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Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Groundwater Study
Study Plan Section 7.5

Initial Study Report

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

Geo-Watershed Scientific

February 2014 Draft

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LIST OF ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

Abbreviation	Definition
AEA	Alaska Energy Authority
ARLIS	Alaska Resources Library and Information Services
ARRC	Alaska Railroad Corporation
cm	centimeter
DO	dissolved oxygen
FA	Focus Area
FERC	Federal Energy Regulatory Commission
GIS	Geographic Information System. An integrated collection of computer software and data used to view and manage information about geographic places, analyze spatial relationships, and model spatial processes.
GPS	Global positioning system. A system of radio-emitting and -receiving satellites used for determining positions on the earth.
GW	groundwater
GW/SW	Groundwater/Surface Water
GWS	Geo-Watersheds Scientific
GWSI	USGS Groundwater Site Inventory
HSC	Habitat Suitability Criteria
HSI	Habitat Suitability Index
ISR	Initial Study Report
LiDAR	Light Detection and Ranging. An optical remote sensing technology that can measure the distance to a target; can be used to create a topographic map.
NAVD88	North American Vertical Datum of 1988
PRM	Project River Mile; determined during 2012-2013 studies
QC	Quality Control
RIFS	Riparian Instream Flow Study
RPD	Riparian Process Domain

Abbreviation	Definition
RSP	Revised Study Plan
RTK	Real Time Kinematic
SPD	Study Plan Determination
TIR	Thermal Infrared
TM	Technical Memorandum
TWG	Technical Work Group
USGS	United States Geological Survey
USR	Updated Study Report
WELTS	Well Log Tracking System

EXECUTIVE SUMMARY

Groundwater Study 7.5	
Purpose	The Groundwater Study is one part of a set of interdisciplinary resource studies that are designed to evaluate the overall effects of the Susitna-Watana Hydroelectric Project (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 groundwater/surface water (GW/SW) interactions. The Groundwater Study uses existing information and data, as well as newly collected data to provide an overall understanding of GW/SW interactions in support of the Aquatic Instream Flow Study, Riparian Instream Flow Study, Water Quality Study, Ice Processes Study and Geomorphology Study.
Status	The Groundwater Study was initiated in 2013. Groundwater Study FSP 2013 data collection program was successfully completed, meeting all objectives. Automated data collection stations for measuring groundwater, surface water, soil, meteorological, streambed temperature profiles and water quality conditions were installed in five Focus Areas. Sixty six (66) groundwater wells were installed in various Focus Areas as planned. Data collection locations and elevations were established to Project survey standards. The groundwater, surface water, water quality, meteorological, and ice processes data collection stations are continuously collecting data with a majority of the stations on a telemetry network providing study teams regular, near-real-time, data access.
Study Components	The Groundwater Study has nine study elements. These include: (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. The majority of the Groundwater Study efforts are supporting aquatic and riparian habitat evaluations. Aquatic evaluations include observations and measurements of basic surface-water and groundwater hydrology and water quality processes. Riparian evaluations include measurements, modeling, and analysis of groundwater and surface-water interactions and moisture flux and soil pore-water availability in the unsaturated soils above shallow water tables.

Groundwater Study 7.5	
2013 Variances	AEA implemented the methods as described in the Study Plan with the exception of the variances listed below. • The schedule for completion of the annotated bibliography and literature review was adjusted to be complete in the next year of study. (See Section 4.1.1) • The schedule for completion of the mapping of geohydrologic units and associated analysis will be completed in the next year of the study. (See Section 4.2.1) • The schedule for completion of the groundwater flow models, including model input and calibration data sets, files and model documentation was rescheduled into the next year of the study. (See Section 4.5.1) • The schedule for completion of the groundwater flow models, including model input and calibration data sets, files and model documentation was rescheduled into the next year of the study. (See Section 4.6.1) • The schedule for completion of the groundwater flow models, including model input and calibration data sets, files and model documentation was rescheduled into the next year of the study. (See Section 4.7.1) • Water quality data from other studies completed in the first study year will be used in the next year of study to describe the differences between productive and non-productive habitat types. (See Section 4.7.1)
Steps to Complete the Study	As explained in the cover letter to this draft ISR, AEA's plan for completing this study will be included in the final ISR filed with FERC on June 3, 2014.

Groundwater Study 7.5	
Highlighted Results and Achievements	The Groundwater Study began installation of data collection stations in spring 2013 and completed all the planned 57 station installations and 66 shallow groundwater wells by end of summer field operations. Data collection was ongoing during this period at continuously operated stations. Manual empirical measurements of groundwater and surface water were also made in support of project objectives. Data station collection efforts are ongoing during the winter season. Empirical data collected, and field observations through the spring, summer, fall and early winter periods of the hydrologic cycle, have resulted in a more complete and defensible understanding of existing groundwater conditions. Furthermore, these observations contribute to the characterization of important habitat elements. Observations from the groundwater, surface-water and meteorological stations provide all of the physical process modeling efforts (aquatic IFS, riparian IFS, water quality, geomorphology, and ice processes) on-the-ground empirical verification benchmarks for calibration and verification of the physical process models. Shallow groundwater was found to be prevalent in the Middle River portion of study area. Hillslope hydrological contributions from adjacent sides of the river valley to the floodplain were observed and measured. These include; springs and seeps, upland beaver ponds, areas without winter snow due to shallow groundwater conditions, and observed open water conditions in a majority of the sloughs and creeks (open leads). Interactions between river stage and groundwater processes were observed and measured. Field observations and data collection are ongoing daily through the winter period and will continue during the second year of the study.

1. INTRODUCTION

On December 14, 2012, Alaska Energy Authority (AEA) filed its Revised Study Plan (RSP) with the Federal Energy Regulatory Commission (FERC or Commission) for the Susitna-Watana Hydroelectric Project, FERC Project No. 14241, which included 58 individual study plans (AEA 2012). Included within the RSP was the Groundwater Study (GW), Section 7.5. RSP Section 7.5 focuses on providing an overall understanding of Groundwater/Surface Water (GW/SW) interactions at both the watershed- and local-scales.

On February 1, 2013, FERC staff issued its study determination (February 1 Study Plan Determination (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 with 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.*

Consultation on the interrelated riparian vegetation, riparian instream flow and riparian GW/SW study plans was accomplished with Technical Working Group (TWG) representatives in two meetings; held April 23, 2013 and June 6, 2013. Licensing participants were provided the opportunity to address technical details 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 (R2 Resource Consultants et al. 2013). 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 July 1, 2013.

Following the first study season, FERC's regulations for the Integrated Licensing Process (ILP) require AEA to "prepare and file with the Commission an initial study report describing its overall progress in implementing the study plan and schedule and the data collected, including an explanation of any variance from the study plan and schedule." (18 CFR 5.15(c)(1)) This Initial Study Report on the Groundwater Study has been prepared in accordance with FERC's ILP regulations and details AEA's status in implementing the study, as set forth in the FERC-approved RSP and as modified by FERC's April 1 SPD and Riparian/GW TM (collectively referred to herein as the "Study Plan").

2. STUDY OBJECTIVES

The nine study objectives were established in RSP Section 7.5.1:

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 Fish and Aquatic Instream Flow Study 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 (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 (Fish and Aquatic Instream Flow Study 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 (Fish and Aquatic Instream Flow Study (Study 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).

3. STUDY AREA

As established by RSP Section 7.5.3, the study area related to groundwater processes includes primarily the Middle River Segment of the Susitna River that extends from PRM 102.4 to PRM 187.1 as well as portions of the Lower River Segment associated with domestic wells and riparian transect locations in the Lower River, and the lower most portion of the Upper River Segment near the proposed dam site associated with potential groundwater changes relative to reservoir construction and operations. Figure 3-1 shows these river segments and the general watershed boundary of the Susitna River. Figure 3-2 shows the location of Instream Flow Study (Section 8.5, 8.6) Focus Areas and geomorphic reaches for the Middle River Segment. Figure 3-3 shows the Lower River Segment with the geomorphic reaches defined.

Following the completion of the Open-water Flow Routing Model in Q1 2013, the study areas for the riparian studies, including the riparian vegetation study, was extended to PRM 29.5. This increase in Riparian IFS activities in the Lower River was supported by the Groundwater Study.

4. 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 fourth component, upwelling/springs mapping is linked to the Ice Processes Study (Study 7.6), Geomorphology Study (Study 6.5), Water Quality Study (Study 5.5), and the Fish and Aquatics Instream Flow Study (Study 8.5). Likewise, the seventh component, Water Quality, is linked to the Water Quality Study (Study 5.5) and the Fish and Aquatics Instream Flow Study (Study 8.5).

4.1. Existing Data Synthesis

AEA implemented the methods as described in the Study Plan with the exception of variances explained below (Section 4.1.1). Data from prior Susitna River hydroelectric evaluations and other studies is being used to help develop a detailed reference set of available data to access 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 (summer and winter) and how these interactions 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 hydrology (ice, snow, water processes and interaction) on groundwater and surface-water interactions. An example of the information discovered for this effort is seen in Appendix A, which shows a series of image comparisons from a 1970s set of infrared aerial images found in University of Alaska Fairbanks archives, which had not been previously known to be available in Susitna River resource collections.
- Identify similar studies, reports, and data for hydroelectric projects in northern latitudes and cold climates including reviews of GW/SW interactions in cold regions. The literature search for this task will be coordinated with the University of Alaska Fairbanks – Geophysical Institute Keith B. Mather Library and the Alaska Resources Library and Information Services (ARLIS) library, which already contains extensive references to northern research basins and circumpolar literature sources. The ARLIS library will help obtain references for the study and will house select references that can be distributed under the reference copyright authorizations. References obtained through study activities will be available online when possible under the applicable copyright restrictions.
- Identify applicable geology, soils, and other geohydrologic references for the Susitna River watershed. Information and references will be used that are collected by the Geology and Soils Characterization Study (Study 4.5) and the Ice Processes Study (Study 7.6). Water quality data and references will be provided by the Baseline Water Quality Study (Study 5.5) for groundwater and surface water. Additional water quality data will be provided by the Fish and Aquatics Instream Flow Study (Study 8.5) historical information reviews.

4.1.1. Variances

AEA implemented the methods as described in the Study Plan with the exception of the variances described below.

- The schedule for completion of the annotated bibliography and literature review was adjusted to be complete in the next year of study. This will allow additional information to be incorporated from the 1980s references located that the ARLIS library is still processing. This change in schedule will not impact the objectives of the study.

4.2. Geohydrologic Process-Domains

AEA implemented the methods as described in the Study Plan with the exception of variances explained below (Section 4.2.1). Project operations effects may 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 within select Focus Areas are being used to help characterize these potential effects for key aquatic and riparian habitats. This is being accomplished by first defining the significant geohydrologic units in the Susitna basin that provide or affect 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" is being used to help define the geohydrologic units (ASTM 2008b). ASTM D6106 "Standard Guide for Establishing Nomenclature of Groundwater Aquifers" is being used to help establish the aquifer nomenclature and naming of geohydrologic features (ASTM 2010a). The geohydrologic units (e.g., bedrock, alluvial) are then related to geomorphologic and riparian mapping units (process-domain river segments) in coordination with the Geomorphology Study (Study 6.5) and Riparian Instream Flow Study (Study 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 is 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 approach follows methods used on a similar study for the Tanana watershed, as reported by Anderson (1970). ASTM standard D6106 is used to help characterize the groundwater aquifers relevant to Project proposed operations. The final step is to identify 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 Area studies back to the larger process-domain river segments.

4.2.1. Variances

AEA implemented the methods as described in the Study Plan with the exception of the variances described below.

- The schedule for completion of the mapping of geohydrologic units and associated analysis will be completed in the next year of the study. This will allow incorporation of supporting information from other studies to be used to meet the study objectives. This change in schedule will not impact the objectives of the study.

4.3. Watana Dam/Reservoir

AEA implemented the methods as described in the Study Plan with no variances. 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 (Study 4.5) are providing information to help evaluate the groundwater conditions in the Project area and evaluate the potential for groundwater impacts downstream of the dam. The analysis is first evaluating engineering geology information from the dam and reservoir area. This information is being obtained from the Geology and Soils Characterization Study (Study 4.5) and past geotechnical studies of the proposed dam location. This will include geologic well logs, pump tests, seismic data if available, permafrost information, water level records and other geotechnical information provided through the engineering and geology studies. The analysis will require close coordination with engineering, as well as the Geomorphology and Fluvial Geomorphology Modeling studies in the Middle River Segment (Studies 6.5 and 6.6, respectively). This is 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 is being developed in the vicinity of the Watana Dam and Reservoir. This includes a characterization of known permafrost and bedrock hydrogeology in the Watana Dam vicinity. From this, conceptual GW/SW models are being developed that describe pre-Project conditions and post-Project conditions. These models will assist in identifying key potential groundwater flow pathways in the Project operations area (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 groundwater flow bypassing the dam. The conceptual models and empirical data are being used to evaluate the potential changes in groundwater flow as a result of Project construction and operations.

The operation of the proposed reservoir will also result in aquatic and riparian habitat loss on the Susitna River floodplain due to permanent inundation below the low pool level. Existing aquatic and riparian habitat in the Susitna River floodplain at the upstream end of the reservoir will be inundated for different durations between the low pool and high pool elevations. To evaluate this, a field reconnaissance trip was conducted to collect site-specific data in October 2013 to help characterize the area. Mapping data from the Geomorphology Study (Study 5.5) and the Vegetation and Wildlife Habitat Mapping Study (Study 11.5), along with existing aerial and LiDAR GIS information are being used to develop maps and cross-sections of the study area. This combined information is being 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 are being produced.

4.3.1. Variances

No variances from the methods described in the Study Plan occurred during the 2013 study season.

4.4. Upwelling / Springs Broad-Scale Mapping

AEA implemented the methods as described in the Study Plan with no variances. 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 developed from several other resource studies including the Ice Processes Study (Study 7.6), Geomorphology Study (Study 6.5), and the Water Quality Study (Study 5.5). These studies will collectively provide a suite of broad-scale mapping information that will be used in identifying areas of groundwater influence. This component of the Groundwater Study is developing the compilation, review, and interpretation of the different mapping work products that will result in a GIS map layer that depicts groundwater-influenced areas. This work is 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 will help identify specific Focus Areas that warrant detailed groundwater study.

This study is relying on the following activities and work products provided from other resource studies:

- Aerial and global positioning system (GPS) mapping of winter open leads, in Q1 and Q2 of 2013 as completed by the Ice Processes Study (Study 7.6). Open leads in the Middle River Segment are being 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 in coordination with the Ice Processes Study. Geographic Information System (GIS) coverage of the winter open leads is being developed. The Groundwater Study is focusing 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 (Study 6.5) and Characterization of Aquatic Habitats Study (Study 9.9). The aerial photography and videography will be used in addition to site visits 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 was completed during Q1 2013 as part of Water Quality Study (Study 5.5). In coordination with the Fish and Aquatics Studies (Study 9) a determination was made to collect additional TIR imaging data in the Lower River Segment and in Focus Areas, and select tributary mouths and aquatic habitat areas in 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.

- Observations of 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 (Study 8.5.4.5.1.1.4), as well as fish tracking studies completed as part of the Salmon Escapement Study (Study 9.7). In these studies, where aggregations of spawning or rearing fish were observed, temperature probes were installed to determine whether or not upwelling is present by using temperature vertical profiling techniques (e.g., measuring the vertical temperature profile and 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 they are likely to be (1) mainstem flow/stage dependent, (2) regional/upland groundwater dependent, or (3) mixed influence.

4.4.1. Variances

No variances from the methods described in the Study Plan occurred during the 2013 study season.

4.5. Riparian Vegetation Dependency on Groundwater / Surface-Water Interactions

AEA implemented the methods as described in the Study Plan with the exception of variances described below (Section 4.5.1). This study component is directly linked to the Riparian Instream Flow Study (Study 8.6) and associated with a number of other multidisciplinary resource studies that are jointly working on the Focus Areas including the Fish and Aquatics Instream Flow Study (Study 8.5), Geomorphology Study (Study 6.5), Ice Processes Study (Study 7.6), and Water Quality Study (Study 5.5). The overall goal of this study component is to collect information and data to define riparian vegetation and GW/SW interactions and function at a number of Focus Area locations. Focus Area results will be used to extrapolate effects to the riparian domain scale. These process relationship analyses will allow for assessment of potential Project operation effects on GW/SW interactions and associated riparian vegetation.

Physical models, including surface water hydraulic (1-D and 2-D), geomorphic reach analyses, GW/SW interactions, and ice processes will be integrated, allowing assessment of physical process controls of riparian vegetation recruitment and establishment to be quantitatively assessed (see Study 8.6) under both existing conditions and Project operation scenarios.

Empirical data are being collected at select Focus Areas to define riparian GW/SW interactions. The data collection stations serve multiple study needs. The stations are identified by primary station purpose (Figure 4.5-1), though most stations collect a wide range of data to provide empirical data for multiple studies. The figures provide a key for using the station names. The Focus Areas include FA-138 (Gold Creek) (Figure 4.5-2), FA-128 (Slough 8A) (Figure 4.5-3), FA-115 (Slough 6A) (Figure 4.5-4), FA-113 (Oxbow 1) (Figure 4.5-5), and FA-104 (Whiskers Slough) (Figure 4.5-6). Each of the Focus Areas is supporting activities of both aquatic and riparian studies, except for FA-113 (Oxbow 1), which is primarily in support of aquatic instream flow studies. Empirical data collection includes the use of shallow wells (piezometers) installed at stations along the liner transects. Pressure transducers recording water level and temperature,

temperature sensors, and selected water quality sensors and meters (conductivity, temperature) to help characterize GW/SW interactions were installed in the wells. The use of conductivity sensors in wells and streambeds are for detection of transient changes in GW/SW conditions and less on actual conductivity levels because the sensors are buried and cannot have regular maintenance and quality assurance checks. Professional judgment was used to select the transect locations where hydrologic boundaries were likely to occur, such as slough and side channels. Wells were placed to help describe the groundwater conditions at boundaries and at varying distances from these boundaries to help measure the hydrologic boundary conditions and the time lag in groundwater level response to changes in surface water stage.

Shallow groundwater wells were installed using the drive point method. This was an approach similar to that used for some wells in the 1980s. Wells in the riparian sections were all constructed with 1.5-inch galvanized pipe and well screen material. A Mobile Drill Minuteman portable drill was used to pre-drill the holes to promote a faster installation of wells. Some wells in areas with shallow groundwater were installed using a portable soil auger to pre-drill the holes. Cobble and boulder substrate commonly caused well material to break and multiple drill holes to be installed. Native material was used to fill any annular space at the surface, though this was rarely needed due to the drive-point installation method. All wells were completed with a top cap, or cover to help house instrumentation associated with the well monitoring. This same installation approach was used for wells drilled for aquatic transects.

Well locations take into account the riparian vegetation mapping units. The Focus Areas that have Groundwater Study activities are located in the Riparian Process Domain three and four (Figure 4.5-7). Some wells were placed at boundaries of the groundwater model simulation domains to provide model boundary input data, or validation datasets. Additional information, such as unfrozen volumetric soil moisture content and soil temperature profiles, is being measured to help understand the characteristics of active freeze/thaw processes and moisture transfer from infiltration and underlying dynamic groundwater tables in shallow soils critical to riparian root zones. Soil water content is being measured using content reflectometers at specific soil depths (Model CS 650, Campbell Scientific, Inc., Logan UT) to determine available moisture within the soil profile. Soil water content sensors were installed at 5, 10, 20, 50, 110, and 200 cm and 5, 10, 25, 44, 65, and 85 cm in depth at FA-104 and FA-128, respectively. The asymmetric levels were chosen to more accurately represent vertical variation in the rooting depths (Wilson et al. 2001).

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

A listing of the stations installed in the Focus Areas and a description of the measured parameters are found in Tables 4.5-1 to 4.5-4. The short name, primary station purpose, and measured parameters are presented in the table. The naming convention for the station short name is shown in Figure 4.5-1. Time-lapse cameras were installed at locations in each Focus Area to visually document surface water, riparian conditions, ice and snow conditions, and groundwater influences on surface-water conditions. Most cameras are located at hydrologic features, such as slough, side channels and streams. The camera image data will support better understanding of a number of processes, including the seasonal changes in vegetation (leaf-on, growth, leaf-out), snowmelt, precipitation, general weather information, stage changes in surface water features, water clarity (turbidity), and winter hydrology and ice processes. Table 4.5-5 lists the time-lapse camera locations and the various features covered by each camera location.

The Riparian Instream Flow Study (Study 8.6) is also studying transects in the Lower River, which involve an evaluation of GW/SW interactions and the relationship to riparian vegetation. Each transect (LR1, LR2, and LR3) has a Groundwater Station with two wells, a surface-water measurement point, and a time-lapse camera. Geomorphic reach LR4 has two stations to help describe differences in the central portion of the river and at the eastern boundary of the braided river reach. Figures 4.5-8 through 4.5-11 show the location of these five stations.

Figures 4.5-12 through 4.5-24 show the location of groundwater wells and continuously measured parameters. Locations where surface-water stage and temperature, groundwater levels and temperature, streambed and soil temperature profiles, and time-lapse images are shown for each Focus Area in the Middle River and each riparian transect location in the Lower River Segment.

Representative examples of data collection standards and other metadata are presented in Appendix B with one example for each major station type. The full set of the station data collection standards and output file formats are available for download at http://gis.suhydro.org/reports/isr. Representative examples of the Campbell Scientific Inc. data collection station programs and wiring diagrams are found in Appendix C.

Empirical data are being used to quantify, model, and analyze the relationship between floodplain shallow water-table aquifers and floodplain plant community types. The importance of the empirical data for understanding the hydrologic processes, developing numerical GW/SW models, and developing the final relationship and analysis approaches is shown in Figure 4.5-25. Another part of the data collection program to support aquatic and riparian habitat evaluations is the use of time-lapse camera systems. These cameras are described in more detail in Section 4.8. The camera images are an important form of empirical data to understand the hydrology and riparian vegetation conditions on an annual basis. Example representative images from time-lapse cameras are shown in Appendix D.

In GW/SW stations, the minimum recording interval for water levels, temperature, and other parameters is 15 minutes. At stations with Campbell Scientific Inc. data acquisition and control systems, 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 responses in the water-table aquifer systems and to provide input, calibration and validation datasets for groundwater model development, and simulation goals. Groundwater monitoring programs began on a small scale in winter 2012–2013 and increased during the summer of 2013.

Survey standards are important for any hydrology program. Elevation accuracy is very important when studying systems that have reversing flow directions, both horizontal and vertical The survey efforts in this study are coordinated with the Instream Flow Study establishment of survey standards and primary benchmarks (Study 8.5). Monitoring wells were surveyed with a combination of Real Time Kinematic (RTK) survey methods and optical level-loop methods. Selected examples of survey control points and level-loop data calculation sheets are shown in Appendix E. This surveying was conducted after installation of groundwater wells to determine measurement heights at the top of each well casing and will be done at least two times a year, or more frequently if well movements are recorded. Survey control points were also established for surface-water stage measurement locations. Each Focus Area studied during the 2013 study season had a series of primary horizontal and vertical survey control points established by the registered land surveyor for the Project. These were then used to establish a series of secondary control points at each station to allow subsequent level-loop surveying for verification of measurement location elevations and surveying of nearby water levels in side channels, sloughs, and streams.

Pressure transducer measurements were verified with manual measurements when visited during summer months, and will be measured three to four times during winter periods. Both calibration (for determining offsets) and verification water level data will be collected. Calibration checks were performed on conductivity and temperature sensors during field installations, and field calibration checks were performed 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 [Study 8.6]). The groundwater and surface-water field measurement collection interval for continuously measured sensors is 15 minutes or less. Groundwater model numerical simulations will also be 15 minutes or less, based on analysis of modeling results. Depending on the analysis objectives, longer time steps may be used if the simulation objectives require it. This information will produce time series datasets from which water level summary statistics can be calculated for a range of analysis, such as running averages in hourly and daily increments.

MODFLOW (Feinstein et al. 2012; Maddock et al. 2012; USGS 2005) GW/SW numerical models of floodplain water table alluvial aquifer and surface water relationships are being developed for the Focus Areas using the collected empirical data. Similar approaches to understanding GW/SW interactions have been reported in Nakanishi and Lilly (1998). MODFLOW modeling packages are based on ASTM D6170 "Standard Guide for Selecting a Groundwater Modeling Code" (ASTM 2010b). ASTM standard D5981 is being used to help develop calibration goals and procedures for groundwater modeling efforts (ASTM 2008c). Both generic and conceptual models were used to help improve process understanding and design of data collection field programs, and for developing the framework for numerical models that will be used in conjunction with empirical data and analysis to better understand and describe potential Project effects.

The application of snowmelt and precipitation runoff stage-change events is being used to develop and calibrate groundwater models. 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 numerical model simulation capabilities. Data from the study period will be used to provide information to meet similar objectives.

Groundwater, surface-water, and meteorological data collection station locations for the FA-138 (Gold Creek) FA are shown in Figure 4.5-2. This Focus Area has one riparian sample transect to characterize the groundwater interactions in the elevated floodplain wetland areas. An abandoned set of upland sloughs, one containing old beaver dam complexes, has two surface-water stations. Because these abandoned sloughs are groundwater-fed, they are named as groundwater sites.

FA-128 (Slough 8A) is the Focus Area with the highest level of Groundwater Study activity (Figure 4.5-3). There are two riparian transects in the Focus Area. There are also a series of wells characterizing the floodplain water-table aquifer as well as two co-located aquatic transects. The two transects extend from side channels that are adjacent to the main channel toward Slough 8A at the floodplain boundaries along the Alaska Railroad Corporation (ARRC) railroad tracks.

FA-115 (Slough 6A) has one riparian transect (Figure 4.5-4). There is one meteorological station on this transect and seven groundwater stations. Four of the groundwater stations also have surface-water pressure transducers to characterize off-channel water bodies.

FA-104 (Whiskers Slough) has one Riparian Transect located in the central portion of the Focus Area (Figure 4.5-6). There are seven groundwater stations on this transect and one meteorological station. There are three surface-water pressure transducers located at various stations.

The data collection networks in the Focus Areas were designed to benefit the specific objectives of the aquatic and riparian groundwater studies, as well to help provide information on overall Focus Area scale hydrology and supporting empirical data for other studies. Over the 2013 summer and fall field installation period, 66 of the 71 planned shallow groundwater wells were located, drilled, instrumented, and had survey control points established. Four wells not intended for any instrumentation, and low island areas subject to fall and spring ice jamming, were scheduled for the next year of study. Only one well, in an area of dense cobbles and boulders, was not successfully installed (ESGFA104-8). Taking into account all the measurements being made, this loss will not have a negative impact on study objectives. Continuous monitoring stations were established in five Focus Areas; 57 stations were installed in 2013, with hundreds of measurement points covering a range of hydrologic and climate process measurements. Five additional groundwater stations were installed in the Lower River. A total of 22 of the 62 installed stations were self-logging pressure transducers where only water temperature and level were required at a single point. The other 35 stations (Campbell Scientific Inc. data acquisition and control systems) are on the radio telemetry network, providing near-real-time data access to study teams to these remote stations without needing to retrieve data from the field. Additionally, 31 time-lapse camera stations (or additions to existing stations) were installed in 2013, in addition to two near-real-time reporting Campbell Scientific Inc. stations at ESSFA104-1 and ESSFA128-1 (Figure 4.5-6). Tables 4.5-1 through 4.5-6 provide more details for these stations and the variety of empirical measurements being made on a continuous basis.

Empirical data station metadata includes data collection standards and methods. Representative examples of these products are listed in Appendices B through E. Groundwater, surface water, meteorological, and geotechnical (soil temperature, soil moisture) empirical datasets from the 2013 season are described in the methods section above (Section 4) and data passing quality assurance methods are available for download at http://gis.suhydro.org/reports/isr.

4.5.1. Variances

AEA implemented the methods as described in the Study Plan with the exception of the variances described below.

- The schedule for completion of the groundwater flow models, including model input and calibration datasets, files, and model documentation was rescheduled into the next year of the study to provide better integration with other hydrologic modeling efforts. This change in schedule will not impact the objectives of the study.

4.6. Aquatic Habitat Groundwater / Surface-Water Interactions

AEA implemented the methods as described in the Study Plan with the exception of variances explained below (Section 4.6.1). The same general approach as described above for the riparian component is being used for evaluating GW/SW interactions within aquatic habitats as part of the Fish and Aquatics Instream Flow Study (Study 8.5). 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 (PRM 187.1). The model will thus be able to predict water surface elevations (WSEs) proximal to the Focus Areas noted above, as well as in other areas identified as being groundwater-influenced. Empirical water levels and water quality (temperature, conductivity) measured in side channels, sloughs, and groundwater wells installed in the floodplain at the Focus Areas can therefore be related to simulated mainstem WSEs.

Habitat Suitability Criteria (HSC) and a Habitat Suitability Index (HSI) will be developed that include groundwater-related parameters (upwelling/downwelling indexes). Development of HSC and HSI will follow the general procedures outlined in the Fish and Aquatics Instream Flow Study (Study 8.5). Parameters specific to groundwater that are being measured, where appropriate, include turbidity, evidence of upwelling/downwelling, 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 (Study 9).

Mainstem, side channel, and slough habitat models will be developed that incorporate GW/SW related processes (main channel head, upwelling/downwelling) (see Figure 8.5-3 in Study 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 (Study 8.5).

The groundwater study coordinated with both instream flow and fisheries studies on the selection of Focus Areas. The groundwater study is measuring both horizontal and vertical head gradients through combinations of shallow wells and temperature profile strings installed in surface water habitat areas to measure the gradients between surface water sources and underlying groundwater conditions. These gradients will be compared with simulated gradients from groundwater/surface water models under the field conditions measured during the study data collection period.

The Focus Areas, continuous data collection stations, and location of aquatic transects are shown in Figures 4.5-2 through 4.5-6. Figures 4.5-12 through 4.5-24 show the location of key measurement locations and groundwater well locations. Locations where surface-water stage and temperature, groundwater levels and temperature, streambed and soil temperature profiles, and time-lapse images are shown for each Focus Area in the Middle River and each riparian transect location in the Lower River Segment. Figure 4.6-1 shows a typical installation in floodplain areas subject to ice jam flooding. To determine how high stations should be mounted to limit the impacts of flooding, ice-scars were used to determine the general high water levels during ice jam flooding. The station shown (ESSFA104-1) is about 3 feet above the highest ice-scars in the area. Figure 4.6-2 shows some additional examples of typical groundwater and surface-water stations. The data collection stations measure a wide range of sensors (Tables 4.5-1 to 4.5-6).

The data collection networks in the Focus Areas were designed to benefit both the specific objectives of the aquatic and riparian groundwater studies, as well as to help provide information on overall Focus Area scale hydrology and supporting empirical data for other studies. Over the 2013 summer and fall field installation period, 66 of the 71 planned shallow groundwater wells were located, drilled, and instrumented, and had survey control established. Four wells not intended for any instrumentation, and low island areas subject to fall and spring ice jamming, were scheduled for the next year of study. Only one well, in an area of dense cobbles and boulders, was not successfully installed (ESGFA104-8). Taking into account all the measurements being made, this loss will not have a negative impact on study objectives. Continuous monitoring stations were established in five Focus Areas. In 2013, 57 stations were installed, with hundreds of measurement points covering a range of hydrologic and climate process measurements. Five additional groundwater stations were installed in the Lower River. A total of 22 of the 62 installed stations were self-logging pressure transducers where only water temperature and level were required at a single point. The other 35 stations (Campbell Scientific Inc. data acquisition and control systems) are on the radio telemetry network, providing near-real-time data access to study teams to these remote stations without needing to retrieve data from the field. Additionally, 31 time-lapse camera stations (or additions to existing stations) were installed in 2013, in addition to two near-real-time reporting Campbell Scientific Inc. stations at ESSFA104-1 (Figure 4.5-18) and ESSFA128-1 (Figure 4.5-14). Tables 4.5-1 through 4.5-6 provide more details for these stations and the variety of empirical measurements being made on a continuous basis.

Empirical data station metadata includes data collection standards and methods. These work products from the 2013 season are described above in the riparian methods section (Section 4.5), and groundwater, surface water, meteorological geotechnical (soil temperature, moisture) empirical datasets passing quality assurance methods are available for download at http://gis.suhydro.org/reports/isr. Representative examples of metadata standards and supporting documentation are also listed in Appendices B through E. The Groundwater Study is responsible for the coordination and collection of information, analysis, and reporting of final deliverables for this study element.

4.6.1. Variances

AEA implemented the methods as described in the Study Plan with the exception of the variances described below.

- The schedule for completion of the groundwater flow models, including model input and calibration datasets, files, and model documentation was rescheduled into the next year of the study to provide better integration with other hydrologic modeling and habitat modeling efforts. This change in schedule will not impact the objectives of the study.

4.7. Water Quality in Selected Habitats

AEA implemented the methods as described in the Study Plan with the exception of variances explained below (Section 4.7.1). Water quality characteristics are likely to vary with GW/SW interactions and potential effects due to proposed Project operations. Project water quality activities were coordinated with the Riparian Instream Flow Study (Study 8.6), Geomorphology studies (Studies 6.5 and 6.6), and Fish and Aquatics Instream Flow Study (Study 8.5). Data collection under this objective will also be accomplished by the Baseline Water Quality Study (Study 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, dissolved oxygen [DO], conductivity, pH, turbidity, redox potential) data were collected by the Water Quality Study (Study 5.5) in 2013 that define habitat conditions and characterize GW/SW interactions. This included data collection at selected wells, sloughs, and side channels. For example, where possible, differences between 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. This data collection will continue in the second year of study.

To improve the understanding of the water quality differences and related GW/SW processes, 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. For example, results from fish population and habitat studies (Studies 9.6 and 9.9) will be used and coordinated with the Fish and Aquatics Instream Flow Study (Study 8.5) to select paired productive and non-productive habitats.

Empirical data station metadata includes data collection standards and methods. These work products from the 2013 season are described in the riparian methods section above (Section 4.5), and groundwater, surface water, meteorological, geotechnical (soil temperature, soil moisture) empirical datasets from the 2013 season passing quality assurance methods are available for download at http://gis.suhydro.org/reports/isr. Representative examples of metadata standards and supporting information are also listed in Appendices B through E.

4.7.1. Variances

AEA implemented the methods as described in the Study Plan with the exception of the variances described below.

- The schedule for completion of the groundwater flow models, including model input and calibration datasets, files, and model documentation was rescheduled into the next year of the study to provide better integration with other hydrologic modeling and habitat modeling efforts.
- Water quality data from other studies completed in the first study year will be used in the next year of study to describe the differences between productive and non-productive habitat types. These habitat types will be defined in the Instream Flow Study (Study 8.5). This change in schedule will not impact the objectives of the study.

4.8. Winter Groundwater / Surface-Water Interactions

AEA implemented the methods as described in the Study Plan with no variances. 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/pressures are being 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 is being measured as part of the Instream Flow Study (Study 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 (Study 7.6).

Hydrologic stations installed for the aquatic and riparian study elements were designed to operate year-round, both summer and winter. The interpretation of winter hydrology and GW/SW interactions is covered under this study section. Data collection includes groundwater levels, surface-water levels, water temperature, meteorological parameters, and other measurements that will contribute to the winter studies taking place in the Focus Areas. Ice and snow cover on side channels and sloughs is important to characterize for winter hydrology programs. A series of time-lapse cameras was installed in the five Focus Areas that are part of the aquatic and riparian study activities. These cameras were installed in coordination with the

Ice Processes Study (Study 7.6) and Instream Flow Study. The installed time-lapse cameras were concentrated in aquatic lateral habitat areas and connecting locations to side and main channel areas. The cameras were installed in the fall and early winter of 2013 in time to help capture vegetation "leaf-off", early snowfall, and the early winter freeze-up of side sloughs and channels. The time-lapse interval for the cameras will vary over the year. The cameras will be set to 15-minute intervals for the river freeze-up and break-up periods. During the rest of the year, the cameras will be set to an hourly image collection interval. The camera sites are visited at various times when other work is being carried out in the respective Focus Areas. Selected representative images from time-lapse cameras are shown in Appendix D.

Empirical data station metadata includes data collection standards and methods. These work products from the 2013 season are described in the methods section above (Section 4), and data passing quality assurance methods are available for download at http://gis.suhydro.org/reports/isr. Representative examples of these products are also listed in Appendix B through E.

4.8.1. Variances

No variances from the methods described in the Study Plan occurred during the 2013 study season.

4.9. Shallow Groundwater Users

AEA implemented the methods as described in the Study Plan with no variances. 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. In 2013, three wells were selected for monitoring in the Gold Creek area and one well in the Chase community area. Because these areas are closer to the upstream location of the proposed dam, the potential impacts would be expected to be greater. In the initial phases of the study, four wells were instrumented with self-logging pressure transducers that measure water level and temperature. Data will be downloaded during winter and summer trips to the Focus Areas for general data collection activities. At this time, basic water quality parameters will be measured, including temperature, conductivity, and dissolved oxygen (when sampling conditions allow). 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 are being 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 were selected with high potential to be affected by the Susitna River flow regime and well levels and

river stage are being 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.

Empirical data station metadata includes data collection standards and methods. These work products from the 2013 season are described above in the methods section (Section 4), and data passing quality assurance methods are available for download at http://gis.suhydro.org/reports/isr. Representative examples of these products are also listed in Appendix B through E. The Groundwater Study is responsible for the coordination and collection of information, analysis, and reporting of final deliverables for this study element.

4.9.1. Variances

No variances from the methods described in the Study Plan occurred during the 2013 study season.

5. RESULTS

5.1. Existing Data Synthesis

Data synthesis efforts in 2013, in coordination with the Instream Flow Study (Study 8.5), resulted in finding significant additional 1980s Susitna references and other forms of information. The 1970s infrared aerial images of select areas in the Susitna River, mainly in the Middle River Segment, were located at the University of Alaska Fairbanks (Appendix A). Figure 5.1-1 shows an example of one of the early geohydrology study maps from the 1980s in the Slough 8A area. This figure shows the location of groundwater wells installed with similar drive-point methods. Some of these wells have been found and will be used by the study. The annotated bibliography, located at the ARLIS Library Susitna Collection, will be completed in the second year of the study.

5.2. Geohydrologic Process-Domains

Study activities in 2013 were concentrated on acquisition and review of materials related to this study element.

In addition, while traveling in helicopters for support of other data collection activities, oblique aerial photographs were taken to help characterize the important geographic and hydrologic features that will relate to the development of the process-domain maps. Figure 5.2-1 illustrates an example observation for the recharge areas for Slough 21, found in FA-144 (Slough 21).

AEA is in the process of reviewing this material and expects that the results for this study component to be completed in the second year of the study.

5.3. Watana Dam/Reservoir

To inform the assessment of potential aquatic and riparian habitat effects from predicted fluctuating reservoir pool elevations at the upper end of the dam reservoir, a fall 2013 reconnaissance field trip was conducted. The reconnaissance survey focused on documenting upper reservoir channel lateral margin aquatic and riparian habitat conditions to provide data for evaluating potential reservoir pool fluctuation effects on GW/SW and ice processes, and associated aquatic and riparian habitats.

The modeled low pool to high pool elevation zone was photographically documented from both on-the-ground and helicopter aerial vantage points. Figures 5.3-1 and 5.3-2 show the left bank conditions at the location of the proposed high-pool elevation (elevation 2,050 feet NAVD88). One hundred and thirty six aerial photographs from helicopter- and ground-based vantage points were collected and are available for download at http://gis.suhydro.org/reports/isr. These photographs were taken using a GPS-equipped camera and have GPS coordinates embedded in the image information. The photographs document general floodplain and river conditions from the low pool elevation (1,850 feet NAVD88) (PRM 222.5) to about 2 miles upstream of the high pool elevation (PRM 232.5).

5.4. Upwelling / Springs Broad-Scale Mapping

The Groundwater Study provided water surface temperature measurements to the Thermal Infrared (TIR) Imagery processing staff to assist in the calibration and validation of the TIR imagery surveys. TIR surveys were conducted to identify areas of measurable groundwater upwelling in mainstem and lateral channel habitats using TIR surface water temperature maps to rapidly cover large areas. Water temperature signature differences may be used as a tracer to identify the source of warm or cold water because flowing surface water and groundwater have distinctive temperature profiles. Synchronous water temperature measurements from Focus Area and mainstem stations, in or near the areas of TIR coverage, were compared with synchronous TIR imagery measurements taken by fixed-wing aircraft. Figures 5.4-1 and 5.4-2 provide two examples of data provided to assist in the TIR imagery analysis. The TIR analysis will be used in the next year of the study to provide a better understanding of areas where in-channel groundwater upwelling is occurring. Water temperature data that were used for the TIR analysis are available for download at http://gis.suhydro.org/reports/isr. Water temperature data collected for Aquatic IFS and Water Quality Studies, described in Sections 5.6 through 5.7, will also be used to calibrate and validate TIR aerial imagery.

5.5. Riparian Vegetation Dependency on Groundwater / Surface Water Interactions

Four sets of data were collected in support of Riparian IFS riparian vegetation GW/SW hydroregime analysis (Section 5.6): (1) groundwater depth at wells, (2) surface water elevations at both in-channel and floodplain water bodies, (3) meteorological parameters at Focus Area met stations, and (4) geotechnical parameters including soil temperature and soil moisture. These data were collected at FAs 104, 115, 128, and 138. The following results provide examples of how Groundwater Study data are used to identify and quantify linkages between key GW/SW processes and riparian vegetation, specifically vegetation root zone.

Multiple hydrologic events occurred in early fall and winter that are providing an improved understanding of GW/SW interactions. Figure 5.5-1 illustrates groundwater and surface-water level changes at groundwater station ESGFA115-5, located on the Riparian Transect in FA-115 (Slough 6A) (Figure 4.5-16). The December rise in water levels was due to early winter ice jamming on the mainstem of the Susitna River (Figure 5.5-1). The water levels in the beaver pond do not respond to the early water level changes in the mainstem due to the beaver pond dam outlet control on maximum water surface elevations. Figure 5.5-2 shows water temperature data for the same station. The beaver pond, warming in the summer, shows decreasing water temperatures with the onset of winter. The groundwater temperature is lagging behind the surface-water temperature in the beaver pond. By the end of December, they have reached the same temperature and rate of decline. These paired groundwater and surface-water observations provide empirical information critical to both analysis and modeling of riparian vegetation associated with floodplain beaver ponds and associated wet meadows.

Data collected in 2013 met the goals of recording transient water level changes within groundwater and adjacent surface-water systems. Figure 5.5-3 is an example illustrating the relationship between precipitation, ice jamming, and groundwater elevation response for groundwater station ESGFA104-8. The groundwater levels have several distinct water level peaks. The first two are related to late fall precipitation events, and the large peak in the second half of November is related to the early winter ice jamming on the mainstem Susitna River. The surface-water sensor was damaged during the early winter ice jamming in the channel. The difference in water levels between the surface water in Whiskers Side Channel and the nearby groundwater well demonstrates the kinematic pressure pulse moving up the hydraulic grade line.

The Riparian Transect in FA-104 (Whiskers Slough) has a groundwater station (ESGFA104-3) at the upper portion of the transect (Figure 4.5-6). This location will help serve as an input boundary condition for water level conditions away from the main channel. An example of water level changes in response to precipitation, main channel stage, and ice jamming backwater stage is shown in Figure 5.5-4. The water level information shows the relative difference in groundwater conditions and response to the water level changes in the mainstem for the same time period as data shown for ESGA104-8 in Figure 5.5-2. The groundwater level response to local precipitation is more pronounced for ESGFA104-3 than for ESGFAFA104-8. The reverse relationship is seen in the late November peak, which resulted from stage increases on the mainstem associated with early winter ice jams.

The relationship between riparian vegetation and shallow groundwater is influenced by other sources of water, primarily precipitation and resulting infiltration of water through the root zone. Losses of water via evapotranspiration are important to quantify with empirical data and analysis. Figures 5.5-5 through 5.5-7 illustrate examples of data being used to quantify moisture dynamics in the root zone. Figure 5.5-5 shows an example temperature profile from FA-104 (Whiskers Slough) Riparian Transect at meteorological station ESMFA104-2. The temperature data help in understanding the depth and duration of the active-layer (i.e., seasonal depth of soil freezing) and unfrozen periods when water may be infiltrating through the soils. Figure 5.5-6 shows the volumetric unfrozen soil moisture at different depths. Soil moisture changes in the upper portion of the soil column indicate that the riparian root zone has pulses of soil moisture increases associated with local-area precipitation events. Figure 5.5-7 shows an example of data from the same station for solar radiation, which is used to estimate evapotranspiration water losses at the land surface to the atmosphere. These results illustrate that solar radiation is varying with cloud cover and decreasing light during the fall and winter seasons.

These examples illustrate how hydrologic data collection in 2013 will be used to help understand floodplain groundwater response to Susitna mainstem stage levels. The wide range of data being collected is meeting data quality objectives and helping study teams better understand the field hydrologic conditions. Data developed in support of the ISR are available for download at http://gis.suhydro.org/reports/isr.

5.6. Aquatic Habitat Groundwater / Surface-Water Interactions

There is a wide range of data being collected that supports the assessment of aquatic habitats and associated critical GW/SW processes. All of the data collection stations planned for installation in 2013 were installed, as well as all the groundwater wells. Data collection is ongoing at all stations. Some sites will need to be visited during winter and following months to download data from data collection stations not on telemetry. Data collection focused on understanding the relationship between aquatic habitat and surface-water is concentrated in the Focus Areas at short aquatic transects. Data collection in support of Riparian Study (Section 8.6) objectives will also be used in the analysis of GW/SW conditions and general hydrology of the lateral habitat areas in each Focus Area.

Four sets of data were collected in support of Aquatic IFS aquatic habitat GW/SW interaction analysis (Section 5.5): (1) groundwater depth at wells, (2) surface water elevations at both in-channel and floodplain water bodies, (3) meteorological parameters at Focus Area met stations, and (4) water quality parameters including surface and subsurface temperatures. These data were collected at FAs 104, 113, 115, 128, and 138. The following results provide examples of how Groundwater Study data are used to identify and quantify linkages between key GW/SW processes and aquatic habitat.

Groundwater and surface water interaction linkages were identified and measured using combinations of groundwater wells and surface water recorders. Figure 5.6-1 shows an example of data collection in FA-104 (Whiskers Slough) at groundwater station ESGFA104-10, located on the Whiskers Side Channel aquatic transect. Relative water levels between the side channel and adjacent groundwater conditions are seen to reverse during rapid stage changes in the side channel during late November and early December and illustrate the effect of an early winter ice jamming event on GW/SW interactions. Initially, groundwater levels are higher than surface-water levels and groundwater flow is into the channel. Surface-water levels in the side channel rapidly came up approximately 10 feet due to ice jamming, resulting in surface-water levels higher than groundwater and reversing groundwater flow directions. As high water levels created by the ice jam receded, groundwater levels recovered to near pre-jam conditions by the end of December.

Another example of data collection to support aquatic analysis is illustrated in Figure 5.6-2 for FA-113 (Oxbow 1) (Figure 4.5-5). This aquatic transect has a single station, ESGFA113-1, collecting data from two wells, an unnamed stream, and the Oxbow 1 side channel (Figure 4.5-17). The figure illustrates variations in groundwater and surface-water conditions from August through December 2013. The peaks in August and September are the result of mainstem Susitna River stage increases in response to precipitation. In comparison, groundwater levels are higher in the abandoned slough and beaver pond complex that drains into the stream. This is shown in the higher water levels in Well W1. These data illustrate how groundwater and surface water recorders are used to identify and measure GW/SW linkages and interactions. Data developed in support of the ISR is available for download at http://gis.suhydro.org/reports/isr.

5.7. Water Quality in Selected Habitats

Three sets of data were collected in support of the water quality analyses of lateral channel habitats for Aquatic IFS (Section 5.5): (1) water temperature, (2) electrical conductivity, (3) dissolved oxygen, and (4) time lapse photographs of in-channel turbidity. Water temperature was measured at all water level, groundwater, and streambed profiles. Electrical conductivity was measured at select aquatic GW/SW transects. Dissolved oxygen was measured manually at select sites during stream surveys. Time lapse cameras of in-channel processes are operating at all Focus Areas. These data were collected at FAs 104, 113, 115, 128, and 138. The following results provide examples of how Groundwater Study data are used to measure Aquatic IFS water quality parameters.

One of the primary water quality parameters being measured in support of aquatic habitat assessments is water temperature. One example of groundwater and surface water temperature measurements is illustrated in Figure 5.7-1 for FA-113 (Oxbow 1) groundwater station ESGFA113-1 (Figure 4.5-5, Figure 4.5-12, Figure 4.5-13). Temperature variations in two wells, an unnamed stream, and the side channel are shown. Seasonal variation between summer conditions (warmer surface water) and winter conditions (colder surface water) are illustrated at this aquatic study location. For comparison, streambed temperature conditions in the Oxbow 1 side channel are shown in Figure 5.7-2. There is a change from summer to winter conditions as the profile gets cooler; however, streambed temperatures are still above the temperatures at the streambed interface (measured at the pressure transducer, Figure 5.7-1).

The conditions in Slough 11(FA-138 [Gold Creek]) groundwater station ESGFA138-1 (Figure 5.7-3) are different than in the Oxbow 1 side channel, illustrating temporal influence of groundwater and mainstem channel hydrologic connectivity on slough water temperatures. Figure 5.7-3 shows the temperature variation for Slough 11 and the two adjacent wells on the right bank. Groundwater flow into Slough 11 keeps the surface-water temperature relatively high. This temporarily changed in mid-December when mainstem stage conditions changed with ice jamming, resulting in cold mainstem water overtopping the inlet to Slough 11 and flushing out the warmer water in the slough. As water levels in the mainstem dropped and the flow ceased to overtop the inlet, water temperature conditions returned to levels closer to early December levels.

Surface water temperature and streambed temperature conditions are important for spawning, egg incubation, and rearing habitat conditions and their measurement is illustrated in Figure 5.7-4, ESGFA138-1. This figure shows stable temperature environment in the streambed before the overtopping flows increased water stage level and lowered temperatures. This resulted in a reversal of groundwater flow directions and an influx of cold water into the streambed sediments (downwelling). The presence of groundwater inflow into and out of the streambed (upwelling) results in warmer streambed substrate conditions than if groundwater recharge was not occurring.

Data collected for this study can help in understanding groundwater and surface-water interactions, and water temperature can be used as an indicator of relative groundwater and surface-water influences. Figure 5.7-5 shows the streambed temperature profile for FA-138 (Gold Creek) Upper Side Channel 11, measured from groundwater station ESGFA138-2. Figure 5.7-6 then shows the same data combined with the stage elevation for the side channel. The rapid increase in surface-water level in the side channel resulted in a reversal of groundwater flow direction. This temporary "downwelling" resulted in displacement of warmer groundwater in the streambed with cold surface water. By early January, the streambed conditions returned to those prior to the ice jam event.

FA-104 (Whiskers Slough) has three streambed temperature monitoring sites. These are locations at groundwater stations ESGFA104-9 and ESGFA104-10, and surface-water station ESSFA104-1 (Figures 4.5-6 and 4.5-18). ESGFA104-9 and ESSFA104-1 are located in Whiskers Slough while ESGFA104-10 has two wells and is located at the upstream end of Whiskers Side Channel (Figures 4.5-18 and 4.5-19). Figures 5.7-7 through 5.7-10 show the streambed temperature profiles for these measurement locations. The groundwater temperature influences are different in the side channel (Figures 5.7-9 and 5.7-10) compared to Whiskers Slough (Figures 5.7-7 and 5.7-8). The lower end of Whiskers Slough has colder streambed temperature conditions compared to the middle section of the slough. The Whiskers Side Channel has more stable and warmer streambed conditions just before the transient exchanges that took place in November between groundwater and surface water due to mainstem ice jamming.

The use of time-lapse cameras also provides useful data for understanding water quality differences and exchanges between summer turbid waters from the mainstem and clear groundwater-recharged lateral aquatic lateral habitats. Figures 5.7-11 and 5.7-12 are example images at the confluence of Slough 8A and a side channel on September 1 and August 31, 2013.

The significant amount of hydrologic data being provided by the field monitoring program will help achieve the study objective for assessing current aquatic water quality conditions. Data developed in support of the ISR are available for download at http://gis.suhydro.org/reports/isr.

5.8. Winter Groundwater / Surface-Water Interactions

Five sets of data were collected in support of Aquatic IFS winter GW/SW interactions analyses (Section 5.5): (1) groundwater depth at wells, (2) surface water elevations at both in-channel and floodplain water bodies, (3) meteorological parameters at Focus Area met stations, (4) water quality parameters including surface and subsurface temperatures, and (5) time lapse photographs of in-channel ice and open lead conditions. These data were collected at FAs 104, 113, 115, 128, and 138. The following results provide examples of how Groundwater Study data are used to identify and quantify linkages between key GW/SW processes and aquatic habitat.

Groundwater has an influence on ice processes in lateral habitats and in the mainstem. Winter ice cover also impacts GW/SW interactions by providing transient boundary conditions; data collected demonstrate the complex nature of ice jams and the impact they have on stage levels. Example data shown in Sections 5.5 and 5.7 describe related processes taking place during the winter season (longer than the summer season). Data and observations were collected at the end of the 2012–2013 winter season, and at the beginning of the 2013–2014 winter season. Figure 5.8-10 shows example conditions in Whiskers Slough at camera station ESCFA104-22 on November 21, 2013 at 15:15. Ice jams on the mainstem changed the slough conditions during the night. Figure 5.8-11 represents conditions on the next day, at 11:00 in the morning. Figure 5.8-12 shows conditions on November 23, 2013 at 13:15 in the afternoon. The time series of photos documents increasing water levels, and the build-up of ice cover indicates water flooding on top of ice from the main stem and subsequent freezing. These images and others were used for this period to help understand and quality-check groundwater and surface water level measurements made in the Focus Area. The Groundwater Study uses these collective synoptic observations and measurements to identify and quantitatively describe the relationship between groundwater upwelling, in-channel ice formation, and formation of winter channel open leads. Identification and mapping of Focus Area in-channel upwelling sites, a critical element of winter aquatic habitat studies, are significant aspects of the winter Groundwater Study. Time lapse photography provides photographic data documenting in-channel ice conditions driving water level changes as observed in groundwater wells and surface water recorders. Without in-channel time lapse photography, these in-channel ice-driven changes in river stage, and subsequent GW/SW levels, would be unobserved. Therefore, the time lapse photography data are essential to identifying ice process effects on groundwater and surface water.

Winter groundwater-surface water interactions study to-date has documented the relationship between groundwater upwelling, groundwater and surface water temperature, and the formation of channel and slough winter open leads at FAs 104, 113, 115, 128, and 138. Data developed in support of the ISR are available for download at http://gis.suhydro.org/reports/isr.

5.9. Shallow Groundwater Users

Four homeowner wells were instrumented with continuously recording pressure transducers in 2013. Three homeowner wells were located in the FA-138 (Gold Creek) Focus Area, and one in the FA-104 (Whiskers Slough) Focus Area. The data from these wells will be collected during the winter study efforts. Figure 5.9-1 shows a typical installation of pressure transducers in a homeowner well (Station ESGFA138-HW1) in FA-138 (Gold Creek). The use of the data across study objectives will benefit the analysis related to Focus Area aquatic and riparian assessments, as well as in understanding the groundwater relationships with the river for shallow groundwater users. Data developed in support of the ISR are available for download at http://gis.suhydro.org/reports/isr.

6. DISCUSSION

The 2013 field station installation and data collection efforts are meeting the objectives of the first year of study. The continuous data collection stations are providing data for a number Groundwater Study objectives and also supporting the Instream Flow Study (Study 8.5), Riparian Instream Flow Study (Study 8.6), and other studies requiring empirical hydrology measurements and observations in select Focus Areas and lower river transect locations.

6.1. Existing Data Synthesis

The study efforts in 2013 are meeting the needs of the study objectives, in coordination with the ARLIS library staff managing Susitna reference resources. Important aerial photography information from the 1970s was located at University of Alaska Fairbanks, Geophysical Institute mapping archives. The data synthesis portion of the study is helping to provide key references, especially those from geohydrology studies conducted in the 1980s. Important aerial photography information from the 1970s was located at University of Alaska Fairbanks, Geophysical Institute mapping archives. The geohydrology mass balance studies conducted in the 1980s in Slough 8A, Slough 9, and Slough 11 helped with the design of the 2013 field effort, approach to well installations, and in the data collection design so that the prior information and studies will be able to be better utilized in the next year of the study. The relevant reference reviews that will be completed in the second year of the Riparian Instream Flow Study (Study 8.6) will be incorporated into the Groundwater Study literature review.

6.2. Geohydrologic Process-Domains

The level of effort in 2013 was adequate for meeting the study objectives during the next year of the study. The general fieldwork, observations, and information gained during 2013 will help improve the development of process-domains. Information developed at the end of 2013 and in next year study efforts by the Riparian Instream Flow Study (Study 9.8) and the Geomorphology Study (Study 6.5) will also be used and will contribute to this study objective.

6.3. Watana Dam/Reservoir

Reference information collected in 2013, and that planned for collection in the second year of the study, will meet the study objectives. The field survey in late fall 2013 for the upstream end of the upper pool elevation provides photographic documentation necessary to characterize this portion of the field area. The study analysis objectives will rely on the use of engineering program data and information produced in the next year of the study. The 1980s data and references located in 2013 and in the second year of the study will help characterize the geohydrology in the vicinity of the proposed dam. These efforts are meeting study objectives set forth in the FERC-approved Study Plan.

6.4. Upwelling / Springs Broad-Scale Mapping

The field data collection by the Ice Processes study (Study 7.6) and the Water Quality Study (Study 5.5) will be used to help meet the objectives of mapping upwelling areas. Information collected for the 2013–2014 winter period will be available in the second year of the study. TIR imagery was flown in late fall 2013 and included areas in the lower river and select Focus Areas. The synthesis of 2012 TIR imagery, 2013 TIR imagery, mapping of open water leads from the Ice Processes Study, and hydrology information collected in Focus Areas by the Groundwater study will meet the study objectives. These efforts are meeting study objectives set forth in the FERC-approved Study Plan.

6.5. Riparian Vegetation Dependency on Groundwater / Surface-Water Interactions

All of the major objectives of the 2013 field effort were achieved. Data collection stations and wells were installed in five Focus Areas—FA-138 (Gold Creek), FA-128 (Slough 8A), FA-115 (Slough 6A), FA-113 (Oxbow 1), and FA-104 (Whiskers Slough) (Tables 4.5-1 through 4.5-6)—and at four transect locations in the lower river to support the Riparian Instream Flow Study (Study 8.6). The data collection stations are currently reporting data online over the Project data collection network, using a radio telemetry system. These data include groundwater and surface-water levels, meteorological (air temperature, relative humidity, wind speed, wind direction, solar radiation, net radiation, precipitation, soil surface heat flux, soil temperature), and geotechnical (soil temperature and moisture) information. There is ongoing access to the data by the Groundwater Study and Riparian Instream Flow Study (Study 8.6) teams. The Riparian Instream Flow Study (Study 8.6) jointly participated in the installation of sap flow and geotechnical sensors during 2013 and collected additional measurements related to root zone characteristics and sap flow in trees that will be used in combination with the data collected by this study to meet the study objectives in the second year of the study. The combination of hydrology, meteorology, and observations data will provide an adequate basis for the development of groundwater/surface numerical 2-D cross-sectional models (MODFLOW) and a 3-D numerical model (MODFLOW) in FA-128 (Slough 8A). These efforts are meeting study objectives set forth in the FERC-approved Study Plan.

6.6. Aquatic Habitat Groundwater / Surface-Water Interactions

Data collection for the aquatic habitat and riparian habitat objectives will be used in combination to better understand the GW/SW interactions and overall hydrology in the Focus Areas being studied. Data collection stations and wells were installed in five Focus Areas—FA-138 (Gold Creek), FA-128 (Slough 8A), FA-115 (Slough 6A), FA-113 (Oxbow 1), and FA-104 (Whiskers Slough) (Tables 4.5-1 through 4.5-6)—and at four transect locations in the lower river to support the Instream Flow Study (Study 8.5). The data collection stations are currently reporting data online over the Project data collection network, using a radio telemetry system. These data include groundwater and surface-water levels, meteorological (air temperature, relative humidity, wind speed, wind direction, solar radiation, net radiation, precipitation, soil surface heat flux, soil temperature), and water quality (water temperature and conductivity) information. There is ongoing access to the data by the Groundwater Study and Instream Flow Study (Study 8.5) teams. The combination of hydrology, meteorology, and observations data will provide an adequate basis for the development of groundwater/surface numerical 2-D cross-sectional models (MODFLOW). The 1980s information in the selected Focus Areas will be used in the study analysis and will help improve the understanding gained in 2013 and the second year of the study. These efforts are meeting study objectives set forth in the FERC-approved Study Plan.

6.7. Water Quality in Selected Habitats

The water quality data collected in 2013 included temperature, conductivity, and dissolved oxygen. The Water Quality Study (Study 5.5) also collected data in the Focus Areas, in coordination with the Instream Flow Study (Study 8.6). Data collection stations and wells were installed in five Focus Areas—FA-138 (Gold Creek), FA-128 (Slough 8A), FA-115 (Slough 6A), FA-113 (Oxbow 1), and FA-104 (Whiskers Slough) (Tables 4.5-1 through 4.5-6)—to support the Instream Flow Study (Study 8.5). All water level pressure transducers measure water temperature, which is the priority for water quality characterization and understanding GW/SW interactions. At each aquatic transect in the Focus Areas, conductivity is also being measured in wells and surface water bodies. The data collection stations are currently reporting data online over the Project data collection network, using a radio telemetry system. These data include groundwater and surface-water levels, meteorological (air temperature, relative humidity, wind speed, wind direction, solar radiation, net radiation, precipitation, soil surface heat flux, soil temperature), and water quality (water temperature and conductivity) information. There is ongoing access to the data by the Groundwater Study and Instream Flow Study (Study 8.5) teams. The study efforts and data collection networks set up in 2013 will meet the study objectives of characterizing the water quality of aquatic lateral habitats. These efforts are meeting study objectives set forth in the FERC-approved Study Plan.

6.8. Winter Groundwater / Surface-Water Interactions

The hydrologic data collected in 2013 during the 2012–2013 winter season and the early part of the 2013–2014 winter season included groundwater and surface-water levels and temperature. The Ice Processes (Study 7.6) also collected aerial data in the Focus Areas, in coordination with the Groundwater Study and the Instream Flow Study (Study 8.6). Data collection stations and wells were installed in five Focus Areas: FA-138 (Gold Creek), FA-128 (Slough 8A), FA-115 (Slough 6A), FA-113 (Oxbow 1), and FA-104 (Whiskers Slough) (Tables 4.5-1 through 4.5-6). All water level pressure transducers measure water temperature, which is the priority for water quality characterization and understanding winter GW/SW interactions. The stations were installed to operate throughout the winter of 2013–2014, providing key datasets for understanding winter hydrology and assessing lateral aquatic habitat. The data collection stations are currently reporting data online over the Project data collection network, using a radio telemetry system. These data include groundwater and surface-water levels, meteorological, and water quality (water temperature and conductivity) information. There is ongoing access to the data by the Groundwater Study and Instream Flow Study (Study 8.5) and Ice Processes Study (Study 7.6) teams. The study efforts and data collection networks set up in 2013 will meet the study objectives of characterizing the winter GW/SW interactions and winter hydrology of aquatic lateral habitats. These efforts are meeting study objectives set forth in the FERC-approved Study Plan.

6.9. Shallow Groundwater Users

Four homeowner wells had self-logging pressure transducers installed in 2013. Groundwater observation wells in the lower river will also help with the analysis for this study objective. The homeowner wells chosen in 2013 were chosen for their locations in FA-138 (Gold Creek) and FA-104 (Whiskers Slough). Their data will help in achieving the Focus Area study objectives, and the additional data collected in the Focus Areas will complement the homeowner shallow groundwater well analysis objectives. The data from both efforts are being collected in a coordinated fashion with similar data standards. By selecting wells in the middle river, where potential Project effects may be greater, the analysis will be more applicable to those homeowners who will be most affected. These efforts are meeting study objectives set forth in the FERC-approved Study Plan.

7. COMPLETING THE STUDY

[As explained in the cover letter to this draft ISR, AEA's plan for completing this study will be included in the final ISR filed with FERC on June 3, 2014.]

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9. TABLES

Table 4.5-1. Groundwater Study primary purpose, location and parameters for data collection stations at FA-138 (Gold Creek).

Note: The data collection parameters include the following: air temperature, AT; camera images, Cam; groundwater level, GWL; groundwater temperature, GWT; groundwater conductivity GWC; net radiation, NR, relative humidity, RH; sap flow, SF; soil heat flux, SHF; soil-moisture profile, SMP; soil-temperature profile, SoTP; streambed temperature profile, STP; summer precipitation, SP; solar radiation, SR; surface-water conductivity, SWC, surface-water height, GH; surface-water temperature, WT; wind direction, WD; wind speed, WS. A (#) indicates more than one measurement location.

Station Short Names	Station Primary Purpose	Latitude	Longitude	Data Collection Parameters
ESGFA138-1	Groundwater	62.75758	149.70694	AT, GWL(2), GWT(2), GH, WT, STP, SWC, SP
ESGFA138-2	Groundwater	62.76464	149.70595	GWL(2), GWT(2), GH, WT, STP, SWC
ESGFA138-3	Groundwater	62.75675	149.70559	GWL, GWT
ESGFA138-4	Groundwater	62.76513	149.70604	GWL, GWT
ESGFA138-5	Groundwater	62.76555	149.70621	GWL, GWT
ESGFA138-6	Groundwater	62.76934	149.70984	GH, WT
ESGFA138-7	Groundwater	62.76779	149.70720	GH, WT
ESCFA138-8	Camera	62.75268	149.70792	Cam
ESCFA138-9	Camera	62.75686	149.70529	Cam
ESCFA138-10	Camera	62.76477	149.70522	Cam
ESCFA138-11	Camera	62.76770	149.70755	Cam

Table 4.5-2. Groundwater Study primary purpose, location and parameters for data collection stations at FA-128 (Slough 8A).

Note: The data collection parameters include the following: air temperature, AT; camera images, Cam; groundwater level, GWL; groundwater temperature, GWT; groundwater conductivity GWC; net radiation, NR, relative humidity, RH; sap flow, SF; soil heat flux, SHF; soil-moisture profile, SMP; soil-temperature profile, SoTP; streambed temperature profile, STP; summer precipitation, SP; solar radiation, SR; surface-water conductivity, SWC, surface-water height, GH; surface-water temperature, WT; wind direction, WD; wind speed, WS. A (#) indicates more than one measurement location.

Station Short Names	Station Primary Purpose	Latitude	Longitude	Data Collection Parameters
ESSFA128-1	Surface Water	62.66384	149.90494	AT, GH, WT, STP, Cam
ESGFA128-2	Groundwater	62.67204	149.89403	GWL, GWT, GH, WT
ESGFA128-3	Groundwater	62.67179	149.89390	GWL, GWT, SF
ESGFA128-4	Groundwater	62.67049	149.89341	GWL, GWT
ESGFA128-5	Groundwater	62.66765	149.89352	GWL, GWT, GH, WT, SF
ESGFA128-6	Groundwater	62.66660	149.89320	GWL, GWT, GH, WT
ESGFA128-7	Groundwater	62.66550	149.89707	GWL(2), GWT(2), GWC, GH, WT, SWC, STP
ESMFA128-8	Meteorological	62.67052	149.89485	AT, RH, SMP, SR, SoTP, SHF, WD, WS
ESGFA128-9	Groundwater	62.66349	149.90730	GWL(2), GWT(2), SF
ESGFA128-10	Groundwater	62.66393	149.90766	GWL, GWT, SF
ESGFA128-11	Groundwater	62.66596	149.91077	GWL, GWT, GH, WT
ESGFA128-12	Groundwater	62.66711	149.91272	GWL, GWT, GH, WT
ESGFA128-13	Groundwater	62.68626	149.90953	GWL(2), GWT(2), GWC, GH, WT, SWC, STP
ESSFA128-14	Surface Water	62.67271	149.89112	GH, WT

Table 4.5-2 continued. Groundwater Study primary purpose, location and parameters for data collection stations at FA-128 (Slough 8A).

Station Short Names	Station Primary Purpose	Latitude	Longitude	Data Collection Parameters
ESSFA128-15	Surface Water	62.67273	149.88573	GH, WT
ESSFA128-16	Surface Water	62.67015	149.88548	GH, WT
ESSFA128-17	Surface Water	62.66888	149.88489	GH, WT
ESGFA128-18	Groundwater	62.66538	149.89694	GWL, GWT
ESGFA128-19	Groundwater	62.66525	149.89681	GWL, GWT
ESGFA128-20	Groundwater	X[1]	X[1]	GWL, GWT
ESGFA128-21	Groundwater	62.66485	149.90892	GWL, GWT
ESGFA128-22	Groundwater	62.66088	149.91993	GH, WT
ESGFA128-23	Groundwater	62.66466	149.91168	GWL, GWT
ESGFA128-24	Groundwater	62.66534	149.90681	GWL, GWT
ESGFA128-25	Groundwater	62.66767	149.90671	GWL, GWT
ESGFA128-26	Groundwater	62.66946	149.89789	GWL, GWT
ESGFA128-27	Groundwater	62.67092	149.88946	GWL, GWT
ESCFA128-29	Camera	62.67251	149.88567	Cam
ESCFA128-30	Camera	62.66804	149.88652	Cam
ESCFA128-31	Camera	62.66549	149.89812	Cam
ESCFA128-32	Camera	62.66754	149.89376	Cam
ESCFA128-33	Camera	62.67179	149.89376	Cam
ESCFA128-34	Camera	62.66719	149.91216	Cam
ESCFA128-35	Camera	62.66307	149.91039	Cam
ESCFA128-36	Camera	62.66167	149.91676	Cam

Notes: (1) Data forthcoming, Latitude/Longitude data for this station not available at time of publication.

Table 4.5-3. Groundwater Study primary purpose, location and parameters for data collection stations at FA-115 (Slough 6A).

Note: The data collection parameters include the following: air temperature, AT; camera images, Cam; groundwater level, GWL; groundwater temperature, GWT; groundwater conductivity GWC; net radiation, NR, relative humidity, RH; sap flow, SF; soil heat flux, SHF; soil-moisture profile, SMP; soil-temperature profile, SoTP; streambed temperature profile, STP; summer precipitation, SP; solar radiation, SR; surface-water conductivity, SWC, surface-water height, GH; surface-water temperature, WT; wind direction, WD; wind speed, WS. A (#) indicates more than one measurement location.

Station Short Names	Station Primary Purpose	Latitude	Longitude	Data Collection Parameters
ESMFA115-1	Meteorological	62.51892	150.12688	AT, RH, SMP, SR, SoTP, SHF, GWL(2), GWT(2), WD, WS
ESGFA115-2	Groundwater	62.51929	150.13084	GWL, GWT, GH, WT
ESGFA115-3	Groundwater	62.51905	150.12550	GWL, GWT, GH, WT
ESGFA115-4	Groundwater	62.51906	150.12470	GWL, GWT
ESGFA115-5	Groundwater	62.51876	150.12258	GWL, GWT, GH, WT
ESGFA115-6	Groundwater	62.51868	150.12135	GWL, GWT
ESGFA115-7	Groundwater	62.51863	150.12064	GWL, GWT, GH, WT
ESGFA115-8	Groundwater	62.51914	150.12948	GWL, GWT
ESCFA115-11	Camera	62.51933	150.13072	Cam
ESCFA115-12	Camera	62.51896	150.12046	Cam
ESCFA115-13	Camera	62.51507	150.12476	Cam
ESCFA115-14	Camera	62.51357	150.12182	Cam

Table 4.5-4. Groundwater Study primary purpose, location and parameters for data collection stations at FA-104 (Whiskers Slough).

Note: The data collection parameters include the following: air temperature, AT; camera images, Cam; groundwater level, GWL; groundwater temperature, GWT; groundwater conductivity GWC; net radiation, NR, relative humidity, RH; sap flow, SF; soil heat flux, SHF; soil-moisture profile, SMP; soil-temperature profile, SoTP; streambed temperature profile, STP; summer precipitation, SP; solar radiation, SR; surface-water conductivity, SWC, surface-water height, GH; surface-water temperature, WT; wind direction, WD; wind speed, WS. A (#) indicates more than one measurement location.

Station Short Names	Station Primary Purpose	Latitude	Longitude	Data Collection Parameters
ESSFA104-1	Surface Water	62.37676	150.16934	AT, GH, WT, STP, Cam
ESMFA104-2	Meteorological	62.37863	150.17190	AT, RH, SMP, SR, SoTP, SHF, GWL, GWT, WD, WS
ESGFA104-3	Groundwater	62.37934	150.17373	GWL, GWT
ESGFA104-4	Groundwater	62.37908	150.17363	GWL, GWT, SF
ESGFA104-5	Groundwater	62.37810	150.17029	GH(2), WT(2), GWL, GWT
ESGFA104-6	Groundwater	62.37800	150.16912	GWL(2), GWT(2), SF
ESGFA104-7	Groundwater	62.37764	150.16822	GWL, GWT, SF
ESGFA104-8	Groundwater	62.37692	150.16562	GWL, GWT, SF, GH, WT
ESGFA104-9	Groundwater	62.37626	150.17091	GWL(2), GWT(2), GH, WT, STP, SWC, other
ESGFA104-10	Groundwater	62.38402	150.15125	GWL(2), GWT(2), GH, WT, STP(2)

Table 4.5-4 continued. Groundwater Study primary purpose, location and parameters for data collection stations at FA-104 (Whiskers Slough).

Station Short Names	Station Primary Purpose	Latitude	Longitude	Data Collection Parameters
ESGFA104-11	Groundwater	62.37622	150.16996	GWL, GWT
ESGFA104-12	Groundwater	62.37622	150.16996	GWL, GWT
ESGFA104-13	Groundwater	62.37824	150.17100	GWL, GWT
ESCFA104-16	Camera	62.37457	150.16850	Cam
ESCFA104-17	Camera	62.37676	150.17157	Cam
ESCFA104-18	Camera	62.37943	150.16961	Cam
ESCFA104-19	Camera	62.37986	150.16679	Cam
ESCFA104-20	Camera	62.38351	150.15477	Cam
ESCFA104-21	Camera	62.38388	150.15211	Cam
ESCFA104-22	Camera	62.38180	150.16376	Cam

Table 4.5-5. Groundwater Study Focus Area time-lapse camera locations and intended study applications.

Station Short Names	Station Primary Purpose	Date Installed	Latitude	Longitude	Data Collection Applications								
					Aquatic Transect	Riparian Transect	Inlet/Outlet	Main Channel	Side Channel	Slough/Stream	Leaf-out/Leaf-off Timing	Ice Processes	Near-Real-Time Access
FA-138 (Gold Creek)													
ESCFA138-8	Camera	11/6/13	62.75268	149.70792			X			X	X	X	
ESCFA138-9	Camera	11/6/13	62.75686	149.70529	X					X	X	X	
ESCFA138-10	Camera	11/6/13	62.76477	149.70522	X		X	X	X		X	X	
ESCFA138-11	Camera	11/6/13	62.76770	149.70755		X		X			X	X	
FA-128 (Slough 8A)													
ESSFA128-1	Surface Water		62.66384	149.90494					X	X	X	X	X
ESCFA128-29	Camera	9/29/13	62.67251	149.88567			X		X		X	X	
ESCFA128-30	Camera	9/29/13	62.66804	149.88652						X	X	X	
ESCFA128-31	Camera	10/25/13	62.66549	149.89812	X					X	X	X	
ESCFA128-32	Camera	10/25/13	62.66754	149.89376		X					X		
ESCFA128-33	Camera	9/29/13	62.67179	149.89376		X					X		
ESCFA128-34	Camera	11/3/13	62.66719	149.91216		X	X	X	X		X	X	
ESCFA128-35	Camera	9/24/13	62.66307	149.91039	X	X				X	X	X	
ESCFA128-36	Camera	11/3/13	62.66167	149.91676			X		X	X	X	X	

Table 4.5-5 continued. Groundwater Study Focus Area time-lapse camera locations and intended study applications.

Station Short Names	Station Primary Purpose	Date Installed	Latitude	Longitude	Data Collection Applications								
					Aquatic Transect	Riparian Transect	Inlet/Outlet	Main Channel	Side Channel	Slough/Stream	Leaf-out/Leaf-off Timing	Ice Processes	Near-Real-Time Access
FA-115 (Slough 6A)													
ESCFA115-11	Camera	11/3/13	62.51933	150.13072		X				X	X	X	
ESCFA115-12	Camera	11/3/13	62.51896	150.12046		X			X		X	X	
ESCFA115-13	Camera	11/2/13	62.51507	150.12476						X	X	X	
ESCFA115-14	Camera	11/2/13	62.51357	150.12182			X		X	X	X	X	
FA-113 (Oxbow 1)													
ESCFA113-2	Camera	11/2/13	62.49253	150.10396			X	X	X		X	X	
ESCFA113-3	Camera	10/31/13	62.48663	150.09798			X	X	X		X	X	
ESCFA113-4	Camera	10/31/13	62.48896	150.10530	X				X	X	X	X	

Table 4.5-5 continued. Groundwater Study Focus Area time-lapse camera locations and intended study applications.

Station Short Names	Station Primary Purpose	Date Installed	Latitude	Longitude	Data Collection Applications								
					Aquatic Transect	Riparian Transect	Inlet/Outlet	Main Channel	Side Channel	Slough/Stream	Leaf-out/Leaf-off Timing	Ice Processes	Near-Real-Time Access
FA-104 (Whiskers Slough)													
ESSFA104-1	Surface Water		62.37676	150.16934			X			X	X	X	X
ESCFA104-16	Camera	10/31/13	62.37457	150.16850			X		X	X	X	X	
ESCFA104-17	Camera	10/31/13	62.37676	150.17157						X	X	X	
ESCFA104-18	Camera	10/31/13	62.37943	150.16961						X	X	X	
ESCFA104-19	Camera	10/31/13	62.37986	150.16679			X		X	X	X	X	
ESCFA104-20	Camera	10/31/13	62.38351	150.15477					X		X	X	
ESCFA104-21	Camera	10/31/13	62.38388	150.15211	X			X	X		X	X	
ESCFA104-22	Camera	10/31/13	62.38180	150.16376			X		X	X	X	X	
Lower River Study Sections													
ESGLR1-1	Groundwater	10/06/13	62.25163	150.14323		X			X		X	X	
ESGLR2-1	Groundwater	10/12/13	61.94988	150.11497		X			X		X	X	
ESGLR3-1	Groundwater	10/06/13	61.77883	150.19319		X			X		X	X	
ESGLR4-1	Groundwater	10/12/13	61.62188	150.36803		X		X	X		X	X	
ESGLR4-2	Groundwater	10/12/13	61.62126	150.35319		X			X		X	X	

Table 4.5-6. Processes, data collection parameters and associated sensors that will be used for the Groundwater Study at selected Focus Areas.

Process	Parameter	Sensor Type
Surface-water stage fluctuation	Pressure – calculated water levels	CSI CS 451 pressure transducer INW PT2x vented pressure transducer
Surface-water quality	Temperature	CSI CS 451 pressure transducer INW PT12, PT2x vented pressure transducer
Groundwater level fluctuation	Pressure – calculated water levels	CSI CS 451 pressure transducer INW PT12, PT2x vented pressure transducer
Groundwater quality, GW/SW exchange and mixing	Temperature	CSI CS 451 pressure transducer INW PT12, PT2x vented pressure transducer
GW/SW Interaction, Water Quality	Conductivity	CSI CS457 Water conductivity and temperature sensor
Active-layer freezing and thawing Groundwater recharge	Resistance – calculated temperature	GWS-YSI vertical thermistor strings
GW/SW Fluxes Into/Out-of Streambeds (Downwelling/Upwelling)	Resistance – calculated temperature	GWS-YSI vertical thermistor strings
Active-layer freezing and thawing, Moisture availability, root-zone moisture dynamics Groundwater recharge	Unfrozen volumetric moisture content (%)	CSI CS650 soil-moisture sensors
Evapotranspiration	Air temperature, Relative Humidity	CSI HC2S3 AT/RH sensor
Evapotranspiration	Wind Speed, Direction	RM Young 05103 WS/WD sensor
Evapotranspiration	Solar Radiation, Net Radiation	Kipp and Zonen NR Lite2 Net Radiometer and LiCor LI200 pyranometer
Evapotranspiration	Soil-surface temperature	GWS-YSI thermistor
Evapotranspiration	Barometric Pressure	CS100 Setra 278 sensor
Evapotranspiration Recharge	Precipitation (shielded)	TI 525-US tipping bucket rain gage
Soil Thermal Energy Balance	Soil Heat Flux	HFP01SC Self-Calibrating Soil Heat Flux Plate
Plant transpiration	Delta-Temperature	DI – Dynagage and TDP sensors and sap flow algorithms

10. FIGURES

[See separate file(s) for figures.]

APPENDIX A: EXAMPLE 1970 AND 2011 FOCUS AREA IMAGERY

[See separate file for Appendix.]

APPENDIX B: DATA-COLLECTION STATION METADATA EXAMPLES

[See separate file for Appendix.]

APPENDIX C: DATA-COLLECTION STATION PROGRAMS AND WIRING DIAGRAM EXAMPLES

[See separate file for Appendix.]

APPENDIX D: SELECTED FOCUS AREA TIME-LAPSE PHOTO EXAMPLES

[See separate file for Appendix.]

APPENDIX E: LEVEL-LOOP SURVEY AND SURVEY CONTROL POINTS EXAMPLES

[See separate file for Appendix.]