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Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Groundwater Study
Study Plan Section 7.5

Final Study Plan

Prepared for

Alaska Energy Authority

July 2013

7.5. Groundwater 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 Groundwater Study, Section 7.5. RSP Section 7.5 focuses on providing an overall understanding of GW/SW interactions at both the watershed- and local-scales.

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 7.5 was one of the 13 approved with modifications. In its April 1 SPD, FERC recommended the following:

Evapotranspiration Model

> *- We recommend that AEA consult wie th the TWG on the construction of the necessary data sets for the MODFLOW RIP-ET package, and file no later than June 30, 2013, the following:.*
>
> > *1) A detailed description of the specific methods to be used to relate the data of Study 11.6 (riparian vegetation) to plant functional groups.*
> >
> > *2) A detailed description of the specific methods to be used to relate the rooting depth data from Study 8.6 (riparian instream flow) and the water level data from Study 7.5 (groundwater) to extinction and saturated extinction depths.*
> >
> > *3) A detailed description of the specific methods to be used to estimate the shape of the transpiration flux curves.*
> >
> > *4) Documentation of consultation with the TWG, including how its comments were addressed.*

In addition FERC recommended AEA conduct a literature review include studies of hydroelectric project effects on surface water/groundwater interactions in cold regions.

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) summarizes details concerning sampling design, proposed field protocols and analytical methodologies related to FERC Determination requests. The document is organized to address details for each of the three RSPs: Groundwater Study 7.5, Riparian Instream Flow Study 8.6, and Riparian Vegetation Study 11.6. The Riparian/GW TM was filed with FERC on June 30, 2013. The Riparian/GW TM addresses each of the four components of the above FERC recommendation. Information in the Riparian/GW TM supersedes relevant details within this Final Study Plan.

7.5.1. General Description of the Proposed Study

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

The overall objectives of this study are as follows:

1. Synthesize historical and contemporary groundwater data available for the Susitna River groundwater and groundwater dependent aquatic and floodplain habitat, including that from the 1980s and other studies including reviews of GW/SW interactions in cold regions.

2. Use the available groundwater data to characterize large-scale geohydrologic process-domains/terrain of the Susitna River (e.g., geology, topography, geomorphology, regional aquifers, shallow groundwater aquifers, GW/SW interactions).

3. Assess the potential effects of Watana Dam/Reservoir on groundwater and groundwater-influenced aquatic habitats in the vicinity of the proposed dam.

4. Work with other resource studies to map groundwater-influenced aquatic and floodplain habitat (e.g., upwelling areas, springs, groundwater-dependent wetlands) within the Middle River Segment of the Susitna River including within selected Focus Areas (see Section 8.5.4.2.1.2).

5. Determine the GW/SW relationships of floodplain shallow alluvial aquifers within selected Focus Areas as part of the Riparian Instream Flow Study (Section 8.6).

6. Determine GW/SW relationships of upwelling/downwelling in relation to spawning, incubation, and rearing habitat (particularly in the winter) within selected Focus Areas as part of the Fish and Aquatics Instream Flow Study (Section 8.5).
7. Characterize water quality (e.g., temperature, dissolved oxygen [DO], conductivity) of selected upwelling areas that provide biological cues for fish spawning and juvenile rearing, in Focus Areas as part of the Fish and Aquatics Instream Flow Study (Section 8.5).
8. Characterize the winter flow in the Susitna River and how it relates to GW/SW interactions.
9. Characterize the relationship between the Susitna River flow regime and shallow groundwater users (e.g., domestic wells).

7.5.2. Existing Information and Need for Additional Information

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

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

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

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

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

7.5.3. Study Area

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

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

7.5.4. Study Methods

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

7.5.4.1.1. Existing Data Synthesis

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

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

7.5.4.1.1.1. Work Products

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

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

7.5.4.1.2. Geohydrologic Process-Domains

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

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

7.5.4.1.3. Work Products

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

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

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

7.5.4.2. Watana Dam/Reservoir

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

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

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

7.5.4.2.1. Work Products

Information provided from this study component will include:

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

7.5.4.3. Upwelling / Springs Broad-Scale Mapping

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

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

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

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

7.5.4.3.1. Work Products

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

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

7.5.4.4. Riparian Vegetation Dependency on Groundwater / Surface Water Interactions

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

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

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

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

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

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

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

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

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

7.5.4.4.1. Work Products

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

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

7.5.4.5. Aquatic Habitat Groundwater / Surface- Water Interactions

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

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

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

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

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

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

7.5.4.5.1. Work Products

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

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

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

7.5.4.6. Water Quality in Selected Habitats

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

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

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

7.5.4.6.1. Work Products

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

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

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

7.5.4.7. Winter Groundwater / Surface Water Interactions

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

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

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

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

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

7.5.4.7.1. Work Products

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

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

7.5.4.8. Shallow Groundwater Users

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

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

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

7.5.4.8.1. Work Products

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

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

7.5.5. Consistency with Generally Accepted Scientific Practice

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

7.5.6. Schedule

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

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

7.5.7. Relationship to Other Studies

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

7.5.7.1. Existing Data Synthesis

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

7.5.7.2. Geohydrologic Process-Domains and Terrain

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

7.5.7.3. Watana Dam/Reservoir

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

7.5.7.4. Upwelling / Springs Broad-Scale Mapping

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

7.5.7.5. Riparian Vegetation Dependency on Groundwater / Surface Water Interactions

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

7.5.7.6. Aquatic Habitat Groundwater / Surface Water Interactions

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

7.5.7.7. Water Quality in Selected Habitats

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

7.5.7.8. Winter Groundwater / Surface Water Interactions

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

7.5.7.9. Shallow Groundwater Users

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

7.5.8. Level of Effort and Cost

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

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

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

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

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7.5.10. Tables

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

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

Notes:

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

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

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

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

7.5.11. Figures

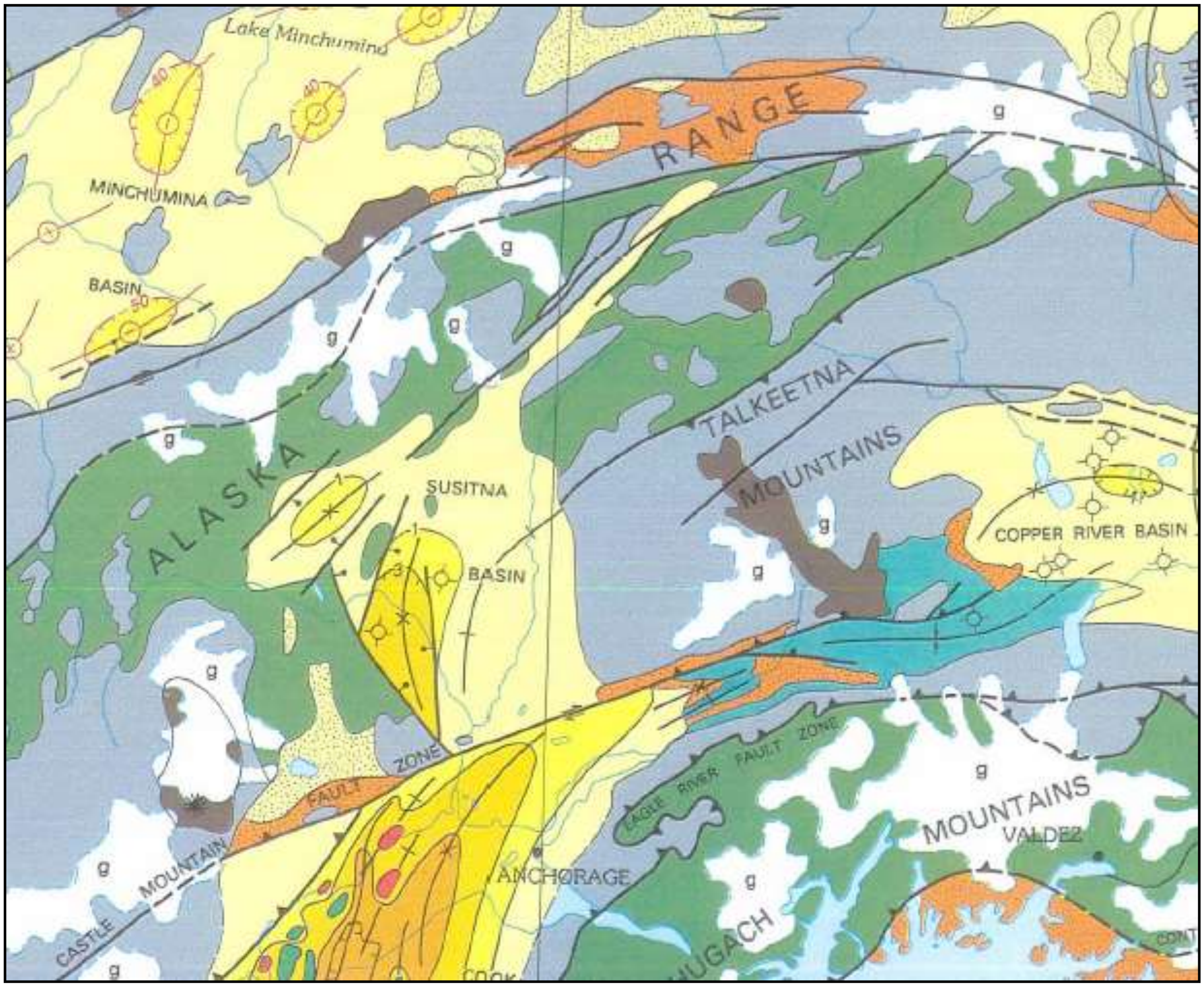

Figure 7.5-1. Sedimentary basins and geologic structure in the Susitna watershed (modified from Kirschner 1994).

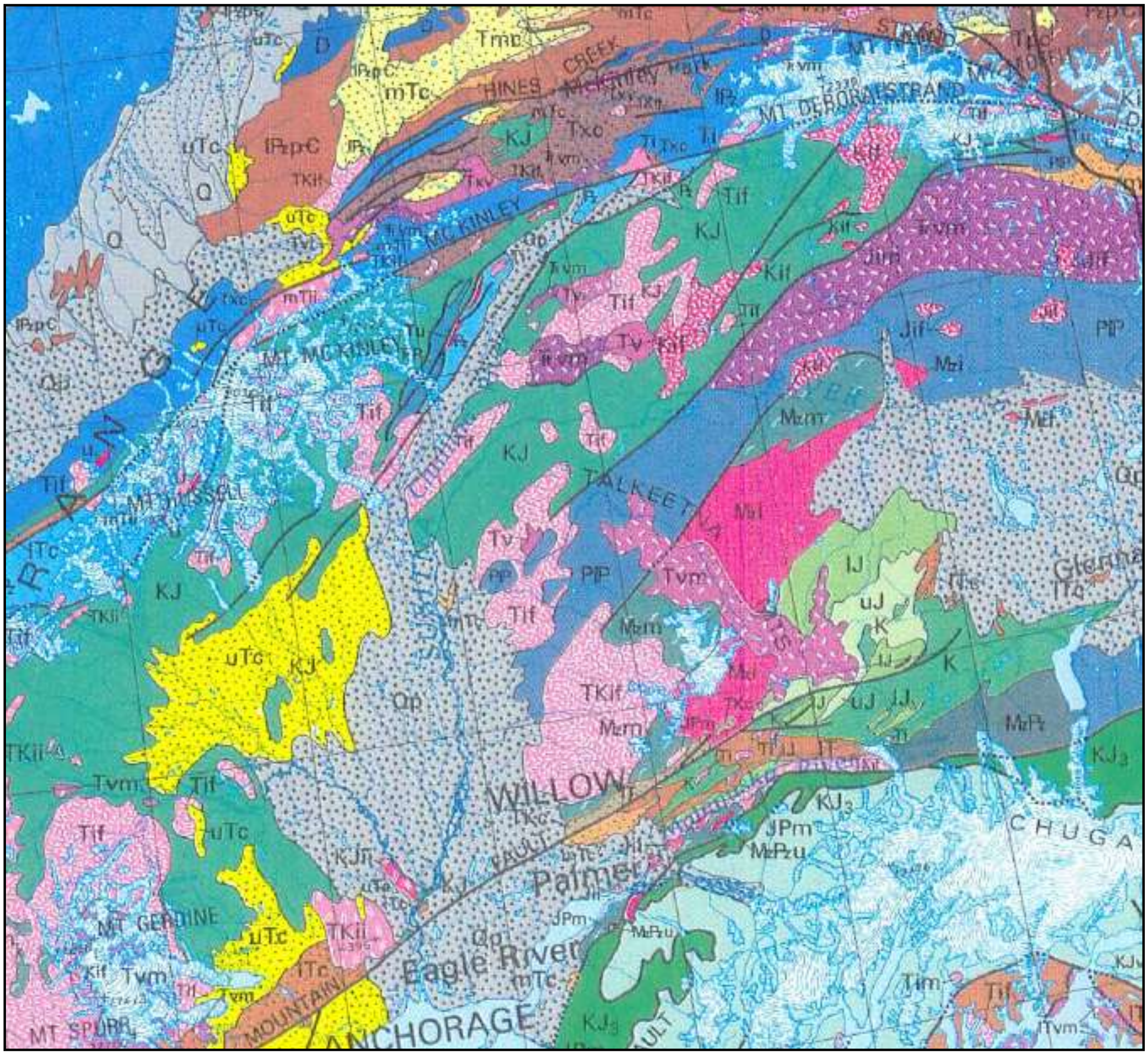

Figure 7.5-2. Geologic units in the Susitna watershed (modified from Beikman 1994).

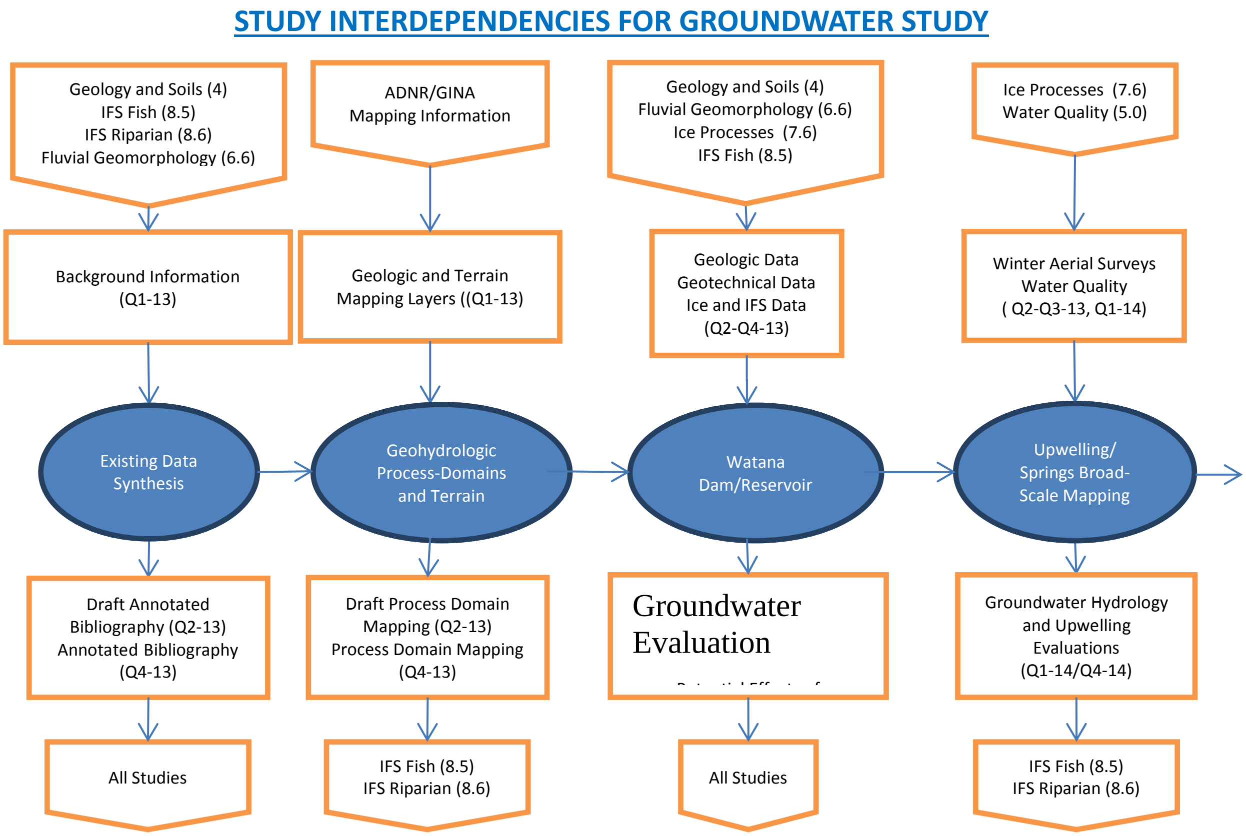

Figure 7.5-3. Study interdependencies for the Groundwater Study.

STUDY INTERDEPENDENCIES FOR GROUNDWATER STUDY

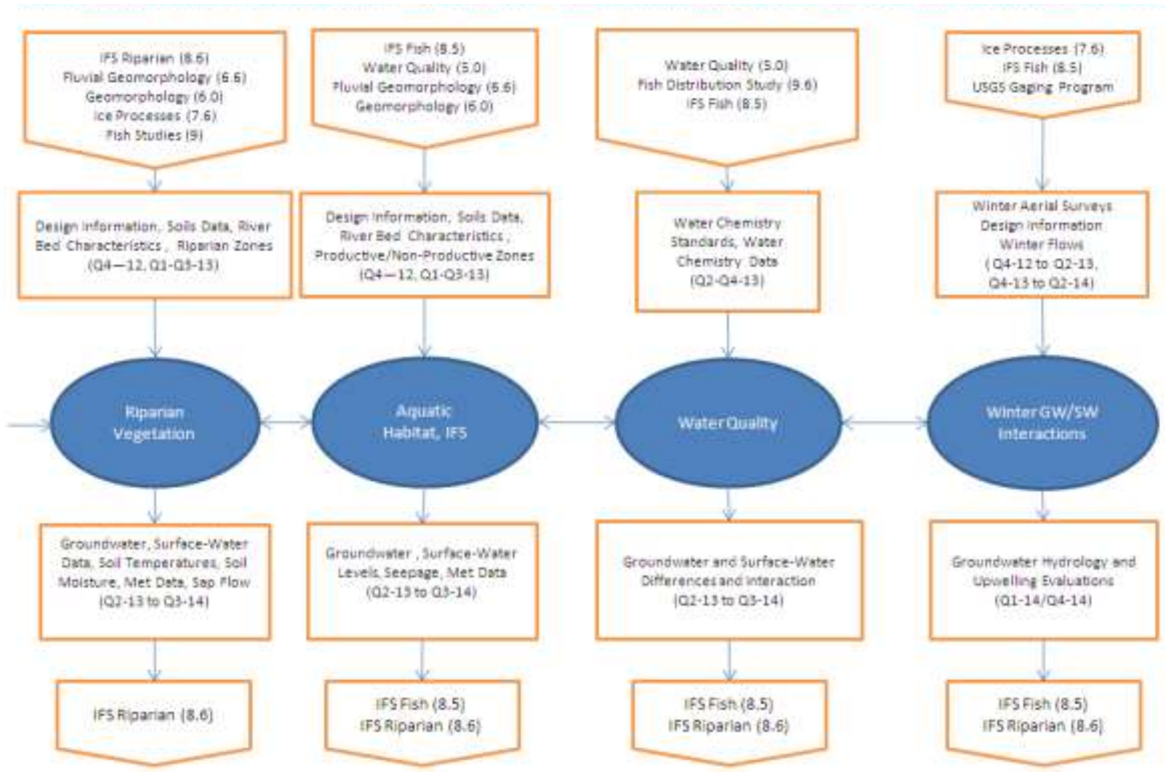

Figure 7.5-3. Study interdependencies for the Groundwater Study (continued).

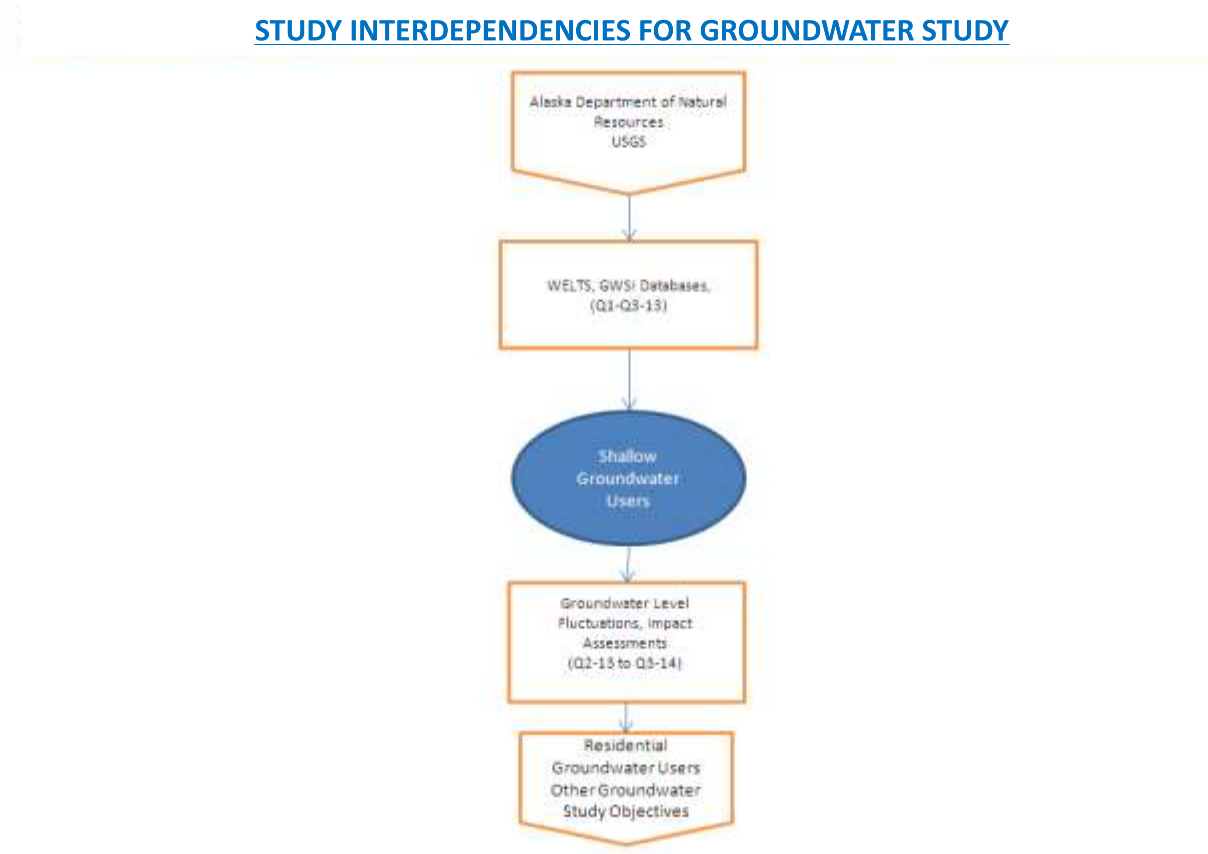

Figure 7.5-3. Study interdependencies for the Groundwater Study (continued).

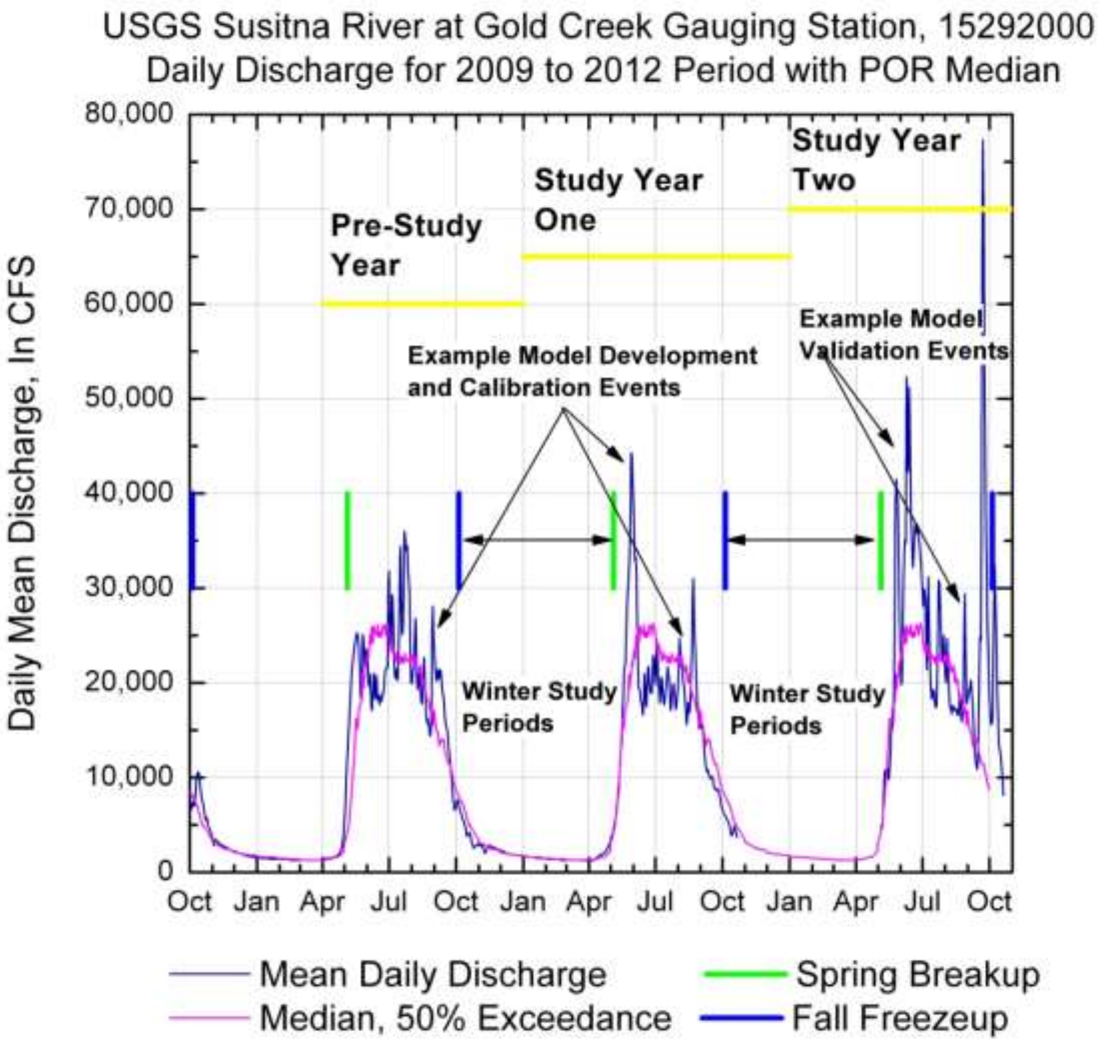

Figure 7.5-4. Discharge hydrograph and analysis examples for the Susitna River at Gold Creek.

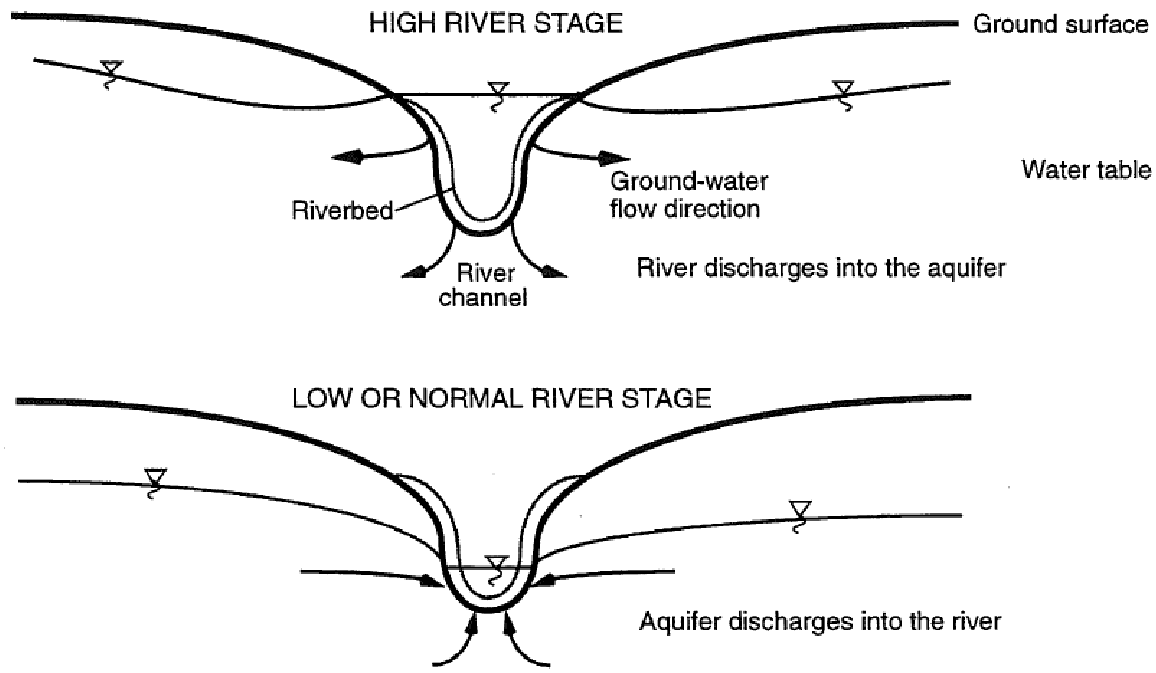

Figure 7.5-5. Illustration of groundwater and surface-water interactions with changing stage levels.

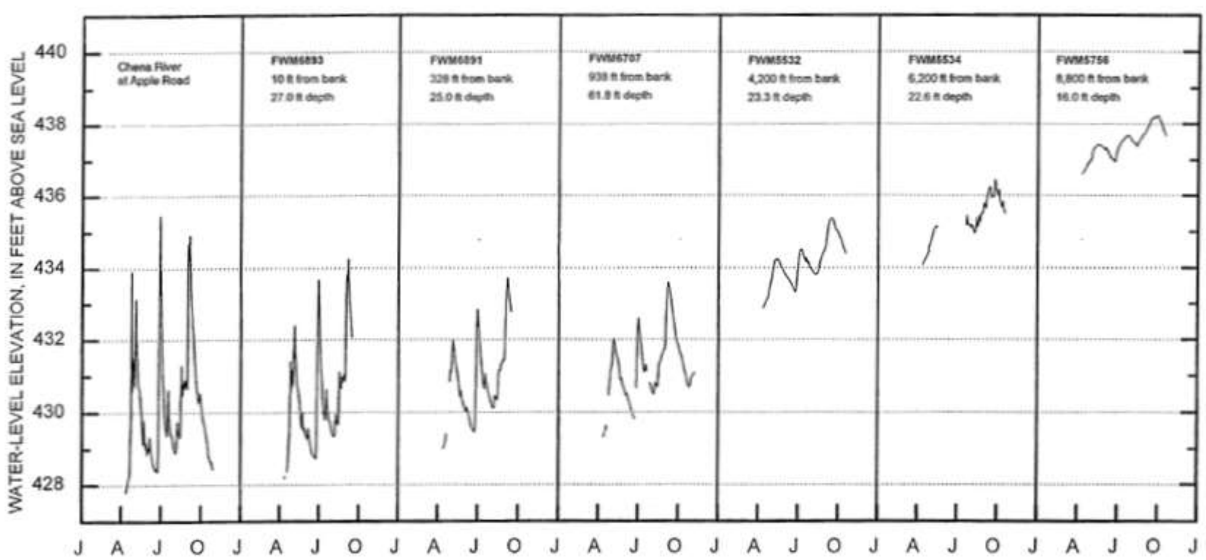

Figure 7.5-6. Groundwater responses to stage changes in the Chena River (Nakanishi and Lilly 1998).

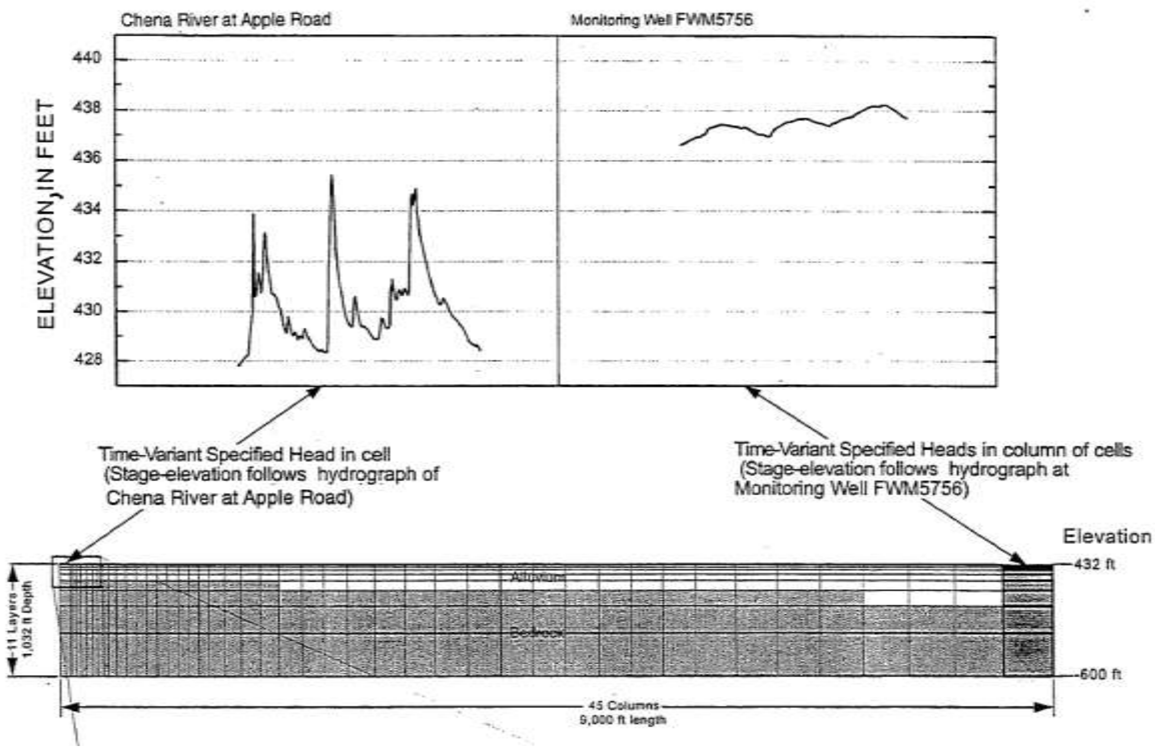

Figure 7.5-7. An example of applying surface water stage conditions and groundwater levels from a well as input to boundary conditions to a two-dimensional groundwater model (Nakanishi and Lilly 1998).

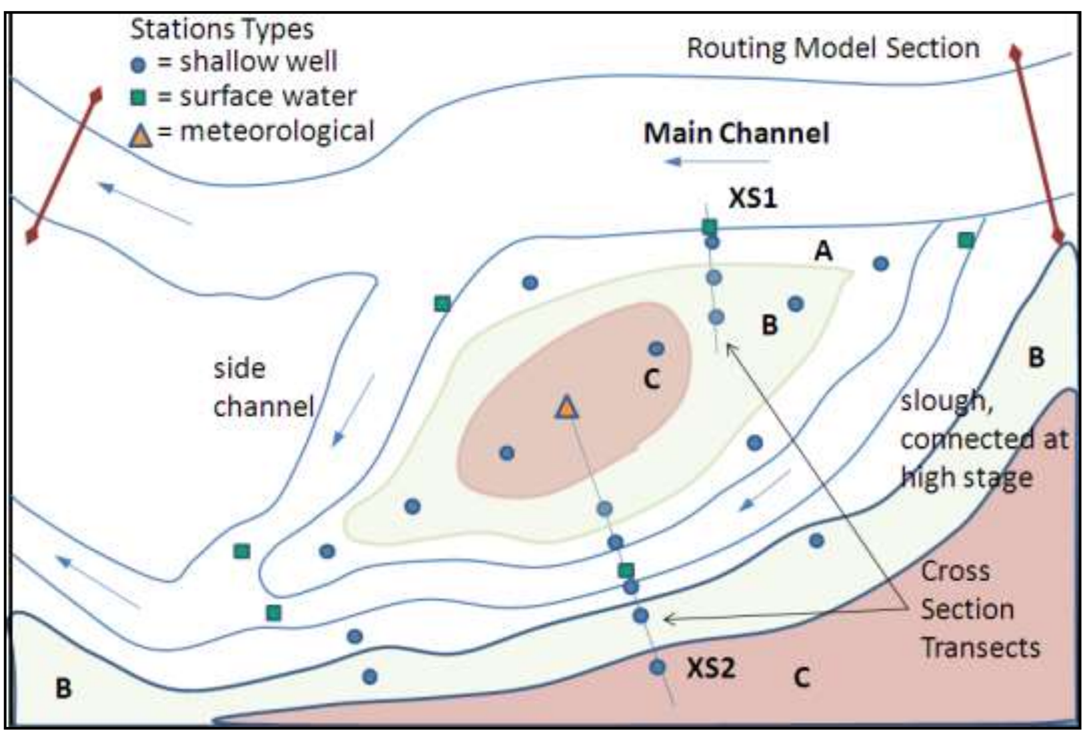

Figure 7.5-8. Example schematic of groundwater well and surface water station network in a hypothetical Focus Area targeting riparian analysis.

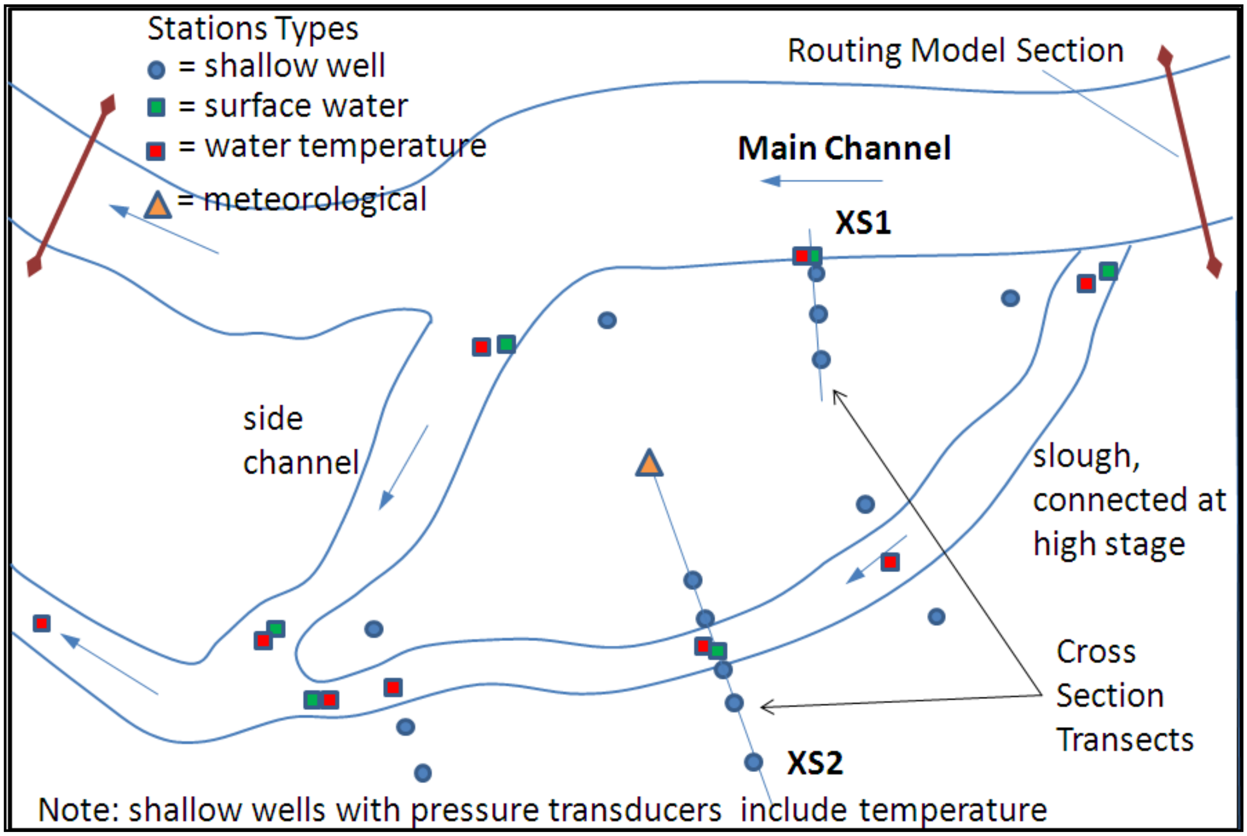

Figure 7.5-9. Example schematic of groundwater well and surface water station network in a hypothetical Focus Area targeting fish and aquatic habitat analysis.

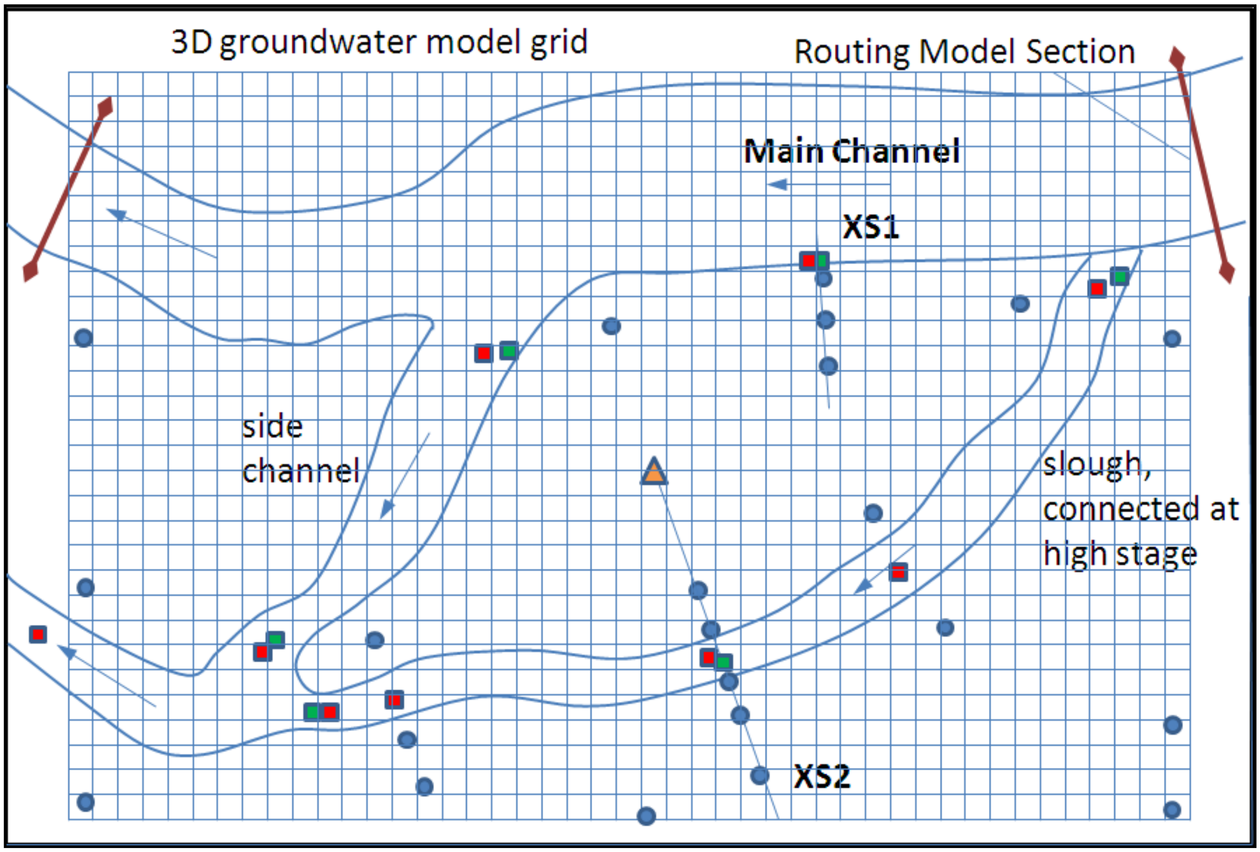

Figure 7.5-10. Example schematic of a 3D groundwater model grid in a hypothetical Focus Area targeting fish and aquatic analysis. 2D cross-section models would be developed in this hypothetical case at sections XS1 and XS2.

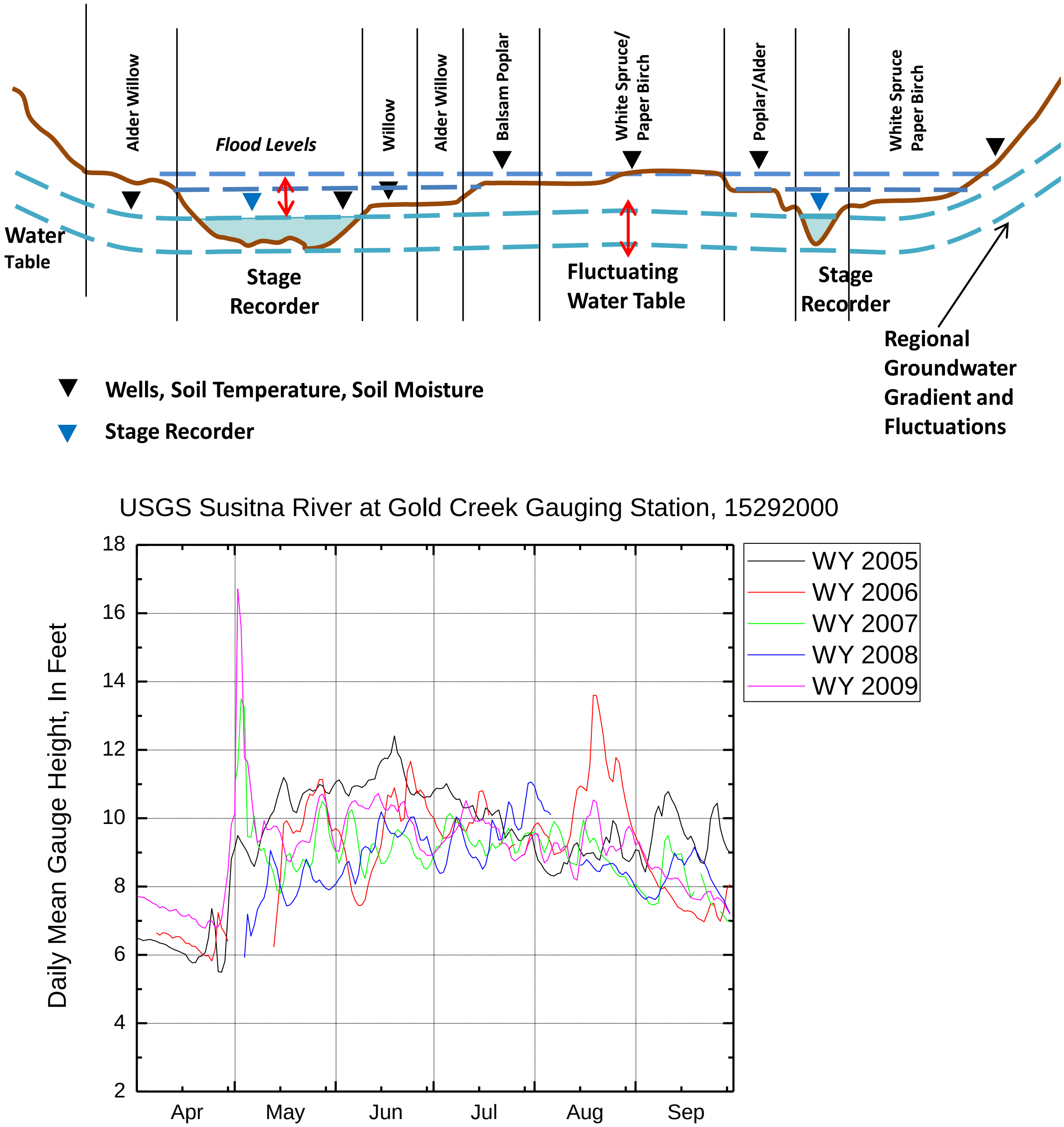

Figure 7.5-11. The upper graphic is an example schematic of a 2D cross-section across the floodplain, main channel, and a side channel or slough. Groundwater and surface water interactions and examples data collection stations are shown. The lower plots show the daily mean gage height for the Susitna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