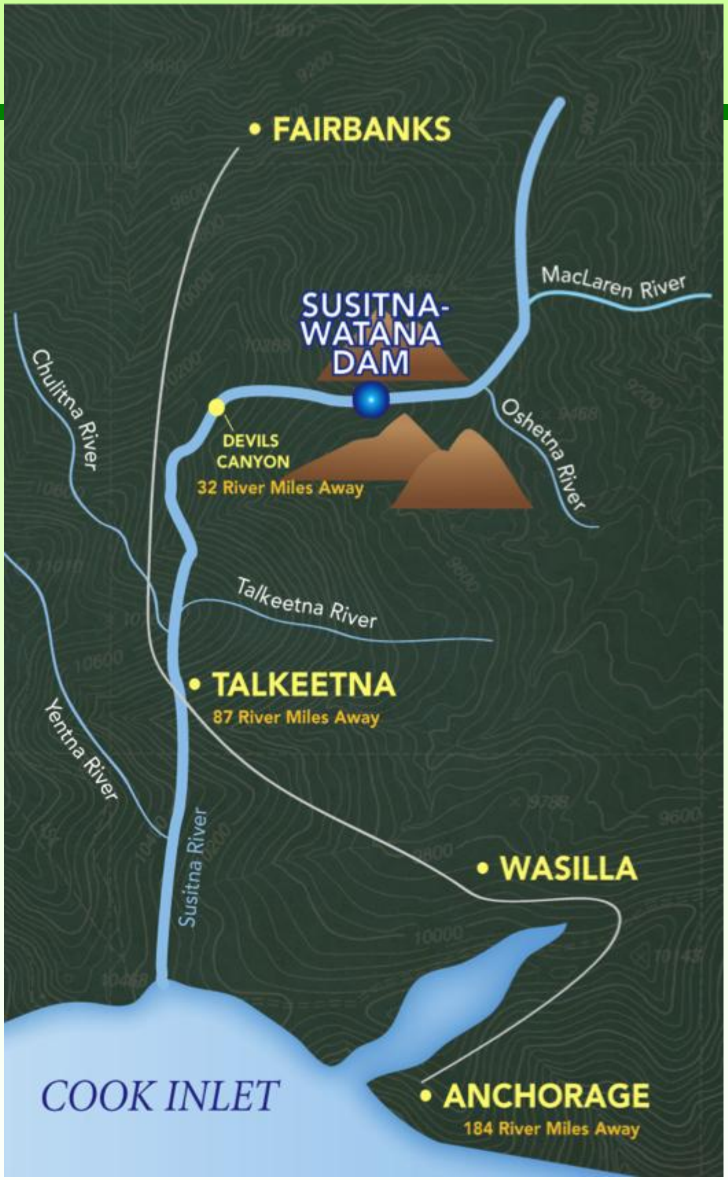
The Susitna Project:

An integrated resource approach to evaluating potential flow and water level regulation effects from the proposed Susitna-Watana Hydroelectric Project, Alaska –

Challenges for managing uncertainty related to data and analyses adequacy.

Instream Flow Council Meeting
April 29, 2015

Dudley Reiser
R2 Resource Consultants
and many others



R2 Resource Consultants, Inc.

Acknowledgements and Contributors

- Alaska Energy Authority – (AEA)
- ABR, Inc
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- HDR
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- Geovera
- URS
- LGL Limited
- DESIT Inc.
- Golder Associates
- University of Alaska Fairbanks

www.susitna-watanahydro.org

- Alaska Department of Fish and Game
- Alaska Department of Natural Resources
- U.S. Fish and Wildlife Service
- National Marine Fisheries Service
- Environmental Protection Agency
- Federal Energy Regulatory Commission

Let's Boil this Down

- Have the End in Sight at the Beginning
- Proper Planning and Scoping
- Identification of Resource Issues
- Preparation of Analytical Framework
- Development/Implementation of <u>Integrated</u> Resource-specific Study Plans
  - Application of Appropriate Methods and Models
- Dealing with Uncertainty
- Decision Support System (DSS)/Analysis

Seeking FERC License

FERC Mandated ILP Study Plan Development Process

- Pre-Application Document (PAD) – 2011
- Scoping – Scoping Documents 1 and 2 (May and December 2012)
- 2012 Environmental Studies – early actions
- **FORMAL STUDY PLAN DEVELOPMENT PROCESS**

→ **Aquatic and Fish Resources Study Requests** →

→ Proposed Study Plans (PSP) → **Comments** →

→ Revised Study Plan (RSP) → **Comments** →

→ Final Study Plan

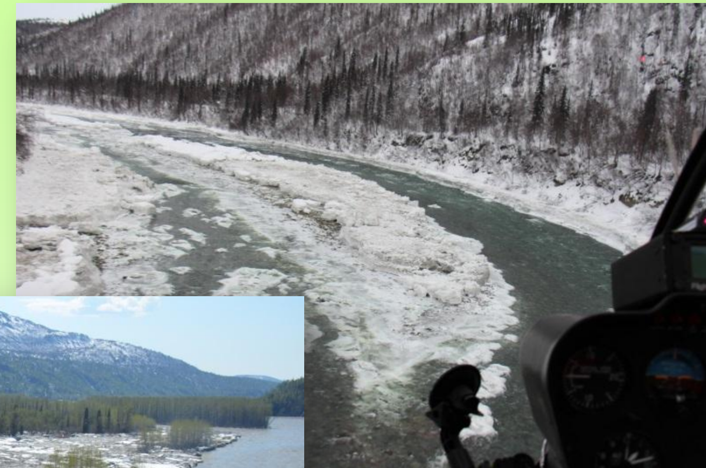
→ **STUDY IMPLEMENTATION (2013, 2014, 2015)**

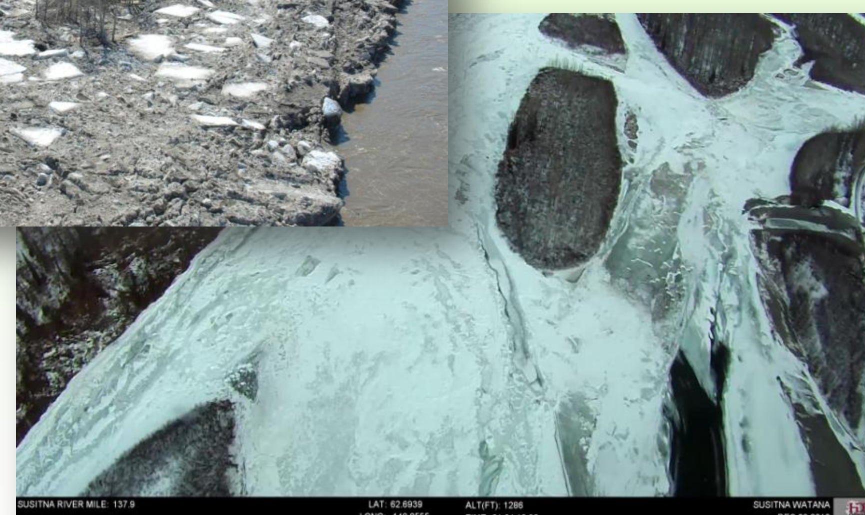
→ **License Application - 2016/2017?**

Have the End in Sight at the Beginning


What’s different about the Susitna Project???

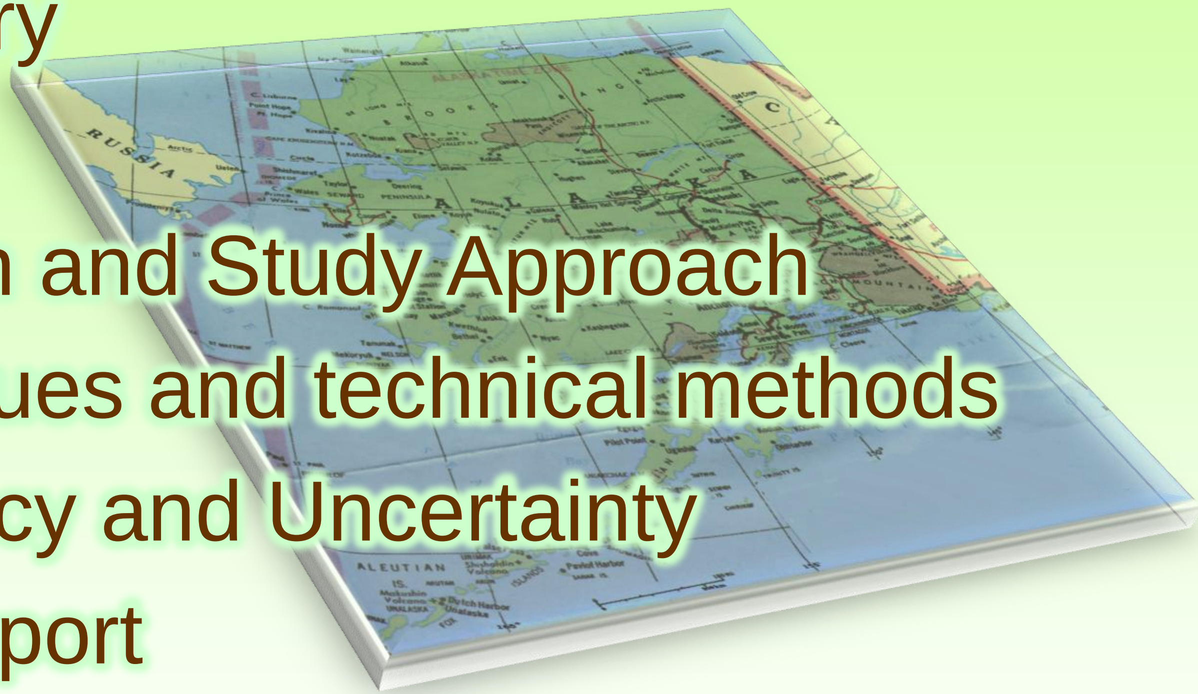
ICE – Freeze-up, Mid Winter, Break-up



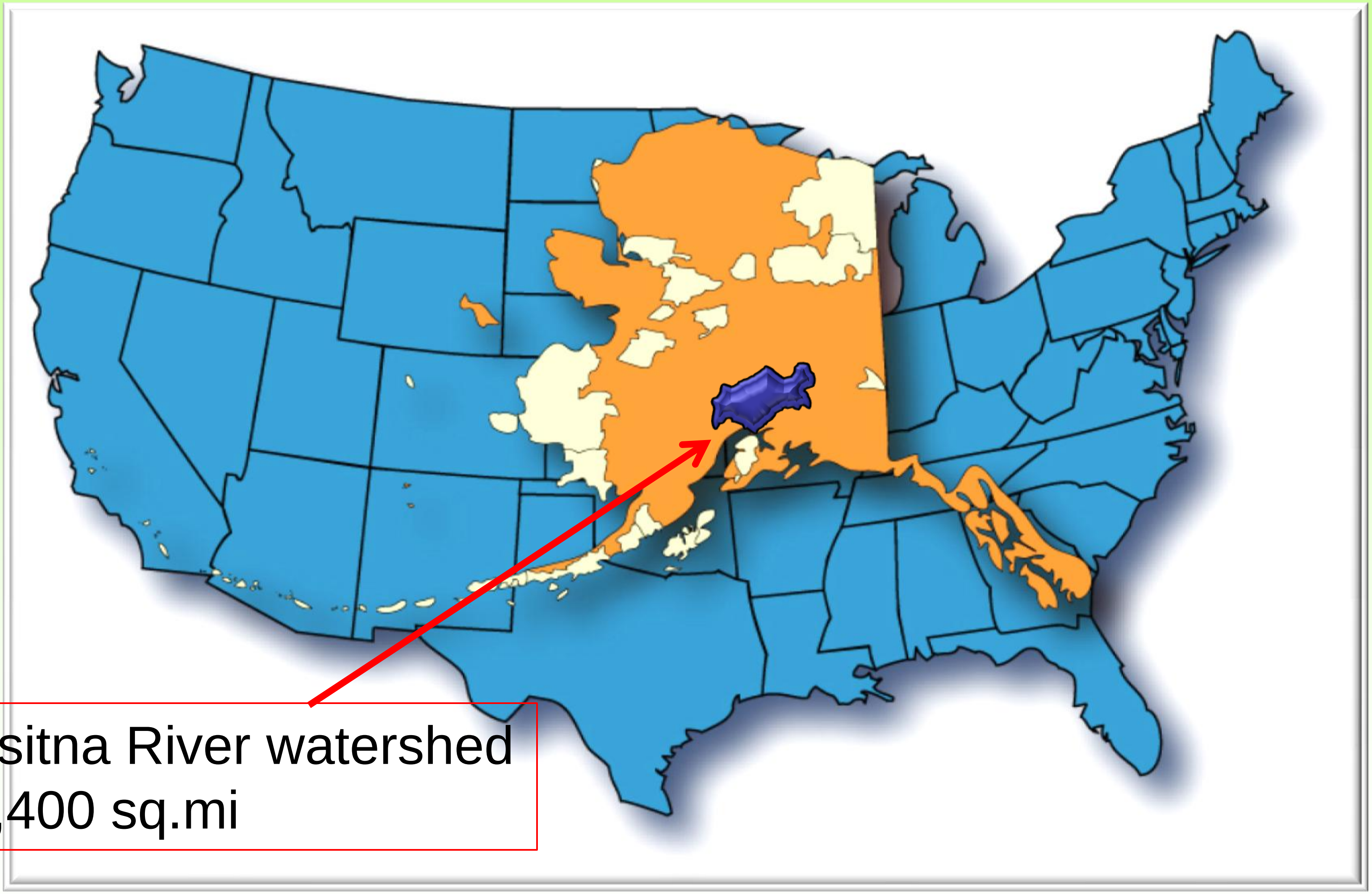


Road Map of Presentation

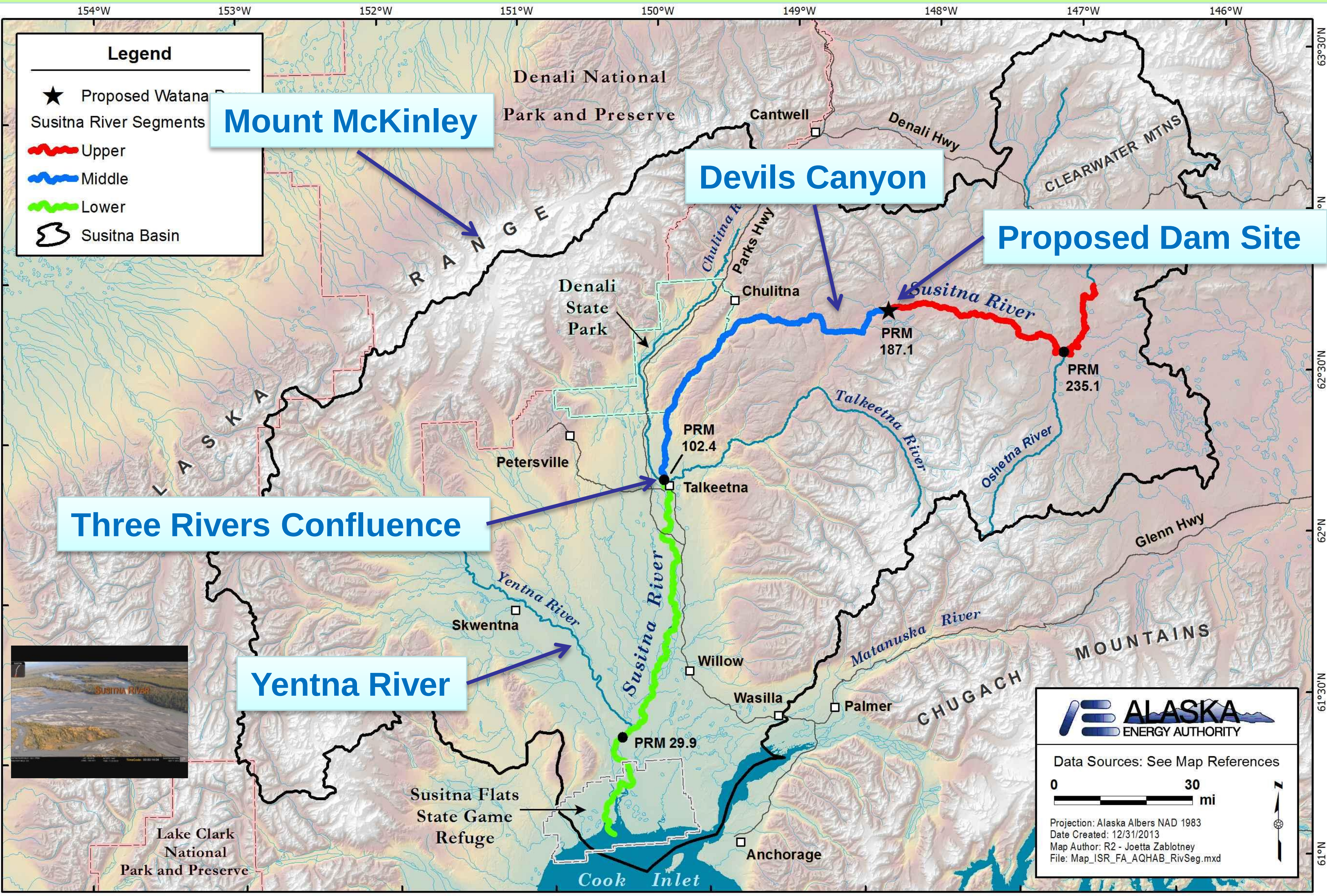
- Project Overview – location/scale/operations
- A Bit of History
- Challenges
- Site Selection and Study Approach
- Resource issues and technical methods
- Data Adequacy and Uncertainty
- Decision Support



Scale and Location

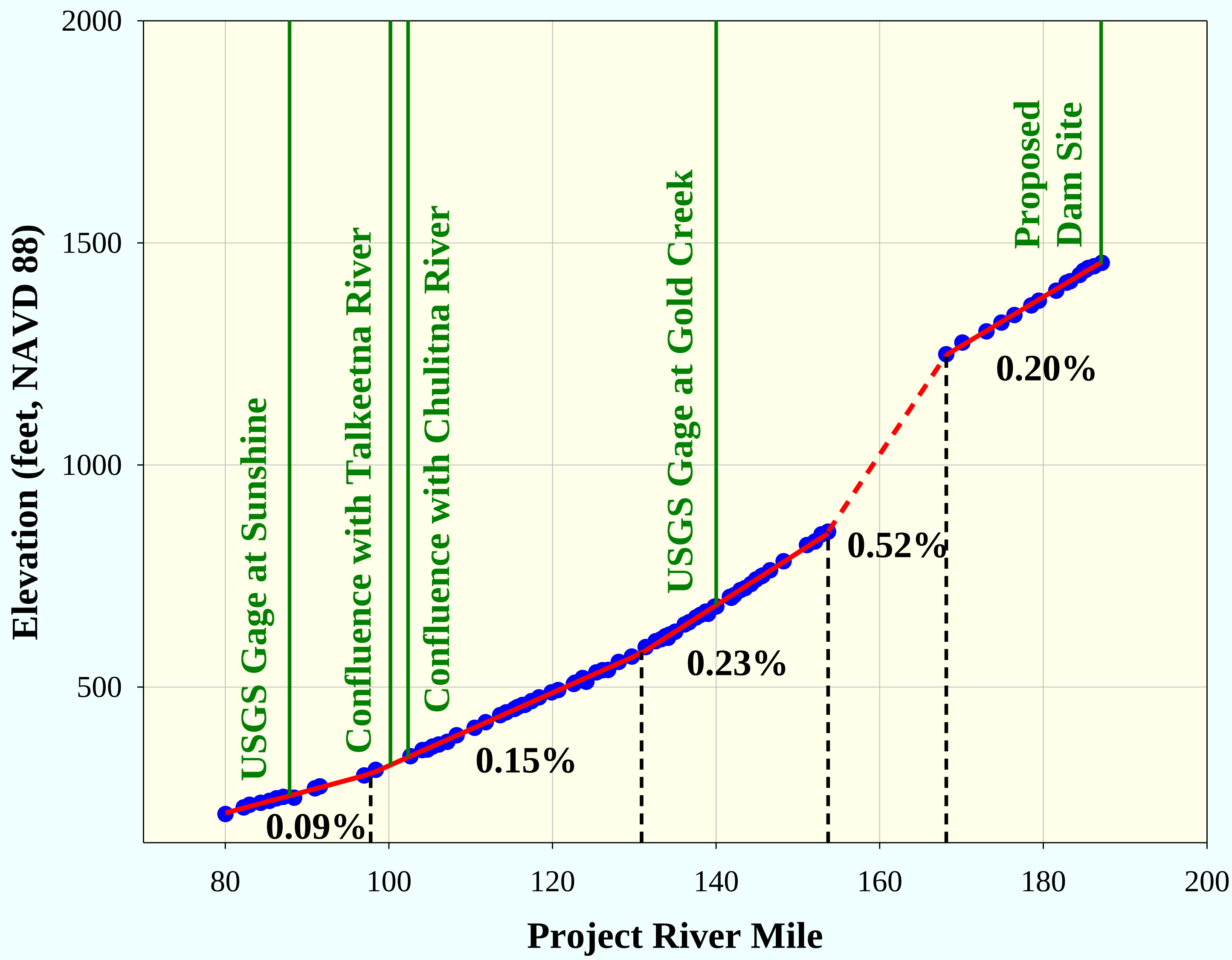


Susitna River watershed
19,400 sq.mi



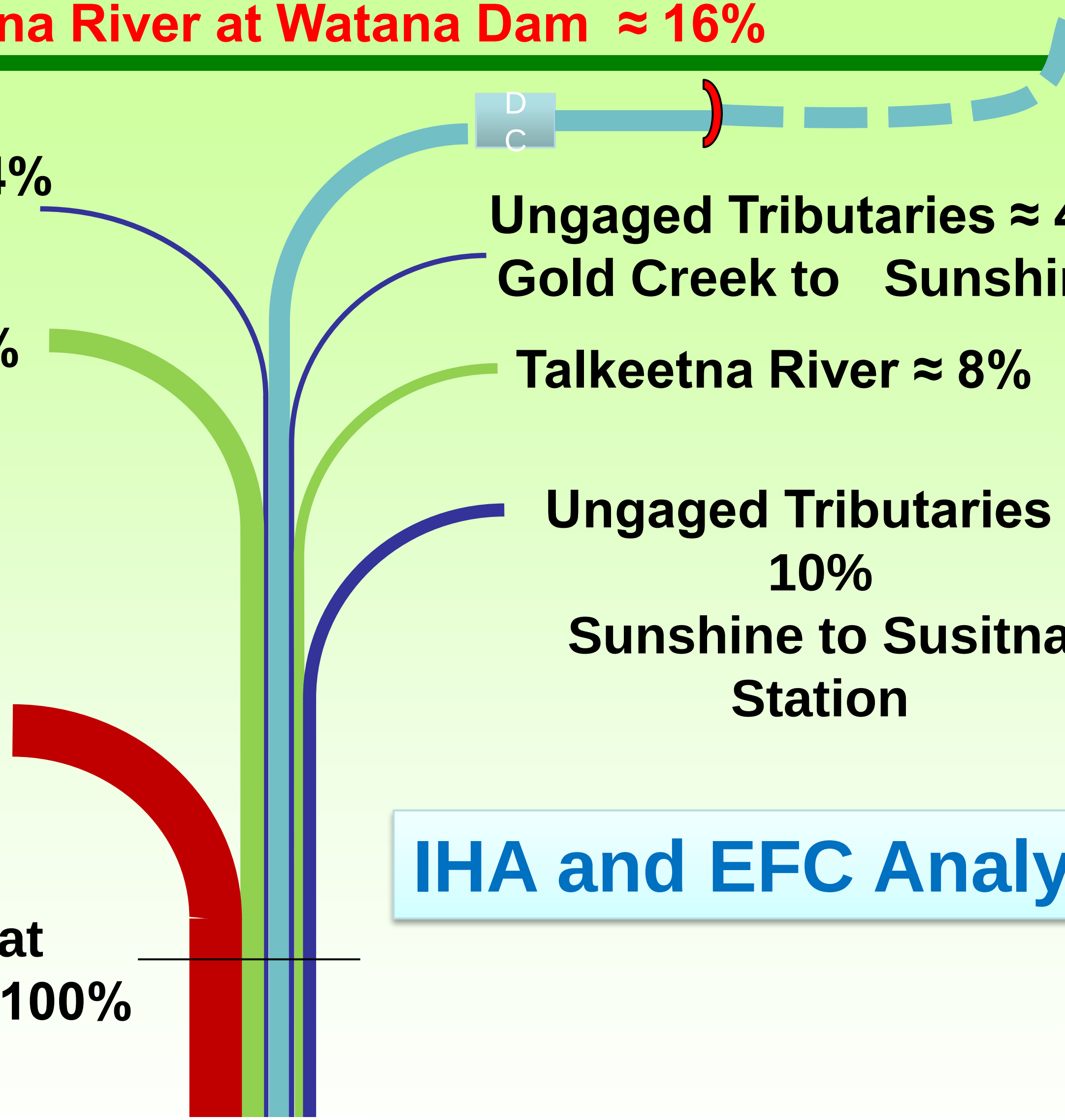
Legend
Proposed Watana Dam
Susitna River Segments
Upper
Middle
Lower
Susitna Basin
Mount McKinley
Devils Canyon
Proposed Dam Site
Three Rivers Confluence
Yentna River
Denali National Park and Preserve
Cantwell
Denali Hwy
CLEARWATER MTNS
ALASKA RANGE
Chulitna River
Parks Hwy
Chulitna
Denali State Park
Susitna River
PRM 187.1
PRM 235.1
PRM 102.4
Talkeetna
Talkeetna River
Oshetna River
Petersville
Glenn Hwy
Yentna River
Skwentna
Susitna River
Willow
Matanuska River
MOUNTAINS
CHUGACH
Wasilla
Palmer
PRM 29.9
Susitna Flats State Game Refuge
Lake Clark National Park and Preserve
Anchorage
Cook Inlet
ALASKA ENERGY AUTHORITY
Data Sources: See Map References
0
30
mi
Projection: Alaska Albers NAD 1983
Date Created: 12/31/2013
Map Author: R2 - Joetta Zablotney
File: Map_ISR_FA_AQHAB_RivSeg.mxd
154°W
153°W
152°W
151°W
150°W
149°W
148°W
147°W
146°W
63°30'N
62°30'N
62°N
61°30'N
61°N

Longitudinal Thalweg Profile



Average Annual Flow Contributions

Susitna River at Watana Dam ≈ 16%



IHA and EFC Analysis

Fishery Resources



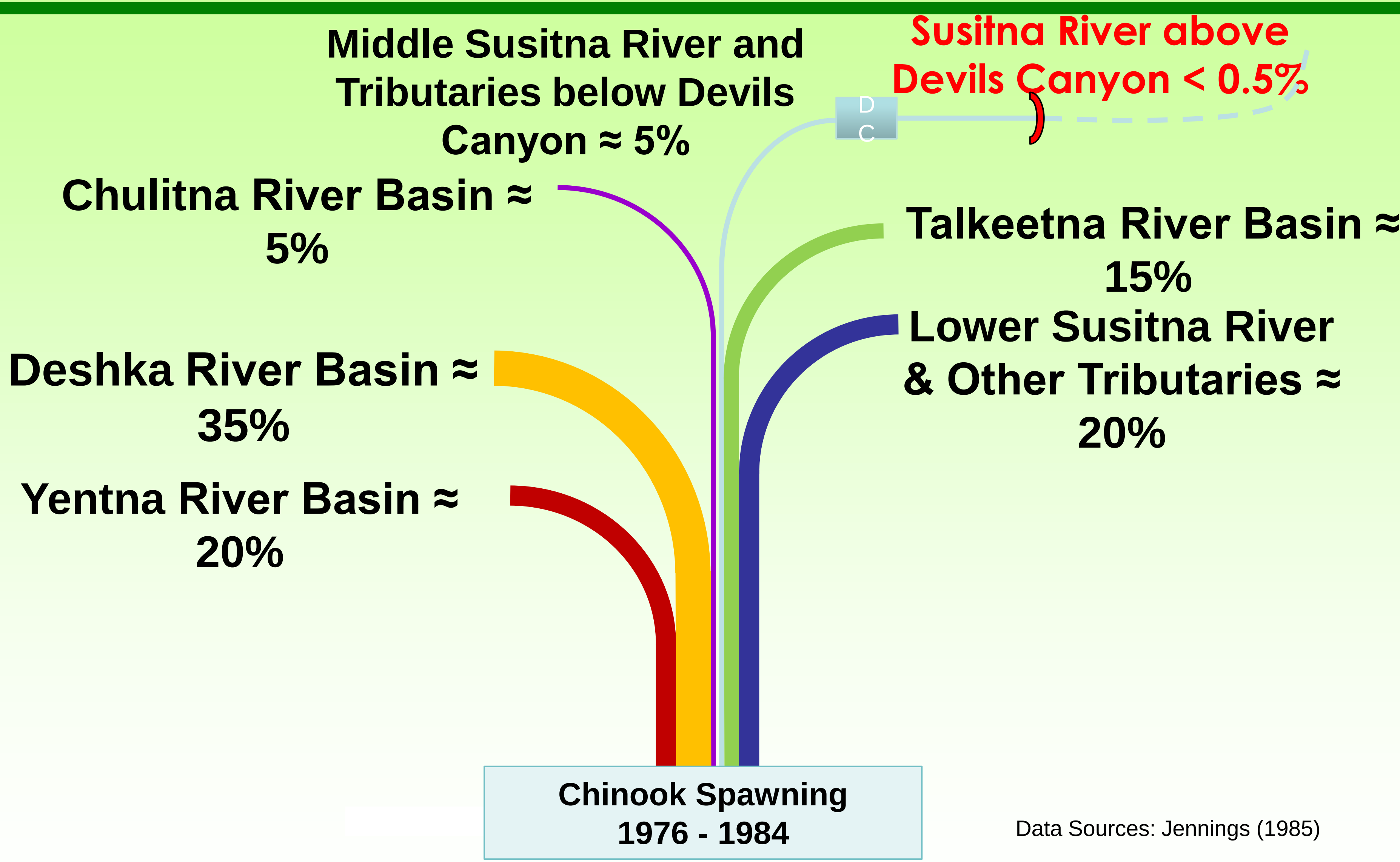






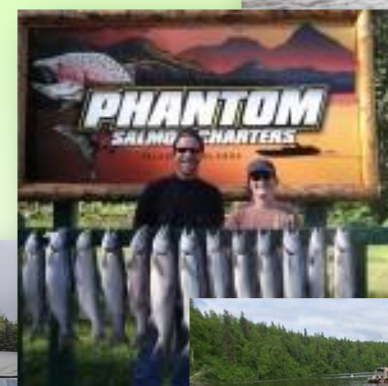


Historical Chinook Salmon Spawning Distribution by Basin



Data Sources: Jennings (1985)

Recreational Resources



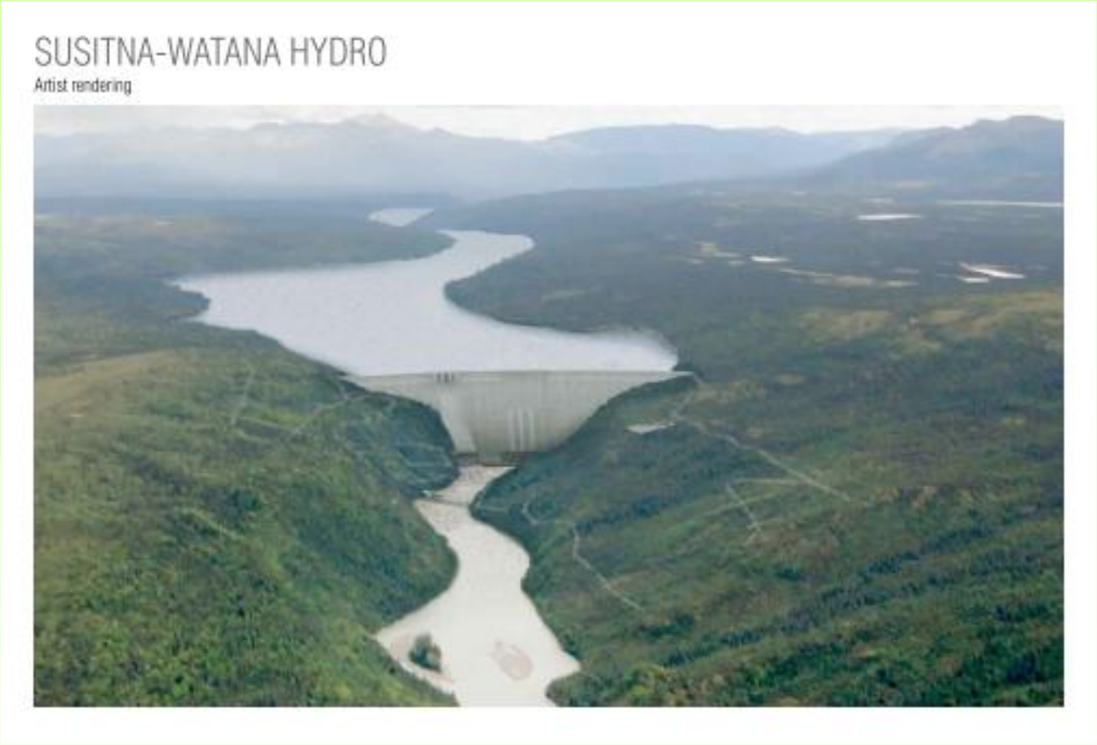
Some photos courtesy of Phantom-TriRivers and Fisherman’s Choice charters and Mahay’s Jet-boat adventures

Brief History of the Susitna River Hydroelectric Project

- 1950s – Bureau of Reclamation
- 1970s – U.S. Army Corps of Engineers
- 1980s – Alaska Power Authority
  - Two-dam concept (Watana Dam and Devils Canyon Re-regulation Dam)
- 2012 – Alaska Energy Authority
  - Single-dam concept (Susitna-Watana)

1980s Studies: ARLIS Library – 3,000 documents

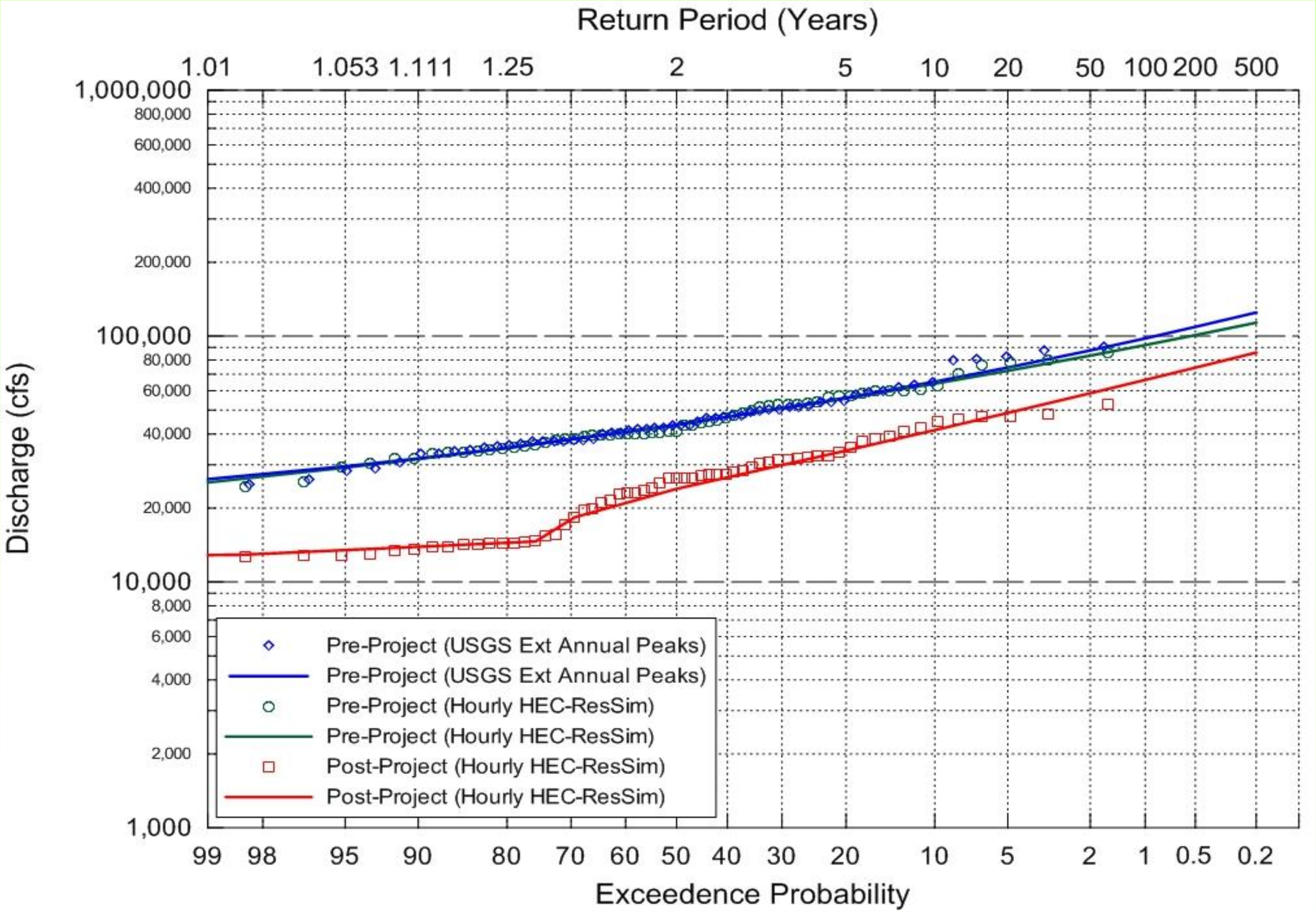
Current Project: Proposed Operations



Artist Rendering

- Single Dam configuration
- Would change natural hydrograph seasonally:
  - Summer Flows Lower
  - Winter Flows Higher
  - Flood Flows (reduced magnitude and frequency)
- Load following mode maximized during the winter months of November through April.
  - Powerhouse discharges could vary Daily/hourly in the winter months with flows ranging between 3,000 – 10,000 cfs.

Project Operations – Changes in Flood Frequency (Gold Creek gage)



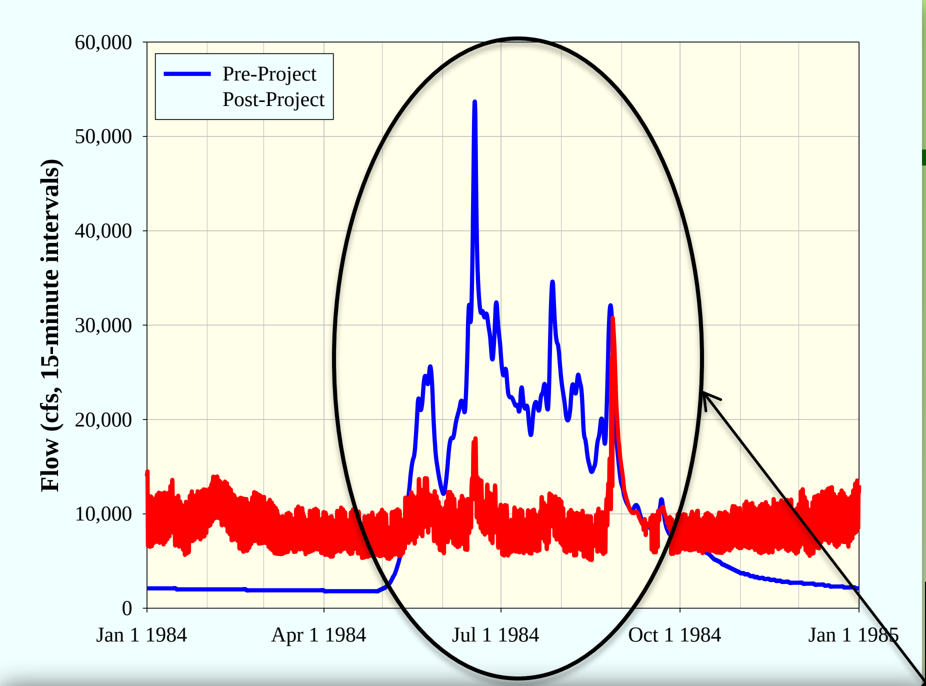
Post-project = OS-1 scenario

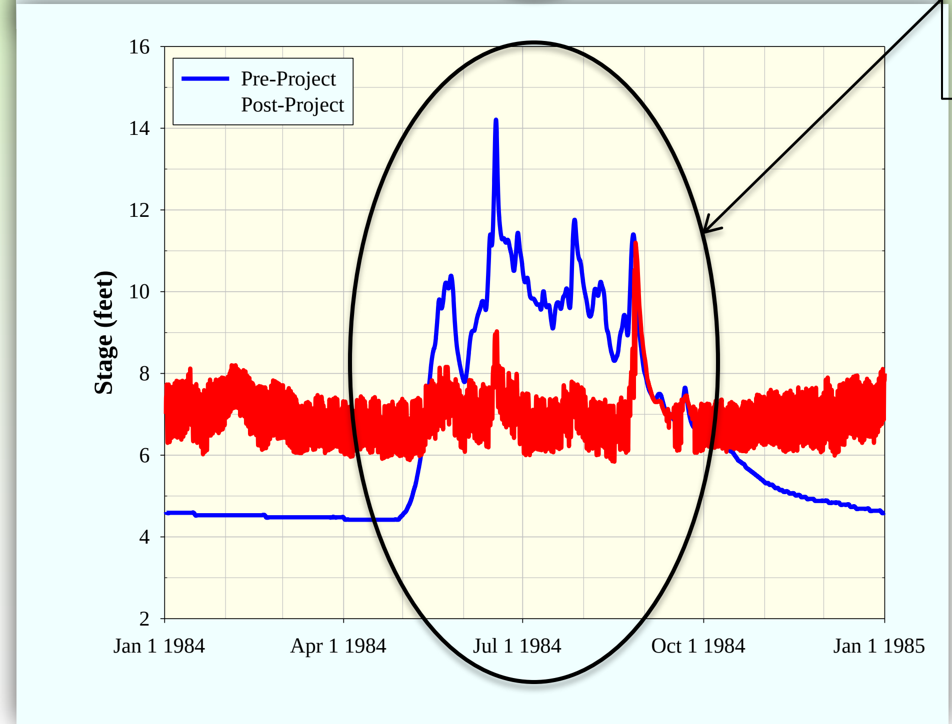
From: Tetra Tech 2013 – Streamflow Assessment

Effects of Project - Load Following

(Open-water Flow Routing Model results)
15-Minute Flows and Stage in Susitna River at Gold Creek Gage - 1984

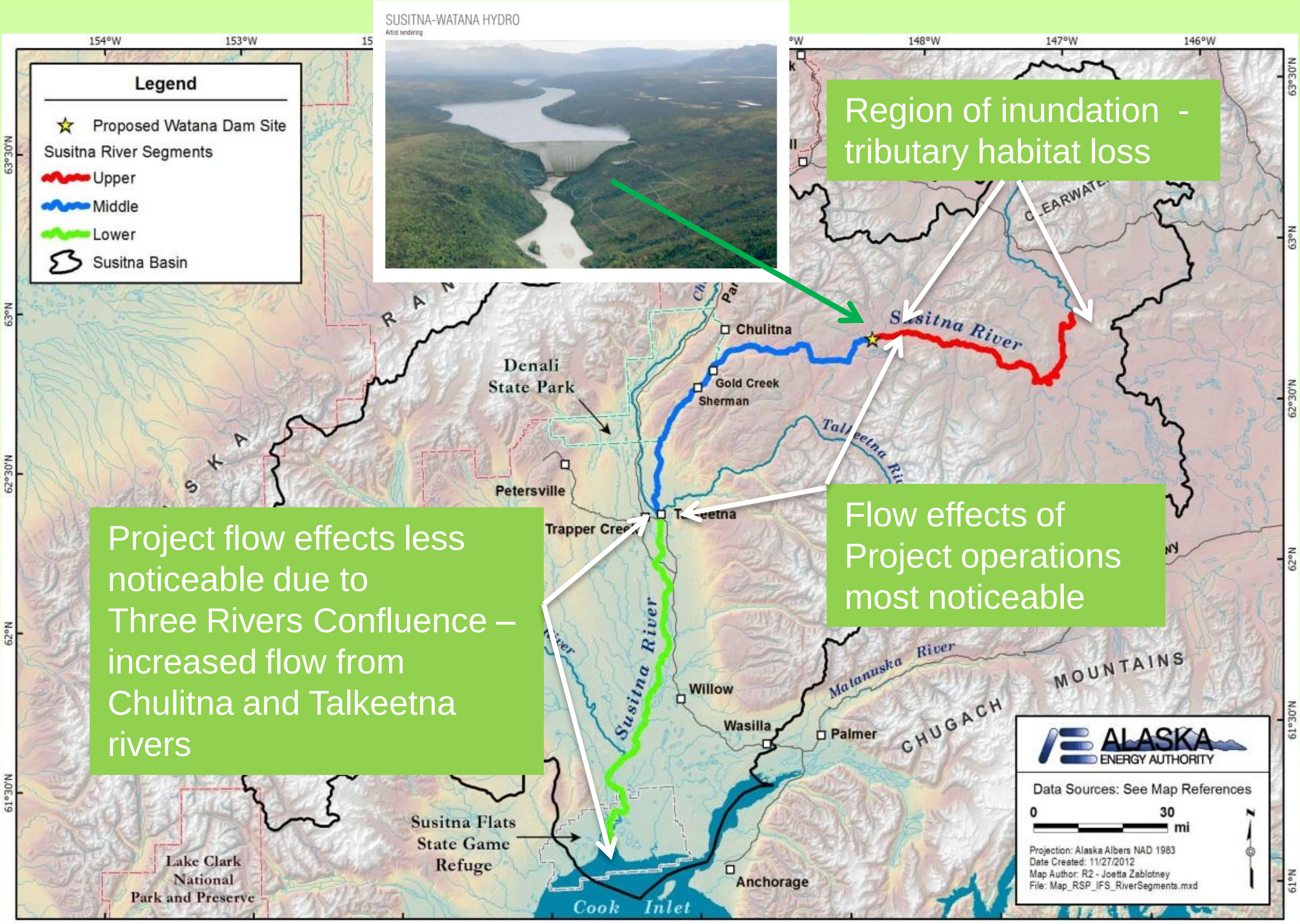
OS-1 Scenario – Maximum load following





Open-water periods

The Susitna River
Upper, Middle, and Lower Segments



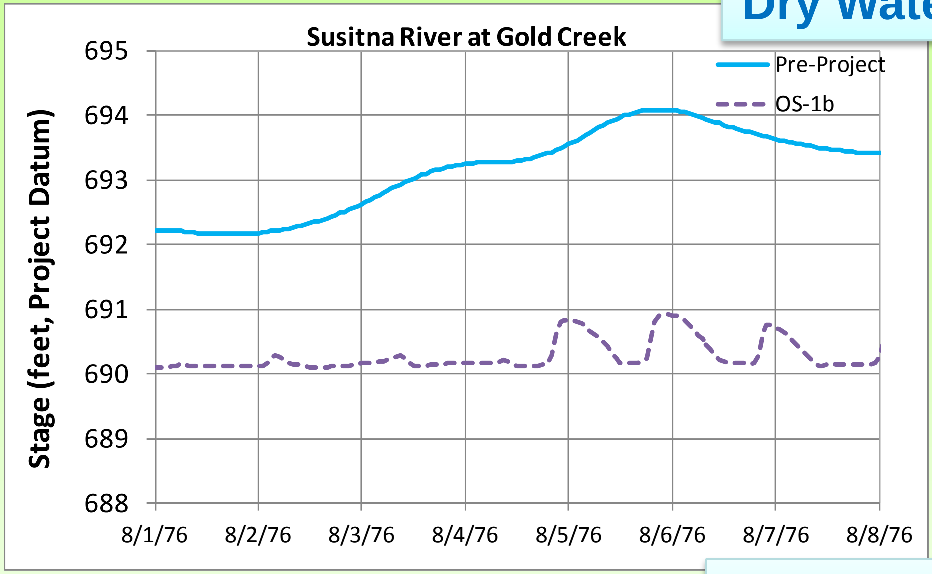
Region of inundation - tributary habitat loss

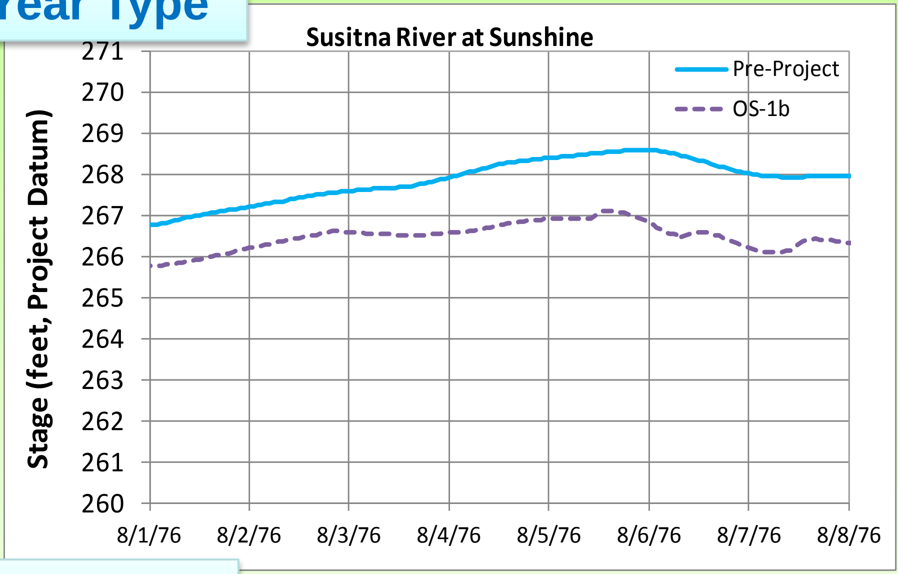
Flow effects of Project operations most noticeable

Project flow effects less noticeable due to Three Rivers Confluence – increased flow from Chulitna and Talkeetna rivers

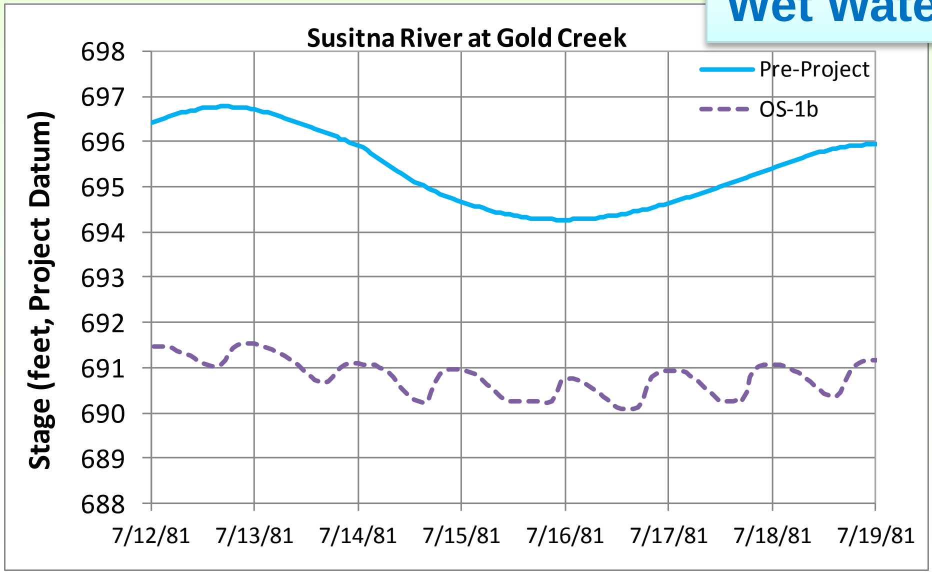
Project Operations – Open-water

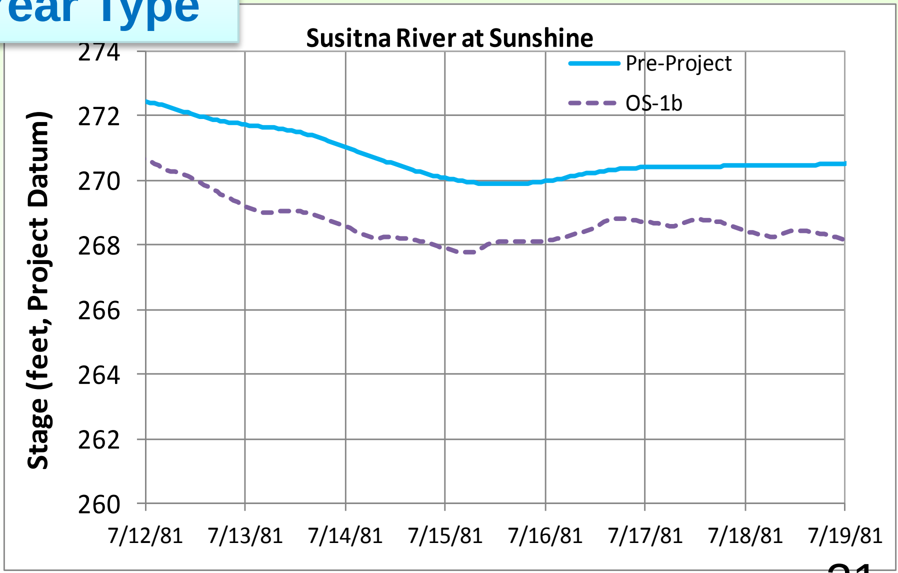
Dry Water Year Type





Wet Water Year Type





Challenges

- Remote – boat and helicopter access (snow-machine in winter)
- Logistics – field camps
- Safety - swiftwater training, bear guards, etc.
- Multiple resource studies = lots of people
- No flow control
- Access – Land Ownership

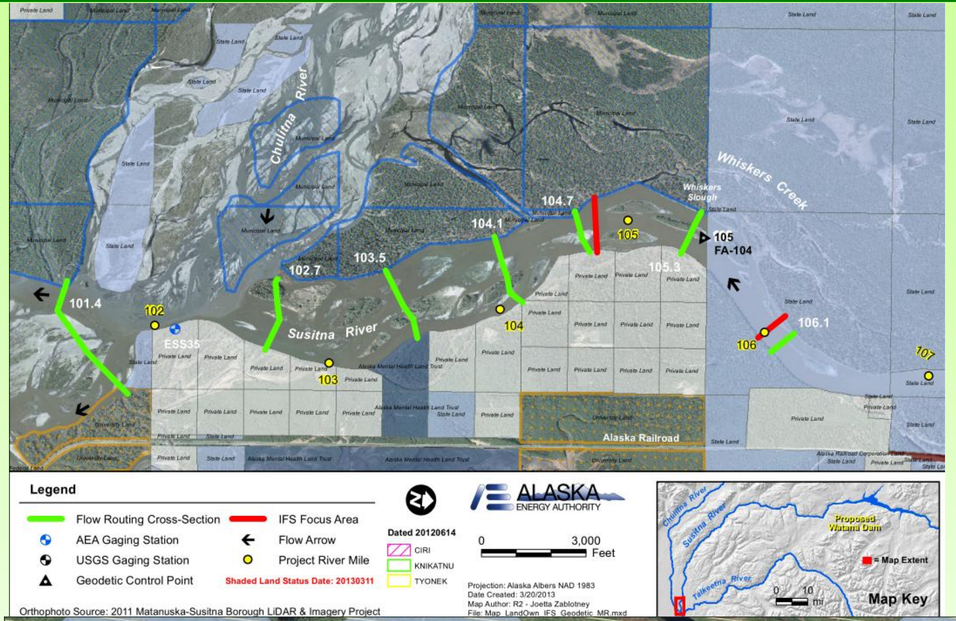


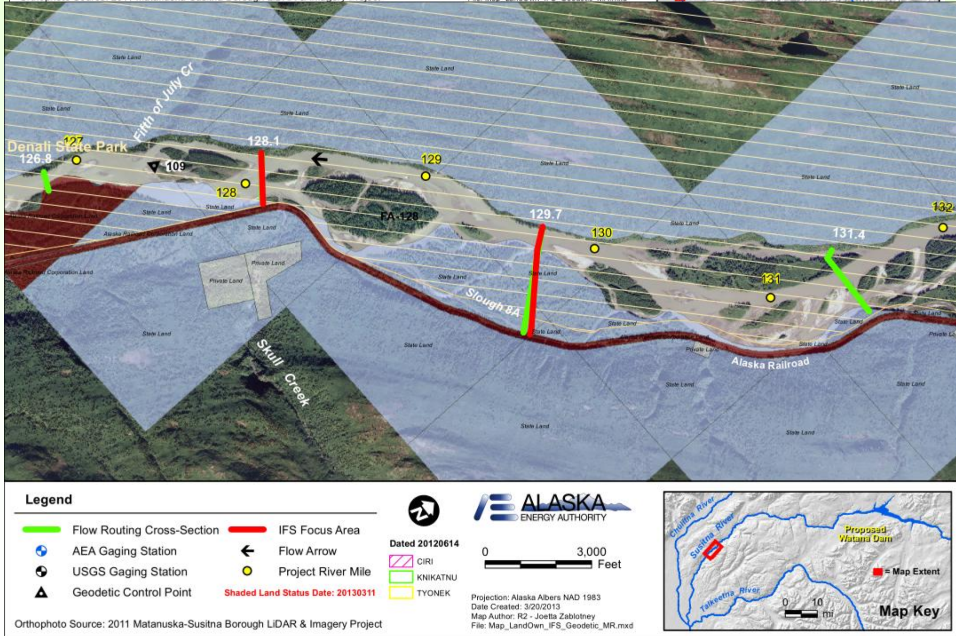




Land Ownership – Permitting

- Alaska Department of Natural Resources – navigable waters (state)
- State of Alaska, Division of Mining, Land and Water (state)
- Matanuska-Susitna Borough (municipal)
- Denali State Park (state)
- Bureau of Land Management (federal)
- Alaska Railroad Corporation
- Alaska Mental Health Trust Authority
- Cook Inlet Region, Inc.
- Ahtna, Inc.
- Private land owners





Key Aquatic Biological Questions

1. Spawning/incubation/emergence habitat?
2. Juvenile rearing habitats during open water and during ice cover?
3. Timing/intensity/duration of spring breakup and effects on fish habitat?
4. Juvenile passage out of lateral habitats (sloughs, tributaries, side channels) during outmigration?
5. Adult upstream passage conditions into lateral spawning habitats and in the mainstem river passage within and through the Devils Canyon Reach?
6. Riparian plant and forest communities?
7. Sediment transport and channel form?
8. Others……water quality, wildlife, recreation, etc........

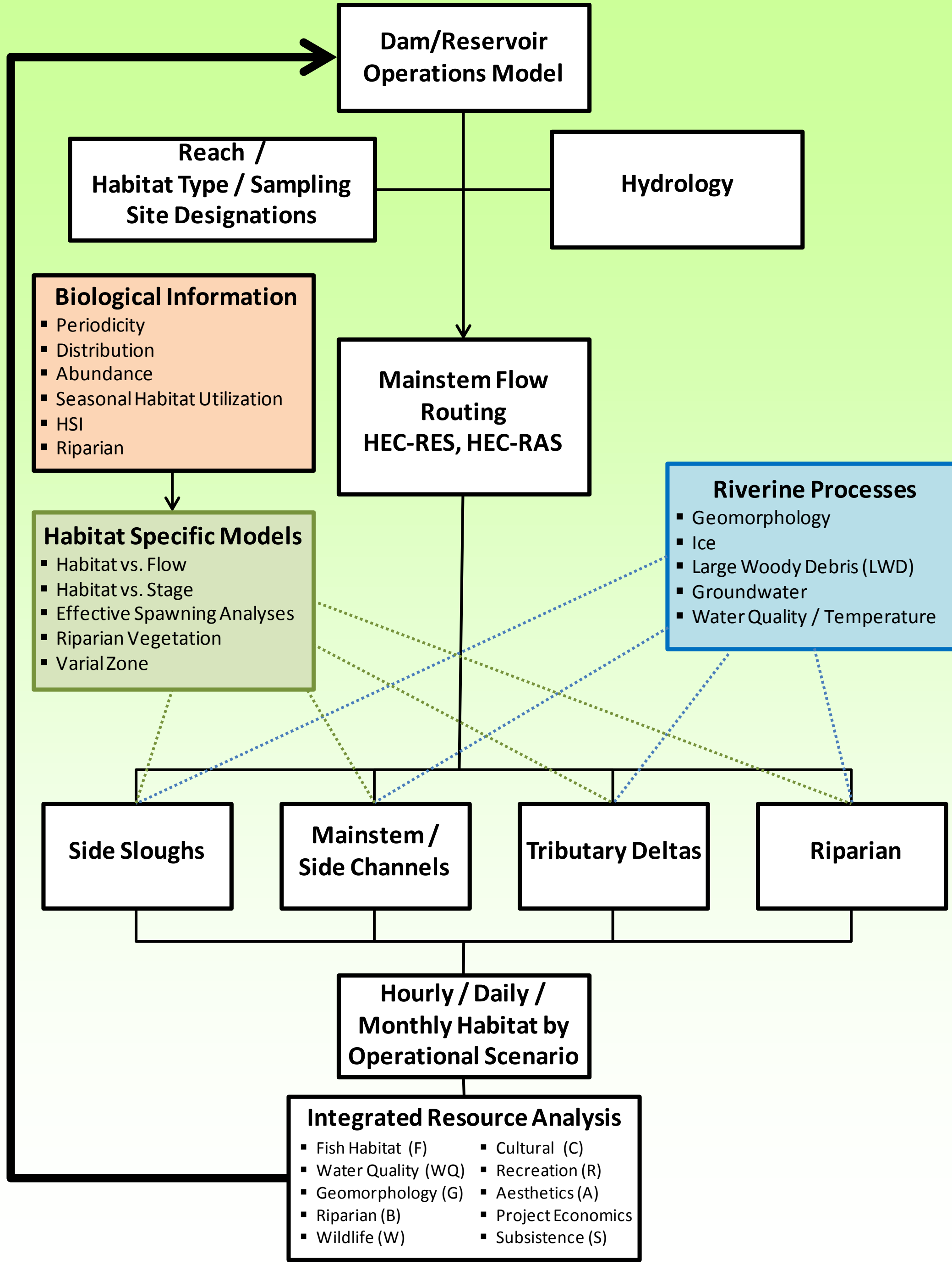
PLANNING and SCOPING

Stakeholder Consultation – Technical Work Group Meetings

October 3-4, 2012
TWG Instream Flow Site Tour

Analytical Framework of the Susitna – Watana Instream Flow Study (IFS)

- Models represent the core tools to address Biological Questions: Pre- and Post-Project conditions

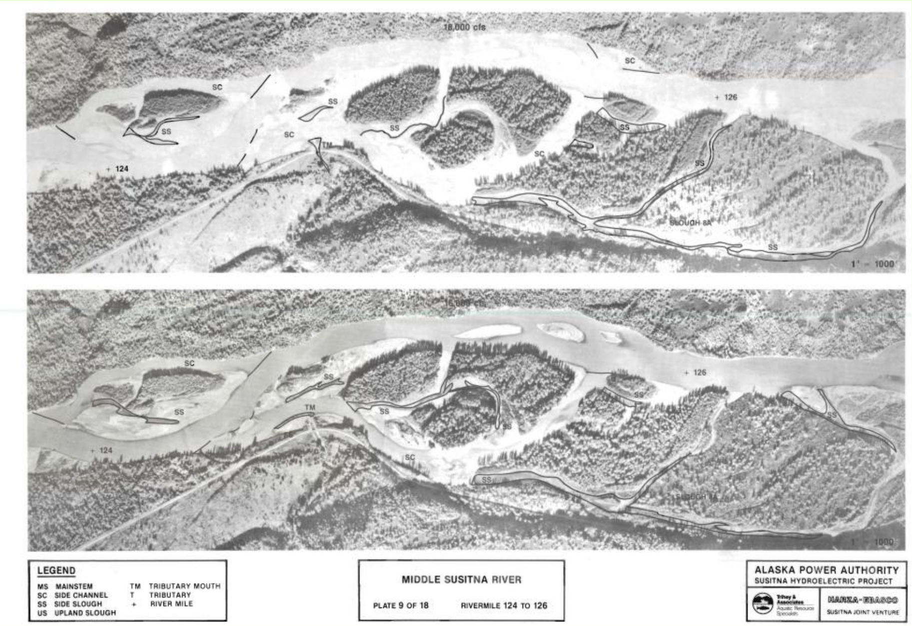


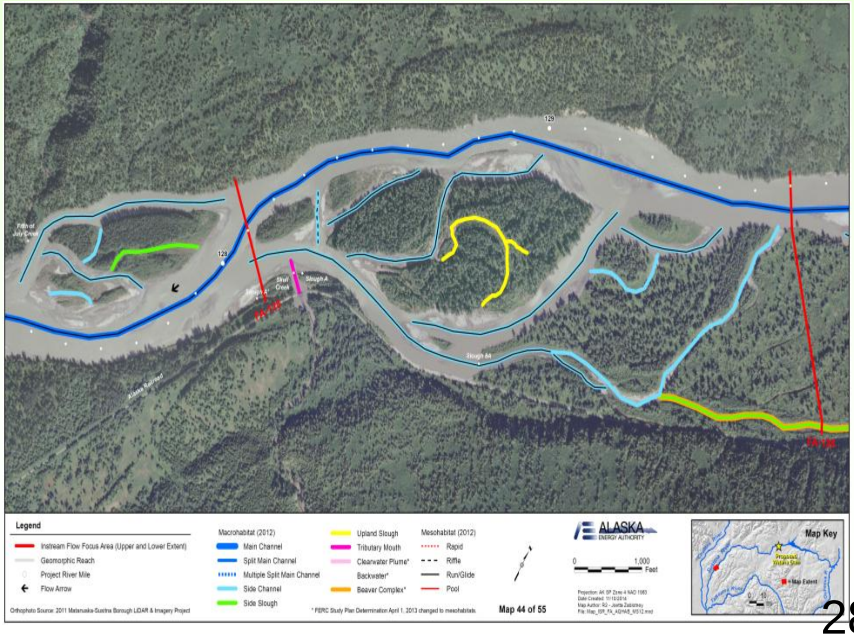
Stratification and Site Selection Process

- **Segment → Geomorphic Reach → Mainstem Habitat Type → Main channel Mesohabitats→ Edge Habitat Types**
- Geomorphic Reach – M1 through M8
- Mainstem Habitat Types (Macro-habitats)
  - Main channel habitats
    - Split main channel
    - Braided main channel
    - Side channel
  - Off channel habitats
    - Side slough
    - Upland slough
    - Backwater
    - Beaver complex

Habitat Mapping – then and now

- 1980s –
  Manual planimeter directly on aerial images – entire river at different Qs (labor intensive)
- Current –
  GIS/computer based analysis of aerial imagery – digitization (entire river)





The Upper Susitna River – General Views

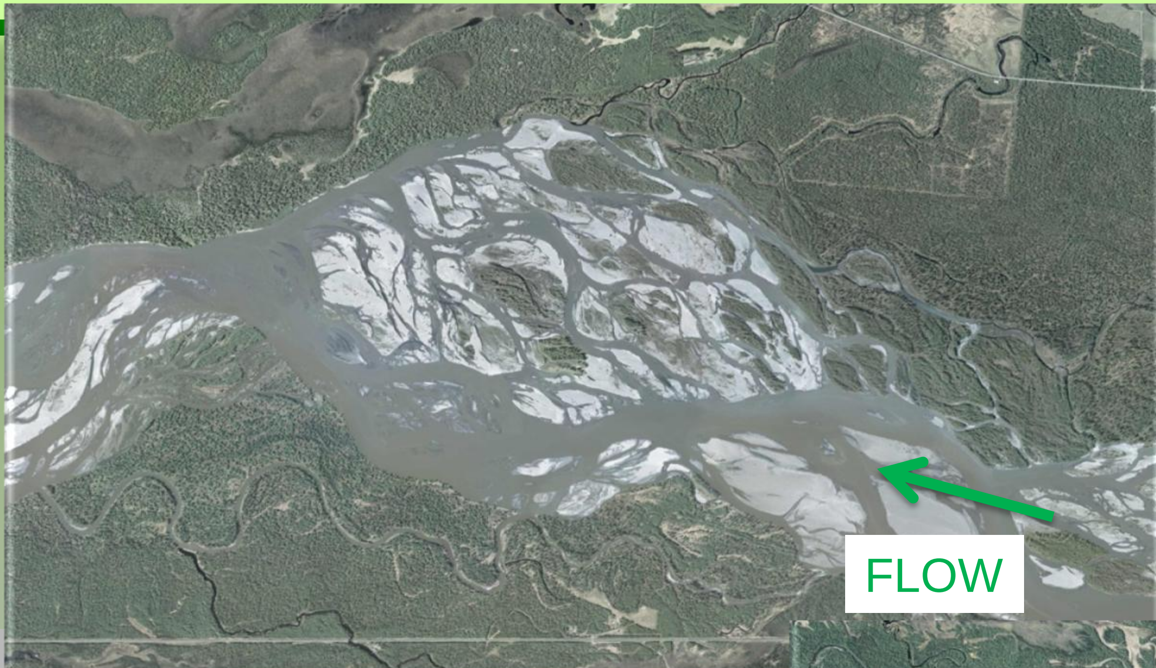
Project river miles (PRM):
187 - 235

The Middle Susitna River – General Views

Project river miles (PRM): 102.4 -187

The Lower Susitna River – General Views

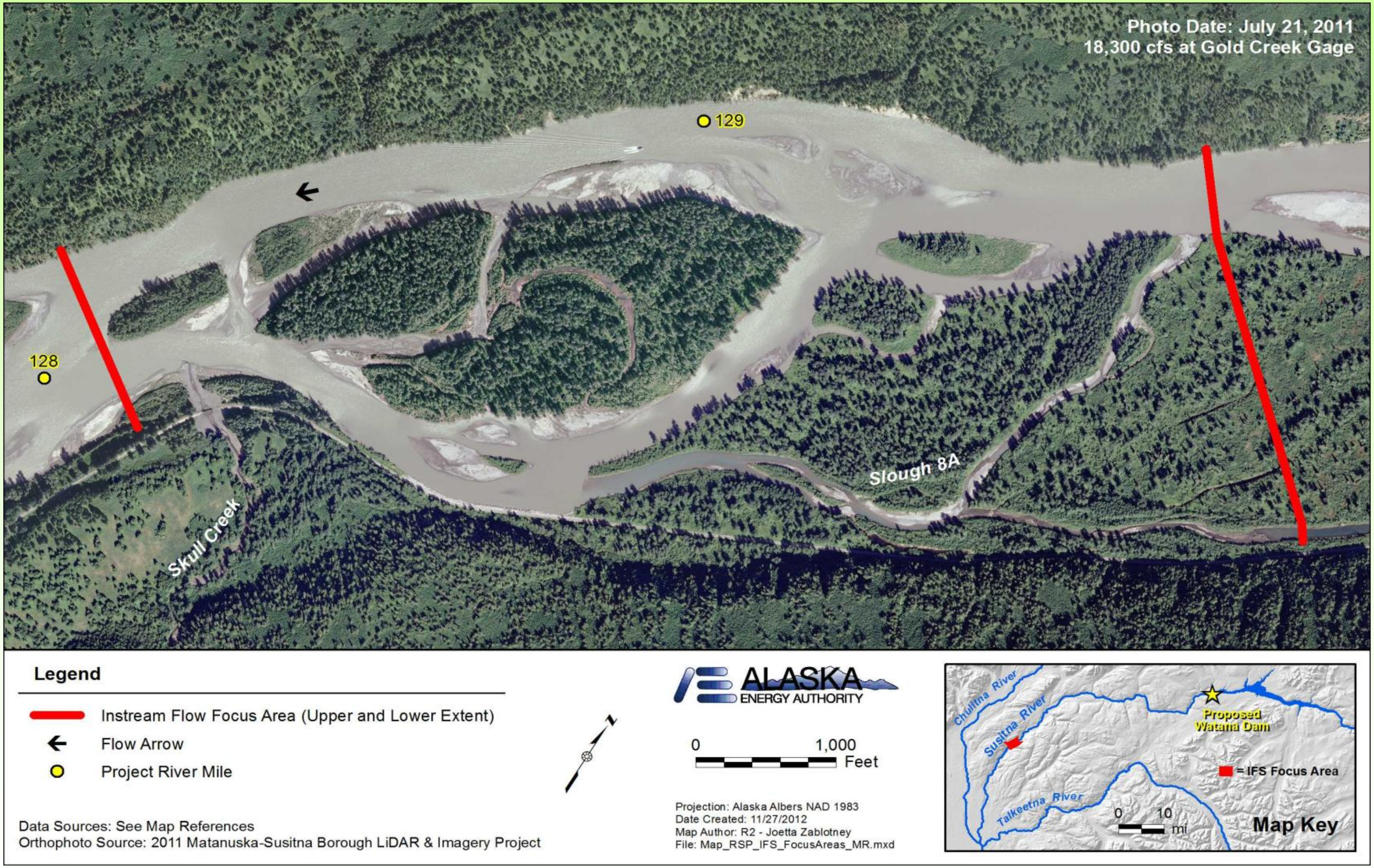
Project river miles (PRM): 102.4 -187



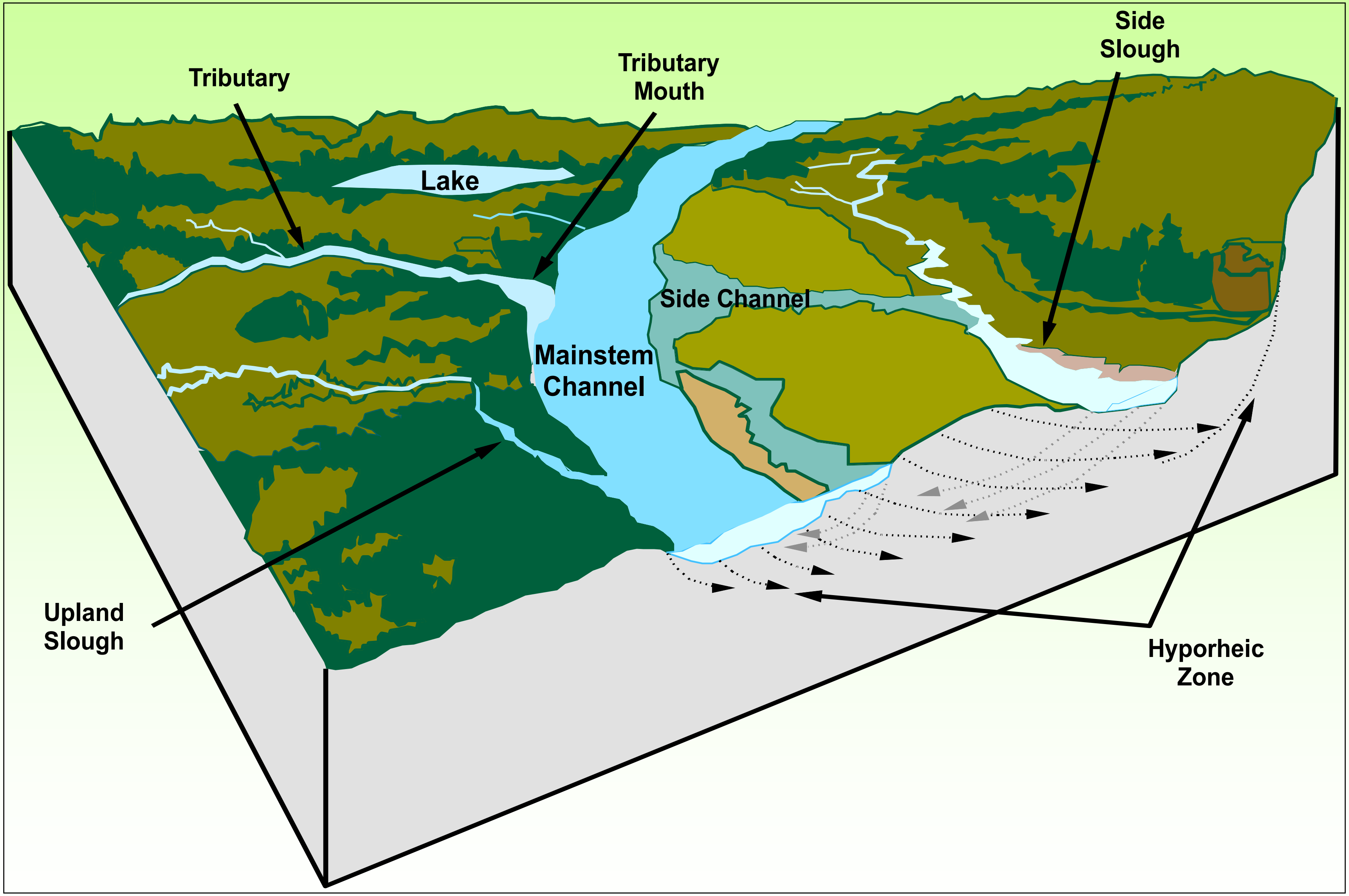
PRM 97 to PRM 93

PRM 72 to PRM 65

Middle Susitna River – Closer Look



Mainstem Habitat Types



Lateral Habitats Key

Pre-Project Winter Varial Zone

Post-Project Winter Varial Zone

LOAD - FOLLOWING effects on:

- **dewatering /inundation magnitude, frequency, timing and duration**
- **varial zone ice formation**
- **slough and intergravel temperatures**
- **stranding/trapping**

Study Area Selection

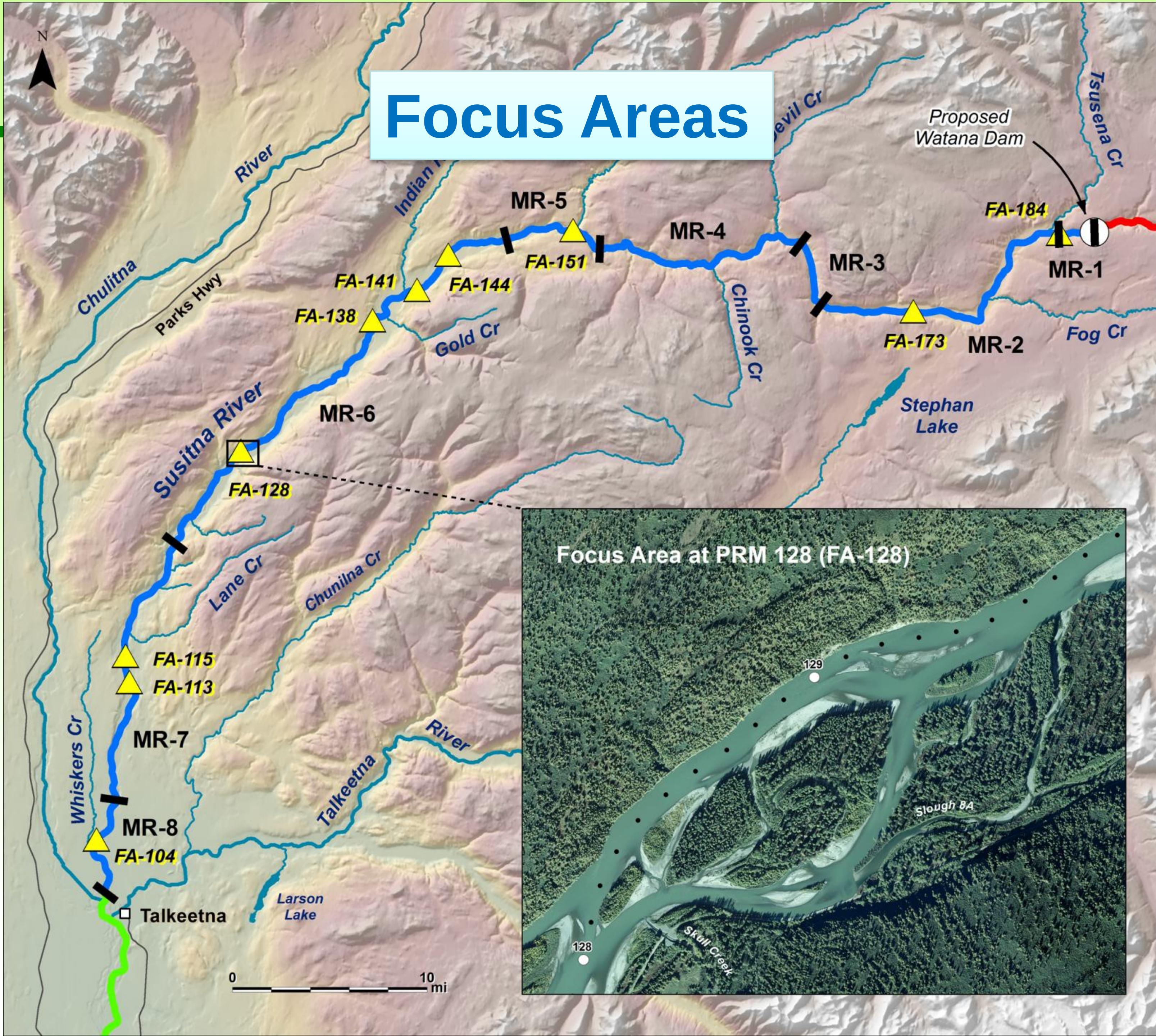
- Independent study site selection by each resource discipline
  - Representative/Critical/Random?

OR

- Coordinated study site selection by combined resource disciplines

FOCUS AREA APPROACH

Focus Areas



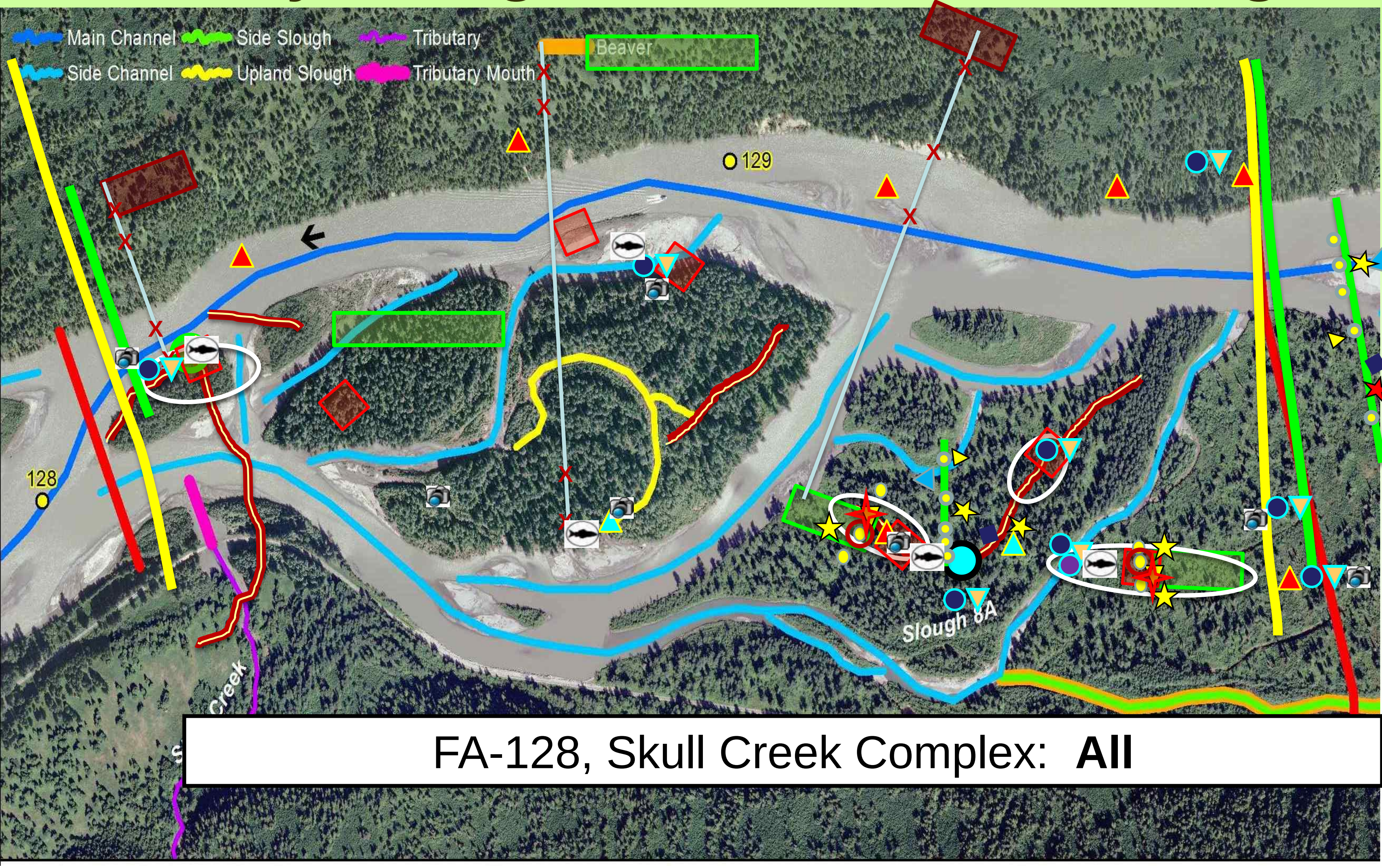
N
Proposed
Watana Dam
Tsusena Cr
FA-184
MR-1
MR-2
MR-3
MR-4
MR-5
MR-6
MR-7
MR-8
FA-151
FA-144
FA-141
FA-138
FA-173
FA-128
FA-115
FA-113
FA-104
Chulitna
River
Parks Hwy
Indian R
Gold Cr
Chinook Cr
Fog Cr
Stephan
Lake
Susitna River
Lane Cr
Chunilna Cr
Talkeetna
River
Whiskers Cr
Talkeetna
Larson
Lake
0
10
mi
Focus Area at PRM 128 (FA-128)
129
128
Slough 8A
Skull Creek

Instream Flow Related Studies

- Instream Flow - Fish and Aquatic Habitat
- Instream Flow - Riparian
- Fluvial Geomorphology and Sediment Transport
- Groundwater (General/F&A/Riparian)
- Water Quality (General/F&A)
- Ice Processes

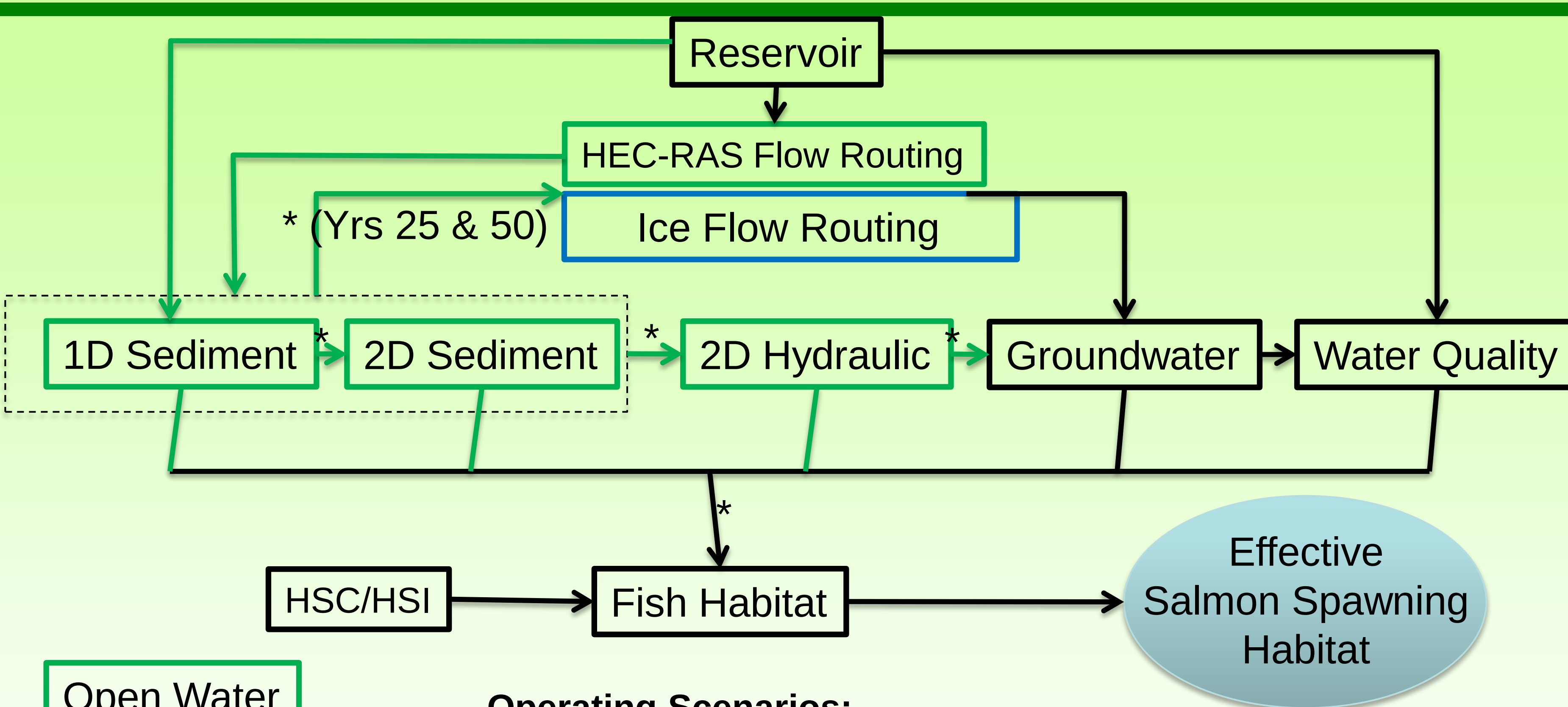
.... and a full complement of Fish and Aquatics studies

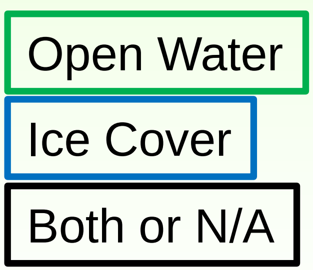
Study Integration and Modeling



FA-128, Skull Creek Complex: **All**

Modeling: Interdependencies Flow Chart



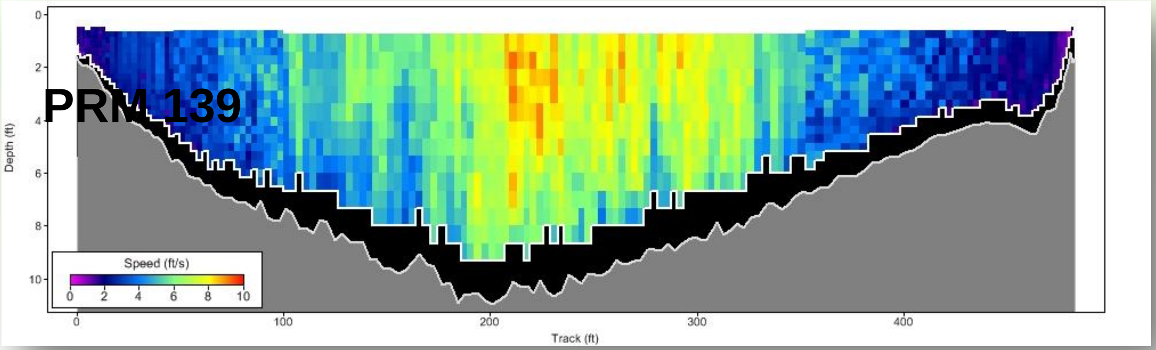


Operating Scenarios:

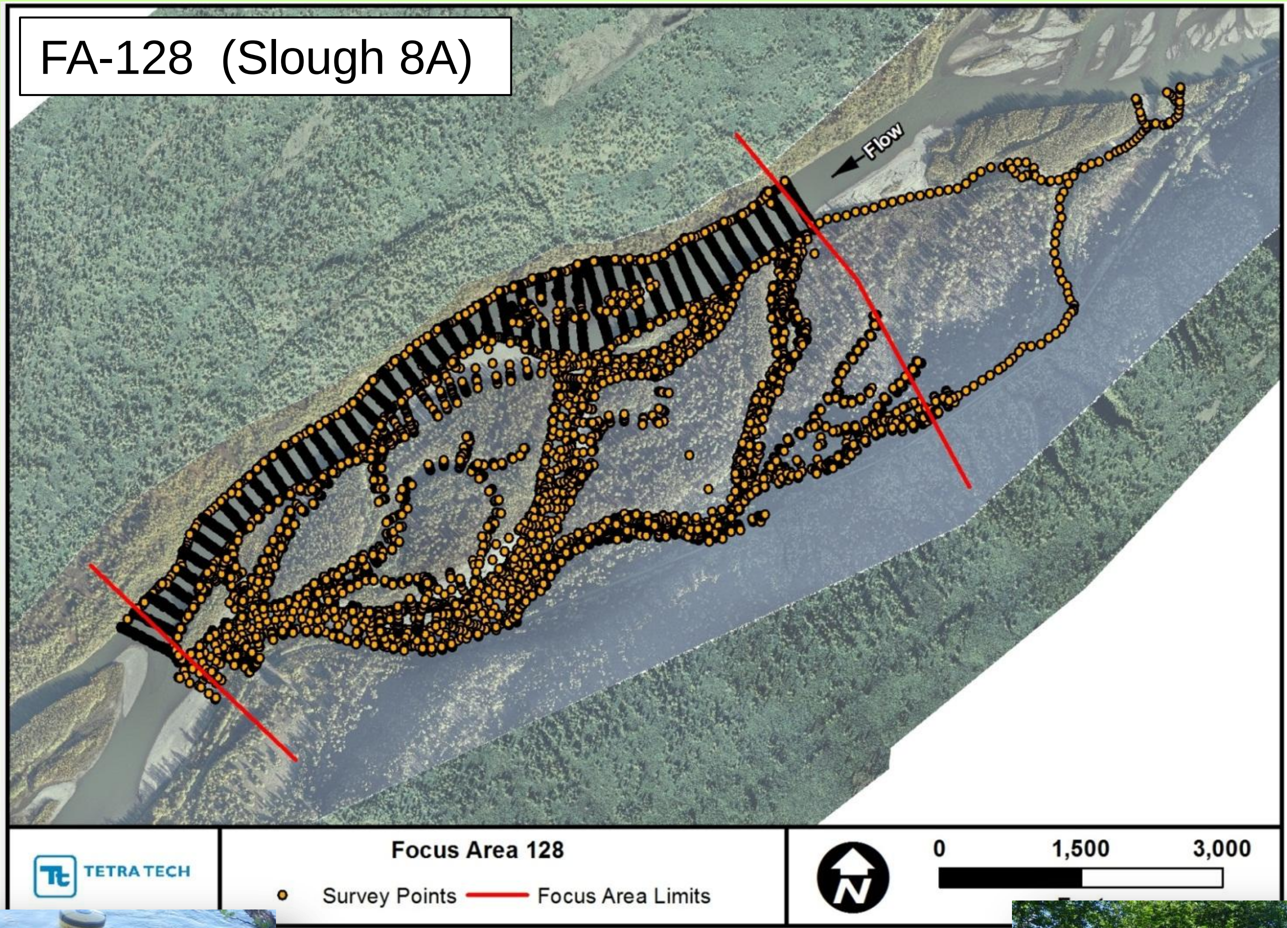
- Base Load
- Intermediate Load Following
- Maximum Load Following
- Run of the River

FA-IFS: Focus Area Data Collection

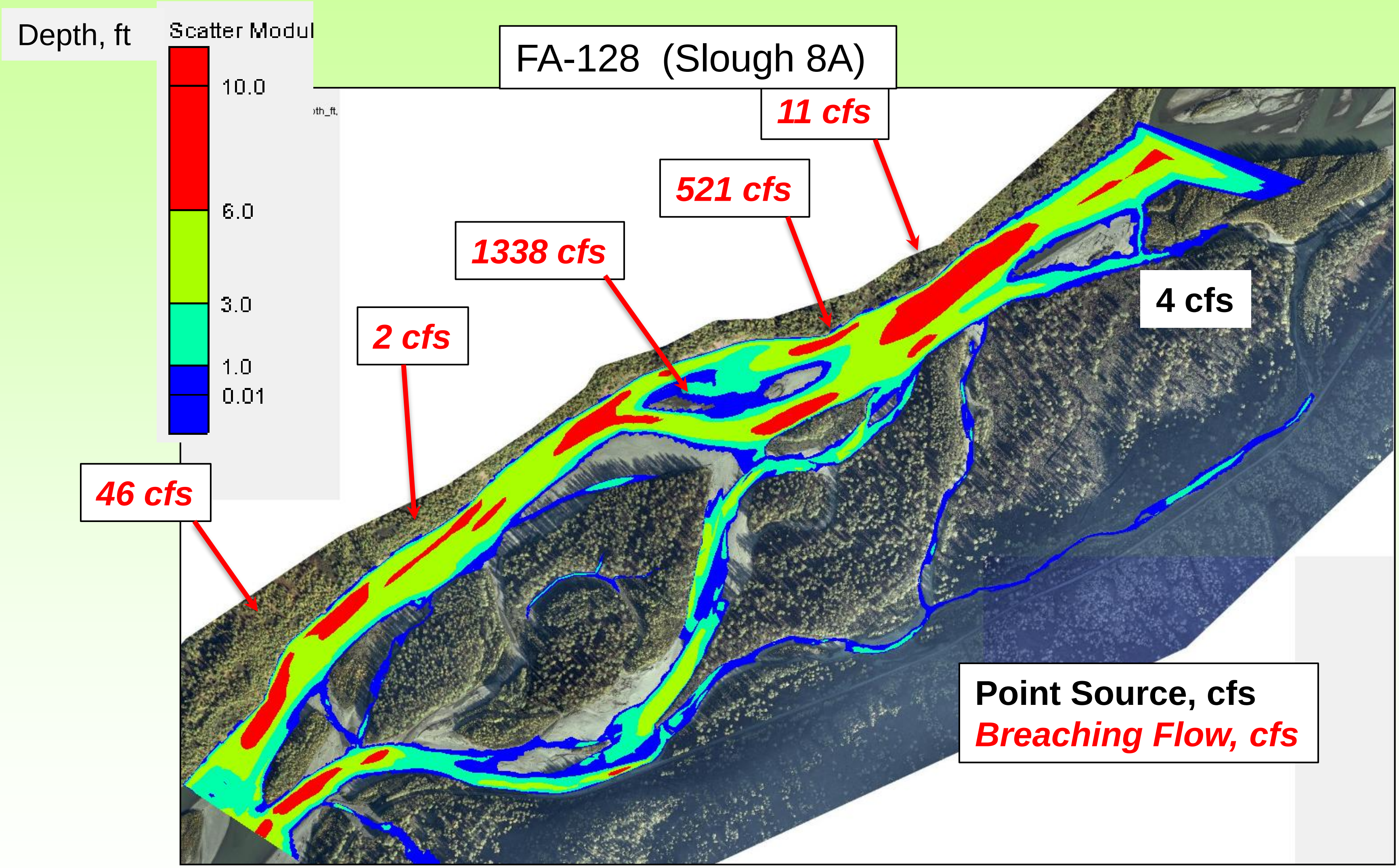
- Bathymetric Surveys
- ADCP Calibration
- Substrate characterization
- Data QA/QC
- Bathymetric and RTK data point maps; triangulated irregular network (TIN) maps; Topographic maps



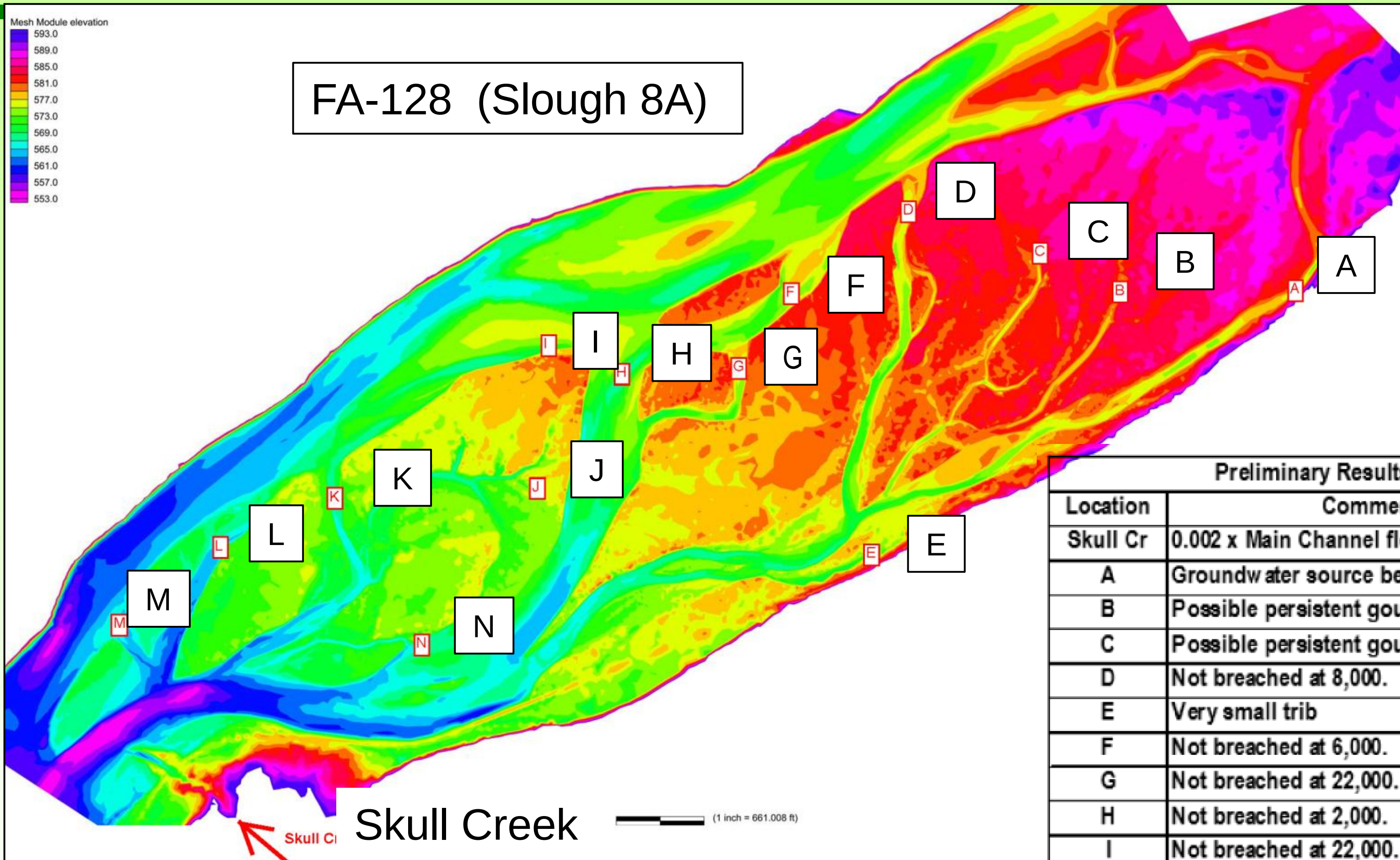
Model Development:
Survey and Bathymetric Data



Hydraulic Model 12,000 cfs Depth

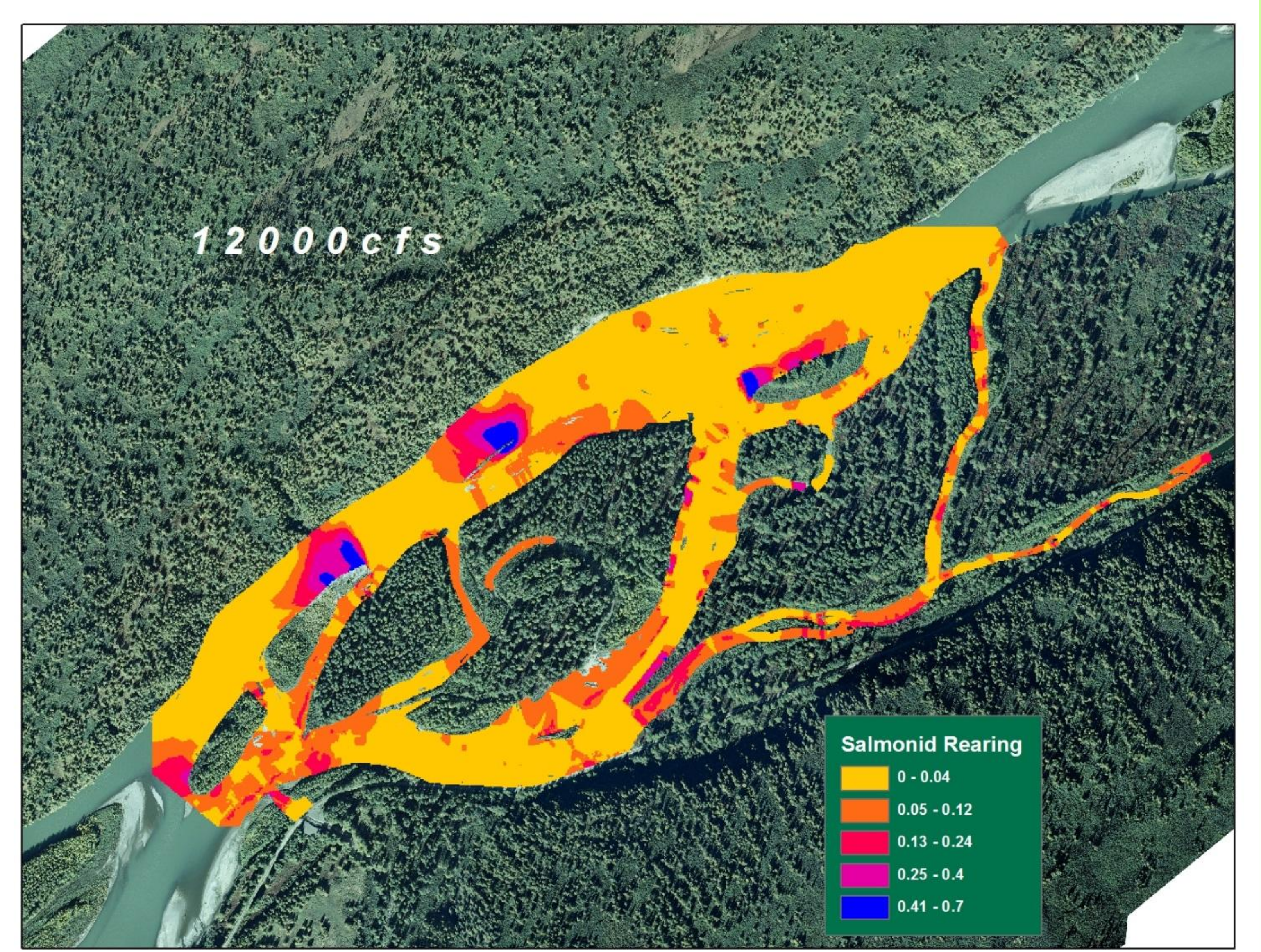


Surface/Ground Water Interactions

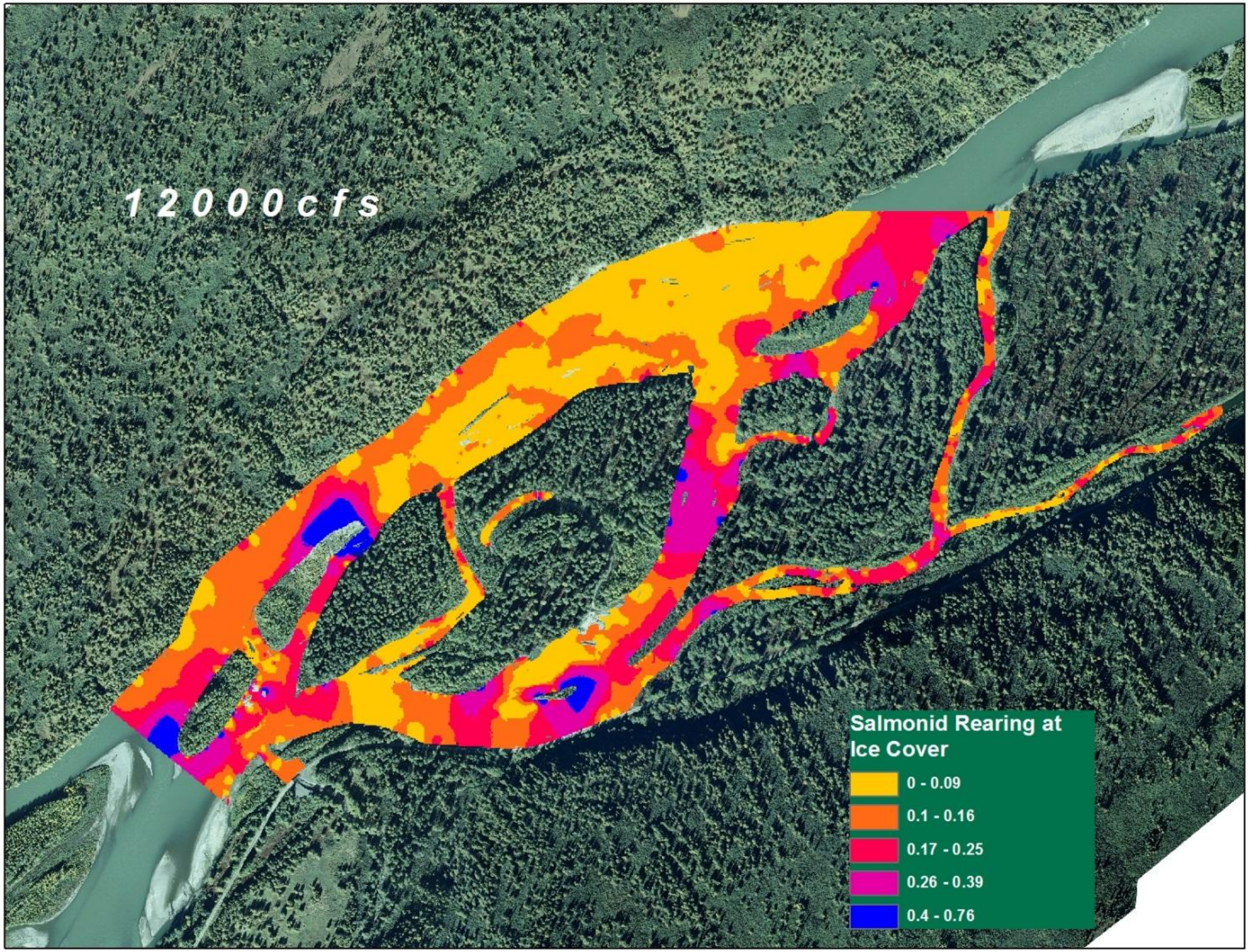


Preliminary Results	
Location	Comment
Skull Cr	0.002 x Main Channel flow
A	Groundwater source below ~30,000 cfs
B	Possible persistent goundwater source
C	Possible persistent goundwater source
D	Not breached at 8,000. 11 cfs at 12,000
E	Very small trib
F	Not breached at 6,000. 38 cfs at 8,000
G	Not breached at 22,000. 86 cfs at 30,000
H	Not breached at 2,000. 22 cfs at 4,000
I	Not breached at 22,000.
J	Halfmoon bay, muliple sources.
K	Not breached at 12,000. 8 cfs at 16,000
L	Not breached at 8,000. 2 cfs at 12,000
M	Not breached at 8,000. 46 cfs at 12,000
N	Not breached at 22,000. 24 cfs at 30,000

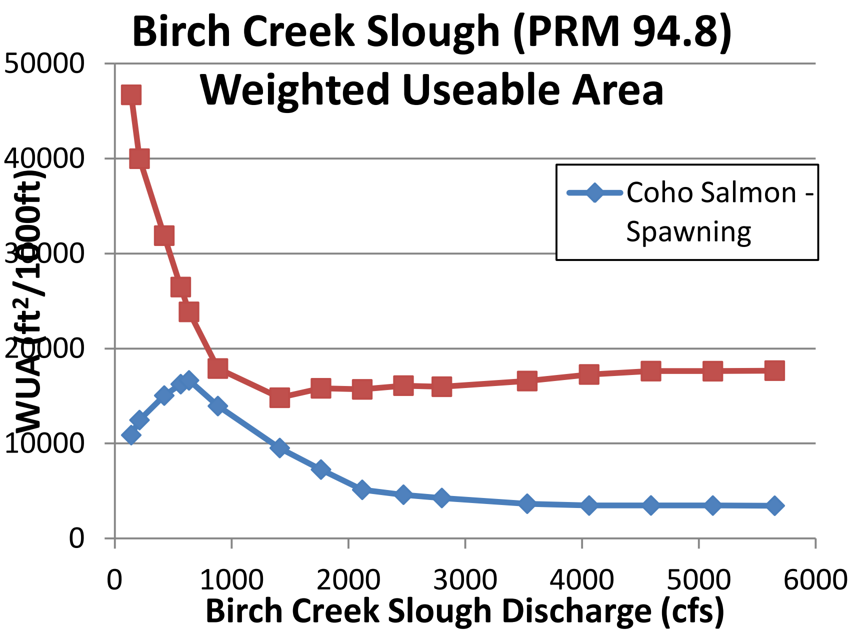
FA-128 (Slough 8A) Salmonid Rearing
12,000 cfs simulation

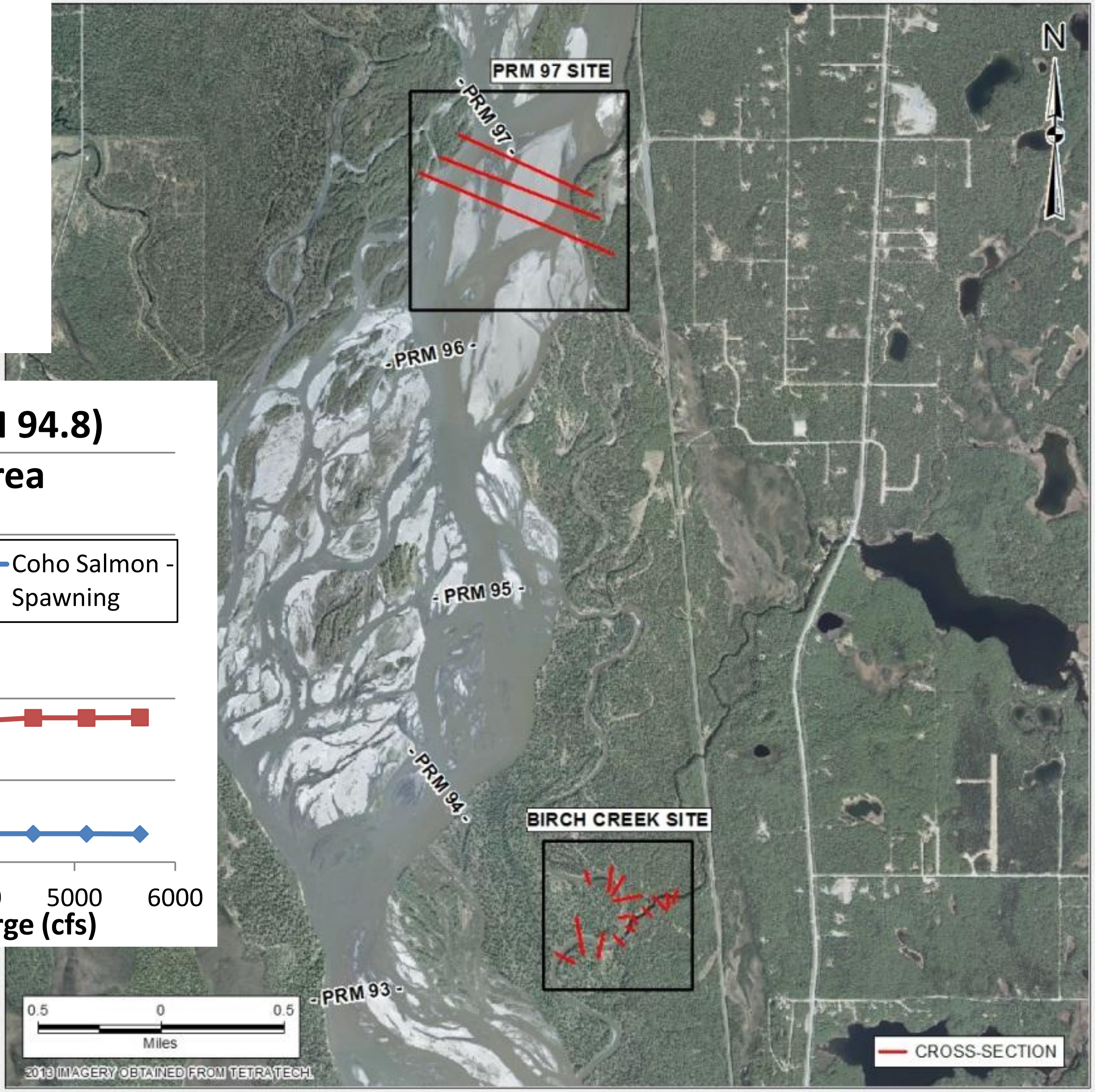


FA-128 (Slough 8A) Ice Cover Salmonid Rearing 12,000 cfs simulation

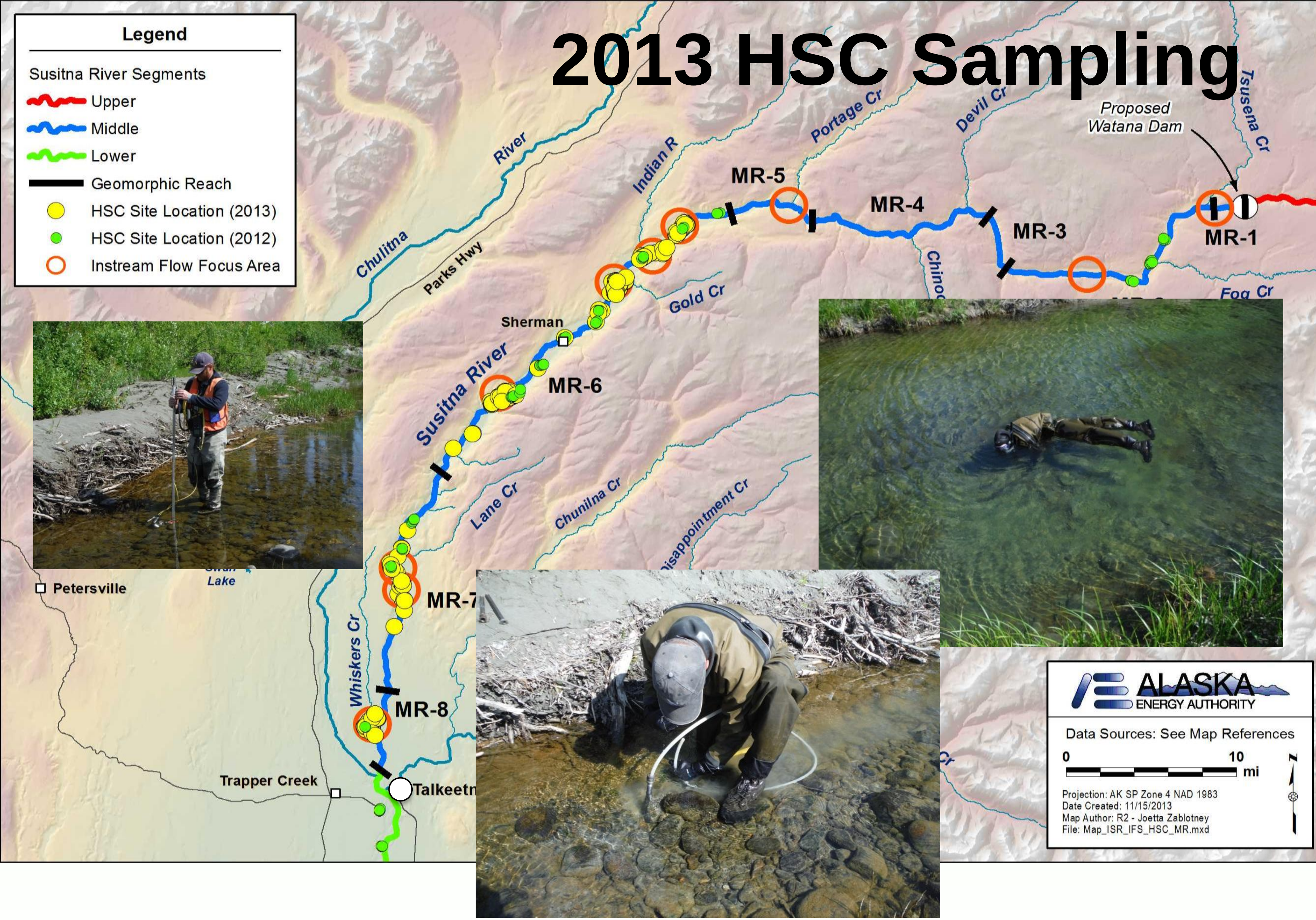


Lower River 1-D Fish Habitat Instream Flow Study Sites

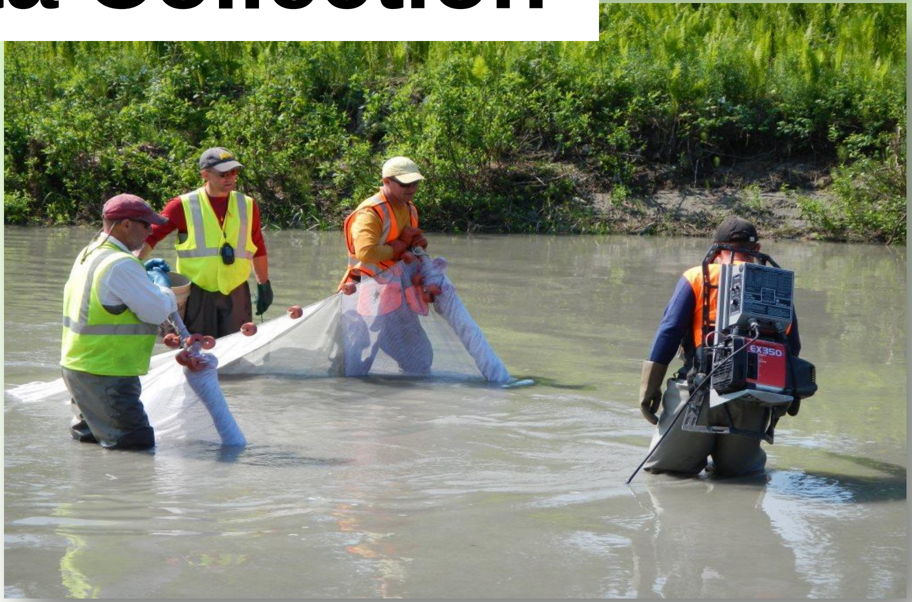




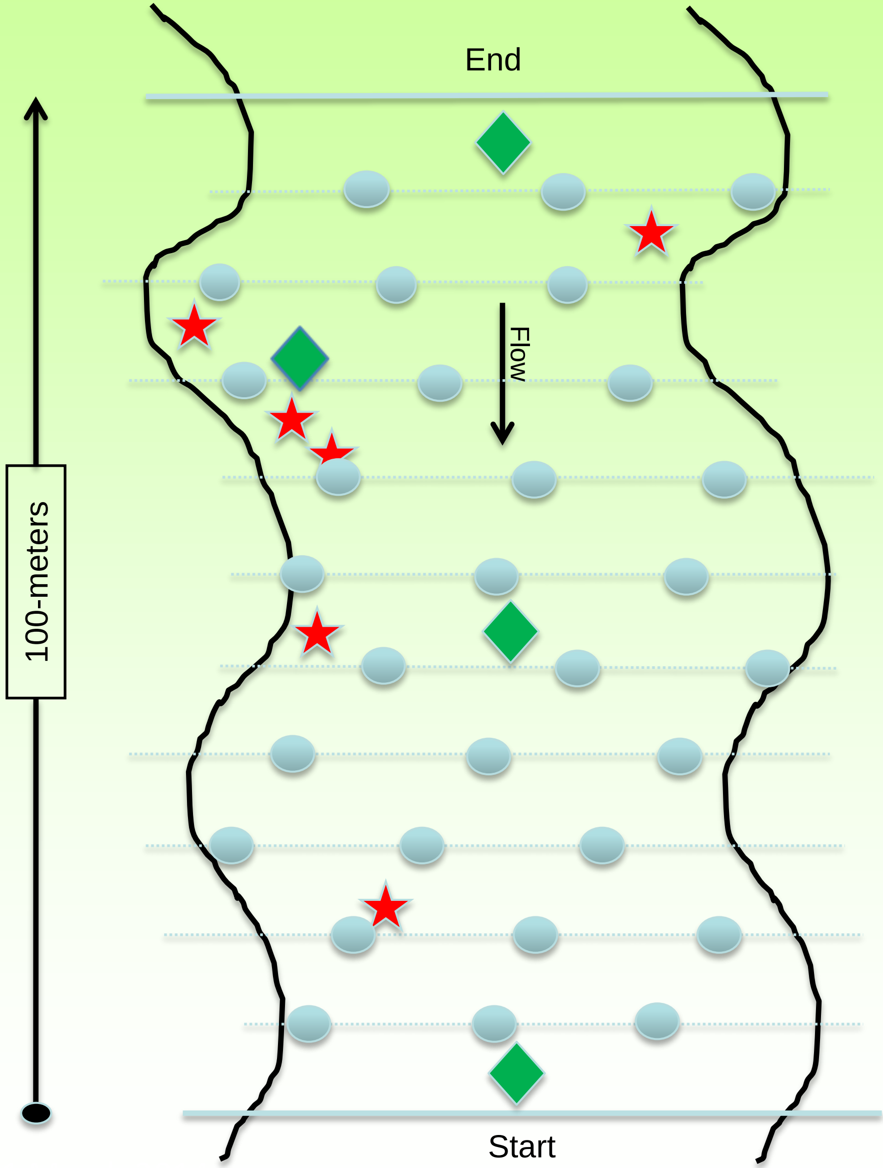
2013 HSC Sampling



Biological Data Collection



Example Plot Depicting HSC and Water Quality Locations and Sampling Grid



Red Stars - Utilization Measurements

- Depth
- Velocity
- Substrate
- % Embeddedness
- Cover
- Distance from Start
- Distance from water's edge

Blue Dots - Availability Measurements

- Depth
- Velocity
- Substrate
- % Embeddedness
- Cover

Green Diamond - Water Qual. & VHG

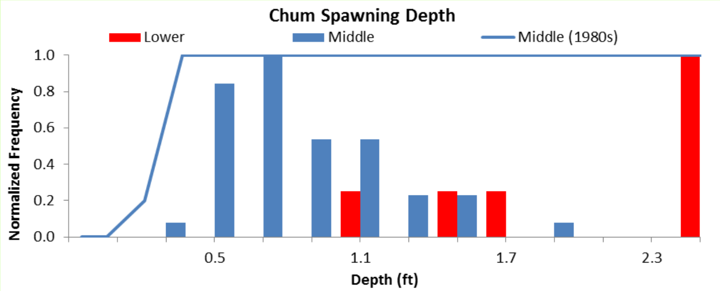
- Temperature
- Dissolved Oxygen
- Conductivity
- Turbidity
- Vertical Hydraulic Gradient

More Robust Regression Models

Habitat suitability criteria

- Standard approach: univariate curves fitted to histograms then multiplied to develop overall suitability curve

Composite Suitability for cell I =
HSCvel * HSCdepth *HSCsubstrate
= 0.9 * 0.55 * 0.7 = 0.3465



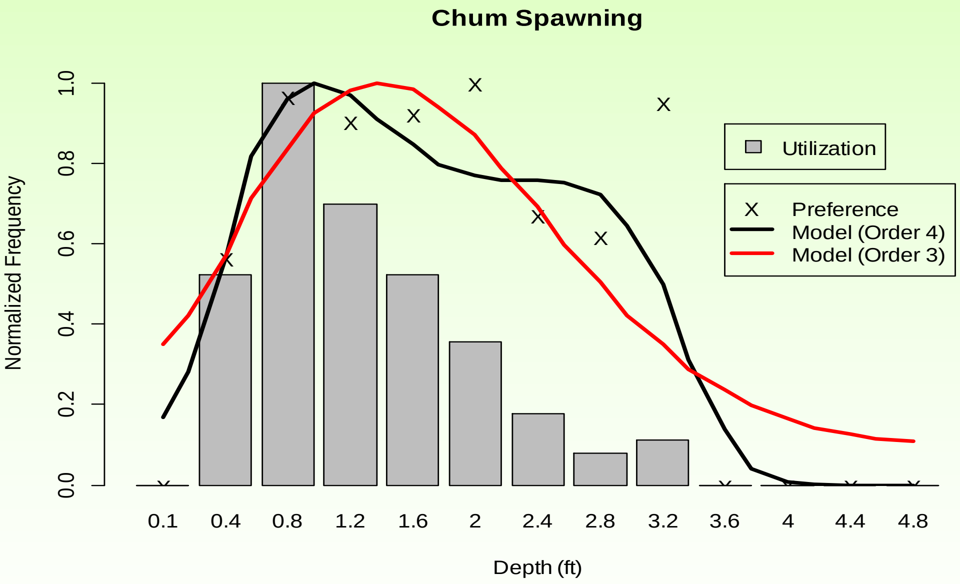
- Modified process: multivariate analyses using most appropriate statistical models

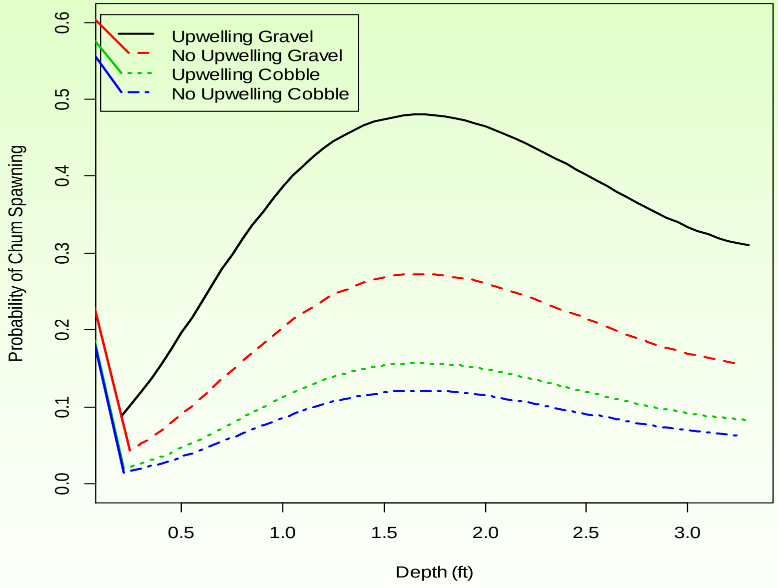
$$\log\left(\frac{p}{1-p}\right) = C_k + 4.33 * depth - 1.91 * depth^2 + 0.246 * depth^3 + 1.52vel - 0.714vel^2 + \gamma_{site} + \varepsilon$$

- ✓ Objective
- ✓ Defensible
- ✓ “best fit”
- ✓ Incorporates natural uncertainty

Generalized Mixed Effects Regression Models for HSC

- Generalized regression: predicting probability (p) of chum spawning within a model cell using logistic regression
- Multivariate: Depth, velocity, substrate, upwelling all in one model
- Random effect for site - combination of data across sites with different levels of spawning activity without fitting separate models





Variables Considered for HSC

- Depth
- Velocity
- Substrate
- Cover
- Upwelling
- Water

Temperature
- DO
- Conductivity
- Turbidity

HSC Chum Spawning Model – Best Fit

$$\log\left(\frac{p}{1-p}\right) = C_k + 19depth - 18depth^2 + 6.8depth^3 - 0.91depth^4 + 3.9vel - 1.9vel^2 + \gamma_{site} + \varepsilon,$$

where

$$C_{UPGR} = -10$$
$$C_{UPCO} = -14$$
$$C_{NOGR} = -13$$
$$C_{NOCO} = -15$$

Objective is to build a multivariate preference model that predicts the *relative* probability of fish use in a habitat cell based on measurable predictable habitat characteristics

Winter HSC Studies

3 trips each winter

- February, March, April

Continuous monitoring

- Stage
- Temperature: Surface & Intragravel
- Dissolved oxygen: Intergravel

Spot measurements

- WQ: Surface, intergravel
- Ice thickness
- Groundwater: Micro-piezometer

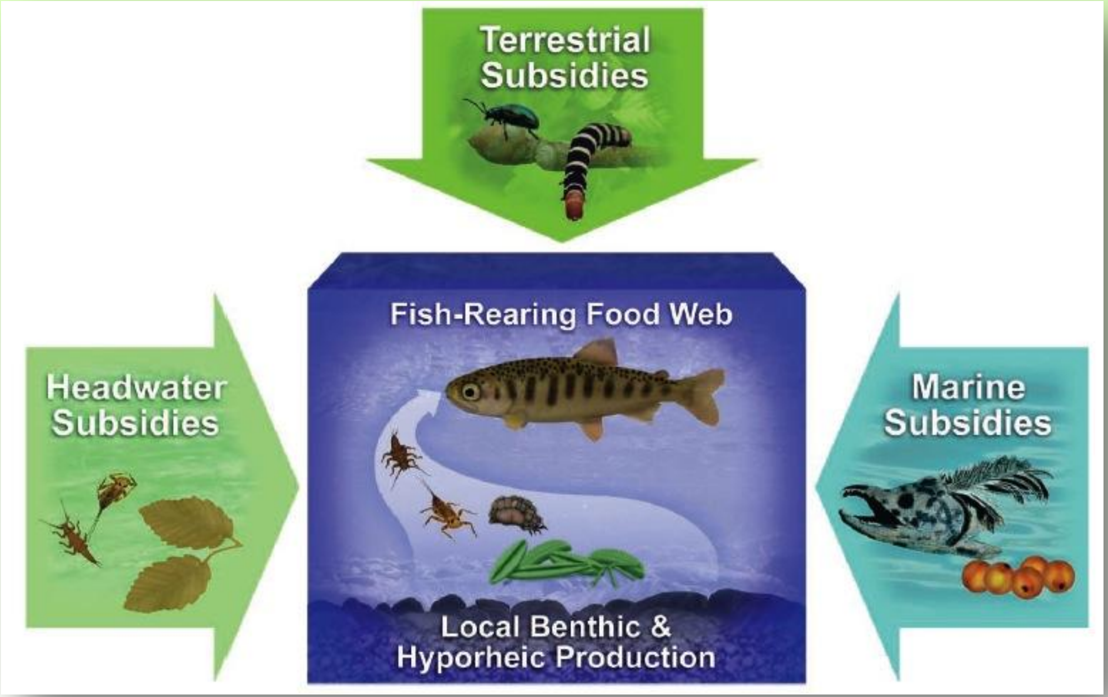
Fish observations & capture

- Day & night surveys
- Electrofishing & video
- HSC measurements

River Productivity

- Sample multiple components of the food web in freshwater stream systems to understand what is driving the system.

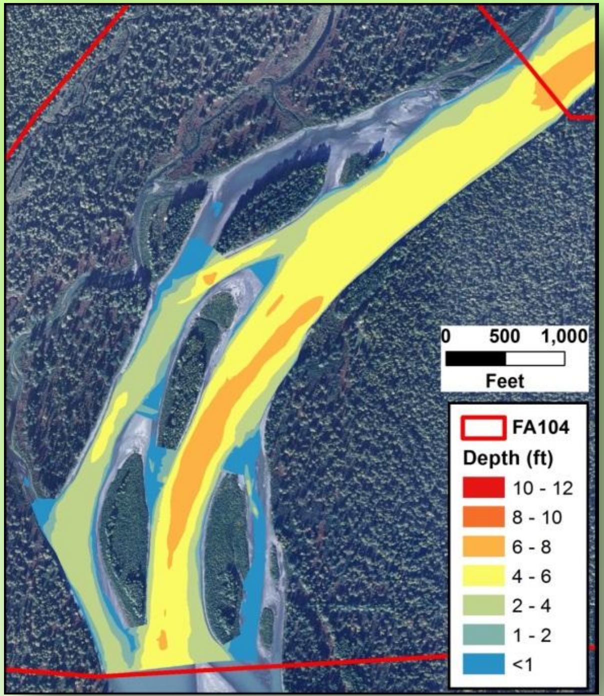
- Macroinvertebrates
- Algae/Periphyton
- Organic Matter
  - Fish
  - Eggs
  - Carcasses
- Stomach contents

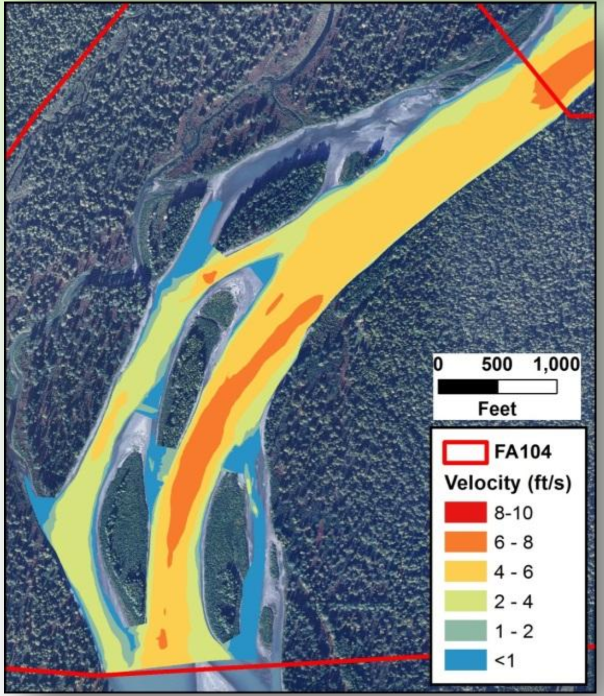


Wipfli and Baxter 2010

Fluvial Geomorphology Modeling - Provide Information to Evaluate Potential Project Effects on:

- Aquatic Habitat
- Riparian Habitat
- Ice Processes
- Flow Routing
- Groundwater
- Property/Infrastructure
- Navigability
- Recreation and Aesthetics





<u>Example:</u> Geomorphic Surface Mapping – how frequent do surfaces flood?

MC = Main Channel

MC GB = Main Channel Gravel Bar

SC = Side Chanel

SC = Side Channel Gravel Bar

SS = Side Slough

US = Upland Slough

TR = Tributary

OFP = Old Floodplain

TCE = Terrace

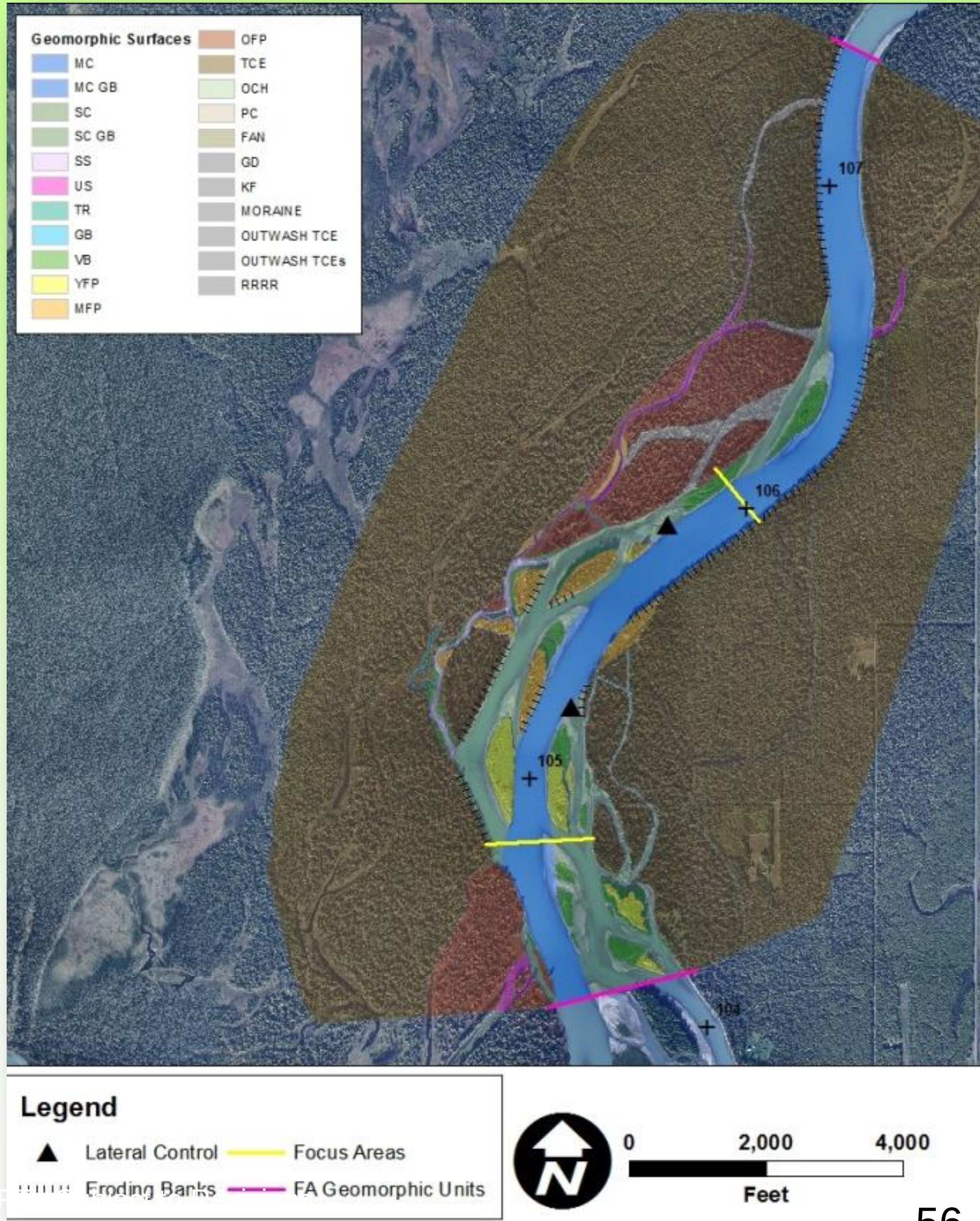
OCH = Overflow Channel

PC = Paleo Channel

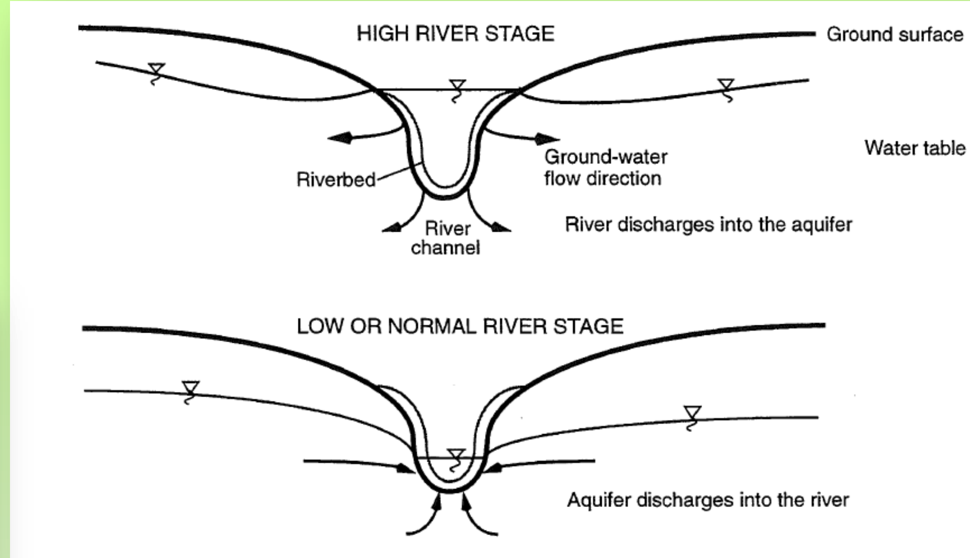
FAN = Alluvial Fan

GD = Grano Diorite

KF = Kahlitna Flysch

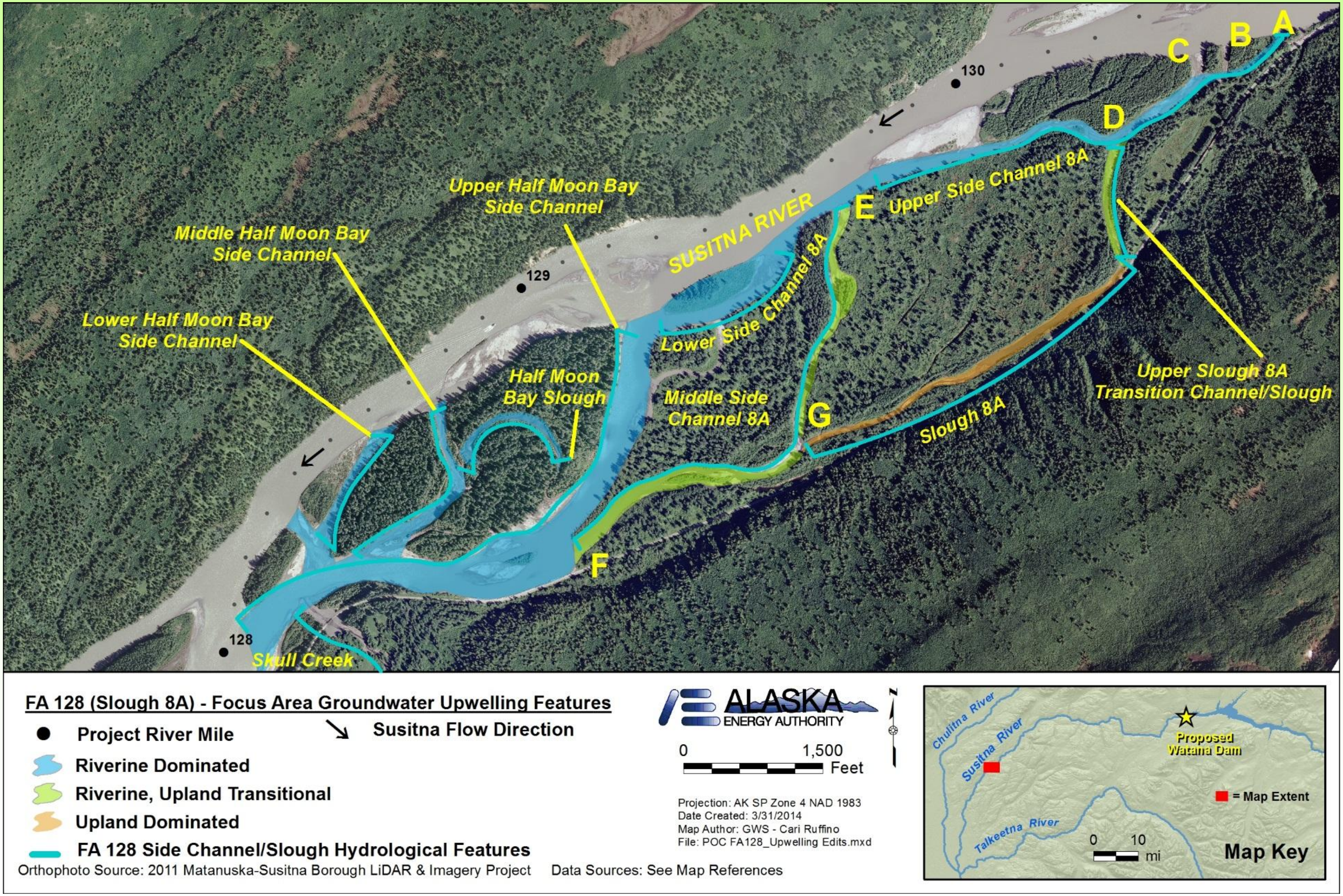


Groundwater Study Modeling & Analysis Integration



ESSFA128-1 Example - Time-Lapse Cameras

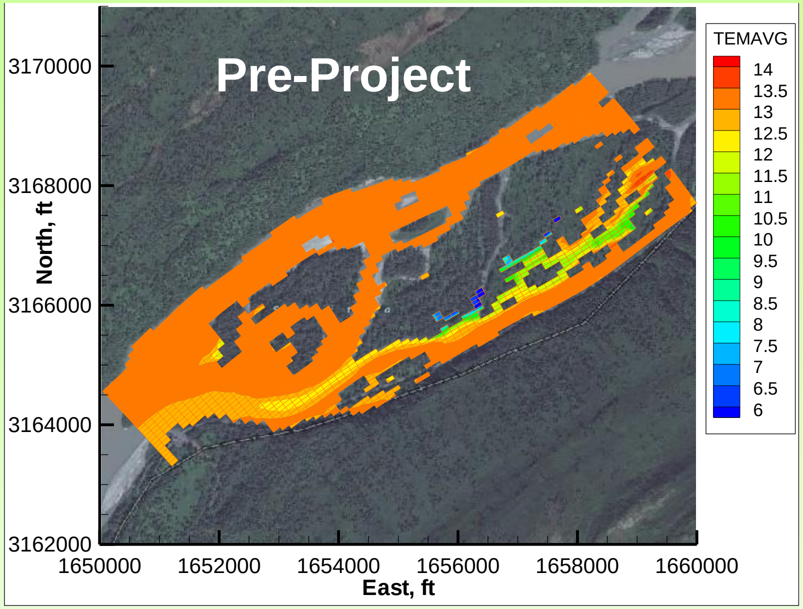
GW/SW FA-128 (Slough 8A) Upwelling Zones

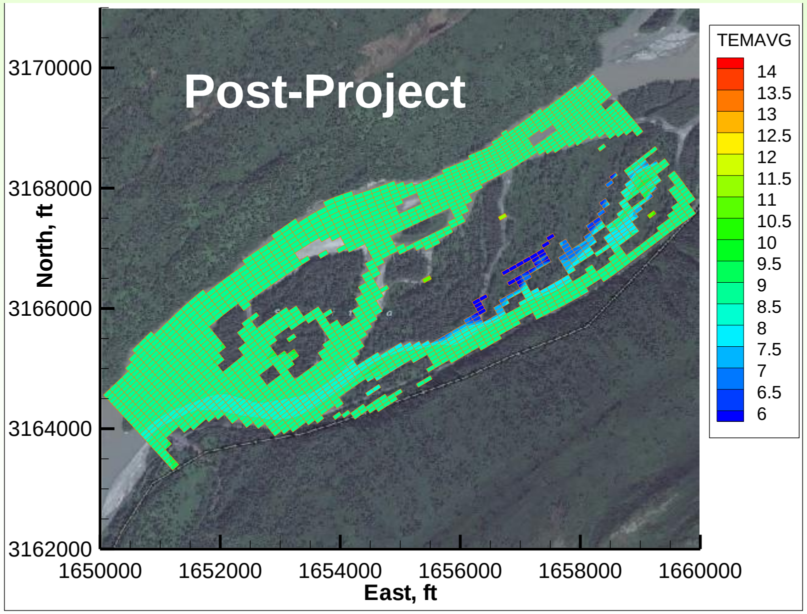


Water Quality Modeling – Reservoir and Riverine

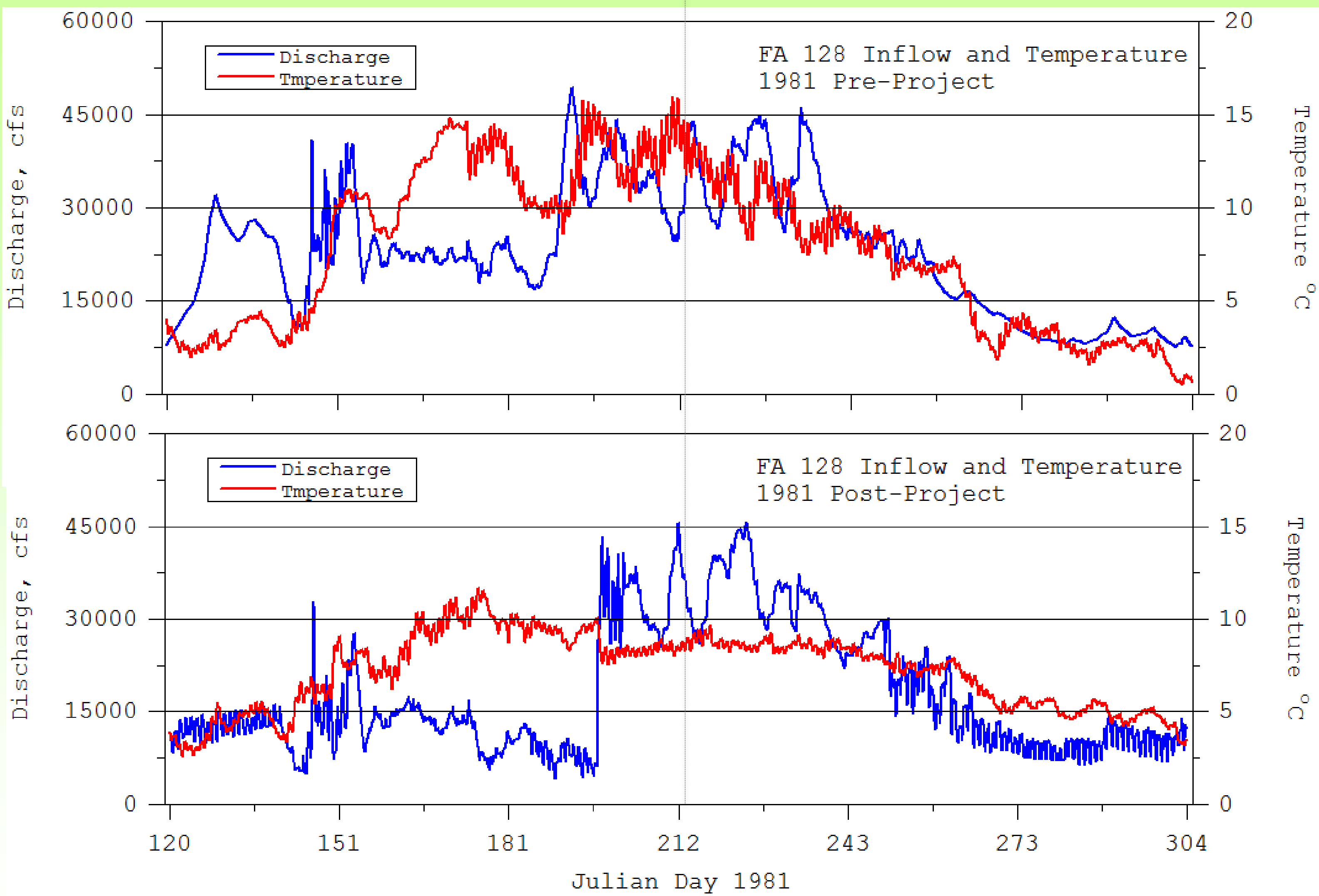
- Water Temperature
- Dissolved Oxygen
- pH
- Nutrients
- Other constituents

– 401 Certification



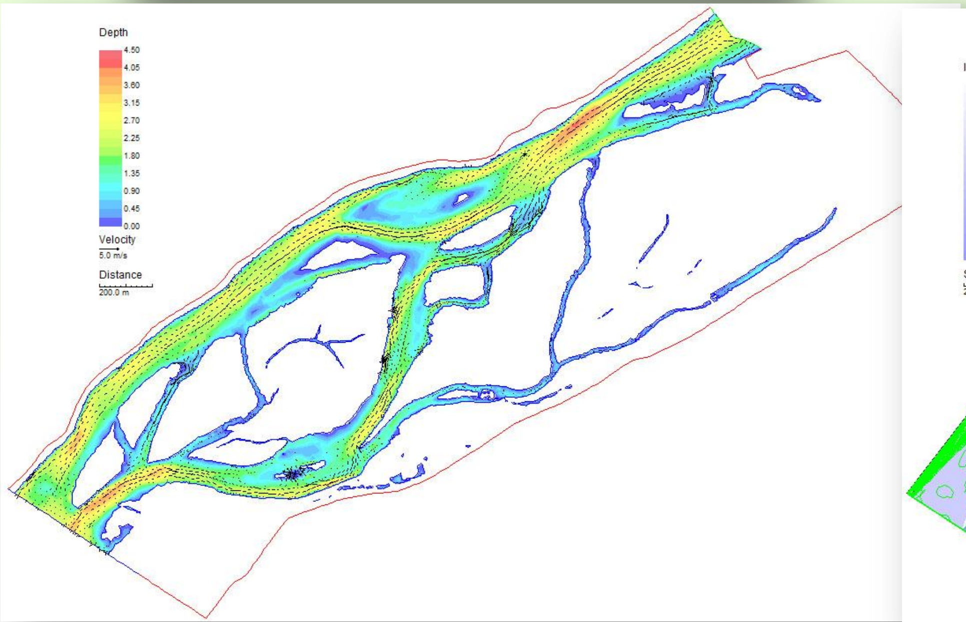


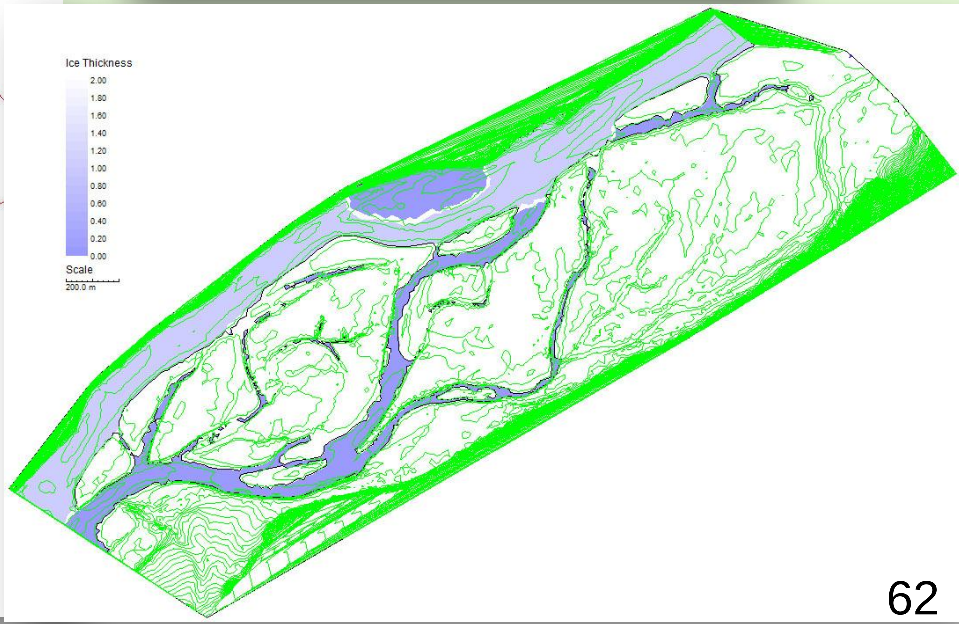
May-October 1981 Temperature



Ice Processes Modeling (River1D and River2D)

Project operations → higher and more frequent flows in winter than current conditions: effects?





Riparian Instream Flow Modeling

- Project Operational effects on:
  - Seedling establishment
  - Changes in Ice formation and ice out effects on riparian community ecology
  - Reduced flood flows on riparian ecosystem
  - Groundwater/surface water interactions

Tree Ice Scar Mapping 2013

Ice Scar Mapping
September 2013

Whiskers Slough 2013 Ice Break-up

Data Adequacy – How much is enough?

- More data are always better
- 1980s Studies: 5 years data – matches 5 year life cycle of salmon
- Current ILP process: 2 years of data – enough?

Yes

provided impact assessment models fully developed and populated with appropriate data

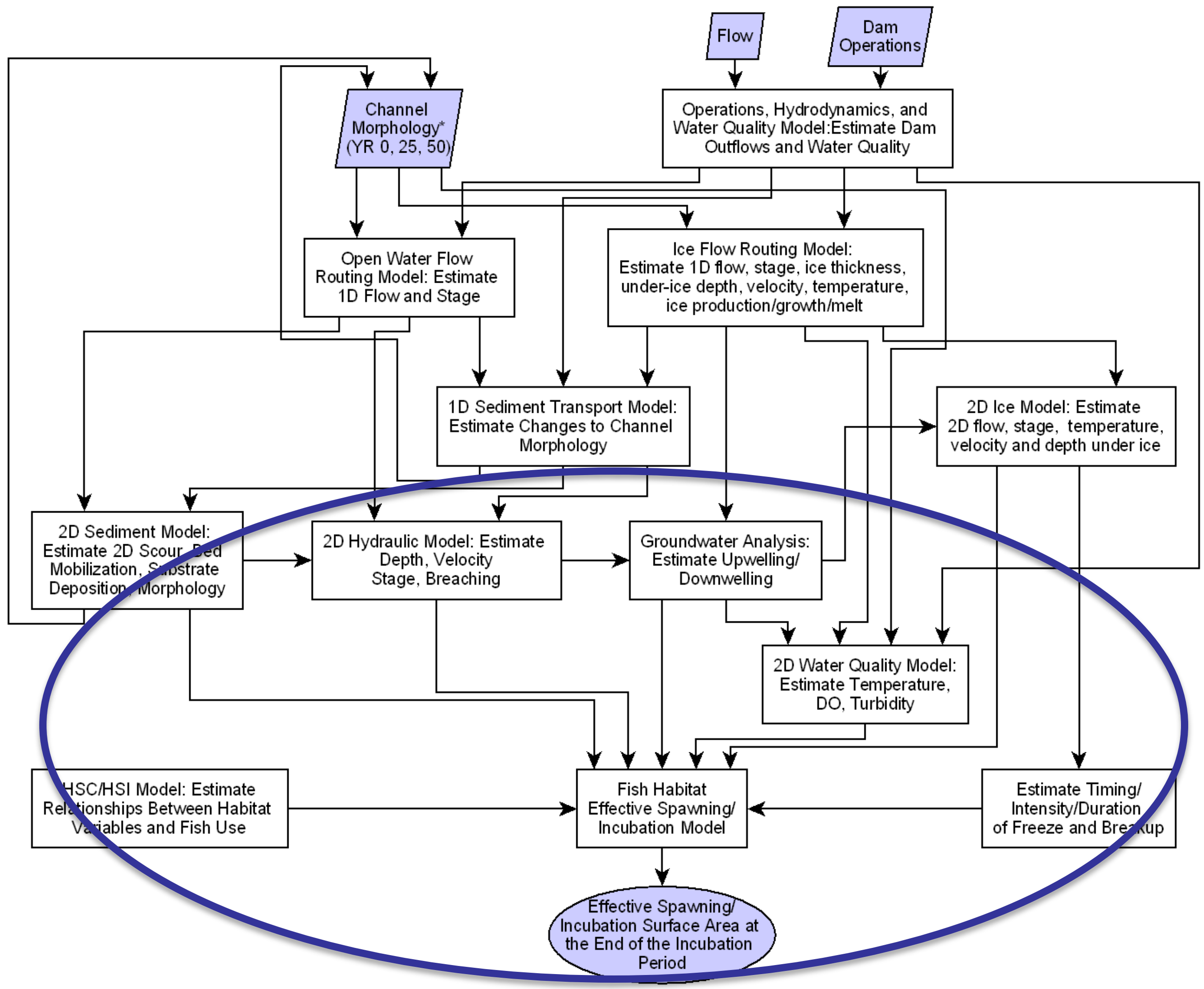
Data Adequacy: Proof of Concept

- Demonstrate Resource-specific Model development process
  - Input data
  - Model calibration process
- Demonstrate Model Integration to Address Key Resource Questions

Prove

that the Models can be reliably used for addressing resource questions

What are Project Impacts to Total Effective Spawning/Incubation/Emergence Habitat Area in FA-104 (Whiskers Slough)?



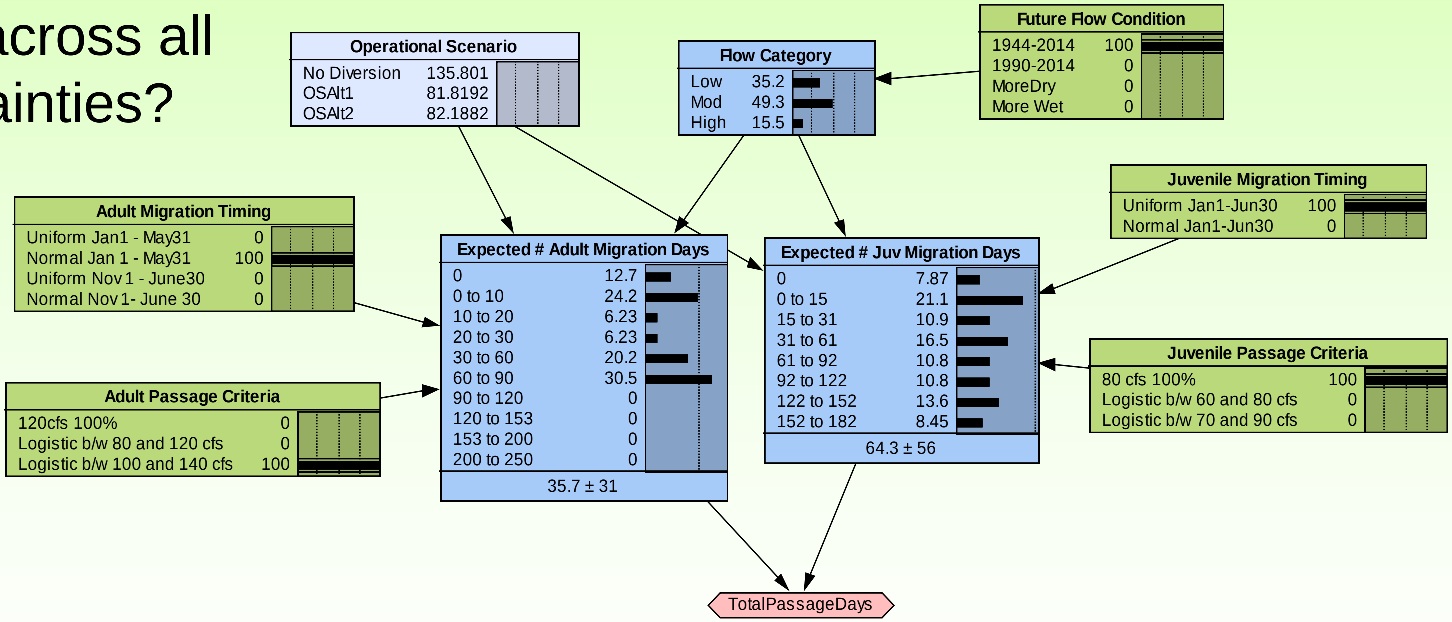
* Channel morphology in Year 0 is current condition, Year 25 and 50 are dependent on flow and operations assumptions, and are estimated by models.

Dealing with Uncertainty?

- Live with it?
- Standard statistics – SD, variance, etc.
- Model Calibration details
- Employ a Statistician
  - Bayesian Belief networks
- Other kinds of Uncertainty?

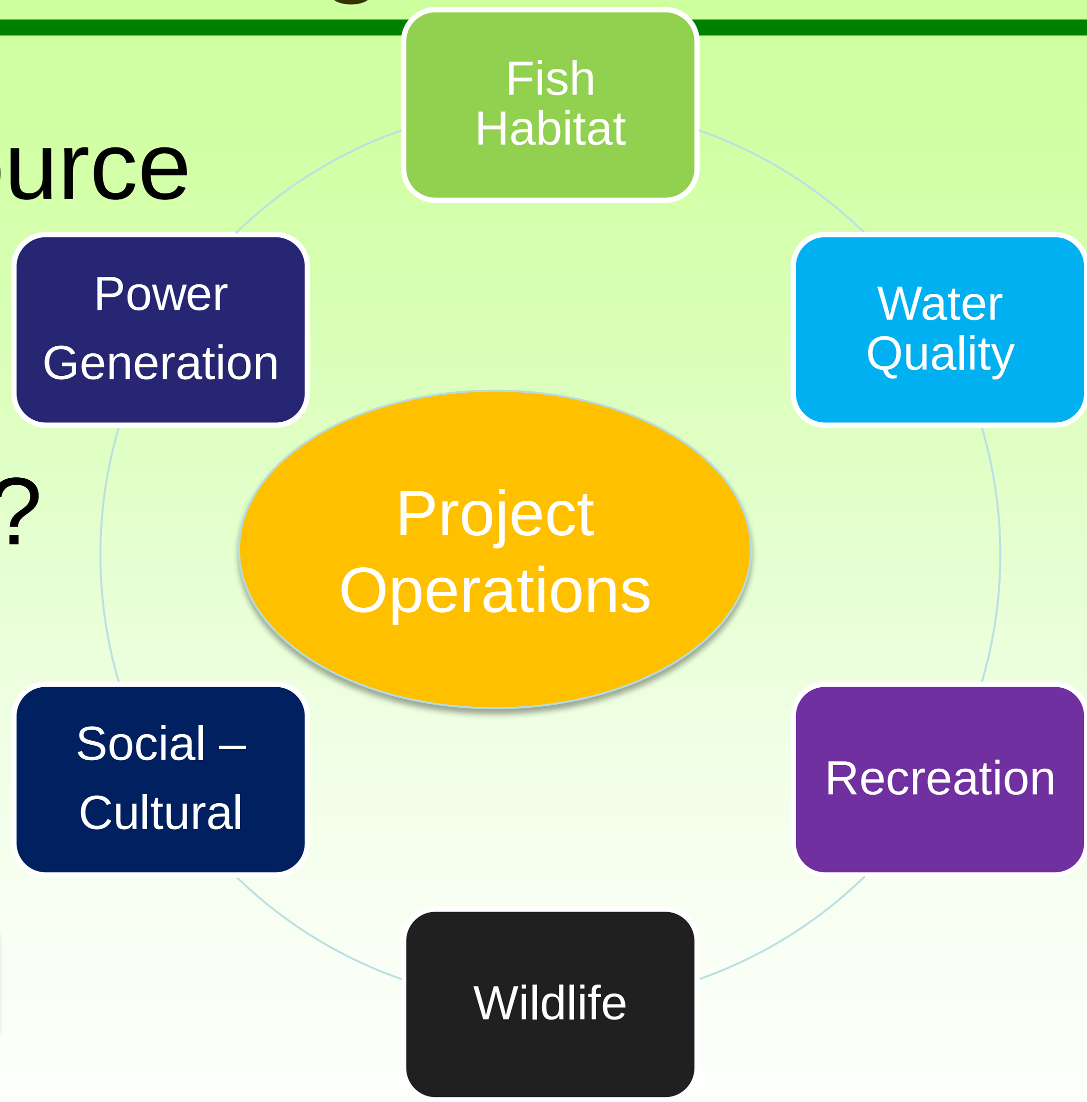
Bayesian Belief Networks for Effects Analyses

- *Uncertainty propagation* for multi-step hydrology/biology estimates
- *Sensitivity analysis –* what uncertainties have most impact
- *Decision Support* – which decisions have best result across all uncertainties?



Tying It All Together

How will other resource issues factor into determining Project Operations?



Decision Support System

Decision Support System

- “The goal of a decision support system is not to make a decision, but rather to *reduce the complexity* of information and *focus attention on tradeoffs* involved in the decision.” (USGS: Auble, et al 2009, DSS for Gunnison River)

Decision Support System

- Evaluate the benefit and potential impacts of alternative operational scenarios
- Focus attention on attributes stakeholders believe are highest priority for evaluation of operational scenarios

DSS: Potential Approaches

- Manual Matrix Method
- USGS DSS for water management
  - Gunnison, Upper Yakima, Delaware Rivers
- Decision Analysis/Bayesian Belief Networks

Matrix Methods

- Operational and Flow Scenarios

  Evaluation Metrics
- Some spatial and/or temporal variability included
  - Future 50 years is weighted average of dry, average, wet years responses
  - Averaged over Focus Areas in MR
- Uncertainties/assumptions are dealt with ahead of time
  - Choice of “average” flow year; choice of models; HSC methods
- Result = decision matrix comparing all operational scenarios for all EMs

DECISION SUPPORT SYSTEM MATRIX – Example

Resource Area	Temporal Scale	Spatial Scale	Evaluation Metrics (EXAMPLE)	Existing Conditions	OS1	OS2	OS3
Power	Nov-March average over expected 50 year flow	n/a	Power Generation (MWh)				
Hydrologic	Nov-March minimum over expected 50 year flow	n/a	2Day Low Flow (cfs)				
Riparian	Years 10-20	Geomorphic Reach	Floodplain Plant Community Colonization Area (acres)				
Resident Fish	Averaged over expected 50 year flow	Geomorphic Reach	Grayling weighted usable spawning habitat (ft2)				
Ice processes	Median date at year 50	n/a	Timing of ice breakup				
Anadromous Fish	Averaged over expected 50 year flow	Focus Area	Coho effective spawning/incubation habitat area in FA-104, averaged over expected 50 year flow.				
Anadromous Fish	Averaged over expected 50 year flow	Focus Area	Chinook effective spawning/incubation habitat area in FA-104, averaged over expected 50 year flow.				
Anadromous Fish	Averaged over expected 50 year flow	Focus Area	Chinook juvenile rearing habitat area in FA-104, averaged over expected 50 year flow.				
Anadromous Fish	Averaged over expected 50 year flow	Focus Area	Coho juvenile outmigration habitat area in FA-104, averaged over expected 50 year flow.				
Anadromous Fish	Averaged over expected 50 year flow	Focus Area	Chinook adult migration habitat area in FA-104, averaged over expected 50 year flow.				

Enough talking: Let’s WRAP this UP

- Know The Process
- Know The Project (Setting, Resources, Potential Operations)
- Stakeholder Involvement
- Coordination & Integration of Resource Disciplines Into Study Designs – Define Model Dependencies
- Selection And Application Of Appropriate Resource-specific Methods and Models
- Deal With Uncertainty - Expect the Unexpected
- Decision Support System


QUESTIONS ????????