

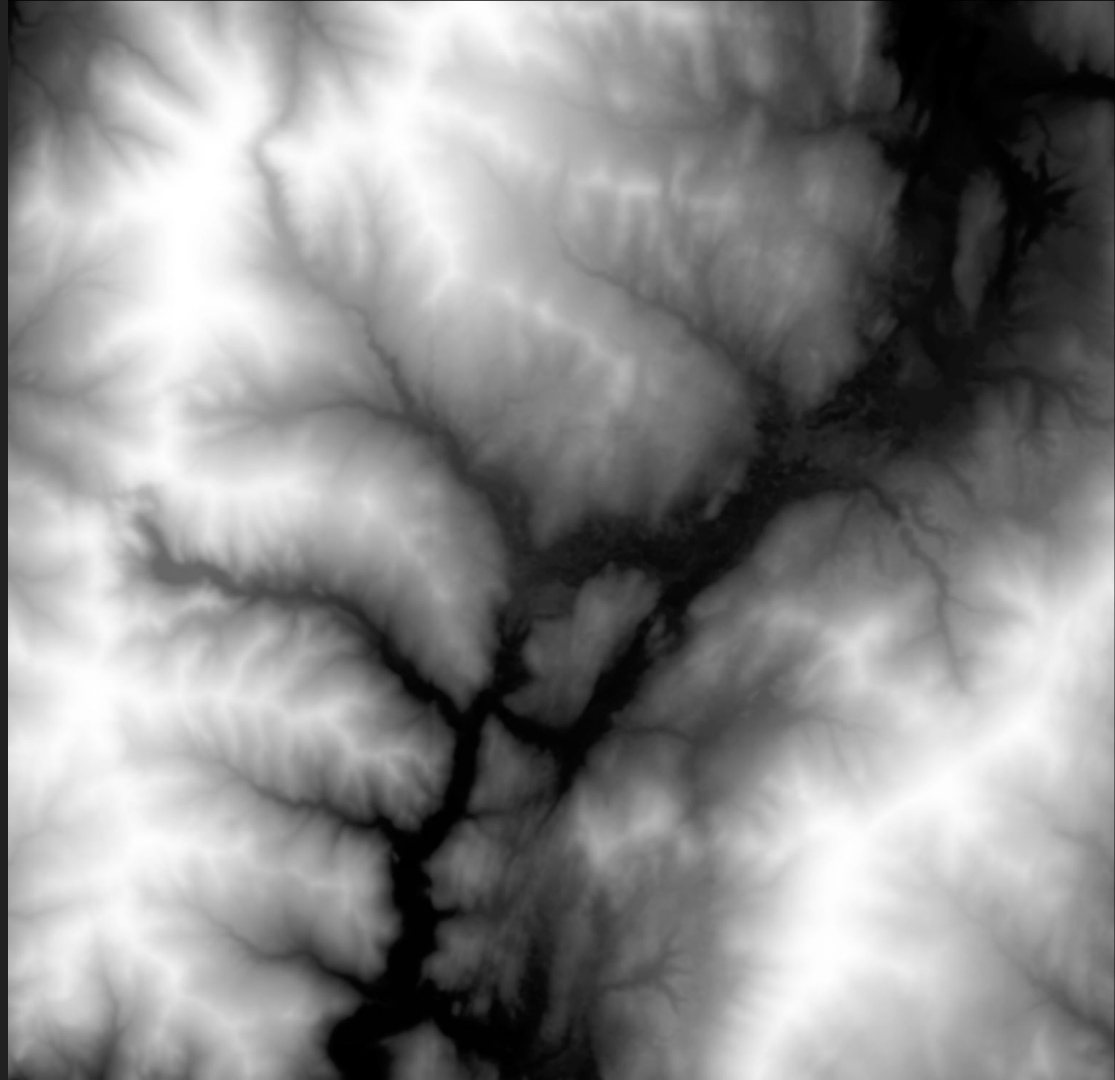
Geographic Information Systems

ESM 263 - Winter 2023

Terrain and Watershed Analysis

Digital Elevation Model (DEM)

raster of elevations



Slope

- Magnitude of gradient
- $\tan(\text{slope}) = ((\partial z/\partial x)^2 + (\partial z/\partial y)^2)^{1/2}$



Aspect (aka Exposure)

- Direction of gradient
- $\tan(\text{aspect}) = -(\partial z / \partial y) / (\partial z / \partial x)$
- NB: cyclical
 - wraps around at 360°
 - this image →
 - white: south
 - black: north



Slope & Aspect: Calculation Neighborhoods

4 nearest neighbors

- "rook's case"
- GDAL: ZevenbergenThorne

	e_2	
e_1	C_0	e_3
	e_4	

8 nearest neighbors

- "queen's case"
- diagonal weights = $1 / \sqrt{2}$
- GDAL: Horn

e_1	e_2	e_3
e_4	C_0	e_5
e_6	e_7	e_8

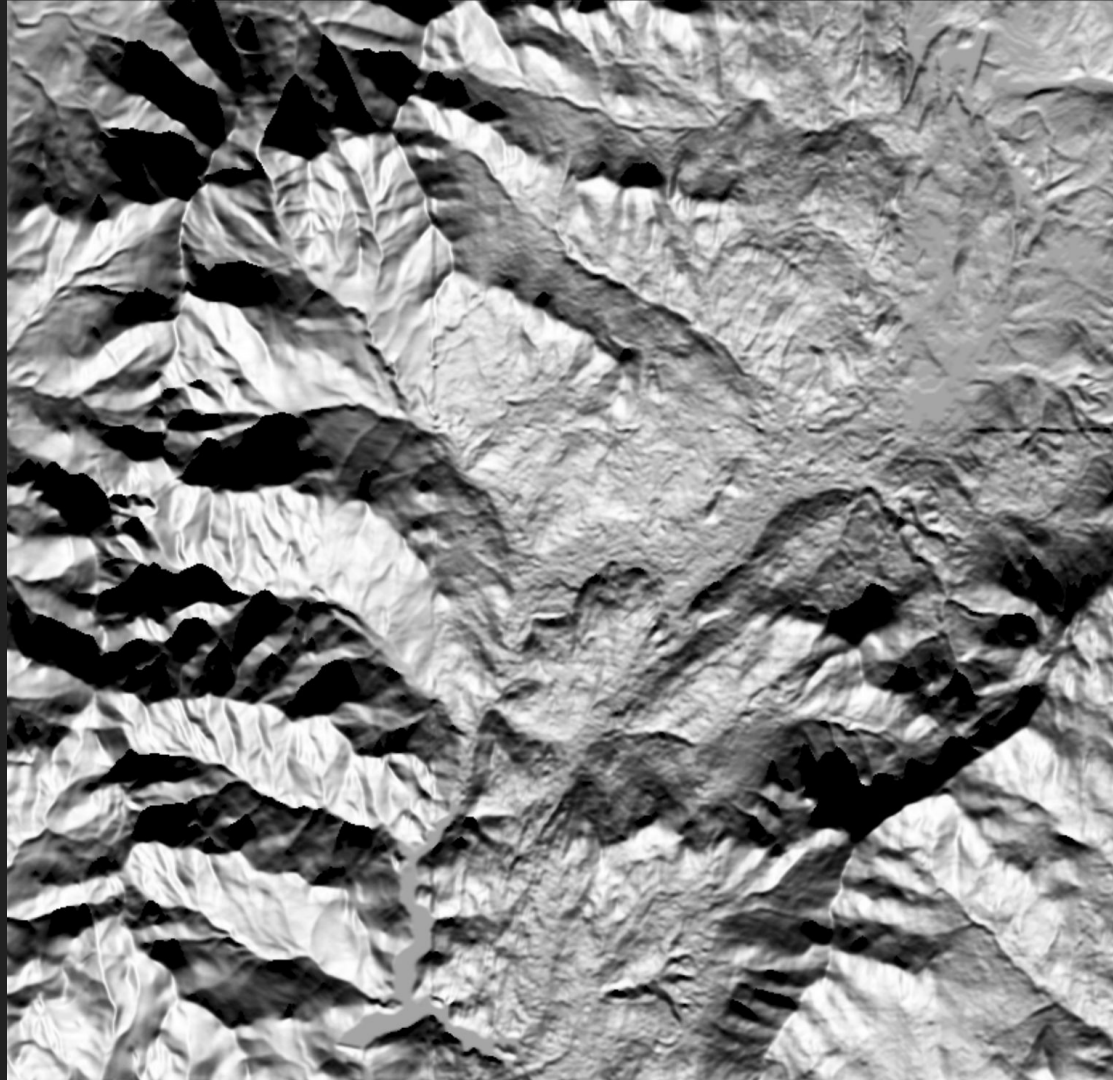
Hillshade

- local sun angle
- $\cos(Z) = \cos(Z_{\text{sun}}) \times \cos(S) + \sin(Z_{\text{sun}}) \times \sin(S) \times \cos(A_{\text{sun}} - A)$
- this image →
 - $Z_{\text{sun}} = 47.5^\circ$
 - $A_{\text{sun}} = 180^\circ$



Hillshade with Shadows

Shadowed pixels $\rightarrow 0$



Aspect vs Hillshade

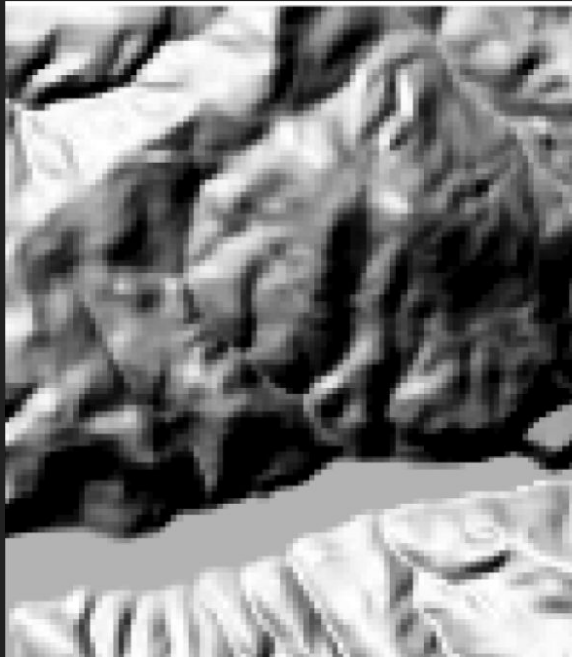
aspect



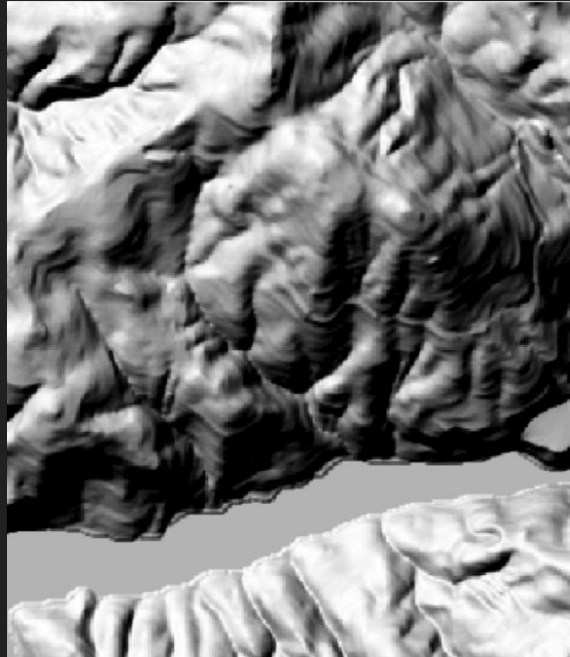
Hillshade ($Z_{\text{sun}} = 47.5^\circ$, $A_{\text{sun}} = 180^\circ$)



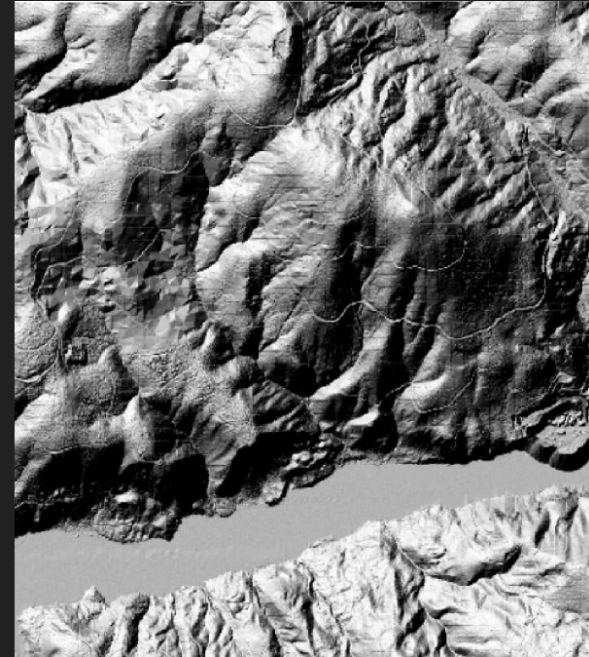
DEM Resolution



30 m (USGS)

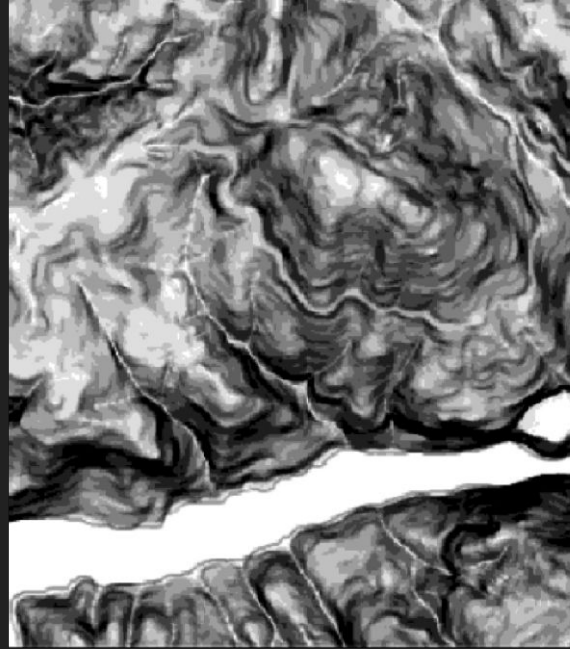
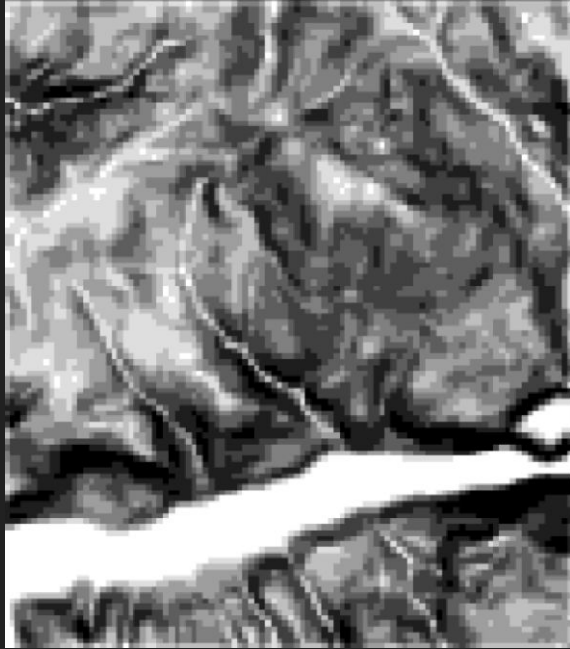


10 m (USGS)



1.830 (LIDAR)

DEM Resolution: Derived Products



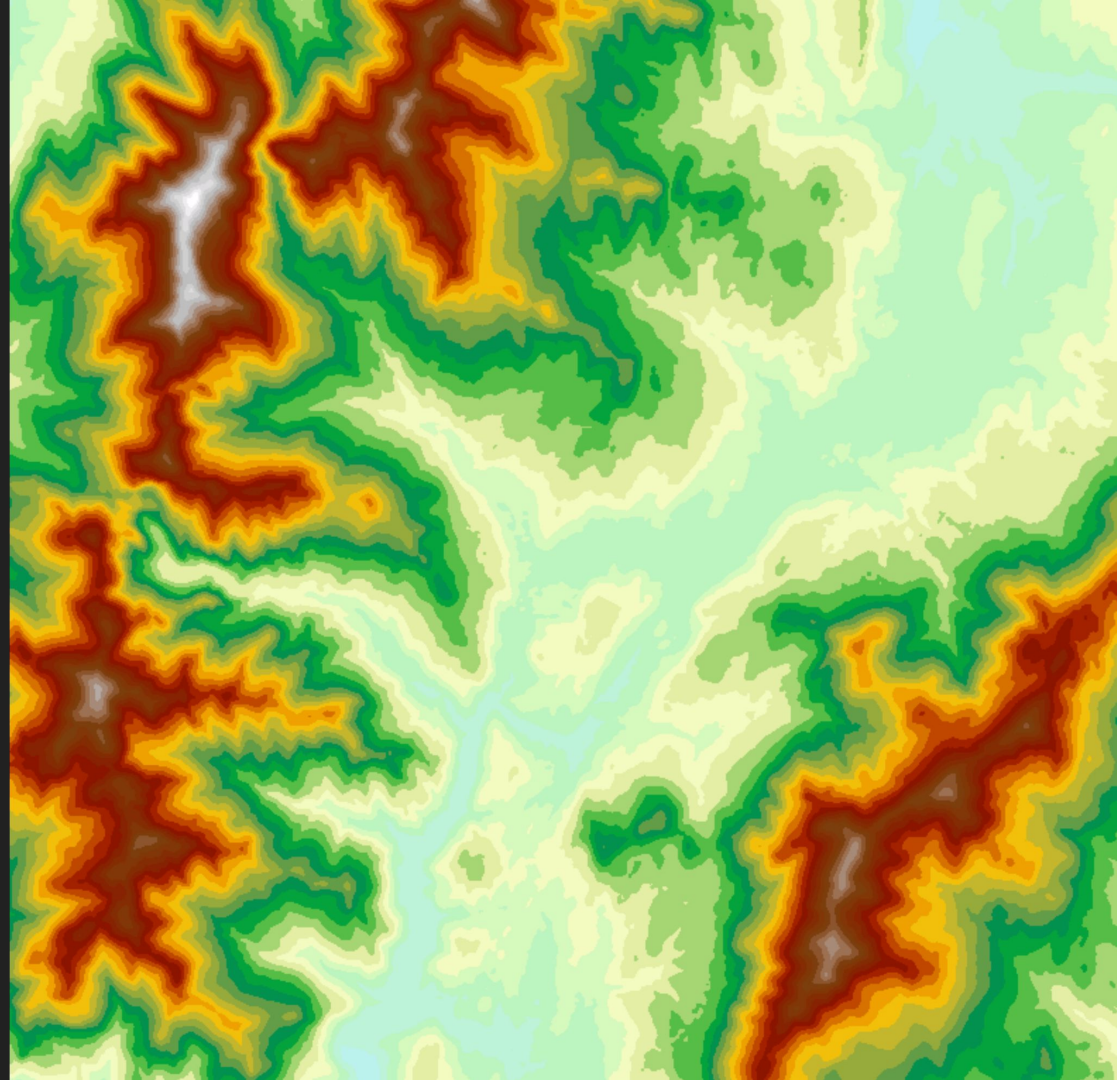
Slope layers derived from three previous DEMs

DEM Rendering: Hypsometric Map

Classified DEM

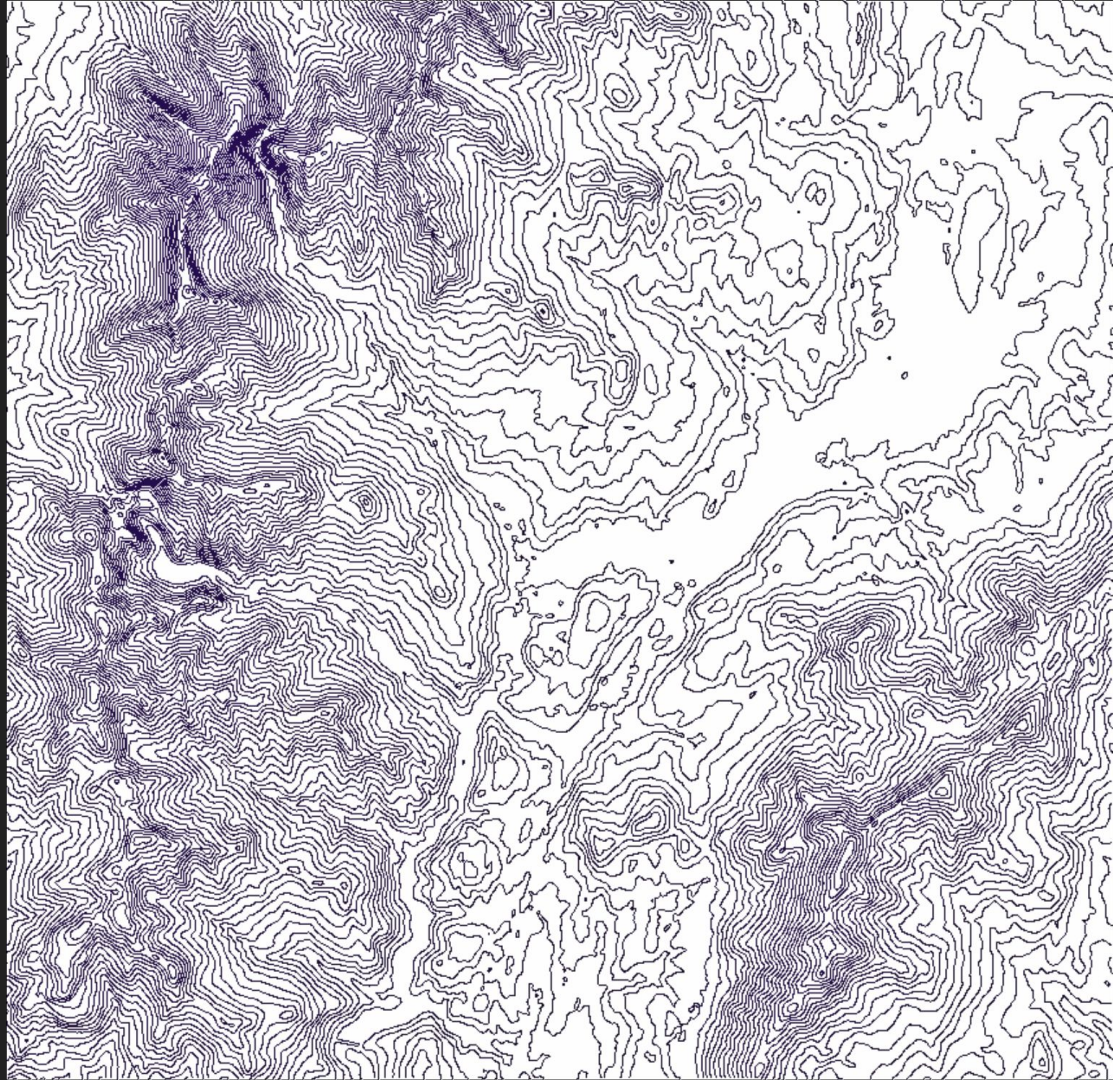
Color: elevation “band”

QGIS: Setting a Color Ramp



DEM Rendering: Contour Map

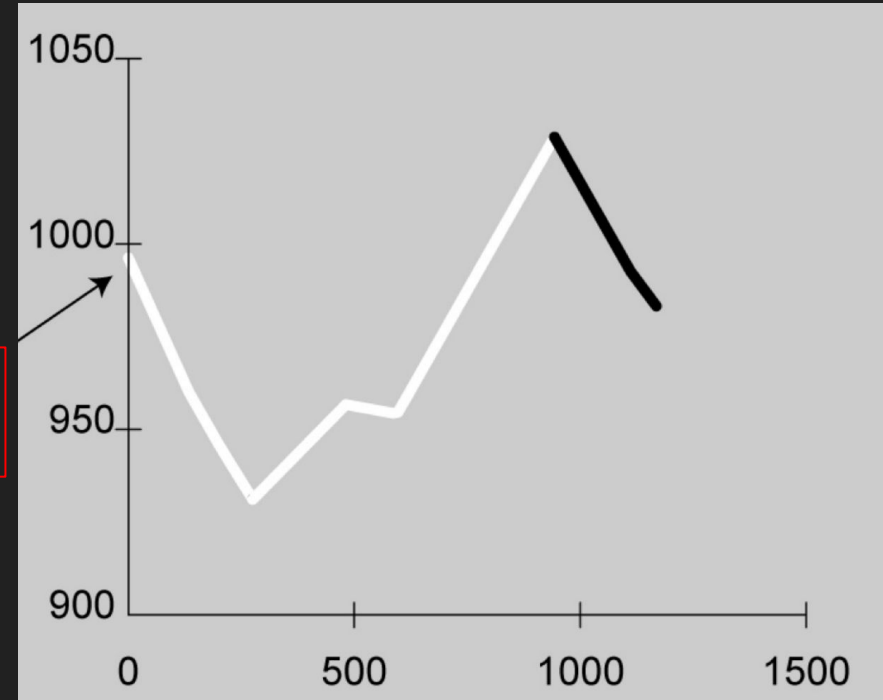
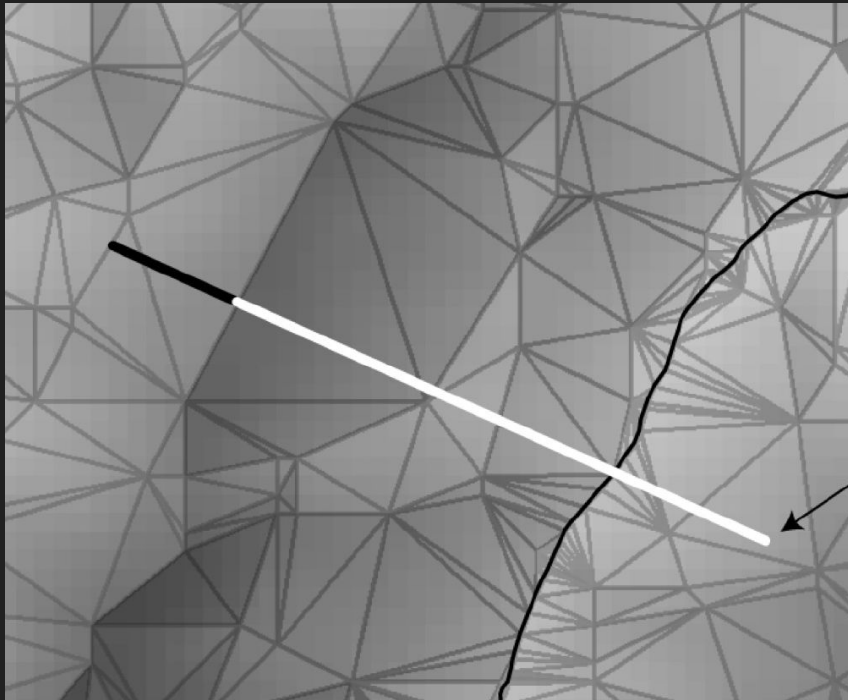
Lines of constant elevation



Visibility: Sightlines

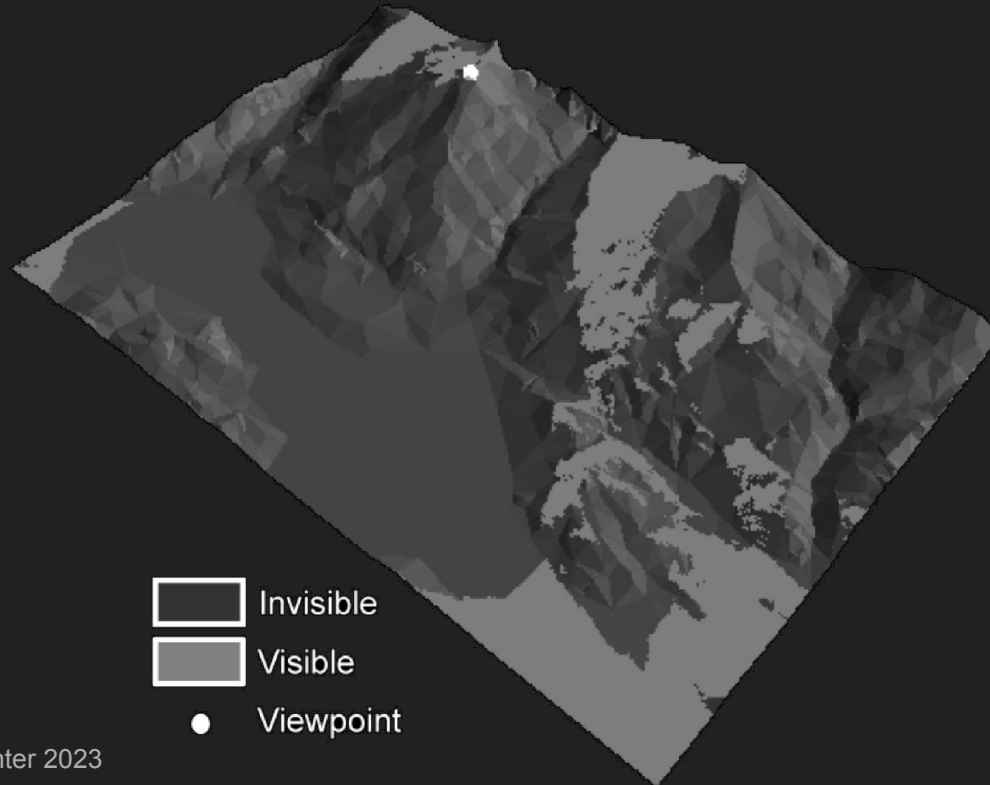
Sightline = visibility between points

- white: visible
- black: obscured



Visibility: Viewshed

Viewshed = area visible from point

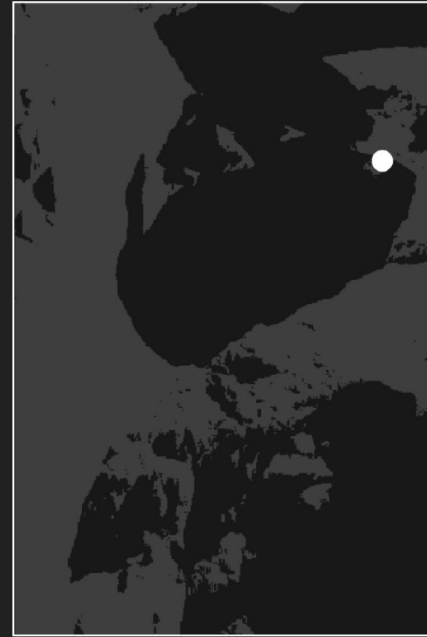


Viewshed = $f(\text{Elevation})$

(b) higher than (a) \rightarrow larger viewshed



(a)



(b)

Viewshed = f(Search Radius)

edge of DEM



(a)

fixed radius



(b)



Viewshed: Cumulative

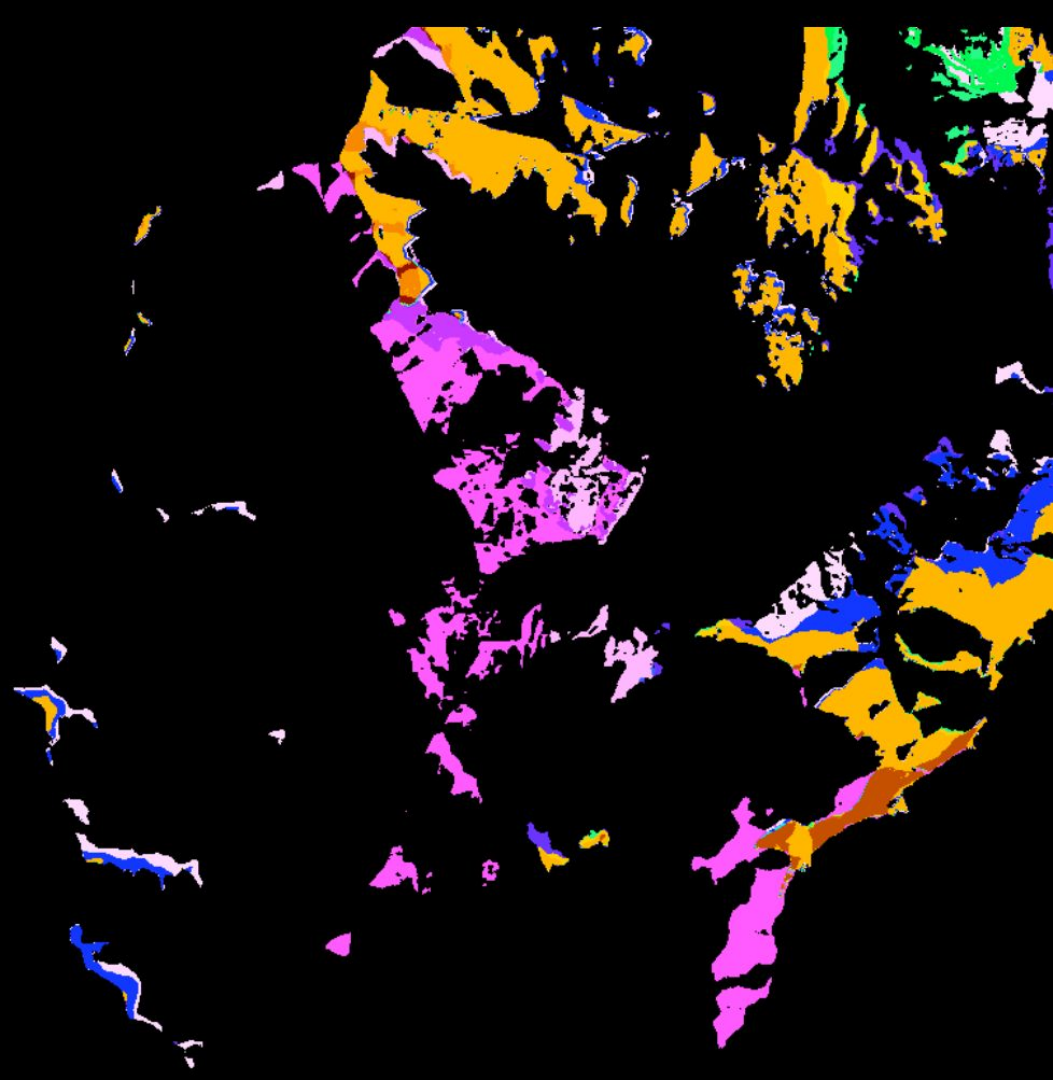
- green areas visible from at least one point
- pink areas invisible from any point



Viewshed: Specific

Cell values code all possible combinations of search points

code = visible from points(code)



Watershed Analysis

- Watershed
 - area that drains surface water to a common outlet
 - defined by topographic divides
- Watershed analysis
 - Use
 - DEMs
 - raster operations
 - To
 - derive topographic features
 - e.g. stream networks
 - delineate watersheds

Watershed Delineation

- "Coarse"
 - maximal areas that drain off edge of DEM
- "Fine"
 - minimal areas that drain into each stream segment

Automated Watershed Delineation (coarse)

1. Fill sinks (depressions) in DEM
2. Derive flow direction raster
 - direction water will flow out of each cell
3. Derive watershed raster
 - mark all cells that flow towards common outlet

Flow Direction

For 8-neighborhood:

- calculate distance-weighted drop
 - 4 immediate neighbors: center - neighbor
 - 4 corner neighbors: $(\text{center} - \text{neighbor}) / \sqrt{2}$
- flow direction = maximum drop

1014	1011	1004
1019	1015	1007
1025	1021	1012

(a)

+1	+4	+11
-4		+8
-10	-6	+3

(b)

	→	

(c)

Automated Watershed Delineation (fine)

1. Fill sinks (depressions) in DEM
2. Derive catchment areas
 - accumulated water flow through each cell
3. Derive channel network
 - apply threshold value to catchment area
4. Derive watershed basins
 - areas draining into each channels

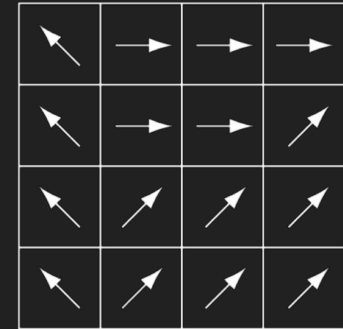
Flow Accumulation

1. filled elevation raster
2. flow direction raster
3. flow accumulation raster
 - shaded cells have same accumulation value
 - top cell receives flow from left and lower-left cells
 - bottom cell receives flow from lower-left cell
 - already had accumulation value of 1

(a)

1014	1011	1004	996
1019	1015	1007	999
1025	1021	1012	1003
1033	1029	1020	1003

(b)

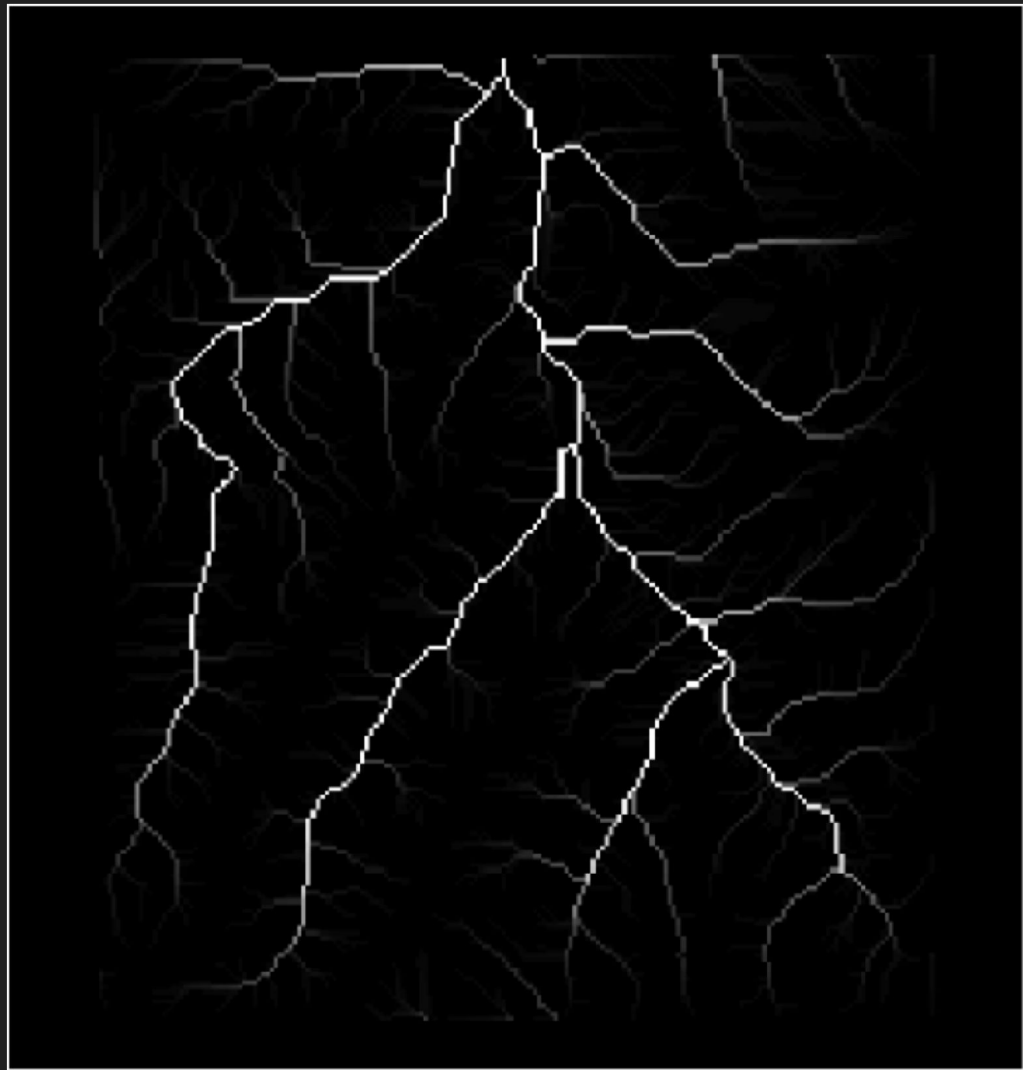


(c)

0	0	1	2
0	0	2	6
0	0	2	3
0	1	2	3

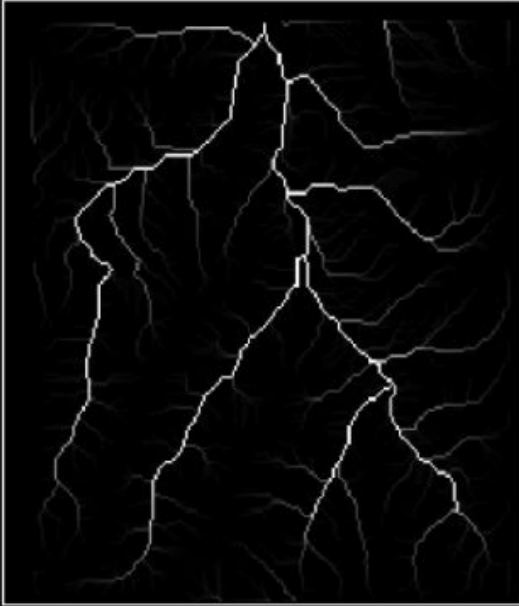
Flow Accumulation

brighter symbols
= higher accumulation values



Stream Network

flow accumulation raster

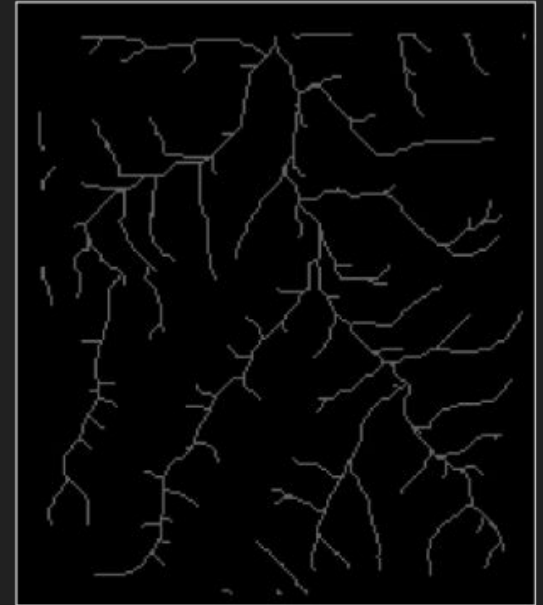


(a)

stream network (threshold = 500) stream network (threshold = 100)



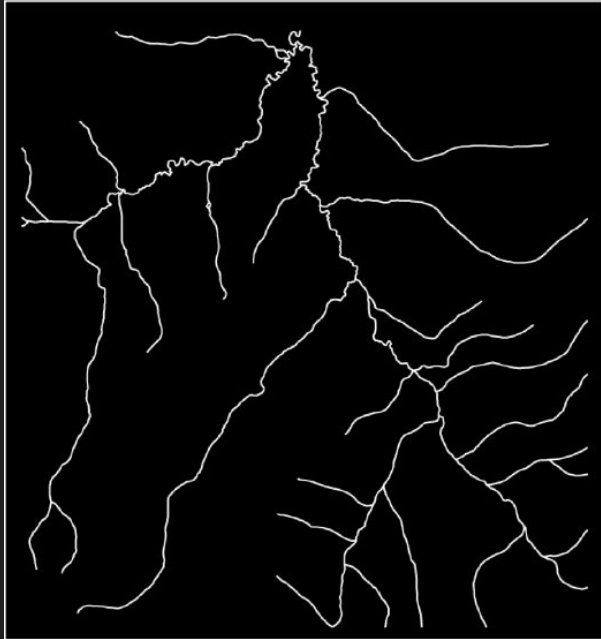
(b)



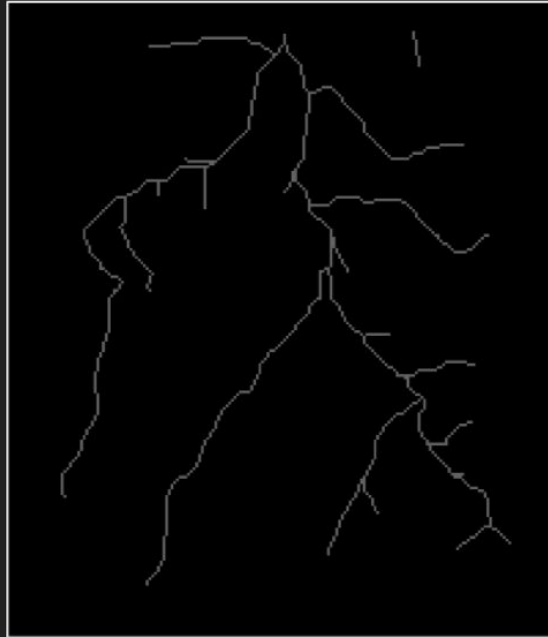
(c)

Stream Network

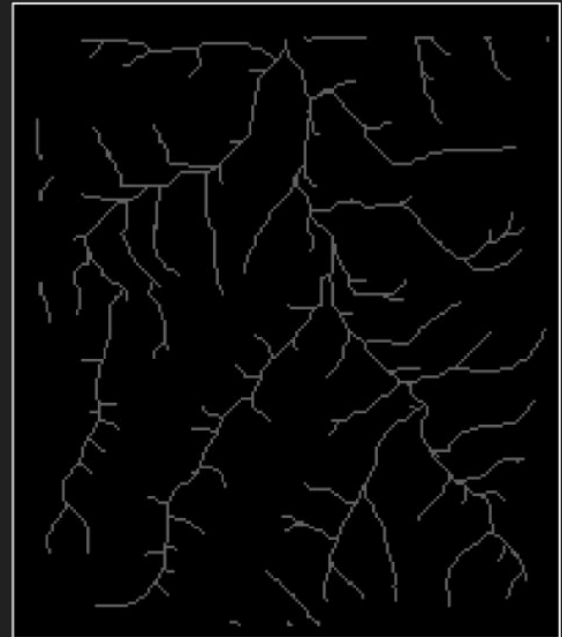
mapped (1:24000DLG)



Calculated (threshold = 500)

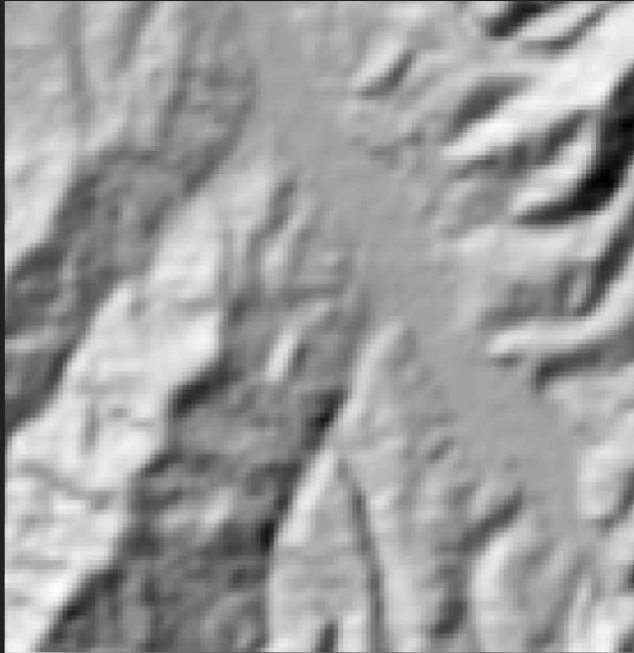


Calculated (threshold = 100)

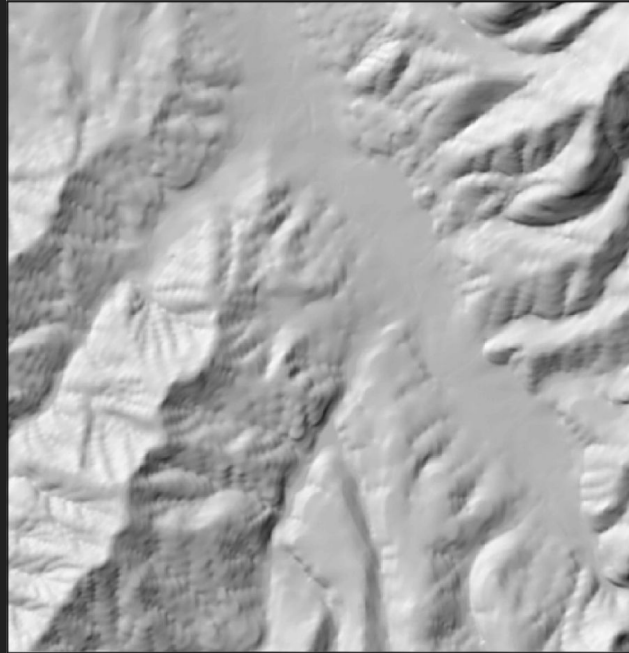


Resolution Affects Watershed Analysis

30 m DEM

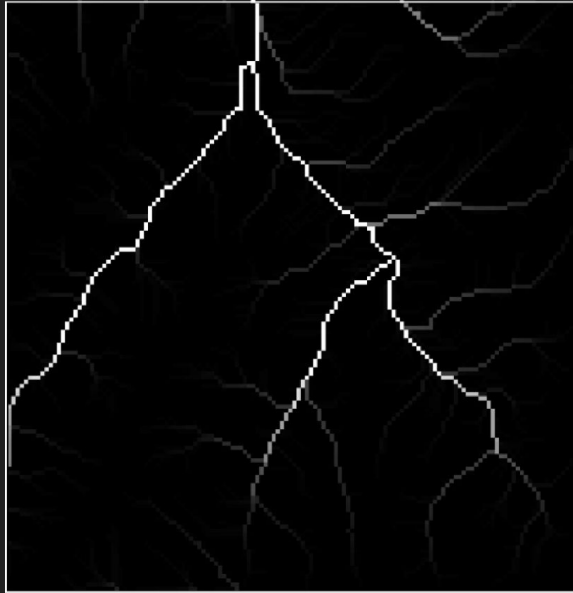


10 m DEM



Resolution Affects Watershed Analysis

Strem network from
30 m DEM



(a)

Strem network from
10 m DEM



(b)

Relief Affects Watershed Analysis

- gray raster lines
= stream segments from D8 method
- thin black lines = stream segments from
1:24,000-scale DLG
- Agreement:
 - good in valleys
 - poor in flat areas

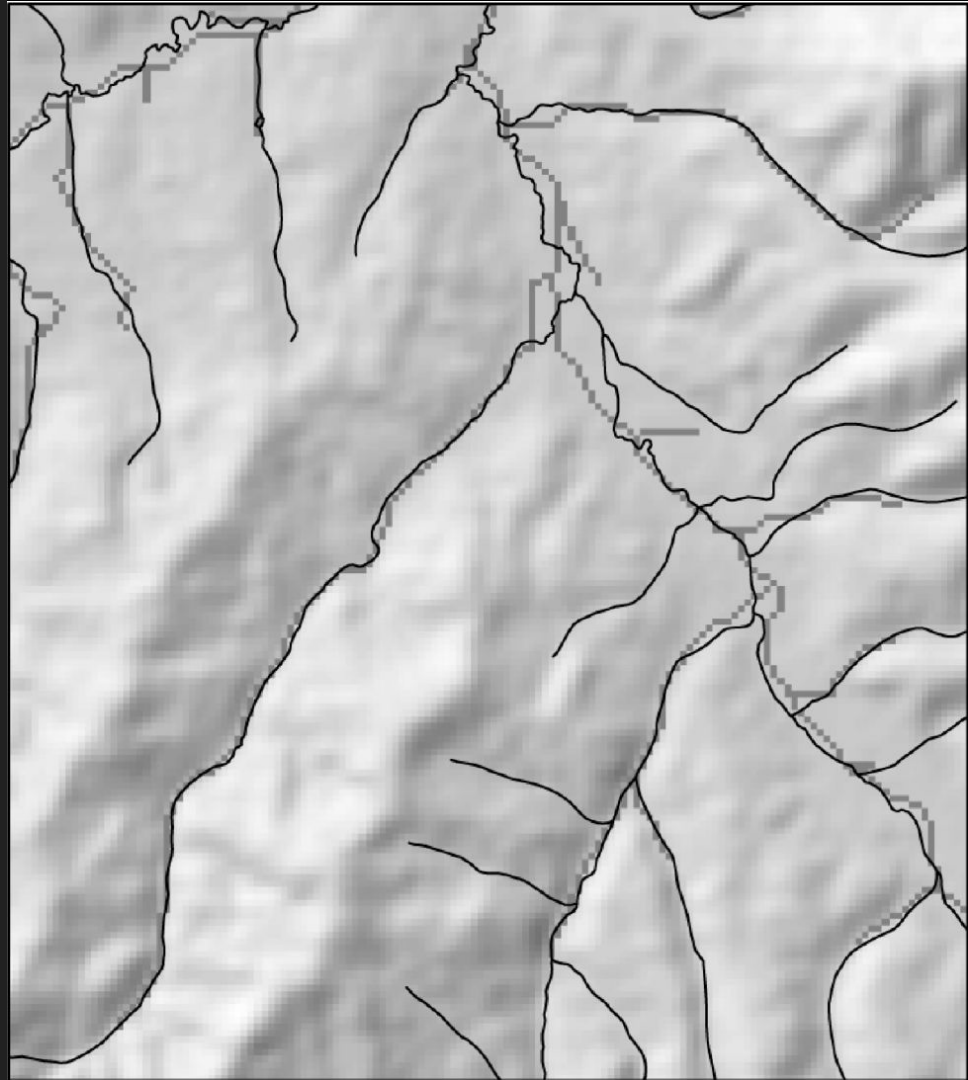


Figure Credits

- Introduction to Geographic Information Systems, 4th ed.
 - ISBN 978-0-07-305115-2
- ArcMap Help