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Managing Water in the West

Identifying Salmonid Habitat With a Two-Dimensional Hydraulic Model for the Yakima Basin Storage Study

U.S. Department of the Interior
Bureau of Reclamation

Presentation Outline

- Introduction and Purpose of the Models
- Reaches Modeled
- Data Sources for Surface
  - Terrestrial LiDAR
  - Bathymetric LiDAR
- Model Specifics
  - Mesh Generation
  - Hydraulic Model, GSTAR-W
- Habitat Characteristics Identified with the Model
  - Pool, Riffle, Glide via Froude Number
  - Flow Depth
  - Velocity
- Thanks to Dave Mooney for assistance with modeling

Introduction

- Why are we doing this?
- This study is being performed in conjunction with the Yakima Basin Storage Study
  - To better understand the habitat availability over a wide range of flows
    - How much water is enough?

Introduction

- Information from the 2-D models are being used by the Reclamation Storage Study as input to the Ecosystem Diagnosis and Treatment (EDT) model
  - To quantify the biological potential of stream habitat for salmonid fish species
  - Habitat evaluated over a wide range of flows
  - 2-D models provide continuous data throughout the reach modeled
  - Output from the models is rectified values of:
    - Depth averaged velocity
    - Flow depth
    - Froude number
    - Water surface elevation

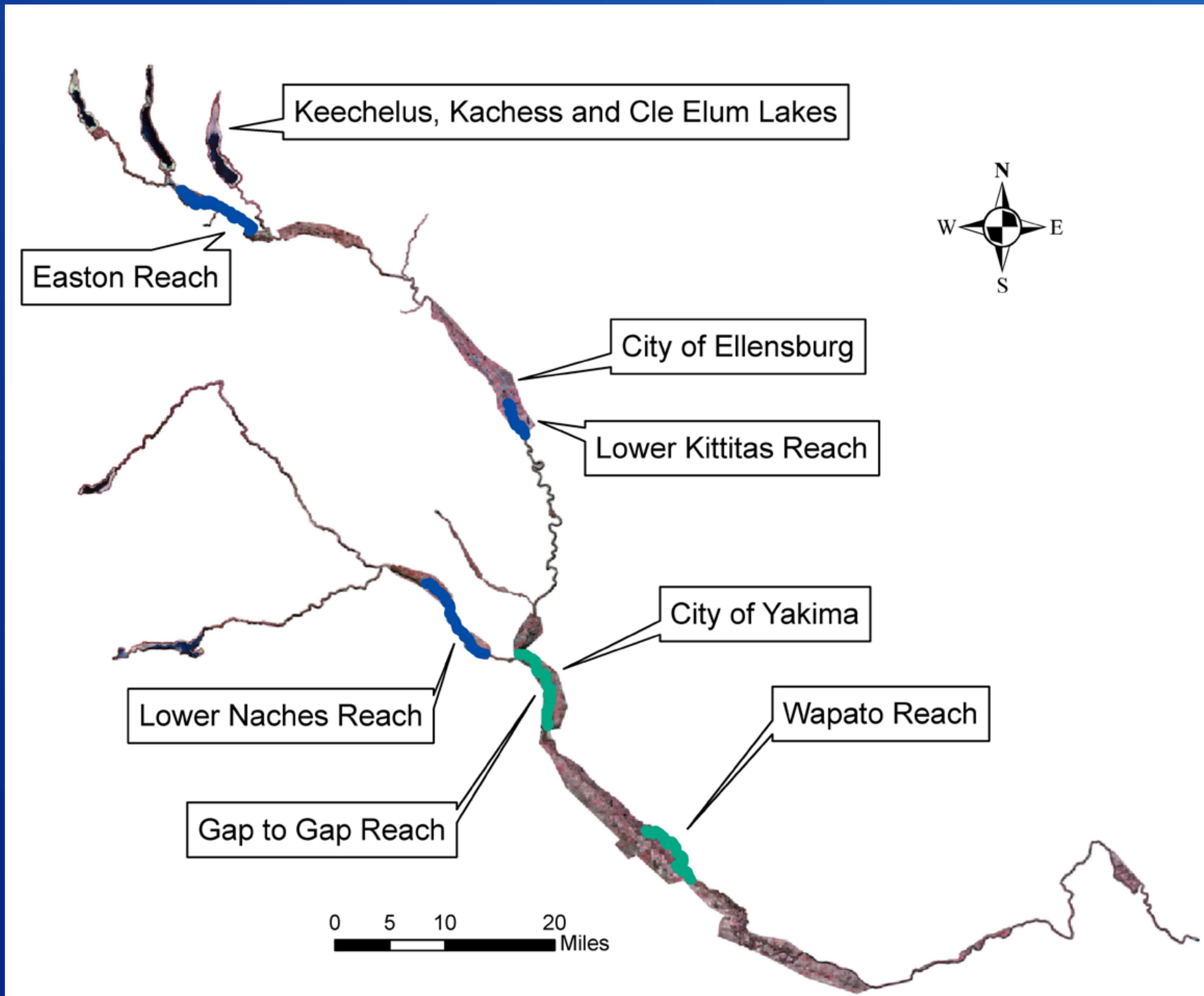
Introduction

- Wetted area will show which side channels are inundated at specific flow rates
- Output can be displayed and mathematically manipulated in a GIS

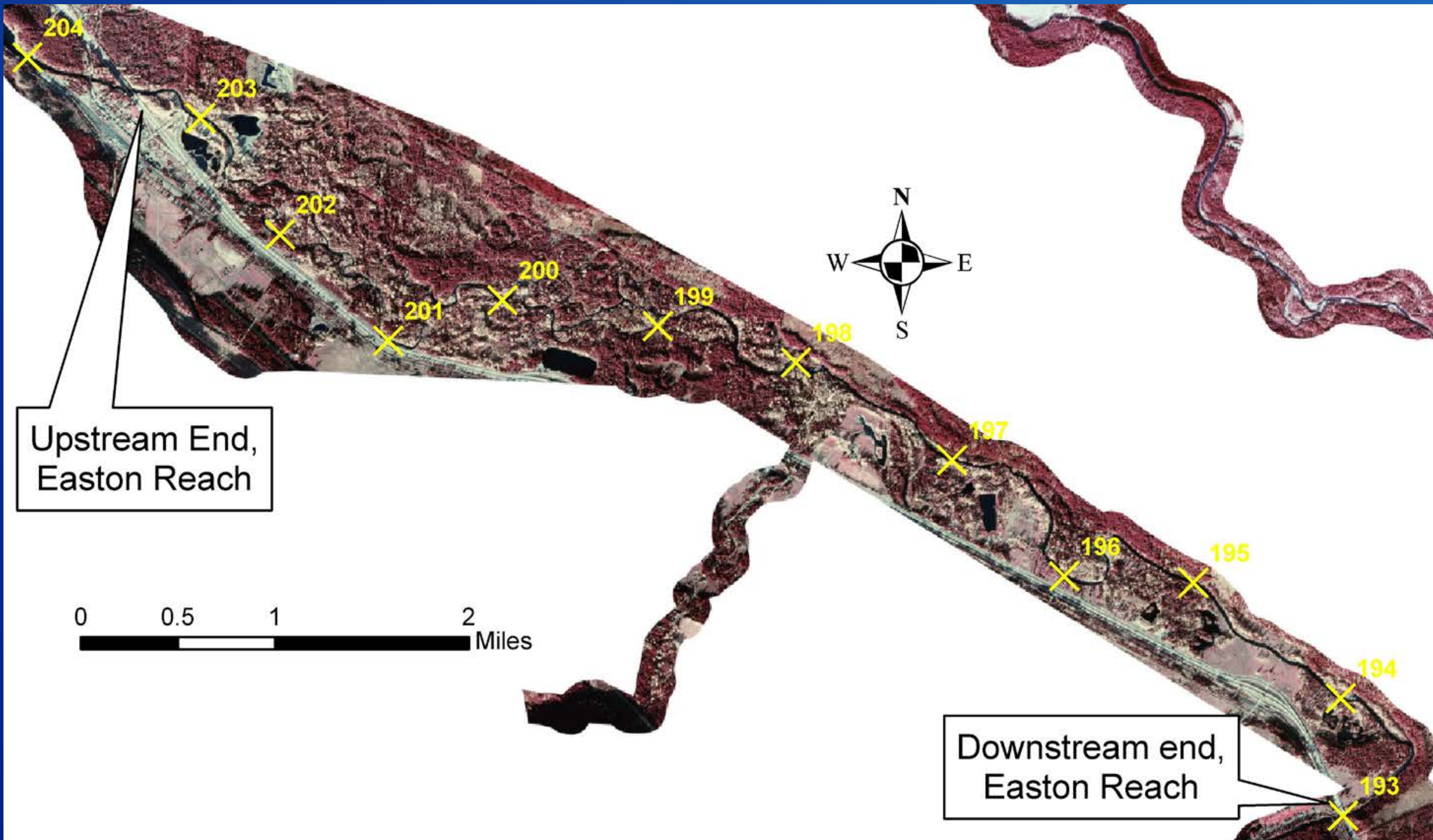
Reaches Modeled

- Reclamation modeled three reaches
  - Easton, (11 RM) I-90 bridge just below Easton Dam to I-90 crossing upstream of Cle Elum R. mouth
  - Kittitas, (4.5 RM) Upstream of Hansen Ponds to head of Yakima Canyon
  - Naches, (10 RM) Naches Br. to Powerhouse Br. At Cowiche Dam
- USGS modeling the Gap-to-Gap and Wapato reaches
  - Using River2D
  - Still in work

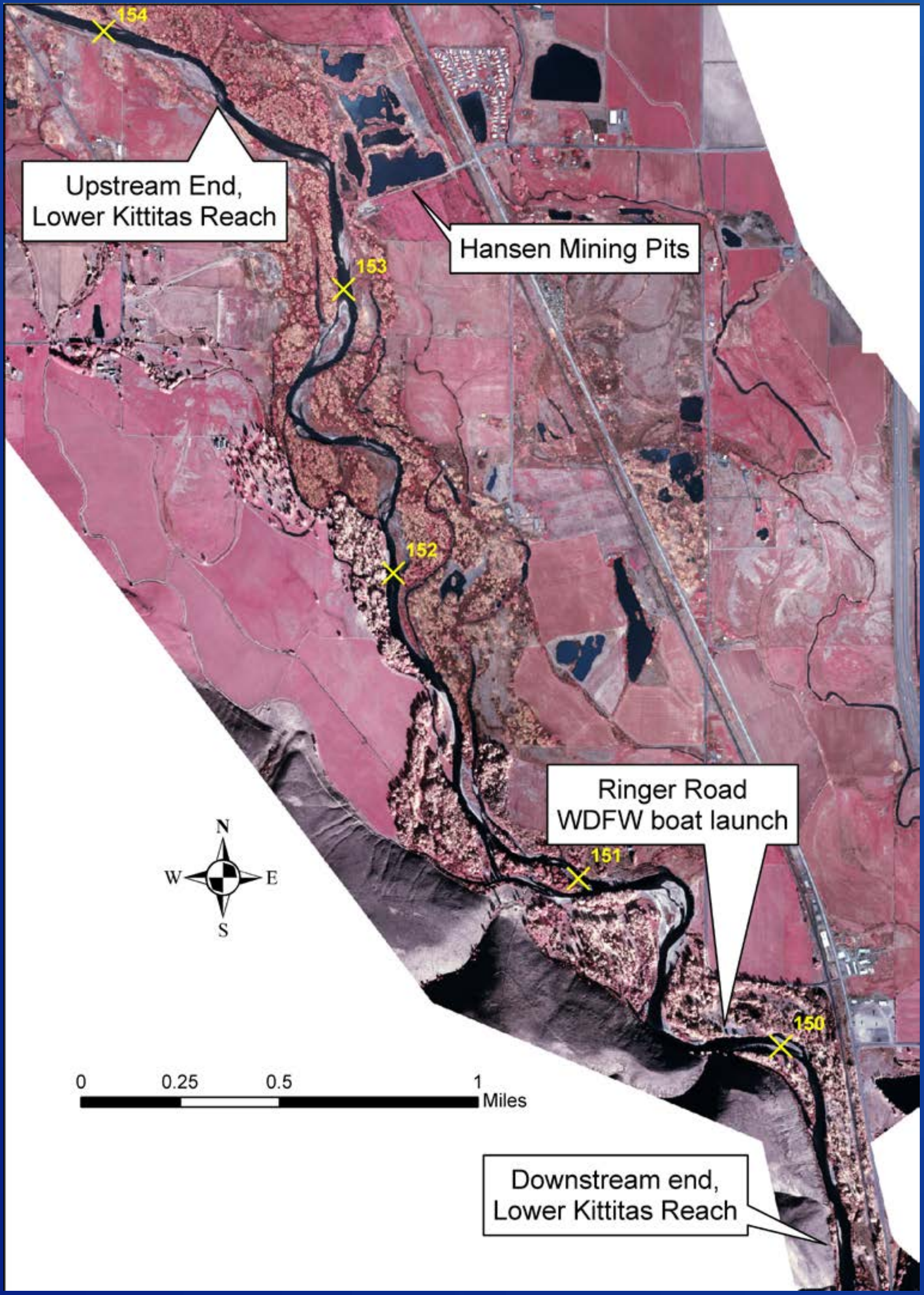
Modeled Reaches



Easton Reach



Kittitas Reach



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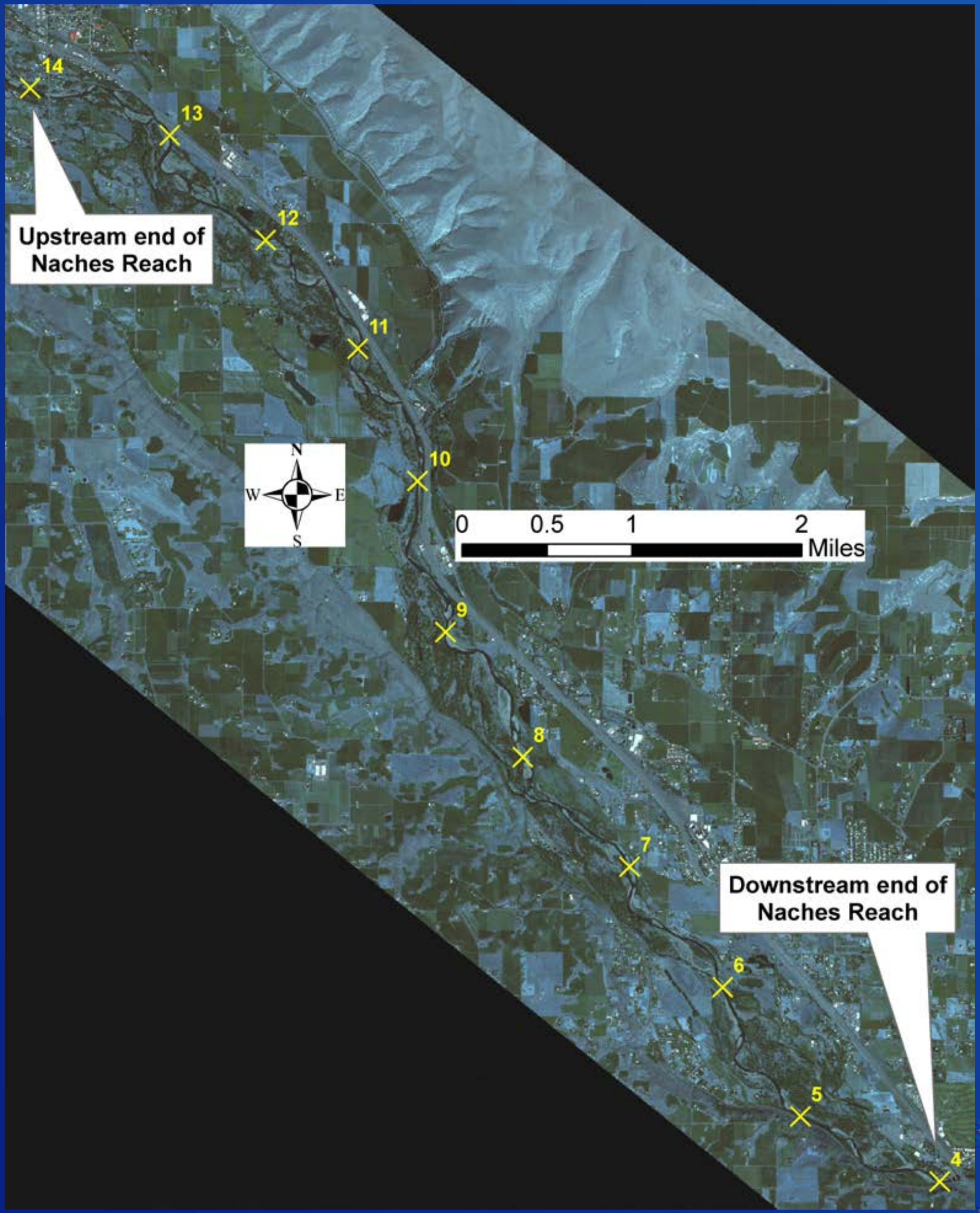

Naches Reach

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Data Sources

- Terrestrial LiDAR flown ~ November, 2000
- Bathymetric LiDAR flown September, 2004 and May, 2005
- Combined these point data sets to obtain a complete TIN surface
  - Required some manipulation in areas where channel migrated into the banks on the Naches reach
  - Used 2003 photography to assist this process on the Naches reach

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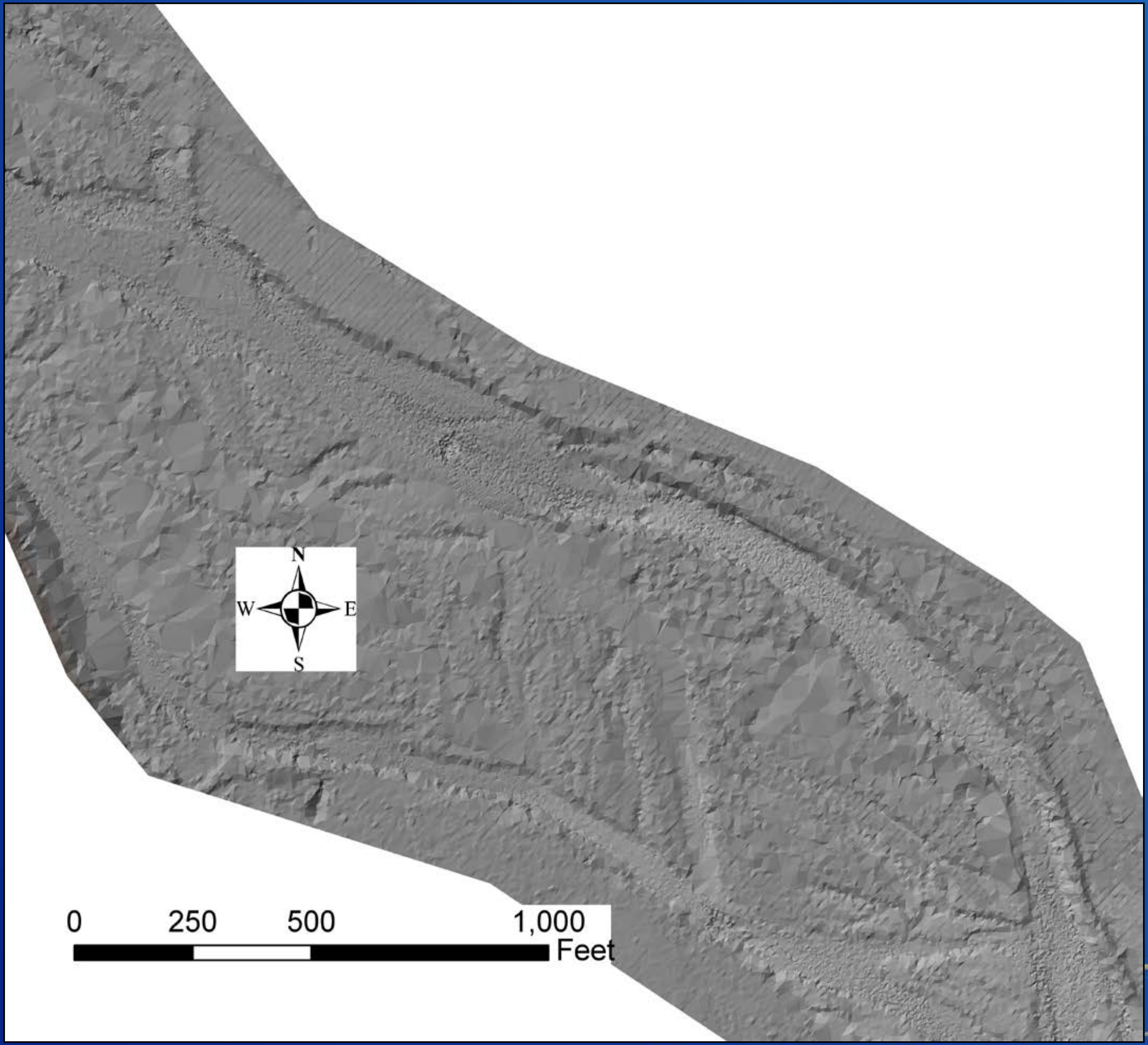
Data Sources

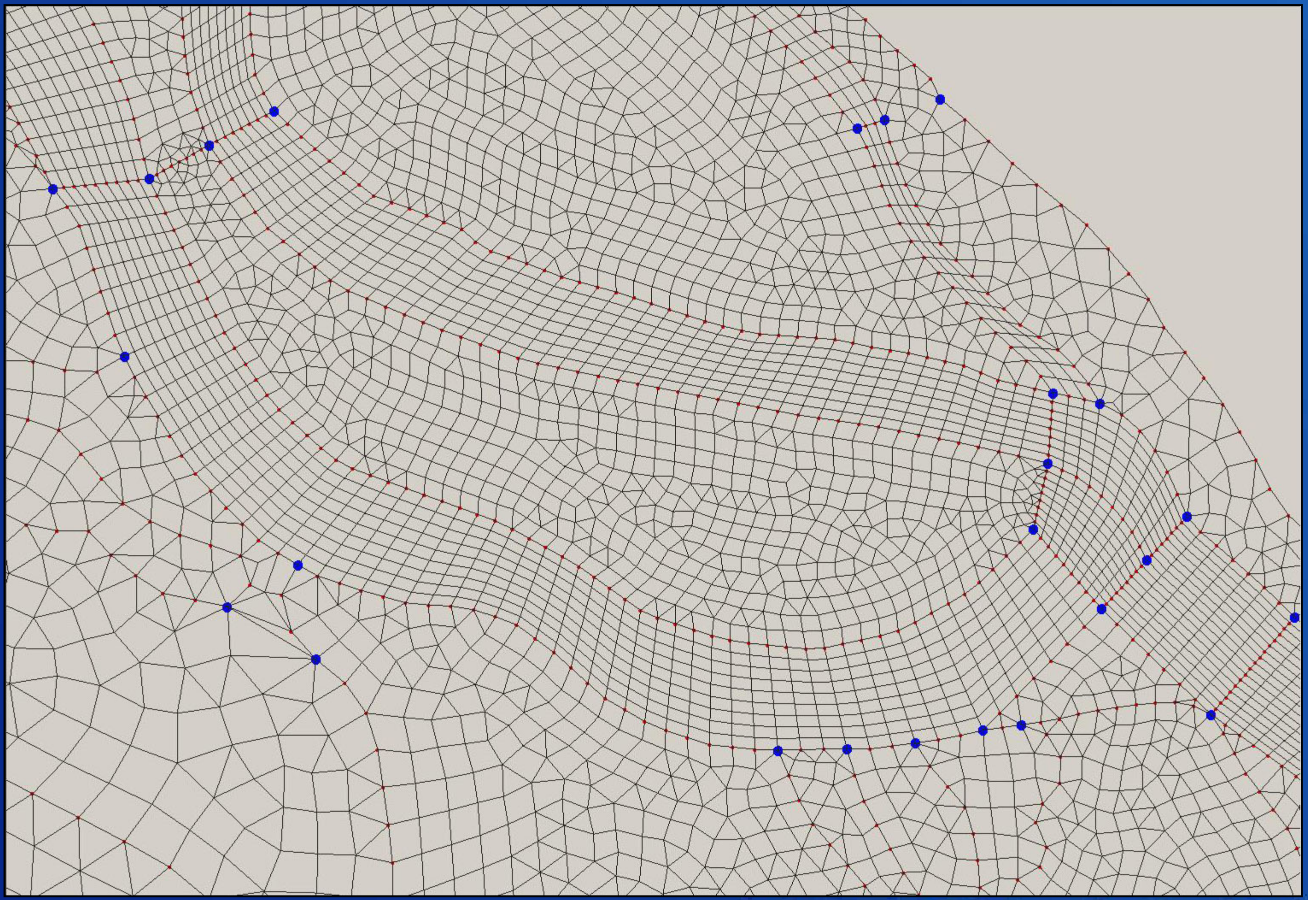


Mesh Generation

- Mesh generation
  - Mesh generated in Surface Water Modeling System (SMS, EMS-I)
  - Uses a combination of structured and unstructured mesh
    - Structured portions within areas of greatest interest – channels
    - Unstructured portions in areas of less interest – floodplains
  - Greatest resolution within the channel
    - Typical mesh size ~ 10ft. X 18ft. within the channel
      - Rectangular, structured mesh
    - Outside of channel varying resolution
      - Polygon, unstructured mesh

Mesh Generation

- Example of the mesh used in these models



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Model Specifics

- GSTAR-W -- Generalized Sediment Transport for Alluvial Rivers and Watersheds (Lai, 2006)
  - Two-dimensional (2D) hydraulic and sediment transport model for river systems and watersheds
  - Coupled modeling of channels, floodplains, and overland flow
  - Solves 2-D form of the diffusive or dynamic wave equations, using an implicit scheme
  - Uses steady or unsteady flows over all flow regimes (subcritical, critical, and transcritical
- This application used: steady flow, diffusive wave solver with an implicit scheme

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Model Specifics

- Output of GSTAR-W for this application is spatially rectified values of:
  - Depth averaged velocity in x and y direction
  - Magnitude velocity
  - Flow depth
  - Water surface elevation
  - Froude number

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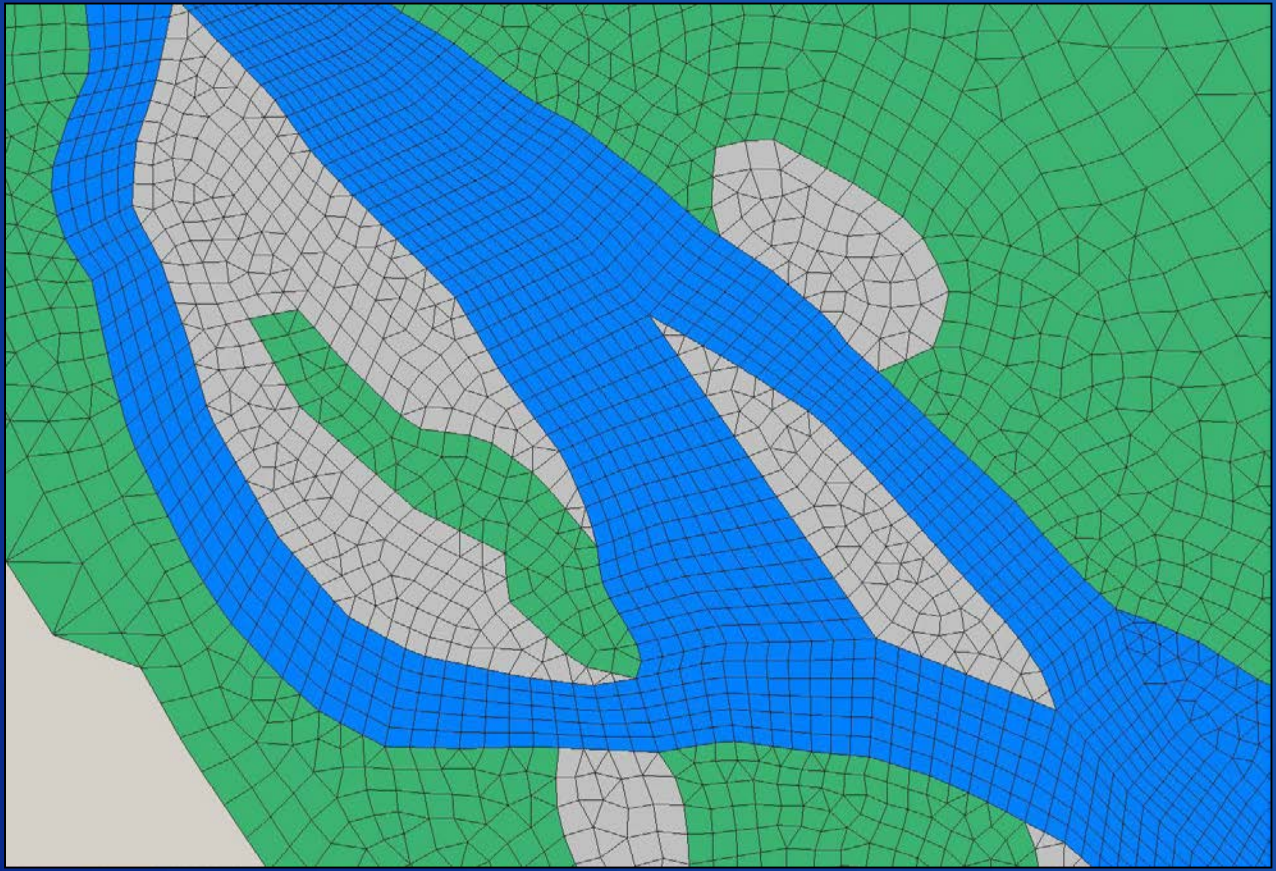
Model Specifics

- Four sets of roughness values used (Manning's *n)*
  - Main channel
  - Side channels and littered gravel bars
  - Forested floodplain
  - Cultivated floodplain

Main channel	Side channel/ littered gravel bar	Cultivated field areas	Forested areas
0.03-0.04	0.035-0.045	0.04-0.045	0.055-0.075

Model Specifics

- Example of roughness designations



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Model Specifics

- Boundary conditions
  - Upstream boundary – steady flow rate
  - Downstream boundary – constant water surface elevation determined by a verified 1-D model at the downstream end
  - Slip boundary – essentially a ‘friction free’ wall bounding the modeled surface

Model Specifics

- Model verification
  - All three models were verified with surveyed water surface elevations at locations throughout the reach at a minimum of two flow rates

Reach	Flow Rate (cfs)	Mean Error	Std. Deviation	Number of locations
Easton	250	-0.02	0.33	7
Easton	500	0.18	0.27	4
Kittitas	3146	-0.04	0.43	N/A
Kittitas	1032	0.23	0.49	4
Naches	720	0.01	0.36	5
Naches	2680*	0.31	0.36	4

*Flows at the Naches Gage @ Naches fluctuated 80 ft^3/s during the survey. Additionally, flows fluctuated spatially throughout the reach by 63 ft^3/s due to irrigation diversion and return. An average of the estimated flows at each location was used for the modeled flow rate.

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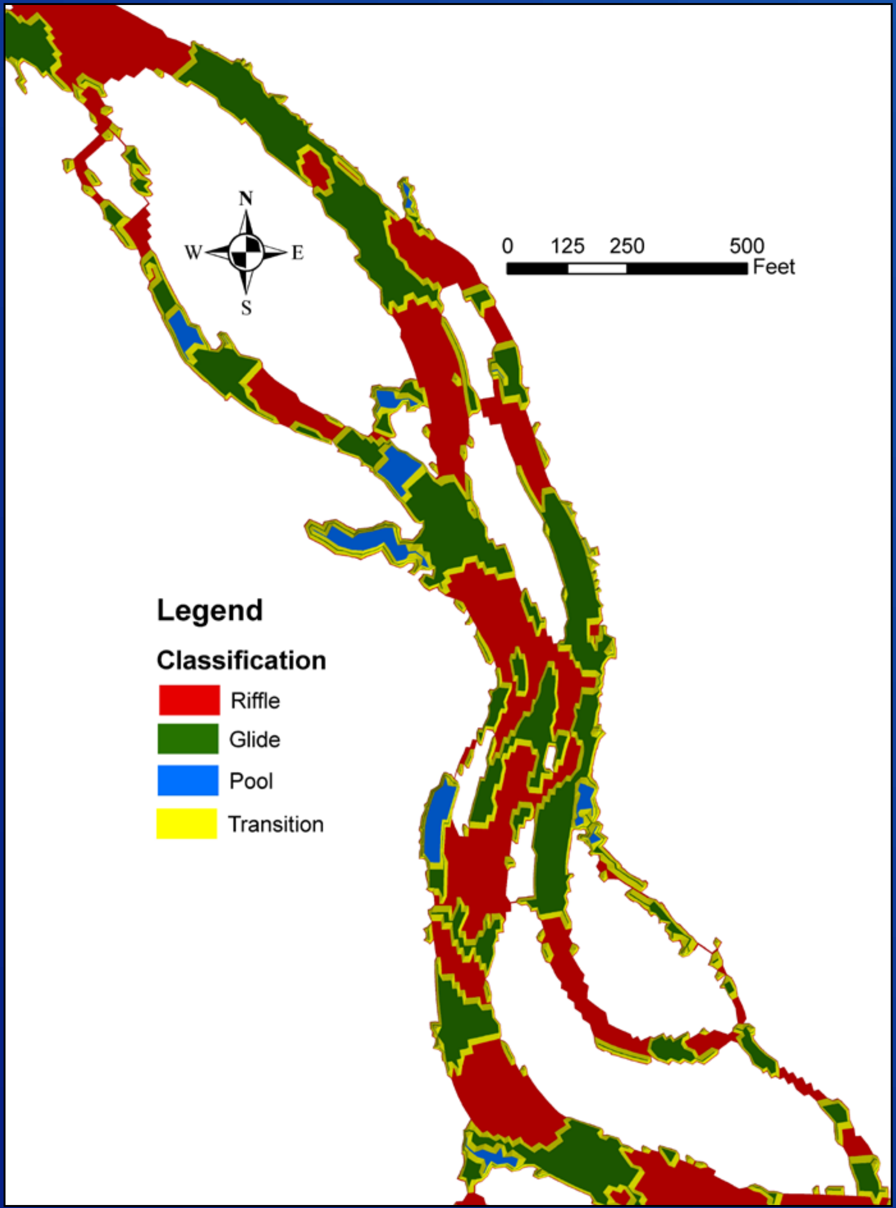
Habitat Characteristics

- Pool-Riffle-Glide habitat determined with the Froude number
  - Measure of inertial forces divided by gravitational forces
  - Most commonly used to describe free surface flows

$$\left(F_r = \frac{V}{\sqrt{gh}} \right)$$

  - Used piecewise function to determine individual habitats
  - Pool Fr < 0.09
  - Glide 0.09 ≤ Fr ≤ 0.42
  - Riffle Fr > 0.42
    - Following the method of Jowett, 1993

Habitat Characteristics



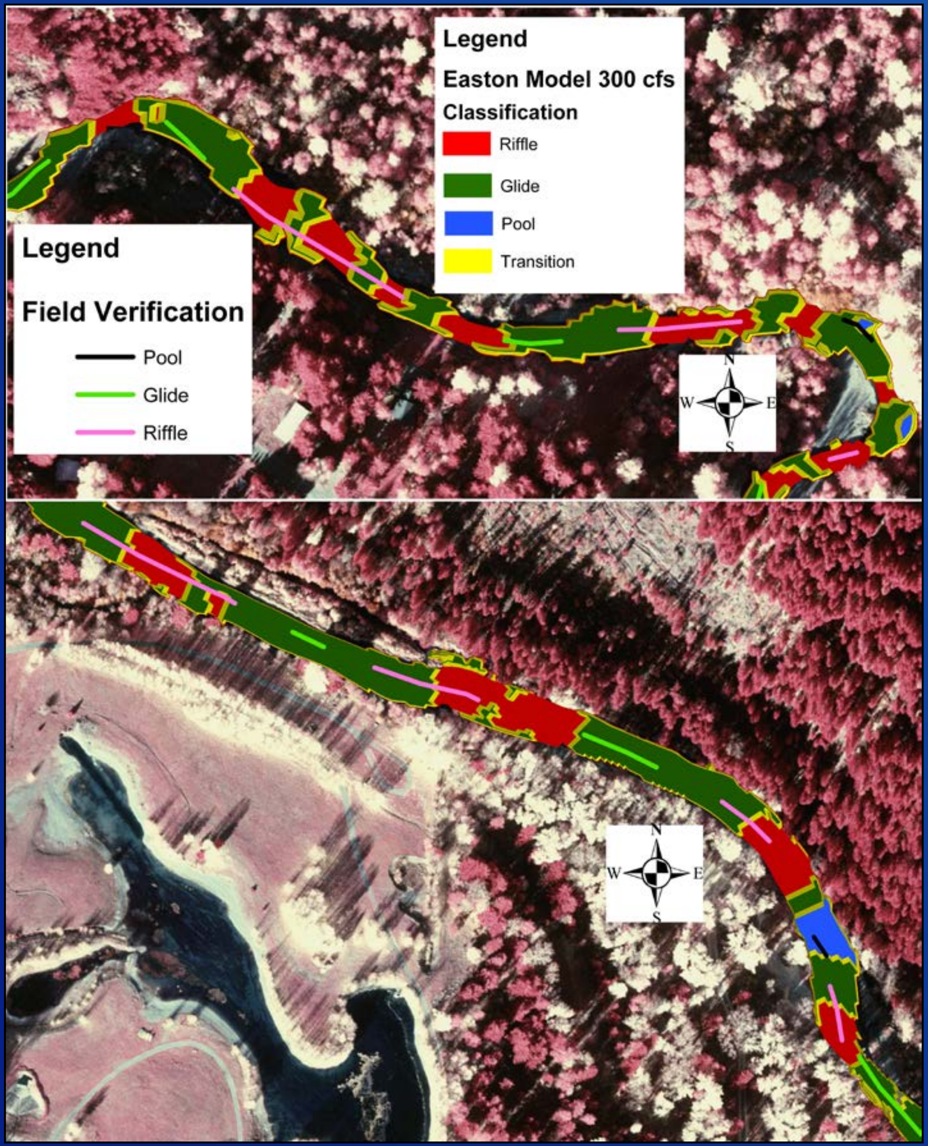
- Example of Pool-Riffle-Glide classification
  - Naches Reach, 720 cfs

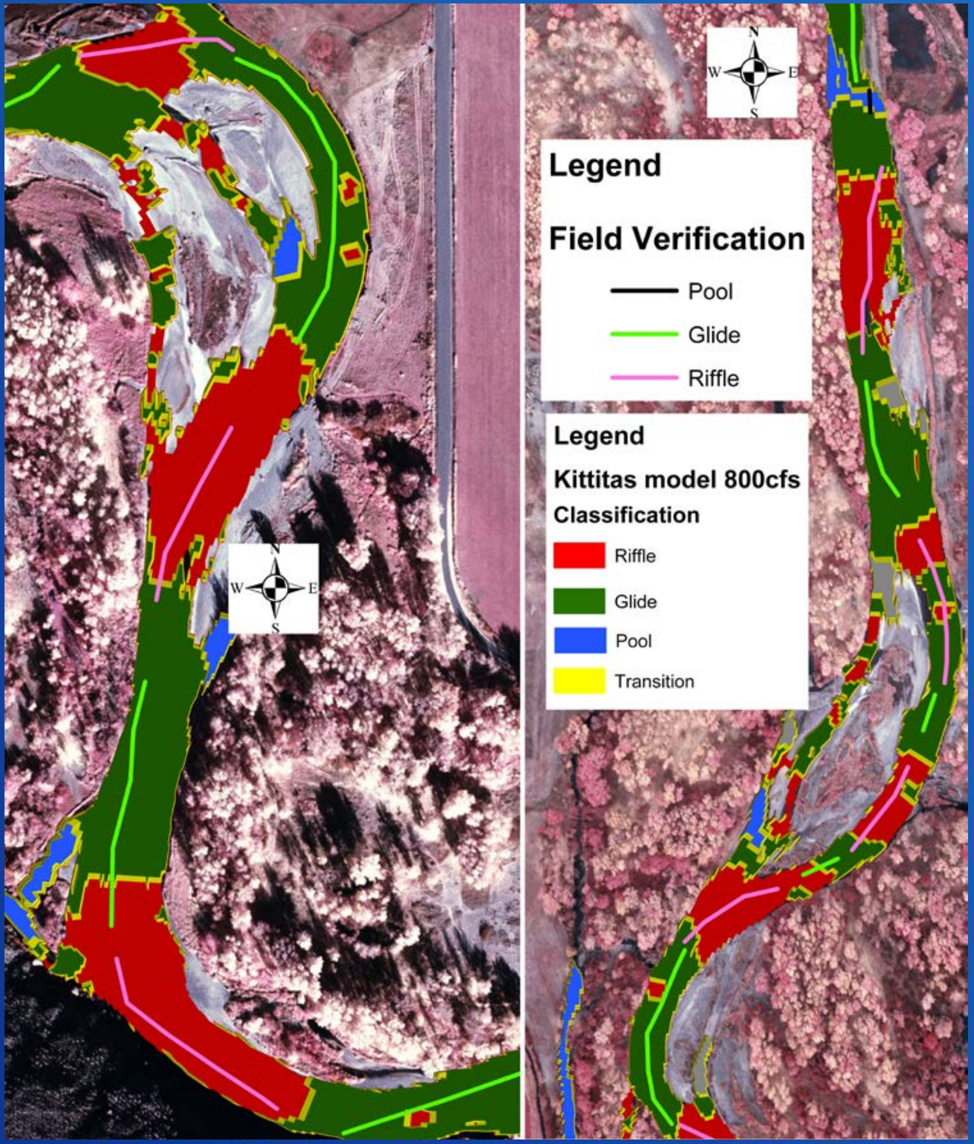
Habitat Classification

- Verification of method
  - Habitat classification was surveyed in each reach from a raft
  - Beginning and end of each feature was marked with a hand-held GPS receiver
  - That data was put into Arc GIS and compared to model classification results at the same flow rate

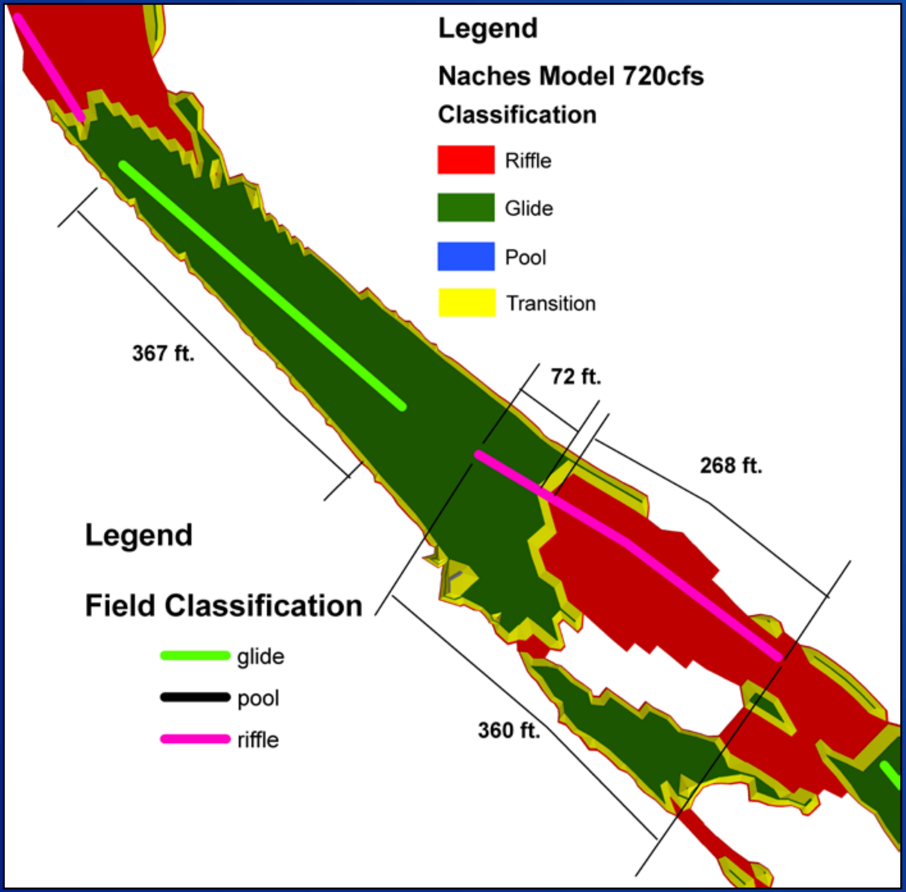
Habitat Characteristics

- Example of verification of Froude number habitat classification





Habitat Characteristics

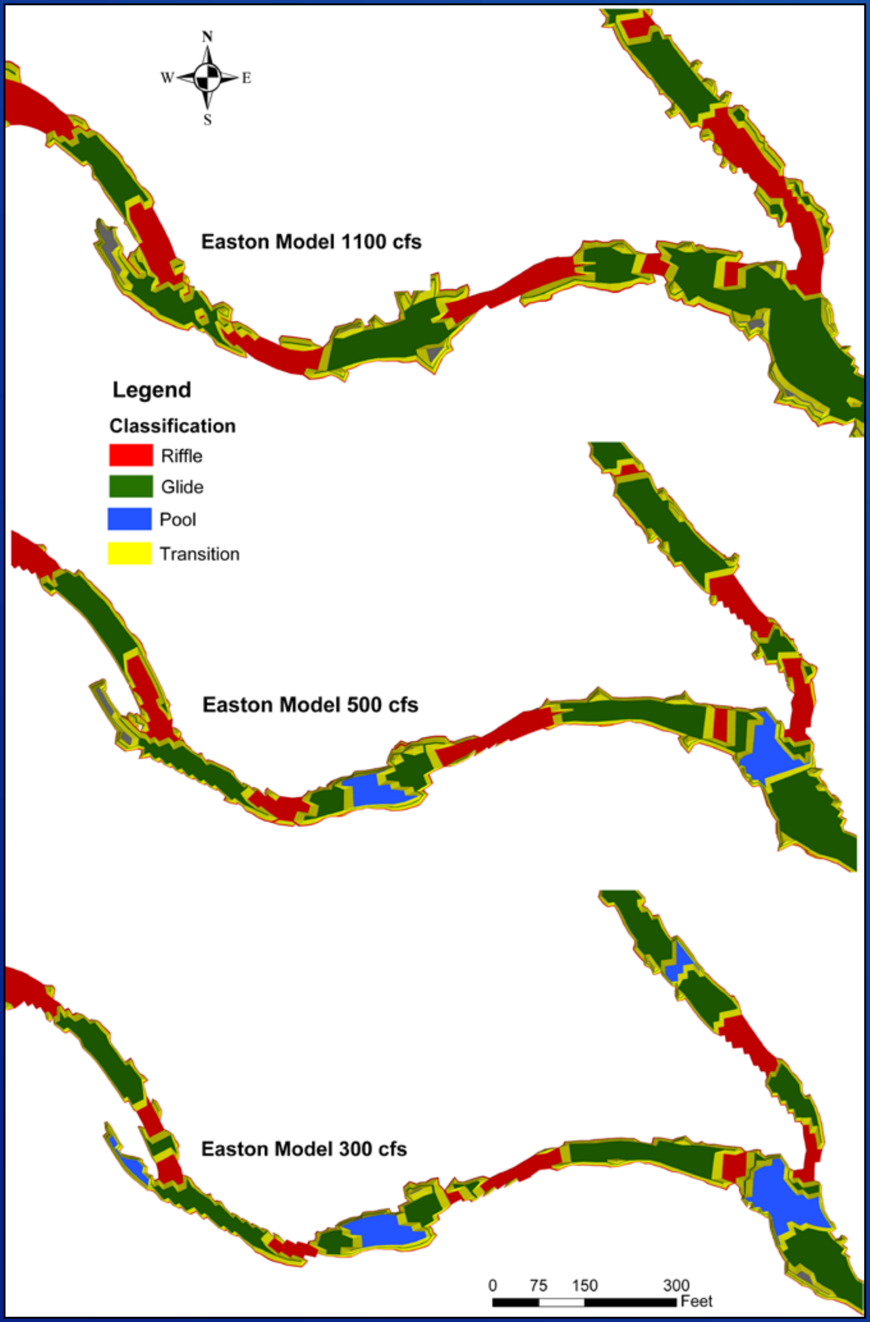


- Measuring the success of modeling habitat

Reach	Success for all features (%)	Success for Riffles (%)	Success for Glides (%)	Success for Pools (%)	Number of Each Feature Identified in the Field
Easton	73	63	87	64	69 Riffles 66 Glides 19 Pools
Kittitas	85	83	91	50	17 Riffles 15 Glides 2 Pools
Naches	81	87	77	0	34 Riffles 31 Glides 1 Pool

(1 – (72/360))*100 = 80%

Habitat Characteristics



- Change in pool-riffle-glide classification with change in flow

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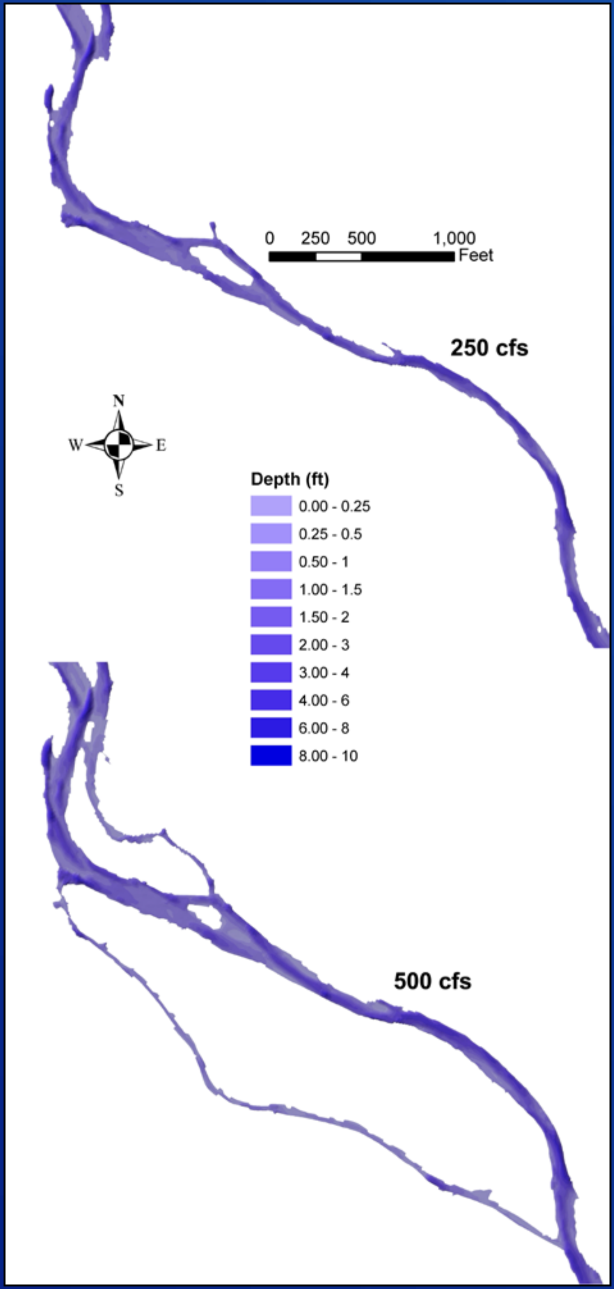
Habitat Characteristics



- Example of side channels becoming inundated at 500 cfs that were dry at 250 cfs

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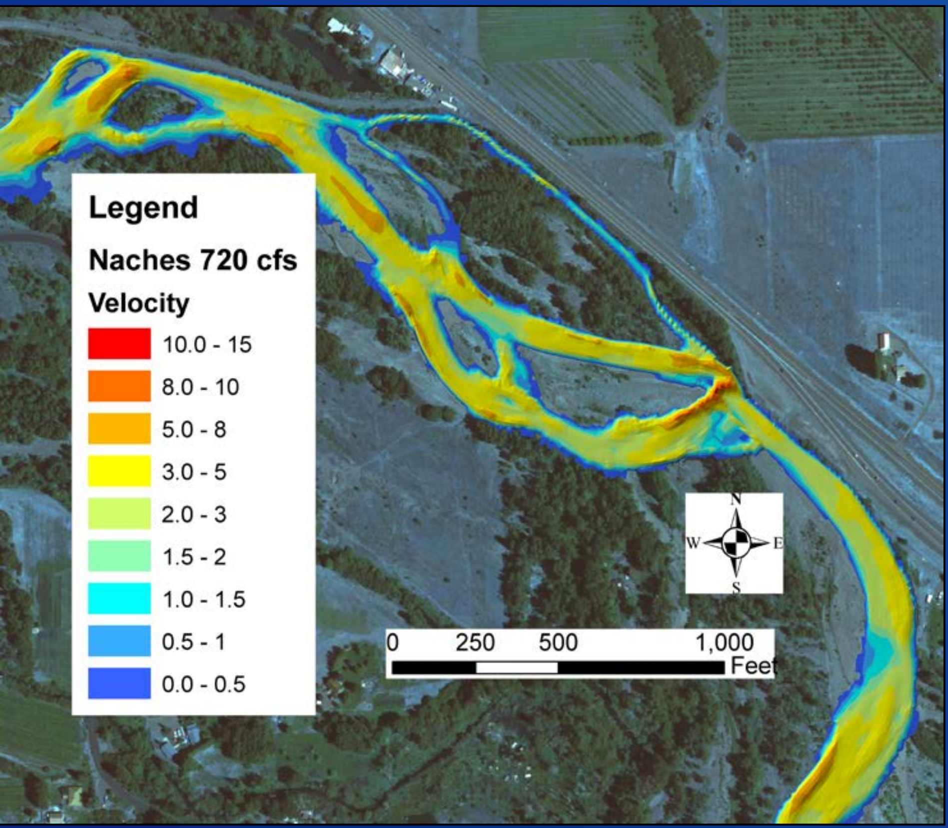
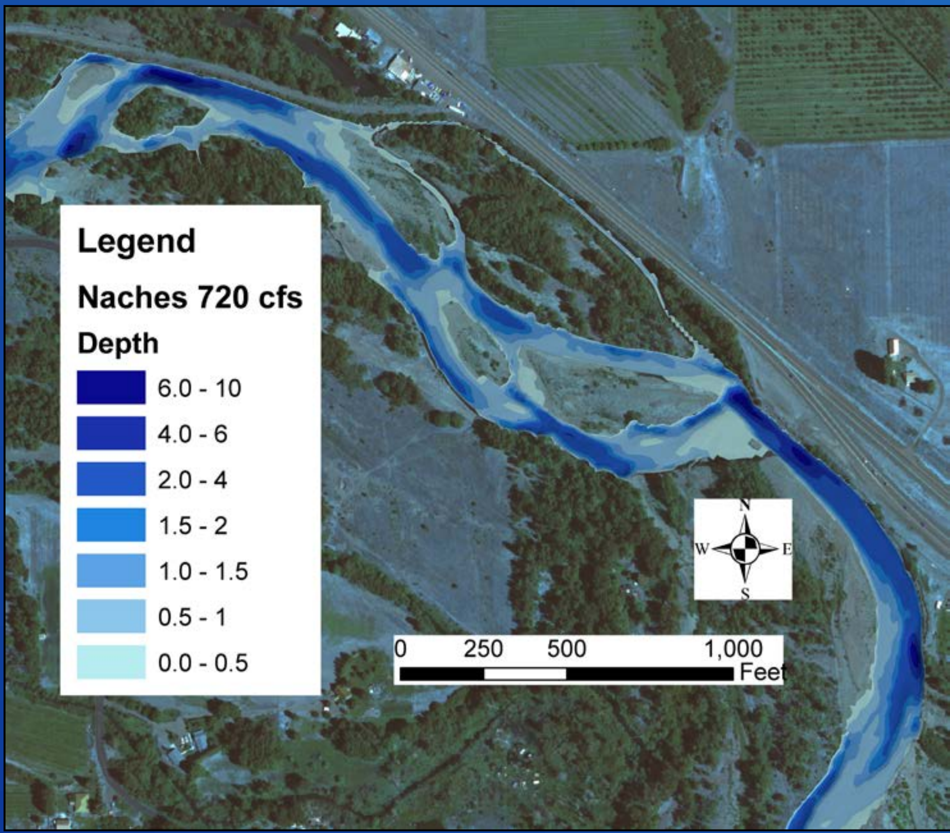
Habitat Characteristics

- Flow depth and depth averaged velocity examples





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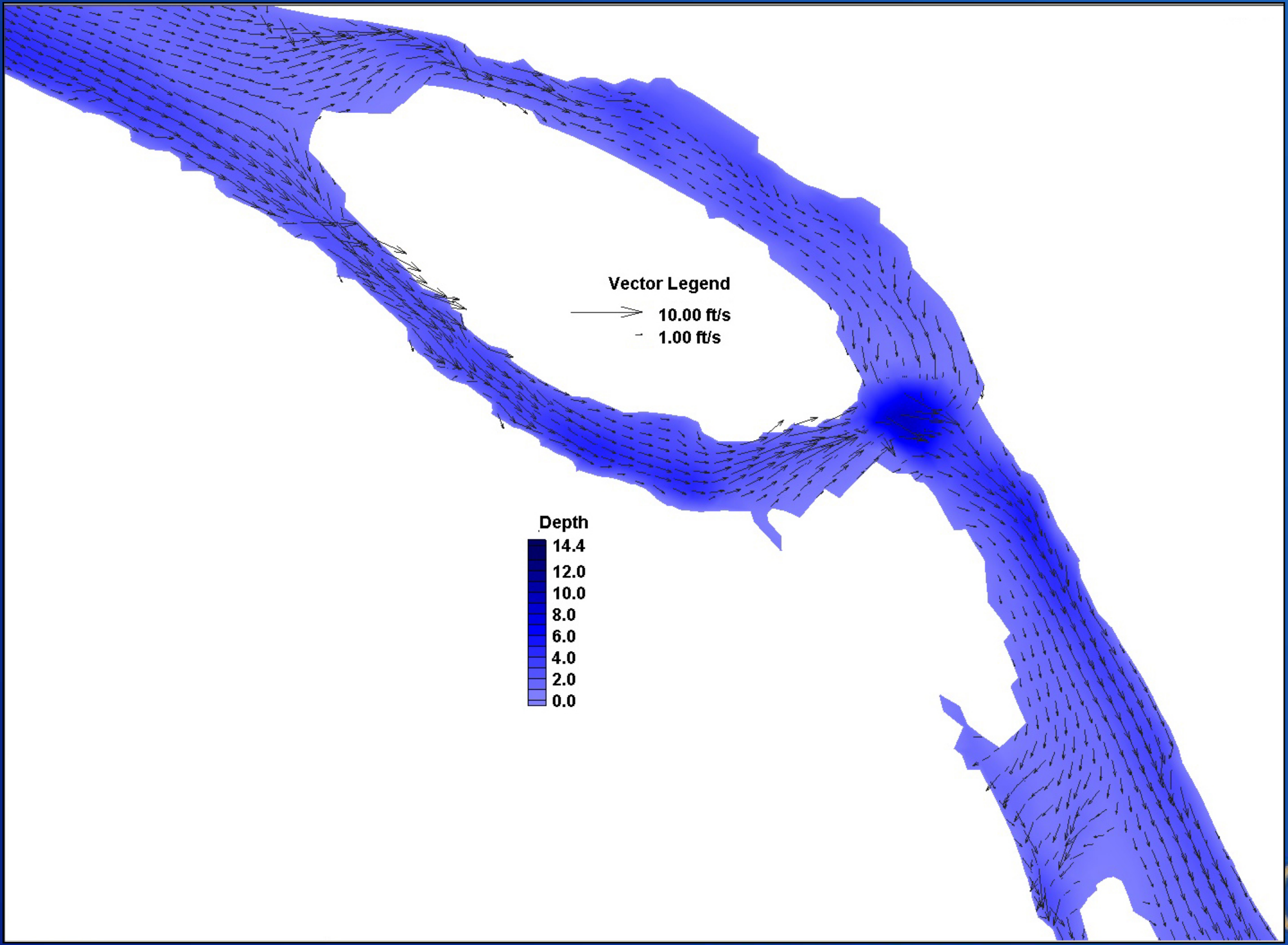
Habitat Characteristics

- Another example of flow depth and velocity displayed in SMS



Making Use of 2-D Habitat Data

- How will all this information be used?
- To provide input to EDT
  - Pool-Riffle-Glide areas will be quantified in GIS for each flow
  - Side channel habitat will be quantified over the range of flows
  - Depth and velocity values will be used to construct meso-habitat maps for the range of flows (Ken Bovee, USGS)
    - These will be used for a decision support system used in conjunction with EDT

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Questions?