BUREAU OF RECLAMATION

Revitalizing the LA River: From Car Chases to Fish Passage

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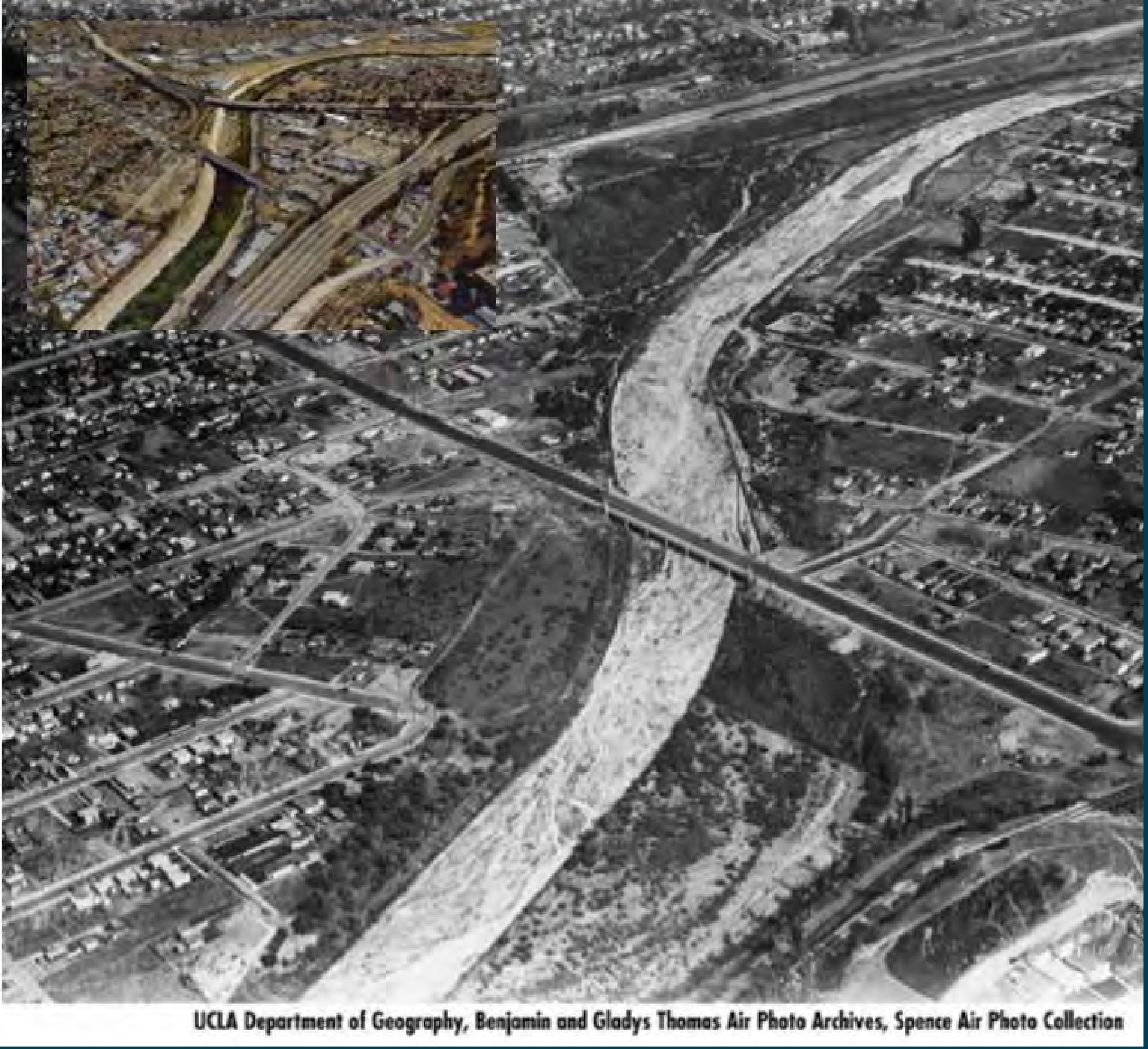
Car Chases

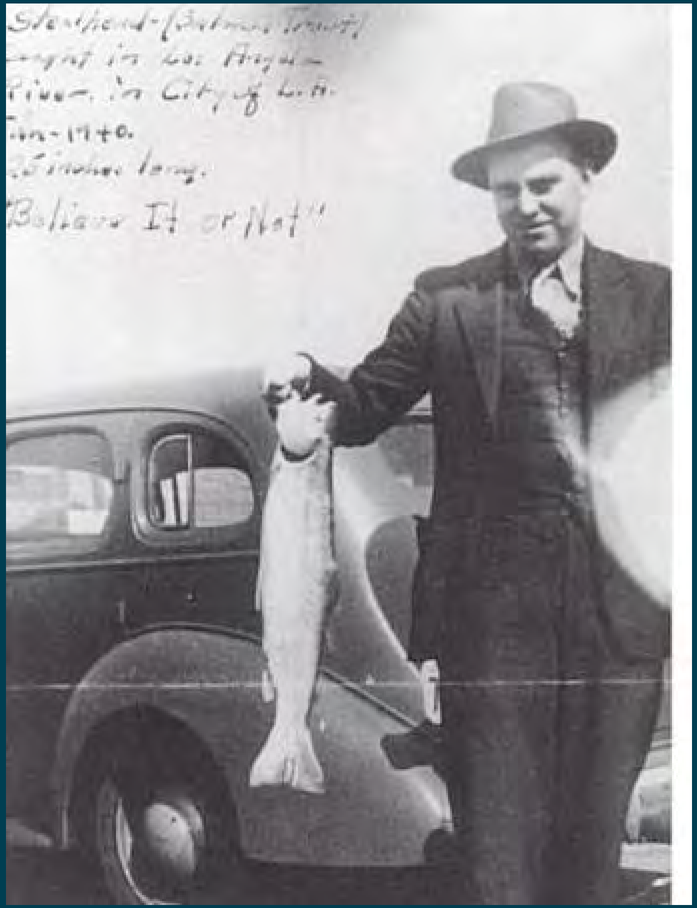
Grease (1978)

Gone in 60 Seconds (2000)

The Italian Job (2003)

Fish Passage





Oct 1928 Air Photo (from TNC, 2016)

Jan 1940 steelhead caught in LA River

1938 Flood

- Feb 27 – Mar 3, 1938
- 115 deaths
- Construction: 1938 – 1958
- Downtown LA: 1940 – 1941

Photos: https://www.vintag.es/2014/12/35-black-and-white-photos-of-1938-los.html

Existing Conditions (no fish passage)

- Depth too shallow, velocity too fast (usually supercritical flow)
- n = 0.013 S = 0.45% (smooth bed at relatively steep slope)

Study Question

- Can ecosystem features be designed within urban flood control channels to increase habitat values without significantly raising flood stage?
- Pilot Site: Los Angeles River (downtown LA)

LA River Watershed

- Tributaries and headwaters no longer accessible for anadromous fish due to depth and velocity passage barriers

- Figure from Los Angeles River Ecosystem Restoration Integrated Feasibility Report (USACE, 2015)

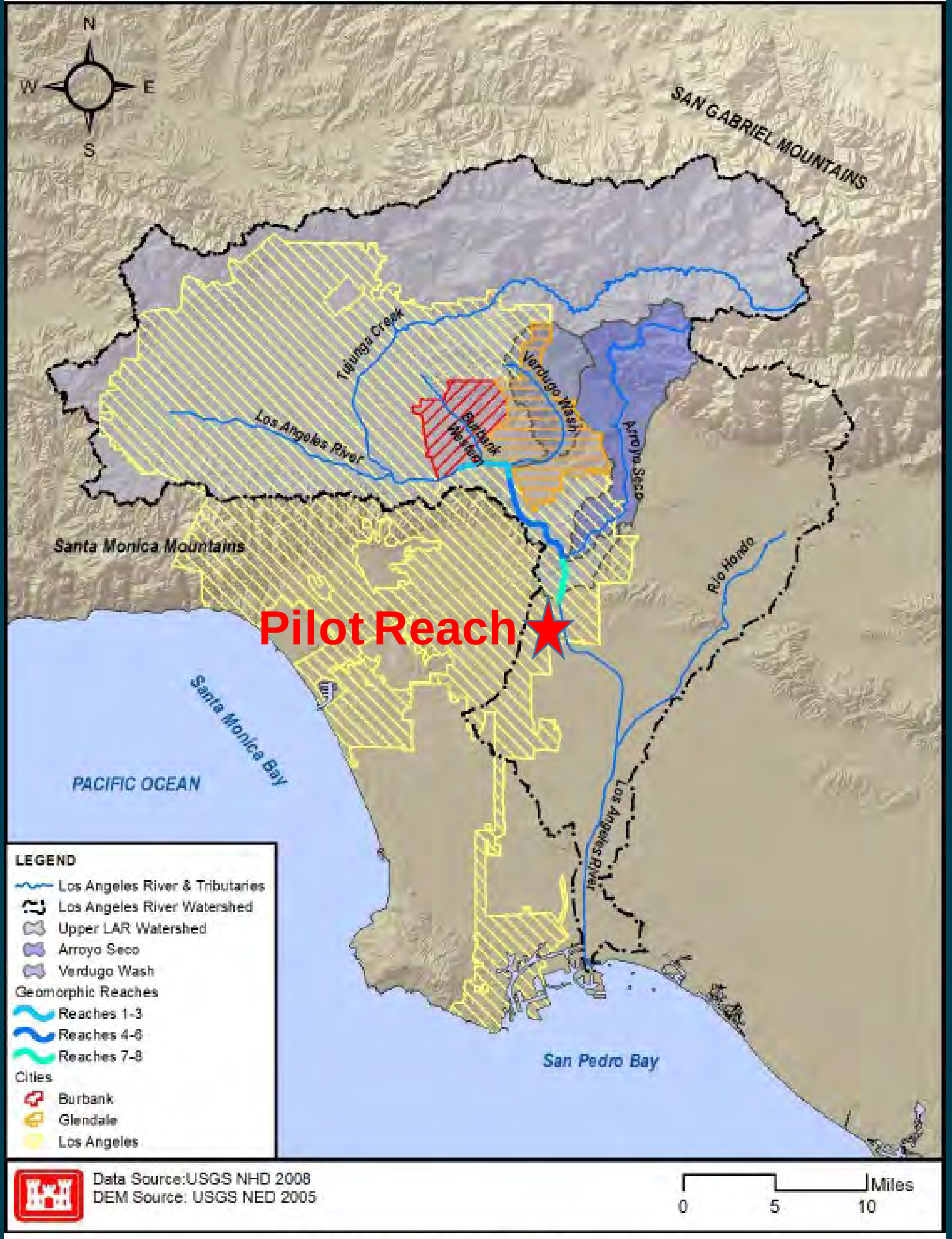
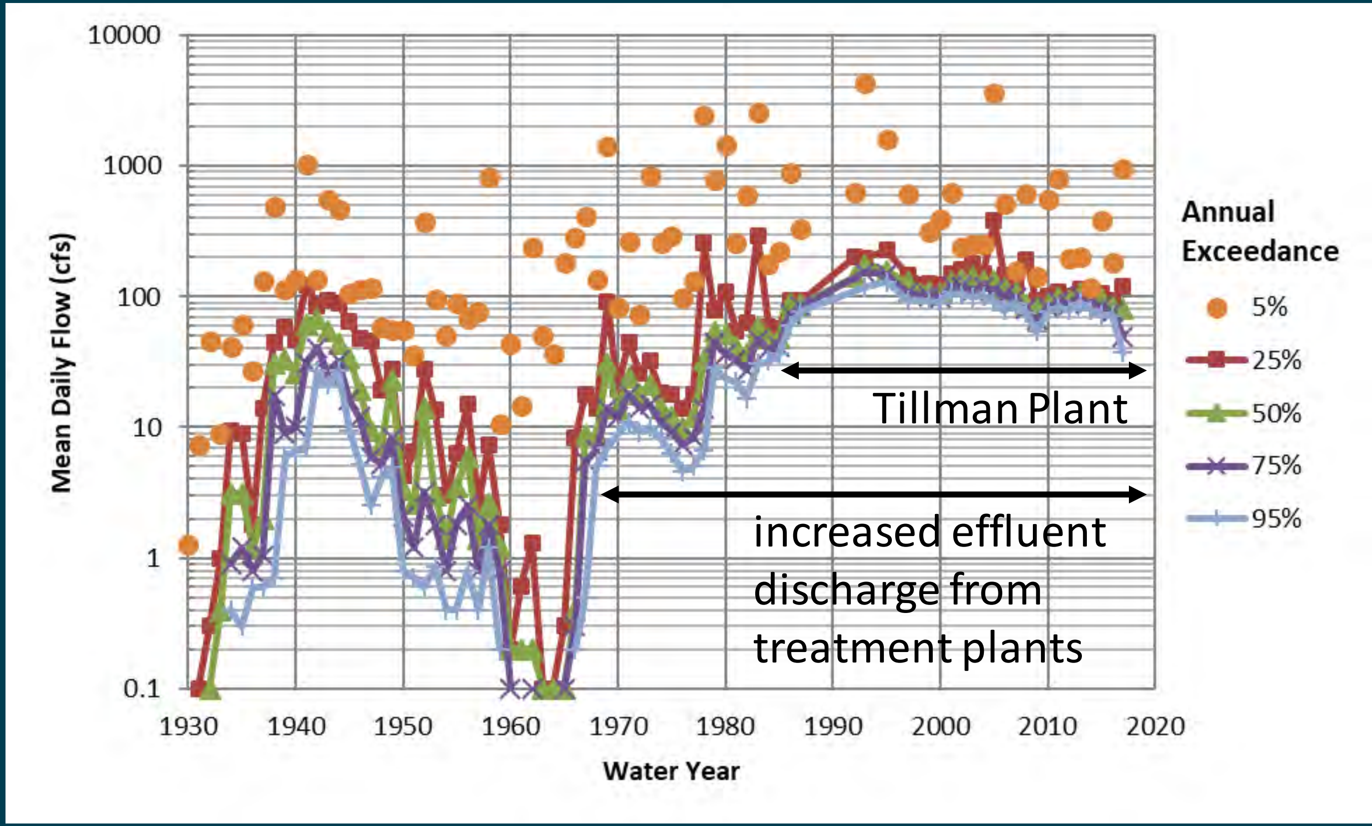


Figure ES- 2 Los Angeles River Watershed

Pilot Design Reach

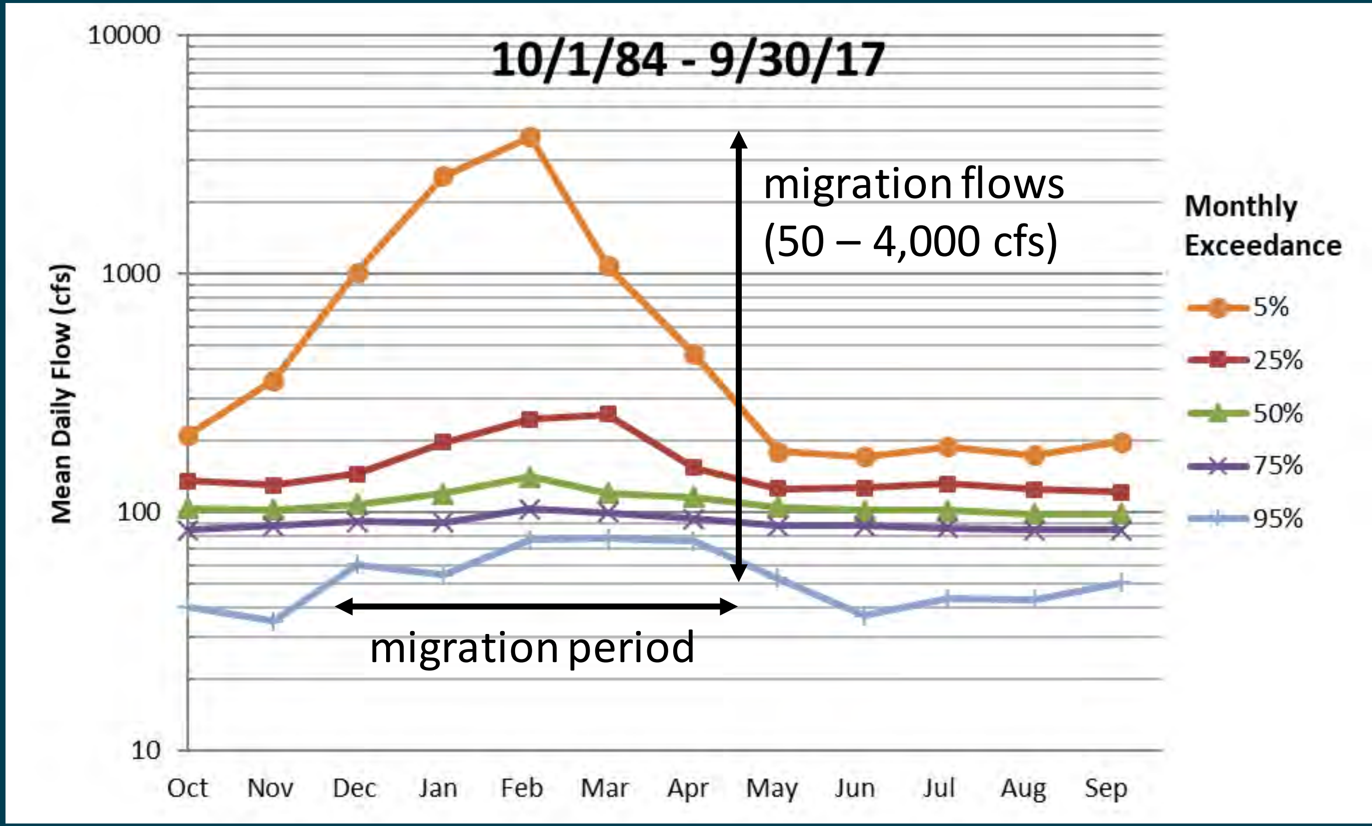
- Downtown Los Angeles

LA River Hydrology



- WY 1930 – 2017. F57C Gage (LA River above Arroyo Seco)

LA River Hydrology



- WY 1985 – 2017. F57C Gage (LA River above Arroyo Seco)

Fish Passage Criteria

- Adult southern steelhead (Oncorhynchus mykiss)

Depth Range	Description
< 1 ft	Depth would limit passage
≥ 1 ft	Depth would not limit passage

Velocity Range	Description
< 3 ft/s	High quality resting velocity
3 – 5 ft/s	Low quality resting velocity
5 – 12 ft/s	Prolonged swimming speed
12 – 26 ft/s	Darting swimming speed

Initial Vision

- Single thread meandering low-flow channel
- Recreation, aesthetics

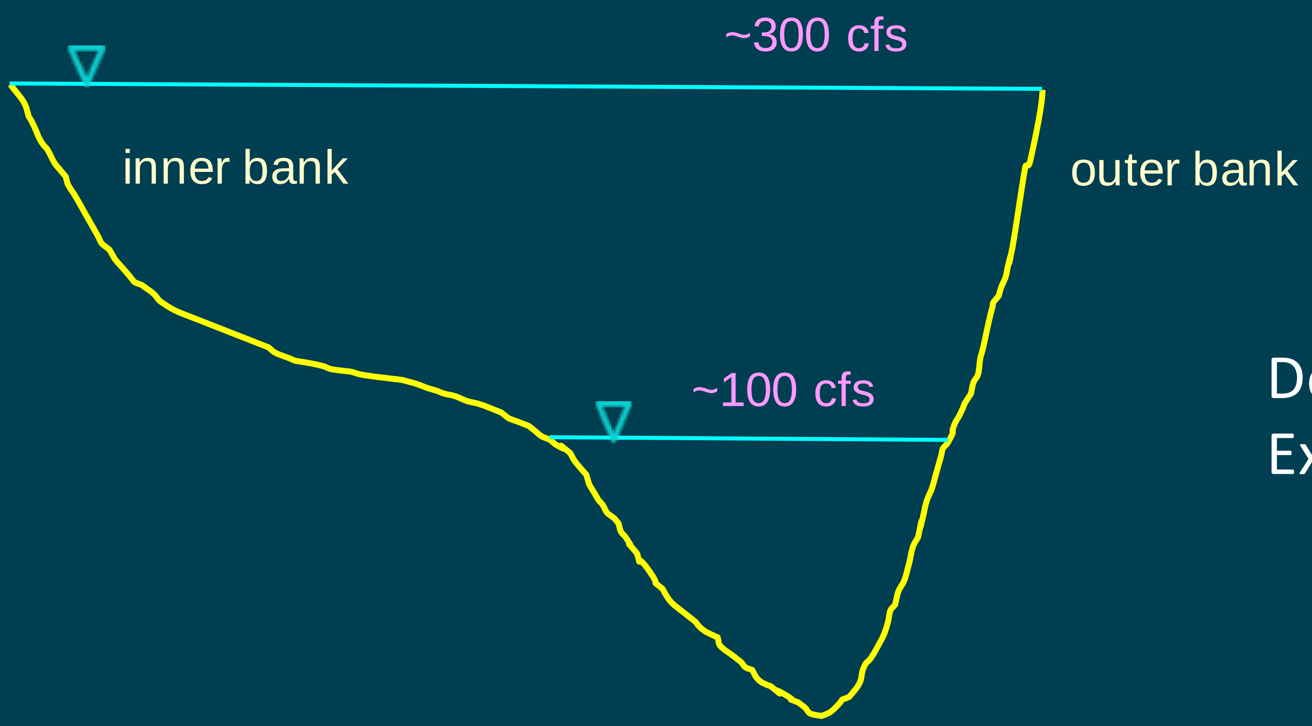
- Artist's rendering from Los Angeles River Revitalization Master Plan (LARRMP, 2007)

Existing: Looking north along the existing channel section above 1st Street in Downtown Los Angeles. (2006)

Future: The channel bottom with a restored riparian corridor with native plants.

Conceptual Cross Section

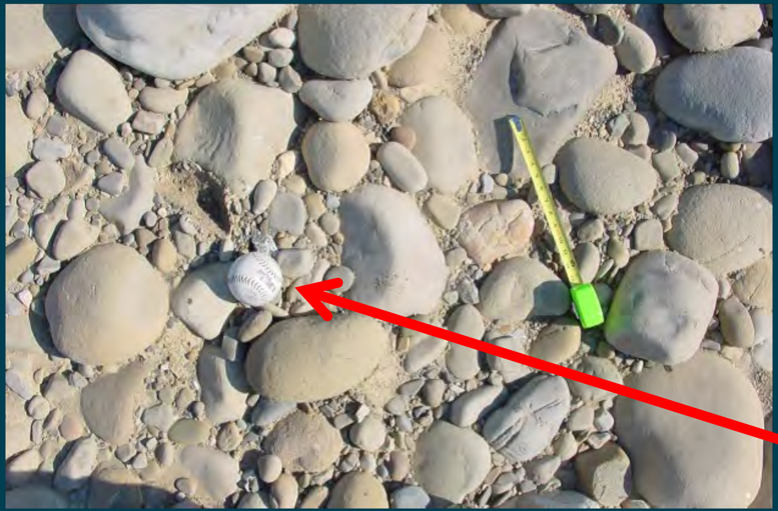
- Roughened low-flow channel inset within existing channel
  - 100 cfs (50% annual mean daily flow exceedance)
  - 300 cfs (10% annual mean daily flow exceedance)



Design: 64 ft wide x 2 ft deep
Existing: 20 ft x 0.5 ft

Channel Roughness

- Need to increase roughness to reduce velocity within suitable range
- Assume n = 0.035 for designs (typical gravel/cobble bed)



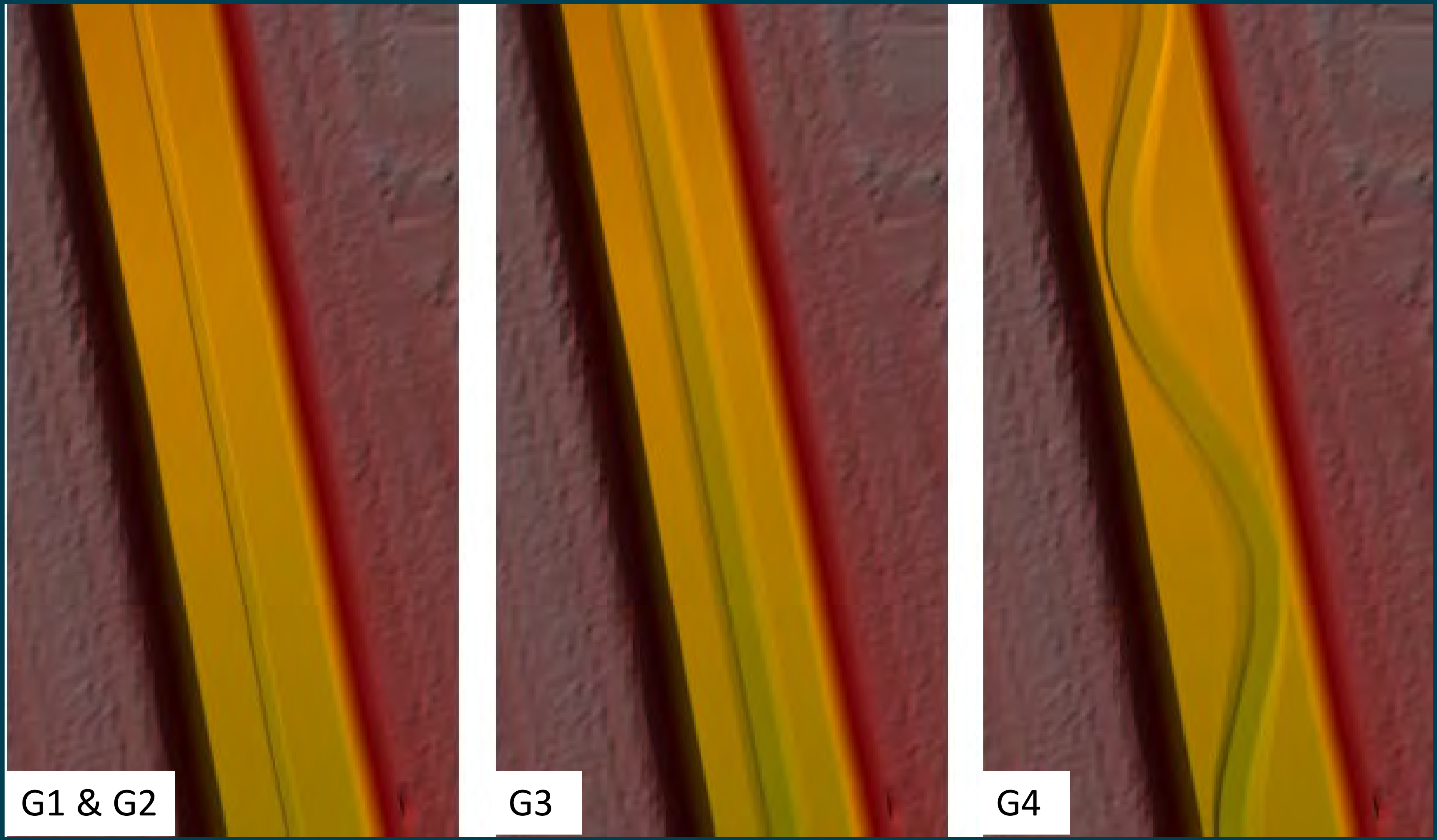
softball for scale

Ventura River surface bed material.
n = 0.04 (S ≈ 0.007)
(Greimann, 2006)

Conceptual Designs

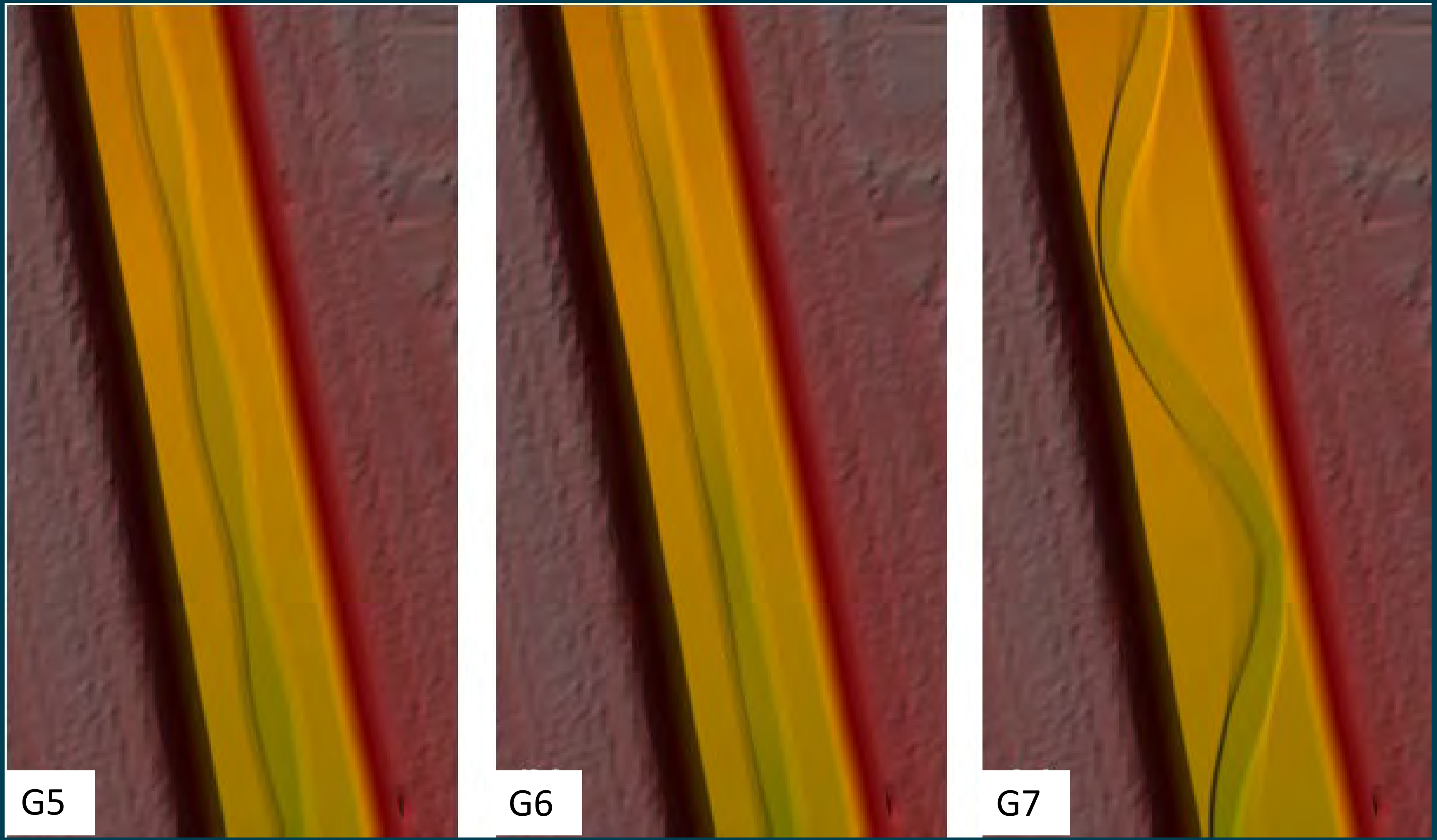
- Sequentially developed designs for low-flow channel (LFC) options
- Planform: straight, meandering, deflectors, multi-threaded, backwaters, boulder clusters, islands and bars
- Width: constant, variable
- Profile: constant, pool-riffle
- Roughness: concrete, cobble LFC, lightly vegetated islands and bars

Conceptual Designs



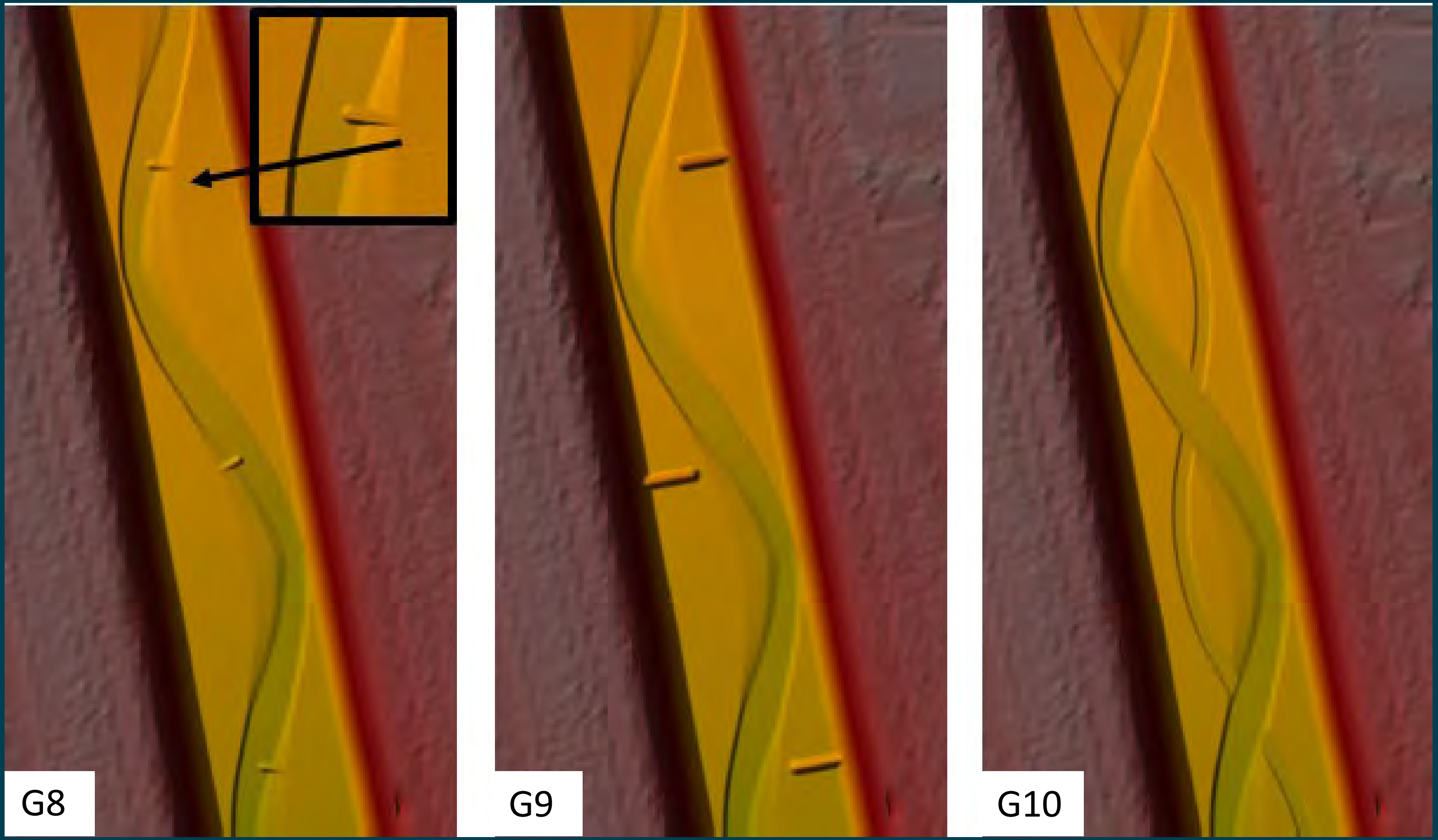
- G1: existing
- G2: existing with roughened LFC
- G3: increased width and depth
- G4: meandering

Conceptual Designs



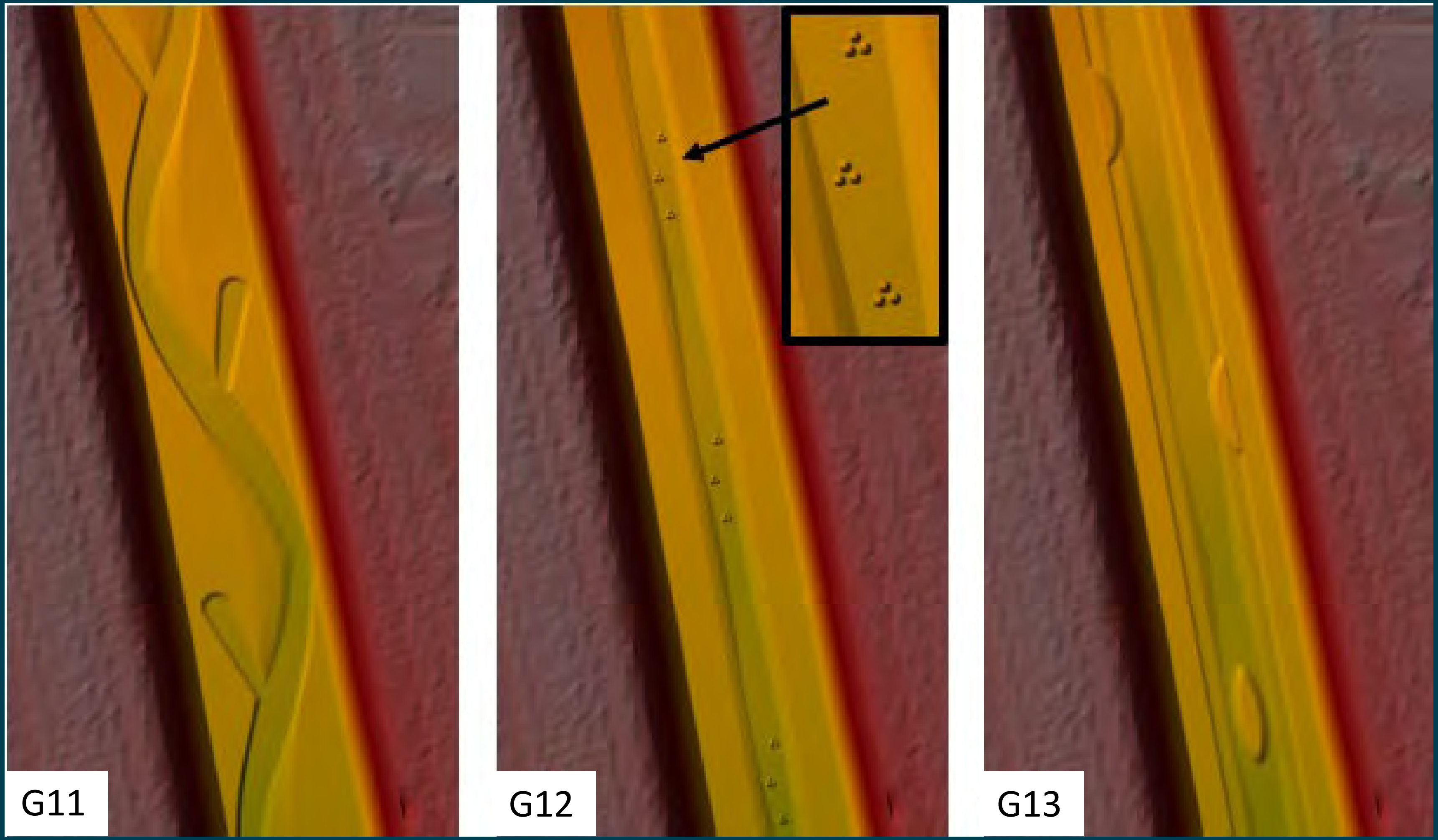
- G5: variable width
- G6: pool-riffle
- G7: meandering, pool-riffle

Conceptual Designs



- G8: deflectors within LFC
- G9: deflectors outside LFC
- G10: multi-threaded

Conceptual Designs

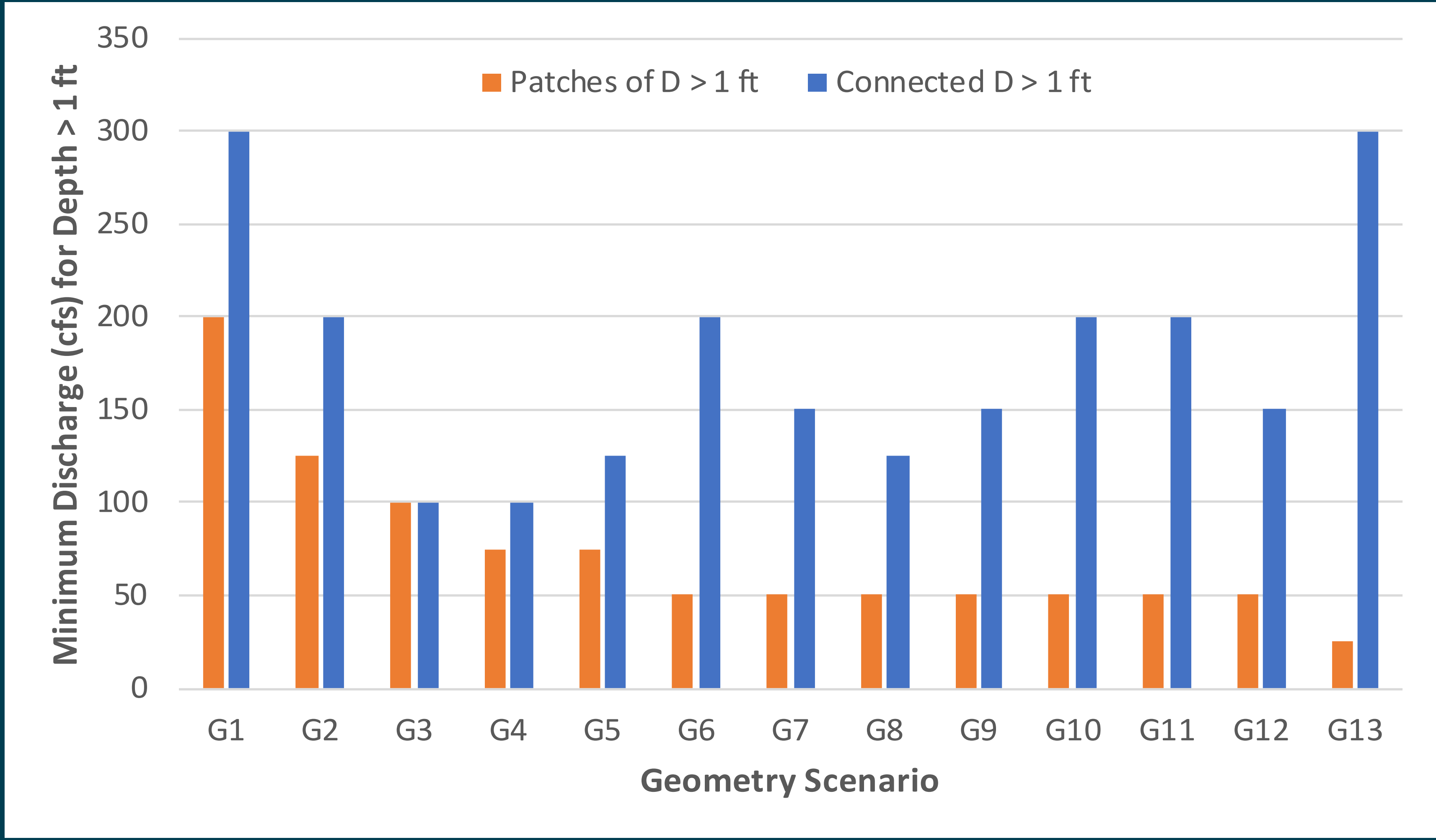


- G11: backwaters
- G12: boulder clusters
- G13: mid-channel islands and alternating bars

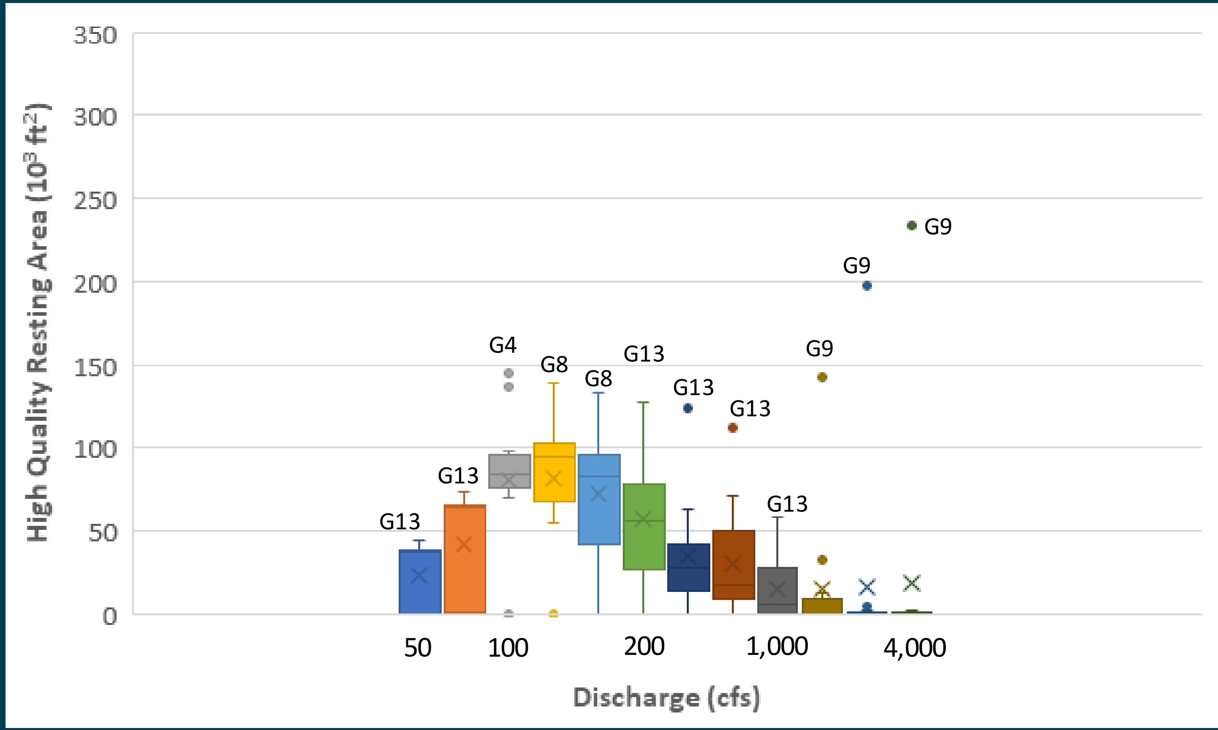
Analysis Methods

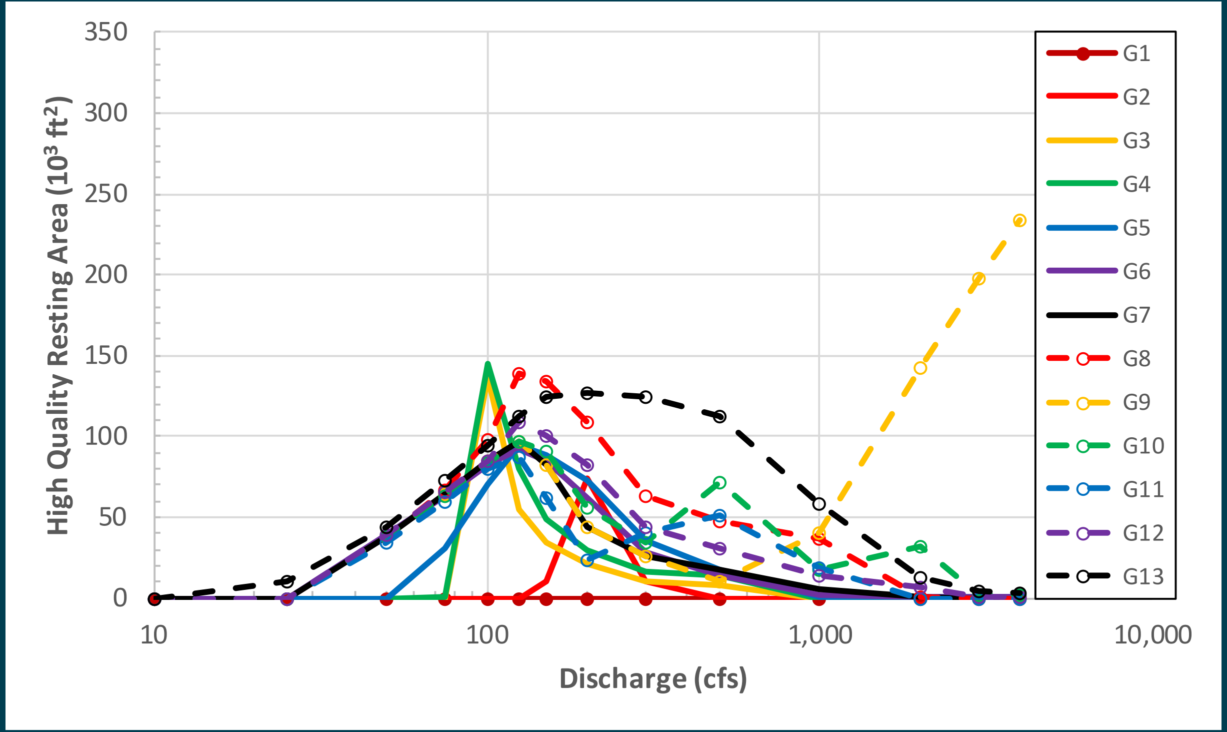
- 2D fixed bed numerical model
  - 14 fish passage flows (10 – 4,000 cfs) for each geometry scenario (G1 – G13)
    - Quantified and mapped depth and velocity zones based on fish passage criteria
  - 100-yr flow (109,000 cfs) for flood stage evaluation
    - Compared WSE for each geometry scenario (G1 – G13)
- Laboratory physical model
  - 4 types of boulder cluster configurations
  - 3 – 4 densities for each configuration
  - 2 flows for each combination of cluster type and density

Numerical Model Results (depth)



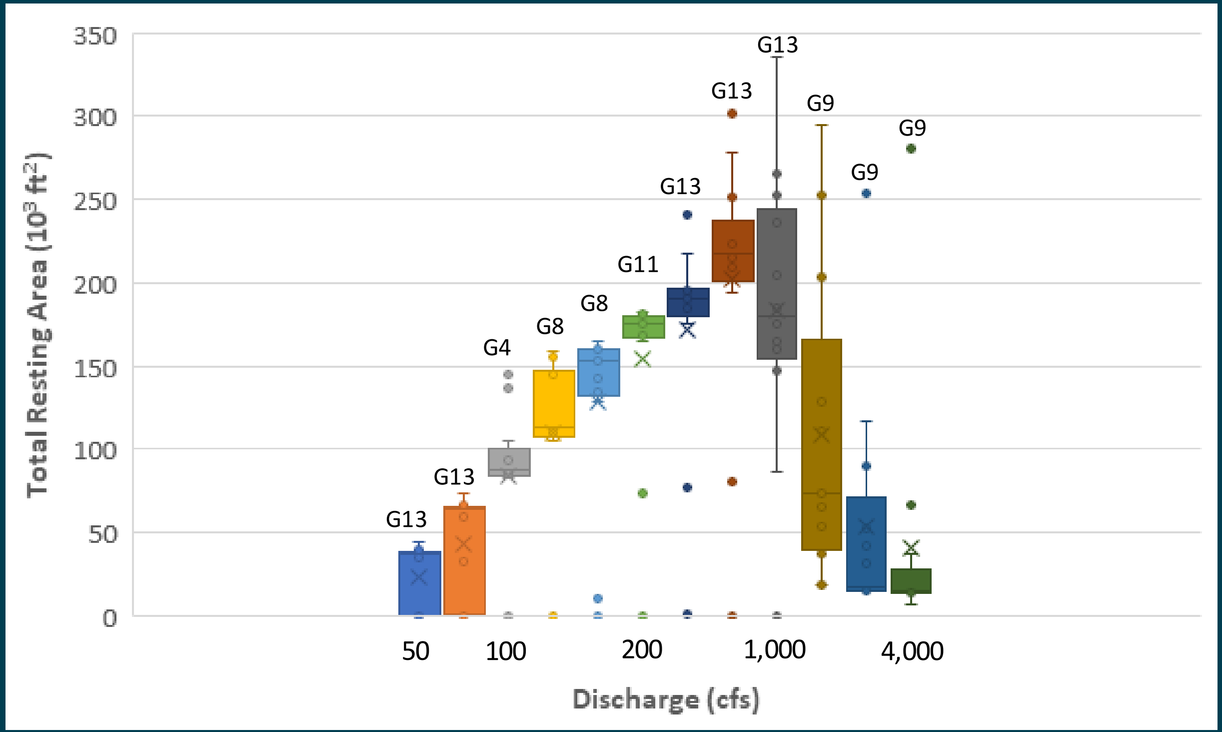
Numerical Model Results (velocity)

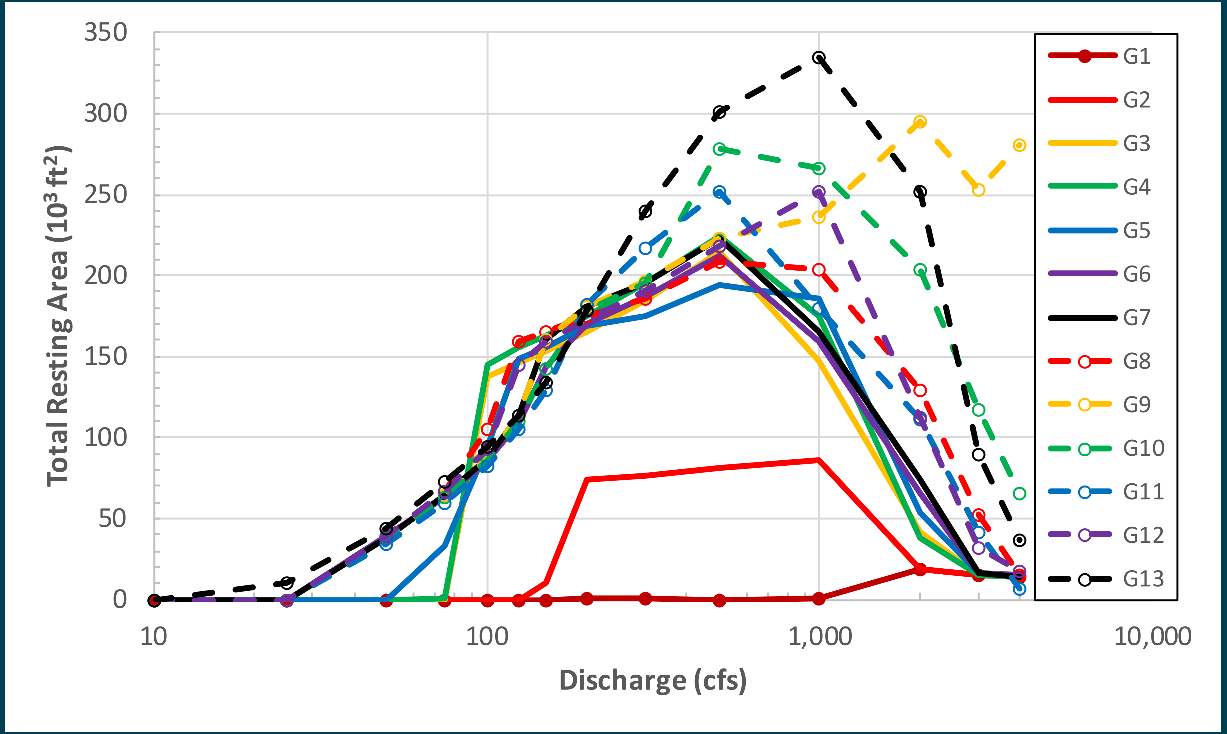




- High quality resting area (velocity < 3 ft/s and depth ≥1 ft)

Numerical Model Results (velocity)

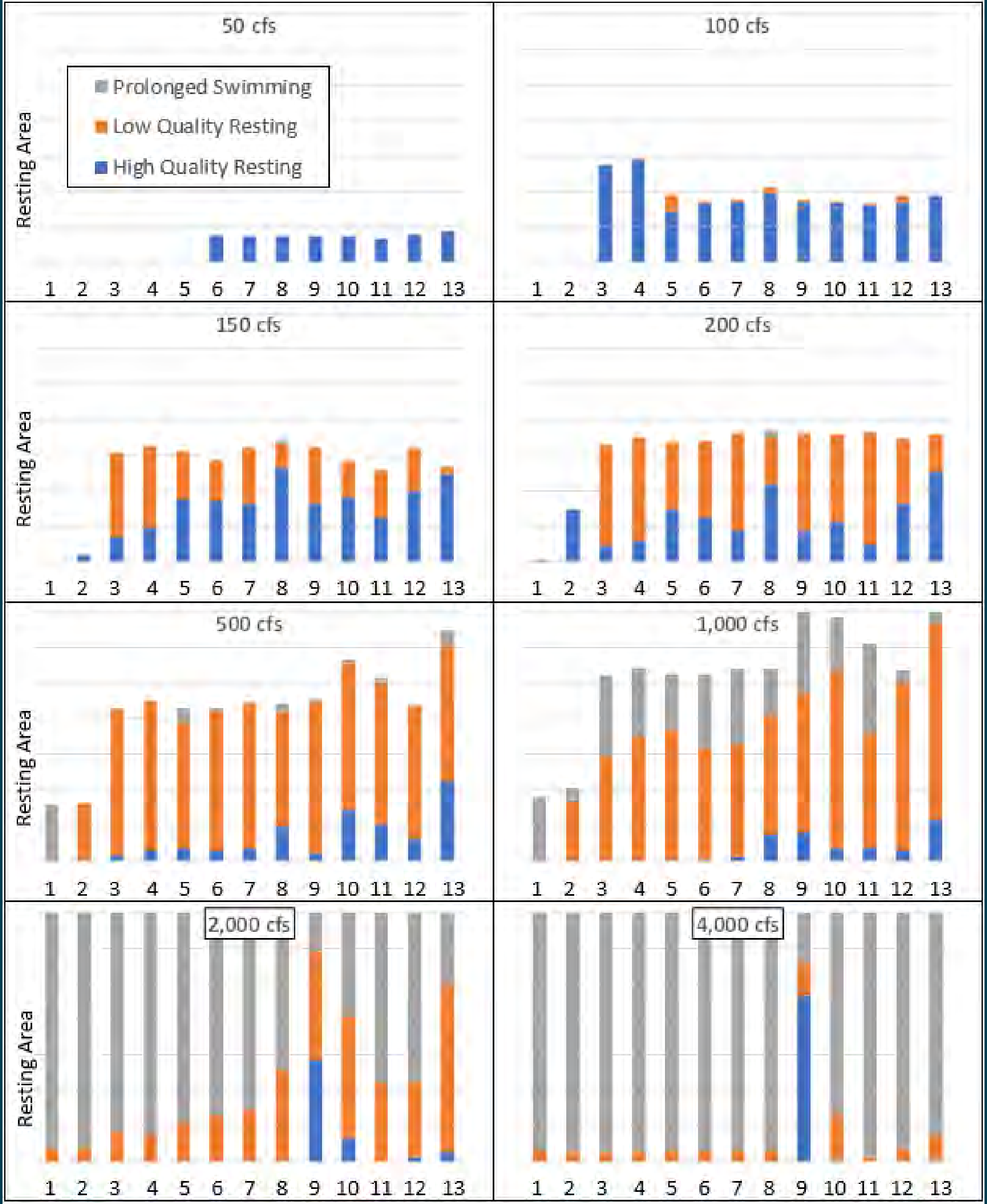




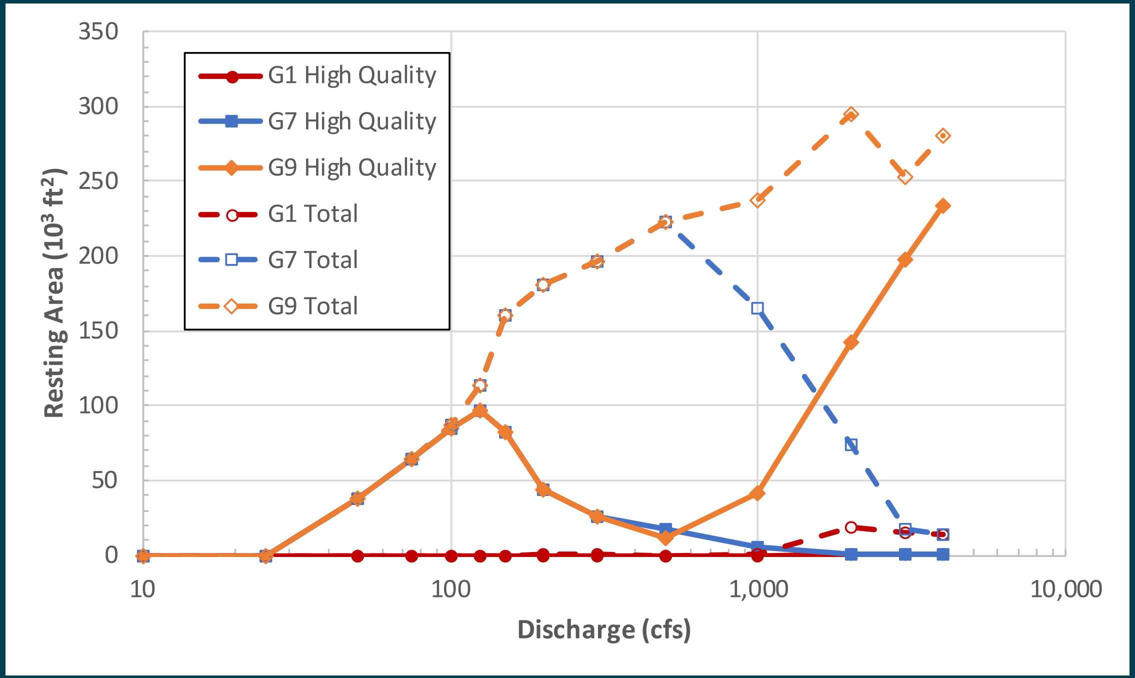
- Total resting area (velocity < 5 ft/s and depth ≥1 ft)

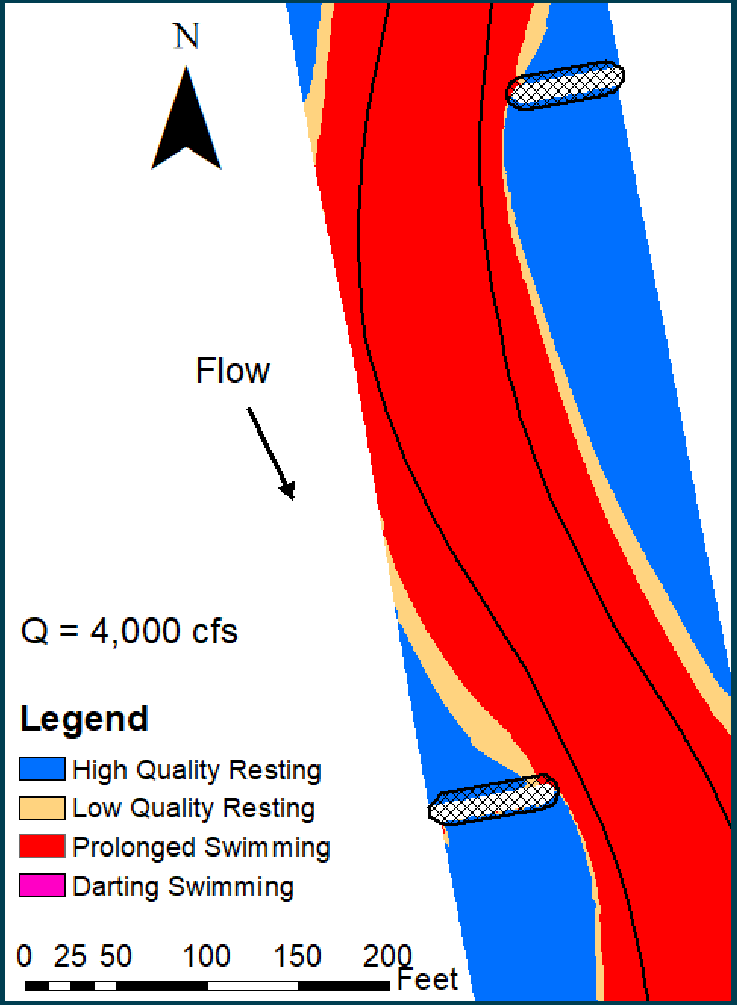
Model Results

- High quality (blue) (< 3 ft/s)
- Low quality (orange) (3 – 5 ft/s)
- Prolonged swimming (gray) (5 – 12 fts)
- All have depth ≥ 1 ft



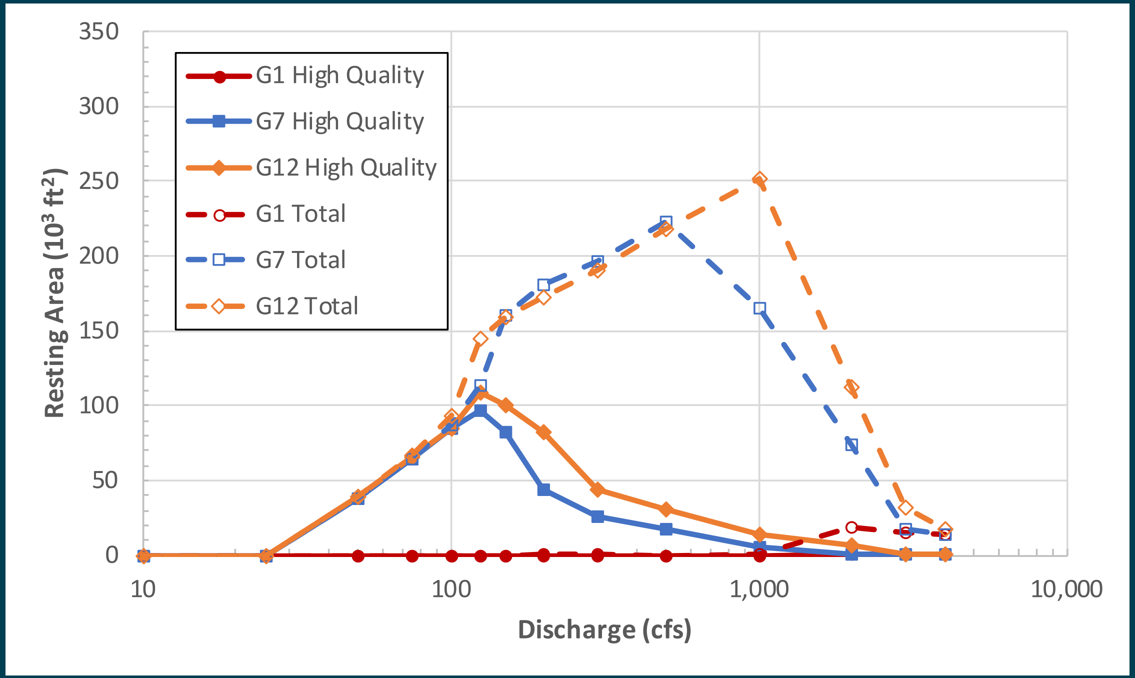
Deflectors outside LFC (Geometry 9)

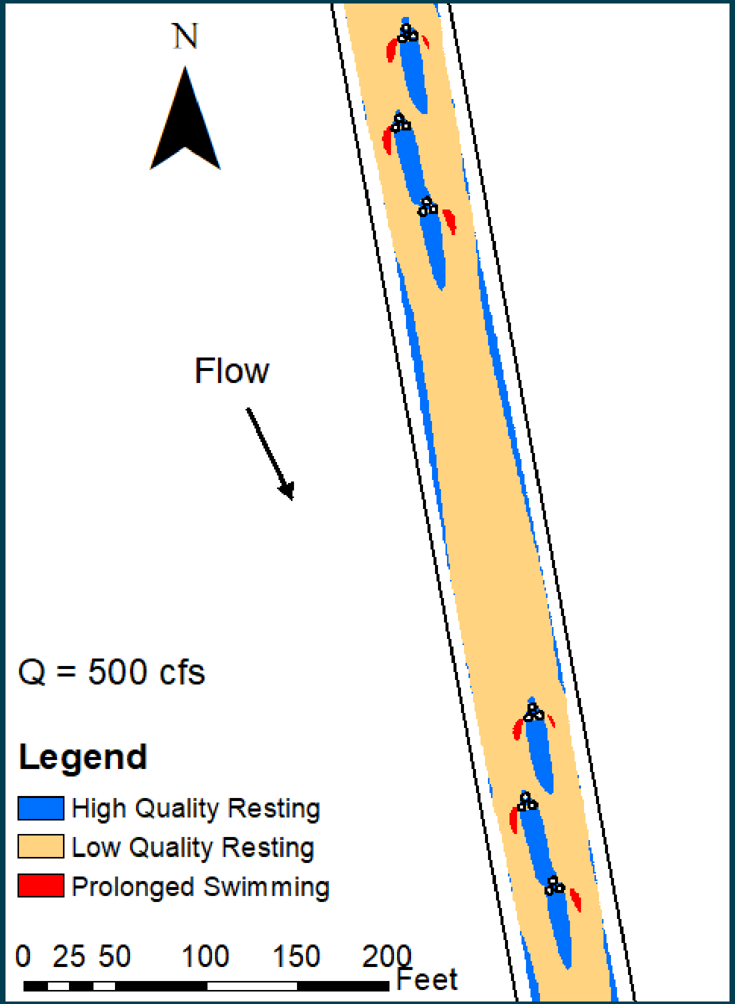




- Benefit at Q ≥ 1,000 cfs

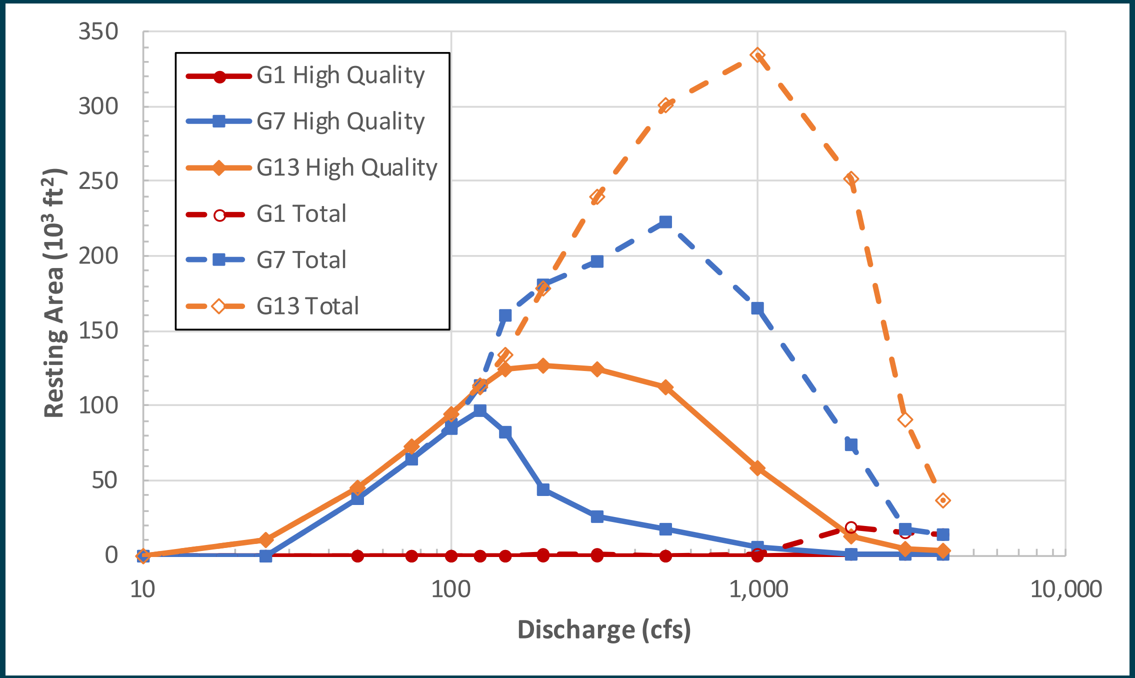
Boulder Clusters (Geometry 12)

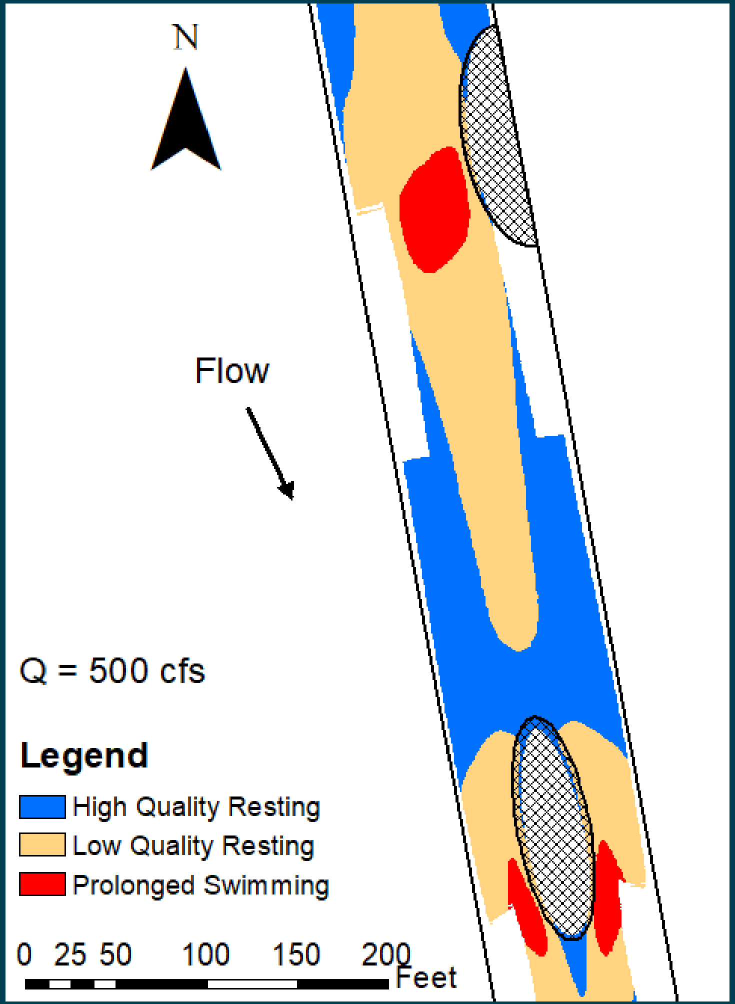




- Local benefits, but small area

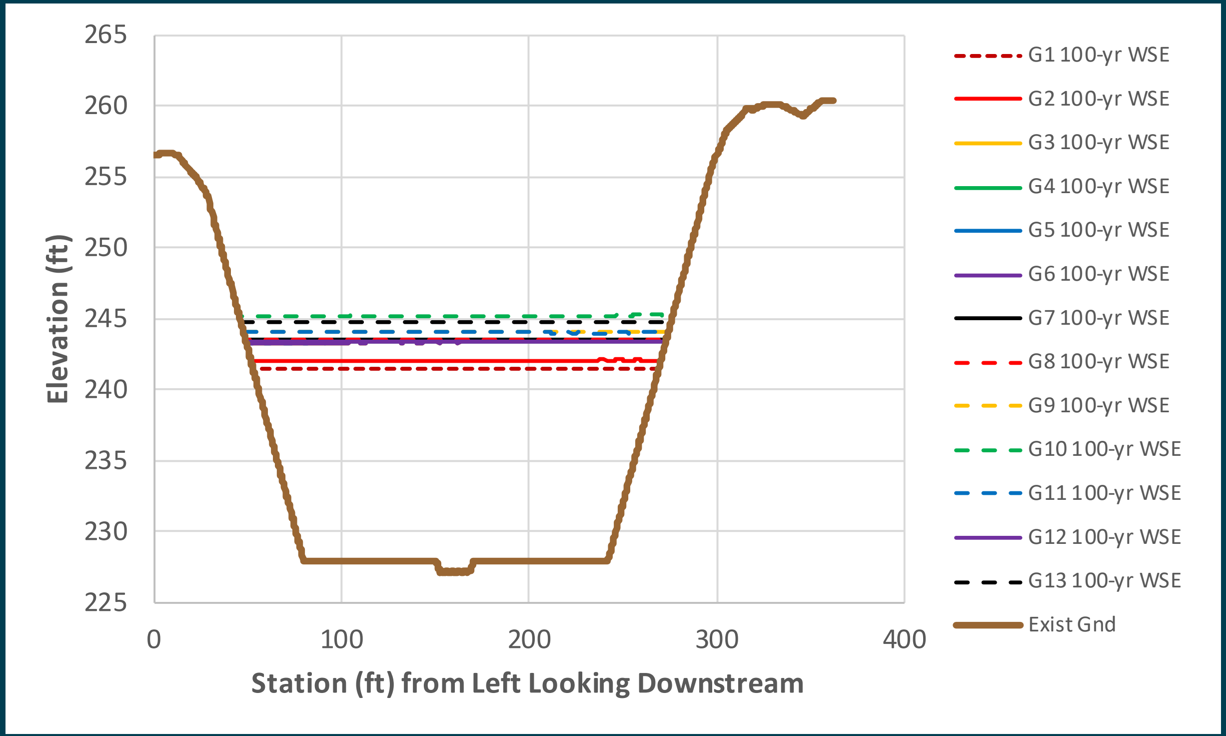
Islands and Bars (Geometry 13)

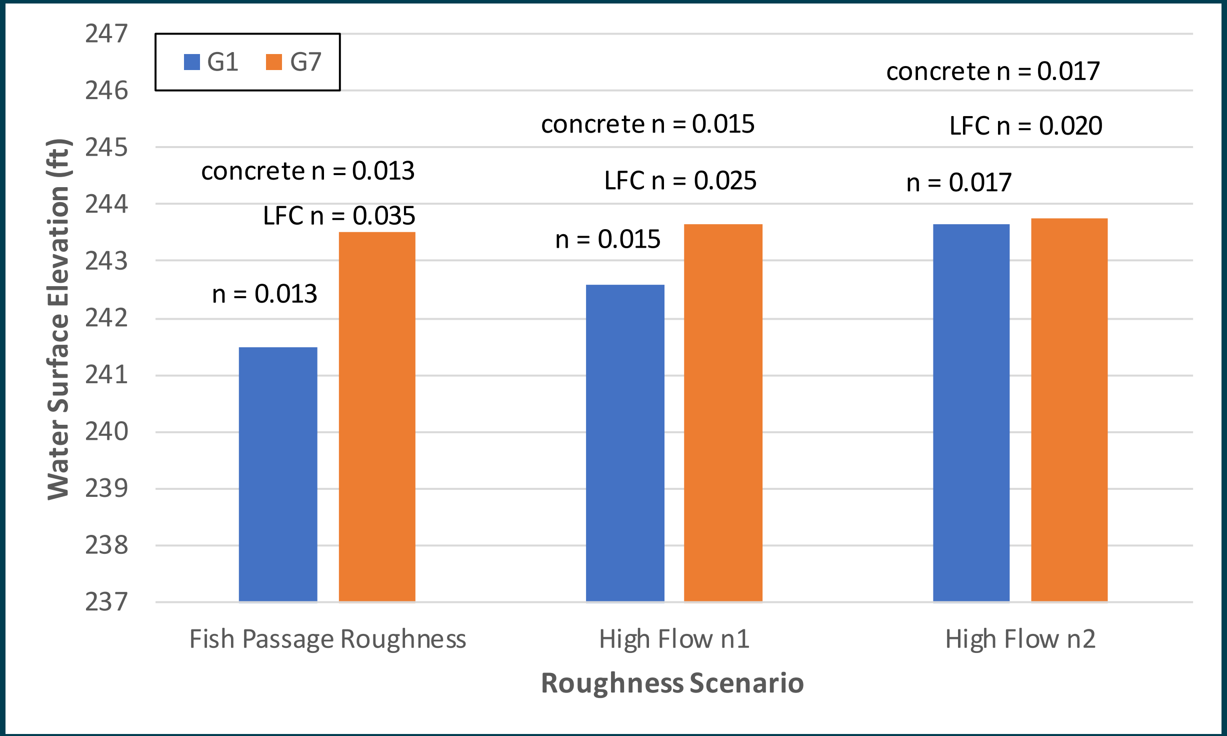




- Increased area w/larger features

Numerical Model Results (flood stage)





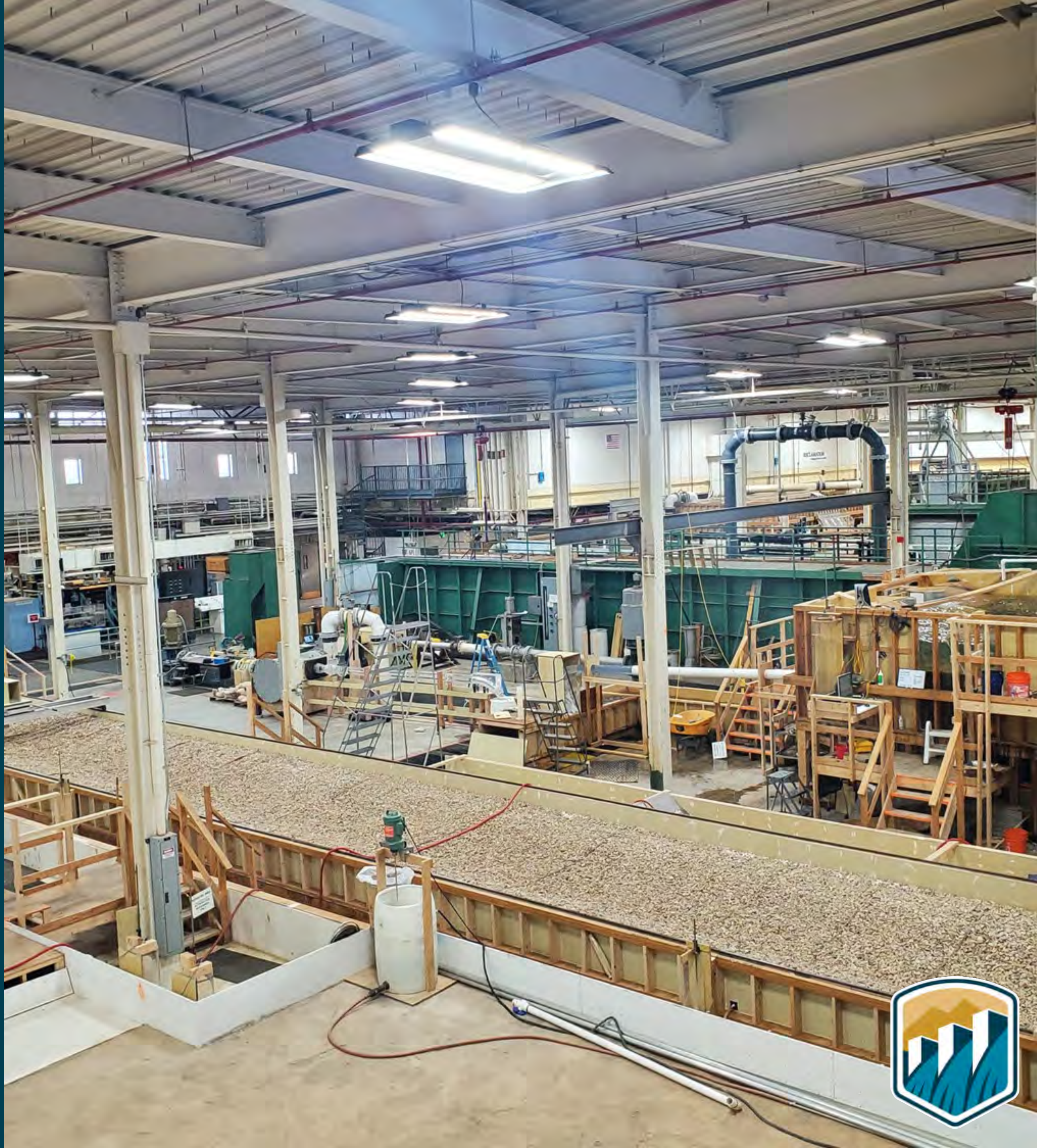
- WSE at 100-yr flow
- Results sensitive to roughness assumption

Physical Hydraulic Model: Purpose

- Physical hydraulic model: roughened low flow channel
- Collect detailed hydraulic data around boulder cluster configurations
- Identify the most effective boulder cluster configurations to create low-velocity resting habitat

Hydraulic Investigations and Laboratory Services

- Bureau of Reclamation- Denver Technical Service Center
- Utilizes venturi system with 12” horizontal pumps
- 240,000 gal reservoir
- Venturi meters calibrated using 44,000 pound volumetric weigh tank
- Accuracy of ±0.25%.



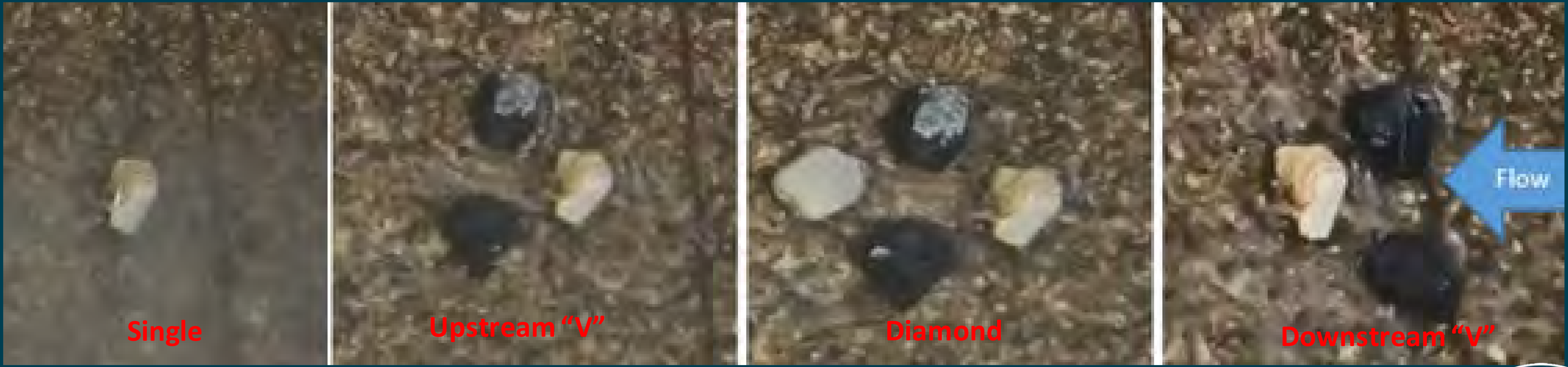
Physical Hydraulic Model

- Set up: template system

- Distorted Vertical Scale
  - Distortion Ratio of 2
  - Allows for increased water depth in model
  - Beneficial for river models
- Model Dimensions
  - Top width: 8 ft
  - Bottom width: 3.75 ft
  - Avg Slope: 0.0089 ft/ft
  - Length: 100 ft

Configurations and Density

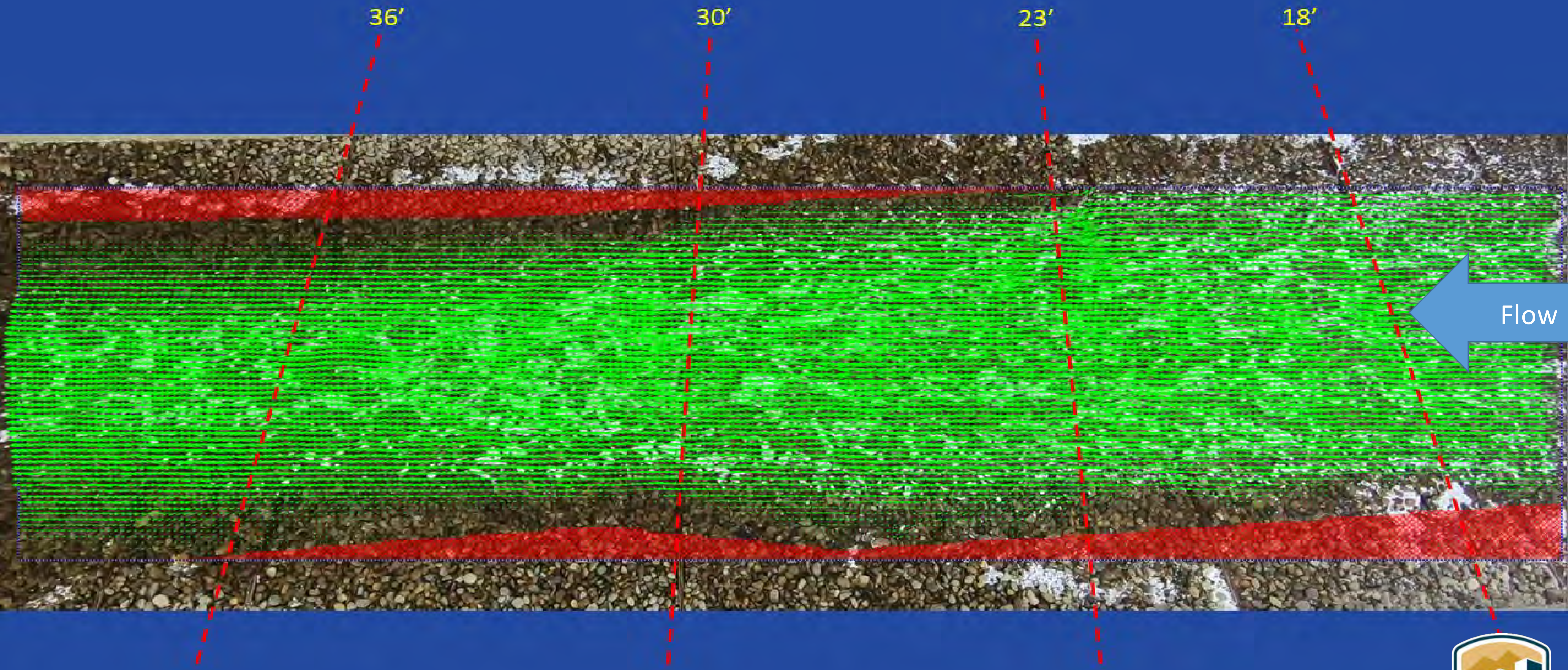
- Baseline: roughened channel with scaled gravel
- Four configurations; 3-4 densities
- Two flow rates: 300 cfs and 600 cfs (prototype)



Testing Techniques

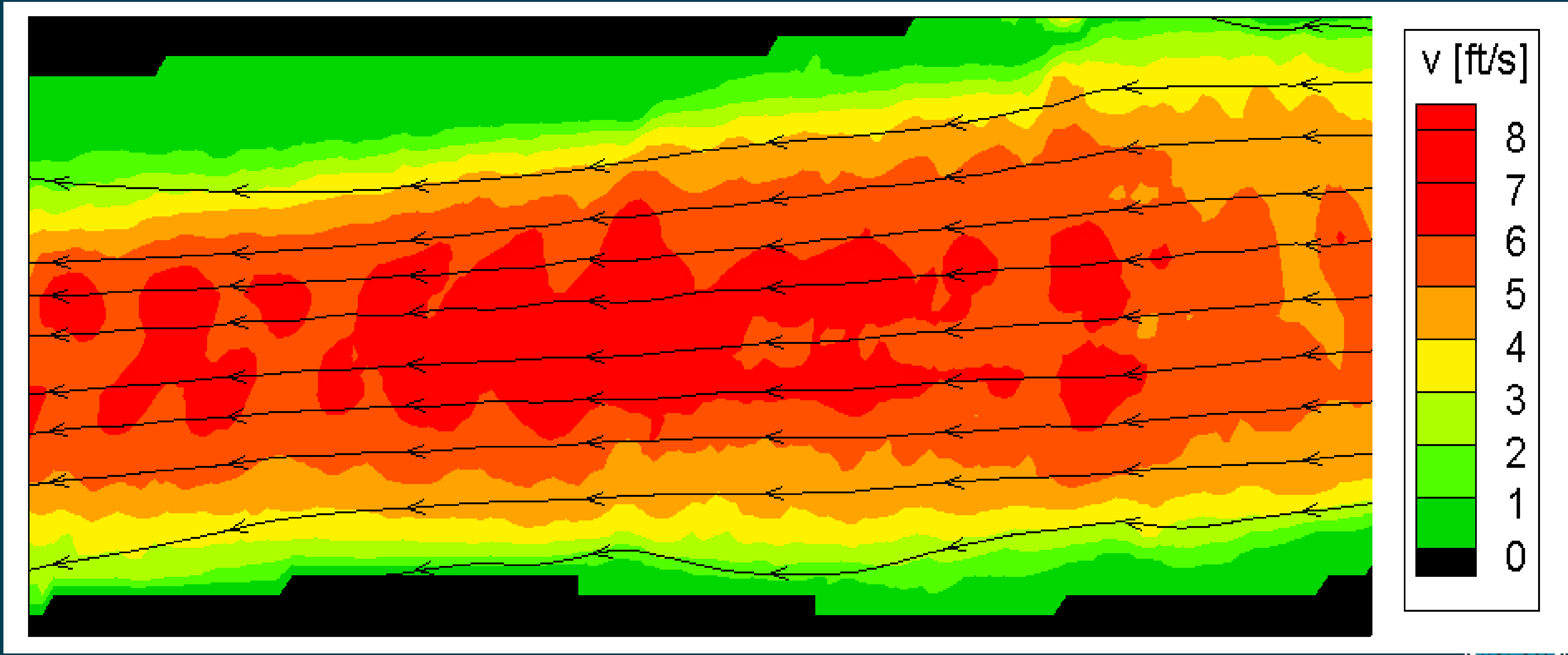
- Large Scale Particle Image Velocimetry (LSPIV)
    - Surface velocities
    - Streamlines around the rocks
- Acoustic Doppler Velocimeter (ADV)
    - Single point at 60% of water depth
    - Around clusters including upstream and downstream

LSPIV Results- 300 cfs Baseline

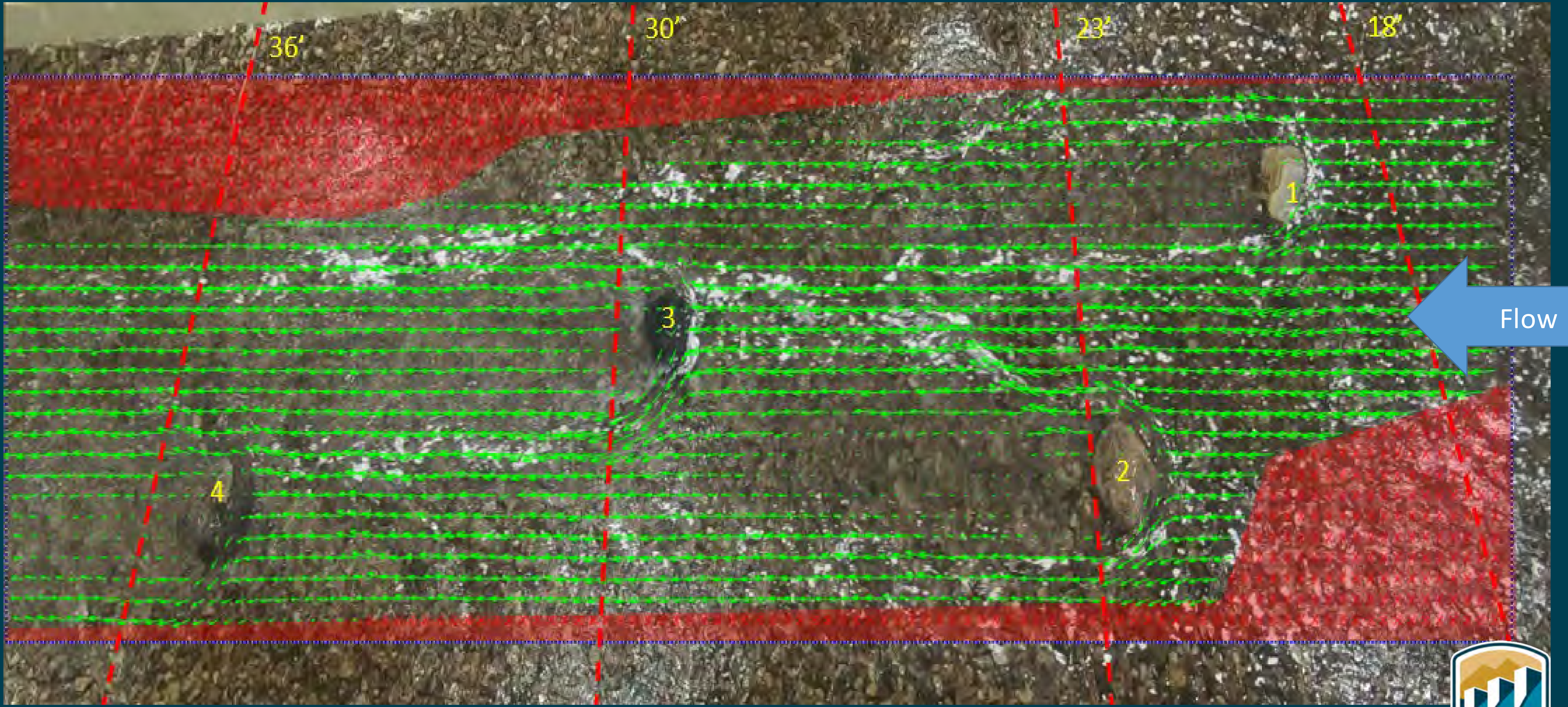


Prototype: 300 cfs. Model: 4.7 cfs

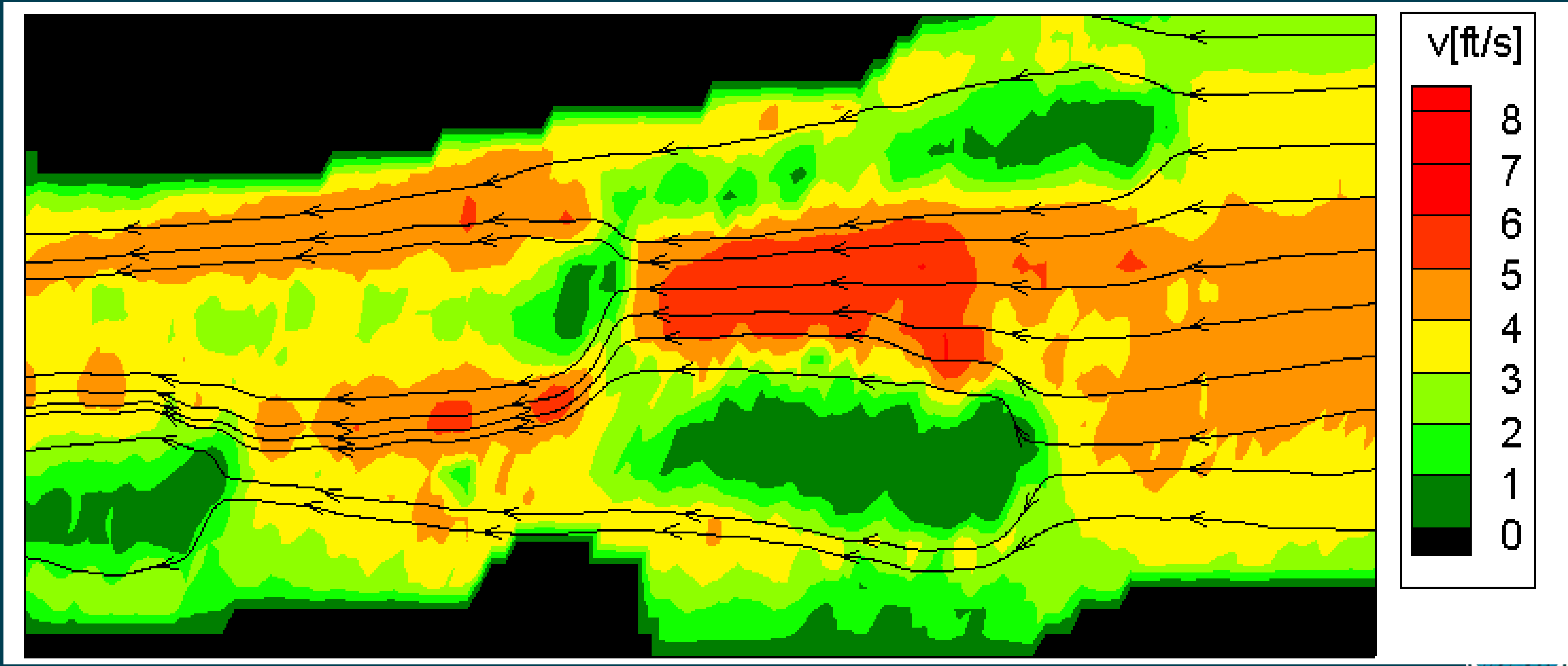
TecPlot Results: 300 cfs Baseline



LSPIV Results- 300 cfs Single Rock Medium Density



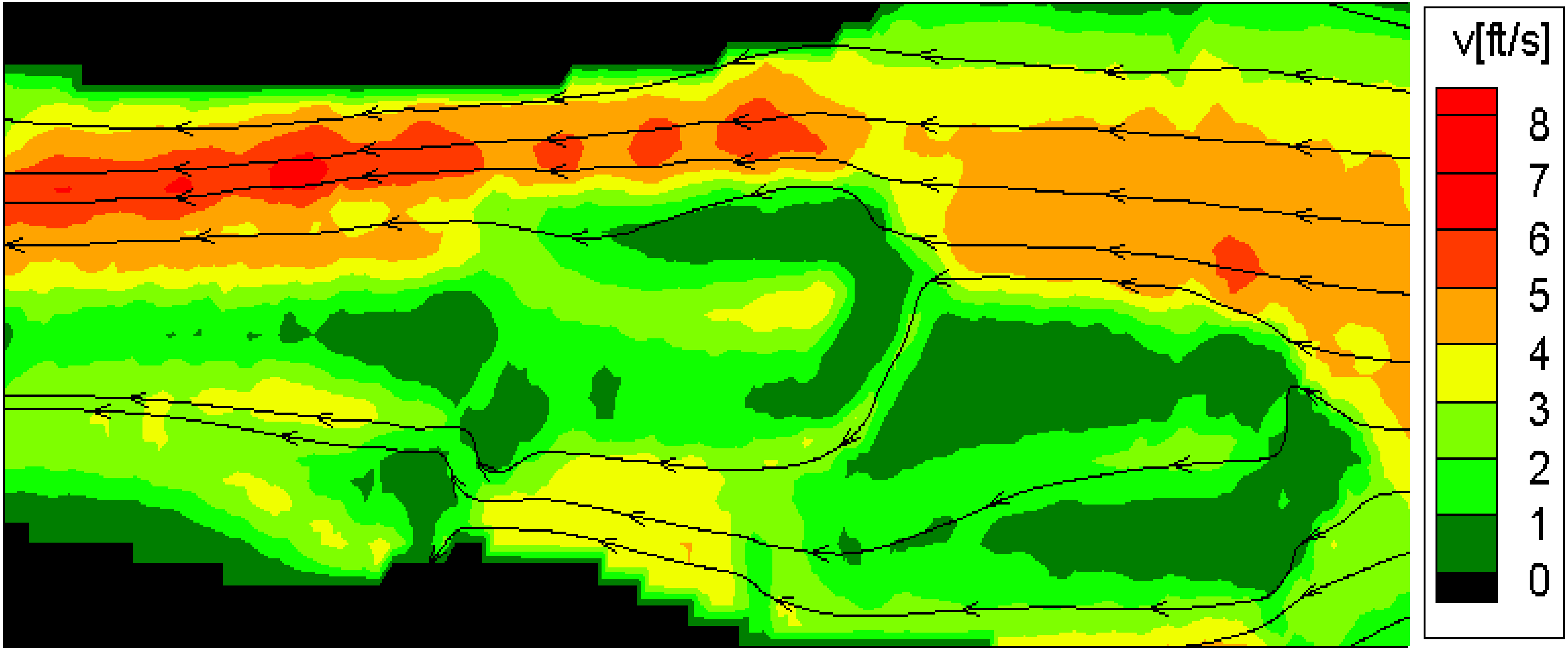
TecPlot Results: 300 cfs Single Rock Medium Density



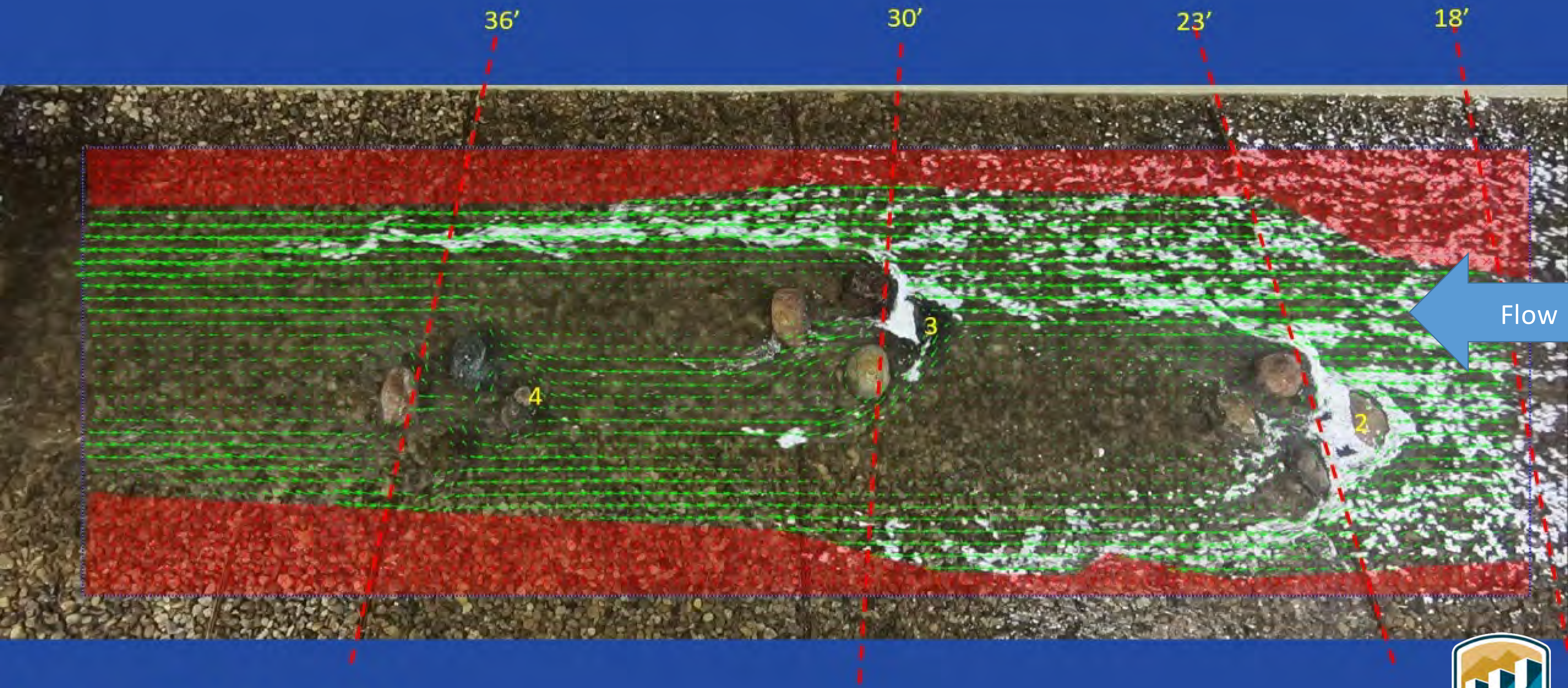
LSPIV Results- 300 cfs Upstream “V” Medium Density

Prototype: 300 cfs. Model: 4.7 cfs

TecPlot Results: 300 cfs Upstream “V” Medium Density

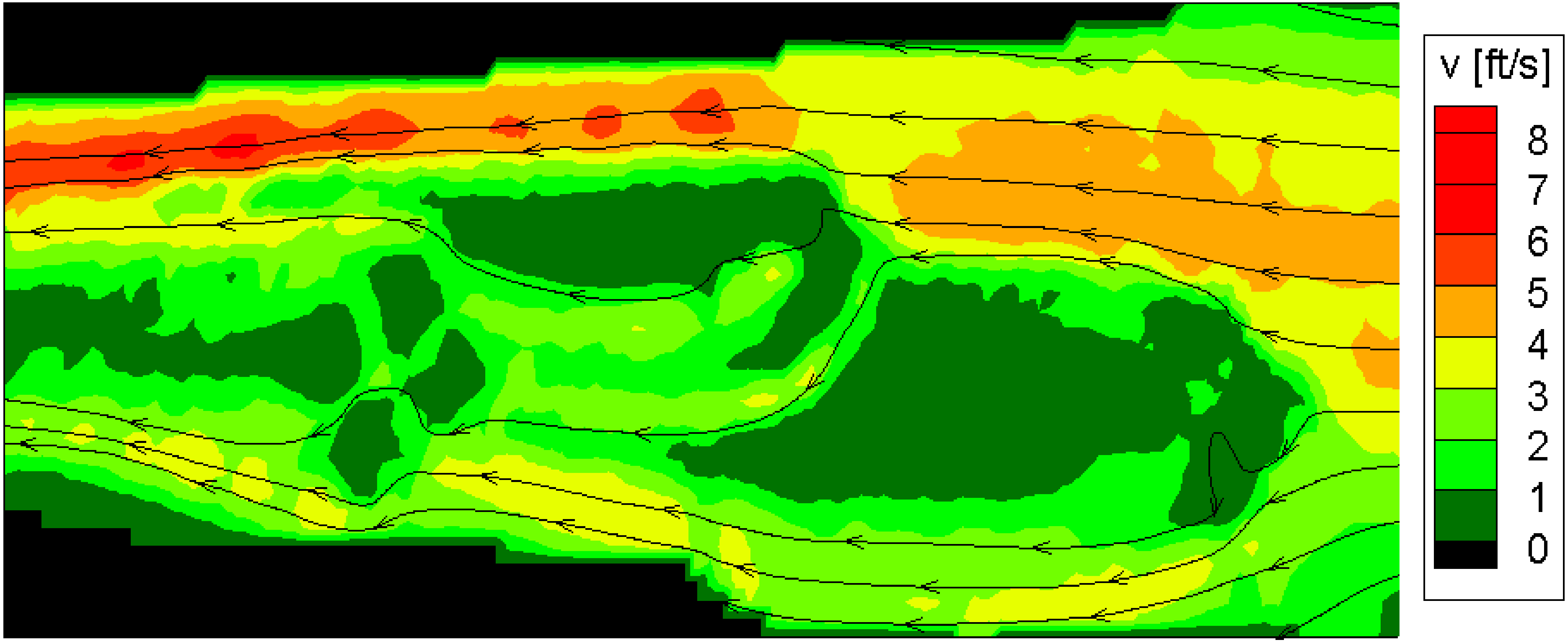


LSPIV Results- 300 cfs Diamond Medium Density

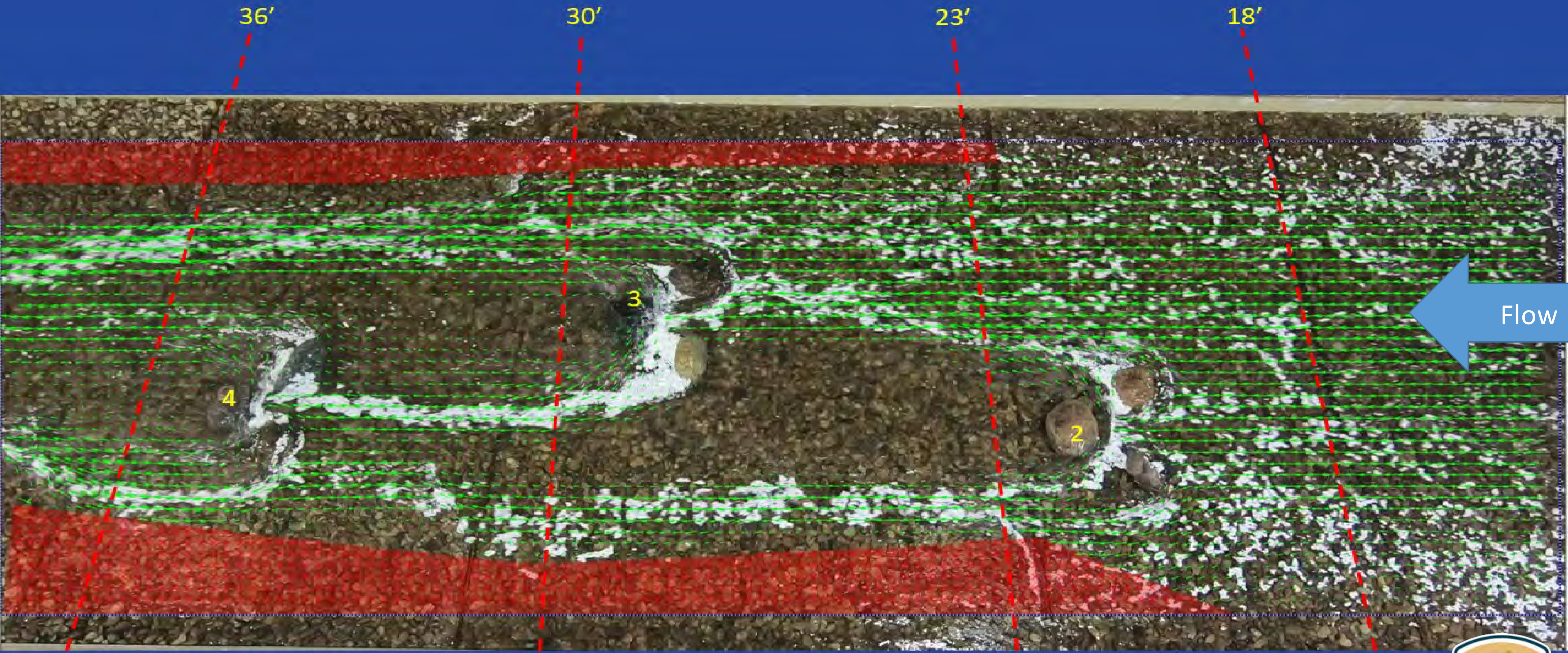


Prototype: 300 cfs. Model: 4.7 cfs

TecPlot Results: 300 cfs Diamond Medium Density

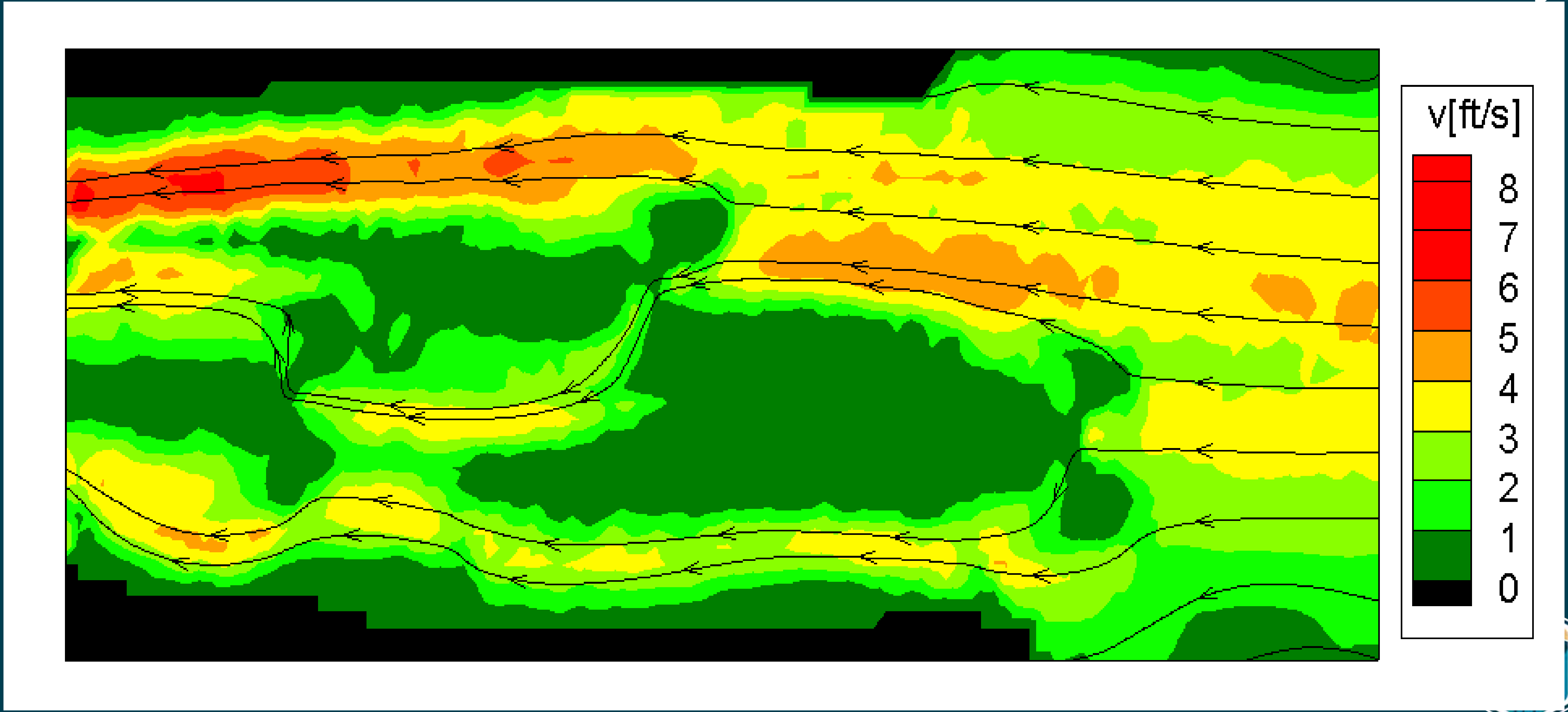


LSPIV Results- 300 cfs Downstream “V” Medium Density

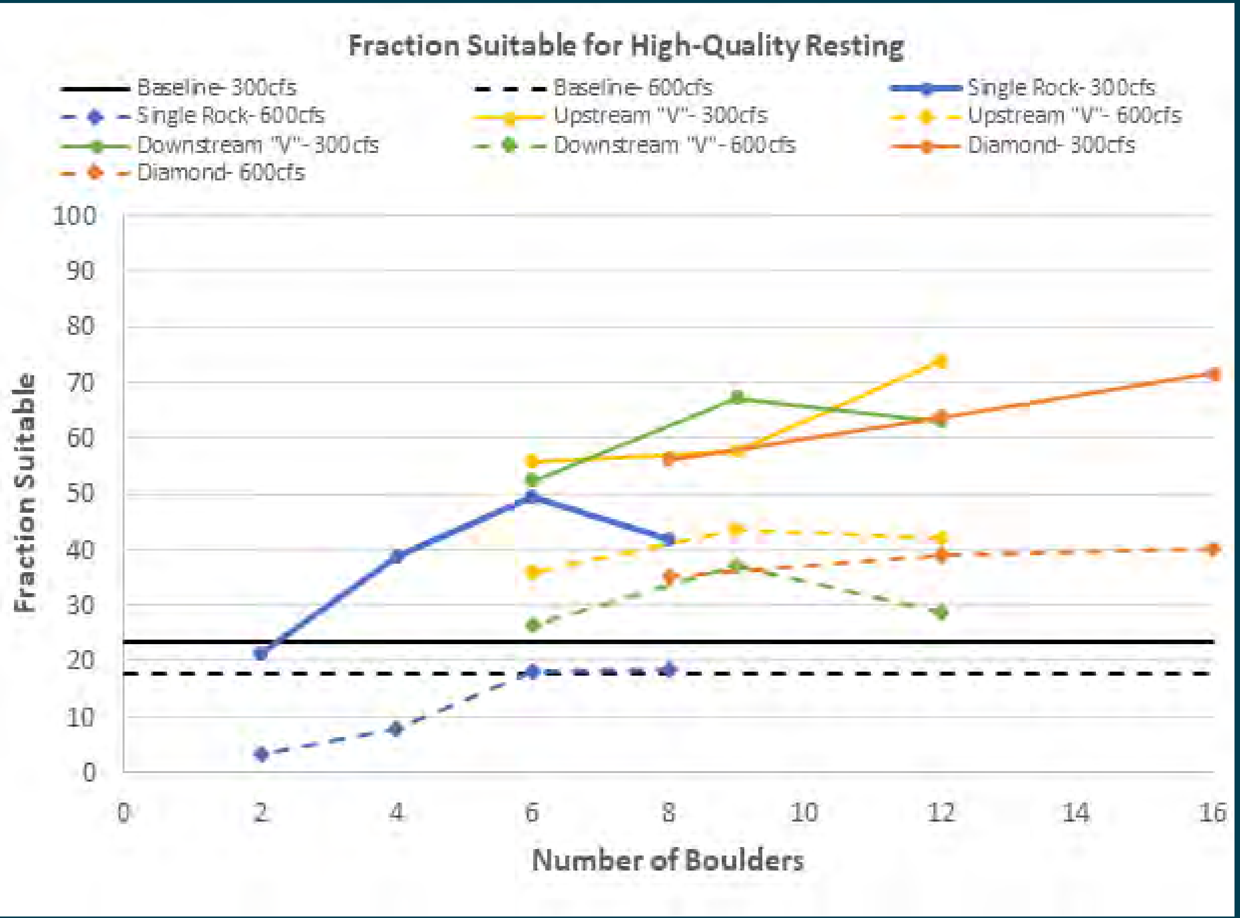


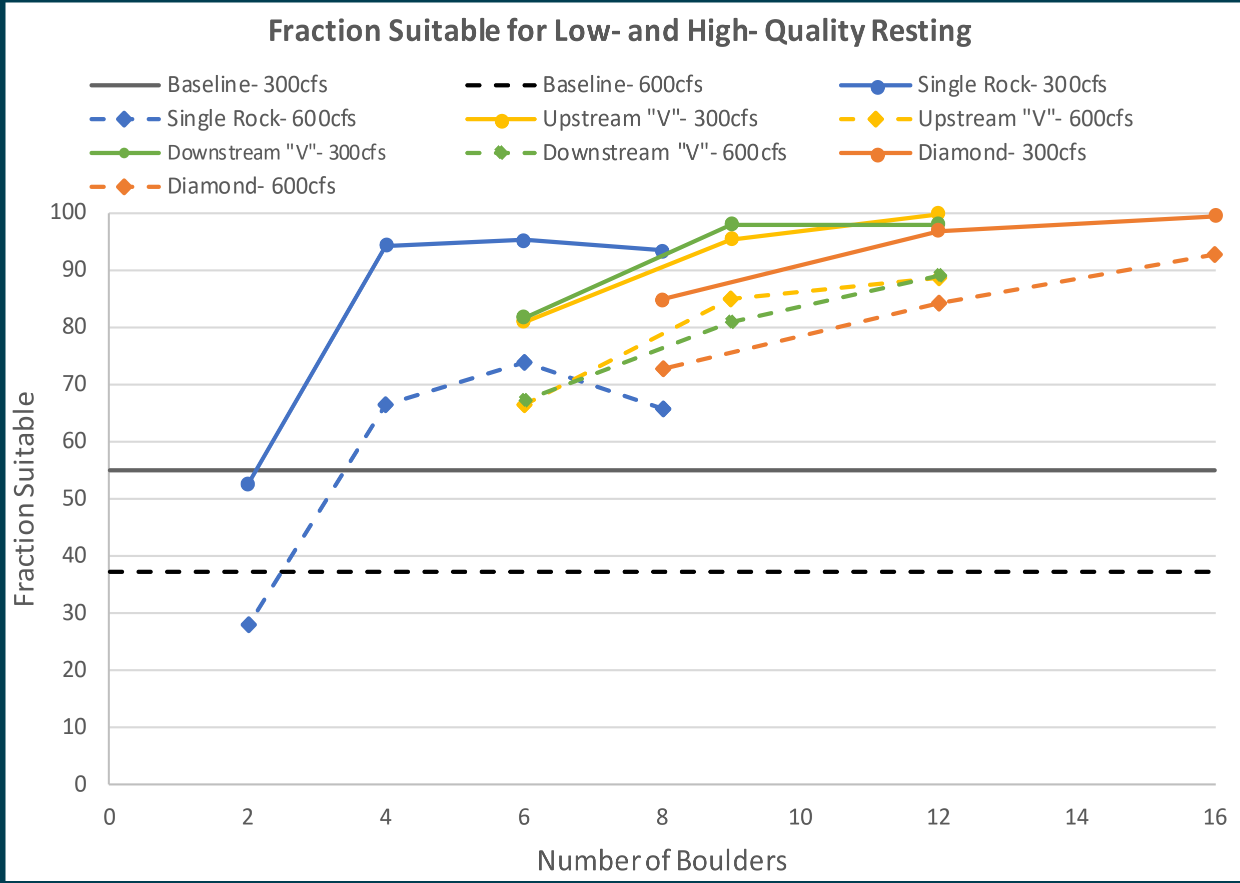
Prototype: 300 cfs. Model: 4.7 cfs

TecPlot Results: 300 cfs Downstream “V” Medium Density



Overall Results





Conclusions

- LA River existing conditions do not provide fish passage at any discharge (shallow depth and fast velocity)
- Deeper and rougher low-flow channel (LFC) is required
- Relatively simple and uniform LFC provides passage at $Q \leq 200$ cfs
- Additional design features are needed at higher flows
- Islands and bars provides the greatest resting velocity area at 300 – 1,000 cfs
- Deflectors outside LFC provides the greatest resting velocity area at 2,000 – 4,000 cfs

Conclusions (cont.)

- Useful design features provide flow obstruction (deflectors, boulders, islands and bars)
- Obstructions steer the flow and create flow separation and local backwater zones, thereby creating patches of lower velocity
- Total area of low velocity patches scales to percentage of flow area or channel width that is blocked by obstructions
- Flood stage
  - Designs generally cause a small rise in WSE at the 100-yr flow, but depends on roughness assumption
  - Designs exceed freeboard requirements at 100-yr flow

Physical Hydraulic Model Conclusions

- Single rock: creates patches of low-quality resting velocity, but not much high-quality resting area
- Downstream “V”: local backwater effects upstream from clusters
- Upstream “V”: provides most resting habitat at high flows
- Diamond “V”: performed similar to Upstream “V” but requires an additional rock

Future Research & Next Steps

- Depth criteria sensitivity: smaller min. depth, larger "holding" depth
- Design: combinations of features, increased variability
- Roughness sensitivity
- Physical Model:
  - Utilize a wider channel
  - Different arrangements, density, and location
  - Flow obstructing alternatives other than boulder clusters
  - Comparison with 2D numerical model
- Group of LA River stakeholders has received grant for 60% design

Acknowledgements

- Reclamation's Science and Technology (S&T) Program
- Reclamation's Southern California Area Office (Doug McPherson)
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    - Vince Benoit
    - Blair Greimann

https://www.usbr.gov/research/projects/detail.cfm?id=1726

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