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GIS: Geographic Information Systems

Module 10: Terrain

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What is a Digital Elevation Model (DEM)?

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- Digital representation of topography
  - Typically, a raster dataset
  - Each a cell has a single value (elevation) which represents the entire area covered by the cell
- Advantages
  - Easy to use
  - Importance of terrain in hydrology and environmental modeling
  - Visualization of landscapes

Raster DEM with Traditional Color Ramp

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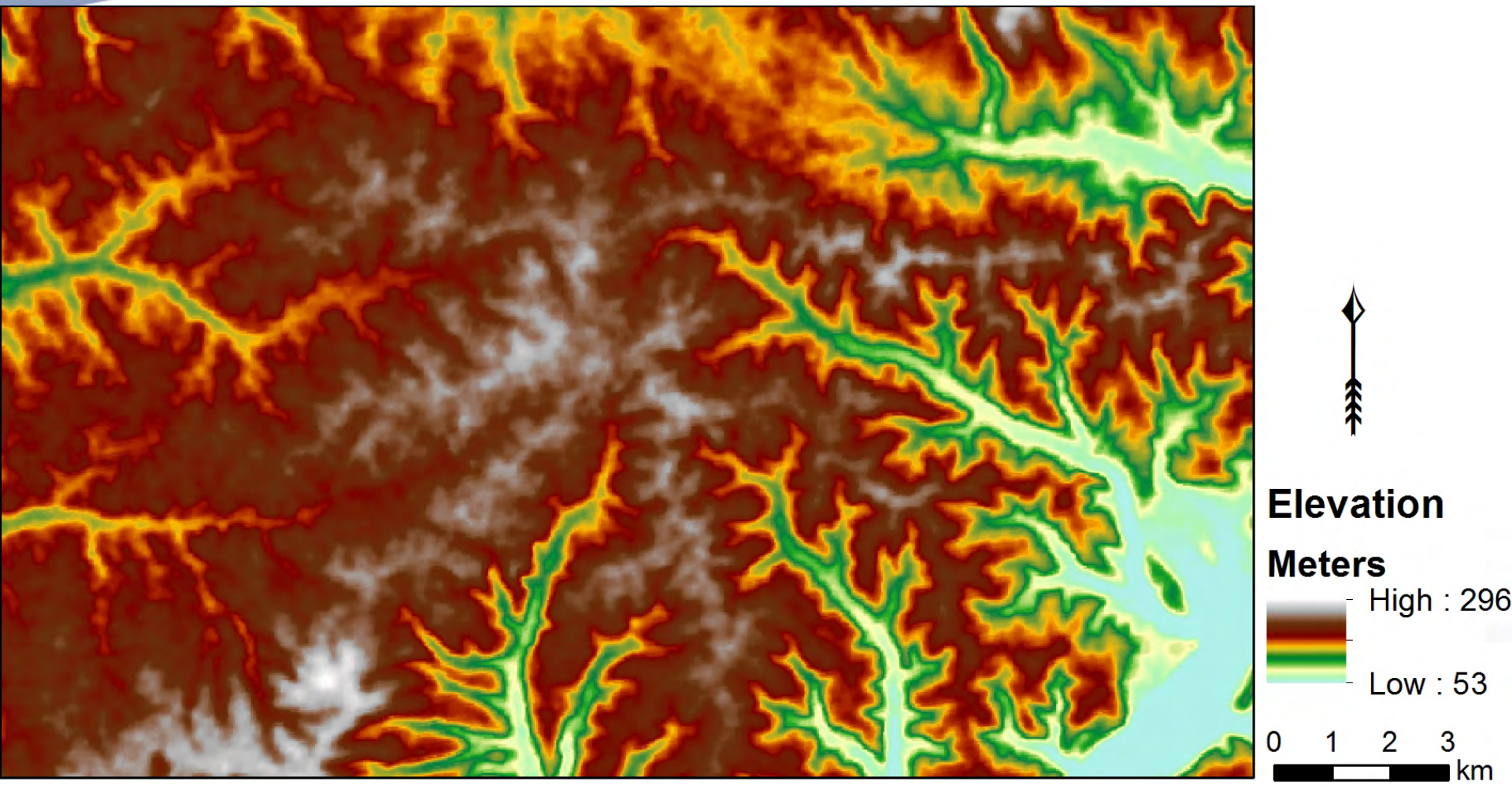

DEM data storage

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340	335	330	340	345
337	332	330	335	340
330	328	320	330	335
328	326	310	320	328
320	318	305	312	315

A DEM is a matrix of elevations with a uniform cell size

Triangulated Irregular Network (TIN) Terrain Model

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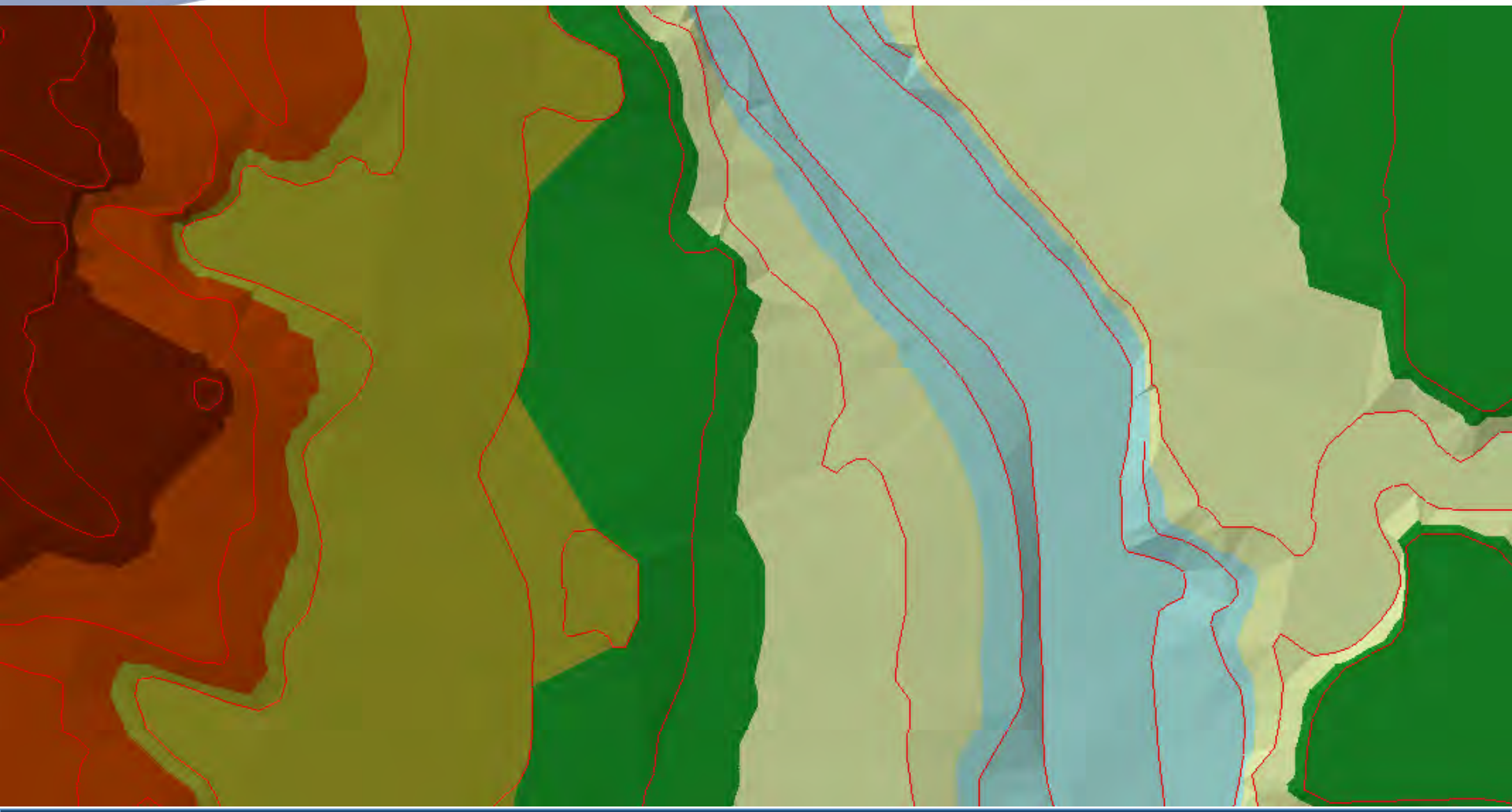

Terrain Model Terminology

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- TIN = Triangulated Irregular Network
  - Essentially a vector model
- DEM = Digital Elevation Model
  - A raster-based model
- Digital Terrain Model
  - General term referring to either

Creation of DEMs

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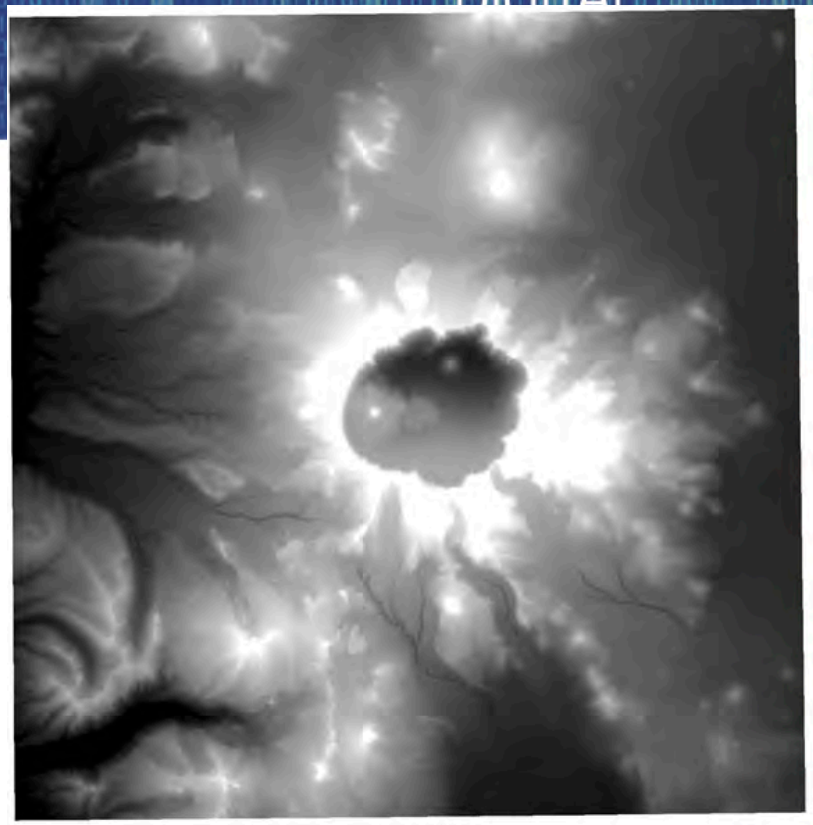
- Conversion of paper maps
  - Scanned, vectorized contour lines
  - USGS produces 10 and 30 meter DEMs
- From original photogrammetry
- From Space Shuttle topography mission
  - 30 meter data in US, 90 meter data elsewhere
- Interpolation from measured points

Crater Lake

- National Park in Oregon

Crater Lake, Oregon, Topographic Map

USGS *Topinka, USGS/CVO, 1999; Map modified from: U. S. National Park Service Map*



Crater Lake DEM

Elevation (m)

2323.7

945.4

Uses of DEMs

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- Determine characteristics of terrain
  - Slope, aspect, spot elevations
- Source for contour lines
  - Finding terrain features
- Watersheds,drainage networks, stream channels
  - Modeling of hydrologic functions

Derived Datasets from Digital Terrain Models

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- Contour polylines
- Slope
- Aspect
- Hillshade
- Flow direction and other hydrological datasets
- Visibility

Estimating slopes in a DEM

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- Slopes are calculated locally using a neighborhood function, based on a moving 3*3 window
- Distances are different in the diagonal

1.41...	1	1.41...
1	0	1
1.41...	1	1.41...

- Only the steepest slope is used

Slope Calculation

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340	335	330
337	332	330
330	328	320

Elevation

8 / 42.47	3 / 30	2 / 42.47
5 / 30	0	-2 / 30
-2 / 42.47	-4 / 30	-12 / 42.47

Difference / distance

30 meter spatial resolution

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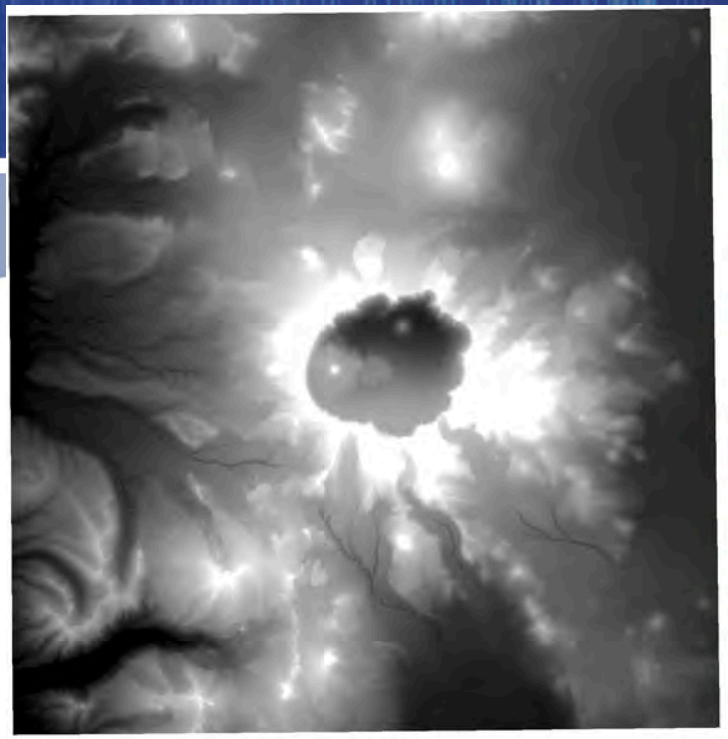
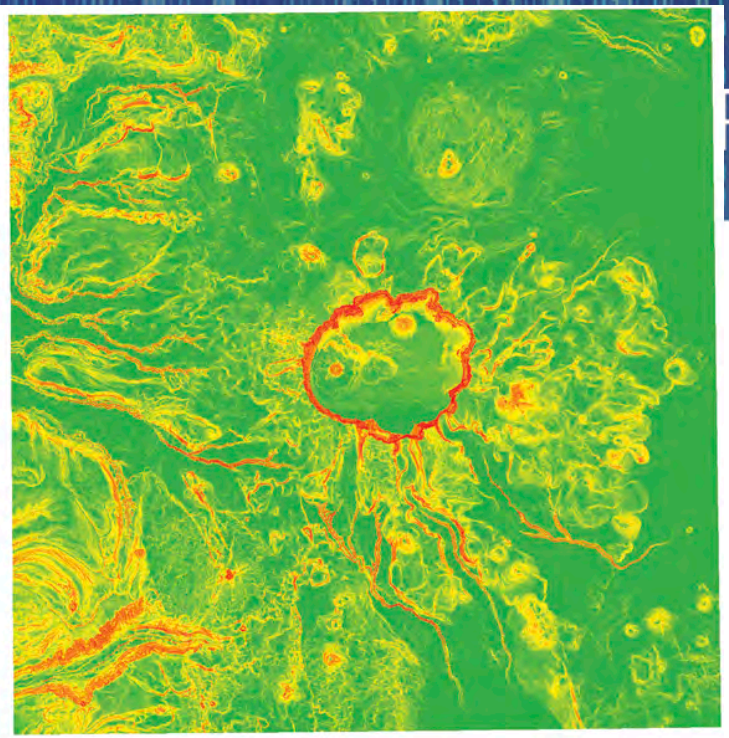


Crater Lake DEM

Elevation (m)

2323.7

945.4



Slope Degrees

- 0 - 4
- 4.0 1- 8
- 8.01 - 12
- 12.01 - 18
- 18.01 - 24
- 24.01 - 30
- 30.01 - 40
- 40.01 - 50
- 50.01 - 85

Aspect calculation

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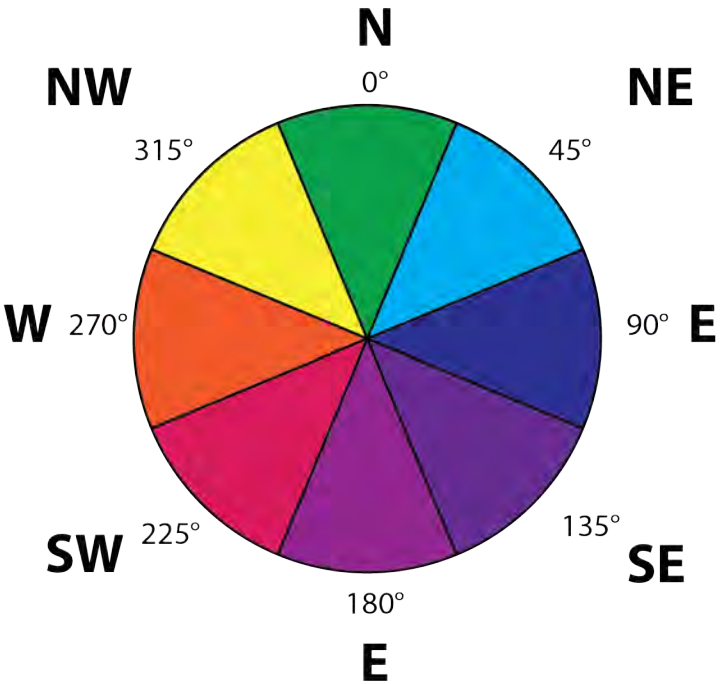
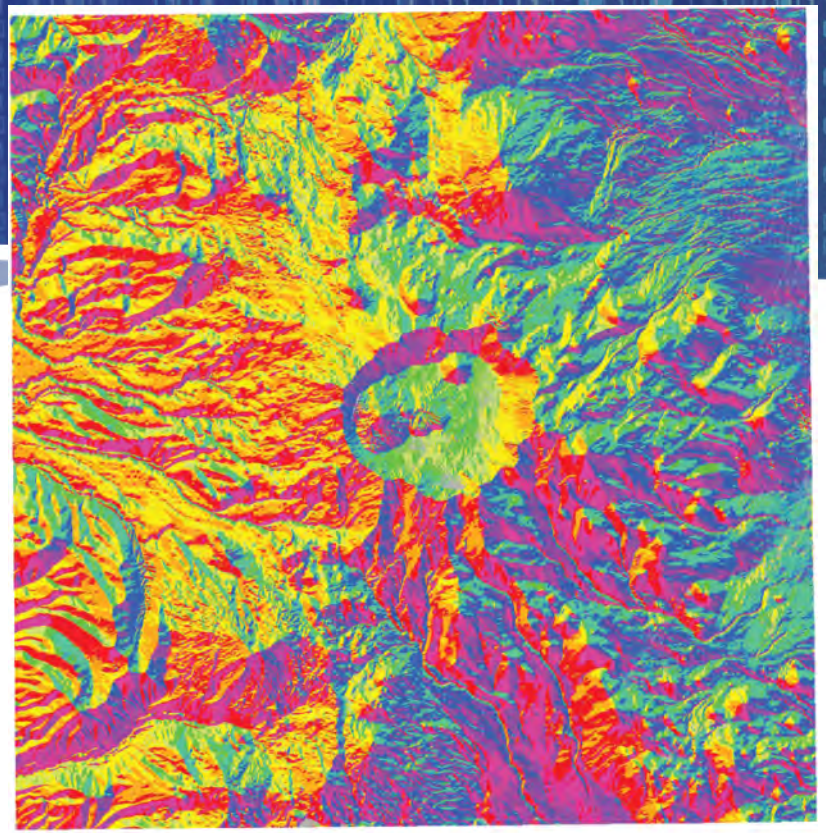
- ***Aspect***: The direction that each cell of the DEM is facing
  - Useful for several other calculations
    - Solar radiation
    - Erosion (based on prevailing winds)





- Flat (-1)
- North (0-22.5)
- Northeast (22.5-67.5)
- East (67.5-112.5)
- Southeast (112.5-157.5)
- South (157.5-202.5)
- Southwest (202.5-247.5)
- West (247.5-292.5)
- Northwest (292.5-337.5)
- North (337.5-360)

Calculating Hillshade

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- Hillshade: Given a certain orientation of the sun, uses the DEM to calculate areas that are shaded
- More complex calculations can show the percentage of shade throughout the day or even year
- Forms the basis for calculations of solar radiation
- Also useful for creating a false 3D shading

Hillshade parameters

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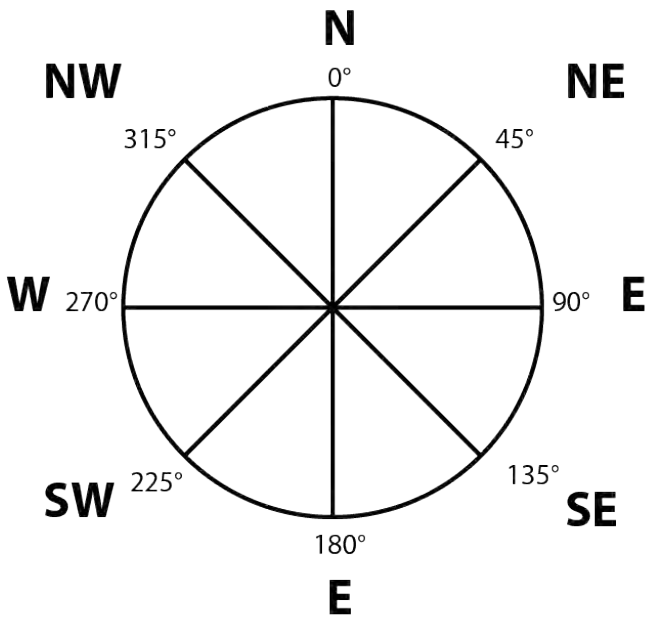
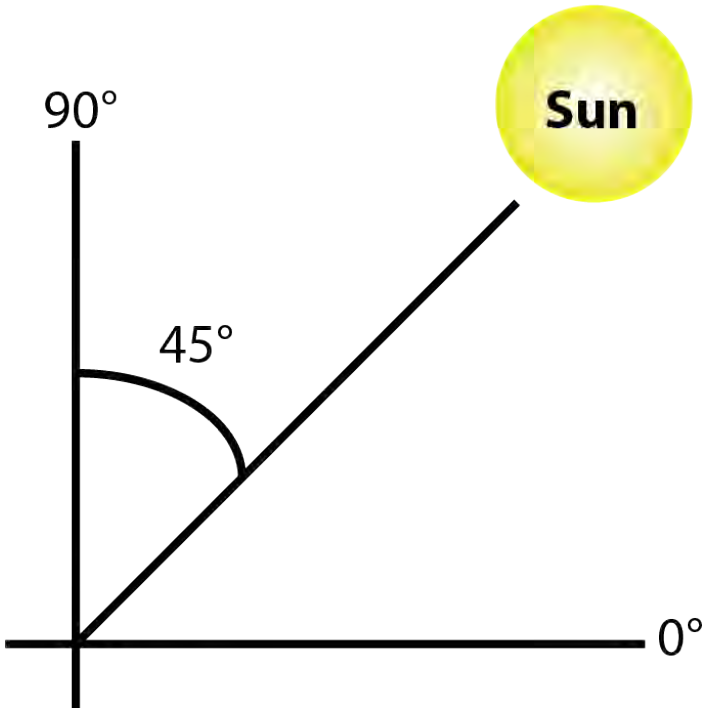
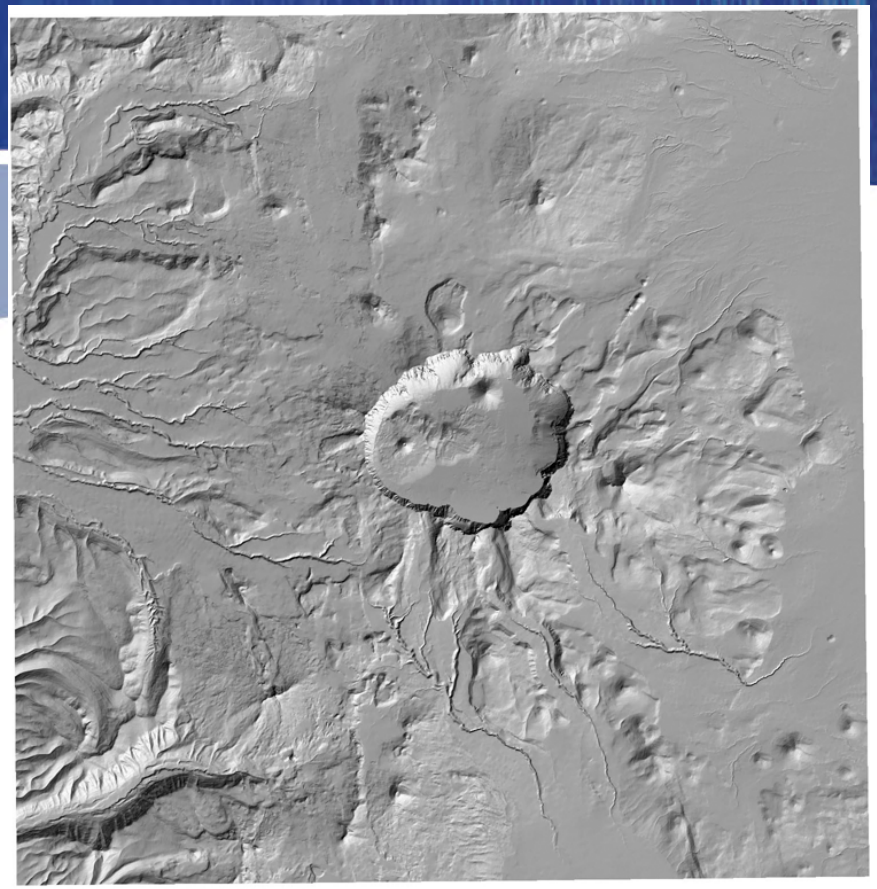
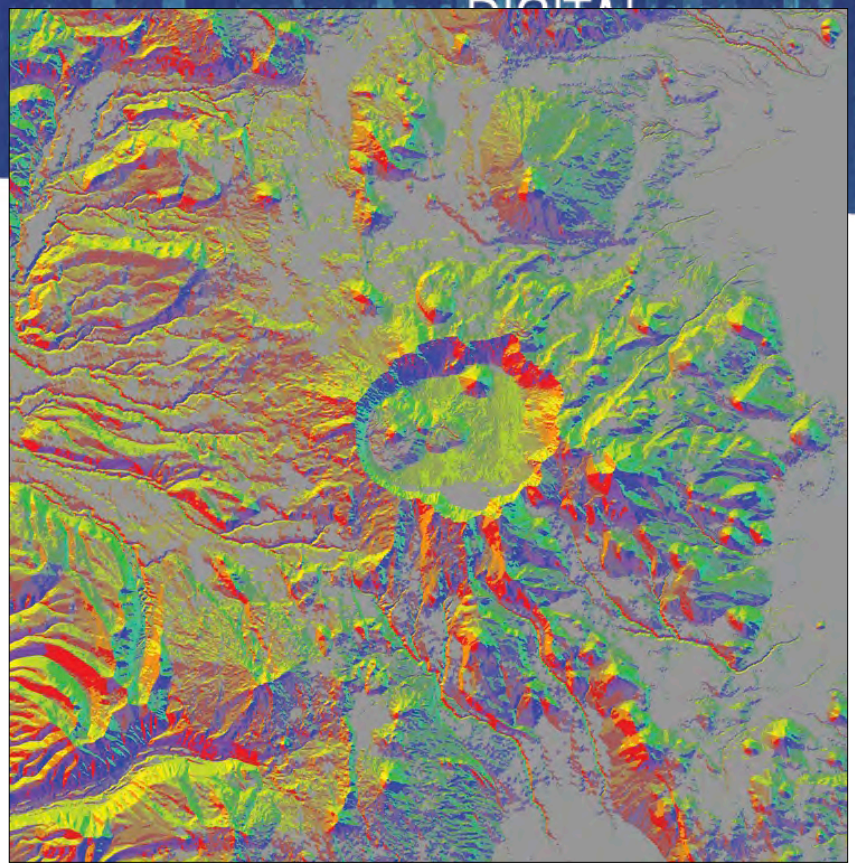
Azimuth



Altitude







Illumination

Value

High : 254

Low : 0

Visibility

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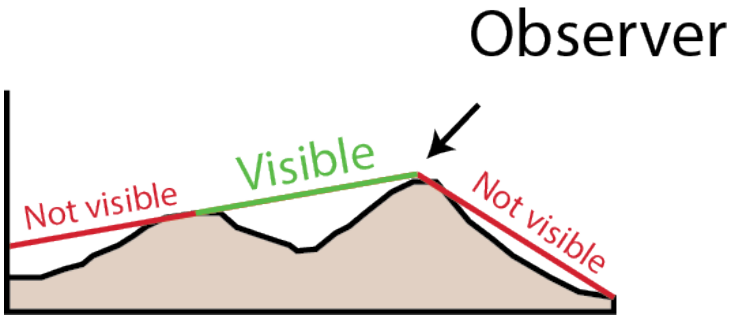
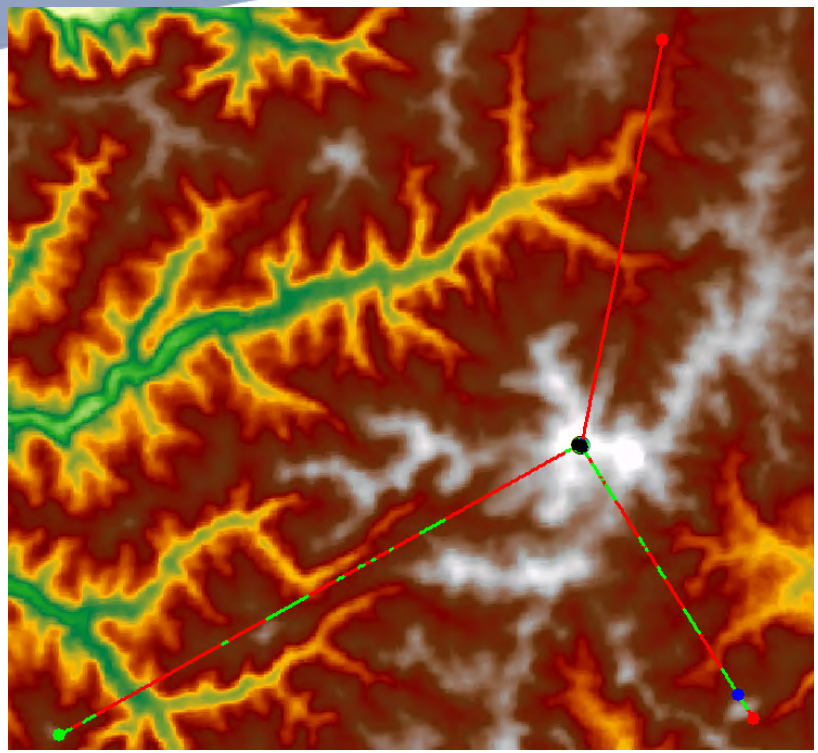
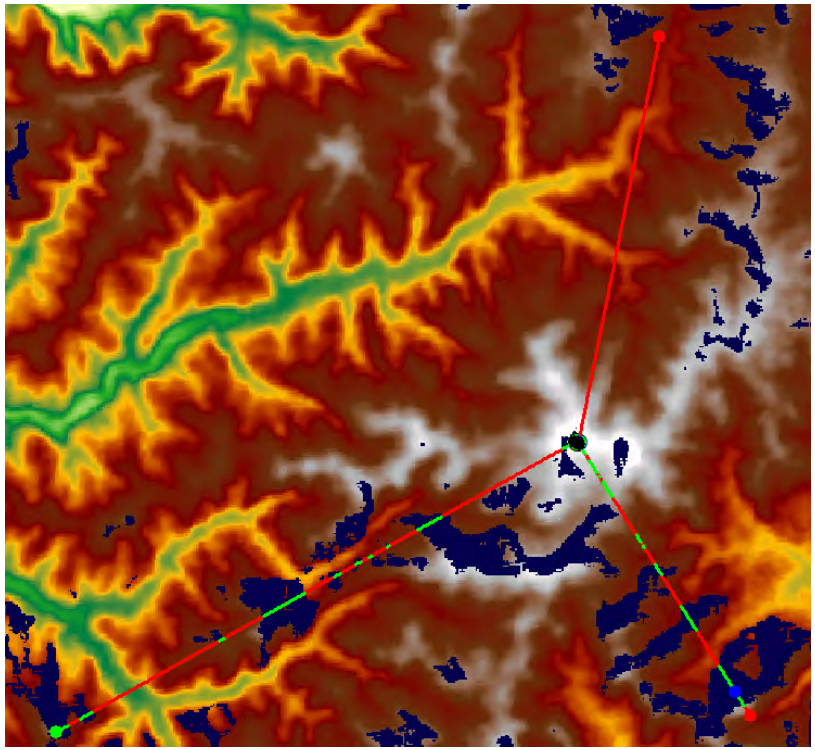
- The DEM can also be used to determine what area of the land is visible from a give point
- Viewshed Analysis: Methods of determining what is visible from a location on the landscape





Individual Lines of sight



Blue areas are coded as visible

Overlaying imagery on DEM in 3D

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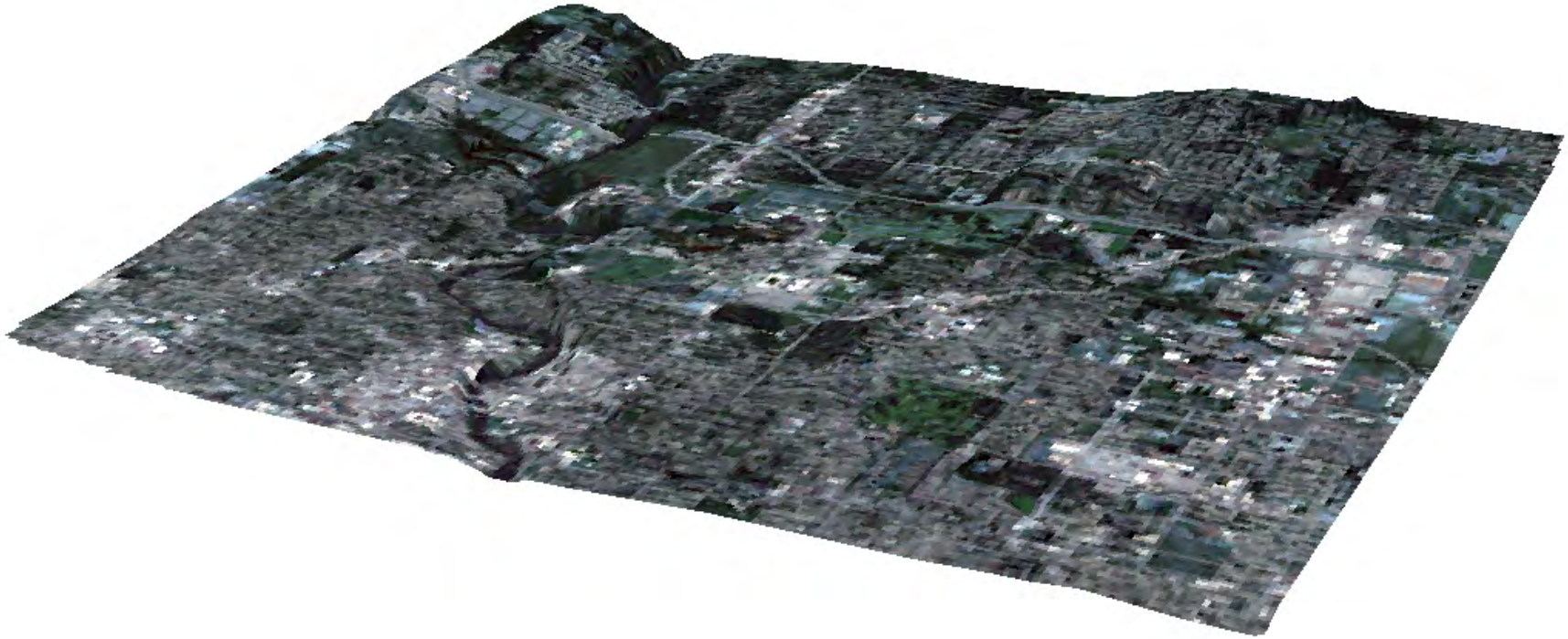

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Digital Terrain Models and Interpolation

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Sources for Terrain Data

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- Raster paper maps (scanned)
- Vectorized contours
- Spatial Interpolation

Paper maps

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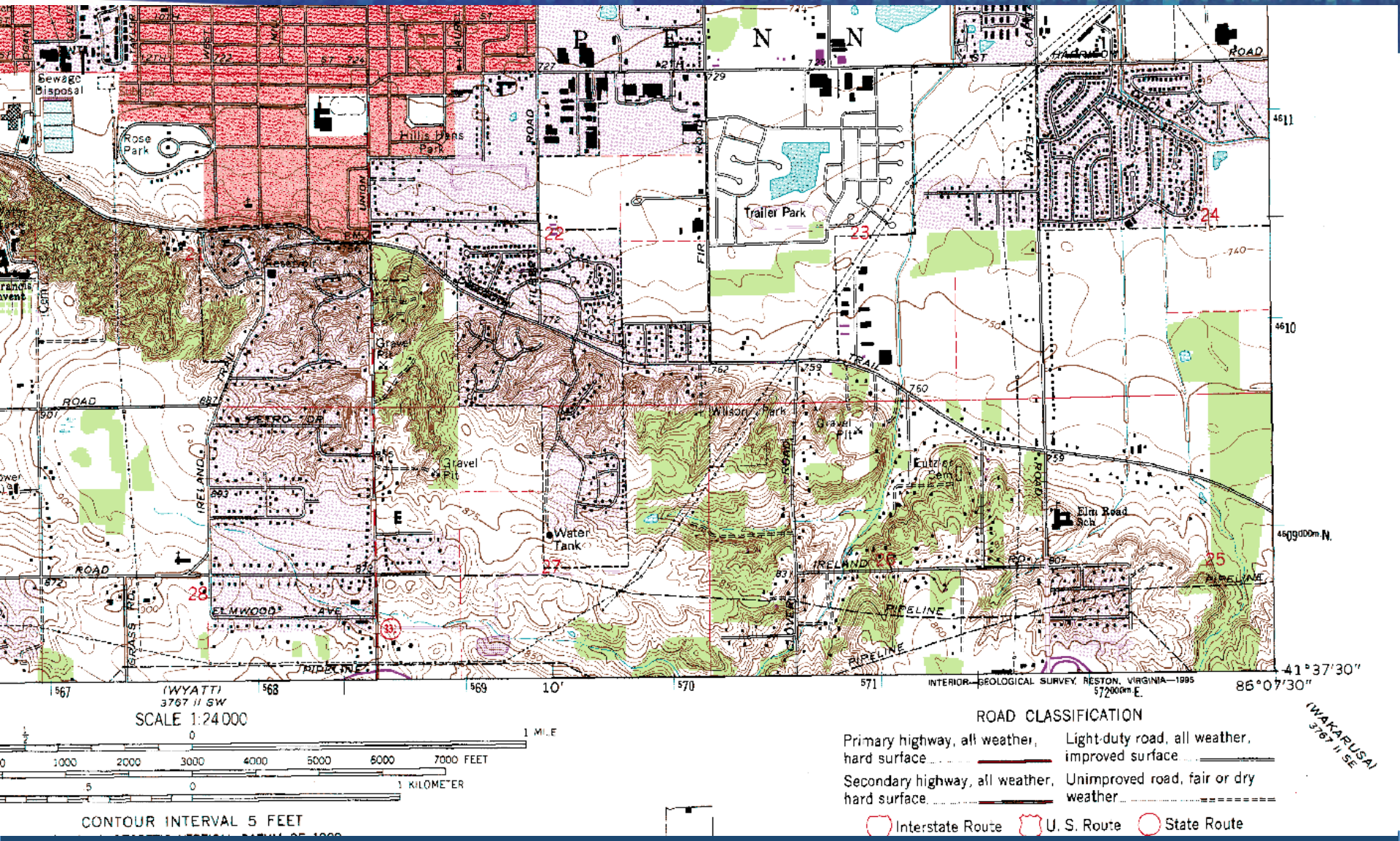

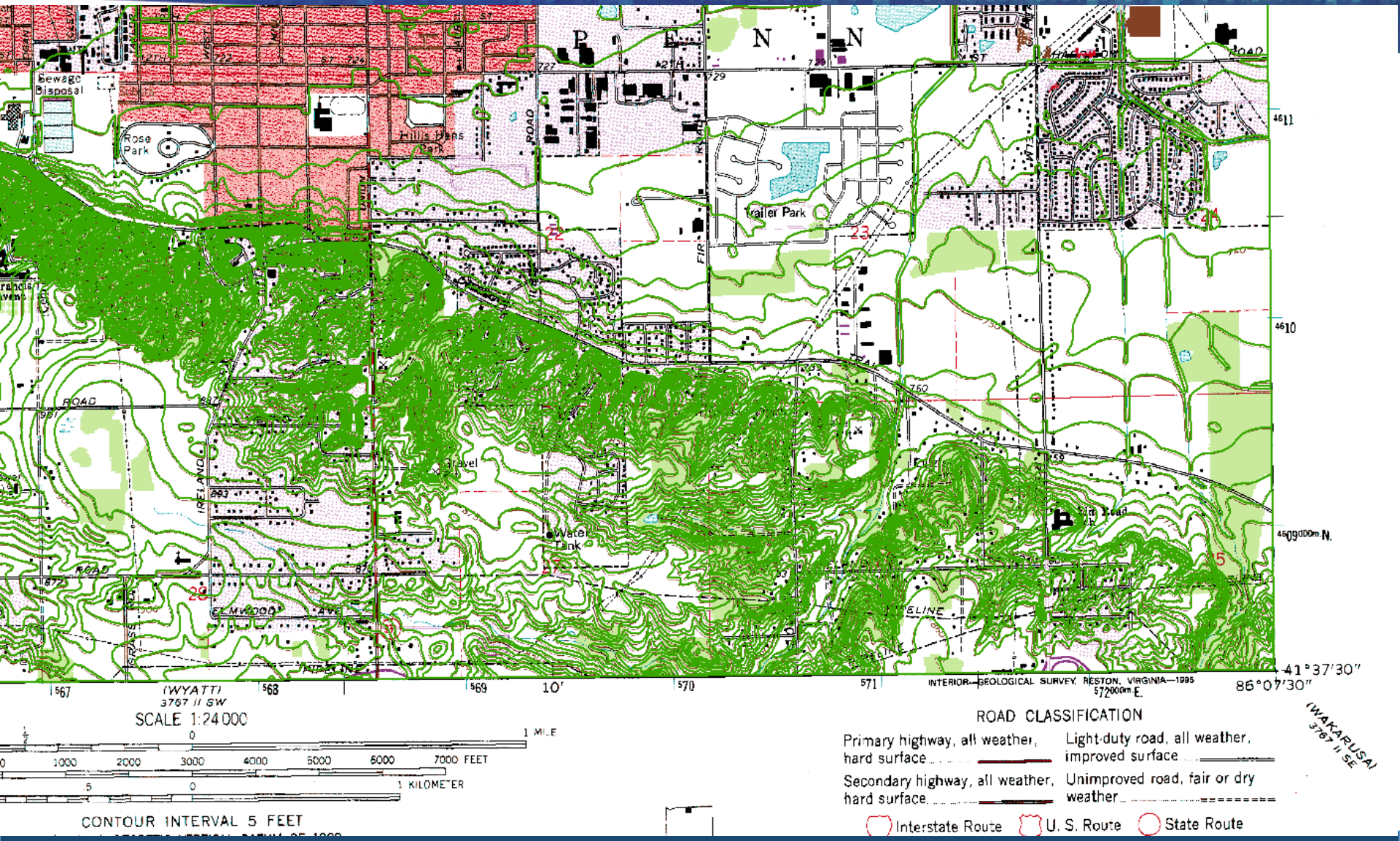
Sewage Disposal
Rose Park
Hills Pass Park
Trailer Park
Gravel
Water Tank
ROAD
IRELAND
ELMWOOD
FIR
ELINE
(WYATT)
3767 II SW
(WAKARUSA)
3767 II SE
567
568
569
570
571
572000m E.
10'
4611
4610
4609000m N.
41°37'30"
86°07'30"
INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1995
SCALE 1:24 000
1 MILE
7000 FEET
1 KILOMETER
CONTOUR INTERVAL 5 FEET
ROAD CLASSIFICATION
Primary highway, all weather, hard surface
Light-duty road, all weather, improved surface
Secondary highway, all weather, hard surface
Unimproved road, fair or dry weather
Interstate Route
U. S. Route
State Route

Vectorized (Digitized) Contour data

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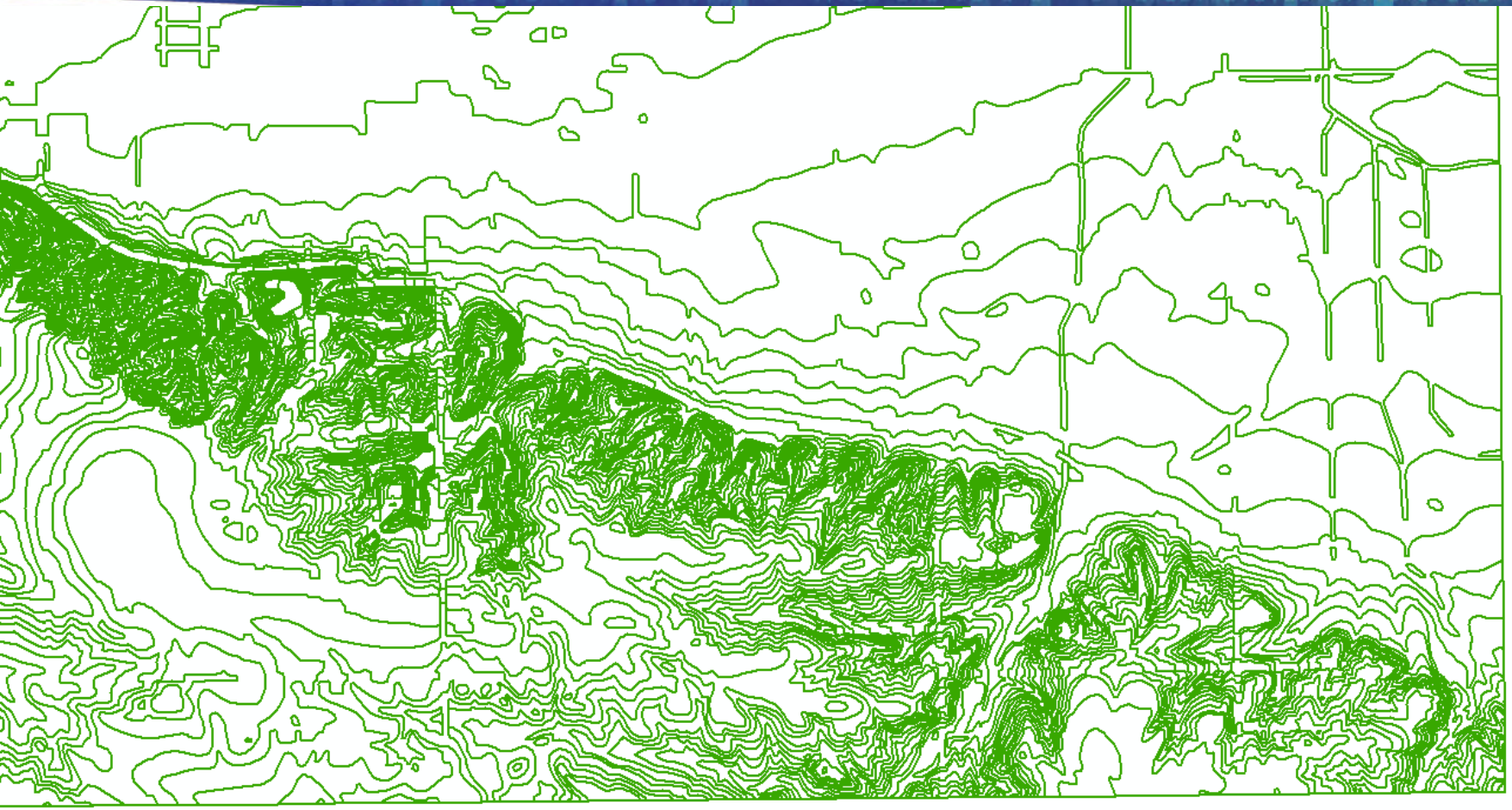

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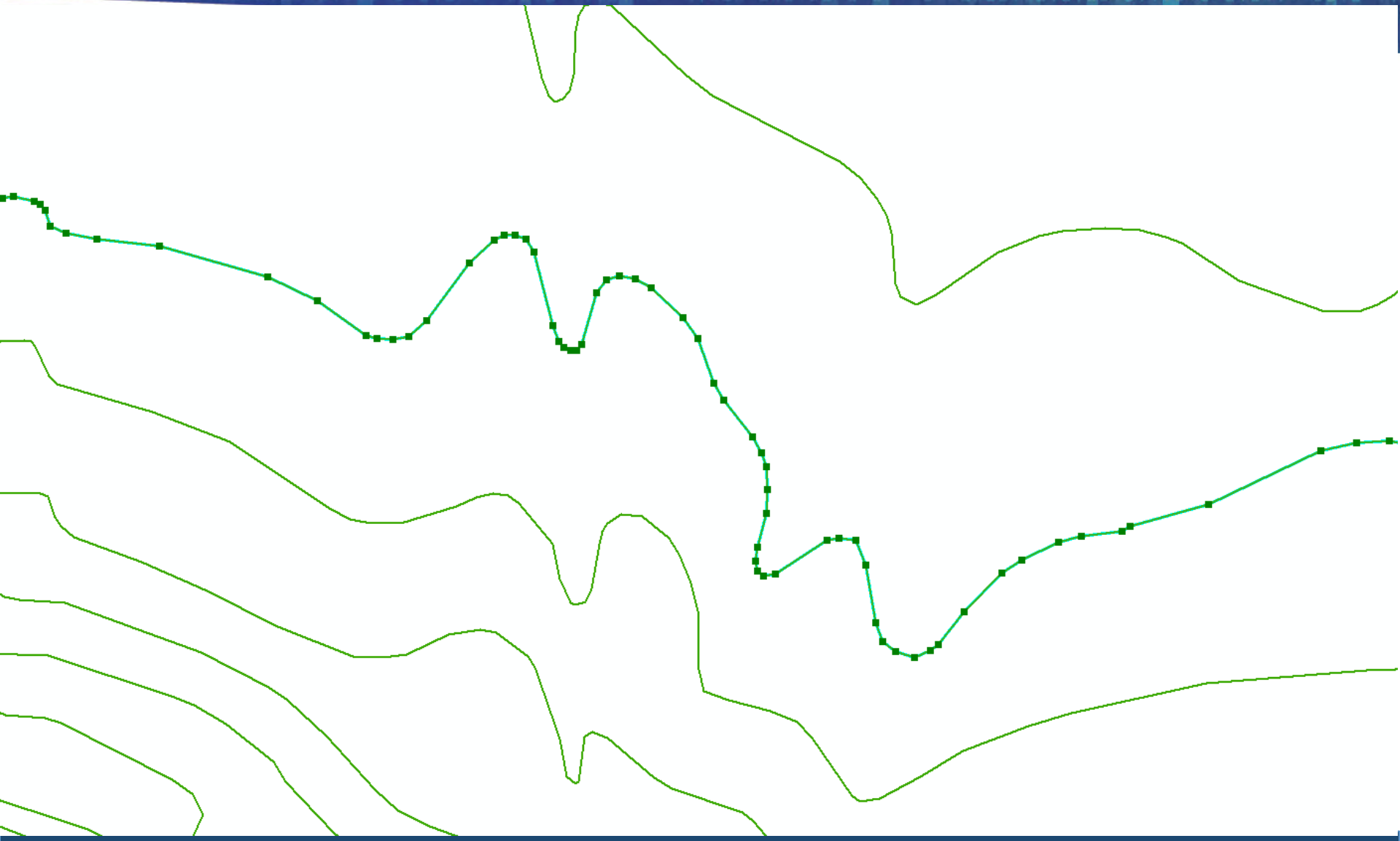
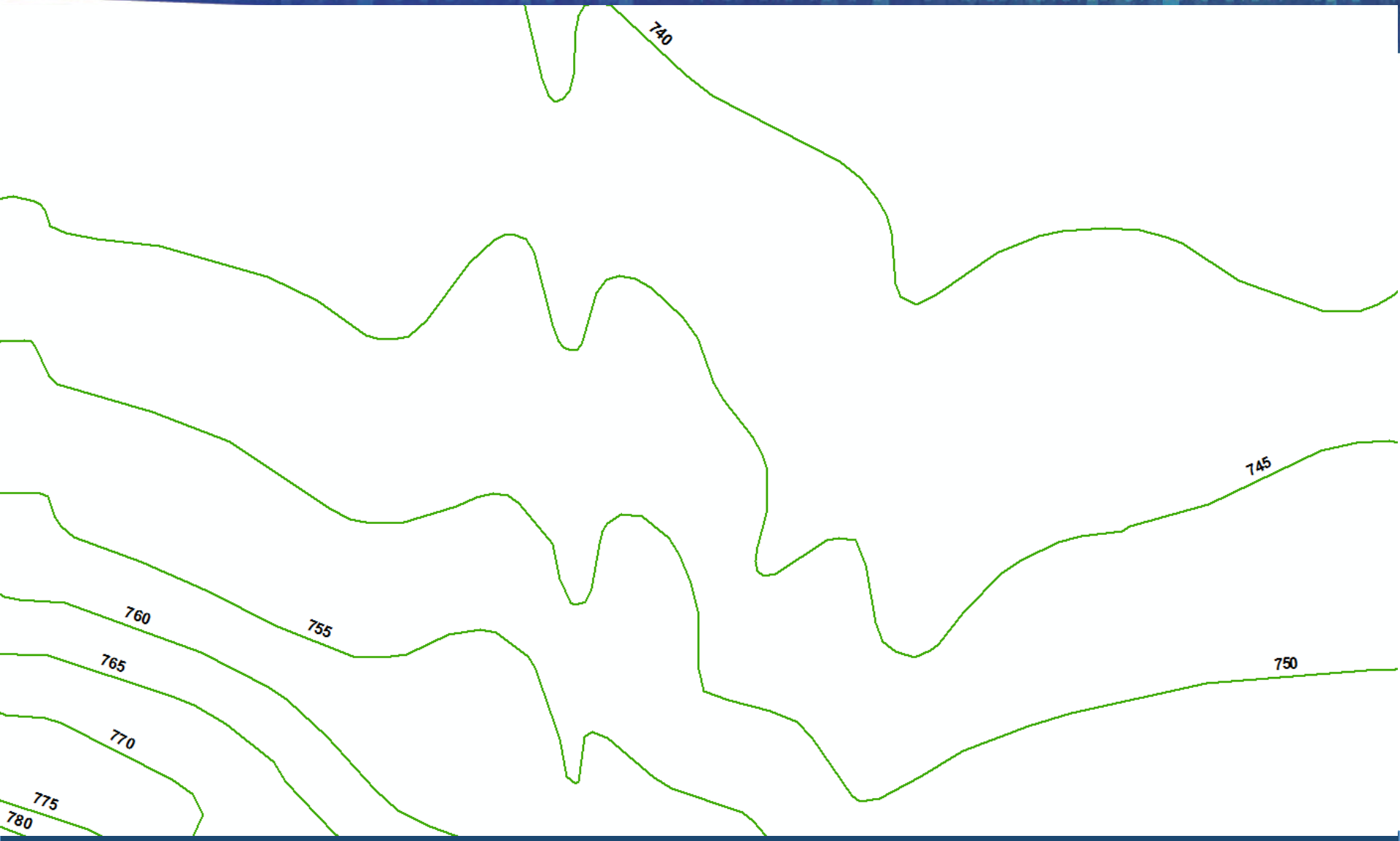
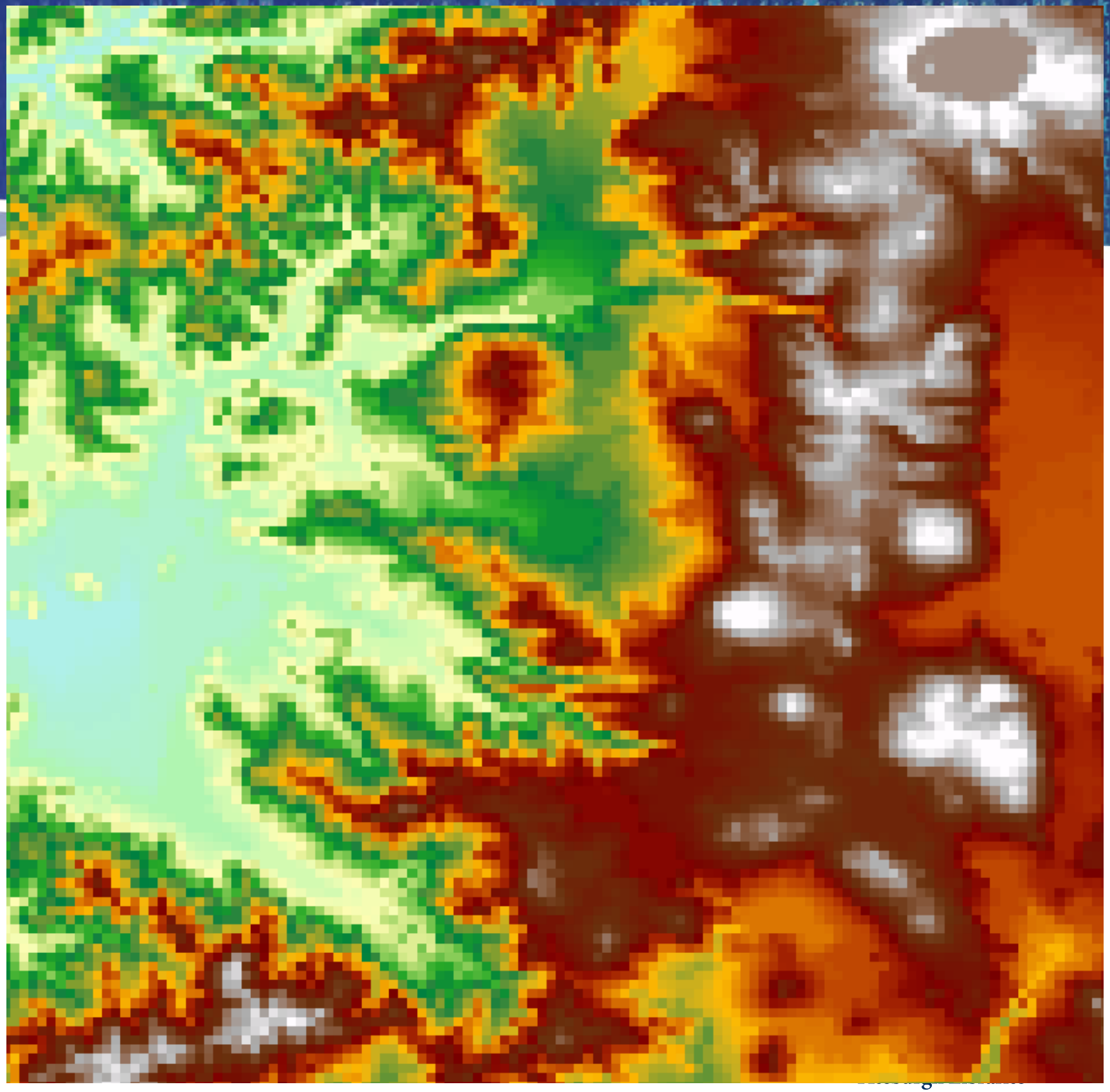



740
745
750
755
760
765
770
775
780

USGS GTOPO30
(1km resolution)



USGS EarthExplorer

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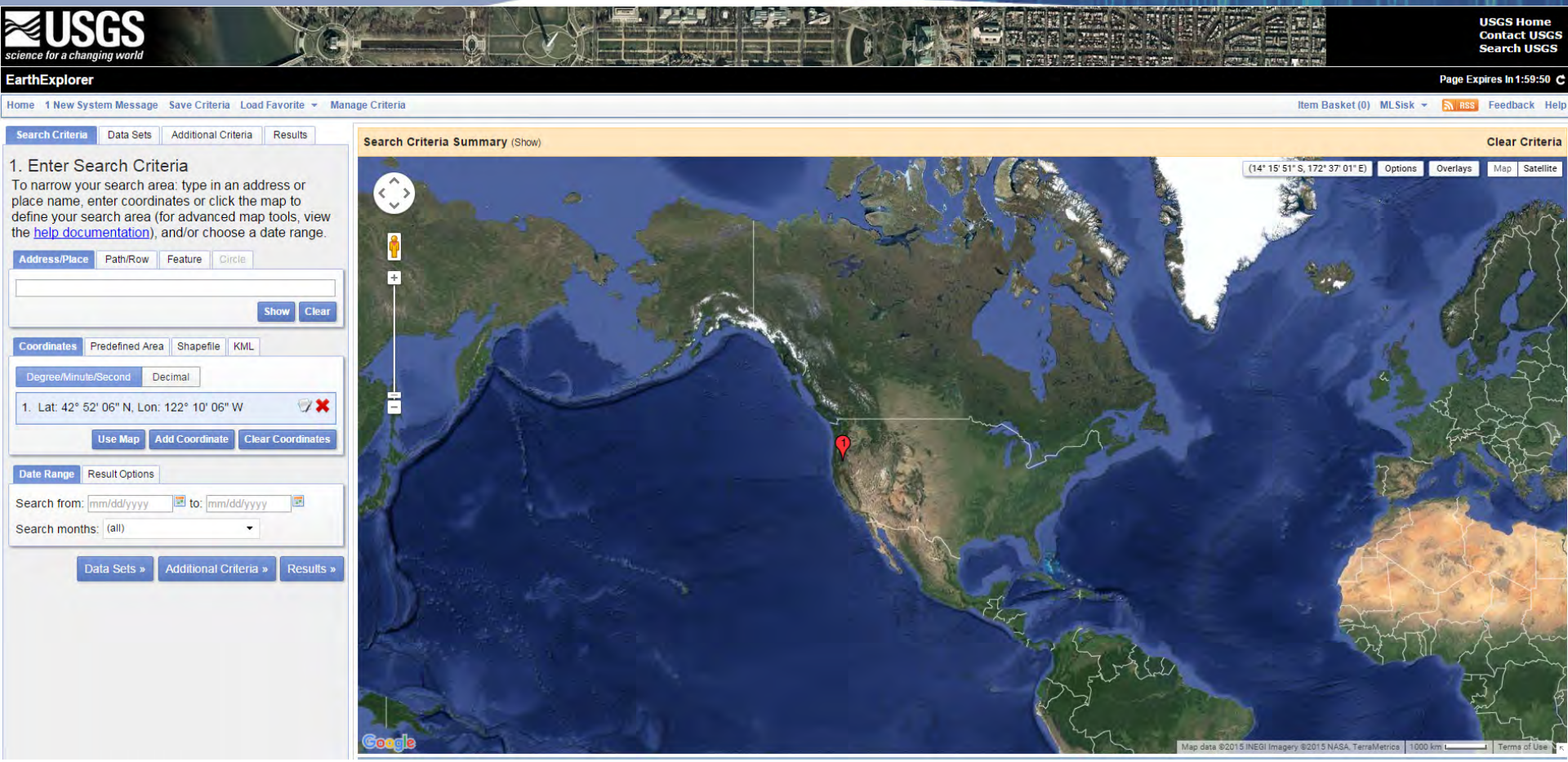

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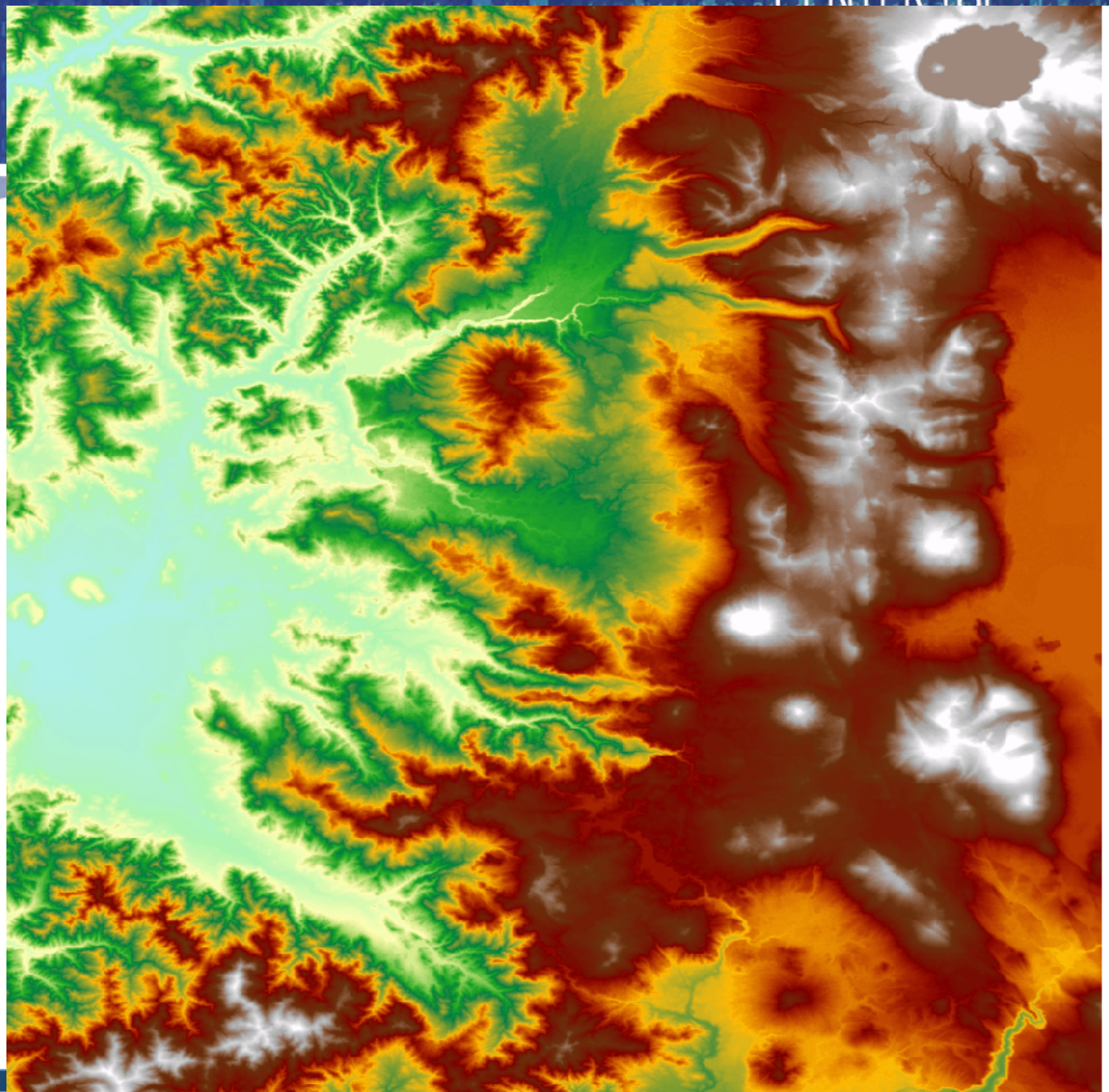
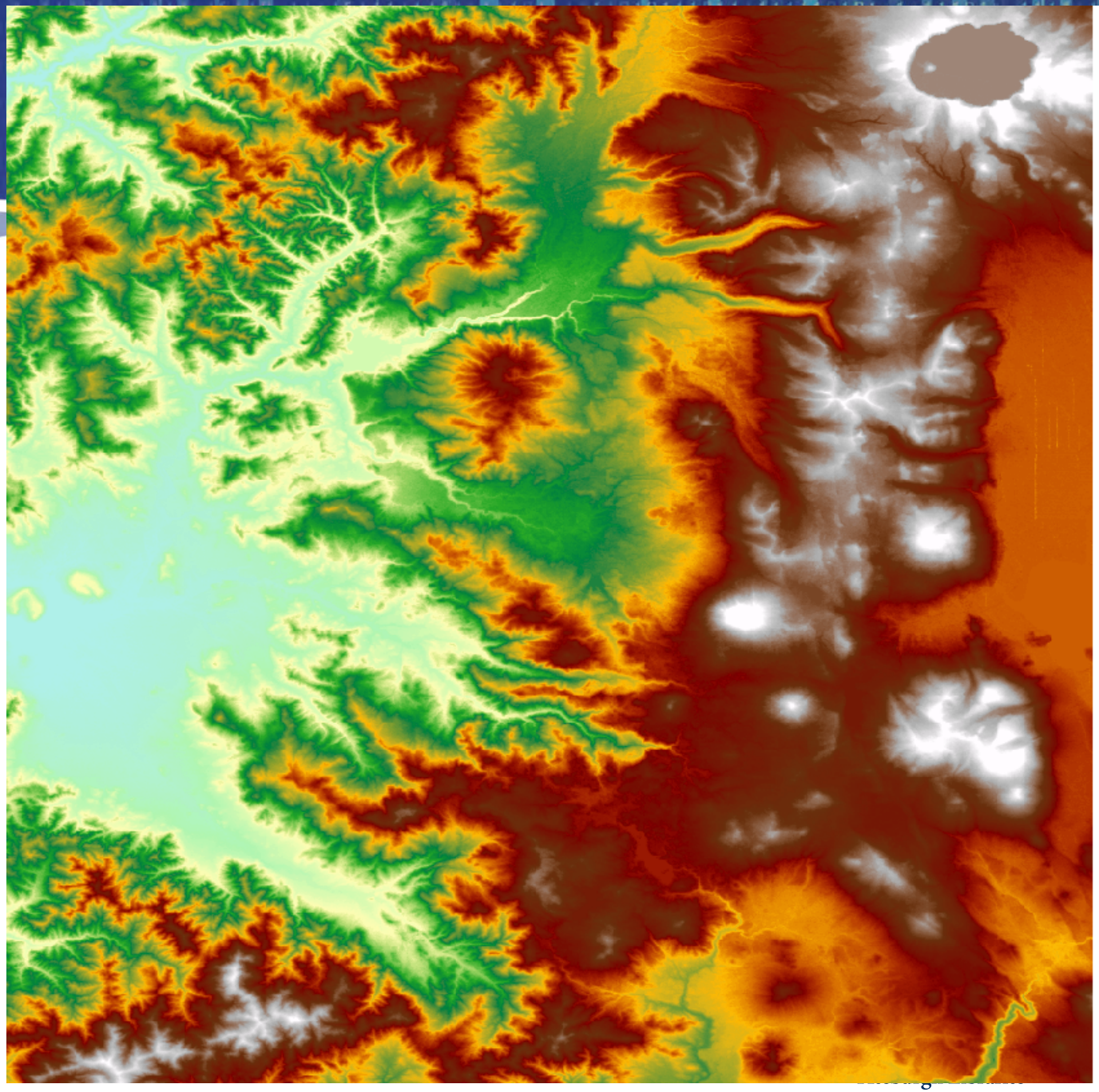
Shuttle Radar Topography Mission (SRTM) 30m resolution



ASTER 30m GDEM



Spatial Interpolation

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- Spatial interpolation is a process of using points with known values to estimate values at other points
- A way of converting point data into surface data
- Example:
  - When mapping precipitation if there is no weather reporting station within the grid cell, an estimate can be created based on nearby weather stations
  - Same can be done for topography

Control points

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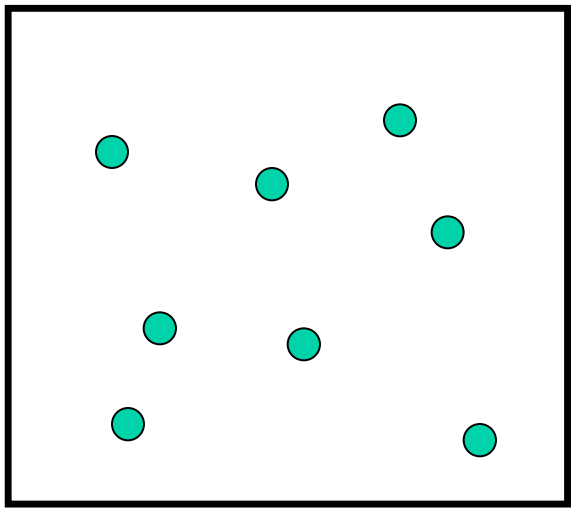
- **Control** points: points with known values used to calculate the interpolation
- Basic assumption in spatial interpolation is that the value to be estimated at a point is more influenced by nearby control points than those that are farther away
- Tobler's first law of geography
- Ideally, the points are well distributed across the area
- Uncommon in the real world

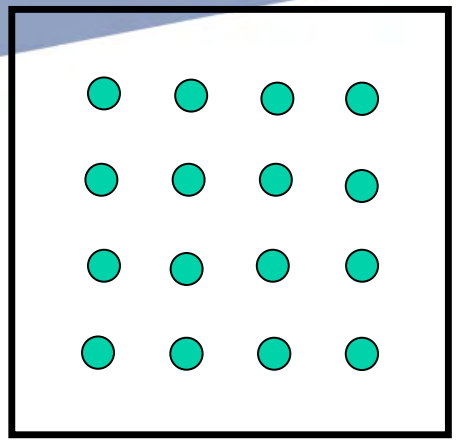
Control Points



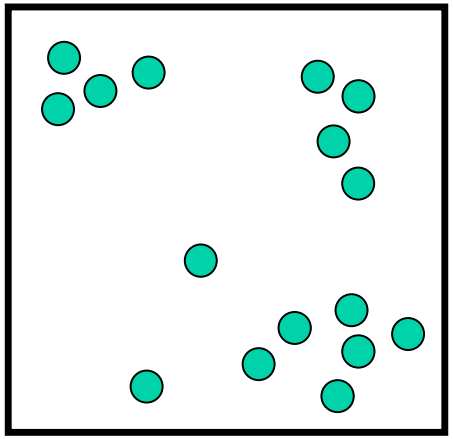
Sampling points

- The data constitute a sample of the underlying, continuous field.
- For example:
  - Weather station (e.g. temperature)
  - Pollution monitor station (e.g. CO_2 concentration)

Control Points



- **Surface random samples**: control points locations are chosen without reference to the surface being sampled.



- **Surface specific sampling**: points are located at places thought to be important in defining the surface

Points to surface

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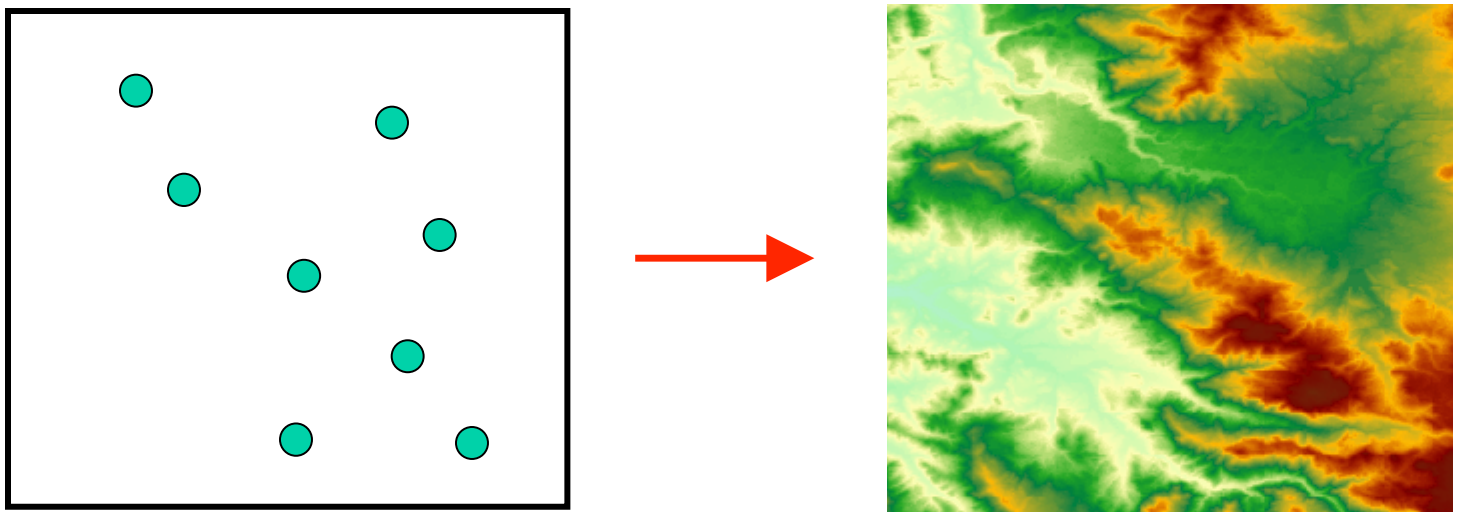
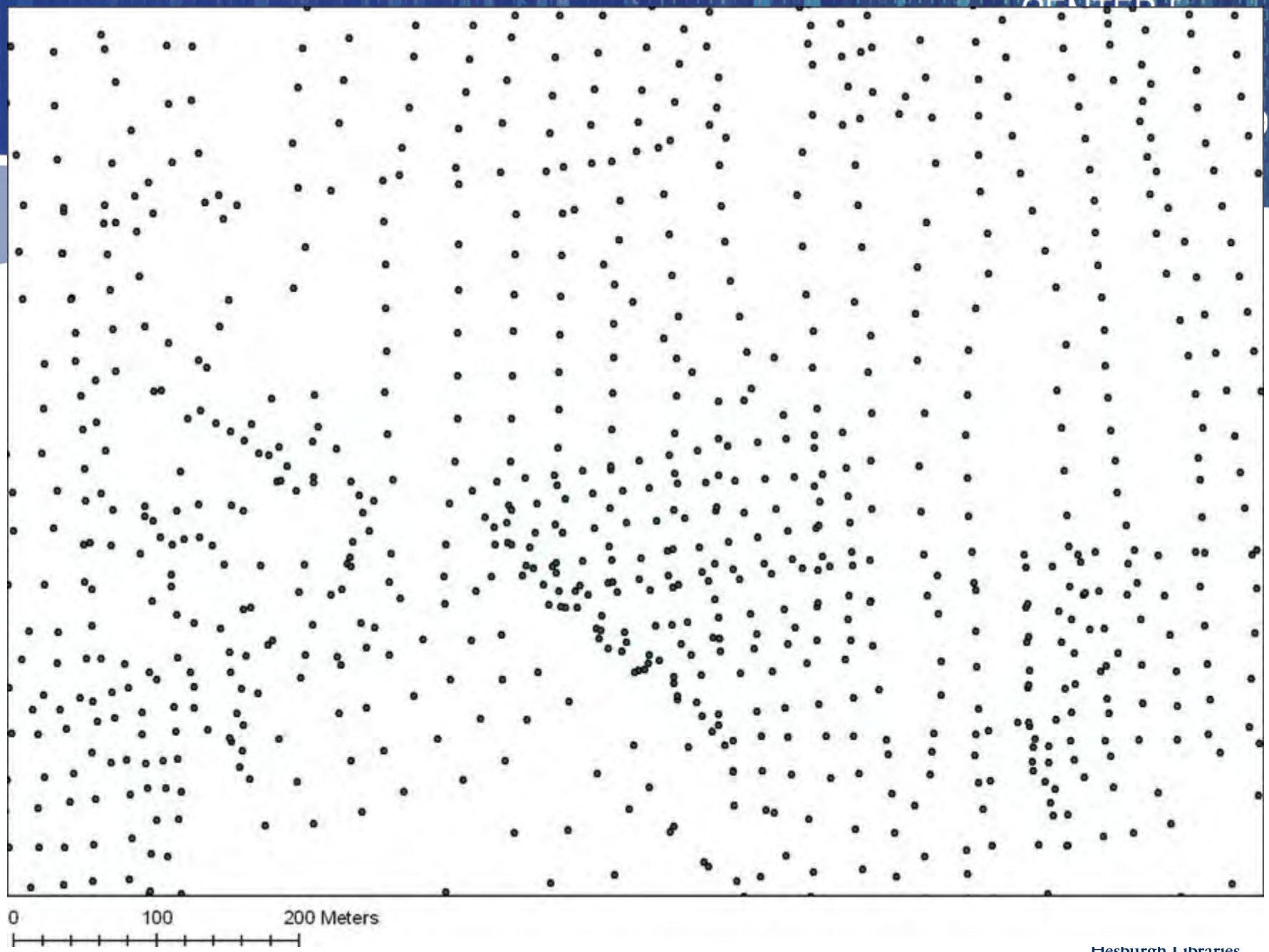
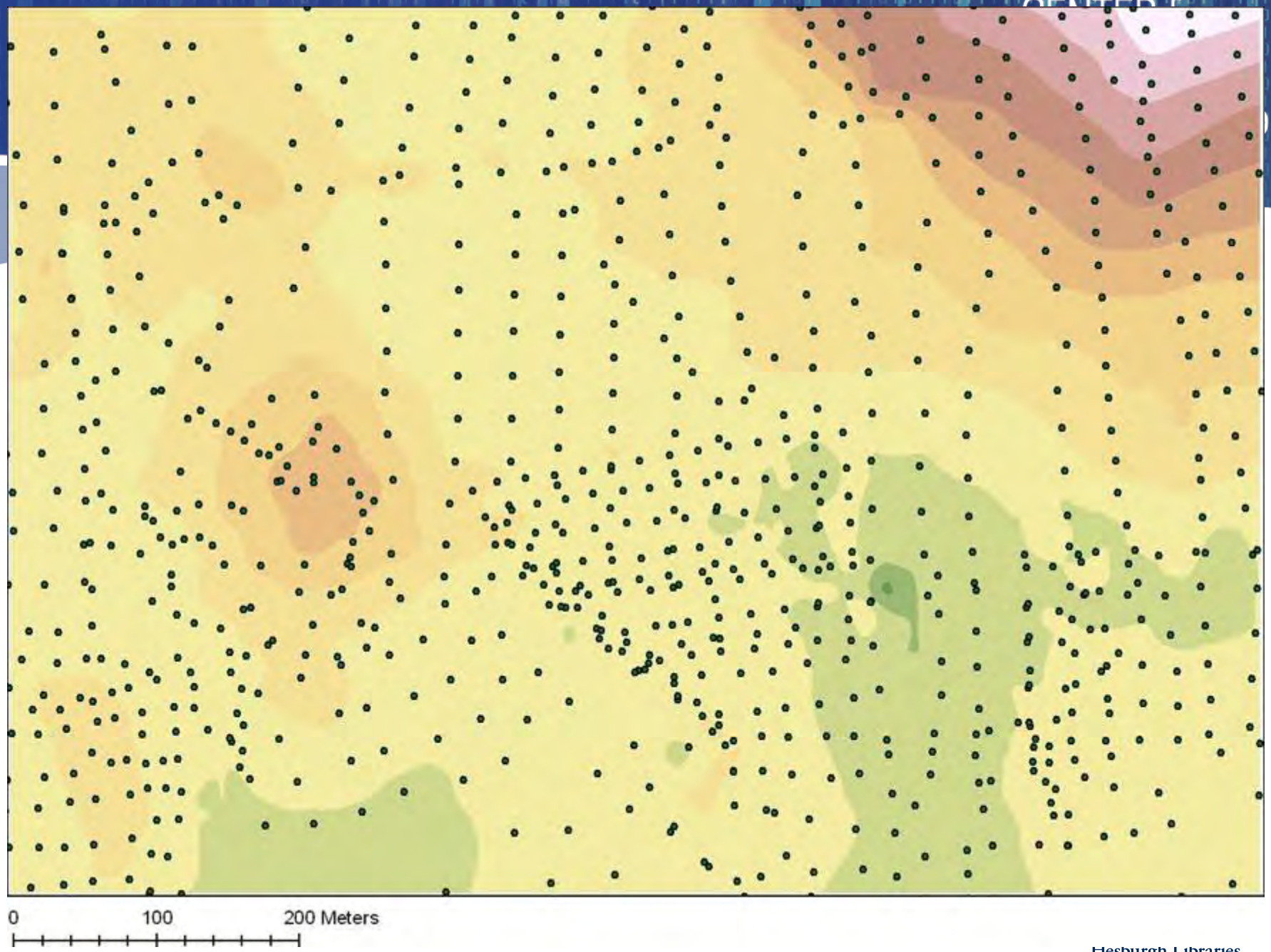
Interpolation: reconstruct the underlying continuous surface of data from the limited evidence of the control points (samples)




0
100
200 Meters


0
100
200 Meters

Interpolation methods

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Two main types

1. **Global methods**: use every control point available to make the estimate of each unknown value
2. **Local methods**: use a sample of control points for estimation, usually the closest points

Comparison of Local Methods

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Local methods

1. Thiessen Polygons
2. Local Spatial Average
3. Inverse Distance Weighted
4. Splines

- Kriging

- Similar results, but large errors in data-poor areas
- Accuracy must be determined by cross-validation analysis.
  - remove a point and recalculate comparing the error between estimate and known
  - if sufficient points, split sample and compare known with estimates

Interpolation of other data

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- Any point-based samples can be interpolated to generate a surface
  - Should only be things that we assume would vary consistently across the surface
  - Like topography, areas with sparse data will be inaccurate

Geostatistical Analyst

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- These allow you to identify trends in your data.
- Also have error-checking devices.