Susitna-Watana Hydroelectric Project Document
ARLIS Uniform Cover Page

Title: Groundwater study, Study plan Section 7.5, 2014-2015 Study Implementation Report	**SuWa 289**
Author(s) – Personal:	
Author(s) – Corporate: R2 Resource Consultants, Inc. ; Geo-Watershed Scientific ; Pacific Groundwater Group.	
AEA-identified category, if specified: November 2015; Study Completion and 2014/2015 Implementation Reports	
AEA-identified series, if specified:	
Series (ARLIS-assigned report number): Susitna-Watana Hydroelectric Project document number 289	**Existing numbers on document:**
Published by: [Anchorage : Alaska Energy Authority, 2015]	**Date published:** *Main report and Appendices A and C:* November 2015 *Appendices B and D:* October 2015
Published for: Alaska Energy Authority	**Date or date range of report:**
Volume and/or Part numbers: Study plan Section 7.5	**Final or Draft status, as indicated:**
Document type:	**Pagination:** 310 pages total in 5 volumes
Related work(s):	**Pages added/changed by ARLIS:**

Notes:

Contents:

- 2014-2015 Study Implementation Report
- Appendix A. Preliminary water table contour maps for Focus Areas FA-104 (Whiskers Slough), FA-115 (Slough 6A), FA-128 (Slough 8A), and FA-138 (Gold Creek) / prepared by Pacific Groundwater Group
- Appendix B. Preliminary MODFLOW three dimensional groundwater model for FA-128 (Slough 8A) / prepared by Pacific Groundwater Group
- Appendix C. Summary review of Susitna River hydrogeologic studies conducted in the 1980s with relevance to proposed Susitna-Watana Dam Project and other non-Project related studies / prepared by Pacific Groundwater Group
- Appendix D. December 5, 2014 Technical Team Meeting notes and presentation / prepared by Geo-Watershed Scientific.

The main report and each appendix of Section 7.5 appear in separate electronic files.

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Groundwater Study
Study Plan Section 7.5

2014-2015 Study Implementation Report

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

R2 Resource Consultants, Inc.
Geo-Watershed Scientific
Pacific Groundwater Group

November 2015

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

LIST OF ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

Abbreviation	Definition
AEA	Alaska Energy Authority
ARLIS	Alaska Resources Library and Information Services
ASTM	American Society for Testing and Materials
cfs	cubic feet per second
FA	Focus Area
FDAML	Fish Distribution and Abundance in the Middle and Lower River Study (Study 9.6)
FERC	Federal Energy Regulatory Commission
ft	feet
GINA	Geographic Information Network of Alaska
GW	Groundwater
GWS	Geo-Watersheds Scientific
HSC	Habitat Suitability Criteria
HSI	Habitat Suitability Index
IFS	Instream Flow Study (Study 8.5)
ILP	Integrated Licensing Process
ISR	Initial Study Report
OWFRM	Open-water Flow Routing Model
PHABSIM	Physical Habitat Simulation
PRM	Project River Mile
QC	Quality Control
RIFS	Riparian Instream Flow Study (Study 8.6)
RSP	Revised Study Plan
SIR	Study Implementation Report
SPD	Study Plan Determination
SW	Surface Water
TIR	Thermal Infrared
TM	Technical Memorandum
USGS	United States Geological Survey

1. INTRODUCTION

This Groundwater (GW) Study, Section 7.5 of the Revised Study Plan (RSP) (AEA 2012) approved by the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project, FERC Project No. 14241, focuses on providing an overall understanding of Groundwater (GW)/Surface Water (SW) interactions at both the watershed- and local-scales. This understanding will be used in evaluating Project operational effects on GW/SW interactions and resulting effects on riparian and aquatic habitats.

A summary of the development of this study, together with the Alaska Energy Authority's (AEA) implementation of it through the 2013 study season, appears in Part A, Section 1 of the Initial Study Report (ISR) filed with the FERC in June 2014 (AEA 2014). As required under the FERC's regulations for the Integrated Licensing Process (ILP), the ISR describes AEA's "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)).

Since filing the ISR in June 2014, AEA has continued to implement the FERC-approved Study Plan for the GW Study. For example:

- Data collection has continued via a combination of telemetered wells, self-logging temperature and water level recorders and remote cameras, In addition, quality control (QC) checks of existing data have continued resulting in QC3 level data being made available to other resource users. The QC3 analysis was on data (water levels, water temperature, geotechnical and/or water-surface elevations) that were downloaded in 2014 from manual and telemetered installations as well as telemetered data received up through July 31, 2015.
- Two Technical Memoranda were prepared and submitted in September 2014 that presented results of preliminary GW/SW analysis related to GW Study Objective 5 that pertains to the Riparian Instream Flow Study (RIFS) (Study 8.6) and GW Study Objective 6 that pertains to the Fish and Aquatics Instream Flow Study (IFS) (Study 8.5). These included the following:
    - Groundwater and Surface-Water Relationships in Support of Riparian Vegetation Modeling – Technical Memorandum submitted to the FERC September 30, 2014 (GWS and R2 2014a)
    - Preliminary Groundwater and Surface-Water Relationships in Lateral Aquatic Habitats within Focus Areas FA-128 (Slough 8A) and FA-138 (Gold Creek) in the Middle Susitna River – Technical Memorandum submitted to the FERC September 30, 2014 (GWS and R2 2014b)
- Three technical reports have been prepared and are included as appendices to this Study Implementation Report (SIR). Two of the reports describe further analysis of GW data including development of a series of water table maps for respective Focus Areas, and development and application of a preliminary MODFLOW GW model for FA-128 (Slough 8A). The third report provides a literature review of the 1980s GW studies and some

additional contemporary relevant information pertaining to GW/SW interactions. The appendices include:

- Appendix A – Preliminary Water Table Contour Maps for Focus Areas FA-104, FA-115, FA-128, and FA-138, submitted to the FERC November 2015 (PGG 2015a)
- Appendix B – Preliminary MODFLOW Three Dimensional Groundwater Model for Focus Area FA-128 (Slough 8A), submitted to the FERC November 2015 (PGG 2015b)
- Appendix C – Summary Review of Susitna River Hydrogeologic Studies Conducted in the 1980s and other Non-Project Related Studies with Relevance to Proposed Susitna-Watana Dam Project, submitted to the FERC November 2015 (PGG 2015c)

- On December 5, 2014 AEA held a Groundwater Study Technical Team Meeting to discuss and solicit questions from Licensing Participants regarding the October 2014 ISR meetings and on the two September 2014 TMs noted above. A meeting summary was subsequently prepared and made available to the Licensing Participants on AEA's public website. A copy of the presentation materials and the meeting summary are included in this SIR Study 7.5, Appendix D (GWS 2015).

In furtherance of the next round of ISR meetings and the FERC Director's Study Determination expected in 2016, this SIR describes AEA's overall progress in implementing the GW Study through the end of calendar year 2014 and up through and including the submittal of this SIR in 2015. The SIR is not intended to provide a comprehensive reporting of all field work, data collection, and data analysis since the beginning of AEA's study program, but rather to provide an update of information presented in ISR Part A for the GW Study. The SIR and its appendices describe the methods and results of these efforts, and discuss the results in terms of the nine stated objectives of the GW Study (Study 7.5). Although each of the nine objectives are included in the SIR, only those for which substantial work was completed are discussed in detail.

2. STUDY OBJECTIVES

The nine study objectives of the GW Study (Study 7.5) as established in RSP Section 7.5.1 are as follows:

1. Synthesize historical and contemporary GW data available for the Susitna River GW and GW dependent aquatic and floodplain habitat, including that from the 1980s and other studies including reviews of GW/SW interactions in cold regions (RSP Section 7.5.4.1.1).
2. Use the available GW data to characterize large-scale geohydrologic process-domains/terrain of the Susitna River (e.g., geology, topography, geomorphology, regional aquifers, shallow GW aquifers, GW/SW interactions) (RSP Section 7.5.4.1.2).
3. Assess the potential effects of Watana Dam/Reservoir on GW and GW-influenced aquatic habitats in the vicinity of the proposed dam (RSP Section 7.5.4.2).

4. Work with other resource studies to map GW-influenced aquatic and floodplain habitat (e.g., upwelling areas, springs, GW-dependent wetlands) within the Middle River Segment of the Susitna River including within selected Focus Areas (IFS Study 8.5) (RSP Section 7.5.4.3).
5. Determine the GW/SW relationships of floodplain shallow alluvial aquifers within selected Focus Areas as part of the RIFS (Study 8.6) (RSP Section 7.5.4.4).
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 IFS (Study 8.5) (RSP Section 7.5.4.5).
7. Characterize water quality (e.g., temperature, dissolved oxygen, conductivity) of selected upwelling areas that provide biological cues for fish spawning and juvenile rearing, in Focus Areas as part of the IFS (Study 8.5) (RSP Section 7.5.4.6).
8. Characterize the winter flow in the Susitna River and how it relates to GW/SW interactions (RSP Section 7.5.4.7).
9. Characterize the relationship between the Susitna River flow regime and shallow GW users (e.g., domestic wells) (RSP Section 7.5.4.8).

3. STUDY AREA

As established by RSP Section 7.5.3, the study area related to GW processes includes primarily the Middle River Segment of the Susitna River that extends from Project River Mile (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 Segment, and the lower most portion of the Upper River Segment near the proposed dam site associated with potential GW 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 Program (Studies 8.5 and 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 (OWFRM) in Q1 2013, the study areas for the riparian studies, including the riparian vegetation study, was extended to PRM 29.9. This increase in RIFS activities in the Lower River Segment was supported by the GW Study.

4. METHODS

The GW Study is divided into nine study components related to the study objectives outlined in Section 2 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 GW users. Each of the components and its related study methods have been explained in ISR Part A, Study 7.5 Section 4. This section provides an update of activities related to each of the objectives that have occurred

since the June 2014 ISR. Only objectives for which work has been completed since June 2014 are discussed in detail; others are cross-referenced back to the methods in the ISR.

4.1. Existing Data Synthesis

Since the June 2014 ISR, AEA has completed the review of literature and prepared a document that summarizes the information in Appendix C. For this, the Alaska Resources Library and Information Services (ARLIS) database was queried for reports for the Susitna River prior to the ongoing studies. The terms Susitna hydrogeology, geohydrology, hydrology, geology, and ice were searched, with the subject terms chosen with the intent of identifying reports likely to contain data relating to the following five hydrogeologic concepts/properties that are important for understanding GW/SW interactions within the Susitna River:

- Aquifer extent and thickness
- Aquifer properties (transmissivity, hydraulic conductivity, and storage)
- Horizontal GW gradients and flow direction
- Nature and extent of vertical GW gradients along the Susitna River
- Groundwater and SW interactions within the Susitna River valley

A total of 278 document matches were obtained from ARLIS, and documents that were electronically available and had potentially relevant titles were downloaded. Report table of contents were then reviewed to assess if relevant hydrogeologic data were likely present in the report. If relevant data appeared to be present, sections of the report with hydrogeologic data were reviewed. In some instances older reports were superseded by younger reports (as in the case of draft and final reports, or seasonal/single year data reports versus multi-year reports with an overlapping timespan), and in these cases the more recent reports were reviewed. The information obtained from ARLIS was supplemented via targeted Internet searches for studies concerned with evaluating changes to GW/SW interactions due to hydroelectric developments in cold regions. The information obtained from the review and preparation of the literature review document (Appendix C) is expected to benefit current and future GW studies by compiling existing hydrogeologic data (or reference to it) within one document and highlighting previous studies that current resource investigators may be unaware of.

4.1.1. Variances

AEA implemented the methods as described in the Study Plan with no variances. With the preparation of the Summary Review of Susitna River Hydrogeologic Studies Conducted in the 1980s and other Non-Project Related Studies with Relevance to Proposed Susitna-Watana Dam Project presented as Appendix C to this SIR, the objective of this particular component of the GW study has been met.

4.2. Geohydrologic Process-Domains

As described in ISR Study 7.5, Section 4.2, AEA implemented the methods associated with this study element in accordance with the Study Plan. However, there has been no substantive activity on this element since completion of the June 2014 ISR.

4.2.1. Variances

AEA implemented the methods as described in the Study Plan with exception of the variance mentioned in ISR Study 7.5, Section 4.2.1 regarding the schedule:

- The schedule for completion of the mapping of geohydrologic units and associated analysis will be completed once all of the necessary information has been assembled and reviewed.

4.3. Watana Dam/Reservoir

As described in ISR Study 7.5, Section 4.3, AEA implemented the methods associated with this study element in accordance with the Study Plan. There has been no substantive GW specific activity on this element since completion of the June 2014 ISR. However, AEA has continued Project Engineering Feasibility Studies Geotechnical Investigations, and the Geology and Soils Characterization Study (Study 4.5) since the June 2014 ISR; (see SIR Study 4.5 for description of work). Results of those investigations will be used in part to evaluate the GW conditions in the Project area and evaluate the potential for GW impacts downstream of the dam.

4.3.1. Variances

AEA implemented the methods as described in the Study Plan with no variances.

4.4. Upwelling / Springs Broad-Scale Mapping

AEA implemented the methods as described in the Study Plan with no variances. Since completion of the June 2014 ISR, the primary activity on this element has been associated with the differentiation of upwelling areas within FA-128 (Slough 8A) into three categories: Riverine Dominated, Riverine – Upland Transitional, and Upland Dominated. These categories were derived from a combination of data sources that included photographs taken during the winter that depicted areas of open-water leads, aerial photography and aerial videography of the ice-free period showing turbid and clear water habitats, and thermal infrared imagery (TIR) collected in October 2012 and October 2013 (see ISR Study 5.5, Appendix J, TIR Images submitted to the FERC June 3, 2014 [Tetra Tech 2014] for detailed results of the TIR mapping).

AEA is applying the same general process for identifying GW areas throughout the entire Middle River Segment of the Susitna River. Results of that analysis will be available at the end of 2015.

4.4.1. Variances

AEA implemented the methods as described in the Study Plan with no variances.

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

AEA implemented the methods as described in the Study Plan and further detailed in the ISR (ISR Study 7.5, Section 4.5), with the exception of variances described below (Section 4.5.1). Since the June 2014 ISR, AEA has completed the following GW related activities associated with meeting this objective: preparation and submittal of a Technical Memorandum (TM) describing

preliminary analysis of GW/SW interactions supportive of the RIFS (Study 8.6) (GWS and R2 2014a), completion of a Technical Team Meeting as a follow-up to questions raised during the October 2014 ISR meeting (Appendix D), development of a preliminary MODFLOW GW model for FA-128 (Slough 8A) (Appendix B), development of a time-series of water table maps for selected Focus Areas (Appendix A), and the continued collection of data from within selected Focus Areas as well as at selected locations in the Lower River Segment. These activities are described further below.

4.5.1. Preparation and Submittal of Technical Memorandum – GW/SW Relationships to Support Riparian Vegetation Modeling

Since the June 2014 ISR, AEA completed a preliminary analysis of 2013 and 2014 data to illustrate GW/SW relationships within various Focus Areas and their influence on riparian vegetation. The results of the analysis were presented in a TM (GWS and R2 2014a) and discussed in part during a Technical Team Meeting on December 5, 2014 (Section 4.5.3). The TM provided a status update concerning general 2014 GW/SW data collection activities in support of RIFS, and presented GW/SW analyses and results using FA-115 (Slough 6A) as a primary example, with additional analyses presented for FA-128 (Slough 8A) and FA-138 (Gold Creek).

4.5.2. Groundwater Technical Team Meeting

On December 5, 2014, AEA convened a Groundwater Technical Team Meeting as a follow-up to the October 2014 ISR meetings. The meeting served to address a variety of questions raised during the ISR meeting related to the overall GW Study, and included a discussion of the TM noted above. The presentation materials and meeting notes associated with the meeting are included as Appendix D to this SIR.

4.5.3. Preliminary Three-dimensional MODFLOW Model for FA-128 (Slough 8A)

Since the June 2014 ISR, AEA has developed a preliminary three dimensional MODFLOW model (MODFLOW) for FA-128 (Slough 8A) following the methods specified in the GW Study Plan (RSP Section 7.5.4.4). Selection of FA-128 for model development was consistent with earlier resource studies that utilized FA-128 as part of the Proof of Concept demonstrations (ISR Study 8.5, Appendix N, Middle River Fish Habitat and Riverine Modeling Proof of Concept submitted to the FERC June 3, 2014 [R2 2014a]) Model code selection and calibration procedures followed American Society for Testing and Materials (ASTM) standard D6170 (ASTM 2010) and D5981 (ASTM 2008) respectively. Specified snowmelt runoff stage-change events from the 2014 monitoring period were used to develop and perform preliminary model calibrations and to demonstrate evaluations of GW/SW interactions critical for riparian and aquatic habitat. The MODFLOW model was designed and calibrated to data collected from field stations within FA-128 (Slough 8A) during 2014 (Figure 4.5-1).

The total domain of the model covers approximately 18.2 square miles, with the active part of the domain representing the alluvial aquifer within the Susitna River floodplain from approximately PRM 126.4 to 131.7 (Figure 4.5-2). Focus Area FA-128 (Slough 8A) extends from PRM 128.1 to 129.7; however, the model was extended another 1.5 miles upgradient and 1.5 miles downgradient of the upper and lower boundaries of the Focus Area to set far field general head boundary

conditions that would not influence the result of the simulation in the Focus Area. The model domain also extends about 1.5 miles to the northwest and 1.5 miles to the southeast beyond the Susitna River floodplain towards local topographic divides. Although this area of the model is currently inactive, the extension of the domain to beyond the Susitna River floodplain will allow for the future simulation of the regional GW flow system if/when data become available. The active model domain (simulated alluvial aquifer within the Susitna River floodplain from PRM 126.4 to 131.7) covers approximately 3.3 square miles.

The preliminary MODFLOW model includes both a steady state and a transient model. The steady state model was developed first to simulate average "baseflow" conditions (i.e., when little flooding is occurring in the Susitna River and side channels are predominantly fed by GW). Calibration of the steady state model was performed by adjusting aquifer parameters to best match target GW elevations measured in FA-128 (Slough 8A). The solution to the steady state model was then used as the initial GW condition at the start of the transient model. The transient model was developed to simulate a time-varying flooding event during the 2014 period and associated changes in GW gradients and fluxes. The transient model was run, and compared to observed aquifer responses. Some limited transient calibration was achieved by varying the aquifer storage coefficient term but additional calibration efforts will be needed to further test model performance and make adjustments once additional data are incorporated into the model. The transient simulation only involved changing the model river stages during discrete stress periods in the simulation. All other model parameter values were held constant. Details regarding the calibration and preliminary outputs of the MODFLOW model are presented in Section 5.4; the model is fully described in Appendix B.

4.5.4. Water Table Maps

AEA has also prepared a time series of water table maps for four Focus Areas (FA-104 [Whiskers Slough], FA-115 [Slough 6A], FA-128 [Slough 8A], and FA-138 [Gold Creek]), that depict GW elevations under different seasonal flow conditions. Example maps for each of these areas for a single time period were presented and discussed during the December 5, 2014 Technical Team Meeting (Appendix D) and proved useful for spatially depicting GW levels over the entire Focus Area and for potentially differentiating riverine versus upland dominated categories of GW. To expand that analysis, a total of six maps corresponding to six different time periods were developed for FA-104 (Whiskers Slough) and FA-128 (Slough 8A), three maps corresponding to three time periods were developed for FA-138 (Gold Creek), and two maps corresponding to two periods were developed for FA-115 (Slough 6A). The time periods were selected to be representative of conditions during the Fall (September 13, 2013), Late Fall (October 9, 2013), Ice Cover/Ice Jam (February 20, 2014), Pre-breakup (April 20, 2014), Post-breakup (July 11, 2014), and Summer (August 13, 2014) conditions.

The number of maps developed for each Focus Area was based in part on the availability of GW data from the respective network of wells within each area, and the relative number of time steps needed to evaluate important biological functions occurring in each. For example, both FA-104 (Whiskers Slough) and FA-128 (Slough 8A) support important fish life history functions on a year-round basis including spawning (Fall and Late Fall), egg incubation and overwintering juvenile rearing (Late Fall, Ice Cover/Ice Jam, Pre-breakup), and fry emergence, juvenile rearing, and smolt outmigration (Post-breakup and Summer). In comparison, FA-115 (Slough 6A) contains primarily

juvenile rearing habitat which can be limiting during the Late Fall (low flow) and Post-breakup (relatively high flow) periods.

Selection of representative dates for the open-water periods was based on a review of flow records for United States Geological Survey (USGS) Gage on the Susitna River at Gold Creek (Gage No. 15292000). The Post-breakup and Fall dates represent higher flows and the Late Fall and Summer dates represent relatively low flows. The date selected for Summer conditions included diurnal glacial melt fluctuations. Selection of dates during the ice covered period was based on a review of discharge measurements during those periods that coincided with GW well data. The Ice Cover/Ice Jam date coincided with development of an ice jam and flooding of lateral habitats within FA-128 (Slough 8A); the Pre-breakup date represented a relatively low flow under ice condition. The specific dates selected for the respective Focus Areas are depicted in Table 4.5-1.

4.5.5. Continuation of Data Collection and QC3 Data Review

Groundwater related data have continued to be collected via a combination of telemetered wells, self-logging temperature and water level recorders placed in non-telemetered wells, and remote time-lapse cameras. These data are being collected within Focus Areas FA-104 (Whiskers Slough) (ISR Study 7.5, Figure 4.5-6), FA-113 (Oxbow 1) (ISR Study 7.5, Figure 4.5-5), FA-115 (Slough 6A) (ISR Study 7.5, Figure 4.5-4), FA-128 (Slough 8A) (ISR Study 7.5, Figure 4.5-3), and FA-138 (Gold Creek) (ISR Study 7.5, Figure 4.5-2), as well as within five stations in the Lower River Segment (ISR Study 7.5, Figures 4.5-8 through 4.5-11) that were established to support the RIFS (Study 8.6).

Some of the recording stations have been damaged due to high flows and debris, ice flows and ice jacking and have stopped recording/reporting. AEA has conducted a review and evaluation of the damaged stations and has completed a field operation to remove damaged equipment and equipment no longer needed (i.e., equipment that was installed to support data collection tasks that are complete – e.g., sap flow meters), and to service and repair high priority stations. Table 4.5-2 has been adapted from the ISR Study 7.5, Tables 4.5-1 to 4.5-4 to provide a listing and a current status report of all of the stations previously installed to support this objective.

In addition to data collection, AEA has continued the data Quality Assurance/Quality Control (QA/QC) review process resulting in QC3 level data being made available to other resource users. The QC analysis was completed on data (water levels, water temperature, geotechnical and/or water-surface elevations) that have been downloaded in 2014 from manual and telemetered installations as well as telemetered data received up through July 31, 2015 whose values were consistent with prior data from the same stations (i.e., indicating no station impairment). Table 4.5-3 summarizes the overall status of QC3 data that have been delivered to Geographic Information Network of Alaska (GINA) and are publically available.

4.5.6. Variances

AEA implemented the methods as described in the Study Plan with the exception of a variance related to the schedule for development of GW models that was noted in the June 2014 ISR (Study 7.5, Section 4.5.1). However, since then a preliminary MODFLOW GW model has been developed for FA-128 (Slough 8A) and is described in Appendix B. The model has been structured

to allow its integration with other resource models and will be applicable for evaluating Project operational effects on GW/SW relationships within Focus Areas. Importantly, the methods and techniques utilized in development of the MODFLOW model for FA-128 (Slough 8A) can be applied in the development of MODFLOW models at other Focus Areas including FA-104 (Whiskers Slough), FA-115 (Slough 6A), and FA-138 (Gold Creek). Since the June 2014 ISR, a series of water table maps have also been developed for FA-104 (Whiskers Slough), FA-115 (Slough 6A), FA-128 (Slough 8A), and FA-138 (Gold Creek). The water table maps will be useful for spatially depicting GW levels and identifying areas of potential model parameter heterogeneity in areas with sufficient well density.

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 IFS (Study 8.5). Since the June 2014 ISR, AEA has completed the following GW related activities associated with meeting this objective: preparation and submittal of a TM describing preliminary analysis of GW/SW interactions supportive of the IFS (Study 8.5) (GWS and R2 2014b); completion of a Technical Team Meeting on December 5, 2014 as a follow-up to questions raised during the October 2014 ISR meeting (Appendix D); development of a preliminary MODFLOW GW model for FA-128 (Slough 8A) (Appendix B); development of a time-series of water table maps for selected Focus Areas (Appendix A); and the continued collection of data from within selected Focus Areas as well as at selected locations in the Lower River Segment. These activities are described further below.

4.6.1. Preparation and Submittal of Technical Memorandum – GW/SW Relationships in Lateral Aquatic Habitats

Since the June 2014 ISR, AEA completed a preliminary analysis of 2013 and 2014 data to illustrate GW/SW relationships within various Focus Areas and their influence on lateral aquatic habitats. The results of the analysis were presented in a TM (GWS and R2 2014b) and discussed in part during a Technical Team Meeting on December 5, 2014 (Section 4.5.3). The TM provided a status update concerning general 2014 GW/SW data collection activities in support of the IFS (Study 8.5), and presented GW/SW analyses and results using FA-128 (Slough 8A) as a primary example, with additional analyses presented for FA-138 (Gold Creek).

4.6.2. Groundwater Technical Team Meeting

On December 5, 2014, AEA convened a Groundwater Technical Team Meeting as a follow-up to the October 2014 ISR meetings. The meeting served to address a variety of questions raised during the ISR meeting related to the overall GW Study, and included a discussion of the TM noted above. The presentation materials and meeting notes associated with the meeting are included as Appendix D to this SIR.

4.6.3. Preliminary Three-dimensional MODFLOW Model for FA-128

As described in Section 4.5.3 above, since the June 2014 ISR, AEA has developed a preliminary three dimensional MODFLOW model (MODFLOW) for FA-128 (Slough 8A) following the methods specified in the GW Study Plan (RSP Section 7.5.4.4). Selection of FA-128 for model development was consistent with earlier resource studies that utilized FA-128 as part of the Proof of Concept demonstrations (ISR Study 8.5, Appendix N [R2 2014a]). Development of the MODFLOW GW model for FA-128 will be particularly important for evaluating Project effects on important GW upwelling areas that are biologically significant for spawning and egg incubation. Output from the MODFLOW model can be linked with the PHABSIM 2D Habitat Models that have incorporated "Upwelling" as one of the metrics in the Habitat Suitability Criteria (HSC) (SIR Study 8.5, Section 4.5 and Appendix D) for evaluating Project operational effects on spawning and incubation habitats. Specifically, GW response functions can be developed from the MODFLOW output as analytical expressions which can be used to quantify the predicted changes in GW fluxes due to different scenarios of project operations. Project induced changes to GW temperatures that are important for overwintering egg incubation can also be evaluated with model output but will require additional model refinement.

Details regarding the development, calibration and preliminary outputs of the MODFLOW model are presented in Appendix B.

4.6.4. Water Table Maps

AEA also prepared a time series of water table maps for four Focus Areas FA-104 (Whiskers Slough), FA-115 (Slough 6A), FA-128 (Slough 8A), and FA-138 (Gold Creek) that depict GW elevations under different seasonal flow conditions. As described in Section 4.5.4, a total of six maps corresponding to six different time periods were developed for FA-104 (Whiskers Slough) and FA-128 (Slough 8A), three maps corresponding to three time periods were developed for FA-138 (Gold Creek), and two maps corresponding to two periods were developed for FA-115 (Slough 6A). The time periods were selected to be representative of conditions during the Fall (September 13, 2013), Late Fall (October 9, 2013), Ice Cover/Ice Jam (February 20, 2014), Pre-breakup (April 20, 2014), Post-breakup (July 11, 2014), and Summer (August 13, 2014) conditions. The water table maps will be important for evaluating changes in GW levels under different river stage conditions within important fish habitats in the lateral margins of the Susitna River including side channels, side sloughs and upland sloughs.

4.6.5. Continuation of Data Collection and QC3 Data Review

As noted in Section 4.5.5, GW related data have continued to be collected via a combination of telemetered wells, self-logging temperature and water level recorders placed in non-telemetered wells, and remote time-lapse cameras.

In addition, AEA collected a series of discharge measurements over a five day period in September (September 23-27, 2014) within various lateral habitats and at tributary mouths in seven Focus Areas, including FA-104 (Whiskers Slough), FA-115 (Slough 6A), FA-128 (Slough 8A), FA-138 (Gold Creek), FA-141 (Indian River) and FA-144 (Slough 21). These measurements were conducted as part of a joint effort between the IFS (Study 8.5) and Geomorphology Modeling

(Study 6.6) and were designed to occur during a relatively low-flow period in the Susitna River. Flows in the Susitna River as measured at the Gold Creek Gage (No. 15292000) ranged from around 17,000 cubic feet per second (cfs) on September 23 to 12,500 cfs on September 27. The discharge measurements provided data that will be useful for refining the distribution of flows within the respective channels in the SRH-2D model grid, and also for understanding GW contributions. Additional details concerning this data collection effort are presented in the Geomorphology Modeling (Study 6.6) SIR in Section 5.1.2.4.

In addition to data collection, AEA has continued the data QA/QC review process resulting in QC3 level data being made available to other resource users.

4.6.6. Variances

AEA implemented the methods as described in the Study Plan with the exception of a variance related to the schedule for development of GW models that was noted in the June 2014 ISR (Study 7.5, Section 4.5.1). However, since then a preliminary MODFLOW GW model has been developed for FA-128 (Slough 8A) and is described in Appendix B. The model has been structured to allow its integration with other resource models and will be applicable for evaluating Project operational effects on GW/SW relationships within Focus Areas. Importantly, the methods and techniques utilized in development of the MODFLOW model for FA-128 can be applied in the development of MODFLOW models at other Focus Areas including FA-104 (Whiskers Slough), FA-115 (Slough 6A), and FA-138 (Gold Creek).

4.7. Water Quality in Selected Habitats

AEA implemented the methods as described in the Study Plan and ISR Study 7.5, Section 4.7, ISR Study 5.5, Section 4.4.2 and ISR Study 8.5, Sections 4.5.1.5, 4.5.1.6 and 4.5.1.10. The overall objective of this work was to evaluate water quality characteristics within areas that may be influenced by GW and that are known to be biologically important for fish (e.g., spawning and incubation). Since the June 2014 ISR, AEA has completed several tasks to meet this objective.

First, as part of Study 8.5 and in response to the FERC Study Plan Determination (SPD) (Pages B-84-B-86 of April 1, 2013 SPD [FERC 2013]), AEA completed a detailed evaluation of the relationship between fish abundance and specific microhabitat variables that included several water quality parameters (water temperature, dissolved oxygen, pH, alkalinity, macronutrients, dissolved organic carbon, as well as surface-groundwater exchange flux) and reported results in a TM titled Evaluation of Relationships between Fish Abundance and Specific Microhabitat Variables, submitted to the FERC September 17, 2014 (R2 2014b). AEA has also, as part of Study 8.5 HSC analysis (ISR Study 8.5, Section 4.5), continued the collection and analysis of ancillary water quality data (dissolved oxygen, water temperature and conductivity) from SW locations some of which are influenced by GW upwelling, and from continuous temperature (surface and intergravel) and dissolved oxygen (intergravel) recorders placed in Focus Areas with known spawning activity (FA-104 [Whiskers Slough], FA-128 [Slough 8A], FA-138 [Gold Creek] and FA-144 [Slough 21]). The dissolved oxygen monitors were deployed prior to spawning and have recorded data throughout the egg incubation and fry emergence periods that has included winter under ice conditions. The dissolved oxygen monitors were serviced in September 2015 and have been redeployed to continue collecting data over the 2015-2016 winter period. Further discussion

related to the analyses of water quality data in Focus Areas are presented in SIR Study 8.5, Appendix A and Appendix D, and SIR Study 8.5, Sections 5.5 and 6.5. In addition and more broadly, the Baseline Water Quality Study (Study 5.5) has prepared a Study Completion Report (SCR Study 5.5). That report includes the results of the water quality sampling that was conducted in the Focus Areas in SWs and in selected GW wells.

4.7.1. Variances

AEA implemented the methods as described in the Study Plan with no variances. As described above, the objective of this particular component of the GW Study has been met.

4.8. Winter Groundwater / Surface-Water Interactions

AEA implemented the methods as described in the Study Plan with no variances. The objective of this study element was to characterize the winter flow in the Susitna River and how it relates to GW/SW interactions.

Since the June 2014 ISR, AEA has continued to collect and analyze winter data from GW wells and SW recording stations in FA-104 (Whiskers Slough), FA-113 (Oxbow 1), FA-115 (Slough 6A), FA-128 (Slough 8A), and FA-138 (Gold Creek). The time-lapse cameras installed within Focus Areas have also continued to capture images of main channel and lateral habitats under varying flow under varying seasonal conditions.

Data collected as part of the coordinated 2014 winter studies were evaluated and presented and discussed as part of the September TM pertaining to GW/SW relationships in lateral habitats (GWS and R2 2014b). Those data consisted of winter discharge measurements collected during three time periods within various Focus Areas. Measurements made during the first two periods, March 3-16, 2014 and April 1-13, 2014 were collected at selected locations in FA-104 (Whiskers Slough), FA-128 (Slough 8A) and FA-138 (Gold Creek). Measurements were recorded in open-water and ice covered areas within side channel, side slough and upland slough habitats. Discharge was measured at eight locations in FA-104 (Whiskers Slough), five locations in FA-128 (Slough 8A) and at six sites in FA-138 (Gold Creek). Measurement locations were established in habitats with substantial GW influence and known fish habitat use during winter. An additional series of end-of-winter discharge measurements to document GW recharge or discharge in SW features were made from April 16-26, 2014 in the same three Focus Areas noted above. For those measurements, channel sections were chosen that had no or minimal ice and snow conditions, so an open channel measurement could be made. Paired measurements were made in select areas to measure the difference in discharge for certain channel reaches. Because the goal of these measurements was to measure small differences in GW for GW recharge to the sloughs or side channels, triplicate measurements were made at some locations when field logistics allowed. The winter discharge data will be useful in the calibration process of the River1D and River2D Ice Processes models (Study 7.6). These models will be used in part for evaluating Project effects on stage and flow distributions within lateral habitats under ice covered conditions.

When linked, the River1D and River2D Ice Processes models and the MODFLOW GW models (Section 4.5) will be able to evaluate Project operational effects on GW/SW interactions during the winter ice covered periods. Outputs from these models will be combined with the HSC/Habitat

Suitability Index (HSI) curves and input to the 2D – PHABSIM Fish Habitat models to calculate habitat quantities by species and life stage under different winter-time flow conditions (ISR Study 8.5, Section 5.6). Information collected as part of the IFS (Study 8.5) and Fish Distribution and Abundance in the Middle and Lower River (FDAML) (Study 9.6) winter studies will be used in part to support development of the HSC/HSI curves used for the modeling. The IFS (Study 8.5) winter studies, specified in RSP Section 8.5.4.5.1.2.1, was specifically designed to evaluate potential relationships between mainstem Susitna River stage and the quality and quantity of winter aquatic habitats that support embryonic, juvenile, and adult life stages of fish species and to record fish behavior and habitat utilization in support of HSC/HSI development (AEA 2012). The FDAML (Study 9.6) winter effort, described in RSP Section 9.6.4.5, was developed to describe winter ecology of fish species in the Middle and Lower Susitna River (AEA 2012). Detailed results of the IFS and FDAML winter studies were presented as part of ISR Study 8.5, Appendix L, 2012-2013 Instream Flow Winter Pilot Studies, submitted to the FERC June 3, 2014 (R2 2014c) and ISR Study 9.6, Appendix C, Winter Sampling Report (2012-2013) submitted to the FERC June 3, 2014 (R2 and LGL 2014a) and as Technical Memoranda (2013-2014 Instream Flow Winter Studies submitted to the FERC September 17, 2014 [R2 2014d] and 2013-2014 Winter Fish Study submitted to the FERC September 17, 2014 [R2 and LGL 2014b]).

4.8.1. Variances

AEA implemented the methods as described in the Study Plan with no variances.

4.9. Shallow Groundwater Users

AEA implemented the methods as described in the Study Plan with no variances. Since the June 2014 ISR, AEA continued to monitor several domestic private wells proximal to the Susitna River as a means to characterize the relationship between Susitna River flows and GW levels in the wells. A total of four wells have been monitored including one at Gold Creek, two within FA-138 (Gold Creek), and one near the Chase community area across from FA-104 (Whiskers Slough). The wells have been monitored since 2013 and have provided a robust data set from which to evaluate the relationship between Susitna River flow and water levels in the wells. AEA plans on continuing to monitor the wells near Gold Creek but has removed the recorder from the Chase Creek area.

4.9.1. Variances

AEA implemented the methods as described in the Study Plan with no variances.

5. RESULTS

Field data that has been QA/QC'd, and used in developing: 1) ISR Study 7.5; 2) Post-ISR TMs (Groundwater and Surface-Water Relationships in Support of Riparian Vegetation Modeling TM [GWS and R2 2014a] and Preliminary Groundwater and Surface-Water Relationships in Lateral Aquatic Habitats within Focus Areas FA-128 [Slough 8A] and FA-138 [Gold Creek] in the Middle Susitna River TM [GWS and R2 2014b]); and 3) SIR Study 7.5 are available on the GINA website at the links below.

- http://gis.suhydro.org/isr/07-Hydrology/7.5-Groundwater/
- http://gis.suhydro.org/Post_ISR/07-Hydrology/7.5-Groundwater/
- http://gis.suhydro.org/SIR/07-Hydrology/7.5-Groundwater/

See Table 4.5-3 for a listing of data files pertaining to this SIR on the GINA website.

5.1. Existing Data Synthesis

Of the 278 documents initially identified, 18 were determined to contain information especially relevant to GW/SW interactions, 12 of which contained findings of Project studies conducted during the 1980s. These documents were summarized in the literature review (Appendix C) and detailed information gleaned specific to each of the five categories of information:

- Aquifer extent and thickness
- Aquifer properties (transmissivity, hydraulic conductivity, and storage)
- Horizontal groundwater gradients and flow direction
- Nature and extent of vertical groundwater gradients along the Susitna River
- Groundwater and surface water interactions within the Susitna River valley

Pertinent information available for each category from the documents was described and summarized, and a table of aquifer properties was prepared (Table 5.1-1)

Overall, the hydrogeologic Project reports from the 1980s focused on documenting differences between mainstem and slough temperatures and fluxes in an effort to predict slough flows under post-Project conditions. Water levels in monitoring wells, sloughs, and the mainstem were also documented to better understand slough upwelling flows. Based on detailed studies in Sloughs 9 and 8A, and to a lesser extent in Sloughs 11 and 21, it was concluded that many sloughs exhibit differing and complex hydrologies (with flow regimes affected by tributaries, GW upwelling, berm overtopping, and geologic/geomorphic features) that prevents simple regression relationships between mainstem discharge and slough upwelling from being widely applicable. In general, slough upwelling is affected by mainstem flows, but the relative amount of GW contribution to slough flow can vary in time and space based on mainstem conditions and antecedent precipitation.

One of the conclusions of the studies (R&M Consultant and Woodward-Clyde 1985) was that "Detailed projections cannot be made of the slough discharge or temperature variations which might result from changes in mainstem conditions as a result of project operation. Because of the substantial differences among the sloughs in their hydraulic and thermal behavior, it would be necessary to construct mathematical models of each individual slough in order to make detailed predictions of the effects on the sloughs of changes in mainstem conditions." However, as part of addressing GW Study (Study 7.5) Component 2 (Geohydrologic Domains), the differentiating characteristics of sloughs (such as the presence of tributaries, upland soil/geology type, apparent influence from mainstem flows, influence from overtopped-berm flows, etc.) will be reviewed along with their hydrologic responses to see if sloughs with similar characteristics show similar responses. If this is the case, the simulated results from the representative Focus Area sloughs that are being modeled, could be extrapolated to other sloughs that are expected to have similar

responses. Much of the water level and temperature data necessary for initial comparisons have already been collected at multiple sloughs.

With the preparation of Appendix C, the objective of the existing data synthesis component of the GW study has been met.

5.2. Geohydrologic Process-Domains

There has been no substantive activity on this element since completion of the June 2014 ISR.

5.3. Watana Dam/Reservoir

There has been no substantive GW related activity on this element since completion of the June 2014 ISR. However, AEA has continued Project Engineering Feasibility Studies Geotechnical Investigations, and the Geology and Soils Characterization Study (Study 4.5) (see SIR Study 4.5 for description of work).

5.4. Upwelling / Springs Broad-Scale Mapping

As noted in Section 4.4, the primary activity on this element has been associated with the differentiation of upwelling areas within FA-128 (Slough 8A) into three categories: Riverine Dominated, Riverine-Upland Transitional, and Upland Dominated. An example delineation of these categories was completed for FA-128 and presented during the December 5, 2014 Technical Team Meeting (Figure 5.4-1).

As noted in Section 4.4, AEA is applying the same general process for identifying GW upwelling areas throughout the entire Middle River Segment of the Susitna River, although differentiating upwelling into the three categories will not be possible.

5.5. Riparian Vegetation Dependency on Groundwater / Surface Water Interactions

Activities completed by AEA since the June 2014 ISR are described below.

5.5.1. Preparation and Submittal of Technical Memorandum – GW/SW Relationships to Support Riparian Vegetation Modeling

The TM (GWS and R2 2014a) was prepared and submitted in September 2014. The TM described analytical methods that are being employed for evaluating lateral hydraulic gradient relationships and how those relationships would be used in assessing Project effects on riparian vegetation communities. Examples of relationships were provided for FA-115 (Slough 6A), FA-128 (Slough 8A), and FA-138 (Gold Creek) and are depicted in Figures 5.5-1 and 5.5-2, Figures 5.5-3 and 5.5-4, and Figures 5.5-5 and 5.5-6 respectively. These relationships illustrate differences between upland dominated GW conditions that would be largely unaffected by Project operations and riverine dominated conditions that would be directly influenced by Project operations.

5.5.2. Groundwater Technical Team Meeting

A Groundwater Technical Team Meeting was conducted on December 5, 2014 as a follow-up to the October 2014 ISR meetings and to discuss the two Technical Memoranda that were prepared relative to the RIFS (Study 8.6) (see above) and IFS (Study 8.5) (Section 4.4.1) studies. The presentation materials and meeting notes associated with the meeting are included as Appendix D to this SIR.

5.5.3. Preliminary Three-dimensional MODFLOW Model for FA-128

A preliminary three dimensional MODFLOW model was successfully developed for FA-128 (Slough 8A). The model consisted of both a steady state model and a transient model. The steady state model was developed to simulate average "baseflow" conditions in FA-128 (i.e., when little flooding is occurring in the Susitna River and side channels are predominantly fed by GW). The results of the steady state model were then used as starting GW conditions for the transient model which was developed to simulate the spring melt flooding event in May 2014 and responses to GW elevations, gradients between GW and SW, and fluxes between GW and SW.

The steady state model was calibrated to observed GW elevations and required little calibration because steady state GW elevations are largely controlled by the assigned river stages in the model (i.e., a relatively good calibration could be achieved with a range of aquifer parameters assigned to the model). The transient model was partially calibrated against observed changes in GW elevations and gradients between the GW and SW. The transient model calibration was limited to adjustment of the aquifer storage coefficient parameter.

5.5.3.1. Steady State Model Calibration

The steady state model was calibrated to 14 observed GW elevations (targets) in FA-128 (Slough 8A) through trial and error (Table 5.5-1). Calibration focused primarily on adjustment of hydraulic conductivity of the alluvial aquifer and the river bed sediments (Table 5.5-2). These values were assumed to be spatially consistent throughout the model; however, future model refinements may include incorporation of heterogeneity to improve model calibration. Other values that may be varied in calibration include storage coefficient, anisotropy, river conductance, recharge, and boundary conditions. These variables may also be varied spatially over the model. Future calibration of these parameters would likely result in an improved simulations.

Specific fluxes along the sides of the model (regional GW subflow) were initially assigned a value of 2.1 ft^2/day per unit length of valley wall based on a previous rough estimate of regional GW fluxes to the Susitna River valley (HESJV 1984), but was later reduced by an order of magnitude to improve the overall calibration.

The best model fit to the GW elevation targets was achieved using a horizontal hydraulic conductivity of 6 ft/day, a vertical hydraulic conductivity of 0.66 ft/day, and a river bed hydraulic conductivity of 6 ft/day (Table 5.5-2). Figure 5.5-7 shows a plot of observed and simulated GW elevations; a perfect fit would fall along the straight line. Figure 5.5-8 shows a map of the head target locations and corresponding residuals (difference between simulated and observed GW elevations). A negative residual value indicates the simulated GW elevation is too high and a positive residual indicates it is too low. The target residuals were evenly divided between negative

and positive values indicating the model does not trend towards over prediction or under prediction of GW elevations. The absolute value of all target residuals was less than 1 foot, except at station 128-26 (3.25 feet) and station 128-4 (-1.37). The poorer fit of the model at these stations may indicate the presence of aquifer heterogeneities not represented with the current model configuration (Figure 5.5-8).

The simulated steady state GW elevations are strongly influenced by the assigned river stages in the model and adjustments of the hydraulic conductivity of the aquifer and river bed sediments resulted in only slight improvements or worsening of the overall calibration. A number of flooded model cells occurred in layer 1 in the farfield area of the steady state model (Figure 5.5-9). Flooded cells are areas where the simulated GW elevations are above the land surface and overestimate the saturated thickness of the aquifer in layer 1. These are analogous to seeps or springs. The amount of flooding ranged from less than 1 foot to about 10 feet in these areas. Future model refinements can reduce flooded cells with the incorporation of the MODFLOW Drain Package, which simulates GW seepage diversion from the aquifer.

A few dry cells also occurred in layer 1 near valley walls in the far field area of the model, but are not expected to have much effect on the model results (Figure 5.5-9). Dry cells are areas where the simulated GW elevations are below the bottom elevation of model layer 1. Future refinements of the model may include additional model layers to refine simulation of vertical gradients in the aquifer. Simulation of drying and rewetting model cells can be resolved during future refinements of the model with the use of MODFLOW-NWT instead of the current MODFLOW-2000 code.

5.5.3.2. Transient Model Calibration

As noted in 4.5.3, some limited transient calibration was achieved by varying the aquifer storage coefficient term within acceptable ranges to achieve a reasonable fit to the transient targets. Except for the prescribed transient changes in river stages, all other model input parameters were held constant from the calibrated best fit steady state model. The storage coefficient was initially set to 0.2, but was eventually reduced to a value of 0.001 to achieve a better match to the observed GW elevation response. This value is somewhat low for an unconfined aquifer and may suggest the aquifer is semi-confined.

The simulated transient changes in GW elevations were compared to observed changes at 15 target locations (Table 5.5-1). The comparison shows the model generally obtained a good fit for target stations located adjacent to simulated SW features (Figure 5.5-10), but targets further from the river were less well matched (Figure 5.5-11); either the magnitude of the elevation change was off, and/or the timing of the response was delayed. Despite the poor match to GW elevation changes at some stations, the calibration statistics for the transient model were relatively good (Table 5.5-2).

Like the steady state model, the transient model simulation also resulted in an increase in the number of flooded model cells during the peak of the flooding event. As mentioned above, future simulations can resolve flooded model cells with the use of the MODFLOW Drain Package (Section 7.0).

5.5.3.3. Simulated Transient Gradients and Fluxes

Output from the MODFLOW model can be used to quantify changes in vertical gradients and fluxes between GW and SW during natural flooding events and some preliminary model runs were completed to demonstrate this. However, additional model refinement and calibration will be necessary before the model can be used to evaluate potential GW related impacts from different Project operational scenarios on aquatic and floodplain habitats.

Plots of the monitored and simulated differences between GW elevations and adjacent SW stages were made for four target stations (128-6, 128-7, 128-11, and 128-13) during a transient simulation. The plots can be used to evaluate periods of upwelling and downwelling GW responses before, during, and after the flooding event. At all stations, the simulated GW response showed downwelling conditions prevailing during the flooding event as river stages increased above the GW elevations in the underlying aquifer; Figure 5.5-12 depicts the plot for target station 128-6 and is provided for illustrative purposes (see Appendix B for all four target stations). Following the peak flood event, the simulated downwelling conditions were followed by a relatively quick change to upwelling conditions as the river stage dropped and GW drained back into the river.

However, the observed GW response at a specific location differed somewhat from the simulated response. The observed response at some stations showed upwelling conditions prevailing during the initial flooding, which could be due to aquifer recharge from higher flooding stages upgradient of that location. Alternatively, the observed GW response could be partly related to changes in horizontal gradients since the monitoring wells are not immediately adjacent to the SW gaging station. Distances between wells and SW gages range from about 20 to 100 feet distance. The calculated differences between GW elevations and SW stages could therefore represent a combination of horizontal and vertical gradients.

Plots of the simulated transient fluxes between SW and GW at the four target stations (128-6, 128-7, 128-11, and 128-13) show that as the flooding event occurred, fluxes out of the river (downwelling) increase as SW stages rise above GW elevations. This is illustrated in Figure 5.5-13 for target 128-6 (see Appendix B for all four target stations). Downwelling fluxes are quickly followed by conversion to upwelling fluxes as GW flows back towards the SW.

Of note is that the simulated differences between GW and SW elevation can be as little as 0.1 feet, which is much less than the calibrated target residuals of the model. This indicates that the current preliminary MODFLOW model will require further calibration before simulation of small vertical gradients (both in magnitude and direction) can be made. Also, the transient river stages are currently based on estimates of an equivalent open water stage during the spring melt flooding event). More representative flooding stages will be obtained via output from the River1D and River2D Ice Processes models once they are complete (SIR Study 7.6).

5.5.4. Water Table Mapping

As described in Section 4.5.4, a total of six water table maps corresponding to six different time periods were developed for FA-128 (Slough 8A) and FA-104 (Whiskers Slough), three maps corresponding to three time periods were developed for FA-138 (Gold Creek), and two maps

corresponding to two periods were developed for FA-115 (Slough 6A). Specific time periods assigned to each Focus Area are listed in Table 4.5-1.

Development of the water table maps was achieved by first assembling the respective QC3 water level data for each of the wells and SW measurement stations within the area for the specified dates. These data sets included both telemetered and self-logging data as well as manual measurements as available. The Open-water Flow Routing Model (OWFRM) was also used to estimate water levels within the centerlines of each of the Focus Areas for the respective dates during the open-water period. These data sets were then combined and served as the basis for geo-spatially defining elevational isopleths within each Focus Area. Specific contours were defined by a combination of visual interpretation and interpolation. Figures 5.5-14, Figure 5.5-15, Figure 5.5-16 and Figure 5.5-17 depict water table maps for FA-104 (Whiskers Slough), FA-115 (Slough 6A), FA-128 (Slough 8A), and FA-138 (Gold Creek) respectively for one of the six periods (Late Fall - October 9, 2013). Appendix A provides a complete description of the methods used in developing the maps and contains the water table maps for each of the Focus Areas for the times specified.

These water table maps will be useful for evaluating GW/SW interactions and responses under different river stage conditions, and also for interpreting GW level changes under different project operations. The water table maps may also be useful in the calibration and validation process of the MODFLOW GW models.

5.5.5. Continuation of Data Collection and QC3 Data Review

As noted in SIR Study 7.5, Section 4.5, since the June 2014 ISR, AEA has continued to collect data from many stations located within the Middle River Segment of the Susitna River and selected locations in the Lower River Segment.

The data being collected will serve to support not only the RIFS (Study 8.6), but also a number of other multidisciplinary resource studies including the IFS (Study 8.5), Geomorphology Study (Study 6.5 and 6.6), Ice Processes Study (Study 7.6), and Water Quality Study (Study 5.5). A description of the types of data being collected at each of the Focus Area stations is described in ISR Study 7.5, Section 4.5 and displayed in ISR Study 7.5, Figures 4.5-1 through 4.5-4.

5.6. Aquatic Habitat Groundwater / Surface-Water Interactions

Groundwater activities completed in support of the IFS (Study 8.5) were described in Section 4.6 and in most cases, were the same as those described in Section 5.5 for the RIFS (Study 8.6). These are summarized below.

5.6.1. Preparation and Submittal of Technical Memorandum – GW/SW Relationships in Lateral Aquatic Habitats

A TM (GWS and R2 2014b) was prepared and submitted in September 2014 that described analytical methods being applied for evaluating GW/SW interactions within lateral aquatic habitats. The TM provided an overview of the importance of GW to fish habitat in the Susitna River and described data collection and analysis activities designed to evaluate how Project

operations may affect such habitats. Several examples of data analysis were presented for FA-128 (Slough 8A) that demonstrated relationships between SW stage and GW levels (Figure 5.6-1), and SW and GW temperatures (Figure 5.6-2). The TM also discussed the dynamics of GW upwelling and downwelling and provided examples of both as reflected by plots of streambed temperature at depth in comparison to SW/well water levels in FA-128 (Slough 8A) (Figure 5.6-3) and FA-138 (Gold Creek) (Figure 5.6-4). The TM also defined the following three categories of lateral habitats as influenced by differing GW processes:

- Riverine Hydrology Dominated
    - Flow, stage, and water quality conditions in lateral habitats are predominantly influenced by mainstem flow, stage, and water quality conditions.
- Transitional Hydrology Dominated
    - Flow, stage and water quality conditions in lateral habitats vary between riverine and upland dominated sources of flow due to seasonal and event related flow conditions.
- Upland (or Hillslope) Dominated
    - Flow, stage and water quality conditions in lateral habitats are predominantly influenced by sources of GW and SW that originate in upland areas.

As described in Section 5.4, these categories will be applied (where possible) to the GW mapping exercise being conducted by AEA.

5.6.2. Groundwater Technical Team Meeting

A Groundwater Technical Team Meeting was conducted on December 5, 2014 as a follow-up to the October 2014 ISR meetings and to discuss the two Technical Memoranda that were prepared relative to the RIFS (Study 8.6) (see above) and IFS (Study 8.5) (Section 4.4.1) studies.

5.6.3. Preliminary Three-dimensional MODFLOW Model for FA-128 (Slough 8A)

As described in Section 5.5.3 above, a preliminary three dimensional MODFLOW model was successfully developed for FA-128 (Slough 8A) and is more fully described in Appendix B. Once fully calibrated, the MODFLOW model can be used, in conjunction with outputs provided by the OWFRM, River1D and River 2D Ice Processes models and the 2D hydraulic models (SRH-2D), to evaluate the effects of different Project operational scenarios on GW/SW interactions. The output from MODFLOW can also be linked with the 2D PHABSIM Habitat Models that have incorporated “Upwelling” as one of the HSC metrics (SIR Study 8.5, Section 5.5 and Appendix D) for evaluating Project operational effects on spawning and incubation habitats. Specifically, GW response functions can be developed from the MODFLOW output as analytical expressions that can be used to quantify predicted changes in GW fluxes due to different scenarios of project operations. Project induced changes to GW temperatures that are important for overwintering egg incubation can also be evaluated with model output but will require additional model refinement.

5.6.4. Water Table Mapping

As described in Section 5.5.4, AEA prepared a time series of water table maps for four Focus Areas (FA-104 [Whiskers Slough], FA-115 [Slough 6A], FA-128 [Slough 8A], and FA-138 [Gold Creek]), that depict GW elevations under different seasonal flow conditions (Appendix A).

5.6.5. Continuation of Data Collection and QC3 Data Review

As noted in SIR Study 7.5, Section 4.6, since the June 2014 ISR, AEA has continued to collect data from many stations located within the Middle River Segment of the Susitna River and selected locations in the Lower River Segment.

Results from the September 2014 field effort to collect discharge measurements within Focus Areas are presented in Table 5.6-1, which is a duplicate of SIR Study 6.6, Table 5.1-14 from Geomorphology Modeling (Study 6.6). Overall, a total of 52 measurements were made consisting of seven measurements in FA-104 (Whiskers Slough), three in FA-113 (Oxbow 1), five in FA-115 (Slough 6A), fourteen in FA-128 (Slough 8A), twelve in FA-138 (Gold Creek), one in FA-141 (Indian River) and ten in FA-144 (Slough 21). These data will support not only the GW Study but also a number of other multidisciplinary resource studies including the IFS (Study 8.5), Geomorphology Study (Study 6.5 and 6.6), Ice Processes Study (Study 7.6), and Water Quality Study (Study 5.5).

5.7. Water Quality in Selected Habitats

Activities related to this objective completed by AEA since the June 2014 ISR were described in Section 4.7.

Overall, AEA has collected a robust set of water quality data from a number of studies (Studies 4.5, 5.5, 7.5 and 8.5) that has included data from GW wells and adjoining areas. ISR Study 7.5, Section 5.7 provides additional detail regarding types of water quality data that have been collected within the Focus Areas and presents several examples that illustrate how surface flows can influence GW temperatures. Analyses have been completed to evaluate potential relationships of microhabitat variables to fish abundance and the Baseline Water Quality Study has been completed. Sufficient data have been collected and will be used in conjunction with Fish Habitat Models, Water Quality Models (Study 5.6), and the MODFLOW models to more fully evaluate how Project operations may affect both surface and GW water quality conditions. The objective of this particular GW Study element has been met.

5.8. Winter Groundwater / Surface-Water Interactions

As noted in Section 4.8 above, data collected as part of the coordinated 2014 winter studies were evaluated and presented and discussed as part of the September TM pertaining to GW/SW relationships in lateral habitats (GWS and R2 2014b) Those data consisted of winter discharge measurements collected during three time periods within three Focus Areas. Those data were summarized and presented as Table 3.1-2 in the TM; raw data were provided in Appendix B of the TM. In part, the discharge measurements provided estimates of GW inflow occurring between upper and lower measurement points. AEA has continued to collect data during the winter period

from a number of the GW well stations and remote cameras. Those data will be used not only for evaluating GW/SW interactions but also by the Ice Processes Study (Study 7.6) for calibration of the River2D models within Focus Areas.

5.9. Shallow Groundwater Users

Four homeowner wells were instrumented with continuously recording pressure transducers in 2013 and have provided data up through September 2015. Data from these wells will be used in combination with SW data collected on the mainstem Susitna River, as well as output from the OWFRM and River1D hydrology models to evaluate potential Project operational effects on shallow GW wells within the Middle River Segment.

6. DISCUSSION

6.1. Existing Data Synthesis

Since the June 2014 ISR, AEA has completed the review of literature and prepared a document that summarizes the information (Appendix C). The document included the review of 12 reports and documents completed as part of the 1980s studies, as well as a review of more contemporary literature pertaining to GW/SW relationships as evaluated for hydroelectric projects in cold regions. The objective of this particular component of the GW Study has been met.

6.2. Geohydrologic Process-Domains

There has been no substantive activity completed on this study component since the June 2014 ISR. However,a substantial amount of data have been collected from field studies, observations, and information gathered as part of the literature review as well as from other studies from which to develop a conceptual understanding of the regional GW processes. The next step is to define the GW regional scale relationship to local flow systems in the Middle River and Lower River segments and the relationship with the process-domain river segments. Additional analysis will be needed to determine those processes at the Focus Area scale, which will provide an indication of how those processes are functioning within the entire Middle River Segment.

6.3. Watana Dam/Reservoir

There has been no substantive GW related activity on this element since completion of the June 2014 ISR. However, AEA has continued Project Engineering Feasibility Studies Geotechnical Investigations, and the Geology and Soils Characterization Study (Study 4.5) (see SIR Study 4.5 for description of work) and these efforts are meeting study objectives set forth in the FERC-approved Study Plan.

6.4. Upwelling / Springs Broad-Scale Mapping

The primary activity on this element has been associated with the differentiation of upwelling areas within FA-128 (Slough 8A) AEA is applying the same general process for identifying GW areas throughout the entire Middle River Segment of the Susitna River.

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

Since the June 2014 ISR, AEA completed a number of GW activities (described in Sections 4.5 and 5.5) related to this objective. One of the key elements needed to meet the objective is development of GW models that can be used to assess Project operational effects on GW/SW interactions and how those may translate into effect on the riparian community. As noted in Section 5.5, a preliminary three-dimensional MODFLOW GW model has been developed for FA-128 (Slough 8A) (Appendix B). This model, once fully calibrated will be used for making that assessment at FA-128. Additional MODFLOW models can be developed for FA-104 (Whiskers Slough), FA-115 (Slough 6A), and FA-138 (Gold Creek) and can likewise be used for evaluating Project effects on GW/SW interactions in those areas. The time series of water table maps that have been developed and presented in Appendix A provide useful information regarding pre-project GW/SW interactions and how these change due to stage changes.

The combination of data and analysis collected and completed in 2013 up through June 2014, coupled with additional data and analysis completed in 2014 and 2015 has provided a solid framework of information and allowed the development of modeling tools from which to evaluate Project operational effects on GW/SW interactions and resulting effects on riparian vegetation. However, the modeling tools will require further development and refinement before they can be reliably used for evaluating overall project effects. Overall, the activities that have been completed to date are consistent with those specified in the FERC-approved Study Plan.

6.6. Aquatic Habitat Groundwater / Surface-Water Interactions

Activities related to this study component largely mirror those of the RIFS component described above (Section 6.5), except that a separate TM was prepared that described the preliminary analysis of GW/SW interactions supportive of the IFS (Study 8.5). Specific activities were described in SIR Study 7.5, Section 5.5. Like the RIFS GW/SW analysis described above, one of the key elements needed to meet this study objective is development of GW models that can be used to assess Project operational effects on GW/SW interactions and how those may translate into effects on important fish and aquatic habitats that are being evaluated as part of the IFS (Study 8.5). The MODFLOW model developed for FA-128 (Appendix B), once fully calibrated will be used for making that assessment at FA-128. Additional MODFLOW models can be developed for FA-104 (Whiskers Slough), FA-115 (Slough 6A), and FA-138 (Gold Creek) and can likewise be used for evaluating Project effects on GW/SW interactions and resulting effects on fish and aquatic habitats in those areas. Overall, the activities that have been completed to date are consistent with those specified in the FERC-approved Study Plan.

6.7. Water Quality in Selected Habitats

AEA has collected sufficient water quality data related to GW/SW interactions that can be used in conjunction with Fish Habitat models (Study 8.5), Water Quality models (Study 5.6), and the MODFLOW GW models to evaluate how Project operations may affect both surface and GW water quality conditions that comprise important fish and aquatic habitat. The objective of this particular GW Study element has been met.

6.8. Winter Groundwater / Surface-Water Interactions

Data collected as part of the coordinated 2014 winter studies were evaluated and presented and discussed as part of the September TM pertaining to GW/SW relationships in lateral habitats (GWS and R2 2014b) AEA has continued to collect data during the winter period from a number of the GW well stations and remote cameras. Overall, the activities that have been completed to date are consistent with those specified in the FERC-approved Study Plan.

6.9. Shallow Groundwater Users

Overall, the activities that have been completed to date are consistent with those specified in the FERC-approved Study Plan.

7. CONCLUSION

Data collection during the 2013 field effort provided a robust set of data contributory to meeting each of the study objectives. As described in ISR Study 7.5 and in SIR Study 7.5, Sections 4 through 6 above, data collection and analysis activities have continued throughout 2014 and into 2015 and have resulted in meeting several of the study objectives, as well as advancing the work progress on the others. Importantly, data collection will continue at selected stations to provide additional GW related data that can be used by other resource studies including the IFS (Study 8.5), RIFS (Study 8.6), Ice Processes (Study 7.6) and other studies requiring empirical surface and GW data and observations. Based on data collection completed in 2013, preliminary analyses, and plans for continued data collection, AEA expects to achieve the objectives of this study. Conclusions regarding the status of each of the nine objectives in the GW Study (Study 7.5) are presented below.

7.1. Existing Data Synthesis

AEA has completed the review of literature and prepared a document that summarizes the information (Appendix C). The objective of this particular component of the GW Study has been met.

7.2. Geohydrologic Process-Domains

Completion of geohydrologic process-domains will utilize existing data and information that have been collected and compiled in the GW Study and as part of the RIFS (Study 8.6) and Geomorphology (Study 6.5 and 6.6) studies.

Additional analysis will be completed to define the GW regional scale relationship to local flow systems in the Middle River and Lower River segments. This will be completed by first evaluating GW vertical gradient response functions resulting from precipitation, flow and ice processes at the Focus Area scale. This understanding can then be expanded to other sections of the Middle River Segment.

7.3. Watana Dam/Reservoir

AEA has continued Project Engineering Feasibility Studies, Geotechnical Investigations, and the Geology and Soils Characterization Study (Study 4.5) (see SIR Study 4.5 for description of work) and these efforts are meeting the study objectives set forth in the FERC-approved Study Plan.

7.4. Upwelling/Springs Broad-Scale Mapping

The upwelling/springs broad-scale mapping study component is ongoing.

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

Substantial data have been and are continuing to be collected and analyzed consistent with the FERC Approved Study Plan. A preliminary three-dimensional MODFLOW GW model has been developed for FA-128 (Slough 8A). The model will require further calibration and refinement and will then be used for evaluating Project operational effects as defined by the OWFRM, SRH-2D hydraulic model, and the River1D and River2D Ice Processes models, on GW/SW interactions within that Focus Area. The model outputs can be linked with the RIFS riparian models (SIR Study 8.6, Section 6.6) for evaluating how the resulting GW/SW interactions will influence riparian floodplain vegetation. Additional MODFLOW models can be developed for FA-104 (Whiskers Slough), FA-115 (Slough 6A), and FA-138 (Gold Creek) and can likewise be used for evaluating Project effects on GW/SW interactions in those areas.

Additional analysis of well data collected within Riparian transects in the Lower River Segment (SIR Study 8.6) will provide an understanding of how Project operational changes may influence riparian vegetation.

7.6. Aquatic Habitat Groundwater / Surface-Water Interactions

Substantial data have been and are continuing to be collected and analyzed consistent with the FERC Approved Study Plan.

A preliminary three-dimensional MODFLOW GW model has been developed for FA-128 (Slough 8A). The model will require further calibration and refinement and will then be used for evaluating Project operational effects as defined by the OWFRM, SRH-2D hydraulic model, and the River1D and River2D Ice Processes models, on GW/SW interactions within that Focus Area. The model outputs can be linked with the 2D Fish Habitat (PHABSIM) models (SIR Study 8.5) for evaluating how the resulting GW/SW interactions will influence fish and aquatic habitats. Additional MODFLOW models can be developed for FA-104 (Whiskers Slough) FA-115 (Slough 6A), and FA-138 (Gold Creek) and can likewise be used for evaluating Project effects on GW/SW interactions and effects on fish habitat in those areas.

7.7. Water Quality in Selected Habitats

AEA has collected sufficient water quality data related to GW/SW interactions that can be used in conjunction with 2D Fish Habitat (PHABSIM) Models, Water Quality Models (Study 5.6), and the MODFLOW GW models to evaluate how Project operations may affect both surface and GW

water quality conditions that comprise important fish and aquatic habitat. The specific objective of characterizing water quality characteristics in selected habitats has been met.

7.8. Winter Groundwater / Surface-Water Interactions

AEA will continue to collect data at selected GW well stations throughout the winter period. These data along with GW and SW data collected during the winters of 2012/2013, and 2013/2014 will provide a substantial database of information from which to evaluate winter GW/SW interactions.

The development of calibrated MODFLOW GW models in FA-104 (Whiskers Slough), FA-115 (Slough 6A), FA-128 (Slough 8A), and FA-138 (Gold Creek) will be used for evaluating effects of Project operations on GW/SW interactions (including upwelling and downwelling) during the winter period. These models will use outputs from the OWFRM (SIR Study 8.5, Appendix B) and the River1D and River2D Ice Processes models (SIR Study 7.6) to provide stage data based on bathymetric maps of each of the Focus Areas. This modeling will be linked with the 2D Fish Habitat models for evaluating Project operational effects on GW/SW interactions and effects on overwintering egg incubation and embryo survival.

7.9. Shallow Groundwater Users

Data collected from the homeowner wells can be used in combination with SW data collected on the mainstem Susitna River, as well as output from the OWFRM and River1D hydrology models to evaluate potential Project operational effects on shallow GW wells within the Middle River Segment.

8. LITERATURE CITED

Alaska Energy Authority (AEA). 2012. Revised Study Plan. Susitna-Watana Hydroelectric Project, FERC Project No. 14241 Submittal: December 14, 2012. http://www.susitna-watanahydro.org/study-plan.

Alaska Energy Authority (AEA). 2014. Initial Study Report. Susitna-Watana Hydroelectric Project, FERC Project No. 14241 Submittal: June 3, 2014. http://www.susitna-watanahydro.org/type/documents/.

American Society for Testing and Materials (ASTM). 2008. D5981 - 96(2008) Standard Guide for Calibrating a Groundwater Flow Model Application, ASTM, 19 pp.

American Society for Testing and Materials (ASTM). 2010. D6170 - 97(2010) Standard Guide for Selecting a Groundwater Modeling Code, ASTM, 19 pp.

Federal Energy Regulatory Commission (FERC). 2013. Study Plan Determination on 14 remaining studies for the Susitna-Watana Hydroelectric Project. Susitna-Watana Hydroelectric Project, FERC No. P-14241. April 1, 2013. http://elibrary.FERC.gov/idmws/file_list.asp?accession_num=20130401-3022.

Geo-Watersheds Scientific (GWS) and R2 Resource Consultants (R2). 2014a. Groundwater and Surface-Water Relationships in Support of Riparian Vegetation Modeling. Susitna-Watana Hydroelectric Project, FERC No. P-14241 Submittal: September 30, 2014, Attachment D, Study 7.5 Technical Memorandum. Prepared for Alaska Energy Authority, Anchorage, Alaska. http://www.susitna-watanahydro.org/wp-content/uploads/2014/09/07.5_GW_GWS_T5_TM_Riparian_Final_Draft_20140926.pdf.

Geo-Watersheds Scientific (GWS) and R2 Resource Consultants (R2). 2014b. Preliminary Groundwater and Surface-Water Relationships in Lateral Aquatic Habitats within Focus Areas FA-128 (Slough 8A) and FA-138 (Gold Creek) in the Middle Susitna River. Susitna-Watana Hydroelectric Project, FERC No. P-14241 Submittal: September 30, 2014, Attachment C, Study 7.5 Technical Memorandum. Prepared for Alaska Energy Authority, Anchorage, Alaska. http://www.susitna-watanahydro.org/wp-content/uploads/2014/09/07.5_GW_GWS_T6_TM_Aquatic_Hydro_Final_Draft_20140925.pdf.

Geo-Watershed Scientific (GWS). 2015. December 5, 2014 Technical Team Meeting Notes and Presentation. Susitna-Watana Hydroelectric Project, FERC No. P-14241 Submittal: November 2015, 2014-2015 Study Implementation Report, Study 7.5, Appendix D. Prepared for Alaska Energy Authority, Anchorage, Alaska.

Harza-Ebasco Susitna Joint Venture (HESJV). 1984. Susitna Hydroelectric Project Slough Geohydrology Studies. Prepared in cooperation with R&M Consultants, Inc. for the Alaska Power Authority April. APA Document No. 1718.

Pacific Groundwater Group (PGG). 2015a. Preliminary Water Table Contour Maps for Focus Areas FA-104, FA-115, FA-128, and FA-138. Susitna-Watana Hydroelectric Project, FERC No. P-14241 Submittal: November 2015, 2014- 2015 Study Implementation Report, Study 7.5, Appendix A. Prepared for Alaska Energy Authority, Anchorage, Alaska.

Pacific Groundwater Group (PGG). 2015b. Preliminary MODFLOW Three Dimensional Groundwater Model for Focus Area FA-128 (Slough 8A). Susitna-Watana Hydroelectric Project, FERC No. P-14241 Submittal: November 2015, 2014-2015 Study Implementation Report, Study 7.5, Appendix B. Prepared for Alaska Energy Authority, Anchorage, Alaska.

Pacific Groundwater Group (PGG). 2015c. Summary Review of Susitna River Hydrogeologic Studies Conducted in the 1980s and other Non-Project Related Studies with Relevance to Proposed Susitna-Watana Dam Project. Susitna-Watana Hydroelectric Project, FERC No. P-14241 Submittal: November 2015, 2014-2015 Study Implementation Report, Study 7.5, Appendix C. Prepared for Alaska Energy Authority, Anchorage, Alaska.

R & M Consultants, Inc. and Woodward-Clyde Consultants. 1985. Instream Flow Relationships Report Series Physical Processes of the Middle Susitna River Technical Report No. 2. Prepared under contract with Harza-Ebasco Susitna Joint Venture for the Alaska Power Authority. APA Document No. 2828. Available at: http://www.arlis.org/docs/vol1/Susitna/28/APA2828.pdf

R2 Resource Consultants, Inc. (R2). 2014a. Middle River Fish Habitat and Riverine Modeling Proof of Concept. Susitna-Watana Hydroelectric Project, FERC No. P-14241 Submittal: June 3, 2014, Initial Study Report, Study 8.5, Part C, Appendix N. Prepared for Alaska Energy Authority, Anchorage, Alaska. http://www.susitna-watanahydro.org/wp-content/uploads/2014/06/08.5_IFS_ISR_PartC_2_of_2.pdf.

R2 Resource Consultants (R2). 2014b. Evaluation of Relationships between Fish Abundance and Specific Microhabitat Variables. Susitna-Watana Hydroelectric Project, FERC No. P-14241 Submittal: September 17, 2014, Attachment G, Study 8.5 Technical Memorandum. Prepared for Alaska Energy Authority, Anchorage, Alaska. http://www.susitna-watanahydro.org/wp-content/uploads/2014/09/08.5_IFS_R2_TM_FishAbundance-MicrohabitatVariables_FINAL.pdf.

R2 Resource Consultants, Inc. (R2). 2014c. 2012-2013 Instream Flow Winter Pilot Studies. Susitna-Watana Hydroelectric Project, FERC No. P-14241 Submittal: June 3, 2014, Initial Study Report, Study 8.5, Part C, Appendix L. Prepared for Alaska Energy Authority, Anchorage, Alaska. http://www.susitna-watanahydro.org/wp-content/uploads/2014/06/08.5_IFS_ISR_PartC_2_of_2.pdf.

R2 Resource Consultants, Inc. (R2). 2014d. 2013-2014 Instream Flow Winter Studies. Susitna-Watana Hydroelectric Project, FERC No. P-14241 Submittal: September 17, 2014, Attachment H, Study 8.5 Technical Memorandum. Prepared for Alaska Energy Authority, Anchorage, Alaska. http://www.susitna-watanahydro.org/wp-content/uploads/2014/09/08.5_IFS_R2_TM_2013-2014WinterStudies.pdf.

R2 Resource Consultants (R2) and LGL Alaska Research Associates (LGL). 2014a. Winter Sampling Report (2012-2013). Susitna-Watana Hydroelectric Project, FERC No. P-14241 Submittal: June 3, 2014, Initial Study Report, Study 9.6, Part A, Appendix C. Prepared for Alaska Energy Authority, Anchorage, Alaska. http://www.susitna-watanahydro.org/wp-content/uploads/2014/05/09.06_FDAML_ISR_PartA_4_of_5_App_C.pdf.

R2 Resource Consultants (R2) and LGL Alaska Research Associates (LGL). 2014b. 2013-2014 Winter Fish Study. Susitna-Watana Hydroelectric Project, FERC No. P-14241 Submittal: September 17, 2014, Attachment D, Study 9.6 Technical Memorandum. Prepared for Alaska Energy Authority, Anchorage, Alaska. http://www.susitna-watanahydro.org/wp-content/uploads/2014/09/09.06_FDAML_Winter_TM.pdf.

Tetra Tech. 2014. TIR Images, Study 5.5. Susitna-Watana Hydroelectric Project, FERC No. P-14241 Submittal: June 3, 2014, Initial Study Report, Study 5.5, Part A, Appendix J. Prepared for Alaska Energy Authority, Anchorage, Alaska. http://www.susitna-watanahydro.org/wp-content/uploads/2014/05/05.5_WQ_ISR_PartA_6_of_6_App_J.pdf.

9. TABLES

Table 4.5-1. Focus Areas and respective target dates for development of Water-Level Contour Maps for the Susitna River.

Focus Area	9/13/2013 Fall	10/9/2013 Late Fall	2/20/2014 Ice Cover / Ice Jam	4/20/2014 Pre-breakup	7/11/2014 Post-breakup	8/13/2014 Summer
FA-104 (Whiskers Slough)	X	X	X	X	X	X
FA-115 (Slough 6A)		X			X	
FA-128 (Slough 8A)	X	X	X	X	X	X
FA-138 (Gold Creek)		X		X	X	

Table 4.5-2. Groundwater Study data collection stations in the Lower River, FA-104 (Whiskers Creek), PRM 112, FA-113 (Oxbow 1), FA-115 (Slough 6A), FA-128 (Slough 8A), FA-138 (Gold Creek), FA-141 (Indian River), FA-144 (Slough 21), and the ESS Stations. (Updated ISR Study 7.5 Tables 4.5-1 to 4.5-4.)

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.

Location	Station Short Names	Station Primary Purpose	Latitude	Longitude	Data Collection Parameters	Status
Lower River	ESGLR1-1	Groundwater	62.2517	-150.14339	WT, CAM	Removed [1,2]
Lower River	ESGLR2-1	Groundwater	61.950062	-150.11470	WT, CAM	Removed [1,2,6]
Lower River	ESGLR3-1	Groundwater	61.778998	-150.19232	WT, CAM	Removed [1,2]
Lower River	ESGLR4-1	Groundwater	61.621293	-150.36835	WT, CAM	Removed [1,2]
Lower River	ESGLR4-2	Groundwater	61.621845	-150.35375	WT, CAM	Removed [1,2]
PRM 112	ESSPRM112-1	Surface Water	62.47246	-150.11835	GH	Removed [1]
PRM 112	ESSPRM112-2	Surface Water	62.4706	-150.11489	GH	Removed [1]
PRM 112	ESSPRM112-3	Surface Water	62.46608	-150.11682	GH	Removed [1]
FA-104	ESSFA104-1	Surface Water	62.37676	-150.16934	AT, GH, WT, STP, Cam	Maintained
FA-104	ESMFA104-2	Meteorological	62.37863	-150.1719	AT, RH, SMP, SR, SoTP, SHF, GWL, GWT, WD, WS, NR	Maintained [5]
FA-104	ESGFA104-3	Groundwater	62.37934	-150.17373	GWL, GWT	Maintained
FA-104	ESGFA104-4	Groundwater	62.37908	-150.17363	GWL, GWT, SF	Removed [7]
FA-104	ESGFA104-5	Groundwater	62.3781	-150.17029	GH(2), WT(2), GWL, GWT	Maintained [8]
FA-104	ESGFA104-6	Groundwater	62.378	-150.16912	GWL(2), GWT(2), SF	Maintained [9]
FA-104	ESGFA104-7	Groundwater	62.37764	-150.16822	GWL, GWT, SF	Maintained [9]
FA-104	ESGFA104-8	Groundwater	62.37692	-150.16562	GWL, GWT, SF, GH, WT	Maintained [9]
FA-104	ESGFA104-9	Groundwater	62.37626	-150.17091	GWL(2), GWT(2), STP, SWC, other	Maintained [7]
FA-104	ESGFA104-10	Groundwater	62.38402	-150.15125	GWL(1), GWT(1), GH, WT, STP(1)	Maintained [8]
FA-104	ESGFA104-11	Groundwater	62.37622	-150.16996	GWL, GWT	Maintained
FA-104	ESGFA104-12	Groundwater	62.37622	-150.16996	GWL, GWT	Maintained
FA-104	ESGFA104-13	Groundwater	62.37824	-150.171	GWL, GWT	Maintained
FA-104	ESCFA104-16	Camera	62.37457	-150.1685	Cam	Removed [1,4]
FA-104	ESCFA104-17	Camera	62.37676	-150.17157	Cam	Removed [1,4]
FA-104	ESCFA104-18	Camera	62.37943	-150.16961	Cam	Removed [1]
FA-104	ESCFA104-19	Camera	62.37986	-150.16679	Cam	Removed [1]
FA-104	ESCFA104-20	Camera	62.38351	-150.15477	Cam	Removed [1]
FA-104	ESCFA104-21	Camera	62.38388	-150.15211	Cam	Removed [1]
FA-104	ESCFA104-22	Camera	62.3818	-150.16376	Cam	Removed [1]

Location	Station Short Names	Station Primary Purpose	Latitude	Longitude	Data Collection Parameters	Status
FA-104	ESSFA104-23	Surface Water	62.38629	-150.15412	GH	Removed [1]
FA-104	ESSFA104-24	Surface Water	62.37968	-150.16311	GH	Removed [1]
FA-113	ESGFA113-1	Groundwater	62.489471	-150.10515	GWL(2), GWT(2), STP, GH(2), WT(2), WSE, Q	Removed [1,2]
FA-113	ESCFA113-2	Camera	62.492532	-150.10396	Cam	Removed [1]
FA-113	ESCFA113-3	Camera	62.48663	-150.09798	Cam	Removed [1]
FA-113	ESCFA113-4	Camera	62.488959	-150.10530	Cam	Removed [1]
FA-113	ESSFA113-5	Surface Water	62.49647	-150.11095	GH	Removed [1]
FA-113	ESSFA113-6	Surface Water	62.49245	-150.11003	GH	Removed [1]
FA-113	ESSFA113-7	Surface Water	62.48765	-150.10101	GH	Removed [1]
FA-115	ESMFA115-1	Meteorological	62.51892	-150.12688	AT, RH, SMP, SR, SoTP, SHF, GWL(2), GWT(2), WD, WS, NR	Maintained
FA-115	ESGFA115-2	Groundwater	62.51929	-150.13084	GWL, GWT, GH, WT	Maintained
FA-115	ESGFA115-3	Groundwater	62.51905	-150.1255	GWL, GWT, GH, WT	Maintained
FA-115	ESGFA115-4	Groundwater	62.51906	-150.1247	GWL, GWT	Maintained
FA-115	ESGFA115-5	Groundwater	62.51876	-150.12258	GWL, GWT, GH, WT	Maintained
FA-115	ESGFA115-6	Groundwater	62.51868	-150.12135	GWL, GWT	Maintained
FA-115	ESGFA115-7	Groundwater	62.51863	-150.12064	GWL, GWT, GH, WT	Maintained [7]
FA-115	ESGFA115-8	Groundwater	62.51914	-150.12948	GWL, GWT	Removed [1,2]
FA-115	ESCFA115-11	Camera	62.51933	-150.13072	Cam	Removed [1]
FA-115	ESCFA115-12	Camera	62.51896	-150.12046	Cam	Removed [1]
FA-115	ESCFA115-13	Camera	62.51507	-150.12476	Cam	Removed [1,4]
FA-115	ESCFA115-14	Camera	62.51357	-150.12182	Cam	Removed [1]
FA-115	ESSFA115-15	Surface Water	62.51542	-150.12418	GH	Removed [1]
FA-115	ESSFA115-16	Surface Water	62.51407	-150.12243	GH	Removed [1,4]
FA-115	ESSFA115-17	Surface Water	62.51747	-150.12516	GH	Removed [1]
FA-115	ESSFA115-18	Surface Water	62.51809	-150.12337	GH	Removed [1]
FA-115	ESSFA115-19	Surface Water	62.51696	-150.12987	GH	Removed [1]
FA-115	ESSFA115-20	Surface Water	62.51675	-150.12465	GH	Removed [1]
FA-128	ESSFA128-1	Surface Water	62.66384	-149.90494	AT, GH, WT, STP, Cam	Maintained
FA-128	ESGFA128-2	Groundwater	62.67204	-149.89403	GWL, GWT, GH, WT	Maintained [7]
FA-128	ESGFA128-3	Groundwater	62.67179	-149.8939	GWL, GWT, SF	Maintained [9]
FA-128	ESGFA128-4	Groundwater	62.67049	-149.89341	GWL, GWT	Maintained
FA-128	ESGFA128-5	Groundwater	62.66765	-149.89352	GWL, GWT, GH, WT, SF	Maintained [7,9]
FA-128	ESGFA128-6	Groundwater	62.6666	-149.8932	GWL, GWT, GH, WT	Maintained
FA-128	ESGFA128-7	Groundwater	62.6655	-149.89707	GWL(2), GWT(2), GWC, GH, WT, SWC, STP	Removed [1,4,2]
FA-128	ESMFA128-8	Meteorological	62.67052	-149.89485	AT, RH, SMP, SR, SoTP, SHF, WD, WS, NR	Maintained
FA-128	ESGFA128-9	Groundwater	62.66349	149.90730	GWL(2), GWT(2), SF	Maintained [9]

Location	Station Short Names	Station Primary Purpose	Latitude	Longitude	Data Collection Parameters	Status
FA-128	ESGFA128-10	Groundwater	62.66393	-149.90766	GWL, GWT, SF	Maintained
FA-128	ESGFA128-11	Groundwater	62.66596	-149.91077	GWL, GWT, GH, WT	Maintained
FA-128	ESGFA128-12	Groundwater	62.66711	-149.91272	GWL, GWT, GH, WT	Maintained
FA-128	ESGFA128-13	Groundwater	62.68626	-149.90953	GWL(2), GWT(2), GWC, GH, WT, SWC, STP	Maintained
FA-128	ESSFA128-14	Surface Water	62.67271	-149.89112	GH, WT	Maintained
FA-128	ESSFA128-16	Surface Water	62.67015	-149.88548	GH, WT	Removed [1]
FA-128	ESSFA128-17	Surface Water	62.66888	-149.88489	GH, WT	Removed [1]
FA-128	ESGFA128-18	Groundwater	62.66538	-149.89694	GWL, GWT	Maintained
FA-128	ESGFA128-19	Groundwater	62.66525	-149.89681	GWL, GWT	Maintained
FA-128	ESGFA128-20	Groundwater	62.663048	-149.90938	GWL, GWT	Maintained
FA-128	ESGFA128-21	Groundwater	62.66485	-149.90892	GWL, GWT	Maintained
FA-128	ESGFA128-22	Groundwater	62.66088	-149.91993	GH, WT	Removed [1,4]
FA-128	ESGFA128-23	Groundwater	62.66466	-149.91168	GWL, GWT	Removed [1,4]
FA-128	ESGFA128-24	Groundwater	62.66534	-149.90681	GWL, GWT	Maintained
FA-128	ESGFA128-25	Groundwater	62.66767	-149.90671	GWL, GWT	Maintained
FA-128	ESGFA128-26	Groundwater	62.66946	-149.89789	GWL, GWT	Removed [2,4]
FA-128	ESGFA128-27	Groundwater	62.67092	-149.88946	GWL, GWT	Maintained [8]
FA-128	ESFFA128-28	Support	62.66442	-149.90244	PIT tag array support	Removed [1]
FA-128	ESCFA128-29	Camera	62.67251	-149.88567	Cam	Maintained
FA-128	ESCFA128-32	Camera	62.66754	-149.89376	Cam	Maintained
FA-128	ESCFA128-33	Camera	62.67179	-149.89376	Cam	Removed [1,4]
FA-128	ESCFA128-34	Camera	62.66719	-149.91216	Cam	Maintained
FA-128	ESCFA128-35	Camera	62.66307	-149.91039	Cam	Maintained
FA-128	ESCFA128-36	Camera	62.66167	-149.91676	Cam	Maintained
FA-128	ESSFA128-37	Surface Water	62.66764	-149.89849	GH	Not Serviced in 2015[3]
FA-128	ESSFA128-38	Surface Water	62.668	-149.88803	GH	Removed [1,4]
FA-128	ESSFA128-39	Surface Water	62.66296	-149.92723	GH	Removed [1]
FA-128	ESSFA128-40	Surface Water	62.66459	-149.92271	GH	Removed [1]
FA-138	ESGFA138-1	Groundwater	62.75758	-149.70694	AT, GWL(2), GWT(2), GH, WT, STP, SWC, SP	Maintained
FA-138	ESGFA138-2	Groundwater	62.76464	-149.70595	GWL(2), GWT(2), GH, WT, STP, SWC	Maintained
FA-138	ESGFA138-3	Groundwater	62.75675	-149.70559	GWL, GWT	Maintained
FA-138	ESGFA138-4	Groundwater	62.76513	-149.70604	GWL, GWT	Maintained
FA-138	ESGFA138-5	Groundwater	62.76555	-149.70621	GWL, GWT	Maintained
FA-138	ESCFA138-8	Camera	62.75268	-149.70792	Cam	Removed [1]
FA-138	ESCFA138-9	Camera	62.75686	-149.70529	Cam	Removed [1]
FA-138	ESCFA138-10	Camera	62.76477	-149.70522	Cam	Removed [1]

Location	Station Short Names	Station Primary Purpose	Latitude	Longitude	Data Collection Parameters	Status
FA-138	ESCFA138-11	Camera	62.7677	-149.70755	Cam	Removed [1]
FA-138	ESSFA138-12	Surface Water	62.76654	-149.71311	GH	Removed [1]
FA-138	ESSFA138-13	Surface Water	62.76584	-149.71349	GH	Removed [1]
FA-138	ESSFA138-14	Surface Water	62.76679	-149.71101	GH	Removed [1]
FA-138	ESSFA138-15	Surface Water	62.7624	-149.70091	GH	Removed [1]
FA-138	ESSFA138-16	Surface Water	62.75414	-149.70740	GH	Removed [1]
FA-138	ESSFA138-17	Surface Water	62.76037	-149.69924	GH	Removed [1]
FA-141	ESSFA141-1	Surface Water	62.78811	-149.64994	GH	Removed [1]
FA-141	ESSFA141-2	Surface Water	62.78992	-149.64351	GH	Removed [1]
FA-141	ESSFA141-3	Surface Water	62.78138	-149.69122	GH	Removed [1]
FA-141	ESSFA141-4	Surface Water	62.78028	-149.68922	GH	Removed [1]
FA-141	ESSFA141-5	Surface Water	62.77979	-149.68848	GH	Removed [1]
FA-144	ESSFA144-1	Surface Water	62.81369	-149.57595	GH	Removed [1]
FA-144	ESSFA144-2	Surface Water	62.81477	-149.57385	GH	Removed [1]
FA-144	ESSFA144-3	Surface Water	62.81541	-149.57478	GH	Removed [1]
FA-144	ESSFA144-4	Surface Water	62.80695	-149.59156	GH	Removed [1]
PRM 17.4	ESS10	Surface Water	61.40541	-150.46021	AT, CAM, WT, GH	Removed [1]
PRM 24.7	ESS15	Surface Water	61.48954	-150.56207	AT, CAM, WT, GH	Removed [1]
PRM 29.9	ESS20	Surface Water	61.54425	-150.51533	AT, CAM	Maintained
PRM 98.4	ESS30	Surface Water	62.29455	-150.11599	AT, CAM, WT, GH	Removed [1]
PRM 107.2	ESS40	Surface Water	62.39915	-150.13722	AT, CAM, WT, GH	Maintained
PRM 116.6	ESS45	Surface Water	62.52558	-150.11487	AT, CAM, WT, GH	Maintained
PRM 124.1	ESS50	Surface Water	62.61718	-150.01509	AT, CAM, WT, GH	Removed [1,6]
PRM 152.2	ESS55	Surface Water	62.83052	-149.38391	AT, CAM, WT, GH	Maintained
PRM 176.5	ESS65	Surface Water	62.76461	-148.77414	AT, CAM, WT, GH	Removed [1]
PRM 187.1	ESS70	Surface Water	62.82299	-148.53834	AT, CAM, WT, GH	Maintained
PRM 225	ESS80	Surface Water	62.69777	-147.54729	AT, CAM, WT, GH	Maintained

Notes:

1 Station removed but survey control left in place.

2 Station removed but well left in place.

3 Station not serviced due to bear activity.

4 Station was damaged/removed.

5 Radiation sensor removed due to damage (NR no longer collected).

6 Station removed but antennae left in place.

7 Surface-water Pressure Transducer and temperature profile string were removed due to damage (GW and WT no longer collected).

8 Well was damaged/removed (GWL and GWT no longer collected).

9 Sap flow sensors removed (SF no longer collected).

10 Station not serviced because owner-permission not received.

Table 4.5-3. Summary of the QC3 data files used in support of this SIR and its appendices that have been delivered to GINA and are publically available (http://gis.suhydro.org/SIR/07-Hydrology/7.5-Groundwater/).

Component[1]	Data File Name	Description
Appendix A	SIR_7_5_GW_WaterTableMapData_20151104.xlsx	Elevation data for Focus Area water table maps
Appendix B	SIR_7_5_GW_FA-GWSW_Network_WaterLevel_ESGFA128-21_20151104.xlsx	Station ESGFA128-21 groundwater well fifteen-minute sample water levels
Appendix B	SIR_7_5_GW_FA-GWSW_Network_WaterLevel_ESGFA138-4_20151104.xlsx	Station ESGFA138-4 groundwater well fifteen-minute sample water levels
Appendix B	SIR_7_5_GW_FA-GWSW_Network_WaterLevel_ESGFA138-5_20151104.xlsx	Station ESGFA138-5 groundwater well fifteen-minute sample water levels
Appendix B	SIR_7_5_GW_GW_WaterLevel_ESGFA128-11_20151104.xlsx	Station ESGFA128-11 groundwater well and side channel fifteen-minute sample, average, maximum, and minimum water levels
Appendix B	SIR_7_5_GW_GW_WaterLevel_ESGFA128-13_20151104.xlsx	Station ESGFA128-13 groundwater well and slough fifteen-minute sample, average, maximum, and minimum water levels
Appendix B	SIR_7_5_GW_GW_WaterLevel_ESGFA128-18_20151104.xlsx	Station ESGFA128-18 groundwater well fifteen-minute sample water levels
Appendix B	SIR_7_5_GW_GW_WaterLevel_ESGFA128-19_20151104.xlsx	Station ESGFA128-19 groundwater well fifteen-minute sample water levels
Appendix B	SIR_7_5_GW_GW_WaterLevel_ESGFA128-2_20151104.xlsx	Station ESGFA128-2 groundwater well and water surface fifteen-minute sample and average water levels
Appendix B	SIR_7_5_GW_GW_WaterLevel_ESGFA128-23_20151104.xlsx	Station ESGFA128-23 groundwater well fifteen-minute sample water levels
Appendix B	SIR_7_5_GW_GW_WaterLevel_ESGFA128-24_20151104.xlsx	Station ESGFA128-24 groundwater well fifteen-minute sample water levels
Appendix B	SIR_7_5_GW_GW_WaterLevel_ESGFA128-25_20151104.xlsx	Station ESGFA128-25 groundwater well fifteen-minute sample water levels
Appendix B	SIR_7_5_GW_GW_WaterLevel_ESGFA128-26_20151104.xlsx	Station ESGFA128-26 groundwater well fifteen-minute sample water levels
Appendix B	SIR_7_5_GW_GW_WaterLevel_ESGFA128-27_20151104.xlsx	Station ESGFA128-27 groundwater well fifteen-minute sample water levels
Appendix B	SIR_7_5_GW_GW_WaterLevel_ESGFA138-6_20151104.xlsx	Station ESGFA138-6 groundwater well fifteen-minute sample water levels
Appendix B	SIR_7_5_GW_GW_WaterLevel_ESGFA138-7_20151104.xlsx	Station ESGFA138-7 groundwater well fifteen-minute sample water levels

Notes:

Appendix A: Preliminary Water Table Contour Maps for Focus Areas FA-104, FA-115, FA-128, and FA-138

Appendix B: Preliminary MODFLOW Three Dimensional Groundwater Model for Focus Area FA-128 (Slough 8A)

Table 5.1-1. Summary of hydrogeologic parameters identified from the 1980s groundwater studies and other relevant materials for the Susitna River watershed, Alaska. (Source: SIR Study 7.5, Appendix C, Table 1.)

Source	Location or Study Area	Alluvial Aquifer Sediment Thickness (ft)	Alluvial Aquifer Saturated Thickness (ft)	Alluvial Aquifer Extent (ft)	Alluvial Aquifer Kh (ft/d)	Alluvial Aquifer Kv (ft/d)	T (ft2/d)	Storage Coeff.	Horizontal Hydraulic Gradient
Acres American (1980)	Devil Canyon	**35**							
Acres American (1980)	Vee (~ PRM 224)	**125**							
Acres American (1980)	Watana	**50 - 80**							
Acres (1982)	Watana	**40 - 80**							
R&M Consultants (1982)	Slough 8A	**> 9.5**			*226 - 1000; 328 - 3280 assumed for calculations*			*0.2*	**0.0022 - 0.003**
R&M Consultants (1982)	Slough 9	**> 11**							
R&M Consultants (1982)	Slough 9B	**> 43**	**> 35**					*0.2*	**0.0033**
Acres American (1983)	Slough 9		*100*		*170 - 1000; 200 assumed for calculations*		*9,000*	*0.18*	
Harza-Ebasco (1983)	Watana	**mean 80, locally up to 140**			**4.3 – 340, low bias since only fine grained sediments tested**				
Harza-Ebasco (1984)	Slough 8A to 11, Middle Susitna River		*100*	**3000^**	67		*6,700*	*0.2 (unconf); 0.0002 (conf)*	*0.003*
Harza-Ebasco (1984)	Talkeetna Fire Hall	**> 100**	**> 70**		**84**		**1858 - 5900***		
Harza-Ebasco (1984)	Talkeetna Area Wells				**22 - 133 (mean 57)**		*334 - 1070*		
Harza-Ebasco (1984)	Middle Susitna River Valley Walls		*500*		*0.014*		*7.1*		*0.3*
R&M Consultants (1985)	Slough 9				**0.15 - 31**		**0.2 - 92**		
R&M Consultants & Woodward-Clyde (1985)	Gold Creek Railway Bridge	**100**							

Source	Location or Study Area	Alluvial Aquifer Sediment Thickness (ft)	Alluvial Aquifer Saturated Thickness (ft)	Alluvial Aquifer Extent (ft)	Alluvial Aquifer Kh (ft/d)	Alluvial Aquifer Kv (ft/d)	T (ft2/d)	Storage Coeff.	Horizontal Hydraulic Gradient
Penn Jersey Drilling (2007)	Curry	**> 120**	**> 70**		**123**		**7600**		
USGS (2013)	Lower Susitna Basin	*250 - 400*			*16.9 - 19.2*	*1 (riverbed sediments)*			*0.004 - 0.006*

Notes:

1 Kh = horizontal hydraulic conductivity; Kv = vertical hydraulic conductivity; T = transmissivity.

2 Bold values are measured values, italicized values are either assumed, estimated, or calibrated values.

3 Vertical hydraulic gradient data were presented, and therefore are not tabulated.

4 Interpretation of valley-fill sediment extent was based on aerial photos between Slough 11 and 8A.

5 See text Section 5.2 for a discussion of transmissivity interpretations.

Table 5.5-1. Groundwater and Surface Water Field Stations and MODFLOW Calibration Targets. (Source: SIR Study 7.5, Appendix B, Table 4-1.)

Field Station Full Name	Field Station Short Name	Station Type	Steady State Target	Transient Target
ESGFA128-10-W1	128-10-W1	Groundwater well	No	No
ESGFA128-11-W1	128-11-W1	Groundwater well	Yes	Yes
ESGFA128-12	128-12-W1	Groundwater well	No	No
ESGFA128-13-W1	128-13-W1	Groundwater well	Yes	Yes
ESGFA128-13-W2	128-13-W2	Groundwater well	No	No
ESGFA128-18-W1	128-18-W1	Groundwater well	Yes	Yes
ESGFA128-19-W1	128-19-W1	Groundwater well	Yes	Yes
ESGFA128-20-W1	128-20-W1	Groundwater well	No	No
ESGFA128-21-W1	128-21-W1	Groundwater well	Yes	Yes
ESGFA128-23-W1	128-23-W1	Groundwater well	Yes	Yes
ESGFA128-24-W1	128-24-W1	Groundwater well	Yes	Yes
ESGFA128-25-W1	128-25-W1	Groundwater well	Yes	Yes
ESGFA128-26-W1	128-26-W1	Groundwater well	Yes	Yes
ESGFA128-27-W1	128-27-W1	Groundwater well	Yes	Yes
ESGFA128-2-W1	128-2-W1	Groundwater well	No	Yes
ESGFA128-3-W1	128-3-W1	Groundwater well	No	No
ESGFA128-4-W1	128-4-W1	Groundwater well	Yes	Yes
ESGFA128-5-W1	128-5-W1	Groundwater well	Yes	Yes
ESGFA128-6-W1	128-6-W1	Groundwater well	Yes	Yes
ESGFA128-7-W1	128-7-W1	Groundwater well	Yes	Yes
ESGFA128-7-W2	128-7-W2	Groundwater well	No	No
ESMFA128-8-W1	128-8-W1	Groundwater well	No	No
ESGFA128-9-W1	128-9-W1	Groundwater well	No	No
ESGFA128-9-W2	128-9-W2	Groundwater well	No	No
ESSFA128-1	128-1	Surface-water gage	No	No
ESGFA128-11	128-11	Surface-water gage	No	No
ESGFA128-12	128-12	Surface-water gage	No	No
ESGFA128-13	128-13	Surface-water gage	No	No
ESSFA128-14	128-14	Surface-water gage	No	No
ESSFA128-15	128-15	Surface-water gage	No	No
ESSFA128-16	128-16	Surface-water gage	No	No
ESSFA128-17	128-17	Surface-water gage	No	No
ESGFA128-2	128-2	Surface-water gage	No	No
ESSFA128-22	128-22	Surface-water gage	No	No
ESGFA128-5	128-5	Surface-water gage	No	No
ESGFA128-6	128-6	Surface-water gage	No	No
ESGFA128-7	128-7	Surface-water gage	No	No

Table 5.5-2. Model Calibration Results - shaded simulations = best fit model run. (Source: SIR Study 7.5, Appendix B, Table 5-1.)

		Parameters Adjusted during Model Calibration[1]					Model Calibration Statistics[2]						
Model Name	Model (Steady State or Transient)	Specified Flux (ft^2/dy per unit length)	Kh (ft/dy)	Kz (ft/dy)	Kv (ft/dy)	Storage Coefficient (S)	Residual Mean (ft)	Residual Standard Deviation (ft)	Absolute Residual Mean (ft)	Residual Sum of Squares (ft)	Residual Mean Square Error (ft)	Target Range (ft)	Scaled RMSE (%)
Susitna_SS_V12	SS	2.1	66	66	6.6		0.61	1.33	0.91	30.10	1.47	12.09	12.2
Susitna_SS_V18	SS	0.21	6	0.66	1		-0.20	1.10	0.79	17.40	1.12	12.09	9.3
Susitna_SS_V19	**SS**	**0.21**	**6**	**0.66**	**6**		**0.18**	**1.07**	**0.80**	**16.50**	**1.09**	**12.09**	**9.0**
Susitna_SS_V20	SS	0.21	66	6	6		0.63	1.34	0.93	30.60	1.48	12.09	12.2
Susitna_SS_V21	SS	0.21	100	10	10		0.69	1.35	0.96	32.00	1.51	12.09	12.5
Susitna_SS_V22	SS	0.21	20	1	1		0.12	1.28	0.84	23.10	1.28	12.09	10.6
Susitna_SS_V23	SS	0.21	10	1	1		0.02	1.18	0.82	19.50	1.18	12.09	9.8
Susitna_SS_V24	SS	0.21	10	1	6		0.44	1.14	0.81	20.70	1.22	12.09	10.1
Susitna_SS_V25	SS	0.21	66	0.1	6		0.61	1.29	0.89	28.70	1.43	12.09	11.8
Susitna_SS_V26	SS	0.21	20	2	2		0.38	1.26	0.82	24.40	1.32	12.09	10.9
Susitna_SS_V27	SS	0.21	50	5	5		0.61	1.33	0.92	29.80	1.46	12.09	12.1
Susitna_T_V19_Run1	**T**	**0.21**	**6**	**0.66**	**6**	**0.001**	**-0.01**	**1.27**	**0.91**	**1200**	**1.27**	**13.25**	**9.6**

Notes:

1 Kh = aquifer horizontal hydraulic conductivity; Kz = aquifer vertical hydraulic conductivity; Kv = river bed vertical hydraulic conductivity, and S = aquifer storage coefficient (not required for steady state model).

2 Scaled RMSE = (Residual Sum of Squares)/(Target Range)

Table 5.6-1. 2014 collected discharge measurements in Focus Areas. (Source: SIR Study 6.6, Table 5.1-14.)

Date	Flow (cfs)	Location	Reference PRM	Northing (feet)	Easting (feet)
		FA-104 Whiskers Slough			
9/27/2014	10[a]	Near head of right bank side channel	105.8	3,063,308	1,615,080
9/27/2014	1[a]	Upstream connection into Slough 3B	105.4	3,062,647	1,613,263
9/27/2014	0.1[a]	Near head of left bank side channel	104.9	3,059,123	1,613,857
9/27/2014	0.14	Near head of left bank side channel	105.2	3,060,336	1,613,509
9/27/2014	0.3[a]	Near mouth of left bank side channel	104.9	3,058,879	1,613,582
9/27/2014	1.22[b]	Downstream of beaver dam in Slough 3B	105.4	3,062,266	1,612,578
9/27/2014	0.07	Near head of left bank side channel	105.2	3,060,134	1,613,640
		FA-113 Oxbow			
9/23/2014	0.82	Mouth of Oxbow I	113.7	3,101,369	1,623,125
9/23/2014	6.20	Mouth of Gash Creek	115.1	3,107,391	1,622,840
9/23/2014	0.46	Mouth of Slash Creek	114.8	3,106,250	1,623,153
		FA-115 Slough 6A			
9/23/2014	0.45[b]	Mouth of Unnamed Tributary 115.4	115.4	3,108,780	1,621,080
9/23/2014	0.15	Inflow from beaver dam at head of Slough 6A	116.1	3,112,010	1,619,438
9/23/2014	0.32	Groundwater inflow at head of Slough 6A	116.1	3,111,090	1,619,438
9/23/2014	1.04	Mouth of tributary into Slough 6A	116.0	3,111,431	1,619,417
9/23/2014	0.84[b]	Side channel in mid-channel island	115.9	3,111,547	1,620,764
		FA-128 Slough 8A			
9/26/2014	1.01	Near head of Slough 8A	130.1	3,167,600	1,659,832
9/26/2014	1[a]	Unnamed Tributary to Slough 8 A	129.9	3,166,924	1,659,026
9/26/2014	1[a]	Unnamed Tributary to Slough 8A	130.0	3,167,209	1,659,443
9/26/2014	4.65	Downstream of beaver dam on Slough 8A	129.7	3,166,393	1,658,118
9/26/2014	10[a]	Channel across mid-channel island	128.3	3,165,013	1,650,820
9/26/2014	0.1[a]	Mouth of channel on south side of mid-channel island	128.6	3,164,469	1,652,751
9/26/2014	0.1[a]	Mouth of channel on north side of mid-channel island	128.8	3,166,472	1,652,610
9/25/2014	1[a]	Near head of channel into Slough 8A	129.5	3,166,780	1,656,565
9/25/2014	1.39	Near mouth of channel into Slough 8A	129.4	3,166,043	1,656,332
9/25/2014	9.22	Slough 8A above confluence with channel	129.4	3,165,724	1,656,500
9/25/2014	0.51	Near mouth of Slough A	128.1	3,163,824	1,650,824
9/25/2014	0.60	Head of channel across mid-channel island	128.7	3,166,031	1,652,420
9/25/2014	No flow	Near head of Half-Moon Slough	128.9	3,165,827	1,653,557
9/25/2014	1.96	Near mouth of channel across mid-channel island	128.4	3,164,548	1,651,705
		FA-138 Gold Creek			
9/24/2014	1.69	Near head of Upper Side Channel 11	139.9	3,203,504	1,691,698
9/24/2014	2.13	Near mouth of Upper Side Channel 11	139.6	3,202,738	1,689,788
9/24/2014	60[a]	Near head of channel into mouth of Slough 12	138.7	3,199,419	1,688,668
9/24/2014	0.1[a]	Near mouth of Slough 12	138.8	3,199,475	1,689,142
9/24/2014	0.21	Near mouth of Slough 13	139.0	3,200,668	1,688,970
9/24/2014	1[a]	Outlet from beaver impounded pond along right bank	139.5	3,203,481	1,688,936
9/24/2014	0.25	Near head of Slough 11	139.4	3,202,434	1,690,710
9/24/2014	0.37	Left channel downstream of beaver dam in Slough 11	138.9	3,200,220	1,690,204
9/24/2014	1.16	Middle channel downstream of beaver dam in Slough 11	138.9	3,200,235	1,690,195
9/24/2014	0.62	Right channel downstream of beaver dam in Slough 11	138.9	3,200,249	1,690,182
9/24/2014	1.56	Left channel near mouth of Slough 11	138.7	3,199,033	1,689,404
9/24/2014	1.65	Right channel near mouth of Slough 11	138.7	3,198,943	1,689,382
		FA-141 Indian River			

Date	Flow (cfs)	Location	Reference PRM	Northing (feet)	Easting (feet)
9/25/2014	0.1[a]	Mouth of Slough 17	142.3	3,211,169	1,698,990
FA-144 Slough 21					
9/24/2014	14.3	Mouth of Unnamed Tributary 144.6	144.5	3,217,382	1,708,369
9/24/2014	10.3	Side Channel 21 near mouth of Unnamed Tributary 144.6	144.6	3,217,686	1,708,391
9/24/2014	1.25	Mouth of channel across mid-channel island	144.9	3,218,990	1,709,017
9/24/2014	No flow	Mouth of channel across mid-channel island	145.0	3,219,661	1,709,360
9/23/2014	300[a]	Mouth of channel across mid-channel island	144.5	3,217,850	1,707,901
9/24/2014	1[a]	Near inlet berm into channel on mid-channel island	145.5	3,221,584	1,711,078
9/24/2014	0.01[a]	Near head of channel across mid-channel island	145.5	3,221,237	1,711,539
9/24/2014	0.23	Downstream of beaver dam in Slough 21	145.2	3,219,949	1,710,390
9/24/2014	0.90	Slough 21	145.1	3,219,801	1,710,244
9/24/2014	1.50[a]	Mouth of channel across mid-channel island	145.1	3,219,801	1,709,815

Notes:
a = estimated flow
b = flow measured with current meter

10. FIGURES

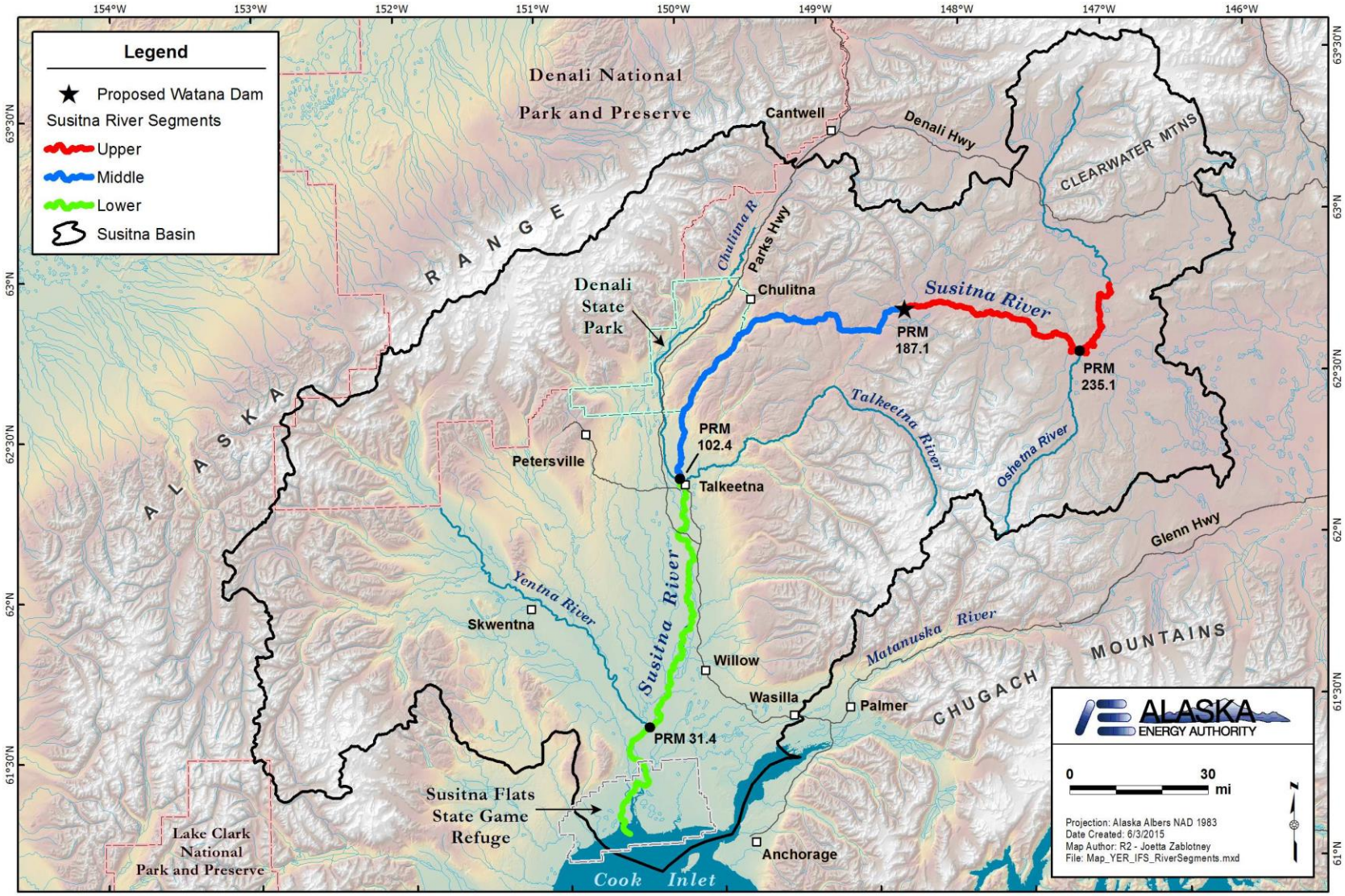

Figure 3-1. Susitna Watershed basin boundaries, showing the Project designation of upper, Middle and Lower river segments (Source: ISR Study 7.5, Figure 3-1).

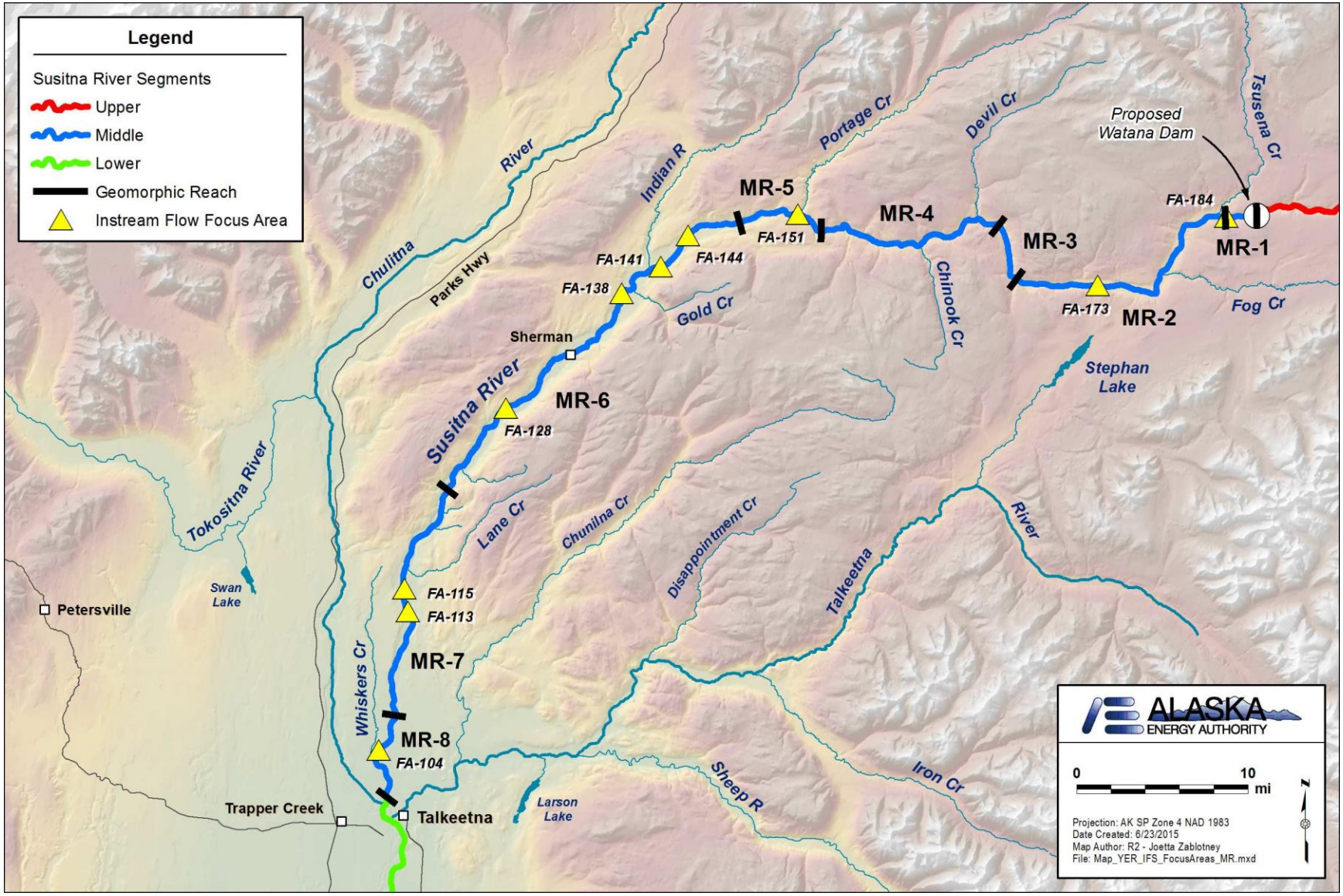

Figure 3-2. Susitna Watershed Middle River Segment, with geomorphic reaches and Focus Areas indicated (Source: ISR Study 7.5, Figure 3-12.)

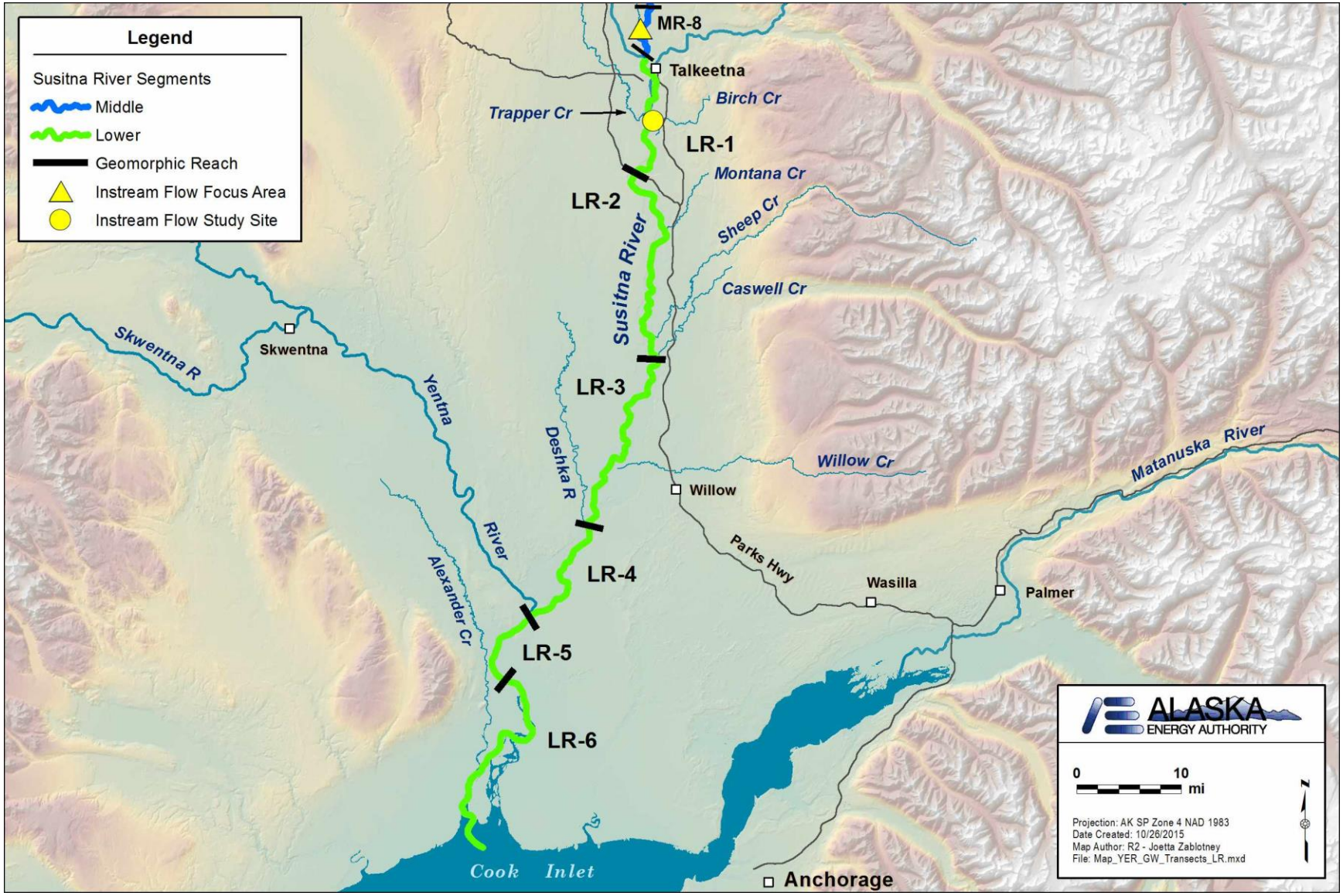

Figure 3-3. Susitna Watershed Lower River Segment, with geomorphic reaches indicated (Source: ISR Study 7.5, Figure 3-3).

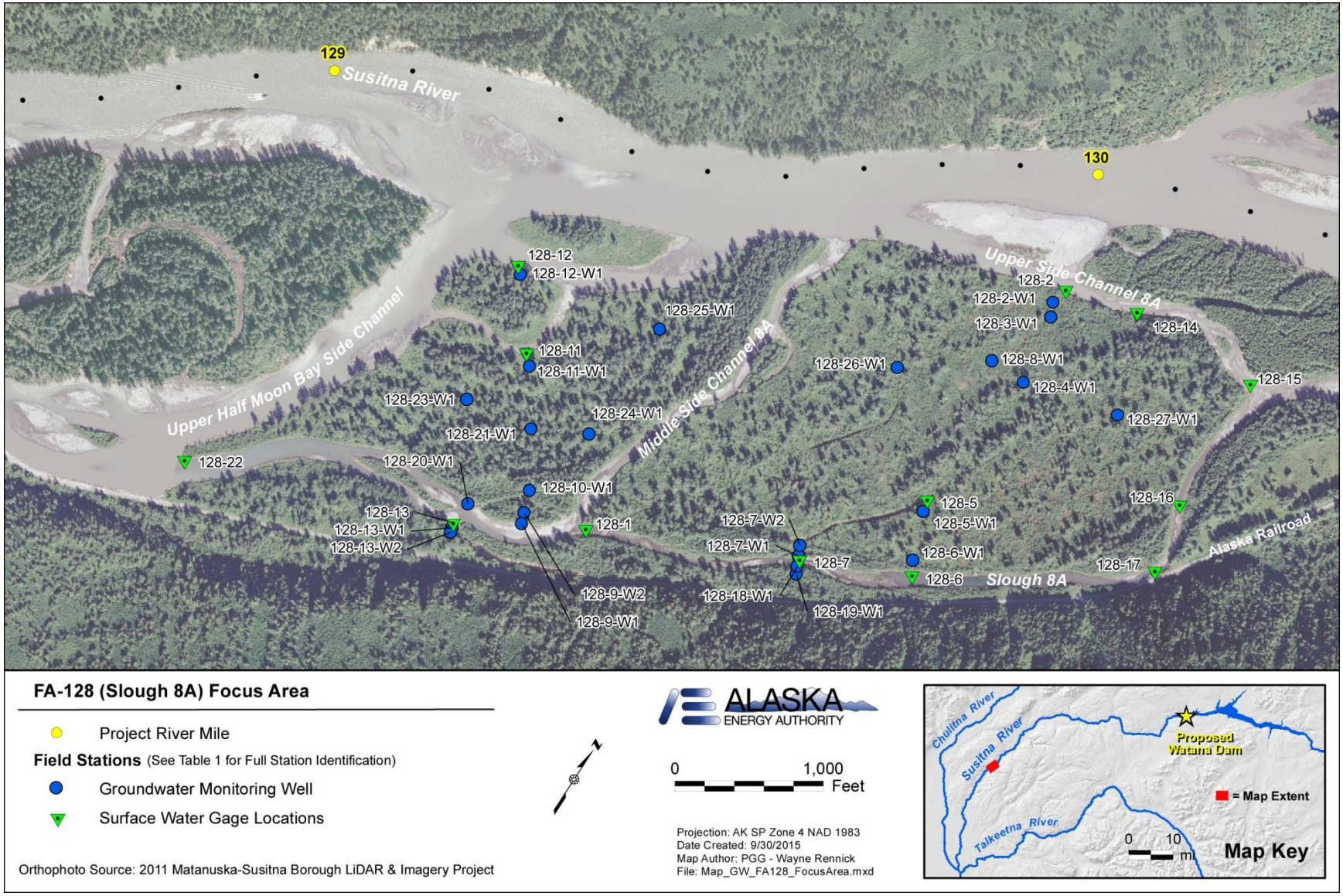

Figure 4.5-1. FA-128 (Slough 8A) Focus Area with groundwater and surface water monitoring locations (Source: ISR Study 7.5, Appendix B, Figure 3-3).

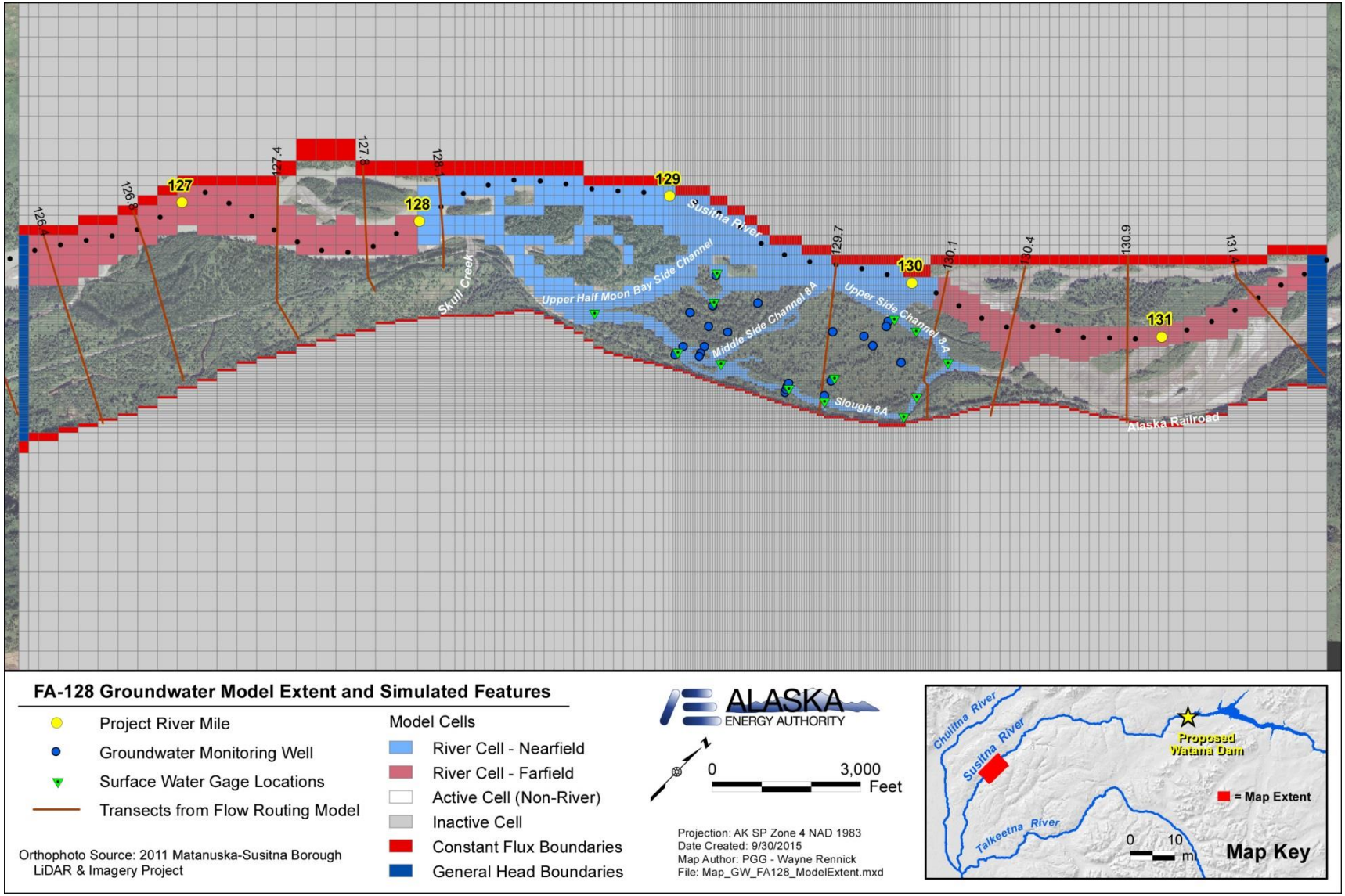

Figure 4.5-2. Groundwater Model Extent and Simulated Features in FA-128 Area (Source: ISR Study 7.5, Appendix B, Figure 4-2).

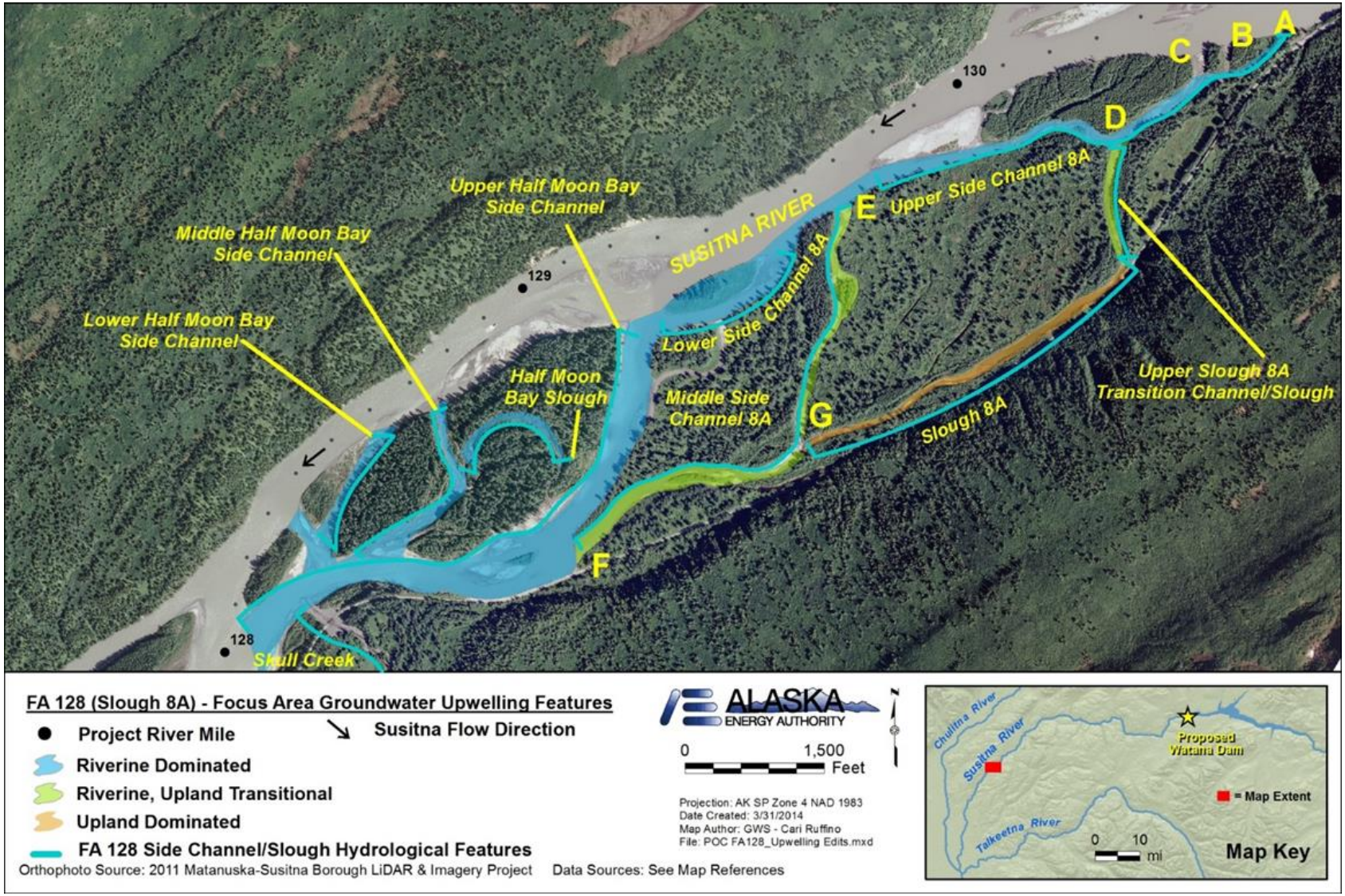

Figure 5.4-1. Example delineation of Riverine Dominated, Riverine-Upland Transitional, and Upland Dominated. (Source: SIR Study 7.5, Appendix D, presentation slide 30.)

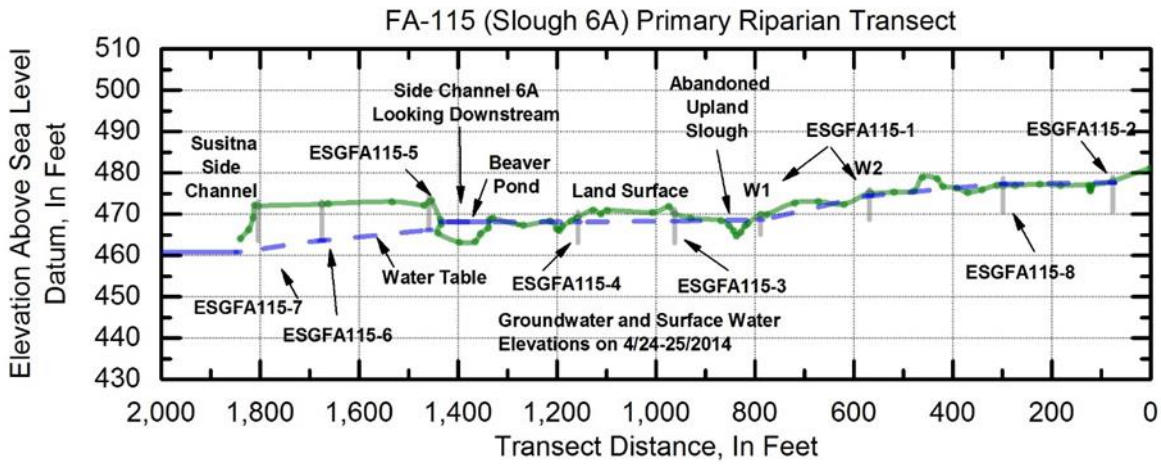

Figure 5.5-1. Primary riparian cross section at FA-115 (Slough 6A) showing location of groundwater wells, surface-water measurement locations, and the measured water levels on April 24-25, 2014, with inferred water table. (Source: GWS and R2 2014a - Figure 22.)

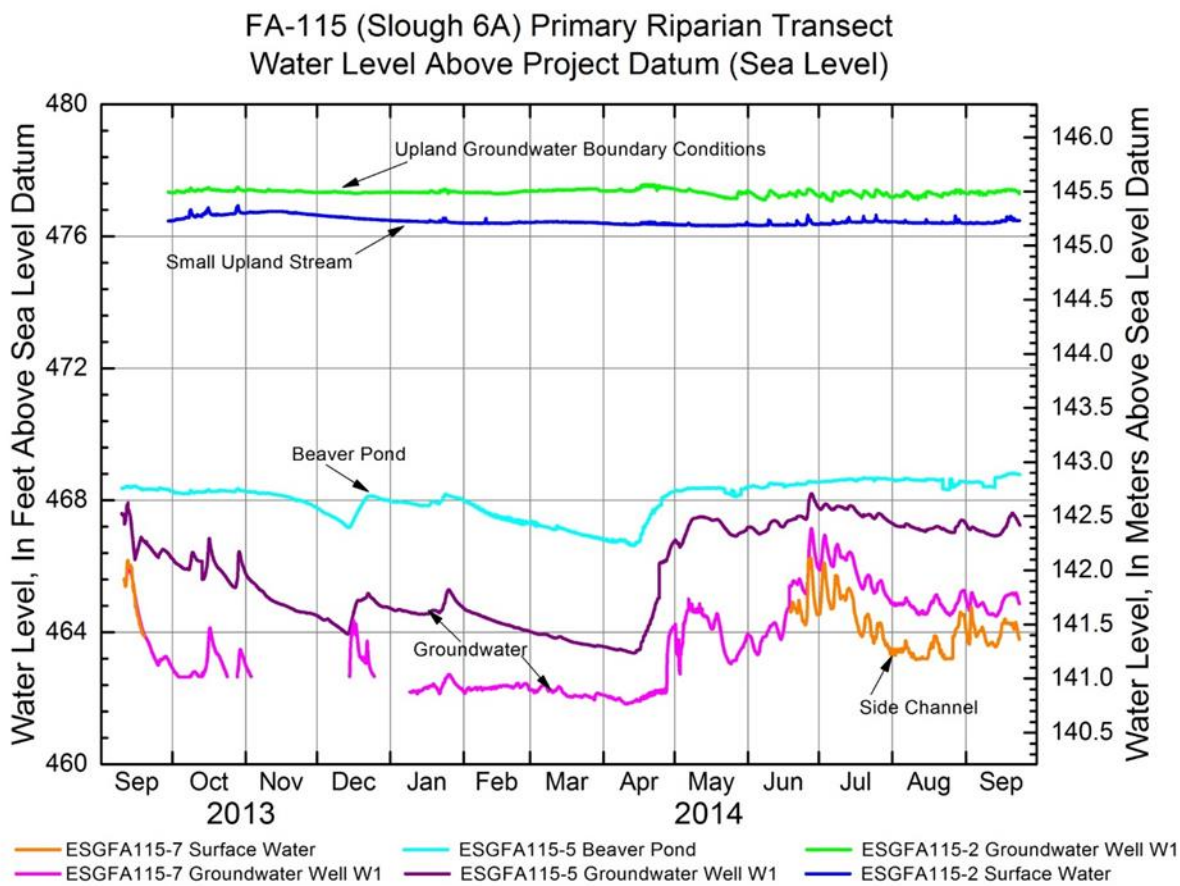

Figure 5.5-2. Groundwater elevations and surface-water levels for selected stations in FA-115 (Slough 6A) representing upland groundwater conditions and lower groundwater wells affected by riverine processes. (Source: GWS and R2 2014a - Figure 23.)

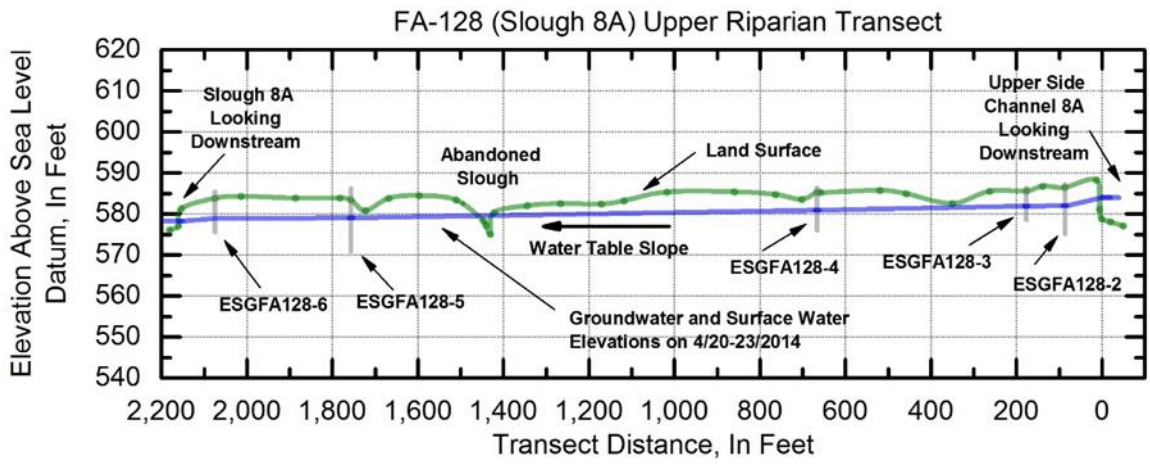

Figure 5.5-3. Cross-section profile of the Upper Riparian Transect in FA-128 (Slough 8A) showing the land surface profile, location of groundwater wells and surface water measuring points on Upper Side Channel 8A and Slough 8A. Water levels are shown for the April 20-23, 2014. Water levels in Upper Side Channel 8A are ice affected. (Source: GWS and R2 2014a - Figure 26.)

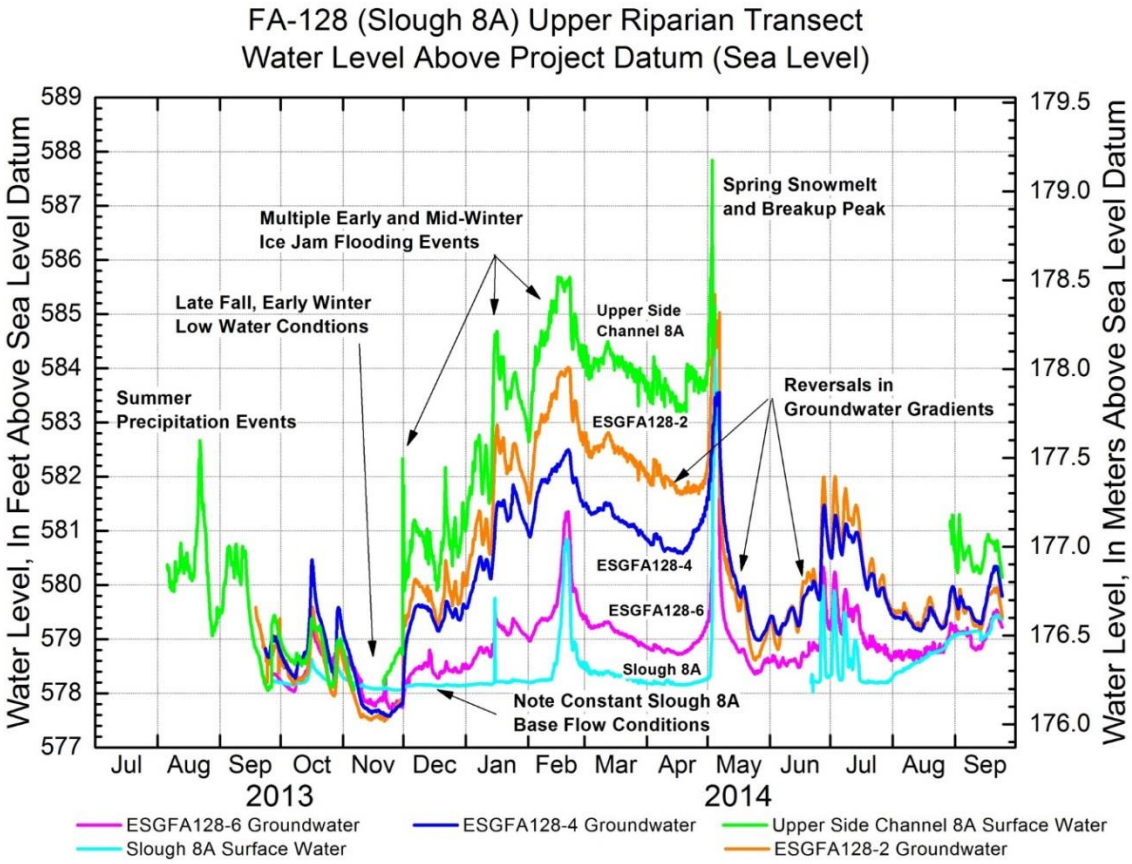

Figure 5.5-4. Water level data for Upper Side Channel 8A, Slough 8A, and groundwater wells between the two surface-water features on the Upper Riparian Transect in FA-128 (Slough 8A). (Source: GWS and R2 2014a - Figure 27.)

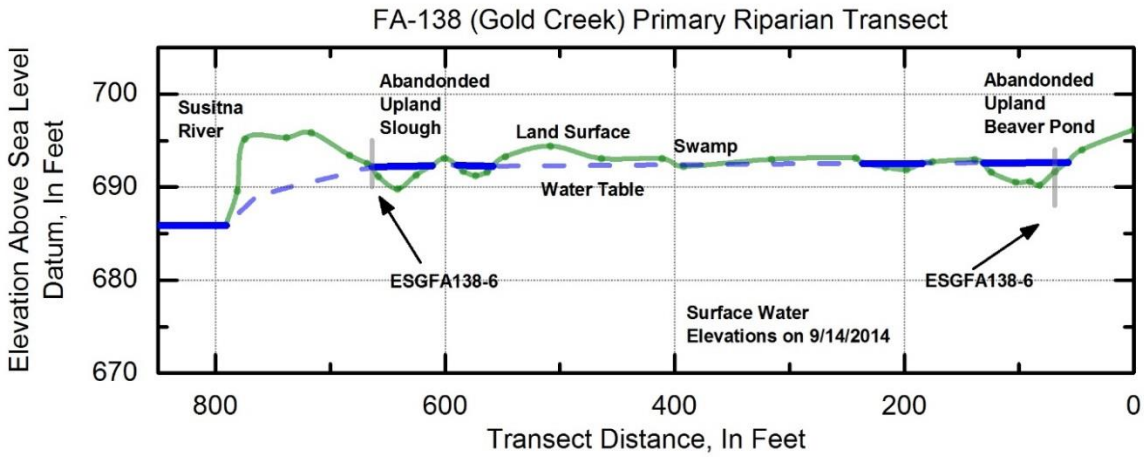

Figure 5.5-5. Primary riparian cross section at FA-138 (Gold Creek) showing locations of surface-water measurement locations, and typical upland features that indicate shallow groundwater conditions. Water levels are shown for the cross-section survey date of 9/14/2014. (Source: GWS and R2 2014a - Figure 24.)

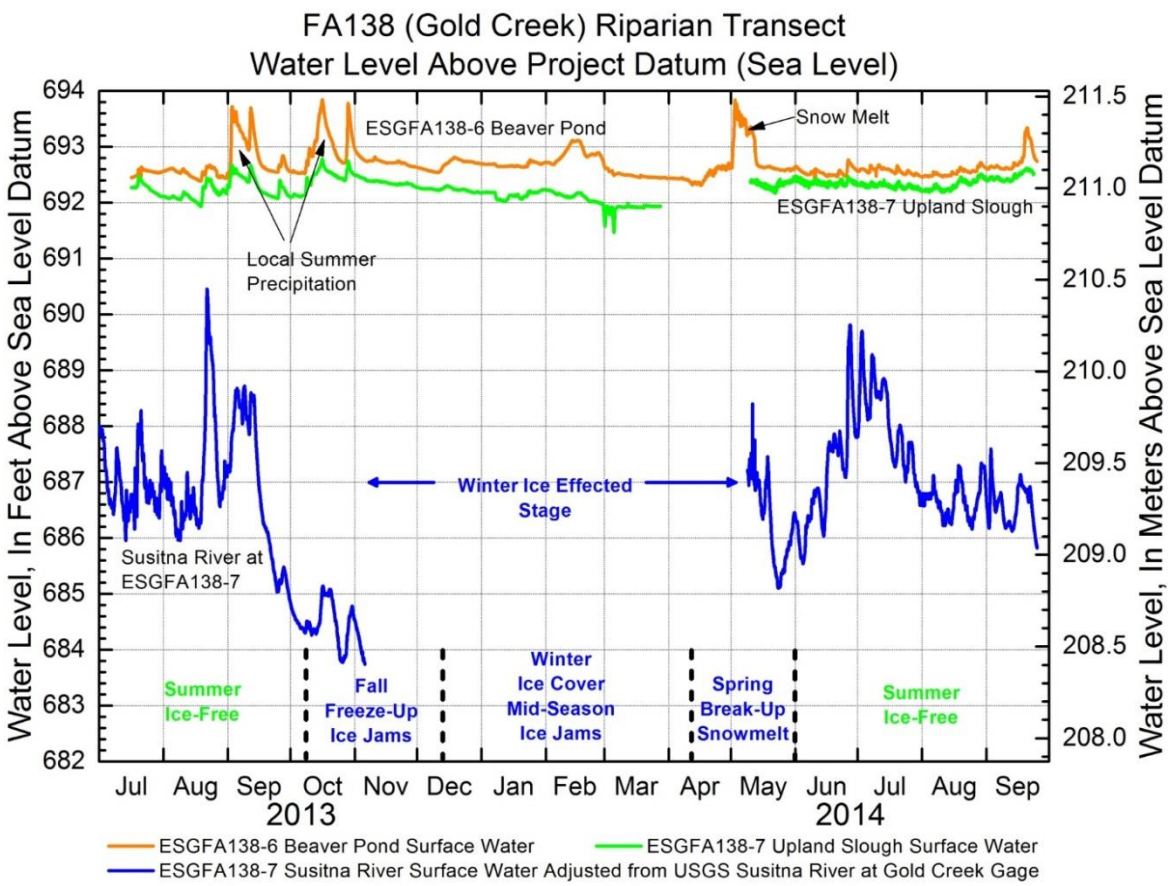

Figure 5.5-6. Surface-water levels for stations in the FA-138 (Gold Creek) riparian transect. Major hydrologic periods are indicated to show how the variation in water levels relate to the climate and hydrologic processes relevant to these periods. (Source: GWS and R2 2014a - Figure 25.)

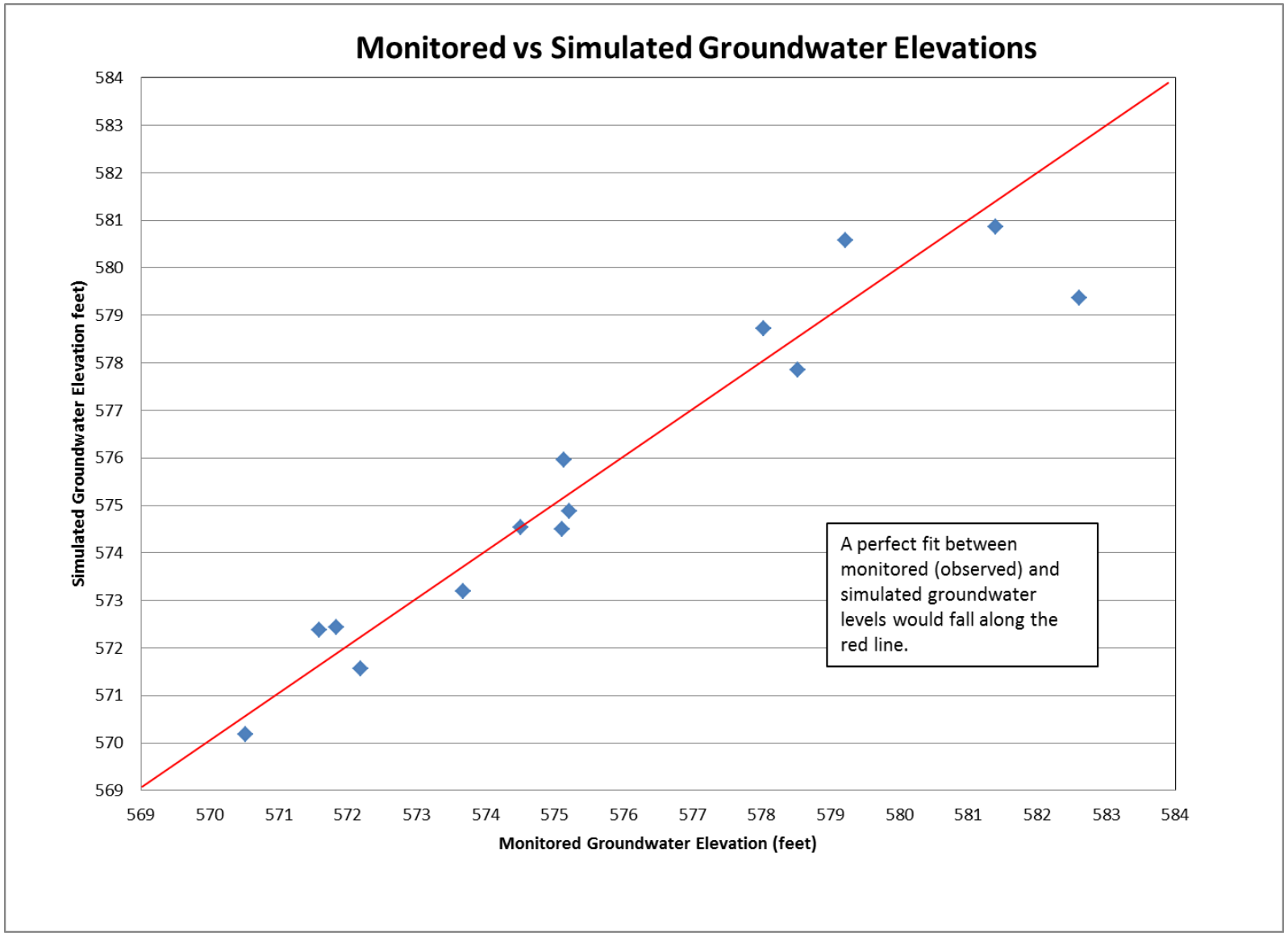

Figure 5.5-7. Monitored versus Simulated Steady State Groundwater Elevations. (Source: SIR Study 7.5, Appendix B, Figure 5-1.)

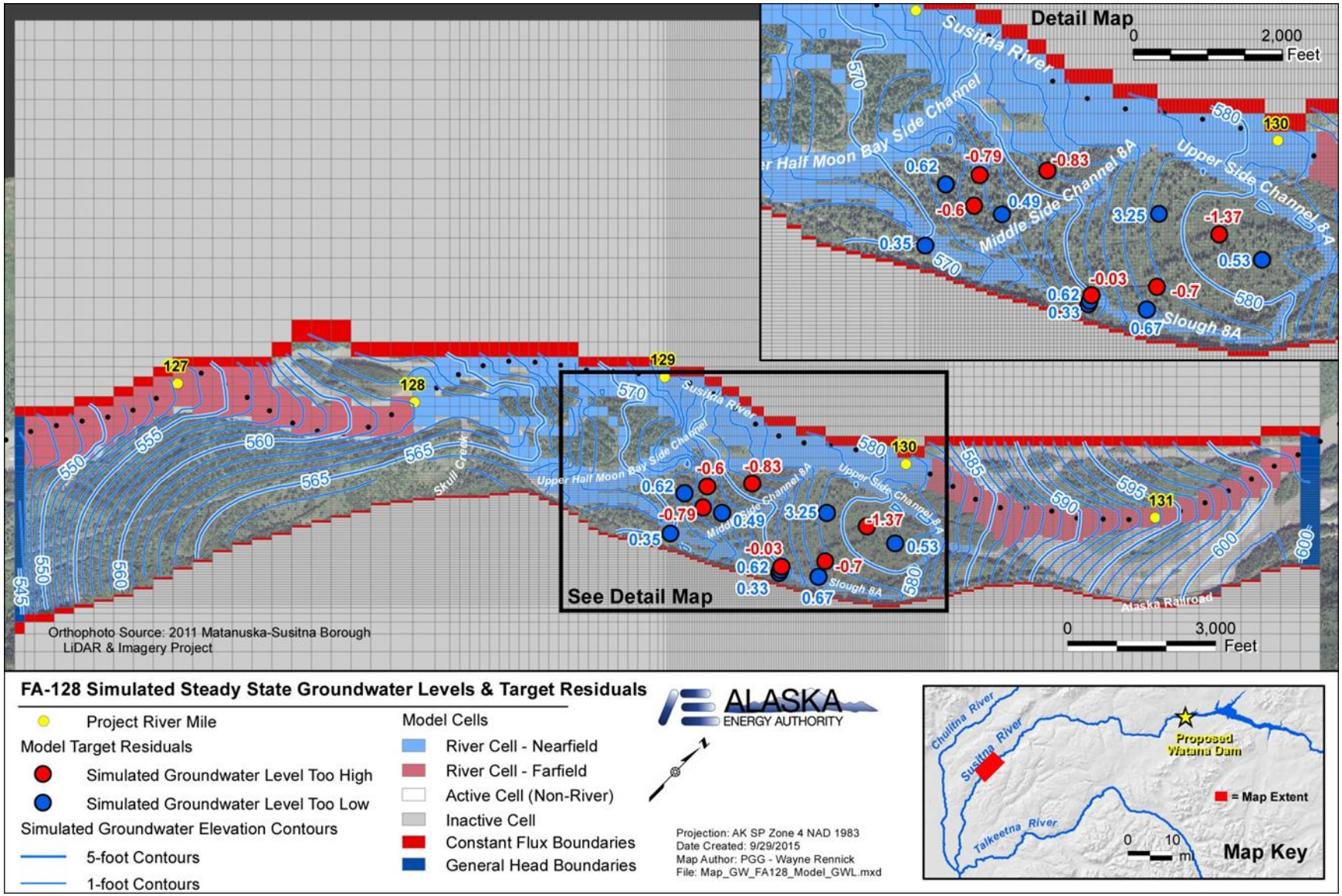

Figure 5.5-8. Simulated Steady Stage Groundwater Elevations and Model Target Residuals in FA-128 Area. (Source: SIR Study 7.5, Appendix B, Figure 5-2.)

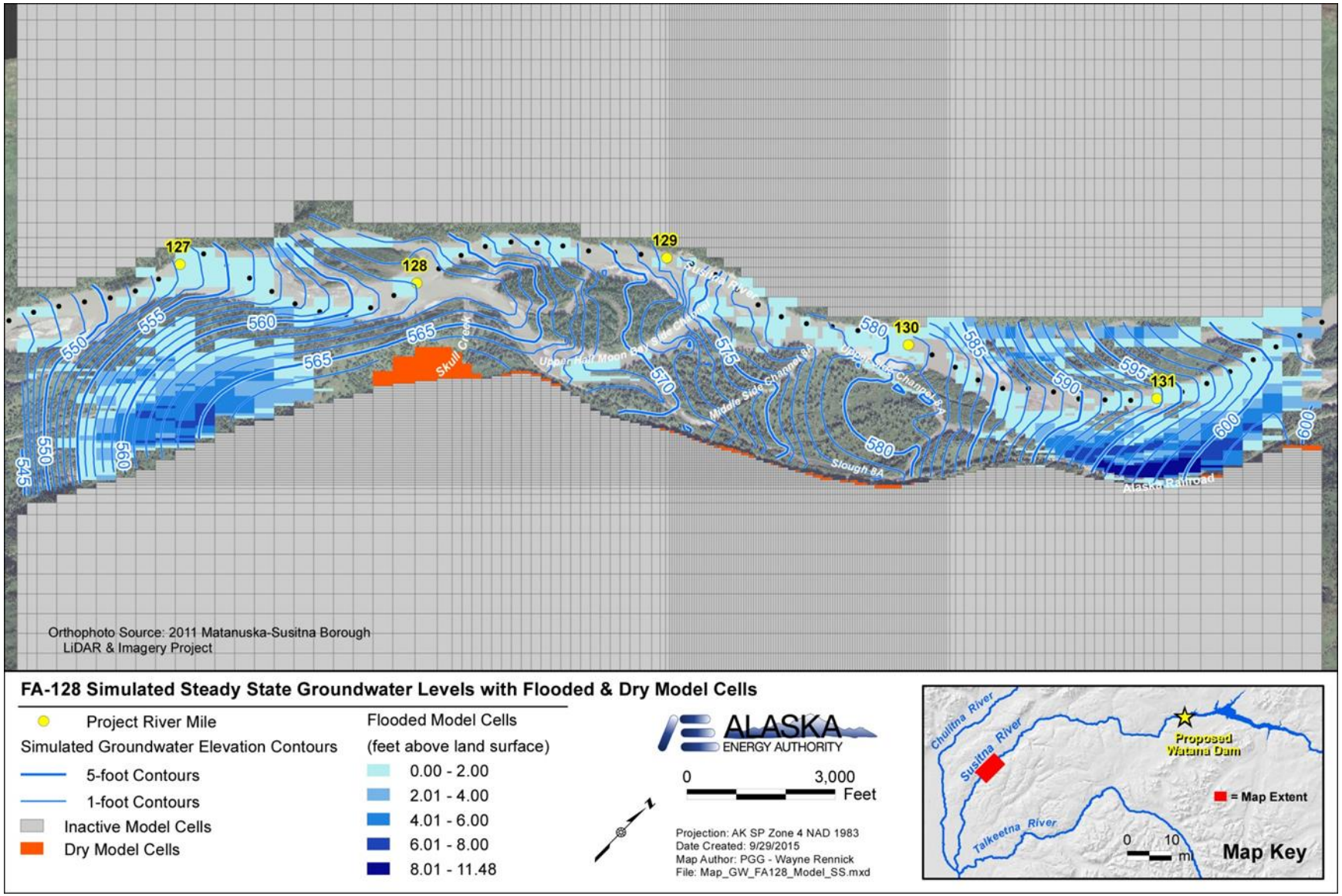

Figure 5.5-9. Simulated Steady Stage Groundwater Elevations with Flooded and Dry Model Cells Shown. (Source: SIR Study 7.5, Appendix B, Figure 5-3.)

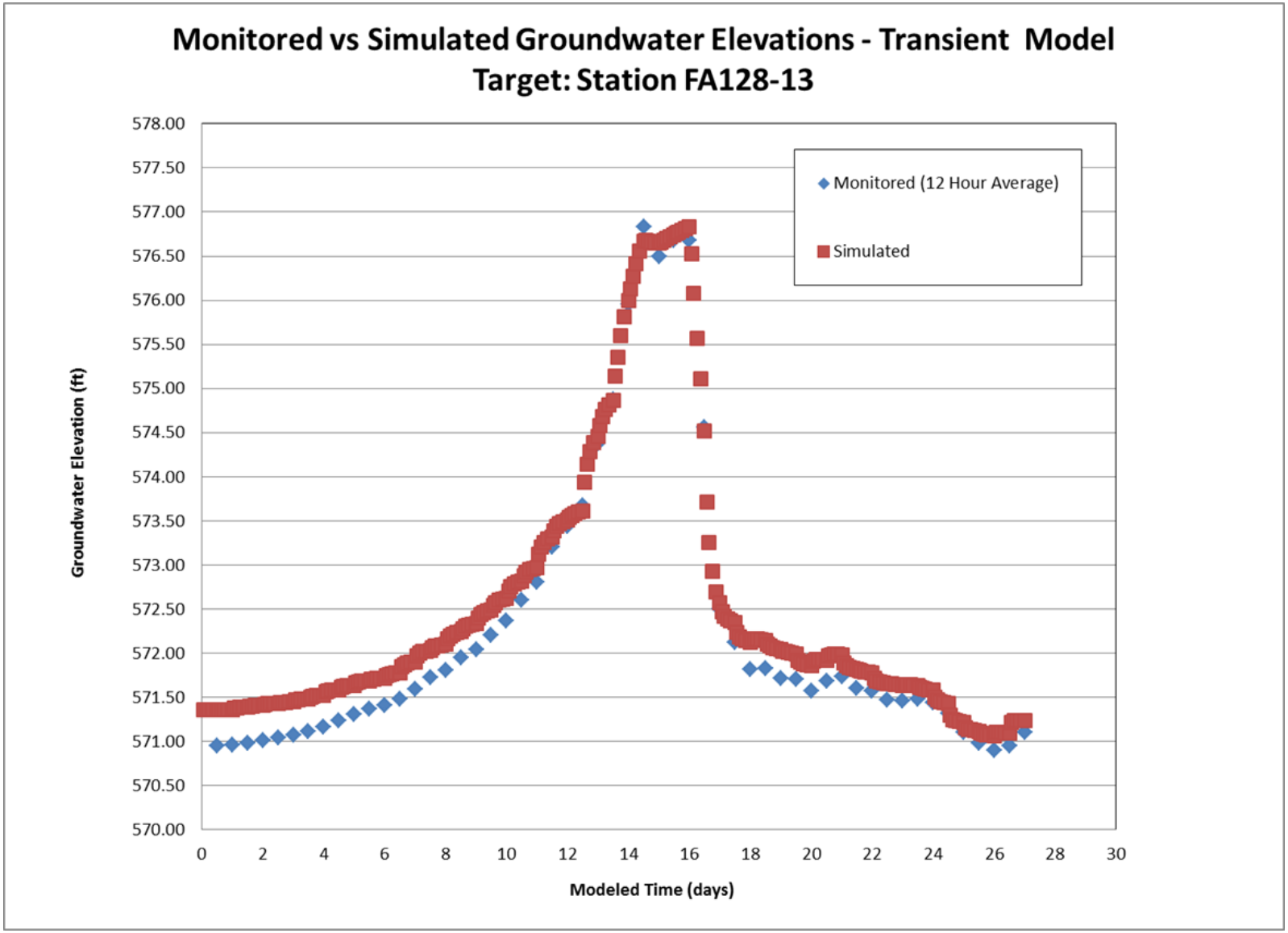

Figure 5.5-10. Monitored versus Simulated Steady State Groundwater Elevations (Station 128-13). (Source: SIR Study 7.5, Appendix B, Figure 5-4.)

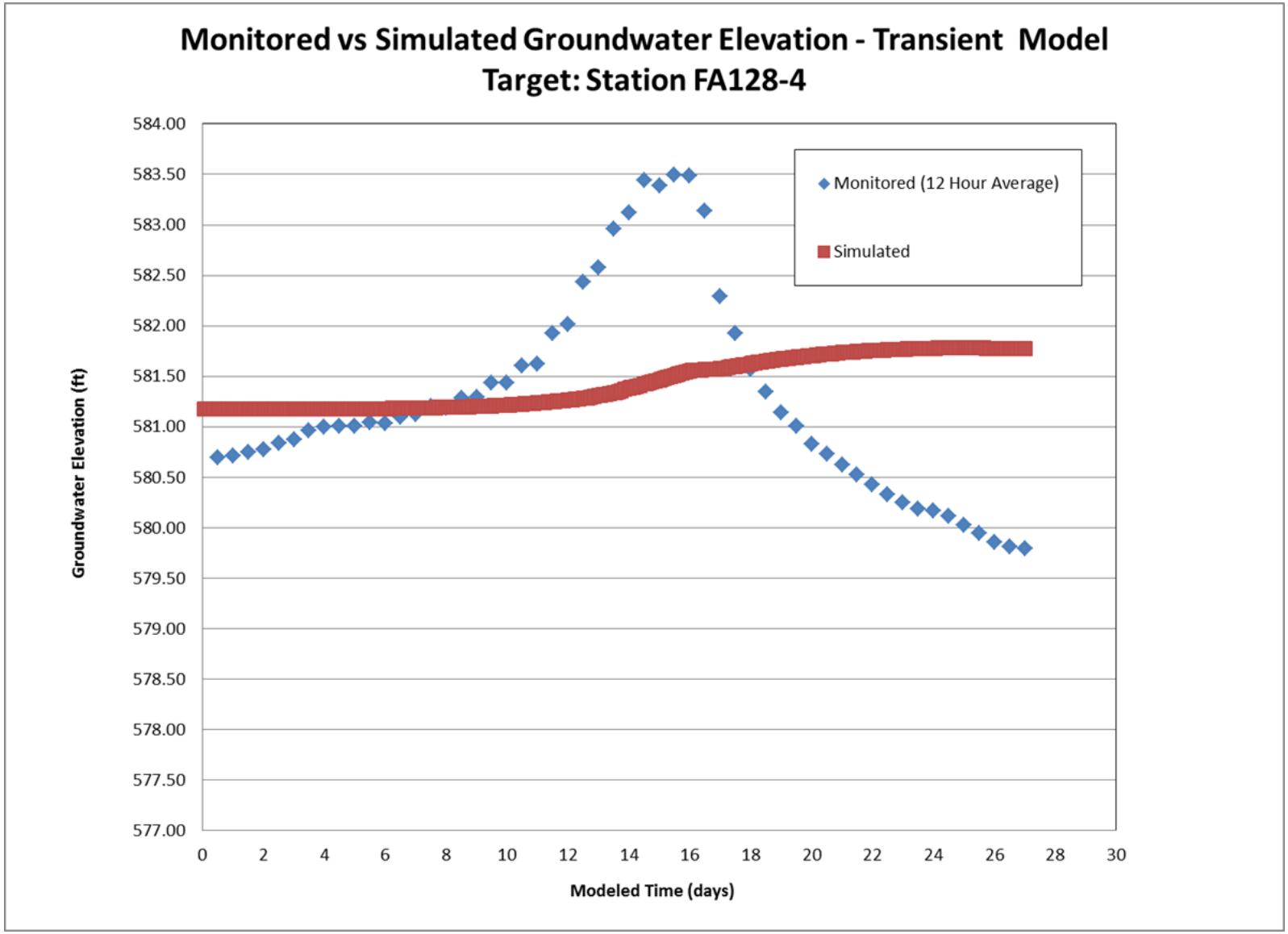

Figure 5.5-11. Monitored versus Simulated Steady State Groundwater Elevations (Station 128-4). (Source: SIR Study 7.5, Appendix B, Figure 5-5.)

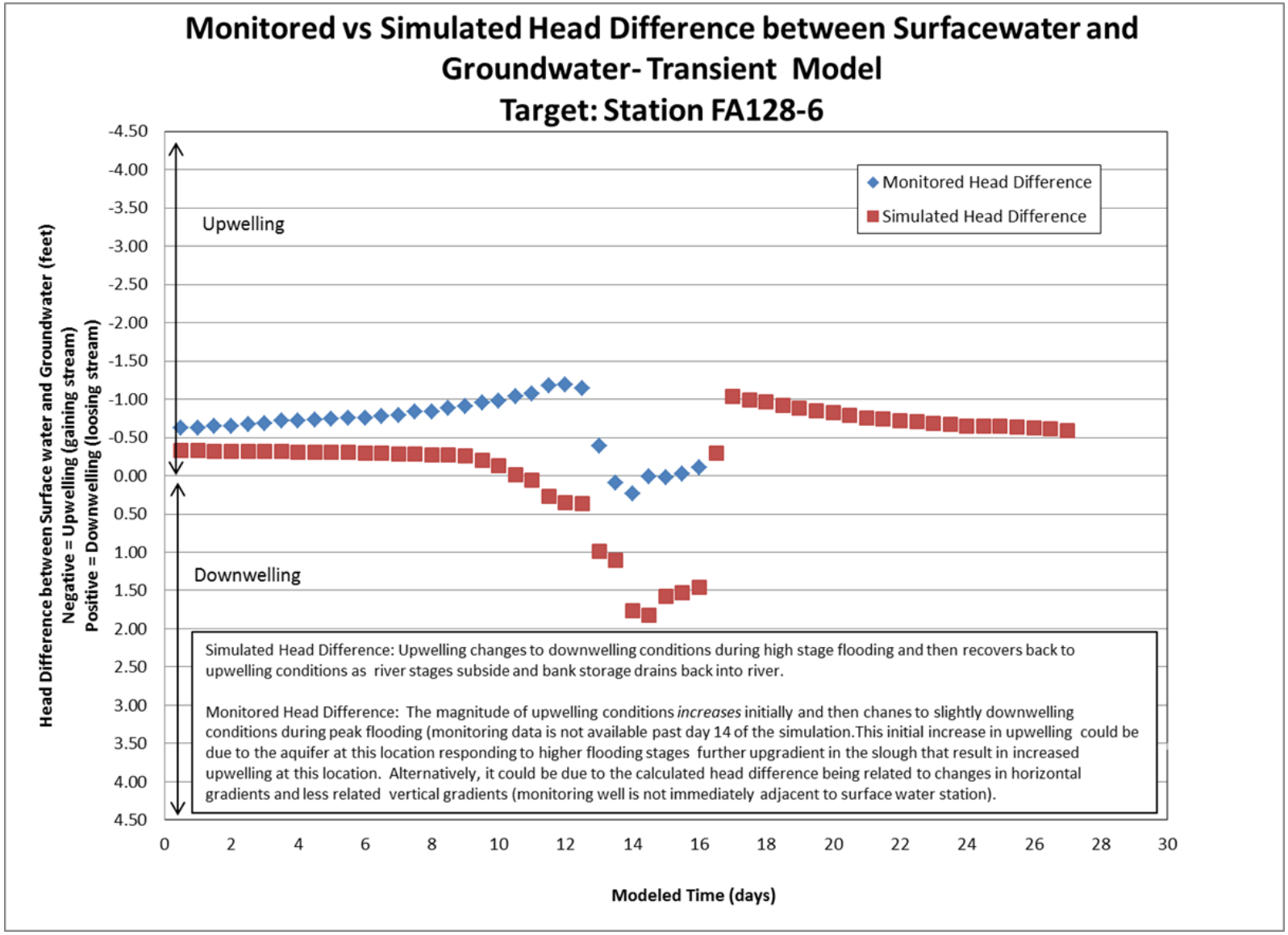

Figure 5.5-12. Monitored versus Simulated Transient Head Difference between Surface water and Groundwater at Target Station 128-6. (Source: SIR Study 7.5, Appendix B, Figure 5-6.)

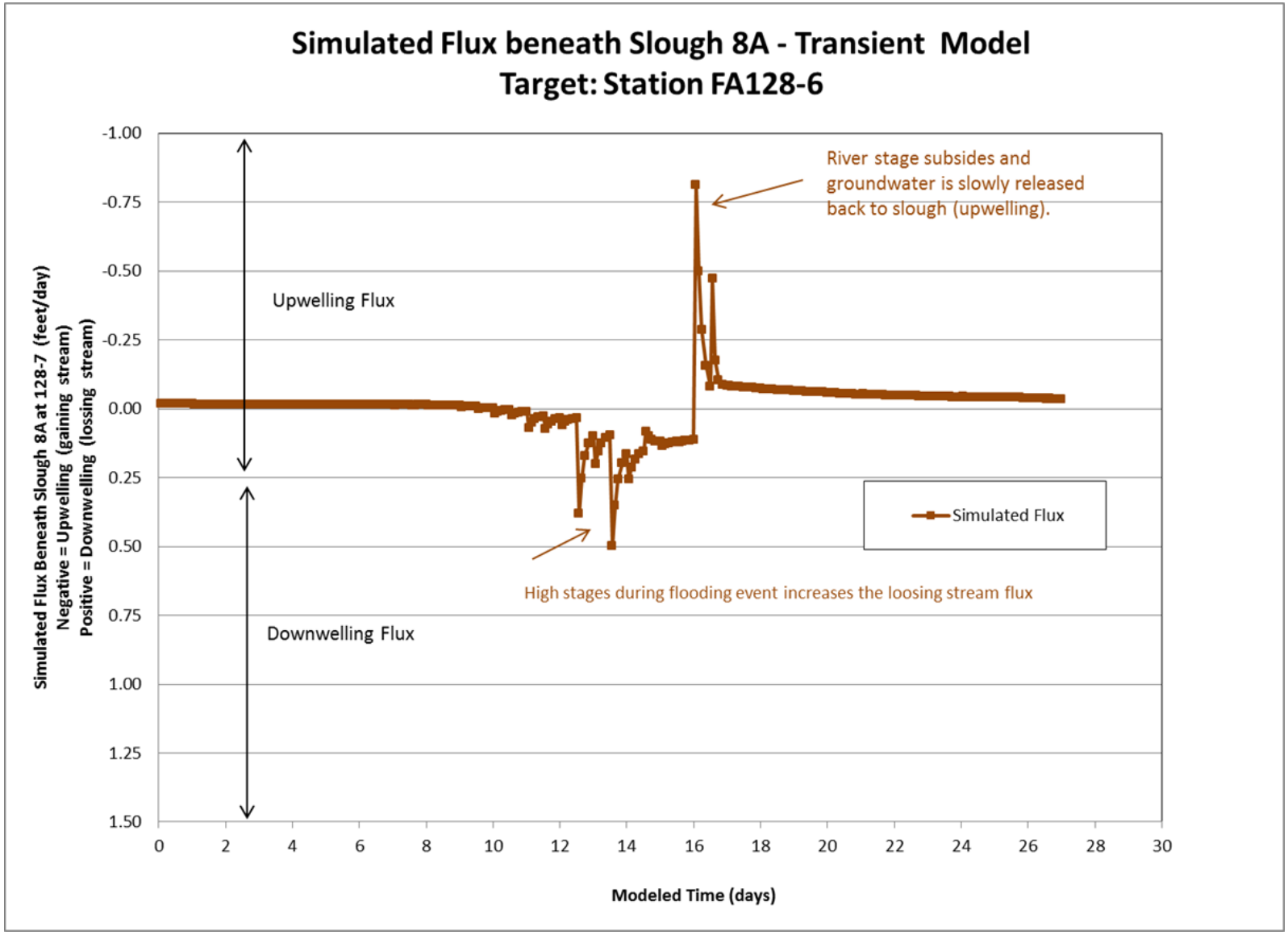

Figure 5.5-13. Monitored versus Simulated Transient Flux beneath Slough 8A at Target Station 128-6. (Source: SIR Study 7.5, Appendix B, Figure 5-10.)

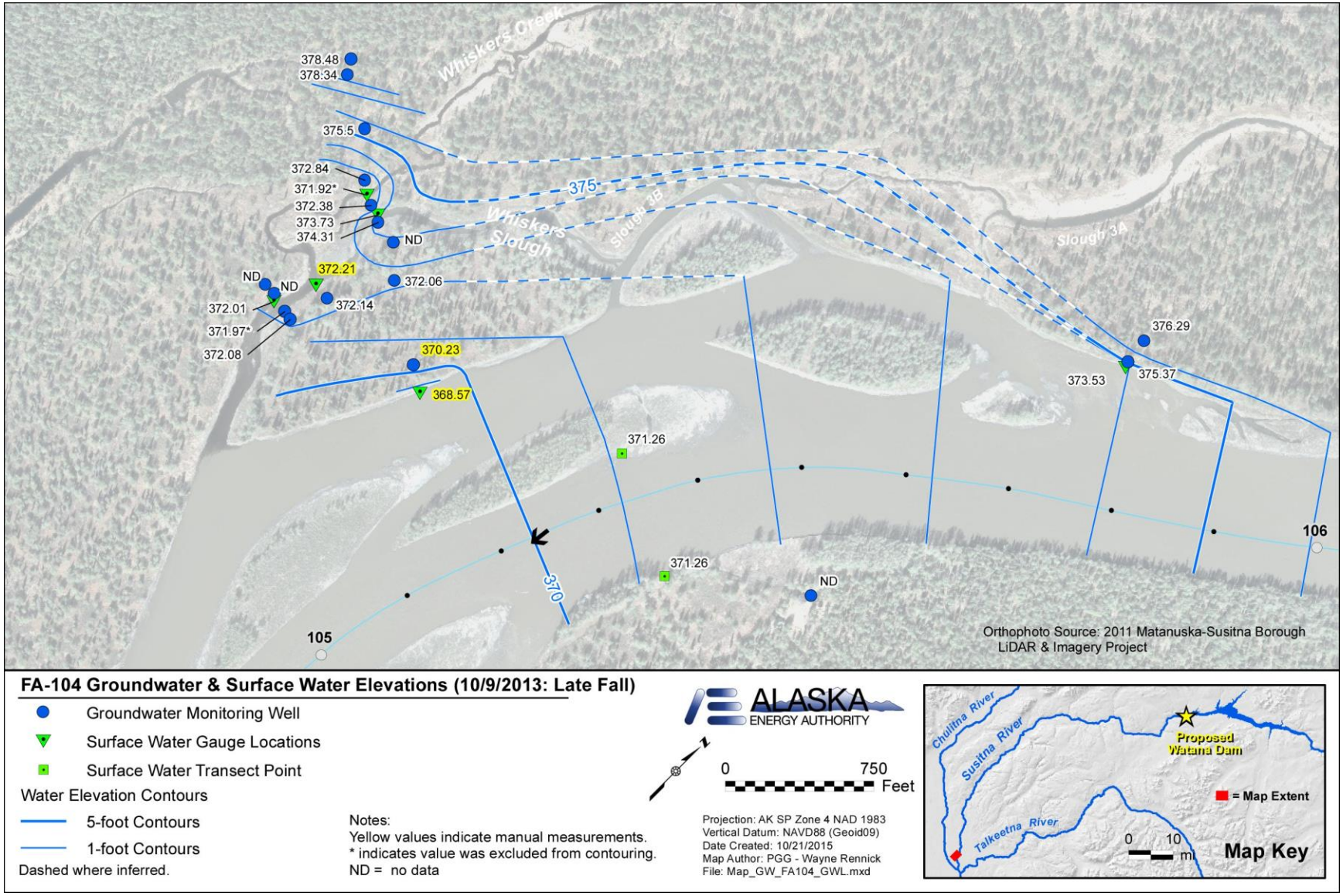

Figure 5.5-14. FA-104 (Whiskers Slough), showing water-level elevation contours for Late Fall – October 9, 2013, Susitna River. (Source: SIR Study 7.5, Appendix A, Figure 5.1-3.)

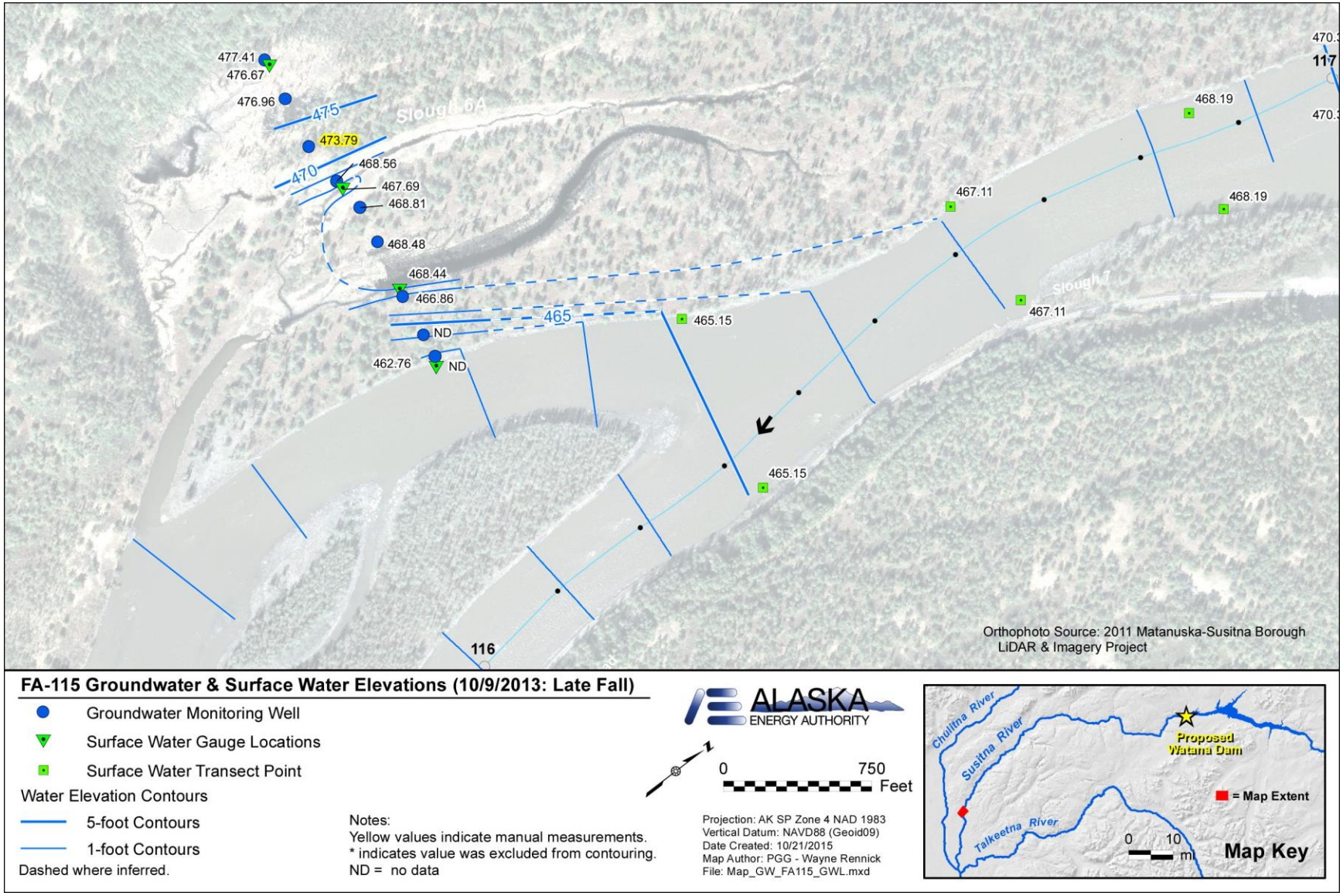

Figure 5.5-15. FA-115 (Slough 6A), showing water-level elevation contours for Late Fall – October 9, 2013, Susitna River. (Source: SIR Study 7.5, Appendix A, Figure 5.2-2.)

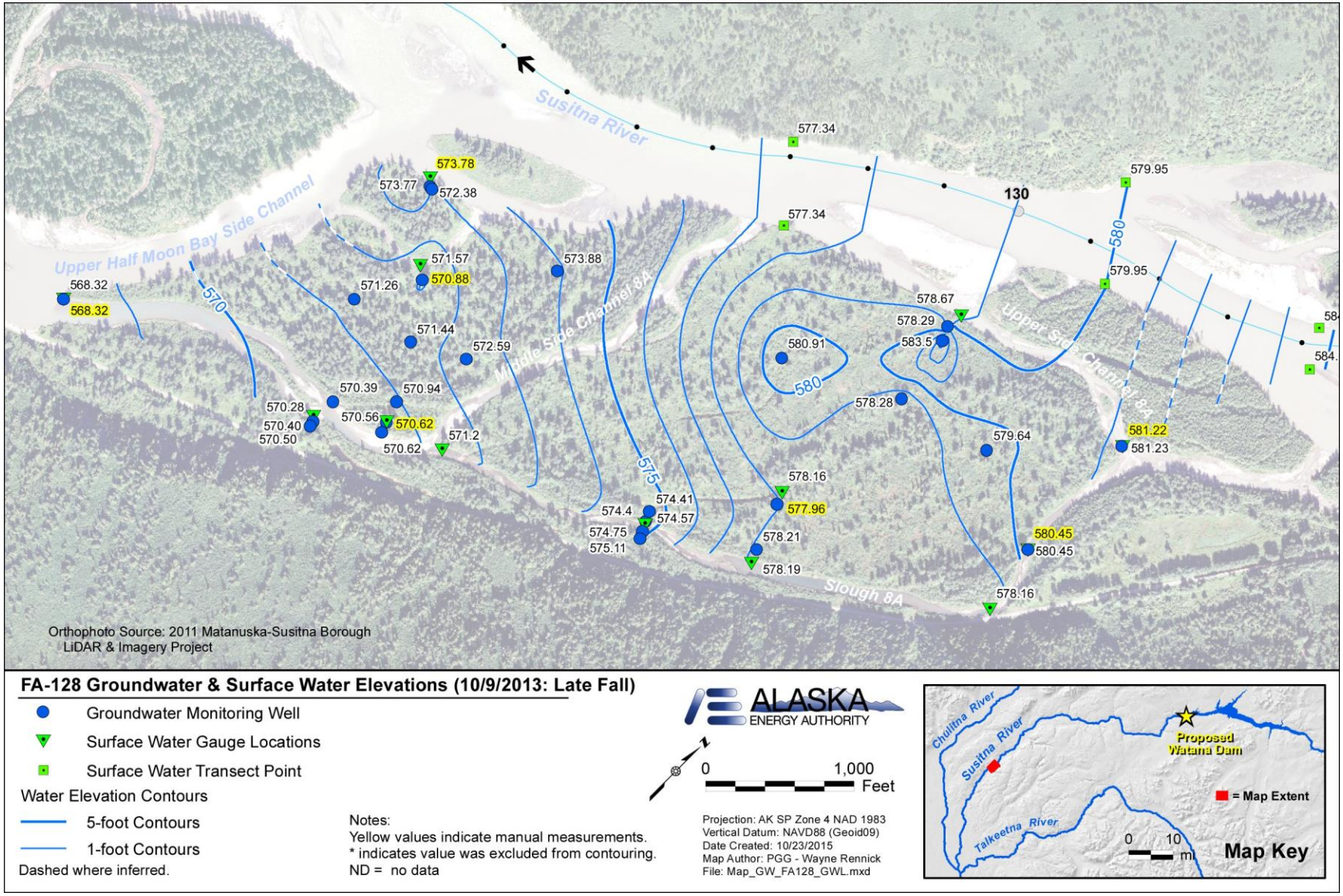

Figure 5.5-16. FA-128 (Slough 8A), showing water-level elevation contours for Late Fall – October 9, 2013, Susitna River. (Source: SIR Study 7.5, Appendix A, Figure 5.3-3.)

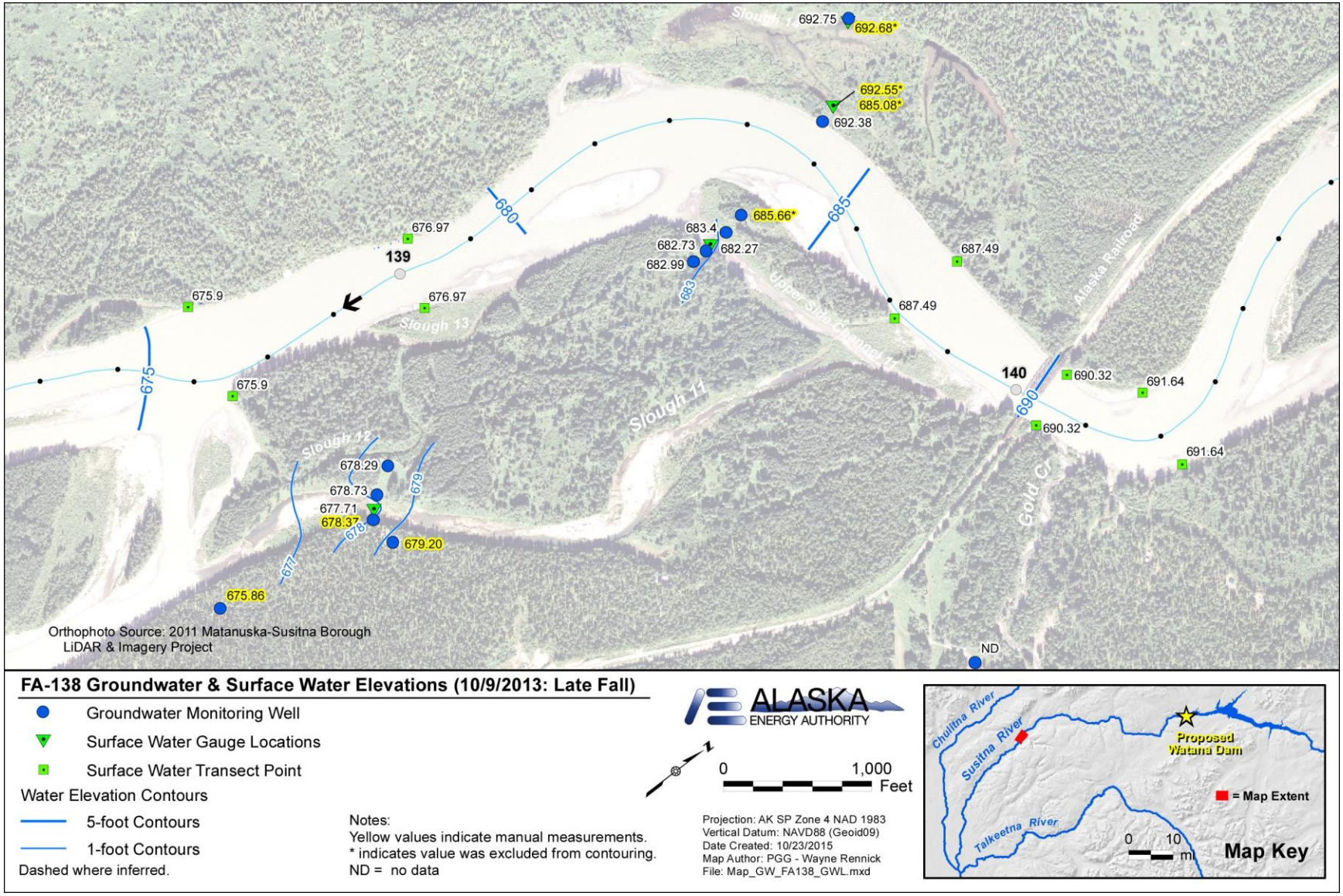

Figure 5.5-17. FA-138 (Gold Creek), showing water-level elevation contours for Late Fall – October 9, 2014, Susitna River. (Source: SIR Study 7.5, Appendix A, Figure 5.4-2.)

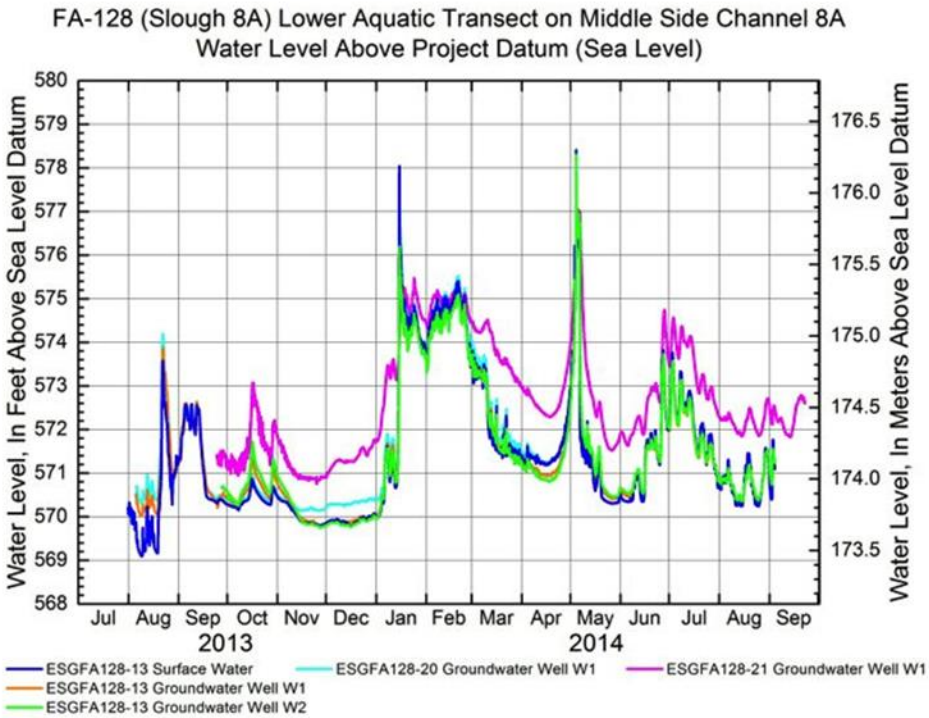

Figure 5.6-1. Groundwater Station ESGFA128-13 groundwater levels in wells adjacent to Middle Side Channel 8A and surface-water stage in Middle Side Channel 8A, and groundwater levels from wells at ESGFA128-20 and ESGFA128-21. (Source: GWS and R2 2014b - Figure 4.1-14.)

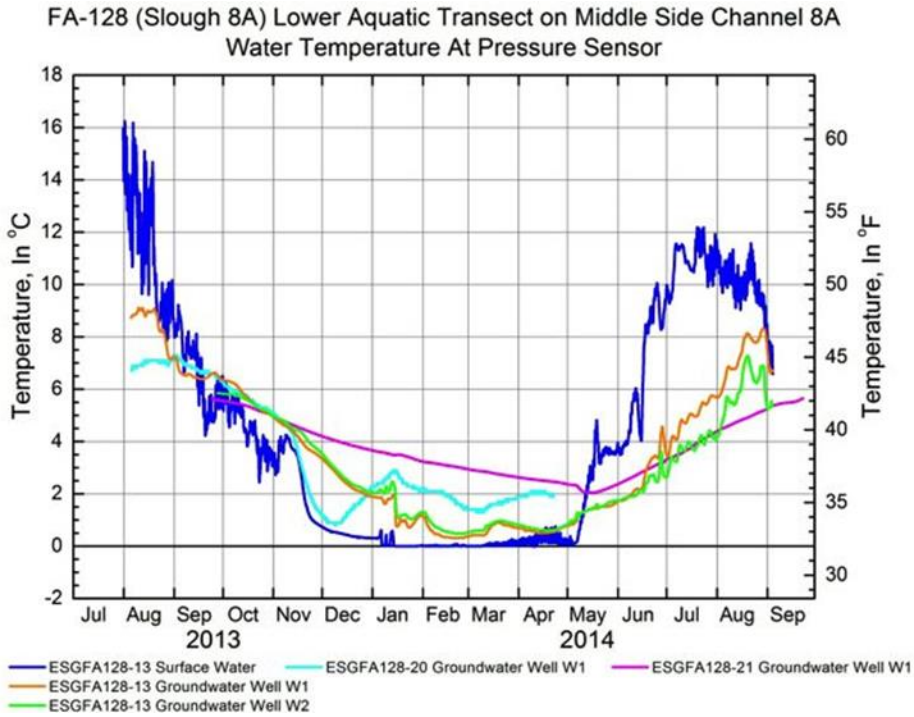

Figure 5.6-2. Groundwater Station ESGFA128-13 groundwater temperature in wells adjacent to Middle Side Channel 8A and surface-water temperature in Middle Side Channel 8A, and groundwater temperature from wells at ESGFA128-20 and ESGFA128-21. (Source: GWS and R2 2014b - Figure 4.1-15.)

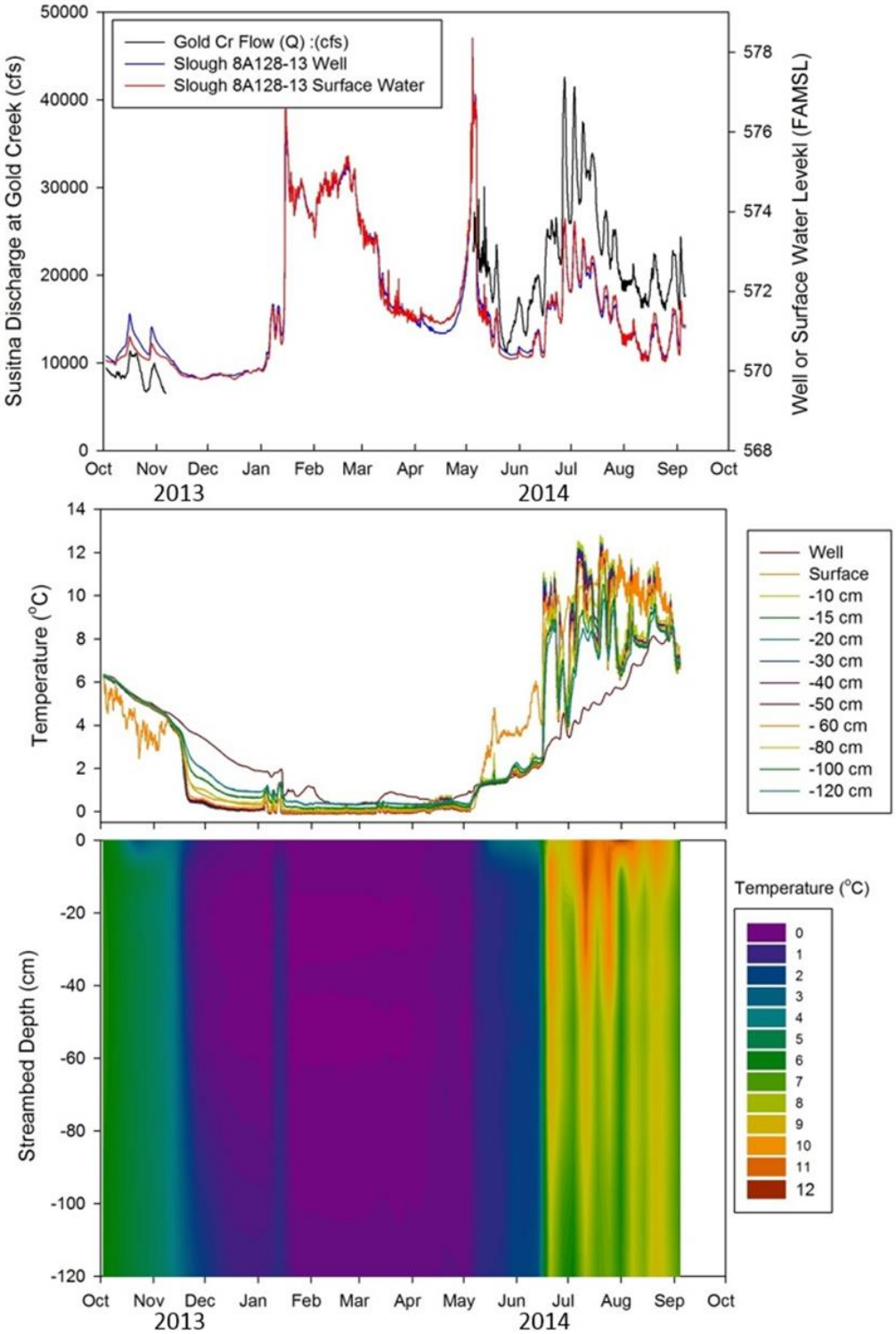

Figure 5.6-3. Downwelling example in Middle Side Channel 8A in FA-128 (Slough 8A) showing groundwater and surface-water levels, stream-bed temperatures, and thermal profile of the stream bed conditions through the major hydrologic periods. (Source: GWS and R2 2014b - Figure 4.3-32.)

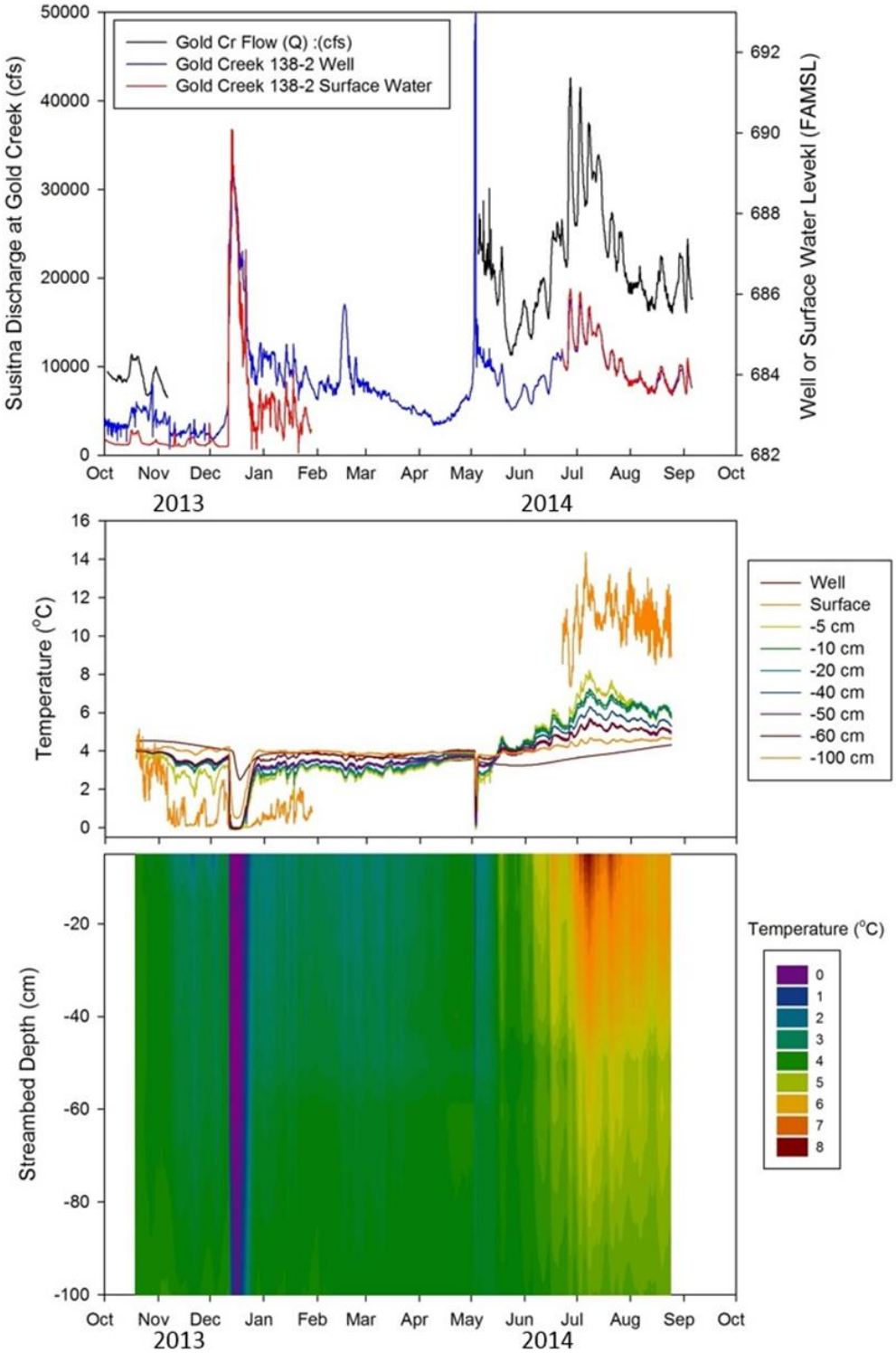

Figure 5.6-4. Upwelling example in Upper Side Channel 11 in FA-138 (Gold Creek) showing groundwater and surface-water levels, stream-bed temperatures, and thermal profile of the stream bed conditions through the major hydrologic periods. (Source: GWS and R2 2014b - Figure 4.3-33.)