APPLICATIONS OF 2D HYDRAULIC MODELLING TO ECOSYSTEM RESTORATION

2-D Hydraulic modeling & UAV Technology

Presented By

Robert Stewart Ph.D., PE

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PRESENTATION OVERVIEW

- WHAT IS 2D HYDRAULIC MODELLING
- WHAT QUESTIONS DO WE ASK OF 2D HYDRAULIC MODELS?
- CASE STUDIES
  1. TRINITY RIVER,
     - SALMONID HABITAT ESTIMATES
     - SEDIMENT TRANSPORT
  2. 4 MILE RUN
     - STAKEHOLDER VISUALIZATIONS
     - SHEAR STRESS
  3. CHURCHILL VALLEY
     - FLOW DEPTH (FLOODING)
     - SHEAR STRESS (RISK ANALYSES)

PRESENTATION OVERVIEW

- WHAT IS 2D HYDRAULIC MODELLING
- WHAT QUESTIONS DO WE ASK OF 2D HYDRAULIC MODELS?
- CASE STUDIES

1. TRINITY RIVER, — Dynamic Construction
    - SALMONID HABITAT ESTIMATES
    - SEDIMENT TRANSPORT
2. 4 MILE RUN — Natural Channel Design
    - STAKEHOLDER VISUALIZATIONS
    - SHEAR STRESS
3. CHURCHILL VALLEY — Legacy Sediment Removal (Stage Zero)
    - FLOW DEPTH (FLOODING)
    - SHEAR STRESS (RISK ANALYSES)

WHAT IS 2D HYDRAULIC MODELLING?

6.1 Flow Equations

Most open channel flows are relatively shallow and the effect of vertical motions is negligible. As a result, the most general flow equations, the three-dimensional Navier-Stokes equations, may be vertically averaged to obtain a set of depth-averaged two-dimensional equations, leading to the following well known 2D St. Venant equations:

$$\frac{\partial h}{\partial t}+\frac{\partial hU}{\partial x}+\frac{\partial hV}{\partial y}=e \qquad (1)$$

$$\frac{\partial hU}{\partial t}+\frac{\partial hUU}{\partial x}+\frac{\partial hVU}{\partial y}=\frac{\partial hT_{xx}}{\partial x}+\frac{\partial hT_{xy}}{\partial y}-gh\frac{\partial z}{\partial x}-\frac{\tau_{bx}}{\rho}+D_{xx}+D_{xy} \qquad (2)$$

$$\frac{\partial hV}{\partial t}+\frac{\partial hUV}{\partial x}+\frac{\partial hVV}{\partial y}=\frac{\partial hT_{xy}}{\partial x}+\frac{\partial hT_{yy}}{\partial y}-gh\frac{\partial z}{\partial y}-\frac{\tau_{by}}{\rho}+D_{yx}+D_{yy} \qquad (3)$$

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Inputs

1. Mesh (topography)
2. Boundary Conditions
3. Surface Roughness

Outputs

1. Pretty Pictures
2. Velocity
3. Depth
4. Shear Stress
5. Water Elevations
6. Froude Number
7. Pretty Pictures

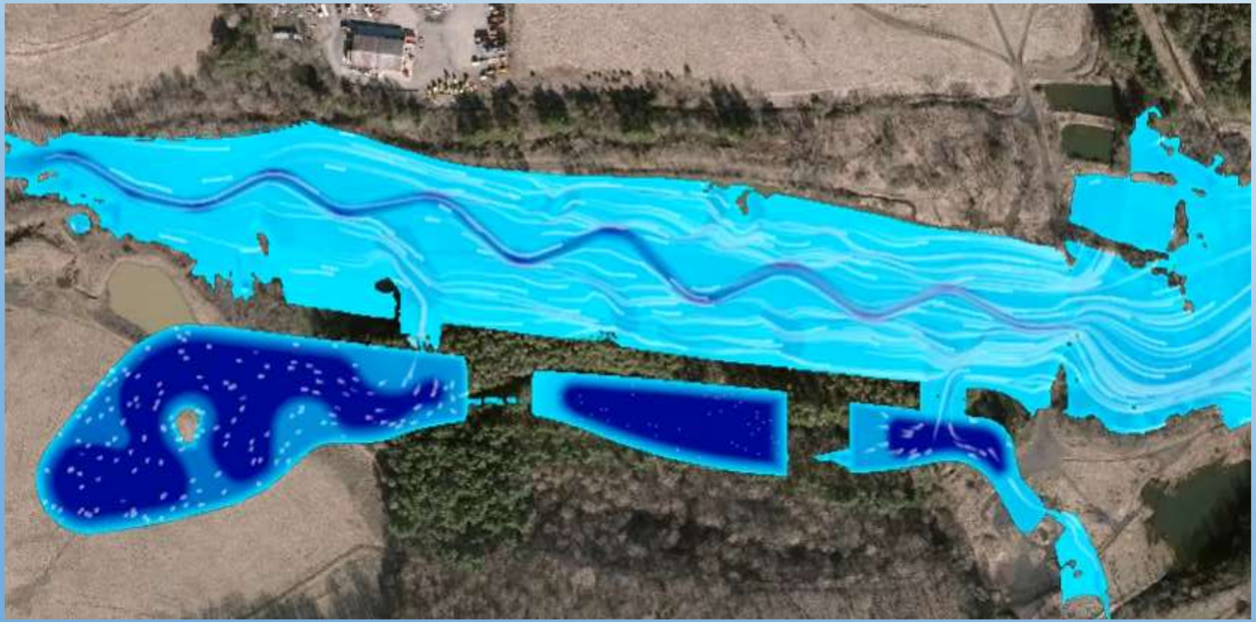
WHAT QUESTIONS DO WE ASK OF 2D HYDRAULIC MODELS?

Direct Outputs

1. Velocity (Erosion)
2. Depth (Bathymetry)
3. Shear Stress (Erosion)
4. Water Elevations (Flooding)
5. Froude Number (Hydraulic Jumps)

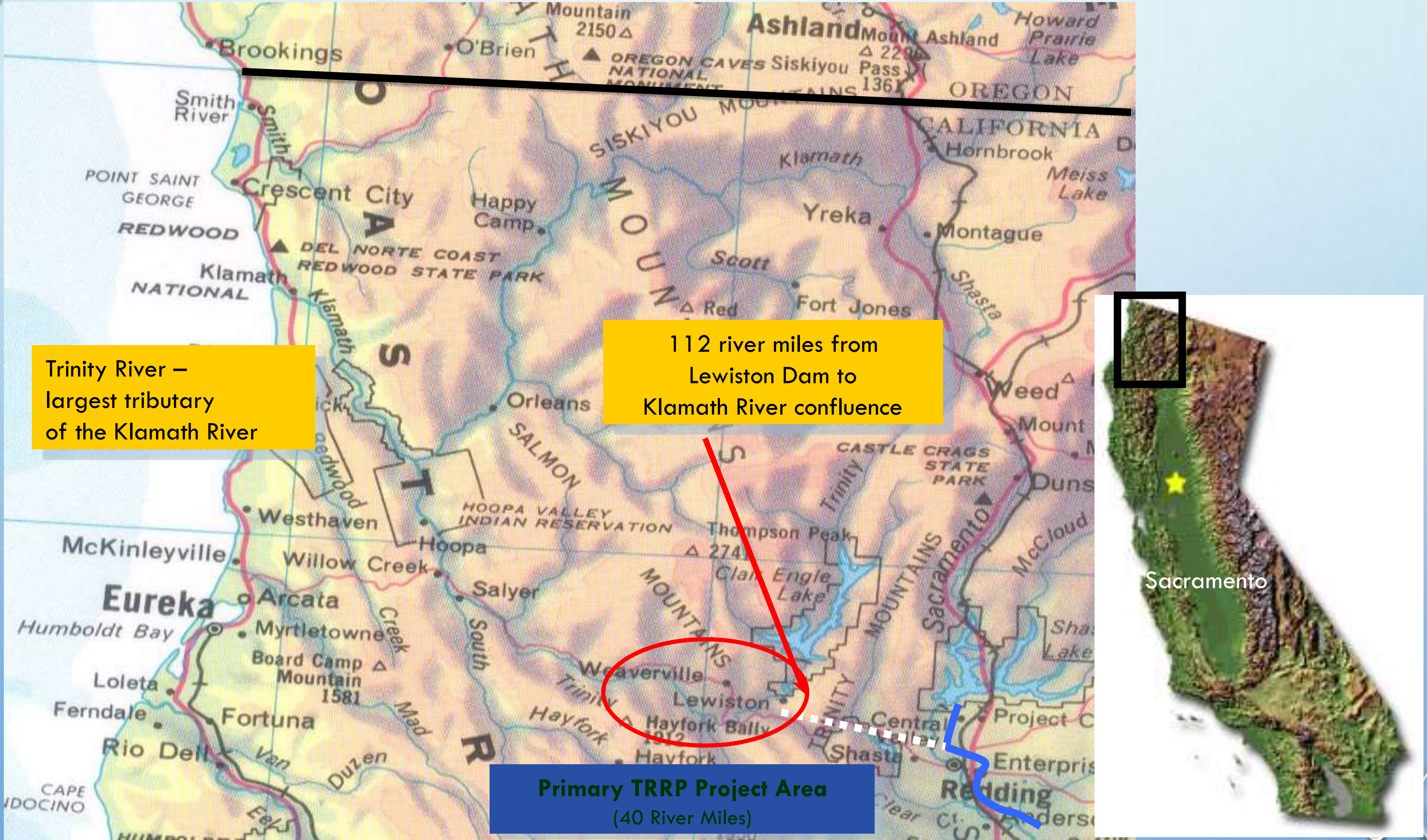
Derived Outputs

1. Fct(Velocity, Depth, Ecology) = Fish Habitat
2. Depth*Velocity= Unit Discharge
3. Fct(Shear, Velocity, Sediment) = Sediment Transport
4. Shear = Structure Placement
5. Water Elevation = Riparian Vegetation
6. Pretty Pictures and Video



WHAT IS 2D HYDRAULIC MODELLING?

TRINITY RIVER, SALMONID HABITAT ESTIMATES



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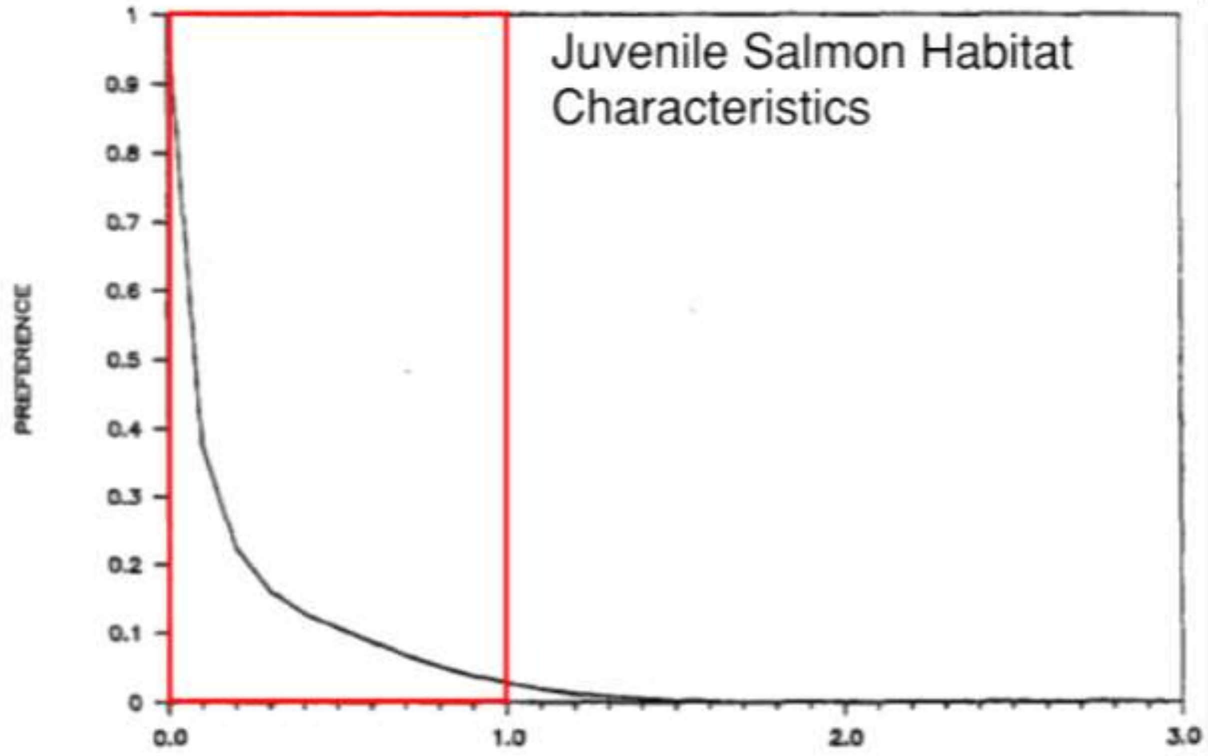

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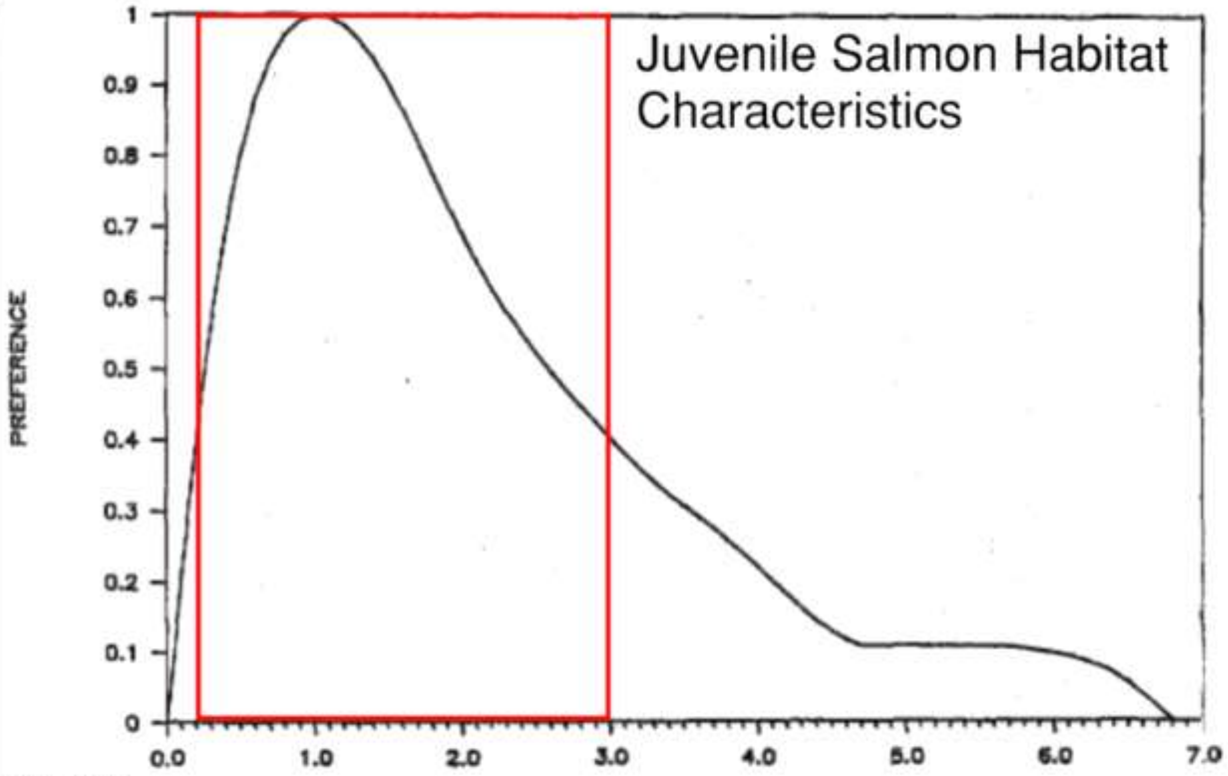
MEAN COLUMN VELOCITY (FT/SEC)



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Hampton et al. 1988

WATER DEPTH (FT)

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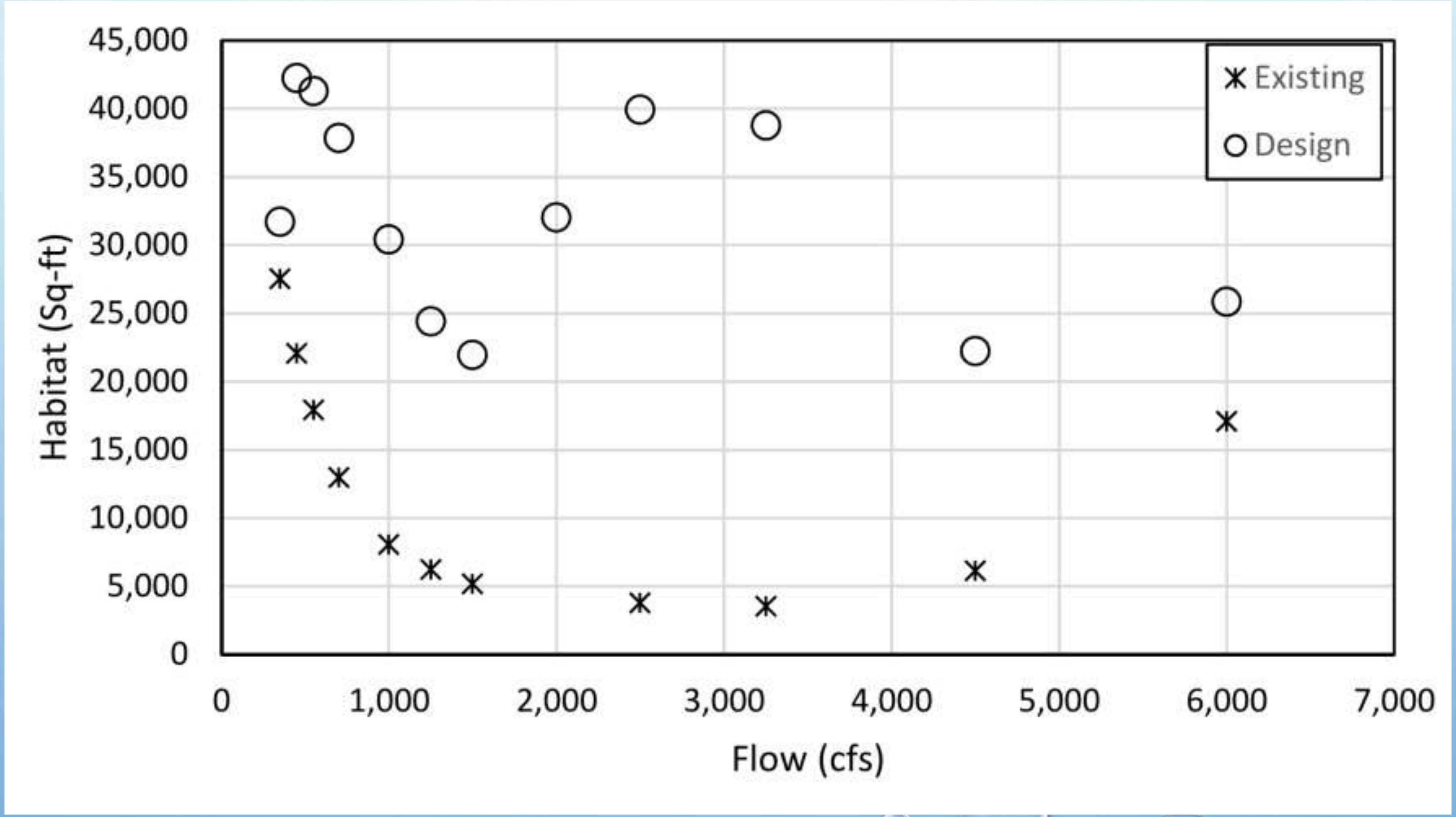

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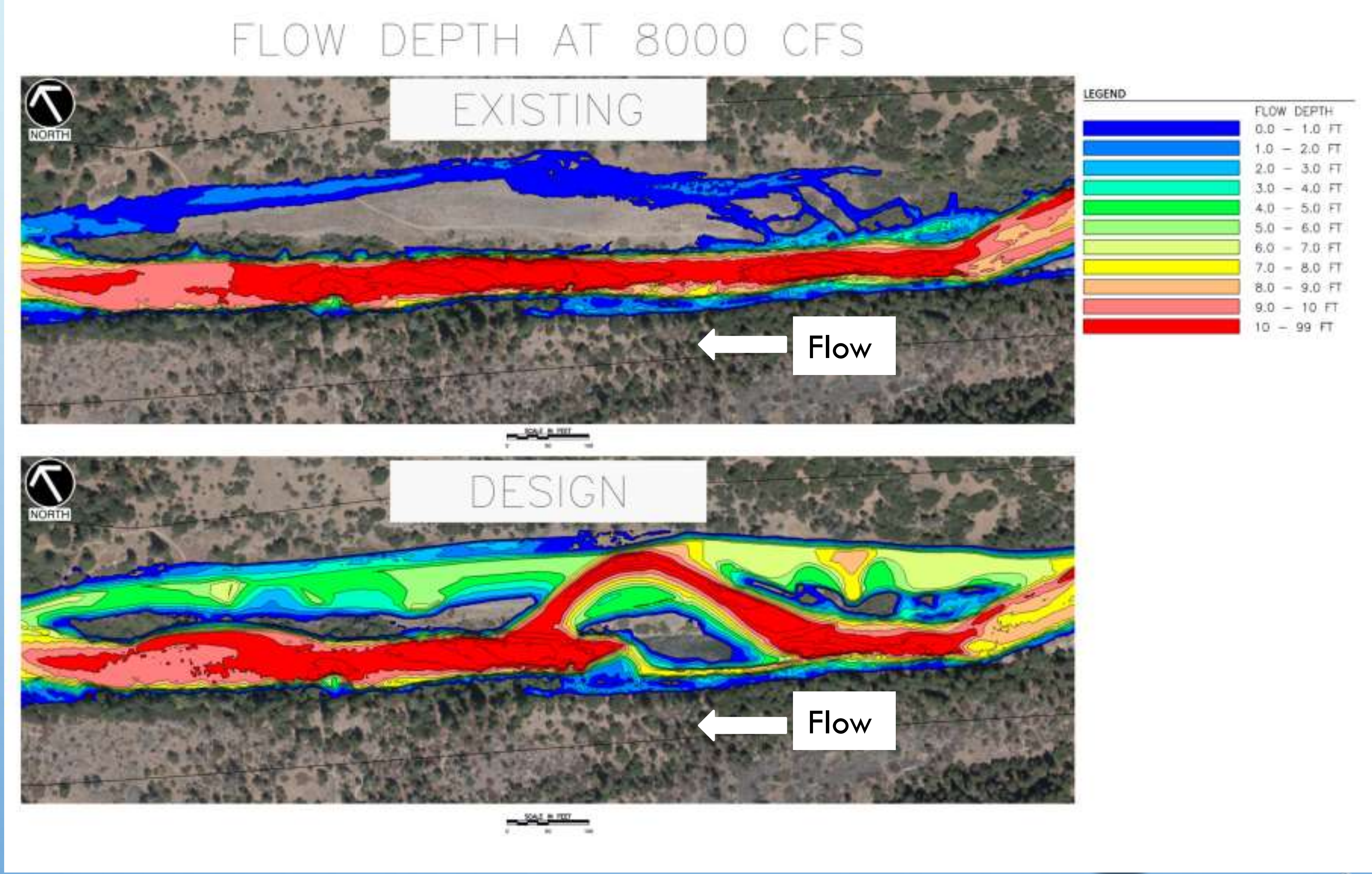

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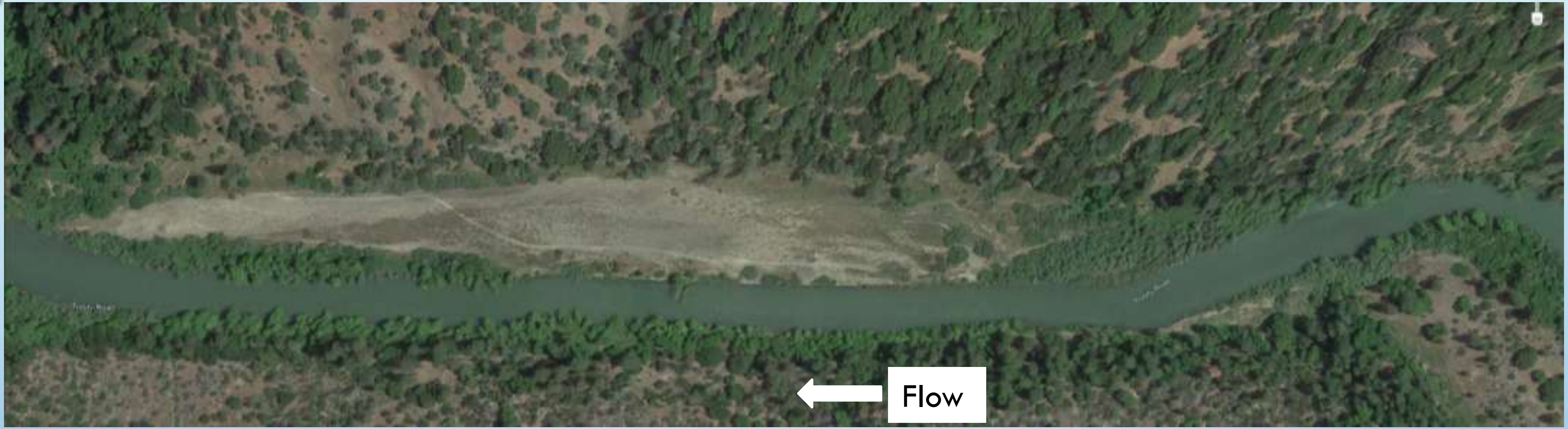
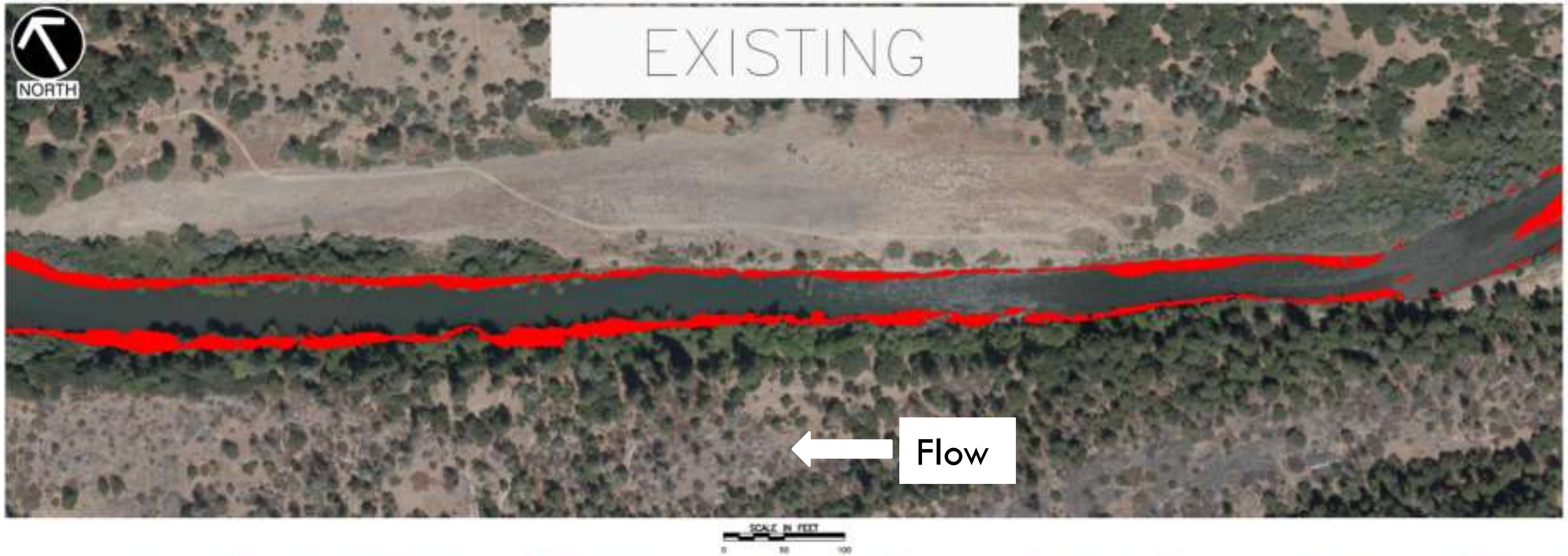
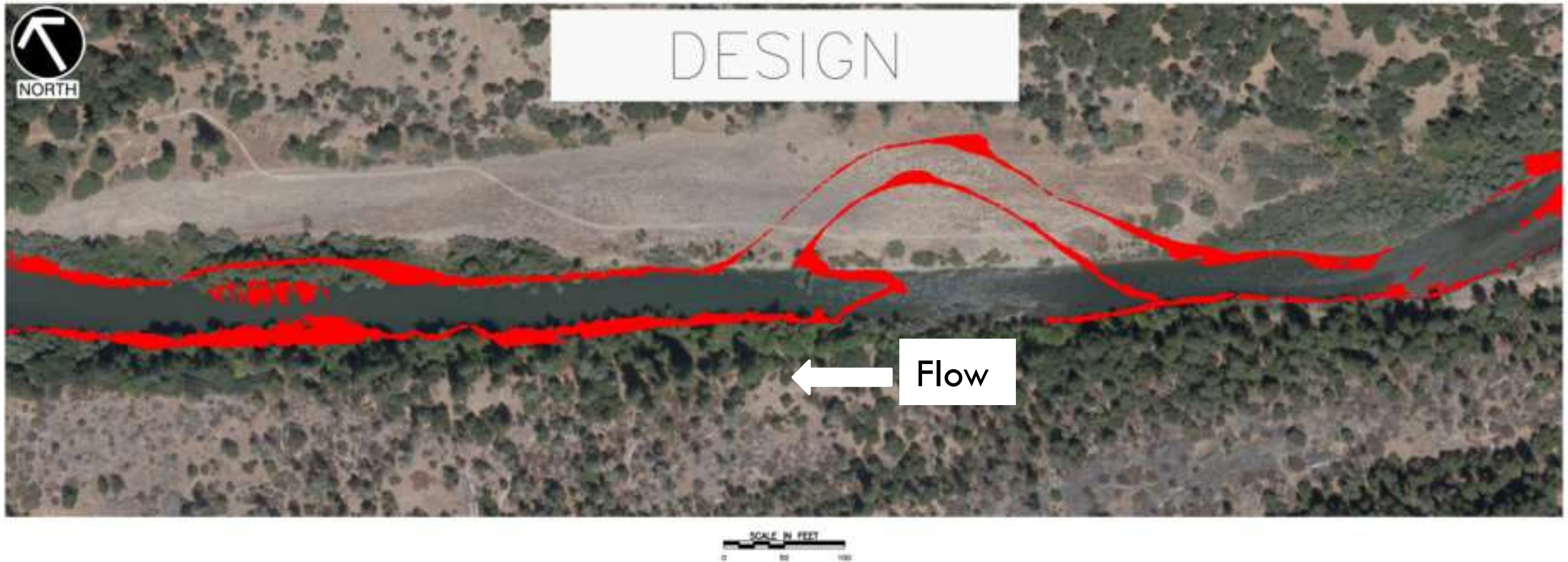


FRY HABITAT AT 350 CFS





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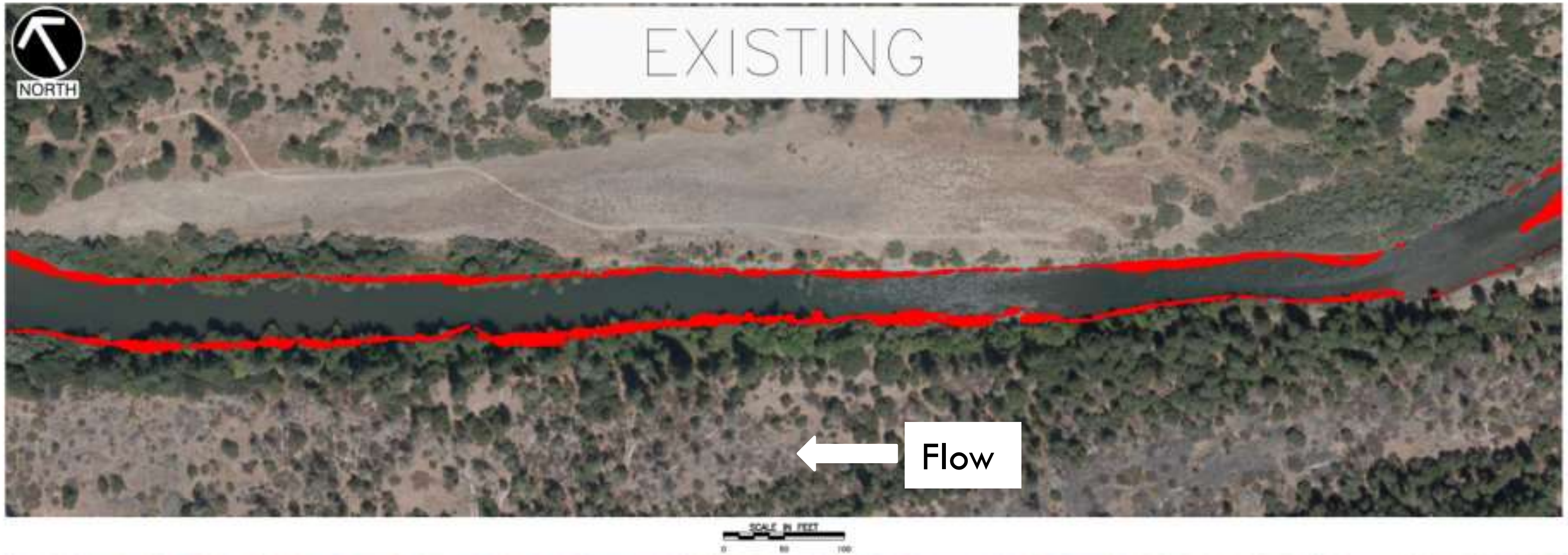
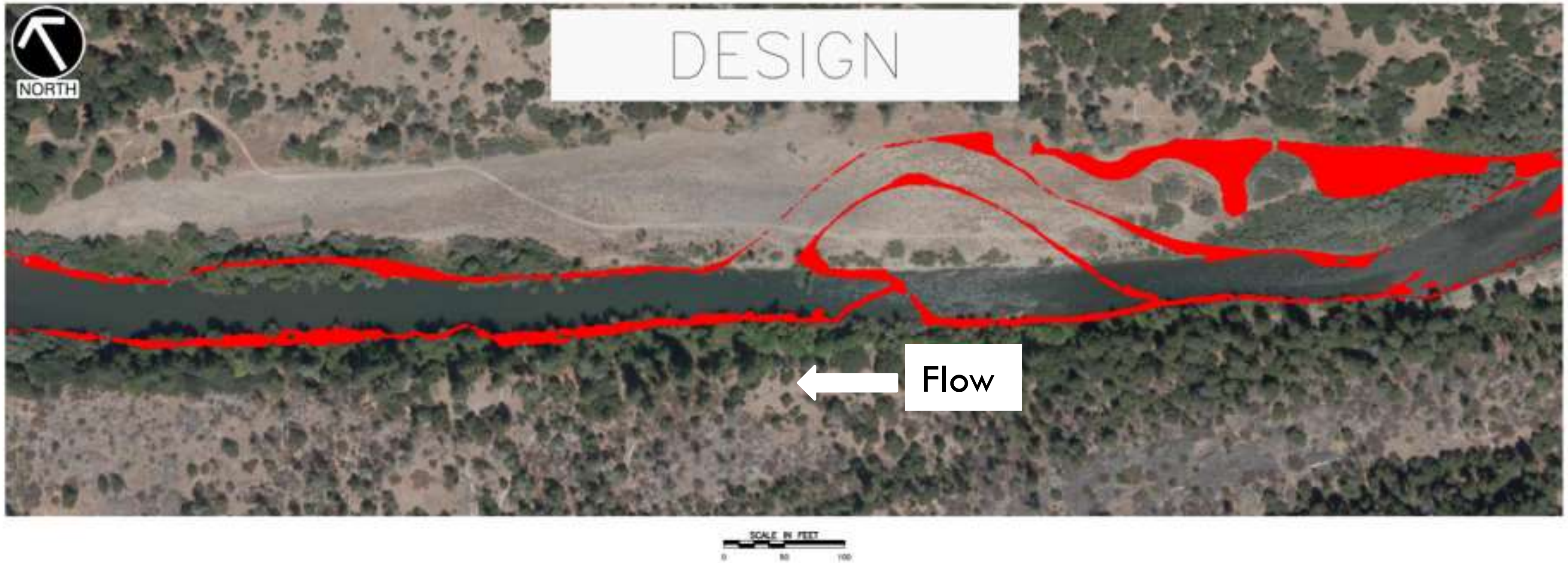
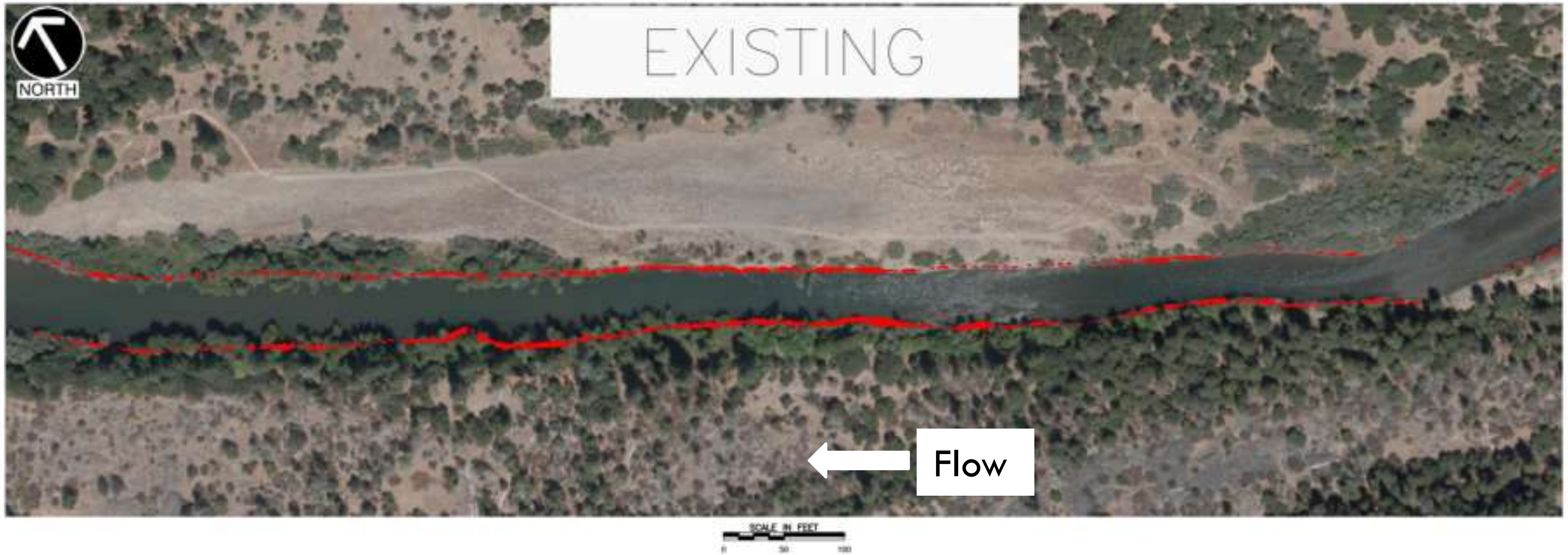
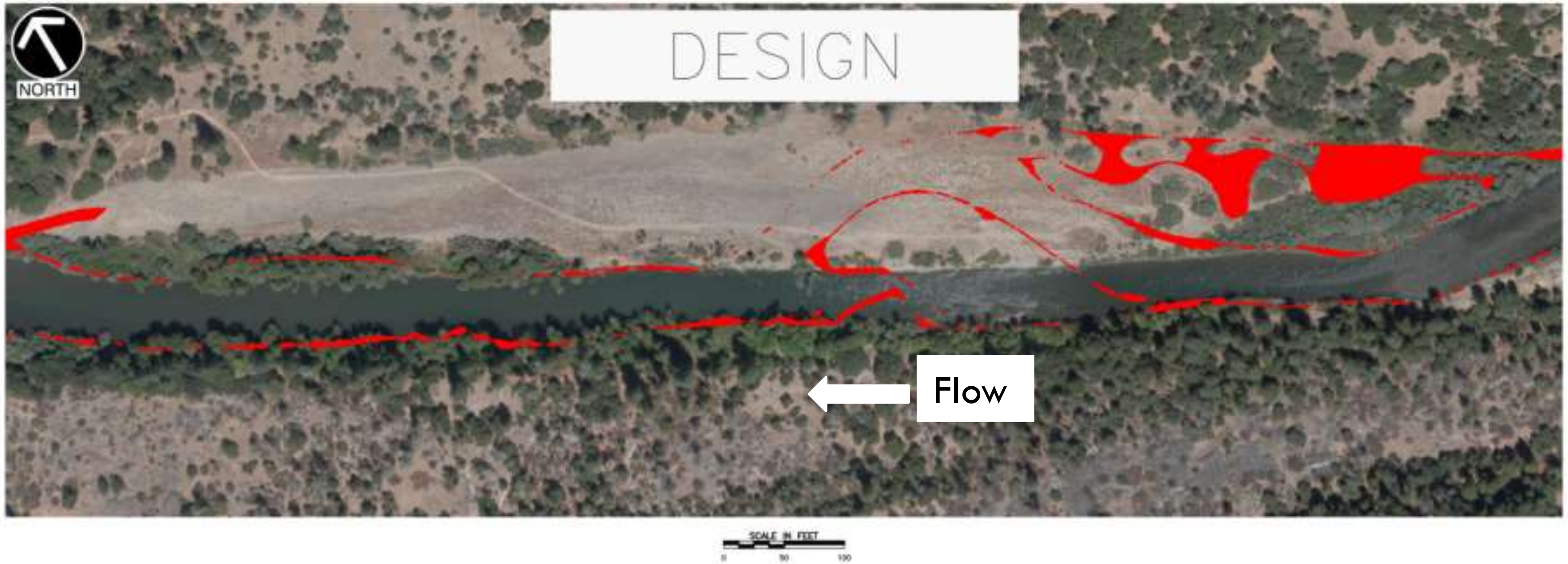


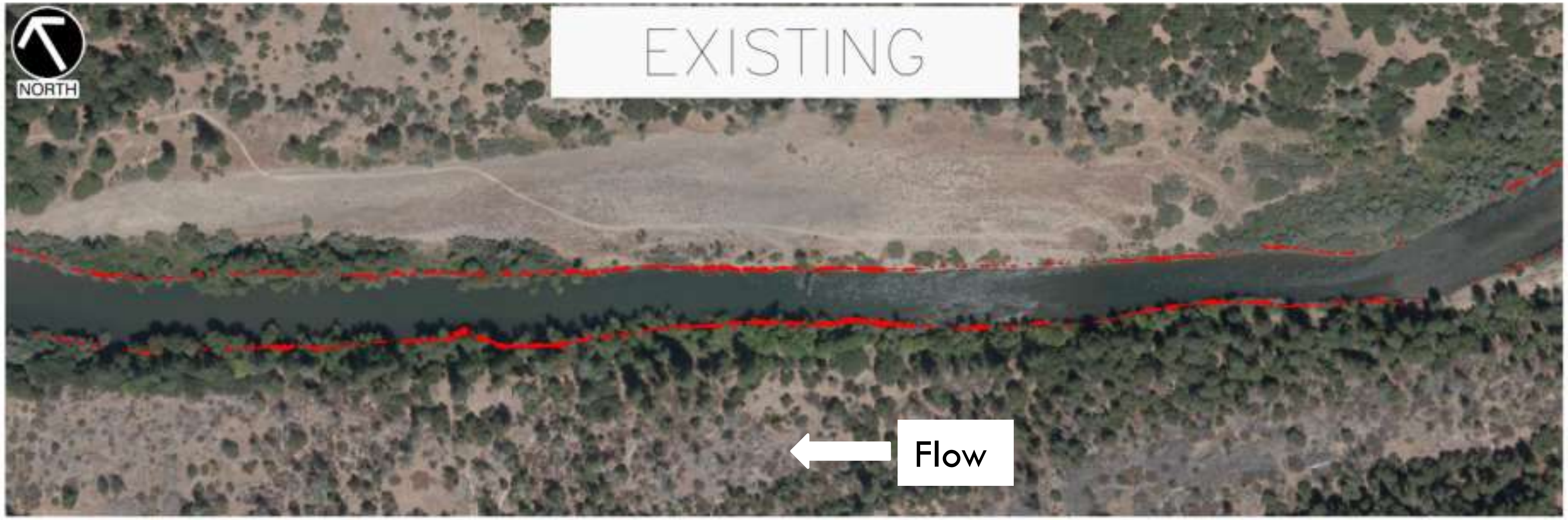


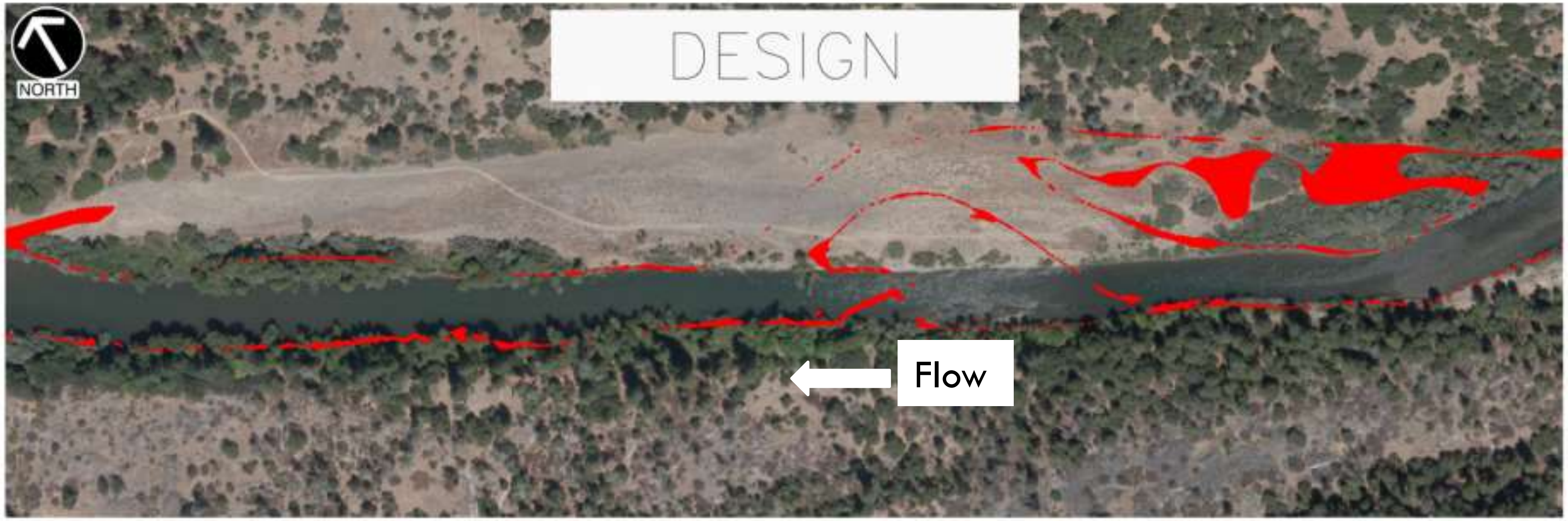
FRY HABITAT AT 1250 CFS



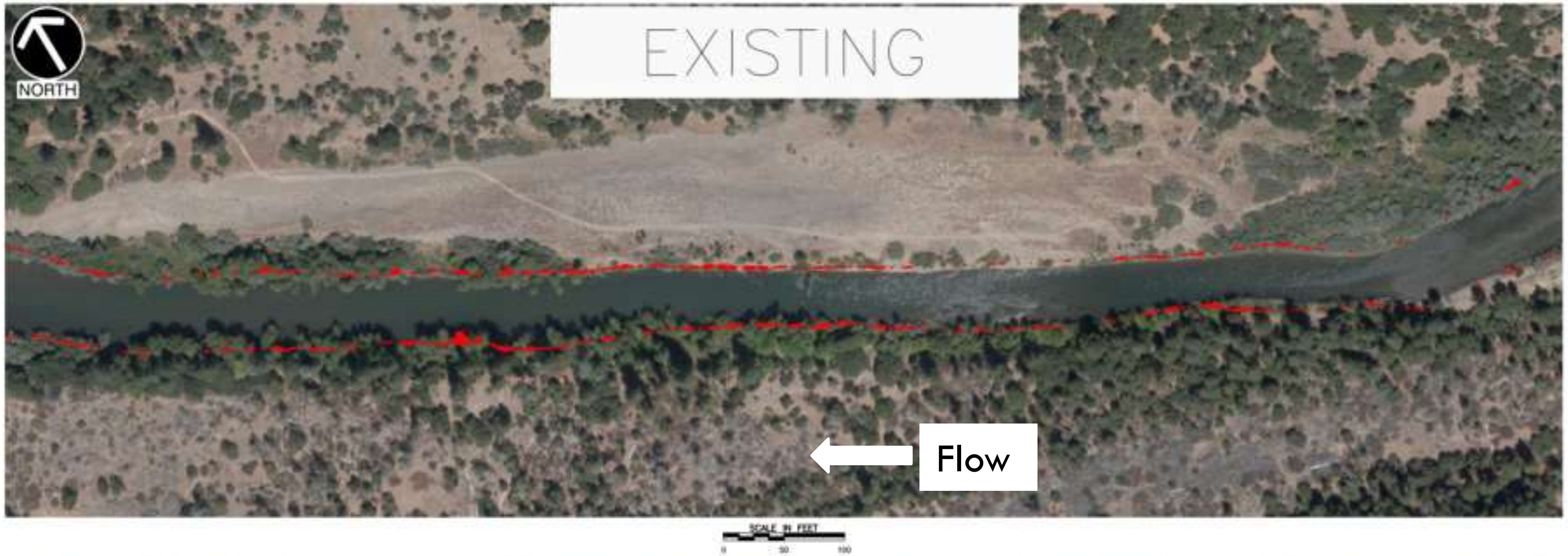


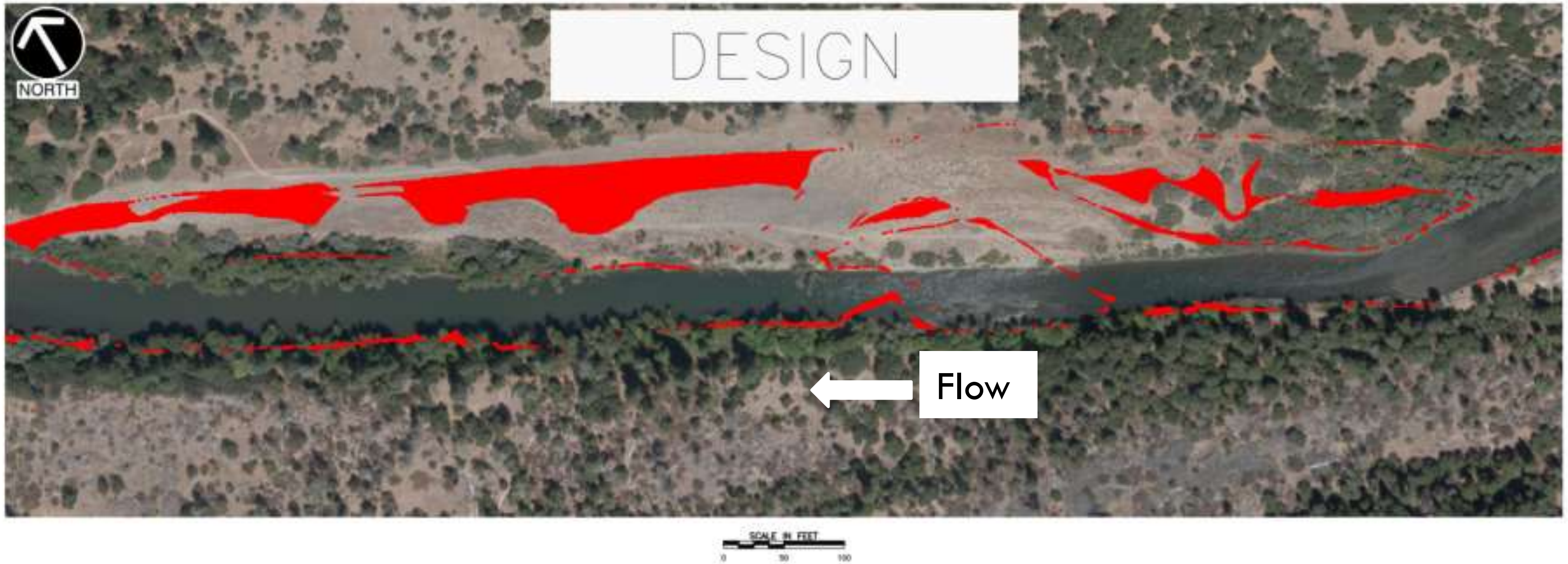
FRY HABITAT AT 1500 CFS



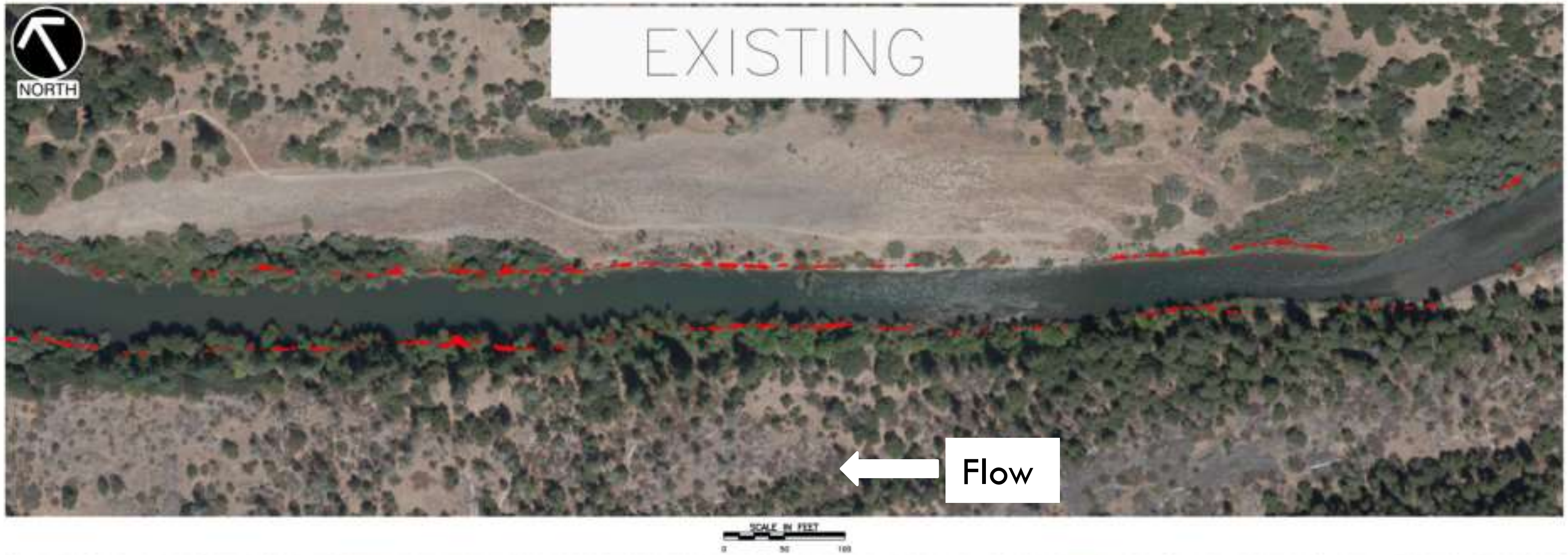


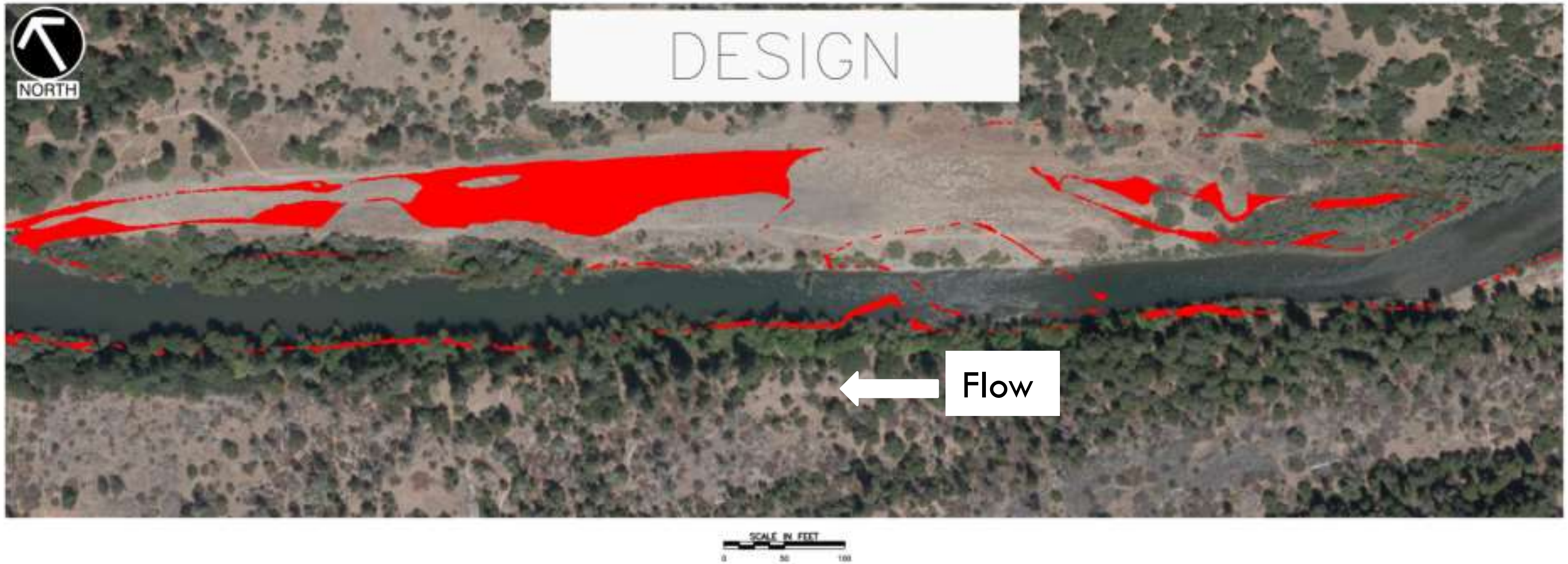
FRY HABITAT AT 2500 CFS



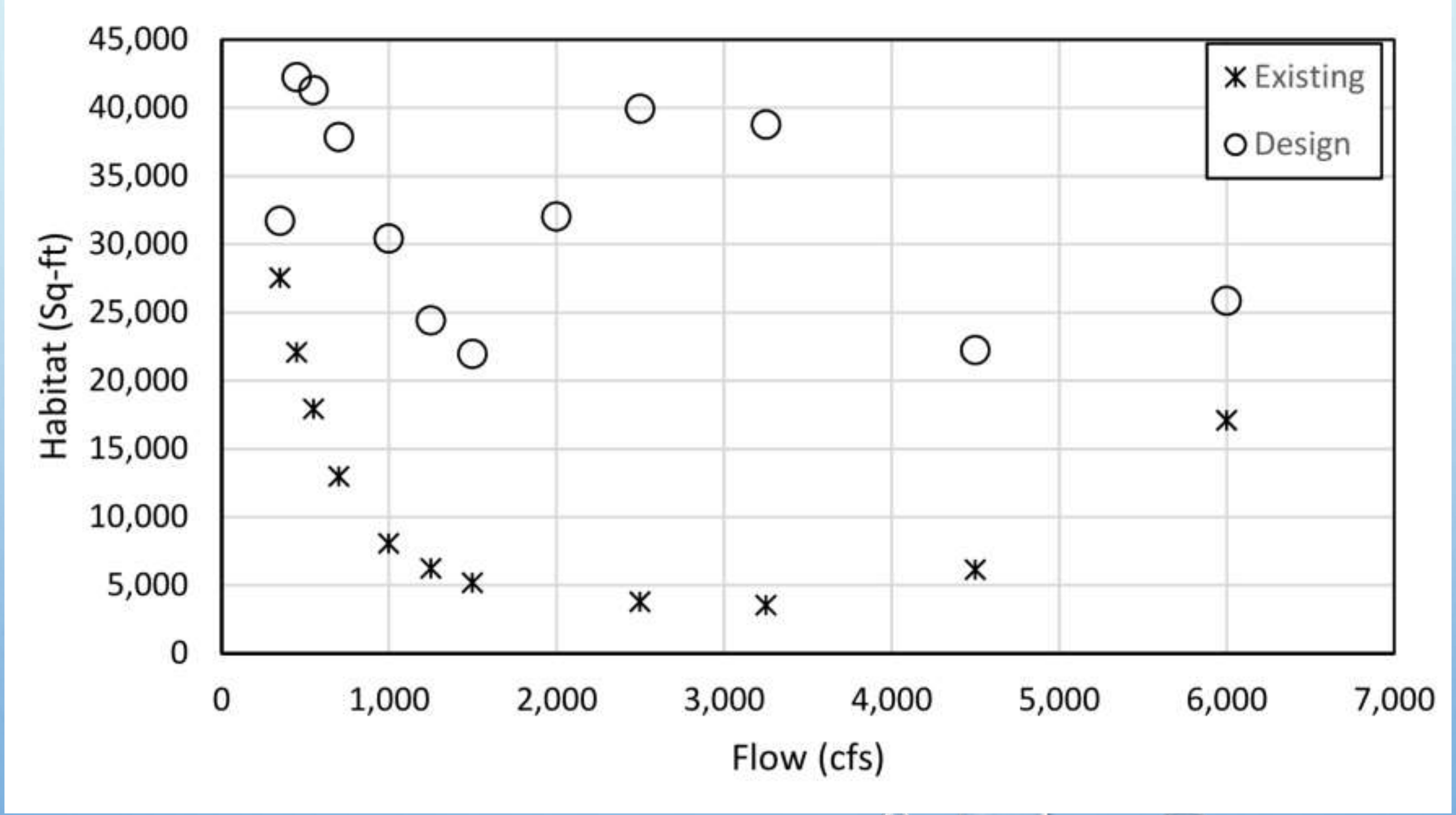


FRY HABITAT AT 3250 CFS





TRINITY RIVER, SALMONID HABITAT ESTIMATES



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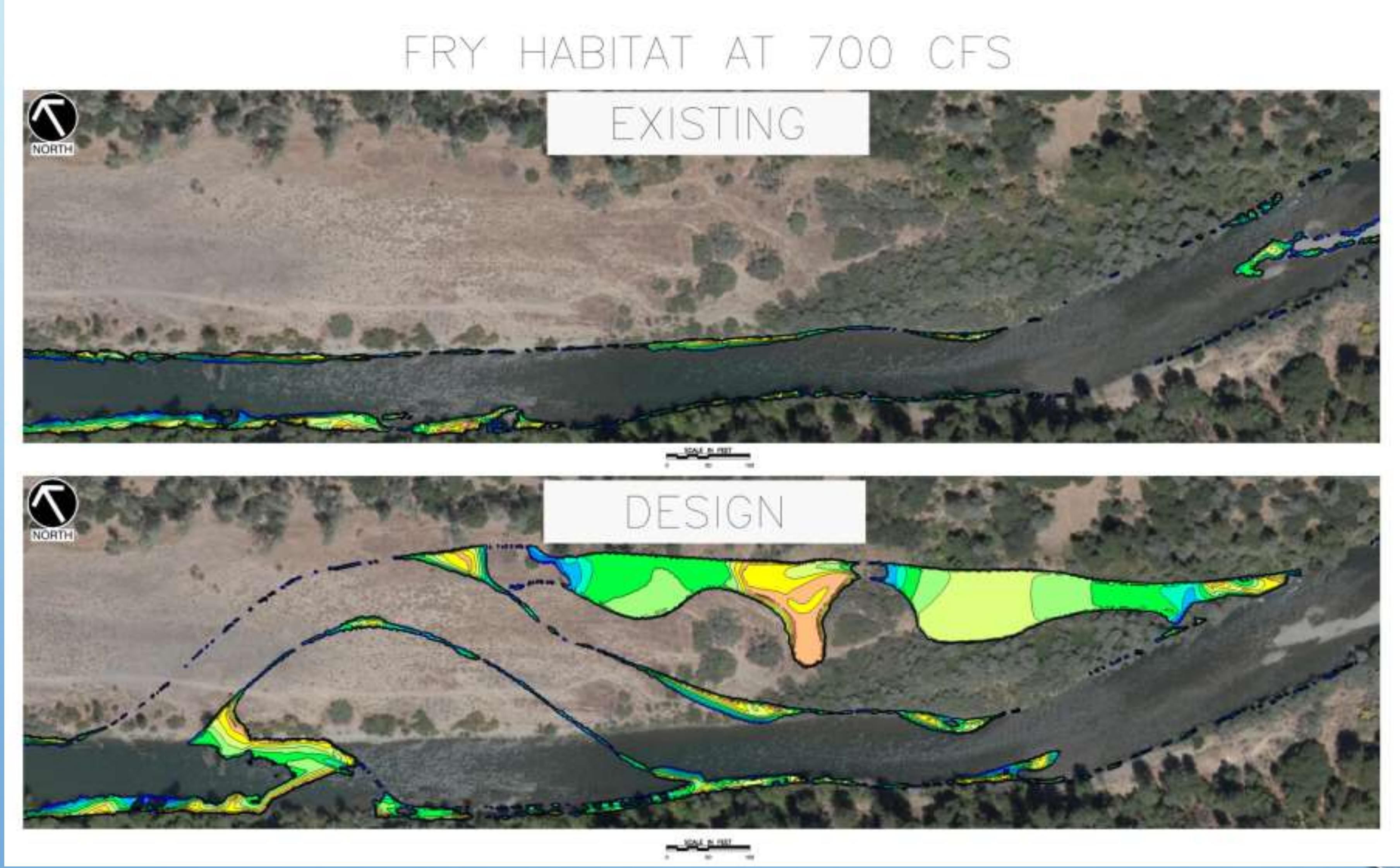
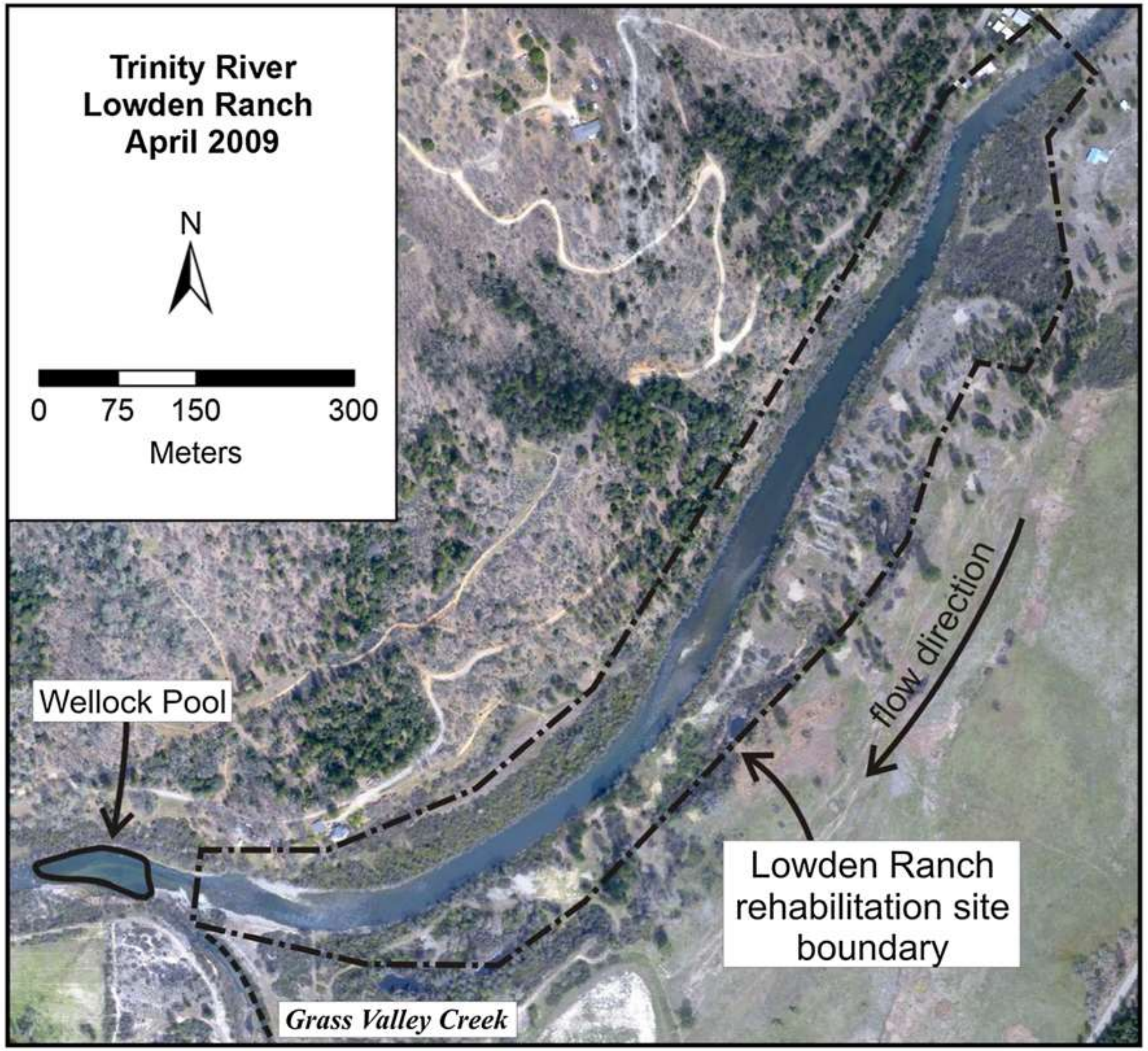
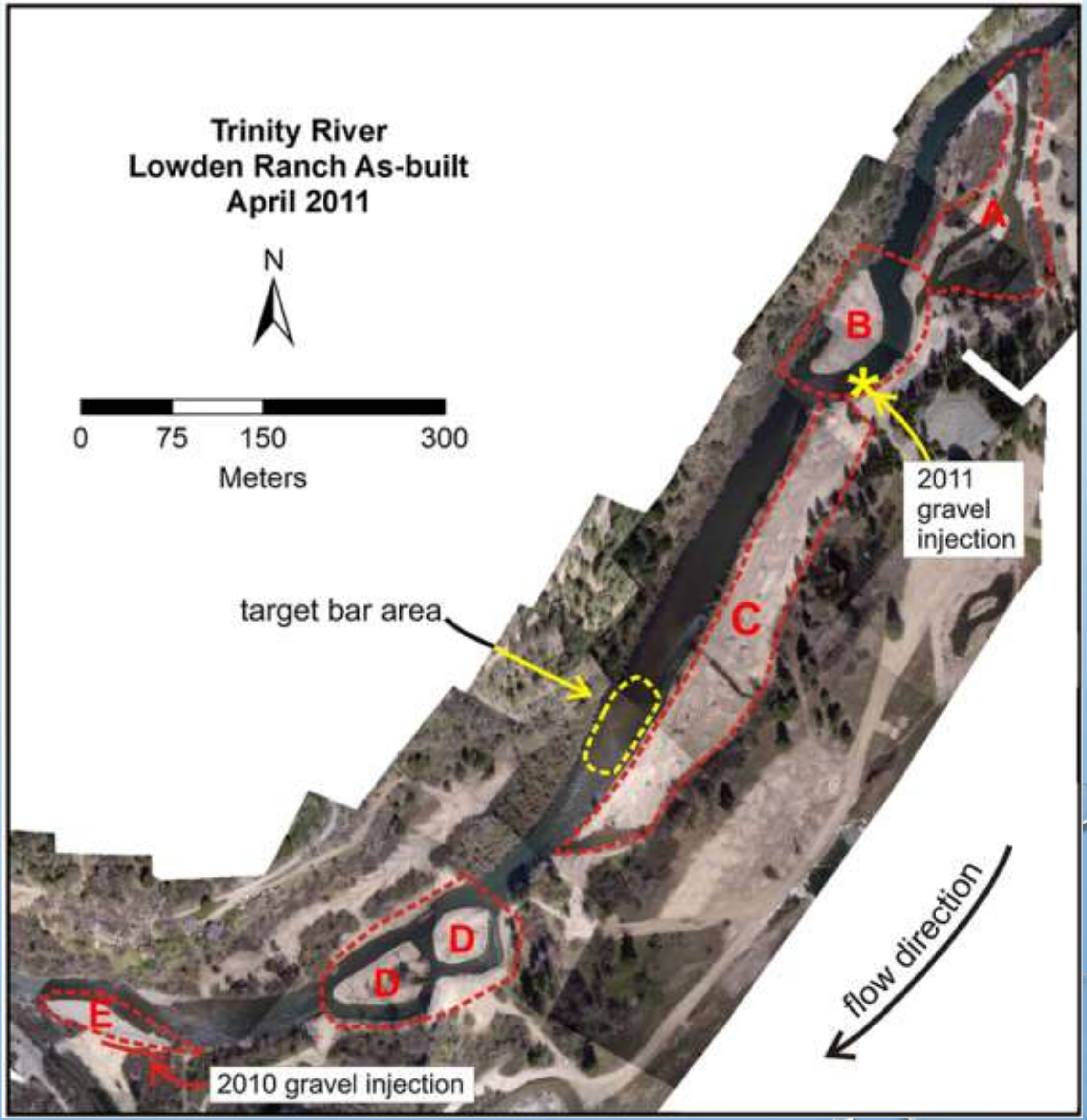


Weighted Usable Area (WUA)

TRINITY RIVER, SALMONID HABITAT ESTIMATES





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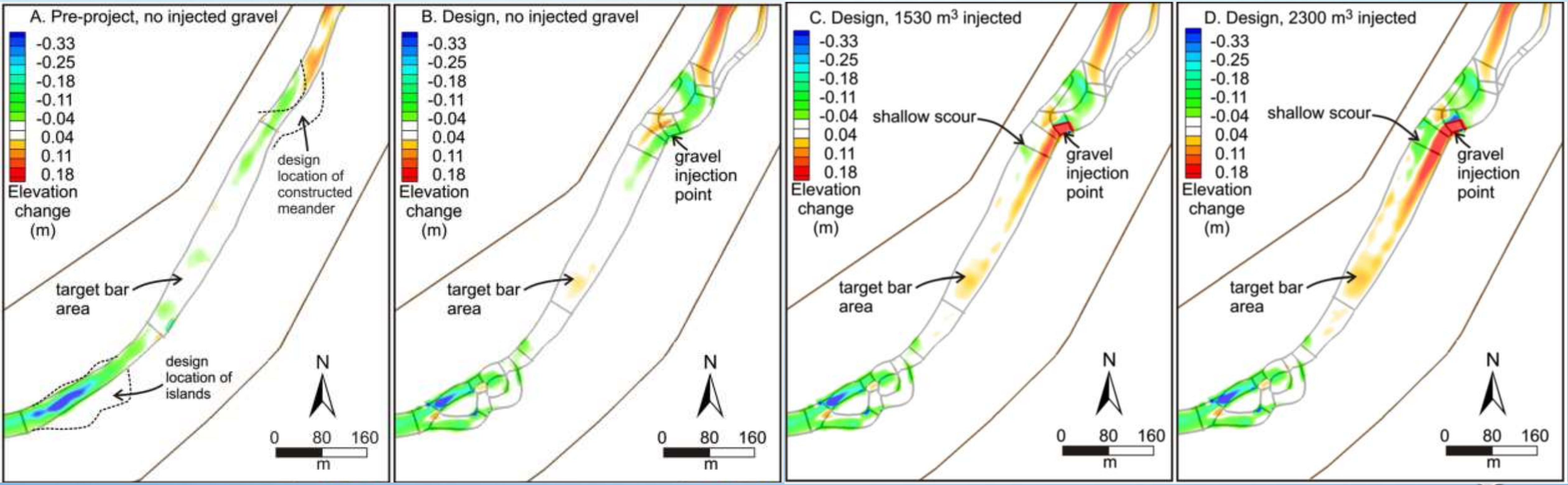

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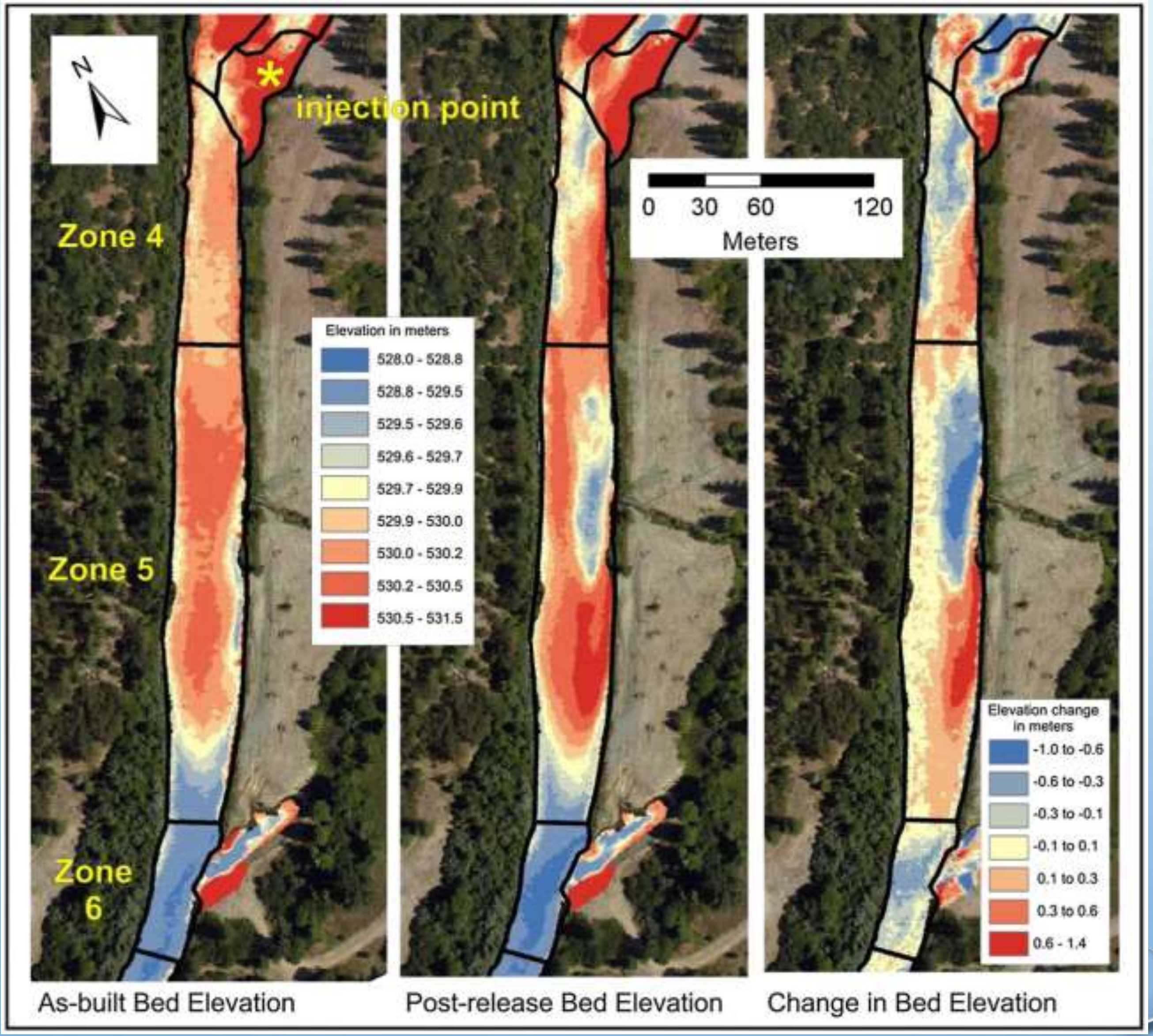
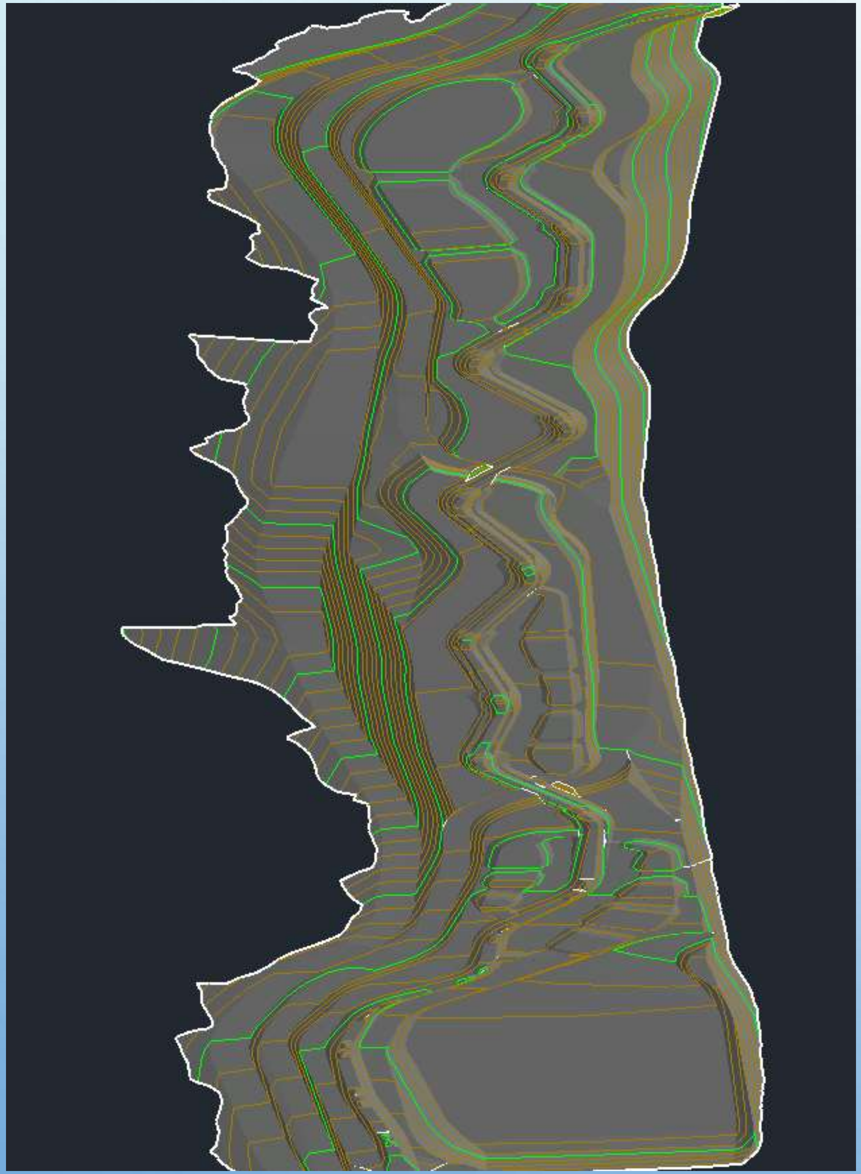


4 MILE RUN, STAKEHOLDER VISUALIZATIONS

OBJECTIVES

- REDUCE COMBINED SEWER OVERFLOW
- REDUCE FLOODING
- INCREASE HABITAT
- ENHANCE PARK EXPERIENCE

4 MILE RUN, STAKEHOLDER VISUALIZATIONS

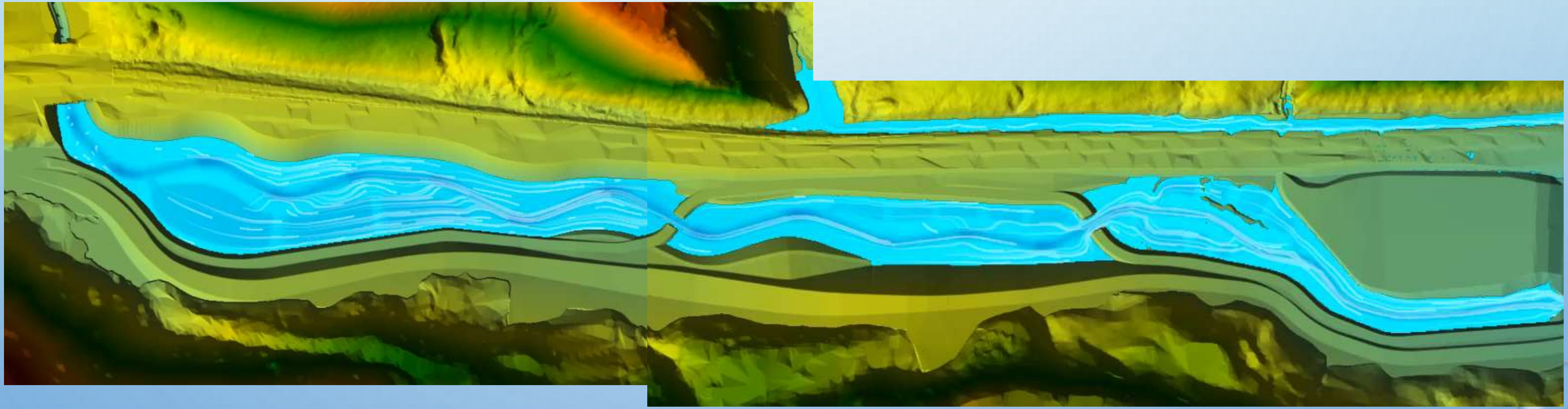


DAY-LIGHTED 3D STREAM DESIGNED

- BANKFULL CHANNEL
- FLOODPLAIN
- DEPRESSIONAL WETLANDS
- TRAILS
- RECTANGULAR PLAYING FIELD

4 MILE RUN, STAKEHOLDER VISUALIZATIONS

- FLOODING EXTENTS
- PARTICLE TRACING FLOW PATH VISUALIZATION
- VIDEOS



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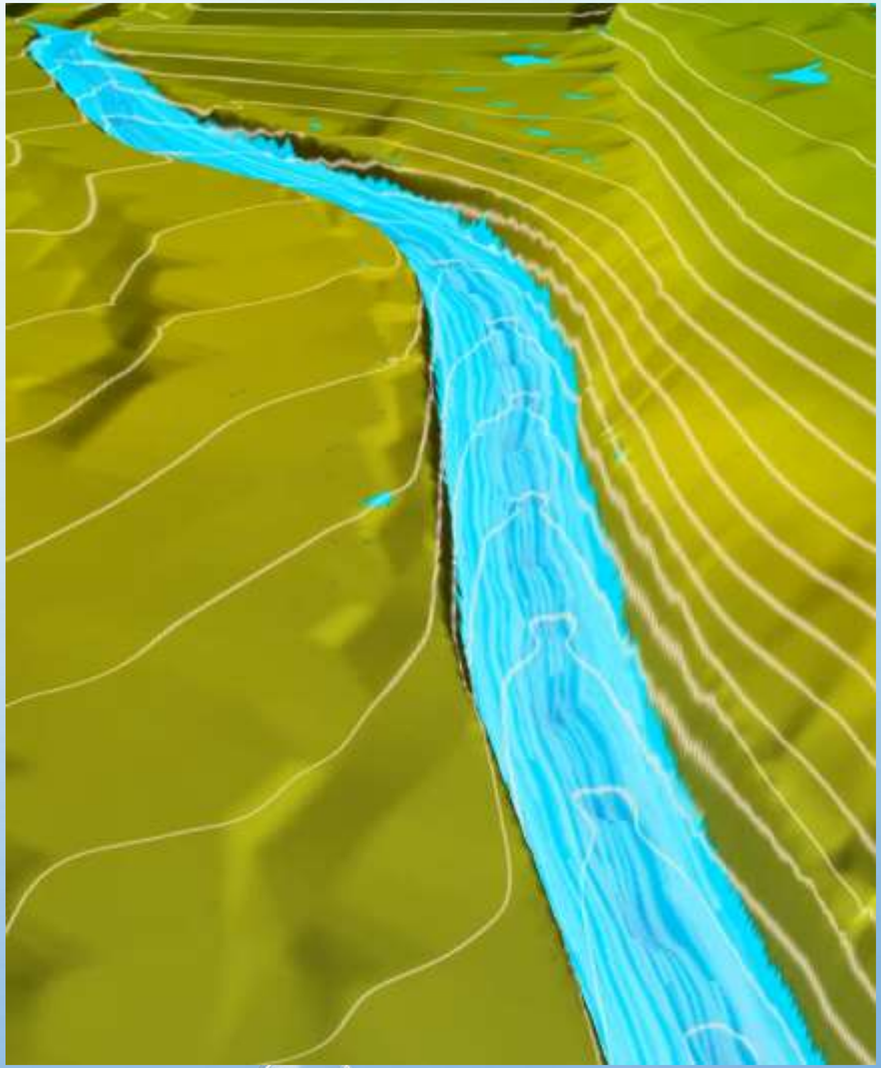
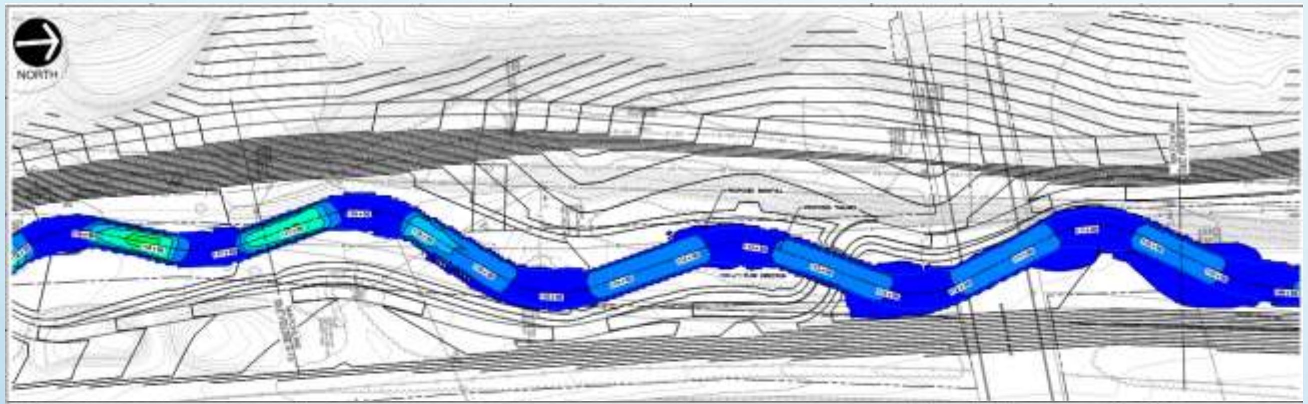


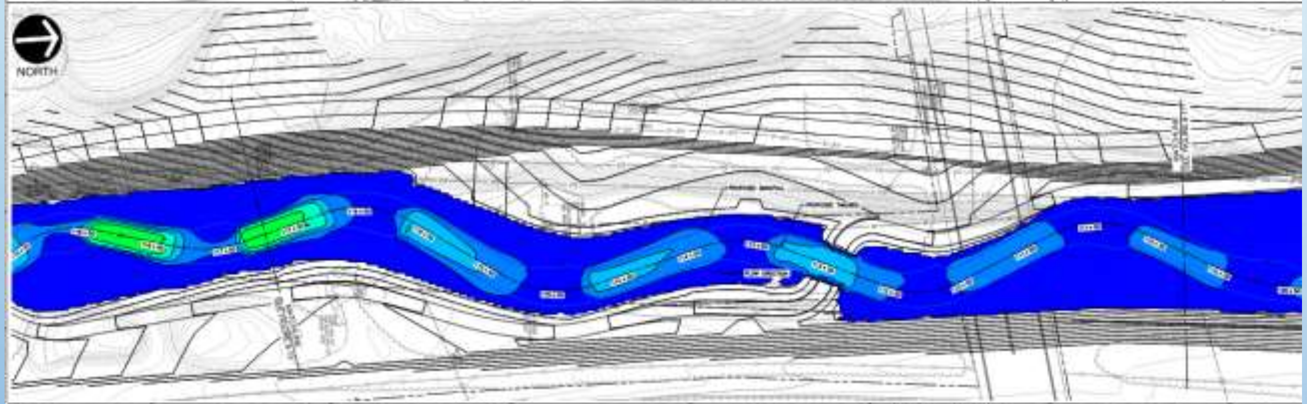
4 MILE RUN, STAKEHOLDER VISUALIZATIONS

Flow



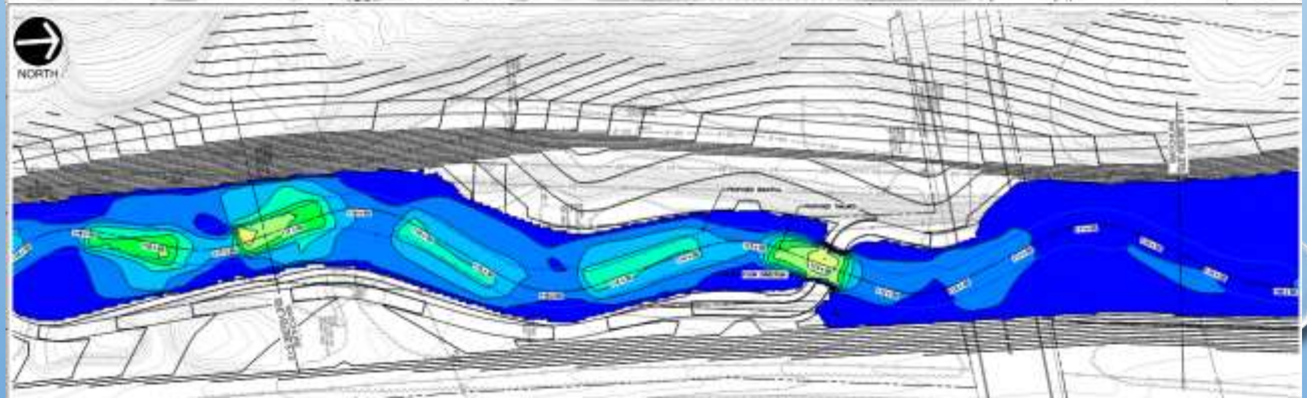
SHEAR STRESS AT BKF (80 CFS)

Flow



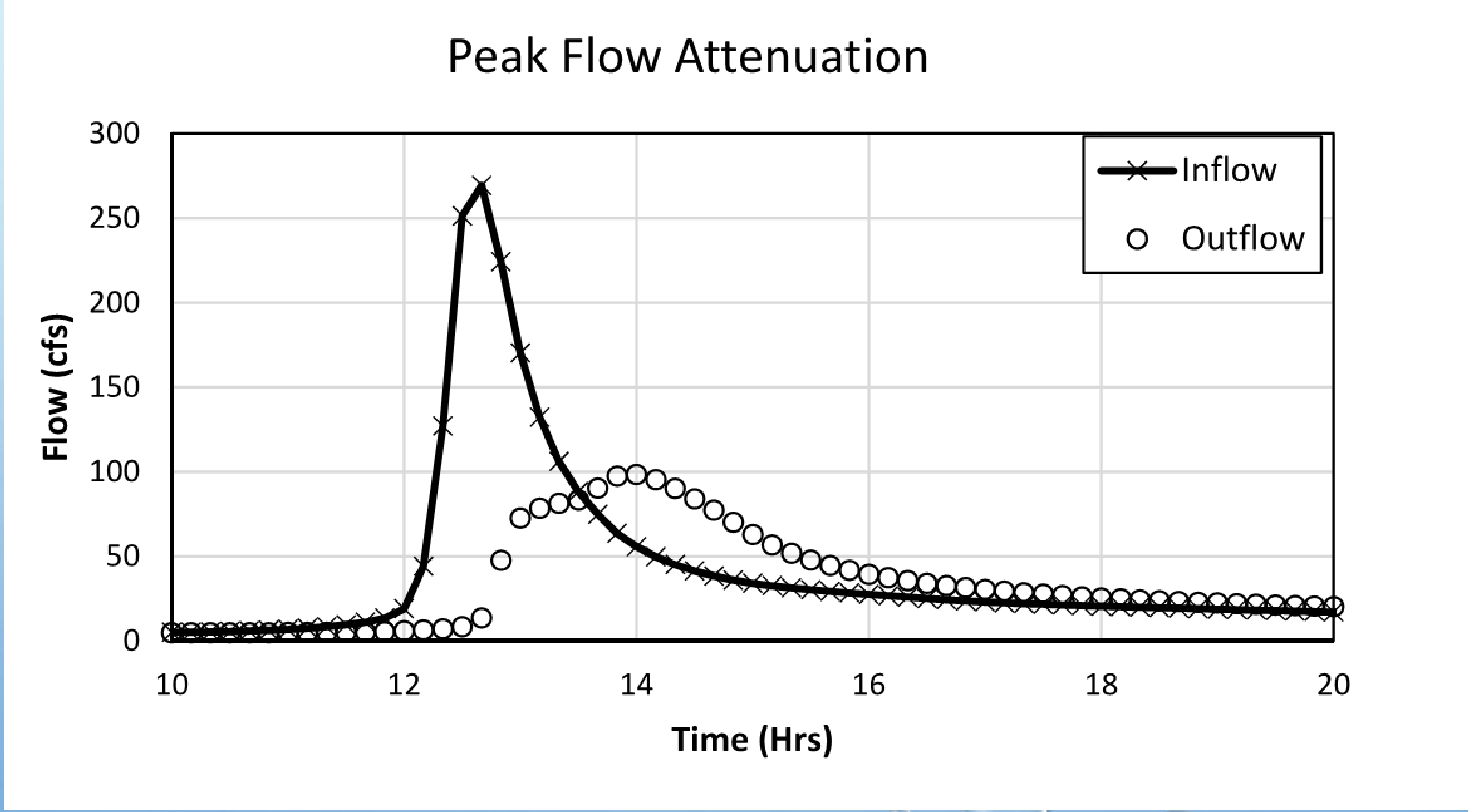
SHEAR STRESS AT 150 CFS

Flow

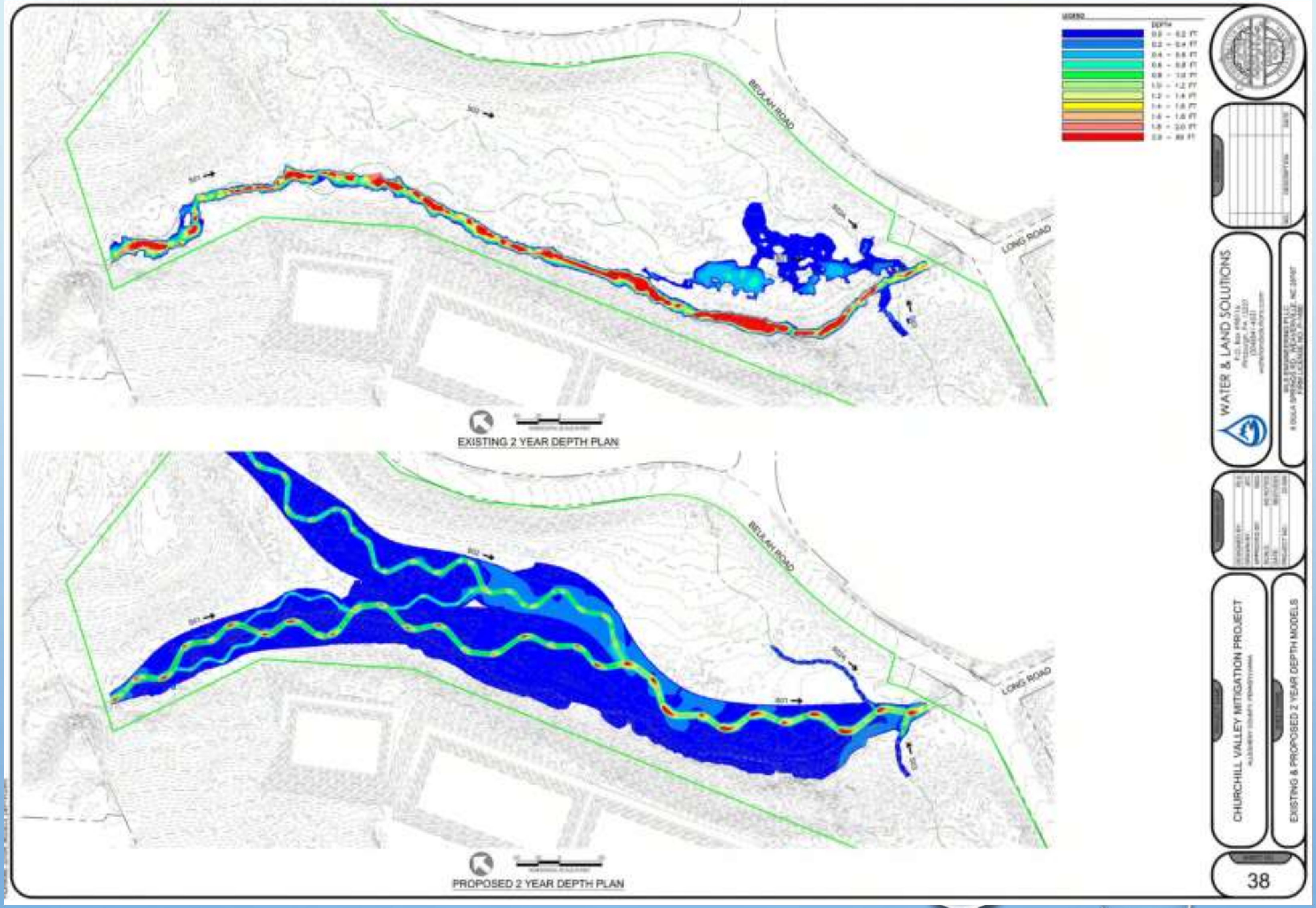


SHEAR STRESS AT 350 CFS

4 MILE RUN, STAKEHOLDER VISUALIZATIONS



CHURCH HILL, LEGACY SEDIMENT REMOVAL



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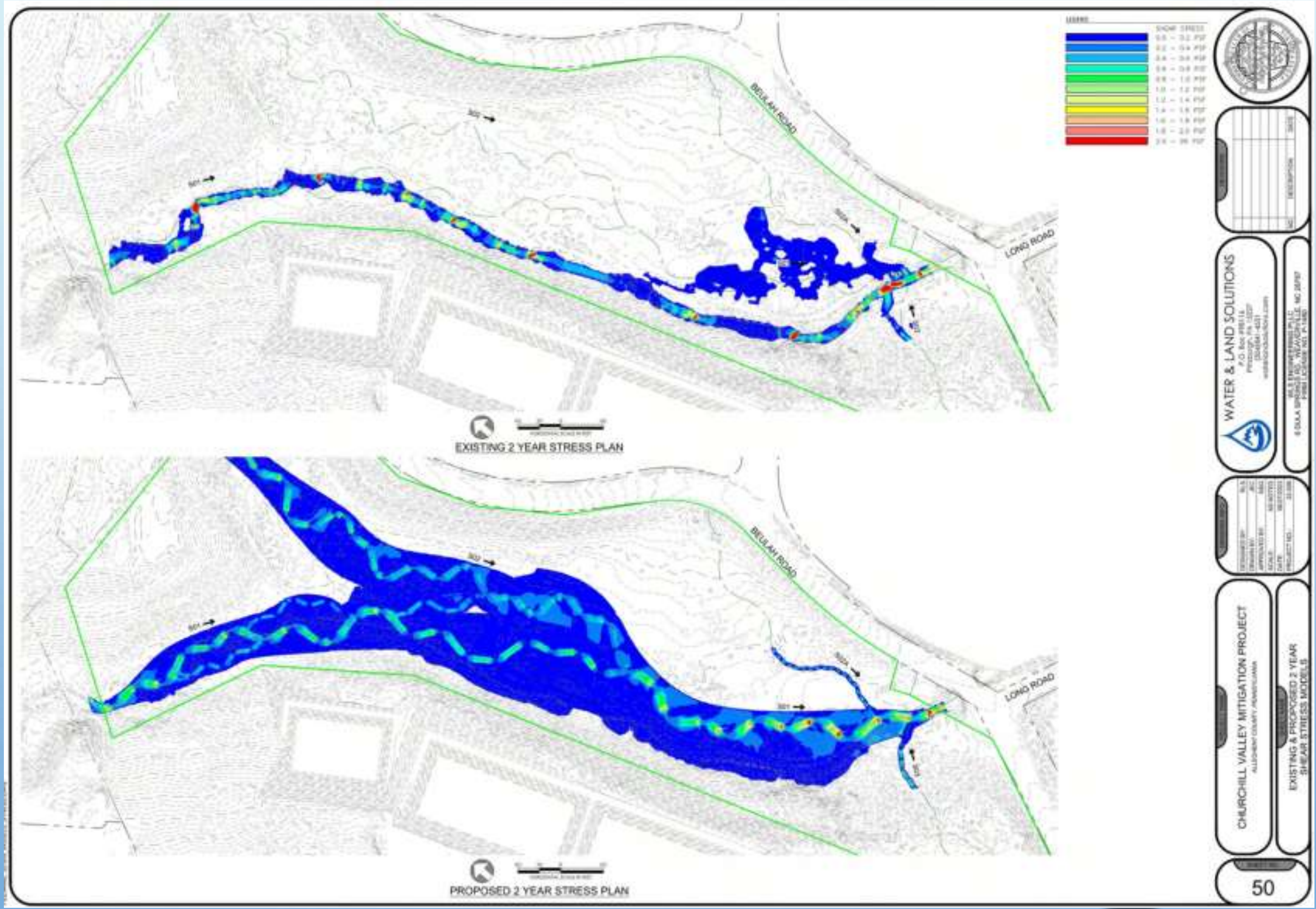
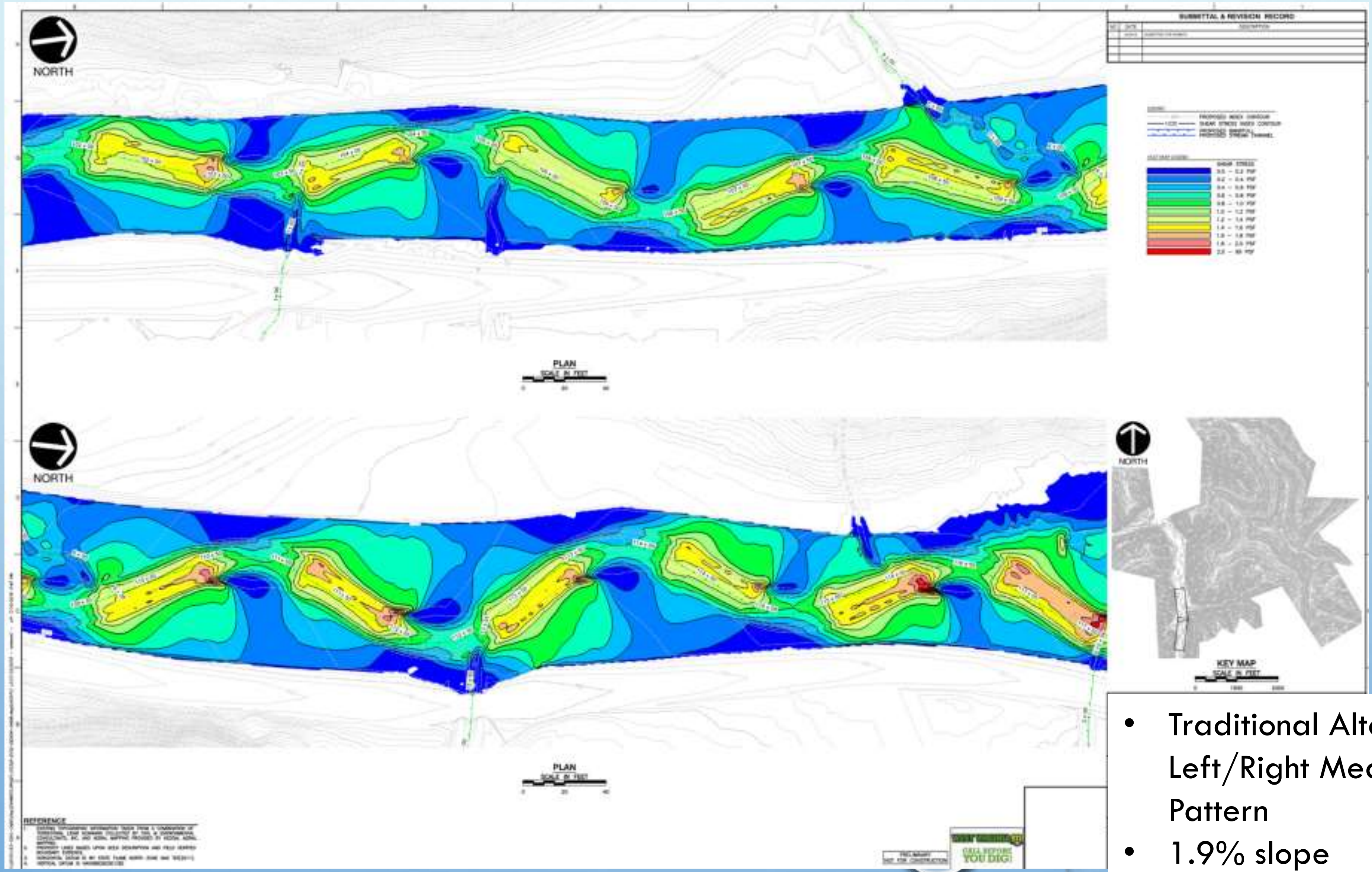


THE END…

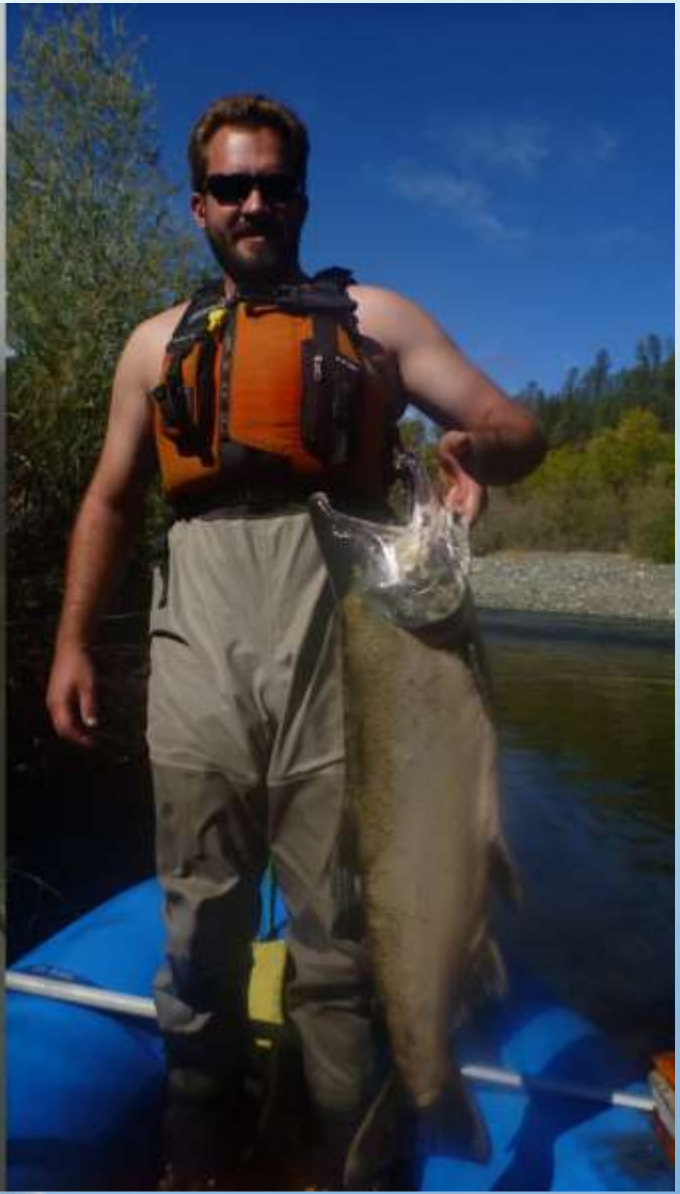
QUESTIONS?

MORE PICTURE?

POST CONSTRUCTION MODELLING



- Traditional Alternating Left/Right Meander Pattern
- 1.9% slope
- Drainage Area = 8 mi^2

TRINITY RIVER, SALMONID HABITAT ESTIMATES