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LiDAR Technology & Products

Elevation Framework Kickoff Meeting

Thursday May 20, 2010

10:00am – 3:00pm

Brian Mayfield

Tim Blak

Brian Batten, Ph.D.

What is LiDAR

- Light Detection And Ranging
- Active Sensing System
  - Uses its own energy source
- Measures range distances
  - Based on time between emission, reflection and receive time
- Direct terrain measurements, unlike photogrammetry which is inferred
- Day or night operation except when coupled with digital camera

What LIDAR is NOT

- All-weather
  - Target must be visible within the selected EM spectrum
  - No rain or fog
  - Must be below clouds
- Able to "penetrate vegetation"
  - LIDAR can penetrate openings in the vegetation cover but cannot see through closed canopies

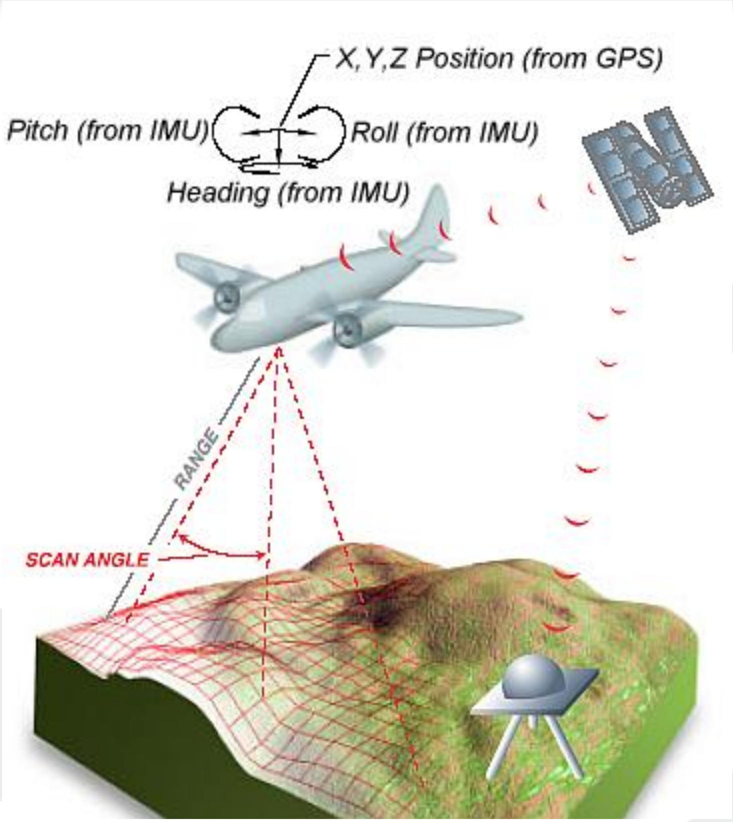
LiDAR Basics

- A pulse of light energy is emitted and the precise time is recorded.
- The reflection of that pulse is detected and the precise time is recorded.
- Knowing the speed of light, the range can be determined.
- Knowing the position & attitude of the sensor, the XYZ coordinate of the target can be calculated.

LiDAR Components

Three major components of a LiDAR system

1. GPS
2. Inertial Measurement Unit (IMU)
3. Laser Scanner



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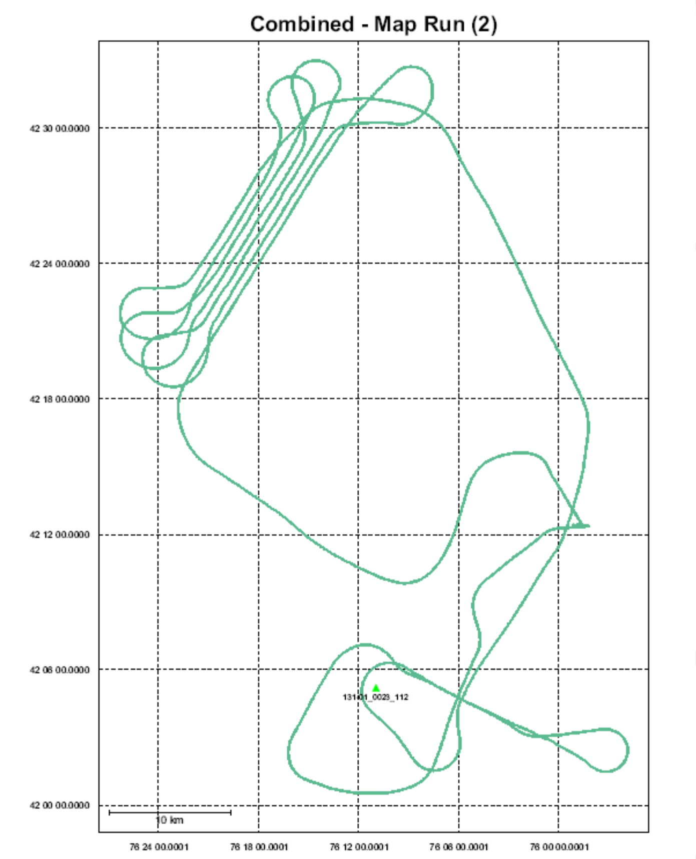
GPS – ABGPS

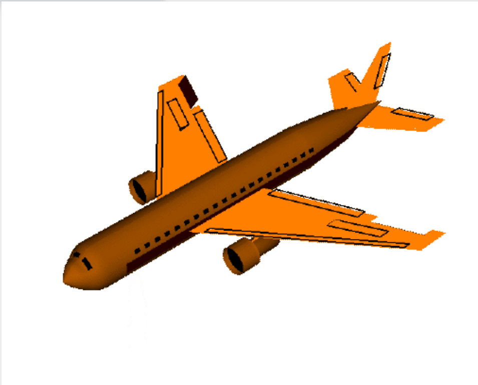
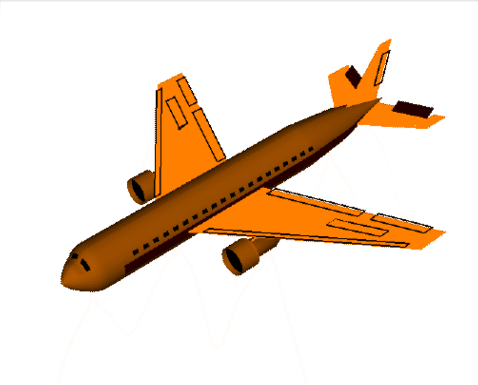
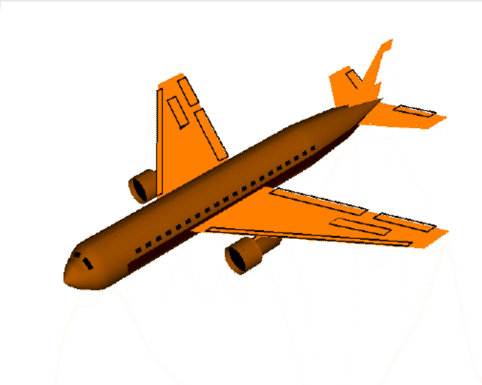
- Positions the aircraft every one second
- Integrates with IMU – blends the GPS position fixes and the IMU orientation fixes for a complete record of the aircraft motion
- Largest source of positional error!
- Minimize baseline length for best accuracy



Inertial Measurement Unit - IMU

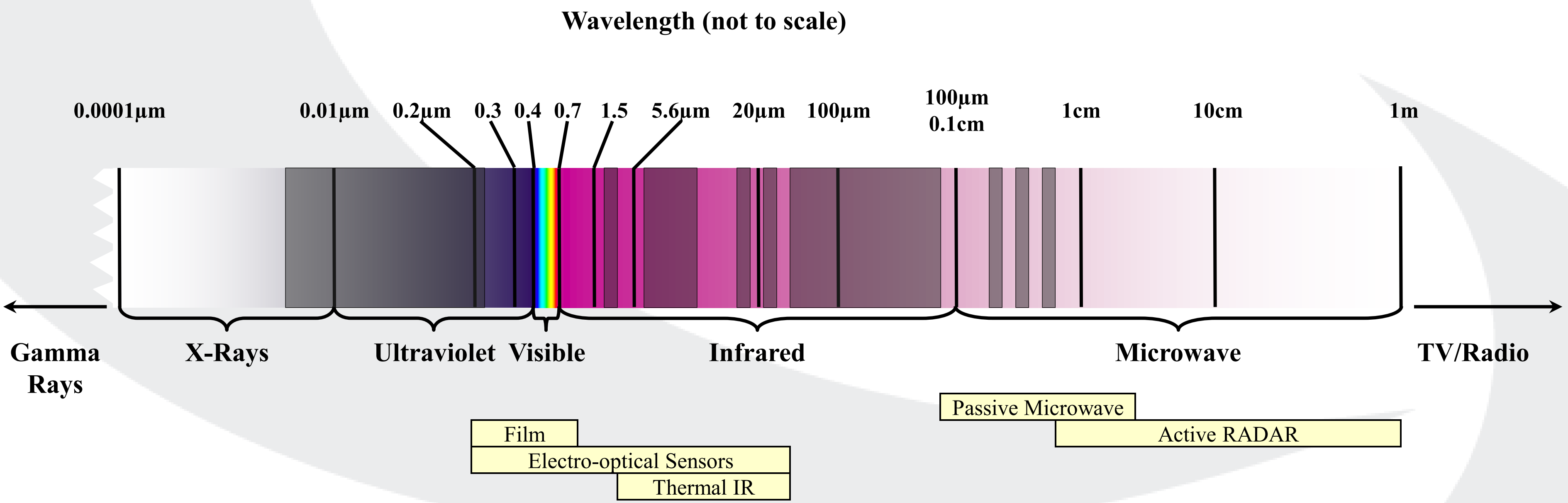
- Position and Orientation system utilizes a combination of gyros and accelerometers
- Outputs position, roll, pitch and heading of airborne sensors real time and post processing
- Capable of 0.005 pitch/roll, 0.008 heading accuracies (POS AV 510 post processed)
- 5-10 cm sensor positioning (post-processed)
- 200 Hz data rates

IMU - Orientation

Roll	Pitch	Yaw

Laser Range – EM Spectrum



Courtesy of EarthData Technologies

Lasers

- Infrared Light (typically 1064 nm)
- Invisible and strongly reflected by vegetation
- Narrow dispersion angle (0.3 mrad)
- Spot size varies with flying height and angle
- Eye safety must be considered

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LiDAR Animation

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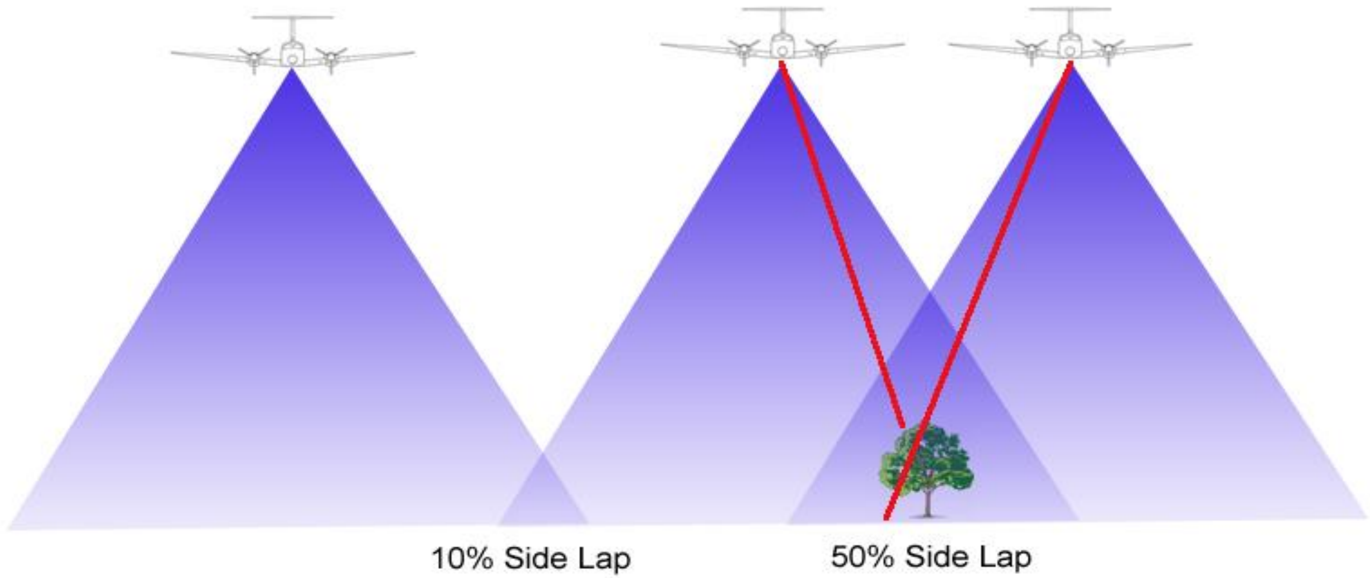
Swath Width Consideration



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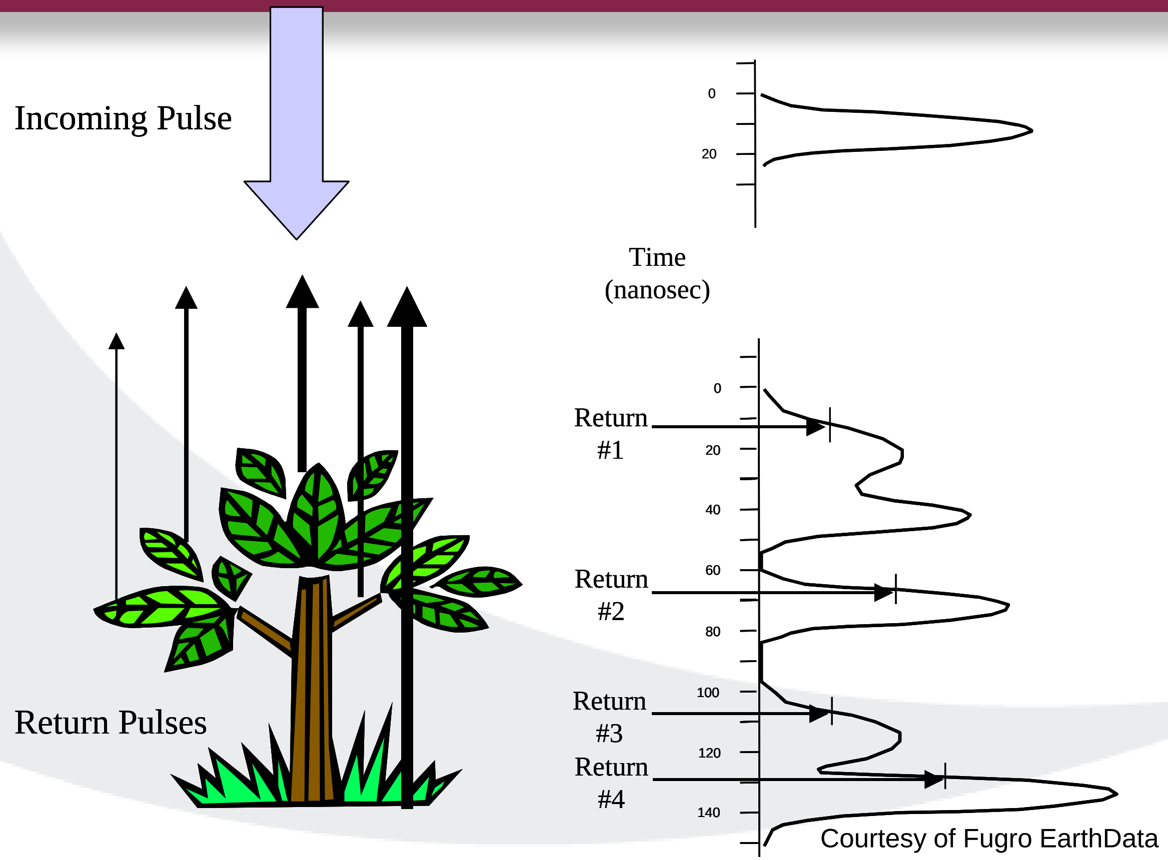
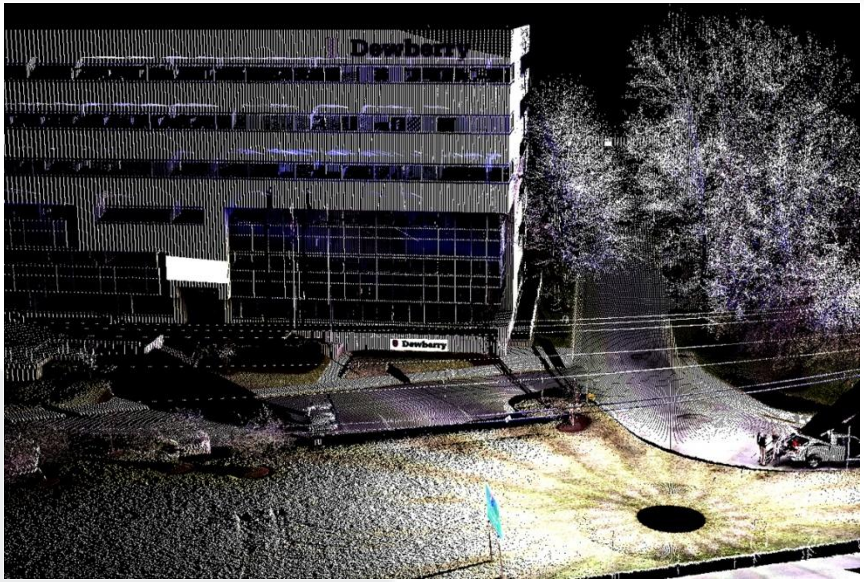
Laser Returns

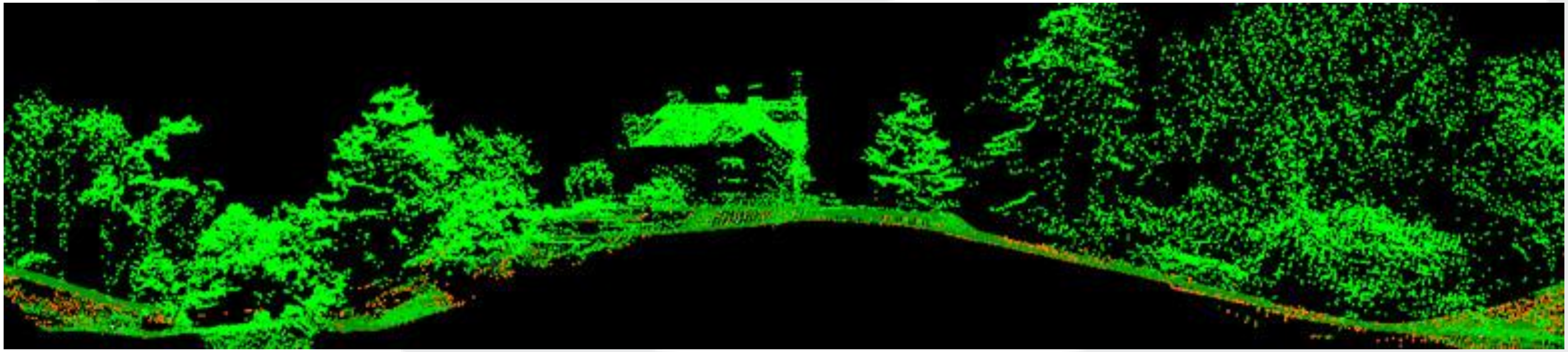
- First
  - Ideal for surface models
- Last
  - Ideal for generating bare-earth terrain models
- Intermediate
  - Ideal for determining vegetation structure

Laser Returns



LiDAR is Point Clouds





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LiDAR Intensity Image

Dewberry's USGS GPSC2 Task Order

- Planning, Acquisition, Processing, Derivative Product Development and Quality Assurance of LiDAR data for:
  - 10 Counties: Northumberland, Lancaster, Middlesex, Gloucester, Isle of Wight, King and Queen, James City, Mathews, Suffolk and Surry
  - 1 City: Williamsburg
  - Total Area – 2,575 square miles

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Dewberry's USGS GPSC2 Task Order

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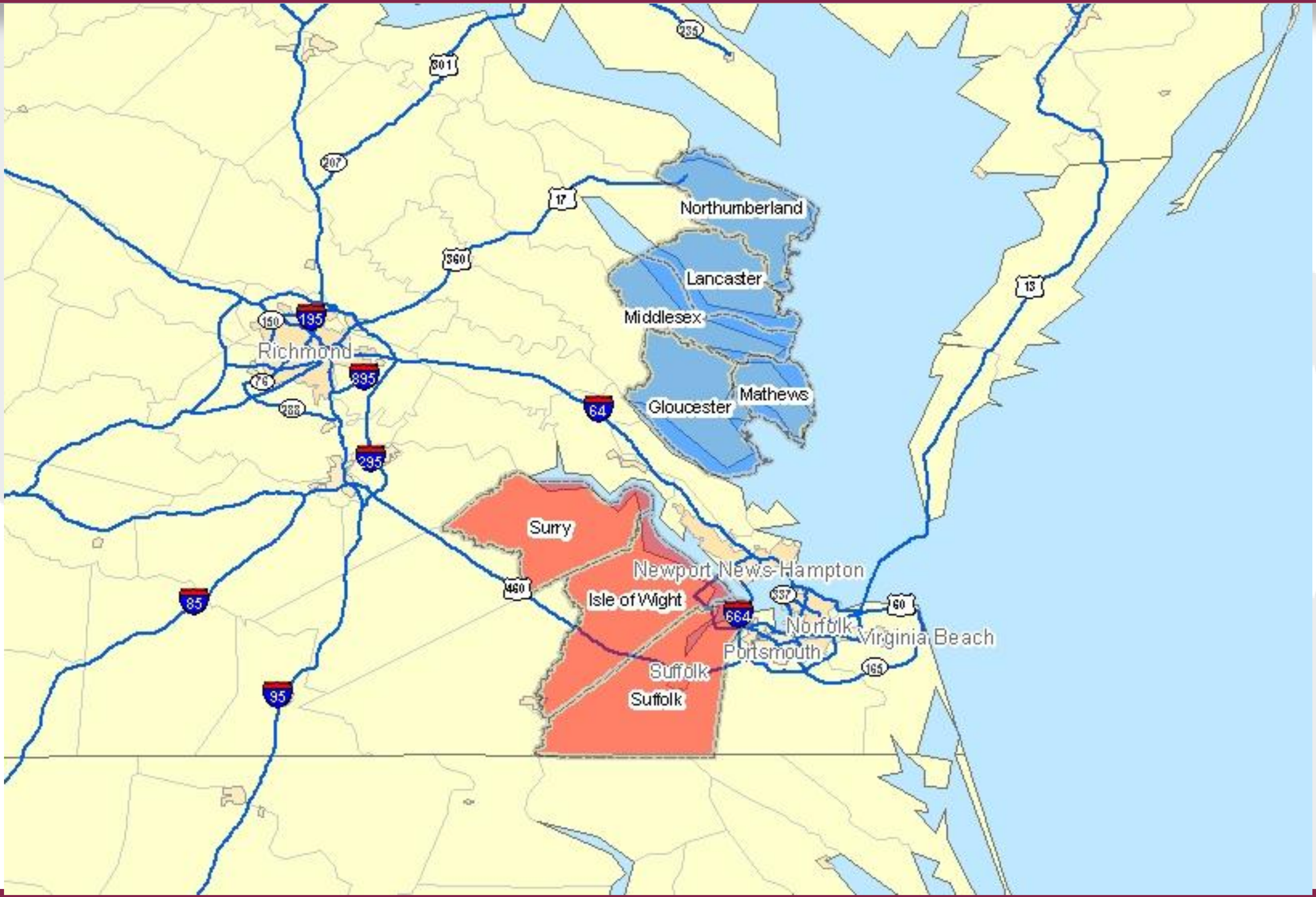
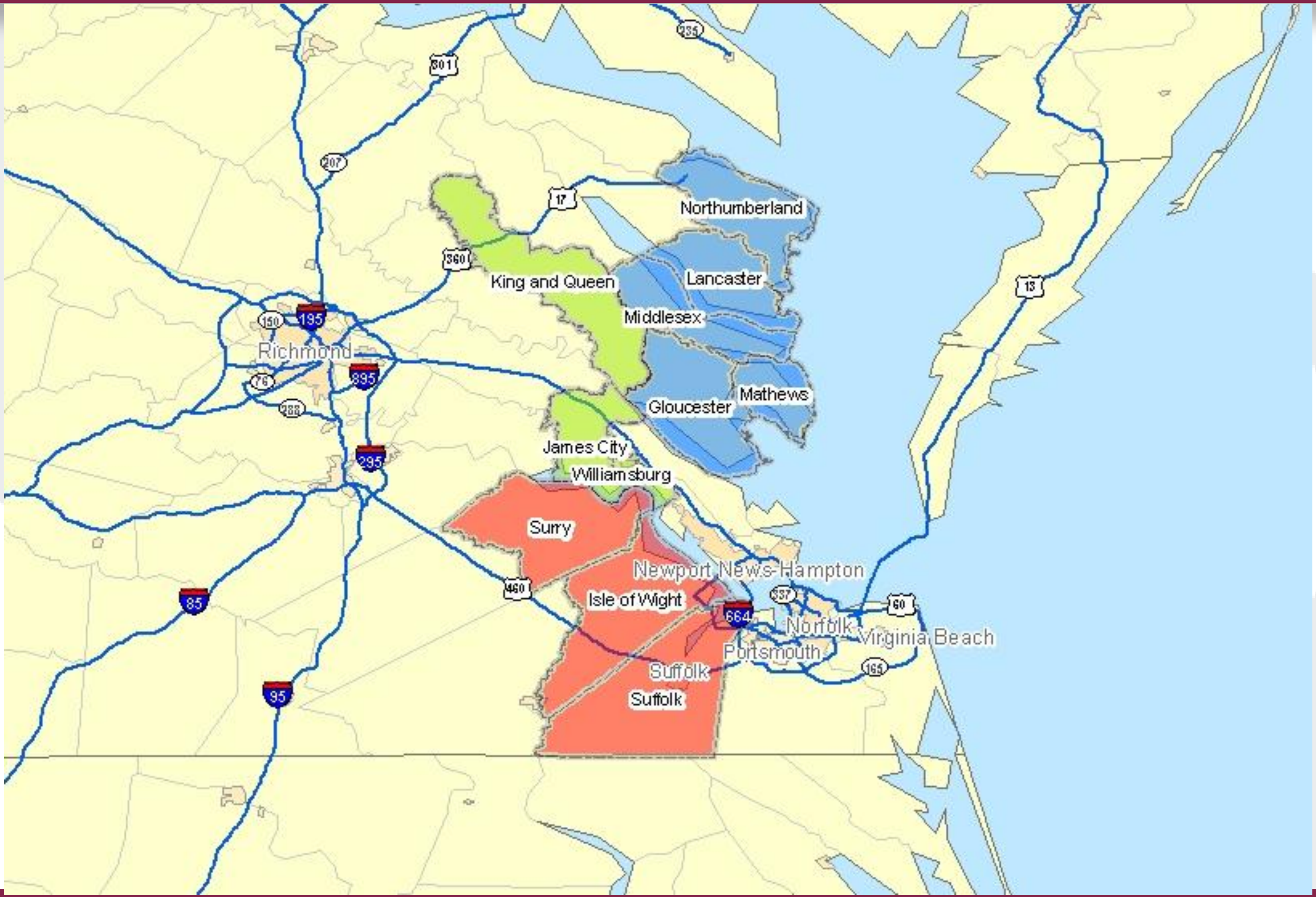


Dewberry's USGS GPSC2 Task Order



Dewberry's USGS GPSC2 Task Order

- All data developed to:
  - U.S. Geological Survey National Geospatial Program Base LiDAR Specifications, Version 13
    - LiDAR Requirements:
      - Nominal Post Spacing (NPS) – 2 meters
      - Collection Area buffered by 200*NPS
      - 15 cm $RMSE_z$ (30cm $Accuracy_z$ – 95% Confidence Level)
      - 10 cm relative accuracy between adjacent flight lines
      - LAS 1.2, Point Record Format 1
    - Hydro Flattened DEM's
      - Requires a limited amount of breakline development

Dewberry's USGS GPSC2 Task Order

- LiDAR Acquisition Parameters

Laser Firing Rate:	33000
Altitude (ft. AGL):	4400
Swath Overlap (%):	50
Approx. Ground Speed (mph):	150
Scan Rate (Hz):	23.8
Scan Angle ( ):	20
Computed along track spacing (mtr):	1.4
Computed cross track spacing (mtr):	1.4
Average Raw Point Spacing (mtr)	1.0
Computed Swath Width (mtr):	871
Line Spacing (mtr)	435

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Tidal Breaklines

Description	Definition	Capture Rules
TIDAL_WATERS	The coastal breakline will delineate the land water interface using LiDAR data as reference. In flight line boundary areas with tidal variation the coastal shoreline may require some feathering or edge matching to ensure a smooth transition.	The feature shall be extracted at the apparent land/water interface, as determined by the LiDAR intensity data, to the extent of the tile boundaries. Differences caused by tidal variation are acceptable and breaklines delineated should reflect that change with no feathering. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding LiDAR points. Acceptable variance in the negative direction will be defined for each project individually. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water. Breaklines shall snap and merge seamlessly with linear hydrographic features.

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Inland Streams & Rivers Breaklines

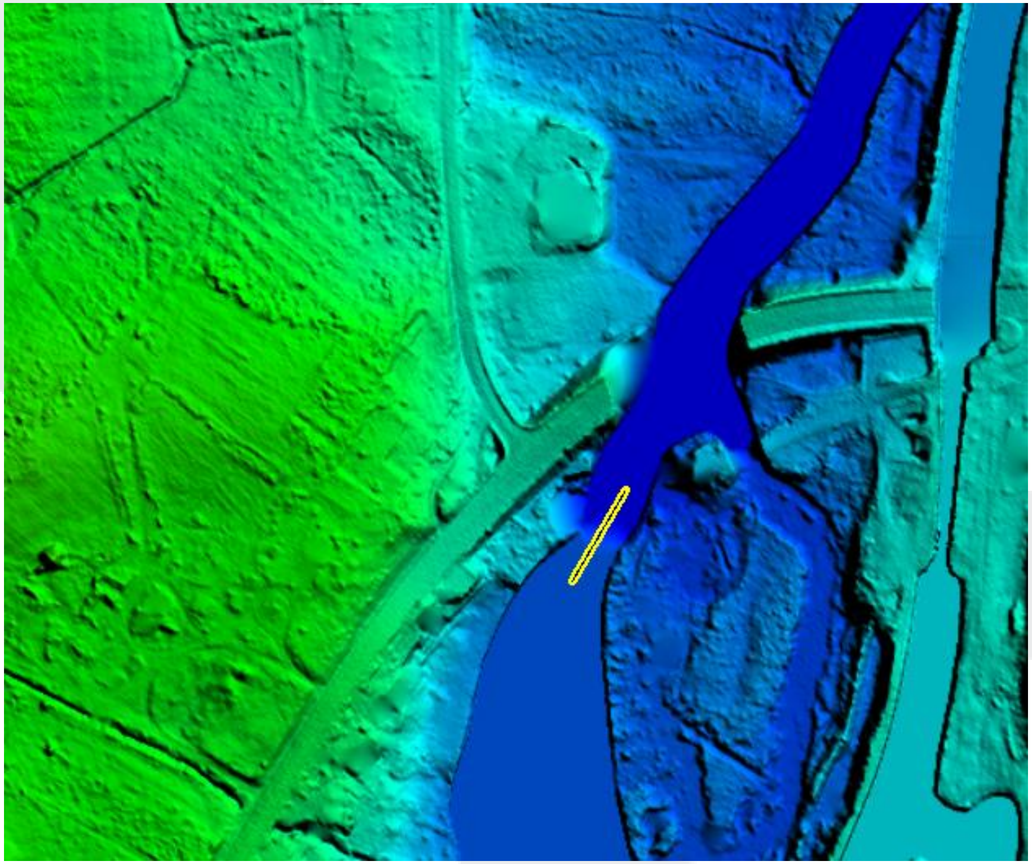
Description	Definition	Capture Rules
Streams and Rivers	Linear hydrographic features such as streams, rivers, canals, etc. with an average width greater than 100 feet in length. In the case of embankments, if the feature forms a natural dual line channel, then capture it consistent with the capture rules. Other natural or manmade embankments will not qualify for this project.	Capture features showing dual line (one on each side of the feature). Average width shall be great than 100 feet to show as a double line. Each vertex placed should maintain vertical integrity and data is required to show "closed polygon". Generally both banks shall be collected to show consistent downhill flow; following the gradient. There are exceptions to this rule where a small branch or offshoot of the stream or river is present. The banks of the stream must be captured at the same elevation to ensure flatness of the water feature. If the elevation of the banks appears to be different see the task manager or PM for further guidance. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding LiDAR points. Acceptable variance in the negative direction will be defined for each project individually. These instructions are only for docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water. Every effort should be made to avoid breaking a stream or river into segments. When changing from a double line stream to a single line stream the double line feature should tapper down to the single line stream to improve the quality of the data and allow for hydro-flattening. Dual line features shall break at road crossings (culverts). In areas where a bridge is present the dual line feature shall continue through the bridge. Islands: The double line stream shall be captured around an island if the features on either side of the island meet the criteria for capture. In this case a segmented polygon shall be used around the island in order to allow for the island feature to remain as a "hole" in the feature.

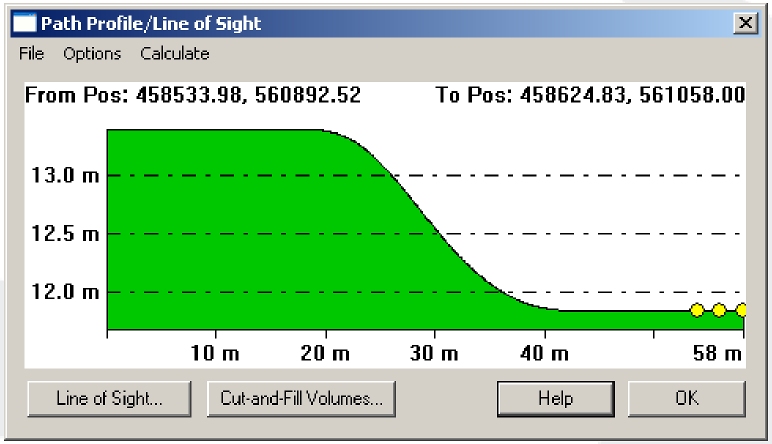
Inland Ponds & Lakes Breaklines

Description	Definition	Capture Rules
Ponds and Lakes	Land/Water boundaries of constant elevation water bodies such as lakes, reservoirs, ponds, etc. Features shall be defined as closed polygons and contain an elevation value that reflects the best estimate of the water elevation at the time of data capture. Water body features will be captured for features 2 acres in size or greater. “Donuts” will exist where there are islands within a closed water body feature.	Water bodies shall be captured as closed polygons with the water feature to the right. The compiler shall take care to ensure that the z-value remains consistent for all vertices placed on the water body. The field “WATERBODY_ELEVATION_MS” shall be automatically computed from the z-value of the vertices. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding LiDAR points. Acceptable variance in the negative direction will be defined for each project individually. An Island within a Closed Water Body Feature will also have a “donut polygon” compiled in addition to an polygon. These instructions are only for docks or piers that follow the coastline or water’s edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water’s edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water.

Resultant Hydro-Flattened DEMs

- Breaklines enforce monotonicity of hydro features





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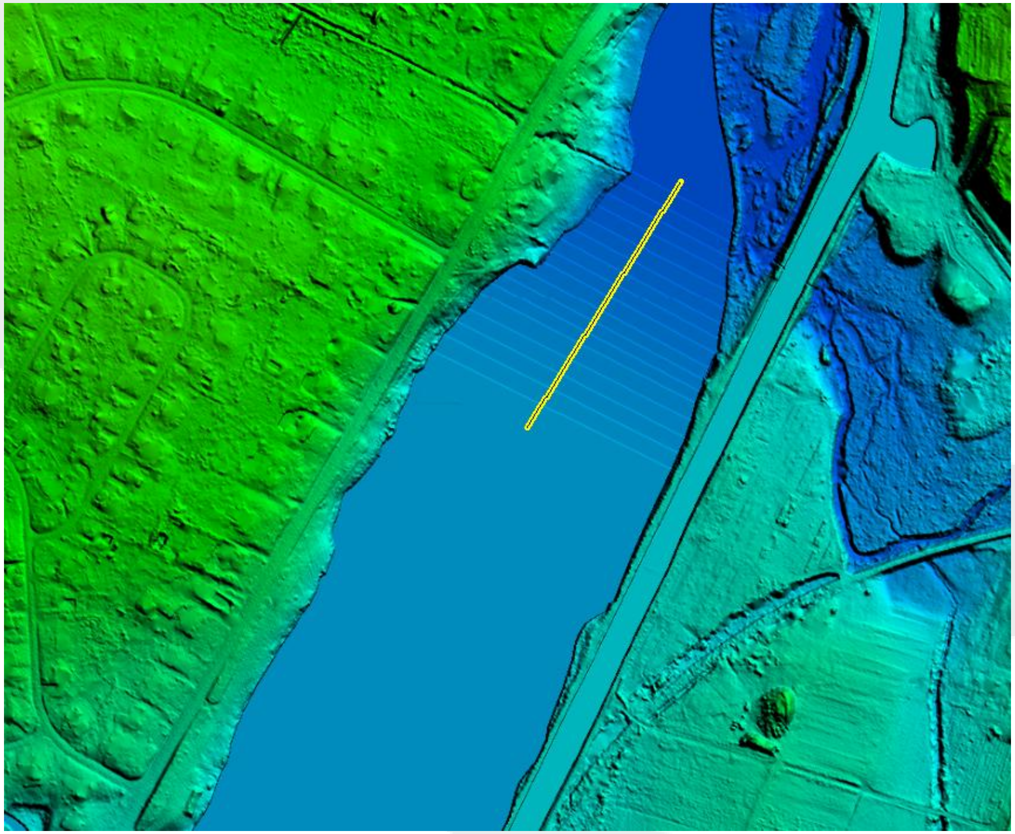
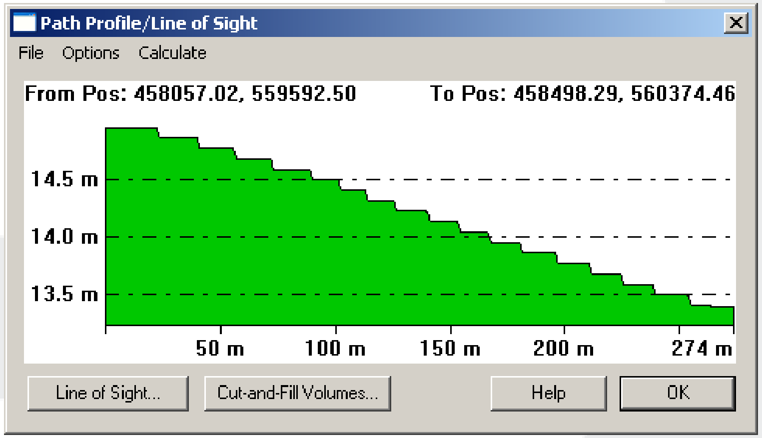
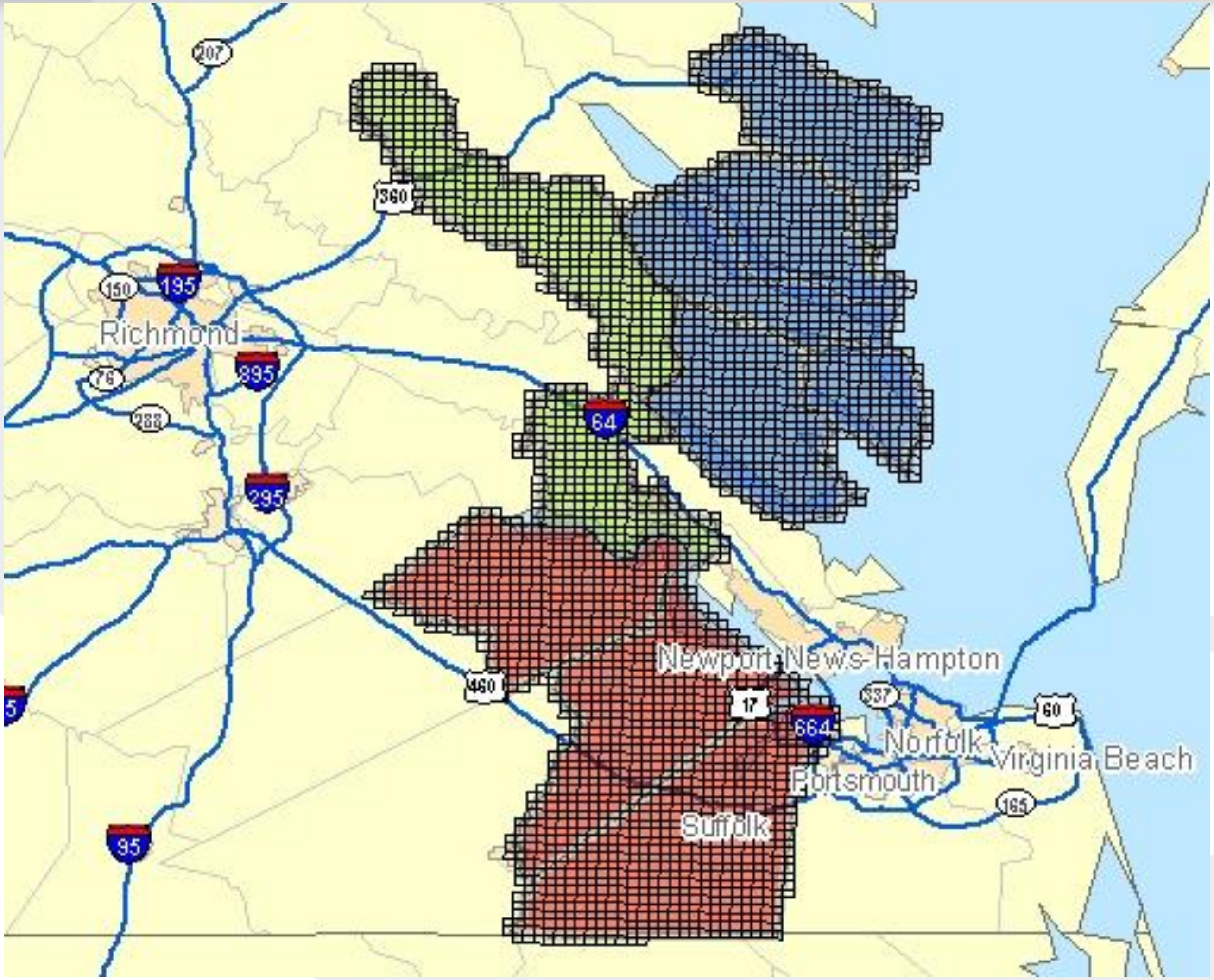




Data Tile Structure

- Follows the VGIN VBMP tiling schema
  - 5,000’ x 5,000’ tiles (non-overlapping)
  - VA SPCS, NAD83 HARN, US Survey Feet
  - Naming convention matches VBMP digital orthos with the lone exception being prefix – changed from “DO_” to “LAS_”
- 3,199 tiles will be delivered
  - Partial tiles will be delivered on the project boundary
- Tiles will apply to both LAS and DEM data
  - Breaklines will be delivered in a single file geodatabase

Data Tile Structure



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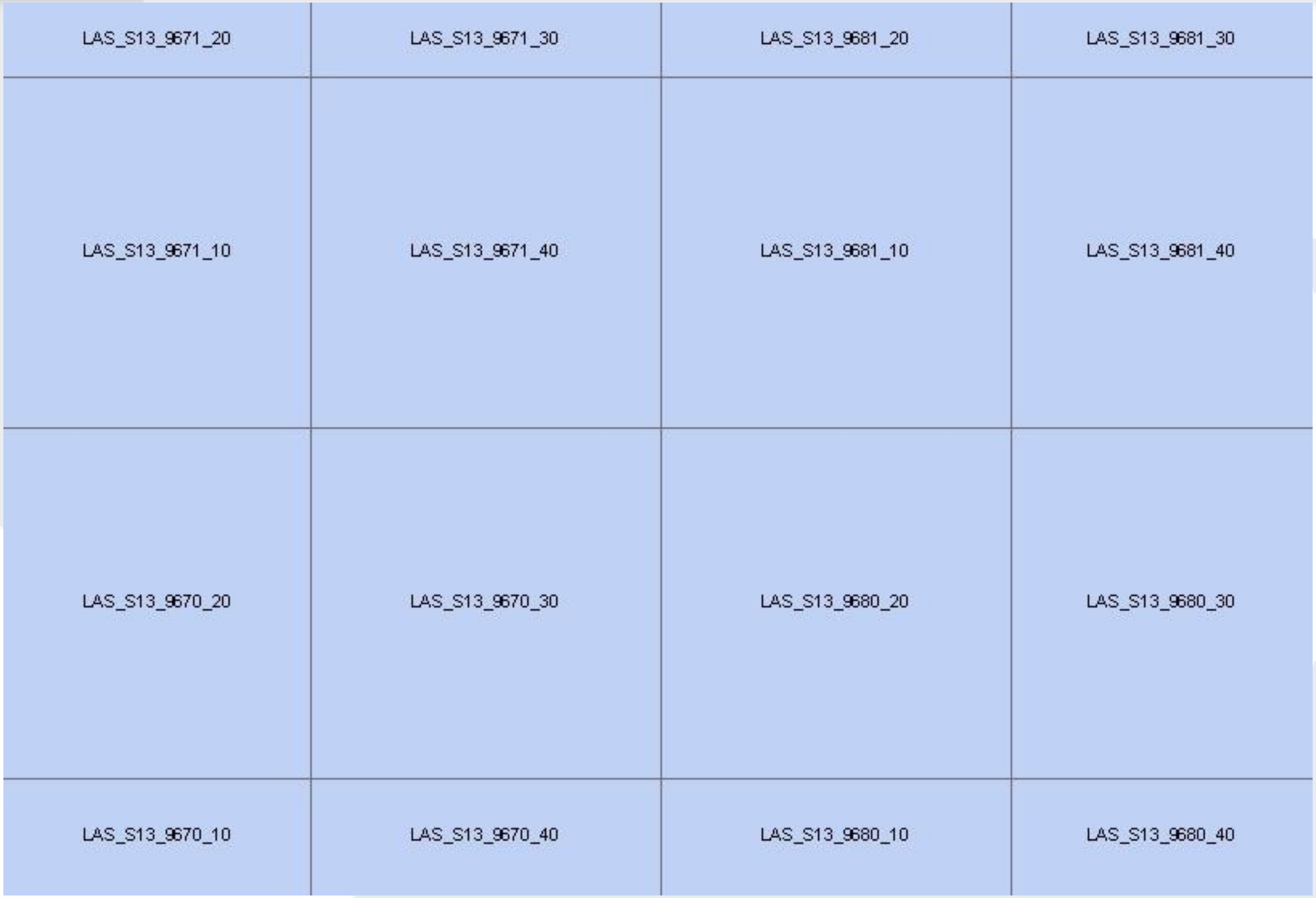
Data Tile Structure



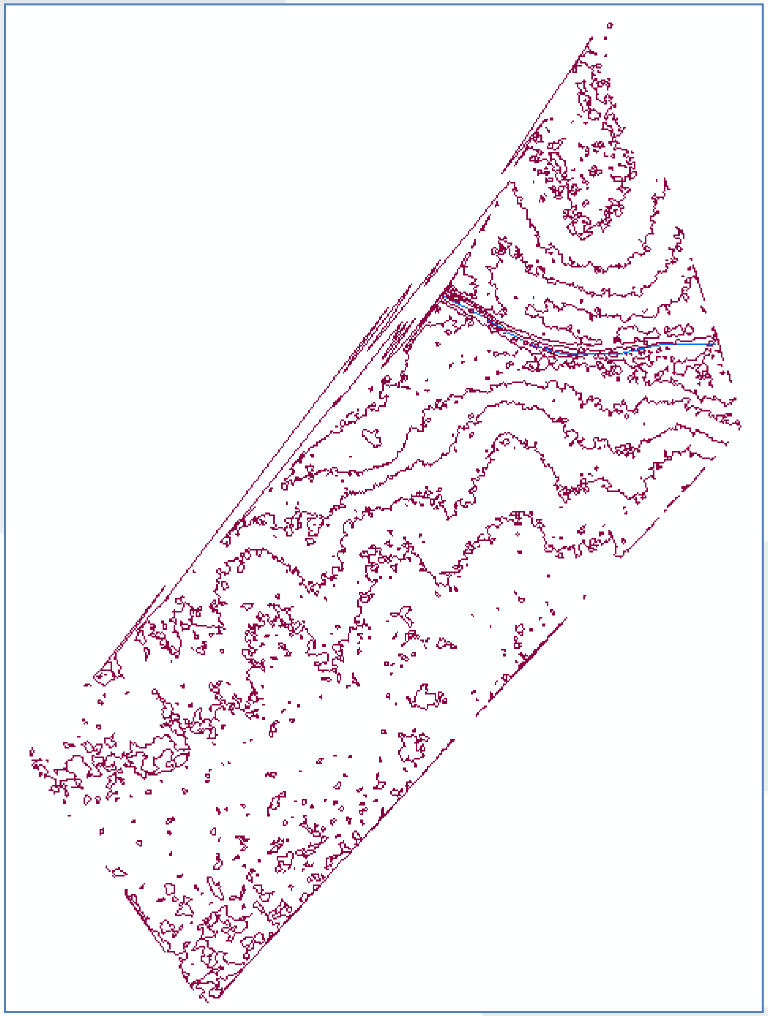
Now what - Optional Products

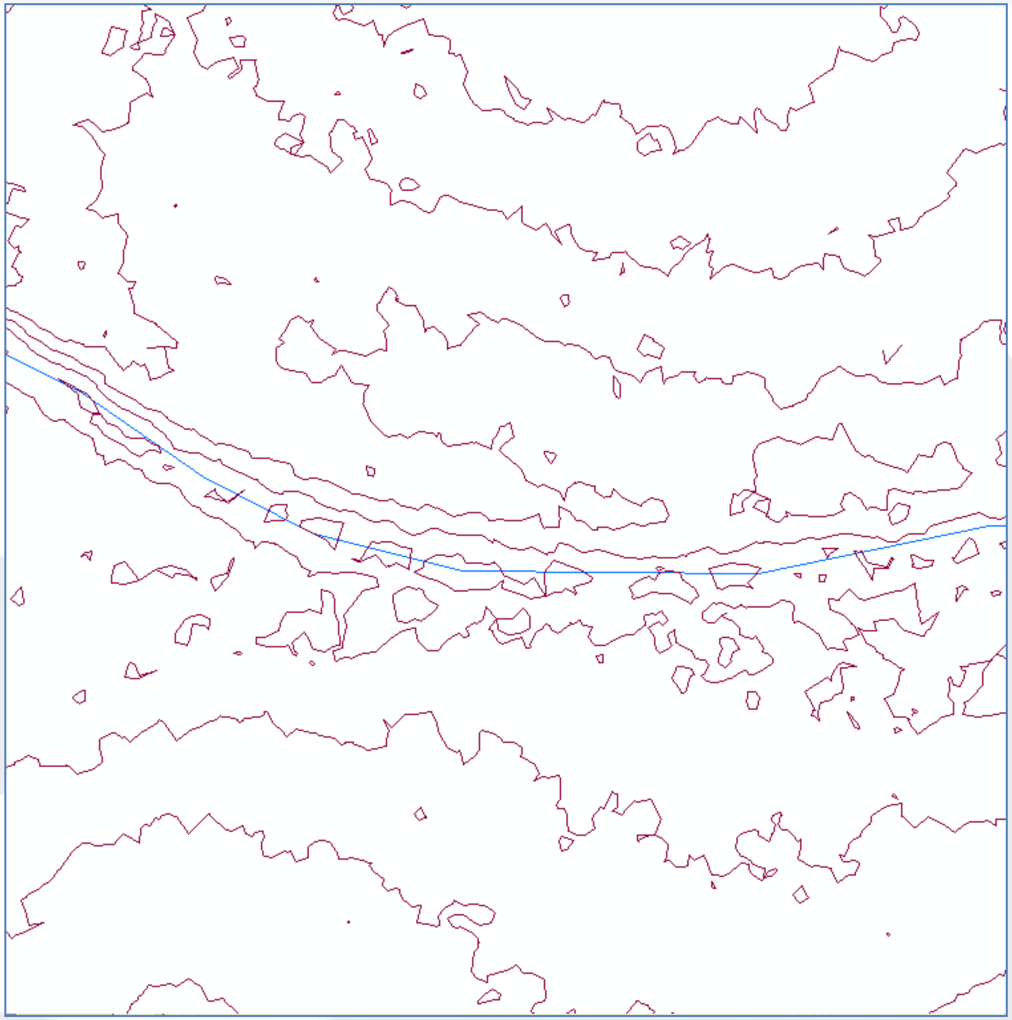
- New LiDAR can be leveraged in many ways:
  - 2’ Contours
    - Engineering (push-button)
    - Cartographic
    - Breakline Enhanced Cartographic
  - Fusion with VBMP’s new multi-spectral digital orthophotography
    - Assign discrete pixel values to individual LiDAR returns

Engineering Contours

- Easily created using Spatial Analyst in ArcGIS or similar modeling applications
- No algorithmic correction for smoothing, small tops/saddles, etc…
- Very utilitarian and not the easiest for human interpretation
- Cheapest to produce because any user with basic GIS tools can produce themselves with minimal effort

Engineering Contours

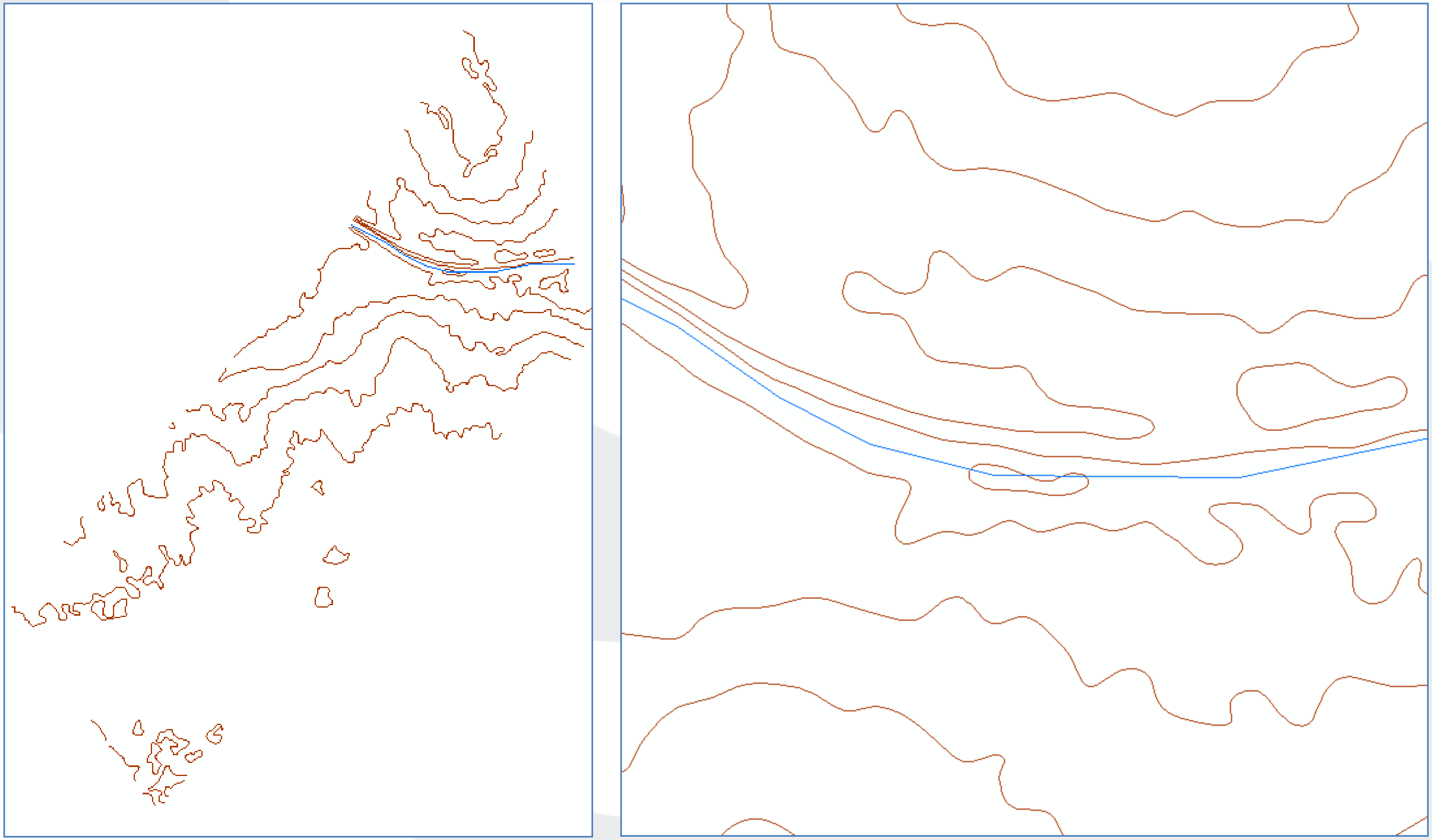




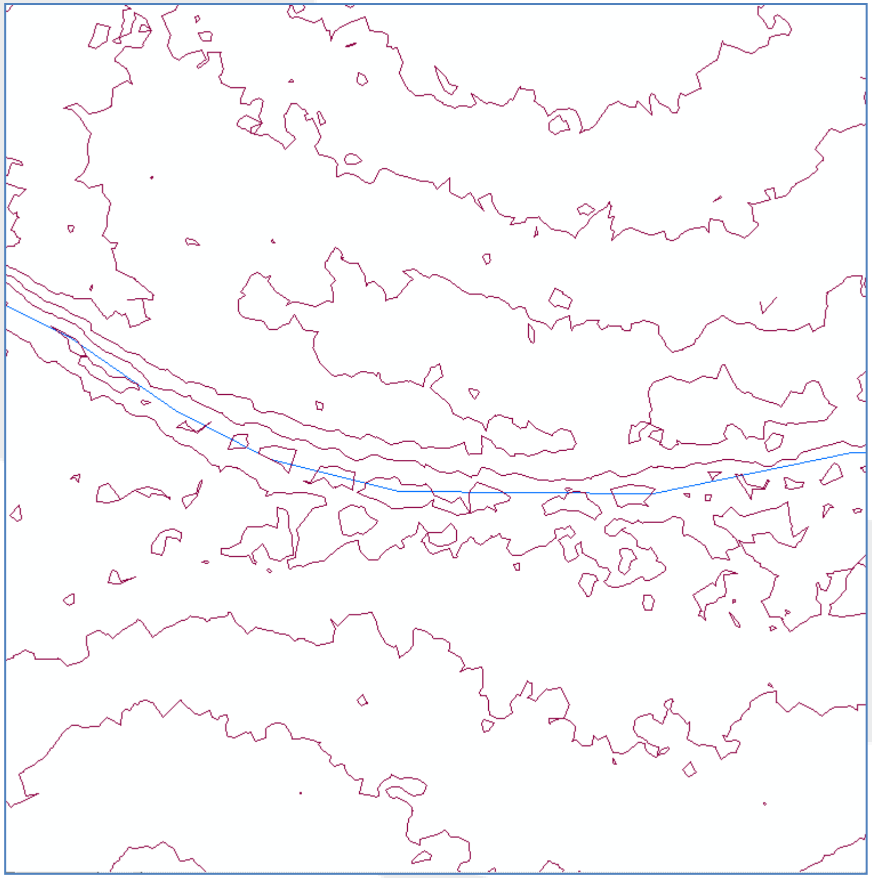
Cartographic Contours

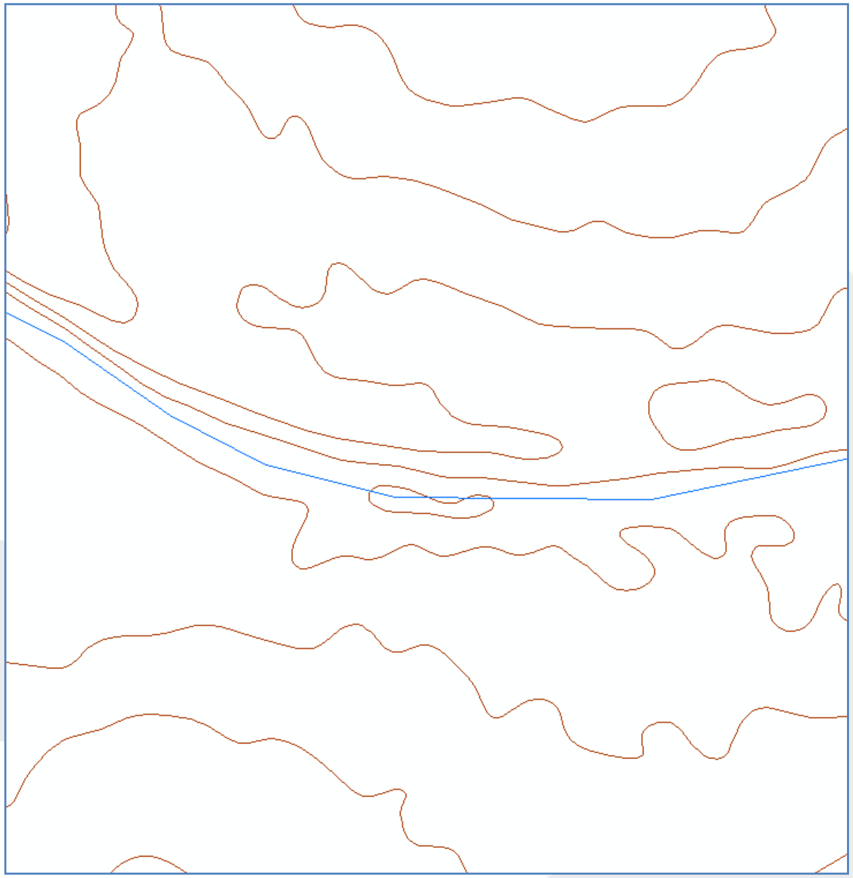
- Utilize a number of additional proprietary contour modeling algorithms
- Improved smoothing
- Additional contour coding (like depression contours) available through this process
- Algorithmic correction applied to remove small tops/saddles, etc…
- Easier human interpretation
- More expensive to produce because it would likely involve contracting to a mapping company since specialized tools are involved.

Cartographic Contours



Contour Comparison

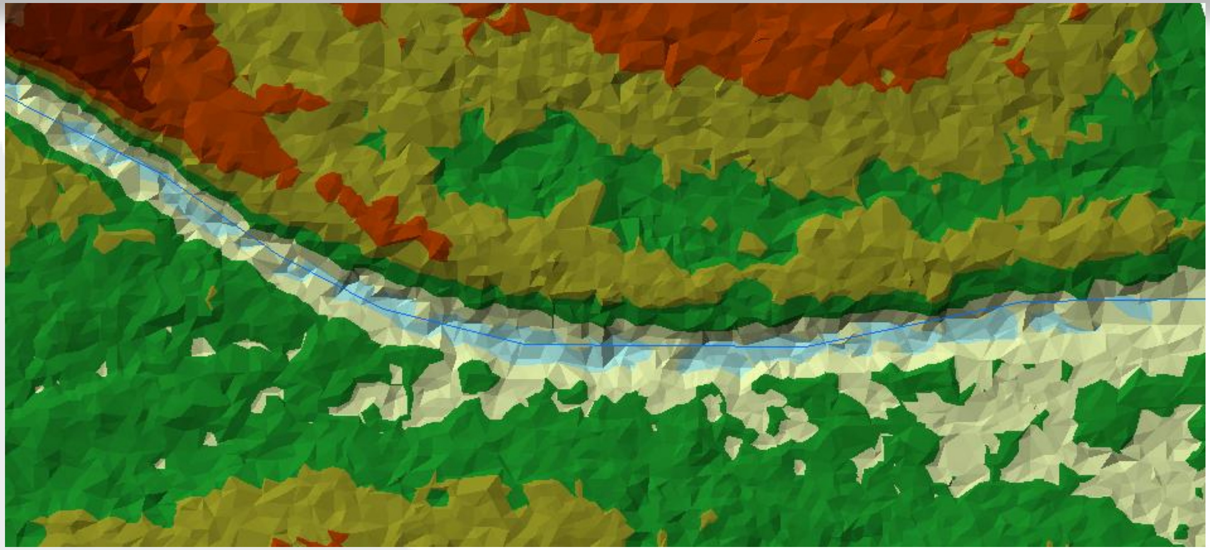


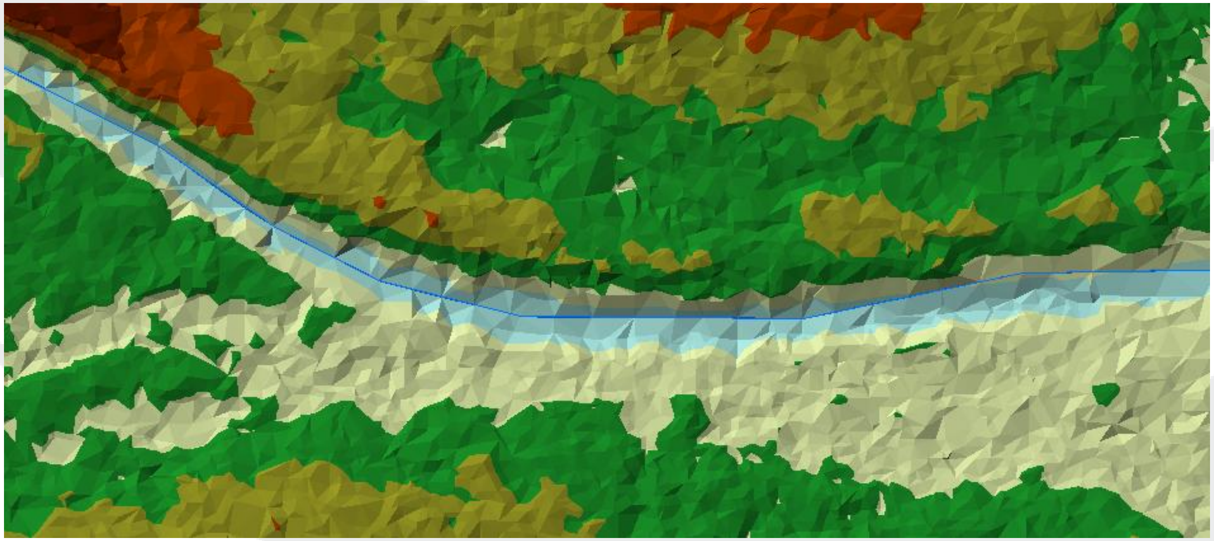


Breakline Enhanced Contours

- Utilize VBMP's existing DTM breaklines
  - Breaklines must fit horizontally with LiDAR
    - Will likely be a case-by-case analysis
  - Breaklines draped to assume a new z-value derived from the LiDAR
  - TIN or Terrain used for contour modeling updated to include breakline enforcement

Breakline Enhanced Contours





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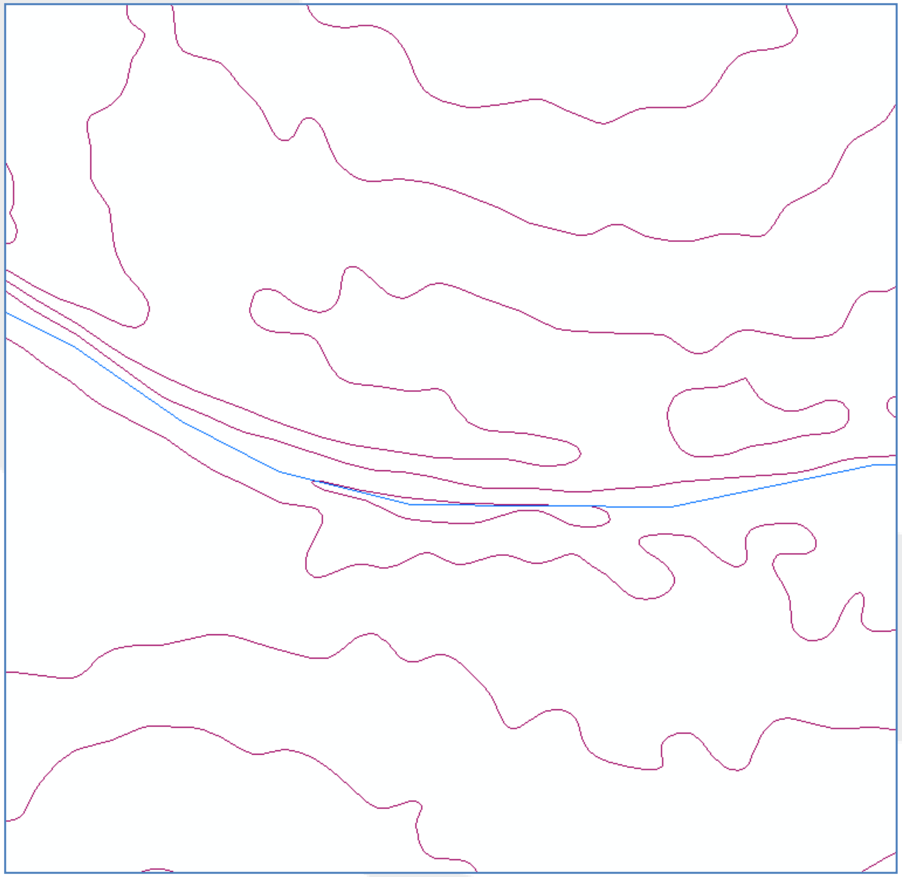
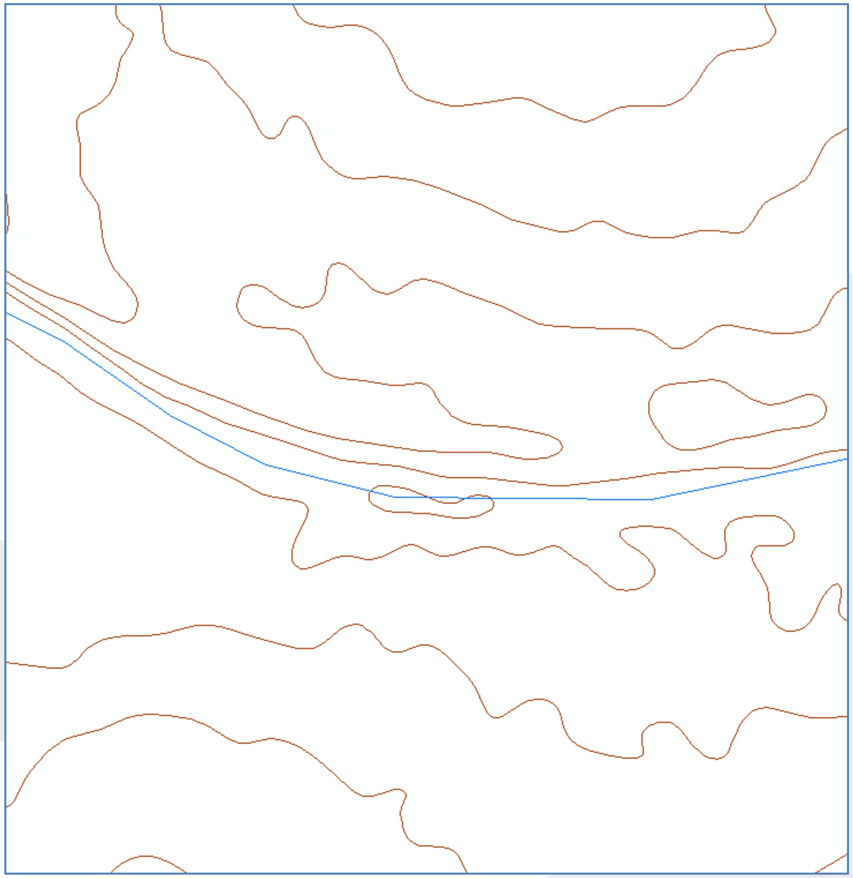
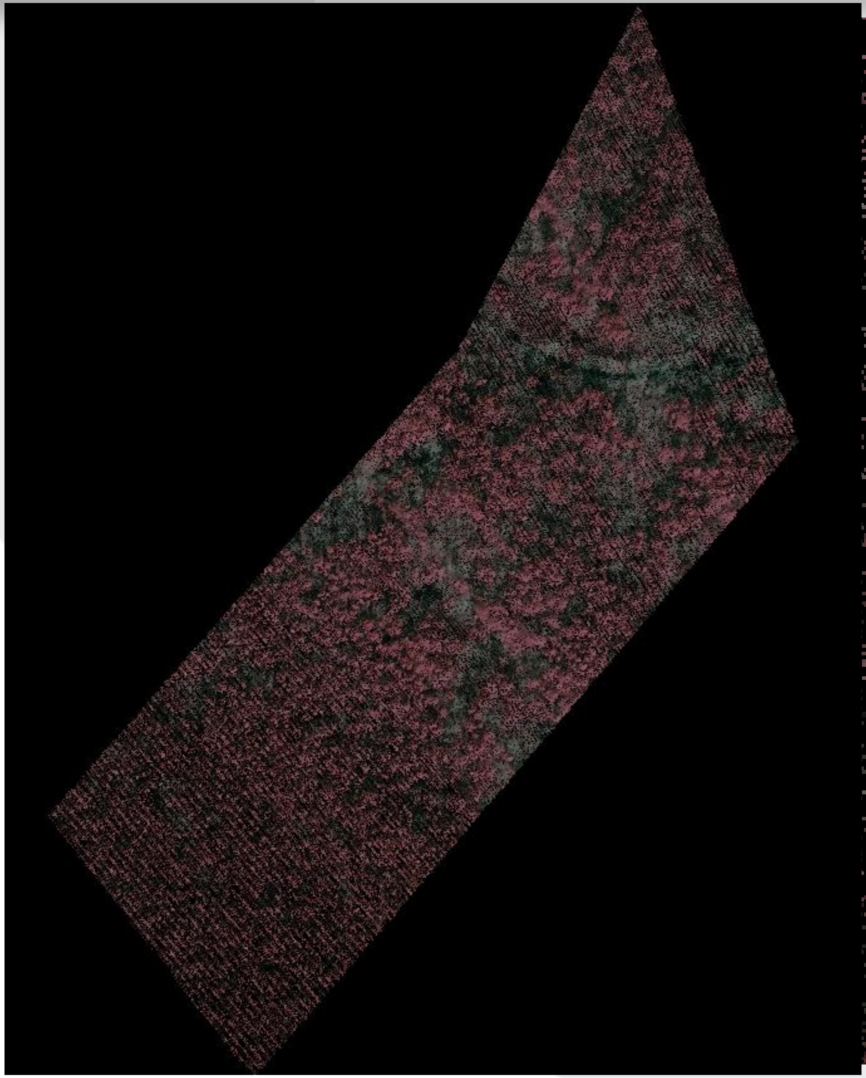


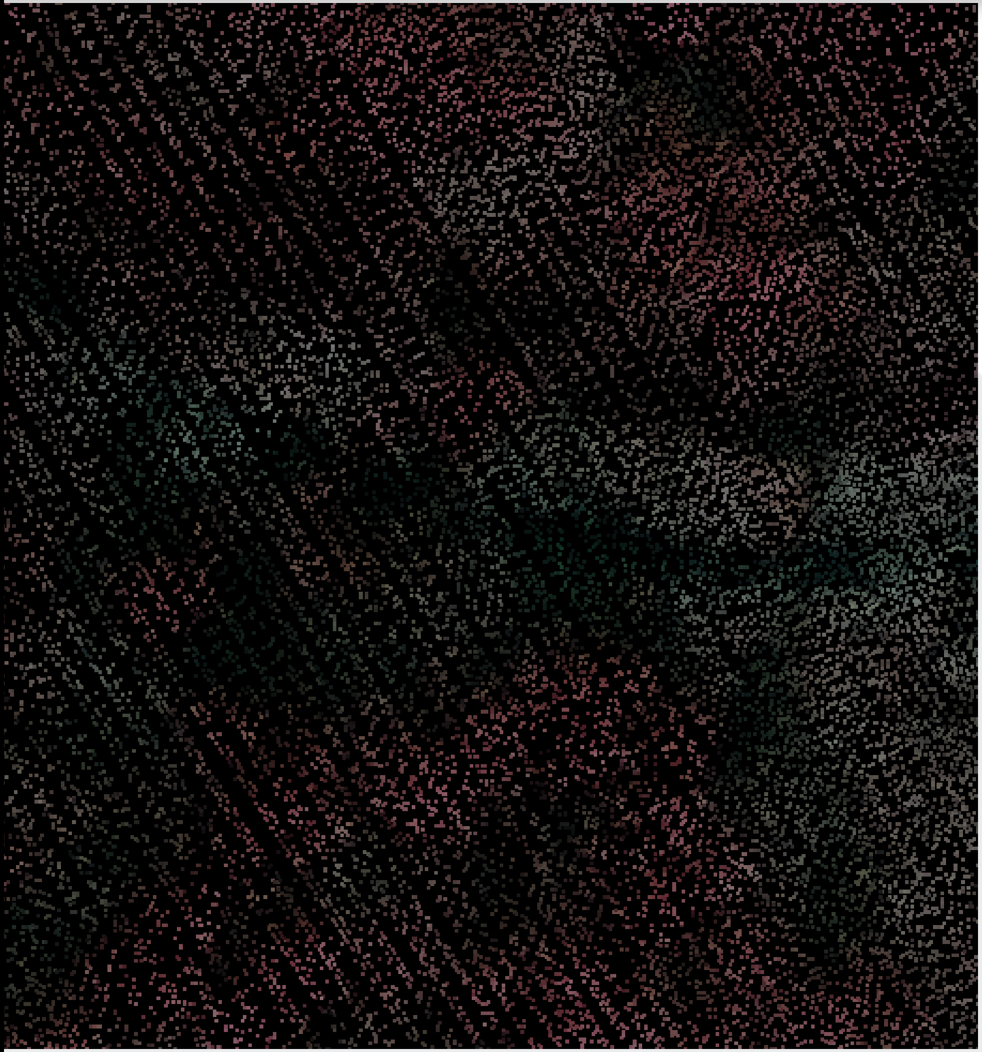


LiDAR Fusion

- Requires specialized LiDAR software
- Leverages existing VBMP multi-spectral ortho assets
- Each LiDAR point assumes discrete pixel content
  - Can be used to improve analysis
  - Aids studies for things like biomass determinations

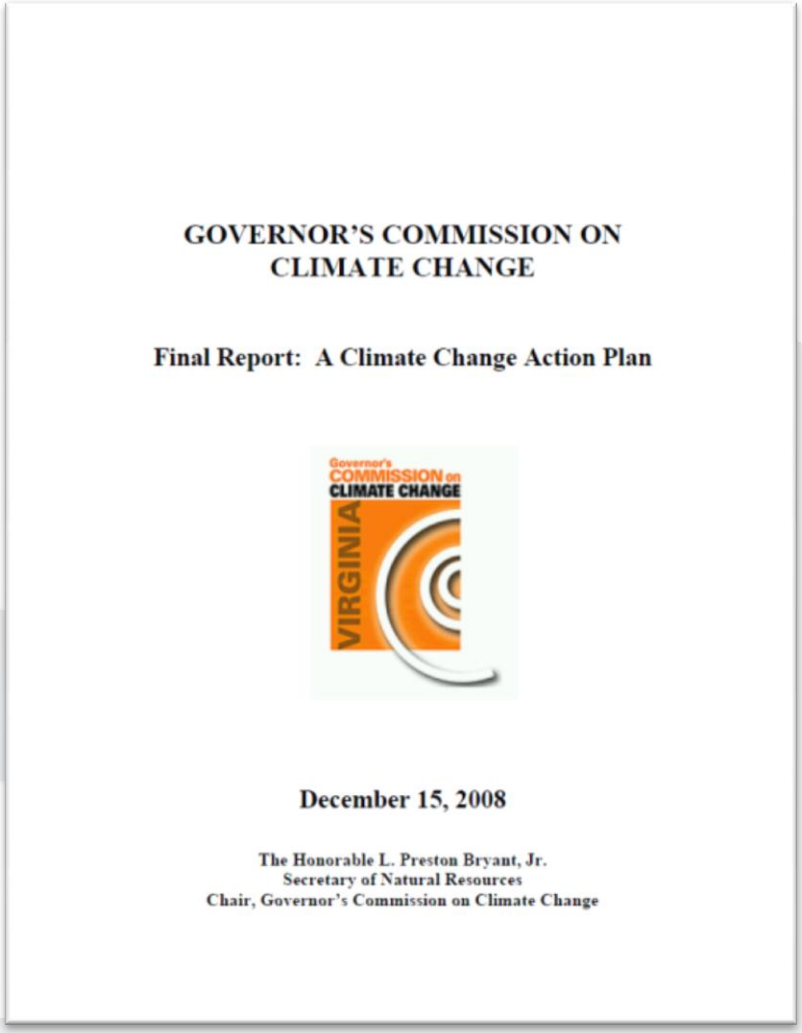
LiDAR Fusion





LiDAR Application to Coastal SLR

- Risks:
  - Norfolk Naval Facilities
  - Land loss
  - Transportation Infrastructure
  - Tourism
  - Water Quality, Ecology
- Actions
  - FP management
  - Vulnerability to rep. losses
  - SLR Adaptation Strategy
- Identified Need:
  - LiDAR


GOVERNOR'S COMMISSION ON
CLIMATE CHANGE

Final Report: A Climate Change Action Plan

Governor's COMMISSION on CLIMATE CHANGE VIRGINIA

December 15, 2008

The Honorable L. Preston Bryant, Jr.
Secretary of Natural Resources
Chair, Governor's Commission on Climate Change

Accuracy in an Uncertain World

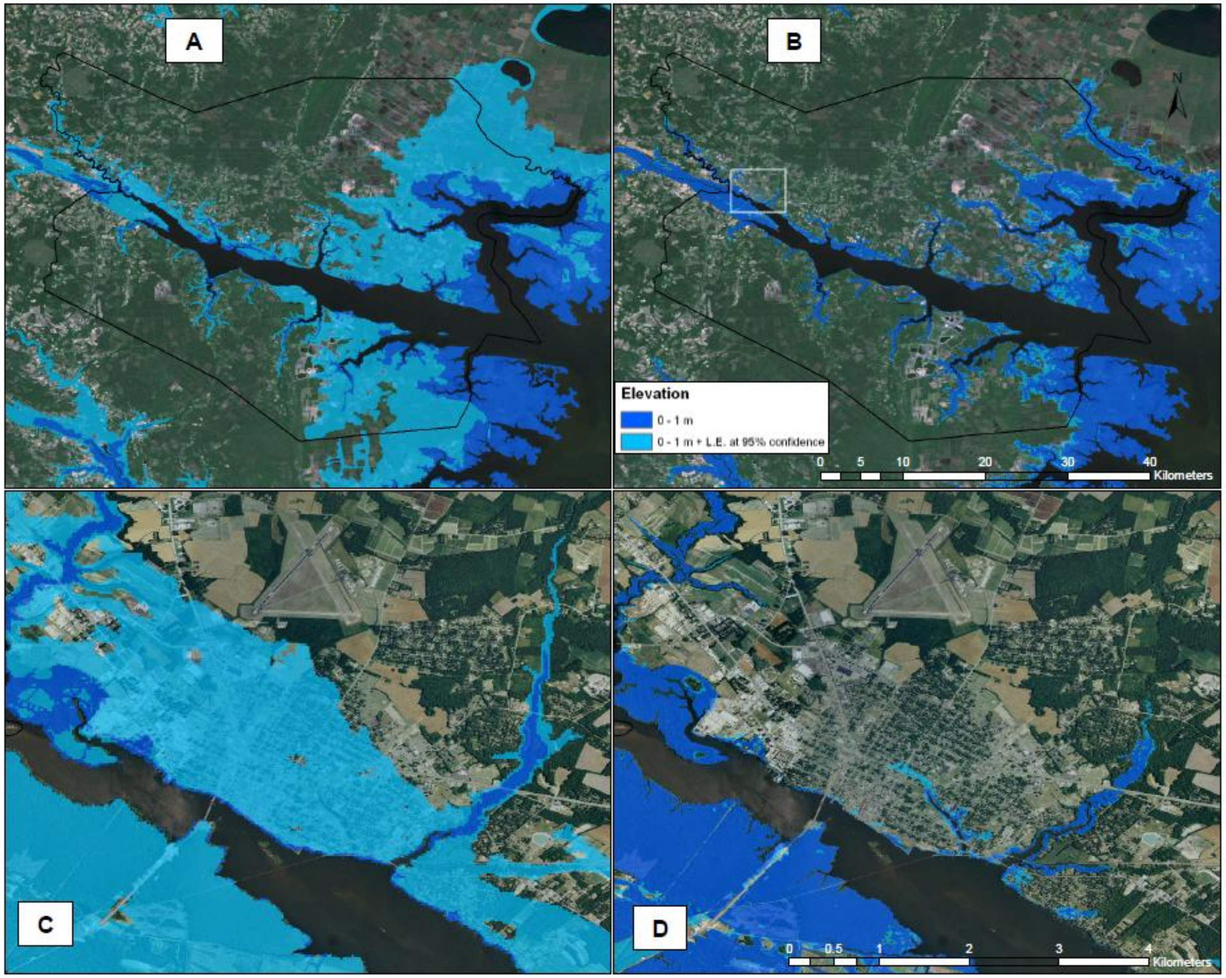


Figure 4. Maps of lands vulnerable to a 1-meter sea-level rise. (A) and (B) cover Beaufort County, North Carolina. (C) and (D) are detailed images of the city of Washington (area within the white box on B). (A) and (C) are derived from 1-arc-second NED (30-meter DEM source). (B) and (D) are derived from 1/9-arc-second NED (lidar source).

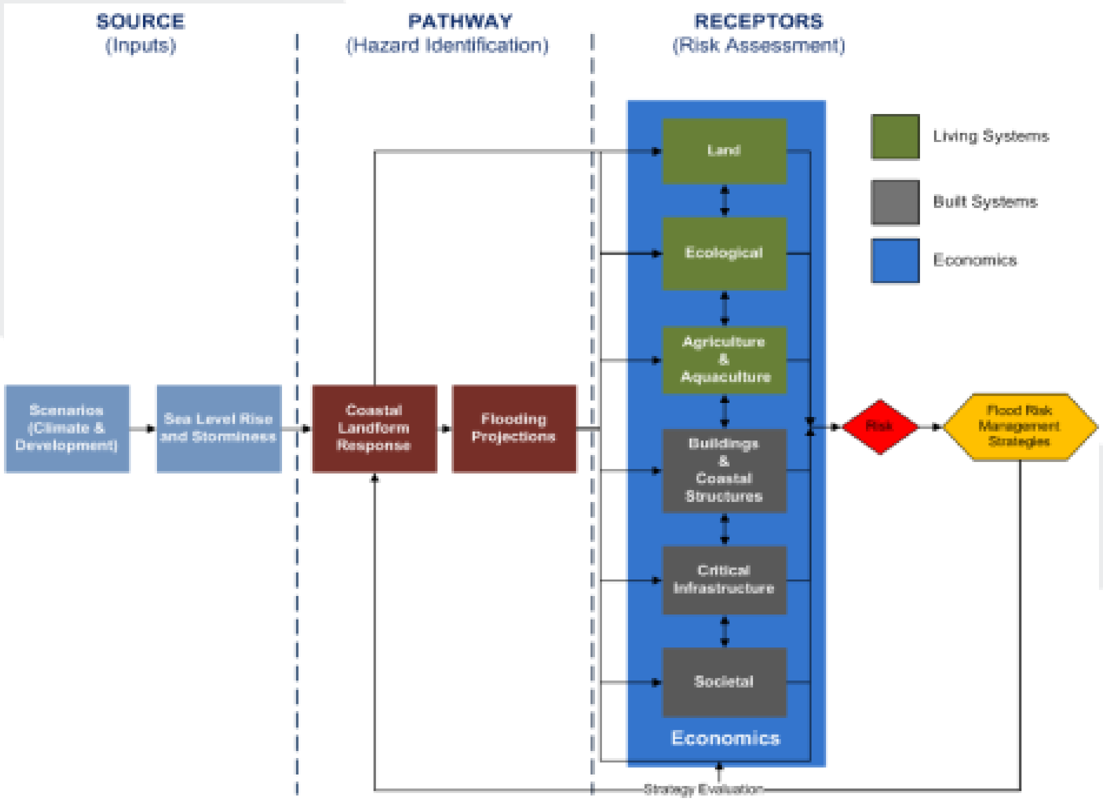
Assessing Exposure and Risk

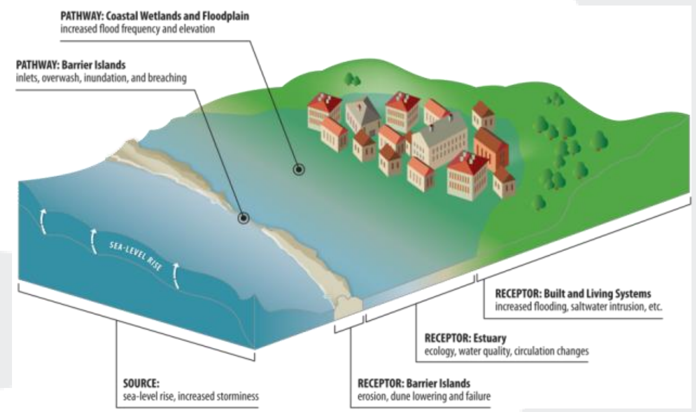
- Accuracy becomes > SLR Scenarios
  - Confidence in near-term projections
- Moving past inundation mapping
  - Enables property level assessment
  - Improved vulnerability estimates

Parcel level:
Prop. Value
$1^{st}/2^{nd}$ Floor Elevation
HAG
LAG
Depth of inundation by scenario
=
Accurate damage est./scenario

Leveragable Analytical Framework

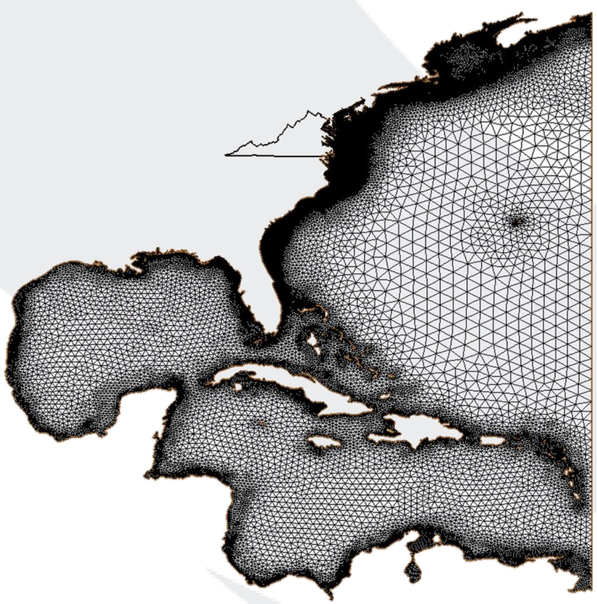
- North Carolina Sea-Level Rise Risk Management Study

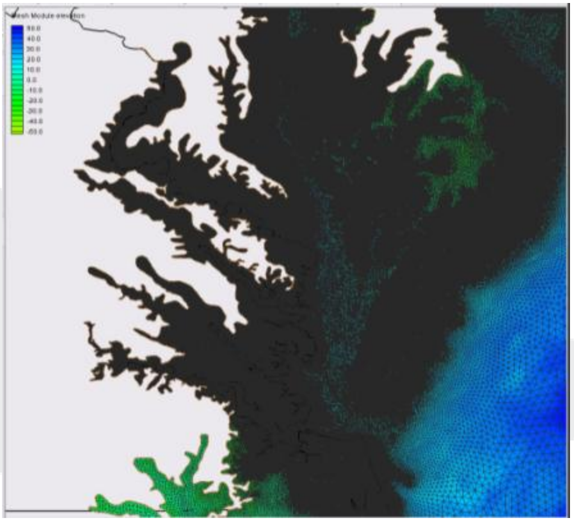


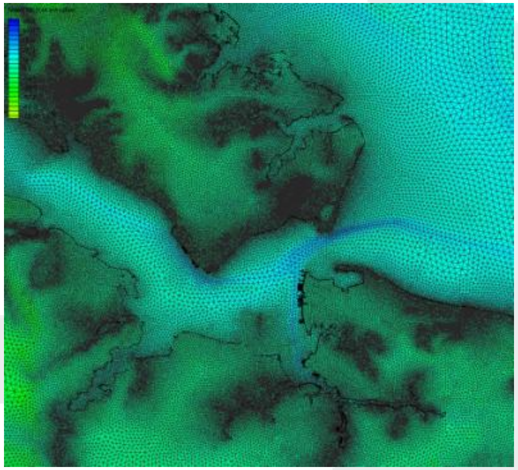


Leveragable Analytical Framework

- FEMA RIII FIS Study







Questions