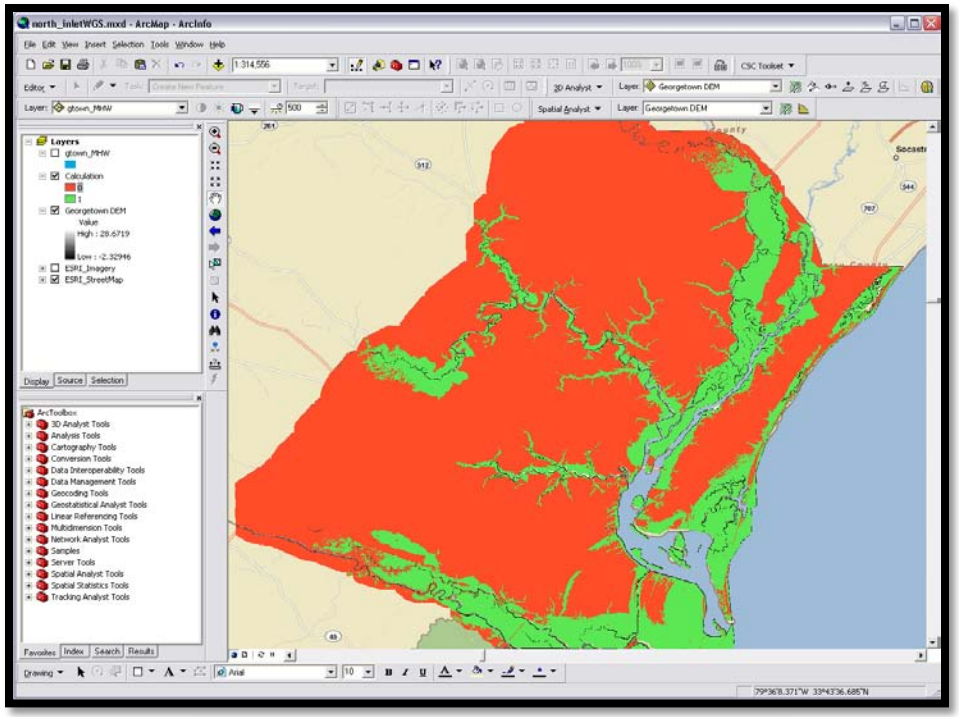


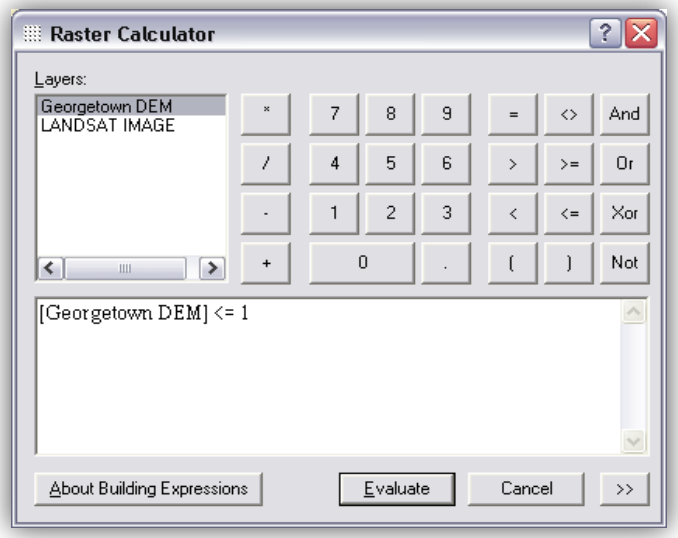


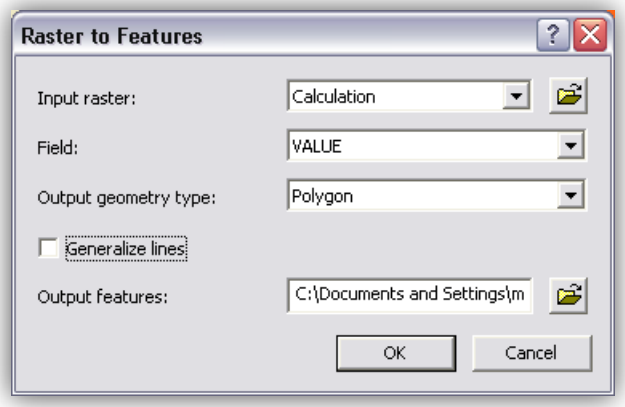
Editor Toolbar > Start Editing

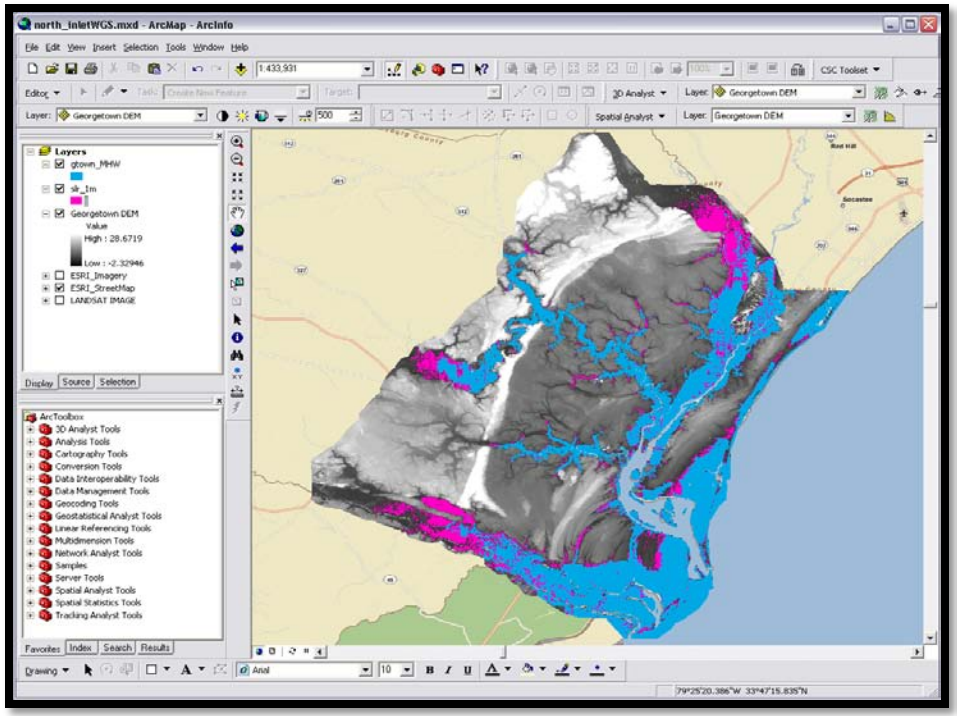
- **Select By Attributes**
- **"GRIDCODE" = 0**
- **Deletes "Dry" Features**
- **Save Edits – Stop Editing**

+1 m Sea-Level Rise









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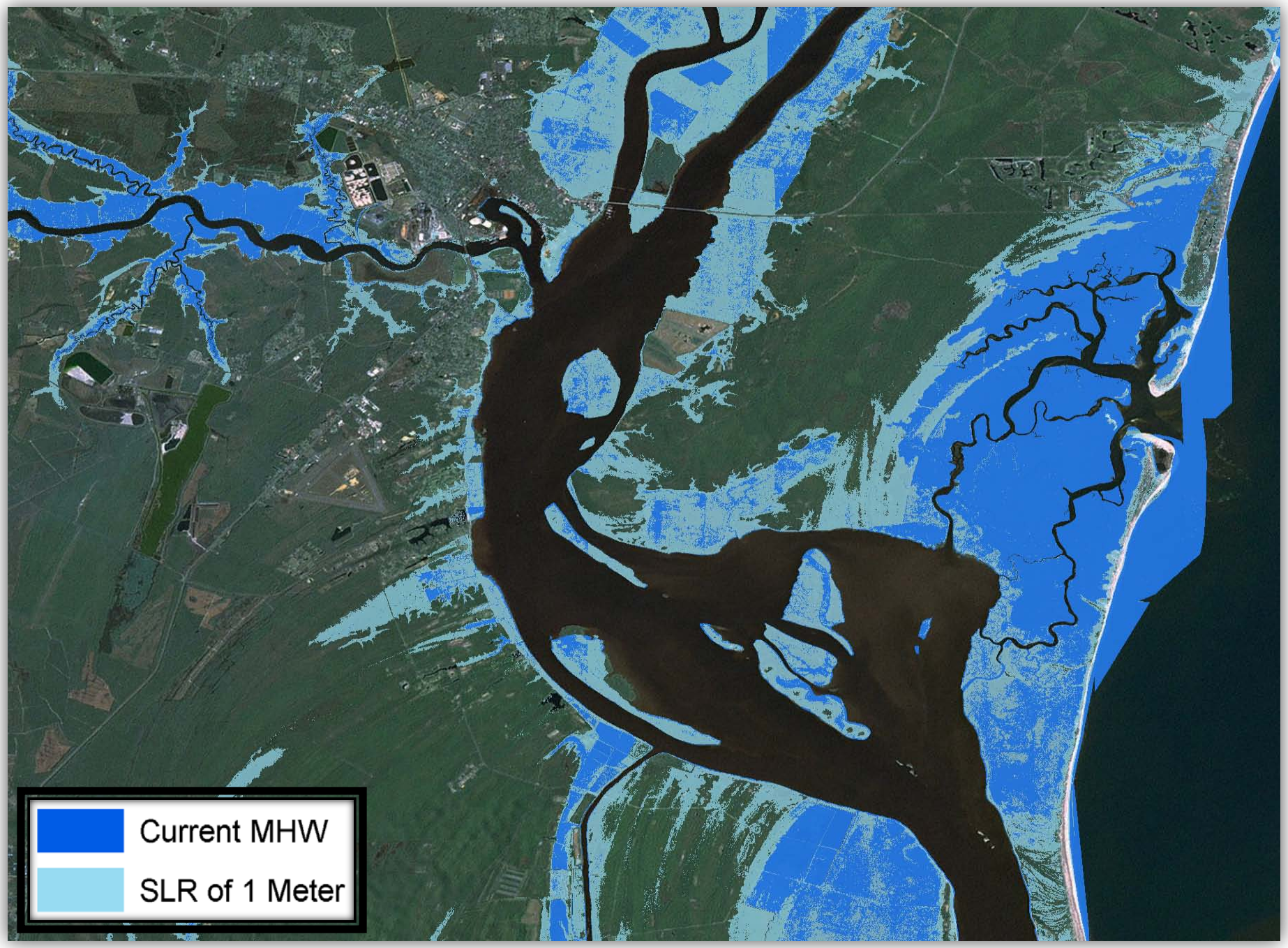
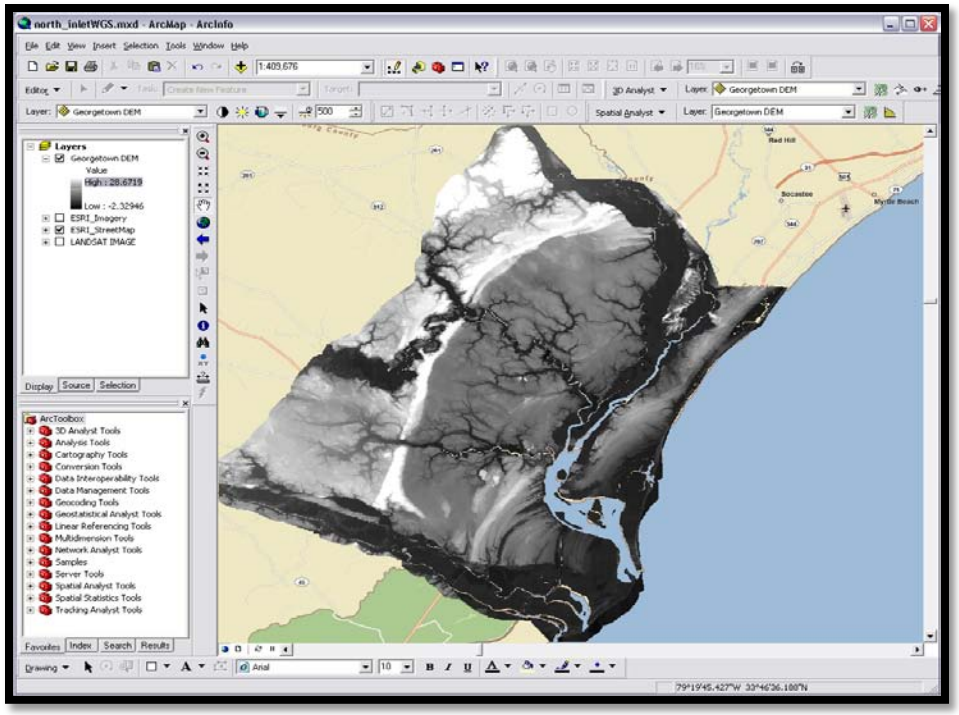

Current MHW
SLR of 1 Meter

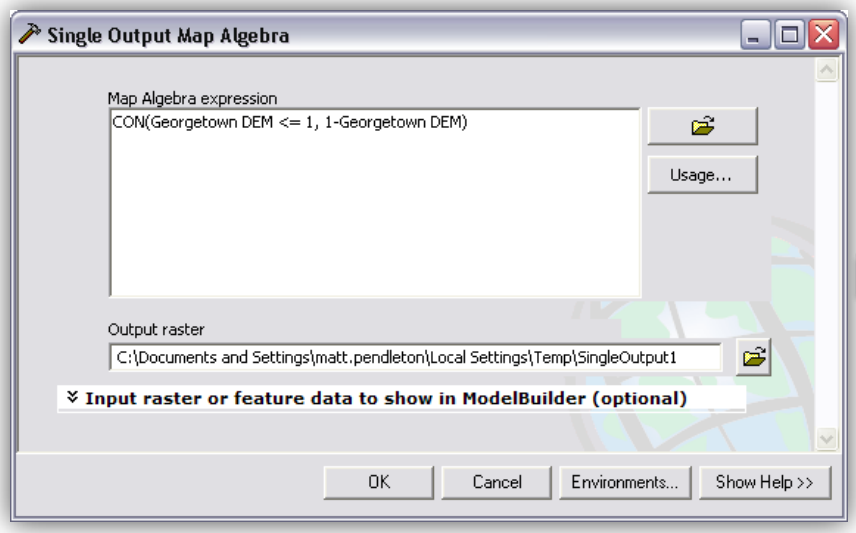
Creating Depth Grids

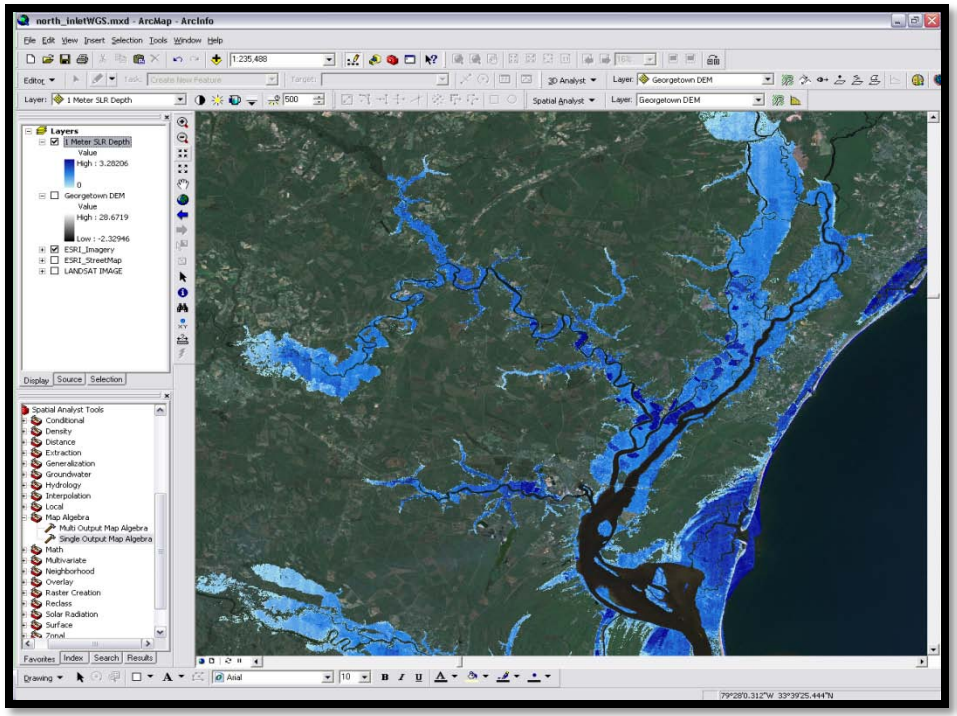
1 m Sea-Level Rise Depth



Spatial Analyst Toolbox
> Map Algebra
> Single Output Map Algebra

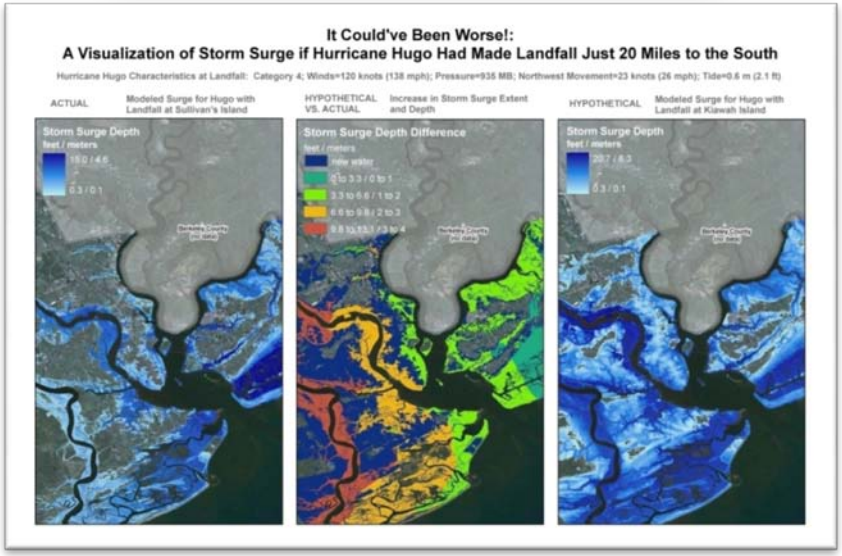
CON (Georgetown DEM <= 1, 1- Georgetown DEM)

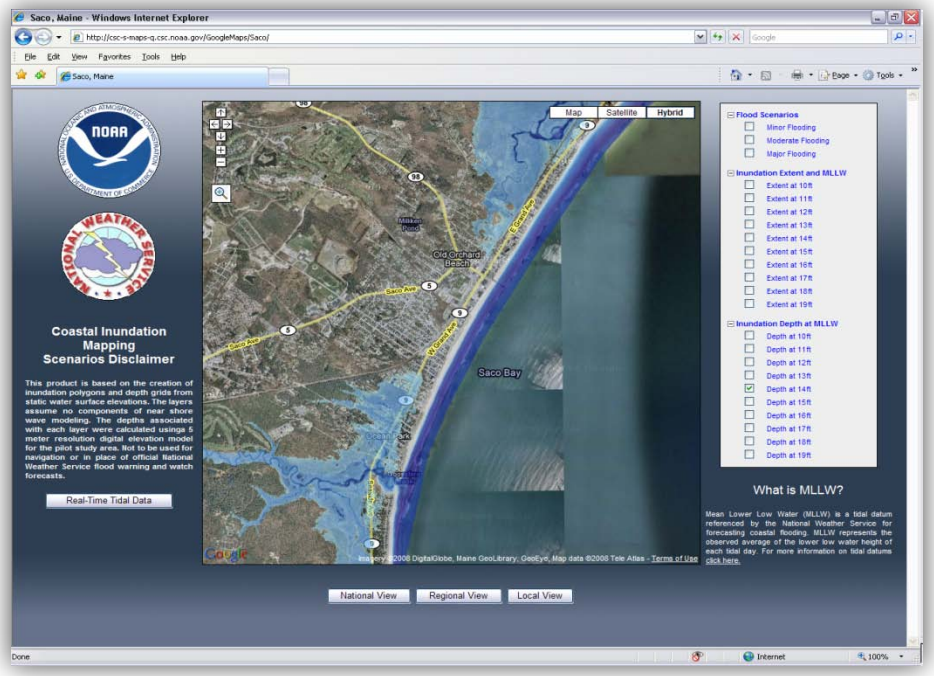




Depth
3.2 m
0

Visualizing Results





Questions?