Estimating Stream Gradient Using NHD Stream Lines and DEM Data

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July 14, 2010

BOISE AQUATIC SCIENCES LAB

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DEPARTMENT OF AGRICULTURE

Stream Channel Gradient

Rate of elevation change

High

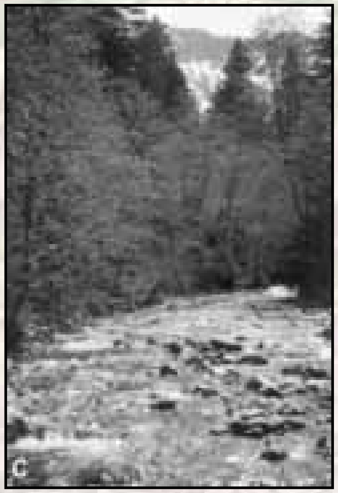
Low

Reasons for Modeling Stream Gradient

- Predictor of channel morphology

Pool-riffle

< 1.5%



Plain-bed

1.5 – 3%

Step-pool
and Cascade

> 3%

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

Predict stream bed grain size to identify salmon spawning habitat at basin scales

Median grain size $$D_{50} = \frac{\rho h S}{(\rho_s - \rho)\tau *}$$

S = channel slope
ρ = water density
ρ_s = sediment density
h = bankfull flow depth
τ* = bankfull Shields stress

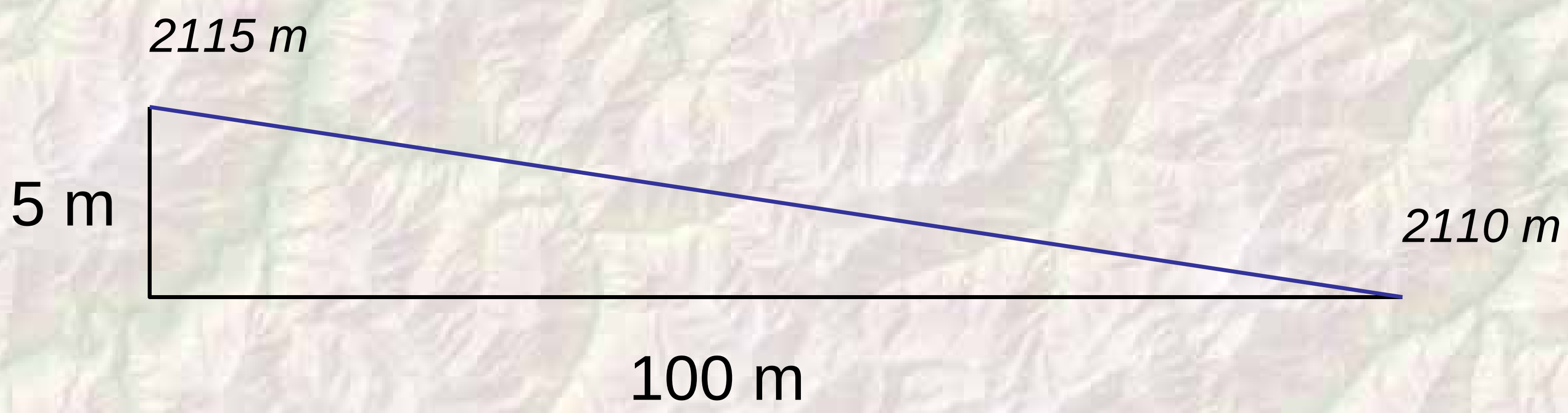
(Buffington et al., 2004, Can. J. Fish. Aquat. Sci. 61: 2085-2096)

Suitable grain size for Chinook salmon spawning

D_{50} = 16 – 51 mm

Computing Gradient

Rise / Run = Slope



5 / 100 = .05 = 5% slope

Objectives

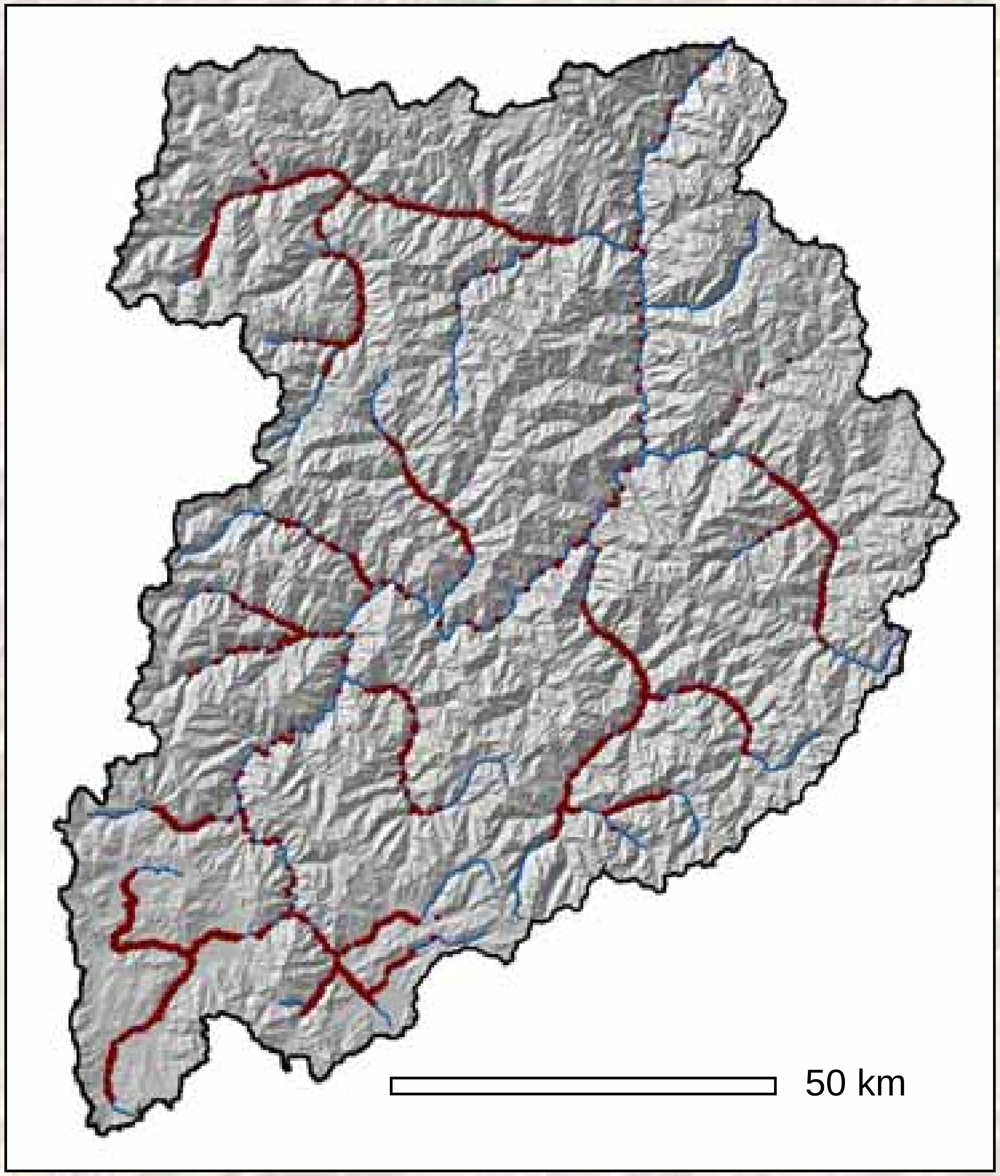
1) Determine the best data to use
2) Suggest a procedure for processing the data

Study Area

10,000 km of rivers and streams

~ 1,000 km used by salmon

Chinook Salmon Spawning Sites 1995 - 2004



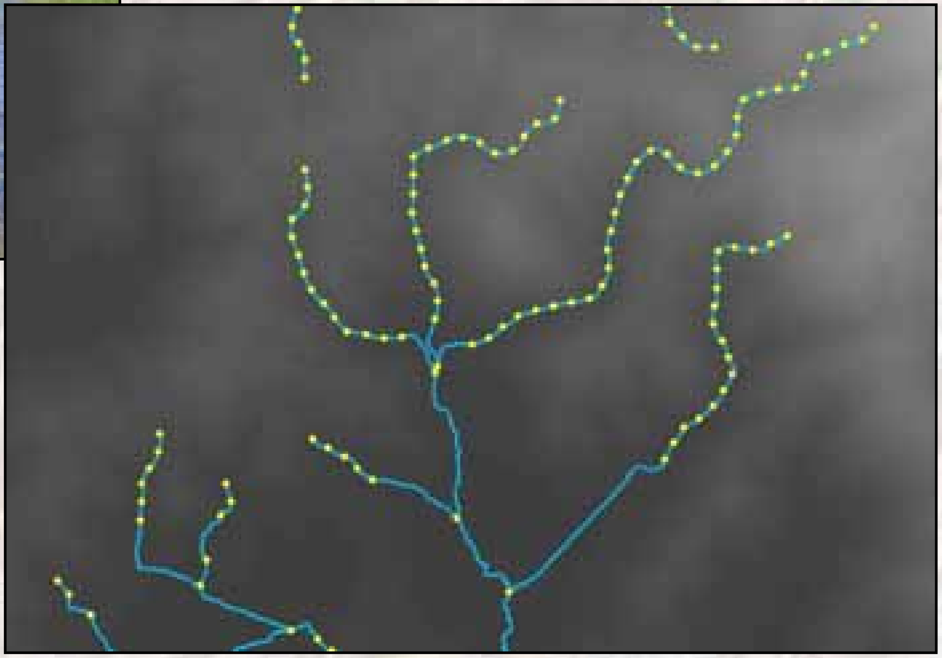
Research questions

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

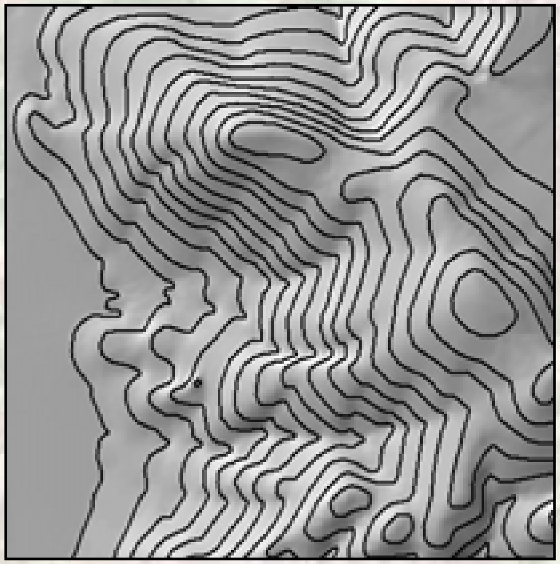


Digital Data

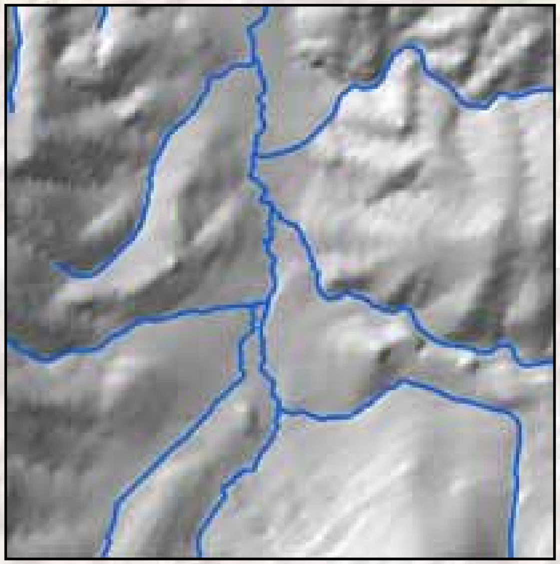
Some preliminary information

Necessary Data

1) Elevation - to compute rise

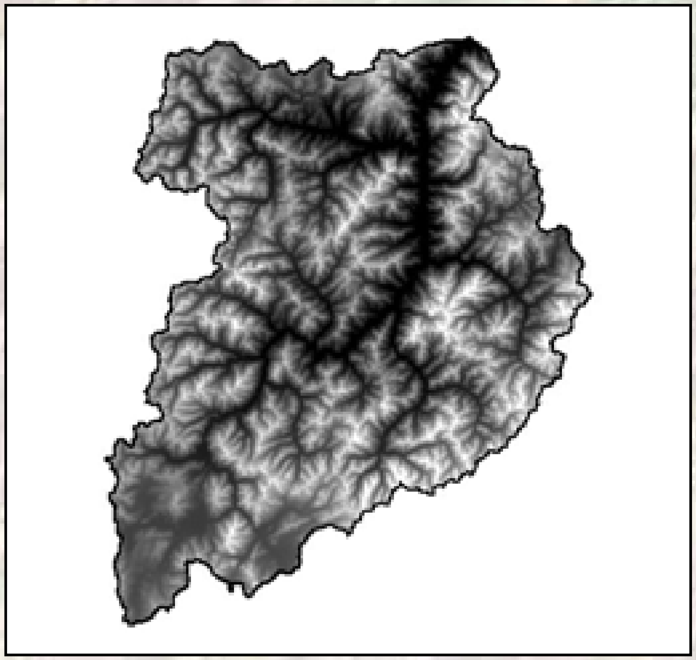


2) Stream lines - to compute run



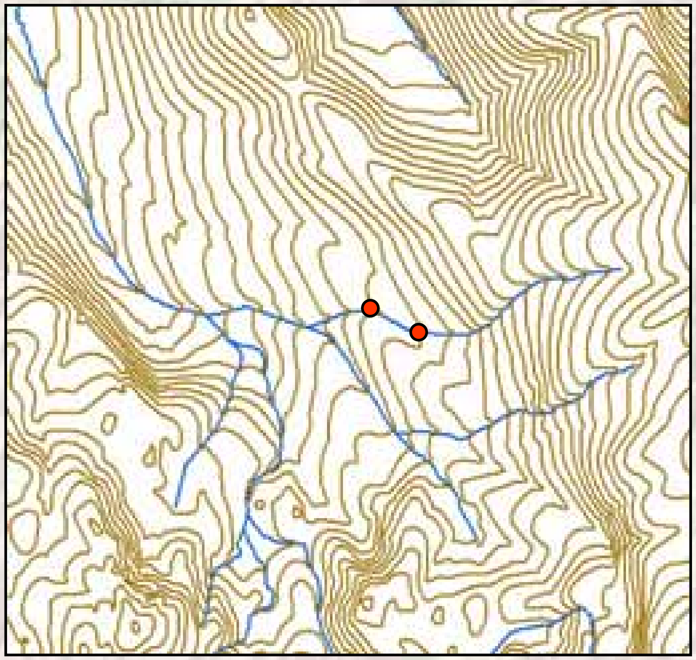
Choose Elevation Data

Digital Elevation Model (DEM)



USGS National Elevation Dataset (NED)

Contour lines

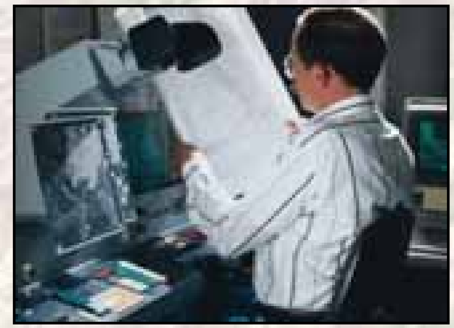


USGS 1:24,000 scale

DEM Production Process

1) Aircraft

2) Aerial photo



3) Stereo plotter

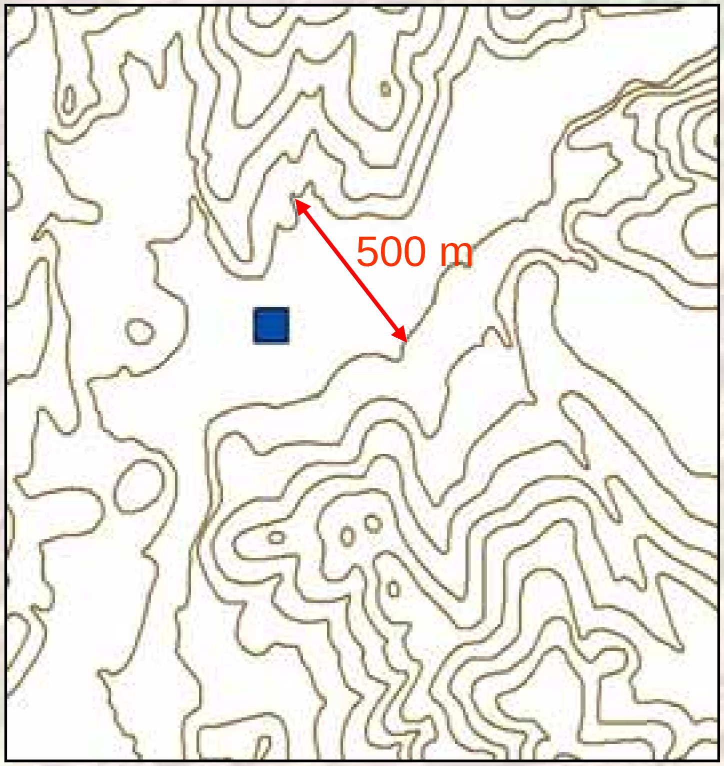
4) Map production

5) Scan and tag

6) LT4X

LT4X, Infotec Development, Inc.

Original Contours and 10 m DEM Model



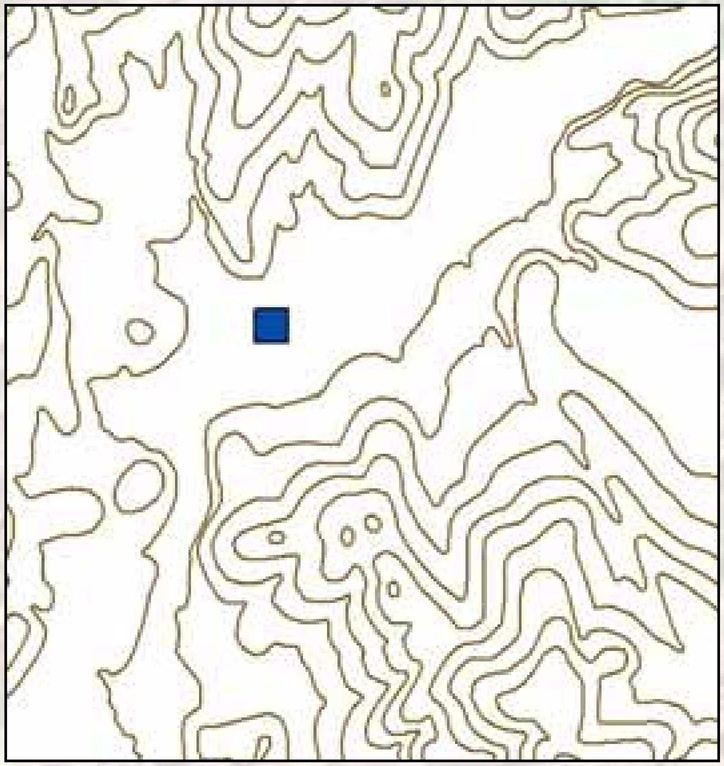
LT4X

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

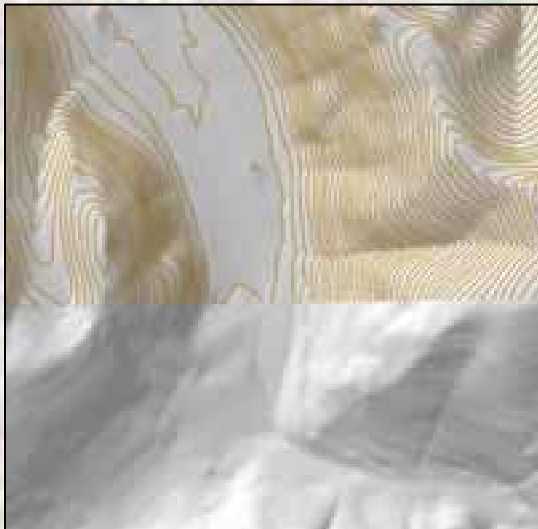


LT4X

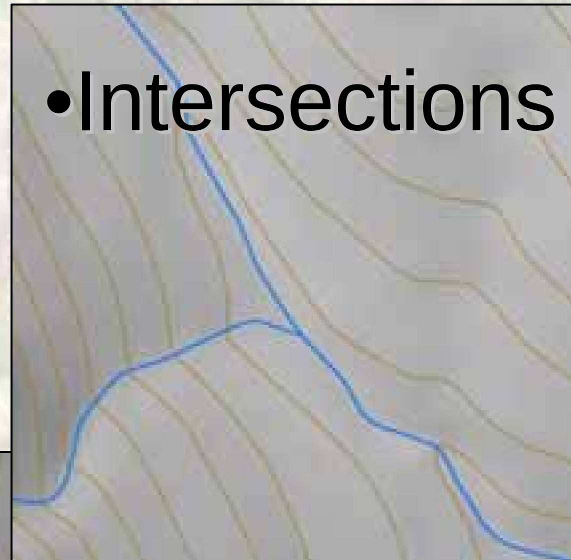
Original 40’ contours

2 m contours derived from 10 m DEM

Quad contour lines are the most accurate, but present technical problems

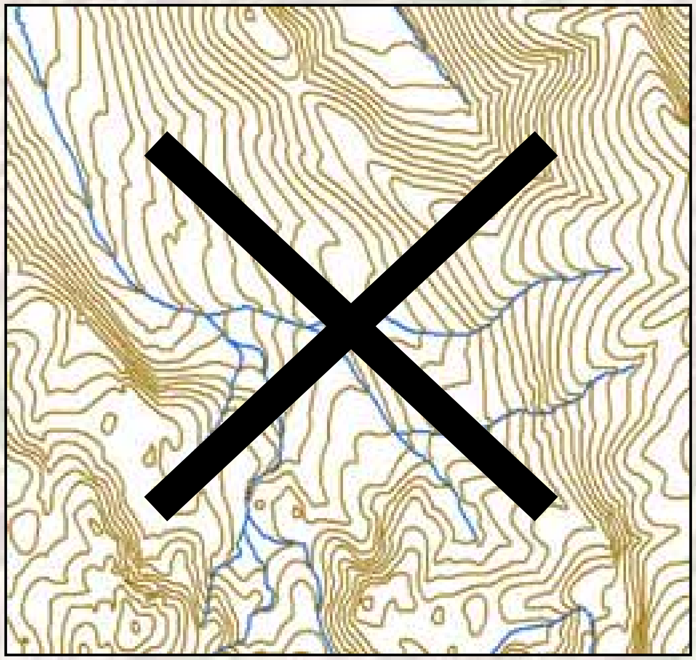


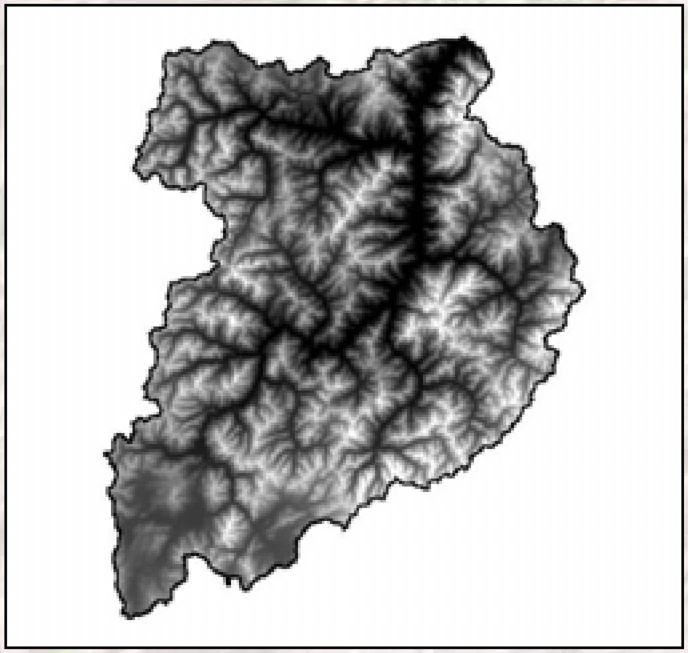
•Incomplete coverage (quad scans)



•Double crossing (DEM derived)

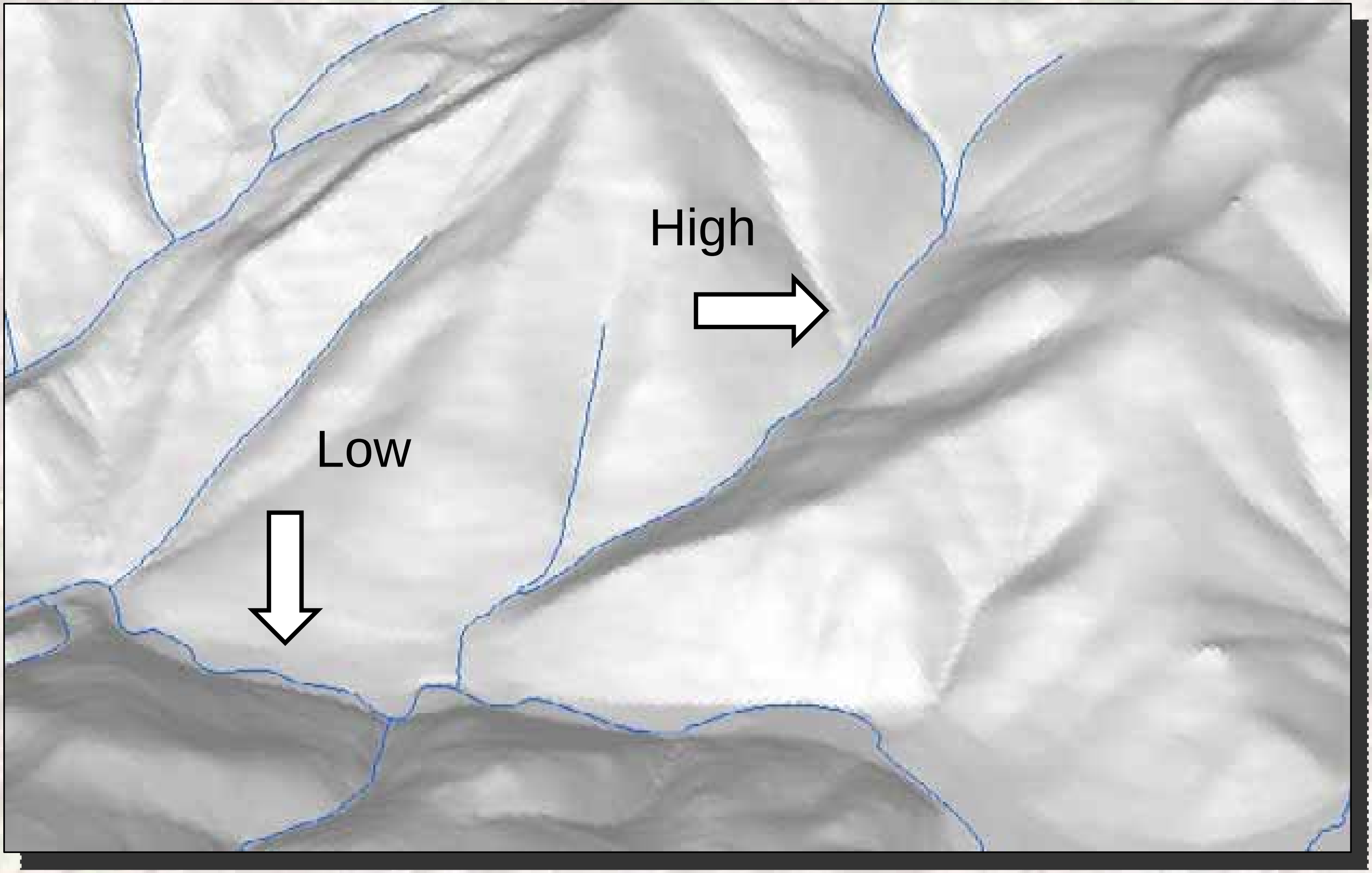
Eliminate contours as a viable option for large scale, automated gradient mapping





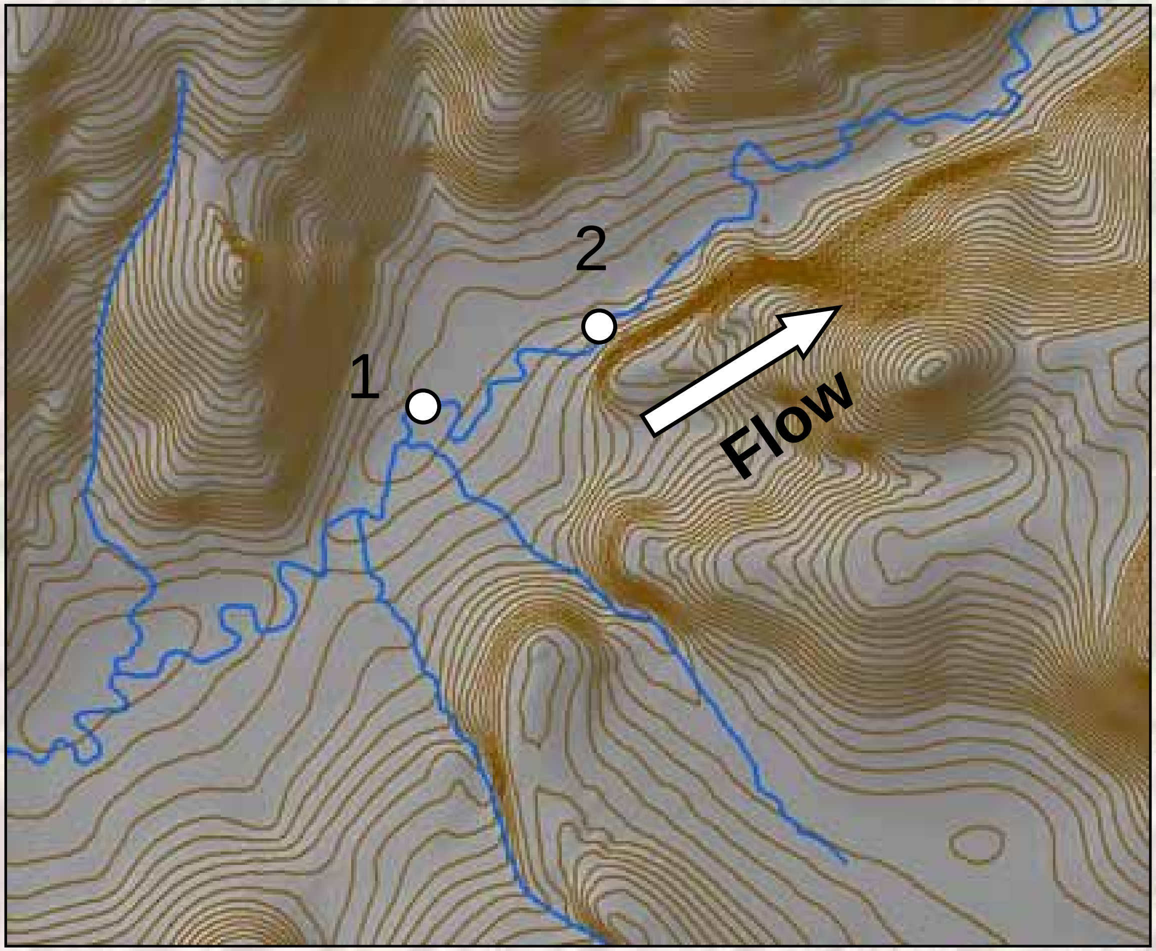
Consider raster DEMs because they are more easily analyzed in GIS

Higher gradient channels are better represented in the DEM than lower sloping streams



NHD and 10 m DEM

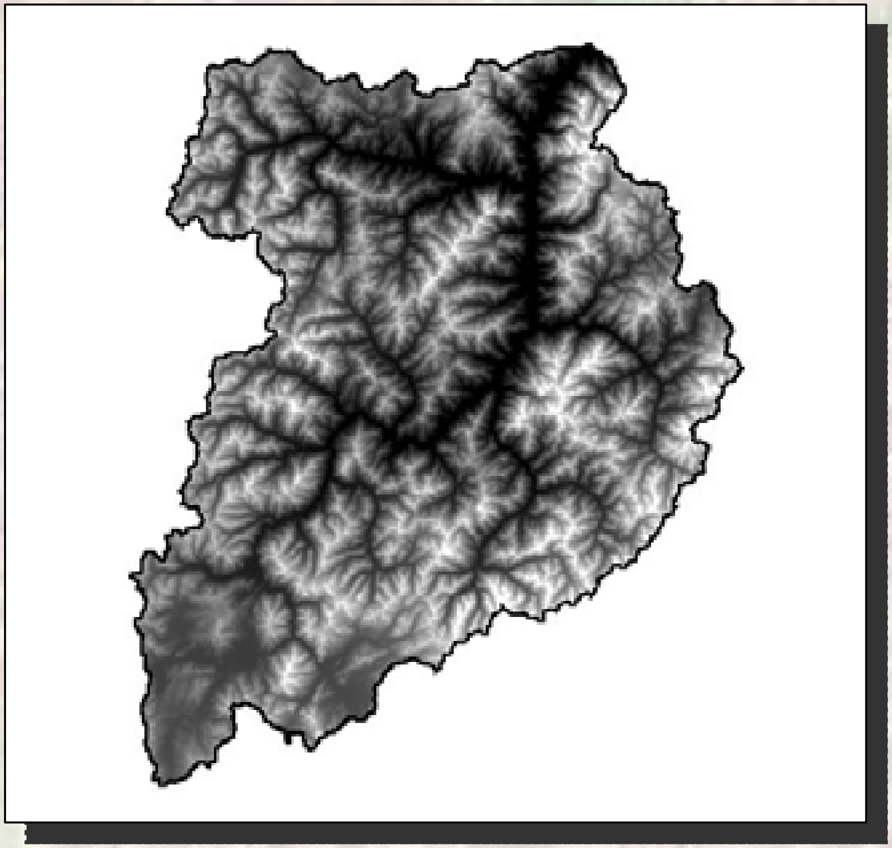
2 m contour interval



Operationally, DEMs have many advantages

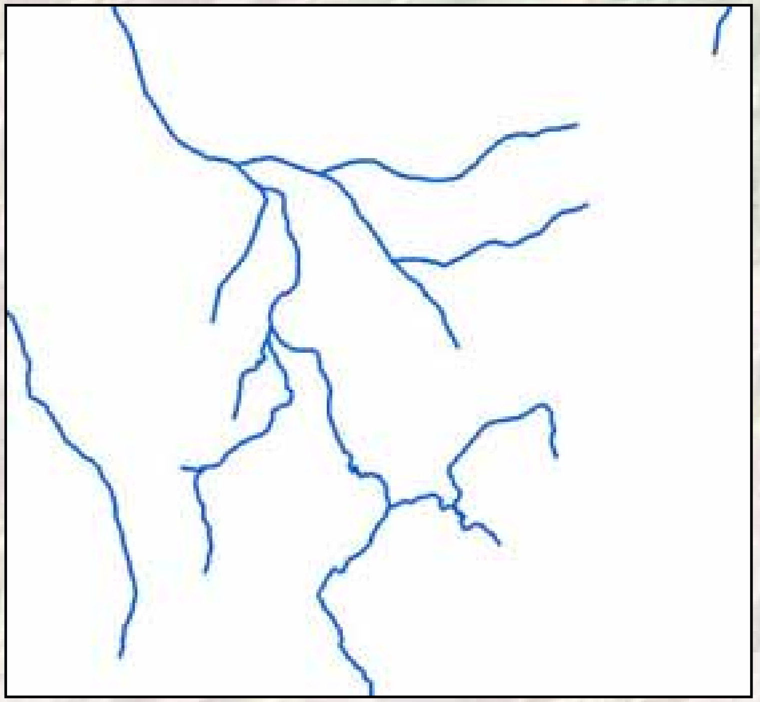
1) Continuous coverage
2) The raster model is computationally efficient
3) Topology isn't a concern

“Rise” Conclusion

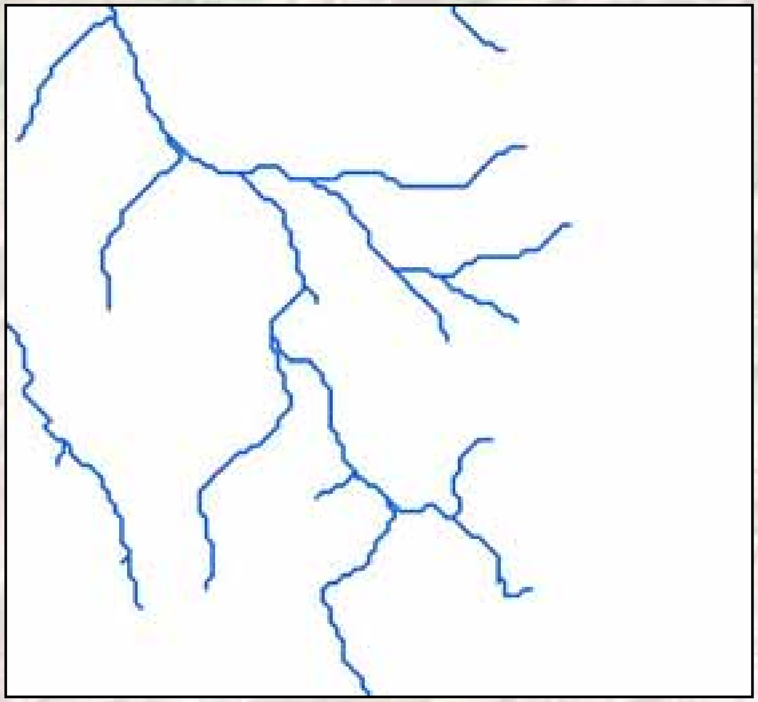


DEMs are imperfect, but have advantages over contours for estimating “rise” because contours present difficult technical issues

Choose Stream Line Data

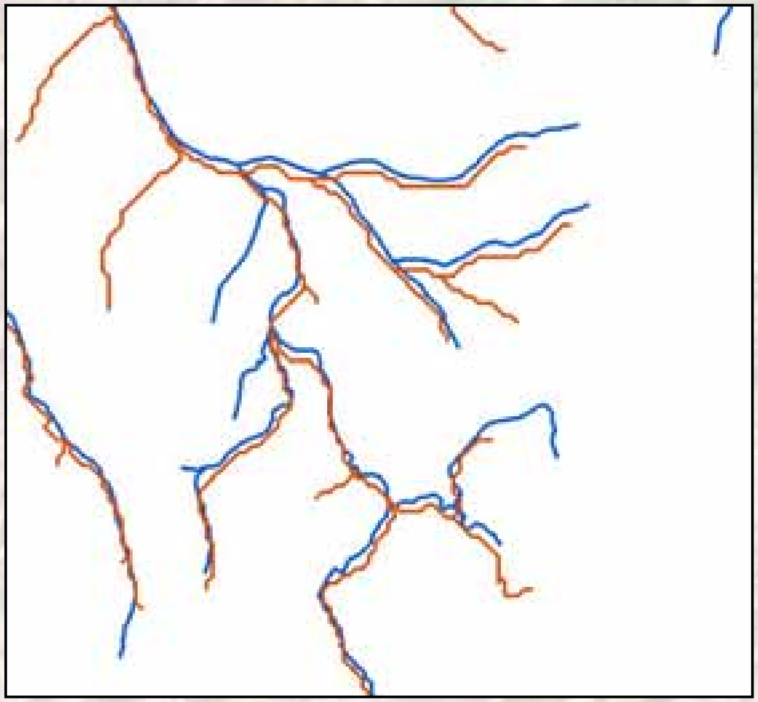


National Hydrography Dataset (NHD)

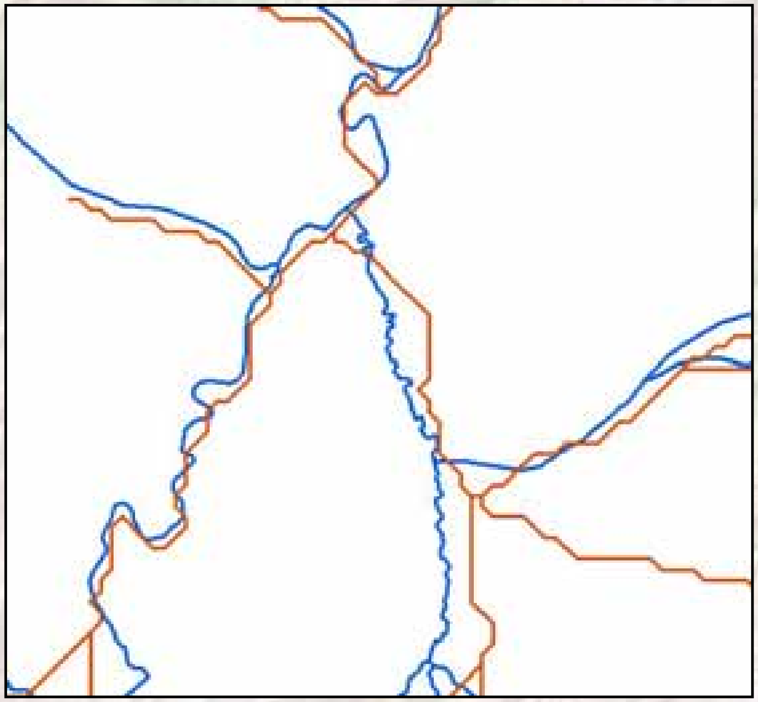


Synthetic stream lines

NHD and Synthetic Comparison

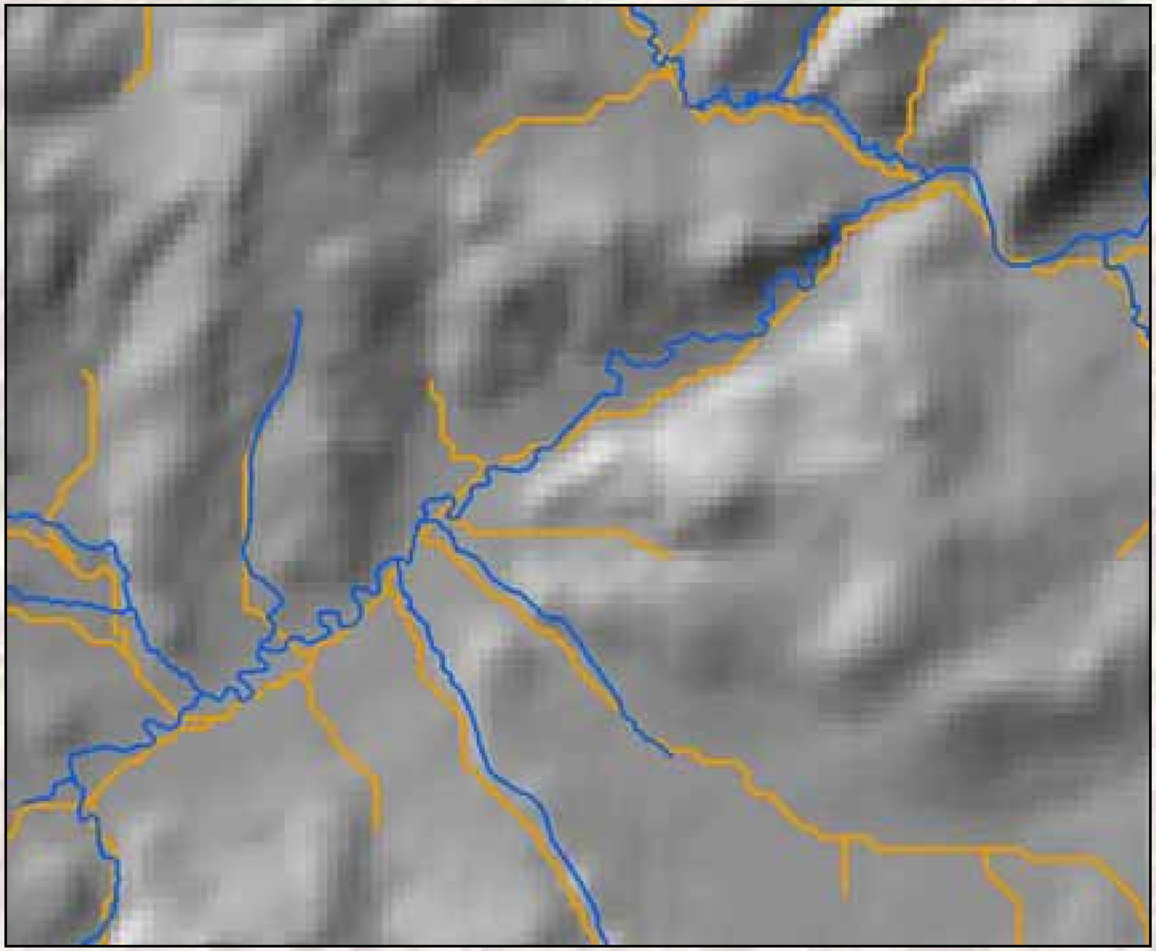


Higher gradient

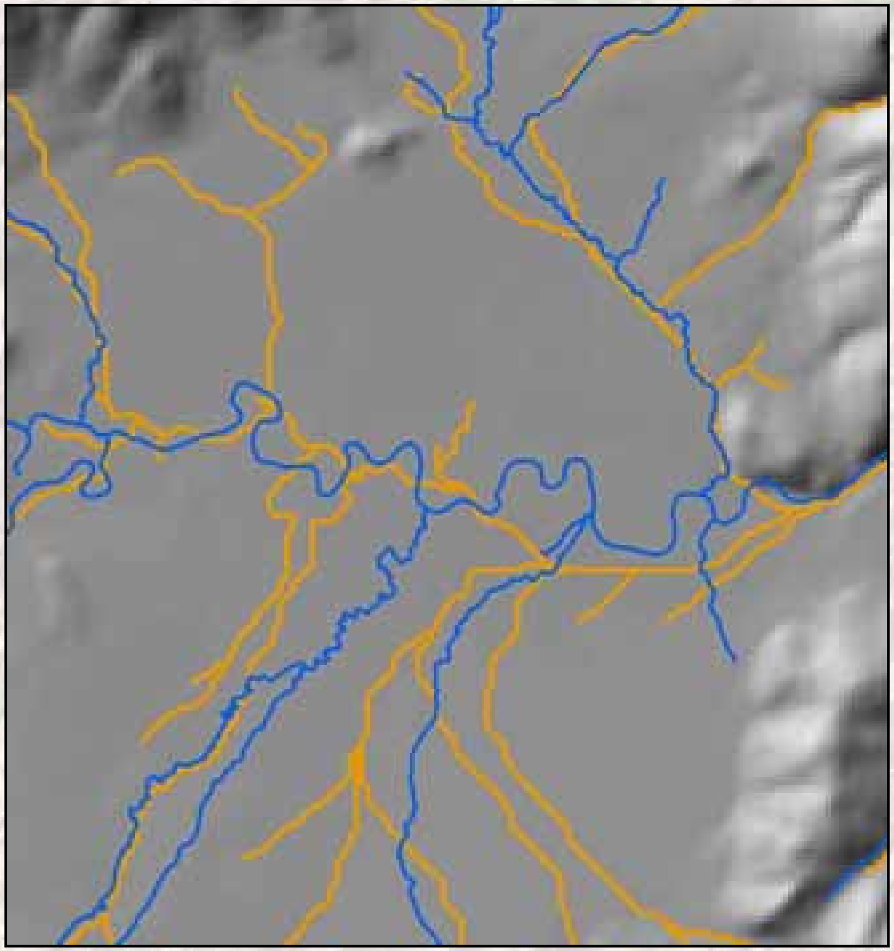


Low gradient

NHD Streams Represent Sinuosity More Accurately



Shortening with Synthetic Streams is Substantial



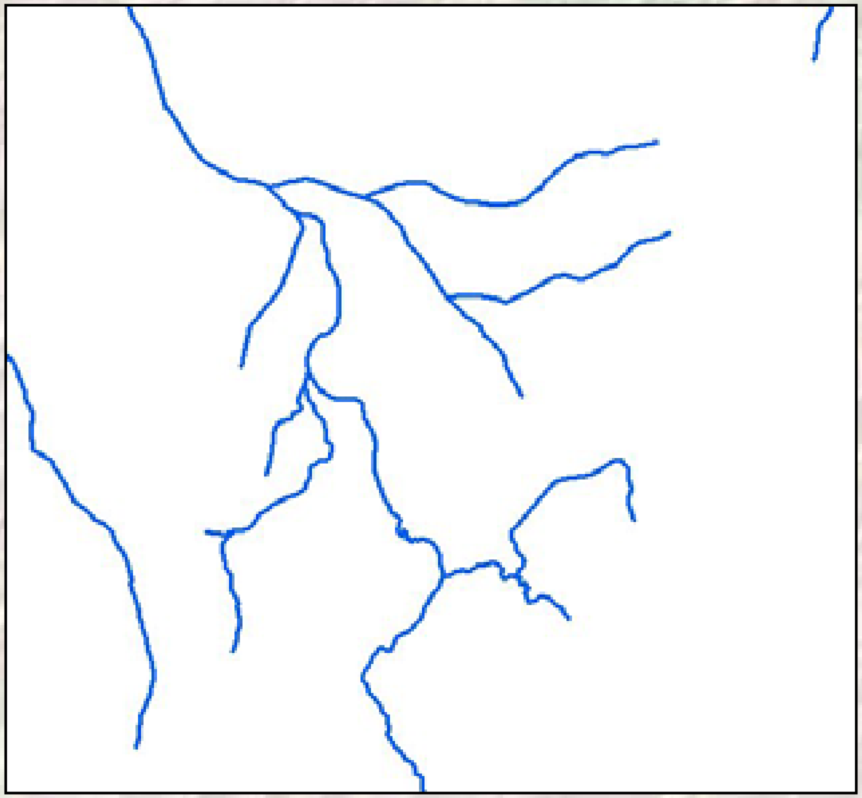
In low gradient areas, synthetic streams can underestimate stream length by approximately 25%, increasing gradient predictions

5412 m vs. 4092 m

Spatial accuracy of NHD streams

varies but is generally good

"Run" Conclusion



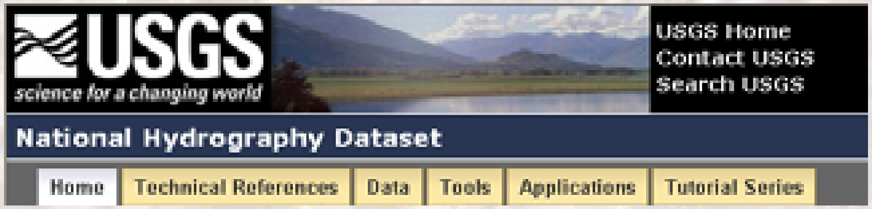
NHD stream lines are imperfect, but better than synthetic streams for estimating "run"

Best Data Choices for Computing Stream Channel Gradient

1) 10 m NED DEM dataset

http://ned.usgs.gov/

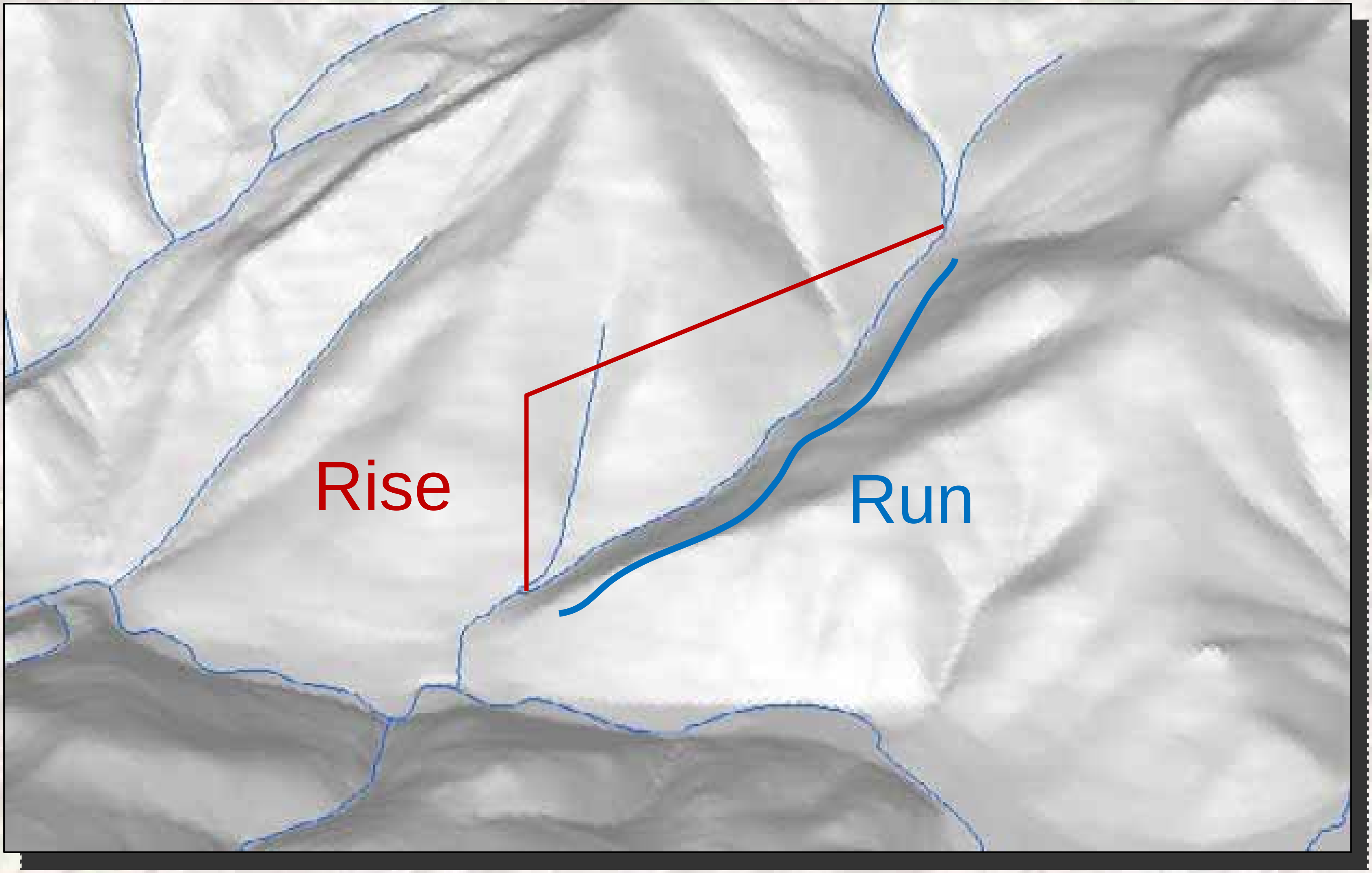
2) NHD stream lines



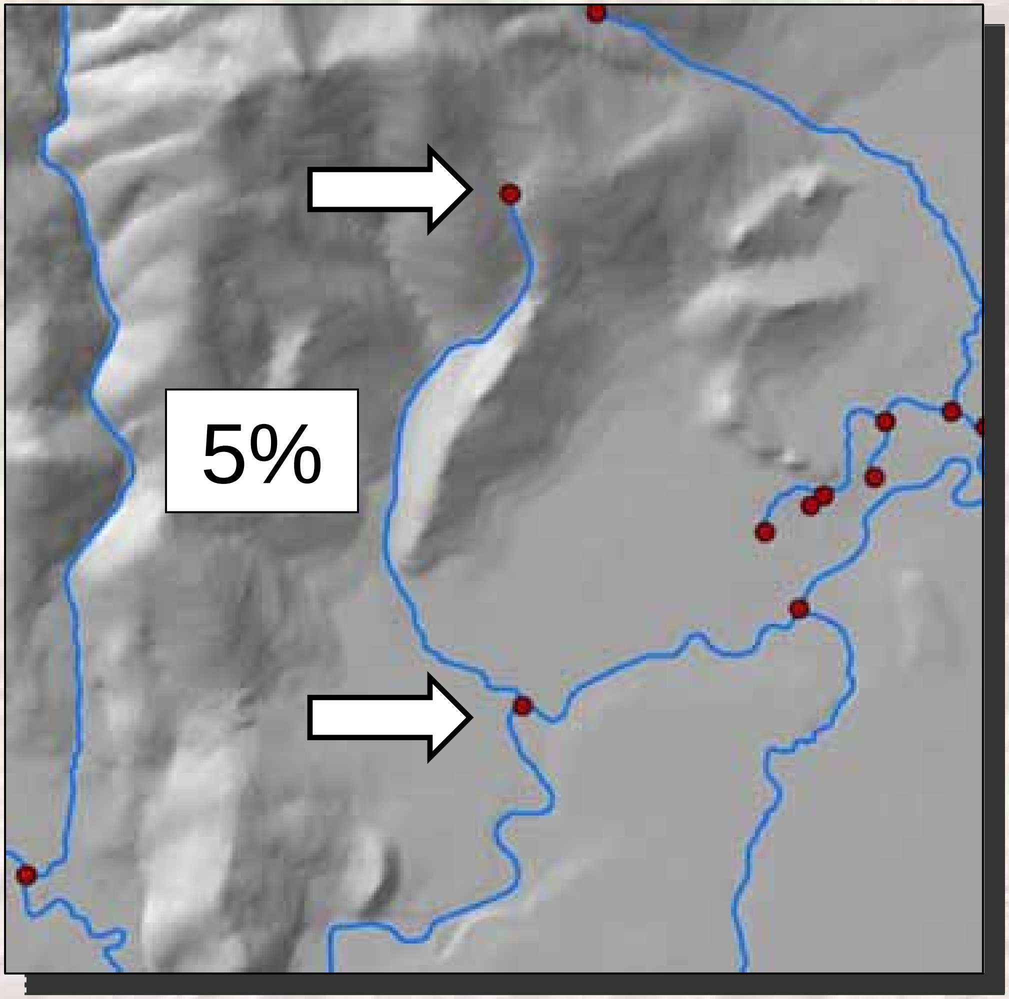
http://nhd.usgs.gov/

Computing Gradient

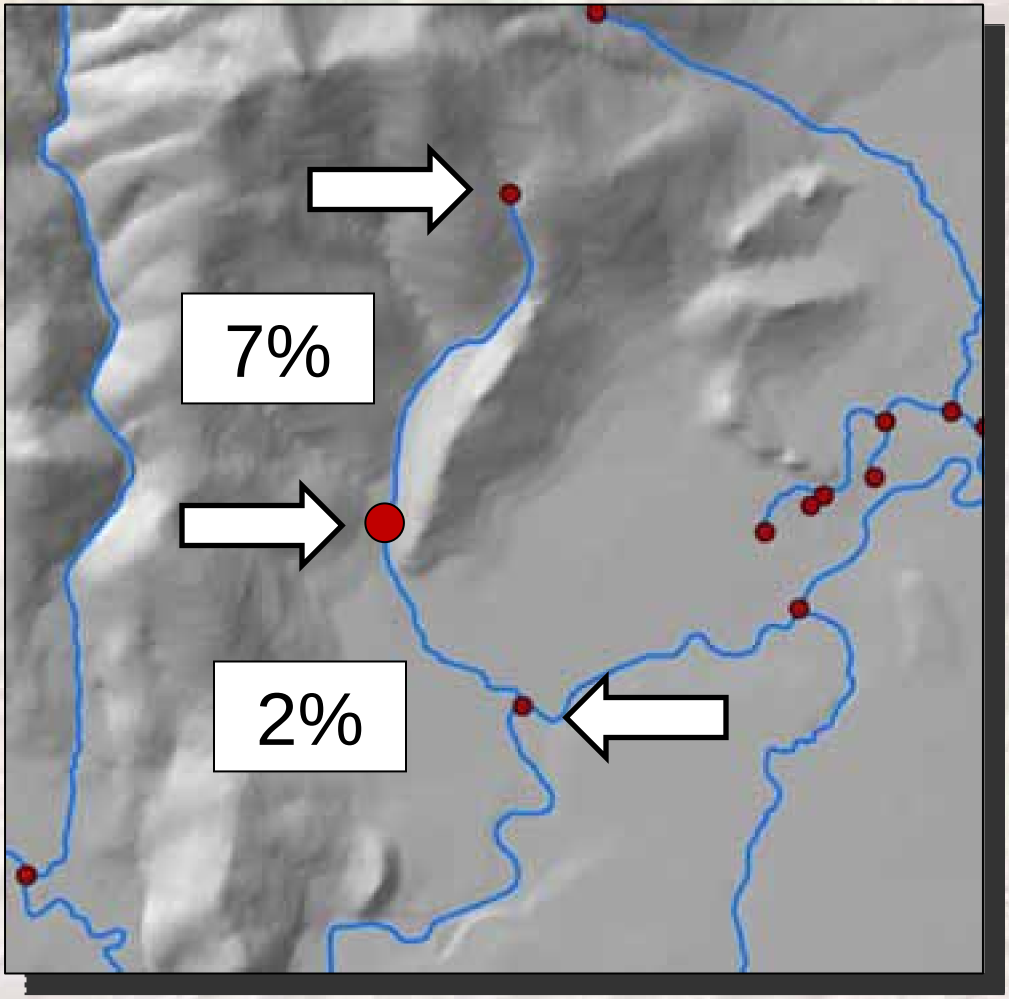
Rise from DEM
Run from NHD stream lines



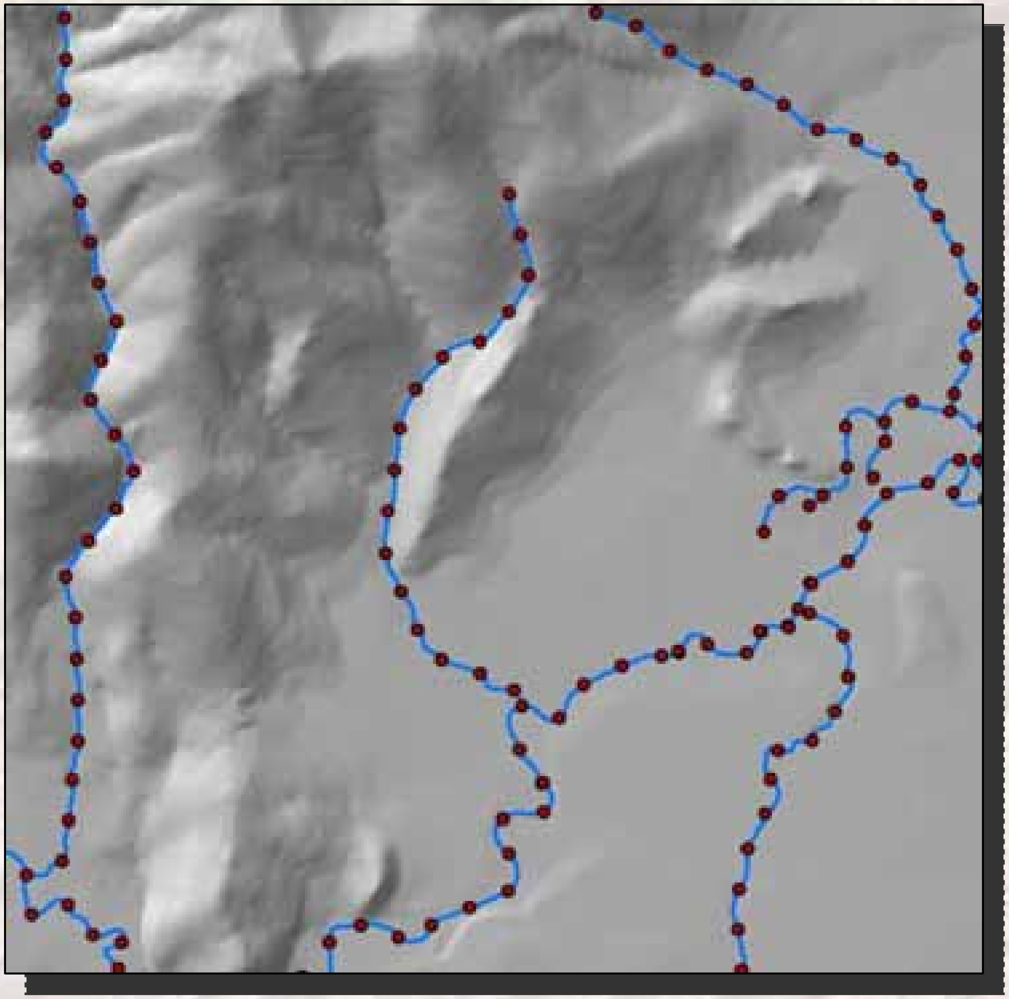
Some programs compute slope between endpoints and junctions (at stream intersections)



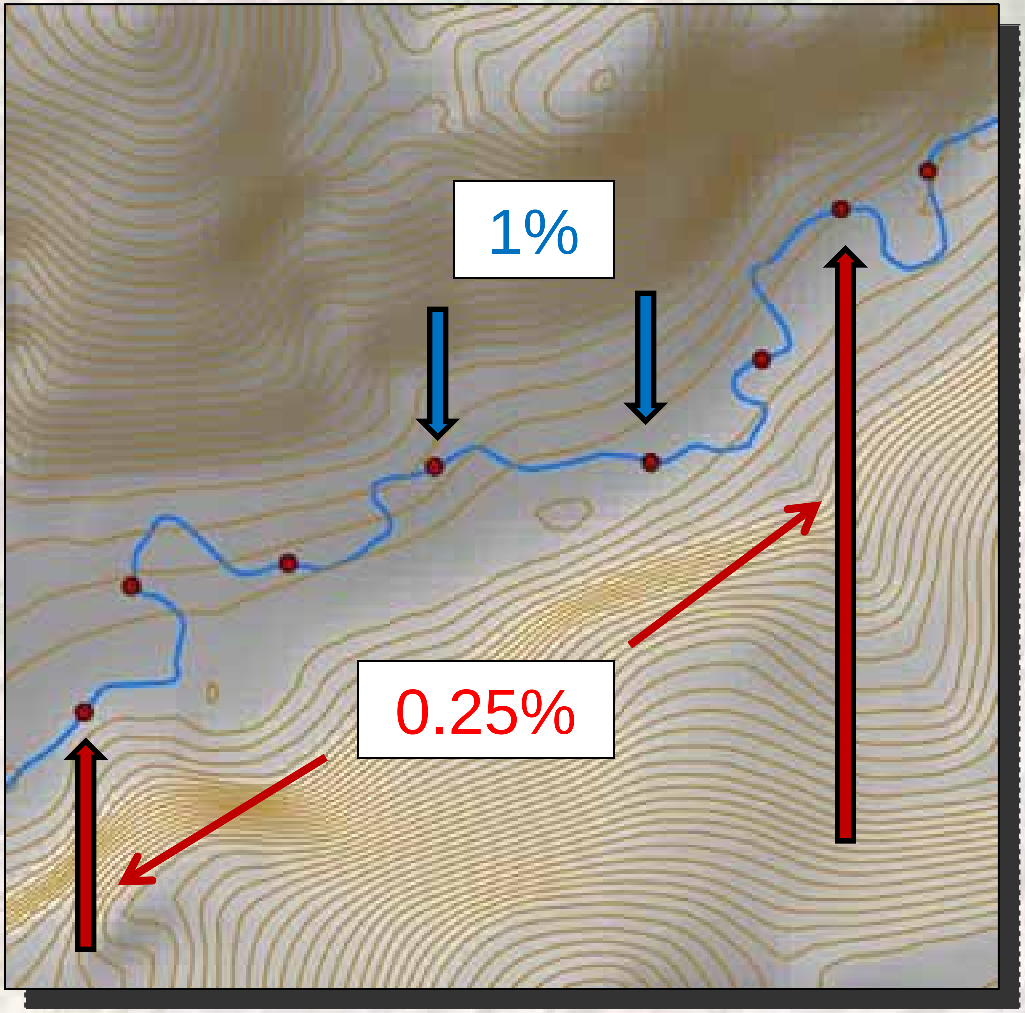
However, that approach may over-average gradient



A fine interval spacing will catch more variation along the channel in high gradient streams



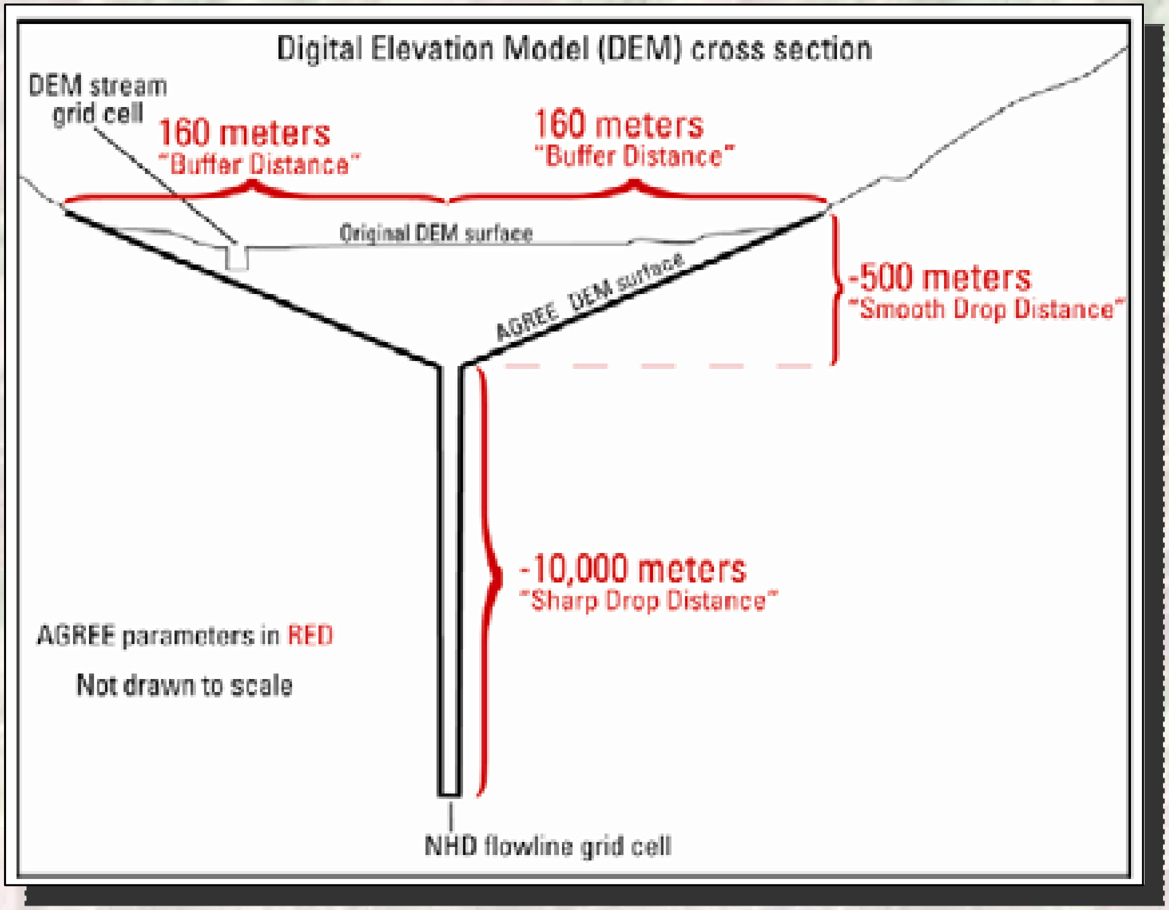
However, a fine interval may increase errors in lower gradient reaches



Actual = ~ 0.1%

Could drainage enforcement help?

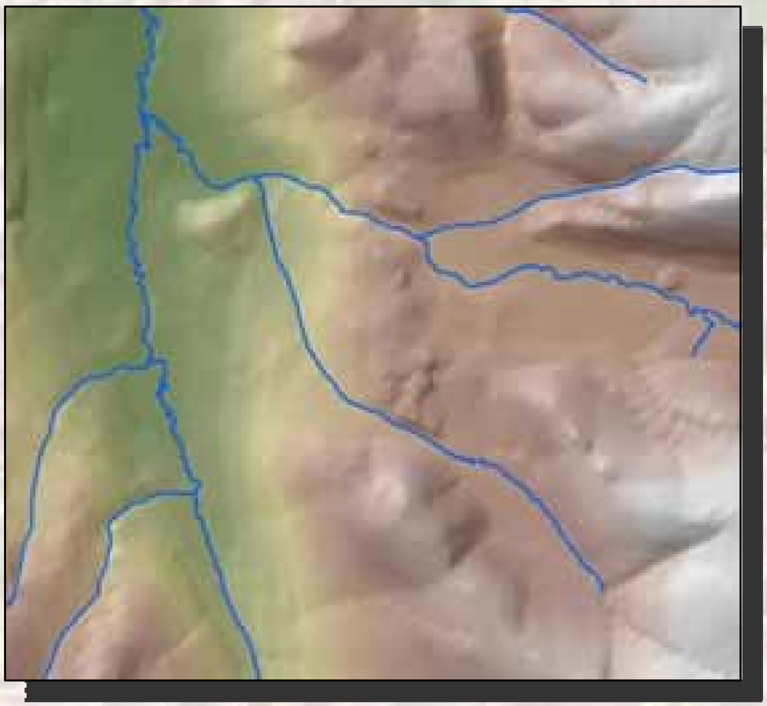
AGREE Algorithm for Drainage Enforcement



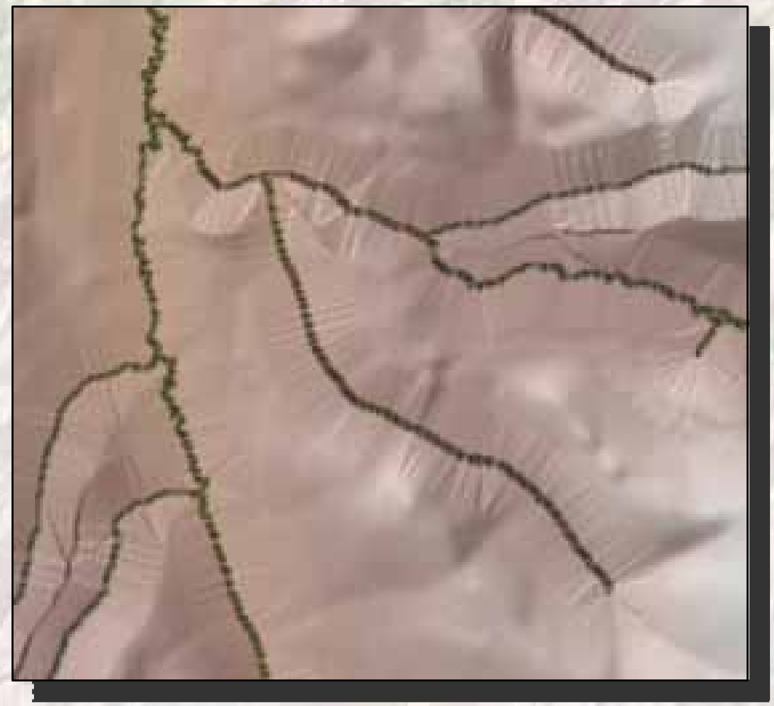
Dewald, T., NHDPlus User Guide, U.S. EPA and USGS, April 29, 2008

Hellweger, F., 1997. AGREE — DEM surface reconditioning system. Center for Research in Water Resources

Drainage Enforcement, Trenching, or DEM Reconditioning

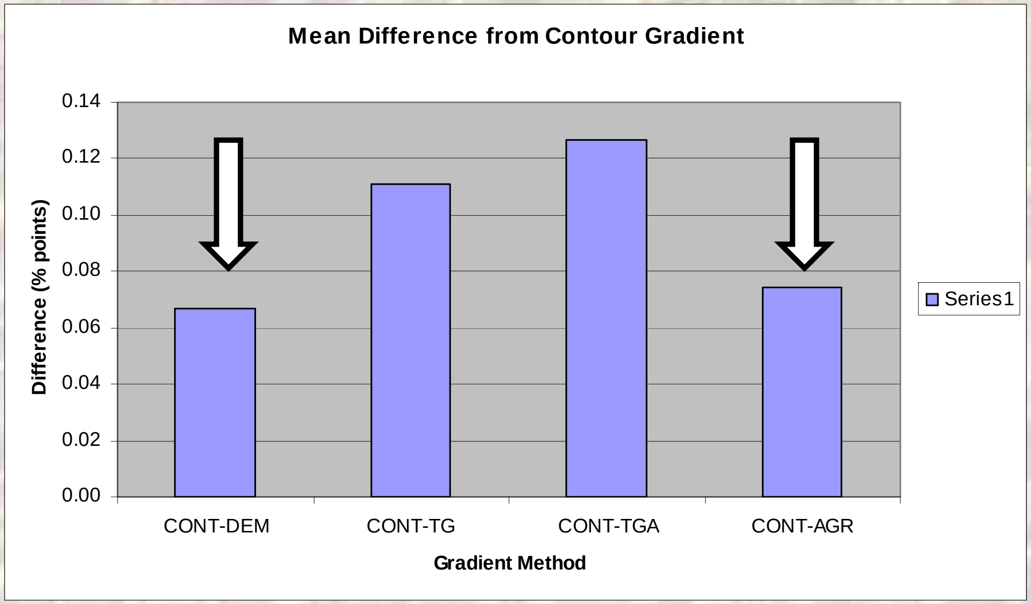


Original



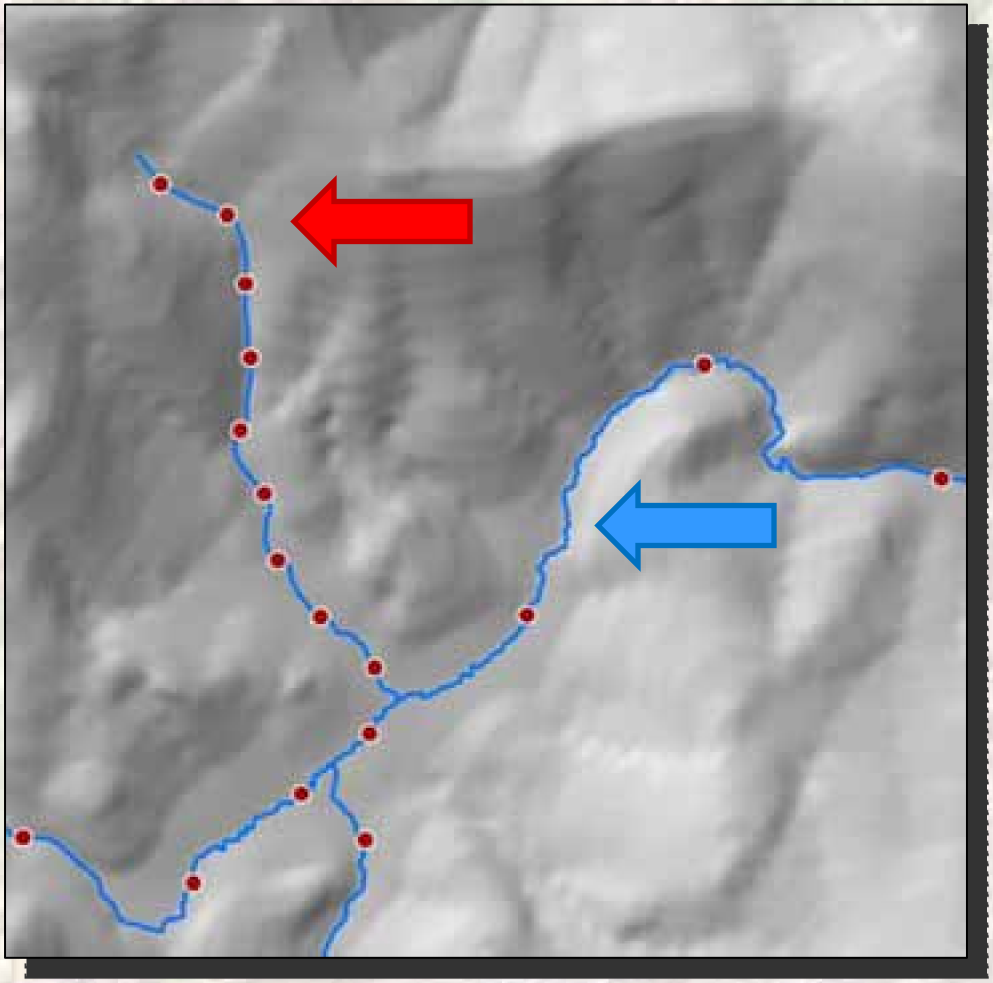
Reconditioned

Drainage Enforcement Results



Generally speaking, little or no improvements were noted when drainage enforcement was used in our study area

Our solution is a variable interval spacing, which varies by slope class and approximates the original quad map contour spacing

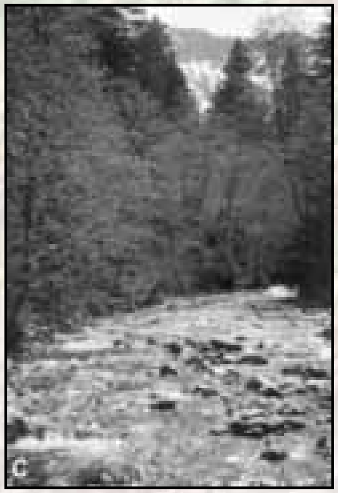


High gradient = short intervals

Low gradient = longer intervals

Preprocess stream reaches into four slope classes

1) Cascade (> 7.5%)
2) Step-pool (3-7.5%)

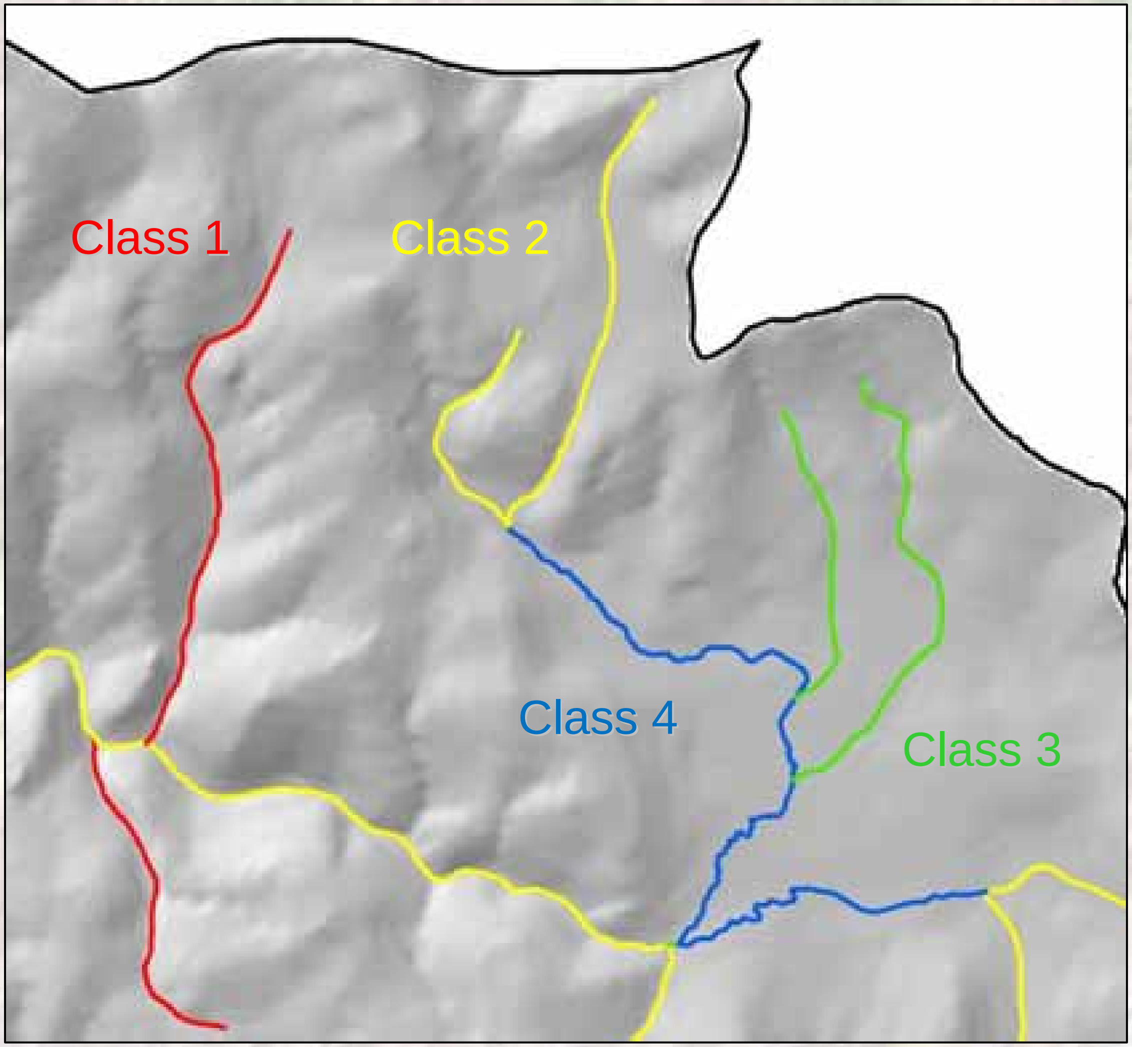


3) Plane-bed (1.5-3%)

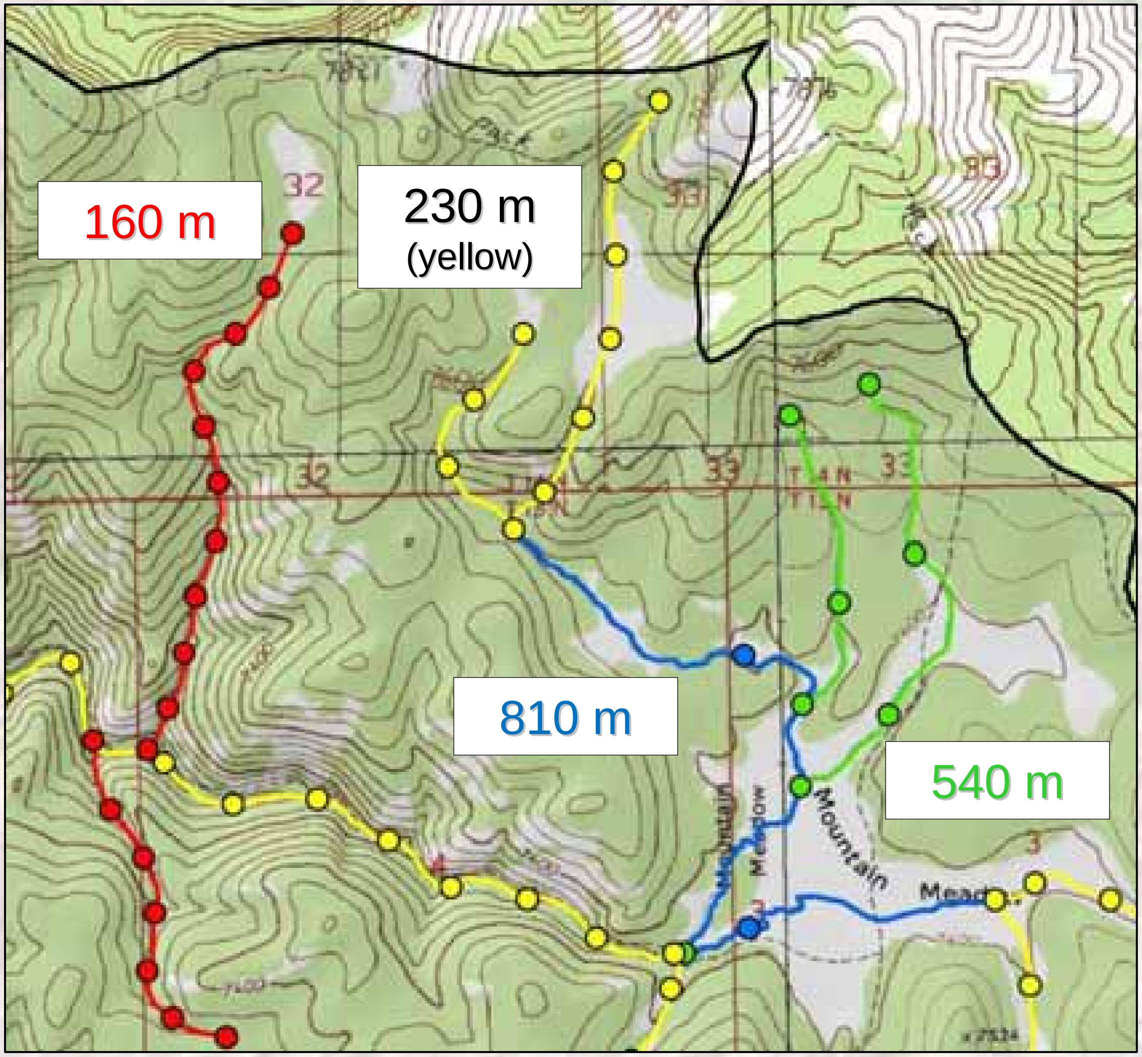
4) Pool-riffle (< 1.5%)

Buffington, J.M., D.R. Montgomery, H.M. Greenberg, Can. J. Fish. Aquat. Sci. 61: 2085-2096 (2004)

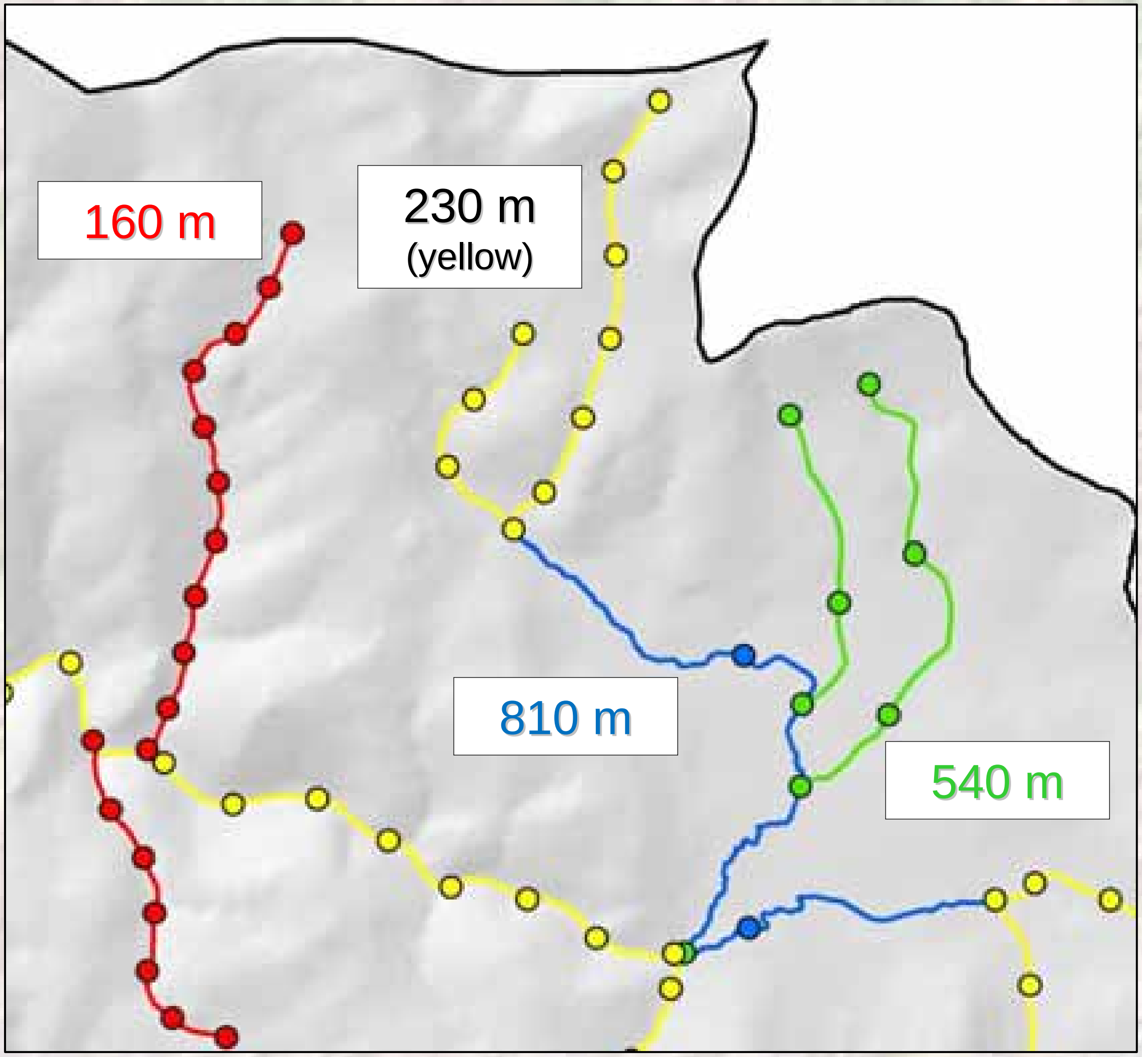
Each stream segment is assigned a gradient class based on its average channel slope between tributary junctions



Each gradient class is assigned an interval spacing that approximates the quad contour spacing

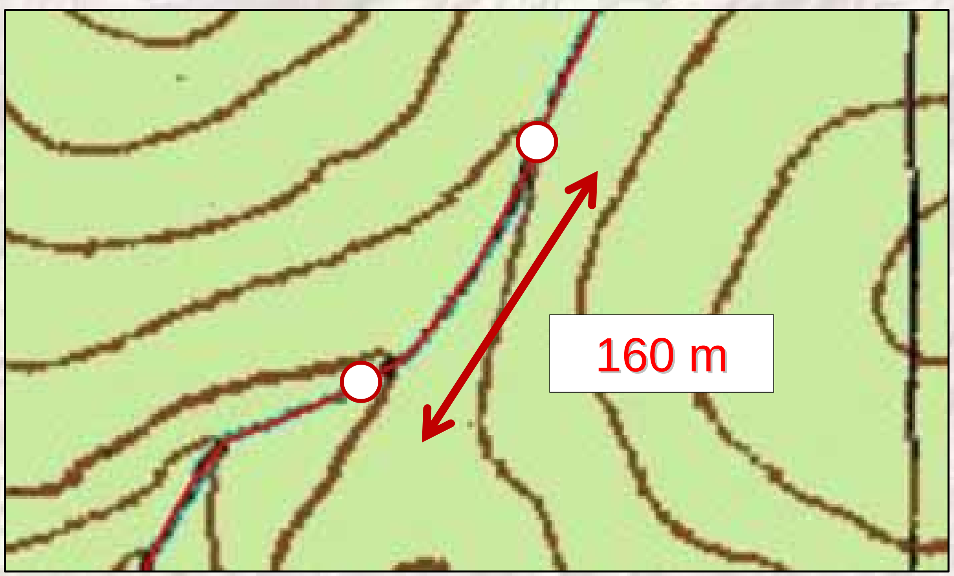


Each gradient class is assigned an interval spacing that approximates the horizontal quad contour spacing



These interval spaces are set by the horizontal contour distance for 40’ contours on USGS quads

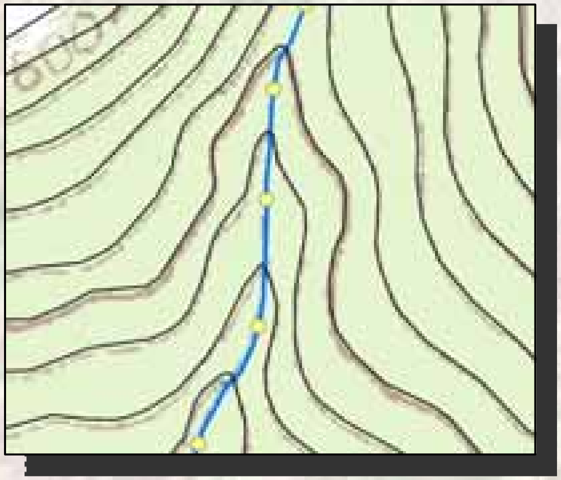
1) Cascade (> 7.5%)	160 m
2) Step-pool (3-7.5%)	230 m
3) Plane-bed (1.5-3%)	540 m
4) Pool-riffle (< 1.5%)	810 m



Cascade = 160 m

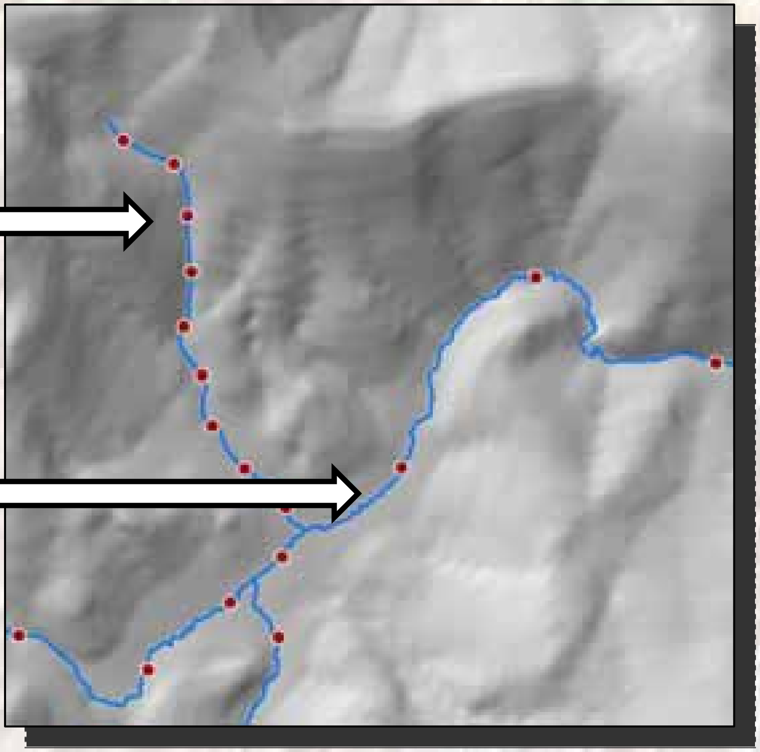
Accuracy

Accuracy was tested using the quad contour elevations as “truth” against our variable interval spacing method

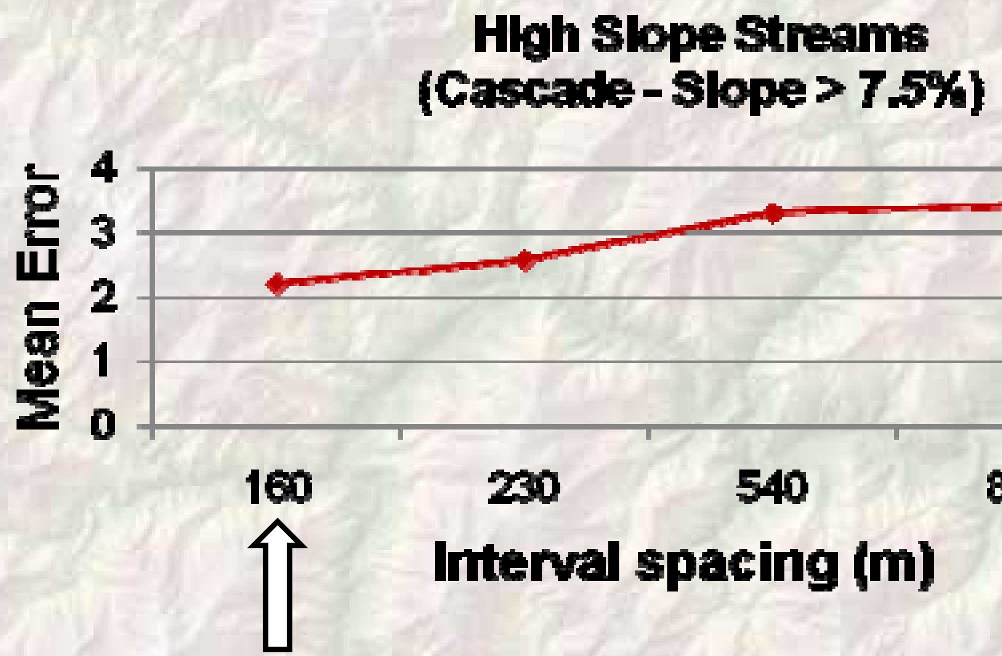


Error decreased when we used shorter intervals in high gradient streams.

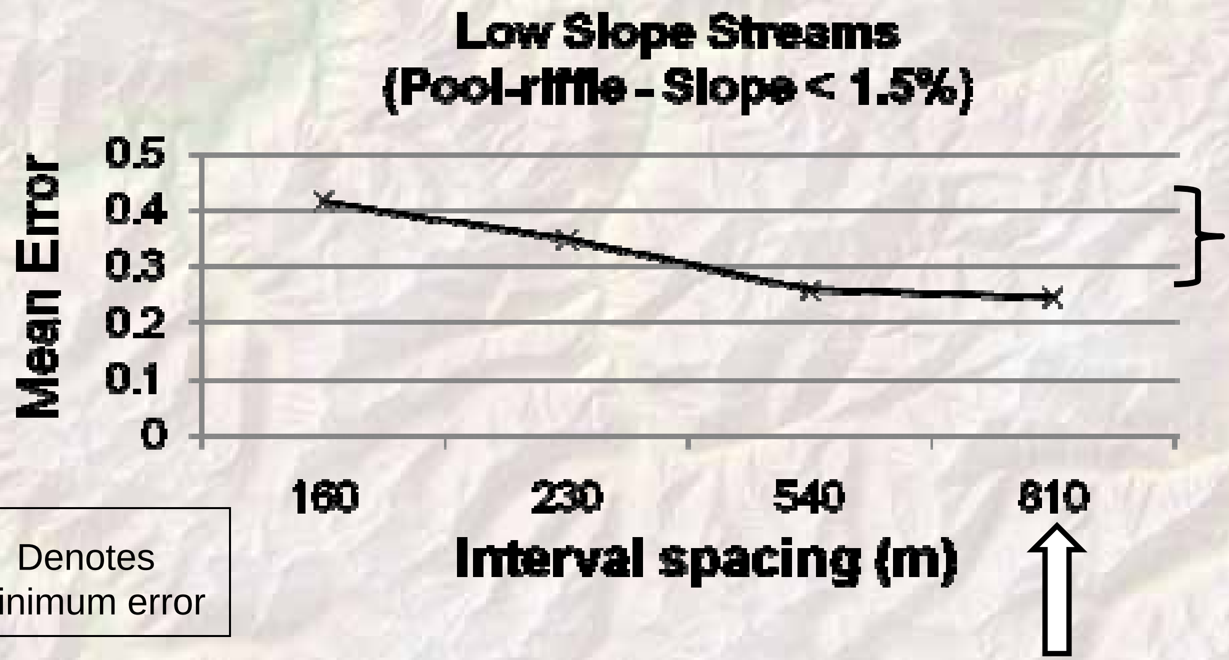
Likewise, error decreased when we used longer intervals in lower gradient streams.



Mean error = ABS(contour slope – interval slope)



36% improvement over 810 m



40% improvement over 160 m

⇧ Denotes minimum error

ANOVA

	Class 1 > 7.5% Cascade		Class 2 3 - 7.5% Step-pool		Class 3 1.5 - 3% Plane-bed		Class 4 < 1.5% Pool-riffle	
Interval Spacing	**ABS Mean Diff.**	**P-value**	**ABS Mean Diff.**	**P-value**	**ABS Mean Diff.**	**P-value**	**ABS Mean Diff.**	**P-value**
160	2.20	Test case	1.02	0.93471	0.65	0.84568	0.42	0.00108
230	2.57	0.00026	1.01	Test case	0.63	0.98947	0.35	0.01288
540	3.31	3.6E-14	1.50	1.9E-06	0.63	Test case	0.26	0.66960
810	3.42	5.4E-12	1.95	5.7E-12	0.77	0.19048	0.25	Test case

Red = non-significant difference from Test case

When compared against the quad contour gradient ("truth"), the accuracy of the variable interval method was better than any single interval

	Normalized mean diff.	P-value
Variable method	0.23	Test case
Interval 160	0.44	1.04792E-16
Interval 230	0.40	1.48937E-15
Interval 540	0.37	6.92426E-16
Interval 810	0.38	7.11304E-18

Normalized mean diff. = ABS(contour slope – DEM slope)/ contour slope

The absolute accuracy of the variable interval method was dependent on the gradient class being measured

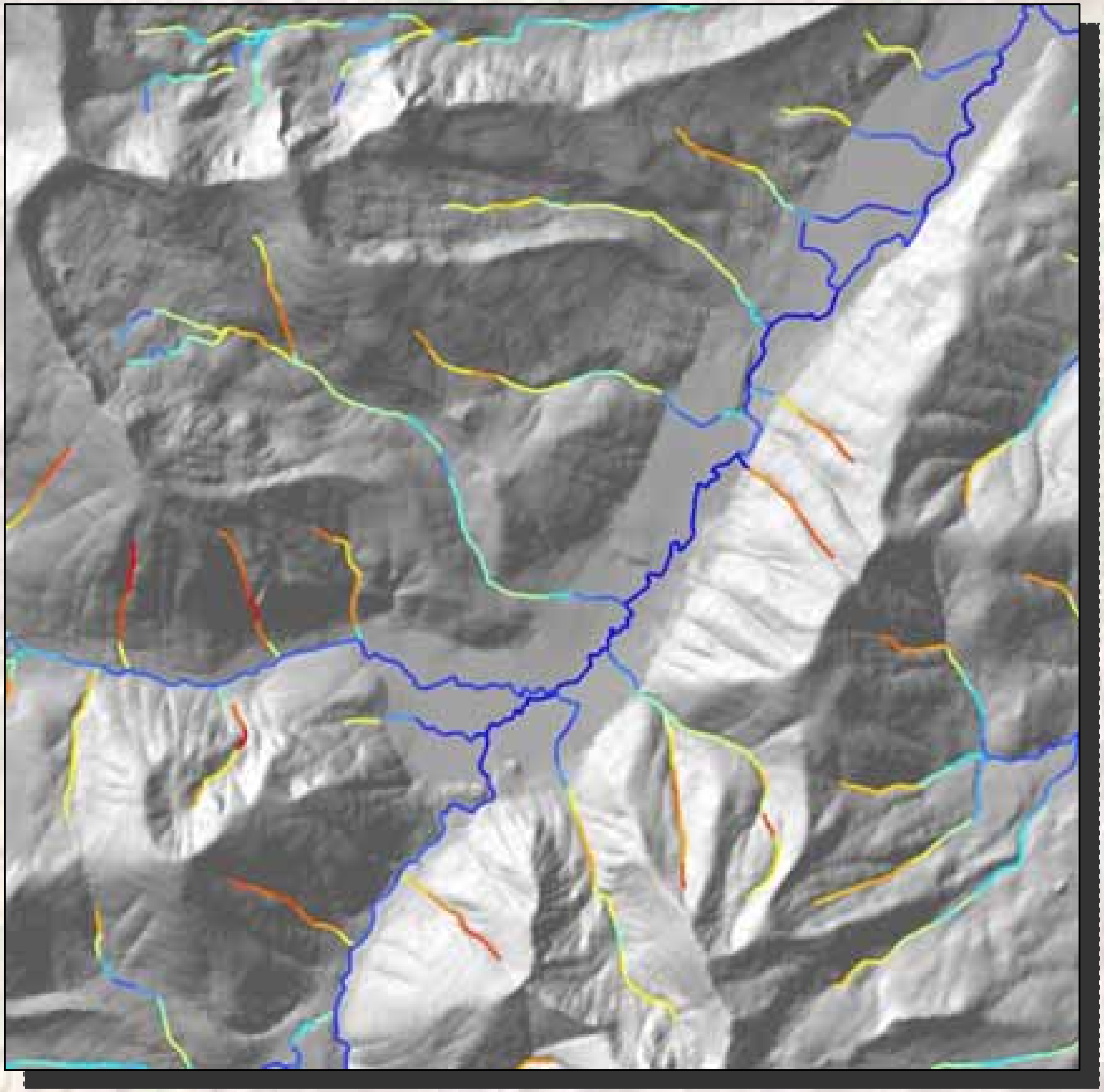
	ABS Mean Diff.	St. Dev.	n
Class 1 > 7.5%	2.33	2.55	1670
Class 2 3 - 7.5%	1.08	1.54	763
Class 3 1.5 - 3%	0.80	1.20	225
Class 4 < 1.5%	0.32	0.46	328

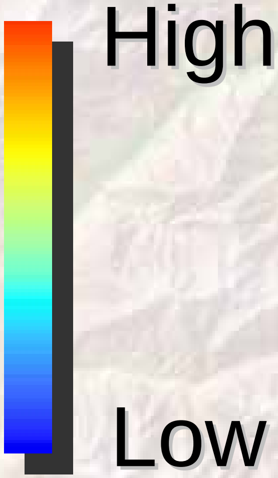
ABS mean diff. = (contour slope – DEM slope)

Conclusions

1) 10 m NED DEMs are more computationally practical than digitized contour lines for computing gradient
2) NHD stream lines provide a better measure of sinuosity than synthetic stream lines
3) Drainage enforcement does not substantially improve gradient results
4) A variable interval method provides better results than any single interval spacing

Final Channel Gradient





Acknowledgements

RMRS – Boise Lab

Sharon Parkes – GIS Specialist
Russ Thurow – Research Fisheries Biologist
John Guzevich – Fisheries Biologist

Bob Smith – Idaho Department of Lands