



2D or not 2D?

Use of a 2-dimensional hydraulic model for indirect discharge estimation and other applications in stream gaging

David Saba & Diane Wagner
Water Sciences Bureau





What's the n?

Semi-Automated 2D Hydraulic Modeling for Rating Curve
Development
and Other Cool Stuff too



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Roadmap

- ◆ Project Goals
- ◆ Survey Methods
- ◆ 2D Model Calibration
- ◆ Results from Mill Creek
- ◆ What's Next...



A Brief History

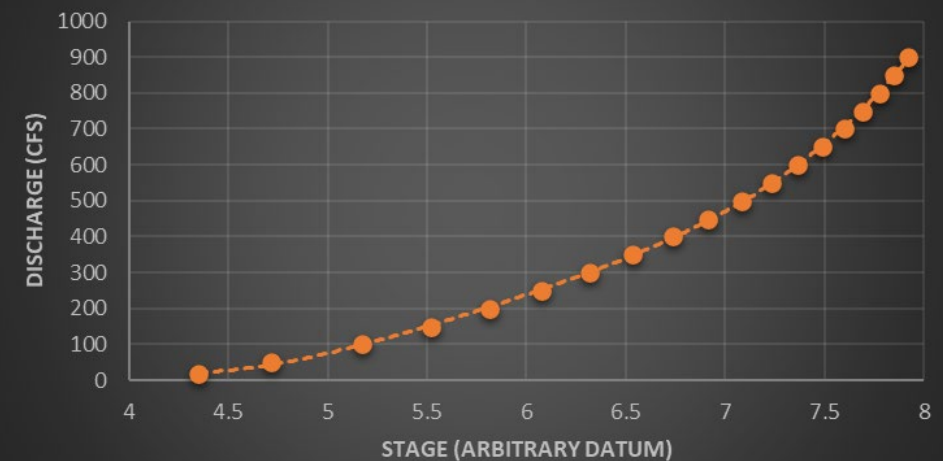
- ◇ 1991 – Legislative directive for monitoring on impaired watercourses
- ◇ 2015- Dedicated stream gage program in WMB
- ◇ 2020- StAGE web application
- ◇ 2023- HB2 adds 32 gages and doubles staff
- ◇ DNRC-WRD maintains 84 gages at present
 - ◇ 22- maintained by the State Water Projects Bureau
 - ◇ 62- maintained by the Water Sciences Bureau
 - ◇ WSB will have 78 by July 1ST 2025
 - ◇ 8 full-time staff



Project Goals

- ◆ Develop a method to estimate high discharge at DNRC stream gage sites
 - ◆ Data must be up-to-date & high resolution
 - ◆ Calibrated with direct discharge measurements
 - ◆ Use high water marks or gage data (indirect)
 - ◆ Low uncertainty
 - ◆ Semi-automated
 - ◆ Flexible

Gage 41H08990



Implications

- ◆ A more accurate MIHMS (Montana Integrated Hydrologic Modeling System)
 - ◆ Framework for integrating existing hydrologic, river routing, groundwater, ET models into a single usable system
 - ◆ Can use accurate gage data to calibrate these models
- ◆ Water Rights Implications
 - ◆ Watershed Groups, Water Commissioners, and Water Compacts
- ◆ Flood-Warning Applications
 - ◆ Information to local landowners
 - ◆ Tie into existing FEMA maps for real time inundation products
- ◆ Recreation
 - ◆ More accurate stream information for boaters/outfitters



East Rosebud Creek near Roscoe, MT

Methods

- ◆ Topography & Bathymetry Survey

- ◆ Aerial Topography via Drone
- ◆ Survey Channel Topography

- LiDAR on RTK capable drone
- Drone flies at ~330 ft & 22 mph
- 90-min flight time & 500-acres max
- Survey ground control points
- 3 points minimum

- ◆ Process Terrain Data

- ◆ Georeference and create DTM

- ◆ Build Working 2D Model

- ◆ HEC-RAS 6.4.1

- ◆ Calibrate Channel Roughness

- ◆ Use in-stream discharge measurements

- ◆ Optimize overbank roughness and discharge

- ◆ Same method as channel with discharge as an unknown variable



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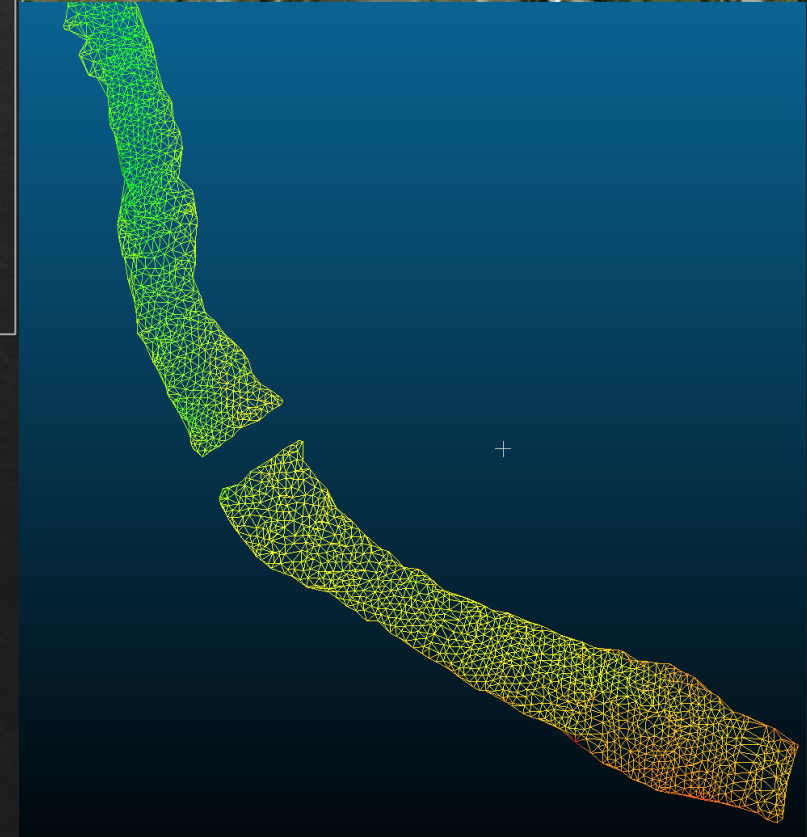
- GNSS Survey of Channel Topography

- Cross Section Method

- Taken every 1-2 stream widths

- 3D Mesh Method

- Density of $\sim 0.5\text{pt}/\text{m}^2$ (variable)



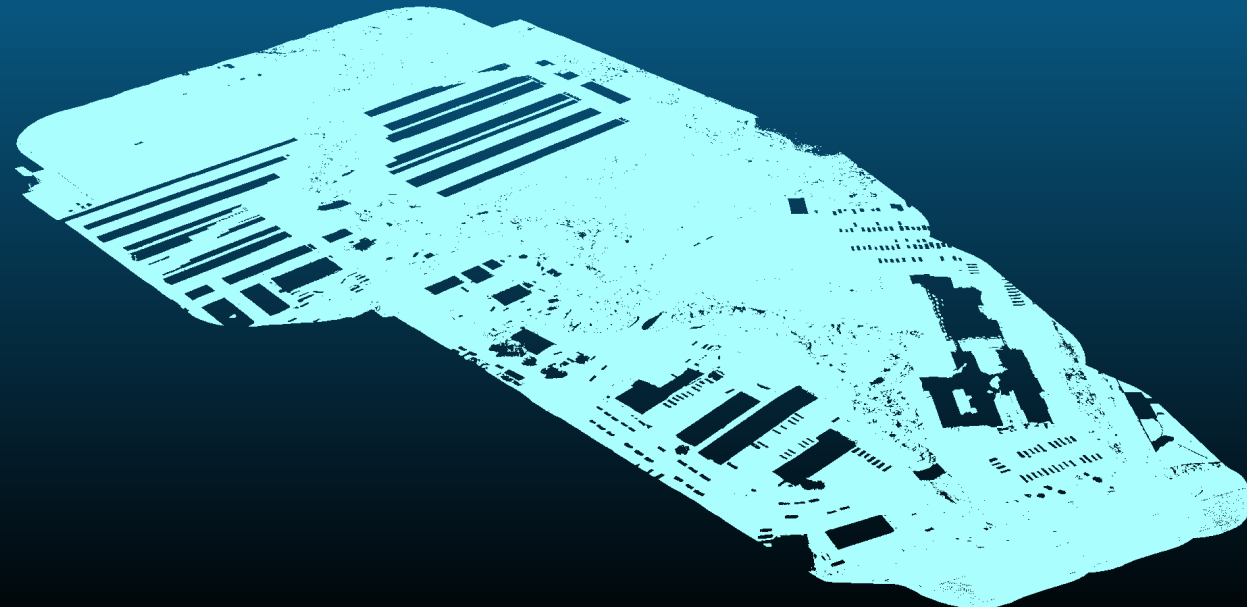
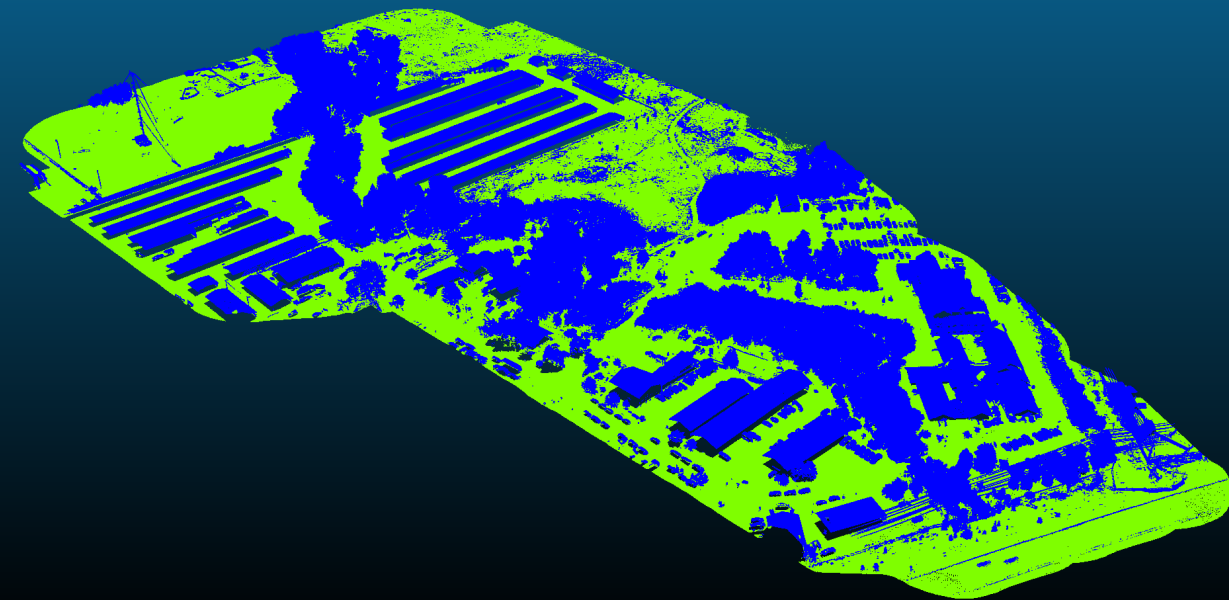


CloudCompare
3D point cloud and mesh
processing

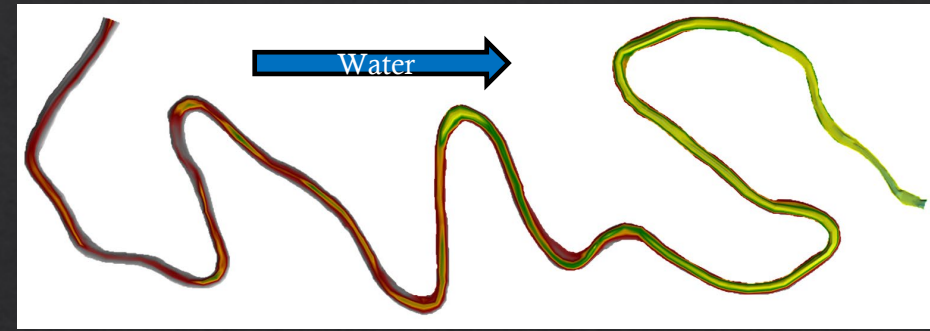
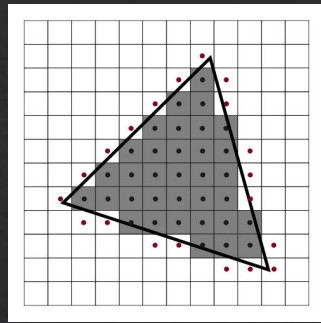
Methods

- ◇ Topography & Bathymetry Survey
 - ◇ Aerial Topography via Drone
 - ◇ Survey Channel Topography
- ◇ Process Terrain Data
 - ◇ Georeference and create DTM

- Classify ground points
- Georeference with minimum of 3 GCP's
- Rasterize point clouds
- Mosaic DTM's



Methods



- ◆ Topography & Bathymetry Survey
 - ◆ Aerial Topography via Drone
 - ◆ Survey Channel Topography

- Classify ground points
- Georeference with minimum of 3 GCP's
- Rasterize point clouds (0.2m)
- Mosaic DTM's

◆ Process Terrain Data

- ◆ Georeference and create DTM

◆ Build Working 2D Model

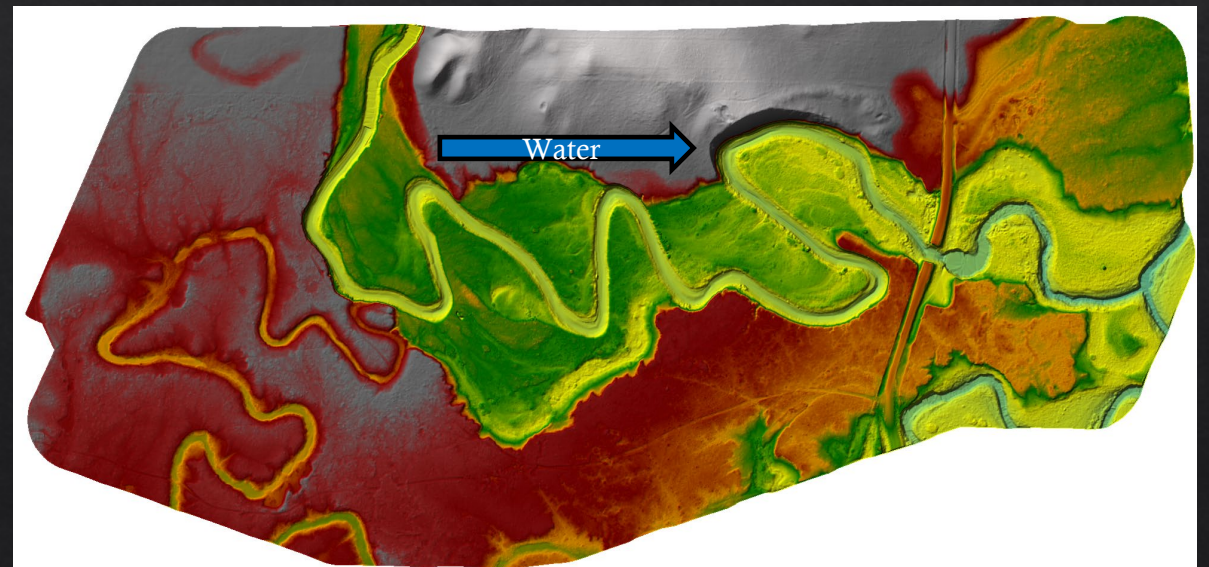
- ◆ HEC-RAS 6.4.1

◆ Calibrate Channel Roughness

- ◆ Use in-stream discharge measurements

◆ Optimize overbank roughness and discharge

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Sage Creek near Box Elder, MT

Methods

- ◆ Topography & Bathymetry Survey
 - ◆ Aerial Topography via Drone
 - ◆ Survey Channel Topography

$$Q = VA = \left(\frac{1.00}{n} \right) AR^{\frac{2}{3}} \sqrt{S}$$

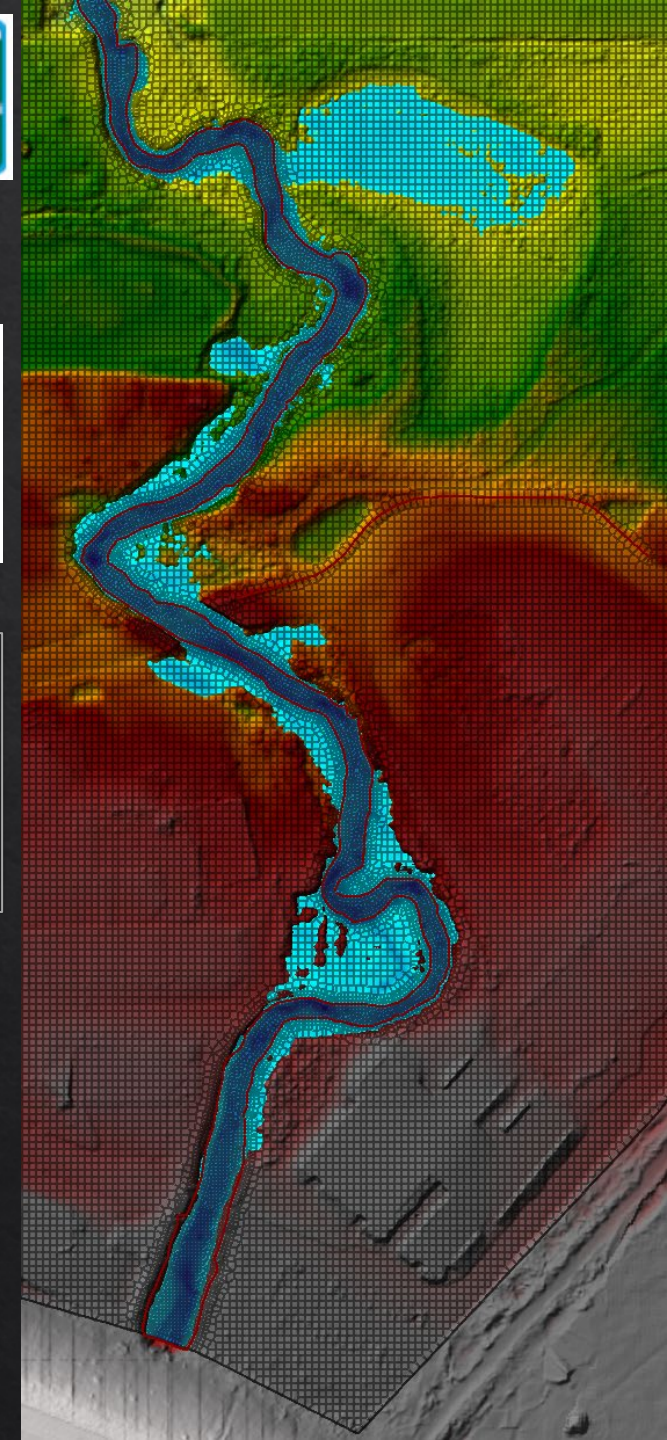
- ◆ Process Terrain Data
 - ◆ Georeference and create DTM

- ◆ Build Working 2D Model
 - ◆ HEC-RAS 6.4.1

- Construct 2D Unsteady Flow Model
- Insert structures as needed
- Use best guess for manning's n values
- Test initial model

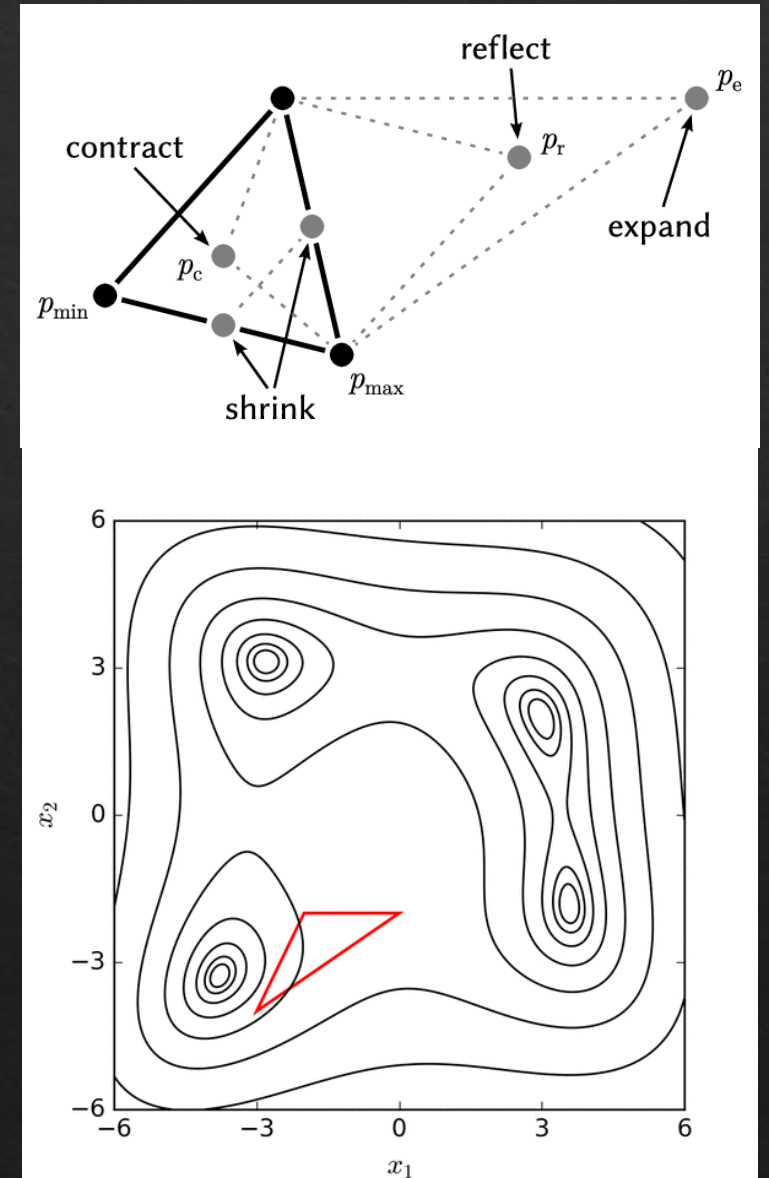
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AutoRAS (taking alternate name suggestions)

- ◇ Python based HECRAS controller/calibrator
- ◇ Uses a Nelder–Mead optimization algorithm
 - ◇ Minimizes the RMSE of observation points
 - ◇ Will solve for multiple unknown parameters
 - ◇ Enter bounds & best guess so it won't “get stuck”
- ◇ Current Capabilities:
 - ◇ Calibrates channel n-values (known Q)
 - ◇ Solves for discharge & overbank n-values (known HWM's)
 - ◇ Generates rating curve for StAGE gages
 - ◇ Exports inundation area shapefiles
 - ◇ Runs model with current reporting Q

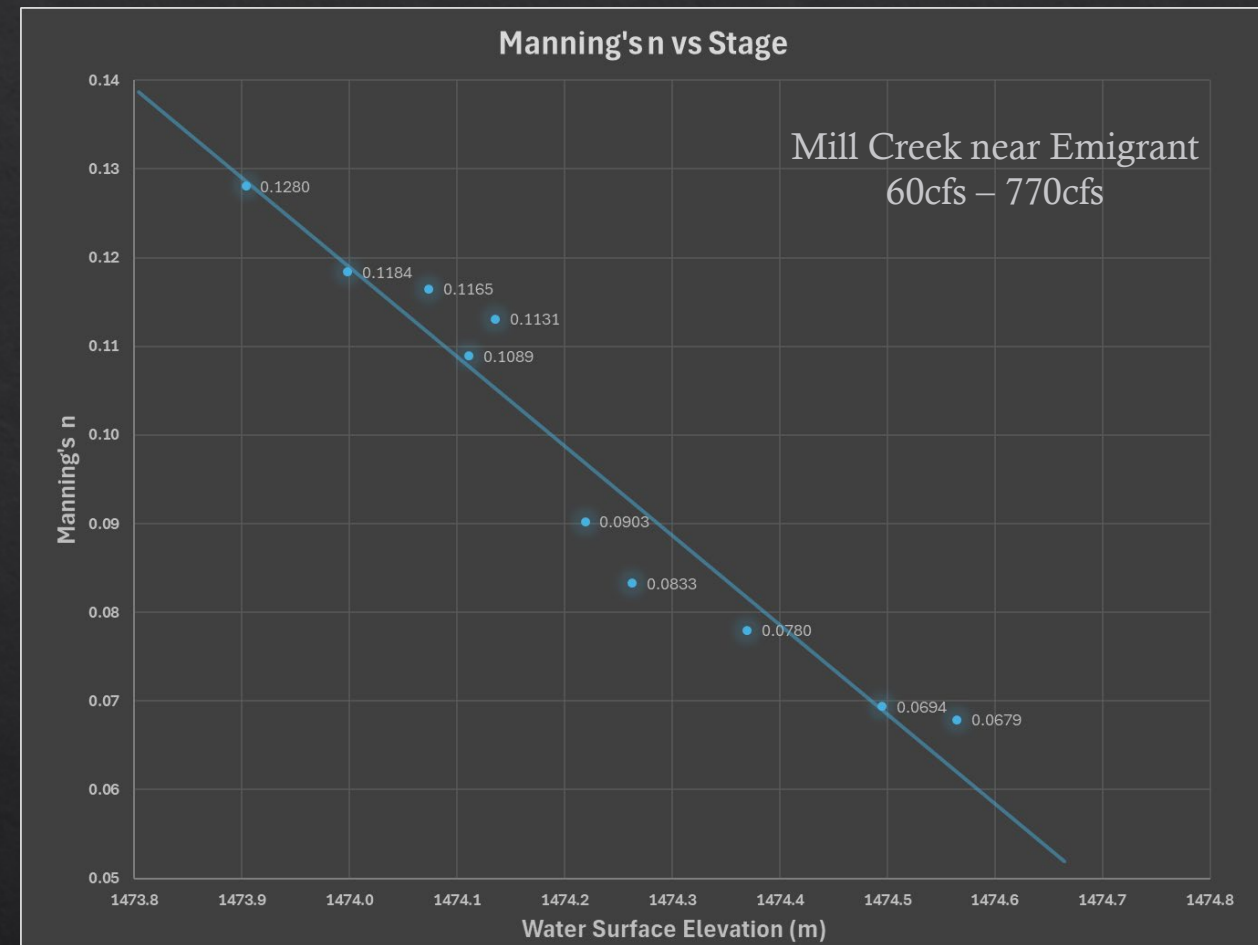


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 - ◇ Georeference and create DTM
- ◇ Build Working 2D Model
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◇ Calibrate Channel Roughness

- ◇ Use in-stream discharge measurements
- ◇ Optimize overbank roughness and discharge
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- Change channel n-values while keeping discharge constant
- RMSE is observed vs modeled stream gage value
- Can calibrate multiple regions and structures

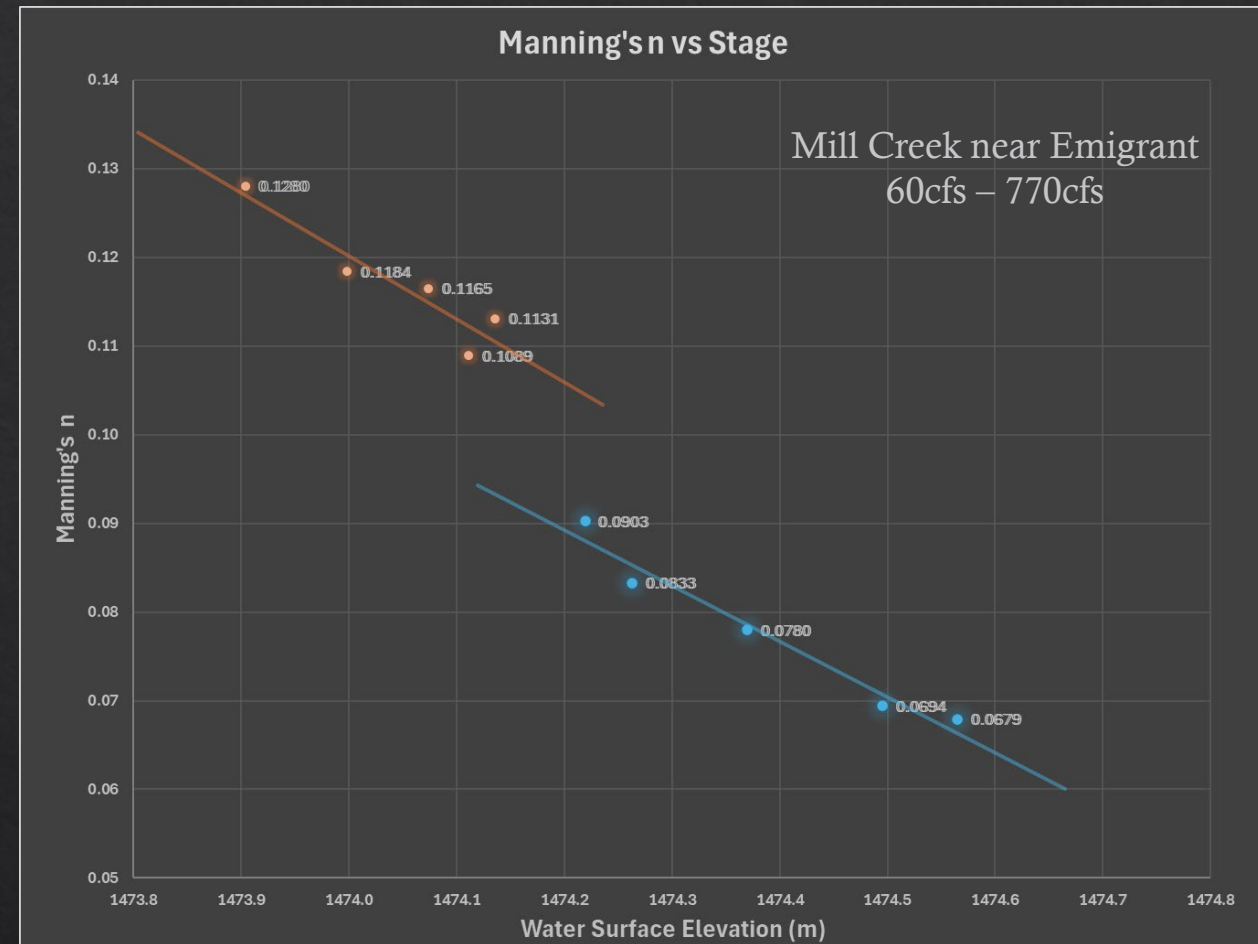
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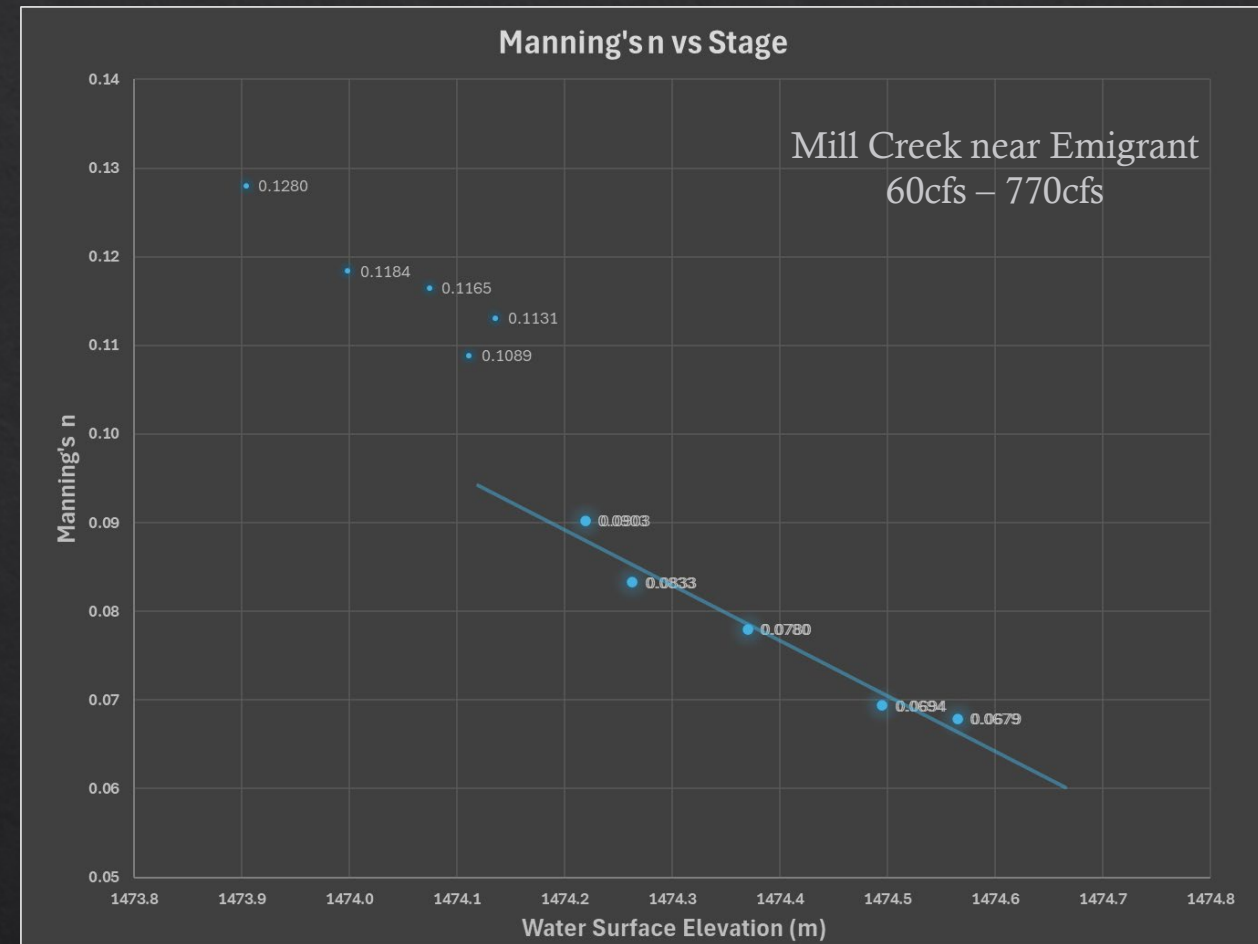
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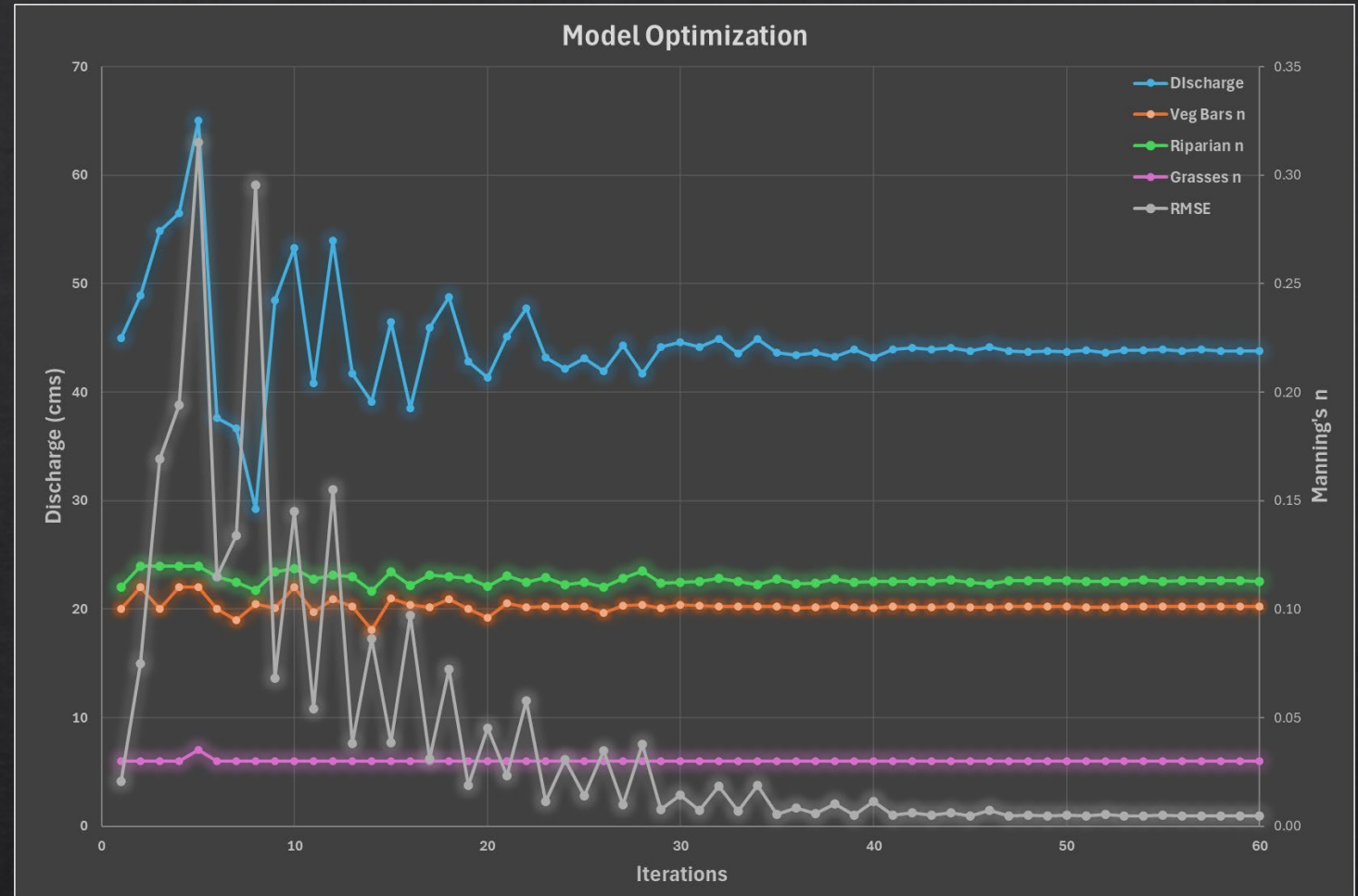
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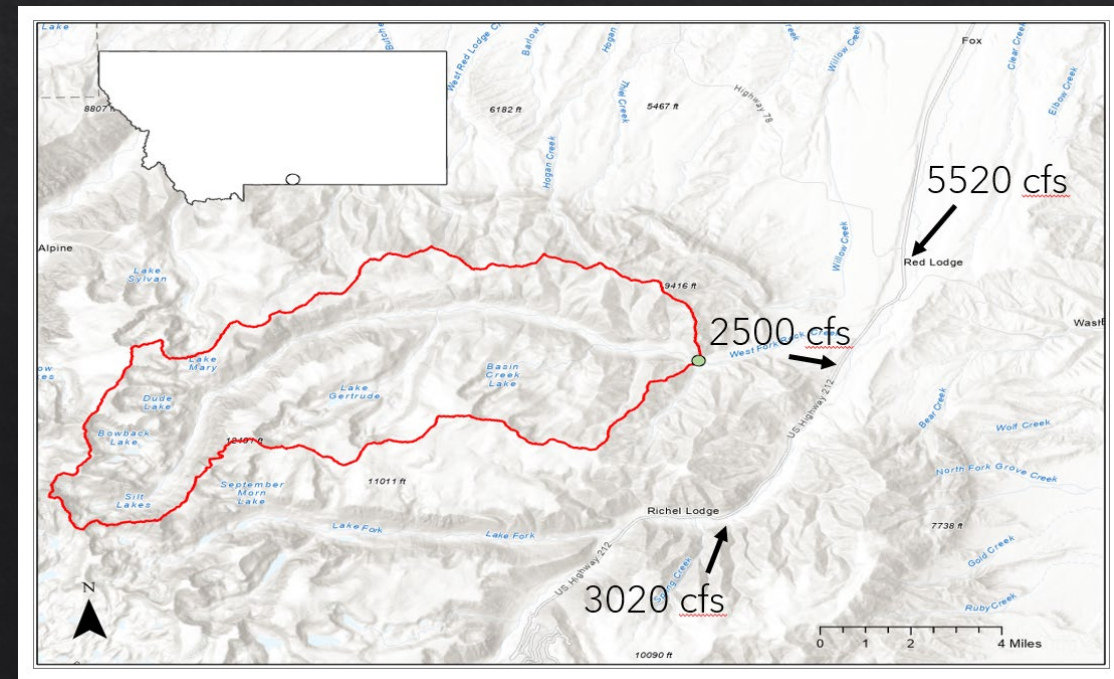
-Alter Q and overbank n-values while keeping channel n-value constant.

-More land classifications, the more iterations required to solve

Recap

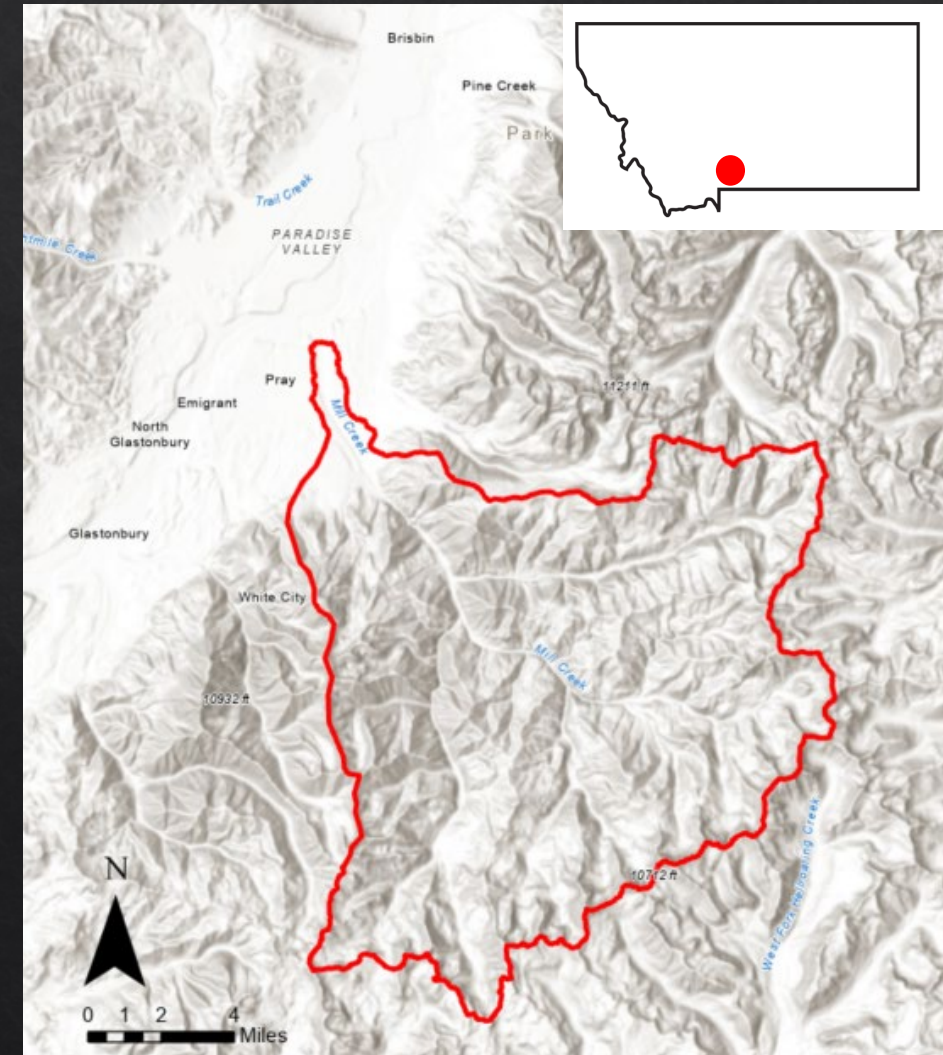
2023 West Fork Rock Cr near Red Lodge case study (Todd Blythe)

- ◆ Determined necessity of LiDAR derived terrain
- ◆ Indirect discharge of June 2022 event comparable to USGS determined values (± 200 cfs or 8%)
- ◆ Time-efficient and flexible



Mill Creek near Emigrant, MT

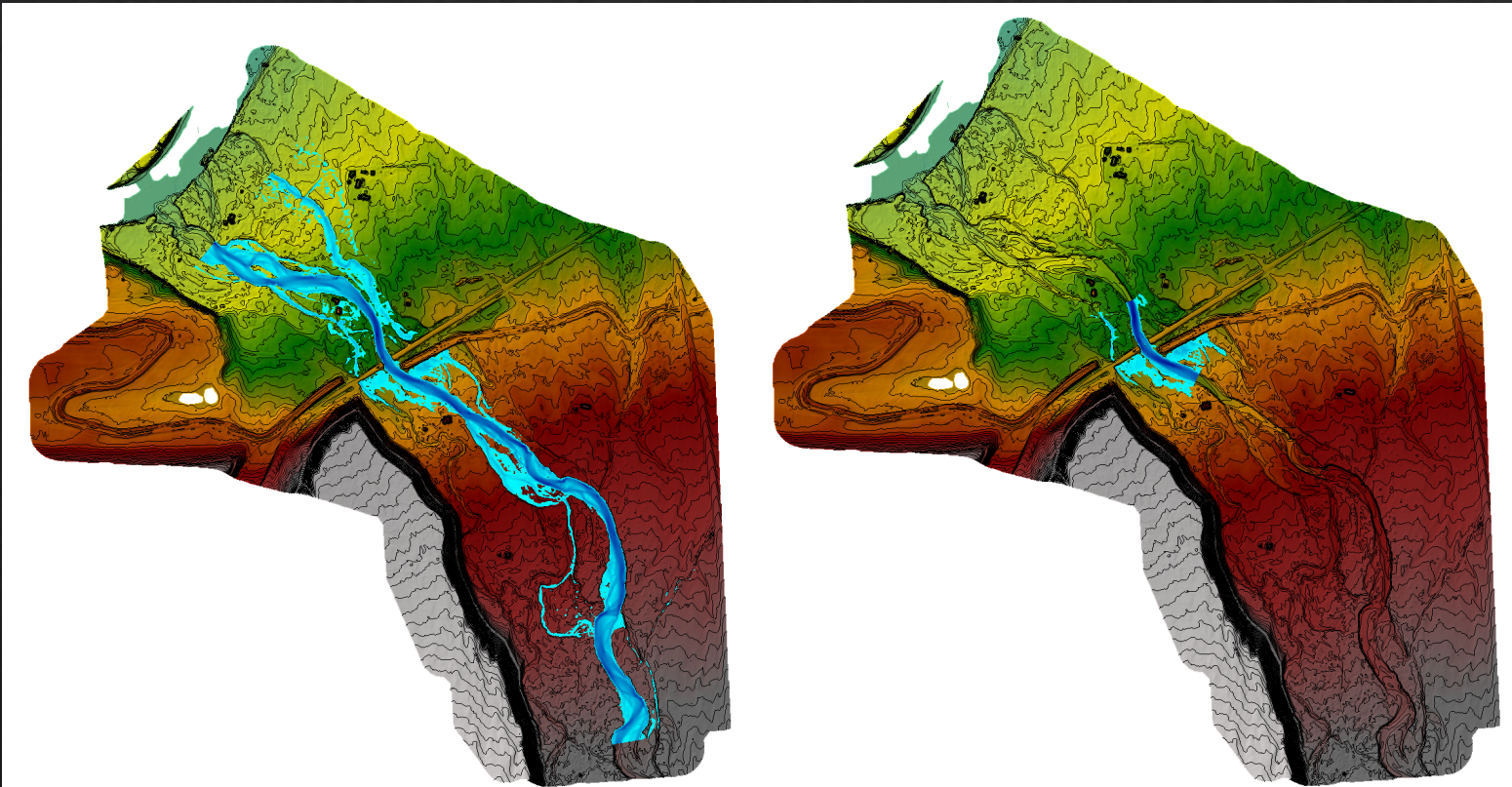
- ◇ 162 sq mi watershed
- ◇ Steep gradient (1.2% grade near Yellowstone confluence)
- ◇ Two surveyed high-water marks from June 2022 event
- ◇ Gage reach runs dry late summer



Model Size Comparison

Reach Length: 1550m

Reach Length: 220m



Channel Calibration using 770cfs ADCP measurement

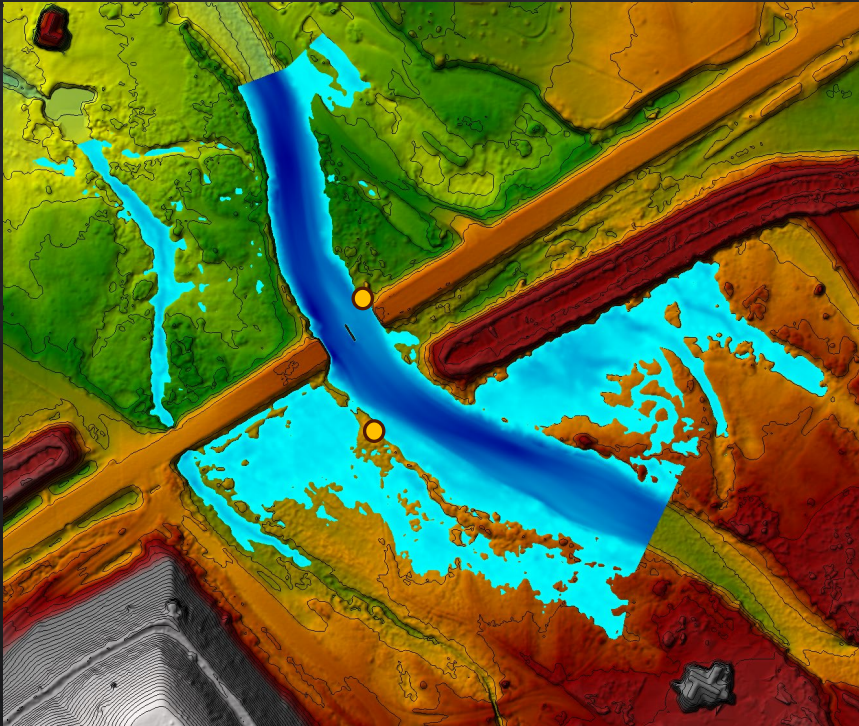
	Large LiDAR	Small LiDAR	% error
Manning's n	0.0672	0.0698	3.84

Indirect Calibration using 2-HWM

	Large LiDAR	Small LiDAR	% error
Q (m ³ /s)	43.81	42.99	1.88
Grasses n	0.03	0.03	0
Dense Riparian n	0.1133	0.0943	16.84
Veg Bars n	0.101	-	-
RMSE	0.0045	0.0116	

Bathymetry Method Comparison

- ◇ Bare-Earth LiDAR (control) – none
- ◇ Mesh Method (manual point cloud) – 2200pts
- ◇ Cross Sections (linear interpolation) – 300pts



Channel Calibration using 770cfs ADCP measurement			
	LiDAR	Mesh	X-Sections
Manning's n	0.0698	0.0654	0.0685
% error		6.33	1.90

Indirect Calibration using 2-HWM			
	LiDAR	Mesh	X-Sections
Q (m ³ /s)	42.99	44.15	43.80
% error		2.71	1.89
Grasses n	0.03	0.03	0.03
Dense Riparian n	0.0943	0.0995	0.0868
RMSE	0.0116	0.0188	0.0014

Best Methods

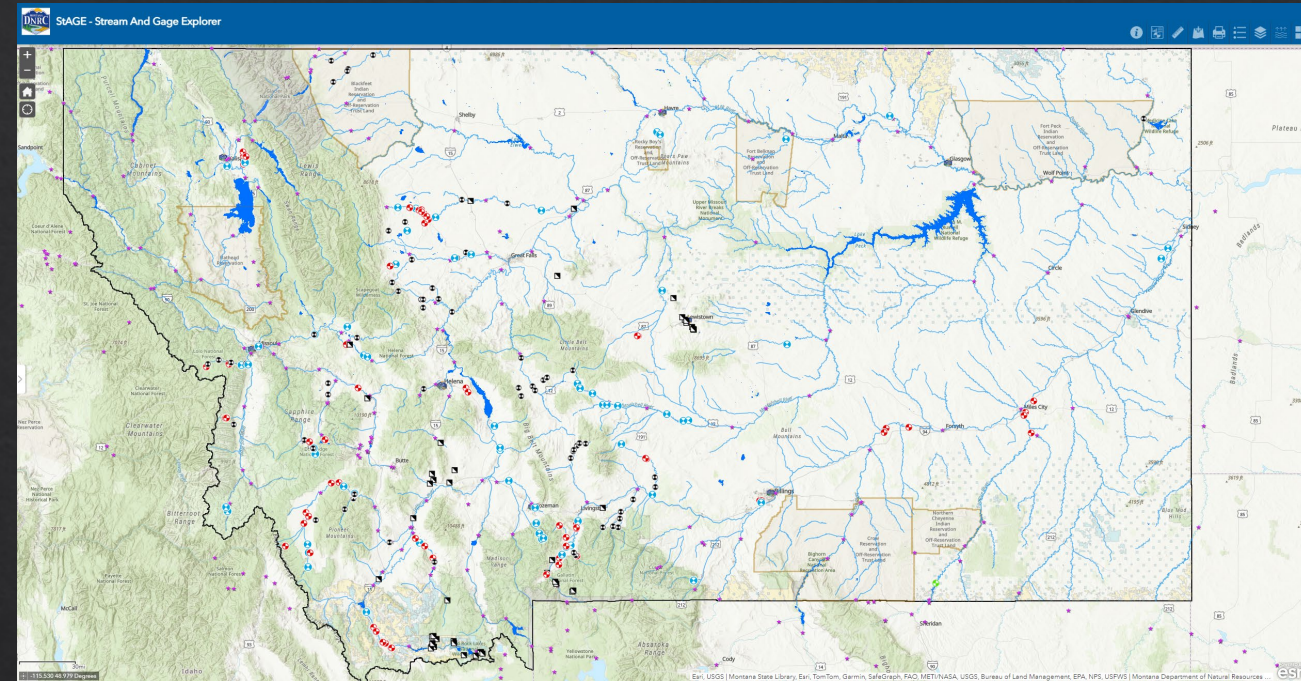
- ◇ Manning's n linear interpolation when data is available
 - ◇ Highly variable with depth
- ◇ Larger models perform marginally better (listen to the morphology)
 - ◇ Less sensitive to boundary conditions
- ◇ Use cross sections
 - ◇ Far more efficient
 - ◇ Sometimes smoother is better
- ◇ There's a script for that
 - ◇ Continue to leverage automation to increase efficiency



Blackfoot River near Clearwater, MT

What's Next...

- ◇ New drones!? 😊 😞
- ◇ Tie into FEMA Floodplains
 - ◇ Advanced flood warning system pilot (Augusta & Roscoe)
- ◇ Live inundation mapper
- ◇ AutoRAS:
 - ◇ Options for alternative optimization functions
 - ◇ GUI
 - ◇ Integration with MIHMS & StAGE
 - ◇ MODEL EVERYTHING!
 - ◇ 16 surveys
 - ◇ 8 completed models
- ◇ Technical methods report (Q1 2025)

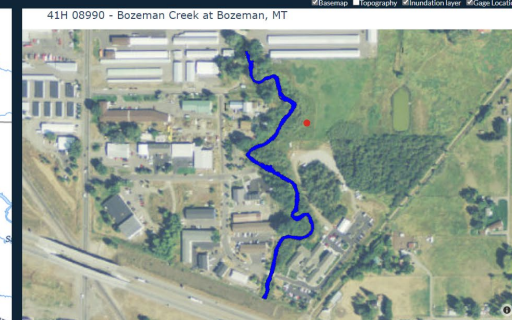
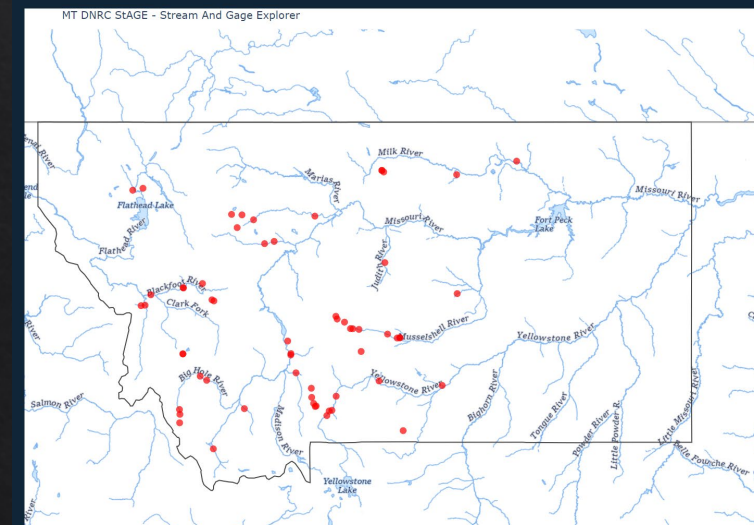


MIHM StAGE Viewer

STAGE - Stream and Gage Explorer

Bozeman Creek at Bozeman, MT

● Current ● 24hr_Min ● 24hr_Max



Notice: Inundation areas may not accurately reflect current stream conditions.

Thank You

co-contributors
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- Matt Norberg
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Now Entertaining Questions...

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Data Section



West Fork Rock Creek near Red Lodge, MT

