SKAGIT RIVER GORGE BYPASS REACH HYDRAULIC AND INSTREAM FLOW MODEL DEVELOPMENT STUDY INTERIM REPORT

ATTACHMENT G

WORKSHOP 1 MATERIALS

Seattle City Light

MEETING AGENDA

Skagit Hydroelectric Project Relicensing Meeting

Fish Passage Evaluations and Modeling in the Bypass Reach – Technical Meeting

May 17, 2021, 1:00 PM to 5:00 PM

Webex Meeting: https://meethdr.webex.com/meethdr/j.php?MTID=md626437a9c68be9a255308c98bc5bce8

Conference Call: 1-408-418-9388 (Meeting ID: 187 136 5797)

MEETING OBJECTIVES

- **Fish Passage Evaluation Objectives** – Provide an overview of study objectives, expectations, possible outcomes, and limitations.
- **Fish Passage Evaluation Methods** – Discuss in more detail the approach and strategies to evaluating fish passage in the Bypass Reach.
- **Hydraulic Modeling** – Discuss the role of modeling in the overall fish passage evaluation methodology and provide examples of how hydraulic models have been used at other projects to gain insight on the ability of fish to ascend various hydraulic features.
- **Use of HEC-RAS 2D** – Address concerns regarding use of HEC-RAS 2D as a fish passage evaluation tool.
- **LP Discussion on Study Design**

AGENDA

1:00 – 1:10 p.m. (10 min)	**Introductions** – *Joy Juelson (Triangle Facilitator)* ▪ Roll Call Introduction
1:10 – 1:20 (10 min)	**Meeting Objectives and Agenda Overview –** *Joy Juelson (Triangle Facilitator) and Mike Garello (HDR)* ▪ Review Meeting Objectives and Agenda
1:20 – 1:40 (20 min)	**Evaluation of Fish Passage in the Bypass Reach** – *Mike Garello (HDR)* ▪ Overview of study objectives ▪ Influence of results on related studies ▪ Limitations of fish passage evaluation
1:40 – 2:05 (25 min)	**Observable Discharges** – *Malcolm Leytham (NHC)* ▪ Discussion of releases selected for instream-flow and fish passage evaluation ▪ Opportunity for data collection at higher flows
2:05 – 2:10 (5 min)	**Break**
2:10 – 2:55 (45 min)	**Fish Passage Evaluation Methods and Tools** – *Mike Garello (HDR) and Chris Long (NHC)* ▪ Process overview of fish passage evaluation methodology ▪ Biological and ecohydraulic metrics used in fish passage evaluations ▪ Strategies for site inspection and visual observation ▪ Collection of flow magnitude, depth, elevation, and velocity data ▪ Example Fish Passage Evaluation Projects o Summary of project examples illustrating the wide range of numerical strategies used in fish passage evaluations

2:55 – 3:55 (60 min)	**Use of Hydraulic Model to Support Fish Passage Interpretations** – *Mike Garello (HDR) and Chris Long (NHC)* ▪ The role of modeling in the proposed study ▪ Selection and perceived efficacy of different modeling platforms ▪ How HEC-RAS 2D will be used in the fish passage evaluation strategy
3:55 – 4:00 (5 min)	**Break**
4:00 – 4:40 (40 min)	**LP Discussion on Study Design** - *Facilitator and Meeting Participants*
4:40 – 5:00 (20 min)	**Schedule, Action Items, Next Steps** – *Facilitator and Meeting Participants* ▪ Study schedule review ▪ Review meeting action items ▪ Next steps
5:00	**Meeting Adjourned**

SKAGIT RIVER INSTREAM FLOW STUDY FISH PASSAGE EVALUATIONS AND MODELING IN BYPASS REACH

May 17, 2021

INTRODUCTIONS

- Role call and introduction of meeting attendees

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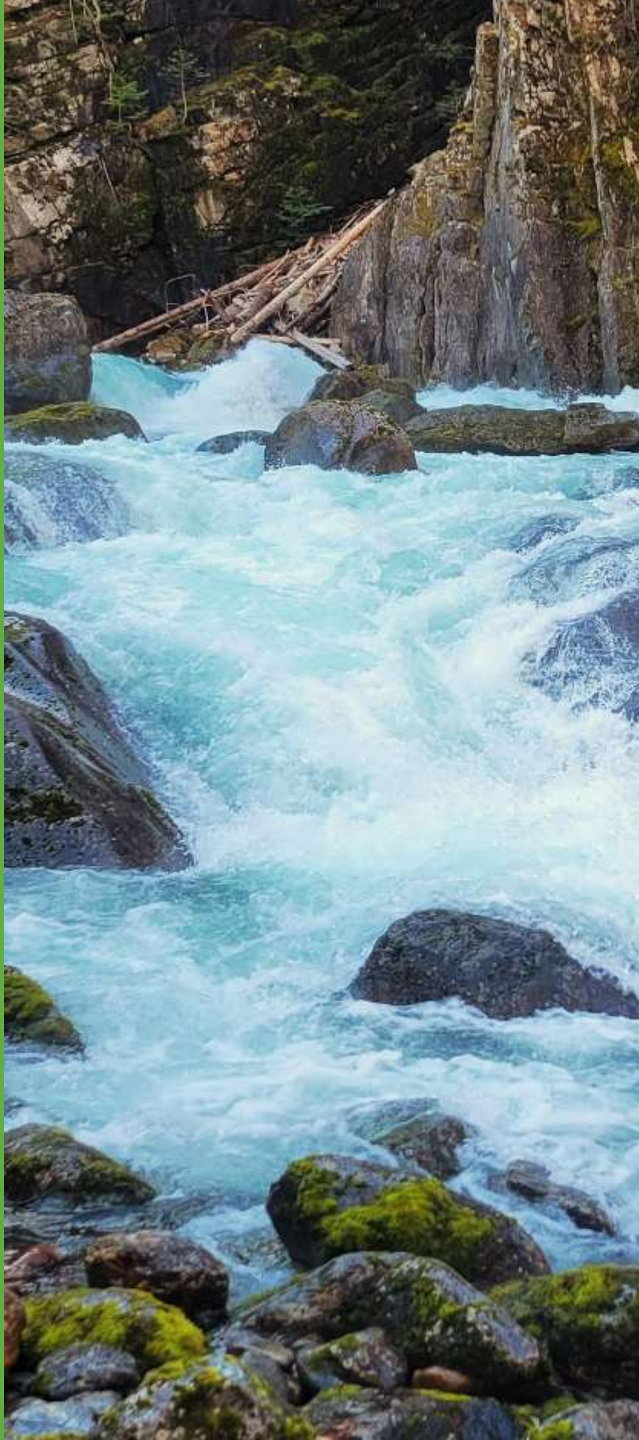
MEETING OBJECTIVES AND AGENDA OVERVIEW



MEETING OBJECTIVES AND AGENDA OVERVIEW

Meeting Objectives

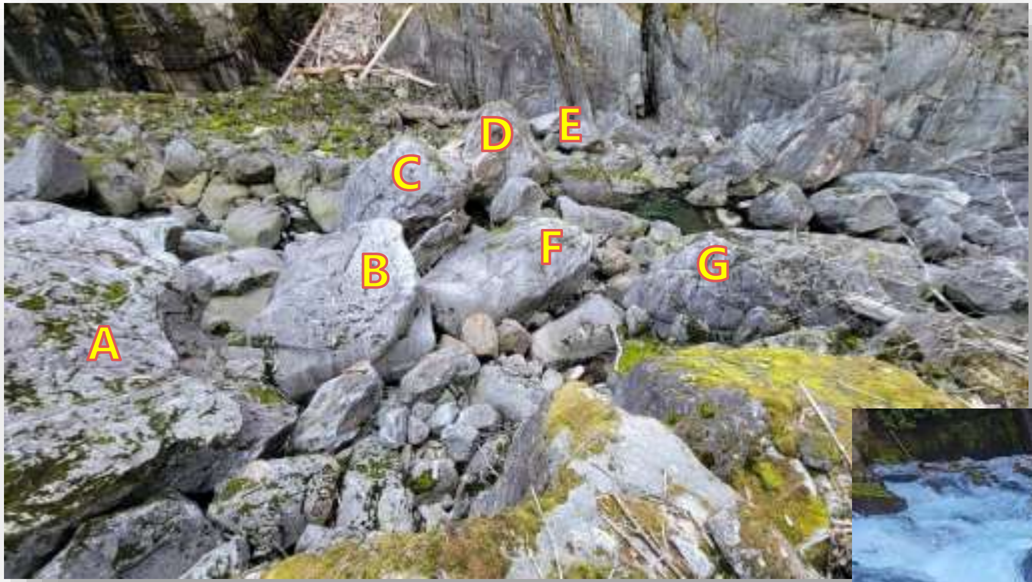
- Review fish passage evaluation objectives
- Discuss fish passage evaluation methods
- Discuss the role of hydraulic modeling in fish passage evaluations
- Address the strategy using HEC-RAS 2D
- LP concurrence with study design

MEETING OBJECTIVES AND AGENDA OVERVIEW

<u>Agenda Overview</u>

- Evaluation of fish passage in the Bypass Reach
- Observable discharges
- Fish Passage evaluation methods and tools
- Use of hydraulic models and HEC-RAS 2D
- LP concurrence with study design

MEETING OBJECTIVES AND AGENDA OVERVIEW



Base flow ~5 to 10 cfs

~1,200 cfs

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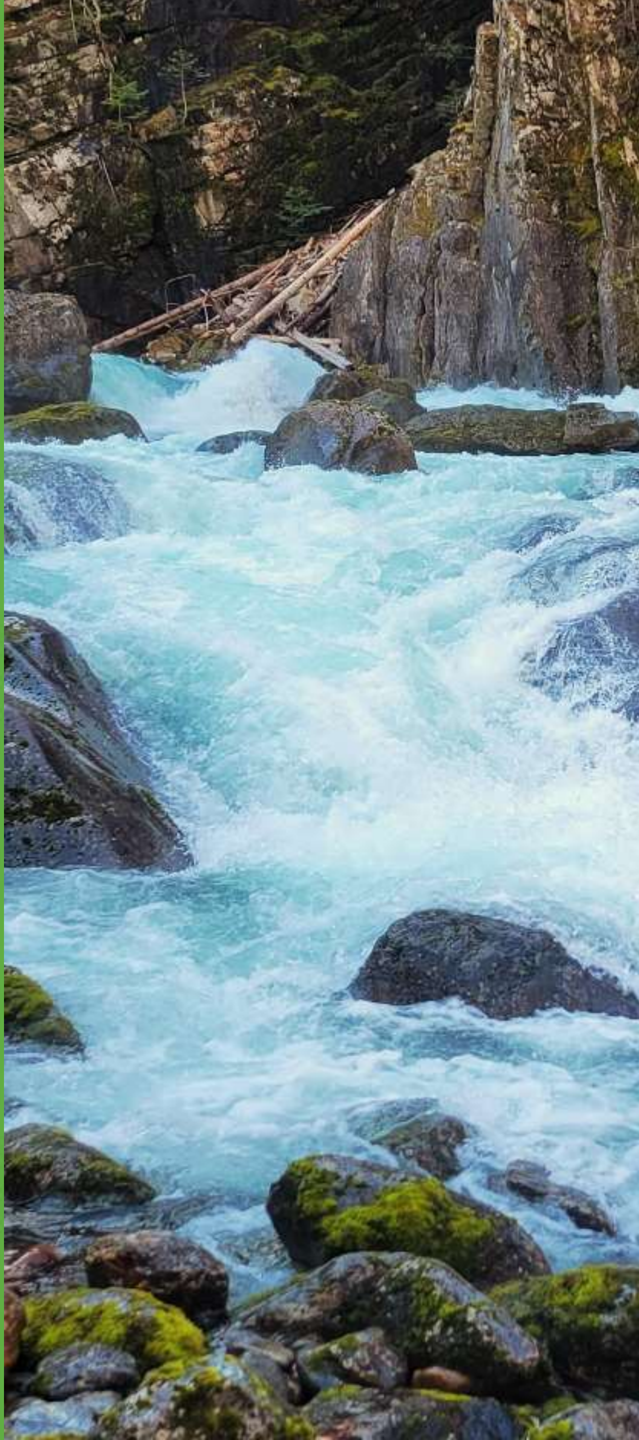
FISH PASSAGE EVALUATION IN THE BYPASS REACH



EVALUATION OF FISH PASSAGE IN THE BYPASS REACH

Key Objectives

- Gain a more detailed understanding of current feature geometry
- Characterize hydraulic pathways that potentially accommodate fish passage
- Better understand conditions that impede and promote fish passage for species considered
- Continuity among features
- Inform related, concurrent studies

EVALUATION OF FISH PASSAGE IN THE BYPASS REACH

Influence on related studies

- Fish Passage Facility Alternatives Study
  - Abundance and rate of passage influences facility type, size, and complexity
  - Potential siting of fish passage facilities to be studied in alternatives assessment
- Habitat and Production Potential
  - Conditions required for passage
  - Use and access of habitat in the bypass reach

EVALUATION OF FISH PASSAGE IN THE BYPASS REACH

Study limitations

- Factors that cause inherent variability
  - Prediction of fish behavior and ability
  - Unique site-specific conditions influence input and output – site complexity
- Level of certainty (qualitative vs. quantitative)
- All methods subject to professional judgement, experience, and interpretation

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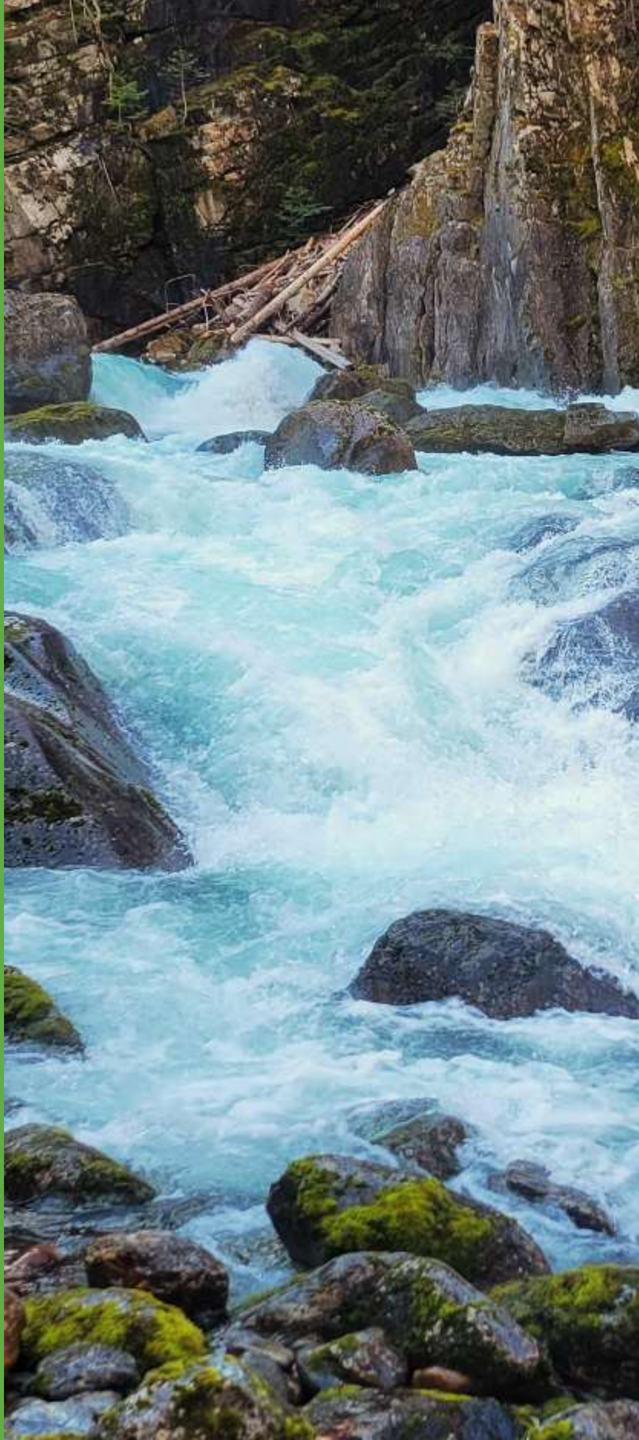
OBSERVABLE DISCHARGES



OBSERVABLE DISCHARGES

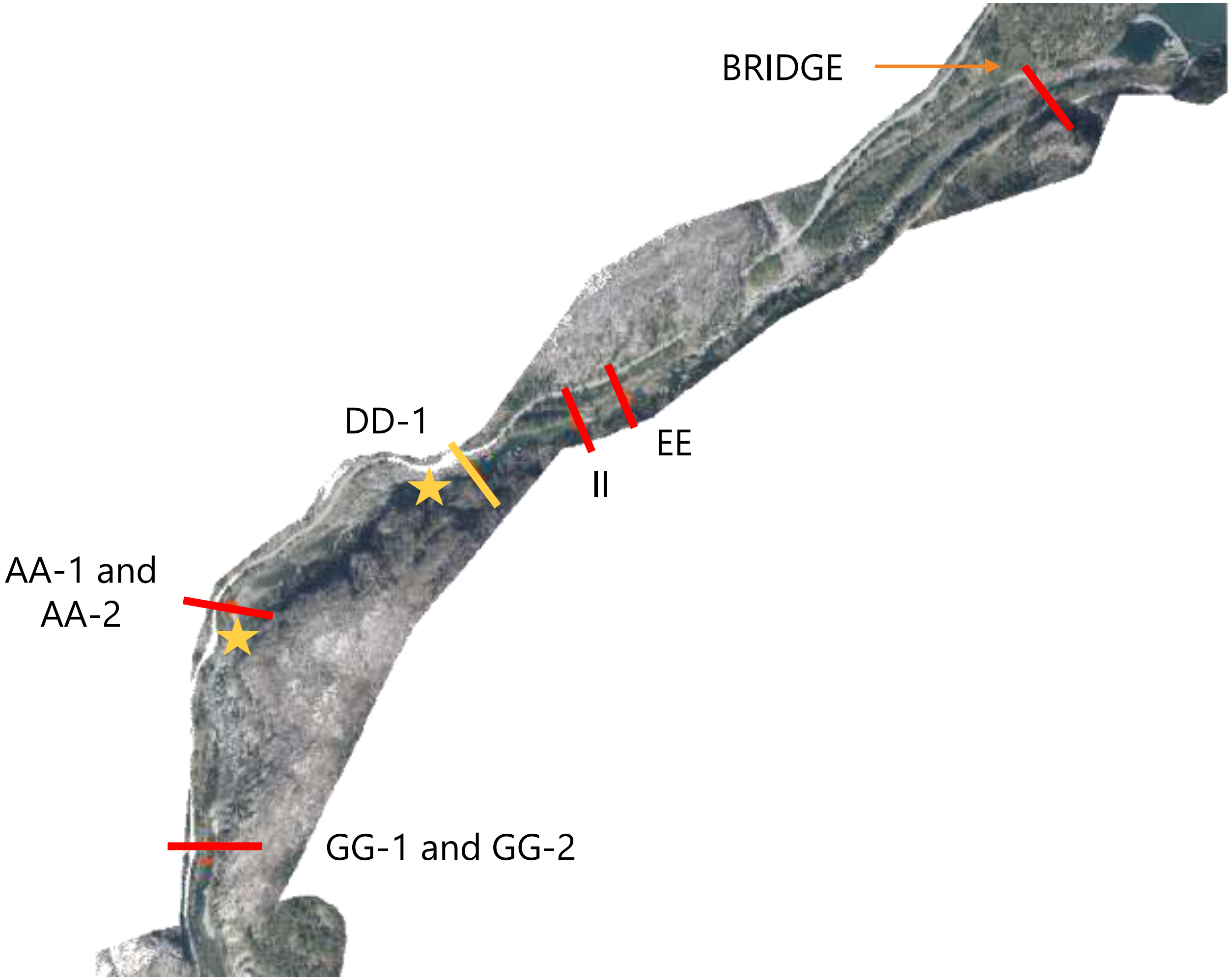
- Releases selected for instream-flow and fish passage evaluation
- Opportunity for data collection at higher flows

PROPOSED DATA COLLECTION

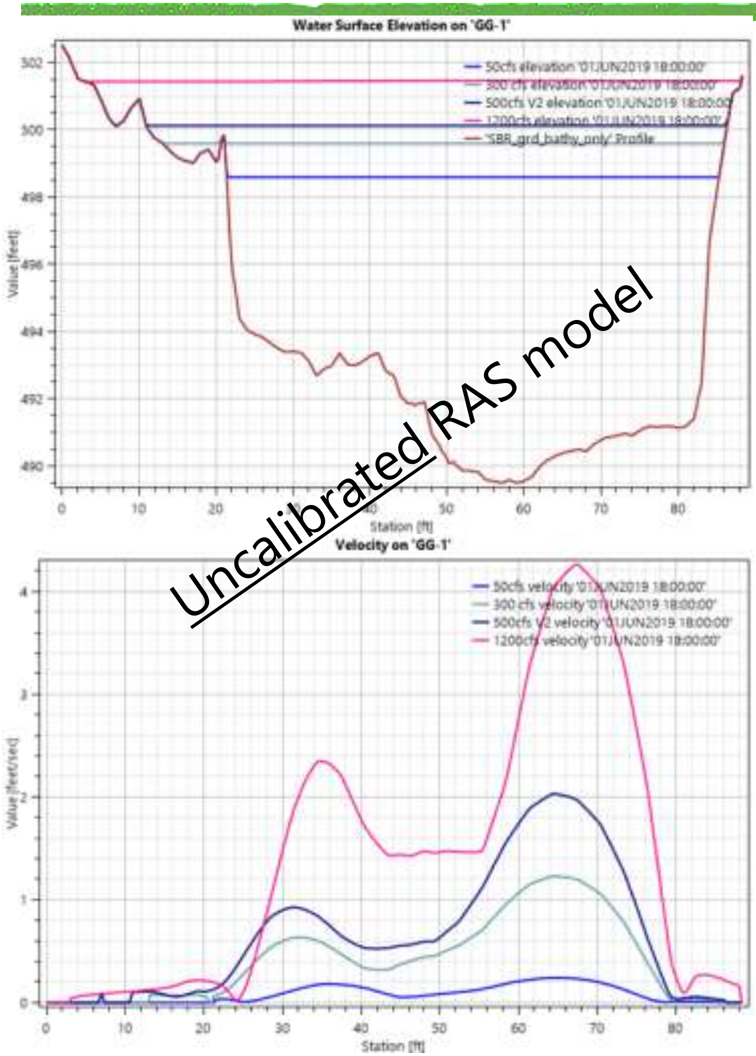
- Water surface elevation profiles for baseflow (no release from Gorge Dam) and controlled releases of 50 cfs, ~300 cfs, 500 cfs and 1,200 cfs.
- Detailed monitoring (depth, velocity, discharge) at 5 transects under baseflow and controlled releases.
- 12 continuous water level recorders provide data to refine model in passage barrier sections and support fish passage evaluation – for both controlled releases and unscheduled spill in monitoring period.
- Time lapse cameras.
- Drone imagery for controlled releases (subject to drone use authorization)

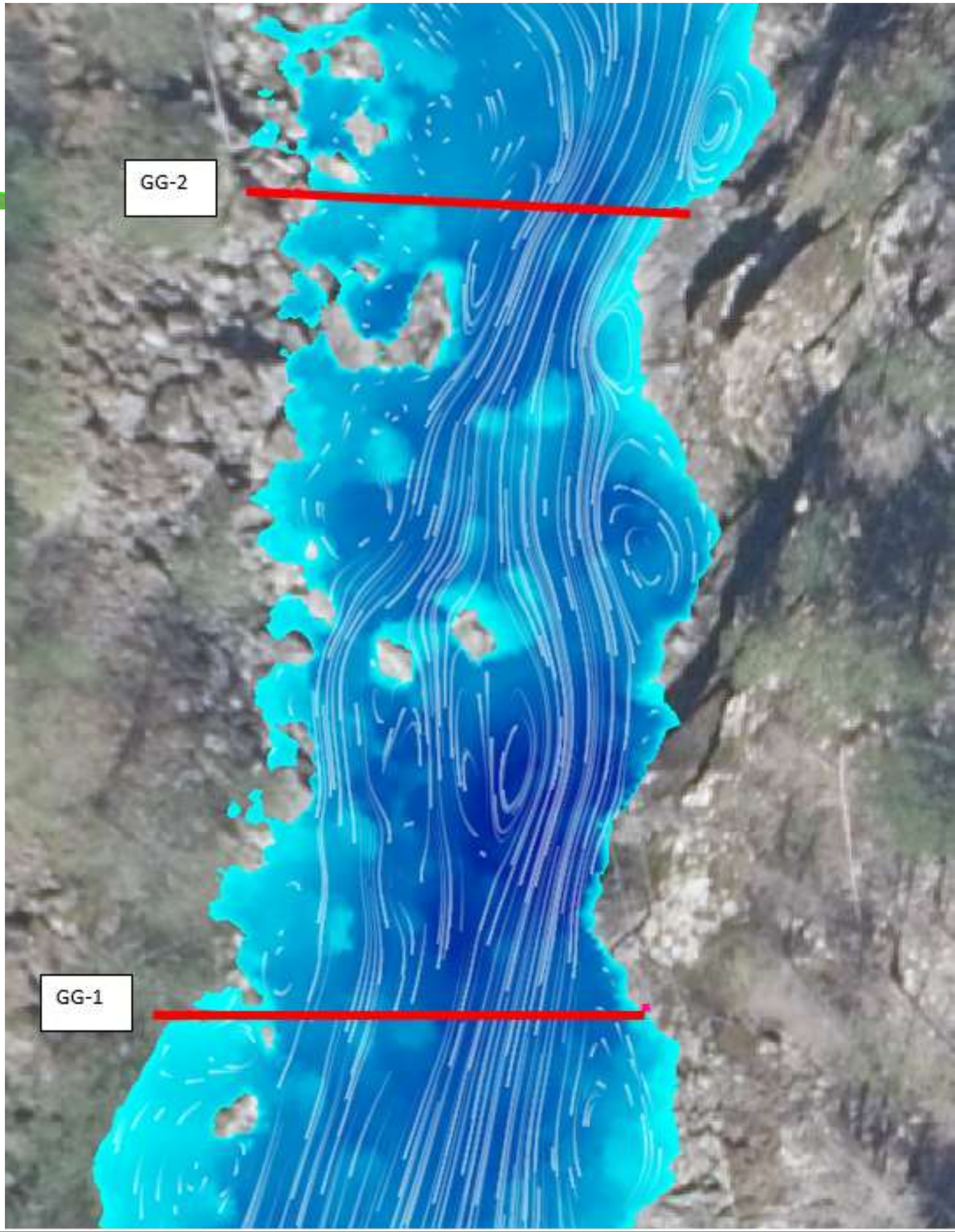
TRANSECTS

- GG-1
- **GG-2**
- **AA-1**
- AA-2
- DD
- **II**
- **EE**
- **BRIDGE**



TRANSECT GG-1





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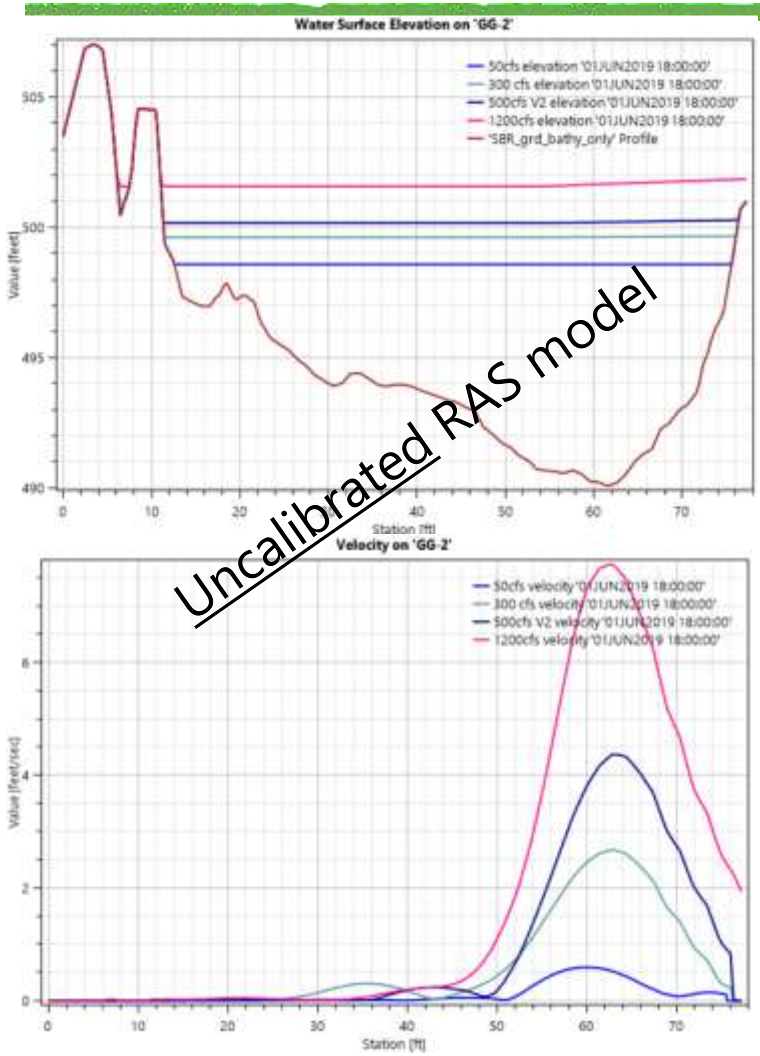

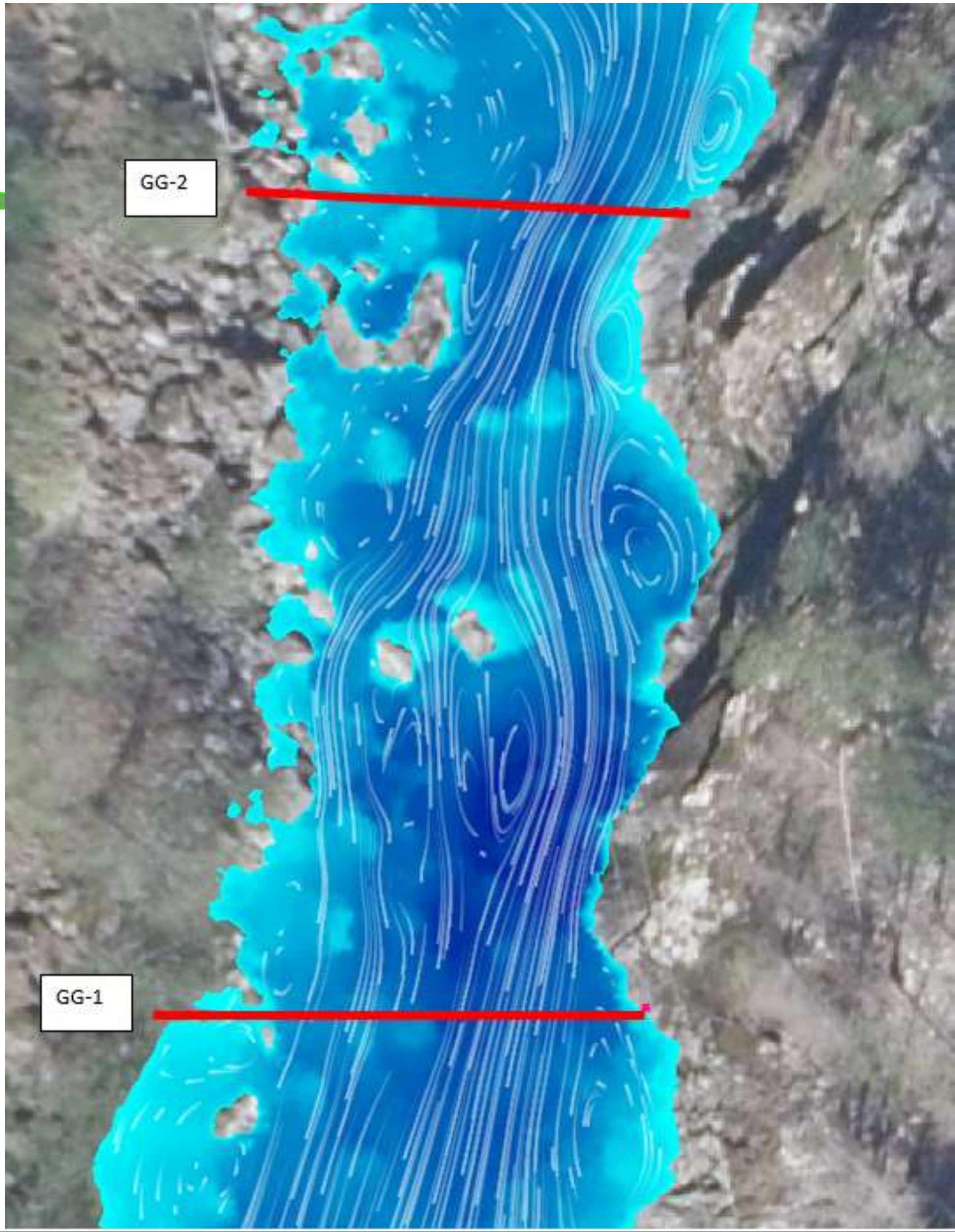

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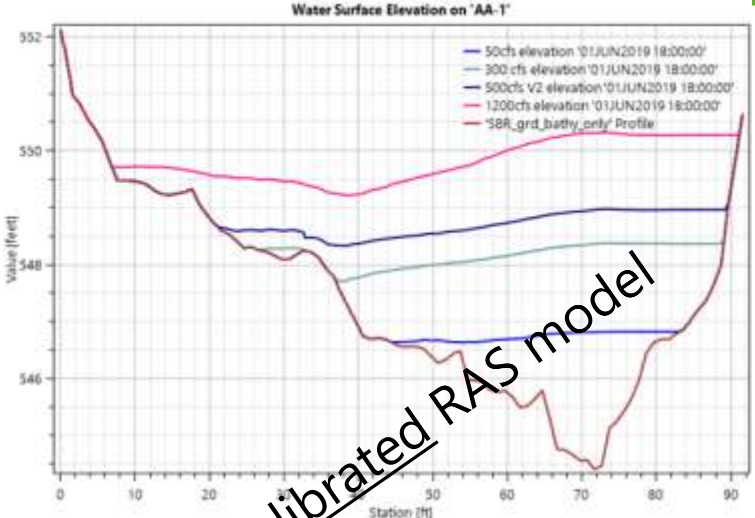

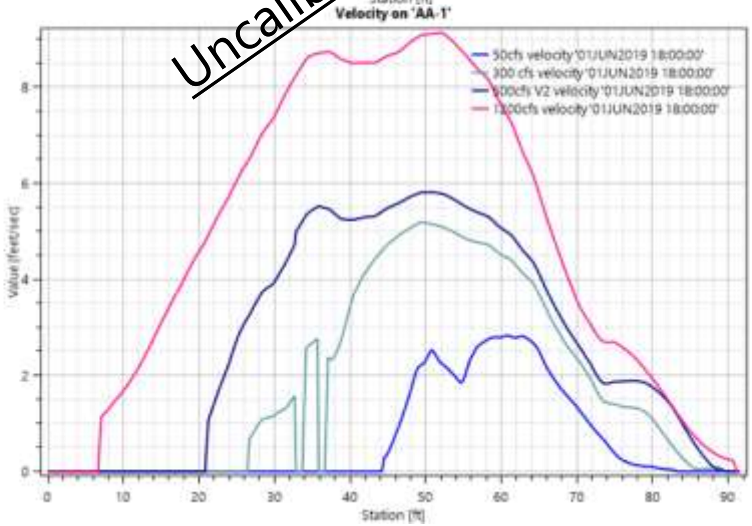

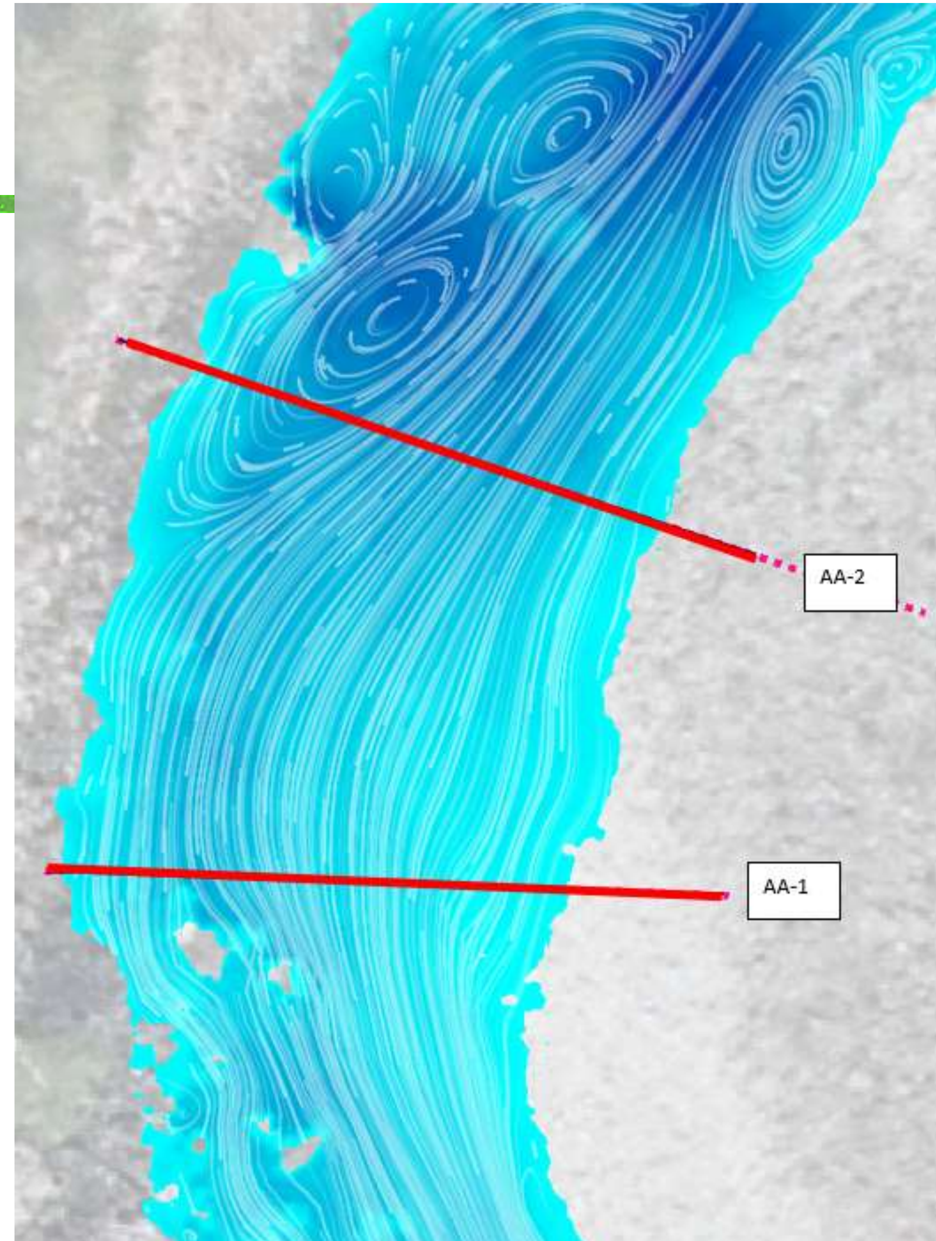

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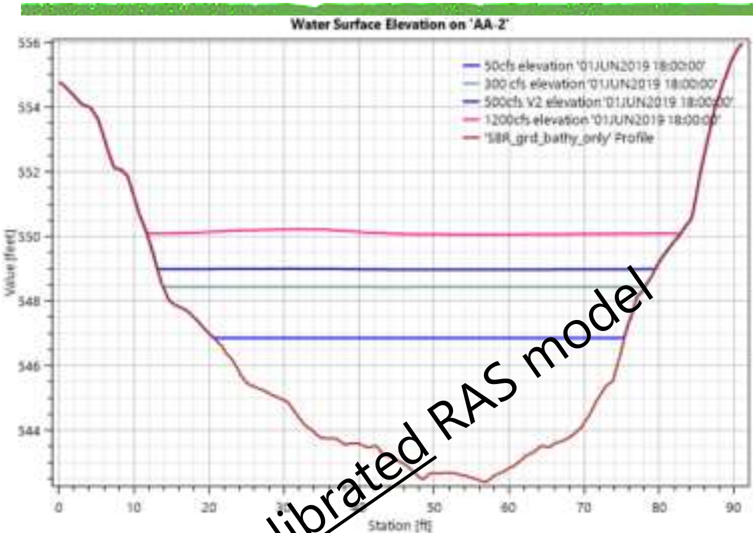
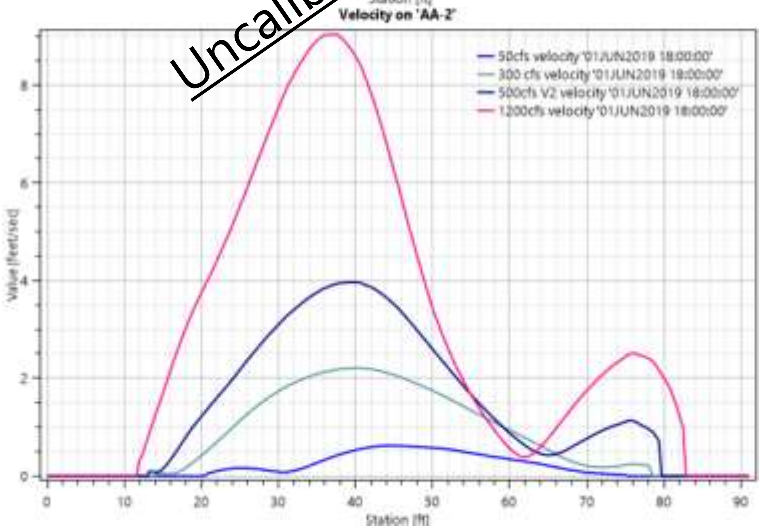
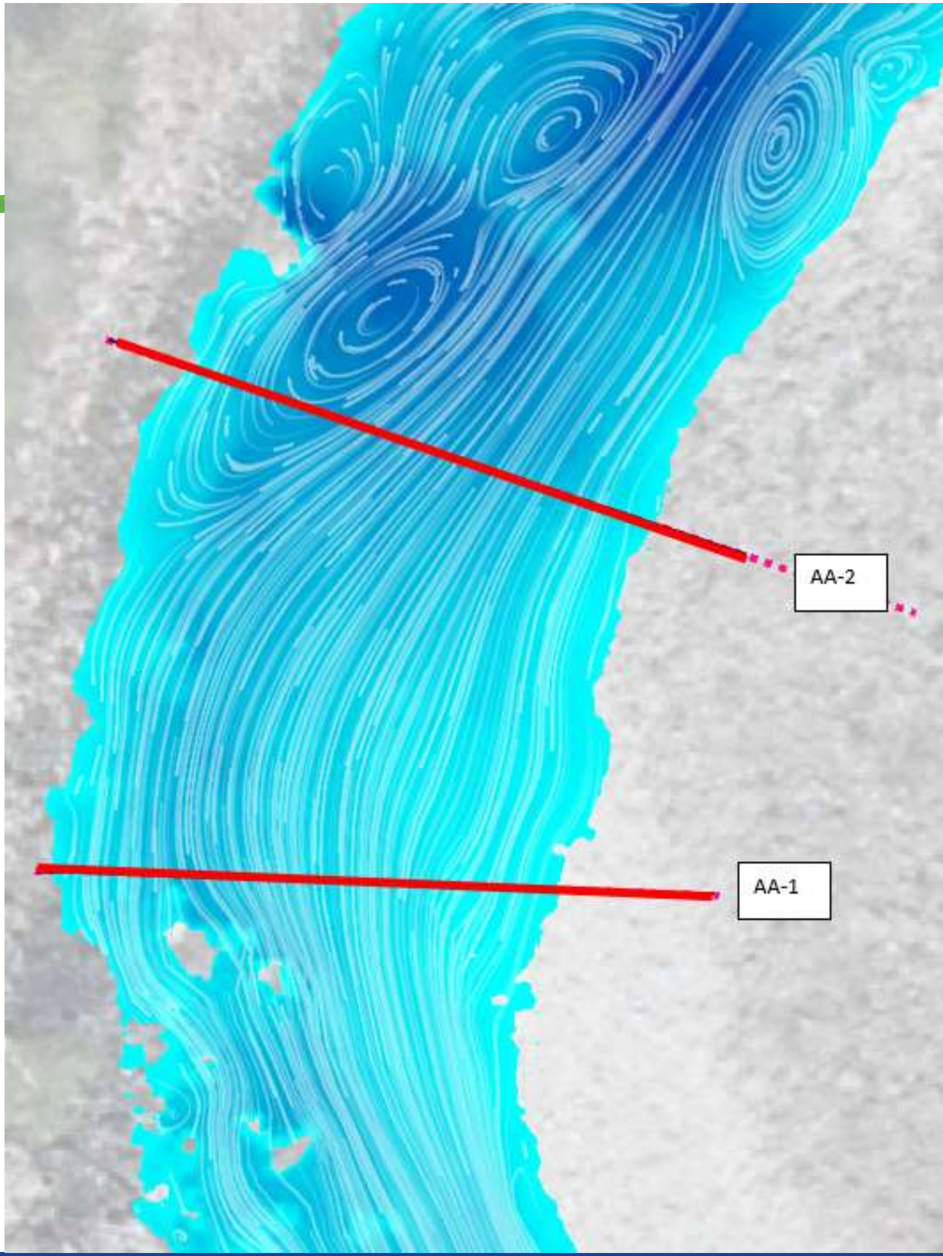
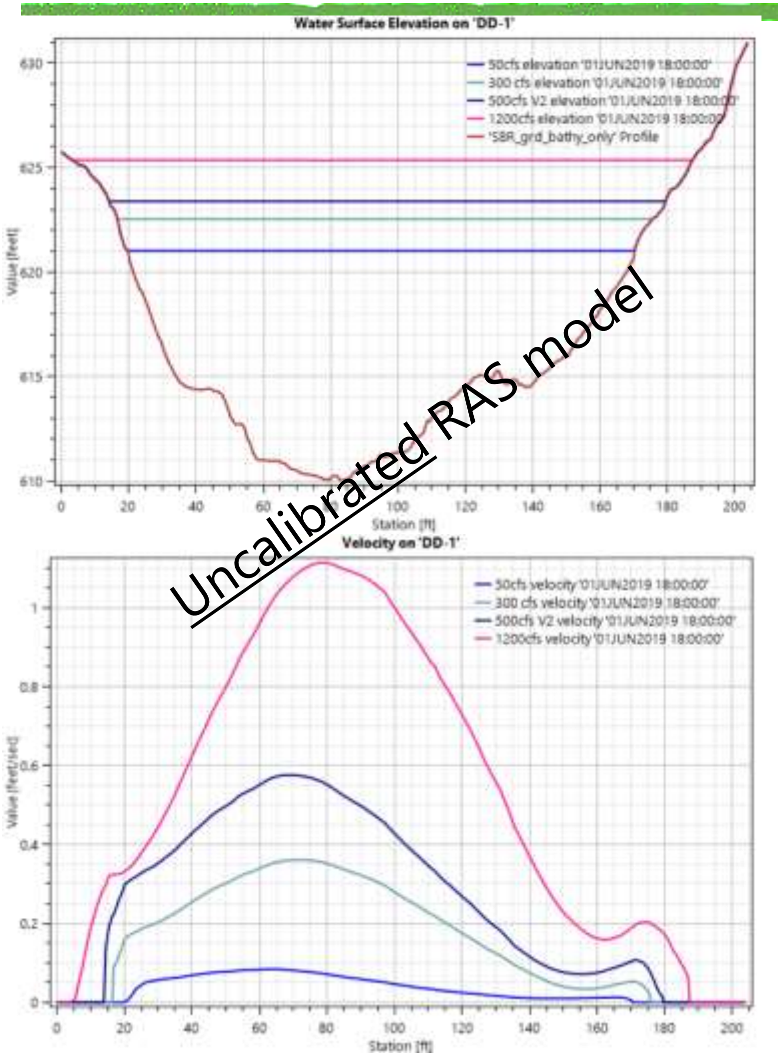




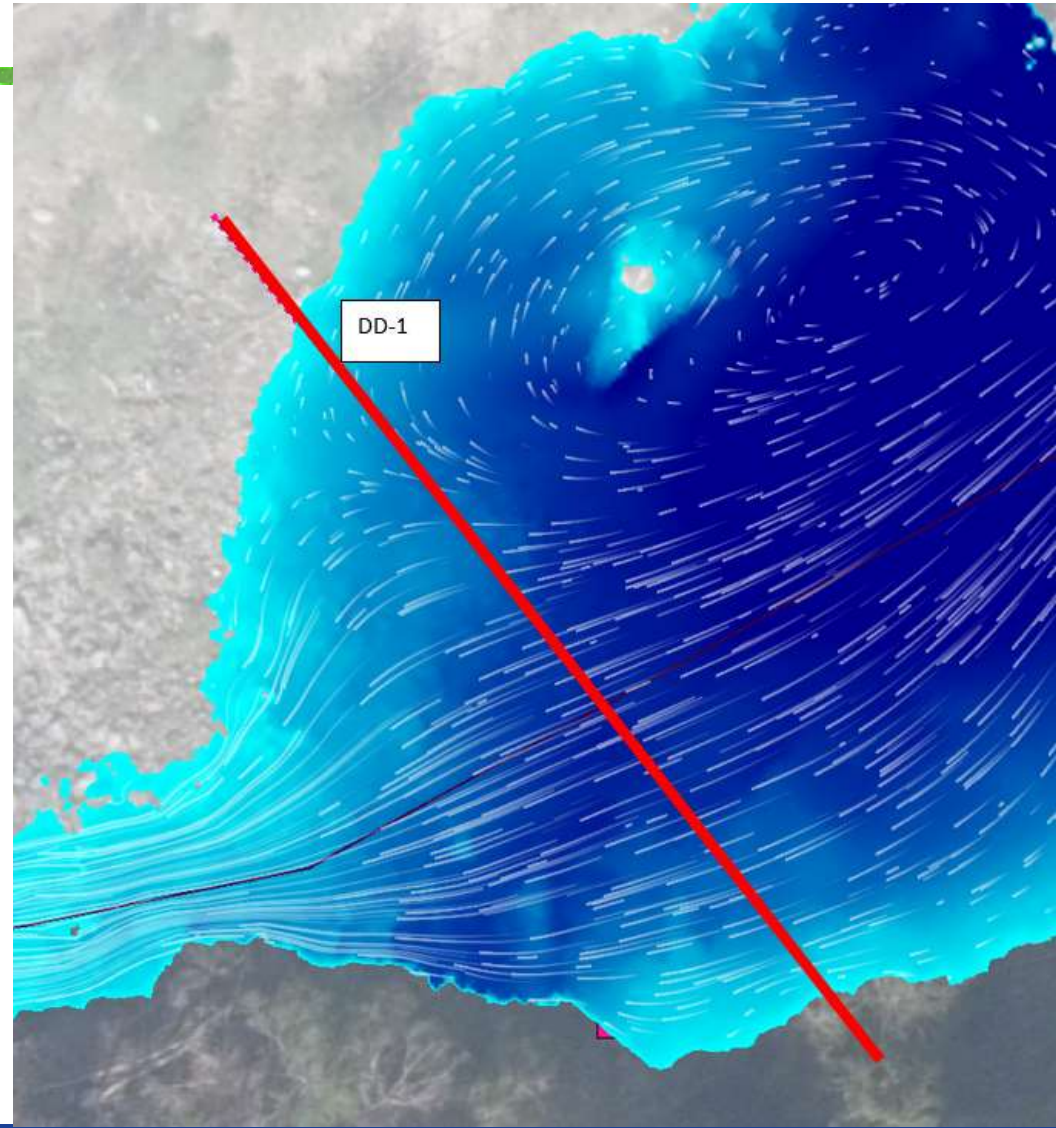
Uncalibrated RAS model



TRANSECT DD

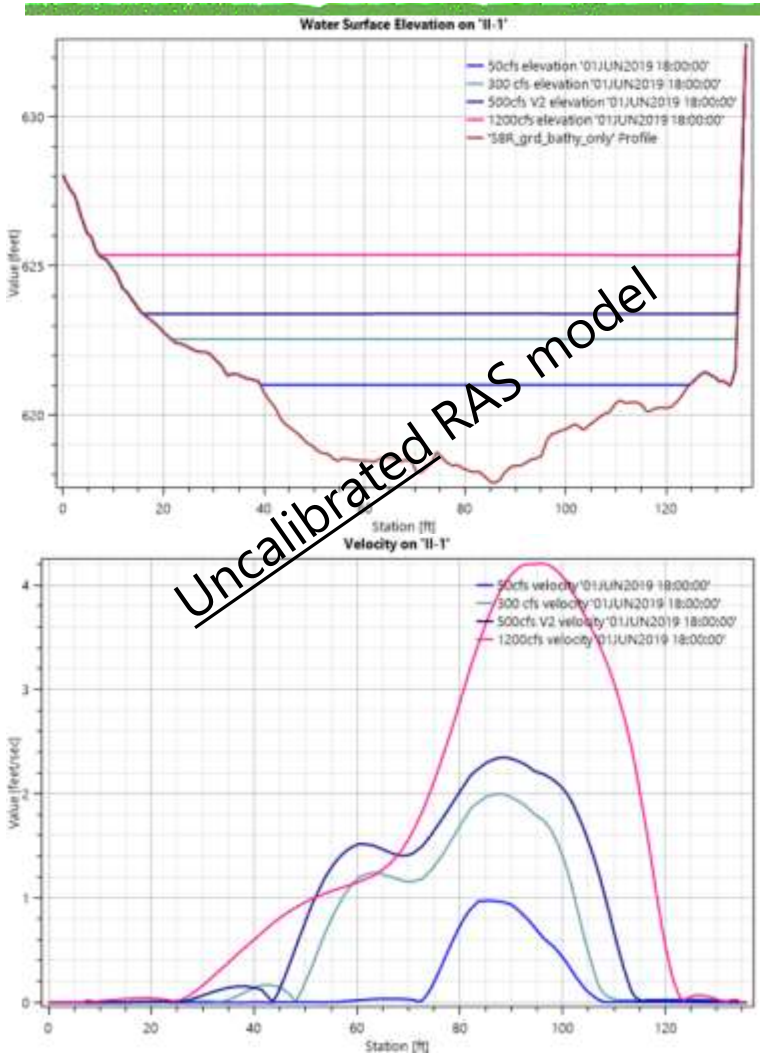


Water Surface Elevation on 'DD-1'
50cfs elevation '01JUN2019 18:00:00'
300 cfs elevation '01JUN2019 18:00:00'
500cfs V2 elevation '01JUN2019 18:00:00'
1200cfs elevation '01JUN2019 18:00:00'
'SBR_grd_bathy_only' Profile
Value [feet]
630
625
620
615
610
0
20
40
60
100
120
140
160
180
200
Station [ft]
Velocity on 'DD-1'
50cfs velocity '01JUN2019 18:00:00'
300 cfs velocity '01JUN2019 18:00:00'
500cfs V2 velocity '01JUN2019 18:00:00'
1200cfs velocity '01JUN2019 18:00:00'
Value [feet/sec]
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
140
160
180
200
Station [ft]
Uncalibrated RAS model

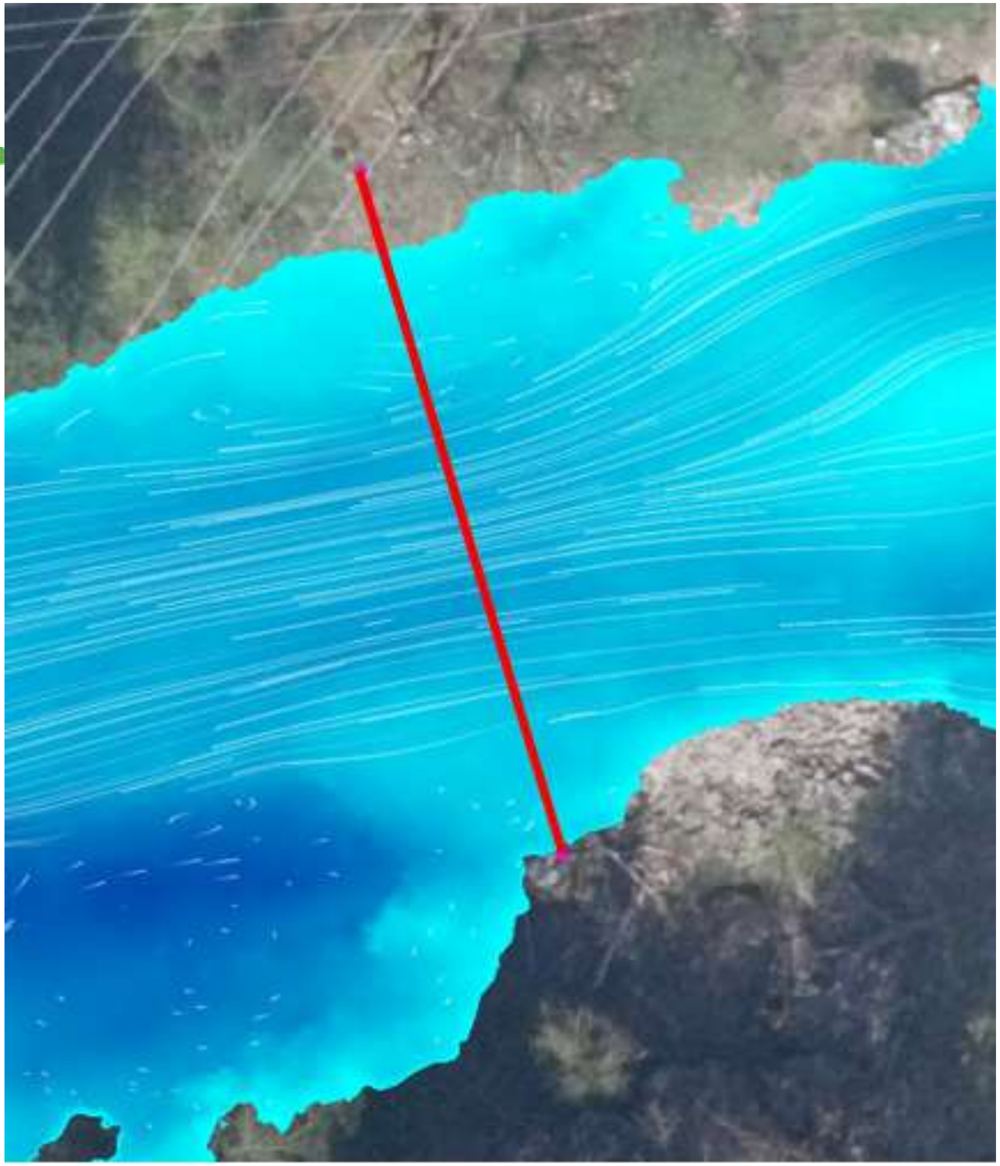


DD-1

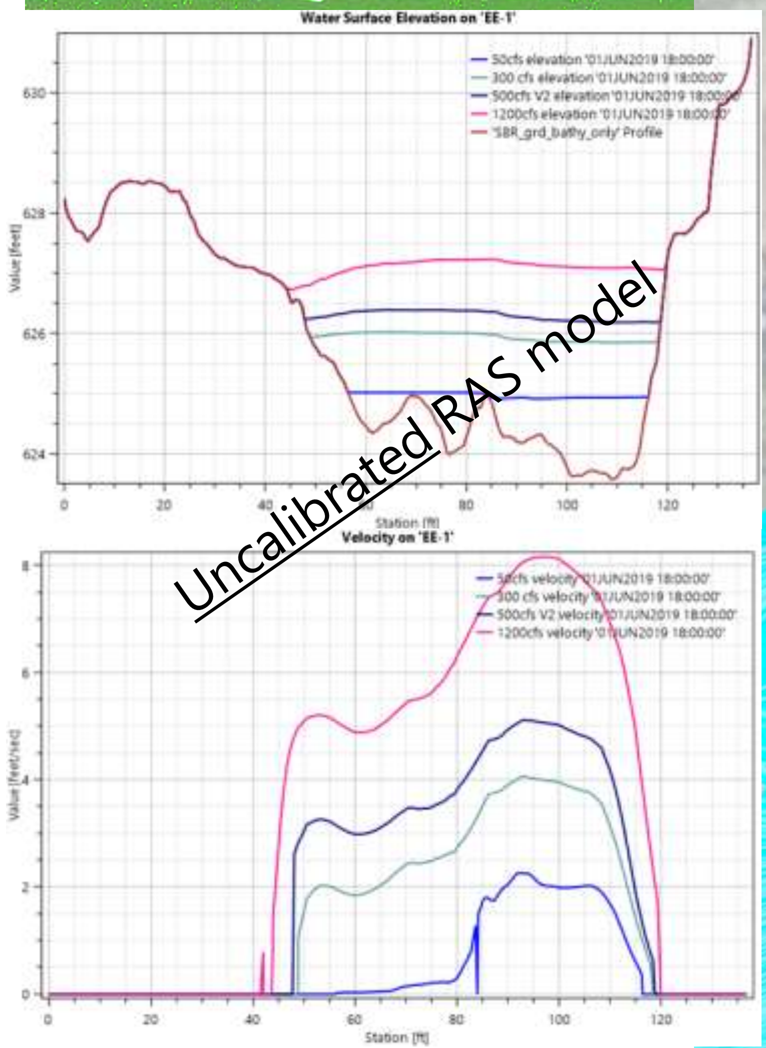
TRANSECT II

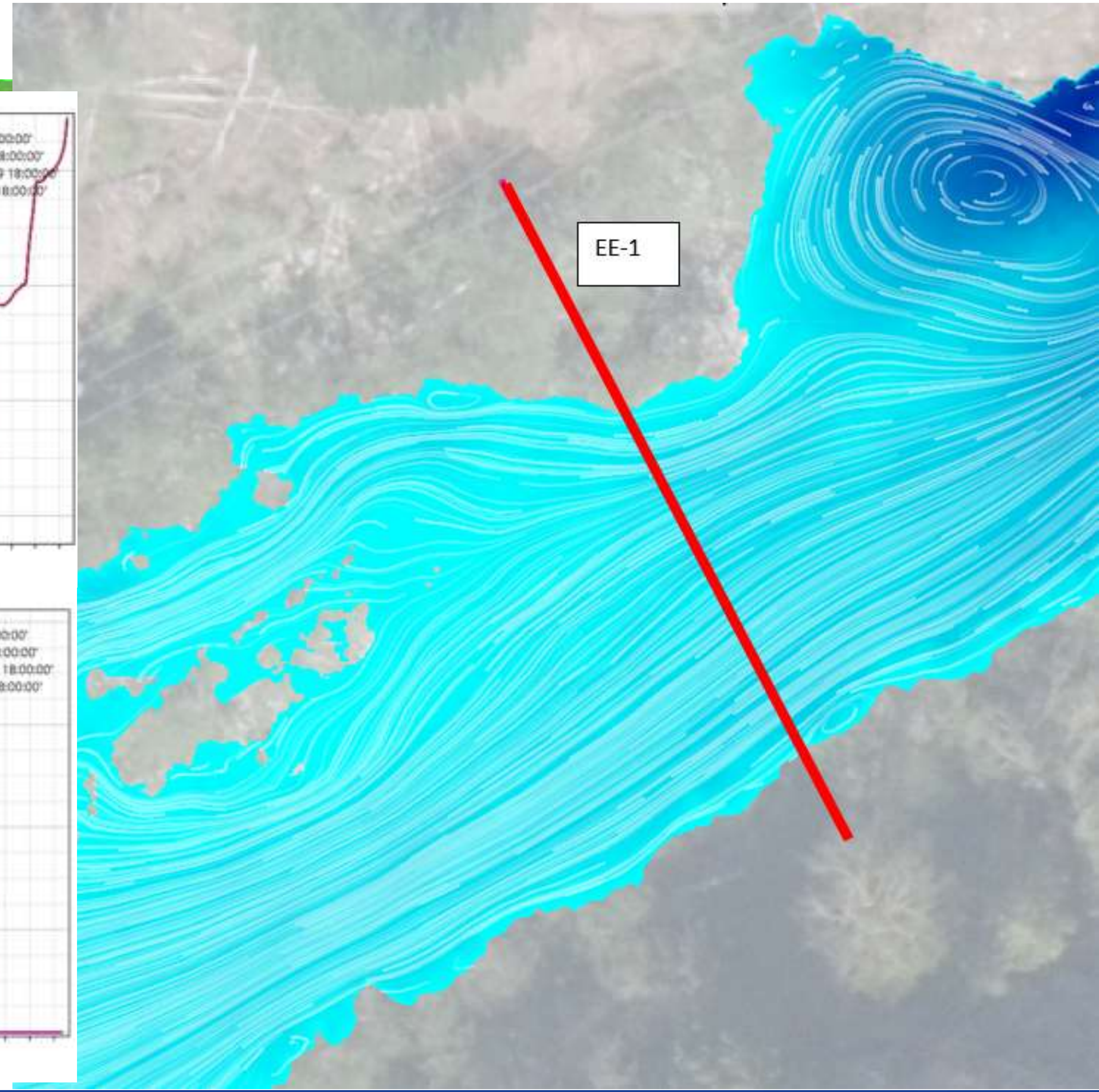


Water Surface Elevation on 'II-1'
50cfs elevation '01JUN2019 18:00:00'
300 cfs elevation '01JUN2019 18:00:00'
500cfs V2 elevation '01JUN2019 18:00:00'
1200cfs elevation '01JUN2019 18:00:00'
'SBR_grd_bathy_only' Profile
Value [feet]
630
625
620
0
20
40
60
80
100
120
Station [ft]
Velocity on 'II-1'
50cfs velocity '01JUN2019 18:00:00'
300 cfs velocity '01JUN2019 18:00:00'
500cfs V2 velocity '01JUN2019 18:00:00'
1200cfs velocity '01JUN2019 18:00:00'
Value [feet/sec]
4
3
2
1
0
0
20
40
60
80
100
120
Station [ft]
Uncalibrated RAS model

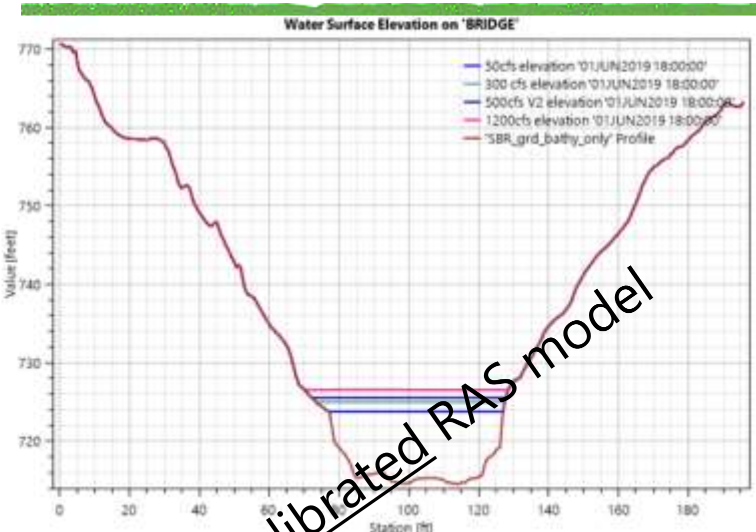


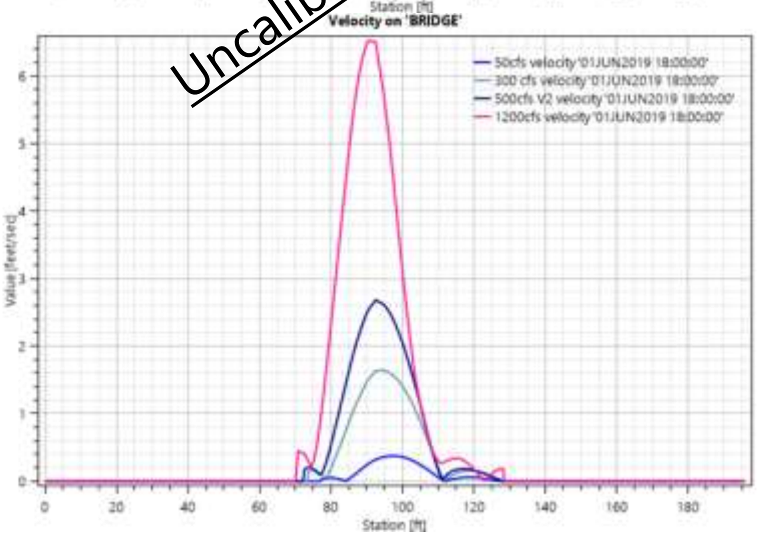
TRANSECT EE

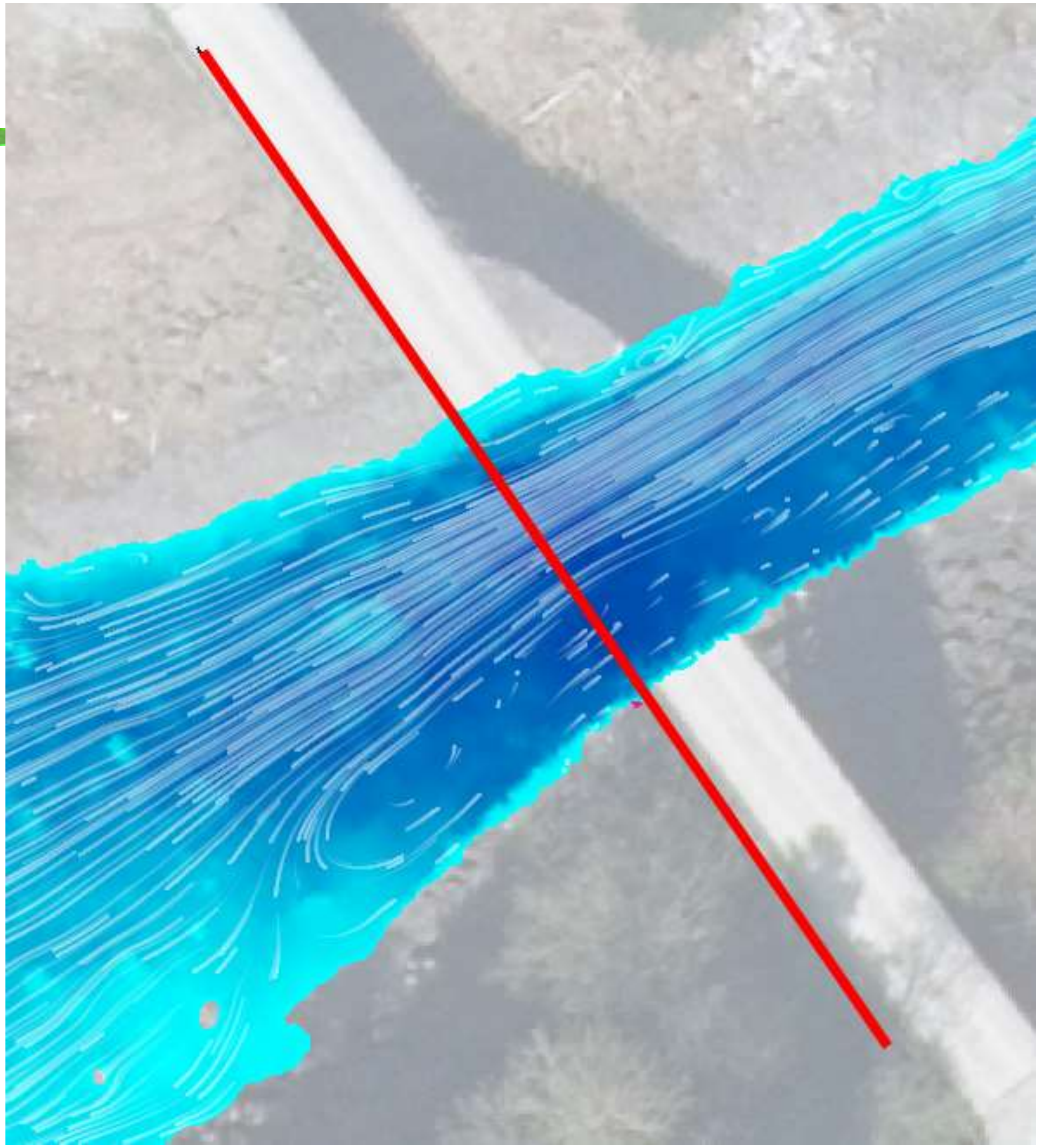

Water Surface Elevation on 'EE-1'
50cfs elevation '01JUN2019 18:00:00'
300 cfs elevation '01JUN2019 18:00:00'
500cfs V2 elevation '01JUN2019 18:00:00'
1200cfs elevation '01JUN2019 18:00:00'
'SBR_grd_bathy_only' Profile
Value [feet]
Station [ft]
Velocity on 'EE-1'
50cfs velocity '01JUN2019 18:00:00'
300 cfs velocity '01JUN2019 18:00:00'
500cfs V2 velocity '01JUN2019 18:00:00'
1200cfs velocity '01JUN2019 18:00:00'
Value [feet/sec]
Station [ft]
Uncalibrated RAS model


EE-1

TRANSECT BRIDGE



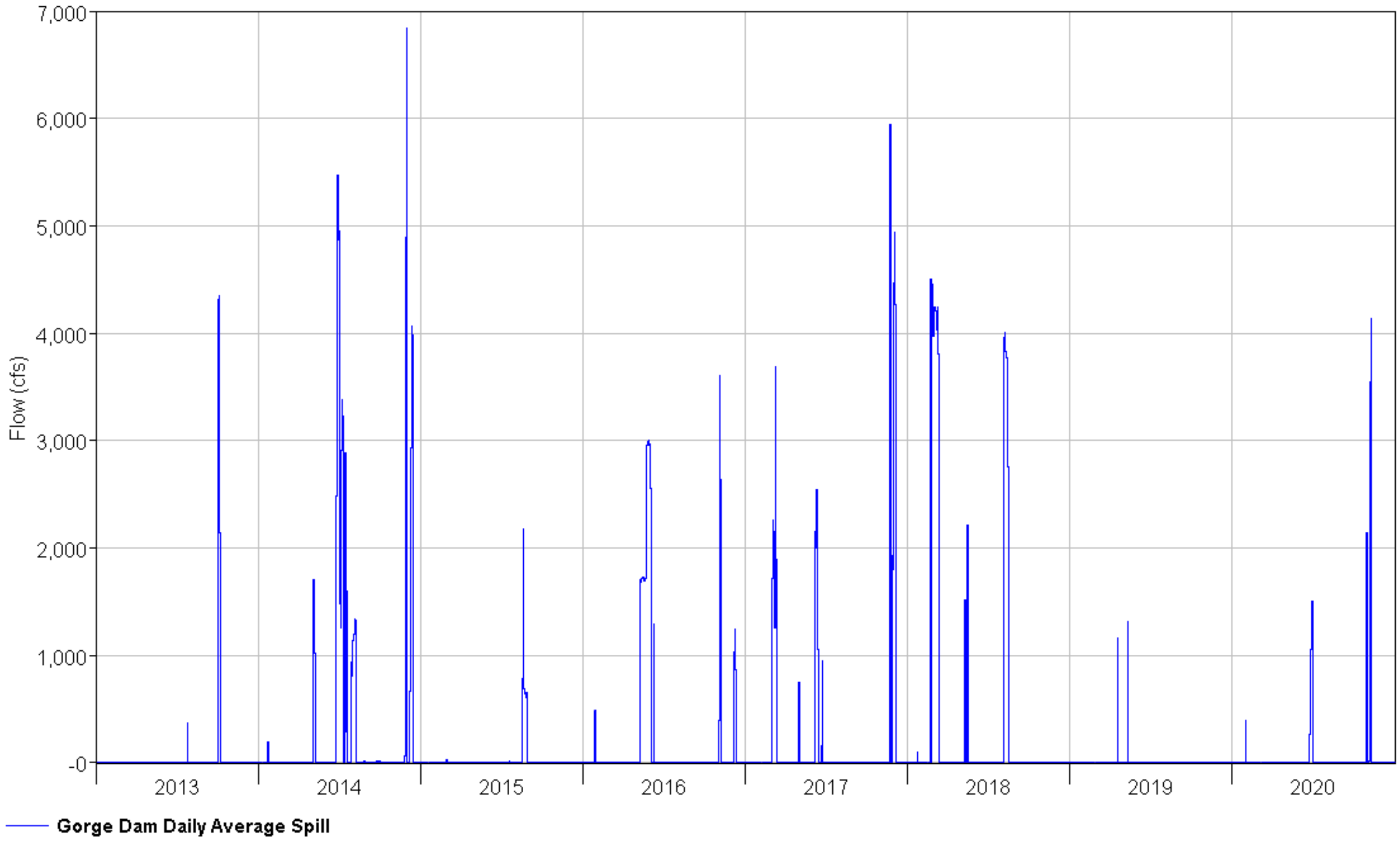




OBSERVABLE DISCHARGES

- Opportunistic Spill - opportunity for data collection at higher flows
  - Flows up to 5000+ cfs observed in records for spring/early summer freshet; 10,000+ cfs in fall/early winter storms.
  - Level loggers and time lapse cameras will be collecting data throughout this period
  - Duration variable dependent upon spill occurrence

OBSERVABLE DISCHARGES



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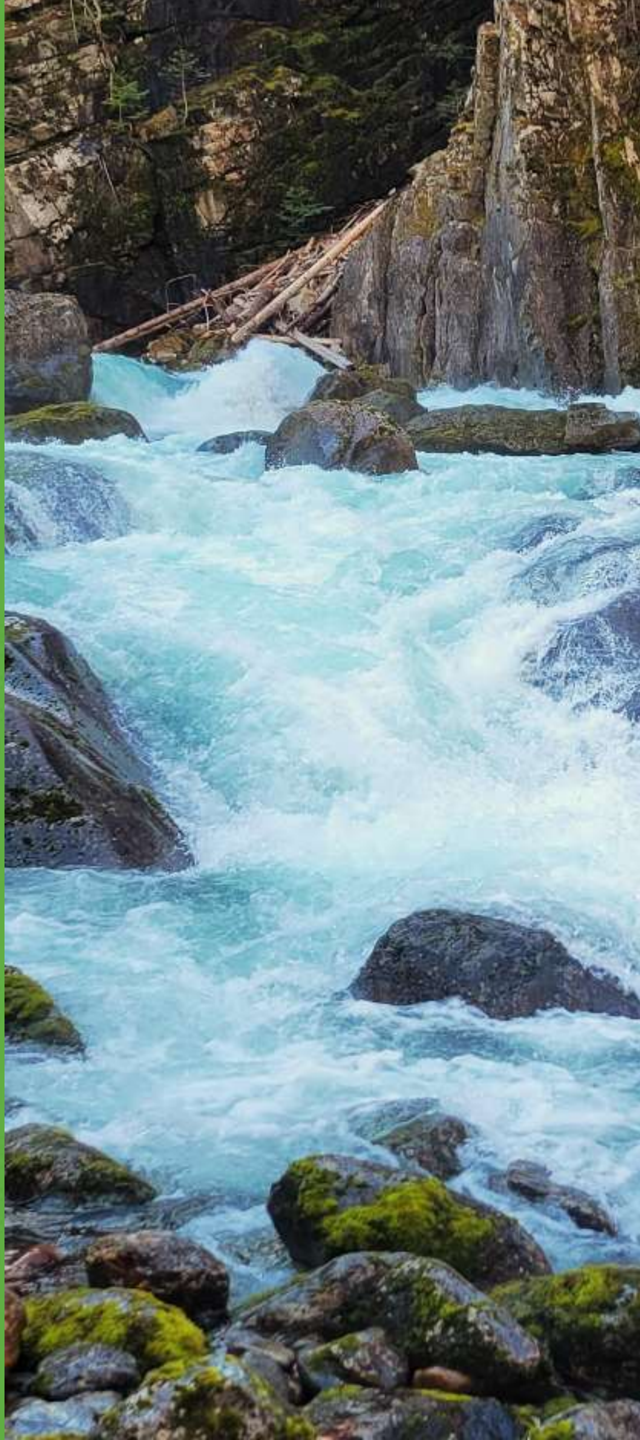
BREAK



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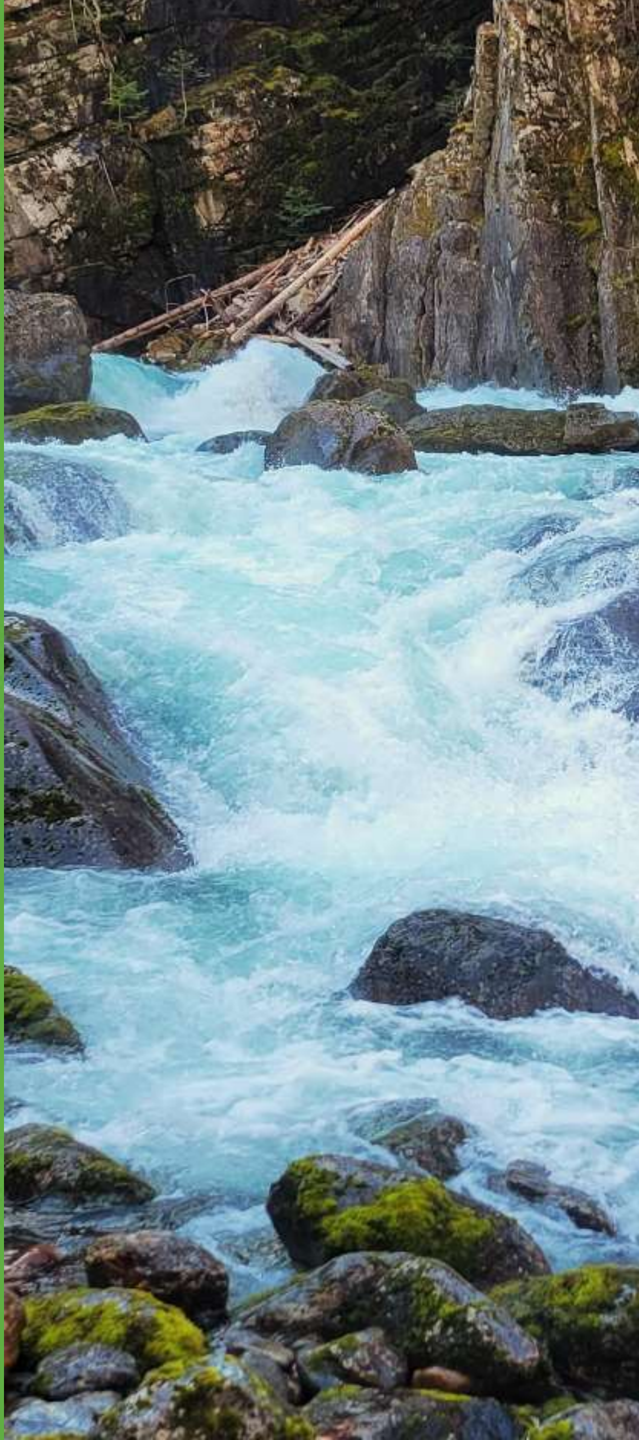
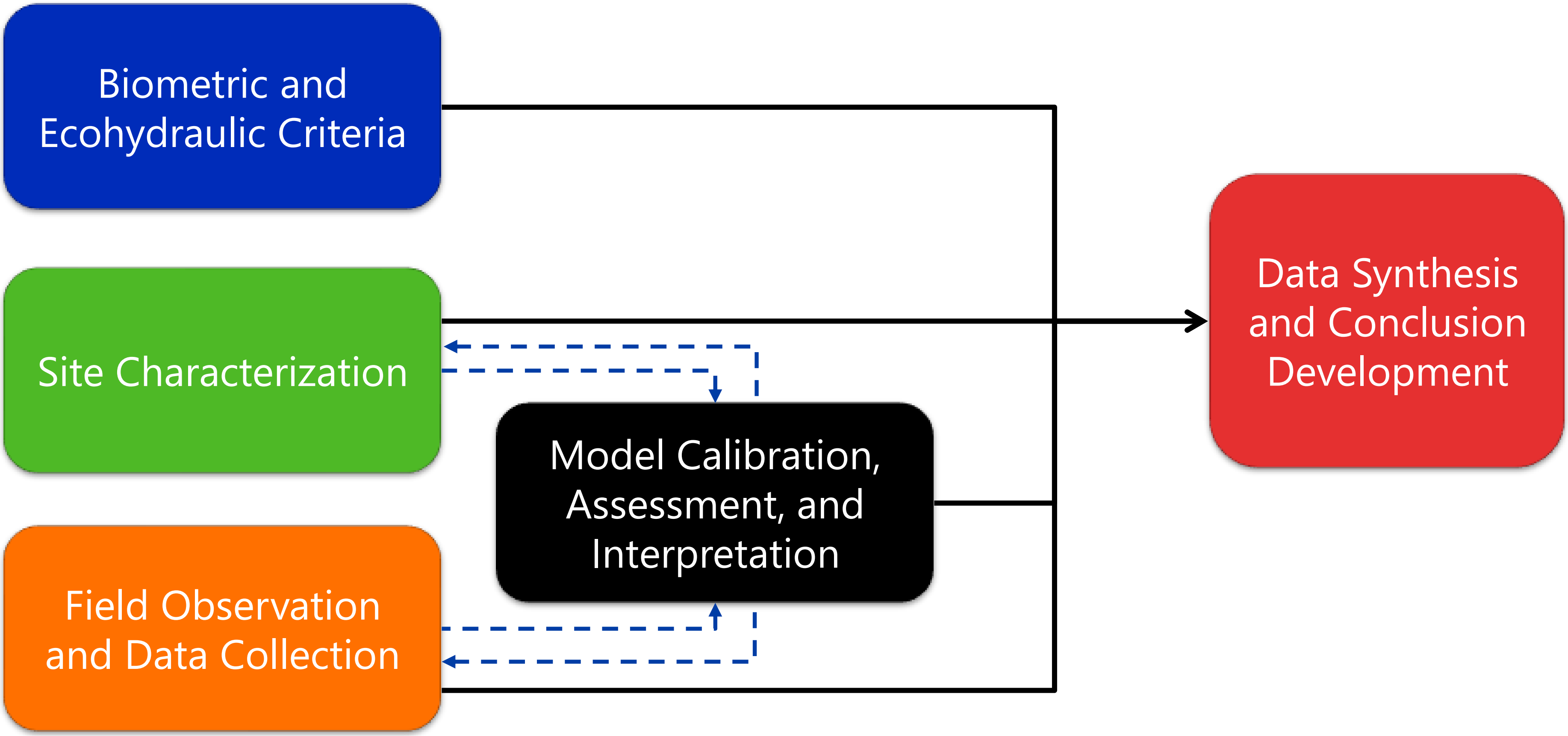
FISH PASSAGE EVALUATION METHODS AND TOOLS



FISH PASSAGE METHODS AND TOOLS



FISH PASSAGE METHODS AND TOOLS

Biometric and Ecohydraulic Criteria

- Fish species and characteristics
- Swimming capability
- Leaping capability

Field Observation and Data Collection

- Video Documentation
- Photo Documentation
- Flow Measurement
- Water depth and elevation data
- Velocity

Data Synthesis and Conclusion Development

Site Characterization

- Topography
  Aerial photography
- Site Inspection
- Site Characterization

Model Calibration and Assessment

- Hydraulic pathways
- Hydraulic trends and variability assessment
- Water surface profile assessment
- Water velocity assessment

FISH PASSAGE METHODS AND TOOLS

- Biological characteristics of species considered
  - Range of size by species
  - Condition upon arrival
  - Swimming capability
  - Leaping capability
- Availability and variance in information available influences basis of biometric or ecohydraulic comparisons

BIOLOGICAL AND ECOHYDRAULIC METRICS

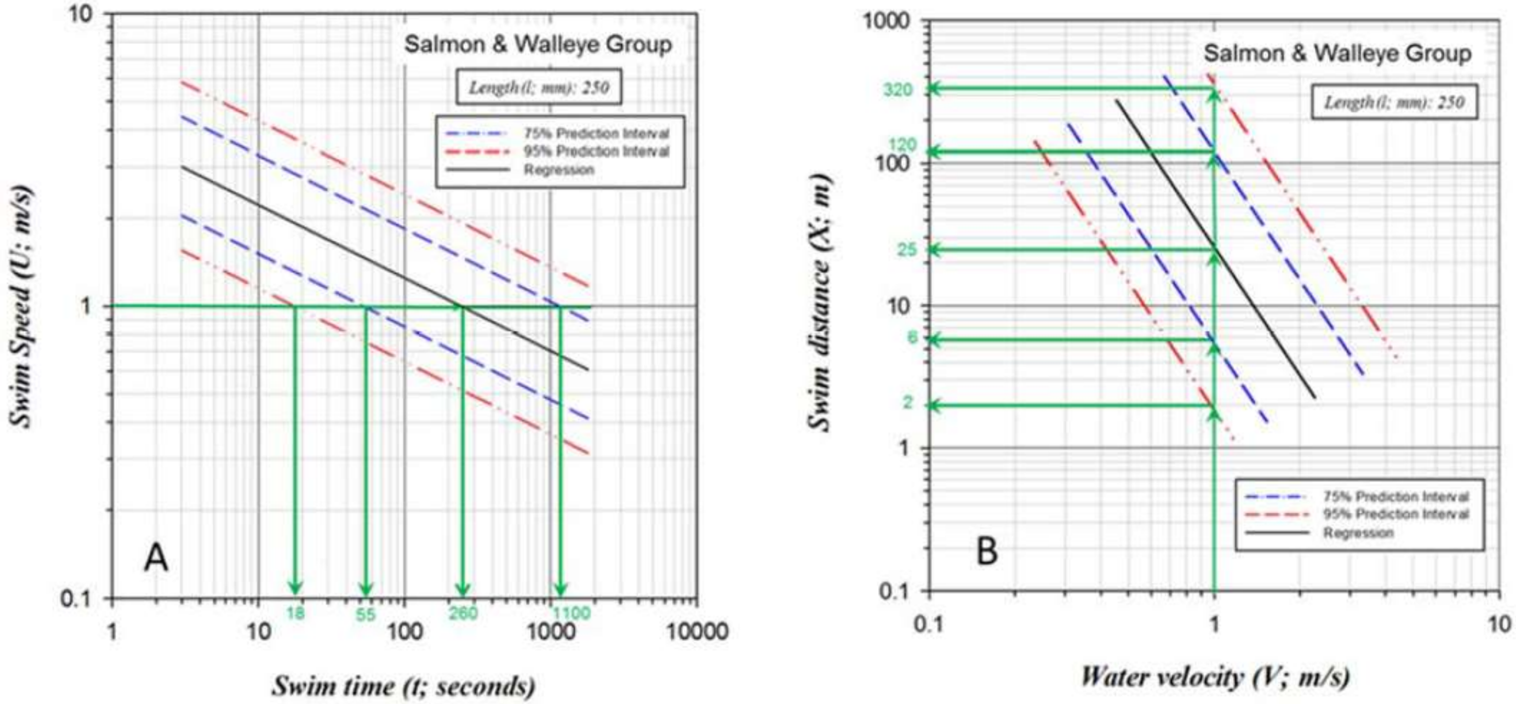
- Example biological and ecohydraulic metrics
  - Hunter and Mayor (1986) - Swimming ability and time to exhaustion calculated based upon regression curves using historical flume data
    - Calculated “sustained,” “prolonged,” and “burst” swim speeds and durations were used to assess those situations where steep gradients create high velocity, turbulent conditions through chutes or cascades.
    - The combination of calculated swimming and leaping capabilities was used to identify whether or not a hydraulic feature (high velocity or leap condition) is passable.

FISH PASSAGE METHODS AND TOOLS

- Example biological and ecohydraulic metrics
  - Powers and Orsborn (1985)
    - Leaping ability calculated based upon species, size, and condition upon arrival

BIOLOGICAL AND ECOHYDRAULIC METRICS

- Example biological and ecohydraulic metrics
  - Katopodis and Gervais (2016) – swimming fatigue curves



Example of swim endurance and distance estimates for Salmon and Walleye groups for fish length of 250 mm, in Figure A endurance times corresponding to a swimming speed of 1 m/s are shown and in Figure B swim distances corresponding a water velocity of 1 m/s are shown.

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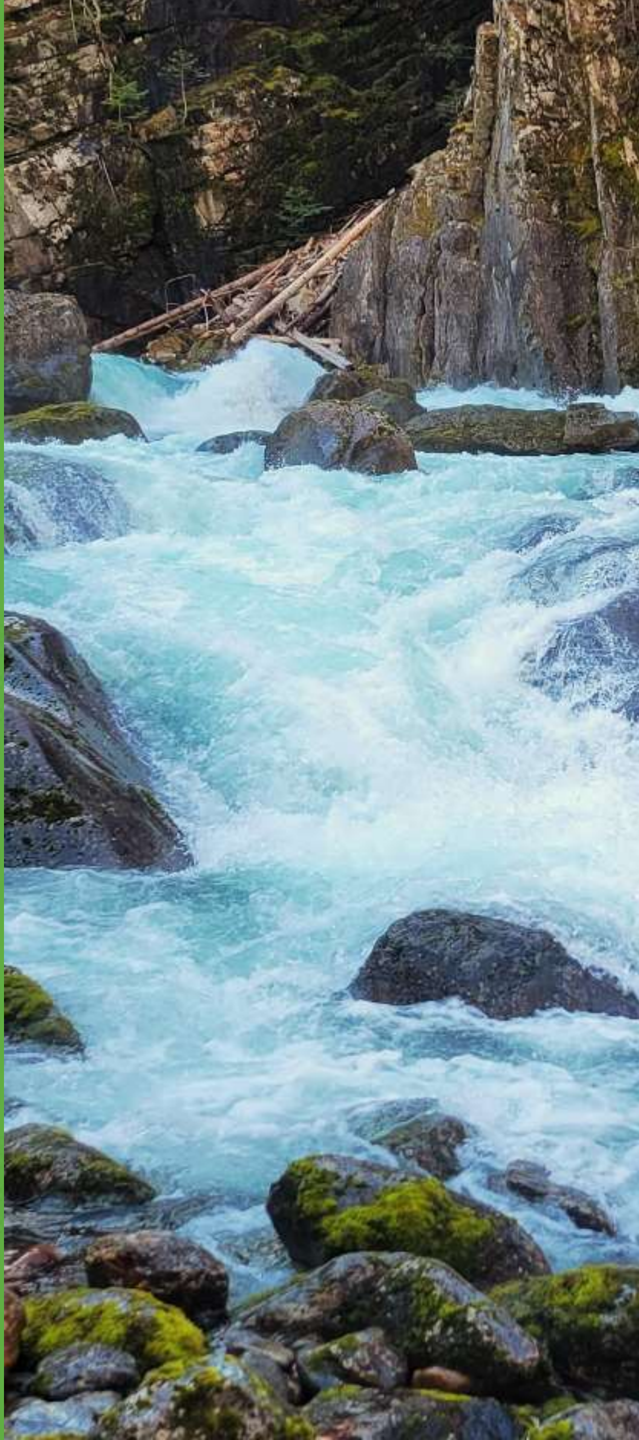
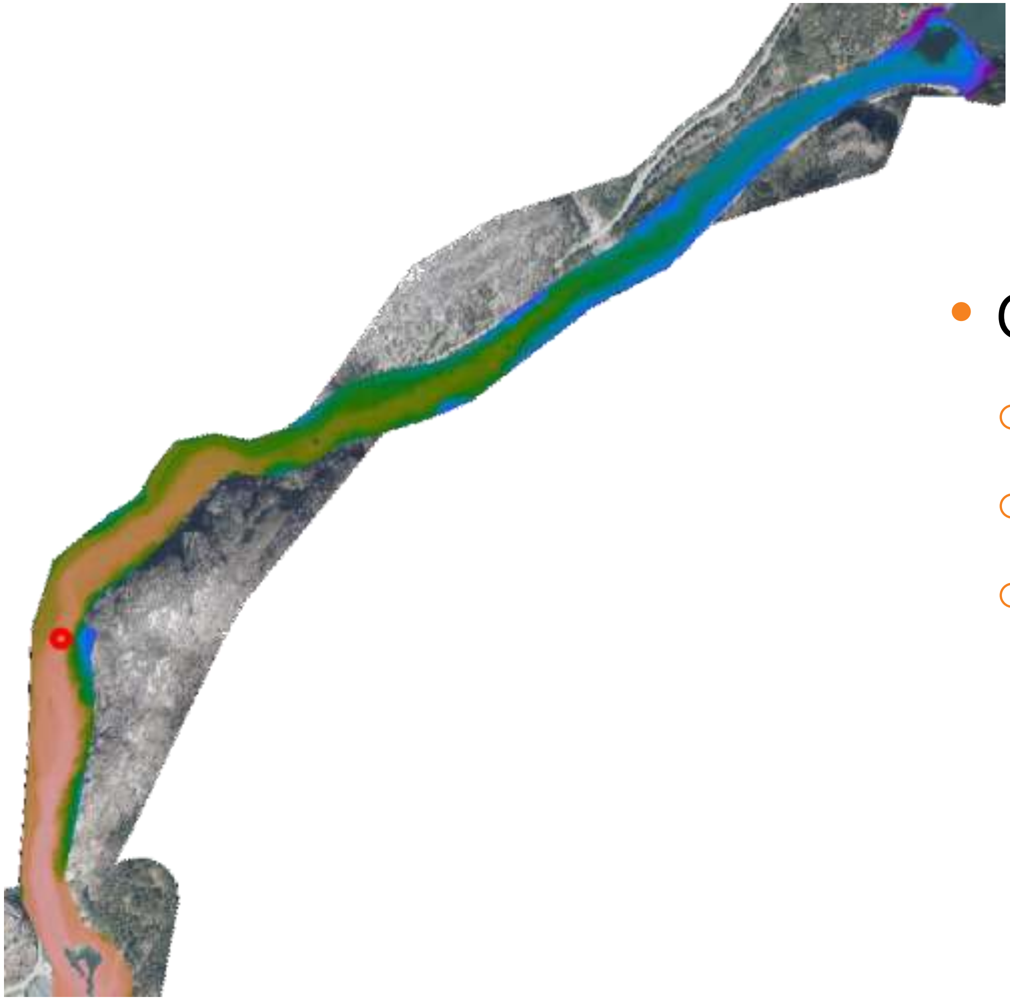
SITE INSPECTION, SURVEYING, AND VISUAL OBSERVATION



FISH PASSAGE METHODS AND TOOLS

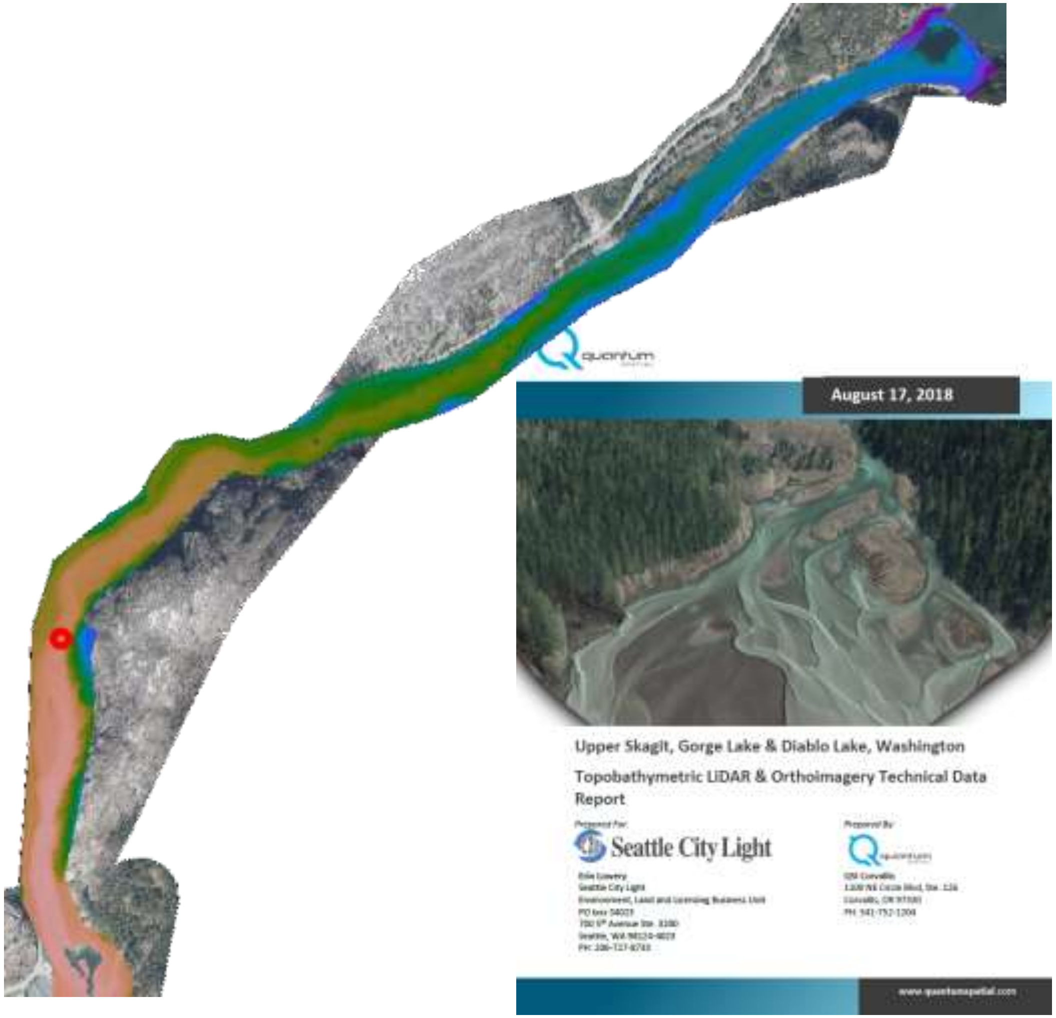
- Site inspection and visual observation
  - Feature Topography - LiDAR
  - Site Inspection
  - Photo and video documentation

FEATURE TOPOGRAPHY



- Quantum Spatial 2018
  - “green” LiDAR
  - water penetrating
  - 3 voids
    - Gorge Dam plunge pool
    - Gorge Powerhouse pool
    - 20’x50’x25+’ deep hole

FEATURE TOPOGRAPHY


August 17, 2018

Upper Skagit, Gorge Lake & Diablo Lake, Washington

Topobathymetric LiDAR & Orthoimagery Technical Data Report

Seattle City Light

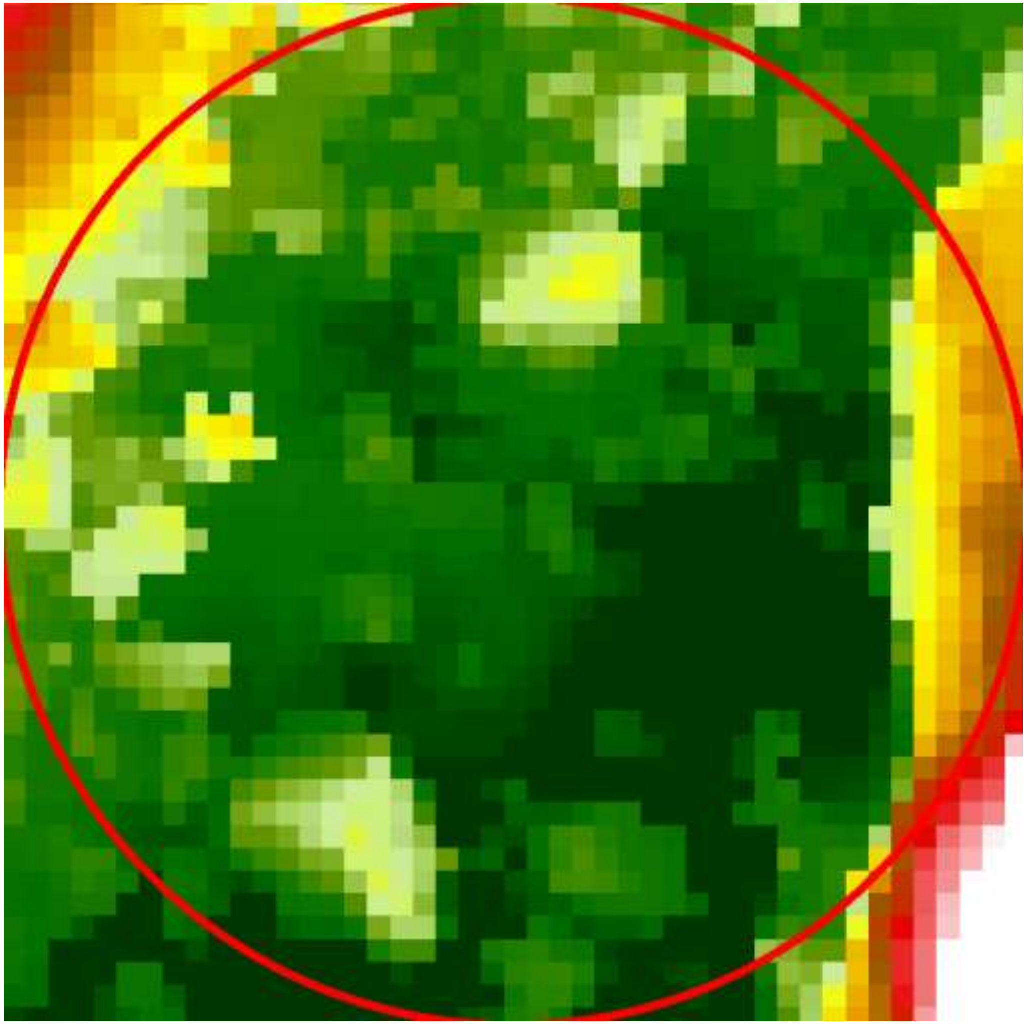
- 3′ Topo Raster
- 6″ Imagery
- NVA = 0.201′
  - 95% confidence
- Bathymetric VA = 0.366′
  - 95% confidence

FEATURE TOPOGRAPHY

FEATURE TOPOGRAPHY

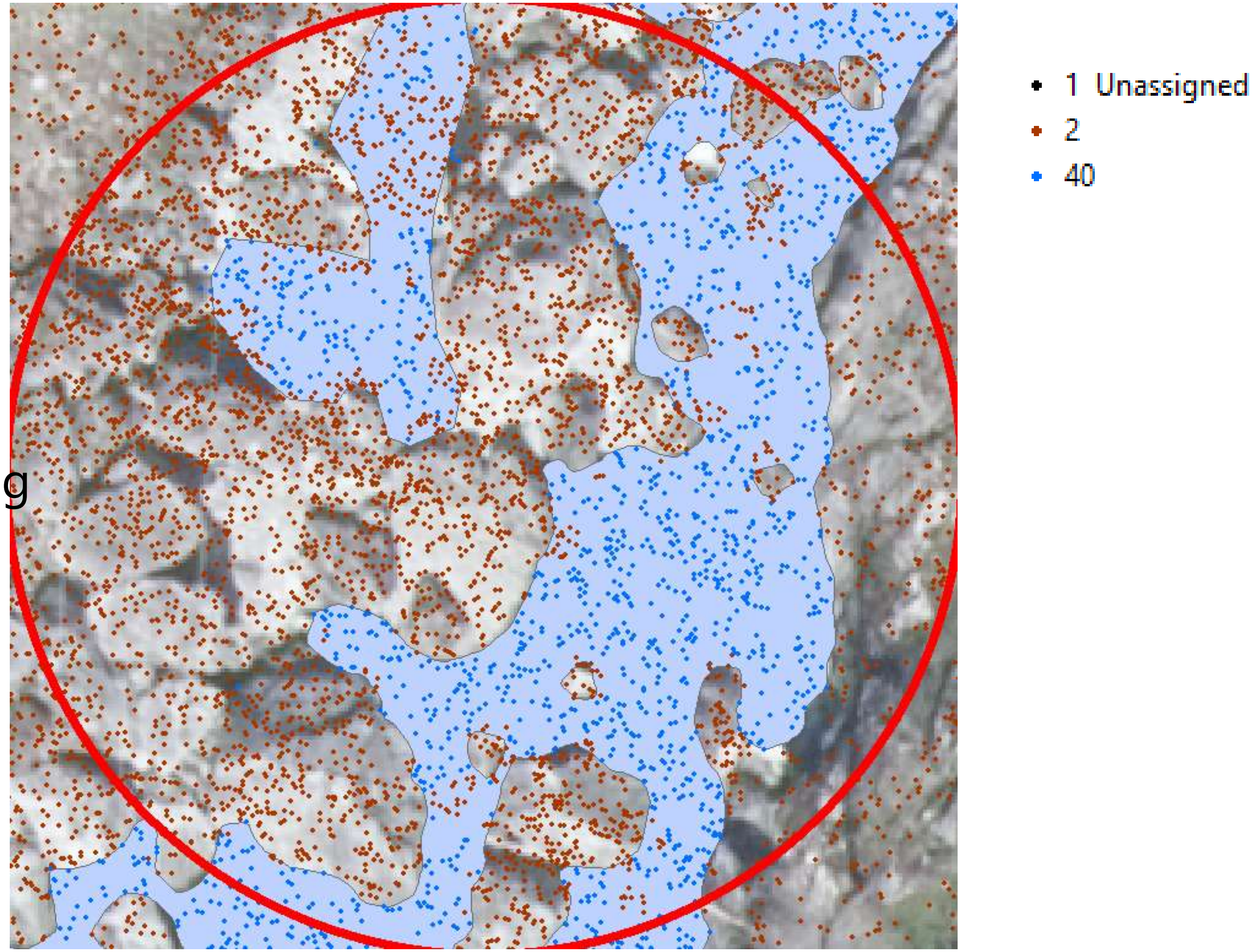
FEATURE TOPOGRAPHY

- 3′ raster



TOPOGRAPHY

- Avg density
  - 6 pulses/m^2
- Pulse spacing
  - 0.41 m
- 2 X pulse spacing
  - 2.7 feet



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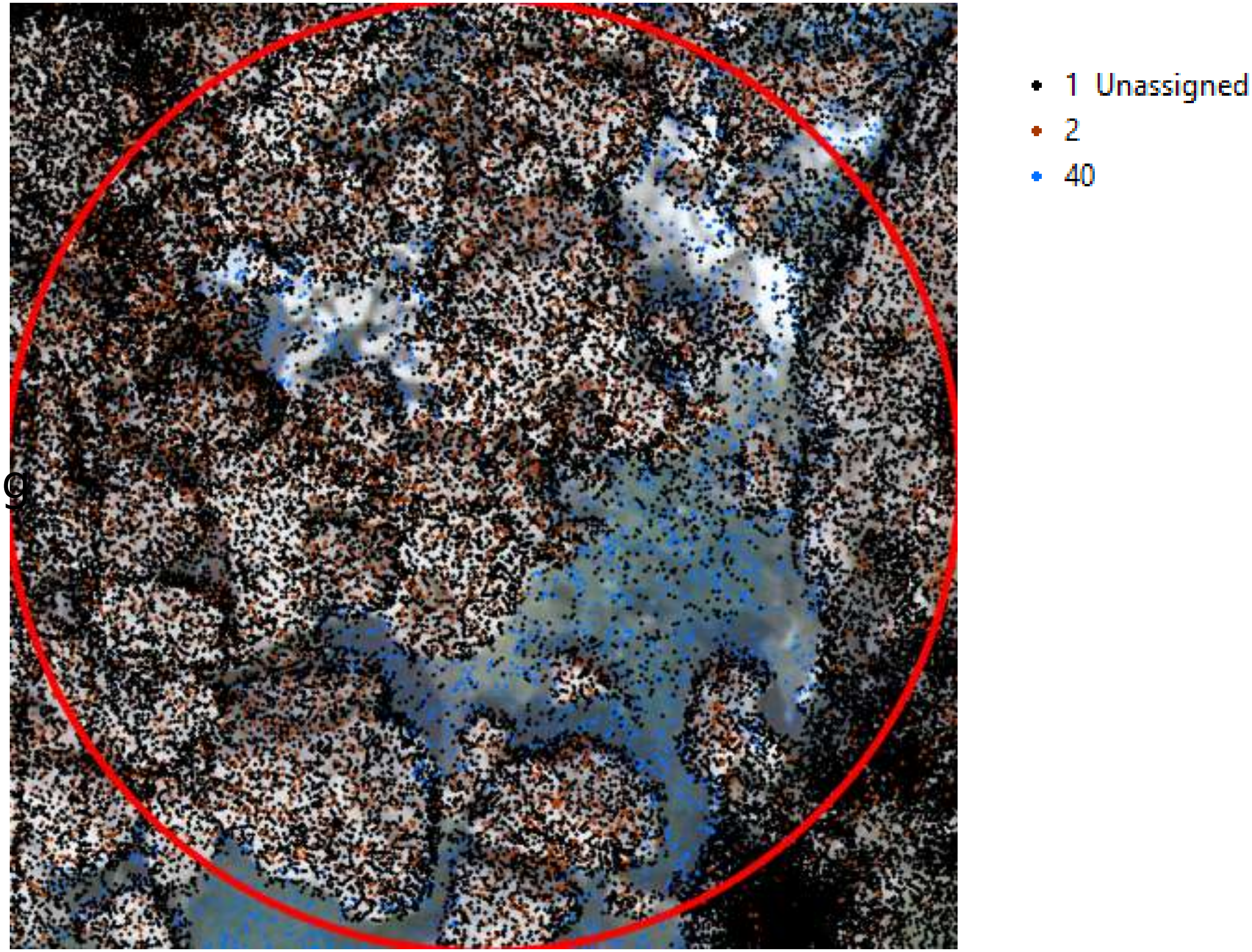
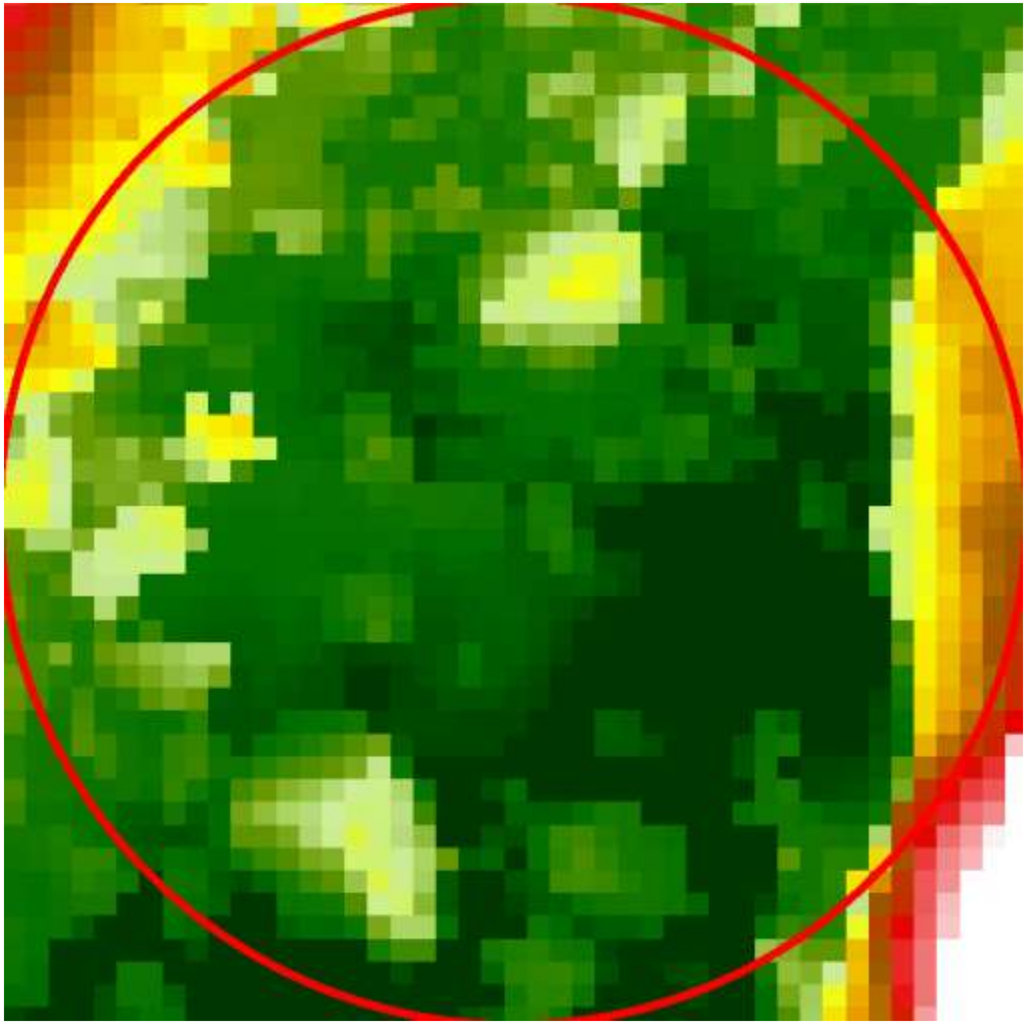


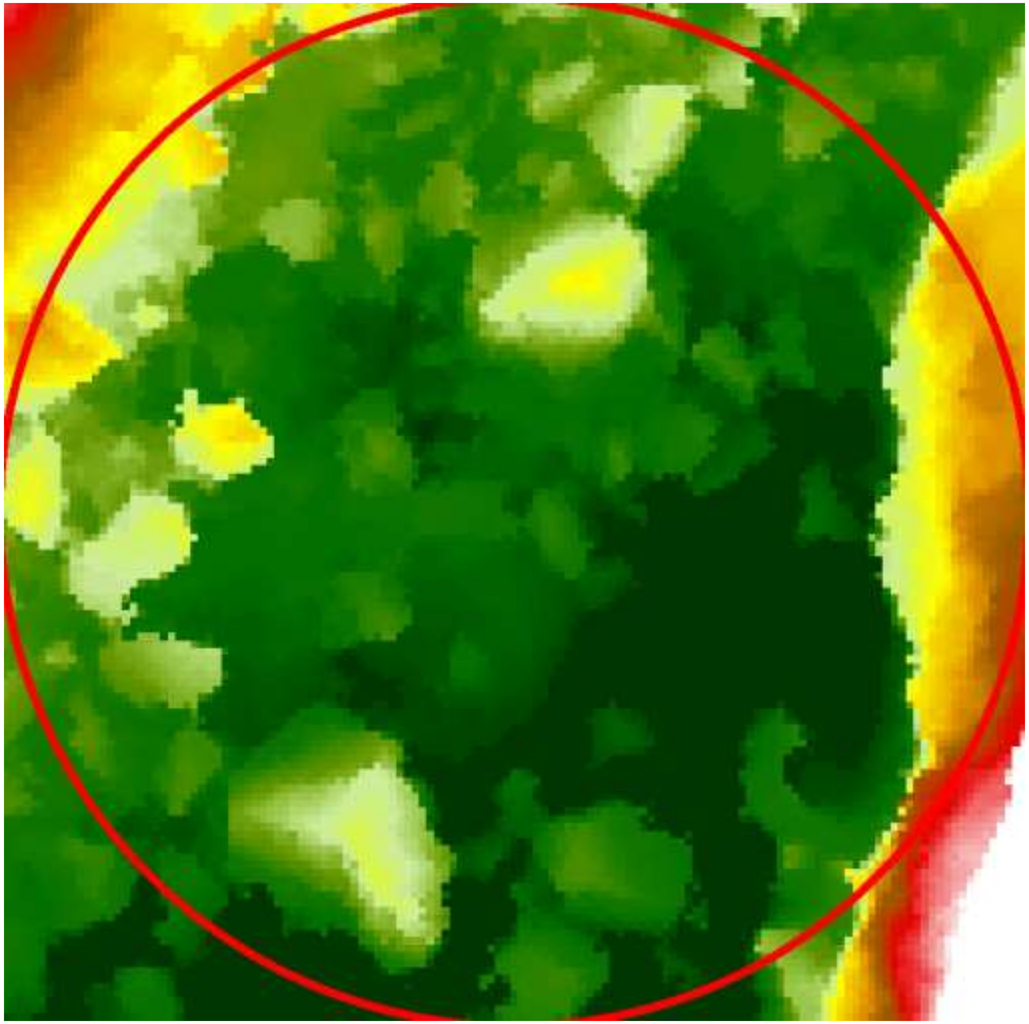
FEATURE TOPOGRAPHY

- 3′ raster

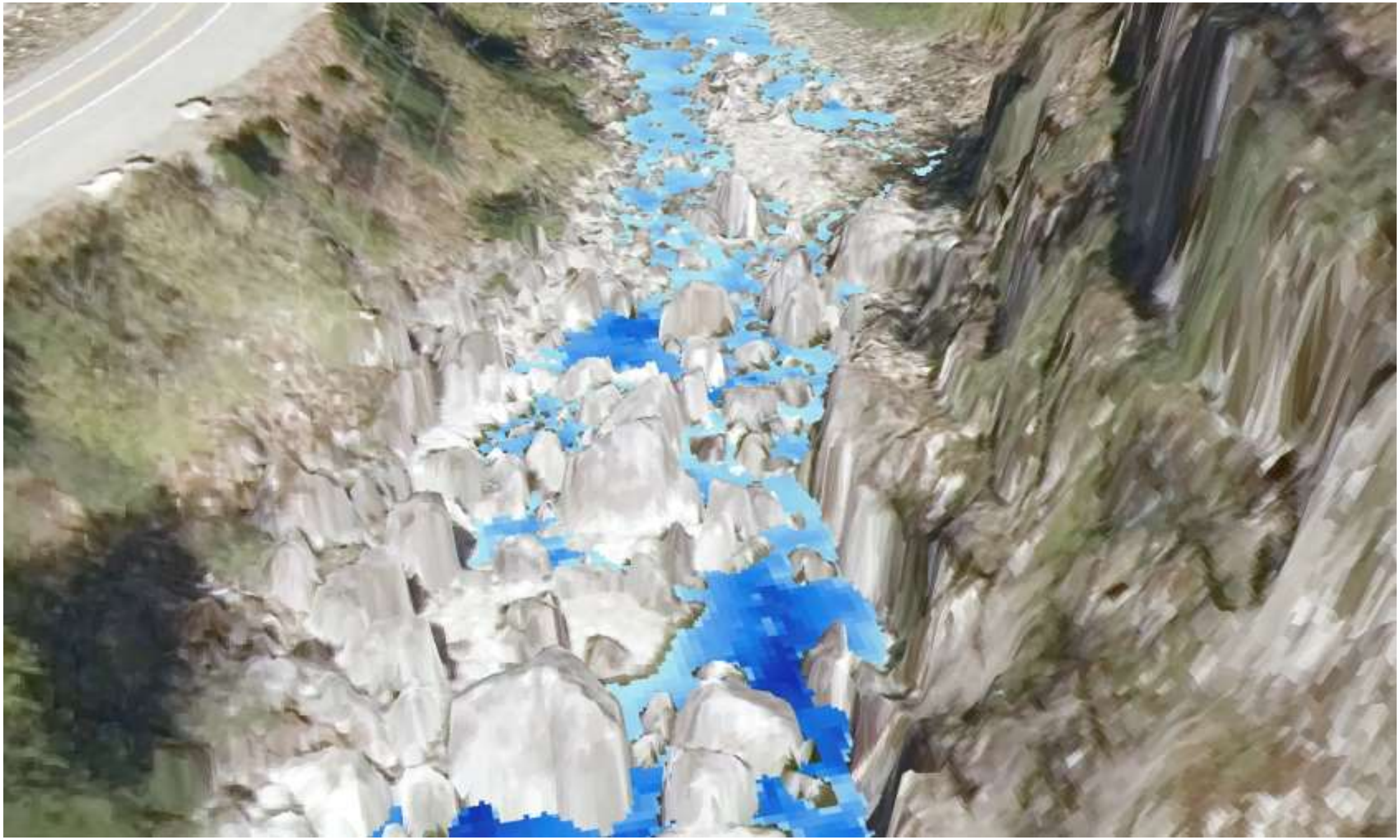


FEATURE TOPOGRAPHY

- 1′ raster



FEATURE TOPOGRAPHY



FEATURE TOPOGRAPHY

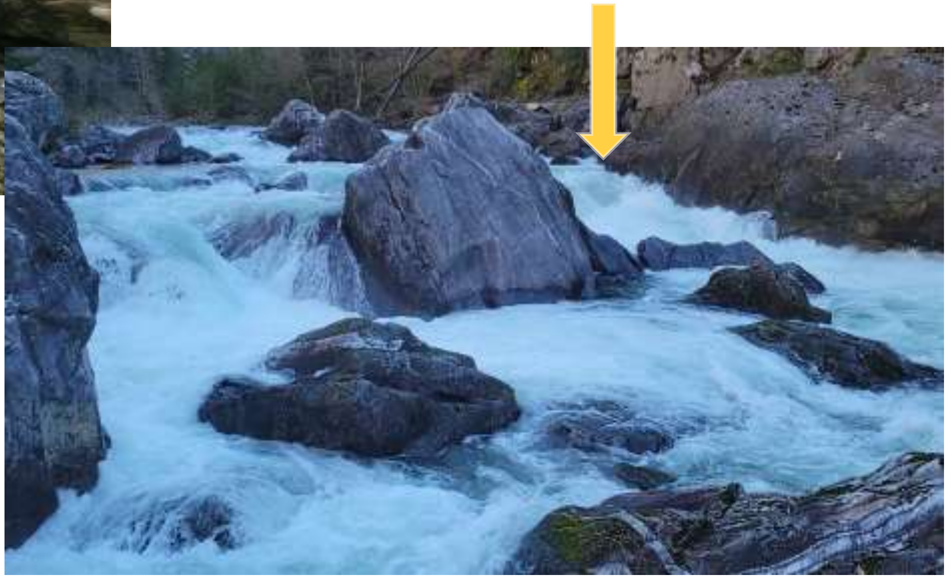
SITE INSPECTION AND VISUAL OBSERVATION

- Minimum observation at range of flows from ~5 to 1,200 cfs
- Anticipated opportunity to capture images and video up to 5,000 cfs
- Time lapse photography at two locations established prior to controlled release period

SITE INSPECTION AND VISUAL OBSERVATION

Feature 1

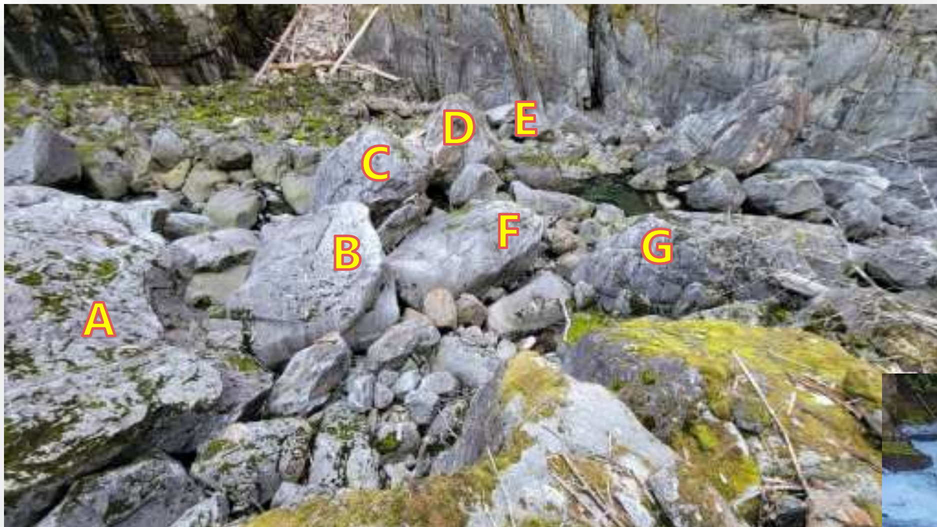
Base flow ~5 to 10 cfs



~1,200 cfs

SITE INSPECTION AND VISUAL OBSERVATION

Feature 2



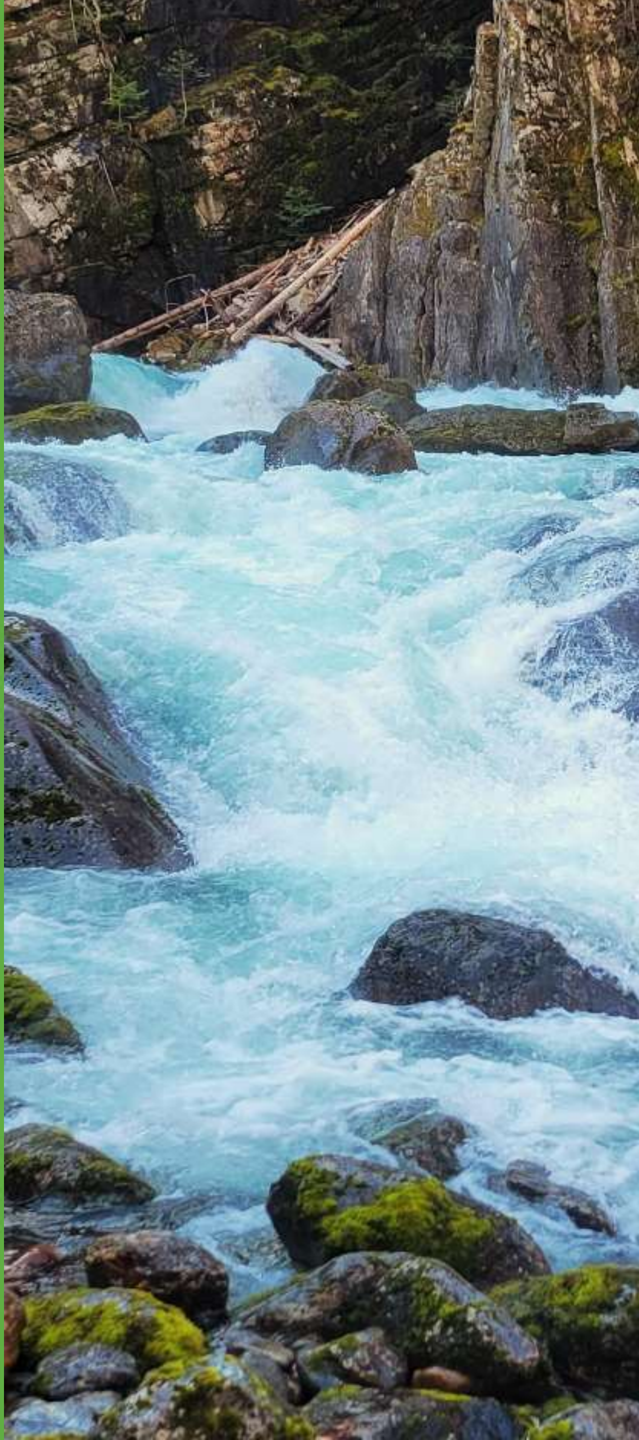
Base flow ~5 to 10 cfs

~1,200 cfs

SITE INSPECTION AND VISUAL OBSERVATION

Feature complexity

COLLECTION OF FLOW MAGNITUDE, DEPTH, ELEVATION, AND VELOCITY DATA



FISH PASSAGE METHODS AND TOOLS

- Data collection
  - Flow
  - Depth
  - Velocity

FLOW MEASUREMENT

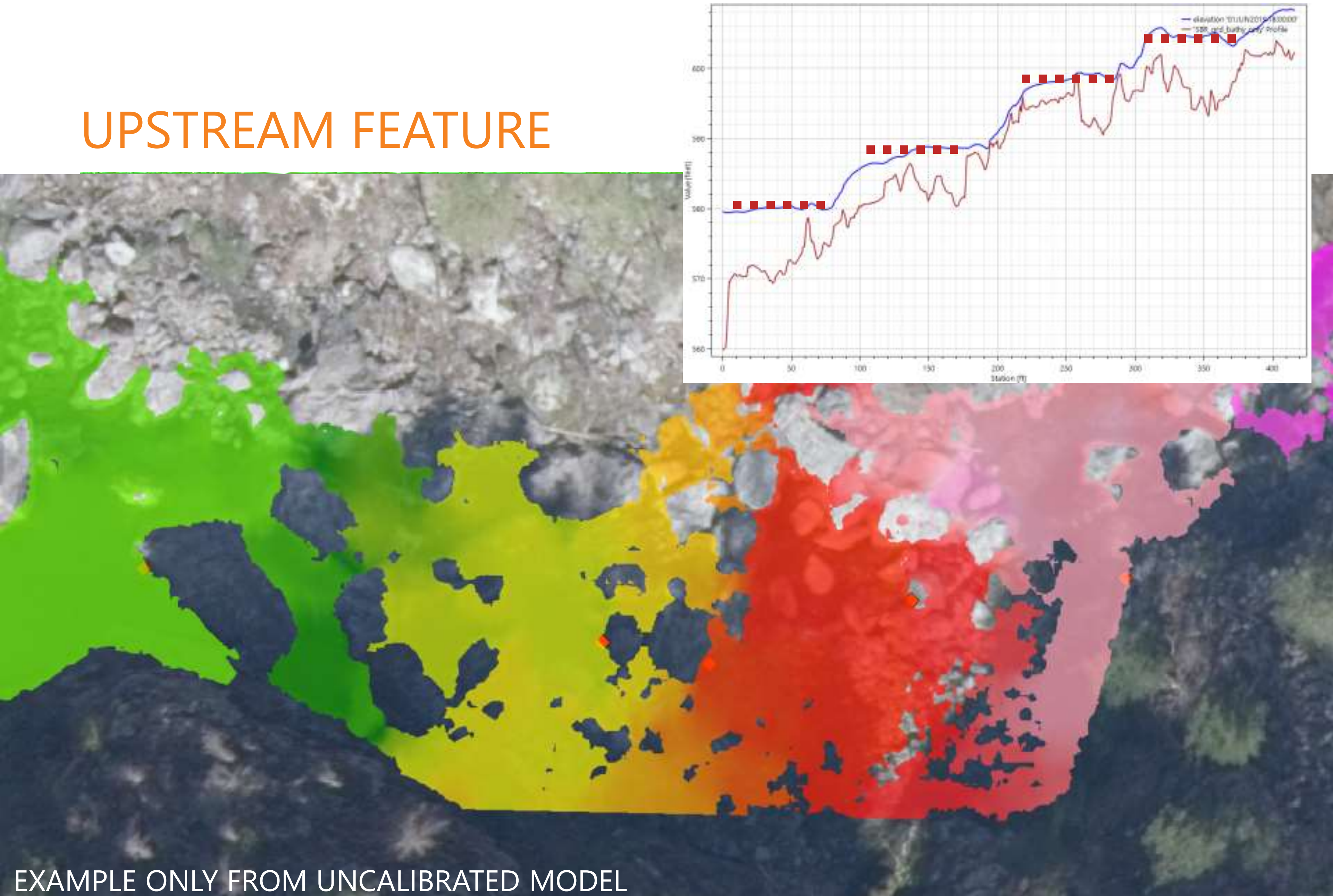
- Proposed Transects and Cableways
  - GG-2
  - AA-1
  - II
  - EE
  - BRIDGE

DEPTH MEASUREMENT

- Depth monitoring locations identified using site investigation and initial/uncalibrated 2D model
- Deployment of level probes at 12 select locations
  - 5 at each feature (total of 10)
  - 2 at selected flow measurement transects
- Locations refined further after observations of features at ~1,200 cfs

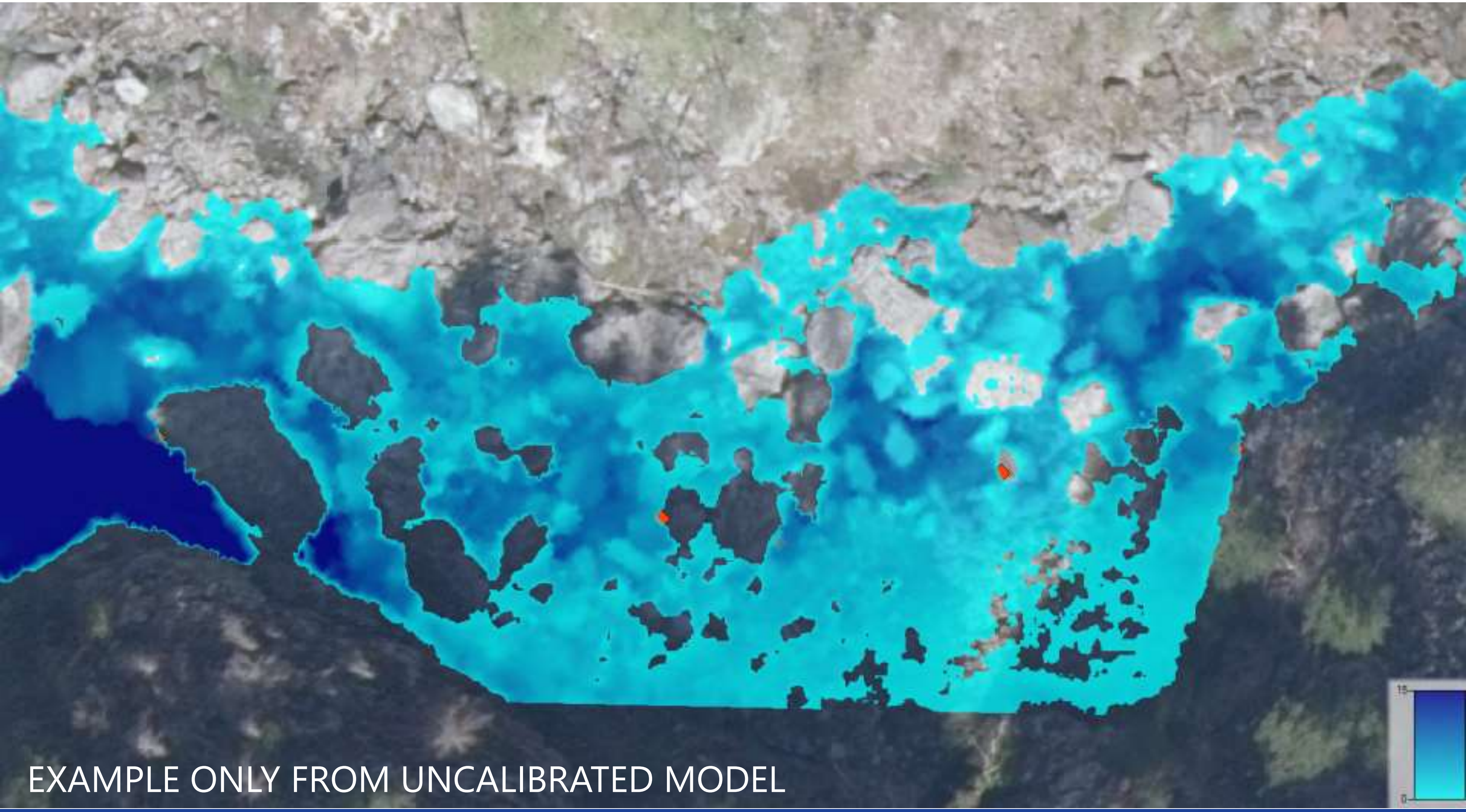
UPSTREAM FEATURE

UPSTREAM FEATURE

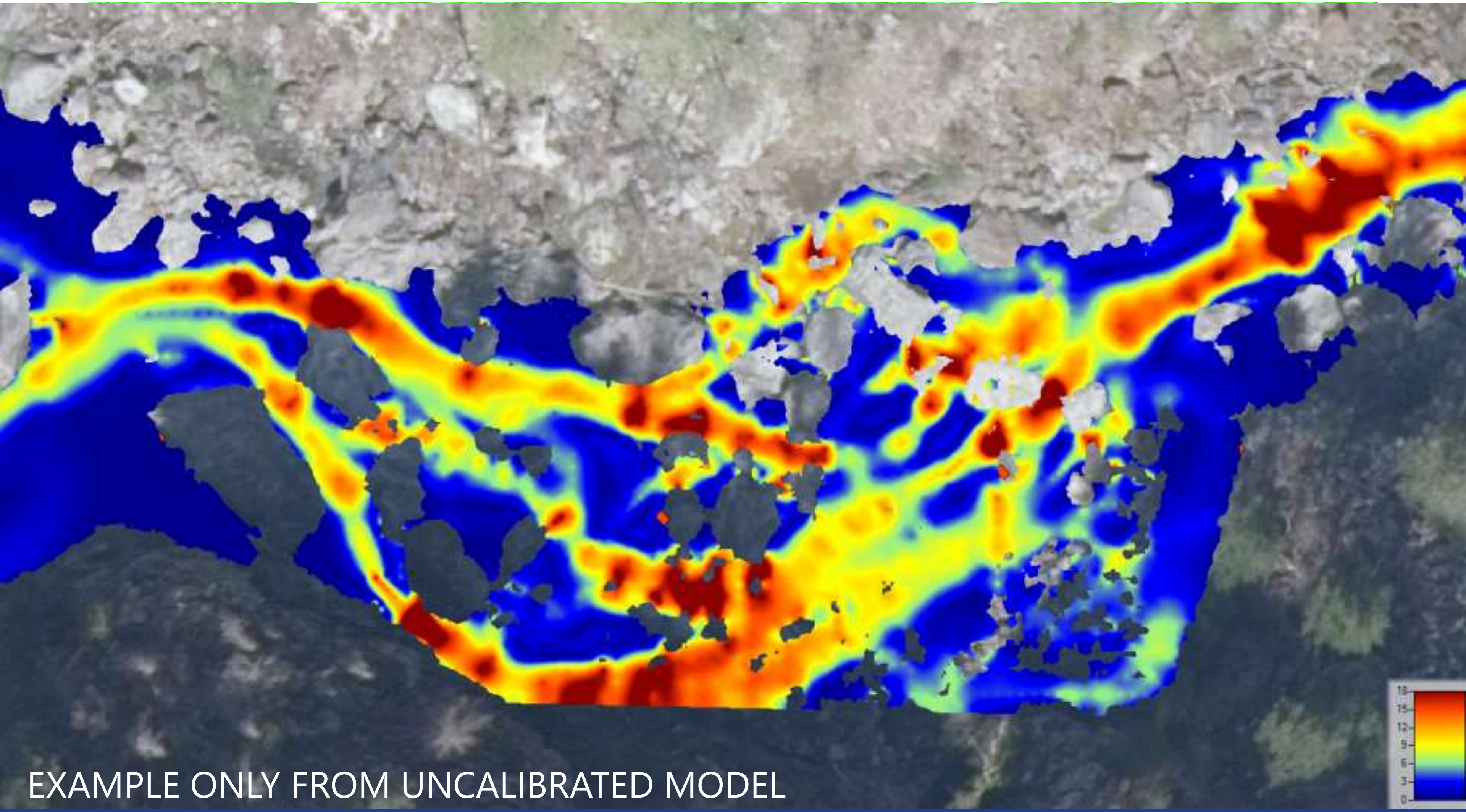


EXAMPLE ONLY FROM UNCALIBRATED MODEL

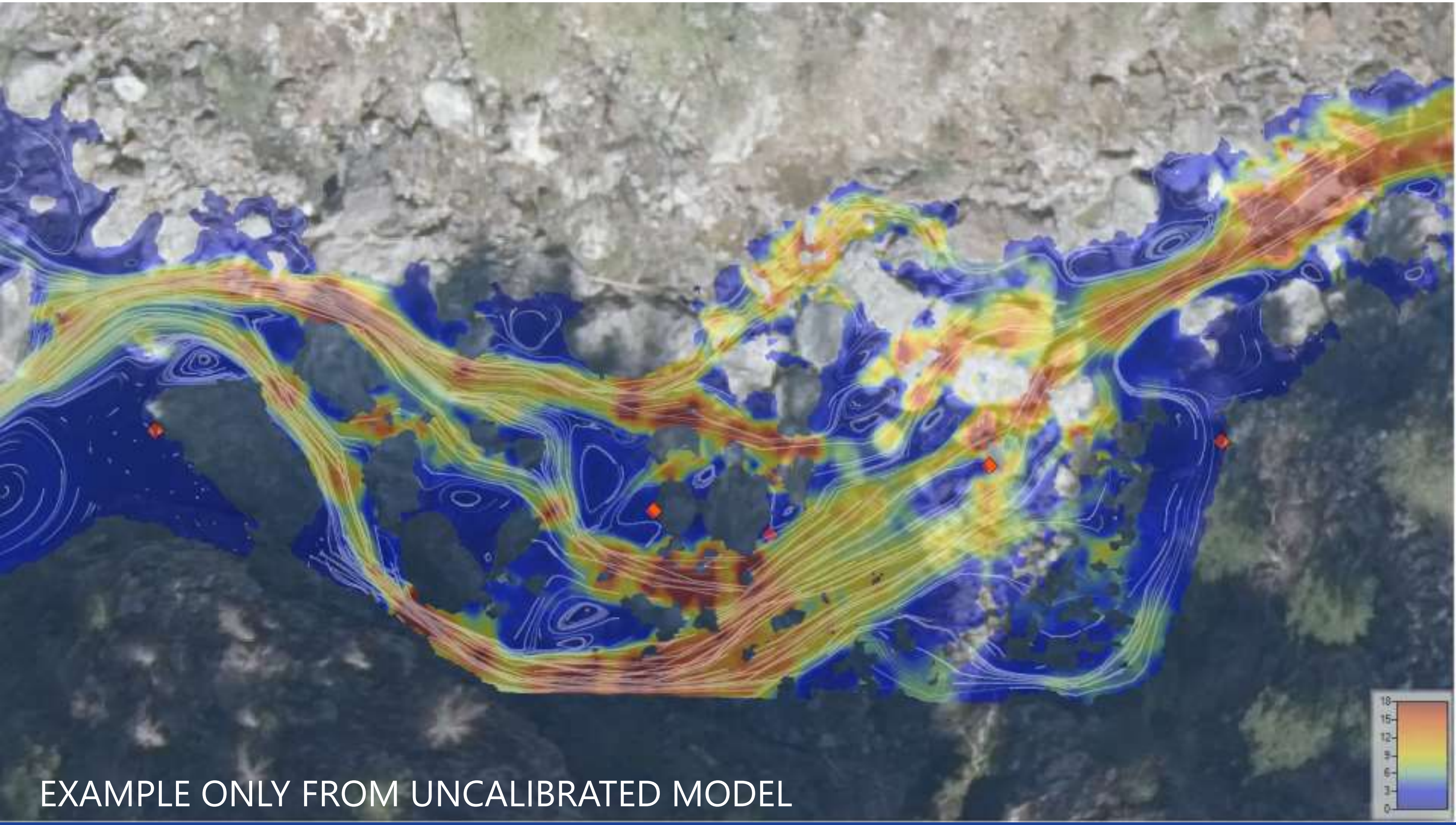
UPSTREAM FEATURE



UPSTREAM FEATURE



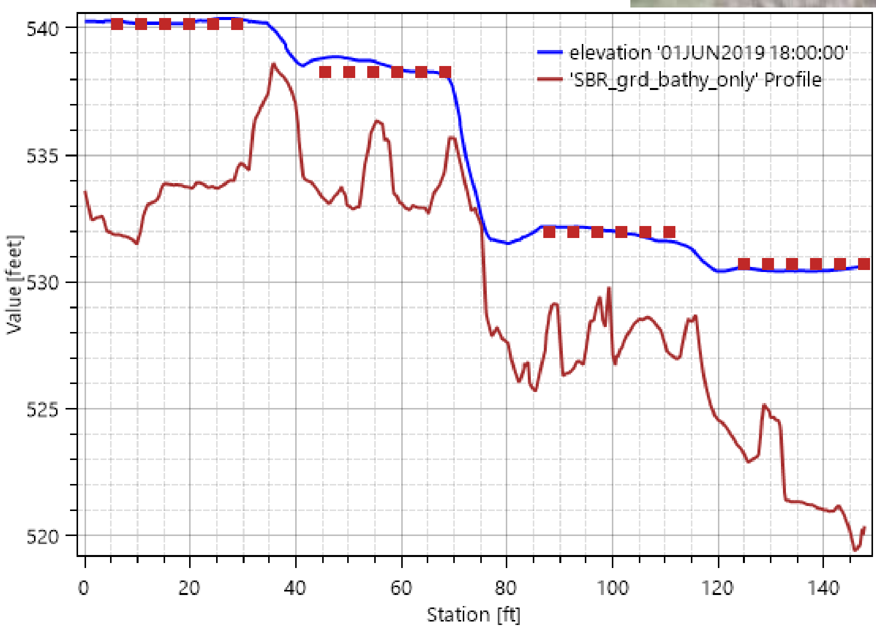
UPSTREAM FEATURE

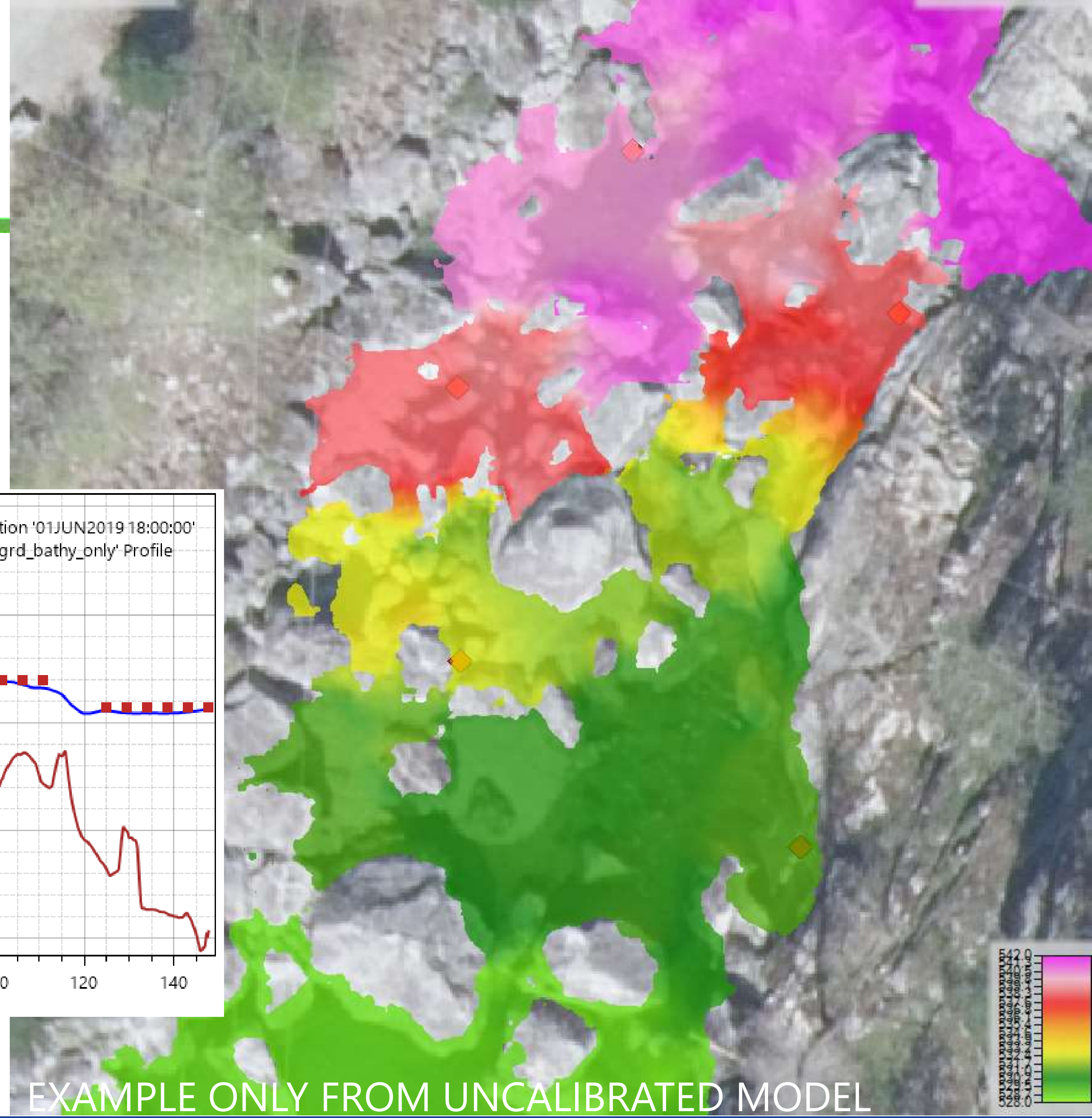


EXAMPLE ONLY FROM UNCALIBRATED MODEL

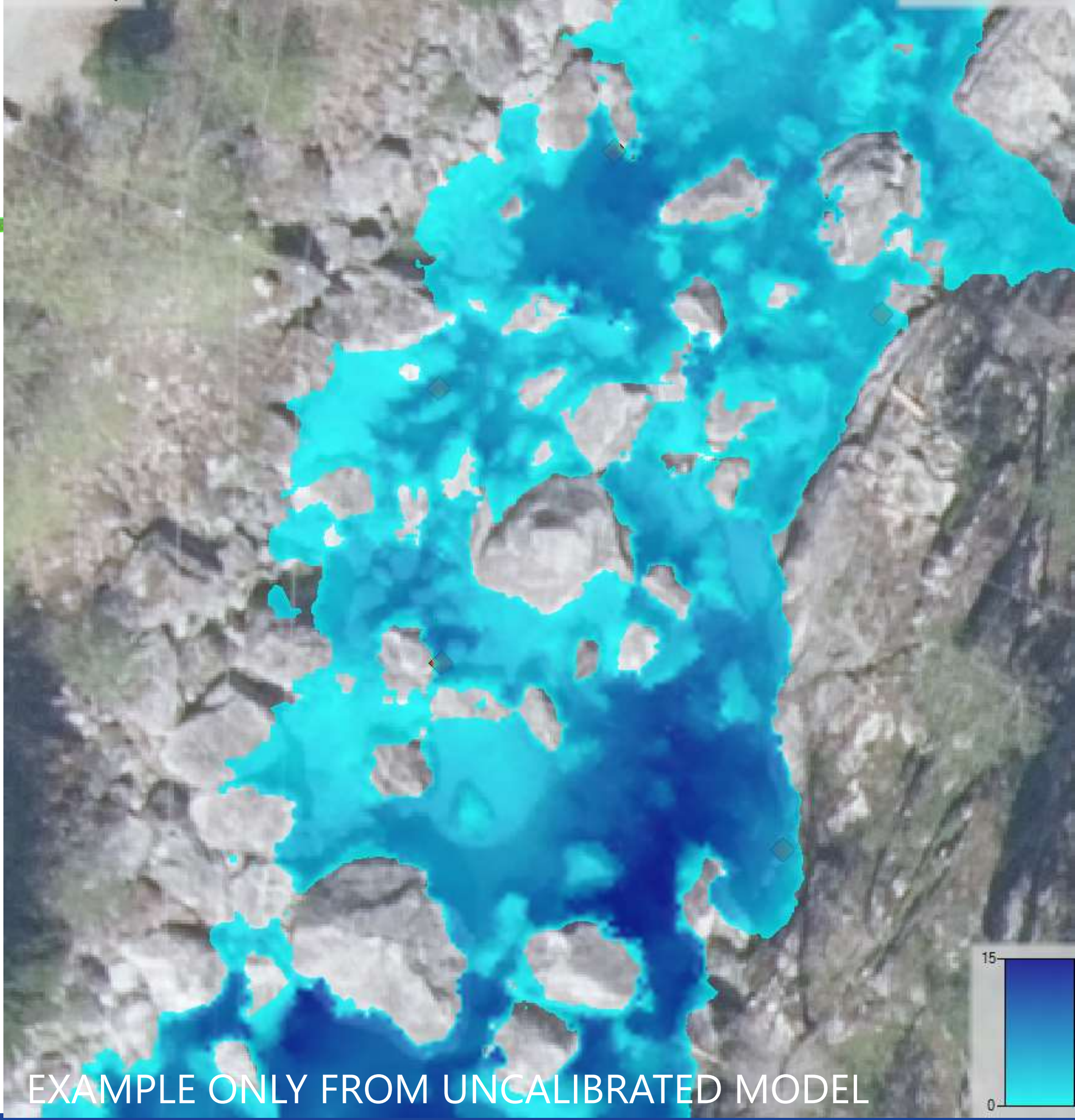
DOWNSTREAM FEATURE

DOWNSTREAM FEATURE





DOWNSTREAM FEATURE



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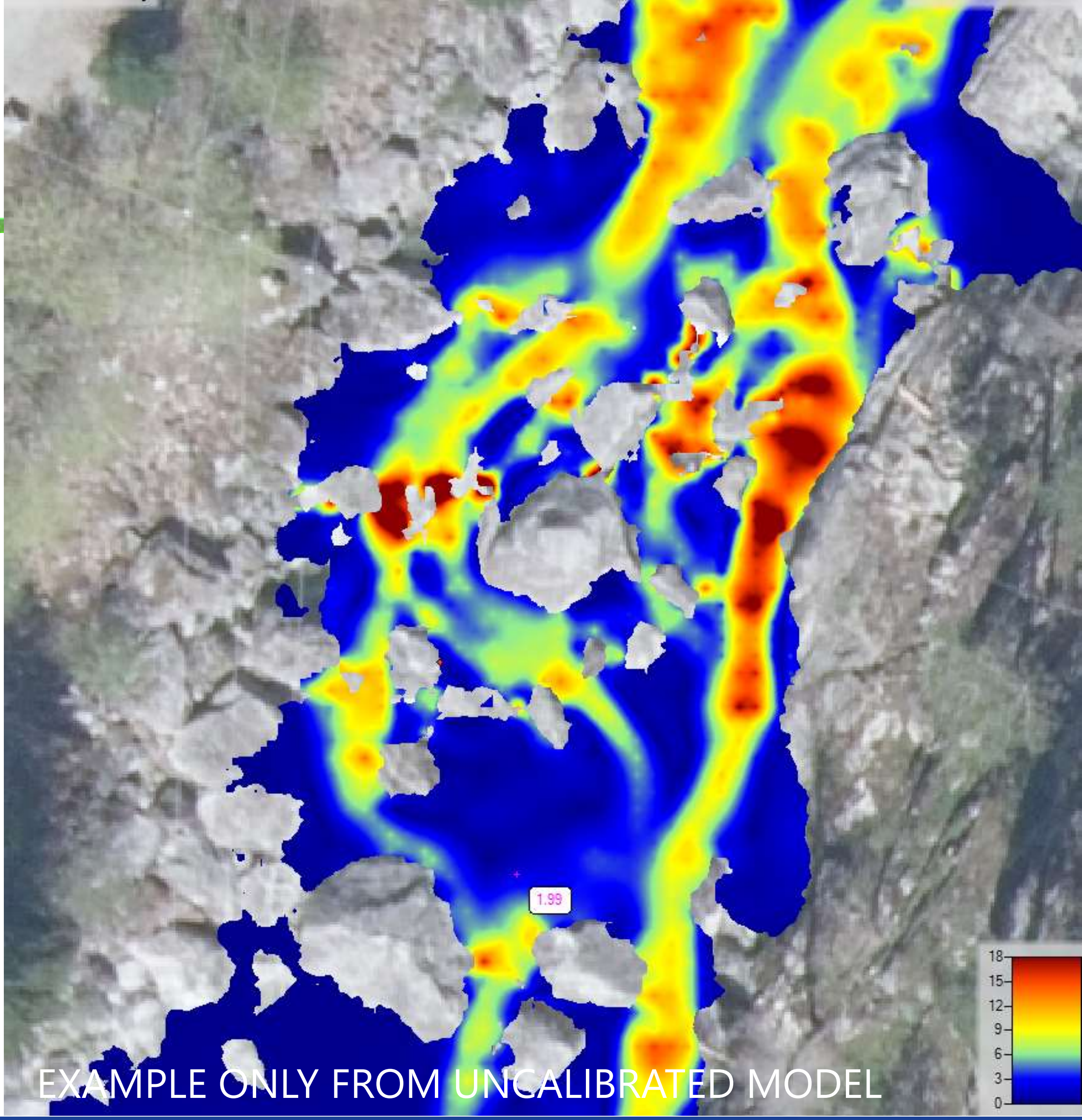
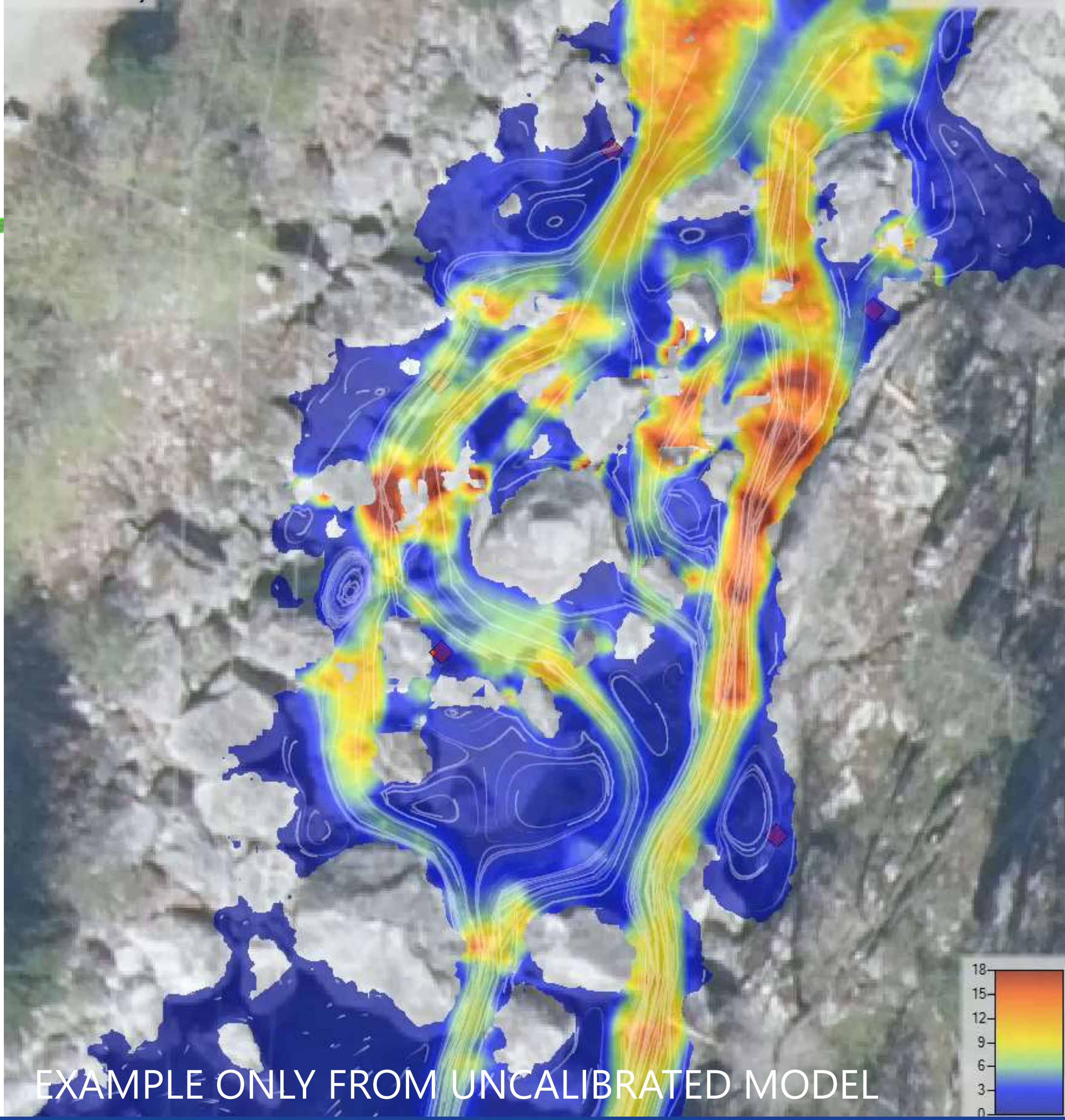


DOWNSTREAM FEATURE

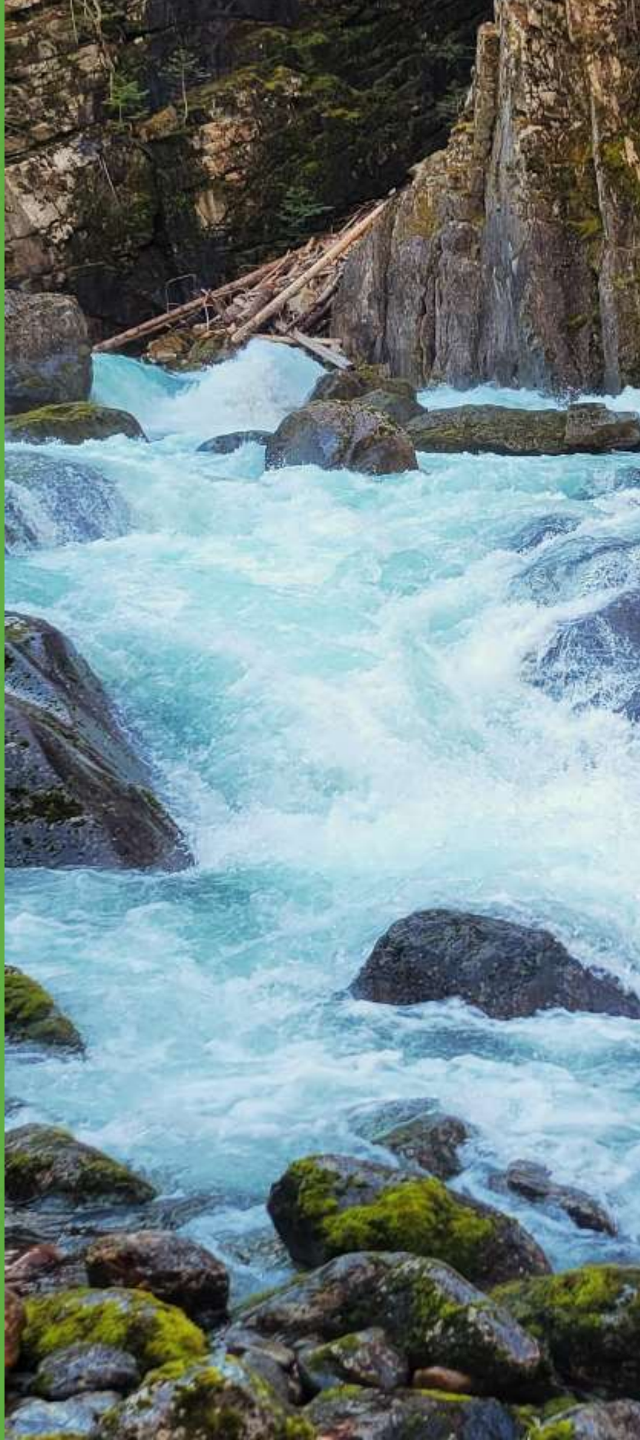


VELOCITY MEASUREMENT

- Difficult and unsafe access at flows above 50 cfs
- High levels of turbulence and multi-directional flow
- Conventional methods likely inadequate
- Potential options
  - Approximation using hydraulic modeling tools
  - UAV with Particle tracking

Seattle City Light

EXAMPLE FISH PASSAGE EVALUATION PROJECTS



FISH PASSAGE METHODS AND TOOLS

- Numerous examples of fish passage evaluation methods and complexities exist
- Standardized methods provide insight consistent with their purpose and within a range of applicable conditions
- Custom methods suit more unique site-specific conditions
- Not intended to replace or replicate results and conclusions from long-term monitoring programs

FISH PASSAGE METHODS AND TOOLS

- Example fish passage evaluations
  - Clearwater River
  - Mission Creek
  - Nelson Dam Removal
  - Example fish passage simulation technique

SF CLEARWATER RIVER

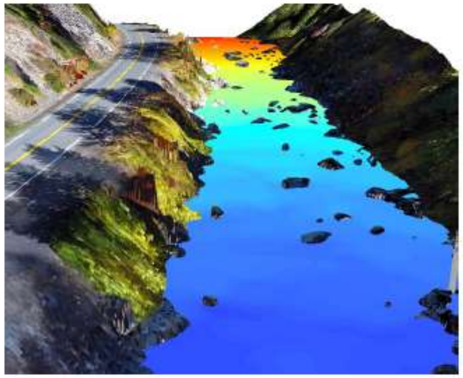
CRAMER FISH SCIENCES
An Employee Owned Consulting Company

nhc
northwest hydraulic consultants

SOUTH FORK CLEARWATER RIVER

MP 28 Hypothesized Velocity Barrier

Final Report



Prepared for:

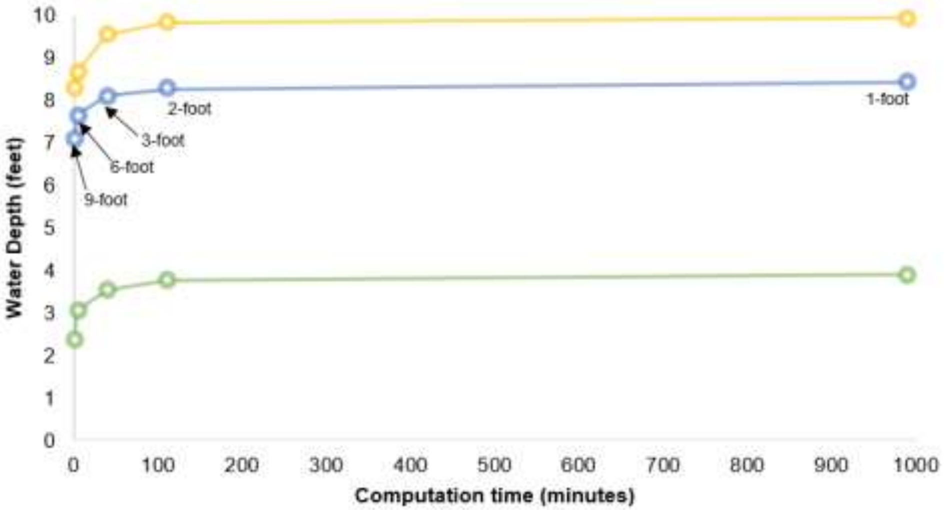
Mark Johnson, Nez Perce Tribe

Prepared by:

Ray Timm, Lucius Caldwell, Dana Stroud, and Phil Roni – Cramer Fish Sciences

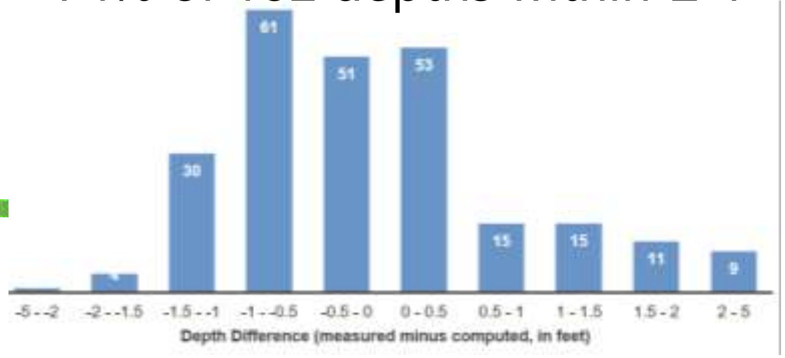
Andrew Nelson, Chris Long – Northwest Hydraulic Consultants

January 18, 2017



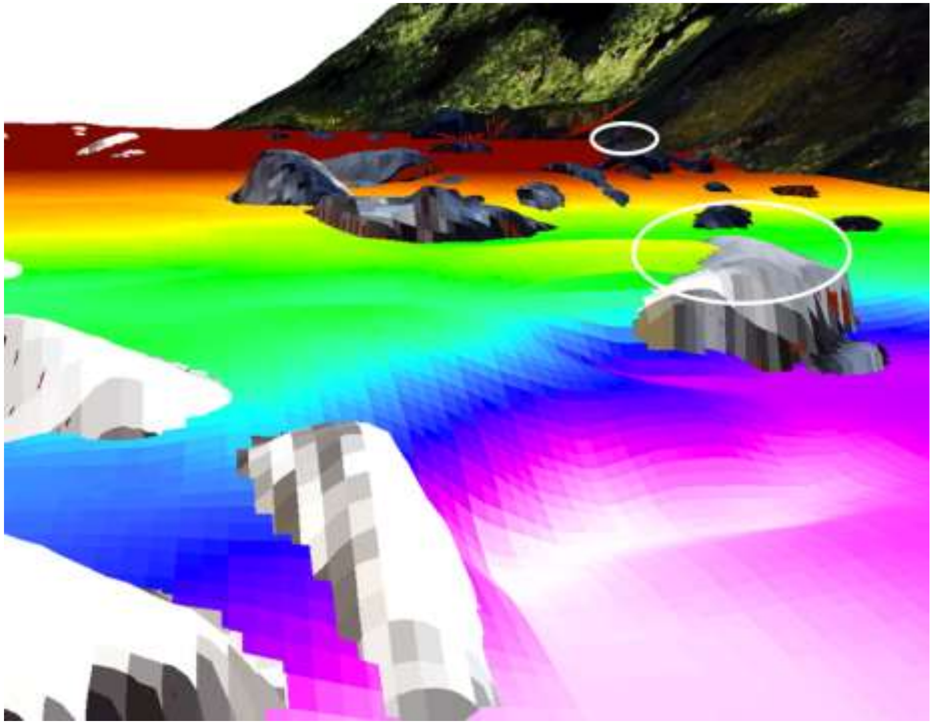
SF CLEARWATER RIVER

- 74% of 182 depths within ± 1′



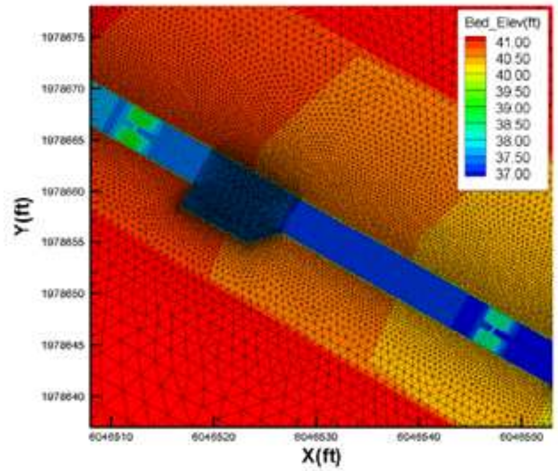
- May 5, 2016 (~1074 cfs)

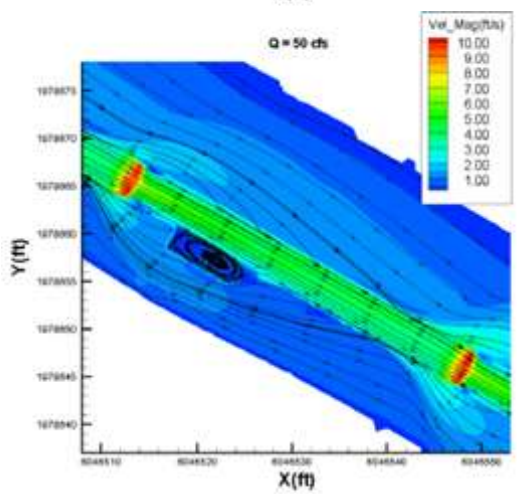
- Calibrated RAS model (1100 cfs)

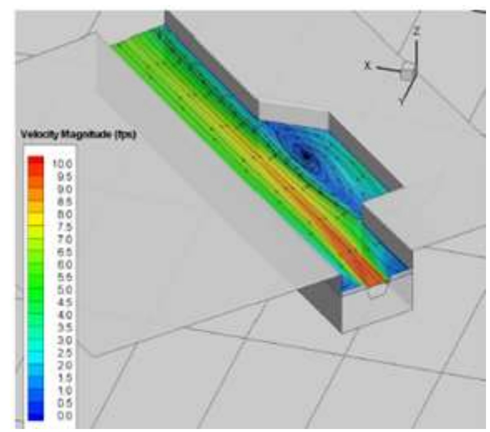


MISSION CREEK

- 1D, 2D, 3D, and physical model development
- 2D model calibrated from physical model results
- 2D model results used to perform energy expenditure simulation informing steelhead passage







TRABUCO CREEK PHYSICAL MODEL STUDIES

- Metrolink Rail Crossing
  - 1:6 Fishway Model
  - 1:20 Comprehensive Model
  - Fish Passage around 30-ft Barrier
  - Objective: Fish Passage
  - Target: California Steelhead


Metrolink Existing Barrier


1:20 Comprehensive

1:6 Fishway


I-5
Comprehensive

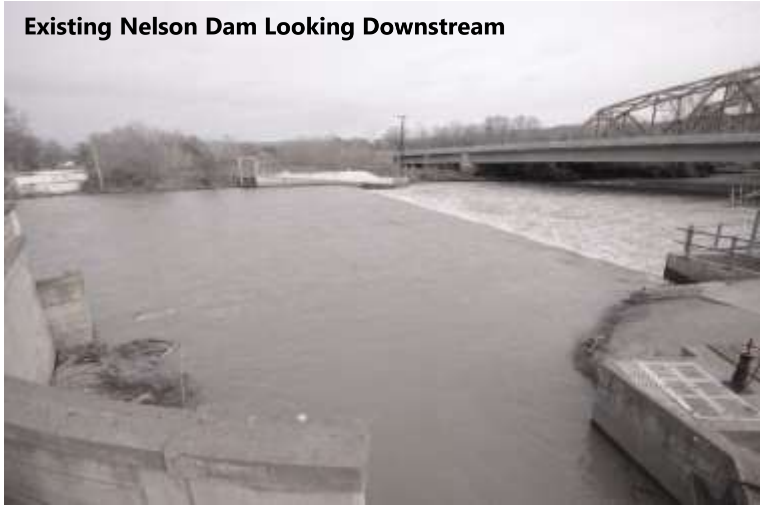

I-5 Fishway
Entrance


I-5 Fishway

- I-5 Crossing
  - 1:8 Fishway Model
  - 1:25 Comprehensive Model
  - Fish Passage through Existing Concrete Culverts and Stilling Basin
  - Objective: Fish Passage
  - Target: California Steelhead

NELSON DAM REMOVAL PHYSICAL MODEL STUDIES

- 1:24 Scale Model
- Objective: Dam Removal & Fish Passage
- Fish Channel and Sluiceway



NELSON DAM REMOVAL FISH PASSAGE EVALUATION

Figure 2-3. Swim Distance vs. Flow Velocity for 250 mm and 1,000 mm Salmonids

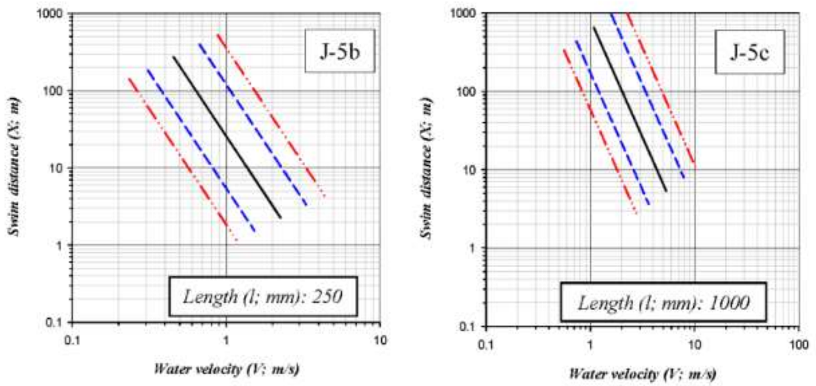
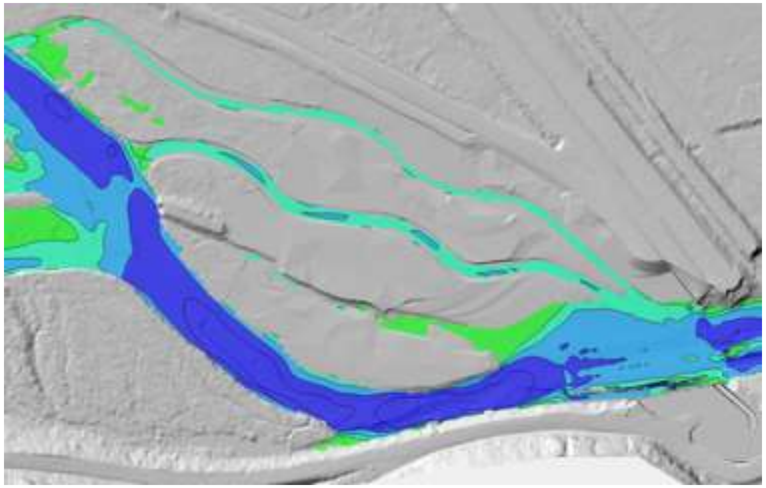
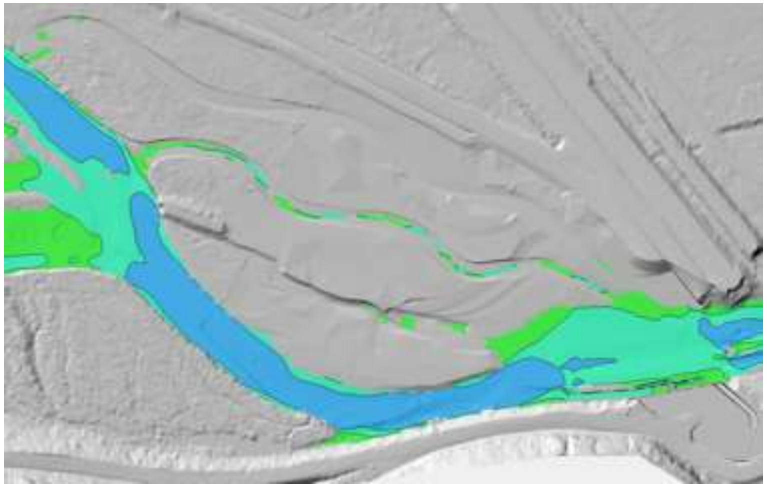


Table 4-8. Swimming Speeds For 250-mm, 1,000-mm, And 710-mm Salmonids for 75th Percentile

Fish Length	Time	Water Velocity (fps)	Swim Distance (ft)	Correlated Swim Speed (fps)
250mm[a] (10 inches)	5 seconds	9.5	16.4	12.8
	20 seconds	6.9	45.9	9.2
	3 minutes	4.3	229.6	5.5
	30 minutes	2.1	1,312.0	2.9
710mm[b] (28 inches)	5 seconds	18.0	30.5	24.1
	20 seconds	12.7	86.2	17.0
	3 minutes	7.3	450.9	9.8
	30 minutes	4.0	2,418.5	5.4

[a] Obtained from Katopodis and Gervais (2016), Appendix E, Charts J-5b and J-5c.
[b] Interpolated from Katopodis and Gervais (2016) data using dimensionless length ratio.





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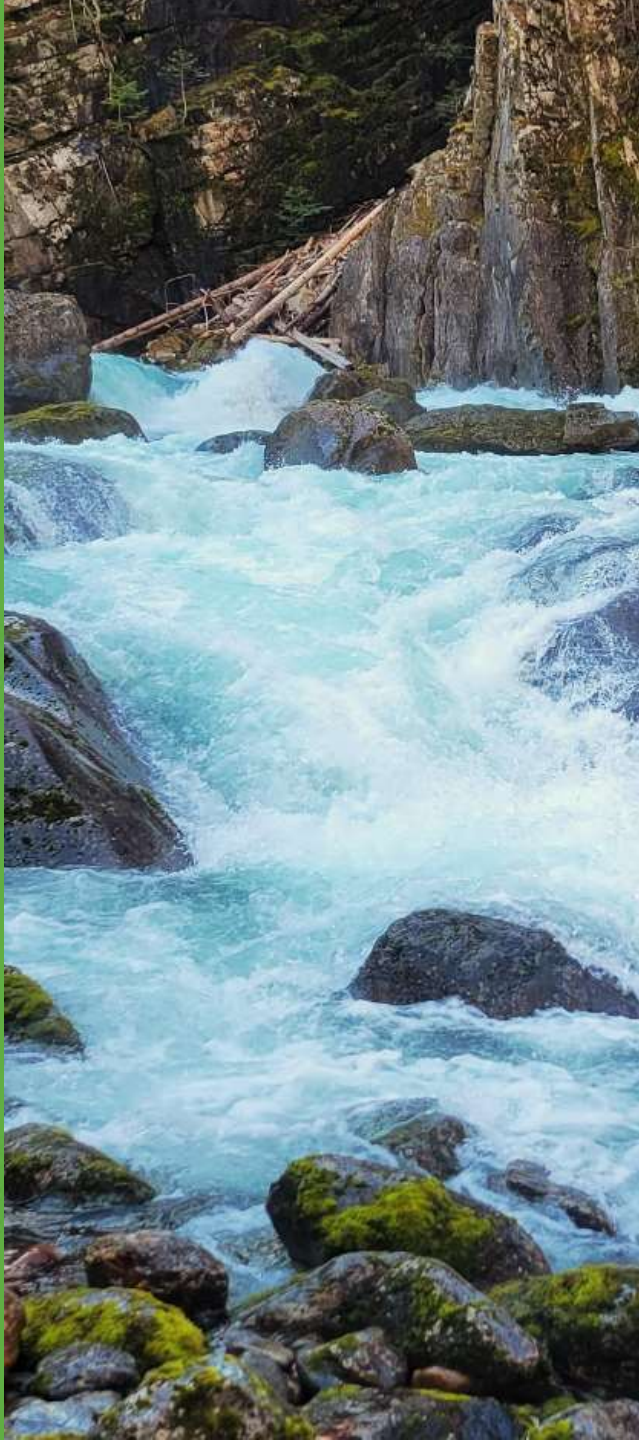
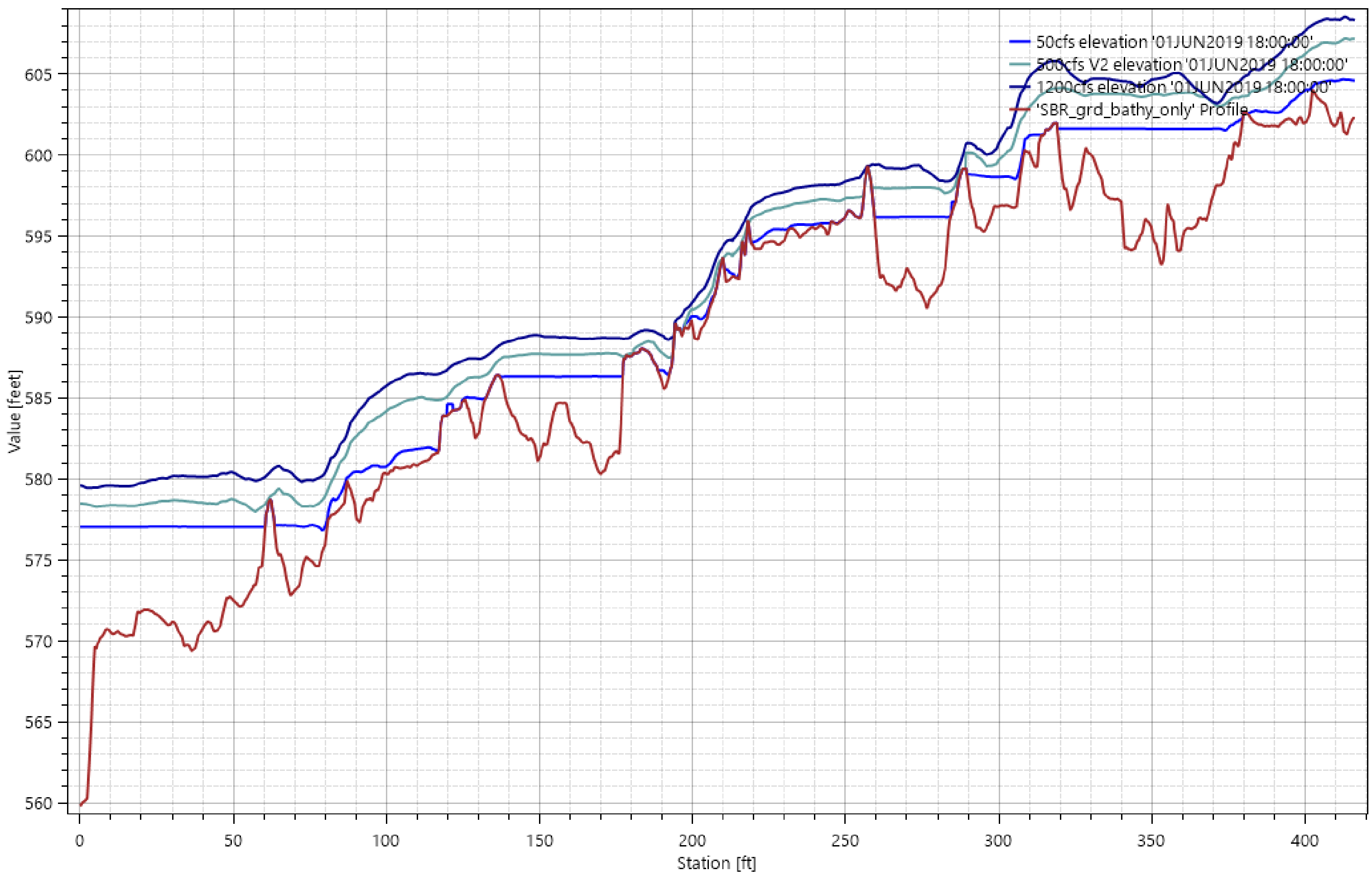
USE OF HYDRAULIC MODELS TO SUPPORT FISH PASSAGE INTERPRETATIONS



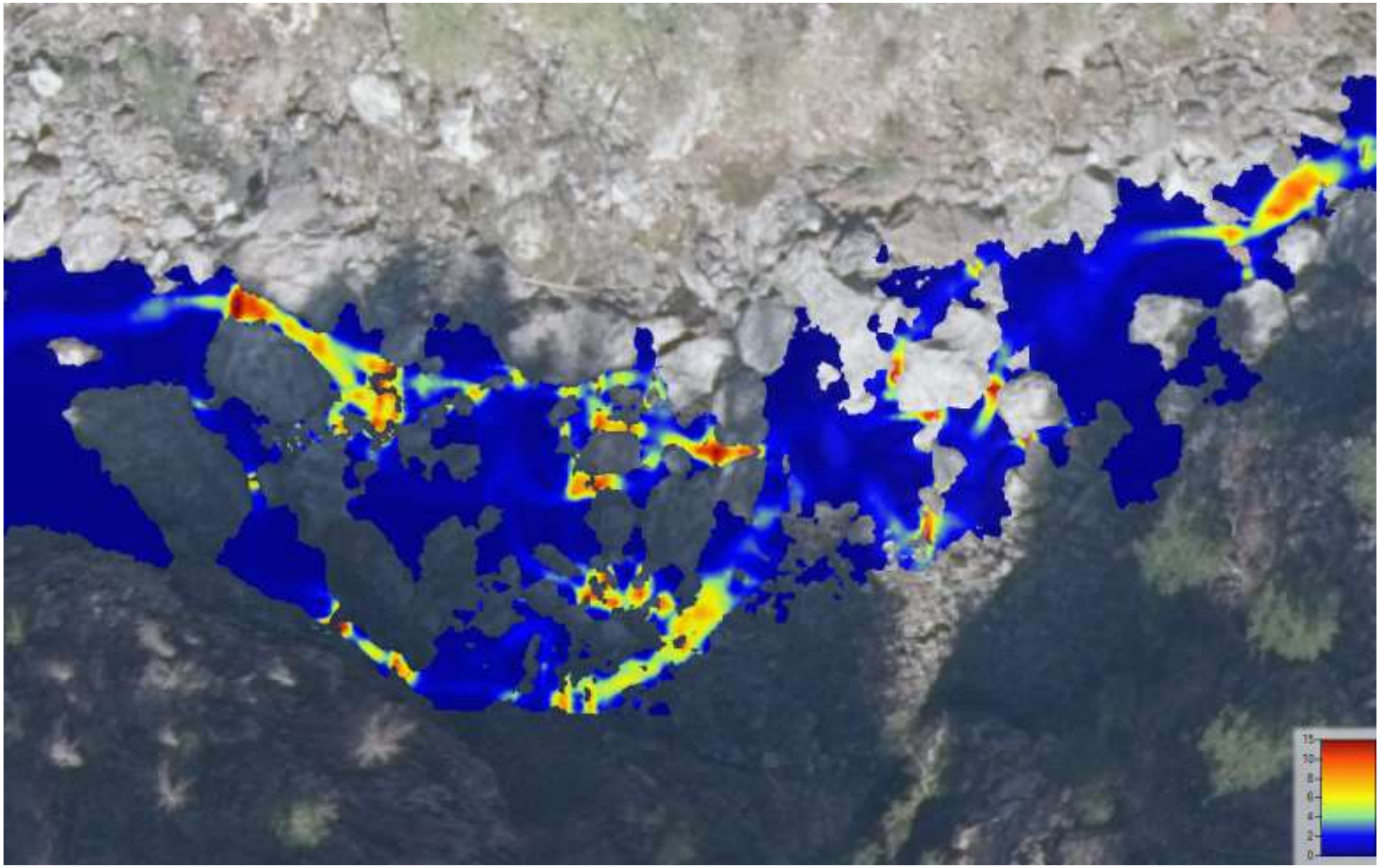
THE ROLE OF HYDRAULIC MODELING IN THE PROPOSED STUDY

- Informs data collection methods
- Informs development of hydraulic pathways that may provide passage
- Informs transition between plunging and streaming flow regimes – leaping vs swimming conditions
- Provides a tool to study trends across the range of flows experienced at the site
- Not intended to be a quantitative tool to dictate pass or fail

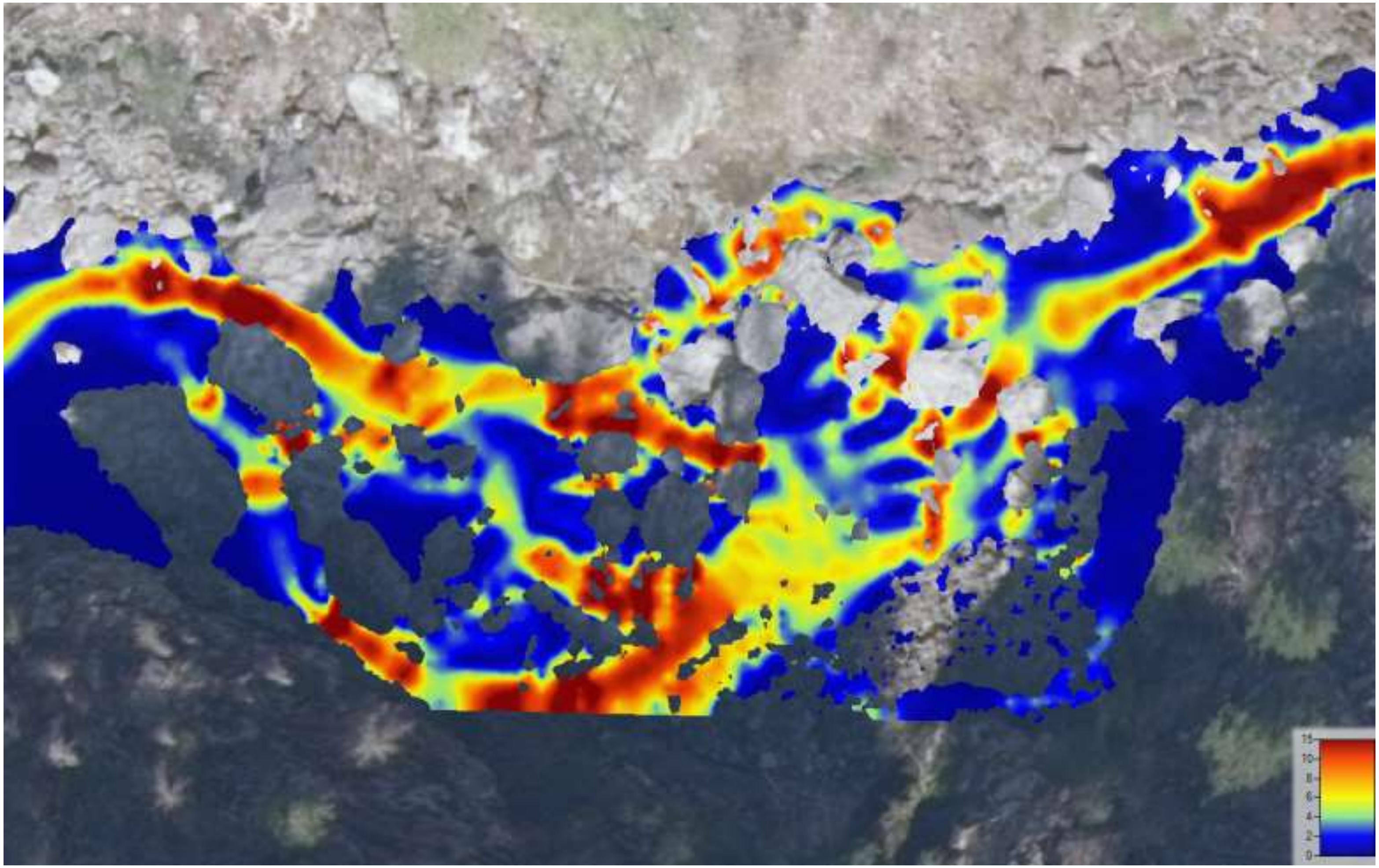
UNCALIBRATED HEC-RAS MODEL – WSEL PROFILE



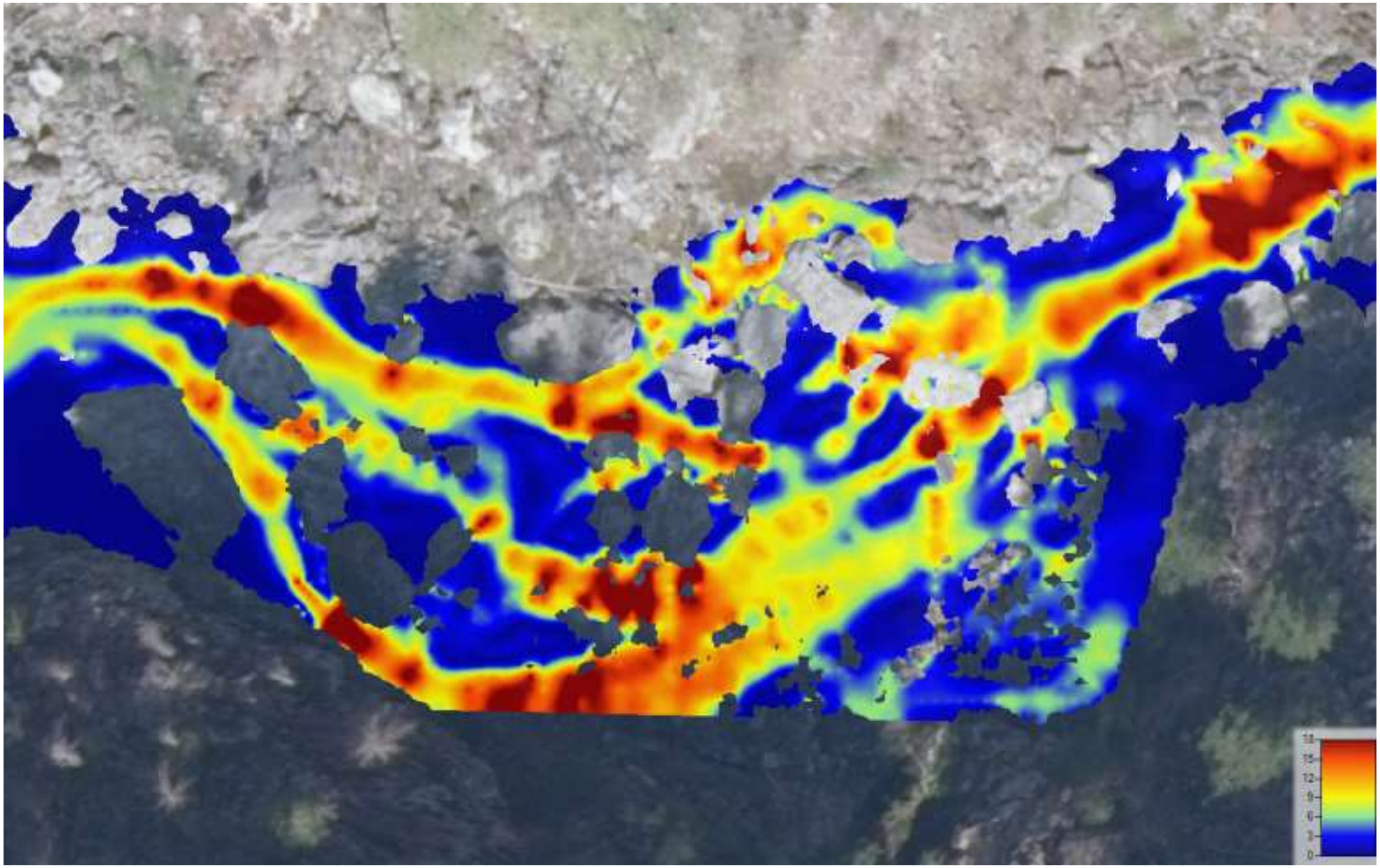
UNCALIBRATED HEC-RAS MODEL – 50 CFS



UNCALIBRATED HEC-RAS MODEL – 500 CFS



UNCALIBRATED HEC-RAS MODEL – 1200 CFS



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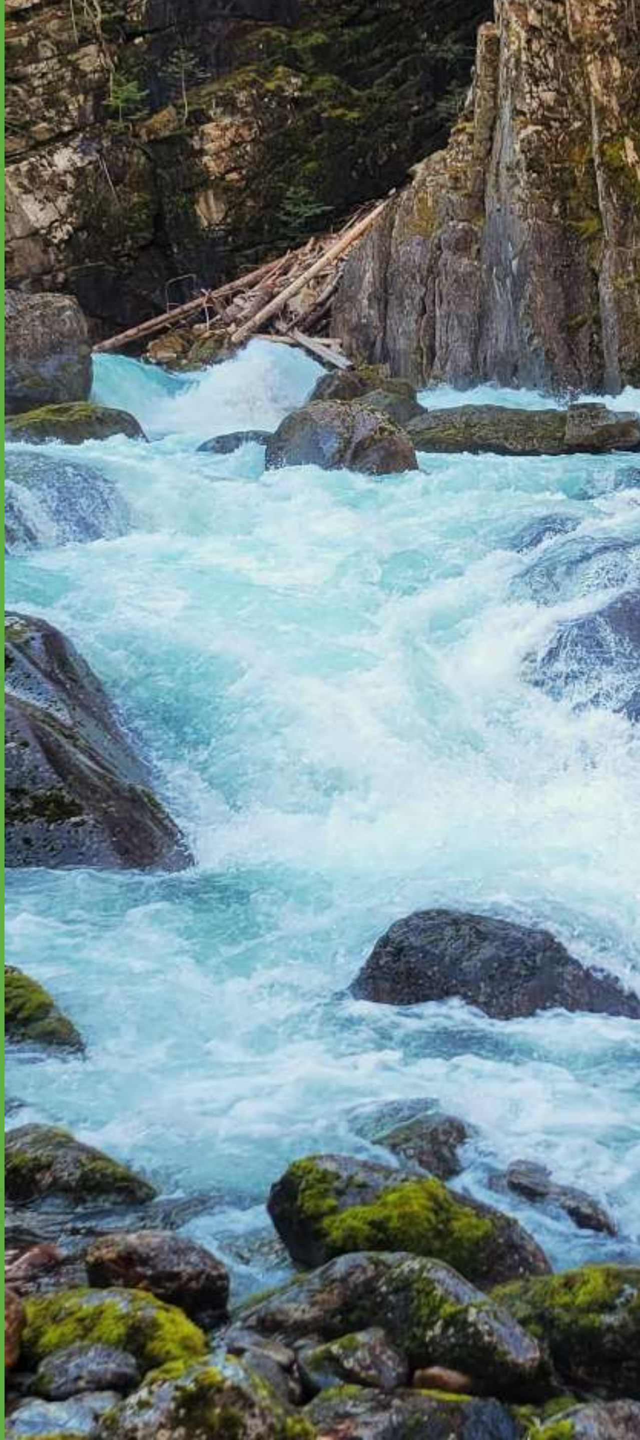
SELECTION AND APPLICABILITY OF MODELING PLATFORMS



HYDRAULIC MODEL SELECTION

All models are wrong, but some models are useful. So the question you need to ask is not "Is the model true?" (it never is) but "Is the model good enough for this particular application? – George Box

HYDRAULIC MODEL SELECTION

- All model applications are influenced by
  - Physical environment, digital terrain, and selected mesh size
  - Calibration – effort and available data
  - Hydraulic complexity
  - Understanding of model limits
  - Experience of the user

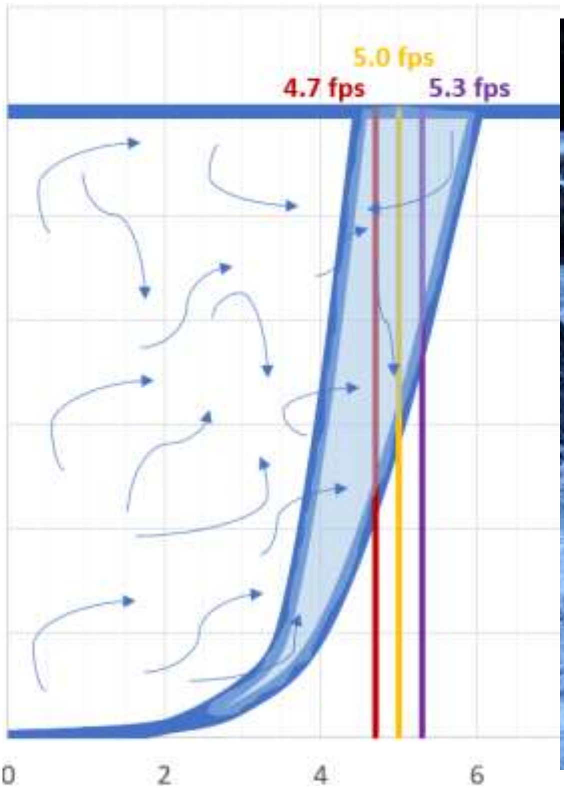
2D MODELS MOST COMMON IN WESTERN WA

- Flo-2D, difference
- River2D, element
- RiverFlow2D, volume
- Telemac-2D, volume/element
- Mike21, volume
- SRH-2D, volume
- HEC-RAS 2D, volume

MODEL COMPARISON

	HEC-RAS	SRH2D	RiverFlow2D	River2D	Telemac2D	Delft3D	PC-SWMM
Floodplain Modeling							
Large domain mesh (computation speed)							
Dam break							
Levee Breach							
Bridge Pressure Flow							
Bridge Piers							
Hydraulic structures (culverts, weirs)							
Tidal Influence							
Fish Habitat							
Ice Cover							
Graphical Display							
Sediment Transport							
FEMA Approved							
Temperature							
Active Development							
Support							
Cost/Licensing							
		can port into RiverFlow2D	can port into SRH2D	can port into Telemac2D	can be port into 3D		

DEPTH AVERAGED VELOCITY IN BYPASS REACH



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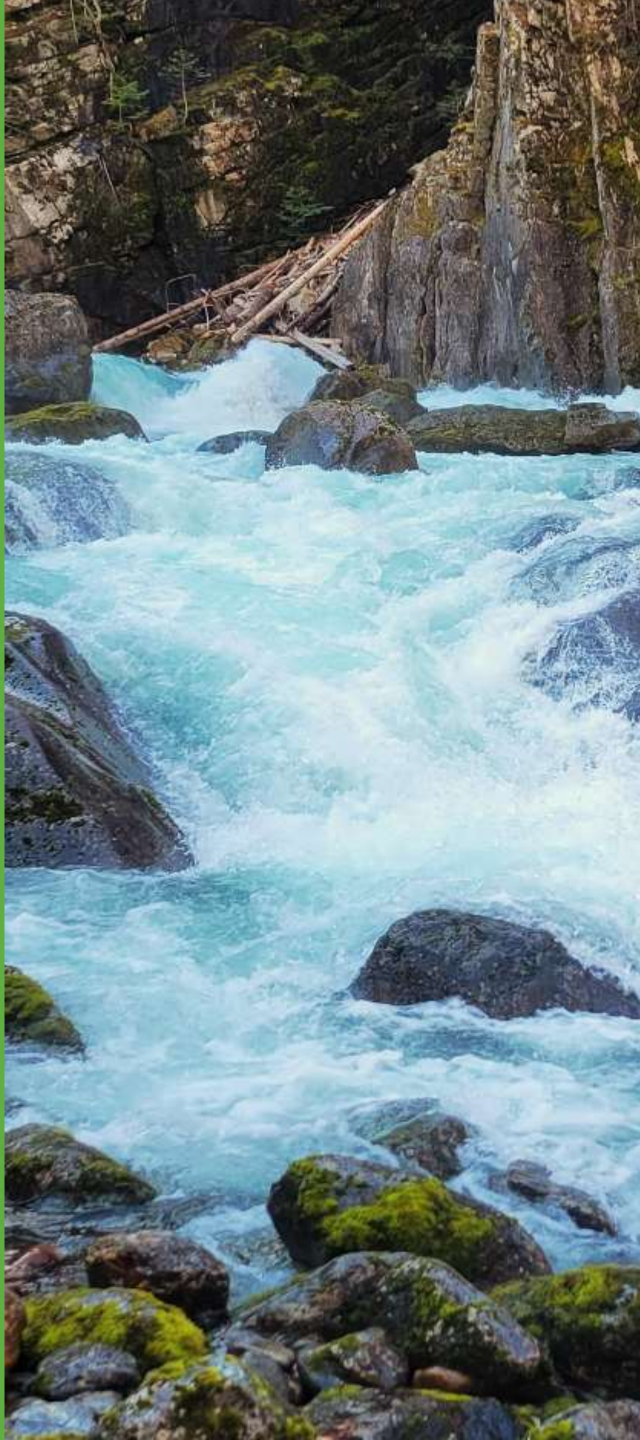
HEC-RAS 2D



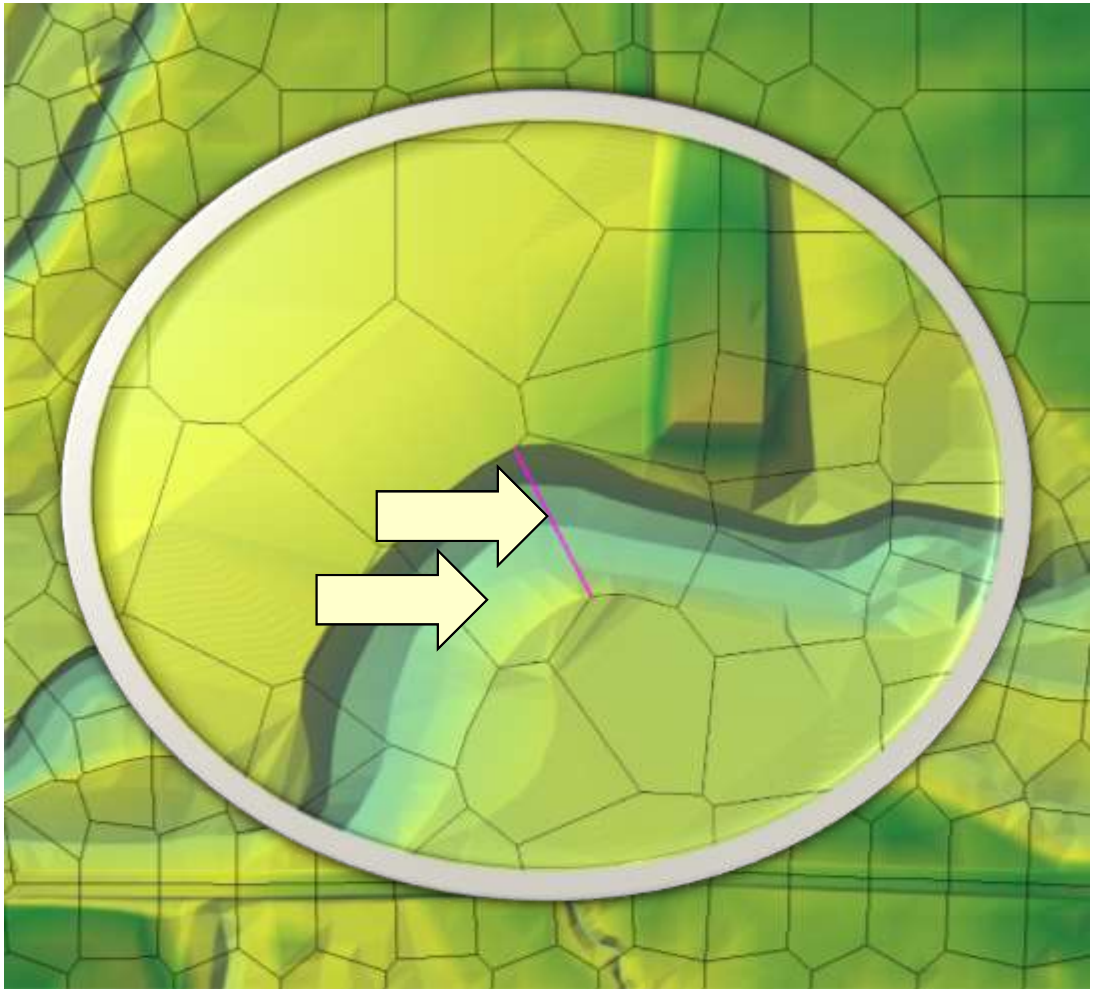
HEC-RAS 2D VERSIONS

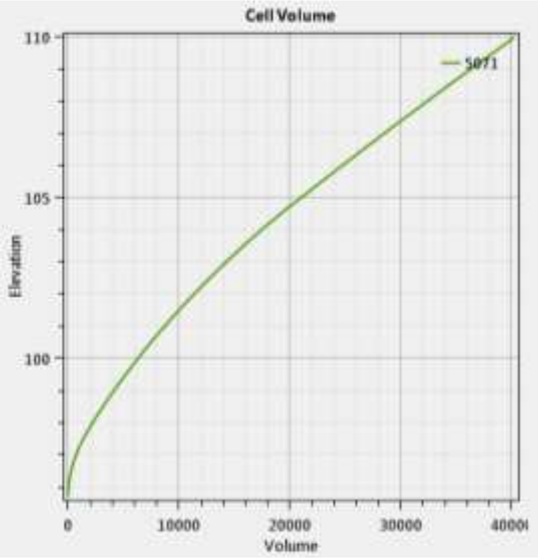
- 4.2 Alpha 2 *(2013)*
- 5.0 Beta *(2014)*
- 5.0 *(2016)*
- 5.0.1 through 5.07 *(2016-2019)*
- 6.0 Beta 3 *(March 2021)*

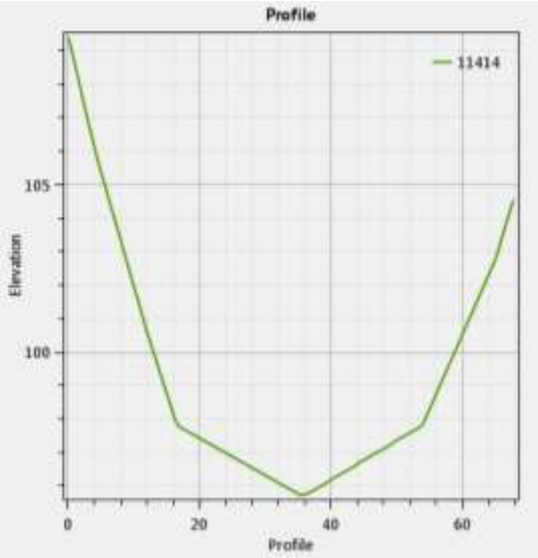
HEC-RAS 2D FEATURES

- SWE – Finite Volume (implicit)
- Wetting/drying robust, sudden rush (dam break)
- Subcritical, supercritical, mixed flow
- 1D-2D coupled
- Structured and unstructured mesh
- High-resolution subgrid model
  - hydraulic property tables vs. primitive geometry at higher resolution

HIGH RESOLUTION SUBGRID MODEL

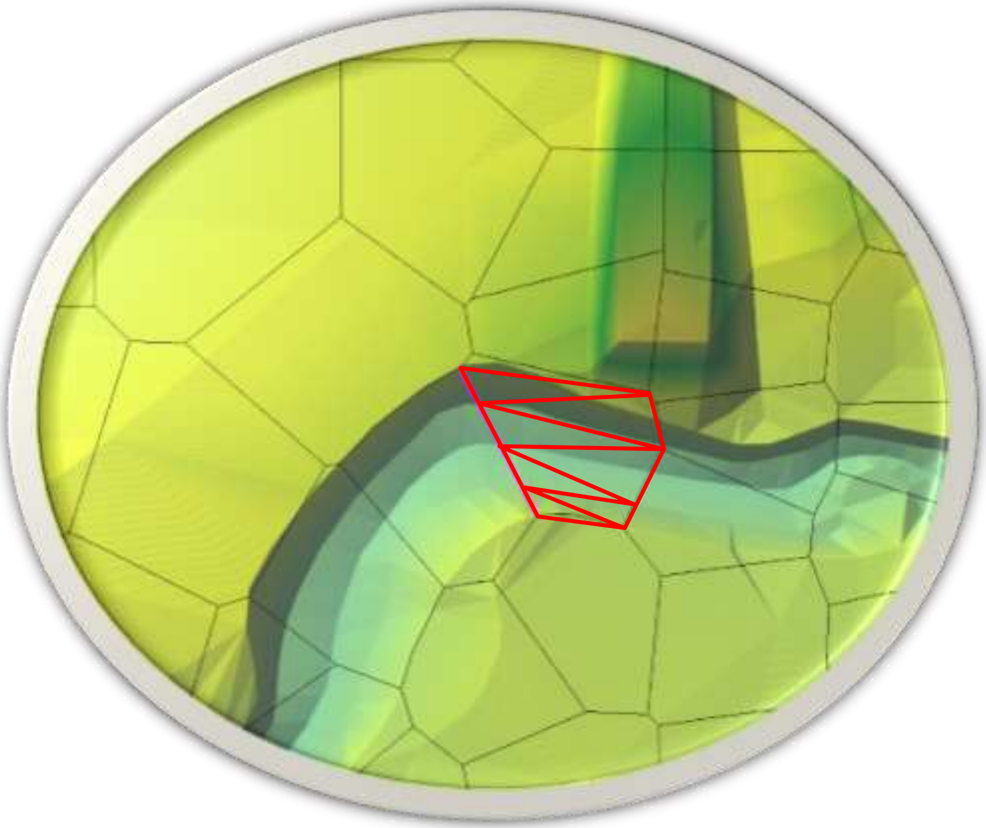


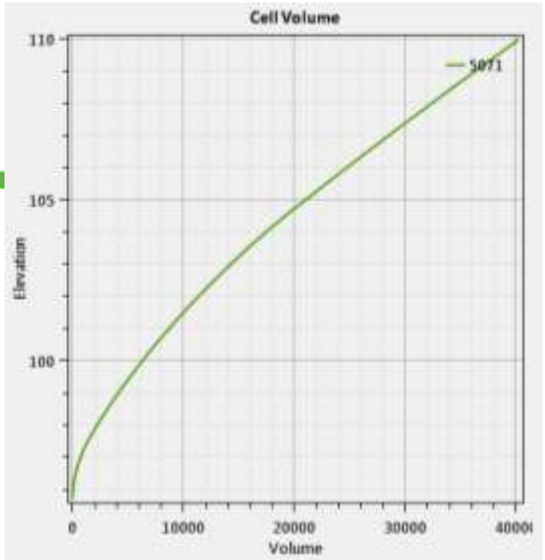


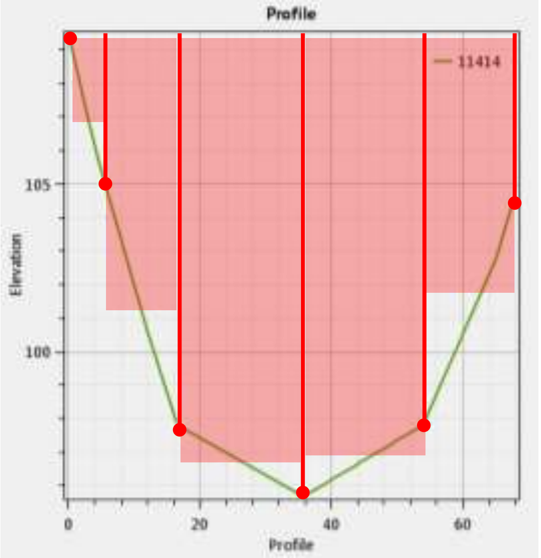


HIGH RESOLUTION SUBGRID MODEL

- Larger cells without loss of resolution







HEC-RAS TESTING

US Army Corps
of Engineers
Hydrologic Engineering Center

HEC-RAS
Verification and Validation Tests

April 2018

Approved for Public Release. Distribution Unlimited.

RD-52

US Army Corps
of Engineers
Hydrologic Engineering Center

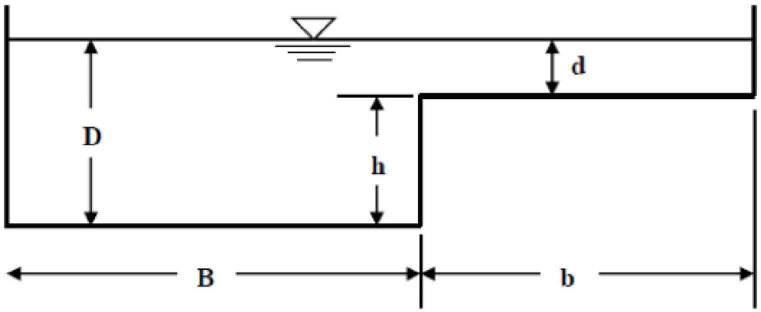
Benchmarking of the HEC-RAS Two-Dimensional Hydraulic Modeling Capabilities

April 2016

Approved for Public Release. Distribution Unlimited.

RD-51

HEC-RAS VALIDATION TESTING



- Flow in a compound channel

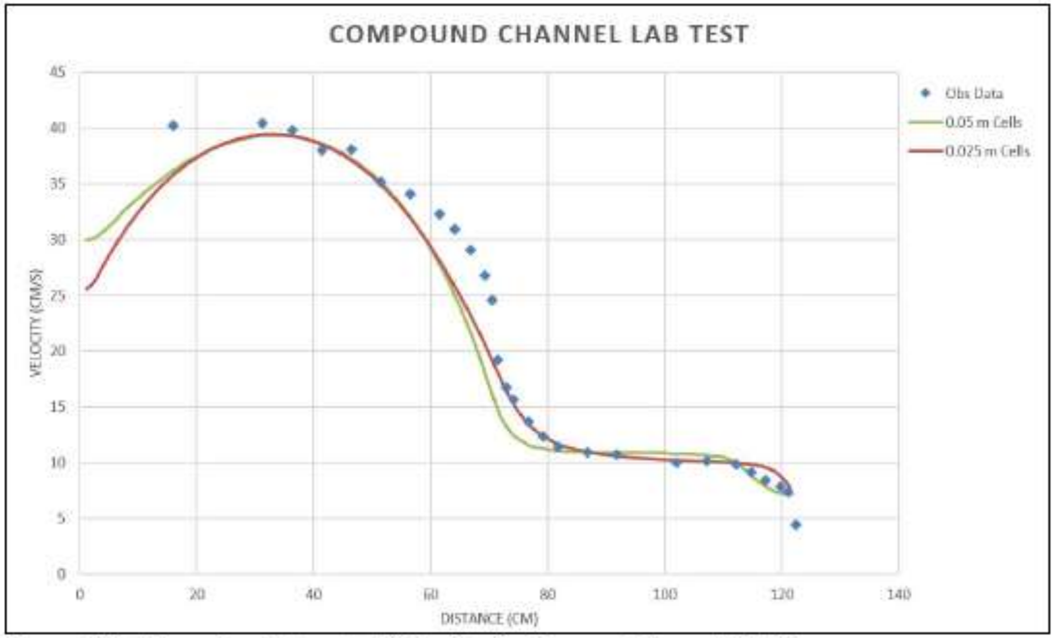
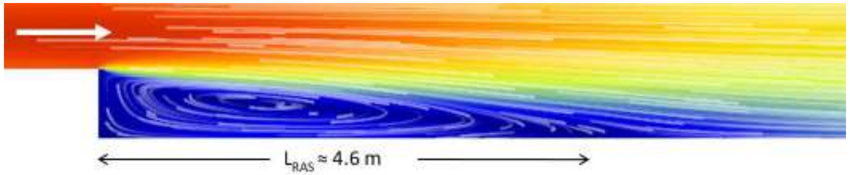


Figure 4-32. Observed and Computed Velocities for Compound Channel Test Case

HEC-RAS VALIDATION TESTING



- Flow in a rectangular channel with sudden expansion

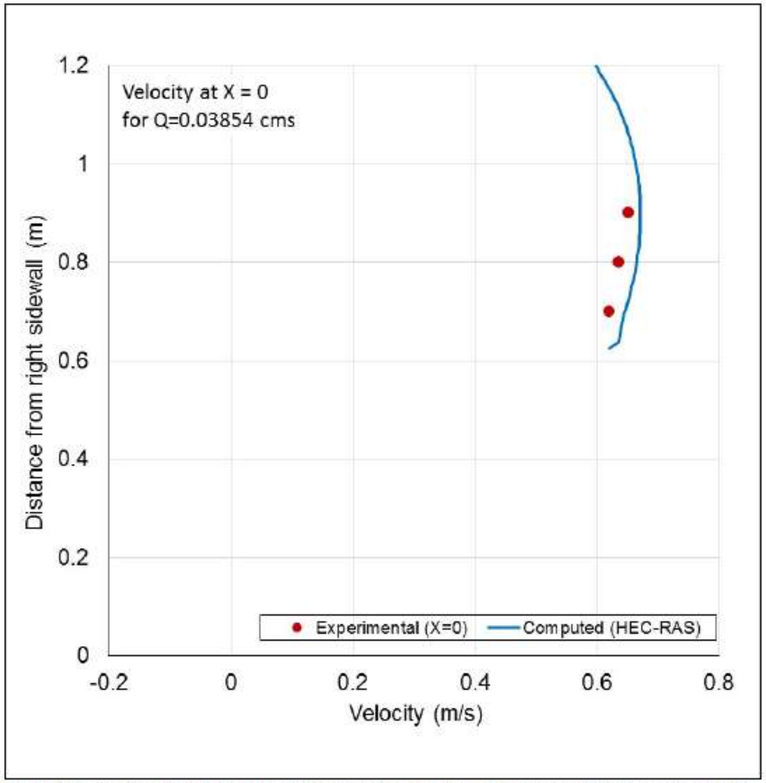


Figure 4-41. Velocity Profile (computed and experimental), at X = 0 (just upstream of the expansion) for Q = 0.03854 cms

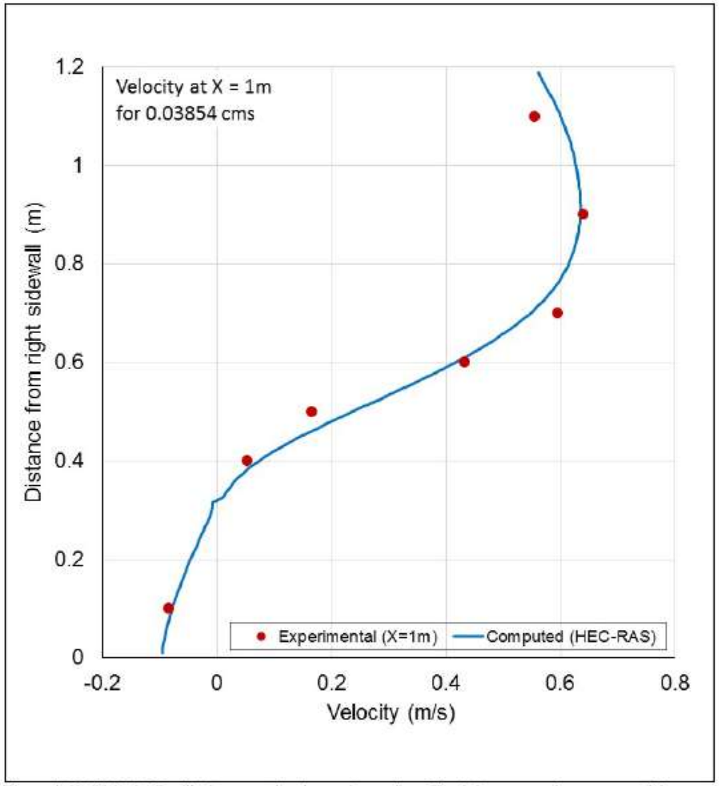


Figure 4-42. Velocity Profile (computed and experimental), at X = 1 (one meter downstream of the expansion) for Q = 0.03854 cms

HEC-RAS VALIDATION TESTING

- Flow in a rectangular channel with sudden expansion

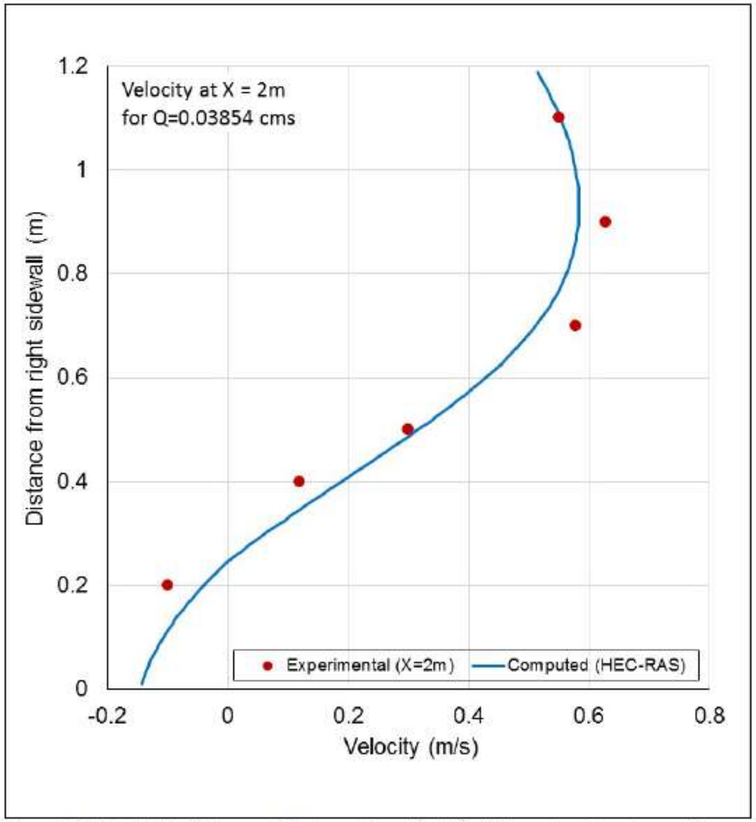


Figure 4-43. Velocity Profile (computed and experimental), at X = 2 (two meters downstream of the expansion) for Q = 0.03854 cms

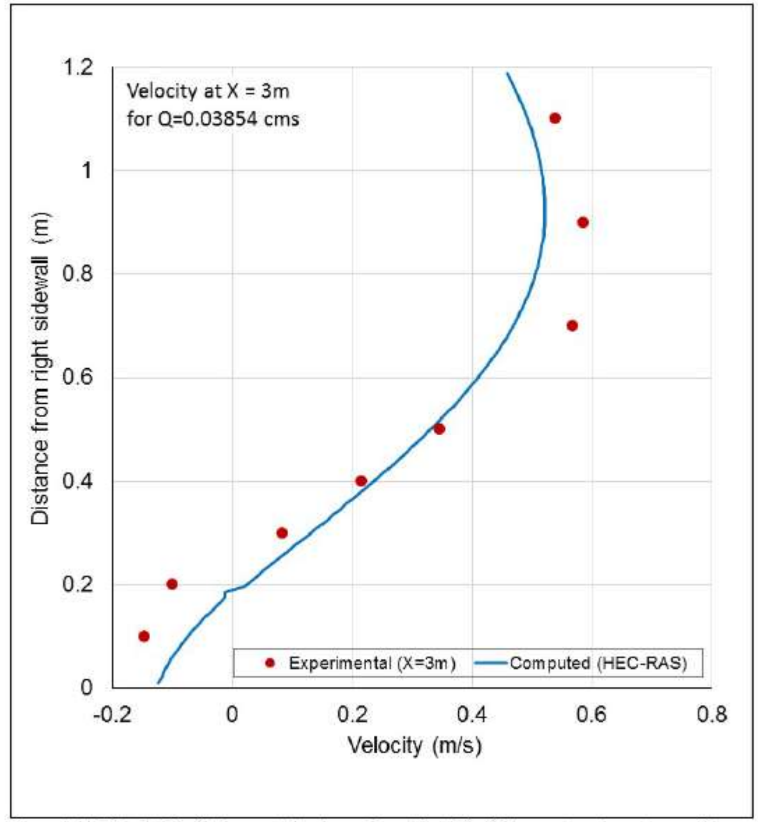


Figure 4-44. Velocity Profile (computed and experimental), at X = 3 (three meters downstream of the expansion) for Q = 0.03854 cms

HEC-RAS VALIDATION TESTING

- Flow in a rectangular channel with sudden expansion

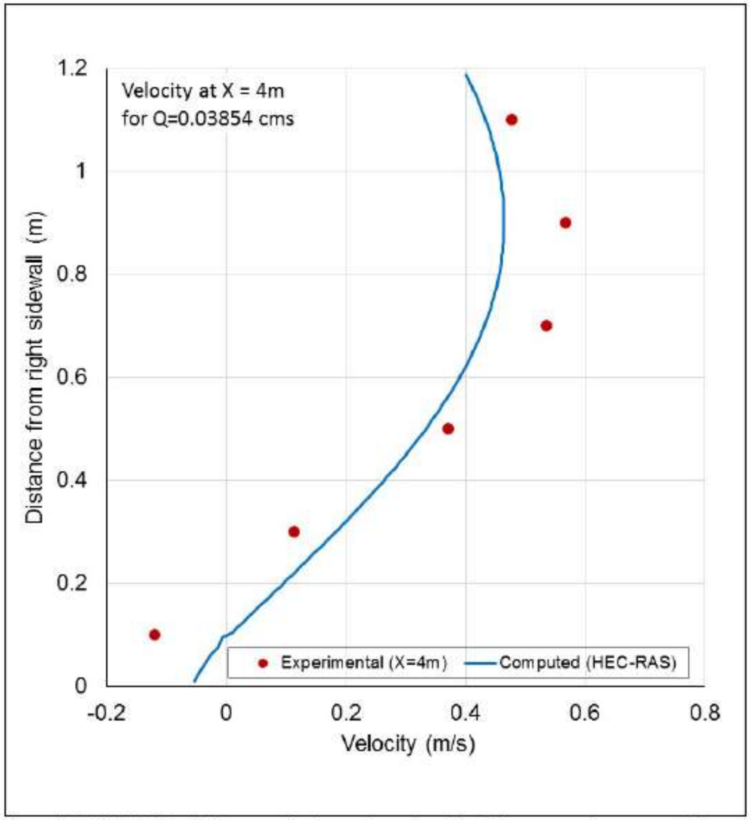


Figure 4-45. Velocity Profile (computed and experimental), at X = 4 (four meters downstream of the expansion) for Q = 0.03854 cms

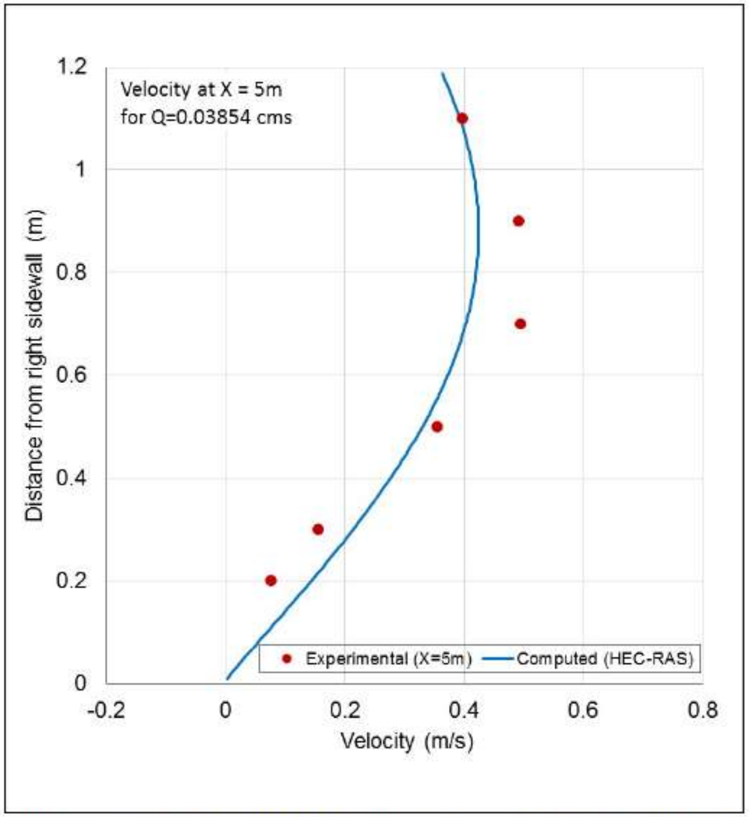


Figure 4-46. Velocity Profile (computed and experimental), at X = 5 (five meters downstream of the expansion) for Q = 0.03854 cms

HEC-RAS VALIDATION TESTING

- Rectangular channel with 180-degree bend

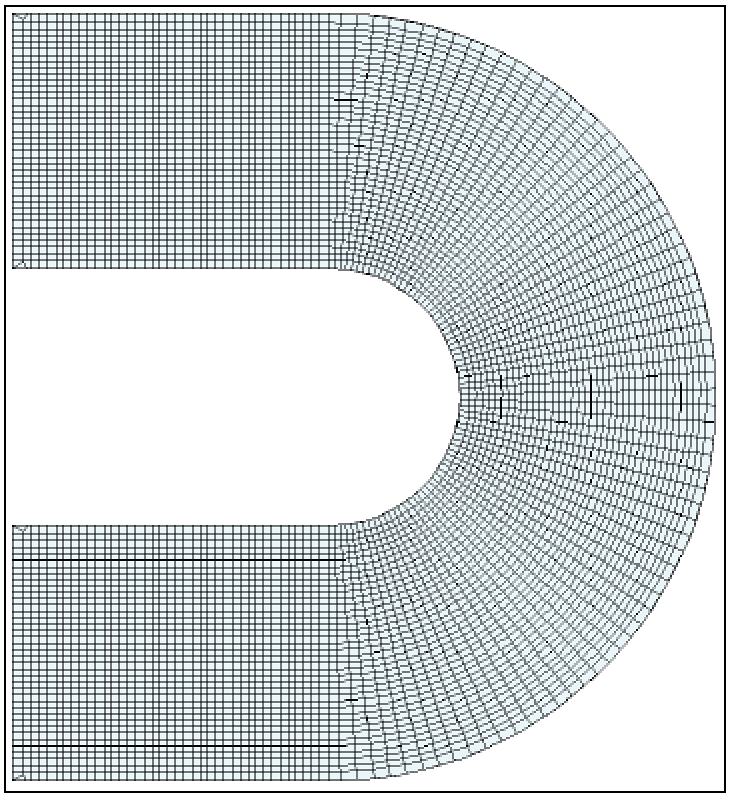


Figure 4-54. Curvilinear Computational Mesh for the 180-degree Bend Test Case

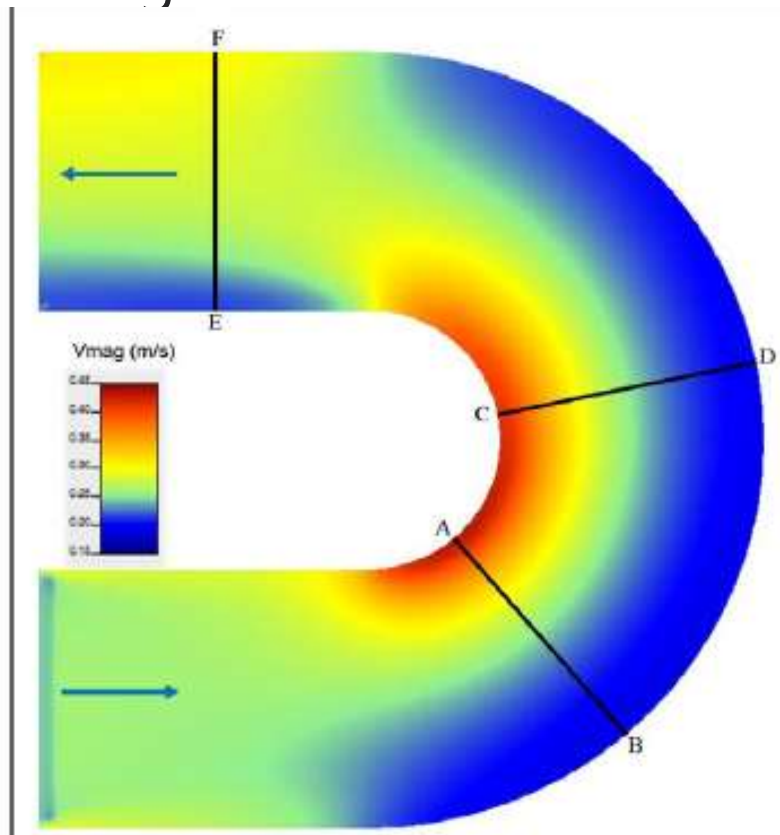


Figure 4-55. Velocity Magnitude (computed by HEC-RAS), with Faster Velocity

HEC-RAS VALIDATION TESTING

- Rectangular channel with 180-degree bend

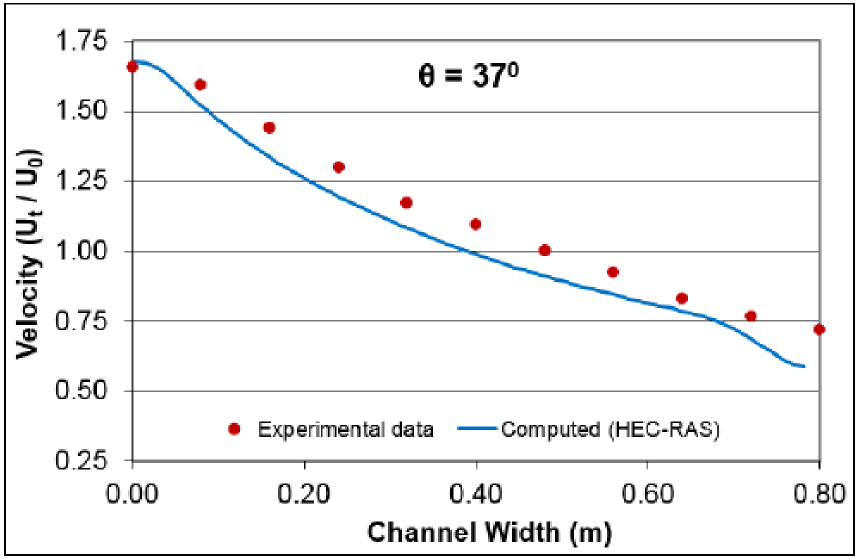


Figure 4-56. Velocity Profile (computed and experimental), at Section A-B in Figure 4-55 (with entrance velocity $U_0 = 0.265$ m/s)

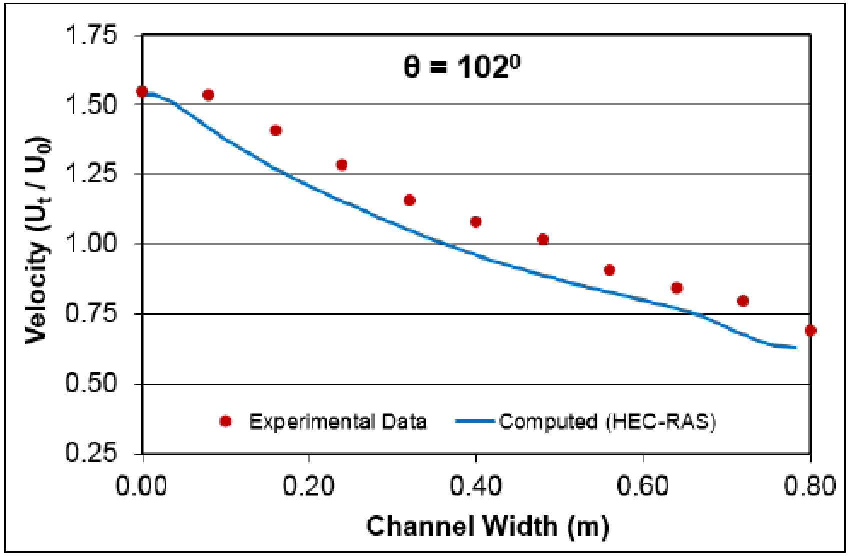
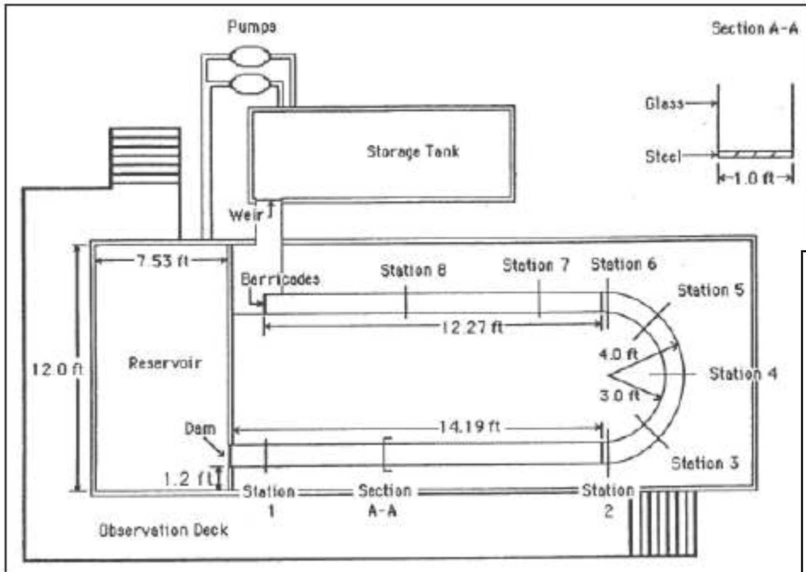


Figure 4-57. Velocity Profile (computed and experimental), at Section C-D in Figure 4-55 (with entrance velocity $U_0 = 0.265$ m/s)

HEC-RAS VALIDATION TESTING

- Dam break in channel with 180-degree bend



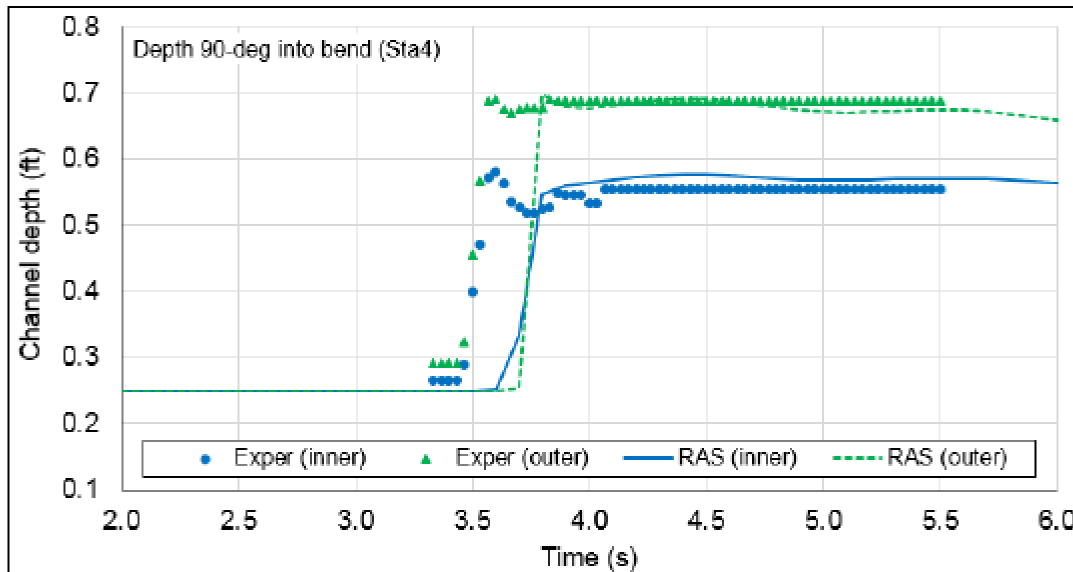


Figure 4-70. Depth Hydrograph (computed and experimental), at Station 4 in Figure 4-68 (midway through bend, 90-degrees)

HEC-RAS VALIDATION TESTING

- Flow around a Spur-Dike

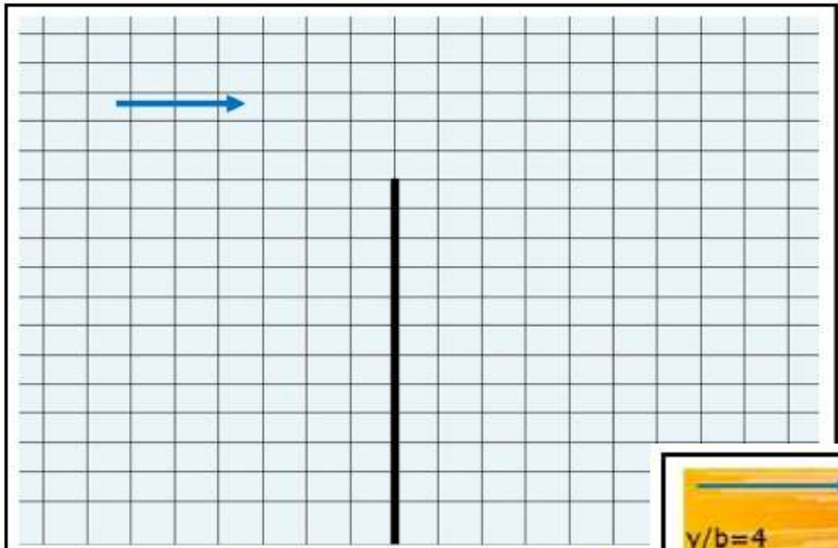


Figure 4-73. Computational Mesh for the Spur-Dike (zoomed-in near the spur

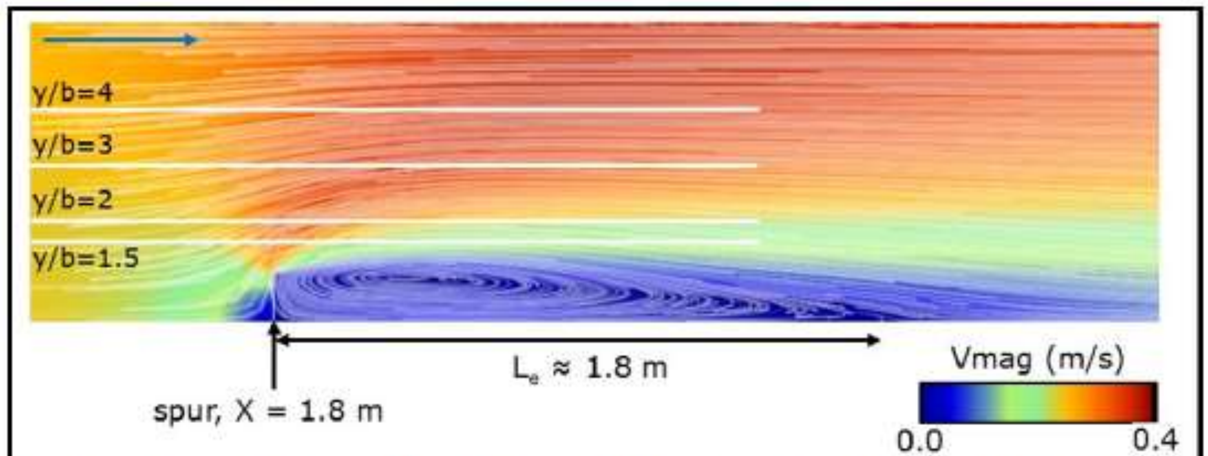
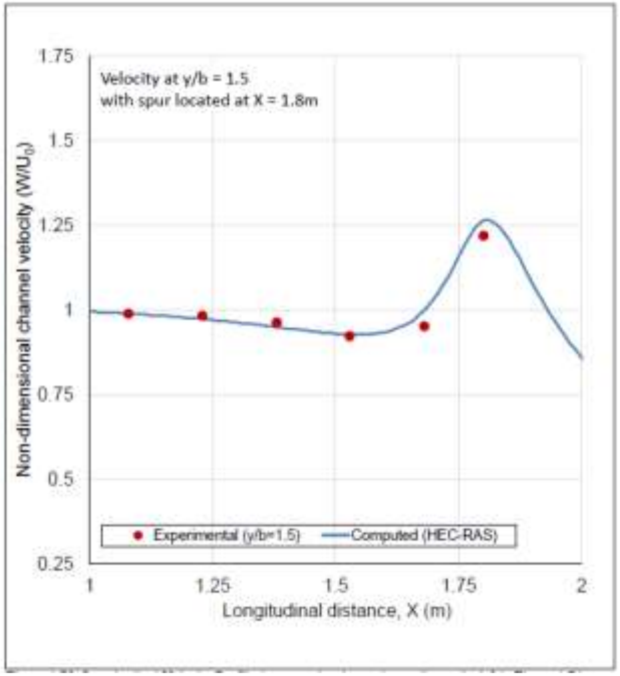
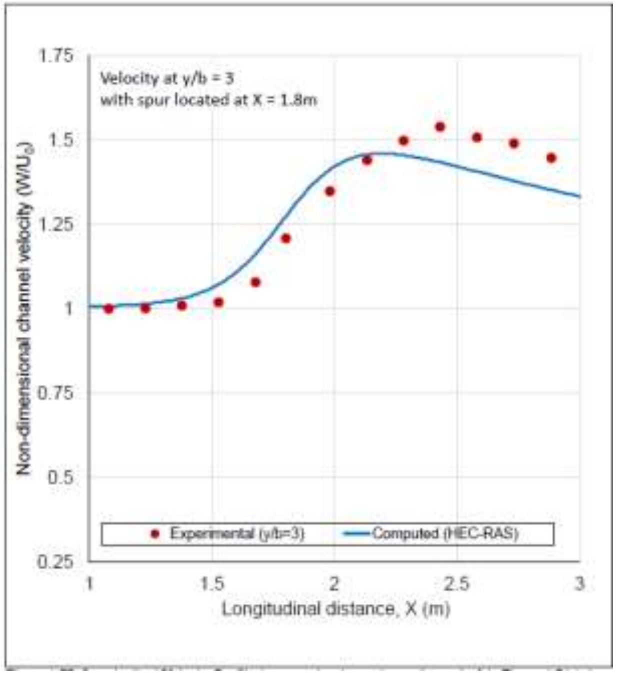


Figure 4-74. Computed Velocity Magnitude Plot with Particle Traces, the Blue Shaded Eddy Zone is Clearly Evident Downstream of the Spur-Dike

HEC-RAS VALIDATION TESTING

- Flow around a Spur-Dike





HEC-RAS VALIDATION TESTING

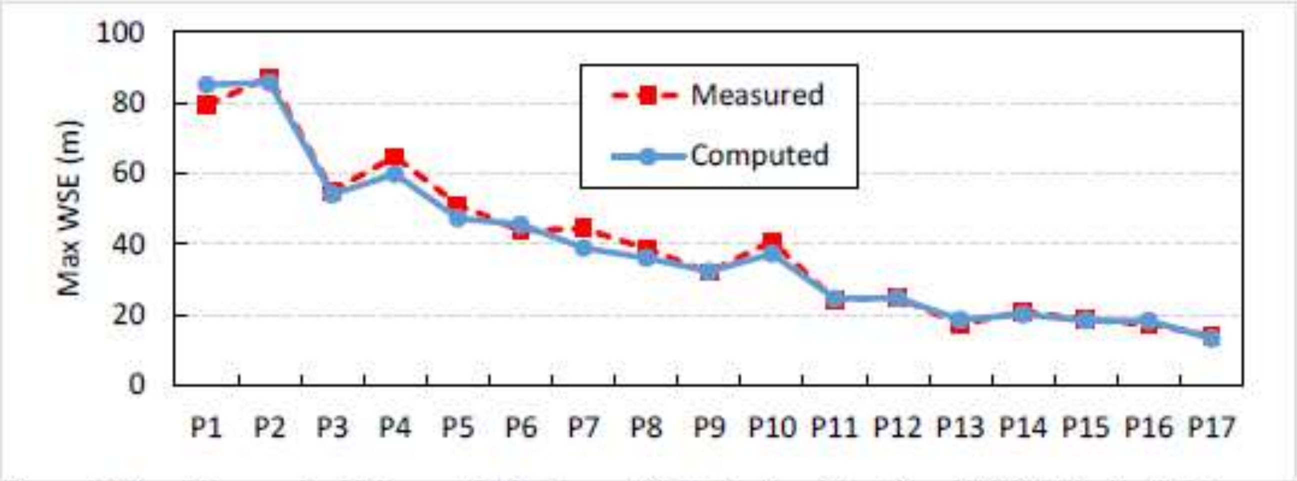


Figure 4-99. Measured and Computed Maximum Water Surface Elevations (WSEL) for the High-Water Marks Collected by the Police after the Malpasset Dam Break

- Malpasset Dam Break

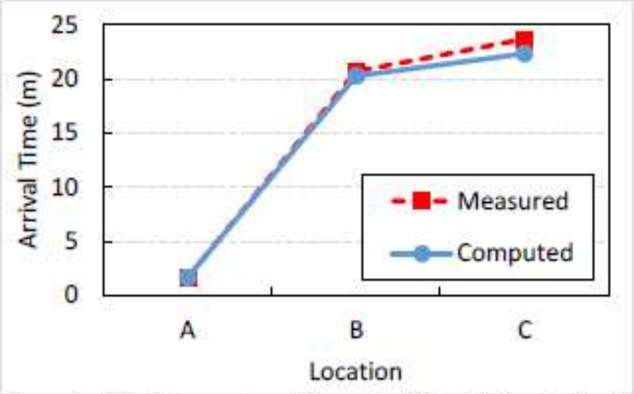
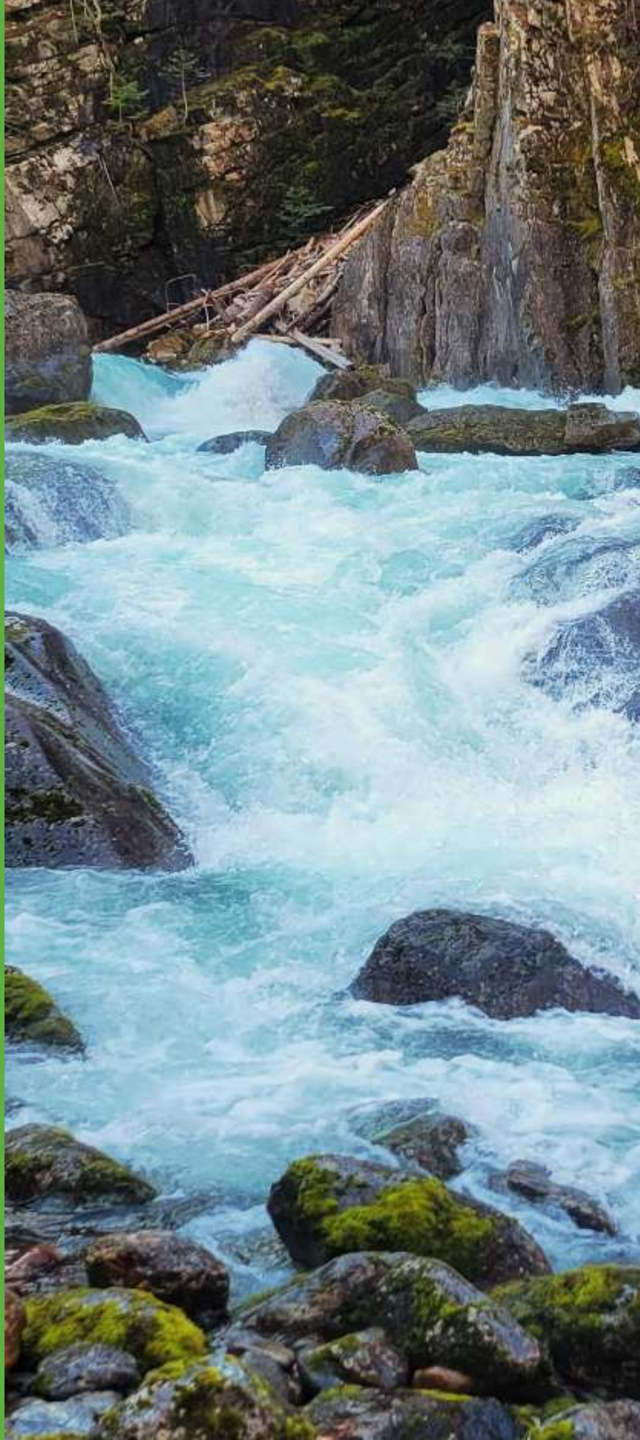


Figure 4-100. Measured and Computed Flood Wave Arrival Times for the Malpasset Dam Break at Three Locations where Electric Transformers were Damaged

Seattle City Light

SRH-2D

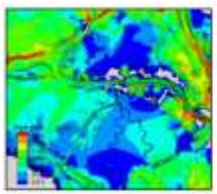


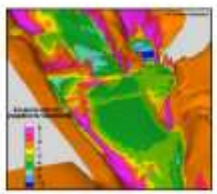
SRH-2D VERIFICATION CASES

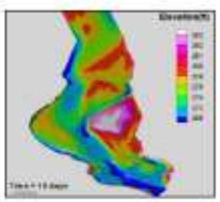
RECLAMATION
Managing Water in the West

SRH-2D version 2: Theory and User's Manual

Sedimentation and River Hydraulics – Two-Dimensional River Flow Modeling







U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

November 2008

Two-Dimensional Depth-Averaged Flow Modeling

with an Unstructured Hybrid Mesh

by

Yong G. Lai[1]

ABSTRACT

An unstructured hybrid mesh numerical method is developed to simulate open channel flows. The method is applicable to arbitrarily-shaped mesh cells and offers a framework to unify many mesh topologies into a single formulation. The finite-volume discretization is applied to the two-dimensional depth-averaged St. Venant equations, and the mass conservation is satisfied both locally and globally. An automatic wetting-drying procedure is incorporated in conjunction with the segregated solution procedure that chooses the water surface elevation as the main variable. The method is applicable to both steady and unsteady flows and covers the entire flow range: subcritical, transcritical and supercritical. The proposed numerical method is well suited to natural river flows with a combination of main channels, side channels, bars, floodplains and in-stream structures. Technical details of the method are presented, verification studies are performed using a number of simple flows, and a practical natural river is modeled to illustrate issues of calibration and validation.

KEYWORDS: 2D Model, Depth-Averaged Model, Hybrid Mesh, Unstructured Mesh

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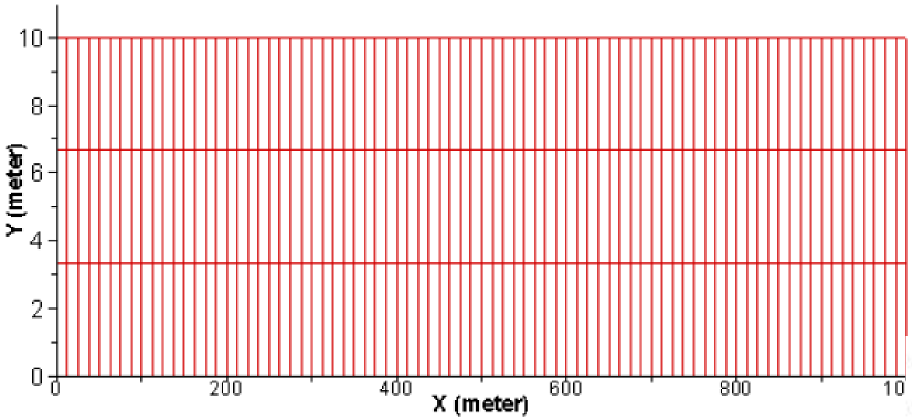
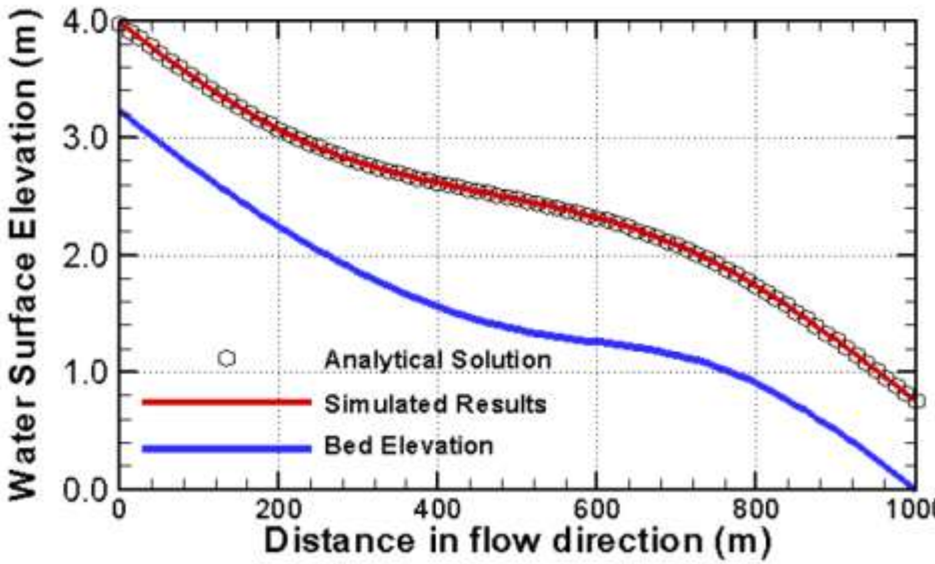
SRH-2D VERIFICATION CASES

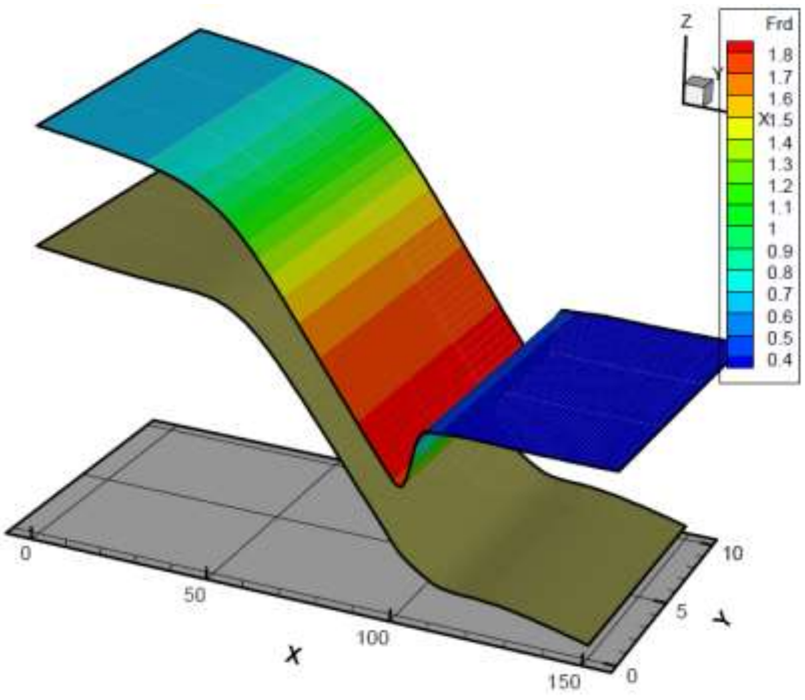
- Subcritical Flow in a 1D Channel

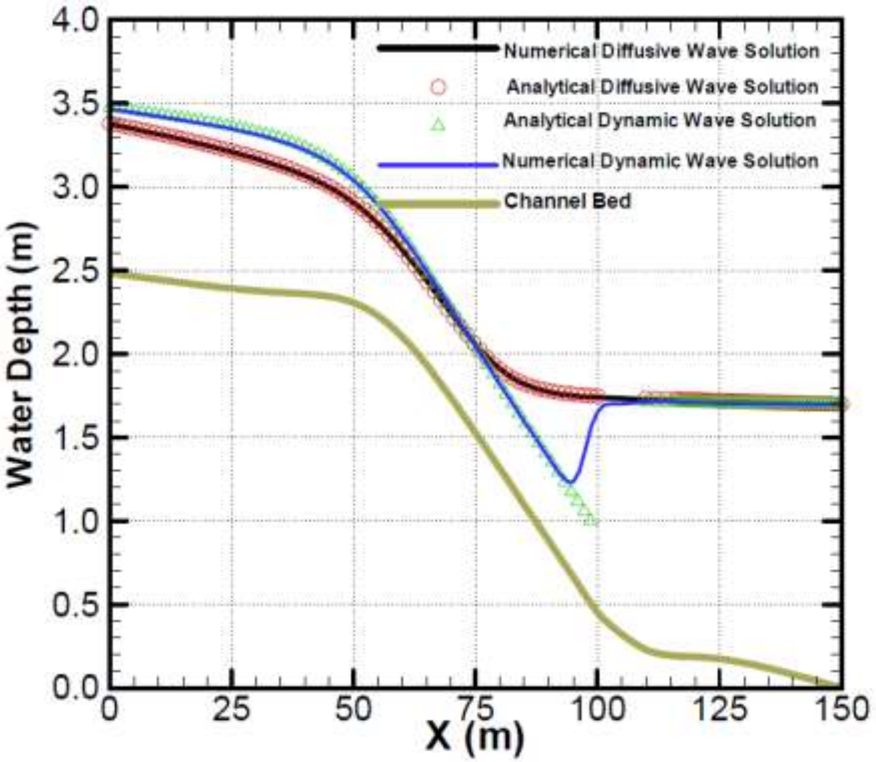




SRH-2D VERIFICATION CASES

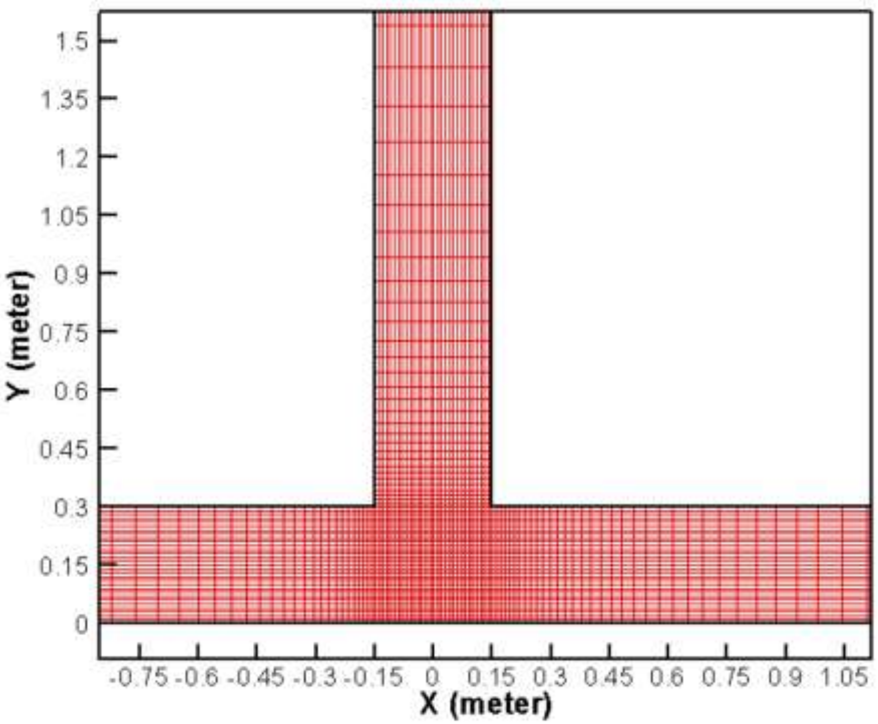
- Transcritical Flow in a 1D Channel

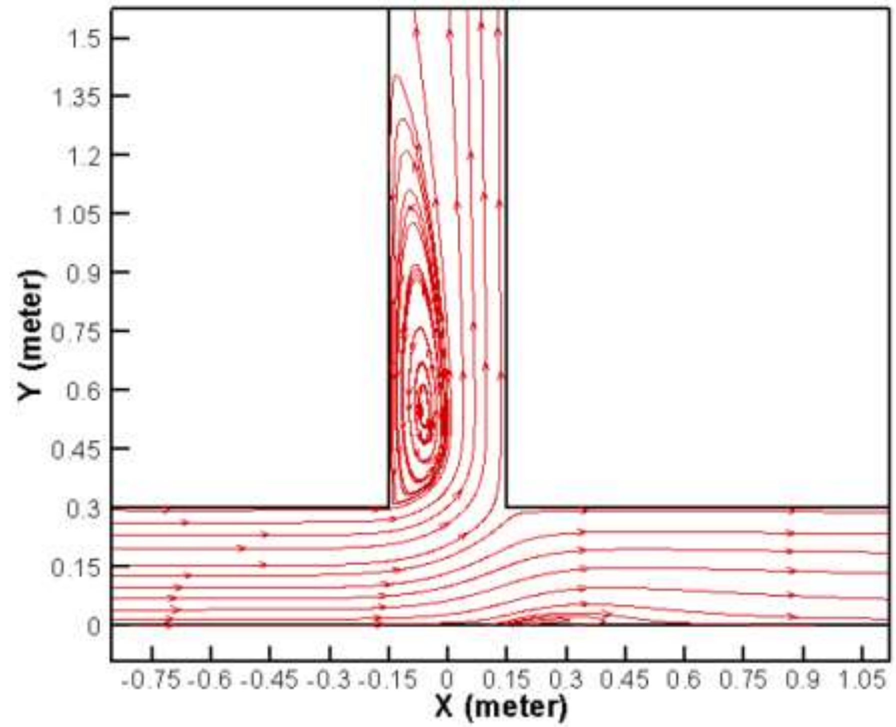




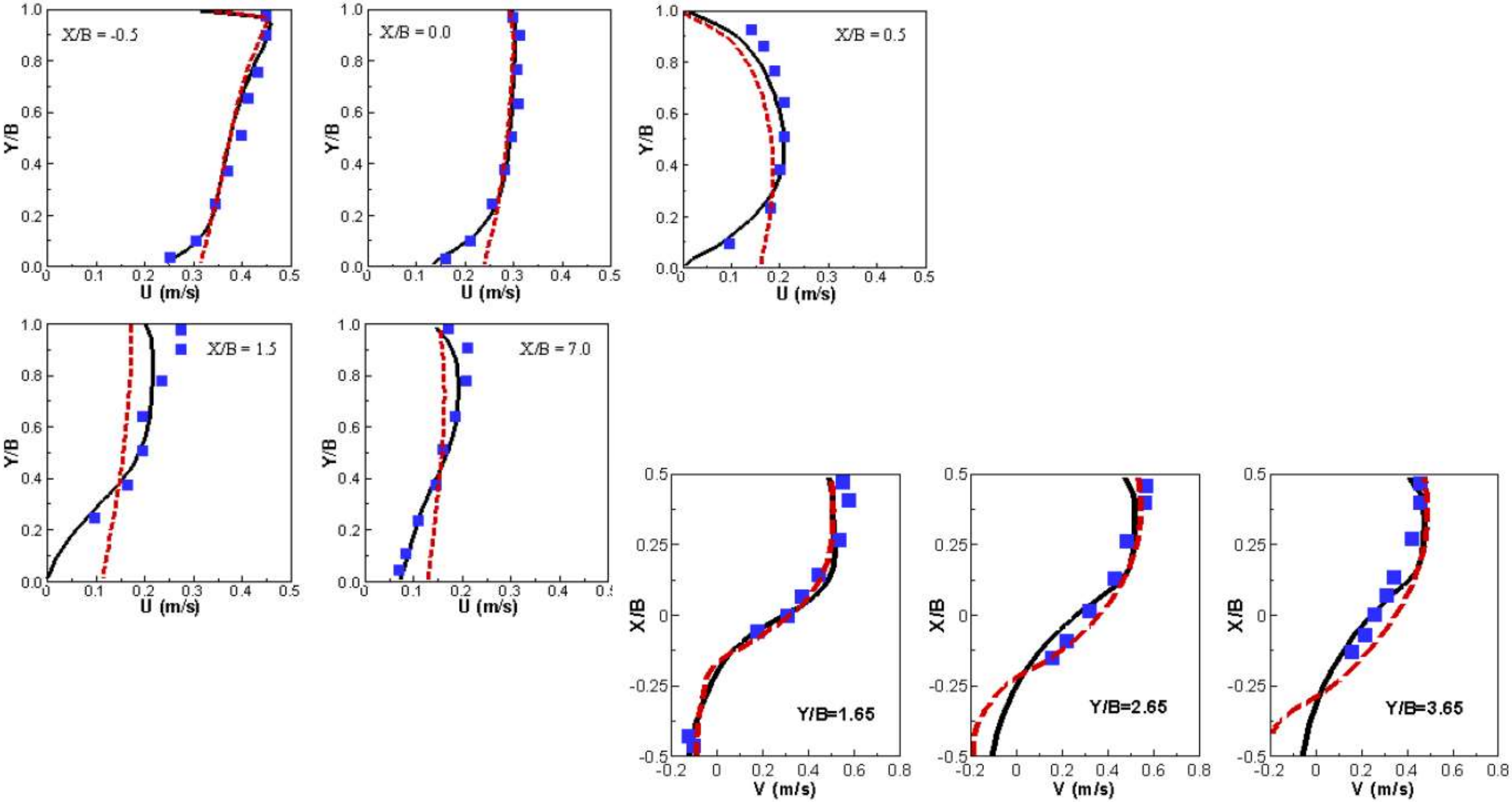
SRH-2D VERIFICATION CASES

- 2D Diversion Flow in a Channel



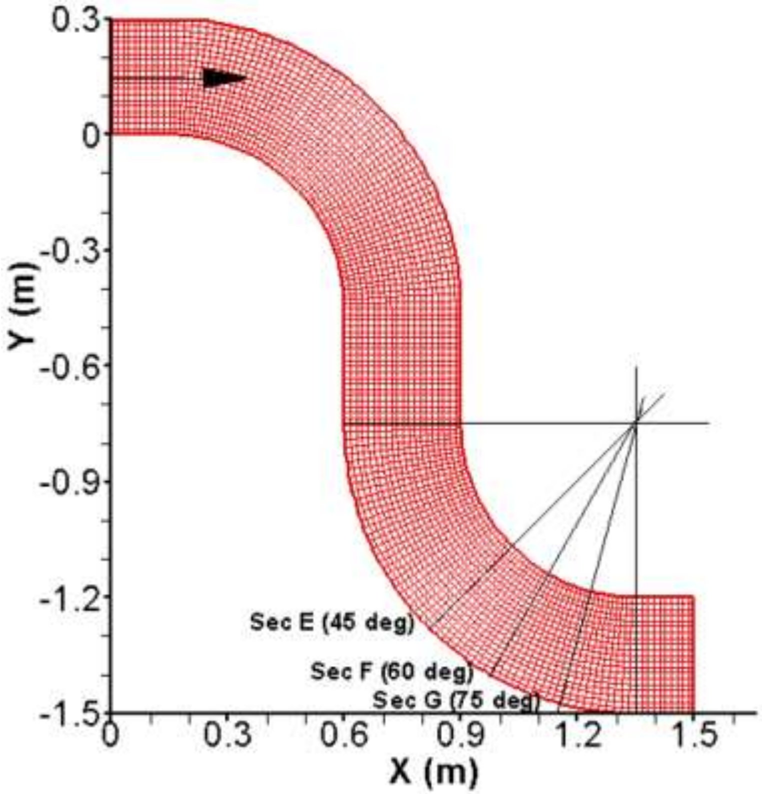


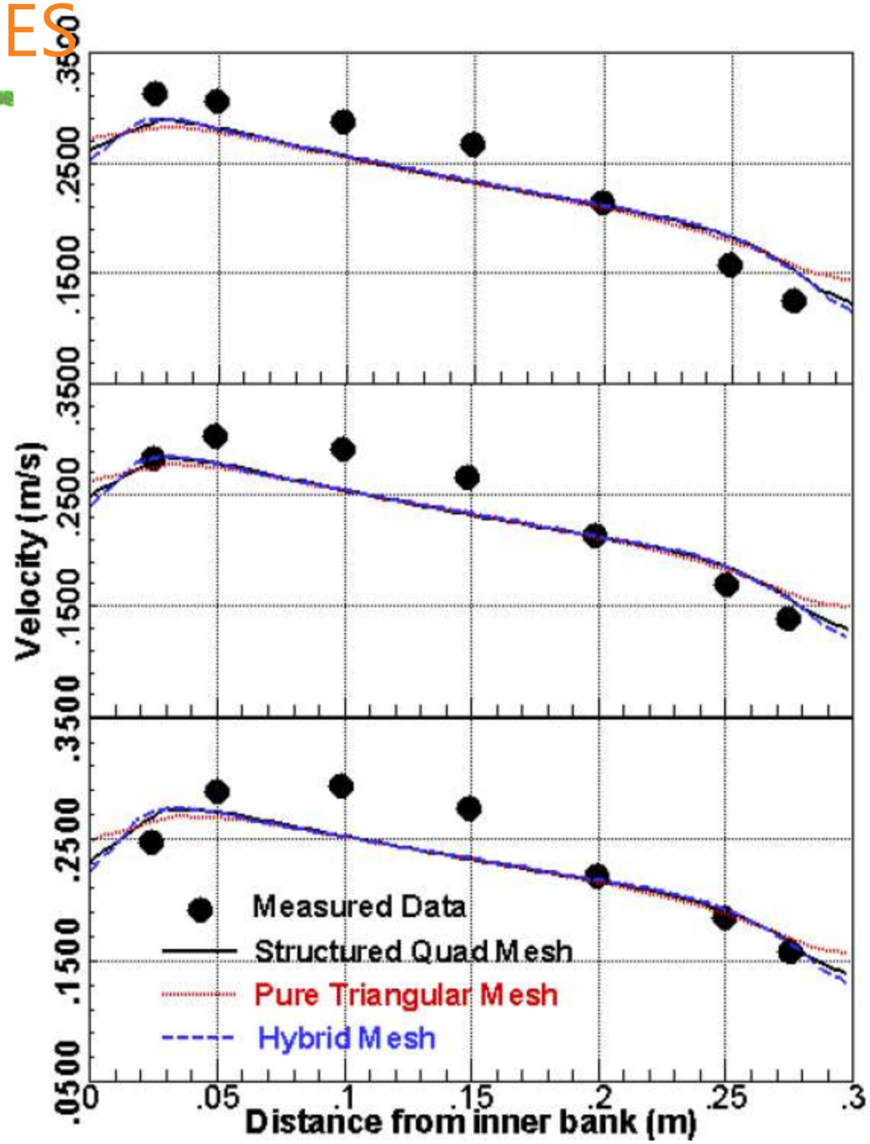
SRH-2D VERIFICATION CASES



SRH-2D VERIFICATION CASES

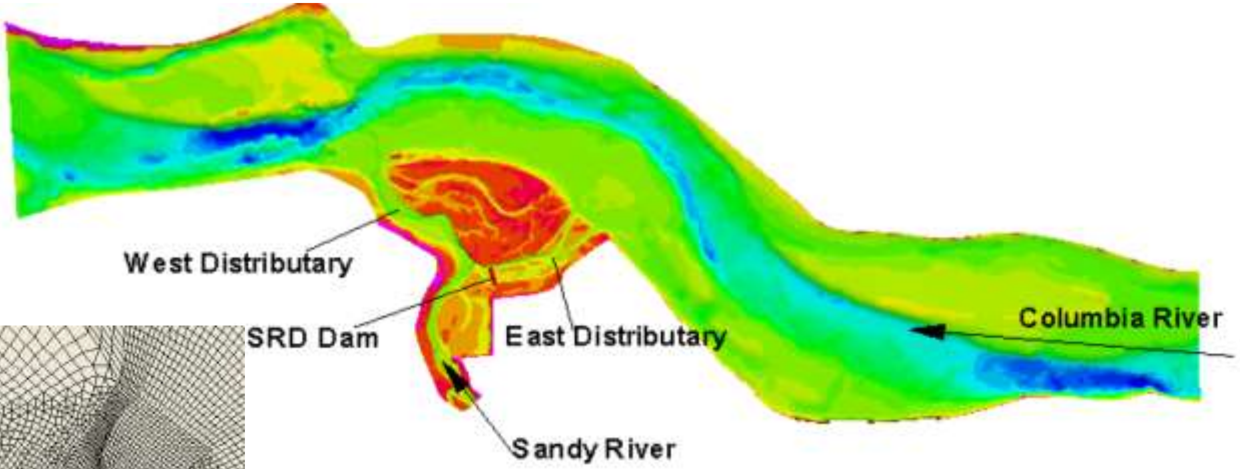
- Meandering Channel with 90° bends

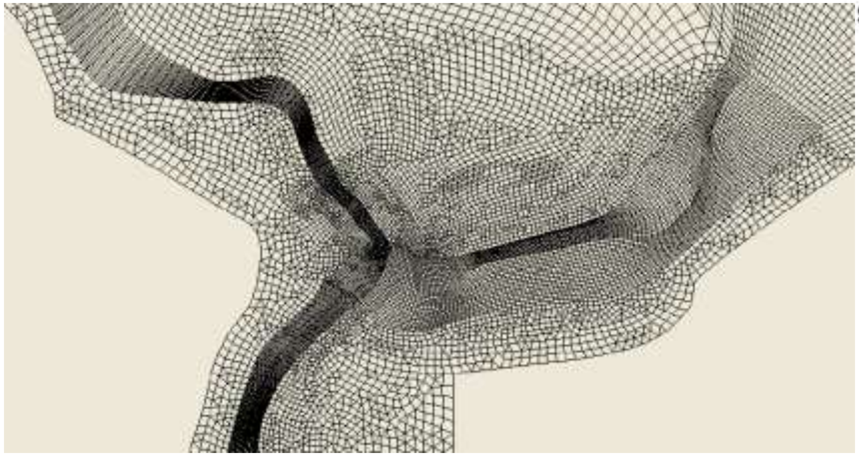




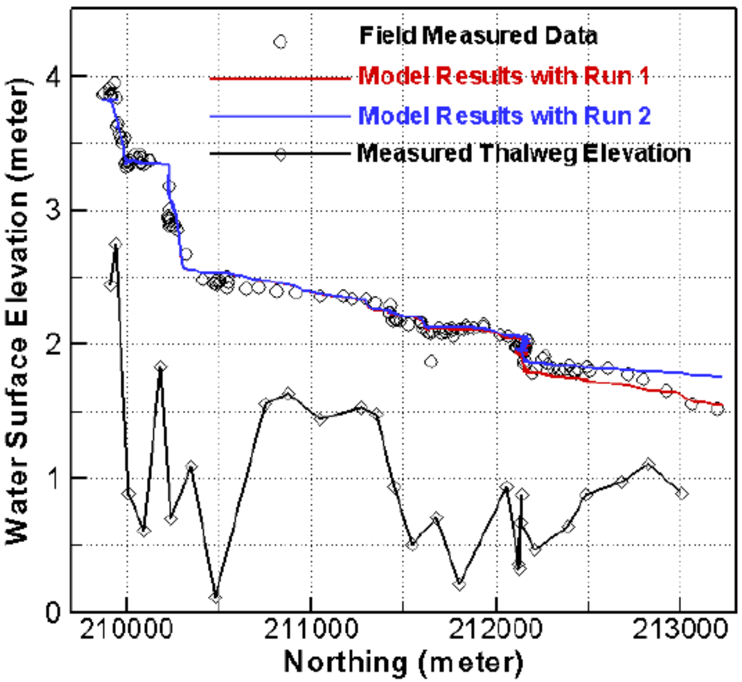
SRH-2D VERIFICATION CASES

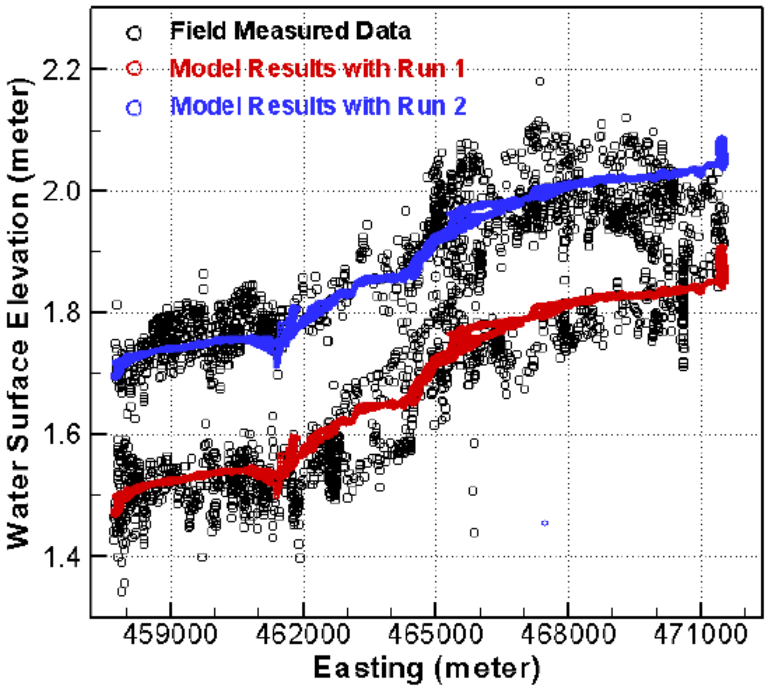
- Sandy and Columbia River confluence





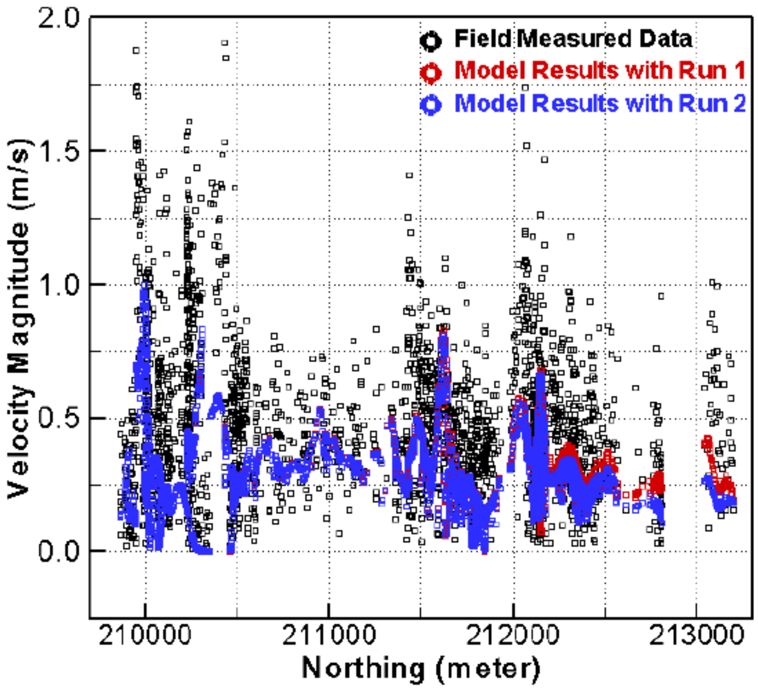
SRH-2D VERIFICATION CASES



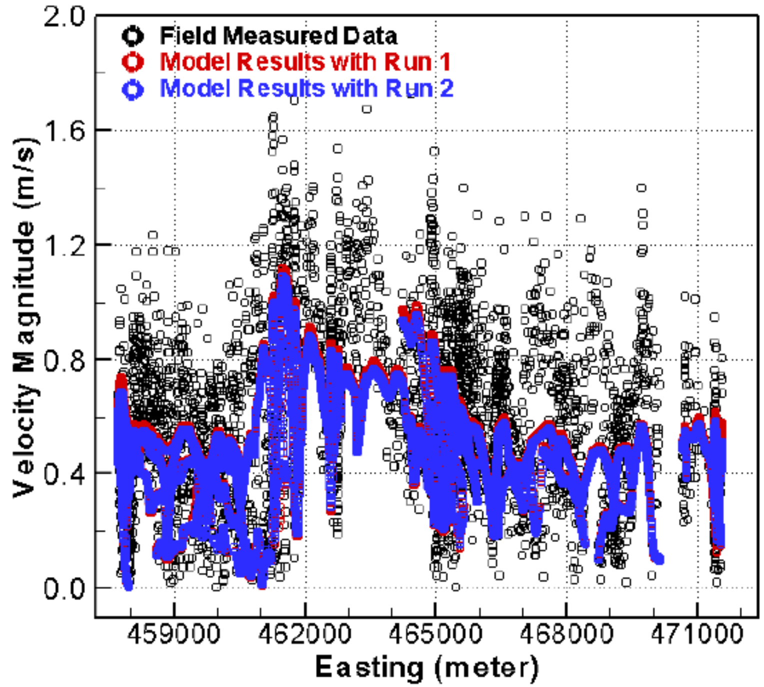


- Sandy River
- Columbia River

SRH-2D VERIFICATION CASES

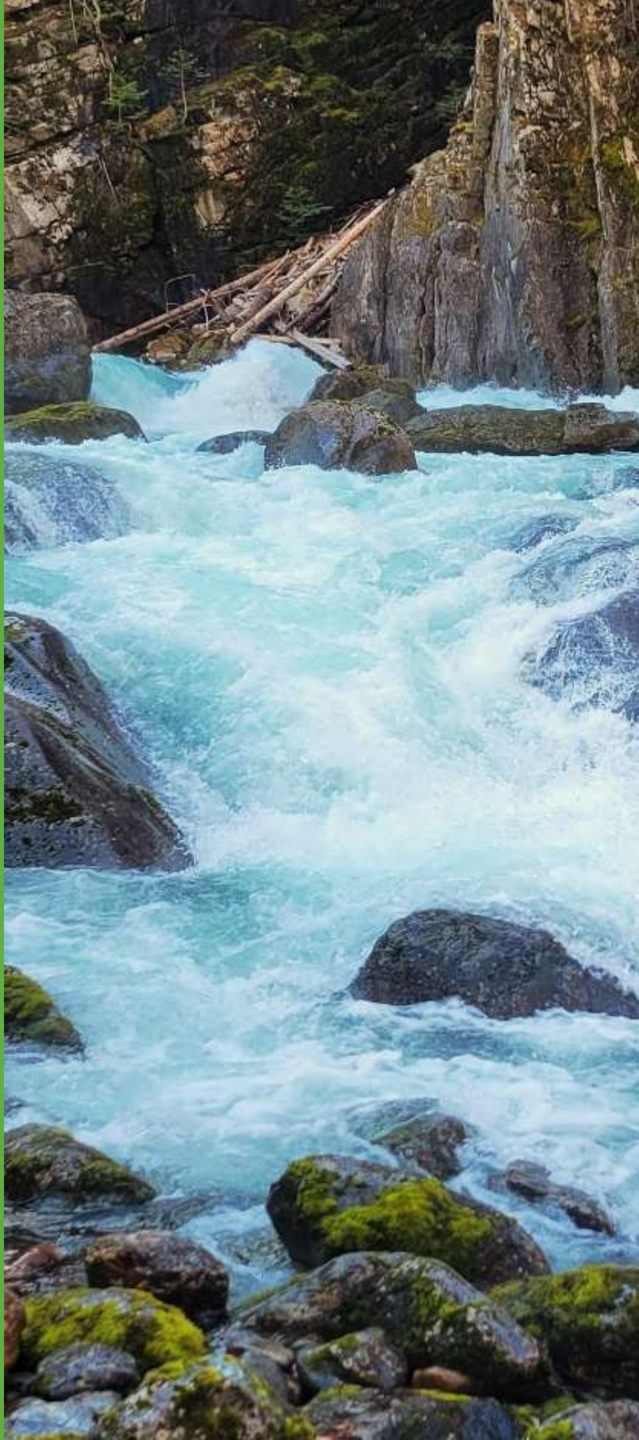


- Sandy River



- Columbia River

COMPARISON OF HEC-RAS AND SRH-2D



HYDRAULIC MODEL COMPARISON

Report No. KS-17-02 • FINAL REPORT • May 2017

A Comparison Study of One- and Two-Dimensional Hydraulic Models for River Environments

Evan C. Deal
A. David Parr, Ph.D.
C. Bryan Young, Ph.D., P.E.

The University of Kansas

Kansas Department of Transportation

- HEC-RAS 1D
- HEC-RAS 2D
- SRH-2D

MODEL COMPARISON TESTS

1. Basic Flow Around a Bend
2. Turbulence and Roughness Sensitivity Tests
3. Mixed Flow Regime Test
4. Bridge Flume (short model)
5. Bridge Flume (long model)
6. Noedesha Floodplain Study
7. Sumner County Study
8. Butler County Study

MODEL COMPARISON CONCLUSIONS

1. 1D models are still useful
2. 2D models require judgement and sensitivity
3. 2D models can aid setup of 1D models
4. 2D model response to roughness change concerning
5. Difference 2D vs 1D model results at bridge openings
6. WSEL computed with RAS2D typically > SRH-2D
7. Useful application of 1D/2D models

MODEL COMPARISON POINTS

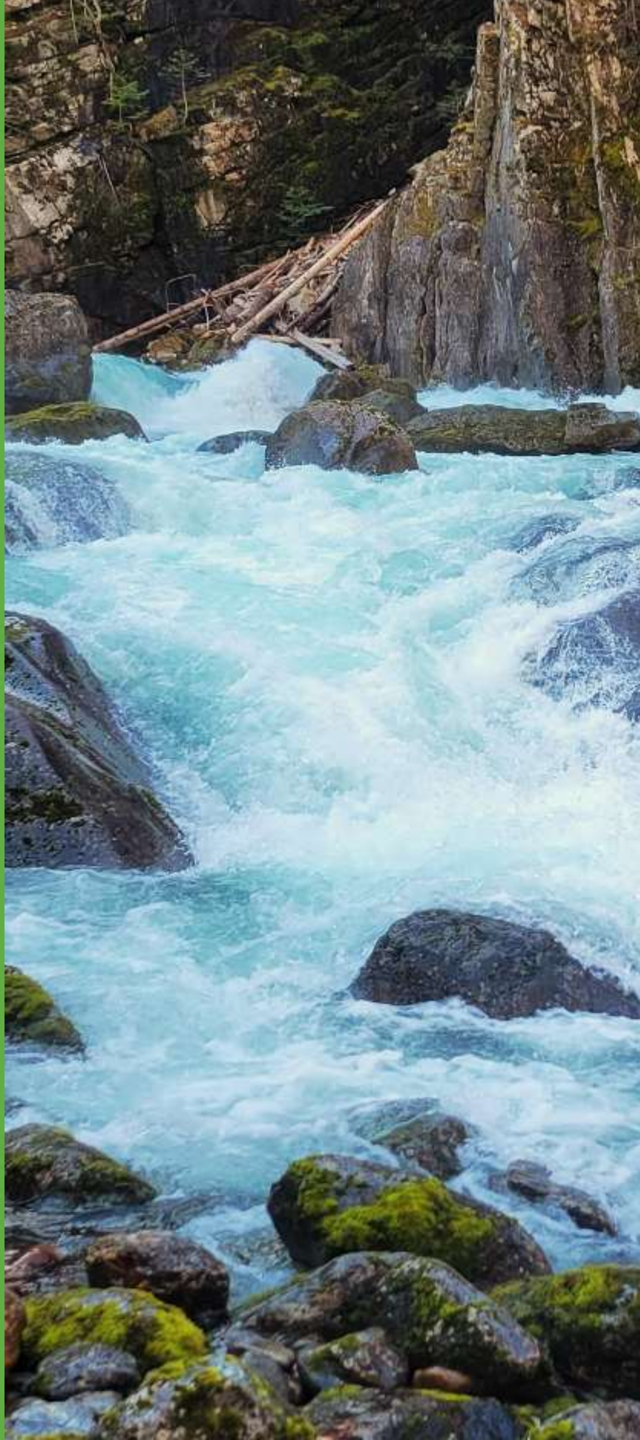
1. Runtime: RAS2D faster than SRH-2D
2. Pre/Post-Processing: RAS2D built in, SRH-2D requires 3rd party, RAS2D more readily interfaces with GIS
3. Setup: Similar
4. Accuracy: Comparisons made; both models strong
5. Flexibility: Comparisons made; each has strengths
6. Support: Similar; both models federally funded
7. Manning's n: Research needed for values in 2D models

MODEL COMPARISON POINTS

8. Channel vs Overbank: Both have options
9. Cell size: Requires user experience; rules of thumb
10. Modeling piers: Both have options
11. Timestep: Requires user experience, sensitivity testing
12. Breaklines: Both have options
13. Hydrology: Useful application of 1D models
14. Bridge overtopping: 1D models recommended

Seattle City Light

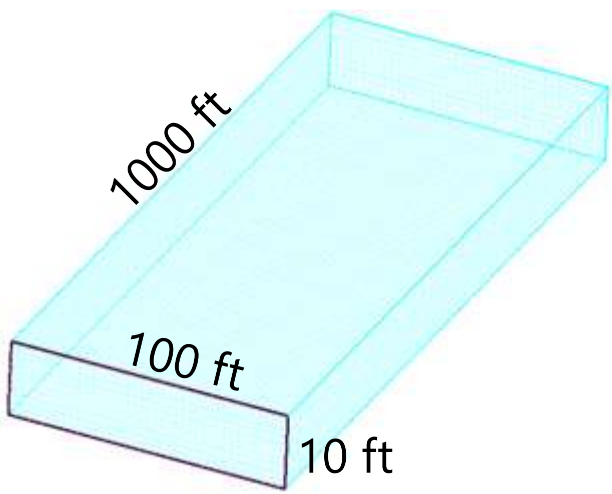
USE OF 3D CFD MODEL PLATFORMS FOR FEATURE ASSESSMENT



USE OF 3D CFD MODELS

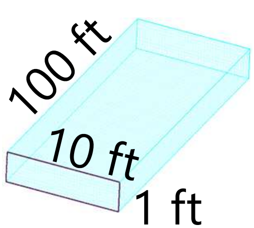
- 3D CFD model good for detailed simulations in small reach (“near field”), but not for long reaches
- Practical size of 3D modeling reach becomes smaller when flows and water depth reduce
- For small flows, 3D model may cover a short reach with a few pools
- For long reaches (“far field”), 2D models are more practical used

USE OF 3D CFD MODELS



High flow, H = 10 ft.

- Cell size = 1 ft.
- L = 1000 ft
- W = 100 ft
- Number of cells = 1 million



Low flow, H = 1 ft.

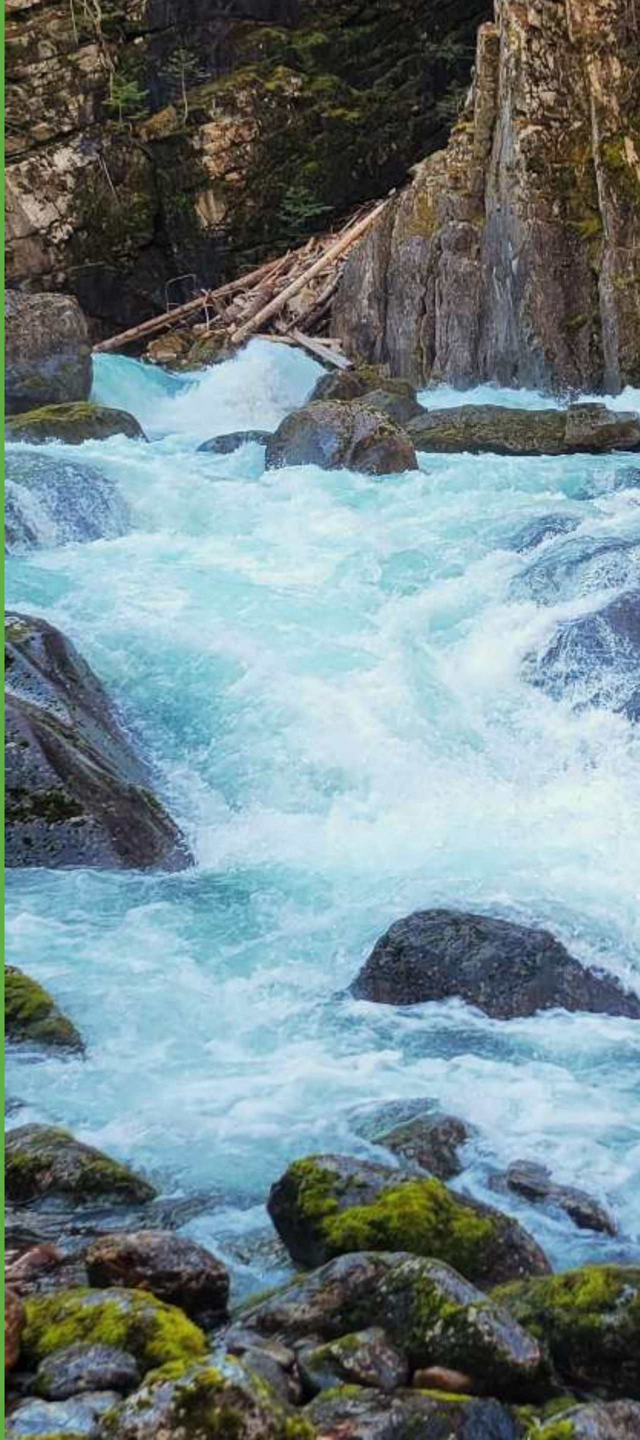
- Cell size = 0.1 ft.
- L = 100 ft
- W = 10 ft
- Number of cells = 1 million

USE OF 3D CFD MODELS

- 3D CFD model good for detailed simulations in small reach ("near field"), but not for long reaches
- Practical size of 3D modeling reach becomes smaller when flows and water depth reduce
- For small flows, 3D model may cover a short reach with a few pools
- For long reaches ("far field"), 2D models are more practical used

Seattle City Light

BREAK



DISCUSSION

- Concurrence on the proposed study plan

CLOSING

- Schedule
- Action items
- Next steps

Skagit River Hydroelectric Project
Seattle City Light (City Light)
Fish Passage Evaluations and Modeling in the Bypass Reach – Technical Meeting
May 17, 2021, 1:00 PM to 5:00 PM

DRAFT Meeting Summary

Disclaimer: These notes are provided to serve as high-level summary of the meeting and as a communication tool for the benefit of committee continuity. They are not intended as a formal record of the meeting.

Attendance

Licensing Participants (LPs):
Brock Applegate, Washington Department of Fish and Wildlife (WDFW)
Stuart Beck, Swinomish Indian Tribal Community (Swinomish)
Curtis Clements, Upper Skagit Indian Tribe (USIT)
Jeff Garnett, US Fish and Wildlife Service (USFWS)
Kiza Gates, WDFW
Rick Hartson, USIT
Jonathan Kohr, WDFW
Mike Larrabee, NPS
Kyle Taylor Lucas, Cooks Ferry Indian Band and Tulalip Tribes
Logan Negherbon, NMFS
Jim Pacheco, Washington Department of Ecology (Ecology)
Dudley Reiser, Swinomish Tribe
Kara Symonds, Skagit County
Larry Wasserman, Swinomish Tribe
Erik Young, Skagit Fisheries Enhancement Group (SFEG)

Seattle City Light (City Light):
Michael Aronowitz, City Light
Jeff Fisher, City Light
Erin Lowery, City Light

Federal Energy Regulatory Commission (FERC):
Matt Cutlip, FERC

Consultant Team:
Michael Garello, Consultant Team
Meghan Gavin, Cascadia Law
Danielle Hanson, Consultant Team
Becky Holloway, Consultant Team
Bao Le, Consultant Team
Malcolm Leytham, Consultant Team
Chris Long, Consultant Team
Angie Scangas, Consultant Team
Jose "Pepe" Vasquez, Consultant Team

Facilitation Team:
Joy Juelson, Facilitation Team
Alex Sweetser, Facilitation Team

Meeting Materials

Available upon request
- Meeting Agenda
- Meeting PowerPoint Slides: Fish Passage Evaluations and Modeling in the Bypass Reach

Action Items

Action	Responsibility	Deadline
LP Action Items		
There was general concurrence from LPs on the selection of the HEC-RAS 2D model to meet both the instream flow/habitat objectives and the evaluation of passage at natural feature objectives of the FA-05 Study Plan. Ecology and WDFW will brief their federal partners to seek concurrence on this decision and notify City Light.	Ecology and WDFW	End of this week
There was general concurrence from LPs to add an additional planned flow release of approximately 250 cfs to the already proposed flow releases of 50, 500, and 1,200 cfs, as well as to maintain the numbers of bypass reach transects (5) to support development of the hydraulic model. Ecology and WDFW will brief their federal partners to seek concurrence on this decision and notify City Light.	Ecology and WDFW	End of this week
City Light Action Items		
Follow up with the photogrammetrist to determine if as part of LiDAR reclassification to a high-resolution raster surface, determine if development of a Triangular Irregular Network (TIN) would provide better interpolation between points thus resulting in a surface with greater resolution and accuracy for modeling purposes.	City Light	As soon as possible
Convey to City Light management FERC's request that any material changes to the study be filed with FERC as soon as possible.	City Light	As soon as possible
Facilitation Team Action Items		
Prepare draft meeting summary and send to LPs for review.	Triangle Associates	Next Week

Summary of Issues Discussed, Action Items, and Decisions

Welcome, Introductions, Agenda Overview

The Facilitator, Joy Juelson, welcomed participants. She led a roll call and explained that the agenda and meeting purpose had been set in coordination with Ecology and City Light. Joy explained that this is the third meeting in a series of technical meetings scheduled to inform time sensitive data collection this summer. The purpose of the first meeting on April 28th was to share information on the instream flow models and the purpose of the second meeting on May 12th was to discuss habitat suitability criteria (HSC) curves and the periodicity table. Additionally, HDR and Triangle Associates will be reaching out soon to schedule future technical workshops and planning meetings.

Joy noted the intent of the meeting summaries is to serve as a high-level review of what was discussed, track issues and discussion topics across meetings, and identify areas of agreement. They are not technical documents (though the meetings are technical in nature) or verbatim records of what was said.

The objectives for this meeting were to:

- Review fish passage evaluation study objectives and discuss fish passage evaluation methods.
- Discuss the role of hydraulic modeling in fish passage evaluations methodology and provide examples of how hydraulic models have been used at other projects.
- Address concerns regarding the use HEC-RAS 2D as a fish passage evaluation tool.

- Discuss and reach concurrence with LPs on study design to identify areas of agreement, areas that need to be updated, and areas for future conversations.

Evaluation of Fish Passage in the Bypass Reach

Mike Garello, Consultant Team, presented the Fish Passage Evaluations and Modeling in the Bypass Reach meeting slides (see meeting slides for details). He noted the intent of this meeting was to have a discussion on the approach for these studies and how modeling will be accomplished.

Mike Garello explained the purpose of this evaluation is to gain a more detailed understanding of feature geometry in the bypass, characterize hydraulic pathways that could potentially provide fish passage, better understand conditions that promote or impede fish passage, and to inform concurrent studies.

- In response to a question about use of different HEC-RAS 2D model domains and resolution, one for habitat and one for fish passage, Mike clarified they will use the same model for each.
- Jim Pacheco, Ecology, noted there is not a lot of fish habitat in the high elevation reach and a higher mesh size could be used. Chris discussed how there did not appear to be a significant change when reducing model resolution to differentiate fish passage and habitat, so the same resolution will be used on all hydraulic features.
- In response to a question about how visual fish observations will be incorporated, Mike noted visual observations will be incorporated and additional research is needed on flows and their impact on fish passage. By understanding the relationship between flow and fish passage, this study will inform other studies such as the Passage Facility Alternatives Study.
- Rick Hartson, Upper Skagit Tribe, and Kyle Taylor Lucas, Cooks Ferry Indian Band and Tulalip Tribes, expressed concern over the quick timing of the meeting and narrow distribution list. Jim Pacheco explained that he set the schedule of the three instream flow meetings to resolve time-sensitive issues that require resolution prior to approval of the study design. Joy noted decisions at these meetings are technical decisions that resolve study design issues and that policy decisions will be elevated at future meetings.
- In response to a question about this study's ability to identify flows that allow fish passage, Mike explained that this study can provide a range of flows that may allow fish passage but will not provide a definitive answer on the flows required for fish passage.

Observable Discharges

Malcolm Leytham, Consultant Team, provided an overview of observable discharges and the proposed data collection program. The data will be used for calibration of the hydraulic model and inform visual assessment of fish passage. There are two components to data collection: 1) controlled releases; and 2) water level loggers to assess discharge and opportunistic spills over a longer timeframe. Malcolm reviewed several transect maps to demonstrate the uncalibrated RAS model (see meeting slides for graphics).

- Malcom noted that water level recorders and time lapse cameras will likely be installed in the coming weeks and stay through November. The goal is for them to capture higher flows during the late spring/early summer snowmelt season and fall and early winter. Mike explained that there will be two cameras in a fixed position taking photos on a regular timeframe. The cameras will be useful for visualizing controlled releases and providing photo documentation of flows at flow meters. Additionally, the cameras will be used for monitoring opportunistic spills, which they intend to include in the analysis.

- In response to a question about when controlled releases are being proposed, Malcolm noted release times are not fixed, but they are aiming for between the last week of June and the third week in July.
- In response to a question about whether baseflow measurements are being used for calibration and verification or for historical purposes, Malcolm clarified baseflows are not useful for calibration and are being used to document conditions.

__Fish Passage Evaluation Methods and Tools__

Michael Garello provided an overview of the fish passage evaluations methods and tools. He discussed biological and ecohydraulic metrics that could be used to calculate swimming fatigue curves around hydraulic features (see meeting slides for details).

Site Inspection, Surveying, and Visual Observation

Chris Long, Consultant Team, provided an overview of site inspection and visual observation methods. LiDAR will be used to provide the topography that will form the basis of the model. The data collection methods used will be supported by site inspection and photo or video documentation. Several examples of outputs were presented (see meeting slides for graphics).

Mike Garello noted that for site inspection and visual observation the minimum range of flows is 5 cfs to 1200 cfs. However, there are anticipated opportunities to collect data up to 5,000 cfs.

Collection of Flow Magnitude, Depth, Elevation, and Velocity Data

Mike Garello provided an overview of data collection methods for flow magnitude, depth, elevation, and velocity. Depth monitoring locations were identified using site investigation and the initial uncalibrated 2D model. Locations were further refined after observing features at ~1,200 cfs. Several examples from the uncalibrated model were presented to demonstrate depth and flow (see meeting slides for graphics). Velocity measurements are difficult and there are unsafe conditions above 50cfs. Additionally, high levels of turbulence and a multi-directional flow mean conventional data collection methods are likely inadequate. Potential options to get around these challenges include approximation with hydraulic modeling or utilizing an Unmanned Aerial Vehicle (UAV).

Chris Long briefly presented examples of modeling results from other fish passage evaluation projects.

- Stuart Beck, Swinomish, recommended the development of a Triangular Irregular Network (TIN) as part of LiDAR reclassification to a high-resolution raster surface. Chris noted the consulting team can follow-up with a photogrammetrist to determine if developing a TIN would increase surface resolution and accuracy for modeling purposes.
- In response to a question about how biological analysis will support modeling, Mike clarified that there are several methods for biological analysis. He provided an example developed from Katopodis and Gervais (2016), which showed swim distance and speeds for fish based on fish size, time, and water velocity.
- Brock Applegate, WDFW, requested the field team to look for lamprey attachment sites during sampling and installation of meters and loggers.

Action Item: Follow up with the photogrammetrist to determine if as part of LiDAR reclassification to a high-resolution raster surface, development of a Triangular Irregular Network (TIN) would provide better interpolation between points thus resulting in a surface with greater resolution and accuracy for modeling purposes.

<u>Use of Hydraulic Model to Support Fish Passage Interpretations</u>

Mike Garello provided an overview of the use of the hydraulic models to support fish passage interpretations. He explained that modeling will inform data collection methods, development of hydraulic pathways that may provide passage, inform transitions between leaping vs swimming conditions, and will provide a tool to study trends across a range of flows. The models are not intended to be a quantitative tool for dictating fish passage as a pass or a fail. Mike presented several examples of the HEC-RAS 2D model, including output graphics and the model's ability to identify pathways at different flows (see meeting slides for graphics).

Selection and Applicability of Modeling Platforms

Chris Long provided an overview of how HEC-RAS 2D was selected and the applicability of hydraulic models, which are influenced by multiple factors. Several 2D models were assessed based on their strengths and limitations.

Chris Long compared HEC-RAS with SRH-2D and reviewed verification studies of these two models.

- Stuart Beck, Swinomish, noted that one study showed that HEC-RAS 2D was not good at predicting the location of hydraulic jumps and tended to predict jumps too soon compared to SRH-2D.

Use of 3D CFD Model Platforms for Feature Assessment

Jose "Pepe" Vasquez, Consultant Team, provided an overview of the use and application of 3D CFD models. 3D CFD models are good for detailed simulations of small reaches, but not good for long reaches, which is why 2D models were selected to model the longer bypass reach.

- Jim Pacheco noted it is unclear if the passage areas are too large for a 3D model. In response, it was stated that the passage features are too large for 3D modeling but that a 3D model could be used to model flow at the scale of an individual boulder.
- Meeting participants suggested using 3D models in isolated passage spots or for verification of passage at individual features. However, it would be difficult to implement another model at such a small scale and impractical to use different models. Concurrence was not reached on this suggestion.
- In response to a question about how a 2D model could inform management decisions, Jim noted the graphics could show velocity near river features, which will enable managers to better evaluate passage. Mike clarified that biometrics will also be used to inform passage scenarios.

<u>LP Discussion on Study Design</u>

Meeting participants were asked to evaluate their comfort level around the proposed approach for using the HEC-RAS 2D model.

- There was general concurrence from LPs on the selection of the HEC-RAS 2D model to meet both the instream flow/habitat objectives and the evaluation of passage at natural feature objectives of the FA-05 Study Plan.
- In response to a suggestion to develop and utilize 3D models to evaluate specific areas of passage or blockage, there was general agreement that it was not practical to use multiple models and methods in different sections.
- In response to a question about whether both upstream and downstream passage will be evaluated at the plunge pool where a proposed fish passage facility could be built, Mike clarified that the fish passage study would assess the location of the facility, as well as upstream and downstream passage at the plunge pool.

Meeting participants discussed the suite of controlled releases that were proposed at a previous meeting. These proposed flow releases were 50, 300, 500, and 1,200 cfs.

- Malcolm noted that the proposed 300 cfs controlled release appeared to be too high based on the model and proposed setting it to 250 cfs instead. After discussing the proposed change, there was general concurrence from LPs to use 250 cfs as the additional planned flow release (to the already proposed flow releases of 50, 500, and 1,200 cfs) and to maintain the numbers of bypass reach transects (5) to support development of the hydraulic model.
- LPs from Ecology and WDFW noted they will need additional time to consider this change and brief their federal partners to seek concurrence on this decision.

Matt Cutlip, FERC, expressed concerns about these areas of concurrence being resolved before the FERC study plan determination and requested City Light to file any material changes to the study with FERC as soon as possible.

Action Item: There was general concurrence from LPs on the selection of the HEC-RAS 2D model to meet both the instream flow/habitat objectives and the evaluation of passage at natural feature objectives of the FA-05 Study Plan. Ecology and WDFW will brief their federal partners to seek concurrence on this decision and notify City Light.

Action Item: There was general concurrence from LPs to reduce the proposed 300 cfs planned flow to 250 cfs. This would be added to the already proposed flow releases of 50, 500, and 1,200 cfs. Additionally, there was general concurrence from LPs to maintain the numbers of bypass reach transects (5) to support development of the hydraulic model. Ecology and WDFW will brief their federal partners to seek concurrence on this decision and notify City Light.

Action Item: Convey to City Light management FERC's request that any material changes to the study be filed with the FERC as soon as possible.

<u>Review Action Items and Next Steps</u>

The facilitator reviewed the action items and areas of concurrence from the meeting.

Action Item: *Triangle will prepare a draft meeting summary and send to LPs for review.*

The meeting was adjourned at 5:05 p.m.

SKAGIT RIVER GORGE BYPASS REACH HYDRAULIC AND INSTREAM FLOW MODEL DEVELOPMENT STUDY INTERIM REPORT

ATTACHMENT H

WORKSHOP 3 MATERIALS

Seattle City Light DRAFT **MEETING AGENDA**

Skagit Hydroelectric Project Relicensing Meeting

FA-05 Gorge Bypass Reach Hydraulic and Instream Flow Model Development, Workshop #3

August 26, 2021, 8:30 am – 1:30 pm

WEBEX

Webex Meeting Link: https://triangleassociates.my.webex.com/meet/jjuelson

Call in Information: +1-510-338-9438,,629101299## USA Toll

MEETING PURPOSE

- Review Controlled and Uncontrolled Spill Data Collection
- Review Model Terrain Development
- Provide Overview of Hydraulic Model Development Approach

FACILITATOR

Thomas Christian, Triangle Associates

AGENDA

8:30 – 8:45 (15 minutes)	**Introduction** – *Facilitator, Triangle* ▪ Roll Call Introduction ▪ Background and Context ▪ Review Action Items from Previous Meeting
8:45 – 9:00 (15 minutes)	**Study Overview** – *Erin Lowery, City Light and Chris Long, NHC* ▪ Background ▪ Review Meeting Objectives and Agenda
9:00 – 10:00 (60 minutes)	**Controlled Spill Monitoring: Transect Data** – *Donnie Jones, NHC* ▪ Observed Flows ▪ Depth and Velocity Measurements Questions and Discussion (30 minutes)
10:00 – 10:15 (15 minutes)	**Break**
10:15 – 11:00 (45 minutes)	**Controlled Spill Monitoring: UAV Data** – *Chris Long, NHC* ▪ Observed Surface Velocities at Hydraulic Features ▪ Orthoimagery Questions and Discussion (15 minutes)
11:00 – 11:30 (30 minutes)	**Level Logger Data** – *Malcolm Leytham, NHC* ▪ Data Collected ▪ Discuss use of level logger data for model development Questions and Discussion (15 minutes)
11:30 – 11:45 (15 minutes)	**Break**

11:45 –12:15 (30 minutes)	**Terrain** – *Donnie Jones, NHC* ▪ Terrain Development ▪ Model Implementation Questions and Discussion (15 minutes)
12:15 – 1:15 (60 minutes)	**Hydraulic Model Development Approach** – *Donnie Jones, NHC* ▪ Roughness ▪ Mesh ▪ Calibration and Validation Questions and Discussion (30 minutes)
1:15 – 1:30 (15 minutes)	**Action Item Review and Agenda Items for Next Meeting –** *Triangle and NHC*
1:30	**Meeting Adjourned**

Action Items From FA-05 Bypass Reach Workshop (5/17)

Action Items

Action	Responsibility	Timeframe
LP Action Items		
There was general concurrence from LPs on the selection of the HEC-RAS 2D model to meet both the instream flow/habitat and evaluation of passage at natural feature objectives of the FA-05 Study Plan. Ecology and WDFW will brief their federal partners to seek concurrence on this decision and notify City Light.	Ecology and WDFW	Complete
There was general concurrence from LPs to add an additional planned flow release of approximately 250 cfs (to the already proposed flow releases of 50, 500, and 1,200 cfs) and to maintain the numbers of bypass reach transects (5) to support development of the hydraulic model. Ecology and WDFW will brief their federal partners to seek concurrence on this decision and notify City Light.	Ecology and WDFW	Complete
City Light Action Items		
Follow up with the photogrammetrist to determine if as part of LiDAR reclassification to a high-resolution raster surface, determine if development of a Triangular Irregular Network (TIN) would provide better interpolation between points thus resulting in a surface with greater resolution and accuracy for modeling purposes.	City Light	Complete
Convey to City Light management FERC's request that any material changes to the study be filed with the Commission as soon as possible.	City Light	Complete
Facilitation Team Action Items		
Prepare draft meeting summary and send to LPs for review.	Triangle	Complete

Seattle City Light

SKAGIT RIVER GORGE BYPASS REACH HYDRAULIC AND INSTREAM FLOW MODEL DEVELOPMENT – WORKSHOP 3

August 26, 2021

STUDY STATUS UPDATE

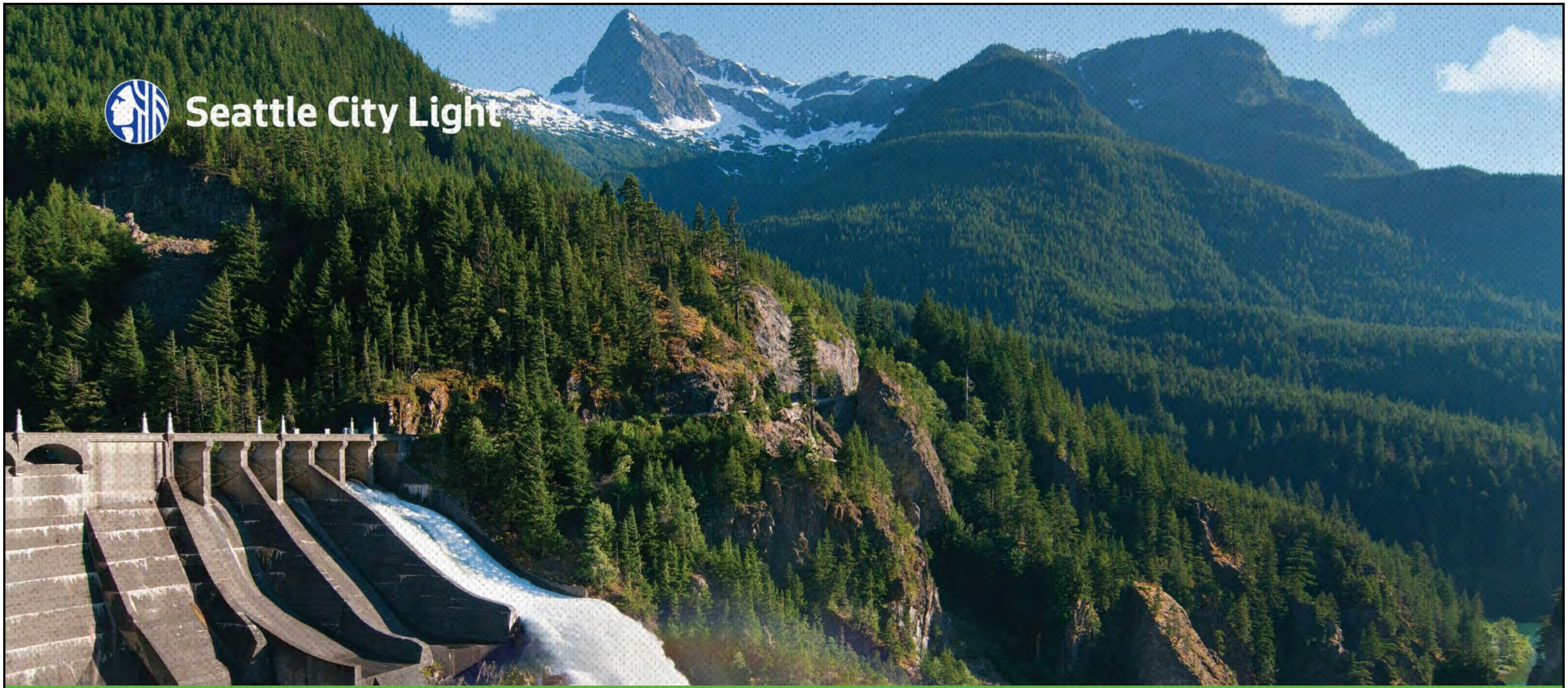
- FA-02 study currently more advanced than FA-05
  - FA-02 started field data collection August 2020
- FA-05 model will develop more quickly than FA-02
  - More limited in size
  - Less calibration data
- Just finished intense week of field data collection
- Presentation focus
- Limited update on hydraulic modeling

STUDY ROAD MAP/SCHEDULE

	May	June	July	August	September	October	November	December	January	February		
Field Data Collection											Initial study report March 2022	Alternative scenario identification and evaluation: February - September 2022
Hydrometric data collection for model calibration												
Substrate and cover data collection												
Hydraulic Model Development												
Modify terrain data												
Hydraulic model construction												
Hydraulic model calibration/validation												
Biological and Habitat Information												
Review, field validation and selection of HSCs												
Integration with hydraulic data												
Workshops (HSC focused workshops not shown)												

WORKSHOPS

Workshop	Date	Topics
~~1A~~	~~May 2021~~	~~Overview development of hydraulic and instream flow model for the Gorge Bypass Reach~~
~~2~~	~~July 2021~~	~~Updates to biological and habitat metrics based on discussions and input from FA-02 Workshop 1~~
3	August 2021	Field monitoring debrief and hydraulic model development kickoff
4	November 2021	Hydraulic model calibration ongoing
5	February 2022	Final hydraulic model calibration results and discussion of future model application



CONTROLLED SPILL MONITORING TRANSECT DATA

August 26, 2021

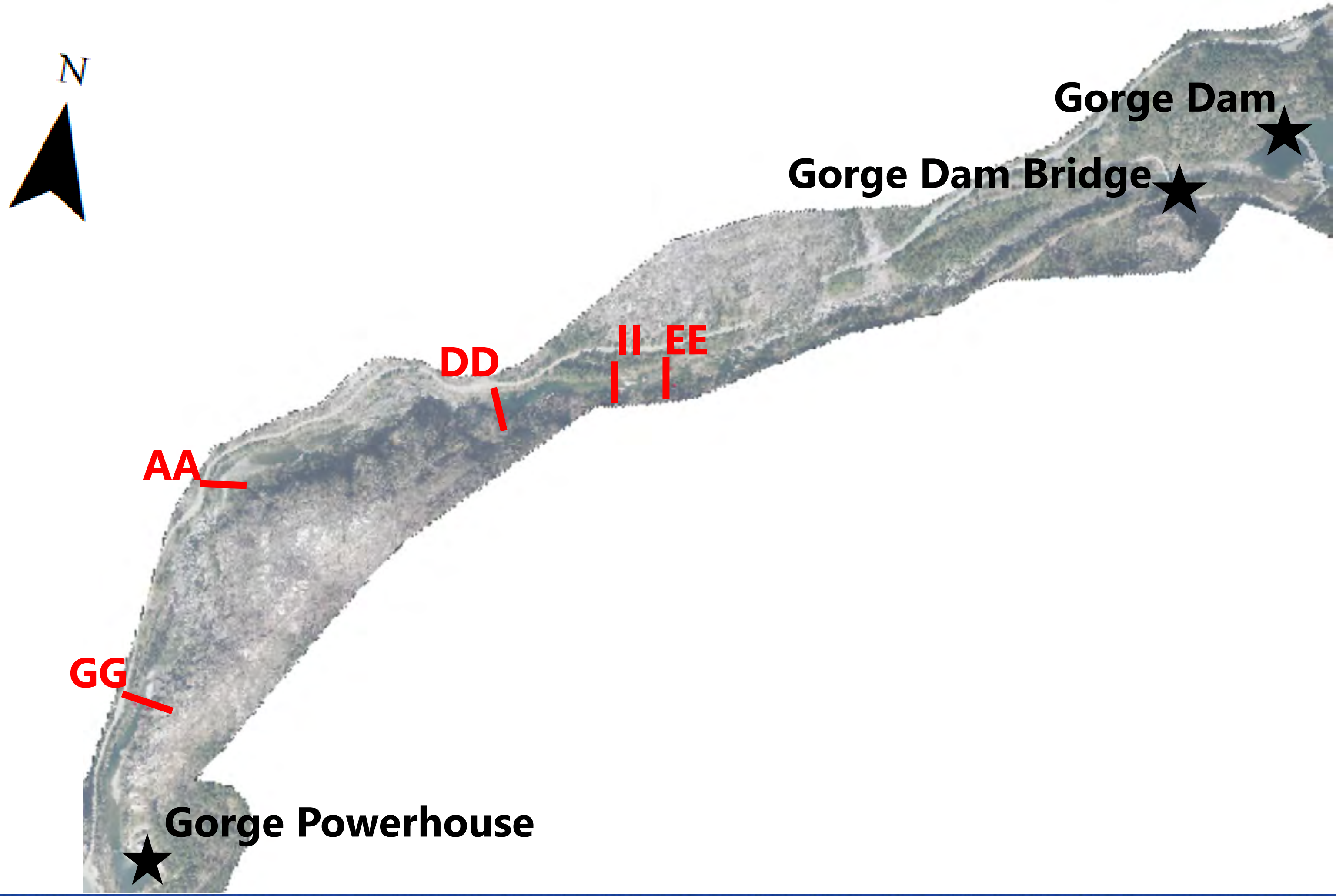
OVERVIEW

- Purpose
- Transect Locations
- Instruments
  - ADCP
  - ADV
  - Deployment
- Measurements
  - Methodology
  - Observed Flows
  - Observed Depths and Velocities

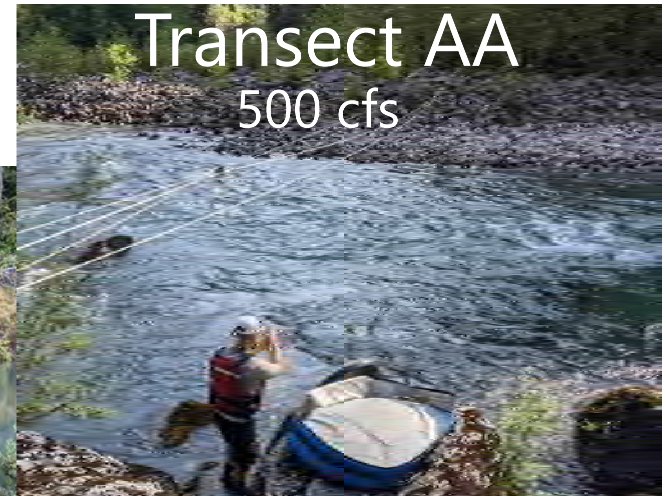
PURPOSE

- Determine controlled spill flows
  - o Expected releases of 1200, 500, 250, and 50 cfs
- Collect velocity and depth data for model calibration

TRANSECT LOCATIONS

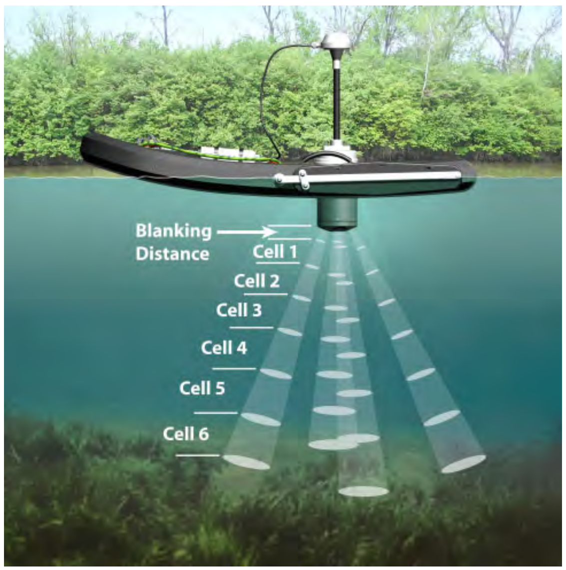


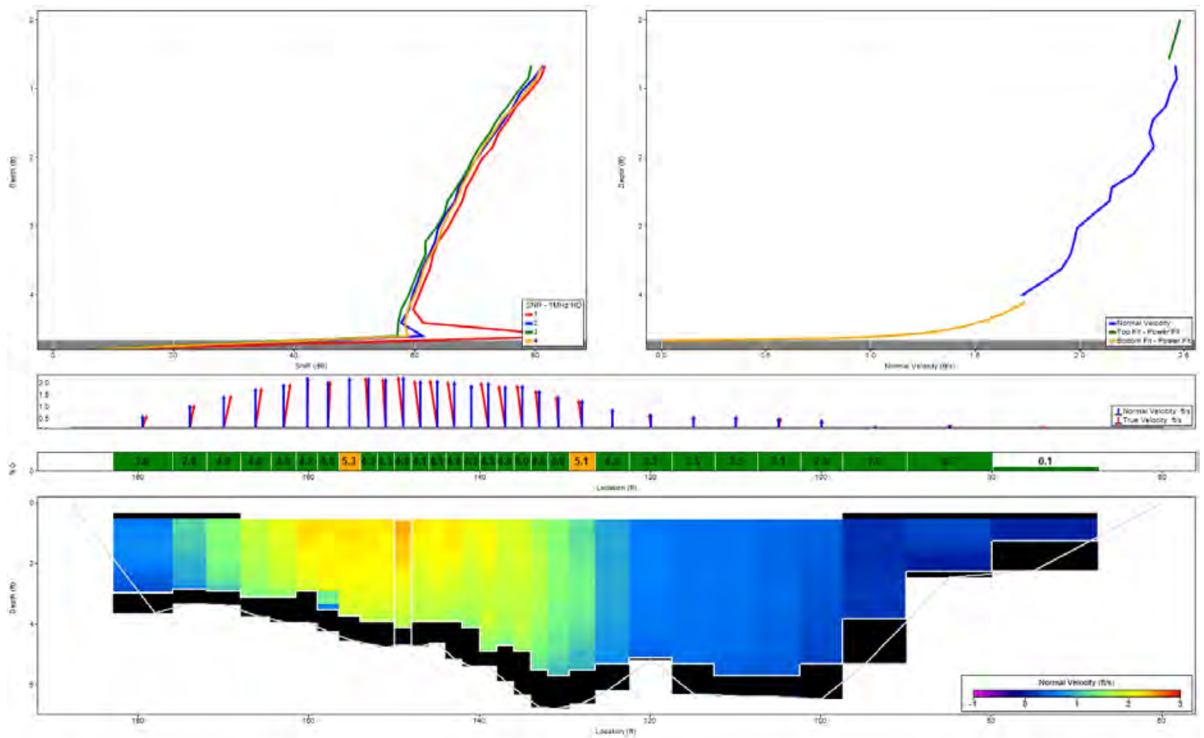
TRANSECT LOCATIONS



INSTRUMENTATION - ADCP

- ADCP (Acoustic Doppler Current Profiler) – Sontek RiverSurveyor M9
  - Velocity and depth profiling
  - Depths >1ft

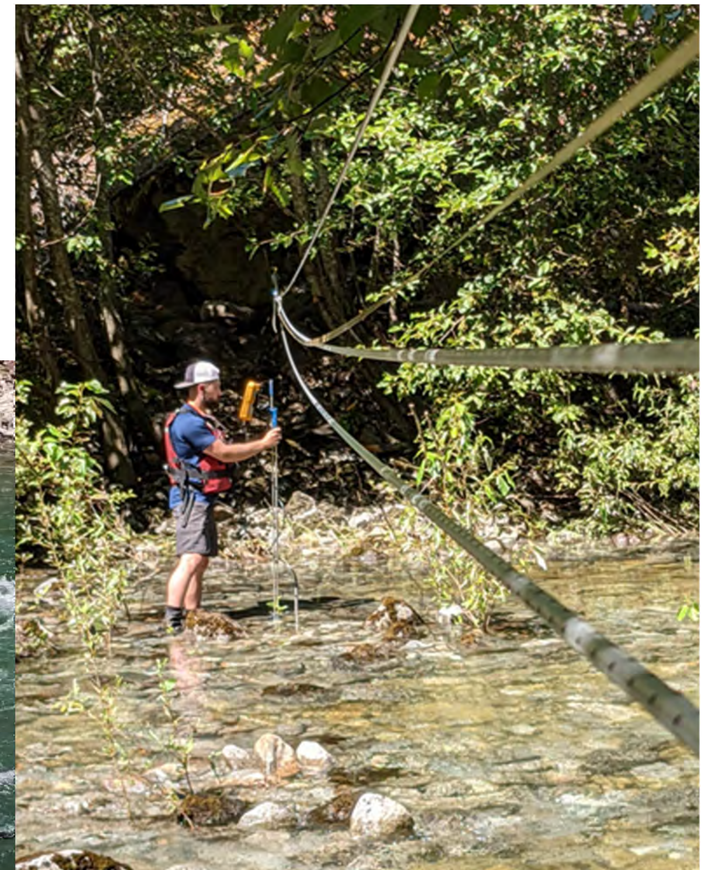




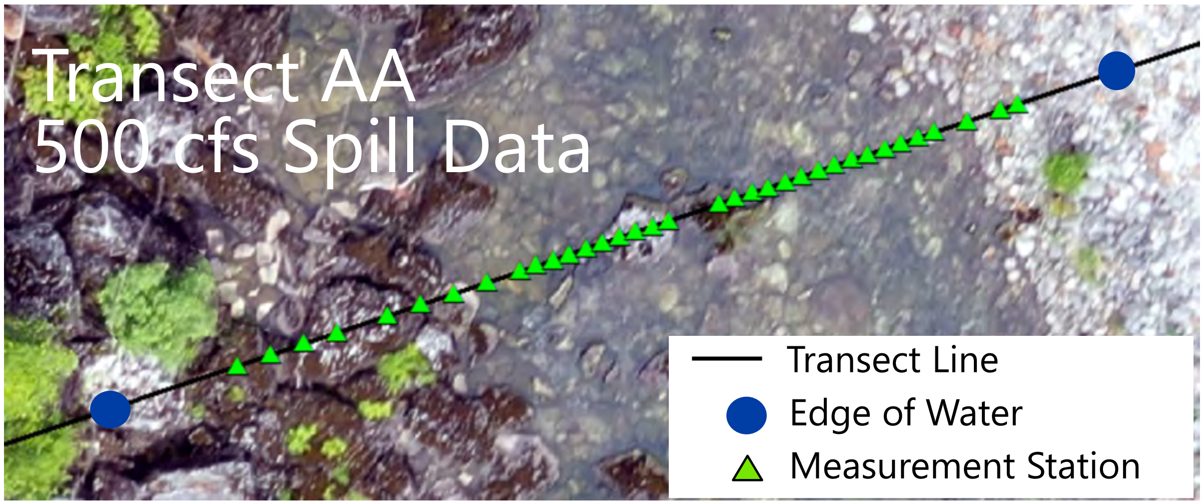
INSTRUMENTATION - ADV

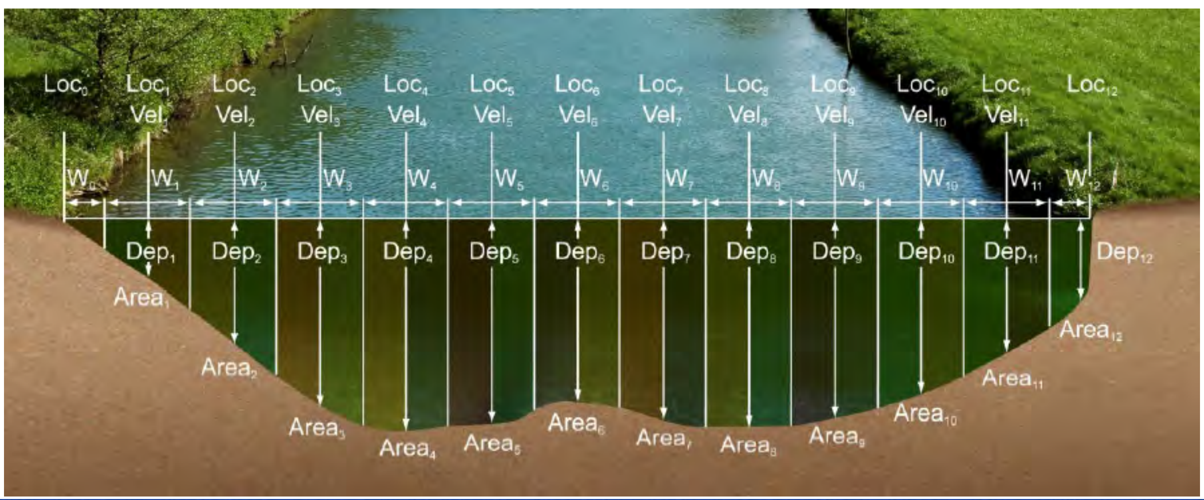
- ADV (Acoustic Doppler Velocimeter) – Sontek FlowTrackerII
  - Point velocities
  - Depth with rod
  - Shallow depths

INSTRUMENTATION - DEPLOYMENT

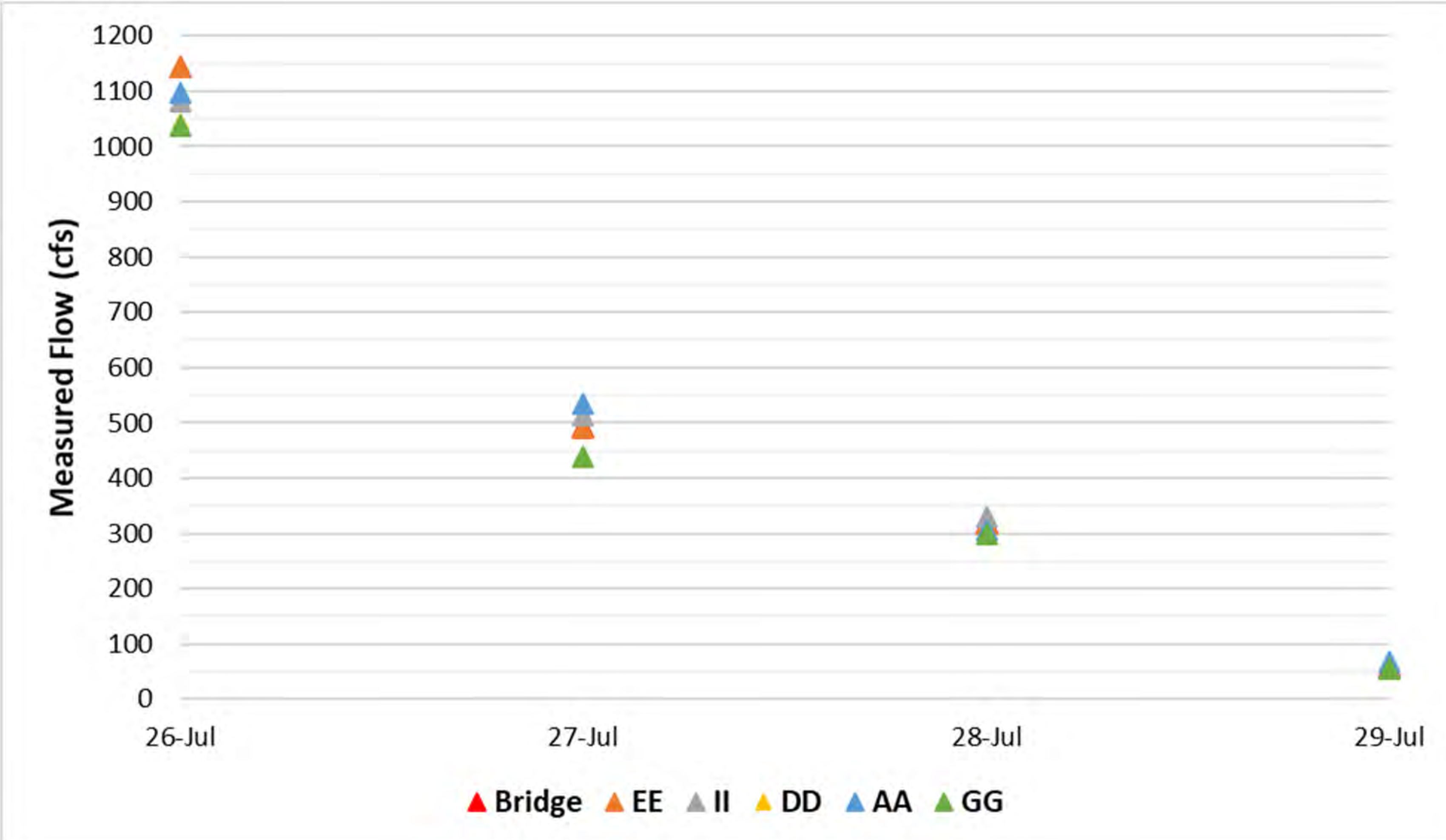


MEASUREMENTS - METHODOLOGY



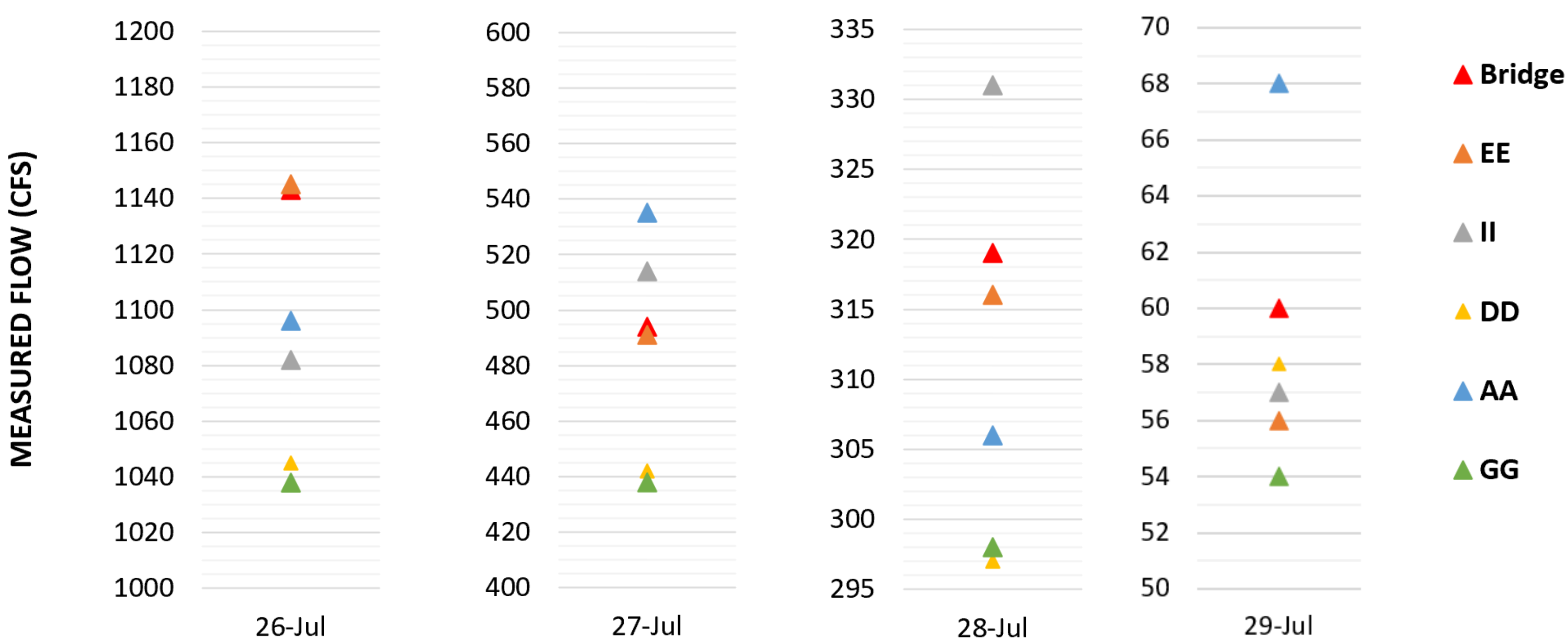


MEASUREMENTS - OBSERVED FLOWS

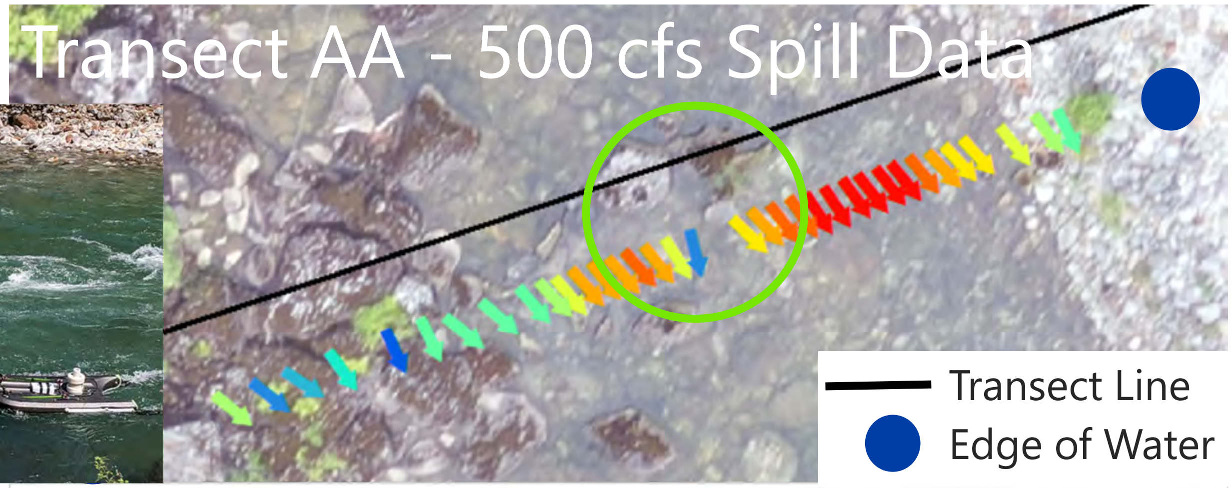


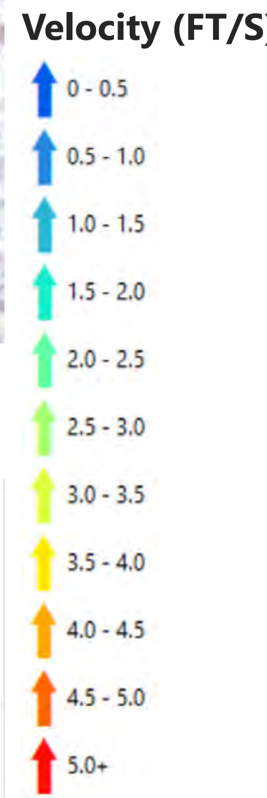
MEASUREMENTS - OBSERVED FLOWS

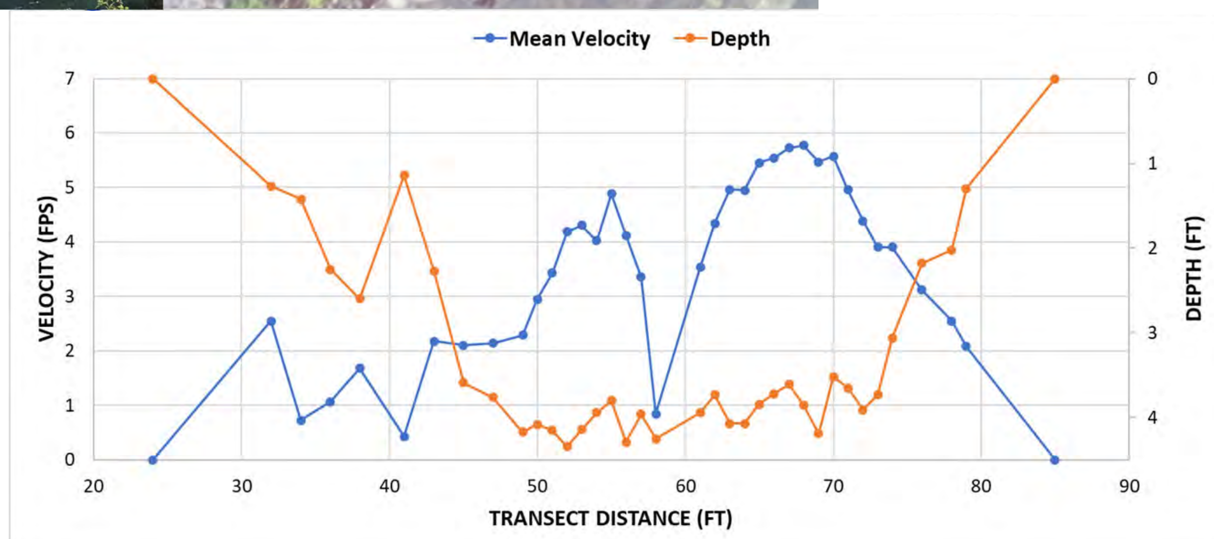
	26-Jul	27-Jul	28-Jul	29-Jul
TARGET RELEASE (CFS)	1200	500	250	50
SCL REPORTED RELEASE (CFS)	1095-1097	435-445	246-258	Log Chute (~50 cfs)



MEASUREMENTS – DEPTHS AND VELOCITIES







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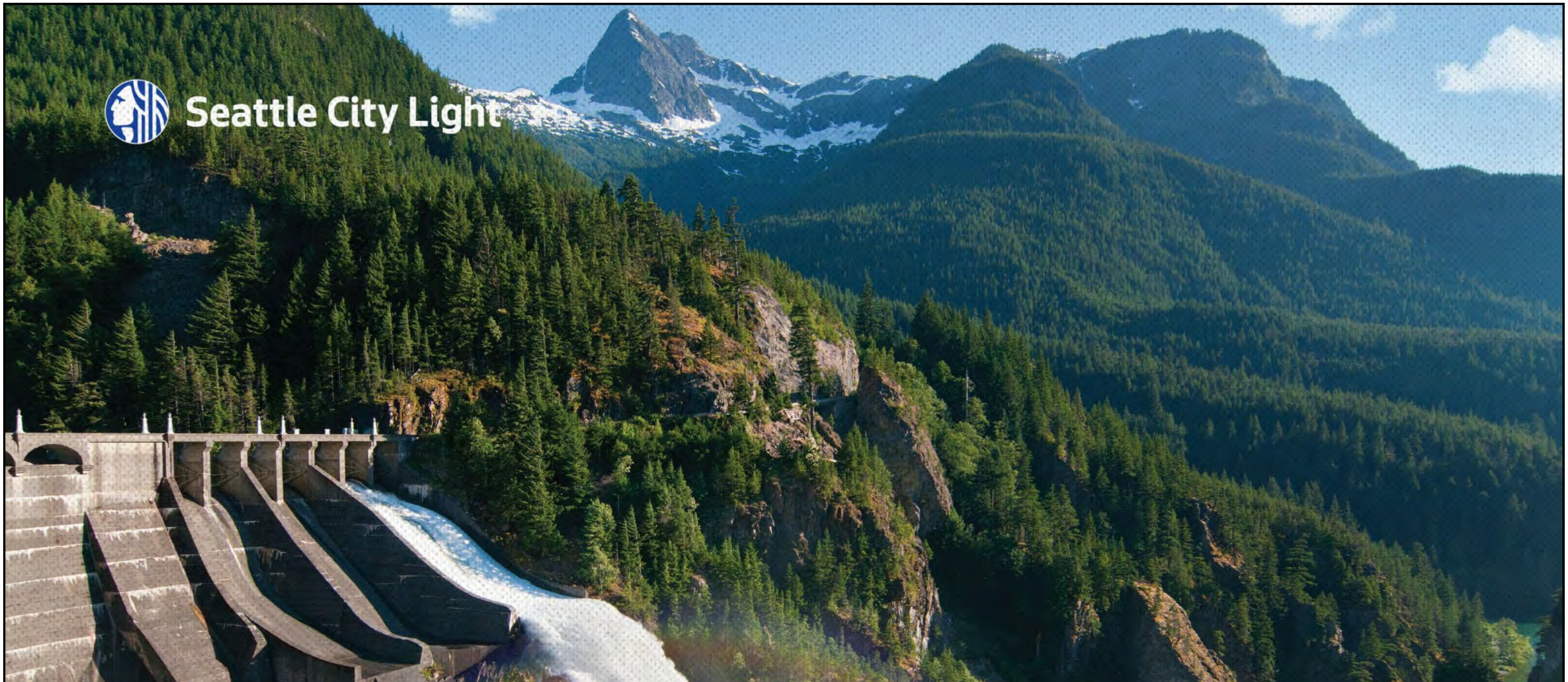
DISCUSSION



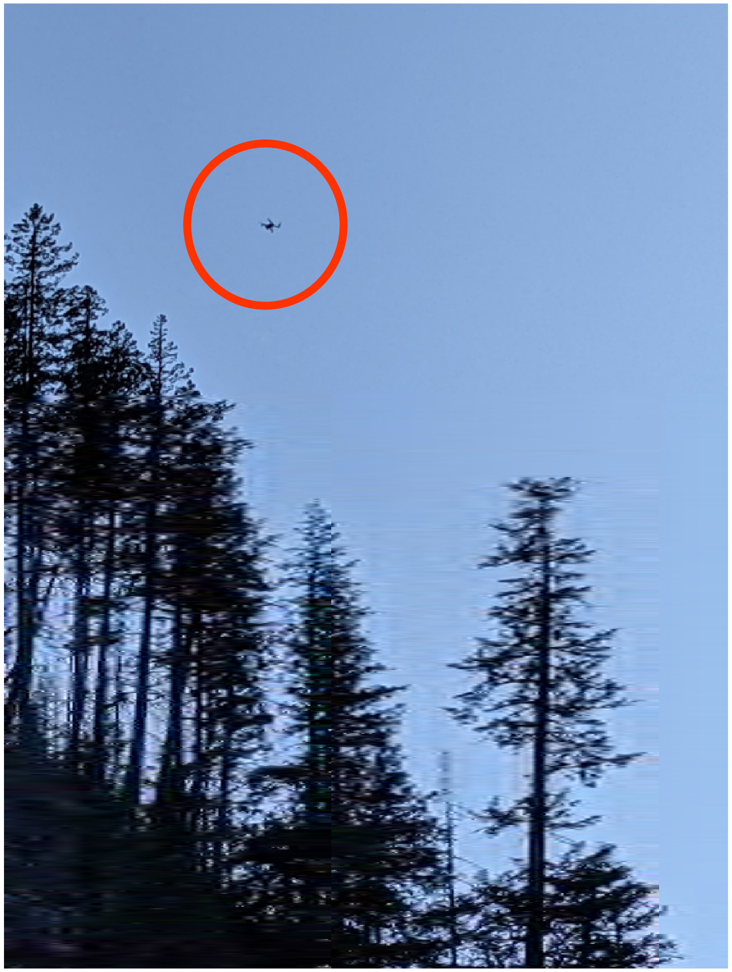
CONTROLLED SPILL MONITORING UAV DATA

August 26, 2021

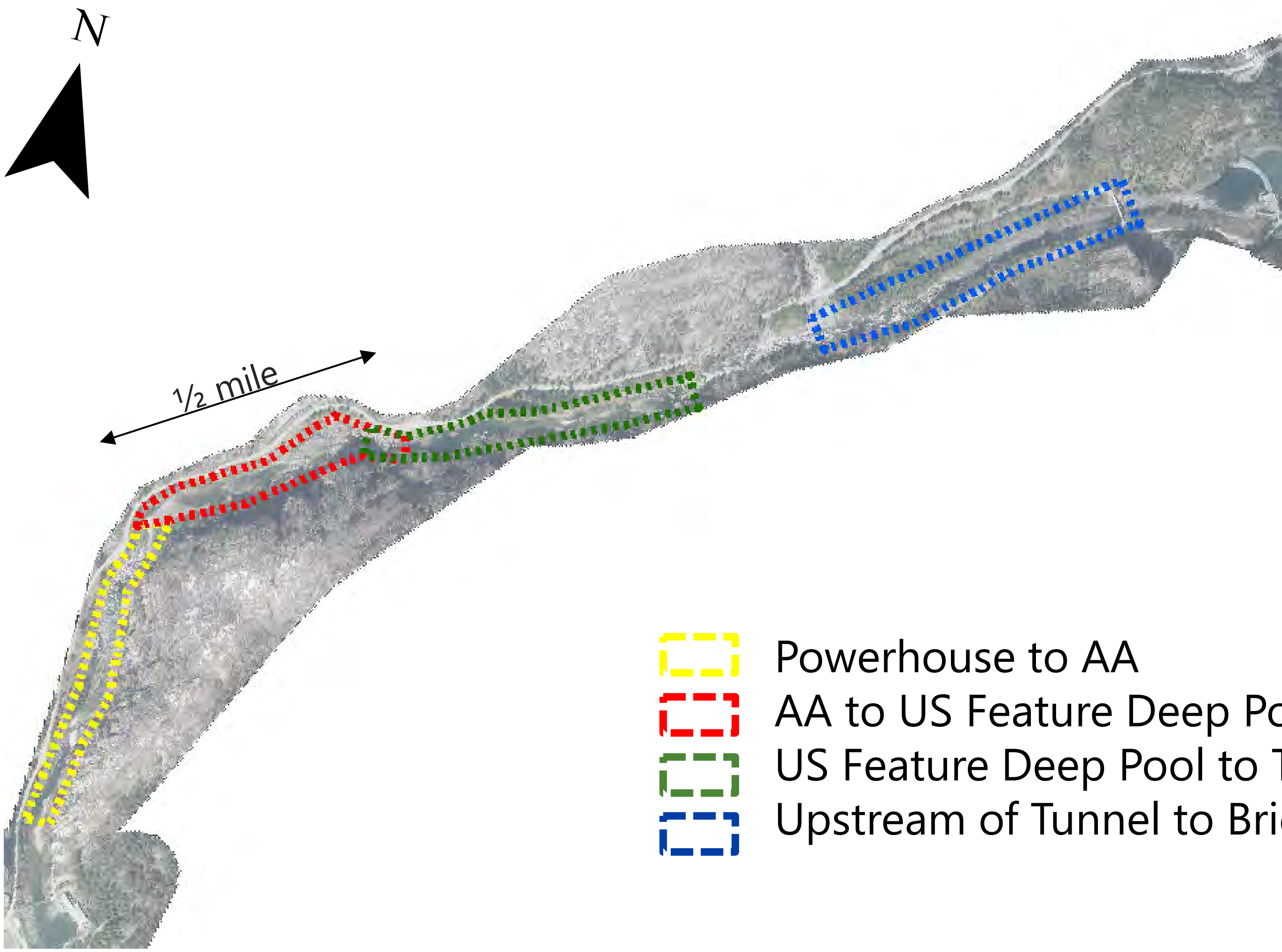
OVERVIEW

- UAV photos
  - Deployment
  - SfM
  - Geo-reference
  - Application
- UAV videos
  - LSPIV
  - Methodology
  - Locations
  - Application

UAV DEPLOYMENT

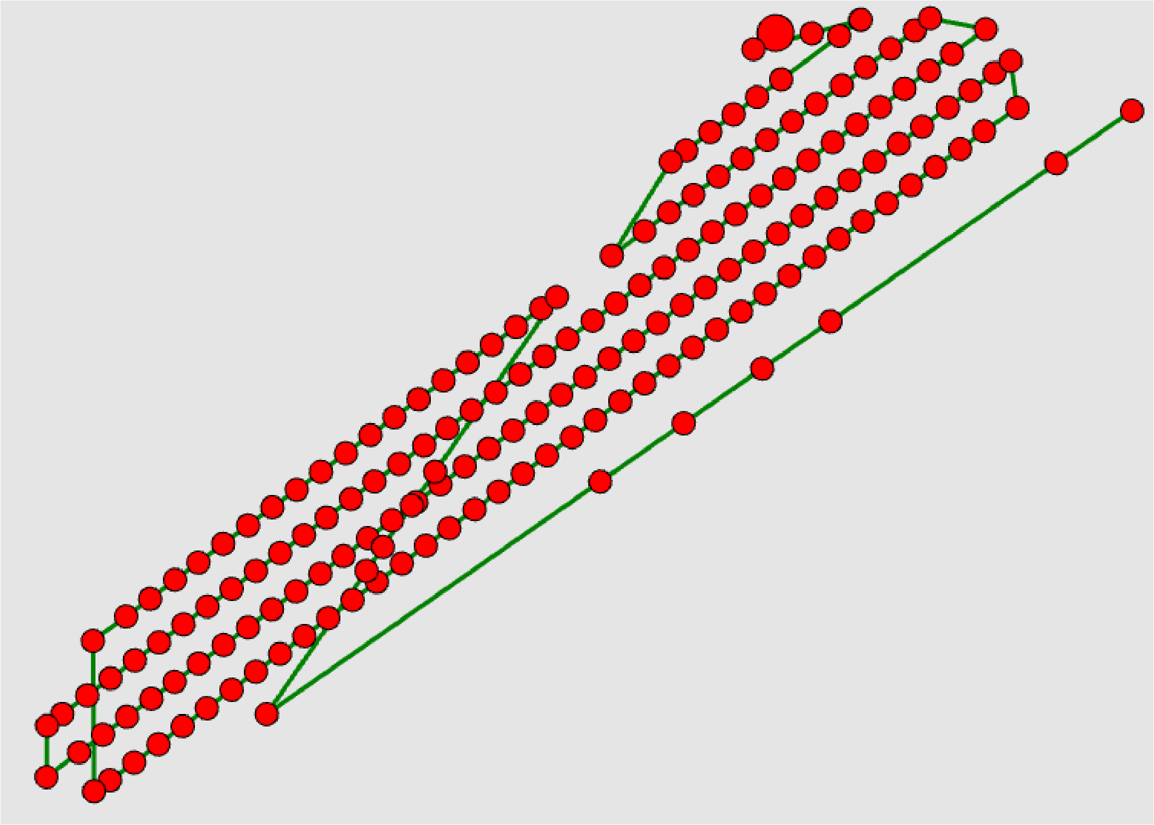


UAV DEPLOYMENT - ZONES

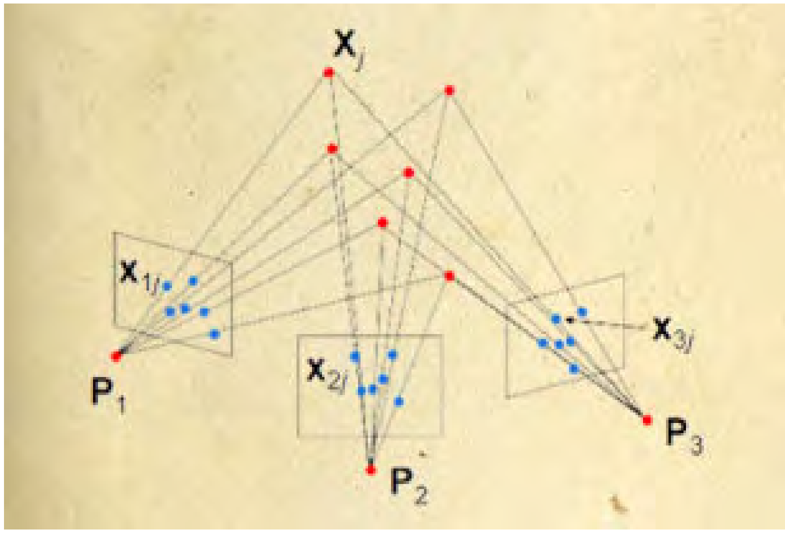


Powerhouse to AA
AA to US Feature Deep Pool
US Feature Deep Pool to Tunnel
Upstream of Tunnel to Bridge

UAV DEPLOYMENT – EXAMPLE MISSION PLAN



STRUCTURE FROM MOTION

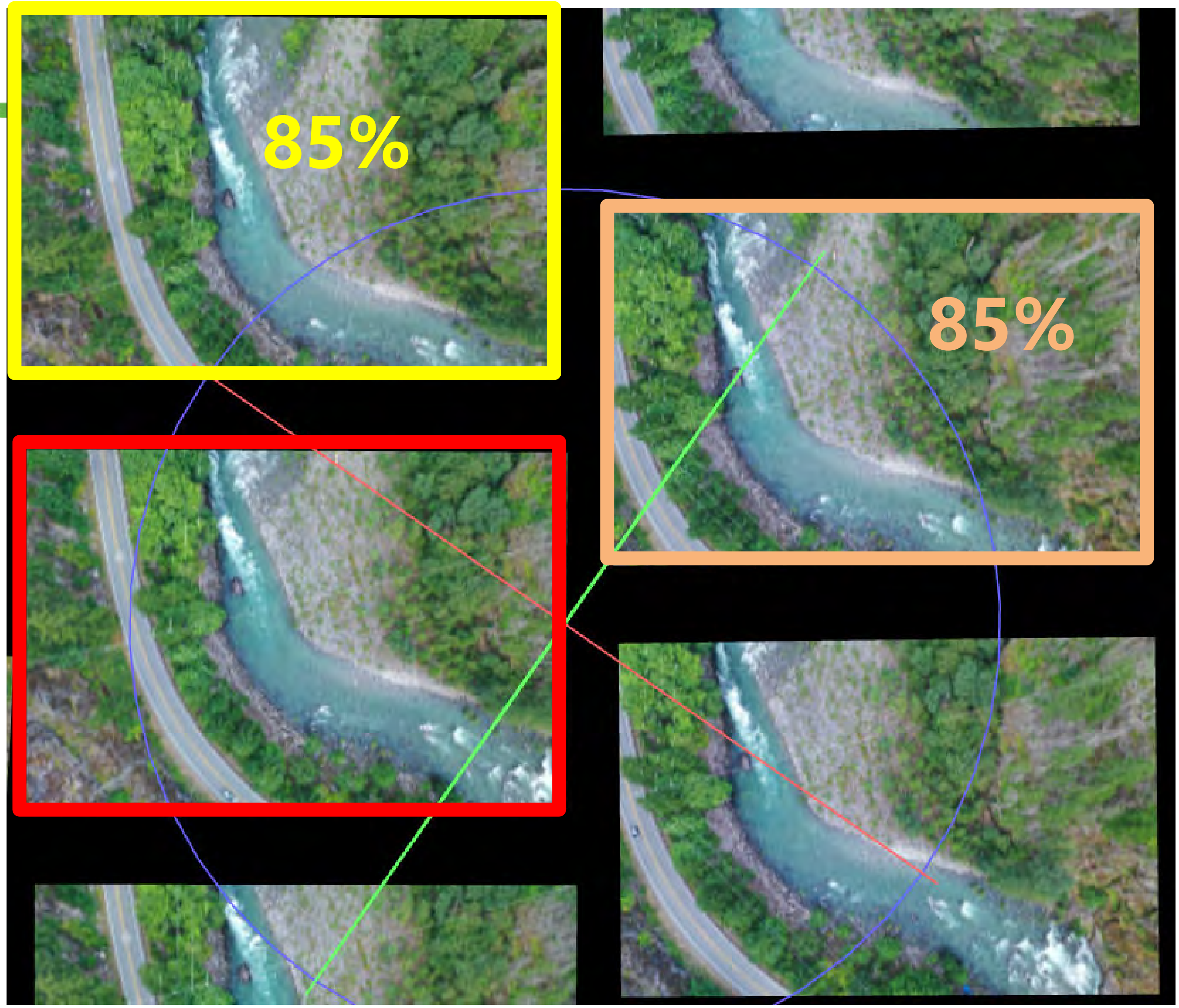


- SfM is workflow and set of algorithms used to determine 3D coordinates of an object space from a series of overlapping photos

STRUCTURE FROM MOTION

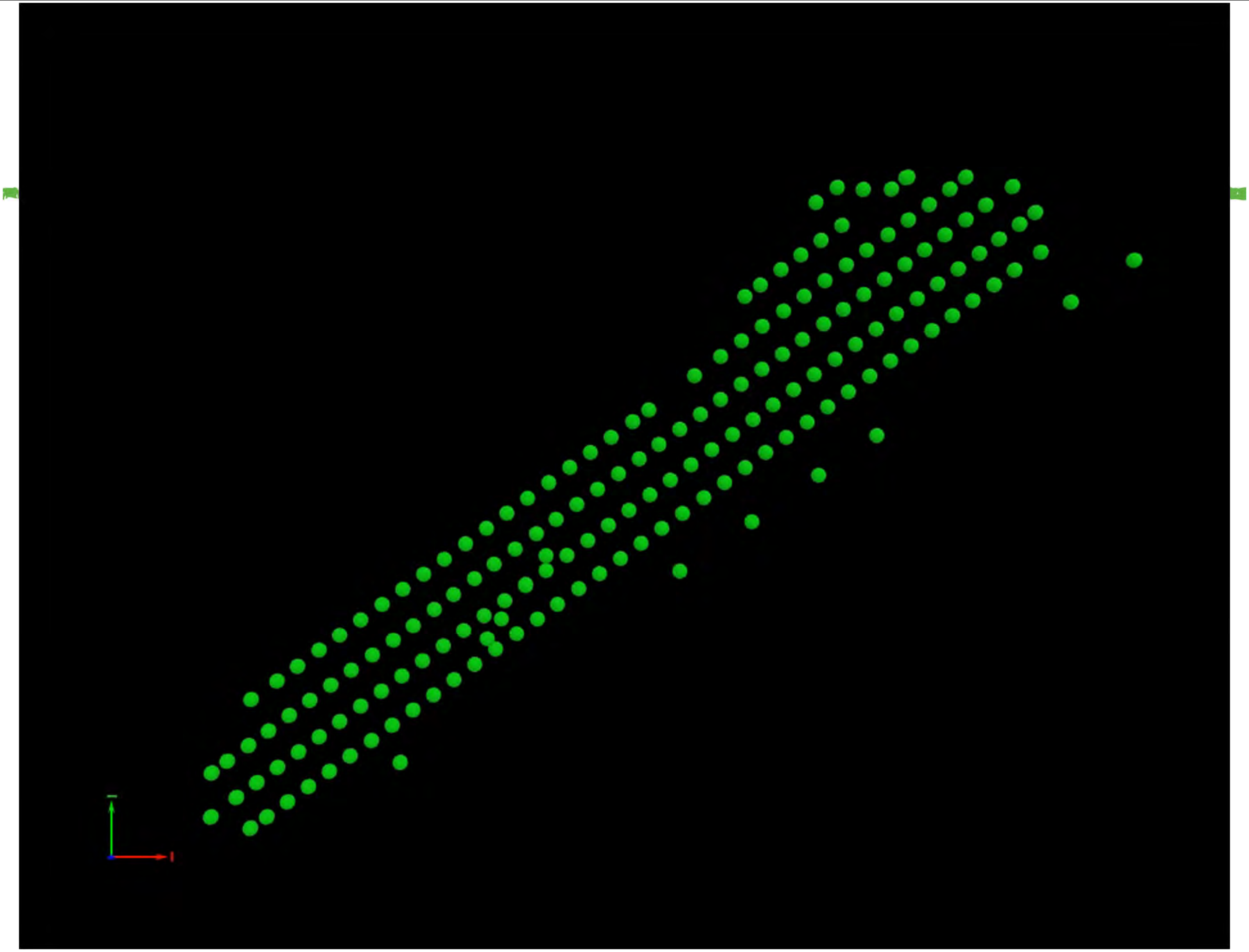
- Form of photogrammetry
  - 3D structure resolved from a series of overlapping, offset 2D images
  - Requires high image overlap
- Fundamentally different than traditional photogrammetry
  - No a priori knowledge necessary (camera 3D location & pose or GCPs)
  - No control required (but no scale, orientation, position)
- Match multiple features in multiple overlapping images

OVERLAP

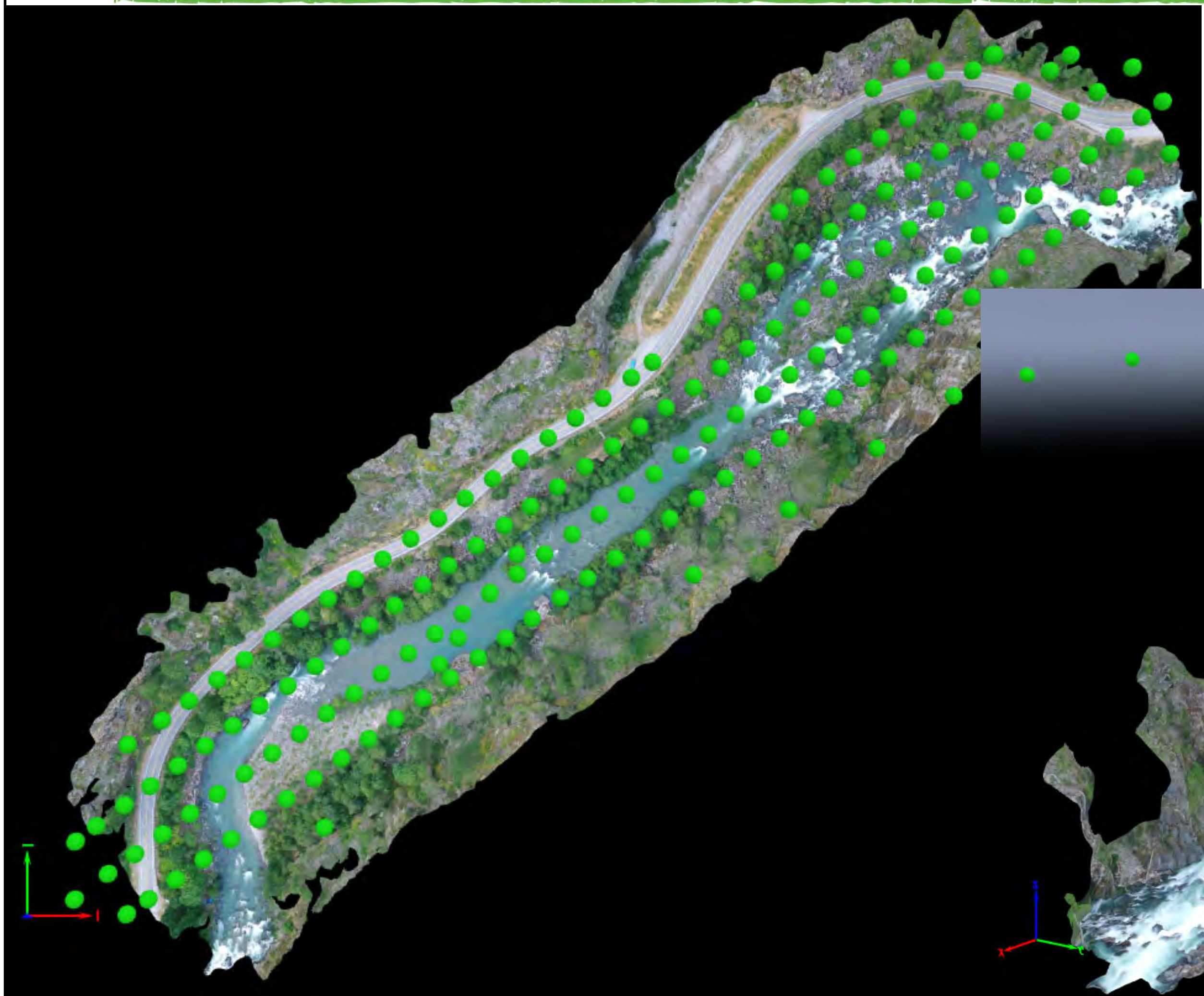


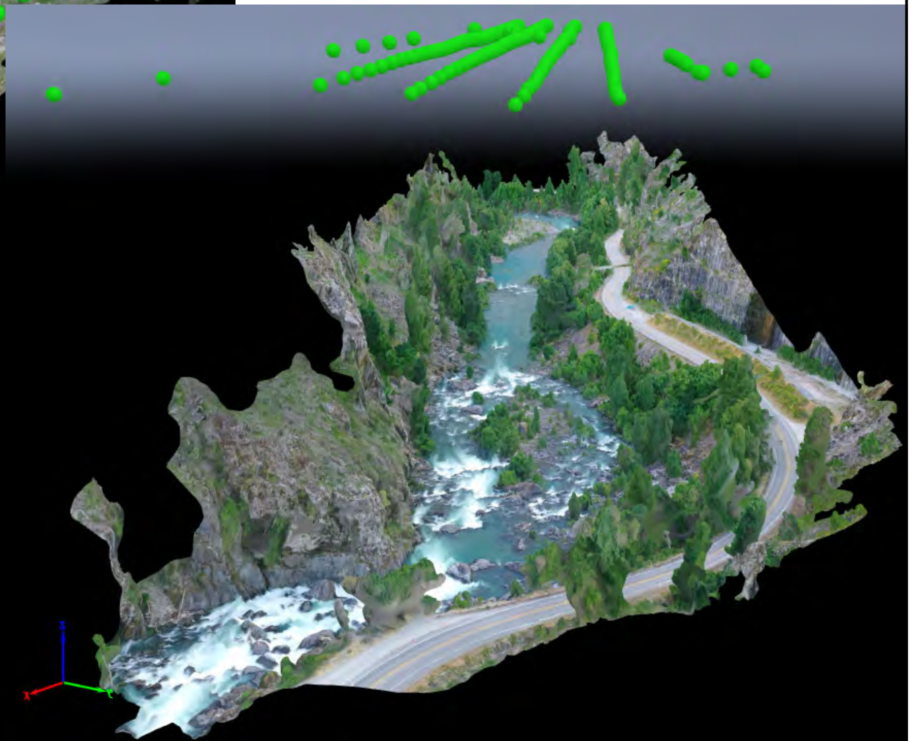
STRUCTURE FROM MOTION

- SfM process automated and bundled – Pix4D
- Result is a 3D model of keypoints
- 3D model -> 2D surface and orthomosaic
- Orthomosaic NOT result of the stitching together imagery, but rather projection of individual pixels from the original imagery

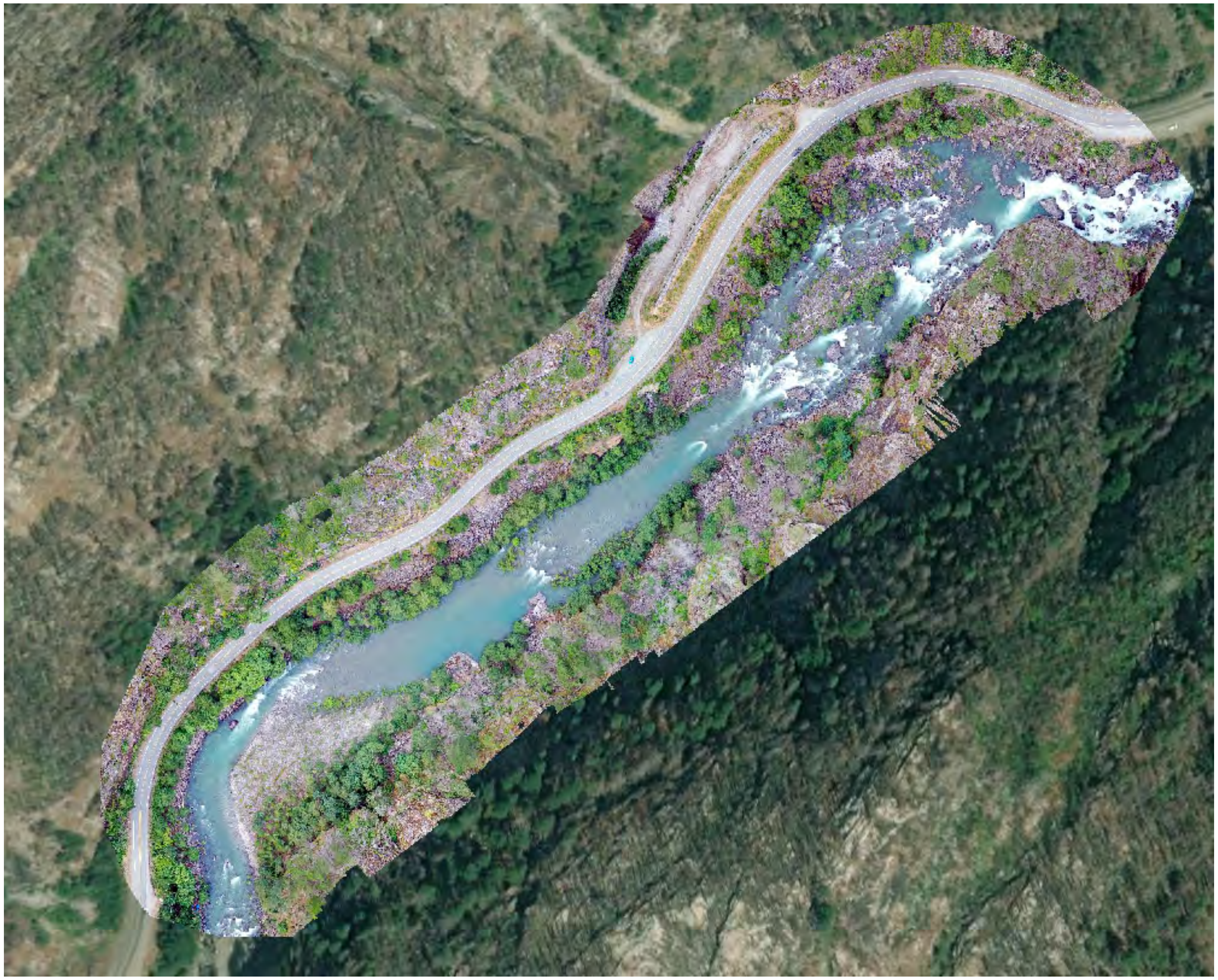


SFM – POINT CLOUD

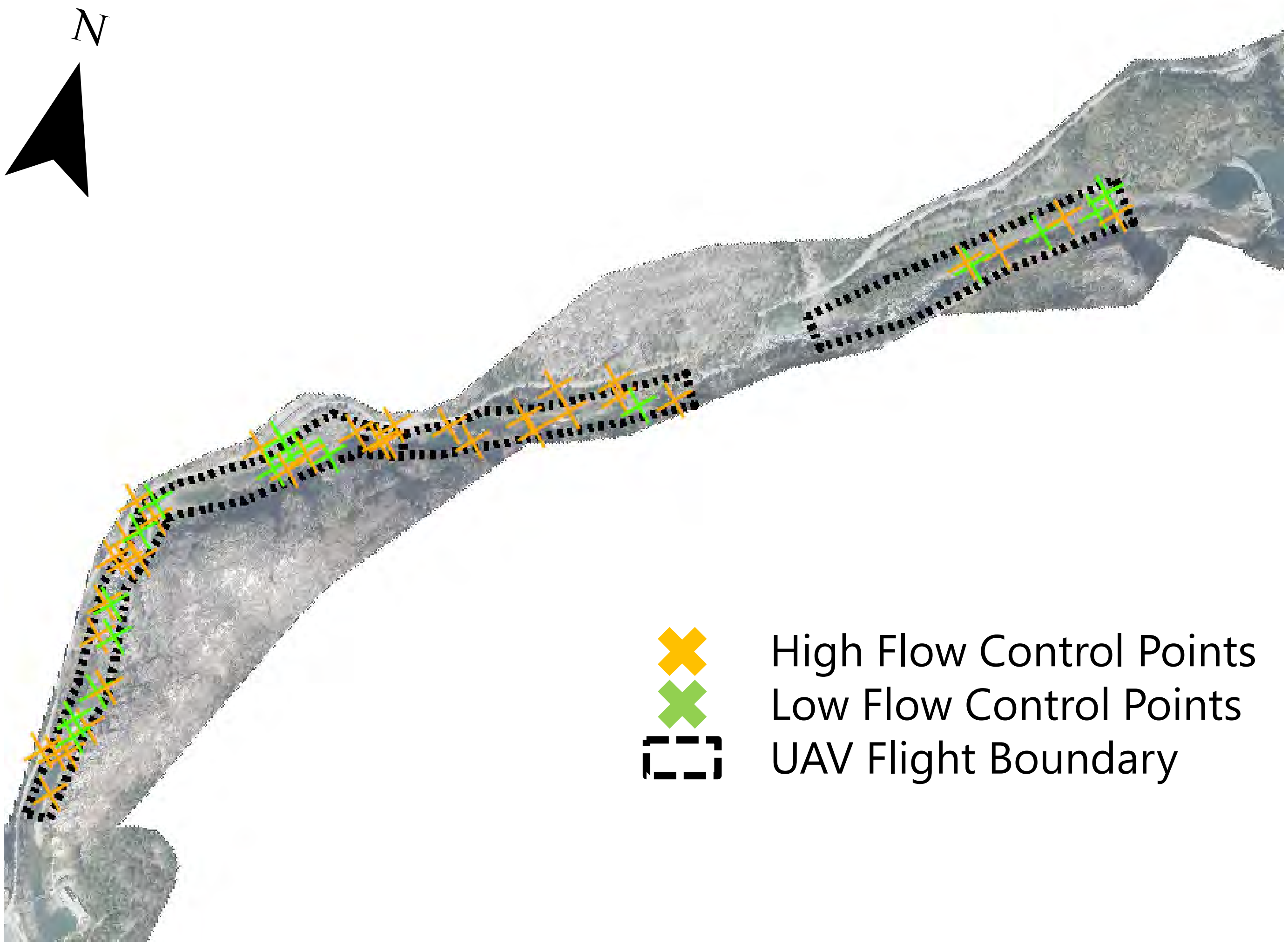




SFM – COMPOSITE ORTHOMOSAIC



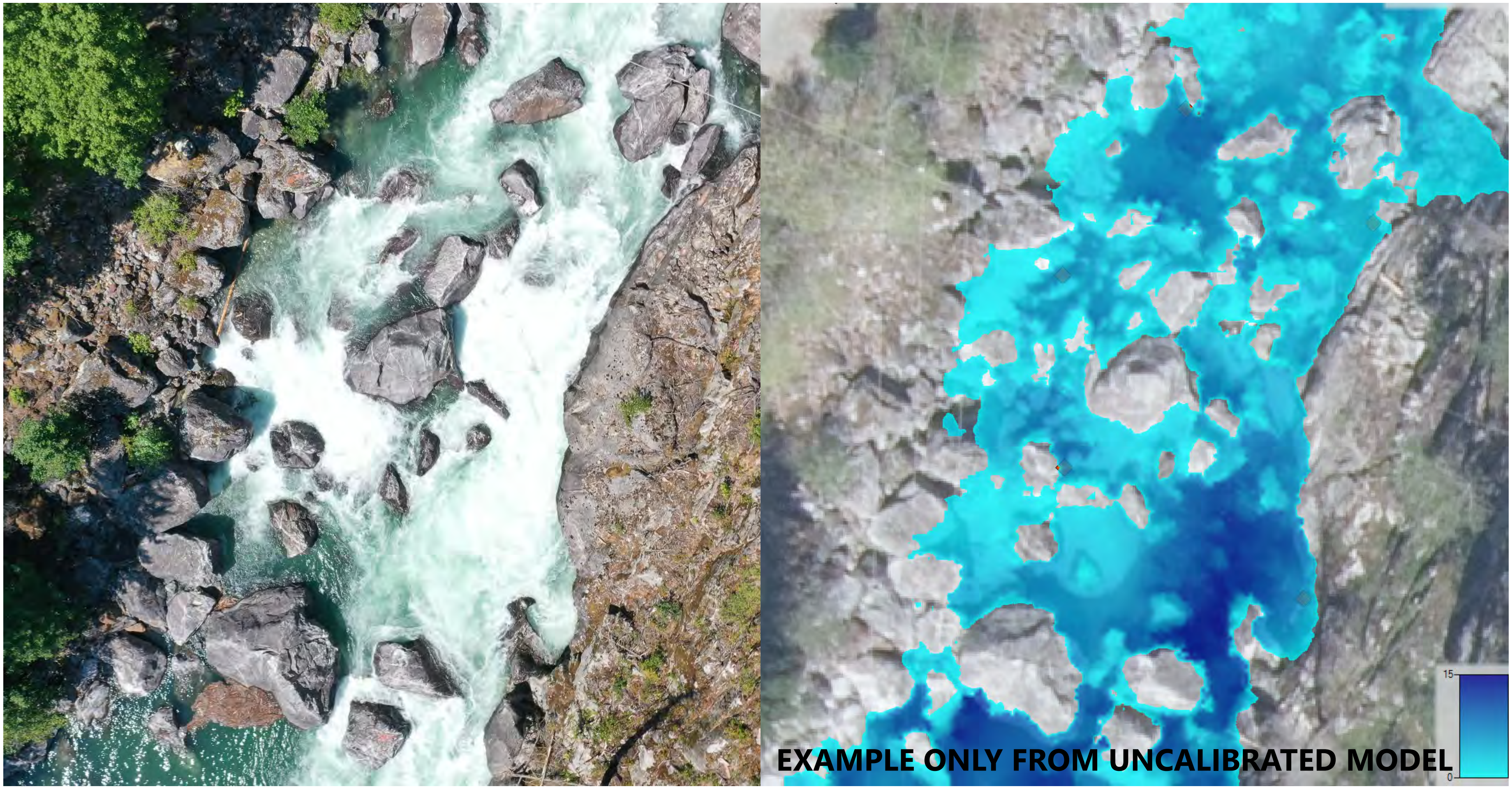
SFM MODEL – GEOREFERENCING



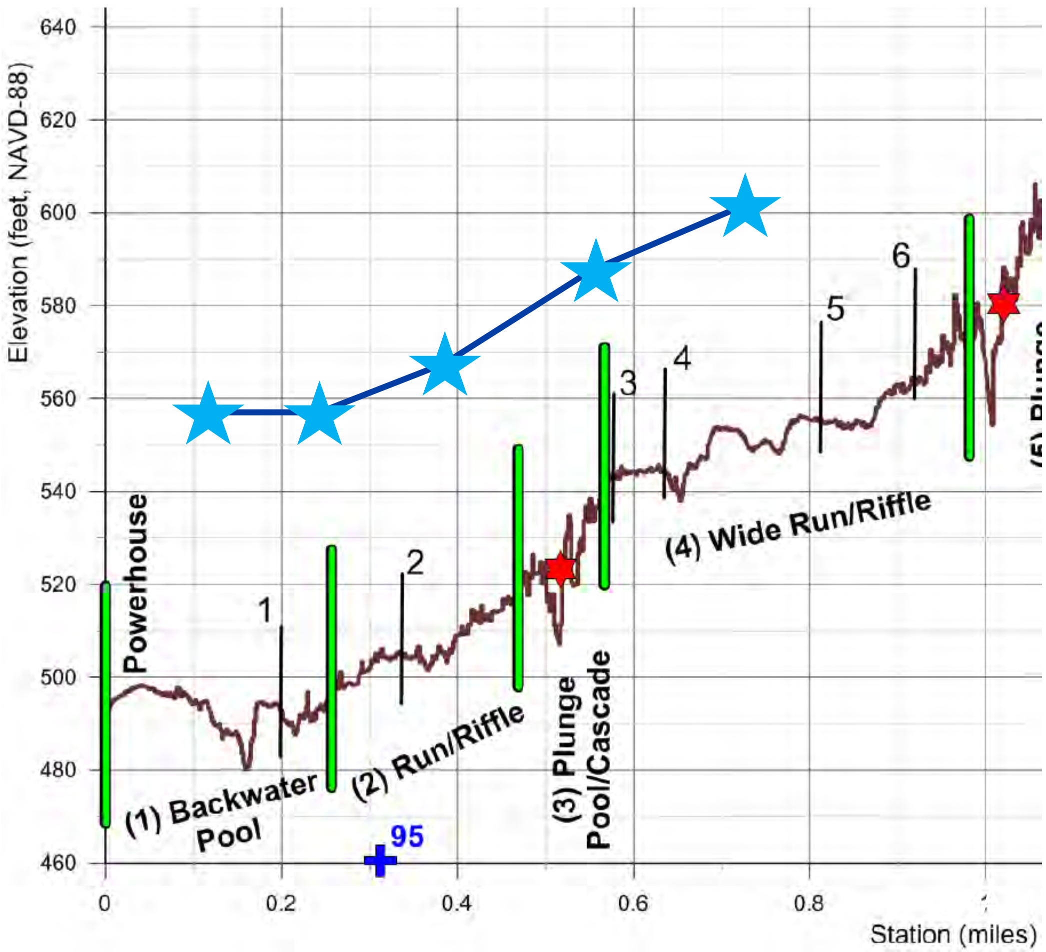
SURVEY – GEOREFERENCING

UAV APPLICATION - VISUALIZATION

UAV APPLICATION – COMPARE WITH MODEL

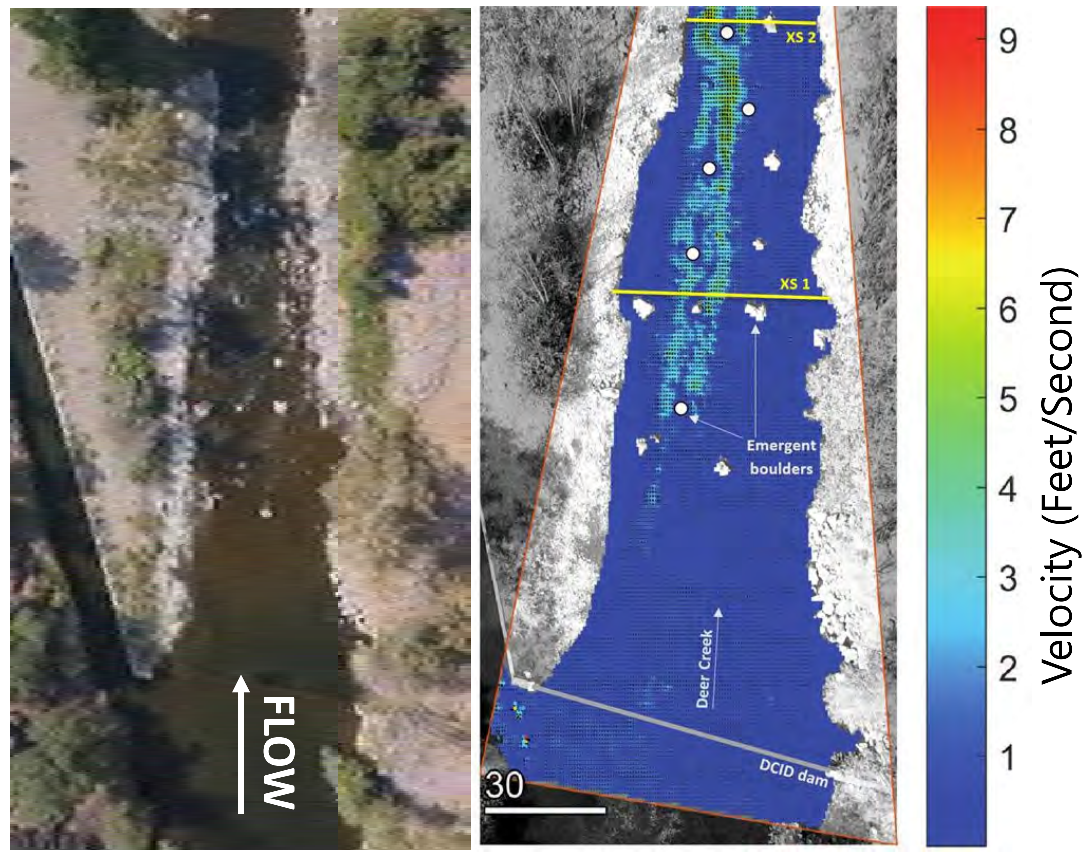


UAV APPLICATION – WSEL PROFILE



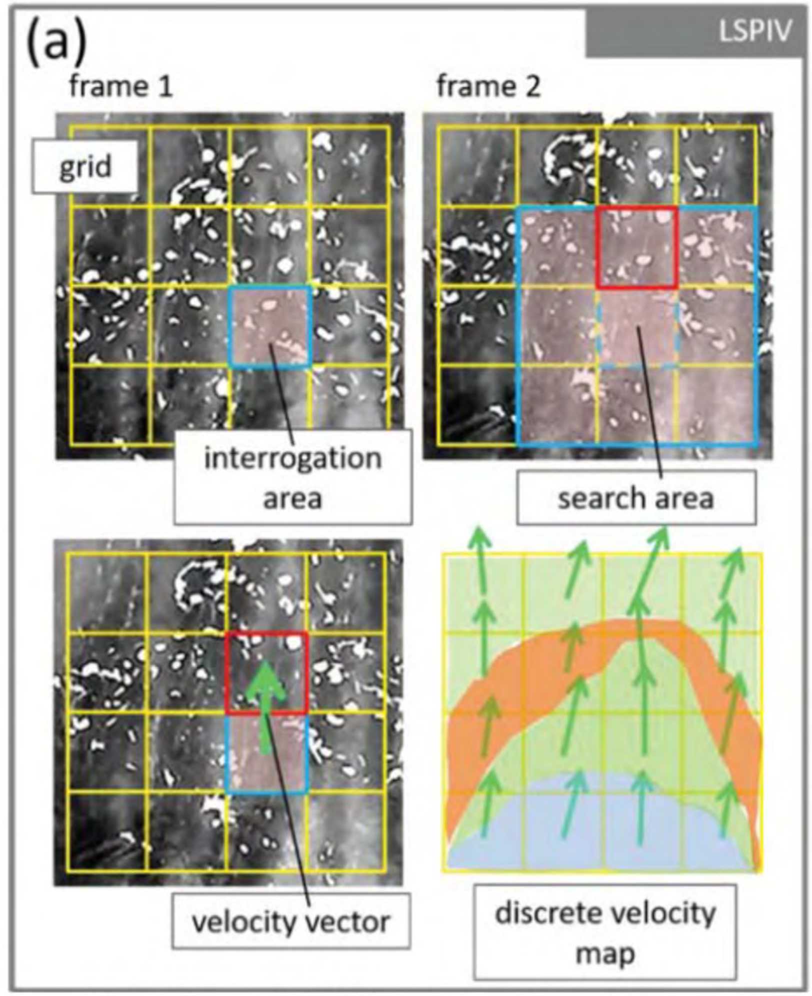
LSPIV - GOAL

- **L**arge **S**cale **P**article **I**mage **V**elocimetry
- Surface velocity vectors
- Uses:
  - o Ground truth numerical model
  - o Another view of fish passage potential
- LSPIV vector density comparable to numerical model mesh resolution



LSPIV - PRINCIPLE

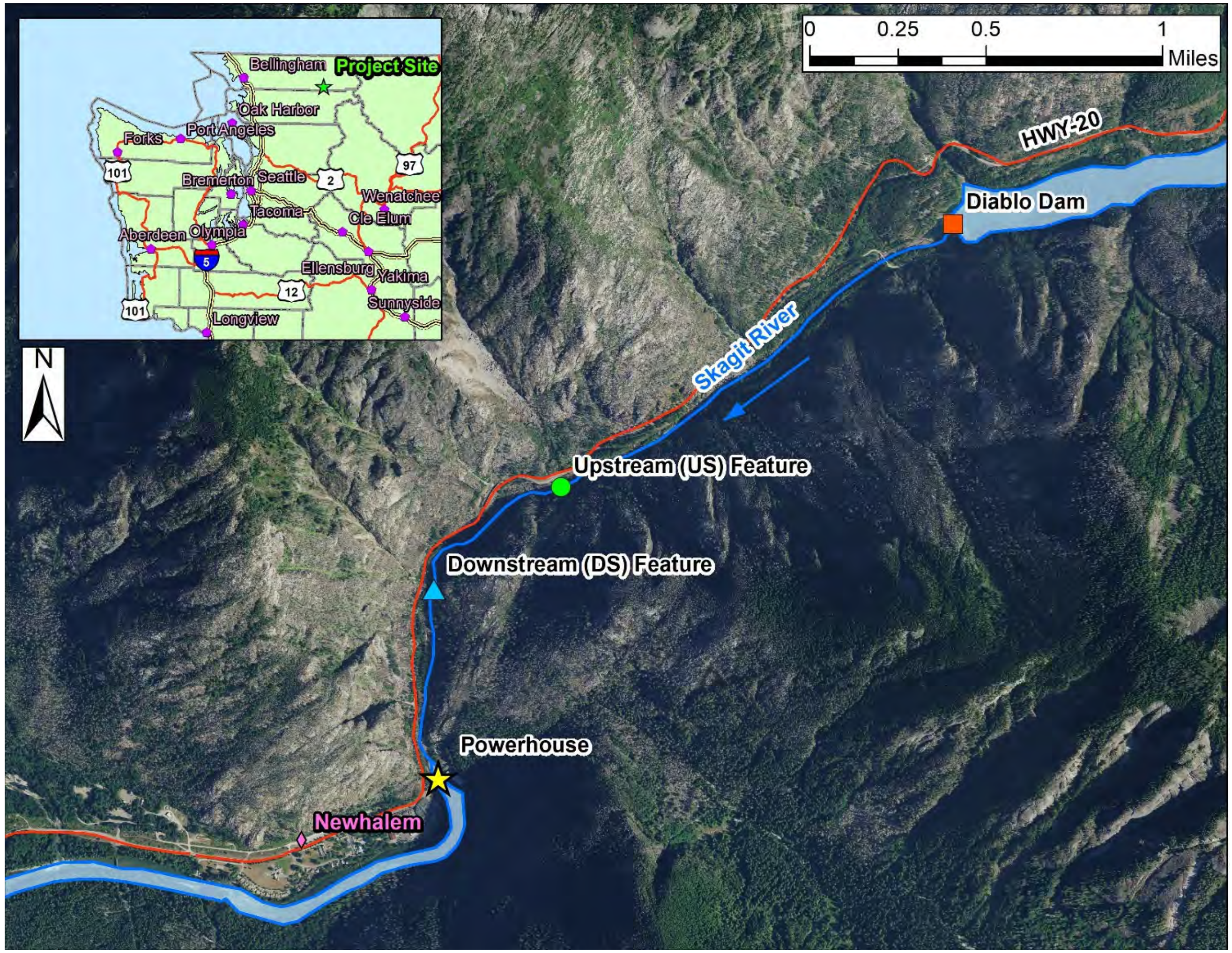
- Seed flow with buoyant tracer particles that follow the flow streamlines
    - Seed material must contrast with water to be visible in camera
- Capture the tracer movement on video with known frame rate
- Calculate tracer movement within interrogation areas for every successive pair of video frames



Source: Tauro et al., (2017 –Water Resources Research)

LSPIV – PROJECT SITE

- Upstream (US) feature
- Downstream (DS) feature



LSPIV – UPSTREAM (US) FEATURE

- Image at Base Flow

LSPIV – DOWNSTREAM (DS) FEATURE

- Image at Base Flow

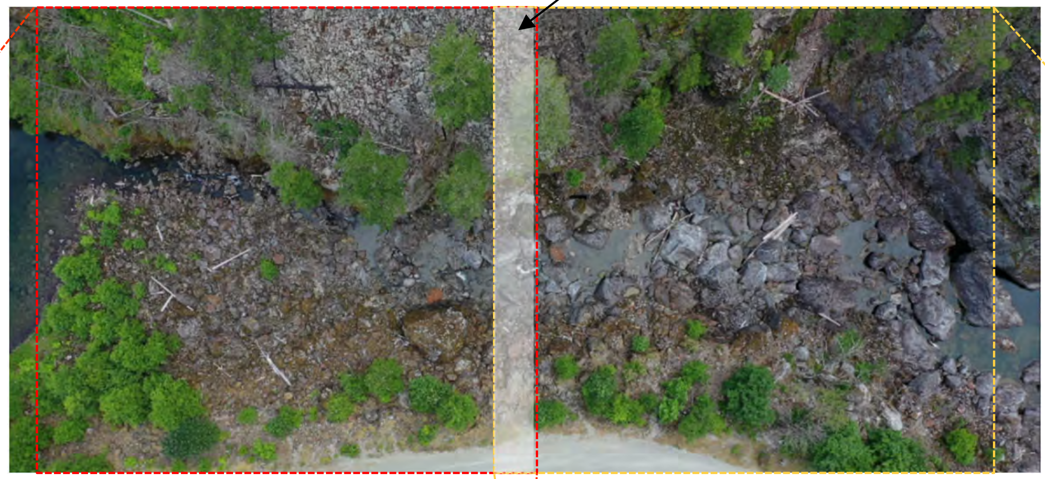
LSPIV – SEEDING MATERIAL

- Bark Chips
- Buoyant
- Good Contrast to Whitewater

LSPIV – UAV VIDEO CAPTURE

- Upstream (US) Feature @ 1,200 cfs
- Successive Flow Fields to Allow for Comparable Velocity Vector Resolution to that of the Numerical Model

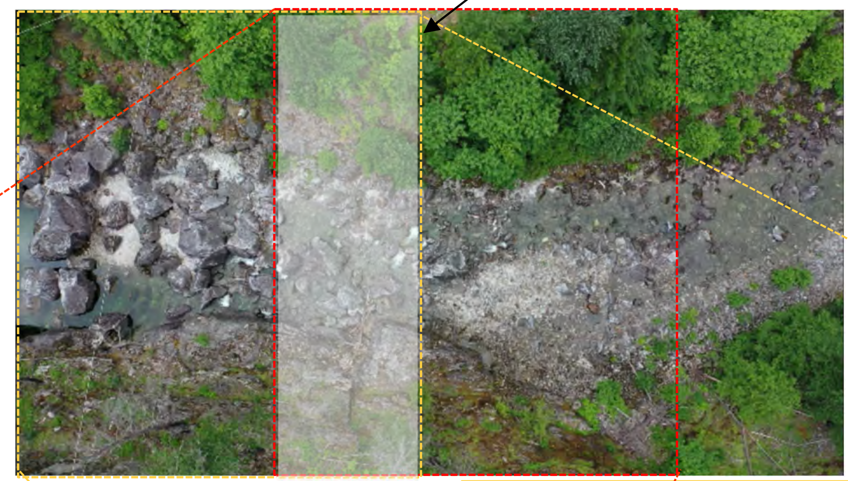
FRAME OVERLAP



FLOW

LSPIV – UAV VIDEO CAPTURE

- Downstream (DS) Feature @ 1,200 cfs
- Successive Flow Fields to Allow for Comparable Velocity Vector Resolution to that of the Numerical Model

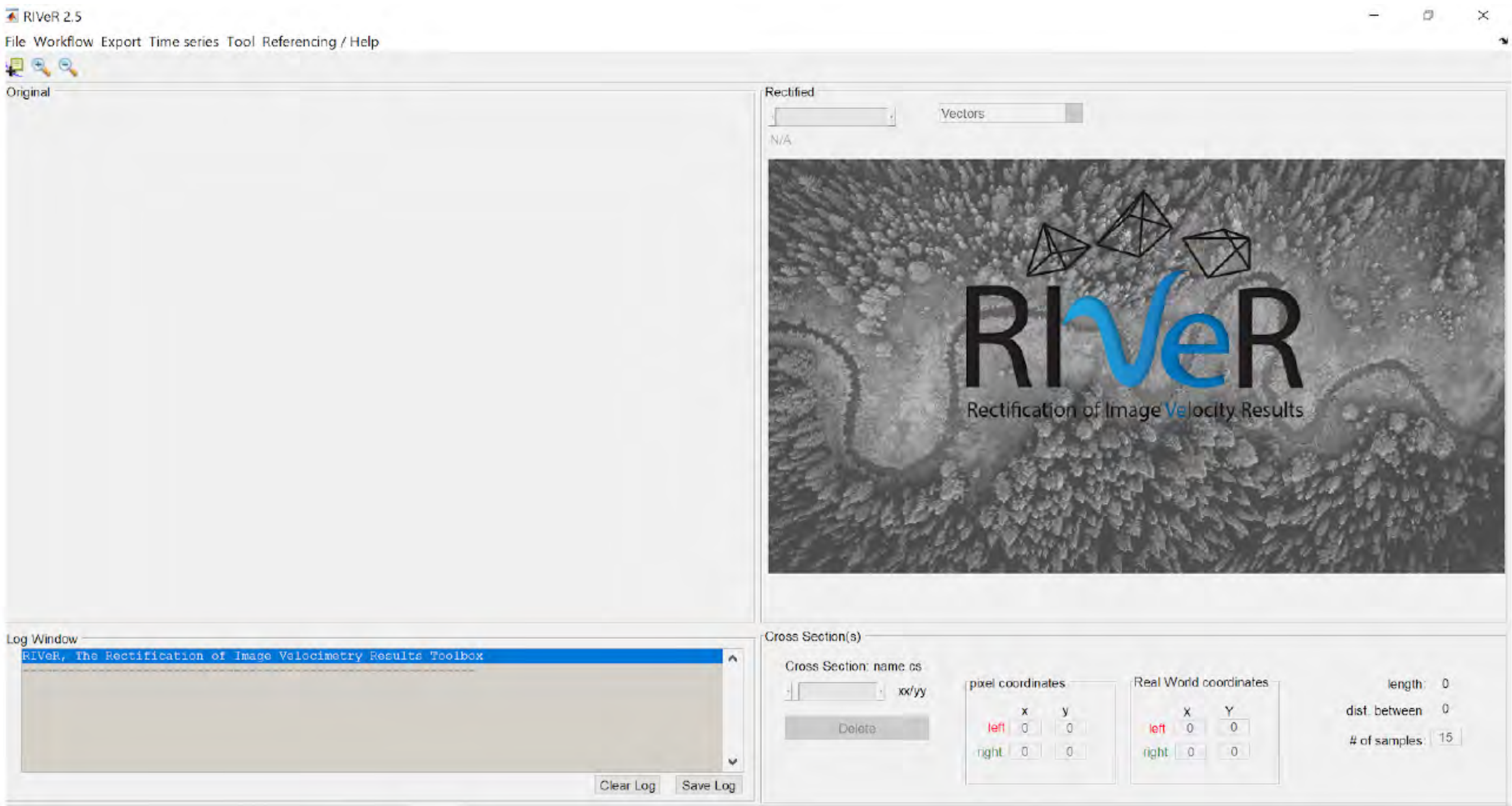


NOTE IMAGE ORIENTATION IS OPPOSITE

LSPIV – CAPTURED VIDEO

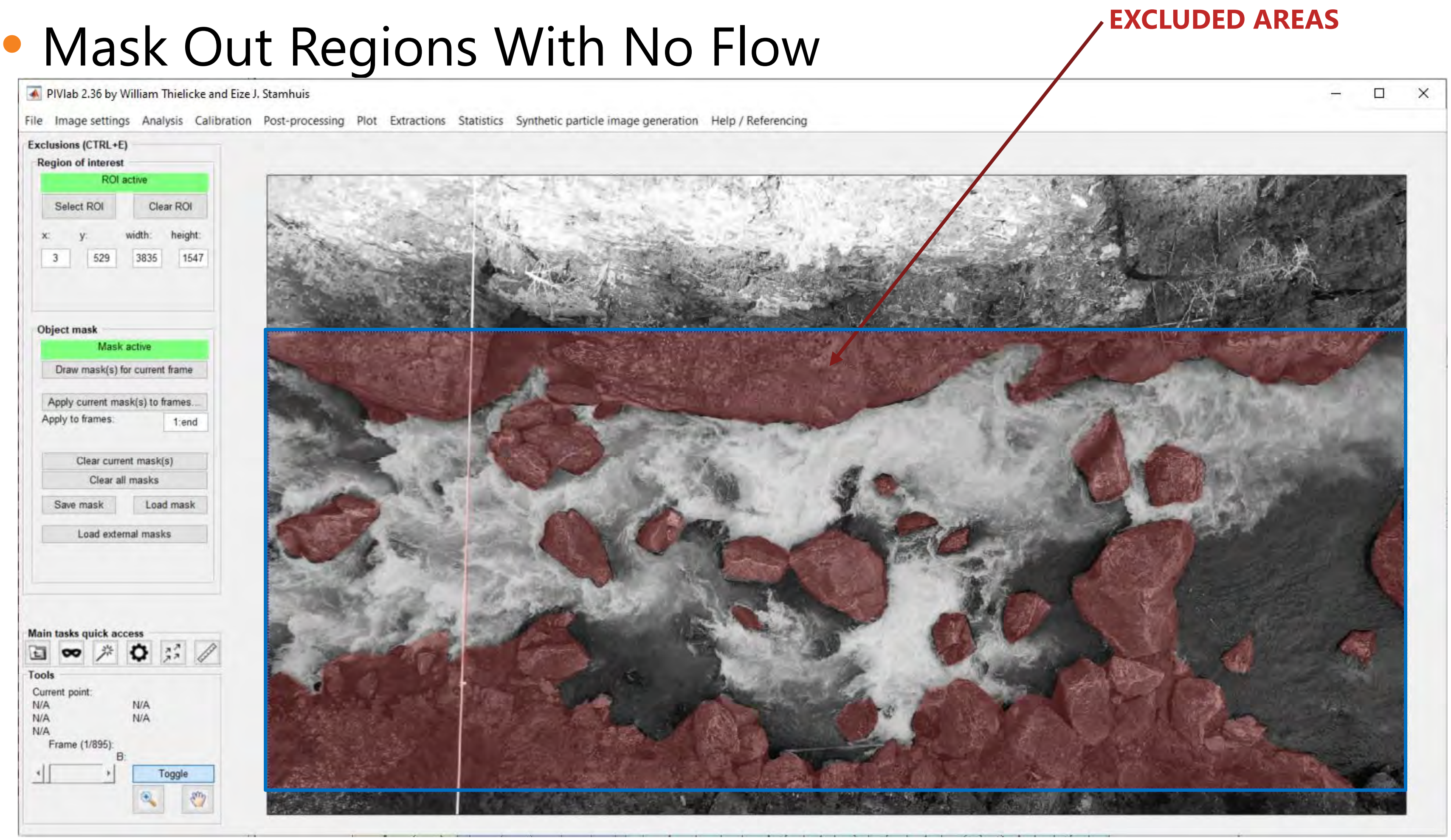
LSPIV – ANALYSIS

- RIVeR Software



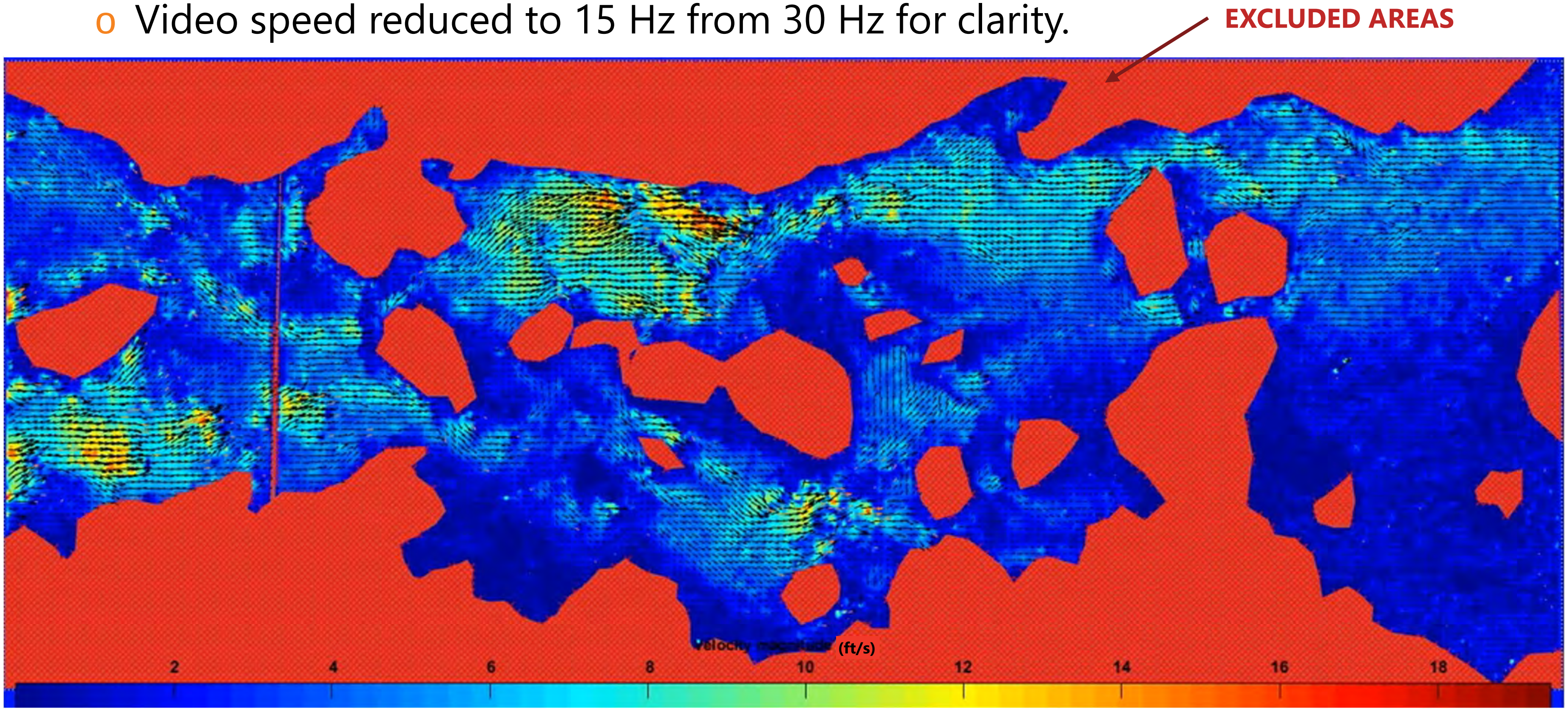
LSPIV – ANALYSIS

- Mask Out Regions With No Flow



LSPIV – RESULTS

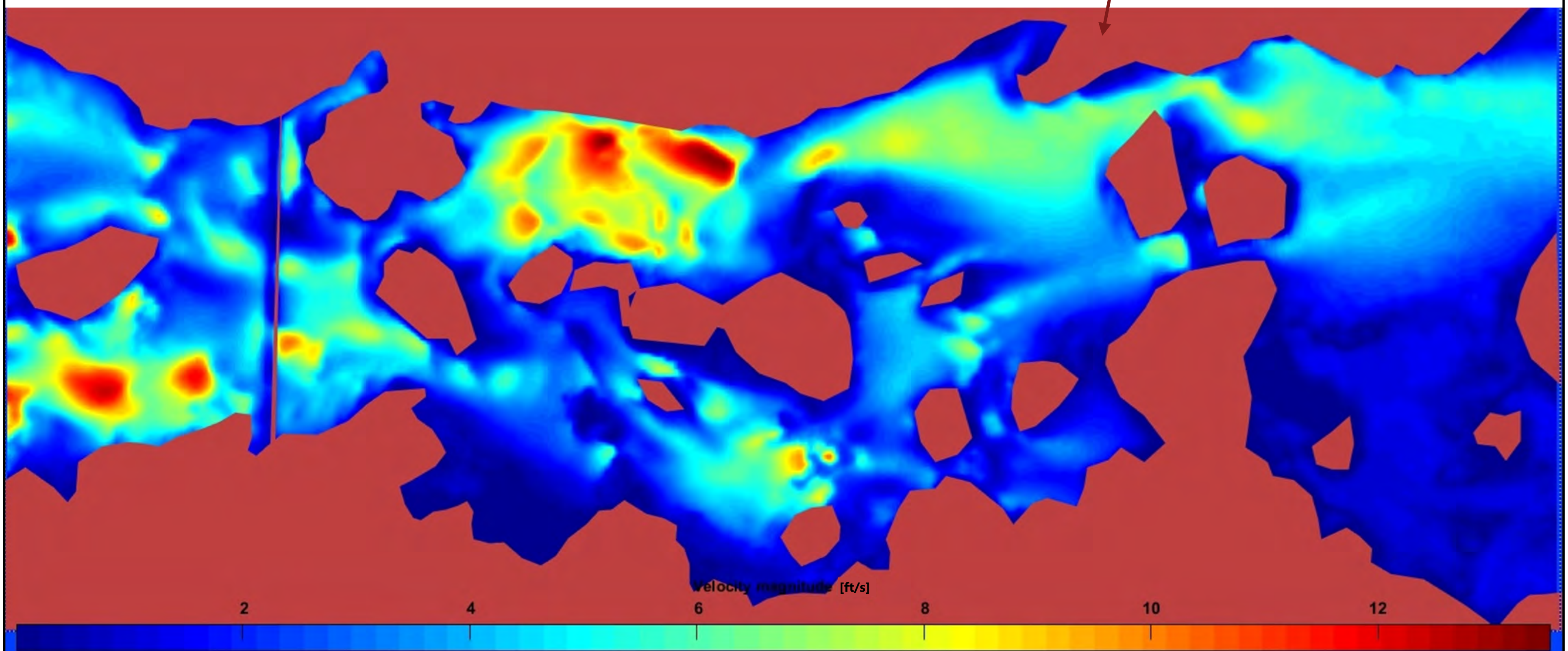
- Instantaneous Raw Velocity Vectors
  - Velocity vector spacing: 1.1 feet; Video shows only every second vector for clarity.
  - Video speed reduced to 15 Hz from 30 Hz for clarity.



LSPIV – RESULTS (CONT'D)

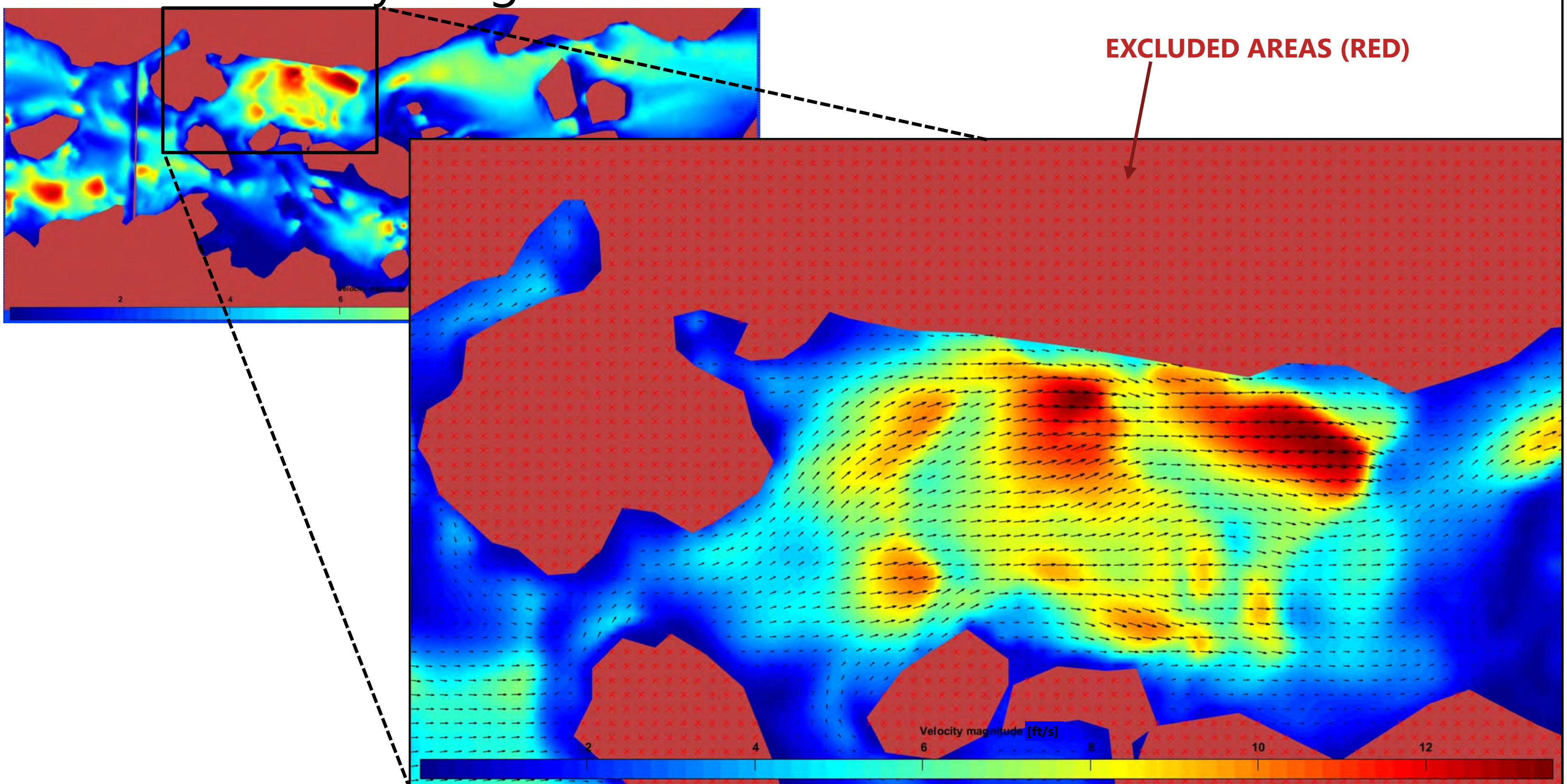
- Mean Velocity Magnitude

EXCLUDED AREAS (RED)



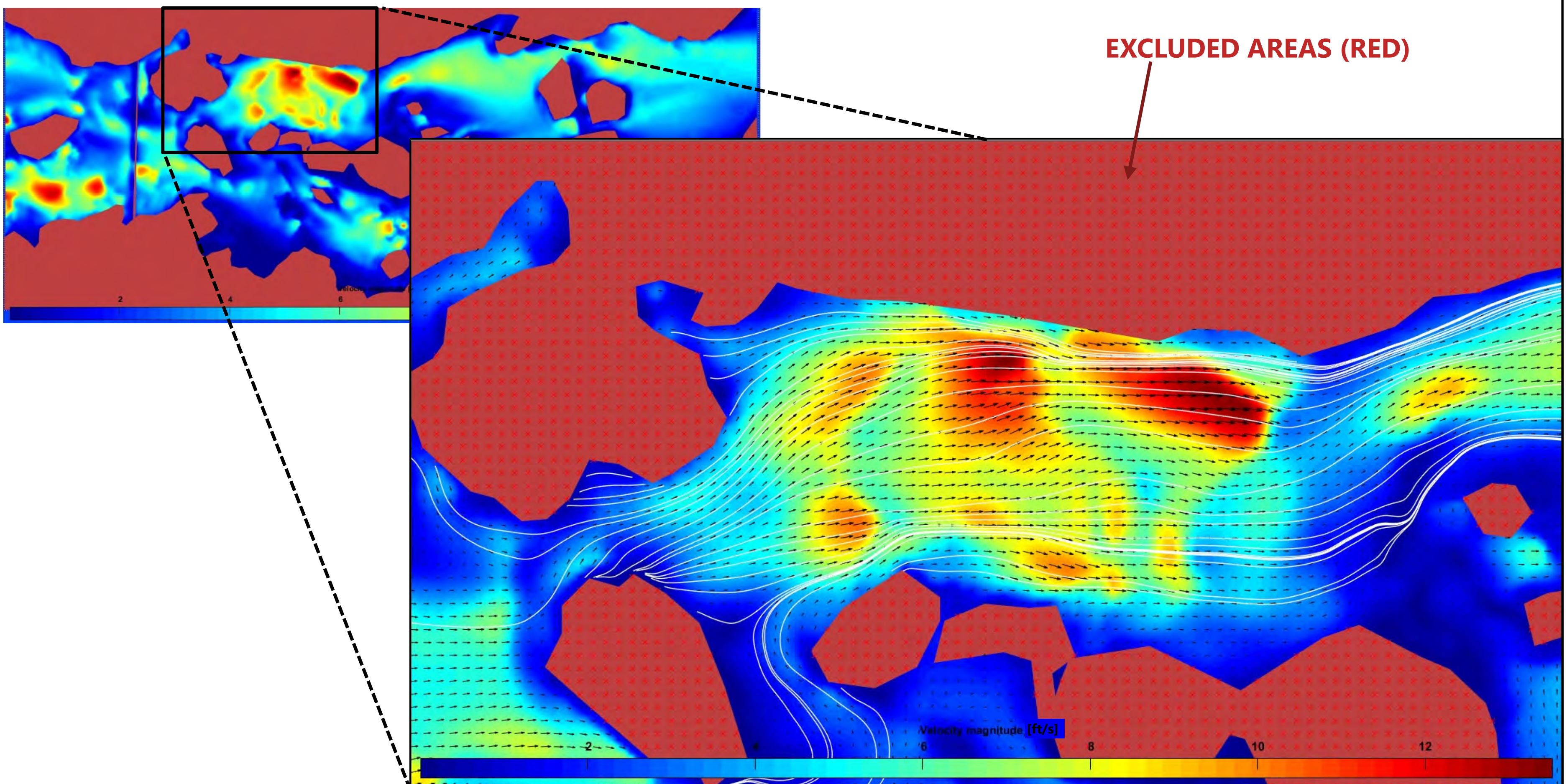
LSPIV – RESULTS

- Mean Velocity Magnitude



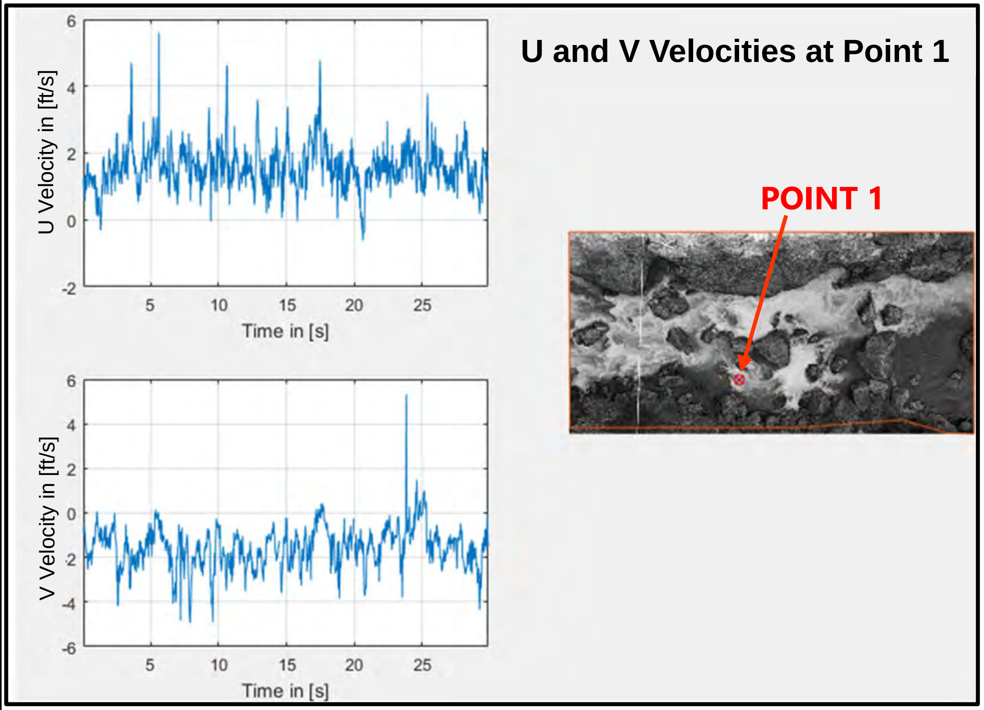
LSPIV – RESULTS

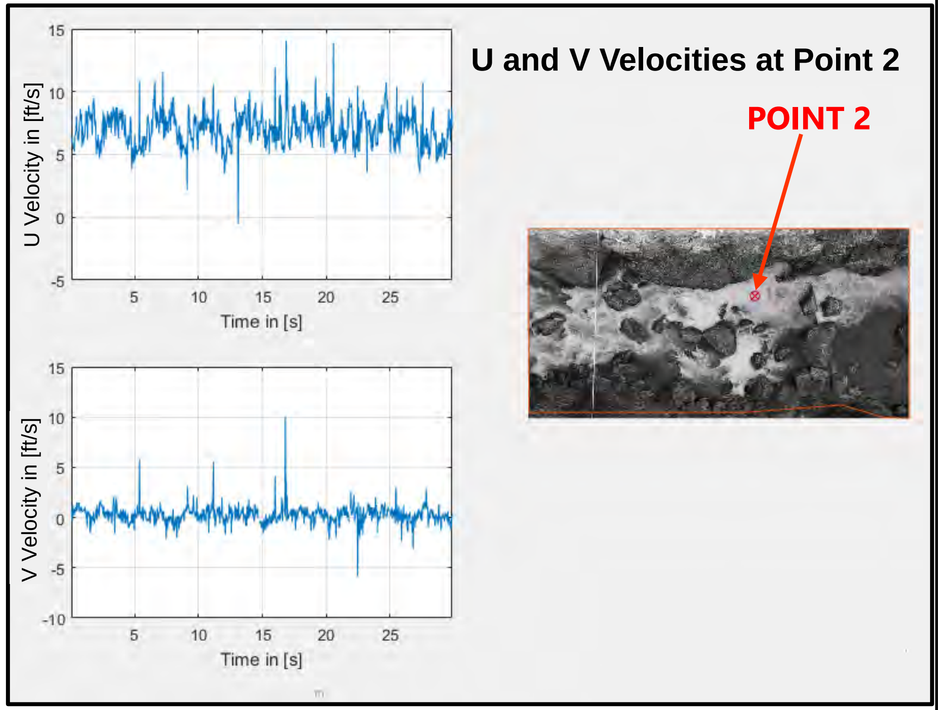
- Streamlines



LSPIV – RESULTS

- Streamwise (U) and Transverse (V) Velocity Components at a Point Over the Video Duration





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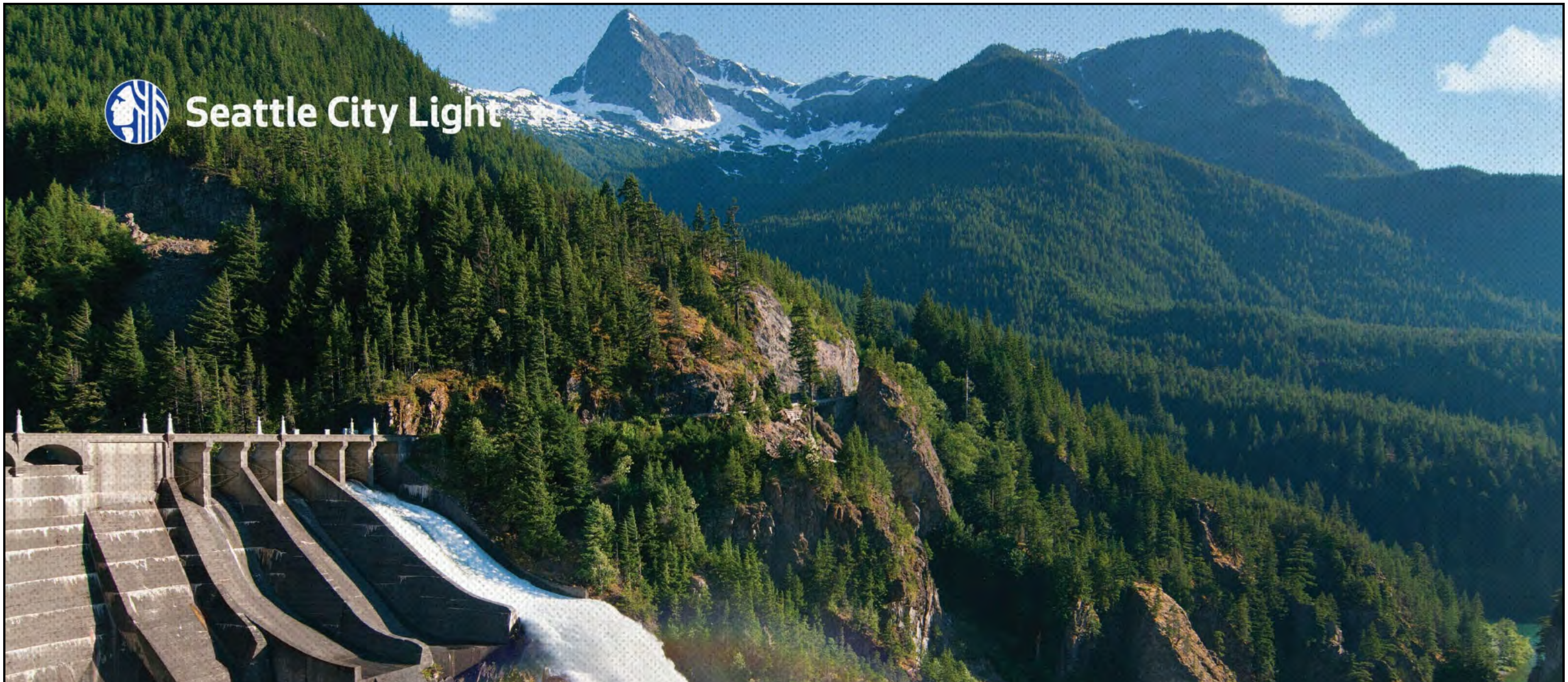
DISCUSSION



LEVEL LOGGER DATA

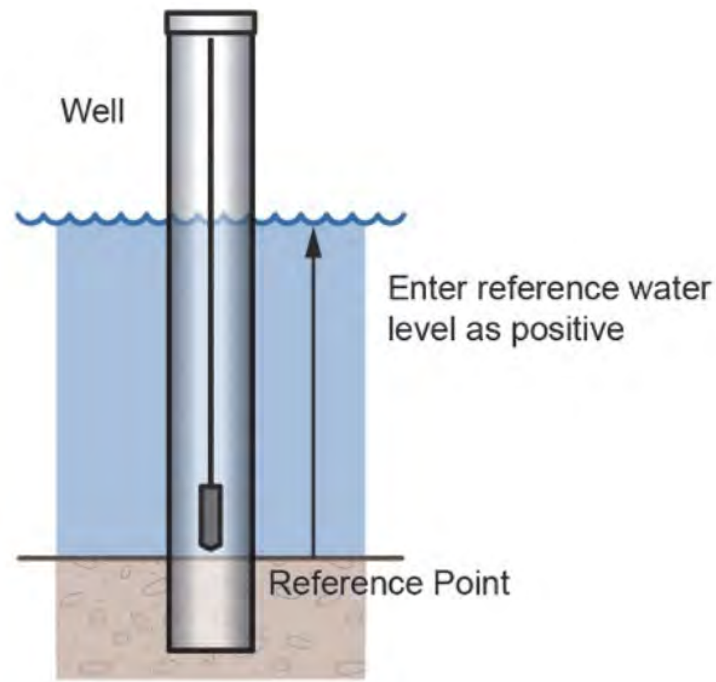
August 26, 2021

OVERVIEW

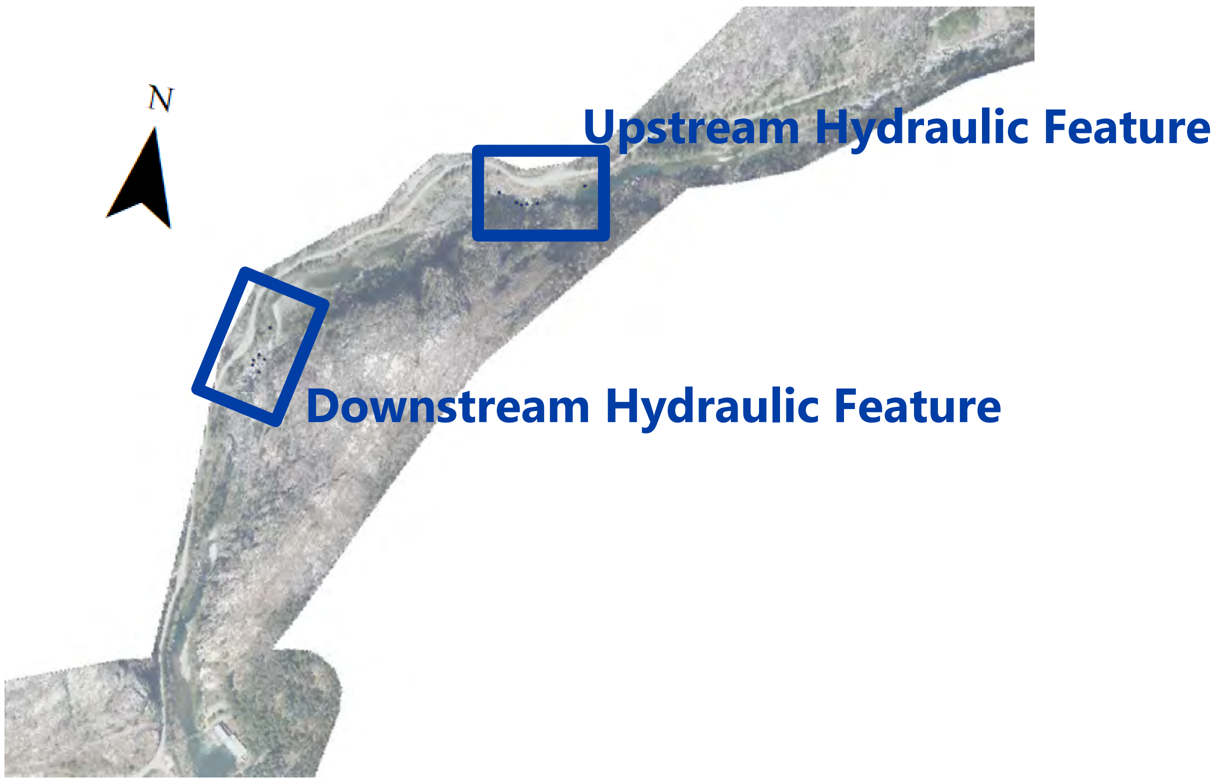
- Instrumentation
  - Onset HOBO Level Loggers
  - Installation
  - WSEL datum corrections
- Data Collected
  - Controlled spill events (26 July – 29 July)
  - Unplanned spill event (28 June – 2 July)

INSTRUMENTATION

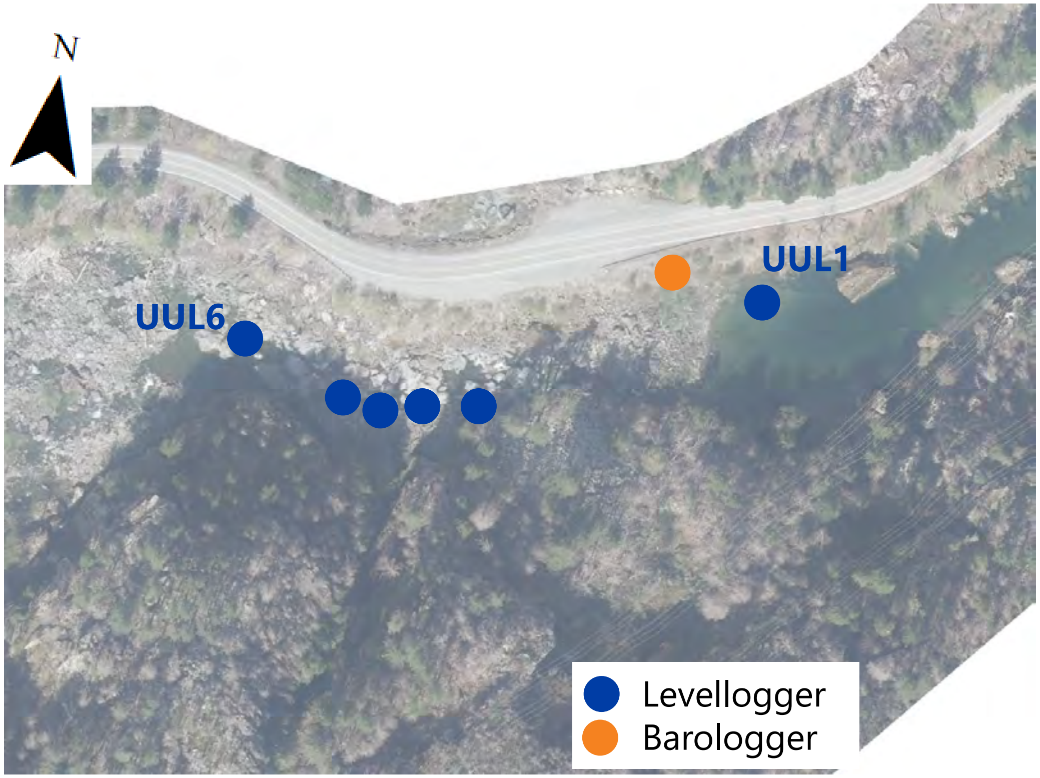
- Onset HOBO Level Logger
  - o Measures pressure
  - o Computes depth
  - o Barometric correction



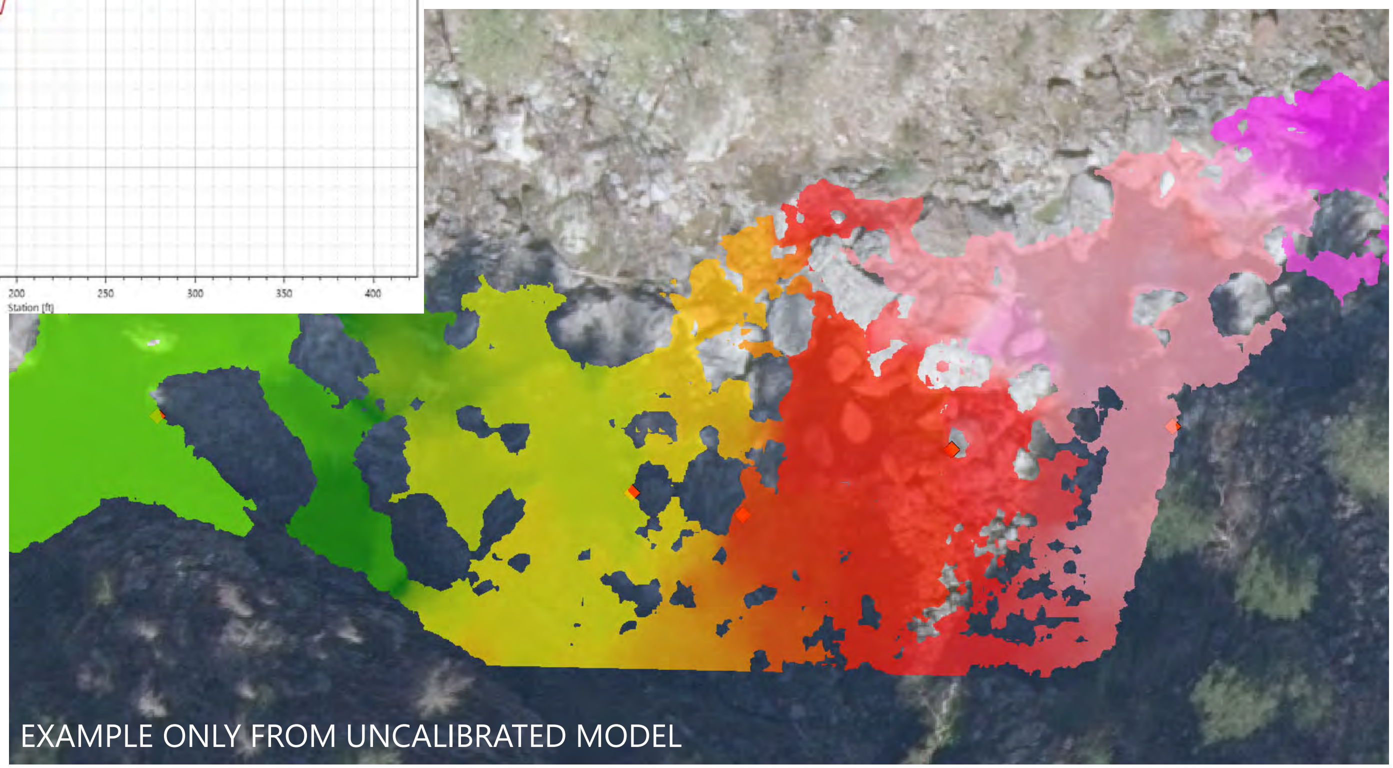
INSTALLATION



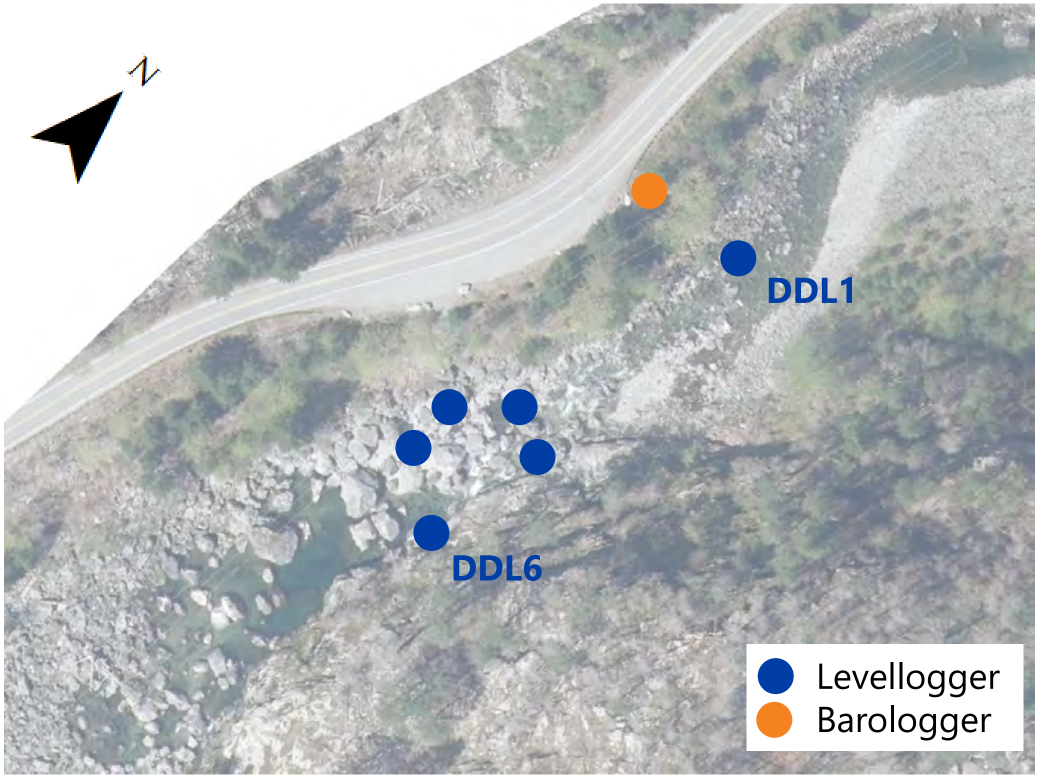
INSTALLATION – UPSTREAM FEATURE



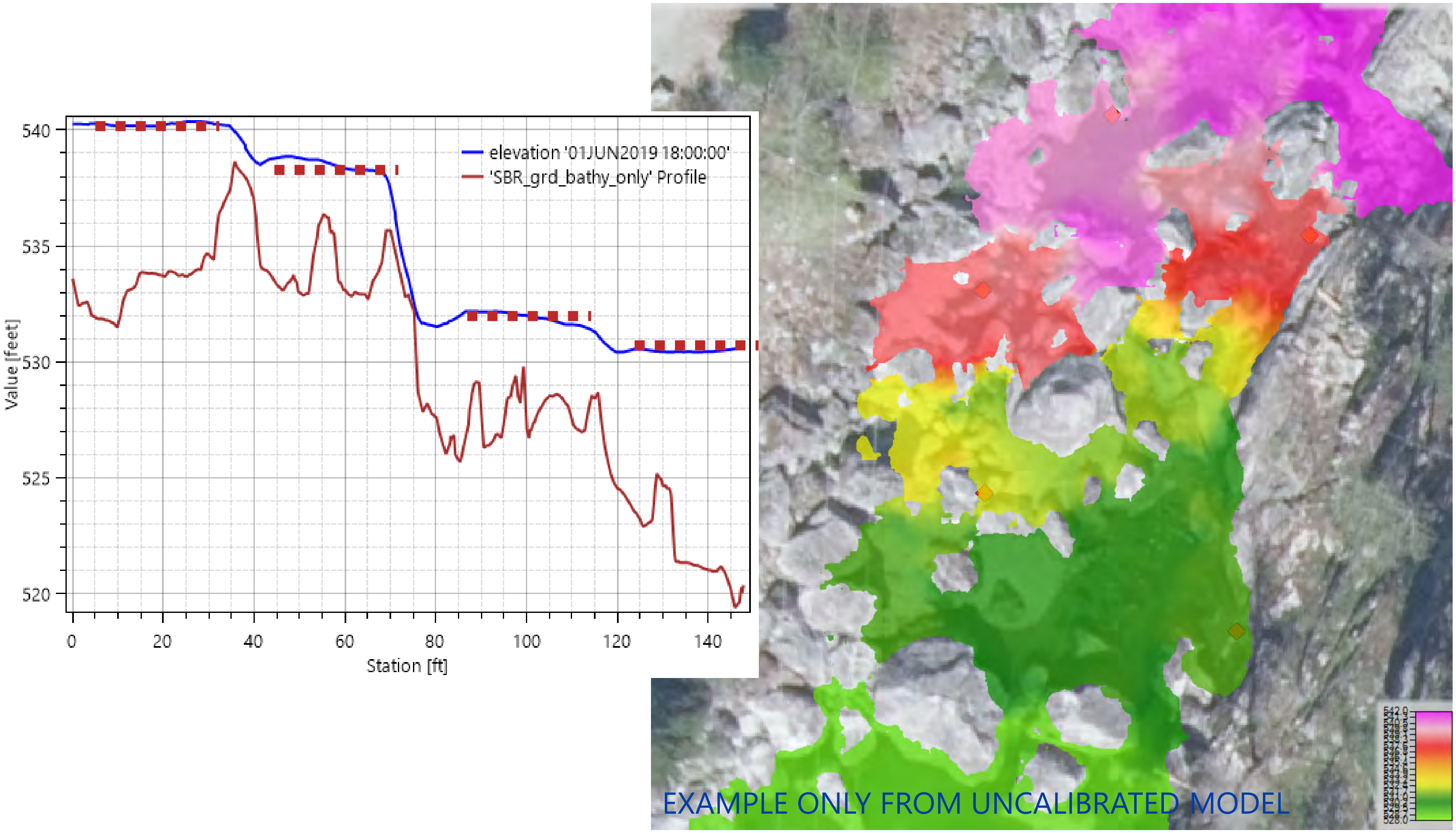
UPSTREAM FEATURE



INSTALLATION – DOWNSTREAM FEATURE



DOWNSTREAM FEATURE



INSTALLATION

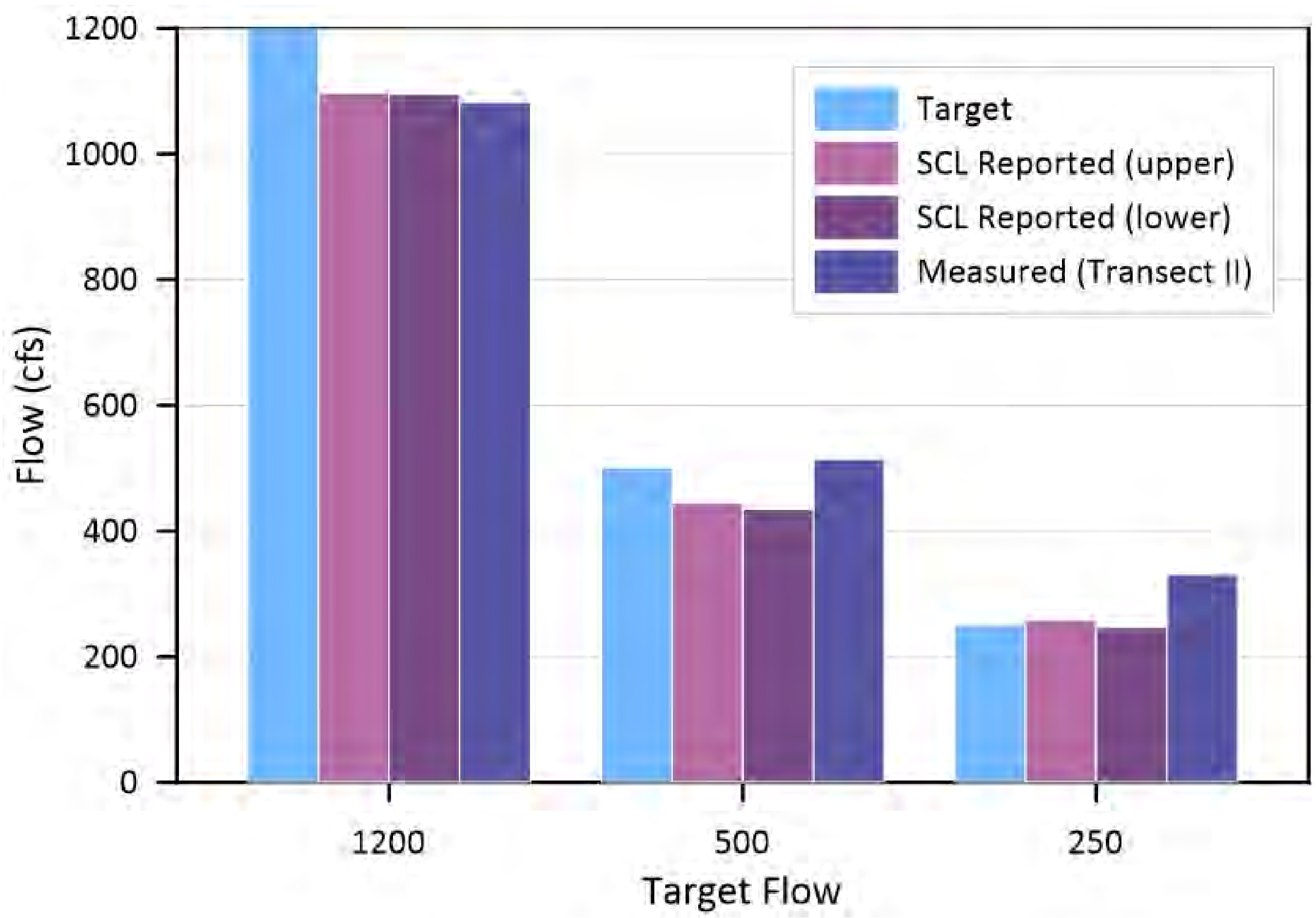
WSEL DATUM CORRECTIONS

- Total station survey to reference bolt gives bolt elevation to NAVD88.
- Measure down from bolt to water surface gives water surface elevation to NAVD88.
- Subtract HOBO water depth to give HOBO “zero” to NAVD88.

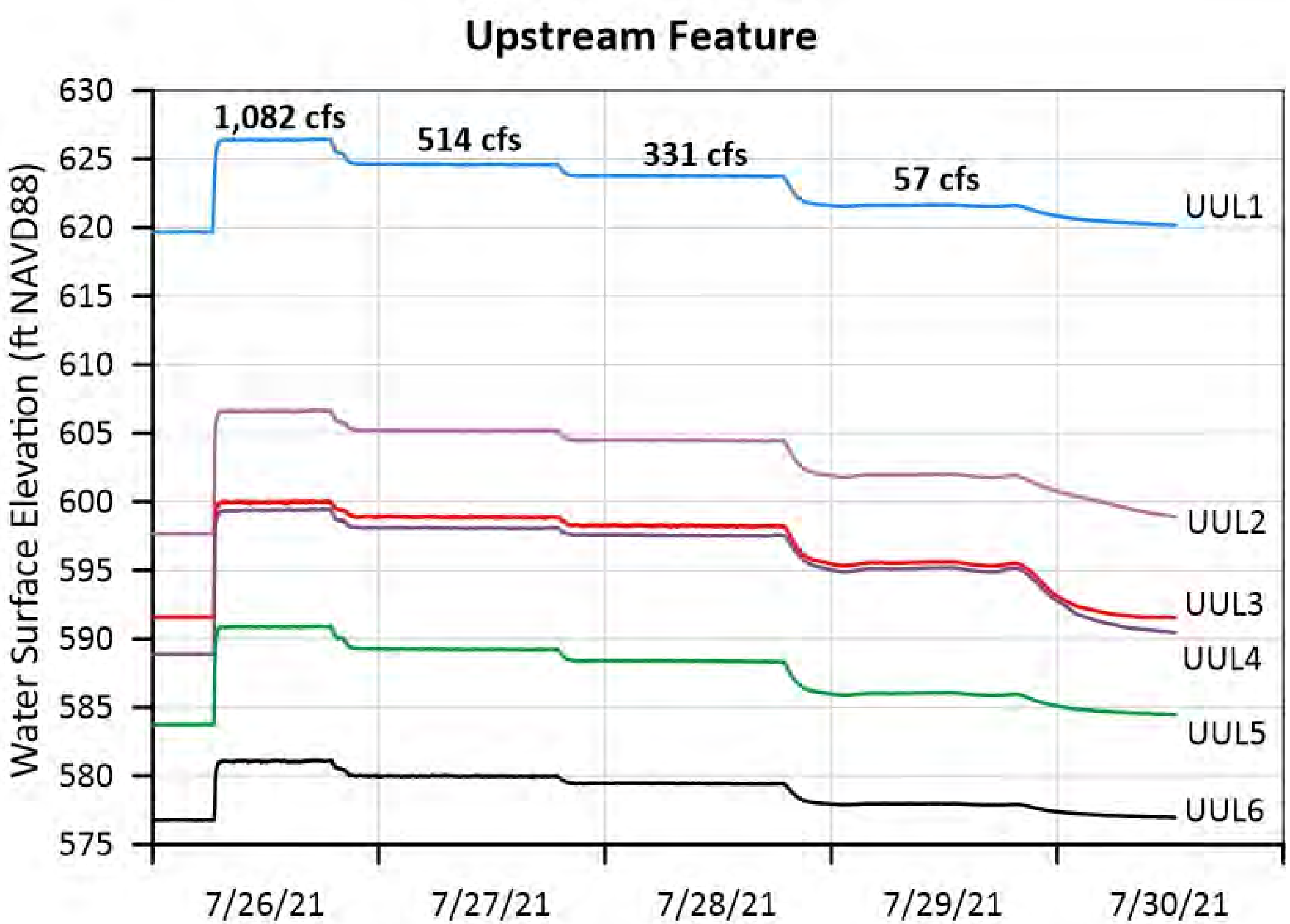
DATA COLLECTION

- Initial deployment 28 May 2021
- Measurement interval:
  - 10-minute 28 May – 25 July
  - 5-minute since 25 July
- Monthly downloads (~ 45-day logger data capacity)

CONTROLLED RELEASE – DATA COMPARISON



CONTROLLED SPILL DATA – UPSTREAM FEATURE



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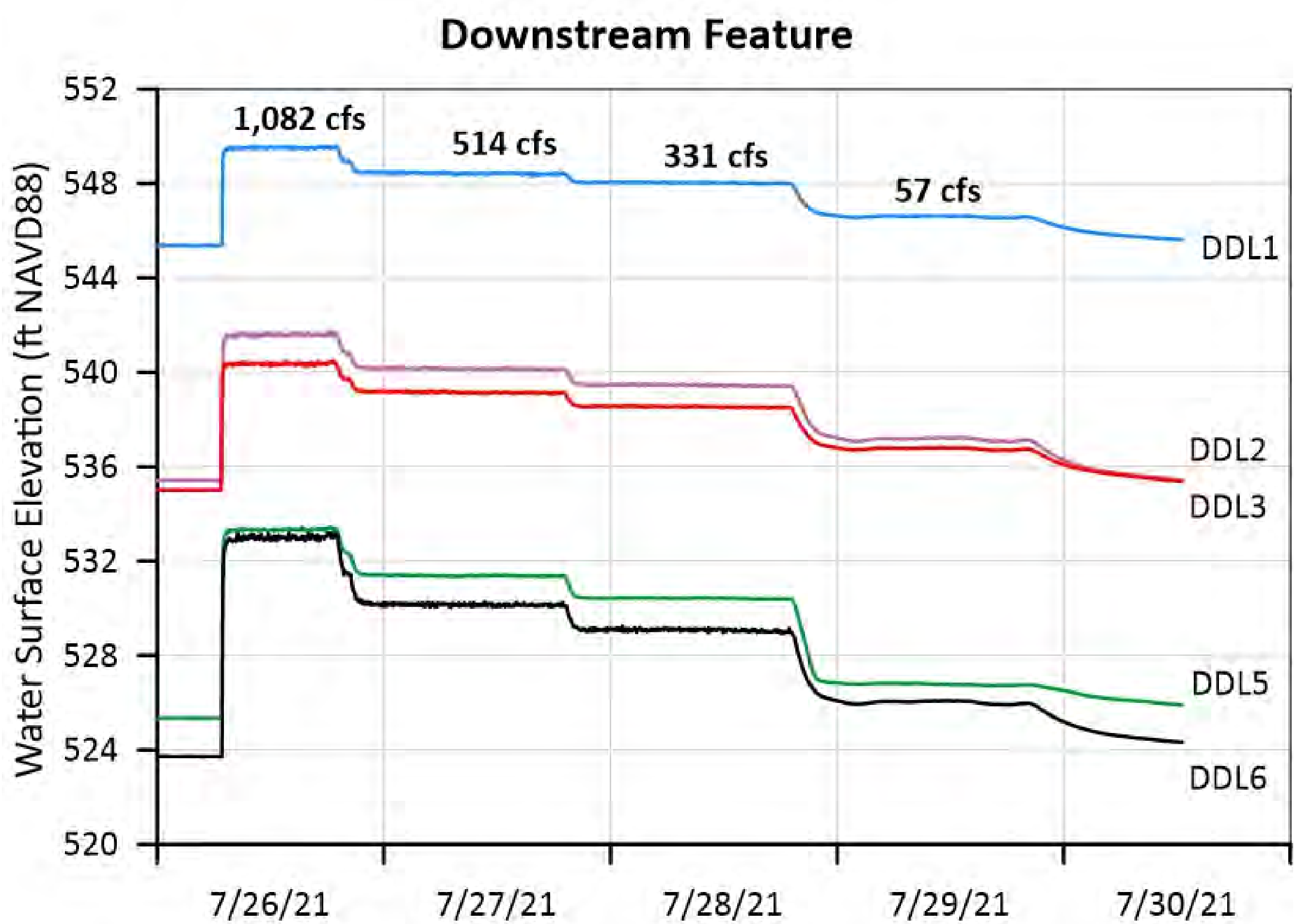
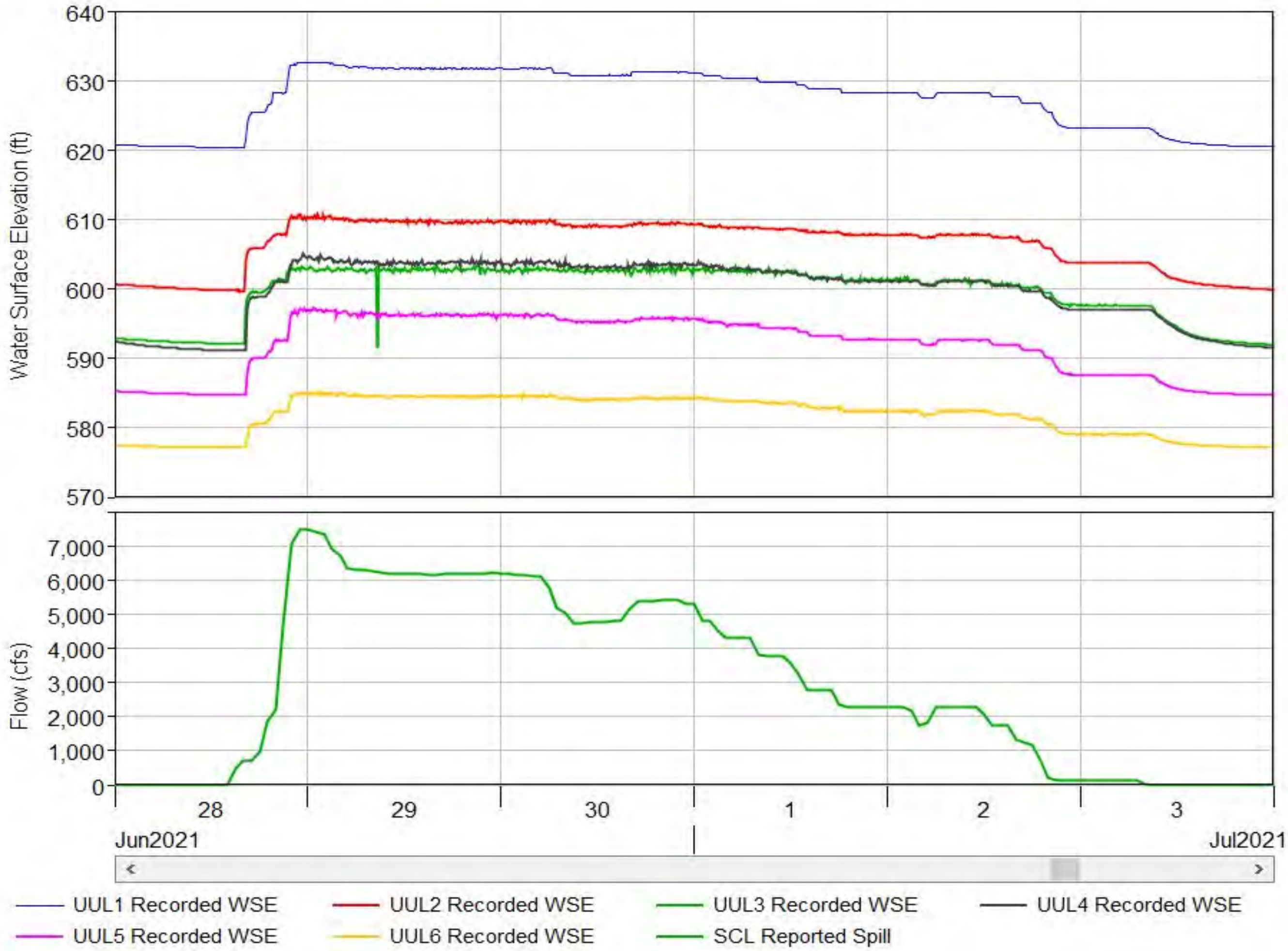
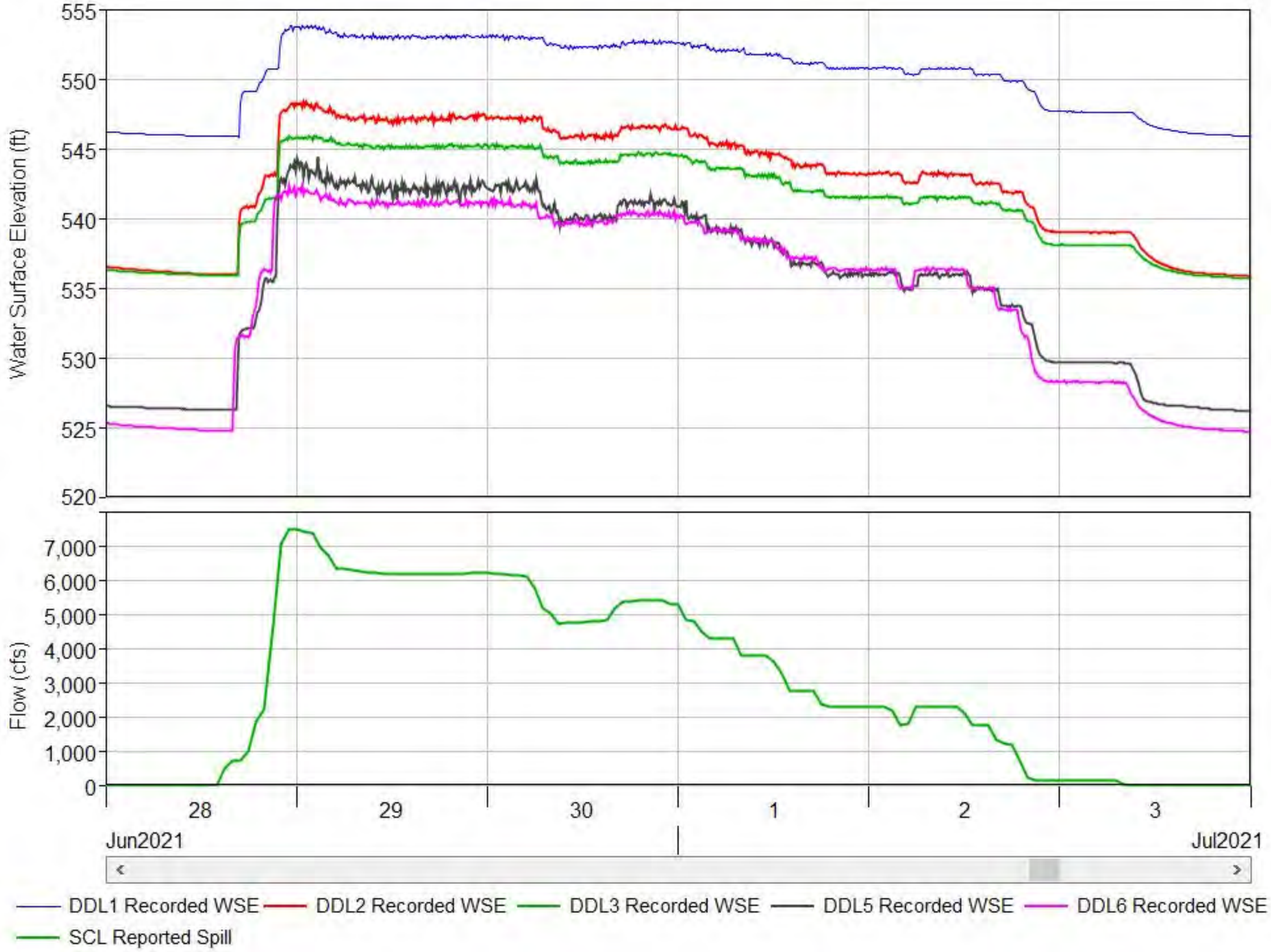


JUNE/JULY SPILL DATA – UPSTREAM FEATURE



JUNE/JULY SPILL DATA – DOWNSTREAM FEATURE



JUNE/JULY SPILL DATA – DATA CHECK

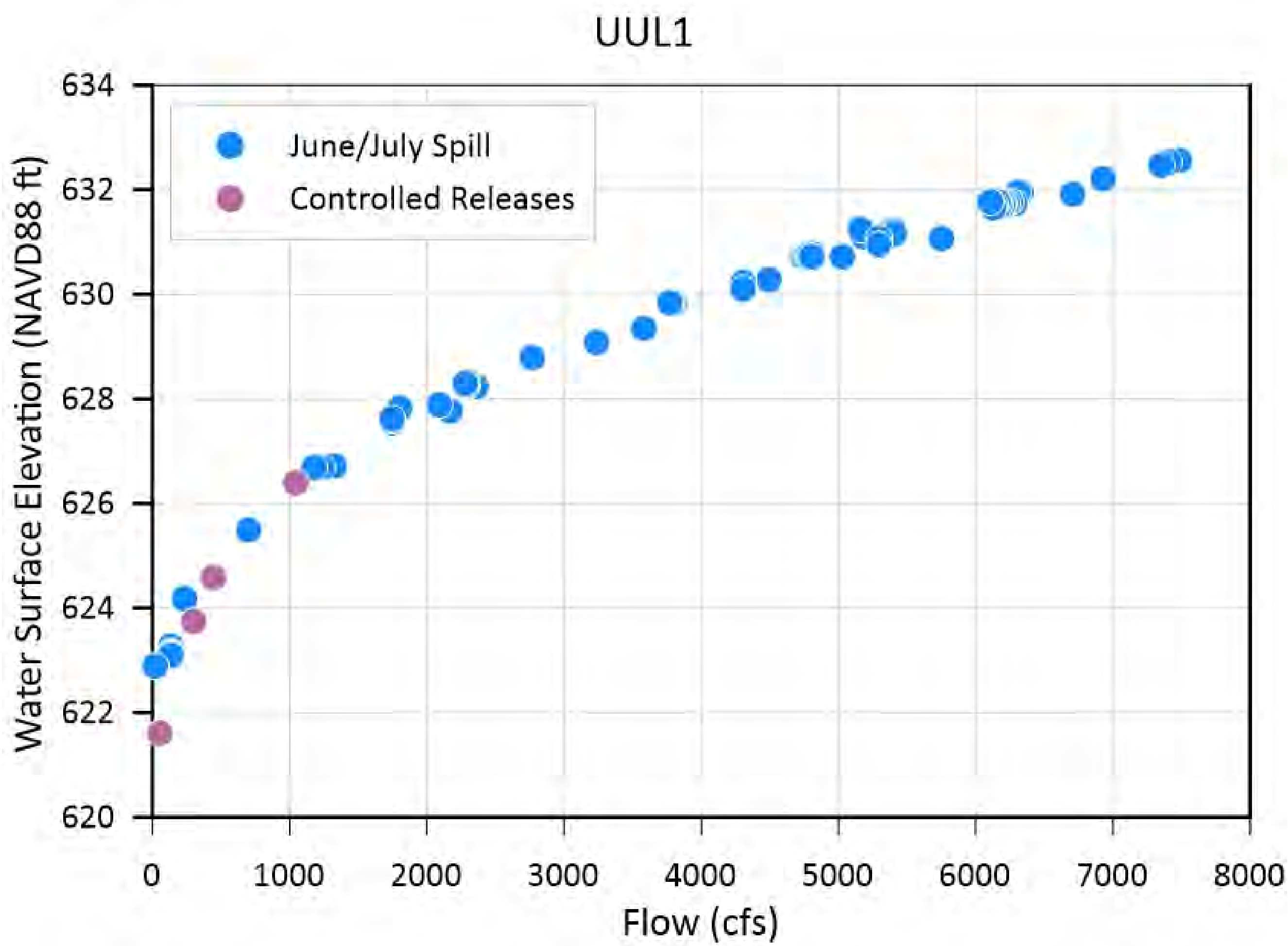
DOWNSTREAM FEATURE – 4,700 CFS

DOWNSTREAM FEATURE – 300 CFS

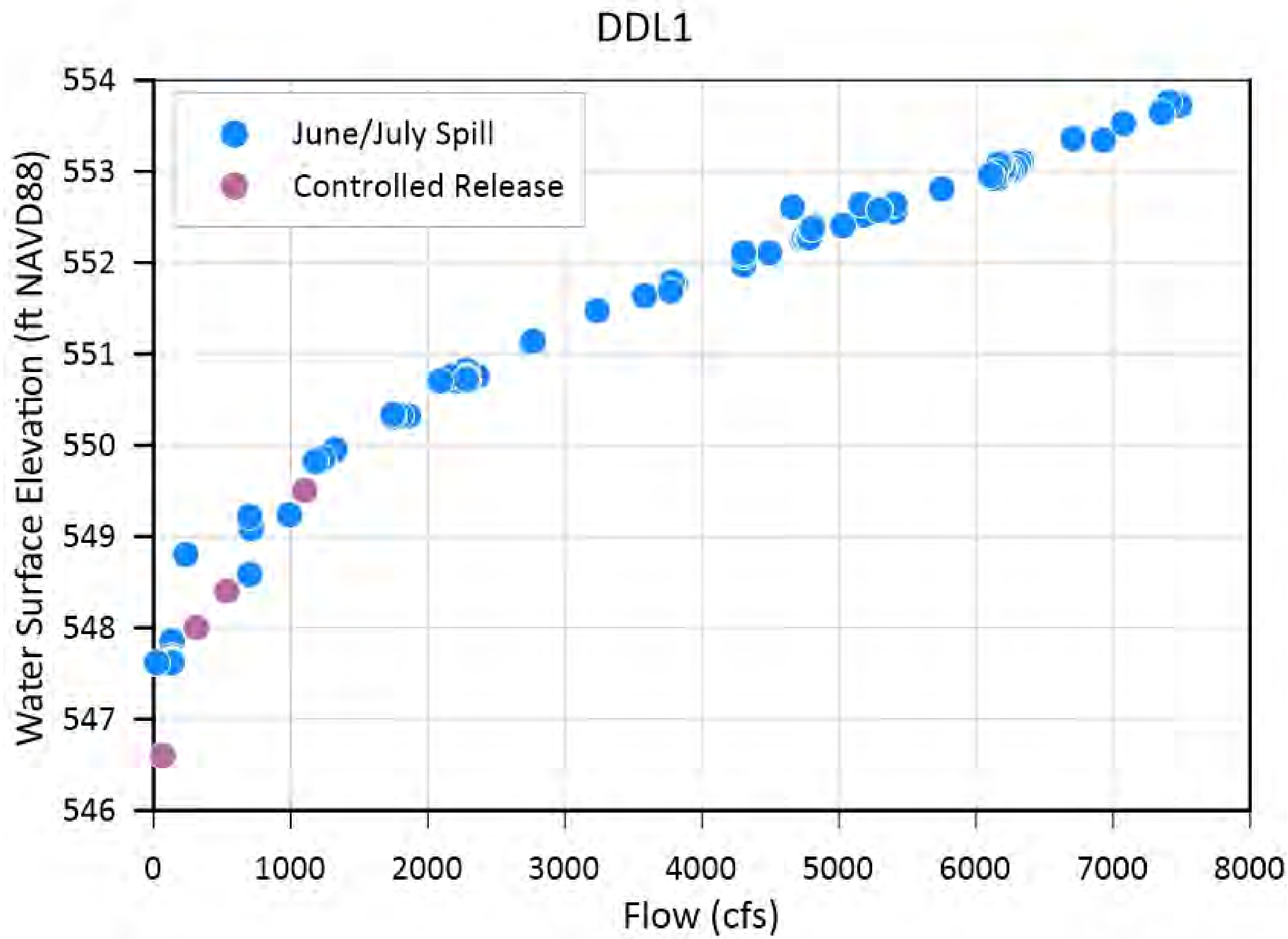
UPSTREAM FEATURE – 4,700 CFS

UPSTREAM FEATURE – NO SPILL

LOGGER RATING – UUL1

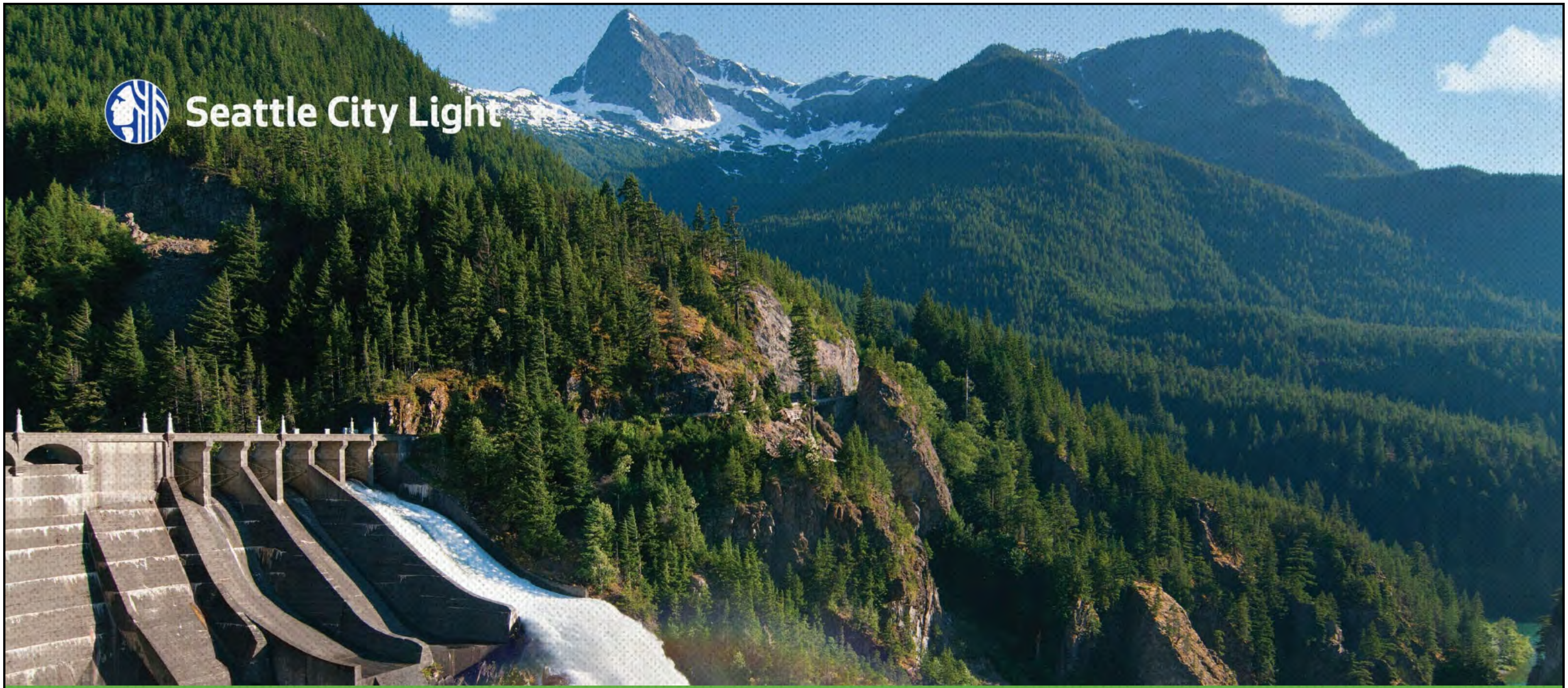


LOGGER RATING – DDL1



Seattle City Light

DISCUSSION

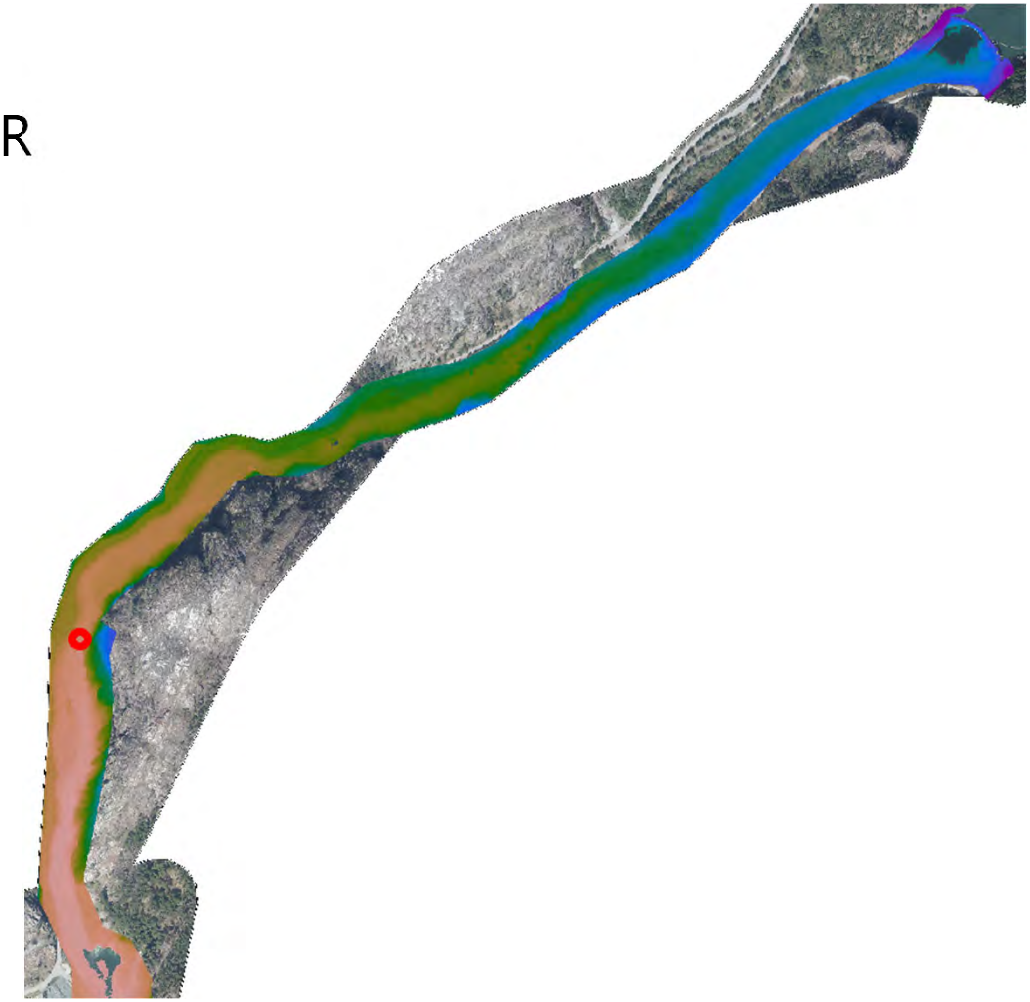


HYDRAULIC MODEL TERRAIN

August 26, 2021

OVERVIEW

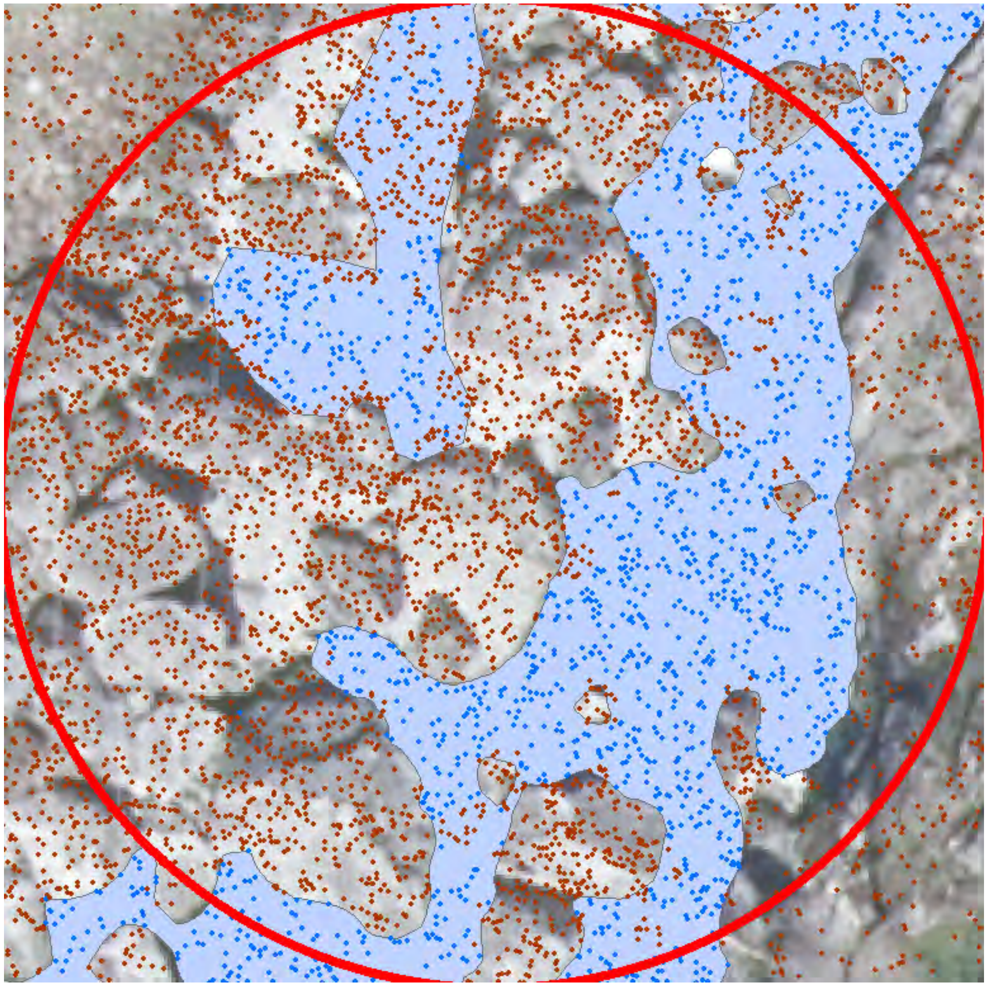
- Quantum Spatial 2018
  - Water Penetrating LiDAR
- 3 voids
  - Gorge Dam plunge pool
  - Gorge Powerhouse tailrace
  - 20’x50’x25+’ deep hole
- 0.52 points/ft^2 density
- NVA = 0.201’
- Bathy VA = 0.366’
- Original Resolution = 3ft



SAMPLE LIDAR DENSITY

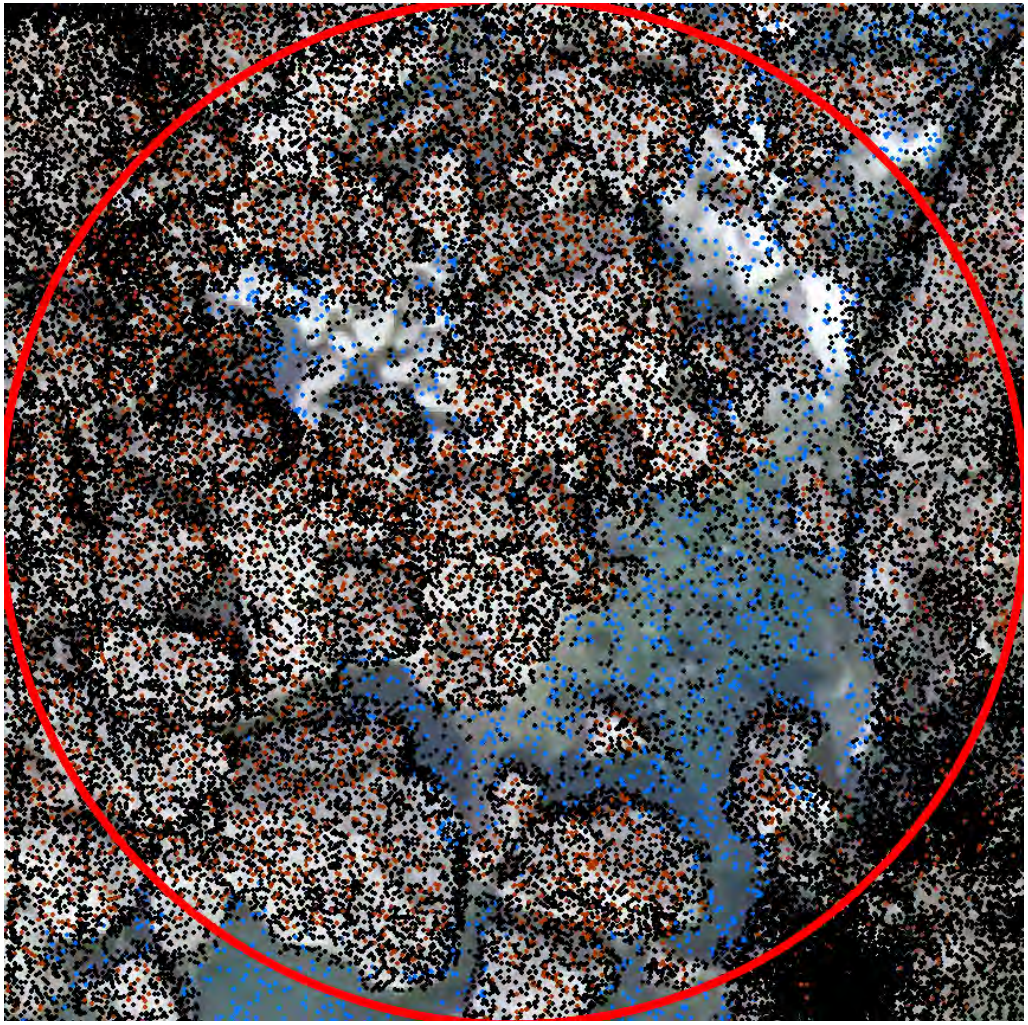
LIDAR DENSITY

- Avg density
  - o 6 pulses/m^2
- Pulse spacing
  - o 0.41 m
- 2 X pulse spacing
  - o 2.7 feet



- Ground
- Bathymetry

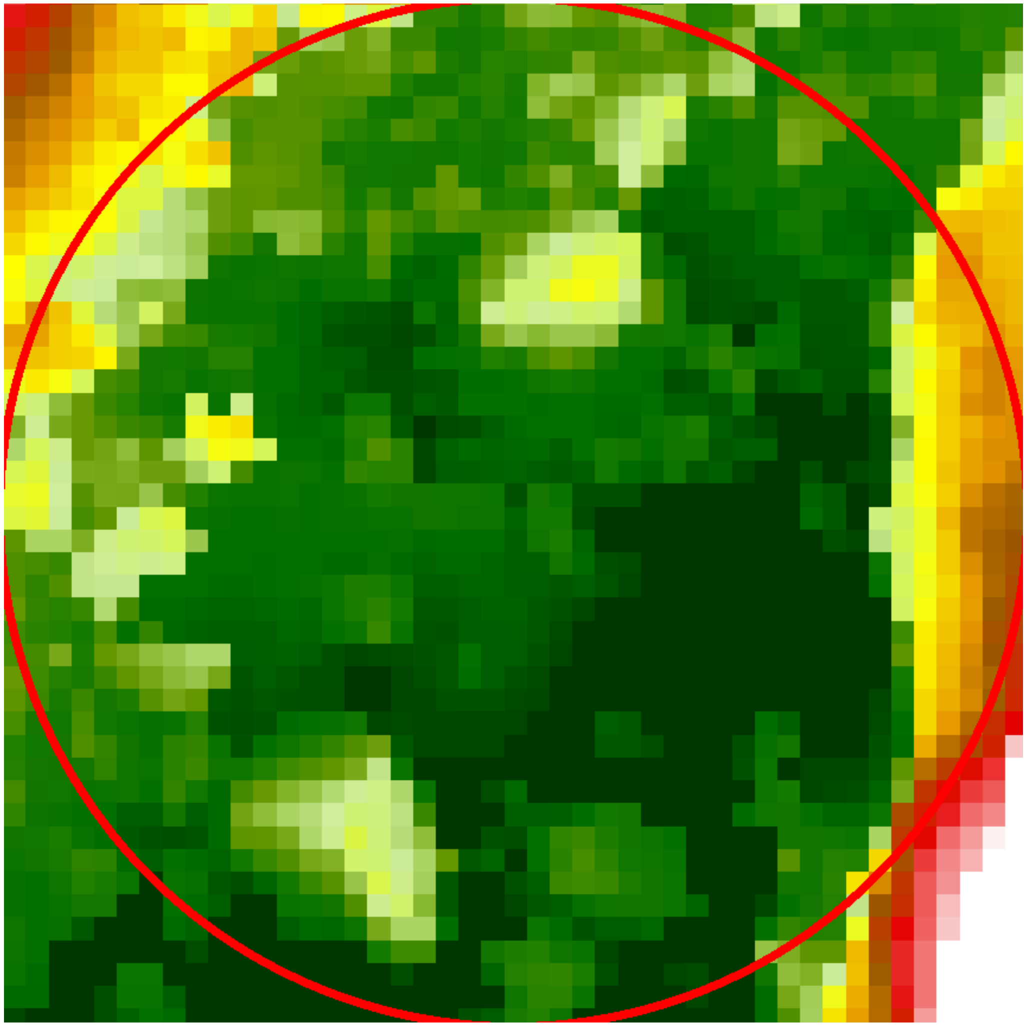
LIDAR DENSITY



- Unassigned
- Ground
- Bathymetry

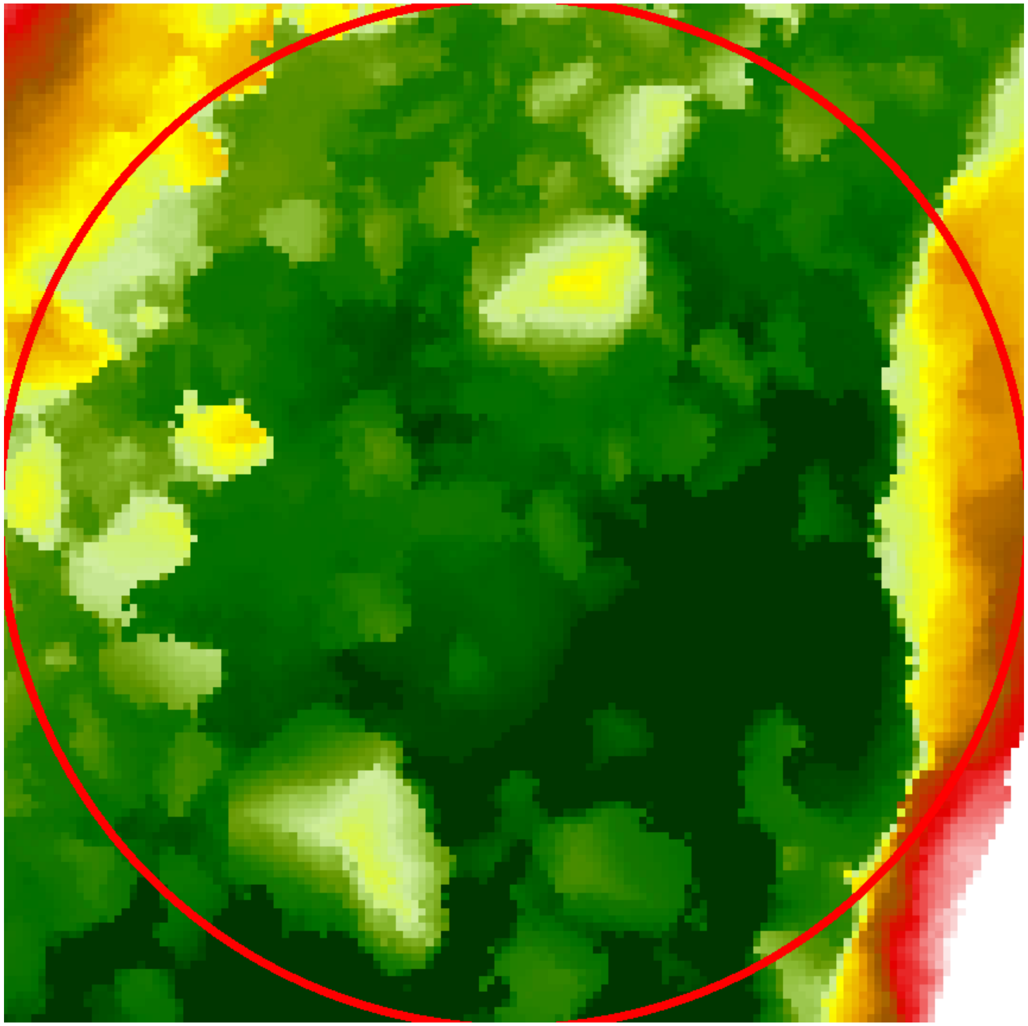
ORIGINAL RESOLUTION

- 3′ raster



TARGET RESOLUTION

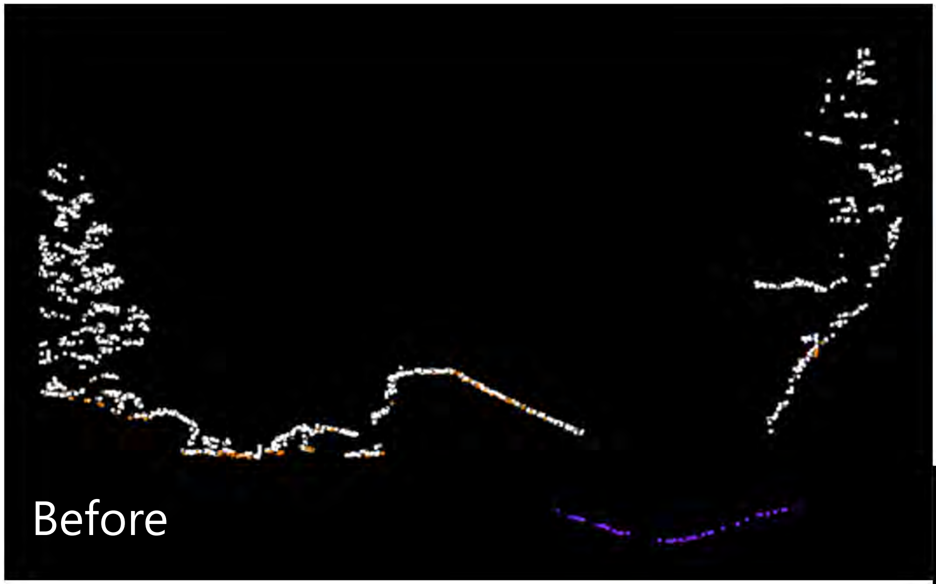
- 1′ raster



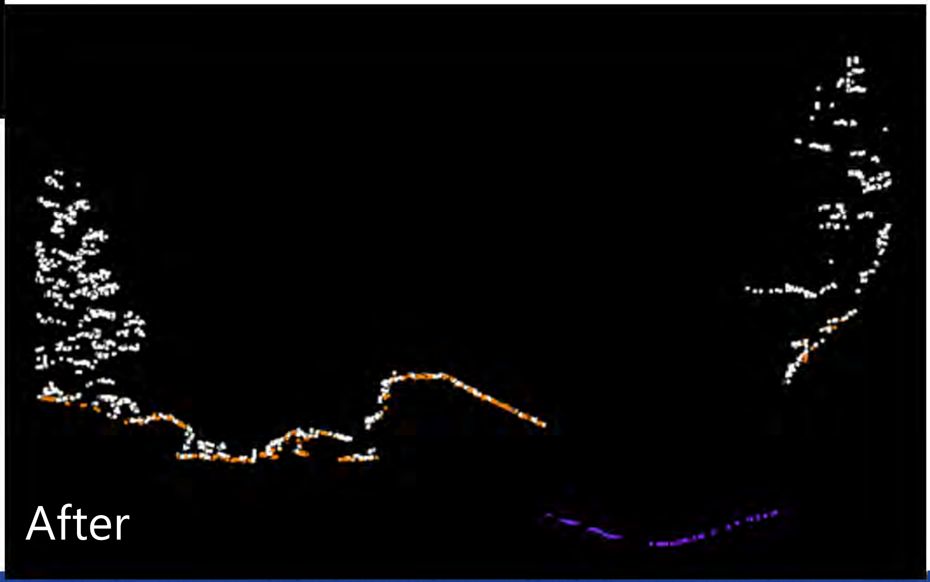
TERRAIN REFINEMENT

- Focus areas
  - Hydraulic features
  - Dry Channel

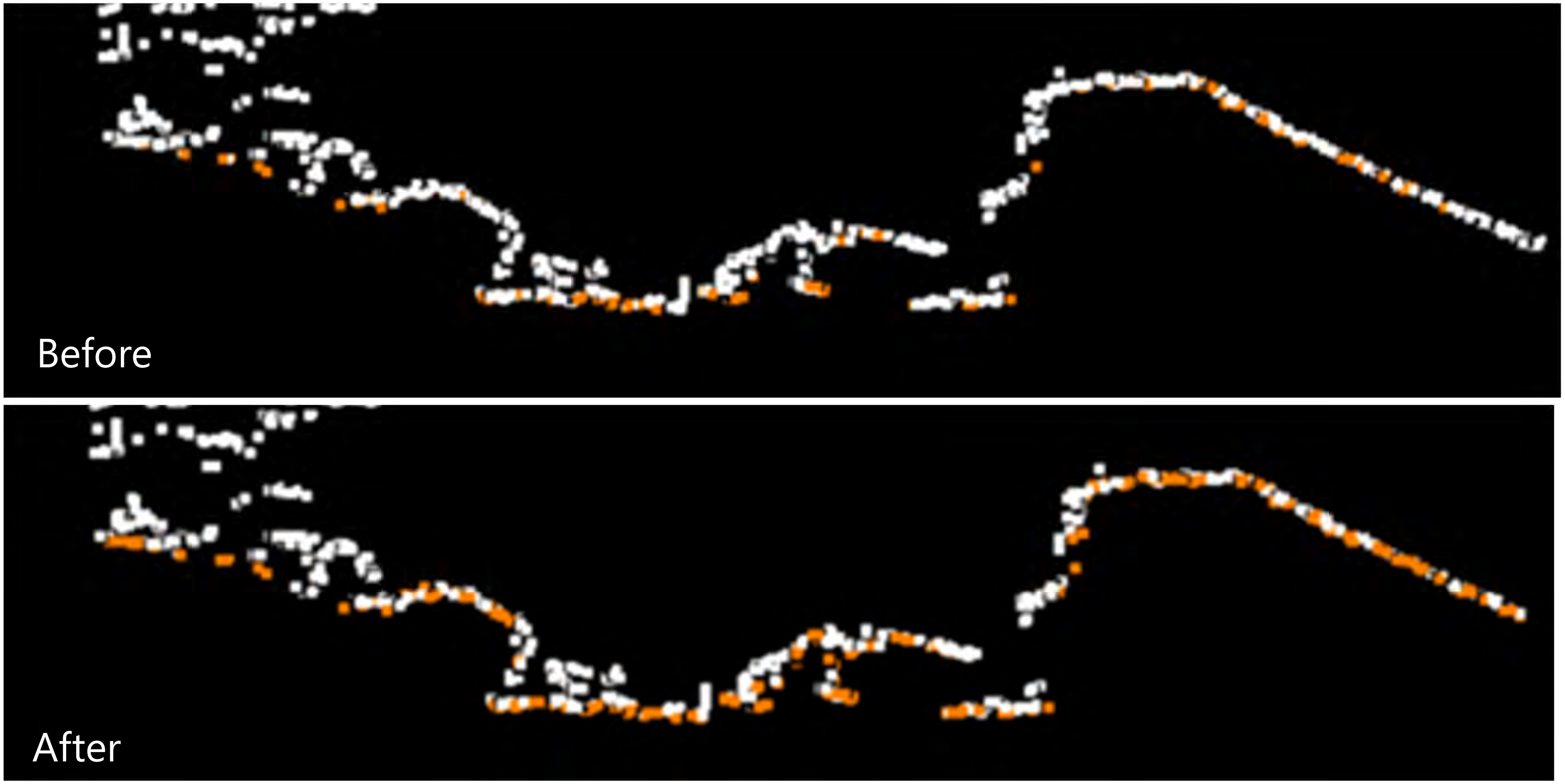
POINT RECLASSIFICATION



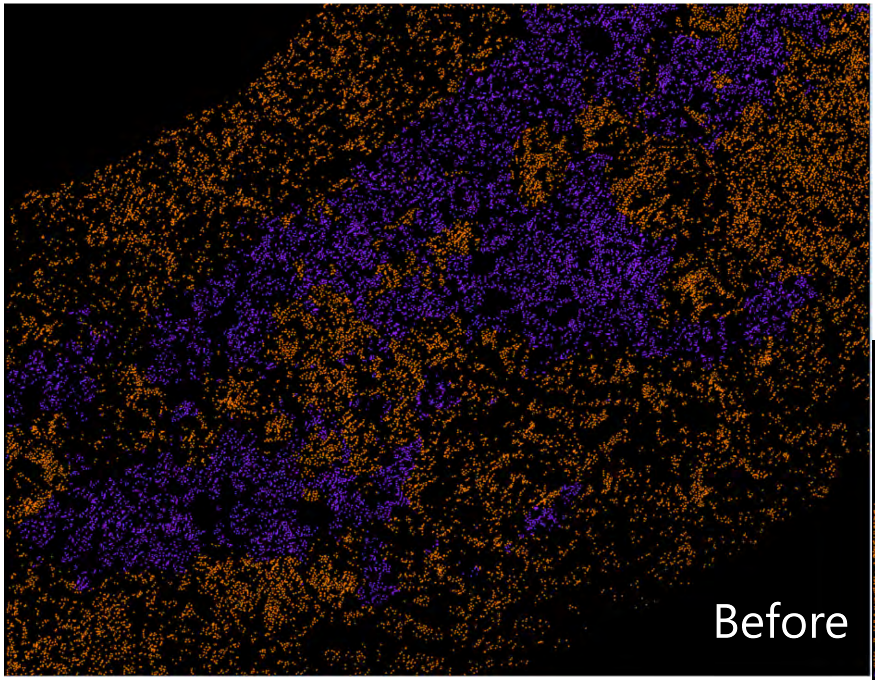
- White = Default
- Orange = Ground
- Purple = Bathymetric Bottom



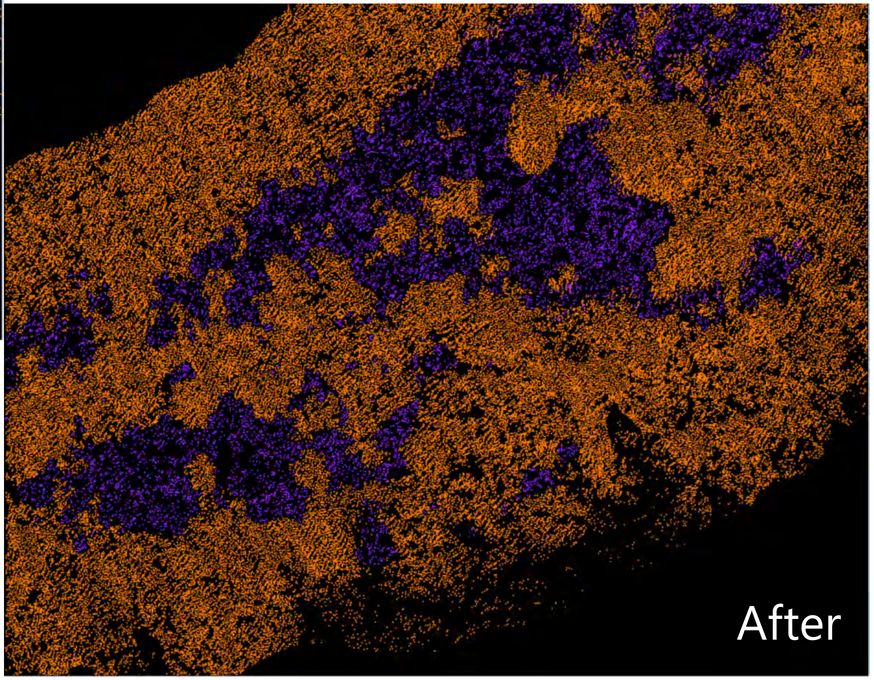
POINT RECLASSIFICATION



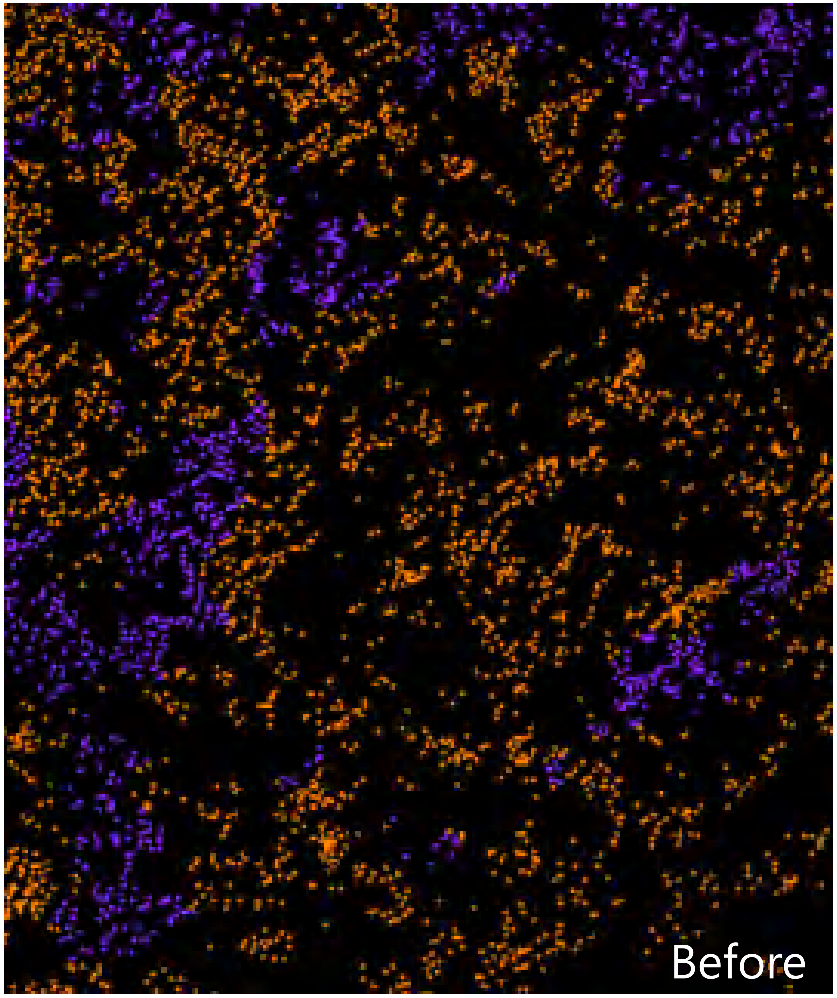
POINT RECLASSIFICATION

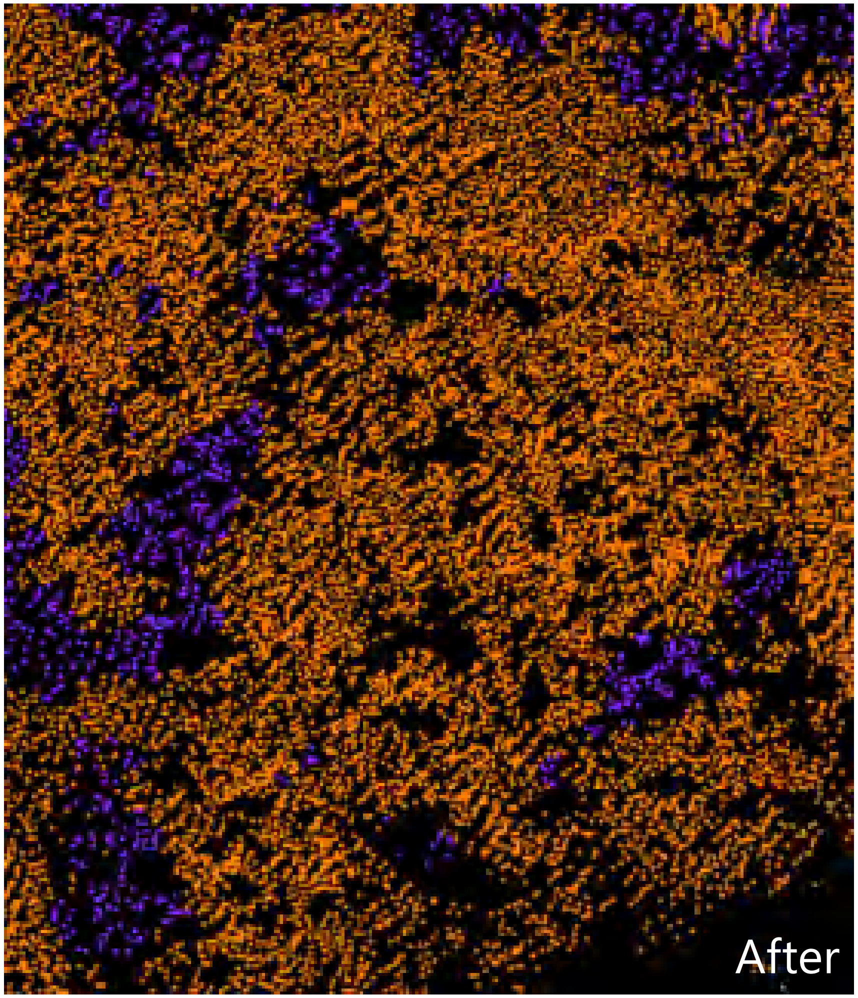


- Orange = Ground
- Purple = Bathymetric Bottom



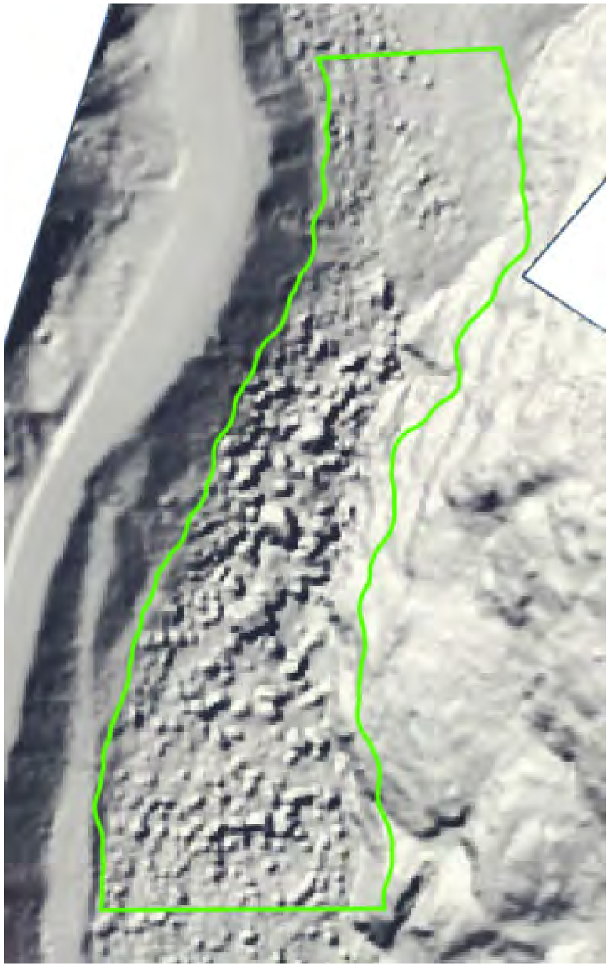
POINT RECLASSIFICATION



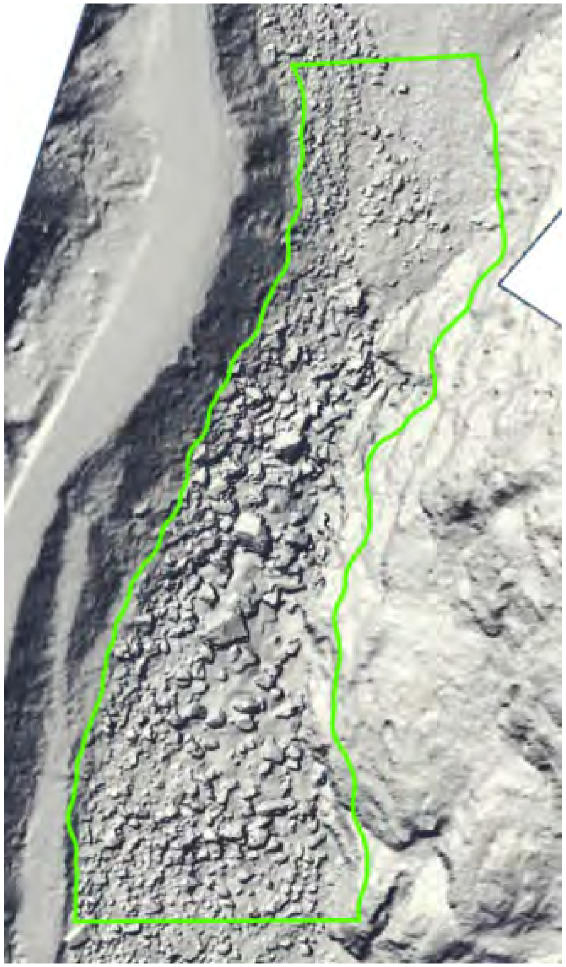


FOCUS AREA 1 – 1′ GRID

Before (3ft Cell Resolution)

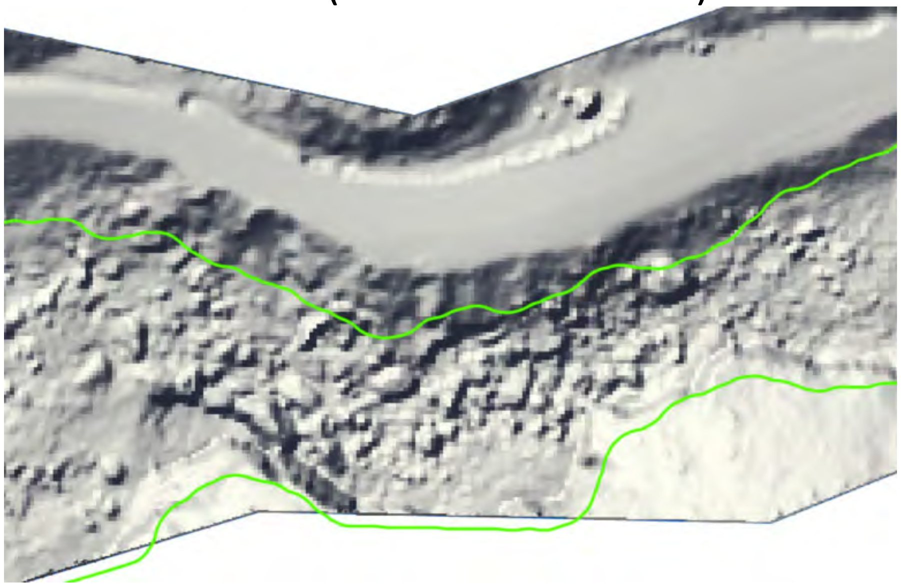


After (1ft Cell Resolution)

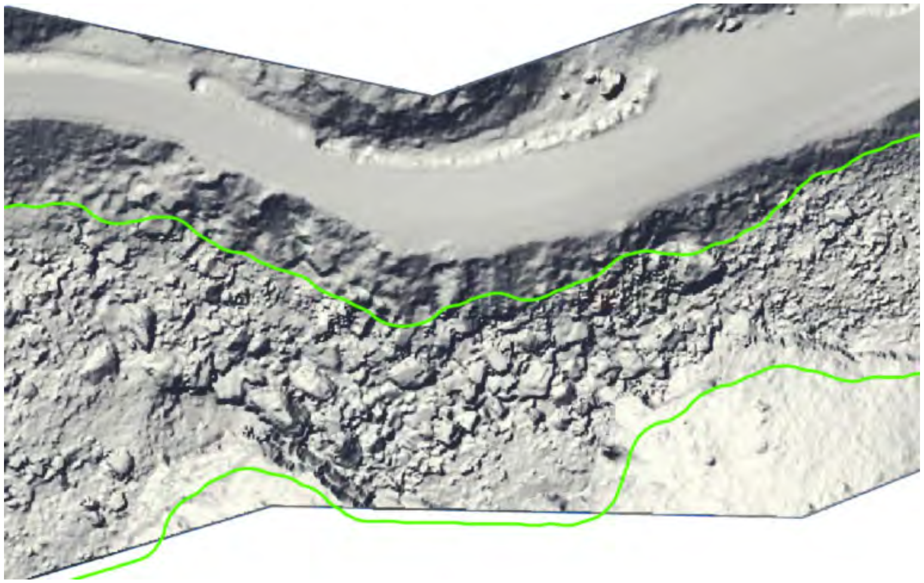


FOCUS AREA 2 – 1′ GRID

Before (3ft Cell Resolution)

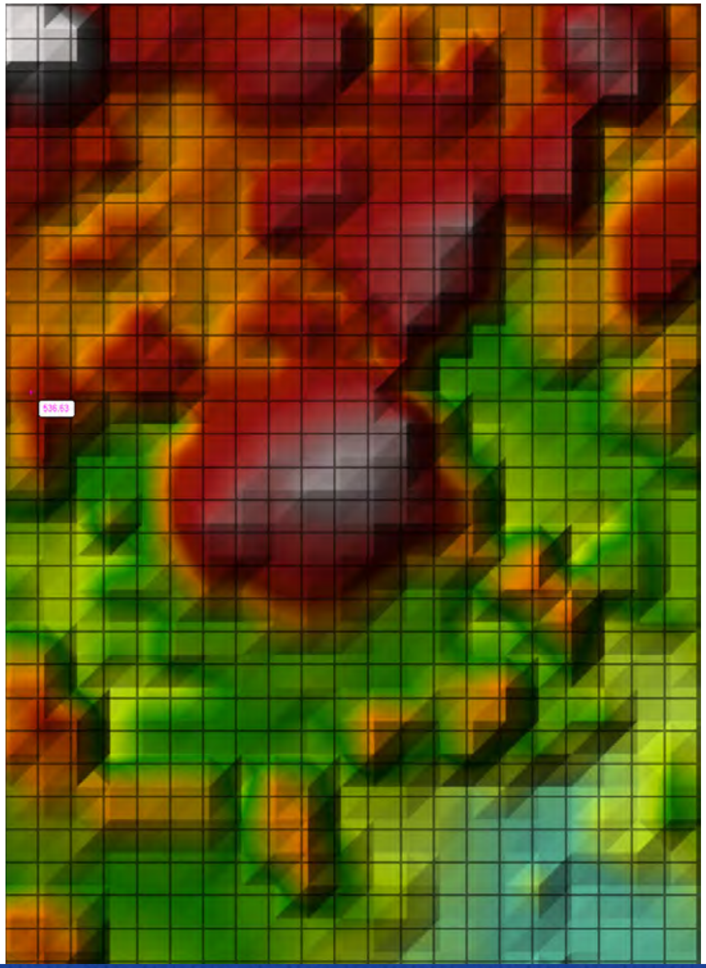


After (1ft Cell Resolution)

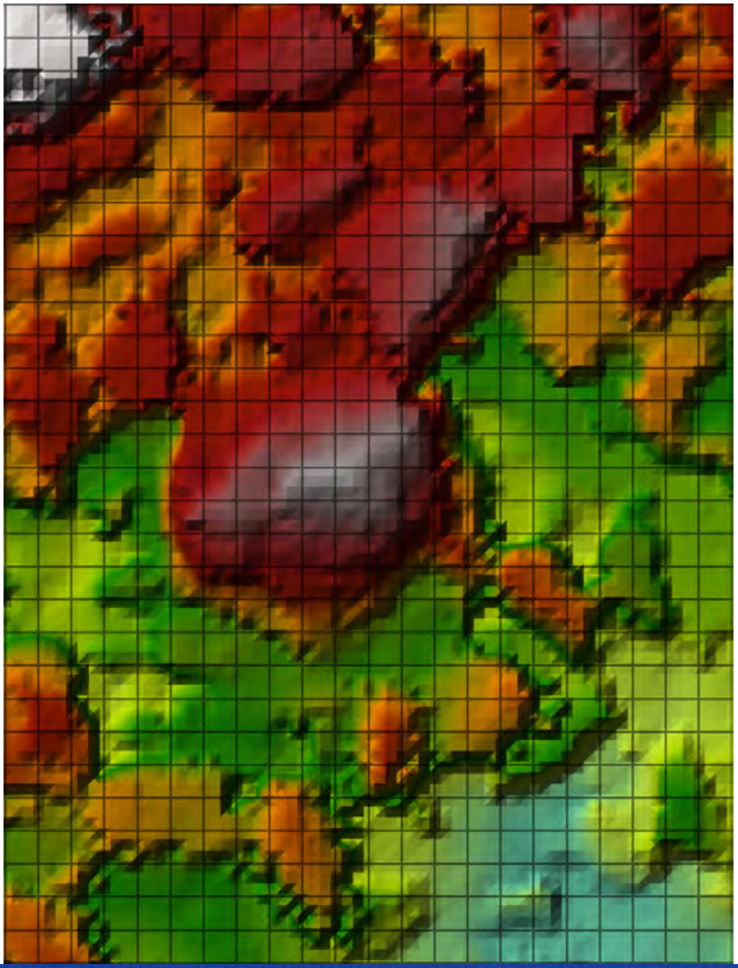


MODEL IMPLEMENTATION

3ft Resolution

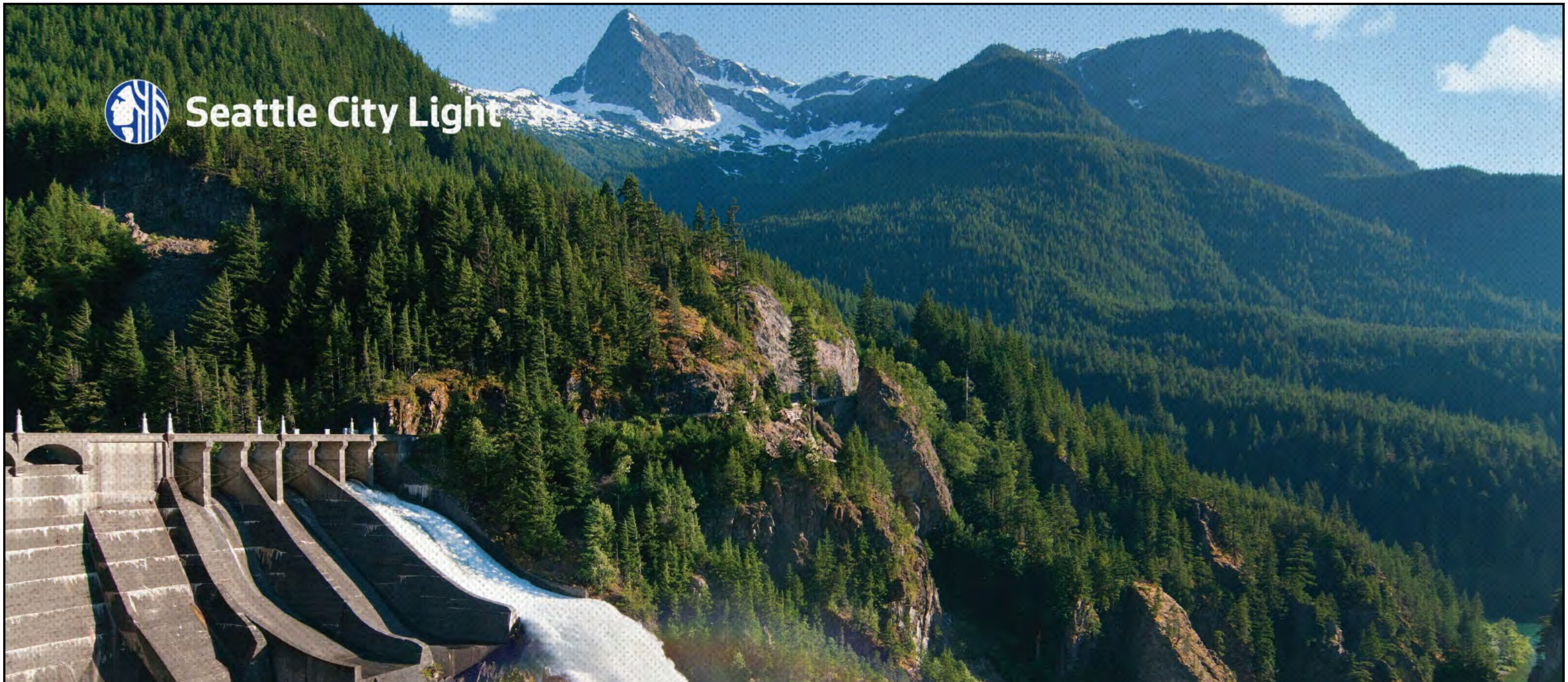


1ft Resolution



Seattle City Light

DISCUSSION



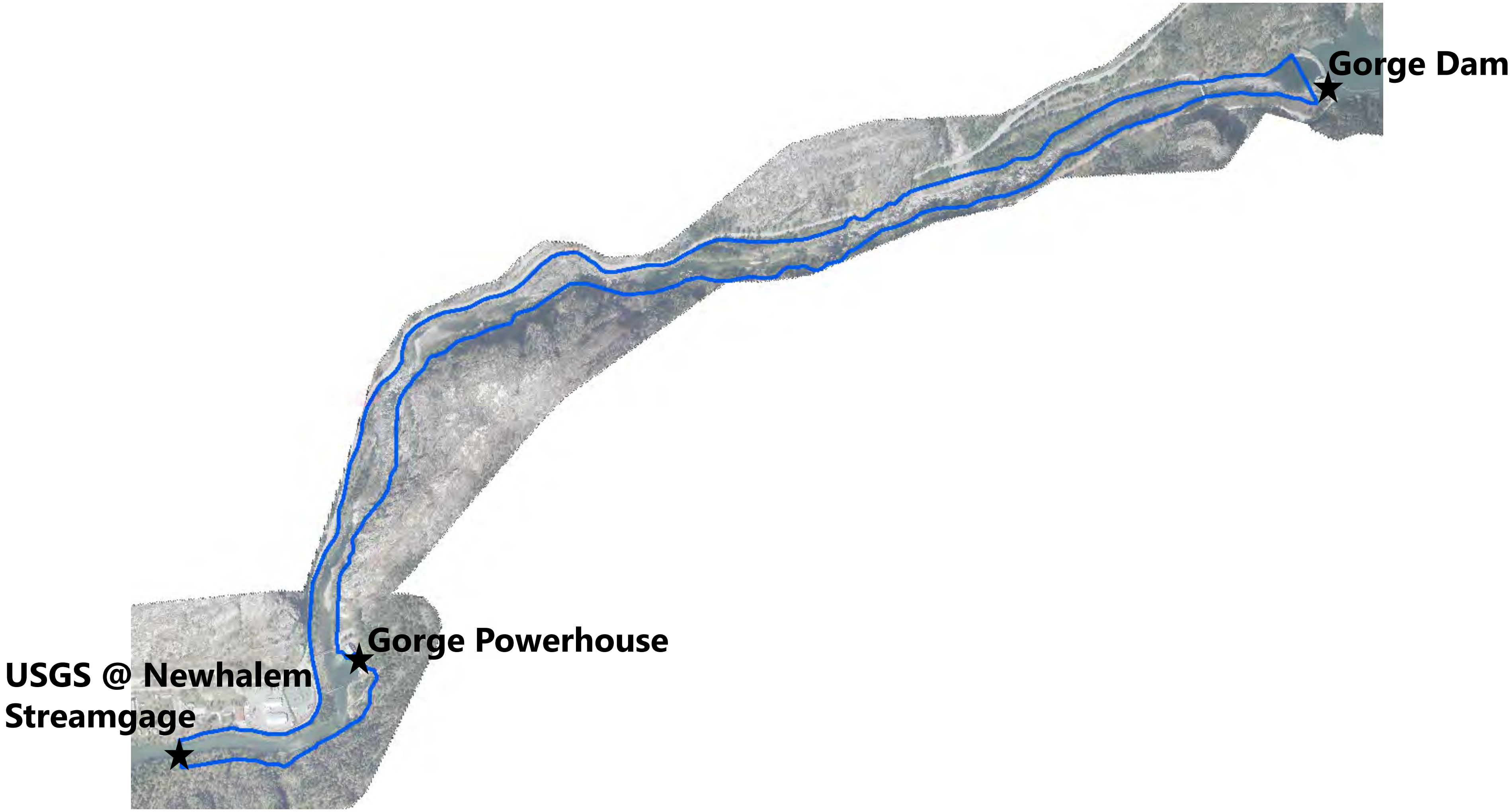
HYDRAULIC MODEL DEVELOPMENT APPROACH

August 26, 2021

OVERVIEW

- Mesh
  - Model Extent
  - Cell size
- Roughness Categories
- Turbulence
- Calibration and Validation
- 2D Model Context

MODEL EXTENT

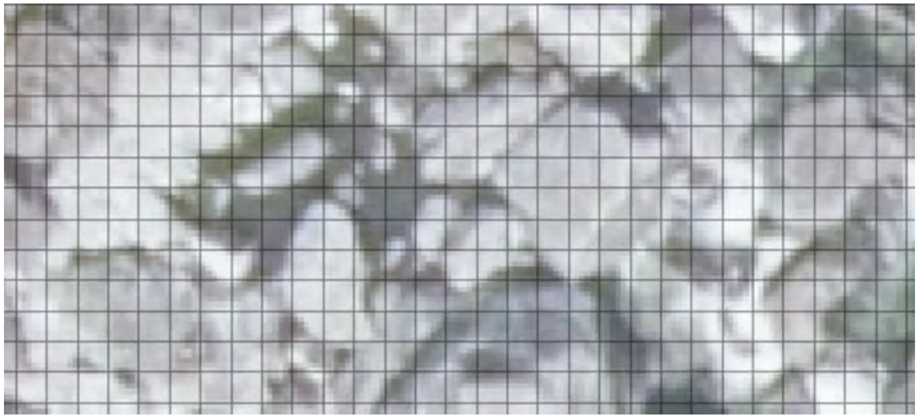


CELL SIZE – MODEL PRECISION/ACCURACY

1′ Cells

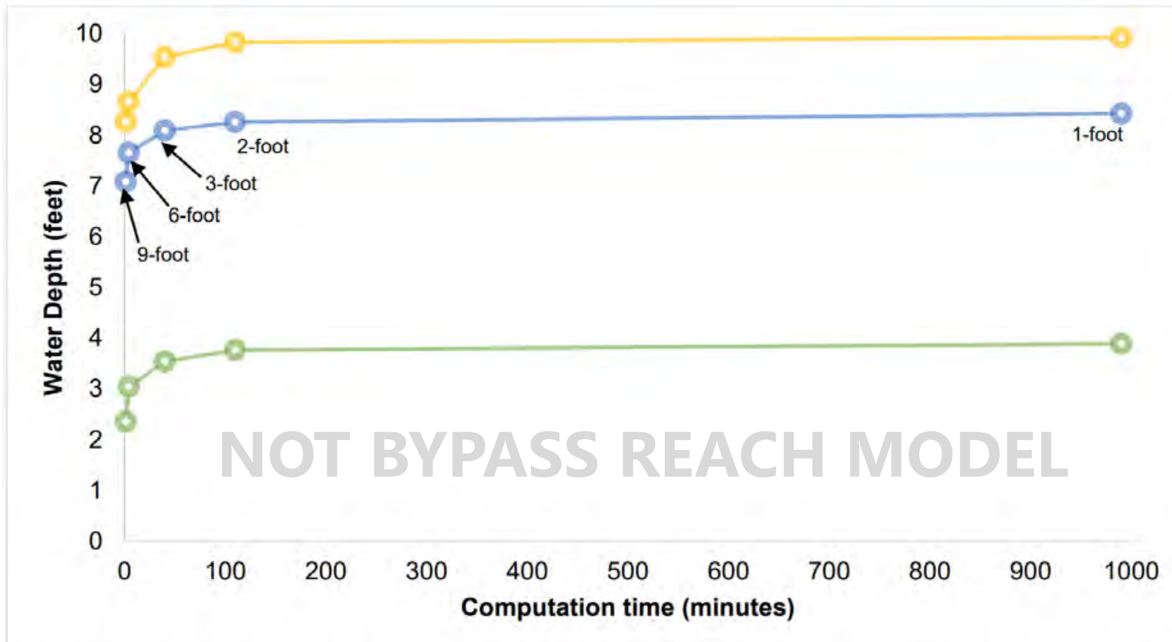
2′ Cells

3′ Cells



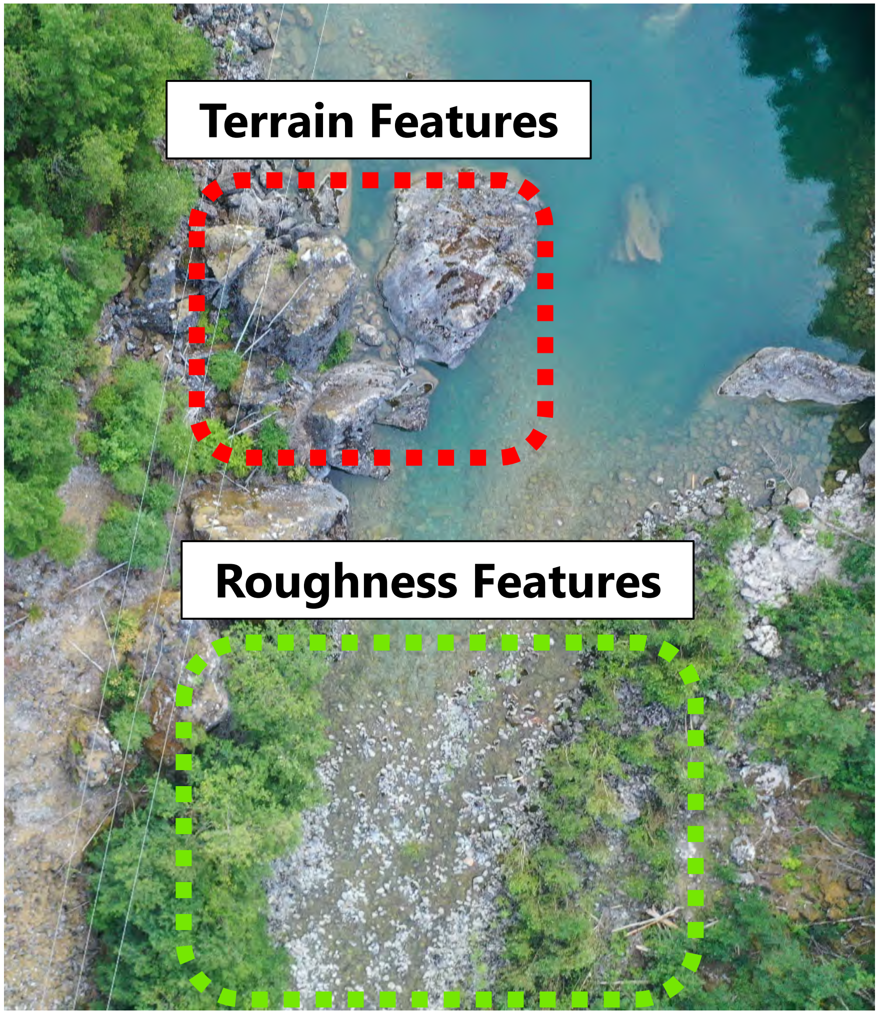
CELL SIZE – MODEL EFFICIENCY

- More cells = longer runtime
  - 3′ – 500,000 cells
  - 2′ – 1,100,000 cells
  - 1′ – 4,500,000 cells
- Timestep selection



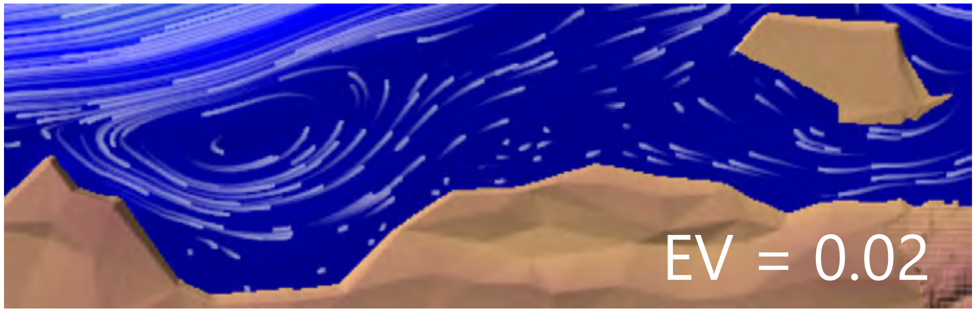
ROUGHNESS CATEGORIZATION

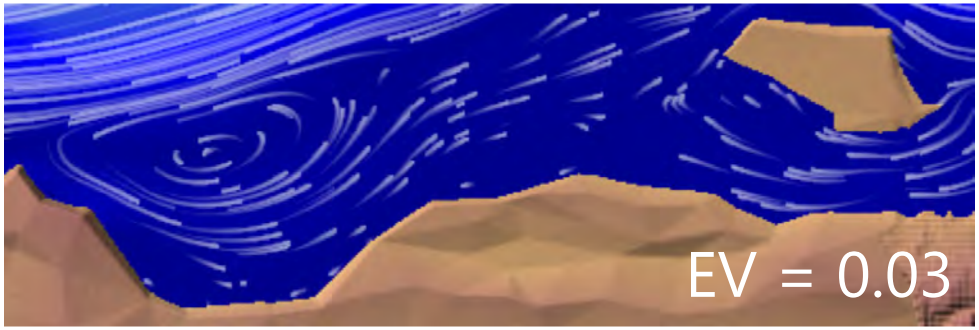
- Influencing factors
  - Substrate vs Grid Size
  - Vegetation
- Roughness values determined through calibration

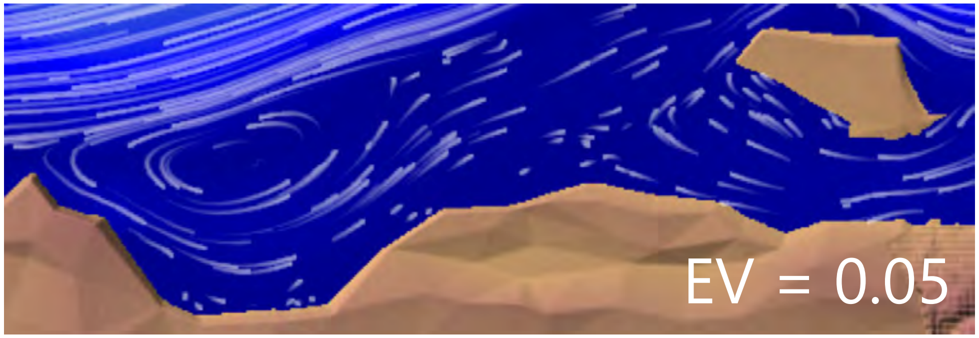


TURBULENCE

- Momentum transfer due to chaotic motion
  - o Represented by numerical diffusion in model
- Eddy viscosity coefficient
  - o Calibrates best to spatially distributed velocities
  - o Affects WSEL and velocity





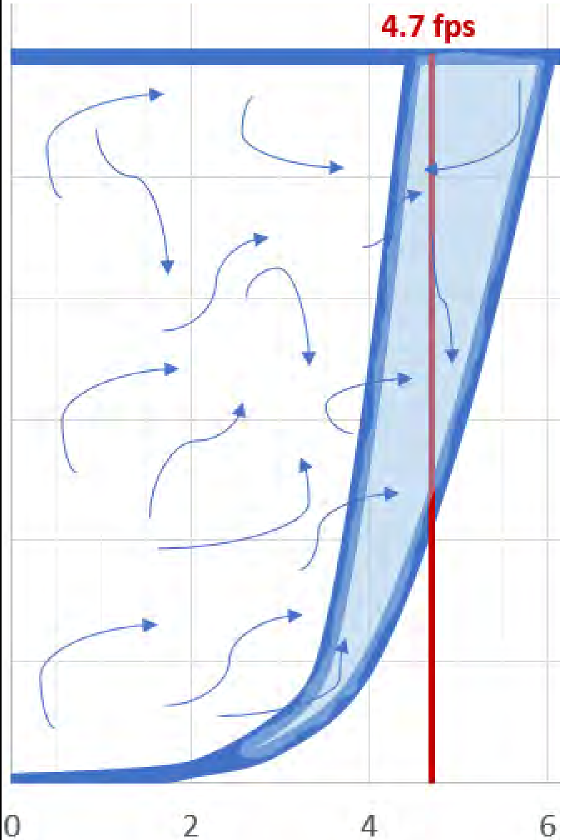


CALIBRATION AND VALIDATION

- Information
  - Continuous WSEL profiles from 4 controlled releases
  - Level loggers
    - 4 controlled releases
    - 1 unplanned spill
  - 5 transects from 4 controlled releases
- Parameters
  - Roughness
  - Turbulence
- Some measurements reserved for model validation

2D MODEL CONTEXT

- Depth-averaged



U/S Feature - April 12, 2021 – 1200 cfs

Seattle City Light

DISCUSSION

Skagit River Hydroelectric Project
Seattle City Light (City Light)
FA-05 Gorge Bypass Reach Hydraulic and Instream Flow Model Development, Workshop #3
August 26, 2021

Meeting Summary

Disclaimer: These notes are provided to serve as a high-level summary of the meeting and as a communication tool to benefit work group continuity. They are streamlined and focused on action items, unresolved issues, future discussion items, and high-level discussion points. They are not intended as a formal record of the meeting.

Attendance

Licensing Participants (LPs):
Brock Applegate, Washington Department of Fish and Wildlife (WDFW)
Stuart Beck, Kleinschmidt Group (for Swinomish Tribe)
Curtis Clement, Upper Skagit Indian Tribe (USIT)
Kiza Gates, WDFW
Kirk Gehl, Nlaka'pamux Nation Bands Coalition
Rick Hartson, USIT
Jonathan Kohr, WDFW
Kevin Lautz, WDFW
Jim Myers, National Marine Fisheries Services (NMFS)
Jim Pacheco, Washington Department of Ecology (Ecology)
Duncan Pfeifer, WDFW
Ashley Rawhouser, National Park Service (NPS)
Dudley Reiser, Kleinschmidt Group (for Swinomish Tribe)
Kara Symonds, Skagit County
Amy Trainer, Swinomish Tribe
Stan Walsh, Skagit River System Cooperative (SRSC)
Erik Young, Skagit Fisheries Enhancement Group (SFEG)

Seattle City Light (City Light):
Andrew Bearlin, City Light
Erin Lowery, City Light
Vanessa Lund, City Light Consultant

Cascadia Law:
Matt Love, Cascadia Law

Consultant Team:
Jenna Borovansky, Consultant Team
Danielle Hanson, Consultant Team
Becky Holloway, Consultant Team
Donnie Jones, Consultant Team – NHC
Bao Le, Consultant Team
Malcolm Leytham, Consultant Team – NHC
Chris Long, Consultant Team – NHC
Theo Malone, Consultant Team

Facilitation Team:
Thomas Christian, Facilitation Team
Alex Sweetser, Facilitation Team

Meeting Materials

Meeting materials are stored in this folder on the Skagit SharePoint site.

- Meeting Agenda
- Meeting Slides: Skagit River Gorge Bypass Reach Hydraulic and Instream Flow Model Development Workshop 3

Action Items

Action	Responsibility	Deadline
LP Action Items		
None identified at this meeting		
City Light Action Items		
Consultant Team will provide a technical memorandum about the confidence/variance of observed flows. It will include a longitudinal profile of the flow data.	City Light	Before next workshop
City Light will provide LPs a technical memo on flow stabilization for their reference.	City Light	Before next workshop
Facilitation Team Action Items		
Prepare draft meeting summary and send to LPs for review.	Triangle	Two weeks

Summary of Issues Discussed, Action Items, and Decisions

Welcome, Introductions, Agenda Overview

The facilitator, Thomas Christian, welcomed the group and led a roll call. He briefly walked through the agenda and reviewed action items from the last *Gorge Bypass Reach Hydraulic and Instream Flow Model Development Workshop* held on May 17, 2021.

Erin Lowery, City Light, noted this meeting is intended as an information-sharing meeting on hydraulic model development. There will be room on each agenda item for questions and discussion. He reviewed the meeting objectives, which were to:

- Review controlled and uncontrolled spill data collection
- Review model terrain development
- Provide an overview of the hydraulic model development approach

Study Overview

Chris Long, Consultant Team, provided a status update on the Instream Flows studies (see slides 1–4). He noted the FA-02 study is more advanced because field data collection started in August 2020 and field data collection for FA-05 only happened in the last month. However, progress on FA-05 will quickly jump ahead due to the limited size and ~~scope of~~ quantity of calibration data for the model.

- In response to a question, Chris clarified that the modeling team just started synthesizing the field data collected in July 2021 and profiles from the model will not be presented today.

Chris reviewed the study road map and noted there will still be a monthly collection of data from level loggers. Referencing the standing workshop calendar, Chris explained the next workshop will likely be in early November 2021 and will cover ongoing model calibration. Another workshop to present the finalized model is anticipated for February 2022.

Controlled Spill Monitoring: Transect Data

Donnie Jones, Consultant Team, provided a presentation on controlled spill monitoring data (see slides 5–17). He explained the purpose of the controlled spill flows was to collect velocity and depth data for model calibration through expected releases of 1200, 500, 250, and 50 cfs. Donnie presented the transect locations, described the methodologies for the Acoustic Doppler Current Profiler (ADCP) they used to collect the data, observed flows data in the Bypass Reach, and measured depths and velocities.

Questions/Discussion

- In response to a question about how the ADCP collected data, Donnie explained they used a station-to-station~~ary data~~ instead of moving-vessel approach~~ it~~. This approach allowed them to collect 40 seconds of data at each sampling location to average out temporal fluctuations.
- In response to a question about the gains and losses of observed flows, Chris and Donnie noted losses were most notable in transects DD and GG. They hypothesize this loss was caused by groundwater conversion ~~within these transects~~at the Afternoon Creek pool. Chris elaborated this hypothesis was not due to observations but based on the quality, pattern, and confidence of the data.
- Jim Pacheco, Ecology, expressed that the bridge transect was expected to be the most stable, but had an inconsistent distribution of measured flows across targeted releases. Donnie explained ~~the~~ flow ~~within~~at this transect was not as uniformly distributed as expected and that larger features, such as the ~~bridge~~abrupt shotcrete walls at the channel margins, made it difficult to characterize the ~~channel~~flow field at high discharges.
- Jim Pacheco shared that Ecology often uses a dual-state discharge method and said it would be helpful if the model could recognize gains and losses of flows within the river reaches. Chris clarified that sources and sinks can be added to the model during the model calibration phase.
- In response to a question from Curtis Clement (USIT) about which transect the consultant team has the most confidence in, Donnie noted they have the most confidence in the data at transect II, and the bridge transect under certain conditions.
- LPs requested that City Light revise the observed flows graph on slide 15 to show the confidence of the data at each observation. Additionally, LPs requested this include a longitudinal profile of the flow data.

Action Item: The Consultant Team will provide a technical memorandum about the confidence/variance of observed flows. It will include a longitudinal profile of the flow data.

Controlled Spill Monitoring: UAV Data

Chris Long presented the controlled spill monitoring UAV data collection and data analysis methodologies (see slides 18–51). He explained the drone flew Monday through Friday in one week and collected data ~~for~~in four different zones in~~ a~~ pre-planned missions. Then, they used overlapping photos from the drone to develop a 3D structure of the study area, which could be added as a layer beneath the hydraulic model to compare the model simulation to field observations.

Chris explained they will be using ~~the~~ Large Scale Particle Image Velocimetry (LSPIV) analysis~~ tool~~ to measure surface velocity, ground-truth (but not calibrate) the numerical model, and provide another view of potential fish passage through the Bypass Reach. The LSPIV software tracks "seeding material" – objects floating on the surface of the water – in a video and calculates the speed and orientation of the objects across video frames to calculate the direction and magnitude of the river's flow. ~~It can also~~

~~demonstrate turbidity.~~ Seeding material can be natural or artificially added, such as bark chips, as was done for this study.

Questions and Discussion

- In response to a question from Stuart Beck, consultant for Swinomish Tribe, about the drone's height above the river, Chris clarified the drone was about 250ft above ground level for the LSPIV videos and 300-350ft for the still photos.
- In response to a question if the surface velocities from the LSPIV tool could be used to help refine the 2D hydraulic model, Chris explained these measures could help to ground truth the model, but would not be as useful for model calibration. The LSPIV outputs are for surface water velocity, whereas the 2D model's output is depth averaged, which means the values would not align. Additionally, the LSPIV output shows active turbulence, which alters the surface flow values.
- In response to a question about the cost~~s~~ and utility of using the UAV to track gravel movement, Chris explained the UAV itself only costs a couple hundred dollars~~ and is not expensive~~, but the analysis software, which costs between $3,000 – $6,000, and paying the field crews is what costs the most. This means data collection is inexpensive, but planning and post-processing the data is expensive. ~~Chris noted there are several ways they could track gravel movement, but it is not currently being tracked.~~

Level Logger Data Collection

Malcolm Leytham, Consultant Team, provided an overview of the level logger equipment, instrument~~level logger~~ installation, and ~~level logger~~ data collection methodologies and results (see slides 52–75). He noted they installed six level loggers at the upstream feature and six level loggers at the downstream feature. Additionally, the Consultant Team believes they have gotten the data necessary to calibrate the model ~~up to~~at ~~4~~6,000 cfs after the large uncontrolled spill event in June. Malcolm noted they are still processing the level logger data.

Questions and Discussion

- Rick Hartson, USIT, expressed concern about the ability of the level loggers to ~~date data~~measure at higher flows and the accuracy of high flow data. Malcolm responded that due to safety and logistical considerations, they ~~we~~are unable to measure velocities ~~with the level loggers~~ at the uncontrolled high-flow event; however, the model will use the level logger data for river ~~height~~stage, and they have photos as a qualitative reference for this event. ~~Additionally, the level logger data will be used for calibration.~~ He explained the level loggers will remain in place until November or December in case there is another high flow event this fall. However, they have a good dataset from the uncontrolled release event.
- In response to a question from Ashley Rawhouser about the travel time between Gorge Dam and the Newhalem Gage and how this may affect stabilization time, Malcolm answered the travel time is about an hour. Malcolm explained the stage stabilization time is longer and closer to four to five hours, which was considered when planning field data collection. Andrew Bearlin, City Light, noted City Light can provide a technical memo on flow stabilization to LPs for their reference.

Action Item: City Light will provide LPs a technical memo on flow stabilization for their reference.

Terrain

Donnie Jones presented on the hydraulic model terrain development ~~and data outputs~~ (see slides 76–91) including~~. Additionally, he provided~~ an overview of the methods for refining the model to a 1ft raster and point reclassification results. As part of terrain refinement, Donnie noted there ~~needs to be~~is a manual assessment of unassigned LiDAR points, which ~~cannot~~will not be done in wetted areas but~~ is possible~~ in dry areas only.

Questions and Discussion

- In response to a question from Johnathan Kohr, WDFW, Malcolm explained the terrain outputs ~~from this part of the model~~ are primarily for ~~terrain layout in the~~ model topography and not for habitat cover. Bao Le, Consultant Team, clarified that~~ a full cover map of~~ substrate and habitat cover~~age~~ is being field mapped separately and will follow Ecology guidelines.
- In response to a question from Rick Hartson about ~~lost data due to~~ the ~~model's~~ inability to increase LiDAR point density in wetted areas, Donnie explained the LiDAR data was collected in baseflow (dry) conditions and that most of the wet areas were shallow pools ~~of flows~~ between rocks and cobble. For these areas, the impact of ~~loss~~lesser ~~of~~ data resolution is minimal~~ due to it being a case of diminishing returns~~.

Hydraulic Model Development Approach

Donnie presented the approach for developing the hydraulic model (see slides 92–101). The model extent is from ~~the~~ Gorge Dam to the Newhalem stream gage. Donnie noted that smaller cell sizes results in~~ a~~ better resolution, but at the cost of~~greatly~~ increasing~~e~~ the model~~'s~~ run time. ~~The~~He illustrated from a pervious hydraulic model analogous to the Bypass Reach that the largest increase in computational runtime with ~~small~~least accuracy gains ~~i~~was ~~in~~ between the 2ft to 1ft resolution. Donnie also explained ~~the~~ roughness values will be determined ~~through~~during model calibration. ~~Lastly, Donnie noted any remaining measures will be reserved for model validation after the model is calibrated.~~

Questions and Discussion

- In response to a question from Kevin Lautz, WDFW, about if roughness is ~~being~~ scaled by depth, Donnie explained that in HEC-RAS roughness is scaled to flow magnitude, which is related to flow depth. If roughness scaling is included, it would be through this method with a roughness coefficient.
- In response to a question about using a 1ft raster resolution for the entire model, Donnie noted ~~this will not be an issue with their software. However,~~ the 1ft resolution can be selectively applied in different areas where it offers greater improvements.
- In response a question about the model being calibrated to 7,000 cfs, Malcolm explained the level logger record~~ model becomes~~ is unsteady at this flow. Instead, there is a 6,000 cfs stable period that calibration could be based on. ~~Chris added that extremely high flows become very turbid and chaotic, so there is a concern about false accuracy in the model at these higher flows.~~
- In response to a question, Donnie clarified grid sizes will vary by focus area.

- In response to a question, Donnie clarified actual water velocity varies both vertically and horizontally. The model provides a vertical (depth) average ~~of~~ velocity.
- In response to a question, Donnie clarified that air entrainment is not represented in the model.
- Rick Hartson noted turbulence is very important for fish passage and asked how this model will inform the wider fish passage and river modeling toolset. Donnie responded it depends on how well the model outputs for velocity, depth, and water surface elevation match data to corresponding locations. Additionally, the model can better characterize larger features and is less accurate with smaller features and cobble. Chris added that the model ~~appears smooth because the velocity and heigh measures are averaged, which means this model~~ does not simulate the true chaotic and periodic nature of turbulence. This requires the ~~team on the~~ FA-04 Fish Passage Technical Studies Program team~~will need~~ to understand the model limitations and that model outputs are not absolute for fish passage estimates. This model will be one of the ~~many~~several tools the team uses to assess fish passage. Jim Pacheco added this indicates unpassable velocity measures in the model may be passable in the real world due to the high level of variance caused by turb~~idity~~ulence.

General Question

- In response to a question from Stuart Beck about the risk of fish stranding or trappings when ramping down flows after a controlled release, Erin Lowery, City Light, clarified dam operators are meeting ramping rates rules that are inclusive of several considerations for fish. However, there is potential for gravel bar and pothole stranding. Stuart expressed concern about ramping rates not specifically being addressed in the Bypass Reach and the potential for pothole stranding within the Bypass Reach.

Review Action Items and Next Steps

The Consultant Team noted a topic for the next FA-05 Workshop will be to discuss model calibration. The facilitator noted Triangle is working with City Light to establish a standing meeting calendar and the next Flows Work Group meeting will likely fall into that standing calendar time.

Action Item: Consultant Team will provide a technical memorandum about the confidence/variance of observed flows. It will include a longitudinal profile of the flow data.

Action Item: City Light will provide LPs a technical memo on flow stabilization for their reference.

Action Item: Triangle will prepare a draft meeting summary and send to LPs for review.

The meeting was adjourned at 1:00 p.m.

SKAGIT RIVER GORGE BYPASS REACH HYDRAULIC AND INSTREAM FLOW MODEL DEVELOPMENT STUDY INTERIM REPORT

ATTACHMENT I

WORKSHOP 4 MATERIALS

Seattle City Light DRAFT **MEETING AGENDA**

Skagit Hydroelectric Project Relicensing: Flows Work Group Meeting

FA-05 Gorge Bypass Reach Hydraulic and Instream Flow Model Development, Workshop #4

November 2, 2021, 8:30 a.m. – 1:15 p.m.

WEBEX

Webex Meeting Link:
https://triangleassociates.my.webex.com/triangleassociates.my/j.php?MTID=med4871c742b1d1e0d00da4363e231b79

Call in Information: +1-510-338-9438,,25565666087#74985787# USA Toll

MEETING PURPOSE

- Review selection and associated uncertainty of flows used for model calibration
- Review model development and sensitivity analyses
- Present current progress of model calibration
- Outline remaining work for completing model calibration and validation
- Provide updates on substrate and cover mapping and HSC and periodicity development
- Preview hydraulic model integration with biological/habitat data

RESOURCES

- NOA Commitments
- Flows Work Group Discussion Tracker

FACILITATION TEAM

Joy Juelson, Triangle Associates, Facilitation
Alex Sweetser, Triangle Associates, Documentation

AGENDA

8:30 – 8:45 a.m. (15 minutes)	**Introduction** – *Facilitator, Triangle* ▪ Roll Call Introduction ▪ Background and Context ▪ Review Action Items from Previous Meeting
8:45 – 9:00 a.m. (15 minutes)	**Study Overview** – *Erin Lowery, City Light and Chris Long, NHC* ▪ Background ▪ Review Meeting Objectives and Agenda
9:00 – 9:45 a.m. (45 minutes)	**Present and Discuss Calibration Flow Selection and Uncertainty Analysis** – *Donnie Jones, NHC* ▪ Late June 2021 Spill ▪ July 26-29 Controlled Spill Events Questions and Discussion (30 minutes) ▪ Discussion topic: Assessing uncertainty of uncontrolled spill event. – *Rick Hartson (15 minutes)*

9:45 – 10:45 a.m. (60 minutes)	**Update and Discuss Model Development and Sensitivity Analysis** – *Donnie Jones, NHC* ▪ Model Terrain ▪ Model Geometry Overview ▪ Sensitivity Tests ▪ Final Mesh Selection Questions and Discussion (15 minutes)
10:45 – 11:00 a.m. (15 minutes)	**Break**
11:00 – 12:30 p.m. (90 minutes)	**Present and Discuss Model Calibration and Validation**– *Donnie Jones, NHC* ▪ Observed data ▪ Calibration Procedure ▪ Current Progress ▪ Future Progress Questions and Discussion (20 minutes)
12:30 – 1:00 p.m. (30 minutes)	**High-level Overview of the Development of Biological/Habitat Data and Integration with Hydraulic Model** – *Ty Ziegler, HDR and Chris Long, NHC* ▪ Update on substrate and cover mapping ▪ Update on HSC and periodicity development ▪ Preview of Biological/Aquatic Habitat Integration ▪ Preview of hydraulic data generation for fish passage analysis Questions and Discussion (10 minutes)
1:00 – 1:15 p.m. (15 minutes)	**Review Action Items and Discussion Tracker and Develop Agenda Items for Next Meeting –** *Triangle and NHC*
1:15 p.m.	**Meeting Adjourned**

Action Items From FA-05 Workshop 3 (8/26)

Action Items		
Action	**Responsibility**	**Timeframe**
City Light Action Items		
Consultant Team will provide a technical memorandum about the confidence/variance of observed flows. It will include a longitudinal profile of the flow data.	City Light	Before next workshop
City Light will provide LPs a technical memo on flow stabilization for their reference.	City Light	Before next workshop
Facilitation Team Action Items		
Prepare draft meeting summary and send to LPs for review.	Triangle	Complete

SKAGIT RIVER GORGE BYPASS REACH HYDRAULIC AND INSTREAM FLOW MODEL DEVELOPMENT – WORKSHOP 4

November 2, 2021

WORKSHOPS

Workshop	Date	Topics
~~1A~~	~~May 2021~~	~~Overview development of hydraulic and instream flow model for the Gorge Bypass Reach~~
~~2~~	~~July 2021~~	~~Updates to biological and habitat metrics based on discussions and input from FA-02 Workshop 1~~
~~3~~	~~August 2021~~	~~Field monitoring debrief and hydraulic model development kickoff~~
4	November 2021	Hydraulic model calibration ongoing
5	February 2022	Final hydraulic model calibration results and discussion of future model application

STUDY ROAD MAP/SCHEDULE

	May	June	July	August	September	October	November	December	January	February		
Field Data Collection											Initial study report March 2022	Alternative scenario identification and evaluation: February - September 2022
Hydrometric data collection for model calibration												
Substrate and cover data collection												
Hydraulic Model Development												
Modify terrain data												
Hydraulic model construction												
Hydraulic model calibration/validation												
Biological and Habitat Information												
Review, field validation and selection of HSCs												
Integration with hydraulic data												
Workshops (HSC focused workshops not shown)	↑			↑			↑			↑		

WORKSHOP 4 AGENDA

- Calibration flow selection and uncertainty
- Model development and sensitivity analysis
- Model calibration and validation
- Development and integration of biological/habitat data

Seattle City Light

CALIBRATION FLOW SELECTION AND UNCERTAINTY ANALYSIS

November 2, 2021

OVERVIEW

- Late June spill
  - Basis for spill calculations
  - Sources of uncertainty
- July 26-29 Controlled Releases
  - Measurement data
  - Uncertainty quantification
  - Possible flow loss in Bypass Reach

GORGE DAM – OUTLET WORKS

07/28/2021 19:00
~50 cfs

GORGE DAM – OUTLET WORKS

07/28/2021 18:00
~250 cfs

GORGE DAM – JUNE 2021 SPILL

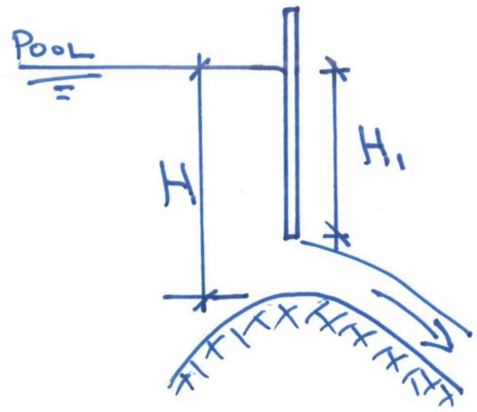
06/30/2021
~ 4700 cfs

GORGE DAM – SPILL CALCULATIONS

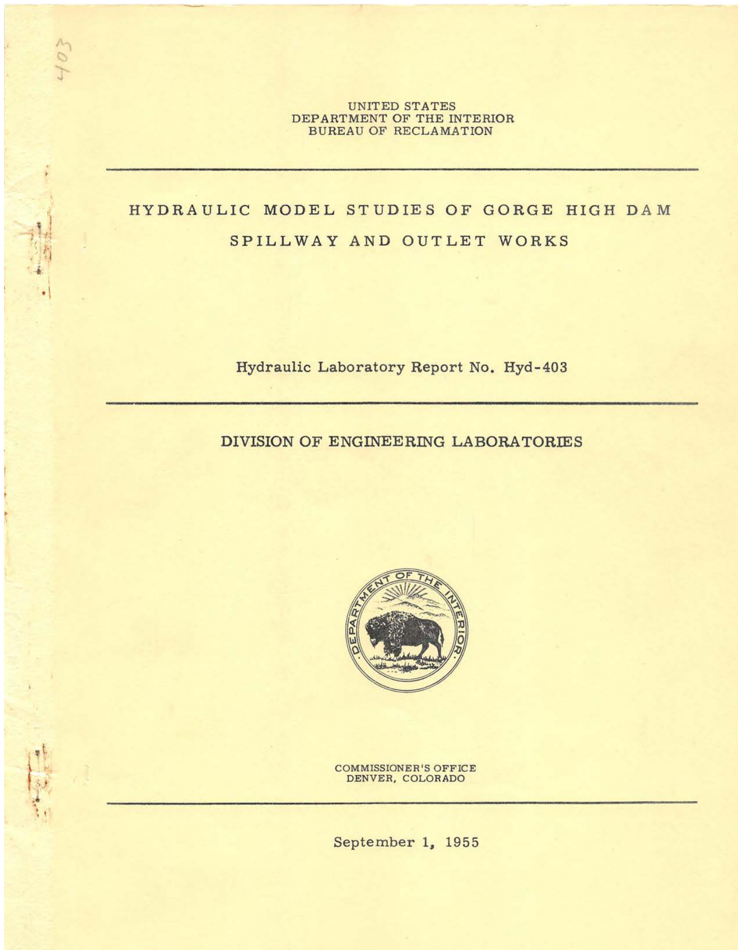
$$Q = CW\sqrt{2g}(H^{1.5} - H_1^{1.5})$$

Q = discharge (cfs)
C = coefficient of discharge
W = gate width (feet)
H = head on gate seat (feet)
H_1 = head on gate lip (feet)

Gate Opening = H – H_1



GORGE DAM – SPILLWAY RATING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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF GORGE HIGH DAM
SPILLWAY AND OUTLET WORKS

Hydraulic Laboratory Report No. Hyd-403

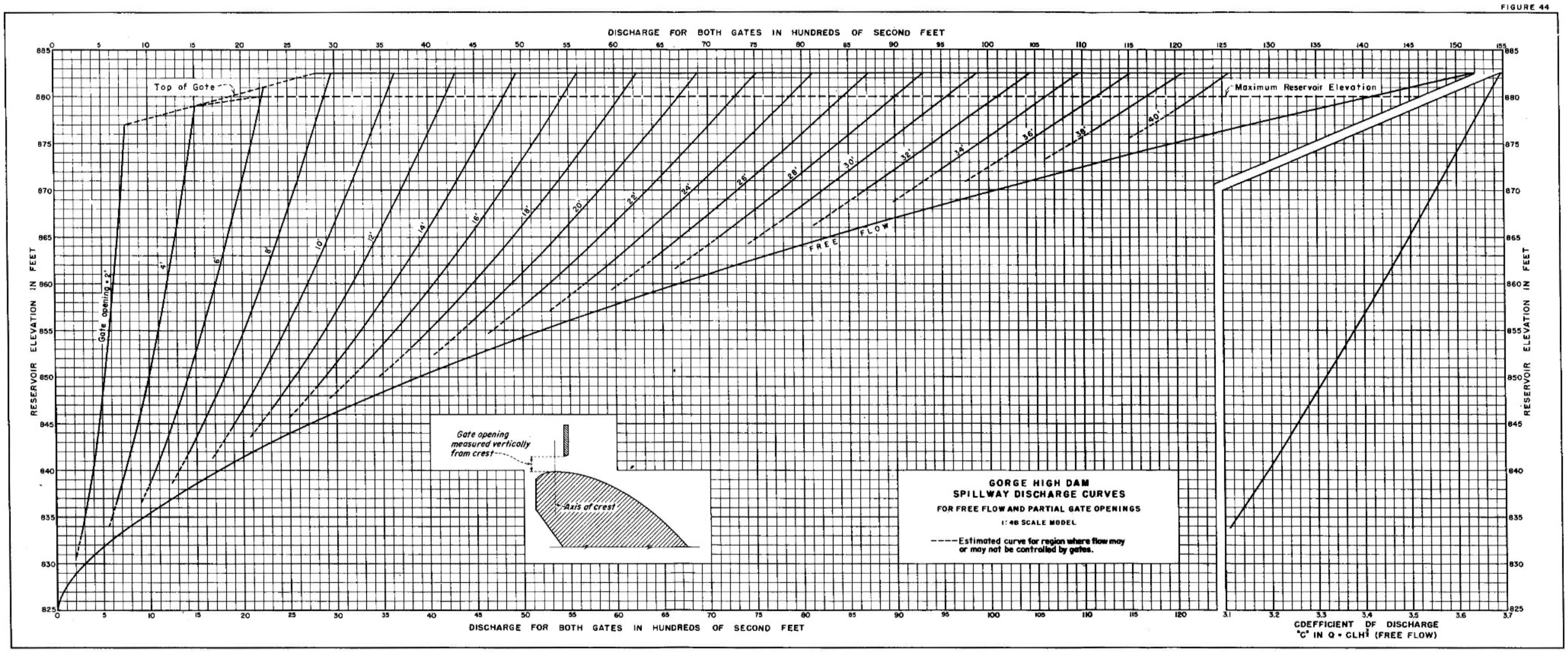
DIVISION OF ENGINEERING LABORATORIES

COMMISSIONER'S OFFICE
DENVER, COLORADO

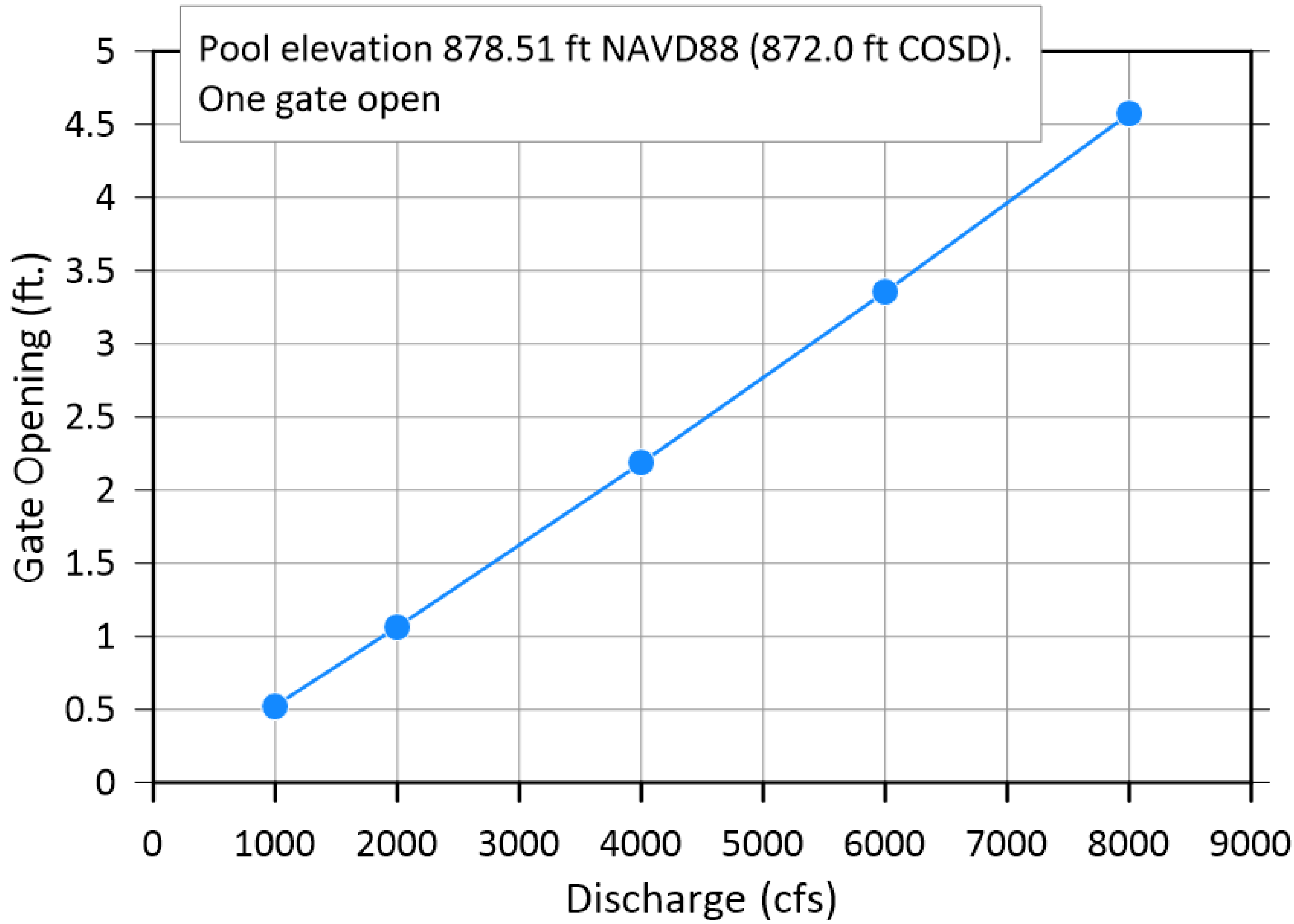
September 1, 1955

- Spillway rating from USBR hydraulic model study.
- Well-established theoretical discharge relationship.
- Laboratory experiments predict discharges to +/- 2% (e.g. Hager and Bremen, J. Hydr. Eng., ASCE, 1988).

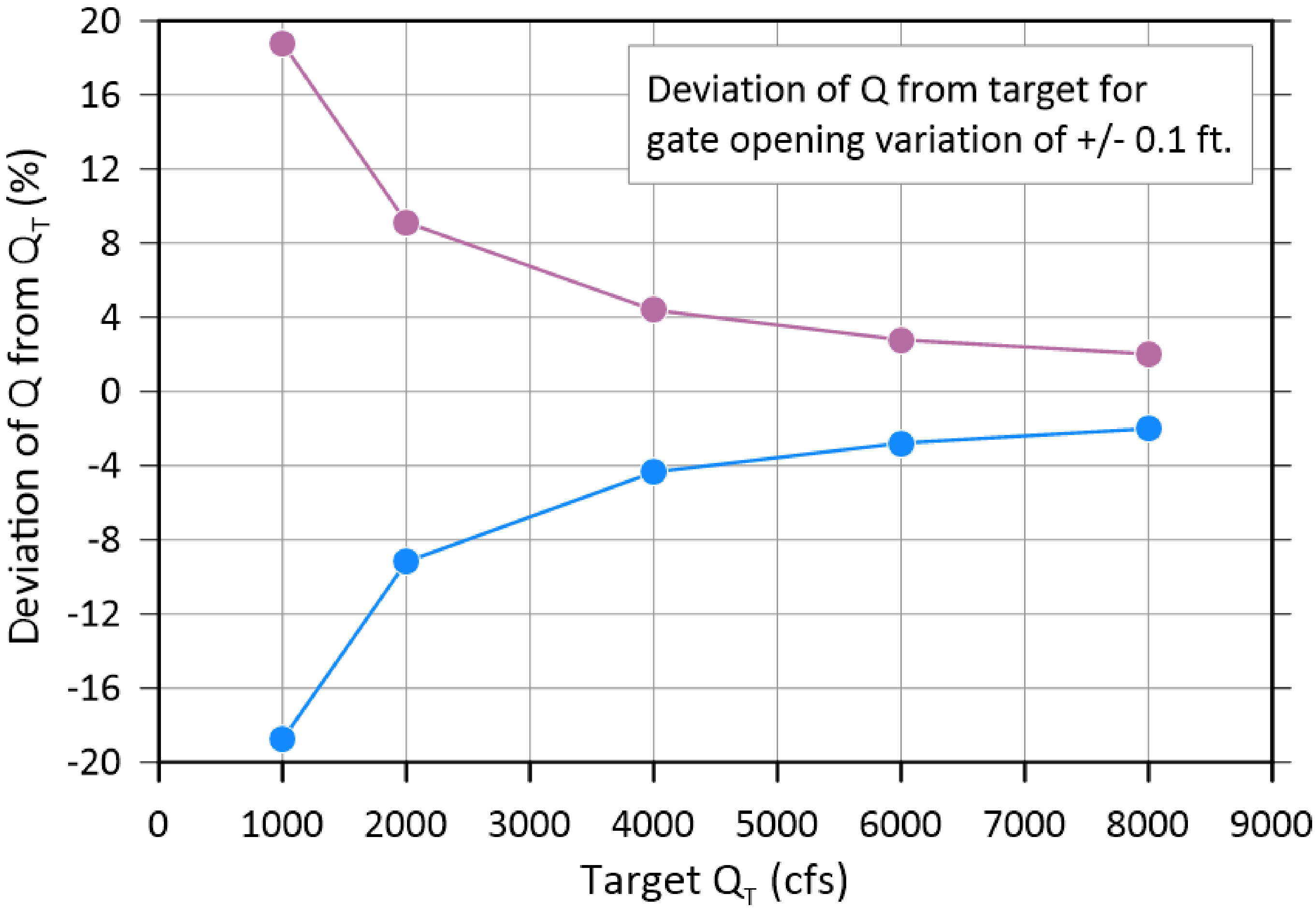
GORGE DAM – SPILLWAY RATING



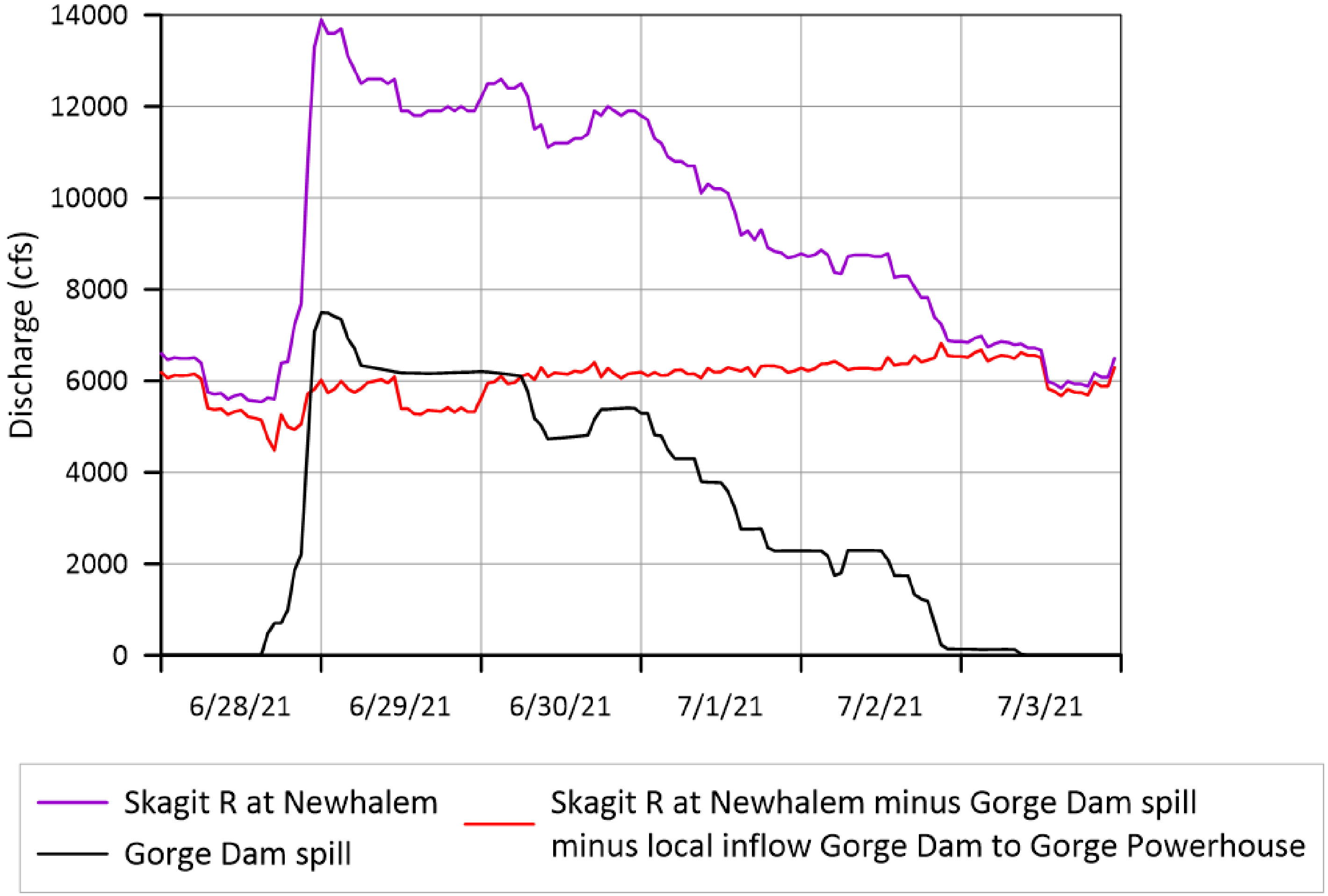
GORGE DAM – SINGLE GATE RATING



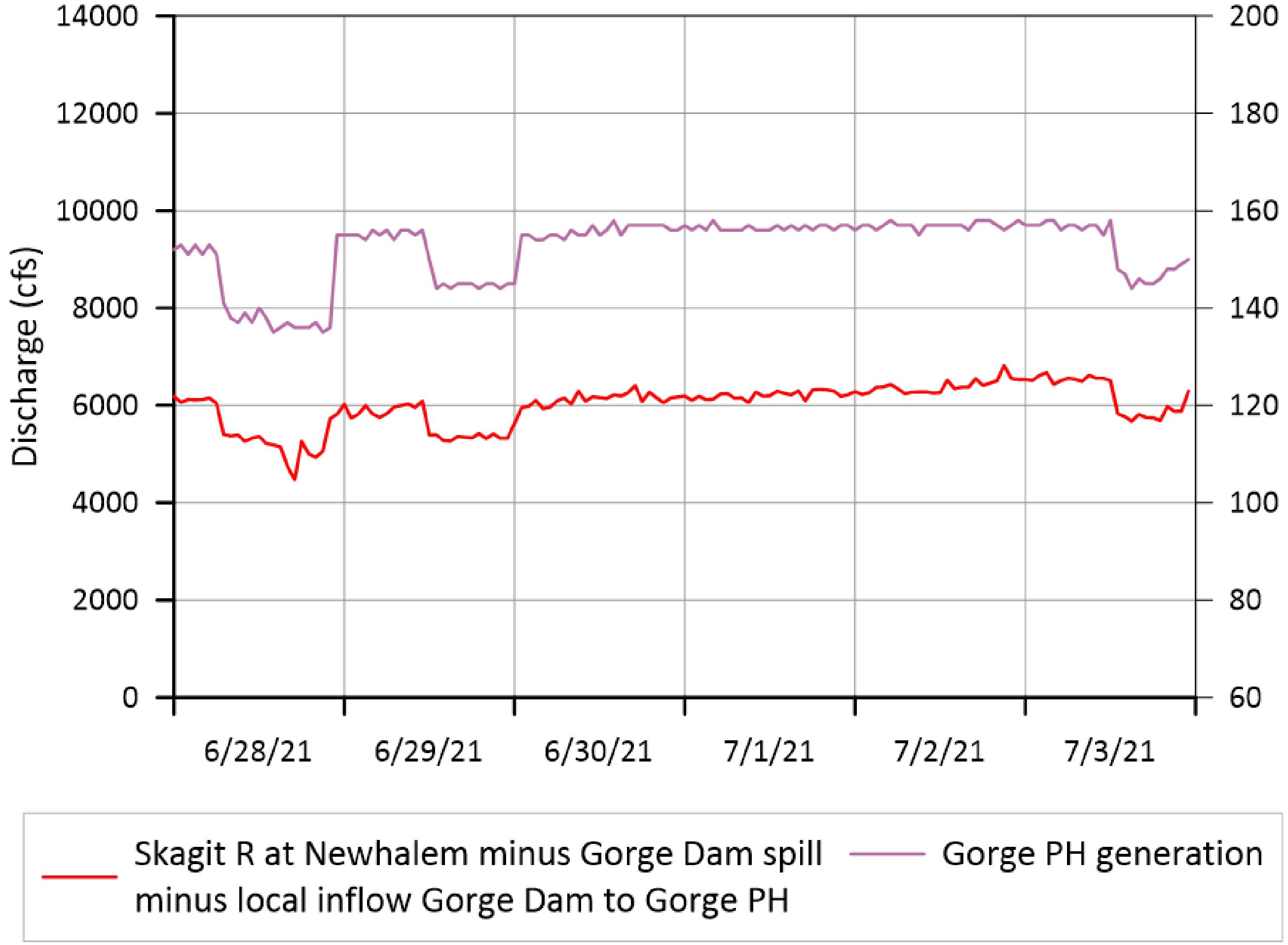
GORGE DAM – DISCHARGE SENSITIVITY TO GATE OPENING



JUNE/JULY SPILL DATA – CONSISTENCY CHECK



JUNE/JULY SPILL DATA – CONSISTENCY CHECK

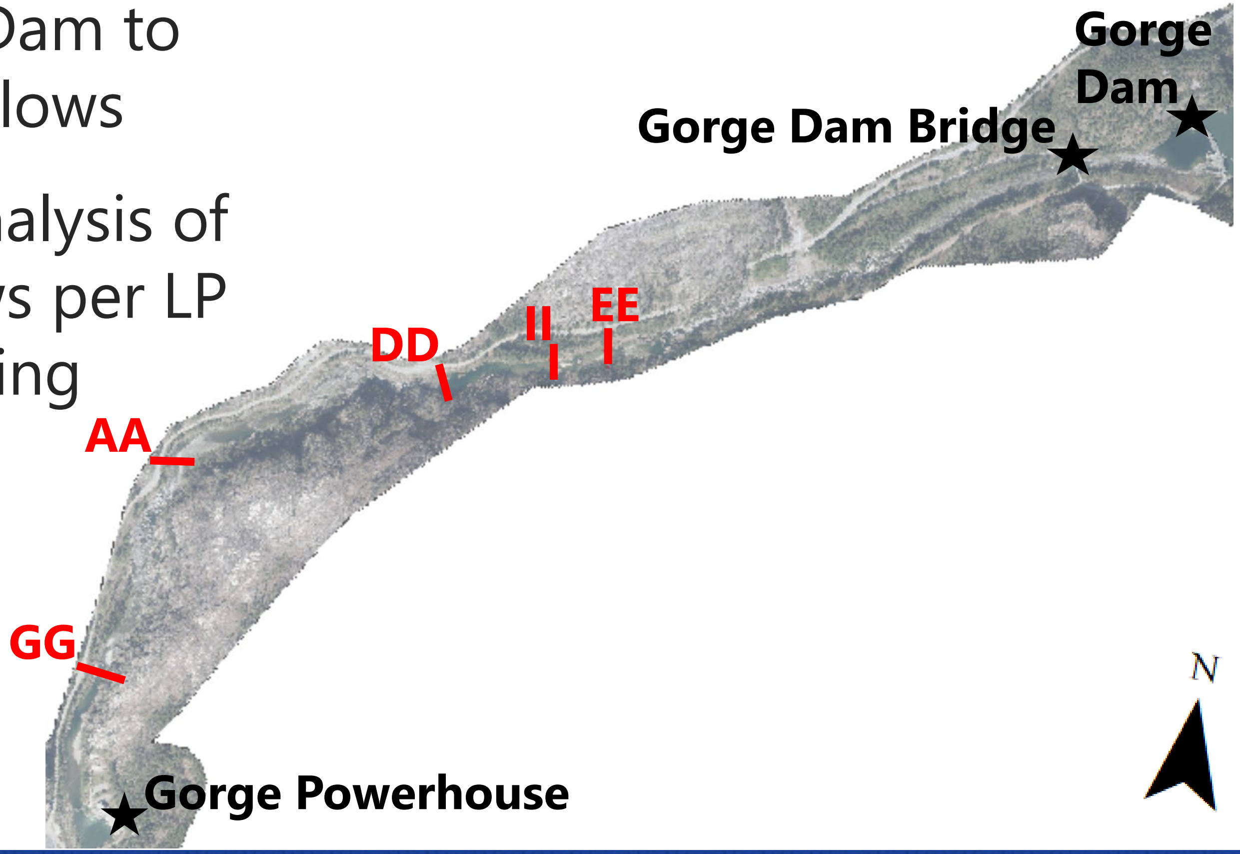


Seattle City Light

DISCUSSION

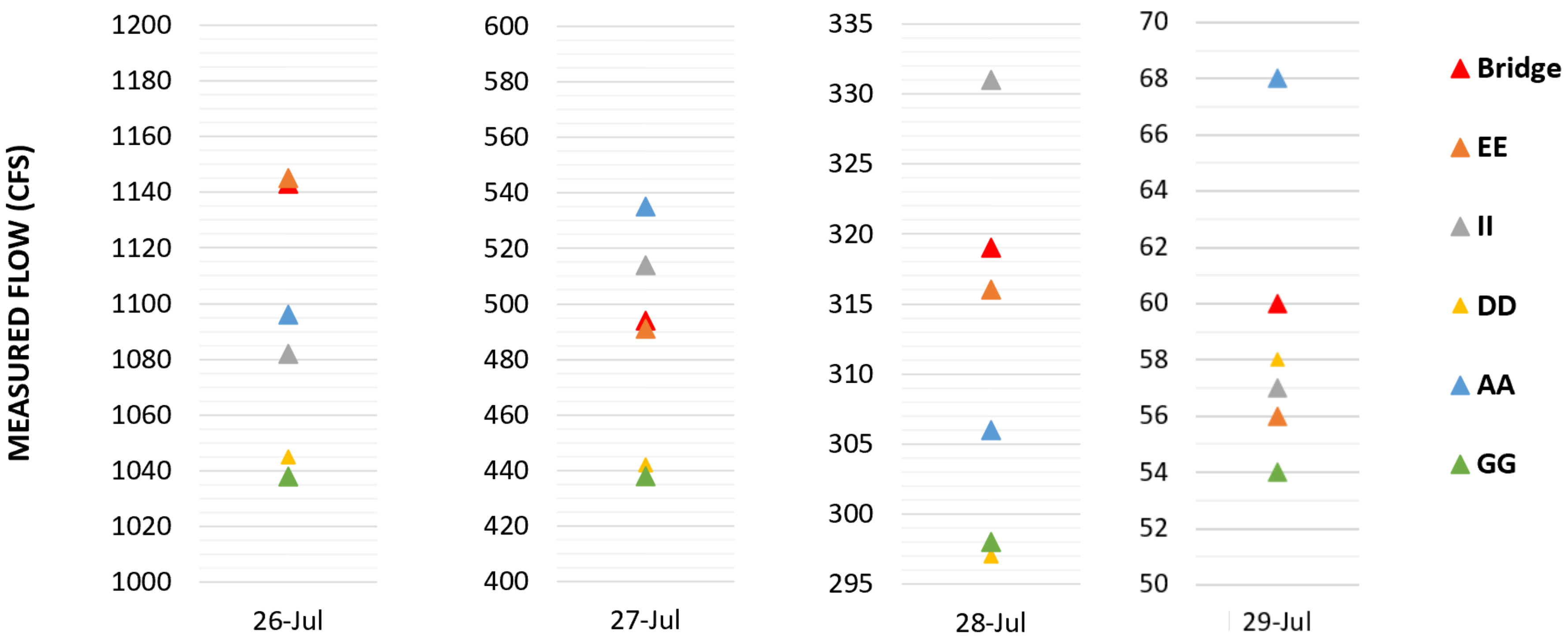
JULY 26-29 CONTROLLED RELEASE FLOWS

- Discharge measured at transects and bridge below Gorge Dam to verify release flows
- Uncertainty analysis of measured flows per LP request following Workshop 3



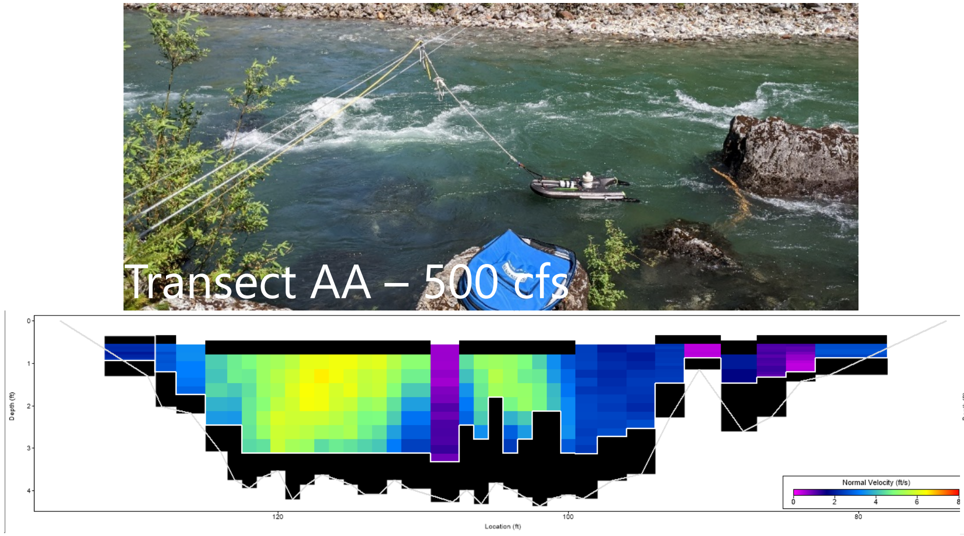
JULY 26-29 CONTROLLED RELEASE FLOWS

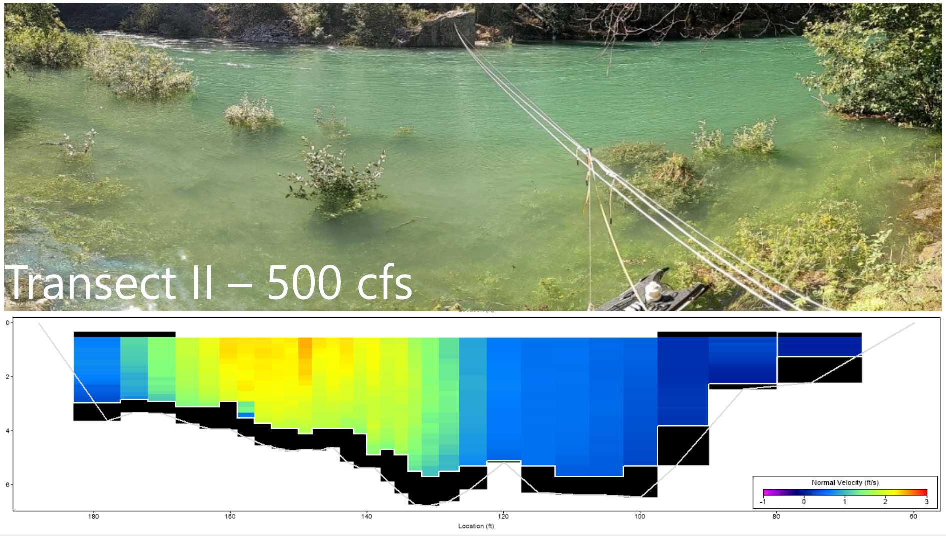
TARGET RELEASE (CFS)	1200	500	250	50
SCL REPORTED RELEASE (CFS)	1095-1097	435-445	246-258	Log Chute (~50 cfs)



JULY 26-29 DISCHARGE MEASUREMENT UNCERTAINTY

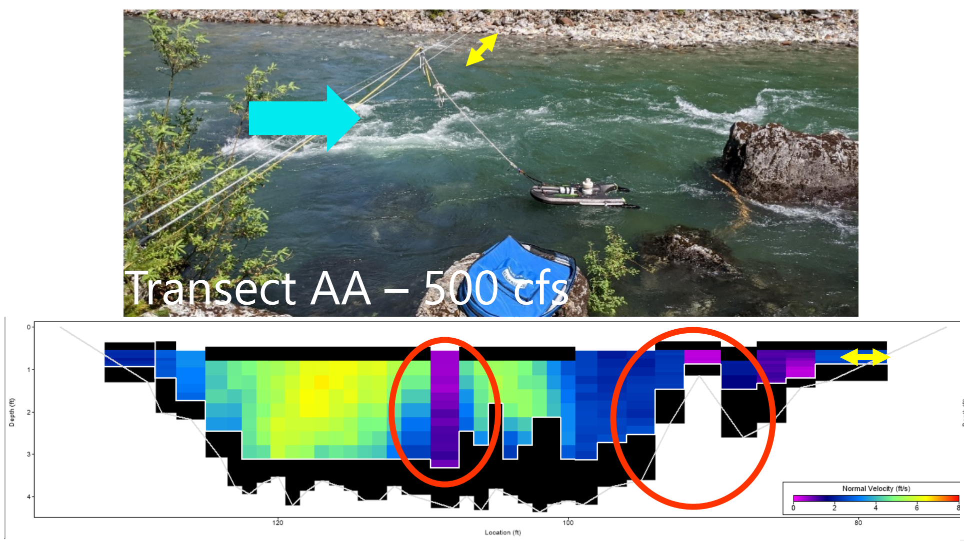
- Discharge quality at transects
  - Transect AA not used - poor conditions
  - Transects II, DD, and bridge most reliable
  - Transects EE and GG acceptable

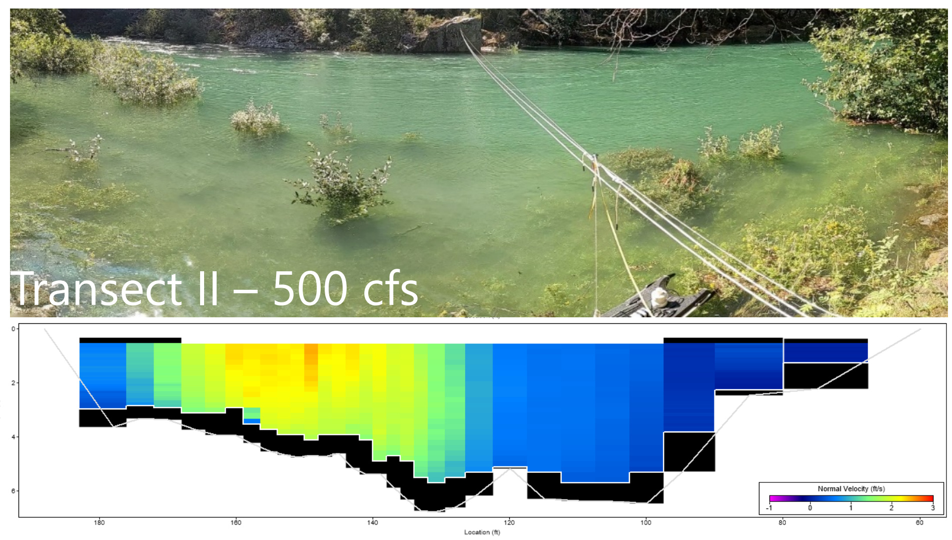




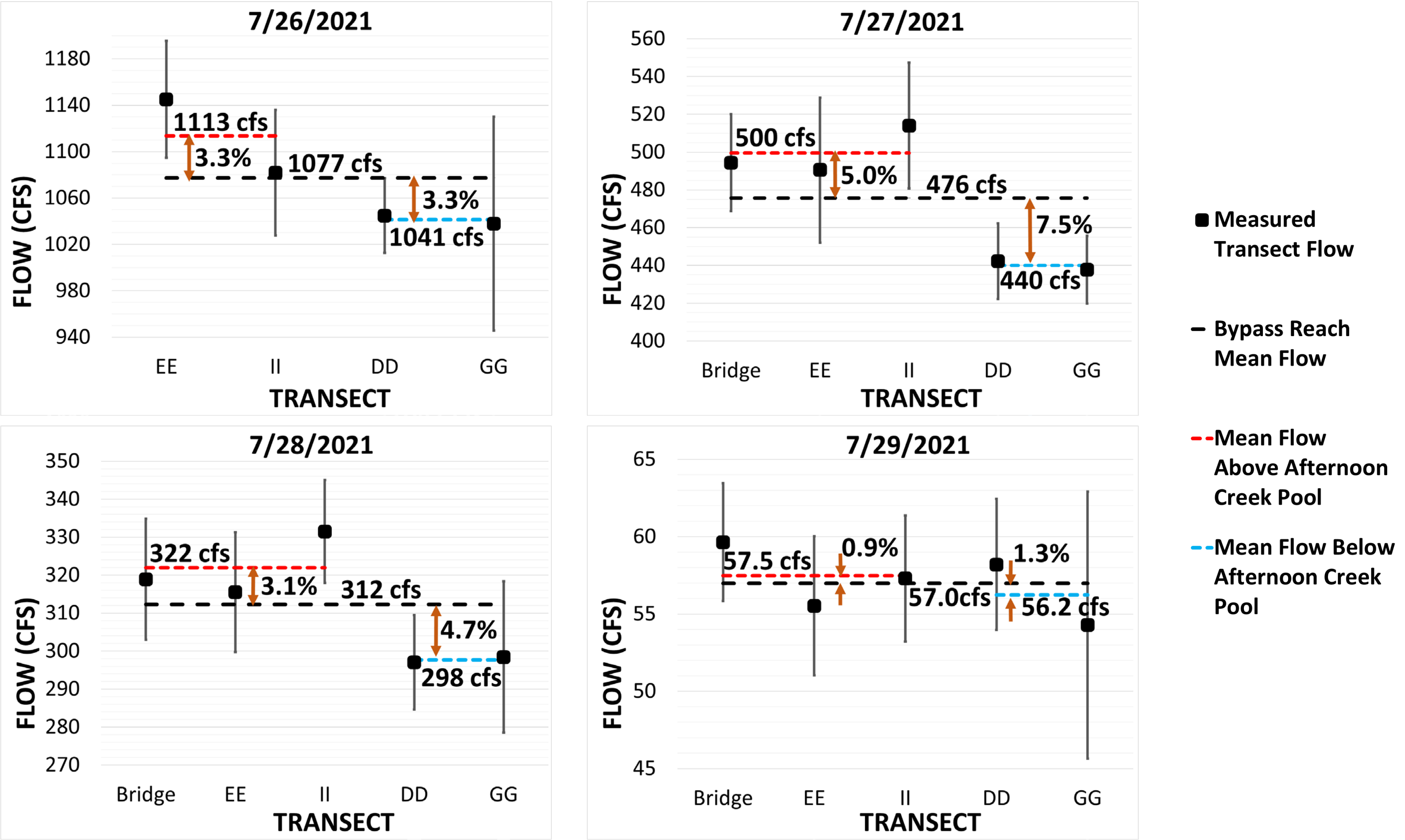
JULY 26-29 DISCHARGE MEASUREMENT UNCERTAINTY

- Quantified uncertainty
  - Change in depth and velocity between stations
  - Angle of primary flow direction
  - Estimated distance to far edge of water





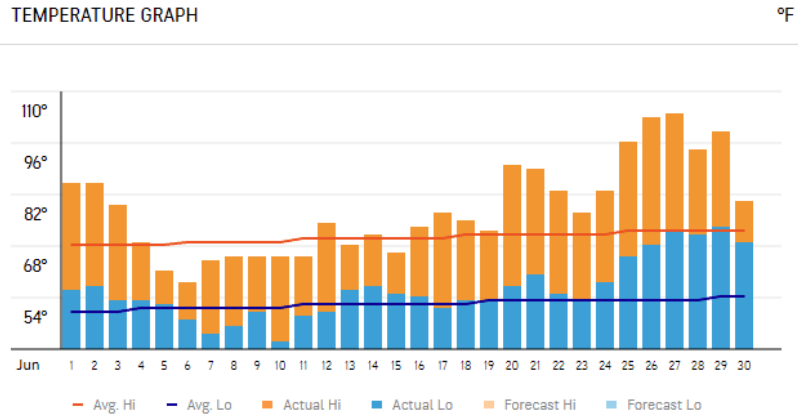
JULY 26-29 DISCHARGE MEASUREMENT UNCERTAINTY



POTENTIAL FOR FLOW LOSS

- Coarse material deposits provide groundwater storage and subsurface flow paths
  - Landslide material along Afternoon Creek pool

- Dry antecedent conditions
  - Late June heat dome
  - Low July base flow (<10 cfs)

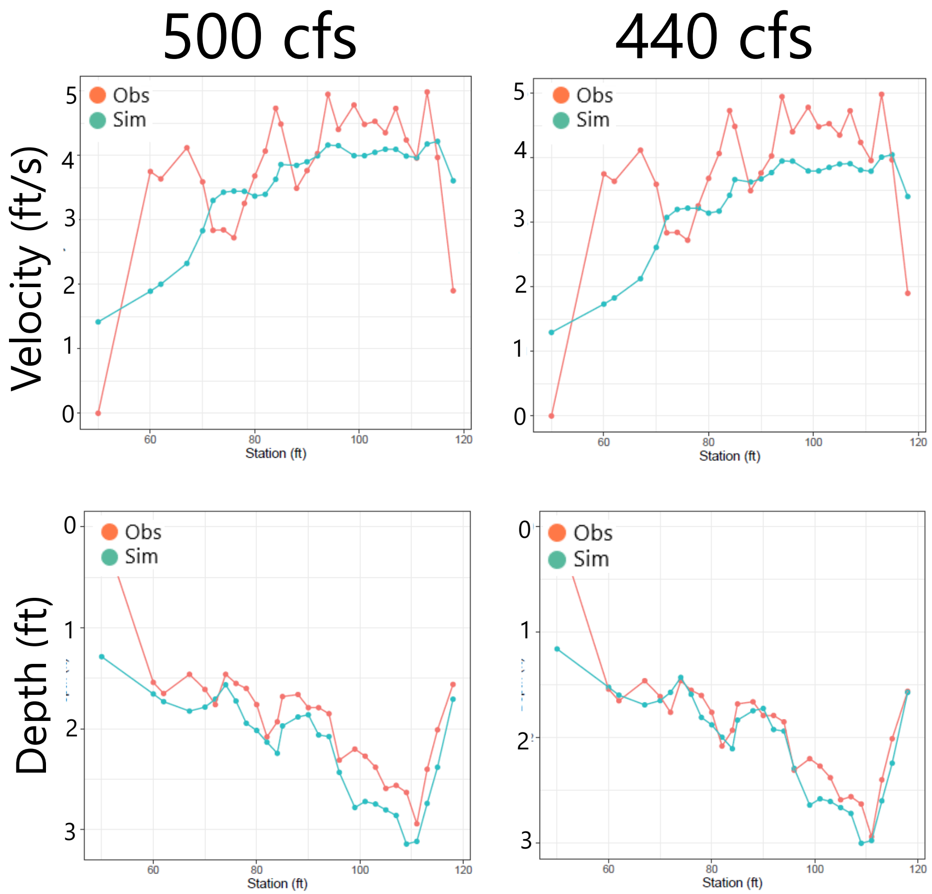


MODEL CALIBRATION FLOWS

Calibration Simulation	U/S Mean Flow (cfs)	D/S Mean Flow (cfs)
July 26, 2021	1113	1041
July 27, 2021	500	440
July 28, 2021	322	298
July 29, 2021	57	57

CALIBRATION FLOW SENSITIVITY

Transect EE



Seattle City Light

DISCUSSION

MODEL DEVELOPMENT AND SENSITIVITY ANALYSIS

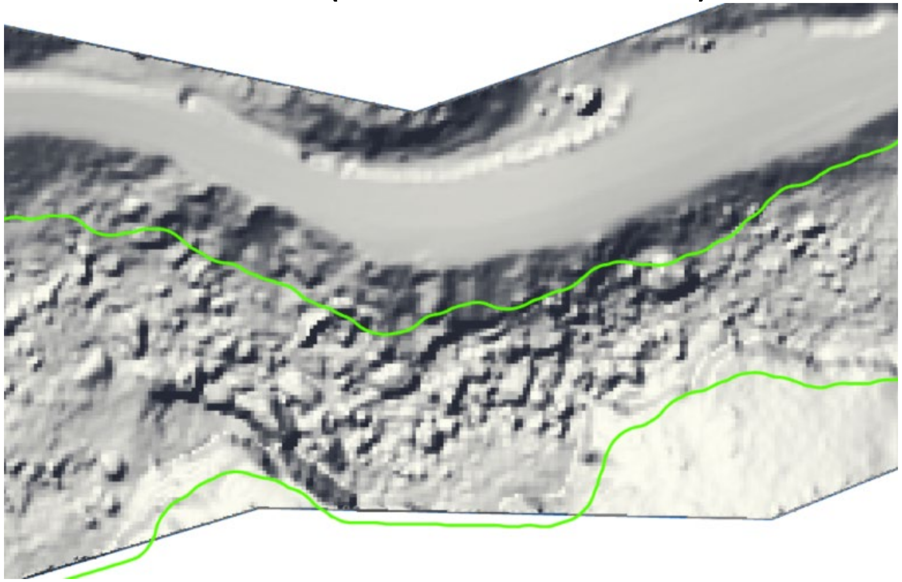
November 2, 2021

OVERVIEW

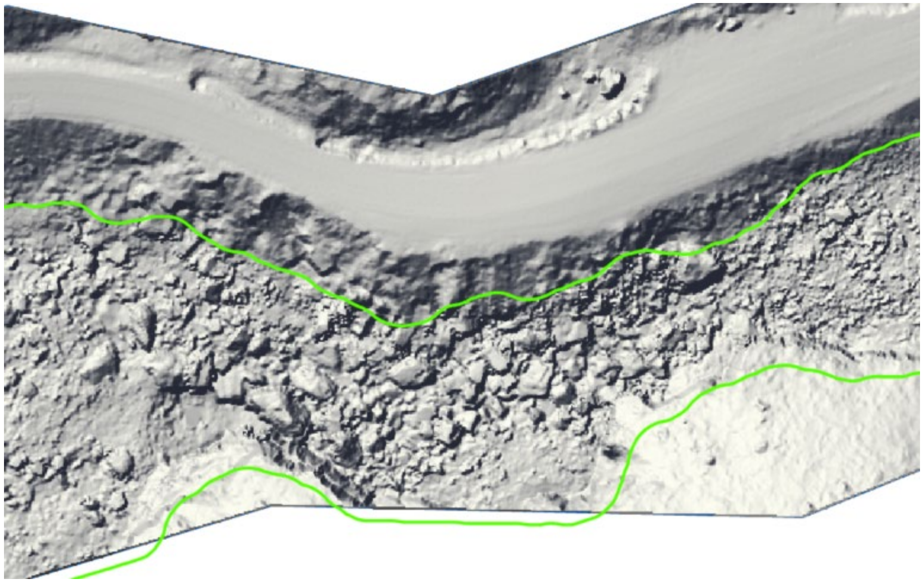
- Model Terrain
- Model Geometry
- Sensitivity Tests
- Base Model Selection

TERRAIN REFINEMENT

Before (3ft Cell Resolution)

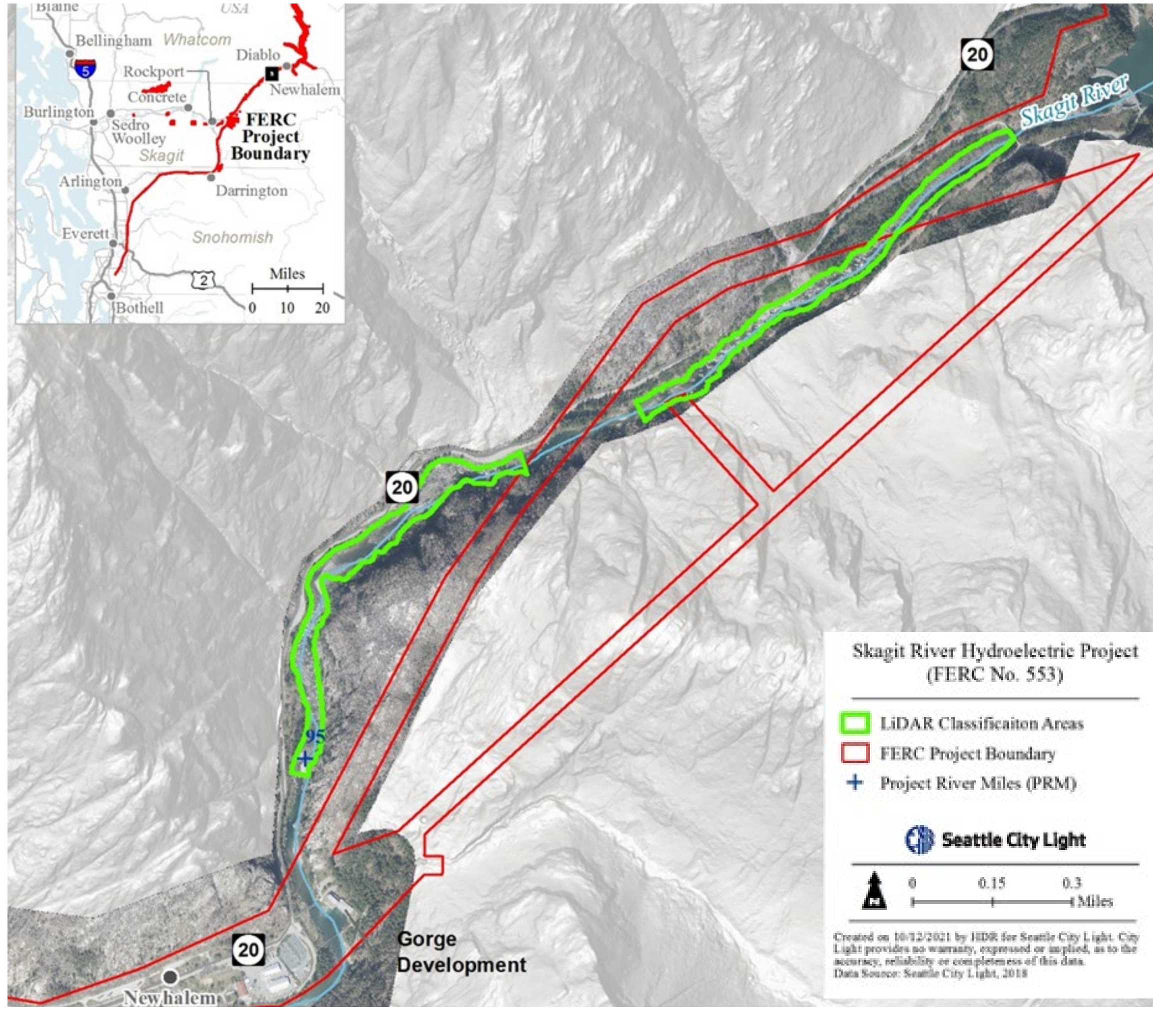


After (1ft Cell Resolution)



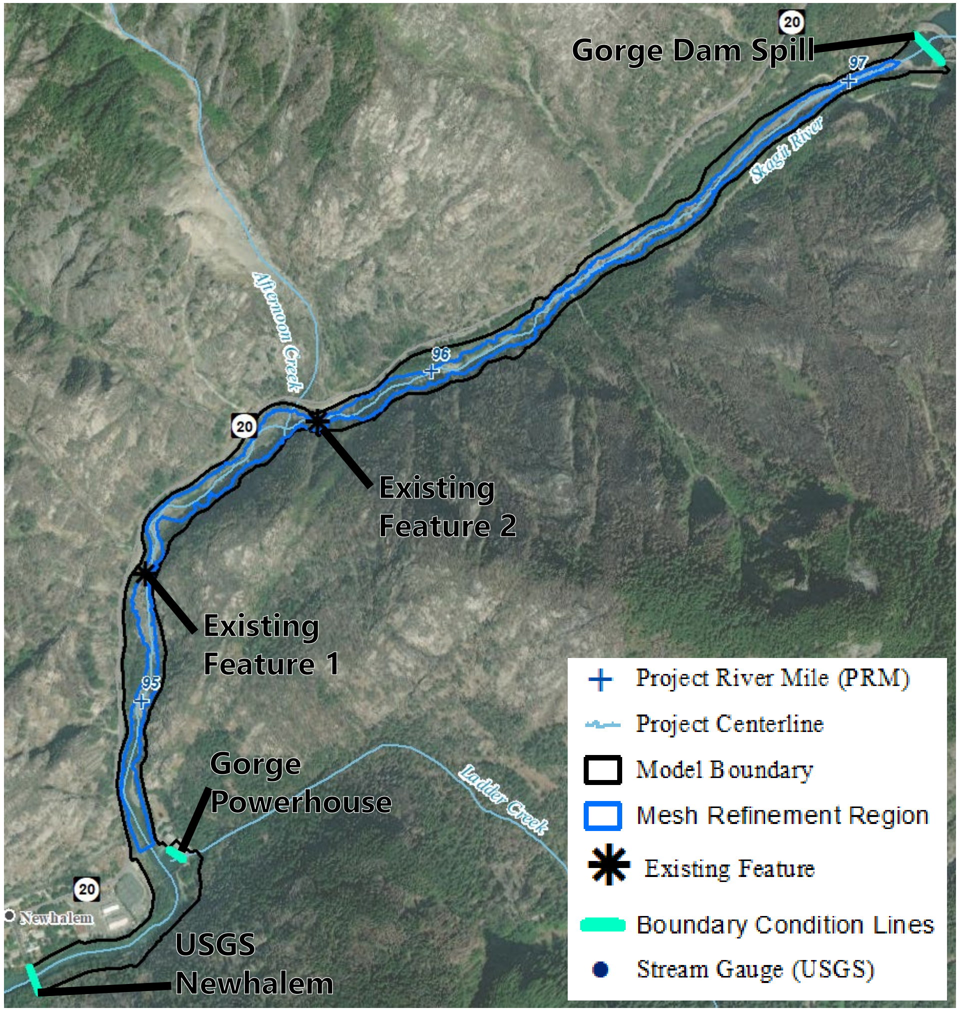
TERRAIN REFINEMENT

- Refinement extents
  - Dry Channel
  - Bank toe below vegetation
- Areas not reclassified
  - Afternoon Creek Pool
  - Gorge Dam Pool
  - Powerhouse pool/backwater



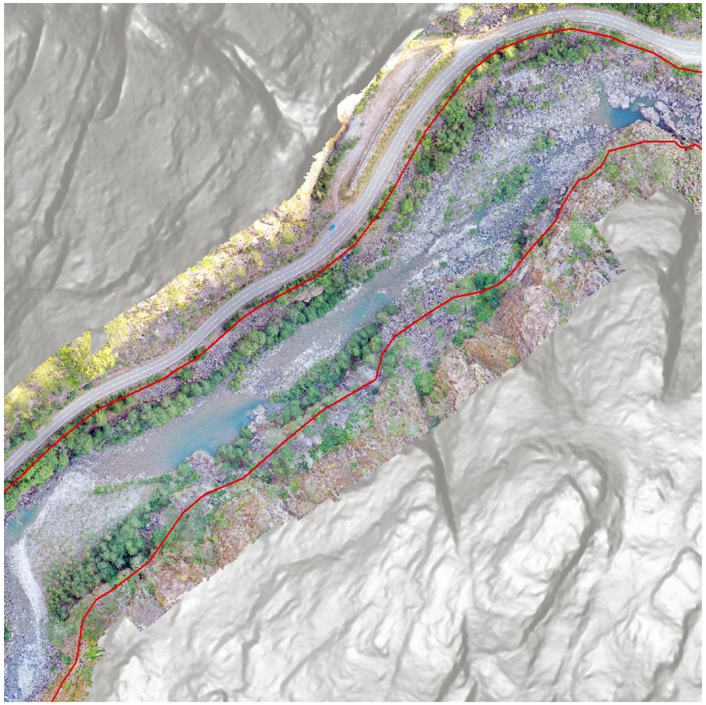
MODEL GEOMETRY

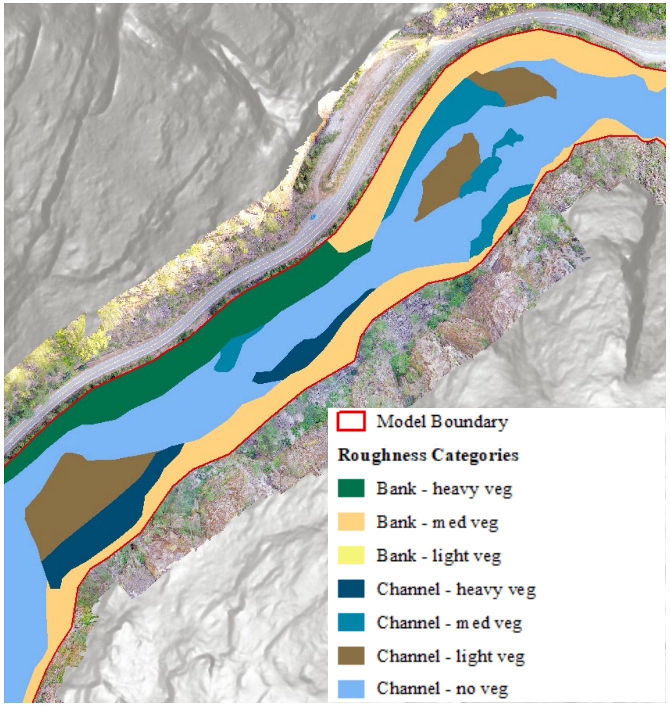
- Model Domain
  - Gorge Dam spill pool to USGS Newhalem
- Boundary Conditions
  - Gorge Dam spill
  - Gorge Powerhouse release
  - USGS Newhalem stage
- Channel refinement region
  - Channel and unvegetated bank toe
  - Covers 1′ terrain refinement



ROUGHNESS DELINEATION

- Channel and overbank – orthoimagery and preliminary model results
- Vegetation - orthoimagery





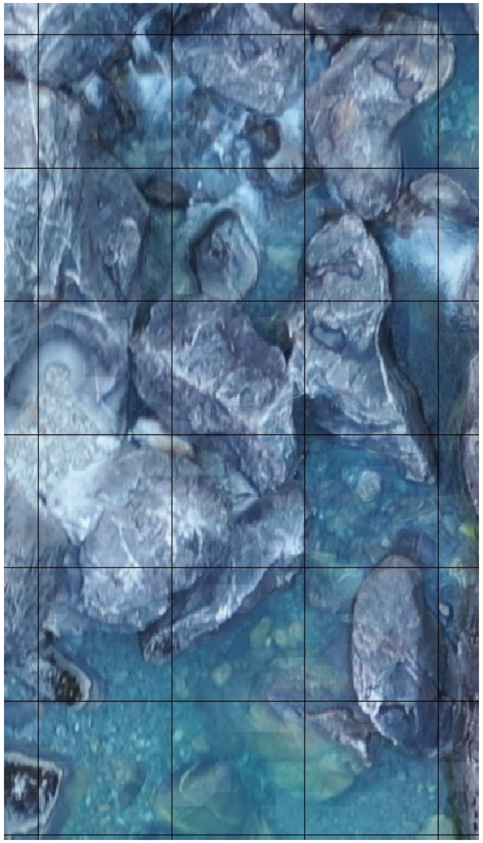
SENSITIVITY TESTS

- Cell Size
  - Timestep
- Roughness coefficient (Manning's n)
- Turbulence

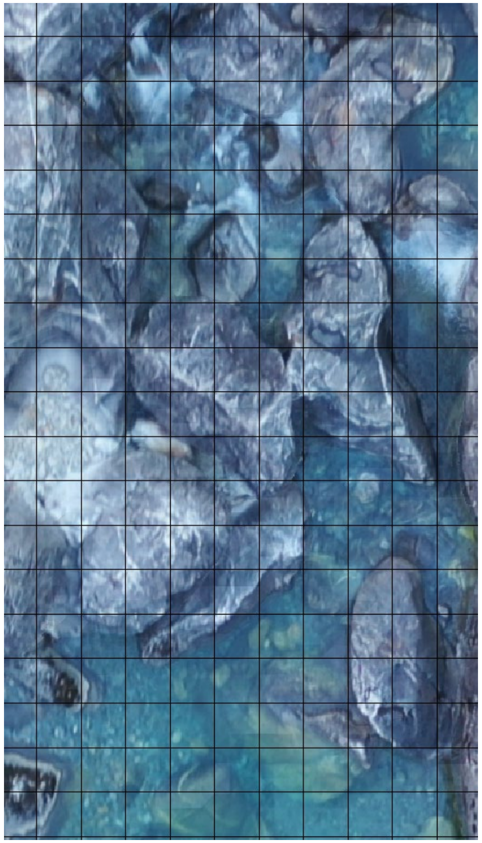
CELL SIZE SENSITIVITY

- Tested 9′, 6′, 3′, 2′, and 1′ cell size

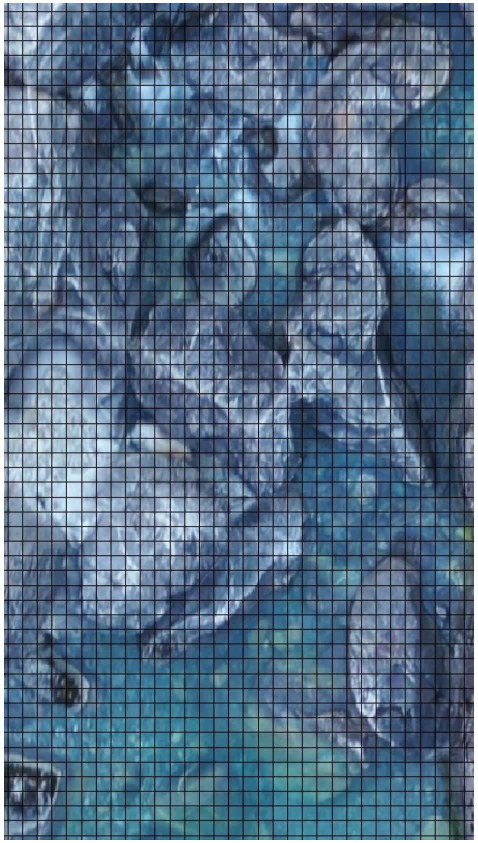
9′ Cells



3′ Cells



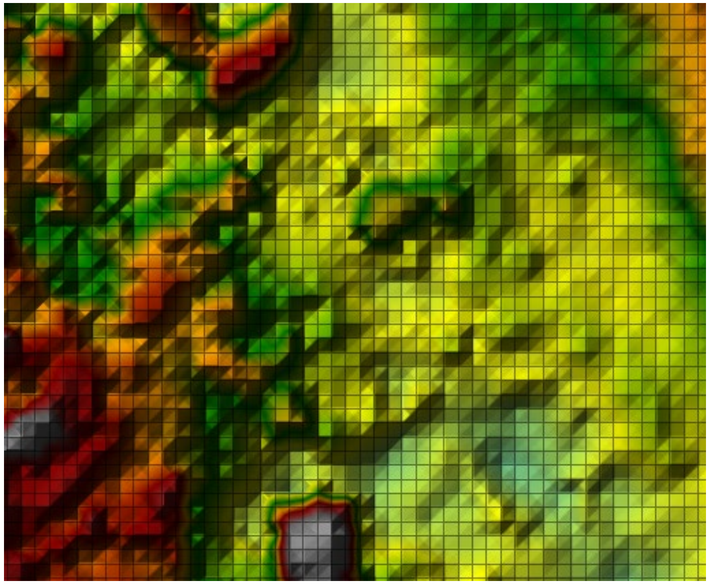
1′ Cells



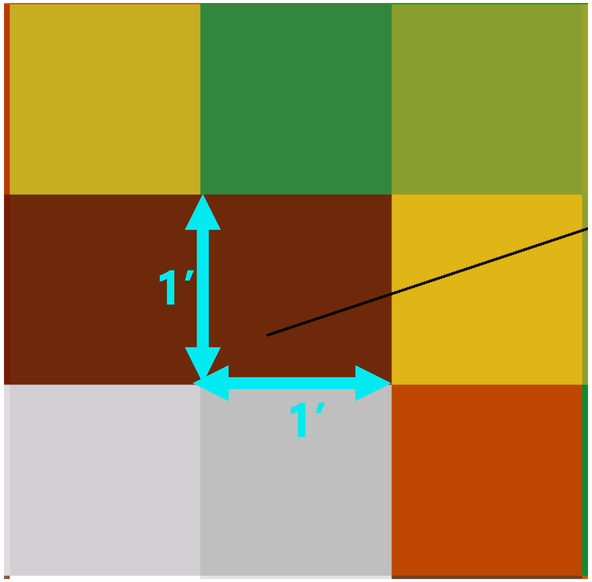
CELL SIZE SENSITIVITY

- 1-foot minimum cell size
  - Restricted by terrain resolution

1-ft Mesh Cells

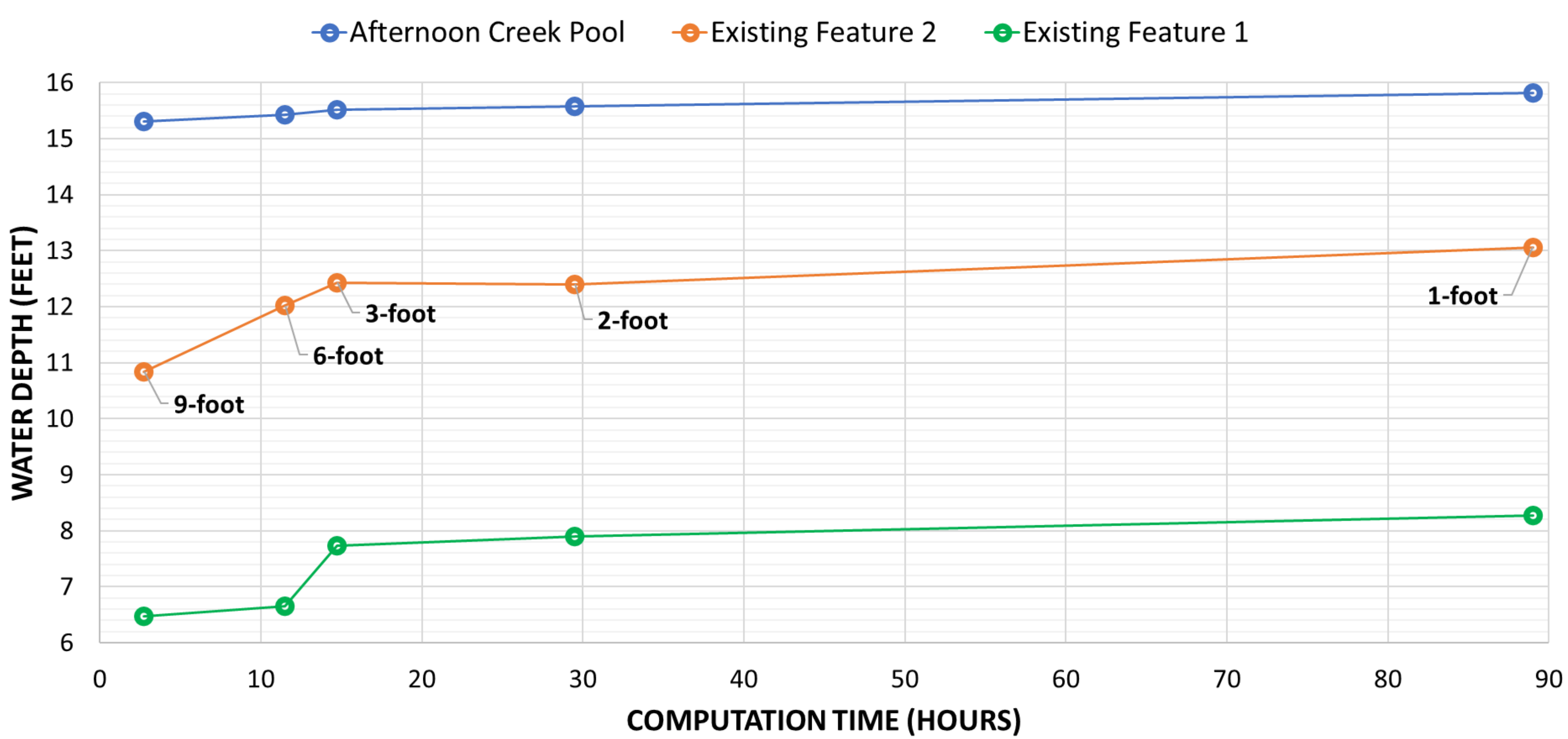


Terrain Resolution



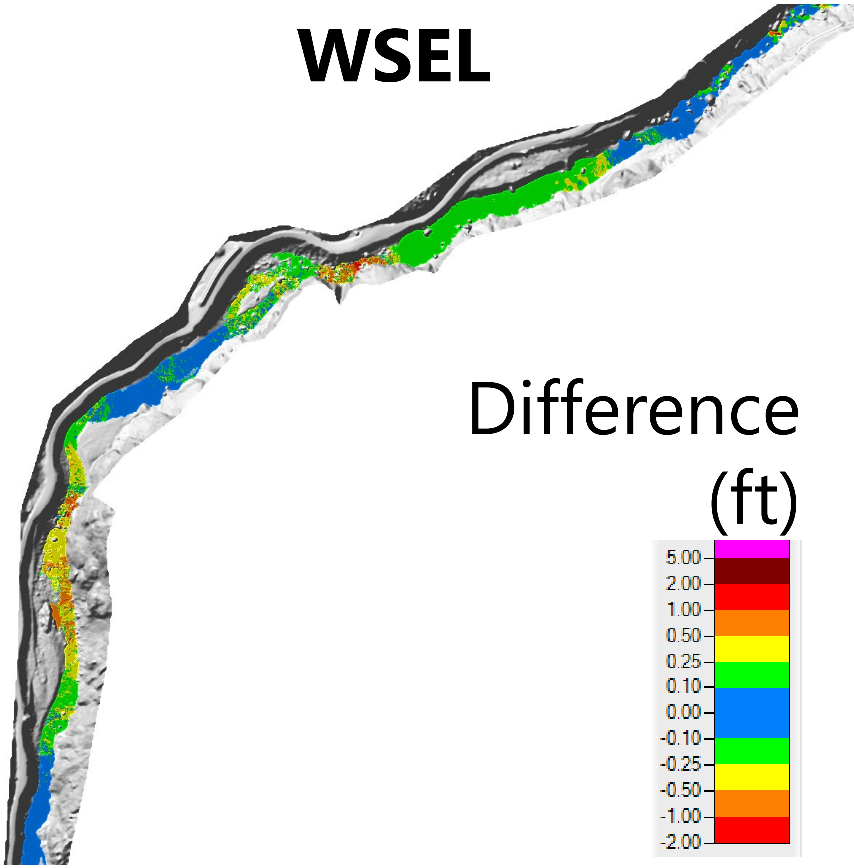
CELL SIZE SENSITIVITY

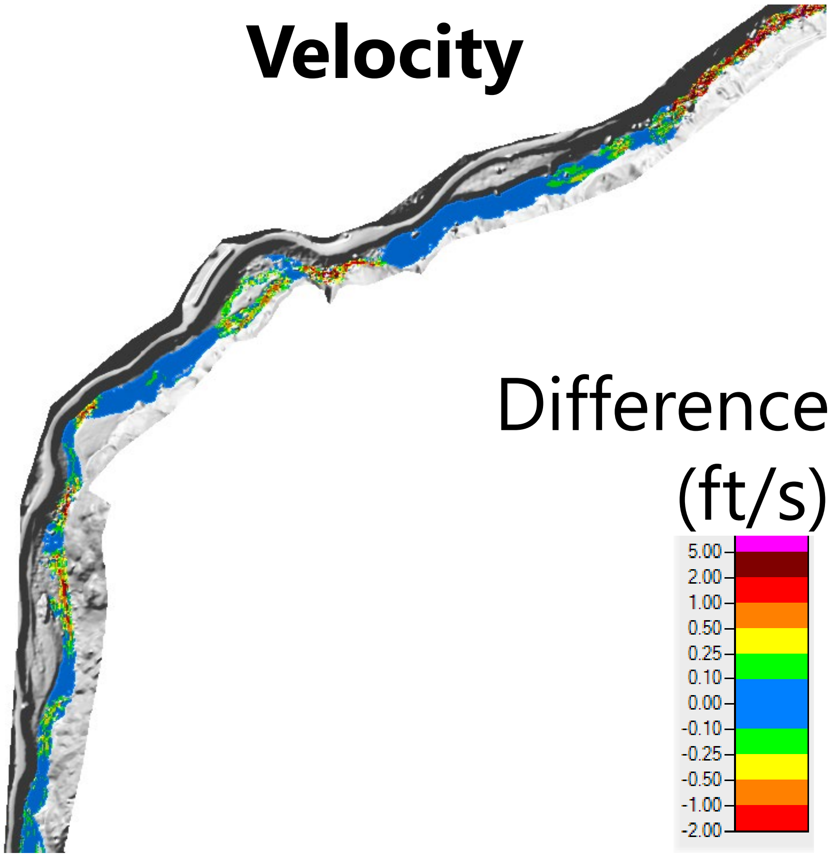
- Model results sensitive up to 1′ resolution



2' VS 1' CELL SIZE

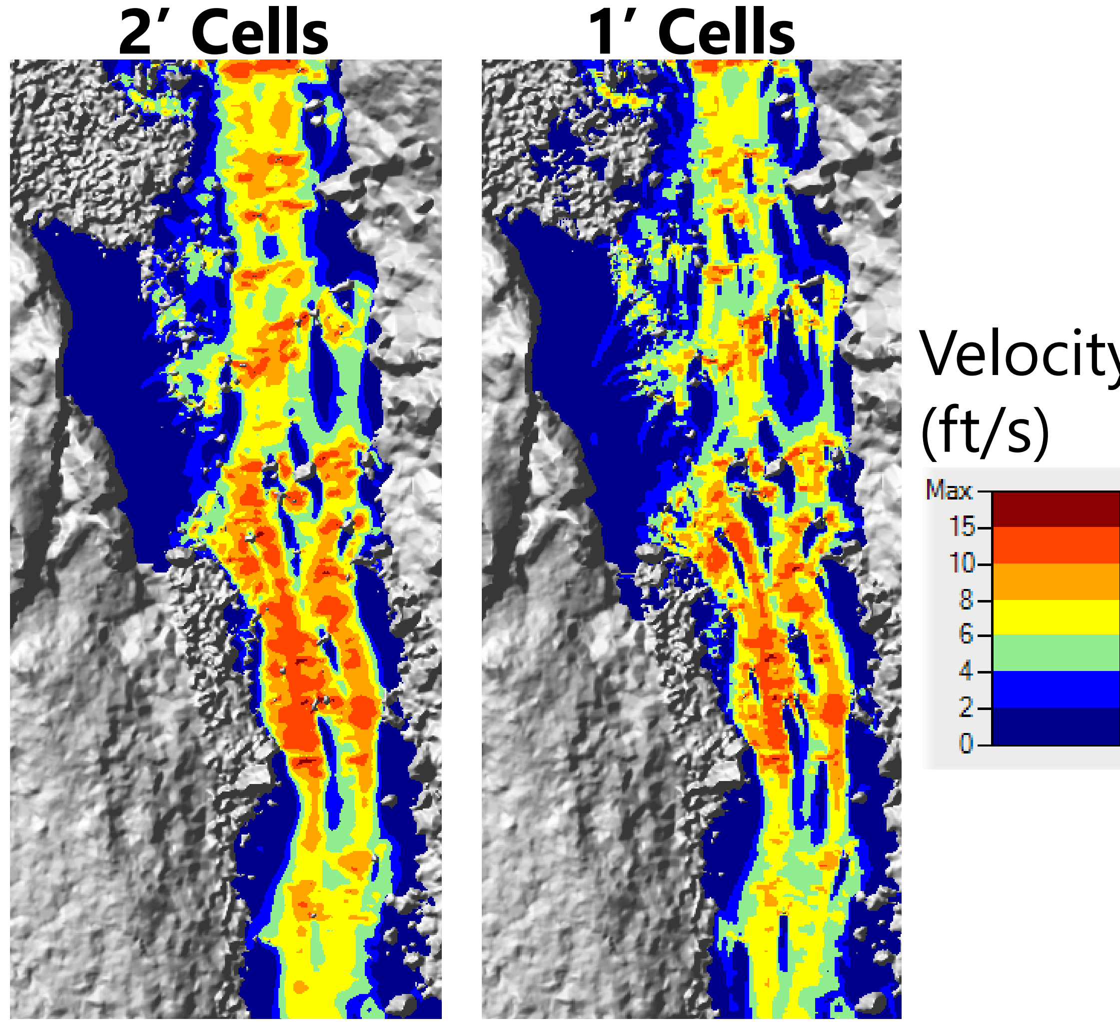
- Spatial results of cell size testing





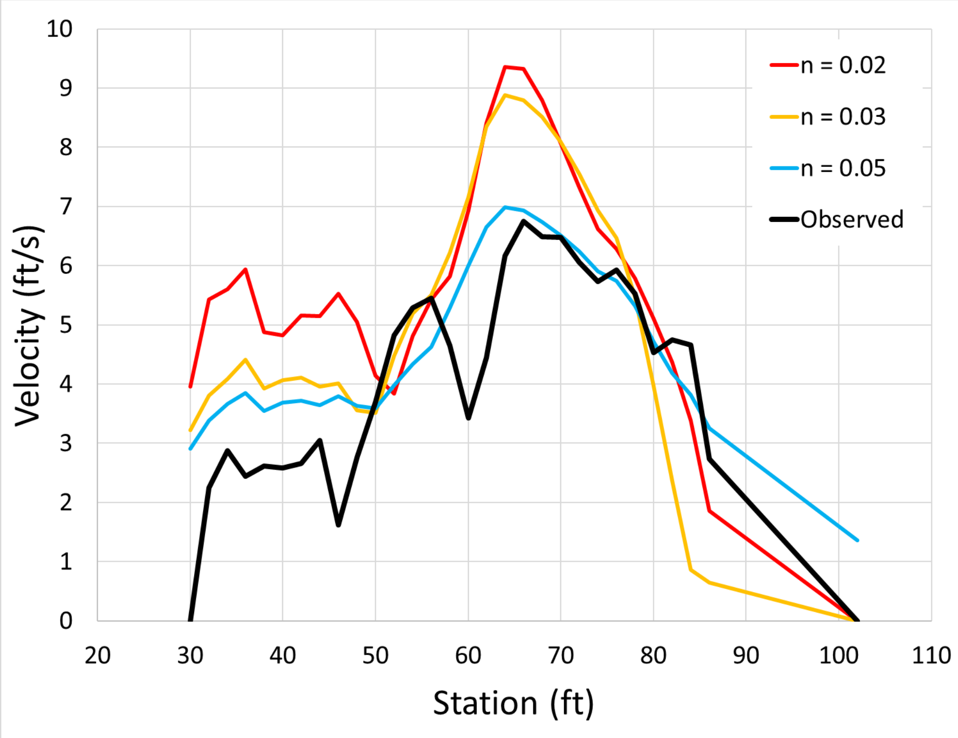
CELL SIZE SENSITIVITY

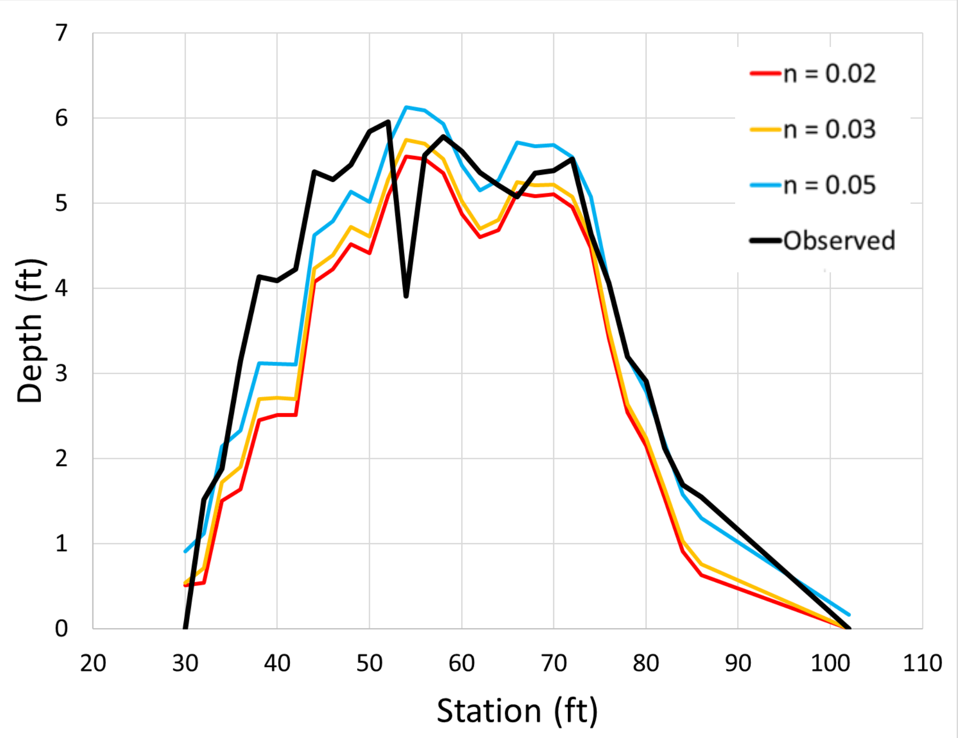
- Cell size impacts characterization of channel geometry
  - Velocity distribution



CHANNEL ROUGHNESS

Channel Roughness Sensitivity

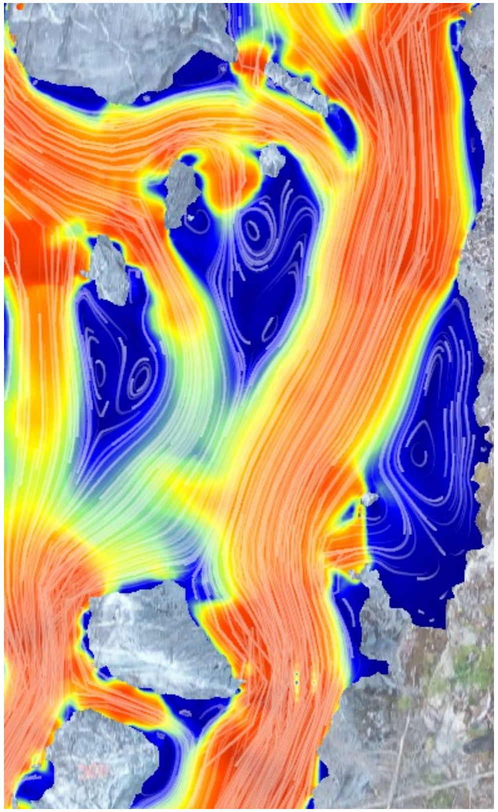




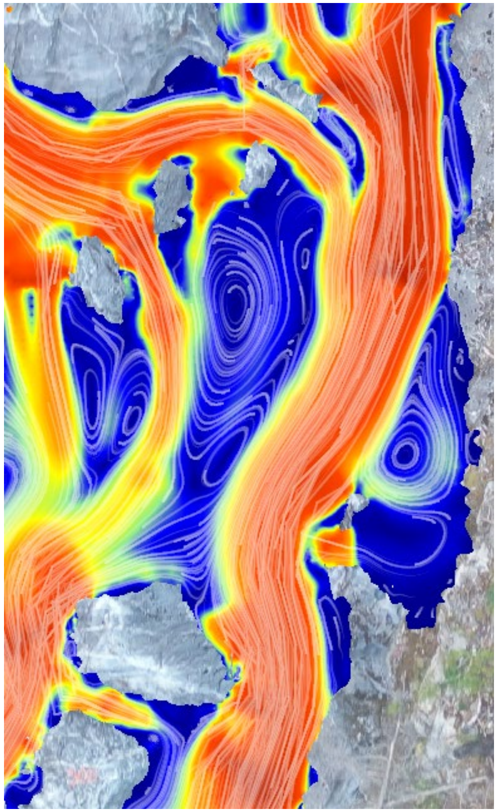
TURBULENCE SENSITIVITY

- More turbulence =
  - Stronger eddies
  - High velocity paths narrower and stronger

Turbulence Off



Max Allowable Turbulence Coefficients



BASE MODEL SELECTION

- 1′ channel cell size
  - 0.2 second timestep
- Default turbulence parameters
  - May be adjusted during model calibration

Seattle City Light

DISCUSSION

MODEL CALIBRATION AND VALIDATION

November 2, 2021

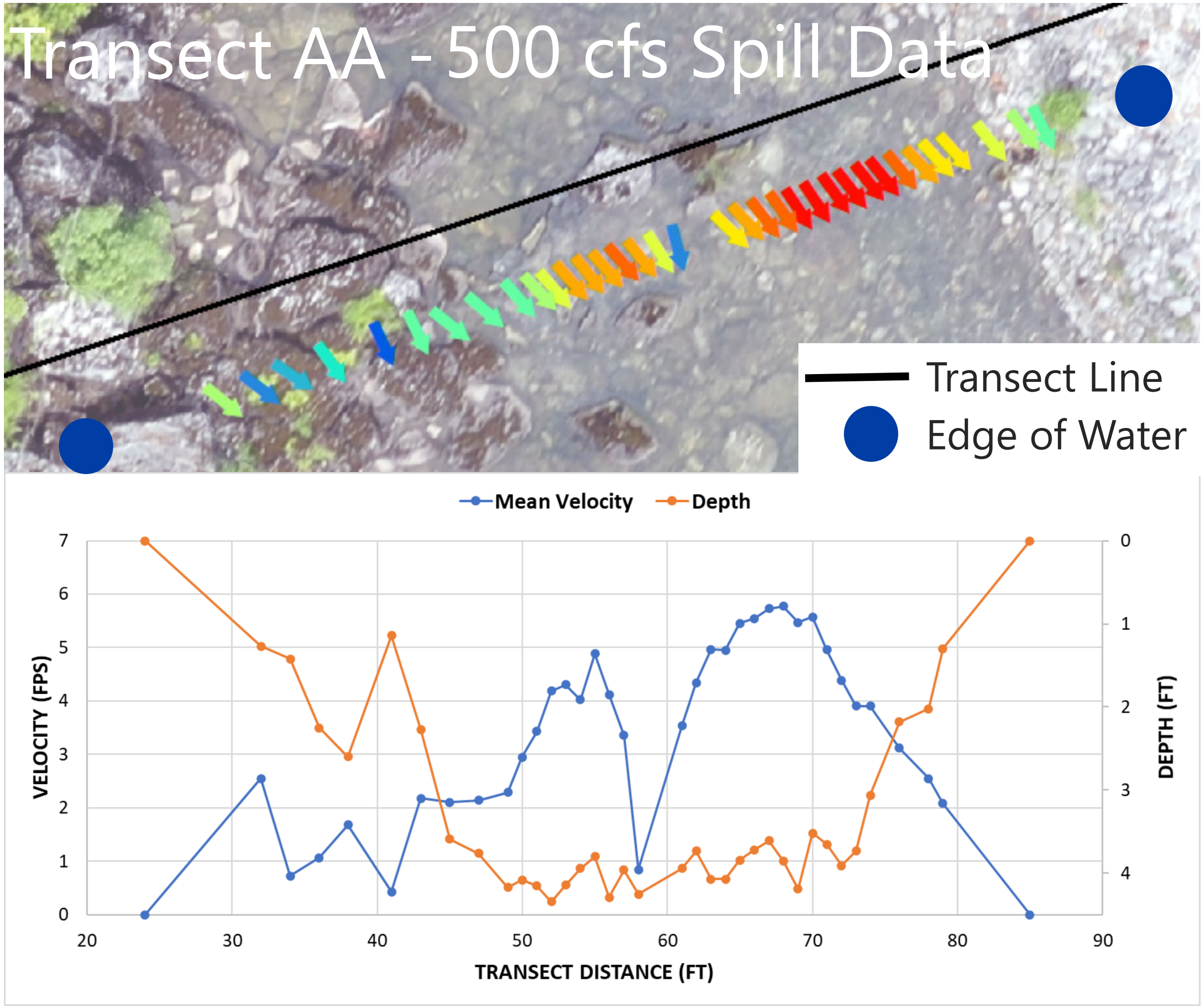
OVERVIEW

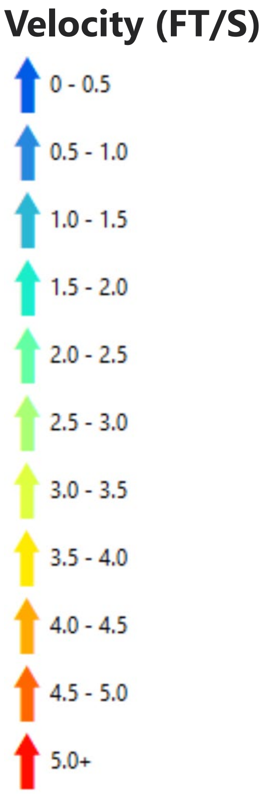
- Observed Data
- Calibration Procedure
- Current Status
- Future Trajectory

OBSERVED DATA

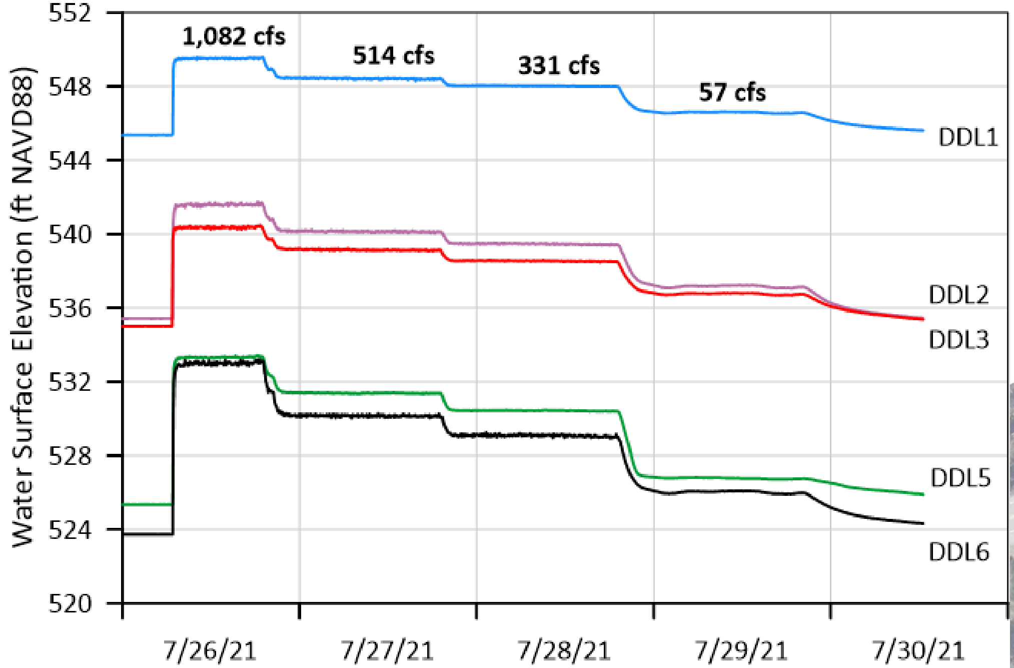
- Observations at 4 discharges + dry
  - Transects (5)
  - Level Loggers (12)
  - Drone-based ortho-images
  - Drone-based video

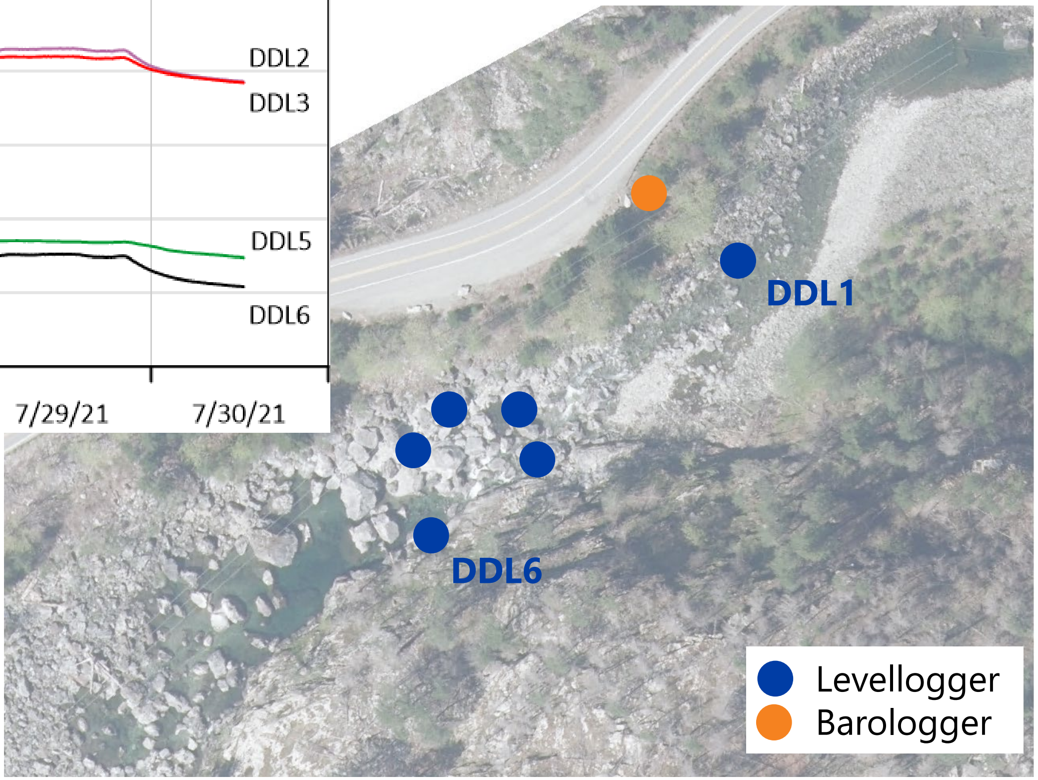
TRANSECT


Transect AA - 500 cfs Spill Data
Transect Line
Edge of Water
Mean Velocity
Depth
VELOCITY (FPS)
DEPTH (FT)
TRANSECT DISTANCE (FT)
0
1
2
3
4
5
6
7
20
30
40
50
60
70
80
90


Velocity (FT/S)
0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
3.0 - 3.5
3.5 - 4.0
4.0 - 4.5
4.5 - 5.0
5.0+

EXISTING FEATURE 1 WATER LEVELS





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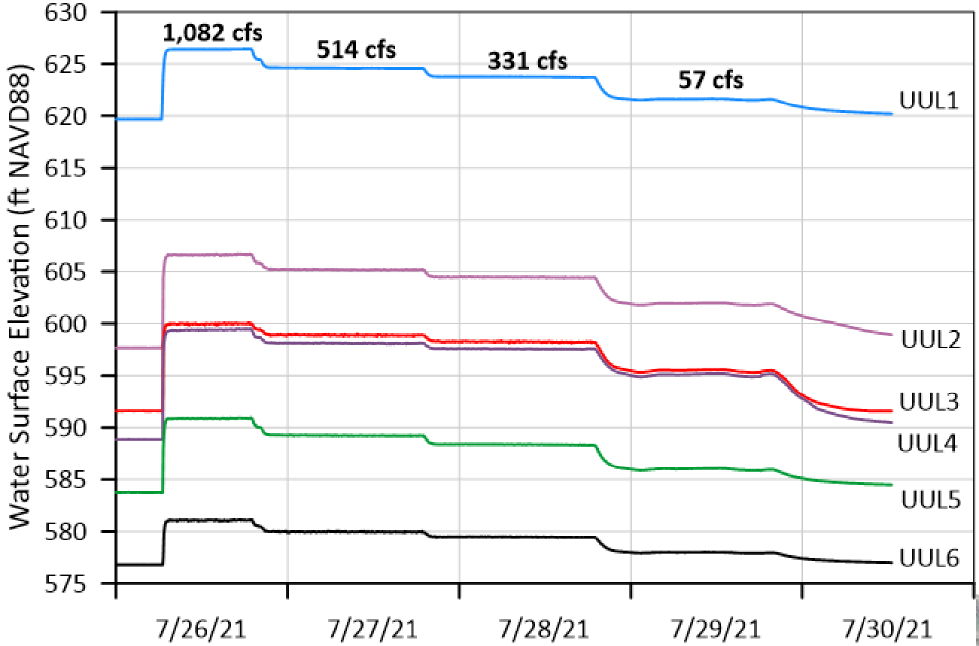
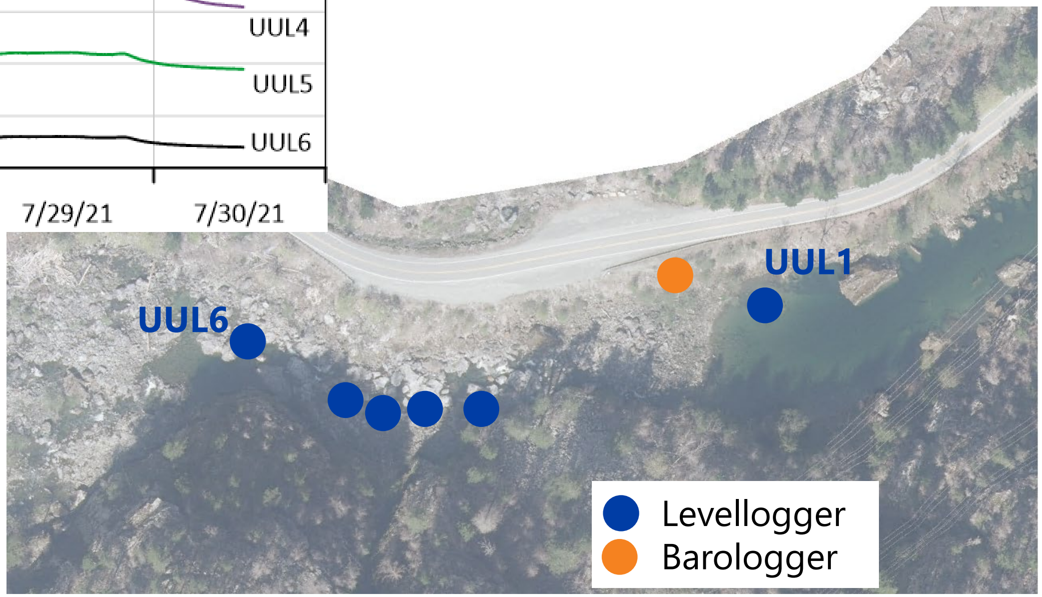
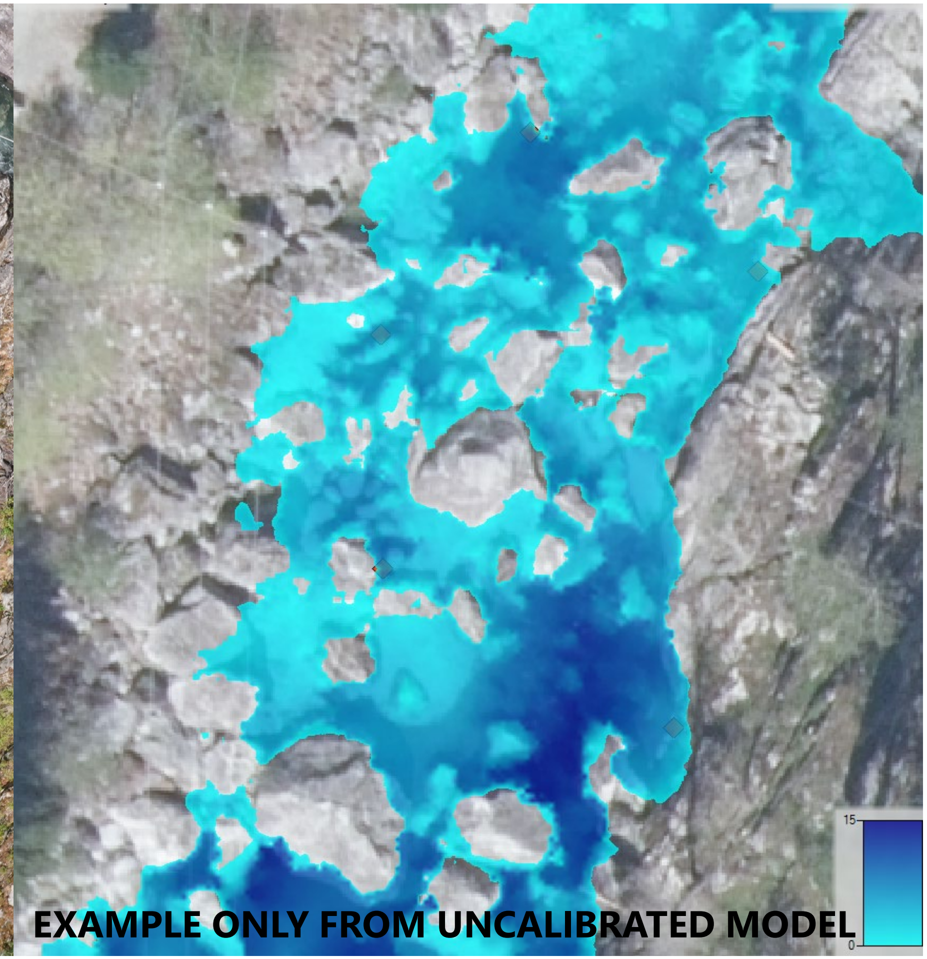
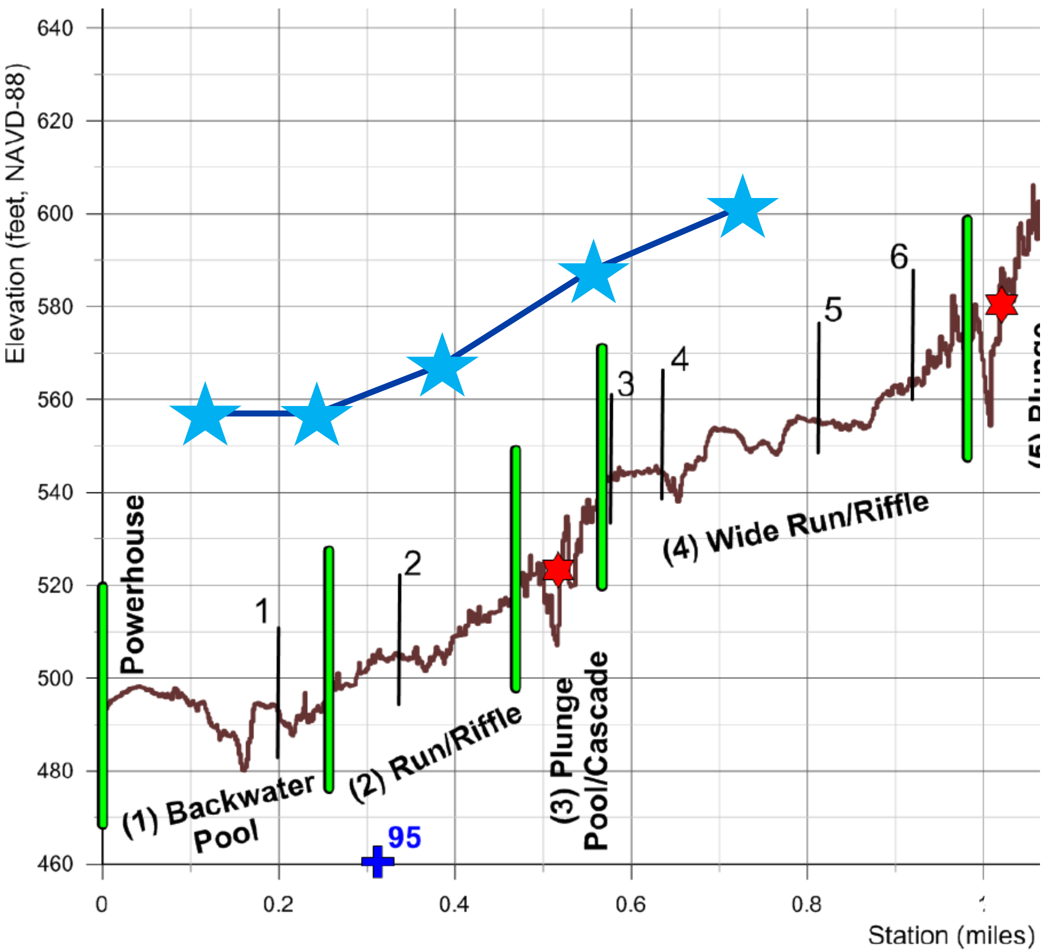




DRONE-BASED ORTHOIMAGERY – INUNDATION EXTENTS

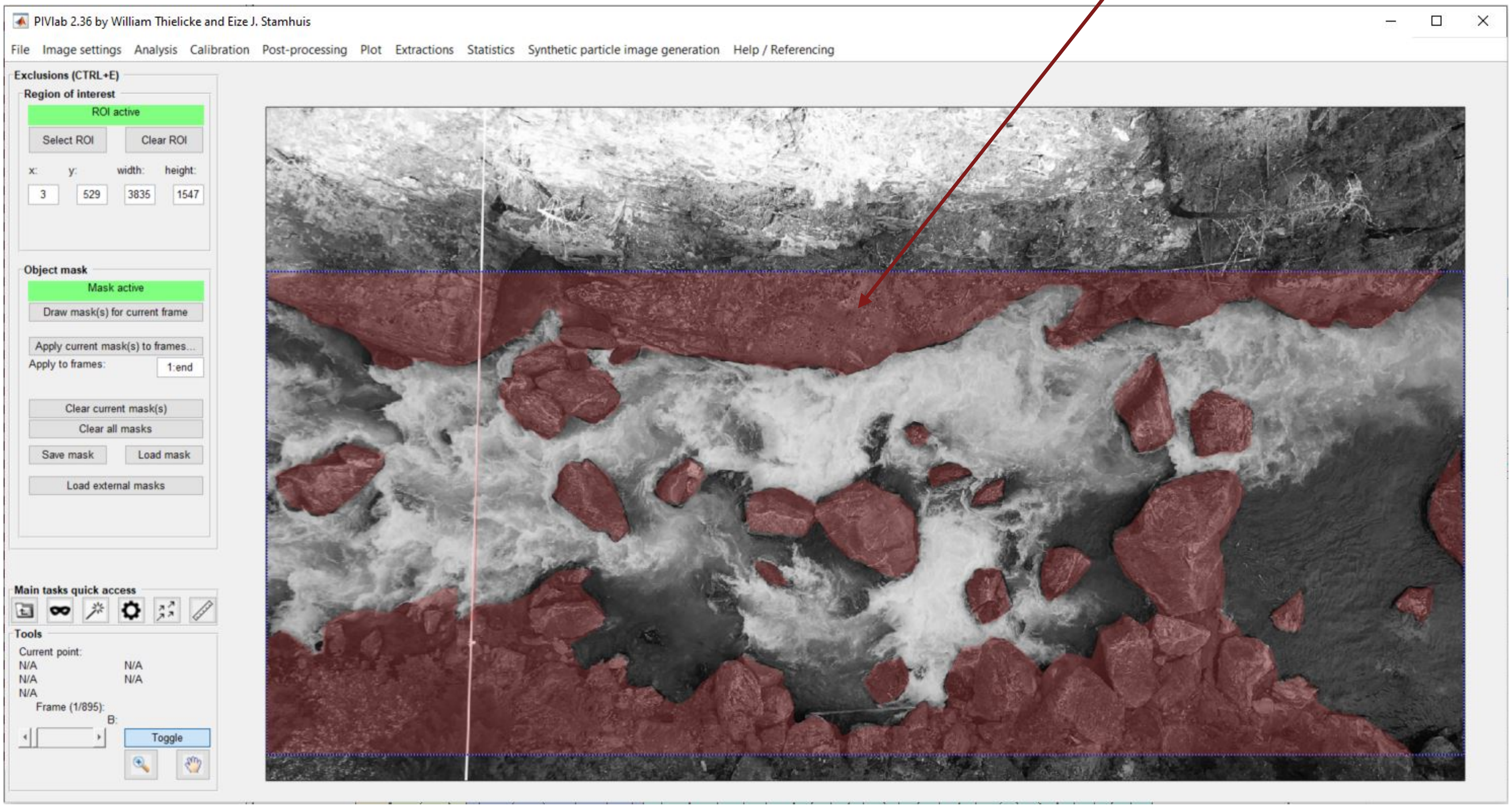


DRONE-BASED ORTHOIMAGERY – WSEL PROFILE



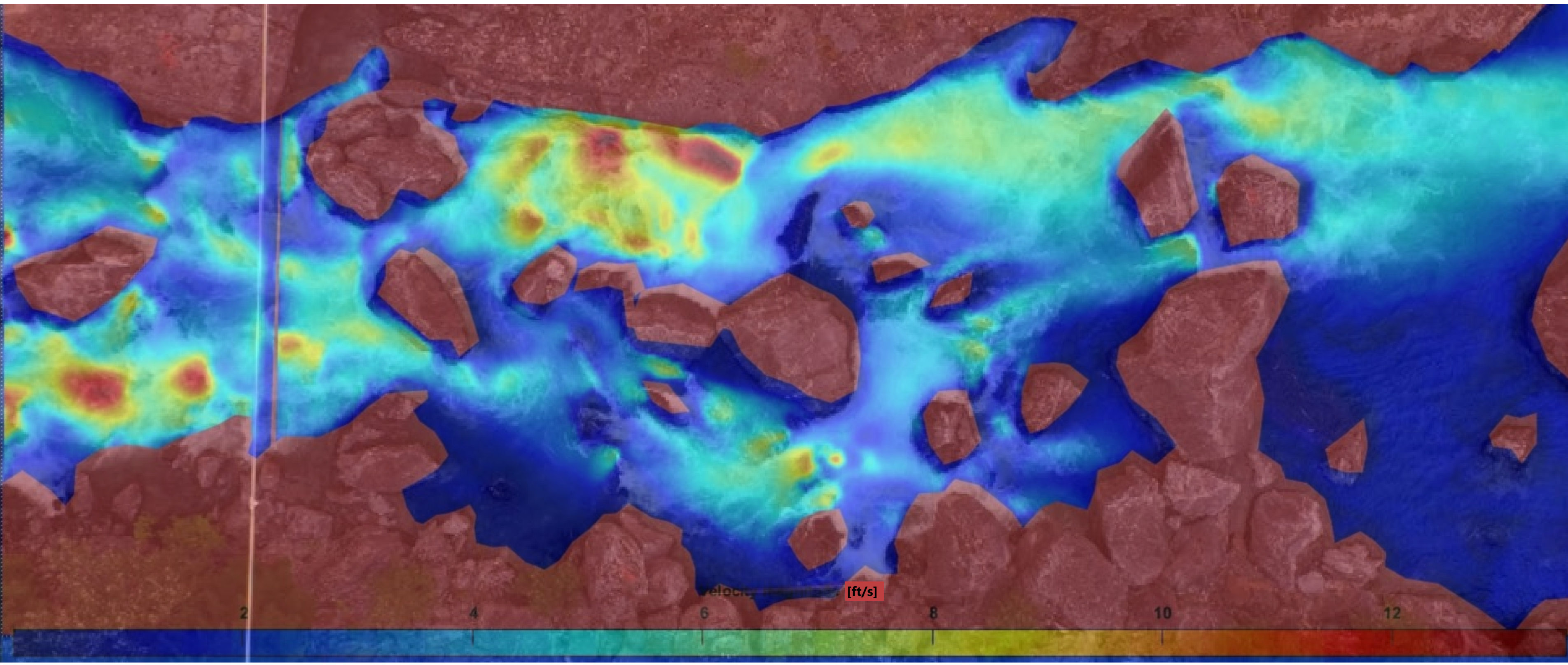
DRONE-BASED VIDEO - LSPIV

EXCLUDED AREAS

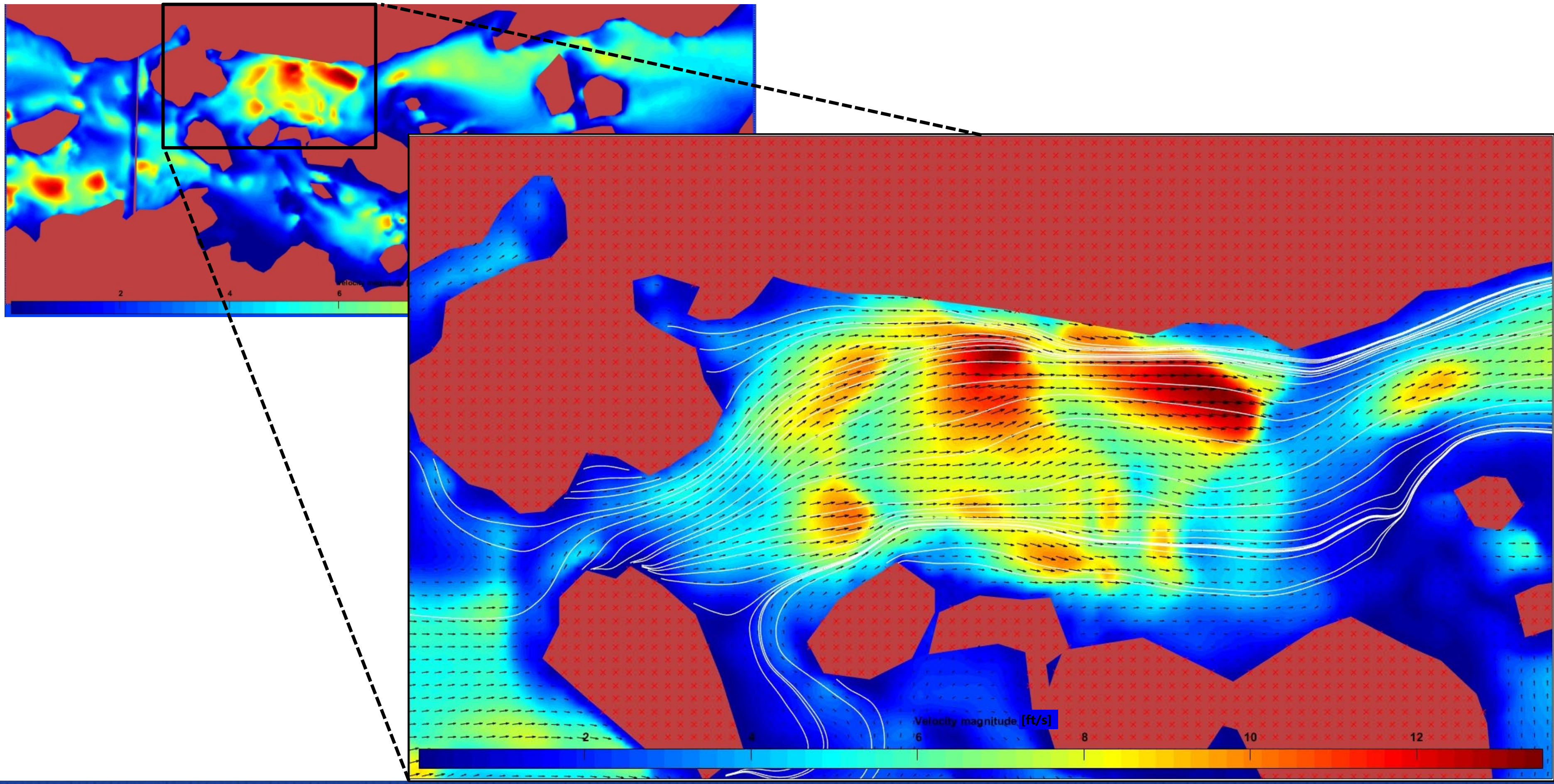


DRONE-BASED VIDEO - LSPIV

- Mean Velocity Magnitude

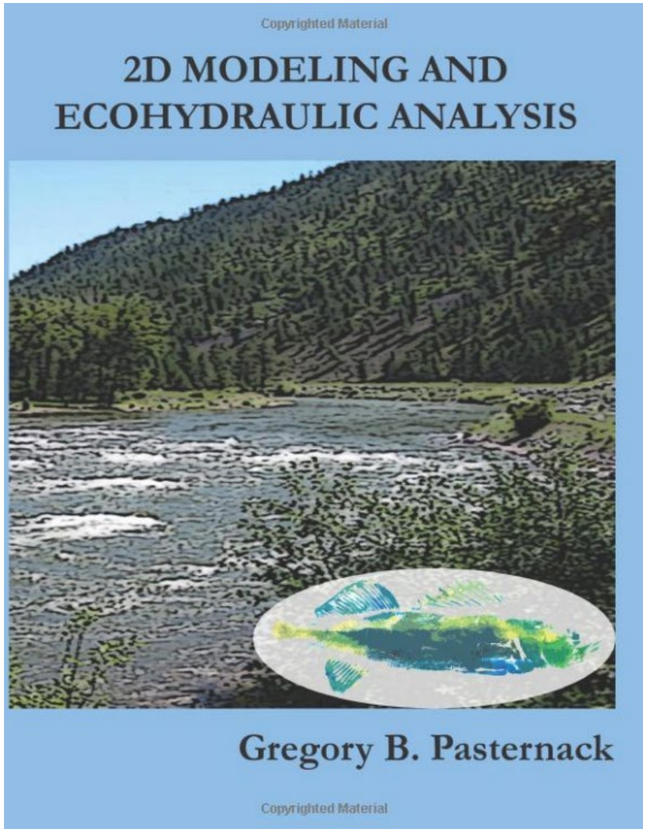


DRONE-BASED VIDEO - LSPIV



PERFORMANCE EVALUATION

- Performance evaluation standards lacking for 2D models
- Pasternack
  - http://pasternack.ucdavis.edu/
- Most common: WSEL, V_{mag}
  - Deviation, correlation, regression statistics



QUANTITATIVE PERFORMANCE INDICATORS

- Observed vs. Modeled WSEL(Depth) & V_{mag}
  - Deviation statistics (raw, %)
  - Coefficient of determination (r^2)
  - Regression line slope ~1:1
  - Zero intercept of regression line; offset?
  - Relative cross-sectional pattern ->spatial associations model error
  - Observed vs. Modeled hydraulic phase-space plots (D vs V_{mag})
- NO quantitative standards for these performance indicators have been proposed or adopted through scientific consensus

PERFORMANCE EVALUATION

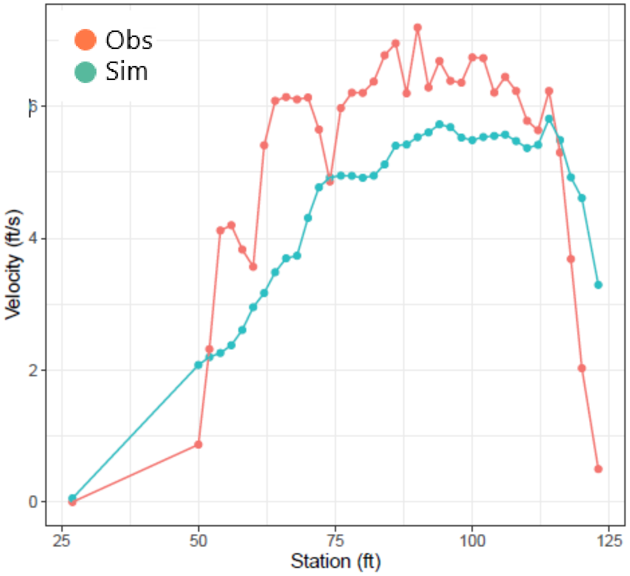
- Performance never perfect!
  - Uncertainty in observed data
  - Assumptions & simplifications in SWE and solution procedures
- Performance testing -> characterizing uncertainty

CURRENT STATUS

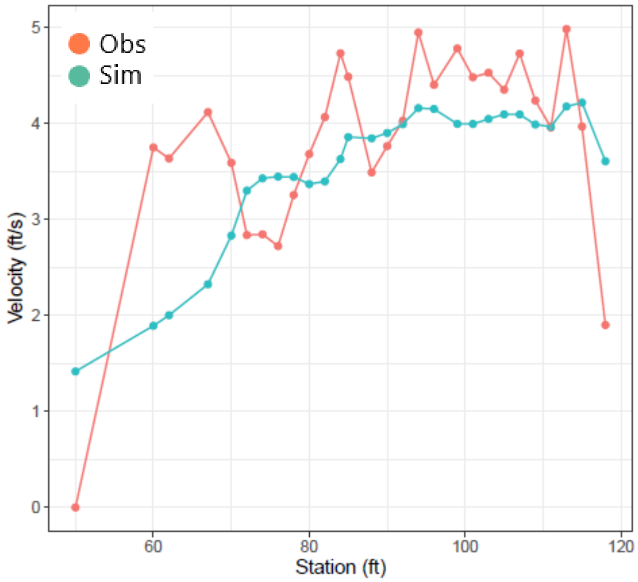
- Compare to transect and level logger data
- Focus on roughness delineation and values
- No turbulence adjustment

TRANSECT EE EVALUATION - VELOCITY

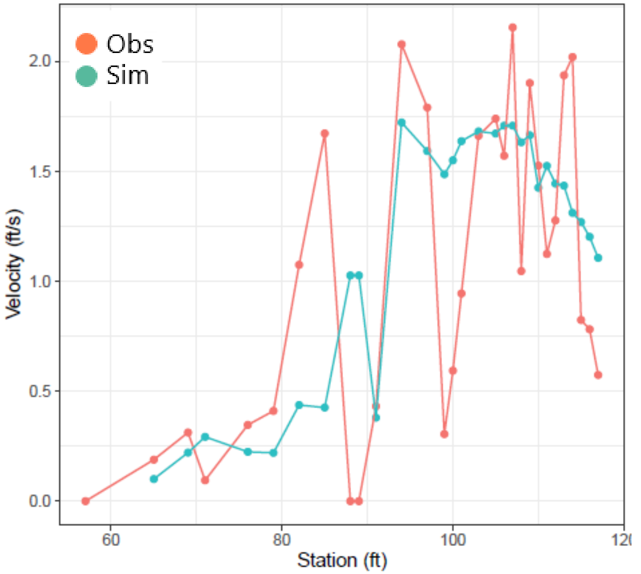
1200 cfs



500 cfs

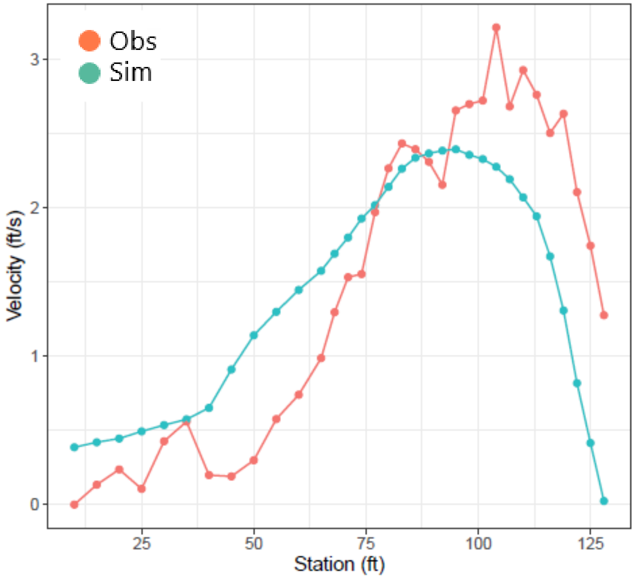


50 cfs



TRANSECT II EVALUATION - VELOCITY

1200 cfs



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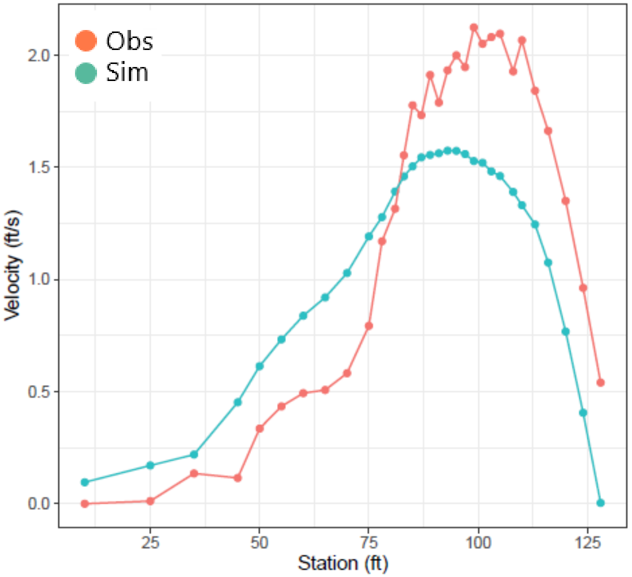

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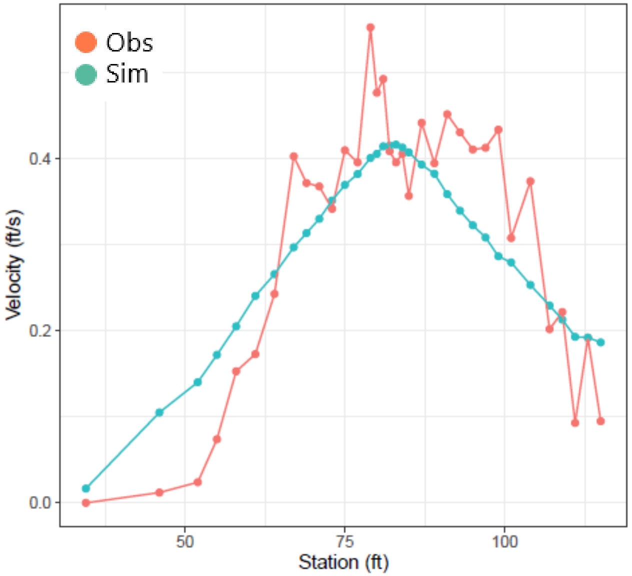
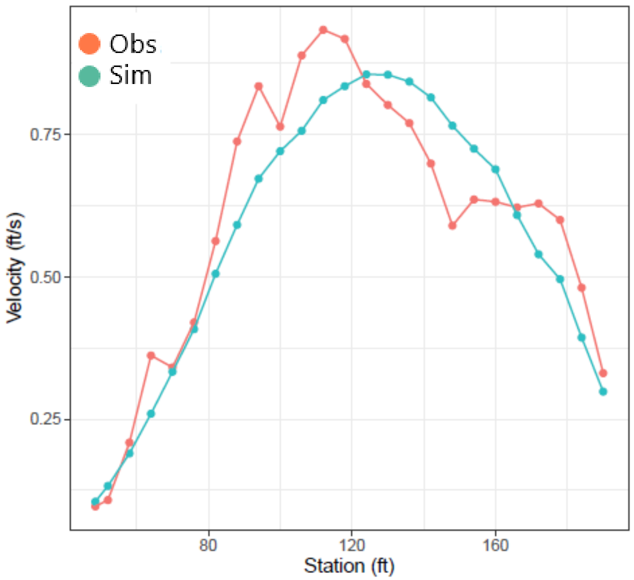


TRANSECT DD EVALUATION - VELOCITY

1200 cfs



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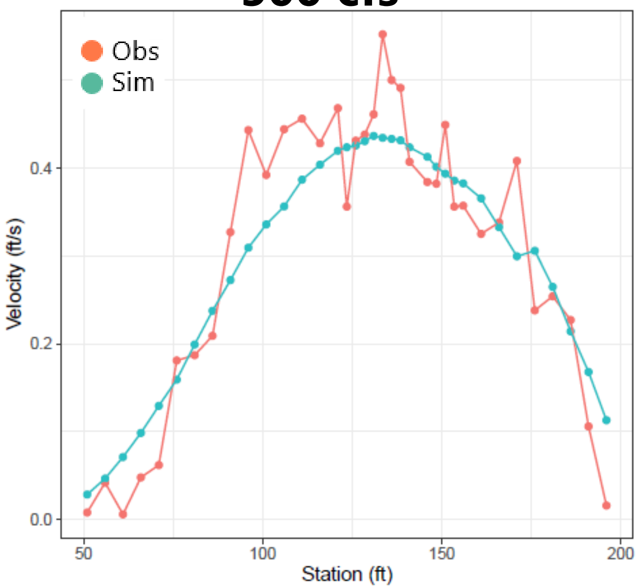

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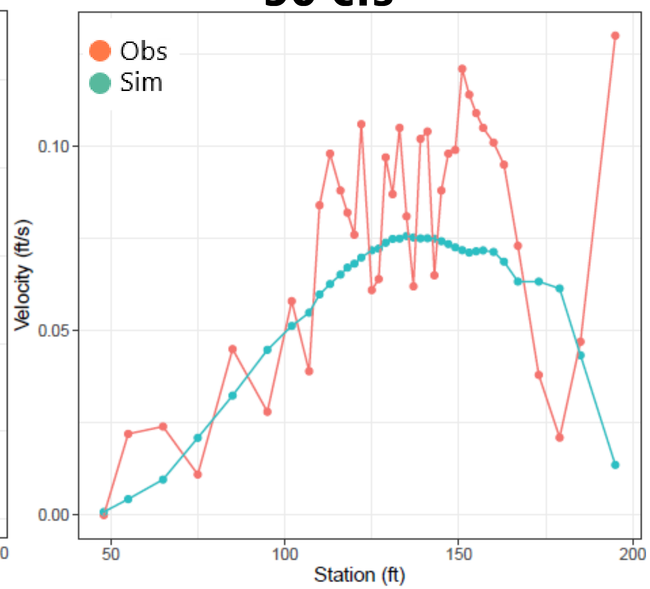
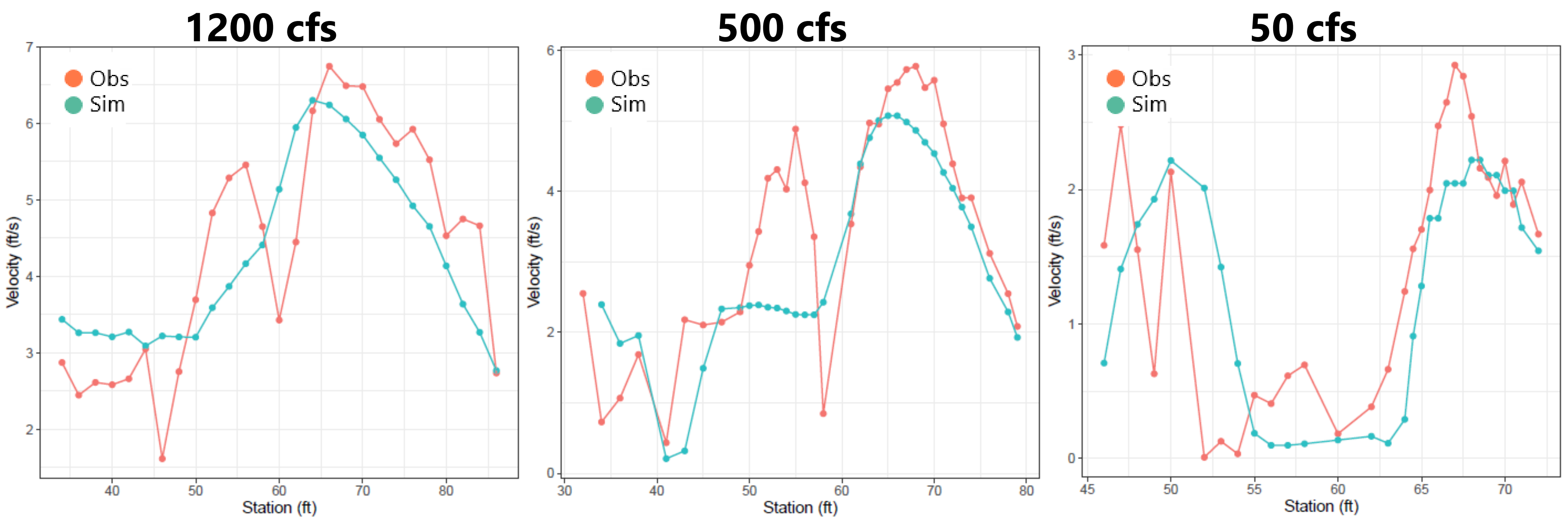
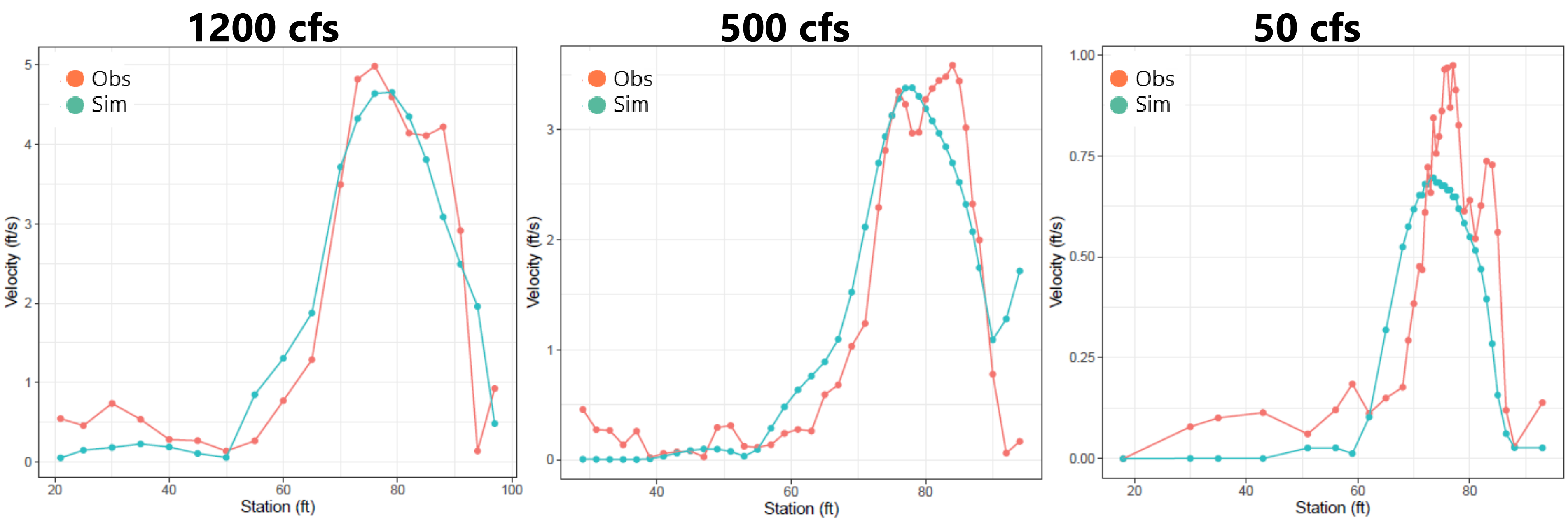


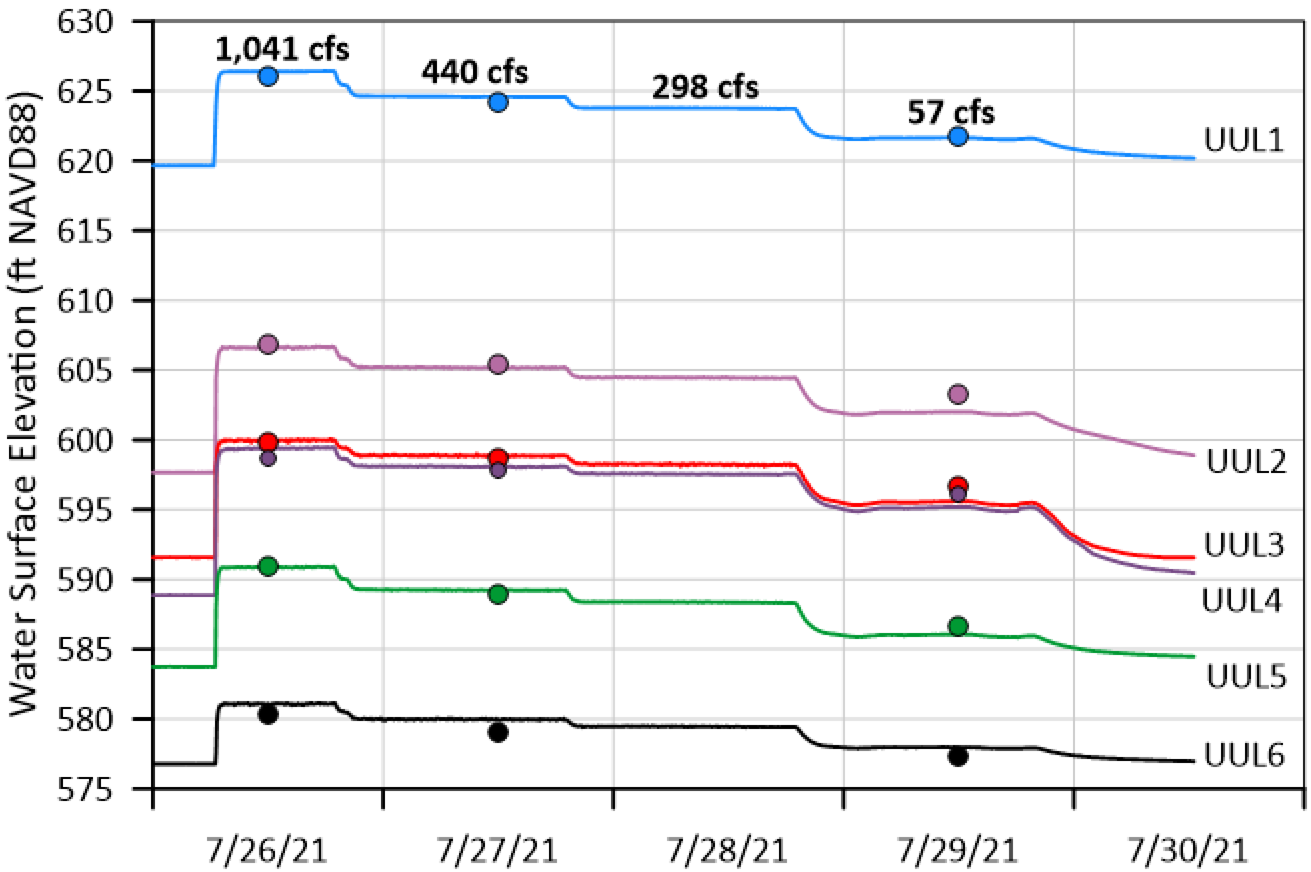
TRANSECT AA EVALUATION - VELOCITY



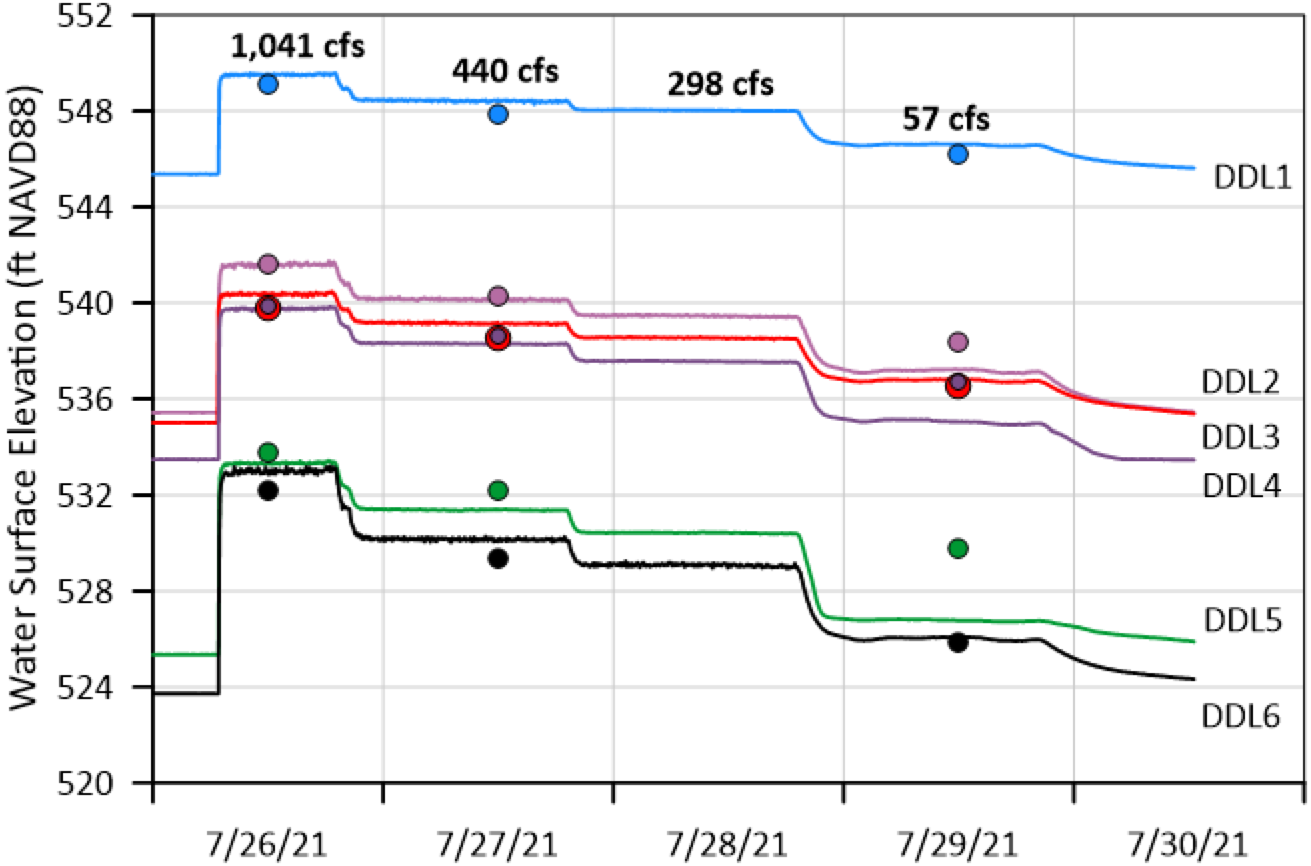
TRANSECT GG EVALUATION - VELOCITY



CURRENT PROGRESS – EXISTING FEATURE 2 EVALUATION



CURRENT PROGRESS – EXISTING FEATURE 1 EVALUATION



FUTURE TRAJECTORY

- Further calibration to observed transect data
  - Roughness delineation and magnitude
  - Turbulence
- Water surface elevation profiles
  - Longitudinal roughness variation in channel
- Level logger data
  - Calibrate to 6200 cfs at Existing Features
- Validate model output with 250 cfs observations
- LSPIV – qualitative verification

Seattle City Light

DISCUSSION

DEVELOPMENT OF BIOLOGICAL/HABITAT DATA AND INTEGRATION WITH HYDRAULIC MODEL

November 2, 2021

OVERVIEW

- Substrate and Cover Mapping Update
- HSC and Periodicity Development Update
- Aquatic & Biologic Habitat Integration Preview
- Hydraulic Data Generation for Fish Passage Analysis

SUBSTRATE/COVER MAPPING

- Field-based substrate/cover mapping occurred during July – October 2021. This data is currently being QC'd.
- Next steps will focus on filling in data gaps for areas that were difficult to access and where visibility was poor due to turbidity and/or depth. This process will be taking place over the next month to create a more complete map of substrate and cover for the bypass reach and mainstem.
- Mapping data will be shared with Geomorphology Team.

HABITAT SUITABILITY CRITERIA (HSC)

- HSC Development – Small Group Technical Meetings
  - Comprised of LPs, City Light, and Consultant team members
  - Initial focus of the group has been on developing preliminary HSC curves based on existing curves, studies and/or literature.
  - Future efforts will focus on species/life stages where field validation data is being collected.
  - HSC curves to be used for both bypass reach and below Gorge Powerhouse instream flow modeling.
  - Anticipate review of preliminary HSC curves with LPs in early January 2022.

HSC FIELD VALIDATION STUDIES

- Focus species / life stages
    - Steelhead spawning (Spring)
    - Chinook, Pink, Chum spawning (Fall/Winter)
    - Steelhead, Chinook, Bull Trout juveniles
- Data from these studies will be used to help validate (and/or potentially modify) existing HSC curves that will be used in the habitat modeling.

PERIODICITY

- Periodicity Technical Group Meetings
  - Periodicity is used to help focus habitat model results on periods that are relevant to each species/life stage being modeled.
  - Smaller technical working group comprised of LPs, City Light, and Consultant team members has been meeting to review existing information and recommend modifications to the preliminary periodicity table.
  - Periodicity is relevant to not only the FA-02 and FA-05 instream flow model studies, but several other fisheries-related studies.

AQUATIC & BIOLOGIC HABITAT INTEGRATION PREVIEW

- Calculate combined HSI and UA (not ***W***UA)
  - Substrate & cover layers
  - Modeled depths & velocities for each flow scenario
  - HSI curves for depth, velocity, substrate and cover per fish species and life stage
  - Calculate HSI and UA values
    - Calculate HSI at each point by multiplying:
      - (DEPTH HSI) * (VELOCITY HSI) * (SUBSTRATE HSI) * (COVER HSI)
    - Calculate UA values at each point by multiplying:
      - AREA * combined HSI
- Output: tabular and/or maps

HYDRAULIC DATA GENERATION FOR FISH PASSAGE ANALYSIS (FA-04)

- Per the RSP – "The calibrated hydraulic model will be run for a range of flows determined in consultation with LPs and study team fish passage specialists to generate hydraulic data to support the fish passage evaluation. The evaluation of fish passage will be conducted as part of the Fish Passage Study (FA-04)."
- Also providing:
  - Drone photos of Bypass Reach (controlled releases)
  - LSPIV raster maps (controlled releases)
  - Recorded level logger data (full record)

Seattle City Light

DISCUSSION

Skagit River Hydroelectric Project
Seattle City Light (City Light)
Flows Work Group
FA-05 Gorge Bypass Reach Hydraulic and Instream Flow Model Development, Workshop #4
November 2, 2021

Draft Meeting Summary

Disclaimer: These notes are provided to serve as a high-level summary of the meeting and as a communication tool to benefit work group continuity. They are streamlined and focused on action items, unresolved issues, future discussion items, and high-level discussion points. They are not intended as a formal record of the meeting.

Attendance

Licensing Participants (LPs):
Brock Applegate, Washington Department of Fish and Wildlife (WDFW)
Stuart Beck, Kleinschmidt Group (for Swinomish Tribe)
Steve Copps, National Marine Fisheries Services (NMFS)
Susannah Erwin, National Park Service (NPS)
Kiza Gates, WDFW
Kirk Gehl, Nlaka'pamux Nation Bands Coalition
Rick Hartson, Upper Skagit Indian Tribe (USIT)
Jonathan Kohr, WDFW
Ashley Rawhouser, NPS
Dudley Reiser, Kleinschmidt Group (for Swinomish Tribe)
Alison Studley, Skagit Fisheries Enhancement Group (SFEG)
Kara Symonds, Skagit County
Stan Walsh, Skagit River System Cooperative (SRSC)

Federal Energy Regulatory Commission (FERC):
Matt Cutlip, FERC

Seattle City Light (City Light):
Andrew Bearlin, City Light
Erin Lowery, City Light

Consultant Team:
Danielle Hanson, Consultant Team - HDR
Donnie Jones, Consultant Team – NHC
Bao Le, Consultant Team – HEC
Malcolm Leytham, Consultant Team – NHC
Chris Long, Consultant Team – NHC
Ty Ziegler, Consultant Team – HDR

Facilitation Team:
Joy Juelson, Facilitation Team
Alex Sweetser, Facilitation Team

Meeting Materials

Meeting materials are stored on the Skagit SharePoint site.

- Meeting Agenda
- Meeting Slides: FA-05 Gorge Bypass Reach Hydraulic and Instream Flow Model Development, Workshop #4
- Memo: GHD/Bypass Reach Model Flow Testing (Test 0)
- Memo: GHD/Bypass Reach Model Flow Testing (Test 1)
- Memo: GHD/Bypass Reach Model Flow Testing (Test 2)
- Memorandum: Gorge Bypass Reach Discharge Measurement Uncertainty Analysis

Action Items

Action	Responsibility	Deadline
LP Action Items		
None identified at this meeting.		
City Light Action Items		
Confirm with the FA-04 Fish Passage Study Team that the study's passage analysis at existing features will assess passage (both hydraulically and temporally) for each target species.	City Light	Before next workshop
Provide information to support comparison of bypass reach controlled releases vs. unregulated flows to LPs.	City Light	Before next workshop
Facilitation Team Action Items		
Prepare draft meeting summary and send to LPs for review.	Triangle	Two weeks

Summary of Issues Discussed, Action Items, and Decisions

Welcome, Introductions, Agenda Overview

The facilitator, Joy Juelson, welcomed the group and led a roll call. She briefly walked through the agenda and reviewed action items from the last *Gorge Bypass Reach Hydraulic and Instream Flow Model Development Workshop* held on August 26, 2021.

Study Overview

Erin Lowery, City Light, explained that today's meeting is the fourth of five *Gorge Bypass Reach Hydraulic and Instream Flow Model Development* (FA-05) workshops. The next meeting will be in February 2022. He noted the initial hydraulic model for the Bypass Reach has been completed, and this meeting will discuss the model's calibration.

Chris Long, Consultant Team, reviewed the purpose of the meeting, outlined in the agenda. He explained that the Consultant Team is approximately halfway through model calibration. As part of the meeting, the team will outline and discuss the calibration flow selection and the uncertainty analysis with LPs. To address an action item from the last FA-05 workshop on the Gorge Bypass Reach Discharge Measurement Uncertainty Analysis, NHC developed and shared a memorandum, included in the meeting materials. Additionally, Ty Ziegler, Consultant Team, will discuss the development and integration of biological and habitat data being collected and reviewed as part of the study's Habitat Suitability Criteria (HSC) curves.

Present and Discuss Calibration Flow Selection and Uncertainty Analysis

Malcolm Leytham, Consultant Team, presented on calibration flow selection and the uncertainty analysis (see slides 5–16), including an overview of a high flow late June spill and controlled releases between July 26-29. Additionally, he explained the methodology for spillway discharge calculations.

- In response to a question about the 878.51 pool elevation used for the single gate rating, Malcolm explained there is no difference in the pool elevation because it is a fixed value with variable discharges.
- In response to a question about variable pool elevations at different locations in Gorge Lake, Malcolm clarified that this should be accounted for in the pool elevation measurement location.

Controlled release flows (July 26-29)

Donnie Jones, Consultant Team, gave an overview of flows data collected during the controlled releases between July 26-29th. He explained that discharge was measured at five transects and the bridge below the Gorge Dam. Discharge measurements at transects II, DD, and the bridge were the most reliable, and discharges from transects EE and GG were acceptable. Measured discharges from transect AA were not used.

- Donnie clarified that measured depths and velocities at Transect AA were of high quality and will be used for model calibration. However, there was a higher degree of computed discharge uncertainty, which is why the discharge measurements from transect AA were not used.
- In response to a question about the data collection methods, Donnie explained the Consultant Team used a station-by-station method using USGS standard ~~statistical~~ methods. Data is continuously collected from a stationary position over 40 seconds at each station; there is not a need for repeat measurements.
- In response to a question, Donnie explained that when the sampling raft is tethered, there is generally less than a foot of lateral movement~~, which is why the minimum cell size is half a foot for their measurements~~.
- In response to a question about measurement stations, Donnie explained that ADCP measurements were spaced such that each measurement sampled 5% or less of the total flow at a transect.
- Donnie and Chris Long clarified that all the data collected at Transect AA is useful for measuring depth and velocity. The measured uncertainty does not mean there is a lack of confidence in the depth and velocity measurements. Instead, the uncertainty is around the ~~discharge at those depths and velocities compared to the~~ calculated discharge.

Additionally, Donnie presented the uncertainty analysis of measured flows, as requested by LPs at the previous FA-05 workshop. Discharge was presented in longitudinal plots, with uncertainty presented in black bars on the graph. Measured discharges were compared to the 1) mean flows in the Bypass Reach, 2) mean flows above Afternoon Creek, and 3) mean flows below Afternoon Creek. Lower mean flows below Afternoon Creek indicate potential flow loss at transects DD and GG.

- Malcolm and Donnie explained that it is difficult to hit lower flow release targets through the spillway gates and log chute. Due to this difficulty at the controlled release flow range, they could not reliably use City Light's reported releases from the spill gates.
- In response to a question, Donnie noted spills were held for approximately 12 hours. Erin Lowery added that the three memos provided by City Light engineers (see meeting materials) explain the methodology used to determine when equilibrium was reached so that flows were stabilized. Any gains or losses of flows ~~in data collection~~ occurred when the flow was at equilibrium.

- Donnie explained that the Consultant Team worked with John Riedel, NPS (*retired*), to consider possible explanations for the loss of flow. They theorized that flow loss may reflect groundwater storage and subsurface flow paths through coarse material deposited throughout the Bypass Reach. Additionally, dry conditions in late June due to the heat dome and low base flows in July provided more potential for groundwater storage.
- In response to a question about the small difference in U/S and D/S mean flows on July 29th, Chris Long noted thate ~~historical temperatures in June led to increased flows from melting ice. This may have led to the~~ subsurface pathways may have filleding during the higher flows earlier in the week. ~~The measures indicate a clear trend of loss occurring after Afternoon Creek.~~
- In response to an LP question, Malcolm explained there is no plan to collect additional data to test for flow loss in the bypass reach during periods of higher groundwater saturation ~~due to the extensive field program and the late June uncontrolled release~~.

Update and Discuss Model Development and Sensitivity Analysis

Donnie Jones presented on the development of model terrain, model geometry, sensitivity tests, and base model selection (see slides for technical details 28-41).

Since the last meeting, the model terrain was refined to a 1-foot resolution and the channel cell size was set to one ft based on sensitivity testing. Deep pools were not refined due to the negligible impact on hydraulic model calculations. Roughness delineation was developed through orthimagery and preliminary model results.

- In response to a question about an inconsistency ~~the channel roughness dip in depth~~ in modeled velocity compared to field observations at Transect AA ~~60 feet~~, Chris Long explained the terrain used in the sensitivity analysis was the original 3-foot terrain~~, but not refined terrain~~. This terrain has been reclassified at a 1-foot resolution, and the inconsistency ~~dip~~ may be caused by a channel feature that will be captured at the increased resolution.

Present and Discuss Model Calibration and Validation

Chris Long presented an overview of observed data, the calibration procedure used to calibrate the model, the status of model calibration and validation, and the process for the study moving forward.

Observed data

Chris Long explained data was collected in the last week of July at four discharges over five transects and 12 level loggers in the Bypass Reach. The level loggers were evenly divided between the two existing features and placed in coordination with the Fish Passage Technical Studies Program (FA-04) team. Additional data was gathered with drone-based orthoimagery and used to compare the model to observed conditions.

- In response to a question, Chris noted that the Consultant Team has not yet ground-truthed model velocities at the Existing Features with surface velocities derived from drone video. Since the drone products will be digital, they plan to use spatial analyses to determine differences.

Current Status

Donnie Jones presented the status of the Bypass Reach model calibration and walked through the velocity comparison at each transect. Additionally, he presented the current progress to evaluate the two existing features in the Bypass Reach. Moving forward, further calibration of observed data is needed for roughness delineation, velocity magnitude, and turbulence. Level logger data will be used to calibrate the model to 6200 cfs at the existing features, and model outputs will be validated with 250 cfs observations.

High-level Overview of the Development of Biological/Habitat Data and Integration with Hydraulic Model

Ty Ziegler, HDR, gave a high-level overview of biological and habitat data collection and its integration with the hydraulic model. He noted field-based substrate and cover mapping occurred between July – October 2021, and once it is quality controlled, the next step will be filling in data gaps. Then, the mapping data will be shared with the Geomorphology Team.

Ty explained that a small technical group of LPs, City Light, and Consultant Team members has met several times to review existing Habitat Suitability Criteria (HSC) curves and/or develop HSC curves using other studies and literature review (as appropriate). Field validation data will be collected in 2021 to help validate HSC curves for several species/life stages. The resulting preliminary HSC curves will be used for flow-habitat assessments in both the Bypass Reach and below Gorge Powerhouse. He noted the small group anticipates reviewing the preliminary HSC curves in early January and will meet on November 4th to update the Flows-HSC Work Group.

Ty noted another small technical group of LPs, City Light, and Consultant Team members has been meeting to discuss periodicity, which is used to help focus habitat model results on periods that are relevant to each species/life stage being modeled. Periodicity will not only tie into the FA-02 and FA-05 studies but several other fish-related studies.

Chris Long provided a preview of aquatic & biological habitat integration and hydraulic data generation for the FA-04 Fish Passage Study (see slides 73-74). He noted that the calibrated hydraulic model will be used to generate hydraulic data to support the fish passage evaluation. In addition to the hydraulic model, the FA-05 Consultant Team will provide drone photos of the bypass reach, LSPIV raster maps, and the full record of recorded level logger data.

Questions and Discussion

- LPs requested that City Light confirm with the FA-04 Fish Passage Study Team that the study's passage analysis at existing features will assess passage (both hydraulically and temporally) for each species of concern. This was added as an action item.
- In response to a question, Erin Lowery explained the model is of current scenarios and is being developed to explore different future scenarios. It will be integrated with the operations model once that is developed.
- LPs requested that City Light provide information to support comparison of Bypass Reach controlled releases vs. unregulated flows to LPs. This was added as an action item.
- An LP representative from USIT expressed concern about model calibration for velocity at higher flow events and requested more information on data collection efforts for more uncontrolled high flow events. Consultant Team members explained they had collected a full data set with higher flows, which should be adequate. Model calibration results for high flow events will be presented at the next meeting.

Action Item: Confirm with the FA-04 Fish Passage Study Team that the study's passage analysis at existing features will assess passage (both hydraulically and temporally) for each species of concern.

Action Item: Provide information to support comparison of Bypass Reach controlled releases vs. unregulated flows to LPs.

Review Action Items and Next Steps

Erin Lowery provided an overview of next steps and explained that City Light is nearing the point they will be integrating and cross-walking across different studies. As tools are developed, workshops will shift to discussions with LPs about this integration. He noted the next meeting is anticipated for the standing Flows Work Group calendar hold for February and will focus on model calibration.

Action Item: Triangle will prepare a draft meeting summary and send to LPs for review.

The meeting was adjourned early at 12:00 p.m.