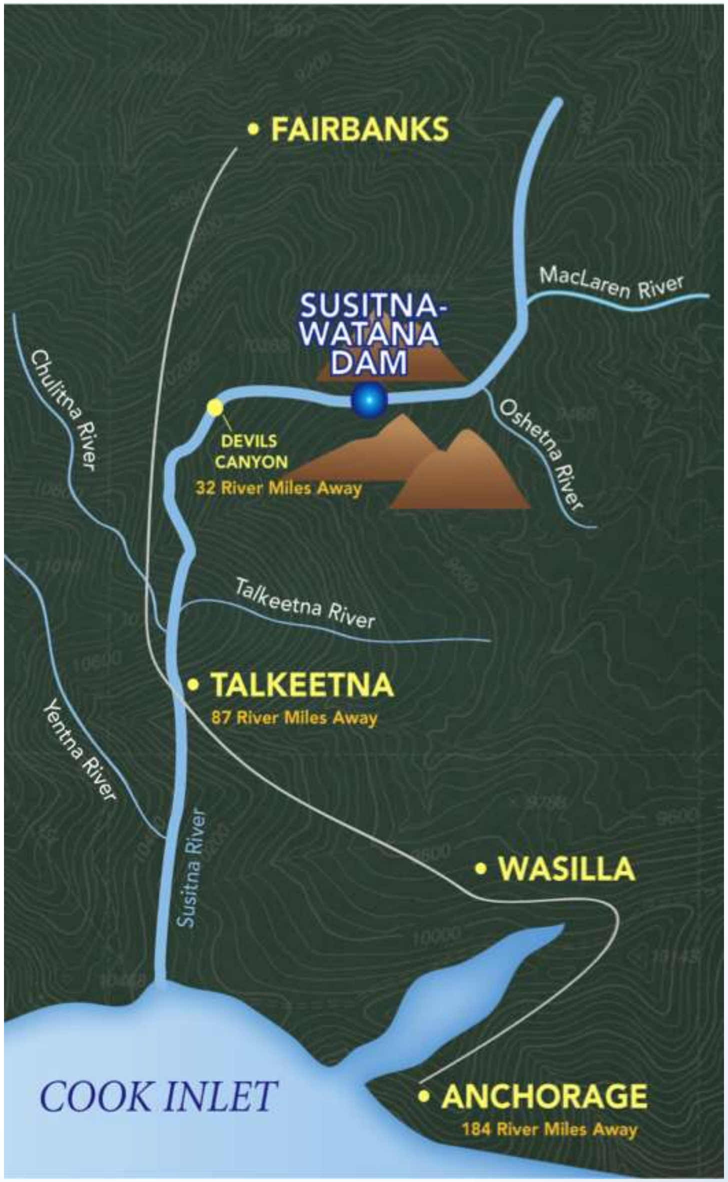
Technical Team Meeting

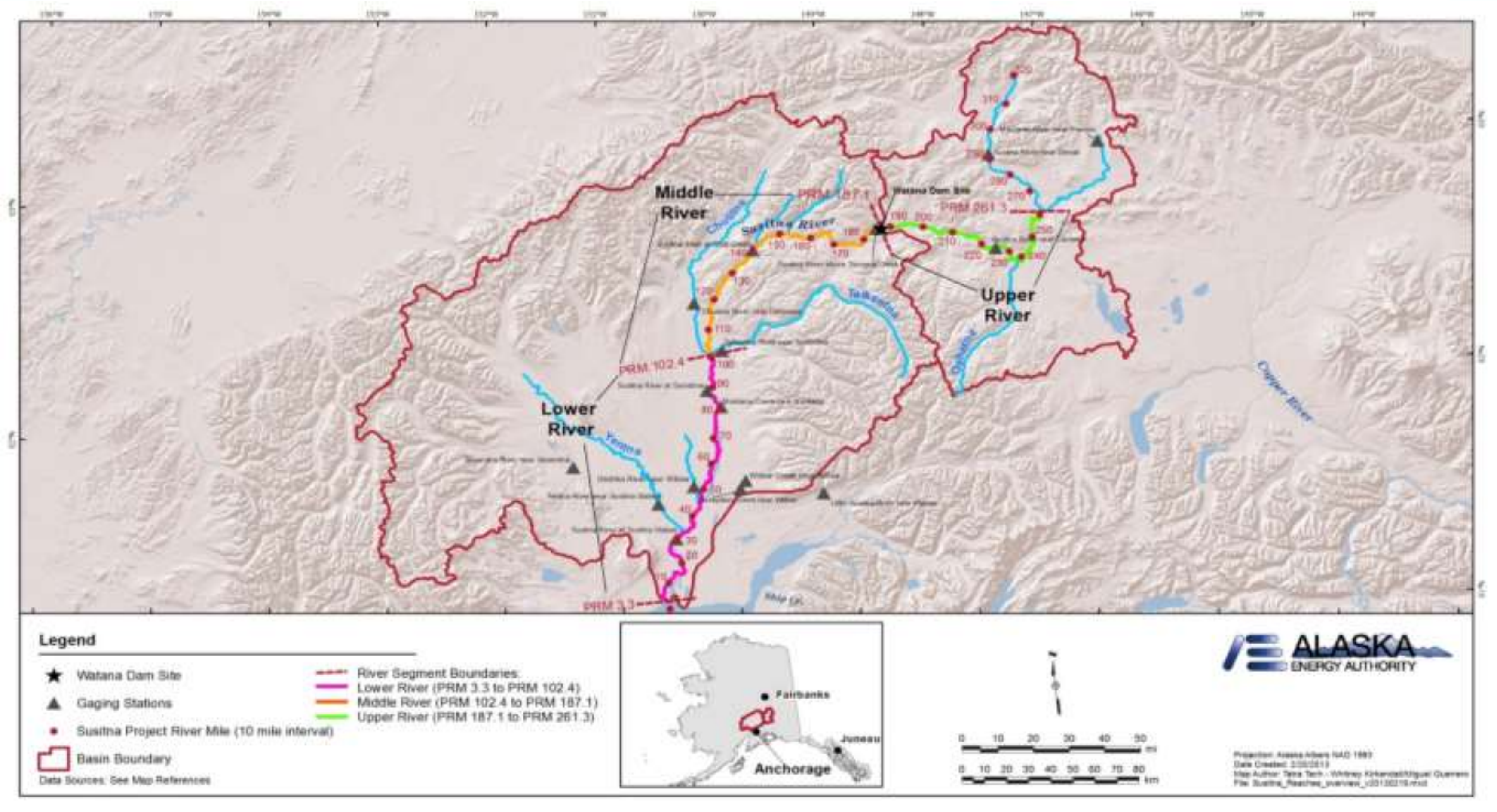
Fluvial Geomorphology
Modeling Approach
May 21, 2013

Prepared by: Tetra Tech

Prepared for: Alaska Energy Authority



Susitna River Basin



SUSITNA-WATANA HYDRO *Clean, reliable energy for the next 100 years.*

Purpose and Objectives of TM

Address FERC Study Plan Determination

Recommendations on Fluvial Geomorphology Modeling

- Modeling in Focus Areas
  - Specify the 1- and 2-D models for FGM
  - Provide rationale and criteria for model selection
  - Identify location and extent of models
  - Provide overview of model development
- Interaction at Three Rivers Confluence
  - Describe approach for evaluating geomorphic change at confluence of Susitna, Chulitna, and Talkeetna Rivers
- Incorporating LWD and Ice Processes
  - Describe approaches for 1- and 2-D modeling

Background

Questions to be addressed by Fluvial Geomorphology Modeling

- Is the system in dynamic equilibrium?
- If not, what is expected evolution over license term?
- Will the Project affect morphologic evolution?
- If so, what are the expected changes over license term?

Scale Issues

- Reach-Scale 1-D Modeling
  - Long time periods (decades)
  - Conditions along river (10^1 – 10^0 x Susitna River width)
  - Conditions over subareas (channel, L/R floodplains)
- Local-Scale 2-D Modeling
  - Short time periods (< 1 year)
  - Conditions in river (10^0 – 10^{-1} x Susitna River width)
  - Conditions in side channels (10^{-1} – 10^{-2} x Susitna River width)
  - Conditions in floodplains and islands (10^0 – 10^{-1}x Susitna River width)

Model Selection Criteria

- 1-D and 2-D model requirements
  - Sufficient number of sediment sizes
  - Computes transport by size fraction (armoring and sorting)
  - Includes Wilcock & Crowe or Parker transport relations
  - Only public domain and commercial models considered
- 1-D model requirements
  - Large Extent (number of cross sections)
  - Long Duration (number of hydrograph ordinates)
  - Closed loop transport (split flow around islands)
- 2-D model requirements
  - Detailed spatial resolution (large number of elements)
  - Flexible (irregular) mesh

1-D Model Selection

- HEC-RAS version 4.1 (USACE)
  - Eliminated: no closed loop capability
- SRH-1D version 2.8 (USBR)
  - Meets requirements but not selected
  - Disadvantages: limited use, no GUI, potential limitation on number of sediment size classes
  - Advantage: fully unsteady
- MIKE 11 version 2011 (DHI)
  - Eliminated: Does not include required transport relations
- HEC-6T version 5.13.22-08 (MBH)
  - Selected – meets requirements
  - Advantages: widespread use and modeling team experience
  - Disadvantages: quasi-unsteady, basic GUI

2-D Model Selection

- MIKE 21 version 2011 (DHI)
  – Eliminated: Does not include required transport relations
- ADH version 4.3 (USACE)
  – Eliminated: Does not include required transport relations
- MD_SWMS-SToRM (USGS)
  – Eliminated: Does not currently include sediment transport
- RiverFLO-2D version 3 (Hydronia LLC)
  – Eliminated: single sediment size and does not include required sediment transport relations

2-D Model Selection

- SRH-2D version 3 (USBR)
  - Meets requirements
  - Disadvantages: limited to 16,000 elements for sediment transport simulations
  - Advantages: modeling team experience, robust wetting/drying
- River2D (R2DM) (U. Alberta & U. British Columbia)
  - Meets requirements
  - Advantages: Used by other study team members (ice and habitat), large number of elements
  - Disadvantages: potential problems with continuity from wetting/drying, no sediment transport experience

2-D Model Recommendation

- Test and compare SRH-2D and River2D
  - One focus area
  - One sediment transport simulation
  - One set of habitat simulations
- Final selection criteria
  - Capabilities to produce representative results (primary criteria)
    - Observed water surface, depth, velocity
    - Sediment transport capacity, bed evolution and armoring
    - Flow continuity and flow distribution
  - Model use (secondary criteria)
    - Ease of model development and use
    - Limitations in resolution or other limitations
    - Execution speed
    - Ease of post processing

Overview of* Overview of Model Development

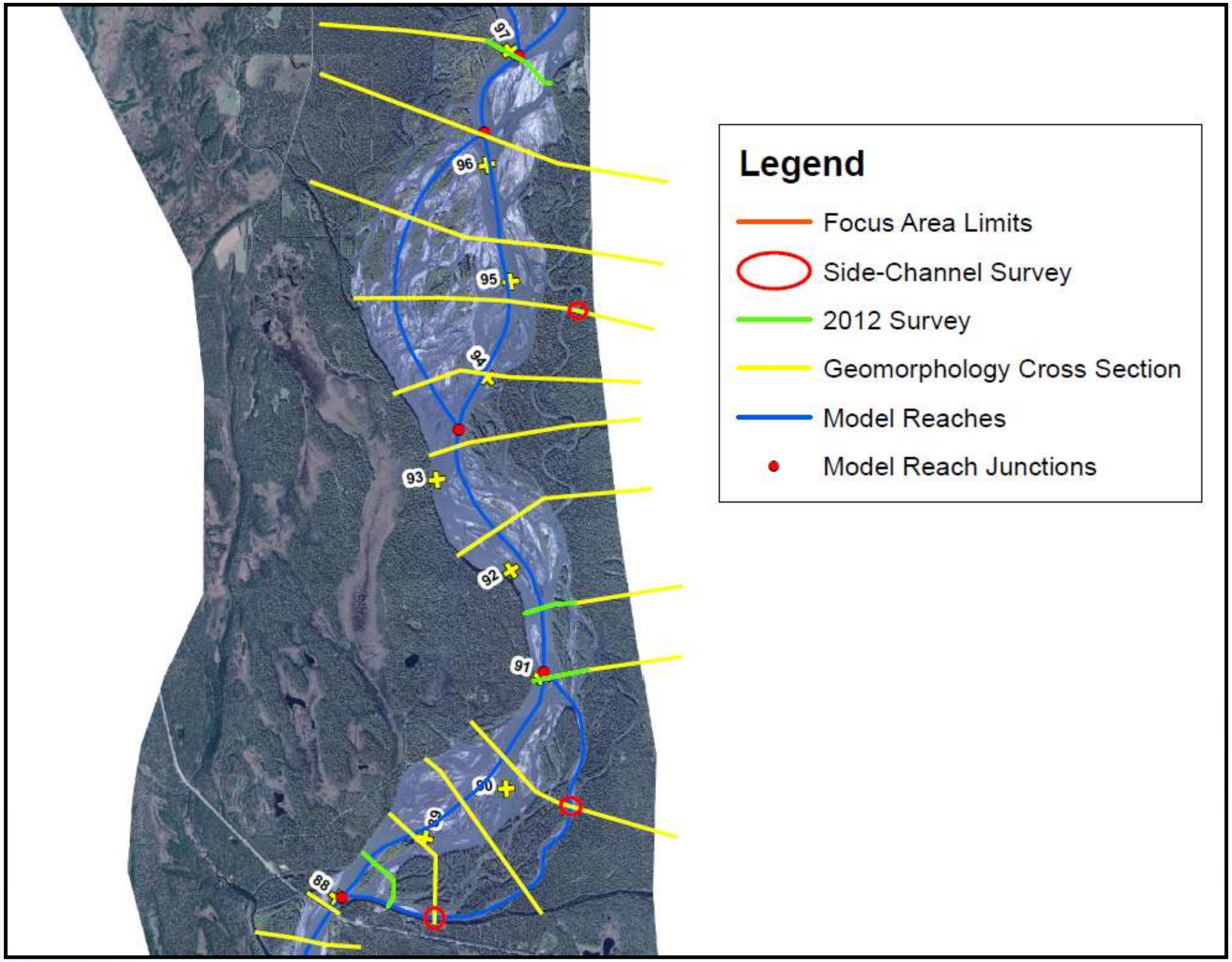
- Model layout
- Cross section (1-D) and geometry (2-D) data
- Flow resistance (1-D & 2-D) and turbulence (2-D) input
- Bed material data (gradations and layer thickness)
- Boundary conditions
- Other considerations
- Test, calibrate, and validate hydraulics
- Test, calibrate, and validate sediment transport
- Simulations
- Evaluation of results and post processing

*Sections 3.1.1 and 3.2.1 provide detail for each bullet

1-D Model Extent

- Susitna River
  - Lower limit PRM 29.9 (Susitna Station)
  - Upper limit PRM 187.1 (Wantana Dam Site)
- Chulitna River
  - Approximate Lower 10 miles to narrowing of channel
- Talkeetna River
  - Approximate Lower 4 miles to single channel and gage location

1-D Model Example Cross Sections



Three Rivers Confluence Modeling Objectives

Chulitna and Talkeetna Rivers included in 1-D models to evaluate geomorphic change at Three Rivers Confluence

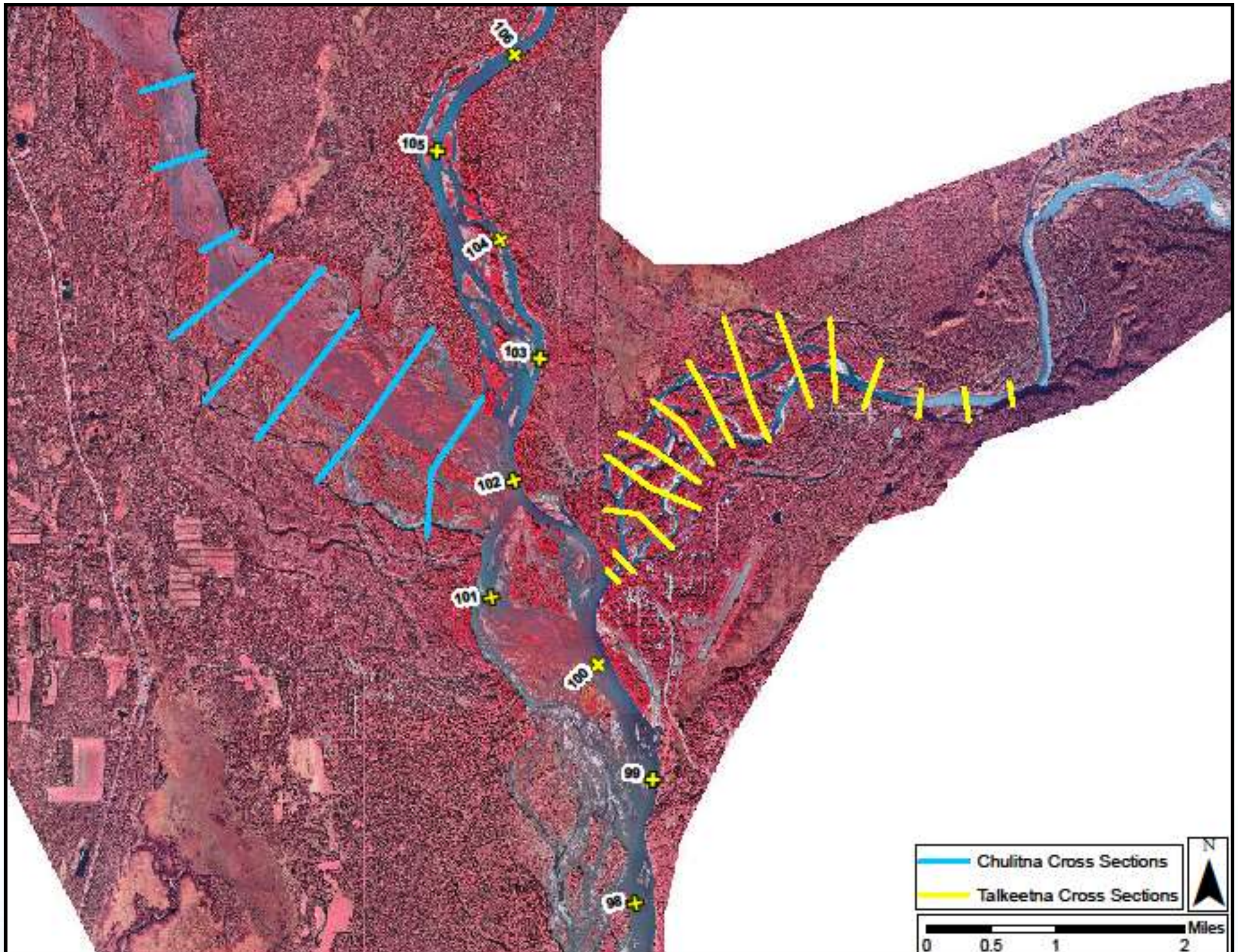
- Compare existing conditions to with-Project to evaluate
  - Hydraulic interactions
  - Sediment transport interactions
  - Channel change

Three Rivers Confluence Modeling Outcomes

Information on hydraulics, sediment transport, and channel form through analysis of:

- Velocity
- Depth
- Water Surface
- Sediment loads
- Effective Discharge
- Aerial photo analysis
- Coincident flows and stage
- Bed material gradation
- Aggradation & degradation
- Channel profiles
- Channel width
- Channel plan form

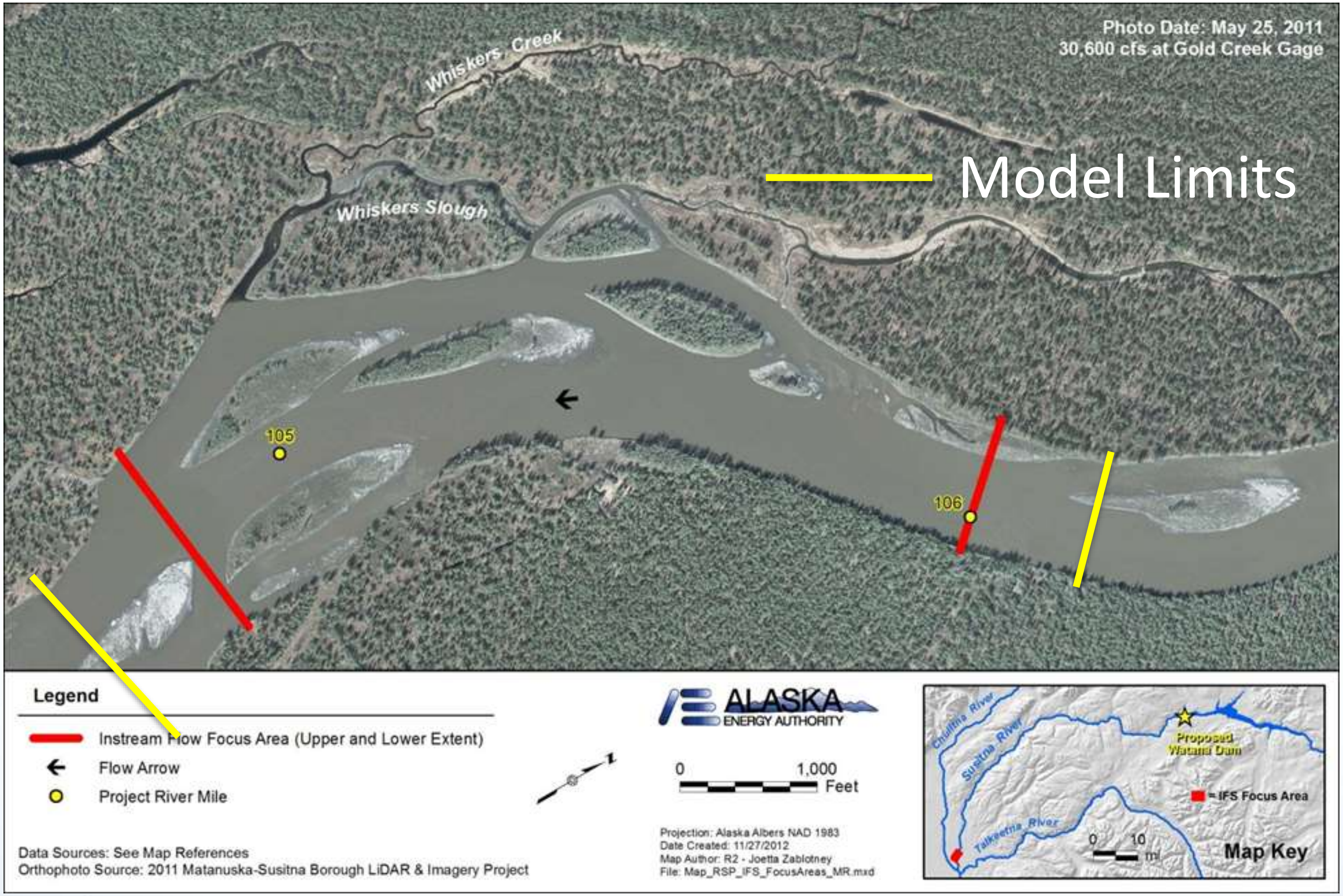
1-D Model 3 Rivers Confluence



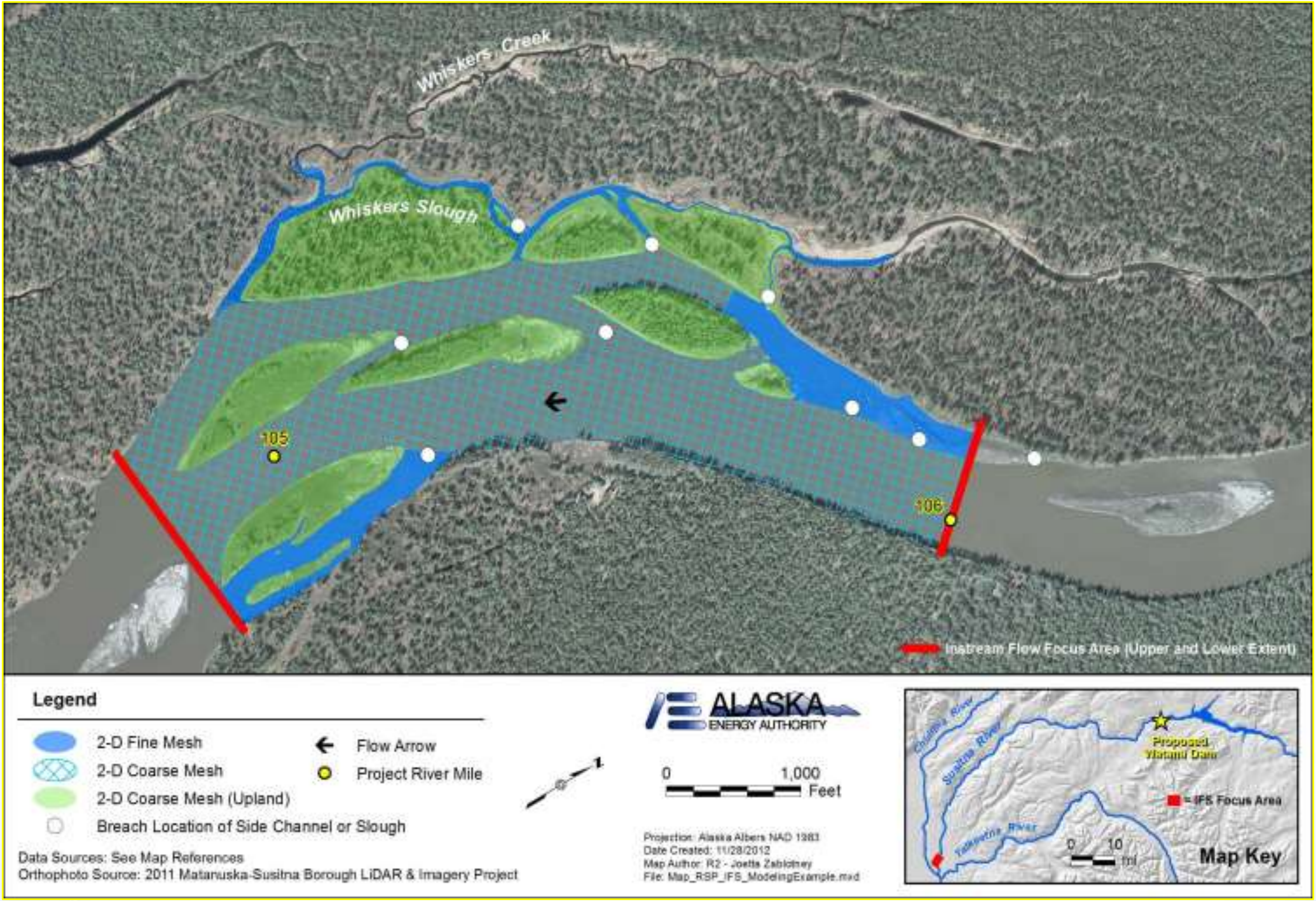
2-D Model Extent at 10 Focus Areas

- Focus Areas and extent selected through TWG consultation
- Models include:
  - Main channel(s)
  - Lateral features (side channels/side sloughs/upland sloughs)
  - Tributaries
  - Islands
  - Floodplains
- Model limits may extend further upstream and downstream to develop adequate boundary conditions, but habitat analysis is limited to FA extent

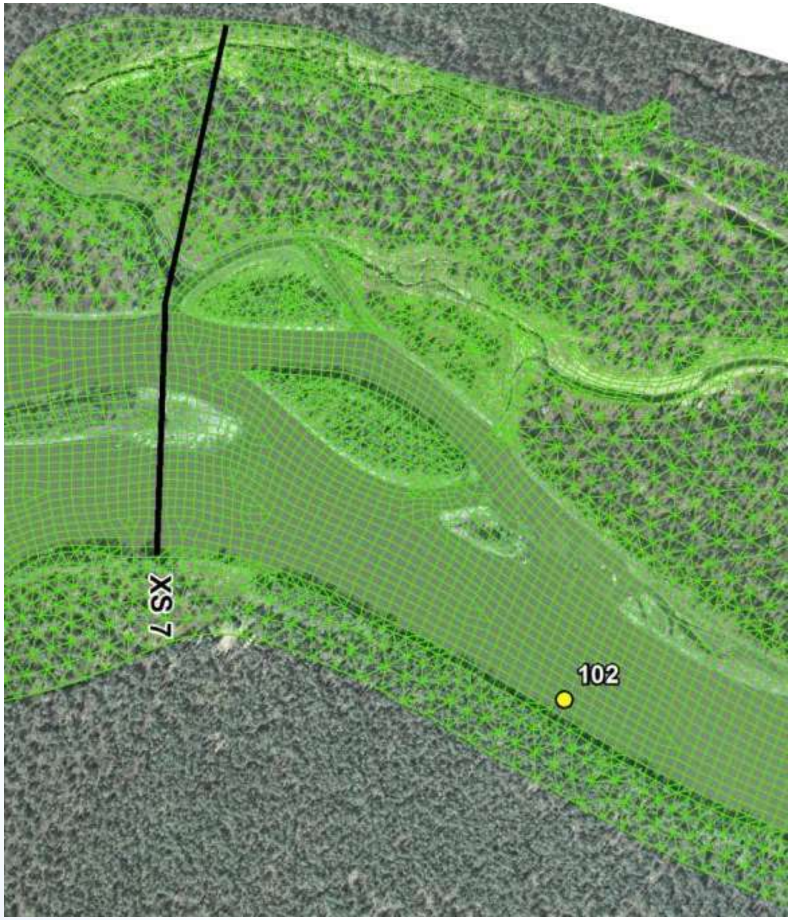
2-D Models (10 Focus Areas)

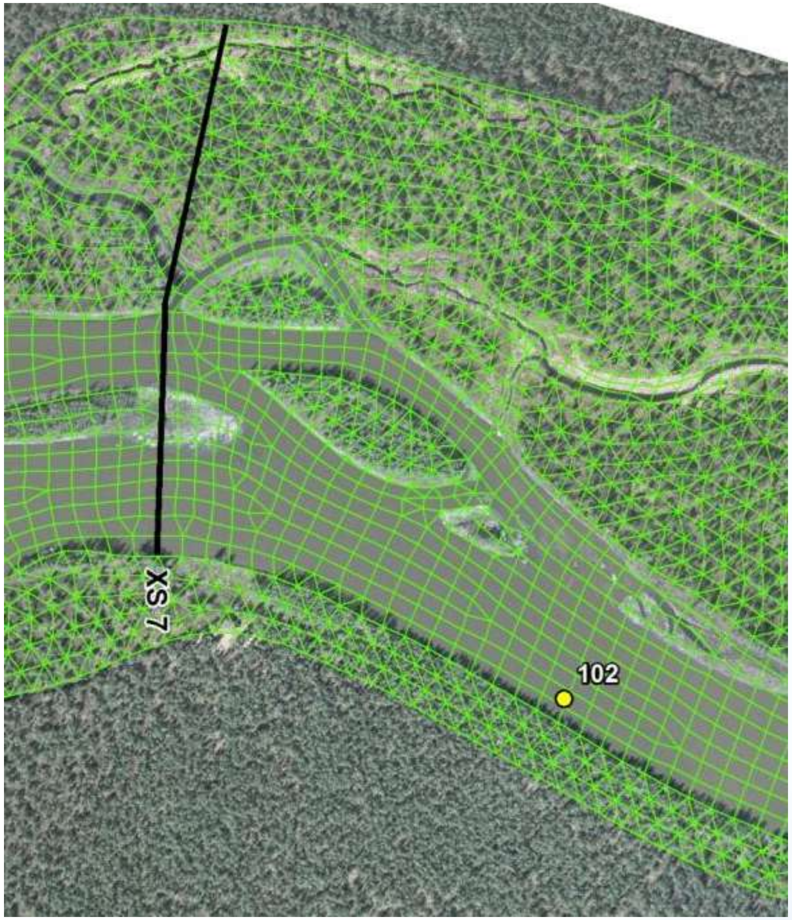


2-D Models (10 Focus Areas)



Detailed vs. Coarse 2-D Models



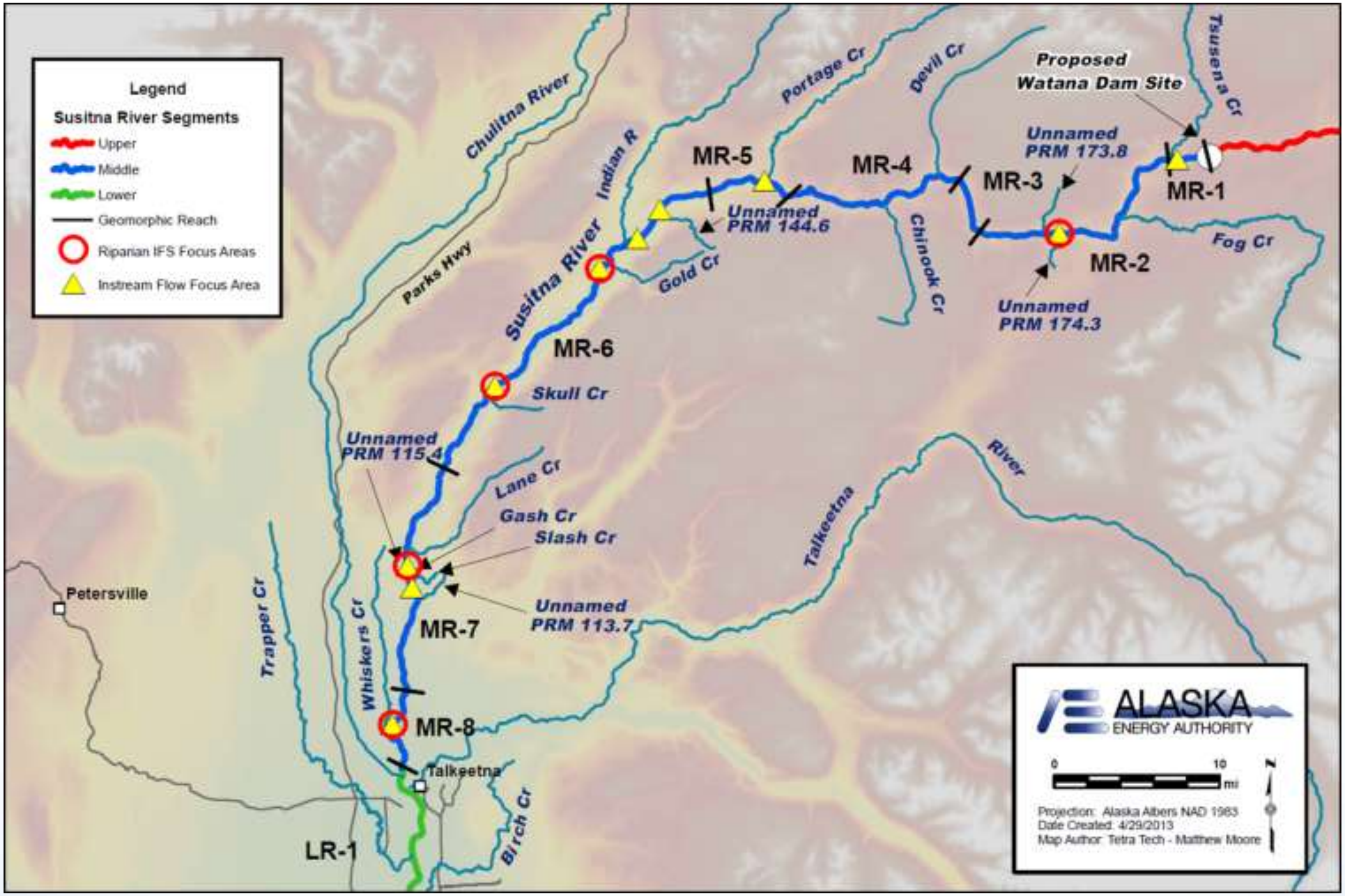


Tributary Models

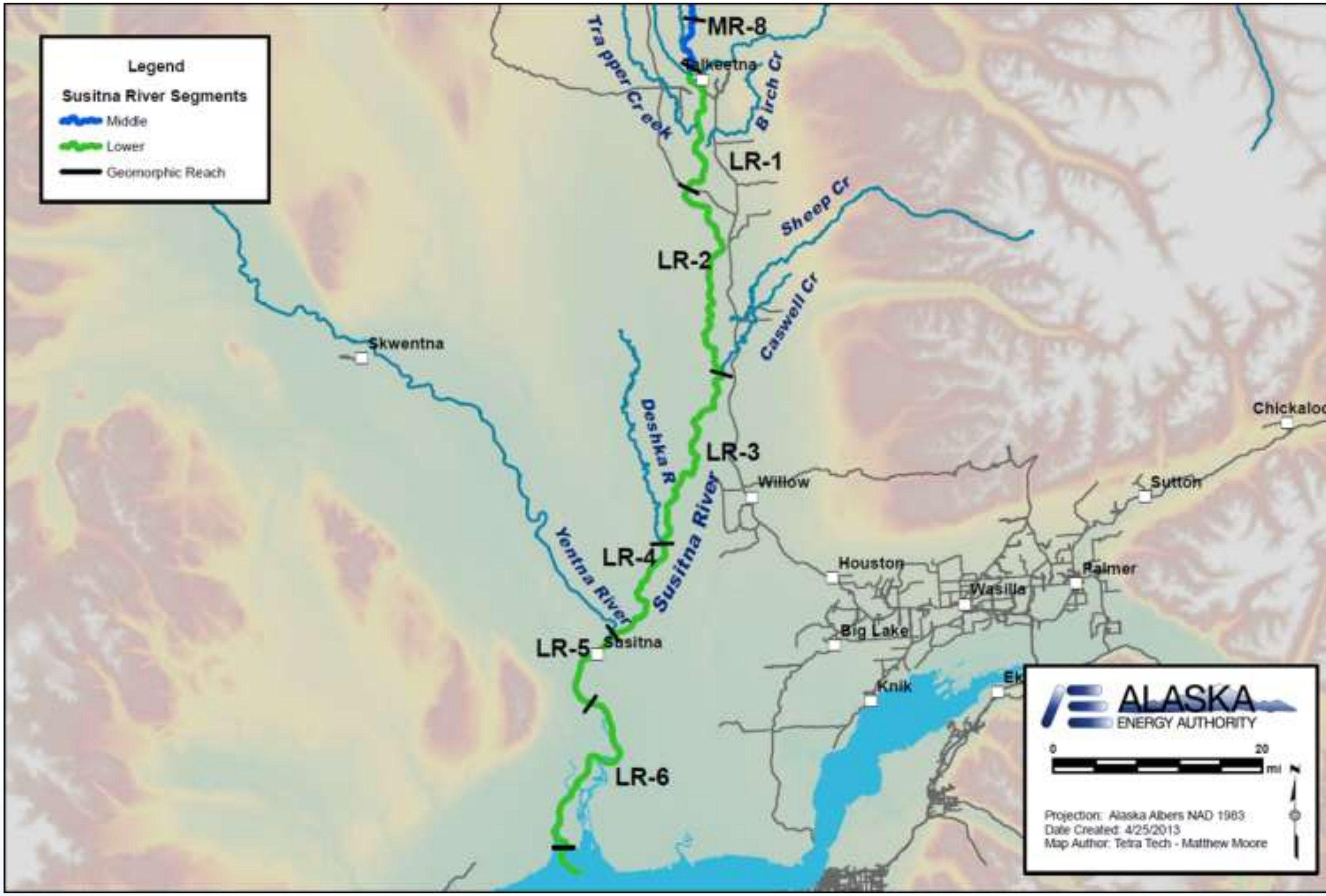
- Middle River Focus Areas
  - Sediment input to 1-D and 2-D models
  - Tributary delta modeling
- Lower River
  - Sediment input to 1-D models
  - 1-D tributary conditions
- Middle River sediment only
  - Sediment input to 1-D models

Tributary Name	PRM	Entering Bank	Geomorphic Reach	Focus Area	Sediment Input only	1-D or 2-D
Tsusena Creek	184.6	RB	MR-2		X	1-D
Fog Creek	179.3	LB	MR-2		X	1-D
Unnamed	174.3	LB	MR-2	FA173		2-D
Unnamed	173.8	RB	MR-2	FA173		2-D
Portage Creek	152.3	RB	MR-5	FA151		2-D
Unnamed	144.6	LB	MR-6	FA144		2-D
Indian River	142.1	RB	MR-6	FA141		2-D
Gold Creek	140.1	LB	MR-6		X	1-D
Skull Creek	128.1	LB	MR-6	FA128		2-D
Lane Creek	117.2	LB	MR-7		X	1-D
Unnamed	115.4	RB	MR-7	FA115		2-D
Gash Creek	115.0	LB	MR-7	FA113		2-D
Slash Creek	114.9	LB	MR-7	FA113		2-D
Unnamed	113.7	LB	MR-7	FA113		2-D
Whiskers Creek	105.1	RB	MR-8	FA104		2-D
Trapper Creek	94.5	RB	LR-1			1-D
Birch Creek	92.5	LB	LR-1			1-D
Sheep Creek	69.5	LB	LR-2			1-D
Caswell Creek	67.0	LB	LR-2			1-D
Deshka River	45.0	RB	LR-3			1-D

Tributary Models – Middle River



Tributary Models – Lower River



1-D Tributary Modeling Approach

- HEC-RAS models of short tributary reach
  - Steep tributaries < 0.5 mile model reaches
  - Flat tributaries may require > 0.5 mile model reaches
  - Will be determined in field
- Models provide sediment input to:
  - Reach-Scale 1-D models
  - Local-Scale 2-D models
- Also used for tributary habitat in Lower Susitna River

Comprehensive Modeling Approach

1-D Reach-Scale Morphology Models

Hydro. & Sed. input: Existing & 3-OS – continuous 50-year simulations

	Year 0	Year 25	Year 50
Geometry:	Existing	"Existing" & 3-OS	"Existing" & 3-OS

Provides Yr-25 & 50 sediment inflow, geometry and d/s rating curves

2-D Morphology Unsteady Models at FAs

~6 month simulations for Yr-0, 25 & 50

Provides input on Yr-25 & 50 substrate & lateral feature geometry

2-D Hydraulic (habitat) Steady Models at FAs

	Year 0	Year 25	Year 50 .
Geometry:	Existing	"Existing" & 3-OS	"Existing" & 3-OS

Provides hydraulic data to habitat models for range of flows.

Reach-Scale 1-D Modeling Approach

- 50-year simulations
  - Existing conditions
  - Three operational scenarios
- Boundary conditions
  - Upstream flow boundary hydrographs from Instream Flow Routing study
  - Upstream sediment supply from Instream Flow Routing and Sediment Trapping studies
- Provides boundary conditions for Local-Scale 2-D models of Focus Areas
  - Upstream sediment supply
  - Downstream water surface

Reach-Scale 1-D Modeling Approach (continued)

- Hydraulic results
  - Velocity
  - Depth
  - Wetted area
  - Water surface elevation
- Sediment transport
  - Sediment loads
  - Effective discharge
  - Changes in bed material character
- Channel morphology
  - Aggradation and degradation
  - Channel width change
  - Channel profile

Channel Width Change

- Anticipated due to change in hydrologic regime
  - ~2-yr recurrence interval flows
  - Effect discharge
  - Also influenced by sediment supply and riparian vegetation
- Review hydraulic geometry for current conditions
- Differentiate Middle and Lower Susitna River
  - MR - hydrologic and sediment change all 50-yrs
  - LR - immediate hydrologic and delayed sediment change
- Anticipate using Rate Law (exponential decay) with rapid initial change approaching asymptote
- Team and Agency coordination
- Width change affects hydraulics and sediment transport

Two Types of Local-Scale 2-D Modeling

- All 10 Focus Areas
- Unsteady morphology modeling to evaluate trends in channel and lateral feature evolution
- Steady fixed-bed hydraulic modeling provides input for habitat analysis

Local-Scale 2-D Morphology Modeling Approach

- <1-year unsteady flow simulations of wet, average and dry seasonal hydrographs of warm/cold PDO
  - Existing Geometry – year-0
  - Future geometry of year-25 and -50 potential conditions from 1-D model changes in bed elevation, width, and bed material
- Flow and sediment input scenarios
  - Existing conditions
  - Three operational scenarios
- Boundary conditions
  - Flow hydrographs from Instream Flow Routing study
  - Sediment supply from Reach-Scale 1-D models
  - Downstream water surface from Reach-Scale 1-D models

Local-Scale 2-D Hydraulic Modeling Approach

- Steady-Flow simulations of range of flows
  - Existing Geometry
  - Future geometry of year-25 and year-50 potential conditions of three operational scenarios
- Boundary conditions
  - Downstream water surface from Reach-Scale 1-D models
- Habitat analysis
  - Georeferenced coordinates (x, y) and hydraulic results (z)
    - Velocity
    - Depth
    - Water surface
  - Timing and durations of flows based on Instream Flow Routing Study

Comprehensive Modeling Approach

1-D Reach-Scale Morphology Models

Hydro. & Sed. input: Existing & 3-OS – continuous 50-year simulations

	Year 0	Year 25	Year 50
Geometry:	Existing	"Existing" & 3-OS	"Existing" & 3-OS

Provides Yr-25 & 50 sediment inflow, geometry and d/s rating curves

2-D Morphology Unsteady Models at FAs

~6 month simulations for Yr-0, 25 & 50

Provides input on Yr-25 & 50 substrate & lateral feature geometry

2-D Hydraulic (habitat) Steady Models at FAs

	Year 0	Year 25	Year 50 .
Geometry:	Existing	"Existing" & 3-OS	"Existing" & 3-OS

Provides hydraulic data to habitat models for range of flows.

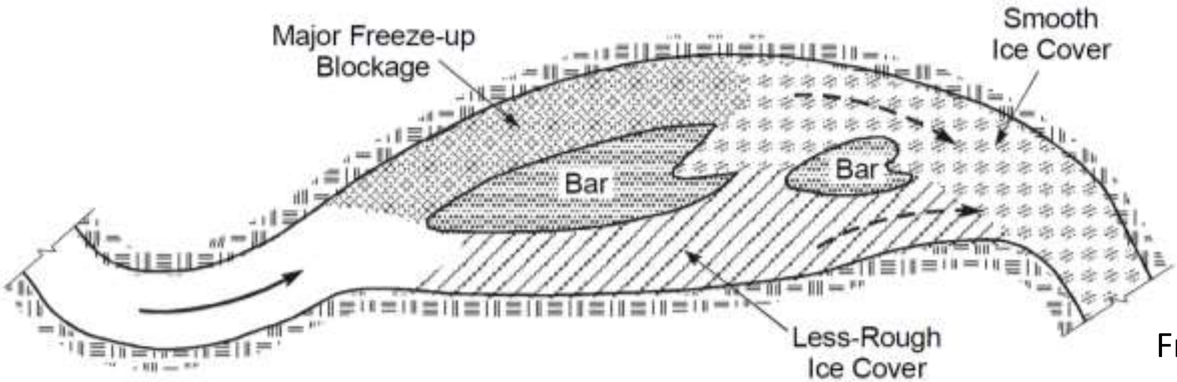
Large Woody Debris Effects

- 1-D Modeling
  - Existing and with-Project scenarios of LWD loading
  - Adjustments to flow resistance will affect sediment transport
- 2-D Modeling
  - Existing and with-Project scenarios of LWD accumulations
  - Adjustments to mesh elevations, erodibility, and refinement to reflect changes in LWD obstructions
  - Erosion in vicinity of LWD due to flow acceleration
  - Adjustments (large) to flow resistance to represent blockage
  - Scour calculations may also be performed
  - Lab data show little difference between solid, porous and rough debris on scour and no observable difference in dye tracing

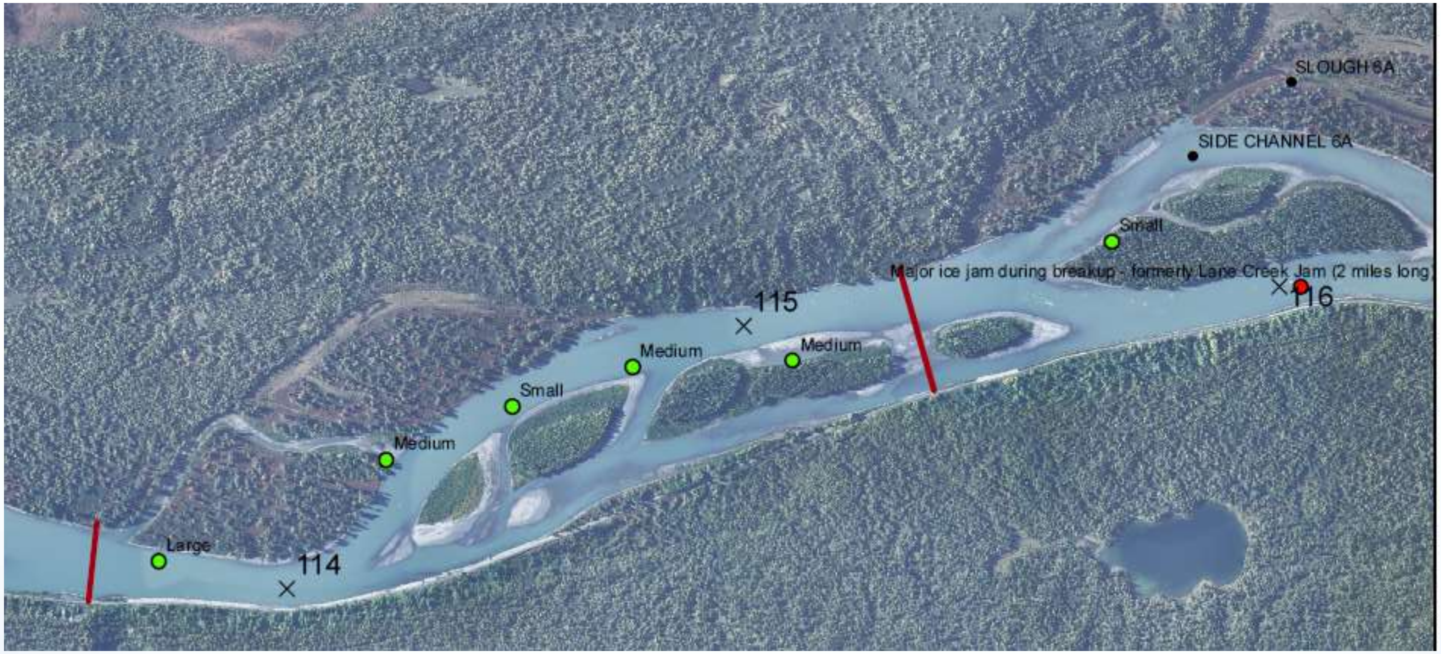
2-D Erosion/Sedimentation Ice Models

- Ice jam surge modeling
  - Unsteady HEC-RAS models provide surge hydrographs
- Ice blockage
  - Full or partial blockage of main or secondary channels
  - Diversion of flow onto floodplain
- Shear stress analysis
  - Scour and removal of vegetation
  - Scour in unvegetated areas
- Floodplain sedimentation
  - Sedimentation rates from flows diverted onto floodplain
- River1D and River2D modeling of ice conditions by Ice Processes Study

Ice Models



From Zabilansky 2002



CONCLUSIONS

- Approach provides a comprehensive analysis for Fluvial Geomorphology Modeling
  - Reach-Scale 1-D modeling
  - Local-Scale 2-D modeling
  - Special cases of LWD, ice, & floodplain accretion
  - Tributaries (large to small)
- We will adapt approaches during modeling process