Comparison of Methods for Estimating Stream Channel Gradient Using GIS

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BOISE AQUATIC SCIENCES LAB

RMRS

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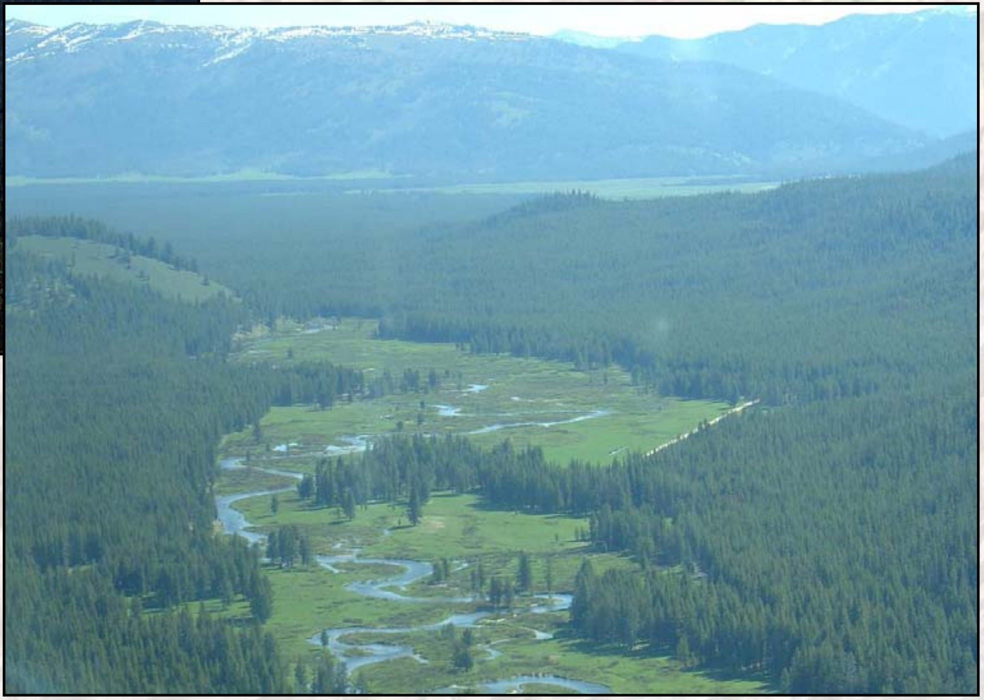
Stream Channel Gradient

Rate of elevation change

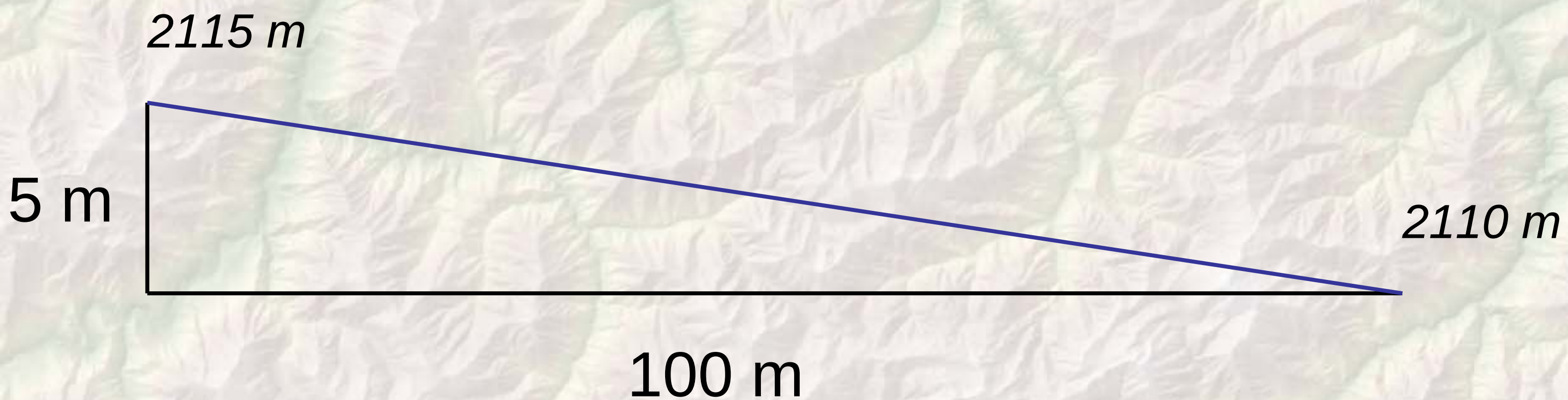
High



Low

Computing Gradient

Rise / Run = Slope

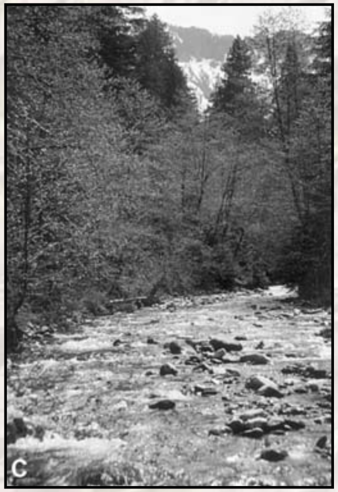


5 / 100 = .05 = 5% slope

Reasons for Modeling Stream Gradient

- Predictor of channel morphology

Pool-riffle
1%



Plain-bed
3 - 4%

Step-pool
10%

Reasons for Modeling Stream Gradient

- Estimate distribution of aquatic organisms

*"**Channel gradient** and channel morphology appeared to account for the observed differences in salmonid abundance, which reflected the known preference of juvenile coho salmon Oncorhynchus kisutch for pools."*

- Hicks, Brendan J. and James D. Hall, 2003

Reasons for Modeling Stream Gradient

- Predict debris flow transport and deposition

"Transportation and deposition of material in confined channels are governed primarily by water content of debris, channel gradient, and channel width."

- Fannin, R. J and T. P. Rollerson, 1993

Our Purpose for Modeling Stream Gradient

- Estimate stream bed grain size to identify salmon spawning habitat

$$Grain\ Size = \frac{1000\rho g h S}{(\rho_s - \rho) g \tau *} = \frac{1000\rho\left(cA^f S\right)^{1-n}\left(aA^b\right)^n}{(\rho_s - \rho)k}$$

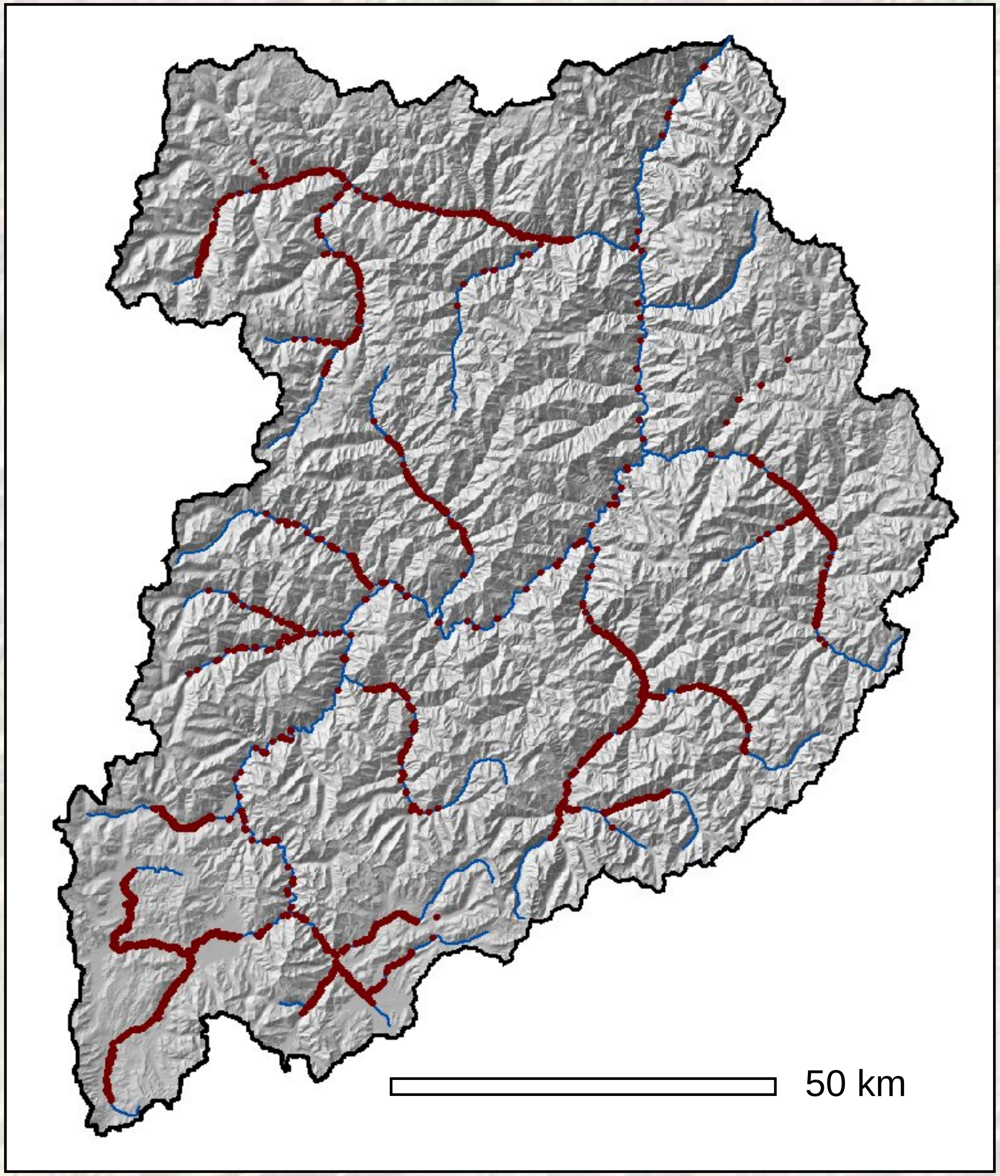
S = channel slope

Grain size 16 – 51 mm

Study Area

10,000 km of rivers and streams

Chinook Salmon Spawning Sites 1995 - 2004

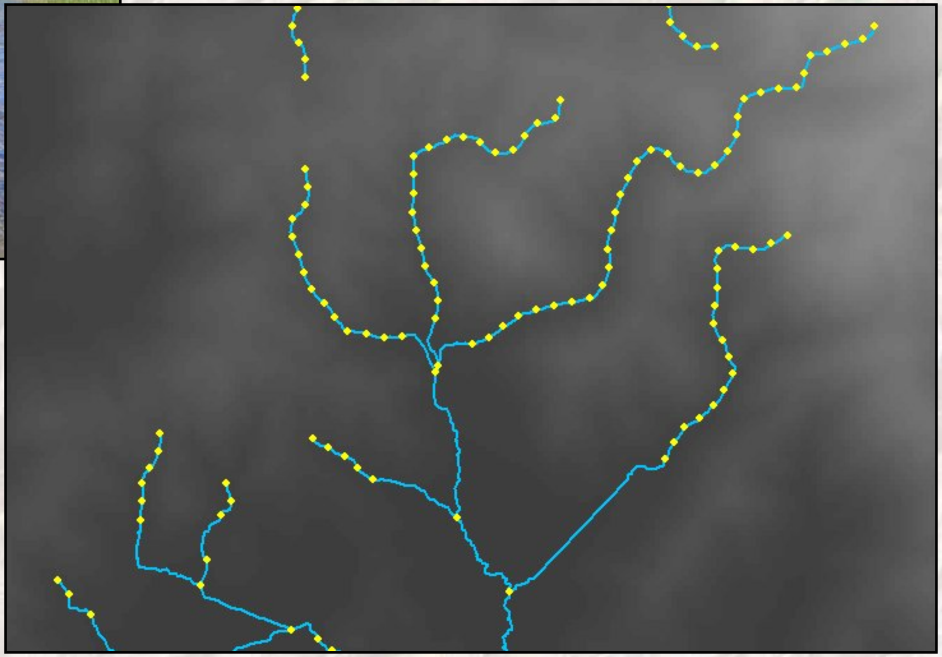


Research questions

1) Where are the optimum spawning sites?
2) Where might spawning expand if populations increased to historical levels?
3) Can grain size prediction be applied elsewhere?

Measuring Gradient

Directly



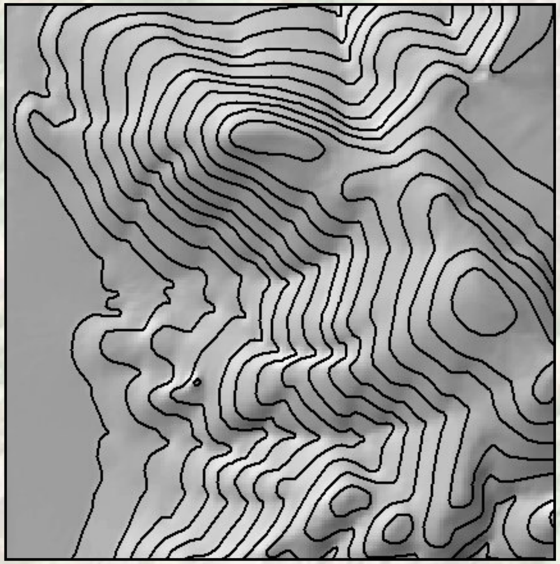
Remotely

Digital Data

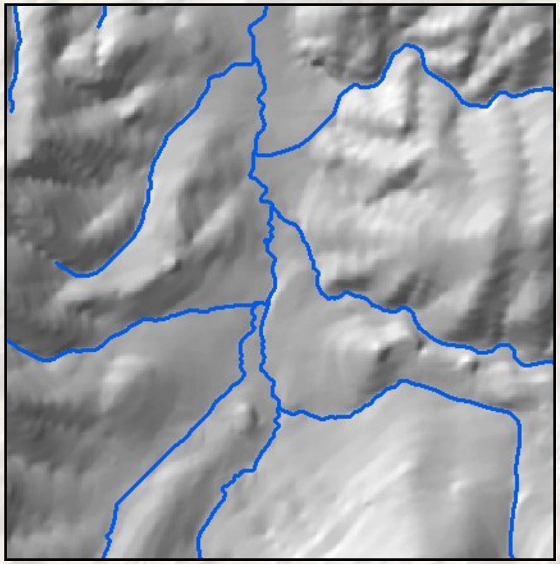
Some preliminary information

Necessary Data

1) Elevation - to compute rise

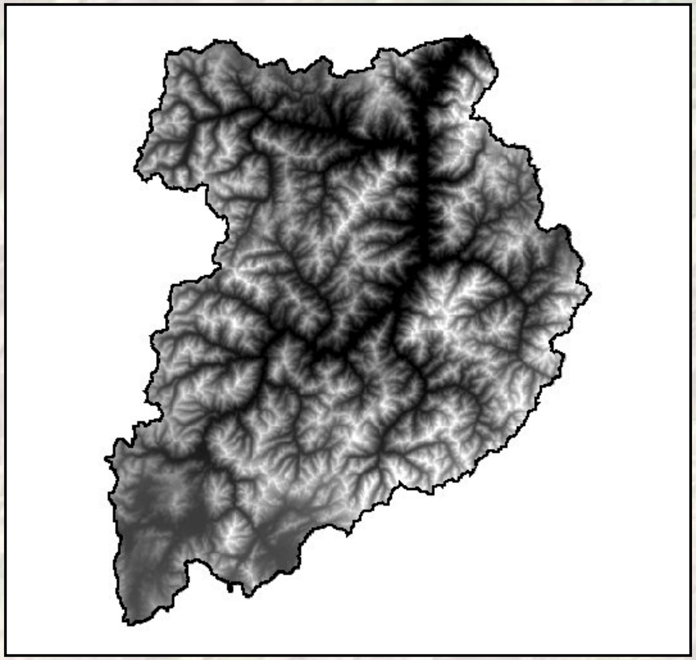


2) Stream lines - to compute run



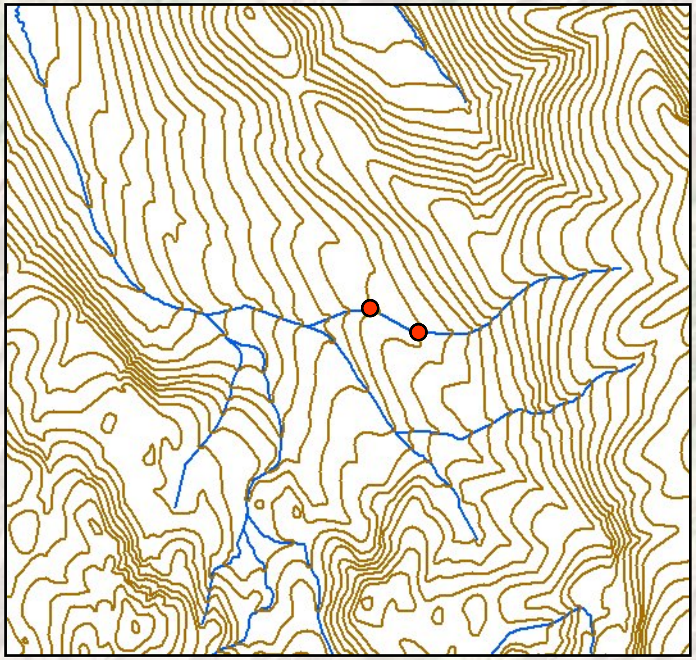
Choose Elevation Data

Digital Elevation Model (DEM)



USGS National Elevation Dataset (NED)

Contour lines



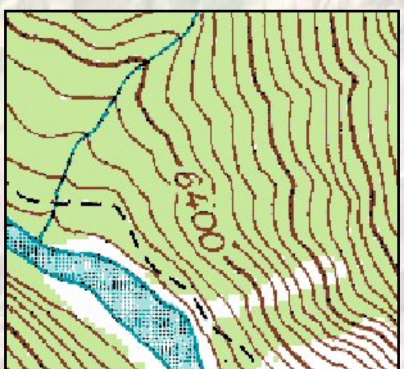
USGS 1:24,000 scale

DEM Production Process

1) Aircraft

2) Aerial photo

3) Stereo plotter

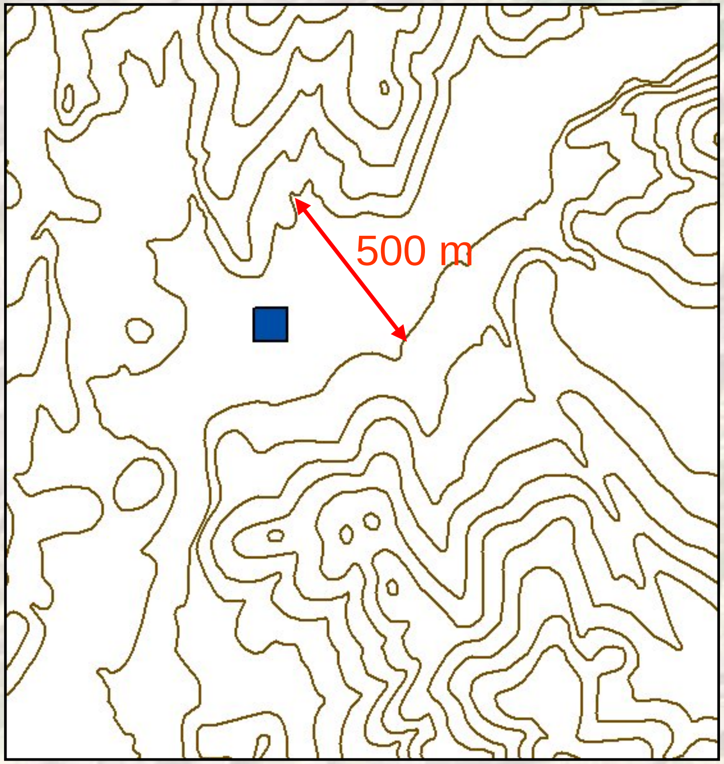


4) Map production

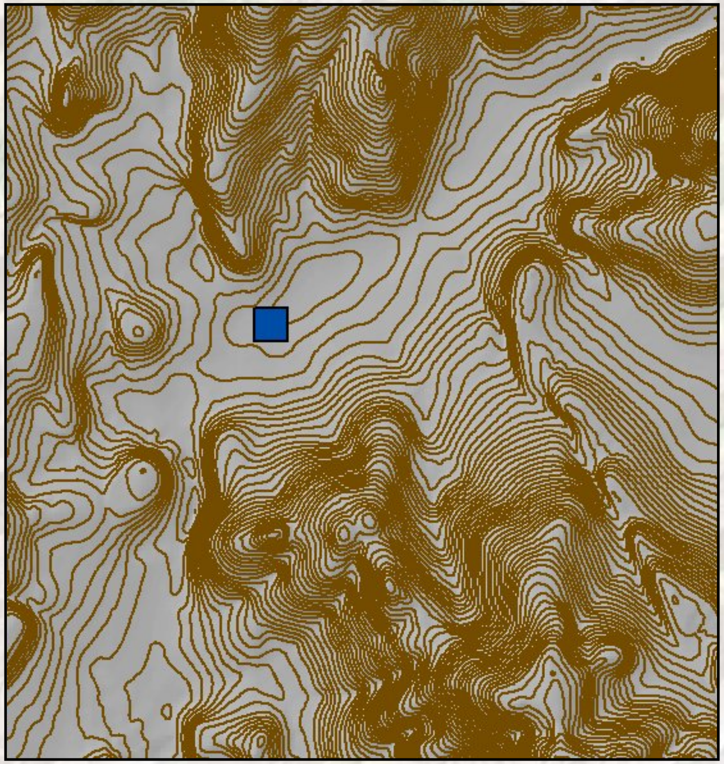
5) Scan and tag

6) LT4X

Original Contours and 10 m DEM Model



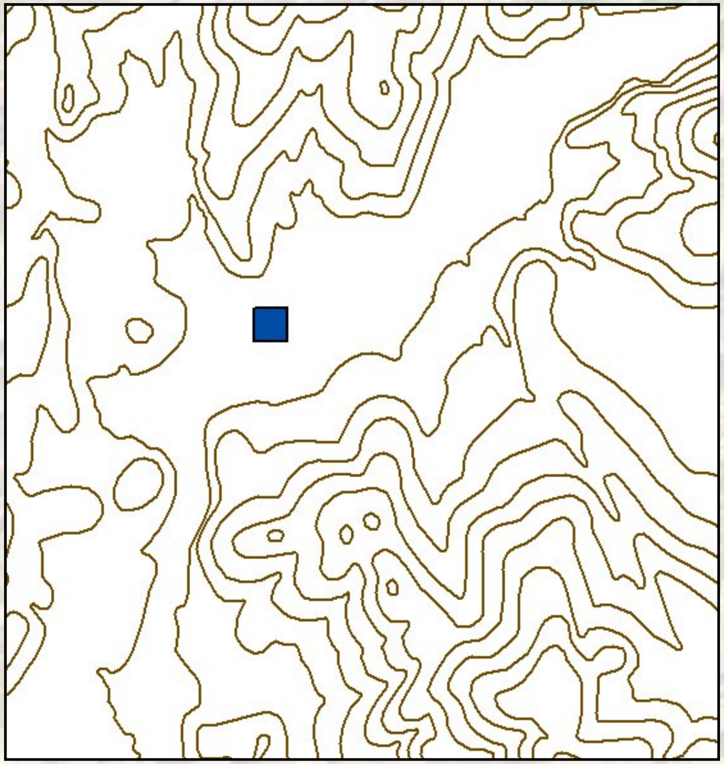
Original 40’ contours



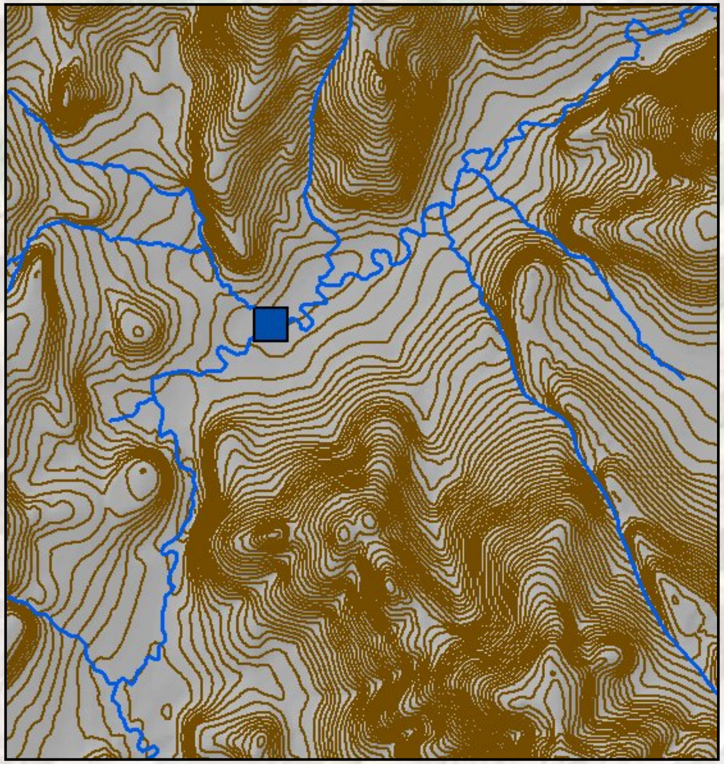
2 m contours derived from 10 m DEM

Blue box = 100 m x 100 m

Original Contours and 10 m DEM Model



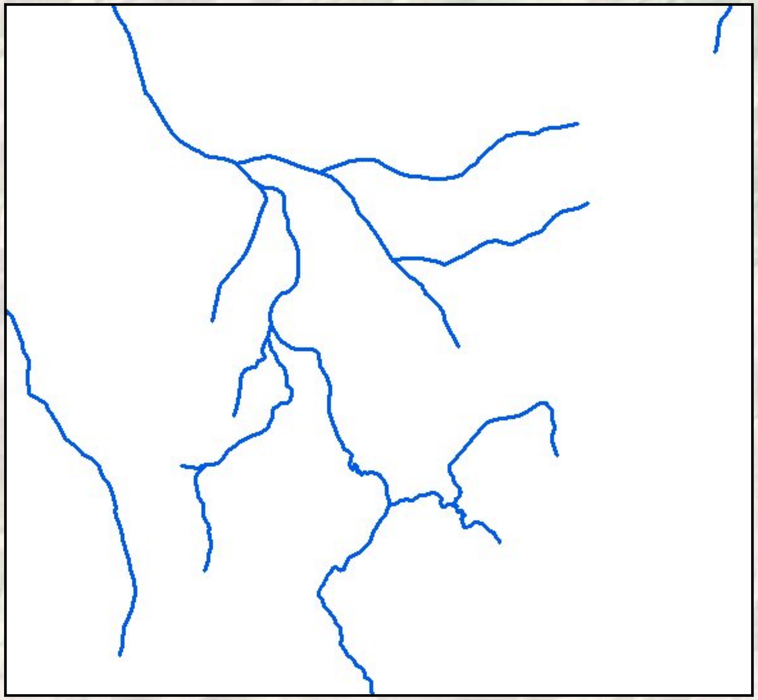
LT4X



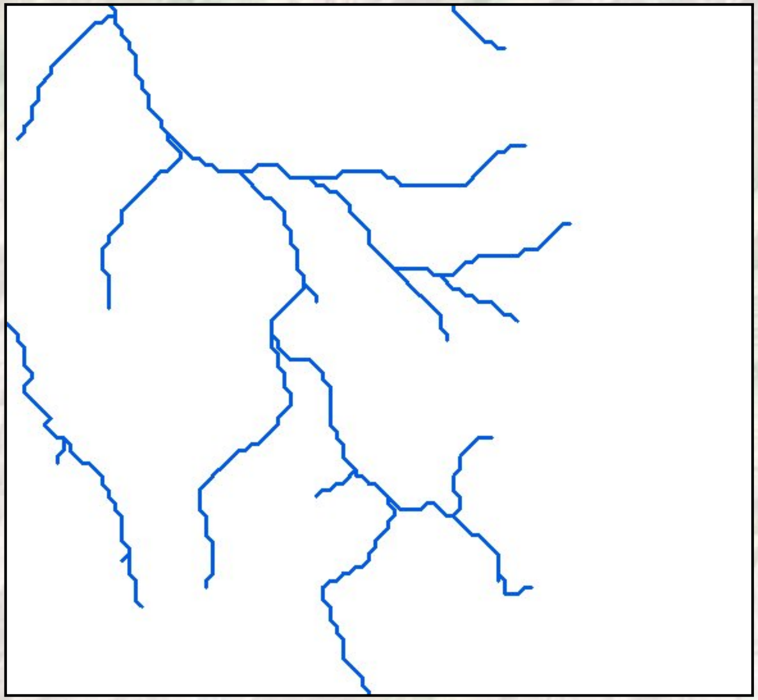
Original 40’ contours

2 m contours derived from 10 m DEM

Choose Stream Line Data

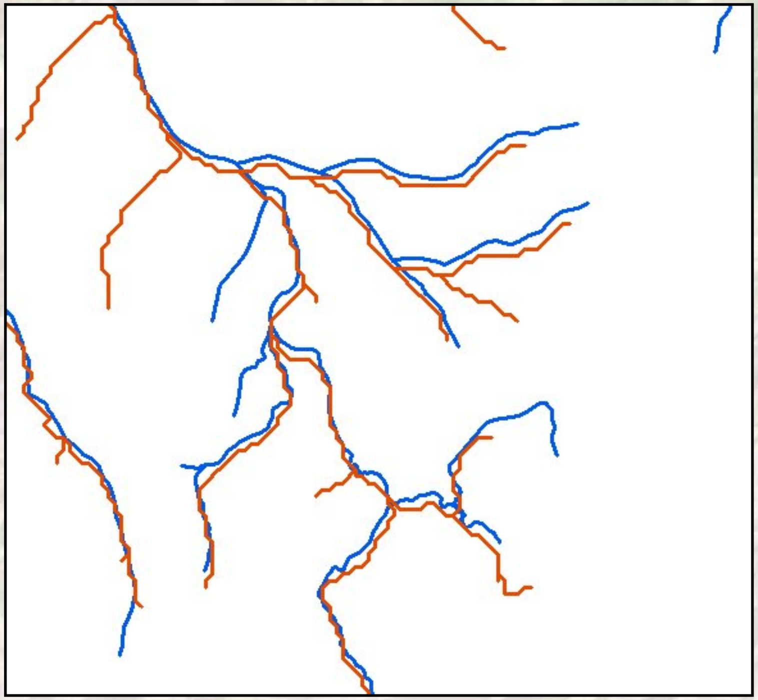


National Hydrography Dataset (NHD)

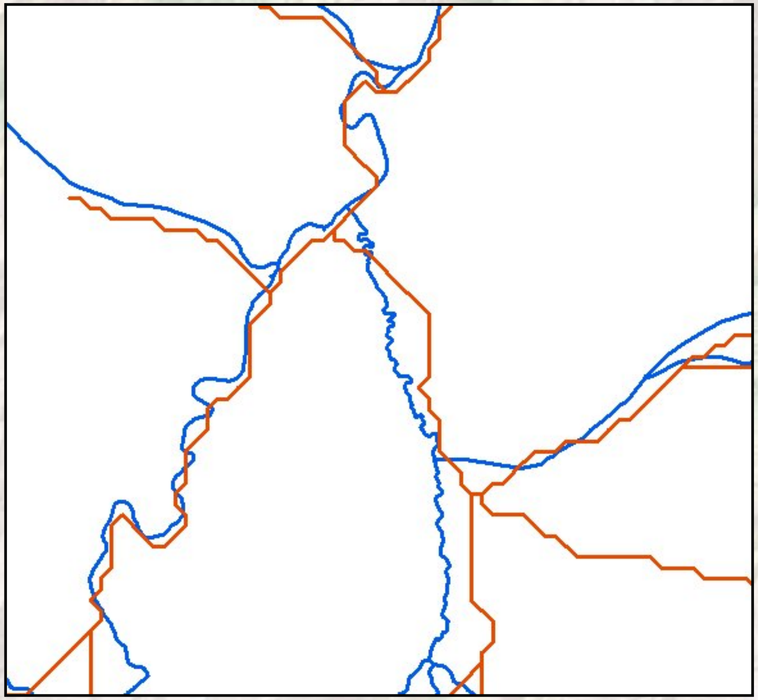


Synthetic stream lines

NHD and Synthetic Comparison

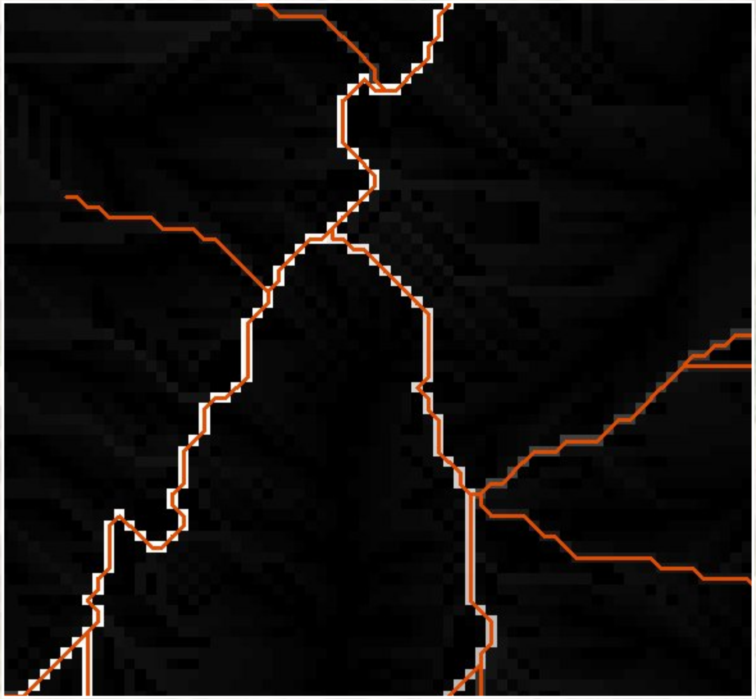


Higher gradient

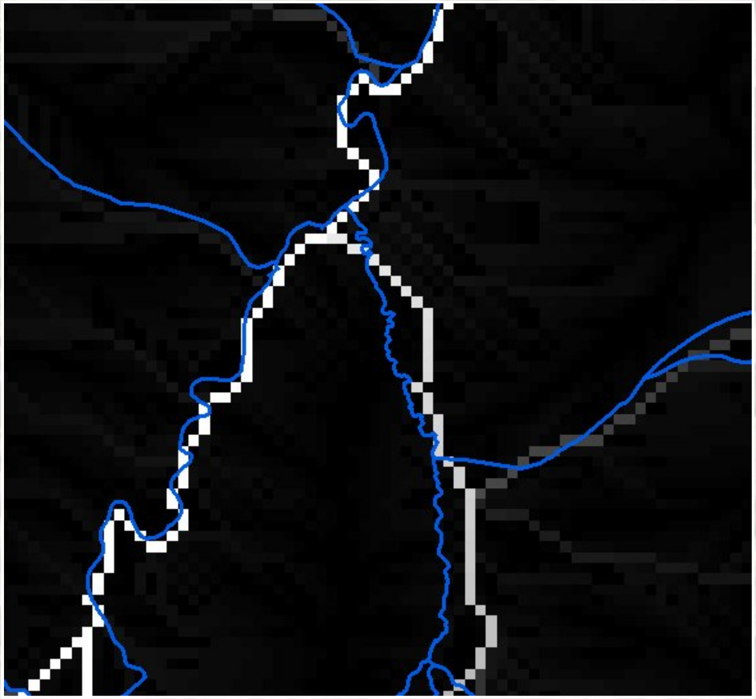


Low gradient

Synthetic Streams "Fit" the DEM



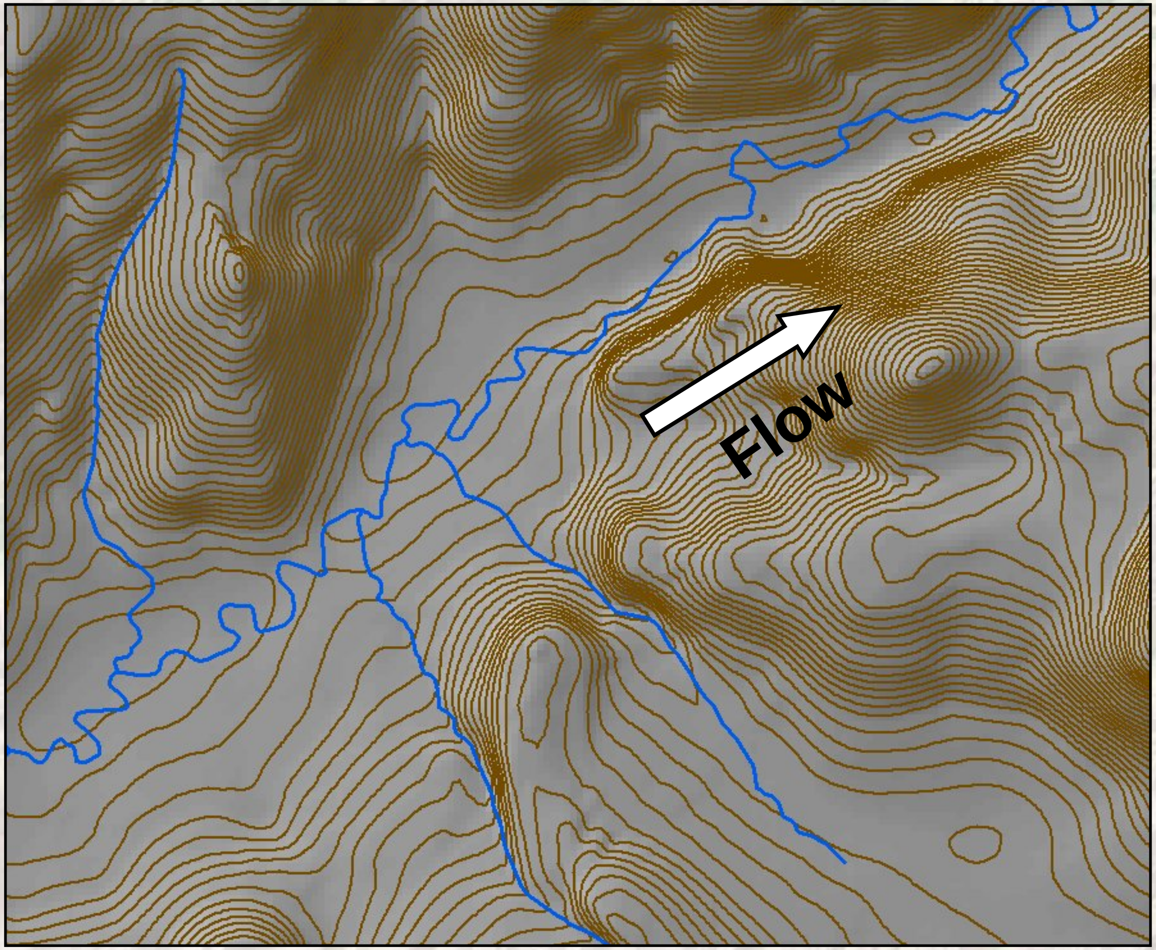
Synthetic streams follow the flow accumulation path and fall within the DEM channel



NHD streams often fall on DEM side slopes

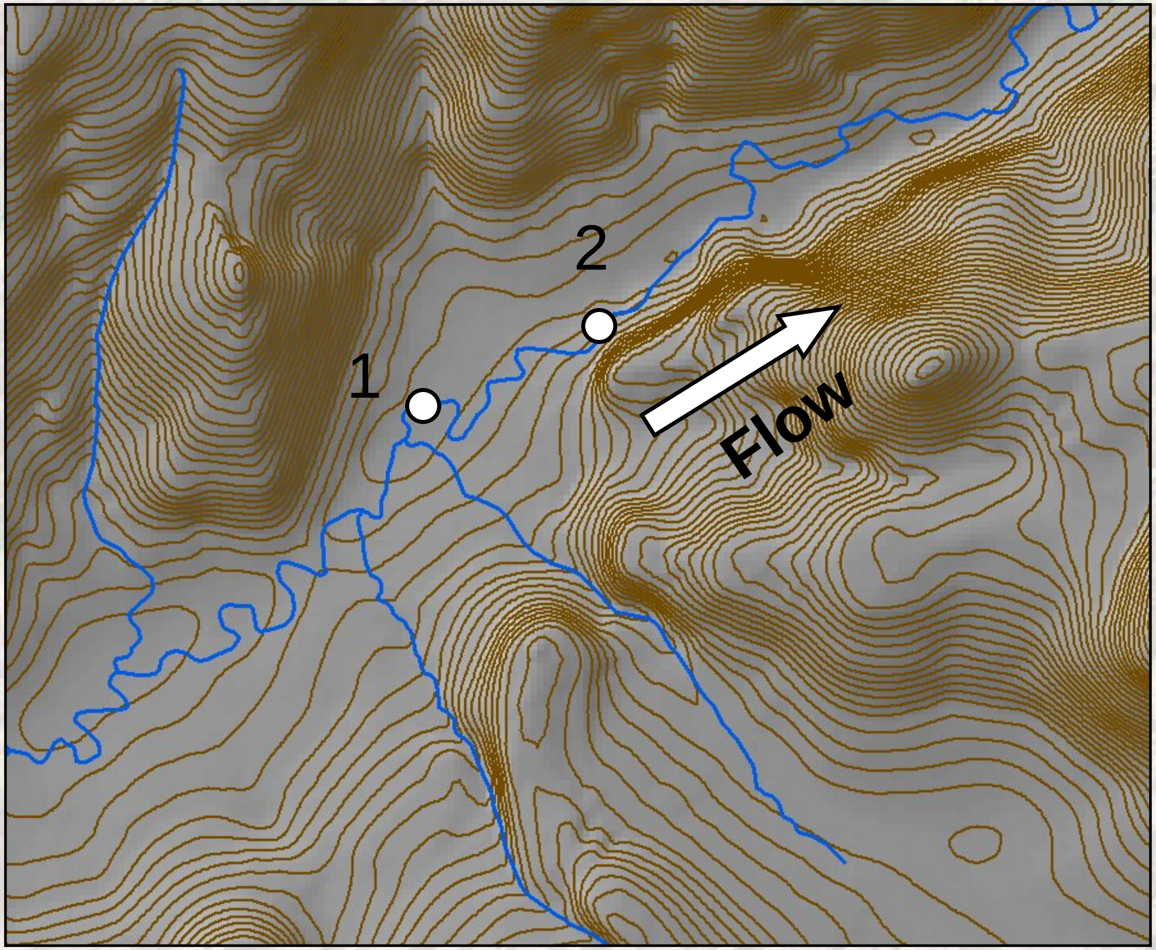
NHD and 10 m DEM Contours

2 m interval

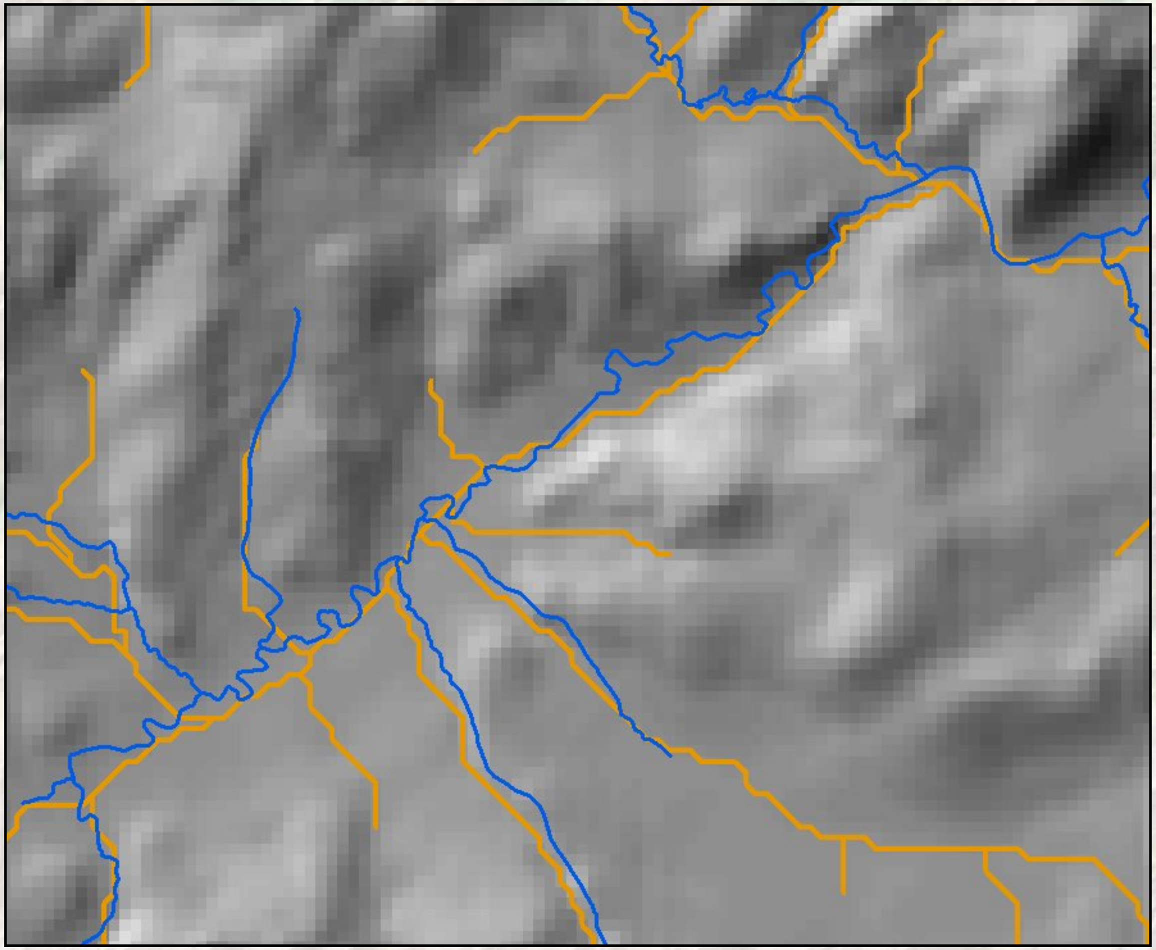


NHD and 10 m DEM Contours

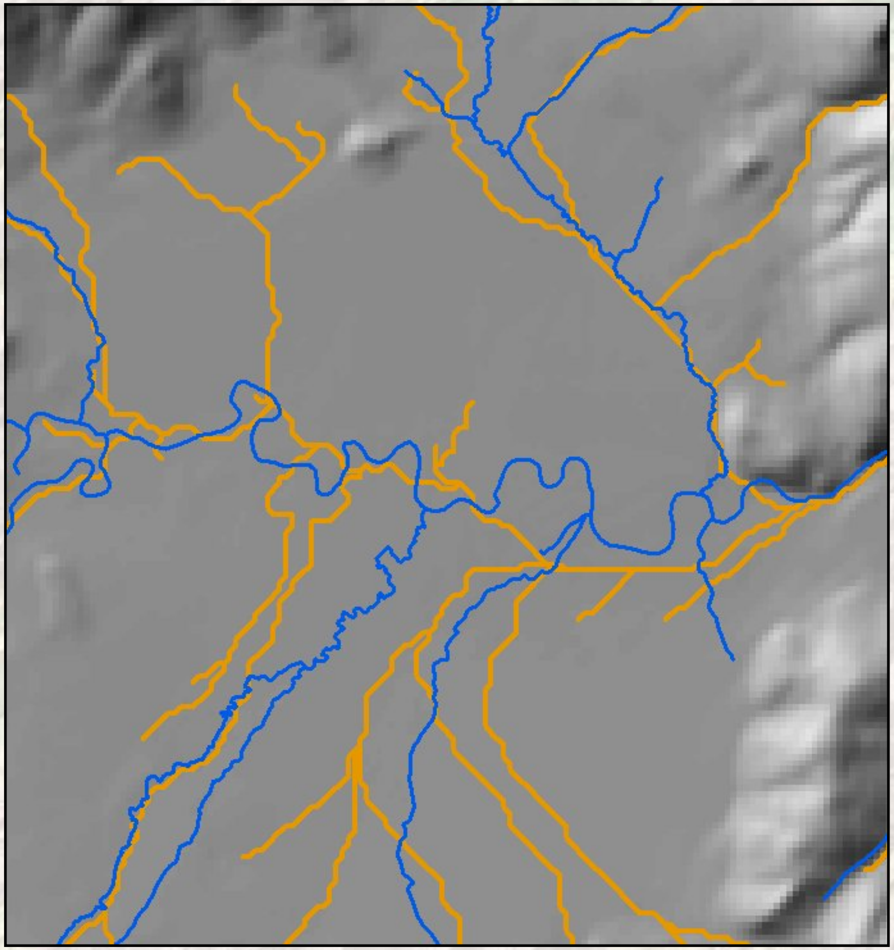
2 m interval



NHD Streams Represent Sinuosity More Accurately



Shortening with Synthetic Streams is Substantial



In low gradient areas, synthetic streams can underestimate stream length by approximately 25%

5412 m vs. 4092 m

The Dilemma

Elevations along synthetic streams consistently flow down hill and represent elevation (rise) more normally

However….

Stream channel length, or sinuosity (run) is better represented by NHD stream lines

Rise / Run = Slope

Best Data Choices for Computing Stream Channel Gradient

1) 10 m NED DEM
2) NHD stream lines

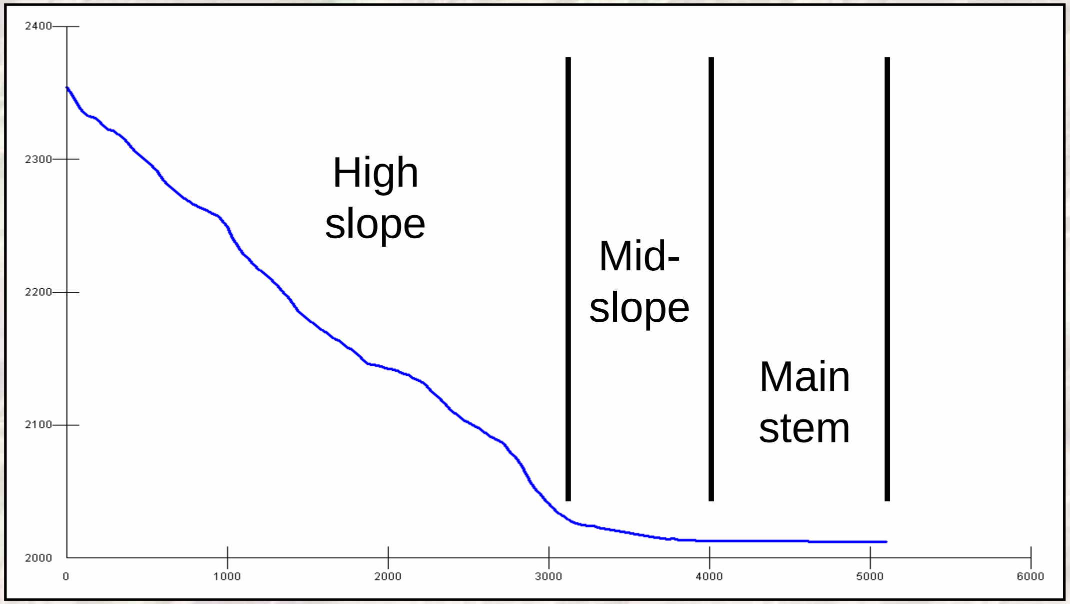
Spatial Accuracy of NHD

Measuring Gradient

Measuring Gradient

We used three approaches dependent on gradient

1) High slope – 3% - 50% gradient
2) Mid-slope – 1.4% mean
3) Main stem – 1.0% or less



Stream channel profile

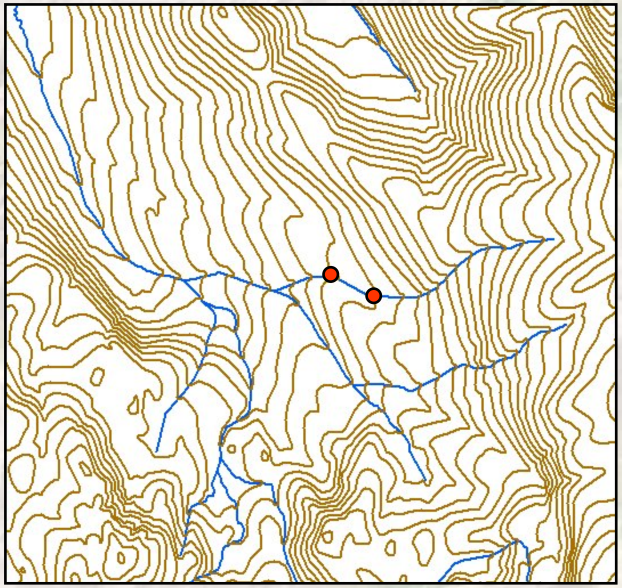
Why Use Three Approaches?

DEM accuracy changes depending on the original quad contour spacing

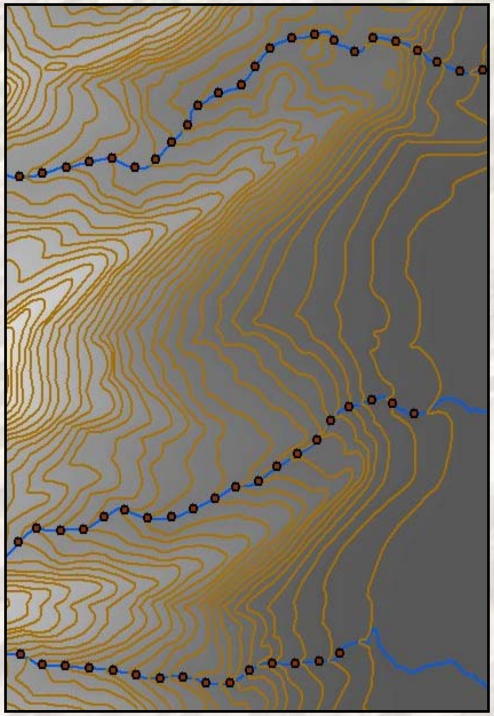
and

Landscape position

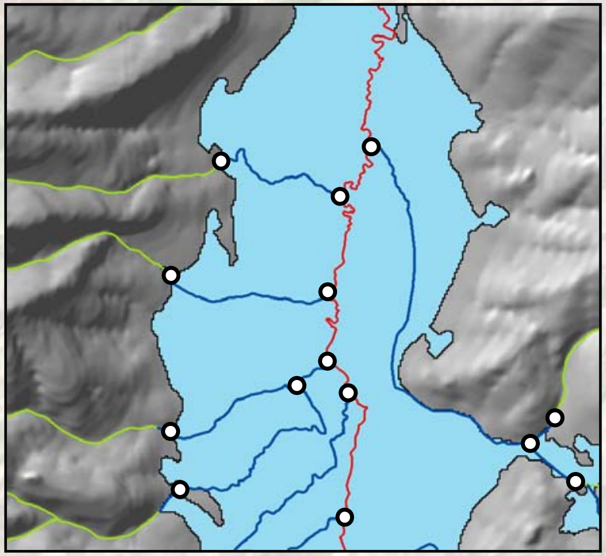
Possible Approaches



At contour crossings



Equal interval

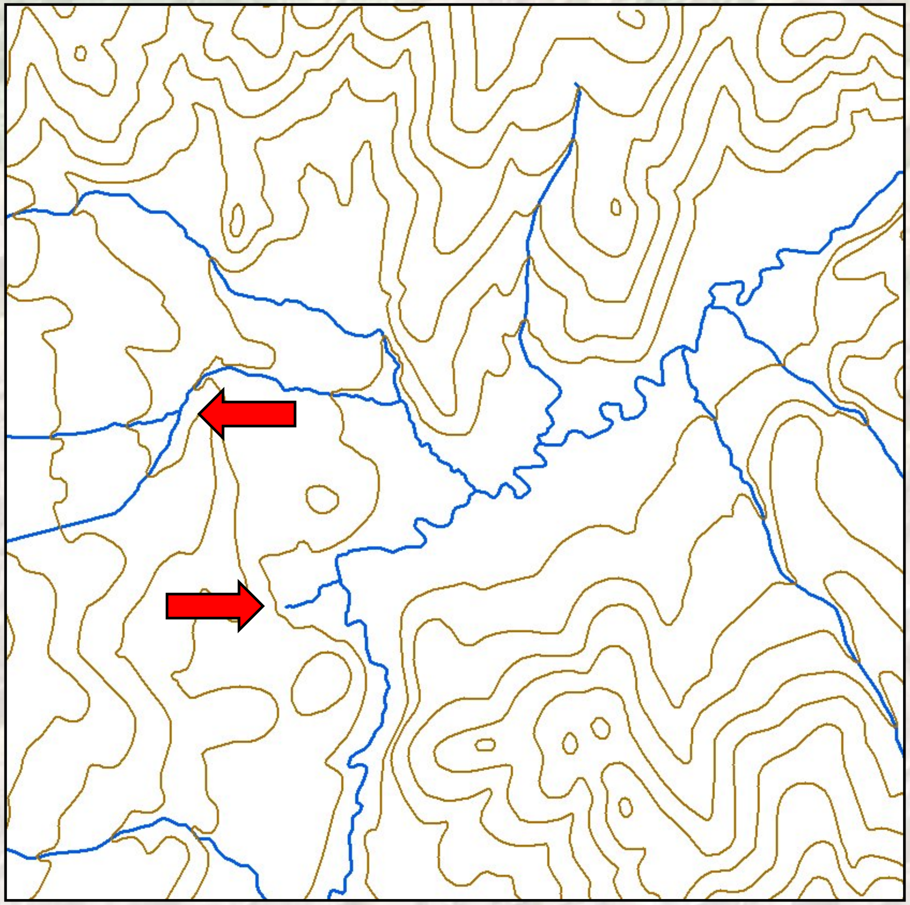


At stream intersections

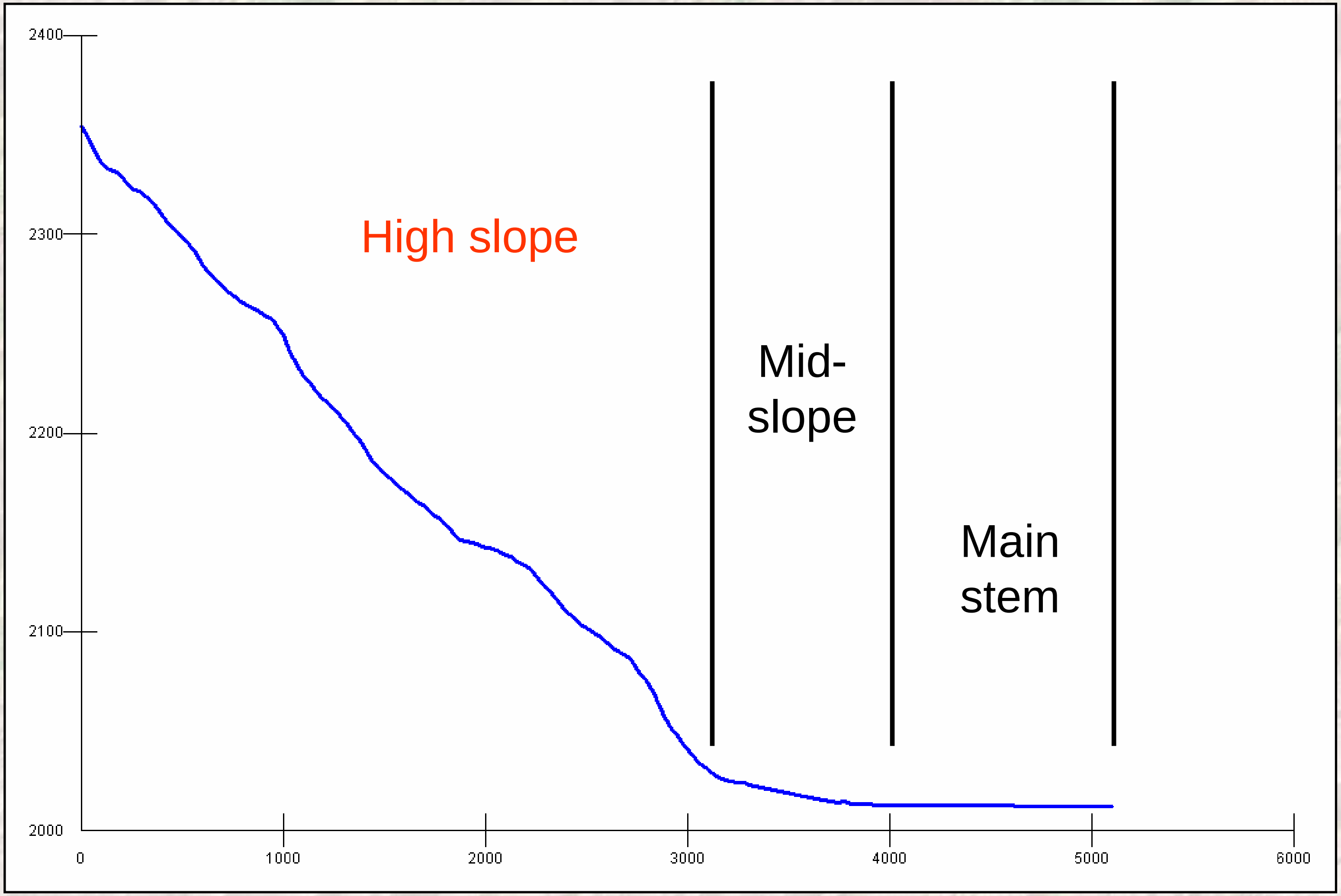
Why Not Use Contour Crossings for Entire Study Area?

1) Not available for the entire study area

2) Tag ends and stream intersections create technical problems

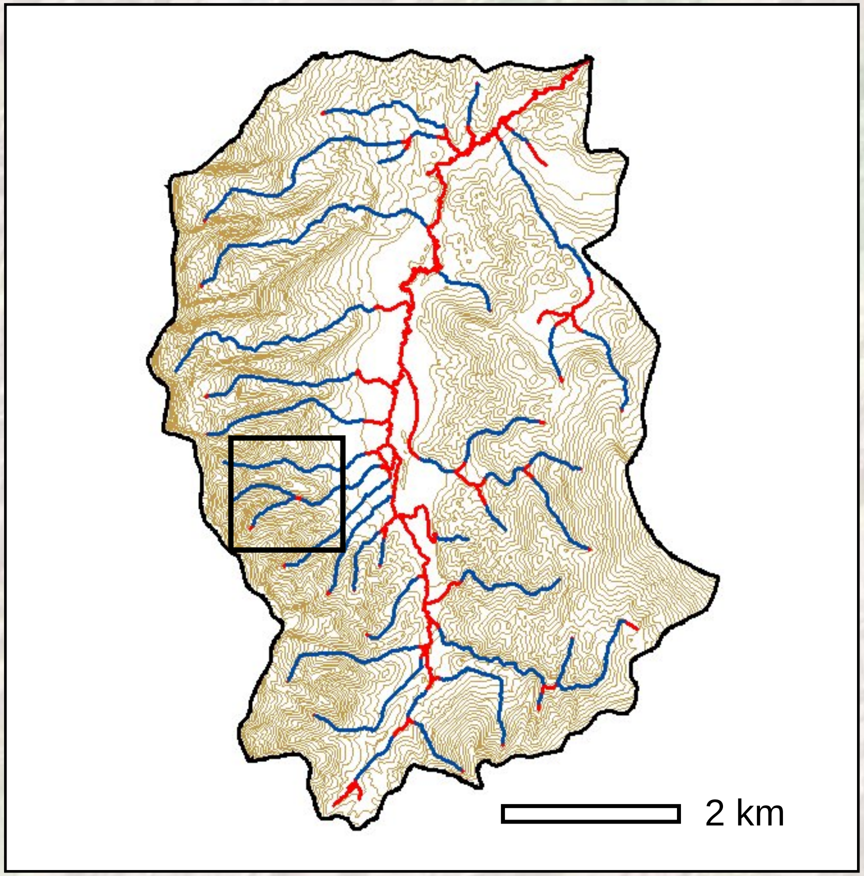


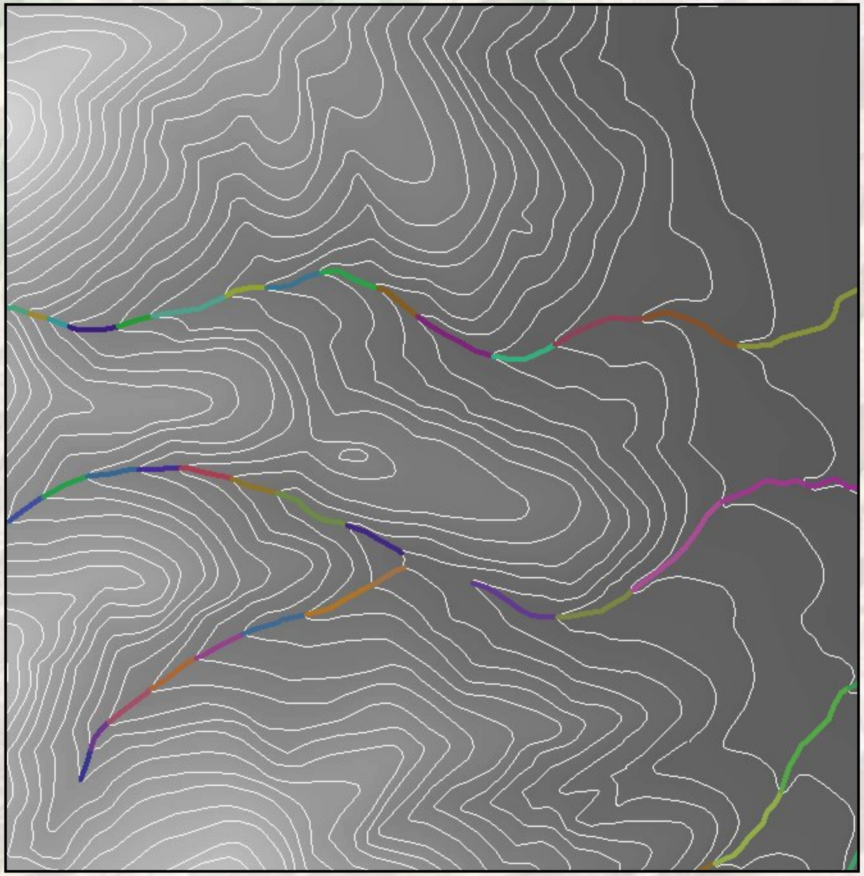
High Slope



We’ll use 100 m equal intervals

10 m DEM Accuracy in Higher Gradient Areas

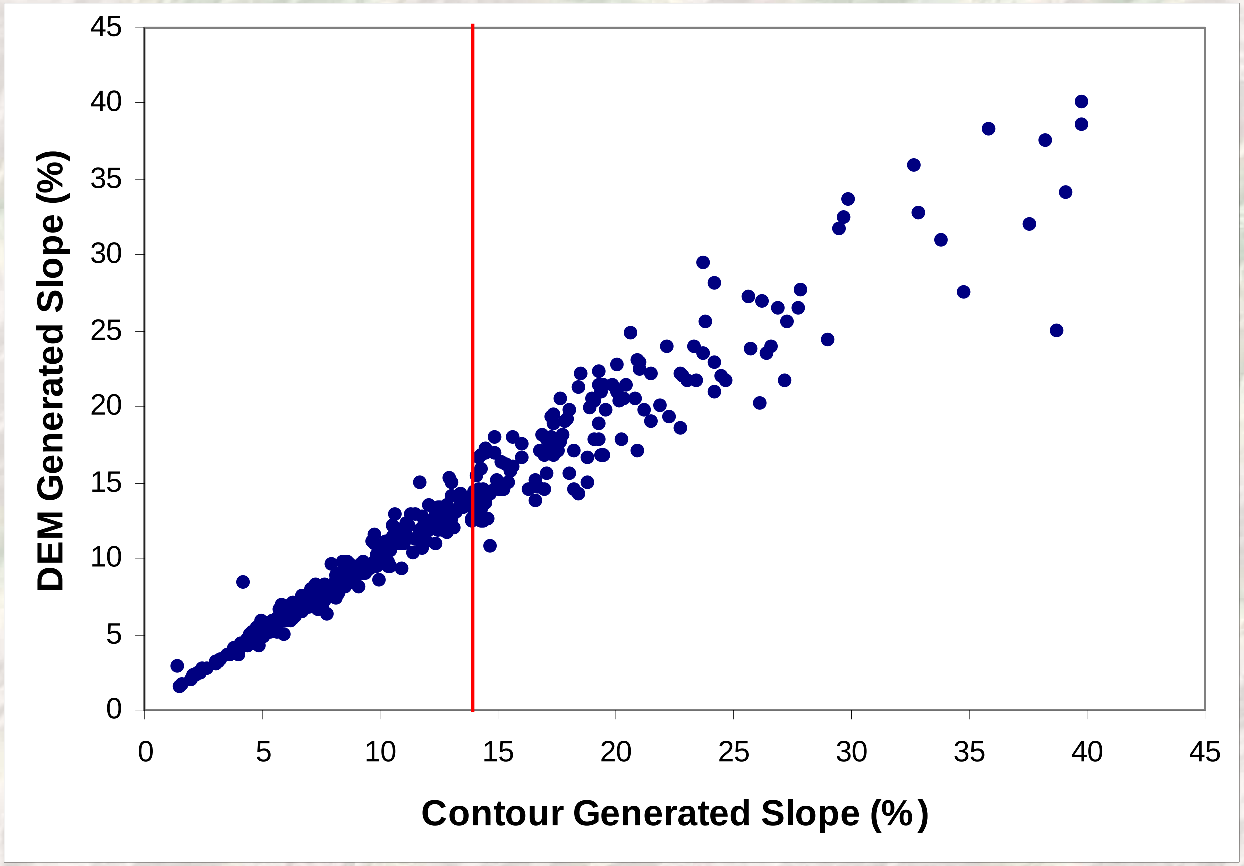




Blue = higher gradient streams

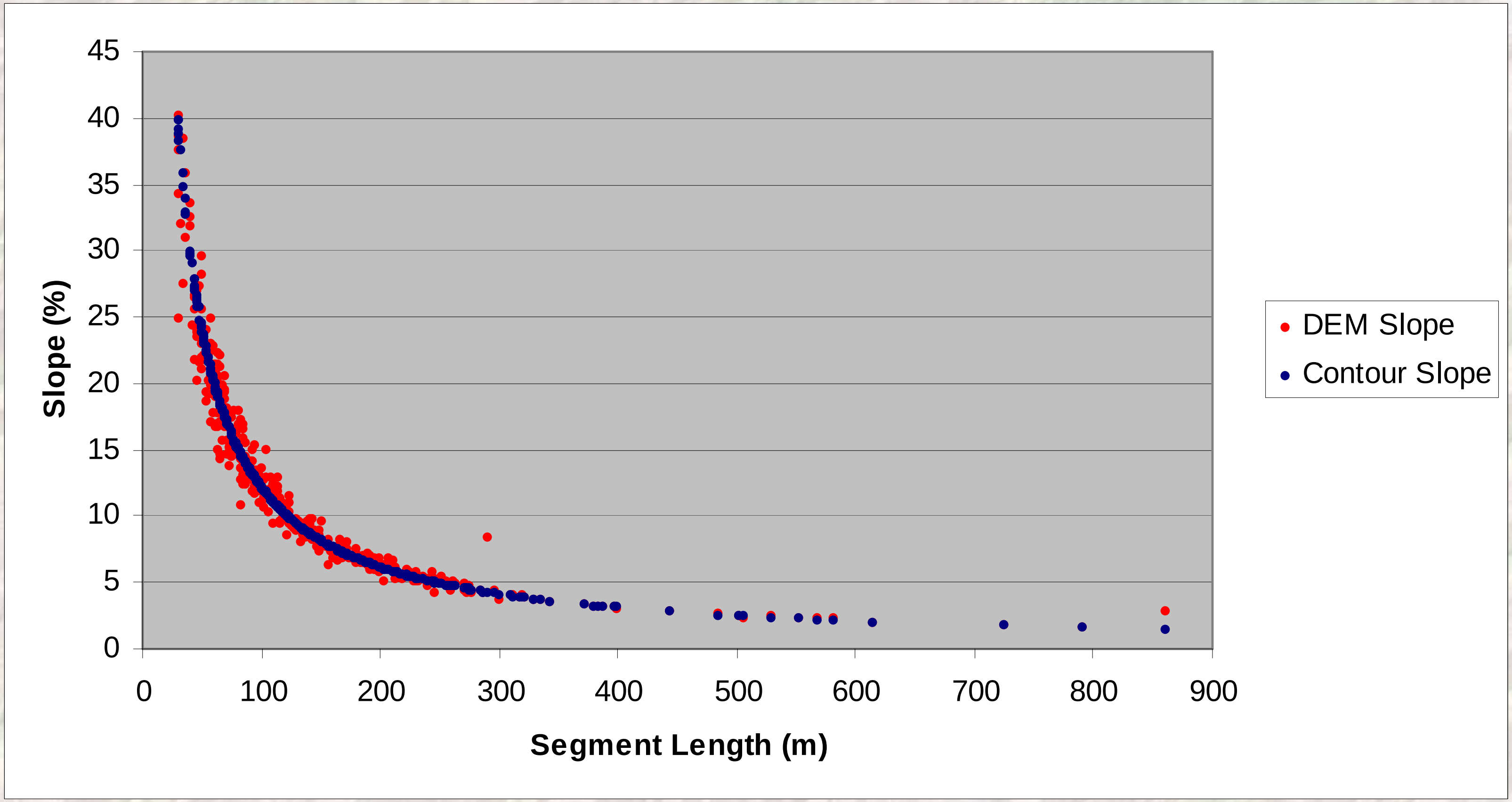
For comparison, compute slope using 1:24 k contours and DEM

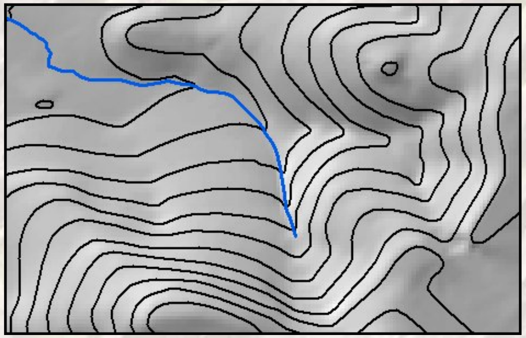
Contour and DEM Generated Slope Comparison



Note divergence at higher slopes

Slope and Segment Length

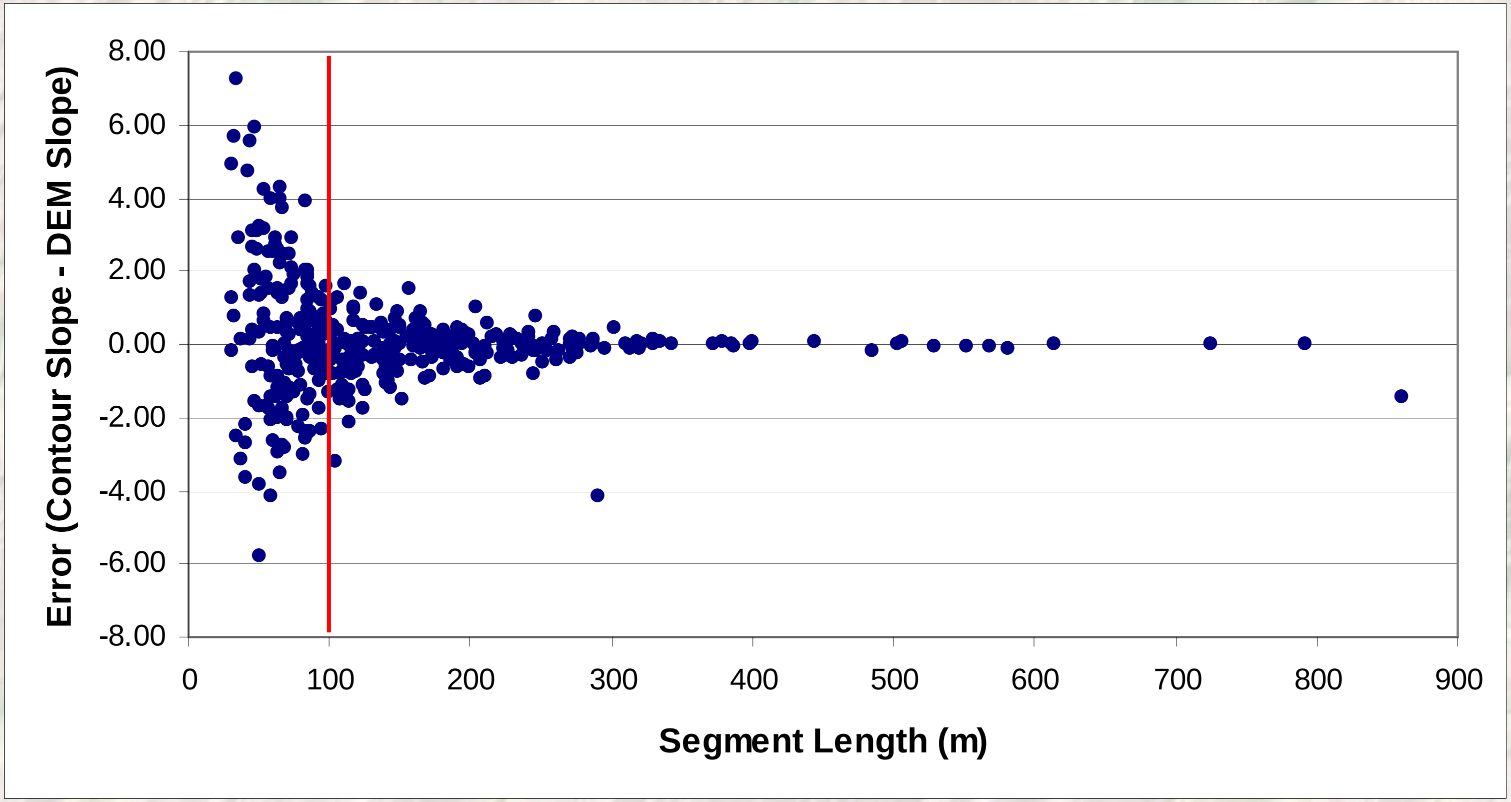


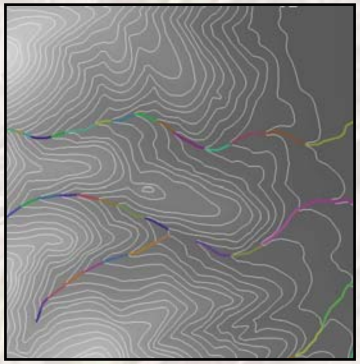


Contours get closer together at higher slopes and segment length decreases

Note error in DEM model

Errors vs. Stream Segment Length



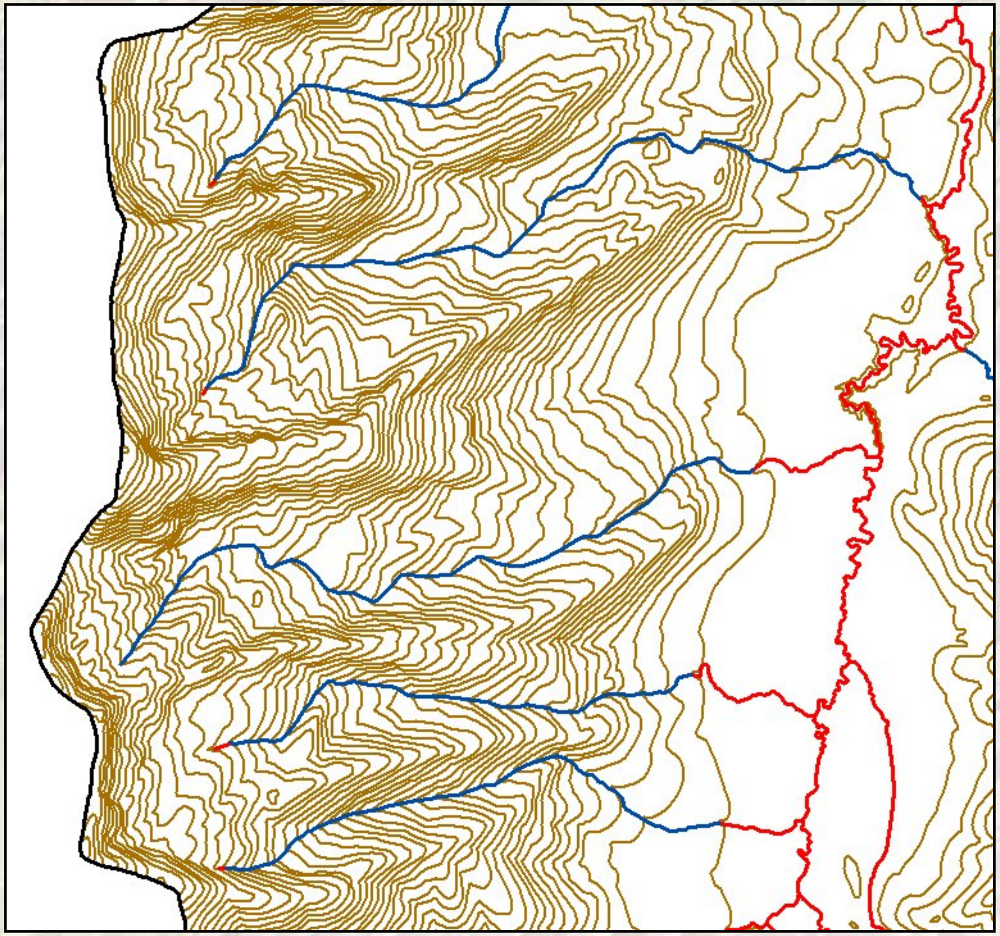


Mean slope error for segment lengths:

Greater than 100 m	.42% pts
Equal to 100 m	.68% pts
Less than 100 m	1.64% pts

Median Stream Segment Length

40' Contour Interval

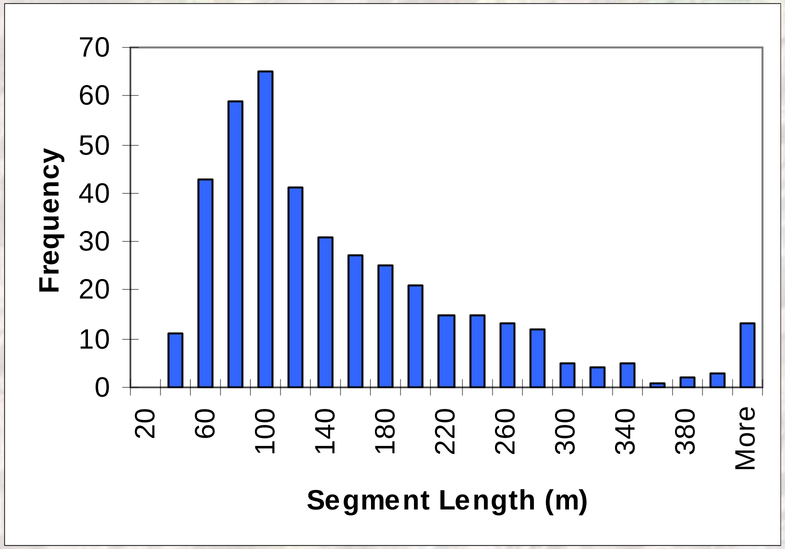


Segment length between contours

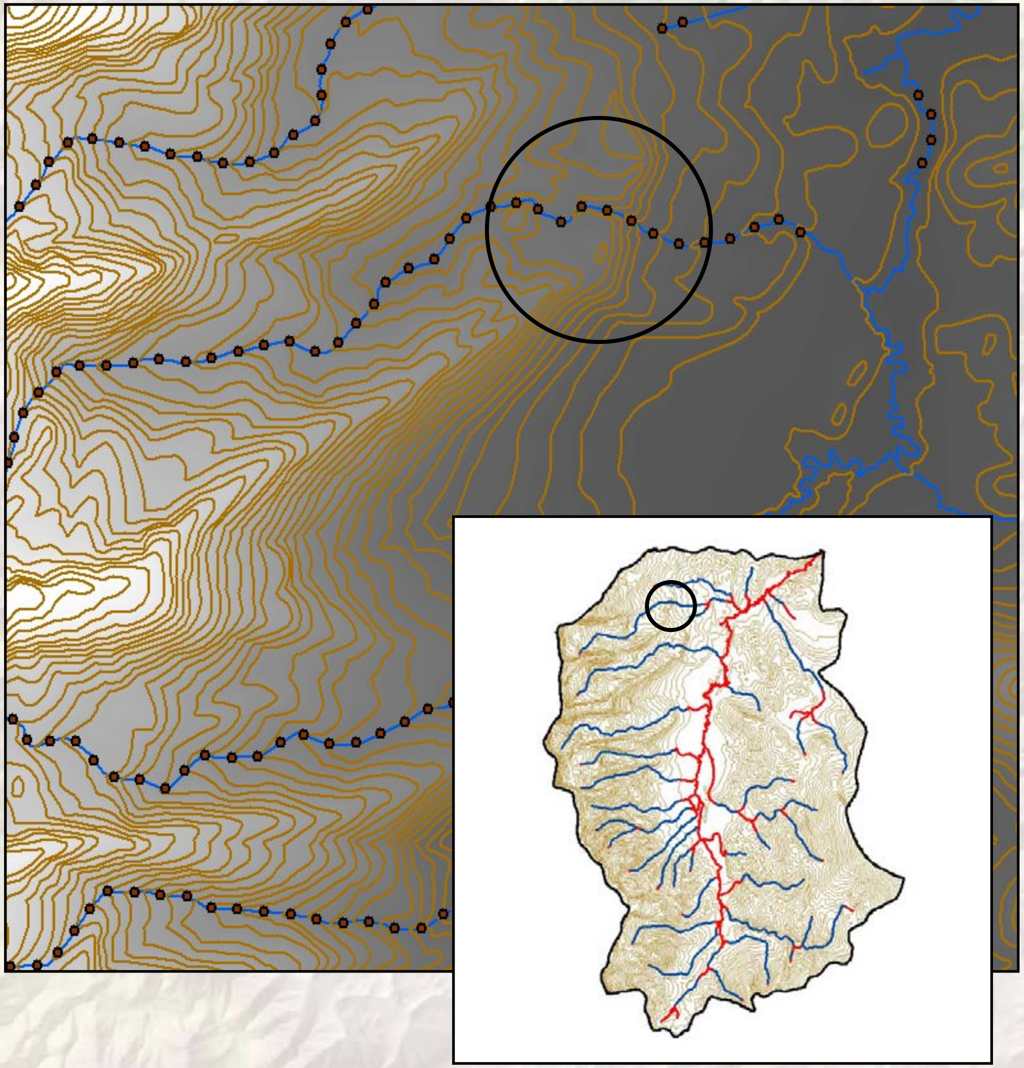
Mean = 147 m

Median = 114 m

n = 411



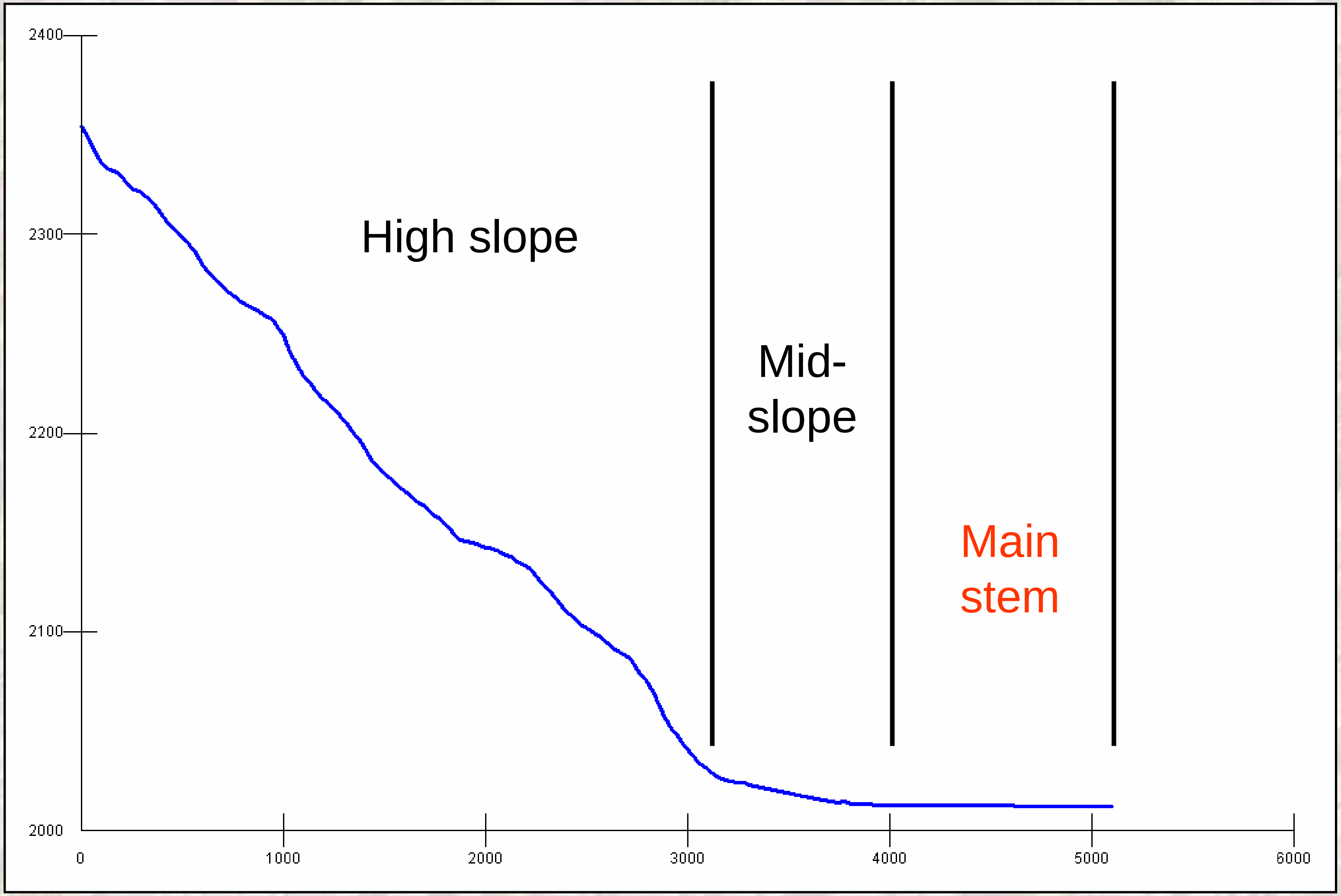
Gradient Calculation for Higher Slope Reaches – 100 m Spacing



1) We used 100 m interval spacing along NHD lines with 10 m DEM.
2) Fine enough resolution to detect some natural barriers (slope > 20%)
3) Not so coarse that undesirable averaging occurs

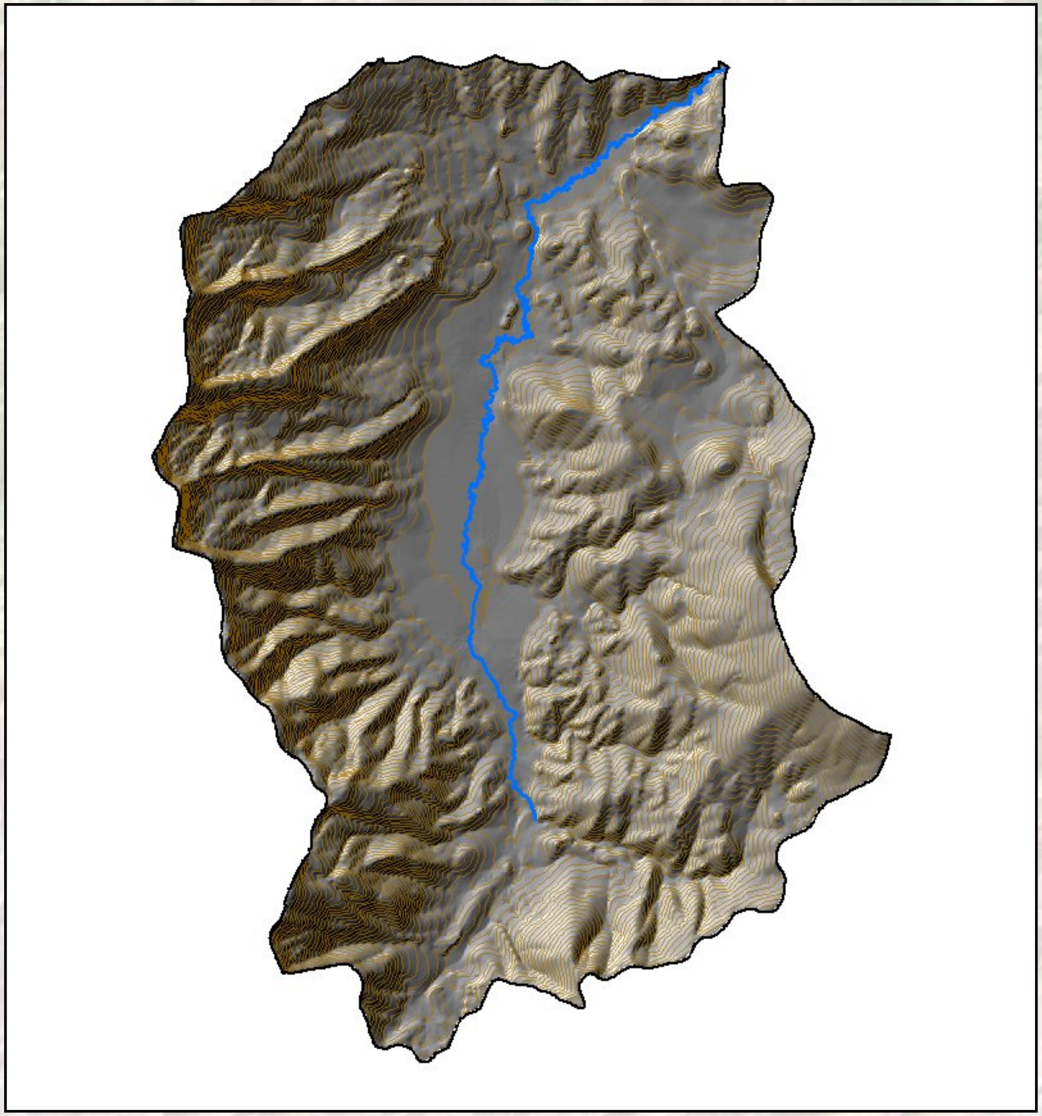
Average error = 0.68% pts

Main Stem

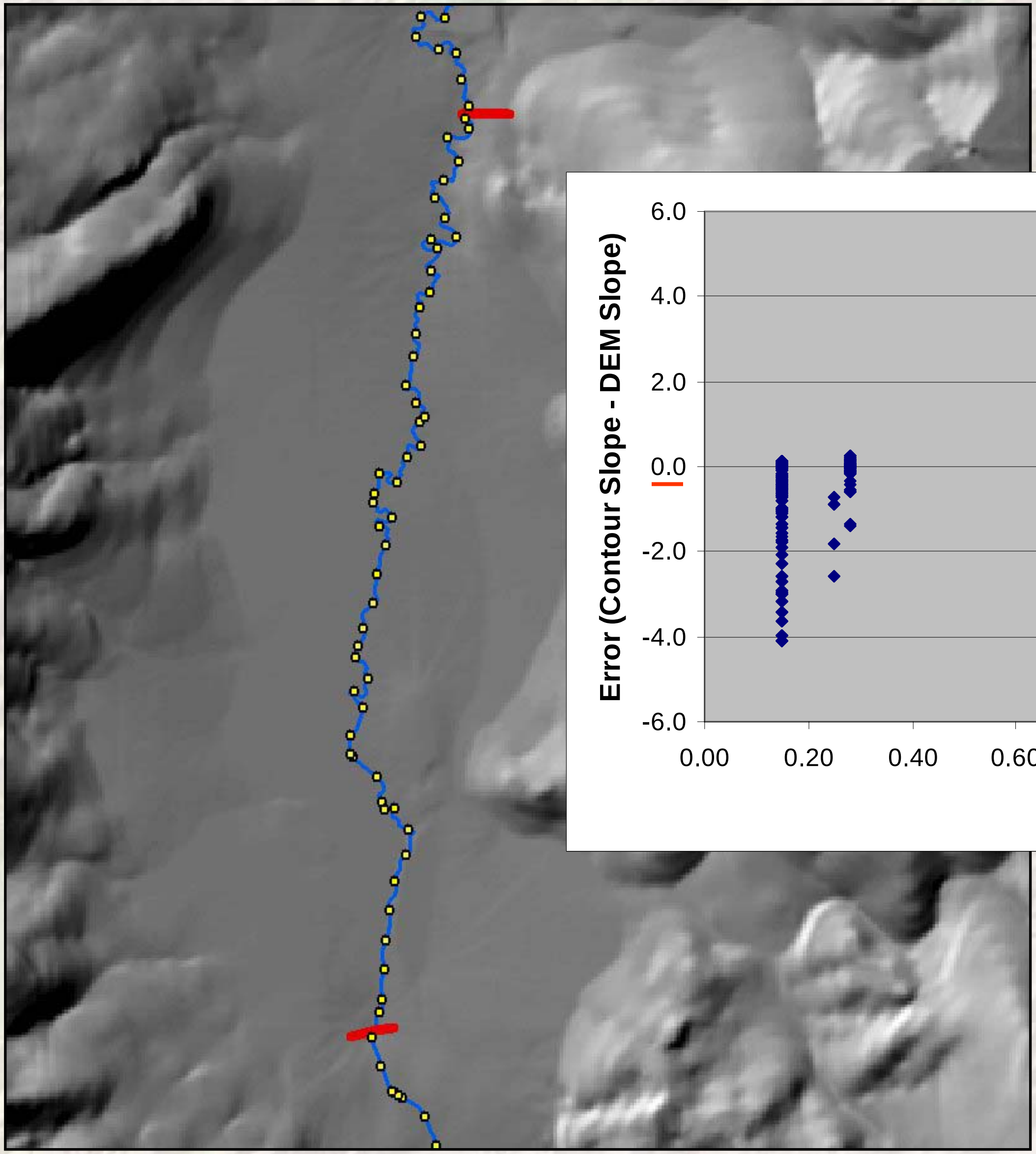


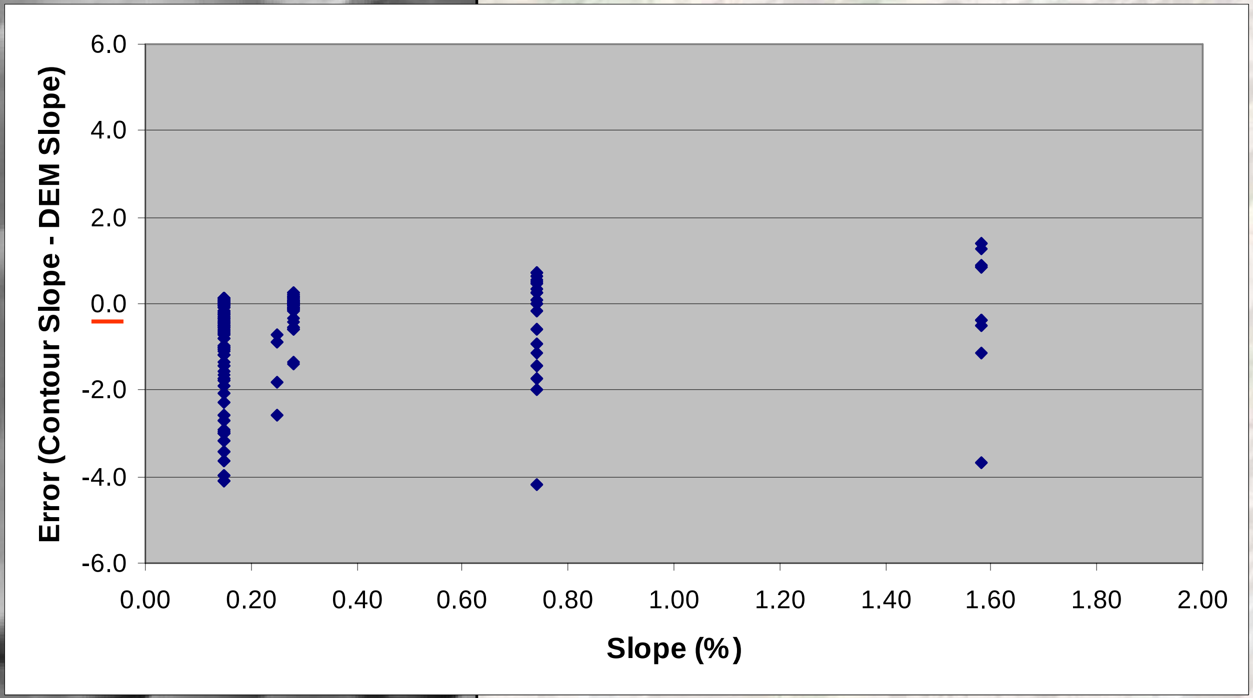
2400
2300
2200
2100
2000
0
1000
2000
3000
4000
5000
6000
High slope
Mid-
slope
Main
stem

Gradient Calculation for Main Stem Reaches



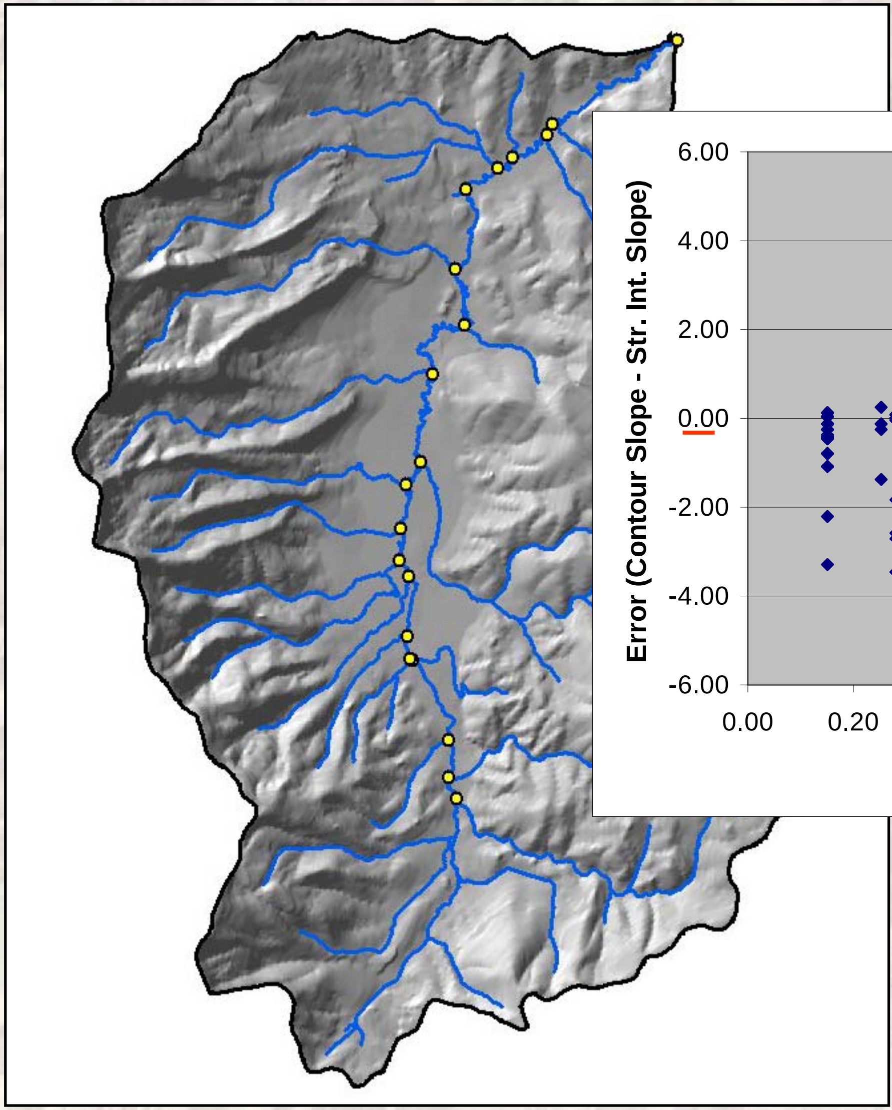
Contour Slope vs. 100 m Interval

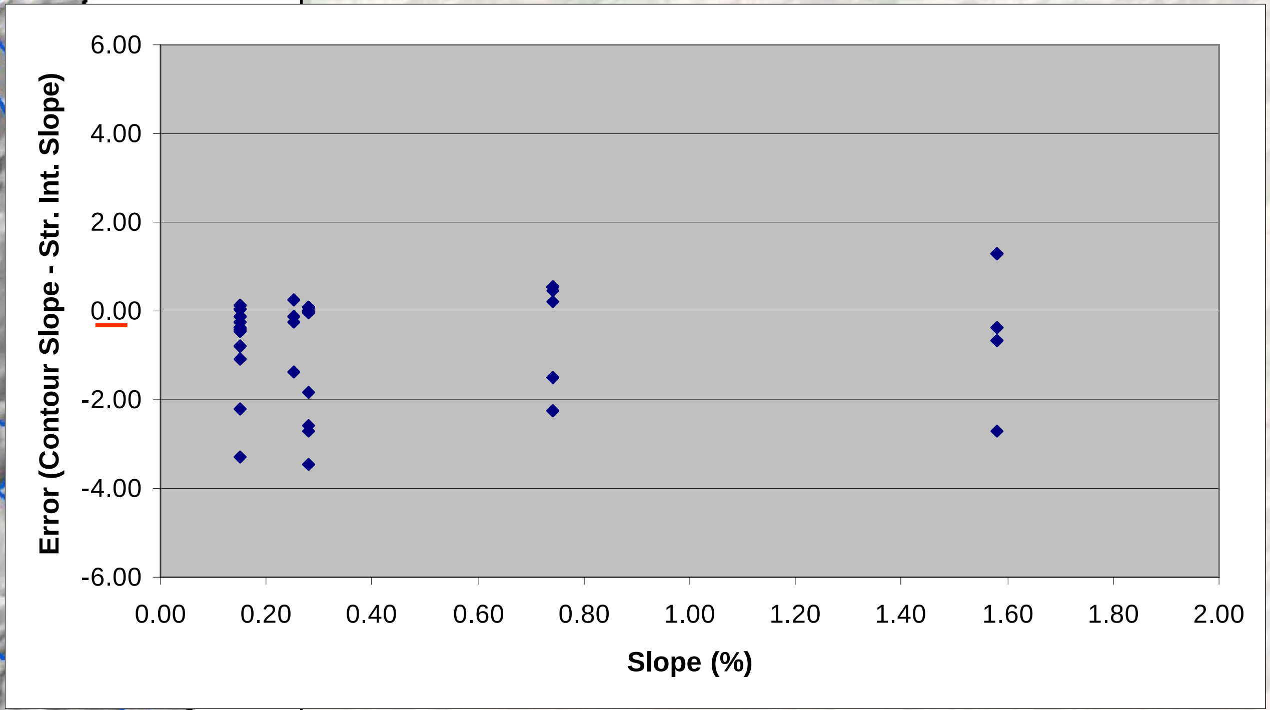




Average error = .75% pts

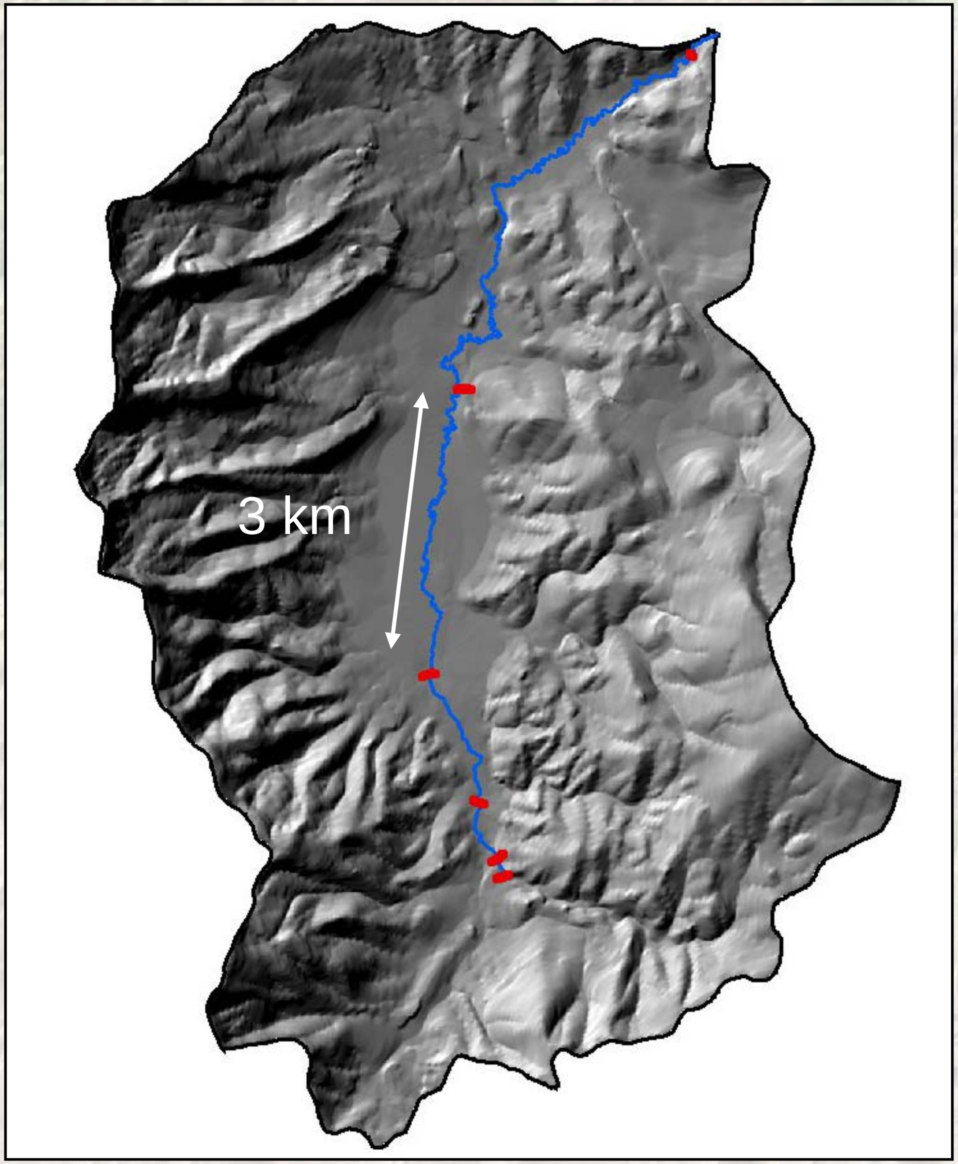
Gradient Calculation for Main Stem Reaches
Stream Intersections



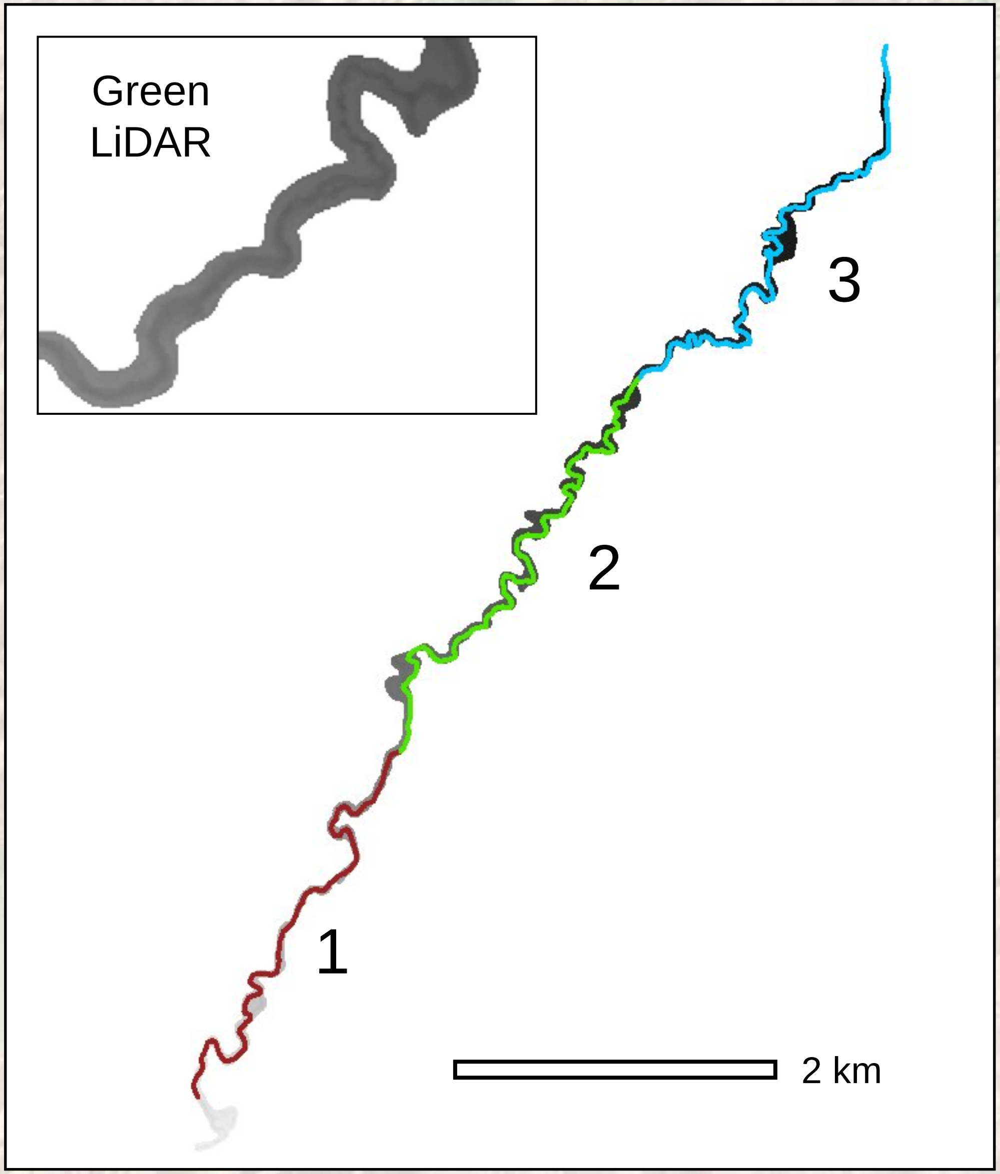


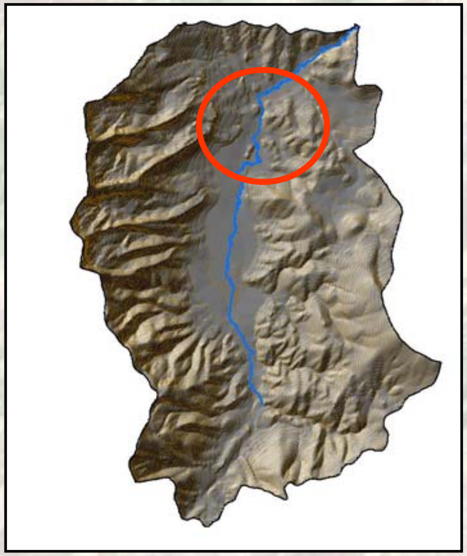
Average error = .39% pts

Gradient Calculation for Main Stem Reaches at Contour Crossings



LiDAR vs. Contour Gradient Comparison

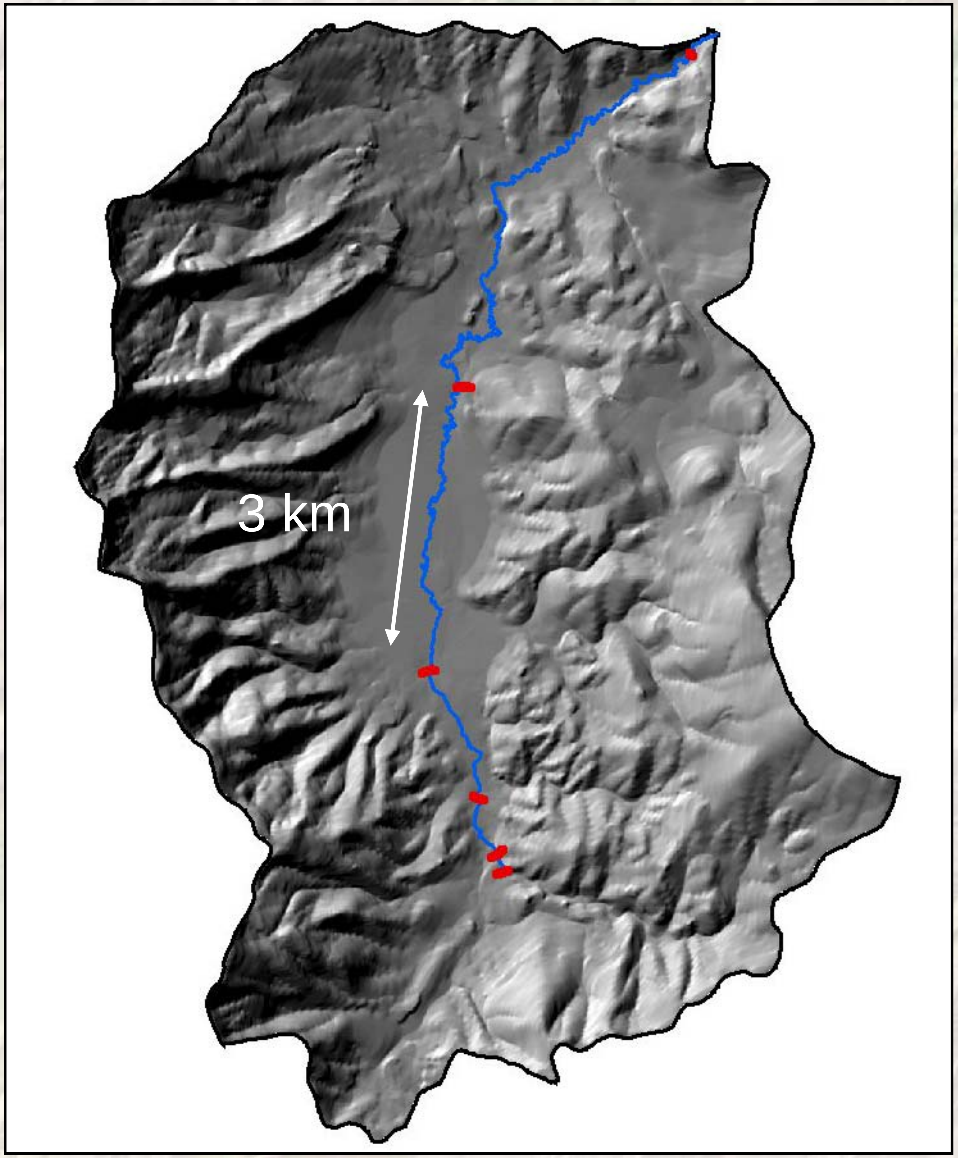




Segment No.	Contour Slope	LiDAR Slope
1	.41%	.45%
2	.35%	.35%
3	.36%	.32%

Average error = .03% pts

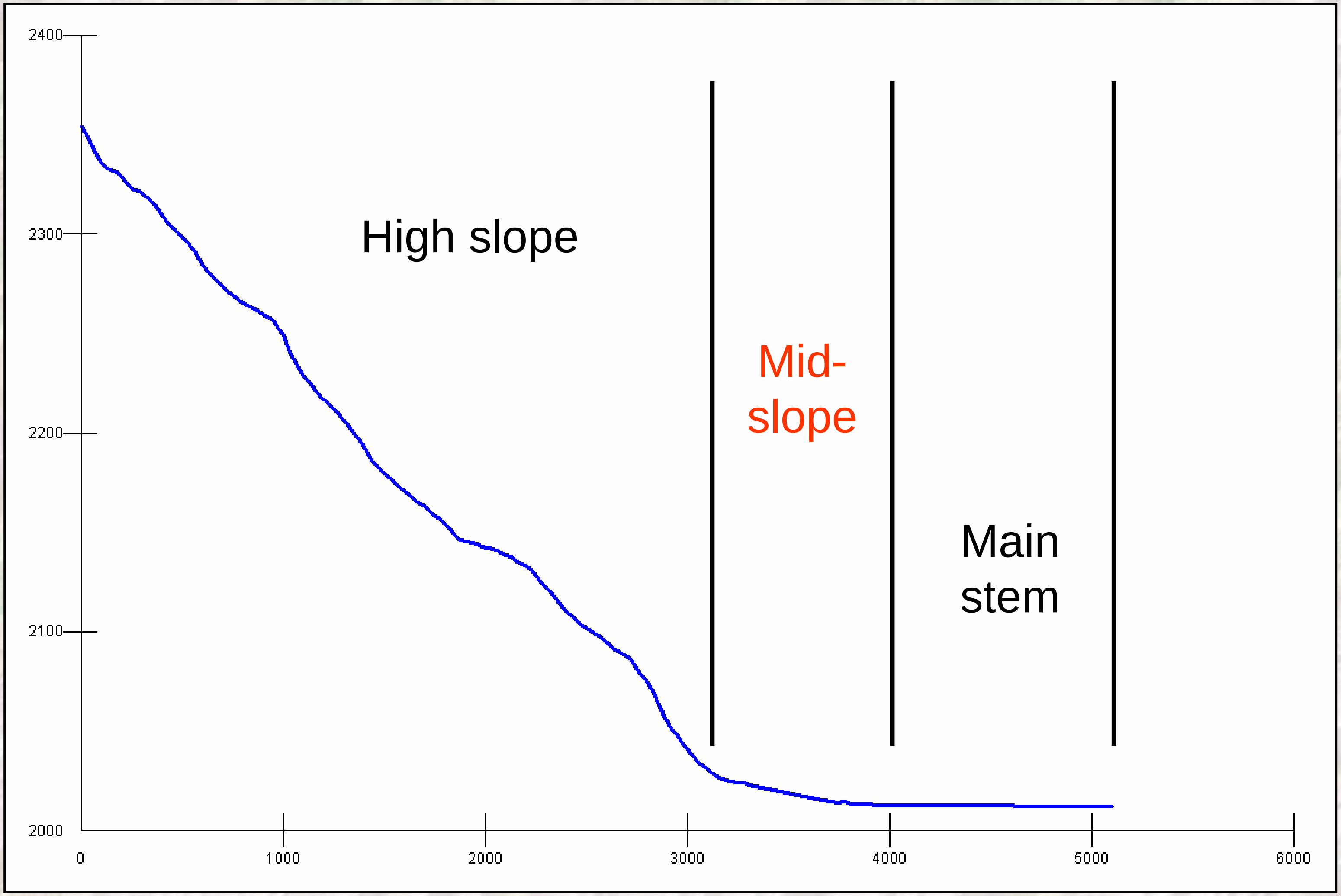
Gradient Calculation for Main Stem Reaches



- We used quad contour crossings along main stem
- Contour crossings were digitized on-screen from DRGs

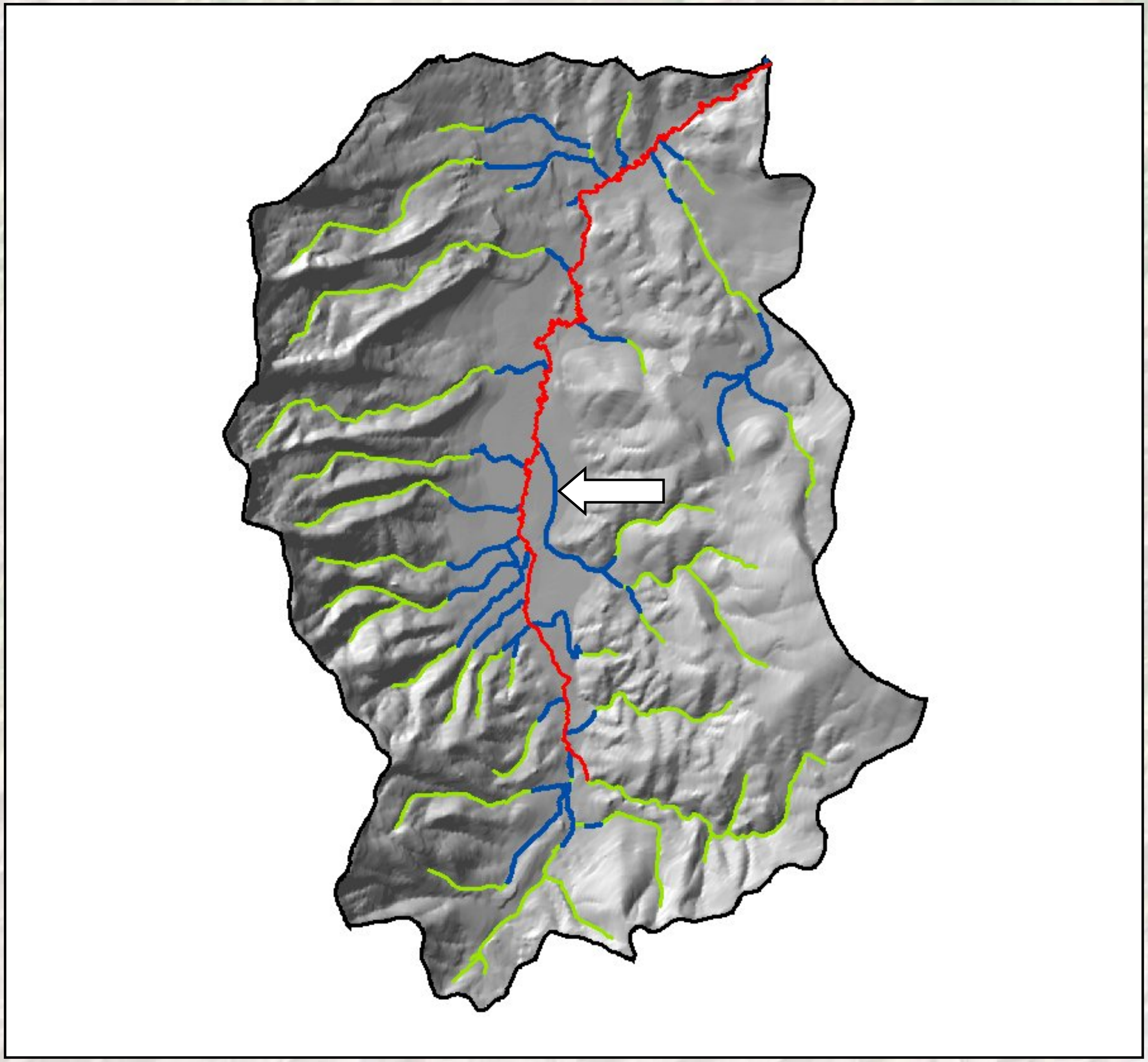
Average error = .03% pts

Mid-slope

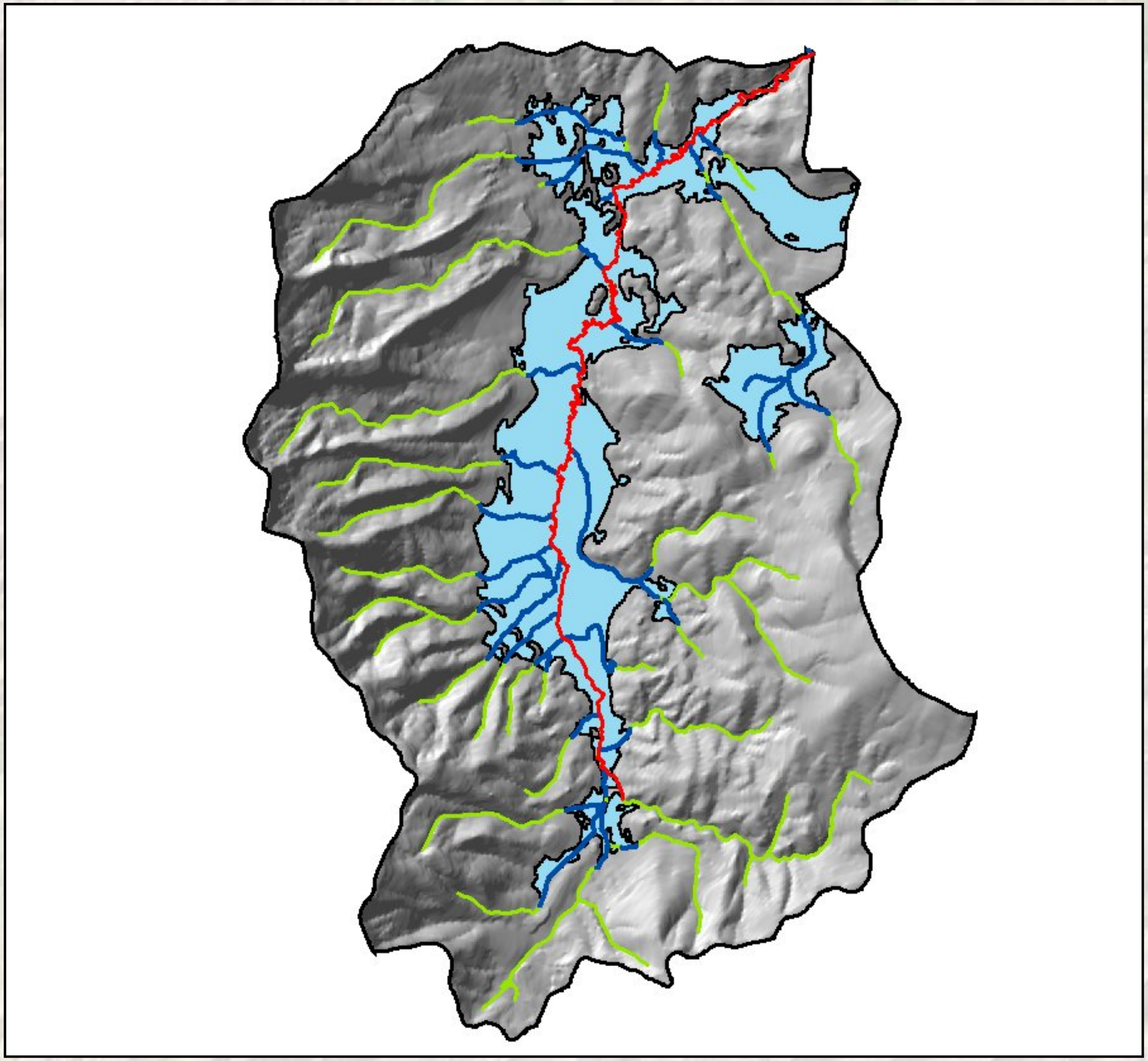


2400
2300
2200
2100
2000
0
1000
2000
3000
4000
5000
6000
High slope
Mid-
slope
Main
stem

Mid-slope Reaches



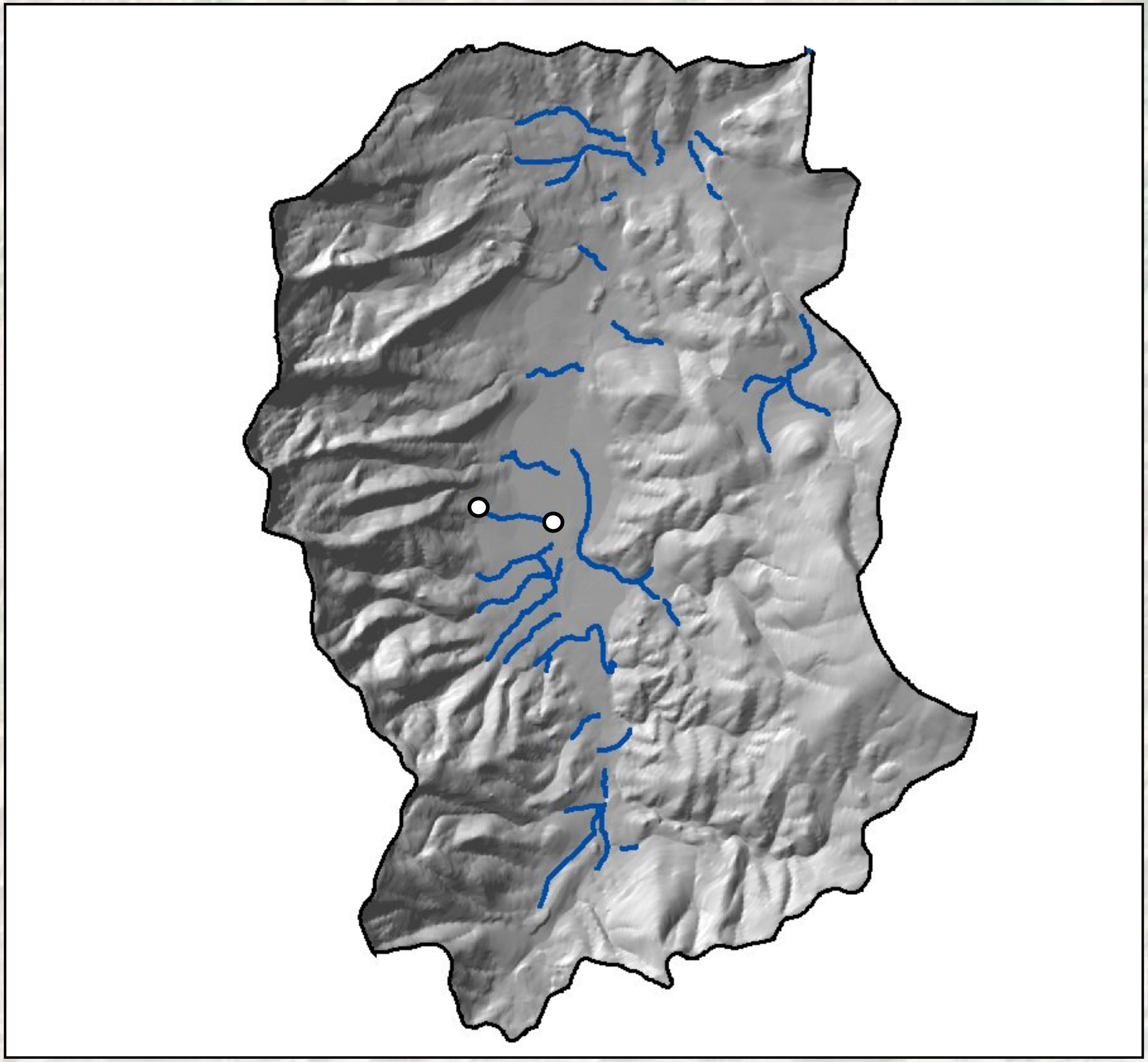
Mid-slope Reaches and Flat Valley Bottom Delineation



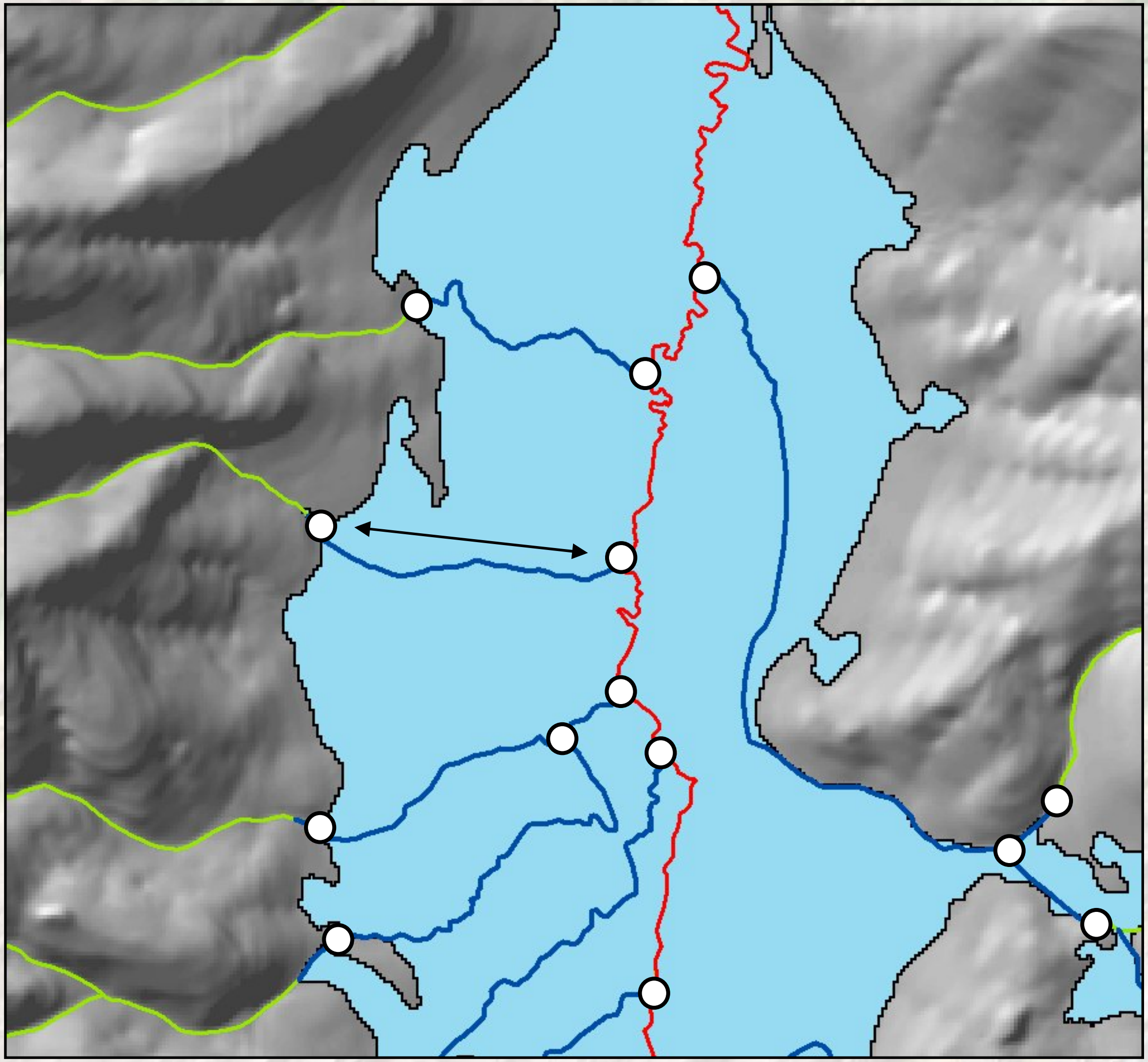
Procedure

1) Overlay valley bottom
2) Exclude main stem reaches

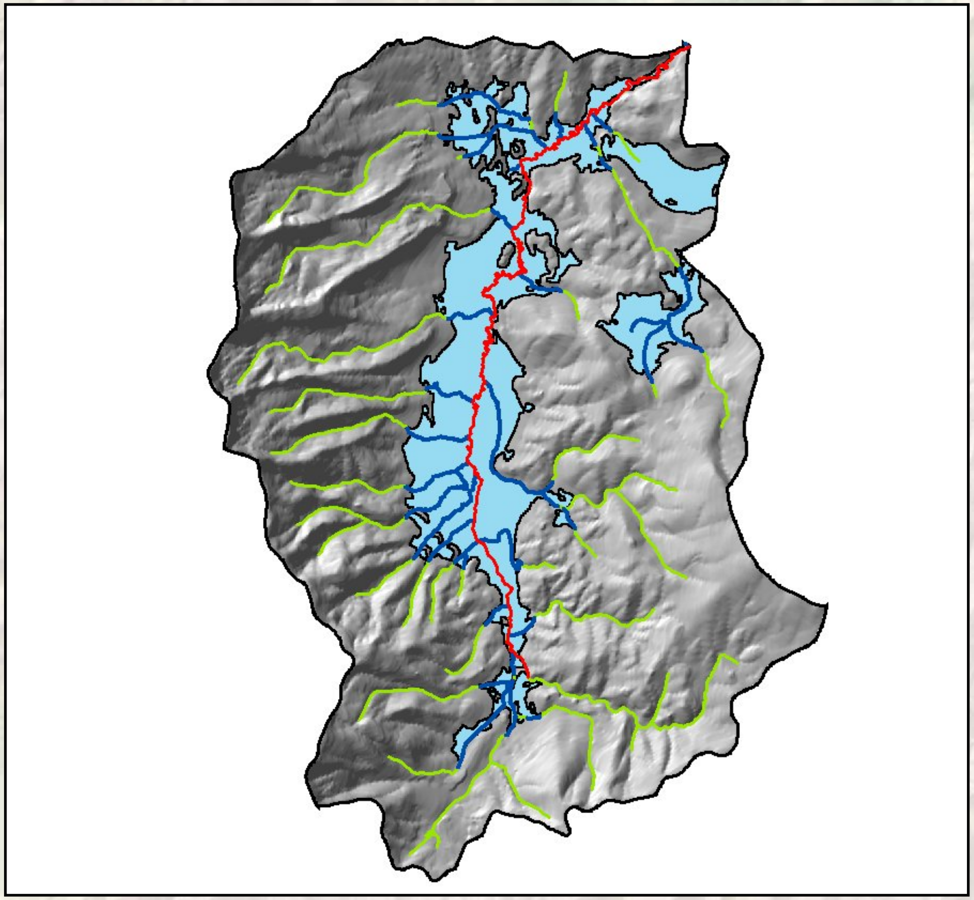
Mid-slope Reaches



Compute Slope Between Break Lines and Stream Intersections with 10 m DEM



Gradient Calculation for Mid-slope Reaches

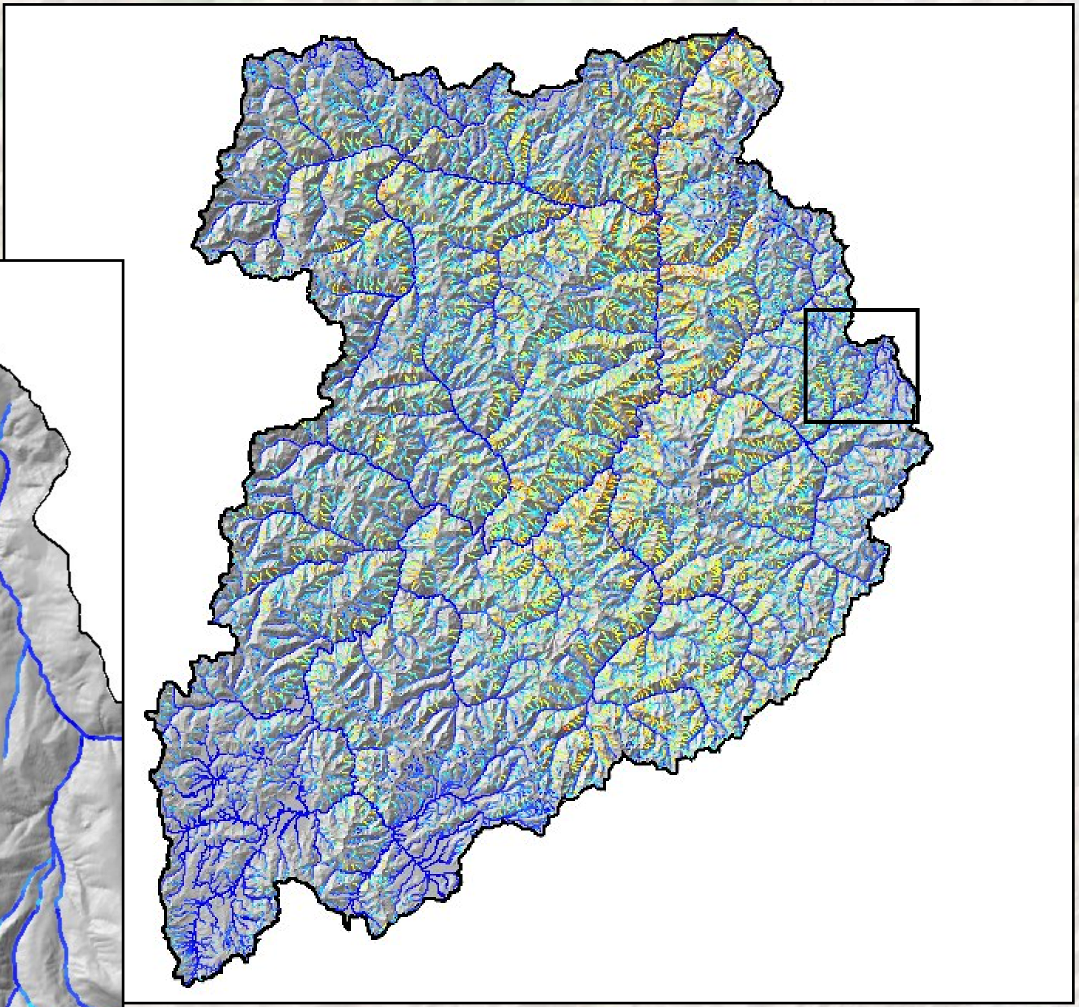


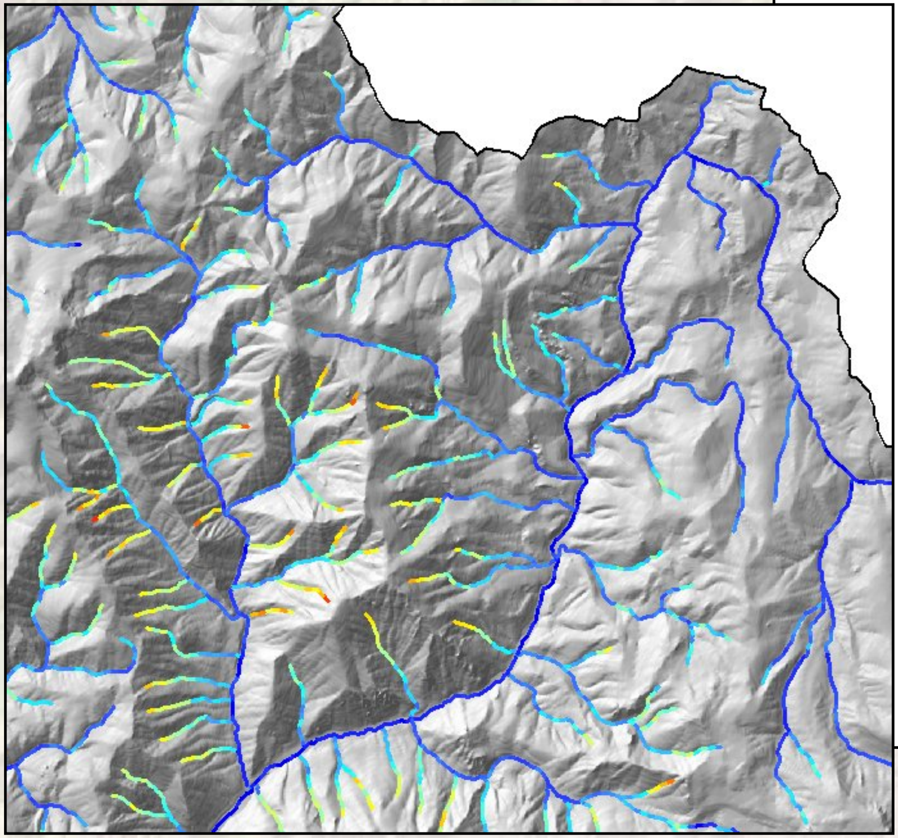
1) We used 10 m DEM elevations at valley bottom break lines and stream intersections

2) Output not validated against contours, but should be better than main stem results at intersections

Average error < .39% pts

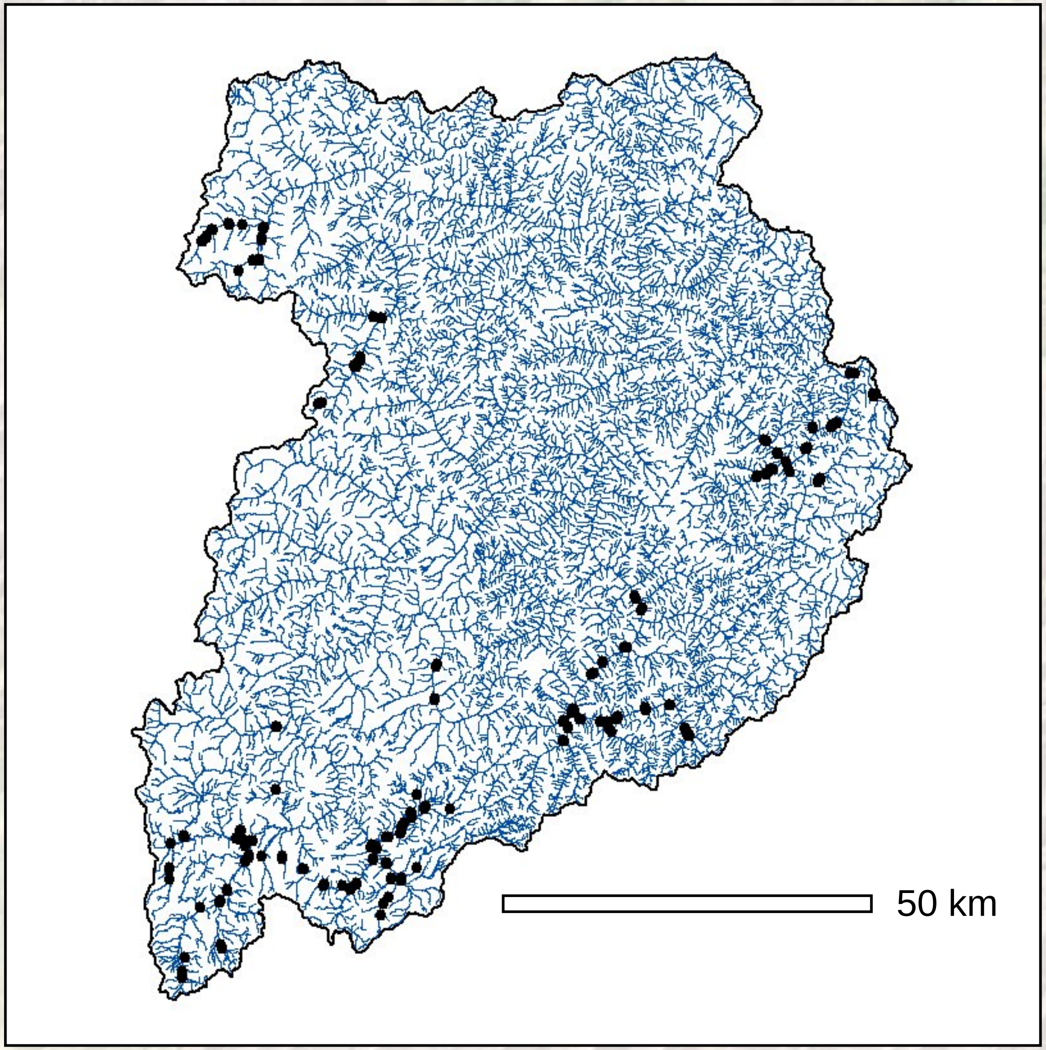
Final Stream Gradient Map



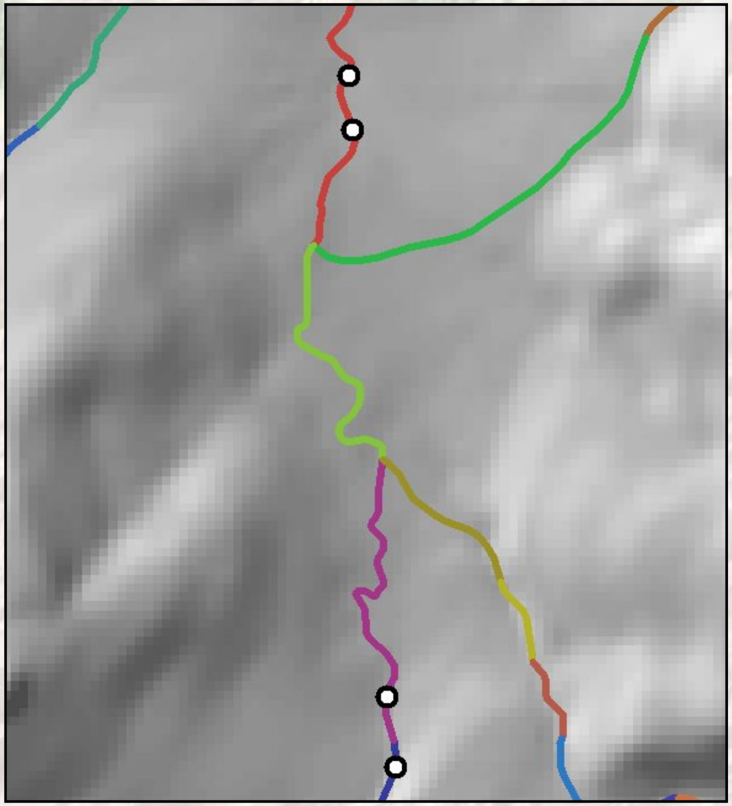


Field Data

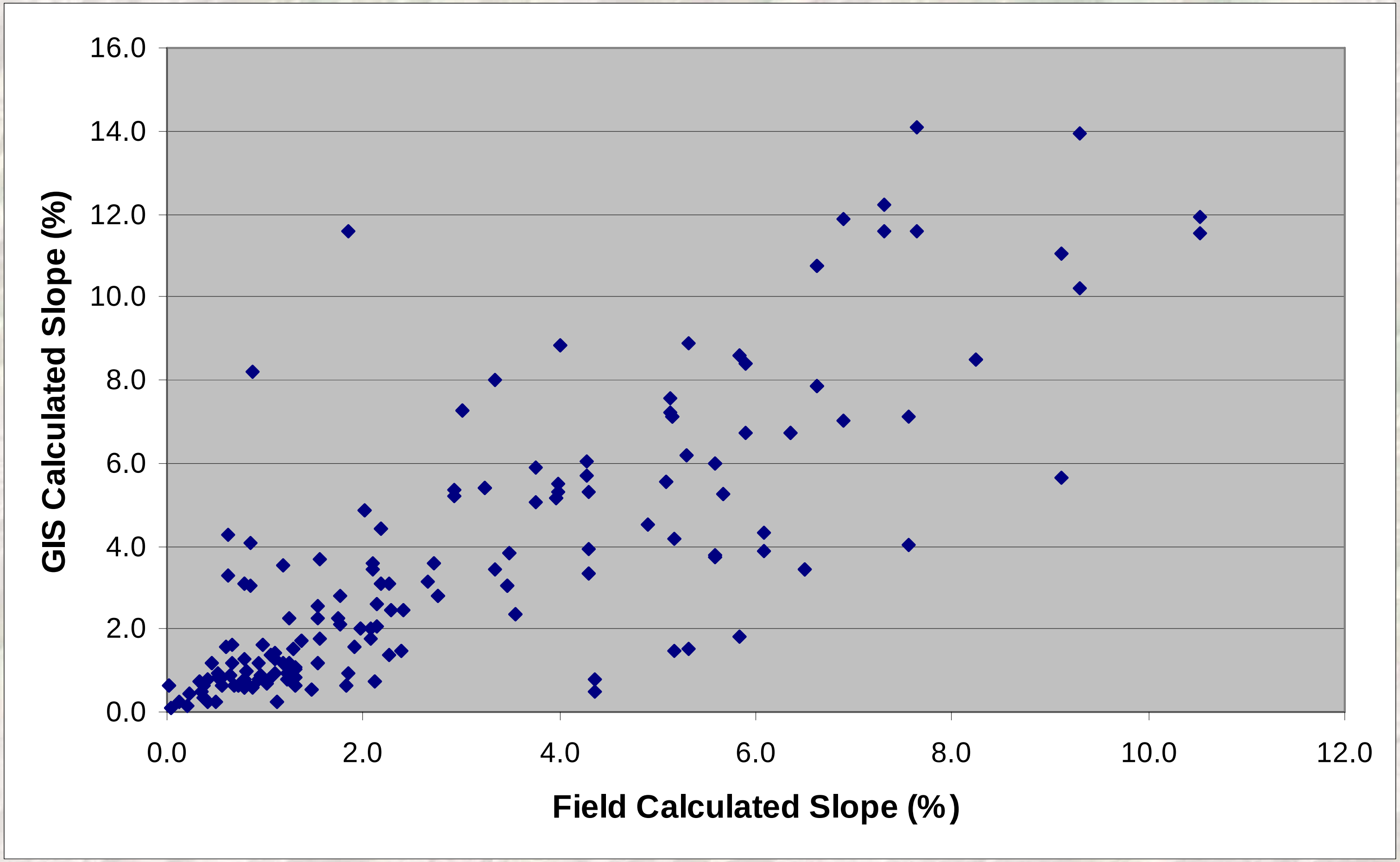
Field Calculated vs. GIS Calculated Gradient



n = 238



Field Calculated vs. GIS Calculated Gradient



Average error = 1.54% pts
R-squared = .67

Conclusions

1) The most appropriate interval spacing for measuring slope in higher gradient areas is about 100 m when using 10 m DEM data. Average error ~ 0.68% pts.
2) For main stem, low gradient channels, gradient is best computed between quad contour intervals. Average error ~ 0.03% pts.
3) At intermediate slopes, gradient can be computed between valley bottom break lines and stream intersections with 10 m DEM data. Average error < 0.39% pts.

Recommendation

10 m DEM data have variable accuracy dependent on slope and landscape position

Fish and watershed models that incorporate stream gradient should account for these errors

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