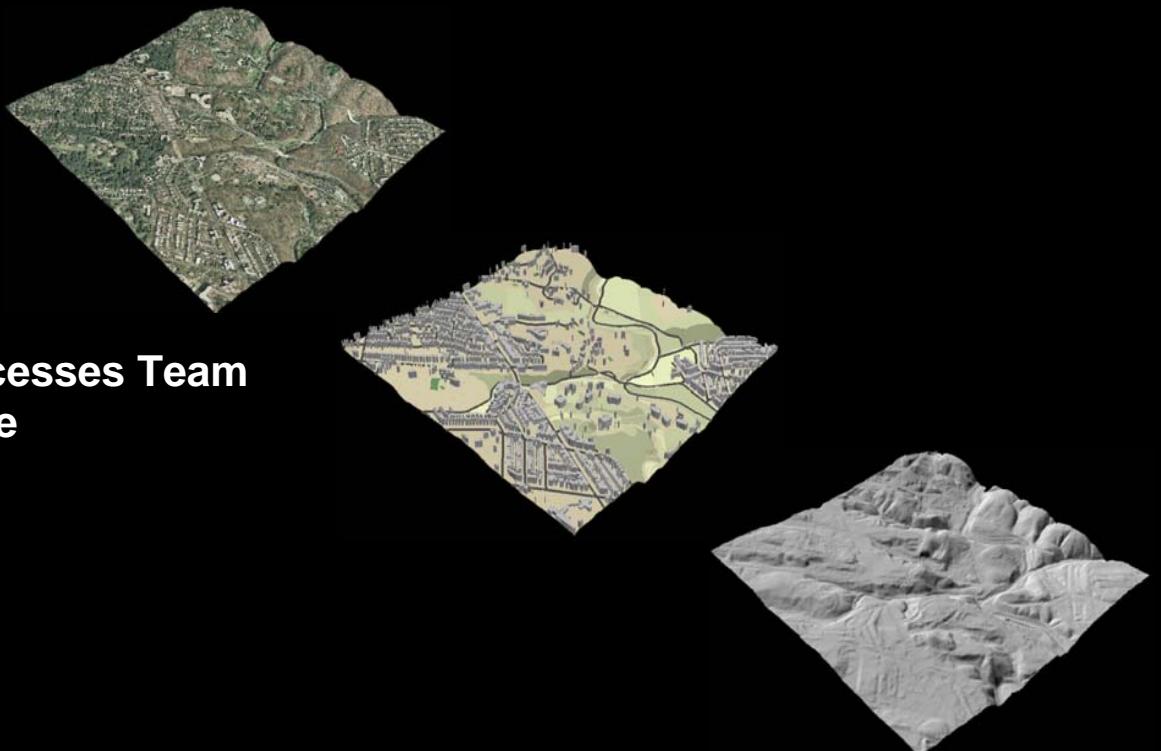




Quantitative Mapping of 3-Dimensional Land Surface Elevation Changes in Washington D.C.

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Reston, Virginia 20192



**U.S. Department of the Interior
U.S. Geological Survey**



Land Surface Elevation Change

Goals:

- ◆ To measure and quantify historical change in orthometric heights due to natural or human induced processes through the creation, processing, and validation of historical and current elevation data.
- ◆ To understand and describe the process under which the changes occur.
- ◆ To analyze what affect the changes have on the landscape.



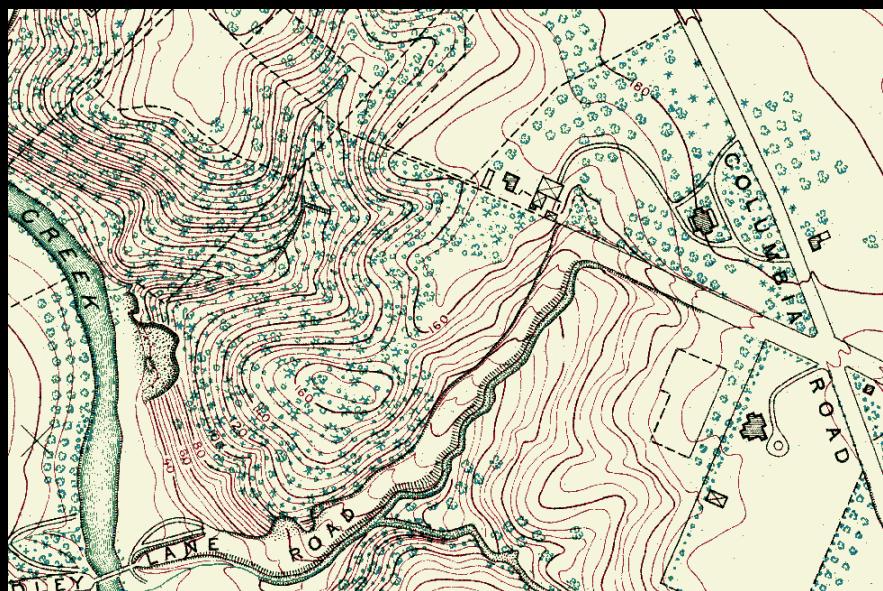
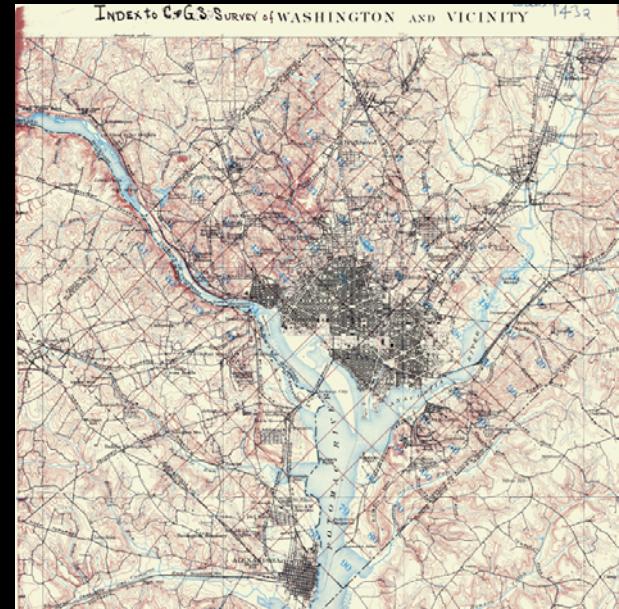
NGS Historical Photo Archives



Land Surface Elevation Change

Washington DC:

- ◆ Map Scale: Historical 1888: 1:4,800
Current 1999: 1:7,200
- ◆ Contour Interval: Historical: 5 feet
Current: 1 meter
- ◆ LSEC Map Cell Size: 5m
- ◆ Expected Vertical Accuracy: ± 4.14 feet





Land Surface Elevation Change

Methodology:

- ◆ Digitize contours, hydrography, and spot elevations from historical and current sources.
- ◆ Create digital elevation models (DEM) using the Topogrid command (ANUDEM algorithm).
- ◆ Compute the surface elevation change:

$$\Delta s = [e_c \pm v] - [e_h \pm v]$$

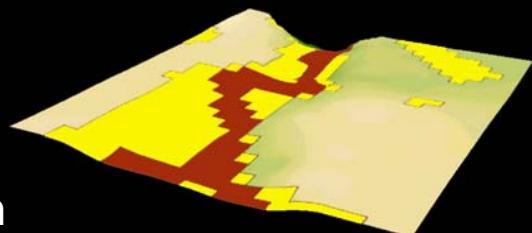
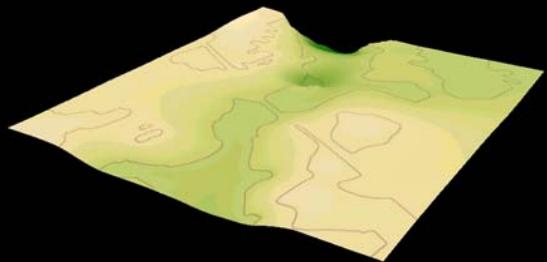
where:

e_h = historical elevation

e_c = current elevation

v = vertical datum adjustment

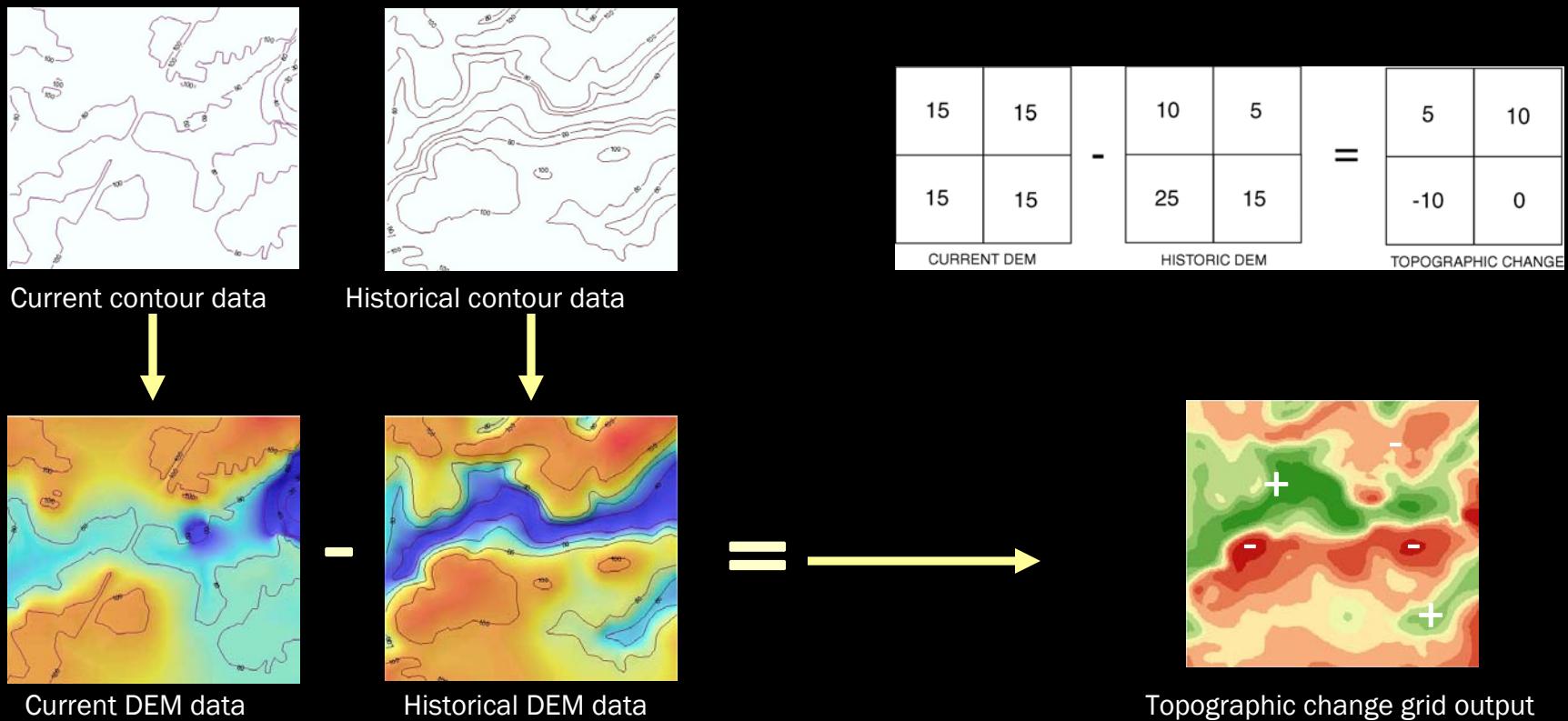
- ◆ Calculate horizontal and vertical accuracy assessment based on GPS and drill hole ground truth data.





Land Surface Elevation Change

Methodology:



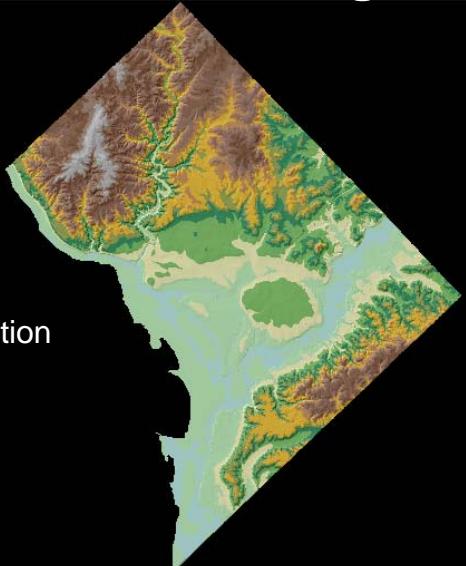
Positive (+) values indicate accretion of material or “fill”.
Negative (-) values indicate removal of material or “cut”.



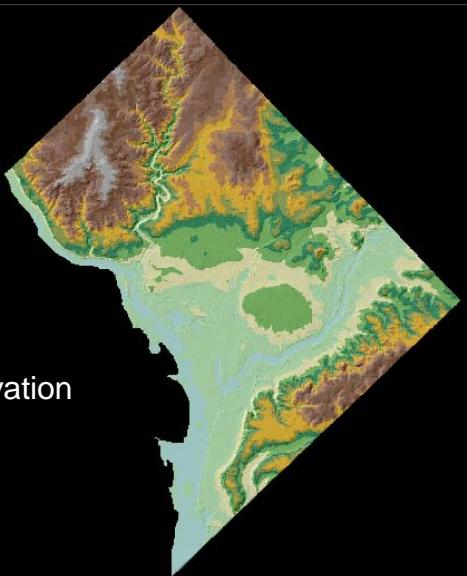
Land Surface Elevation Change

Washington DC: Changes in Elevation

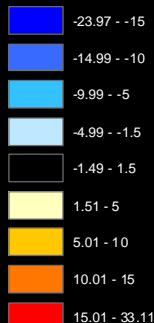
Surface Elevation
1888



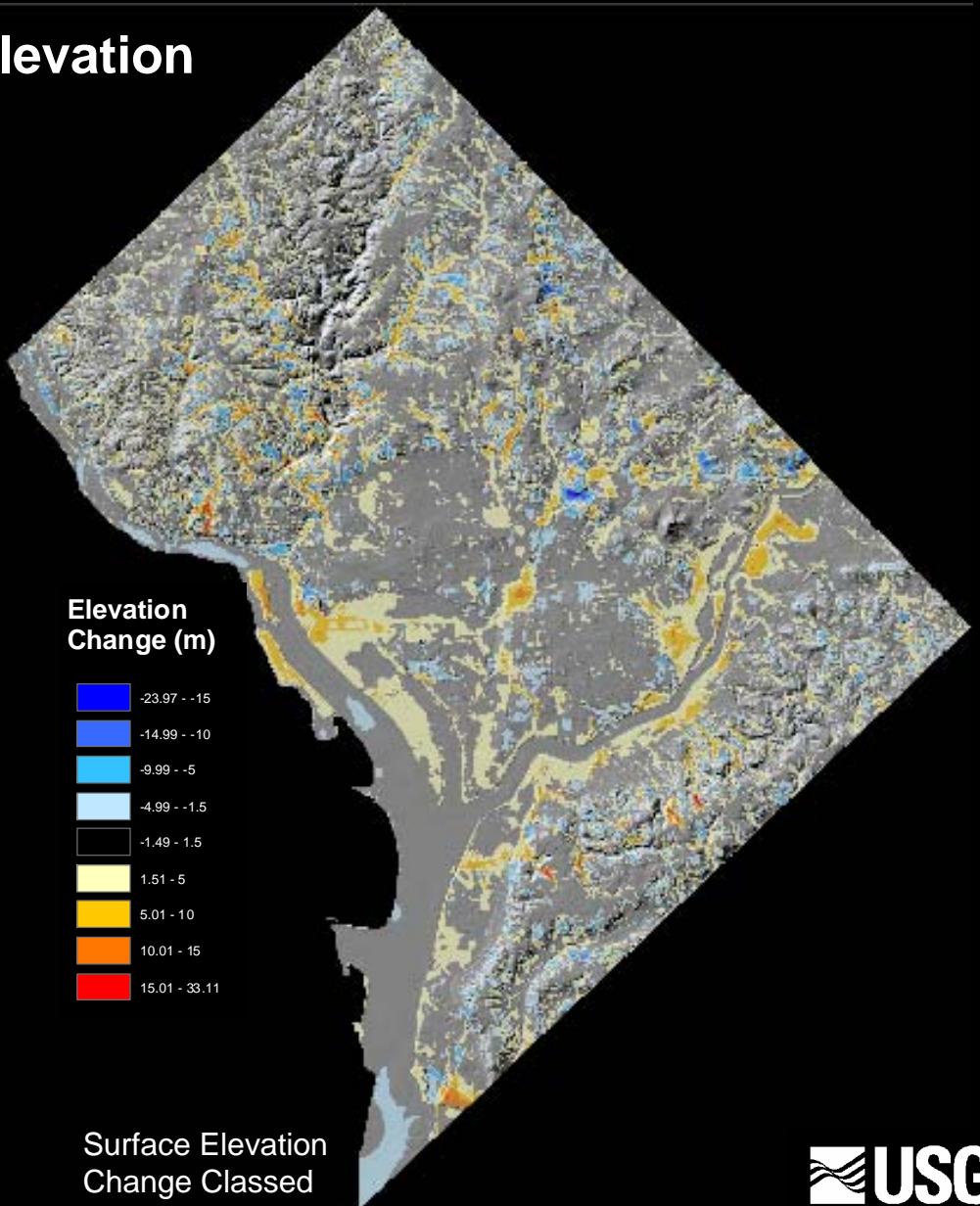
Surface Elevation
1999



Elevation
Change (m)



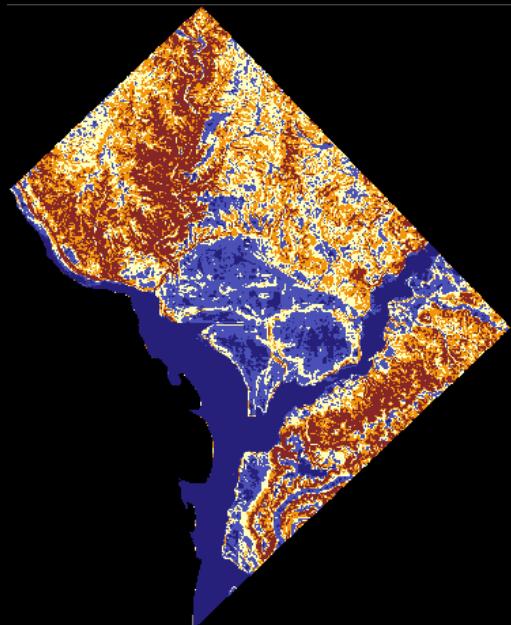
Surface Elevation
Change Classed



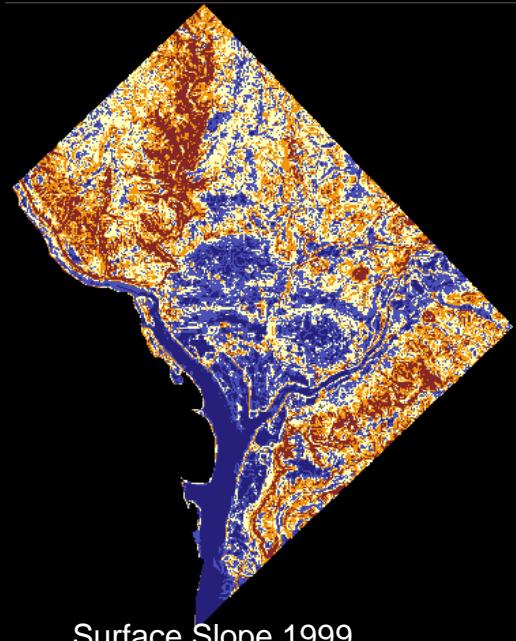


Land Surface Elevation Change

Washington DC: Changes in Slope

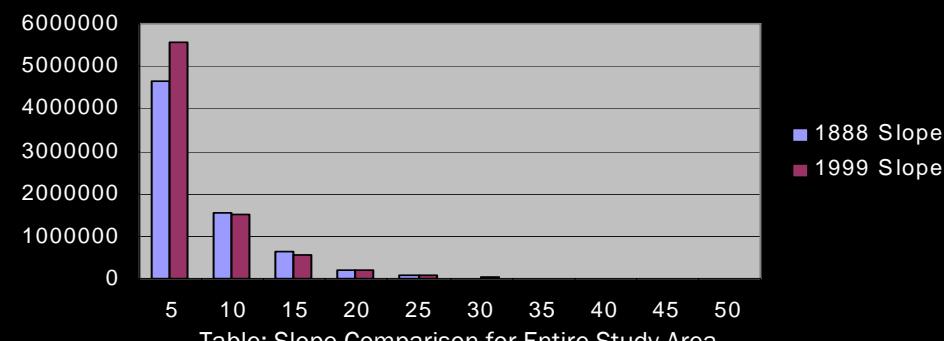


Surface Slope 1888



Surface Slope 1999

Slope Comparison

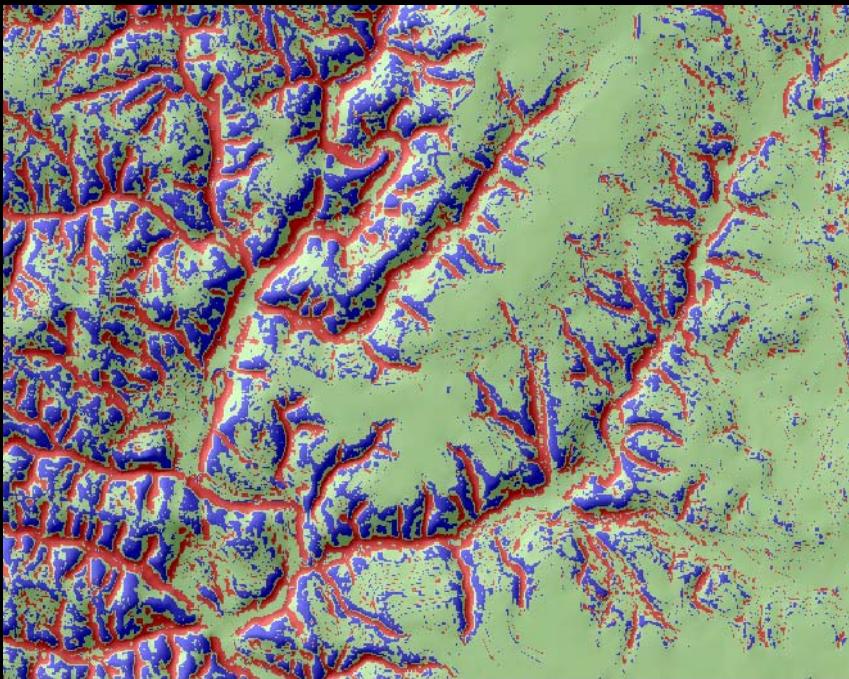




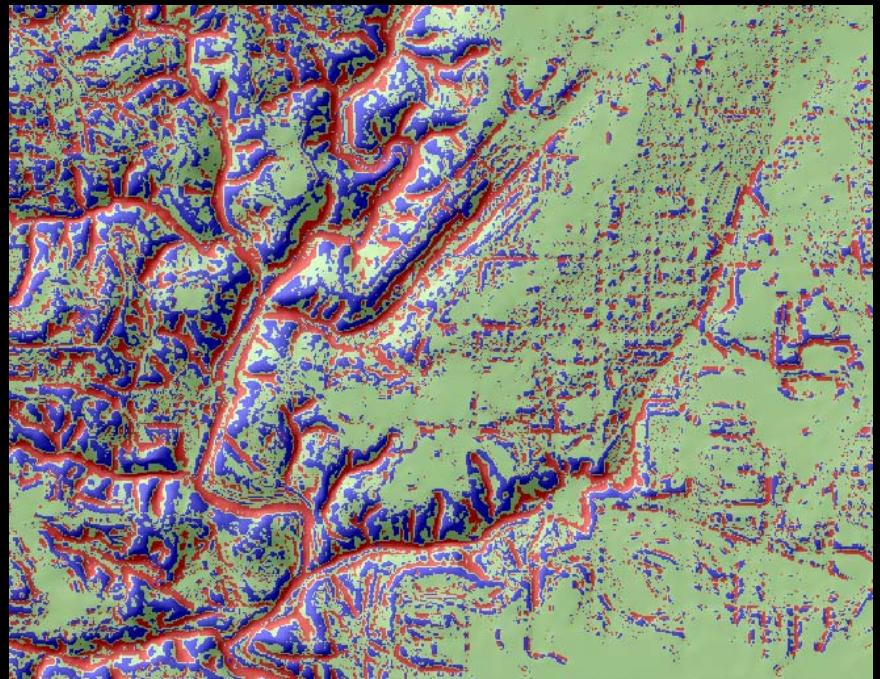
Land Surface Elevation Change

Washington DC: Changes in Curvature

Surface Curvature 1888



Surface Curvature 1999

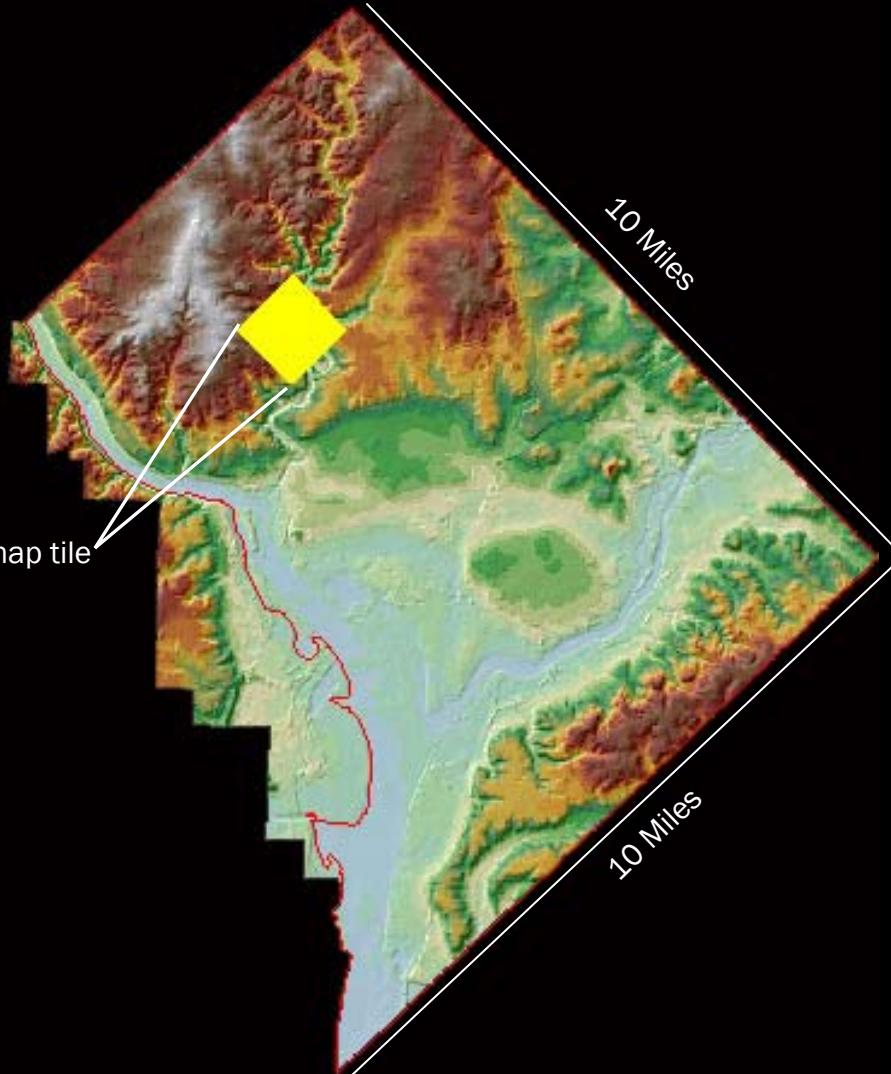
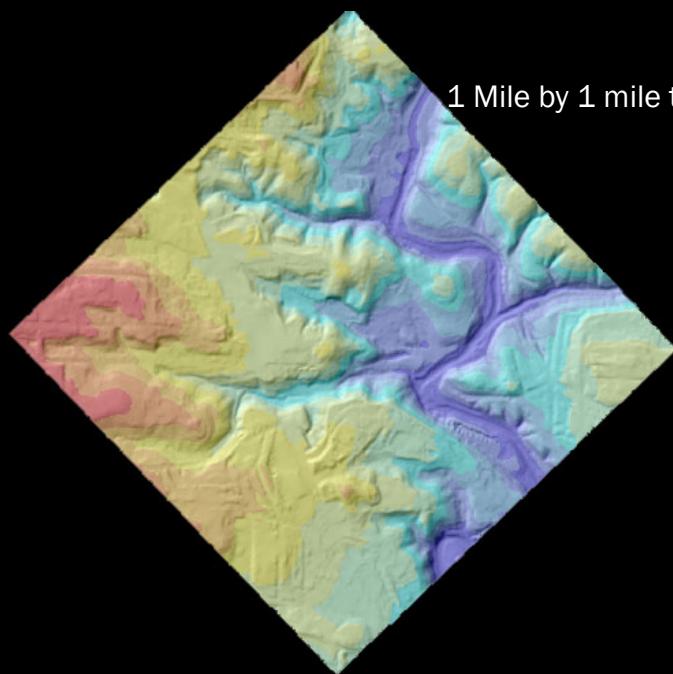




Land Surface Elevation Change

Washington DC:

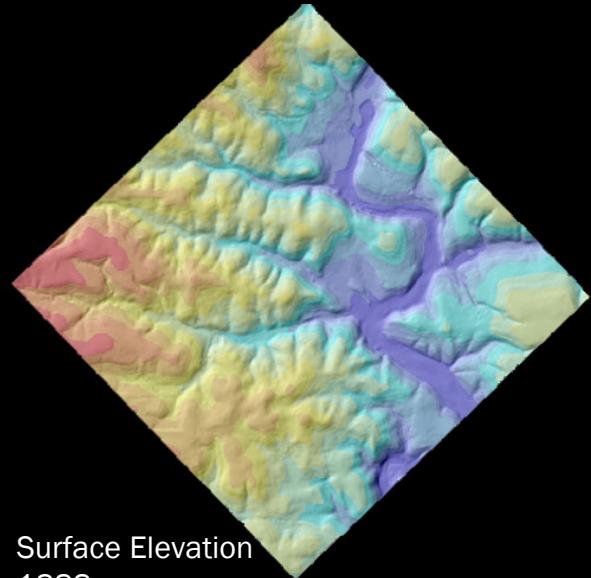
◆ Connecticut Avenue Test Area



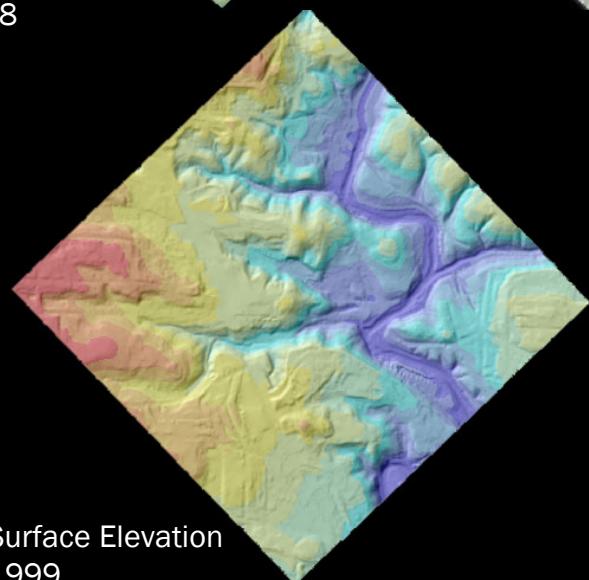


Land Surface Elevation Change

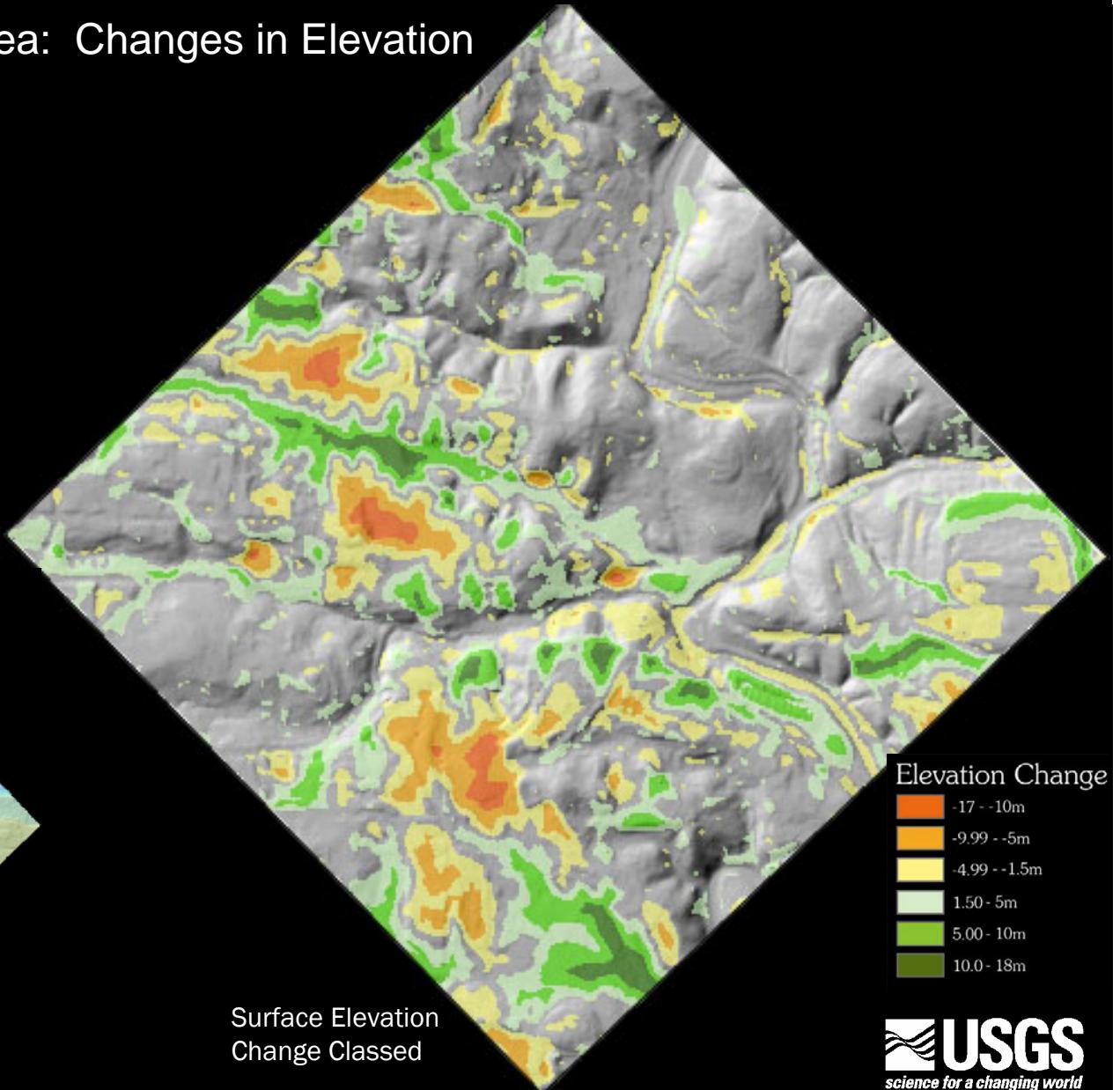
Connecticut Avenue Test Area: Changes in Elevation



Surface Elevation
1888



Surface Elevation
1999

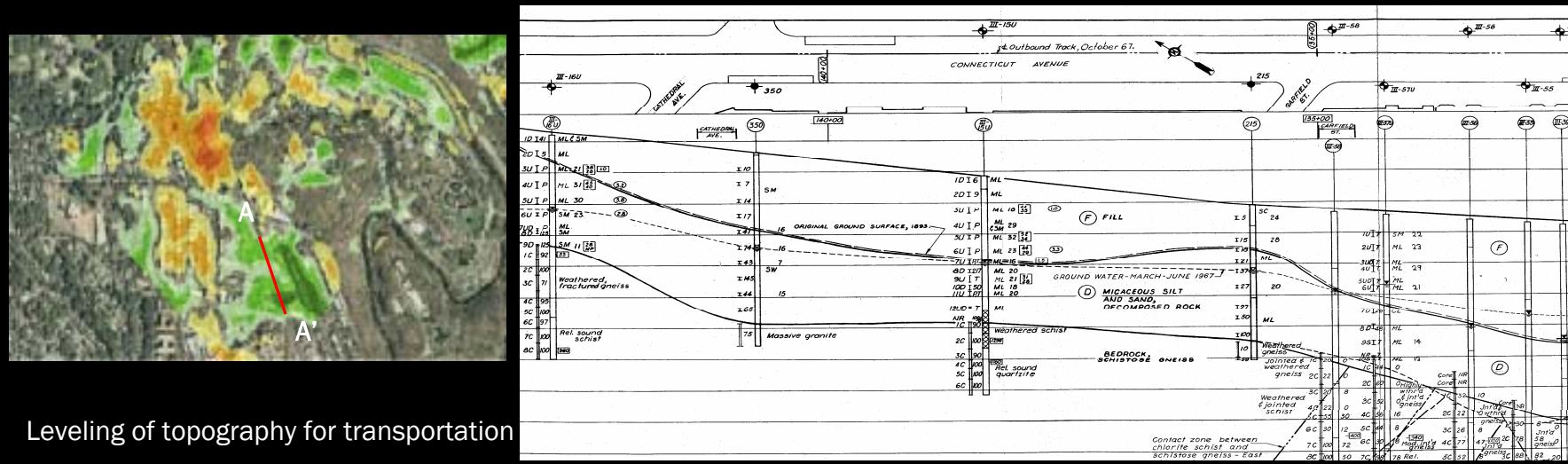
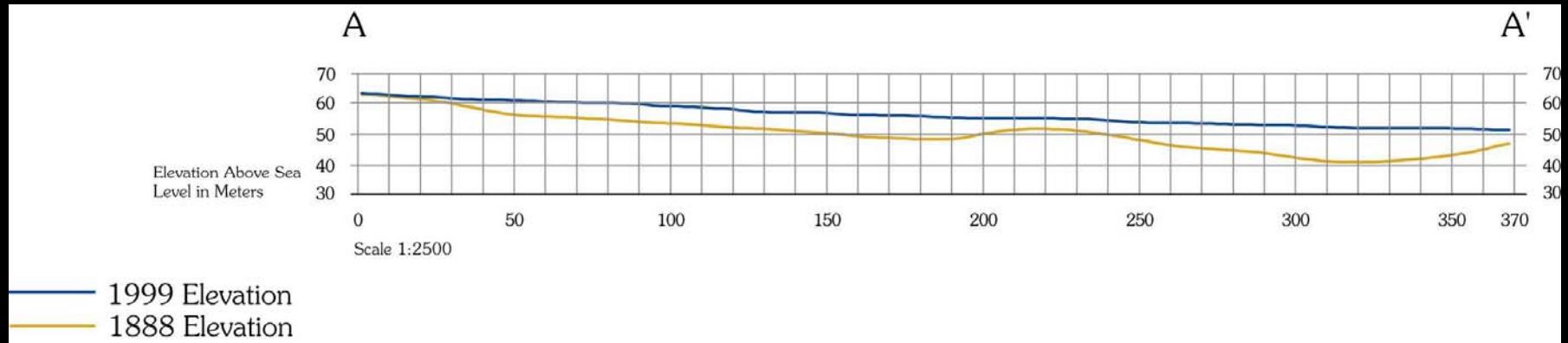




Land Surface Elevation Change

Washington DC:

- ◆ Topographic profiles along Connecticut Ave.

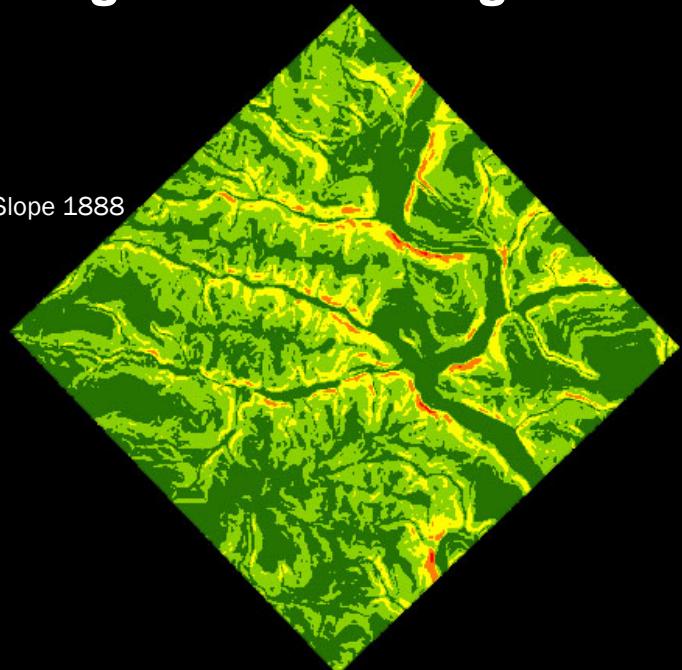




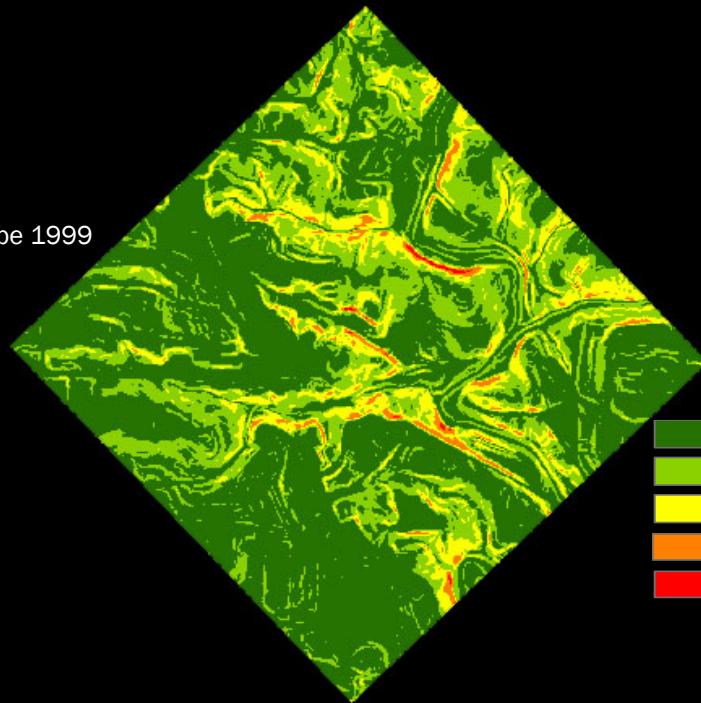
Land Surface Elevation Change

Washington DC: Changes in Slope

Surface Slope 1888

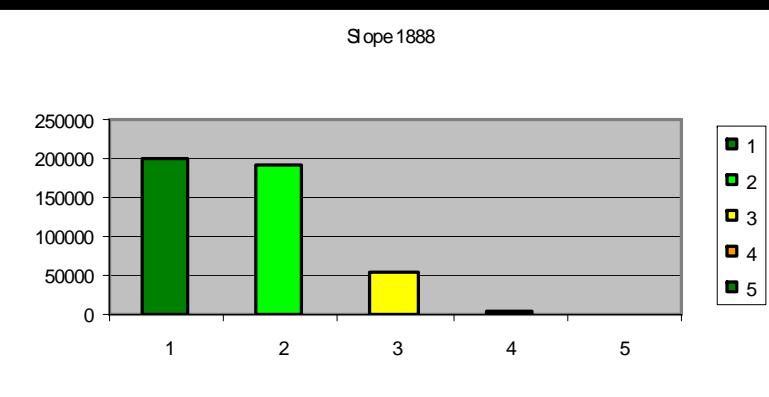


Surface Slope 1999

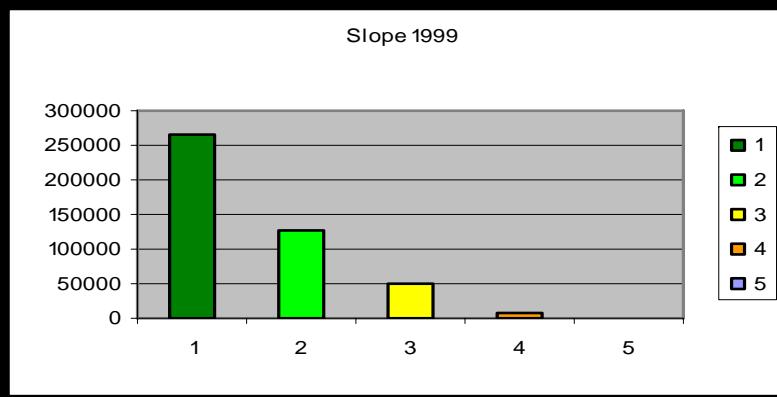


0-10 degrees
10-20 degrees
20-30 degrees
30-40 degrees
40 + degrees

Slope 1888



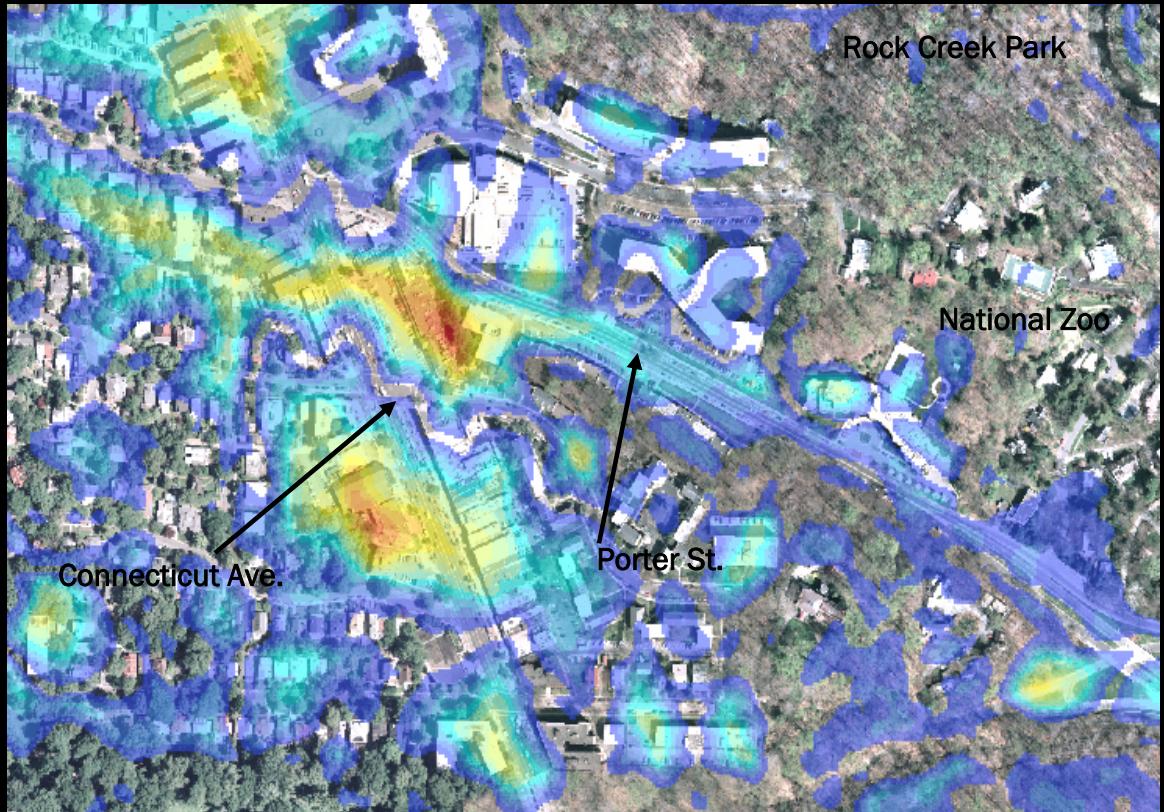
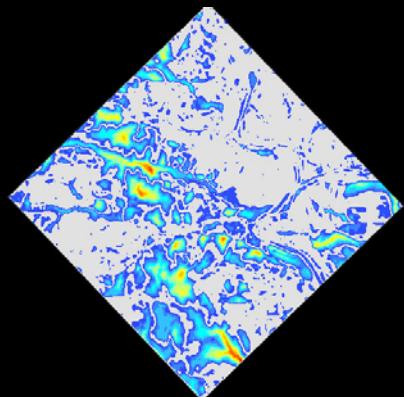
Slope 1999





Land Surface Elevation Change

Washington DC: Absolute Value of Elevation Change - Correlation with Land Use



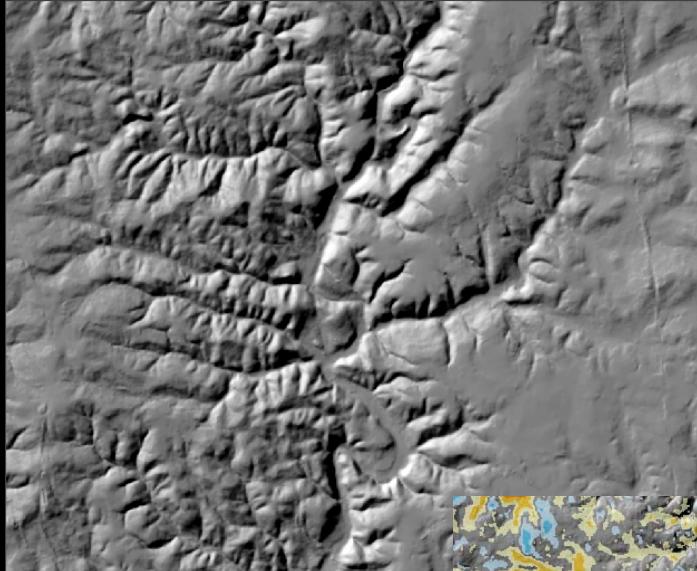
Landcover	MIN	MAX	RANGE	MEAN	STD
Open Water- 11	0.00	9.85	9.85	0.91	0.83
LI Residential - 21	0.00	24.39	24.39	1.56	1.79
HI Residential - 22	0.00	23.72	23.72	1.44	1.67
Com/Ind/Trans- 23	0.00	22.21	22.21	1.92	2.13
Transitional - 33	0.01	14.45	14.44	2.96	2.78
Deciduous For -41	0.00	31.60	31.60	1.40	1.76
Evergreen For - 42	0.00	15.17	15.17	1.38	1.60
Mixed For - 43	0.00	29.25	29.25	1.38	1.72
Pasture/Hay - 81	2.68	2.68	0.00	2.68	0.00
Urban/Rec Grass - 85	0.00	19.83	19.83	2.25	2.31
Woody Wetlands - 91	0.00	12.19	12.19	1.14	1.67
Emer- Herb Wet - 92	0.00	17.01	17.01	1.49	2.01

Absolute change grid overlaid on USGS orthophoto: Connecticut Ave.

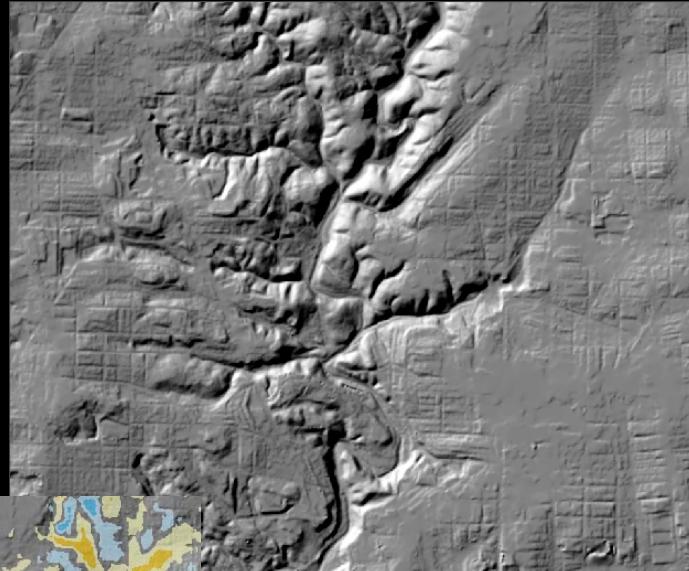


Land Surface Elevation Change

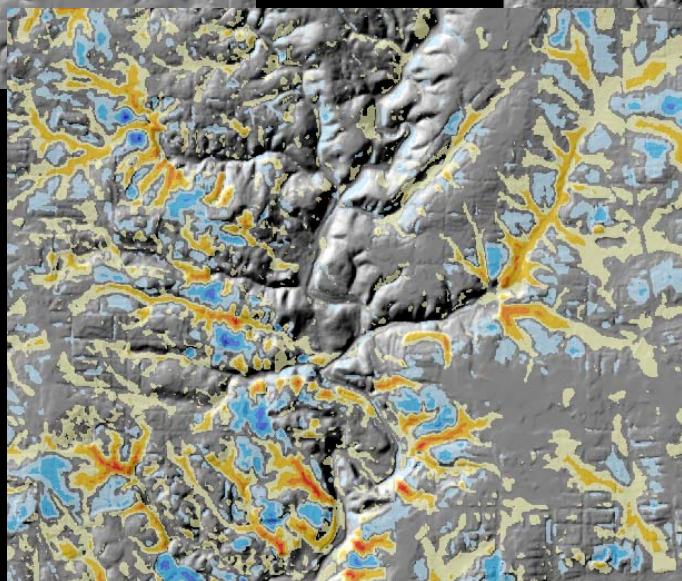
Rock Creek and Tributaries: Changes in Elevation



Surface Elevation
1888



Surface Elevation
1999

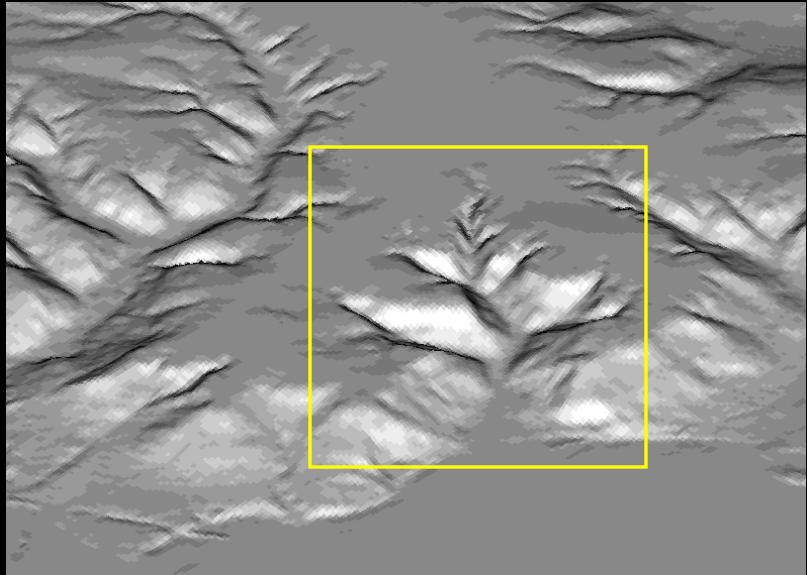


Surface Elevation
Change Classed

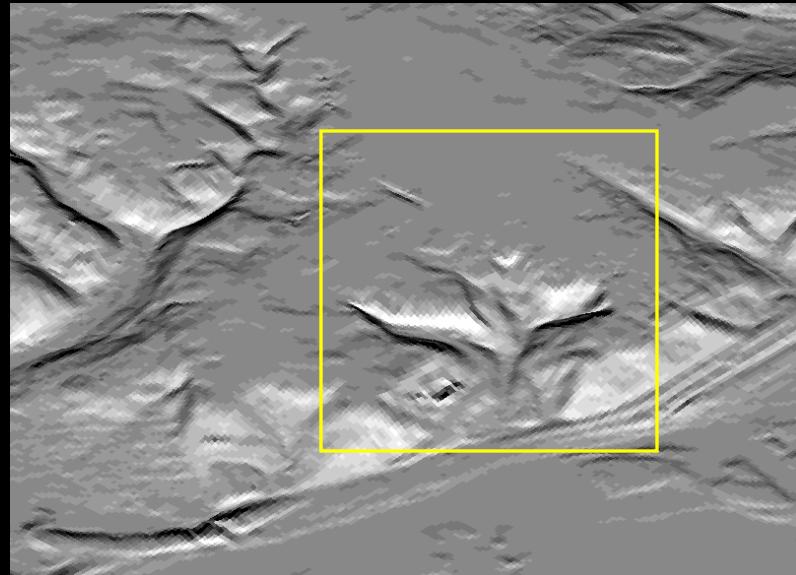


Land Surface Elevation Change

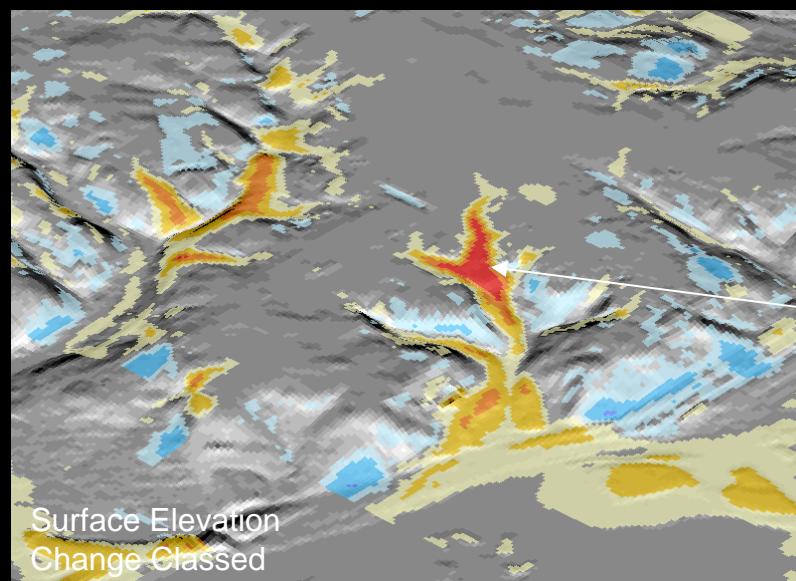
Washington DC: St. Elizabeth's Stream Valley Fill



Surface Elevation
1888



Surface Elevation
1999



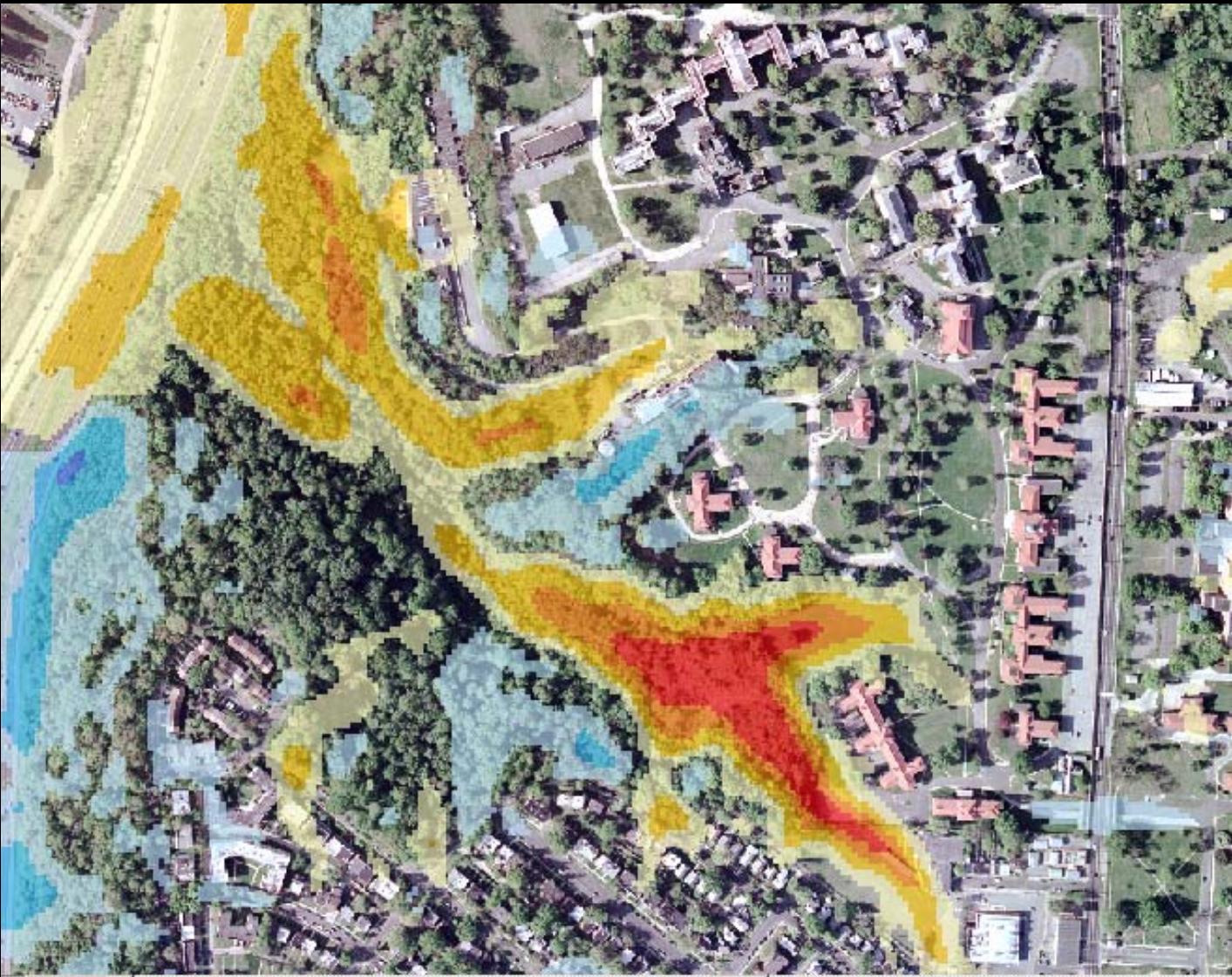
Surface Elevation
Change Classified

Site of recorded
Coal Ash Fill



Land Surface Elevation Change

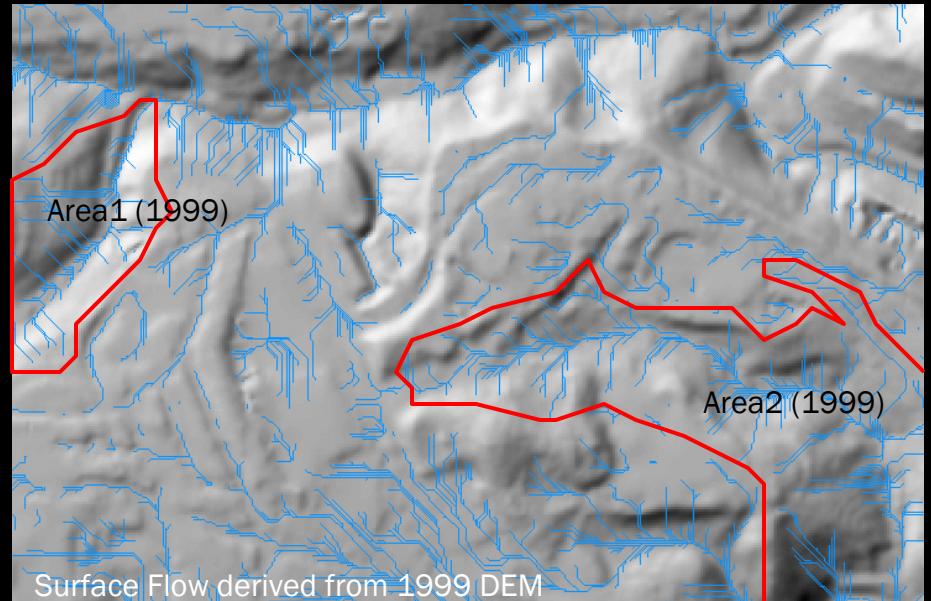
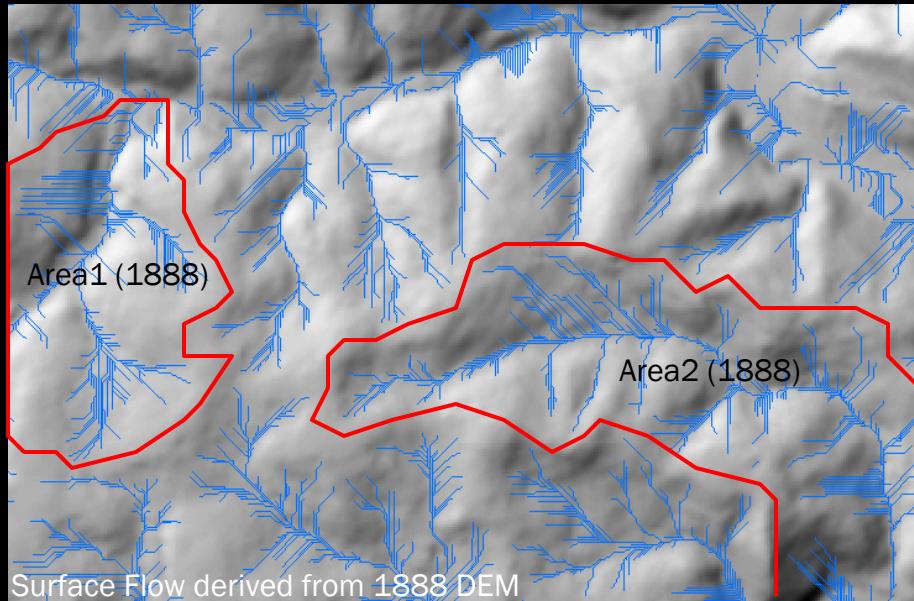
Washington DC: St. Elizabeth's Stream Valley Fill





Land Surface Elevation Change

Washington DC: Surface Water Flow Changes



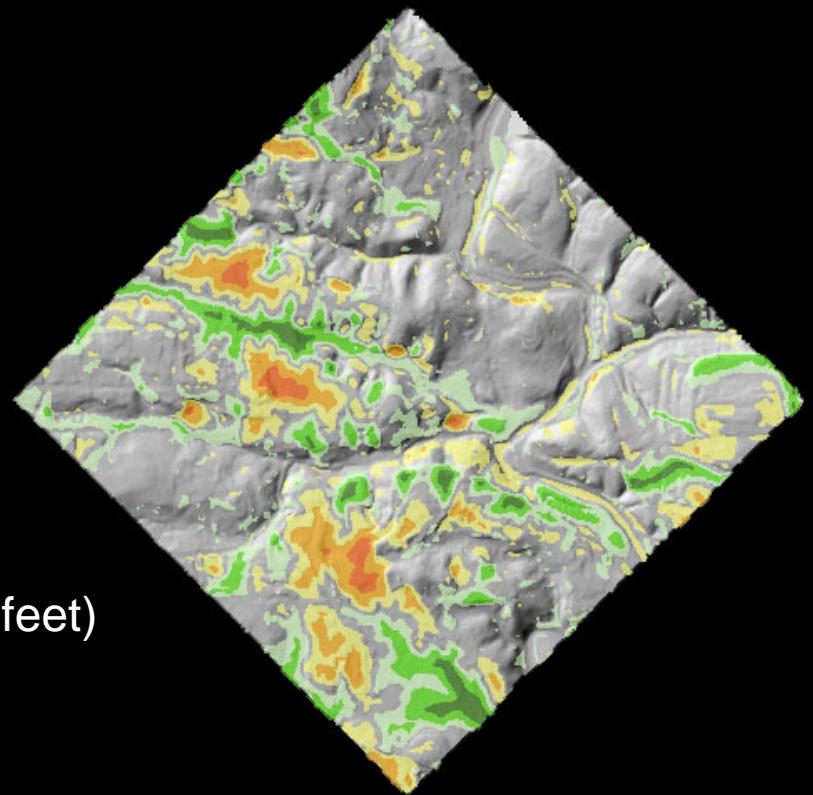
Sub-basin flow path/drainage areas comparison



Land Surface Elevation Change

Washington DC:

- ◆ Map Scale: Historical 1888: 1:4,800
Current 1999: 1:7,200
- ◆ Contour Interval: Historical: 5 feet
Current: 1 meter
- ◆ LSEC Map Cell Size: 5m
- ◆ Observed Vertical Changes: \pm 18 meters (59 feet)
- ◆ Expected Vertical Accuracy: \pm 4.14 feet
- ◆ Drill Hole Data Test: 90% correlation between drill holes and mapped areas - map predicts depth with \pm 6 feet.
- ◆ Results demonstrate ability to determine horizontal and vertical extent of surface change.





Land Surface Elevation Change

Washington DC:

◆ Area and Volume Statistics

Accretion (fill)

PLANE_HEIGHT: 1.50

REFERENCE: ABOVE_PLANE

2D_AREA: 40409691.75

3D_AREA: 40682979.00

VOLUME: 79,600,319.13 (cubic meters)

Removal (cut)

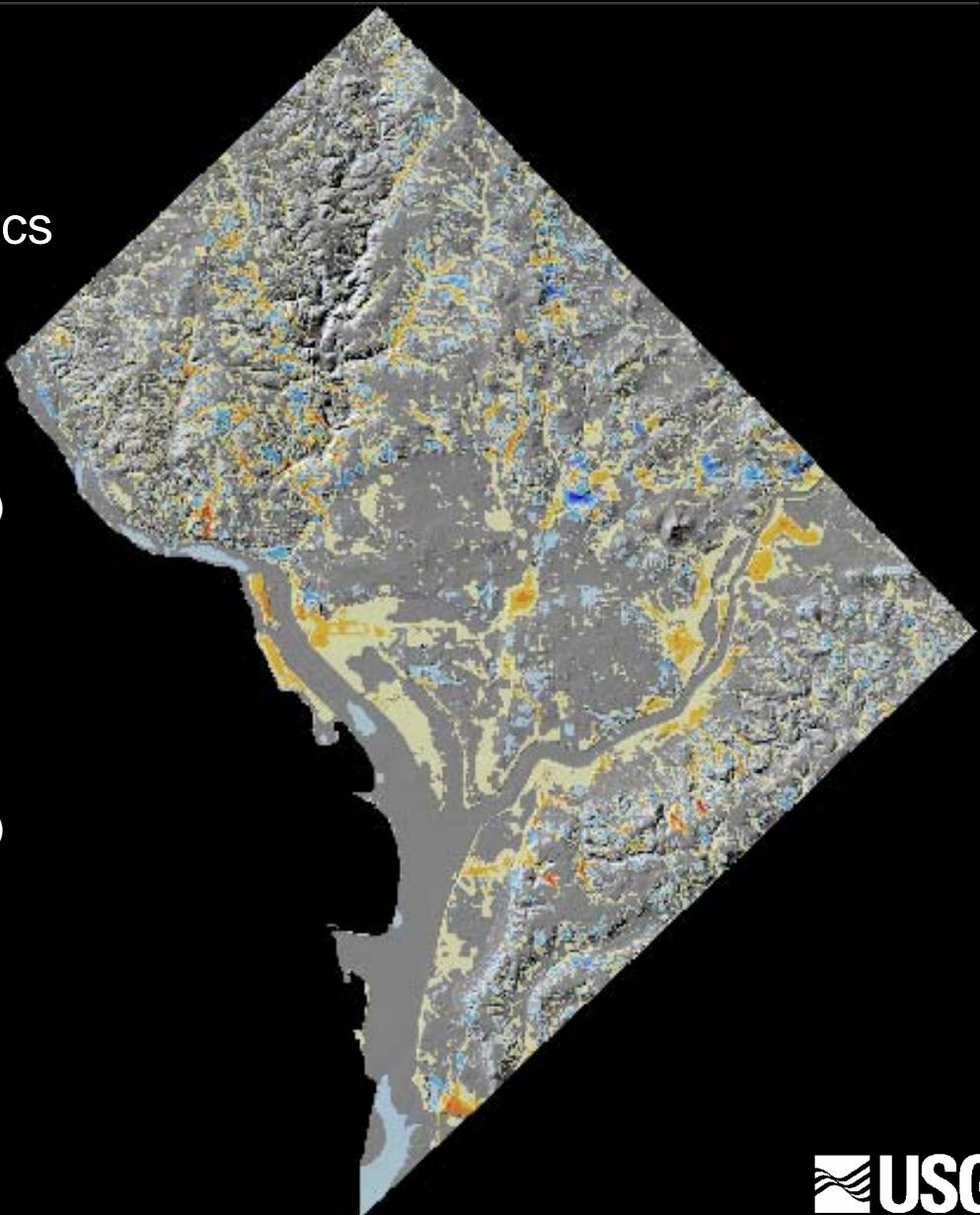
PLANE_HEIGHT: -1.50

REFERENCE: BELOW_PLANE

2D_AREA: 19463931.64

3D_AREA: 19600254.47

VOLUME: 32,144,214.37 (cubic meters)





Land Surface Elevation Change

Conclusion

- ◆ The Land Surface Change methodology can be used to map the horizontal and vertical extent of landscape change.
- ◆ Provides a repeatable and quantifiable (not interpretive) mechanism for defining land surface change.
- ◆ Mapping land surface elevation change provides a critical component for analyzing change.

Future Research

- ◆ Continue the testing and validation of change models and refine minimum and maximum error classifications.
- ◆ Compile database of large scale historical map data (including aerial photography).
- ◆ Develop additional applications
 - Watershed changes: flow rates, flow direction, stormwater/sewer network
 - Correlate changes with flooding, subsidence, and erosion.
 - Mountaintop Mining
 - Brownfields: Land-use/Land-cover history