7. HYDROLOGY-RELATED RESOURCES

7.1. Introduction

Operation of the Susitna-Watana Hydroelectric Project (Project) is expected to change the hydrology characteristics of the riverine portion of the drainage downstream of the proposed dam and the mainstem Susitna River reach inundated by the Project reservoir. Proposed Project operations will affect flow, water depth, surface water elevation, channel characteristics, and sediment regimes. The potential effects of the Project on ice formation, surface and groundwater temperature and quality, geomorphology, and other hydrologic characteristics need to be carefully evaluated as part of the licensing process, because changes to these parameters can affect aquatic and riparian habitat quality, which can in turn affect fish populations, riparian-dependent species, and roads, bridges, structures, and recreation opportunities along the river corridor.

This section includes three study plans: Groundwater Study; Ice Processes Study; and Glacier Runoff Changes Study.The overall goal of the studies is to collect data to characterize baseline conditions for these hydrologic resources and evaluate potential Project effects. These results and analyses will be incorporated into the environmental assessment that will be conducted in support of AEA's FERC License Application. A glossary of hydrology-related terms is included in Attachment 7-1.

7.2. Nexus Between Project Construction / Existence / Operations and Effects on Resources to be Studied

Construction and operation of the Project have the potential to alter the GW/SW interactions and ice processes in the Susitna River. Changes to these processes may affect channel morphology and aquatic habitat downstream of the Project site. Understanding existing conditions provides baseline information needed for predicting the likely extent and nature of potential changes to the river that may occur due to Project construction and operations.

For any hydropower project it is important to understand the variability of the discharge. On-going retreat of the glaciers feeding the Upper Susitna drainage, along with the anticipated long life of the Project, means that glacial retreat could have significant impacts to the ecosystem, economics of the Project, and proposed mitigation measures. These impacts from natural changes to the environment may be additive to impacts from the proposed Project operations. The effects will be varied and could include the following:

- Glacial retreat can affect runoff contribution from glaciers that could result in reduced summertime stream flows.
- Decreased snowpack and glacial runoff, combined with increased air temperatures, could change the thermal regime of the Susitna River and affect fish and aquatic invertebrates.
- Sedimentation changes could affect Project longevity and thus cost-benefit calculations for the reservoir. The rate of sedimentation is strongly tied to erosion processes, which may change as glacial ice becomes a smaller contribution to the total runoff.
- An understanding of changes in the hydrologic regime (water timing, quantity, and quality) in combination with Project operations will inform post-construction monitoring

needs. This could include stream temperature measurements, assessment of fish habitat conditions under changing conditions, instream flow throughout the system to assess changes in flow contribution from tributaries, and stream temperature monitoring in the reservoir and downstream.

7.3. Resource Management Goals and Objectives

Water quality in the state is regulated by a number of state and federal regulations. This includes the federal Clean Water Act (CWA), and the State of Alaska Title 18, Chapter 70, of the Alaska Administrative Code (18 AAC 70). Aquatic resources including fish and their habitats, and wildlife resources, are generally protected by a variety of state and federal mandates. In addition, various land management agencies, local jurisdictions, and non-governmental interest groups have specific goals related to their land management responsibilities or special interests. These goals are expressed in various statutes, plans, and directives.

In addition to providing information needed to characterize the potential Project effects, these water resources studies will inform the evaluation of possible conditions for inclusion in the Project license. These studies are designed to meet Federal Energy Regulatory Commission (FERC) licensing requirements and also to be relevant to recent, ongoing, and/or planned resource management activities by other agencies.

7.4. Summary of Consultation with Agencies, Alaska Native Entities, and Other Licensing Participants

Input regarding the issues to be addressed in these studies has been provided by the TWG during workgroup meetings commencing in late 2011. During 2012, workgroup meetings were held in January, March, April, June, August, September, and October, during which resource issues were identified and discussed and objectives of the studies were defined. A one-and-one-half day field reconnaissance was also conducted in October 2012 with agency representatives to tour three of the proposed Focus Areas and discuss riparian, groundwater, and fish habitat sampling and modeling. Various agencies and other parties (USFWS, NMFS, ADF&G, etc.) provided written comments that have been considered and will be addressed in this plan. Summary tables of comments and responses from formal comment letters filed with FERC through November 14, 2012 are provided in Appendix 1. Copies of the formal FERC-filed comment letters are included in Appendix 2. In addition, a single comprehensive summary table of comments and responses from consultation, dated from PSP filing (July 16, 2012) through release of Interim Draft RSPs, is provided in Appendix 3. Copies of relevant informal consultation documentation are included in Appendix 4, grouped by resource area.

7.5. Groundwater Study

7.5.1. General Description of the Proposed Study

Project construction and operation will affect Susitna River flows downstream of the proposed dam; the degree of these effects will ultimately depend on final Project design and operations. Project operations will cause seasonal, daily, and hourly changes in Susitna River flows compared to existing conditions. The potential alteration in flows will influence downstream resources/processes, including fish and aquatic biota and their habitats, channel form and function including sediment transport, water quality, groundwater/surface water interactions (GW/SW), ice dynamics, and riparian and wildlife communities (AEA 2011). The overall goal of this study is to understand the effects of the Project on GW/SW interactions at multiple spatial and temporal scales as they relate to aquatic and floodplain species in the Susitna River. Additionally, one task is focused on evaluating the potential impacts to shallow groundwater well users in the Susitna River corridor. The study is one part of a set of interdisciplinary resource studies that are designed to evaluate the overall effects of Project operations. The Groundwater Study is specifically linked with both the Riparian Instream Flow Study and the Fish and Aquatics Instream Flow Study since the ecological functionality of riparian and aquatic habitats can be directly influenced by GW/SW interactions. It is therefore important to understand whether and the extent to which Project operations may influence those interactions, and how those effects may impact riparian and aquatic habitats. The study will use existing information and data, as well as new data collected during this and other studies to provide an overall understanding of GW/SW interactions at both the watershed- and local-scales.

The overall objectives of this study are as follows:

1. 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.
2. 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).
3. Assess the potential effects of Watana Dam/Reservoir on groundwater and groundwater-influenced aquatic habitats in the vicinity of the proposed dam.
4. 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 Section 8.5.4.2.1.2).
5. Determine the GW/SW relationships of floodplain shallow alluvial aquifers within selected Focus Areas as part of the Riparian Instream Flow Study (Section 8.6).

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 (Section 8.5).
7. 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 (Section 8.5).
8. Characterize the winter flow in the Susitna River and how it relates to GW/SW interactions.
9. Characterize the relationship between the Susitna River flow regime and shallow groundwater users (e.g., domestic wells).

7.5.2. Existing Information and Need for Additional Information

Groundwater/surface water interactions in the Susitna River watershed have been studied at different locations in the river and at different times. The lower Susitna River watershed is part of the geologic Susitna Basin (Kirschner 1994) (Figure 7.5-1). This region has generally been referred to as the lower Susitna River. The major physiographic regions of the Susitna watershed are described in Wahrhaftig (1994) and Kenneson (1980a, 1980b), and include: a) the Alaska Range on the northern portion of the watershed, which also forms the watershed boundary in the headwaters of the watershed; b) the Talkeetna Mountains that cross the central portion of the watershed and result in physiographic features such as Devils Canyon and Watana Canyon; and c) the upper Matanuska Valley that covers the lower portion of the watershed and is bounded on the downstream end by Cook Inlet. The watershed-scale geology covers a range of highly metamorphic marine sedimentary formations, referred to as Flysch belts (Beikman 1994) (Figure 7.5-2). There are also younger volcanic deposits in the middle portion of the watershed. The Susitna River flows out of the Talkeetna Mountains in the vicinity of Talkeetna, where it then flows through the sedimentary Susitna Basin.

Hydropower-related studies of the Susitna River watershed during the 1980s included observations and monitoring of GW/SW interactions. These studies focused on river habitats such as side channels, side sloughs, and upland sloughs that were determined to be important fish habitat. A large amount of physical hydrology data (e.g., stage-discharge relationships, main stage versus upwelling discharge, piezometers), water quality data (e.g., temperature), aquatic habitat, and other observations were reported for various study sites (see Section 8.5.2.1).

Since the 1980s, various wells have been drilled for domestic water supply, mining exploration, oil and gas exploration, railroad operations, and other activities associated with resource development or evaluations in the watershed.

The Groundwater Study is needed to first define the role that existing GW/SW interactions play in the development and sustainability of riparian communities proximal to the Susitna River, and how these interactions serve to create and maintain certain flow dependent biological cues (e.g., upwelling, downwelling, temperature moderation) used by salmonids for spawning, egg incubation, and rearing. In addition, shallow groundwater wells used by residents (e.g., domestic) may also be dependent on Susitna River GW/SW interactions.

The information developed in the Groundwater Study will be used to define and evaluate existing GW/SW interactions as they relate to the ecology of riparian and aquatic habitats, and then use that information for assessing how Project construction and operation may alter those interactions and the corresponding riparian and aquatic habitats.

7.5.3. Study Area

The study area related to groundwater processes includes primarily the Middle River Segment of the Susitna River that extends from RM 98.5 to RM 184, as well as portions of the Lower River Segment associated with domestic wells, and the lowermost portion of the Upper River Segment near the proposed dam site associated with potential groundwater changes relative to reservoir elevation change. The groundwater investigations in the Middle River Segment will include those designed to evaluate GW/SW interactions relative to riparian and aquatic habitats, as well as GW/SW interactions on domestic wells. The study in the Middle River Segment will be concentrated within a series of Focus Areas that have been identified for detailed investigation. As noted in Section 8.5.4.2.1.2., the Focus Areas are intended to serve as specific geographic areas of the river that will be the subject of intensive investigation by multiple resource disciplines including Fish and Aquatics Instream Flow Study (Section 8.5), Riparian Instream Flow Study (Section 8.6), Groundwater Study, Geomorphology studies (Sections 6.5 and 6.6), Ice Processes Study (Section 7.6), and Water Quality studies (Sections 5.5 and 5.6). The Focus Areas were selected during an inter-disciplinary resource meeting that involved a systematic review of aerial imagery within each of the Geomorphic Reaches (MR-1 through MR-8) for the entire Middle River Segment of the river (see Table 8.5-5 in Section 8.5 for a listing of nested and tiered habitat mapping units, categories and definitions that are being used across resource disciplines). Overall, ten potential Focus Areas have been identified, (see Table 8.5-6 in Section 8.5) although GW/SW interactions will not be intensively studied at each of these ten Focus Areas. Rather, the studies will be limited to those Focus Areas exhibiting GW/SW interactions that relate to the ecology of riparian and/or aquatic habitats. These will be determined pending further evaluation of each of the Focus Areas.

Determining how far downstream Project operational effects will extend will depend in part on the results of the Open-water Flow Routing Model (see Section 8.5.4.3), which is scheduled to be completed in Q1 2013 as well as results of the operations model (Section 8.5.4.3.2). The results of the Open-water flow routing model completed in Q1 2013 will be used to determine whether and the extent to which Project operations related to load-following as well as seasonal flow changes occur within a section of the Lower River Segment that includes all of geomorphic reach L1 and a portion of L2 (down to RM 75). Thus, an initial assessment of the downstream extent of Project effects will be developed in Q1 2013 with input from the Technical Workgroup. This assessment will include a review of information developed during the 1980s studies and study efforts initiated in 2012, such as sediment transport (Section 6.5), habitat mapping (Sections 6.5 and 9.9), operations modeling (Section 8.5.4.2.2), and the Mainstem Open-water Flow Routing Model (Section 8.5.4.3). Nevertheless, the review of background information and large-scale geohydrologic process-domains/terrain of the Susitna River covers all three segments of the Susitna River. This overview is important for determining the boundary conditions affecting groundwater flow conditions along the entire river corridor.

7.5.4. Study Methods

The Groundwater Study is divided into nine study components related to the study objectives outlined above: (1) Existing Data Synthesis, (2) Geohydrologic Process-Domains and Terrain; (3) Watana Dam/Reservoir, (4) Upwelling/Springs Broad-Scale Mapping, (5) Riparian Vegetation Dependency on GW/SW Interactions, (6) Fish Habitat GW/SW Interactions, (7) Water Quality in Selected Habitats, (8) Winter GW/SW Interactions, and (9) Shallow Groundwater Users. Each of the components and its related study methods are explained further in the following subsections. The methods described represent standard approaches for summarizing data and assessing the physical/biological processes related to groundwater and aquatic habitat. Many of the study components represent contributory elements of other resource studies, for example the 4th component, Upwelling-Springs mapping is linked to both the Ice Processes Study (Section 7.6), the Geomorphology Study (Section 6.5), the Water Quality Study (Section 5.5) and the Fish and Aquatics Instream Flow Study (Section 8.5). Likewise, the 7th component, Water Quality is linked to both the Water Quality Study (Section 5.5) as well as Fish and Aquatics Instream Flow Study (Section 8.5).

7.5.4.1.1. Existing Data Synthesis

Data from prior Susitna River hydroelectric evaluations and other studies will be used to help develop a detailed reference source of available data to support the study elements and GW/SW interactions and processes related to potential Project operations and design. The addition of the historical data will help provide a more thorough review of the geohydrology of the watershed and relevant GW/SW interactions and how they may change under the various Project operational designs. The use of existing information will also help meet the need for detailed analysis under the proposed Project timeframe. The specific steps of the data synthesis include the following:

- Identify existing reports and data from the 1980s licensing effort, prior studies, and more recent studies that relate to geology and geohydrology of the Susitna River watershed and GW/SW interactions and related aquatic habitat in the Susitna River. The reference search will include any information related to the past geohydrology studies, groundwater data and information related to main channel interactions, and impacts of winter ice cover and thickness on groundwater and surface-water interactions.
- Identify similar studies, reports and data for hydroelectric projects in northern latitudes and cold climates. The literature search for this task will be coordinated with the University of Alaska Fairbanks – Geophysical Institute research library, which already contains extensive references to northern research basins and circumpolar literature sources.
- Identify applicable geology, soils, and other geohydrologic references for the Susitna River watershed. Information will be used that is collected by the Geology and Soils Characterization Study (Section 4.5). Water quality data and references will be provided by the Baseline Water Quality Study (Section 5.5) for groundwater and surface water (Figure 7.5-3). Additional water quality data will be provided by the Fish and Aquatics Instream Flow Study (Section 8.5) historical information reviews.

7.5.4.1.1.1. Work Products

The information and data obtained as part of this review will provide valuable background information for the Groundwater Study and will also be integrated into appropriate sections of the Initial Study Report (Initial Study Report). In addition, this component will provide:

- A searchable and annotated bibliography of references and data sources for use by study teams and resource agencies. The annotated bibliography will be coordinated with the Alaska Resources Library and Information Services (ARLIS) resource library staff to follow their Susitna reference standards. The annotated bibliography will be provided to ARLIS as part of its Project resource collection program.

7.5.4.1.2. Geohydrologic Process-Domains

Project operations could influence GW/SW interactions at different locations along the river, from the proposed dam and reservoir location to below the Three Rivers Confluence. Site-specific groundwater studies will help characterize these influences for key aquatic habitat and riparian study areas within selected Focus Areas. This will be done by first defining the significant geohydrologic units in the Susitna basin that provide groundwater recharge to the mainstem and associated main channel, side channels, side sloughs, upland sloughs and wetlands. ASTM standard D5979 "Standard Guide for Conceptualization and Characterization of Groundwater Systems" will be used to help define the geohydrologic units (ASTM 2008b). ASTM D6106 "Standard Guide for Establishing Nomenclature of Groundwater Aquifers" will be used to help establish the aquifer nomenclature and naming of geohydrologic features (ASTM 2010a). The geohydrologic units (e.g., bedrock, alluvial) will then be related to geomorphologic and riparian mapping units (process-domain river segments) in coordination with the Geomorphology Study (Section 6.5) and Riparian Instream Flow Study (Section 8.6) studies (Montgomery 1999). The geohydrologic units serve as a background layer to riparian process domains, similar to soil or geology map units. The definition of geohydrologic units is independent of riparian, fish or aquatic habitat definitions.

The next step will be to define the groundwater regional scale relationship to local flow systems in the Middle River and Lower River segments and the relationship with the process-domain river segments. This will be based on methods used on a similar study for the Tanana watershed, as reported by Anderson (1970). ASTM standard D6106 will be used to help characterize the groundwater aquifers relevant to Project proposed operations. The final step will be identifying the relationship between the process-domain river segments and the planned Focus Areas. This will facilitate the expansion of the analysis of potential Project effects on GW/SW interactions from the Focus Areas individual study areas back to the larger process-domain river segments.

7.5.4.1.3. Work Products

The results of this study component will be incorporated into appropriate sections of the Initial Study Report, to be filed with FERC in February 2014. The analysis presented will include:

- A detailed description of the significant geohydrologic units in the Susitna basin that provide groundwater recharge to the mainstem and associated main channel, side channels, side sloughs, upland sloughs and wetlands.
- Descriptions and references defining geohydrologic units.

- Relationship between geohydrologic map units and Focus Areas.
- GIS map layers of the geology a geohydrologic units that are defined.
- An approach for expanding the site specific Groundwater Study results from the Focus Areas to the process-domain river segments.

7.5.4.2. Watana Dam/Reservoir

Project construction and operation may influence groundwater conditions downstream of the dam and the characteristics of the discontinuous permafrost conditions in the vicinity of Project operations. Variation in reservoir levels will result in transient head conditions on the upstream side of the dam. Project Engineering Feasibility Studies (ongoing), the Geotechnical Investigation Program and the Geology and Soils Characterization Study (Section 4.5) will provide information to help evaluate the groundwater conditions in the Project area and evaluate the potential for groundwater impacts downstream of the dam. This will be accomplished by first evaluating engineering geology information from the dam and reservoir area. This information will be obtained from the Geology and Soils Characterization Study (Section 4.5) and past geotechnical studies of the proposed dam location (Figure 7.5-3). This will include geologic well logs, pump tests, seismic data if available, permafrost information, and water level records. The analysis will require close coordination with engineering, as well as the Geomorphology and Fluvial Geomorphology Modeling studies in the Middle River Segment (Sections 6.5 and 6.6, respectively). This will be important for identifying and applying data from existing programs and determining the need for additional data collection.

Based on the information, a description of the pre-Project groundwater conditions will be developed in the vicinity of the Watana Dam and Reservoir. This will include a characterization of known permafrost and bedrock hydrogeology in the Watana Dam vicinity. From this, conceptual GW/SW models will be developed that describe pre-Project conditions and post-Project conditions. These models will assist in identifying key potential groundwater flow pathways with the Project (e.g., Deadman Creek drainage) and how the proposed dam construction may affect groundwater flow. The engineering design of the dam includes a goal of grouting all groundwater pathways that could be subject to bypass groundwater flow in the vicinity of the dam. The models will also be used to evaluate the potential changes in groundwater flow as a result of Project operations.

The operation of the proposed reservoir will also result in riparian habitat loss due to permanent inundation below the low pool level. Existing riparian and aquatic habitat at the upstream end of the reservoir will be inundated for different durations between the low pool and high pool elevations. To evaluate this, field reconnaissance trips will be conducted to collect site specific data in late summer and early fall to help characterize the area. Mapping data from the Geomorphology Study (Section 5.5) and the Vegetation and Wildlife Habitat Mapping Study (Section 11.5), along with existing aerial and LiDAR GIS information will will be used to develop maps and cross-sections of the study area. This combined information will be used to evaluate the timing and durations of inundation of the potential riparian and aquatic habitats in the area at the upstream end of the reservoir. Inundation timing and duration curves will be produced. Channel Profile and cross-sections will also be produced.

7.5.4.2.1. Work Products

Information provided from this study component will include:

- Documentation of geologic cross-sections, groundwater data, photos, survey data, geotechnical information, geologic well log, and available seismic data.
- Conceptual model of the geohydrology of the dam area, including potential pathways for groundwater flow in the area of the proposed Dam.
- GIS map layers of the geology, and geohydrologic units and features near the proposed Watana Dam site.

7.5.4.3. Upwelling / Springs Broad-Scale Mapping

This study component is focused on determining the locations of areas in the Middle River Segment and upper portion of the Lower River Segment that are currently influenced by groundwater inflow. This will rely upon work products that will be developed from several other resource studies including the Ice Processes Study (Section 7.6), Geomorphology Study (Section 6.5) and the Water Quality Study (Section 5.5). These studies will collectively provide a suite of broad-scale maps that will be used in identifying areas of groundwater influence. This component of the Groundwater Study will provide for the compilation, review and interpretation of the different mapping work products and will result in development of a GIS map layer that depicts groundwater influenced areas. This work will be closely coordinated with the Fish and Aquatics Instream Flow Study and Riparian Instream Flow Study. The identification of these areas will be important for understanding the spatial extent to which Project induced effects to existing GW/SW interactions may occur, and from a planning perspective, will help inform the selection of specific Focus Areas warranting detailed groundwater study.

This study will rely on the following activities and work products that will be provided from other resource studies:

- Aerial and global positioning system (GPS) mapping of winter open leads, in Q1 and Q2 of 2013, and 2014 as completed by the Ice Processes Study (Section 7.6) (Figure 7.5-3). Open leads in the Middle River Segment will be compared with the location of open leads documented in 1984–1985, as appropriate. To provide some context, air temperatures from 1984–1985 will be compared with air temperatures measured during the 2012–2013 and 2013–2014 winter seasons from the closest long-term monitoring site with data covering both periods. Geographic Information System (GIS) coverages of open leads will be developed. The Groundwater Study will focus on the entire Middle River Segment and the upper portion of the Lower River Segment upstream from RM 84 (located near USGS Gage on Susitna River at Sunshine).
- Aerial photography and aerial videography of the ice-free period showing turbid and clear water habitat that was completed in Q3 and Q4 2012 as part of the Geomorphology Study (Section 6.5) and Characterization of Aquatic Habitats Study (Section 9.9). The aerial photography and videography will be used in part to document turbid and clear water (i.e., groundwater-influenced) habitats. Clear water inflow from side drainages (e.g., Portage Creek) will be separated from that dominated by groundwater recharge (upwelling).

- Thermal Infrared Imagery (TIR) of the Middle River Segment of the Susitna River as provided from a pilot study to be completed during Q1 2013 as part of Water Quality Study (Section 5.5). In coordination with the Fish and Aquatics Studies (Section 9) a determination will be made about the value of the TIR and whether additional imaging data should be collected in the Lower River Segment or in other portions of the Middle River Segment. If TIR can successfully identify spatially discrete areas of groundwater upwelling as validated through on-the-ground confirmatory surveys, then these areas can be mapped within the entire river segment.
- Observational data concerning GW/SW interactions collected as part of the Habitat Suitability Criteria (HSC) studies associated with spawning and/or rearing fish conducted under the Fish and Aquatics Instream Flow Study (Section 8.5.4.5.1.1.4) as well as fish tracking studies completed as part of the Salmon Escapement Study (Section 9.7). In these studies, where aggregations of spawning or rearing fish are observed, temperature probes test whether or not upwelling is present by using temperature profiling techniques (e.g., measuring the vertical temperature profile or measuring the temperature along the bottom of the river along a transect).
- Characterize the identified upwelling/spring areas at a reconnaissance level to determine if the identified upwelling/spring areas using the methods outlined above are likely either to be (1) main flow/stage dependent, (2) regional/upland groundwater dependent, or (3) mixed influence.

7.5.4.3.1. Work Products

This component of the Groundwater Study will provide for the compilation, review and interpretation of the different mapping work products and will result in development of a GIS map layer depicting groundwater upwelling and influenced areas. Results will be provided in appropriate sections of the Initial Study Report. Information resulting from this study component will include the following:

- GIS map layer of upwelling and groundwater influenced areas.
- Analysis of the identified upwelling/spring areas to determine if they are (1) main flow/stage dependent, (2) regional/upland groundwater dependent, or (3) of mixed influence.

7.5.4.4. Riparian Vegetation Dependency on Groundwater / Surface Water Interactions

This study component is directly linked to the Riparian Instream Flow Study and associated with a number of other multidisciplinary resource studies that will be jointly working on the Focus Areas including the Fish and Aquatics Instream Flow Study (RSP- Section 8.5), Geomorphology Study (Section 6.5, Ice Processes Study (Section 7.6), and Water Quality Study (Section 5.5). Figure 7.5-3 shows the relationship between these studies and the Groundwater Study. The overall goal of this study component is to collect information and data to define GW/SW interactions and relationships to riparian community health and function at a number of Focus Area locations so results can be used to scale up to other locations in the river. These relationships will then allow for a determination of how Project operations may influence GW/SW interactions and the riparian communities at unmeasured areas.

This will be accomplished in part through development of physical groundwater models (Montgomery 1999) at Focus Areas applicable for evaluating riparian community structure. Physical models, including surface water hydraulic (1-D and 2-D), geomorphic reach analyses, GW/SW interactions, and ice processes will be integrated such that physical process controls of riparian vegetation recruitment and establishment can be quantitatively assessed (see Section 8.6) under both existing conditions and under different Project operations.

Empirical data will be collected at the Focus Areas to define GW/SW interactions. This will include the use of piezometers, stage recorders, thermographs, dissolved oxygen recorders and selected water quality meters (conductivity, pH, turbidity). These data will be collected along linear transect arrays of groundwater wells, piezometers, and stage gages. Wells will be placed to help describe the hydrologic conditions at internal boundaries (such as sloughs, side channels) and at varying distances from these boundaries to help measure the time lag in groundwater level response to changes in surface water stage. Well locations will take into account the riparian vegetation mapping units. Some wells will be placed at boundaries of the groundwater model simulation domains to provide model boundary input data, or validation data sets. Additional information, such as unfrozen volumetric soil moisture content and soil temperature profiles will be measured to help understand the characteristics of active freeze/thaw processes and moisture transfer from infiltration and underlying dynamic groundwater tables in the soil horizon critical to riparian root zones. Table 7.5-1 shows a listing of the data collection system sensors and measurements. The data will be used to quantify, and model, the relationship between floodplain shallow surface aquifers and floodplain plant community types.

Precipitation data will also be measured at the Focus Areas. Shielded summer precipitation gages will be installed in early spring 2013 in time for the 2013 summer season. This information will be compared with the recent update to the statewide precipitation evaluation and new index maps. Additionally, precipitation information collected by the Glacier and Runoff Changes Study (Section 7.7) will be incorporated into the precipitation analysis for the Focus Areas.

In groundwater wells and surface water measurement stations, the minimum recording interval for water levels, temperature, and other parameters will be 15 minutes. There will be some locations close to surface water sources where stage changes are expected to be rapid; for these areas, data collection intervals may be reduced down to one minute. In all cases, hourly maximum, minimum, and average values will be recorded, as well as daily statistics. The data collection intervals are intended to provide data for studying and understanding transient pressure pulses in the GW/SW systems and to provide both input and calibration data sets for groundwater model development and simulations goals. The current network of surface flow gaging stations started in the summer of 2012 will continue operation through 2014. Technical evaluations will be made in the summer of 2014 about which gaging stations need to be operated during Q4 2014 and Q1 2015. Groundwater monitoring programs will begin on a small scale in winter 2012-2013 and increase during the summer of 2013. The monitoring of groundwater wells will continue into 2014. At that time, a subset of the groundwater wells may be monitored for the winter of 2014-2015.

Monitoring wells will be surveyed with a combination of RTK survey methods and optical level loop methods. This will be done at least two times a year, or more frequently if well movements are recorded. Pressure transducer measurements will be verified with manual measurements at least monthly during summer months, and three to four times during winter periods. Both calibration (for determining offsets) and verification water levels will be collected. Calibration checks will be performed on conductivity and temperature sensors before field installations, and field calibration checks will be performed monthly during summer months. Calibration checks during winter months will be performed at least once during the mid-winter period when safe access and weather conditions allow, and before spring break-up and fall freeze-up.

The Groundwater Study will provide a time series of measured and simulated groundwater levels and will provide summary statistics needed for developing plant-response curves (see Riparian Instream Flow Study, Section 8.6). The groundwater and surface water field measurements for continuously monitored stations will be 15 minutes or less. Model simulations will also be 15 minutes or less, based on analysis of modeling results. This information will produce time series data sets from which water level summary statistics can be calculated for a range of analysis objectives, such as running averages in hourly and daily increments.

Where appropriate, MODFLOW (Feinstein et al. 2012; Maddock et al. 2012; USGS 2005, 2012) GW/SW interaction models of floodplain shallow alluvial aquifer and surface water relationships will be developed. The selection of MODFLOW modeling package will utilize ASTM D6170 “Standard Guide for Selecting a Groundwater Modeling Code” as the guideline for documenting the code selection process (ASTM 2010b). MODFLOW GW/SW interaction models will be used to model GW/SW relationships using empirical monitoring data collected at the Focus Areas. Similar approaches to understanding GW/SW interactions have been reported in Nakanishi and Lilly 1998. ASTM standard D6170 will also be used to help determine the model code and approach used for analysis (ASTM 2008b). ASTM standard D5981 will be used to help develop calibration goals and procedures for groundwater modeling efforts (ASTM 2008c). Both generic and interpretative models will be used to help improve process understanding and design of data collection field programs, and for developing the framework for predictive models that will simulate Project effects. The application of snowmelt and precipitation runoff stage-change events will be used to develop and calibrate groundwater models, and independent hydrologic events will be used to validate the models. Thus, a year with snowmelt peak and three precipitation peaks may provide three peaks for model development and calibration and one event to validate the model simulation capabilities. Figure 7.5-4 illustrates the use of snowmelt or precipitation peaks for collection of data for hydrologic model (surface and groundwater) development, calibration, and validation. The daily discharge for the last three years is shown to illustrate how future hydrologic data will be used with the modeling development planned for the study. Data from the 2013–2014 study periods will be used to provide information similar to that provided for the period of record shown in the figure. The interaction between the river stage changing and adjacent groundwater is shown in Figure 7.5-5. An example of GW/SW interactions is shown in Figure 7.5-6 for the Chena River and a line of adjacent wells installed at varying distances from the river up to 8,800 feet away (Nakanishi and Lilly 1998). The Chena River stage is shown on the left, with groundwater levels show for wells that are increasing distances away from the Chena River. The spring snowmelt peal and two primary precipitation peaks in the Chena River can be seen in each of the groundwater hydrographs shown. The pressure response to the river stage changes is illustrated by each of the groundwater hydrographs. The three main stage peaks on the Chena River are shown in each well out to the farthest well 8,800 feet away. Figure 7.5-7 illustrates the application of river and groundwater levels being used as boundary conditions for a two-dimensional groundwater flow model.

Example groundwater, surface-water, and meteorological data collection networks for a typical Focus Area is shown in Figure 7.5-8. This figure illustrates wells placed along transect locations, along surface-water hydrologic boundaries, and various riparian zones. The same approach will be used for the Fish and Aquatics Instream Flow Study as displayed in Figure 7.5-9.

7.5.4.4.1. Work Products

This component of the Groundwater Study will provide for the installation, data collection efforts and analysis of the GW/SW interactions and will support the Riparian Instream Flow Study (Section 8.6). Results will be provided in the Initial Study Report, to be filed with FERC February 2014. The study component will result in the following work products:

- Data collection networks and stations metadata, including data collection standards and methods, wiring diagrams, programs, horizontal and vertical survey control network data.
- Groundwater, surface water, meteorological, geotechnical (soil temperature, soil moisture) data sets.
- Groundwater modeling archived flow models, model input and calibration data sets and files, groundwater model documentation.

7.5.4.5. Aquatic Habitat Groundwater / Surface- Water Interactions

The same general approach as described above for the riparian component will be used for evaluating GW/SW interactions within aquatic habitats as part of the Fish and Aquatics Instream Flow Study (Section 8.5) (see Figure 7.5-9). Hydraulic unsteady flow routing will help identify water surface elevations. The mainstem flow routing model will serve to predict water surface elevations under different flow conditions longitudinally throughout the length of the river below the Watana Dam site (RM 184). The model will thus be able to predict water surface elevations (WSEs) proximal to the Focus Areas noted above, as well as other areas identified as being groundwater-influenced. The WSEs empirically measured in side channels, sloughs, and groundwater wells installed in the floodplain at the Focus Areas can therefore be related to mainstem WSEs, allowing for a detailed analysis of spatial and temporal changes in WSE under different operating conditions, including base load and load-following scenarios.

Habitat Suitability Criteria (HSC) and a Habitat Suitability Index (HSI) will be developed that include groundwater-related parameters (upwelling/downwelling). Development of HSC and HSI will follow the general procedures outlined in the Fish and Aquatics Instream Flow Study (Section 8.5). Parameters specific to groundwater that will be measured, where appropriate, include turbidity, evidence of upwelling/downwelling currents, substrate characteristics, and water temperature. Other parameters may also be included. These parameters will be incorporated into the development of HSC type curves that reflect utilization of these parameters by fish. This work will be closely coordinated with the fish studies (Section 9).

Mainstem, side channel, slough habitat models will be developed that incorporate GW/SW related processes (main channel head, upwelling/downwelling) (see Figure 8.5-3 in Section 8.5, Fish and Aquatics Instream Flow Study). An integral part of the Fish and Aquatics Instream

Flow Study will be development of habitat-specific models that can be used in evaluating flow (and WSE) relationships between the mainstem river and other habitat types (including those influenced by groundwater) under different operational scenarios. These types of models (e.g., flow routing) are generally described in more detail in the Fish and Aquatics Instream Flow Study (see Section 8.5).

The groundwater aquatics study is coordinating with both instream flow and fisheries studies on the selection of Focus Areas. The groundwater study will be measuring both horizontal and vertical head gradients through combinations of nested wells installed at different depths and shallow wells installed in surface water habitat areas to measure the gradients between surface water sources and underlying groundwater conditions. Details on the measurement of fluxes are described in Section 7.4.5. These gradients will be compared with simulated gradients from groundwater/surface water models under the field conditions measured in 2013 and 2014 and compared with Project operation scenarios. Example groundwater, surface-water, and meteorological data collection networks for a typical Focus Area is shown in Figure 7.5-9. This figure illustrated wells placed along transect locations, along surface-water hydrologic boundaries, and various riparian zones. The same approach will be used for evaluating aquatic habitats within Focus Areas, with less of a focus on riparian zones and more on surface-water habitat (main channel, side channel, side slough, upload slough) features. The application of 3D and 2D groundwater flow models is illustrated in this same example in Figure 7.5-10. This figure also shows the addition of several wells to provide water-level information for boundary conditions at several of the groundwater model boundaries. Figure 7.5-11 illustrates some of the interaction that may take place between groundwater and surface water. The top figure shows a typical cross across the floodplain, main channel, side channel or slough and island. Example fluctuation surface water levels and groundwater tables are illustrated. The fluctuations driven by river station during the summer will be transient and vary each year. The lower portion of the figure shows how the Susitna River at Gold Creek stage has varied between 2005 and 2009. These fluctuations in stage will create fluctuations in water table levels which can be used to help define geohydrologic properties. This example illustrates a number of concepts that will be applied to all of the geohydrologic cross-sections and resulting data stations supporting the riparian and aquatic analysis efforts.

The Groundwater Study will be responsible for the coordination and collection of information, analysis and reporting of final deliverables for this study element.

7.5.4.5.1. Work Products

This component of the Groundwater Study will provide for the installation, data collection efforts and analysis of the GW/SW interaction important for support of the Fish and Aquatic Instream Flow Study (Section 8.5). Results will be provided in the Initial Study Report, to be filed with FERC in February 2014. Information provided will include the following:

- Data collection networks and stations metadata, including data collection standards and methods, wiring diagrams, programs, horizontal and vertical survey control network data, well logs.
- Groundwater, surface water, meteorological, geotechnical (soil temperature, soil moisture) data sets.

- Groundwater modeling archived flow models, model input and calibration data sets and files, groundwater model documentation.

7.5.4.6. Water Quality in Selected Habitats

Water quality characteristics are likely to vary with GW/SW interactions and potential impacts due to proposed Project operations. Project water quality activities will be coordinated with the Riparian Instream Flow Study (Section 8.6), Geomorphology studies (Sections 6.5 and 6.6), and Fish and Aquatics Instream Flow Study (Section 8.5). The work under this objective will be accomplished by the Baseline Water Quality Study (Section 5.5). The following methods will be used in coordination with the indicated studies to understand water quality characteristics and the variation between groundwater and surface water. This will help evaluate the potential changes in water quality related to GW/SW interactions and potential impacts related to proposed Project operations.

At selected instream flow, fish population, and riparian study sites, basic water chemistry (temperature, DO, conductivity, pH, turbidity, redox potential) data will be collected that define habitat conditions and characterize GW/SW interactions (Section 5.5). For example, where possible, differences between groundwater representative of regional groundwater conditions, groundwater in the mixing zone at the GW/SW interface (slough or river bed), and surface water sources (sloughs and side channels) will be characterized.

Water quality differences will be characterized between a set of key productive aquatic habitat types (three to five sites) and a set of non-productive habitat types (three to five sites) that are related to the absence or presence of groundwater upwelling to improve the understanding of the water quality differences and related GW/SW processes. For example, results from fish population and habitat studies (Sections 9.6 and 9.9) will be used and coordinated with the Fish and Aquatics Instream Flow Study (Section 8.5) to select paired productive and non-productive habitats.

7.5.4.6.1. Work Products

This component of the Groundwater Study will provide for the installation, data collection efforts and analysis of the GW/SW - waterquality interactions important for support of the Fish and Aquatic Instream Flow Study (Section 8.5). Results will be provided in the Initial Study Report, to be filed with FERC February 2014. Information provided will include the following:

- Data collection networks and stations metadata, including data collection standards and methods, wiring diagrams, programs, horizontal and vertical survey control network data, well logs.
- Groundwater, surface water, meteorological, geotechnical (streambed temperature) data sets, including water quality meter and sensor calibration and calibration validation data and forms.
- Groundwater modeling archived flow models, model input and calibration data sets and files, groundwater model documentation.

- Water quality differences between a set of key productive aquatic habitat types (three to five sites) and a set of non-productive habitat types (three to five sites) that are related to the absence or presence of groundwater upwelling.

7.5.4.7. Winter Groundwater / Surface Water Interactions

Winter GW/SW interactions are critical to aquatic habitat functions. Proposed Project operations will have an impact on the winter flow conditions of the mainstem and side channels and sloughs. The collection of hydrologic conditions (i.e., water levels, discharge, ice conditions) is critical to understanding current winter flow conditions and evaluating the potential impacts of Project operations.

Water levels/pressure will be measured at the continuous gaging stations on the Susitna River during winter flow periods. Continuous gaging stations will be measuring water levels and temperature as part of the instream flow studies. Water levels measured during full ice cover are generally referred to as water pressure and represent the hydrostatic head of the river. The Project is expected to increase average monthly flows in the Susitna River during the winter months, and this may have an impact on GW/SW interactions during that season.

Winter discharge measurements will help identify key sections of the mainstem with groundwater baseflow recharge to the river (upwelling). Winter discharge will be measured as part of the instream flow study (Section 8.5) and in coordination with U.S. Geological Survey (USGS) winter measurement efforts at USGS gaging stations to identify winter gaining and losing reaches. These field activities will be closely coordinated with the Ice Processes Study (Section 7.6).

In Focus Areas, channel/slough temperature profiles will be measured to help characterize the GW/SW interactions and temporal variations over the winter flow season.

The Groundwater Study will be responsible for the coordination and collection of information, analysis and reporting of final deliverables for this study element.

7.5.4.7.1. Work Products

This component of the Groundwater Study will provide for the data collection efforts and analysis of the winter GW/SW interactions important for support of the Fish and Aquatic Instream Flow Study (see Section 8.5). Results will be provided in the Initial Study Report, to be filed with FERC February 2014. Information provided will include the following:

- Groundwater, surface water, meteorological, geotechmical (streambed temperature,) data sets, including water quality meter and sensor calibration and calibration validation data and forms.

7.5.4.8. Shallow Groundwater Users

There are a number of groundwater wells located in the Susitna River floodplain that have demonstrated the interconnections between groundwater and surface water. The influence of proposed Project operations could change water levels and water quality in water supply wells. A majority of the wells are expected to be private homeowner wells. The methods listed below will be used to evaluate the potential impacts of the Project on water supply wells in the area under potential impact by the Project:

- The Alaska Department of Natural Resources Well Log Tracking System (WELTS) and the USGS Groundwater Site Inventory (GWSI) Database will be used to map domestic and other water supply wells along the Susitna River downstream of the proposed Watana Reservoir.
- At a reconnaissance level, wells will be stratified by potential to be affected by the Susitna River flow regime (high, medium, and low) using factors such as depth and proximity to the Susitna River. A small number of representative wells will be selected with high potential to be affected by the Susitna River flow regime and well levels and river stage will be monitored. River stage information will come from correlations with the gaging stations measuring water levels that are part of the instream flow studies.
- Based on the results from the well monitoring and an analysis of potential Project operations flow data, the potential effects of the Project will be determined on shallow groundwater wells and it will be determined if additional monitoring of wells may be appropriate. ASTM method D6030 will be used to help address groundwater vulnerability (ASTM 2008a).
- The data from this study element will also be used for the other study elements, where appropriate, to help extend the application of the data and analysis regarding shallow groundwater well users to other Groundwater Study objectives.

The Groundwater Study will be responsible for the coordination and collection of information, analysis and reporting of final deliverables for this study element.

7.5.4.8.1. Work Products

This component of the Groundwater Study will provide for the installation, data collection efforts and analysis of the GW/SW interaction important for private groundwater well users. Results will be provided in the Initial Study Report, to be filed with FERC February 2014. Information provided will include the following:

- Data collection stations metadata, including data collection standards and methods, wiring diagrams, programs, horizontal and vertical survey control network data, well logs.
- Groundwater and surface water data sets.

7.5.5. Consistency with Generally Accepted Scientific Practice

The proposed study methodology was cooperatively developed with the assistance of science and technical experts from state and federal management agencies. Many of these technical experts have experience in multiple FERC licensing and relicensing proceedings. The methods for data collection, data analysis, modeling, and interpretation are consistent with common scientific and professional practices. ASTM and USGS standards and practices will be used with each study component, as applicable. The scope of each of the studies is consistent with common approaches used for other FERC proceedings and reference specific protocols and survey methodologies, as appropriate.

7.5.6. Schedule

The groundwater study will occur during the 2013 and 2014 study period (Table 7.5-2). Coordination with other studies will occur throughout the licensing period (Figures 7.5-3, 7.5-4, 7.5-5). The collection of information for the existing data synthesis will be initiated at the beginning of the study period and be completed by the end of summer 2013. The definition and development of geohydrologic process domains and terrains will take place in the same time period to help guide other study design and field efforts during the summer of 2013.

Winter focus studies will begin with existing data collection activities started in 2012 and increase with the installation of data collection systems in study sites in early summer 2013. Data from water quality, instream flow, and other studies will be provided after data quality assurance review has been completed, normally within a month of data collection in the field. Coordination with each of the associated studies providing data will occur at the beginning of the study period and be part of the schedules for each study. The Initial Study Report and the Updated Study Report will be issued February 2014 and February 2015, respectively. Updates on study progress will be presented at Technical Workgroup meetings, to be held quarterly during 2013 and 2014.

7.5.7. Relationship to Other Studies

The Groundwater Study is designed to interact and support a number of other studies. It is providing data, references, process understanding on groundwater/surface-water interactions to help determine the potential effects of Project operations on various natural resources, such as riparian and aquatic, and the public, primarily for shallow groundwater well users. The following sections describe the relationship of each study element to other environmental and engineering studies. Some of the study elements also support other Groundwater Study elements.

7.5.7.1. Existing Data Synthesis

The existing data synthesis will coordinate and use data from other studies, such as Geology and Soils Characterization (Section 4.5), Baseline Water Quality Study (Section 5.5), Geomorphology (Section 6.5), Fish and Aquatics Instream Flow Study (Section 8.5), and Riparian Instream Flow Study (Section 8.6) but will not be dependent on the other studies as the primary focus of the synthesis is geohydrology information. The synthesis will coordinate with the major library networks (ARLIS and UAF Geophysical Institute Library), the Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys, and USGS information sources and information specialists. The products of this study element can be used by all study groups as needed, but are designed primarily to support the additional Groundwater Study objectives. These independencies are illustrated in Figure 7.5-3.

7.5.7.2. Geohydrologic Process-Domains and Terrain

The geohydrologic process domain study element will primarily obtain its data from sources found in the data synthesis and statewide data sources at Alaska Department of Natural Resources and UAF-GINA (Figure 7.5-3). The products generated for this study element will be available to all studies, but will primarily be needed by Fish and Aquatics Instream Flow Study (Section 8.5), and Riparian Instream Flow Study (Section 8.6).

7.5.7.3. Watana Dam/Reservoir

The study objectives for the proposed Watana Dam area will require coordination with the Engineering Feasibility Studies (ongoing) Geotechnical Investigation Program and the Geology and Soils Characterization Study (Section 4.5) (Figure 7.5-3). The study will coordinate any data collection activities with these two projects. Geotechnical drilling and potential well installations will be under the engineering studies. The products from this study element will be available to all studies, but no studies have specific dependencies on the information. The information will support the general assessments of aquatic habitat and potential Project effects.

7.5.7.4. Upwelling / Springs Broad-Scale Mapping

This study element has specific dependencies on Baseline Water Quality Study (Section 5.5), Ice Processes Study (Section 7.6) and Fish and the Aquatics Instream Flow Study (Section 8.5) (Figure 7.5-3). The Groundwater Study will use the observations of open leads, water quality (temperature, conductivity), thermal imaging, winter discharge measurements, hydrologic data collection network data for the broad-scale mapping of the groundwater discharge (upwelling) areas. This information will primarily be used by Fish and Aquatics Instream Flow Study (Section 8.5), and Riparian Instream Flow Study (Section 8.6) for habitat assessment and upscaling of Focus Area studies to unmeasured sites (see Section 8.5.4.7).

7.5.7.5. Riparian Vegetation Dependency on Groundwater / Surface Water Interactions

This study element will have a number of active dependencies to other projects, primarily to the Riparian Instream Flow Study (Section 8.6) (Figure 7.5-3). Other important studies providing data input to this study element are Baseline Water Quality Study (Section 5.5), Geomorphology (Section 6.5), Fluvial Geomorphology Modeling Below Watana Dam Study (Section 6.6), Ice Processes Study (Section 7.6), and Fish and Aquatics Instream Flow Study (Section 8.5). Coordination with the Riparian Instream Flow Study will be ongoing, with data collection and analysis activities conducted jointly by both studies. Riparian study leads will provide priorities and input to the groundwater leads throughout the project. The primary user of the products from this study element is the Riparian Instream Flow Study (Section 8.6).

7.5.7.6. Aquatic Habitat Groundwater / Surface Water Interactions

This study element will have a number of active dependencies to other projects, primarily to the Fish and Aquatics Instream Flow Study (Section 8.5) (Figure 7.5-3). Other important studies providing data input to this study element are Baseline Water Quality Study (Section 5.5), Geomorphology (Section 6.5), Fluvial Geomorphology Modeling Below Watana Dam Study (Section 6.6), Ice Processes Study (Section 7.6), and Riparian Instream Flow Study (Section 8.6). Coordination with the Fish and Aquatics Instream Flow Study will be ongoing, with data collection and analysis activities conducted jointly by both studies. Aquatics study leads will provide priorities and input to the groundwater leads throughout the Project. This study element will closely coordinate between the riparian and aquatics studies on activities in the Focus Areas where data collection networks will be optimized to serve the objectives of both studies and limit unneeded duplication. The primary user of the products from this study element is the Fish and Aquatics Instream Flow Study (Section 8.5).

7.5.7.7. Water Quality in Selected Habitats

This study element will have a number of active dependencies to other projects, primarily to the Baseline Water Quality Study (Section 5.5) and Fish and Aquatics Instream Flow Study (Section 8.5) and the Study of Fish Distribution and Abundance in the Middle and Lower Sustina River (Section 9.6) (Figure 7.5-3). Coordination with the Fish and Aquatics Instream Flow Study will be ongoing, with data collection and analysis activities conducted jointly by both studies. Aquatics study leads will provide priorities and input to the groundwater leads throughout the Project. This study element will closely coordinate between the chemistry and aquatics studies on activities in the Focus Areas where data collection networks will be optimized to serve the objectives of both studies and limit unneeded duplication. The primary user of the products from this study element is the Fish and Aquatics Instream Flow Study study (Section 8.5).

7.5.7.8. Winter Groundwater / Surface Water Interactions

This study element will have a number of active dependencies to other studies, primarily to the Fish and Aquatics Instream Flow Study (Section 8.5) (Figure 7.5-3) and Ice Processes Study (Section 7.6). This study element will also involve coordination with USGS winter data collection efforts. Coordination with the Fish and Aquatics Instream Flow Study will be ongoing, with data collection and analysis activities conducted jointly by both studies. Aquatics study leads will provide priorities and input to the groundwater leads throughout the Project. The primary user of the products from this study element is the Fish and Aquatics Instream Flow Study (Section 8.5) and the Riparian Instream Flow Study (Section 8.6).

7.5.7.9. Shallow Groundwater Users

This study element will coordinate with Alaska Department of Natural Resources (ADNR) for identifying shallow groundwater well users. The ADNR-WELTS database and USGS GWSI database will be used to help identify the number of shallow groundwater well users and technical details of the wells and water use (Figure 7.5-3). The products from this study element will also be used to help in the analysis objectives for other Groundwater Study elements.

7.5.8. Level of Effort and Cost

The level of effort for the groundwater study objectives is distributed in this and other studies. The groundwater study costs reflect the analysis of data collected in this and other studies. The study objectives and associated primary costs associated with each objective for the 2013–2014 study period are as follows:

- 7.5.4.1 – Existing Data Synthesis
  - Groundwater Study
- 7.5.4.2 – Geohydrologic Process-Domains and Terrain
  - Groundwater Study

- 7.5.4.3 – Watana Dam/Reservoir
  - Groundwater Study–analysis only
  - Engineering, Geology (Section 4.5), Geomorphology (Sections 6.5, 6.6) studies include field and data collection costs
- 7.5.4.4 – Upwelling / Springs Broad-Scale Mapping
  - Groundwater Study–analysis only
  - Ice Processes (Section 7.6), Geomorphology (Sections 6.5, 6.6), Instream Flow (Section 8.5), and Water Quality (Sections 5.5, 5.6) studies include field and data collection costs
- 7.5.4.5 – Riparian Vegetation Dependency on Groundwater / Surface Water Interactions
  - Groundwater Study–field installation of groundwater wells and data collection stations and instrumentation, coordination, and analysis
  - Riparian Instream Flow Study (Section 8.6) includes field and data collection costs
- 7.5.4.6 – Fish Habitat Groundwater / Surface Water Interactions
  - Groundwater Study – field installation of groundwater wells and data collection stations and instrumentation in combination with Fish and Aquatics Instream Flow Study (Section 8.5), coordination and analysis
  - Fish and Aquatics Instream Flow Study (Section 8.5) also includes field and data collection costs
- 7.5.4.7 – Water Quality in Selected Habitats
  - Groundwater Study–coordination and analysis only, some sensors in coordination with riparian and instream flow study elements
  - Water Quality (Sections 5.5, 5.6), Fish and Aquatics Instream Flow (Section 8.5) studies include field and data collection costs
- 7.5.4.8 – Winter Groundwater / Surface Water Interactions
  - Groundwater Study–field data collection, coordination and analysis
  - Fish and Aquatics Instream Flow Study (Section 8.5) also includes some field and data collection costs
- 7.5.4.9 – Shallow Groundwater Users
  - Groundwater Study

The groundwater study costs are estimated to be about $2,000,000 beyond the data collection costs allocated throughout the studies mentioned above. The final cost will be determined by the final number of Focus Areas that are selected and included in the riparian and instream flow studies. The instrumentation, wells installation, and analysis could be $250,000 depending on the scale of each site.

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7.5.10. Tables

Table 7.5-1. Data collection parameters and associated sensors that will be used for the Groundwater Studyat selected Focus Areas.

Process	Parameter	Sensor Type
Surface-water stage fluctuation	Pressure – calculated water levels	CSI CS 450 Pressure transducer
Groundwater stage fluctuation	Pressure – calculated water levels	CSI CS 450 Pressure transducer
Active-layer freezing and thawing	Resistance – calculated temperature	GWS-YSI Vertical thermistor strings
Active-layer freezing and thawing, Moisture availability	Unfrozen volumetric moisture content (%)	CSI CS616 Soil-moisture sensors
Evapotranspiration	Air temperature, Relative Humidity	CSI HC2S3 AT/RH sensor
Evapotranspiration	Wind Speed, Direction	RM Yound 05103 WS/WD sensor
Evapotranspiration	Radiation	CMP3 – Kipp & Zonen Pyranometer
Evapotranspiration	Soil-surface temperature	GWS-YSI Thermistor
Evapotranspiration	Precipitation	TI 525-US Tipping bucket rain gage
Plant transpiration	Delta-Temperature	DI – Dynagage and TDP sensors and sap flow algorithms

Notes:

1 Campbell Scientific Inc., CSI; Dynomax Inc., DI; Texas Instruments, TI, GW Scientific, GWS.

Table 7.5-2. Schedule for implementation of the Groundwater Study.

Activity	2012		2013				2014				2015
	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q
7.5.4.1 Existing Data Synthesis			—	—	—	—					
7.5.4.2 Geohydrology Process-Domains and Terrain			—	—	—	—					
7.5.4.3 Watana Dam/Reservoir					—	—	—	—	—	—	
7.5.4.4 Upwelling/Springs Broad-Scale Mapping				—	—	—	—	—	—	—	
7.5.4.5 Riparian Vegetation Dependency on SW/GW Interactions			—	—	—	—	—	—	—	—	
7.5.4.6 Aquatic Habitat GW/SW Interactions		—	—	—	—	—	—	—	—	—	
7.5.4.7 Water Quality in Selected Habitats		—	—	—	—	—	—	—	—	—	
7.5.4.8 Winter GW/SW Interactions		—	—	—		—	—	—			
7.5.4.9 Shallow Groundwater Users			—	—	—	—	—	—	—	—	
Initial Study Report /Updated Study Report							Δ				▲

Legend:
- —— Planned Activity
- Δ Initial Study Report
- ▲ Updated Study Report

7.5.11. Figures

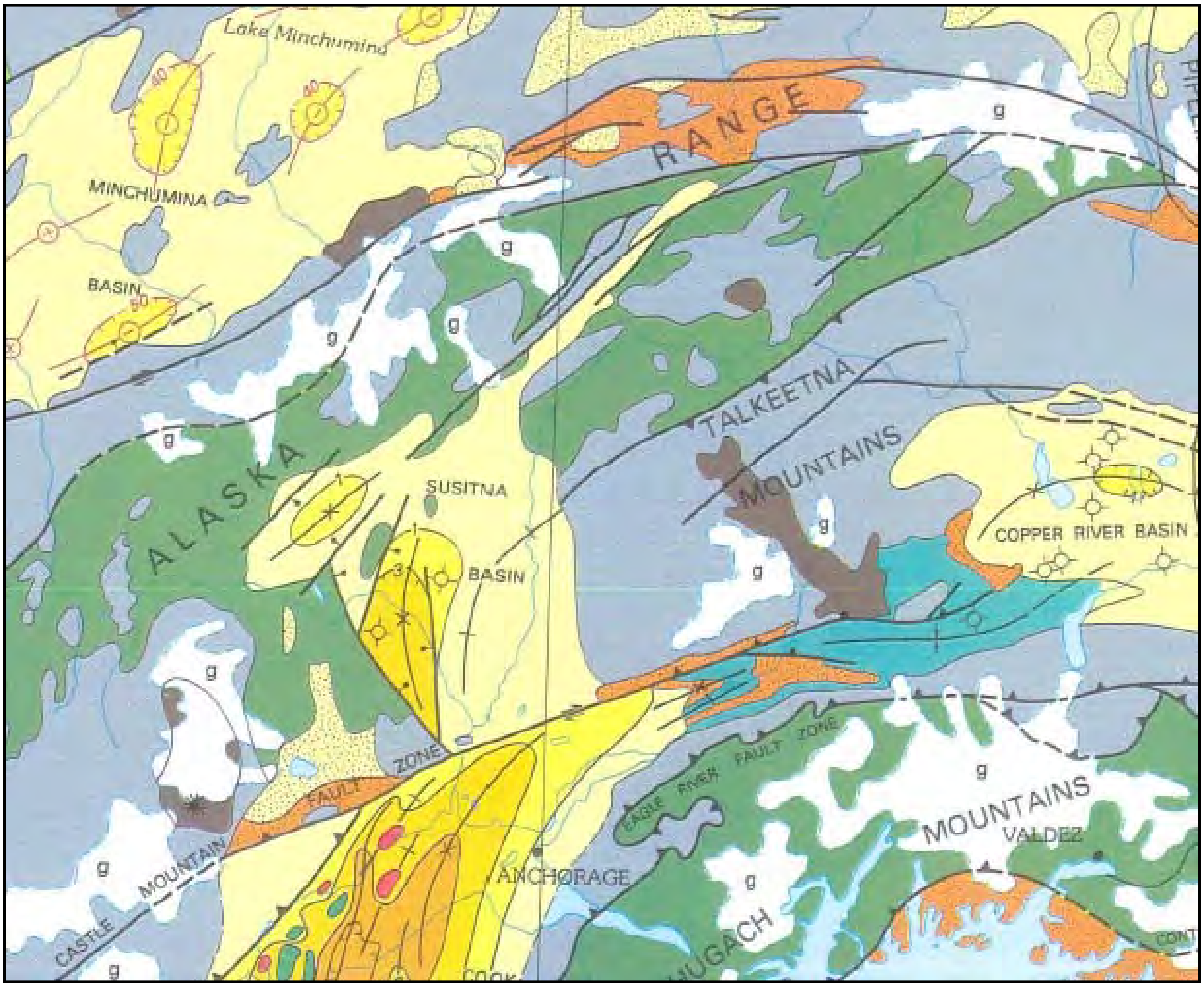


Figure 7.5-1. Sedimentary basins and geologic structure in the Susitna watershed (modified from Kirschner 1994).

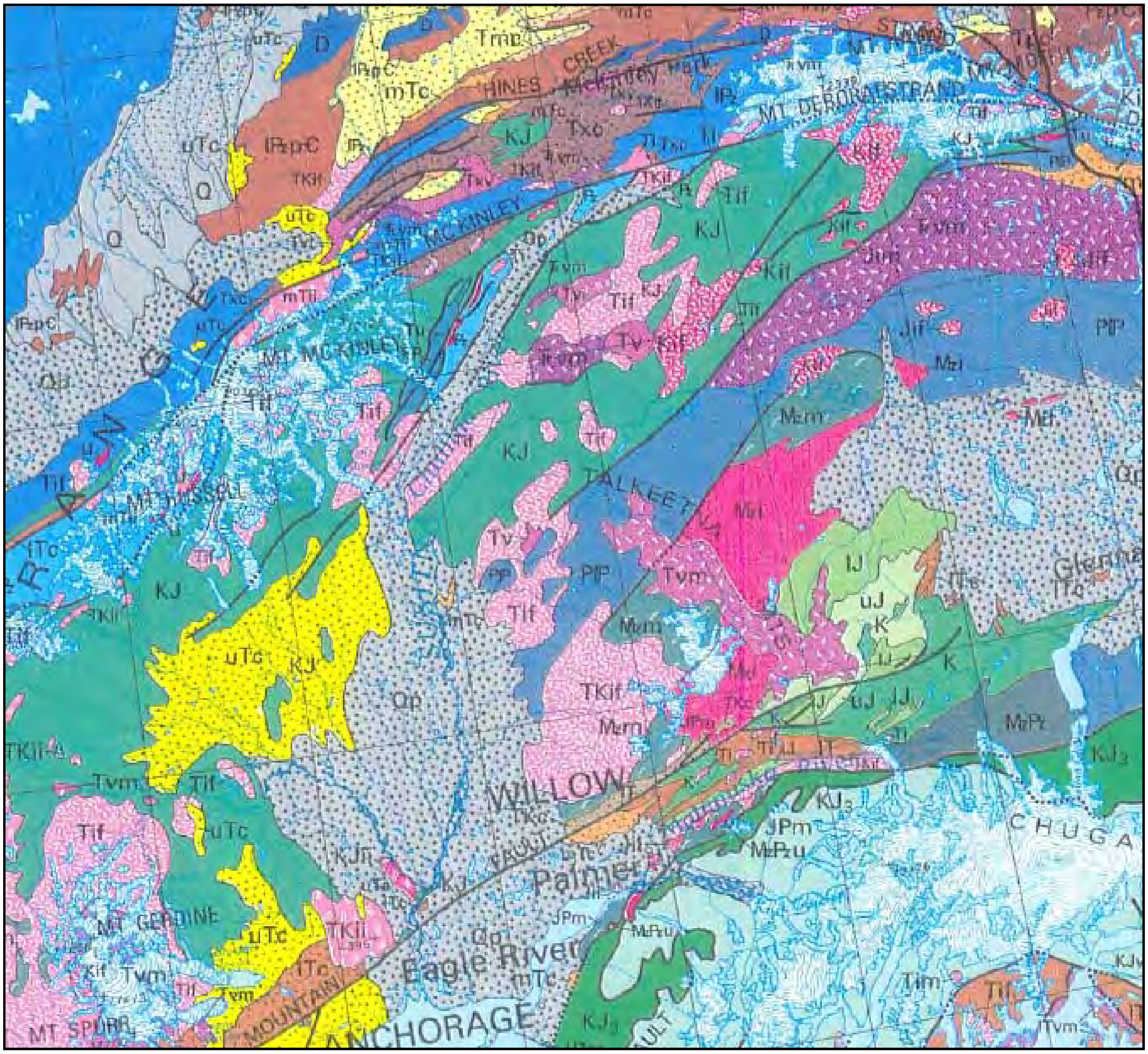


Figure 7.5-2. Geologic units in the Susitna watershed (modified from Beikman 1994).

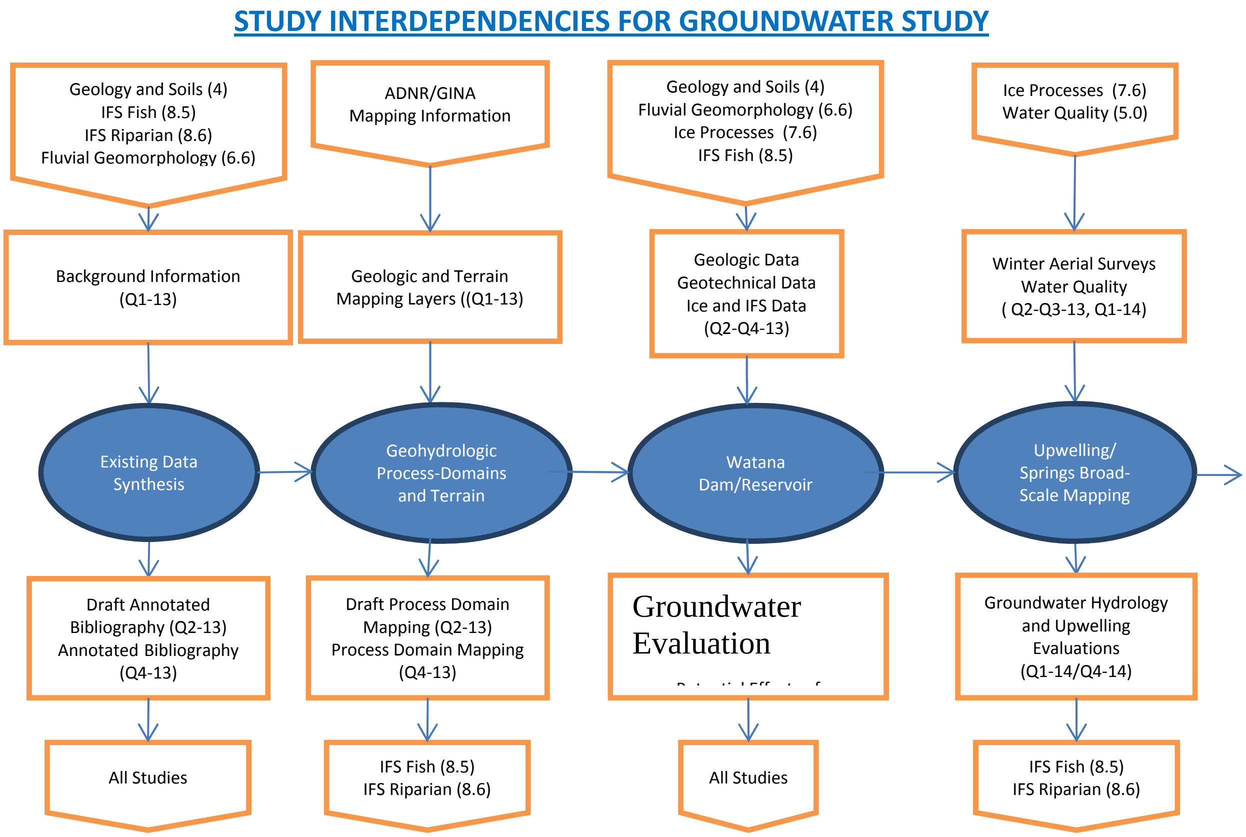


Figure 7.5-3. Study interdependencies for the Groundwater Study.

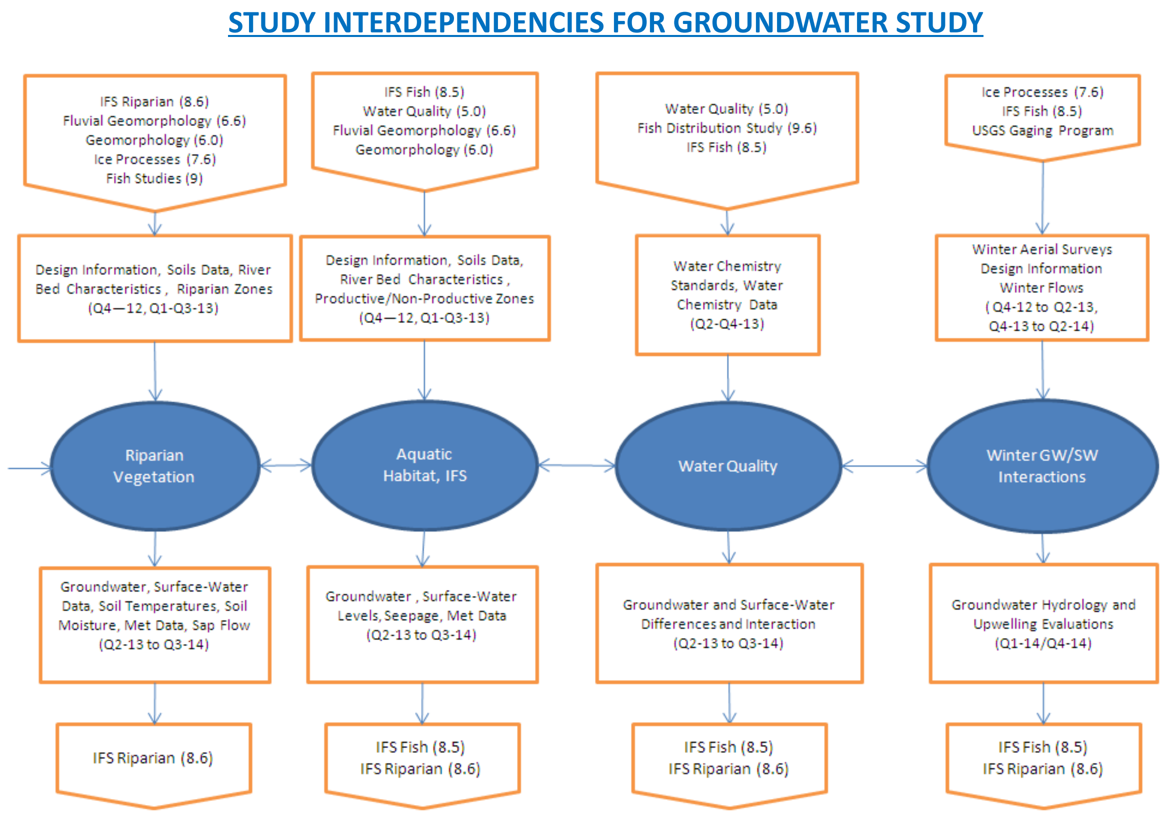


Figure 7.5-3. Study interdependencies for the Groundwater Study (continued).

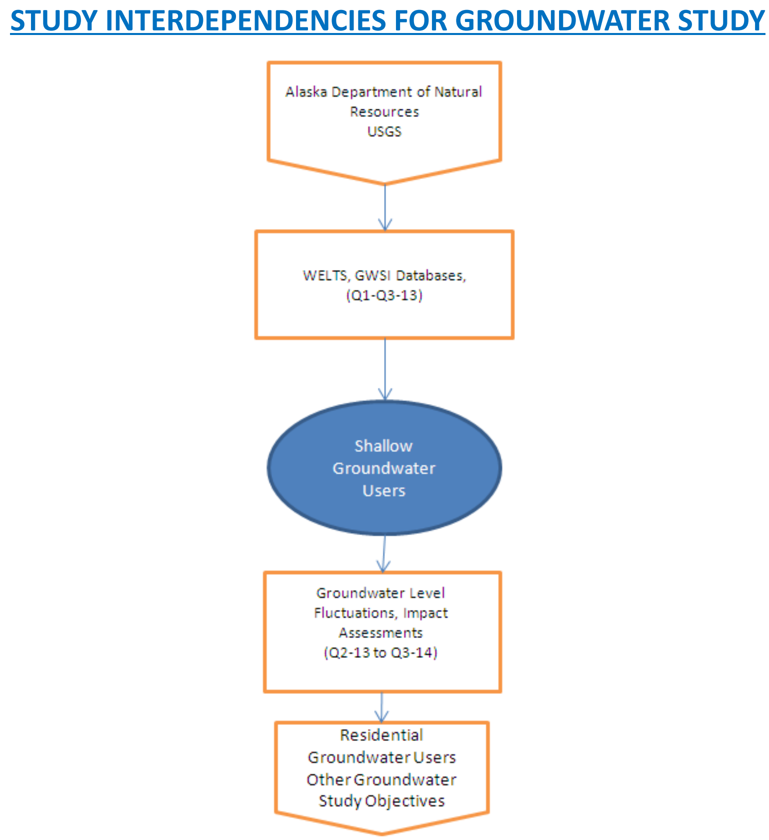


Figure 7.5-3. Study interdependencies for the Groundwater Study (continued).

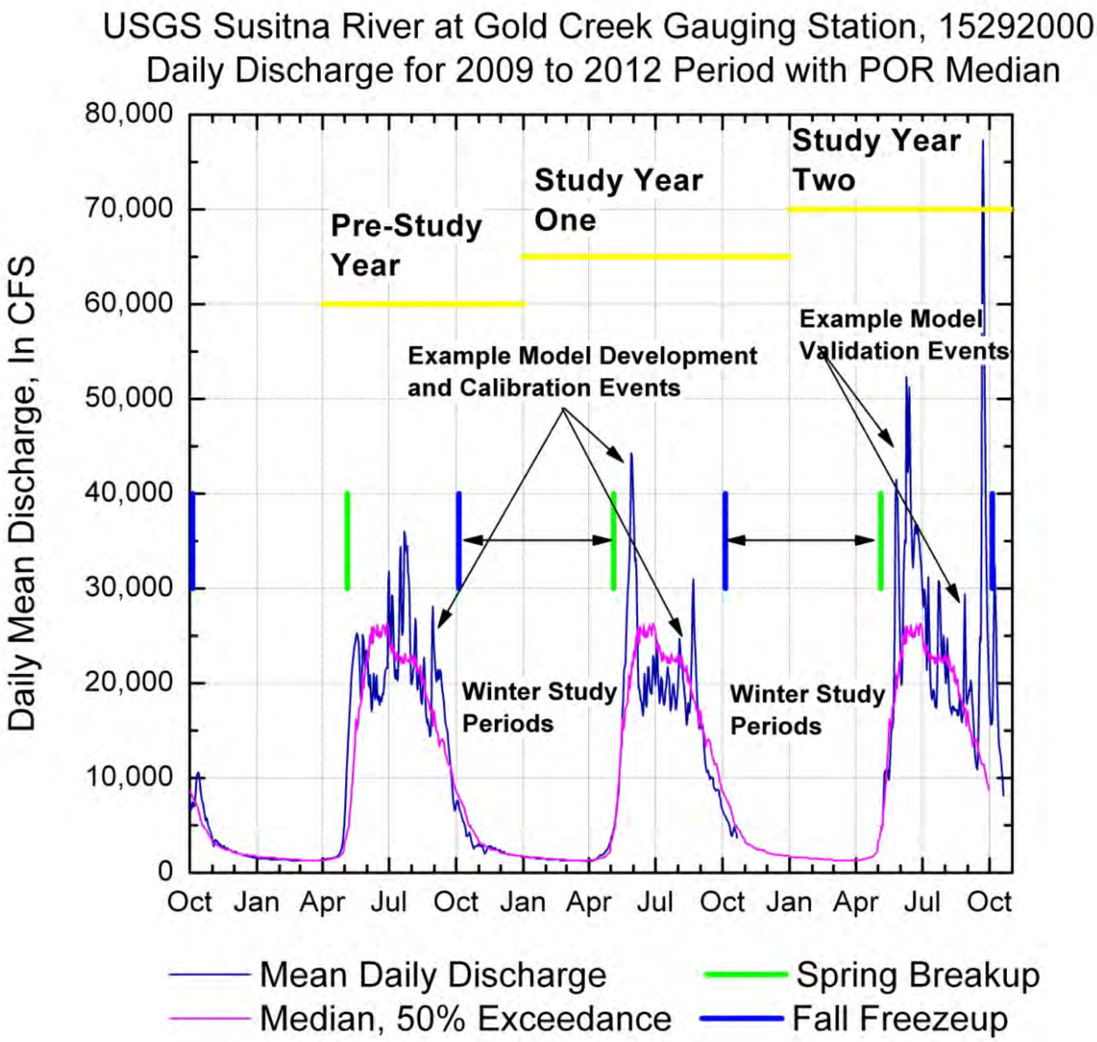


Figure 7.5-4. Discharge hydrograph and analysis examples for the Susitna River at Gold Creek.

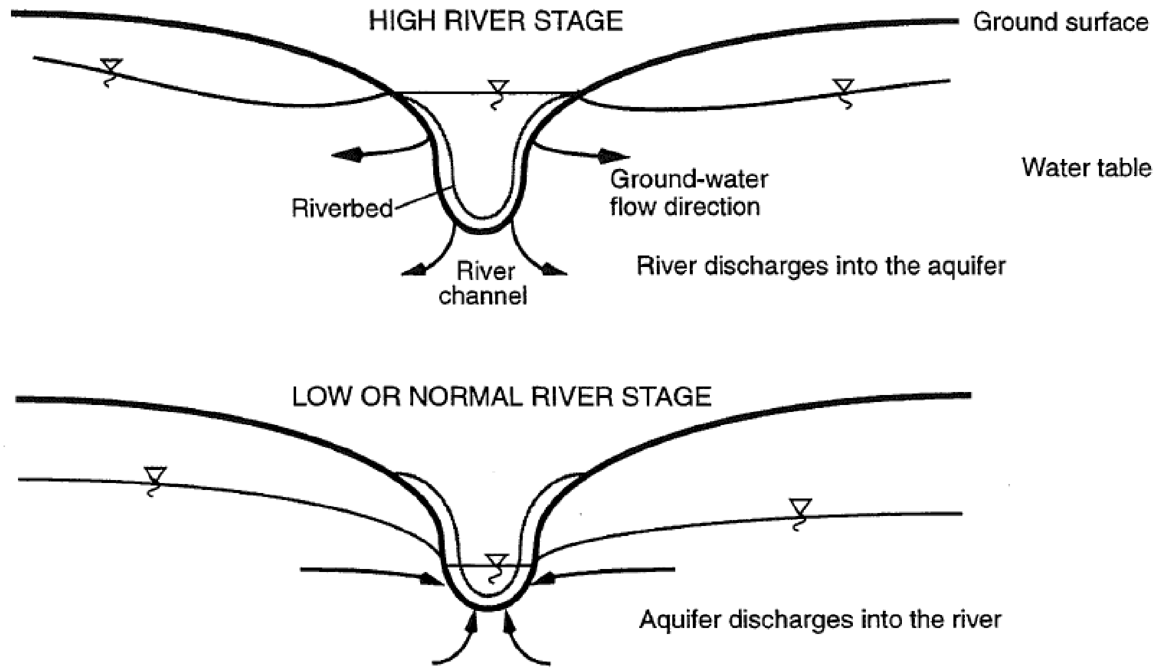


Figure 7.5-5. Illustration of groundwater and surface-water interactions with changing stage levels.

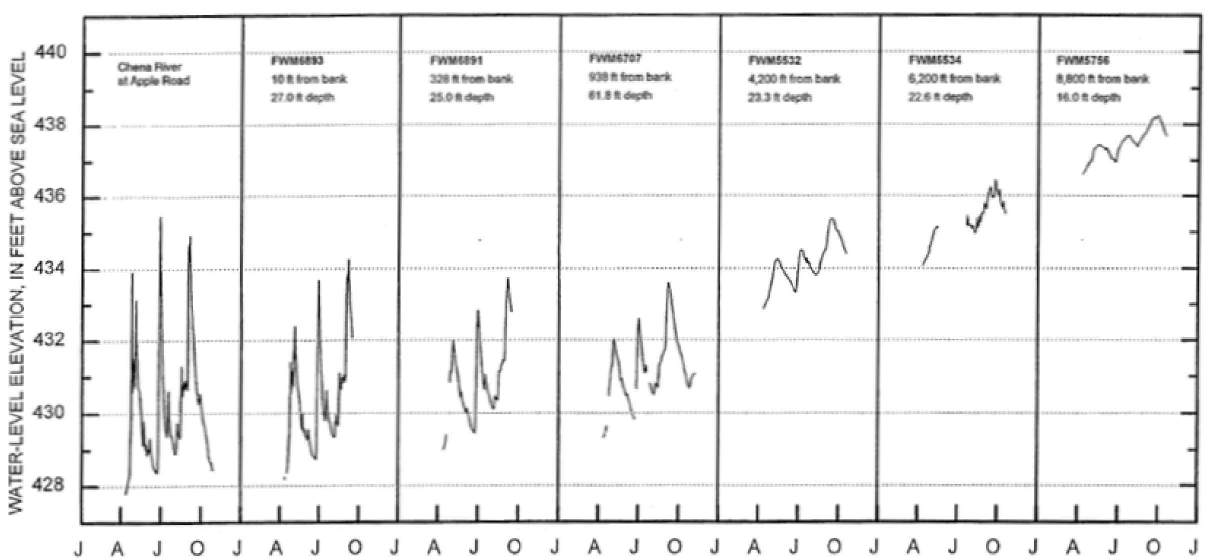


Figure 7.5-6. Groundwater responses to stage changes in the Chena River (Nakanishi and Lilly 1998).

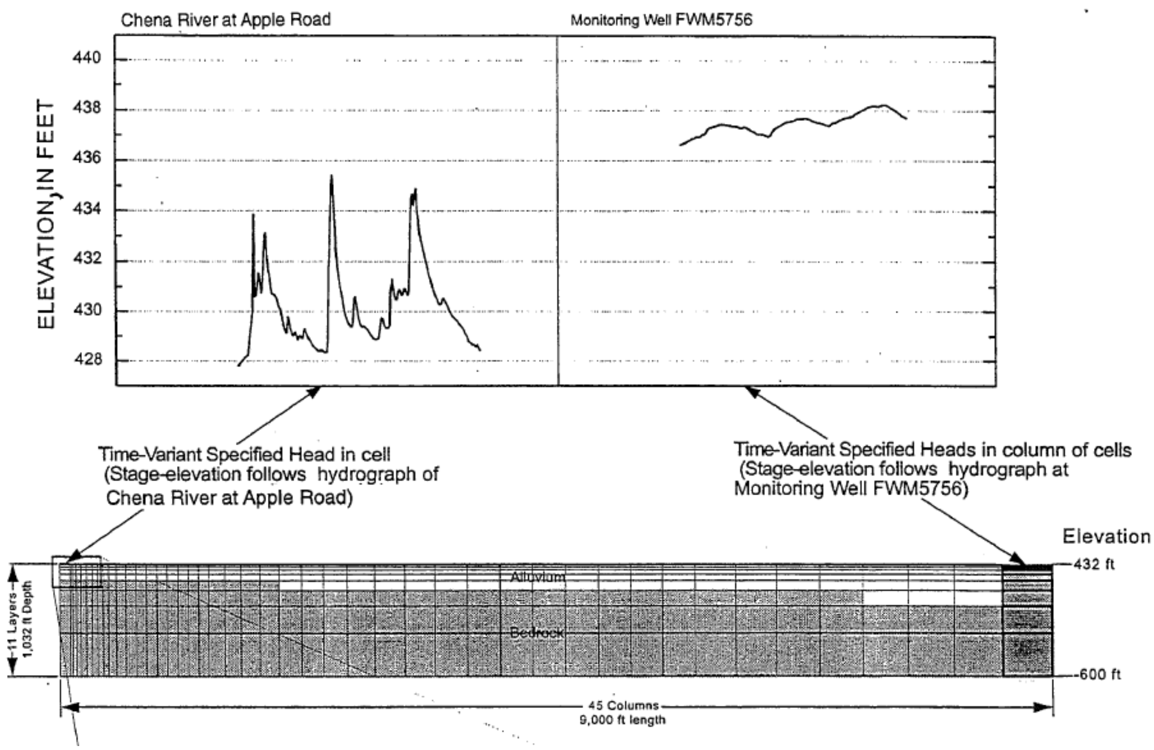


Figure 7.5-7. An example of applying surface water stage conditions and groundwater levels from a well as input to boundary conditions to a two-dimensional groundwater model (Nakanishi and Lilly 1998).

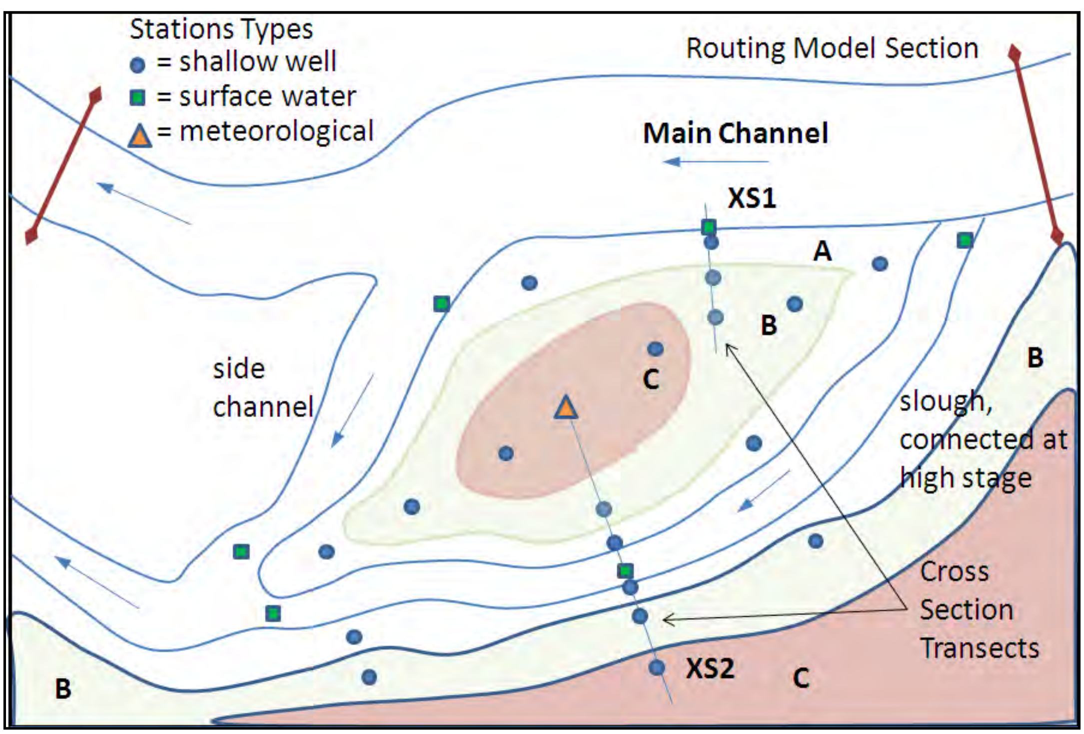


Figure 7.5-8. Example schematic of groundwater well and surface water station network in a hypothetical Focus Area targeting riparian analysis.

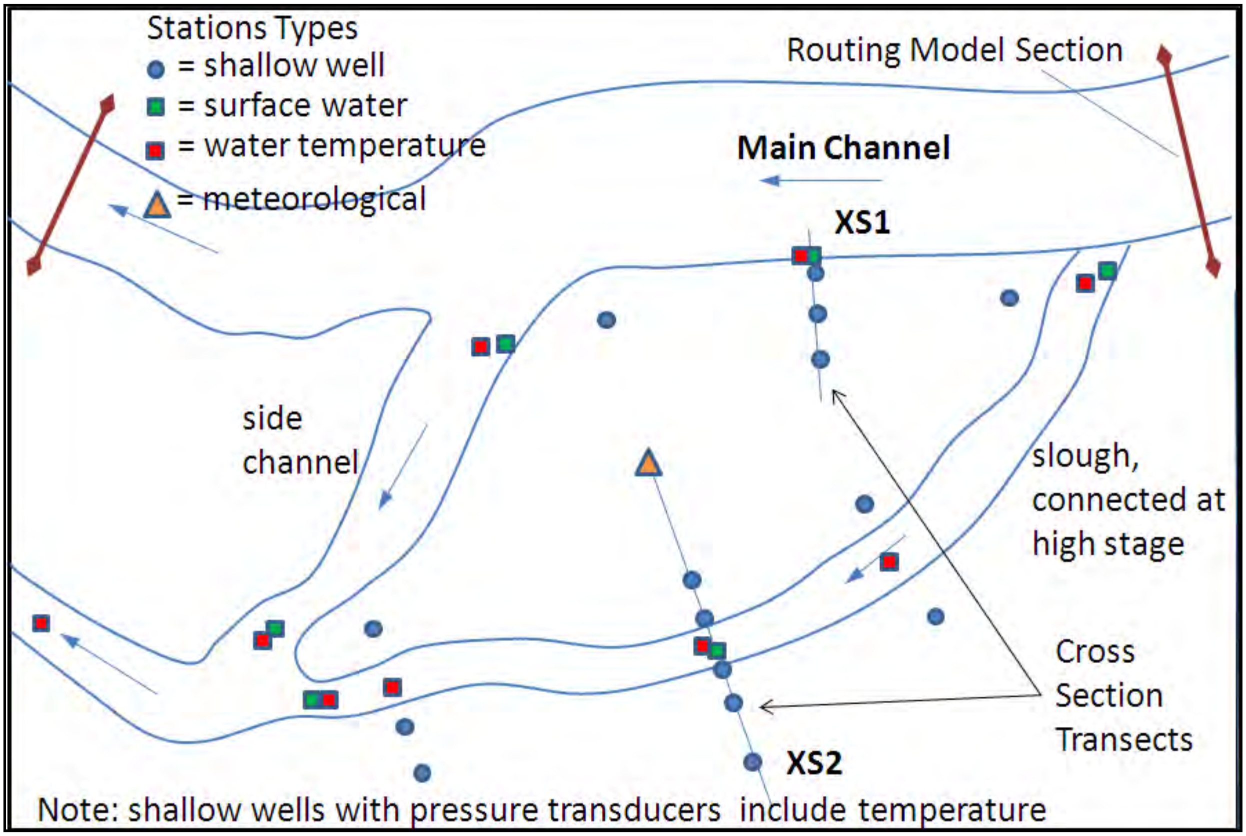


Figure 7.5-9. Example schematic of groundwater well and surface water station network in a hypothetical Focus Area targeting fish and aquatic habitat analysis.

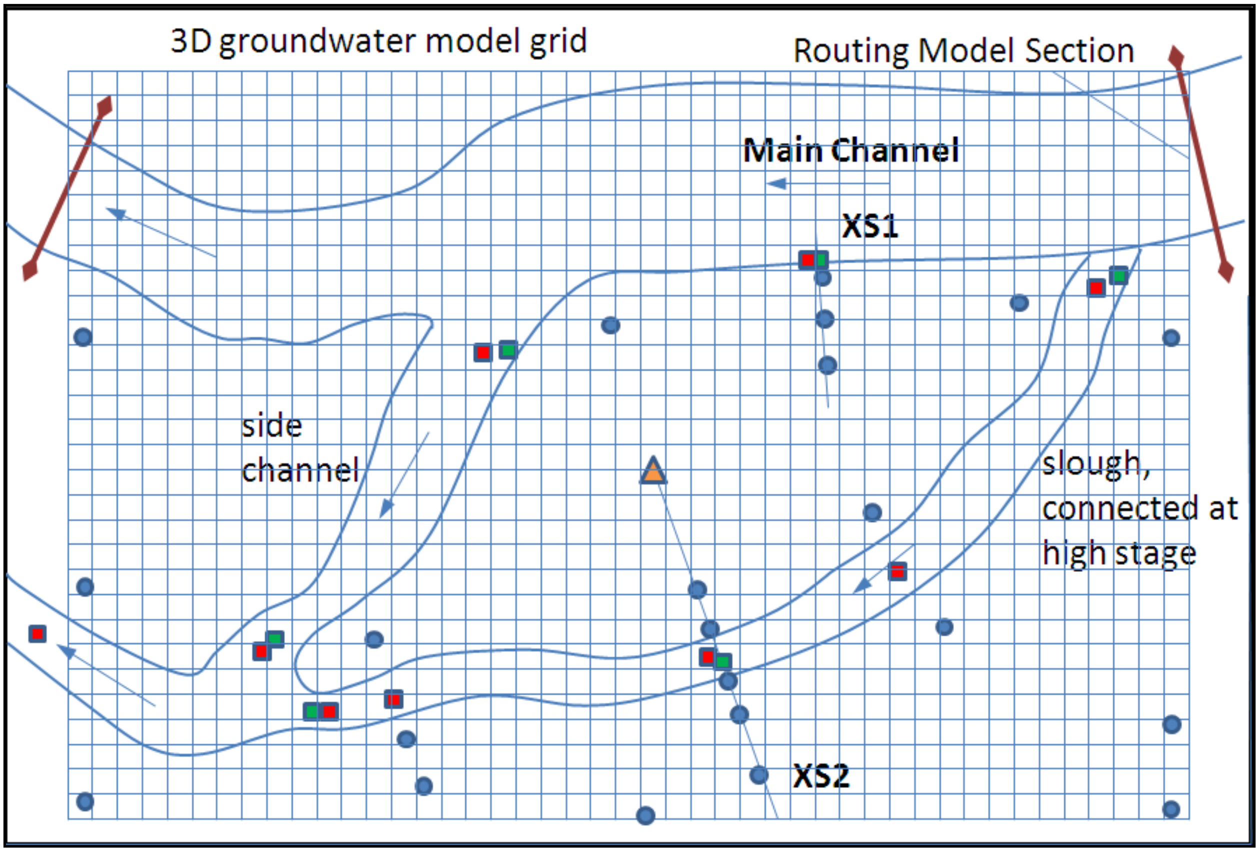
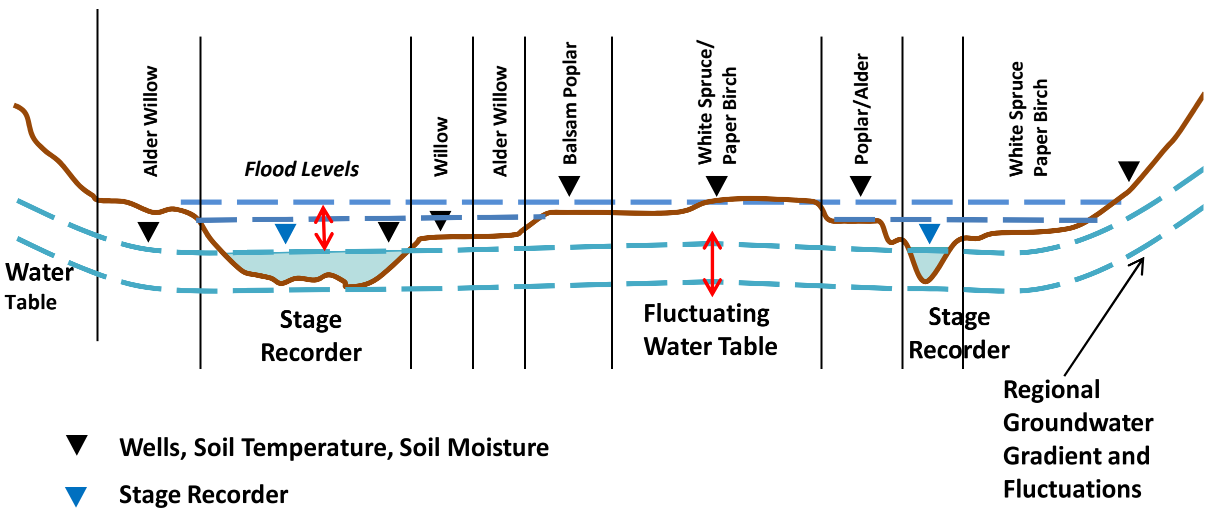


Figure 7.5-10. Example schematic of a 3D groundwater model grid in a hypothetical Focus Area targeting fish and aquatic analysis. 2D cross-section models would be developed in this hypothetical case at sections XS1 and XS2.



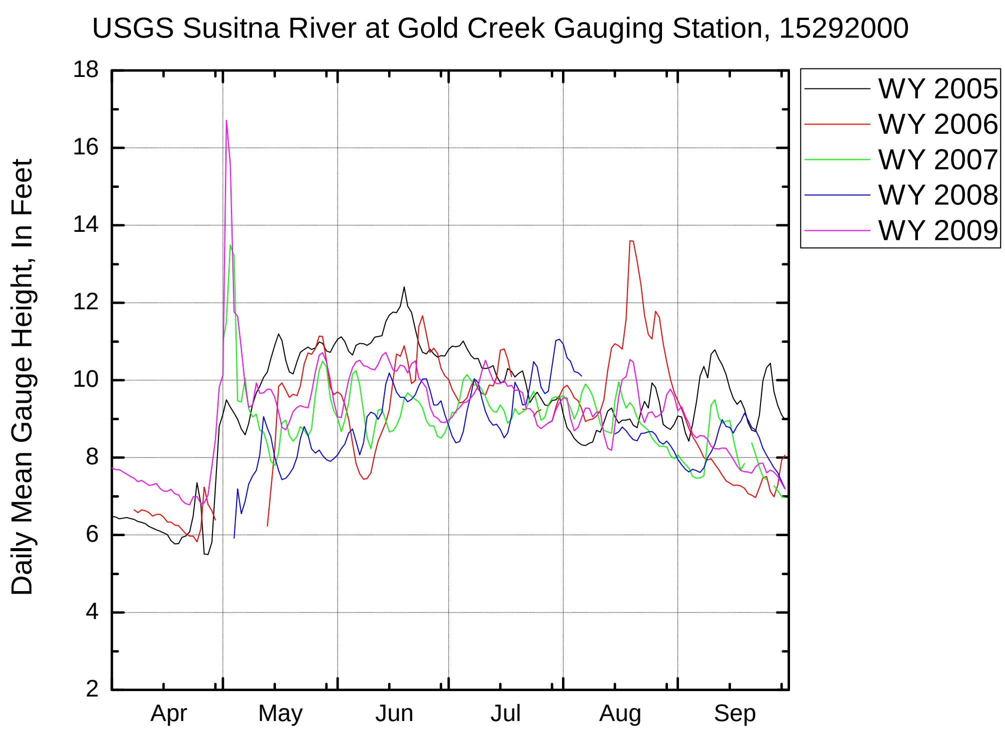


Figure 7.5-11. The upper graphic is an example schematic of a 2D cross-section across the floodplain, main channel, and a side channel or slough. Groundwater and surface water interactions and examples data collection stations are shown. The lower plots show the daily mean gage height for the Susitna River at Gold Creek.

7.6. Ice Processes in the Susitna River Study

7.6.1. General Description of the Proposed Study

The Ice Processes in the Susitna River Study will further the understanding of natural ice processes in the Susitna River and provide a method to model/predict pre-Project and post-Project ice processes in the Susitna River. The study will provide a basis for impact assessment, which will inform the development of any necessary protection, mitigation, and enhancement measures. The study also will provide ice processes input data for other resource studies with winter components (e.g., fluvial geomorphology modeling, instream flow, instream flow riparian, and groundwater).

Study Goals and Objectives

The overall goals of the ice processes study are to understand existing ice processes in the Susitna River and to predict post-Project ice processes. The specific objectives are as follows:

- Document the timing, progression, and physical processes of freeze-up and break-up during 2012–2014 between the Oshetna River confluence (river mile [RM] 233.4) and tidewater (RM 0), using historical data, aerial reconnaissance, stationary time-lapse cameras, and physical evidence.
- Determine the potential effect of various Project operational scenarios on ice processes downstream of Watana Dam using modeling and analytical methods.
    - Develop a modeling approach for quantitatively assessing ice processes in the Susitna River.
    - Calibrate the model based on existing conditions. Use the model to determine the extent of the open water reach downstream of Watana Dam during Project operations.
    - Use the model to determine the changes in timing and ice-cover progression and ice thickness and extent during Project operations.
- Develop detailed models and characterizations of ice processes at instream flow Focus Areas in order to provide physical data on winter habitat for the instream flow study.
- Provide observational data of existing ice processes and modeling results of post-Project ice processes to the fisheries, instream flow, instream flow riparian, fluvial geomorphology, groundwater, recreation, and socio-economic studies.
- Research and summarize large river ice processes relevant to the Susitna River, analytical methods that have been used to assess impacts of projects on ice-covered rivers, and the known effects of existing hydropower operations in cold climates.

Thermal and ice modeling for the reservoir and the general thermal modeling for the river during the five months when ice is not present will be accomplished under the Water Quality Modeling Study (Section 5.6). The output from that work will be used in this river ice processes study. Likewise, open water flow routing will be performed under the Fish and Aquatics Instream Flow Study (Section 8.5), while ice-affected flow routing will be performed by this study.

7.6.2. Existing Information and Need for Additional Information

7.6.2.1. Existing Information

Ice affects the Susitna River for approximately seven months of the year, between October and May. When air and water temperatures drop below freezing in September and October, border ice grows along the banks of the river, and frazil ice begins accumulating in the water column and flowing downstream. Flowing ice eventually clogs the channel in shallow or constricted reaches, or at tidewater, forming ice bridges. Frazil pans flowing downstream accumulate against ice bridges, causing the ice cover to progress upstream. By January, much of the river is under a stable ice cover, with the exception of persistent open leads corresponding with warm upwelling water or turbulent, high-velocity flows. Flows generally drop slowly throughout the winter until snowmelt commences in April. During April and May, river stages rise and the ice cover weakens, eventually breaking into pieces and flushing downstream (R&M 1982b). Ice jams are recurrent events in some reaches of the river. If severe, jams can flood upstream and adjacent areas, drive ice overbank onto gravel bars and into sloughs and side channels, shear-off or scar riparian vegetation, and threaten infrastructure such as the Alaska Railroad and riverbank property (R&M 1982b).

Ice processes were documented between the mouth of the Susitna River (RM 0) and the proposed dam site (RM 184) between 1980 and 1985 (R&M 1981, 1982a, 1983, 1984, 1985, 1986). Both freeze-up and break-up progressions were monitored using aerial reconnaissance. Locations of ice bridges during freeze-up and ice jams during break-up were recorded each season. One winter, a time-lapse camera was installed in Devils Canyon to observe ice processes through the narrow, turbulent rapids. Additional ice data were collected to calibrate a model. These included ice thicknesses at selected river transects, top-of-ice elevations, air and water temperatures at meteorological stations and Gold Creek, slush ice porosity at selected transects in the Middle and Lower River, and frazil concentration and density at Gold Creek.

Winter observations have spanned a range of climatic conditions. The freeze-up period of 1985 was unusually cold, with about twice the accumulated freezing-degree days as the long-term average (R&M 1986), while the freeze-up period of 1984 was warm (R&M 1985). In the 1980s modeling studies, cold, average, and warm conditions were simulated using records from the winters of 1971–1972, 1976–1977, and 1981–1982, respectively (Harza-Ebasco 1984b). The winter of 1971–1972 still stands as one of the coldest on record at Talkeetna; however, according to the Western Regional Climate Data Center, the warmest winter on record occurred in 2002–2003.

Of particular interest was the influence of freeze-up and ice cover on salmon habitat areas. Water levels at certain sloughs in the Middle River and Lower River were monitored during the winter to determine whether staging during freeze-up and ice cover diverted water into side channels and sloughs (R&M 1984).

Other entities (National Weather Service, U.S. Geological Survey [USGS], and U.S. Army Corps of Engineers [USACE]) also have collected and compiled ice thickness, break-up, and freeze-up data for various locations on the river (Bilello 1980). Although these data were not collected for the purpose of understanding the potential effects of the Project, they are relevant for furthering our understanding of winter hydrology along the Susitna River.

Freeze-up and melt-out processes in the Middle River (between Gold Creek and Talkeetna) were modeled using ICECAL, a numerical model developed by the USACE Cold Regions Research and Engineering Laboratory (CRREL) (Harza-Ebasco 1984). The model utilized the outputs from a temperature model developed for the river (SNTEMP) and empirical data on frazil production and ice-cover progression derived from observations. Both the Watana-only and Watana-Devils Canyon operations, as proposed in the 1980s, were modeled for a range of meteorological conditions that had been encountered, including a cold winter (1971–1972), a very warm winter (1976–1977), a warm winter (1982–1983), and an average winter (1981–1982). The results of the model included predictions of the extent of ice cover, the timing of ice-cover progression, ice surface elevations, and the inundated area beneath the ice cover for selected cross-sections. The elevation of water flowing beneath the ice was compared to the elevation necessary to overtop slough berms at selected fish habitat study areas in the Middle River in order to assess the impacts of Project operation on winter flow in these sloughs. Empirical data on frazil production and ice-cover progression was used to estimate changes in ice-cover progression between tidewater and Talkeetna. Reservoir ice was simulated using a DYRESM model and calibrated to conditions at Eklutna Lake (Harza-Ebasco 1986).

Key findings of the 1980s modeling effort included the following (for the Watana-only scenarios):

- The open water reach would likely extend 44–57 miles downstream of the dam site.
- Ice thicknesses were generally similar under project conditions, where ice was predicted to occur.
- Winter water surface elevations under ice would be 2–7 feet higher under project conditions, and would result in the flooding of some sloughs with mainstem water in the Middle River without mitigation.
- Freeze-up would be delayed by 2–5 weeks in the fall, and ice-out would occur 5–7 weeks earlier in the spring.
- Ice jams during break-up would be reduced in severity post-project because of the regulation of spring snowmelt flows.

R&M undertook a survey of ice-affected hydropower projects in other northern regions (Harza-Ebasco 1985). The results of the survey indicated that other hydroelectric projects generally relied on observations and operator experience to limit adverse effects of flow regulation on winter conditions. Ice jamming during the freeze-up and subsequent flooding of infrastructure and communities were the primary concerns.

7.6.2.2. Additional Information Needs

The need for additional information beyond what was gathered and analyzed during the 1980s is driven by four factors: (1) the new proposed configuration of the Project and Project operational scenarios; (2) advances in predictive models of winter flow regimes beyond what was available in the 1980s; (3) the need to capture any changes (due to channel or climate changes) since the 1980s; and (4) the need to supply ice-related hydraulic data in greater detail for Focus Areas selected for the instream flow study.

The 1980s Su-Hydro project was envisioned as a two-dam project, with an upper dam, reservoir, and powerhouse near river mile (RM) 184 (Watana Dam). It was envisioned that the upper development would be operated in load-following mode to meet power demands. A lower dam, reservoir, and powerhouse (Devils Canyon Dam) would provide additional power generation, but would also re-regulate flow releases from the upper development. Downstream flow releases from the Devils Canyon Dam would not have the daily flow fluctuations associated with load-following operations of the upper development.

The Pre-Application Document (PAD) describes an operational scenario that would release more water in the winter, with a potential for day-to-day fluctuations. The ICECAL model was a steady flow model, and thus could not simulate flow fluctuations or route winter flows. A dynamic model will be able to simultaneously predict flow and temperature fluctuations downstream of the dam, as well as ice-cover progression. Finally, the ICECAL model was only calibrated to flows between Talkeetna and Gold Creek. There are several important fish habitat areas upstream of Gold Creek where knowledge of winter conditions is necessary to predict post-Project habitat changes.

Despite changes in channel form, which are likely to have the greatest effect at the Chulitna confluence near Talkeetna, most of the detailed data collected in the 1980s can be used in the current effort, including verifying the model. Freeze-up progression upstream from tidewater was catalogued each year of the study, including the rate of ice front advance, ice bridging locations, daily frazil discharges at Gold Creek and weekly discharges for the Yentna, Chulitna, Talkeetna, and Middle Susitna. Daily meteorological observations were recorded in Talkeetna and near the dam site. Staging observations were made in the Lower and Middle Rivers, which described the rise in water level immediately upstream from the progressing ice front. Ice thicknesses and elevations were collected in the Lower and Middle Rivers each year of the study, and the shape of the ice cover across transects was characterized, since thicknesses varied between the bank and the thalweg. Open leads were mapped in the late winter for several years, including open sloughs and side channels. Break-up progression was monitored each spring of the study, and ice jam locations were mapped. All of these observations are relevant to the current study. Detailed observations were also made if frazil density, in order to determine the source of frazil, and effects of snowfall, low and high discharges, and variable temperatures on ice cover development. It is especially important to have detailed observations for a range of climatic conditions so that the role of meteorological factors in influencing ice cover formation can be better understood.

Freeze-up and break-up processes depend on a complex suite of variables, some of which currently are outside the realm of predictive modeling, usually because the process depends on very local conditions, or sequence of events. Ice bridging locations are an example of a process that cannot currently be predicted by a model; thus, analytical methods to predict ice-cover progression depend on multiple years of observations. The presence of open thermal leads is another phenomenon that is not captured by ice processes models because it depends on local hyporheic flow conditions or groundwater contributions. Additional documentation is needed to determine whether locations of these features and timing of ice-cover progression are similar to conditions observed in the 1980s. In addition, in the 1980s, the location of frazil production early in the freeze-up period varied significantly between study years. An assessment is needed to determine the importance of the Susitna River upstream and downstream of the proposed dam in frazil production for a range of meteorological conditions.

7.6.3. Study Area

7.6.3.1. Observations

The ice processes observation study area includes the 234-mile segment of river between tidewater and the Oshetna River confluence (from RM 0 to RM 233.4). Observations of open leads, break-up progression, and freeze-up progression will be made in this area. In addition, ice thickness, top-of-ice elevations, and under-ice water stages will be surveyed in the Middle River to calibrate and verify a predictive ice model.

7.6.3.2. Middle River River1D Modeling

Predictive ice, hydrodynamic, and thermal modeling using River1D is planned for the Middle River between the proposed dam and the Three Rivers Confluence near Talkeetna (from RM 184 to RM 100).

7.6.3.3. Middle River Detailed Modeling (Focus Areas)

Several Focus Areas determined in conjunction with the instream flow habitat and riparian studies in the Middle River will receive more detailed ice modeling and observation attention. Depending on the local channel geometry, either detailed River1D or River2D models will be developed, and observations of ice-cover progression, ice thickness, and open leads will be more detailed in order to calibrate these models. See the Fish and Aquatics Instream Flow Study (Section 8.5) for criteria and potential sites.

7.6.3.4. Lower River

There are currently no accepted models for predicting dynamic ice processes on complex braided channels, such as those found in the Lower Susitna River downstream of Talkeetna; therefore, no hydrodynamic modeling is planned for the 100-mile reach between tidewater and the Talkeetna River (from RM 0 to RM 100). However, there is a need to assess the potential for change to ice cover on the Lower River both for fish habitat studies and to understand the potential effects of the Project on winter transportation access and recreation, which depend on ice cover on the Lower Susitna River. Project effects to the Lower River will be determined based on the magnitude of change seen at the downstream boundary of the River1D model (approximately RM 100), the estimated contributions of frazil ice to the Lower River from the Middle River from observations and modeling, and with simpler steady flow models (HEC-RAS with ice cover) for short sections of interest in the Lower River (Section 7.6.4.10).

7.6.4. Study Methods

The observation and modeling efforts described below will be used to characterize the Susitna River ice regime, identify spatial and temporal variations in ice processes, and provide information on the physical channel environment in the winter to other study disciplines. Some of the information (aerial reconnaissance and transect data) is similar to information collected in the 1980s. Collecting the same observations over a period of years will help define the year-to-year variability in the ice regime. Characterizing the existing ice regime ans its variability will provide a basis for evaluating the impacts of the project.

7.6.4.1. Aerial Reconnaissance

Aerial reconnaissance and global positioning system (GPS) mapping of ice features, including ice jams, ice bridges, frazil accumulations, and open leads during the break-up and freeze-up periods will be performed from tidewater to the Oshetna River confluence (from RM 0 to RM 233.4). The number of observations will vary depending on ice process conditions, but it is anticipated that approximately 10 reconnaissance trips per spring will occur during break-up and 15 reconnaissance trips per winter will occur during freeze-up in 2012, 2013, and 2014. The data collected will include concentrations of frazil ice, locations of ice features and open leads, timing of ice-cover progression, geo-referenced photographs, and videos of ice processes. Ice processes field observation standards follow those of EM-1110-2-1612, Ice Engineering, developed by USACE (2002) and Michel (1972). Aerial reconnaissance will include observations of the main Sustina River, and mouths of major tributaries including the Yentna, Chulitna, and Talkeetna rivers.

7.6.4.2. Time-Lapse Camera Monitoring

Time-lapse cameras will monitor break-up and freeze-up at locations corresponding to flow routing model instrumentation, key ice processes, and fish habitat locations. Time-lapse cameras are set to take photos of the main channel or a side slough at one-hour intervals, and the results are compiled into a video. Key information to be derived from time-lapse videos includes the timing of ice cover advance and decay past the camera location, the relative abundance of frazil ice visible in the channel during freeze-up, the growth of border ice during freeze-up from the shore, and the local interaction of ice with the floodplain. The selection of camera locations may be refined when the final determination of Focus Areas is made for the instream flow study, or if aerial observations indicate other more important locations. The current locations of the time-lapse cameras for 2012 are as follows:

- RM 9.5 – Near Upper Tidal Influence
- RM 25.6 – Susitna Station
- RM 59 – Rustic Wilderness Side Channel
- RM 88 – Birch Creek Slough
- RM 99 – Slough 1 (2012 break-up only)
- RM 101.5 – Whiskers Slough (2012 freeze-up)
- RM 103 – Talkeetna Station
- RM 121 – Curry Slough
- RM 129 – Slough 9
- RM 141 – Slough 21
- RM 149 – Mouth of Portage Creek
- RM 184 – Dam Site

Planned camera locations for 2013–2014 include the following:

- RM 9.5 – Near Upper Tidal Influence
- RM 25.6 – Susitna Station
- RM 101 – Whiskers Slough
- RM 112 – Slough 6A

- RM 124 – Slough 8A
- RM 135 – Slough 11
- RM 138 – Indian River
- RM 141 – Slough 21
- RM 149 – Mouth of Portage Creek
- RM 171 – MR2-wide
- RM 184 – Dam Site

Additional telemetered time-lapse cameras are located at the following sites by the flow transect study:

- RM 11 – Susitna River near Flathorn Lake (ESS10)
- RM 13 – Susitna River near Dinglishna Hill (ESS15)
- RM 26 – Susitna River at Susitna Station (ESS20)
- RM 96 – Susitna River near Twister Creek (ESS30)
- RM 98 – Susitna River near Chulitna River (ESS35)
- RM 103 – Susitna River above Whiskers Creek (ESS40)
- RM 113 – Susitna River below Lane Creek (ESS45)
- RM 121 – Susitna River at Curry (ESS50)
- RM 149 – Susitna River below Portage Creek (ESS55)
- RM 165 – Susitna River near Devil Creek (ESS60)
- RM 176.5 – Susitna River near Fog Creek (ESS65)
- RM 184 – Susitna River below Deadman Creek (ESS70)
- RM 223 – Susitna Gage near Cantwell (now ESS80)

And by the USGS at the following stations:

- RM 182 – Susitna River Above Tsusena Creek
- RM 137 – Susitna River at Gold Creek
- RM 84 – Susitna River at Sunshine Station
- Chulitna River near the Susitna confluence

7.6.4.3. Transect Data

Winter field data will be collected at the 13 transects identified above for the flow routing model study (ESS80-ESS10). These transect data will be used to calibrate the existing condition ice processes model. The following data will be collected in conjunction with the flow routing study:

- Ice thickness, including total and submerged ice thicknesses and slush ice thickness (January and March) using drill or auger and plunge pole.
- Top-of-ice elevation (January and March) using standard survey techniques and established benchmarks.
- Air temperature (continuously).
- Water temperature (continuously where sensors survive freeze-up).
- Water stage (continuously where sensors survive freeze-up, January and March otherwise) using pressure transducers.

- Discharge (January and March, except at ESS10 and ESS15) and under-ice velocity profiles using current meter and ADCP.
- Thickness of snow cover (January and March).

7.6.4.4. Focus Area Field Data Collection

When Focus Area locations have been determined, a winter field data collection program will be established at each site in consultation with the instream flow, geomorphology, riparian, and groundwater studies. At a minimum, winter data collected at Focus Areas will include ice thicknesses, elevations, and water depths sufficient to characterize the ice cover and calibrate a detailed model of the short reach. Freeze-up timing and processes, the presense of open leads, and historical ice jam processes will be characterized for each site in order to further understanding of how winter conditions affect fish habitat and geomorphology.

Field conditions during winter data collection are likely to occasionally be challenging, owing to hazardous weather, limited daylight, and river ice conditions. Where large open leads or questionable ice stability preclude measurements at established transects, measurements may need to be relocated upstream or downstream of the transect. Likewise, equipment such as pressure transducers, temperature probes, and cameras will likely fail from time to time. The field data collection program may be revised where needed to overcome these challenges.

7.6.4.5. Other Field Data

The Riparian Instream Flow Study (Section 8.6) will be collecting field data on ice interactions with floodplains and vegetation, including tree scars and floodplain disturbance by ice. These data indicate locations where ice events have been significant. The results of the Riparian Instream Flow Study will be used to delineate reaches of the river where ice processes, primarily break-up jams, have occurred in the past. The Riparian Instream Flow Study will use these data to develop a model of riparian–floodplain interactions, while the ice study will use these data to supplement historical observations of ice jams.

7.6.4.6. River Ice Processes Model Development for Existing Conditions

A River1D model will be developed and applied to the Susitna River between the proposed dam site and Talkeetna. River1D is a hydrodynamic flow routing and thermal model that also models frazil generation, ice-cover progression, and decay (Hicks and Steffler 1992; Andrishak and Hicks 2005a and 2005b; She and Hicks 2006; She et al. 2009; She et al. 2012). The model has the ability to route reservoir releases downstream at small time-steps (hourly or less) and was designed to be able to predict when fluctuating flows can destabilize a winter ice cover (She et al. 2012). The model has been developed by the University of Alberta River Ice Engineering Program (Hicks 2005; Andrishak and Hicks 2005a). Updated code is due to be released to the public domain on January 1, 2013.

The Susitna River Ice Processes Model will be used to simulate time-variable flow routing, heat-flux processes, seasonal water temperature variation, frazil ice development, ice transport processes, and ice-cover growth and decay. The first step is to calibrate an open-water model using known discharge events. The second step is to simulate pre-Project ice processes to verify that the model is correctly working on the Susitna River. The model will also be used to provide boundary conditions to more detailed Focus Area models embedded in the reach. Inputs to the existing condition model include the following:

- River geometry from the instream flow routing study
- Discharge as measured by gages along the modeled reach
- Air temperature and solar radiation from meteorological stations
- Water temperature along the river and tributaries from the Water Quality Study (Section 5.0)
- Boundary conditions for ice-cover progression (bridging locations and ice concentrations)

The model will be verified using ice thickness and elevation measurements at Flow Routing Transects, and observed timing of ice-cover progression and decay. Data from the 1980s will be used to verify the model for differing climate conditions. The existing conditions model may be updated with 2013 or 2014 data if new information is gained that will improve model accuracy.

7.6.4.7. River Ice Processes Model Projections for Proposed Conditions

For the Middle River, the calibrated River1D model will be used to model the proposed Project operational scenarios. The model will predict water temperature, frazil ice production, ice cover formation, elevation and extent of ice cover, and flow hydrograph (winter flow routing and water levels) between the proposed dam site and Talkeetna. The model will also predict ice cover stability, including potential for jamming, under load-following fluctuations. For the spring melt period, the model will predict ice-cover decay, including the potential for break-up jams. Proposed operational scenarios will include, at a minimum, the load-following scenario described in the PAD and a base load scenario.

Additional inputs to the proposed conditions model include the following:

- Flow releases from Watana Dam provided by the Reservoir Operations Model
- Temperature of released flow provided by the Water Quality Model
- Range of meteorological conditions (warm, cold, wet, and dry winters) as developed in coordination with the Water Quality Study (Section 5.0)

The River1D model will model temperature between freeze-up and break-up on the Susitna River, while the EFDC Water Quality Model (Section 5.6) will model temperature during the open water season and the HEC-RAS model (Section 8.5) will model flow routing during open water conditions. Both temperature models will use the same meteorological and water temperature baseline data outlined in Section 5. The models will overlap during early freeze-up, usually mid-September to October, and late break-up, usually late April to mid-May. This will provide an independent check of model accuracy. When the models predict that river temperatures will reach freezing (32^{o}F) for a portion of the mainstem, the Ice Processes Model results will take precedence for temperature and hydraulic routing.

7.6.4.8. Focus Areas Ice Processes Model

The River1D model will be at the same scale as the Mainstem Open-water Flow Routing Model (Section 8.5.4.3), and will be using the same river channel geometry. Focus Areas selected by the ISF study (Section 8.5.4.2) will be subject to more detailed geometric surveys and modeling in order to evaluate Project effects to smaller scale habitat. In some of the proposed Focus Areas near the dam site, the river may not be predicted to freeze over post-Project. For these sites, year-round conditions will be modeled using the open-water model. If ice cover is predicted by the River1D model to occur at these sites post-Project, winter hydraulic conditions at these sites will be modeled using either more detailed River1D models or River2D models, depending on channel geometry and the influence of two-dimensional hydraulics. In some cases, the River1D model may be applied to split flow or bend reaches if the advantages of computational simplicity appear to outweigh the potential reduction in accuracy of not simulating cross-channel flow. The extent of the detailed models may be modified from the instream flow Focus Area boundaries to accommodate appropriate boundary conditions for ice processes.

Boundary conditions for the Focus Area models will be derived from the River1D flow routing model, and geometric input will include more detailed ice cover characterization based on 2013-2014 winter measurements. Location-specific details such as open leads, channel blockage by ice, or ice jam flood releases may be modeled. These processes will be simulated if needed by other studies and if sufficient calibration data (open lead locations, ice-scars, ice jam dimensions, etc.) can be determined or estimated from observations. The hydraulic data to be derived from the Focus Area ice models will be determined on a case-by-case basis by the needs of instream flow, geomorphology, and other studies, but will include at a minimum extent of inundation, flow stages and velocities for post-Project winter conditions under load-following and base-load scenarios.

7.6.4.9. Model Accuracy and Error Analysis

The limitations of the ice model fall under three basic categories: 1) simplifying assumptions in the governing equations, 2) interpolation between measured points, and 3) error in measuring input data. The error introduced to the model for each of these categories will be analyzed as part of the ice processes model development.

All hydraulic and ice-processes models rely on simplifying assumptions in order to render the governing equations solvable. For instance, frictional resistance to flow in a channel is a complex phenomenon influenced by channel geometry, bed material, turbulence, and the texture of the underside of the ice cover, if present. However, most hydraulic models simplify all frictional resistance into a single value known as Manning's n. Estimating Manning's n for different flow conditions introduces error to the model. This error can be evaluated by varying Manning's n and determining the difference in results that would occur if the input value were 50% greater or smaller than the chosen value.

Models are generally limited in application to hydraulic conditions that best match the assumptions of the simplifying equations. River1D is a hydrodynamic and thermal model designed to route rapidly varying flows (such as reservoir releases) and calculate heat transfer between the atmosphere and the river. As a 1-D model, it assumes flow vectors are parallel across the channel and that water surface elevations are constant across a transect. Where flow is split into multiple channels or makes sharp curves, River1D would still assume all flow is parallel, even though in reality flow is diverging and converging. For most of the Middle River, this assumption should still allow reasonably accurate predictions of the effects of project operations on ice processes and winter flow routing. For smaller scale investigations into hydraulic conditions at specific side slough habitats, for instance, more accurate determination of flow around an island or bend may be needed. Thus, River2D may be applied to portions of some of the Focus Areas. The primary limitations of River2D are input data needs (detailed geometry and calibration data) and computational complexity. These limitations currently preclude the application of River2D to long reaches.

Models also rely on interpolation between measured input values, such as surveyed transects and meteorological data. Modeled values at surveyed cross-sections will be more accurate than those derived from the model between surveyed cross-sections. Surveyed sections were thus chosen carefully to coincide with changes in channel geometry. Air temperature and solar radiation varies along the river in between measurement points. Data collected in the 1980s in different locations and in 2012-2013 at ESS10-ESS80 will allow us to analyze the variability and estimate the likely error at unmeasured locations.

An assessment of model accuracy and sources of error will be included in the discussion of model results. The main sources of error to be analyzed include the following:

- Error associated with measuring input data (air temperature, solar radiation, water temperature, and ice concentration). This will be estimated by performing a sensitivity analysis to variance in each of these parameters.
- Error associated with estimating Manning's n under ice. This will be estimated by performing a sensitivity analysis using different values of Manning's n.
- Error associated with interpolating measured values over distances (river channel geometry between measured cross-sections, air temperature and solar radiation between meteorological stations). In some cases, this will be evaluated using a sensitivity analysis (for instance, to assess the impact of temperature variations between stations). To reduce the error associated with geometric interpolation, only results at measured cross-sections will be reported.

The limitations of applying a simplified model to complex conditions, such as applying River1D to sections of river with two-dimensional flow, will be assessed by comparing the results of the existing condition model to observed conditions (i.e., model calibration). The methods for calibration are described in Sections 7.6.4.1 through 7.6.4.4.

7.6.4.10. Lower River Assessment

The primary impact of Project operations on the Lower River in the winter is likely to be increased stage owing to reservoir releases in excess of natural winter discharge. Increased stage will be modeled where transect data exist. Transect data exist between RM 75 and RM 100 (from the 2012 hydrology study), at Susitna Station at RM 26, and at RM 40, RM 48, and RM 60 (R&M 1985). Projected maximum monthly discharge from the preliminary reservoir operations model will be modeled with a range of ice thicknesses based on historical measurements. The potential for ice-cover delay in the Lower River will be assessed based on the estimated contributions of frazil ice to the Lower River from the Middle River using observations and model output.

7.6.4.11. Review and Compilation of Existing Cold Regions Hydropower Project Operations and Effects

Hydropower projects in northern North America, especially in Canada, and in other northern countries have operated on ice-covered rivers for many decades (National Research Council of Canada 1990). Other river systems where ice modeling has been completed include the following:

- Peace River, Canada (Andrishak and Hicks 2005b; Andrishak and Hicks 2008; Hicks and Steffler 1992; She et al. 2012)
- Athabasca River, Canada (Katopodis and Ghamry 2005)
- Ohio River, USA (Shen et al. 1991)
- St. Clair River, USA (Kolerski and Shen 2010)
- Romaine River, Canada (Thériault et al. 2010)

The product of this portion of the study will be a memorandum that will summarize the following:

- ice processes on the Susitna River as they relate to impacts of the project on fish habitat and other resources,
- the impacts of other hydropower projects on river ice processes in northern regions.
- Methods of analysis and modeling used to assess hydropower impacts to ice processes and fish habitat in other systems, and a discussion of how these methods may be applicable to the Susitna River.

Relevant references will be summarized and study authors contacted to obtain additional information that may be relevant to the Susitna River.

7.6.5. Consistency with Generally Accepted Scientific Practice

This study's methodologies for data collection, analysis, modeling, field schedules, and study durations are consistent with generally accepted practice in the scientific community. Field study methods follow those of the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL) Engineering Manual (USACE 2002) and Michel (1972). The study plans were developed with the input of technical experts including the University of Alberta Ice Engineering Group. The River1D model is a state-of-the-art numerical model designed to evaluate freeze-up and break-up processes on large rivers, including the effects of hydropower regulation, and it will be applied under the guidance of the model developers.

7.6.6. Schedule

Field data will be collected as follows (freeze-up and break-up dates will vary depending on meteorological conditions, but are expected to fall within the range specified below):

- Continuous time-lapse camera data will be collected during the break-up and freeze-up periods 2012–2014.

- Freeze-up reconnaissance observations will be conducted between October 1 and January 15, 2012, 2013, and 2014.
- Ice thickness and elevation data along transects will be collected in conjunction with winter discharges collected by the instream flow routing study in January and March of 2013, and again in January and March of 2014.
- Open lead locations will be documented between March 1 and April 1 of 2012, 2013, and 2014.
- Break-up reconnaissance observations will be conducted between April 1 and May 15, 2012, 2013, and 2014.

Model development and calibration will occur continuously during 2013 and 2014 (see Table 7.6-1). Preliminary modeling runs for existing conditions will be calibrated to 2012 and 2013 conditions by the end of 2013, and proposed operations scenarios will be run primarily in 2014. AEA will issue Initial and Updated Study Reports documenting actions taken to date within one and two years, respectively, of FERC's Study Plan Determination (i.e., February 1, 2013).

7.6.7. Relationship with Other Studies

The interdependency of the ice study with other studies is illustrated in Figures 7.6-1 and 7.6-2. Field observations of ice-scars and ice-related floodplain impacts from the Riparian Instream Flow Study (Section 8.6) will contribute to the Ice Processes in the Susitna River Study. The instream flow habitat and geomorphology studies will help define where Focus Areas should be for detailed winter data collection and modeling. The instream flow routing study will contribute winter stage and discharge measurements at transect locations. The Ice Processes in the Susitna River Study will contribute observations of open lead locations to the groundwater study , and observations of ice thickness and extent at Focus Areas and transect locations to the instream flow habitat, instream flow riparian, and geomorphology studies. General observations about break-up and freeze-up processes, especially where these processes impact the floodplain and riparian vegetation, will contribute to the instream flow riparian and geomorphology studies. These data will be provided in the form of aerial photographs and videos, GIS map layers, tabular data, and field reports.

The ice modeling study requires input data primarily from the water quality and instream flow routing studies. The water quality study will contribute baseline water temperature and meteorological data for the existing conditions model and predicted outflow temperatures for the proposed condition model. The instream flow routing study will contribute river channel geometry, rating curves, and predicted outflow hydrographs to the Ice Processes Model. Output from the model includes under-ice flow routing, temperature, ice thickness and elevation, and extent and timing of freeze-up and break-up. These data will be used by a number of studies including geomorphology, riparian, transportation, recreation, and instream flow. These data will be provided in tabular form and map form, where applicable.

The ice modeling study will perform detailed 1-D and 2-D modeling at Focus Areas defined by the instream flow study. The results of these models may include hydraulic properties of ice jam flood releases in reaches where ice jams have been observed. These results will be used by the geomorphology and instream flow riparian studies to estimate the effects of ice jam floods on sediment transport and riparian vegetation. Details of how these models will be applied will be worked out when the Focus Areas have been agreed upon, and the applicability of ice jam floods to local floodplain processes is assessed.

Several hydraulic and temperature models will be developed for the Middle River and Focus Areas. The Ice Processes River1D Model will provide flow routing and temperature results for the Middle River for the ice-affected period. The ice-affected period begins when a portion of the river cools to 32 degrees and ice begins to form in the fall, and continues until ice has flushed out of the river in the spring and ice is no longer affecting water temperature or river hydraulics. As discussed above, the Water Quality Temperature Model and the Open-Water Hydraulic Routing Model will provide flow routing and temperature results for the Middle River for the ice-free period. The detailed River2D and River1D models developed for instream flow Focus Areas will provide hydraulic data for the ice-affected period for these Focus Areas.

7.6.8. Level of Effort and Cost

Below is an estimate of costs associated with field documentation and model development in 2013–2014, which are the major components of the ice study.

Costs of Field Observation Effort

The 2013–2014 field components include the following, and are anticipated to roughly total about $1.5M (including helicopter hours):

- Ice thickness and elevation measurements
- Open lead reconnaissance, mapping, and video processing
- Break-up reconnaissance, mapping, and video processing
- Time-lapse camera setup, maintenance, and processing
- Freeze-up reconnaissance, mapping, and video processing

The 2013–2014 modeling components include the following, and are anticipated to roughly total about $850,000:

- Geometric and meteorological data compilation and input
- Open water flow routing model development and calibration
- Existing condition ice-covered model development and calibration
- Focus Area geometry input
- Existing condition Focus Area model development
- Proposed condition hydrologic and meteorological data compilation and input
- Project alternative River1D model development
- Project alternative Focus Area model development
- Lower River HEC-RAS assessment

7.6.9. Literature Cited

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7.6.10. Tables

Table 7.6-1. Schedule for implementation of the Ice Processes in the Susitna River Study.

Activity	2012				2013				2014				2015
	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1Q
Open Lead Surveys, ice thickness and elevation	—				—				—				
Break-up Reconnaissance		—				—				—			
Freeze-up Reconnaissance				—	—			—	—				
Initial Study Report								—	Δ				
Existing Condition 1-D Model Development					—	—	—	—	······	······	······	······	
Proposed Condition 1-D Model Development								—	—	—	—	—	······
Intensive Site Models									—	—	—	—	······
Updated Study Report											—	—	▲

Legend:

—— Planned Activity
----- Follow-up activity (as needed)
Δ Initial Study Report
▲ Updated Study Report

7.6.11. Figures

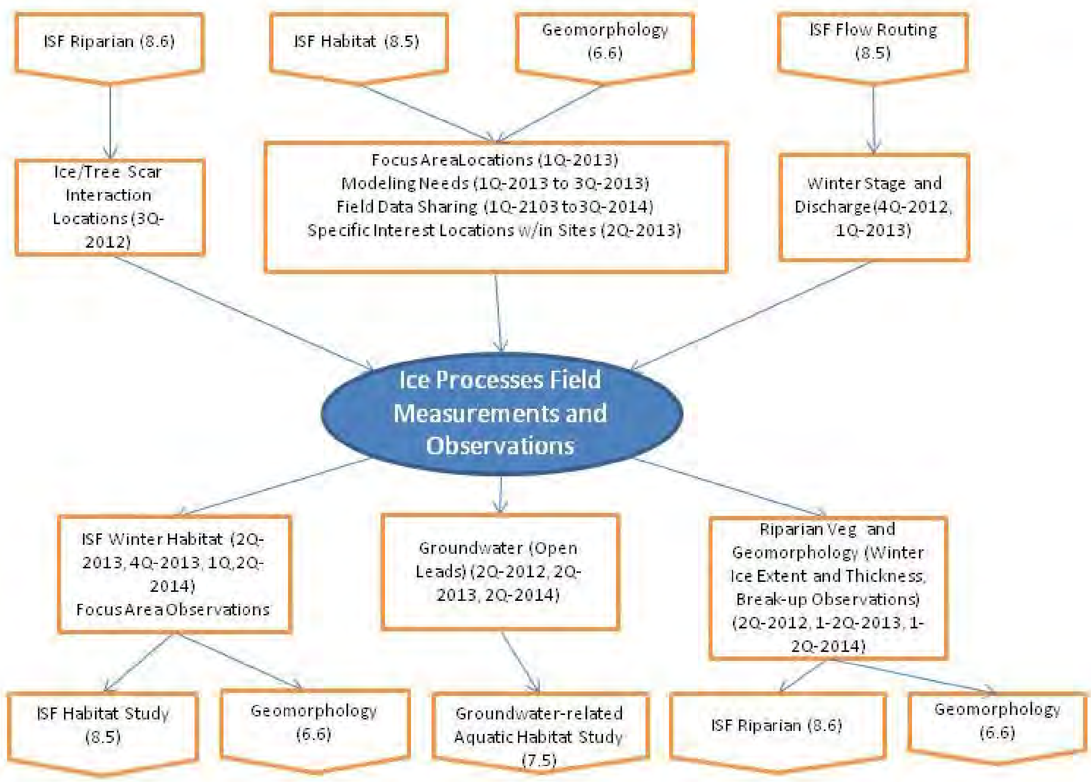

Figure 7.6-1. Relationship of ice observations to other studies.

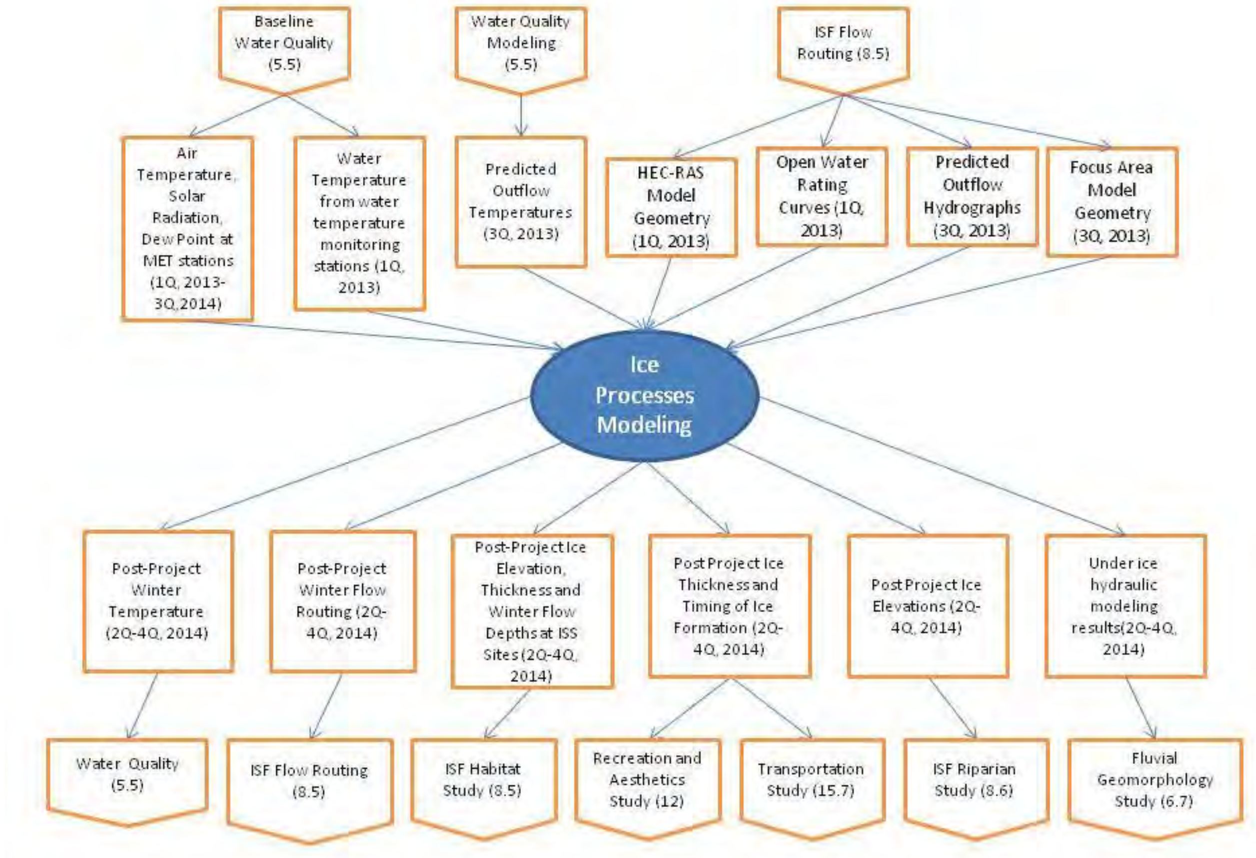

Figure 7.6-2. Relationship of ice modeling to other studies.

7.7. Glacier and Runoff Changes Study

7.7.1. General Description of the Proposed Study

Glaciers have generally retreated during the last century (Kaser et al. 2006; Meier et al. 2007), and glaciers in Alaska are currently subject to some of the highest glacial wastage rates on Earth (Arendt et al. 2002; Hock et al. 2009). Projections indicate that Alaskan glaciers may lose up to 60 percent of their current volume within the next 100 years (Radic and Hock 2011). Figure 7.7-1 provides an example of a glacier within the Upper Susitna basin that has recently retreated.

Such changes will alter stream flow both in quantity and timing (Hock and Jansson 2005a). This is because glaciers temporarily store water as snow and ice during varying time scales with the release controlled by both climate and internal drainage (Jansson et al. 2003).

Typical characteristics of discharge from glacier-dominated drainages include pronounced diurnal patterns and mid- to late summer high flows due to the dominance of glacier meltwater over precipitation. Annual runoff from a glaciered basin strongly depends on glacier mass balance. During years of positive glacier net, balance water is withdrawn from the annual hydrological cycle into glacier storage, and total stream flow is reduced. During years of negative glacier mass, balance water is released from storage and total stream flow increases.

Glaciers also tend to dampen interannual streamflow variations, where melting variations tend to offset precipitation variations. As little as 10 percent glacierization in a hydrologic basin reduces year-to-year variability in precipitation to a minimum (Huber 2005). As glaciers retreat, total glacier runoff will initially increase but then be followed by a reduction in runoff as the mass of the glacier dwindles (Figure 7.7-2).

With a high fraction of ice cover in the drainage basin, the increases in runoff during glacial mass wasting events can temporarily exceed any other component of the water budget. Nevertheless, glaciers tend to be only crudely represented in hydrological modeling (Hock et al. 2005b). Hence, the watershed runoff response due to glacier retreat is not well understood.

The primary goal of this study is to analyze the potential impacts of glacier wastage and retreat on the Susitna-Watana Hydroelectric Project (Project). Specifically, how will glacier wastage and retreat, along with associated changes to the climate, affect the flow of water into the proposed reservoir? Currently several glaciers flow down the southern flanks of the Alaska Range near 13,832-foot Mount Hayes to form the three forks of the Upper Susitna River (Figure 7.7-3).

Glaciers in this area provide a significant portion of the total runoff within the Upper Susitna drainage, and it is well documented that these glaciers are currently retreating (Molnia 2008). Given this trend, changes to the runoff represented by glacial melting may occur in the future, and may affect the Project. Therefore, it is important to understand how changes to the upper basin hydrology due to glacial retreat and climate change can affect Project operations and environmental resources.

Specific objectives of the study are as follows:

1) Review existing literature relevant to glacier retreat in Southcentral Alaska and the Upper Susitna watershed. This review will summarize the current understanding of potential future changes in runoff associated with glacier wastage and retreat.

2) Develop a hydrological modeling framework that includes the effects of glacier wastage and retreat on runoff in the Susitna basin, and estimate potential glacier mass changes until the year 2100.
3) Simulate the inflow of water to the proposed Watana Reservoir and project this runoff from the Upper Susitna basin to the year 2100 using downscaled climate projections.
4) Analyze the response of the Susitna River above the proposed Watana Dam site to changes in climate with respect to annual runoff, seasonality, and peak flows.
5) Analyze potential changes to sediment load resulting from glacial surges.
6) Summarize the results in a technical report.

Modeling will rely on two existing coupled models. Hydrological processes outside the glacier will be modeled using the Water Balance Simulation Model (WaSiM), and glacier response will be simulated using the glacier melt and runoff model by Hock (1999), which is now included in WaSiM.

7.7.2. Existing Information and Need for Additional Information

Approximately 5 percent of the Upper Susitna River basin is covered by glaciers. Permafrost is generally discontinuous, although seasonal freeze and thaw cycles affect the entire basin. Long-term, discontinuous (~60 years) stream flow observations from the U.S. Geological Survey (USGS) are available at five locations in the basin: Denali, Cantwell, Gold Creek, Sunshine, and Susitna Station.

7.7.2.1. Existing information on Glacier Retreat in Alaska

There has been extensive melting of glaciers in Alaska in recent decades (Molnia 2008). Statewide, Alaskan glaciers lost 10.1 mi^3 (41.9 km^3) of water per year, plus or minus 2.1 mi^3 (8.6 km^3) of water per year, between 1962 and 2006 (Berthier et al. 2010). However, like temperature and precipitation, glacier ice loss is not uniform across wide areas; even while most glaciers in Alaska are losing mass, a small number have been advancing (e.g., Hubbard Glacier in Southeast Alaska). Alaska glaciers with the most rapid mass loss are those terminating in sea water or lakes (Markon et al, 2012).

7.7.2.2. Documented Changes in Climate

Scenarios Network for Alaska and Arctic Planning (SNAP) (2011) reported that Alaska has seen a statewide increase in temperatures of 2.69 degrees Fahrenheit (°F) since 1971. This has not been equal across the state. Statewide, Barrow displayed the greatest increase (4.16°F) and Kodiak showed the least (0.87°F). The U.S. Global Change Research Program (2009) reported that Alaska has experienced a 3.4°F rise in average annual temperatures over the past 50 years, with an increase in winter temperatures of 6.4°F. These increases in temperatures have led to other related changes in climate. For example, the average snow-free days have increased across Alaska by 10 days, and the number of frost-free days has steadily increased in Fairbanks, Alaska (Figure 7.7-4).

Precipitation rates are generally increasing across the state. On the whole, Alaska saw a 10 percent increase in precipitation from 1949 to 2005, with the greatest increases recorded during winters (U.S. Global Change Research Program 2009). However, this trend is very location-specific across Alaska. Figure 7.7-5 shows that while temperatures have increased in Talkeetna, mean annual precipitation has remained relatively constant (Alaska Climate Research Center 2012).

7.7.2.3. Projections of the Future

For any hydropower project it is important to understand the variability of the discharge as it directly affects power generation.

The observed trends in temperature, precipitation, and snowpack are largely consistent with climate model projections for Alaska (Christensen et al. 2007; Karl et al. 2009). The magnitude of projected changes depends on many factors and will vary seasonally. Projected changes in climate will translate into hydrologic changes through alteration of rain and snowfall timing and intensity, evapotranspiration, and groundwater and surface flows. For example, precipitation is predicted to increase in the Susitna basin, but this may be offset by an increase in evapotranspiration from warmer temperatures. Milder winters could result in reductions in snowpack because a higher percentage of precipitation would occur as rain. But given the elevation of the Upper Susitna basin, increases in precipitation may simply result in increased seasonal snow storage, resulting in greater spring runoff.

Both air temperature and precipitation are currently predicted to increase over time in Alaska, including the southcentral region (SNAP 2011). Temperatures in this region are projected to increase over the coming decades at an average rate of about 1^{o}F (~0.6 ^{o}C) per decade (SNAP 2011).

7.7.3. Study Area

The proposed study area is the Susitna River basin upstream of the proposed Watana Dam site.

7.7.4. Study Methods

The studies and study components to be conducted include the following:

- Review existing literature relevant to Southcentral Alaska, the Susitna watershed, and glacier retreat, and document trends in the historic record.
- Develop a hydrological modeling framework.
- Analyze changes in glacial systems, temperature, and precipitation, and their impacts on watershed hydrology, and project future runoff in a set of climate projection scenarios to year 2100.
- Analyze potential changes to sediment load resulting from glacial surges.
- Summarize results in a technical report.

7.7.4.1. Review Existing Literature

Existing literature will be reviewed to summarize the current understanding of the rate and trend of glacier retreat and the contribution of glacial mass wasting to the overall flow of the Upper Susitna watershed. This will include trend analyses of glacier retreat, temperature, and precipitation.

7.7.4.2. Develop a Modeling Framework

The study will use the fully-distributed temperature index mass balance model by Hock (1999, 2003), that computes snow and ice melt and resulting runoff on hourly to annual time scales based on temperature and precipitation data. The model incorporates the effects of topography on melt by varying the degree-day factor according to potential direct solar radiation, which is computed from topography and solar geometry. The model converts mass changes into glacier geometry changes, and thus it is able to model the effects of a changing geometry on the mass balance.

The model has been used world-wide on many glaciers of different sizes and located in a wide range of climatic settings for a wide range of applications in different disciplines, including basic and applied research, and ranging from providing the mass balance input to ice flow modeling on valley glacier and continental ice sheet scales (Schneeberger et al. 2001), predicting the response of glaciers and glacier discharge to future climate (Schuler et al. 2005; de Woul and Hock 2005), quantifying the risk for glacier outburst floods (Schuler et al. 2002; Huss et al. 2007), assessing the glacial history of empty cirques (Dühnforth and Anderson 2011), and reconstructing the mass balance history on a century time scale (Huss et al. 2008). Applications have recently been broadened by using global climate datasets including output from global and regional climate models for impact studies (Hock et al. 2007). The model requires a digital elevation model (DEM), temperature, and precipitation data.

Data generated from the glacier mass balance model will be input into the WaSiM to analyze the present and future runoff, soil water storage variations, and permafrost distribution. WaSiM (Schulla 2012) is a well-established tool for modeling the spatial and temporal variability of hydrological processes in complex basins ranging from less than 0.4 mi^2 (1 km^2) (Liljedahl et al. 2009) to more than 193,000 mi^2 (500,000 km^2) (Kleinn et al. 2005). It has been widely used by both research scientists and state agencies for water resources management. In total, WaSiM has been applied to more than 55 watersheds on all continents resulting in more than 120 publications documenting the wide range of applications that have led to constant improvement and refinement of the model.

WaSiM calculates evapotranspiration, snow accumulation, snow and glacier melt, runoff, interception, infiltration, soil water storage, and runoff, such as surface, interflow, and baseflow. Recently, the model has been enhanced to include soil heat transfer and permafrost (Liljedahl et al. 2012). Minimum input data requirements include a digital elevation model, vegetation and soil maps, precipitation, and air temperature. Complementary inputs are wind speed, vapor pressure, and shortwave incoming radiation. Spatial interpolation of the meteorological input data may be applied along with corrections of precipitation and adjustment of radiation due to solar and local geometry. The model can be run with hourly to monthly time steps.

WaSiM currently includes a simple glacier melt model that describes the melt of firn, ice, and snow on glaciers as well as routing of the water through the glacier. The melt model is represented by an extended temperature index method including potential direct radiation (Hock 1999), and the water is routed through the glacier using three linear reservoirs (Hock and Noetzli 1997) to account for the different travel times for firn, snow, and ice storages. WaSiM is considered the ideal model for this Project because of the following:

- The model is robust and has been successfully applied to many watersheds as evidenced by the extensive publication record.
- WaSiM is a reasonable compromise between detailed physical basis and minimum data requirements and, therefore, suitable in data-sparse regions such as Alaska.
- WaSiM is a very suitable model because it includes a heat transfer model and it couples a soil thermal regime model to the Richards equation, two dimensional (2-D) groundwater module, and the soil moisture evapotranspiration dynamics.
- The model is coded in a modular way allowing easy adjustments and modifications in model formulations, and it can also easily be coupled to existing glacier models.
- The model is user-friendly and includes a very detailed model description and user manual facilitating use of the model code (Schulla 2012).

Although this approach has been shown to be highly efficient in modeling glacier runoff (Hock et al. 2005b), the model does not allow any changes in glacier firn extent, glacier geometry, and area, i.e., the glacier cannot retreat nor advance. Hence, the model will not be able to accurately predict the runoff changes due to expected glacier retreat as the reservoir of ice is depleted. Also, because the firn areas (i.e., the high reaching accumulation areas) are assumed constant in the current version, the model is not able to account for a faster runoff generation when firn areas decline and more bare ice becomes exposed at the surface. The glacier module will be enhanced by allowing for a time-variant firn area and by updating the glacier extent after each mass-balance year. This will be accomplished by volume-area scaling (Bahr et al. 1997; Radic et al. 2008). By accounting for glacier retreat/advance, the model will be able to represent changes in glacier volume and their effects on long-term river runoff.

Input data will include air temperature, precipitation, relative humidity, wind speed, and radiation data. These will be obtained in part from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) dataset (OSU 2012). PRISM is a unique knowledge-based system that uses point measurements of precipitation, temperature, and other climatic factors to produce continuous, digital grid estimates of monthly, yearly, and event-based climatic parameters. To obtain daily and sub-daily data, a WGEN (Weather Generator) model will be used that provides daily values for precipitation, maximum temperature, minimum temperature, and solar radiation. The model accounts for the persistence of each variable, the dependence among the variables, and the seasonal characteristics of each variable (Richardson and Wright 1984). For re-analysis and present-day assessment, the North America Regional Reanalysis (NARR) will be used, which was computed at NCEP and initially covers the period from 1979 to 2003. The highest resolution output is 20 miles (32 kilometers) every 3 hours. Where available, meteorological data will be used with hourly time resolution from the National Weather Service and from the Alaska-Pacific River Forecast Center, Anchorage.

Field data will be generated from locally installed meteorological stations stations to aid in downscaling the data from gridded climate products (see the Baseline Water Quality Study, Section 5.5). The data will allow smaller-scale climate variability to be accessed and guide determination of some model parameters (for example, the temperature lapse rate).

Future hydrological simulations will be forced with the five-model SNAP (monthly) composite projection scenarios. The SNAP dataset includes the years 1980–2099, with data downscaled to 2-kilometer grid cells. Future projections from SNAP are derived from a composition of the five best-ranked General Circulation Models (out of 15 used by the Intergovernmental Panel on Climate Change [IPCC]) models for Alaska. Based on how closely the model outputs matched climate station data for temperature, precipitation, and sea level pressure for the recent past, their individual ranking order for overall accuracy in Alaska and the far north was as follows: (1) ECHAM5, (2) GFDL21, (3) MIROC, (4) HAD, and (5) CCCMA. The five-model composite uses mean values from the outputs of these models. Results from three emission scenarios (A2, A1B, and B2) are available from the SNAP website (http://www.snap.uaf.edu/home). Input parameters to the permafrost model within WASIM are spatial datasets of vegetation and soil thermal properties, which are specific for each vegetation and soil class and geographical area. The following datasets will be used:

- **Soils Properties.** Input parameters to the heat transfer model within WaSiM, enabling the modeling of permafrost impacts on the hydrology, are thermal and hydraulic soil characteristics defined by spatial datasets. The parametrization will be based on the U.S. General Soil Map (STATSGO) Data, a digital general soil association map developed by the National Cooperative Soil Survey and distributed by the Natural Resources Conservation Service of the U.S. Department of Agriculture. The soil map units, in Esri digital format, are linked to tabular data stored in an Access Database, containing estimated data on the physical and chemical soil properties, soil interpretations, and static and dynamic metadata. Further data for calibration and validation purposes will be acquired through the Permafrost Laboratory at the Geophysical Institute, University of Alaska, Fairbanks (Jafarov et al. 2012).
- **Land cover map.** Land cover properties will be specified for a land cover map obtained from the National Land Cover Database 2001 (Homer et al. 2007). The dataset, produced through a cooperative project conducted by the Multi-Resolution Land Characteristics (MRLC) Consortium, is derived from 30-m resolution Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper-plus (ETM+) circa 2001 satellite imagery and is available since 2008 (Selkowitz and Stehman 2011). In their accuracy assessment, Selkowitz and Stehman (2011) evaluated these data to be reasonable for a wide variety of research, analysis, and modeling efforts. The seasonality of different land cover classes will be parameterized according to products available through the Earth Resources Observation System (EROS) Data Center. These include MODIS-based products (ranging from 250-m to 1-km resolution), such as leaf area index (LAI) maps, and are provided through the Land Processes Distributed Active Archive Center (LP DAAC).

The models will be calibrated and validated against existing and new AEA-collected river discharge records and glacier mass balance data. The model will be run over the period from 1960 to present. Future simulations will be forced with the SNAP projection scenarios and, if available, the newer AR5 simulations. Assessment of changes in glacier mass and river runoff will be the primary focus, but detailed output from the WaSiM model, such as future permafrost and active layer and soil water storage, will also be analyzed. Change in streamflow will be analyzed on annual, seasonal, and single event (observational period only) time scales. Results will allow quantification of the integrated glacier-hydrology responses to climate change for the Upper Susitna basin.

7.7.4.3. Analyze Potential Changes in Sediment Delivery to Watana Reservoir

Glaciers in Alaska can exhibit surges (advancement of the ice) with a sudden onset, extremely high (tens of meters/day) maximum flow rate, and a sudden termination, often with a discharge of stored water. Glacial surges have been reported for a number of Alaskan glaciers (Humphrey and Raymond 1994; Clarke et al. 1986), including those that are located in the Alaska Range. Glacial surges have been reported for the Susitna and West Fork glaciers in the Upper Susitna basin (Harrison 1994).

Suspended sediment loads as a result of a glacial surge on the Variegated Glacier were reported to increase significantly (Humphrey and Raymond 1994), and it has been suggested that the increased suspended sediment loads resulting from glacial surges might increase sediment delivery to the Watana Reservoir, thereby accelerating reservoir sedimentation (R&M Consultants and Harrison 1981; Harrison 2012).

This study will analyze potential changes to sediment load resulting from glacial surges. Unpublished sediment data at the West Fork Glacier, Denali Highway Bridge, and Gold Creek following the 1987–1988 surge of the West Fork Glacier (Harrison 2012) will be obtained and reviewed to determine whether the glacial surge produced significantly increased sediment loads at those locations.

It should be noted that the presence of extensive braided streams between the termini of the Upper Susitna basin glaciers and the head of the Watana Reservoir is likely to buffer the impacts of any surge-related increase in sediment concentration at the reservoir. The braided streams strongly suggest that sediment delivery to the Watana Reservoir will not be supply-dependent. Also, there is typically an order of magnitude variability in the suspended sediment loads during times without a glacial surge (Meyer 2012). Because of this sediment delivery, glacial surge may be within normal background variations.

An initial investigation of the potential loading of sediment from a glacial surge will be developed. The potential for increased sediment loading to the Watana Resovoir from a glacial surge will be based on the following:

- The magnitude of previous glacial surges in the Upper Susitna River basin glaciers as reported by Harrison (1994) and Humphrey and Raymond (1994).
- The sediment transport capacity of the reaches of the Susitna River upstream of the reservoir.

At the end of this study it may be determined that the increased sediment load will impact project operations and a sediment loading scenario accounting for glacial surge will be added to the reservoir geomorphology study component of the Geomorphology Study. This would include an estimate of the reduction in reservoir life that could result from sediment loading associated with periodic glacial surges.

7.7.4.4. Assess the Potential Effects on Basin Hydrology

Changes in snowpack, temperature, and precipitation have been previously documented over time in the state (Christensen et al. 2007; Karl et al. 2009). The magnitude of future changes depends on many factors and will vary seasonally. Projected changes in climate will translate into hydrologic changes through alteration of rain and snowfall timing and intensity, evapotranspiration, and groundwater and surface flows. This study will quantitatively evaluate the effects of projected changes in precipitation and temperature on watershed hydrology over the next 100 years in the Upper Susitna basin.

7.7.4.5. Summarize Results in a Technical Report

The technical report will include a description of the assumptions made, methods used (including models and projection scenarios), and other background information. Additionally, this report will include an analysis of the impacts of future climate scenarios on the watershed hydrology of the Upper Susitna basin.

7.7.5. Consistency with Generally Accepted Scientific Practice

Modeling will rely on two existing models. Glacier response will be simulated using the glacier melt and runoff model by Hock (1999), which will be fully coupled to WaSiM, a physically-based hydrological model.

7.7.6. Schedule

The study elements will be completed in several stages and based on the timeline summarized in Table 7.7-1. In 2014 and 2015, licensing participants will have opportunities to review and comment on the study reports (ISR in early 2014 and USR in early 2015). Updates on the study progress will be provided during Technical Workgroup meetings which will be held quarterly in 2013 and 2014.

7.7.7. Relationship with Other Studies

A flow chart (Figure 7.7-6) describing interdependencies outlines the origin of existing data and related historical studies, specific output for each element of the study, and where the output information generated will be directed. Integral portions of this interdependency chart are previous studies performed on glacier retreat, and historical aerial photographs of the area. In addition, climate change studies providing parameters for anticipated precipitation and temperature changes are relevant to the study. The results of this study will feed directly into the water quality modeling for the reservoir and downstream areas.

7.7.8. Level of Effort and Cost

The total estimated cost is $1,000,000.

7.7.9. Literature Cited

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7.7.10. Tables

Table 7.7-1. Glacier and Runoff Changes Study schedule.

Activity	2012				2013				2014				2015
	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q
Compile data, review glacier wastage & watershed hydrology literature					—								
Process remote sensing imagery					—	—	—						
Spring fieldwork (winter balance measurements and instrument and station deployment)						—				—			
Fall fieldwork (summer balance measurements and data collection)							—				—		
Analyze glacier mass balance and meteorological data							—					—	
Glacier extent variation						—	—	—					
Hydrological & glacier melt model development					—	—							
Hydrological & glacier melt model calibration and validation							—	—	—	—	—	—	—
Initial study report issued									Δ				
Updated study report issued													▲

Legend:

— Planned Activity
Δ Initial Study Report
▲ Updated Study Report

7.7.11. Figures

Figure 7.7-1. September 1999 oblique aerial photograph of the terminus of an unnamed glacier that drains to the East Fork of the Susitna River, looking northeast. The western end of the lake corresponds to the 1955 position of the terminus. The large trimline suggests that the glacier has recently thinned significantly more than 50 meters (164 feet) and retreated more than 2 kilometers (1.2 miles). From Molnia 2008.

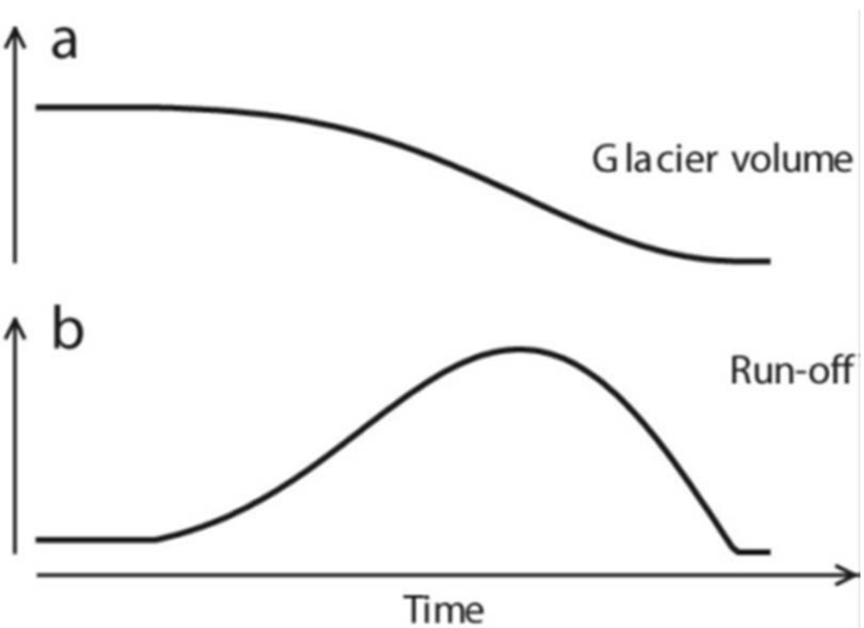


Figure 7.7-2. Schematic representation of the long-term effects of negative glacier mass balances on a) glacier volume and b) glacier runoff. Note that runoff is initially larger during prolonged mass wasting until the glacier is small enough to reduce excess runoff (Jansson et al. 2003).

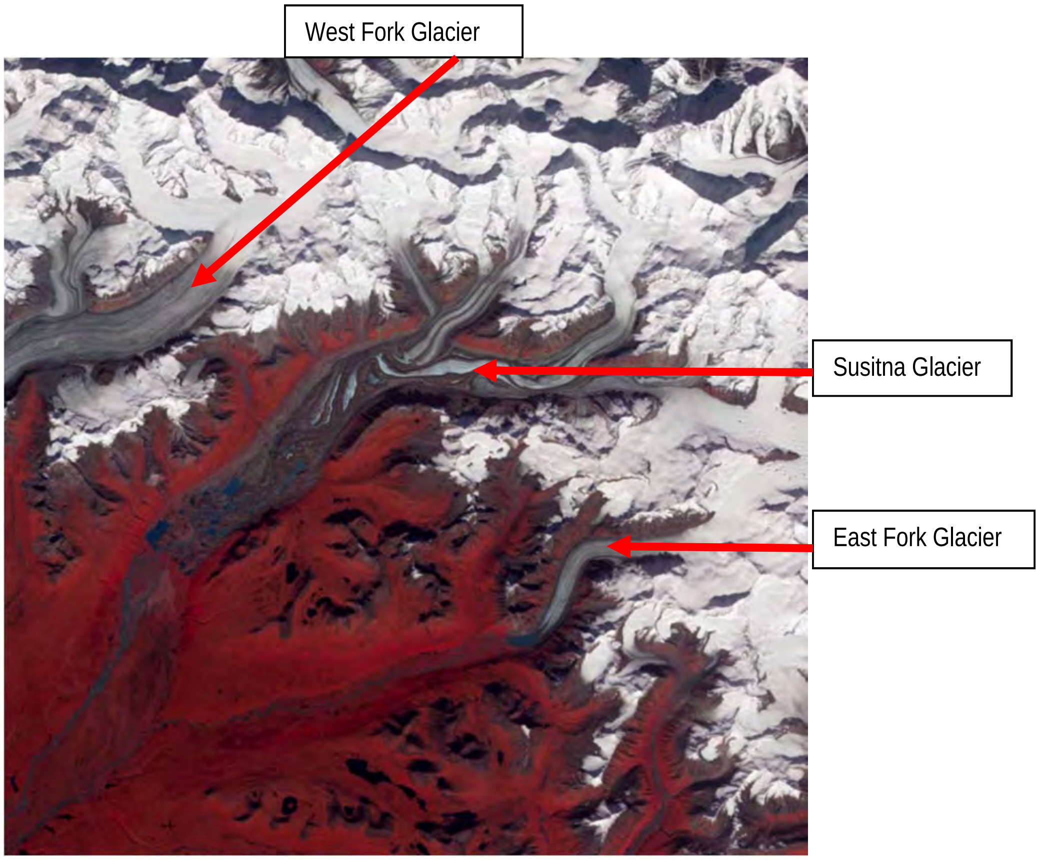


Figure 7.7-3. Susitna Glacier and other unnamed glaciers contributing to Upper Susitna River drainage.

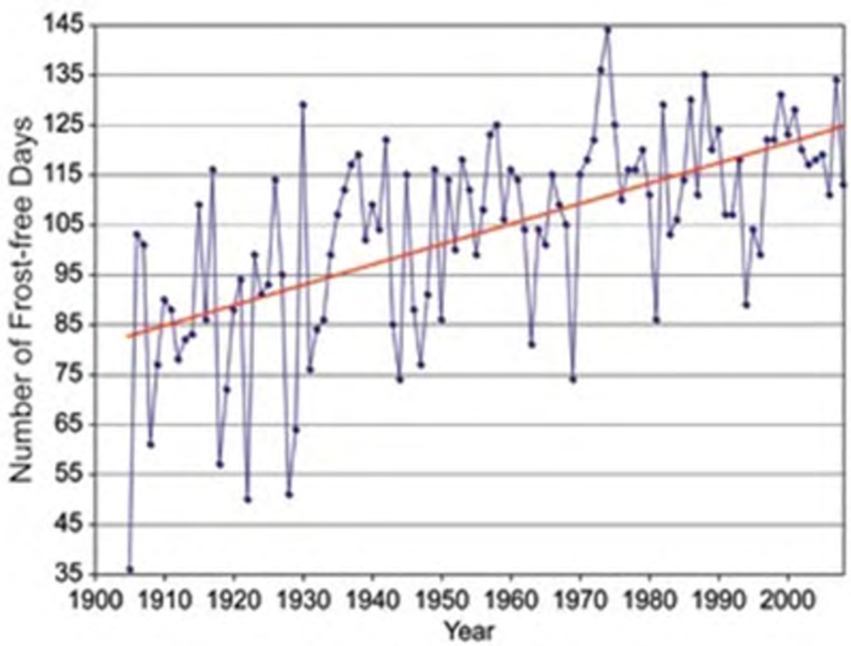
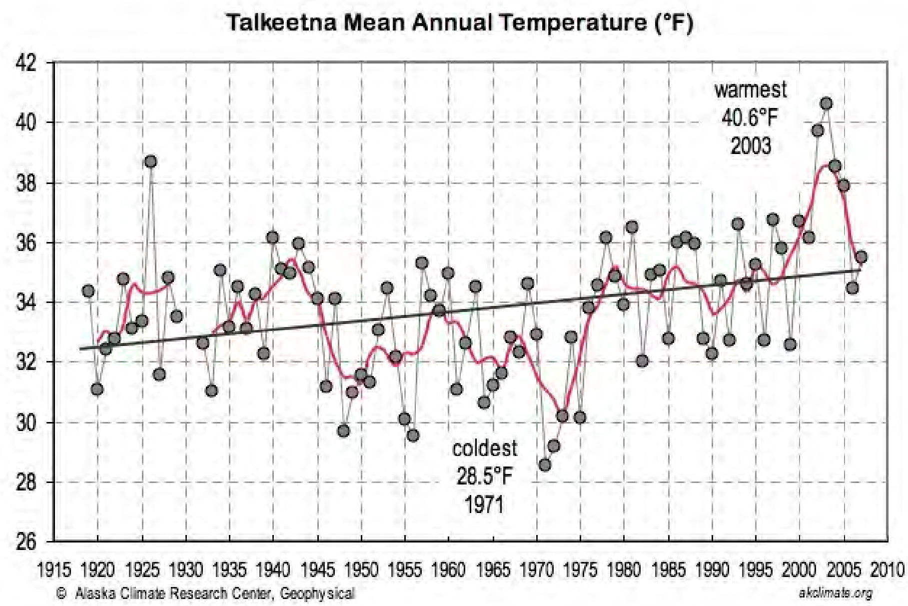


Figure 7.7-4. Fairbanks Frost-Free Season, 1904 to 2008. Over the past 100 years, the length of the frost-free season in Fairbanks, Alaska, has increased by 50 percent. U.S. Global Change Research Program (2009).



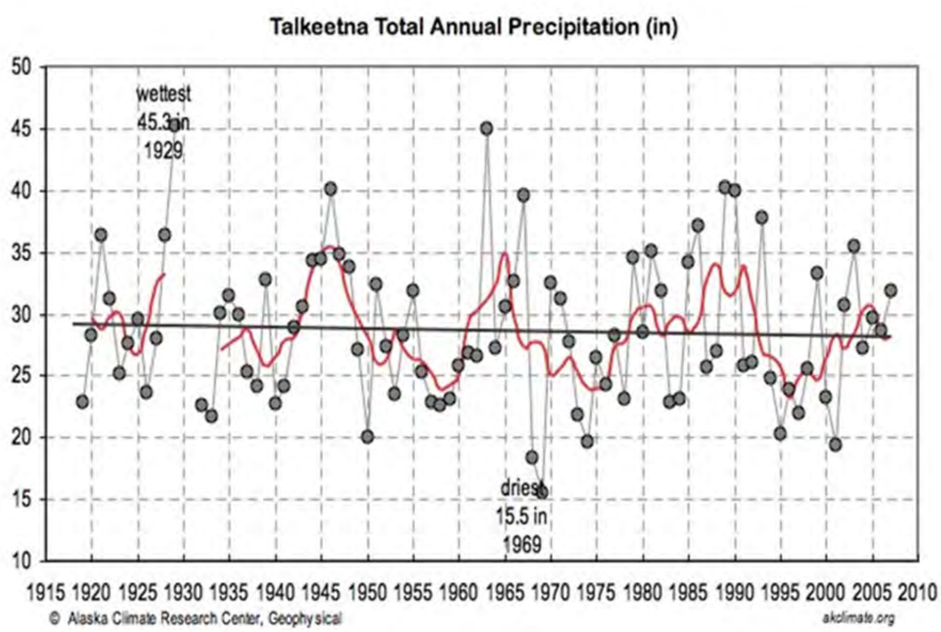


Figure 7.7-5. Mean annual temperature and total annual precipitation at Talkeetna, Alaska 1915–2010 showing the trend line. From Alaska Climate Research Center, http://climate.gi.alaska.edu/Climate/Location/TimeSeries/Talkeetna.html.

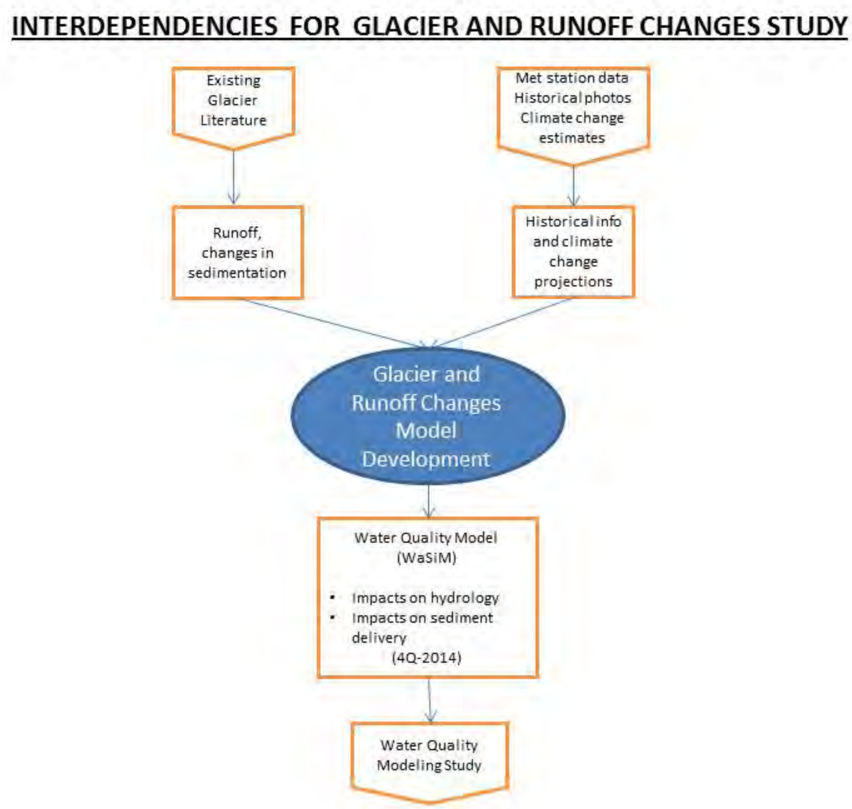


Figure 7.7-6. Interdependencies for Glacier and Runoff Changes Study.

7.8. Attachments

ATTACHMENT 7-1. GLOSSARY OF TERMS AND ACRONYMS – HYDROLOGY.

ATTACHMENT 7-1

GLOSSARY OF TERMS AND ACRONYMS – HYDROLOGY

Glossary of Terms and Acronyms
Hydrology

Included in this list are definitions obtained from the glossary prepared by the Instream Flow Council (Locke et al. 2008), the *Multi-language Glossary of Permafrost and Pelated Ground-Ice Terms* (van Everdingen 1998), and the USGS Hydrologic Definitions (USGS 2012), as well as definitions developed for the Susitna-Watana Hydroelectric Project.

Active floodplain	The flat valley floor constructed by a river during lateral channel migration and deposition of sediment under current climate conditions.
AEA	Alaska Energy Authority.
Anchor ice	Submerged ice attached or anchored to the bottom, irrespective of the nature of its formation. Often accumulates as frazil slush in open reaches.
Aquifer	A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to springs and wells.
Bank	The sloping land bordering a stream channel that forms the usual boundaries of a channel. The bank has a steeper slope than the bottom of the channel and is usually steeper than the land surrounding the channel.
Baseflow	The portion of stream flow that comes from the sum of deep subsurface flow and delayed shallow subsurface flow. It should not be confused with groundwater flow.
Border ice	Ice sheet in the form of a long border attached to the bank or shore; *shore ice*.
Braided streams	Stream consisting of multiple small, shallow channels that divide and recombine numerous times. Associated with glaciers, the braiding is caused by excess sediment load.
Brash ice	Accumulations of floating ice made up of fragments not more than about 2 meters (6 feet) across; the wreckage of other forms of ice.
Break-up	Disintegration of ice cover.

Break-up jam	Ice jam that occurs as a result of the accumulation of broken ice pieces. Break-up jams usually occur in the spring after a stable ice cover has formed, and are caused by a combination of increased discharge and thermal decay of the ice cover.
Break-up period	Period of disintegration of an ice cover.
Calibration	In the context of hydrologic modeling, calibration is the process of adjusting input variables to minimize the error between predicted and observed water surface elevations or other hydrologic parameters.
Capillary fringe	The subsurface layer in which groundwater seeps up from a water table by capillary action to fill soil pores.
CCCMA	Canadian Centre for Climate Modeling and Analysis.
Channel	A natural or artificial watercourse that continuously or intermittently contains water, with definite bed and banks that confine all but overbank stream flows.
Cirques	A bowl-shaped depression on the side of a mountain at the head of a glacier.
Conductivity	In terms of water conductivity, the ability of water to conduct electricity, normally through the presence of dissolved solids that carry electrical charges. It can be an indication of total dissolved solids (TDS).
Confluence	The junction of two or more rivers or streams.
Consecutive dry days	Number of days in a row without precipitation.
Consecutive wet days	Number of days in a row with precipitation. Soil can hold precipitation, but as more consecutive days of precipitation occur, runoff increases.
Cross-section	A plane across a river or stream channel perpendicular to the direction of water flow.
CRREL	U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire.

Degree-day	Also termed *freezing degree-day*, a measure of the departure of the mean daily temperature *below* a given standard, usually 0°C (32°F). For example, a day with an average temperature of –5°C (23°F) represents 9 freezing degree-days by the Fahrenheit scale (5 freezing degree-days by the Celsius scale). Accumulated freezing degree-days (AFDD) are simply the sum of any number of degree-days. For example, the AFDD of a week with mean daily temperatures of –5, 0, +5, 0, –5, –10, and –5°C is 20 freezing degree-days by the Celsius scale (23, 32, 41, 32, 23, 14, and 23°F) and 36 freezing degree-days by the Fahrenheit scale.
Datum	A geometric plane of known or arbitrary elevation used as a point of reference to determine the elevation, or change of elevation, of another plane (see gage datum).
DEM	Digital elevation model.
Depth	Water depth at the measuring point (station).
Direct solar radiation	Sunlight not blocked by clouds.
Discharge	The rate of stream flow or the volume of water flowing at a location within a specified time interval. Usually expressed as cubic meters per second (cms) or cubic feet per second (cfs).
Discontinuous permafrost	Permafrost that is laterally discontinuous, or isolated by thawed soils or bedrock.
Dissolved oxygen (DO)	The amount of gaseous oxygen (O_2) dissolved in the water column. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a waste product of photosynthesis. More than 5 parts oxygen per million parts water is considered healthy; below 3 parts oxygen per million is generally stressful to aquatic organisms.
Diurnal	Any pattern that reoccurs daily.
Downwelling	The downward movement of water from rivers, streams, sloughs and other surface water features into soils and bedrock. Water movement can be into unsaturated or saturated material. This is also called groundwater recharge and may be associated with a losing reach of a river or stream.
Drainage area	The total land area draining to any point in a stream. Also called catchment area, watershed, and basin.
Duration of ice cover	The time from freeze-up to break-up of an ice cover.

ECHAM5	A global climate model developed by the Max Planck Institute for Meteorology.
Electrofishing	A biological collection method that uses electric current to facilitate capturing fishes.
EROS	Earth Resources Observation System.
Evapotranspiration	The sum of evaporation and plant transpiration to the atmosphere.
Firn	Granular, partially consolidated snow that has passed through one summer melt season but is not yet glacial ice.
FLIR	Forward looking infrared (FLIR) is an imaging technology that senses infrared radiation. Can be used for watershed temperature monitoring.
Flood	Any flow that exceeds the bankfull capacity of a stream or channel and flows out on the floodplain.
Floodplain	1. The area along waterways that is subject to periodic inundation by out-of-bank flows. 2. The area adjoining a water body that becomes inundated during periods of over-bank flooding and that is given rigorous legal definition in regulatory programs. 3. Land beyond a stream channel that forms the perimeter for the maximum probability flood. 4. A relatively flat strip of land bordering a stream that is formed by sediment deposition. 5. A deposit of alluvium that covers a valley flat from lateral erosion of meandering streams and rivers.
Floodplain vegetation – groundwater / surface water regime functional groups	Assemblages of plants that have established and developed under similar groundwater and surface water hydrologic regimes.
Focus Area	Areas selected for intensive investigation by multiple disciplines as part of the AEA study program.
Frazil	Fine spicules, plates, or discoids of ice suspended in water. In rivers and lakes it is formed in supercooled, turbulent waters.
Frazil pan	A circular agglomerate of loosely packed frazil that floats.
Freeze-up jam	Ice jam formed as frazil ice accumulates and thickens during the freeze-up period.
Freeze-up period	Period of initial formation of an ice cover.

Gaging station	A specific site on a stream where systematic observations of stream flow or other hydrologic data are obtained.
Geographic Information System (GIS)	An integrated collection of computer software and data used to view and manage information about geographic places, analyze spatial relationships, and model spatial processes. A GIS provides a framework for gathering and organizing spatial data and related information so that it can be displayed and analyzed. In the simplest terms, GIS is the merging of cartography, statistical analysis, and database technology.
Geohydrology	The study of water in the Earth's surface, commonly called groundwater.
Geohydrologic unit	An aquifer, a confining unit, or a combination of aquifers and confining units comprising a framework for a reasonably distinct geohydrologic system.
Glacial mass wasting	When large amounts of glacial ice rapidly disintegrate and melt.
Glacial surge	Relatively rapid movement of a glacier down-gradient. Frequently accompanied by increased flow of meltwater and additional sediment production. These events typically have a sudden onset, extremely high (tens of meters/day) maximum flow rate, and a sudden termination, often with a discharge of stored water.
Glacier geometry changes	Changes in the size or shape of a glacier over time.
Glacier mass balance	The difference between accumulation and ablation of a glacier. Changes in mass balance control a glacier's long-term behavior, and cause either advance or retreat.
Glacier outburst	A sudden release of water from a glacier.
Glacier retreat	The upslope migration of the terminus of a glacier.
Global positioning system (GPS)	A system of radio-emitting and -receiving satellites used for determining positions on the earth. The orbiting satellites transmit signals that allow a GPS receiver anywhere on Earth to calculate its own location through trilateration. Developed and operated by the U.S. Department of Defense, the system is used in navigation, mapping, surveying, and other applications in which precise positioning is necessary.
Gradient	The rate of change of any characteristic, expressed per unit of length (see Slope).

Grounded ice	Ice that has run aground or is in contact with the ground underneath it.
Groundwater (GW)	In the broadest sense, all subsurface water; more commonly that part of the subsurface water in the saturated zone.
GW/SW interactions	The physical interactions between groundwater and surface water. Interactions can include pressure, thermal, or mass exchanges between groundwater and surface water. GW/SW interactions are predominately transient processes.
Hanging dam	A mass of ice composed mainly of frazil or broken ice deposited under an ice cover in a region of low flow velocity.
Heat transfer model	A model for migration of heat from a warm body to cold.
Hummocked ice	Ice piled haphazardly, one piece over another, to form an uneven surface.
Hydraulic head	A measure of energy or pressure, expressed in terms of the vertical height of a column of water that has the same pressure difference.
Hydraulic model	A computer model of a segment of river used to evaluate stream flow characteristics over a range of flows.
Hydrograph	A graph showing stage, flow, velocity, or other property of water with respect to time.
Hyporheic	The hyporheic zone is the subsurface volume of sediment and porous space beneath and lateral to a river or streambed, where there is mixing of shallow groundwater and surface water.
Hyporheic flow	Shallow subsurface (groundwater) flow through porous sediments adjacent to river channels.
Ice bridge	A continuous ice cover of limited size extending from shore to shore like a bridge. Often grows upstream via accumulation of frazil pans into an ice cover in lower gradient reaches. In higher gradient reaches, ice bridges may remain limited in extent as floating frazil is sucked underneath.
Ice concentration	The ratio (in eighths or tenths) of the water surface actually covered by ice to the total area of surface, both ice-covered and ice-free, at a specific location or over a defined area.
Ice cover	A significant expanse of ice of any form on the surface of a body of water.

Ice floe	Free-floating piece of ice greater than about 1 meter (3 feet) in extent.
Ice-free	No floating ice present.
Ice jam	A stationary accumulation of fragmented ice or frazil that restricts or blocks a stream channel.
Ice run	Flow of ice in a river. An ice run may be light or heavy, and may consist of frazil or broken sheet ice.
Instream flow	The rate of flow in a river or stream channel at any time of year.
Interannual stream flow variations	Changes in stream flow on a year-to-year basis.
Interflow	The lateral movement of water in the upper part of the unsaturated zone, or vadose zone, which directly enters a stream channel or other body of water. It is above the regions where baseflow takes place. Interflow is slower than throughflow but faster than groundwater flow.
Intergravel	Intergravel refers to the subsurface environment within the riverbed.
IPCC	Intergovernmental Panel on Climate Change.
LAI	Leaf area index. LAI is the one-sided green leaf area per unit ground area in broadleaf canopies, or as the projected needle leaf area per unit ground area in needle canopies.
Leading edge of ice cover	The upstream extent of a continuous ice cover that is progressing upstream via juxtaposition (accumulation) of frazil ice pans.
LiDAR	Light detection and ranging. An optical remote sensing technology that can measure the distance to a target; can be used to create a topographic map.
LP DAAC	Land Processes Distributed Active Archive Center.

Main channel

Main Channel Habitat Types:
Main Channel: Single dominant main channel
Split Main Channel: Less than 3 distributed dominant channels
Braided Main Channel: Greater than 3 distributed dominant channels
Side Channel: Channel that is turbid and connected to the active main channel but represents non-dominant proportion of flow
Tributary Mouth: Clear water areas that exist where tributaries flow into the Susitna River main channel or side channel habitats

Mainstem

Mainstem refers to the primary river corridor, as contrasted to its tributaries. Mainstem habitats include the main channel, split main channels, side channels, tributary mouths, and off-channel habitats.

Manning's equation

V = 1.486 *R*2/3*S*1/2/*n* in English units (*V* = *R*2/3*S*1/2/*n* in SI units) where *V* = mean flow velocity, *R* = hydraulic radius, and *S* = hydraulic slope; *n* is a coefficient of roughness.

MET

Meteorological stations.

MIROC

Model for Interdisciplinary Research on Climate.

MODFLOW

The name of a common USGS finite difference 3-D groundwater flow model.

MRLC

Multi-Resolution Land Characteristics.

NARR

North America Regional Reanalysis.

Off-channel

Those bodies of water adjacent to the main channel that have surface water connections to the main river at some discharge levels.
Off-channel Habitat Types:
Side Slough: Overflow channel contained in the floodplain, but disconnected from the main channel. Has clear water.2
Upland Slough: Similar to a side slough, but contains a vegetated bar and is rarely overtopped by mainstem flow. Has clear water. 2
Backwater: Found along channel margins and generally within the influence of the active main channel. Water is not clear.
Beaver Complex: Complex ponded water body created by beaver dams

Open lead

Elongated opening in the ice cover caused by water current (velocity lead) or warm water (thermal lead).

Overbank flow	Flow that exceeds the level of a river's banks and extends into the floodplain. Also *overflow*.
Period of record	The length of time for which data for an environmental variable has been collected on a regular and continuous basis.
Permafrost	Earth materials that remains continuously at or below 0oC for at least two consecutive years.
Permeability	The capacity of a rock for transmitting a fluid; a measure of the relative ease with which a porous medium can transmit a liquid.
Piezometer	A type of groundwater well installed to specifically measure water levels or pressure levels. A piezometer can be deep or shallow and is usually not used for water supply applications. A piezometer can also be called a groundwater well, or groundwater monitoring well.
pH	A measure of the acidity or basicity of a solution. Pure water is said to be neutral, with a pH close to 7.0 at 25 °C (77 °F). Solutions with a pH less than 7 are said to be acidic, and solutions with a pH greater than 7 are said to be basic or alkaline.
Porosity	The ratio of the volume of voids in a rock or soil to the total volume.
Potentiometric surface	An imaginary surface representing the static head of ground water in tighty cased wells that tap a water-bearing rock unit (aquifer); or, in the case of unconfined aquifers, the water table.
PRECPTOT	Total precipitation for a year.
PRISM	Parameter-elevation Regressions on Independent Slopes Model. PRISM uses point measurements of precipitation, temperature, and other climatic factors to produce continuous, digital grid estimates of monthly, yearly, and event-based climatic parameters.
Process domains	Define specific geographic areas in which various geomorphic processes govern habitat attributes and dynamics (Montgomery 1999).
Pump test	A method of determining aquifer properties by pumping water from a well and measuring the water level drawdown or recovery in the well, and nearby piezometers or wells.

Q	Hydrological abbreviation for discharge, usually presented as cfs (cubic feet per second) or cms (cubic meters per second). Flow (discharge at a cross-section).
Refugia	An area protected from disturbance and exposure to adverse environmental conditions where fish or other animals can find shelter from sudden flow surges, adverse water quality, or other short-duration disturbances.
Regime	The general pattern (magnitude and frequency) of flow or temperature events through time at a particular location (such as snowmelt regime, rainfall regime).
Reservoir	A body of water, either natural or artificial, that is used to manipulate flow or store water for future use.
Riffle	A fast water habitat with turbulent, shallow flow over submerged or partially submerged gravel and cobble substrates. Generally broad, uniform cross section. Low gradient; usually 0.5-2.0% slope.
Riparian	Pertaining to anything connected with or adjacent to the bank of a stream or other body of water.
Riparian process domain	Define specific geographic areas in which various geomorphic processes govern floodplain habitat attributes and dynamics.
Riparian vegetation	Vegetation that is dependent upon an excess of moisture during a portion of the growing season on a site that is perceptively more moist than the surrounding area.
Riparian zone	A stream and all the vegetation on its banks that is influenced by the presence of the stream, including surface flow, hyporheic flow and microclimate.
River	A large stream that serves as the natural drainage channel for a relatively large catchment or drainage basin.
River corridor	A perennial, intermittent, or ephemeral stream and adjacent vegetative fringe. The corridor is the area occupied during high water and the land immediately adjacent, including riparian vegetation that shades the stream, provides input of organic debris, and protects banks from excessive erosion.
River mile	The distance of a point on a river measured in miles from the river's mouth along the low-water channel.

RTK	Real time kinematic, in reference to a GPS survey method.
Side channel	Lateral channel with an axis of flow roughly parallel to the mainstem, which is fed by water from the mainstem; a braid of a river with flow appreciably lower than the main channel. Side channel habitat may exist either in well-defined secondary (overflow) channels, or in poorly-defined watercourses flowing through partially submerged gravel bars and islands along the margins of the mainstem.
Simple daily intensity index	Known also as SDII, it is the annual total precipitation divided by the number of wet days in the year.
Slope	The inclination or gradient from the horizontal of a line or surface. The degree of inclination can be expressed as a ratio, such as 1:25, indicating one unit rise in 25 units of horizontal distance or as 0.04 height per length. Often expressed as a percentage and sometimes also expressed as feet (or inches) per mile.
Slush ice	An agglomerate of loosely packed frazil floating on the water surface or adhered to the bed or underside of the ice cover.
SNAP	Scenarios Network for Alaska and Arctic Planning.
Soil heat transfer	Heat flow between the soil surface and the deeper layers. Heat transfer varies with soil type, moisture, horizon, etc. The flow of heat is directed from warmer layers to cooler layers. Heat transfer in soil is substantially influenced by the snow cover, vegetation, and terrain.
Soil water storage variations	Seasonal changes in where and how water is stored in a hydraulic system.
Solar geometry	Angle of the sun's rays to the surface.
Spring	Area where there is a concentrated discharge of groundwater that flows at the ground surface.
Stage	The distance of the water surface in a river above a known datum.
Staging	Increase in water levels upstream of the leading edge of ice cover caused by the partial blockage of the channel by ice.

STATSGO	U.S. General Soil Map Data, a digital general soil association map developed by the National Cooperative Soil Survey and distributed by the Natural Resources Conservation Service of the U.S. Department of Agriculture.
Streambed	The bottom of the stream channel; may be wet or dry.
Supercooled water	Water with a temperature slightly below the freezing point (0°C or 32°F).
SW	Surface water. Water that has not infiltrated below ground surface, including rivers, streams, sloughs, lakes, ponds, wetlands.
Terminus	The down-gradient end of a glacier.
Thermal break-up	Melting in place. Also called *in situ* breakup.
Thermal ice	Solid ice formed in place in low-velocity areas.
TM	Thematic Mapper. One of the Earth observing sensors introduced in the Landsat program.
Tracer study	In terms of groundwater applications, the use chemical or physical (usually temperature) properties to determine groundwater pathways and mass exchange with surface water. Natural tracer studies commonly use water temperature and conductivity to help understand groundwater movement and GW/SW interaction.
Tributary	A stream feeding, joining, or flowing into a larger stream (at any point along its course or into a lake). Synonyms: feeder stream, side stream.
Trimline	Soil stripped of vegetation by a glacier.
WaSiM	Water Balance Simulation Model.
Unconfined aquifer	Aquifer whose upper surface is a water table free to fluctuate.
Upwelling	The movement of groundwater into rivers, stream, sloughs and other surface water features. This is also called groundwater discharge and may be associated with a gaining reach of a river or stream.
Unsaturated zone	A subsurface zone above the water table where the pore spaces may contain a combination of air and water.

Water slope	Change in water surface elevation per unit distance.
Water stage	The water surface elevation above the bottom of the river channel or above some arbitrary datum.
Water table	The top water surface of an unconfined aquifer at atmospheric pressure.
WGEN	Weather generator model that can be used to generate daily values for precipitation, maximum temperature, minimum temperature, and solar radiation. The model accounts for the persistence of each variable, the dependence among the variables, and the seasonal characteristics of each variable.

Citation information:

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8. INSTREAM FLOW STUDY: FISH, AQUATICS, AND RIPARIAN

8.1. Introduction

Project construction and operation will affect Susitna River flows downstream of the dam; the degree of these effects will ultimately depend on final Project design and operating characteristics. The Project will be operated in a load-following mode. Project operations will cause seasonal, daily, and hourly changes in Susitna River flows compared to existing conditions. The potential alteration in flows will influence downstream resources/processes, including fish and aquatic biota and their habitats, channel form and function including sediment transport, water quality, groundwater/surface water interactions, ice dynamics, and riparian and wildlife communities (AEA 2011).

The potential operational flow-induced effects of the Project will need to be carefully evaluated as part of the licensing process. This Revised Study Plan (RSP) describes the Susitna-Watana Instream Flow Study (IFS) that will be conducted to characterize and evaluate these effects. The plan includes a statement of objectives, a description of the technical framework that is at the foundation of the IFS, the general methods that will be applied, and the study nexus to the Project. This plan will be subject to revision and refinements as part of the Technical Workgroup (TWG) review and comment process identified as part of the Integrated Licensing Process (ILP). Pursuant to the standards, schedule, and process described below, these details will be developed in consultation with the TWG as part of the continuing study planning process and during study implementation.

The RSP has already benefitted from formal written comments submitted to the Federal Energy Regulatory Commission (FERC) from Proposed Study Plan (PSP) filing (July 16, 2012) through submittal of Interim Draft RSPs (October 31, 2012), and formal comment letters filed with FERC between November 1 and 14, 2012 (see Section 8.4). In addition, comments and suggestions have been provided during eight agency and licensing participant TWG meetings that were conducted to describe various elements of the proposed studies. These meetings were conducted in 2012 on January 1, March 2, April 5, June 13, August 16, September 14, October 2, and October 24 and included specific discussions on study area selection, methods and models, and linkages with other resource studies. Detailed notes were recorded during each of these meetings that highlighted action items and/or technical issues and comments that have been considered in the current RSP. A one-and-one-half-day field reconnaissance was also conducted with the agencies on October 3–4, 2012, to visit three of the proposed study areas (termed Focus Areas (Focus Areas)—see Section 8.5.4.2.1.2) and discuss sampling methodologies. These agency interactions, coupled with direct communications via e-mail and telephone, have all contributed to refinements in the IFS plan that are reflected in this RSP. Even so, as noted above and depicted in the IFS schedule (see Section 8.5.6), refinements will continue to be made to the plan as more information from this and other interdependently-linked studies is collected and evaluated.

8.2. Nexus Between Project Construction / Existence / Operations and Effects on Resources to be Studied

As described above, the operational strategy of the Project could result in a variety of flow responses to the river below Watana Dam. These may include seasonal, daily, and hourly changes in river stage that would vary longitudinally along the river. Having a clear understanding of Project effects on instream flow and riparian habitats and biological resources present within the Susitna River corridor will be critical to environmental analysis of the Project.

8.3. Resource Management Goals and Objectives

Several natural resources agencies have jurisdiction over aquatic species and their habitats in the Project area. These agencies will be using, in part, the results of the IFS and other fish and aquatic studies to satisfy their respective mandates. The federal and state agencies and Alaska Native entities mentioned below have identified their resource management goals, or provided comments in the context of FERC licensing related to instream flow and riparian resource issues.

8.3.1. National Marine Fisheries Service

The following text is an excerpt of the May 31, 2012, National Marine Fisheries Service (NMFS) letter and Instream Flow Study Request:

> *NMFS has authority to request water quality and other natural resource studies related to the project pursuant to the: Magnuson-Stevens Fishery Conservation and Management Act, as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267), National Environmental Policy Act (NEPA) of 1969 (83 Stat. 852; 42 U.S.C. §4321 et seq.), Endangered Species Act (ESA) of 1973 (87 Stat. 884, as amended; 16 U.S.C. §1531 et seq.), Bald and Golden Eagle Protection Act (BGEPA) (54 Stat. 250, as amended, 16 U.S.C. §668a-d), Migratory Bird Treaty Act (MBTA) (40 Stat. 755, as amended; 16 U.S.C. §703 et seq.), Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. §661 et seq.), and Federal Power Act (16 U.S.C. § 91 et seq.).*
>
> *Under Section 18 of the FPA, NMFS and the USFWS have authority to issue mandatory fishway prescriptions for safe, timely, and effective fish passage. Under Section 10(j) of the FPA, NMFS and USFWS are authorized to recommend license conditions necessary to adequately and equitably protect, mitigate damages to, and enhance, fish and wildlife (including related spawning grounds and habitat) affected by the development, operation, and management of hydropower projects. Section 10(a)(1) of the FPA requires FERC to condition hydropower licenses to best improve or develop a waterway or waterways for the adequate protection, mitigation, and enhancement of fish and wildlife (including related spawning grounds and habitat) based on NMFS and Service recommendations and plans for affected waterways. Therefore, one of the resource management goals of NMFS is to inform development of fishway prescriptions for this project pursuant to Section 18 of the FPA.*
>
> *A number of Federal regulations address the need to protect and preserve fish and wildlife resources and their habitats, including preventing the "take" of certain species (or groups of species). The following is a list of some of the most important of these*

regulations which are applicable or may be applicable to the proposed license applications:

- Federal Power Act
  - *FERC is required to give equal consideration to "protection, mitigation of damage to, and enhancement of, fish and wildlife (including spawning grounds and habitat)."*
- Magnuson-Stevens Fishery Conservation Act
  - *Magnuson-Stevens Fishery Conservation and Management Act, as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267), established a new requirement to describe and identify EFH in each fishery management plan. The EFH provisions of the MSA (§305(b)) require federal agencies to consult with NMFS on all actions, or proposed actions, authorized, funded, or undertaken by the agency, that may adversely affect EFH*
- Fish and Wildlife Coordination Act
  - *Requires equal consideration and coordination of wildlife conservation with other water resources development programs.*
- National Environmental Policy Act
  - *Requires evaluation of project alternatives, cumulative effects.*
- Endangered Species Act
  - *Section 7(a)(2) requires Federal agencies to ensure that their activities are not likely to jeopardize the continued existence of listed species or adversely modify designated critical habitat.*
- Anadromous Fish Conservation Act

8.3.2. U.S. Fish and Wildlife Service

The following text is an excerpt of the May 31, 2012, U.S. Fish and Wildlife Service (USFWS) Instream Flow Study Request:

The U.S. Fish and Wildlife Service (USFWS), U.S. Department of Interior, has authority to request fish and wildlife resources studies related to this project pursuant to:

The National Environmental Policy Act (NEPA) of 1969 (83 Stat. 852; 42 U.S.C. 4321 et seq.), the Endangered Species Act (ESA) of 1973 (87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.), the Bald and Golden Eagle Protection Act (BGEPA) (54 Stat. 250, as amended, 16 U.S.C. 668a-d), the Migratory Bird Treaty Act (MBTA) (40 Stat. 755, as amended; 16 U.S.C. 703 et seq.), the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.), and the Federal Power Act (16 U.S.C. § 791 et seq.).

Under Section 18 of the Federal Power Act (FPA), the National Marine Fisheries Service (NMFS), U.S. Department of Commerce and the USFWS have authority to issue mandatory fishway prescriptions for safe, timely, and effective fish passage. Under

Section 10(j) of the FPA, NMFS and USFWS are authorized to recommend license conditions necessary to adequately and equitably protect, mitigate damages to, and enhance, fish and wildlife (including related spawning grounds and habitat) affected by the development, operation, and management of hydropower projects. Section 10(a)(1) of the FPA requires FERC to condition hydropower licenses to best improve or develop a waterway or waterways for the adequate protection, mitigation, and enhancement of fish and wildlife (including related spawning grounds and habitat) based on NMFS and USFWS recommendations and plans for affected waterways.

Consistent with our mission and with the legal authorities described above, our resource goal in this matter is to conserve existing fish and wildlife resources and their habitats in the Susitna River basin. With regard to fish passage, we will recommend scientifically-based and coordinated studies, collaborate with others, and ensure development of the best information possible to inform potential development of fishway prescriptions for this project pursuant to Section 18 of the Federal Power Act.

8.3.3. Alaska Department of Fish and Game

The following text is an excerpt of the May 30, 2012, ADF&G letter and Instream Flow Study Request:

The Fish and Game Act requires the Alaska Department of Fish and Game to, among other responsibilities, "…manage, protect, maintain, improve, and extend the fish, game and aquatic plant resources of the state in the interest of the economy and general well-being of the state" (AS 16.05.020).

8.3.4. Alaska Native Entities

8.3.4.1. Chickaloon Village Traditional Council

The Chickaloon Native Village provided comments on Project licensing activities in a May 31, 2012, letter to the FERC. Chickaloon Native Village is a federally recognized Alaska Native tribe. Chickaloon Village is an Ahtna Athabascan Indian Tribe governed by the nine-member Chickaloon Village Traditional Council. The Chickaloon Village Traditional Council strives to increase traditional Ahtna Dene' practices for the betterment of all residents in the area. Preserving and restoring the region's natural resources is one way of supporting Ahtna culture and the regional ecosystem.

8.4. Summary of Consultation with Agencies, Alaska Native Entities, and Other Licensing Participants

Input regarding the issues to be addressed in the IFS has been provided by the TWG during workgroup meetings commencing in late 2011. During 2012, workgroup meetings were held in January, March, April, June, August, September, and October, during which resource issues were identified and discussed and objectives of the instream flow studies were defined. A one-and-one-half day field reconnaissance was also conducted in October 2012 with agency representatives to tour three of the proposed Focus Areas and discuss riparian, groundwater, and fish habitat sampling and modeling. In addition, agency interactions via e-mail and telephone contributed to refinements in the IFS. Various agencies and other parties (USFWS, NMFS, ADF&G, etc.) provided written comments specific to this study that have been considered and will be addressed as part of this plan. Summary tables of comments and responses from formal comment letters filed with FERC through November 14, 2012 are provided in Appendix 1. Copies of the formal FERC-filed comment letters are included in Appendix 2. In addition, a single comprehensive summary table of comments and responses from consultation, dated from PSP filing (July 16, 2012) through release of Interim Draft RSPs, is provided in Appendix 3. Copies of relevant informal consultation documentation are included in Appendix 4, grouped by resource area.

8.5. Fish and Aquatics Instream Flow Study

8.5.1. General Description of the Study

8.5.1.1. Focus of IFS

The 2013–2014 IFS plan is specifically directed toward establishing an understanding of important biological communities and associated habitats, and the hydrologic, physical, and chemical processes in the Susitna River that directly influence those resources. The focus of much of this work will be on establishing a set of analytical tools/models based on the best available information and data that can be used for defining both existing or base conditions, i.e., without Project, and how these resources and processes will respond to alternative Project operational scenarios.

8.5.1.2. Study Objectives

The goal of the IFS and its component study efforts is to provide quantitative indices of existing aquatic habitats that enable a determination of the effects of alternative Project operational scenarios. Achievement of this goal will require close coordination with a number of interrelated studies (e.g., Fish Distribution/Abundance [see Section 9.6], Characterization of Aquatic Habitats [see Section 9.9], Geomorphology [see Section 6.0], Water Quality [see Section 5.0], etc.) that will provide important inputs into an overall Project effects analysis (see Figure 8.5-1). Specific objectives of this and associated companion studies include the following:

1. Map the current aquatic habitat in main channel and off-channel habitats of the Susitna River affected by Project operations. This objective will be completed as part of the Characterization of Aquatic Habitats Study (see Section 9.9) (see Figure 8.5-1).
2. Select study areas and sampling procedures to collect data and information that can be used to characterize, quantify, and model mainstem and lateral Susitna River habitat types at different scales. This objective will be completed via a collaborative process involving this study, Riparian Instream Flow (see Section 8.6), Groundwater (see Section 7.5), Geomorphology (see Section 6.0), Water Quality (see Section 5.0), and Fish and Aquatics (see Section 9.0).
3. Develop a Mainstem Open-water Flow Routing Model that estimates water surface elevations and average water velocity along modeled transects on an hourly basis under alternative operational scenarios.
4. Develop site-specific Habitat Suitability Criteria (HSC) and Habitat Suitability Indices (HSI) for various species and life stages of fish for biologically relevant time periods selected in consultation with the TWG. Criteria will include observed physical phenomena that may be a factor in fish preference (e.g., depth, velocity, substrate, embeddedness, proximity to cover, groundwater influence, turbidity, etc.). If study efforts are unable to develop robust site-specific data, HSC/HSI will be developed using the best available information and selected in consultation with the TWG.
5. Develop integrated aquatic habitat models that produce a time series of data for a variety of biological metrics under existing conditions and alternative operational scenarios. These metrics may include (but are not limited to) the following:

- Water surface elevation at selected river locations
- Water velocity within study areas subdivisions (cells or transects) over a range of flows during seasonal conditions
- Length of edge habitats in main channel and off-channel habitats
- Habitat area associated with off-channel habitats
- Clear water area zones
- Effective spawning and incubation habitats
- Varial zone area
- Frequency and duration of exposure/inundation of the varial zone at selected river locations
- Habitat suitability indices

6. Evaluate existing conditions and alternative operational scenarios using a hydrologic database that includes specific years or portions of annual hydrographs for wet, average, and dry hydrologic conditions and warm and cold Pacific Decadal Oscillation (PDO) phases.
7. Coordinate instream flow modeling and evaluation procedures with complementary study efforts including Riparian (see Section 8.6), Geomorphology (see Sections 6.5 and 6.6), Groundwater (see Section 7.5), Baseline Water Quality (see Section 5.5), Fish Passage Barriers (see Section 9.12), and Ice Processes (see Section 7.6) (see Figure 8.5-1). If channel conditions are expected to change over the license period, instream flow habitat modeling efforts will incorporate changes identified and quantified by riverine process studies.
8. Develop a Decision Support System-type framework to conduct a variety of post-processing comparative analyses derived from the output metrics estimated under aquatic habitat models. These include (but are not limited to) the following:
    - Seasonal juvenile and adult fish rearing
    - Habitat connectivity
    - Spawning and egg incubation
    - Juvenile fish stranding and trapping
    - Ramping rates
    - Distribution and abundance of benthic macroinvertebrates

8.5.2. Existing Information and Need for Additional Information

8.5.2.1. Summary of Existing Susitna River Information

Substantial physical, hydrologic, and biological information is available for the Susitna River as a result of previous hydropower licensing efforts conducted during the 1970s and 1980s. The extent and details of many of those studies were provided in the Draft Environmental Impact

Statement (FERC 1984) for the previously-proposed Susitna-Hydroelectric (Su-Hydro) Project (FERC No. 7114) along with companion appendices and attachments in the way of Alaska Department of Fish and Game (ADF&G) reports. A gap analysis conducted by HDR (2011) summarized some of the data. The gap analysis provided an initial listing of salient reports and data that warranted more detailed evaluations.

A more focused review of existing reports and data specific to the Su-Hydro Project proposed in the 1980s was initiated by Alaska Energy Authority (AEA) in 2012. This has included the identification, acquisition, and compilation of study plans, reports, data, maps, drawings, photographs, and technical correspondence pertaining to the 1980s Su-Hydro Project. Although a substantial amount of this information had already been provided to and made available through the Alaska Resources Library and Information Services (ARLIS), AEA has identified and is working with ARLIS in acquiring the majority of original files, documents, maps, drawings, and other information that had been archived in several locations in Alaska. These documents are in a variety of formats including textual, microfiche, and maps. The majority of documents will be housed in the ARLIS library in Anchorage, Alaska (some are available online through the University of Alaska, Fairbanks library) and will be made available either electronically or by on-site review to interested parties, licensing participants, and Project team members.

As part of the 2012 effort, AEA also commissioned the targeted review of reports, data, and other information specific to the 1980s studies of fish, fish habitats, and instream flow-related assessments. This work is nearing completion and will result in the preparation of Technical Memoranda (TMs) that summarize the salient fish and instream flow-related information from those studies. To date, over 60 reports from the 1980s and earlier have been identified and reviewed. These documents include 83 separate volumes containing descriptions of field studies and reports with tabular data, figures, and maps. The reports describe studies that were focused on a wide range of interrelated topics designed to provide information that would allow for an evaluation of the potential effects of the Su-Hydro Project operations on downstream fish and aquatic resources and habitats. These included studies focused on the following:

- Adult salmon passage in sloughs and side channels
- Adult salmon spawn timing and distribution
- Salmon Habitat Suitability Criteria
- Salmon spawning habitat evaluation
- Juvenile salmon abundance and distribution including winter studies
- Resident fish abundance, distribution, and life history
- Channel geometry investigations
- Groundwater upwelling detection
- Hydrological investigations and modeling of anadromous and resident fish habitat

The documents are well organized and rich in detail regarding study rationale, site descriptions, methods applied, and results. With respect to instream flow analysis, the studies generally followed the Instream Flow Incremental Methodology (IFIM) described by Bovee (1982), and therefore careful consideration was given to study design, site selection, data collection, and data analysis and modeling. In addition, recognizing the spatial variability in the diversity and complexity of habitat types within different segments of the Susitna River, substantial effort was spent on developing approaches that could be used for expansion/extrapolation of flow-habitat model results obtained from one location to unmeasured sites (Aaserude et al. 1985). Overall, the documents represent a remarkable source of information that is directly relevant to the types of studies that are proposed in this RSP. Indeed, many of the study components presented in the RSP have been founded on certain elements provided in one or more of the earlier reports. However, the studies presented in the RSP are not simply repeating or duplicating those conducted in the 1980s. Rather, the earlier studies have been appropriately used to make informed decisions regarding study design, methods selection, and modeling approaches that are best suited to address the specific objectives of the RSP as stated in Section 8.5.1.2.

One consideration that was taken into account relative to the applicability of the earlier studies was that the 1980s Su-Hydro Project was envisioned as a two-dam project, with an upper dam, reservoir, and powerhouse near river mile (RM) 184 (Watana Dam). It was envisioned that the upper development would be operated in load-following mode to meet power demands. A lower dam, reservoir, and powerhouse (Devils Canyon Dam) would provide additional power generation, but would also re-regulate flow releases from the upper development. Downstream flow releases from the Devils Canyon Dam would not have the daily flow fluctuations associated with load-following operations of the upper development. In addition, because the Devils Canyon Dam would create a reservoir that would inundate much of the river between the two dams, the instream flow and riparian study efforts in the 1980s focused on the effects of flow releases to the Susitna River downstream of the Devils Canyon Dam site, and the reach between the Devils Canyon Dam and Watana Dam sites was not modeled as part of the instream flow study. Instream flow-related issues that were the focus of studies completed in the 1980s were thus more concerned with determining the effects of changes in the timing and magnitude of flows on the quantity and quality of fish habitats that would occur with the two dams as configured, rather than flow fluctuations.

The Project, as currently proposed, without the re-regulation of flows that a second dam would allow, will require the evaluation of downstream effects of load-following operations on fish and wildlife resources downstream of the Watana Dam site, in addition to an assessment of overall effects due to shifts and changes in flow timing and magnitude. These are important differences between the current proposal and that of the 1980s, and have directly factored into the design of studies proposed in the RSP. In particular, the proposed studies now include the development of a flow routing model that will predict water surface elevation changes at different locations in the river under variable flow conditions. Linkage of this model with those developed as part of this RSP that are focused on defining habitat-flow relationships in different habitat types of the river will allow for an integrated evaluation of Project effects under different operational scenarios, including load-following. Other related resource studies (e.g., Riparian [see Section 8.6], Geomorphology [see Section 6.0], Water Quality [see Section 5.0], and Ice Processes [see Section 7.6]) will also rely on this model and will use it to evaluate Project operational effects on their respective resources.

As background and to provide context for the studies that are contained in this RSP, some of the salient information from the 1980s studies is summarized below.

8.5.2.2. Habitat Distribution

The spatial distribution and characterization of existing habitat conditions in the Susitna River are important aspects of 2013–2014 instream flow studies. Fish species in the Susitna River basin rely on a range of aquatic habitats, and specific habitat types may be selectively used by different species and life stages (Jennings 1985; Sundet and Pachek 1985). Furthermore, fish utilization of specific habitats may vary seasonally or spatially within the basin (Suchanek et al. 1985). The distribution of aquatic habitats in the Susitna River will be an important consideration during instream flow studies to evaluate potential effects of stream flow fluctuations on habitat and fish communities.

Habitat distribution mapping was performed during 1980s studies at the macro-habitat scale (i.e., main channel, side channel, side slough, upland slough, tributary mouth, tributary, and lake) (see Section 9.9). The character and distribution of habitat during the 1980s were mapped using aerial photography based on hydrology and channel morphology (Trihey 1982; ADF&G 1983). The aerial photos were recorded at various stream flow levels to identify the effect of Susitna River discharge on habitat distribution (Figure 8.5-2) (Klinger-Kingsley et al. 1985). Most of the mapping effort targeted the Middle River Segment and relatively less for the Lower River Segment; very little habitat data are available for the Upper River Segment from the 1980s (Klinger-Kingsley et al. 1985; Buckwalter 2011). A more complete summary of the existing information relating to habitat distribution in the Susitna River is provided in Section 9.9 (Characterization of Aquatic Habitats in the Susitna River).

8.5.2.3. Fish Distribution and Abundance

The distribution and abundance of fish species in the Susitna River will play an important role in evaluating the potential flow-induced effects of the Project, particularly in the Middle and Lower Susitna River. The distribution of fish species among Susitna River segments (Upper, Middle, and Lower) and among main channel, off-channel, and tributary habitats is essential information for 2013–2014 instream flow studies to identify species and life stages that may be affected by Susitna River stream flow fluctuations. Relative abundance of fish species among river segments and habitats will similarly provide a basis for evaluating the effects of hydrologic changes on fish in the Susitna River.

Extensive studies were conducted during the 1980s related to fish distribution and abundance and more recent fish distribution studies performed during the 2000s have supplemented data collected during the earlier efforts (see Section 9.0). At least 20 anadromous and resident fish species are known to inhabit the Susitna River between headwater areas and Cook Inlet (RM 0.0) (Jennings 1985; Delaney et al. 1981a, 1981b). Species richness is greatest in the Lower River Segment and declines in the Middle and Upper River segments (Jennings 1985; Delaney et al. 1981b). Steep, high-velocity cascades in Devils Canyon (RM 152 – 160) represent the upstream extent of distribution for many species (Jennings 1985; Delaney et al. 1981a). Fish species found in the Middle and Lower River segments include, but are not limited to, Pacific salmon species (Chinook, sockeye, chum, coho, and pink), Arctic grayling, rainbow trout, Dolly Varden, humpback whitefish, round whitefish, and burbot (Jennings 1985; Delaney et al. 1981b, 1981c). Within the Middle and Lower River segments, these fish species utilize main channel, off-channel, and tributary habitats (Jennings 1985; Delaney et al. 1981b, 1981c). In terms of instream flow studies, fish utilization in main channel and off-channel habitats is of principal importance because these areas are influenced by Susitna River stream flow fluctuations. A more detailed synthesis of fish distribution and abundance is provided in Section 9.0 (Fish and Aquatics).

8.5.2.4. Salmonid Spawning and Incubation

Salmonid spawning and egg incubation are critical life history phases and are important considerations for development of Susitna River instream flow studies. Water depth, velocity, and temperature of surface stream flow are important habitat characteristics for spawning adult salmonids, while intergravel flow and water quality can be critical for salmonid egg incubation and emergent fry survival. As a result, each biological process is sensitive to stream flow fluctuations. As part of Susitna River instream flow studies, it is important to identify the distribution and timing of salmonid spawning in the Susitna River (see Section 9.0). Main channel (main channels, side channels, and tributary mouths), off-channel (side sloughs, upland sloughs, and backwater areas), and tributary habitats are used by adult salmonids for migration and spawning, though main channel and off-channel habitats are of principal importance with regard to instream flow studies because these areas are most influenced by Susitna River stream flow fluctuations. Knowledge of the timing of salmonid spawning and associated migrations will help identify the periods during which fish populations may be affected by changes in Susitna River stream flow. In addition, the behavior of spawning salmonids, such as colonization rates of new spawning areas and redd residence time by spawners, is an important aspect of this life history stage and will help guide instream flow studies in the Susitna River.

Pacific salmon species are known to utilize Middle and Lower Susitna River habitats for migration and spawning between RM 206.8 and Cook Inlet (RM 0.0) (Jennings 1985; Thompson et al. 1986; Buckwalter 2011). During upstream spawning migrations, all Pacific salmon species utilize the mainstem Susitna River to access spawning areas located in main channel, off-channel, and/or tributary habitats of the Middle and Lower Susitna River. For spawning in the Middle Susitna River, adult sockeye, chum, and pink salmon utilized main channel and off-channel habitats during the 1980s, while Chinook and coho salmon typically spawned in tributary habitats not influenced by Susitna River stream flow conditions (see Section 8.5.2.1.2) (Jennings 1985; Barrett et al. 1985; Thompson et al. 1986). In the Lower Susitna, the primary spawning areas for chum and pink salmon occurred in main channel and off-channel habitats, while Chinook, coho, and sockeye salmon generally used tributaries for spawning (Barrett et al. 1983; Barrett et al. 1985; Thompson et al. 1986).

The timing of salmon spawning migrations in the Susitna River during the 1980s began in late May and continued through September, though specific timing of movement differed by species (see Section 8.5.2.1.7). In the Middle and Lower Susitna River, salmon species that utilized main channel and off-channel habitat for spawning typically spawned from late July through early October (see Section 8.5.2.1.7) (Jennings 1985; Barrett et al. 1985; Thompson et al. 1986). The period of salmon egg incubation occurred from the onset of spawning through the end of fry emergence, which was estimated to begin in late January and continue through April and/or May (see Section 8.5.2.1.7) (Bigler and Levesque 1985; Jennings 1985; Stratton 1986; Vining et al. 1985). Among habitats utilized by spawning salmon, side channel and side slough habitats were observed to be most vulnerable to dewatering and/or freezing as a result of fluctuations in Susitna River discharge (Vining et al. 1985).

8.5.2.5. Study Area Selection

In general, the Susitna River was divided in the 1980s studies into segments, sub-reaches, and study sites based on hydrology, channel morphology, tributary input, macro- and mesohabitat features, and fish use. At the broadest scale, the Susitna River was divided into three reaches following the historic river mile convention used at the time:

1. Upper river – Representing that portion of the watershed above the proposed Devils Canyon Dam site at RM 152.
2. Middle river – Extending approximately 53.5 miles from RM 152 downstream through Devils Canyon to the Three Rivers Confluence at RM 98.5.
3. Lower river – Extending 98.5 miles downstream from the Three Rivers Confluence to Cook Inlet (RM 0).

These three breaks formed the first order level of stratification in the 1980s studies.

A second level of stratification was designated based on classifying riverine-related habitats of the Susitna River into six macro-habitat categories consisting of mainstem, side channel, side slough, upland slough, tributaries, and tributary mouths (Estes and Vincent-Lang 1984). The distribution and frequency of these habitats varied longitudinally within the river depending in large part on its confinement by adjoining floodplain areas, size, and gradient. The habitat types were described by ADF&G with respect to mainstem flow influence in the *Susitna Hydroelectric Aquatic Studies Procedures Manual* (ADF&G 1984) as follows, with additional clarification added here where considered appropriate:

- **Mainstem habitat** consists of those portions of the Susitna River that normally convey stream flow throughout the year. Both single and multiple channel reaches are included in this habitat category. Groundwater and tributary inflows appear to be inconsequential contributors to the overall characteristics of mainstem habitat. Mainstem habitat is typically characterized by high water velocities and well-armored streambeds. Substrates generally consist of boulder- and cobble-size materials with interstitial spaces filled with a grout-like mixture of small gravels and glacial sands. Suspended sediment concentrations and turbidity are high during summer due to the influence of glacial meltwater. Stream flows recede in early fall and the mainstem clears appreciably in October. An ice cover forms on the river in late November or December.
- **Side channel habitat** consists of those portions of the Susitna River that normally convey stream flow during the open-water season but become appreciably dewatered during periods of low flow. Side channel habitat may exist either in well-defined overflow channels, or in poorly defined water courses flowing through partially submerged gravel bars and islands along the margins of the mainstem river. Side channel streambed elevations are typically lower than the mean monthly water surface elevations of the mainstem Susitna River observed during June, July, and August. Side channel habitats are characterized by shallower depths, lower velocities, and smaller streambed materials than the adjacent habitat of the mainstem river.
- **“Side” slough habitat** is located in spring- or tributary-fed overflow channels between the edge of the floodplain and the mainstem and side channels of the Susitna

River and is usually separated from the mainstem and side channels by well-vegetated bars. An exposed alluvial berm often separates the head of the slough from mainstem or side channel flows. The controlling streambed/stream bank elevations at the upstream end of the side sloughs are slightly less than the water surface elevations of the mean monthly flows of the mainstem Susitna River observed for June, July, and August. At intermediate- and low-flow periods, the side sloughs convey clear water from small tributaries and/or upwelling groundwater (Estes et al. 1981). These clear water inflows are essential contributors to the existence of this habitat type. The water surface elevation of the Susitna River generally causes a backwater to extend well up into the slough from its lower end (Estes et al. 1981). Even though this substantial backwater exists, the sloughs function hydraulically very much like small stream systems and several hundred feet of the slough channel often conveys water independent of mainstem backwater effects. At high flows the water surface elevation of the mainstem river is sufficient to overtop the upper end of the slough (Estes et al. 1981). Surface water temperatures in the side sloughs during summer months are principally a function of air temperature, solar radiation, and the temperature of the local runoff.

- **"Upland" slough habitat** differs from the side slough habitat in that the upstream end of the slough is not interconnected with the surface waters of the mainstem Susitna River or its side channels at less than bankfull flows. The upstream end can be vegetated with mature trees, although a morphologic signature of a converging inlet and gravel levee closure can still be discerned. These sloughs are characterized by the presence of beaver dams and an accumulation of silt covering the substrate resulting from the absence of mainstem scouring flows. They are not truly "upland" in the geomorphic sense, but the use of this nomenclature in the 1980s studies reflects the observation that the understanding of floodplain and channel forming processes was in the early stage in fisheries, where some variation in interpretation existed over what constituted a floodplain versus an upland terrace (e.g., see Williams 1978). Essentially, the main distinguishing characteristic between a "side" slough and an "upland" slough was the level of high flow at which each was engaged.
- **Tributary habitat** consists of the full complement of hydraulic and morphologic conditions that occur in the tributaries. Their seasonal stream flow, sediment, and thermal regimes reflect the integration of the hydrology, geology, and climate of the tributary drainage. The physical attributes of tributary habitat are not dependent on mainstem conditions.
- **Tributary mouth habitat** extends from the uppermost point in the tributary influenced by mainstem Susitna River or slough backwater effects to the downstream extent of the tributary plume that extends into the mainstem Susitna River or slough (Estes et al. 1981).

A schematic of these types of habitats as applied in the 1980s studies is depicted in Figure 8.5-3. These categories were also used by Trihey and Associates in its instream flow modeling studies (Aaserude et al. 1985). Beginning in the 1983 open-water studies, however, a fundamental change was made in how side sloughs and side channels were identified during field studies (Dugan et al. 1984). During 1981 and 1982, side sloughs and side channels were distinguished primarily on their morphology. Side sloughs included an unvegetated berm at the head of the slough and were rarely overtopped. In contrast, a side channel conveyed mainstream flow during most of the year. During 1983 and following years, if a berm was overtopped and a channel conveyed mainstem flows it was characterized as a side channel. If the berm was not overtopped it was characterized as a side slough. Consequently, during the latter years of the 1980s Fish and Aquatic Program an area may have been characterized as a side channel during periods of high flows and a side slough during periods of lower flows.

Specific sites chosen for completion of the various studies by ADF&G between 1981 and 1985 varied from year to year and study to study. In general, sampling was relatively broad during 1981 and 1982, and more focused during 1983 to 1985. The 1981 Aquatic Habitat Studies were focused on 'Fishery Habitat' evaluations and 'Selected Habitat' evaluations (Estes et al. 1981). The Fishery Habitat evaluations collected point information on observed fish habitat use and general habitat evaluations (water quality, hydrology, and mapping). The Selected Habitat evaluations collected water quality, discharge, and mapping information at selected sloughs between Talkeetna and Devils Canyon.

A total of 5 river reaches were delineated and 8 to 13 representative study sites were selected in each, without consideration of proportional sampling or optimal allocation (e.g., see Cochran 1977). These included the following:

- Yentna Reach (Cook Inlet to Little Willow Creek; RM 0.0–50.5): 13 sites
- Sunshine Reach (Rustic Wilderness to Parks Highway Bridge; RM 58.1–83.5): 10 sites
- Talkeetna Reach (Parks Highway Bridge to Curry; RM 83.5–120.7): 11 sites
- Gold Creek Reach (Curry to Portage Creek; RM 120.7–148.8): 12 sites
- Impoundment Reach (Devils Canyon to Denali Highway; RM 151–281): 8 tributaries

With few exceptions, the sites sampled for aquatic habitat studies were the same as those sampled under resident and juvenile anadromous fish studies in 1981 and 1982. Selection of specific sampling sites was apparently not based upon a statistical sampling design. Instead, sites were considered representative of each reach, and were based effectively on where fish were found. This basis was carried forward in subsequent years. For example, in 1982, habitat information was collected where spawning fish were located within the mainstem Susitna River downstream of Devils Canyon (tributary/mainstem confluence areas and sloughs were not sampled). Only spawning sites for chum salmon were observed in the mainstem, which led to the identification of eight mainstem spawning locations between Lane Creek (RM 113.6) to Devils Canyon.

In addition, 17 Designated Fish Habitat (DFH) sites were chosen in 1982 based upon four criteria (Estes and Schmidt 1983; ADF&G 1983):

1. Areas that will be affected by changes in discharge of the mainstem Susitna.
2. Sites identified from previous studies to have significant populations of resident and juvenile anadromous species.
3. Access to areas will not create severe logistics problems and limit the overall scope of the studies.

4. Sites selected represent a cross-section of critical areas available to resident and juvenile anadromous fish of the Susitna River.

Five of the DFH sites were located downstream of Talkeetna from RM 88.4 to 73.1 and twelve were located in the reach from Portage Creek (RM 148.8) to Whiskers Creek (RM 101.2).

During 1983 and 1984, studies became focused on collecting specific data needed to develop three types of instream flow models: Resident and Juvenile Habitat (RJHAB) models, Instream Flow Group (IFG) models, and Direct Input Habitat (DIHAB) models developed by Trihey and Associates (Hilliard et al. 1985). As before, sites were selected based on where fish were found. During 1983, 32 sites (11 tributaries, 3 upland sloughs, 8 side slough/channel, 6 side channel, 4 side slough) were sampled in the reach from Talkeetna to Devils Canyon for fish distribution, and 13 sites were modeled by ADF&G with either the RJHAB (2 upland sloughs, 2 side channel/ sloughs, 1 side slough, 1 side channel) approach or IFG approach (3 side slough/channels, 1 side slough, 3 side channels). The 13 modeled sites were chosen based upon observations of large numbers of spawning salmon or concentrations of juvenile salmon during 1981 and 1982 studies (Dugan et al. 1984). They were also selected as being representative of the habitat types present between the Chulitna River and Devils Canyon likely to be affected by changes in mainstem flow from the proposed project (Dugan et al. 1984; Marshall et al. 1984).

Sampling in 1984 focused on main channel margins, side channels, side sloughs, and tributary mouth habitats in the middle and lower river segments between RM 147.1 and 35.2. During 1984, crews sampled three types of study sites:

- RJHAB sites (16 sites)
- IFG sites (6 sites)
- DIHAB sites (14 sites)
- Opportunistic sites (31 sites)

Opportunistic sites were sampled only once to expand the understanding of juvenile and resident fish distribution (Suchanek et al. 1985).

Instream flow modeling of spawning habitat was conducted for chum and sockeye salmon at mainstem margin, side channel, upland slough, and side slough habitat types. Modeled sites were considered to represent the range of spawning conditions for sloughs and side channels present in the mainstem between the Chulitna River and Devils Canyon. In addition, instream flow studies were performed to describe juvenile Chinook habitat-flow responses within mainstem margins, side channels, side sloughs, and upland sloughs of the middle river. The modeling studies relied effectively on the habitat classification, and manipulations thereof, for stratifying and extrapolating model results from sampled sites to larger study reaches (Steward et al. 1985; Ashton and Klinger-Kingsley 1985; and Klinger-Kingsley et al. 1985). The overall approach proposed for the extrapolation process was described in Aaserude et al. (1985) and consisted of methods for both single thread and multiple thread portions of the river. However, project funding was curtailed in 1985 and the approach was never implemented.

8.5.2.6. HSC

An important element of these studies was the collection of microhabitat data of various species and life stages of fish reflective of a suite of different parameters influenced by, or potentially influenced by, flow. These included water depth, water velocity, substrate, upwelling occurrence, and turbidity.

A more detailed synthesis of pertinent information will be completed as part of the IFS and supplemented by analysis of aquatic-related information conducted as part of the Fish and Aquatics Study (see Section 9.0). As part of this synthesis, information will be compiled and reviewed related to instream flow regimes implemented at other large hydropower projects, with a special emphasis on projects developed in arctic and sub-arctic environments.

An extensive set of Habitat Suitability Criteria were developed as part of the 1980s instream flow studies. These criteria were developed using a combination of site-specific data collected through fish sampling and literature sources, and through refinement based on the professional judgment of project biologists. Table 8.5-1 summarizes the species and life stages for which HSC were developed during the 1980s efforts. Also described are the various habitat parameters for which curves describing HSC were developed (e.g., depth).

HSC for rearing juvenile salmon were developed for the habitat parameters of depth, velocity, and cover used by juvenile Chinook, coho, sockeye, and chum salmon (Suchanek et al. 1984b). These HSC were developed based on field data collected at representative tributary, slough, and side channel sites between the Chulitna River confluence and Devils Canyon (Middle Susitna River) and were considered to be specific to this reach. Fish observations were obtained by beach seining (turbid water) or electrofishing (clear water) systematically established 300-square-foot cells with relatively uniform physical habitat (within cells) that captured the overall variability of site habitat conditions (across cells). Fish observations were then related to depth, velocity, and cover conditions characterized by each cell and collectively used to develop HSC for these parameters. In addition, if differences in habitat utilization were apparent at varying turbidity levels, separate HSC were developed for turbid vs. clear water conditions for those species with sufficient sample sizes (i.e., juvenile Chinook). An example of HSC developed through this effort is shown in Figure 8.5-4. A subsequent effort used similar methods to verify the applicability of these juvenile salmon rearing HSC curves for the lower river downstream of the Chulitna River confluence (Suchanek et al. 1985). Findings from this effort resulted in some modifications to HSC for use in the Lower River, particularly for water depth.

Spawning HSC for chum and sockeye salmon were developed from redd observations in sloughs and side channels of the middle Susitna River (Vincent-Lang et al. 1984b). Data collection sites were concentrated in areas used for hydraulic simulation modeling to maximize the concomitant collection of utilization and availability data necessary for the evaluation of preference. HSC for chum salmon were modified using limited preference data; however, preference could not be incorporated for sockeye salmon. HSC for depth, velocity, and substrate were developed from this effort. Additionally, modified HSC were developed for substrate that reflected the presence or absence of upwelling. A related study also examined chum salmon spawning habitat utilization in select tributary mouths of the middle Susitna River and found that the range of utilized depths, velocities, and substrates was generally comparable to redds in sloughs in side channels (Sandone et al. 1984). Spawning habitat utilization for Chinook, coho, and pink salmon was evaluated in tributaries of the middle Susitna River (Vincent-Lang et al. 1984a). Sufficient data were collected to develop depth, velocity, and substrate HSC curves for Chinook salmon. However, observations for spawning coho and pink salmon were insufficient to develop HSC. Instead, spawning HSC for these two species were based solely on literature data and modified using qualitative field observations.

HSC for resident fish species were developed based on data collected through electrofishing, beach seining, and hook-and-line sampling in tributary mouths, tributaries, and sloughs of the middle Susitna River (Suchanek et al. 1984a). Cover and velocity HSC were developed for adult rainbow trout, arctic grayling, round whitefish, and longnose sucker. HSC for cover were developed separately for turbid vs. clear water conditions. A single depth HSC was developed for all of these species combined. Only round whitefish were collected in sufficient numbers to develop separate HSC for juveniles.

8.5.2.7. Winter Studies

Winter instream flow conditions are a critical component of fish habitat, particularly with respect to egg incubation and juvenile rearing. Intergravel flow and groundwater upwelling are critical for egg incubation and emergent fry survival, while depth, velocity, and temperature of surface flow are important habitat characteristics for juvenile and adult fish. Project operations will likely result in substantially higher flows during the winter period, which may influence the quality and quantity of existing rearing and holding habitats for juvenile and adult fish and may affect the extent and degree of intergravel flow or lateral exchange between mainstem and off-channel habitats, which can consequently alter subsurface water temperatures critical for salmonid egg incubation and fry survival. Winter studies conducted in the Susitna River during the 1980s were primarily focused on relationships between salmon egg incubation and discharge, water quality and temperature, and fish movement and habitat utilization.

Success of salmon egg incubation during winter is dependent on discharge conditions in addition to water quality and temperature. During winter studies conducted during 1983–1984 in the middle Susitna River, redd dewatering and freezing were observed to be primary sources of chum salmon egg mortality as discharge levels declined after the fall spawn period through winter (Vining et al. 1985). During the study, chum salmon eggs located in side channel habitats were most susceptible to mortality, while eggs located in side slough habitats that were less affected by main channel stream flow and influenced by groundwater upwelling were less prone to freezing and dewatering (Vining et al. 1985). Similar results were observed during a concurrent study on the lower Susitna (Bigler and Levesque 1985). Groundwater upwelling can provide a thermal buffer for incubating eggs from climatic changes and colder surface stream flow and aid egg development in terms of increasing intergravel water exchange, replenishment of dissolved oxygen, and removal of metabolic wastes (Vining et al. 1985; Burgner 1991). Based on the results of the 1983–1984 study, Vining et al. (1985) observed that the amount of spawning habitat available in fall does not necessarily predict the amount of egg incubation habitat and recommended that future analyses of effective spawning habitat area account for seasonal changes in Susitna River discharge (Vining et al. 1985). In addition, Vining et al. (1985) also noted that future project operations could cause higher Susitna River winter discharges and that the effect of such changes on redd dewatering and/or freezing might depend on whether temperatures of Project outflows were higher or lower than existing stream temperatures.

The rate of salmonid egg incubation is a function of water temperature because egg development occurs more quickly in warmer winter temperatures and slower in colder thermal regimes, with mortality occurring at the point of freezing (Burgner 1991). In the Susitna River during the 1980s, intergravel water temperatures were observed to vary among habitat types, such that intergravel water temperatures in tributary and main channel areas were strongly affected by surface water and were near freezing during winter, while temperatures in side sloughs were more stable as a result of groundwater influence (Figure 8.5-5) (Hoffman et al. 1983; Seagren and Wilkey 1985; Vining et al. 1985). In side channel areas, intergravel temperature was highly variable and was most dependent on-site-specific conditions that controlled the relative influence of groundwater and surface water sources (Vining et al. 1985). Vining et al. (1985) recorded faster development times among salmon eggs fertilized on the same date and artificially planted in Susitna River side channel and side slough habitats fed by groundwater upwelling relative to main channel areas with no groundwater influence. Similarly, the development times of chum and sockeye salmon eggs in laboratory conditions that reflected winter temperature regimes from main channel and side slough Susitna River habitats were faster in warmer side slough water temperature regimes influenced by groundwater upwelling (Wangaard and Burger 1983). Water quality conditions at salmon spawning sites during winter varied between surface and intergravel water and according to the relative influence of groundwater (Hoffman et al. 1983; Vining et al. 1985). Vining et al. (1985) observed that the difference between intergravel and surface water dissolved oxygen levels was greatest for slough habitat and least for tributary and mainstem habitats, while differences were intermediate in side channel habitats. In terms of salmon egg incubation, dissolved oxygen levels in the Susitna River were generally above recommended values (7.19 mg/L; Alderdice and Velsen 1978) and low levels of dissolved oxygen were most likely ameliorated by the presence of upwelling water (Vining et al. 1985).

Substrate was characterized among salmon spawning areas in main channel, side channel, and slough habitats in the Susitna River during winter 1983–1984 (Vining et al. 1985). Vining et al. 1985 observed that slough habitats had the highest level of fines, followed by side channel, tributary, and mainstem habitats, though fine sediment compositions in substrates sampled directly from redds were typically lower than in the surrounding habitat. Percent composition of fine substrates among sampled slough habitats in the middle Susitna indicated greater than 35 percent fines; however, the percent of fine substrate at redd locations among slough samples did not exceed 16 percent in five of the six sites evaluated (Vining et al. 1985). Bigler and Levesque (1985) similarly concluded that substrate was not a limiting factor to embryo development.

Little information is available about winter habitat use by juvenile salmon in the Susitna River. Surveys during the winter of 1980 to 1981 by Delaney et al. (1981c) found that the majority of juvenile Chinook salmon captured between Cook Inlet and Devils Canyon occurred at slough and mainstem Susitna River sites. The majority of juvenile coho salmon captured between Cook Inlet and Talkeetna during winter occurred at tributary mouth sites, whereas between Talkeetna and Devils Canyon, winter occurrence was greater at slough sites. Stratton (1986) studied overwinter habitat use by Chinook and coho salmon at four locations (Indian River, Slough 9A, Slough 10, and Slough 22) from October 1985 to April 1986. Findings suggested that coho salmon preferred areas with greater depth and cover consisting of debris, vegetation, and undercut banks, and beaver dams and ponds in particular. Chinook salmon preferred shallower, slightly higher velocity and cover consisting of rocks and boulders. Bigler and Levesque (1985) captured Chinook salmon juveniles using fyke nets at several side channels in the Lower Susitna River Trapper side channel in April and May, suggesting these side channels were being utilized as overwintering habitat.

8.5.2.8. Periodicity

Fish periodicity analyses will describe the temporal and spatial utilization of mainstem and tributary habitats in the Susitna River by individual fish species and life stages and will be essential to evaluate potential effects of Susitna River stream flow fluctuations on fish communities. Fish spawning and egg incubation are critical life history stages that are particularly sensitive to fluctuations in stream flow. Moreover, rearing and holding conditions in main channel and off-channel habitats in the Susitna River that are utilized by juvenile and adult fish can be transformed in response to Susitna River discharge. During 2013–2014 instream flow studies, periodicity analyses will be used to inform selection of study areas and guide habitat-specific modeling and spatial and temporal habitat analyses.

Periodicity of fish habitat use in the middle and lower Susitna River during the 1980s was developed based on data collected during fish distribution and abundance studies. Salmon species in particular were studied intensively during the 1980s to identify the distribution, abundance of each life stage, and species that used available aquatic habitats in the Susitna River. Periods of peak and off-peak habitat use by salmon in the Susitna River during the 1980s were developed by species and life stage based on juvenile and adult salmon distribution and abundance investigations conducted primarily during 1981–1985 (Table 8.5-2) (see Fish and Aquatics, Section 9.0). Other anadromous and freshwater resident fish species were studied, primarily to identify spawn locations and timing of seasonal movement patterns.

Adult salmon species (Chinook, sockeye, chum, coho, and pink) migrate upstream from marine areas into the Susitna River beginning in late May and continue through September, though specific timing of movement differs by species (Table 8.5-2). Salmon spawning timing in the Middle and Lower Susitna River typically occurs from late July through early October in tributary, main channel, and off-channel habitats (Jennings 1985; Barrett et al. 1985; Thompson et al. 1986). During the 1980s studies, Chinook and coho salmon spawned almost exclusively in tributary habitats that were not directly influenced by Susitna River stream flow, whereas sockeye, chum, and pink utilized habitats that were hydrologically connected to main channel stream flows (Jennings 1985; Barrett et al. 1985; Thompson et al. 1986). Subsequent to the spawn period, salmon egg incubation in the Susitna River occurred from July through the end of fry emergence in April and May during the following spring (Table 8.5-2) (Bigler and Levesque 1985; Jennings 1985; Vining et al. 1985). Among habitats utilized by spawning salmon, side channel and side slough marginal habitats were observed to be most vulnerable to dewatering and/or freezing as a result of fluctuations in Susitna River discharge (Vining et al. 1985).

Juvenile salmon exhibit a range of life history patterns in the Susitna River. Chum and pink salmon typically emigrate from riverine areas to the ocean soon after emerging from the gravel or within the first several months (Table 8.5-2) (Jennings 1985). Most Chinook, coho, and sockeye salmon utilize Susitna River nursery habitats for at least one year prior to emigrating to marine areas (Table 8.5-2) (Jennings 1985). During the period of residence in the Susitna River, salmon fry were observed to use a wide range of habitats during 1980s studies (Dugan et al. 1984). Salmon fry and juveniles were typically most abundant in off-channel areas, though habitat utilization appeared to vary seasonally and by ontogenetic stage (Dugan et al. 1984; Stratton 1986). The timing of salmon emigration to estuarine and marine areas typically occurs over a long period in the spring and early summer in the Susitna River, from March through early August (Table 8.5-2) (Jennings 1985; Roth and Stratton 1985; Roth et al. 1986).

For resident and non-salmonid fish, the timing and distribution of juvenile and adult fish, location and periodicity of adult spawning, and descriptions of seasonal movements patterns were described in association with fish distribution and abundance studies during 1981–1985 (see Fish and Aquatics, Section 9.0). Studies during the 1980s were conducted in the lower, middle, and upper Susitna River and included rainbow trout, Arctic grayling, burbot, round whitefish, humpback whitefish, longnose sucker, Bering cisco, and Dolly Varden.

8.5.2.9. Instream Flow Methods and Models

Instream flow studies conducted during the 1980s focused on the middle and lower Susitna River downstream of Devils Canyon. Studies during the 1980s evaluated changes in fish habitat relative to changes in mainstem Susitna River stream flow using hydraulic and/or habitat modeling and habitat mapping techniques. Modeling and mapping efforts were performed during 1983 and 1984 at 20 sites in the lower Susitna River between RM 35 and RM 92 and at 36 sites in the middle Susitna River between RM 101 and RM 148 (Table 8.5-3). Fish habitat availability was modeled over a range of Susitna River discharges using the following habitat models: IFIM HABTAT, Direct Input Habitat (DIHAB), and Resident Juvenile Habitat (RJHAB). The IFIM HABTAT model was used in conjunction with Instream Flow Group (IFG) hydraulic models, whereas no hydraulic modeling was completed in association with DIHAB or RJHAB models. Two-dimensional mapping was also used to quantify available habitat at tributary mouths in the middle river and was done independently of IFG hydraulic modeling. Habitat model selection was based on-site-specific channel and hydrologic characteristics, the desired resolution of microhabitat simulation, and the field logistics associated with each method.

Instream flow sites during the 1980s were primarily located in side channel, side slough, and upland slough habitats with relatively few sites in tributary mouths and mainstem channel margins. The IFIM HABTAT model was used in conjunction with IFG hydraulic models at sites characterized by steady or uniform flow conditions and rigid stream channels and where stream flow was assumed to be the primary determinant of fish habitat quality (Trihey 1979; Hilliard et al. 1985). In the middle and lower Susitna River, IFG models were applied in side channel and slough habitats (Hilliard et al. 1985). The IFG and HABTAT models were used to model changes in juvenile and adult fish habitats at 6 sites in the lower river in 1983 and at 15 sites in the middle river during 1983 and 1984 (Vincent-Lang 1984b; Hilliard et al. 1985) (Table 8.5-3). At each site, water depth and velocity data were measured at multiple cross-sections at multiple Susitna River stream flows to model hydraulic conditions at the site over a range of flows. Modeled stream flow data were used in conjunction with channel geometry and substrate data from the site to model changes in usable fish habitat area over the modeled flow range. Examples of IFG site locations in various side channel habitats in the Middle Susitna River are depicted in Figure 8.5-6 and Figure 8.5-7.

The DIHAB model was created for areas where steady, gradually varied flow did not exist (Hilliard et al. 1985). During the 1980s, DIHAB models were used at chum spawning sites characterized by spatially variable hydraulic conditions or near zero water velocities; such conditions were incompatible with IFG hydraulic models (Hilliard et al. 1985). The DIHAB models were used to evaluate changes in adult chum spawning habitat at 14 sites located on mainstem margins and side channel habitats in the middle river in 1984 (Table 8.5-3). In addition to water depth and velocity and substrate data, the presence of upwelling was incorporated into DIHAB models as a binary variable (i.e., present, not present). DIHAB models used hydraulic and channel geometry data to estimate changes to habitat area over the range of measured stream flows, but did not incorporate hydraulic models. An example DIHAB site location in side channel habitat is shown in Figure 8.5-7.

The RJHAB habitat model was a simplified means of estimating changes in fish habitat without using hydraulic models. RJHAB modeling was applied at 22 side channel, tributary mouth, side slough, and upland slough sites in 1983 and 1984 in the middle and lower river (Table 8.5-3) (Marshall et al. 1984; Quane et al. 1985; Suchanek et al. 1985). At each RJHAB site, multiple cross-sections were established and divided into shoreline and mid-channel cells (Figure 8.5-8). Depth, velocity, and instream and overhead cover data measured in shoreline and mid-channel cells at a range of Susitna River stream flows were assumed to be representative of the usable fish habitat at each cross-section and for the site (Marshall et al. 1984). An example of an RJHAB site location in Whiskers Creek side slough is shown in Figure 8.5-7.

Habitat mapping was conducted at tributary mouths in the middle river in 1983 to characterize changes in spawning habitat independent of hydraulic modeling. The two tributary mouth sites measured in 1983 were considered to be representative of the 14 major tributary confluences in the middle river (Table 8.5-3) (Sandone et al. 1984). At habitat mapping sites, depth, velocity, and substrate habitat parameters were measured across multiple transects at four separate Susitna River stream flows. These data were used to create two-dimensional parameter-specific maps delineating the area of suitable chum spawning habitat. The three separate parameter-specific maps were overlaid to identify the composite area of habitat suitability that was available at each measured flow level (Sandone et al. 1984).

The output provided by IFIM HABTAT, DIHAB, and RJHAB habitat models was generally similar to that supplied by the habitat mapping method used at tributary mouths. Each method characterized changes in fish habitat by relating the amounts of wetted surface area and area usable for juvenile and adult fish to Susitna River discharge. The amount of wetted surface area at modeling sites invariably increased with rising stream flows; however, the relationship between the amount of habitat area suitable for juvenile and adult fish use was often not directly correlated with Susitna River discharge. Suitable depth, velocity, substrate, and/or cover habitat was defined for each life stage of anadromous and resident fish species in the form of HSC. Species and life stage-specific HSC provided a basis for evaluating the amount of usable habitat at observed and simulated stream flow levels for each habitat model.

Results from intensively studied modeling sites were extrapolated to non-modeled habitats throughout the Susitna River based on characterization of aquatic habitats over a range of stream flow levels and classification of habitats into discrete groups. In 1984, 172 specific areas of the middle river, including modeled and non-modeled areas, were characterized in terms of the hydrology, hydraulics, and channel morphology at the site using aerial photography recorded at various stream flow levels and site-specific data (Aaserude et al. 1985; Klinger-Kingsley et al. 1985). Based on hydrological, hydraulic, and morphological site characteristics, specific areas were stratified into 10 representative habitat groups, which served as the basis for extrapolation of modeled results to non-modeled sites (Aaserude et al. 1985; Steward et al. 1985). The relationship between usable fish habitat area to changes in Susitna River stream flow was evaluated at the micro-habitat scale at individual modeling sites and these results were summarized to create a composite habitat-discharge relationship for all habitats within the same group (Aaserude et al. 1985; Steward et al. 1985). To address variability in structural habitat characteristics (i.e., fish cover type, substrate size and embeddedness, channel geometry and streamside vegetation) among individual areas within representative groups, structural habitat indices were developed (Aaserude et al. 1985). Extrapolation of habitat availability results from modeled sites to non-modeled sites with an adjustment for differences in structural habitat (Aaserude et al. 1985).

8.5.2.10. Need for Additional Information

The 1980s reports and information serve as a valuable resource and reference point from which to view conditions in the Susitna River as they existed in the early 1980s. The information also provides details on fish species distribution and abundance and riverine processes as they were operating at that time and includes distinct habitat-flow response relationships that were defined for different habitat types and different locations. However, additional information needs to be collected to provide a contemporary understanding of the baseline conditions existing in the Susitna River, and among other things test hypotheses regarding the validity of the 1980s habitat-flow response relationships. In addition, the configuration and proposed operations of the Project are different from the previously proposed project and must be evaluated within the context of the existing environmental setting. This includes consideration of potential load-following effects on important aquatic and riparian habitats downstream of the proposed Watana Dam site (including both the Middle River and Lower River segments, as appropriate). Potential effects of proposed Project operations on aquatic habitats and biota and potential benefits and impacts of alternative operational scenarios have not been quantitatively analyzed. The aquatic habitat-specific models will provide an integrated assessment of the effects of Project operations on biological resources and riverine processes. These models will provide an analytical framework for assessing alternative operational scenarios and quantitative metrics that will provide the basis for the environmental assessment and aid in comparing alternatives that may lead to refinements in proposed Project operations.

8.5.3. Study Area

During the 1980s studies, the Susitna River was characterized into three segments extending above and below the two proposed dam sites. After researching potential Project configurations, AEA is proposing a single dam configuration at the Watana Dam site at RM 184. The proposed study characterizes the Susitna River as three segments (Figure 8.5-9). The Upper River Segment represents that portion of the watershed above the Watana Dam site at RM 184, the Middle River Segment extends from RM 184 downstream to the Three Rivers Confluence at RM 98.5, and the Lower River Segment extends from the Three Rivers Confluence to Cook Inlet (RM 0). Potential Project effects to the Upper River Segment above the Watana Dam site are addressed in Section 9.0, Fish and Aquatics; Section 10.0, Wildlife; Section 11.0, Botanical; and other studies. Potential Project effects to the Upper River Segment will not be addressed in the IFS (see Section 8.5). The study area of the IFS includes the two lower segments of the river: the Middle River Segment and the Lower River Segment.

The Middle River Segment encompasses approximately 85 miles between the proposed Watana Dam site (at RM 184) and the Three Rivers Confluence, located at RM 98.5. The river flows from Watana Canyon into Devils Canyon, the narrowest and steepest gradient reach on the Susitna River. In Devils Canyon, constriction creates extreme hydraulic conditions including deep plunge pools, drops, and high velocities. The Devils Canyon rapids appear to present a partial barrier to the migration of anadromous fish, hindering upstream passage at some flow conditions; only a few adult Chinook salmon have been observed upstream of Devils Canyon. Downstream of Devils Canyon, the Middle Susitna River widens but remains essentially a single channel with stable islands, occasional side channels, and sloughs.

The Lower River Segment consists of an approximate 98-mile section between the Three Rivers Confluence and Cook Inlet (RM 0). An abrupt change in channel form occurs where the Chulitna River joins the Susitna River near the town of Talkeetna. The Chulitna River drains a smaller area than the Middle River Segment at the confluence, but drains higher elevations (including Denali and Mount Foraker) and many glaciers. The annual flow of the Chulitna River is approximately the same as the Susitna River at the confluence, though the Chulitna contributes much more sediment than the Susitna River. For several miles downstream of the Three Rivers Confluence, the Susitna River becomes braided, characterized by unstable, shifting gravel bars and shallow subchannels. For the remainder of its course to Cook Inlet, the Susitna River alternates between single channel, braided, and meandering plan forms with multiple side channels and sloughs. Major tributaries drain the western Talkeetna Mountains (the Talkeetna River, Montana Creek, Willow Creek, Kashwitna River), the Susitna lowlands (Deshka River), and the Alaska Range (Yentna River). The Yentna River is the largest tributary in the Lower River Segment, supplying about 40 percent of the mean annual flow at the mouth.

Although both Middle and Lower River segments are under consideration as part of this IFS, the majority of detailed study elements described in this RSP are concentrated within the Middle River Segment. This is because Project operations related to load-following and variable flow regulation will likely have the greatest potential effects on this segment of the river. These effects tend to attenuate in a downstream direction as channel morphologies change, and flows change due to tributary inflow and flow accretion. The diversity of habitat types and the information from previous and current studies that indicate substantial fish use of a number of slough and side channel complexes within this segment, also support the need to develop a strong understanding of habitat–flow response relationships in this segment.

Determining how far downstream Project operational effects will extend will depend in part on the results of the Open-water Flow Routing Model (see Section 8.5.4.3), which is scheduled to be completed in Q1 2013 as well as results of the operations model (see Section 8.5.4.3.2). The results of the Open-water Flow Routing Model completed in Q1 2013 will be used to determine whether and the extent to which Project operations related to load-following as well as seasonal flow changes occur within a section of the Lower River Segment that includes all of Geomorphic Reach LR-1 and a portion of LR-2 (down to RM 75). Thus, an initial assessment of the downstream extent of Project effects will be developed in Q1 2013 with review and input of the TWG. This assessment will include a review of information developed during the 1980s studies and study efforts initiated in 2012, such as sediment transport (see Section 6.5), habitat mapping (see Sections 6.5 and 9.9), operations modeling (see Section 8.5.4.2.2), and the Mainstem Open-water Flow Routing Model (see Section 8.5.4.3). The assessment and the following criteria will be used to evaluate the need to extend studies into the Lower River Segment and if studies are needed, will identify which geomorphic reaches require instream flow analysis in 2013. The criteria include: 1) Magnitude of daily stage change due to load-following operations relative to the range of variability for a given location and time under existing conditions (i.e., unregulated flows); 2) Magnitude of monthly and seasonal stage change under Project operations relative to the range of variability under unregulated flow conditions; 3) Changes in surface area (as estimated from relationships derived from LiDAR and comparative evaluations of habitat unit area depicted in aerial digital imagery under different flow conditions) due to Project operations; 4) Anticipated changes in flow and stage to Lower River off-channel habitats; 5) Anticipated Project effects resulting from changes in flow, stage and surface area on habitat use and function, and fish distribution (based on historical and current information concerning fish distribution and use) by geomorphic reaches in the Lower River Segment; and 6) Initial assessment of potential changes in channel morphology of the Lower River (see Section 6.5.4.6) based on Project-related changes to hydrology and sediment supply in the Lower River. Results of the 2013 studies will then be used to determine the extent to which Lower River Segment studies should be adjusted in 2014.

8.5.4. Study Methods

Evaluation of potential Project effects to Middle and Lower river habitats will consist of the following components (these components will be refined based on TWG review and input):

- IFS Analytical Framework (see Section 8.5.4.1)
- River Stratification and Study Area Selection (see Section 8.5.4.2)
- Hydraulic Routing (see Section 8.5.4.3)
- Hydrologic Data Analysis (see Section 8.5.4.4)
- Habitat Suitability Criteria Development (see Section 8.5.4.5)
- Habitat-Specific Model Development (see Section 8.5.4.6)
- Temporal and Spatial Habitat Analyses (see Section 8.5.4.7)
- Instream Flow Study Integration (see Section 8.5.4.8)

Details concerning each of these components including proposed methodologies and resulting work products are provided below.

8.5.4.1. IFS Analytical Framework

The Instream Flow Study is designed to characterize the existing, unregulated flow regime and the relationship of instream flow to riparian and aquatic habitats under alternative operational scenarios. The instream flow framework is designed to integrate riverine processes, including geomorphology, ice processes, water quality, and groundwater-surface water interactions to quantify changes in indicators used to measure the integrity of aquatic resources. Figure 8.5-10 depicts the analytical framework of the IFS that will be used to evaluate unregulated flows and alternative operational scenarios under average, wet, dry, warm, and cold hydrological conditions. The overall framework includes analytical steps that are consistent with those described in the Instream Flow Incremental Methodology (IFIM) (Stalnaker et al. 1995), which will be used as a guide for completing the instream flow evaluation for the Project.

The proposed Project will alter stream flow and sediment and large woody debris (LWD) transport downstream of the proposed dam site. These stressors will affect channel morphology and the quantity, quality, and timing of downstream habitats. The IFS framework will be used to assess Project effects on downstream habitats under existing channel conditions, and will also provide for the evaluation of alternative operational scenarios under estimated future channel conditions. Changes in flow, ice processes, and sediment and LWD transport may cause channel degradation, avulsion, and other channel changes and may contribute to changes in the distribution and abundance of various habitat units (see page 2 of Figure 8.5-10). Integration of the Geomorphology Study (see Section 6.0) and other riverine process studies will allow future channel change to be evaluated at future time steps within the expected term of the license. These time steps will be determined in consultation with the TWG after initial geomorphology investigations provide insight into the magnitude and rate of downstream channel change.

Figure 8.5-10 depicts the analytical framework of the IFS commencing with the Reservoir Operations Model (ROM) that will be used to generate Project flow releases under alternative operational scenarios. The ROM (see Section 8.5.4.3.2) will provide input data to the mainstem open-water flow routing model (see Section 8.5.4.3.1) and Ice Processes Model (see Section 7.6) that will be used to predict hourly flow and water surface elevations at multiple downstream locations, taking into account accretion and flow attenuation. Coincident with the development of the open-water flow routing model, a series of biological and riverine process studies will be completed to supplement the information collected in the 1980s, as necessary, to assess the temporal and spatial relationships between riverine and biological functions. These analyses will result in development of a series of flow-sensitive models that will quantify Project effects on indicators for each aquatic and riparian resource.

Resource and process effects will be location- and habitat-specific (e.g., responses are expected to be different in off-channel sloughs versus main channel versus split channel versus tributary delta versus riparian habitats), but there will also be a cumulative analysis that translates effects throughout the Susitna River. The IFS framework provides for the analysis of indicators that estimate flow-habitat response patterns for different species and life stages of fish and other aquatic biota. These models represent core tools that will be used for assessing changes in aquatic habitats under alternative operational scenarios. Additionally, a fish passage analysis (see Section 9.12) will be used to develop the relationship between main channel flow and connectivity with side channel and off-channel areas. Data collection and modeling for the Fish Passage Study will be coordinated with the Instream Flow, Fish and Aquatics (see Section 9.0), and Geomorphology (see Section 6.0) studies to ensure identification of potential fish passage barriers and hydraulic control points (see Figure 8.5-1).

Alternative operational scenarios will likely affect habitats and riverine processes on both a spatial and temporal scale. The habitat and process models will therefore be spatially discrete (e.g., by Focus Area, reach, and segment) and yet able to be integrated to allow for a holistic evaluation by alternative operational scenario. This will allow for an Integrated Resource Analysis (IRA) of multiple resources for each operational scenario and provides feedback, leading to potential modifications of alternative operational scenarios (see Section 8.5.4.8).

The IFS framework (Figure 8.5-10) represents a measurement-oriented approach to assessing the relationship of hydrologic and geomorphic variables to the biological and ecological resources of concern. Stressors associated with Project effects include changes in the volume, timing, and quality of instream flow, and changes in ice processes and sediment and large woody debris transport. The effects of these stressors on resources of concern will be evaluated using indicators that measure changes in habitat suitability, quality, and accessibility. Reference conditions establish the range of variation for each indicator and are defined by analysis of unregulated flows under average, wet, and dry hydrologic conditions and warm and cold Pacific decadal oscillation phases. Project effects under alternative operational scenarios are defined as departures from the reference conditions. The IFS framework provides the tools to identify operational scenarios that balance resource interests and quantify any loss of aquatic resources and their habitats that result from Project operations.

As part of the analytical framework, an Instream Flow Study–Technical Workgroup (IFS-TWG) has been formed consisting of technical representatives from the TWG. The IFS-TWG will provide input into specific study design elements pertaining to the IFS including selection of study areas, selection of methods and models, selection of HSC criteria, review and evaluation of hydrology and habitat-flow modeling results, and review of Project operations/habitat modeling results. For example, a TWG meeting occurred on September 14, 2012, and focused on the study area selection process. Additional TWG meetings are expected to occur on a regular basis through development of the License Application.

8.5.4.2. River Stratification and Study Area Selection

8.5.4.2.1. Proposed Methodology

8.5.4.2.1.1. River Stratification

The fundamental question in stratifying the river system for the 2012–2014 studies is as follows: How many levels of stratification are necessary for each study focus before study areas should be selected? Effects to physical processes and aquatic resources will be resource type-, location-, and habitat-specific. For example, at the site scale level, responses of fish habitat to changes in flow are expected to be different in side sloughs versus mainstem versus side channel versus tributary delta versus riparian habitats. At a broader scale, e.g., segment, it is plausible that effects to the same mainstem habitat types will differ depending on location in the river network, not only at the Project footprint scale listed above, but also between geomorphic reaches. In addition, there will be a cumulative effect running down the length of the Susitna River below the dam. Different Project operations will likely affect different habitats and processes differently, both spatially and temporally. The habitat and process models will therefore need to be spatially discrete, at potentially the site/area level, mainstem habitat type level, and segment levels, and yet able to be integrated to allow for a holistic evaluation of each alternative operational scenario.

As noted in Section 8.5.3, the study area consists of two segments of the river:

- Middle River Segment – Susitna River from Watana Dam site to confluence of Chulitna and Talkeetna rivers (Three Rivers Confluence) (RM 184 to RM 98.5)
- Lower River Segment – Susitna River extending below Talkeetna River to mouth (RM 98.5 to RM 0)

The Middle River Segment represents the section of river below the Project dam that is projected to experience the greatest effects of flow regulation caused by Project operations. Within this reach, the river flows from Watana Canyon into Devils Canyon, the narrowest and steepest gradient reach on the Susitna River. The Devils Canyon constriction creates extreme hydraulic conditions including deep plunge pools, drops, and high velocities. Downstream of Devils Canyon, the Susitna River widens but remains essentially a single main channel with stable islands, numerous side channels, and sloughs.

The Lower River Segment receives inflow from three other large river systems. An abrupt, large-scale change in channel form occurs where the Chulitna and Talkeetna rivers join the Susitna River near the town of Talkeetna. The annual flow of the Chulitna River is approximately the same as the Susitna River at the confluence, though the Chulitna contributes much more sediment than the Susitna. The Talkeetna River also supplies substantial flow rates and sediment volumes. Farther downriver, the Susitna River becomes notably more braided, characterized by unstable, shifting gravel bars and shallow subchannels. The Yentna River is a large tributary to the Lower Susitna River and supplies about 40 percent of the mean annual flow at the mouth.

Geomorphic analysis of both the Middle River and Lower River segments confirmed the distinct variations in geomorphic attributes (e.g., channel gradient, confinement, channel planform types, and others) (see Section 6.5). That analysis resulted in a further refinement of the classification into eight geomorphic reaches in the Middle River Segment (Figure 8.5-11) and six geomorphic reaches in the Lower River Segment (Figure 8.5-12).

Further refinements to the stratification system being applied to the Susitna River have been made since the PSP as a result of discussions during the August, September, and October 2012 TWG meetings and two interdisciplinary team meetings that were focused on study area selection and habitat mapping. Although the major divisions associated with the Middle and Lower segments have been retained, these are now incorporated into a more refined hierarchical stratification system that scales from relatively broad to more narrowly defined categories as follows:

Segment → Geomorphic Reach → Mainstem Habitat Type →

Main Channel Mesohabitat Types → Edge Habitat Types

The highest level category is termed **Segment** and refers to the Middle River Segment and the Lower River Segment. The **Geomorphic Reach** level is next and consists of the eight categories *(MR-1 through MR-8)* for the Middle River Segment and six categories *(LR-1 through LR-4)* for the Lower River Segment (see Section 6.5.4.1.2.2 and Table 8.5-4). The geomorphic reach breaks were based in part on the following five factors: 1) Planform type (single channel, island/side channel, braided); 2) Confinement (approximate extent of floodplain, off-channel features); 3) Gradient; 4) Bed material / geology; and 5) Major river confluences. This level is followed by **Mainstem Habitat Types,** which capture the same general categories applied during the 1980s studies but includes additional sub-categories to provide a more refined delineation of habitat features (Table 8.5-5). Major categories and sub-categories under this level include <u>Main Channel Habitats</u> *consisting of Main Channel, Split Main Channel, Braided Main Channel, Side Channel, and* <u>*Off-channel Habitats*</u> *that include Side Slough, Upland Slough, Backwater and Beaver Complexes; and Tributary Habitats that consist of the segment of the tributary influenced by mainstem flow.* The next level in the hierarchy is **Main Channel and Tributary Mesohabitats,** which classifies habitats into categories of *Cascades, Riffle, Pool, Run, and Glide*. The mesohabitat level of classification is currently limited to the main channel and tributary mouths for which the ability to delineate these features is possible via aerial imagery and videography. Mesohabitat mapping in side channel and slough habitat types will require ground surveys. The last level in the classification is **Edge Habitat** and is intended to provide an estimate of the length of shoreline in contact with water within each habitat unit. The amount of edge habitat within a given habitat unit will provide an index of habitat complexity, i.e., more complex areas that consist of islands, side channels, etc. will contain more edge habitat than uniform, single channel areas. These stratification levels are described in Table 8.5-5 with further information provided in both the Geomorphic Study Plan (see Section 6.5.4.1.2.2) and the Habitat Characterization Study Plan (see Section 9.9).

The fundamental goal of stratification is to define segments/reaches with effectively similar characteristics where, ideally, repeated replicate sampling would result in parameter estimates with similar statistical distributions. The stratification/classification system described above is designed to provide sufficient partitioning of sources of variation that can be evaluated through focused study efforts that target each of the habitat types, and from which inferences concerning habitat–flow responses in unmeasured sites can be drawn.

8.5.4.2.1.2. Selection of Study Areas/Study Sites

The selection of study areas or study sites represents an important aspect of instream flow study development inasmuch as the sites or areas studied are those that will ultimately be used for evaluating Project effects. It is therefore fundamentally important that the logic and rationale for the selection of such areas be clearly articulated, understood, and agreed to by agencies and licensing participants.

In general (as noted by Bovee 1982), there are three characteristic approaches to instream flow studies that pertain to site selection that have been considered for application in the Project. These are described below.

Representative Sites – where professional judgment or numerically and/or qualitatively derived criteria are relied on to select one or more sites/areas that are considered representative of the stratum or larger river. Representative sites typically contain all habitat types of importance. In general, the representative site approach can be applied fairly readily to simple, single thread channel reaches, where the attributes that are measured are extrapolated linearly based on stream length or area. In this case, the goal of stratification will be to identify river segments that are relatively homogenous in terms of mesohabitat mixes, and the methods used for stratification tend to be classification-based using logical or heuristic rules. This approach typically requires completing some form of mapping up front, and using the results to select sites that encompass the range of habitat conditions desired. The number of replicate sites can be identified via power analysis, although this ideally requires *a priori* knowledge of the statistical variance associated with a measurable quantity. In the absence of such knowledge, a distribution may be assumed (e.g., standard normal, Student’s t statistic, other).

> - *Applicability to the Susitna–Watana Project: Yes, but will require results of more detailed habitat mapping that will be completed in Q1 2013 to determine representativeness of study areas.*

Critical Sites – where available knowledge indicates that either (i) a sizable fraction of the target fish population relies on a specific location, (ii) a particular habitat type(s) is (are) highly important biologically, or (iii) where a particular habitat type is well known to be influenced by flow changes in a characteristic way, and the decision is made to focus on those areas. For example, in the case of the Susitna River, historical fish studies repeatedly showed the importance of certain side slough, upland slough, and side channel areas for spawning and juvenile rearing. Critical sites or areas are typically selected assuming that project effects to other areas are secondary in terms of implications to fish population structure, health, and size. This assumption can only really be tested if other sites are identified that are similar looking but were not deemed critical, and sampling is performed on those sites as well to confirm the critical nature of the sites that were identified as such.

> *- Applicability to the Susitna–Watana Project: Yes, especially with respect to selection of side channel/side slough/upland slough complexes that have been shown to be influenced by main channel flows and that are biologically important.*

Randomly Located Sites – where sites, areas, or measurement locations are selected randomly from each defined stratum or habitat type, and replicate sites or cross-sections are sampled to estimate variance (e.g., Williams, 1996; Payne et al. 2004). Site selection based on random sampling tends to involve statistical multivariate grouping or stratification approaches, such as cluster analysis or ordination techniques. In this case, initial groundwork is necessary to identify relevant variables suitable for grouping, and then the data need to be collected or derived to describe those variables spatially. The approach is the least subject to potential for bias, because it relies on distinct rules and algorithms. However, this approach becomes increasingly difficult to apply in site selection when the sites become more complex, such as is the case on the Susitna River. In addition, the number of sites will be contingent on the variability within the universal data set: the greater the number of clusters, the greater the potential number of sites. Strict random sampling is therefore not likely applicable for evaluating off-channel habitats and sloughs where the morphology of multiple channels varies substantially and in complex ways within and across sites.

> *- Applicability to the Susitna–Watana Project: Yes, but more appropriate with respect to main channel mesohabitat sampling (i.e., riffle, run, glide, pool) or selection of mainstem habitat types for HSC sampling (see Section 8.5.4.5).*

These approaches were reviewed at a recent TWG meeting (September 11, 2012) and the proposed process and criteria used for the selection of study areas/sites presented.

Focus Areas

During the September 11, 2012, TWG meeting, the concept of “intensive study areas” was introduced and discussed. Such areas represent specific sections of the river that will be investigated across resource disciplines that will provide for an overall understanding of interrelationships of river flow dynamics on the physical, chemical, and biological factors that influence fish habitat.

The concept represents a combination of all three of the methods described above, inasmuch as (1) the areas would contain habitat types *representative* of other areas; (2) the areas would include certain habitat types repeatedly used by fish and therefore can be considered “*critical* areas”; and (3) sampling of certain habitat features or mesohabitat types within the areas would be best approached via *random* sampling.

A total of 10 intensive study areas (hereafter referred to as Focus Areas [Focus Areas]), were presented and discussed with the TWG and are proposed in this RSP for detailed study within the Middle River Segment. Locations of the Focus Areas are depicted in Figure 8.5-11. The Focus Areas are intended to serve as specific geographic areas of the river that will be the subject of intensive investigation by multiple resource disciplines including Fish and Aquatics Instream Flow, Riparian Instream Flow (see Section 8.6), Groundwater (see Section 7.5), Geomorphology (see Section 6.0), Ice Processes (see Section 7.6), and Water Quality (see Section 5.0). The Focus Areas were selected during an inter-disciplinary resource meeting that involved a systematic review of aerial imagery within each of the Geomorphic Reaches (MR-1 through MR-8) for the entire Middle Segment of the river. Focus Areas were selected within Geomorphic Reach MR-1 (one Focus Area), Geomorphic Reach MR-2 (two Focus Areas), Geomorphic Reach MR-5 (one Focus Area), Geomorphic Reach MR-6 (four Focus Areas), Geomorphic Reach MR-7 (one Focus Area), and Geomorphic Reach MR-8 (one Focus Area). Focus Areas were not selected for Geomorphic Reaches MR-3 or MR-4 due to safety considerations related to Devils Canyon. MR-3 is a relatively short (3.5-mile) steep (17 ft/mi.) reach located just upstream from the Devils Canyon reach. The reach is confined within a relatively narrow canyon. Although flow routing transects were initially considered for this reach, any attempt to sample it was abandoned once field teams were on the ground and realized it could not be safely measured. Of particular concern were the swift currents within the reach and the lack of any margin of safety for recovering someone before they would be swept into Devils Canyon. MR-3 consists primarily of single-thread main channel habitat with two areas with split-main channel islands. No major tributaries enter the reach and it is likely that any anadromous salmonids (Chinook) that make it through Devils Canyon simply pass through MR-3. The main channel portions of the reach are similar to those in MR-2 and MR-1. The Devils Canyon Reach (MR-4) is non-navigable and cannot, under any flow condition, be safely surveyed.

The areas selected were those deemed representative of the major features in the geomorphic reach and included mainstem habitat types of known biological significance (i.e., where fish have been observed based on previous and/or contemporary studies), as well as some locations (e.g., Slough 17) where previous sampling revealed few/no fish. The Focus Areas include representative side channels, side sloughs, upland sloughs, and tributary mouths.

Three of the Focus Areas in Geomorphic Reach MR-6 and one in Geomorphic Reach MR-8 contain specific habitat types that were found, during the 1980s studies, to be consistently used by salmon for spawning and/or rearing. These areas included Slough 21, Slough 11, and Skull Creek in Geomorphic Reach MR-6 and Whiskers Slough in Geomorphic Reach MR-8. Overall, 92 percent of the sockeye, 70 percent of the chum, and 44 percent of the slough-spawning pink salmon were found in just these four sloughs. By definition, these areas represent “critical areas” and were included in the Focus Areas to allow some comparisons with the 1980s data. Although other portions of these same Focus Areas were not studied during the 1980s, these areas will be studied as part of the RSP. The upper three Focus Areas (one in Geomorphic Reach MR-1 and two in Geomorphic Reach MR-2) were selected based on their representativeness of the respective geomorphic reaches and the inclusion of a mix of side channel and slough habitat types. However, there is no existing fish information on these areas because they were not sampled in the 1980s. Nominally, the Focus Areas range in length from 0.5 mile to 1.9 miles. Details of each of the Focus Areas including their identification number, common name, description, geomorphic reach assignment, location (RM), length, habitat types included in the Focus Area, fish use and types of instream flow studies conducted in the 1980s, and the rationale for selection, are presented in Table 8.5-6; schematic photos of each of the areas are depicted in Figure 8.5-13 through Figure 8.5-22. A similar process will be applied to the Lower Segment of the river in December 2012 but will focus on the upper portions of that segment that will be most susceptible to flow modification.

These 10 areas have been selected for planning purposes but will be evaluated further for their representativeness of other areas based on results of habitat mapping that will be completed at the end of 2012. The results of this evaluation will be discussed with the TWG and refinements in Focus Area selection made prior to commencement of the 2013 studies. The initial set of study areas will be developed in consultation with the TWG by February/March of 2013 to enable detailed field studies to occur. The data and information collected in 2013 from this study and other related investigations (e.g., fish distribution – Section 9.5; radio-tagging – Section 9.7; habitat characterization – Section 9.9; and others) will be reviewed, and necessary refinements to existing sites made or new sites added to the studies completed in 2014. This adaptive management approach to site selection will allow for shifts in study focus to other areas, should results of 2013 studies reveal their biological importance and sensitivity to flow modifications.

It should be noted that the criteria applied in the selection of the Focus Areas incorporated (or will incorporate) elements from all three of the above mentioned selection methods and considered the following:

- All major habitat types (main channel, side channel, side slough, upland slough, tributary delta) will be sampled within each geomorphic reach.
- At least one (and up to three) Focus Area(s) per geomorphic reach (excepting geomorphic reaches associated with Devils Canyon – MR-3 and MR-4) will be studied that is/are r**epresentative** of other areas.
- A replicate sampling strategy will be used for measuring habitat types within each Focus Area, which may include a **random selection** process of mesohabitat types.
- Areas that are known (based on existing and contemporary data) to be biologically important for salmon spawning/rearing in mainstem and off-channel habitats will be sampled (i.e., **critical areas**).
- Areas for which little or no fish use has been documented or for which information on fish use is lacking will also be sampled.

Sites Outside of the Focus Areas

In addition to the identified Focus Areas, a total of 80 cross-sectional transects in the Middle River Segment and 8 transects in the Lower River Segment have been established and flow data collected to support development of the open-water flow routing model (see Section 8.5.4.3 and Table 8.5-7). These transects were primarily located across single thread sections of the river; however, some do extend across more complex sections. In most cases, two to three sets of flow measurements have been made at each transect. The resulting data sets can be used, at a minimum, for evaluating velocity-depth distributions across the channel that can be related to biologically relevant criteria associated with various life stage requirements (e.g., spawning, adult holding, juvenile rearing). In many cases (pending review of the cross-sectional data), it should be possible to develop actual habitat-flow relationships following a 1-D PHABSIM type analysis (see Section 8.5.4.6). The cross-sectional transects represent an important dataset that can be used to characterize habitat-flow response characteristics of the main channel of the Susitna River. These types of data were never collected during the 1980s studies and no main channel habitat-flow relationships were developed. Importantly, once the main channel habitat mapping is completed (see Section 9.9), the transect locations will be assigned to specific mesohabitat types (e.g., riffle, run, glide, pool) that could be randomly selected for analysis. These additional transects may also be useful for extrapolating results/relationships from measured to unmeasured sites (see Section 8.5.4.7). Supplemental main channel transects will be established as needed to more fully characterize main channel habitats, either as part of the Focus

Area analysis or at separate locations associated with specific mesohabitat types. The need for and exact number of the supplemental transects will be determined based on results of the habitat mapping.

8.5.4.2.2. Work Products

A detailed description of the rationale and methods used in the selection of study areas and study sites will be provided in the Instream Flow Study Report. Information provided will include the following:

- Maps and orthophotos depicting geomorphic reach breaks and highlighting locations of Focus Areas as well as locations of all Open Water Flow Routing Model cross-sections.
- Aerial photos of each of the Focus Areas depicting upper and lower boundaries and highlighting the different habitat types contained within each Focus Area.
- Results of mainstem habitat mapping presented in both tabular and graphical formats that present the relative proportions of habitat features contained in the Focus Areas within a given geomorphic reach relative to those features contained in the entire geomorphic reach.
- Ground-based, geo-referenced, and labeled digital images of each of the Focus Areas to include specific habitat types and features within each Focus Area.
- Detailed narrative describing the study area selection process leading to the selection of Focus Areas. This will include stratification procedures, site/area criteria development and application, as well as results of any statistical analysis including both perspective and retrospective power analysis used for determining sample size.

8.5.4.3. Hydraulic Routing and Operations Modeling

Project operations will likely store water during the snowmelt season (May through August) and release it during the winter (October through April; AEA 2011). This would alter the seasonal hydrology in the Susitna River downstream from the dam, resulting in lower flows from May through August and higher flows from October through April. In addition to these seasonal changes, the Project may be operated in a load-following mode. Daily load-following operations will typically release higher volumes of water during peak-load hours, and lower volumes of water during off-peak hours. Flow fluctuations that originate at the powerhouse will travel downstream and attenuate, or dampen, as they travel downstream. The waves created by load-following operations will affect the aquatic habitat of the Susitna River downstream from the powerhouse, especially along the margins of the river alternately wetted and dewatered (the varial zone).

8.5.4.3.1. Proposed Methodology

To analyze the impacts of alternative Project operational scenarios on habitats downstream of the Watana Dam site, an open-water flow routing model will be used to translate the effects of changes in flow associated with Project operations to downstream Susitna River locations; the open-water flow routing model will be extended downstream until the flow fluctuations are within the range of the without-Project natural variation and conditions.

Steady-state flow models assume that velocity or flow at a given location remains constant. Unsteady flow models are used when flows change rapidly and the consideration of time is an additional variable. One-dimensional unsteady flow hydraulic models are commonly used to route flow and stage fluctuations through rivers and reservoirs. Examples of public-domain computer models used to perform these types of processes include FEQ (USGS 1997), FLDWAV (U.S. National Weather Service 1998), UNET (U.S. Army Corps of Engineers 2001), and HEC-RAS (U.S. Army Corps of Engineers 2010a, 2010b, and 2010c). The HEC-RAS model has proven to be very robust under mixed flow conditions (subcritical and supercritical), as will be expected in the Susitna River. The HEC-RAS model also has the capability of automatically varying Manning's "n" with stage through the use of the equivalent roughness option. Another feature of HEC-RAS is the capability of varying Manning's "n" on a seasonal basis. The robust performance and flexibility of HEC-RAS make this model an appropriate choice for routing stage fluctuations downstream from the proposed Project dam under open-water conditions (i.e., summer, ice-free). Under winter ice-covered conditions, the CRISSP1D (Comprehensive River Ice Simulation System Project) model or the River1D model could be used to route unsteady flows downstream through the Susitna River. CRISSP1D is a one-dimensional unsteady flow model that can be used to analyze water temperature, thermal ice transport processes, and ice cover break-up (Chen et al. 2006). Likewise, River1D, developed by the University of Alberta, is an alternate one-dimensional unsteady flow model that could be used to analyze ice processes. The seasonal timing of the transition from the HEC-RAS model to the Ice Processes Model and vice versa will vary from year-to-year and will depend on seasonal climate conditions. The Ice Processes Model and how it will be used to model flow in the Susitna River is described in Section 7.6. This section, 8.5.4.3, concentrates on how the HEC-RAS model will be developed and calibrated for the mainstem open-water period.

The foundation of the IFS analyses rests with the development of the Susitna River Mainstem Flow Routing Models (MFRM) (HEC-RAS, Ice Processes Model) that will provide hourly flow and water surface elevation data at numerous locations longitudinally distributed throughout the length of the river extending from RM 184 downstream to RM 75 (about 23 miles downstream from the confluence with the Chulitna River). Two different flow routing models will be developed: an open-water model (HEC-RAS) and a winter model to route flows under ice-covered conditions. The HEC-RAS routing model will initially be developed based on river cross-sections and on gaging stations on the Susitna River that were established and measured in 2012 as part of the IFS program. A list of the river cross-sections that were surveyed is provided in Table 8.5-7. A total of 88 cross-sections were surveyed in 2012 (16 between the proposed dam site and Devils Canyon, 59 between Devils Canyon and the Three Rivers Confluence, and 13 downstream from the Three Rivers Confluence). The table shows the preliminary river mile of each section, the date of measurement, the measured discharge, and reference discharge from the USGS Susitna River at Gold Creek. Both sets of discharge values are currently preliminary and in the review process. The cross-sections were measured during three field trips intended to capture high-flow (28,000 cfs), medium-flow (16,000 cfs), and low-flow (8,000 cfs) conditions corresponding to the USGS gage station at Gold Creek (No 15292000). The first two trips were successful at capturing high-flow and medium-flow conditions during late June-early July and August, respectively. However, the low-flow trip that began on September 14 was interrupted by a 25-year flood event that required evacuation of the field team on September 20. Work resumed on September 29, but was suspended on October 6 when a second late fall storm resulted in unseasonably high flows. A final attempt commenced on October 15, but abundant river ice and slush pans precluded accurate flow measurements.

At each river cross-section, ground surface and water surface elevations were surveyed using Real Time Kinematic (RTK) GPS instrumentation. River bathymetry and flow velocities were measured using an Acoustic Doppler Current Profiler (ADCP) system consisting of a Sontek M9 equipped with RTK GPS positioning. Water surface slopes were also measured at each section. Photographs of each section were also taken and vegetation descriptions were also developed.

Examples of some of the river cross-sections that were surveyed in 2012 are shown in Figure 8.5-23. At RM 170 (between the proposed dam site and Devils Canyon), the channel had a single thread with a width of about 600 feet. At RM 75 (downstream from the Three Rivers Confluence), the channel was multi-threaded with a total width of about 1 mile.

At each river cross-section, a minimum of four passes across the channel width were used to measure the flow in accordance with U.S. Geological Survey (USGS) standards. An example of the output from one of the passes is shown in Figure 8.5-24 for RM 170 on June 21, 2012. While maximum velocities in the 10 to 15 feet per second (fps) range were recorded, the cross-sectional average velocity was 8.0 fps.

A total of 13 gaging stations were established on the Susitna River in 2012 at the locations listed in Table 8.5-8. These stations were set up to measure stage in real time every 15 minutes. The stations will be maintained in 2013–2014. Data recorded at these stations will be used to calibrate flow pulse arrival time in the open-water flow routing model, based on measured diurnal glacial melt pulses and rainstorm-generated flood peaks.

The hourly flow records from USGS gaging stations on the Susitna River will also be utilized to help develop the HEC-RAS routing model. Depending on the initial results of the flow routing models, it may be necessary to add additional transects to improve the performance of the models between RM 75 and RM 184, and to possibly extend the models farther downstream past RM 75. Additional transects between RM 75 and RM 184 will be added if calibration of certain sections of the river proves problematic without supplementing the HEC-RAS model with additional intermediate cross-sections.

Results of the draft open-water flow routing model will be available in Q1 2013. These initial results will be used to assess the magnitude, timing, and frequency of hourly flow and stage changes associated with proposed load-following operations during ice-free periods. Project operations will likely include storing water during the snowmelt season (May through August) and releasing it during the winter (October through April) (AEA 2011). This would reduce flows downstream of the dam site from May through August and increase flows October through April. During Q1 2013, results of the draft open-water flow routing model will also be used to evaluate downstream changes in flow and stage associated with reduced Project flow releases during the open-water portions of the reservoir refill period. Because the results of the Ice Processes Model will not be available prior to the start of the 2013 summer field season, the downstream extent of Project effects on flow and stage during the winter will be assessed by routing winter flow releases identified by the operations model (see Section 8.5.4.3.2) downstream using the open-water flow routing model. Although stage and flow projections during the winter will not be robust, they will provide sufficient information on downstream flow and stage effects to support early 2013 decisions regarding the need to extend resource studies into the Lower River Segment. Should extension of an open-water flow routing model downstream of RM 75 be needed to address data needs of riverine process and habitat modeling studies, the additional channel and hydraulic data can be collected in Q3 2013.

During the development and calibration of the HEC-RAS model, the drainage areas of ungaged tributaries will be quantified and used to help estimate accretion flows to the Susitna River between locations where flows are measured. The flow estimates developed for ungaged tributaries will be refined based on flows measured in those tributaries in 2013 and 2014.

The gaging stations initially installed in 2012 will be maintained through 2013 and 2014 to help calibrate and validate the flow routing models and provide data supporting other studies. The gaging stations will be used to monitor stage and flow under summer ice-free conditions and to monitor water pressure under winter ice-covered conditions. The stations record additional measurements including water temperature and camera images of the river conditions (summer and winter). Continuous measurement of water pressures during the 2012–2013 and the 2013–14 winter periods under ice-covered conditions will produce information different from open-water conditions. During partial ice cover, the pressure levels measured by the pressure transducers are affected by flow velocities, ice-cover roughness characteristics, and other factors such as entrained ice in the water column. The pressure-head data are important for understanding groundwater/surface water interactions.

Periodic winter discharge measurements (January and March) will be completed at selected gaging stations in the winter, in coordination with USGS winter measurement programs, and will provide valuable information for understanding hydraulic conditions in the river during a season when groundwater plays a more prominent role in aquatic habitat functions. Winter flow measurements will also be used to help develop the Ice Processes Model and supporting analysis (see Section 7.6).

Once developed and calibrated, the HEC-RAS model can be provided a time history of flow releases from the dam and it will predict the flow and stage history at each of the downstream cross-sections. These predicted flow and stage responses can then be evaluated at multiple levels to assess the impacts to aquatic habitat.

Output from the flow routing models will provide the fundamental input data to a suite of habitat-specific and riverine process-specific models that will be used to describe how the existing flow regime relates to and has influenced various resource elements (e.g., salmonid spawning and rearing habitats and the accessibility to these habitats in the mainstem, side channels, sloughs, and tributary deltas; invertebrate habitat; sediment transport processes; ice dynamics; large woody debris (LWD); the health and composition of the riparian zone). These same models will likewise be used to evaluate resource responses to alternative Project operational scenarios, again via output from the routing models, including various baseload and load-following alternatives, as appropriate. As an unsteady flow model, the routing models will be capable of providing flow and water surface elevation information at each location on an hourly basis and therefore Project effects on flow can be evaluated on multiple time steps (hourly, daily, and monthly) as necessary to evaluate different resource elements.

The study objective for the flow routing data collection effort is to provide input, calibration, and verification data for a river flow routing model extending from the proposed dam site to RM 75. Specific objectives are as follows:

- Survey cross-sections to define channel topography and hydraulic controls between RM 75 and RM 184, excluding Devils Canyon (for safety reasons).
- Measure stage and discharge at each cross-section during high and low flows, with the potential addition of an intermediate flow measurement.
- Measure the water surface slope during discharge measurements, and document the substrate type, groundcover, habitat type, and woody debris in the flood-prone area for the purposes of developing roughness estimates.
- Install and operate 13 water-level recording stations within the mainstem Susitna River.

The HEC-RAS routing model will rely upon existing Susitna River hydrology as well as on output from the ROM.

8.5.4.3.2. Operations Model

The U.S. Army Corps of Engineers, Hydrologic Engineering Center (HEC) reservoir system simulation model HEC-ResSim (USACE 2007) Version 3.0 will be used to develop the reservoir outflows used in the Instream Flow Study. HEC-ResSim is a general-purpose, sequential stream flow routing model. The model is free and in the public domain. HEC-ResSim includes a graphical user interface, and graphics and reporting facilities. HEC's Data Storage System (HEC-DSS) is used for storage and retrieval of input and output time-series data.

Essential HEC-ResSim capabilities applicable to Watana Reservoir are summarized in this section. The model time increment of operation, which is an input variable, will be hourly. Reservoir operations are driven by a set of operating rules. Refinements are achieved through iterative model runs. HEC-ResSim incorporates a reservoir water balance such that inflow minus outflow, minus losses such as evaporation, equals the change in reservoir storage for the time period.

Although the HEC-ResSim program contains river channel routing capabilities, the more detailed hydraulic channel routing capabilities of HEC-RAS will be used in the Instream Flow Study for river channel flow routing downstream from Watana Dam. Therefore, a description of HEC-ResSim river channel flow routing capabilities has not been included. Where specific data values are provided herein for the dam, reservoir, and operating parameters, it must be understood that all values are preliminary and subject to change as studies progress.

8.5.4.3.2.1. Hydrology

Required model input data includes long-term reservoir inflow time-series data. For Watana Dam, the reservoir inflows will be a continuous 61-year record of daily flows for Water Years 1950 through 2010. The U.S. Geological Survey (USGS) provided the basis for the continuous long-term daily flows with a Susitna River watershed record extension study (Curran 2012). Two of the USGS gages included in the record extension study were Susitna River at Gold Creek (USGS gage 15292000) that has a drainage area of 6,160 square miles, and Susitna River near Cantwell (USGS gage 15291500) that has a drainage area of 4,140 square miles. Watana Dam has a drainage area of 5,180 square miles, about half-way between these two USGS gages. Inflows to Watana Reservoir were based on proportioning the USGS flows based on drainage area.

Providing environmental flows at the Gold Creek USGS gage is a primary reservoir operating criterion. With Watana Dam, a majority of the flow tributary to the Gold Creek USGS gage will be regulated, but significant natural inflows between Watana Dam and Gold Creek must also be included. To accomplish this, a 61-year daily record was constructed from the Gold Creek USGS gage flows minus the calculated Watana Reservoir inflows and used as time-series natural inflow data for input to the model.

8.5.4.3.2.2. Reservoir Operations

The basic reservoir input data includes a table of values for elevation (feet), reservoir storage (acre-feet), and water surface area (acres), and a table of values for release capacities based on elevation including the spillway, valves, and the turbines. Release capabilities can be broken down by individual valve or spillway bay.

Releases from the reservoir in the HEC-ResSim model are based on zones, defined by reservoir water surface elevations, and a reservoir operating scheme. The initially defined zones in the model configuration were an Inactive zone up to 1,850 feet in elevation, a Conservation zone up to 2,050 feet in elevation, a Flood Control zone up to 2,064 feet in elevation and a Spillway Operation zone that extended to the top of the dam crest at 2,075 feet in elevation. It is possible to create additional user-defined zones in HEC-ResSim. The operating scheme in HEC-ResSim is defined by adding rules to the zones, with the exception of the Inactive zone from which releases cannot occur. A rule represents the goals and constraints upon the releases. The reservoir operating scheme, called an operations set, controls releases from the various reservoir outlets, and therefore, the downstream discharge resulting from the Project. The rules within each zone are prioritized to control the actual releases from the reservoir outlets. The allocation of releases from the outlets can also be specified.

The highest priority rules in the Conservation zone would be the minimum and maximum flow requirements at Gold Creek (USGS gage No. 15292000), which was initially used as a downstream control point for releases from the reservoir based on studies from the 1980s. The initial environmental flow requirements from Case E-VI in the 1985 FERC License Application Amendment were used, with the exception of the flow requirements from October 29 to May 5, which were updated to reflect an increase from 2,000 cfs to 3,000 cfs. A sequential release allocation for the reservoir outlets was also added in order to increase the flow, as necessary, through the powerhouse when the flow to meet the hourly Watana load was less than the minimum release required from the reservoir to meet flow requirements at Gold Creek. Hydropower operations in the Conservation zone form the other primary reservoir release rule. The Flood Control zone used the same operating rules as the Conservation zone and included a release rule for the low-level fixed-cone outlet valves. The Spillway Operation zone included a release rule for operation of the gated spillway.

8.5.4.3.2.3. Hydropower Operations

Basic hydropower input data includes installed capacity and unit efficiencies as a constant or as a function of flow, reservoir elevation, or operating head. A tailwater rating table, hydraulic losses as a constant or a function of flow, turbine hydraulic capacities, and an allowance for station use are also included as input data.

Hydropower rules specify the minimum releases needed from a reservoir's powerhouse to meet a power generation requirement and schedule. The hydropower rules available in the model specify the generation requirement as a function of time of year (month, week, or day with hourly load factors), power guide curve, or as an external time-series dataset of the load. The release from the powerhouse, which is a function of the plant's generating efficiency, the hydraulic head, and the required energy can also be specified based on limits to the rate of change of flow through the powerhouse and downstream flow requirements, which in turn affect the energy generation.

The initial Watana powerhouse hydropower rule was to specify time-series energy generation requirements for each hour of the year (8,760 values). The required generation values were based on the Watana powerhouse generating a specified part of the total Railbelt energy demand. As studies progress, the hourly time-series generation requirements at Watana are expected to be based on studies that integrate the Watana generation capabilities into the Railbelt system. The hourly load data for Watana would then be based on the total projected load for the Project considering the capability of other Railbelt Utilities loads and resources in the region. Factors such as outages of other Railbelt generating units could then be incorporated in the generation requirements at Watana Dam.

8.5.4.3.2.4. Model Output

HEC-ResSim can provide results for many parameters such as the simulated reservoir elevation and powerhouse generation. Data can be plotted or output in standard or user-customized reports. Only one parameter, total reservoir outflow, must be provided from HEC-ResSim for input to the HEC-RAS model. Total reservoir outflow is the summation of all outlets including the powerhouse, spillway, and the fixed-cone outlets. The extent of data to be provided is yet to be determined, but it could include hourly outflow for all 61 years of operation (over 500,000 values). The outflows could also be provided on a daily average flow basis if needed.

8.5.4.3.3. Work Products

Work products for open-water flow routing will consist of a calibrated executable model and a draft and final report. Specific work products will include the following:

- A detailed description of the methods used to develop the routing model.
- Map displaying the location of all mainstem transects used as part of open-water flow routing modeling.
- Data used in the modeling effort including topographic, bathymetric, and digital terrain model data, USGS flow records, and water surface elevations.
- Plot of channel cross-section profiles for all transects used as part of the modeling.
- Details of model calibration including calibration period, observed and simulated water surface elevations, Manning's roughness values, and tabular listing of calibration results.

These work products will be compiled and presented in the open-water flow routing component of the Initial Study Report (ISR) and Updated Study Report (USR).

8.5.4.4. Hydrologic Data Analysis

The assessment of hydrology data will include a summary of seasonal and long-term hydrologic characteristics for the river including daily, monthly, and annual summaries, exceedance summaries, and recurrence intervals of small and large floods. The recent record extension analysis performed by USGS (Curran 2012) will be used to develop the synthetic period of record (POR) flows for the past 61 years at selected tributaries. The hydrologic data collection at tributaries will provide data required for the simulation of flows at hourly intervals required for evaluating potential Project effects.

8.5.4.4.1. Proposed Methodology

8.5.4.4.1.1. Hydrologic Data Collection

As part of the 2013–2014 IFS, hydrologic data collection will include stage and discharge measurements, cross-sectional and areal bathymetric surveys, velocity mapping, and roughness determinations. The IFS will also incorporate hydrologic data collected by other studies, including water quality (see Section 5.0), water temperature, and ice process data (see Section 7.6).

Stage and discharge measurements were performed in 2012 at 88 cross-sections between RM 75 and RM 184. Twelve of these cross-sections are located at or near gaging stations operated by USGS or AEA. Stage and discharge measurements were also performed at inactive USGS gaging stations in the Lower River (Susitna River at Susitna Station [ESS20], RM 20) and in the upper basin (Susitna River near Cantwell [ESS80], RM 224) (see Table 8.5-8 for gaging station naming convention). Gaging equipment was re-installed at these locations, as well as at two tidal monitoring stations in the Susitna delta. Water level, water temperature, camera images, and meteorological data from these stations are shared online via an internal project website.

Depending on results of the 2012 open-water flow routing model and analysis from other studies, additional cross-sections will be surveyed in 2013 and 2014. The geomorphology studies (see Sections 6.5 and 6.6) will require 50 to 100 additional cross-sections for the development of the 1-D sediment transport model and other geomorphologic analysis. The location for these sections and the field data collection will closely coordinate with the Geomorphology Discipline Lead and relevant study staff. These cross-sections should satisfy most of the additional cross-sections needed for the open-water flow routing model. Sections of the river that demonstrate changes in cross-section profiles seasonally, or event-based (floods), may require additional cross-section measurements during each summer season. Stage and discharge measurements will be used to calibrate the flow routing models, and to develop or confirm ratings for new and existing gaging stations.

Instantaneous stage measurements will be performed using either RTK GPS methods or optical levels, using benchmarks and geodetic control points that are part of the Project control network. The 2012 river cross-section field program established that the RTK survey method allowed for the greatest number of cross-sections to be surveyed each day and helped maintain safety objectives. In addition, the RTK data quality parameters and time stamp information contained in the field controller database files ensured the accuracy of the water level measurements and eliminated the possibility for transformation of numbers by the field crews. The GPS Project survey-control (CP) network (horizontal and vertical) will be evaluated each spring. Vertical datum will be verified and any missing benchmarks due to bank erosion or other issues replaced if needed. Additional CP surveys will be conducted to support Focus Areas and other studies from the Lower River Segment to the Upper River Segment, as needed. RTK survey control points will be placed at final Focus Areas to provide study field teams with horizontal and vertical control networks designed to allow efficient ground surveying with RTK, optical levels, or other conventional survey methods.

A standard operating procedure (SOP) guide will be established to provide uniform survey methods and data reporting standards. This will include the use of Focus Area survey control networks (horizontal and vertical) by the various field study teams working in these areas. The SOP will include the appropriate reporting of RTK survey methods and data. All surveying information will be provided in data sets applicable to existing or developing relational or spatial databases.

While conducting field surveys for new or existing survey control points in study Focus Areas, additional survey control points will be established to verify the accuracy of Project Light Detection and Ranging (LiDAR) information. The field plans for collecting the LiDAR validation data will be coordinated with the study teams depending on this data and the Project Geographic Information System (GIS) technical group. Existing RTK river cross-section survey control points will be relabeled in the spring of 2013 to reflect final Project River Mile (PRM) designations.

During 2012, a number of 1980s cross-section and survey-control points were found and surveyed to current horizontal and vertical datum standards. Additional survey control points will be reviewed from any newly found 1980s information. The potential 1980s information will be evaluated for follow-up field surveying. An evaluation will be made on how to project the 1980s project survey-control datum (horizontal and vertical) to current Project standards.

Any new AEA gaging or water level stations will have RTK or CP surveys established as well as temporary benchmarks (TBMs) to allow efficient optical level-loop surveys. Project survey control will be maintained, or established if needed, at USGS gaging stations on the Susitna River within the Project study area, and at key tributaries. The offsets from USGS local datum to Project elevation datum will be maintained to provide USGS to Project vertical datum conversion standards. These conversions are critical to using the USGS gage water levels in all relevant Project hydrology modeling and studies.

Together with water temperature and meteorological data, continuous stage measurements will be recorded at AEA gaging stations with a minimum of 15-minute intervals and made available to studies via the near-real-time reporting data network. Continuous stage measurements are made using vented pressure transducers accurate to within about 0.02 feet. The gaging stations will require periodic elevation surveys, either performed by RTK surveying or by optical level-loop survey methods. The elevations surveys will be conducted during discharge measurements, changes or repositioning of pressure transducers, and before and after major hydrologic events such as fall freeze-up and spring break-up. The data collection stations will be operated throughout the year to support both summer (open-water) and winter (ice covered) study needs for the IFS and other studies. Table 8.5-9 shows a listing of the current 2012 stations in the near-real-time reporting data network.

Maintaining a constant stage record during river freeze-up and spring break-up is a challenge. River ice jams and ice jam break-ups will result in some minor losses of stage data. In the early winter, when ice conditions become more stable and safe for field crews to operate on the ice, pressure transducers and water temperature sensors will be added at gaging stations to provide the Ice Processes Study team (see Section 7.6) with winter pressure (water pressures under ice, water levels in ice-free or partial ice cover reaches) and water temperature measurements. Sensors lost during spring break-up will be replaced as soon as it is safe and practical to install new pressure transducers. All data are recorded on Campbell Scientific CR1000 data loggers, with internal memory backup. AEA gaging stations also have data archived through hourly data retrievals over the radio telemetry network. This approach will help ensure that no data are lost from icing conditions except for the narrow period when pressure transducers are damaged at a gaging station and new sensors have not yet been installed.

Additional gaging stations will be added at selected tributaries to help provide additional hydrologic analysis for hydrologic and fisheries studies. These tributaries will include Fog Creek, Portage Creek, and Indian River. These gaging stations will be installed in spring 2013 to help measure the spring snowmelt peaks. The stations will use the same Metadata standards as the existing AEA gaging stations and will report similar data. Additional stations may be added to the near-time-reporting network as warranted by study activities and analysis needs and deadlines. Additional gaging stations may be added on additional tributaries based on the drainage area evaluations being performed by UAF-GINA.

During open-water conditions, mainstem discharge measurements will be performed using acoustic Doppler current profilers (ADCPs) following current USGS guidance (Mueller and Wagner 2009). Due to their shallow depths, tributary inflows will usually be measured using conventional current meter methods (Rantz et al. 1982). Winter mainstem flows will be measured using a combination of current meter and ADCP methods. The winter gaging program will be coordinated with USGS so that the measurements from both programs occur at the same general time period. The current schedule is to conduct winter measurements in January and March of 2013 and 2014. The winter discharge measurement will occur at the AEA gaging stations from ESS80 downstream to ESS20 (Table 8.5-8). Winter discharge measurement will not be collected at ESS10 and ESS15. These discharge measurements will help assess gaining and losing river reaches during winter conditions. This effort will be coordinated with Ice Processes (see Section 7.6) so that measurements also have direct applications to the ice processes analysis and model development efforts. The winter and summer discharge measurement events will likely involve multiple teams to allow collection of data under a shorter period so flow conditions can be more similar for comparisons between gaging stations in the network.

In accordance with current USGS guidance (Mueller 2012), all discharge measurements will include sufficient quality assurance data to rate the measurements as Excellent, Good, Fair, or Poor, corresponding to categories of uncertainty ranging from 0 to over 8 percent.

During 2012, cross-sectional bathymetric surveys were performed as part of discharge measurements completed using the Sontek M9 ADCP. The Sontek M9 is equipped with a 0.5-megahertz (MHz) vertical-beam depth sounder and RTK GPS positioning. A minimum of four transects were completed at each cross-section, and results were used to prepare a digital elevation model of the streambed. Together with shore-based RTK GPS surveys, the digital elevation model was used to develop cross-sections for use in the open-water flow routing model.

Additional cross-sections will be needed for geomorphology modeling, flow routing, and other IFS models. Depending on the need for concurrent flow data, the cross-sections will be surveyed using either ADCPs or single-beam depth sounders. In either case, bathymetric data will be referenced to the Project geodetic control network using RTK GPS survey methods.

Roughness determinations will be made by solving Manning's equation using field measurements of discharge and water-surface slope. Each cross-section will have vegetation descriptions and photographs (upstream, downstream, into bank, opposite bank) above ordinary high water elevations. The distance away from shoreline for cross-section surveys is determined in the field by the Lead Field Hydrologist. These results will be compared against visual estimates based on handbook values.

8.5.4.4.1.1.1. Hydrologic Data Real-time Reporting Network Operations

Project hydrologic studies include river-flow routing models (see Section 8.5) ice, geomorphology (see Section 6.6) and water quality (see Section 5.6) models and several studies to look at the potential effects of the Project and how to minimize them. In order to accurately simulate unsteady flows, the studies require a series of gaging (water level and discharge), water level, and meteorological stations. These stations are connected through a radio telemetry system using spread-spectrum radio communication and a network of base stations. The purpose of the radio telemetry system is to provide a number of key Project objectives, described below.

Safety

- Real-time access to data can reduce field hours associated with data retrieval; in some cases this reduces trips per year, or time on-site for each trip.
- Providing real-time access to field weather conditions for travel logistics such as helicopters or small aircraft. The data reporting network was used for supporting helicopter logistics and inclement weather evaluations.

Data Quality

- Real-time access to data can allow easier and more cost effective data monitoring; thus, field-related problems (e.g., ice jam floods, bears, lightning strikes) can be detected quickly, and site conditions better understood before going in the field, all of which reduces data loss.
- Real-time data access minimizes data loss by enabling timely response to problems caught when they occur, rather than their discovery during a site visit. By providing information on a specific problem, proper equipment replacements and tools can be brought along for the site visit, ensuring that the problem will be corrected without necessitating an additional trip.
- Real-time retrieval of data also allows off-site data storage, so if a site is severely damaged, there is no data loss, even if there is a complete failure of data acquisition equipment. Data are preserved both on the data servers and the data loggers to provide redundant data security.
- Study teams have access to data for ongoing data quality control (QC) before going into the field, so teams can better address potential sensor or programming issues and

proactively plan for field repairs. Two-way communications allow programming updates and modifications to be accomplished without expensive site visits.

Deadlines

- Real-time access allows field staff access to data 24/7, so data QC, reduction, and analysis applications can be accomplished between field trips. This also benefits the effectiveness of field trips by allowing a better understanding of field conditions before going in the field. QC checks and graphs can be set up, tested, and adjusted early in the Project in an unhurried manner. QC can be up-to-date when it is time to create reports.

Data network management includes maintaining network Metadata standards. This results in sharing of common data-acquisition equipment, and allows savings for backup equipment to help support the various station types in the network. Network management also includes the coordination of network operation and maintenance activities; bulk procurement of network station supplies; setup of water level, gaging, repeater, and base stations; and coordinated reporting for the stations in the network linked together with the radio telemetry data communication system.

The data network installed in 2012 established the following equipment standards:

- Campbell Scientific CR1000 data control/acquisition loggers, extended temperature rating
- Campbell Scientific RF450 Spread-Spectrum Radios for data transmissions
- Campbell Scientific CS450 vented pressure transducers for water stage and temperature (at transducer location)
- GWS-YSI Cold-Range air temperature sensors
- Campbell Scientific CC5MPX lower power, cold weather digital cameras with lens heaters for supporting winter operations
- HC2S3-L Rotronic air temperature, relative humidity sensor
- Campbell Scientific CS109 temperature sensors for general water level and soil temperatures
- 12-volt solar power systems for all stations

Data network operations also include data retrieval and online reporting for water level and gaging stations, repeater stations, base stations, meteorological stations, and associated co-located meteorological sensors. Internal information reporting is currently available on an internal website/wiki and includes network status and diagnostics information (Figure 8.5-25). Data reporting includes current conditions pages for each station (Figure 8.5-26), basic station information pages, and near-real-time graphs for selected sensors (such as air temperature, relative humidity, water level over sensor, water temperature, and station diagnostics information). Data plots are set up to display in 7- and 14-day periods, as well as 2-, 4-, 6-, and 12-month graphs. Short-period graphs are updated hourly, while long-period graphs (1 month or longer) are updated every three hours. Cameras will be maintained at gaging stations and selected repeater stations. Low and high resolution cameras image are taken hourly. The low resolution images are transferred to the CR1000 data logger and transmitted with other station data and reported hourly, and displayed online internally in 24-hour sequences. The high resolution camera images are stored locally on the camera on camera internal memory cards and downloaded during regular station visits. All camera images collected are accessible through the online image interface.

The radio telemetry remote collection of data from gaging and meteorological stations is supported by a series of repeater stations. Some data collection stations (gaging or meteorological) also serve as repeater stations. Additional repeater stations may be installed in 2013 and 2014 as the data network changes to meet various study needs. Typically repeater stations will be visited once a year for annual maintenance, or as needed for station problems from issues such as bear damage or extreme weather events.

8.5.4.4.1.2. Hydrologic Data Analyses

The hydrologic period of record for the Project has been established for the 61-year period extending from Water Years 1950 through 2011 (October 1, 1949 to September 30, 2011). Historically, flows have been measured by USGS in the Susitna basin at various locations and over different time periods. USGS gaging stations on the Susitna River are listed in Table 8.5-10, and USGS gaging stations on tributaries of the Susitna River are listed in Table 8.5-11.

The periods of record of measured flows at each of the sites listed in Table 8.5-10 and Table 8.5-11 were extended to cover the 61-year period (Water Years 1950 through 2011) by synthesizing the missing daily flow records to fill in the gaps. This work was performed by USGS (Curran 2012). The 61-year period of record at the sites listed in Table 8.5-10 and Table 8.5-11 will establish a baseline hydrologic condition from which to assess Project effects.

Potential alterations to this baseline condition will be assessed as part of the Glacier and Runoff Changes Study (see Section 7.7). These evaluations will be performed with the WaSiM-ETH model (Water Balance Simulation Model). The WaSiM-ETH model accounts for evapotranspiration, snow accumulation, snow and glacier melt, interception, infiltration, soil water storage, and runoff, such as surface, interflow, and baseflow. The model will be calibrated to match conditions observed from 1960 through 2010, and used to forecast conditions out to the year 2100. The proposed extent of the WaSiM-ETH model is the Susitna River basin upstream from the proposed dam site.

Hydrologic data analyses will include post-processing of discharge data, correction of pressure transducer records and conversions to station gage height records, rating curve development, stream flow computations, and cross-section and bathymetric data post-processing.

Discharge data post-processing will include the elements described in Mueller (2012) for ADCP measurements. A similar procedure will be used for current meter data, resulting in data qualification as Excellent, Good, Fair, or Poor.

Pressure transducer records will be corrected using instantaneous stage measurements and hydrologic data correction software such as Aquarius Workstation. The software maintains a record of all corrections used in the computation of hourly and daily stream flow data. Other data from the gaging, water level, and repeater stations will have monthly quality assurance evaluations performed as well as a shorter timer check made to identify problems with station or sensor operations.

Rating curves for new gaging stations will be developed using rating development software such as the Aquarius Rating Development Toolbox. Stream flow computations will be performed using hydrologic data management software such as Aquarius Workstation.

Bathymetric data will be post-processed using hydrographic data processing software (e.g., HyPack) to obtain a digital terrain model. The digital terrain model can be used to develop cross-sections or as input for 2-D hydraulic and other instream flow models. ADCP files will be post-processed using velocity mapping software (e.g., VMS) to develop cross-sectional or plan-view velocity maps for calibration of hydraulic models.

Data analysis will include the development of daily and hourly inflow routing to Focus Areas from the Susitna open-water flow routing modeling and analysis for selected tributaries. Analysis will also include calculations of hydrologic data statistics for the Susitna River and selected tributaries.

Five representative years will be selected that represent wet, average, and dry conditions, and warm and cold Pacific decadal oscillation phases so that Project effects for various project alternatives can be evaluated under a range of climatic and hydrologic conditions. In addition, a multi-year continuous flow record will be evaluated to identify year-to-year variations independent of average, wet, or dry conditions. The specific representative years and the duration of the continuous flow record will be selected by AEA in consultation with the TWG in Q3 2013 (Table 8.5-14).

8.5.4.4.1.3. Indicators of Hydrologic Alteration and Environmental Flow Components

The assessment of hydrology data will include a summary of seasonal and short-term and long-term hydrologic characteristics for the river including daily, monthly, and annual summaries, and exceedance summaries and recurrence intervals of small and large floods. The analysis will utilize the Indicators of Hydrologic Alteration (IHA) and Range of Variability models developed by The Nature Conservancy (TNC 2009) for computing baseline hydrologic characteristics. The IHA models are components of an analytical software package designed to assess the impacts of a project on unregulated hydrologic conditions (TNC 2009). These analyses are based on hydrologic statistics defined in Table 8.5-12, and Environmental Flow Components (EFC) defined in Table 8.5-13.

The traditional approach developed by The Nature Conservancy utilizes average daily flows to compute parameters that may be categorized in five general groups of statistics:

1. Magnitude of annual extremes (1-, 3-, 7-, 30-, and 90-day maximum and minimum flows)
2. Timing of annual extremes (Julian date of 1-day maximum and minimum)
3. Magnitude of monthly conditions (variability of monthly means over analysis period)
4. Frequency and duration of high and low flow pulses (defined by annual exceedance flows)
5. Rate and frequency of changes in daily flows

The environmental flow components listed in Table 8.5-13 are divided into five parameter groups: (1) monthly low flows; (2) extreme low flows; (3) high flow pulses; (4) small floods; and (5) large floods.

The hydrologic statistics described in Table 8.5-12 and Table 8.5-13 will be reviewed in consultation with the TWG to identify those parameters that are ecologically relevant to Susitna River resources. Pre- and post-Project hydrologic conditions will be assessed by performing IHA/EFC evaluations in the Susitna River at one or more locations downstream from the proposed dam site. The period of assessment will be based on the 61-year duration from Water Years 1950 through 2010 (October 1, 1949 to September 30, 2010). Daily flows will be used to perform these assessments in accordance with standard IHA/EFC statistics; however, modifications to the standard list of statistics are envisioned to address alternative operational scenarios. In addition to the analyses using daily flow records, modifications to the analysis package will be developed in collaboration with the TWG to utilize hourly data instead of daily data to evaluate flow components specific to the evaluation of hydropower load-following operations:

- Minimum, maximum, and mean within-day flow hydrograph
- Hourly rate of stage change for various event types (load-following operations; diurnal meltwater fluctuations)
- Monthly and seasonal frequency of stage change rates
- Reservoir pool levels (annual and monthly extremes; daily stage change)

The aquatic resources working group for the Baker River Hydroelectric Project (FERC No. 2150) used a similar process to evaluate effects of load-following operations on the Skagit River, Washington. To compare baseline and alternative operational scenarios they evaluated standard IHA/EFC parameters using daily flow records, modified flow parameters in response to project-specific applications (e.g., 2-day minimum), and developed additional statistics based on hourly flow records (Hilgert et al. 2008).

For the Susitna-Watana Project, an acceptable range of variation in IHA/EFC indicator condition will be identified by evaluating existing, unregulated flows over individual Water Years selected to represent average, wet, and dry hydrologic conditions and warm and cold Pacific decadal oscillation phases. In addition, the available continuous flow record will be evaluated to identify year-to-year variations independent of average, wet, or dry conditions. The selection of representative hydrologic conditions and the duration of the continuous flow record will be developed in consultation with the TWG in Q4 2013 (Table 8.5-14).

The IHA/EFC-type statistics represent one tool to evaluate comparisons between existing, unregulated flow conditions and alternative operational scenarios. The U.S. Army Corps of Engineers HEC-EFM (Ecosystem Functions Model) program (http://www.hec.usace.army.mil/software/hec-efm/index.html) is another planning tool that aids in analyzing ecosystem responses to changes in flow. The strength of the HEC-EFM is that it can evaluate project-specific functional relationships developed from expert knowledge, it links ecology with established hydrologic, hydraulic, and GIS tools, and it can be applied quickly and inexpensively. The merits of these planning tools will be discussed with the TWG in Q3 2013, and if HEC-EFM is deemed preferable by the TWG, it will be used to support the evaluation of potential Project effects on resources of concern.

The IHA/EFC analysis or the HEC-EFM program, depending on TWG preference, are planning tools that are part of the IFS Analytical Framework. The IFS Analytical Framework (see Section 8.5.4.1) is designed to integrate study and model results of riverine processes and to assess relationships between riverine and biological functions. One objective of the IFS modeling efforts is to extrapolate measured conditions to non-modeled conditions both spatially and temporally. This allows data collected over the study period to be used to evaluate Project effects over the range of environmental conditions that occur naturally. The results of the hydrologic analyses, combined with the results of the habitat modeling efforts, provide guidance when identifying potential modifications to operational rules to minimize harmful Project effects on downstream resources.

In consultation with the TWG, the IHA/EFC or HEC-EFM programs will be used to evaluate existing conditions and alternative operational scenarios for the Susitna-Watana Project. Select hydrologic parameters, considered to be ecologically relevant to Susitna River resources, will be developed in consultation with the TWG in Q3 2013, and initial results and potential modification reviewed by the TWG in Q1 2014 (Table 8.5-14).

8.5.4.4.2. Work Products

The hydrologic data analysis component will include the following work products:

- Period of Record (POR) data files from gaging stations, including gage height calculations of hourly and daily discharge, and rating curve summaries.
- Cross-section profiles and roughness calculations, and measured water surface elevations.
- POR data files from gaging stations for air and water temperature, and camera image data sets for stations with camera systems installed.
- Project GPS Survey Control Network (horizontal and vertical) Annual Reports.
- Tabular summaries of selected IHA-type and general hydrologic statistics.
- Summary charts to provide visual comparisons of selected hydrologic statistics to facilitate discussion of the effect of modeled future operational scenarios on the without-Project hydrologic regime.

Interim results of the IHA-type analyses will be presented in the ISR, and final results presented in the USR in Q1 2015 (Table 8.5-14).

8.5.4.5. Habitat Suitability Criteria Development

Habitat Suitability Criteria and index curves have been utilized by natural resources scientists for over two decades to assess the effects of habitat changes on biota. The abbreviation "HSI" is used in this document to refer to either Habitat Suitability Index (HSI) models or Habitat Suitability Criteria (HSC) curves, depending on the context. HSI models provide a quantitative relationship between numerous environmental variables and habitat suitability. An HSI model describes how well each habitat variable individually and collectively meets the habitat requirements of the target species and life stage, under the structure of Habitat Evaluation Procedures (USFWS 1980). Alternatively, HSC are designed for use in the Instream Flow Incremental Methodology to quantify changes in habitat under various flow regimes (Bovee et al. 1998). HSC describes the instream suitability of habitat variables related only to stream hydraulics and channel structure. Both HSC and HSI models are scaled to produce an index between 0 (unsuitable habitat) and 1 (optimal habitat). Both models are hypotheses of species-habitat relationships and are intended to provide indicators of habitat change, not to directly quantify or predict the abundance of target organisms. For the Susitna-Watana Hydroelectric Project aquatic habitat studies, both HSC (i.e., depth, velocity, and substrate/cover) and HSI (e.g., turbidity, colonization rate, dewatering mortality) models will be used to analyze the effects of alternative operational scenarios.

For the mainstem aquatic habitat model, HSC/HSI curves for some species (e.g., benthic macroinvertebrates, benthic algae, fry) will also need to be developed to describe the response of aquatic organisms to relatively short-term flow fluctuations (i.e., ramping). Methods for development of HSC/HSI for benthic macroinvertebrate and algal habitats are described in the River Productivity Study (see Section 9.8), but in general include the collection of velocity, depth, and substrate composition data during benthic macroinvertebrate and algae sampling. Development of HSC/HSI curves for fish is described in the following section.

8.5.4.5.1. HSC/HSI Proposed Methodology

The fish community in the Susitna River is dominated by anadromous and non-anadromous salmonids, although numerous non-salmonid species are also present (Table 8.5-15). Development of HSC will involve the following steps: (1) selection of target species and life stages, (2) development of draft HSC curves using existing information, (3) collection of site-specific HSC data, (4) development of habitat utilization frequency histograms/preference curves from the collected data, (5) determination of the variability/uncertainty around the HSC curves, and (6) finalization of the HSC curves in collaboration with the TWG. Each of these steps will be described in the following sections.

8.5.4.5.1.1. Habitat Suitability Criteria (HSC)

HSC curves represent an assumed functional relationship between an independent variable, such as depth, velocity, substrate, groundwater upwelling, turbidity, etc., and the response of a species life stage to a gradient of the independent variable (suitability). In traditional instream flow studies, HSC curves for depth, velocity, substrate, and/or cover are combined in a multiplicative fashion to rate the suitability of discrete areas of a stream for use by a species and life stage of interest. HSC curves translate hydraulic and channel characteristics into measures of overall habitat suitability in the form of weighted usable area (WUA). Depending on the extent of data available, HSC curves can be developed from the literature, or from physical and hydraulic measurements made in the field in areas used by the species and life stages of interest (Bovee 1986). HSC curves for the Project will be based on information consisting of the following (in order of preference): (1) new site-specific data collected for selected target species and life stages (seasonally if possible [e.g., winter]); (2) existing site-specific data collected from the Susitna River during the 1980s studies; (3) site-specific data collected from other similar Alaska river systems; and (4) professional opinion (roundtable or Delphi) of local resource specialists that are familiar with habitat use by the species and life stages of interest for this study.

8.5.4.5.1.1.1. Select Target Species and Life Stages

For planning purposes, target species are assumed to include Chinook, coho, chum, and sockeye salmon; rainbow trout; arctic grayling; Dolly Varden; burbot; longnose sucker; humpback whitefish; and round whitefish. The target species are generally considered the most sensitive to habitat loss through manipulation of flows in the Susitna River. Other species and life stages will be considered in collaboration with the TWG (Table 8.5-15). A draft list of target species and life stages will be presented to the TWG during a meeting to be held in Q1 2013. The final list of species and life stages to be included in the HSC/HSI development process will be developed during a subsequent TWG meeting to be held just prior to field activities in Q2 2013.

8.5.4.5.1.1.2. Develop Draft HSC Curves

The initial determination of mainstem, microhabitats used by the target fish species in the Susitna River will rely heavily on information obtained as part of the 1980s assessments, in particular, the Instream Flow Relationships Report (Trihey & Associates and Entrix 1985 a, b) and a four-volume series on the aquatic habitat and instream flow assessment (Hilliard et al. 1985; Klinger-Kingsley et al. 1985; Stewart et al. 1985; Aaserude et al. 1985). This information will be synthesized and compared to findings of other studies and data gaps will be identified. Comparisons will be made to an available set of library-based HSC curve sets including a data set of over 1,300 recently obtained field microhabitat observations for most of the same species found in the Susitna. Study gaps will be identified and plans to fill the gaps integrated into the 2013–2014 HSC sampling plan. The existing HSC curve sets developed during the 1980s will be compared with more contemporary curve sets developed for similar river systems. In addition, the HSC data collected in 2012 will be compared with existing curve sets to see if patterns of use are similar. Several different methods will be evaluated for updating the 1980s HSC curve sets including the following: Enveloping, Habitat Guilds, bootstrapping, roundtable/expert opinion, and statistical approaches as noted by Ahmadi-Nedushan et al. (2006). To the extent available, habitat suitability information will address fish responses to changes in depth, velocity, substrate, cover, groundwater upwelling, and turbidity. A summary of the 1980s data sets available and reviewed to date is presented in Table 8.5-1. The draft HSC curve will be presented in the HSC/Periodicity TM scheduled for completion Q4 2012, and will be reviewed during a Q1 2013 TWG meeting (Table 8.5-14).

8.5.4.5.1.1.3. HSC Study Area Selection

The distribution and number of HSC study areas for the 2013 and 2014 data collection will be based on a stratified random sampling approach, based on the hierarchical classification system described in Section 8.5.4.2.1.1 as well as several other attributes. This will include levels based on river segment, geomorphic reach (see Section 6.0), and mainstem habitat composition (see Section 6.8.4.1) (Table 8.5-5), as well as relative fish use, number of instream flow Focus Areas, mesohabitat composition (see Section 9.9), and site-specific attributes including the presence of groundwater upwelling, water clarity (turbid vs. clear water areas), and safety concerns.

A stratified random sampling scheme will be used to select study areas to cover the range of habitat types. The mainstem Susitna River and its tributaries downstream of the proposed dam will be subjected to Project operations that will affect flow levels on an hourly, daily, seasonal, and annual timeframe. It is assumed that the effects of Project operations on mainstem and tributary habitats will diminish below the Three Rivers Confluence. The mainstem Susitna River and its tributaries upstream of the proposed dam will be within the proposed impoundment zone and therefore are not included as part of the instream flow sampling effort. Hence, sample sites will be stratified and randomly selected from within the Middle River Segment (RM 98-RM 184) and Lower River Segment (RM 77¬RM 98) of the Susitna River.

A second level of stratification will be based on geomorphic reaches as described in Section 8.5.3 and in more detail in Section 6.5) (Table 8.5-4). The Lower and Middle River segments have been delineated into large-scale geomorphic river reaches with relatively homogeneous landform characteristics, including at generally decreasing scales: geology, hydrology (inflow from major tributaries), slope, channel form, braiding or sinuosity index (where relevant), entrenchment ratio, channel width, and substrate size (Figure 8.5-11 and Figure 8.5-12). Reach stratification facilitates a relatively unbiased extrapolation of sampled site data within the individual reaches because sources of variability associated with large-scale features will be reduced.

The third level of stratification that will be employed is based on a modified 1980s classification of river types. Major categories and sub-categories under this level include <u>Main Channel Habitats</u> consisting of Main Channel, Split Main Channel, Braided Main Channel, Side Channel, and <u>Off-channel Habitats</u> that include Side Slough, Upland Slough, Backwater and Beaver Complexes; and Tributary Habitats that consist of the segment of the tributary influenced by mainstem flow. Each of these main channel and off-channel habitat types will be identified and mapped based on the use of aerial imagery, LiDAR, and aerial videography (see Section 6.8.4.1). The distribution and frequency of these habitats vary longitudinally within the river depending in large part on its confinement by adjoining floodplain areas, size, and gradient.

The Geomorphic Study Team will complete the delineation of mainstem habitat units for the Middle River Segment before the end of Q4 2012. Once the mainstem habitat areas are mapped, a minimum of three replicates will be randomly selected from each of the mainstem habitat types (or bins) that are represented within each of the geomorphic reaches.

Applying the stratification system discussed above, the proposed HSC sampling effort for the Lower River Segment (RM 77 – RM 97) will include three replicates of each mainstem channel type for a maximum of 24 sample sites. Similarly, in the Middle River Segment, three sites of each habitat type will be randomly selected from within each of the seven geomorphic reaches (excludes Reach MR-4 due to safety issues) for a maximum of 168 potential sampling locations, including sites within the Focus Areas. For each of the Middle River Segment sampling sites, a special effort will be made to ensure that HSC sampling occurs within each of the main channel mesohabitat types present. The proposed number and distribution of 2013 HSC sampling sites will be presented to the TWG during the Q2 2013 meeting (Table 8.5-14).

Site selection includes completing the geomorphic reach delineation and habitat mapping tasks first. In addition to technical considerations, access and safety will be key non-technical attributes for site selection for all studies. This, too, influenced site selection in the 1980s studies, and will certainly influence site selection in the present studies.

Finally, winter sites will be selected based on information gathered from winter 2012–2013 pilot studies at Whiskers Slough and Skull Creek (Figure 8.5-27). At a minimum, attempts will be made to complete winter sampling at all Focus Areas located downstream of Devils Canyon. Winter sampling upstream of Devils Canyon will be dependent on access/safety issues. The farthest upstream sites will need to be accessed by air travel; sites closer to Talkeetna may be accessed by snow machine. Safety and access are important considerations for the selection of these sites. Sampling methodologies including, but not limited to, under-ice use of Dual Frequency Identification Sonar (DIDSON) and video cameras will be tested in 2012–2013.

8.5.4.5.1.1.4. Collect Site-Specific Habitat Suitability Information

Collection of site-specific habitat suitability information was initiated in the Susitna River during a pilot effort in 2012 and will continue during 2013–2014. The primary goals of the 2012 pilot effort were to evaluate various sampling techniques, assess logistical aspects of site access, and begin collection of site-specific habitat suitability data for target species. Information gathered during the 2012 sampling effort was used to guide development of 2013–2014 study methods.

The 2012 pilot effort consisted of three separate sampling events completed during July 17–19, August 21–23, and September 17–19. During 2012, site-specific habitat data were collected at 22 Middle River Segment sites located in tributary, tributary mouth, main channel, side channel, side slough, and upland slough sites between RM 178.0 and RM 101.4 (Table 8.5-16). In the Lower River Segment, 11 sites were sampled in tributary, tributary mouth, side channel and side slough habitats between RM 95.4 and RM 77.0 (Table 8.5-16). Site-specific observations were obtained using visual means in clear water areas during snorkel surveys and pedestrian surveys of spawning grounds, and using beach seine methods in turbid areas. Specific locations of juvenile fish located during snorkel surveys were identified using colored weights, while fish position was transmitted verbally from the snorkeler to the data recorder. Seine sampling was performed in turbid areas of uniform depth and velocity and micro-habitat data were recorded at a representative location within the seined area. Micro-habitat and biological data recorded during the 2012 sampling effort consisted of the following datum:

- Site location (aerial photographs and/or GPS)
- Mesohabitat type
- Fish species
- Assumed life stage (adult, juvenile, or fry)
- Total fish length (mm) for juvenile fish and/or life stage for adult fish
- Number of fish observed
- Water depth (nearest 0.1 ft) at juvenile observations using a top setting rod
- Water depth at upstream end of the redd (nearest 0.1 ft) for adult spawning observations
- Position in water column of juvenile fish (distance from the bottom)
- Focal point and mean column velocity (feet per second to nearest 0.05 fps) measured using a calibrated Swoffer current meter
- Substrate size (dominant, sub-dominant, percent dominant) characterized in accordance with a Wentworth grain size scale modified to reflect English units (Table 8.5-17)
- Proximity to habitat structure/cover features (juvenile observations): boulder (> 10 inch diameter), large wood debris (> 4 inch diameter, > 10 feet long), aquatic vegetation, undercut bank, overhanging vegetation (< 3.3 ft of water surface), and water depth (> 3.3 ft depth)
- Relevant comments pertaining to fish cover associations and/or behavioral characteristics

- Presence of groundwater upwelling (changes in water clarity, temperature, or visible upwelling)
- Water turbidity (Hach 2100P portable turbidity meter)
- Redd dimensions (length and width in feet to nearest 0.1 ft)

A total of 252 observations of site-specific habitat use were recorded during 2012 in the Middle and Lower segments (Table 8.5-16). Habitat measurements were obtained for juvenile and/or adult stages of Chinook, sockeye, coho, chum, and pink salmon; rainbow trout; Arctic grayling; and longnose sucker.

For 2013–2014 studies, site-specific habitat suitability information will be collected for target species using HSC-focused field surveys to locate and measure micro-habitat use by spawning and rearing (adult and juvenile) life stages. Proposed sampling methods include biotelemetry, pedestrian, snorkel, and seining. Two other possible methods, DIDSON sonar and electrofishing, are being explored for use in detecting habitat use in turbid water conditions. Selected methods will vary based on habitat characteristics, season, and species/life history of interest. Selected methods are subject to ADF&G Fishery Resource Collection Permit requirements. Additionally, winter surveys will utilize underwater video during clear water periods to identify under-ice and open-water habitat use by rearing life stages. Depending on safety concerns, it has been proposed to conduct both daytime and nighttime surveys during winter sampling to determine any differences in habitat use.

For development of site-specific HSC curves, habitat use information (water depth, velocity, substrate type, upwelling, turbidity, and cover) will be collected at the location of each identified target fish and life stage. If possible, a minimum of 100 habitat use observations will be collected for each target species life stage. However, the actual number of measurements targeted for each species and life stage will be based on a statistical analysis that considers variability and uncertainty (Bootstrapping). While information will be collected on all species and life stages encountered, the locations, timing, and methods of sampling efforts may target key species and life stages identified in consultation with the TWG during Q1 of 2013. A description of each of the proposed sampling methods is presented below.

8.5.4.5.1.1.5. Spawning/Redd Surveys

The timing and location of spawning/redd surveys will be based in part on the periodicity data developed in a previous step (see Section 8.5.4.5.1.2) as well as from information obtained during radio telemetry surveys conducted as part of fisheries studies. This information will be used to help identify sampling timing and areas with the highest concentration of spawning activity for the five salmon species (sockeye, coho, Chinook, pink, and chum salmon). A proposed schedule for 2013 and 2014 spawning/redd surveys is presented in Table 8.5-14.

Although several different methods may be used to identify the presence of spawning fish (biotelemetry, pedestrian survey, or DIDSON sonar), once an actively spawning fish or newly constructed redd is identified, each of the following measurements will be made:

- Location of sample area on high-resolution aerial photographs and/or GPS location for individual or groups of measurements

- Species of fish occupying the redd or responsible for construction
- Redd dimensions (length and width in feet to nearest 0.1 ft)
- Water depth at upstream end of the redd (nearest 0.1 ft), using a top setting rod
- Mean water column velocity (feet per second to nearest 0.05 fps), using a Price AA current meter
- Substrate size (dominant, sub-dominant, and percent dominant) characterized in accordance with a Wentworth grain size scale modified to reflect English units (Table 8.5-17)
- Water temperature (to nearest 0.1 degree Celsius)
- Dissolved oxygen, using a hand-held probe
- Indications of the presence of groundwater upwelling (changes in water clarity, temperature, or visible upwelling)
- Turbidity (using a portable turbidity meter) for each group of redds or in mainstem habitat areas with relatively large concentrations of spawning fish (this information to be used for comparison to measurements made during the 1980s survey)

The accuracy of water velocity meters and water quality probes and meters will be assessed prior to each field effort and, if possible, concurrently with field data collection. Price AA current meter accuracy will be tested prior to use by performing a spin test and meter performance will be evaluated continuously during field measurements by monitoring bucket wheel rotation (USGS 1999). For each spin test, the meter bucket wheel should spin freely for a minimum of two minutes, though optimum spin time is more than four minutes (USGS 1999). Results of all Price AA meter spin tests will be recorded in a current meter accuracy test log. Accuracy of hand-held temperature probes will be tested prior to field use in controlled water baths using a National Institute of Standards and Technology thermometer as a control (Dunham et al. 2005). Dissolved oxygen probe accuracy will be tested using known 0 percent oxygen (sodium sulfite) and 100 percent oxygen (water-saturated air) solutions. Turbidity meters will be checked for accuracy prior to each use using multiple turbidity standards that encompass a wide range of turbidity values (< 0.1 NTU – 800 NTU). All data will be recorded on waterproof data sheets to ensure consistent data collection between surveys.

8.5.4.5.1.1.6. Juvenile and Resident Rearing

To ensure the identification of habitat use by adult (resident species) and juvenile rearing species, a combination of survey methods will be employed including snorkel surveys, beach/stick seining, underwater video, and if permitted, electrofishing. Seining and electrofishing techniques will predominately be used in turbid water areas (main channel, side channels, side sloughs) where underwater visibility is limited (generally greater than 4 nephelometric turbidity units [NTU]). The surveys will be conducted by a team of two or three fish biologists with extensive experience in salmonid species identification. A proposed schedule for 2013 and 2014 adult and juvenile rearing surveys is presented in Table 8.5-14. A general description of each of the proposed sampling methods is presented below.

8.5.4.5.1.1.6.1 **Snorkel Survey/Fish Observations**

Prior to each survey, a Secchi disk reading will be taken to determine the visibility corridor for sampling. For this, a Secchi disk will be held underwater by the data recorder, and a tape measure extended by the snorkeler from the Secchi disk outward to a point where the disk is no longer clearly visible. As a general rule, when visibility conditions are less than four feet, no underwater sampling will occur. Water temperature will also be recorded at the beginning of each survey.

To ensure accurate estimation of fish size underwater, the snorkelers will calibrate their sight to a ruler prior to beginning each survey. Rulers and objects of known length (e.g., fingers, marks on diving gloves) will be used during the survey to maintain accuracy in the estimation of fish length. Starting at the lower/downstream point within a study area, the snorkelers will proceed in an upstream direction making observations of all microhabitat types within their line of sight. When two divers are working together, both sides of the clear water slough or side channel will be covered, with the midpoint of the water body serving as the delineation point of coverage for each diver. When only a single diver is conducting the survey, the diver will survey one or both sides of the channel, depending on the range of microhabitats present. When a fish is observed the snorkeler will verbally transmit the following information to the data recorder:

- Location of sample site or area on high-resolution aerial photographs and/or GPS location for individual or groups of measurements
- Fish species
- Assumed life stage (adult, juvenile, or fry)
- Total fish length (mm)
- Number of fish observed
- Mesohabitat type
- Water depth (nearest 0.1 ft) using a top setting rod
- Location in water column (distance from the bottom)
- Focal point and mean column velocity (feet per second to nearest 0.05 fps) measured using a Price AA current meter
- Substrate size (dominant, sub-dominant, and percent dominant) characterized in accordance with a Wentworth grain size scale modified to reflect English units (Table 8.5-17)
- Proximity/affinity to habitat structure/cover features (e.g., boulder, wood debris, aquatic vegetation, undercut bank, and overhanging vegetation)
- Relevant comments pertaining to cover associations and/or behavioral characteristics of the fish observed

All data will be recorded on waterproof data sheets to ensure consistent data collection between surveys. Accuracy of instruments used in association with snorkel observations will be tested as described for equipment used in spawning observations (see Section 8.5.4.5.1.1.5).

Only fish holding over a fixed position will be included in the microhabitat survey. Moving fish will not be enumerated in order to minimize inaccurate habitat measurements, and to prevent double-counting of fish.

8.5.4.5.1.1.6.2 **Pole/Beach Seining**

Pole seining will be used in turbid water areas of all mainstem habitat types that cannot be sampled with underwater techniques due to visibility limitations. Pole seines used for this effort will be 4 feet in depth and 40 feet in length, 3/16-inch mesh (net body) with a 1/8-inch mesh net bag. The pole seine is operated with one person on each pole and the net is worked through the sample area in an upstream direction. A bag is kept in the middle of the net to collect fish as they are directed into the net by the wings. The operators must work carefully to ensure that the lead line is kept on the bottom to prevent the fish from escaping from under the net and to keep the bag expanded as they work the net upstream.

An attempt should be made to sample fish from relatively small areas of approximately 5 meters by 5 meters with consistent depths, velocities, and substrates; however, exact size and dimensions will sometimes change to facilitate sampling larger areas of relatively uniform habitat when fish densities are low. The field crew should measure and record the area sampled by the seine in order to express the number of fish captured per unit area.

Once captured, fish will be identified to species, counted, and released in close proximity to the capture site. For each area sampled, data collection will be similar to that collected during snorkel surveys with the exception of fish distance from the bottom and focal velocity. Because no direct observation of the position of the fish in the water column can be made in turbid water, fish position and focal velocity will not be recorded; a single depth and velocity measurement will be recorded at a location with representative characteristics of the area seined. Additionally, surveyors will need to rely on feeling the channel bottom with their hands and feet to characterize substrate composition. All data will be recorded on waterproof data sheets. Digital photographs will be taken of representative habitat types where fish of different species and size classes are observed.

8.5.4.5.1.1.6.3 **Electrofishing**

If electrofishing is permitted in turbid water areas of the Middle and Lower River segments, barge or backpack electrofishing surveys maybe used to capture fish and determine micro-habitat use. Barge-mounted electrofishing is effective in areas that are wadeable, but have relatively large areas to cover. Backpack electrofishing is effective in wadeable areas that are relatively narrow and shallow. The effectiveness of barge and backpack electrofishing systems can be enhanced through the use of block nets. In all cases the electrofishing unit will be operated and configured with settings consistent with guidelines established by ADF&G. The location of each electrofishing area will be mapped using hand-held GPS units and marked on high-resolution aerial photographs.

Selection of the appropriate electrofishing system will be made as part of site selection. To the extent possible, the selected electrofishing system will be standardized and the methods will be repeated during each sampling period at a specific site to evaluate temporal changes in fish habitat use. HSC measurements will be collected at each site using the methods described in the Pole/Beach Seining section above. Where safety concerns can be adequately addressed, electrofishing may also be conducted after sunset in clear water areas; otherwise, electrofishing surveys will be conducted during daylight hours.

8.5.4.5.1.1.7. Habitat Utilization Frequency Histogram/HSC Curve Development

Histograms (i.e., bar charts) will be developed for each of the habitat parameters (e.g., depth, velocity, substrate, cover, groundwater use, etc.) using the site-specific field observations. The histogram developed using field observations will be compared to the draft HSC curves and literature-based HSC curves. Prior to calculation of the HSC curves, the habitat data from each stream will be organized by species and life stage, entered into commercially available spreadsheets, and subsequently checked for data entry accuracy. Frequency distributions will then be generated for mean velocity, depth, and substrate type for each species and then normalized. Histogram plots of depth and mean column velocity utilization will be developed using bin sizes defined by using the Stuges (1926) formula:

R/(1+3.322Log(n))

Where *R* is the range of values and *n* is the total number of observations. The frequency of the field observations will then be converted into HSC curves by scaling the distribution between 0 and 1 (utilization values divided by the maximum value observed). The resulting curves will be inspected and visually adjusted, in part to smooth-out sharp breakpoints, and in the case of depth, extend the range of the curve to reflect a non-limiting condition.

For comparative purposes, HSC curves for each species and life stage will first be developed using pooled data from all sampling areas and time periods, and then (depending on available data) separate curves will be developed based on stream-specific data (i.e., geomorphic reach, mainstem habitat type, clear vs. turbid water, and upwelling areas) and winter vs. summertime sampling efforts. Thus, for certain species and life stages, four or five separate HSC curves may be generated.

8.5.4.5.1.1.8. Bootstrap Analysis for HSC Curve Development

For data sets with less than the target number of observations (n ≥100), bootstrap analysis will be used to assess the variability and confidence intervals around each of the data sets used to develop the HSC curves. Bootstrapping is a data-based simulation method for assigning measures of accuracy to statistical estimates and can be used to produce inferences such as confidence intervals (Efron and Tibshirani 1993). This method is especially useful when the sample size is insufficient for straightforward statistical inference. Bootstrapping provides a way to account for the distortions that may be caused by a specific sample that may not be fully representative of a population.

To complete the analysis, a group of individual observations (e.g., depth, velocity measurement for a particular species and life stage) will be resampled with replacement up to the number of the original data set. Each sample involves the following steps:

4. A vector of length equal to the observed data set (N) is created.
5. The vector is filled with the N random samples (with replacement) from the observed data set.

6. The observations are then grouped into bins for velocity and depth— bin sizes will be driven by the desire to group a minimum of 25 observations within each velocity and depth bin.
7. The bin counts will be normalized so that the HSC value for the bin with the maximum count equals 1.0.

The resulting bootstrap samples represent 1,000 possible HSC curves that might be generated from empirical data assuming random chance in observing fish. Using the resulting curve sets, confidence intervals can then be derived from the resulting HSC curves.

8.5.4.5.1.2. Habitat Suitability Index (HSI)

Additionally, criteria will be developed related to juvenile fish stranding and trapping in the varial zone (e.g., the size, species, and periodicity of susceptible fish, recolonization rates, critical streambed gradient, cover factor, periodicity of cover factor, isolation elevations with/without cover, and minimum size of trapping areas). These criteria are described in more detail in subsequent sections.

8.5.4.5.1.2.1. Winter Habitat Use Sampling

Susitna River overwintering habitats are critical to juvenile and adult fish species. Susitna River stream flows are typically lowest during the winter period and, with the exception of open-water leads associated with groundwater upwelling, the river is largely covered in surface ice. Although some winter studies were conducted in the Susitna River during the 1980s, information related to salmon egg development and juvenile and adult fish behavior and habitat utilization during winter is limited (see Section 8.5.2.1.6) (Vining et al. 1985; Stratton 1986; Sundet 1986). Project operations will likely result in substantially higher stream flow levels during the winter period, and will likely influence the quality and quantity of existing habitat for salmon egg incubation, and juvenile and adult fish rearing and holding. To understand potential effects of Project operations during winter, it will be important to evaluate the relationship between intergravel flow characteristics in different habitat types (e.g., side channels, side sloughs, upland sloughs) and main channel surface flow and to identify winter habitat use and behavior of juvenile and adult fish species. Observations of site-specific habitat utilization and diurnal behavior of juvenile and adult fish behavior will provide important support to HSC and HSI development and habitat modeling efforts for the 2013–2014 Instream Flow Study.

Winter habitat use and intergravel water quality monitoring studies will be initiated during a 2012–2013 pilot effort and will be continued during winter 2013–2014. The winter 2012–2013 pilot study will be comprised of three components: 1) intergravel temperature, dissolved oxygen, and water level monitoring; 2) fish behavior and habitat use observations; and 3) winter fish capture. The pilot study will evaluate the feasibility of using different instruments, methods, and approaches for winter data collection in preparation for a more developed effort during the winter 2013–2014 study period. The 2012–2013 pilot study will also provide preliminary data and information regarding intergravel temperature and water quality conditions, site-specific fish habitat use and behavior and species richness and size class composition among sampled habitats. These studies will be coordinated with the study leads for fish, geomorphology, groundwater, and ice processes.

The 2012–2013 pilot study will be conducted at two areas in the Middle River Segment that contain a diversity of habitat types with groundwater influence, have documented fish utilization, and are accessible to and from Talkeetna during winter. The tentative areas for the 2012–2013 pilot study are habitat complexes near Whiskers Slough (RM 104.8–106.0) and Skull Creek (RM 128.1–129.7), which are also proposed Focus Areas that will be used across resource disciplines (Figure 8.5-28 and Figure 8.5-29). Within each proposed study area, potential sampling locations have been identified; however, adjustments to each location may be made depending on field conditions and site selection processes described below (Figure 8.5-28 and Figure 8.5-29). The initial work on the 2012–2013 pilot study will consist of a focused review of literature from 1980s studies and more recent research to identify potential methods for each component of 2012–2013 pilot studies.

For the 2012–2013 study component focused on intergravel temperature, dissolved oxygen, and water level monitoring, sites will be selected using a stratified random sampling approach. The Whiskers Slough and Skull Creek study areas will be stratified by habitat type (Beaver complex, backwater, side slough, upland slough, tributary mouth, main channel) and areas in which salmon were observed spawning in 2012. A total of 8–12 monitoring sites will be randomly selected among strata. Depending on individual site characteristics, temperature monitoring devices will be installed at locations of 1) groundwater upwelling, 2) bank seepage and lateral flow from mainstem, 3) mixing between upwelling and bank seepage, 4) no apparent intergravel discharge, fish spawning, and 5) main channel Susitna River flow.

Intergravel temperature will be measured at each monitoring site and surface temperature probes will be co-located at a subset of the monitoring sites to allow for surface and intergravel comparisons. For intergravel temperature measurement, Hobo Tidbit temperature probes will be deployed at three separate gravel depths (5 cm, 20 cm, and 35 cm) corresponding to observed burial depth ranges of chum and sockeye eggs (Bigler and Levesque 1985; DeVries 1997). Probes will be attached to stainless steel cable and inserted into the gravel using a steel installation device (e.g., Nawa and Frissell 1993; Zimmerman and Finn 2012). Dissolved oxygen (DO) will be measured in conjunction with intergravel temperature at one location at each of the two study areas. The DO sensors (HOBO logger with optical sensor) will likewise be inserted into the gravel to a depth of approximately 20 centimeters using a stainless steel cable. Stage response of surface stream flow and subsurface groundwater to fluctuations in Susitna River main channel stage will be assessed using pressure transducers (Solinst level loggers), deployed in side channel, side slough, and main channel areas, and piezometers deployed subsurface in adjacent floodplain areas. The final number and location of monitoring sites will vary depending on site conditions and safety concerns (Figure 8.5-28 and Figure 8.5-29). Temperature, DO, and stage recording equipment will be deployed in January 2013 following the chum and sockeye salmon spawning period; a subset of temperature loggers and DO loggers will be retrieved prior to ice break-up in April 2012, while remaining temperature and water level recorders will remain at deployment sites through June 2013 to record temperature and water stage patterns through the period of ice break-up. Data from the above-gravel loggers (temperature and stage recorders) will be downloaded on a monthly basis and will occur concurrently with times specified as part of the fish observation study. Accuracy of temperature, DO, and water level loggers will be tested prior to deployment using techniques described in Section 8.5.4.5.1.1.5.

Specific tasks for the intergravel temperature, dissolved oxygen, and water level monitoring component of the 2012–2013 pilot study are as follows:

- Monitor intergravel temperature at representative habitats and at 2012 salmon spawning sites at varying gravel depths to encompass salmonid egg burial depths during winter and early spring (January – June); retrieve a subset of loggers prior to ice break-up (April).
- Record surface water temperature at a subset of sites to allow comparison between surface and intergravel temperature.
- Monitor intergravel DO at one monitoring site in each study area.
- Evaluate the potential relationships between water temperature among monitoring sites in off-channel and main channel habitats and Susitna River stage.
- Compare water level (stage) response in off-channel and floodplain areas relative to Susitna River main channel stage.
- Evaluate available data related to species-specific thermal tolerances of salmonid egg incubation and fry emergence.
- Develop recommendations for intergravel temperature monitoring in 2013–2014 studies.

The 2012–2013 winter study component focused on observations of fish behavior will use underwater video cameras and DIDSON sonar to monitor fish communities during day and night conditions. Observational studies will be conducted at five to six sites in slough and side channel habitats of the Whiskers Slough and Skull Creek study areas during February – April 2013 (Figure 8.5-28 and Figure 8.5-29). Observation sites will be monitored with an underwater camera on a monthly basis during the sampling period, at randomly selected times during day and night. The DIDSON sonar will be utilized in turbid conditions (>4 NTU) and opportunistically during clear water conditions to gauge the applicability of DIDSON technology for monitoring fish behavior and habitat utilization. Each method will be used in ice-covered and open-water conditions. For ice-covered areas, the video camera or DIDSON unit will be lowered through auger holes drilled through the ice to make 360-degree surveys. Mueller et al. (2006) found that DIDSON cameras were effective in turbid waters for counting and measuring fish up to 52.5 feet from the camera. Mueller et al. (2006) found that video cameras were only effective in clear water areas with turbidity less than 4 NTU, but that video was more effective at identifying species and observing habitat conditions than DIDSON cameras. In addition to fish observations, video cameras will also be used to characterize winter habitat attributes such as the presence of anchor ice, hanging dams, and substrate type.

In addition to fish observations, measurements of site-specific habitat characteristics (velocity, water depth, substrate, cover, etc.) will be measured at observed fish locations using HSC sampling methods (see Section 8.5.4.5.1.1). Water velocity and depth measurements will be made either through the ice (ice holes) or in open-water leads using a topset wading rod and Price AA meter. HSC measurements will only be collected at those fish observation points where positive fish species identification and estimates of total length can be made. Instantaneous measurements of water temperature and dissolved oxygen will be recorded using hand-held probes to describe water quality conditions in the area of fish observations.

Specific tasks for fish behavior observation and habitat use component of the 2012–2013 pilot study are as follows:

- Utilize underwater cameras and DIDSON sonar to record juvenile and adult fish behavior during day and night conditions to identify potential diurnal patterns in habitat utilization during February – April 2013.
- Obtain measurements of site-specific habitat utilization data for juvenile and adult fish species in support of HSC and HSI development.
- Develop recommendations for 2013–2014 winter fish behavior observation studies.

The results of the 2012–2013 pilot winter study will be used to develop the sampling methods for the 2013–2014 winter studies and will be finalized and distributed to TWG participants by Q3 2013. Proposed study methods for 2013–2014 winter fish distribution studies will be completed during Q3 2013 following analysis of data collected during 2012–2013.

8.5.4.5.1.2.2. Stranding and Trapping

Fluctuations in river flow will cause portions of the channel along the margins to alternate between wet and dry conditions, an area referred to as the varial zone. Flow fluctuations can be the result of precipitation falling as rain or the result of snowmelt and glacial meltwater, but the frequency, timing, and magnitude of flow fluctuations will change under proposed Project operations. In addition to altering the availability of suitable habitat, flow fluctuations associated with Project operations have the potential to cause strand or trap of fish and other aquatic organisms on dewatered portions of the channel bed. While the physical and hydraulic processes associated with stranding and trapping are related, aquatic organisms have different responses to stranding and trapping. Stranding occurs where fish become beached on dewatered streambed areas as water levels recede and is generally associated with shoreline areas having low gradient and/or dewatered areas having sufficient cover to attract fish (Figure 8.5-30). Trapping occurs where fish in channel depressions become isolated from flowing water as water levels recede and are subjected to stress or mortality from predation, reduced dissolved oxygen, water temperature fluctuations, or subsequent stranding if trapping areas drain.

The incidence and severity of stranding and trapping effects will be influenced by a suite of biological and hydrological/geomorphological factors. Stranding susceptibility varies with fish size, time of day, and season.

Based on a review of studies conducted in Washington State, Washington Department of Fish and Wildlife (Hunter 1992) concluded that salmonid fry smaller than 50 mm in length are most susceptible to stranding.

The following excerpts and synopses support Hunter's (1992) hypothesis that salmonid fry smaller than about 50 mm in length are more vulnerable to direct impacts from ramping events than larger fish.

Source	**River Location**	**Comment**
Bauersfeld 1977	Columbia River, Washington	Reporting on stranding of trout, Chinook, coho, and chum salmon, Bauersfeld noted that 86 percent of all stranded fish were between 30 and 50 mm. The majority of fish stranded (78 percent) were Chinook salmon.
Bauersfeld 1978	Cowlitz River, Washington	"A size comparison of Chinook stranded . . .versus fish available . . . shows that stranding was size selective,

		impacting the small (35 to 45 mm) recently emerged fry, even though larger fish were present.”
Olson 1990	Sultan River, Washington	“Susceptibility to stranding was particularly evident for salmon fry less than 50 mm long and for steelhead less than 40 mm long.” All Chinook salmon fry observed (n=44) during downramping trials were 48 mm or less and all but one coho fry were less than 46 mm (n = 12). All steelhead fry stranded were less than 40 mm in length.
R.W. Beck 1989	Skagit River, Washington	“Once [steelhead] fry size increased above 4.0 cm, vulnerability decreased rapidly ... Above a fry size of 4.0 cm the percentage of the main-channel population is always found to be much greater than the associated stranded fry of corresponding size.” R.W. Beck and Assoc. reported that the mean size of Chinook fry stranded was 4.3 cm. Ninety-nine percent of Chinook fry stranded were less than 50 mm.
Stober et al. 1982	Skagit River, Washington	“The 1992 observations indicate that while the fry may be present in the nearshore area, they appear to be less susceptible to stranding once they reach a length of about 40 mm.”

Related to this, size (or life stage) periodicity will dictate the seasonal timing during which vulnerable size classes may be present in the varial zone. Stranding and trapping susceptibility may also vary by species based on differences in periodicity, as well as species-specific habitat preferences and behavior. Recolonization rates, or how quickly organisms return once a dewatered area is rewetted, will also influence cumulative susceptibility to stranding and trapping.

Hydrological/geomorphological factors also affect stranding and trapping rates. Streambed areas with low gradient represent the greatest risk to stranding. Bauersfeld (1978) reported that stranding occurred primarily on bars with less than 4 percent gradient; other studies also reported high incidence of juvenile salmonids stranding on bars with low gradient slope (Hilgert and Madsen 1998; R.W. Beck 1989).

The density of juvenile salmonids may be higher in the vicinity of woody debris and emergent or submergent macrophytes, which contributes to a higher incidence of stranding should those areas become dewatered. At existing hydroelectric projects, site-specific trapping and stranding criteria can be developed through experimental manipulation of flow conditions through project operations. The current pre-Project conditions of the Susitna River preclude this approach. Thus, stranding and trapping criteria for the Susitna River will need to be determined based on a combination of observations under natural flow variations as well as literature-based information derived from other regulated systems where stranding and trapping studies have been conducted.

The general susceptibility of target species and life stages to stranding and trapping will initially be identified based on their life stage periodicity, length frequency, habitat utilization, distribution, and abundance in the Middle and Lower segments, as determined by fish distribution studies (see Section 9.6) and the downstream extent of Project effects. This information will then be used to identify areas for potential field investigations of stranding and trapping. Under existing, unregulated conditions, the frequency, magnitude, and rate of water level fluctuations in the Susitna River will be less than the rate of change associated with load-following operations at existing hydroelectric projects. However, flow reductions under unregulated flows in the Susitna River have the potential to cause stranding and trapping of aquatic organisms. Field surveys of potential stranding and trapping areas will be conducted immediately following flow reduction events. Immediately following such an event, a field crew will conduct a survey of potential stranding and trapping areas following field protocols to be developed in consultation with the TWG. Field surveys will follow a stratified random sampling strategy at potential stranding areas to estimate the number, size, and species of fish stranded or trapped. Field surveys will be conducted at potential stranding and trapping areas on an opportunistic basis following up to three flow reduction events during 2013 and up to three flow reduction events during 2014. The goal of these surveys will be to provide a relative indication of those species, life stages, and sizes susceptible to stranding and trapping to corroborate literature-derived criteria. In addition, the mechanisms through which each stranding or trapping occurs will be identified (e.g., streambed gradient, emergent vegetation, etc.) and reviewed to ensure that subsequent modeling efforts accurately reflect the relevant processes. The risks of fish stranding and trapping will be assessed through the development of models developed to evaluate each process separately. While stranding and trapping are both related to reductions in water surface elevations, the specific mechanisms through which they occur are different, requiring discrete models for each process. Time step increments, used to calculate stage changes, will be identified during calibration of the mainstem open-water flow routing model in Q4 2012 (see Section 8.5.4.3). Depending on the initial calibration results, time steps as short as three minutes may be needed to match predicted to measured stage changes in the open-water flow routing model. In 2014, the calibrated open-water flow routing model will be used to evaluate the effects of Project operations on stranding and trapping using one-hour time steps unless the TWG determines that shorter time steps are needed to evaluate specific fisheries resources. Each model will incorporate relevant criteria, developed as described above, and provide indices to quantify the extent of stranding/trapping for individual events. The stranding index will reflect the area of potential stranding and is conceptually depicted as follows, where SI = stranding index, AS = stranding area in square feet, and CS = cover factor for stranding:

$$SI = A_S * C_S$$

The trapping index will reflect the area of potential trapping and is conceptually depicted as follows, where TI = trapping index, AT = trapping area (square feet), TT(D) = duration of trapping factor, and CT = cover factor:

$$TI = A_T * T_T(D) * C_T$$

These indices will then be considered in relation to the monthly frequency of potential stranding/trapping events for a given Project operational scenario such as the example provided in Table 8.5-18.

8.5.4.5.1.2.3. River Productivity

Development of HSC/HSI for macroinvertebrates and algae will follow a similar general approach, which includes a literature search for available information, conducting field studies to supplement literature-based information and to provide site-specific data, and use of a panel of

TWG participants to finalize the HSC/HSI curves. A complete presentation of the development of the HSC/HSI for macroinvertebrates and algae is provided in Section 9.8. A summary of the methods for developing HSC/HSI for both macroinvertebrates and algae is presented below.

Literature-based draft HSC/HSI curves will be developed for benthic macroinvertebrate and algae communities. Potential sources of information include the Internet, university libraries, peer-reviewed periodicals, and government and industry technical reports. Special emphasis will be given to the existing 1980s study (Hansen and Richards 1985) for applicable information and methodology. Because benthic macroinvertebrate and algae communities are comprised of numerous taxa, the HSC/HSI curves will be developed for commonly used benthic metrics or guilds (e.g., functional feeding groups, taxa habits, habitat preference, diversity, biomass, or dominant taxa) selected to summarize and describe the communities.

Macroinvertebrate sampling will be stratified by reach and mainstem habitat type defined in the Project-specific habitat classification scheme (mainstem, tributary confluences, side channels, and sloughs). To accomplish this objective, sampling will occur at six stations, each with three sites (one mainstem site and two off-channel sites associated with the mainstem site), for a total of 18 sites. Measurements of depth, mean water column velocity, and substrate composition will be taken concurrently with benthic macroinvertebrate sampling at the sample location for use in HSC/HSI development in the instream flow studies (see Section 9.8.4.2). Efforts will be made to locate sampling stations at Focus Areas established by the Instream Flow Study team (see Section 8.5) in an attempt to correlate macroinvertebrate data with additional environmental data (flow, substrates, temperature, water quality, riparian habitat, etc.) for statistical analyses, and HSC/HSI development. Station and site locations will be determined during Q1 2013.

For use in the mainstem aquatic habitat model, HSC/HSI curves will also need to be developed to describe the response of aquatic organisms to cyclic inundation and dewatering of varial zone areas (see Section 8.5.4.6.1.6). For instance, algae (algae growing on substrates) will colonize a site if it contains suitable depth, velocity, and substrate, but colonization may not occur until the area has been inundated for a period of time. Conversely, the effects of dewatering of the site on algae production will depend on the duration of dewatering and conditions at the time of the dewatering (see Section 9.8.4.9).

Next, a histogram (i.e., bar chart) will be developed for each of the habitat parameters (e.g., depth, velocity, substrate, frequency of dewatering) using site-specific field observations. The histogram developed using field observations from 2013 will then be compared to the literature-based HSI curve to validate applicability of the literature-based HSI curve for aquatic habitat modeling. This stage will be conducted by Q3 2014.

8.5.4.5.1.3. Periodicity

A species and life stage periodicity table will be developed applicable to the different segments of the Susitna River. Information presented in the 1980s reports will be used to generate a draft periodicity table that will be included in the HSC/Periodicity TM scheduled for completion in December 2012. Specifically, the TM will summarize fish habitat utilization in terms of periodicity of use among main channel and off-channel macro-habitats in the Upper, Middle and Lower Susitna River based on relevant literature from the 1980s studies. Periodicity and macro-habitat use will be described by species and life stage (e.g., migration, spawning, incubation, emergence, rearing) for target species. An example of the draft periodicity table for Chinook salmon is presented in Table 8.5-2. Periodicity information for target fish species will be obtained from 1980s study results; if necessary, information from other literature sources representing similar regions and fish populations (e.g., Morrow 1980, etc.) and TWG members will be used. Updates and/or revisions to the draft periodicity table will be completed in cooperation with the TWG during proposed meetings to be held in the Q1 2013 and Q4 2014 (Table 8.5-14). The final periodicity table will be developed following the 2014 field season and will incorporate the findings of the 2012, 2013, and 2014 fisheries studies (Table 8.5-14).

Climatic and hydrologic patterns are important considerations in determining salmon distribution and abundance. Large-scale climatic changes (e.g., Pacific Decadal Oscillation) affect regional weather conditions that subsequently influence hydrologic conditions (Hartmann and Wendler 2005). Changes in river hydrology can influence the stability and persistence of aquatic habitats and can determine fish distribution and abundance (Connor and Pflug 2004). Long-term adult salmon escapement data will be examined to identify relationships between temporal patterns in environmental conditions and salmon distribution, abundance, and migration. Analyses of flow-dependent biological cues, such as possible relationships between climatic, hydrologic, and fish habitat indices and salmon abundance and migration timing, will be based on available long-term datasets for Deshka River Chinook salmon and Yentna River sockeye salmon. Other Susitna River basin long-term data sets pertaining to salmon migration timing and abundance will be included if available. Implementation details will be developed in consultation with the TWG in Q2 2013, initial study results discussed with the TWG in Q4 2013, and reported in the ISR in Q1 2014 (Table 8.5-14).

8.5.4.5.2. Work Products

The HSC/HSI Development Study component will include the following work products:

- Draft HSC curves based on information collected during the 1980s studies of the Susitna River and other regional data sources. Data gaps will also be identified as part of this effort.
- Map displaying the number and distribution of HSC sampling locations based on a stratified random sampling approach.
- Summary of site-specific HSC curve data collected for the target fish species and life stages as a function of depth, velocity, and substrate.
- Histogram plots displaying results of site-specific data collection.
- Results of bootstrap analysis used to assess variability and confidence intervals around each of the HSC curves developed from site-specific data.
- HSI curves developed from site-specific data to describe the response of aquatic organisms to groundwater upwelling, turbidity, colonization rates, winter habitat use, and stranding and trapping criteria.
- Analysis of potential relationships between climatic, hydrologic, and fish habitat indices and salmon abundance and migration timing in the Deshka and Yentna rivers.

These work products and other results of the HSC/HSI analyses will be compiled and presented in initial and updated study reports.

8.5.4.6. Habitat-Specific Model Development

This study component develops the core structures of the aquatic habitat-specific models. Development of these models will require careful evaluation of existing data and information as well as focused discussions with technical representatives from the TWG. These models will rely in part on information and technical analyses performed in other study components as a basis for developing model structures (e.g., Habitat Mapping; other riverine process studies). Physical habitat models are often used to evaluate alternative instream flow regimes in rivers (e.g., the Physical Habitat Simulation [PHABSIM] modeling approach developed by USGS; Bovee 1998; Waddle 2001). Methods available for assessing instream flow needs vary greatly in the issues addressed, their intended use, their underlying assumptions, and the intensity (and cost) of the effort required for the application. Many techniques have been used, ranging from those designed for localized site or specific applications to those with more general utility. The summary review reports of Wesche and Rechard (1980), Stalnaker and Arnette (1976), EA Engineering, Science and Technology (1986); the proceedings of the Symposium on Instream Flow Needs (Orsborn and Allman eds. 1976); Electric Power Research Institute (2000); and more recently the Instream Flow Council (Annear et al. 2004) provide more detailed information on specific methods. The methods proposed in the IFS include a combination of approaches that vary depending on habitat types (e.g., mainstem, side channel, slough, etc.) and the biological importance of those types, as well as the particular instream flow issue (e.g., connectivity/fish passage into the habitats, provision of suitable habitat conditions in the habitats, etc.).

8.5.4.6.1. Proposed Methodology

Development of the models will involve completion of a series of tasks as noted below.

- Transect/Study Segment Selection – In coordination with the TWG and riverine process study leads, use the results of the Characterization of Aquatic Habitats (see Section 9.9) component to select transects/study segments within each of the selected habitat types identified in the Susitna River to describe habitat conditions based on channel morphology and major habitat features. Additional habitat transects/segments will be selected to describe distinct habitat features such as groundwater areas, spawning and rearing habitats, overwintering habitats, distinct tributary mouths/deltas, and potential areas vulnerable to fish trapping/stranding. The transects used for defining the open-water flow routing model will also be integrated into this analysis.
- TWG Site Reconnaissance – Conduct a site reconnaissance with personnel from agencies, Alaska Native entities, and other TWG members to review river reaches, select proposed Focus Areas and potential transect/study segment locations, and discuss options for model development. This reconnaissance trip has been scheduled for early-mid September and will encompass a three- to four-day effort. The first day will be an office-based meeting during which specific methods will be reviewed and their applicability to addressing specific questions will be discussed, and the field itinerary reviewed. This will be followed by a one- to two-day field reconnaissance of representative habitat types including but not limited to mainstem channel, side channels, side sloughs, and upland sloughs. Stops will be made at each of these habitat types and assessment methods will be discussed, with the goal of reaching consensus on which methods will be applied for

evaluating flow-habitat relationships. Participants will reconvene in the office on the final day of the trip to discuss observations and reach agreement on assessment methods.

- Model Selection: Field Surveys and Data Collection – Once study areas and transects/study segments have been identified, detailed field surveys will begin. These will be tailored based on habitat types to be measured and the selected models to be used. It is likely this will involve a combination of 1-D and 2-D modeling approaches as well as application of empirically-based methods such as the RJHAB model applied in the 1980s studies (Hale et al. 1984). The RJHAB model was used to assess/model the effects of flow alterations on juvenile fish habitat for off-channel areas. At this time, it is anticipated that two-dimensional modeling will be applied to one or more representative reaches in the Middle River Segment. For this, a multi-stepped approach will be used so that after each field data collection effort, topographic data will be projected via computer analysis to identify locations requiring the collection of more data points. Table 8.5-19 provides a listing of potential models/methods that will be considered as part of the IFS. The most appropriate methods for selected study areas will be determined via careful review of site conditions and the underlying questions needing to be addressed. Methods selection will be done as a collaborative process within the IFS-TWG.

Regardless of specific method, field surveys will involve measurement of water velocities, water depths, water surface elevations, bottom profiles/topography, substrate characteristics, and other relevant data (e.g., upwelling, water temperature) under different flow conditions. One of the tasks for 2012 is to evaluate and determine specific flow targets for these field surveys.

8.5.4.6.1.1. Habitat Model Selection

Identifying and quantifying the predicted changes in aquatic habitat in the Middle and Lower segments of the Susitna River under the proposed Project operational scenarios will require the use of several different hydraulic and biological models. Each of the models proposed for use has been selected to assist in the evaluation of the physical, and biological effects of the proposed Project.

The mainstem aquatic habitat model integrates hydraulic modeling, channel bathymetry, and biological information on the distribution, timing, abundance, and suitability of habitat to estimate metrics (such as varial zone area and frequency of inundation and dewatering) that will be used to compare the effects of the proposed operational scenarios. The following section provides an overview of the habitat and hydraulic models proposed as part of the evaluation of Project-related effects including boundary conditions transects, 2-Dimensional (2-D) modeling, single transect PHABSIM, stranding and trapping, and fish passage/connectivity.

8.5.4.6.1.1.1. Boundary Condition Transects

The upstream and downstream boundaries as well as the lateral extents of the Focus Areas have been chosen so that appropriate boundary conditions can be established for the hydraulic and bed evolution modeling. Considerations included encompassing potential inflow and outflow points to preserve the mass balance and minimize difficulties and assumptions associated with inflow points. Potential upstream connections for side channels, side sloughs, and upland sloughs were also identified and included in the modeling domain. The upstream and downstream limits on the main channel were identified to either provide relatively uniform flow conditions or sufficient distance upstream and downstream from areas of interest so that flow conditions in the area of interest are not significantly affected by the flow directions at the boundary.

Water levels measured during the cross-section and bathymetric surveys for each boundary condition transect will be used to assist in calibrating the 2-D models for each Focus Area. In addition to water surface elevations, the depths and velocities measured at the boundary transects will be used to assist with hydraulic modeling for the single transect PHABSIM sites.

8.5.4.6.1.1.2. 2-D Modeling

Determining the relationship between river flow and the physical and hydraulic characteristics of a river system as dynamic as the Susitna River is a complex undertaking that requires considerable investigation and coordination. This is especially true for assessing project-related impacts to small, local-scale channel areas containing unique morphology and habitat features (e.g., fish spawning, groundwater upwelling, stranding and trapping, fish passage/connectivity). To assist with this effort, 2-D hydraulic modeling will be used to evaluate the detailed hydraulic characteristics of the Susitna River on smaller, more local scales where it is necessary to consider the more complex flow patterns to understand and quantify project effects under various Project operation scenarios. The 2-D model will be applied to specific Focus Areas that are representative of important habitat conditions and the various channel classification types. These sites will be chosen in coordination with the TWG and the Fish and Aquatics Instream Flow, Riparian Instream Flow, Ice Processes, and Fish studies to facilitate maximum integration of available information between the studies (see Section 8.5.4.2). A detailed discussion of the 2-D modeling is presented in Section 6.6.

Selection of the appropriate mesh size for the 2-D bed evolution mode is dictated by several factors including the size and complexity of the site feature(s); the desired resolution of output information such as water surface elevation, velocity, depth, and bed material gradation; and any limitations on the maximum number of elements that the model can simulate.

One approach to reduce the trade-offs between model complexity and physical limitations of the 2-D model is to utilize a variable mesh (also referred to as flexible mesh). A variable mesh allows a finer mesh to be used in areas where either the information desired or the condition being modeled requires higher spatial resolution (RSP 6.6.4). The 2-D models being considered for this study are formulated with a flexible mesh, allowing the size of the model element to be varied. Figure 8.5-31 provides examples of a relatively coarse and relatively fine mesh applied to the potential Focus Area at Whiskers Slough in the Middle River Segment.

Examples of areas that may require finer mesh sizes include sloughs, smaller side channels, spawning areas, stranding and trapping areas, hydraulic control features, and tributary mouths. Areas where lower spatial resolution may be appropriate include main channel, floodplains, and large side channels. In the areas of higher resolution, the mesh size will be on the order of several feet to 25 feet. In areas where lower spatial resolution is appropriate, the mesh size may be in the range of 25 to 100 feet (RSP 6.6.4).

At some Focus Areas, two model meshes may need to be developed. One mesh would be for executing the bed evolution model, which requires orders of magnitude more time to execute than the 2-D model without the moveable bed options running. The other mesh would be associated with a fixed bed representation of the site that would be used to output the hydraulic conditions at a finer resolution for development of aquatic habitat indices.

8.5.4.6.1.1.3. Single Transect PHABSIM

Another model that will be considered for evaluating Project-related effects on fish habitats is the single transect Physical Habitat Simulation (PHABSIM) modeling. The PHABSIM model (Milhous et al. 1981) will be applied to some or all of the open-water flow routing model transects to develop relationships between main channel flow and habitat for the spawning and rearing life stages of the target fish species. Supplemental main channel transects will be established as needed to more fully characterize main channel habitats, either as part of the Focus Area analysis or at separate locations associated with specific habitat types. The need for and exact number of the supplemental transects will be determined based on results of the habitat mapping (see Section 9.9) that will be completed in Q1 2013. PHABSIM-based models will also be applied to selected habitat types within the Focus Areas where 2-D modeling is not warranted. PHABSIM is part of an analytical framework for addressing flow management issues called the Instream Flow Incremental Methodology (IFIM) (Bovee et al. 1998). PHABSIM is used to predict physical habitat changes associated with flow alterations by describing the flow-dependent characteristics of physical habitat in light of selected biological responses of target species and life stages. The stream hydraulic component predicts depths and water velocities at specific locations on a cross-section of a stream. Field measurements of depth, velocity, substrate material, and cover at specific sampling points on a cross-section or transect are taken at different flows. Hydraulic measurements, such as water surface elevations, are also collected during the field survey. These data are used to calibrate the hydraulic models, which are then used to calculate depths and velocities at flows different from those measured. The habitat component weights each stream cell using indices (HSC/HSI) that assign a relative value between 0 and 1 for each habitat attribute, indicating how suitable that attribute is for the life stage under consideration. In the last step of the habitat component, the hydraulic estimates of depth and velocity at different flow levels are combined with the suitability values for those attributes to weight the area of each cell at the simulated flows. The weighted values for all cells are summed – thus the term weighted usable area (WUA).

8.5.4.6.1.1.4. Stranding and Trapping

The purpose of this analysis is to develop indices that provide a relative quantification between proposed Project operational scenarios and the potential for stranding and trapping of aquatic organisms. More specifically, the effort is targeted to evaluating the stranding and trapping potential for juvenile fish. Stranding involves the beaching of fish as the water level recedes and is typically associated with low gradient (<4 percent) shoreline areas or cover conditions that result in fish remaining in an area as it is dewatered. Mortality occurs in stranding as fish are left beached on the dewatered shoreline. Trapping is the retention of fish in pools formed by depressions as the water level recedes. Stress and potential mortality to trapped fish occur from several mechanisms including temperature fluctuations, reduction in dissolved oxygen, predation, and stranding as the water in the pool infiltrates into the substrate. Both the stranding and trapping analyses utilize results of hourly water surface elevation determinations from the Mainstem Open-water Flow Routing Model to track water level fluctuations and calculate numerical indices representing the potential for stranding and the potential for trapping of aquatic organisms.

Indices for predicting stranding and trapping are based on equations that relate physical characteristics of the stranding and trapping areas to the potential for stranding and trapping to occur. The information for the physical site characteristics is derived from the bathymetry and mapping through the application of GIS. The hourly water surface elevations provide the basis for identifying when a stranding or trapping site becomes dewatered or disconnected from the mainstem channel as well as the duration. A detailed description of the criteria and methods for identifying potential stranding and trapping areas is presented in Sections 8.5.4.5.1.2.2 and 8.5.4.6.1.6.

8.5.4.6.1.1.5. Breaching Flows

The breaching or topping of off-channel habitat features by mainstem river flows not only affects the quantity of water within these features but water quality (turbidity and temperature) and habitat quality as well. During the 1980s study of the Susitna River, researchers reported that although breaching flows typically increase the availability of juvenile rearing habitat in small off-channel areas, as mainstem discharge increases the quality of rearing habitat declines as velocities in nearshore areas increase (Schmidt et al. 1985). A similar finding was reported for the effect of water turbidity. Although some turbidity did increase off-channel use by juvenile Chinook salmon, high turbidity resulting from mainstem flows topping reduced juvenile fish use (Steward et al. 1985). Vining et al. 1985, reported that the winter topping of cold mainstem river water into off-channel habitats was the most significant factor contributing to high levels of embryo mortality in habitats used for chum salmon incubation in the Middle River Segment. Determining the relationship between mainstem river flow and overtopping or breaching of sensitive off-channel features will allow for the assessment of potential impacts of proposed winter Project operation scenarios.

8.5.4.6.1.1.6. Fish Passage/Connectivity

Several environmental variables may affect fish passage and connectivity with sloughs and side channels and tributary deltas. In general, at a given passage area the water conditions (primarily depth) interact with conditions of the channel (length and uniformity, substrate size) to characterize the passage conditions that a particular fish encounters when attempting to migrate into, within, and out of a slough, side channel, or tributary delta. The likelihood of a particular fish successfully navigating through a difficult passage reach will depend on the environmental conditions as well as the individual capabilities and condition of the fish.

Depth passage in sloughs, upland sloughs, side channels, and at tributary delta mouths will be assessed following the methods of Sautner et al. (1984a) that focus on salmon passage in sloughs and side channels. Two-dimensional modeling, not available in the 1980s, will also be applied. Although salmon passage remains a key concern, the passage methods are generally applicable to other species where depth passage criteria are known or can be developed. The main goal of the fish passage and off-channel connectivity is to evaluate the potential creation of fish passage barriers within existing habitats (tributaries, sloughs, side channels, off-channel habitats) related to future flow conditions and water surface elevations.

8.5.4.6.1.2. Physical and Hydraulic Data Collection

As part of the 2013–2014 IFS, physical and hydrologic data collection will include hydraulic boundary conditions, stage and discharge measurements, cross-sectional and areal bathymetric surveys, velocity mapping, and roughness (channel substrate) determinations. The IFS will also incorporate hydrologic data collected by other studies, including water quality (see Section 5.0), water temperature, and ice processes data (see Section 7.6). A summary of the data collection effort for each of these study components is provided below.

8.5.4.6.1.2.1. Boundary Conditions Transect

Much of the data collection performed in this task will be shared with and used by other studies including Fluvial Geomorphology (see Section 6.6), Riparian Instream Flow (see Section 8.6), Groundwater (see Section 7.5), and Ice Processes (see Section 7.6) studies. The majority of this data collection effort is to be conducted during the 2013 field season and will be used to support development of single transect PHABSIM and 2-D modeling efforts. The primary field data to be collected at each of the boundary a condition transects will include the following:

- Cross-section survey to define channel topography and hydraulic controls at the upstream- and downstream-most portion of each Focus Area using RTK GPS instrumentation.
- Velocity and discharge measurements collected using an Acoustic Doppler Current Profiler (ADCP) system consisting of a Sontek M9 equipped with RTK GPS positioning to generate the necessary discharge and velocity distribution data. Price AA current meter to be used for all velocity measurements for areas where the ADCP cannot be used.
- Measurement of the water surface elevation during discharge measurements, and documentation of the substrate type, groundcover, habitat type, and woody debris in the flood-prone area for the purposes of developing roughness estimates.
- Measurement of stage and discharge during high and low flows, with the potential addition of an intermediate flow measurement.

Data collected at each of the boundary condition transects will be used to compute the energy slope, velocity, depth, and other hydraulic variables at each cross-section in the Focus Areas and to provide boundary conditions for localized 2-D models.

8.5.4.6.1.2.2. Bathymetry

Within the Focus Areas, bathymetric surveys will be required for 2-D hydraulic and other IFS models. Cross-sectional bathymetric surveys will be performed as part of discharge measurements completed in 2012 and 2013 using the Sontek M9 ADCP and vertical-beam depth sounder and RTK GPS positioning systems. The results of these surveys will be used to prepare a digital elevation model of the streambed. Together with shore-based RTK GPS surveys, the digital elevation model will also be used to develop cross-sections for use in the open-water flow routing model.

It is anticipated that both multi-beam and single-beam sonar systems will be needed to complete the bathymetric surveys in deep and shallow water areas. As a result, single-beam sonar surveys will be conducted along pre-planned survey lines throughout each Focus Area. The planned survey lines will be developed using recent imagery and hydrographic data acquisition software (e.g., HyPack). The density of survey lines will be commensurate with the minimum model grid spacing needed for 2-D hydraulic or other IFS models.

In several of the Focus Areas, water depths and velocities will preclude boat surveys throughout the entire wetted area. Areas of shallow, fast water may require land-based surveying during low water conditions using RTK GPS methods.

Roughness determinations will be made by solving Manning's equation using field measurements of discharge and water surface slope. These results will be compared against visual estimates based on handbook values. Bathymetric data will be post-processed using hydrographic data processing software (e.g., HyPack) to obtain a digital terrain model. The digital terrain model can be used to develop cross-sections or as input for 2-D hydraulic and other instream flow models. ADCP files will be post-processed using velocity mapping software (e.g., VMS) to develop cross-sectional or plan-view velocity maps for calibration of hydraulic models.

8.5.4.6.1.2.3. Fish Passage/Connectivity/Breaching Flows

The physical and hydraulic data collection process used to evaluate potential fish passage, off-channel connectivity, and breaching flows will include but not be limited to the following:

- Identifying fish species to be included in the Fish Passage Barriers Study (see Section 9.12).
- Defining the passage criteria for the identified fish species.
- Defining potential fish passage barriers and hydraulic connectivity points within each of the Focus Area to be sampled.
- Conducting field data collection.
- Coordinating with other interdependent studies.
- Evaluating potential effects of altered river flows on fish access to off-channel habitats and breaching flows.

Data collection for determining potential for fish passage and off-channel connectivity will involve establishing cross-sectional and water surface elevation transects at one or more locations to represent the shallowest conditions (hydraulic control feature) fish may encounter while moving upstream. The basic criteria for defining and modeling fish passage and connectivity to off-channel areas for this study will be water depth as it relates to mainstem flow level. Depth criteria will establish the minimum water depth and the maximum distance (at the minimum depth) through which a fish can successfully pass. Depth requirements for successful passage increase with an increase in the length of passage. Depth criteria will be used to assess access into, within, and out of side channels and sloughs. The ability of fish to enter or exit slough and side channel habitats from the mainstem Susitna River and access spawning or rearing areas within these habitats is primarily a function of water depth and the length of a reach when the water is shallow (Sautner et al. 1984a).

Stage (water surface elevation) and discharge will be monitored at a minimum of one fish passage/connectivity site within each of the Focus Areas. Monitoring of stage and discharge will assist in determining the influence that mainstem river flow has on hydraulic characteristics of off-channel habitats and fish passage potential. To monitor changes in stage resulting from changes in mainstem flow, pressure transducers (Solinst level loggers) will be deployed at the upper and lower ends of selected side channel and slough habitats and in adjoining areas of the main channel Susitna River. The stage and discharge data will be used to develop a stage vs. flow rating curve for use in modeling or predicting the depth across the control feature to aid in determining the mainstem flow required to maintain minimum fish passage depth, off-channel connectivity, and breaching flows.

As noted in Section 9.12, there are 12 major tributaries with names, approximately 50 unnamed tributaries, and approximately 50 sloughs located within the Middle River Segment. Passage evaluation studies in the Middle River Segment will therefore begin in 2013 within each of the Focus Areas that support spawning habitats and center on the associated tributary mouths, side channels, and side sloughs. This will include Focus Area-173, Focus Area-171, Focus Area-151, Focus Area-144, Focus Area-141, Focus Area-138, Focus Area-128, and Focus Area-104 (Table 8.5-6) and with those tributaries and sloughs that will be physically characterized by the ISF and geomorphic study teams. In 2014, barrier surveys will be expanded to include select tributaries, meaning those determined to have fish present based on historic and 2013 data. Surveys will extend from the mouth to the upper extent of Project hydrologic influence. The upper limit of hydrologic influence will be determined from supporting studies including the open-water flow routing model and the geomorphic mapping, among others.

8.5.4.6.1.2.4. Focus Area Depth, Velocity, and Substrate Characterization for Single Transect PHABSIM Modeling

The collection of physical and hydraulic measurements at each of the Focus Area single transect sampling sites will be completed following the procedures for PHABSIM studies outlined by Bovee and Milhous (1978), Bovee (1982), and Trihey and Wegner (1981). The establishment of 1-D PHABSIM transects will be completed as follows:

- Locations of Transects –Transect positions will be recorded using a hand-held GPS unit and mapped in a field book and on low elevation aerial photographs. The position of each transect will be temporarily established using wooden stakes pounded solidly into the ground.
- Establishment of Site Benchmark – A semi-permanent benchmark will be established at each transect. All survey measurements, including water surface and bed elevations, will be referenced to this benchmark. Each benchmark (large boulder or rebar) will be placed above the floodplain of the river and marked with fluorescent flagging for high visibility. The elevation of each transect benchmark will be tied to elevation markers established as part of the open-water flow routing modeling (see Section 7.0, Hydrology-Related Resources).
- Installation of Head Pins – Head pins (rebar) will be installed on the side of the side channel or off-channel area near the starting point of each transect. These head pins serve as a secondary vertical reference point for water surface and bed elevation measurements collected across the stream channel. Differences between transect benchmark and head

pin elevations will be used as a quality control check for surveying accuracy. The head pins are also intended to serve as a backup benchmark in case the transect benchmark is disturbed.

- Establishment of Working Pins – Working pins (wooden stakes) will be established on either end of a transect. These working pins will be positioned in such a way that the line connecting these points is perpendicular to the main flow of the side channel or off-channel area. A surveying tape or incremented Kevlar line will be stretched across the channel and connected to these points during the collection of instream flow data. The survey tape will be tied to the working pin at the same position (e.g., 2 ft on the tape) during each sampling so that velocities can be measured at the same positions across the transect.
- Survey of Benchmark Elevations and Completion of Level Loop – Following the installation of the benchmarks at each transect, a level loop survey will be completed to establish benchmark elevation in relationship to elevation markers established during the open-water flow routing model data collection effort (see Section 7.0). The elevation data will be obtained using an Auto Level and stadia rod (0.01 ft accuracy). The level loop will be considered accurate if closed to within 0.02 ft of the initial benchmark elevation.

Water surface elevations will be measured at the right bank, mid-channel, and left bank of each transect under all of the specified "calibration" discharges. Velocity profiles will then be obtained across each transect at the same tape positions under each of the "calibration" flow measurements.

Data will be collected at established intervals across each transect following the protocols recommended by USGS. The following data were collected at each measurement point (verticals) across each transect:

- Water Depth (measured to nearest 0.1 ft) – Depths will be measured using a top setting rod. Measured water depths are not used during the hydraulic modeling process because the IFG4 model calculates depths by subtracting bed elevations from water surface elevations. Depth measurements, however, can provide a useful quality control check of water surface elevations at each calibration flow.
- Mean Column Water Velocity (measured to nearest 0.1 fps) – Velocities will be measured using a spin-tested Price AA velocity meter[i]; velocities will be measured at 6/10ths depth in the water column for depths less than 2.5 feet, and 2/10ths and 8/10ths depth in the water column for depths greater than 2.5 feet.
- Substrate (dominant and sub-dominant) – Substrate types will be recorded at each transect vertical under clear water conditions. Substrate size (dominant, sub-dominant, and percent dominant) will be characterized in accordance with a modified Wentworth grain size scale.

8.5.4.6.1.3. Hydraulic Model Calibration

8.5.4.6.1.3.1. River Corridor Stage vs. Discharge

Susitna River mainstem flow routing models (HEC-ResSim; HEC-RAS; CRISSP1D; and/or other routing models) will provide hourly flow and water surface elevation data at numerous locations longitudinally distributed throughout the length of the river extending downstream from RM 184. Two different flow routing models will be developed: an open-water model (HEC-RAS) and Ice Processes Model to route flows under ice-covered conditions (CRISSP1D). Output from the flow routing models will provide the fundamental input data to a suite of habitat-specific and riverine process models that will be used to describe how the existing flow regime relates to and has influenced various resource elements (e.g., salmonid spawning and rearing habitats, invertebrate habitat, sediment transport processes, ice dynamics, large woody debris [LWD], and the composition and structure of riparian floodplain vegetation). These same models will likewise be used to evaluate fish habitat responses to alternative Project operational scenarios. As an unsteady flow model, the open-water flow routing model will be capable of providing flow and water surface elevations on an hourly basis and therefore Project effects on flow can be evaluated on multiple time steps (hourly, daily, monthly) as necessary to evaluate different resource elements. During the development and calibration of the HEC-RAS model, the drainage areas of ungaged tributaries will be quantified and used to help estimate accretion flows to the Susitna River between locations where flows are measured. The flow estimates developed for ungaged tributaries will be refined based on flows measured in those tributaries in 2013 and 2014.

8.5.4.6.1.3.2. Focus Area Stage vs. Discharge

Calibration and validation of the stage vs. discharge relationships developed for cross-sections within each of the Focus Areas will follow a stepwise process. First, the hydraulic components of the models will be calibrated by adjusting roughness and loss coefficients to achieve reasonable agreement between measured and modeled water surface elevations, and between measured and modeled velocities. Discharges along the study reach will be obtained from the three USGS gages. These gages will also provide a continuous record of stages and water surface elevations at the gage locations. These data will be supplemented with stage data from at least 10 pressure-transducer type water level loggers that have been or will be installed as part of various studies being conducted in the Middle and Lower River segments. Water levels measured during the cross-section and bathymetric surveys will also be used to calibrate the models. In addition to water surface elevations, the depths and velocities predicted by the 2-D model should be compared with measured data from ADCP measurements at the Focus Areas. Depending on the range of conditions and spatial coverage of the depth and velocity data from the Fish and Aquatics Instream Flow Study, additional data may be needed for calibration specifically for this study. Specific calibration criteria will be established for both the 1-D and 2-D models during the model selection phase. The 2-D water surface elevations will also be compared against water surface elevations generated by the 1-D model and the open-water flow routing model to ensure that the models are producing consistent results.

8.5.4.6.1.3.3. Focus Area Depth, Velocity, and Substrate

Analysis of the physical and hydraulic data collected at each of the Focus Area 1-D sampling sites will include several steps for the development, calibration, and use of the hydraulic modeling output. Hydraulic and habitat simulation modeling will be conducted using the latest version of the PHABSIM computer software (Milhous et al. 1989). The 1-D hydraulic model calibration process will be completed in accordance with the following steps:

1. Raw field data will be entered into Excel spreadsheets, reviewed, and reduced into a form ready for creation of hydraulic data decks. Any data entry errors will be identified, noted in a copy of the review sheet, and corrected. These computer spreadsheets will then be used to generate data input files for the PHABSIM 1-D hydraulic simulation program, IFG4.
2. Stage versus discharge relationships will be developed using one or more hydraulic simulation procedures. Depending upon the hydraulic characteristics of a given transect, a stage-discharge relationship will be developed using one of three methods: a log-log regression method (rating curve developed using the IFG4 program), a channel geometry and roughness method (rating curve developed using the Manning's Equation-based program MANSQ), or a step-backwater method (rating curve developed using the program WSP).
3. Velocities across each transect will be calibrated to provide a realistic distribution of mean column velocities across the river channel for the entire range of flows employed in the habitat simulations.

Stage and discharge measurements were performed in 2012 at 88 cross-sections between RM 76 and RM 184. Twelve of these cross-sections are located at or near gaging stations operated by USGS or AEA. Stage and discharge measurements were also performed at inactive USGS gaging stations in the Lower River Segment (Susitna River at Susitna Station [ESS20], RM 20) and in the upper basin (Susitna River near Cantwell [ESS80], RM 224). Gaging equipment was re-installed at these locations, as well as at two tidal monitoring stations in the Susitna delta. Water level, water temperature, camera images, and meteorological data from these stations are shared online via an internal project website.

Depending on results of the 2012 open-water flow routing model and analysis from other studies, additional cross-sections may be surveyed in 2013 and 2014. Sections of the river that have stable cross-sections will likely not require additional cross-section measurements. Sections of the river that demonstrate changes in cross-section profiles seasonally or event-based (floods) may require additional cross-section measurements. Stage and discharge measurements will be used to calibrate the open-water flow routing models, and to develop or confirm ratings for new and existing gaging stations.

8.5.4.6.1.4. Weighted Usable Area Habitat Metrics

The methods proposed in the IFS include a combination of approaches depending on habitat types (e.g., mainstem, side channel, slough, etc.) and the biological importance of those types, as well as the particular instream flow issue (e.g., connectivity/fish passage into the habitats, provision of suitable habitat conditions in the habitats, etc.). During the 1980s studies, methods were designed to focus on both mainstem and off-channel habitats, although mainstem analysis was generally limited to nearshore areas. PHABSIM-based 1-D models, juvenile salmon rearing habitat models, fish passage models, and others were employed and will be considered as part of the IFS plan. As part of the 2013–2014 study efforts, more rigorous approaches and intensive analyses will be applied to habitats determined as representing especially important habitats for salmonid production. This will include both 1-D and 2-D hydraulic modeling that can be linked to habitat-based models.

As part of the Geomorphology Modeling Study (see Section 6.6), several 2-D models are being considered including the Bureau of Reclamation's SRH2-D, USACE's Adaptive Hydraulics ADH, the USGS's MD_SWMS suite, DHI's MIKE 21, and the suite of River2D models (see Section 6.6 for a description of various 2-D model attributes and references). The River2D model is a two-dimensional, depth-averaged finite-element hydrodynamic model developed at the University of Alberta and is capable of simulating complex, transcritical flow conditions. River2D also has the capability to assess fish habitat using the PHABSIM weighted usable area approach (Bovee 1982). Habitat suitability indices are input to the model and integrated with the hydraulic output to compute a weighted useable area at each node in the model domain. While evaluation of habitat indices is directly incorporated into the River2D suite of models, other 2-D models are also complementary to habitat evaluations. Selection of potential 2-D models for fish and aquatics evaluations will be coordinated with other pertinent studies and the TWG in Q1 2013 and revisited in Q1 2014.

The models noted above will be used to translate changes in water surface elevation/flow at each of the measured transects/study segments into changes in depth, velocity, substrate, cover, and other potential habitat (e.g., turbidity, upwelling). Linking this information with HSC/HSI curves will allow for translation of changes in hydraulic conditions resulting from Project operations into indices of habitat suitability. This will allow for the quantification of habitat areas containing suitable habitat indices for target species and life stages of interest for baseline conditions and alternative operational scenarios.

In response to the effect of potential load-following operations, habitat modeling using weighted usable area indices may need to be developed using both daily and hourly time steps. Evaluating the effects of changes in habitat conditions on an hourly basis may require additional habitat-specific models such as effective habitat and varial zone modeling.

8.5.4.6.1.5. Effective Spawning/Incubation Habitat Analyses

Operation of the Project has the potential to influence the quantity and quality of spawning habitat by altering stream flow in the main channel and off-channel areas of the Susitna River. While changes in physical conditions (i.e., depth, velocity, and substrate) will determine the suitability of habitat for salmon spawning, the subsequent survival of eggs and alevins can be influenced by a different suite of flow-related processes. The eggs of Pacific salmon are laid in nests, or egg pockets, dug by the female in the gravel of the streambed. The female then covers the egg pockets with several inches of gravel by vigorous body and tail movements. Eggs within the spawning site (redd) incubate through the winter and depending on water temperature, hatch in late winter through spring, then remain within the redd as alevin until emergence. Mortality during the incubation period, which includes the egg and alevin stages, is generally high and can be caused by scour associated with flood flows or dewatering and freezing during low flow conditions. The location of redds within the river channel may have a major influence on redd survival. If redds are constructed toward the center of the channel when mainstem flows are low, redds may be scoured by winter flood events. If redds are constructed along the channel margins or in off-channel areas when mainstem flows are high, redds are at risk of dewatering or freezing when flows drop during the winter incubation season. In the Susitna River, as elsewhere, upwelling areas provide stable intergravel conditions and warmer temperatures during the winter incubation period, providing some protection from dewatering or freezing.

Flow changes can influence the prevalence of groundwater upwelling, which in turn can affect the rate of survival and development for eggs and alevins. In the Susitna River, Vining et al. (1985) suggested that upwelling is the single most important feature in maintaining the integrity of incubation in slough habitat as well as localized areas in side channel habitats. Upwelling and intergravel flow also play an important role in determining the water quality at redd sites, particularly with respect to temperature and dissolved oxygen concentrations. Winter increases in mainstem flow or stage may affect upwelling by:

- Decreasing the rate of groundwater upwelling from the adjacent floodplain.
- Diluting relatively warm, stable, upwelling habitats when side channels are breached by mainstem flow.
- Changing the rate of intergravel flows associated with hydraulic gradients between main channel and off-channel habitats.

The risks posed by flow-related processes on salmonid redds and egg/alevin incubation will be assessed by developing an effective spawning/incubation model that incorporates separate but integrated analyses for each process. The spawning/incubation model will be based on identifying potential use of discrete channel areas (cells) by spawning salmonids on an hourly basis. Use of each cell by spawning fish will be assumed to occur if the minimum water depth is suitable and velocity and substrate suitability indices are within an acceptable range defined by HSC/HSI. Species-specific HSC/HSI information used to identify potential use of a cell by spawning fish will be developed as described in Section 8.5.4.5. If suitable spawning conditions exist, that cell will then be tracked on an hourly time step from the initiating time step through emergence to predict whether eggs and alevin within that cell were subject to interrupted upwelling, dewatering, scour, freezing, or unsuitable water quality (e.g., Figure 8.5-32).

This process will be repeated for each hour of the potential spawning period based on the periodicities shown in Table 8.5-2. If sufficient site-specific periodicity information is available, each hour can be weighted depending on whether it occurs during the peak or off-peak of the spawning period. If hydraulic conditions during the spawning season were considered suitable for spawning in a particular cell during the initiating time step, and conditions remained suitable for egg viability every hour through emergence, then the cell area at the initiating time step would be considered effective spawning/incubation habitat. This process is repeated for each cell within the habitat unit containing suitable spawning habitat at time step 1, and the entire process repeated for each time step through the end of incubation. The resulting areas will then be summed to determine the cumulative total effective spawning/incubation area for the habitat unit under existing conditions and alternative operational scenario for each hydrologic year under consideration. The duration of spawning to emergence will be calculated for each target species based on temperature units within the intergravel environment. Shorter incubation periods would be expected with warmer water temperatures and longer incubation periods would be expected with colder water temperatures. The incubation period will be divided into an egg phase and an alevin phase. After salmon eggs hatch, they remain within the gravel environment as alevins, maturing while they absorb their yolk sac. During this post-hatching but pre-emergence period, the alevins are particularly susceptible to dewatering. Assumptions regarding the start, peak, and end of spawning, and duration of egg incubation and alevin life stage, will be developed from previous studies of the Susitna River, meetings with the TWG (Q1 2013), and validated through site-specific biological surveys conducted as part of the licensing effort.

To assess the vulnerability of eggs and alevin to flow-related processes, losses due to dewatering, freezing, or water quality, will be tracked based on the continued presence of upwelling within the cell area. If a cell is exposed to factors that cause mortality, the cell is lost for that initiating hour. If a loss occurs, cell accounting is re-started if the next hour time step is within the potential spawning period. Cumulative spawning activity within each cell will be accounted for on an hourly basis for each target species, using the hourly flow hydrograph determined from the open-water flow routing model.

As shown in Figure 8.5-32, the model will first consider whether upwelling has been reduced during a given time step. During winter low flows, the aquifer discharges relatively warm groundwater from the floodplain into off-channel habitats via upwelling and provides a stable environment for incubation. Increased winter flows can alter the hydraulic gradient of the floodplain, changing the direction of groundwater flow and affecting the prevalence of upwelling. Reduced upwelling may not lead to direct mortality of eggs and alevin. However, the resulting colder water temperatures would prolong the period of incubation, thereby potentially increasing the risk of dewatering, scour, or freezing events. Reduced upwelling could also increase the risk of dewatering or freezing by eliminating sustained flows of warmer water to the redd. Reduced upwelling could also affect dissolved oxygen concentrations within a redd by altering intergravel flow. Some redds may be constructed in areas of upwelling that originate from the hydraulic gradient between main channel and off-channel habitats. Depending on intergravel transit time, this upwelling may mimic the temperature of main channel open-water flow, or may reflect the temperature of the aquifer. Higher main channel river stages may increase this type of upwelling, having either a positive or negative effect on redds depending on the nature of the upwelling. A pilot study is proposed for 2012–2013 to monitor intergravel water temperature and dissolved oxygen levels in off-channel habitats with and without the presence of groundwater upwelling (see Section 8.5.2.1.6). Results of this study will be used to investigate the relationship between mainstem river flow and intergravel water quality conditions.

Persistent upwelling would presumably be mutually exclusive with dewatering, scouring flows, freezing, or unsuitable water quality. However, as described above, it is assumed that the quality (i.e., temperature, dissolved oxygen) and quantity of groundwater upwelling for incubation will be influenced by mainstem flow and stage. Criteria will be developed such that a reduction of upwelling would include any adverse change in water quality below a critical level even if upwelling persisted. The analysis for upwelling will rely on the results of groundwater modeling to predict whether upwelling is reduced for a given cell and time step. If upwelling is not reduced, the area represented by that cell would be carried forward through subsequent time steps. If upwelling persists through emergence, that cell would be tallied as part of the cumulative effective spawning/incubation habitat. If, however, upwelling is reduced at any point during the incubation period, the potential for dewatering, scour, freezing, or unsuitable water quality will be considered.

In a worst case scenario, it could be assumed that all eggs or alevin will be lost if the surface substrate in the cell became scoured, the cell became dewatered or frozen, or water quality fell below critical levels. This assumption is probably overly conservative for several of the potential impact parameters. For example, salmon eggs can survive short periods of dewatering provided that the eggs remain damp (Becker et al. 1983), whereas once intergravel temperature reaches freezing or below, it is assumed that 100 percent mortality occurs. Therefore, separate criteria will need to be defined to assess the degree to which the spawning area is no longer effective (i.e., percent of spawning area rather than a binary result) depending on the severity of the impact. The final criteria for assessing the degree of impact will be developed in collaboration with the TWG during Q1 2013.

All of the analyses associated with the effective spawning/incubation model will be performed at each of the Focus Areas with suitable spawning habitat. The results of the effective spawning/incubation analysis will be a reach-averaged area calculated by weighting the effective spawning area derived for each Focus Area by the proportion of Focus Area within the geomorphic reach (see Section 8.5.4.7). The results are calculated in terms of weighted area (similar to PHABSIM results) and do not represent actual area dimensions. The results cannot be used to calculate numbers of emergent fry but instead provide habitat indicators that will be used to conduct comparative analyses of alternative operating scenarios under various hydrologic conditions.

8.5.4.6.1.6. Varial Zone Modeling

Fluctuations in flow will cause shallow portions of the river channel to alternate between wet and dry conditions; this area of alternating wet and dry is referred to as the varial zone (Figure 8.5-33). Flow reductions along the channel margins can cause stranding and trapping of juvenile fish and benthic macroinvertebrates within the varial zone. Repeated dewatering of the varial zone can result in reduced macroinvertebrate and algae density, diversity, and growth (Fisher and LaVoy 1972; Dos Santos et al. 1988).

Analyses of Project effects on the downstream varial zone can be quantified as the frequency, magnitude, and timing of downramping events exceeding specified downramping rates; the frequency, number, and timing of downramping events that occur following varying periods of inundation; and the frequency, timing, and magnitude of potential stranding and trapping of aquatic organisms.

The proposed load-following operations of the Project will affect hourly flow fluctuations downstream of the Watana Dam site. Based on analyses of studies of the effects of hydropower load-following operations in Washington State, it is generally assumed that faster rates of water surface elevation reduction are correlated to an increased risk of stranding of aquatic organisms (Hunter 1992). Salmonid fry are particularly susceptible to stranding and the daily and seasonal timing of downramping events will influence the potential risk to aquatic organisms.

The goal of the downramping analysis will be to quantify the frequency, magnitude, and timing of downramping rates by downramping event by geomorphic reach downstream of the Watana Dam site. The objectives of this analysis will be to quantify reach-averaged downramping events by rate under existing conditions and under alternative operating scenarios for selected hydrologic years. Using the results of the mainstem flow routing models, a post-processing routine will be used to identify those specific hourly time periods when the water surface elevations are decreasing (i.e., downramping). For those time periods, the hourly reduction in water surface elevation will then be computed and expressed in units of inches per hour. A frequency analysis will be conducted on the hourly downramping hours by downramping event by geomorphic reach. The frequency analysis will determine the number of downramping events exceeding selected numeric categories. These categories will be selected in collaboration with the TWG, but for planning purposes, the following categories are proposed:

- Greater than 0 but less than 1 inch per hour
- Greater than 1 but less than 2 inches per hour
- Greater than 2 but less than 4 inches per hour
- Greater than 8 inches per hour
- Exceeding downramping guidelines developed by Hunter (1992) (Table 8.5-20)

The number of events where downramping rates exceed these categories will be tabulated by month and by annual total under existing conditions and for alternative operating scenarios.

The frequency, number, and timing of downramping events that occur following varying periods of inundation will be quantified to evaluate the effects of downramping events on organisms exhibiting a range of colonization rates. This varial zone analysis can be conducted by total Focus Area or can be conducted by discrete habitat types within a Focus Area (e.g., main channel, side channel, sloughs) using an hourly time step integrated over a specified period that considers antecedent fluctuations in water surface elevations.

The selection of time periods to define the upper and lower extent of the varial zone for the Project will be coordinated with the TWG. However, for planning purposes, three time scales are being considered: 12 hours, 7 days, and 30 days. A 12-hour time series may provide an indication of the effects of water level changes on aquatic biota that rapidly colonize a previously dewatered area. Salmonid fry and some benthic macroinvertebrates may rapidly recolonize or occupy a previously dewatered area when they are moving downstream from upstream areas during out-migration or as a result of displacement from upstream areas. A 7-day time series may be used as an indicator of the risk of dewatering due to hourly and daily changes in load-following operations, such as weekday versus weekend generation. Some aquatic organisms may require several days to colonize an area (algae), or the density of organisms may increase rapidly over the first several days of access to a previously dewatered area. A 30-day time series can be used as an indicator of the risk of dewatering associated with weekly to monthly changes in flow patterns, such as changes in minimum flow requirements or seasonal runoff. A complex assemblage of benthic macroinvertebrates may require weeks to months to become established along channel margins. Information on the rate of colonization, dewatering mortalities, and conditions supporting suitable habitats for organisms of interest will be developed as part of the HSC/HSI study component. Figure 8.5-34 illustrates the concept of a varial zone analyses under antecedent flow conditions.

8.5.4.6.1.6.1. Fish Stranding and Trapping

Though stranding and trapping are related processes, there are differences that require two separate analyses for the effects. Both analyses develop indices that represent the potential effect of reductions in water levels during downramping events on fish and other aquatic organisms. Stranding involves the beaching of fish as the water levels recede and is typically associated with low gradient shoreline areas or cover conditions that attract fish to areas where dewatering occurs. Mortality occurs when stranded fish are beached on dewatered portions of the channel bed. As water levels recede, some fish may become trapped in channel depressions or pools. Although trapped fish may survive for short periods of time, the potential for mortality increases based on factors including temperature fluctuations, reduction in dissolved oxygen, predation, and stranding as the water in the pool infiltrates the substrate.

The approach to the stranding and trapping analyses is similar to other analyses involving the evaluation of the effects of water surface elevation fluctuations in the varial zone. Stranding and trapping indices utilize results of the mainstem flow routing models to determine the water surface elevations on an hourly basis within Focus Areas. Stage fluctuations are applied within Focus Areas using the digital terrain models to quantify the frequency, timing, and magnitude of stranding events under existing conditions and alternative operational scenarios. The results of the mainstem flow routing models and the digital terrain models are also combined to quantify the frequency, timing, and duration of trapping events for discrete channel features within Focus Areas. The stranding and trapping analyses determine evaluation indices based on each water level fluctuation cycle.

The stranding and trapping analyses track the period of dewatering (stranding) or the period of disconnection (trapping). Fish are assumed to return to potential stranding and trapping areas shortly after the water surface elevation rises to once again inundate/connect the side channel areas. Stranding and trapping indices are not treated as values that are summed on an hourly basis; instead, stranding and trapping are viewed as a series of events, and part of the index expression includes this frequency of events. Therefore, the results are computed at the end of an event based on the duration of the event, and then results are summed over the series of events.

Downramping rates will be determined as part of the stranding analyses including the exceedance of specific numeric categories ranging from 1 inch per hour to over 8 inches per hour. For trapping analyses, ramping rates will not be directly incorporated as a factor in the calculation of the indices. Strong relationships between ramping rate and incidence of trapping are not consistently demonstrated in previous studies (Hunter 1992; Higgins and Bradford 1996; R.W. Beck and Associates 1989). The results of both stranding and trapping evaluation indicators can be quantified under existing conditions and alternative operational scenarios for selected hydrologic conditions.

The indices for stranding and trapping are based on equations that relate physical characteristics of the stranding and trapping sites to the potential for stranding and trapping to occur. The information for the physical site characteristics will be derived from the bathymetry and mapping through the application of GIS. The index equations have physical factors related to site area, depth, and cover conditions. The observations and data collected during the stranding and trapping field surveys will assist in developing the ratings for several of these factors (see Section 8.5.4.5).

For planning purposes, potential stranding areas are defined as areas with a bed slope of 4 percent or less, excluding depression areas that are included in the trapping area analysis. Stranding areas are also defined as areas with features, such as emergent vegetation found alongside slough margins, which are observed to contribute to an increased risk of stranding regardless of bed slope based on the results of site-specific surveys. Specific stranding zones are defined at elevation intervals to allow for tracking of dewatering of stranding areas as the water surface elevation rises and falls. Stranding areas are also defined as contiguous areas of 1,000 square feet or greater. The potential presence of fish in a stranding site is assumed to be directly proportional to the size of the stranding area.

The resulting equation for stranding is:

$SI = A_S * C_S$

Where:

- SI = stranding index
- A_S = stranding area in square feet
- C_S = cover factor for stranding

The stranding index (SI) is calculated once for each stranding event. It is assumed that the 1-hour time interval of the modeling is sufficient to cause mortality for fish stranded for this length of time. It was also assumed that once the stranding area is again inundated, it reaches its full potential for stranding; that is, the fish population is replenished.

For planning purposes, the equation for quantifying evaluation indicators for trapping has been formulated as:

$TI = A_T * T_T(D) * C_T$

Where:

- TI = trapping index
- A_T = trapping area (square feet)
- $T_T(D)$ = duration of trapping factor
- C_T = cover factor representing the influence of emergent vegetation and other cover

The factors A_T and C_T represent the risk that fish will be trapped in the pool. The larger these factors, the higher the potential for trapping fish in the pool. $T_T(D)$ represents the potential for mortality of fish trapped in a pool once it becomes isolated from the mainstem; it is the ratio of fish mortalities to total fish trapped. The trapping factors are not species-specific. The results of the trapping index calculations require review of fish periodicity to determine whether species of interest and associated life stages susceptible to trapping are present during a particular period. The trapping index (TI) is calculated once per trapping event and contains factors that describe the likelihood that fish will be trapped in the pool when the pool becomes disconnected from the mainstem flow. The TI is calculated for each individual trapping depression. Each pool has an effective elevation assigned to its outlet, which allows for determination of trapping duration based on application of the hourly elevations available from the open-water flow routing model.

It is only necessary to calculate the index at the end of the event, not at intermediate points. It is assumed that once the trapping area is reconnected, it reaches its full potential for trapping within the one hour that elapses before the next time interval. This assumption represents a 100 percent recolonization within one hour. These and other details of the stranding and trapping analyses will be developed in collaboration with the TWG during Q2 2013 and reviewed in Q2 2014.

8.5.4.6.1.6.2. River Productivity

The production of freshwater fishes in a given habitat is constrained both by the suitability of the abiotic environment and by the availability of food resources (Wipfli and Baxter 2010). Algae are an important base component in the lotic food web, being responsible for the majority of photosynthesis in a river or stream and serving as an important food source to many benthic macroinvertebrates (see Section 9.8). In turn, benthic macroinvertebrates are an essential component in the processes of an aquatic ecosystem due to their position as consumers at the intermediate trophic level of lotic food webs. The significant functional roles that macroinvertebrates and algae play in food webs and energy flow in the freshwater ecosystem make these communities important elements in the study of a stream's ecology.

The operations of the proposed Project would likely affect the abundance and distribution of algae and benthic macroinvertebrate populations, which could ultimately affect fish growth and productivity in the system. The degree of impact on the benthic communities and fish resulting from hydropower operations will necessarily vary depending on the magnitude, frequency, duration, and timing of river flows. The overall goal of the River Productivity Study is to collect baseline data to assist in evaluating the effects of Project-induced changes in flow and the interrelated environmental factors (temperature, substrate, water quality) upon the benthic macroinvertebrate and algal communities in the Susitna River (see Section 9.8).

Both benthic macroinvertebrate and algal communities are groups of organisms that spend most or all of their lives in the channel substrate. These groups of organisms respond to inundation and dewatering of the river channel resulting from fluctuations in water surface elevation caused by Project operations, as well as variation in river flow. To assess the relative impact or change in the quality and quantity of available habitat and colonization rates for both of these groups of organisms, HSC/HSIs representing the influence of habitat quality and the duration of inundation and dewatering will be developed. The HSC/HSI will provide depth, velocity, substrate, cover, colonization, and dewatering criteria for both algae and benthic macroinvertebrates. The HSC/HSI results will be used in the aquatic habitat and varial zone modeling to translate physical characteristics present for different Project operations scenarios to indices of the amount and distribution of potential habitat that is suitable for the selected communities, and the duration of inundation and dewatering of varial zone areas.

The various indices of Project effects on mainstem aquatic habitats will be summarized and tabulated to allow ready comparison of the effects of an existing operations scenario to alternative operational scenarios. It is anticipated that the varial zone analysis will be used as a primary indicator of the effects of operational scenarios on algae and macroinvertebrates in the mainstem Susitna River. Analyses of usable habitat area will be developed for each guild or metric, but the results may be of primary interest in identifying the spatial distribution of potential habitats. Each indicator of environmental effect will be tallied separately, and the relative importance of the effects of Project operations on various aquatic resources may be determined independently by interested parties.

8.5.4.6.1.7. Fish Passage/Off-channel Connectivity

The extent to which mainstem flows dictate connectivity to off-channel habitats will be evaluated via development of models that consider the depth, velocity, and substrate requirements of adult salmon upstream migrations as well as juvenile downstream movements.

This analysis will be initiated in 2013 in the Middle River Segment within each of the Focus Areas that support spawning habitats and center on the associated tributary mouths, side channels, and side sloughs. This will include Focus Area-173, Focus Area-171, Focus Area-151, Focus Area-144, Focus Area-141, Focus Area-138, Focus Area-128, and Focus Area-104 (Table 8.5-6). In 2014, barrier surveys may be expanded to include both additional locations within the Middle River Segment that, based on results from fish distribution (see Section 9.5) and escapement studies (see Section 9.7), indicate are used for spawning, and that based on geomorphic analysis (see Section 6.5) would be susceptible to flow changes resulting from Project operations, as well as locations in the Lower River Segment. To the extent applicable, the analysis will utilize information and modeling results developed during the 1980s studies, but will also collect and analyze entirely new data as a means to test the results of the earlier studies, as well as to apply new technologies in making this evaluation (e.g., possible application of 2-D modeling).

8.5.4.6.2. Work Products

The hydraulic and habitat modeling study components will include the following work products:

- Map displaying hydraulic and habitat sampling areas for each Focus Area including boundary condition transects, 2-D modeling areas, single transect PHABSIM transects, stranding and trapping areas, fish passage/connectivity, and breaching flow hydraulic control features.
- Electronic copies of all physical and hydraulic field data collected at each Focus Area including field notes, photographs, site maps, and datasheets.
- Hydraulic modeling calibration results including cross-sectional profiles, stage vs. discharge relationships, velocity calibrations, 2-D grid (coarse and fine), PHABSIM hydraulic models, and digital terrain modeling.
- Results of flow vs. habitat relationship modeling for each target species and life stage for both single transect and 2-D PHABSIM.
- Results of downramping analysis summarized by month and annually for each hourly change rate in water surface elevation for each habitat transect.
- HSC/HSI curves for macroinvertebrates and algae related to suitability of water velocity and depth, substrate preference, and colonization rates.
- Results of varial zone modeling including effective spawning/incubation area, stranding and trapping analysis, and river productivity for each Focus Area.
- Tabular summary for comparison of the results of habitat modeling for each of the proposed Project operations scenarios.

These work products and other results of the hydraulic and habitat modeling will be compiled and presented in initial and updated study reports.

8.5.4.7. Temporal and Spatial Habitat Analyses

The IFS will result in the collection of data and development of different types of habitat-flow relationships from spatially distinct locations within each of the Focus Areas, and from selected cross-sectional transects outside of the Focus Areas that contain a variety of habitat types. Types of relationships will include but not be limited to those founded on PHABSIM that depict WUA or habitat versus flow by species and life stage; effective habitat versus discharge relationships that define how spawning and incubation areas respond to flow changes; varial zone analysis that quantifies areas of stranding and trapping relative to flow change; and groundwater-surface water flow relationships relative to upwelling and spawning habitats. Additional components that will factor into the habitat – flow relationships will include those associated with breaching flows, upwelling, water temperature, and turbidity. These relationships will be part of the analytical framework and conceptual models that will be used in evaluating the operational effects of the Project (see Section 8.5.4.8) on different habitats. This will require both a temporal analysis that focuses on how the various habitat response variables change with flow over biologically important time periods (i.e., periodicity), and a spatial analysis that can be used not only for evaluating specific relationships on a site/transect specific or Focus Area basis, but also for expanding or extrapolating results from measured to unmeasured habitats within the river. This latter analysis is needed in order to assess system-wide Project effects.

8.5.4.7.1. Proposed Methodology

8.5.4.7.1.1. Temporal Analysis

Temporal analysis will involve the integration of hydrology, Project operations, the Mainstem Open-water Flow Routing Model, and the various habitat-flow response models to project spatially explicit habitat changes over time. Several analytical tools will be utilized for evaluating Project effects on a temporal basis. This will include development and completion of habitat-time series that represent habitat amounts resulting from flow conditions occurring over different time steps (e.g., daily, weekly, monthly), as well as separate analysis that address effects of rapidly changing flows (e.g., hourly) on habitat availability and suitability.

The Mainstem Open-water Flow Routing Model and habitat models will be used to process output from the Project operations model. This will be done for different operating scenarios, hydrologic time periods (e.g., ice free periods: spring, summer, fall; ice-covered period: winter [will rely on Ice Processes Model – Section 7.6]), Water Year types (wet, dry, normal), and biologically sensitive periods (e.g., migration, spawning, incubation, rearing) and will allow for the quantification of Project operation effects on the following:

- Habitat areas (for each habitat type – main channel, side channel, slough, etc.) by species and life stage; this will also allow for an evaluation of the effects of breaching flows on these respective habitat areas and biologically sensitive periods (e.g., breaching flows in side channels during egg incubation period resulting in temperature change).
- Varial zone area (i.e., the area that may become periodically dewatered due to Project operations, subjecting fish to potential stranding and trapping and resulting in reduced potential invertebrate production).
- Effective spawning areas for fish species of interest (i.e., spawning sites that remain wetted through egg incubation and hatching).
- Other riverine processes that will be the focus of the Geomorphology (see Sections 6.5 and 6.6), Water Quality Modeling (see Section 5.6), and Ice Processes (see Section 7.6) studies including mobilization and transport of sediments, channel form and function,

water temperature regime, and ice formation and decay timing. The IFS studies will be closely linked with these studies and will incorporate various model outputs in providing a comprehensive evaluation of instream flow-related effects on fish and aquatic biota and habitats.

As an example, using the habitat versus flow relationships (based on HSC and HSI metrics described in Sections 8.5.4.5.1.1 and 8.5.4.5.1.2) developed within the different Focus Areas and at selected cross-sections, an evaluation of habitat change over time can be completed using habitat time series analysis. The basic premise of a habitat time series analysis is that the physical habitat in a stream at any given time can be calculated from the stream flow using the equation:

$$HA(t) = WUA\{Q(t)\}$$

where WUA = physical habitat versus flow relationship for a given species and life stage;

Q(t) = stream flow at time t; and

HA(t) = habitat area for time t.

The basic steps to calculating a habitat time series are illustrated in Figure 8.5-35, where the habitat versus flow relationship (WUA) is integrated with the daily flow records to derive habitat availability over time. In this form, time series analysis provides a method for assessing the relative impacts from changes in the flow regime resulting from different operational scenarios. The results of the time series analysis can be compared under baseline (unregulated) conditions with one or more Project Operational Scenarios. This type of analysis will be done for each biologically relevant period (e.g., adult migration and holding, spawning, incubation, juvenile rearing, and others) for a given species and life stage, and for different Water Year types (e.g., wet, normal, dry). Consideration will also be given to identifying year types that reflect cold, normal, and above average air temperatures. The analysis will include development of habitat-duration curves that depict habitat exceedances based on the hydrologic record.

Other types of temporal analysis have been previously described in this RSP (see Section 8.5.4.6.1.5 – Effective Spawning Habitat Analyses; and Section 8.5.4.6.1.6 – Varial Zone Modeling). These analyses will be coordinated with other resource studies that will evaluate among other things, temporal changes in physical habitats (e.g., changes in channel form, substrate composition, embeddedness (spawning gravel quality and quantity) etc.) (see RSP Geomorphology – Sections 6.5 and 6.6), and temporal changes in water quality characteristics (temperature – effects on growth and incubation, turbidity, etc.) (see RSP Water Quality Modeling– Section 5.6). The final approach and details concerning the methods that will be used for conducting the temporal analysis, including the time steps (hourly, daily, monthly, etc.), indicator parameters (spawning period, incubation, substrate composition, water temperature, and other biologically relevant indicators), and Project operational scenarios will be worked out in consultation with the TWG in Q4 2013.

8.5.4.7.1.2. Spatial Analysis

How the data and habitat-flow relationships collected and developed from one location relate to other unmeasured locations is the focus of the spatial analysis. This analysis is crucial to providing an overall understanding of how Project operations may affect habitats and riverine processes on a system-wide basis and will feed directly into the Integrated Resource Analysis (see Section 8.5.4.8). This analysis will be completed in Q2 through Q4 2014 after all data are collected and respective models have been developed. Just like the temporal analysis, the final procedure(s) for completing spatial analysis will be developed collaboratively with the TWG and with input from other resource disciplines.

Completion of spatial analyses of the Susitna River will be challenging given its length, widely variable size (width), diverse geomorphologies, and complex habitat types. This variability is readily apparent in the Middle River Segment and becomes even more pronounced in the Lower River Segment with the addition of flow from the Talkeetna and Chulitna rivers and resulting expanded floodplain. This will require the development of an approach that considers the distinctiveness of the different habitat types within a given area and at the same time the similarity of these habitat types to other areas. Development of habitat – flow relationships for specific habitat types (e.g., side channel, side slough) and mesohabitat types (riffle, run, pool, etc.) from one area should then, with appropriate adjustment for dimensional differences and other distinguishing factors, be expandable to unmeasured areas containing similar characteristics.

A substantial effort was already advanced toward development of a spatial habitat analysis approach as part of the 1980s studies (Aaserude et al. 1985; Klinger-Kingsley et al. 1985; Steward et al. 1985). Inspection of those studies indicates that although the tools and computational techniques that were applied may be outdated, the general principles and precepts that served to guide development of the approach remain sound today. As a result, they provide a good starting point from which to build a more contemporary approach founded on new sampling technologies and more sophisticated models that will provide for a more robust spatial analysis, including procedures for extrapolation of habitat-flow relationships from measured to unmeasured areas.

Importantly, the 1980s studies made a clear distinction regarding extrapolation approaches that are suited for single thread channel versus those for multi-thread channels. Aaserude et al. (1985) correctly noted that for single thread channels, it is appropriate and is routinely done today to utilize extrapolation procedures that are based on proportional lengths of mesohabitat types that are identified as part of a habitat mapping exercise. This approach was originally fostered by Morhardt et al. (1983) and has remained in use since. Indeed, this approach, or some modification thereof, will be utilized for extrapolating PHABSIM-based habitat–flow relationships derived from main channel mesohabitat specific transects (e.g., riffle, run, pool, etc.) as identified from the Characterization of Aquatic Habitats Study (see Section 9.9) to unmeasured mesohabitats within a given geomorphic reach. This will be done in a series of steps that include the following:

- Completion of habitat mapping (see Section 9.9) that will delineate main channel mesohabitats into categories of cascades, riffle, pool, run, and glide as described in Section 8.5.4.2.1.1.
- Determination of percentages of each mesohabitat type within each geomorphic reach.
- Assignment of existing transects (those already established as input to the open-water flow routing model (see Section 8.5.4.3) and new main channel transects established either as part of the detailed Focus Area studies (see Section 8.5.4.6.1.2) or added to

capture a specific main channel habitat not represented by the existing transects to a specific mesohabitat category.

- Weight each of the transects within a given geomorphic reach based on the percentages of mesohabitats represented in the reach (e.g., in a reach that is 30 percent riffle with 6 riffle transects; each transect would be assigned a weighting factor of 5 percent (30 percent/6) of the total reach length).
- Apply additional transect weighting based on location to account for tributary and accretion flow.
- Derive habitat-flow relationships (by species and life stage) for a given geomorphic reach based on transect specific habitat-flow relationships by mesohabitat type weighted by the percentages of the reach (based on lineal distance) containing each mesohabitat type (as determined from habitat mapping).

This latter step will then result in a composited habitat-flow relationship that considers all mesohabitat types within a given geomorphic reach. Further compositing of relationships for all geomorphic reaches (with consideration for flow accretion, etc.) will allow for the derivation of habitat-flow relationships (by species and life stage) for the entire segment of the main channel Susitna River. Coupled with the open-water flow routing model, these relationships can then be used to evaluate how main channel habitats may vary under different operational scenarios and will provide one of the tools necessary for completing the spatial analysis. It should be noted that due to sampling and modeling limitations, main channel mesohabitat mapping was not completed in the 1980s studies nor was there any development of main channel habitat-flow response relationships.

A different approach will be needed for multi-thread channels because they contain multiple habitat types (e.g., side channel, side slough, upland slough, etc.) within which each may contain multiple mesohabitat types (e.g., riffle, run, pool, etc.). In addition, flows within some of the habitat types may be governed by groundwater-surface water interactions that cannot be modeled directly by PHABSIM. The framework for evaluating multi-channel habitats described in Aaserude et al. (1985) provides a logical construct for achieving this and as noted above, is the starting point for the current Instream Flow Study. Unlike the approach for a single thread channel where a reasonable assumption is that habitat-flow response relationships will generally be similar among mesohabitat types, the diversity of habitats within a multi-thread channel means that habitat-flow responses are dynamic and highly variable. In addition, multi-thread channels are spatially discontinuous and disconnected so that it is not possible to extrapolate entire multi-channel units to others. As noted by Aaserude et al. (1985), the braided river environment is too dynamic and variable for the development of quantitative relationships between discharge and physical habitat variables such as depth, velocity, and channel structure on a river corridor-wide basis for use in extrapolation. Instead, an approach for evaluating habitat is needed that focuses on portions of the river corridor but then relates the findings of those portions to other areas of similar character.

The method presented by Aaserude et al. (1985) was based on the provision of two separate databases, the first containing habitat-flow response relationships for the full range of habitat and mesohabitat types found within selected portions of the river, the second an expansive database consisting of aerial imagery and targeted measurements of a select number of habitat response variables from essentially all of the habitat types found within the primary multi-threaded channels in the Middle River Segment. Input to the first database was provided largely by a number of site-specific studies that included application of PHABSIM (IFG), DIHAB, and RJHAB models to define habitat-flow response relationships in different habitat types, as well as surveys to determine breaching flows. However, the "one size fits all" concept that may be valid for expansion of mesohabitat types does not apply to the multi-thread network of channels in the Susitna River. Consequently, further stratification of the habitat types (side channel, side slough, upland slough, etc.) was needed and resulted in the designation of 10 "representative groups" that provided a sub-level of categorization to the habitat types (Steward et al. 1985; Aaserude et al. 1985). These 10 groups consisted of "identifiable combinations of flow – related attributes" (Steward et al. 1985) that were deemed readily distinguishable and included the following:

- Group I – Predominantly upland sloughs. Areas are highly stable due to persistence of non-breached conditions. Area hydraulics characterized by pooled clear water with velocities frequently near 0 fps and depths > 1 ft. Pools commonly connected by short riffles with velocities < 1 fps and depths < 0.5 ft.
- Group II – Side sloughs that are characterized by relatively high breaching flows (>19,500 cfs), clear water caused by upwelling groundwater and large channel length to width ratios (> 15:1).
- Group III – Areas with intermediate breaching flows and relatively broad channel sections. These areas consist of side channels which transform into side sloughs at mainstem discharges ranging from 8,200 to 16,000 cfs. These areas are distinguishable from Group II by lower breaching flows and smaller length to width ratios. Upwelling water is present.
- Group IV – Side channels that are breached at low flows and possess intermediate mean velocities (2–5 fps) at a mainstem discharge of approximately 10,000 cfs.
- Group V – Mainstem and side shoal areas that transform to clear water side sloughs as mainstem flows recede. Transformations generally occur at moderate to high breaching flows.
- Group VI – Similar to Group V. Sites within this group are primarily overflow channels that parallel the adjacent mainstem, usually separated by sparsely vegetated gravel bar. Upwelling may or may not be present. Habitat transformations within this group are variable in type and timing.
- Group VII – Side channels that breach at variable yet fairly low mainstem discharges and exhibit characteristic riffle/pool sequence. Pools are frequently large backwater areas near the mouth of the sites.
- Group VIII – Area that dewater at relatively high flows. Flow direction at the head of the channels tends to deviate sharply (> 30 degrees) from the adjacent mainstem.
- Group IX – Secondary mainstem channels that are similar to the primary mainstem channels in habitat character, but distinguished as being smaller and conveying a lesser proportion of the total discharge. Areas within this group have low breaching discharges and are frequently similar in size to large side channels, but have characteristic mainstem features, such as relatively swift velocities (> 5fps) and coarser substrate.

- Group X – Large mainstem shoals and margins of mainstem channels that show signs of upwelling.

Another element of the method described by Aaserude et al. (1985) that was used as part of the representative group designation was its consideration of habitat transformation wherein mainstem areas may functionally transition from side channels to side sloughs and ultimately become dewatered as flows recede. A total of 11 habitat transformation categories were defined and considered when comparing flow conditions; these included comparative categories of clear vs. turbid water, upwelling present vs. absent, and distinct vs. indistinct side channel formation.

Model development from which to base habitat-flow response relationships within each of the groups relied upon the site-specific models applied at different study areas. In addition to traditional metrics of weighted usable area (WUA), a number of other metrics were derived that included Wetted Surface Area (WSA), Gross Habitat Area (GHA), a Habitat Availability Index (HAI), a Habitat Distribution Index (HDI), and a Habitat Quality Index (HQI). These relationships were then applied to un-modeled areas assigned to different "representative groups" taking into account two important distinguishing characteristics—structural habitat quality and breaching flow. Structural habitat quality was evaluated for each site based on field data that considered cover type, percent cover, dominant substrate size, substrate embeddedness, channel geometry, and riparian vegetation. From this, a Structural Habitat Index (SHI) was computed for each un-modeled area. Breaching flows were likewise determined for each unmeasured area. These two elements were then used as adjustment factors for defining the derived non-modeled habitat – flow response relationship; this process is conceptually shown in Figure 8.5-36. Once relationships were derived from un-modeled areas, it was then possible to integrate results into an overall assessment of habitat-flow responses within each representative group; these were presented in Steward et al. (1985). The next step in the process would have been to conduct a system-wide (at least for the Middle River Segment) evaluation of habitat-flow responses that would have aggregated the responses into a system-wide habitat-flow response relationship. However, this step was never completed as part of the 1980s studies.

Review and inspection of Aaserude et al. (1985), Steward et al. (1985), and Klinger and Trihey (1984) clearly indicate that the challenges of model extrapolation from measured to unmeasured areas had received substantial attention and had resulted in a carefully designed and logical approach for application on the Middle River Segment of the Susitna River. This same approach will serve as the starting point for consideration of the spatial analysis that will be completed for multi-channel areas as part of the 2013–2014 Instream Flow Study. However, even though some of the same steps may be applicable for the current studies (e.g., habitat mapping, use of aerial imagery, field data collection, derivation of certain habitat-flow response relationships), the analytical tools that are available (e.g., 2-D modeling, LiDAR, digital orthophotos and videography, Forward Looking Infrared [FLIR], GIS, Real Time Kinematic [RTK]-GPS surveys, etc.) and that will be used are much more sophisticated and will result in a more detailed and robust assessment. Moreover, the analysis will also rely on inputs from other inter-related resource studies, including, in particular Geomorphology (see Sections 6.5 and 6.6), Groundwater (see Section 7.5), Water Quality (see Sections 5.5 and 5.6), and Characterization of Aquatic Habitats (see Section 9.9) (Figure 8.5-1). The Focus Areas identified in this RSP (see Section 8.5.4.2) were purposely selected based, in part, on the diversity of habitat types they contained and their representativeness of other areas in the river. The inter-related resource studies that will be completed at each of these areas will provide a strong base of information, data, and flow-sensitive models that can be used, with proper adjustment, for expanding results to un-measured areas.

However, as noted in Section 8.5.2.2, the 1980s project assumed a two-dam scenario, with the lower dam serving as a re-regulating structure to smooth out load-following effects from the upper dam. Thus, the flow changes assumed to occur in the Middle and Lower River segments were more focused on shifts in the seasonal/monthly timing and magnitude of flows rather than on daily flow fluctuations. The extrapolation methods were therefore narrowly focused on being able to evaluate those effects as they occurred at different locations of the river. The spatial analysis for the Susitna-Watana Project will need to consider both those types of effects as well as the daily flow fluctuations associated with load-following. Methods for expanding the results of the varial zone modeling (see Section 8.5.4.6.1.6) and effective habitat modeling (see Section 8.5.4.6.1.5) will therefore need to be developed and integrated into the extrapolation process.

In addition, decisions regarding whether and the extent to which detailed studies will be extended into the Lower River Segment will be discussed pending results of the open-water flow routing modeling in Q2 2013. If needed, these studies would be scheduled to occur commencing in Q3 2013 and extend into Q3 2014. Temporal and spatial analytical techniques applicable to the Lower River Segment would be developed in Q4 2014.

8.5.4.7.1.3. Finalization of Analytical Methods

The results of the temporal and spatial analyses will include tabular listings of habitat indicator values under existing and alternative flow regimes. Model results will be developed for representative hydrologic conditions and a multi-year, continuous hydrologic record to evaluate annual variations in indicator values. The availability of indicator values over a multi-year record will support sensitivity analyses of the habitat indicators used to evaluate proposed reservoir operations. Sensitivity analyses of individual components of the habitat modeling efforts are a standard technique in model construction, calibration, and assessment and are envisioned as implicit steps in the IFS. For instance, selection of draft HSC/HSI (Section 8.5.4.5.1.1.2) will be subject to sensitivity analyses to identify those inputs where additional data may be required to improve model output, or where the use of available values leads to uncertainty in model outputs. Integrating the level of uncertainty in the various model components will provide the TWG with an overall understanding of the robustness of individual habitat indicators. Analysis of habitat indicators over a multi-year record will identify the sensitivity of indicators to hydrologic conditions and the level of certainty associated with decisions regarding alternative instream flow regimes. The design of the sensitivity analyses for habitat indicators will be developed by AEA and reviewed in consultation with the TWG in Q4 2013 and implemented in Q3 through Q4 2014 (Table 8.5-14).

It will be important to reach consensus with licensing participants and the TWG on the final methods that will be applied for both the temporal and spatial analysis. These methods will be reviewed and discussed during one or more TWG meetings that will occur in Q3 2013. Based on input and comments from the TWG, the method will be finalized and described in the Initial Study Report prepared in Q1 2014. Application of the method will occur in Q4 2014 and be included as part of the Instream Flow Study Integration (see Section 8.5.4.8).

8.5.4.7.2. Work Products

Results of the temporal and spatial analysis will be provided in tabular and graphical formats and described in a detailed report. This will include a summarization of the various indices of Project effects on aquatic habitats to allow ready comparison of the effects of alternative operational scenarios.

Work products associated with the analysis will include but not be limited to the following:

- Tabular listing of habitat quantities under different flows at different times by species and life stage.
- Time series plots depicting habitats over time by species and life stage under unregulated conditions and under different operational scenarios; separate time series will be developed for different Water Year types.
- Habitat – duration curves based on time series analysis.
- Development of extrapolation methods and the application of those methods that will provide an estimate of system-wide effects of Project operations on various habitat indices for both single thread and multiple thread channels.
- Preparation of sections within the Initial Study Report that describe temporal and spatial analytical methods.

8.5.4.8. Instream Flow Study Integration

8.5.4.8.1. Proposed Methodology

Construction and operation of the proposed Project will change downstream flow conditions on an hourly, daily, and seasonal basis. Load-following operations will increase the frequency, timing, and magnitude of hourly and daily flow fluctuations, and increased flow releases during winter months will be followed by decreased flow releases as the reservoir refills. The effects of such flow changes will vary depending on the operational rules guiding power generation. The suite of Project operational rules governing hourly, daily, and seasonal dam releases are termed operational scenarios. Scenarios developed to benefit one specific resource may have a detrimental effect on another resource. For instance, maintaining high flow releases during the spring salmon smolt out-migration period may delay reservoir refill and could affect Project releases for late summer coho rearing. An operational scenario designed to benefit one resource, such as cottonwood germination, may have an unintended detrimental effect on another resource. Constraints on Project flow releases to benefit one natural resource may affect the ability of AEA to meet its energy needs. Identifying an operational scenario that satisfies the interests of all parties requires an evaluation of multiple resource benefits and risks.

Tools to inform the evaluation of flow scenarios have been developed in support of other water control decisions. A Decision Support System (DSS) was developed to support the evaluation of alternative flow regimes on resources of the Black Canyon of the Gunnison National Park (Auble et al. 2009). The DSS developed by Auble was intended to provide decision-makers with the tools to manage large data sets of simulated flow alternatives and evaluate the relative desirability of those alternatives with respect to natural resources. The intent was not to evaluate alternatives, but to provide a tool for informing the evaluation of alternatives. The basic approach was to array differences among alternative flow regimes by calculating values of indicator variables representing different habitat characteristics or processes of the riverine ecosystem. Auble noted that the scientific understanding and quantitative relations between flow and the physical and biological responses of riverine systems are complex and may be imperfectly represented by the indicators. Disagreement about the relative importance or weighting of multiple resource concerns can delay or derail the decision-making process. Ideally, a DSS requires a balance between simplification of assumptions to reduce complexity and oversimplification that does not reflect the constituent variables and calculations. Auble produced a set of indicators grouped into several areas of natural resources concerns. The indicators were replicable calculations that reflected conditions or processes within each area of concern. Alternatives were compared directly in terms of these indicators, each of which could be individually understood and challenged in terms of the assumptions involved in the calculations. Different users could make different decisions using this system because they might weight the importance of multiple indicators differently or value different aspects of the system. Thus, the goal of the DSS was not to make a decision, but rather to reduce the complexity of information and focus attention on trade-offs involved in the decision.

The Yakima River DSS (Bovee et al. 2008) was designed to quantify and display the consequences of alternative water management scenarios to provide water releases for fish, agriculture, and municipal water supply. Output of the Yakima River DSS consisted of a series of conditionally formatted scoring tables that compiled changes in evaluation indicators. Increases in the values of selected indicators were reflected in a color-coded scoring matrix to provide decision-makers with a quick visual assessment of the overall results of an operating scenario. The scoring matrix required that evaluation indicators used to describe resources be rated as comparative values. A variety of weighting strategies were provided during the decision-making process to reflect the relative importance of different indicators.

In support of relicensing decisions for the Baker River Hydroelectric Project, FERC No. 2150, a DSS-style matrix was developed to evaluate multiple resource concerns under alternative operational scenarios (Hilgert et al. 2008). The focus of the operations and aquatic habitat analyses was to identify a mode of operation that would protect aquatic resources while meeting multiple licensing participant interests. Aquatic habitat analyses were run concurrent with analyses of economic, flood control, and other resources. Various licensing participants championed different approaches to the relationships between minimum and maximum flow releases, minimum and maximum reservoir pool levels, and downramping rates. Through study and analysis, some scenarios were proven infeasible and abandoned, others were modified, and others were dissected and recombined with other approaches. Alternative operational scenarios were evaluated using a matrix that presented indicators of resource concerns without applying comparative weighting factors. Collaboration among licensing participants gradually led to consensus on a preferred flow management plan that contributed led to a Settlement Agreement.

Evaluation of Project effects on Susitna River resources will require inventive modeling approaches that integrate aquatic habitat modeling with evaluation of riverine processes such as groundwater-surface water interactions, water quality, and ice processes. The number of reaches, habitat types, target species and life stages, and resource-specific models will result in large data sets for multiple resources that will be difficult to comprehend when evaluating alternative operational scenarios. A DSS-type process will be needed to evaluate the benefit and potential impacts of alternative operational scenarios. For illustration purposes, an example matrix was developed (Table 8.5-21) to display a range of potential indicator variables including the following:

- Power
- Hydrologic
- Reservoir
- Ramping rates
- Stranding and trapping
- Salmon spawning and incubation
- Salmon rearing
- Other fish species
- Riparian
- Recreation
- Other aquatic conditions

As habitat-specific models are developed, they will be used to evaluate existing conditions and the effects of alternative operational scenarios for multiple resources and riverine processes. A Project operations model (see Section 8.5.4.3.2) will be used to simulate Project inflow, outflow, power generation, and reservoir pool levels for alternative operational scenarios under a range of hydrologic years. The operations model will be used to quantify revenue from power generation based on operational constraints selected for each alternative scenario. Types of constraints may include maximum and minimum instream flow releases, ramping rates, and reservoir levels. These constraints may be varied within a hydrologic year according to schedules specified for each alternative. Operations model output may include simulated reservoir elevations, turbine, spill, and total outflow, as well as hourly stream flow immediately below the powerhouse. Output from the operations model will be used as input for the downstream habitat models. Hourly flows immediately below the powerhouse will be routed downstream using the mainstem open-water flow routing models (see Section 8.5.4.3) and Ice Processes Model (see Section 7.6).

Each habitat and riverine processes model can be used to develop large data sets of hourly habitat conditions. The DSS-type process will be used to focus attention on those attributes that the TWG believes are highest priority in evaluating the relative desirability of alternative scenarios with respect to natural resources. Evaluation indicators selected for a DSS-type matrix represent a preliminary analysis to identify the most promising scenarios. When discussion of alternatives focuses on only a few remaining scenarios, those final scenarios will be evaluated using the larger data set of habitat indicators to ensure that environmental effects are consistent with the initial analyses.

The selection of indicator variables will be developed in collaboration with the TWG. For planning purposes, it is assumed that values for each evaluation indicator will be developed and presented for a range of alternative operational scenarios without rating or comparative weighting of various resources. Although incorporating a relative weighting system similar to the Yakima River DSS (Bovee et al. 2008) would simplify the evaluation process, reaching consensus on weighting factors may divert attention from understanding and discussing the merits of constituent variables. Table 8.5-21 represents one option to present Project decision-makers with information on the effects of alternative operational scenarios on resource values. Development of a DSS-type process, and supporting software to efficiently process data analyses, will be initiated in collaboration with the TWG after the initial results of the various habitat modeling efforts are available in 2014 (Table 8.5-14). The intent is to prepare the DSS-type evaluation process by Q1 2015 to assist scenario evaluations in support of the License Application.

8.5.4.8.2. Work Products

Work efforts in support of Instream Flow Study integration will be described in the ISR and USR (Table 8.5-14) to be prepared at the end of each year of study. A DSS-type program will developed in collaboration with the TWG to support decision-makers with the evaluation of alternative operational scenarios. Specific work products for the study integration efforts will consist of the following:

- Summary of any study integration efforts in 2013 to be included in the ISR
- Summary of study integration efforts in 2014 to be included in the USR
- DSS-type matrix with supporting documentation

8.5.5. Consistency with Generally Accepted Scientific Practice

The proposed IFS, including methodologies for data collection, analysis, modeling, field schedules, and study durations, is consistent with generally accepted practice in the scientific community. The study plans were collaboratively developed with technical experts representing the applicant, state and federal resource agencies, Alaska Native entities, non-government organizations, and the public. Many of these technical experts have experience in multiple FERC licensing and relicensing proceedings. The IFS is consistent with common approaches used for other FERC proceedings and the IFS references specific protocols and survey methodologies, as appropriate.

8.5.6. Schedule

The schedule for completing all components of the Mainstem Aquatic Habitat Model is provided in Table 8.5-14. The TWG will have opportunities for study coordination through regularly scheduled meetings, reports, and, as needed, technical subcommittee meetings. Initial and Updated Study Reports will be issued in December 2013 and 2014, respectively. Preparation of reports is planned at the end of 2013 and 2014 for each of the study components. Workgroup meetings are planned to occur on at least a quarterly basis, and workgroup subcommittees will meet or have teleconferences as needed.

8.5.7. Level of Effort and Cost

Based on a review of study costs associated with similar efforts conducted at other hydropower projects, and in recognition of the size of the Project and logistical challenges and costs associated with the remoteness of the site, study costs associated with the Instream Flow Study are expected to be approximately $5,000,000 to $6,000,000. Estimated study costs are subject to review and revision as additional details are developed.

Portions of this study will be conducted in conjunction with water resource, geomorphology, water quality, operational modeling, and fisheries and aquatic resource studies; however, specific costs of those studies will be reflected in those individual study plans.

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8.5.9. Tables

Table 8.5-1. Summary of HSC curves developed during 1980s Susitna Studies.

Species	Life Stage	Depth	Velocity	Substrate	Upwelling	Cover	Turbidity[4]
Coho	Juvenile	✓[1]	✓			✓	
Chinook	Spawning	✓	✓	✓			
	Juvenile	✓[1]	✓			✓	✓
Sockeye	Spawning	✓	✓	✓			
	Juvenile	✓[1]	✓			✓	
Chum	Spawning	✓	✓	✓	✓[3]		
	Juvenile	✓[1]	✓			✓	
Pink	Spawning	✓	✓	✓	✓[3]		
Rainbow Trout	Spawning	✓	✓	✓			
Dolly Varden	Adult	✓[2]	✓			✓	✓
Arctic Grayling	Adult	✓[2]	✓			✓	✓
Humpback Whitefish	Juvenile	✓	✓			✓	✓
Round Whitefish	Adult	✓[2]	✓			✓	✓
Longnose Sucker	Adult	✓[2]	✓			✓	✓
Burbot	Adult	✓	✓			✓	✓

Notes:

[1, 2] Depth curves for multiple species combined
[3] Integrated with substrate suitability
[4] Separate curves developed for clear vs. turbid water for one or more parameters

Table 8.5-2. Periodicity of Pacific salmon habitat utilization in the Middle Segment (RM 184-98.5) of the Susitna River by species and life history stage. Shaded areas indicate timing of utilization and dark gray areas represent peak use.

Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chinook Salmon	Adult Migration												
	Spawning												
	Incubation												
	Fry Emergence												
	Rearing (0+)												
	Rearing (1+)												
	Juvenile Migration (0+)												
	Juvenile Migration (1+)												
Chum Salmon	Adult Migration												
	Spawning												
	Incubation												
	Fry Emergence												
	Rearing (0+)												
	Juvenile Migration (0+)												
Coho Salmon	Adult Migration												
	Spawning												
	Incubation												
	Fry Emergence												
	Rearing (0+)												
	Rearing (1+)												
	Rearing (2+)												
	Juvenile Migration (0+)												
	Juvenile Migration (1+)												
	Juvenile Migration (2+)												

Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sockeye Salmon[1]	Adult Migration[1]												
	Spawning[1]												
	Incubation												
	Fry Emergence												
	Rearing (0+)												
	Rearing (1+)												
	Juvenile Migration (0+)												
	Juvenile Migration (1+)												
Pink Salmon[2]	Adult Migration												
	Spawning												
	Incubation												
	Fry Emergence												
	Juvenile Migration (0+)												

1 Early-run and late-run sockeye salmon exhibit distinct timing of adult migration and spawning, and utilize separate areas for spawning. Periodicity presented here represent that of late-run sockeye, as early-run sockeye do not utilize the Middle Susitna River.

2 No rearing period for age 0+ pink salmon is identified because this species migrates to the estuary soon after emergence.

Table 8.5-3. Instream flow sites and habitat modeling methods used during the 1980s in the Middle and Lower Susitna River (Marshall et al. 1984; Sandone et al. 1984; Vincent-Lang et al. 1984; Hilliard et al. 1985; Suchanek et al. 1985).

River Mile	Site Name	Susitna Segment	Habitat Type	Site Type	No. of Transects	Year(s) Measured
35.2	Hooligan Side Channel	Lower	Side Channel	RJHAB	5	1984
36.2	Eagles Nest Side Channel	Lower	Side Channel	RJHAB	4	1984
36.3	Kroto Slough Head	Lower	Side Slough	RJHAB	5	1984
39.0	Rolly Creek Mouth	Lower	Tributary Mouth	RJHAB	6	1984
42.9	Bear Bait Side Channel	Lower	Side Channel	RJHAB	5	1984
44.4	Last Chance Creek Side Channel	Lower	Side Channel	RJHAB	6	1984
59.5	Rustic Wilderness Side Channel	Lower	Side Channel	RJHAB	5	1984
63.0	Caswell Creek	Lower	Tributary Mouth	RJHAB	8	1984
63.2	Island Side Channel	Lower	Side Channel	IFG-4, RJHAB	9	1984
74.4	Mainstem West Bank	Lower	Side Slough	IFG-4	7	1984
74.8	Goose 2 Side Channel	Lower	Side Channel	RJHAB	6	1984
75.3	Circular Side Channel	Lower	Side Channel	IFG-4	6	1984
79.8	Sauna side channel	Lower	Side Channel	IFG-4	4	1984
84.5	Sucker side channel	Lower	Side Channel	RJHAB	6	1984
86.3	Beaver Dam side channel	Lower	Side Channel	RJHAB	5	1984
86.3	Beaver Dam Slough	Lower	Side Slough	RJHAB	5	1984
86.9	Sunset side channel	Lower	Side Channel	IFG-4	7	1984
87.0	Sunrise side channel	Lower	Side Channel	RJHAB	7	1984
88.4	Birch Slough	Lower	Side Slough	RJHAB	8	1984
91.6	Trapper Creek side channel	Lower	Side Channel	IFG-4, RJHAB	5	1984
101.2	101.2 R, Whiskers East	Middle	Side Channel	IFG-4	9	1984
101.4	Whiskers Slough	Middle	Side Slough	RJHAB	8	1983
101.5	101.5 L, Whiskers West	Middle	Side Channel	IFG-2	5	1984
101.7	101.7 L	Middle	Side Channel	DIHAB	4	1984
105.8	105.8 L	Middle	Mainstem	DIHAB	4	1984
107.6	Slough 5	Middle	Upland Slough	RJHAB	9	1983
112.5	Slough 6A	Middle	Upland Slough	RJHAB	8	1983
112.6	112.6 L, Side Channel 6A	Middle	Side Channel	IFG-2	9	1984
113.6	Lane Creek mouth	Middle	Tributary Mouth	Habitat Mapping	7	1983
113.7	Slough 8	Middle	Side Slough	RJHAB	5	1983
114.1	114.1 R	Middle	Side Channel	DIHAB	3	1984
115.0	115.0 R	Middle	Side Channel	DIHAB	4	1984
118.9	118.9 L	Middle	Mainstem	DIHAB	3	1984
119.1	119.1 L	Middle	Mainstem	DIHAB	3	1984
119.2	119.2 R, Little Rock side channel	Middle	Side Channel	IFG-2	5	1984
125.2	125.2 R	Middle	Side Channel	DIHAB	2	1984
125.3	Skull Creek	Middle	Side Slough	IFG-4	11	1983

River Mile	Site Name	Susitna Segment	Habitat Type	Site Type	No. of Transects	Year(s) Measured
128.8	Slough 9	Middle	Side Slough	IFG-4	10	1983
130.2	130.2 R	Middle	Side Channel	DIHAB	3	1984
131.1	4th of July Creek mouth	Middle	Tributary Mouth	Habitat Mapping	8	1983
131.3	131.3 L	Middle	Side Channel	DIHAB	4	1984
131.7	131.7 L	Middle	Side Channel	IFG-4	7	1984
132.6	132.6 L, Side channel 10A	Middle	Side Channel	IFG-4, RJHAB	9	1983-84
133.8	133.8 R	Middle	Mainstem	DIHAB	3	1984
133.8	Side channel 10	Middle	Side Channel	IFG-4	4	1983
134.9	Lower Side channel 11	Middle	Side Channel	IFG-2	6	1983
136.0	136.0 L, Slough 14	Middle	Side Channel	IFG-4	6	1984
136.3	Upper Side channel 11	Middle	Side Channel	IFG-4	4	1983
137.5	137.5 R	Middle	Side Channel	DIHAB	3	1984
138.7	138.7 L	Middle	Mainstem	DIHAB	3	1984
139.0	139.0 L	Middle	Mainstem	DIHAB	4	1984
139.4	139.4 L	Middle	Side Channel	DIHAB	3	1984
141.2	Side channel 21	Middle	Side Channel	IFG-4	5	1983
141.8	Slough 21	Middle	Side Slough	IFG-4	5	1983
144.4	Slough 22	Middle	Side Slough	RJHAB	8	1983
147.1	147.1 L, Fat Canoe SC	Middle	Side Channel	IFG-2	6	1984

Table 8.5-4. Geomorphic reach designations for the Upper River (UR) Segment, Middle River (MR) Segment, and Lower River (LR) Segment of the Susitna River as described in Section 6.5.4.1.2.2.

Reach Designation	Upstream Limit RM)	Downstream Limit (RM)	Reach Classifi-cation	Slope (ft/mi)	Lateral Constraints
Upper River Segment (UR)					
UR-1	260	248	SC2	N/A	Quaternary Basin Fill
UR-2	248	233	SC1	N/A	Quaternary Basin Fill
UR-3	233	223	SC1	N/A	Quaternary Basin Fill
UR-4	223	206	SC2	N/A	Granodiorite
UR-5	206	201	SC1	N/A	Quaternary Basin Fill
UR-6	201	184	SC2	N/A	Quaternary Basin Fill
Middle River Segment (MR)					
MR-1	184	182	SC2	9	Gneiss
MR-2	182	166.5	SC2	10	Quaternary Basin Fill
MR-3	166.5	163	SC2	17	Granites
MR-4	163	150	SC1	30	Granites
MR-5	150	145	SC2	12	Moraine and Turbidites
MR-6	145	119	SC3	10	Moraines
MR-7	119	104	SC2	8	Moraines
MR-8	104	98.5	MC1/SC2	8	Holocene Lacustrine and Alluvial Terrace deposits
Lower River Segment (LR)					
LR-1	98.5	84	MC1	5	Upper Pleistocene Outwash, Moraine and Lacustrine deposits
LR-2	84	61	MC1	5	Upper Pleistocene Outwash, Moraine and Lacustrine deposits
LR-3	61	40.5	MC3	4	Glaciolacustrine and Moraine deposits
LR-4	40.5	28	MC3	2	Glaciolacustrine and Moraine deposits
LR-5	28	20	SC2	2	Glaciolacustrine and Moraine deposits
LR-6	20	0	MC4	1.4	Glaciolacustrine and Holocene Estuarine deposits

Table 8.5-5. Nested and tiered habitat mapping units, categories, and definitions.

Level	Unit	Category	Definitions
1	Major Hydrologic Segment	Upper, Middle, Lower River	Defined Segment Breaks *Upper River* - RM184-248 (*habitat mapping will only extend up to mainstem RM 233 and will include the Oshetna River.* *Middle River* - RM 98.5-184 *Lower River* - RM 0-98.5
2	Geomorphic Reach	Upper River Segment Geomorphic Reaches 1-6 Middle River Segment Geomorphic Reaches 1-8 Lower River Segment1 Geomorphic Reaches 1-6	Geomorphic reaches that uniquely divide the Major Hydrologic Segments based on geomorphic characteristics.
3	Mainstem Habitat	Main Channel Habitat Off-Channel Habitat Types2 Tributary Habitat	Main Channel Habitat: *Main Channel* – Single dominant main channel. *Split Main Channel* –Three or fewer distributed dominant channels. *Multiple Split Main Channel* – Greater than 3 distributed dominant channels. *Side Channel* – Channel that is turbid and connected to the active main channel but represents non-dominant proportion of flow[3]. *Tributary Mouth* - Clear water areas that exist where tributaries flow into Susitna River main channel or side channel habitats (upstream Tributary habitat will be mapped as a separate effort). Off-Channel Habitat: *Side Slough:* Overflow channel contained in the floodplain, but disconnected from the main channel. Has clear water.[3,4] *Upland Slough:* Similar to a side slough, but contains a vegetated bar at the head that is rarely overtopped by mainstem flow. Has clear water.[3,4] *Backwater:* Found along channel margins and generally within the influence of the active main channel with no independent source of inflow. Water is not clear. *Beaver Complex* – Complex ponded water body created by beaver dams. Tributary Habitat: Tributaries will be mapped to the upper limit of Susitna River hydrological influence.

Level	Unit	Category	Definitions
4	Main Channel and Tributary	Main Channel and Tributary Mesohabitat	<u>Main Channel Mesohabitat</u> *Pool* – slow water habitat with minimal turbulence and deeper due to a strong hydraulic control. *Glide* – An area with generally uniform depth and flow with no surface turbulence. Low gradient; 0-1% slope. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. Generally deeper than riffles with few major flow obstructions and low habitat complexity.[5] *Run* – A habitat area with minimal surface turbulence over or around protruding boulders with generally uniform depth that is generally greater than the maximum substrate size. [5] Velocities are on border of fast and slow water. Gradients are approximately 0.5% to less than 2%. Generally deeper than riffles with few major flow obstructions and low habitat complexity.[5] *Riffle* – A fast water habitat with turbulent, shallow flow over submerged or partially submerged gravel and cobble substrates. Generally broad, uniform cross-section. Low gradient; usually 0.5-2.0% slope.[5] *Rapid* - Swift, turbulent flow including small chutes and some hydraulic jumps swirling around boulders. Exposed substrate composed of individual boulders, boulder clusters, and partial bars. Lower gradient and less dense concentration of boulders and white water than Cascade. Moderate gradient; usually 2.0-4.0% slope.[5] <u>Tributary Mesohabitat:</u> Tributary mesohabitats within the hydrologic zone of influence will be typed using the classification system described in Table 9.9-3, above.
5	Edge Habitat	Length of Shoreline Habitat	*Calculation*- will be determined by doubling the length of the mapped habitat unit.

<u>Notes:</u>

1. For the purposes of this RSP, classification of the Lower River segment will stop at Level 2. A classification system for the Lower River segment is still in development pending determination of Project effects in the Lower River.
2. All habitat within this designation will receive an additional designation of whether water was clear or turbid within the database.
3. The terms Side Channel, Slough, and Upland Slough are similar but not necessarily synonymous with the terms for macrohabitat type as applied by Trihey (1982) and ADF&G (1983).
4. All slough habitat will have an associated area created during the mapping process to better classify size. A sub-sample of side sloughs and upland sloughs will be mapped to the mesohabitat level using the tributary habitat classifications system shown in Table 9.9-3
5. Adapted from Moore et al. 2006.

Table 8.5-6. Locations, descriptions and selection rationale of proposed Focus Areas for detailed study in the Middle River Segment of the Susitna River. Focus Area identification numbers (e.g., Focus Area 184) represent the truncated Project River Mile (PRM) at the downstream end of each Focus Area.

Focus Area ID	Common Name	Description	Geomorphic Reach	Location (PRM)		Area Length (mi)	Habitat Types Present							Fish use in 1980s		Instream Flow Studies in 1980s			Rationale for Selection
				Upstream	Downstream		Main Channel, Single	Main Channel, Split	Side Channel	Tributary Mouth	Side Slough	Upland Slough	Beaver Complex	Spawning	Rearing	IFG	DIHAB	RJHAB	
Focus Area-184	Watana Dam	Area approximately 1.4 miles downstream of dam site	MR-1	185.7	184.7	1.0	X	X	X					*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	Focus Area-184 length comprises 50% of MR-1 reach length (2 miles long) and contains split main channel and side channel habitat present in this reach.
Focus Area-173	Stephan Lake, Complex Channel	Wide channel near Stephan Lake with complex of side channels	MR-2	175.4	173.6	1.8	X		X	X	X			*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	Focus Area-173 contains a complex of main channel and off-channel habitats within wide floodplain. Represents greatest channel complexity within MR-2. Reach MR-2 is 15.5 miles long and channel is generally straight with few side channels and moderate floodplain width (2-3 main channel widths).
Focus Area-171	Stephan Lake, Simple Channel	Area with single side channel and vegetated island near Stephan Lake	MR-2	173.0	171.6	1.4	X		X	X				*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	The single main channel with wide bars, single side channel and moderate floodplain channel width in Focus Area-171 are characteristic of MR-2. Reach MR-2 channel morphology is generally straight with few side channels and moderate floodplain width (2-3 main channel widths).
Focus Area-151	Portage Creek	Single channel area at Portage Creek confluence	MR-5	152.3	151.8	0.5	X			X				X	X				Focus Area-151 is a single main channel and thus representative of the confined Reach MR-5. Portage Creek is a primary tributary of the Middle Segment and the confluence supports high fish use.
Focus Area-144	Side Channel 21	Side channel and side slough complex approximately 2.3 miles upstream Indian River	MR-6	145.7	144.4	1.3	X	X	X	X	X		X	X	X	X			Focus Area-144 contains a wide range of main channel and off-channel habitats, which are common features of Reach MR-6. Side Channel 21 is a primary salmon spawning area. Reach MR-6 is 26 miles long (30% of Middle Segment length) and is characterized by a wide floodplain and complex channel morphology with frequent channel splits and side channels.
Focus Area-141	Indian River	Area covering Indian River and upstream channel complex	MR-6	143.4	141.8	1.6	X	X	X	X		X	X	X	X		X		Focus Area-141 includes the Indian River confluence, which is a primary Middle Susitna River tributary, and a range of main channel and off-channel habitats. Channel and habitat types present in Focus Area-141 are typical of complex Reach MR-6. High fish use of the Indian River mouth has been documented and DIHAB modeling was performed in main channel areas.
Focus Area-138	Gold Creek	Channel complex including Side Channel 11 and Slough 11	MR-6	140.0	138.7	1.3	X	X	X		X	X	X	X	X	X			The Focus Area-138 primary feature is a complex of side channel, side slough and upland slough habitats, each of which support high adult and juvenile fish use. Complex channel structure of Focus Area-138 is characteristic of Reach MR-6. IFG modeling was performed in side channel habitats.
Focus Area-128	Skull Creek Complex	Channel complex including Slough 8A and Skull Creek side channel	MR-6	129.7	128.1	1.6	X	X	X	X	X			X	X	X	X		Focus Area-128 consists of side channel, side slough and tributary confluence habitat features that are characteristic of the braided MR-6 reach. Side channel and side slough habitats support high juvenile and adult fish use and habitat modeling was completed in side channel and side slough habitats.
Focus Area-115	Lane Creek	Area 0.6 miles downstream of Lane Creek, including Upland Slough 6A	MR-7	116.5	115.3	1.2	X	X	X			X	X		X	X		X	Focus Area-115 contains side channel and upland slough habitats that are representative of MR-7. Reach MR-7 is a narrow reach with few braided channel habitats. Upland Slough 6A is a primary habitat for juvenile fish and habitat modeling was done in side channel and upland slough areas.
Focus Area-104	Whiskers Slough	Whiskers Slough Complex	MR-8	106.0	104.8	1.2	X	X	X	X	X	X		X	X	X	X	X	Focus Area-104 contains diverse range of habitat, which is characteristic of the braided, unconfined Reach MR-8. Focus Area-104 habitats support juvenile and adult fish use and a range of habitat modeling methods were used in side channel and side slough areas.
Focus Area-*TBD*	*TBD*	Lower Susitna River *(TBD)*	*TBD*	*TBD*		*TBD*	*TBD*							*TBD*		*TBD*			*TBD*

Table 8.5-7. Partial list of river cross-sections, and flow and water surface elevations measured in 2012 on the Susitna River between River Miles 75 and 184. The list does not include additional measurements in late September/October. Those measurements had not been processed at the time this study plan was prepared.

River Mile[2]	High Q Trip			Medium Q Trip			Low Q Trip		
	Date	Q, cfs[3]	Gold Ck[4]	Date	Q, cfs[3]	Gold Ck[4]	Date	Q, cfs[3]	Gold Ck[4]
184.1	6/17/12	27,698	32,800	8/6/12	14,707	19,300	9/15/12	7,838	10,800
183.4	6/18/12	24,493	32,200	8/6/12	14,419	19,300	9/15/12	7,630	10,800
182.8	6/18/12	25,389	32,300	8/6/12	stage only5		9/15/12	stage only5	
182.6	6/19/12	26,676	34,400	8/6/12	stage only[5]		9/15/12	stage only[5]	
182.2	6/19/12	27,619	35,500	8/6/12	14,239	19,100	9/15/12	7,714	11,000
181.7	6/19/12	27,886	35,500	8/7/12	14,775	18,300	9/15/12	8,353	11,100
180.3	6/20/12	29,426	36,300	8/7/12	14,183	18,200	9/15/12	8,310	11,300
179.8	6/20/12	29,128	36,400	8/7/12	stage only[5]		9/15/12	stage only[5]	
178.9	6/20/12	29,645	36,200	8/7/12	14,705	18,200	9/15/12	8,689	11,500
176.8	6/21/12	30,866	37,500	8/7/12	14,345	18,100	9/14/12	8,361	10,100
176.1	6/16/12	29,756	36,900	8/7/12	14,799	18,000	9/14/12	8,738	10,000
173.9	6/21/12	31,240	37,500	8/8/12	14,559	17,300	9/16/12	10,768	16,500
172.0	6/21/12	31,163	37,300	8/8/12	stage only[5]		9/16/12	stage only[5]	
170.0	6/21/12	30,571	37,000	8/8/12	stage only[5]		9/16/12	11,082	17,200
167.0	6/22/12	31,121	36,700	8/8/12	14,568	17,200	9/16/12	11,137	17,600
164.5	6/22/12	32,265	36,700	8/8/12	14,655	17,300	9/17/12	14,619	20,200
150.2	6/25/12	32,162	35,900	8/10/12	14,588	16,800			
149.5	6/26/12	30,487	35,800	8/10/12	stage only[5]				
148.7	6/26/12	30,036	36,000	8/10/12	15,351	16,800	9/29/12	18,488	20,000
147.6	6/25/12	33,180	36,400	8/10/12	stage only[5]				
144.8	6/26/12	32,114	35,600	8/10/12	14,941	16,600			
143.2	6/27/12	31,030	34,400	8/12/12	stage only[5]				
142.3	6/27/12	31,396	34,500	8/12/12	17,354	18,100	9/29/12	18,131	19,800
142.1	6/27/12	31,868	34,800	8/12/12	stage only[5]				
141.5	6/27/12	31,949	35,100	8/12/12	stage only[5]				
140.8	6/27/12	31,121	35,000	8/12/12	stage only[5]				
140.2	6/28/12	30,330	32,900	8/12/12	17,006	18,100			
139.4	6/28/12	29,492	32,900	8/12/12	stage only[5]				
138.9	6/28/12	29,753	33,200	8/12/12	16,798	18,100	9/29/12	18,301	19,800
138.5	6/28/12	30,583	33,200	8/12/12	16,803	18,000			
138.2	6/28/12	30,555	33,300	8/12/12	stage only[5]				
136.7	6/29/12	30,378	32,300	8/13/12	16,350	17,800	9/30/12	17,619	17,800
136.4	6/29/12	29,071	32,200	8/13/12	stage only[5]				
135.7	6/30/12	28,039	31,000	8/13/12	16,449	17,700			
135.4	6/30/12	28,230	31,000	8/13/12	16,344	17,700			
134.7	6/30/12	28,203	31,000	8/13/12	stage only[5]				
134.3	6/30/12	27,893	31,000	8/13/12	16,409	17,600	9/30/12	17,382	17,700

River Mile[2]	High Q Trip			Medium Q Trip			Low Q Trip		
	Date	Q, cfs[3]	Gold Ck[4]	Date	Q, cfs[3]	Gold Ck[4]	Date	Q, cfs[3]	Gold Ck[4]
133.3	7/1/12	26,756	30,000	8/13/12	stage only[5]				
132.9	7/1/12	26,943	30,000	8/13/12	stage only[5]				
131.8	7/1/12	26,526	29,700	8/13/12	15,627	17,400			
131.2	7/2/12	25,463	28,000	8/13/12	stage only[5]		10/1/12	15,568	15,500
130.9	7/2/12	26,166	27,900	8/14/12	16,491	17,400			
130.5	7/2/12	25,715	28,000	8/14/12	16,275	17,300			
130.0	7/2/12	25,678	27,900	8/14/12	stage only[5]				
129.4	7/2/12	25,046	27,800	8/14/12	16,039	17,300			
128.1	7/3/12	28,628	31,200	8/14/12	stage only[5]				
126.6	7/3/12	28,243	30,900	8/14/12	16,330	17,300			
124.4	7/4/12	26,748	30,000	8/15/12	15,926	17,600			
123.3	7/4/12	27,608	29,900	8/15/12	16,078	17,600	10/1/12	15,582	15,400
122.6	7/5/12	27,248	28,800	8/15/12	stage only[5]				
121.8	7/5/12	26,427	28,500	8/15/12	stage only[5]				
120.7	7/5/12	26,132	27,900	8/15/12	16,161	17,600	10/1/12	15,582	15,300
120.3	7/6/12	23,875	24,700	8/15/12	stage only[5]				
119.3	7/6/12	23,331	24,100	8/15/12	stage only[5]				
119.2	7/6/12	22,890	24,000	8/15/12	16,287	17,600			
117.2	7/6/12	22,687	23,400	8/15/12	stage only[5]				
116.4	7/7/12	20,715	21,600	8/16/12	16,005	17,600	10/3/12	13,998	13,500
115.0	7/7/12	20,656	21,600	8/16/12	stage only[5]				
114.0	7/7/12	20,747	21,100	8/16/12	stage only[5]				
113.0	7/7/12	20,665	21,000	8/16/12	16,136	17,600	10/3/12	14,323	13,400
112.7	7/8/12	23,766	28,600	8/16/12	stage only[5]				
112.2	7/8/12	25,006	28,900	8/16/12	stage only[5]				
111.8	7/8/12	25,958	29,100	8/16/12	stage only[5]				
110.9	7/8/12	25,860	29,100	8/16/12	stage only[5]				
110.0	7/9/12	28,329	31,900	8/16/12	16,311	17,500	10/3/12	13,476	13,400
108.4	7/9/12	28,296	31,900	8/17/12	stage only[5]				
106.7	7/9/12	28,825	31,800	8/17/12	15,254	18,000	10/3/12	14,172	13,400
104.8				8/17/12	16,394	17,900			
103.0	7/9/12	28,409	31,600	8/18/12	15,508	16,300	10/4/12	14,558	13,700
102.4				8/18/12	15,278	16,100			
101.5				8/18/12	15,362	16,000			
101.0				8/18/12	15,377	16,000			
100.4				8/19/12	15,345	16,400			
99.8	7/10/12	26,635	26,900	8/19/12	stage only[5]				
99.6							10/4/12	14,575	13,700
95.0	7/11/12	46,499	22,600	8/20/12	40,623	16,600	10/5/12	39,065	13,800

River Mile[2]	High Q Trip			Medium Q Trip			Low Q Trip		
	Date	Q, cfs[3]	Gold Ck[4]	Date	Q, cfs[3]	Gold Ck[4]	Date	Q, cfs[3]	Gold Ck[4]
94.0	7/11/12	45,118	21,800	8/20/12	40,261	17,400			
87.7				8/21/12	46,330	18,500			
86.9	7/12/12	44,469	20,100	8/21/12	46,197	18,500			
84.6				8/22/12	41,697	18,200			
83.0	7/12/12	42,550	19,700	8/22/12	stage only[5]				
82.0	7/13/12	41,895	18,800	8/22/12	stage only[5]				
81.2				8/22/12	40,468	17,600			
80.0				8/23/12	36,933	16,100			
79.0	7/13/12	41,975	18,700	8/23/12	stage only[5]				
78.0				8/23/12	37,947	15,800			
76.0				8/24/12	36,503	16,200			

[1] Data are provisional pending final review and approval

[2] Approximate river mile to be superseded by new river mile system

[3] Provisional measured flow at cross-section location

[4] Provisional online flow data for USGS gaging station no. 15292000 (Susitna River at Gold Creek)

[5] Only stage was measured at these cross-sections.

Table 8.5-8. Summary of gaging stations established on Susitna River in 2012.

Gaging Station	Approximate River Mile	Segment
Susitna River near Cantwell (ESS80)	223.2	Upper Susitna River
Susitna River below Deadman Creek (ESS70)	184.0	Middle Susitna River (above Devils Canyon)
Susitna River below Fog Creek (ESS65)	173.9	
Susitna River above Devil Creek (ESS60)	164.3	
Susitna River above Portage Creek (ESS55)	148.6	Middle Susitna River (below Devils Canyon)
Susitna River at Curry (ESS50)	120.7	
Susitna River below Lane Creek (ESS45)	113.0	
Susitna River above Whiskers Creek (ESS40)	103.3	
Susitna River at Chulitna River (ESS35)	98.1	
Susitna River below Twister Creek (ESS30)	95.9	Lower Susitna River
Susitna River at Susitna Station (ESS20)	25.7	
Susitna River near Dinglishna Hill (ESS15)	19.9	
Susitna River below Flat Horn Lake (ESS10)	13.7	

Notes:

1. ESS = AEA Susitna River Surface-Water Station.

Table 8.5-9. Susitna Real-Time Reporting Network Stations.

Site Name	Short Name	Parameters
Upper Segment AEA Gaging Stations		
15291500 Susitna River Near Cantwell	ESS80	discharge, water level, water and air temperature, camera
Middle Segment AEA Gaging Stations		
Susitna River Below Deadman Creek	ESS70	discharge, water level, water and air temperature, camera
Susitna River Below Fog Creek	ESS65	discharge, water level, water and air temperature, camera
Susitna River Above Devil Creek	ESS60	discharge, water level, water and air temperature, camera
Susitna River Below Portage Creek	ESS55	discharge, water level, water and air temperature, camera
Susitna River at Curry	ESS50	discharge, water level, water and air temperature, camera
Susitna River Below Lane Creek	ESS45	discharge, water level, water and air temperature, camera
Susitna River Above Whiskers Creek	ESS40	discharge, water level, water and air temperature, camera
Susitna River at Chulitna River	ESS35	discharge, water level, water and air temperature, camera
Susitna River Below Twister Creek	ESS30	discharge, water level, water and air temperature, camera
Lower Segment AEA Gaging Stations		
15294350 Susitna River at Susitna Station	ESS20	discharge, water level, water and air temperature, camera
Susitna River Near Dinglishna Hill	ESS15	water level, water and air temperature, camera
Susitna River Below Flat Horn Lake	ESS10	water level, water and air temperature, camera
Repeater Stations		
Mount Susitna Near Granite Creek	ESR1	air temperature
Repeater, East of ESM1, First Potential Site	ESR2	air temperature
Repeater, Dam Site to Glacial Repeater	ESR3	air temperature
Curry Ridge near McKenzie Creek Repeater	ESR4	air temperature
Curry Pt. To State Park Repeater	ESR5	air temperature, camera
State Park over Devils Canyon Repeater	ESR6	air temperature, camera
Portage Creek Repeater	ESR7	air temperature
ESR2 to ESS80, ESM2 link	ESR8	air temperature
Base Stations		
Talkeetna Base Station	ESB2	N/A

Notes:

1. ESS = AEA Susitna River Surface-Water Station.
2. ESR = AEA Susitna River Repeater Station
3. ESB = AEA Susitna River Base Station

Table 8.5-10. Period of record of flows measured by the USGS on the Susitna River.

Gage Number	Site	Approximate River Mile	Drainage Area (mi^2)	Latitude	Longitude	Elevation (ft, NGVD 29)	Period of Record of Measured Flows
15291000	Susitna River near Denali	290.6	950	63.10389	147.51583	2,440	27 years: 1957-1976; 1978-1986
15291500	Susitna River near Cantwell	223.2	4,140	62.69861	147.54500	1,900	17 years: 1961-1972; 1980-1986
15292000	Susitna River at Gold Creek	136.6	6,160	62.76778	149.69111	677	57 years: 1949-1996; 2001-2011
15292780	Susitna River at Sunshine	83.9	11,100	62.17833	150.17500	270	5 years: 1981-1986
15294350	Susitna River at Susitna Station	25.8	19,400	61.54472	150.51250	40	19 years: 1974-1993

Table 8.5-11. Period of record of flows measured by the USGS on tributaries of the Susitna River.

Gage Number	Site	Approximate River Mile in Susitna River at Confluence	Drainage Area (mi^2)	Latitude	Longitude	Elevation (ft, NGVD 29)	Period of Record of Measured Flows
15291200	Maclaren River near Paxson	259.7	280	63.11944	146.52917	2,866	28 years: 1958-1986
15292400	Chulitna River near Talkeetna	98.0	2,570	62.55861	150.23389	520	20 years: 1958-1972; 1980-1986
15292700	Talkeetna River near Talkeetna	97.0	1,996	62.34694	150.01694	400	47 years: 1964-2011
15294005	Willow Creek Near Willow	48.4	166	61.78083	149.88444	350	25 years: 1978-1993; 2001-2011
15294345	Yentna River near Susitna Station	27.6	6,180	61.69861	150.65056	80	6 years: 1980-1986

Table 8.5-12. List of 33 Index of Hydrologic Alteration (IHA) parameters (The Nature Conservancy 2009).

IHA Parameter Group	Hydrologic Parameters	Ecosystem Influences
1. Magnitude of monthly water conditions	Mean or median value for each calendar month *Subtotal 12 parameters*	• Habitat availability for aquatic organisms • Soil moisture availability for plants • Availability of water for terrestrial animals • Availability of food/cover for forbearing mammals • Reliability of water supplies for terrestrial animals • Access by predators to nesting sites • Influences water temperature, oxygen levels, photosynthesis in water column
2. Magnitude and duration of annual extreme water conditions	Annual minima, 1-day mean Annual minima, 3-day means Annual minima, 7-day means Annual minima, 30-day means Annual minima, 90-day Means Annual maxima, 1-day mean Annual maxima, 3-day means Annual maxima, 7-day means Annual maxima, 30-day means Annual maxima, 90-day means Number of zero-flow days Base flow: 7-day minimum flow/mean flow for year *Subtotal 12 parameters*	• Balance of competitive, ruderal, and stress-tolerant organisms • Creation of sites for plant colonization • Structuring of aquatic ecosystems by abiotic vs. biotic factors • Structuring of river channel morphology and physical habitat conditions • Soil moisture stress in plants • Dehydration in animals • Anaerobic stress in plants • Volume of nutrient exchanges between rivers and floodplains • Duration of stressful conditions such as low oxygen and concentrated chemicals in aquatic environments • Distribution of plant communities in lakes, ponds, floodplains • Duration of high flows for waste disposal, aeration of spawning beds in channel sediments
3. Timing of annual extreme water conditions	Julian date of each annual 1-day maximum Julian date of each annual 1-day minimum *Subtotal 2 parameters*	• Compatibility with life cycles of organisms • Predictability/avoidability of stress for organisms • Access to special habitats during reproduction or to avoid predation • Spawning cues for migratory fish • Evolution of life history strategies, behavioral mechanisms
4. Frequency and duration of high and low pulses	Number of low pulses within each Water Year Mean or median duration of low pulses (days) Number of high pulses within each Water Year Mean or median duration of high pulses (days) *Subtotal 4 parameters*	• Frequency and magnitude of soil moisture stress for plants • Frequency and duration of anaerobic stress for plants • Availability of floodplain habitats for aquatic organisms • Nutrient and organic matter exchanges between river and floodplain • Soil mineral availability • Access for waterbirds to feeding, resting, reproduction sites • Influences bedload transport, channel sediment textures, and duration of substrate disturbance (high pulses)
5. Rate and frequency of water condition changes	Rise rates: Mean or median of all positive differences between consecutive daily values Fall rates: Mean or median of all negative differences between consecutive daily values Number of hydrologic reversals *Subtotal 3 parameters* *Grand total 33parameters*	• Drought stress on plants (falling levels) • Entrapment of organisms on islands, floodplains (rising levels) • Desiccation stress on low-mobility streamedge (varial zone) organisms

Table 8.5-13. List of 34 Environmental Flow Component (EFC) parameters (The Nature Conservancy 2009).

EFC Type	Hydrologic Parameters	Ecosystem Influences
1. Monthly low flows	Mean or median values of low flows during each calendar month *Subtotal 12 parameters*	• Provide adequate habitat for aquatic organisms • Maintain suitable water temperatures, dissolved oxygen, and water chemistry • Maintain water table levels in floodplain, soil moisture for plants • Provide drinking water for terrestrial animals • Keep fish and amphibian eggs suspended • Enable fish to move to feeding and spawning areas • Support hyporheic organisms (living in saturated sediments)
2. Extreme low flows	Frequency of extreme low flows during each Water Year or season Mean or median values of extreme low flow event: • Duration (days) • Peak flow (minimum flow during event) • Timing (Julian date of peak flow) *Subtotal 4 parameters*	• Enable recruitment of certain floodplain plant species • Purge invasive, introduced species from aquatic and riparian communities • Concentrate prey into limited areas to benefit predators
3. High flow pulses	Frequency of high flow pulses during each Water Year or season Mean or median values of high flow pulse event: • Duration (days) • Peak flow (maximum flow during event) • Timing (Julian date of peak flow) • Rise and fall rates *Subtotal 6 parameters*	• Shape physical character of river channel, including pools, riffles • Determine size of streambed substrates (sand, gravel, cobble) • Prevent riparian vegetation from encroaching into channel • Restore normal water quality conditions after prolonged low flows, flushing away waste products and pollutants • Aerate eggs in spawning gravels, prevent siltation
4. Small floods	Frequency of small floods during each Water Year or season Mean or median values of small flood event: • Duration (days) • Peak flow (maximum flow during event) • Timing (Julian date of peak flow) • Rise and fall rates *Subtotal 6 parameters*	Applies to small and large floods: • Provide migration and spawning cues for fish • Trigger new phase in life cycle (i.e., insects) • Enable fish to spawn in floodplain, provide nursery area for juvenile fish • Provide new feeding opportunities for fish, waterfowl • Recharge floodplain water table • Maintain diversity in floodplain forest types through prolonged inundation (i.e., different plant species have different tolerances) • Control distribution and abundance of plants on floodplain • Deposit nutrients on floodplain
5. Large floods	Frequency of large floods during each Water Year or season Mean or median values of large flood event: • Duration (days) • Peak flow (maximum flow during event) • Timing (Julian date of peak flow) • Rise and fall rates *Subtotal 6 parameters* *Grand total 34 parameters*	Applies to small and large floods: • Maintain balance of species in aquatic and riparian communities • Create sites for recruitment of colonizing plants • Shape physical habitats of floodplain • Deposit gravel and cobbles in spawning areas • Flush organic materials (food) and woody debris (habitat structures) into channel • Purge invasive, introduced species from aquatic and riparian communities • Disburse seeds and fruits of riparian plants • Drive lateral movement of river channel, forming new habitats (secondary channels, oxbow lakes) • Provide plant seedlings with prolonged access to soil moisture

Table 8.5-14. Schedule for implementation of the Fish and Aquatics Instream Flow Study.

Activity	2012				2013				2014				2015	
	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2
8.5.2 Existing Information and Need for Additional Information									Δ				▲	
8.5.4.2 River Stratification and Study Area Selection														
Compile aquatic habitat (RSP Sec 9.09) and geomorphology (see Section 6.8.4) characterization study results														
Identify proposed Focus Areas														
Refine Focus Areas and identify supplementary areas if needed for any underrepresented habitats														
TWG confirmation of study areas														
Review available data and modify or add Focus Areas and supplementary sampling areas									Δ					
TWG review of proposed area weighting factors to extrapolate modeled to non-modeled areas														
TWG meeting on area weighting													▲	
8.5.4.3 Hydraulic Flow Routing														
Review 2012 transect data RM 184 to 75														
Develop draft mainstem (open-water) flow routing model														
Model verification using stage recorder data														
Identify need for additional data														
Distribute draft mainstem (open-water) routing model to TWG for review														
Collect additional channel and hydraulic data as needed														
Refine draft mainstem (open-water) flow routing model									Δ					
Use draft model to support IFS, water quality, geomorphology, and fisheries 2013-2014 study efforts														
Refine mainstem (open-water) routing model using 2013 and 2014 data														
Distribute final mainstem (open-water) routing model to TWG for review													▲	
Use final mainstem (open-water) routing model for scenario evaluations														

Activity	2012				2013				2014				2015	
	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2
8.5.4.4 Hydrologic Data Analysis														
Obtain existing daily flow records from USGS														
Obtain basin area calculations from GINA-UAF														
Calculate estimated trib accretion flows														
TWG review of hydrologic record of daily flow														
TWG review of representative years for modeling									Δ					
Collect 15-min stage records from mainstem, tribs and Focus Areas														
Develop hourly flow record for Focus Areas / other mainstem locations														
Develop hourly inflow for select tributaries														
Develop list of potential and recommended IHA-type parameters														
TWG review of selected IHA-type parameters														
Examine 2014 stage data and refine hydrologic record to support scenario evaluations														
TWG meeting to review complete hydrologic record													▲	
Use hydrologic record for scenario evaluations														
8.5.4.5 Habitat Suitability Criteria Development														
Use 1980s Susitna data and other existing HSC curves to develop draft species / life stage HSC curves for the Lower and Middle Susitna River														
Propose target HSC species, life stages, substrate and cover														
TWG meeting on HSC/HSI and data collection study details														
Conduct HSC/HSI summer surveys (snorkel, seining, electrofishing)														
Conduct fish HSC/HSI winter surveys (underwater camera, electrofishing)														
Conduct aquatic biota stranding and trapping surveys														
Coordinate and review adult/spawning HSC data collected by Fish and Aquatic biotelemetry (see Section 9.06)														
Distribute preliminary findings of winter surveys to TWG														

Activity	2012				2013				2014				2015	
	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2
Distribute preliminary results of HSC/HSI surveys and changes to draft HSC/HSI									Δ					
TWG meeting on species and life stage HSC/HSI													▲	
Periodicity														
Review draft species and life stage periodicity data developed under Fish Distribution and Abundance (see Section 9.06)														
Identify specific HSC/HSI periodicity data needs														
Distribute HSC/HSI periodicity to TWG									Δ					
TWG meeting on HSC/HSI periodicity used to model scenarios													▲	
Review and discuss implementation details of flow-dependent biological cue study														
Distribute initial study results to TWG														
Report on flow-dependent biological cues									Δ					
8.5.4.6 Habitat-Specific Model Development														
Habitat Model Selection														
Propose habitat models for Focus Areas and supplemental area														
TWG review and meeting on habitat model selection									Δ					
Physical and Hydraulic Data Collection														
Collect data for digital terrain model														
Collect x-section and stage:discharge data at Focus Areas and supplemental areas														
Collect substrate/cover data at Focus Areas and supplemental areas														
Provide summaries of data collection efforts									Δ				▲	
Hydraulic Model Calibration													▲	
Aquatic Habitat Modeling									Δ				▲	
8.5.4.7 Temporal and Spatial Habitat Analyses													▲	
Develop proposed methods for completing temporal and spatial														

Activity	2012				2013				2014				2015	
	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2
analyses														
Review and discuss temporal and spatial analytical methods with TWG							—							
Distribute temporal and spatial analyses to TWG									Δ					
Apply temporal and spatial analytical methods										—	—	—	▲	→
Develop proposed methods for overall sensitivity analyses of habitat indicators							—	—						
Review methods for sensitivity and analyses with TWG								—	Δ					
Conduct overall sensitivity analyses of modeling outputs											—	—	▲	
8.5.4.8 Instream Flow Study Integration					—	—			—	—	—	—	▲	→
Reporting				—					Δ				▲	
Integrated Resource Analyses												—	—	→

<u>Legend:</u>

—— Planned Activity
------ Follow up activity (as needed)
Δ Initial Study Report
▲ Updated Study Report

Table 8.5-15. Common names, scientific names, life history strategies, and habitat use of fish species within the Lower, Middle, and Upper Susitna River, based on sampling during the 1980s (from HDR 2011).

Common Name	Scientific Name	Life History	Susitna Usage
Arctic grayling	*Thymallus arcticus*	F	O, R, P
Dolly Varden	*Salvelinus malma*	A,F	O, P
Humpback whitefish	*Coregonus pidschian*	A,F	O, R, P
Round whitefish	*Prosopium cylindraceum*	F	O, M2, P
Burbot	*Lota lota*	F	O, R, P
Longnose sucker	*Catostomus catostomus*	F	R, P
Sculpin	*Cottid spp.*	M1, F	P
Eulachon	*Thaleichthys pacificus*	A	M2, S
Bering cisco	*Coregonus laurettae*	A	M2, S
Threespine stickleback	*Gasterosteus aculeatus*	A,F	M2, S, R, P
Arctic lamprey	*Lethenteron japonicum*	A,F	O, M2, R, P
Chinook salmon	*Oncorhynchus tshawytscha*	A	M2, R
Coho salmon	*Oncorhynchus kisutch*	A	M2, S, R
Chum salmon	*Oncorhynchus keta*	A	M2, S
Pink salmon	*Oncorhynchus gorbuscha*	A	M2
Sockeye salmon	*Oncorhynchus nerka*	A	M2, S
Rainbow trout	*Oncorhynchus mykiss*	F	O, M2, P
Northern pike	*Esox lucius*	F	P
Lake trout	*Salvelinus namaycush*	F	U
Pacific lamprey	*Lampetra tridentata*	A,F	U
Alaska blackfish	*Dallia pectoralis*	F	U

Notes:

A = anadromous
M1 = marine
F = freshwater
O=overwintering
R=rearing
P=present
M2 = migration
S=spawning
U=unknown

Table 8.5-16. Site-specific habitat suitability measurements recorded during 2012 at Middle and Lower Susitna River sampling sites, by fish life stage.

Susitna River Segment	River Mile	Site Name	Habitat Type	Fish Life Stage	Number of Observations
Middle	178.3	178.3R	Side Channel	Fry	6
				Juvenile	4
				Adult	5
Middle	176.6	Fog Creek mouth	Tributary Mouth	Fry	4
				Adult	1
Middle	174.2	174.2L	Mainstem	N/A	0
Middle	144.4	Slough 22	Side Slough	Fry	5
				Adult	1
Middle	141.8	Slough 21	Side Slough	N/A	0
Middle	141.2	Side Channel 21	Side Channel	Fry	9
				Adult	7
Middle	138.6	Indian River Mouth	Tributary Mouth	Fry	11
				Adult	8
Middle	135.6	Slough 11	Side Slough	Adult	8
Middle	133.9	Slough 10	Upland Slough	N/A	0
Middle	133.7	Slough 9A	Side Slough	Adult	19
Middle	131.2	Unnamed Side Channel	Side Channel	Adult	11
Middle	131.1	4th of July Creek Mouth	Tributary Mouth	Fry	3
				Adult	8
Middle	128.8	Slough 9	Side Slough	Adult	15
Middle	125.3	Skull Creek	Side Slough	Adult	26
Middle	122.5	Slough 8B	Side Slough	N/A	0
Middle	121.0	Tulips Creek mouth	Tributary Mouth	N/A	0
Middle	115.0	115.0R	Side Channel	Fry	2
Middle	113.7	Slough 8	Side Slough	Fry	4
				Juvenile	1
Middle	113.6	Lane Cr Mouth	Tributary Mouth	Fry	2
				Adult	1
Middle	112.5	Slough 6A	Upland Slough	Fry	15
Middle	101.4	Whiskers Slough	Side Slough	Fry	13
				Adult	3
Middle	101.4	Whiskers Creek Mouth	Tributary Mouth	Fry	12
Lower	95.4	Cache Creek slough	Side Slough	Fry	6
				Juvenile	1
Lower	95.4	Unnamed Side Channel	Side Channel	Fry	4
				Juvenile	1
Lower	93.5	Unnamed Side Channel	Side Channel	Fry	4

Susitna River Segment	River Mile	Site Name	Habitat Type	Fish Life Stage	Number of Observations
				Juvenile	1
Lower	91.6	Trapper Creek Side Channel	Side Channel	Fry	12
				Juvenile	4
Lower	91.5	Trapper Creek	Tributary Mouth	Fry	4
Lower	91.5	Birch Slough	Side Slough	Fry	2
	89.2	Birch Slough	Side Slough	Fry	1
Lower	85.2	Sunshine Creek Side Channel	Side Channel	Fry	13
				Juvenile	3
Lower	85.1	Sunshine Creek	Tributary Mouth	Fry	18
Lower	83.1	Rabideux Creek	Tributary Mouth	N/A	0
Lower	77.0	Montana Creek	Tributary Mouth	Adult	7
			Side Channel	Adult	10

Table 8.5-17. Proposed substrate classification system for use in development of HSC/HSI curves for the Susitna-Watana Project (adapted from Wentworth 1922).

Substrate Code	Substrate Type	Size (Decimal Inches)	Size (mm)
1	Silt, Clay, or Organic	<0.01	<0.1
2	Sand	0.01-0.10	0.1-2.0
3	Small Gravel	0.10-0.30	2.0-8.0
4	Medium Gravel	0.30-1.25	8.0-32
5	Large Gravel	1.25-2.50	32-64
6	Small Cobble	2.50-5.0	64-128
7	Large Cobble	5.0-10.0	128-256
8	Boulder	>10.0	>256
9	Bedrock		

Table 8.5-18. Example of table that will be developed as part of the stranding and trapping analyses to illustrate the frequency of potential stranding and trapping events by month for a given Project operational scenario.

	Existing Condition												Operating Scenario 1												Operating Scenario 2											
Evaluation Indicator	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
>1"/hour																																				
>2"/hour																																				
>4"/hour																																				

Table 8.5-19. Assessment of physical and biological processes and potential habitat modeling techniques.

Physical and Biological Processes	Habitat Types			
	Mainstem	Side Channel	Slough	Tributary Mouths
Spawning	PHAB/VZM	PHAB	PHAB/HabMap	PHAB/RFR
Incubation	RFR/VZM	PHAB	PHAB/HabMap	PHAB/RFR
Juvenile Rearing	PHAB/RFR	PHAB	PHAB/HabMap	PHAB/RFR
Adult Holding	RFR	RFR	PHAB/HabMap	PHAB/RFR
Macroinvertebrates	VZM/WP	VZM/WP	PHAB/HabMap/WP	N/A
Standing/Trapping	VZM	VZM	VZM/WP	VZM/WP
Upwelling/Downwelling	FLIR	HabMap/FLIR	HabMap/FLIR	HabMap/FLIR
Temperature	WQ	WQ	WQ	WQ
Ice Formation	IceProcesses/WQ/RFR	IceProcesses/WQ/RFR	HabMap/Open leads	N/A

Notes:

1. PHAB-Physical Habitat Simulation Modeling (1-D, 2-D, and empirical); VZM-Effective Spawning and Incubation/Varial Zone Modeling; RFR-River Flow Routing Modeling; FLIR – Forward-looking Infrared Imaging; HabMap-Surface Area Mapping; WQ-Water Quality Modeling; WP-Wetted Perimeter Modeling.

Table 8.5-20. Seasonal daylight and night downramping guidelines (Hunter 1992).

Season	Daylight Rates*	Night Rates
February 16 to June 15 (salmon fry)	No Ramping	2 inches/hour
June 16 to October 31 (steelhead and trout fry)	1 inch/hour	1 inch/hour
November 1 to February 15	2 inches/hour	2 inches/hour

Notes:

1. * Daylight is defined as 1 hour before sunrise to 1 hour after sunset.

Table 8.5-21. Conceptual Comparison of Multiple Resource Indicators of the Effects of Alternative Operational Scenarios for the Susitna-Watana Hydroelectric Project. Indicators to be coordinated with resource-specific working groups.

(Indicators provided for illustration purposes only)

		Existing Conditions (EC-01)	Scenario 1 (Ver. 1/20/15) (OS-01)	Scenario 2 (Ver. 02/14/15) (OS-02)	Scenario 3 (Ver. 02/14/15) (OS-03)
Run Description	Average monthly MIF(cfs)				
	Max generation Nov-Mar (cfs)				
	Min generation Nov-Mar (cfs)				
	Max generation Apr-Oct (cfs)				
	Min generation Apr-Oct (cfs)				
	Ramping Rates				
Evaluation Indicators					
Power	Weighted average generation Nov-Mar (MWh)⑤				
	Weighted average generation Apr-Oct (MWh)⑤				
	Weighted annual dependable capacity (MWh)⑤				
Hydrologic	Max 1-day flow (cfs) wet / avg /dry	wet / avg / dry	wet / avg / dry	wet / avg / dry	wet / avg / dry
	Min 2-day low, Nov-Mar (cfs)				
	Min 2-day low Jul-May as % of 2-day max Jul-Sep				
	Freshets (Apr-Jun) $[Qc]>1.5*[Q_{C-1}+Q_{C-2}+Q_{C-3}]/3$				
	Water Particle Travel Time, 25% exceedance, Apr-Jun				
	Other IHA statistics				
Reservoir	Average reservoir volume (KAF)	wet / avg /dry	wet / avg / dry	wet / avg / dry	wet / avg / dry
	Min 2-day reservoir volume (KAF)				
	Weighted annual euphotic zone (KAF)				
	Other Biological/recreation indicators				
Ramping	Weighted avg annual total, Middle Susitna, reach-averaged (ra) downramping events >1-inch pr hour⑤				
	Weighted average annual total, Middle Susitna, reach-averaged downramping events > 2-inch per hour⑤				
	Weighted average annual total, Middle Susitna, reach-averaged downramping events > 4-inches per hour ⑤				
Varial Zone	Median annual, MS, reach-averaged (ra) channel width-ft ⑤				
	Total varial zone, MS, 12-hr/12-hr, ra, median annual channel width-ft ⑤				
	Total varial zone, MS, 12-hr/7-day, ra, median annual channel width-ft ⑤				
	Total varial zone, MS, 12-hr/30-day, ra, median annual channel width-ft ⑤				

	Evaluation Indicators *(Indicators provided for illustration purposes only)*	Existing Conditions (EC-01)	Scenario 1 (Ver. 1/20/15) (OS-01)	Scenario 2 (Ver. 02/14/15) (OS-02)	Scenario 3 (Ver. 02/14/15) (OS-03)
Potential Salmon Habitat	Chum spawning habitat, Devils Canyon to Three Rivers Confluence (DCto3R) reach-averaged(ra), **gross channel width**, (ft)⑤				
	Chum **effective spawning/incubation**, DCto3R-reach-averaged (ra), channel width accounting for dewatering, groundwater/surface water interactions, water quality effects, **net width** (ft)⑤				
	Coho effective spawning/incubation, DCto3R-ra, **net width**, (ft)⑤				
	Sockeye effective spawning and incubation, DCto3R-ra, slough/side channel, **net width** (ft)⑤				
	Pink effective spawning/incubation, DCto3R-ra, slough/side channel, **net width** (ft)⑤				
	Coho juvenile habitat, open-water, DCto3R-ra, channel width (ft) ⑤				
	Coho juvenile habitat, ice-period, DCto3R-ra, channel width (ft) ⑤				
	Chinook juvenile habitat, ice-period, DCto3R-ra, slough/side channel width (ft) ⑤				
Other Fish	Grayling average minimum spawning, Watana Dam to Devils Canyon (DtoDC), reach averaged WUA, (ft^2)⑤				
	Northern pike effective spawning and incubation, DCto3R-reach averaged slough/side channel net width (ft)⑤				
Riparian	Wet meadow area, reach averaged, DC to3R, post-licensing yrs 10-20 (acres)⑤				
	Scrub thickets, reach averaged, DC to 3R, post-licensing yrs 10-20 (acres)⑤				
	Floodplain plant community colonization area, reach averaged, DC to 3R, post-licensing yrs 10-20 (acres)⑤				
	Other riparian indicators				
Recreation	Devils Canyon to 3R, tour boat accessible, May to Sep (days)				
	Three Rivers to Sunshine, days channel exceeds minimum boating depth, May to Sep				
	Devils Canyon to 3 R, upstream extent of January ice cover for snow machine travel				
	Other recreation/access indicators				
Other Aquatics	Other potential indicators of Project effects such as: ▫ minimum slough area, ▫ percent of river length mobilized-D_{25} ▫ downstream extent of ice-free zone, ▫ 30-day wetted euphotic streambed, ▫ other reaches, seasons, life stages, mesohabitats to be determined in consultation with TWG				

Notes:

1. Average of five select years weighted by likelihood of occurrence (Dry Year* 0.077, Somewhat Dry Year* 0.231, Average Year * 0.462, Somewhat Wet Year * 0.115, Wet Year*0.115) (values are for illustration purposes only)

8.5.10. Figures

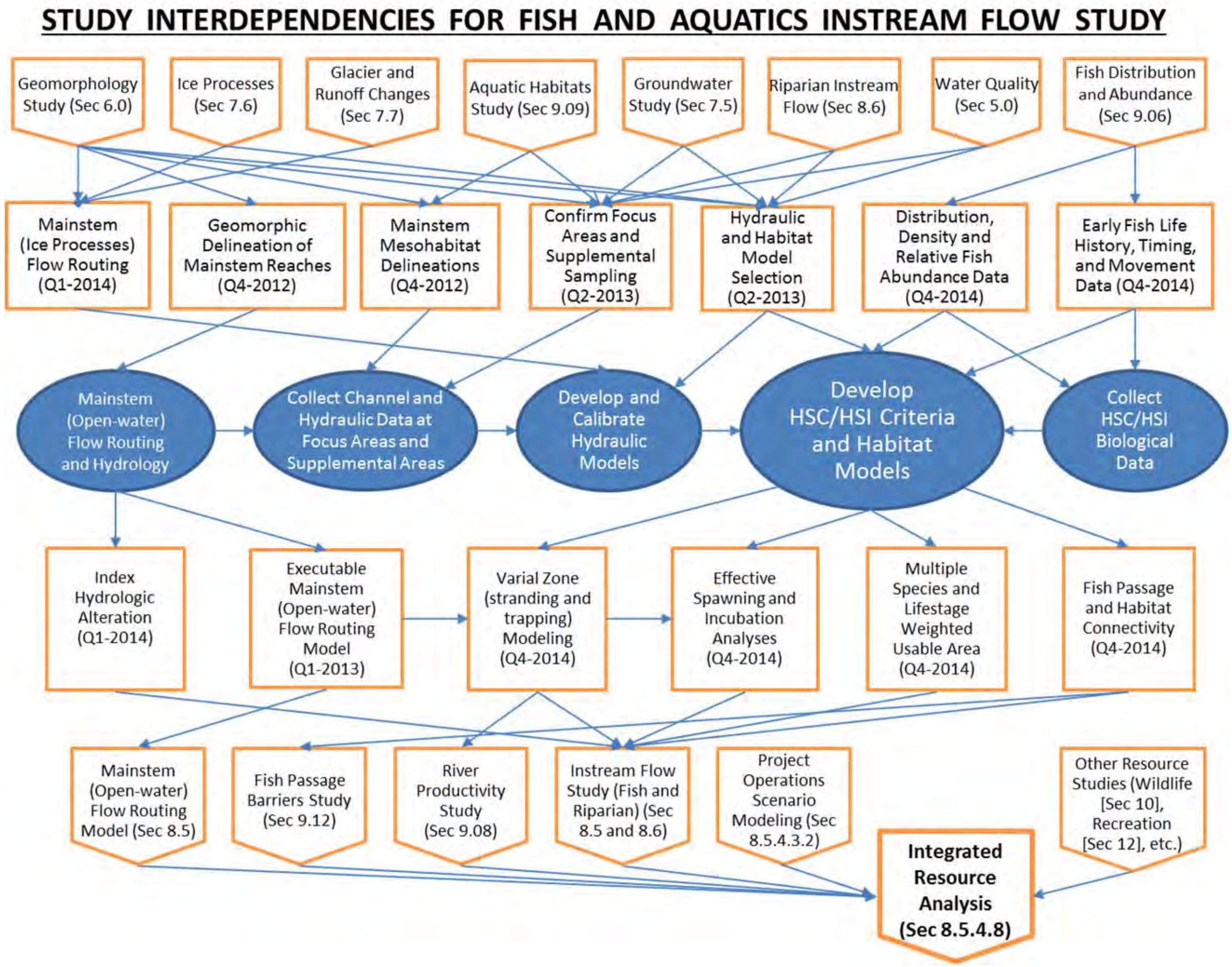


Figure 8.5-1. Study interdependencies for Fish and Aquatics Instream Flow Study.

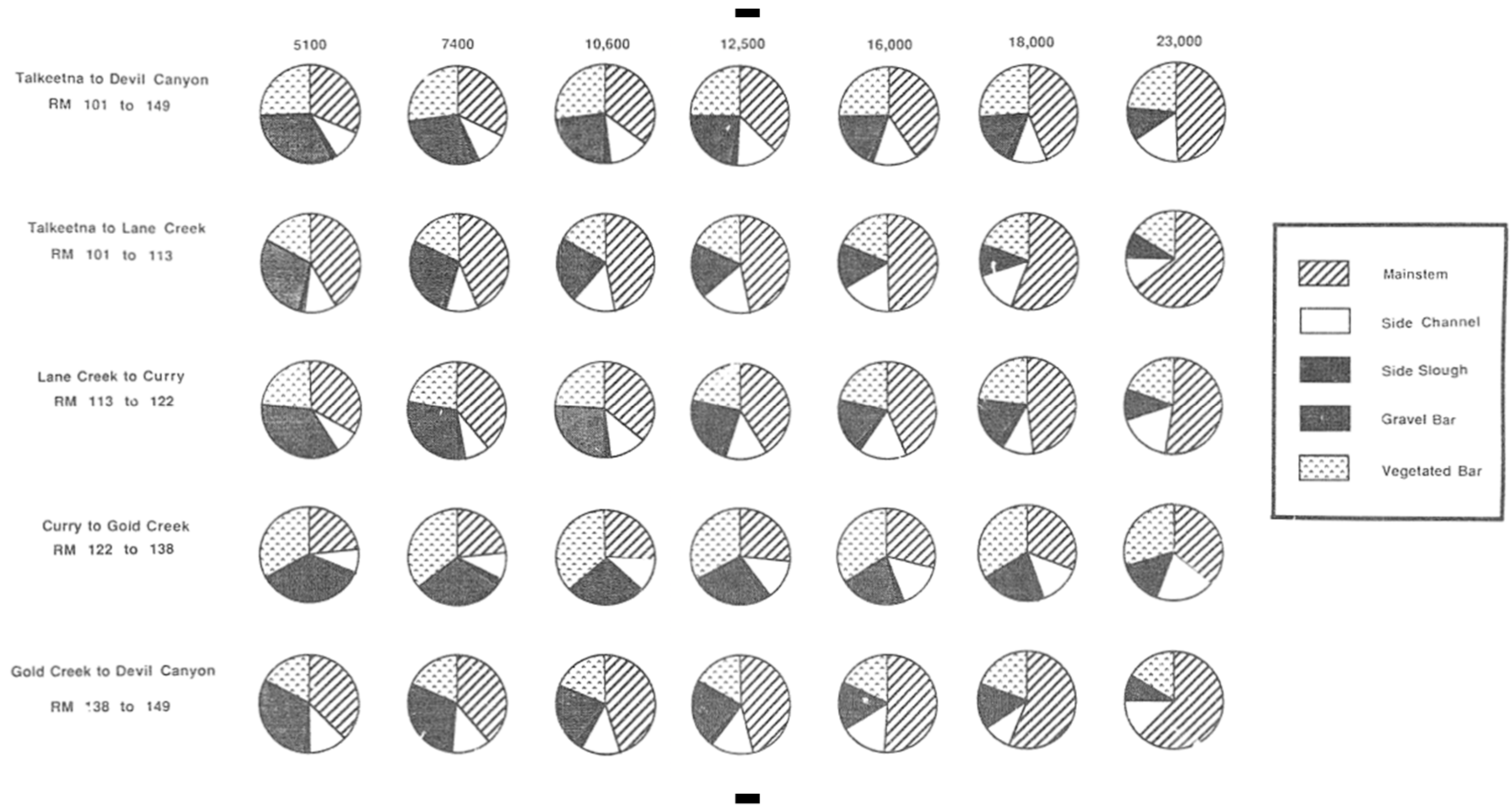


Figure 8.5-2. Relative amounts of habitat types in different areas of the Susitna River at seven mainstem discharges. Source: Klinger-Kingsley et al. (1985).

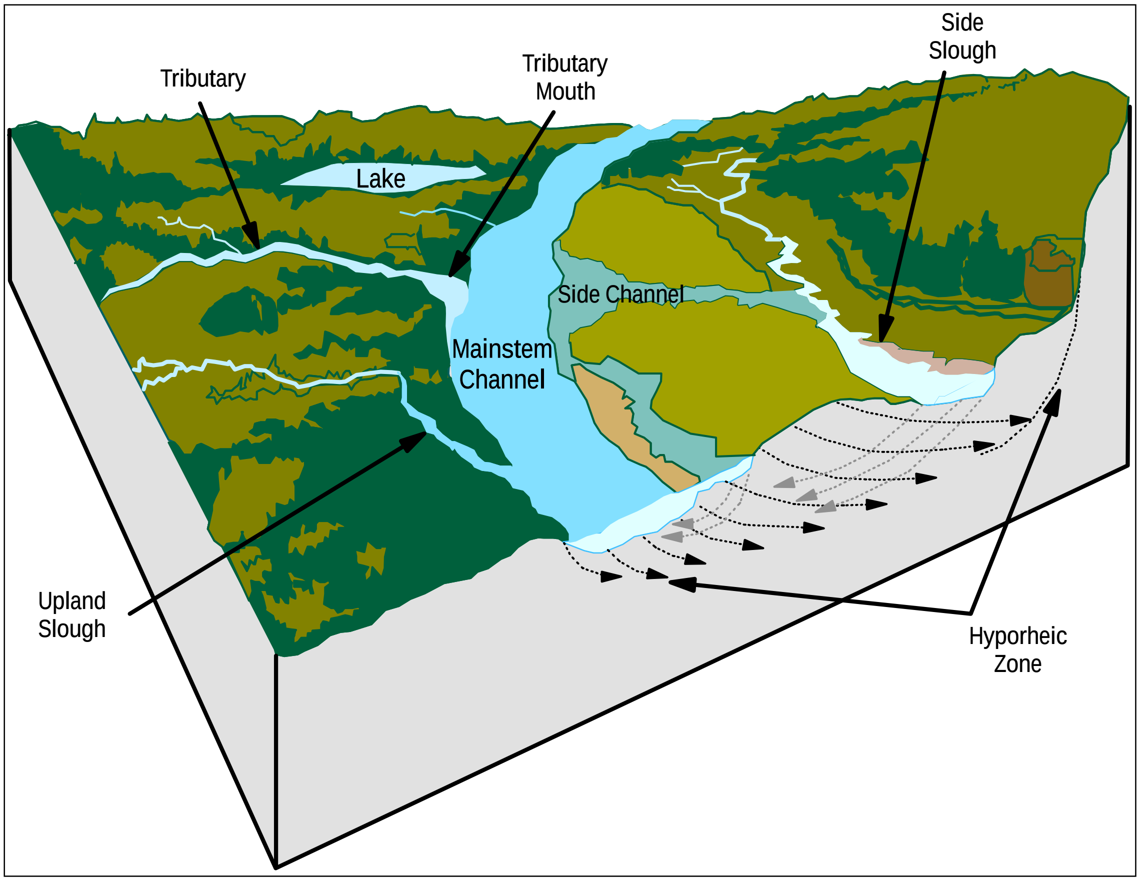


Figure 8.5-3. Habitat types identified in the middle reach of the Susitna River during the 1980s studies (adapted from ADF&G 1983; Trihey 1982).

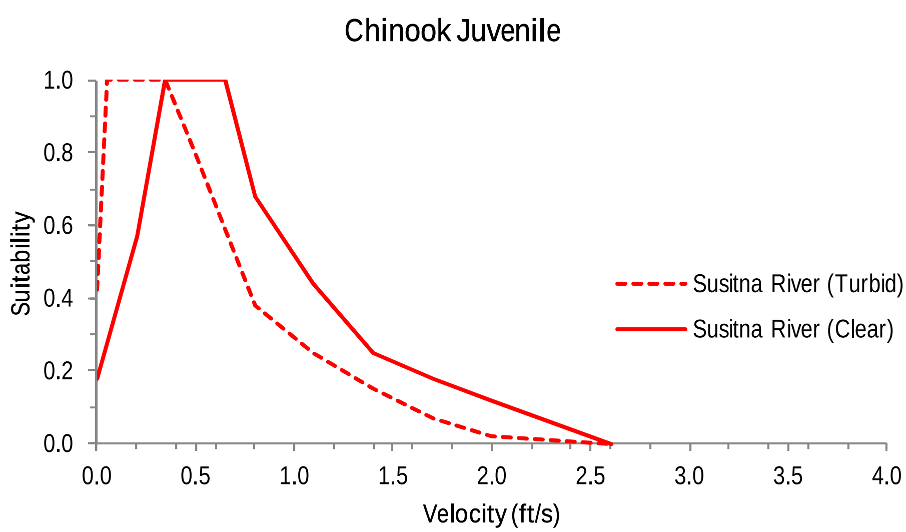


Figure 8.5-4. Example HSC curves for rearing juvenile Chinook salmon in the Middle Susitna River developed during the 1980s instream flow studies. Source: Suchanek et al. 1984b.

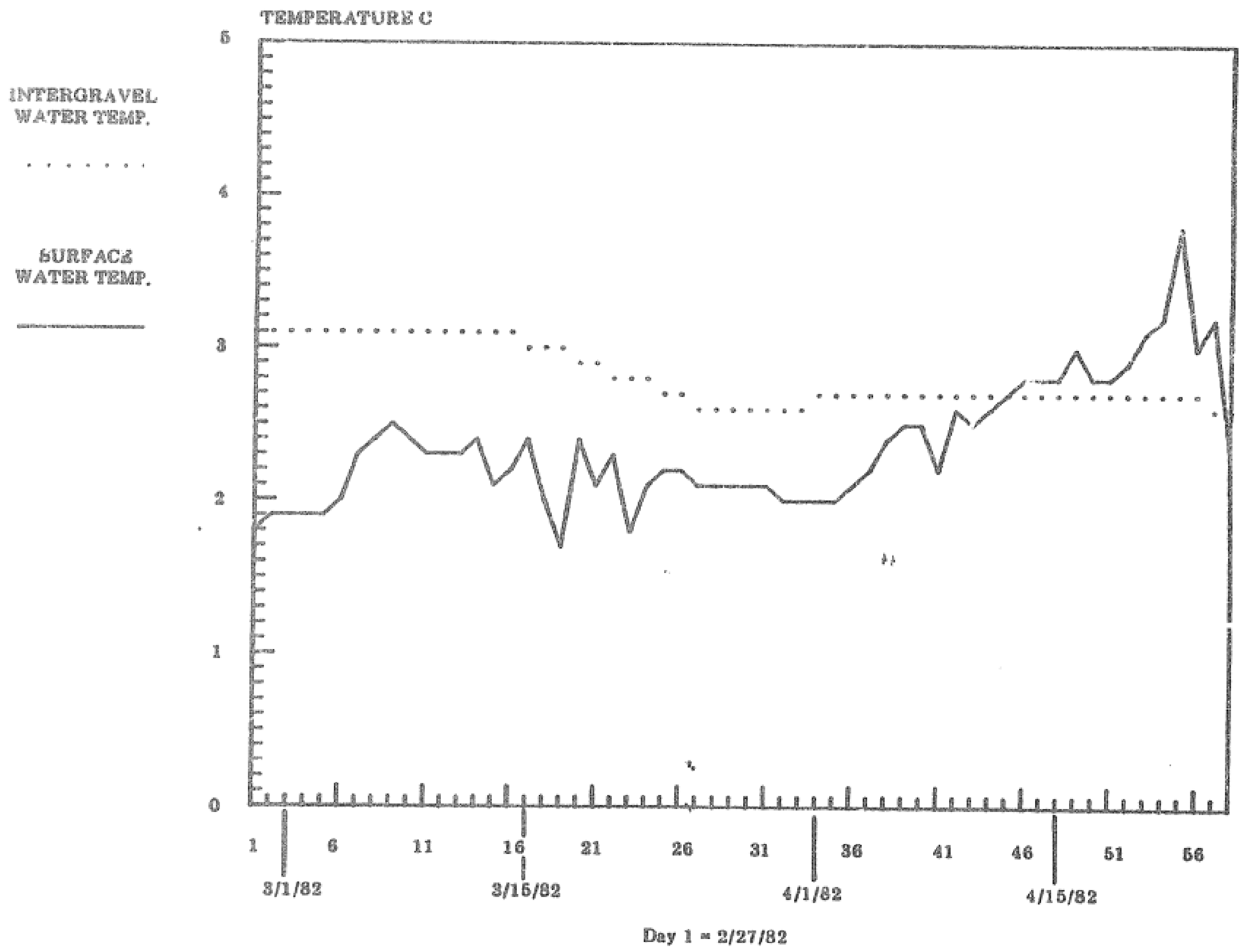


Figure 8.5-5. Mean daily intergravel and surface water temperature data from a spawning site in Skull Creek. Source: Trihey (1982).

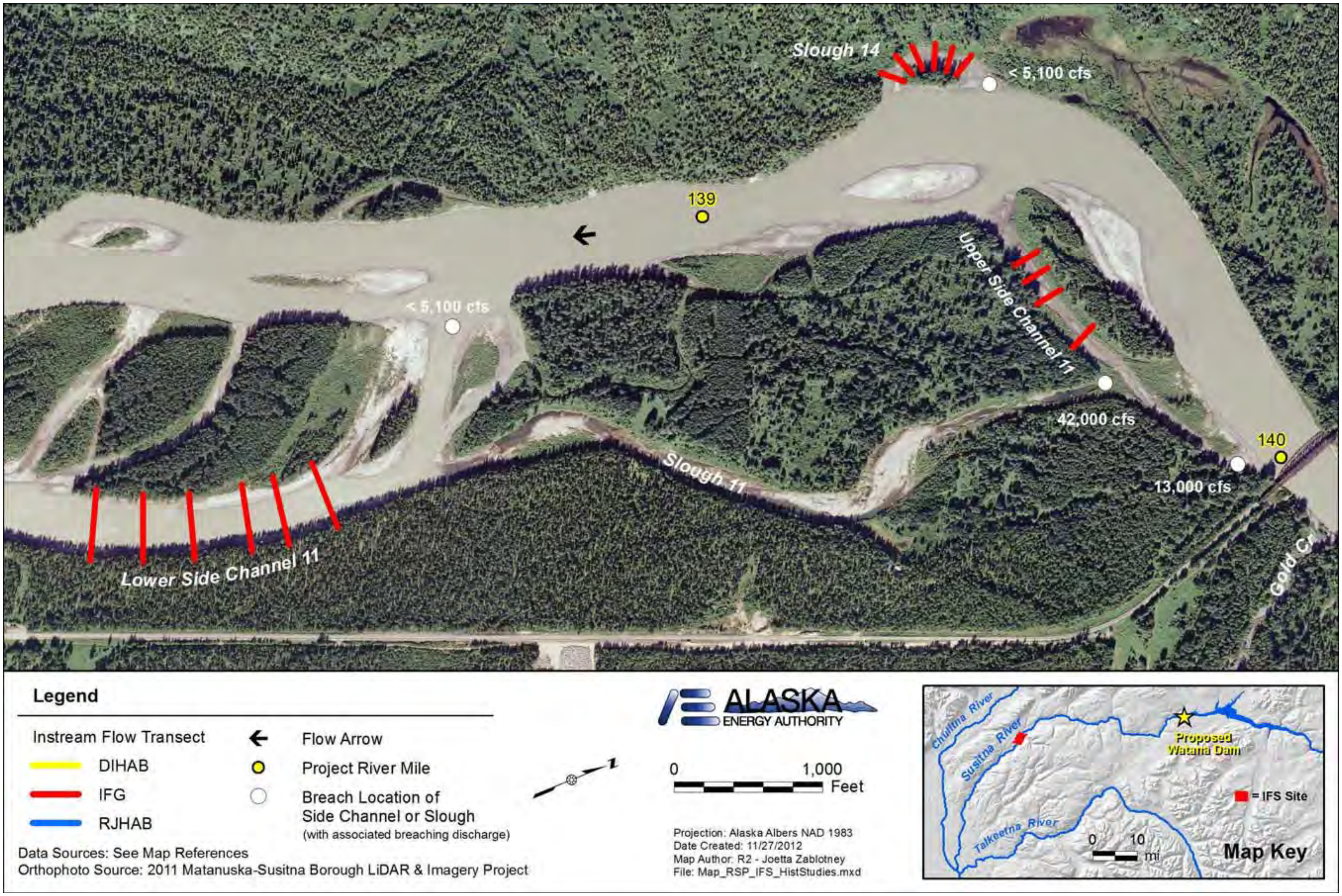


Figure 8.5-6. Locations of instream flow transects and model types applied during the 1980s Su-Hydro studies in lower and upper Side Channel 11 and in Slough 11, located near Gold Creek. Breaching flows based on those studies are also depicted for various side channel and side slough habitats.

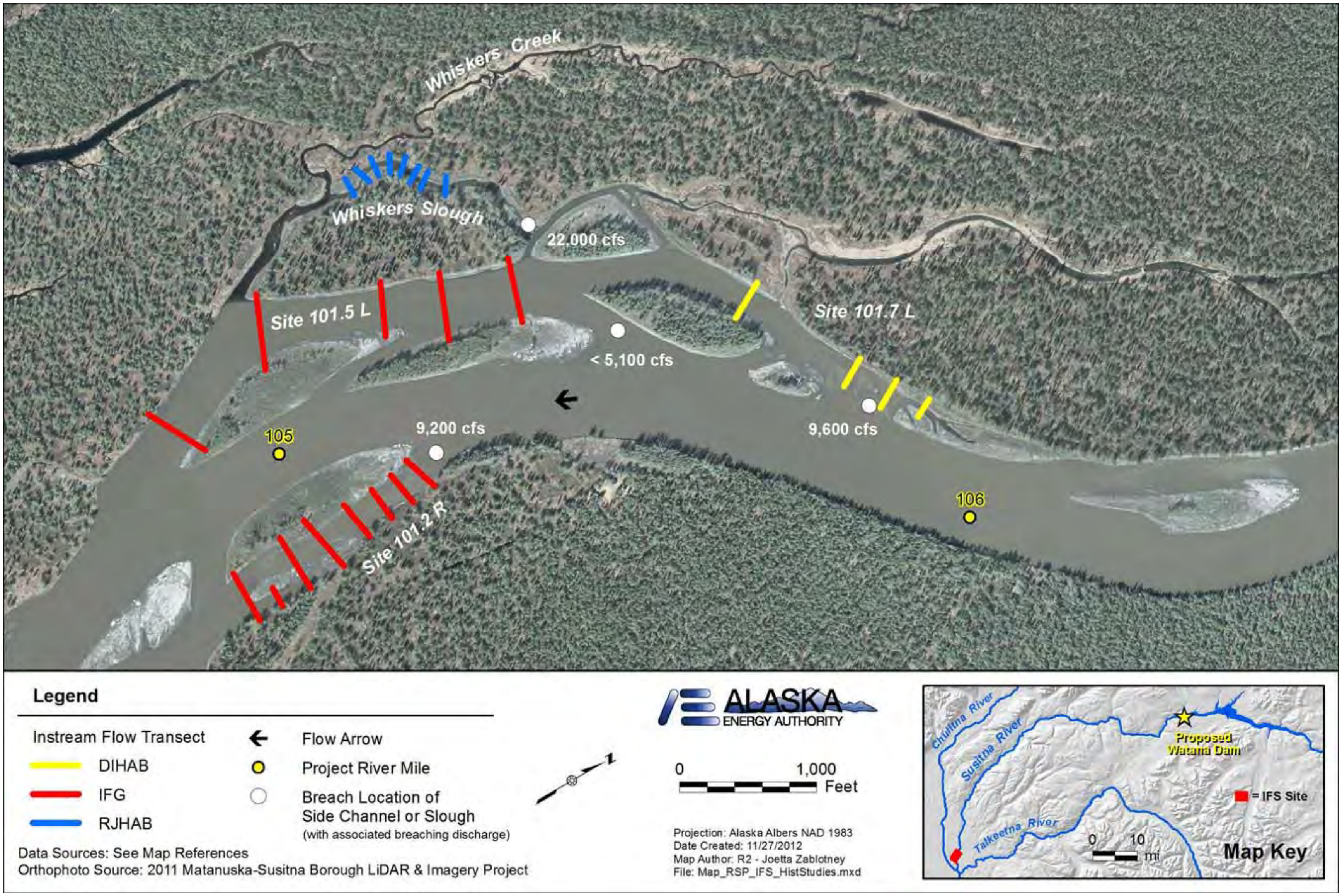


Figure 8.5-7. Locations of instream flow transects and model types applied during the 1980s Su-Hydro studies in the Whiskers Slough complex. Breaching flows based on those studies are also depicted for various side channel and side slough habitats.

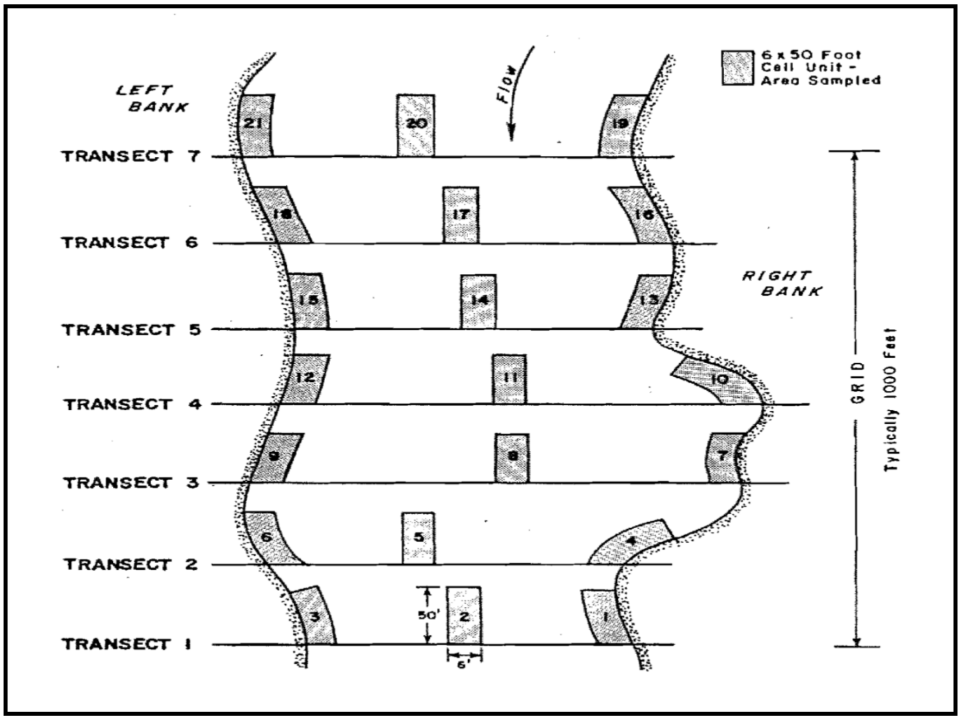


Figure 8.5-8. Transects and shoreline and mid-channel sampling cells associated with RJHAB modeling (Marshall et al. 1984).

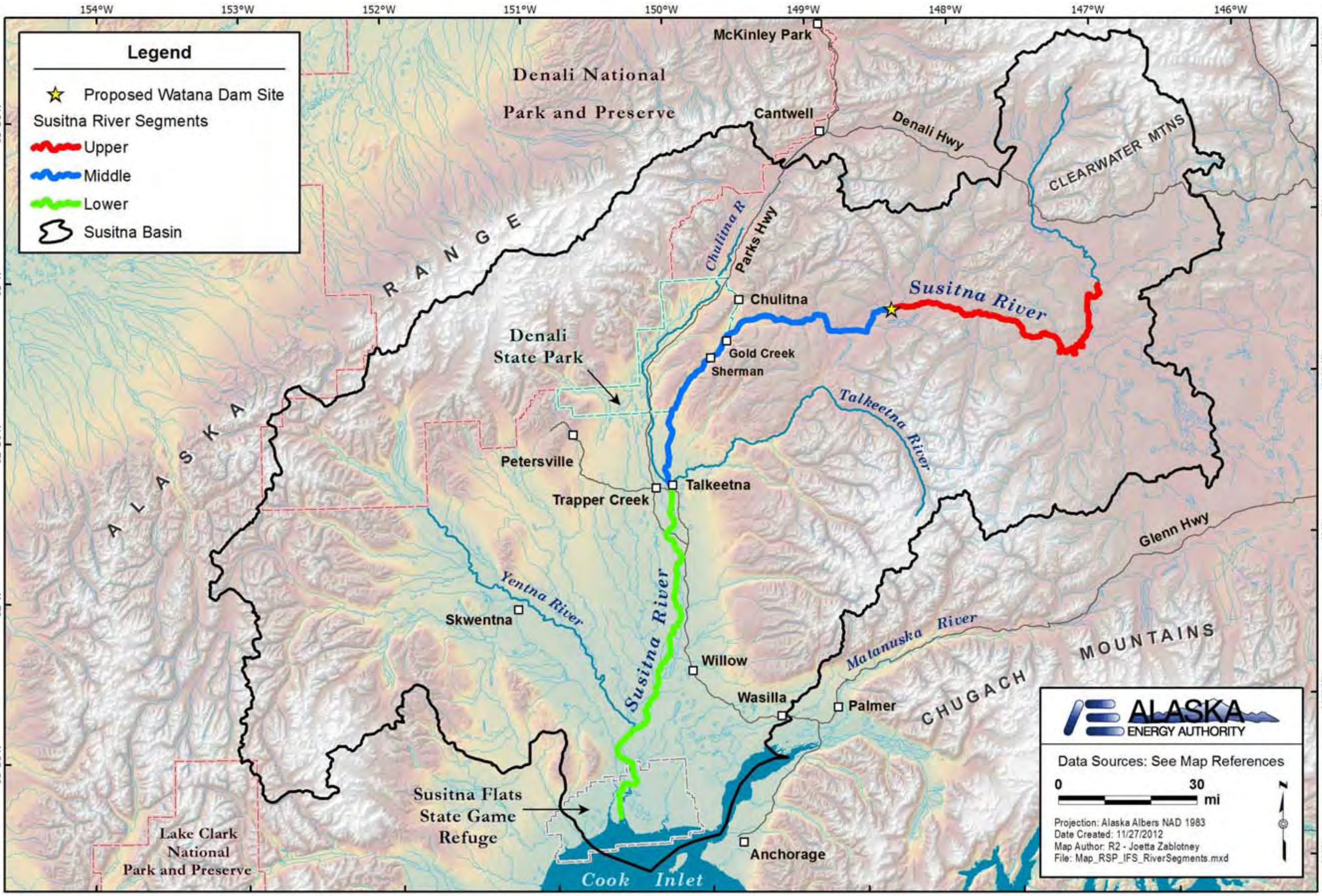
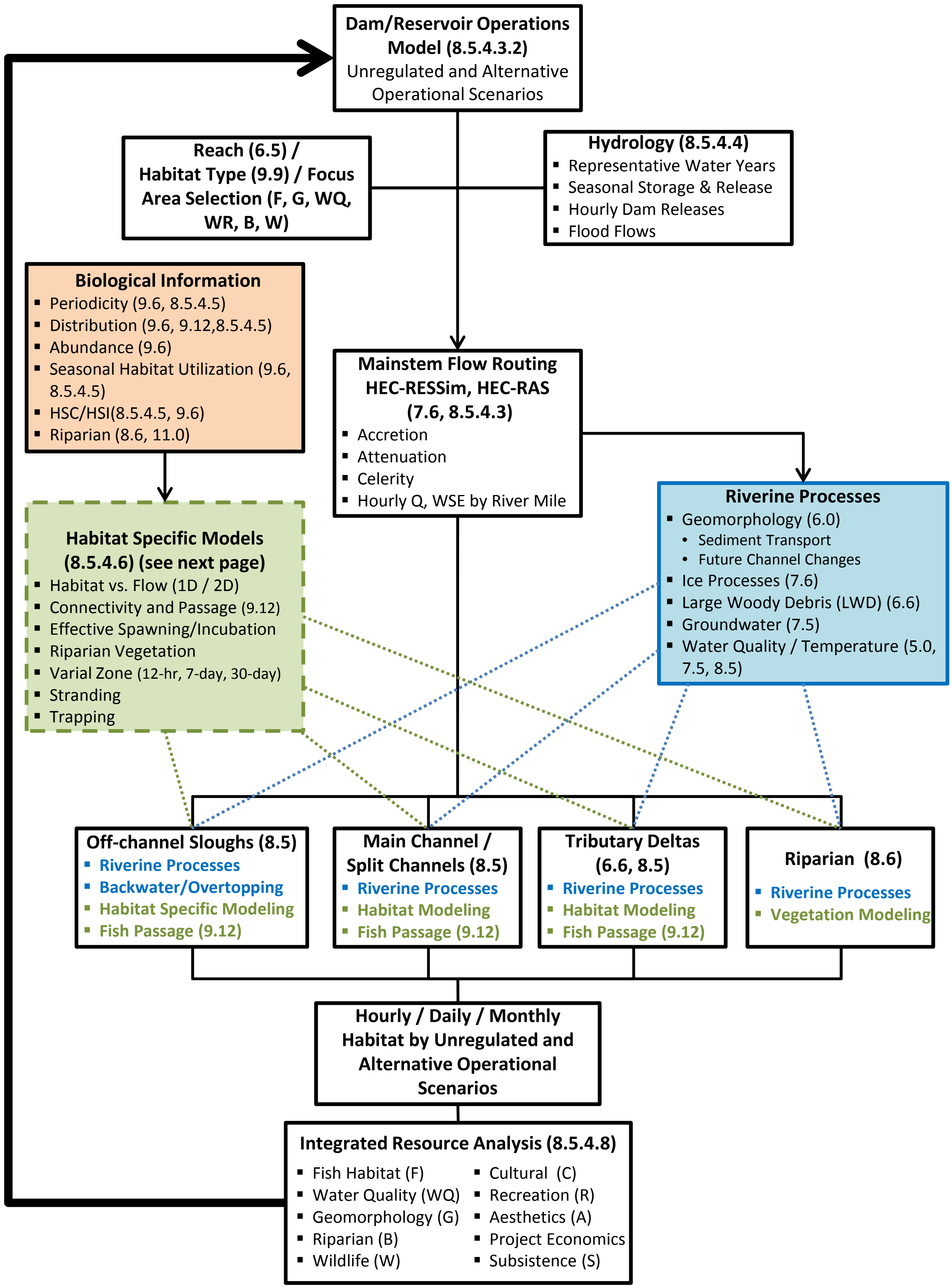


Figure 8.5-9. Map depicting the Upper, Middle and Lower Segments of the Susitna River potentially influenced by the Susitna-Watana Hydroelectric Project.


Dam/Reservoir Operations Model (8.5.4.3.2)
Unregulated and Alternative Operational Scenarios
Reach (6.5) / Habitat Type (9.9) / Focus Area Selection (F, G, WQ, WR, B, W)
Hydrology (8.5.4.4)
Representative Water Years
Seasonal Storage & Release
Hourly Dam Releases
Flood Flows
Biological Information
Periodicity (9.6, 8.5.4.5)
Distribution (9.6, 9.12,8.5.4.5)
Abundance (9.6)
Seasonal Habitat Utilization (9.6, 8.5.4.5)
HSC/HSI(8.5.4.5, 9.6)
Riparian (8.6, 11.0)
Mainstem Flow Routing HEC-RESSim, HEC-RAS (7.6, 8.5.4.3)
Accretion
Attenuation
Celerity
Hourly Q, WSE by River Mile
Riverine Processes
Geomorphology (6.0)
Sediment Transport
Future Channel Changes
Ice Processes (7.6)
Large Woody Debris (LWD) (6.6)
Groundwater (7.5)
Water Quality / Temperature (5.0, 7.5, 8.5)
Habitat Specific Models (8.5.4.6) (see next page)
Habitat vs. Flow (1D / 2D)
Connectivity and Passage (9.12)
Effective Spawning/Incubation
Riparian Vegetation
Varial Zone (12-hr, 7-day, 30-day)
Stranding
Trapping
Off-channel Sloughs (8.5)
Riverine Processes
Backwater/Overtopping
Habitat Specific Modeling
Fish Passage (9.12)
Main Channel / Split Channels (8.5)
Riverine Processes
Habitat Modeling
Fish Passage (9.12)
Tributary Deltas (6.6, 8.5)
Riverine Processes
Habitat Modeling
Fish Passage (9.12)
Riparian (8.6)
Riverine Processes
Vegetation Modeling
Hourly / Daily / Monthly Habitat by Unregulated and Alternative Operational Scenarios
Integrated Resource Analysis (8.5.4.8)
Fish Habitat (F)
Water Quality (WQ)
Geomorphology (G)
Riparian (B)
Wildlife (W)
Cultural (C)
Recreation (R)
Aesthetics (A)
Project Economics
Subsistence (S)

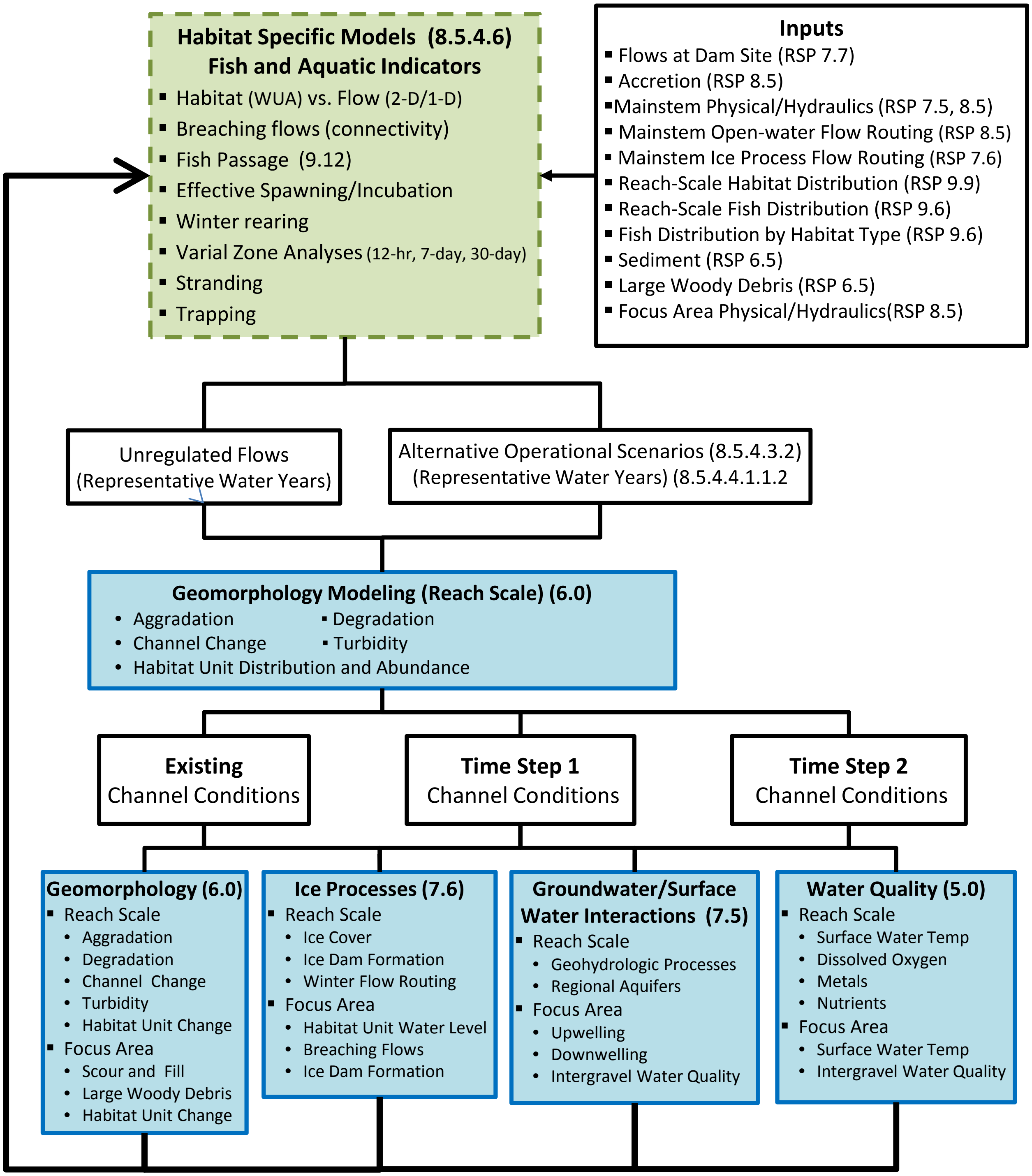


Figure 8.5-10. Conceptual framework for the Susitna-Watana Instream Flow Study depicting integration of habitat specific models and riverine processes to support integrated resource analyses; and integration of riverine processes to develop fish and aquatic habitat specific models.

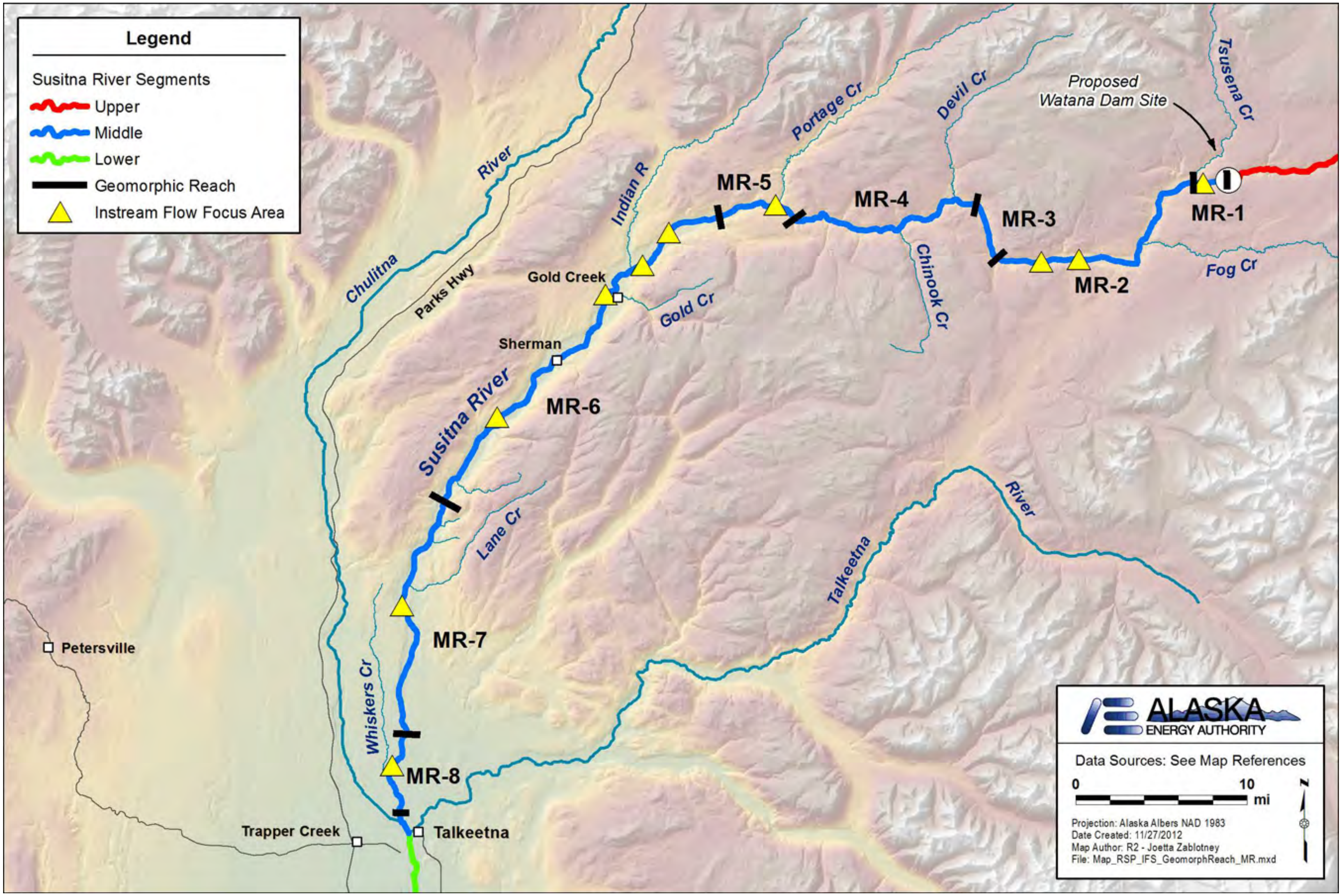


Figure 8.5-11. Map of the Middle Segment of the Susitna River depicting the eight Geomorphic Reaches and locations of proposed Focus Areas. No Focus Areas are proposed for in MR-3 and MR-4 due to safety issues related to sampling within or proximal to Devils Canyon.

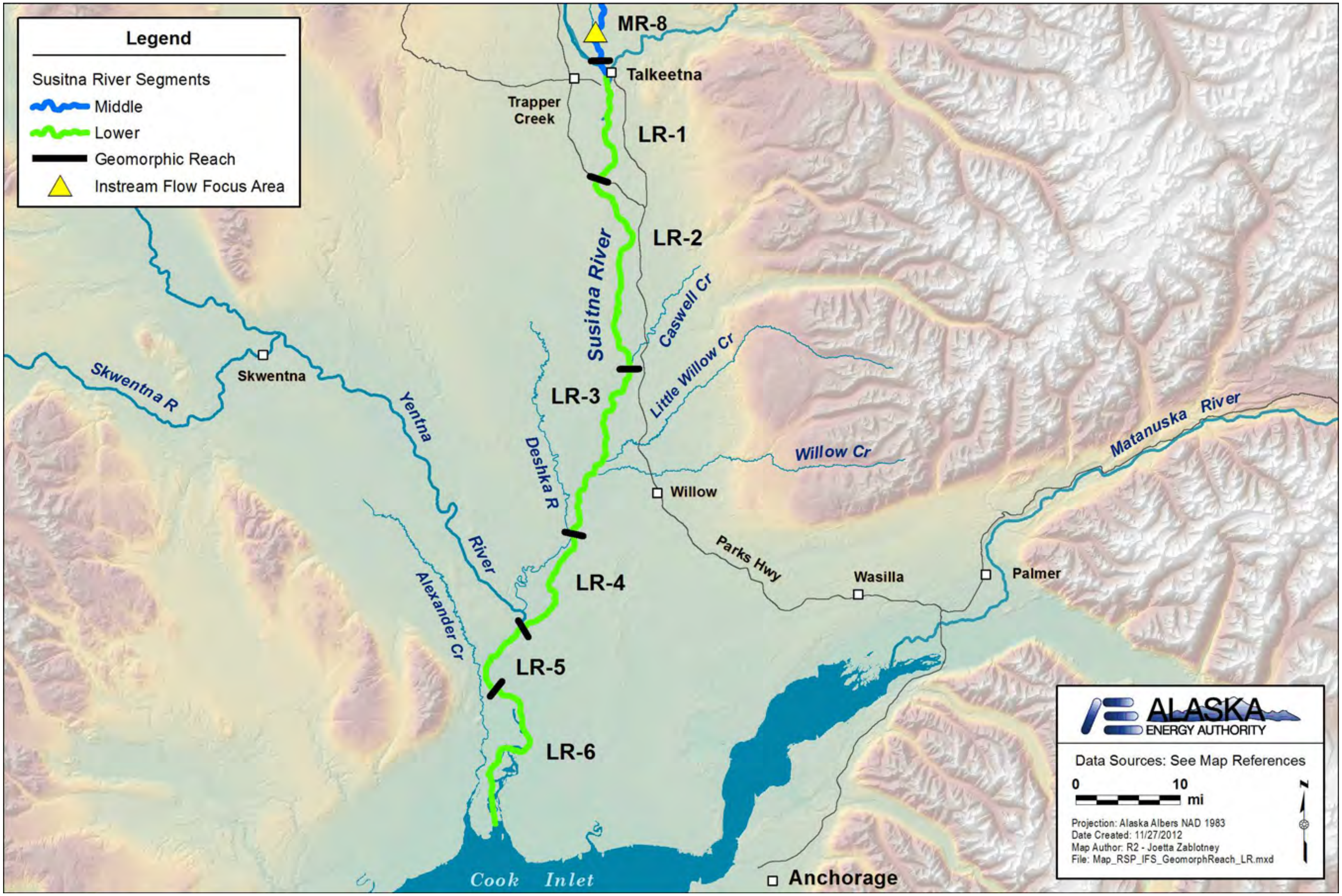


Figure 8.5-12. Map of the Lower Segment of the Susitna River depicting the six Geomorphic Reaches. Focus Areas have not been identified in this segment but will be considered pending results of open-water flow routing modeling.

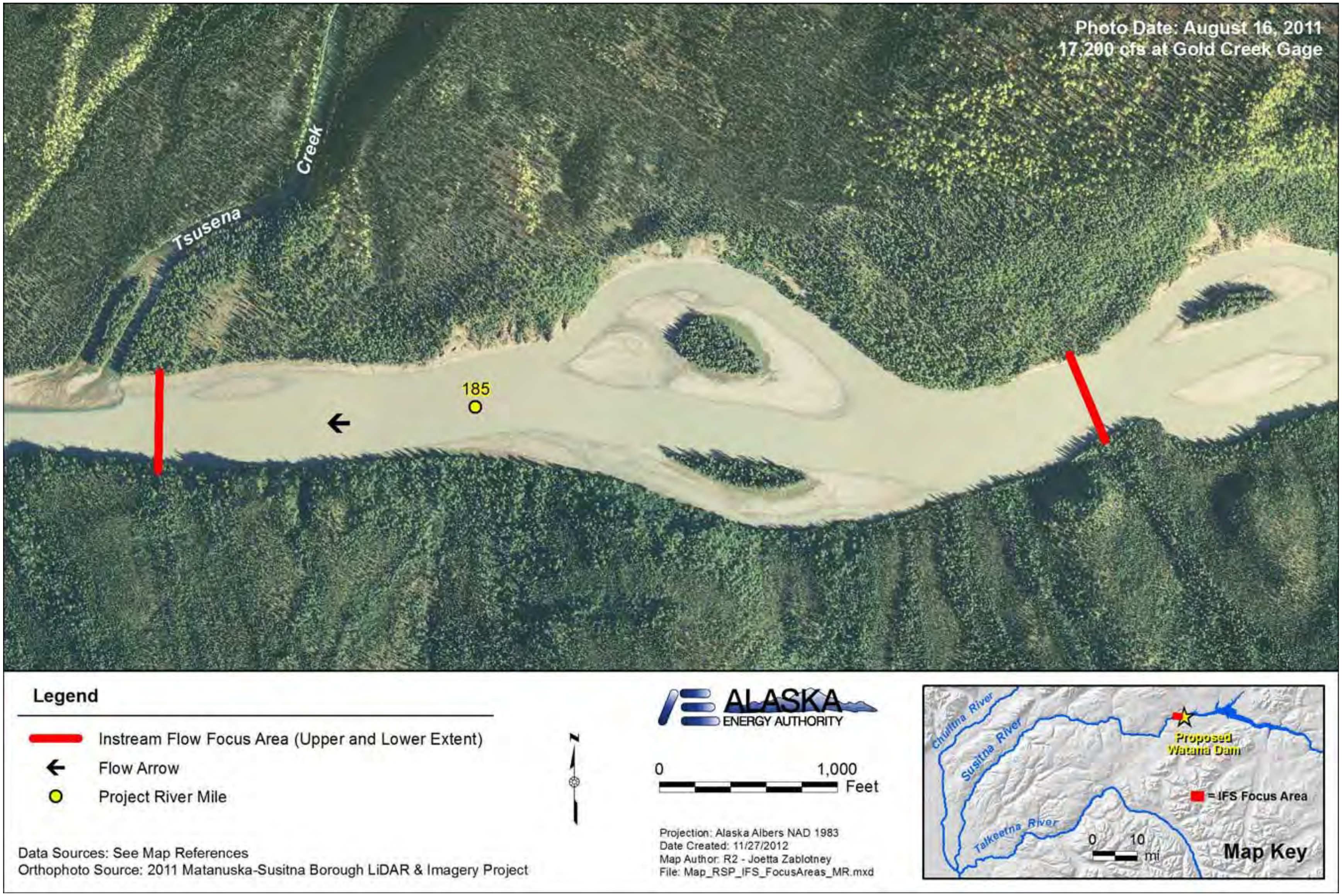


Figure 8.5-13. Map showing Focus Area 184 that begins at Project River Mile 184.7 and extends upstream to PRM 185.7. The Focus Area is located about 1.4 miles downstream of the proposed Watana Dam site near Tsusena Creek.

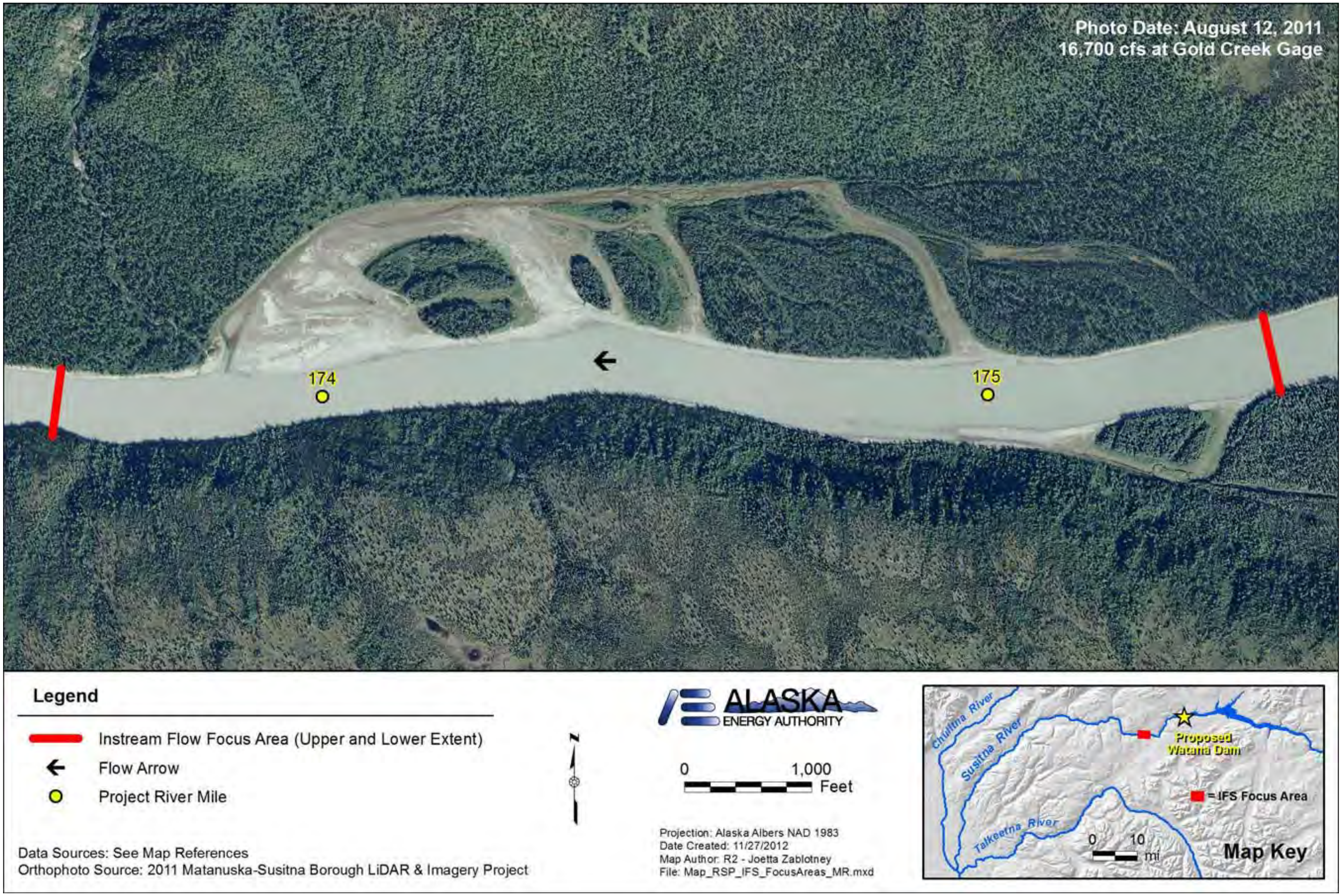


Figure 8.5-14. Map showing Focus Area 173 beginning at Project River Mile 173.6 and extends upstream to PRM 175.4. This Focus Area is near Stephan Lake and consists of main channel and a side channel complex.

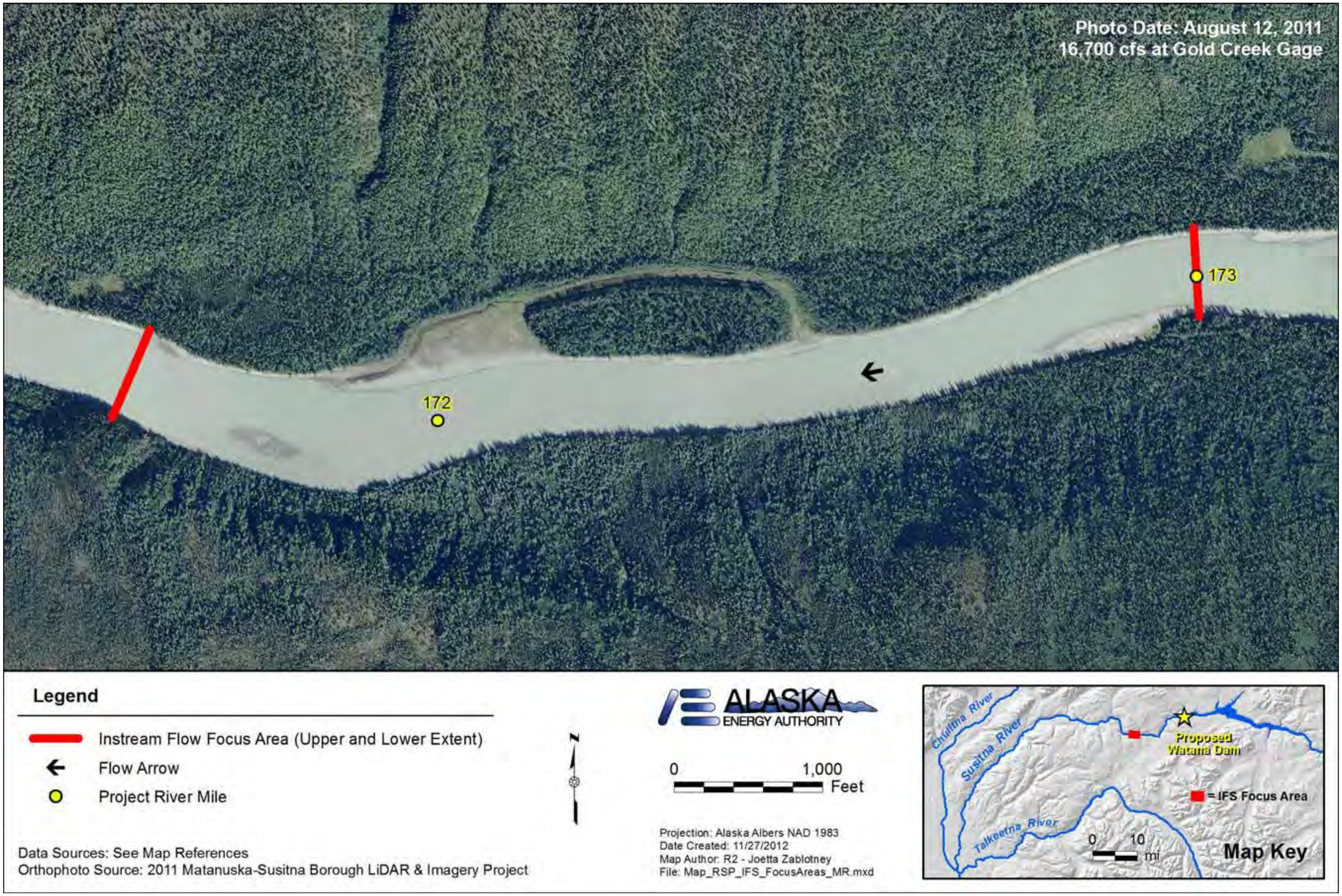


Figure 8.5-15. Map showing Focus Area 171 beginning at Project River Mile 171.6 and extends upstream to PRM 173. This Focus Area is near Stephan Lake and consists of main channel and a single side channel with vegetated island.

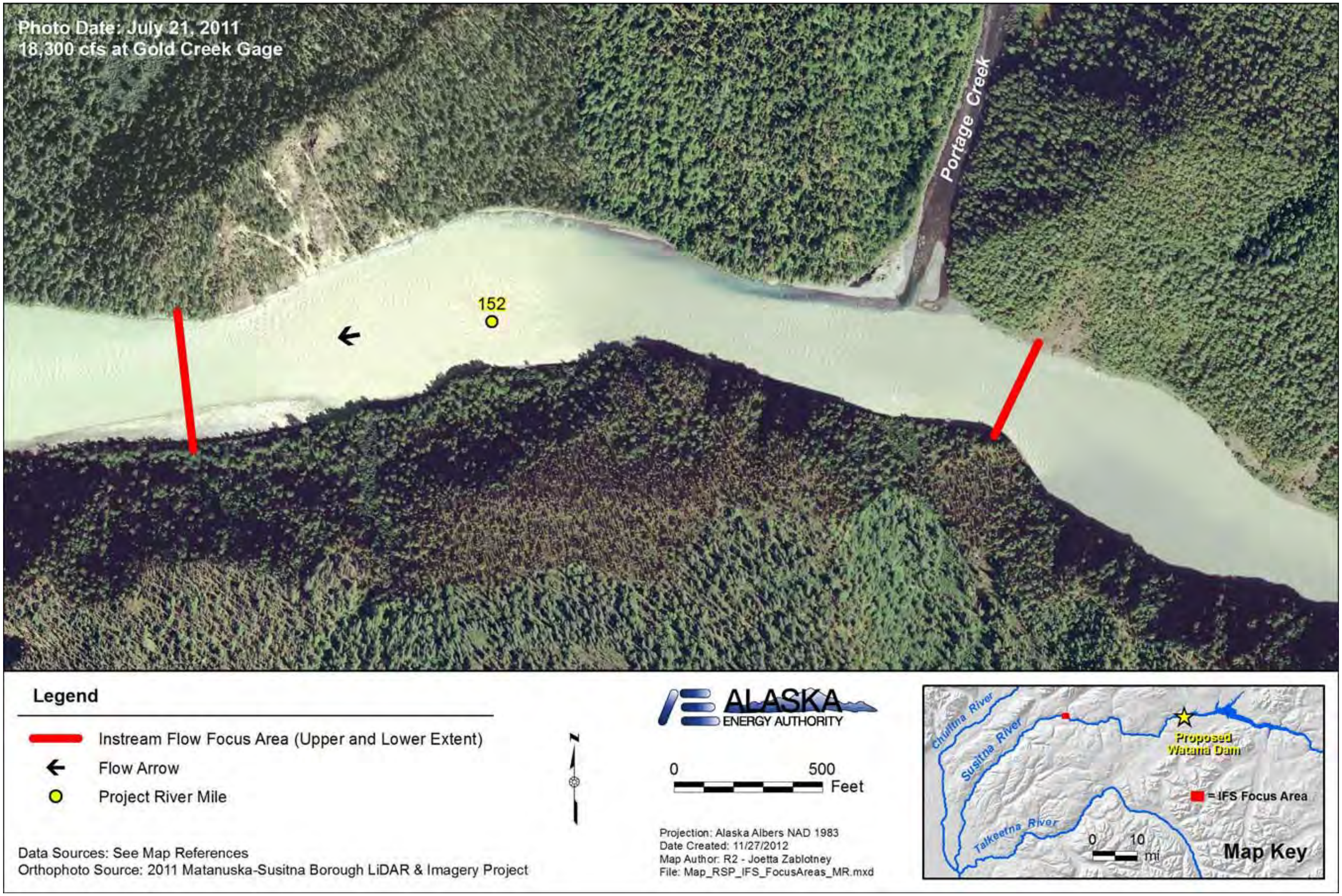


Figure 8.5-16. Map showing Focus Area 151 beginning at Project River Mile 151.8 and extends upstream to PRM 152.3. This single main channel Focus Area is at the Portage Creek confluence.

Figure 8.5-17. Map showing Focus Area 144 beginning at Project River Mile 144.4 and extends upstream to PRM 145.7. This Focus Area is located about 2.3 miles upstream of Indian River and includes Side Channel 21 and Slough 21.

Figure 8.5-18. Map showing Focus Area 141 beginning at Project River Mile 141.8 and extends upstream to PRM 143.4. This Focus Area includes the Indian River confluence and a range of main channel and off-channel habitats.

Figure 8.5-19. Map showing Focus Area 138 beginning at Project River Mile 138.7 and extends upstream to PRM 140. This Focus Area is near Gold Creek and consists of a complex of side channel, side slough and upland slough habitats including Upper Side Channel 11 and Slough 11.

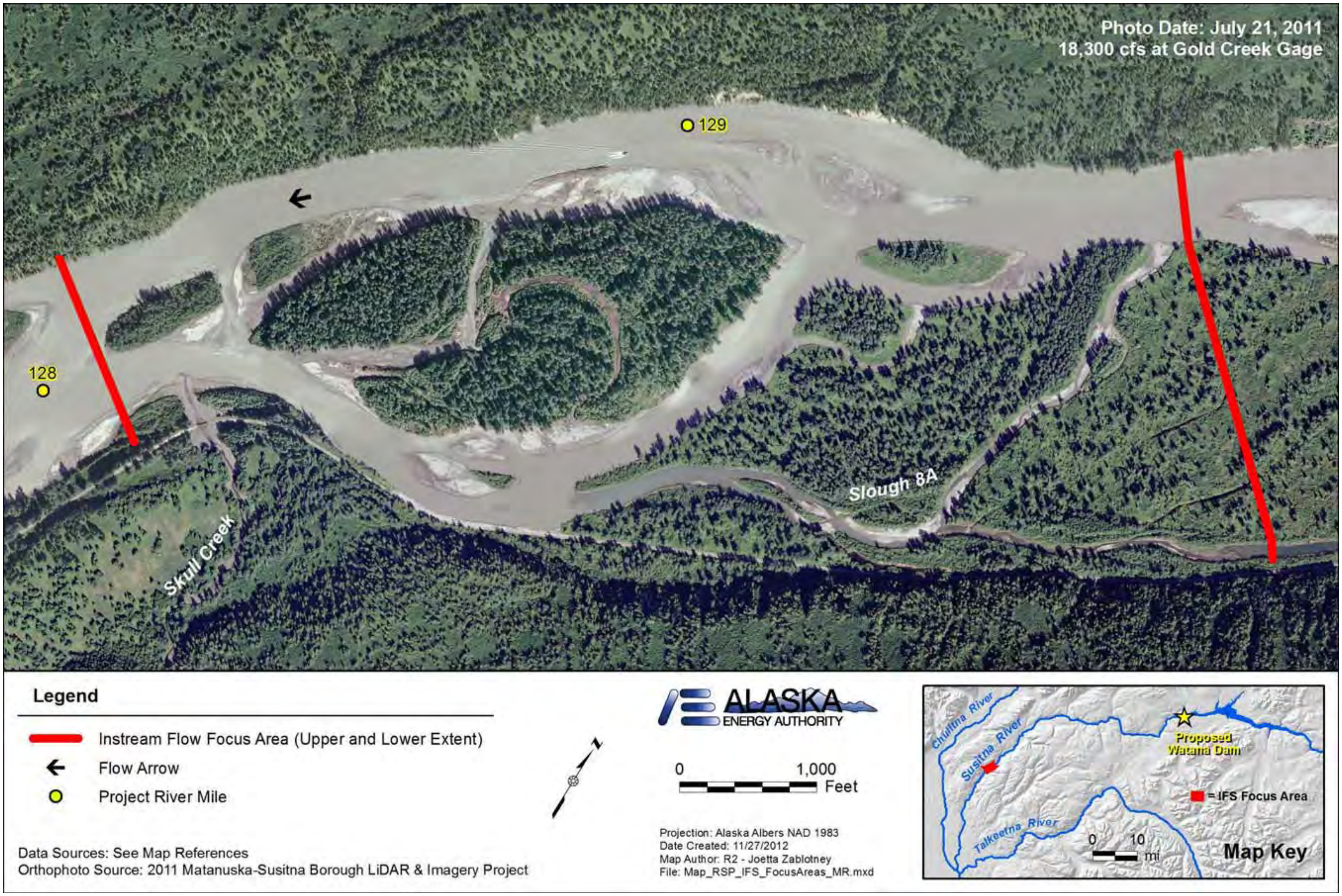


Figure 8.5-20. Map showing Focus Area 128 beginning at Project River Mile 128.1 and extends upstream to PRM 129.7. This Focus Area consists of side channel, side slough and tributary confluence habitat features including Skull Creek.

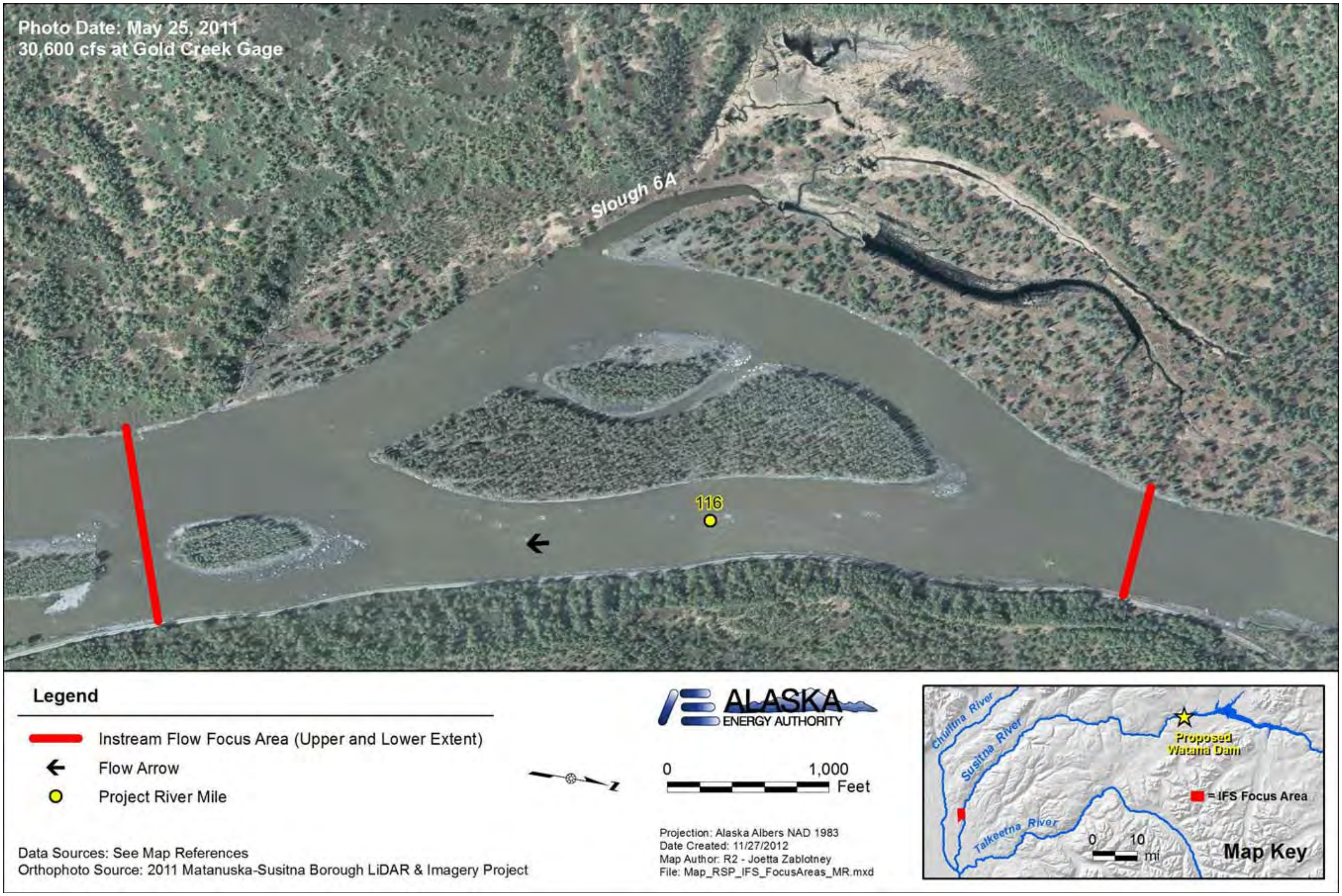


Figure 8.5-21. Map showing Focus Area 115 beginning at Project River Mile 115.3 and extends upstream to PRM 116.5. This Focus Area is located about 0.6 miles downstream of Lane Creek and consists of side channel and upland slough habitats including Slough 6A.

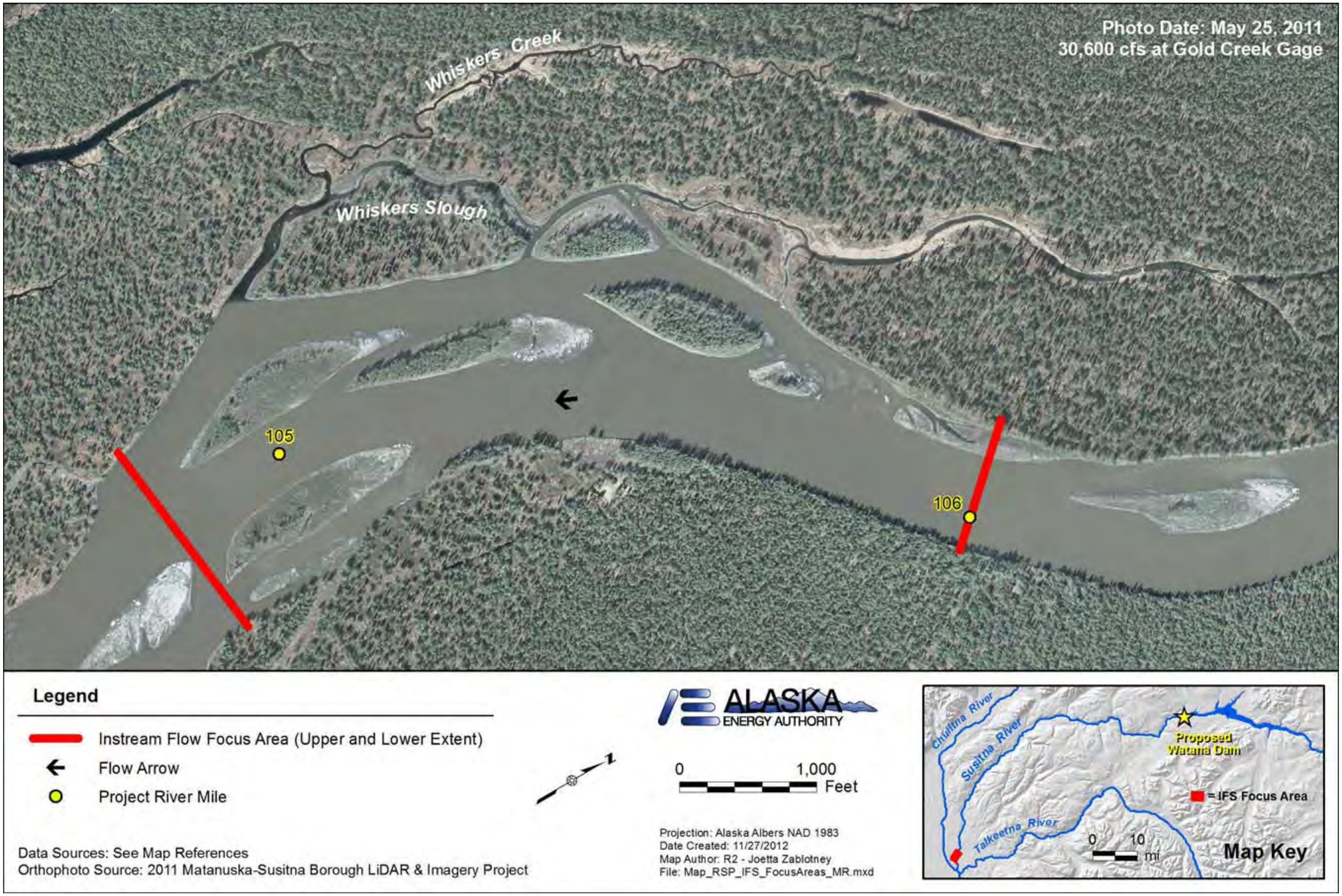


Figure 8.5-22. Map showing Focus Area 104 beginning at Project River Mile 104.8 and extends upstream to PRM 106. This Focus Area covers the diverse range of habitats in the Whiskers Slough complex.

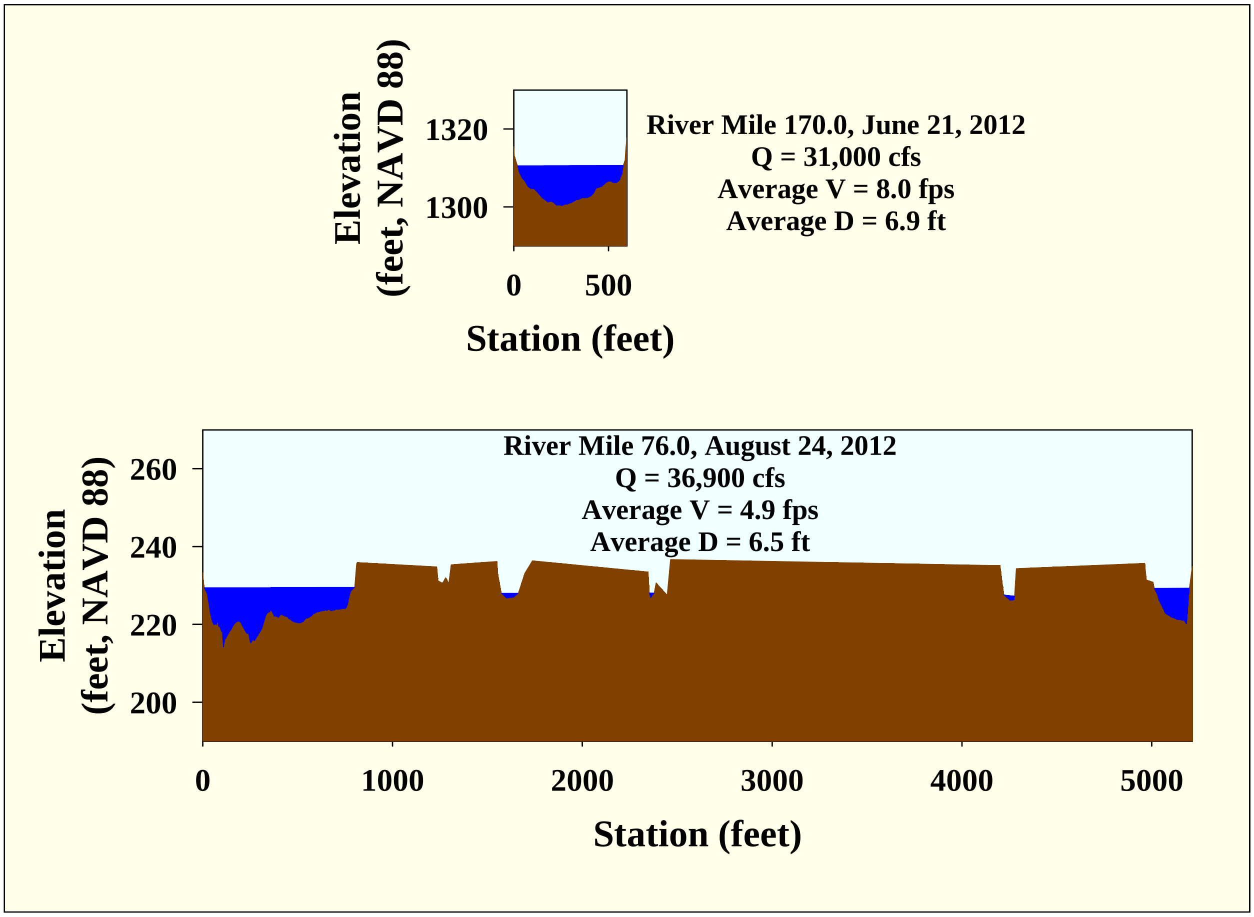


Figure 8.5-23. Examples of cross-sections established on the Susitna River in 2012 at River Miles 170 and 76.

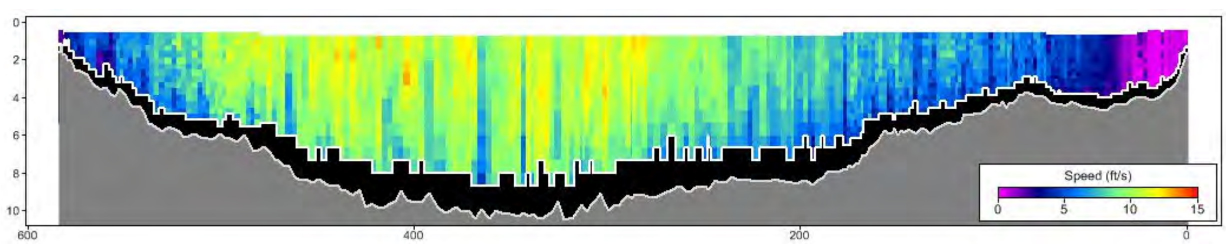


Figure 8.5-24. Output from ADCP from one pass across the Susitna River at River Mile 170 on June 21, 2012.

Susitna-Watana Hydroelectric Data Network Diagnostics

Generated: 2012-10-25 21:37 **(ADT)**

The following information and links to data is for internal use for Susitna-Watana Hydroelectric Data Network staff and project cooperators. Real-time data is preliminary and may not be final. Proper use, QA/QC, and citation is the responsibility of each user and project. This site is monitored for access. For more information, please contact Austin McHugh at 360-441-2023 or Michael Lilly at 907-479-8891.

All times below and in data aquisition system are in Alaska Standard Time (AST)

Legend | Graphs

Station Name / Location	Raw Data	Latest Download **(AST)**	Days Old	Hourly Averages		
				Battery Voltage	Solar Panel Voltage	Data Logger Temperature
Upper Susitna Watershed Meteorological Stations						
ESG1 (Seasonal Station, No Telemetry)	N/A	N/A	N/A	N/A	N/A	N/A
Off-Ice Glacial Site (ESG2)	raw	2012-10-25 20:00:00	-0.02	13.17 V	0.26	-14.3 C
Upper Susitna Watershed Gaging Stations						
Susitna River Near Cantwell (ESS80)	raw	2012-10-25 20:00:00	-0.02	13.34 V	0.07	-11.7 C
Susitna River Below Deadman Creek (ESS70)	raw	2012-10-25 20:00:00	-0.02	12.72 V	0.07	-8.6 C
Middle Susitna Watershed Gaging Stations						
Susitna River Below Fog Creek (ESS65)	raw	2012-10-25 20:00:00	-0.02	13.22 V	0.15	-7.8 C
Susitna River Above Devil Creek (ESS60)	raw	2012-10-25 20:00:00	-0.02	13.18 V	0.07	-8.3 C
Susitna River Below Portage Creek (ESS55)	raw	2012-10-25 20:00:00	-0.02	12.68 V	0.07	-6.9 C
Susitna River at Curry (ESS50)	raw	2012-10-25 20:00:00	-0.02	13.40 V	0.08	-4.1 C
Susitna River Below Lane Creek (ESS45)	raw	2012-10-25 20:00:00	-0.02	13.36 V	0.19	-4.3 C
Susitna River Above Whiskers Creek (ESS40)	raw	2012-10-25 20:00:00	-0.02	13.08 V	0.16	-6.2 C
Susitna River at Chulitna River (ESS35)	raw	2012-10-25 20:00:00	-0.02	13.57 V	0.09	-5.1 C
Susitna River Below Twister Creek (ESS30)	raw	2012-10-25 20:00:00	-0.02	12.74 V	0.27	-5.8 C
Lower Susitna Watershed Gaging Stations						

Figure 8.5-25. Susitna Network Stations Diagnostics Screen. Data fields are color coded to allow quick scans for evaluating station conditions. Email and text messaging are used to communicate warning conditions and non-reporting stations.

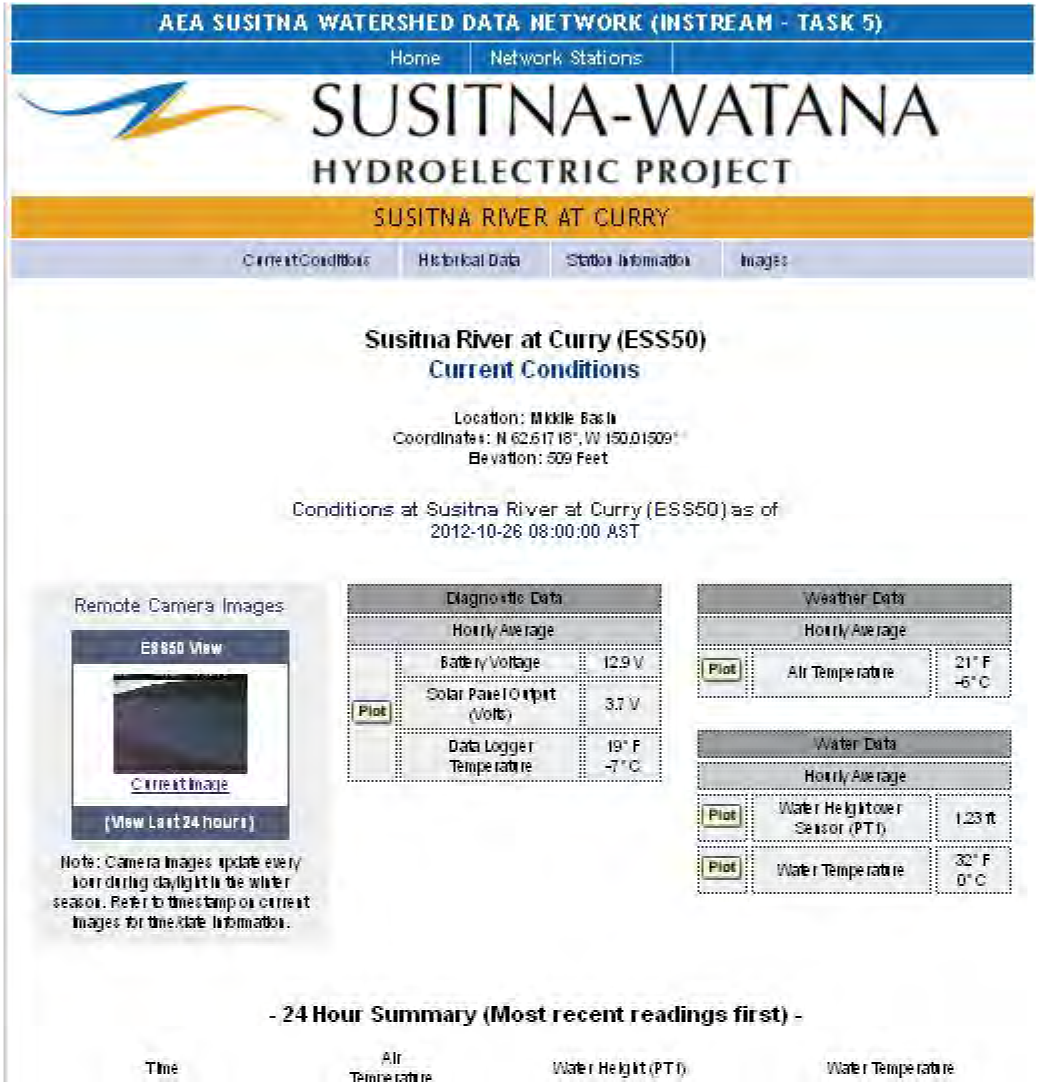


Figure 8.5-26. Typical AEA gaging station current conditions reporting page.

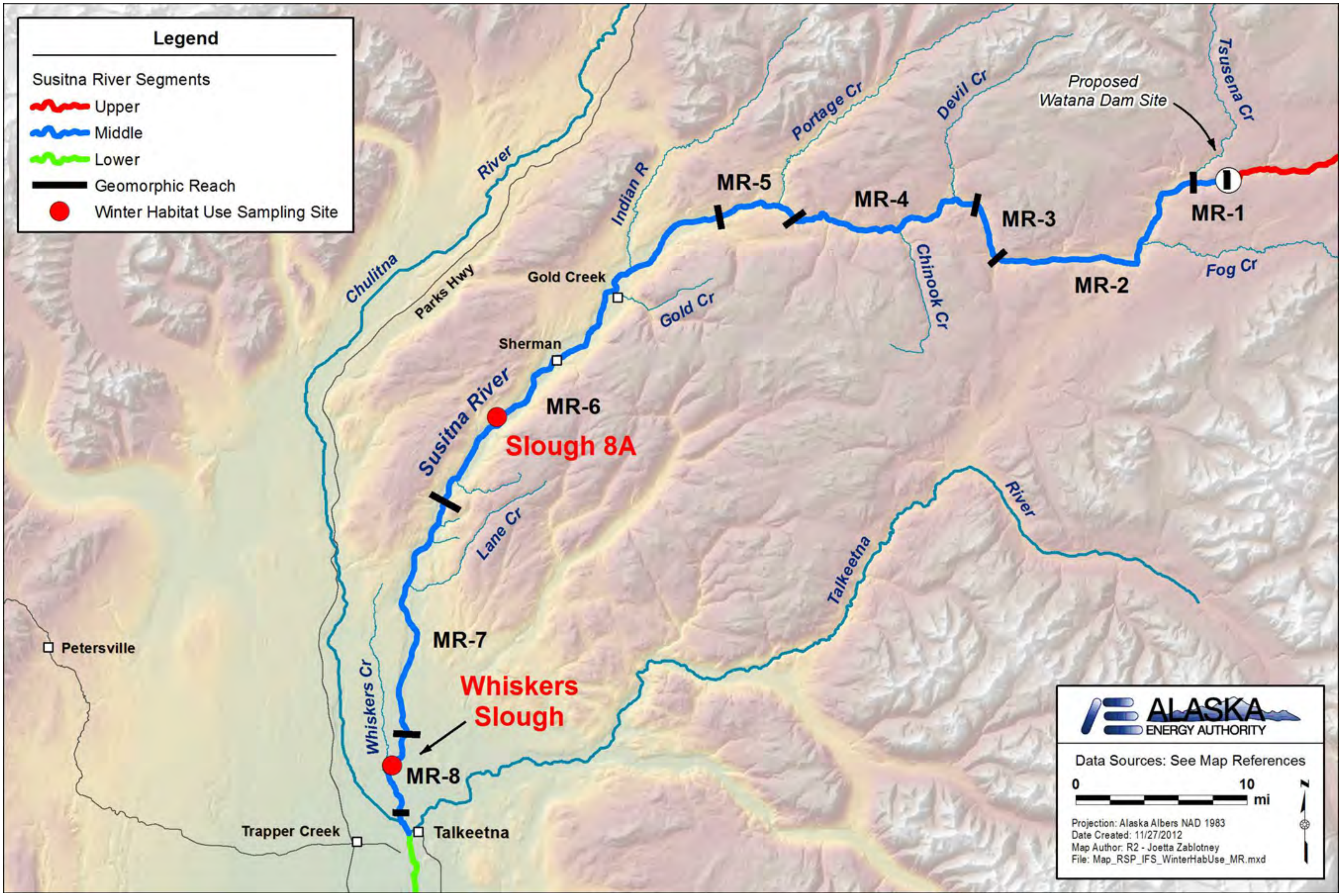


Figure 8.5-27. Geomorphic Reaches and winter habitat use sampling areas in the Middle Susitna River Segment.

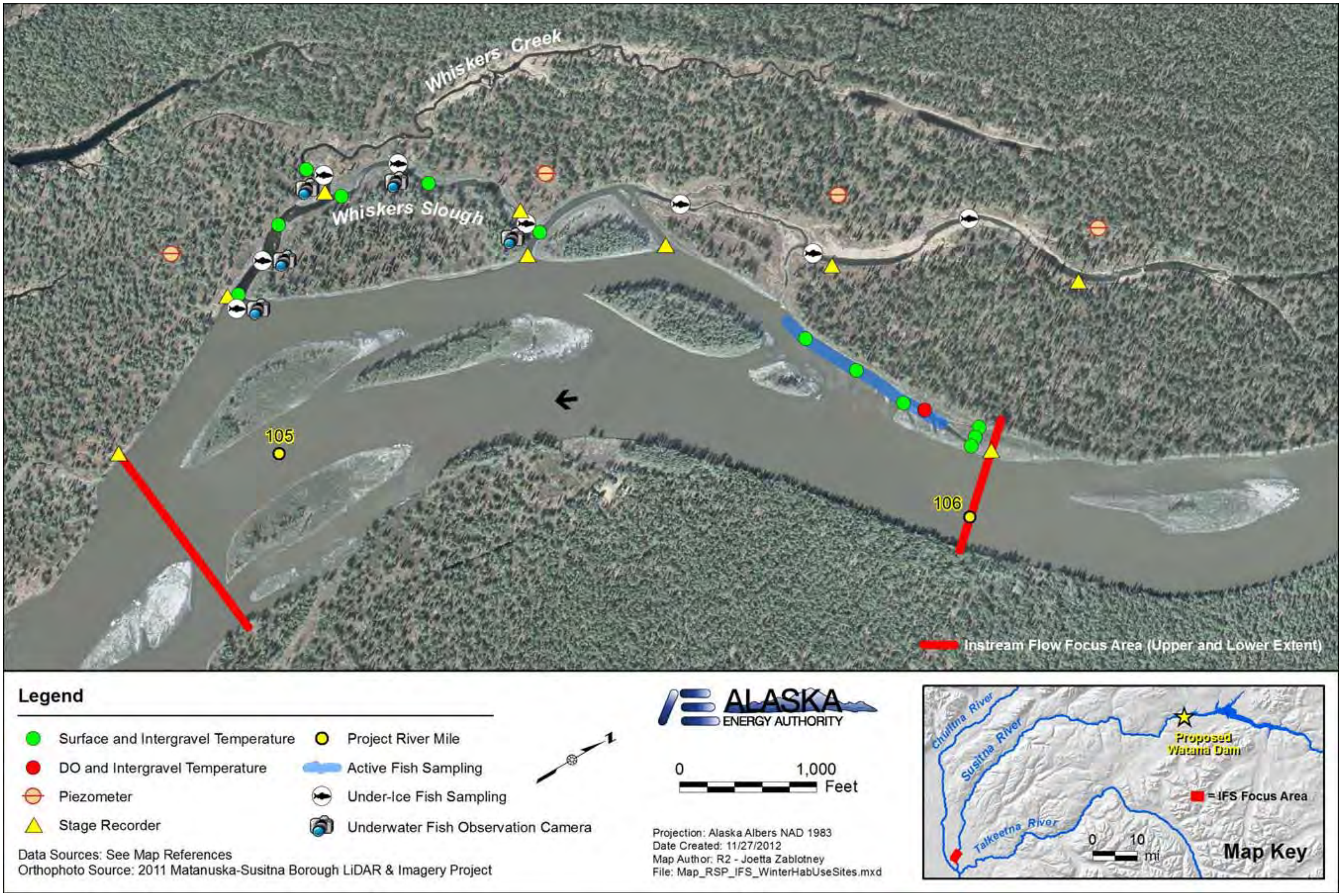


Figure 8.5-28. Location of proposed winter fish habitat use sampling sites at Whiskers Slough in the Middle Susitna River Segment.

Figure 8.5-29. Location of proposed winter fish habitat use sampling sites at the Skull Creek Complex in the Middle Susitna River Segment.

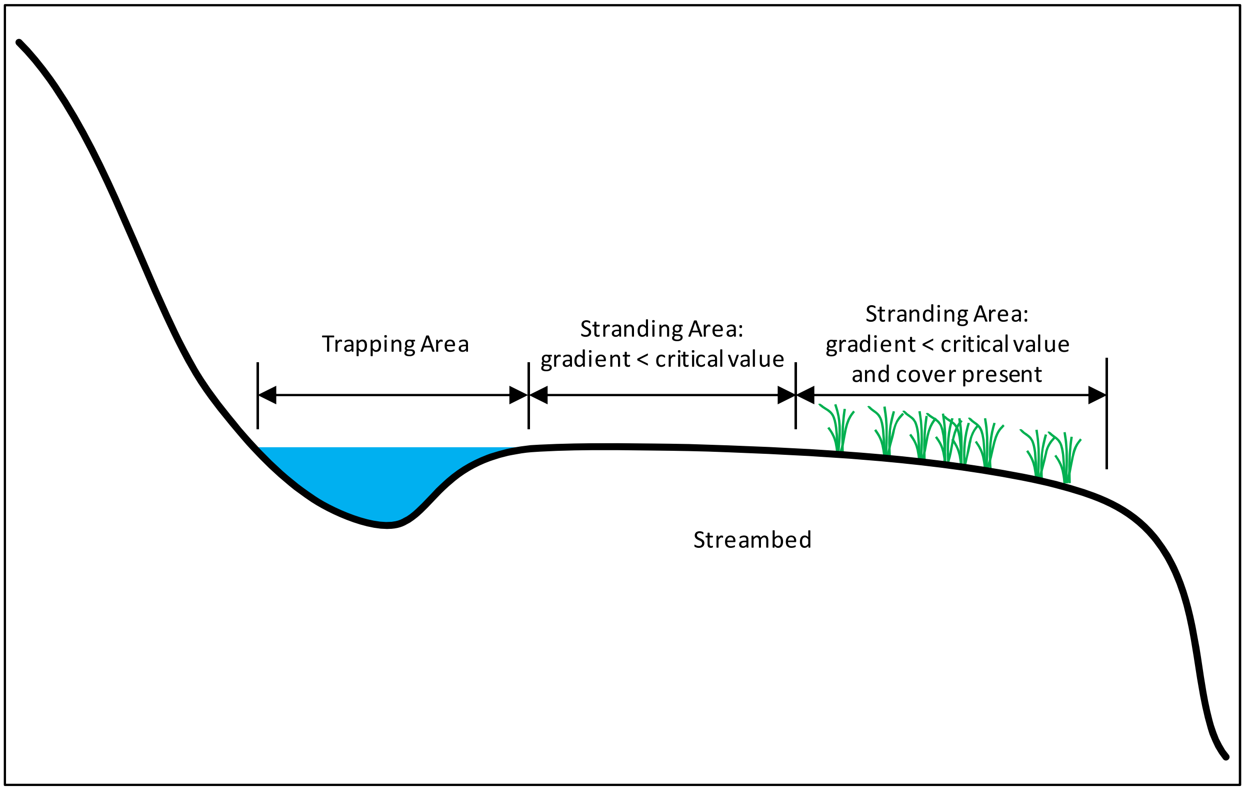


Figure 8.5-30. Cross-sectional conceptual diagram illustrating stranding and trapping areas.

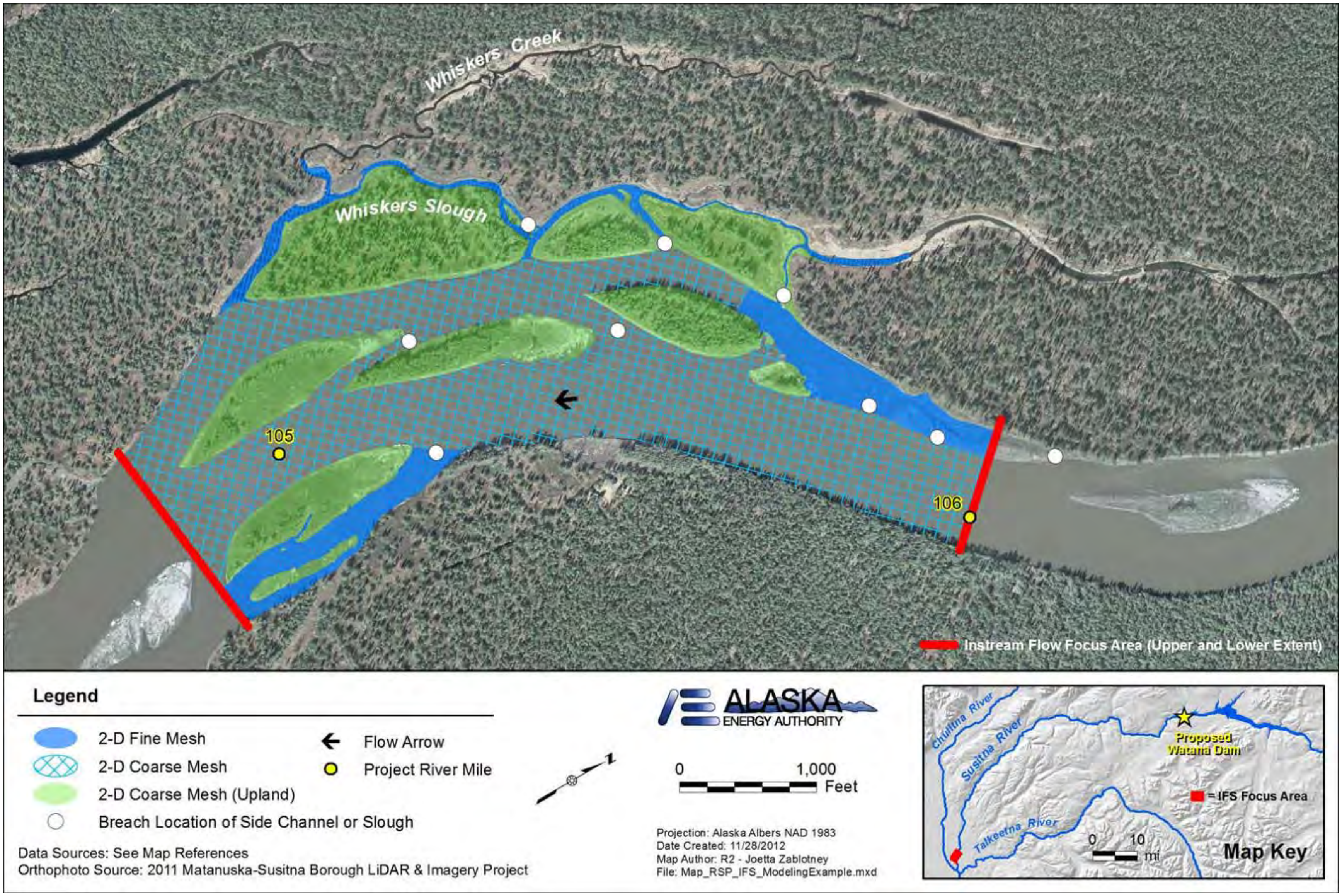
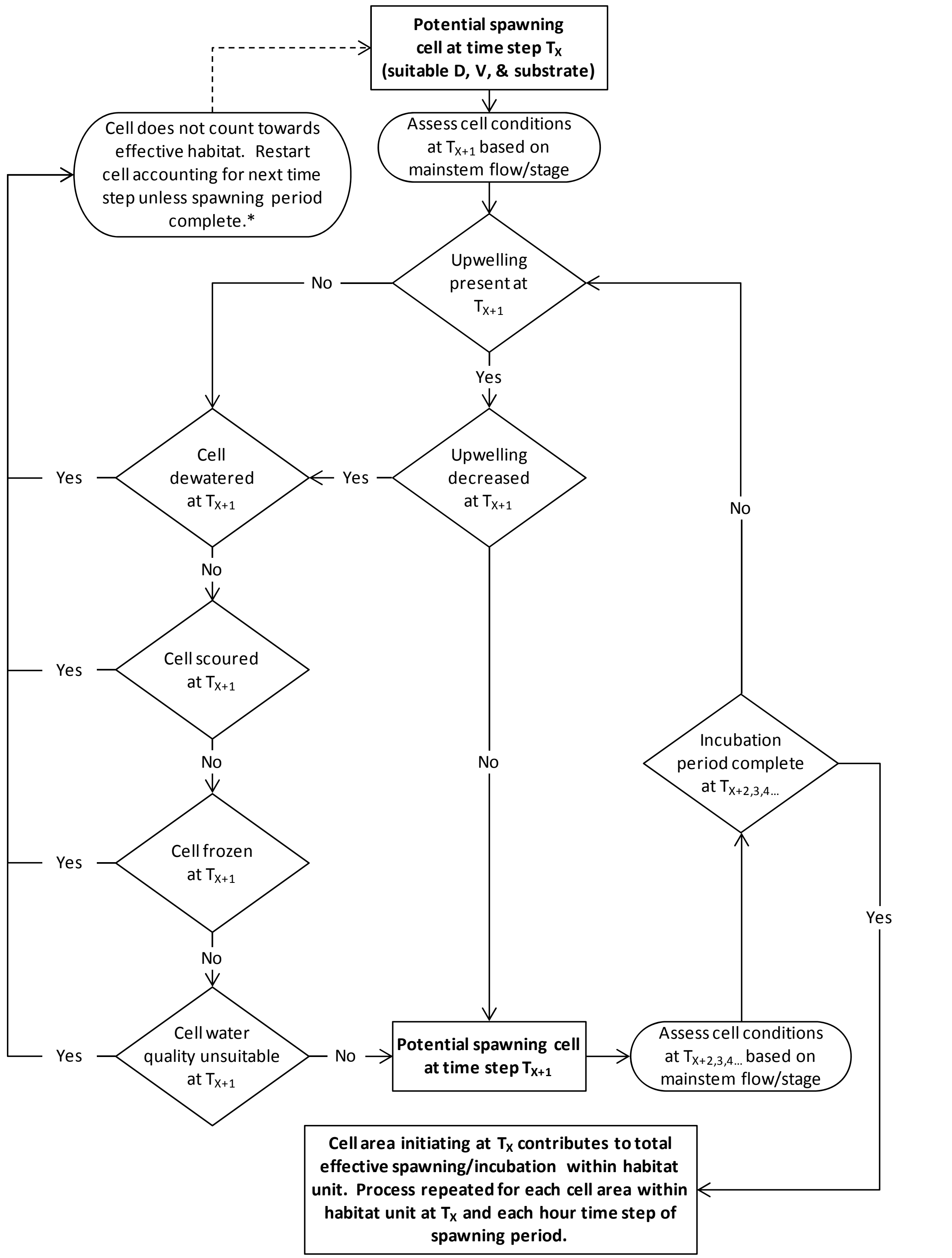


Figure 8.5-31. Conceptual layout of 2-D coarse and fine mesh modeling within the proposed Whiskers Slough Focus Area.



* If subsequent time step is still within the spawning period and the cell still meets criteria for the duration of incubation period, effective habitat for this cell would be weighted according to the duration of the remaining spawning period.

Figure 8.5-32. Conceptual diagram depicting the Effective Spawning/Incubation Model.

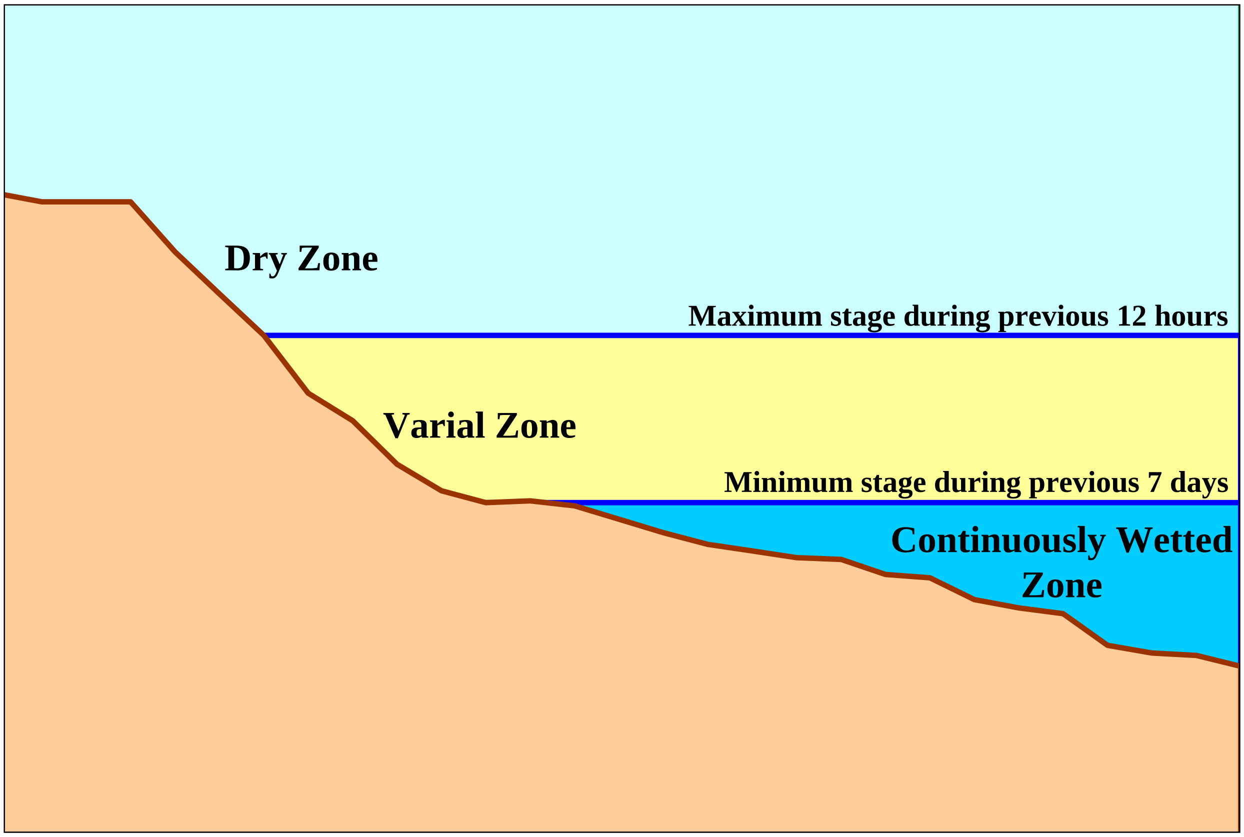
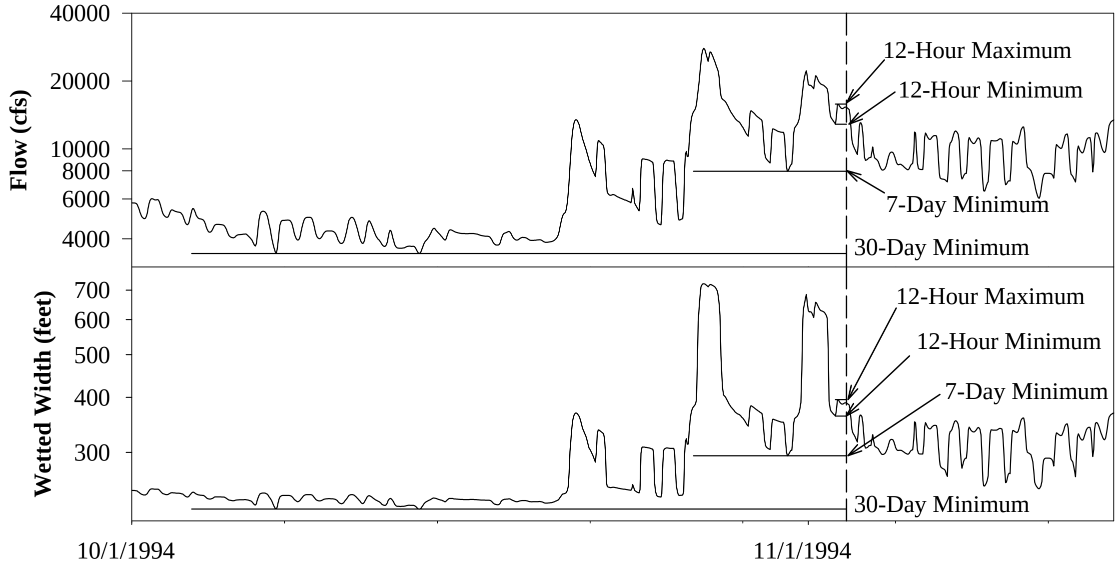


Figure 8.5-33. Conceptual framework of the varial zone model.



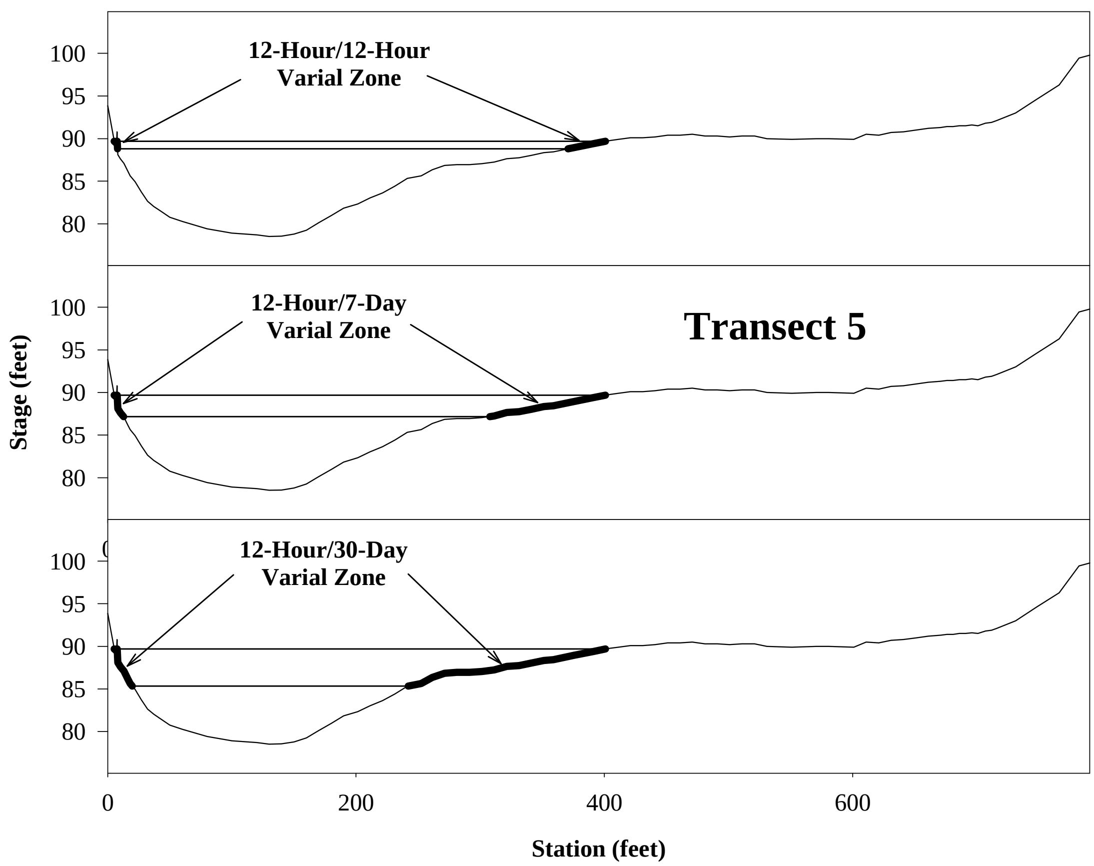


Figure 8.5-34. Illustration of 12-hour/12-hour, 12-hour/7-day, and 12-hour/30-day varial zones modeling scenarios assuming single transect analyses (adapted from Hilgert et al. 2008).

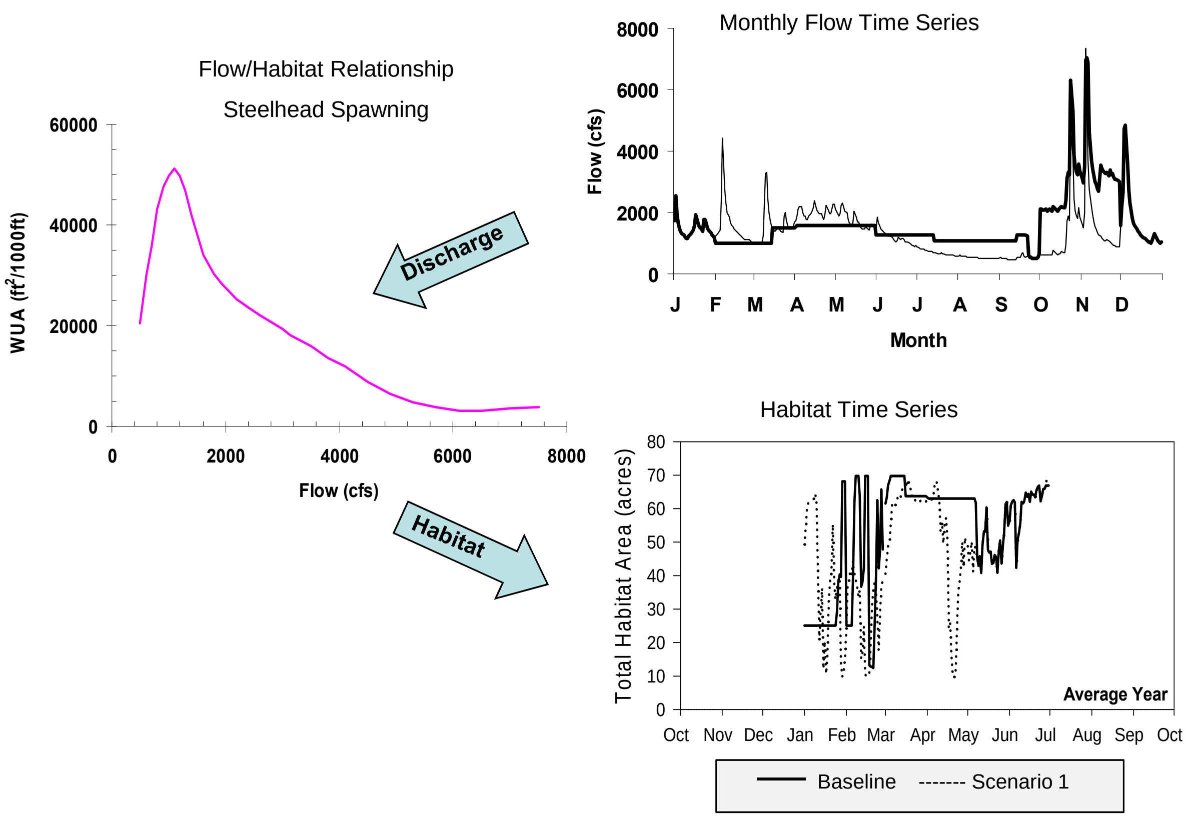


Figure 8.5-35. Example time series analysis.

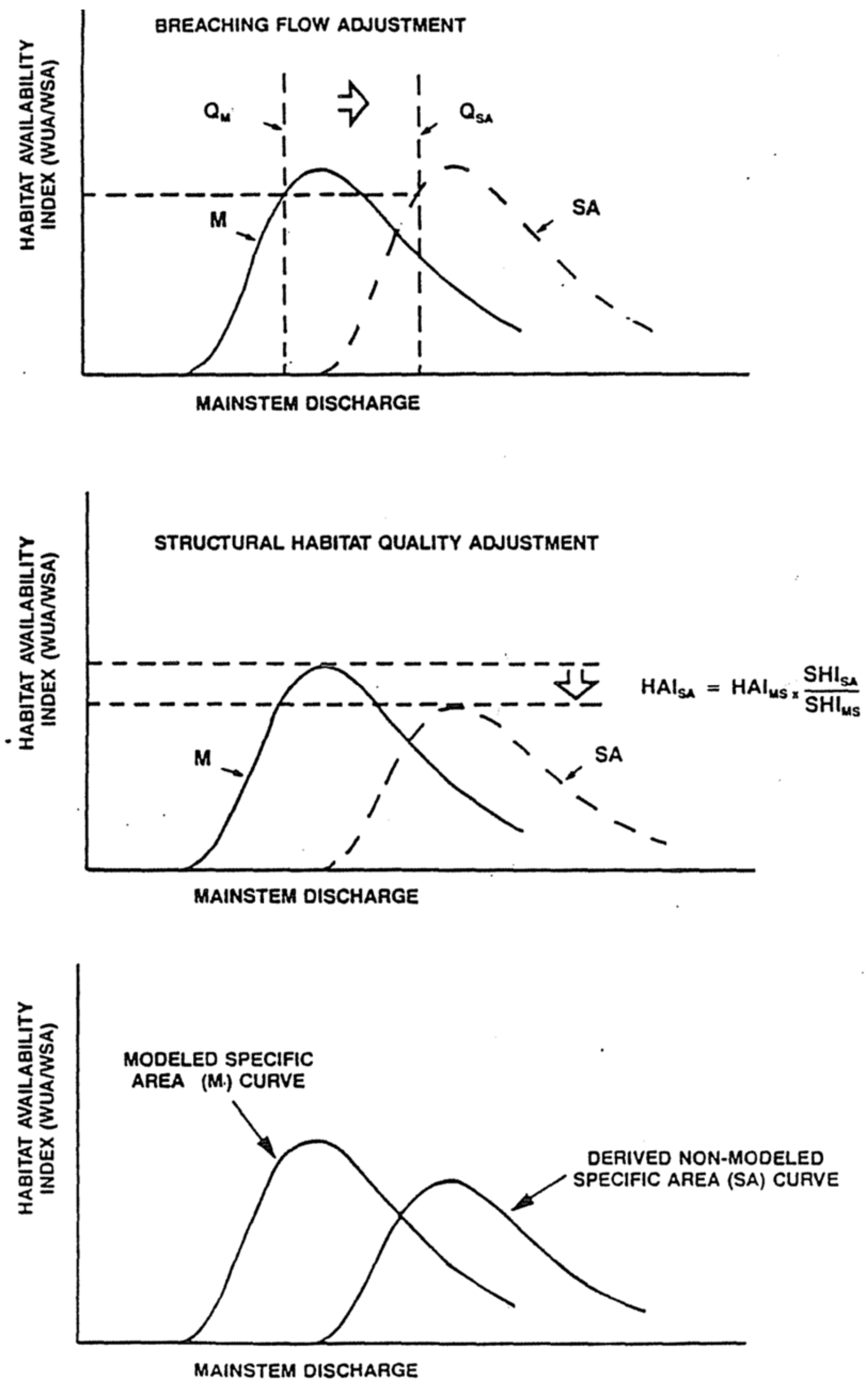


Figure 8.5-36. Conceptual figures illustrating procedure used for deriving non-modeled specific area (sa) Habitat Availability Index curve using a modeled curve, as applied during the 1980s Su-Hydro Studies (see Steward et al. 1985; Aaserude et al. 1985). The procedure included lateral shifts (upper figure) due to adjustments from differences in breaching flows (Qms Qsa) as well as vertical shifts (middle figure) proportional to structural habitat indices (SHIsa/SHIms) to account for differences in structural habitat quality. The lower figure shows final hypothetical modeled and non-modeled specific area curves.

8.6. Riparian Instream Flow Study

8.6.1. General Description of the Proposed Study

8.6.1.1. Riparian IFS Goal and Objectives

The goal of the 2013–2014 Riparian Instream Flow Study (hereafter Riparian IFS) is to provide a quantitative, spatially-explicit model to predict potential impacts to downstream floodplain vegetation from Project operational flow modification of natural Susitna River flow, sediment, and ice process regimes. To meet this goal, a physical and vegetation process modeling approach will be used (Figure 8.5-10). First, existing Susitna River groundwater and surface water (GW/SW) flow, sediment and ice process regimes will be measured and modeled relative to floodplain plant community establishment, recruitment, and maintenance requirements. Second, predictive models will be developed to assess potential Project operational impacts to floodplain plant communities and provide operational guidance to minimize these impacts. Third, the predictive models will be applied spatially in a Geographic Information System (GIS) to the riparian vegetation map produced by the Riparian Botanical Survey Study to produce a series of maps of predicted changes under alternative operational flow scenarios.

The Riparian IFS approach and format have been written to address, and to parallel, the study format proposed in the U.S. Fish and Wildlife Service (USFWS) Riparian IFS Request (May 31, 2012).

Riparian IFS objectives are as follows:

1. Synthesize historic physical and biological data for Susitna River floodplain vegetation, including 1980s studies, studies of hydro project impacts on downstream floodplain plant communities, and studies of un-impacted floodplain plant community successional processes.
2. Delineate sections of the Susitna River with similar environments, vegetation, and riparian processes, termed *riparian process domains*, and select representative areas within each riparian process domain, termed *Focus Areas*, for use in detailed 2013–2014 field studies.
3. Characterize seed dispersal and seedling establishment groundwater and surface water hydroregime requirements. Develop a predictive model of potential Project operational impacts to seed dispersal and seedling establishment.
4. Characterize the role of river ice in the establishment and recruitment of dominant floodplain vegetation. Develop a predictive model of potential Project operational impacts to ice processes and dominant floodplain vegetation establishment and recruitment.
5. Characterize the role of erosion and sediment deposition in the formation of floodplain surfaces, soils, and vegetation. Develop a predictive model of Project operations changes to erosion and sediment deposition patterns and associated floodplain vegetation.
6. Characterize natural floodplain vegetation groundwater and surface water maintenance hydroregime. Develop a predictive model to assess potential changes to natural hydroregime and potential floodplain vegetation change.

7. Develop floodplain vegetation study, Focus Area to riparian process domain scaling and Project operations effects modeling**.**

8.6.1.2. Riparian IFS Analytical Framework and Study Interdependencies

Figure 8.5-10 depicts the overall analytical framework of the Instream Flow Studies commencing with the Reservoir Operations Model (ROM) that will be used to generate alternative operational scenarios under different hydroregimes. The ROM will provide the input data that will be used to predict hourly flow and water surface elevation data at multiple points downstream, taking into account accretion and flow attenuation. A series of biological and riverine processes studies will be completed to supplement the information collected in the 1980s, to define relationships between mainstem flow, riverine processes, and biological resources. This will result in development of a series of flow-sensitive models (e.g., models of selected anadromous and resident fish habitats by species and life stage, models to describe invertebrate habitats, temperature model, ice process model, sediment transport model, turbidity model, large woody debris (LWD) recruitment model, riparian vegetation groundwater and surface water interaction model) that will enable the translation of effects of alternative Project operations on the respective riparian processes and biological resources. While there is likely to be a cumulative effect that translates throughout the entire length of the Susitna River, many of the resource and process effects will be location- and habitat-specific (e.g., responses are expected to be different in side sloughs versus mainstem versus side channel versus tributary delta versus riparian habitats). Additionally, alternative Project operations will likely affect specific habitats and processes differently, both spatially and temporally. Therefore, the habitat and process models will be spatially discrete (e.g., by site, reach) and yet able to be integrated across the entire study area to allow for a holistic evaluation of each alternative operational scenario. This will allow for an Integrated Resource Analysis of separate operational scenarios that includes each resource element, the results of which can serve in a feedback capacity leading to new or, modifications of, existing scenarios.

The Riparian IFS is an interdependent effort coordinated with a range of other study disciplines, and these interdependencies are depicted in Figure 8.6-1. Studies providing input to the Riparian IFS include Fish and Aquatics Instream Flow (see Section 8.5), Groundwater Study (see Section 7.5), Ice Processes Study (see Section 7.6), Fluvial Geomorphology Study (see Section 6.6), and Riparian Vegetation Study (see Section 11.6). The Riparian IFS will provide data and results to the Geomorphology Study (see Section 6.0), Ice Processes Study (see Section 7.6), Wildlife Studies (see Section 10.0), River Productivity Study (see Section 9.8), Riparian Vegetation Study (see Section 11.6), and to Project operational flow design. The Riparian IFS is a modeling effort designed to evaluate potential Project operations effects on downriver floodplain plant communities. The modeling design incorporates both floodplain plant community succession models and physical process models (fluvial geomorphology, sediment transport, ice processes, and groundwater and surface interaction. Together, the vegetation and physical models comprise a hydrogeomorphic approach to modeling the physical floodplain boundary conditions controlling the establishment, recruitment, and maintenance of characteristic riparian floodplain plant communities (Figure 8.6-1and Figure 8.6-2). These vegetation and physical models represent the core tools that will be used for assessing changes in floodplain physical characteristics (flow, sediment and ice process regimes) and associated floodplain plant community composition, succession, and spatial distribution under alternative Project operational scenarios.

8.6.1.3. Existing Information and Need for Additional Information

Information for the study area includes, but is not limited to, 1) recent and historic aerial photography; 2) riparian vegetation surveys and characterizations from recent and early 1980s studies; 3) riparian vegetation succession conceptual models developed from the 1980s data as part of the original Susitna Hydroelectric Project (SHP) Phase I vegetation mapping studies conducted along the Susitna River from the downstream end of Devils Canyon to Talkeetna, and 4) vegetation succession studies conducted in the Susitna River floodplain between Gold Creek and the Deshka River (McKendrick et al. 1982; UAFAFES 1985). The riparian sites visited in the 1980s studies were re-sampled in 1992–1993 (Collins and Helm 1997; Helm and Collins 1997). Of primary importance to the Riparian IFS is the previous vegetation mapping and successional dynamics studies by McKendrick et al. (1982), Collins and Helm (1997), and Helm and Collins (1997). These previous works will serve to inform the development of a stratified sampling protocol for both the Riparian IFS and Botanical Riparian Study vegetation surveys. The riparian study modeling efforts will build upon the Collins and Helm (1997) riparian vegetation succession conceptual model (Figure 8.6-2).

Although substantial data and information concerning riparian vegetation were collected in the 1980s, those data are approximately 30 years old and therefore additional information needs to be collected to provide a contemporary understanding of the riparian conditions existing in the Susitna River. Moreover, previous studies (McKendrick et al. 1982; Collins and Helm 1997; Helm and Collins1997) were largely descriptive of riparian vegetation composition, structure, and forest succession, and as such, do not provide an analytical framework sufficient for assessing potential impacts to floodplain vegetation that may result from Watana Dam operations, nor do they provide the ability to model and develop alternative flow scenarios. In addition, the configuration and proposed operations of the Project have changed and must be evaluated within the context of the existing environmental setting. This includes consideration of potential load-following effects on riparian ecosystems downstream of the Watana Dam site (including the Lower River Segment, as appropriate). Therefore, additional riparian studies are necessary to adequately address the effects of potential Project operations on the riparian floodplain plant communities.

8.6.2. Study Area

The study area includes the Susitna River active floodplain that would be affected by the operation of the Project downstream of Watana Dam. The active floodplain is the valley bottom flooded under the current climate. The longitudinal extent of the formal Riparian IFS study area currently extends to river mile (RM) 75. Determining how far downstream Project operational effects will extend will depend largely on the results of the Open-water Flow Routing Model (see Section 8.5.4.3), which is scheduled to be completed in Q1 2013. Thus, an initial assessment of the downstream extent of Project effects will be developed in Q2 2013 with input from the TWG. This assessment will include a review of information developed during the 1980s studies and study efforts initiated in 2012, such as sediment transport (see Section 6.5), habitat mapping (see Sections 6.5 and 9.9), operations modeling (see Section 8.5.4.2.2), and the Mainstem Open-water Flow Routing Model (see Section 8.5.4.3). The assessment will guide the need to extend studies into the Lower River Segment and if needed, will identify which geomorphic reaches will be subject to detailed instream flow analysis in 2013. Results of the 2013 studies would then be used to determine the extent to which Lower River Segment studies should be adjusted in 2014.

During the 1980s studies, the Susitna River was characterized into three segments extending above and below the two proposed dam sites. After researching potential Project configurations, AEA is proposing a single dam configuration at the Watana Dam site at RM 184. The proposed study characterizes the Susitna River as three segments (Figure 8.5-9). The Upper River Segment represents that portion of the watershed above the Watana Dam site at RM 184; the Middle River Segment (extending from RM 184 downstream to the Three Rivers Confluence at RM 98.5); and the Lower River Segment (extending from the confluence of Chulitna and Talkeetna rivers (Three Rivers) to Cook Inlet (RM 0). Potential Project effects to the Upper River Segment above the Watana Dam site are addressed in Section 9.0, Fish and Aquatic Resources; Section 10.0, Wildlife Resources; Section 11.0, Botanical Resources; and other studies. Potential Project effects to the Upper River Segment will not be addressed in the Instream Flow Study. The study area of the Instream Flow Study is focused on the two lower segments of the river, the Middle River Segment and the Lower River Segment.

The Middle River Segment encompasses approximately 85 miles between the proposed Watana Dam site (at RM 184) and the Three Rivers Confluence, located at RM 98.5. The river flows from Watana Canyon into Devils Canyon, the narrowest and steepest gradient reach on the Susitna River. In Devils Canyon, constriction creates extreme hydraulic conditions including deep plunge pools, drops, and high velocities. The Devils Canyon rapids appear to present a partial barrier hindering upstream passage at some flow conditions to the migration of anadromous fish; only a few adult Chinook salmon have been observed upstream of Devils Canyon. Downstream of Devils Canyon, the middle Susitna River widens but remains essentially a single channel with stable islands, occasional side channels, and sloughs. For purposes of the study, the Middle River Segment was further divided into eight reaches.

The Lower River Segment consists of an approximate 98-mile section between the Chulitna River confluence and Cook Inlet (RM 0). An abrupt change in channel form occurs where the Chulitna River joins the Susitna River near the town of Talkeetna. The Chulitna River drains a smaller area than the Middle River Segment at the confluence, but drains higher elevations (including Denali and Mount Foraker) and many more glaciers. The annual flow of the Chulitna River is approximately the same as the Susitna River at the confluence, though the Chulitna contributes much more sediment than the Susitna. For several miles downstream of the confluence, the Susitna River becomes braided, characterized by unstable, shifting gravel bars and shallow subchannels. For the remainder of its course to Cook Inlet, the Susitna River alternates between single channel, braided, and meandering planforms with multiple side channels and sloughs. Major tributaries drain the western Talkeetna Mountains (the Talkeetna River, Montana Creek, Willow Creek, Kashwitna River), the Susitna lowlands (Deshka River), and the Alaska Range (Yentna River). The Yentna River is the largest tributary in the Lower River Segment, supplying about 40 percent of the mean annual flow at the mouth.

Further refinements to the classification system being applied to the Susitna River have been made since the Proposed Study Plan (PSP), but the major divisions associated with the middle and lower segments have been retained. However, these are now incorporated into a more refined hierarchical classification system that scales from relatively broad to more narrowly defined categories as follows:

Segment → Geomorphic Reach → Mainstem Habitat Type → Mesohabitat Types (Main channel only) → Off-channel Habitat Types.

The highest level category is termed **Segment** and refers to the Middle River Segment and the Lower River Segment.

The **Geomorphic Reach** level is next and consists of eight categories *(MR-1 through MR-8)* for the Middle River Segment and four categories *(LR-1 through LR-6)* for the Lower River Segment. The geomorphic reach breaks were based in part on the following five factors: 1) planform type (single channel, island/side channel, braided); 2) confinement (approximate extent of floodplain, off-channel features); 3) gradient; 4) bed material / geology; and 5) major river confluences.

This is followed by **Mainstem Habitat Types,** which include the same categories applied during the 1980s studies – *Main Channel, Side Channel, Side Slough, Upland Slough, Tributary Mouth, and Tributary.*

The next level in the hierarchy is **Mesohabitat Type,** which at this time is reserved for classifying main channel habitats into categories of *Riffle, Pool, Run, and Glide*.

The last level in the hierarchy is referred to as **Off-channel Habitats** consisting of a number of descriptive categories and quantitative indices including *Turbid/Clear, Beaver Presence (Y/N), Gross Area (Off-channel Habitats), Shoreline Length (includes both Main Channel and Off-Channel Habitats).* These are more fully described in the Fish and Aquatics Instream Flow Study (see Section 8.5), with further information provided in both the Geomorphic Study Plan (see Section 6.0), and the Habitat Characterization Study Plan.

8.6.3. Study Methods

The Riparian IFS will first develop a process-based model of riparian vegetation succession and dynamics driven by riverine hydrogeomorphic processes. The modeling approach will use geomorphic, hydraulic, ice process, and GW/SW interaction models coupled with riparian vegetation succession models based upon riparian vegetation surveys and previous Susitna River riparian forest research (Helm and Collins 1997). Objectives of the modeling approach are as follows:

1. Measure and model riparian vegetation physical process relationships under the natural flow, sediment, and ice regimes.
2. Model potential impacts to riparian vegetation resulting from proposed Project operational changes to natural flow, sediment, and ice regimes.
3. Provide guidance for Project operation scenarios to minimize potential riparian vegetation impacts.

The Riparian IFS methods section is presented in the following format addressing each of the seven Project components and objectives. First, each study component and associated objectives are described. Second, study methods, with appropriate literature citations, are presented. Third, Data Input to the Riparian IFS from other Project studies, and Data Output from Riparian IFS to other Project studies, are detailed. Fourth, expected work products are presented. The Riparian IFS Project schedule is presented in Section 8.6.9 (Table 8.6-1) and a glossary of relevant terms is presented in Attachment 8-1.

8.6.3.1. Synthesize Historic Physical and Biologic Data for Susitna River Floodplain Vegetation, Including 1980s Studies, Studies of Hydro Project Impacts on Downstream Floodplain Plant Communities, and Studies of Un-impacted Floodplain Plant Community Successional Processes

The goal of this study is to critically review and synthesize historic Susitna River riparian vegetation studies within the context of physical process investigations conducted in the 1980s including ice processes, sediment transport, GW/SW, and herbivory. Studies of downriver floodplain vegetation response to hydroregulation on other hydro projects (both North American and circum-polar) will be incorporated into the review to develop a current state-of-the-science analysis of potential Project operational flow effects to Susitna River riparian floodplain vegetation. Additionally, studies of un-impacted temperate and boreal floodplain plant community successional processes will be incorporated into the study as appropriate. Study objectives, methods and expected results are summarized in Table 8.6-2.

The objectives of this study task are as follows:

1. Conduct a critical review of previous Susitna River 1980s floodplain vegetation studies.
2. Place potential Susitna River Project operational effects within context of studies from other hydroregulated rivers in North America.
3. Review, and include relevant findings of, current research concerning temperate and boreal floodplain forest succession and dynamics under natural flow regimes.

8.6.3.1.1. Methods

A critical literature review of all appropriate Susitna 1980s studies, historic and current hydro project floodplain effects studies, and temperate and boreal floodplain forest scientific literature will be conducted. The synthesis of findings will focus on elements relevant to evaluating potential Project operation effects on downstream floodplain vegetation. An annotated, searchable bibliography will be developed.

8.6.3.1.2. Data Input From Other Studies

Data input from other studies will include 1980s Susitna River floodplain study literature, hydro project studies of downstream floodplain vegetation, and studies of un-impacted temperate and boreal floodplain plant community succession.

8.6.3.1.3. Data Output to Other Studies

Output to other studies will include data for Geomorphology and Ice Processes studies, literature review findings concerning Susitna River riparian vegetation and physical process, identification of critical issues from hydro project floodplain vegetation impact analyses, and relevant findings from natural flow regime floodplain vegetation research.

The results of this study will also provide Project operational design guidance.

8.6.3.1.4. Work Products

1. ISR chapter with an annotated, searchable, bibliographic appendix.

2. Product deliverable date: Q4 2013.

8.6.3.2. Focus Area Selection−Riparian Process Domain Delineation

Floodplain plant communities within mountain river corridors are dynamic in that channel and ice processes annually disturb floodplain vegetation resulting in the characteristic patchwork of floodplain vegetation composition, structure, and age together reflecting time since most recent vegetation disturbance (Naiman et al. 1998). Vegetation disturbance can be defined as those processes that remove or otherwise impact plant communities and soils, often setting the system back to an earlier successional state. Floodplain vegetation disturbance types found within the study area include channel migration (erosion and depositional processes), ice processes (shearing impacts, flooding, and freezing), herbivory (beaver, moose, and hare), wind, and, to an infrequent extent, fire. Floodplain disturbance regimes (type, magnitude, frequency, duration and timing) vary systematically throughout river networks and, therefore, their geographic distribution may be mapped (Montgomery 1999).

Process domains define specific geographic areas in which various geomorphic processes govern habitat attributes and dynamics (Montgomery 1999). Within the mountain river network, temporal and spatial variability of channel, ice, and sediment disturbance processes can be classified and mapped, allowing characterization of specific riparian process domains with similar suites of floodplain disturbance types. The riparian process domain approach is hierarchical in structure allowing for river network stratified sampling to statistically describe elements and processes within each process domain. Riparian study sites, including those located within Focus Areas, will be selected to capture the variability in floodplain vegetation types, and geomorphic terrains, within each riparian process domain. The number of Focus Areas necessary to capture process domain variability will be determined through a power analysis. The hierarchical stratification of the Susitna River Study Area into riparian process domains will facilitates both representative sampling and the ‘scaling-up’ of Focus Area modeling results to the larger Study Area.

The issue of pseudoreplication (Hurlbert 1984), and number of adequate sample sites necessary to perform robust statistical analyses, is addressed in the hierarchical riparian process domain sampling design and integration of the Riparian Botanical Survey design. Focus Area sites will be representative of specific riparian process domains and their channel / floodplain characteristics (ice process domains, channel plan form, channel slope, channel confinement). Focus Area physical and vegetation processes will be modeled and floodplain vegetation-flow response relationships statistically described in probabilistic models (Rains et al. 2004). The Riparian Botanical Survey (see Section 11.6 for vegetation statistical sampling protocols) is designed to provide Study Area -wide representative sample replicates of floodplain vegetation, soils, and alluvial terrain relationships. Furthermore, the surface water flood regime for the Study Area will be modeled, and mapped, providing flow regime plant community relationship analysis replicates throughout the greater Study Area, in addition to those modeled at each Focus Area. The riparian process domain and Study Area -wide sampling of the Riparian Botanical Survey are specifically designed to address the question of pseudoreplication. Study interdependencies are presented in Figure 8.6-3. Study objectives, methods and expected results are summarized in Table 8.6-3.

The objectives of the Focus Area selection and riparian process domain delineation are as follows:

1. Develop a riparian process domain stratification of the Study Area.
2. Select Focus Areas representative of each riparian process domain for physical process and vegetation survey sampling and modeling.

8.6.3.2.1. Methods

Riparian process domain delineation, and riparian Focus Area selection is an iterative process (Figure 8.6-3 and Figure 8.6-4). First, in Q1 21013 the results of the 2012 geomorphology study and channel classification (Section 6.6), ice processes study (Section 7.6), riparian botanical survey (Section 11.6) will be used to classify channel, floodplain and floodplain vegetation types. The Lower River (RM 0 to RM 98), the Middle River (RM 98 to RM 184), and the Upper River to the Maclaren River confluence (RM 184 to RM 260) were delineated into large-scale geomorphic river segments (few to many miles) with relatively homogeneous characteristics, including channel width, entrenchment, ratio, sinuosity, slope, geology/bed material, single/multiple channel, braiding index, and hydrology (inflow from major tributaries) for the purposes of stratifying the river into study segments (Figure 8.5-11 and Figure 8.5-12). This type classification data will be used in a spatially constrained cluster analysis process (Brenden et al. 2008) to group Study Area channel reaches and segments into riparian process domains. Second, process domain type variability will be statistically described and a power analysis performed to determine the number of Focus Areas necessary to capture process domain variability in the stratified sampling approach. Third, candidate Focus Areas previously identified through the expert-opinion process for both Aquatic and Riparian IFS will be reviewed (Figures 8.5-13 through 8.5-22). Fourth, results of the cluster analysis, power analysis and expert-opinion process will be presented to the TWG for final selection of Focus Areas.

Additionally, ice process floodplain vegetation interactions will be measured thorough tree ice-scar mapping to be conducted in Q2 and Q3 2013. A preliminary tree ice-scar survey was begun in October 2012. Additional tree ice-scar mapping is being conducted by snow machine in Q4 2012. The preliminary 2012 tree ice-scar mapping data will be processed, mapped and presented with the results of the riparian process domain and Focus Area selection analyses results to the TWG in Q1 2013.

When the ice process mapping is completed in Q4 2013, the riparian process domain analysis and Focus Area selection process will be performed a second time to assess whether additional Focus Areas are necessary to measure and model ice process effects on floodplain vegetation. If the results of this analytical process conclude that additional Focus Areas are necessary they will be selected with input from the TWG for 2014 field sampling.

8.6.3.2.2. Data Inputs from Other Studies

The Geomorphology Study has provided the geomorphic reach classification and stratification. The Ice Process Study will provide further modeling and observational data for refining riparian process domains.

8.6.3.2.3. Data Output to Other Studies

The riparian process domain map will be provided to geomorphology, riparian botanical, ice processes, and fish and wildlife studies.

8.6.3.2.4. Work Products

1. ISR chapter, describing the approach and methodology used to develop the riparian process domain map and Focus Area selection process.
2. Map of Susitna River riparian process domains and Focus Area locations.

Final Focus Areas, of riparian study concern, selection will be finished with input from the Technical Workgroup (TWG) in Q2 2013.

8.6.3.3. Characterize Seed Dispersal and Seedling Establishment Groundwater and Surface Water Hydroregime Requirements. Develop Predictive Model of Potential Project Operational Impacts to Seedling Establishment

Floodplain plant seed dispersal and seedling establishment are critical processes in floodplain plant community succession that may be affected by hydroproject operations (Braatne et al. 1996; Cooper et al. 1999; Rood et al. 2003). In this study dominant woody species seed dispersal and seedling establishment hydrologic requirements will be determined through field surveys and groundwater and surface water interaction measurement and modeling. The study has two subtasks: (1) seed dispersal, hydrology, and local Susitna River valley climate synchrony study, and (2) seedling establishment study.

8.6.3.3.1. Synchrony of Seed Dispersal, Hydrology, and Local Susitna River Valley Climate

Susitna River pioneer riparian tree and shrub species in the family *Salicaceae*, Balsam poplar (*Populus balsamifera*), and willows (*Salix* spp.) are adapted to seasonal snowmelt-driven spring peak flows, in terms of timing of seed dispersal, newly deposited mineral colonization substrates, and concordant near-surface floodplain groundwater conditions, all necessary conditions for poplar and willow seedling establishment and recruitment (Figure 8.6-5; Braatne et al. 1996; Mahoney and Rood 1998; Mouw et al. 2012). Project operations may result in a reduction of June/July peak flows, and associated floodplain groundwater conditions, necessary to dispersal and establishment of cottonwood and willow trees and shrubs. The timing of snowmelt spring flows, and of tree and shrub seedling release and dispersal, is critical to successful establishment and maintenance of riparian floodplain forests (Figure 8.6-6; Braatne et al. 1996; Mahoney and Rood 1998). An empirical model, the "Recruitment Box Model" that captures cottonwood and willow seed dispersal, flow response and recruitment requirements has been successfully demonstrated on rivers throughout North America (Figure 8.6-6; Mahoney and Rood 1998; Rood et al. 2003). The model characterizes seasonal flow pattern, associated river stage (elevation), and flow ramping necessary for successful cottonwood and willow seedling establishment (Figure 8.6-5 and Figure 8.6-6). A recruitment box model for balsam poplar and select willow species for the Susitna River will be developed. Study interdependencies are presented in Figure 8.6-7. Study objectives, methods and expected results are summarized in Table 8.6-4.

Objectives of the seed dispersal, hydrology, and climate synchrony study are as follows:

1. Measure cottonwood and select willow species seed dispersal timing.
2. Model local Susitna River valley climate, and associated seasonal peak flows, relative to cottonwood and willow seed dispersal.

3. Develop a recruitment box model of seed dispersal timing, river flow regime, and cottonwood and willow seed dispersal and establishment.

8.6.3.3.1.1. Methods

To evaluate the natural synchrony of balsam poplar, and select willow species (*Salix alaskensis* and *S. barclayi*) seed release, and Susitna River natural flow regime, the following tasks will be undertaken: (1) conduct a two-year survey of seed release of balsam poplar and select willow species (Q2-3 2013; Q2-3 2014), (2) develop a ‘degree-day’ climate model for the onset of seed release relative to local temperature conditions using methods developed by Stella et al. (2006), and (3) analyze the historic climate and Susitna River flow regime relationship. The results of this study will identify flow regime timing conditions necessary to support riparian cottonwood and willow establishment on the Susitna River.

Four floodplain sites near existing meteorological stations in the Middle and Lower Susitna (Figure 8.6-8) will be selected for balsam poplar and select willow species seed release surveys. At each site, 10 to 15 dominant female balsam poplar trees and willows will be surveyed weekly during the months of June, July, and the first two weeks of August, 2013–2014. Seed release will be measured during each survey by counting open catkins for each tree or shrub using methods developed by Stella et al. (2006). Floodplain riparian plant community characteristics will be sampled for each floodplain seed dispersal site using the riparian botanical survey vegetation sampling techniques (see Section 11.6). Tree data and seed release timing will be analyzed using protocols developed by Stella et al. (2006). At all field sites, local air temperature measurements will be collected from adjacent weather monitoring stations (Figure 8.6-8). A degree-day model using seed release observations and continuous temperature records from the monitoring stations will be developed (Stella et al. 2006).

A recruitment box model (Figure 8.6-6; Mahoney and Rood 1998; Rood et al. 2003) will be developed to evaluate the potential effects of various proposed spring operational flows on cottonwood and willow establishment.

8.6.3.3.1.2. Data Input From Other Studies

The IFS Flow Routing (see Section 8.6) and Geomorphology (see Section 6.6) studies will provide flow modeling (frequency, magnitude, duration, and seasonal timing) for development of the “recruitment box model” of seed dispersal timing and flood regime.

8.6.3.3.1.3. Data Output to Other Studies

The modeling results of the synchrony study will be used to guide Project operations design such that seasonal flow regime supports identified cottonwood and willow seeding establishment requirements.

8.6.3.3.1.4. Work Products

1. ISR and USR chapters detailing study methods, results, and conclusions.
2. Degree-day model of peak seed release window using seed release observations and continuous temperature records from each floodplain sample site.

3. Recruitment box model of cottonwood and select willow species.
4. Model of peak runoff / seed release temporal synchrony for operational flow guidelines.
5. Model of critical summer flow regime necessary to support seedling establishment.

The seed dispersal study fieldwork will be conducted in Q2 and Q3 during both 2013 and 2014. Model development will be conducted during Q1-4 2014.

8.6.3.3.2. Seedling Establishment and Recruitment Study

Riparian vegetation in mountain river networks is adapted to a dynamic physical disturbance regime including flooding, summer desiccation, erosion, sediment burial, ice shearing and freezing, wind, herbivory and, infrequently, fire (Naiman et al. 1998). Seedling establishment, survival, and recruitment are critical phases in the development of floodplain plant communities within this dynamic physical environment (Walker and Chapin 1986; Walker et al. 1986; Karrenberg et al. 2002; Muow et al. 2009, 2012; Rood et al. 2007). The goal of the seedling establishment and recruitment study is to identify, measure, and model potential impacts of Project operational changes to the groundwater, surface water, sediment, and ice regimes, and to assess the effects on seedling establishment and recruitment within the active channel margin / floodplain environment.

Identifying the spatial locations, and groundwater, surface water, and sediment requirements under which new cohorts of dominant riparian plant seedlings establish, survive, and recruit on the Susitna River floodplain is a critical element in evaluating potential floodplain vegetation effects of Project operational alterations of the natural flow and sediment regimes. River ice seedling interactions, an additional critical physical disturbance factor, will be investigated in the ice process modeling study (see Section 8.6.3.4.2).

Seedling recruitment in the Susitna floodplain occurs not only on new flood-deposited sediments along channel and floodplain margins—the primary sites of balsam poplar, willow, thinleaf alder (*Alnus tenuifolia),* and Sitka alder (*Alnus sinuata)* colonization—but also on sediment deposits within the developing and mature floodplain forest (Helm and Collins 1997). Helm and Collins (1997) noted that within the floodplain forest, white spruce (*Picea glauca*) and paper birch (*Betula papyrifera*) seedlings were found to establish, and recruit, on mineral soils associated with both floodplain surface sediment deposits, ice-influenced sediment deposits, and tree wind throw mound soils. Also, during the 2012 Riparian Botanical Survey, white spruce and paper birch seedlings were observed growing on mounds of gravel and sand apparently pushed onto the floodplain interior by ice flows.

Study interdependencies are presented in Figure 8.6-9. Study objectives, methods and expected results are summarized in Table 8.6-5.

A two year study using woody seedling dendrochronology to date the year of seedling year of establishment is adequate to characterize seedling establishment hydrologic conditions. Seedling year of establishment will be used, with the historic discharge record, to model the flood regime at the sample site 1-D or 2-D hydraulic models.

While not included within this study plan, to address a USFWS request, AEA will conduct a longitudinal three-year second-peak seedling cohort establishment and survival analysis to inform the adaptive management components of future Project instream flow regimes. This analysis is described in Attachment 8-2. Specifically, the objective of the analysis is to identify, and measure, seedling and flow regime characteristics in a longitudinal seedling cohort analysis as compared to the two-year study.

The seedling cohort establishment analysis will be initiated in summer 2013 and carried through for three years 2014 to 2016; final results will be presented in a technical memorandum to be prepared Q4 2016. The technical memorandum is not necessary for the environmental analysis supporting AEA's License Application because the anticipated results are not necessary to assess overall Project effects. Instead, AEA anticipates relying upon the technical memorandum for adaptive management of future Project operations.

Objectives of the seedling recruitment study are as follows:

1. Map the spatial locations of seedlings of dominant woody riparian species including balsam poplar, white spruce, paper birch, thinleaf and Sitka alder, feltleaf willow, and Barclay's willow throughout the Focus Area, and Riparian Vegetation Study sites, active channel margins, and floodplain.
2. Use a stratified random sampling approach, with variable plot sizes (Mueller-Dombois and Ellenburg 1974), to sample mapped seedling polygons.
3. Identify seedlings to species, and measure seedling heights and density.
4. Describe and measure seedling site soil characteristics (see Section 8.6.3.7 for methods).
5. Measure and model seedling site GW/SW hydroregimes.
6. Measure seedling xylem water source through isotopic analysis (see Section 8.6.3.6 for methods).
7. Investigate ice process seedling site interactions through empirical observations and ice process modeling.
8. Develop a probabilistic model of seedling hydrologic, sediment, and ice regime processes.

8.6.3.3.2.1. Methods

Dominant riparian woody species will be sampled in this study, including balsam poplar, white spruce, paper birch, thinleaf and Sitka alder, feltleaf willow, and other willow species. In addition to the target woody seedlings, all herbaceous seedlings within the woody species seedling plots will be identified and measured.

Seedlings are defined as those plants established within the current year of sampling, and all plants with stems < 1m in height. At select Riparian Botanical Survey reaches, and at all Focus Areas, seedling patches will be mapped and sampled using a stratified random sampling protocol to obtain statistically representative samples of select woody species (Elzinga et al. 1998; Mueller-Dombois and Ellenberg 1974).

The survey sampling approach is as follows. First, a helicopter survey of each reach will be conducted to locate and map observable seedling areas. Second, four to eight transects will be placed systematically throughout the reach normal to main channel, extending across the adjacent floodplain intersecting observed seedling sites. Each transect will be traversed and all remotely observed, and newly identified on-the-ground seedling locations will be mapped with

GPS. Third, seedling site polygon boundaries will be mapped with GPS. Fourth, seedling patches will be sampled using a stratified random approach to locate sample plots. Seedling species will be identified, or collected for herbarium identification, and abundance (density) and height measured using variable plot size and shapes (Elzinga et al. 1998; Mueller-Dombois and Ellenberg 1974). Fifth, at each plot two to three seedlings of each species will be excavated and rooting depth measured. Excavated woody seedlings will be aged at the root collar in the laboratory and annual rings counted to provide seedling age. Substrate texture and depth to cobbles will be described and measured in soil pits excavated to 50 cm in depth or to gravel/cobble refusal layer. Sixth, a sub-sample of Focus Area site seedlings will be used for xylem isotopic analyses to identify source of water (see Section 8.6.3.6). Results of seedling mapping and characterization will be used to assess groundwater, surface water, and ice regime relationships using 1-D / 2-D, MODFLOW and ice process modeling results from the Groundwater, Geomorphology, and Ice Processes studies.

A probabilistic model of seedling and GW/SW, sediment, and ice regime will be developed using techniques and methods described in Franz and Bazzaz (1977), Rains et al. (2004), Henszey et al. (2004), Baird and Maddock (2005), and Maddock et al. (2012).

The results of the Focus Area modeling will be scaled-up to the riparian process domains using spatially explicit GIS models as described in Section 8.6.3.7.

8.6.3.3.2.2. Data Input from Other Studies

Data input will include groundwater, surface water, and sediment regime characteristics of seedling sites developed in the Groundwater (Section 7.5) and Fluvial Geomorphology (Section 6.6) studies. The Ice Processes Study (Section 7.6) will provide modeled ice influence vertical and horizontal zones.

8.6.3.3.2.3. Data Output to Other Studies

Data output will include groundwater, surface water, and sediment regime seedling requirements to Floodplain Vegetation Study Synthesis, Focus Area to Riparian Process Domain Scaling and Model Project Operations Effects Section 8.6.3.7 and Project operations design.

8.6.3.3.2.4. Work Products

1. ISR and USR chapters detailing study methods, results, and conclusions.
2. Probabilistic seedling hydrologic, sediment, and ice regime model.

The seedling establishment and recruitment study fieldwork will be conducted in Q2 and Q3 during both 2013 and 2014. Results analysis will be conducted during Q1-4 2014.

8.6.3.4. Characterize the role of river ice in the establishment and recruitment of dominant floodplain vegetation. Develop predictive model of potential Project operational impacts to ice processes and dominant floodplain vegetation establishment and recruitment.

Although the role of fluvial disturbance (erosion and sediment deposition) in the development of floodplain vegetation has been well investigated (Naiman et al. 1998; Rood et al. 2007), the role of river ice processes has seen little study (Engstrom et al. 2011; Prowse and Beltaos 2002; Prowse and Culp 2003; Rood et al. 2007). The results of river ice disturbance of floodplain vegetation have been observed in the Susitna River, and reported anecdotally, in Helm and Collins (1997). The 2012 Riparian Botanical Survey Team observed extensive evidence of ice disturbance to floodplain trees, and soils, in the form of tree ice-scars, mechanically disturbed soil stratigraphy, and floodplain gravel deposits throughout the Middle and Lower Susitna River surveys (Figure 8.6-10, Figure 8.6-11, and Figure 8.6-12).

Impacts of ice-related processes to riparian habitat typically occur during break-up when ice scours channel and floodplain surfaces (Prowse and Culp 2003). During break-up, ice accumulation in meander bends can create ice dams elevating backwater surfaces, forcing meltwater to bypass the bend and scour a new meander cutoff, generating new side channels (Prowse and Culp 2003). Elevated backwater, resulting from ice dams, may also float ice blocks onto and through vegetated floodplain surfaces, causing mechanical shearing effects including tree ice-scarring and abrasion, removal of floodplain vegetation, and disturbance of floodplain soils (Engstrom et al. 2011; Rood et al. 2007; Prowse and Culp 2003).

8.6.3.4.1. Empirical Studies of River Ice and Floodplain Vegetation

Given the paucity of studies concerning river ice and floodplain vegetation interactions, multiple lines of evidence will be used to inform a final research study design to address the question of vegetation response to ice shearing influence on the Susitna River floodplain. First, ice vegetation impacts (tree ice-scars) will be observed, mapped, and aged (using dendrochronologic techniques), and gravel floodplain deposits will be mapped throughout the Study Area to develop a Study Area map of river ice floodplain vegetation interaction domains. Preliminary tree ice-scar mapping was begun during the 2012 Riparian Botanical Survey, and early October 2012 Focus Area reconnaissance. Mapping will continue in Q2 and Q3 2013 and throughout the 2013 and 2014 riparian field seasons. Second, local residents will be interviewed (e.g., Mike Wood, who lives across from Whiskers Slough) concerning their knowledge of spatial locations of historic ice dams, years of significant ice occurrence, and other anecdotal historical information concerning ice on the Susitna River. From these two sources of information, a map will be created of Susitna River ice process floodplain vegetation effect domains. The ice process map will be used to: (1) inform riparian process domain delineation (see Section 8.6.3.2) and (2) develop a floodplain vegetation study to compare floodplains affected by ice with those un-impacted by ice, similar to the approach of Engstrom et al. (2011).

Floodplain vegetation surveys will be conducted to quantitatively measure (stratified random sampling of mapped floodplain vegetation ice shear process zones) and statistically describe and compare vegetation characteristics associated with floodplains experiencing ice shear events and floodplain vegetation without observed ice influence. The vegetation study design will build on the design and results of Engstrom et al. (2011) where they studied and assessed the effects of anchor ice on riparian vegetation. Engstrom and others found that species richness was higher at sites affected by anchor ice than at sites where anchor ice was absent, suggesting that ice disturbance plays a role in enhancing plant species richness (Engstrom et al. 2011).

The objective of the ice effects vegetation study will be to quantitatively describe floodplain plant community composition, abundance, age, and spatial pattern to assess the role and degree of influence ice processes have on Susitna River floodplain vegetation. The results of the study will be used to assess how floodplain vegetation pattern and process may change with Project operation alterations of the natural ice process regime. The final study design will be completed in Q2-3 2013, as additional tree ice-scar field data become available.

8.6.3.4.2. Ice Process Modeling Studies

The ice process study will develop and calibrate a dynamic thermal and ice processes model (see Section 7.6 for details). The model will provide maps of ice cover progression and decay, ice cover extent and thickness, and effects of Project operational flow fluctuation on ice cover development and stability. Additionally the model will provide flow routing capability. Ice and flow routing effects on floodplain vegetation and channel morphology will be assessed. The Ice Processes study will also provide videography of ice formation and ice break-up at a number of locations throughout the Study Area. The ice process modeling study will provide the riparian ice vegetation study with estimated horizontal and vertical zones of ice formation, ice thickness, and floodplain impact zones. Model output will be used in conjunction with the empirical survey data to (1) empirically test model output with mapped riparian domains of ice floodplain vegetation interaction, and (2) model changes in locations and types of ice formation processes due to Project operational flow regime. Together, the empirical mapped ice influence zones, empirical studies of vegetation / ice interactions, and modeling confirmation and prediction will be used to understand and predict the influence of Project operational flows on ice and floodplain vegetation interactions.

Study interdependencies are presented in Figure 8.6-13. Study objectives, methods and expected results are summarized in Table 8.6-6.

The objectives of the ice processes floodplain vegetation interaction and modeling study are as follows:

1. Develop an integrated model of ice process interactions with floodplain vegetation.
2. Conduct primary research to identify the effects of ice on floodplain vegetation within mapped Susitna River ice floodplain impact zones.
3. Provide Project operational guidance on potential effects of operations flow on ice formation and floodplain vegetation development.

8.6.3.4.2.1. Methods

1. Mapping of ice floodplain vegetation interactions and soil disturbance throughout the Study Area.
2. Interviews of local Susitna River residents concerning knowledge of ice dam locations and ice process effects.
3. Comparative quantitative vegetation study of ice effects on identified ice floodplain impact and un-impacted zones. Methods will build on those presented in Engstrom et al. (2011).
4. Final ice vegetation field sampling methodology will be developed in Q2, Q3 2013 as tree ice-scar field data become available and ice effect domains are delineated.
5. Integration of ice process modeling results with empirical ice vegetation mapping and ice vegetation interaction studies.

8.6.3.4.2.2. Data Input From Other Studies

Data inputs including ice process modeling results concerning spatial location of ice, vertical extent of ice, and potential ice dam locations will be available beginning Q4 2013 extending through Q4 2014.

8.6.3.4.2.3. Data Output to Other Studies

Data outputs will include Project operation guidance on minimizing alteration of ice processes and subsequent effects to floodplain vegetation.

8.6.3.4.2.4. Work Products

1. ISR and USR chapters detailing study methods, results, and conclusions.

The river ice seedling establishment and recruitment study fieldwork will be conducted in Q2 and Q3 during both 2013 and 2014. Results analysis and technical memorandum, or chapter, will be conducted during Q1-4 2014.

8.6.3.5. Characterize the role of erosion and sediment deposition in the formation of floodplain surfaces, soils, and vegetation. Develop a predictive model of Project operations changes to erosion and sediment deposition pattern and associated floodplain vegetation.

The dynamic of channel migration—sediment transport, and resulting floodplain erosion and sediment depositional patterns—is a critical physical process directly affecting floodplain soil development, and vegetation establishment, recruitment, and spatial location, throughout alluvial segments of the river network (Richards et al. 2002). The life history strategies and establishment requirements of floodplain plant species are adapted to natural flow and sediment regimes (Braatne et al. 1996; Naiman et al. 1998; Karrenberg et al. 2002). As such, alterations of natural hydrologic and sediment regime seasonal timing, magnitude, frequency, and duration may have effects on plant species establishment, survival, and recruitment (Braatne et al. 1996). The goal of this study is to characterize the role of erosion and sediment deposition in evolution of floodplain plan form, soil development, and trajectory of plant community succession, especially vegetation establishment stage. This study, in coordination with the Fluvial Geomorphology Study (see Section 6.6), will investigate the geomorphic evolution of the Study Area floodplain with an emphasis on floodplain sediment deposition, stratigraphy, soil development, and associated plant community succession. Historic sediment deposition rates will be measured throughout the Study Area river network and variations in floodplain forming processes will be assessed. Finally, a predictive model will be developed with the Fluvial Goemorphology Study (see Section 6.6) to assess Project operational effects on hydrologic and sediment regimes, and effects on soil and floodplain plant community development.

In a river that meanders through a wide valley, such as the Susitna River, erosion on one side of the channel will be balanced by deposition on the opposite site as the river migrates laterally. Disturbance to riparian habitat on the eroding bank will be balanced by opportunities for recruitment on the point bar. This type of geomorphic process maintains the characteristic range of floodplain surface elevations and vegetation age classes contributing to the diversity of floodplain vegetation composition and structure (Naiman et al. 1998). The rate of channel migration may be impacted by Project operations with secondary impacts on the riparian community. The Fluvial Geomorphology Study will assess Project alterations to downstream channel bed and floodplain surface elevations through sediment transport modeling and analyses. These potential changes will be provided to the Riparian IFS. Development of the study design, modeling, and methods has been coordinated closely with Geomorphology, Ice Processes, and Riparian Vegetation study teams (Figure 8.6-1).

The fluvial geomorphology modeling approach (see Section 6.6) is based upon (1) 1-D / 2-D modeling of river discharge and stage, (2) 1-D / 2-D sediment transport model, (3) geomorphic reach analyses (aerial photographic analyses of historic channel change), and (4) flow routing model.

Study interdependencies are presented in Figure 8.6-14. Study objectives, methods and expected results are summarized in Table 8.6-7.

The objectives of the study are as follows:

1. Measure the rates of channel migration, and floodplain vegetation disturbance or turnover, throughout the Study Area.
2. Measure the rates of sediment deposition, and floodplain development, throughout the Study Area.
3. Assess / model how Project operations will effect changes in the natural sediment regime, floodplain depositional patterns, and soil development throughout the Study Area.
4. Assess / model how Project operations changes in sediment transport and soil development will affect floodplain plant community succession.

8.6.3.5.1. Methods

1. Floodplain soils and stratigraphy will be sampled throughout the Study Area using a stratified random approach, including pits located in all Focus Areas.
2. Floodplain soil pits will be excavated from the surface to gravel / cobble layer (historic channel bed) and soil stratigraphy will be described and measured using standard NRCS field techniques (Schoeneberger et al. 2002). Standard sediment grain size sieve analysis will be conducted on the entire sediment profile.
3. Direct dating of fluvial sediments will be conducted using isotopic techniques, including, but not limited to, ^{137}Cs and ^{210}Pb measurements as described in Stokes and Walling (2003).
4. Dendrochronologic techniques (Fritts 1976) will be used to age trees and current floodplain surfaces at each soil pit.

Woody species will be sampled, and aged, at all mapped Focus Area plant communities, including seedlings, to determine year of origin. Standard dendrochronologic techniques will be applied for tree and shrub sampling and growth ring measurements (Fritts 1976).

For each Focus Area mapped stand, two to three trees and shrubs per species will be sampled for age determination. Tree and shrub samples will be taken with either an increment borer or by cutting the shrub or sapling stem and removing a stem section for laboratory analysis. Increment cores (two per tree) will be collected from each tree. For each tree sampled, floodplain sediment will be excavated to uncover the stem root collar and depth of sediment aggradation will be measured for further age estimation. Woody species seedlings for each dominant species will be excavated, heights measured, stems sectioned at the root collar, and annual rings measured under a dissecting microscope. A regression analysis will be conducted to assess the relationship between stem age and seedling height. The results will be used to add additional years to trees to account for height of core sample above the root collar.

Tree cores will be taken as close to the ground surface as possible, generally 30 centimeters or less above ground surface. Total height of tree core sample above the root collar will be calculated and used to estimate additional years to estimate tree year of origin. Increment cores will be mounted on pieces of 1-inch by 2-inch wood and sanded with variable grades of sandpaper following standard methods described in Fritts (1976). Ring width measurements will be made, and annual years counted, for both the tree cores and stump sections using a dissecting microscope. Individual trees will be cross-dated, if possible, using standard methods (Fritts 1976).

8.6.3.5.2. Data Input From Other Studies

Geomorphology Study (see Section 6.6) will provide for all Focus Areas: (1) historic channel migration rates, floodplain vegetation disturbance or turnover rate; (2) flood frequency, magnitude, duration, and timing; (3) sediment transport and depositional spatial model.

Instream Flow Study (IFS) flow routing: Study Area -wide flood frequency, magnitude, duration, and timing.

The Riparian Botanical Survey (see Section 11.6) will conduct the sediment and soils fieldwork including stratigraphic description, strata measurements, and floodplain sediment dating for all Focus Areas and Study Area -wide sampling.

8.6.3.5.3. Data Output to Other Studies

To Geomorphology Study: (1) dating of floodplain stratigraphy and surfaces using direct isotopic and dendrochronologic techniques, and (2) floodplain stratigraphic descriptions and grain size analyses.

To Section 8.6.3.7 Floodplain Vegetation Study Synthesis, Focus Area to Riparian Process Domain Scaling and Project Operations Effects Modeling: (1) dating of floodplain stratigraphy and surfaces using direct isotopic and dendrochronologic techniques, and (2) floodplain stratigraphic descriptions and grain size analyses.

8.6.3.5.4. Work Products

1. ISR and USR chapters detailing study methods, results, and conclusions.

Fieldwork will be conducted in Q2 and Q3 during both 2013 and 2014. Analyses will be conducted during Q2-4 2013 and Q1-4 2014.

8.6.3.6. Characterize natural floodplain vegetation groundwater and surface water maintenance hydroregime. Develop a predictive model to assess potential Project operational changes to natural hydroregime and floodplain vegetation.

Water sources for the establishment and maintenance of floodplain vegetation include precipitation, groundwater, and surface water (Cooper et al. 1999; Rood et al. 2003). Identifying both floodplain plant water sources and the GW/SW hydroregime associated with critical riparian plant species life stages is necessary to (1) characterize natural floodplain vegetation establishment and maintenance hydrologic requirements, and (2) evaluate effects of Project operations on these hydroregimes and associated plant communities.

The goal of the floodplain vegetation GW/SW interaction modeling effort is to statistically characterize the relationship between floodplain groundwater and surface water hydroregime and associated floodplain plant communities and to use this model to predict Project operation effects on floodplain vegetation throughout the Study Area. This investigation will (1) characterize dominant floodplain woody plant species establishment and maintenance life stage water sources through stable isotope analyses of groundwater, soil water, and xylem water; (2) develop a floodplain GW/SW model; and (3) develop floodplain vegetation-flow response models.

Riparian woody species establishment has been associated with both surface water flooding and precipitation (Braatne et al 1996; Cooper et al. 1999; Rood et al. 2003). Riparian floodplain vegetation maintenance relies to a large extent on groundwater as a water source (Cooper et al. 1999; Rood et al., 2003; Henszey et al. 2004). Floodplain groundwater depths have been demonstrated to control floodplain plant community composition, species richness, and structure (Henszey et al. 2004; Baird et al. 2005; Mouw et al. 2009). Project operations will alter, on a seasonal basis, the flows in the Susitna River, and on a shorter time scale, flows associated with potential load-following operations potentially affecting floodplain shallow aquifer water elevations. The results of this study will be scaled-up from the Focus Areas, to their respective riparian process domains, to provide a model of the entire Study Area.

8.6.3.6.1. Groundwater and Surface Water Interaction Modeling

A physical model of GW/SW interactions will be developed for all Focus Area sites to model floodplain plant community GW/SW relationships. Developing conceptual model and numerical representations of the GW/SW interactions, coupled with important processes in the unsaturated zone, will help evaluate natural variability in the Susitna River riparian floodplain plant communities, and assesses how various Project operations may potentially result in alterations of floodplain plant community types, as well as improve the understanding of what controlled fluctuations of flow conditions would result in minimal riparian changes.

Regional and local groundwater flow systems are important to floodplain vegetation (Figure 8.6-15). Seasonal river stage fluctuations generate transient GW/SW interactions at a local scale under and adjacent to the river, including side channels, side sloughs, and upland sloughs (Figure 8.6-16 and Figure 8.6-17). A typical system representing several types of surface water features is shown in the Whiskers Slough proposed Focus Area (Figure 8.6-16). This plan view shows both the potential orientation of mainstem and side channel surface water features, along with typical riparian floodplain plant community types found in the Middle River Segment of the Susitna River. A schematic cross-section of a typical profile across the river floodplain from main channel through floodplain, secondary channel and adjacent hillslope is shown in Figure 8.6-18. This figure depicts the relative relationships between surface water stage levels, groundwater levels, land surface elevations, and riparian floodplain plant community types.

Developing conceptual model and numerical representations of the GW/SW interactions, coupled with important processes in the unsaturated zone, will help evaluate natural variability in the Susitna River floodplains, and how various Project operations could result in alterations of floodplain plant community types, as well as improve the understanding of what Project operational fluctuations of flow conditions would result in minimal riparian changes.

8.6.3.6.2. Floodplain Vegetation-GW/SW Regime Functional Groups

Floodplain vegetation−GW/SW regime functional groups are assemblages of plants that have established and developed under similar GW/SW hydrologic regimes. Metrics will be developed for quantitatively describing the relationship between floodplain plant communities and the GW/SW hydroregime. Probabilistic response curves will be developed for select plant species and all riparian plant community types using techniques described in Rains et al. (2004) and Henszey et al. (2004). The results of the response curve analyses will be used to develop floodplain vegetation-GW/SW regime functional groups (Merritt et al. 2010; Rains et al. 2004). These techniques and analyses will form the basis for development of a statistically modeled relationship between individual riparian species, floodplain plant community types, and natural GW/SW hydroregime that will be used to analyze potential effects of Project operations on Susitna River floodplain plant communities. These floodplain vegetation-GW/SW regime statistical relationships will provide a defensible basis for recommended flow prescriptions necessary to support floodplain vegetation establishment, recruitment, and maintenance throughout the Study Area.

The physical modeling and spatial mapping of riparian vegetation conducted in the Botanical Riparian Study will be integrated to analyze the extent and characteristics of riparian vegetation change under various simulated Project operational flows (Pearlstine et al. 1985).

Study interdependencies are presented in Figure 8.6-19. Study objectives, methods and expected results are summarized in Table 8.6-8.

8.6.3.6.3. Methodology

MODFLOW (USGS 2005), the most widely used groundwater model in the U.S. and worldwide, will be used. Additionally, RIP-ET (riparian−evapotranspiration MODFLOW package; Maddock et al. 2012), developed to help better represent plant transpiration processes in the unsaturated zone, will be utilized to more accurately calculate evapotranspiration, separating out plant transpiration from evaporation processes.

Focus Area GW / SW sampling is designed to measure, and model, GW/SW hydroregime for all floodplain plant community types and successional stages including plant establishment, plant recruitment, and mature forest vegetation. The sampling approach and design will include transects and arrays of groundwater wells and surface water stage stations (Figure 8.6-16 and Figure 8.6-17). Complete sampling design details can be found in the Groundwater Study, Section 7.5.

The groundwater and surface water data collection period will begin early July 2013 and continue through September 2014. This will include the fall 2013 winter transition period, winter 2013–2014 conditions, spring 2014, and summer 2014. Physical weather and climate conditions are not the same from year to year, so data collected during summer 2013 cannot be combined with data from 2014.

Field data on riparian plant communities will be collected in coordination with Riparian Vegetation Study (see Section 11.6). Riparian floodplain plant community and soils sampling approach and design is detailed in the Riparian Vegetation Study Section 11.6.

Woody species source of water will be directly determined from stable isotope analyses of groundwater, soil water, precipitation, and xylem water hydrogen and oxygen. Xylem water has been demonstrated to reflect isotopic composition of the source water taken up by roots (Flanigan and Ehleringer 1991; Dawsen and Ehleringer 1991). Stable isotope analysis of deuterium (^{2}H) and oxygen (^{18}O) ratios will be conducted for dominant woody species using standard methods (Cooper et al. 1999; Flanigan and Ehleringer 1991; Dawsen and Ehleringer 1991).

It is critical to measure the depth of the root zone of dominant floodplain plants for accurately modeling groundwater, capillary fringe, and floodplain plant relationships. The rooting depth of dominant floodplain plants will be measured through excavation of trenches within each Focus Area floodplain plant community type in coordination with soil stratigraphic excavations and well point soil pits. Depth and width of dominant plant root systems will be measured, sketched, and photographed. Excavation plot elevations will be surveyed. Additionally, a riverbank survey will be conducted by boat to utilize recently exposed root systems for measurement. The riverbank survey will provide a much greater sample size than possible through trench excavations alone. Root zone excavation and riverbank root zone survey data will be statistically summarized to provide individual plant species and plant community type root zone depth characterization for use in GW/SW modeling

The riparian vegetation GW/SW interactions study approach and design will be integrated with the findings of the riparian plant community succession, geomorphology, and ice processes modeling to characterize physical processes and riparian plant community relationships. The results of these studies will be used to assess (1) changes to physical processes due to dam operations, and (2) response of riparian plant communities to operations alterations of natural flow and ice processes regimes.

The results of the Focus Area modeling will be scaled-up to the riparian process domains as described in Section 8.6.3.7 Floodplain Vegetation Study Synthesis, Focus Area to Riparian Process Domain Scaling and Project Operations Effects Modeling

The detailed GW/SW interaction study approach and methods are presented in the Groundwater Study, Section 7.5.

8.6.3.6.4. Data Input from Other Studies

The Groundwater Study Section 7.5 will provide GW / SW interaction modeling results including a range of GW/SW regime seasonal statistics including frequency, timing and duration of surface-water and groundwater levels. Groundwater monitoring data will be provided to the

Riparian IFS in real time throughout Q3, Q4 2013 and Q1-Q4 2014. MODFLOW results and report will be provided in Q3 and Q4 2014.

8.6.3.6.5. Data Output to Other Studies

Modeling results will be provided to: Riparian Vegetation Study Section 11.6; Fluvial Geomorphology Study Section 6.6; Wildlife Study Section 10.0; and Floodplain Vegetation Study Synthesis, Project operations design Section 8.6.3.7.

8.6.3.6.6. Work Products

1. ISR and USR chapters detailing study methods, results, and conclusions summarizing Focus Area GW /SW modeling results including quantification of frequency, timing and duration of surface water and groundwater levels required to establish, maintain and promote floodplain and riparian plant communities. Fieldwork will be conducted Q2-Q4 2013 and Q2-Q4 2014.

8.6.3.7. Floodplain Vegetation Study Synthesis, Focus Area to Riparian Process Domain Model Scaling and Project Operations Effects Modeling.

The results of floodplain vegetation and soils mapping, forest succession models, seed dispersal study, seedling establishment studies, ice processes study, floodplain erosion and sediment transport study, and groundwater and surface water interaction study will be integrated into a conceptual ecological model of Susitna River floodplain vegetation and physical processes, including flow, sediment and ice process regimes. The results of these studies will be used to develop a dynamic floodplain vegetation model for simulating floodplain vegetation response to Project operation modification of the natural flow, sediment and ice processes regimes (Franz and Bazzaz 1976; Benjankar et al. 2011; Springer et al. 1999).

Fluvial Geomorphology Section 6.6, Ice Processes Section 7.6, and Groundwater Section 7.5 modeling studies will provide modeling results of both existing conditions and Project operation scenarios. Together riparian botanical forest succession models (see Section 11.6), floodplain vegetation GW/SW flow response curve analyses and physical process models (geomorphology, groundwater, ice processes) will be used to model floodplain vegetation transition dynamics (Walker and del Moral 2008) resulting from Project operation scenarios.

Study interdependencies are presented in Figure 8.6-20. Study objectives, methods and expected results are summarized in Table 8.6-9.

Study objectives are to:

1. Develop conceptual ecological model of Susitna River floodplain vegetation establishment and recruitment based on synthesis of Riparian Vegetation Study and Riparian IFS results.
2. Scale-up results of Focus Area floodplain vegetation and physical process modeling results to riparian process domains.
3. Develop a dynamic spatially-explicit floodplain vegetation model for simulating floodplain vegetation response to Project operation modification of the natural flow, sediment and ice processes regimes.

4. Develop spatially explicit maps of modeled Project operations effects throughout the Study Area.
5. Provide guidance to environmental analysis of Project operations.

8.6.3.7.1. Methods

The results of the Focus Area modeling will be scaled-up to the riparian process domains using spatially explicit GIS-based models (Benjankar et al. 2011; Chacon-Moreno et al. 2007). The goal is to model both natural riparian flow-response functional groups and natural Susitna River physical process regimes to measure and map Project operational impacts to floodplain vegetation and riparian ecosystem processes throughout the Study Area. Recent developments in GIS, LiDAR-driven digital terrain models (DEMs), and geo-spatial analytical tools (ARCMAP, ESRI) have provided modelers the capacity to use the results of reach-scale analyses to scale-up to larger geospatially defined areas or domains (Benjankar et al. 2011; Chacon-Moreno et al. 2007). Modeling riparian vegetation response, over a 185-mile Susitna River valley, to alterations of natural flow regimes, is inherently a geospatial analytical problem. Current state-of-the-art and science practice will be utilized to integrate modeling of physical processes (HEC-RAS, MODFLOW), and riparian vegetation-flow response functional groups with GIS geospatial analysis and display (ARCMAP, HEC-GEORAS).

The objectives of the Focus Area scaling model are as follows:

1. Scale-up Focus Area modeling results to riparian process domains.
2. Assess potential impacts of Project operational flows on downriver floodplain plant communities and ecosystem processes.
3. Provide guidance to environmental analysis of Project operations.

8.6.3.7.2. Work Products

1. USR chapter detailing study methods, results, and conclusions summarizing: (1) floodplain vegetation study synthesis, physical process modeling studies, and vegetation succession models, (2) scaling results of floodplain and physical process Focus Area to riparian process domain modeling, and (3) spatially explicit maps of modeled Project operations effects throughout the Study Area.

The modeling synthesis and Project operations modeling will be conducted Q4 2013 and Q1-Q2 2015. Modeling, results analysis, and USR chapter, will be developed in Q2 through Q4 2014 and Q1-2 2015.

8.6.4. Consistency with Generally Accepted Scientific Practice

The proposed Riparian IFS, including methodologies for data collection, analysis, modeling, field schedules, and study durations, is consistent with generally accepted practice in the scientific community. The Riparian IFS is consistent with common approaches used for other FERC proceedings and references specific protocols and survey methodologies, as appropriate. Specifically, riparian vegetation mapping and measurement, the classification of riparian plant communities, and dendrochronologic techniques will follow standard methods generally accepted by the scientific community. Proposed GW/SW models have been widely used throughout the discipline (Baird and Maddock 2005; Maddock et al. 2012; Franz and Bazzaz 1977; Rains et al. 2004).

Current state-of-the-art and science practice will be utilized to integrate modeling of physical processes and riparian vegetation-flow response guilds with GIS geospatial analysis and display (Benjankar et al. 2011; Chacon-Moreno et al. 2007; Van de Rijt et al. 1996).

8.6.5. Schedule

The schedule for completing all components of the Riparian IFS is provided in Table 8.6-1. Licensing participants will have opportunities for study coordination through regularly scheduled meetings, reports, and, as needed, technical subcommittee meetings. Reports will be prepared at the end of 2013 (Initial Study Report) and 2014 (Updated Study Report) for each of the study components. Licensing participants will have the opportunity to review and comment on these reports. Workgroup meetings are planned to occur on at least a quarterly basis, and workgroup subcommittees will meet or have teleconferences as needed.

8.6.6. Level of Effort and Cost

The Riparian Instream Flow Study is planned as a 2+ year effort, with field sampling conducted spring through summers and fall of 2013–2014. The Initial Study Report will be delivered in late 2013 and updated in early 2015.

Riparian Instream Flow Study elements and their estimated levels of effort include the following:

1. Spring/summer 2013 fieldwork investigating eight or more Focus Areas. Field effort will involve approximately two teams of two ecologists one to two weeks per Focus Area to map and sample riparian vegetation.
   - $400,000
2. Spring/summer 2014 fieldwork investigating up to eight Focus Areas. Field effort will involve approximately a team of three ecologists one to two weeks per study site to map and sample riparian vegetation.
   - $310,000
3. Modeling forest succession and physical processes (GW/SW, hydraulic, ice processes, operational flow simulations).
   - $440,000
4. Statistical analyses and report development, meetings, and presentations.
   - $440,000
5. GW/SW interaction study.
   - Costs provided in Groundwater Study, Section 7.5.

The total approximate effort/cost is $1.6 million (not including costs for riparian GW/SW interaction study instrumentation, field installation and monitoring, and MODFLOW modeling). Details and level of field effort will be based upon approved of overall study objectives and design. Field surveys will be conducted for 40 to 50 days in each year, depending on the needs for additional ground-verification data. The Riparian IFS Study will involve extensive, office-based activities including remote sensing interpretation, physical modeling, vegetation modeling, statistical modeling, geospatial analyses, and study report preparation.

The final types and level of physical process modeling will be determined in coordination with the Instream Flow, Geomorphology, Ice Processes, Botanical Riparian, and Groundwater Study teams. Estimated study costs are subject to review and revision as additional details are developed.

8.6.7. Literature Cited

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8.6.8. Tables

Table 8.6-1. Schedule for implementation of the Riparian Instream Flow Study.

Activity	2012				2013				2014				2015	
	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q
Refine and Finalize Study Plan		——	——	——										
Focus Area Study Site Selection			——	——	——			------	------	--				
Critical review of 1980s Susitna River data; current scientific research concerning hydro project floodplain vegetation effects; and unimpacted, natural floodplain vegetation research					——	——	——	——						
Finalize Riparian Groundwater / Surface Water Field Design					——			------	------	---				
Implement Riparian Groundwater / Surface Water Installation and Sampling						——	——	——	——	——	——	——		
Riparian Vegetation: Field data collection		——	——			——	——	—		——	——			
Seed dispersal study		——	——			——	——	—		——	——			
Tree ice-scar mapping		——	——			——	——	—		——	——			
Focus Area vegetation mapping and sampling		——	——			——	——	—		——	——			
Dendrochronology sampling		——	——			——	——	—		——	——			
Soil sampling		——	——			——	——	—		——	——			
Sediment Dating: Sampling and Analysis						——	——	——		——	——	——		
Develop groundwater / surface water models					——	——	——	——	——	——	——	——		
Develop vegetation flow-response models						——	——	——	——	——	——	——		
Develop riparian scaling model: reach to riparian process domain								——	——	——	——	——		
Develop vegetation Project operational flow-response model											——	——	——	——▶
Riparian vegetation impact analyses											——	——	——	——▶
Alternative operational scenarios												——	——	——▶
Reporting									Δ				▲	

Legend:

—— Planned Activity
----- Follow up activity (as needed)
Δ Initial Study Report
▲ Updated Study Report

Table 8.6-2. 8.6.3.1 Floodplain Vegetation and Physical Process Regimes Critical Review, Synthesis and Lessons Learned.

STUDY OBJECTIVES
1. Conduct a critical review of previous Susitna River 1980s floodplain vegetation studies. 2. Conduct a critical review, and synthesis of relevant findings, of circumpolar, temperate and boreal regions, scientific research concerning dam effects on downriver floodplain plant communities. 3. Conduct critical review, and synthesis of relevant current scientific research, concerning temperate and boreal floodplain forest succession and dynamics under natural flow regimes.
METHODS
1. Search libraries and internet for relevant scientific literature. 2. Develop annotated, searchable bibliography. 3. Develop critical review paper with thematic format: a. first, identify critical floodplain ecological processes effected by dams, b. second, compare Project dam operations under current design and compare with scientific literature reported effects, c. third, identify potential alternative operation scenarios to limit effects.
EXPECTED RESULTS
1. State of the science review of scientific findings concerning dam effects on downriver floodplain plant communities. 2. Summary of expected effects of Project operations on Susitna River floodplain plant communities and ecosystems. 3. Set of guidelines for limiting Project operations effects based on current science.

Table 8.6-3. 8.6.3.2 Focus Area Selection−Riparian Process Domain Delineation

STUDY OBJECTIVES
1. Develop a riparian process domain stratification of the Study Area. 2. Select Focus Areas representative of each riparian process domain for physical process and vegetation survey sampling and modeling.
METHODS
1. Riparian process domain delineation, and riparian Focus Area selection is an iterative process. 2. In Q1 21013 the results of the 2012 geomorphology study and channel classification (Section 6.6), ice processes study (Section 7.6), riparian botanical survey (Section 11.6) will be used to classify channel, floodplain and floodplain vegetation types. 3. Constrained cluster analysis will be performed on channel, floodplain and vegetation types. 4. Process domain type variability will be statistically described and a power analysis performed to determine the number of Focus Areas necessary to capture process domain variability in the stratified sampling approach. 5. Candidate Focus Areas previously identified through the expert-opinion process for both Aquatic and Riparian IFS will be reviewed. 6. Results of the cluster analysis, power analysis and expert-opinion process will be presented to the TWG for final selection of Focus Areas. 7. Ice process mapping results, completed in Q4 2013, will be used in a second round of riparian process domain analysis and Focus Area selection. 8. Results of second iterative analysis will be used to assess whether additional Focus Areas are needed to capture ice process effects for 2014 field sampling.
EXPECTED RESULTS
1. Hierarchical stratification of Susitna River Study Area into riparian process domains. 2. Statistically robust selection of representative riparian process domain Focus Areas. 3. Study Area floodplain vegetation and physical process sampling and characterization necessary to support model scaling of Focus Area study results to riparian process domain.

Table 8.6-4. 8.6.3.3.1 Synchrony of Seed Dispersal, Hydrology, and Local Susitna River Valley Climate

STUDY OBJECTIVES
1. Measure cottonwood and select willow species seed dispersal timing. 2. Model local Susitna River valley climate, and associated seasonal peak flows, relative to cottonwood and willow seed dispersal. 3. Develop a recruitment box model of seed dispersal timing, river flow regime, and cottonwood and willow seed dispersal and establishment.
METHODS
1. Conduct a two-year field survey of seed release of balsam poplar and select willow species. 2. Develop a 'degree-day' climate model for the onset of seed release relative to local temperature conditions using methods developed by Stella et al. (2006). 3. Analyze the historic climate and Susitna River flow regime relationship.
EXPECTED RESULTS
1. Degree-day model of peak seed release window using seed release observations and continuous temperature records from each floodplain sample site. 2. Recruitment box model of cottonwood and select willow species. 3. Model of peak runoff / seed release temporal synchrony for operational flow guidelines. 4. Model of critical summer flow regime necessary to support seedling establishment.

Table 8.6-5. 8.6.3.3.2 Seedling Establishment and Recruitment Study

STUDY OBJECTIVES
1. Map the spatial locations dominant woody riparian seedlings including balsam poplar, white spruce, paper birch, thinleaf and Sitka alder, feltleaf willow, and Barclay's willow throughout the Focus Area, and Riparian Vegetation Study sites, active channel margins, and floodplain. 2. Use a stratified random sampling approach, with variable plot sizes (Mueller-Dombois and Ellenburg 1974) to sample mapped seedling polygons. 3. Identify seedlings to species, and measure seedling heights and density. 4. Describe and measure seedling site soil characteristics (see Section 8.6.3.7 for methods). 5. Measure and model seedling site GW/SW hydroregimes. 6. Measure seedling xylem water source through isotopic analysis (see Section 8.6.3.6 for methods). 7. Investigate ice process seedling site interactions through empirical observations and ice process modeling. 8. Develop a probabilistic model of seedling hydrologic, sediment, and ice regime processes.
METHODS
1. Survey sampling approach is as follows. 2. First, a helicopter survey of each reach will be conducted to locate and map observable seedling areas. 3. Second, four to eight transects will be placed systematically throughout the reach normal to main channel, extending across the adjacent floodplain intersecting observed seedling sites. Each transect will be traversed and all remotely observed, and newly identified on-the-ground seedling locations will be mapped with GPS. 4. Third, seedling site polygon boundaries will be mapped with GPS. 5. Fourth, seedling patches will be sampled using a stratified random approach to locate sample plots. Seedling species will be identified, or collected for herbarium identification, and abundance (density) and height measured using variable plot size and shapes (Elzinga et al. 1998; Mueller-Dombois and Ellenberg 1974). 6. Fifth, at each plot two to three seedlings of each species will be excavated and rooting depth measured. Excavated woody seedlings will be aged at the root collar in the laboratory and annual rings counted to provide seedling age. Substrate texture and depth to cobbles will be described and measured in soil pits excavated to 50 cm in depth or to gravel/cobble refusal layer. 7. Sixth, a sub-sample of Focus Area site seedlings will be used for xylem isotopic analyses to identify source of water (Section 8.6.3.6). 8. Seedling establishment model will be developed using techniques and methods described in Franz and Bazzaz (1977), Rains et al. (2004), Henszey et al. (2004), Baird and Maddock (2005), and Maddock et al. (2012).
EXPECTED RESULTS
1. Probabilistic model of seedling establishment requirements based on GW/SW interaction model, sediment transport model, and ice regime model.

Table 8.6-6. 8.6.3.4 Characterize the role of river ice in the establishment and recruitment of dominant floodplain vegetation.

STUDY OBJECTIVES
1. Develop an integrated model of ice process interactions with floodplain vegetation. 2. Conduct primary research to identify the effects of ice on floodplain vegetation within mapped Susitna River ice floodplain impact zones. 3. Quantitatively describe and compare ice influenced and non-ice-influenced floodplain plant community composition, abundance, age, and spatial pattern to assess the role and degree of influence ice processes have on Susitna River floodplain vegetation. 4. Provide Project operational guidance on potential effects of operations flow on ice formation and floodplain vegetation development.
METHODS
1. Multiple lines of evidence will be used to inform a final research study design to address the question of vegetation response to ice shearing influence on the Susitna River floodplain. 2. First, ice vegetation impacts (tree ice-scars) will be observed, mapped, and aged (using dendrochronologic techniques), and gravel floodplain deposits will be mapped throughout the Study Area to develop a Study Area map of river ice floodplain vegetation interaction domains. 3. Second, local residents will be interviewed (e.g., Mike Wood, who lives across from Whiskers Slough) concerning their knowledge of spatial locations of historic ice dams, years of significant ice occurrence, and other anecdotal historical information concerning ice on the Susitna River. 4. From these two sources of information, a map will be created of Susitna River ice process floodplain vegetation effect domains. 5. Floodplain vegetation surveys will be conducted to quantitatively measure (stratified random sampling of mapped floodplain vegetation ice shear process zones) and statistically describe and compare vegetation characteristics associated with floodplains experiencing ice shear events and floodplain vegetation without observed ice influence. The vegetation study design will build on the design and results of Engstrom et al. (2011) where they studied and assessed the effects of anchor ice on riparian vegetation. Engstrom and others found that species richness was higher at sites affected by anchor ice than at sites where anchor ice was absent, suggesting that ice disturbance plays a role in enhancing plant species richness (Engstrom et al. 2011).
EXPECTED RESULTS
1. Ice processes domain and floodplain ice interaction geographic, and elevation, map to inform floodplain ice interaction vegetation study design and ice processes modeling, Section 7.6. 2. Develop a floodplain vegetation ice processes interaction study to compare ice disturbed and un-disturbed floodplains, similar to the approach of Engstrom et al. (2011), 3. The results of the study will be used to assess how floodplain vegetation pattern and process may change with Project operation alterations of the natural ice process regime. The final study design will be completed in Q2-3 2013, as additional tree ice-scar field data become available.

Table 8.6-7. 8.6.3.5 Characterize the role of erosion and sediment deposition in the formation of floodplain surfaces, soils, and vegetation.

STUDY OBJECTIVES
1. Measure the rates of channel migration, and floodplain vegetation disturbance or turnover, throughout the Study Area. 2. Measure the rates of sediment deposition, and floodplain development, throughout the Study Area. 3. Assess / model how Project operations will effect changes in the natural sediment regime, floodplain depositional patterns, and soil development throughout the Study Area. 4. Assess / model how Project operations changes in sediment transport and soil development will affect floodplain plant community succession.
METHODS
1. Floodplain soils and stratigraphy will be sampled throughout the Study Area using a stratified random approach, including pits located in all Focus Areas. 2. Floodplain soil pits will be excavated from the surface to gravel / cobble layer (historic channel bed) and soil stratigraphy will be described and measured using standard NRCS field techniques (Schoeneberger et al. 2002). Standard sediment grain size sieve analysis will be conducted on the entire sediment profile. 3. Direct dating of fluvial sediments will be conducted using isotopic techniques, including, but not limited to, ^{137}Cs and ^{210}Pb measurements as described in Stokes and Walling (2003). 4. Dendrochronologic techniques (Fritts 1976) will be used to age trees and current floodplain surfaces at each soil pit.
EXPECTED RESULTS
1. Dating of floodplain stratigraphy and surfaces using direct isotopic and dendrochronologic techniques for development of floodplain evolution model, 2. Floodplain stratigraphic descriptions and grain size analyses for development of floodplain evolution model and sediment transport modeling. 3. Measurement of rate of channel migration disturbance of floodplain vegetation. Measurement of rate of floodplain turnover or disturbance. 4. Model of how Project operations will effect soil development. 5. Model of alteration of riparian seedling establishment floodplain surfaces and floodplain vegetation succession.

Table 8.6-8. 8.6.3.6 Characterize natural floodplain vegetation groundwater and surface water maintenance hydroregime.

STUDY OBJECTIVES
1. Characterize dominant floodplain woody plant species establishment and maintenance life stage water sources through stable isotope analyses of groundwater, soil water, and xylem water. 2. Measure groundwater and surface water regime at Focus Areas (GW: depth seasonally; SW: river stage) 3. Develop a floodplain GW/SW interaction model (water level frequency, magnitude, depth, duration, timing, interaction response). 4. Develop floodplain vegetation-flow response models. 5. Model Project operational flow effects on floodplain plant communities.
METHODS
1. Focus Area GW / SW sampling for all floodplain plant community types and successional stages including plant establishment, plant recruitment, and mature forest vegetation. 2. Sampling design will include transects and arrays of groundwater wells and surface water stage stations see Groundwater Study Section 7.5 for details. 3. Riparian floodplain plant community and soils sampling approach and design is detailed in the Riparian Vegetation Study Section 11.6. 4. Woody species source of water will be directly determined from stable isotope analyses of groundwater, soil water, precipitation, and xylem water hydrogen and oxygen. 5. The rooting depth of dominant floodplain plants will be measured through excavation of trenches within each Focus Area floodplain plant community type in coordination with soil stratigraphic excavations and well point soil pits. 6. Probabilistic response curves will be developed for select plant species and all riparian plant community types using techniques described in Rains et al. (2004) and Henszey et al. (2004).
EXPECTED RESULTS
1. Probabilistic response curves for select plant species and all riparian plant community types. 2. Floodplain vegetation-GW/SW regime functional groups. 3. Statistically modeled relationship between individual riparian species, floodplain plant community types, and natural GW/SW hydroregime. 4. Model of potential effects of Project operations on Susitna River floodplain plant communities. 5. Basis for recommended flow prescriptions necessary to support floodplain vegetation establishment, recruitment, and maintenance.

Table 8.6-9. 8.6.3.7 Floodplain Vegetation Study Synthesis, Focus Area to Riparian Process Domain Model Scaling and Project Operations Effects Modeling

STUDY OBJECTIVES
Study objectives are to: 1. Develop conceptual ecological model of Susitna River floodplain vegetation establishment and recruitment based on synthesis of Riparian Vegetation Study and Riparian IFS results. 2. Scale-up results of Focus Area floodplain vegetation and physical process modeling results to riparian process domains. 3. Develop a dynamic spatially-explicit floodplain vegetation model for simulating floodplain vegetation response to Project operation modification of the natural flow, sediment and ice processes regimes. 4. Develop spatially explicit maps of modeled Project operations effects throughout the Study Area. 5. Provide guidance to environmental analysis of Project operations.
METHODS
1. Develop a dynamic spatially-explicit floodplain vegetation model for simulating floodplain vegetation response to Project operation modification of the natural flow, sediment and ice processes regimes (Franz and Bazzaz 1976; Benjankar et al. 2011; Springer et al. 1999). 2. Fluvial geomorphology Section 6.6, ice process Section 7.6, and groundwater Section 7.5 modeling studies will provide modeling results of both existing conditions and Project operation scenarios. 3. Riparian botanical forest succession models synthesis. 4. Floodplain vegetation (individual plant species and community types) GW/SW flow response curve analyses and physical process models (geomorphology, groundwater, ice processes) will be used to model floodplain vegetation transition dynamics at riparian process domain scale. 5. Focus Area modeling will be scaled-up to the riparian process domains using spatially explicit GIS models.
EXPECTED RESULTS
1. Conceptual ecological model of Susitna River floodplain vegetation establishment and recruitment floodplain vegetation. 2. Dynamic spatially-explicit floodplain vegetation model for simulating floodplain vegetation response to Project operation modification of the natural flow, sediment and ice processes regimes. 3. Riparian process domain scale model of floodplain vegetation and physical processes. 4. Spatially explicit maps of modeled Project operations floodplain vegetation effects throughout the Study Area. 5. Project operations guidance to minimize modeled floodplain vegetation effects.

8.6.9. Figures

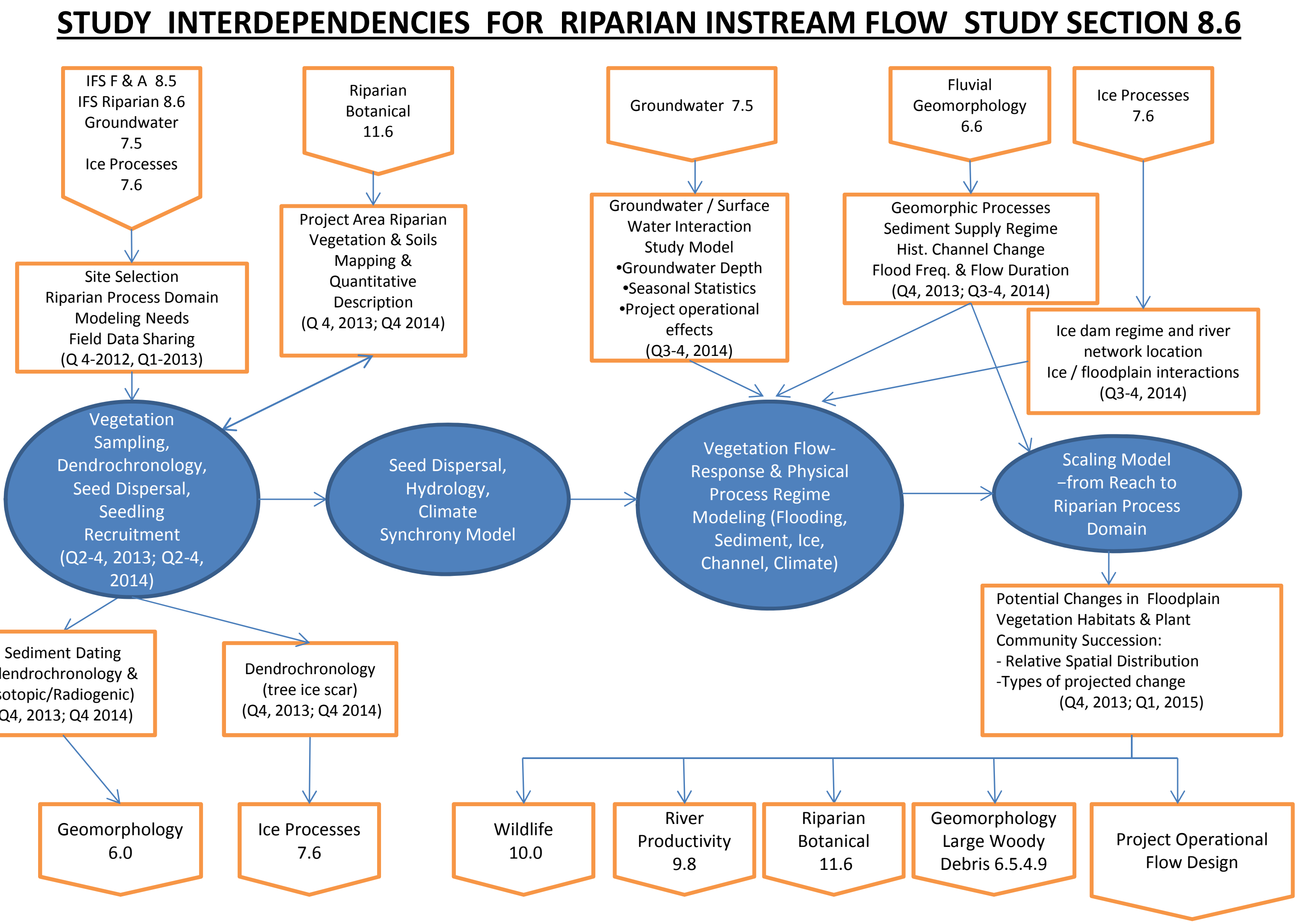


Figure 8.6-1. Study interdependencies for Riparian Instream Flow Study.

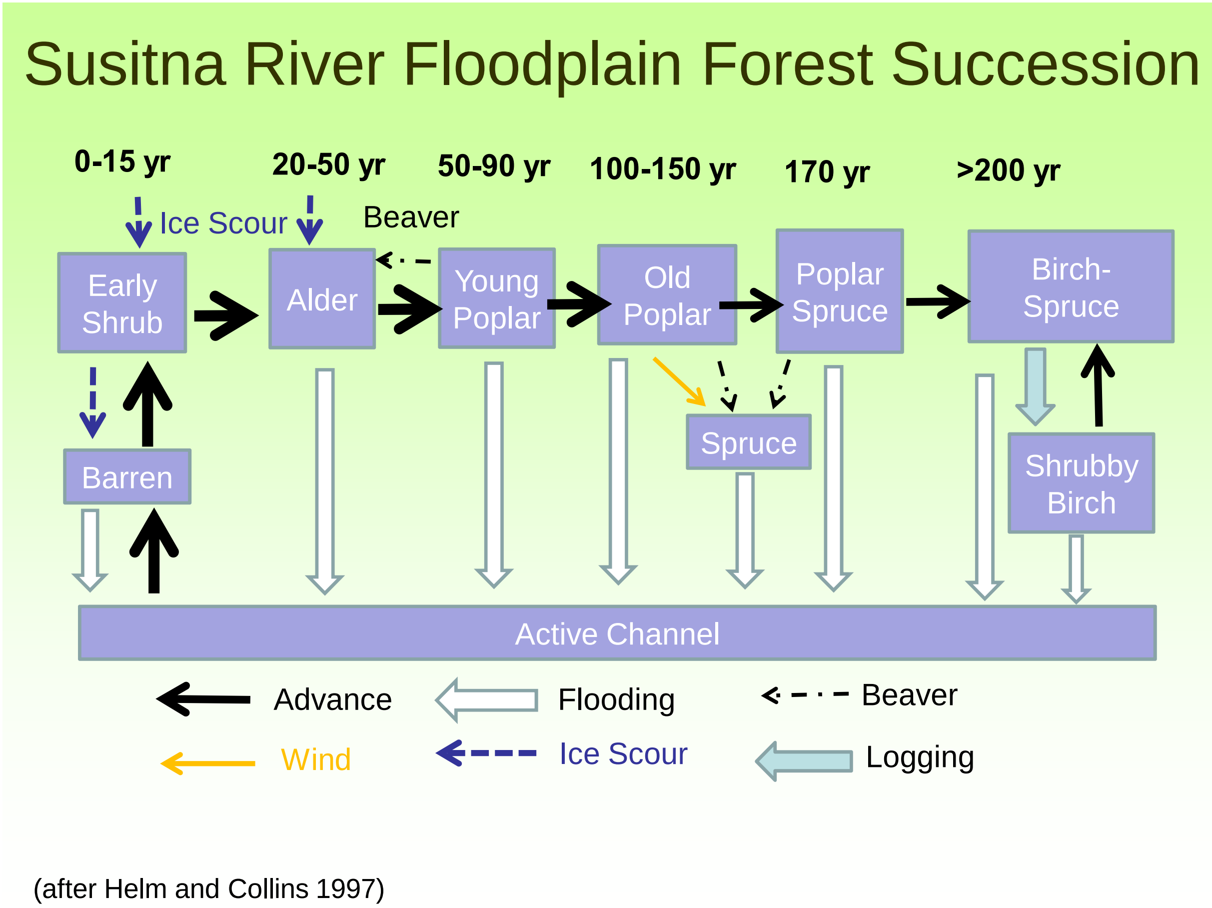


Figure 8.6-2. Helm and Collins (1997) Susitna River floodplain forest succession. Note: model depicts typical floodplain forests found in the Susitna River Middle River and Three Rivers Confluence segments.

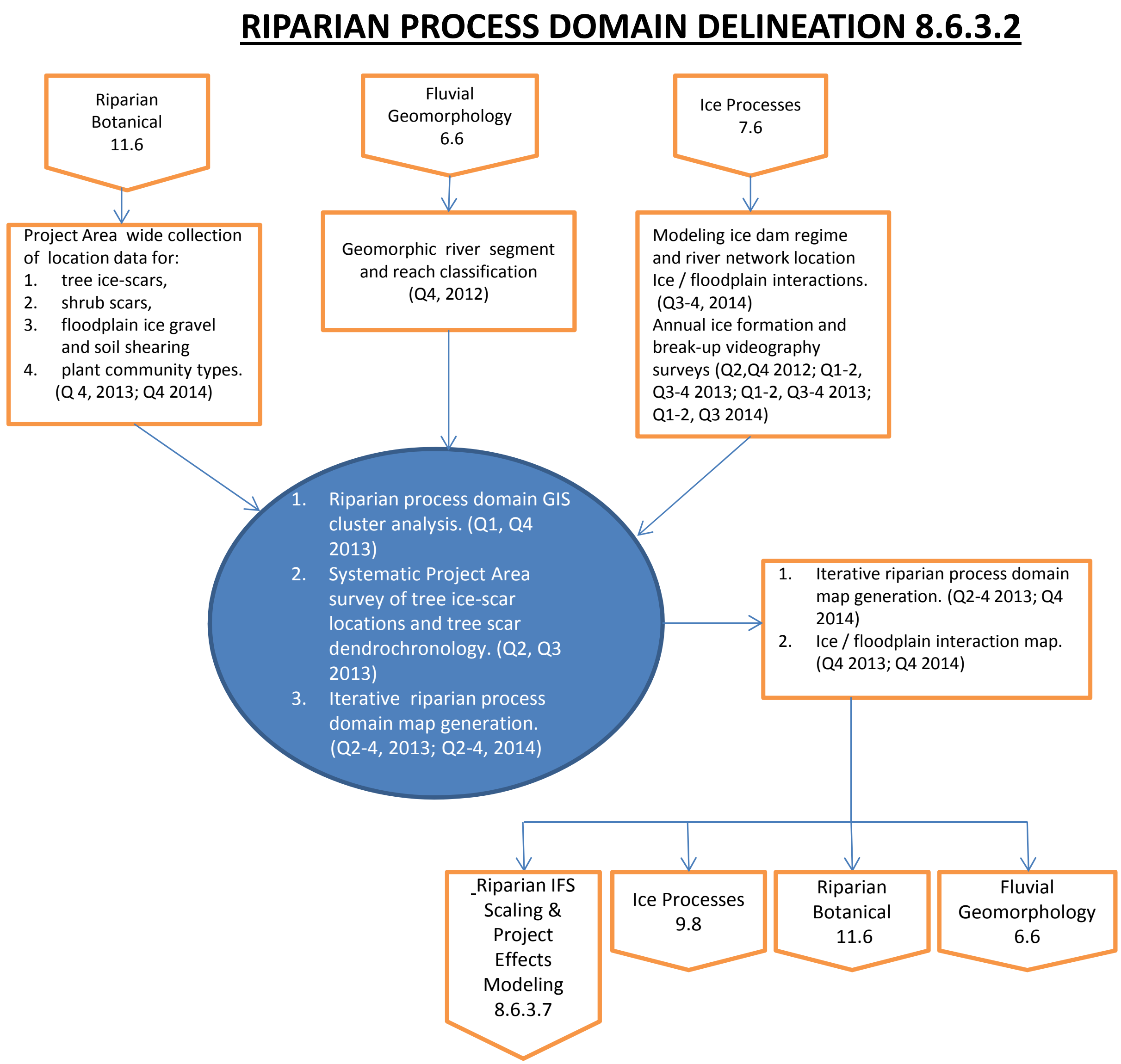


Figure 8.6-3. Riparian Process Domain Delineation 8.6.3.2.

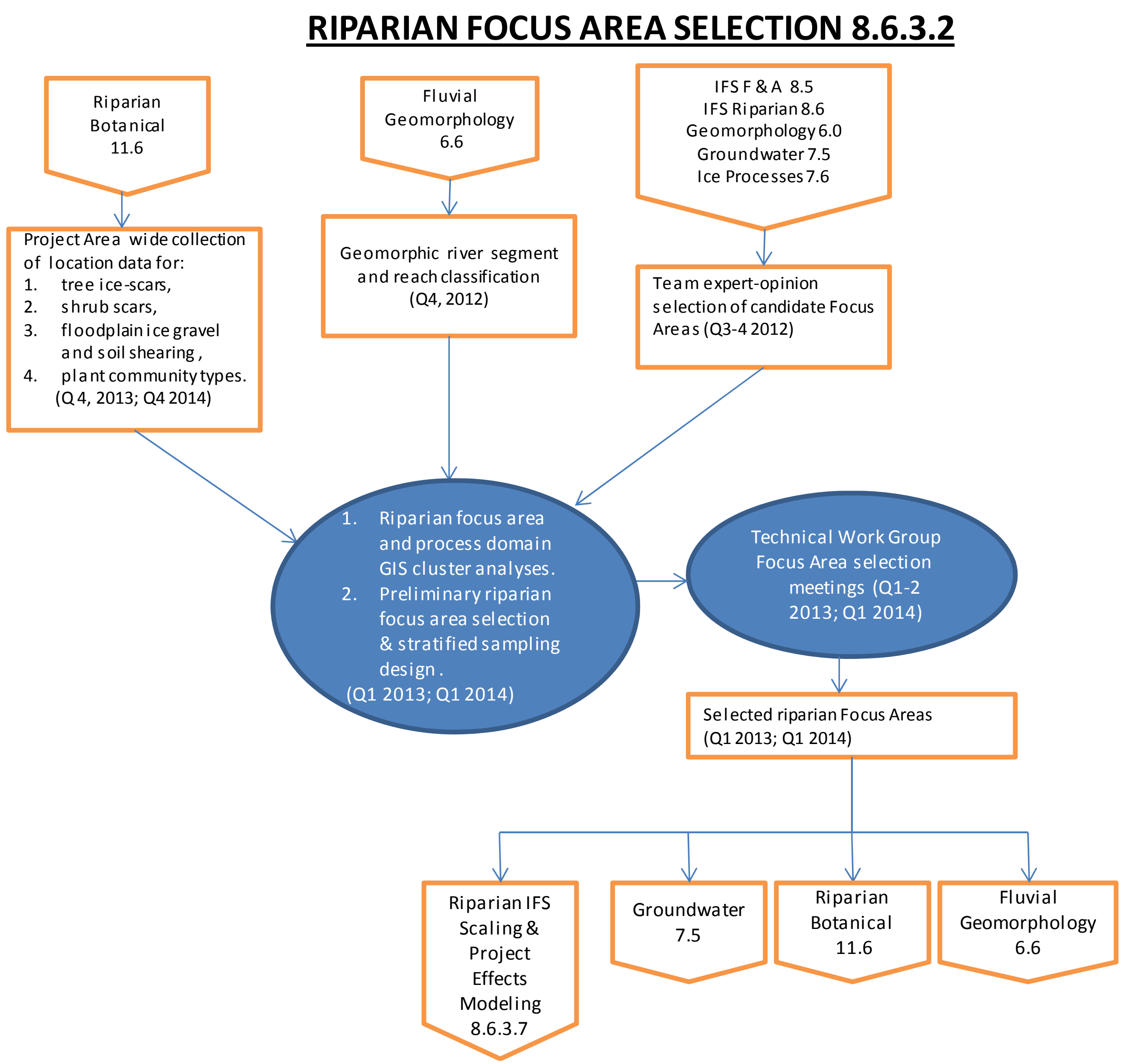


Figure 8.6-4. Riparian Focus Area Selection 8.6.3.2.

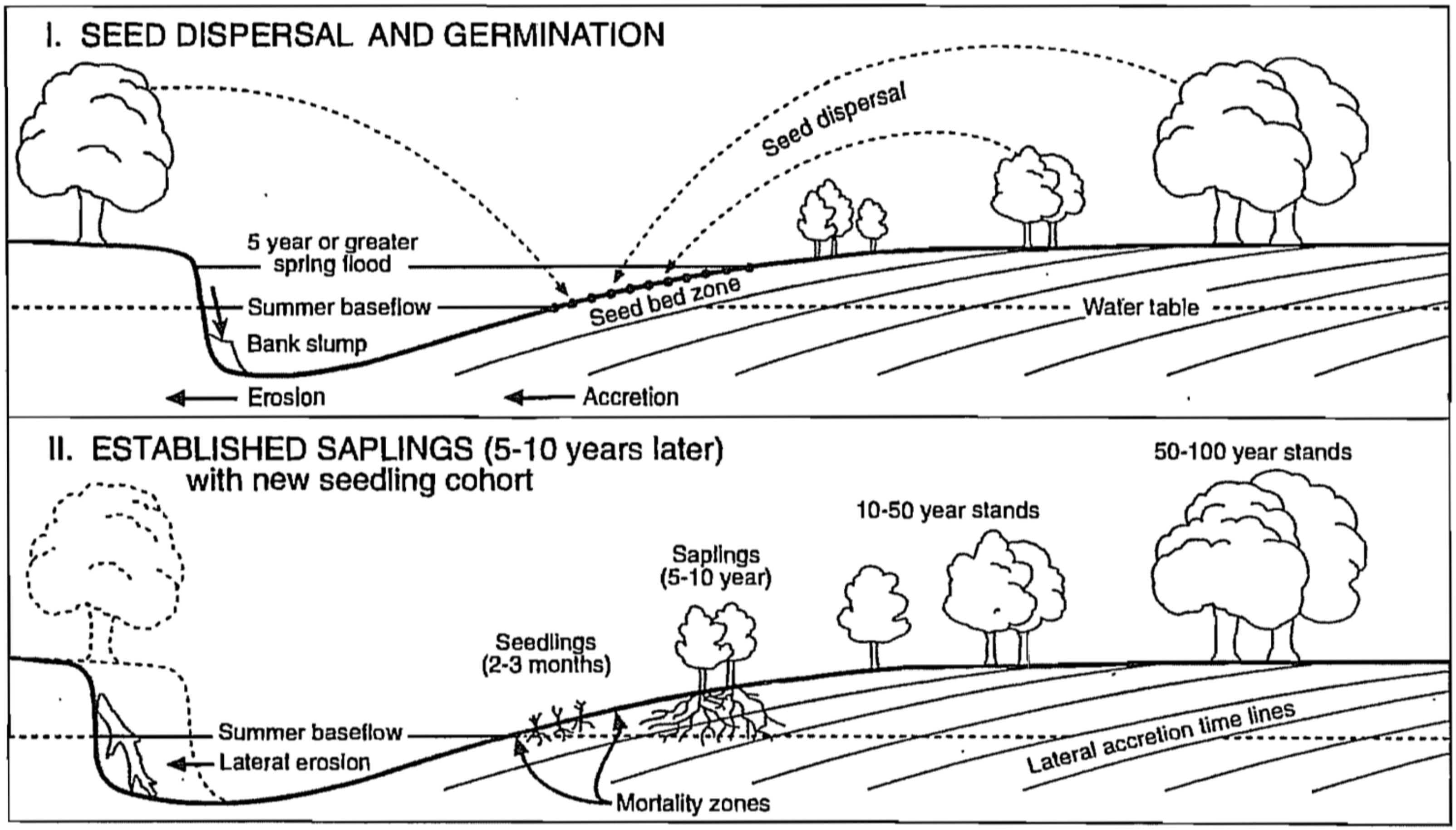


Figure 8.6-5. Cottonwood (Populus) life history stages: seed dispersal and germination, sapling to tree establishment. Cottonwood typically germinates on newly created bare mineral soils associate with lateral active channel margins and gravel bars. Note proximity of summer baseflow and floodplain water table (Braatne et al. 1996).

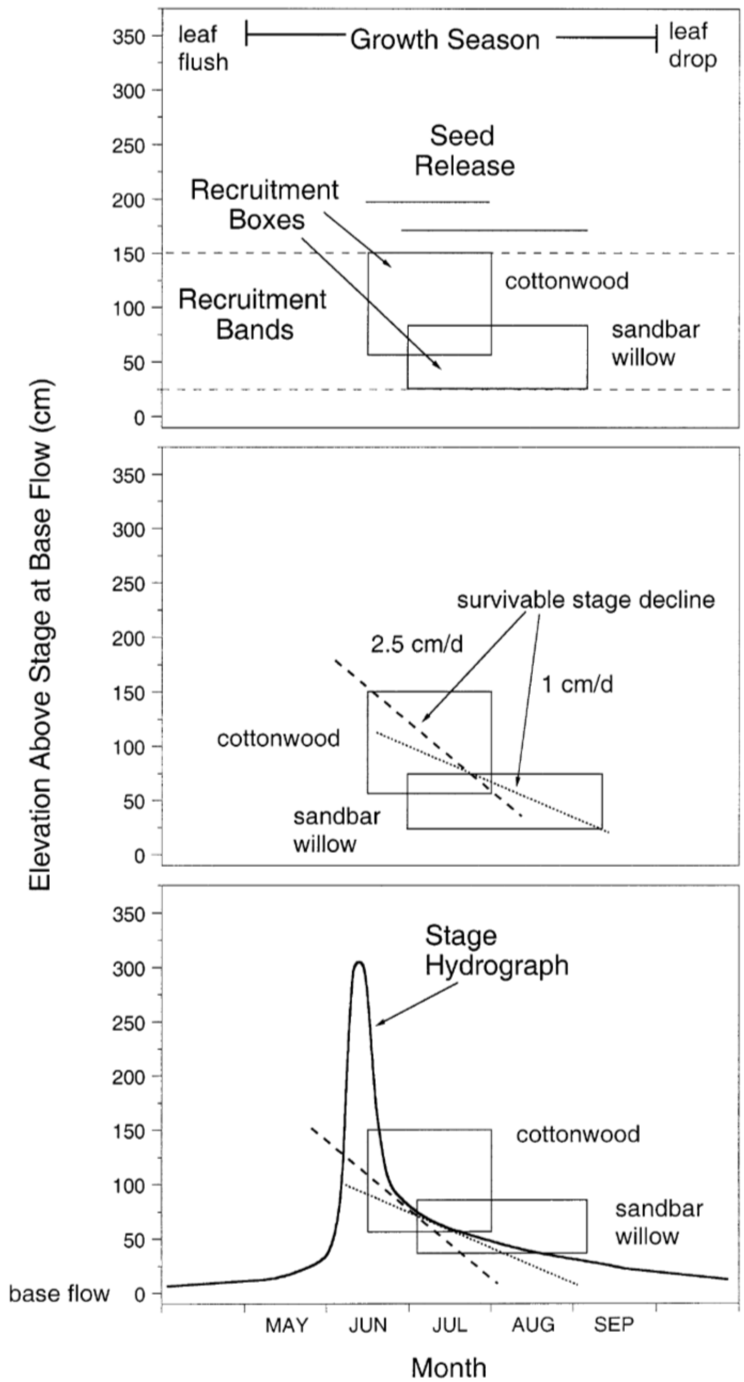


Figure 8.6-6. The riparian "Recruitment Box Model" describing seasonal flow pattern, associated river stage (elevation), and flow ramping necessary for successful cottonwood and willow seedling establishment (from Amlin and Rood 2002; Rood et al., 2005). Cottonwood species (*Populus deltoides*), willow species (*Salix exigua*). Stage hydrograph and seed release timing will vary by region, watershed, and plant species.

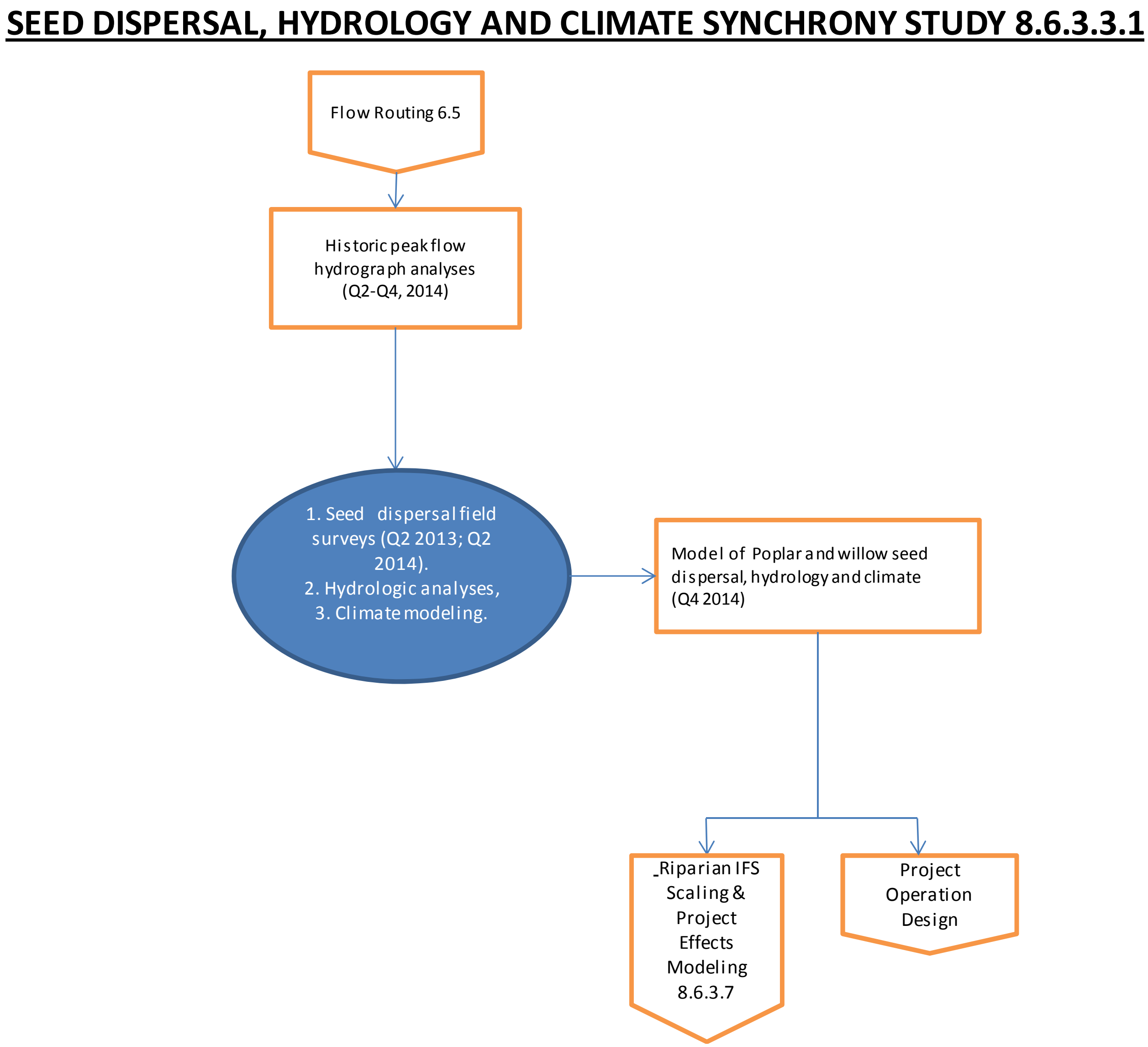


Figure 8.6-7. Seed Dispersal, Hydrology and Climate Synchrony Study8.6.3.3.1.

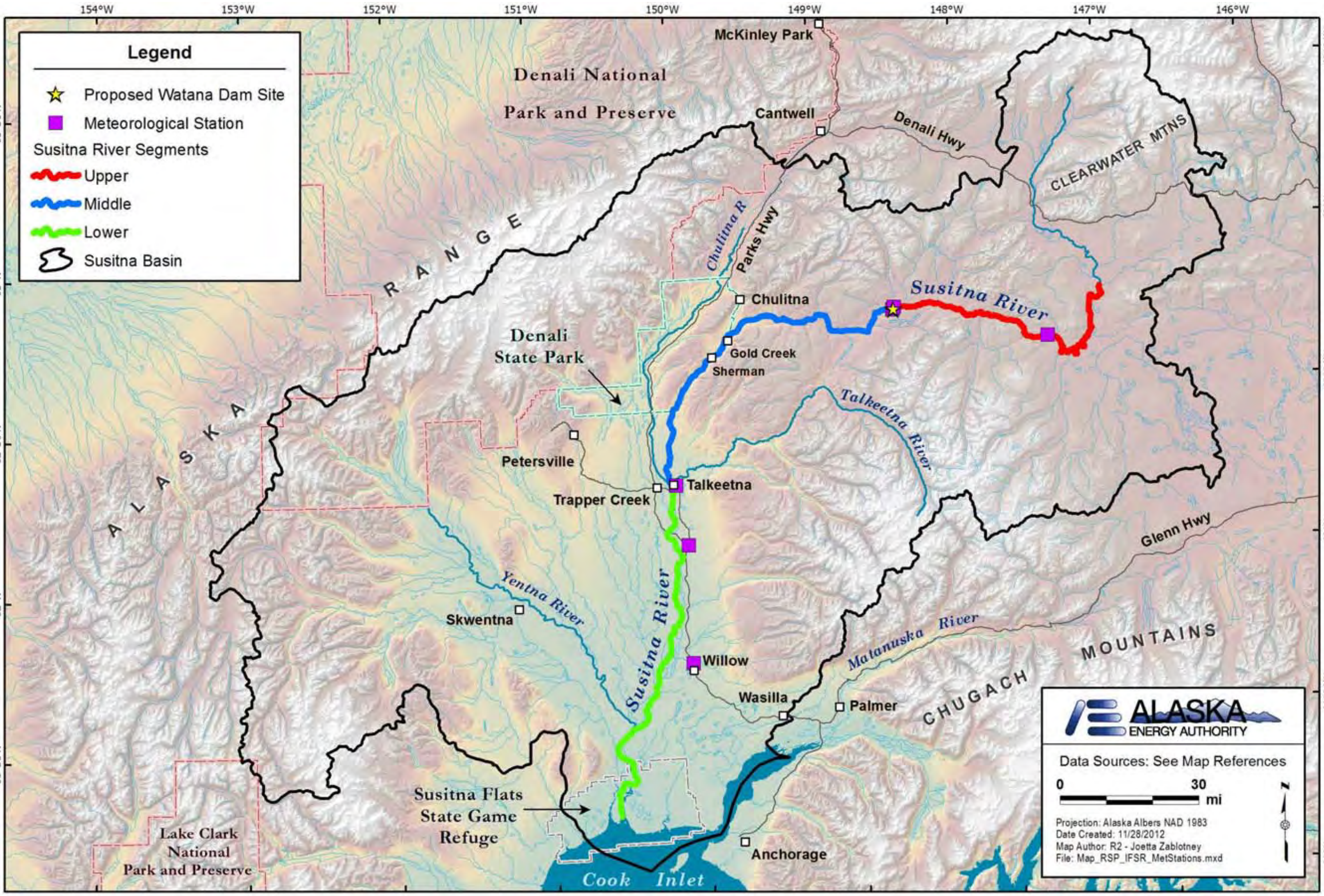


Figure 8.6-8. Susitna Study Area meteorological station locations.

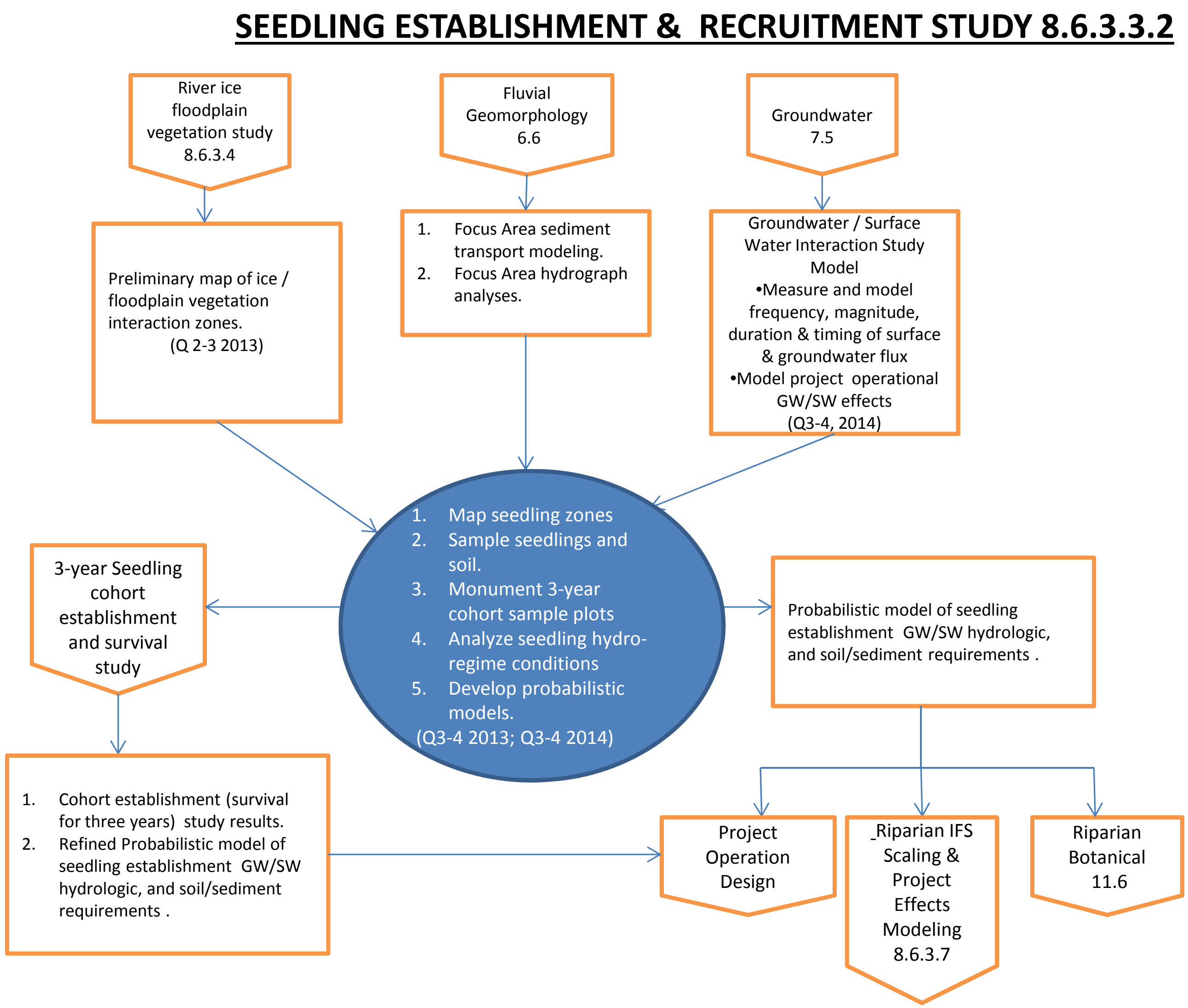


Figure 8.6-9. Seedling Establishment & Recruitment Study 8.6.3.3.2.

Figure 8.6-10. Cottonwood tree ice-scar. Floodplain located immediately above Three Rivers Confluence.

Figure 8.6-11. Cottonwood forest tree ice-scars. Floodplain located immediately above Three Rivers Confluence.

Figure 8.6-12. Floodplain ice deposited gravel piles. Floodplain in braided reach below Three Rivers Confluence.

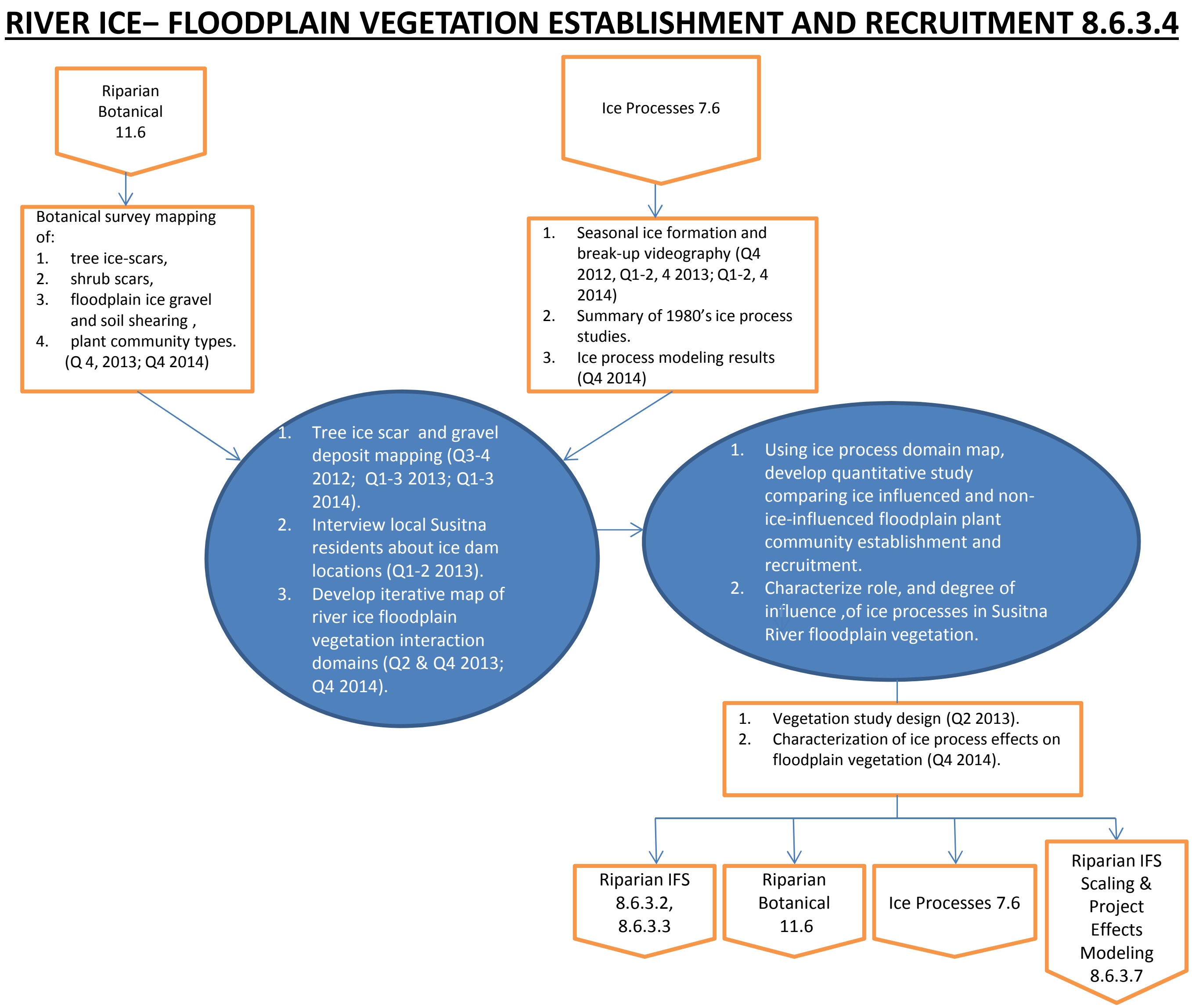


Figure 8.6-13. River Ice-Floodplain Vegetation Establishment and Recruitment 8.6.3.4.

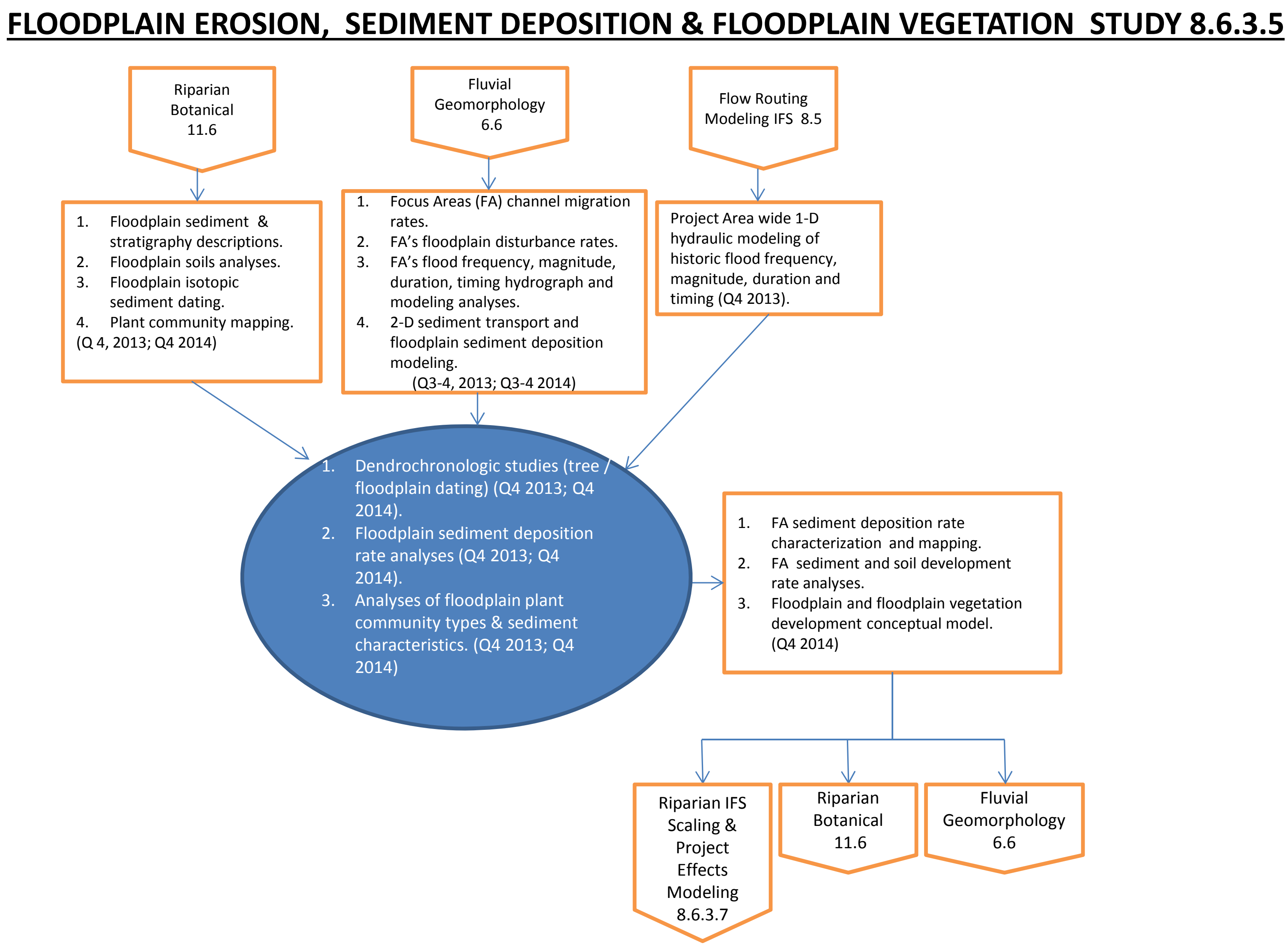


Figure 8.6-14. Floodplain Erosion, Sediment Deposition & Floodplain Vegetation Study 8.6.3.5.

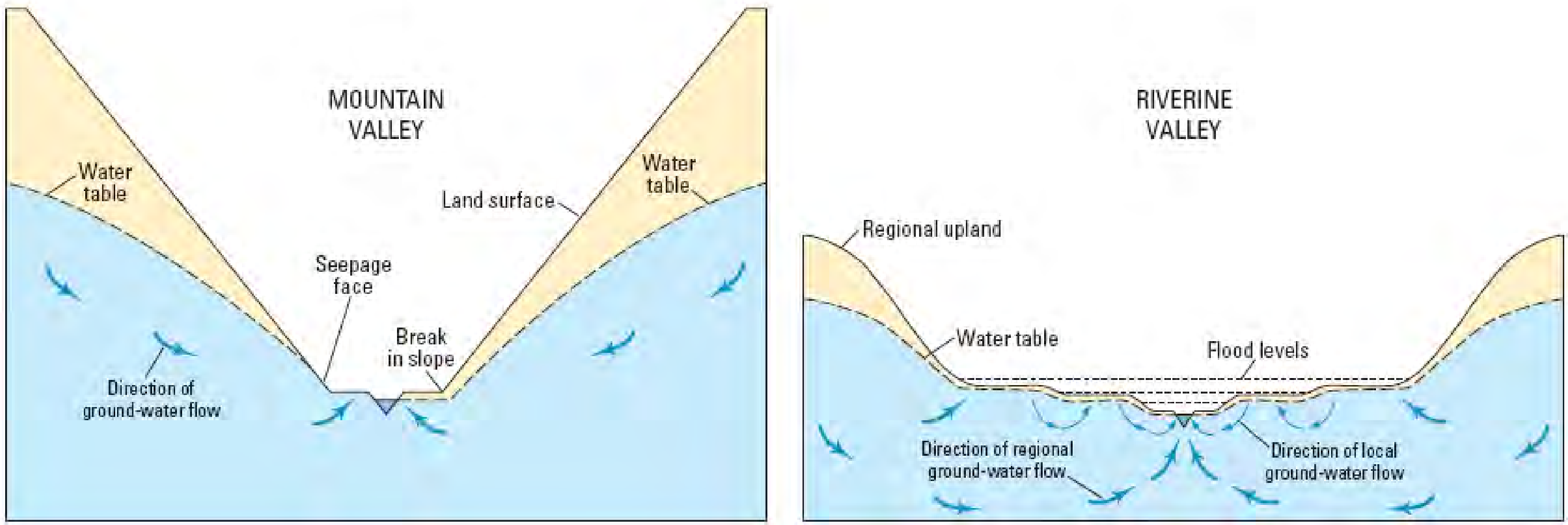


Figure 8.6-15. Riverine hydrologic landscape (Winter 2001).

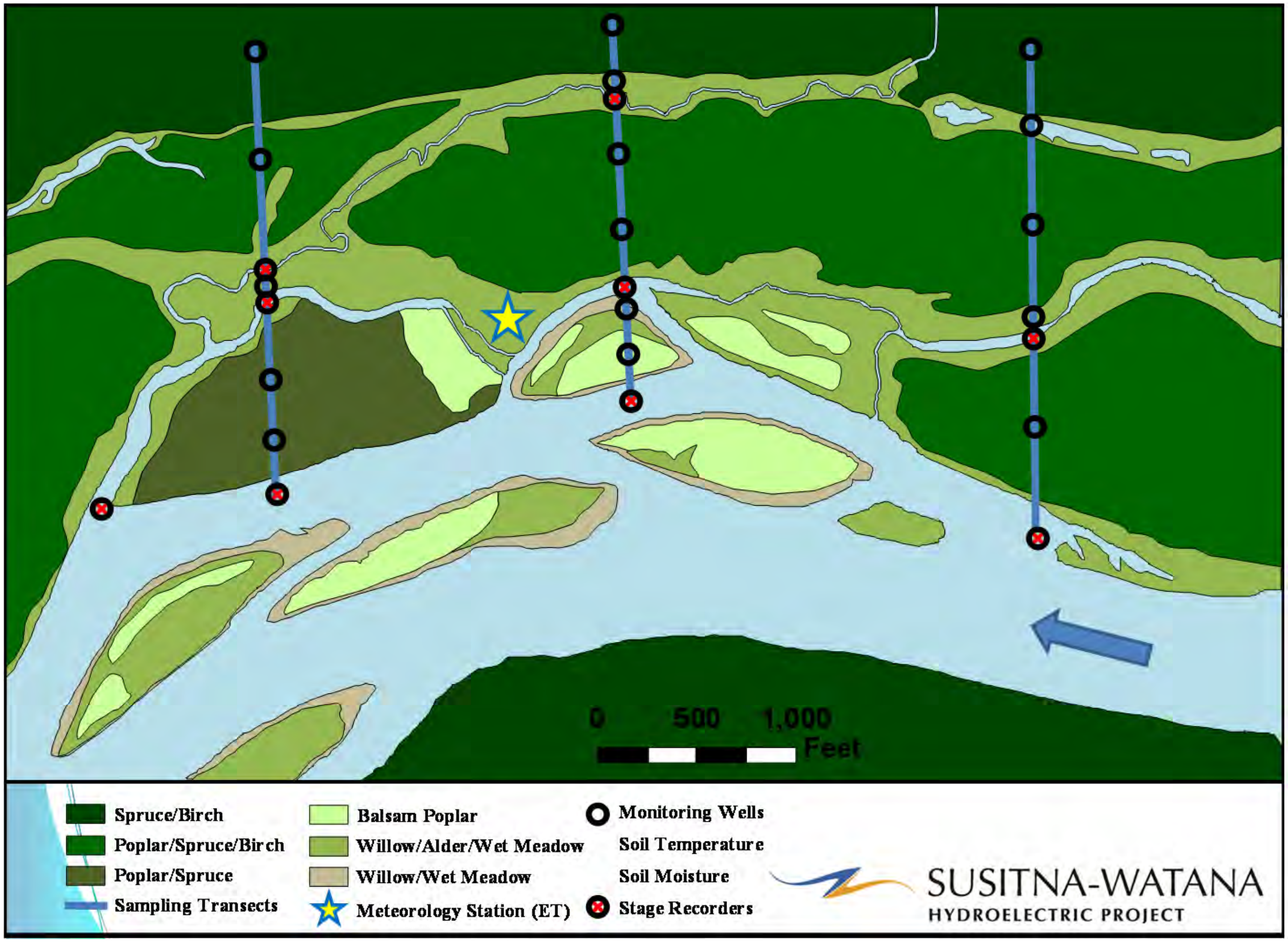


Figure 8.6-16. Whiskers Slough typical Focus Area groundwater / surface water study design illustrating monitoring well and stage recorder transect locations. Typical floodplain plant community types found in the middle segment of the Susitna River are shown.

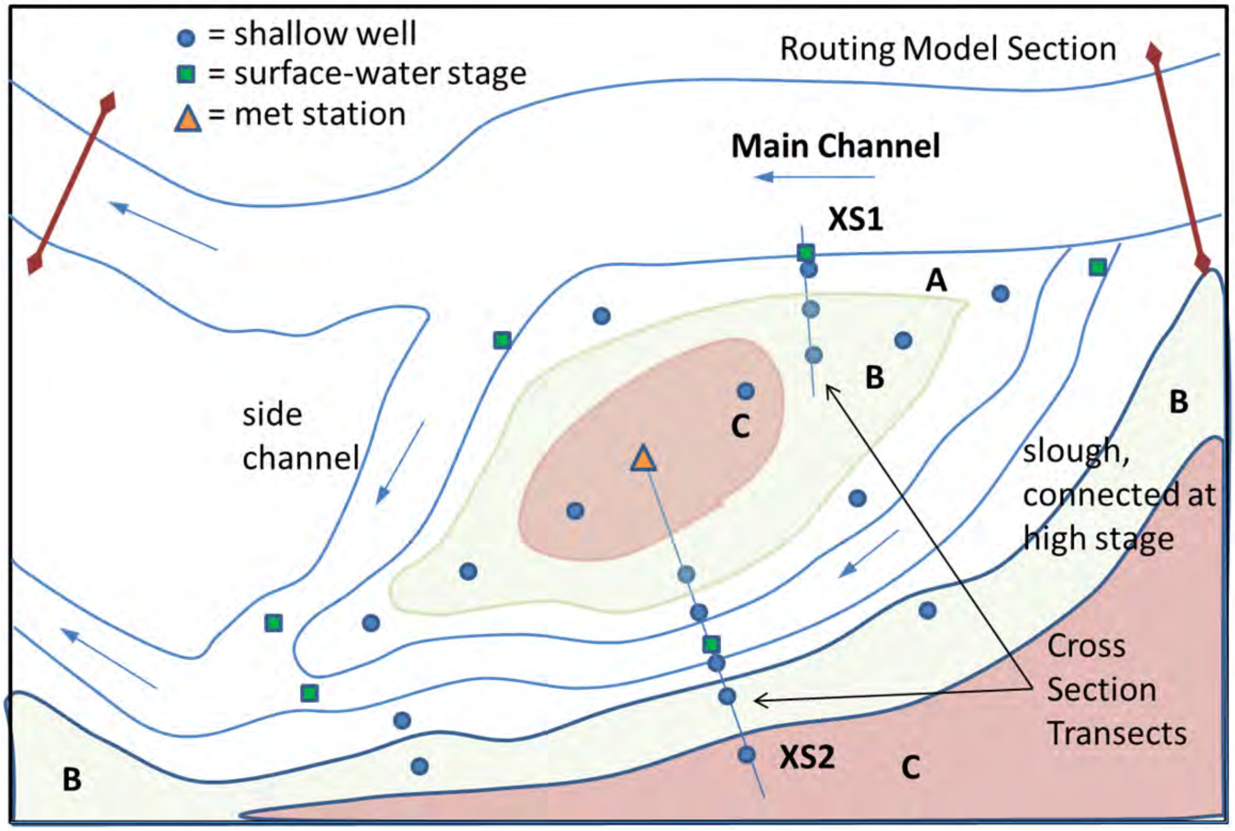
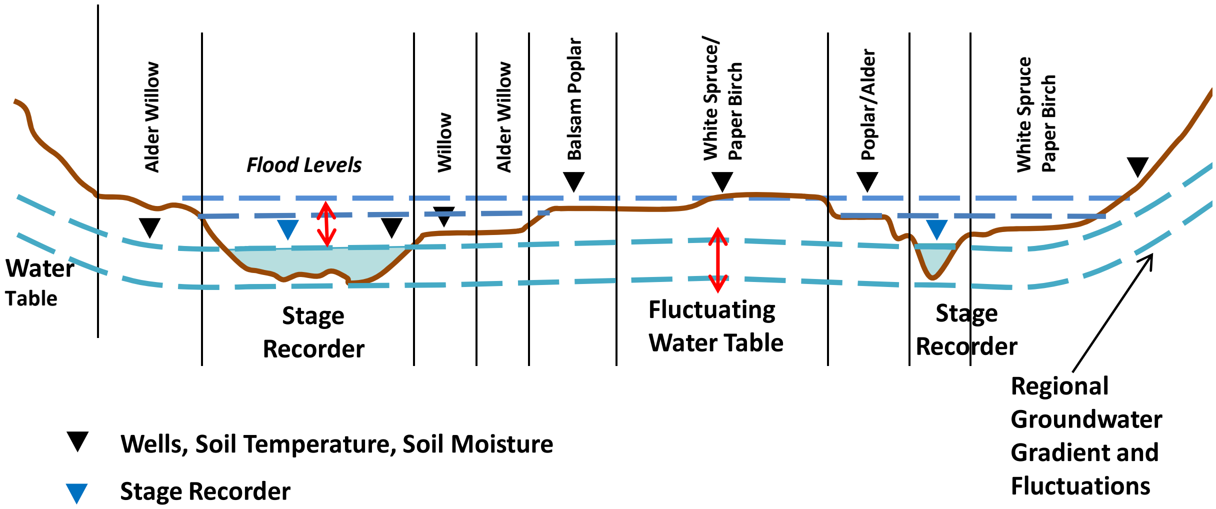


Figure 8.6-17. General schematic of a riparian Focus Area floodplain channel complex bounded by the Susitna River, side slough, and side channel.
Three typical riparian plant communities are depicted (A, B, C). Two transects of groundwater wells and stage stations are shown to help measure hydraulic interactions between the groundwater system and adjacent hydrologic boundaries at surface-water features. Additional wells are located to help define (1) the orientation of the groundwater table across the study area, and (2) conditions at specific plant community locations (e.g., seedling establishment zones). Surface-water stage stations are located to capture main channel, side channel and side slough stage variability. A meteorological station is located in the central study area. Each groundwater well location may include additional subsurface and riparian sensor measurements.



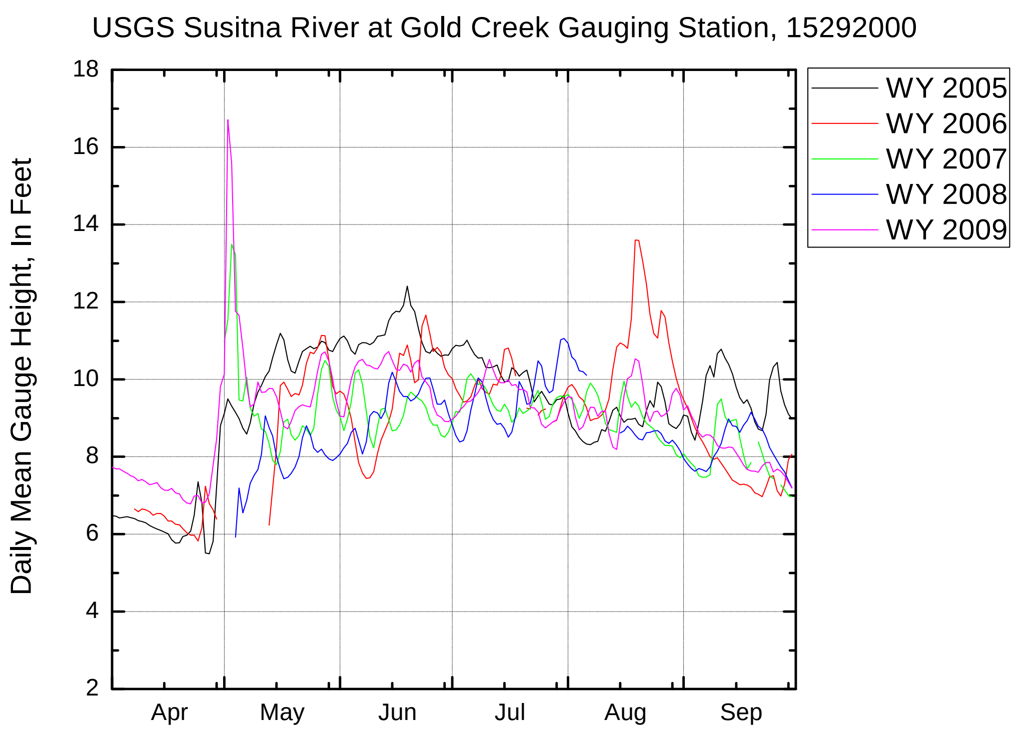


Figure 8.6-18. (A) Transect profile view of typical monitoring well and stage recorder locations looking downriver. (B) Gold Creek Gauge Station, Susitna River April through September 2005-2009.

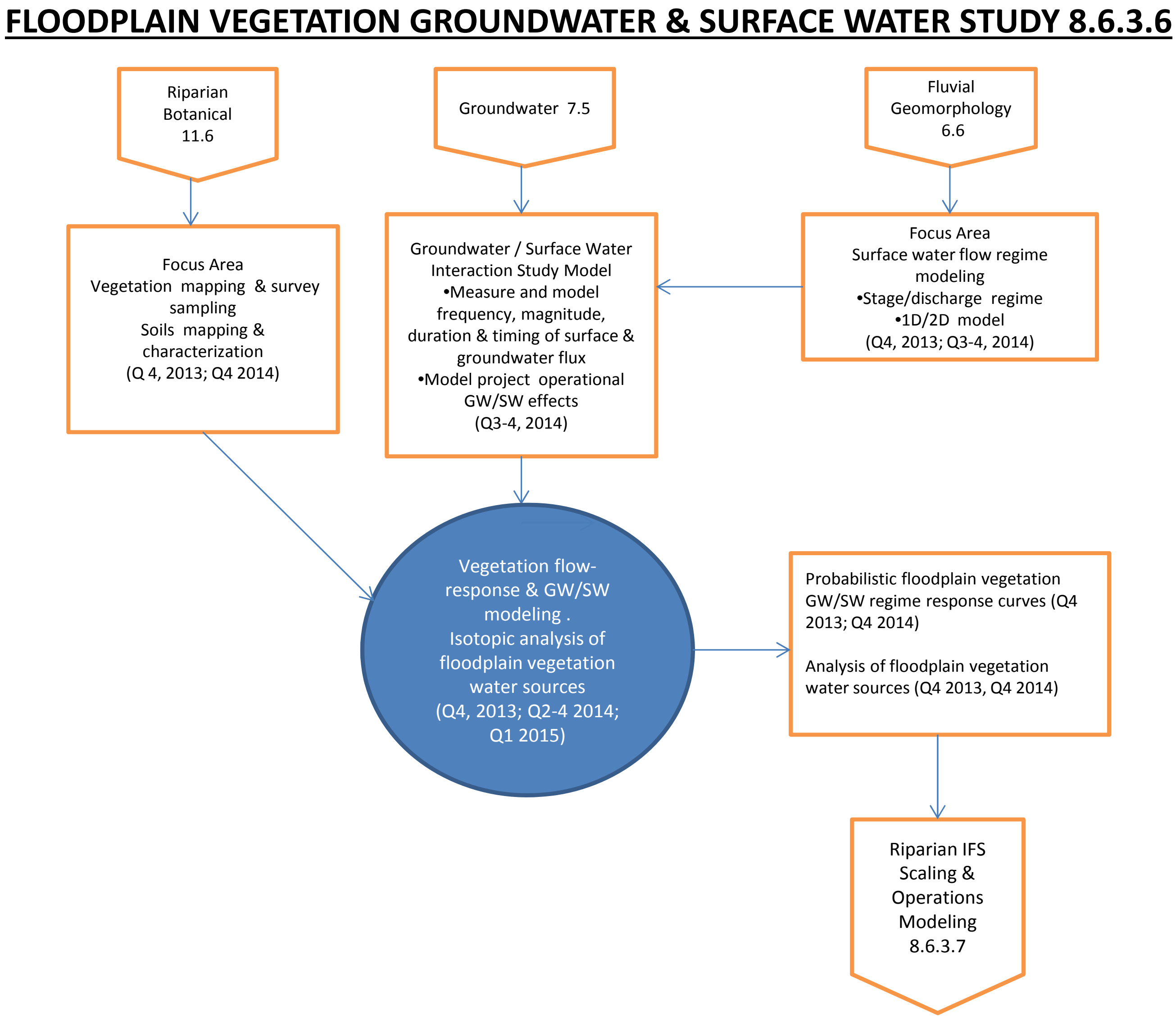


Figure 8.6-19. Floodplain Vegetation Groundwater & Surface Water Study 8.6.3.6.

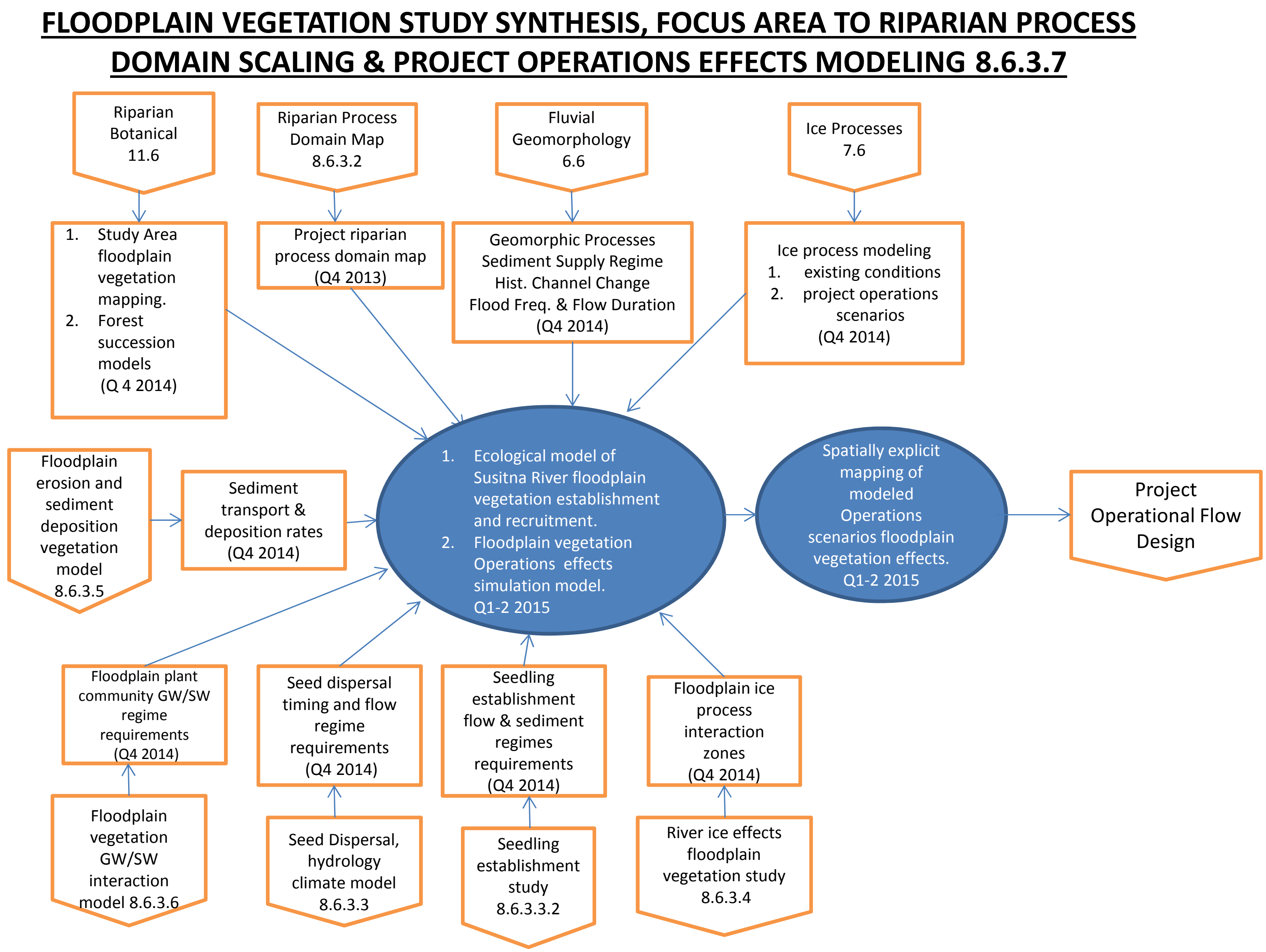


Figure 8.6-20. Floodplain Vegetation Study Synthesis, Focus Area to Riparian Process Domain Scaling & Project Operations Effects Modeling 8.6.3.7.

8.7. Attachments

ATTACHMENT 8-1

GLOSSARY OF TERMS AND ACRONYMS – INSTREAM FLOW

Glossary of Terms and Acronyms
Instream Flow

Included in this list are definitions obtained from the glossary prepared by the Instream Flow Council (Locke et al. 2008) as well as definitions developed for the Susitna-Watana Hydroelectric Project.

Accretion	1. Addition of flows to the total discharge of the stream channel, which may come from tributaries, springs, or seeps. 2. Increase of material such as silt, sand, gravel, water.
Active floodplain	The flat valley floor constructed by river during lateral channel migration and deposition of sediment under current climate conditions.
Adaptive management	A process whereby management decisions can be changed or adjusted based on additional biological, physical or socioeconomic information.
Adfluvial	Fish that spend a part of their life cycle in lakes and return to rivers and streams to spawn.
Adult	Sexually mature individuals of a species.
Age-0 juvenile	The description of an organism that, in its natal year, has developed the anatomical and physical traits characteristically similar to the mature life stage, but without the capability to reproduce.
Aggradation	1. Geologic process in which inorganic materials carried downstream are deposited in streambeds, floodplains, and other water bodies resulting in a rise in elevation in the bottom of the water body. 2. A state of channel disequilibrium, whereby the supply of sediment exceeds the transport capacity of the stream, resulting in deposition and storage of sediment in the active channel.
Anadromous	Fish that mature in salt water but migrate to fresh water to spawn.
Annual flow	The total volume of water passing a given point in one year. Usually expressed as a volume (such as acre-feet) but may be expressed as an equivalent constant discharge over the year, such as cubic feet per second.

Armoring	1. The formation of an erosion-resistant layer of relatively large particles on the surface of a streambed or stream bank that results from removal of finer particles by erosion, and which resists degradation by water currents. 2. The application of materials to reduce erosion. 3. The process of continually winnowing away smaller substrate material and leaving a veneer of larger ones.
Average daily flow	The long-term average annual flow divided by the number of days in the year usually expressed as an equivalent constant discharge such as cubic feet per second. In some settings, the value can be used to represent only the portion of the daily flow values in a defined period such as those that occur within a calendar month.
Bank	The sloping land bordering a stream channel that forms the usual boundaries of a channel. The bank has a steeper slope than the bottom of the channel and is usually steeper than the land surrounding the channel.
Bathymetric	Related to the measurement of water depth within a water body.
Bedload	Material moving on or near the streambed and frequently in contact with it.
Benthic	Associated with the bottom of a body of water.
Benthic macroinvertebrates	Animals without backbones, living in or on the sediments, a size large enough to be seen by the unaided eye, and which can be retained by a U.S. Standard No. 30 sieve (28 openings/inch, 0.595-mm openings). Also referred to as benthos, infauna, or macrobenthos.
Braid	Pattern of two or more interconnected channels typical of alluvial streams.
Breaching flow	The mainstem river flow that overtops the inlet elevation of a side channel.
Calibration	The validation of specific measurement techniques and equipment, or the comparison between measurements. In the context of PHABSIM, calibration is the process of adjusting input variables to minimize the error between predicted and observed water surface elevations.
Capillary fringe	The subsurface layer in which groundwater seeps up from a water table by capillary action to fill soil pores.

Catch per unit effort (CPUE)	The quantity of fish caught (in number or in weight) with one standard unit of fishing effort. CPUE is often considered an index of fish biomass (or abundance). Sometimes referred to as catch rate. CPUE may be used as a measure of economic efficiency of fishing as well as an index of fish abundance.
Channel	A natural or artificial watercourse that continuously or intermittently contains water, with definite bed and banks that confine all but overbank streamflows.
Confidence interval	The computed interval with a given probability that the true value of the statistic – such as a mean, proportion, or rate – is contained within the interval.
Confinement	Ratio of valley width (VW) to channel width (CW). Confined channel VW:CW <2; Moderately confined channel VW:CW 2-4; Unconfined channel VW:CW >4.
Confluence	The junction of two or more streams.
Connectivity	Maintenance of lateral, longitudinal, and vertical pathways for biological, hydrological, and physical processes.
Cover	Structural features (e.g., boulders, log jams) or hydraulic characteristics (e.g., turbulence, depth) that provide shelter from currents, energetically efficient feeding stations, and/or visual isolation from competitors or predators.
Cross section	A plane across a stream channel perpendicular to the direction of water flow.
Cross-sectional area	The area of the stream's vertical cross section, perpendicular to flow.
Cubic feet per second (cfs)	A standard measure of the total amount of water passing by a particular location of a river, canal, pipe or tunnel during a one second interval. One cfs is equal to 7.4805 gallons per second, 28.31369 liters per second, 0.028 cubic meters per second, or 0.6463145 million gallons per day (mgd). Also called second-feet.
Current meter	Instrument used to measure the velocity of water flow in a stream, measured in units of length per unit of time, such as feet per second (fps).
Datum	A geometric plane of known or arbitrary elevation used as a point of reference to determine the elevation, or change of elevation, of another plane (see gage datum).

Decision support system (DSS)	Tools developed to evaluate alternative flow scenarios in support of water control decisions; can include matrices that array differences among alternative flow regimes by calculating values of indicator variables representing different habitat characteristics or processes of the riverine ecosystem.
Degradation	1. A decline in the viability of ecosystem functions and processes. 2. Geologic process by which streambeds and floodplains are lowered in elevation by the removal of material (also see down cutting).
Delta	A low, nearly flat accumulation of sediment deposited at the mouth of a river or stream, commonly triangular or fan-shaped.
Dendrochronology	The science of dating woody species (Fritts 1976).
Density	Number of individuals per unit area.
Deposition	The settlement or accumulation of material out of the water column and onto the streambed.
Depth	Water depth at the measuring point (station).
Dewater	Remove or drain the water from a stream, pond or aquifer.
Discharge	The rate of streamflow or the volume of water flowing at a location within a specified time interval. Usually expressed as cubic meters per second (cms) or cubic feet per second (cfs).
Dissolved oxygen (DO)	The amount of gaseous oxygen (O2) dissolved in the water column. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a waste product of photosynthesis. More than 5 parts oxygen per million parts water is considered healthy; below 3 parts oxygen per million is generally stressful to aquatic organisms.
Disturbance regime	Floodplain vegetation disturbance types found within the Susitna River Study Area corridor include: channel migration (erosion and depositional processes), ice processes (shearing impacts, flooding and freezing), herbivory (beaver, moose, and hare), wind, and, to an infrequent extent, fire. Floodplain soil disturbance is primarily ice shearing and sediment deposition.
Drainage area	The total land area draining to any point in a stream. Also called catchment area, watershed, and basin.

Ecosystem	Any complex of living organisms interacting with nonliving chemical and physical components that form and function as a natural environmental unit.
Electrofishing	A biological collection method that uses electric current to facilitate capturing fishes.
Embeddedness	The degree that larger particles (boulders, rubble, or gravel) are surrounded or covered by fine sediment. Usually measured in classes according to percent of coverage.
Emergent vegetation	An emergent plant is one which grows in water but which pierces the surface so that it is partially in air. Collectively, such plants are emergent vegetation.
Euphotic zone	Surface layer of an ocean, lake, or other body of water through which light can penetrate. Also known as the zone of photosynthesis.
FLIR	Forward looking infrared (FLIR) is an imaging technology that senses infrared radiation. Can be used for watershed temperature monitoring.
Flood	Any flow that exceeds the bankfull capacity of a stream or channel and flows out on the floodplain.
Floodplain	1. The area along waterways that is subject to periodic inundation by out-of-bank flows. 2. The area adjoining a water body that becomes inundated during periods of over-bank flooding and that is given rigorous legal definition in regulatory programs. 3. Land beyond a stream channel that forms the perimeter for the maximum probability flood. 4. A relatively flat strip of land bordering a stream that is formed by sediment deposition. 5. A deposit of alluvium that covers a valley flat from lateral erosion of meandering streams and rivers.
Floodplain vegetation − groundwater / surface water regime functional groups	Assemblages of plants that have established and developed under similar groundwater and surface water hydrologic regimes.
Flushing flow	A stream discharge with sufficient power to remove silt and sand from a gravel/cobble substrate but not enough power to remove gravels.
Focus Area	Areas selected for intensive investigation by multiple disciplines as part of the instream flow study.

Fry	A recently hatched fish. Sometimes defined as a young juvenile salmonid with absorbed egg sac, less than 60 mm in length.
Gaging station	A specific site on a stream where systematic observations of streamflow or other hydrologic data are obtained.
Geographic information system (GIS)	An integrated collection of computer software and data used to view and manage information about geographic places, analyze spatial relationships, and model spatial processes. A GIS provides a framework for gathering and organizing spatial data and related information so that it can be displayed and analyzed. In the simplest terms, GIS is the merging of cartography, statistical analysis, and database technology.
Geomorphic mapping	A map design technique that defines, delimits and locates landforms. It combines a description of surface relief and its origin, relative age, and the environmental conditions in which it formed. This type of mapping is used to locate and differentiate among relief forms related to geologic structure, internal dynamics of the lithosphere, and landforms shaped by external processes governed by the bio-climate environment.
Global positioning system (GPS)	A system of radio-emitting and -receiving satellites used for determining positions on the earth. The orbiting satellites transmit signals that allow a GPS receiver anywhere on earth to calculate its own location through trilateration. Developed and operated by the U.S. Department of Defense, the system is used in navigation, mapping, surveying, and other applications in which precise positioning is necessary.
Gradient	The rate of change of any characteristic, expressed per unit of length (see Slope). May also apply to longitudinal succession of biological communities.
Groundwater	In general, all subsurface water that is distinct from surface water; specifically, that part which is in the saturated zone of a defined aquifer.
Habitat guild	Groups of species that share common characteristics of microhabitat use and selection at various stages in their life histories.
Habitat suitability criteria (HSC)	A graph/mathematical equation describing the suitability for use of areas within a stream channel related to water depth, velocity and substrate by various species/lifestages of fish.

Habitat suitability index (HSI)	An HSI is a numerical index that represents the capacity of a given habitat to support a selected species. HSI model results represent the interactions of the habitat characteristics and how each habitat relates to a given species. The value is to serve as a basis for improved decision making and increased understanding of species-habitat relationships.
Hydraulic control	A horizontal or vertical constriction in the channel, such as the crest of a riffle, which creates a backwater effect.
Hydraulic head	A measure of energy or pressure, expressed in terms of the vertical height of a column of water that has the same pressure difference.
Hydraulic model	A computer model of a segment of river used to evaluate stream flow characteristics over a range of flows.
Hydrograph	A graph showing the variation in discharge over time.
Incised	Lowering of the streambed by erosion that occurs when the energy of the water flowing through a stream reach exceeds that necessary to erode and transport the bed material.
Incremental methodology	The process of developing an instream flow policy that incorporates multiple or variable rules to establish, through negotiation, flow-window requirements or guidelines to meet the needs of an aquatic ecosystem, given water supply or other constraints. It usually implies the determination of a habitat-discharge relation for comparing streamflow alternatives through time.
Instream flow	The rate of flow in a stream channel at any time of year.
Intergravel	Intergravel refers to the subsurface environment within the river bed.
Invertebrate	All animals without a vertebral column; for example, aquatic insects.
Isotopic dating	Direct dating using analyses of stable isotopes.
Large woody debris (LWD)	Pieces of wood larger than 10 feet long and 6 inches in diameter, in a stream channel. Minimum sizes vary according to stream size and region.
LiDAR	Light detection and ranging. An optical remote sensing technology that can measure the distance to a target, can be used to create a topographic map.

Life stage	An arbitrary age classification of an organism into categories relate to body morphology and reproductive potential, such as spawning, egg incubation, larva or fry, juvenile, and adult.
Macroinvertebrate	An invertebrate animal without a backbone that can be seen without magnification.
Main channel	<u>Main Channel Habitat Types</u> **Main Channel:** Single dominant main channel **Split Main Channel:** Less than 3 distributed dominant channels **Braided Main Channel:** Greater than 3 distributed dominant channels **Side Channel:** Channel that is turbid and connected to the active main channel but represents non-dominant proportion of flow **Tributary Mouth:** Clear water areas that exist where tributaries flow into the Susitna River main channel or side channel habitats
Mainstem	Mainstem refers to the primary river corridor, as contrasted to its tributaries. Mainstem habitats include the main channel, split main channels, side channels, tributary mouths, and off-channel habitats.
Manning's n	A measure of channel roughness.
Mesohabitat	A discrete area of stream exhibiting relatively similar characteristics of depth, velocity, slope, substrate, and cover, and variances thereof (e.g., pools with maximum depth <5 ft, high gradient rimes, side channel backwaters).
Microhabitat	Small localized areas within a broader habitat type used by organisms for specific purposes or events, typically described by a combination of depth, velocity, substrate, or cover.
Non-native	Not indigenous to or naturally occurring in a given area. Presence is usually attributed to intentional or unintentional introduction by humans. Non-native species are also termed "exotic" species.
Nose velocity	The velocity at the approximate point vertically in the channel where a fish is located.

Off-channel	Those bodies of water adjacent to the main channel that have surface water connections to the main river at some discharge levels. Off-channel Habitat Types **Side Slough:** Overflow channel contained in the floodplain, but disconnected from the main channel. Has clear water.[2] **Upland Slough:** Similar to a side slough, but contains a vegetated bar and is rarely overtopped by mainstem flow. Has clear water. [2] **Backwater:** Found along channel margins and generally within the influence of the active main channel. Water is not clear. **Beaver Complex**: Complex ponded water body created by beaver dams
Peak load	The greatest of all load demands on an interconnected electric transmission network occurring in a specified period of time.
Period of record	The length of time for which data for an environmental variable have been collected on a regular and continuous basis.
pH	A measure of the acidity or basicity of a solution. Pure water is said to be neutral, with a pH close to 7.0 at 25 °C (77 °F). Solutions with a pH less than 7 are said to be acidic, and solutions with a pH greater than 7 are said to be basic or alkaline.
PHABSIM	(pronounced P-HAB-SIM) The Physical HABitat SIMulation system; a set of software and methods that allows the computation of a relation between streamflow and physical habitat for various life stage of an aquatic organism or a recreational activity.
Physical habitat	Those abiotic factors such as depth, velocity, substrate, cover, temperature, water quality that make up some of an organism's living space.
Pool	Part of a stream with reduced velocity, often with water deeper than the surrounding areas, which is usable by fish for resting and cover.
Powerhouse	A structure that houses the turbines, generators, and associated control equipment.
Process domains	Define specific geographic areas in which various geomorphic processes govern habitat attributes and dynamics (Montgomery 1999).

Q	Hydrological abbreviation for discharge, usually presented as cfs (cubic feet per second) or cms (cubic meters per second). Flow (discharge at a cross-section).
Radiotelemetry	Involves the capture and placement of radio-tags in adult fish that allow for the remote tracking of movements of individual fish.
Ramping rate	The rate of change in discharge (typically inches per hour) below a hydroelectric facility that is fluctuating flow releases.
Recruitment	The number of new juvenile fish reaching a certain size/age class; connotes the process whereby juveniles survive and mature into adults.
Redd	The spawning ground or nest of various fishes.
Refugia	An area protected from disturbance and exposure to adverse environmental conditions where fish or other animals can find shelter from sudden flow surges, adverse water quality, or other short-duration disturbances.
Regime	The general pattern (magnitude and frequency) of flow or temperature events through time at a particular location (such as snowmelt regime, rainfall regime).
Reservoir	A body of water, either natural or artificial, that is used to manipulate flow or store water for future use.
Restoration	To return a stream, river, or lake to its natural, predevelopment form and function. Restoration typically eliminates the human influence that degraded or destroyed riverine processes and characteristics.
Riffle	A fast water habitat with turbulent, shallow flow over submerged or partially submerged gravel and cobble substrates. Gradients are approximately 2 to less than 4%.
Riparian	Pertaining to anything connected with or adjacent to the bank of a stream or other body of water.
Riparian process domain	Define specific geographic areas in which various geomorphic processes govern floodplain habitat attributes and dynamics.
Riparian vegetation	Vegetation that is dependent upon an excess of moisture during a portion of the growing season on a site that is perceptively more moist than the surrounding area.

Riparian zone	A stream and all the vegetation on its banks that is influenced by the presence of the stream, including surface flow, hyporheic flow and microclimate.
River	A large stream that serves as the natural drainage channel for a relatively large catchment or drainage basin.
River corridor	A perennial, intermittent, or ephemeral stream and adjacent vegetative fringe. The corridor is the area occupied during high water and the land immediately adjacent, including riparian vegetation that shades the stream, provides input of organic debris, and protects banks from excessive erosion.
River mile	The distance of a point on a river measured in miles from the river's mouth along the low-water channel.
Scour	The localized removal of material from the streambed by flowing water. This is the opposite of fill.
Sediment	Solid material, both mineral and organic, that is in suspension in the current or deposited on the streambed.
Side channel	Lateral channel with an axis of flow roughly parallel to the mainstem, which is fed by water from the mainstem; a braid of a river with flow appreciably lower than the main channel. Side channel habitat may exist either in well-defined secondary (overflow) channels, or in poorly-defined watercourses flowing through partially submerged gravel bars and islands along the margins of the mainstem.
Sinuosity	The ratio of channel length between two points on a channel to the straight-line distance between the same two points. The amount of bending, winding and curving in a stream or river.
Slope	The inclination or gradient from the horizontal of a line or surface. The degree of inclination can be expressed as a ratio, such as 1:25, indicating one unit rise in 25 units of horizontal distance or as 0.04 height per length. Often expressed as a percentage and sometimes also expressed as feet (or inches) per mile.
Smolt	An adolescent salmon which has metamorphosed and which is found on its way downstream toward the sea.
Smoltification	The physiological changes anadromous salmonids and trout undergo in freshwater while migrating toward saltwater that allow them to live in the ocean.

Spawning	The depositing and fertilizing of eggs by fish and other aquatic life.
Split channel	A river having numerous islands dividing the flow into two channels. The islands and banks are usually heavily vegetated and stable. The channels tend to be narrower and deeper and the floodplain narrower than for a braided system.
Stage	The distance of the water surface in a river above a known datum.
Stage of zero flow (SZF)	No discharge flowing through the cross-section if water stage is equal or lower than SZF. Usually SZF is the channel invert, the lowest point of the channel.
Stage-discharge relationship	The relation between the water-surface elevation, termed stage (gage height), and the volume of water flowing in a channel per unit time.
Stranding	Stranding refers to the beaching of fish and other aquatic organisms on low gradient channel bed as a result of declining river stage.
Streambed	The bottom of the stream channel; may be wet or dry.
Substrate	The material on the bottom of the stream channel, such as rocks or vegetation. Proposed substrate classification system for use in development of HSC/HIS curves for the Susitna-Watana Project.

Code	Substrate Type	Size (Inches)	Size (mm)
1	Silt, Clay, or Organic	<0.01	<0.1
2	Sand	0.01-0.10	0.1-2.0
3	Small Gravel	0.10-0.30	2.0-8.0
4	Medium Gravel	0.30-1.25	8.0-32
5	Large Gravel	1.25-2.50	32-64
6	Small Cobble	2.50-5.0	64-128
7	Large Cobble	5.0-10.0	128-256
8	Boulder	>10.0	>256
9	Bedrock		

Suitability	A generic term used in IFIM to indicate the relative quality of a range of environmental conditions for a target species.
Temporal variability	Pertaining to, or involving the nature of time, occurrence in time, and variability in occurrence over some increment in time (e.g., diurnally, daily, monthly, annually).
Thalweg	The deepest channel of a watercourse.

Time step	The interval over which elements in a time series are averaged.
Time-series analysis	Analysis of the pattern (frequency, duration, magnitude, and time) of time-varying events. These events may be discharge, habitat areas, stream temperature, population factors, economic indicators, power generation, and so forth.
Transferability	1. Applicability of a model (e.g., habitat suitability criteria) to settings or conditions that differ from the setting or conditions under which the model was developed. 2. Applicability of data obtained from a remote source (e.g., a meteorological station) for use at a location having different environmental attributes.
Trapping	Trapping is the isolation of fish and other aquatic organisms in pockets of water with no access to the free-flowing surface water as a result of declining river stage.
Tributary	A stream feeding, joining, or flowing into a larger stream (at any point along its course or into a lake). Synonyms: feeder stream, side stream.
Turbidity	A measure of the extent to which light passing through water is reduced due to suspended materials.
Varial zone	The area of river channel bed exposed to frequent inundation and dewatering caused by daily flow fluctuations associated with hydropower load-following operations.
Velocity	The distance traveled by water in a stream channel divided by the time required to travel that distance.
Velocity adjustment factor (VAF)	$Q_{simulated}/Q_{trial}$, where Q_{trial} is the discharge computed by PHABSIM.
Vertical	A location along a transect across a river where microhabitat-related data are collected.
Weighted usable area (WUA)	The wetted area of a stream weighted by its suitability for use by aquatic organisms or recreational activity.
Wetted perimeter	The length of the wetted contact between a stream of flowing water and the stream bottom in a plane at right angles to the direction of flow.

ATTACHMENT 8-2

THREE-YEAR SEEDLING COHORT LONGITUDNAL ESTABLISHMENT AND SURVIVAL ANALYSIS

Three-Year Seedling Cohort Longitudnal Establishment and Survival Analysis

AEA will conduct a longitudinal three-year second-peak seedling cohort establishment and survival analysis to inform the adaptive management components of future Project instream flow regimes. The objective of the analysis is to identify, and measure, seedling and flow regime characteristics in a longitudinal seedling cohort analysis as compared to the two-year Seedling Establishment and Recruitment Study (Section 8.6.3.3.2).

The seedling cohort establishment analysis will be initiated in summer 2013 and carried through for three years 2014 to 2016; final results will be presented in a technical memorandum to be prepared Q4 2016.

The three-year seedling cohort establishment cohort study will be incorporated into the existing two-year Seedling Establishment and Recruitment Study (Section 8.6.3.3.2) study design as follows:

1. Seedling establishment plots (1 m^2) sampled for the current study design in 2013 will be permanently monumented with magnetic markers (SurvKap®) buried at approximately 20 cm depth at the northwest plot corner point to aid in relocating these plots for follow-up seedling survival measurements in 2014, 2015, 2016.
2. 2013 germinants will be censused and heights measured in early September according to protocols established by Cooper et al. (1999).
3. Seedling sample plots will be located in the full range of alluvial terrain surfaces and hydrologic conditions identified in early to mid-summer seedling establishment surveys.
4. Seedling survival analyses will be summarized in a technical memorandum and submitted to FERC in Q1 2017.

Objectives of the seedling recruitment study are:

1. Map the spatial locations of seedlings of dominant woody riparian species including balsam poplar, white spruce, paper birch, thinleaf and Sitka alder, feltleaf willow, and Barclay's willow throughout the Focus Area, and Riparian Vegetation Study sites, active channel margins, and floodplain.
2. Use a stratified random sampling approach, with variable plot sizes (Mueller-Dombois and Ellenburg 1974) to sample mapped seedling polygons.
3. Identify seedlings to species, and measure seedling heights and density.
4. Describe and measure seedling site soil characteristics (see Section 8.6.3.7 for methods).
5. Measure and model seedling site GW/SW hydroregimes.
6. Measure seedling xylem water source through isotopic analysis (see Section 8.6.3.6 for methods).
7. Investigate ice process seedling site interactions through empirical observations and ice process modeling.

8. Develop a probabilistic model of seedling hydrologic, sediment, and ice regime processes.
9. Measure seedling cohort 3-year survival.

Methods

The dominant riparian woody species will be sampled in this study, including balsam poplar, white spruce, paper birch, thinleaf and Sitka alder, feltleaf willow, and other willow species. In addition to the target woody seedlings, all herbaceous seedlings within the woody species seedling plot will be identified and measured.

Seedlings are defined as those plants established within the current year of sampling, and all plants with stems < 1m in height. At select Riparian Botanical Survey reaches, and at all Focus Areas, seedling patches will be mapped and sampled using a stratified random sampling protocol to obtain statistically representative samples of select woody species (Elzinga et al. 1998; Mueller-Dombois and Ellenberg 1974).

The survey sampling approach is as follows. First, a helicopter survey of each reach will be conducted to locate and map observable seedling areas. Second, four to eight transects will be placed systematically throughout the reach normal to main channel, extending across the adjacent floodplain intersecting observed seedling sites. Each transect will be traversed and all remotely observed, and newly identified on-the-ground seedling locations will be mapped with GPS. Third, seedling site polygon boundaries will be mapped with GPS. Fourth, seedling patches will be sampled using a stratified random approach to locate sample plots. Seedling species will be identified, or collected for herbarium identification, and abundance (density) and height measured using variable plot size and shapes (Elzinga et al. 1998; Mueller-Dombois and Ellenberg 1974). Fifth, at each plot two to three seedlings of each species will be excavated and rooting depth measured. Excavated woody seedlings will be aged at the root collar in the laboratory and annual rings counted to provide seedling age. Substrate texture and depth to cobbles will be described and measured in soil pits excavated to 50 cm in depth or to gravel/cobble refusal layer. Sixth, a subsample of Focus Area site seedlings will be used for xylem isotopic analyses to identify source of water (see Section 8.6.3.6). Results of seedling mapping and characterization will be used to assess groundwater, surface water, and ice regime relationships using 1-D / 2-D, MODFLOW and ice process modeling results from the Groundwater, Geomorphology, and Ice Processes studies.

A probabilistic model of seedling and GW/SW, sediment, and ice regime will be developed using techniques and methods described in Franz and Bazzaz (1977), Rains et al. (2004), Henszey et al. (2004), Baird and Maddock (2005), and Maddock et al. (2012).

The results of the Focus Area modeling will be scaled-up to the riparian process domains using spatially explicit GIS models as described in Section 8.6.3.7.

Data Input from Other Studies

Data input will include groundwater, surface water, and sediment regime characteristics of seedling sites developed in the Groundwater (Section 7.5) and Fluvial Geomorphology (Section 6.6) studies. The Ice Processes Study (Section 7.6) will provide modeled ice influence vertical and horizontal zones.

Data Output to Other Studies

Data output will be to Project operations adaptive management design.

Work Products

1. Probabilistic 3-year cohort seedling hydrologic, sediment, and ice regime model.
2. Technical memorandum detailing study objectives, methods, results, and operational recommendations.

The seedling establishment and recruitment study fieldwork will be conducted in Q2 and Q3 during 2013, 2014, 2015 and 2016. The results and analysis will be reported in a technical memorandum in Q4 2016.