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Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Riparian Instream Flow Study
Study Plan Section 8.6

Final Study Plan

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

July 2013

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

8.6. Riparian Instream Flow Study

On December 14, 2012, Alaska Energy Authority (AEA) filed with the Federal Energy Regulatory Commission (FERC or Commission) its Revised Study Plan (RSP), which included 58 individual study plans (AEA 2012). Included within the RSP was the Riparian Instream Flow Study, Section 8.6. RSP Section 8.6 focuses on providing a quantitative, spatially-explicit model to predict potential impacts to downstream floodplain vegetation from Project operations.

On February 1, 2013, FERC staff issued its study determination (February 1 SPD) for 44 of the 58 studies, approving 31 studies as filed and 13 with modifications. On April 1, 2013 FERC issued its study determination (April 1 SPD) for the remaining 14 studies; approving 1 study as filed and 13 with modifications. RSP Section 8.6 was one of the 13 approved with modifications. In its April 1 SPD, FERC recommended the following:

Seedling Establishment

> *-We recommend that the study plan be modified to require AEA to sample seedling establishment following the initial spring peak flows (e.g., July) and again in September in 2013 and 2014. This is consistent with accepted methods (section 5.9(b)(6)), and would provide information necessary to support the design of the project, assess environmental effects, and evaluate proposed environmental measures.*

Adequacy of MODFLOW and Xylem Water Isotopic Sampling to Establish Groundwater/Hydroperiod Relationships

> *- We discuss the use of RIP-ET and our recommendations in Study 7.5 (groundwater).*
>
> *- Consequently, we recommend that AEA consult with the TWG on the sampling design for collecting plant xylem water; and file no later than June 30, 2013, the following:*
>
> > *1) A detailed description of the sampling sites, frequency, and schedule.*
> >
> > *2) Documentation of consultation with the TWG, including how its comments were addressed.*

Soil Profile Sampling

> *- We recommend that the study plan be modified to specify that sediment grain size measurements would be based on samples taken at soil horizons, rather than at equal depth increments.*

Vegetation Response Curves

> *- AEA would follow the methods of Henszey et al. (2004) to develop vegetation-flow response curves. Prior to developing vegetation flow response curves, Henszey et al. (2004), and more recently Orellana et al. (2012), evaluated a number of different water-level summary statistics to determine which were most strongly correlated with plant frequency and were thus most suitable for inclusion in the vegetation-flow response curves. Testing the statistics for best fit, as recommended by FWS, is a commonly accepted practice (section 5.9(b)(6).*

> *We recommend that AEA do so in consultation with the riparian technical workgroup. Methods of analysis should be reported in the initial and updated study reports.*

Floodplain Vegetation Study Synthesis, Focus Area to Riparian Process Domain Model Scaling, and Project Operations Effects Modeling

> *- We recommend AEA include a schedule and plan for [modeling] development in either the initial or updated study report, as appropriate.*
>
> *- We do not recommend that such models be provided to stakeholders. Stakeholders would have an opportunity at various points in the ILP process (e.g., initial and updated study reports, preliminary licensing proposal, final license application) to identify specific project operation scenarios, which AEA would need to evaluate using the methods described in the study plan.*

Consultation on the interrelated riparian vegetation, riparian instream flow and riparian groundwater/surface water (GW/SW) study plans was accomplished with TWG representatives in two meetings; held April 23, 2013 and June 6, 2013. Licensing participants were provided the opportunity to address technical details and comments and concerns regarding the study's approaches and methods.

The Riparian Instream Flow, Groundwater, and Riparian Vegetation Studies FERC Determination Response Technical Memorandum (Riparian/GW TM) addresses FERC's April 1 SPD request concerning the adequacy of MODFLOW and xylem water isotopic sampling. The Riparian/GW TM was filed with FERC on June 30, 2013.

This Final Study Plan reflects FERC's requested modifications regarding seedling establishment (Section 8.6.3.3.2), soil profile sampling (Section 8.6.3.5), vegetation response curves (Section 8.6.3.6.2), and floodplain vegetation study synthesis, focus area to riparian process domain model scaling, and project operations effects modeling (Section 8.6.3.7).

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 the Glossary of Terms and Acronyms - Instream Flow.

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 the Three-Year Seedling Cohort Longitudinal Establishment and Survival Analysis. 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. Seedling establishment sampling will occur at times following the initial spring peak flows (e.g., July) and again in September in 2013 and 2014.

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 samples taken at soil horizons.
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). Water-level summary statistics will be tested for best fit with input from the TWG. 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

In response to FERC's study plan determination, the methodology of this section has been supplemented with the June 30, 2013 Instream Flow, Groundwater, and Riparian Vegetation Studies Technical Memorandum (Riparian/GW TM).

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. ISR chapter detailing the schedule and plan for model development.
2. 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.

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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	Δ	Initial Study Report
-----	Follow up activity (as needed)	▲	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 samples taken at soil horizons.. 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

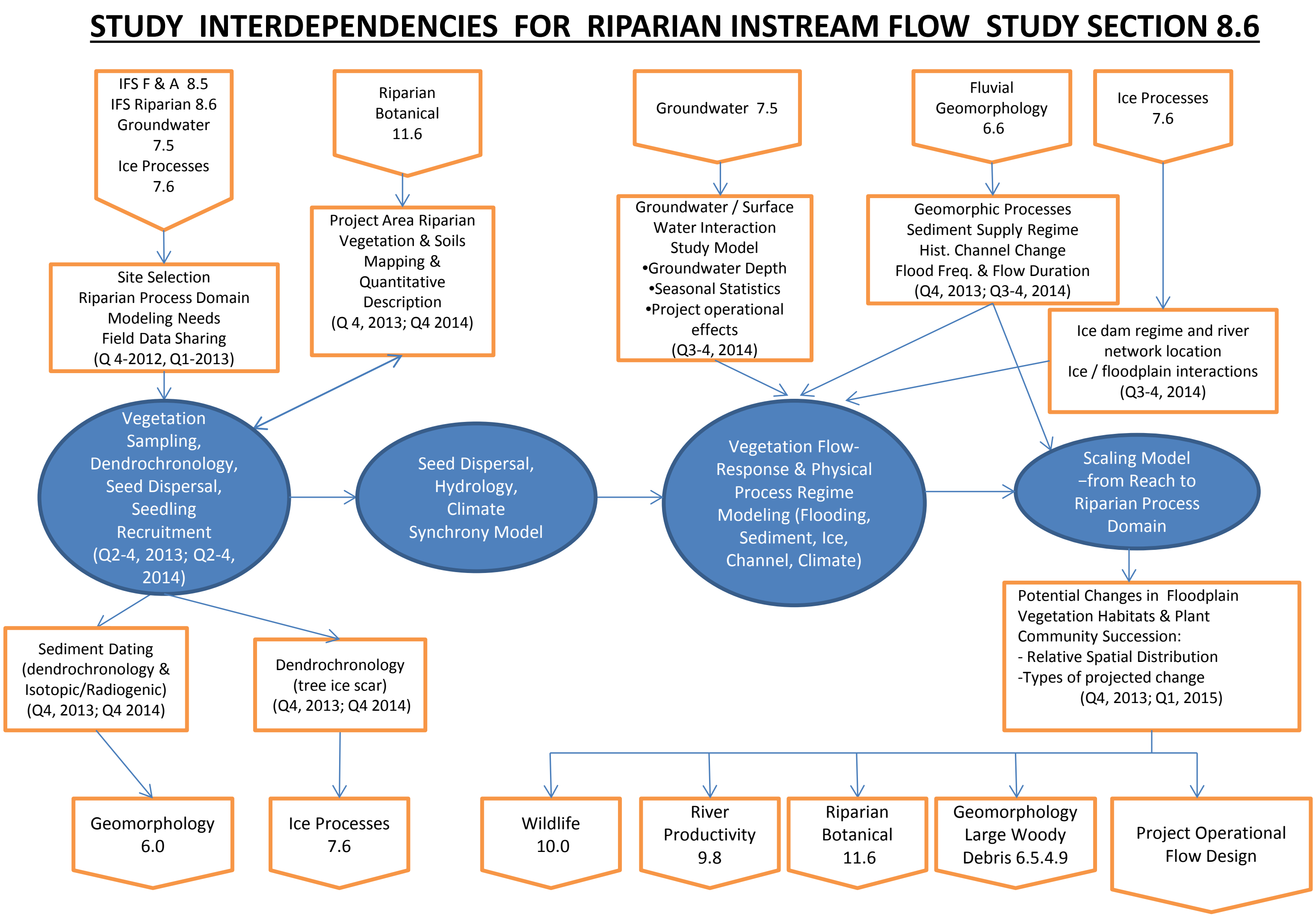

Figure 8.6-1. Study interdependencies for Riparian Instream Flow Study.

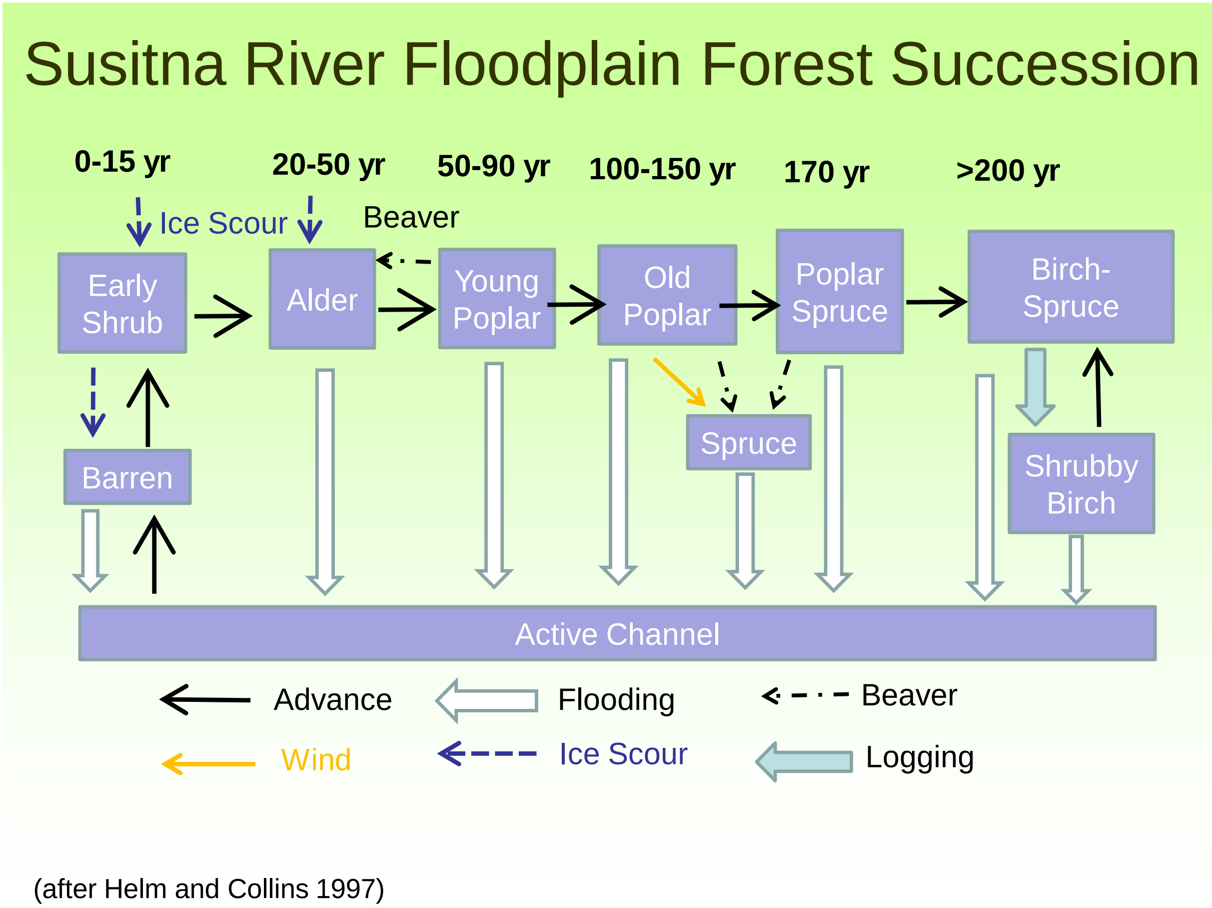

Figure 8.6-2. Helm and Collins (1997) Susitna River floodplain forest succession. Note: model depicts typical floodplain forests found in the Susitna River Middle River and Three Rivers Confluence segments.

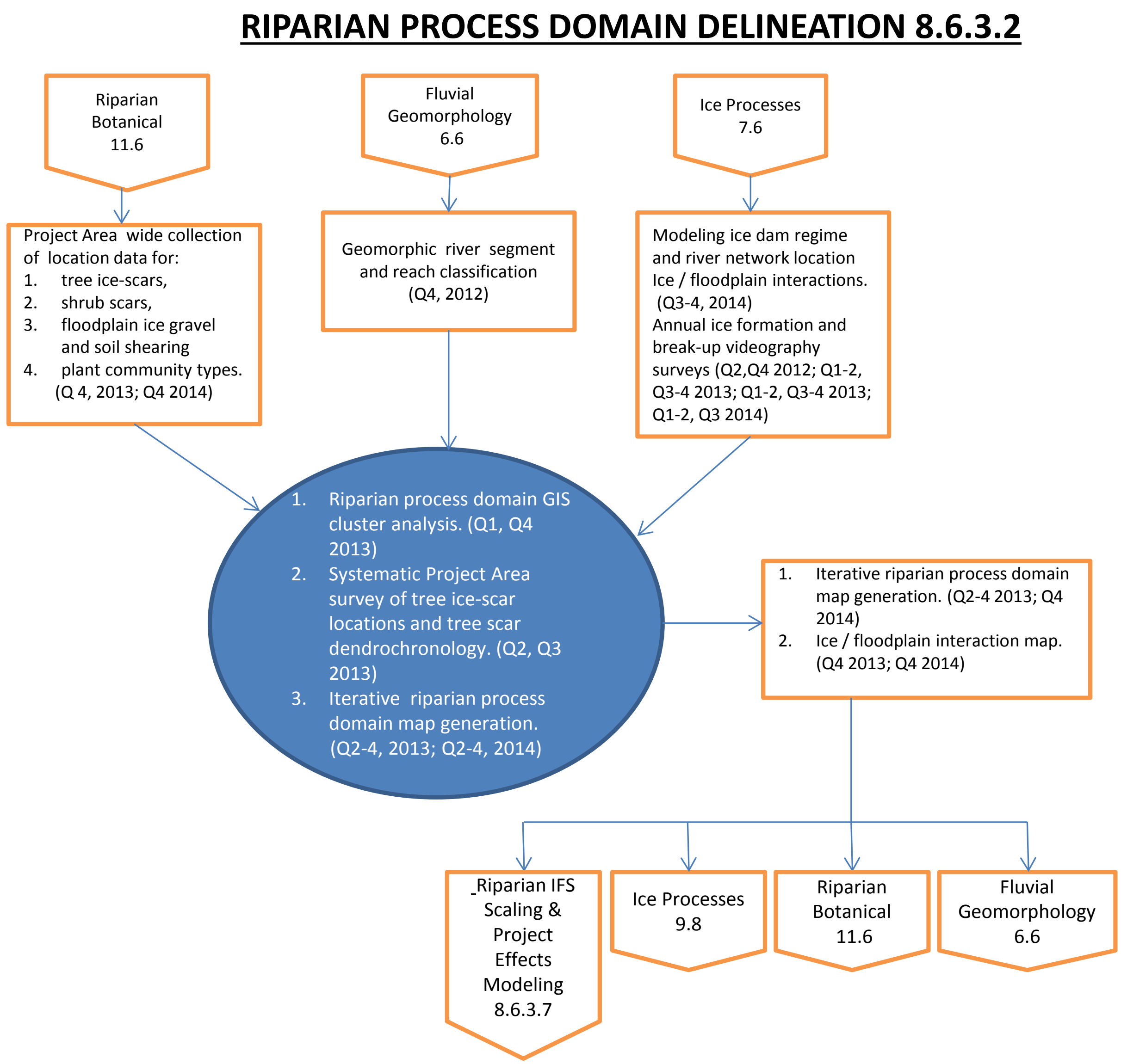

Figure 8.6-3. Riparian Process Domain Delineation 8.6.3.2.

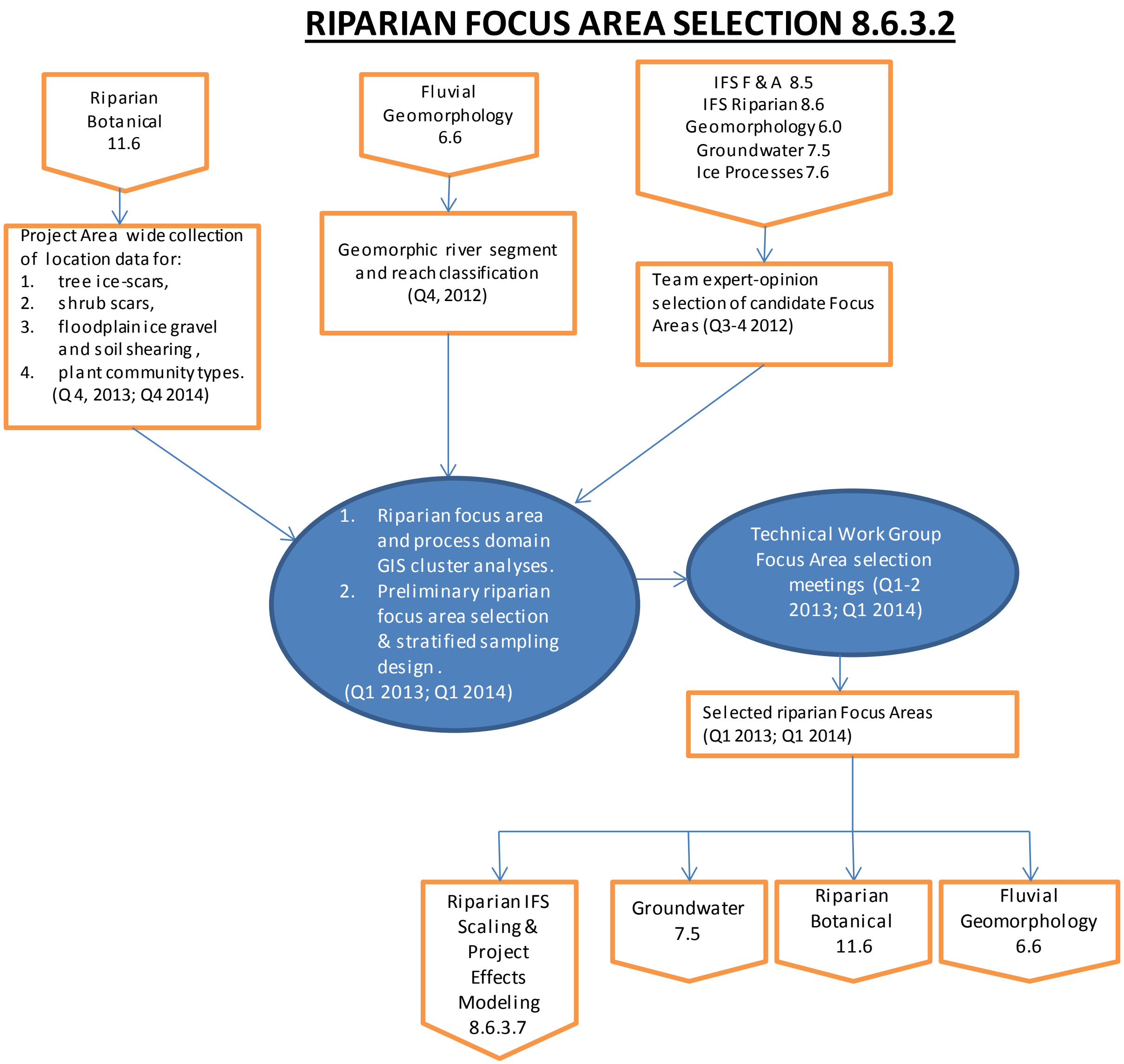

Figure 8.6-4. Riparian Focus Area Selection 8.6.3.2.

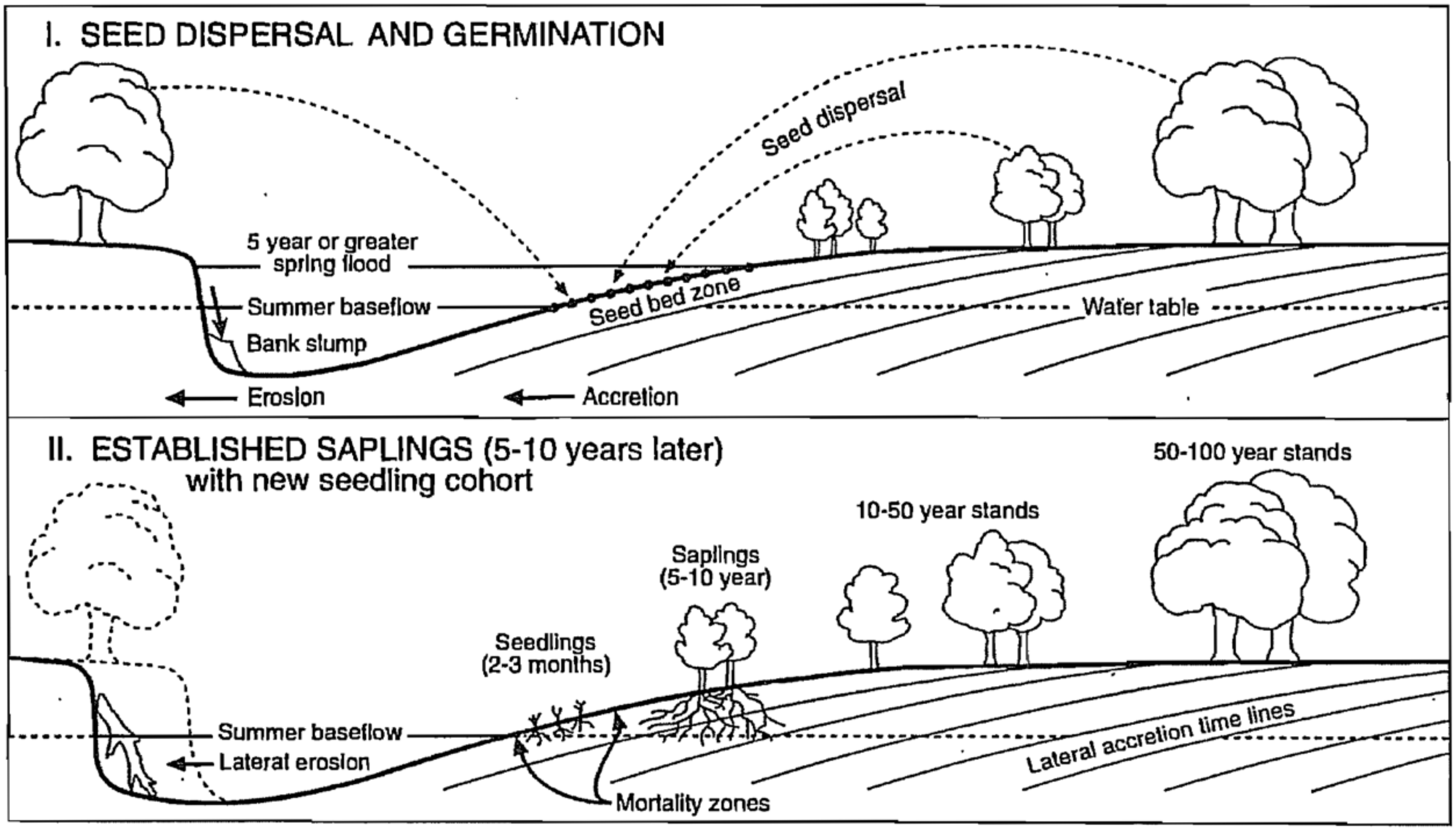

Figure 8.6-5. Cottonwood (Populus) life history stages: seed dispersal and germination, sapling to tree establishment. Cottonwood typically germinates on newly created bare mineral soils associate with lateral active channel margins and gravel bars. Note proximity of summer baseflow and floodplain water table (Braatne et al. 1996).

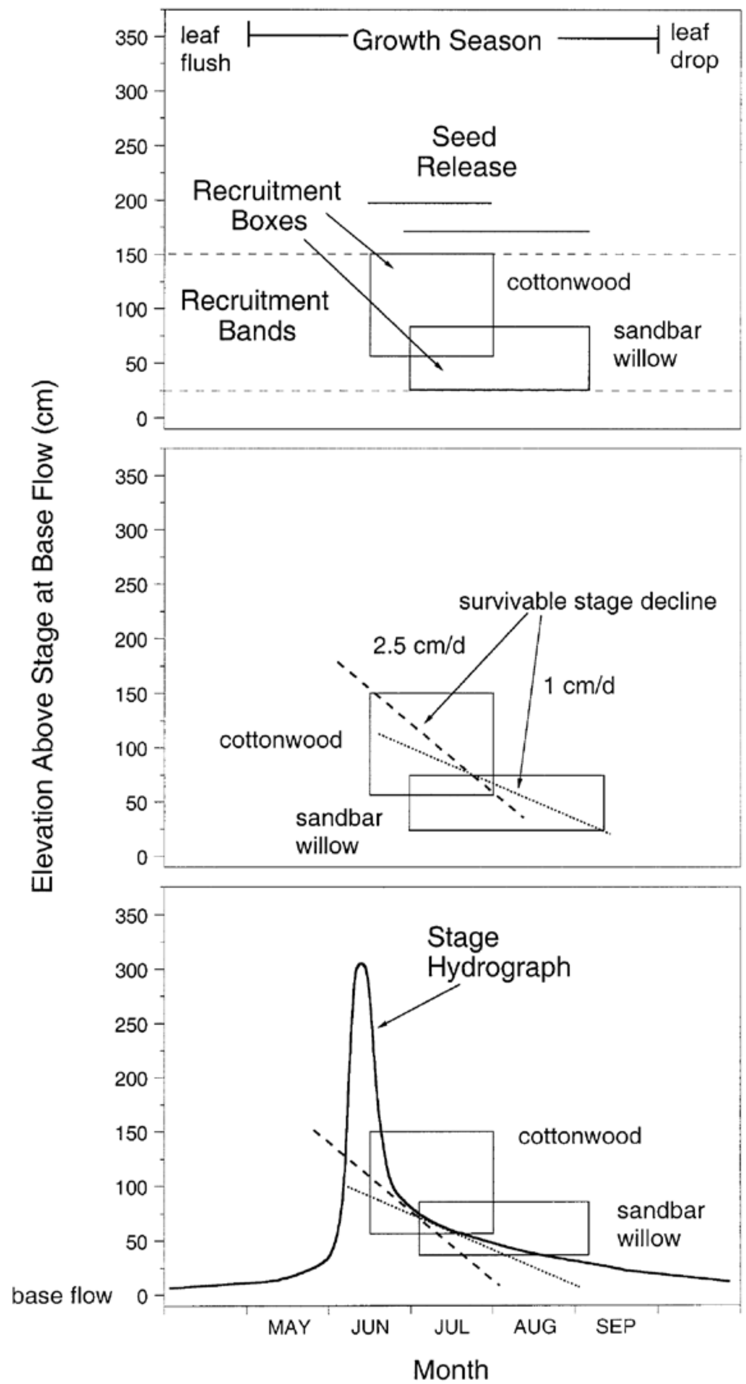

Figure 8.6-6. The riparian "Recruitment Box Model" describing seasonal flow pattern, associated river stage (elevation), and flow ramping necessary for successful cottonwood and willow seedling establishment (from Amlin and Rood 2002; Rood et al., 2005). Cottonwood species (*Populus deltoides*), willow species (*Salix exigua*). Stage hydrograph and seed release timing will vary by region, watershed, and plant species.

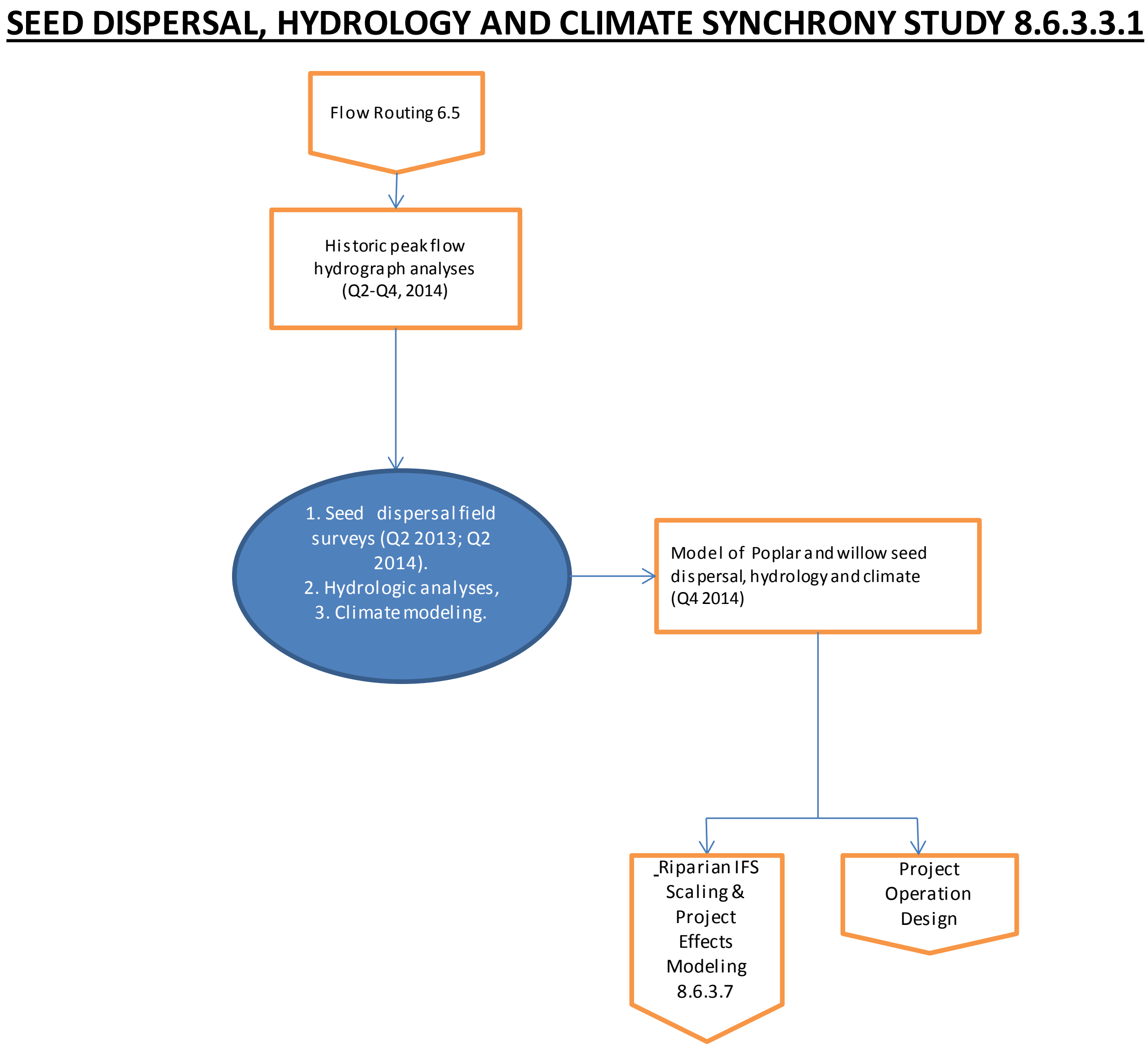

Figure 8.6-7. Seed Dispersal, Hydrology and Climate Synchrony Study8.6.3.3.1.

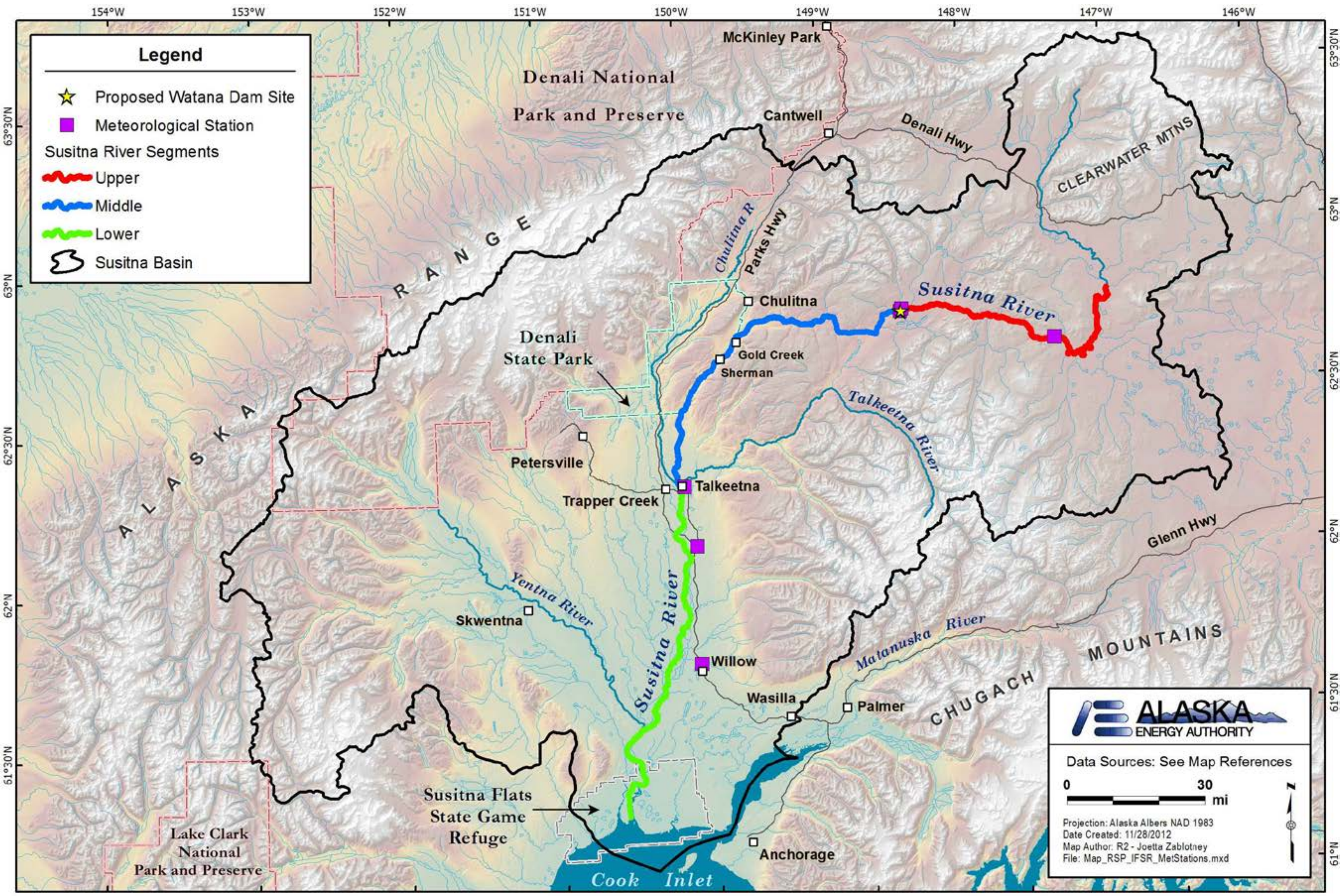

Figure 8.6-8. Susitna Study Area meteorological station locations.

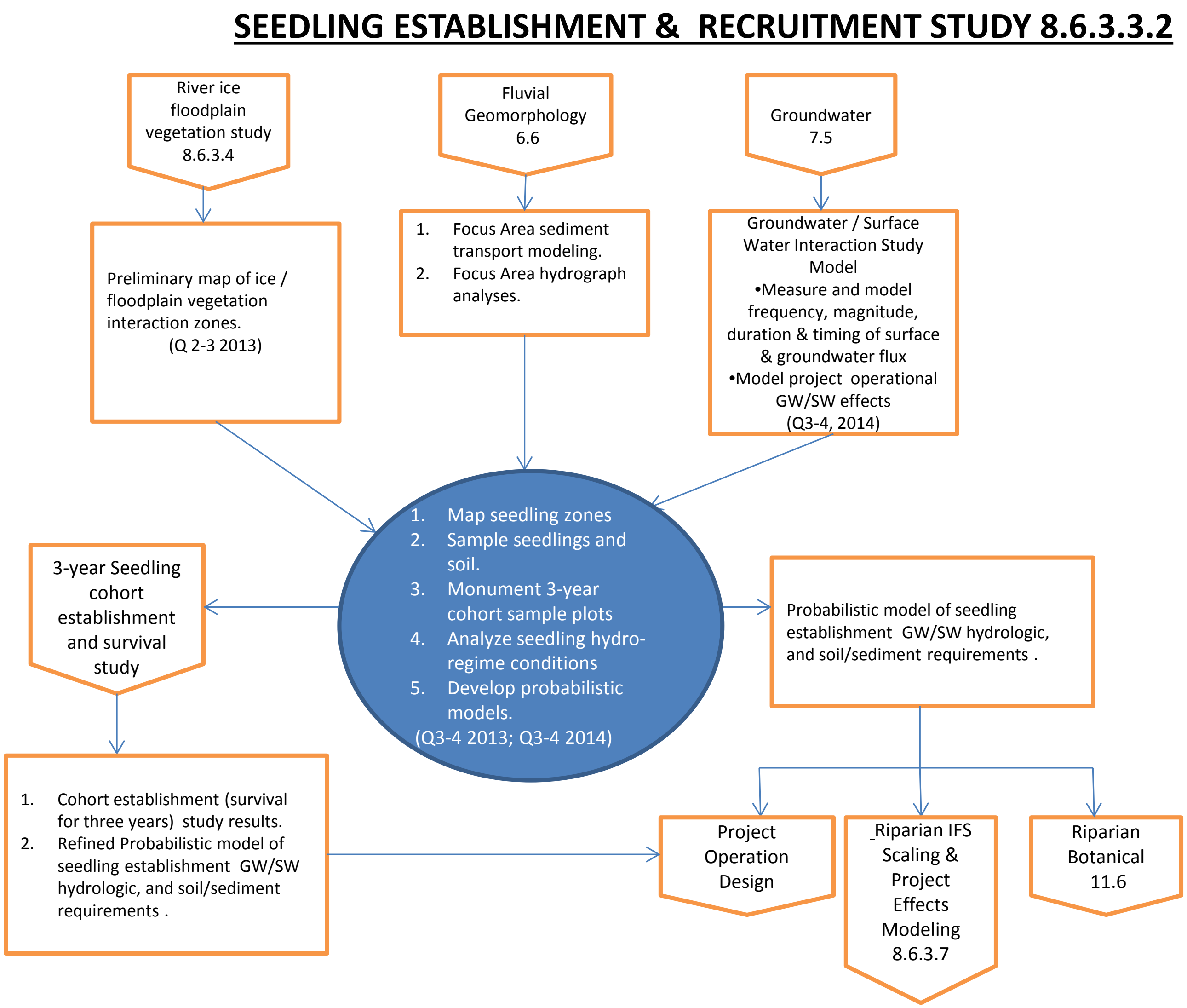

Figure 8.6-9. Seedling Establishment & Recruitment Study 8.6.3.3.2.

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.

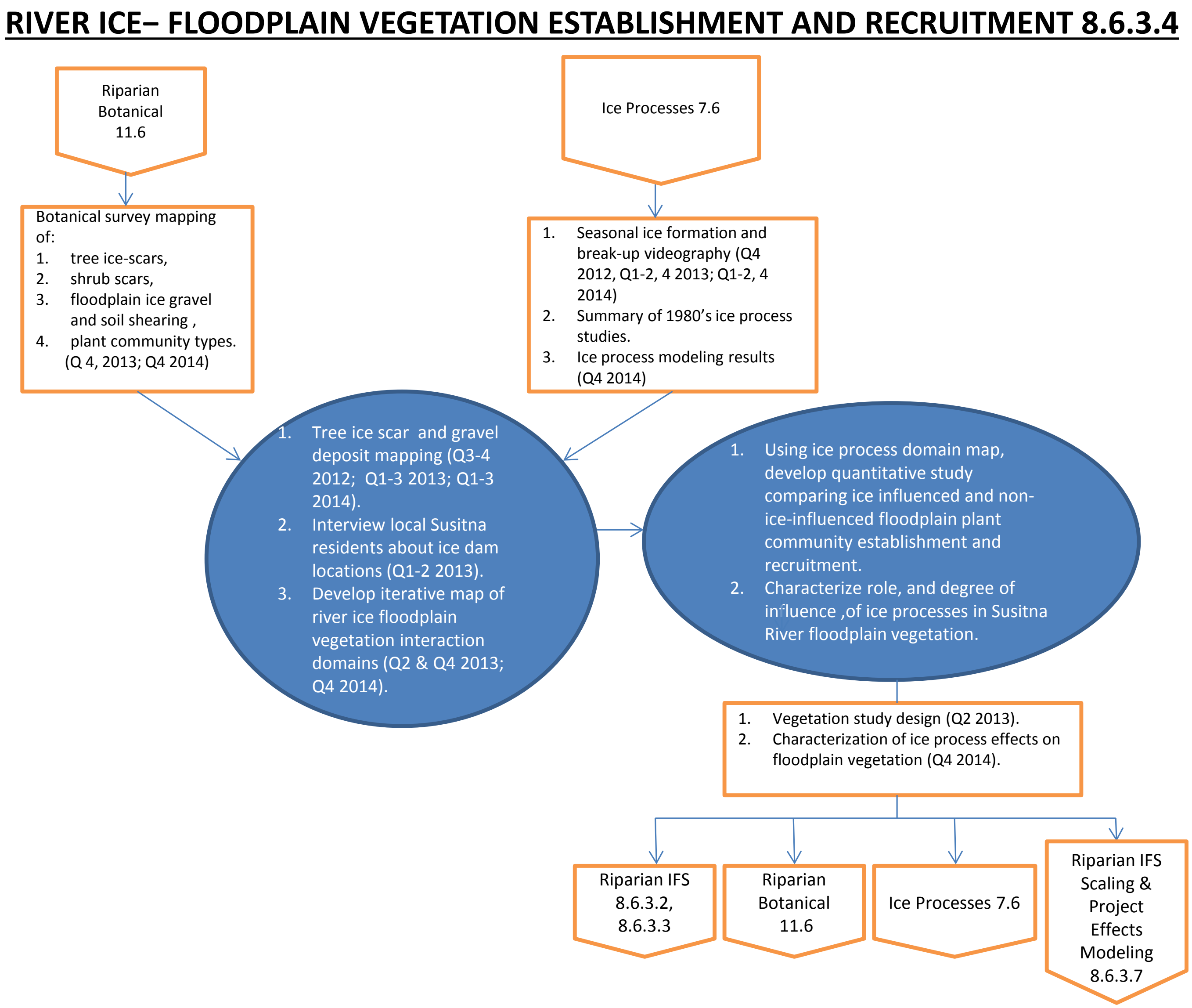

Figure 8.6-13. River Ice-Floodplain Vegetation Establishment and Recruitment 8.6.3.4.

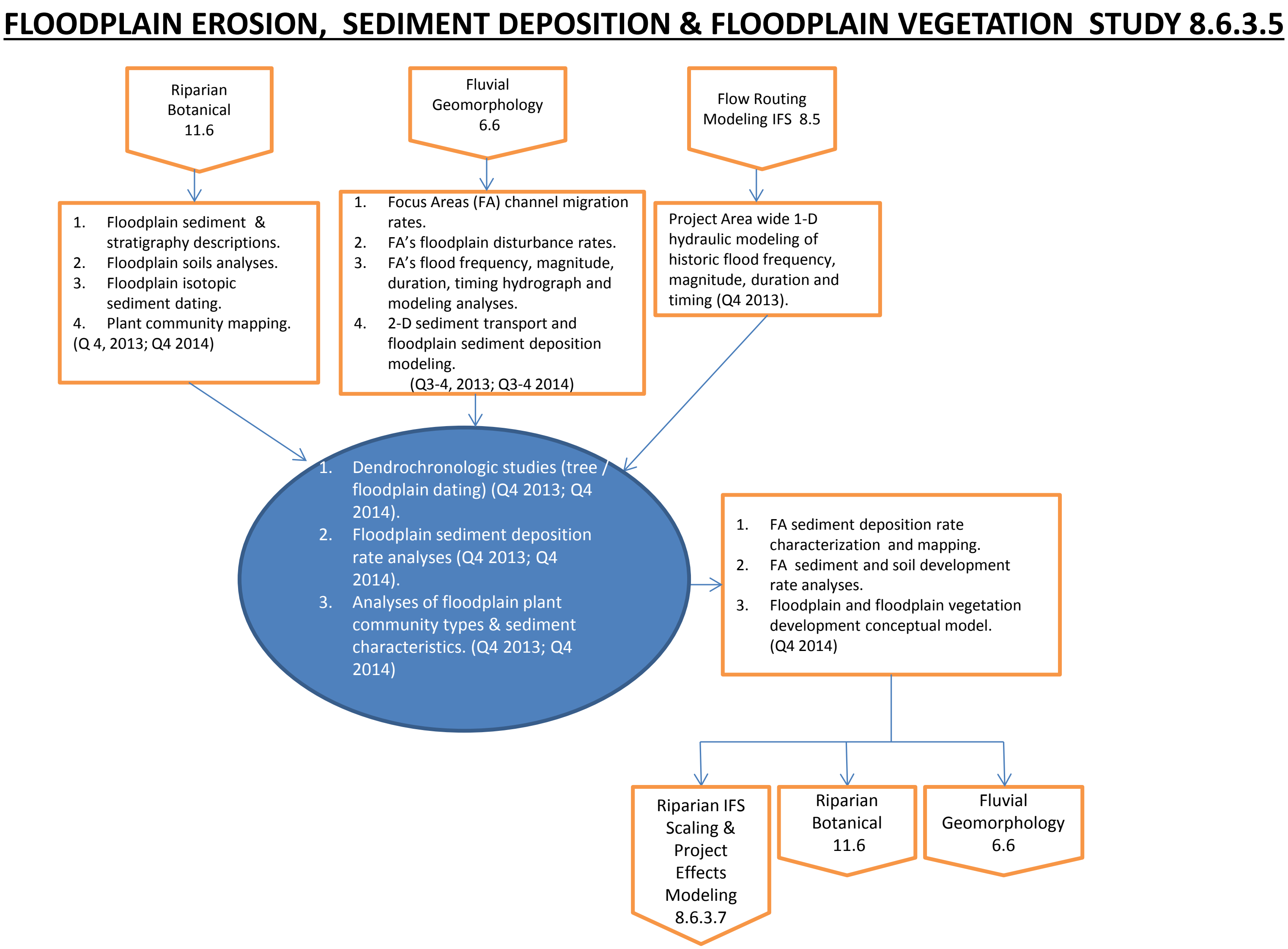

Figure 8.6-14. Floodplain Erosion, Sediment Deposition & Floodplain Vegetation Study 8.6.3.5.

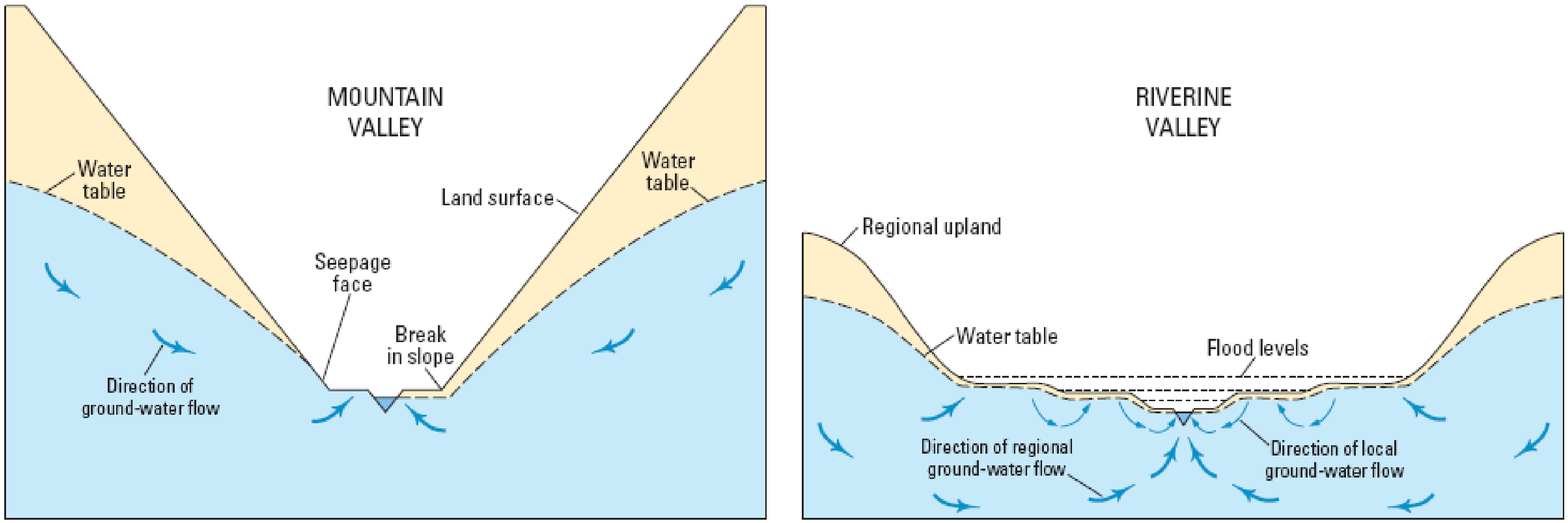

Figure 8.6-15. Riverine hydrologic landscape (Winter 2001).

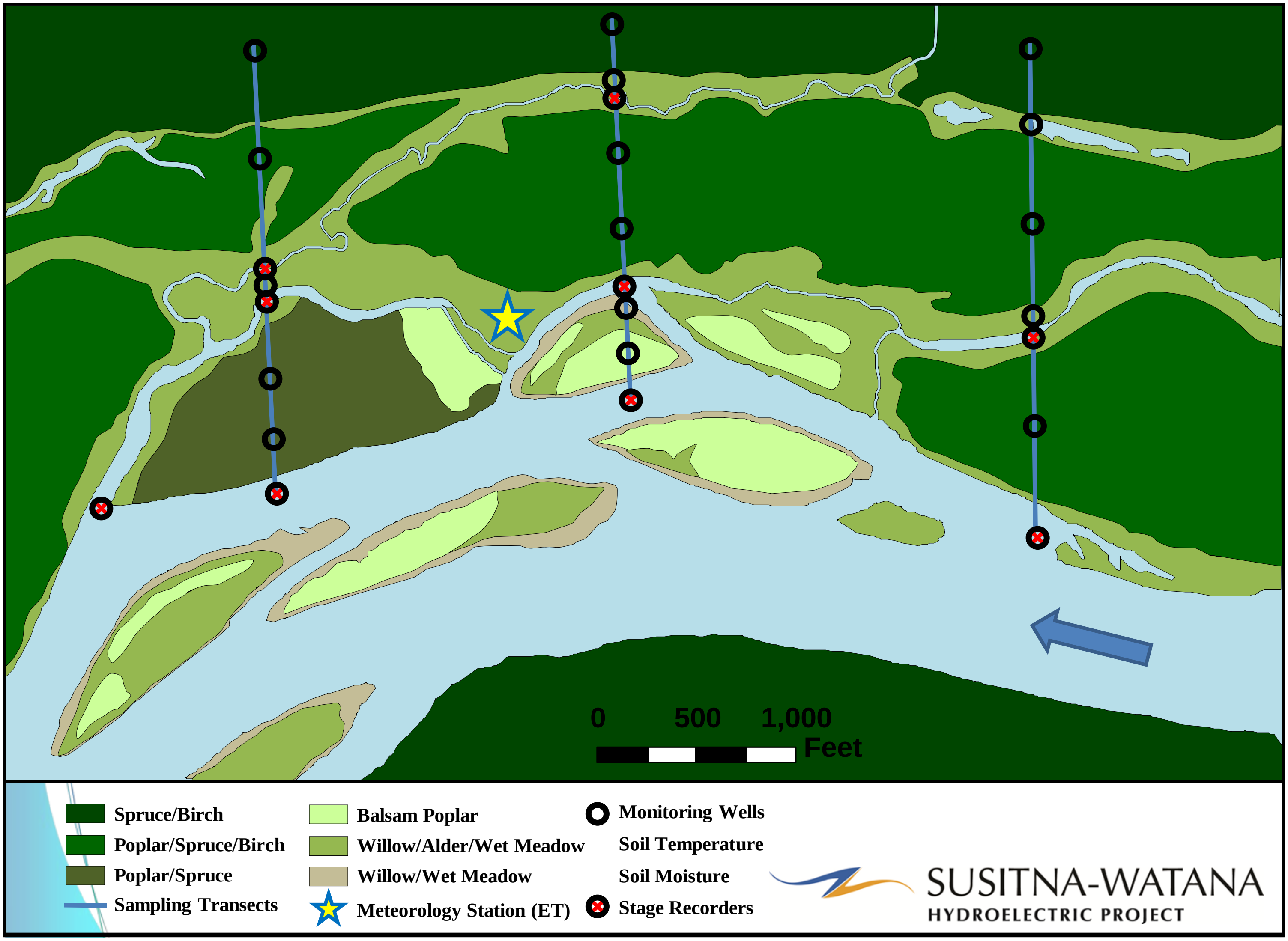

Figure 8.6-16. Whiskers Slough typical Focus Area groundwater / surface water study design illustrating monitoring well and stage recorder transect locations. Typical floodplain plant community types found in the middle segment of the Susitna River are shown.

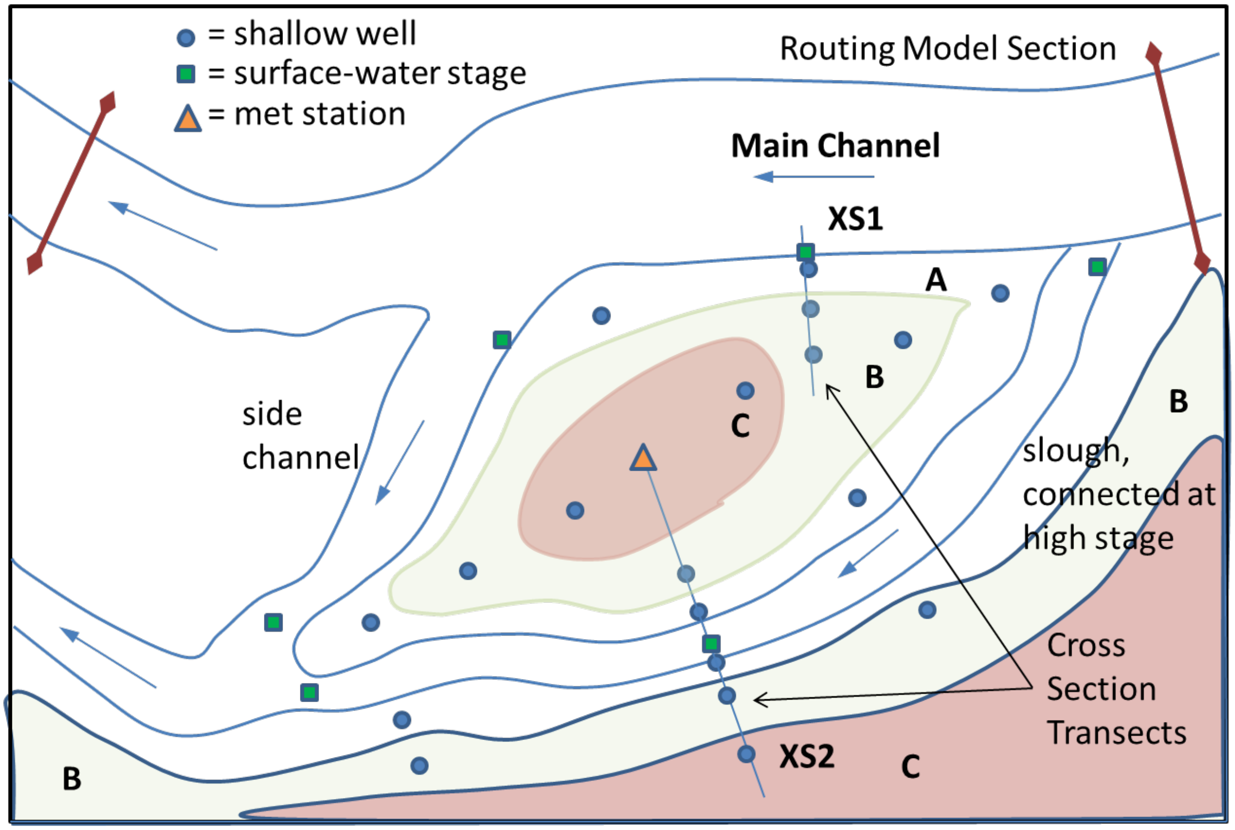

Figure 8.6-17. General schematic of a riparian Focus Area floodplain channel complex bounded by the Susitna River, side slough, and side channel.
Three typical riparian plant communities are depicted (A, B, C). Two transects of groundwater wells and stage stations are shown to help measure hydraulic 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.

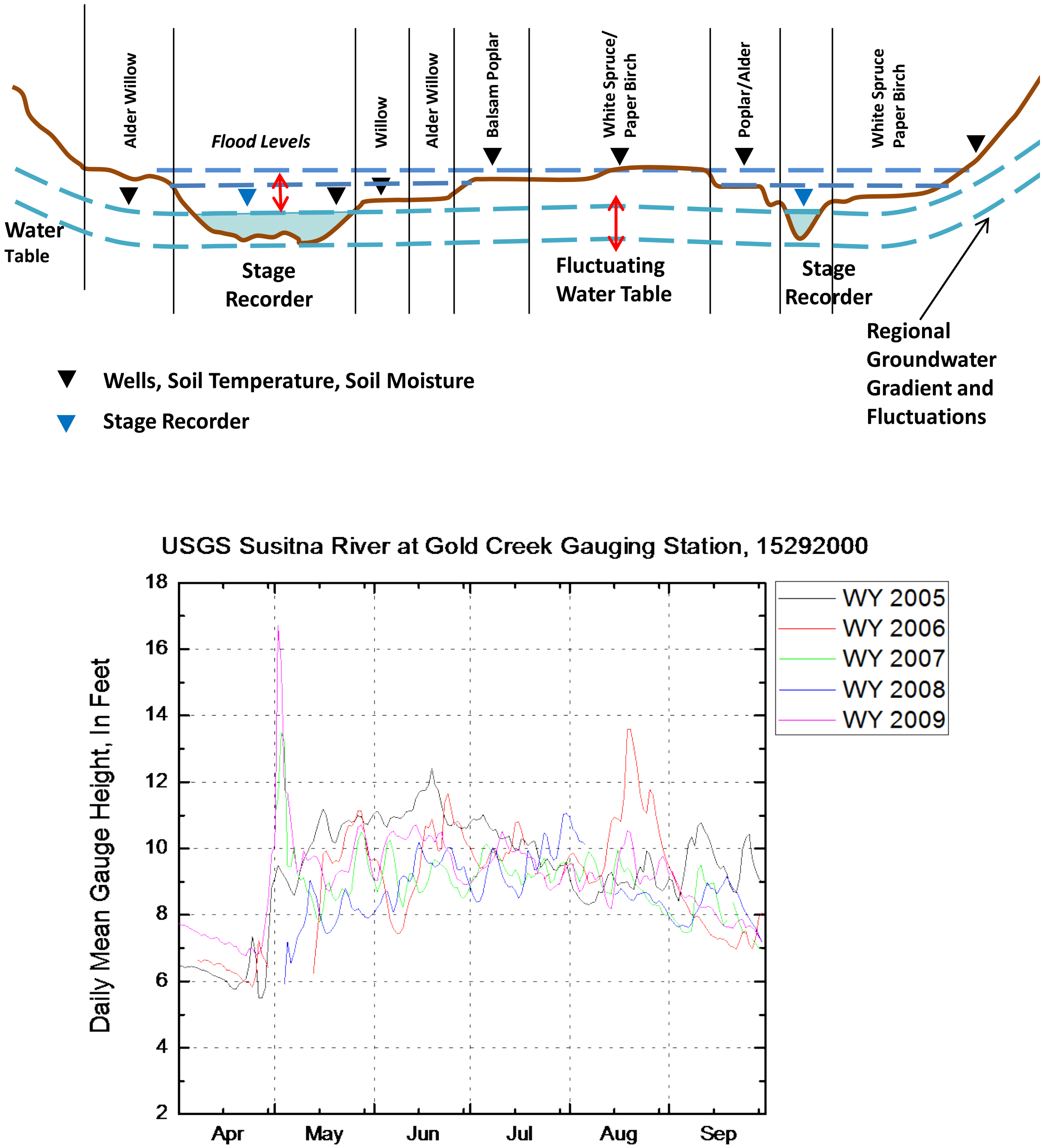

Figure 8.6-18. (A) Transect profile view of typical monitoring well and stage recorder locations looking downriver. (B) Gold Creek Gauge Station, Susitna River April through September 2005-2009.

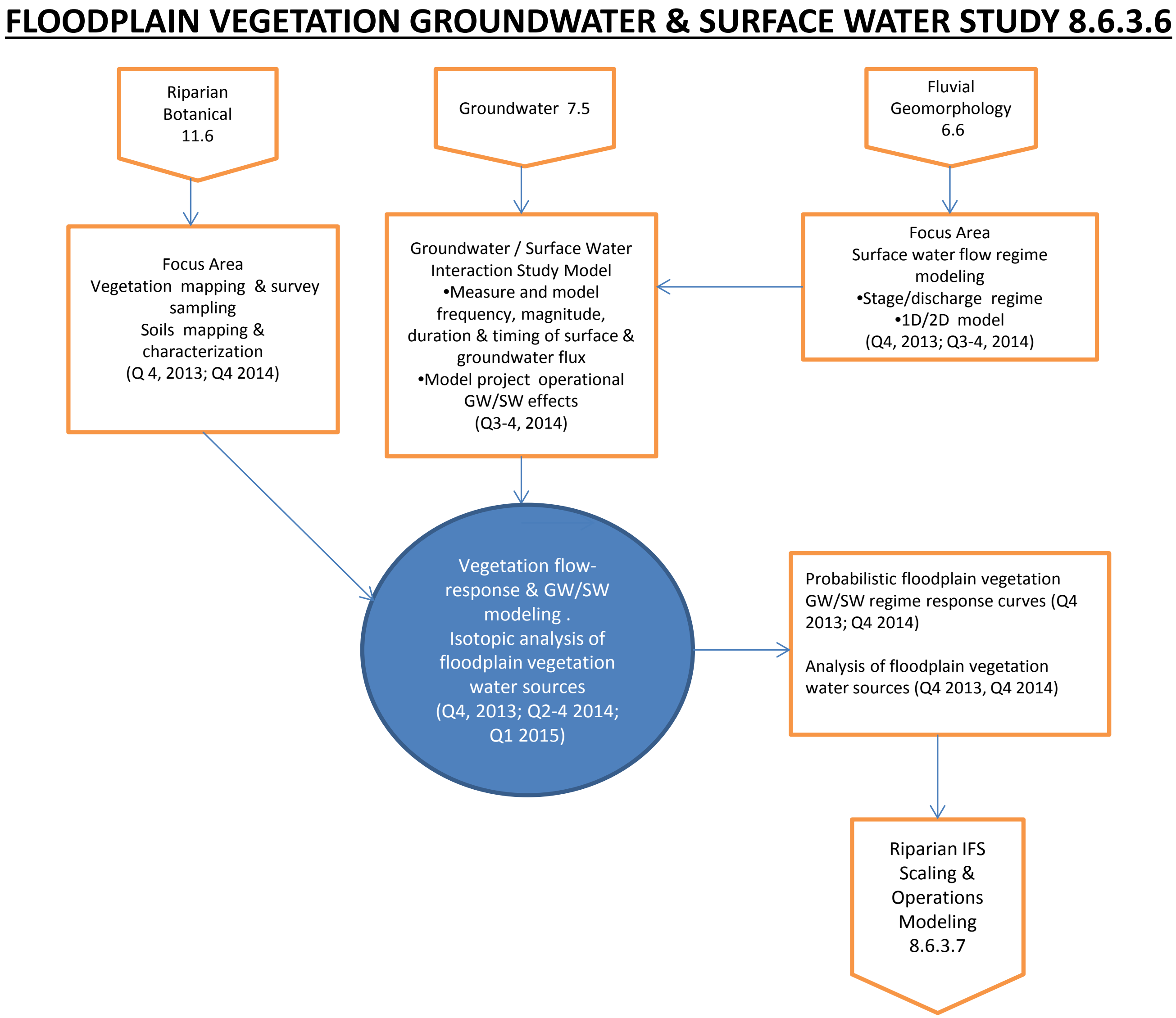

Figure 8.6-19. Floodplain Vegetation Groundwater & Surface Water Study 8.6.3.6.

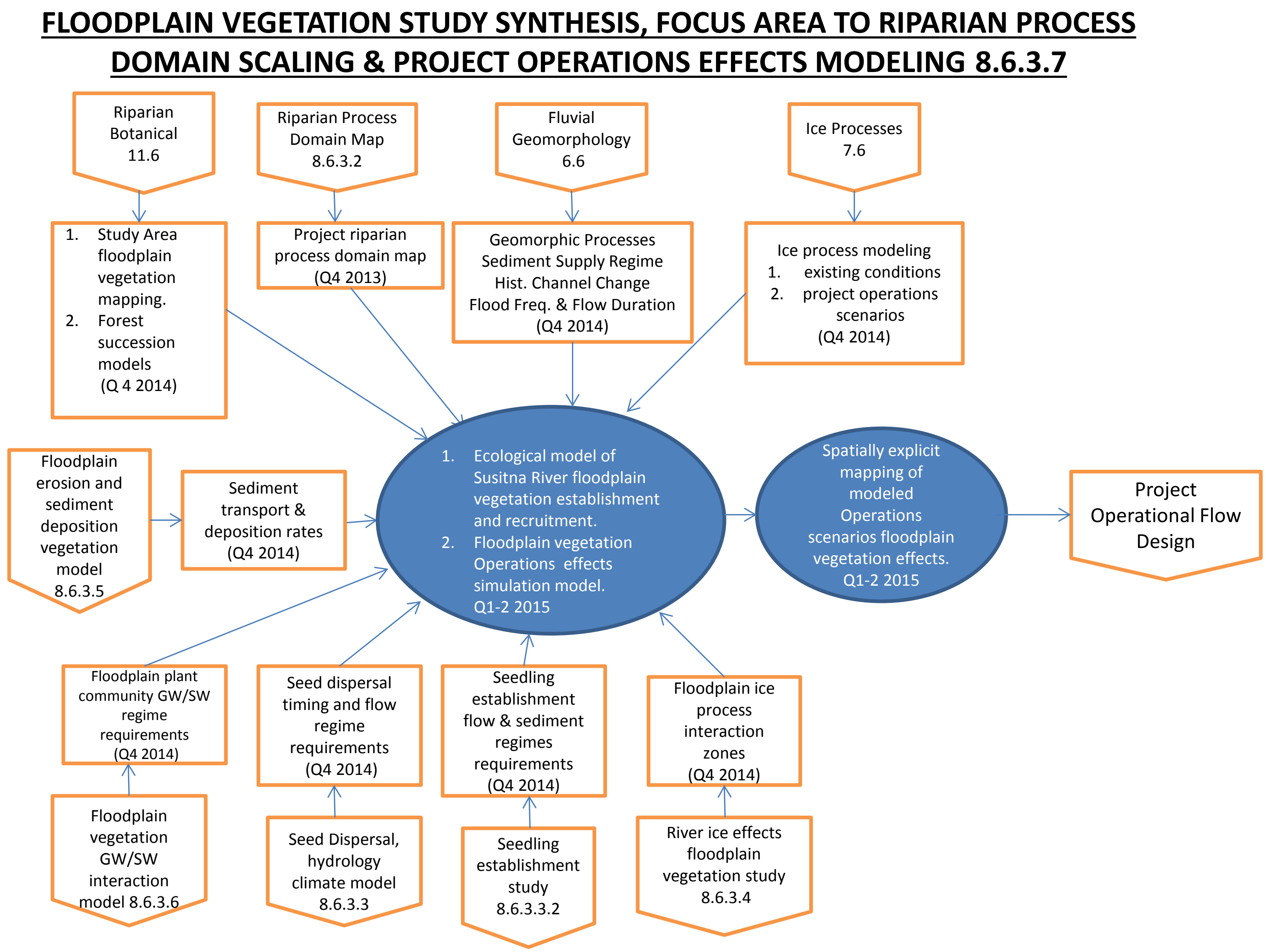

Figure 8.6-20. Floodplain Vegetation Study Synthesis, Focus Area to Riparian Process Domain Scaling & Project Operations Effects Modeling 8.6.3.7.