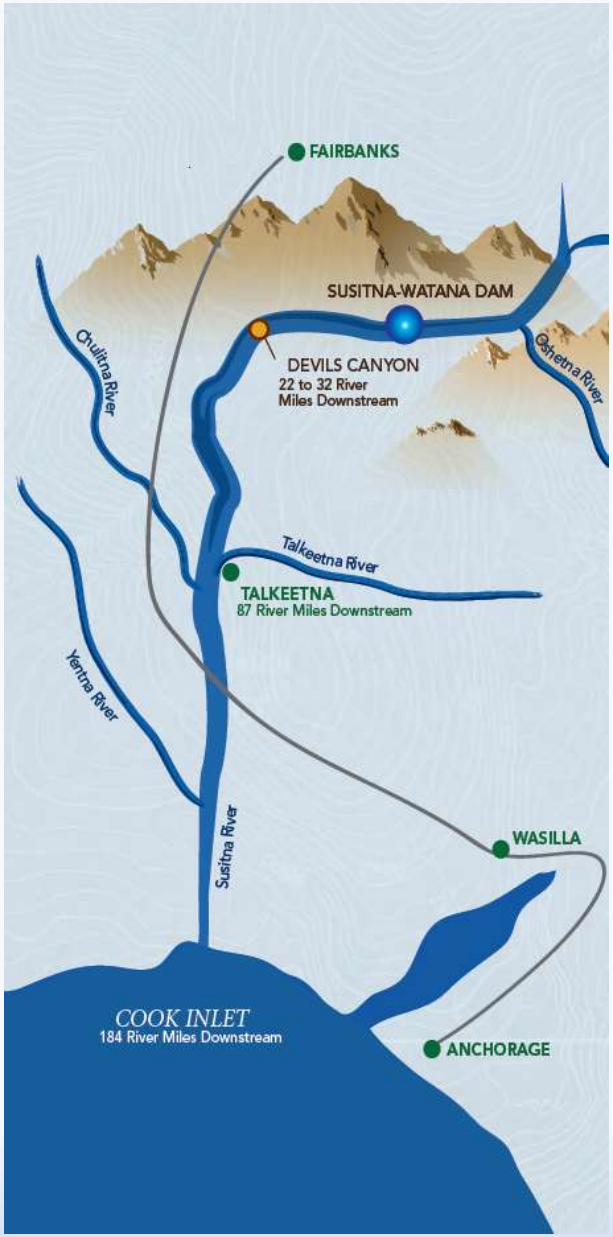


Technical Team Meeting

Study 7.5 Groundwater

December 5, 2014

Prepared by

GW Scientific

Study 7.5 Technical Team Meeting - Agenda

- **9:00 – 9:10 Introductions and Objectives of Meeting**
- **9:10 – 9:40 Summary of Groundwater Study and Discussion of New Materials Post – ISR Meeting – M. Lilly**
  - **Analytical Steps**
  - **Water Table Mapping**
- **9:40 – 10:15 Questions and Discussion of Materials Presented**
- **10:15 – 10:25 Break**
- **10:25 – 10:45 Overview of Technical Memoranda – M. Lilly**
- **10:45 – 11:45 Open Discussion and Questions on Groundwater Topics - All**
- **11:45 – 12:00 Meeting Summary, Next Steps, Adjourn – M. Lilly**

Study 7.5 Technical Team Meeting - Agenda

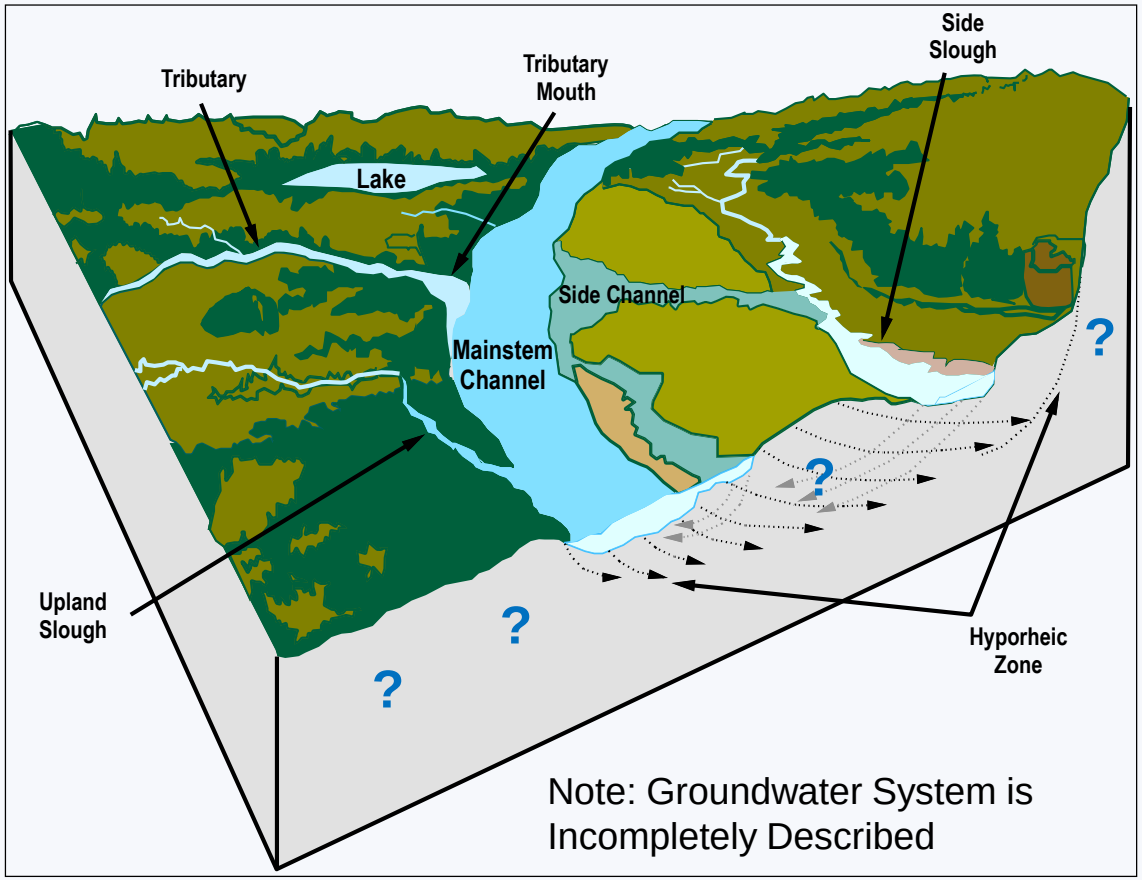
- **9:00 – 9:10 Introductions and Objectives of Meeting**
  - Introductions
  - Meeting Objectives
    - Further discussion and question/answer session on Groundwater Study topics and related aquatic and riparian resource applications
    - Overview of new material Post – ISR Meeting

Study 7.5 Objectives

- **Synthesize** historical and contemporary groundwater data available for the Susitna River groundwater and groundwater dependent aquatic and floodplain habitat, including that from the 1980s and other studies including reviews of **GW/SW interactions in cold regions**
- Use the available groundwater data to **characterize large-scale geohydrologic process-domains/terrain of the Susitna River** (e.g., geology, topography, geomorphology, regional aquifers, shallow groundwater aquifers, GW/SW interactions)
- **Assess** the potential effects of **Watana Dam/Reservoir** on **groundwater and groundwater-influenced aquatic habitats** in the vicinity of the proposed dam
- Work with other resource studies to **map groundwater-influenced aquatic and floodplain habitat** (e.g., upwelling areas, springs, groundwater-dependent wetlands) within the Middle River Segment of the Susitna River including within selected Focus Areas (see Fish and Aquatic Instream Flow Study Section 8.5.4.2.1.2)
- Determine the **GW/SW relationships of floodplain shallow alluvial aquifers** within selected Focus Areas as part of the **Riparian Instream Flow Study** (Riparian Instream Flow Study, Section 8.6)
- Determine **GW/SW relationships** of **upwelling/downwelling** in relation to spawning, incubation, and rearing habitat (particularly in the winter) within selected Focus Areas as part of **the Fish and Aquatics Instream Flow Study** (Fish and Aquatic Instream Flow Study 8.5)
- **Characterize water quality** (e.g., temperature, dissolved oxygen [DO], conductivity) of **selected upwelling areas** that provide biological cues for fish spawning and juvenile rearing, in Focus Areas as part of the **Fish and Aquatics Instream Flow Study** (Fish and Aquatic Instream Flow Study (Study 8.5))
- Characterize the **winter flow in the Susitna River** and how it relates to **GW/SW interactions**
- Characterize the **relationship** between the **Susitna River flow** regime and **shallow groundwater users** (e.g., domestic wells)

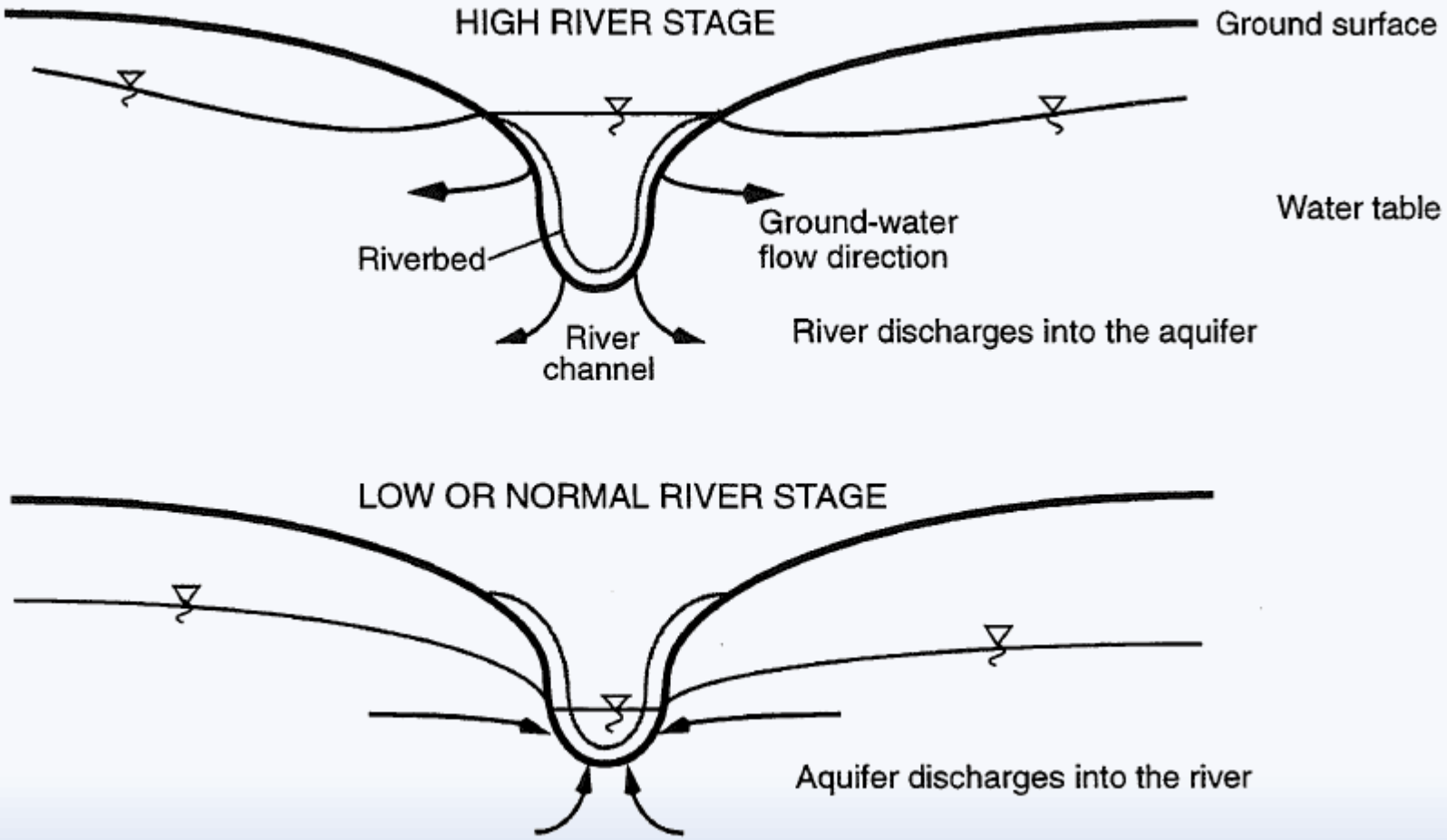
Study 7.5 Overview – Groundwater Effects on Aquatic and Riparian Resources

- Inter-Related
- Impacts on Riparian <u>And</u> Impacts on Aquatic
- Groundwater Questions Have Many Overlaps



Habitat types identified in the Middle River Segment of the Susitna River during the 1980s studies (adapted from ADF&G 1983; Trihey 1982).

Study 7.5 Overview – Groundwater/Surface-Water (GW/SW) Interactions



Study 7.5 Analysis Steps – Post ISR Materials

Supporting Materials for Discussion

- **Analysis Process Steps**
  - Aquatic Habitat, Riparian, Upscaling
- **Water Table Map Examples (Fall 2014)**
  - FA-138 (Gold Creek), FA-128 (Slough 8A)
  - FA-115 (Slough 6A), FA-104 (Whiskers Slough)
- **Discussion/Questions/Break**
- Aquatic Technical Memorandum
  - Preliminary Groundwater and Surface-Water Relationships in Lateral Aquatic Habitats within Focus Areas FA-128 (Slough 8A) and FA-138 (Gold Creek) in the Middle Susitna River
- Riparian Technical Memorandum
  - Groundwater and Surface-Water Relationships in Support of Riparian Vegetation Modeling

Study 7.5 Analysis Steps – Observation Scales

- **Aquatic and Riparian Transect Scale**
- **Focus Area Scale**
- **River Segment Scale**
- **Watershed Scale**

Study 7.5 Analysis Steps – Observation Scales

- **Aquatic and Riparian Transect Scale**
  - GW/SW Interaction Focus, Includes Basic Water Quality
  - Develop Understanding at Critical Habitat Areas
    - Aquatic – Key Spawning, Rearing Areas
    - Riparian – Key Vegetation Classes
  - Transects Perpendicular to Key Hydrologic Boundaries
    - GW/SW Interaction Are Driven By Transient "Pulses"
    - Kinematic Hydraulic Gradient Changes
    - Transient Conditions Dominate
  - Development of Process Understanding
    - Empirical Data – Mainly Continuous = Transient Processes
    - Groundwater Modeling – Process Understanding Tool
- Focus Area Scale
- River Segment Scale
- Watershed Scale

Study 7.5 Analysis Steps – Observation Scales

- Aquatic and Riparian Transect Scale
- **Focus Area Scale**
  - Multiple Focus Areas Allow Representation of Habitat Diversity
    - Both Aquatic and Riparian
  - Some Focus Areas Have Multiple Transects
    - Example: FA-128 (Slough 8A) 2-Aquatic, 2-Riparian Transects
  - Other Off-Transect Measurement Locations and General Field Observations (Aerial Images, Time-Lapse Cameras, Etc.)
  - Other Studies Empirical Information
  - Riverine Modeling Information
  - Scaling To Controlling Boundary Conditions
  - Process Variations from Riverine to Upland Dominated (most)
  - Water Table Mapping
- River Segment Scale
- Watershed Scale

Study 7.5 Analysis Steps – Observation Scales

- Aquatic and Riparian Transect Scale
- Focus Area Scale
- **River Segment Scale**
  - Primary Goal For Upscaling and Project Effects Evaluation
  - Less Data Availability – But Representative Focus Areas
  - Development of Spatial Data Sets (GIS Coverages)
    - Example: DEM, Vegetation Mapping, Geology, Habitat Zones
    - Aerial, Satellite Images
    - Thermal Infrared (TIR) Mapping, Winter Open Leads Mapping
  - River Segment Scale Modeling
    - Flow Routing Models (Winter – Ice Cover, Summer – Ice Free)
    - Temperature, Water Quality
  - Process Upscaling From Focus Areas
  - Applies to Riparian Assessment, General Understanding, Not All Models (For Example Focus Area Habitat Modeling)
- Watershed Scale

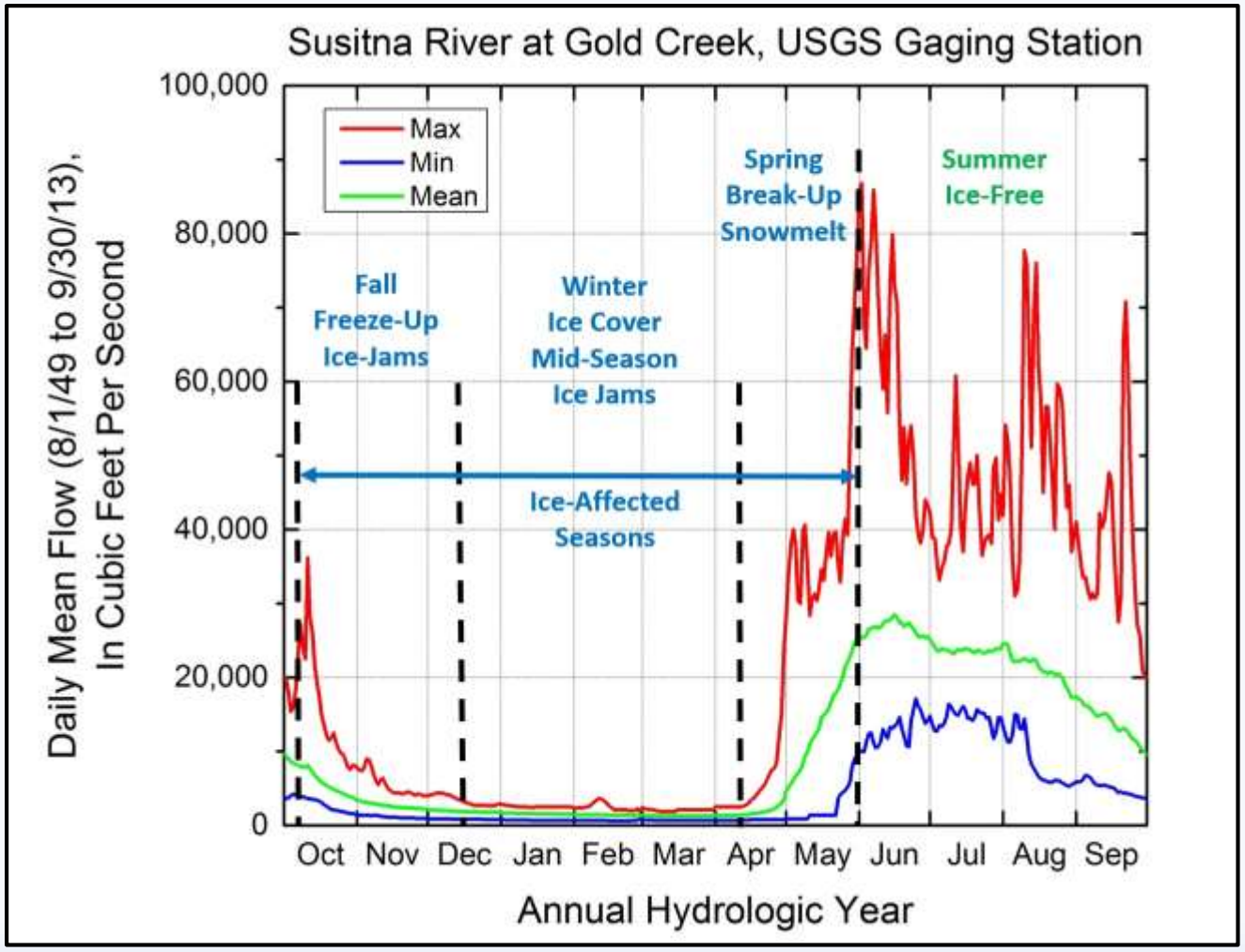
Study 7.5 Analysis Steps – Observation Scales

- Aquatic and Riparian Transect Scale
- Focus Area Scale
- River Segment Scale
- **Watershed Scale**
  - Mainly Development Of Information To Support Other Scales
  - Variations in Climate, Geology, Geohydrology, Vegetation
  - Understanding Orogeny Effects on Hydrology
    - Example: Talkeetna Mountains
  - Boundary Conditions Affecting Upland Hydrology
  - Hydrologic Boundary Conditions

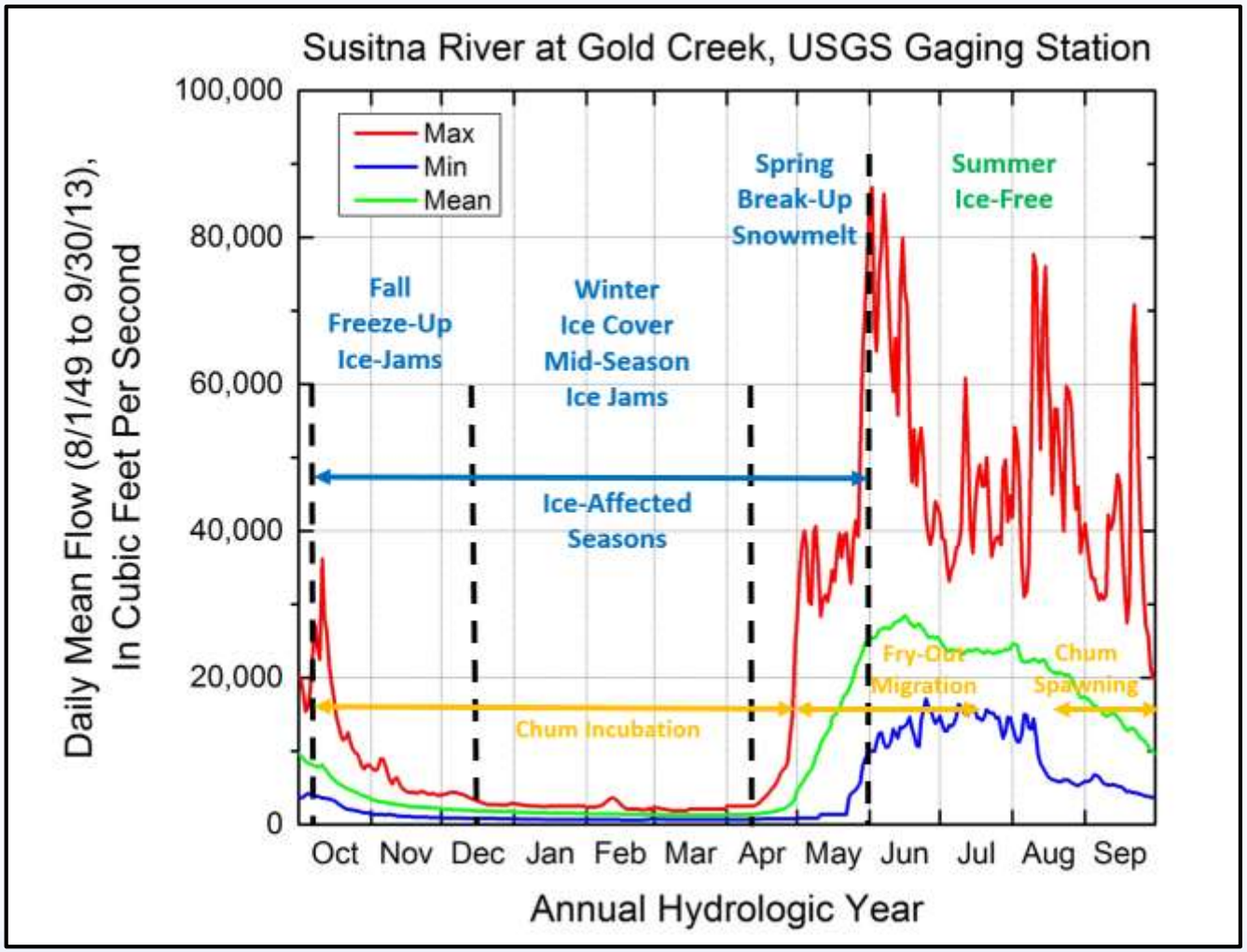
Study 7.5 Analysis Steps – Time Scales

- **Daily**
  - Diurnal Fluctuations
  - Standard Base Collection Internal = 15 minutes
    - Not All Analysis Should Be At 15 Minutes!
  - Process and Question Dependent
  - Important for Calibrating to Peaks and Pulses
- **Seasonal**
  - Annual Hydrologic Year – Winter Dominated
  - Four Primary Hydrologic Seasons
    - Fall Freeze-Up
    - Winter
    - Spring Breakup/Snowmelt
    - Summer
- Operational

Study 7.5 Analysis Steps – Time Scales - Physical



Study 7.5 Analysis Steps – Time Scales - Biological



Study 7.5 Analysis Steps – Time Scales

- Daily
- Seasonal
- **Operational**
  - Construction, Operations Period
  - Years to Decades
  - Aquatic and Riparian Systems Response Over Longer Time Scales

Study 7.5 Analysis Steps – "Upwelling"

- **Scales and Methods** =
  - **Transects**
    - Empirical Data Analysis, Groundwater Modeling (MODFLOW)
    - Primary Purpose = Process Understanding
    - Variations in Transects = Greater Range of Process Understanding
  - **Focus Area**
    - **Water Table Mapping** = Combining Transect Empirical Data To Define General Nature of GW/SW Gradients and "Zones" Where "Upwelling" Takes Place
      - Zones Fluctuate Spatially Over Space and Time
      - Definition of Key Ranges for Zone Delineation
    - Groundwater Modeling (MODFLOW) = One Select Focus Area (FA-128 (Slough 8A)) - To Help Define Spatial Effects of Hydrologic Boundary Conditions On Transient Hydrologic GW/SW Interactions

Study 7.5 Analysis Steps – "Upwelling"

- **Scales and Methods** =
  - Transects
  - **Focus Area**
    - **Water Table Mapping**
      - Development of Point Maps For "**Discrete**" Time Periods
      - Use Of Other Information, Such As Rising/Falling Conditions, TIR Imagery, Open Lead Mapping, Aerial Photographs, Flow Routing Model Surface Water Profile (Stage) Information
      - Development of Groundwater and Surface-Water Contours
      - Definition of Upwelling Zones
      - Definition of Other Factors to Help Define Types of Groundwater Conditions (Ranges?) Within Zones ("Binary Approach")

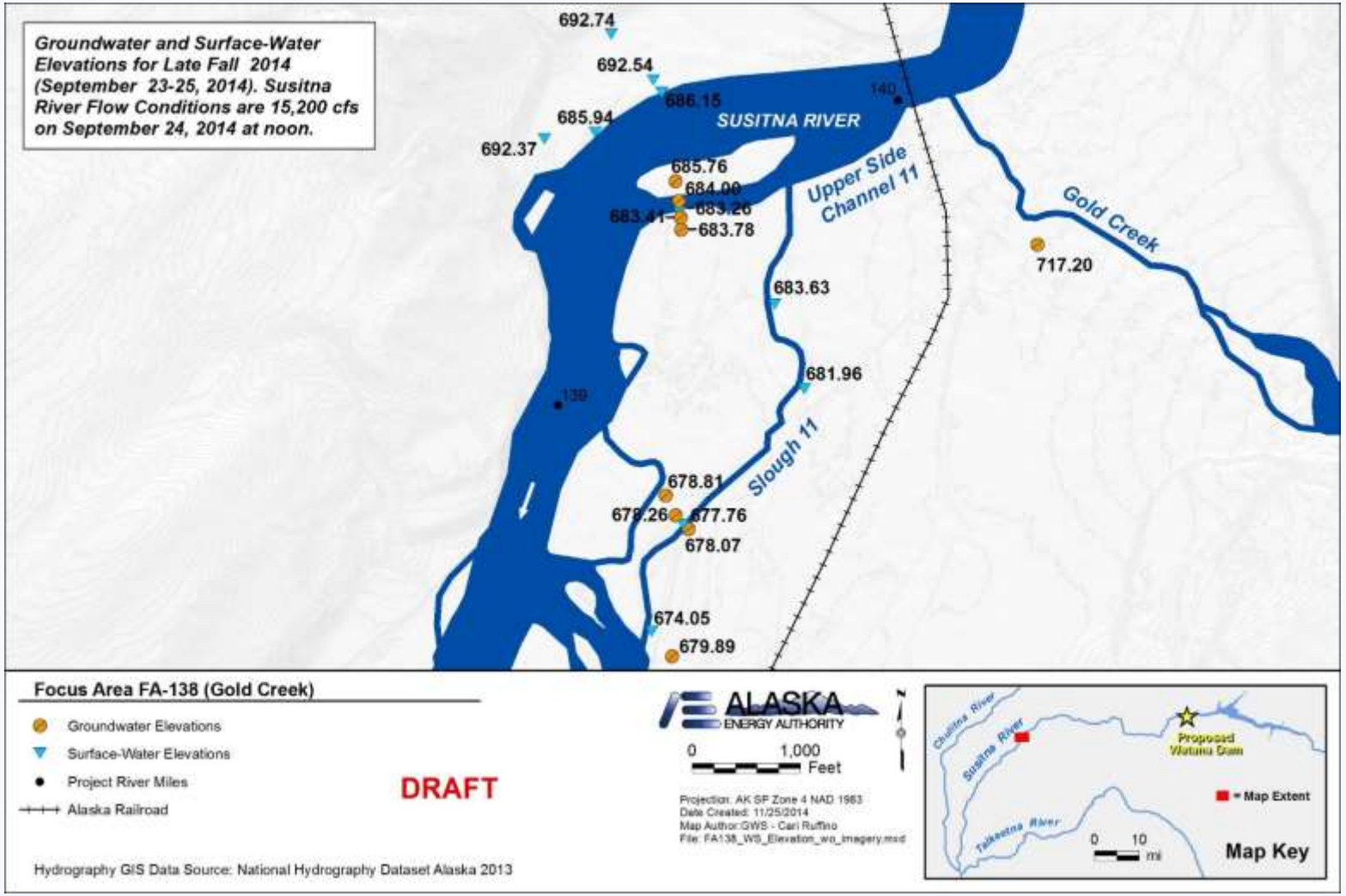
Study 7.5 Analysis Steps – "Upwelling"

- **Scales and Methods** =
  - Transects
  - **Focus Area**
    - **Water Table Mapping**
      - **Development of Point Maps For "Discrete" Time Periods**
        - Groundwater Elevations, Surface-Water Elevations
        - Aerial Photographs, Time-Lapse Images, Water Level Plots for Defining Overall Hydrology Conditions
        - River Stage Elevation Profiles from 1-D Flow Routing Models (Both Ice-Cover and Ice-Free Depending on Timeframe of Map)
        - Miscellaneous Elevations from combination of Aerial and Time-Lapse Images and DEM Information
        - Elevations Posted in ArcMap 10+

Study 7.5 Analysis Steps – "Upwelling"

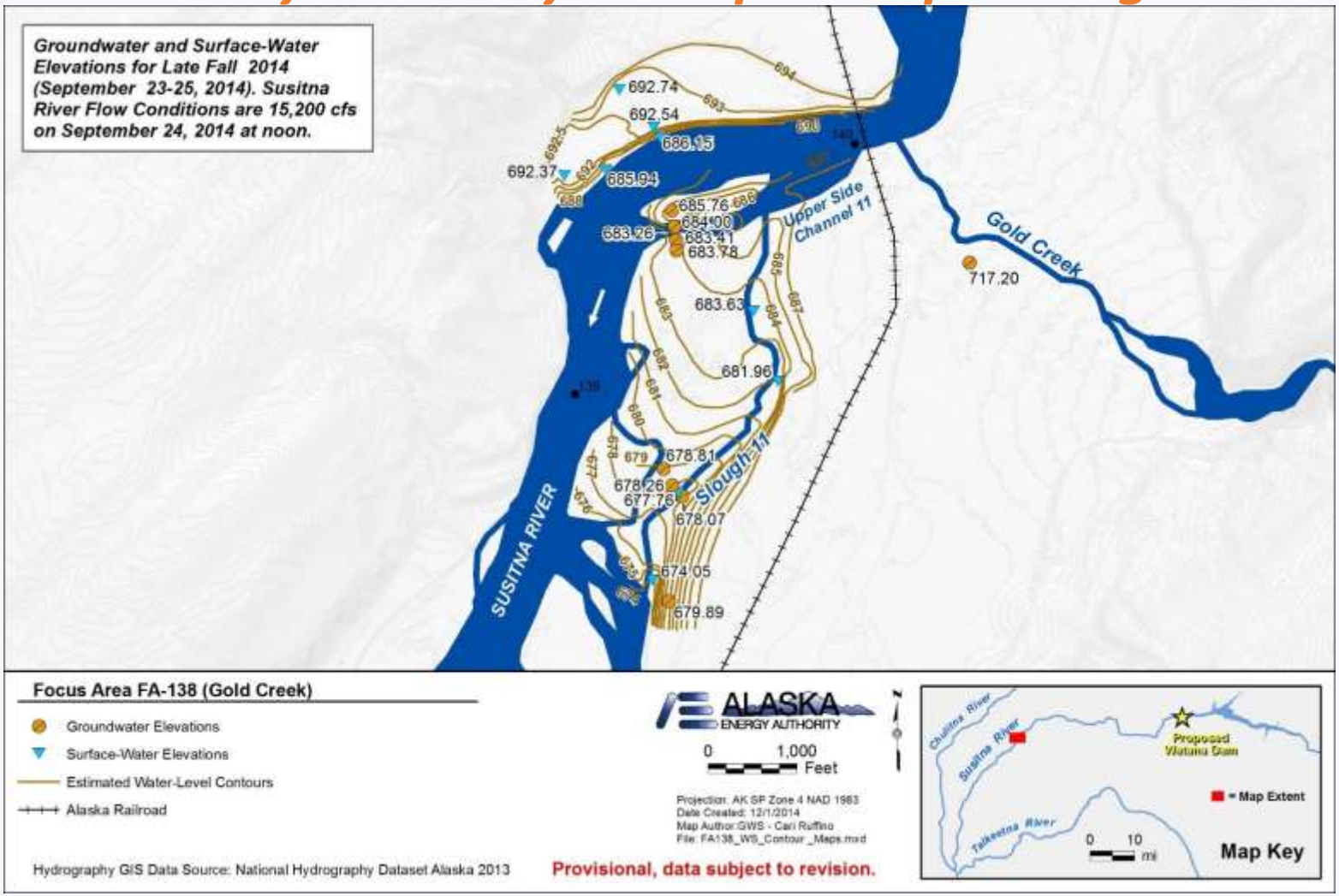
- **Scales and Methods** =
  - Transects
  - **Focus Area**
    - **Water Table Mapping**
      - **Development of Contour Lines (Water Table Surface) For "Discrete" Time Periods**
        - Rising and Falling Stage Information Used To Determine Relationship of Groundwater Contours to Surface-Water Features
        - Flowline May Be Shown, When Needed
        - Upwelling Boundaries Defined From Above Information
        - GIS data (shapefile) for each FA with polygons showing areas of upwelling in ArcGIS 10.x.– serves as input into fish habitat – flow models

Study 7.5 Analysis Steps – "Upwelling"



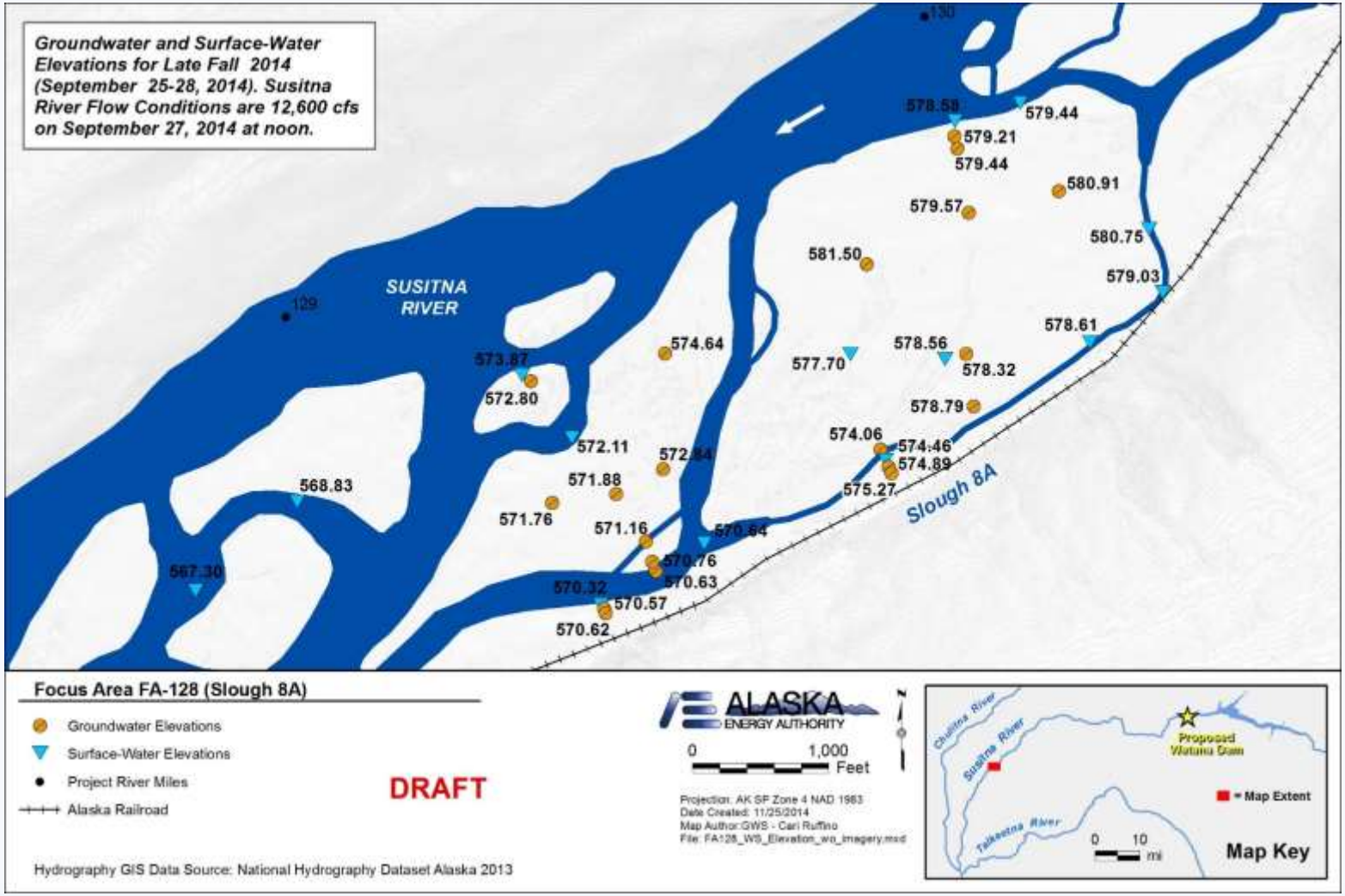
Example Sept/Oct 2014 Groundwater Elevations and Surface-Water Stage Point Maps

Study 7.5 Analysis Steps – "Upwelling"



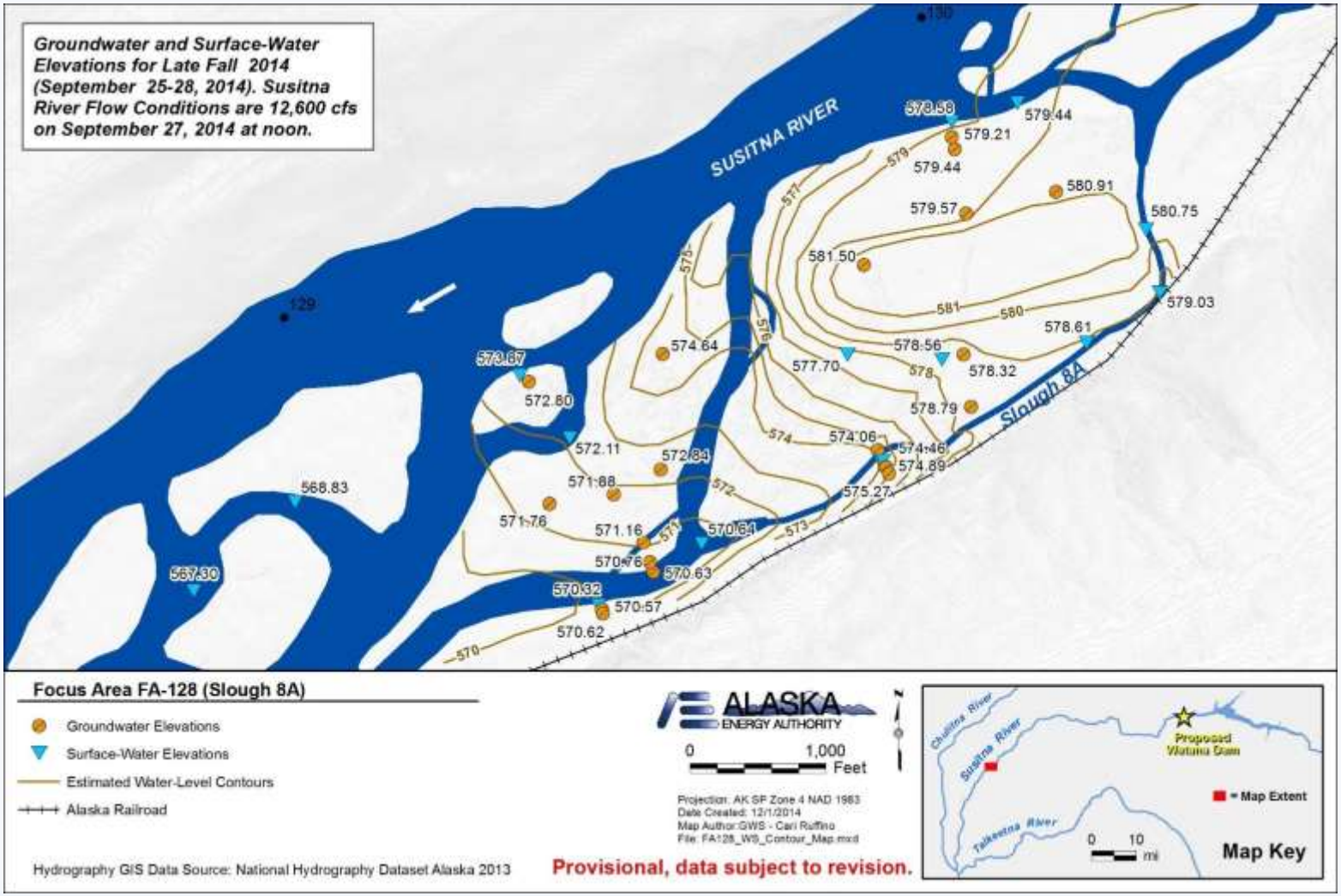
Example Sept/Oct 2014 Groundwater Water Table Contour Maps – FA-138 (Gold Creek)

Study 7.5 Analysis Steps – "Upwelling"



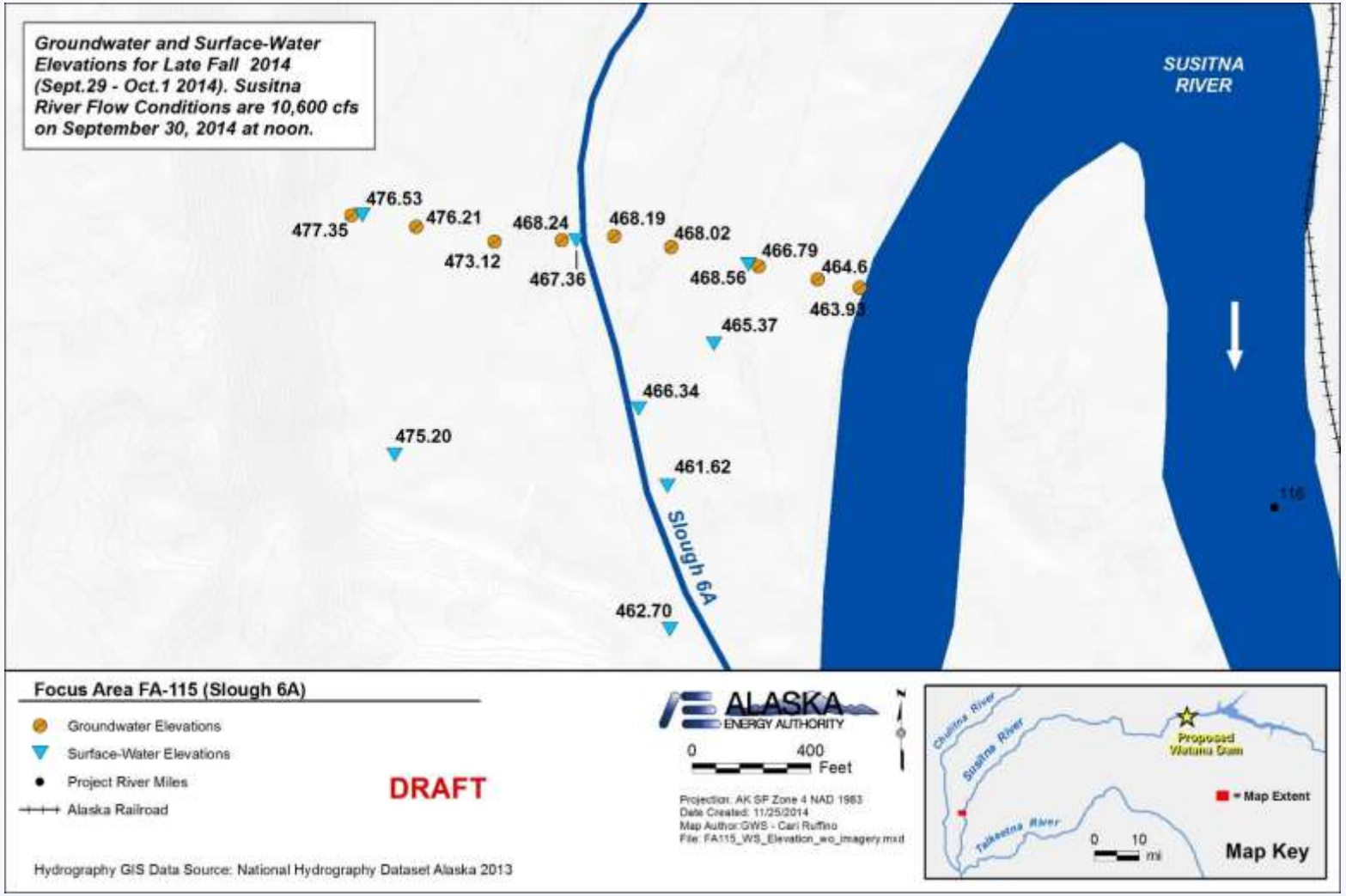
Example Sept/Oct 2014 Groundwater Elevations and Surface-Water Stage Point Maps

Study 7.5 Analysis Steps – "Upwelling"



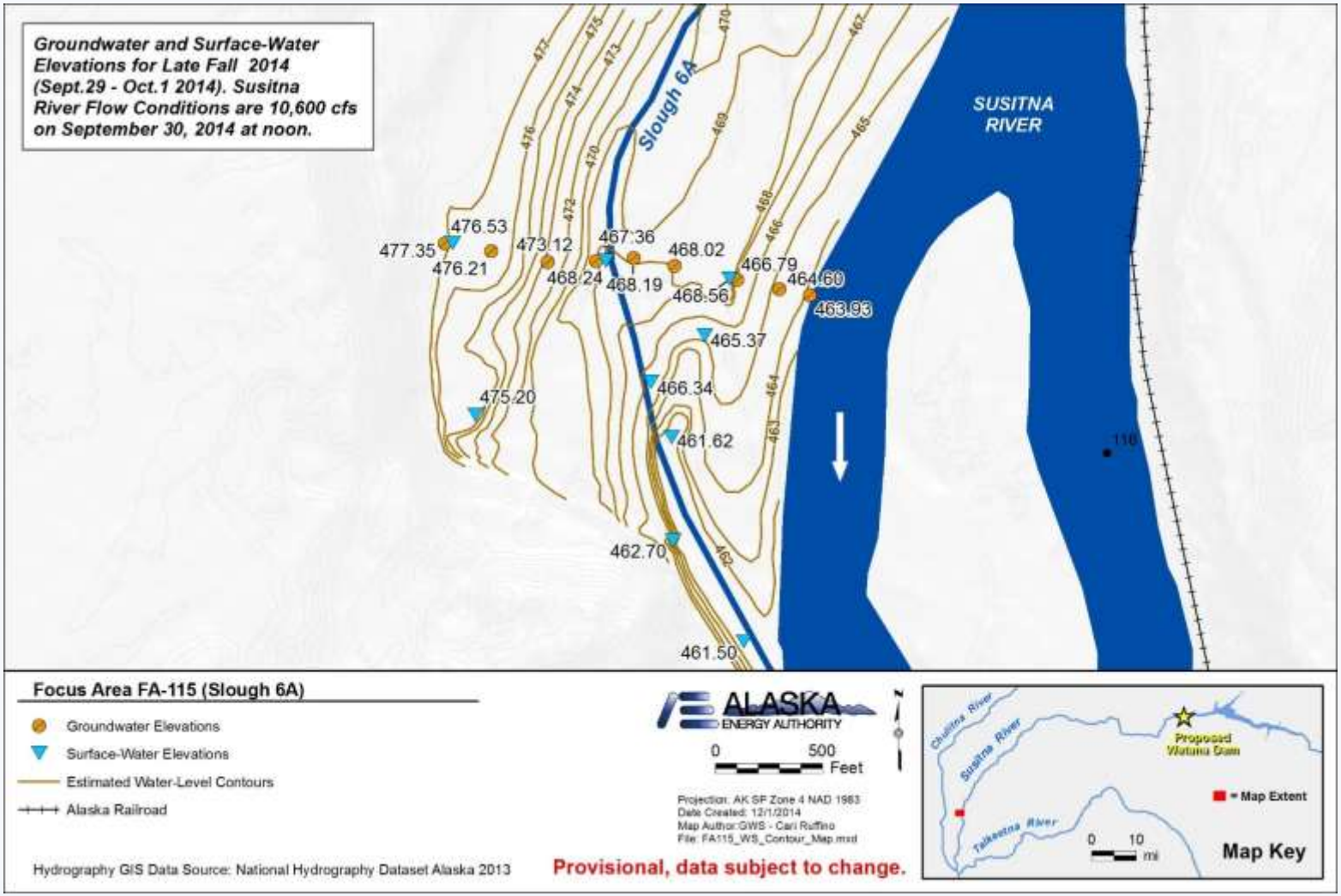
Example Sept/Oct 2014 Groundwater Water Table Contour Maps – FA-128 (Slough 8A)

Study 7.5 Analysis Steps – "Upwelling"



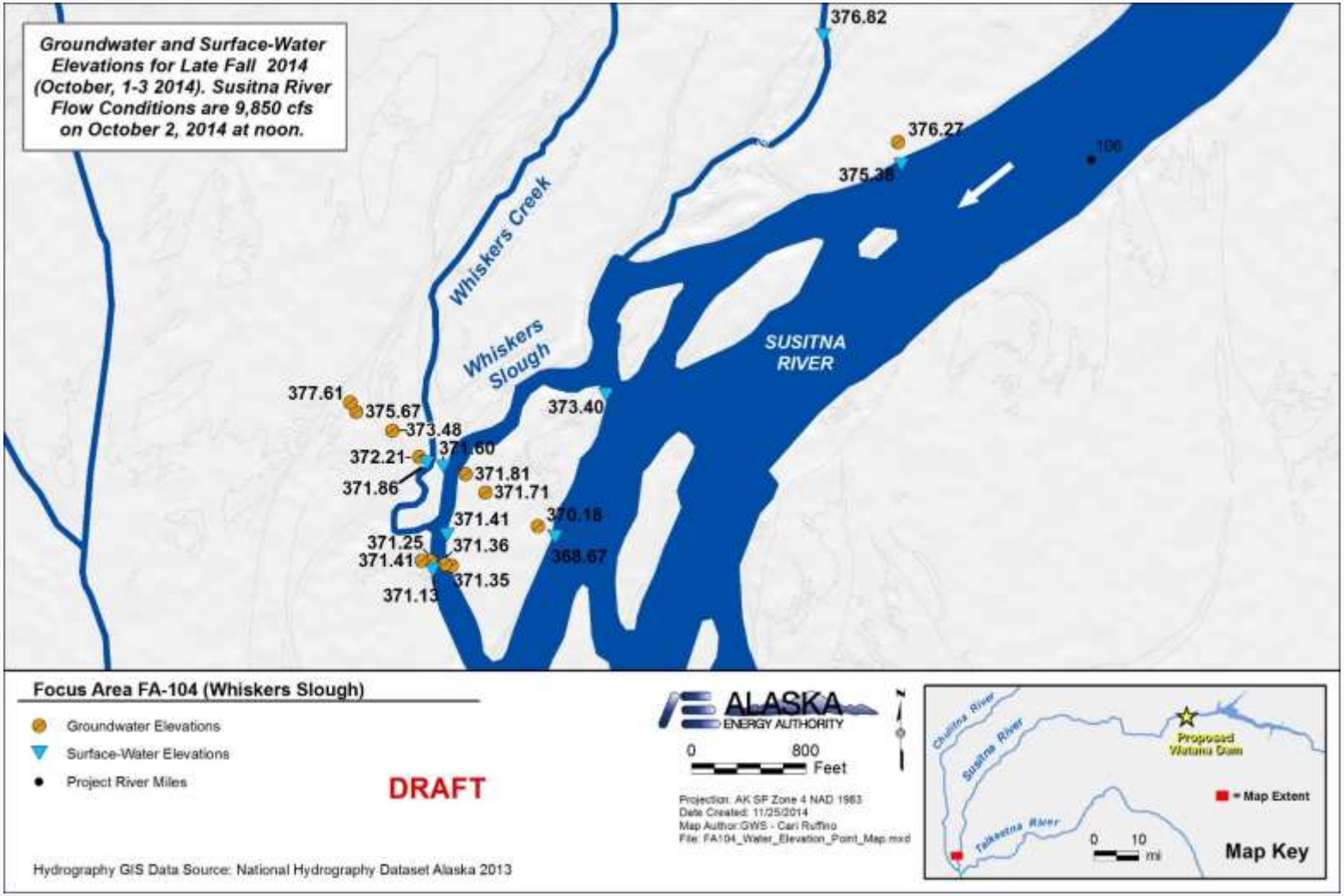
Example Sept/Oct 2014 Groundwater Elevations and Surface-Water Stage Point Maps

Study 7.5 Analysis Steps – "Upwelling"



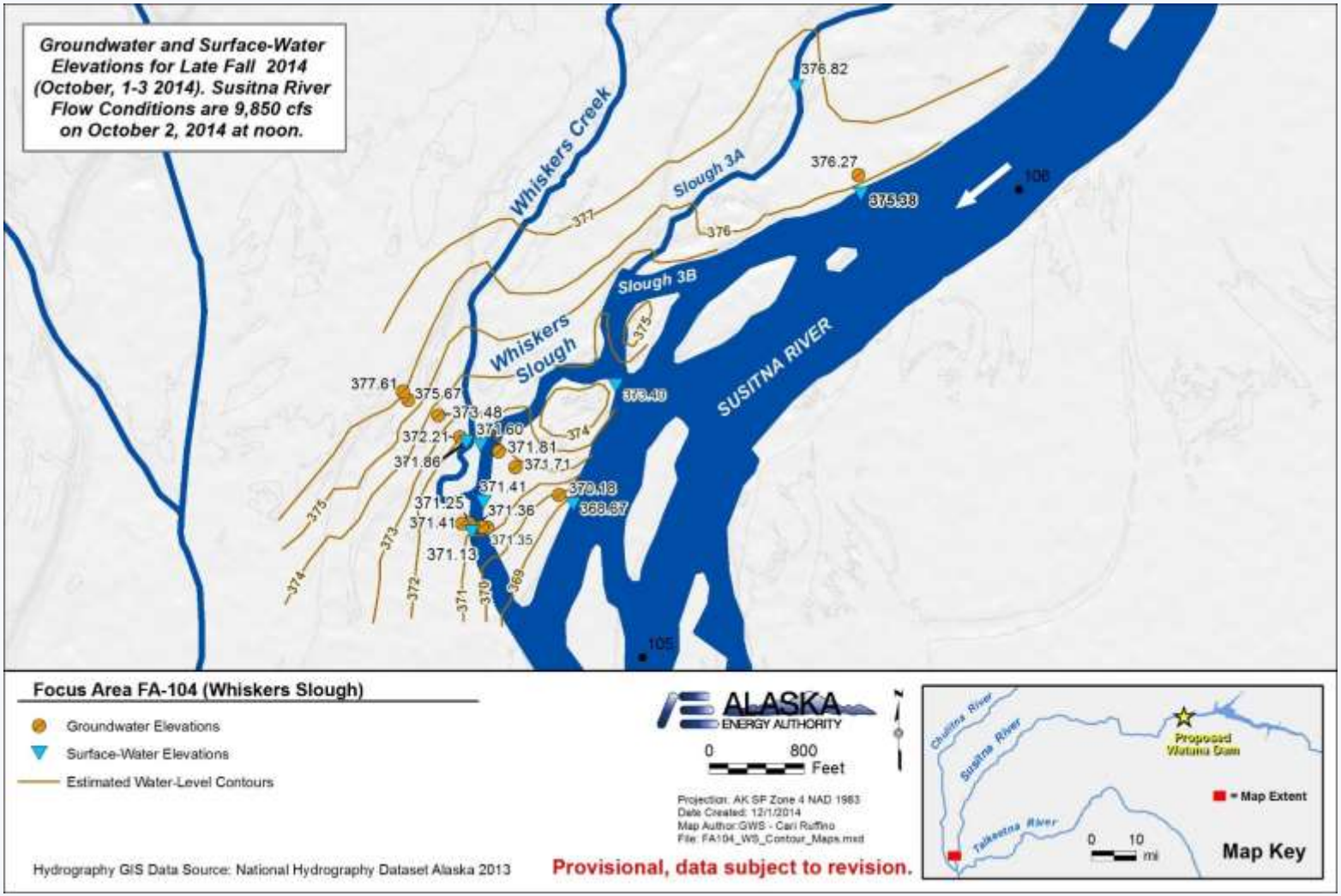
Example Sept/Oct 2014 Groundwater Water Table Contour Maps – FA-115 (Slough 6A)

Study 7.5 Analysis Steps – "Upwelling"



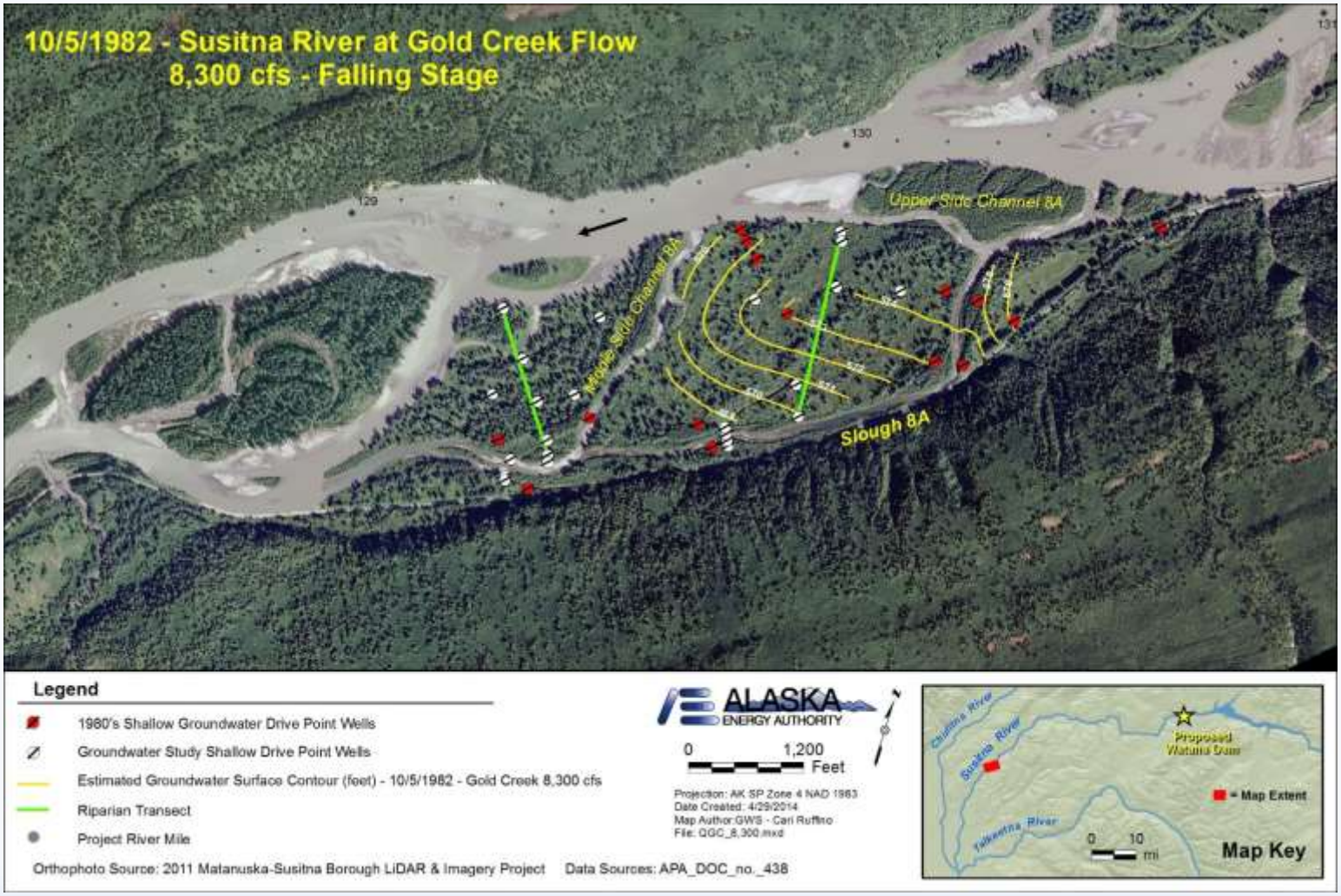
Example Sept/Oct 2014 Groundwater Elevations and Surface-Water Stage Point Maps

Study 7.5 Analysis Steps – "Upwelling"



Example Sept/Oct 2014 Groundwater Water Table Contour Maps – FA-104 (Whiskers Slough)

Study 7.5 Analysis Steps – "Upwelling"



Example Water Table Maps from 1980s

Study 7.5 Analysis Steps – "Upwelling"

Example Upwelling Zone Maps – Only For Illustration

Study 7.5 Analysis Steps – "Upwelling" – GIS Polygons for Fish Habitat-Flow Models

Example Upwelling Zone Maps, Different Flows – Only For Illustration

Study 7.5 Analysis Steps – "Upwelling" – GIS Polygons for Fish Habitat-Flow Models

Example Upwelling Zone Maps, Different Flows – Only For Illustration

Study 7.5 Analysis Steps – "Upwelling"

- **Field Verification Methods** =
  - TIR Imagery When Time Periods and Hydrologic Gradients Match
  - Open Lead Mapping When Time Period and Hydrologic Gradients Match
  - Miscellaneous Vertical Head Indicator (VHI) Information
    - Intended Only for Relative Information (positive/negative)
  - Field Measurements of Discharge Pairs (Differences) and Individual Discharge Measurements
  - VHG Measurement Transects at Key Locations
    - Sensors Left in Place in Stream Bed
    - Aquatic Transects
    - Estimated Boundaries Between Upwelling and Downwelling Areas
  - Vertical Flux Modeling at Thermal Profile Locations in Aquatic Transects (USGS, 1DTempPro Modeling), Aquatic Transects

Study 7.5 Analysis Steps – "Verification Data Examples"

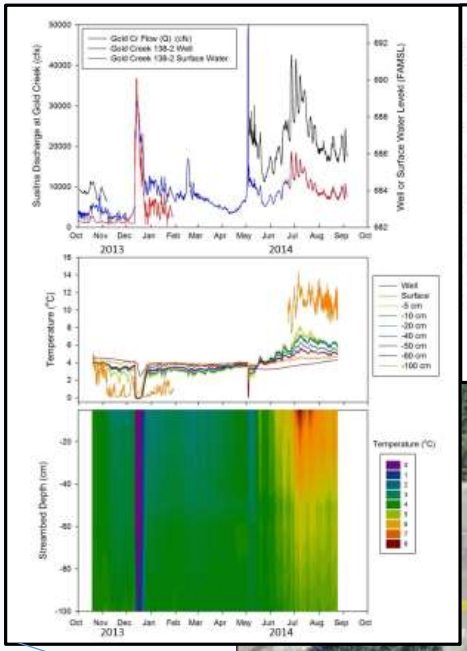
Questions and Discussion of Presented Material

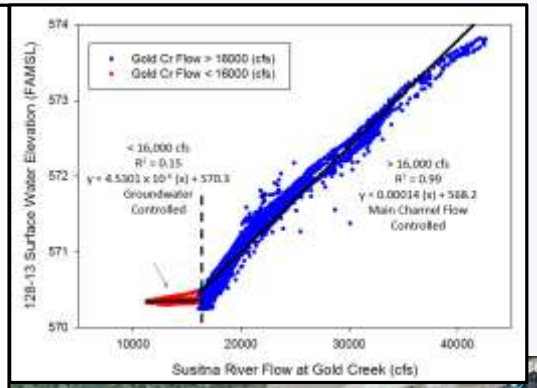
Break

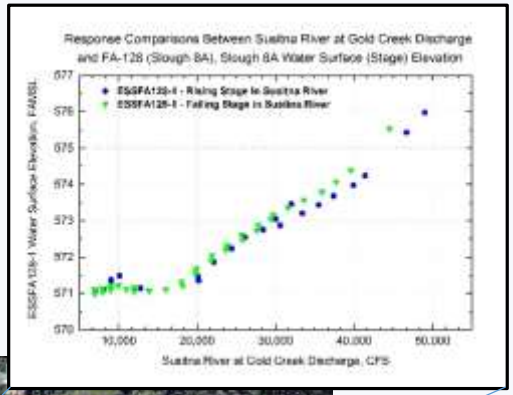
Study 7.5 Analysis Steps – Post ISR Materials

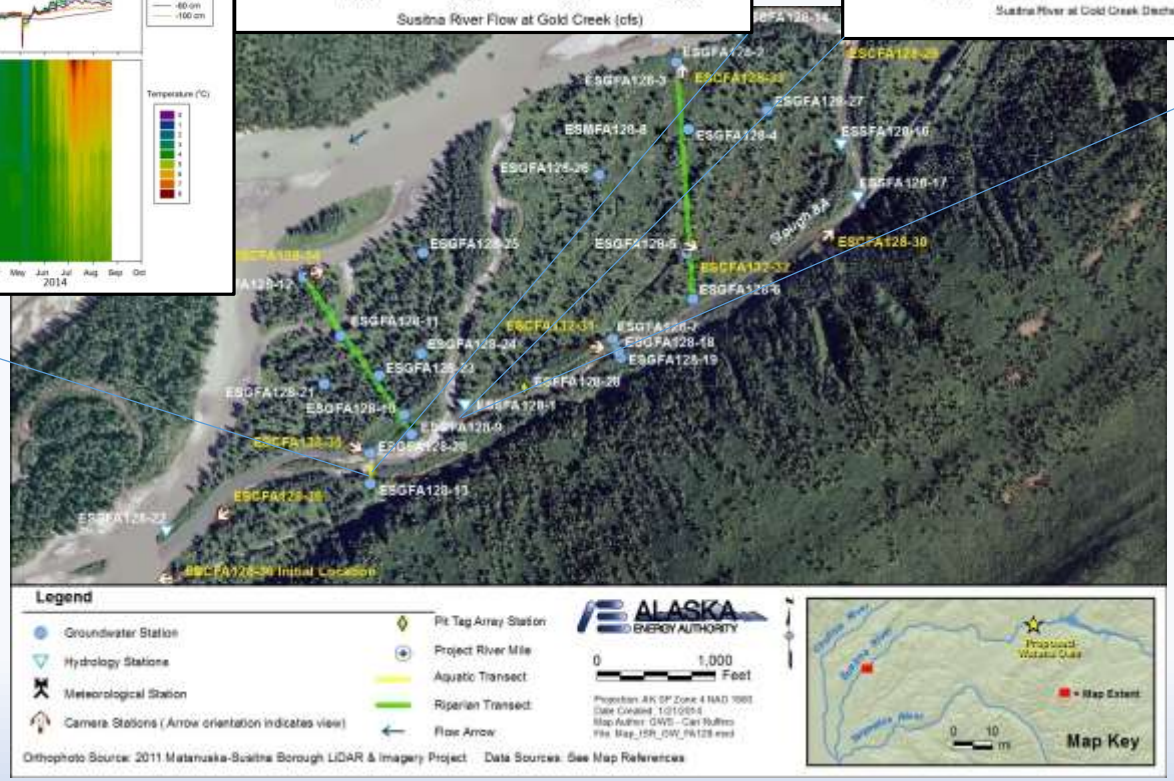
- **Aquatic Technical Memorandum**
  - Preliminary Groundwater and Surface-Water Relationships in Lateral Aquatic Habitats within Focus Areas FA-128 (Slough 8A) and FA-138 (Gold Creek) in the Middle Susitna River
- **Riparian Technical Memorandum**
  - Groundwater and Surface-Water Relationships in Support of Riparian Vegetation Modeling

Study 7.5 Transect Scale – Process Understanding Examples





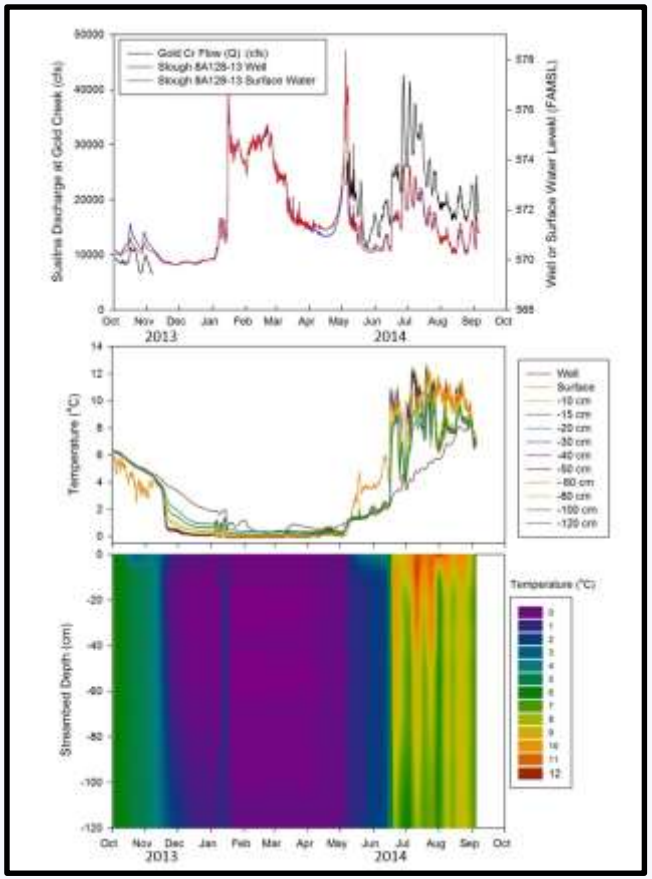




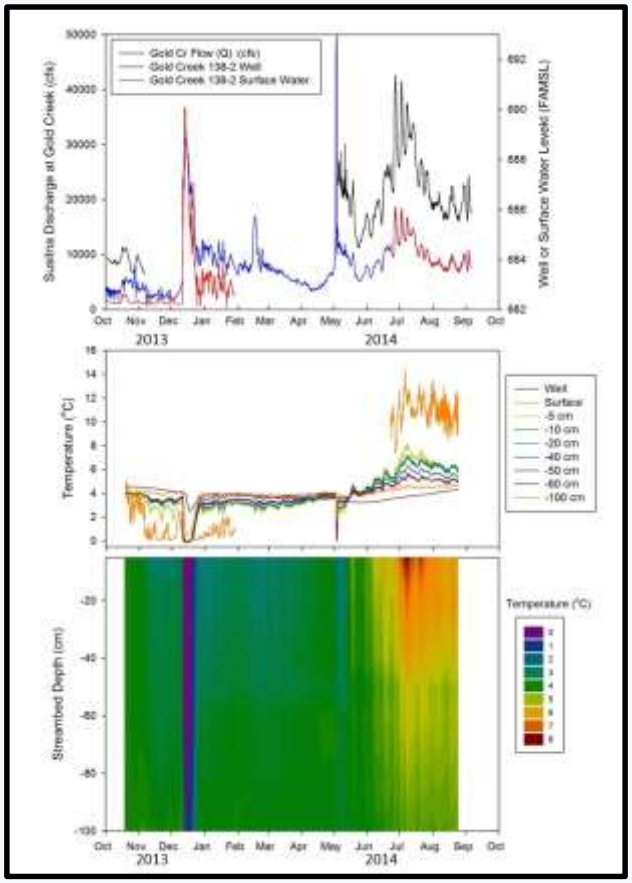
Examples of FA-128 (Slough 8A) Responses To Mainstem Flow *(note – results are preliminary)*

September 2014 Technical Memorandum - Preliminary Groundwater and Surface-Water Relationships in Lateral Aquatic Habitats within Focus Areas FA-128 (Slough 8A) and FA-138 (Gold Creek) in the Middle Susitna River.

Study 7.5 Transect Scale – Process Understanding Examples



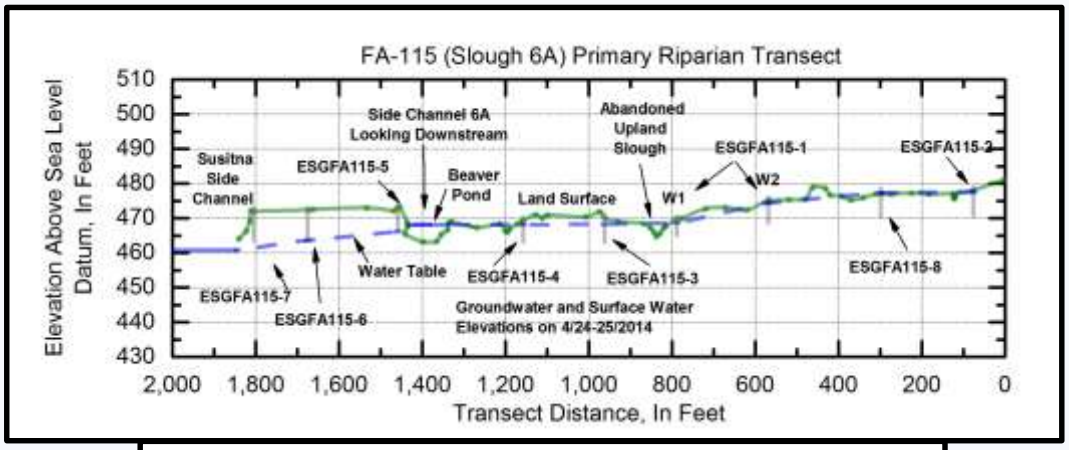
FA-128 (Slough 8A)
Middle Side Channel 8A
Lower Aquatic Transect
Downwelling Example



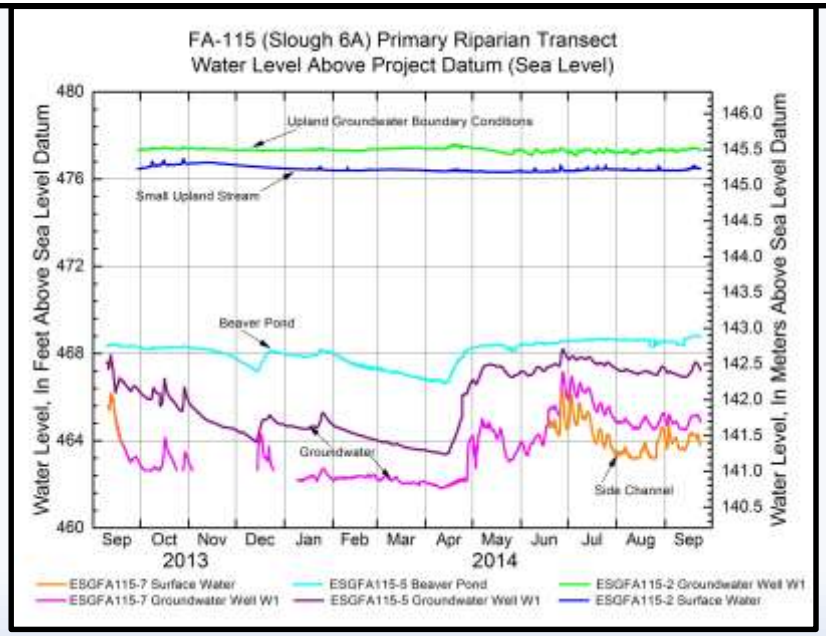
FA-138 (Gold Creek)
Upper Side Channel 11
Upper Aquatic Transect
Upwelling Example

September 2014 Technical Memorandum - Preliminary Groundwater and Surface-Water Relationships in Lateral Aquatic Habitats within Focus Areas FA-128 (Slough 8A) and FA-138 (Gold Creek) in the Middle Susitna River.

Study 7.5 Transect/Focus Area Scale – Process Understanding



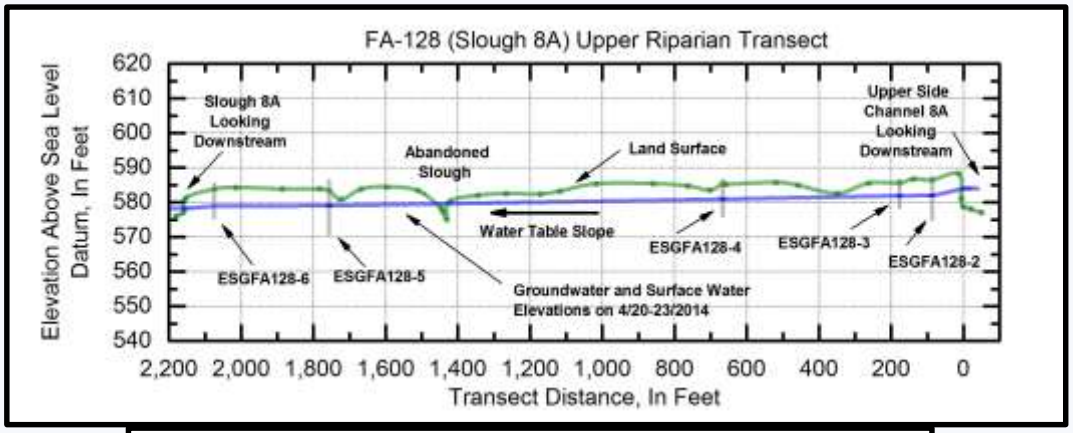
FA-115 (Slough 6A)
Primary Riparian Transect
Lateral Hydraulic Gradients



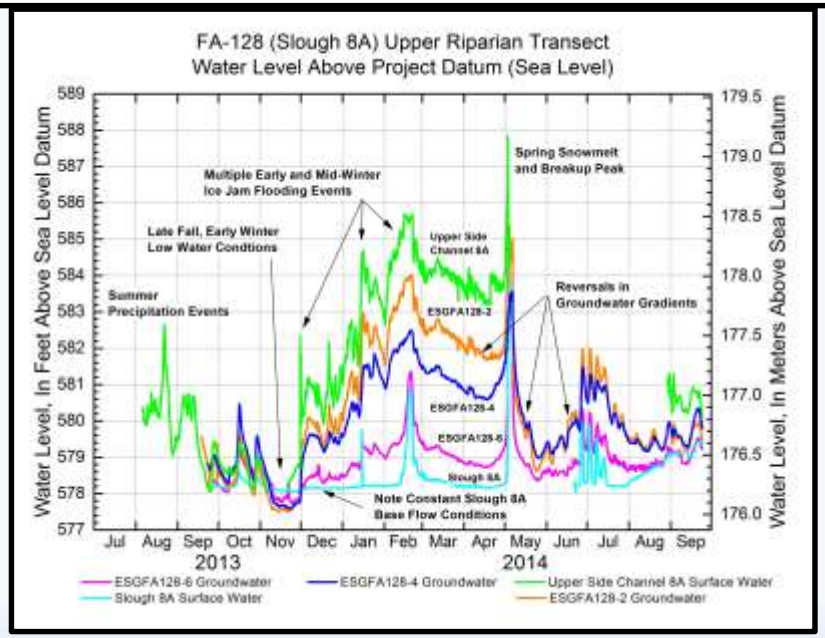
September 2014 Technical Memorandum - Groundwater and Surface-Water Relationships in Support of Riparian Vegetation Modeling

FA-115 (Slough 6A)
Primary Riparian Transect
Seasonal Water-Level Variation

Study 7.5 Transect/Focus Area Scale – Process Understanding



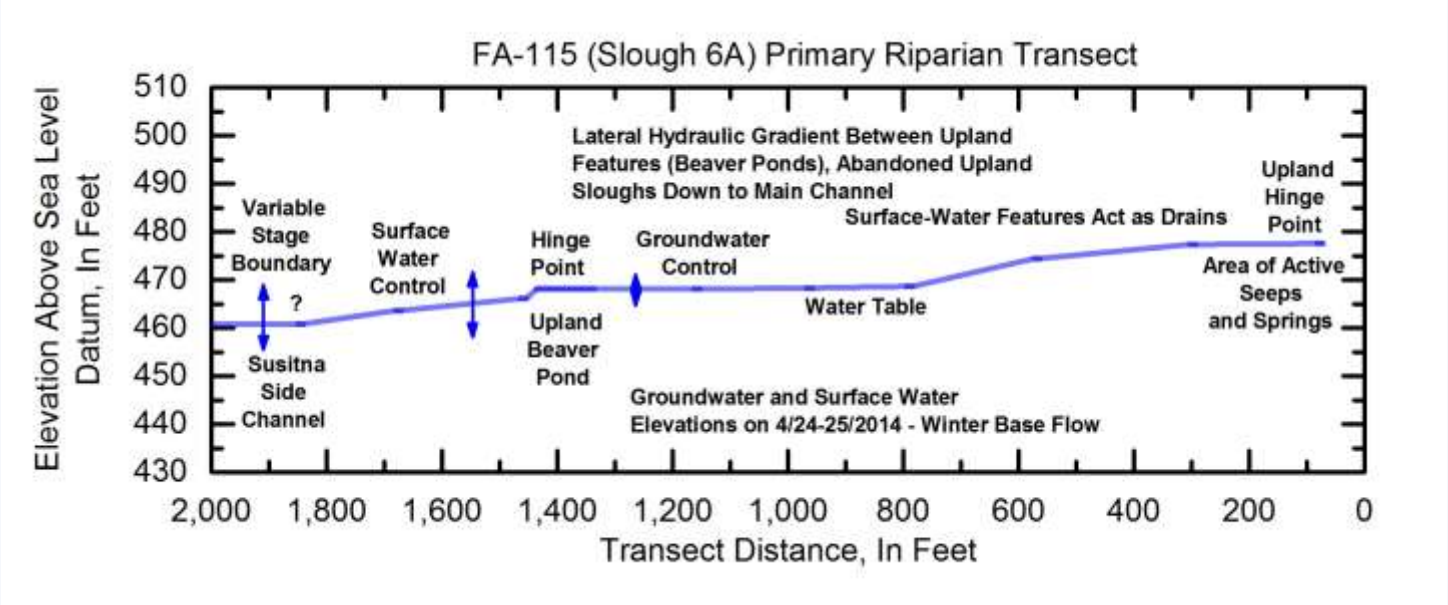
FA-128 (Slough 8A)
Upper Riparian Transect
Lateral Hydraulic Gradients



- September 2014 Technical Memorandum - Groundwater and Surface-Water Relationships in Support of Riparian Vegetation Modeling

FA-128 (Slough 8A)
Upper Riparian Transect
Seasonal Water-Level Variation

Study 7.5 Transect/Focus Area Scale – Process Understanding



An Example Transect Definition of Processes Defining Lateral Hydraulic Gradients, A Hinge Point, and Upland Versus Riverine Dominated Groundwater Conditions – FA-115 (Slough 6A).

September 2014 Technical Memorandum - Groundwater and Surface-Water Relationships in Support of Riparian Vegetation Modeling

Study 7.5 Analysis Steps – "Scaling Up"

- **Scales and Methods** =
  - Focus Area and Lower-River Transect Scale
  - **Focus Area**
    - Development of Process Understanding, Supporting Data, Understanding of Uncertainty
    - Primary and Test Transects
    - Range of Focus Area Conditions = Representative Variation of Riverine to Upland Dominated Transects
    - "Understanding Needed" to Interpret Available Data Between Focus Areas at River Segment Scale
  - River Segment Scale
    - **For IFS Fish and Aquatics**: Scaling Up is Based on Habitat Model Extrapolation (TBD); Habitat Model Incorporates Groundwater Upwelling Within HSC

Study 7.5 Analysis Steps – Riparian "Scaling Up"

- **Scales and Methods** =
  - Focus Area and Lower-River Transect Scale
  - **Focus Area Scale - Riparian**
    - Information Layers
      - Floodplain Water Body Hydrography
        - Beaver Ponds, Other Ponds
        - Sloughs, Streams, Springs, Seeps
      - Groundwater Hydrography
        - Water Table Maps – Focus Areas, Specific Conditions
  - River Segment Scale

Study 7.5 Analysis Steps – Riparian "Scaling Up"

- **Scales and Methods** =
  - Focus Area and Lower-River Transect Scale
  - Focus Area Scale
  - **River Segment Scale - Riparian**
    - GIS Approach
    - Base Land Surface – DEM
    - Hydrologic Landscapes
    - Ice-Free and Ice Flow Routing Model Stage Simulations
    - Information Layers
      - Aquatic Habitat Types
      - Riparian Vegetation Mapping
        - Subsets of Species Indicating Shallow Groundwater
        - Subsets of Species Indicating Deep Groundwater
      - Hydrography

Study 7.5 Analysis Steps – Riparian "Scaling Up"

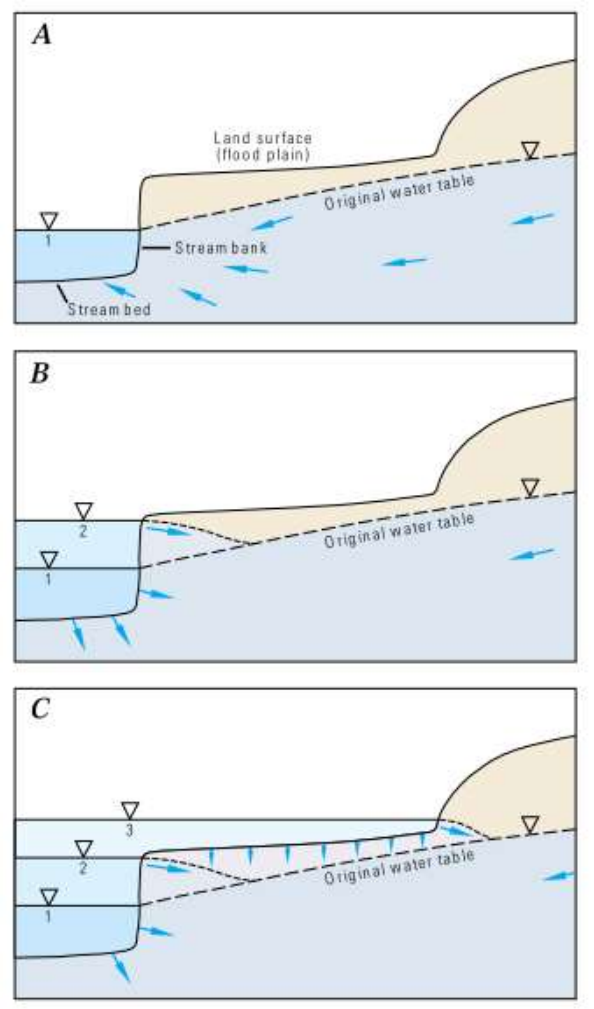
- **Scales and Methods** =
  - Focus Area and Lower-River Transect Scale
  - Focus Area Scale
  - **River Segment Scale - Riparian**
    - Information Layers
      - Hydrography
        - Beaver Ponds, Other Ponds
        - Sloughs, Streams, Springs, Seeps
        - Water Table Maps – Focus Areas, Specific Conditions
      - Geohydrologic Domains
      - Geology
        - Geomorphology Mapping
        - Watershed Scale Geology Mapping
      - Additional Floodplain Water Body/River Stage Measurements

Study 7.5 Analysis Steps – Riparian "Scaling Up"

- **Scales and Methods** =
  - Focus Area and Lower-River Transect Scale
  - Focus Area
  - **River Segment Scale - Riparian**
    - Process
      - Using Prior Features and Information
      - Define Upland Groundwater Elevations
      - Define River Stage Conditions
      - Define Lateral Gradients
      - Define "Hinge Line" Between Upland Dominated And Riverine Dominated Groundwater Conditions
      - Estimate Areas Where Hydraulic Gradient Is Impacted By Changing River Stage Conditions (Project Operations)
      - Evaluate Changes to Habitat (Aquatic, Riparian) In Zones of Potential Impact

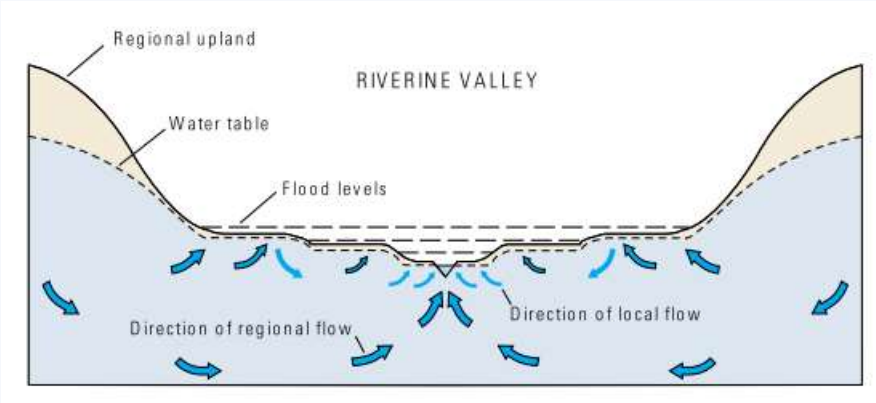
Following Slides Are Only Place Holders
For Potential Use in Discussions

Study 7.5 Analysis Steps – "Scaling Up" Examples



Riverine Terrain:

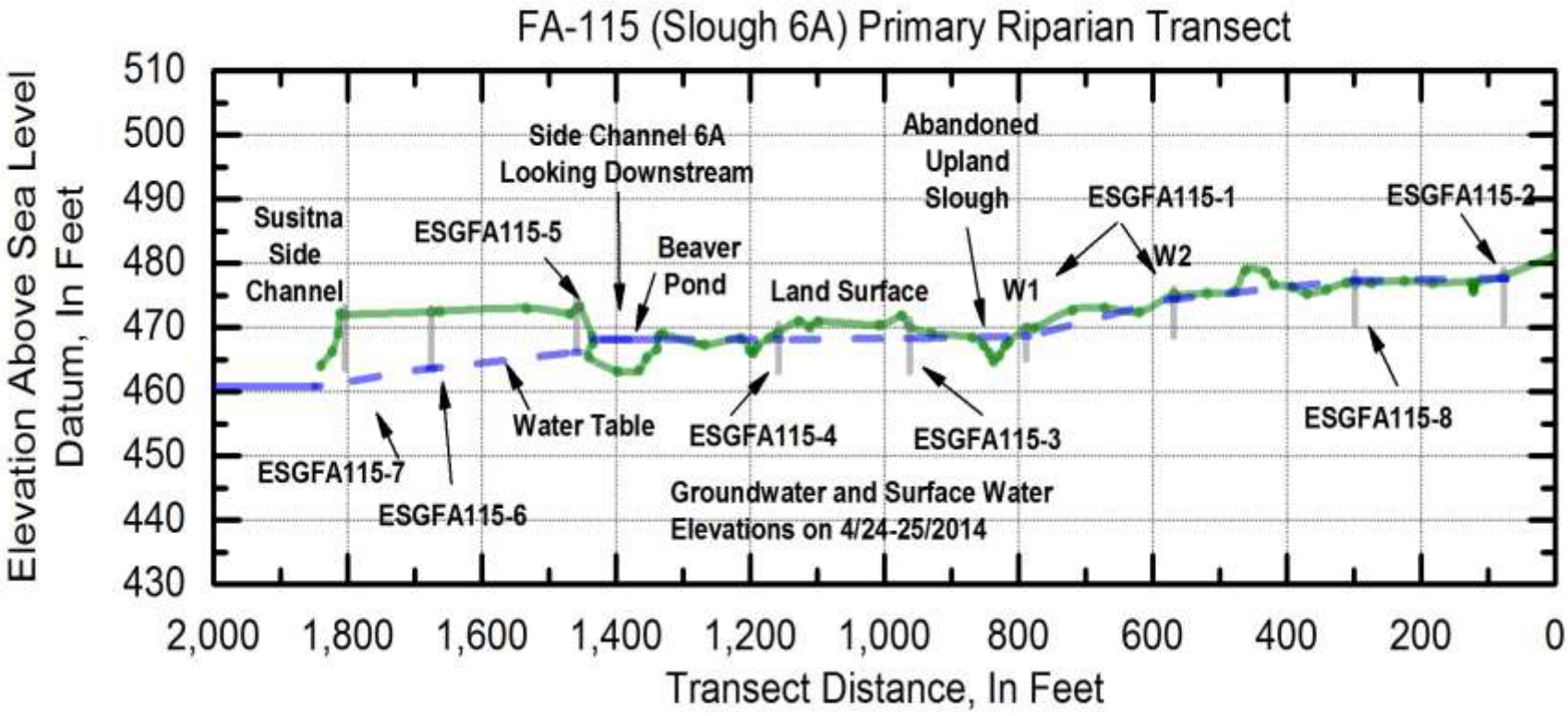
- **Regional vs. local scale flowpaths**
- **Flood waters → "Bank storage"**



Figures from Winter, 1998

Study 7.5 Analysis Steps – "Scaling Up" Examples

Study 7.5 Analysis Steps – "Scaling Up" Examples



Study 7.5 Analysis Steps – "Lateral Gradient" Examples

- FA-138 (Gold Creek)
- How Are Upland Sloughs and Wetlands Impacted By River Stage Levels?
- How Does this Vary Over The Annual Hydrologic Cycle?
- At What Scale are GW/SW Interactions Significant?
- Upland Wetland Hydrology Observations (Study Objective #6; RSP 8.6.3.6)

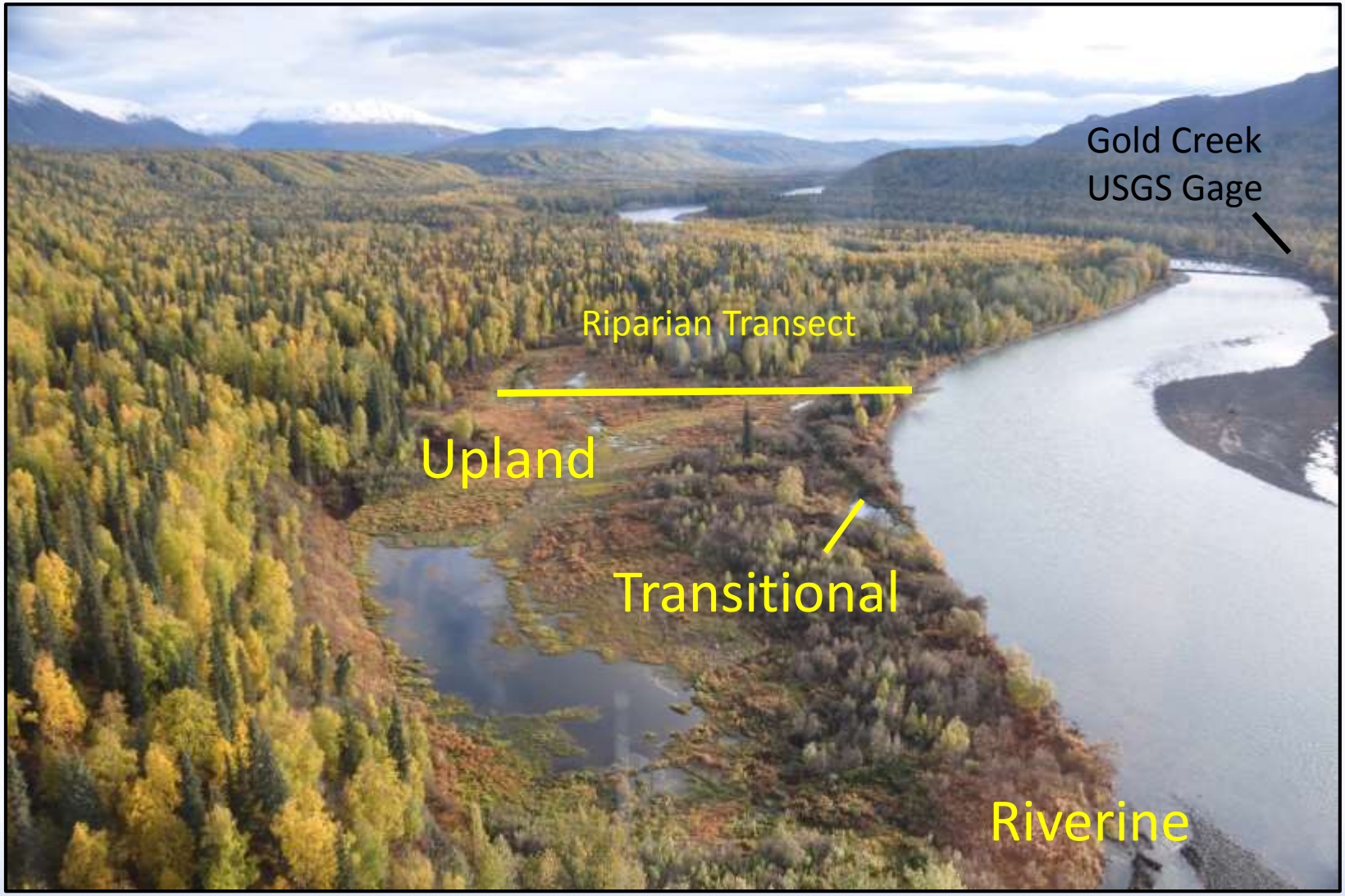
FA-138 (Gold Creek) Focus Area, Right Bank Upland Sloughs and Wetlands, during heavy rainfall and precipitation flood peak on the Susitna River, August 22, 2013

Study 7.5 Analysis Steps – "Lateral Gradient" Examples

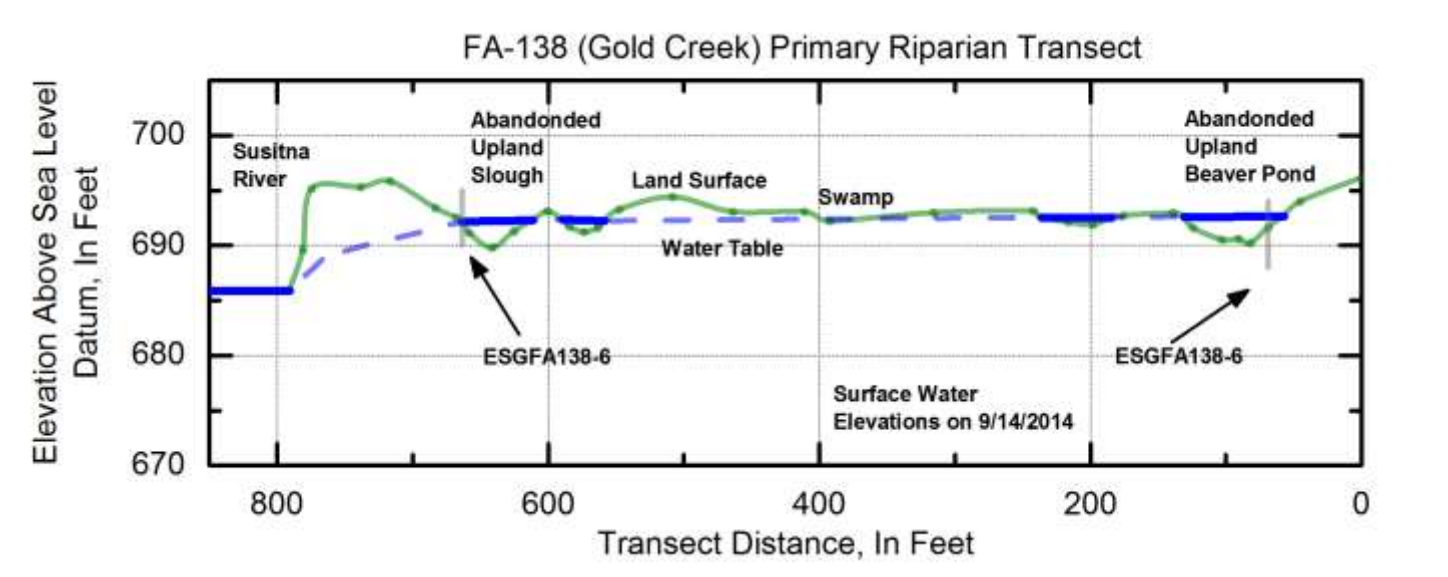
- Does Recharge From Groundwater Help Maintain Wetland Vegetation?
- What Winter Observations Help Understand This?
- What Snowmelt Transition Observations Help Understand This?

FA-138 (Gold Creek) Focus Area, Right Bank Upland abandoned beaver pond during periods of heavy rains, August 22, 2013

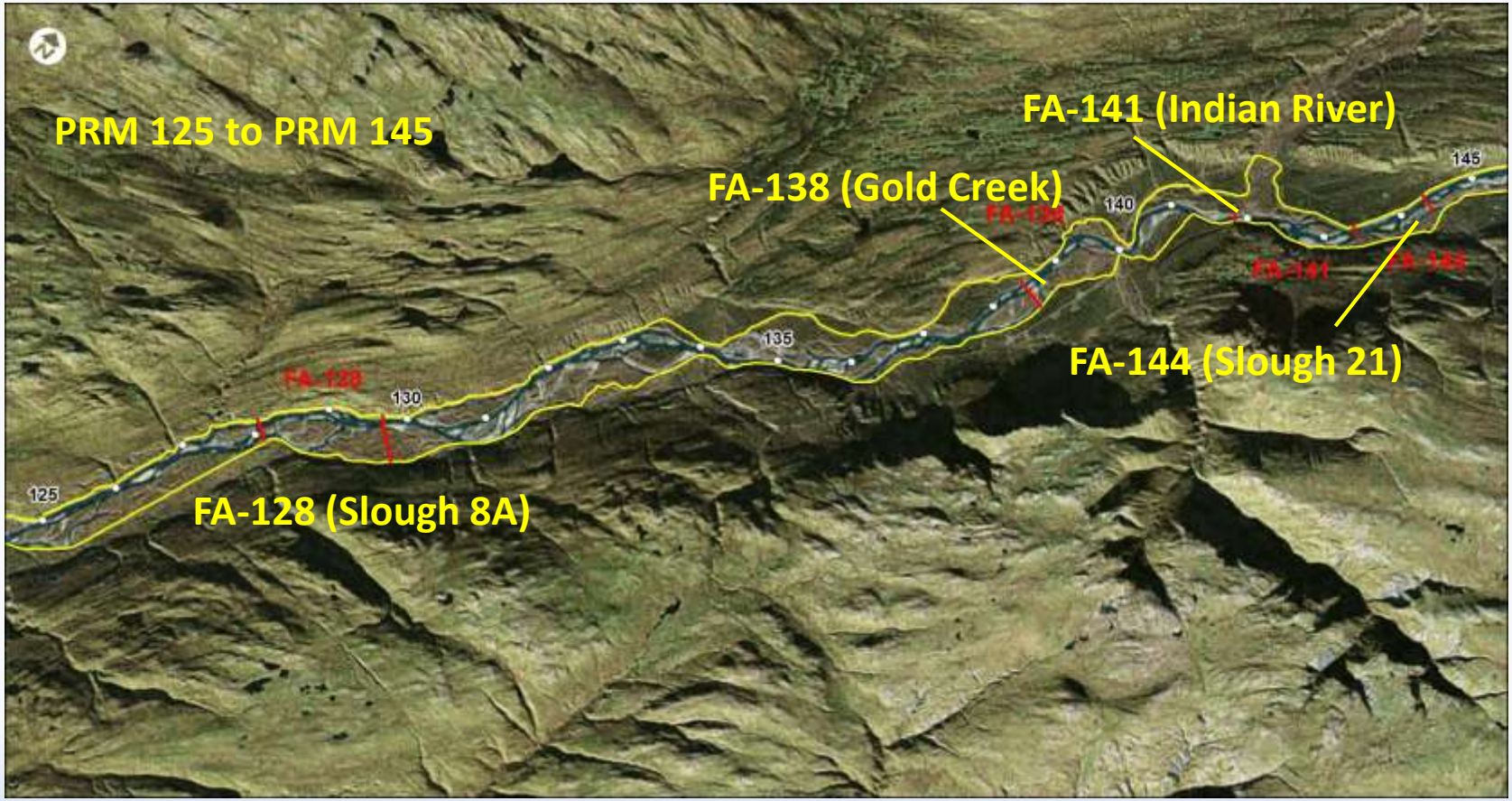
Study 7.5 Analysis Steps – "Lateral Gradient" Examples



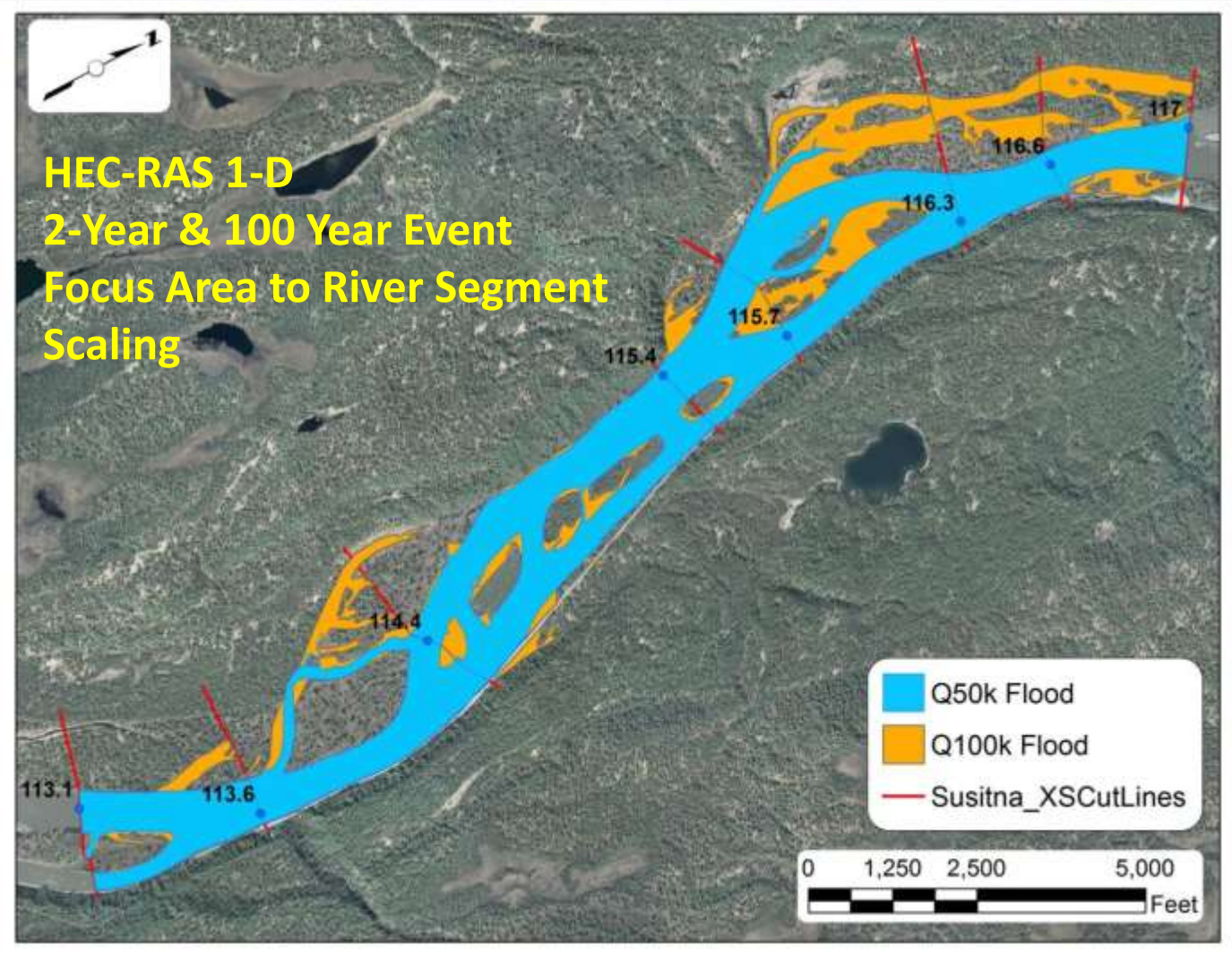
Study 7.5 Analysis Steps – "Lateral Gradient" Examples



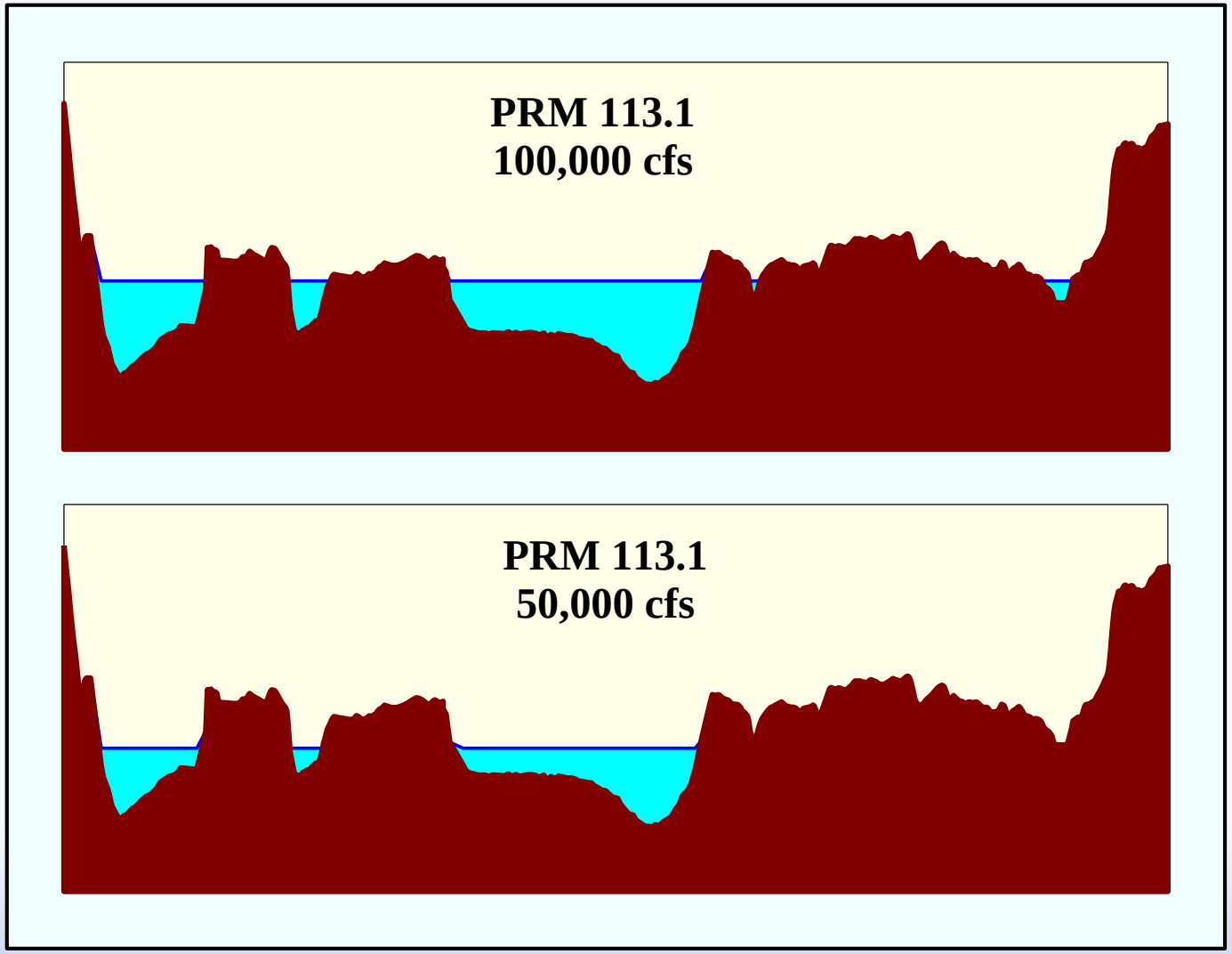
Study 7.5, 8.6 Analysis Steps – "Scaling Up From FA Reach to the River Segment"



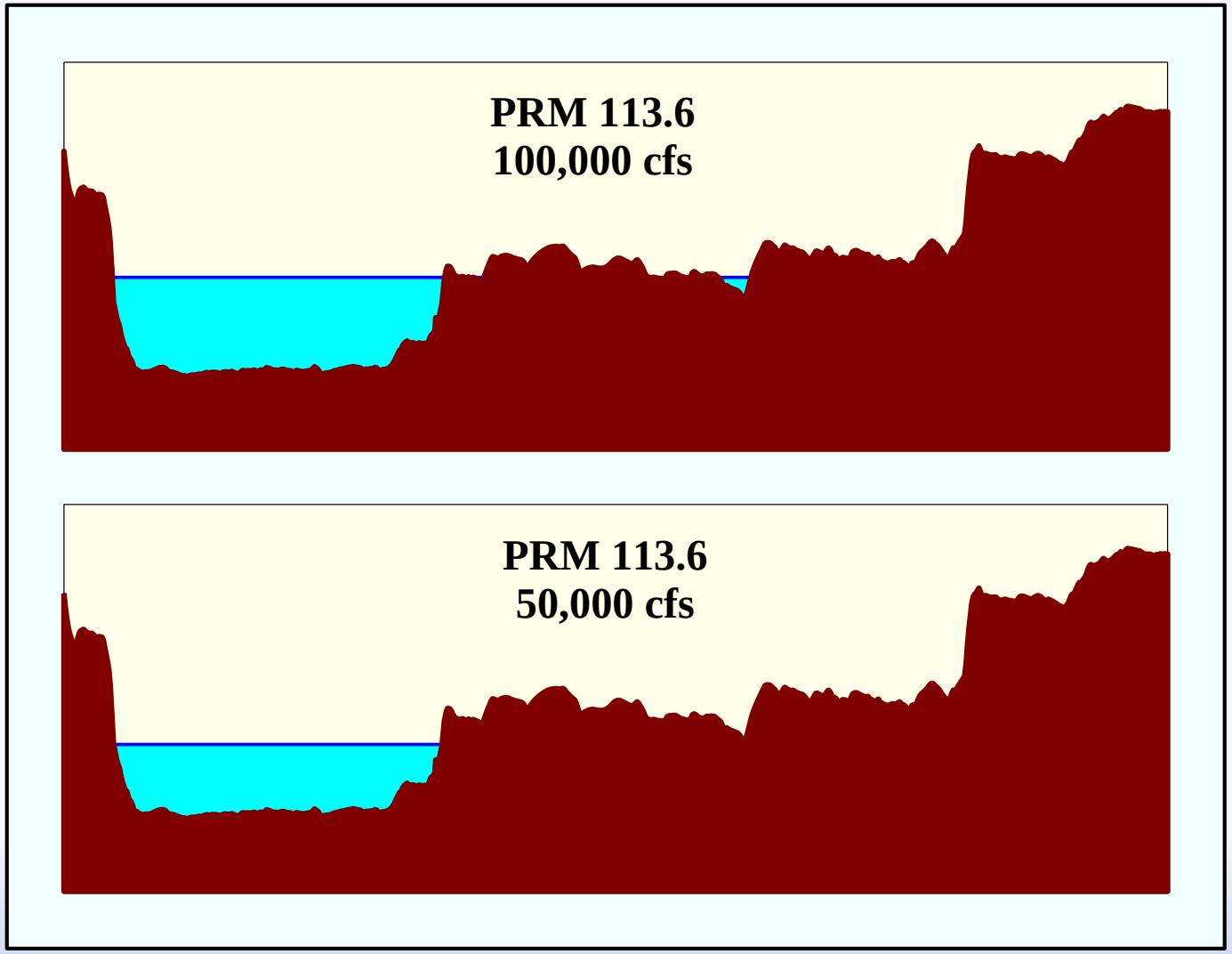
Study 7.5 Analysis Steps – "Scaling Up"
1D Flow Routing Modeling Examples



Study 7.5 Analysis Steps – "Scaling Up"
1D Flow Routing Modeling Examples



Study 7.5 Analysis Steps – "Scaling Up"
1D Flow Routing Modeling Examples



Study 7.5 Analysis Steps – "Scaling Up"
Non-Focus Area Examples – PRM 123

Study 7.5 Analysis Steps – "Upwelling"

- **Scales** = Transect –> Focus Area –> River Segment
- **Timing** = Seasonal Approaches
  - Ice *Versus* Ice-Free = Three Winter Periods *Versus* Summer Period
- **Conditional** = Select Flow Conditions, Winter Conditions, Variations in Hydraulic Boundary (Stage) Conditions
- **Definitions** =
  - Groundwater Discharge = Flow to Surface = "Upwelling"
  - Groundwater Recharge = Flow from Surface = "Downwelling"
  - Hydraulic Gradient = Difference Between Water Elevations Over A Select Distance
  - Groundwater/Surface-Water (GW/SW) Interactions = The Pressure and Mass (Flux) Interactions Taking Place Between Surface-Water Systems and Groundwater
  - Hyporheic Zone = The Groundwater Zone Located at the Boundary Condition with Surface-Water Systems Where Active Mass (Flux) Exchange Occurs, Usually Related To Biogeochemical Interactions

Study 7.5 Analysis Steps – "Upwelling"