LIDAR-DERIVED DIGITAL ELEVATION MAPS OF MARYLAND, DELAWARE AND NEW JERSEY USED TO IDENTIFY CAROLINA BAY LANDFORMS

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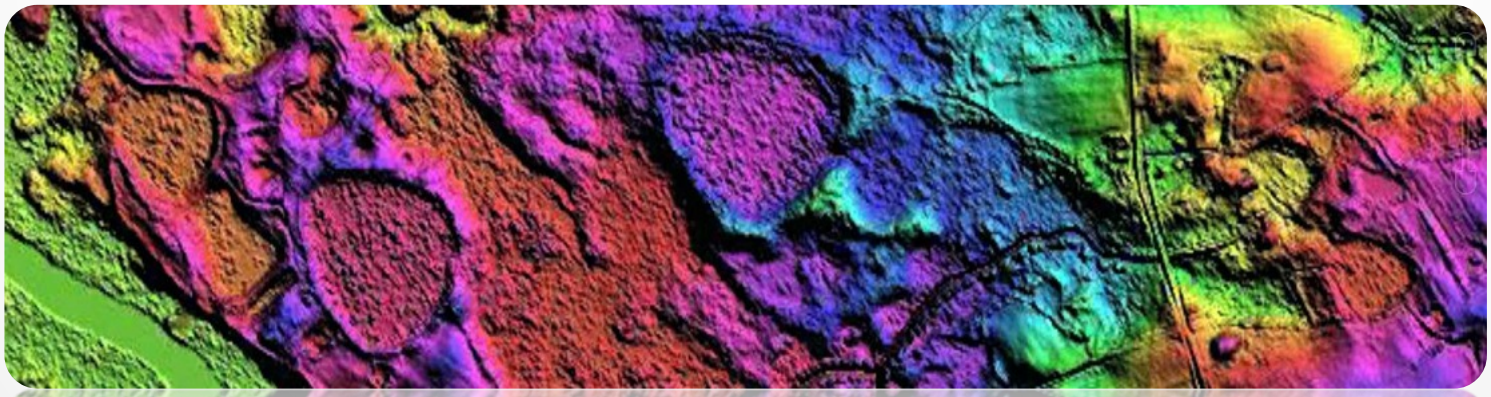
Hartford, CT USA

Michael E. Davias



Visualizing the Enigmatic Coastal Ponds

Abstract

LIDAR-DERIVED DIGITAL ELEVATION MAPS OF MARYLAND, DELAWARE AND NEW JERSEY USED TO IDENTIFY CAROLINA BAY LANDFORMS

DAVIAS, Michael, Stamford, CT 06907, michael@cintos.org

The existence of Carolina bay landforms in the Carolinas has been researched for decades, but their presence on the landscape across Maryland, Delaware, and New Jersey has been slowed by their smaller sizes and more circular presentation. Recent advances in digital elevation mapping using LiDAR (Light Detection And Ranging) technology offer a new perspective on the location and shapes of these shallow basins and their enigmatic circumferal rims. To support a geospatial survey of Carolina bay landforms within the northeastern Atlantic coastal plain, we generated hsv-shaded DEMs (Digital Elevation Maps) as KML-JPEG tile sets for visualization. A majority of these DEMs were generated with LiDAR data, while a small subset used USGA 1/3 arc second data. A gentle progression of planform shape is seen on these maps as the viewer moves from south to north. We demonstrate that the planform of most bays identified suggests a very robust correlation to one of two archetypical shapes. These two shapes were engineered into Google Earth overlay elements, which were placed over candidate basins; by manually adjusting the length, width and rotation from North, the shape of the circumferal bay rim can often be satisfactorily captured. The generic Carolina bay characteristics set includes a pervasive common orientation among neighboring bays. However, as we traverse the coastal plain towards the north, the bays' more-rounded presentation leaves this as a subjective assignment. Using LiDAR-derived imagery, we present our argument for the alignment suggestion that we imbedded in our archetype planform overlays. We demonstrate that when these archetype planforms are overlaid on the basins, their orientation varies systematically by latitude, in a gentle progression similar to that seen further south. The high fidelity LiDAR elevation maps also demonstrates the pervasiveness of the bay planforms against a backdrop of wind-driven sand sheets and parabolic dune formations across this landscape. All LiDAR maps referenced have been made available on the Internet to support independent research. Likewise, the geospatial database of metrics for 2,500 bays we examined in this region is available from an on-line Google Fusion Table:

http://www.google.com/fusiontables/DataSource?snapid=S226571PxmB

Coastal Plain Ponds in LiDAR

- Locally know as "Delaware Basins" or "Spungs"
- Closed Circumpheral Rims differentiate from dunes
- Described as Periglacial Frost-thaw Basins
- Blow-outs refined by prevailing katabatic winds
- Kettle Holes of shoaled icebergs
- Dated as late Pleistocene (Wisconsinan Glaciation)
- Shallow Depressions In the Carolinas
  - Present robust oval shapes
  - Oriented to the NW
- Shallow Depressions On Delmarva Peninsula
  - Shapes historically considered to become chaotic
  - Orientation historically said to shift "112° clockwise" or Bi-Modal

Rasmussen, 1953

- Shot Patterns & Groupings
- Family Characteristics
  - Planform Shape
  - Orientations
  - Sizes
- Areas of No Basins

"Their very randomness of grouping and scatter demands an explanation. As a statistical phenomenon, they deserve to be studied statistically."

W.C. Rasmussen, 1953, *Periglacial Frost-Thaw Basins in New Jersey: A Discussion*, *The Journal of Geology*, Vol. 61, No. 5

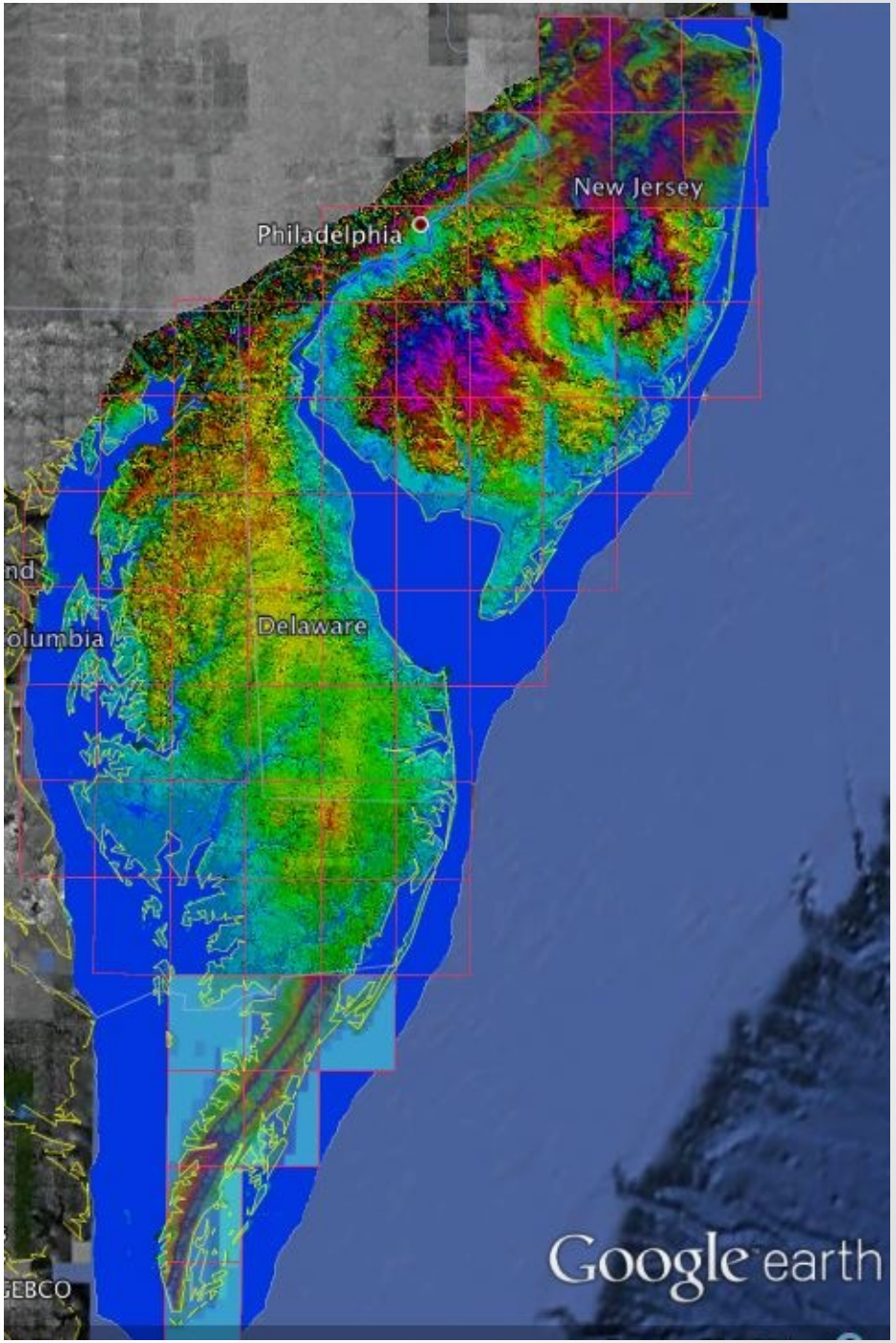
Carolina Bay Survey

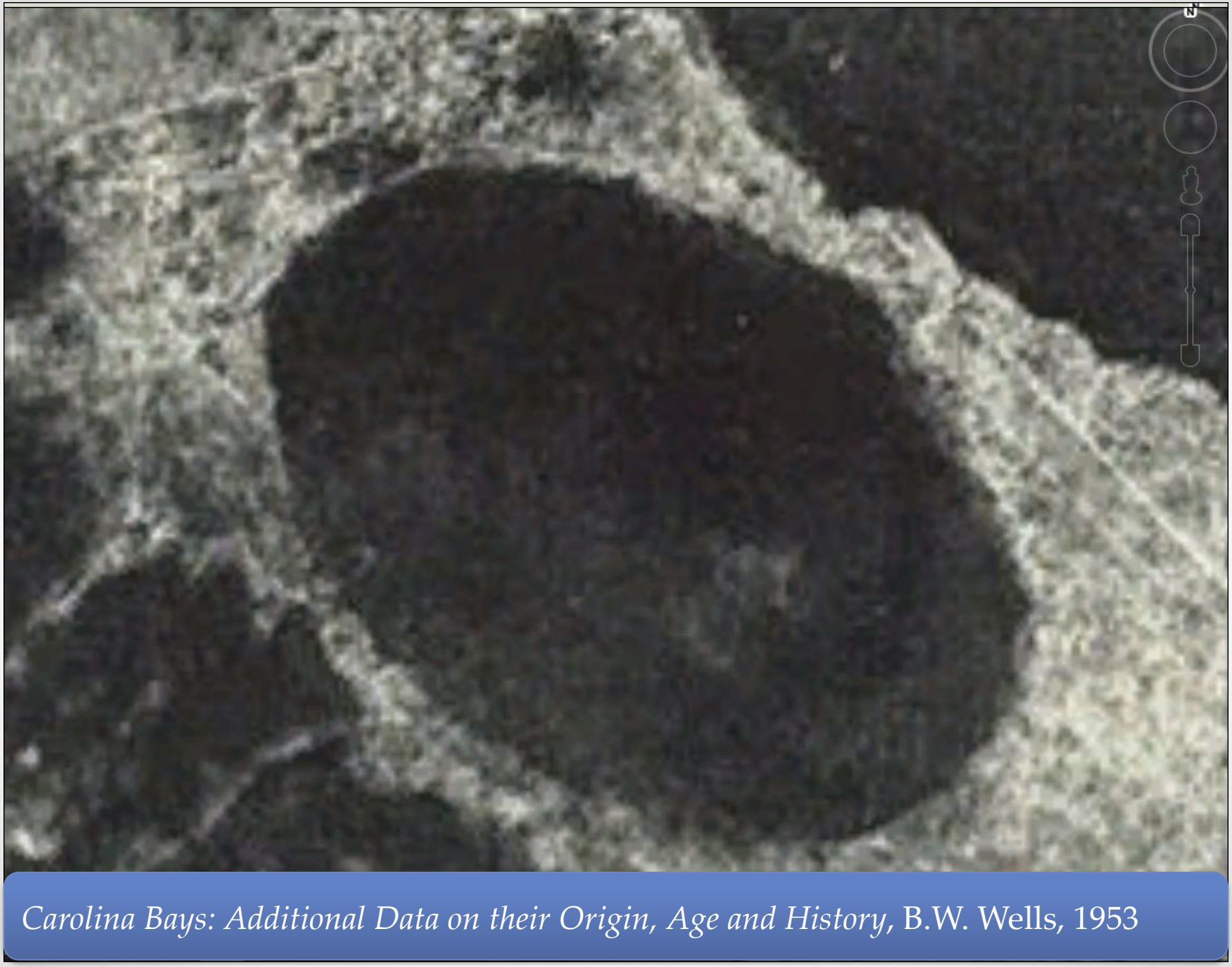
- Undertaking a geospatial survey of bays
  - Remote Sensing
- Alabama to New Jersey
  - Focus today on Delmarva Peninsula and Southern New Jersey
- Leverages LiDAR digital elevation maps
  - USGS, Virginia and NOAA data
  - Hue-Saturation-Value (HSV) imagery created in Global Mapper
  - 20x Elevation Exageration
  - Exported as KML image tile sets 1/4° x 1/4°
- Integrated with Google Earth for Visualization
  - Allows for rapid geocoding and planform measurements
  - Provides open distribution mechanism
  - **http://cintos.org/LiDAR**
- Documented on-line in public Fusion Tables
  - 30,000 individual bays documented
  - 3,700 in NJ & DelMarVa Peninsula
  - Provides web-browser spatial index to bay locations
  - Presents links for download into Google Earth
  - **http://cintos.org/bays**

LiDAR DEM Overlays for DelMarVa & Southern NJ

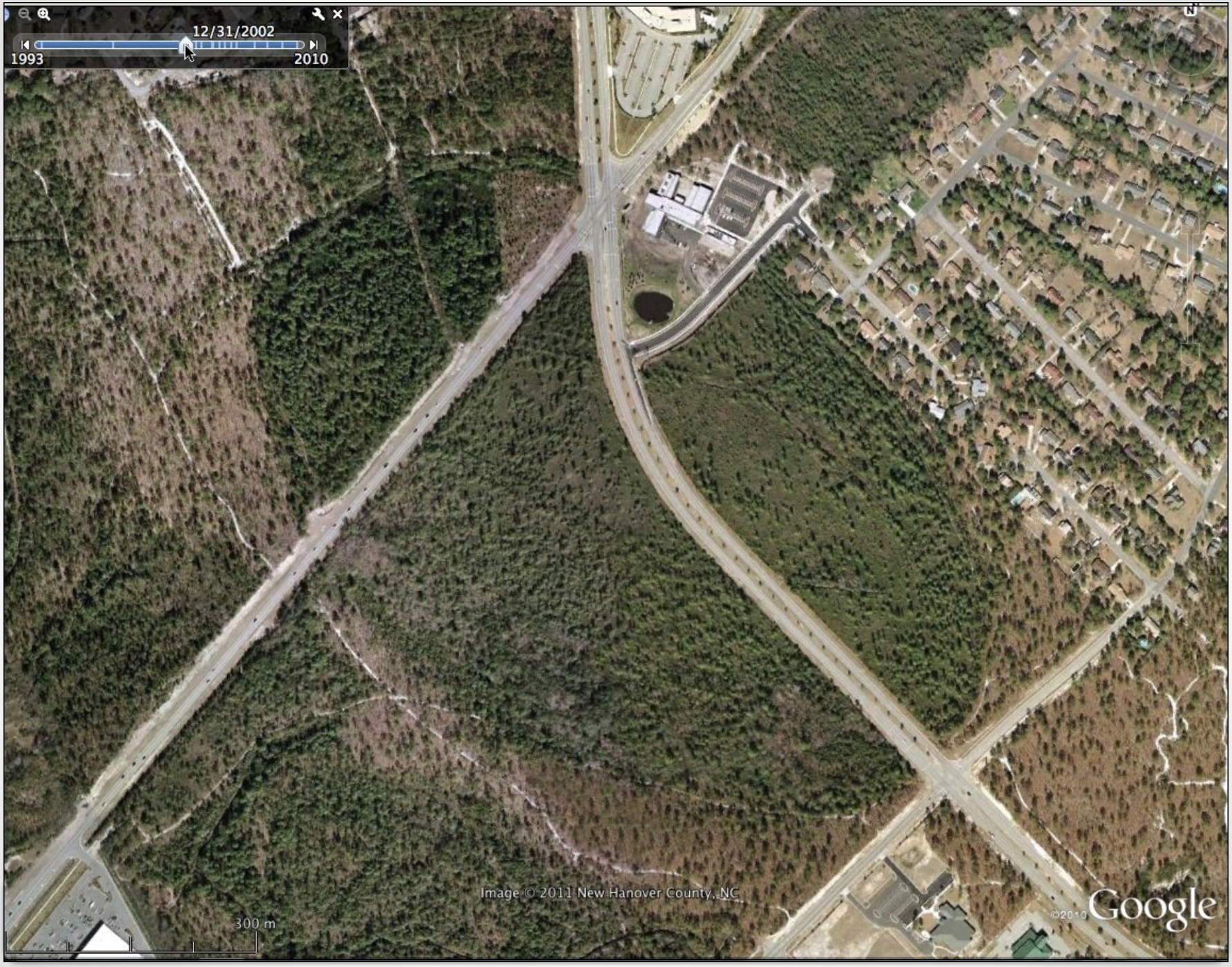
cintos.org/NE-LiDAR

- ✓hsv shaded tile sets
- ✓USGS and Virginia Data
- ✓Network references
- ✓Only 8 Kb size





Carolina Bays: Additional Data on their Origin, Age and History, B.W. Wells, 1953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1993
2010
Image © 2011 New Hanover County, NC
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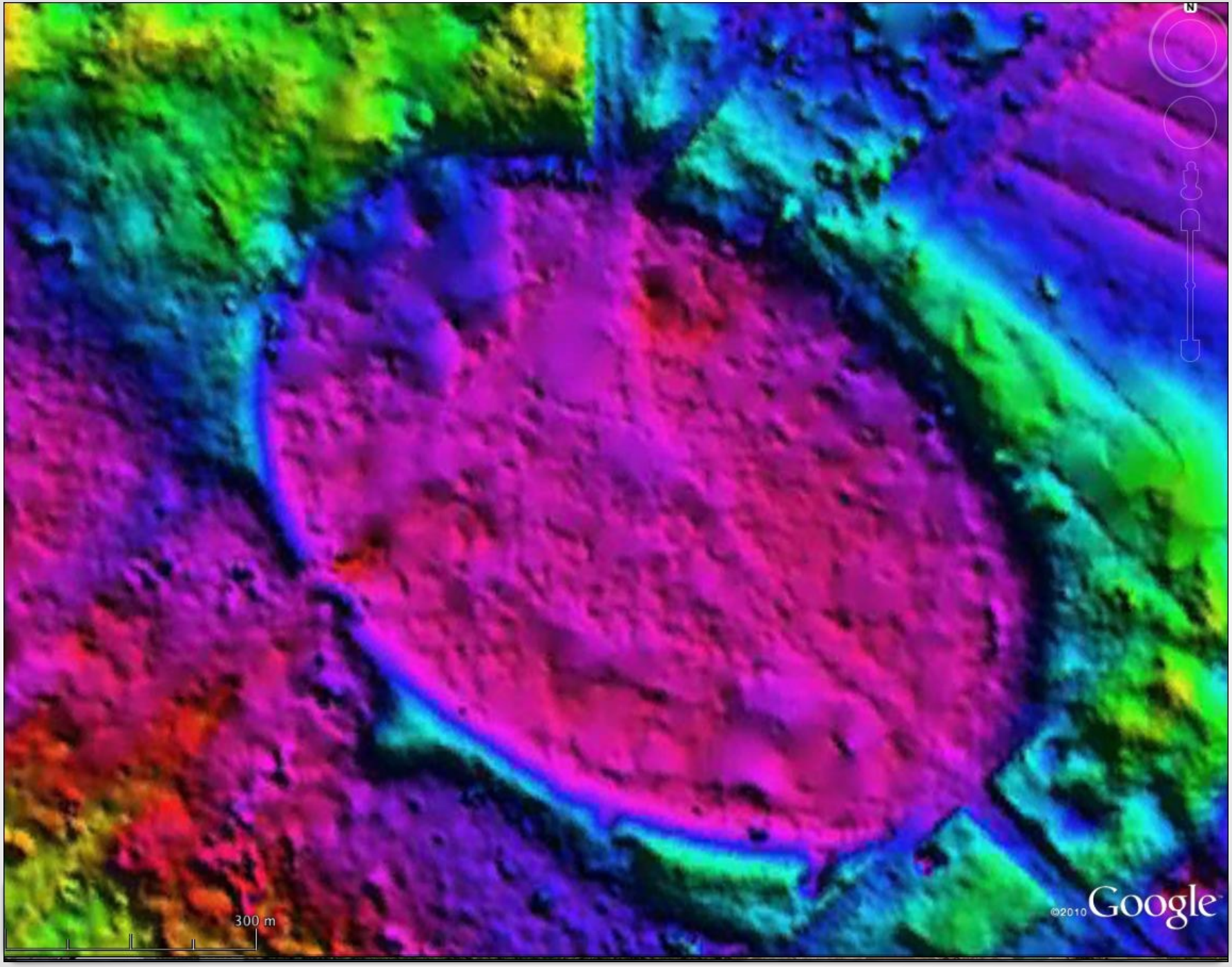
Google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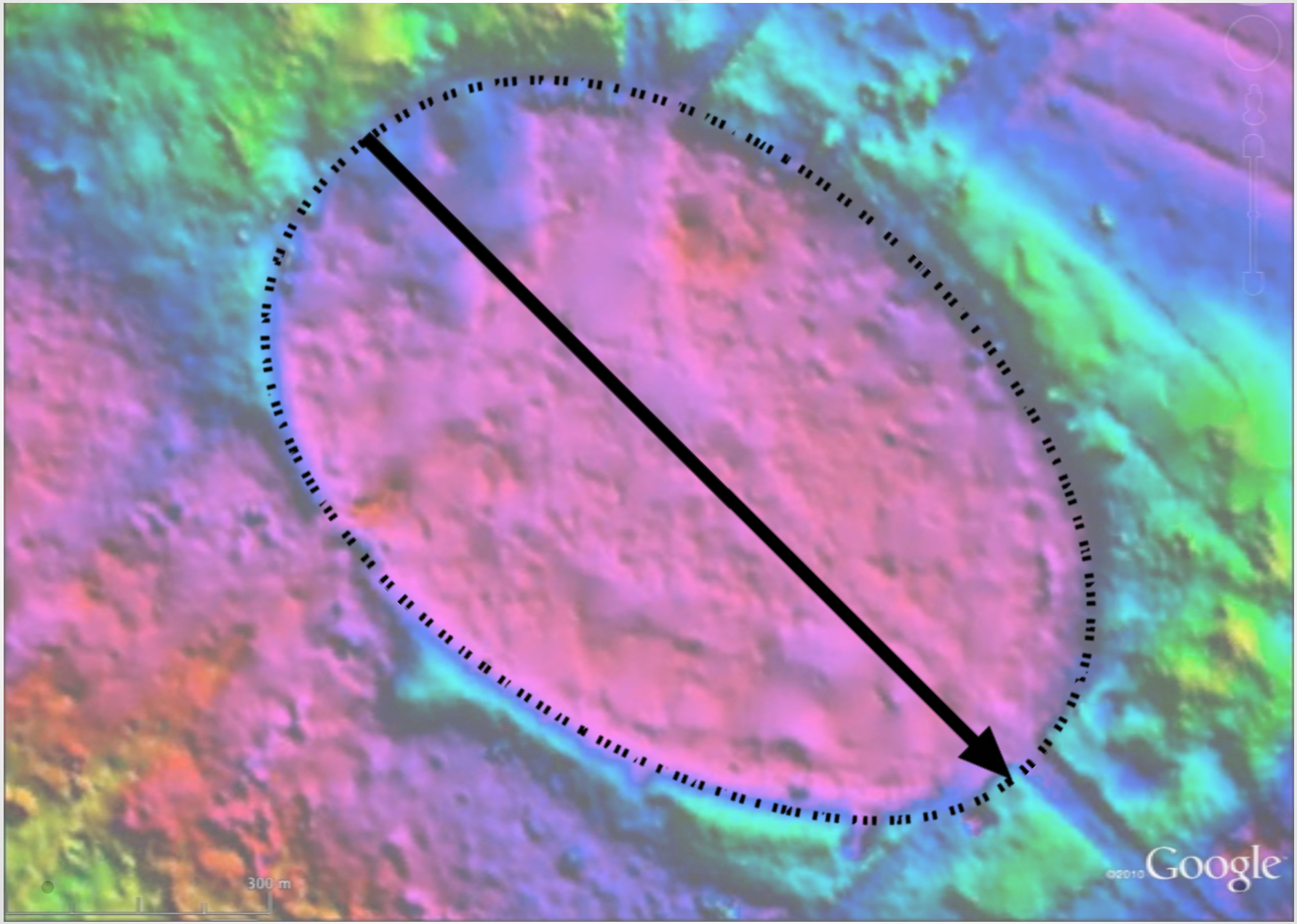
300 m
©2010 Google

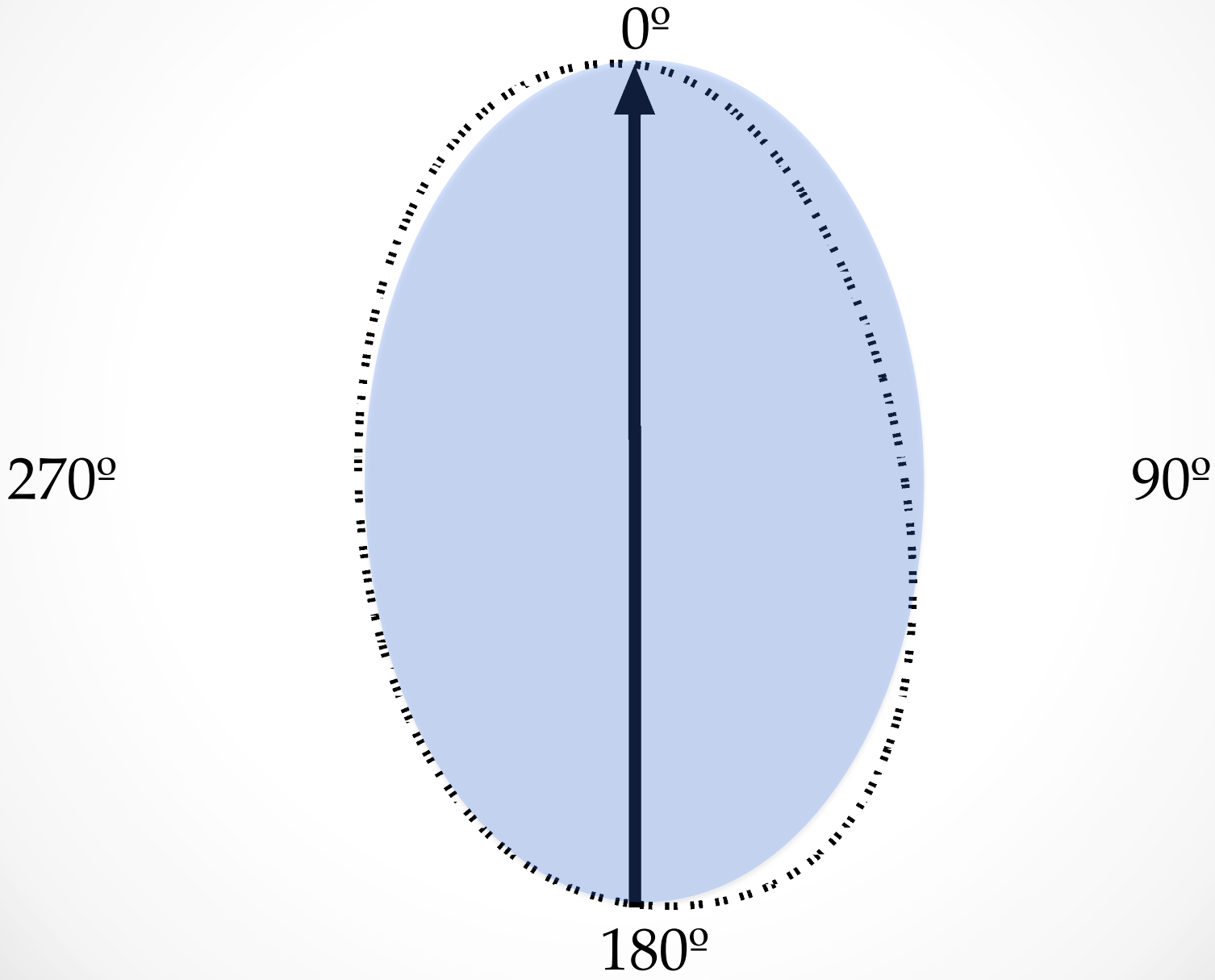
GroundOverlay Template : 2D Measurement

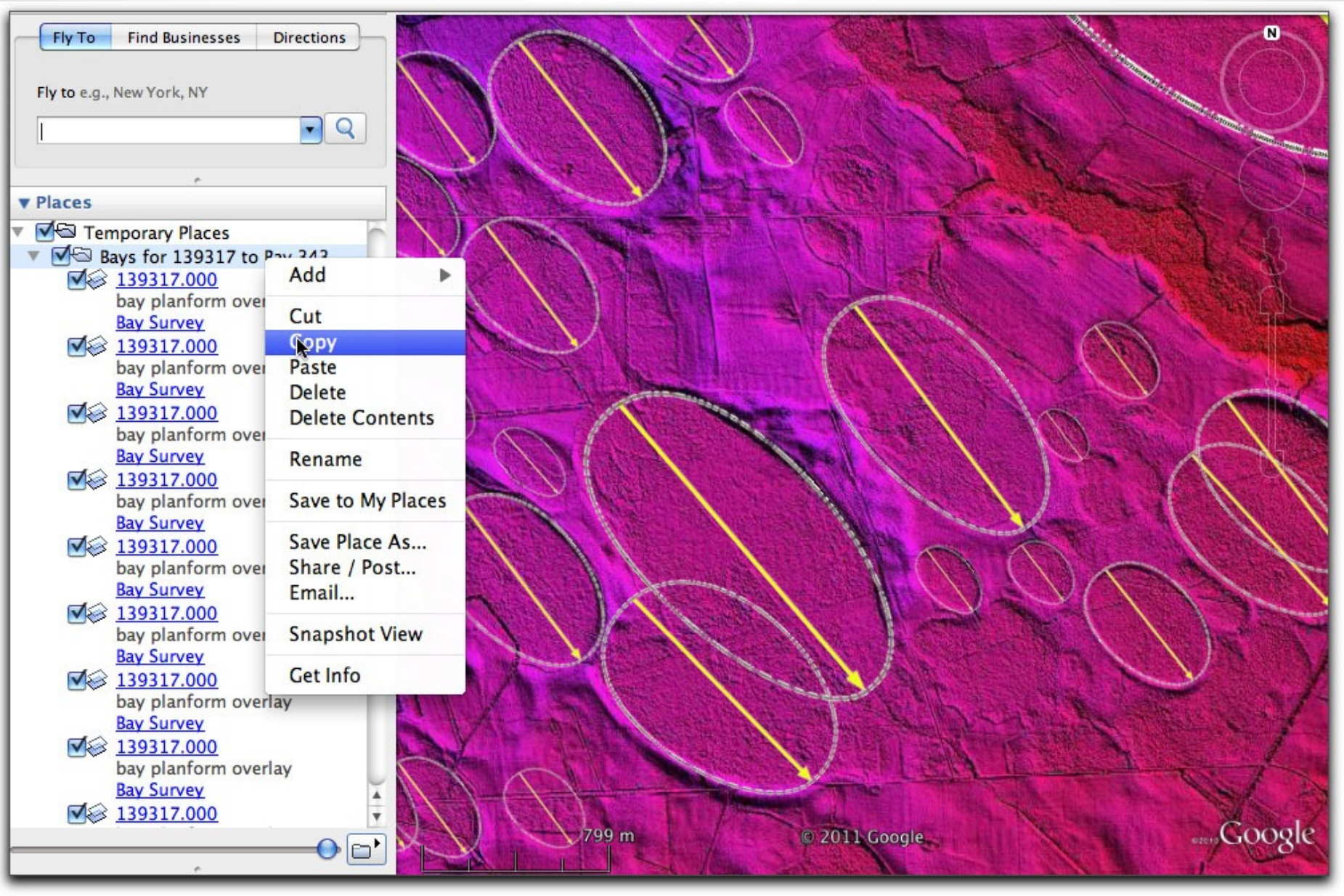
Gauge



GroundOverlay Template : 2D

Measurement Gauge




Fly To
Find Businesses
Directions
Fly to e.g., New York, NY
Places
Temporary Places
Bays for 139317 to Bay 343
139317.000
bay planform overlay
Bay Survey
Add
Cut
Copy
Paste
Delete
Delete Contents
Rename
Save to My Places
Save Place As...
Share / Post...
Email...
Snapshot View
Get Info
N
799 m
© 2011 Google
Google

Keyhole Markup Language Data in GroundOverlay

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         </LatLonBox>
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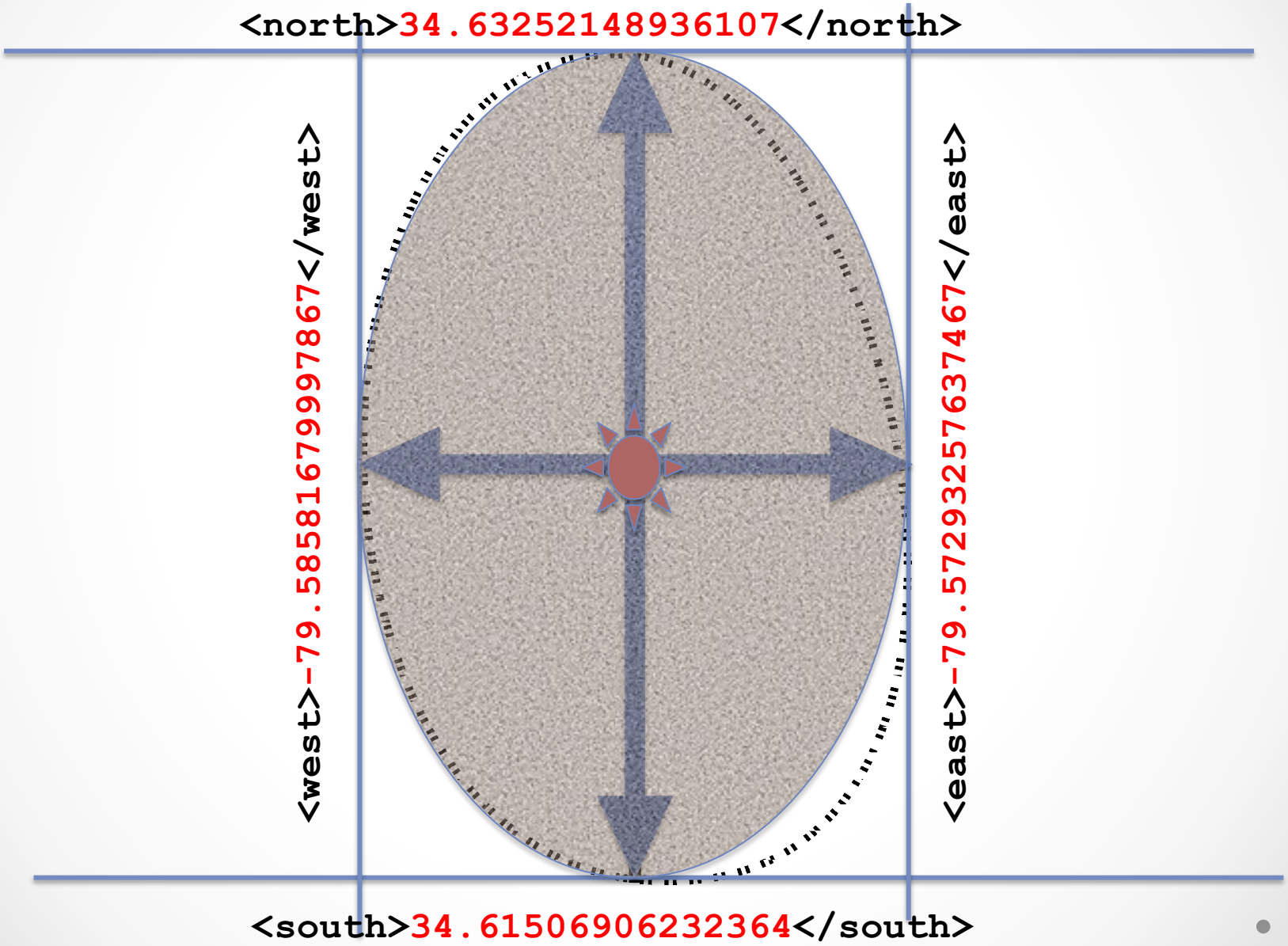
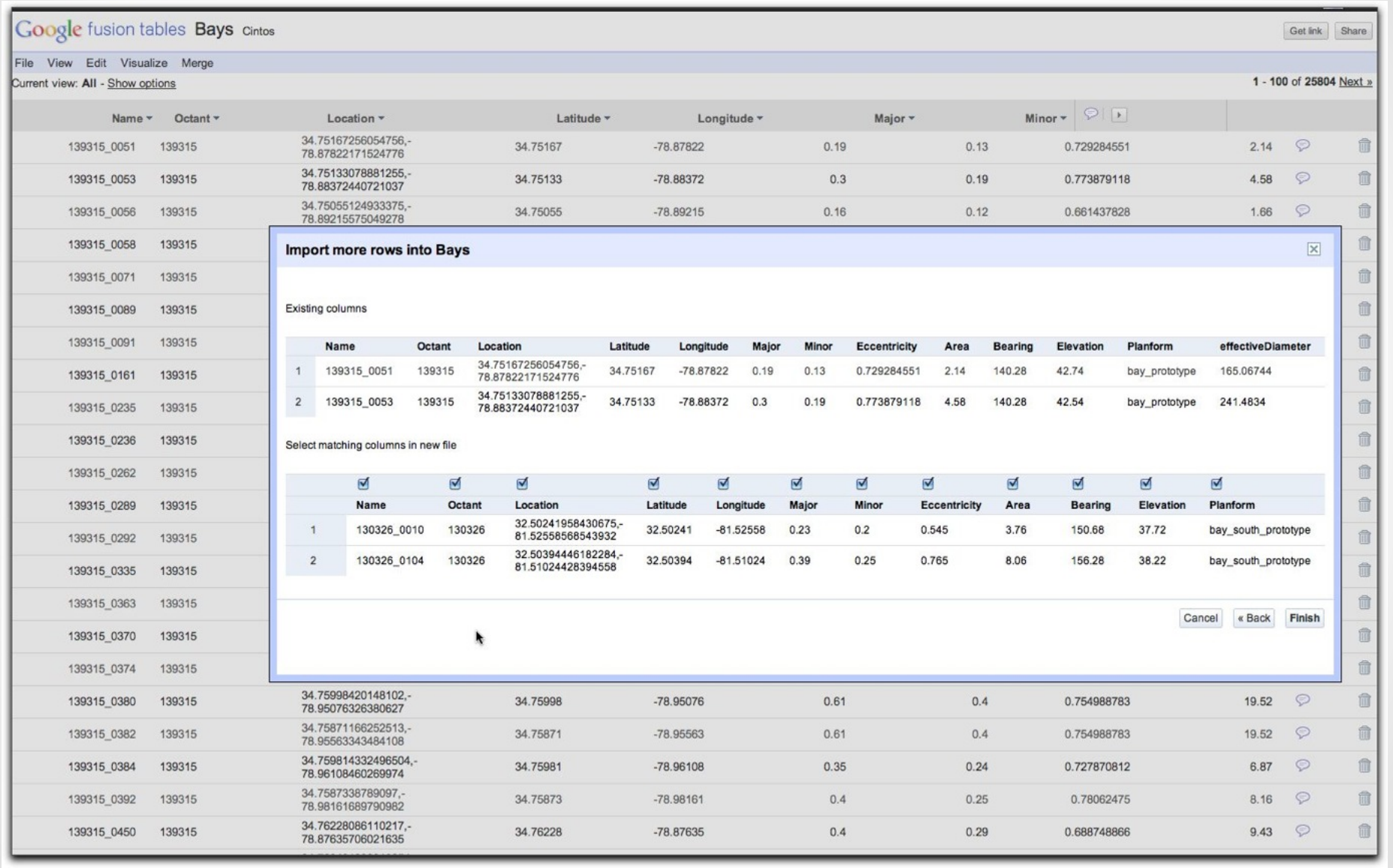
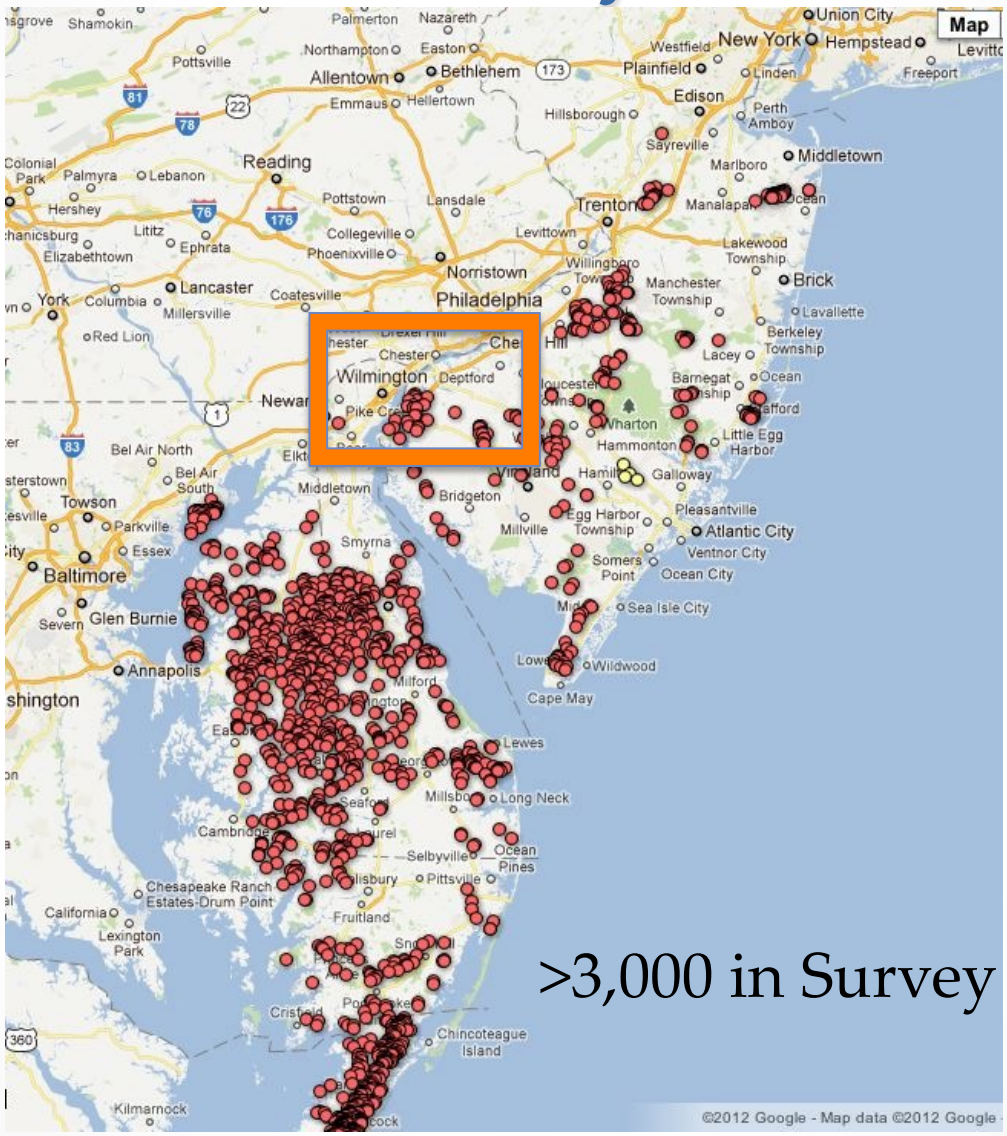
GroundOverlay LatLonBox Computations



Loading Fusion Table



Spatial Extent of Bays in Northeast



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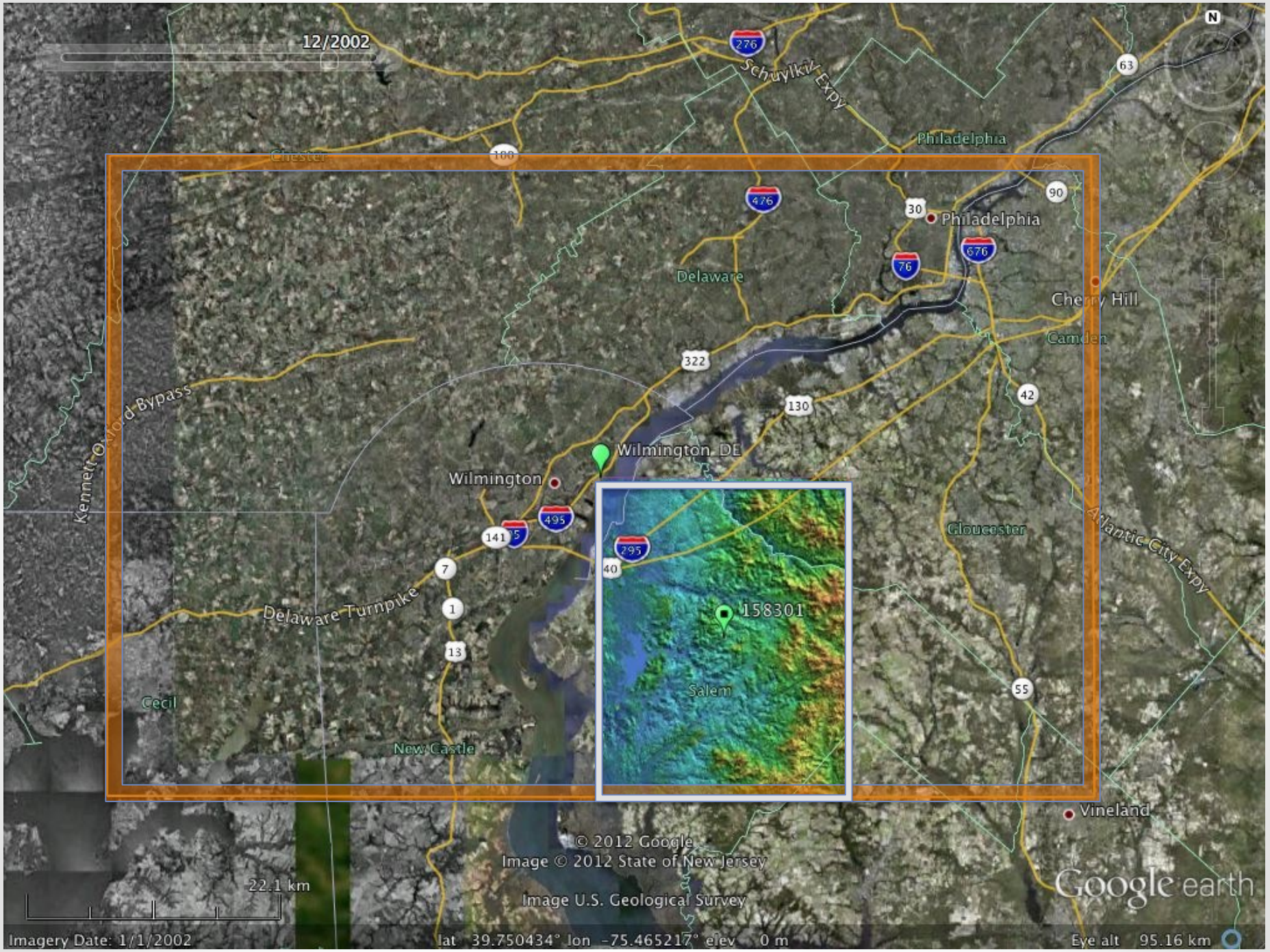
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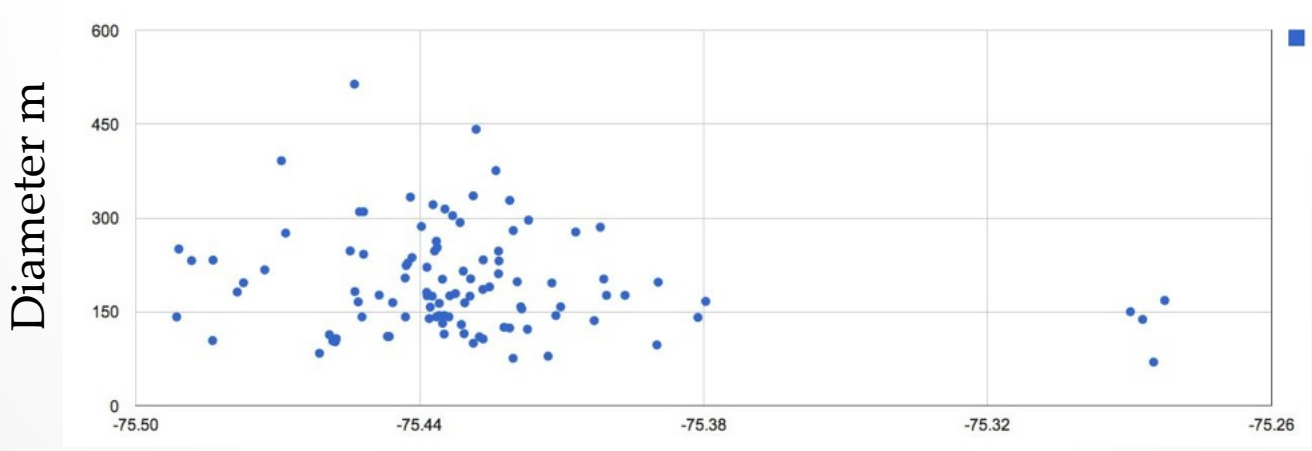
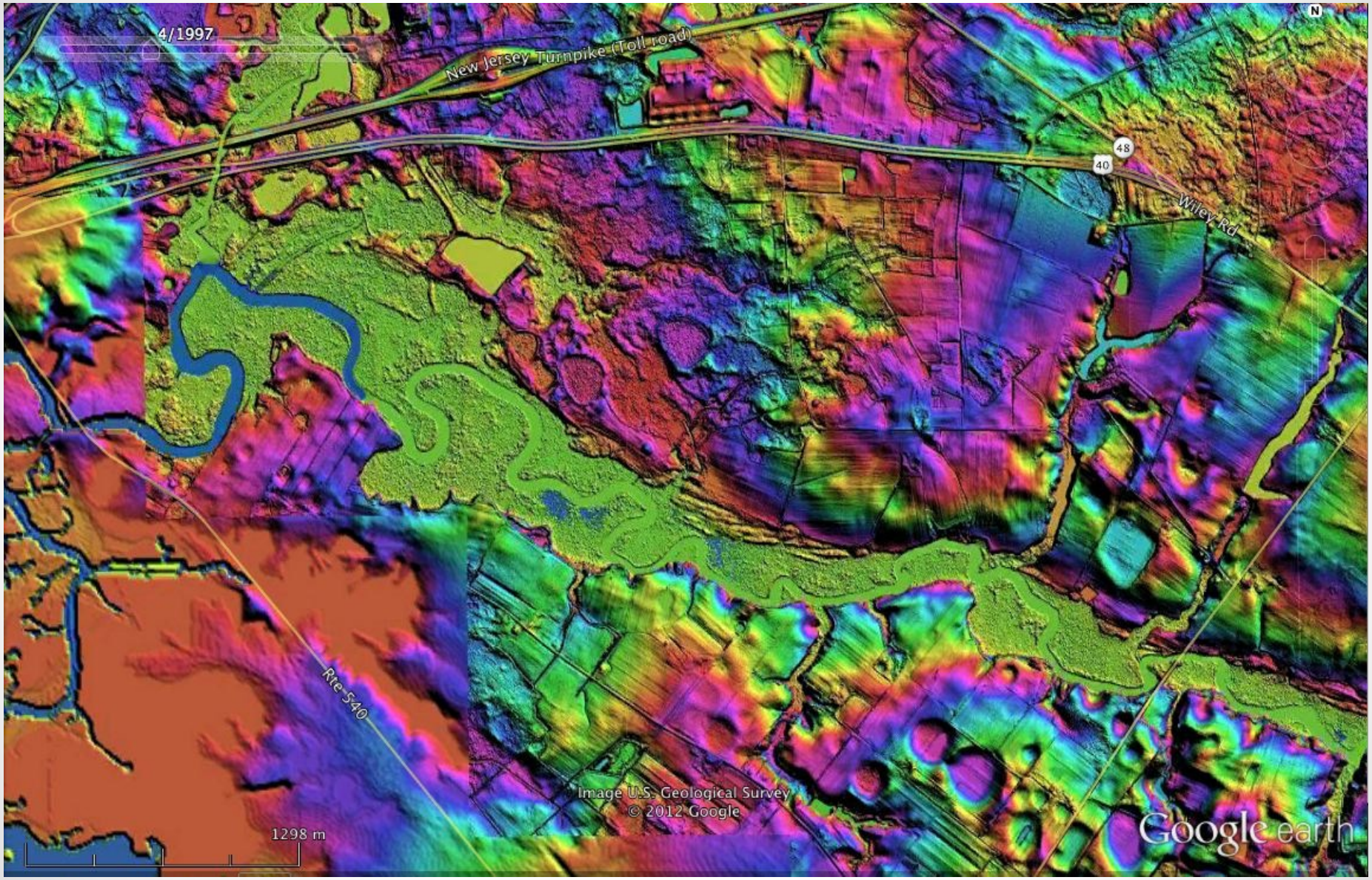
Philadelphia
Chester
Delaware
Cherry Hill
Camden
Wilmington, DE
Wilmington
Gloucester
Cecil
New Castle
Salem
158301
Vineland
Kennett Oxford Bypass
Delaware Turnpike
Atlantic City Expy
Schuylkill Expy
© 2012 Google
Image © 2012 State of New Jersey
Image U.S. Geological Survey
22.1 km
Google earth
Imagery Date: 1/1/2002
lat 39.750434° lon -75.465217° elev 0 m
Eye alt 95.16 km

Octant 158301

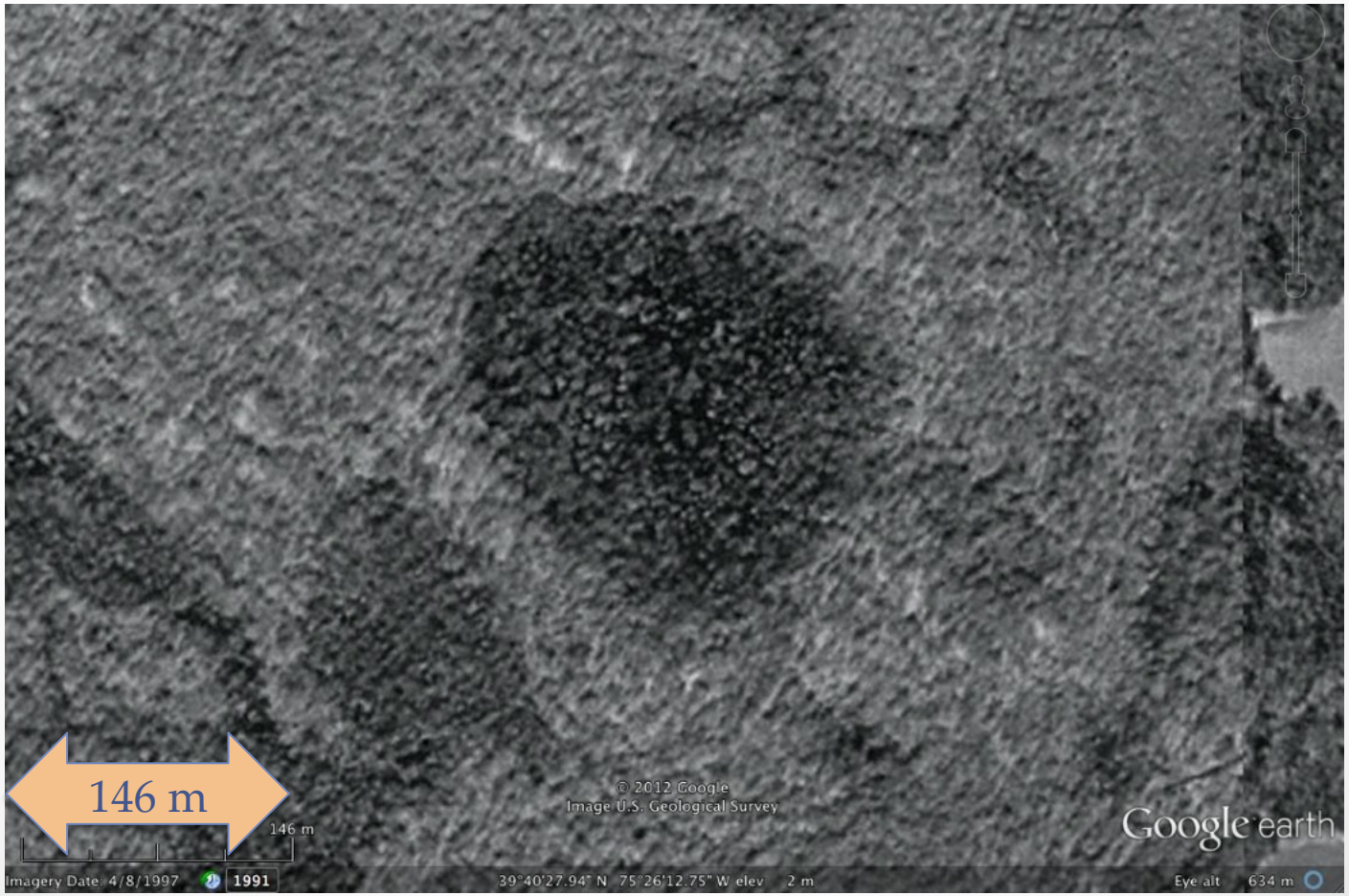
- Wilmington, DE 100k Quad
- East of Delaware River and south of Wilmington
- "bay bell" Planform
- 103 bays identified/measured
- Mean Bearing 118°
- Std dev 6.7°




4/1997
New Jersey Turnpike (Toll road)
48
40
Wiley Rd
Rte 540
1298 m
Image U.S. Geological Survey
© 2012 Google
Google earth

Local Planform

- Shape differs from the classic oval - Triangular
- Closed circumpheral rim
- Shape seen MD to NJ



Local Planform

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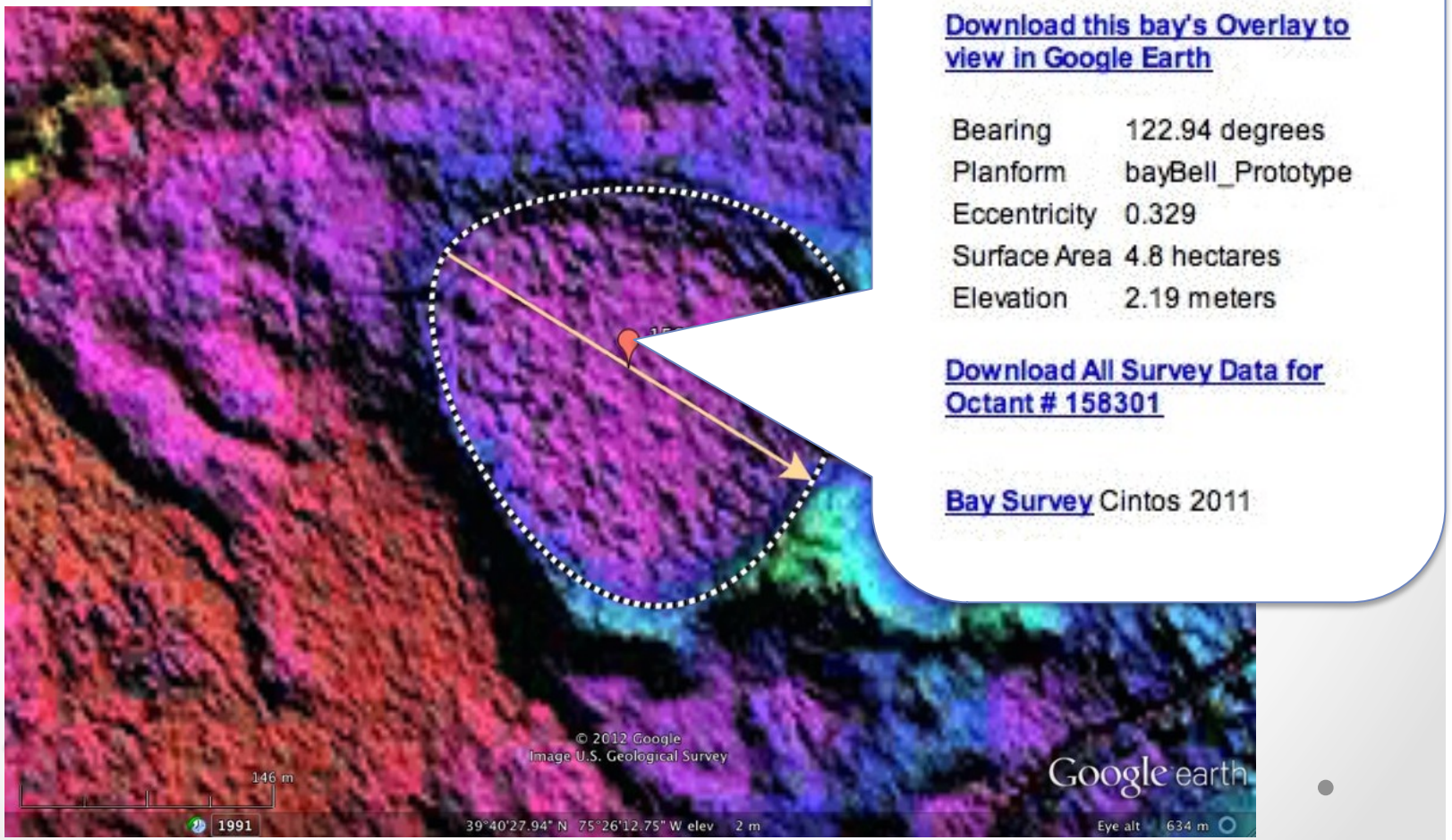
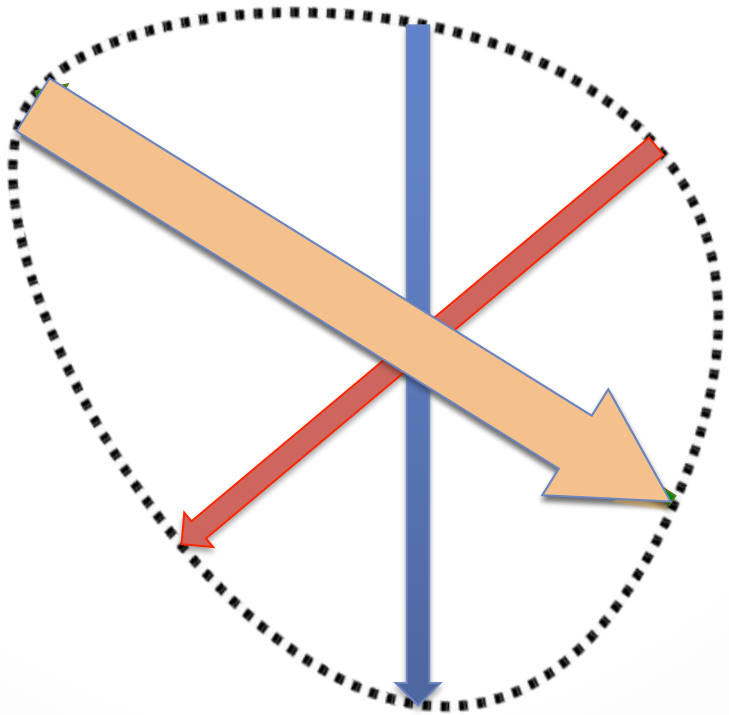
- Closed circumpheral rim
- Shape seen MD to NJ



Look at a "bay" in NJ & DelMarVa

- Shape differs from the classic oval - Triangular
- Closed circumpheral rim
- Nick-Named "Bay-Bell"
- Robust adherence to shape seen MD to NJ
- Orientation in Question



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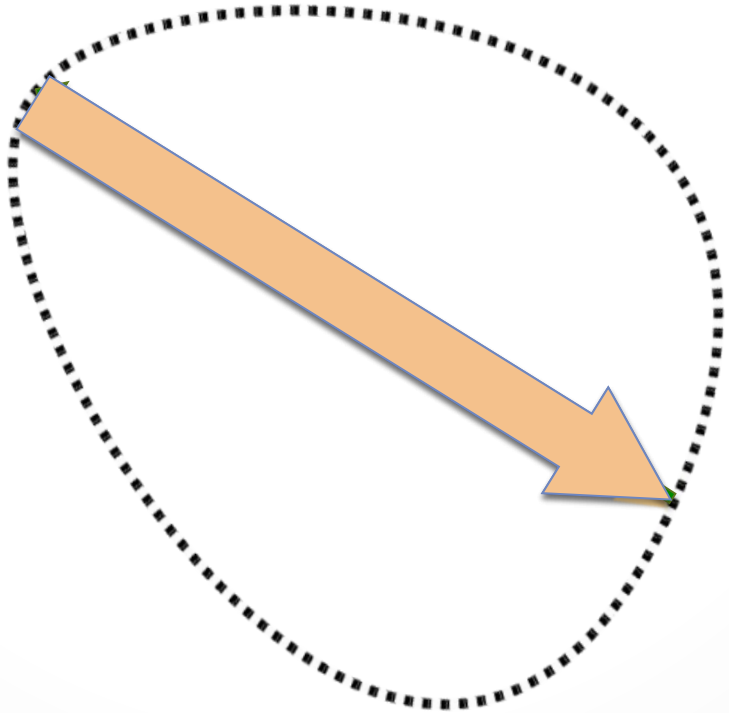
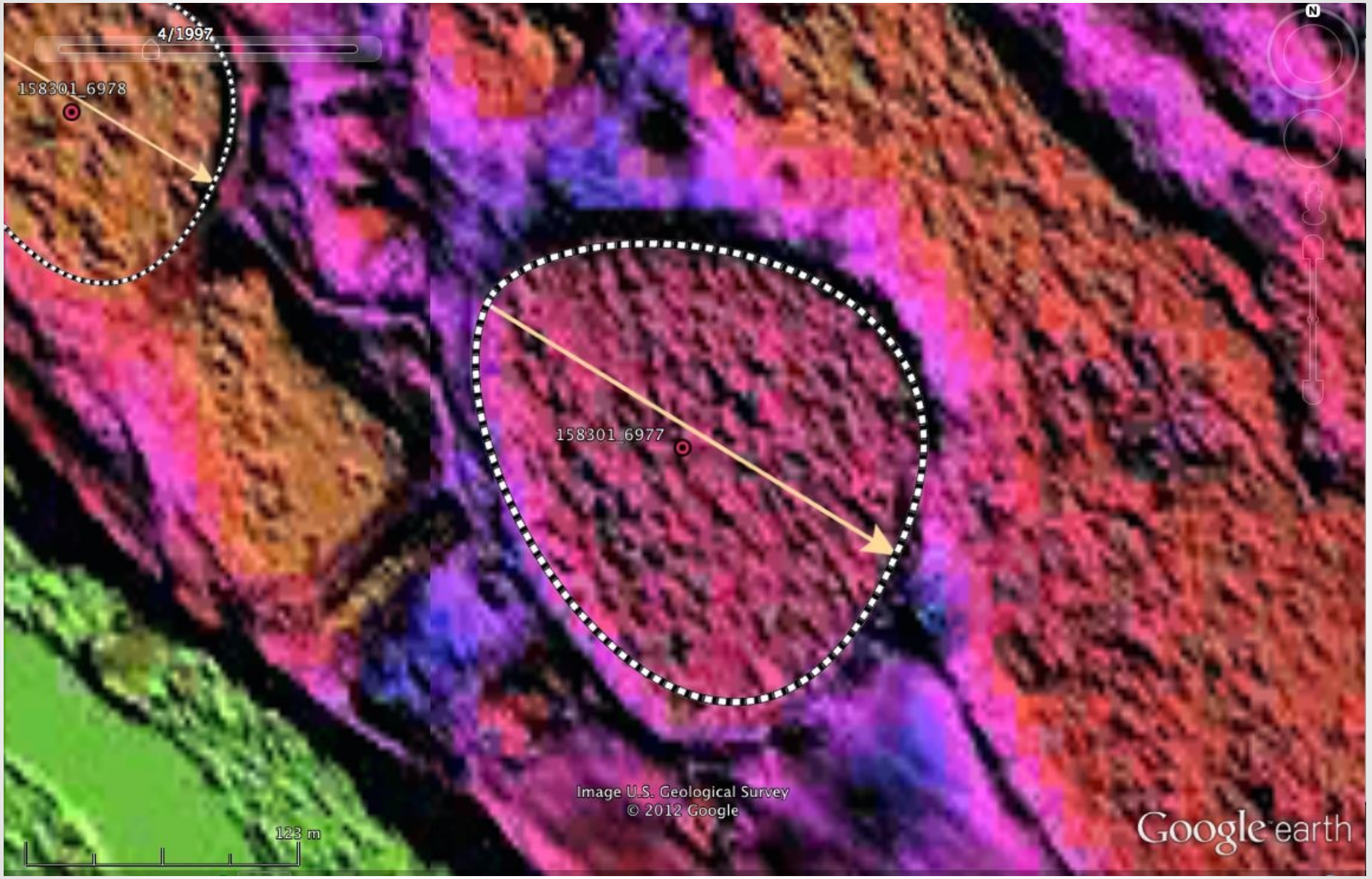
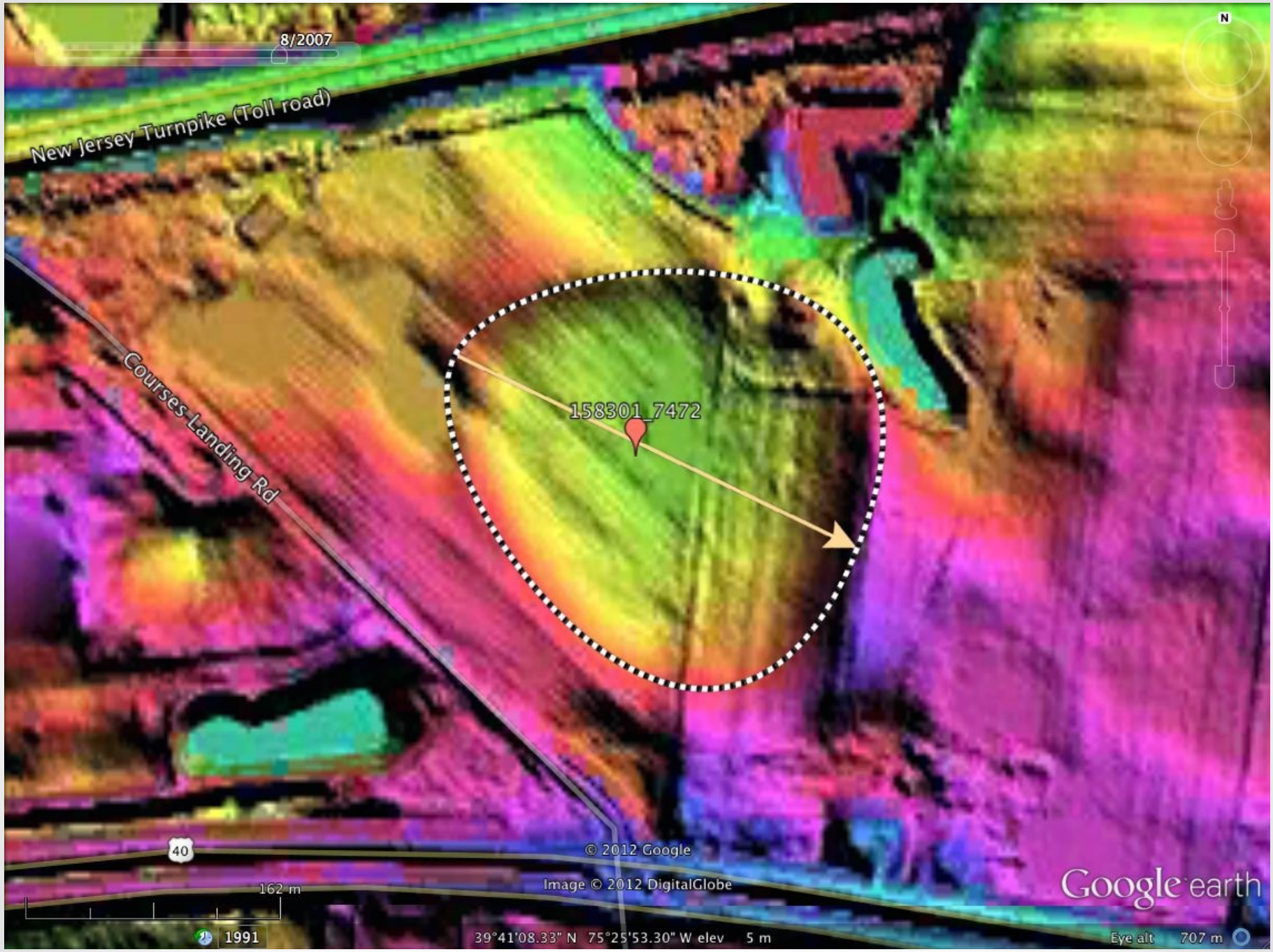



4/1997
158301_6978
158301_6977
Image U.S. Geological Survey
© 2012 Google
123 m
Google earth


8/2007
New Jersey Turnpike (Toll road)
Courses Landing Rd
158301_7472
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© 2012 Google
Image © 2012 DigitalGlobe
Google earth
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1991
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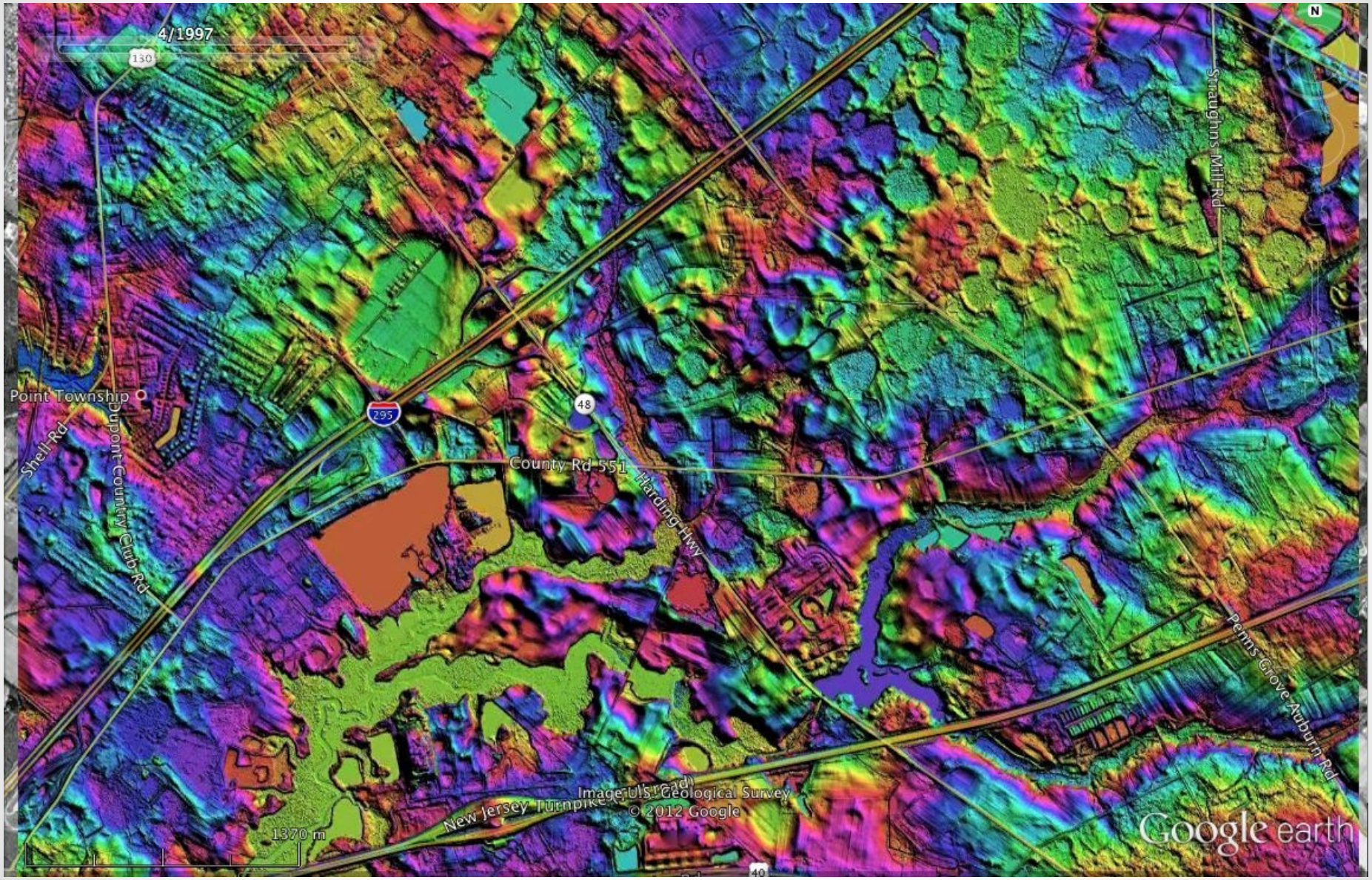
Eye alt 707 m
N


4/1997
130
Straughns Mill Rd
Point Township
295
48
Shell Rd
Dupont Country Club Rd
County Rd 551
Harding Hwy
Penns Grove Auburn Rd
New Jersey Turnpike
Image U.S. Geological Survey
© 2012 Google
1370 m
Google earth

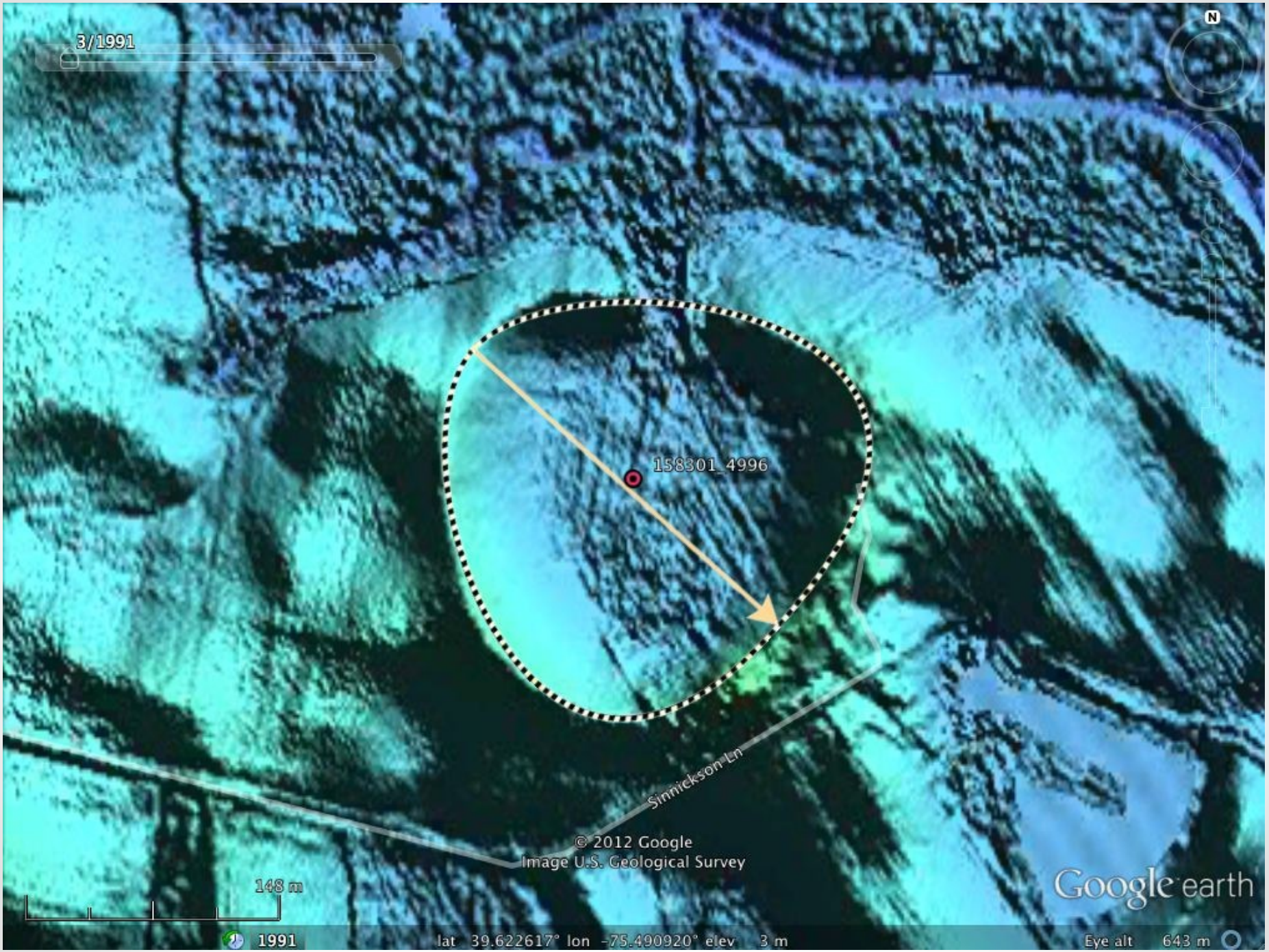
Rasmussen, 1953

"… flying for 4 hours … in the vicinity of Wilmington, Delaware. In general, these "basins" had a long axis in the north-westerly direction, similar to the classic "bays," and were in other respects comparable to the "bays" or "basins" of Delaware and Maryland's eastern shore.

"…any comprehensive theory of the formation of these "bays" or "basins" must either account for their wide geographic distribution on the Atlantic Coastal Plain or show that somewhere along their spread the basins change in character or in origin. "

W.C. Rasmussen, 1953, *Periglacial Frost-Thaw Basins in New Jersey: A Discussion*, *The Journal of Geology*, Vol. 61, No. 5


3/1991
N
158301_4996
Sinnickson Ln
© 2012 Google
Image U.S. Geological Survey
148 m
Google earth
1991
lat 39.622617° lon -75.490920° elev 3 m
Eye alt 643 m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Sinnickson Ln
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Image U.S. Geological Survey
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Google earth
1991
lat 39.622617° lon -75.490920° elev 3 m
Eye alt 643 m


3/1991
N
Rte 540
158301_6281
© 2012 Google
Image U.S. Geological Survey
108 m
Google earth
Imagery Date: 3/10/1991
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Eye alt 469 m

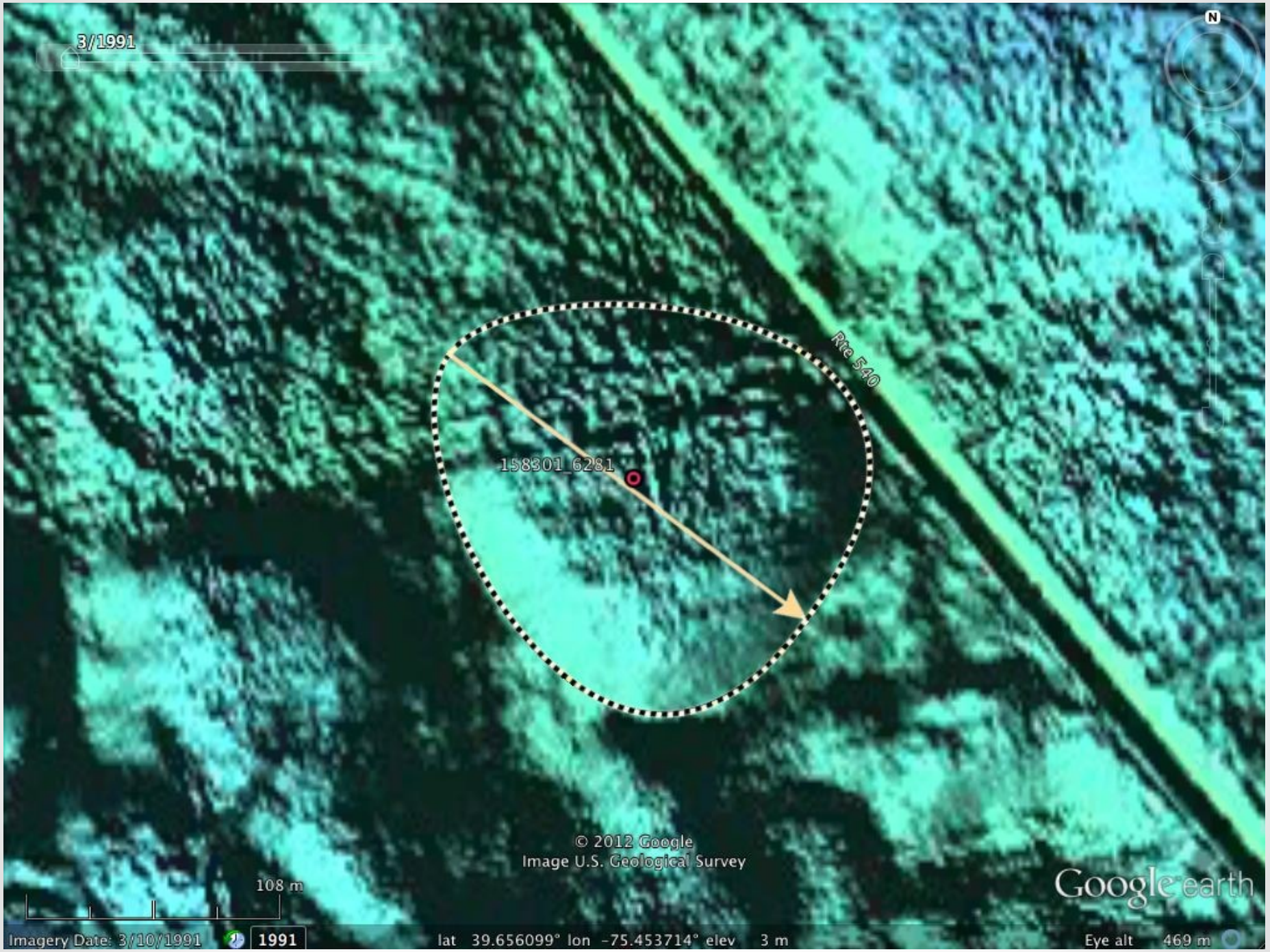
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Image U.S. Geological Survey
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lat 39.656099° lon -75.453714° elev 3 m
Eye alt 469 m


3/1991
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© 2012 Google
Image U.S. Geological Survey
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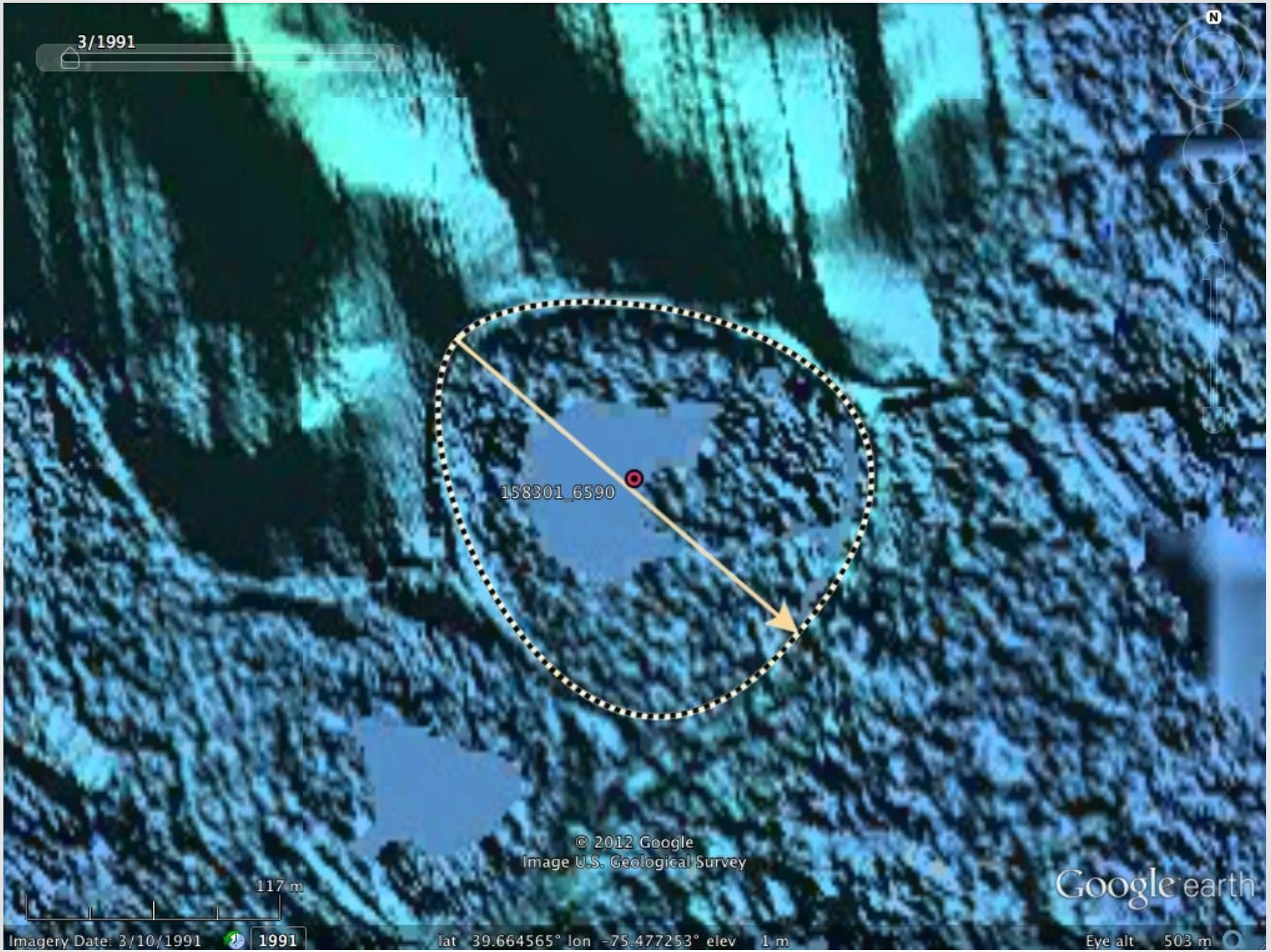
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© 2012 Google
Image U.S. Geological Survey
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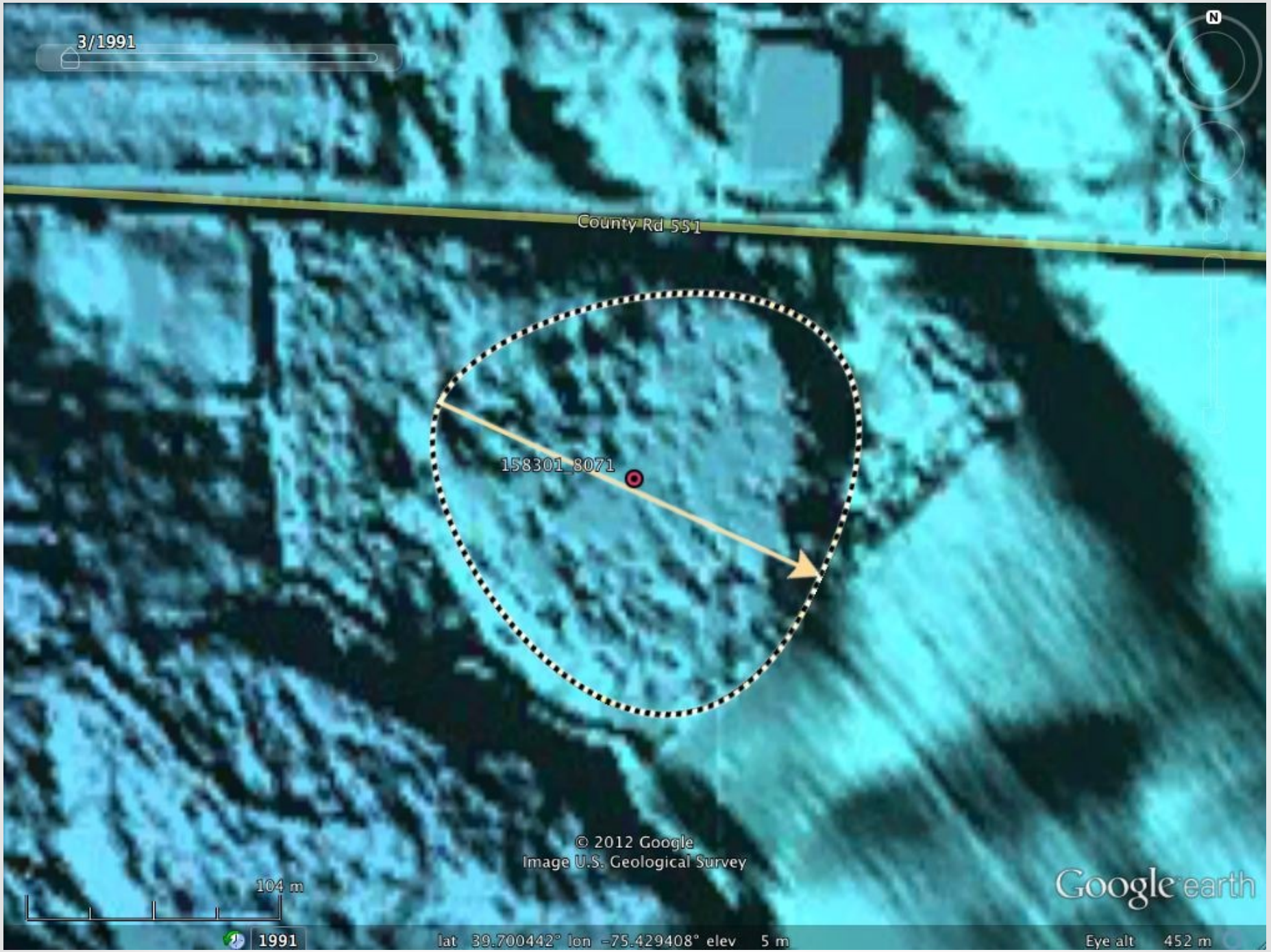
1991
lat 39.664565° lon -75.477253° elev 1 m
Eye alt 503 m


3/1991
N
County Rd 551
158301_8071
© 2012 Google
Image U.S. Geological Survey
104 m
Google earth
1991
lat 39.700442° lon -75.429408° elev 5 m
Eye alt 452 m


3/1991
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County Rd 551
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© 2012 Google
Image U.S. Geological Survey
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Eye alt 452 m


3/1991
N
158301_8270
© 2012 Google
Image U.S. Geological Survey
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1991
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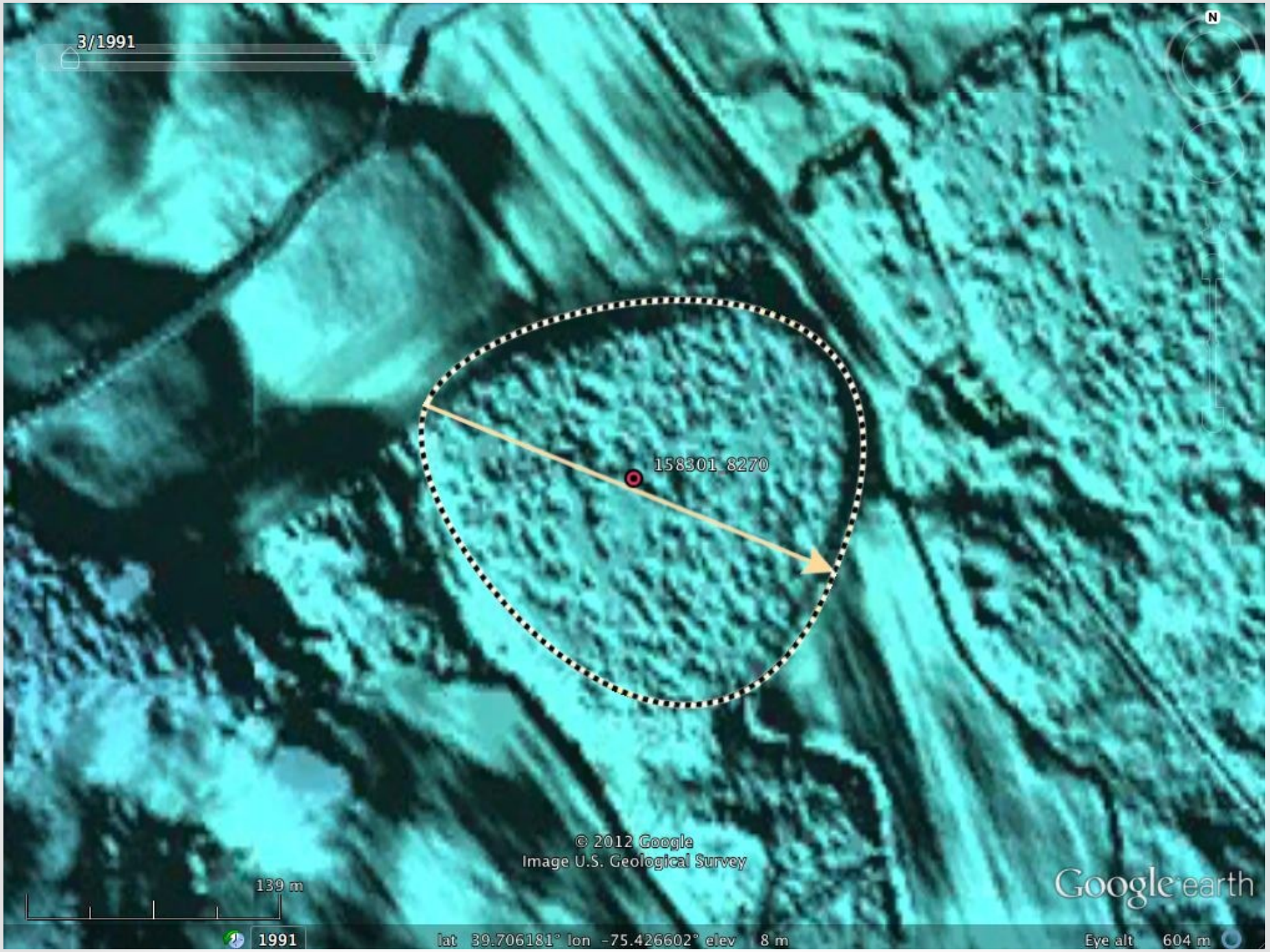
Eye alt 604 m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158301 8270
© 2012 Google
Image U.S. Geological Survey
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Google earth
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lat 39.706181° lon -75.426602° elev 8 m
Eye alt 604 m


3/1991
N
158301_9877
Perkintown Rd
© 2012 Google
Image U.S. Geological Survey
133 m
Google earth
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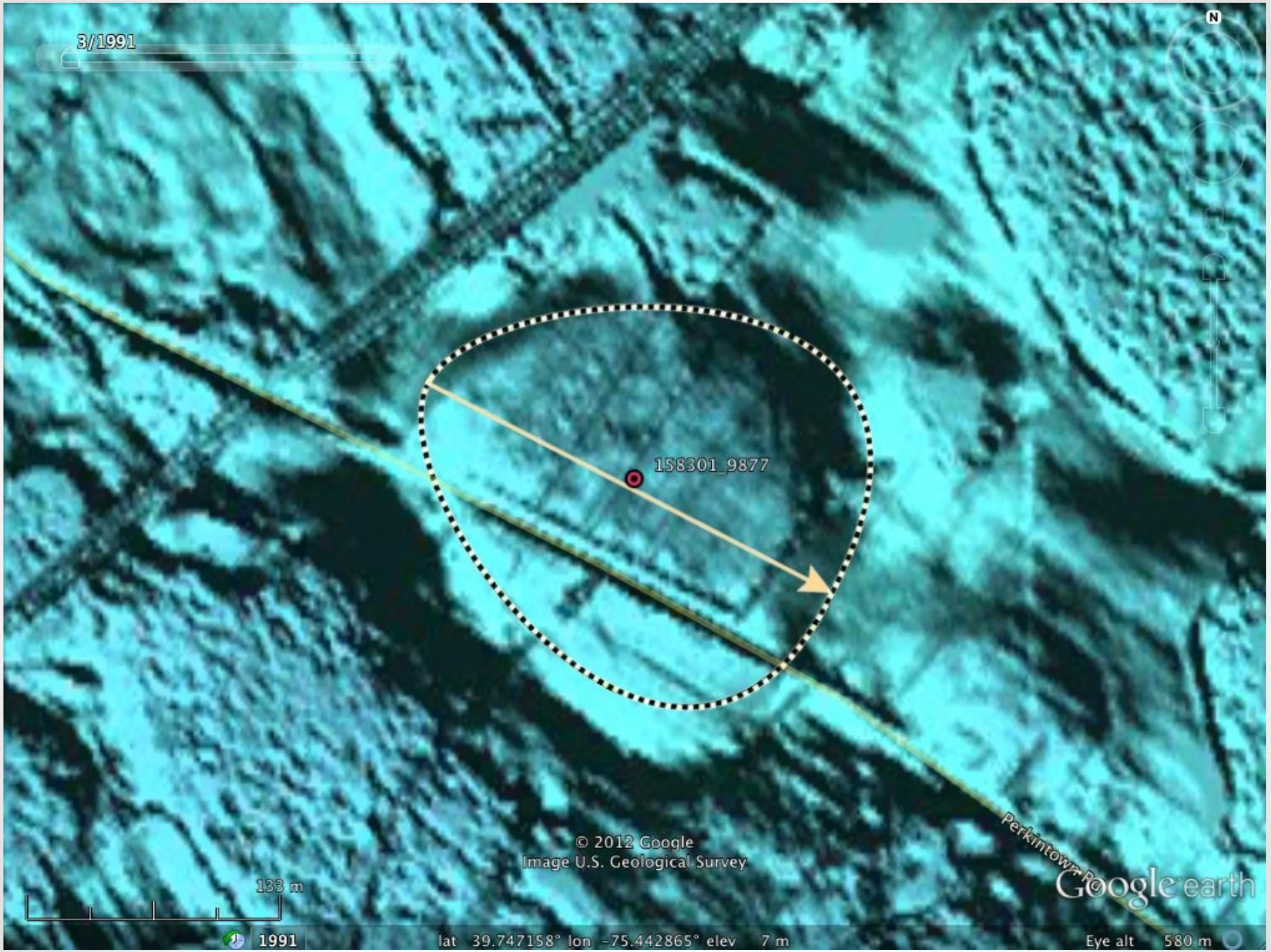
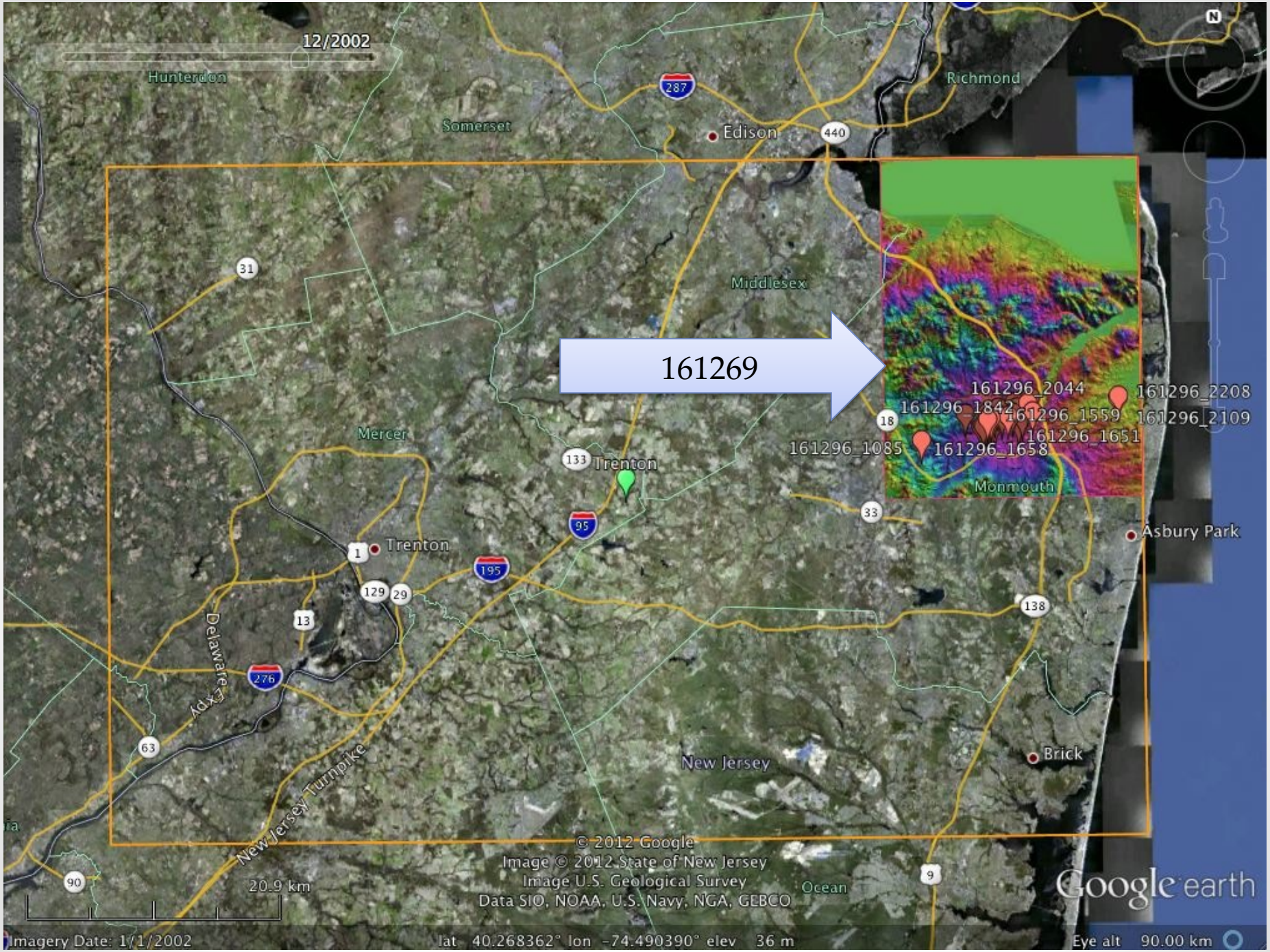
lat 39.747158° lon -75.442865° elev 7 m
Eye alt 580 m

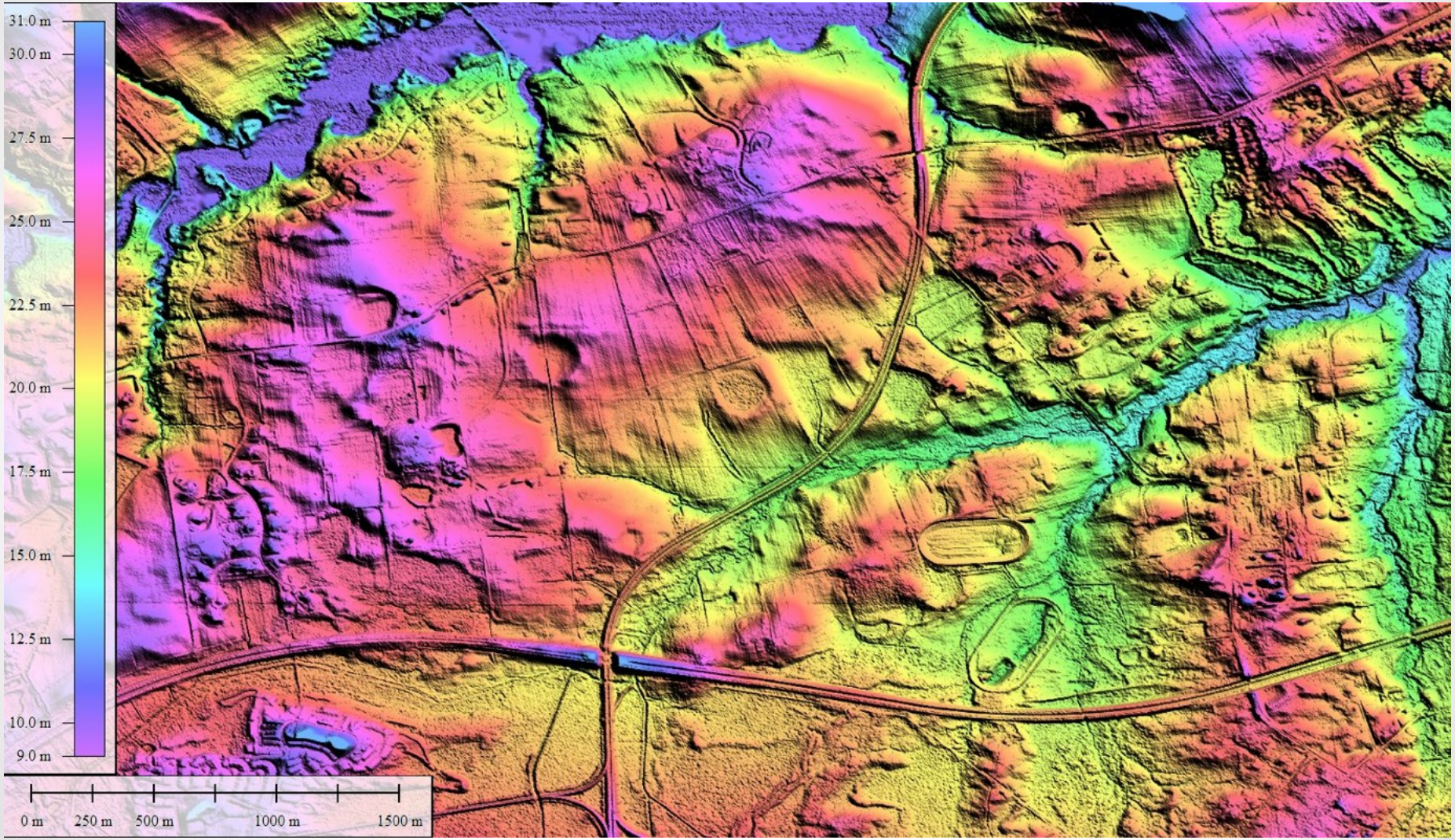

3/1991
N
158301_9877
© 2012 Google
Image U.S. Geological Survey
Perkintowne Rd
133 m
Google earth
1991
lat 39.747158° lon -75.442865° elev 7 m
Eye alt 580 m


12/2002
Hunterdon
Somerset
Edison
Richmond
Middlesex
Mercer
Trenton
Monmouth
Asbury Park
Brick
New Jersey
Ocean
Delaware Expy
New Jersey Turnpike
161269
161296_2044
161296_2208
161296_1842
161296_1559
161296_2109
161296_1651
161296_1085
161296_1658
© 2012 Google
Image © 2012 State of New Jersey
Image U.S. Geological Survey
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
20.9 km
Google earth
Imagery Date: 1/1/2002
lat 40.268362° lon -74.490390° elev 36 m
Eye alt 90.00 km

Octant 161296

- Trenton, NJ 100k Quad
- Monmouth County / Eatontown
- “bay bell” Planform
- 31 bays identified/measured
- Mean Bearing 119°
- Std dev 6.7°

Octant 161296




3/29/1995
N
161296_1654
© 2012 Google
Image U.S. Geological Survey
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Google earth
1995
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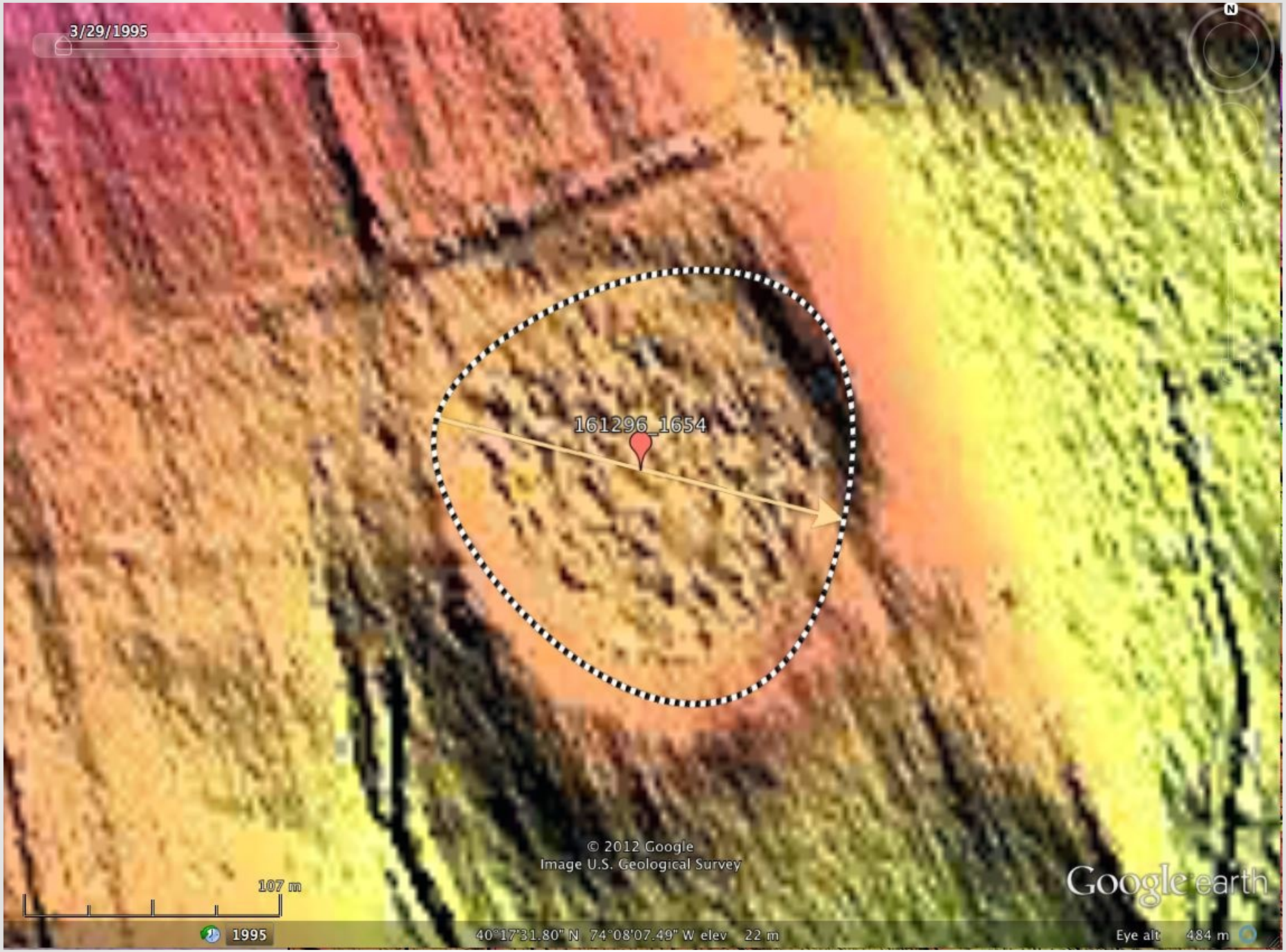
Eye alt 484 m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Google earth
1995
40°17'31.80" N 74°08'07.49" W elev 22 m
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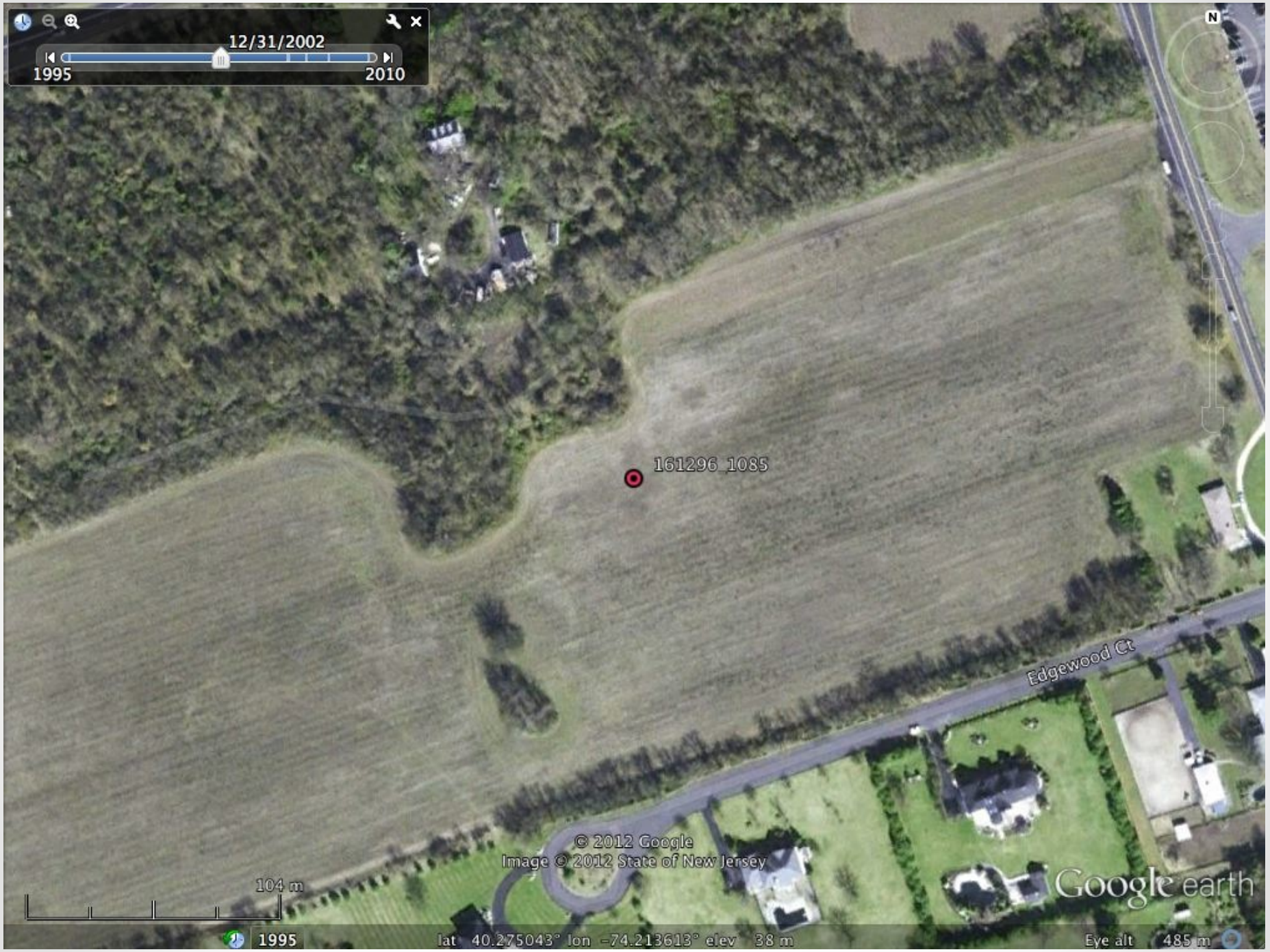
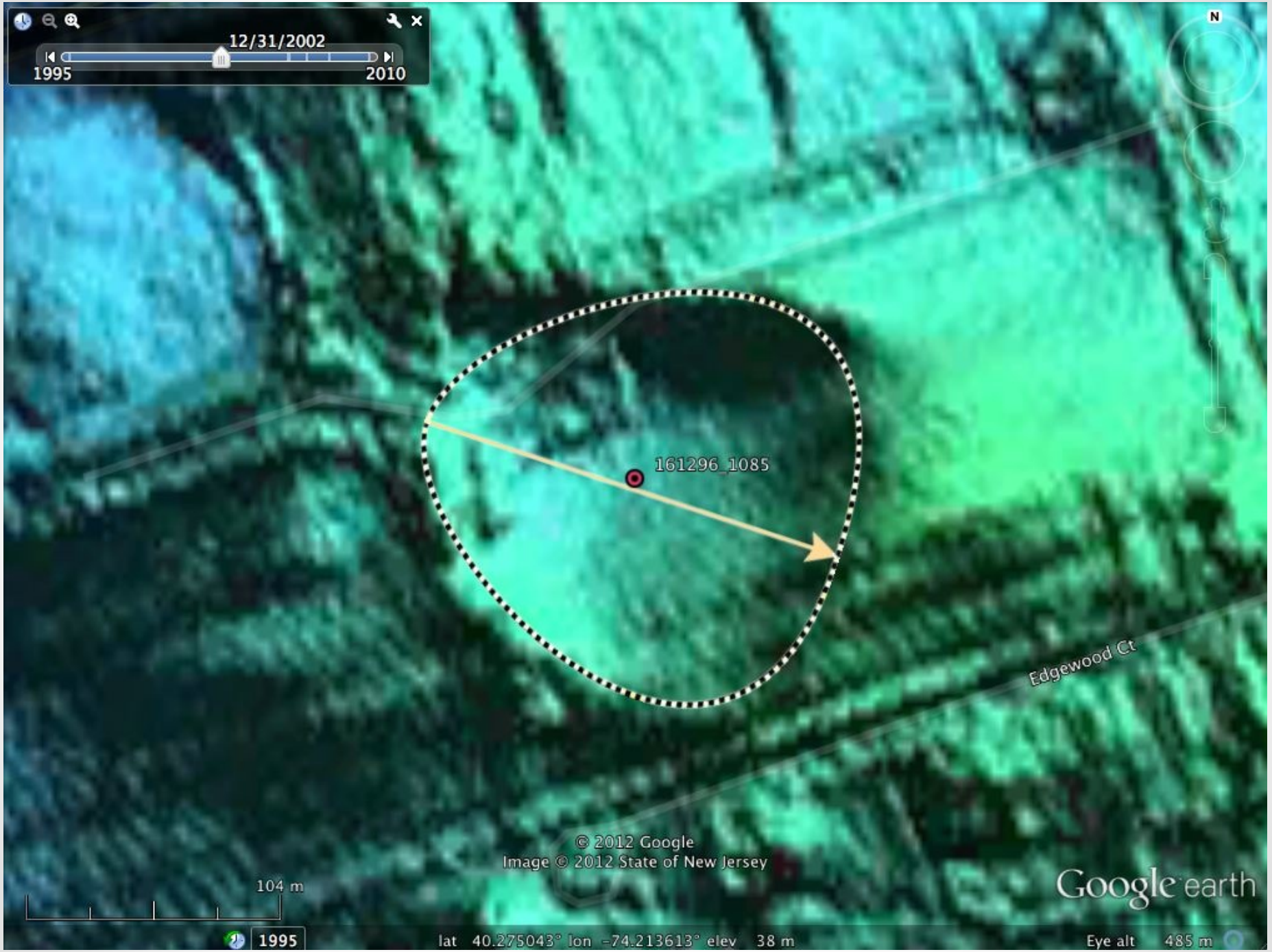
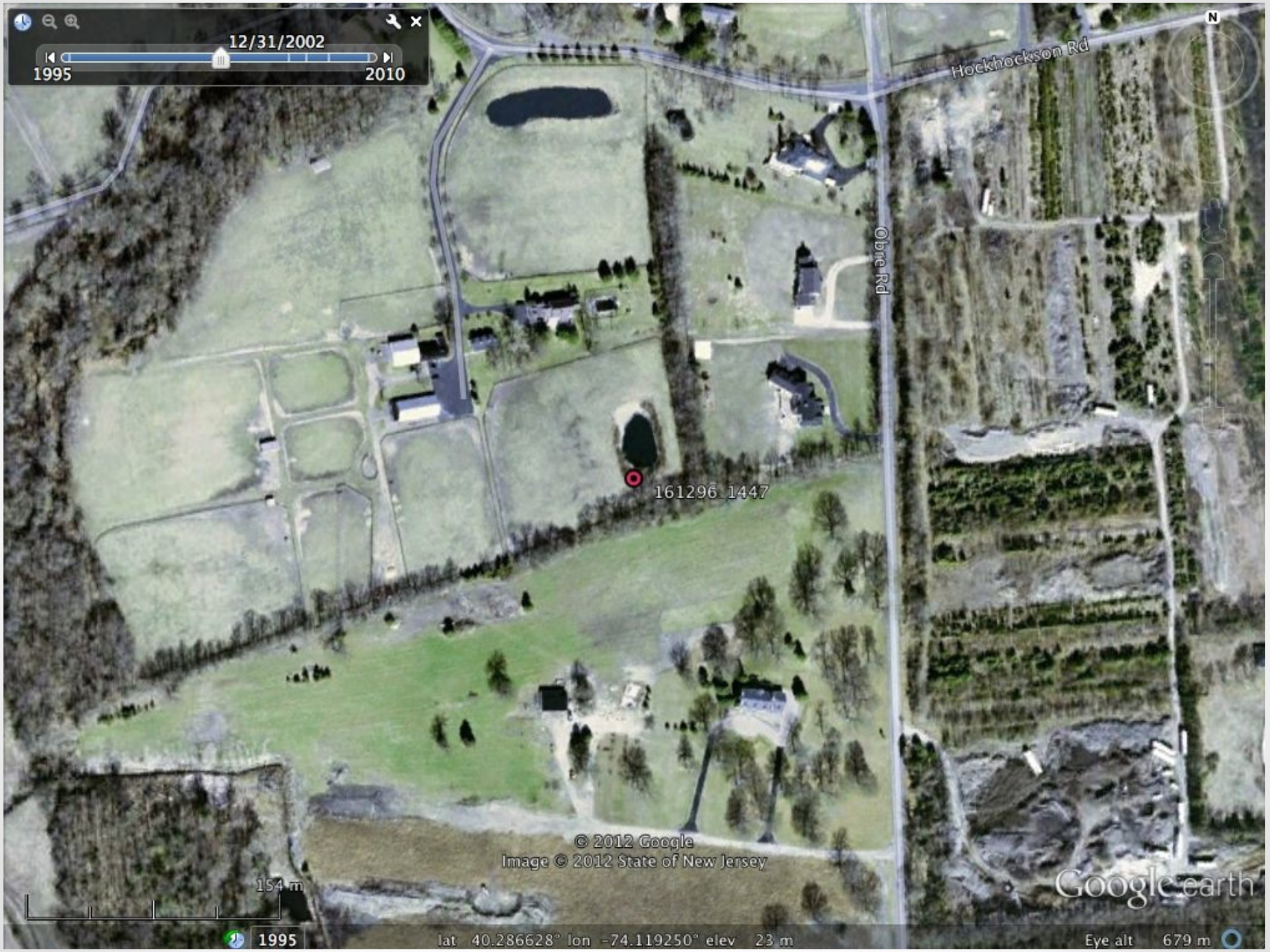
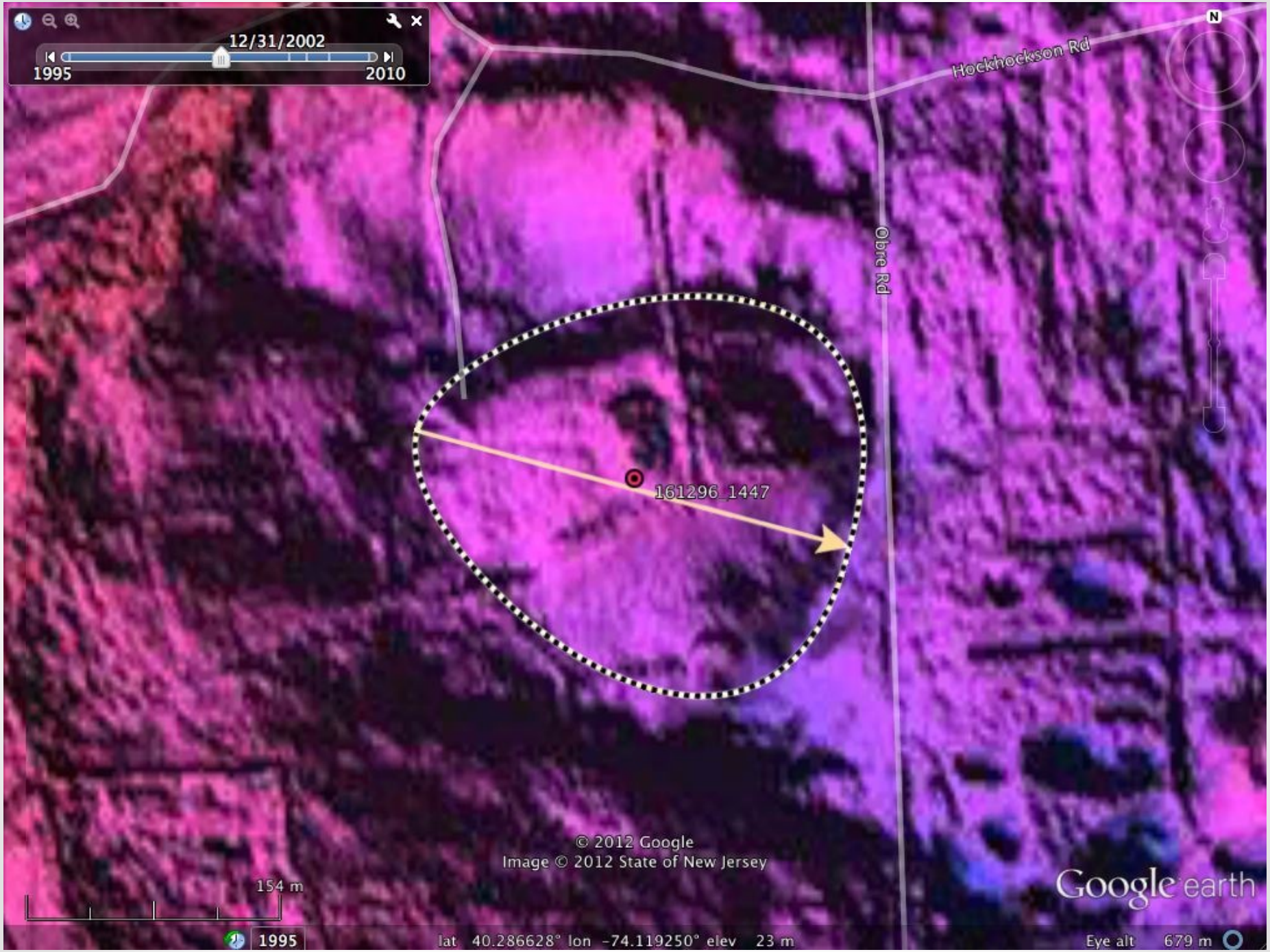

12/31/2002
1995
2010
161296 1085
Edgewood Ct
© 2012 Google
Image © 2012 State of New Jersey
104 m
Google earth
1995
lat 40.275043° lon -74.213613° elev 38 m
Eye alt 485 m

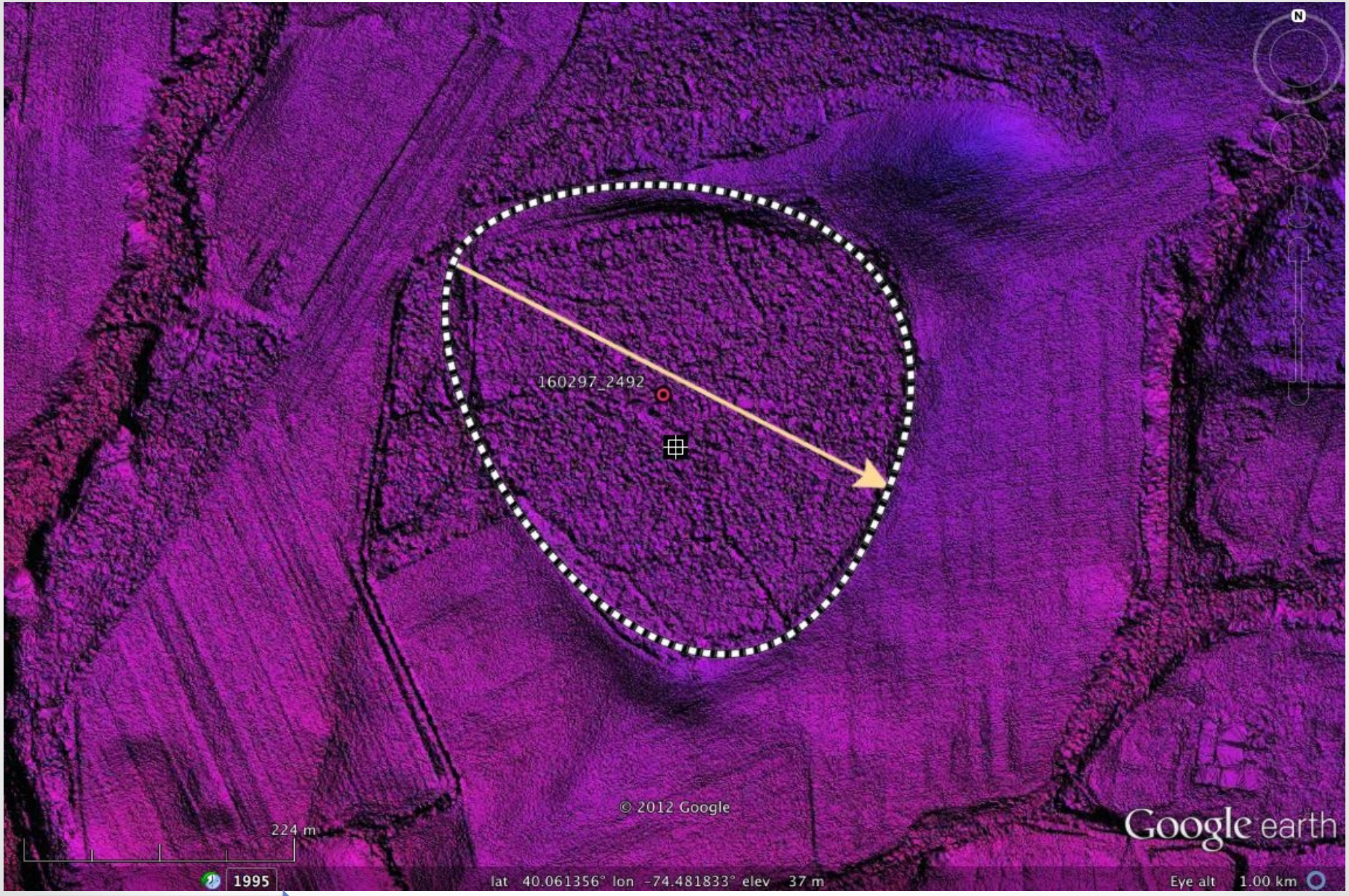

12/31/2002
1995
2010
N
161296_1085
Edgewood Ct
© 2012 Google
Image © 2012 State of New Jersey
104 m
Google earth
1995
lat 40.275043° lon -74.213613° elev 38 m
Eye alt 485 m


12/31/2002
1995
2010
Hockhockson Rd
Obrie Rd
161296 1447
© 2012 Google
Image © 2012 State of New Jersey
154 m
Google earth
1995
lat 40.286628° lon -74.119250° elev 23 m
Eye alt 679 m


12/31/2002
1995
2010
Hockhockson Rd
Obre Rd
N
161296_1447
© 2012 Google
Image © 2012 State of New Jersey
154 m
Google earth
1995
lat 40.286628° lon -74.119250° elev 23 m
Eye alt 679 m


4/16/1995
N
Image U.S. Geological Survey
© 2012 Google
Google earth
224 m
Imagery Date: 4/16/1995
1995
lat 40.061356° lon -74.481833° elev 37 m
Eye alt 1.00 km

224 m


160297_2492
224 m
1995
© 2012 Google
Google earth
lat 40.061356° lon -74.481833° elev 37 m
Eye alt 1.00 km

224 m

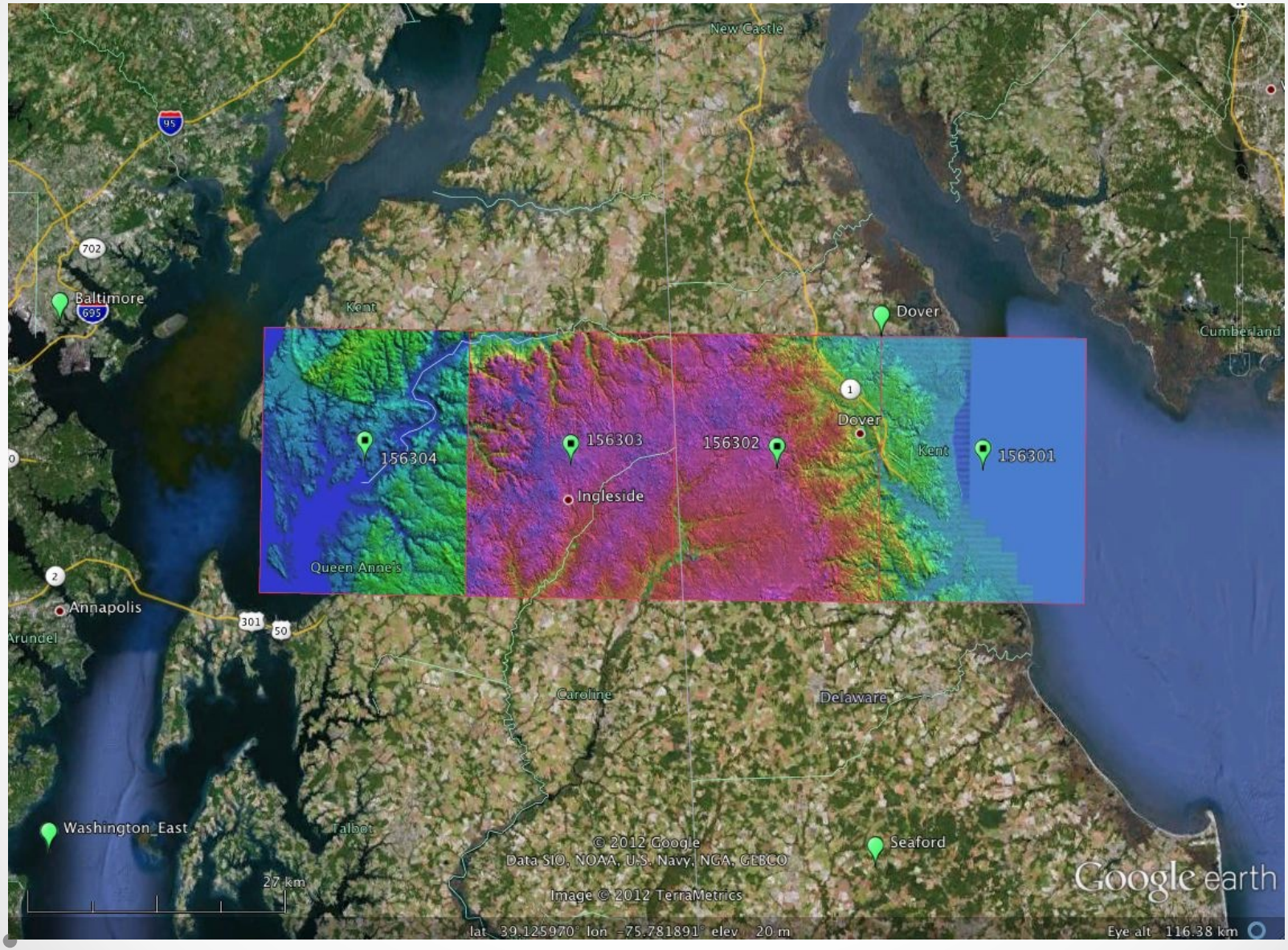

3/1991
1991
2011
N
158301_6955
© 2012 Google
Image U.S. Geological Survey
117 m
Google earth
Imagery Date: 3/10/1991
1991
lat 39.674952° lon -75.389626° elev 14 m
Eye alt 519 m


3/1991
1991
2011
N
158301_6955
© 2012 Google
Image U.S. Geological Survey
117 m
Google earth
1991
lat 39.674952° lon -75.389626° elev 14 m
Eye alt 519 m


128 m
128 m
© 2012 Google
Google earth
1995
39°40'58.95" N 74°13'20.94" W elev 2 m
Eye alt 554 m

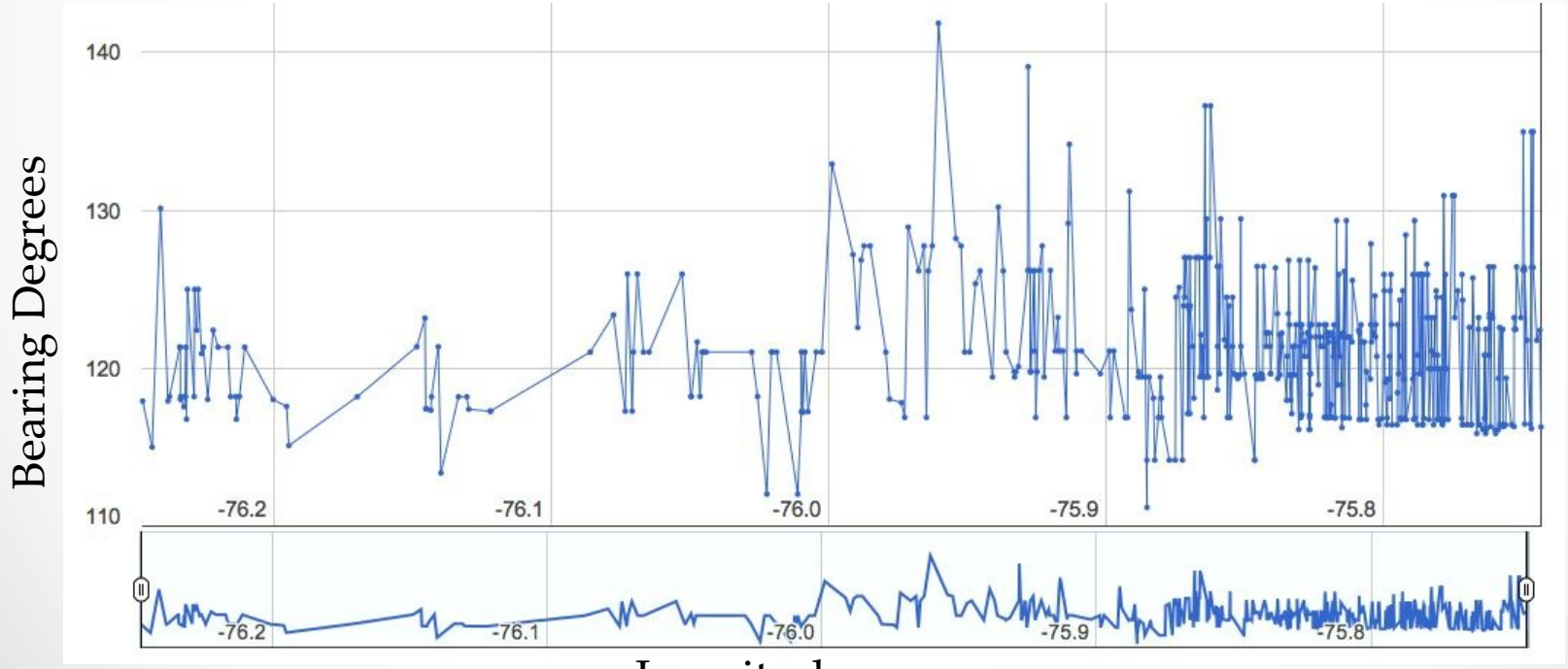

N
© 2012 Google
128 m
1995
39°40'58.95" N 74°13'20.94" W elev 2 m
Eye alt 554 m
Google earth

Octant 156304 - 156301

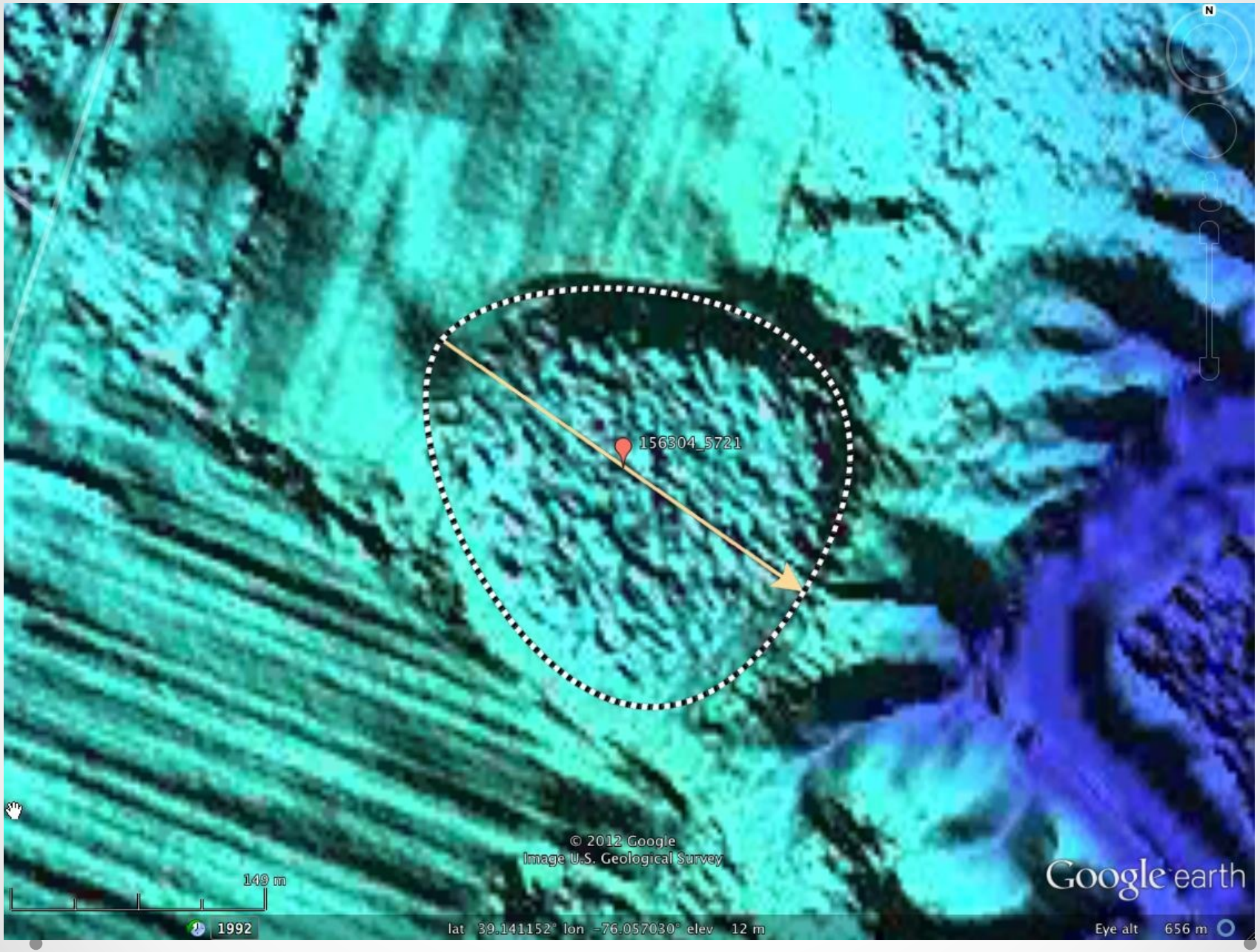


Octants 156304 - 156301

- Baltimore & Dover 100k Quad
- Across Central Maryland and Delaware
- "Bay Bell" Planform
- 1153 bays identified/measured

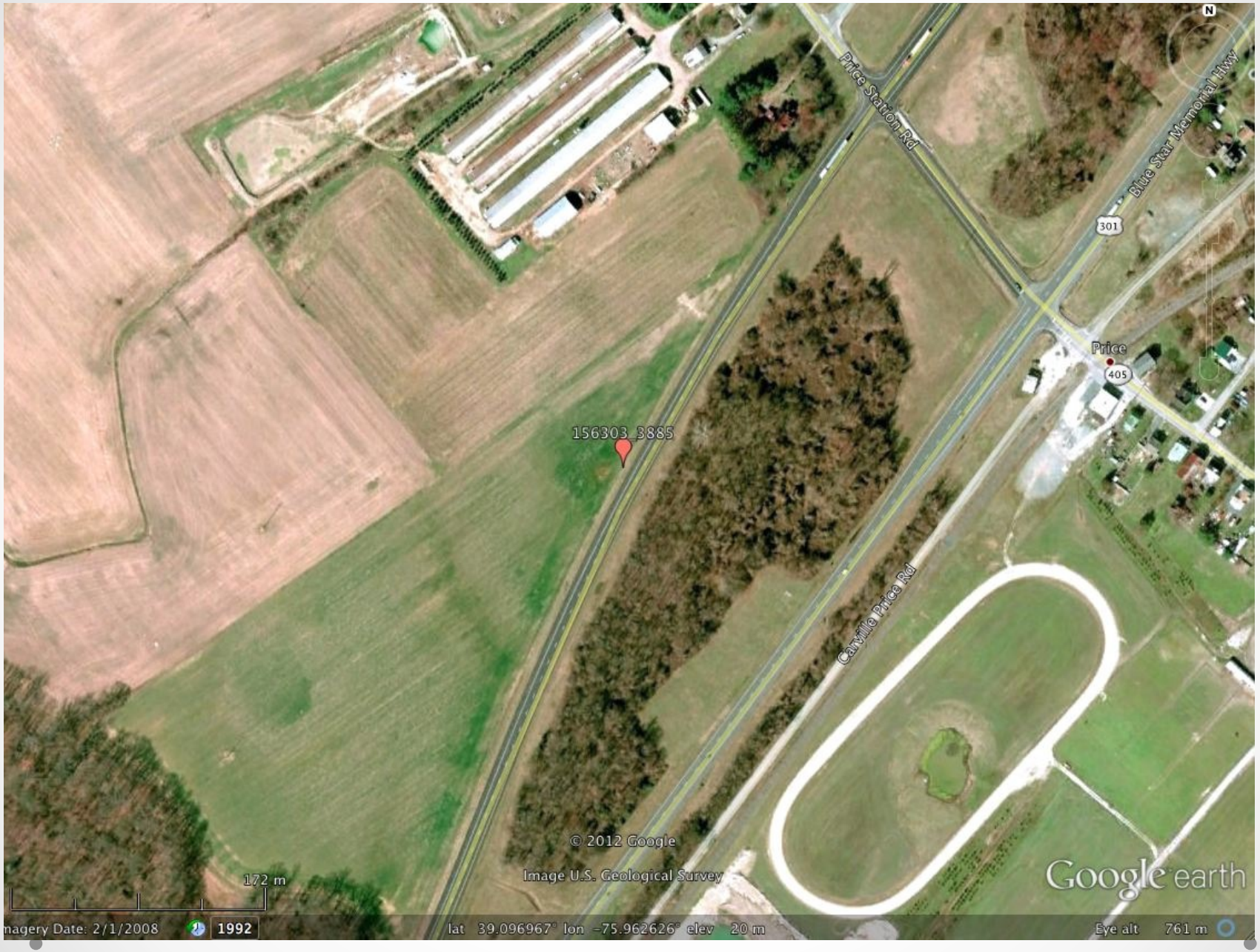


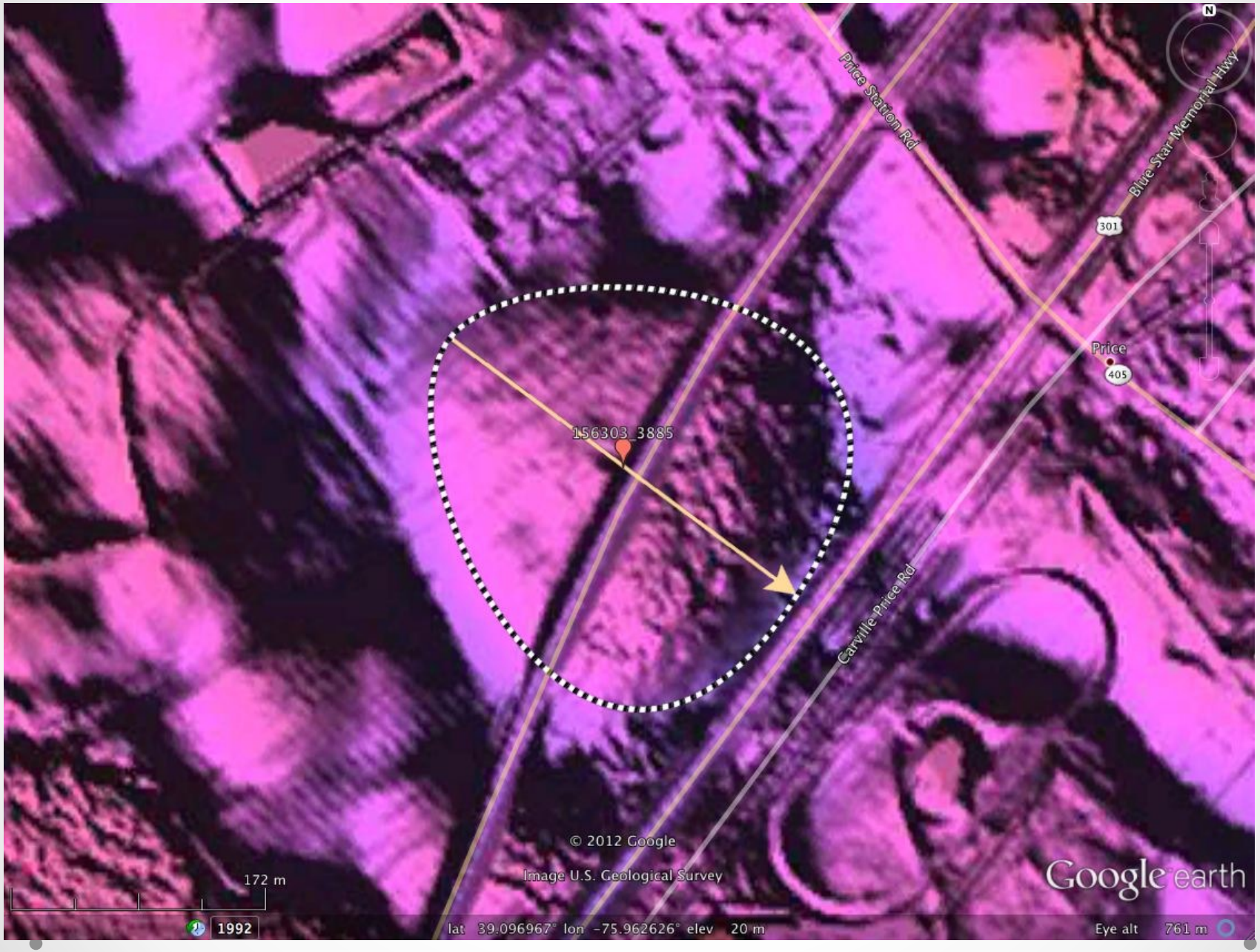

N
156304_5721
© 2012 Google
Image U.S. Geological Survey
149 m
Google earth
1992
lat 39.142953° lon -76.052892° elev 12 m
Eye alt 656 m


N
156304_5721
© 2012 Google
Image U.S. Geological Survey
149 m
1992
lat 39.141152° lon -76.057030° elev 12 m
Eye alt 656 m
Google earth

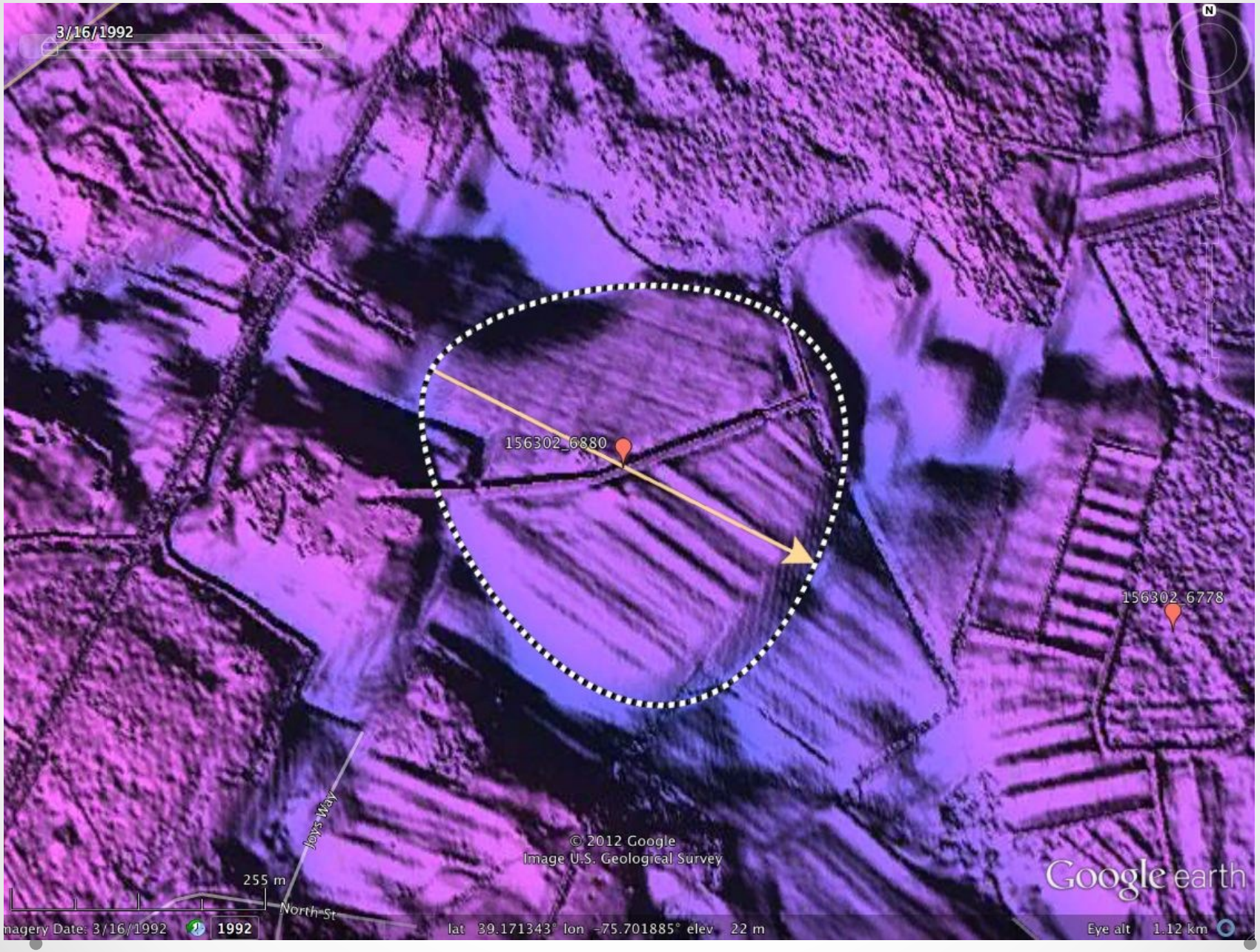

156304_3329
156304_3327
© 2012 Google
Image U.S. Geological Survey
161 m
Google earth
1992
lat 39.083212° lon -76.072611° elev 17 m
Eye alt 714 m


N
156304_3329
156304_3327
© 2012 Google
Image U.S. Geological Survey
Google earth
161 m
1992
lat 39.083212° lon -76.072611° elev 17 m
Eye alt 714 m

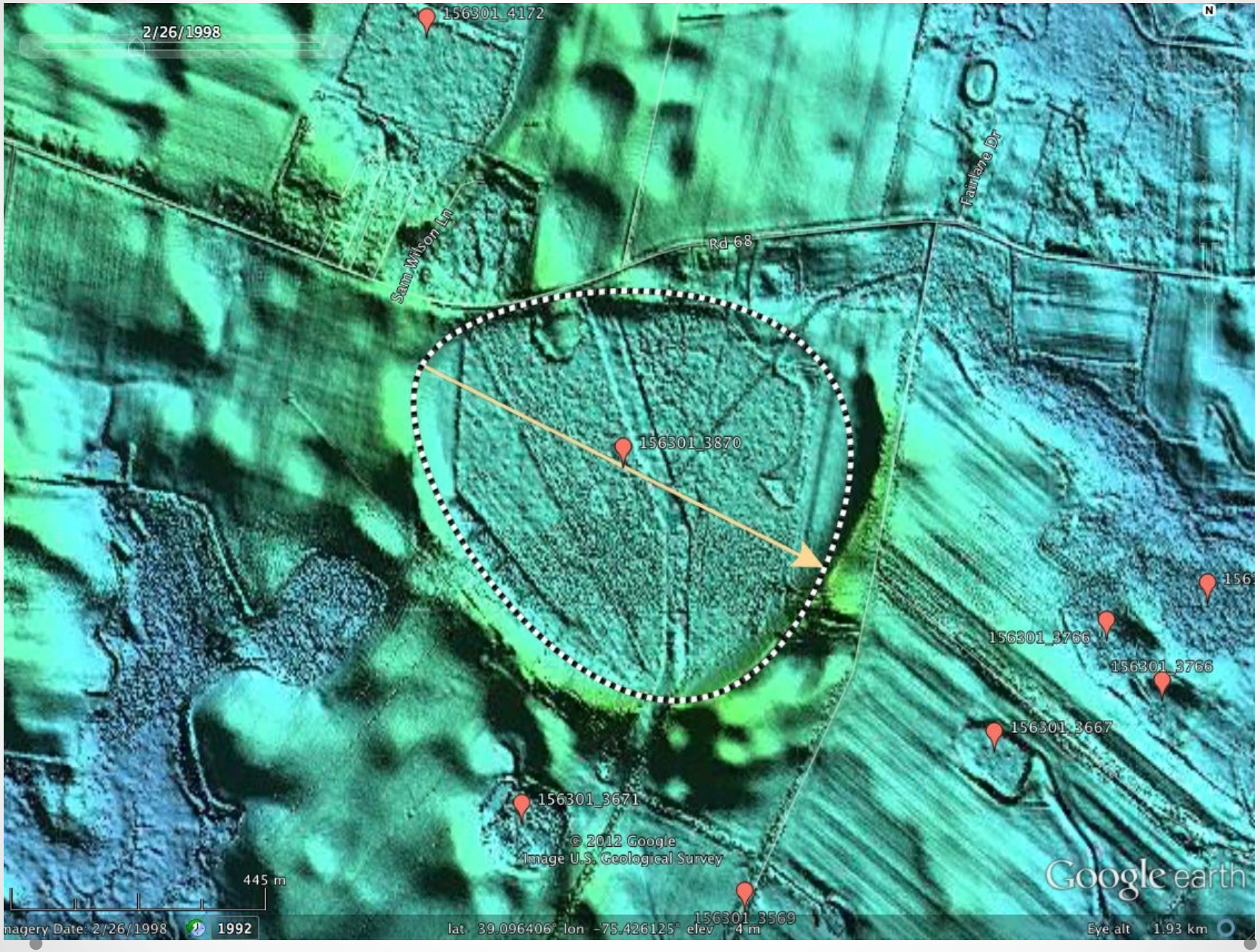

Price Station Rd
Blue Star Memorial Hwy
301
Price
405
156303_3885
Carville Price Rd
© 2012 Google
Image U.S. Geological Survey
Google earth
172 m
nagery Date: 2/1/2008
1992
lat 39.096967° lon -75.962626° elev 20 m
Eye alt 761 m


Price Station Rd
Blue Star Memorial Hwy
301
Price
405
156303_3885
Carville-Price Rd
© 2012 Google
Image U.S. Geological Survey
Google earth
172 m
1992
lat 39.096967° lon -75.962626° elev 20 m
Eye alt 761 m


3/16/1992
156302_6880
156302_6778
Joys Way
255 m
North St
© 2012 Google
Image U.S. Geological Survey
Google earth
nagery Date: 3/16/1992
1992
lat 39.171343° lon -75.701885° elev 22 m
Eye alt 1.12 km


3/16/1992
N
156302_6880
156302_6778
Joys Way
North St
255 m
© 2012 Google
Image U.S. Geological Survey
Google earth
nagery Date: 3/16/1992
1992
lat 39.171343° lon -75.701885° elev 22 m
Eye alt 1.12 km


2/26/1998
156301_4172
Sam Wilson Ln
Rd 68
Fairlane Dr
156301_3870
156301_3766
156301_3766
156301_3667
156301_3671
© 2012 Google
Image U.S. Geological Survey
445 m
156301_3569
Google earth
Imagery Date: 2/26/1998
1992
lat 39.096406° lon -75.426125° elev 4 m
Eye alt 1.93 km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Sam Wilson Ln
Rd 68
Fairlane Dr
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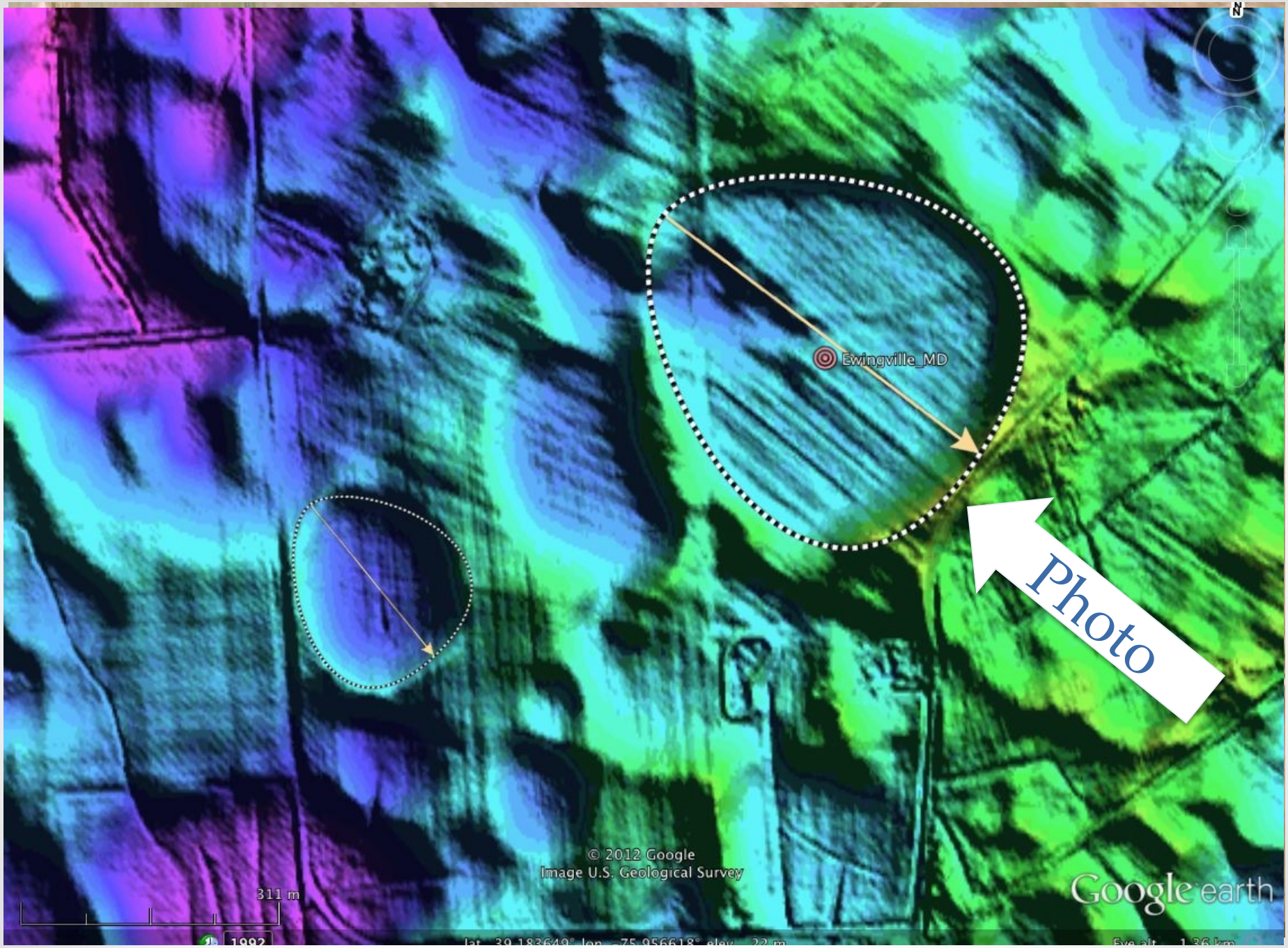
© 2012 Google
Image U.S. Geological Survey
445 m
156301_3569
Google earth
nagery Date: 2/26/1998
1992
lat 39.096406° lon -75.426125° elev 4 m
Eye alt 1.93 km


Ewingville_MD
Photo
© 2012 Google
Image U.S. Geological Survey
311 m
Google earth


Ewingville_MD
Photo
© 2012 Google
Image U.S. Geological Survey
311 m
Google earth

Ewingville, MD Bay 156303_7481

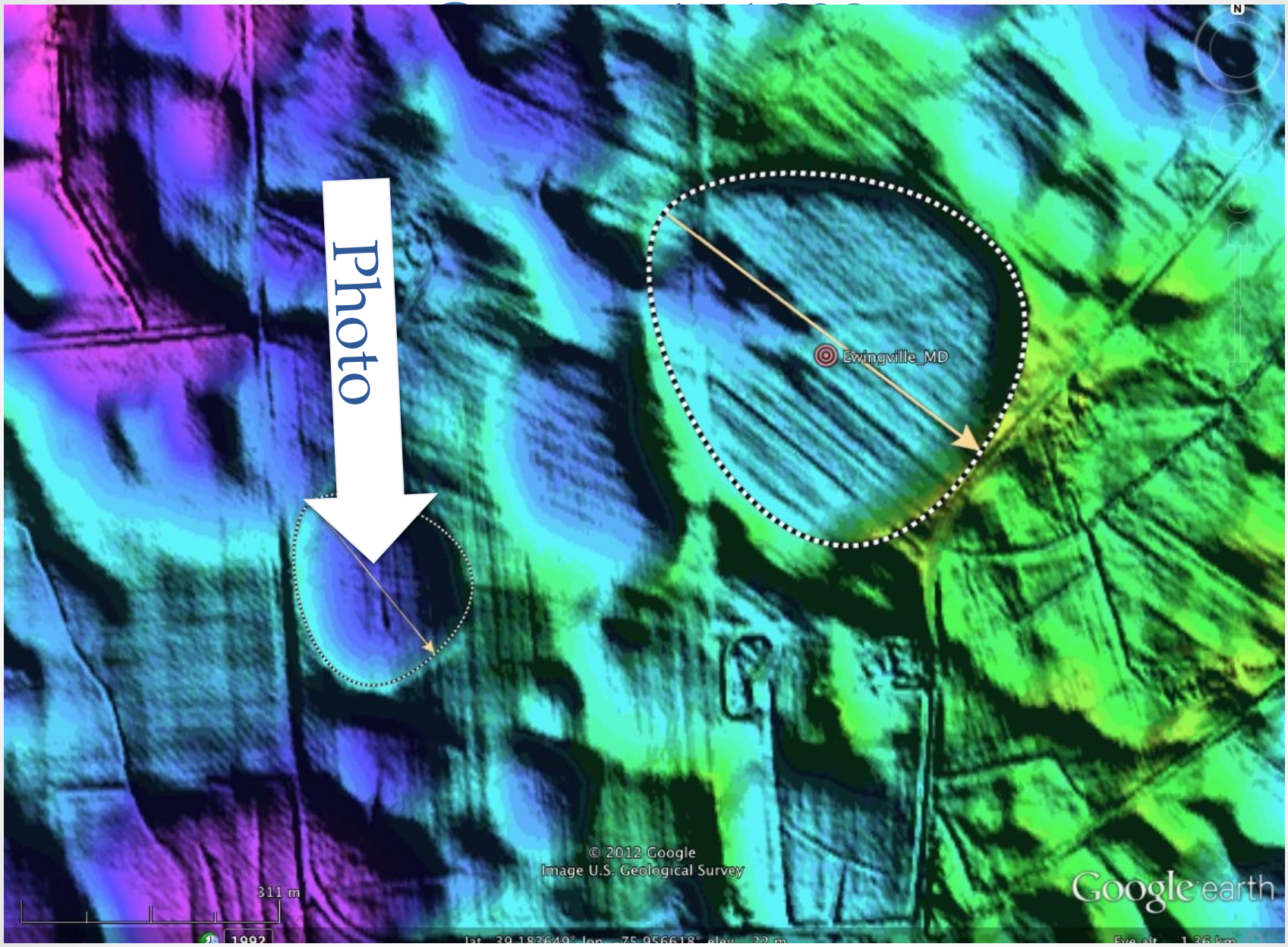
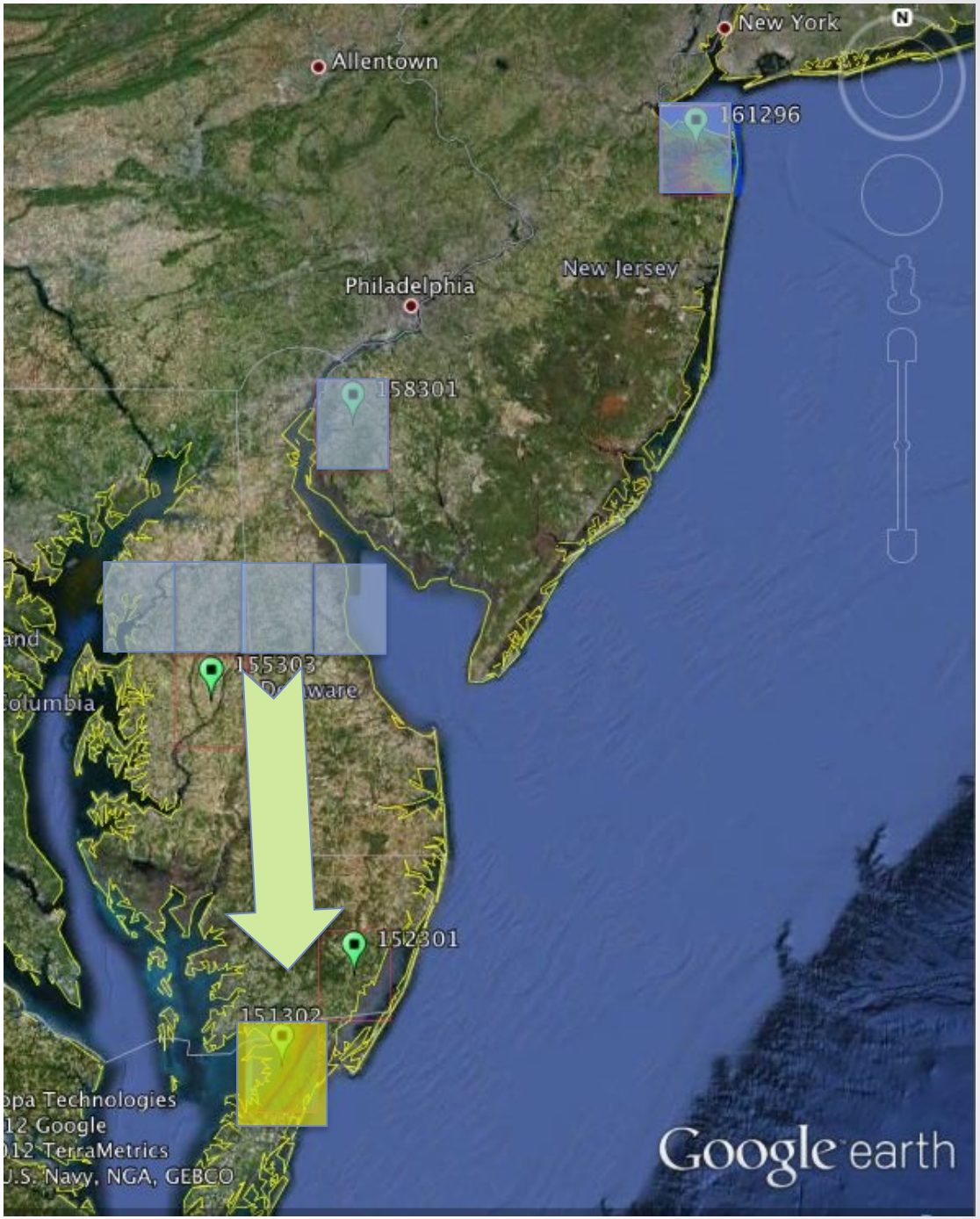
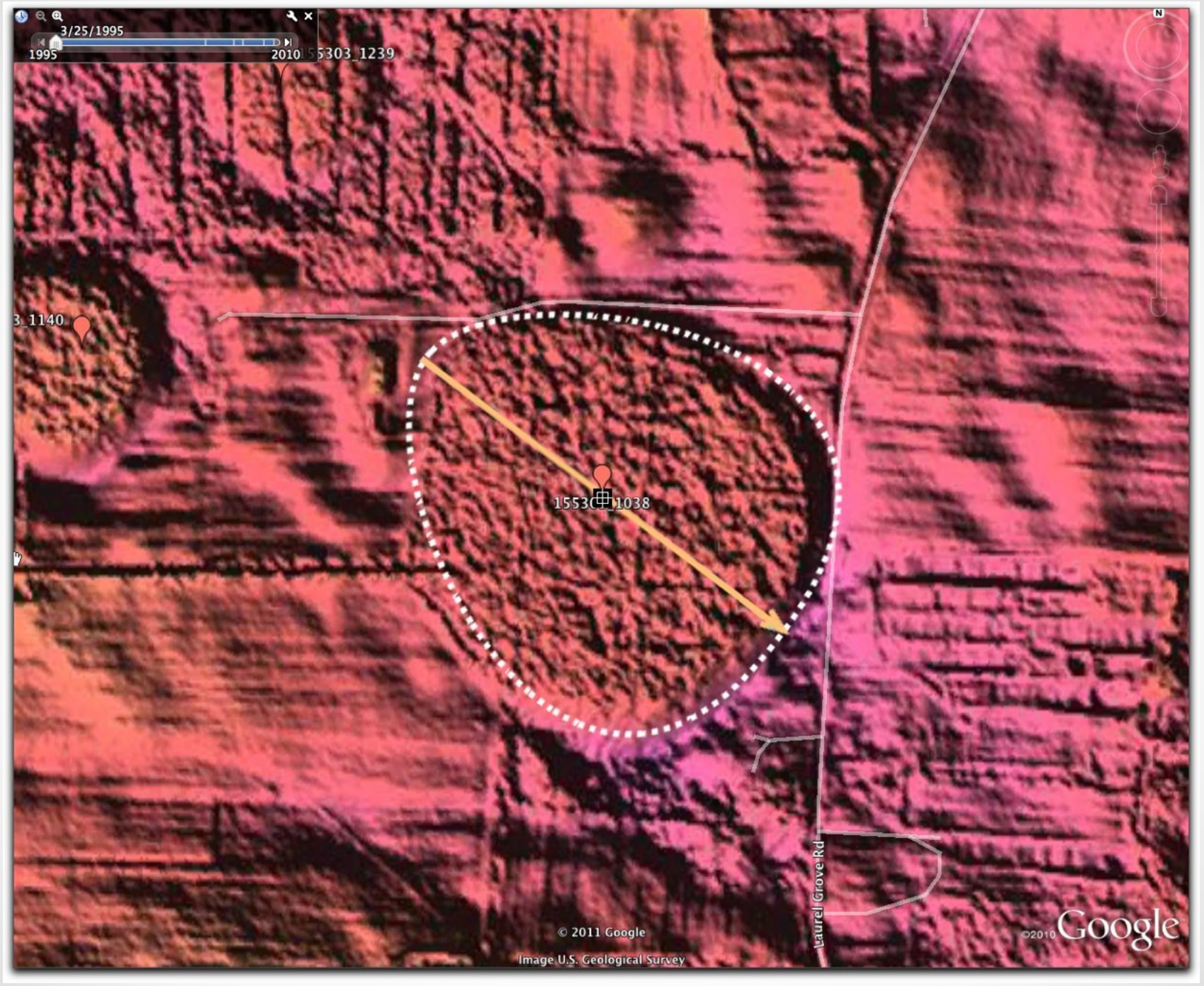


Photo
Ewingville_MD
© 2012 Google
Image U.S. Geological Survey
311 m
Google earth

Crossing Maryland




3/25/1995
1995
2010
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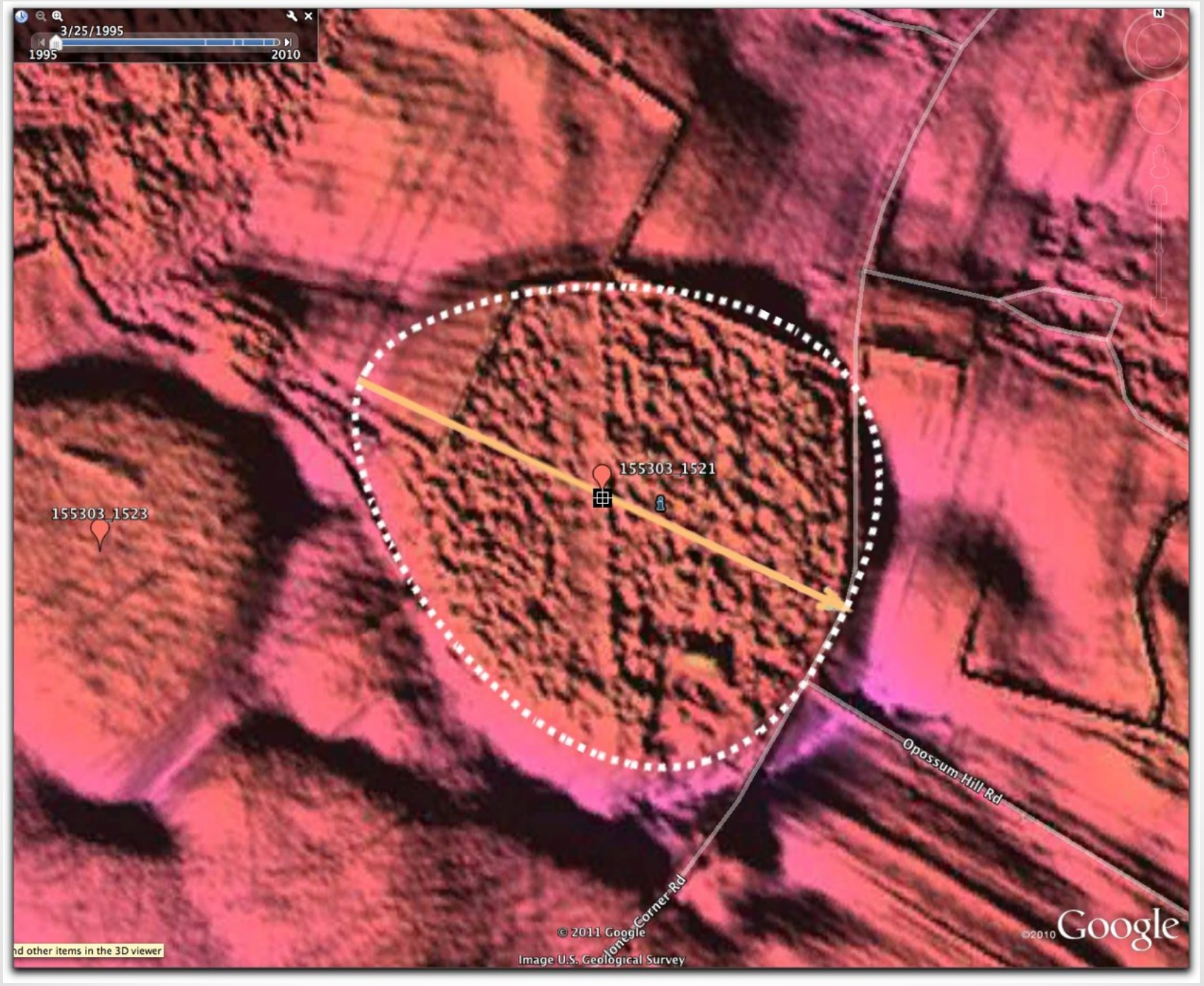
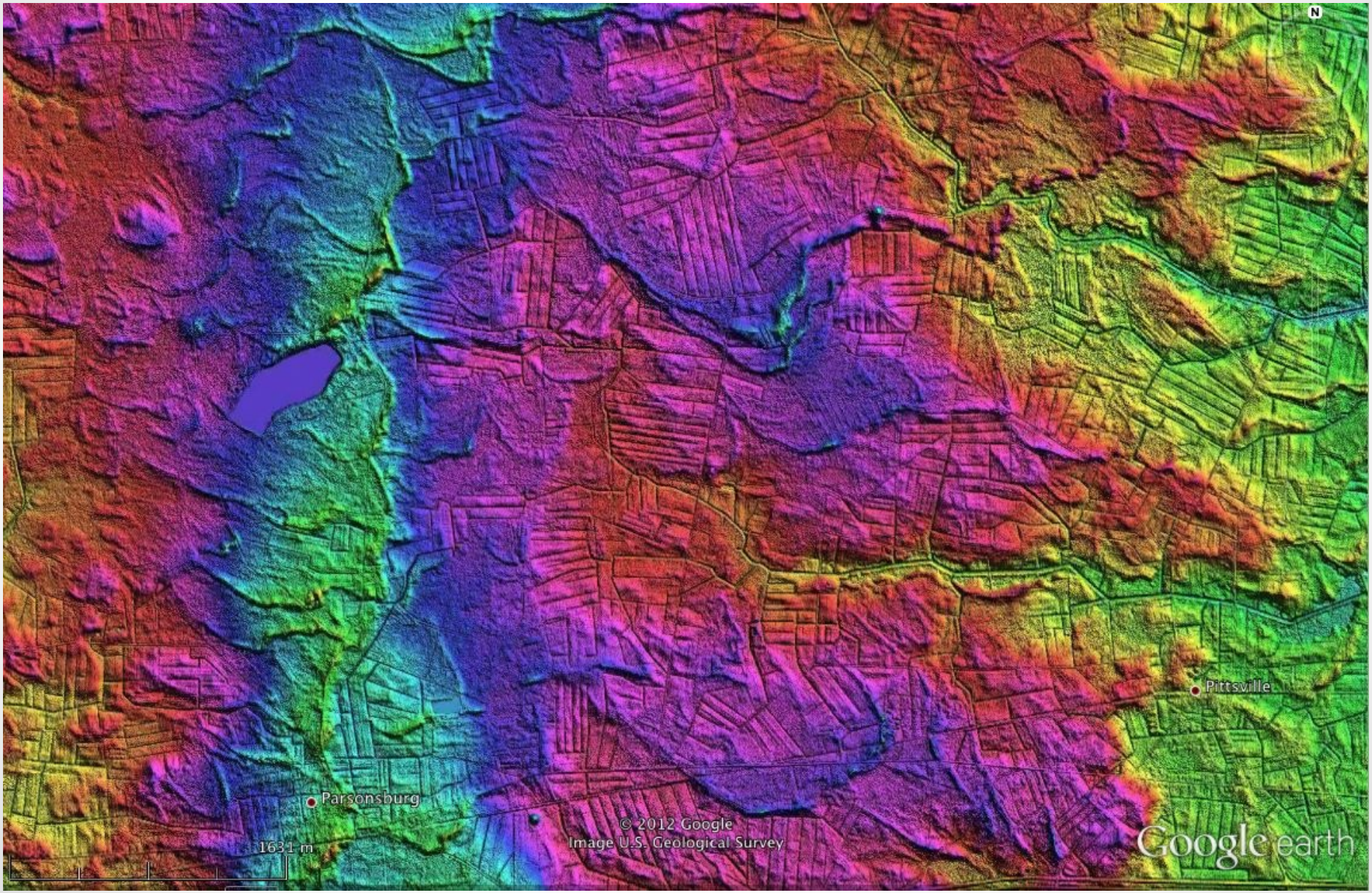
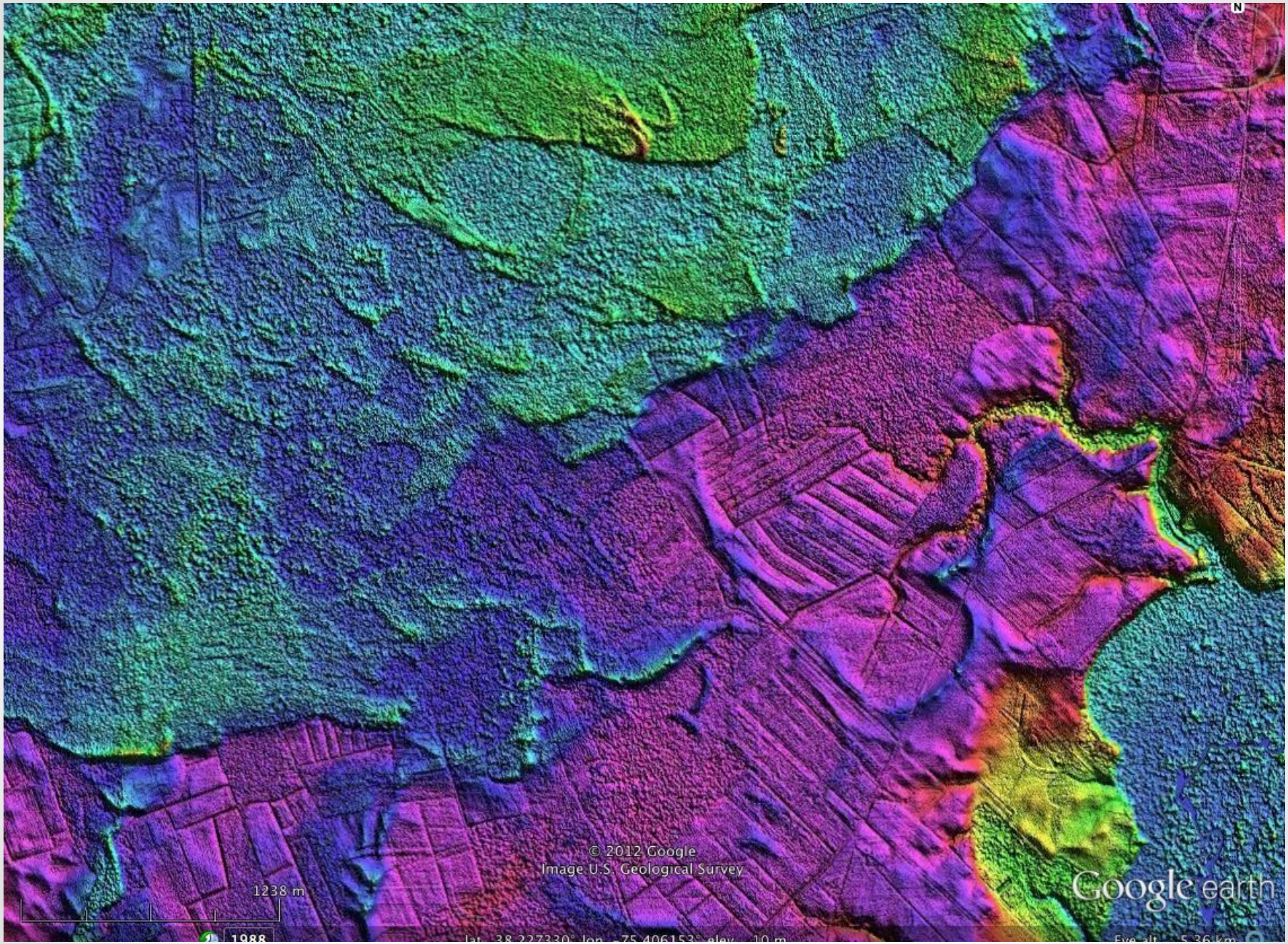
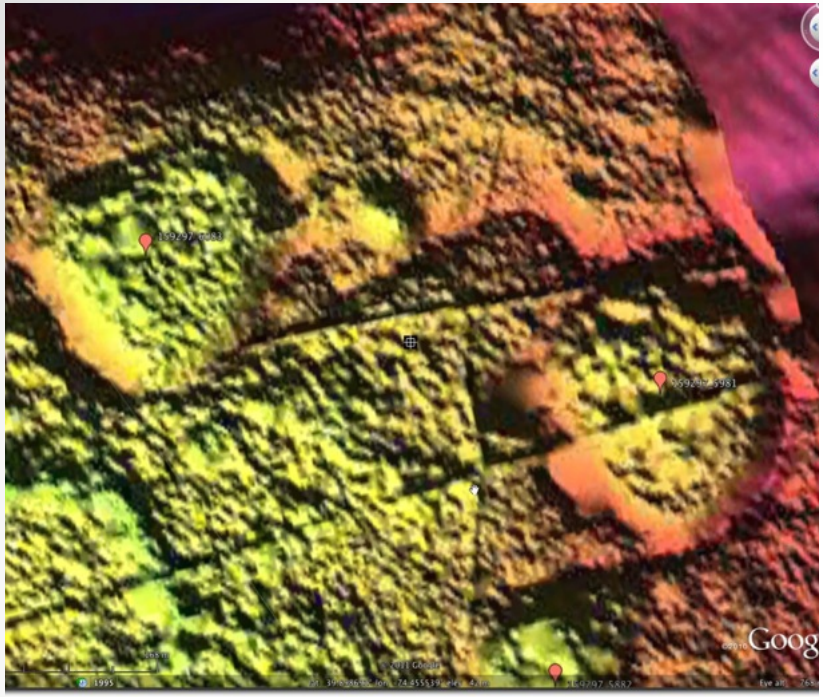
3_1140
1553C_1038
Laurel Grove Rd
© 2011 Google
Image U.S. Geological Survey
©2010 Google

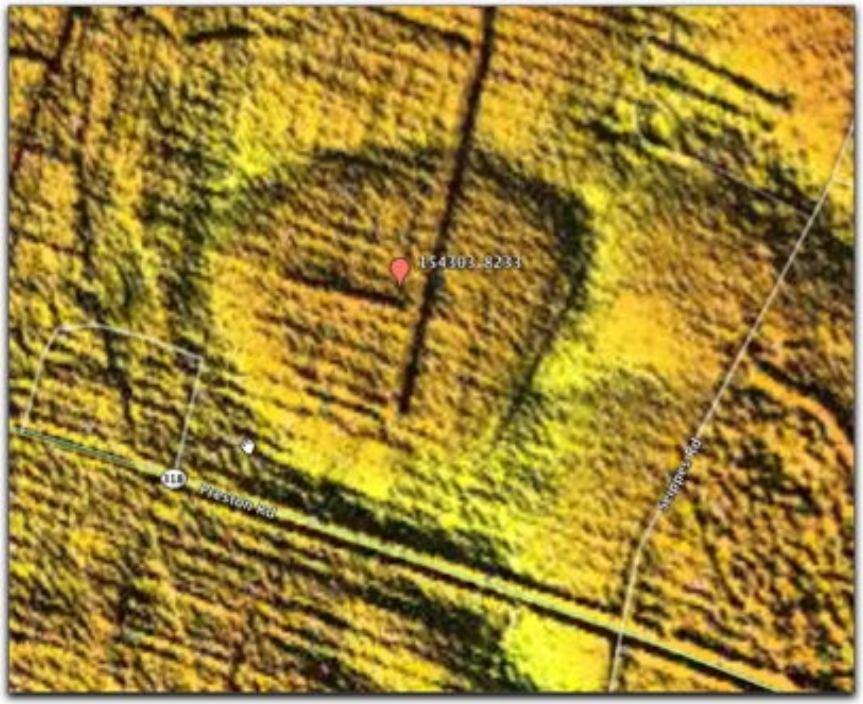

3/25/1995
1995
2010
155303_1521
155303_1523
Opossum Hill Rd
Stone Corner Rd
© 2011 Google
Image U.S. Geological Survey
©2010 Google
nd other items in the 3D viewer

Sand Sheet


N
Pittsville
Parsonsburg
1631 m
© 2012 Google
Image U.S. Geological Survey
Google earth


N
© 2012 Google
Image U.S. Geological Survey
1238 m
Google earth

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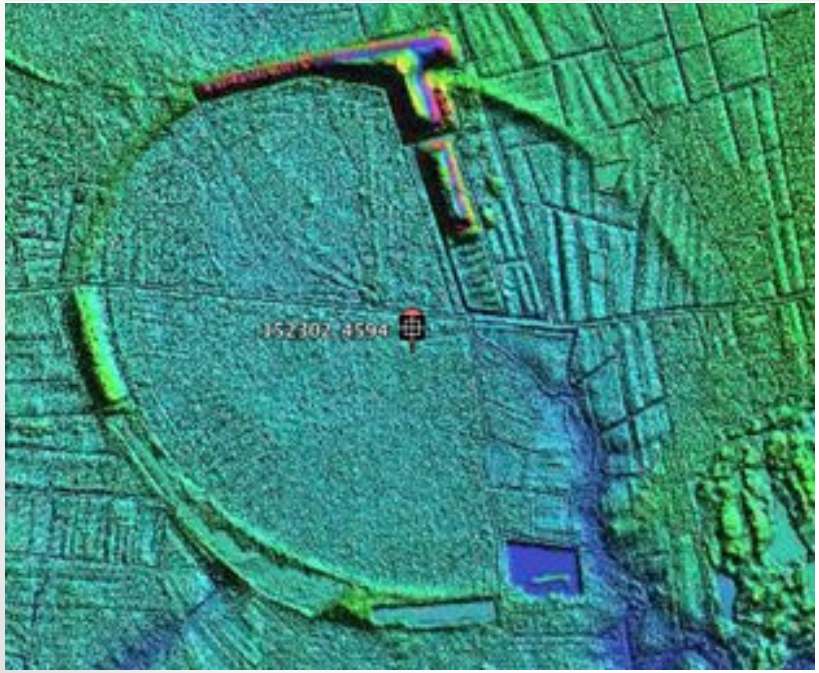
Preston Rd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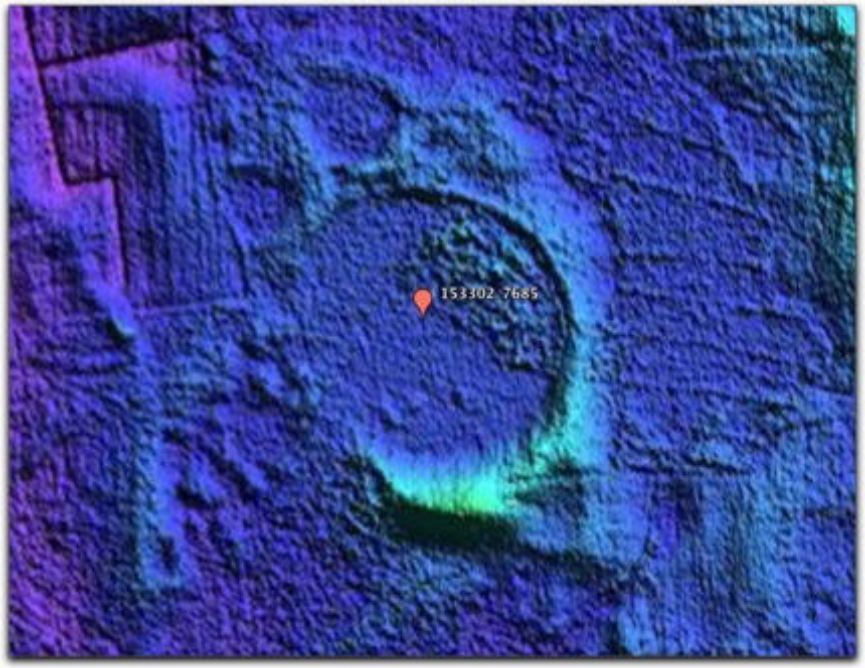
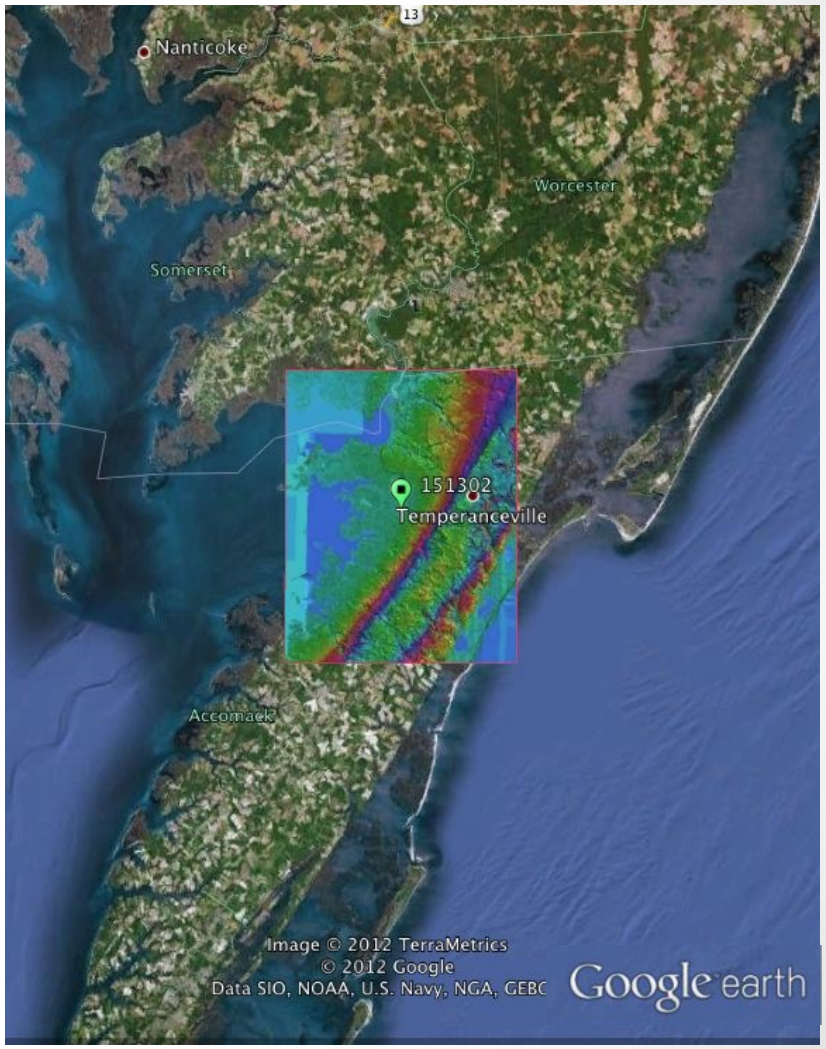
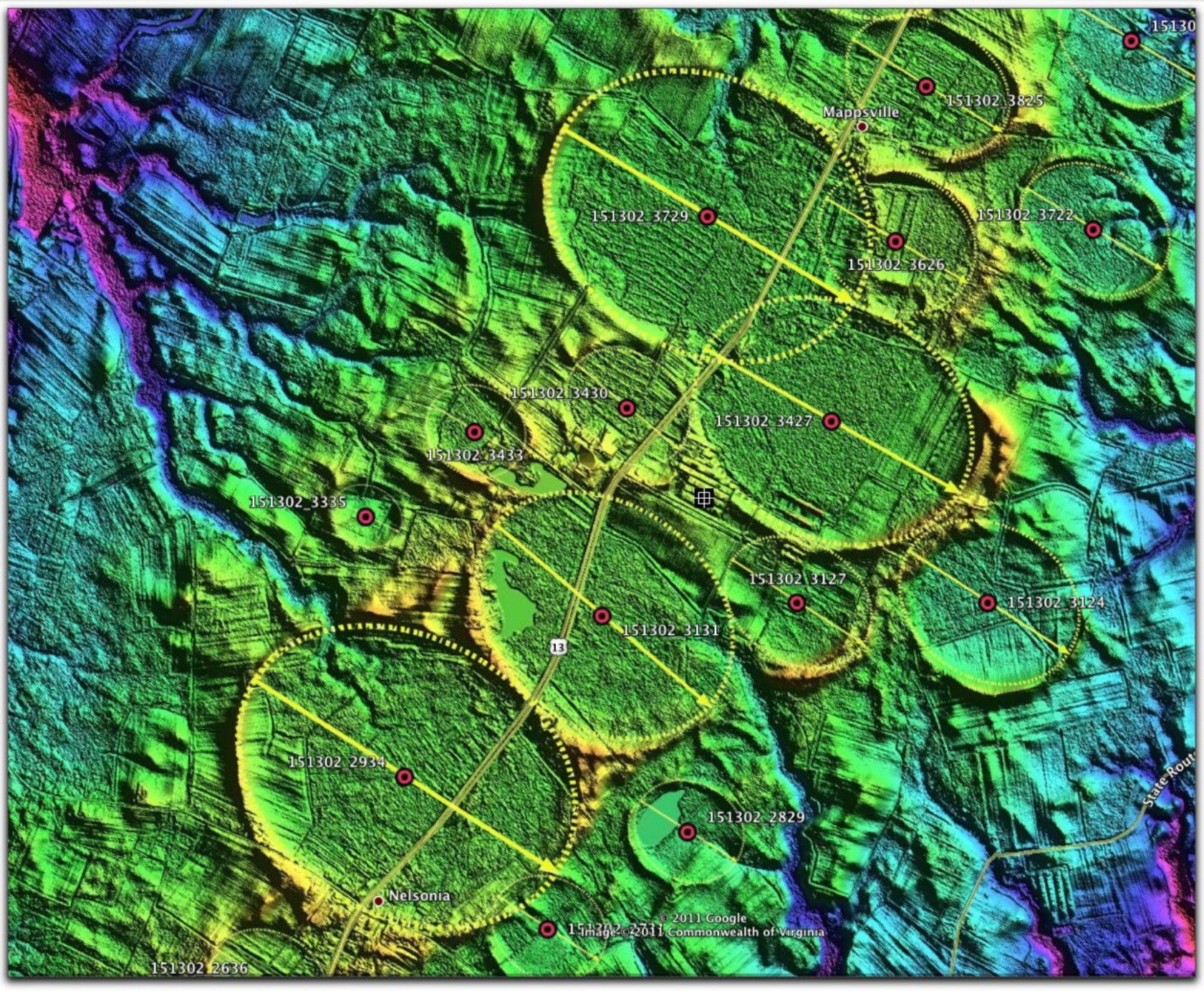

153302.7685

Octant 151302

- Chincoteague 100k Quad
- Eastern shore MD/VA line
- "Oval" Planform
- 227 bays measured
- Mean Bearing 121°
- Std dev 2.1°




Mappsville
13
Nelsonia
© 2011 Google
Image © 2011 Commonwealth of Virginia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151302_3825
Mappsville
151302_3729
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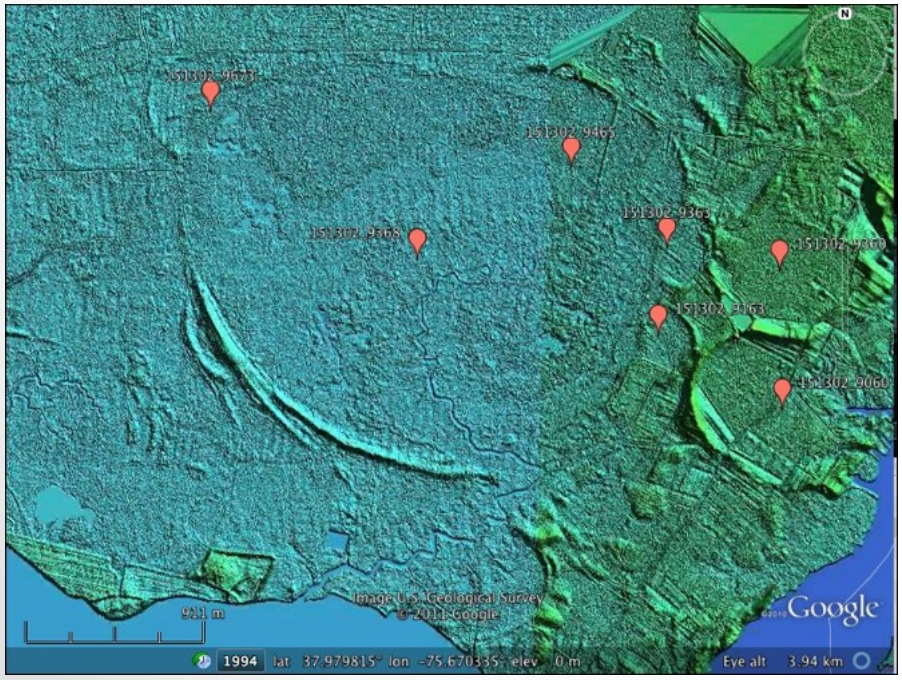
151302_3335
151302_3127
151302_3124
151302_3131
13
151302_2934
151302_2829
Nelsonia
© 2011 Google
Image © 2011 Commonwealth of Virginia
151302_2636


150302_1797
150302_1795
150302_1696
150302_1698
150302_1597
150302_1498
150302_1497
376 m
© 2011 Google
Image © 2011 Commonwealth of Virginia
Google
1994 lat 37.539563° lon -75.745637° elev 2 m
Eye alt 1.63 km


1513103_1809
1513103_1308
Image © 2011 DigitalGlobe
824 m
© 2011 Google
Image © 2011 Commonwealth of Virginia
Google
1994 lat 37.789488° lon -75.769897° elev 0 m
Eye alt 3.52 km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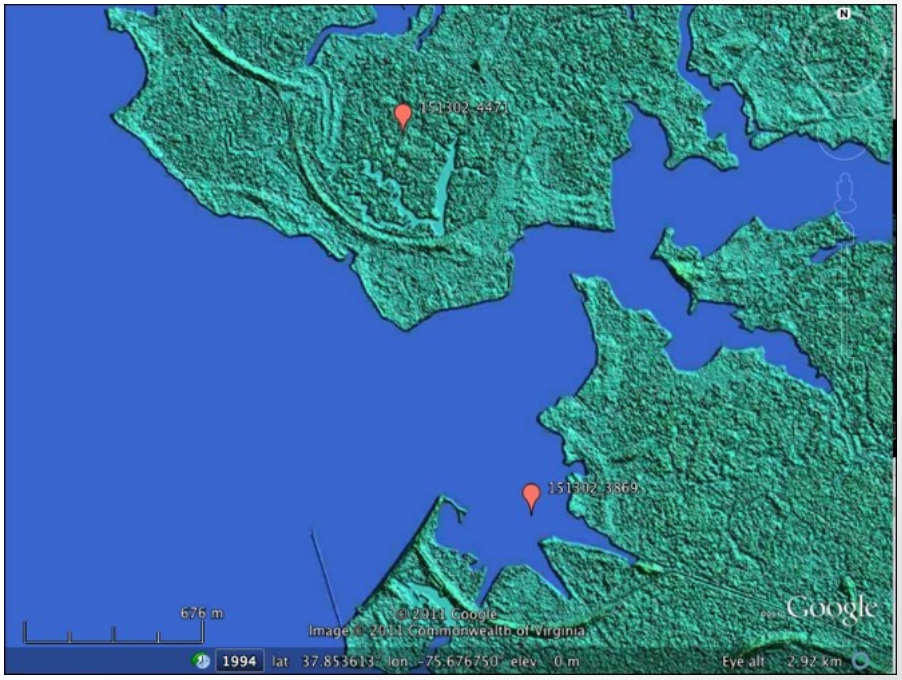
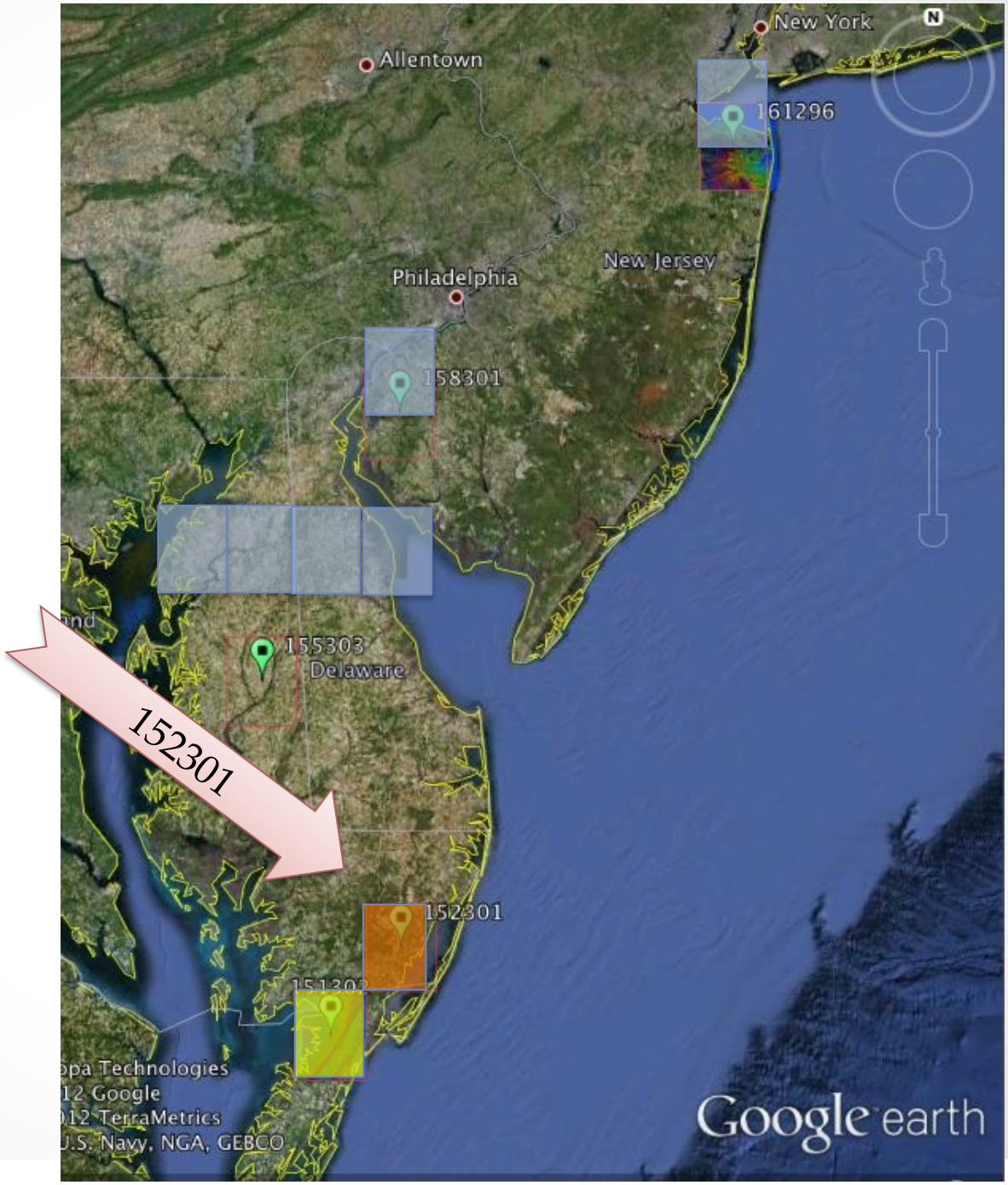
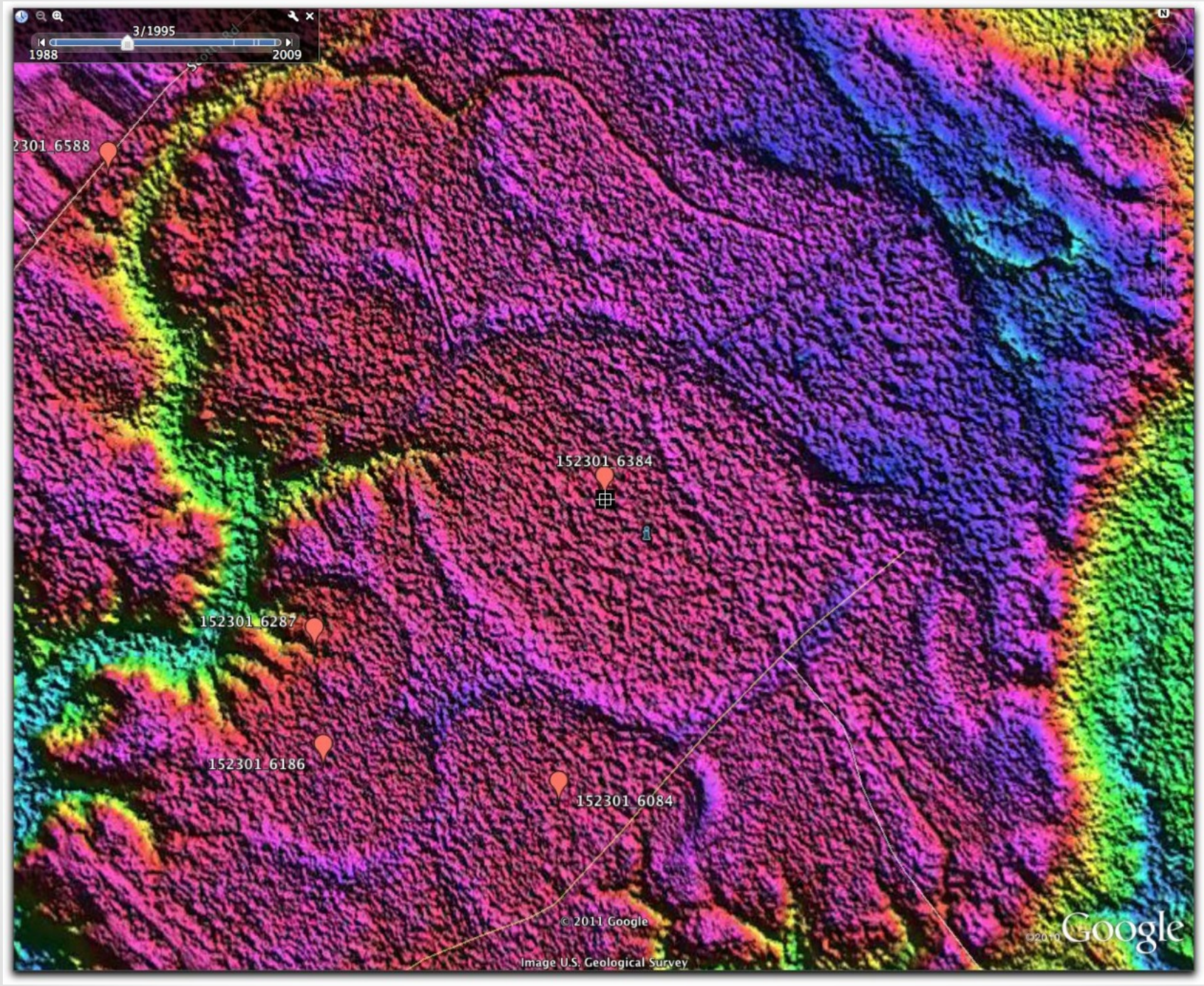
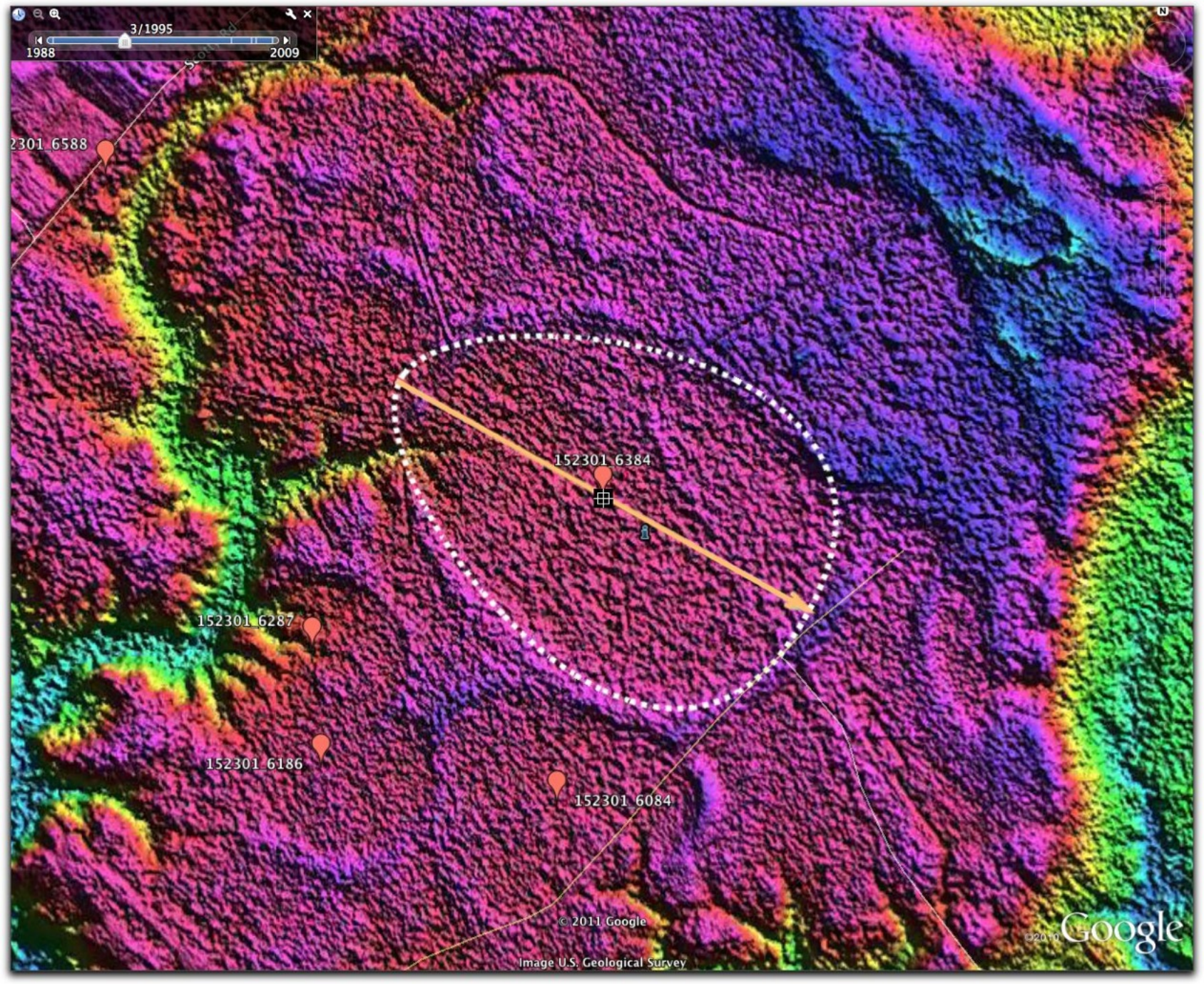
151302_9465
151302_9363
151302_9368
151302_9063
151302_9060
Image U.S. Geological Survey
© 2011 Google
921 m
Google
1994 lat 37.979815° lon -75.670335° elev 0 m
Eye alt 3.94 km


151302_4472
151302_3869
676 m
© 2011 Google
Image © 2011 Commonwealth of Virginia
Google
1994 lat 37.853613° lon -75.676750° elev 0 m
Eye alt 2.92 km

Octant 152301




3/1995
1988
2009
2301 6588
152301 6384
152301 6287
152301 6186
152301 6084
© 2011 Google
Image U.S. Geological Survey
Google


3/1995
1988
2009
2301 6588
152301 6384
152301 6287
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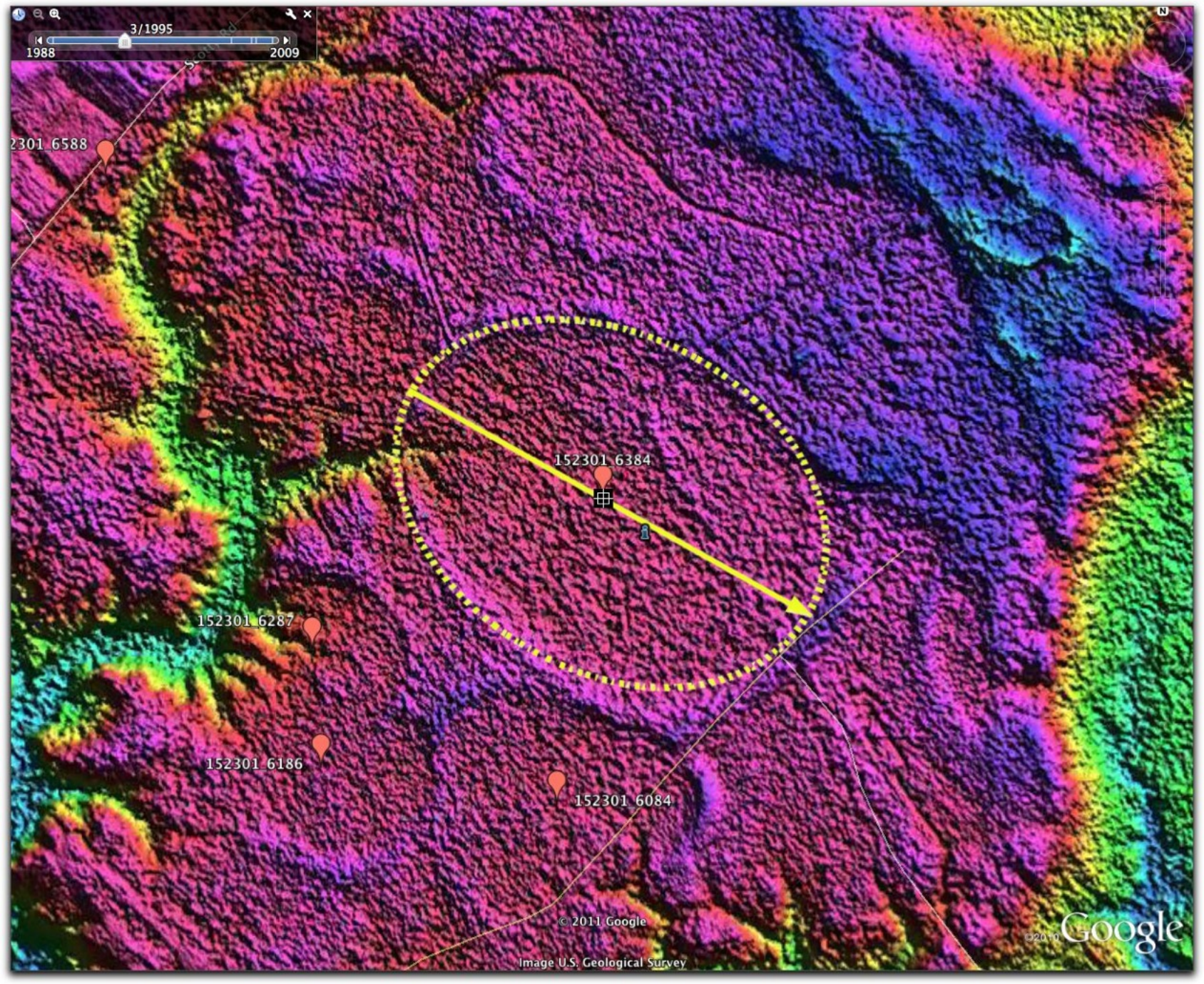
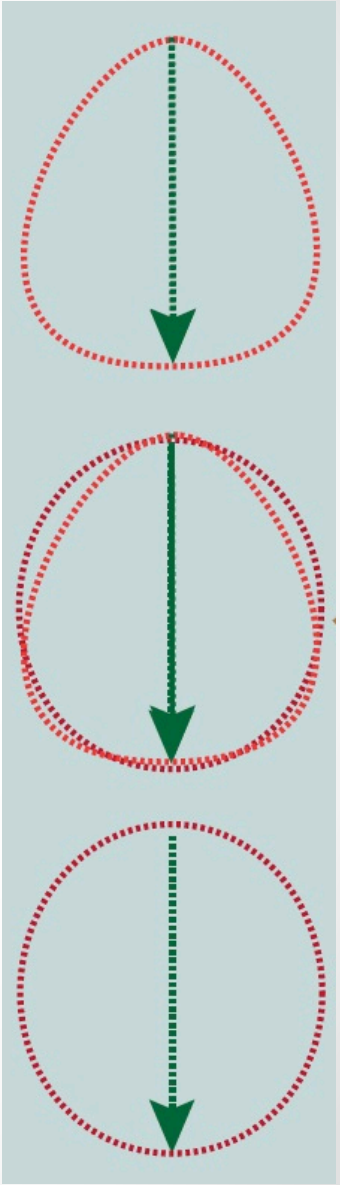
152301 6084
© 2011 Google
Image U.S. Geological Survey
Google


3/1995
1988
2009
2301 6588
152301 6384
152301 6287
152301 6186
152301 6084
© 2011 Google
Image U.S. Geological Survey
Google

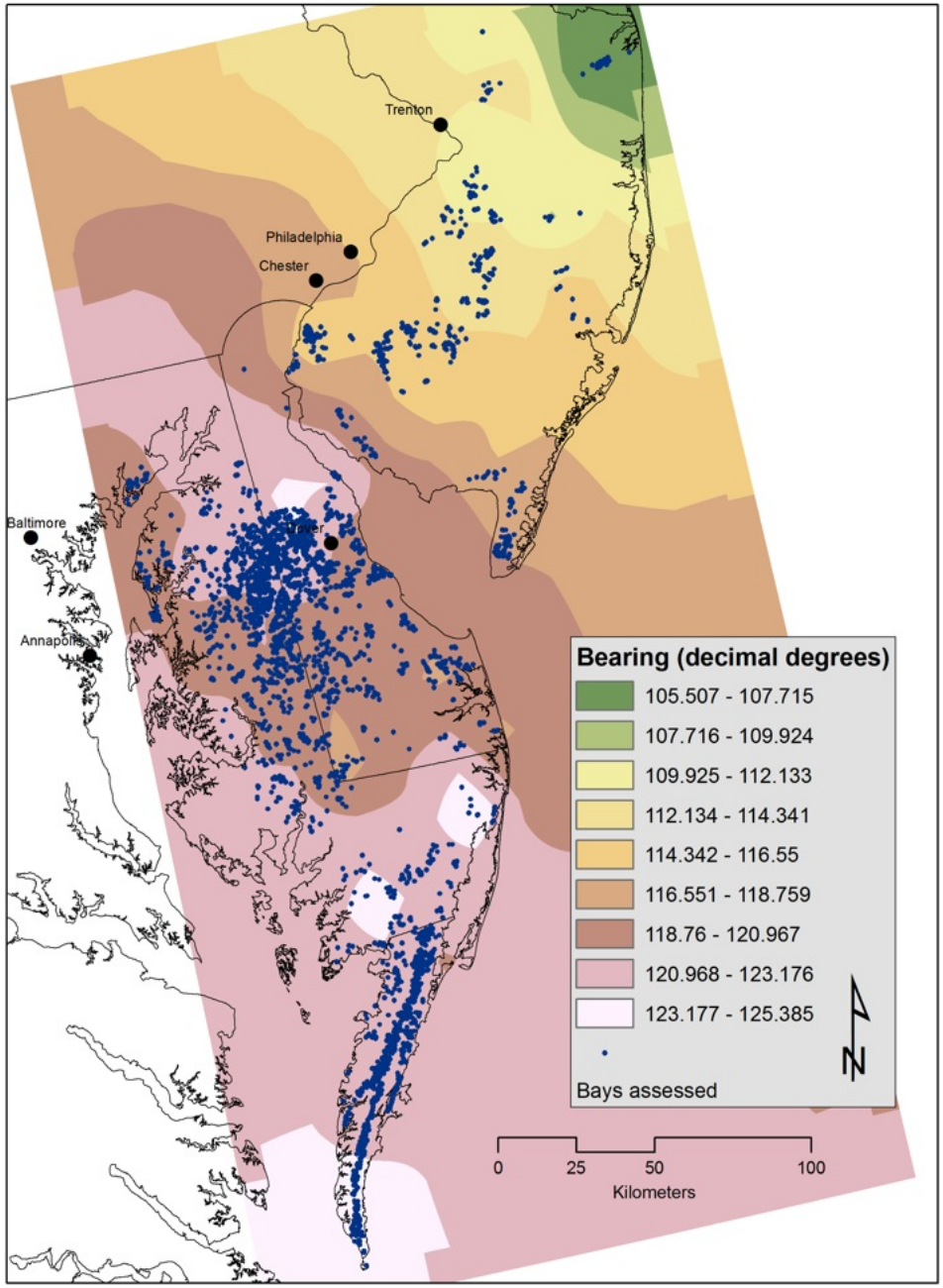
Planform Continuum

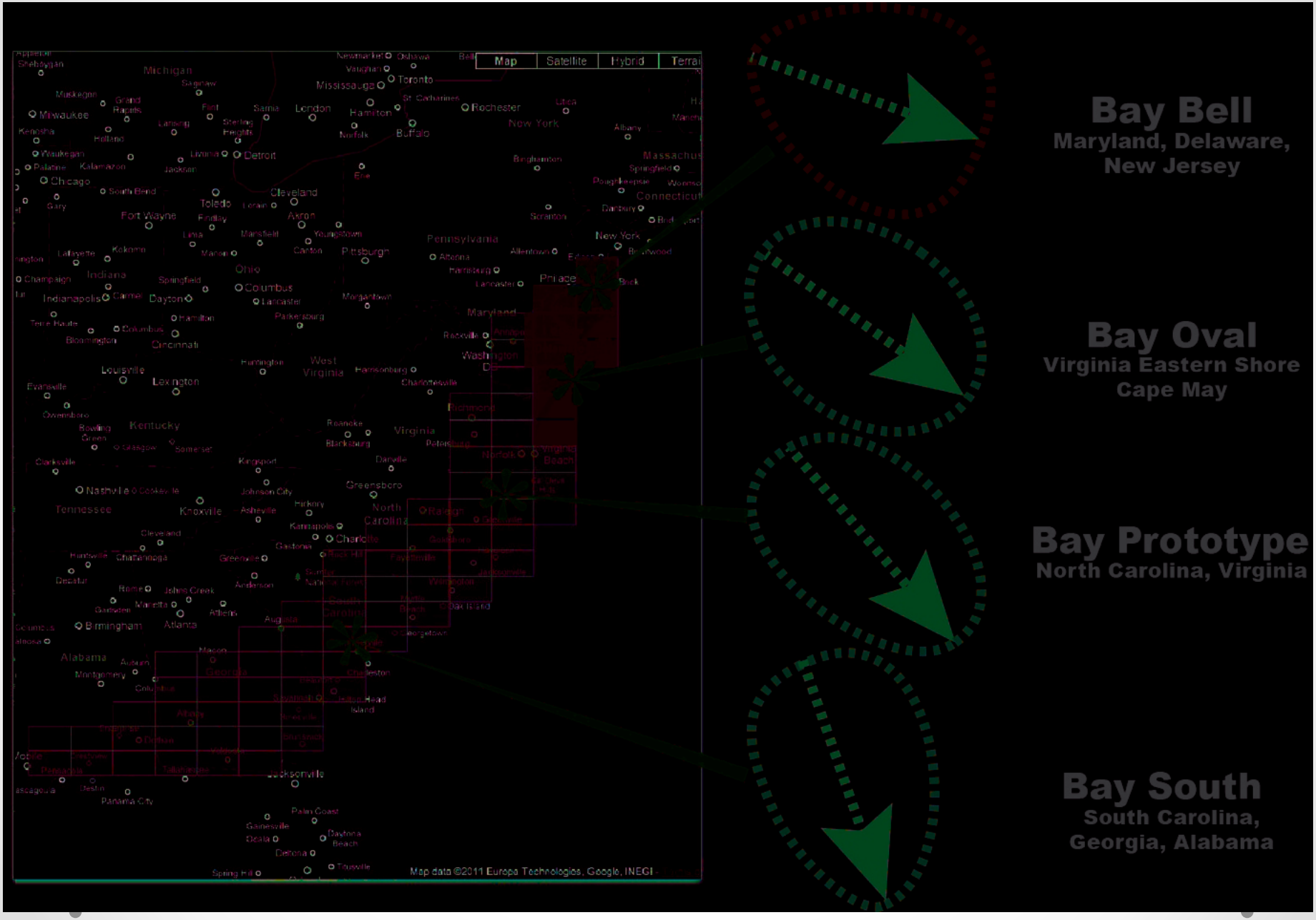
- Carolina bays seen in two Planforms
- Shape changes gradually from one into another
- Is this Continuum a Compelling Argument?
- Can diverse Geomorphologies be Supported?



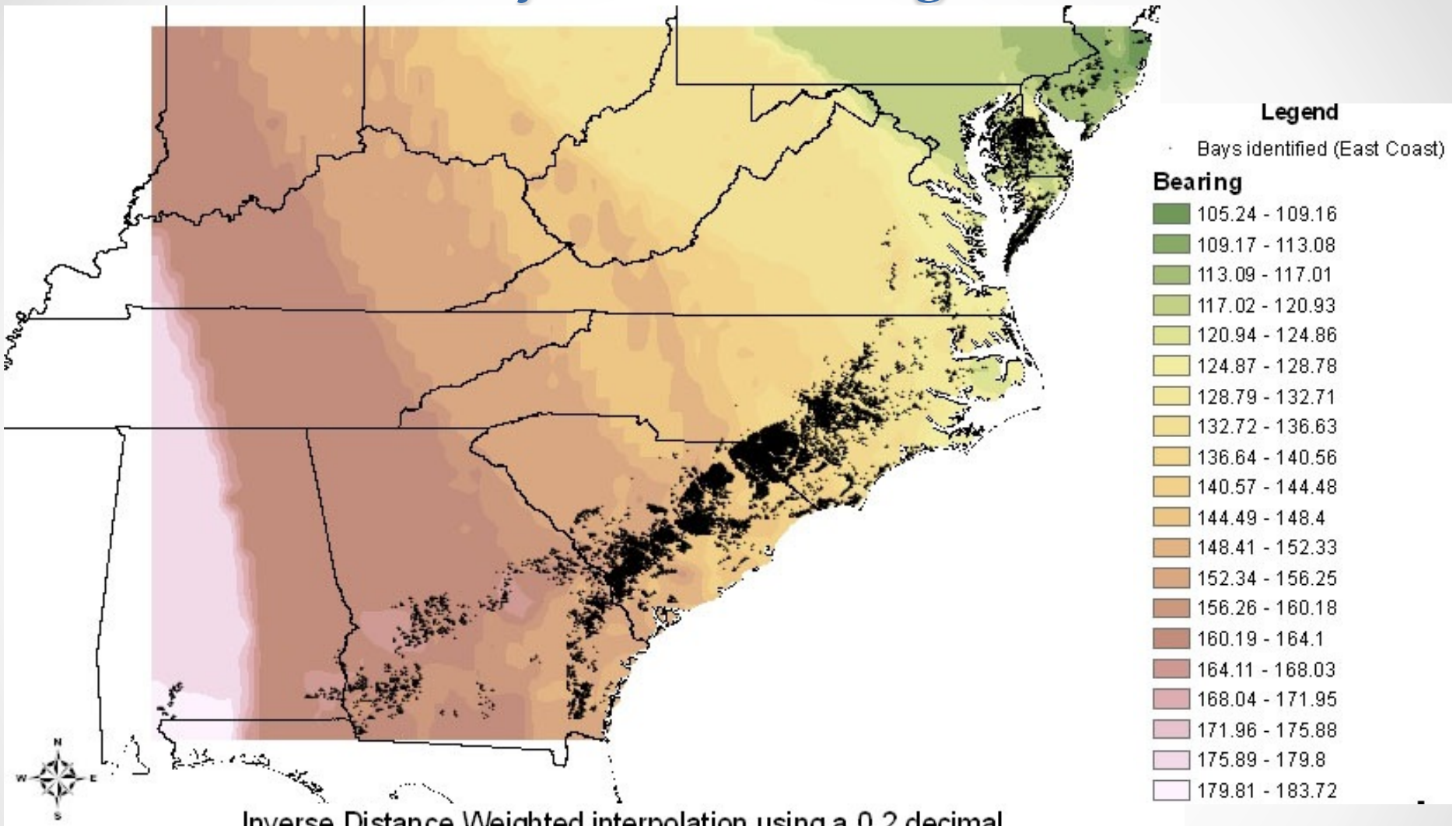
Orientations

Rotates clockwise ~20° from NJ through Eastern Shore



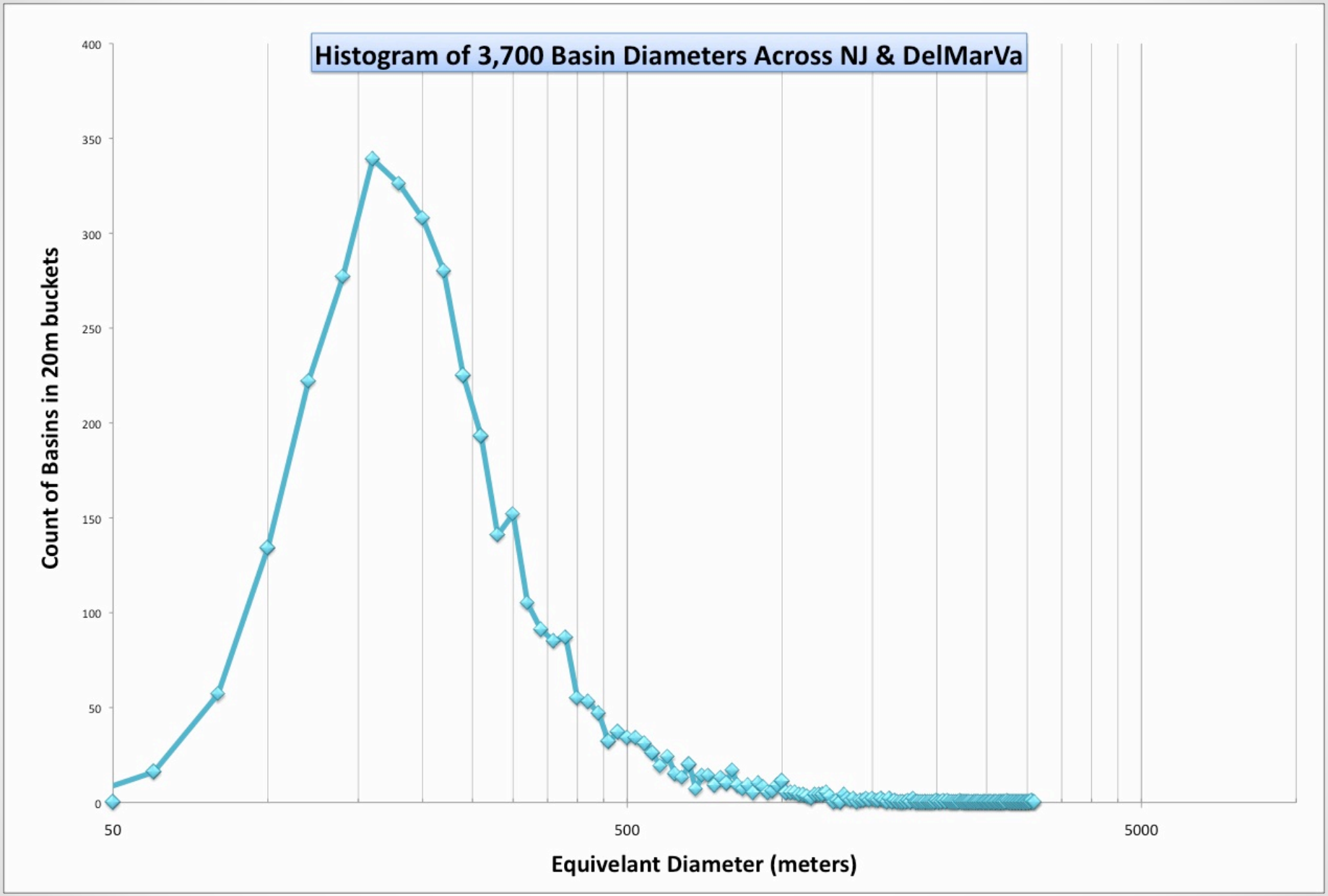

Map
Satellite
Hybrid
Terrain
Map data ©2011 Europa Technologies, Google, INEGI
Bay Bell
Maryland, Delaware,
New Jersey
Bay Oval
Virginia Eastern Shore
Cape May
Bay Prototype
North Carolina, Virginia
Bay South
South Carolina,
Georgia, Alabama

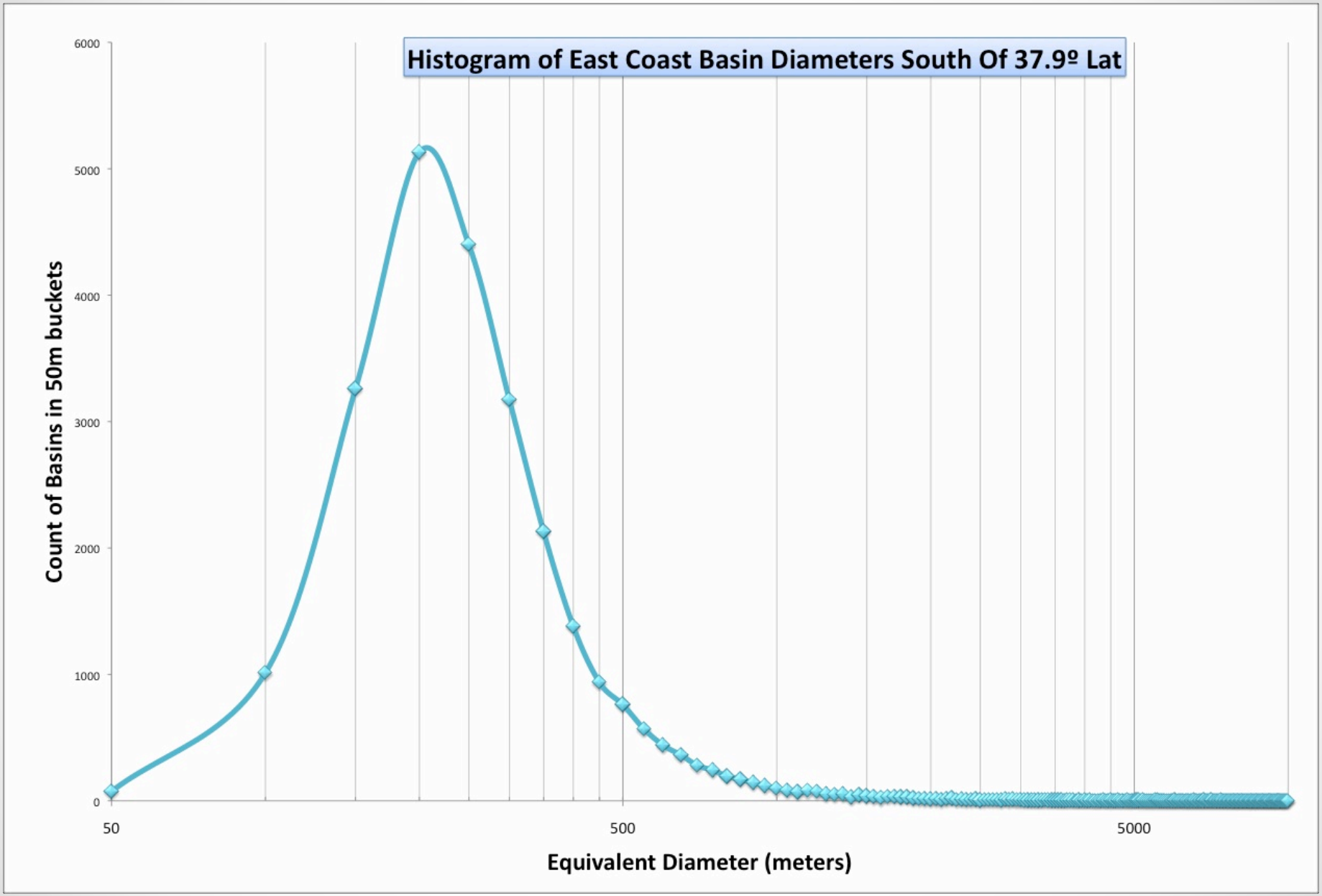
Bays and Bearings



Inverse Distance Weighted interpolation using a 0.2 decimal degree search radius, minimum 3 points, and output grid size of 0.2 decimal degrees.

- Clockwise Rotation of ~75° from NJ through Alabama


Histogram of 3,700 Basin Diameters Across NJ & DelMarVa
Count of Basins in 20m buckets
400
350
300
250
200
150
100
50
0
50
500
5000
Equivelant Diameter (meters)


Histogram of East Coast Basin Diameters South Of 37.9º Lat
Count of Basins in 50m buckets
6000
5000
4000
3000
2000
1000
0
50
500
5000
Equivalent Diameter (meters)

Conclusions

- "Carolina bays" related to "Coastal Ponds"
  - Slightly Different planforms which change on a continuum
  - Not as robustly cookie-cutter as more southerly bays
  - Few multi-km bays
  - Lower eccentricity
- Orientation Seen as NW to SE
- Demonstrate Systematic-by-Latitude Rotation
  - 20° Monmouth County to Cape Charles
  - 75° Monmouth County to Alabama
- Size Distribution Log-Normal
  - Identical statistically with distribution of entire 30,000 bay survey

Rasmussen, 1953

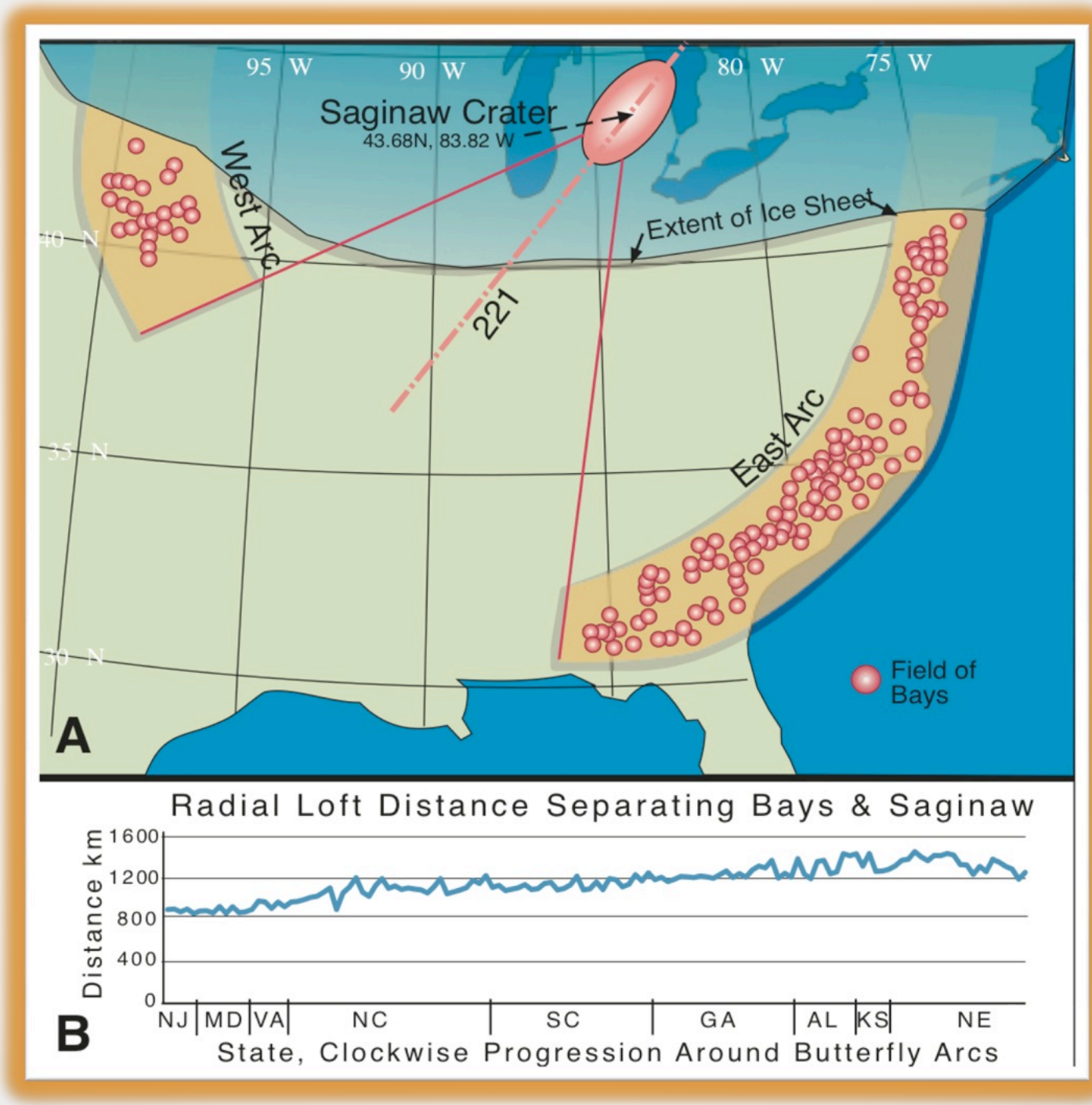
- Wolfe (1953) observed involutions, festoons, and filled wedges in the upper 3-10 feet of sediment in basins
- Proposed as evidence of periglacial action.

"That it may be thereby deduced that the basins were created by periglacial action is a step beyond the evidence presented."

W.C. Rasmussen, 1953, *Periglacial Frost-Thaw Basins in New Jersey: A Discussion*, *The Journal of Geology*, Vol. 61, No. 5

Photo by George Howard


Bubble Wave Front


95 W
90 W
80 W
75 W
Saginaw Crater
43.68N, 83.82 W
West Arc
Extent of Ice Sheet
40 N
221
East Arc
35 N
30 N
Field of Bays
A
Radial Loft Distance Separating Bays & Saginaw
Distance km
1600
1200
800
400
0
NJ
MD
VA
NC
SC
GA
AL
KS
NE
B
State, Clockwise Progression Around Butterfly Arcs