Spivey Mill Dam – Incorporating Sediment Analysis with 2-D Hydraulic Modeling to Predict Potential Dam Removal Outcomes

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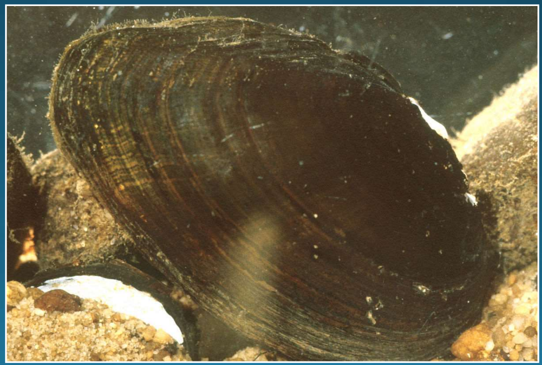
Upper Tennessee River Roundtable

Spivey Mill Dam/Copper Creek

- Biologically significant tributary to the Clinch River
  - 22 federally listed mussels, and critical habitat for Cumberlandian Combshell, Fluted Kidneyshell, Oyster Mussel, Purple Bean, and Rough Rabbitsfoot.
  - 4 federally listed fish species, with critical habitat designation for Yellowfin Madtom
- Copper Creek is a beautiful river in the Ridge and Valley physiographic region of Virginia. The river is 60 miles in length and drains 133 sq miles of watershed.
- The potential removal scenarios for Spivey Mill Dam might reconnect over 50 miles of river and allow unobstructed passage of aquatic organisms and bed material. However, investigation is needed to determine any potential long or short term impacts, and to guide designs to protect this important stream system

Fluted Kidneyshell

Cumberlandian Combshell

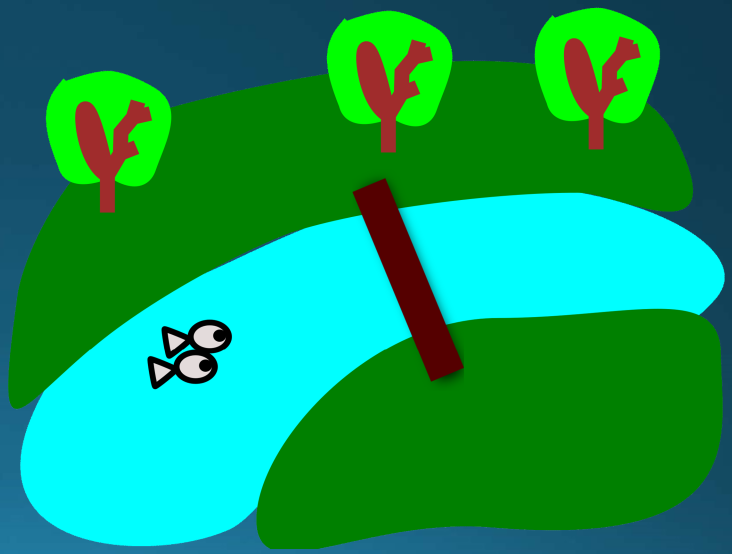


Purple Bean

Yellowfin Madtom

Study Goals

- Evaluate and predict sediment transport dynamics under different scenarios of dam removal.
- Determine volumes, residence times, deposition, distance, and concentrations that might be expected under different durations, storms, and at different stages of the project.
- Apply results to inform potential design options.

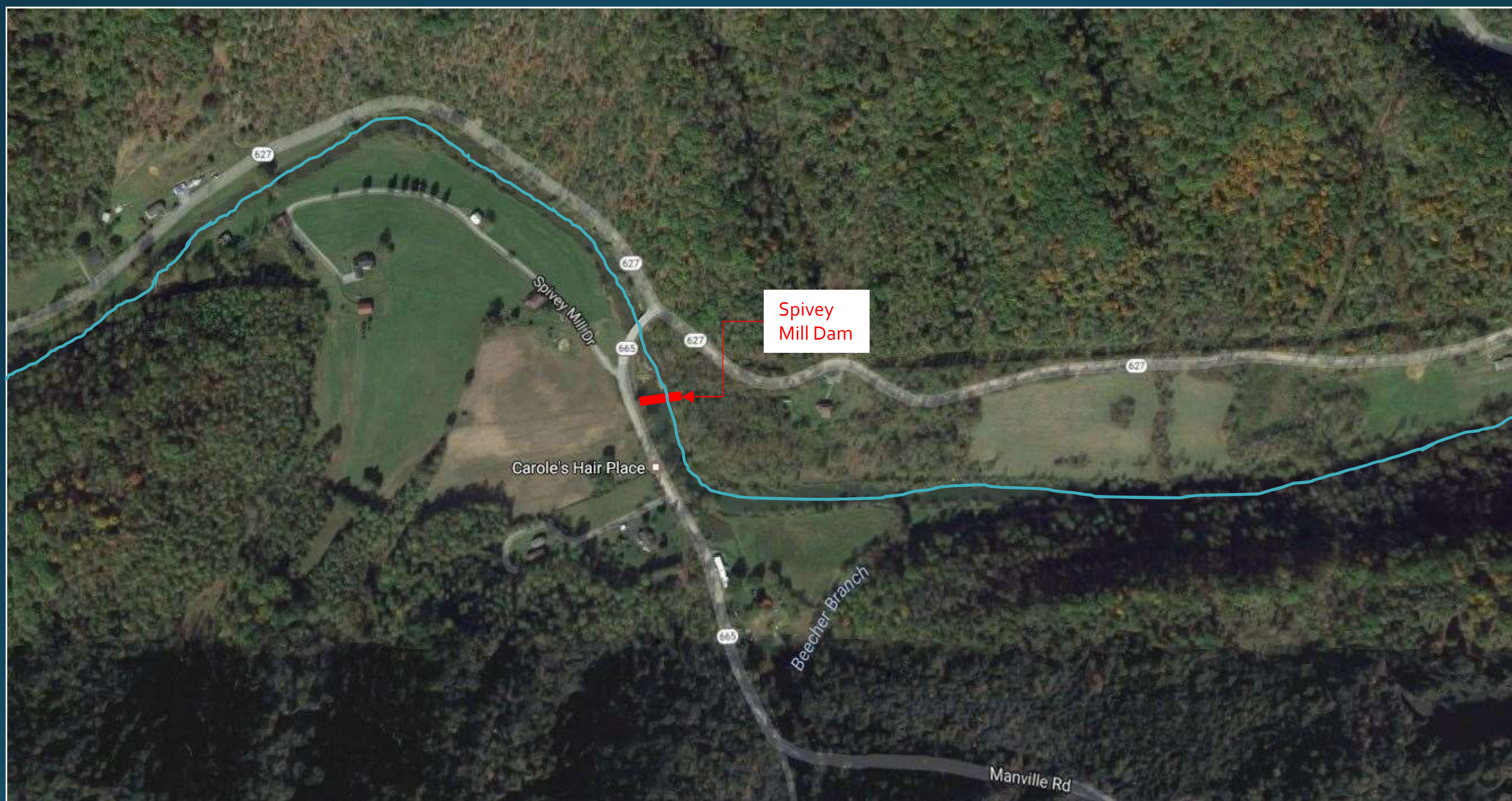


Project Approach

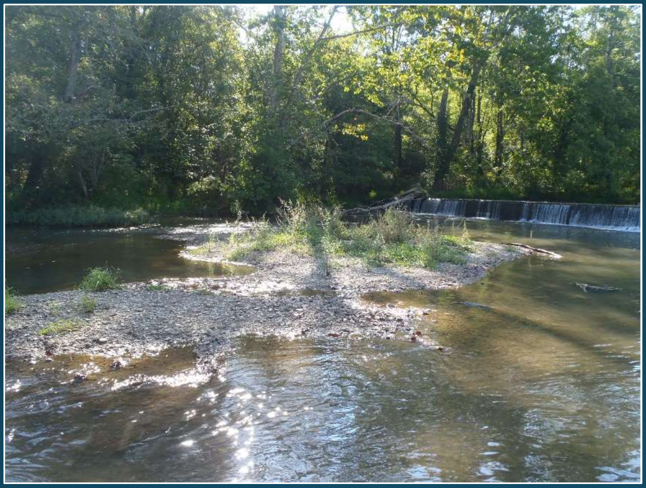
- Survey cross-sections and collect sediment samples from multiple locations in the stream reach
- Conduct sediment transport analysis using HEC-RAS
  - Evaluate multiple time lengths and weather conditions
  - Run simulations with collected sample data as well as uniform substrate inputs
  - Run analysis for both partial and complete dam removal
- Build 2-D model using HEC-RAS to analyze potential stresses acting on the stream after potential dam removal
- Produce detailed report on findings to help answer stakeholder questions about removing Spivey Mill Dam.

KRIS BASS ENGINEERING

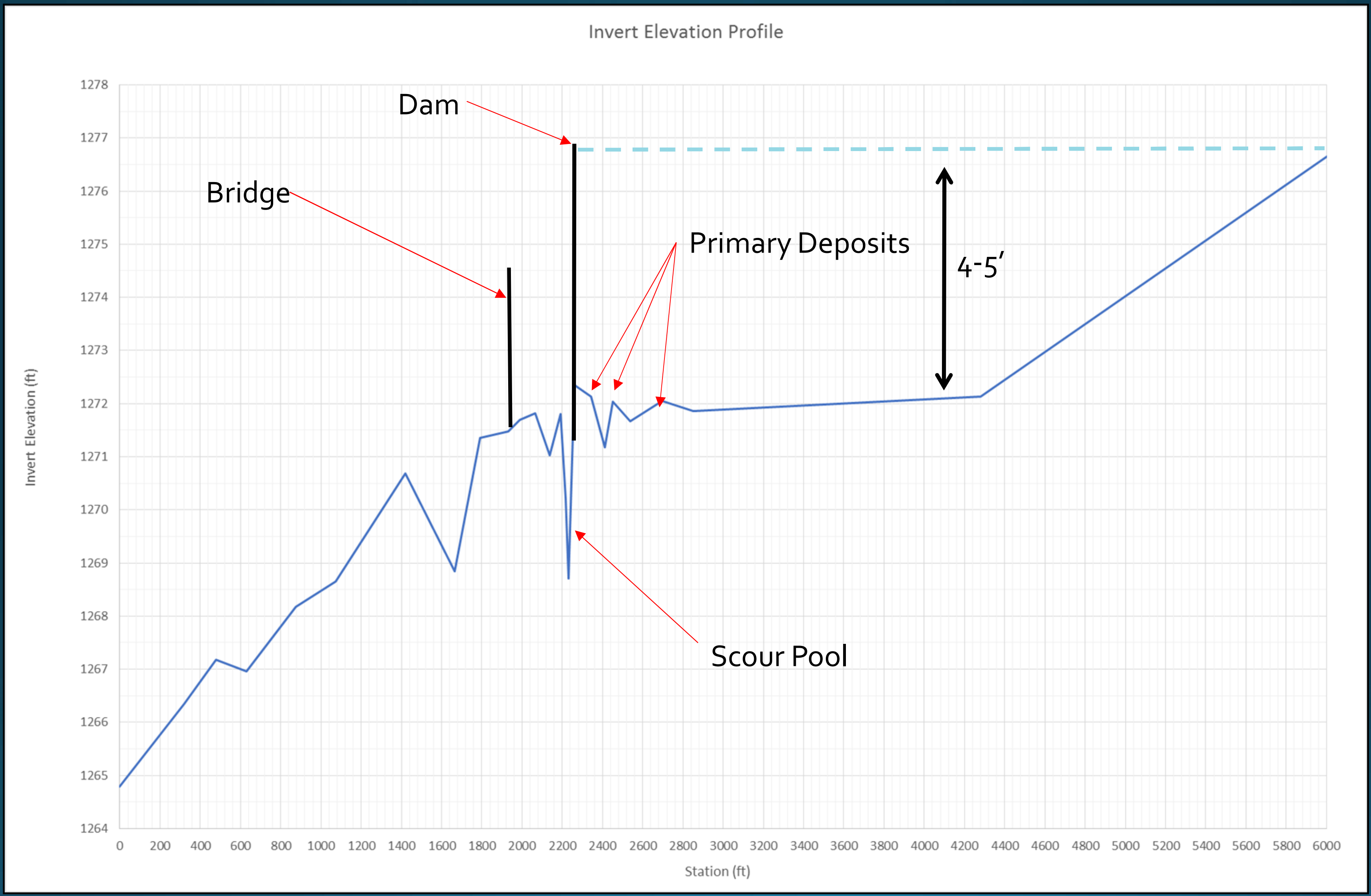
Spivey Mill Dam Project Area



Spivey Mill Dam Project Area

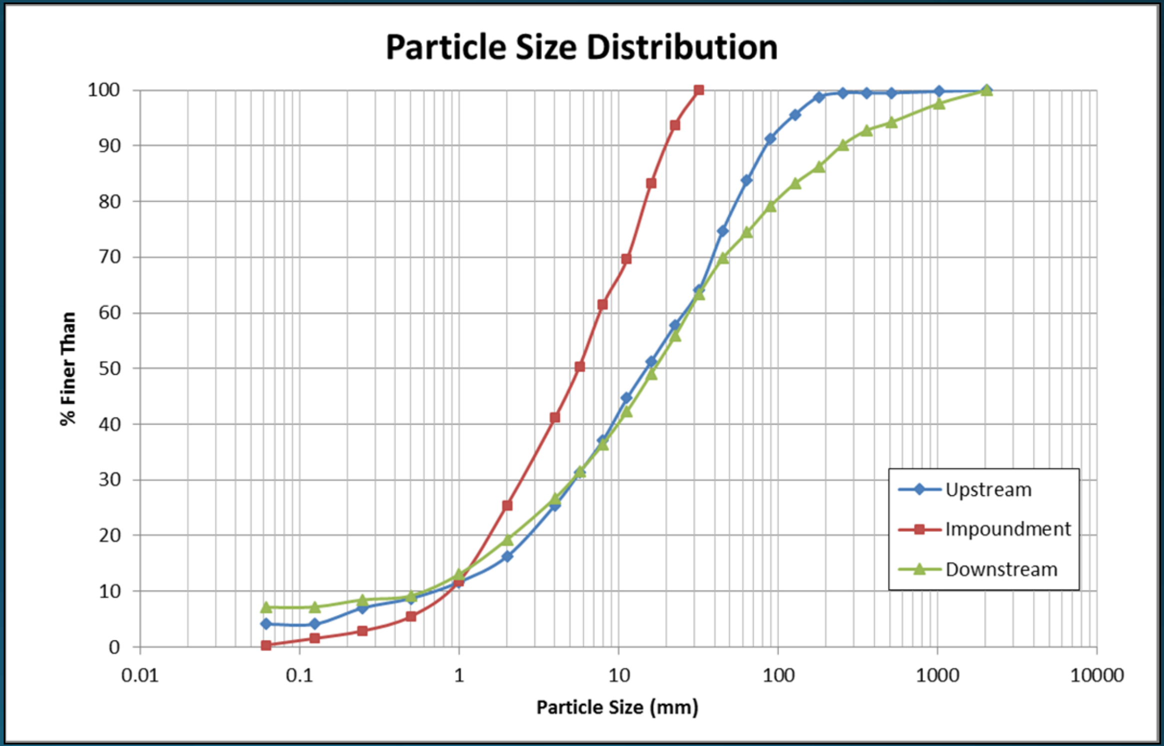






Invert Elevation Profile
Dam
Bridge
Primary Deposits
4-5'
Scour Pool
Invert Elevation (ft)
Station (ft)
1278
1277
1276
1275
1274
1273
1272
1271
1270
1269
1268
1267
1266
1265
1264
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800 4000 4200 4400 4600 4800 5000 5200 5400 5600 5800 6000

Geomorphic Descriptions & Observations

- **Upstream** – mostly riffle run bed morphology dominated by fine gravel material
- **Reservoir area** – mostly mixed gravel with some sand.
- **Downstream** – scour pool immediately below the dam with shallow pools and bedrock seems dominating further downstream. Vegetated bars with fine material do exist primarily where stream has widened.



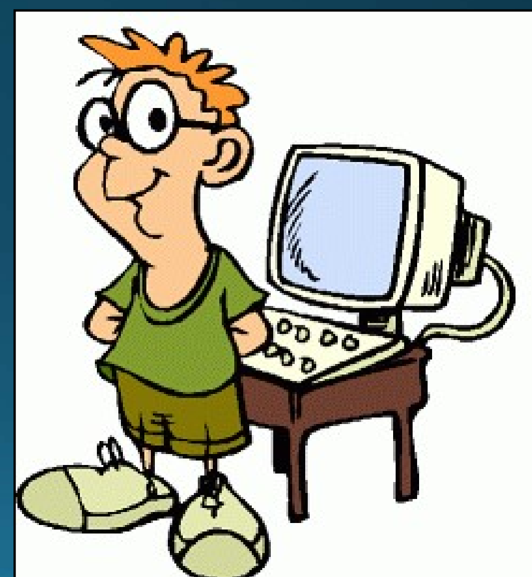
Dam Removal Research

	Length (ft)	Height (ft)	Sediment (tons)	Peak Flows	Notes:
Chiloquin	220	21	49,000-69,000	~2,000 (2yr)	Small changes
Hemlock		26	48,000 – 93,000	2,000 (2yr)	Sediment dredged
Brownsville	115	13	25,000	5,000 (1yr)	Deposition and good ecological recovery
Savage Rapids	295	39	800,000	175,000 (1yr)	Deposition and good ecological recovery
Embrey (Va)	900	22	540,000	> 3,000 (est)	Dredged 50% of sediment (wide river). Partially due to contamination.
Spivey Mill Dam	200	5	500	2,747 (2yr) 5,203 (10yr)	

- Spivey Mill Dam has very little trapped material compared to the amount of water flow. Compared to other dams that have been removed, the flow to sediment ratio is substantial higher at this site.
- Even dams with incredible amounts of trapped material recover biological communities within a few years, despite not always fully recovering geomorphic disturbance in that same timeframe.

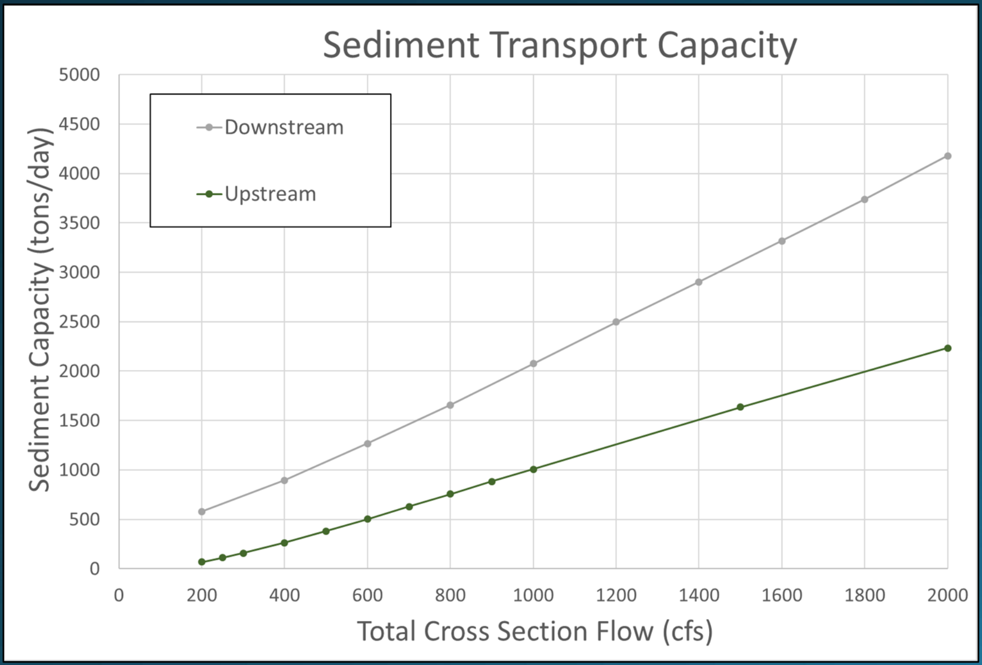
Modeling Approach

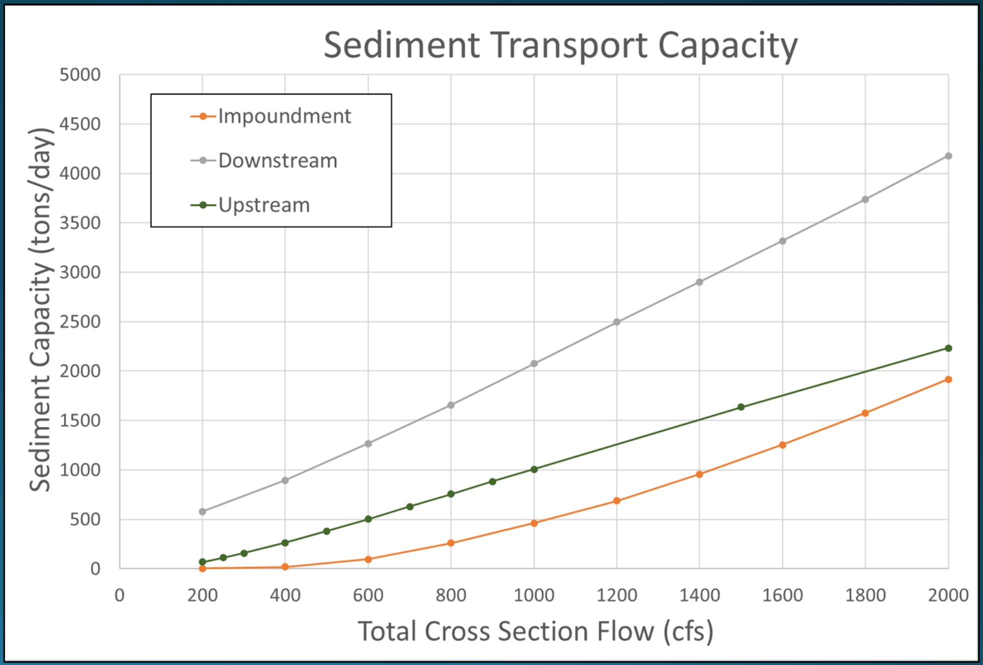
- HEC-RAS is a one dimensional model that uses surveyed cross sections and geomorphic data to preform both hydraulic and sediment transport simulations.
- Modeling of sediment transport in various climate and under removal scenarios.
  - Average flow year
  - Dry flow year
  - Wet flow year
  - Over 10 years of flow records
  - Storm events
  - Existing conditions
  - Dam completely removed
  - Dam partially removed
  - All scenarios analyzed with bed material collected on site.

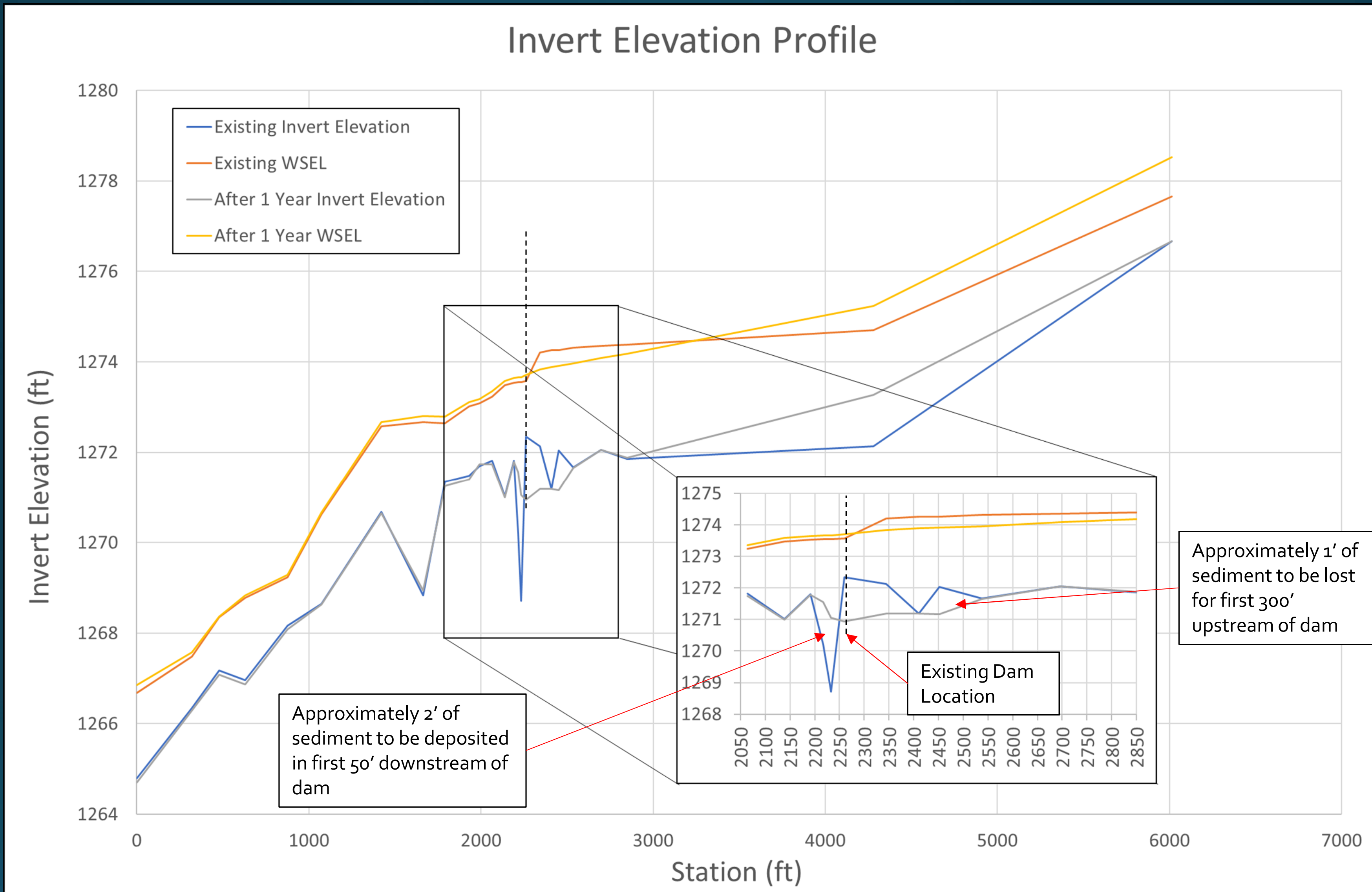


Sediment Transport Capacity

- Upstream Supply->Reservoir Dynamics->Downstream Capacity
- Downstream>Upstream Downstream>Both



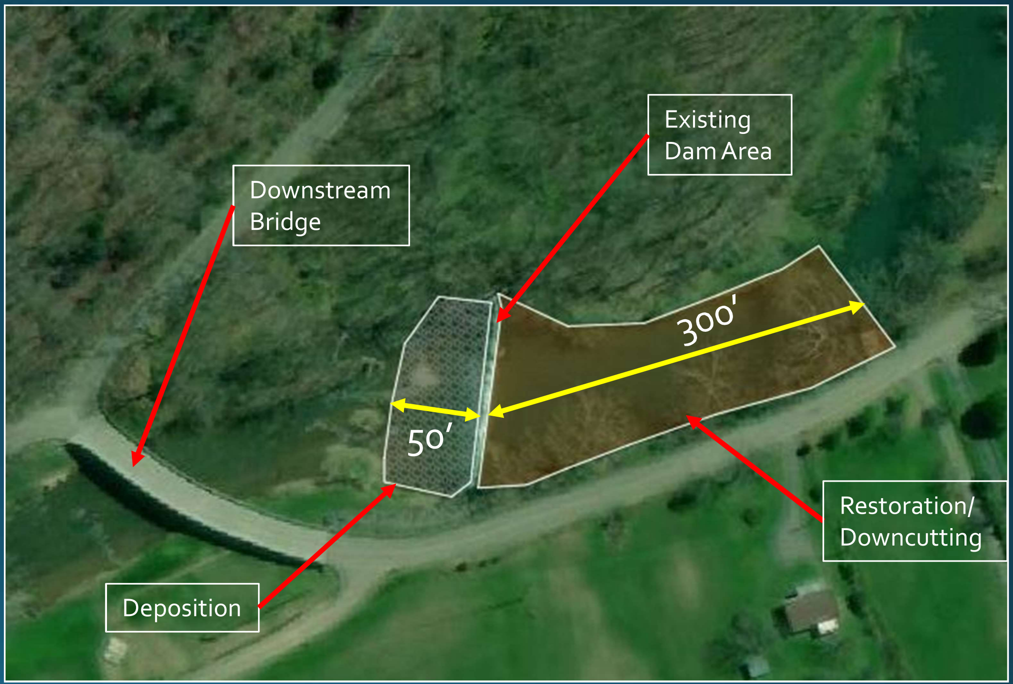




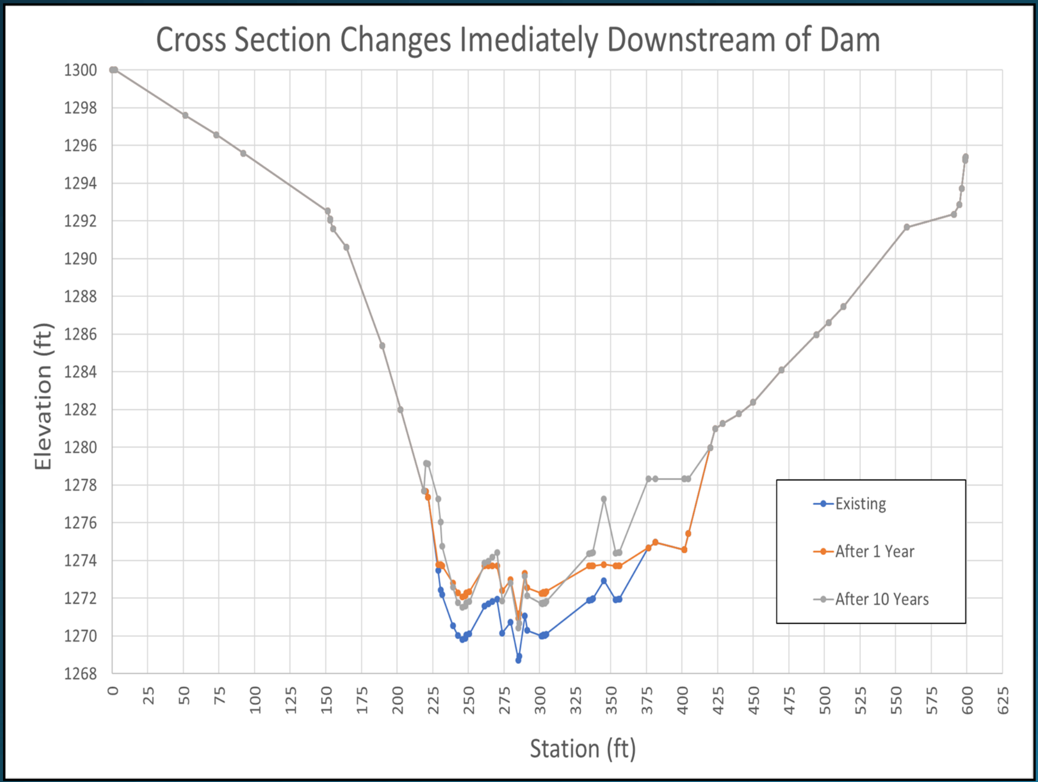
Invert Elevation Profile
Existing Invert Elevation
Existing WSEL
After 1 Year Invert Elevation
After 1 Year WSEL
Invert Elevation (ft)
Station (ft)
1280
1278
1276
1274
1272
1270
1268
1266
1264
0
1000
2000
3000
4000
5000
6000
7000
1275
1274
1273
1272
1271
1270
1269
1268
2050
2100
2150
2200
2250
2300
2350
2400
2450
2500
2550
2600
2650
2700
2750
2800
2850
Approximately 1′ of sediment to be lost for first 300′ upstream of dam
Existing Dam Location
Approximately 2′ of sediment to be deposited in first 50′ downstream of dam

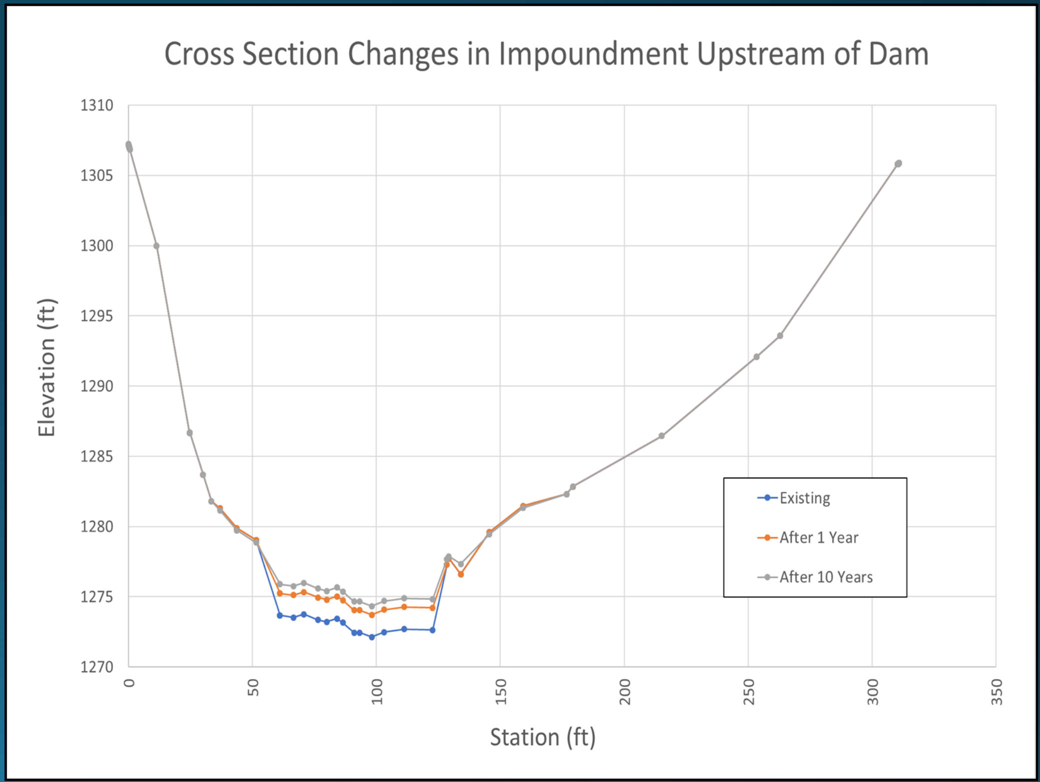
Predicted Stream Impacts

- The greatest changes will occur initially in the scour pool immediately downstream of the dam. This pool will be quickly filled with trapped bed material.
- Upstream of the dam, approximately 300ft of reservoir will exhibit some downcutting and adjustment. This is where the majority of material is deposited. The bed is estimated to lower approximately 1 foot. Over a half mile of reservoir will be restored to natural streambed.
- With adequate flow, both the upstream and downstream reaches could reach a state of equilibrium within a matter of months. (Some simulations indicate this happening in 30-60 days).

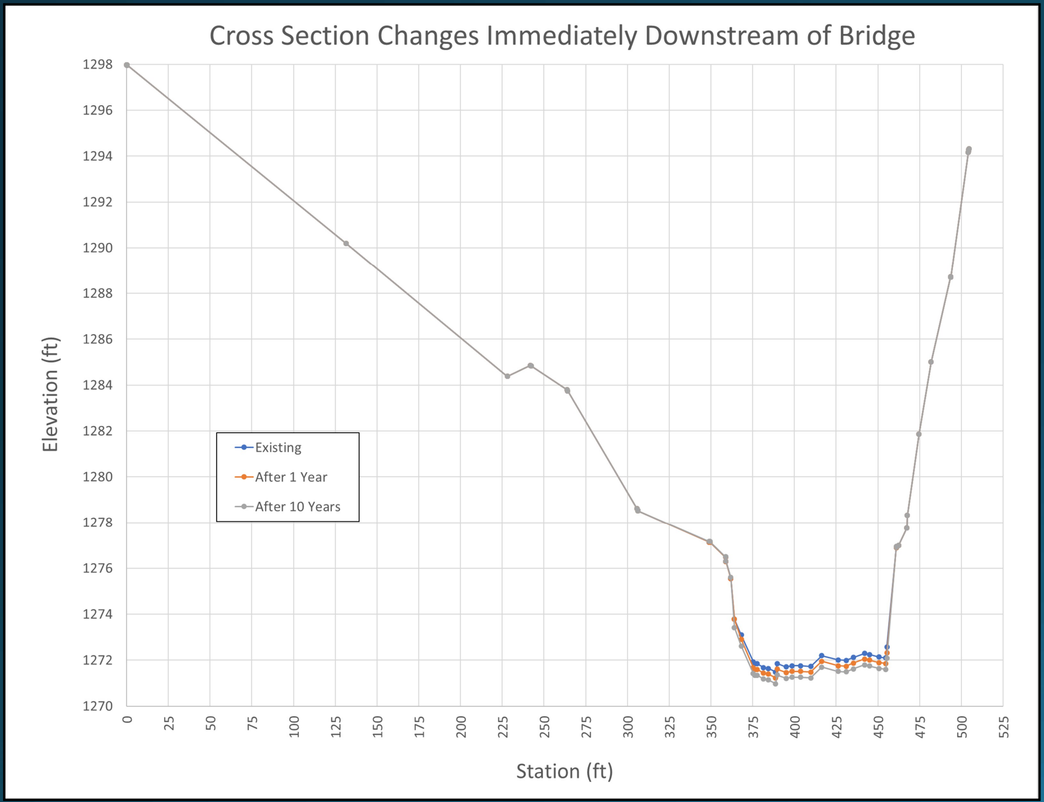


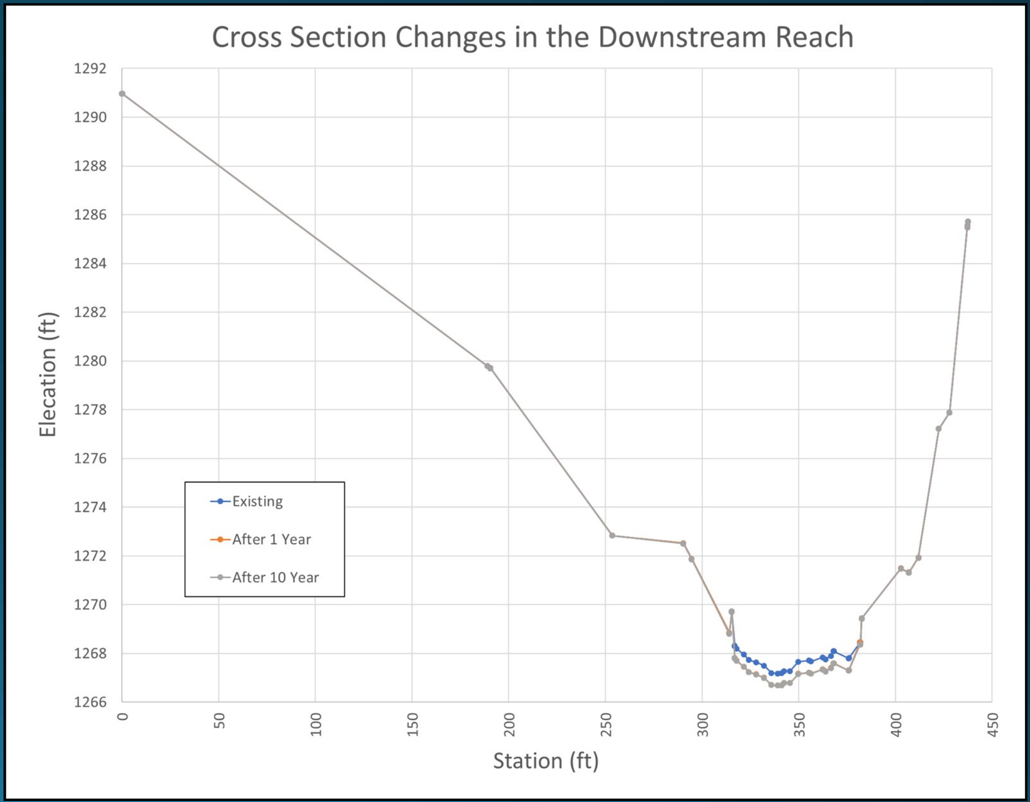
Long-Term Changes in the Dam Area and Impoundment



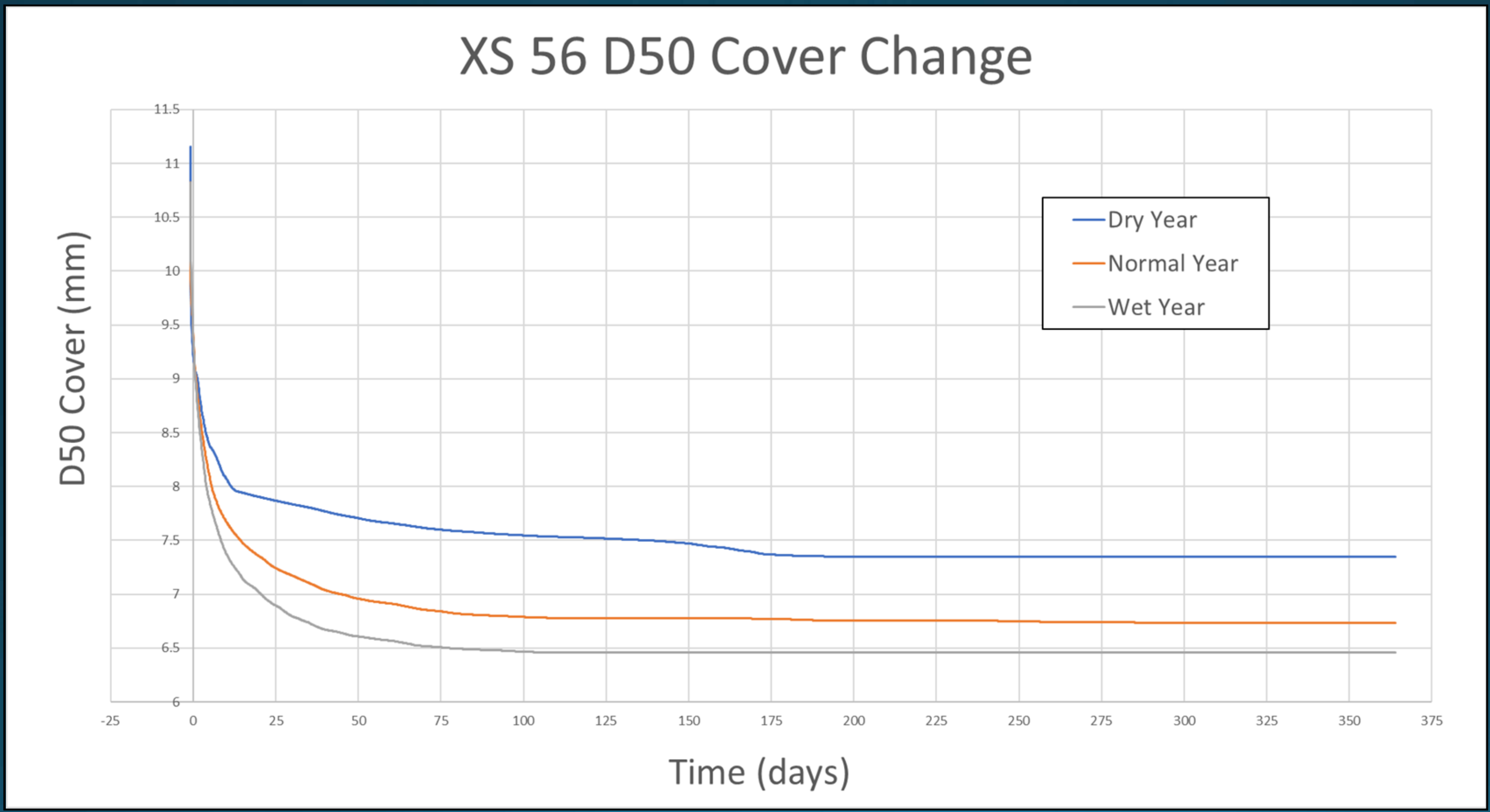


Long-Term Changes Around The Bridge and in the Downstream Reach





D50 Cover Change in the Impoundment

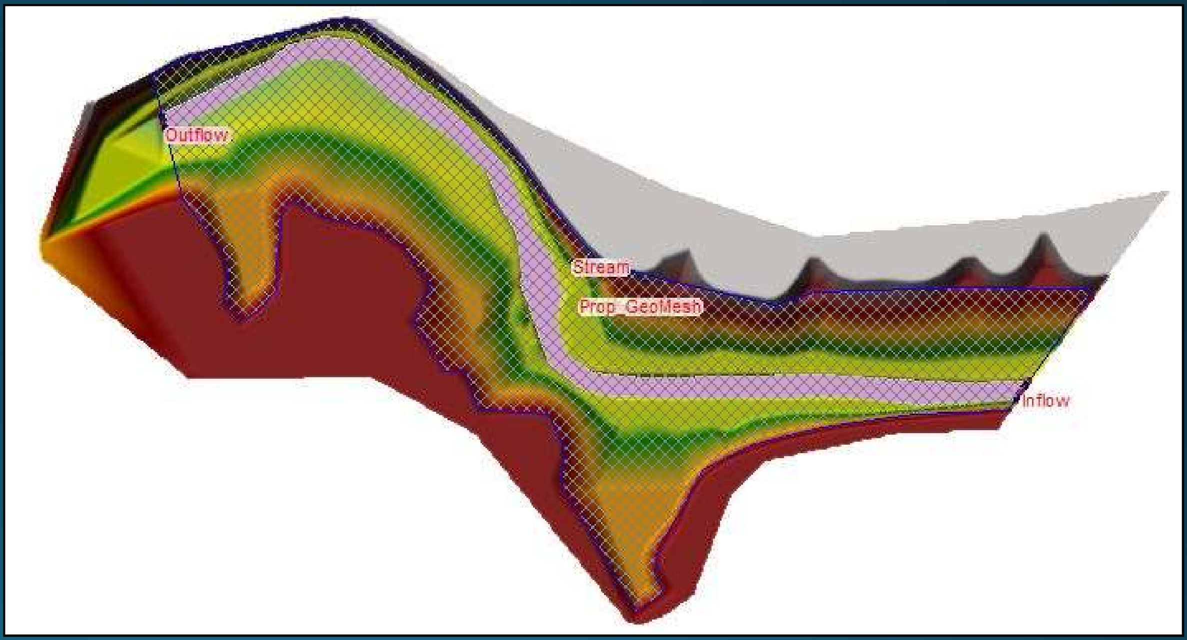


Sediment Analysis Notes

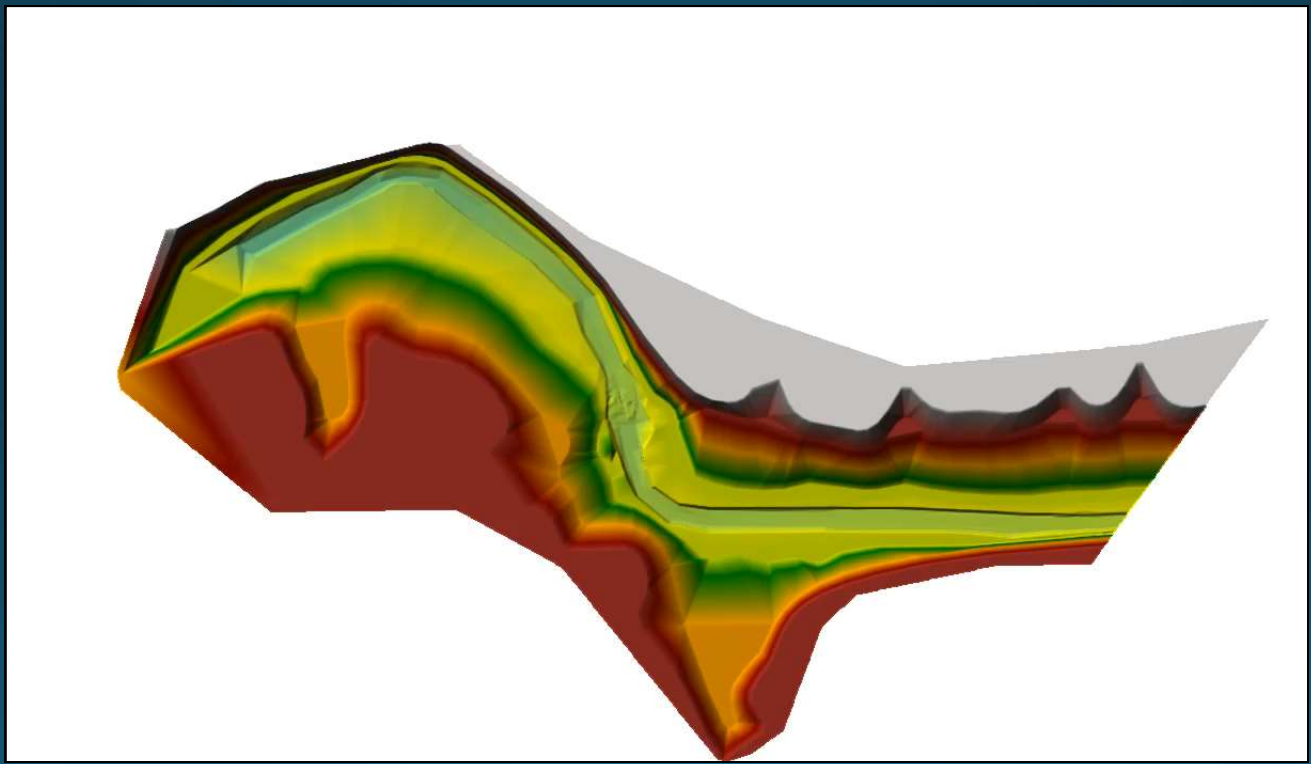
- Sediment transport analysis produces the best results when completely customized to your specific site using surveyed cross sections, sediment samples collected at the site, and gauge data is used to simulate average flows for the reach.
- A lot of questions can be answered thanks to the multiple outputs created by HEC-RAS
- HEC-RAS has the ability to run analysis on many different sediment profiles and many different time intervals relatively quickly.

2-D Modeling

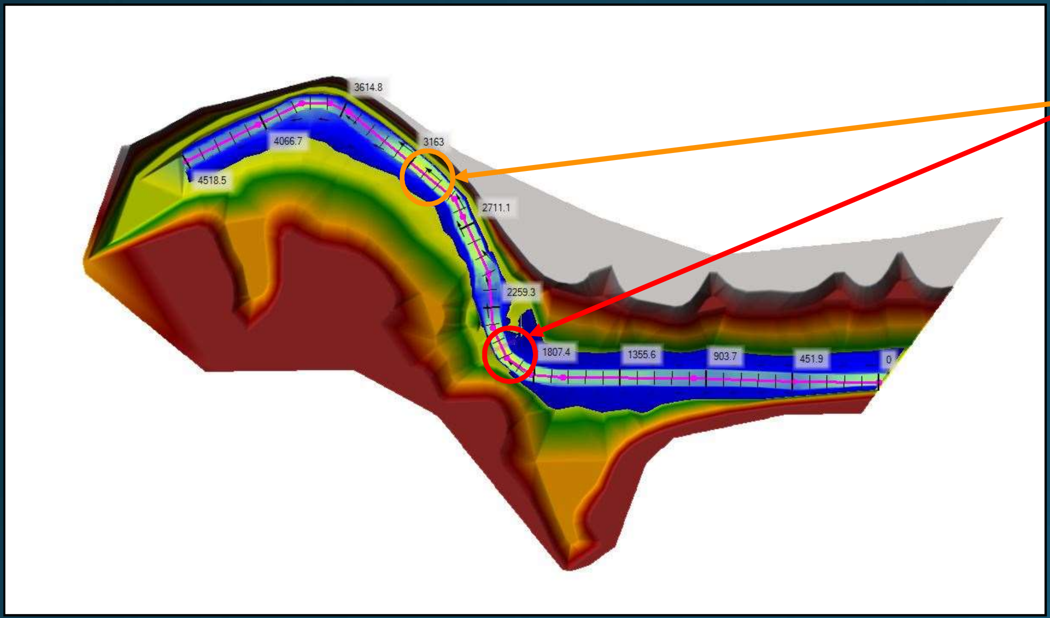
- Concern over a tight bend just upstream of the dam led to additional modeling.
- 2-D modeling is the only way to investigate bend hydraulics post-removal.
- Same data used for the sediment transport analysis.
- Area around dam corrected to match projected changes from a 1 year sediment transport simulation.



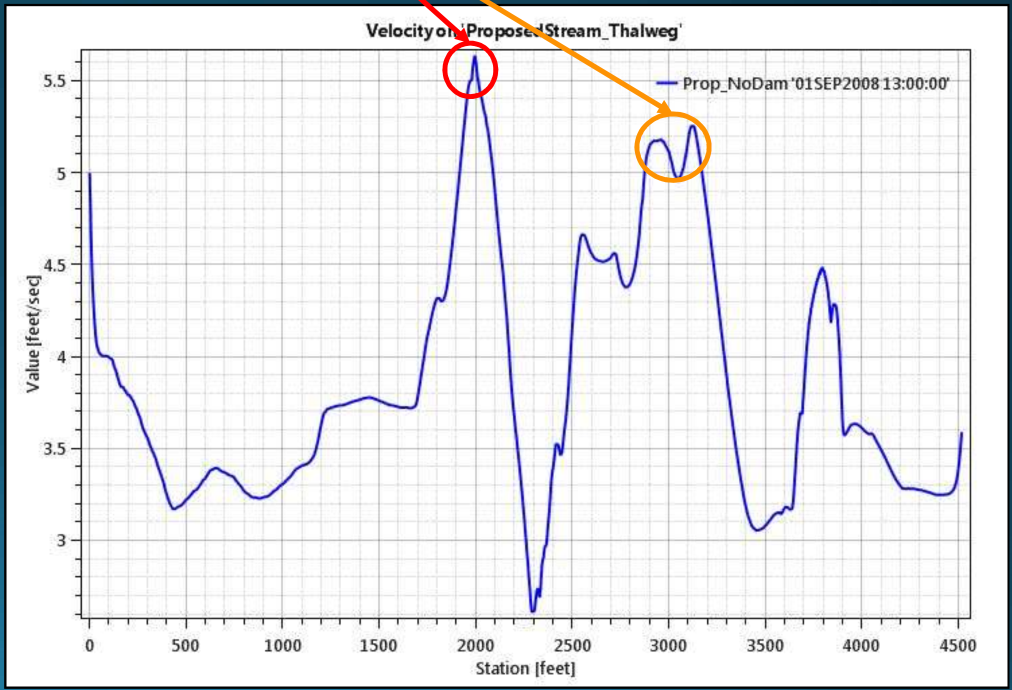
2-D Storm Flow Output



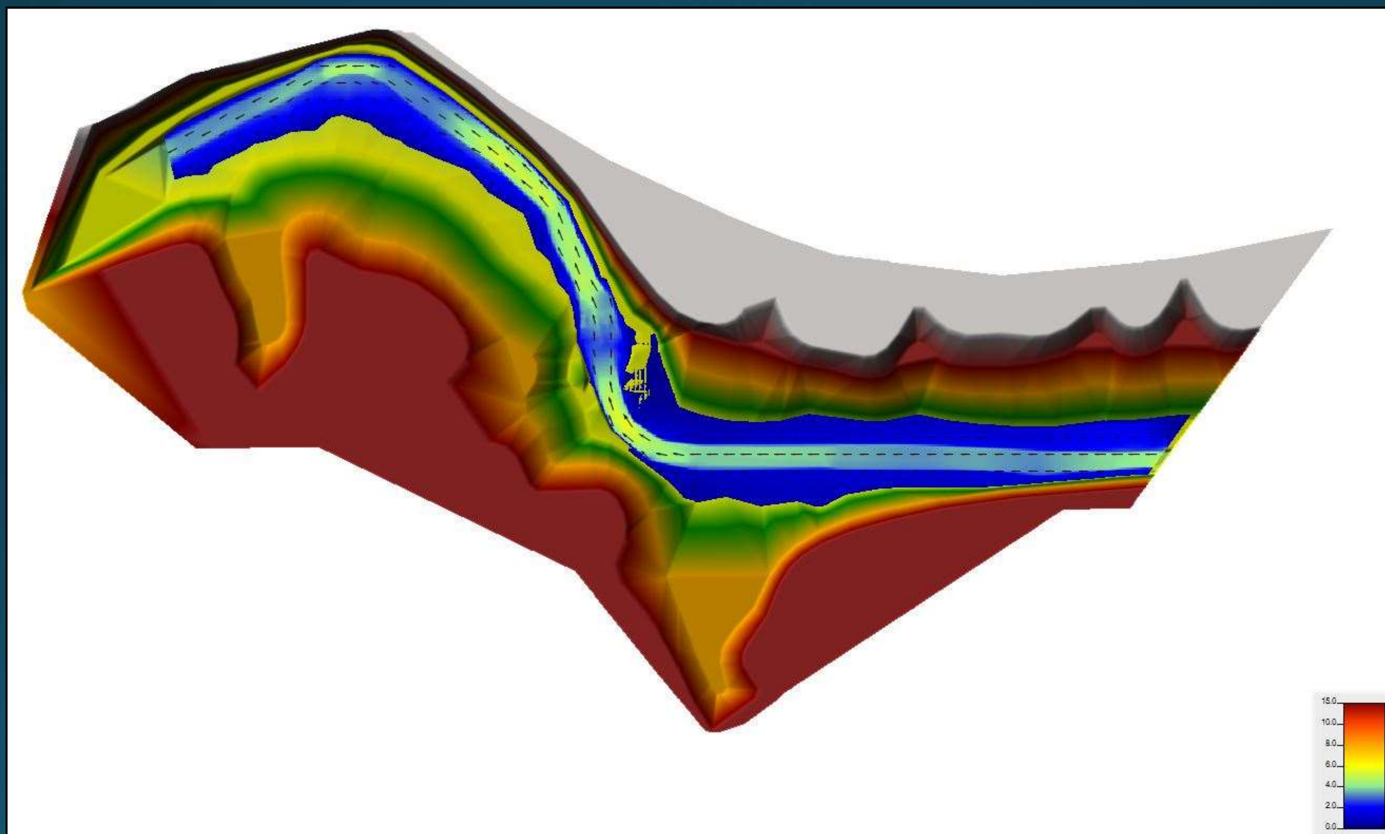
2-D Stream Velocity Output



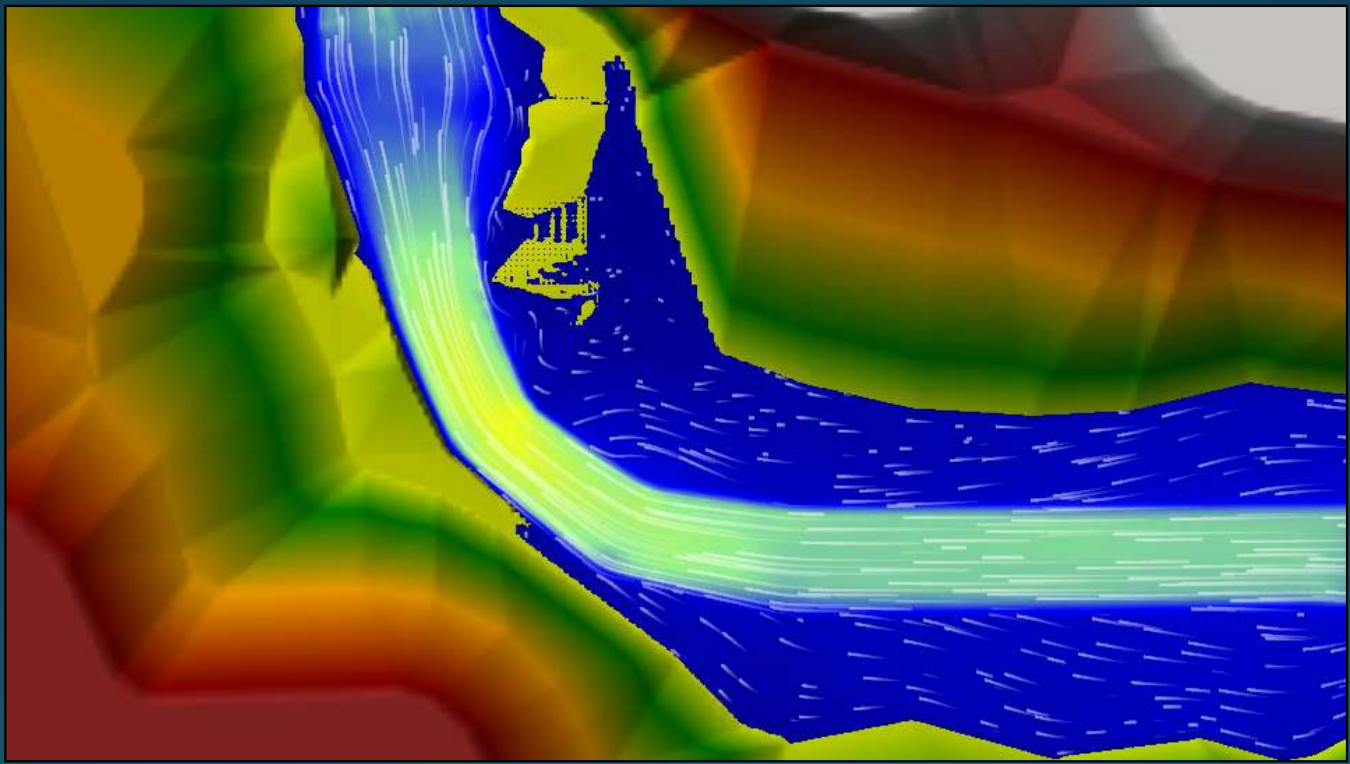
High Velocity



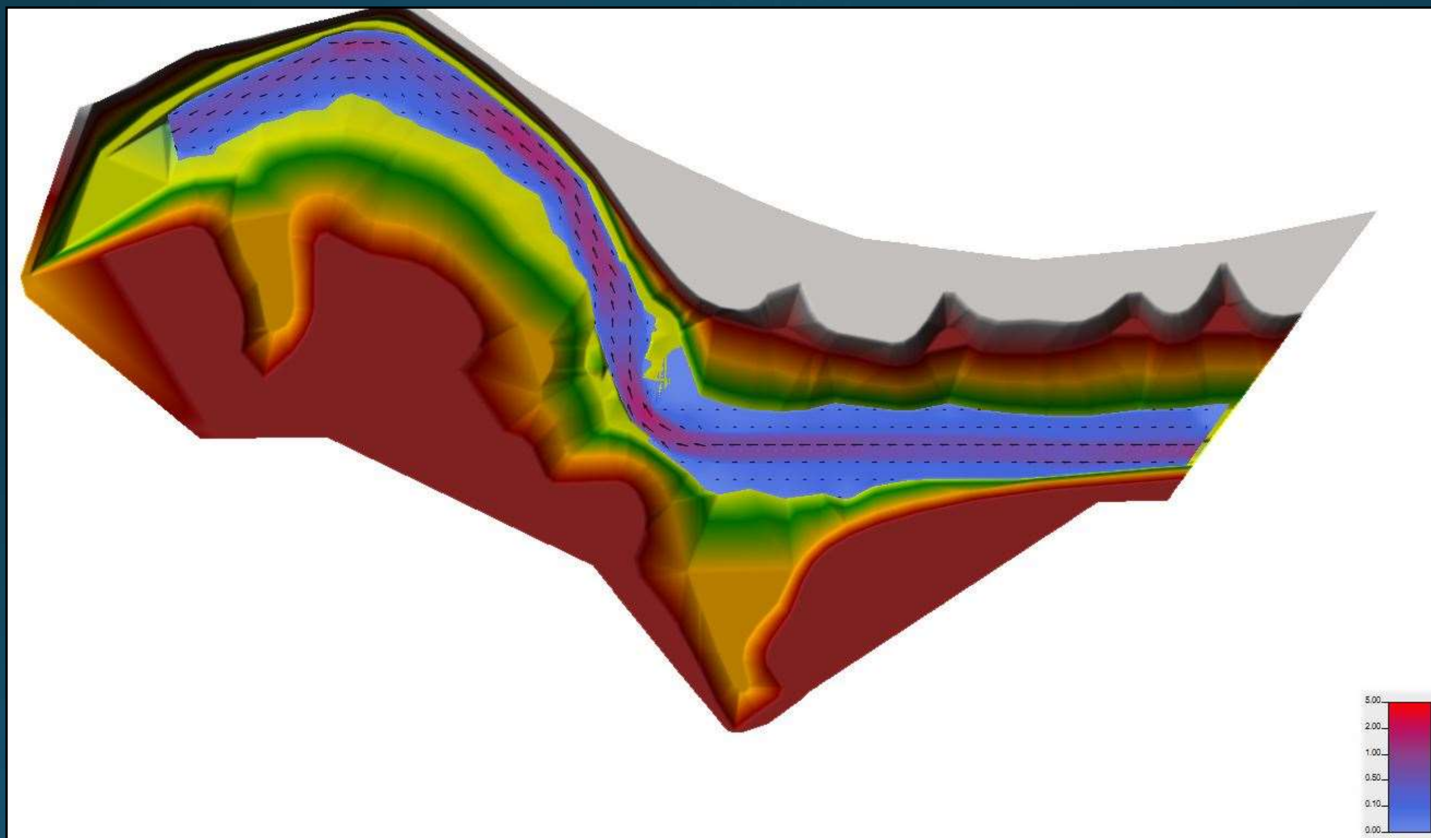
2-D Velocity Vectors



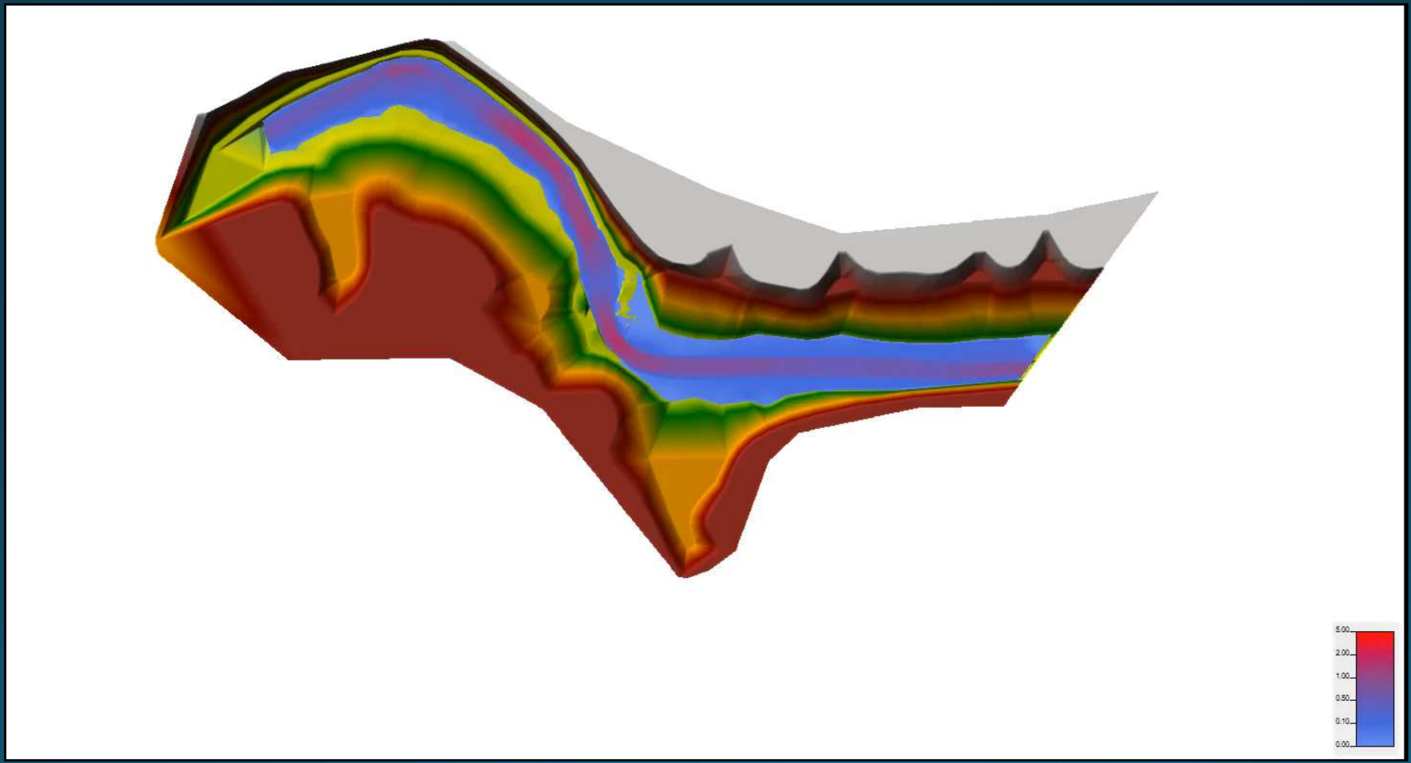
2-D Velocity Particle Tracking



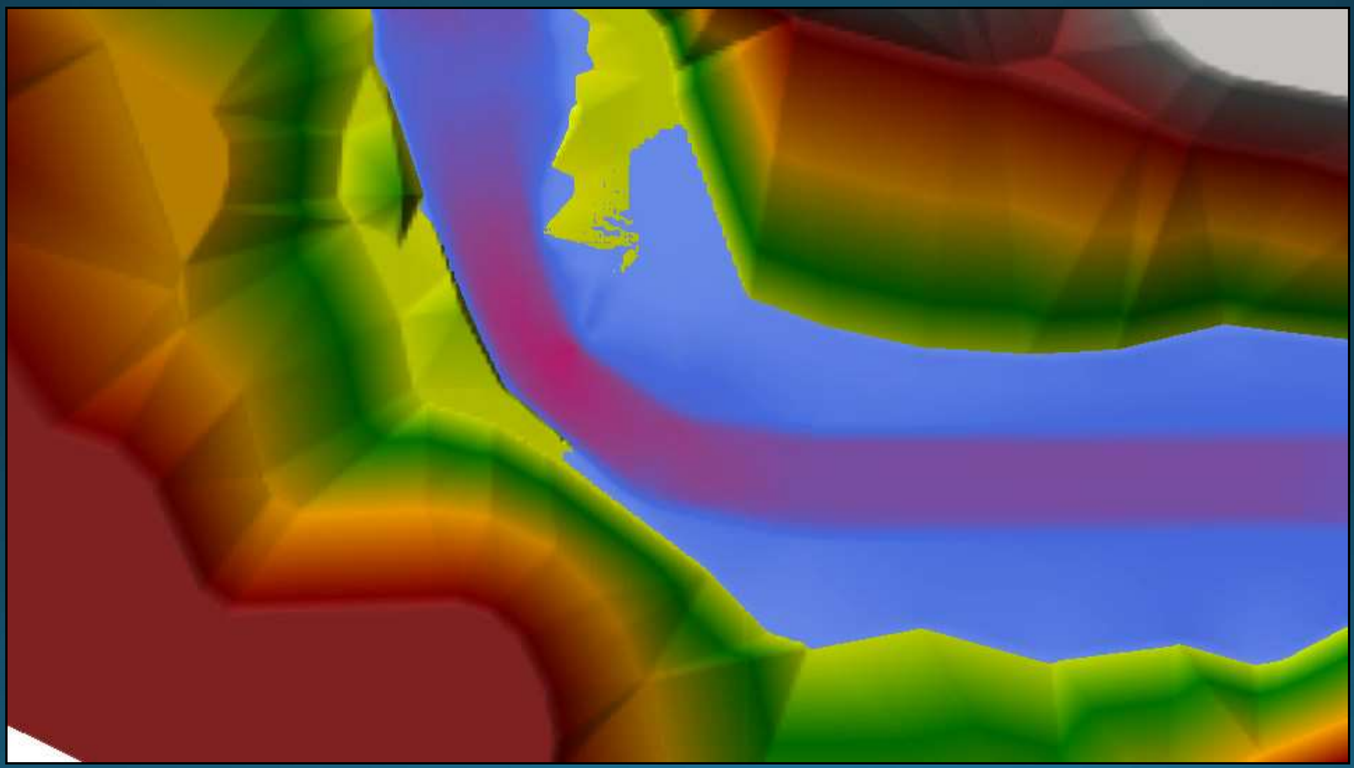
2-D Shear Vectors



2-D Shear Particle Tracking



2-D Bend Shear Particle Tracking



Discussion & Conclusions From Spivey Mill

1. Modeling predicts that the main bed changes are expected within a few hundred feet upstream and downstream of the dam.
2. A partial removal of the dam could have the same restorative benefits and may be more acceptable to the surrounding community.
3. The amount of material trapped behind the dam could be practical for dredging or mechanical redistribution. The area where impacts are predicted would be easily accessible for future restoration if needed.
4. The stream bend just upstream of the existing dam experiences the highest shear stress and velocities of the entire reach but are not very extreme by normal standards.
5. The bend area could benefit from in-stream structures to help turn the water before it hits the stream bank. Other options include boulder toe protection or toe wood to prevent erosion.

Looking Forward With Modeling

- HEC-RAS is a powerful tool for both testing potential designs and for doing environmental studies.
- These analysis may help with dam removals that we previously did not think were possible. We can answer questions about endangered species and communicate effectively to answer biological questions.
- Sediment transport and 2-D modeling provide unique insight and should be utilized during the design process.
- Modeling predicts potential problem areas with a design and is useful for being proactive with potential bank or bed erosion issues.

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