Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Technical Memorandum
2012-2013 Instream Flow Winter Pilot Studies

Prepared for

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LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	Definition
Cfs	Cubic feet per second
FA	Focus Area
FDA	Fish Distribution and Abundance
HSC	Habitat suitability criteria
HSI	Habitat suitability indices
IFS	Instream Flow Study
PRM	Project River Mile
TM	Technical Memorandum

1. INTRODUCTION

The Alaska Energy Authority (AEA) is preparing a License Application that will be submitted to the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project (Project) using the Integrated Licensing Process. The Project is located on the Susitna River, an approximately 300-mile long river in the Southcentral Region of Alaska. The Project's dam site will be located at Project River Mile (PRM) 187.1. As currently envisioned, the Project would include a large dam with an approximately 35,000-acre, 41-mile long reservoir. The Project construction and operation would have an effect on the flows downstream of the dam site, the degree of which will ultimately depend on final Project design and operations. Key flow changes will likely occur in the form of load following during the critical winter months of November through April each year. During Project operation, seasonal streamflow conditions will likely be higher in winter and lower during the summer reservoir refill period relative to current hydrologic conditions. The alteration in Susitna River hydrology would influence downstream resources and processes, including resident and anadromous fish species and aquatic habitats. As a result, AEA developed and the FERC approved (on April 1, 2013) a detailed Instream Flow Study (IFS) plan (contained as Section 8.5 in the December 14, 2012 Revised Study Plan; see AEA 2012) designed to evaluate the potential effects of Project operations.

One element of the IFS plan pertains to the completion of winter studies designed to assess patterns of fish habitat use under winter conditions including under ice as well as in open-water leads influenced by groundwater inflow (RSP 8.5.4.5.1.2.1). Companion winter studies were also specified in the RSP as part of the Fish Distribution and Abundance (FDA) study under the Fish Program (RSP 9.6.4.5) (AEA 2012). The RSP specified two separate field efforts for these studies including an initial pilot effort during the winter of 2012-2013 followed by an expanded effort during the winter of 2013-2014. This Technical Memorandum (TM) describes the methods applied and data and information collected as part of the IFS pilot winter studies; results of the pilot winter studies for FDA are presented in a separate TM included in Appendix C of ISR Study 9.6 (R2 et al. 2014). The results of these two studies will provide information useful for developing the 2013-14 expanded winter program.

1.1. Study Background

Winter instream flow conditions are an importantcomponent of fish habitat in the Susitna River, particularly with respect to egg incubation and juvenile rearing. Intergravel flow and groundwater upwelling are critical for egg incubation and emergent fry survival, while surface water characteristics (e.g., temperature, depth, and velocity) and groundwater input can be important aspects of winter habitat for juvenile and adult fish.

Winter studies were conducted during the 1980s, when a two dam complex (Watana Dam and Devils Canyon Dam) was proposed for the Susitna River. Those studies indicated that groundwater upwelling was the principal factor affecting salmon egg development and survival in the Middle Susitna River (Vining et al. 1985). Groundwater influence in incubation areas is important for maintaining stable water levels, providing warmer water relative to surface streamflow and creating intergravel water exchange, which is critical for maintenance of adequate water quality conditions for embryo development (Vining et al. 1985, Quinn 2005).

Higher winter Susitna River discharge and stage that may result from Project operations may affect groundwater upwelling in various ways, including: decreased extent and/or degree of groundwater input from floodplain sources, altered rates of intergravel flow and exchange associated with hydraulic gradients between mainstem and off-channel habitats, and increased influence of cold main channel surface water in off-channel habitats supported by relatively warm groundwater. These possible modifications to Susitna River streamflow and groundwater relationships may affect the quality and quantity of habitat in main channel and off-channel areas for egg incubation, and juvenile and adult fish rearing and holding.

Intergravel water temperature is a critical factor during salmon egg incubation, affecting the rate of embryo and alevin development and determining the solubility of oxygen in water (Bjornn and Reiser 1991, Quinn 2005). In general, embryos develop faster at warmer water temperatures, but this relationship varies with species. At 5°C, incubation time (fertilization to hatching) was observed to range dramatically among coho (139 days), chum (161 days), sockeye and pink (173 days, each species) and Chinook (191 days) salmon (Murray and McPhail 1988, Quinn 2005). At 2°C, incubation time increased more than 60% for coho, sockeye and Chinook (Murray and McPhail 1988, Quinn 2005). Although incubation may occur at near freezing temperatures, increased mortality can occur at low temperatures during the early stages of incubation (Burgner 1991, Salo 1991, Bjornn and Reiser 1991). In the Susitna River, intergravel water temperatures were observed to vary among habitat types, such that intergravel water temperatures in tributary and main channel areas were strongly affected by surface water and were near freezing during winter, while temperatures in side sloughs were warmer and more stable as a result of groundwater influence (Hoffman et al. 1983; Seagren and Wilkey 1985; Vining et al. 1985). Side channel intergravel temperatures were highly variable and more dependent on site-specific conditions that controlled the relative influence of groundwater and surface water sources (Vining et al. 1985). Redd dewatering and freezing were observed to be primary sources of chum salmon egg mortality in the Susitna River during winter 1983-1984, and eggs located in side channel habitats were more susceptible to mortality relative to eggs in off-channel habitats influenced by groundwater upwelling (Vining et al. 1985).

Groundwater discharge often contains low levels of dissolved oxygen as organic matter is processed by microbes within the intergravel environment (Allan and Castillo 2007). Uptake of dissolved oxygen by salmon embryos may depend on various factors in addition to dissolved oxygen concentration, including gravel permeability and intergravel flow or exchange rates, such that reduced substrate porosity and flow can inhibit embryo development (Quinn 2005). Research with chum salmon embryos indicated that the amount of oxygen needed by the embryo increases with development time and that embryo sensitivity to hypoxia was greatest early in the incubation period (Alderdice et al. 1958, Bjornn and Reiser 1991, Salo 1991). Although acute mortality in salmon embryos occurs at very low dissolved oxygen concentrations (2.0 – 2.5 mg/L), delayed or deformed development of the embryo and premature hatching can occur at levels above this critical minimum (Alderdice et al. 1958, Bjornn and Reiser 1991, Quinn 2005).

Concentration of dissolved oxygen in spawning habitats of the Susitna River varied considerably among habitats and between surface and intergravel environments during winter studies conducted during the 1980s (Hoffman et al. 1983, Vining et al. 1985). Intergravel dissolved oxygen levels were observed to be higher in main channel, side channel and tributary habitats relative to side slough and upland slough habitats during studies conducted in 1983-1984 (Vining et al. 1985). Low dissolved oxygen levels in side slough and upland slough habitats were attributed to the greater influence of groundwater sources in off-channel areas (Vining et al. 1985). Intergravel dissolved oxygen concentrations of 4 mg/L or lower were recorded in each of the four side slough habitats sampled during spring 1983 (Hoffman et al. 1983). In contrast, surface concentrations of dissolved oxygen were generally higher than 8 mg/L among sampled sites (Hoffman et al. 1983).

Susitna River streamflows are typically lowest during the winter period and, with the exception of open-water leads, the river is largely covered in surface ice. Correspondingly, aquatic habitat conditions can be severe for juvenile and adult fish species during winter and are characterized by reduced levels of water temperature, solar radiation, dissolved oxygen and habitat area and increased water clarity relative to summer ice-free conditions (Reynolds 1997). Nearly all fish species exhibit physiological and/or behavioral responses to the seasonal change in habitat from summer to winter (Reynolds 1997), such as movement to off-channel and low velocity habitats (Peterson 1982, Jakober et al. 1998), shifts in diel activity patterns (Roni and Fayram 2000, Heggenes et al. 1993), and decreased territorial aggression (Reynolds 1997).

Habitat utilization among juvenile and adult fish species in the Susitna River during winter is not well understood. Juvenile coho salmon were observed to typically use off-channel habitats and tributaries for winter habitat, while primary winter habitats for juvenile Chinook consisted of side slough and side channel areas (Delaney et al. 1981, Stratton 1986). Most adult resident fish species tracked during 1980s studies in the Middle Susitna River moved from spawning or feeding areas in late summer to winter holding habitats located in the main channel (Sundet and Wenger 1984, Sundet and Pechek 1985). Adult rainbow trout and Arctic grayling migrated from spawning and feeding tributaries in late summer to main channel areas that were typically downstream and proximal to the spawning tributary, though some individuals exhibited long distance (> 20 miles) movements (Hoffman et al. 1983, Sundet and Pechek 1985, Sundet 1986). Limited radio telemetry during the 1980s indicated that adult resident fish distribution in the Middle Susitna River was patchy in main channel areas, which is consistent with observations of Arctic grayling winter distribution elsewhere in Alaska (Sundet and Pechek 1985, Sundet 1986, West et al. 1992, Reynolds 1997). The specific habitat features of Susitna River holding areas used by adult resident species during 1980s winter telemetry studies were difficult to measure, though groundwater upwelling, overhead cover (depth and/or ice cover), lack of frazil and/or anchor ice, and low water velocity appeared to be common characteristics of known holding habitats (Schmidt et al. 1983, Sundet and Pechek 1985).

Winter conditions in the Susitna River are severe and can be limiting for resident and anadromous fish species. Although groundwater has been observed to be an important aspect of aquatic habitat for many fish species and life stages in the Susitna River, the relationships between other habitat criteria and indices relevant to winter conditions are not well understood. Improved understanding of habitat conditions and utilization by fish species and life stages will be necessary to evaluate overall effects of altered Susitna River streamflow that may result from Project operations on the quality and quantity of aquatic habitats. In terms of the IFS program, observations of winter conditions and fish habitat utilization will support Habit Suitability Curve (HSC) and Habitat Suitability Index (HSI) development for individual fish species and life stages that will be used to develop fish habitat-flow relationships.

2. STUDY OBJECTIVES

The overall objectives of the pilot 2012–2013 IFS winter studies were to: 1) investigate 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; 2) test the feasibility of using different instruments, methods, and approaches for winter data collection (in concert with FDA, see R2 2014); and 3) to begin collecting information on fish behavior and habitat utilization during the winter period. Specific tasks of the pilot study were as follows:

- Compare water level (stage) responses in representative habitat types relative to Susitna River main channel stage through the period of salmon egg incubation.
- Monitor surface and intergravel water temperatures in representative habitat types, at salmon spawning sites and in areas with and without groundwater influence through the period of salmon egg incubation.
- Evaluate potential relationships between Susitna River stage and water temperature recorded in off-channel and main channel habitats.
- Monitor intergravel dissolved oxygen at two salmon spawning sites in off-channel habitats with groundwater influence.
- Describe juvenile and adult fish behavior in representative habitats during day and night conditions to discern potential patterns in behavior and habitat use.
- Record site-specific habitat utilization data for juvenile and adult fish species in support of HSC and HSI development.
- Develop recommendations for future winter studies.

3. STUDY AREA

The pilot 2012-2013 IFS winter studies were conducted in the Middle River Segment of the Susitna River between Three Rivers (PRM 102.4) and PRM 129.5. Data collection primarily occurred within two Focus Areas (FAs): FA-104 (Whisker Slough) and FA-128 (Slough 8A) (Figure 1). These FAs were selected for the 2012-2013 pilot study because they contain a diversity of habitat types with groundwater influence, have documented fish utilization by multiple fish species and life stages, and were accessible during winter. Within each proposed study area, potential sampling locations were identified prior to data collection; however, on-site adjustments to each location were made based upon known fish distribution (e.g., spawning site), logistical considerations (e.g., site access, ice cover) and personal safety. Most of the 2012-2013 winter effort was conducted at FA-104 (Whiskers Slough) due to its proximity to Talkeetna, although each study component was tested at both FAs. Work at FA-104 (Whiskers Slough) was based out of Talkeetna, while a remote camp was used for work at FA-128 (Slough 8A).

4. METHODS

The 2012-2013 winter studies were comprised of two primary components: 1) water level and water quality monitoring and 2) fish behavior and habitat use observations. Data collection occurred during three trips in early 2013: February 1-7, March 19-25 and April 8-13. The 2012-2013 winter studies were coordinated with the study leads for Instream Flow (Study 8.5), Fish Distribution and Abundance in the Middle and Lower River (Study 9.6; R2 2014), Groundwater (Study 7.5), Geomorphology (Study 6.5), and Ice Processes (Study 7.6). The initial work on the 2012–2013 pilot study consisted of a focused review of literature from 1980s studies and of more recent research to identify potential methods for each study component.

4.1. Water Surface Elevation

Water level and water quality were continuously monitored at nine sites in FA-104 (Whiskers Slough) during February – April 2013 (Figure 2). Continuous monitoring sites in FA-104 (Whiskers Slough) were established in early February 2013 in the Susitna River within a variety of macrohabitat types. These included main channel, side channel, side slough, upland slough and tributary habitats. The areas selected were comprised of areas with known or suspected groundwater upwelling, bank seepage and lateral intergravel flow from the main channel, areas of mixing between upwelling and bank seepage, areas with no intergravel discharge, and areas where fish had been observed spawning. In FA-128 (Slough 8A), continuous water level and water quality sites were established during March 2013 in side slough and upland slough habitats (Figure 3). Salmon spawning was observed during fall 2012 at FA-104 (Whiskers Slough) sites WSC-30, WSL-20 and WC-10 and at FA-128 Site SL8A-15 (Figure 2 and Figure 3). Habitat designations (e.g., side channel, slough) used during 2012-2013 winter studies were based on 2012 Middle River Segment remote line habitat mapping (HDR 2013). Most water level and water quality instruments were downloaded and removed prior to completion of the April 2013 trip, however, a subset of water level and temperature instruments were downloaded and redeployed in April 2013 to record hydrologic and temperature conditions through spring ice breakup.

Pressure transducers (Solinst leveloggers) were used to record changes in stage at continuous monitoring sites. Transducers were deployed at the substrate surface at each site. To prevent shifting during the deployment period, transducers were anchored with weights and attached to metal stakes driven into the substrate. All transducers were removed during the final data collection period in April 2013, with the exception of instruments in Whiskers Slough (WSL-20) and Slough 3A (SL3A-70) in FA-104 and both sites in FA-128 (Slough 8A) (SL8A-10 and US2-10) (Figure 2 and Figure 3). In FA-104 (Whiskers Slough), comparisons between stage in side channel and off-channel habitats relative to the Susitna River main channel were completed using pressure transducer data normalized to zero at the common start time for all instruments within the FA. At FA-128 (Slough 8A), main channel stage data were not available so stage data recorded at the USGS gage at Gold Creek (#15292000) after ice breakup were used for comparison of main channel and off-channel stage. Pressure data recorded at each continuous monitoring site was compensated with barometric pressure data recorded at FA-104 (Whiskers Slough) and FA-128 (Slough 8A) (Figure 2 and Figure 3).

4.2. Water Quality

Surface and intergravel water temperatures and intergravel dissolved oxygen concentrations were continuously recorded in FA-104 (Whiskers Slough) and FA-128 (Slough 8A) (Figure 2 and Figure 3). Surface water temperature was recorded by pressure transducers at the substrate surface. Intergravel water temperature loggers (Hobo Tidbit v2) were deployed at three separate intergravel depths: 5 centimeters (cm) (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) beneath the substrate surface. These depths reflect observed burial depth ranges of chum and sockeye eggs (Bigler and Levesque 1985; DeVries 1997). Intergravel temperature probes were attached to stainless steel cable and deployed into the gravel using a steel installation device (*sensu* Zimmerman and Finn 2012). Dissolved oxygen loggers (HOBO U26-001), which also recorded water temperature, were bolted within a perforated PVC tube and likewise inserted into the gravel to a depth of approximately 20 cm adjacent to known or historic salmon spawning areas. All intergravel temperature and dissolved oxygen instruments were removed in April 2013 except intergravel temperature loggers at Whiskers Slough (WSL-20) and Whiskers side channel (WSC-30) in FA-104, which were recovered in June 2013 and October 2013, respectively.

The relationship between main channel stage and water temperature was evaluated at three sites in FA-104 (Whiskers Slough) that were observed to support salmon spawning in 2012 (WSC-30, WSL-20, and WC-10). The stage records for each spawning site and the main channel were normalized to zero at the start of data collection and compared to surface and intergravel temperatures.

Instantaneous measurements of surface water quality were recorded at continuous monitoring sites in addition to other main channel and off-channel areas in FA-104 (Whiskers Slough) and FA-128 (Slough 8A) during January, March, and April 2013 using a hand-held water quality meter (YSI Pro 30 or Hanna 98129) (Figure 2 and Figure 3). Measurements of water temperature and specific conductance were recorded on the water surface and at mid-column depth. Instantaneous water quality data were used to characterize surface water quality in each Focus Area and to help discern qualitative differences in groundwater composition among habitats based on water temperature and specific conductance (Rosenberry and LaBaugh 2008).

4.3. Fish Observations

Fish observation and capture efforts occurred in each Focus Area during monthly trips between February-April 2013. Fish observation sites were located in open water and ice-covered areas within off-channel and tributary habitats. Underwater video was used by FDA and IFS staff during each trip at six sites in FA-104 (Whiskers Slough) and at three sites in FA-128 (Slough 8A) to monitor behavior in fish communities and evaluate the effectiveness of different camera types, power supplies, and lighting conditions (AEA 2012, Section 9.6; R2 2014). Dual Frequency Identification Sonar (DIDSON) was utilized by FDA staff at three sites in FA-104 (Whiskers Slough) to gauge its applicability for monitoring fish behavior and habitat utilization during winter (R2 2014). When used in ice-covered areas, the video camera or DIDSON unit was lowered through auger holes drilled through the ice (AEA 2012, Section 9.6). Where possible, video cameras were used to characterize winter habitat attributes such as the presence of anchor ice, hanging dams, and substrate type.

Electrofishing surveys were performed during 2012-2013 IFS winter studies to collect site-specific habitat suitability criteria (HSC) data and augment observations of fish behavior. Surveys were conducted using a backpack electrofisher (Smith Root LR-24) at eight open water sites in FA-104 (Whiskers Slough) and FA-128 (Slough 8A) during day and night surveys in March and April 2013. HSC data (e.g., velocity, water depth, substrate and cover) were measured at the point of fish capture during electrofishing sampling and in association with underwater video monitoring provided fish species and size could be determined during underwater surveys and target fish were observed maintaining a stationary position. Water velocity and depth measurements were made either through holes drilled in the ice or in open-water leads using a wading rod and Price AA water velocity meter. Instantaneous measurements of water temperature, dissolved oxygen and specific conductance were recorded using a hand-held water quality meter (YSI Pro 30) to describe water quality conditions at the location of fish observations.

4.4. Deviations from Study Plan

According to the Study Plan for winter sampling, results of the 2012-2013 winter effort were to be distributed to TWG participants by Q3 2013. Although condensed results from winter data collection were communicated to TWG participants during IFS presentations at quarterly TWG meetings in June, September and December 2013, a more comprehensive report was not distributed. This deviation from the Study Plan is not expected to affect overall study objectives, although it will be important to obtain feedback from TWG participants regarding 2012-2013 winter study results in order to plan for 2013-2014 efforts. This Technical Memorandum is intended to facilitate communication regarding winter data collection so that comments from TWG participants may be incorporated into the 2013-2014 study.

5. RESULTS

5.1. Water Surface Elevation

Water surface levels of the Susitna River main channel in FA-104 (Whiskers Slough) exhibited an overall downward trend during February to April 2013, although some short-term oscillations from 0.05 – 0.30 feet in magnitude occurred throughout the measurement period (Figure 4). Water levels recorded at side channel Site WSC-30 were generally similar to levels in the main channel (MC-50) in terms of the long-term trend and short-term fluctuations based on comparison of normalized water levels (Figure 4). At monitoring sites in side slough and upland slough habitats, the long- and short-term stage patterns were generally much more stable compared to the main channel (Figure 4). At most off-channel sites, water elevation changes through the period of measurement were small (0.02 – 0.05 feet) and the short-term stage fluctuations evident at off-channel monitoring sites in late March 2013 differed from the main channel in terms of magnitude and duration (Figure 4). The magnitude of short-term stage fluctuations at side slough Site WSC-20 (0.02 – 0.07), upland slough Site SL3A-70 (0.02 – 0.06 feet) and side channel Site SL3B-10 (0.02 – 0.04 feet) in late March were typically not as large in magnitude or duration as main channel Site MC-50 (0.05 – 0.30 feet) (Figure 4). The stage record in Whiskers Creek was similar to that of Site SL3B-10 in terms of overall trend and magnitude of short-term fluctuations (0.02 – 0.04 feet) (Figure 4). The inlets to side channel and off-channel habitats in FA-104 (e.g., Whiskers Slough, Slough 3A) were not visible due to snow and ice cover during the February – April 2013 effort, so it was not possible at the time to determine whether channels had been breached by Susitna River main channel streamflow.

Water surface elevations in FA-128 (Slough 8A) exhibited similar stage responses between upland slough (US2-10) and side slough (SL8A-15) habitats in terms of the magnitude and timing of seasonal and daily trends (Figure 5). Diurnal fluctuations before ice break-up in April 2013 were approximately 0.15 feet at each site, while the magnitude of stage change after ice break-up in June 2013 ranged from approximately 0.8 – 1.5 feet (Figure 5). In addition, stage fluctuations at FA-128 (Slough 8A) off-channel sites were generally similar to the main channel Susitna River stage response during and after ice breakup (late May – early August 2013) based on comparison of normalized water levels between FA-128 sites and the recorded stage at the USGS gage at Gold Creek (#15292000) (Figure 5). A large-scale stage fluctuation in mid-June 2013 measured approximately 1.4 feet in magnitude at each of the main channel and off-channel monitoring sites (Figure 5). During March and April 2013 data collection trips, the inlet of Slough 8A did not appear to be breached by Susitna River main channel flow and it is not known whether or how long the Slough 8A inlet may have been breached during spring flood events in May and June 2013.

5.2. Water Quality

Surface and intergravel water temperatures differed among habitat types at FA-104 during the 2012-2013 winter pilot study based on data collected at nine continuous monitoring sites. In the Susitna River main channel (Site MC-50) and side channel Site WSC-30, surface water temperatures were near 0°C throughout the February – April 2013 measurement period and ranged from 0.0 – 0.1°C (Figure 6). Elsewhere, surface water temperatures ranged from 1.1 – 3.8°C at upland slough Site SL3A-70, 0.8 – 3.0°C at side channel Site SL3B-10, 0.1 – 2.8°C at tributary Site WC-10, 0.4 – 2.4°C at side slough Site WSL-20, and 2.7 – 4.8°C at side slough Site WSL-40 (Figure 7 and Figure 8). Intergravel water temperatures were warmer than surface water at all sites, although the difference at the main channel site (MC-50) was negligible. Intergravel water temperature ranged from 0.0 – 0.1°C at main channel Site MC-50, 3.1 – 3.9°C at side channel Site WSC-10, 2.9 – 3.5°C at side slough Site CFSL-10, 1.8 – 3.2°C at upland slough Site SL3A-70, 1.1 – 4.1°C at side channel Site SL3B-10, 0.0 – 2.5°C at side channel Site WSC-10, 0.3 – 2.2°C at tributary Site WC-10, 0.5 – 2.3°C at side slough Site WSL-20, and 2.7 – 5.0°C at side slough Site WSL-40 (Figure 6, Figure 7, and Figure 8).

Diurnal fluctuation of continuous water temperature data was common among FA-104 monitoring sites, but was generally more prevalent among off-channel and tributary monitoring sites relative to mainstem locations (Figure 6, Figure 7, and Figure 8). Diurnal temperature changes were apparent throughout the vertical gradient at nearly all off-channel and tributary sites. The magnitude of daily fluctuation exceeded 1°C in Whiskers Creek, Whiskers Slough, and at sites SL3B-10 and SL3A-70 (Figure 6, Figure 7, and Figure 8). At side channel Site WSC-30 and side slough Site CFSL-10, a fluctuating daily temperature pattern was evident near the substrate surface (-5 cm), but was negligible at intergravel depths of 20 cm and 35 cm (Figure 6). Diurnal temperature variation was not apparent at main channel Site MC-50 (Figure 6).

There was no clear effect of Susitna River main channel water level fluctuations on intergravel temperatures at the three FA-104 sites that were known to support salmon spawning in fall 2012 (WSC-30, WSL-20, WC-10). Although water level at the side channel Site WSC-30 was variable throughout the measurement period and reflected the main channel (Site MC-50) stage response, intergravel water temperatures at Site WSC-30 remained relatively stable; Site WSC-30 intergravel water temperature at -20 cm gravel depth ranged from 3.7 – 3.9°C during the measurement period (Figure 9). At side slough Site WSL-20, stage was stable relative to the main channel and surface and intergravel water temperatures at WSL-20 did not change in relation to main channel stage fluctuations (Figure 9). Responses of stage and water temperatures at Whiskers Creek Site WC-10, suggested they were not influenced by main channel stage fluctuation (Figure 9).

Instantaneous measurements of surface water temperature recorded in April 2013 at FA-104 (Whiskers Slough) indicated generally warmer surface water in side slough and upland slough habitats relative to Susitna River main channel and side channel sites, which was consistent with data recorded at continuous temperature monitoring sites (Figure 10). Specific conductance at mainstem instantaneous measurement sites was conversely higher than off-channel and tributary areas (Figure 10). Exceptions to this general trend were at side channel Site SL3B-10, which exhibited specific conductance and water temperature unlike other side channel sites, and side slough Site CFSL-10 at which the recorded specific conductance was more similar to mainstem habitat than other side slough habitats (Figure 10). Specific conductance measurements at FA-104 ranged from 123.0 – 155.6 µS/cm among main channel (MC-50) and Whiskers Side Channel (WSC) sites, 120.3 µS/cm at side slough Site CFSL-10, 52.0 – 55.9 µS/cm at side channel Site SL3B-10, 19.0 – 49.9 µS/cm at Whiskers Slough (WSL) sites, 19.0 – 20.1 µS/cm at Whiskers Creek Site WC-20, and 53.0 – 61.6 µS/cm at Slough 3A (SL3A) sites (Table 1).

At FA-128, instantaneous water quality measurements measured during April 2014 suggested that side slough and upland slough habitats were generally warmer relative to main channel and side channel areas, but that specific conductance was not substantially different among habitats (Figure 11). Instantaneous surface water temperature measurements ranged from 0.1°C at main channel Site MC-50, 0.2 – 1.9°C at Skull Side Channel (SSC) sites, 0.6 – 4.2°C at Side Channel 8A (SC8A) sites, 0.9 – 4.3°C among Slough 8A (SL8A) sites, 1.9 – 2.9°C at Upland Slough 2 (US2) sites, and 0.8 – 3.0°C at Half Moon Slough (HMSL) sites (Table 1). Specific conductance was lower within Slough 8A (side slough sites) relative to main channel, side channel and upland slough habitats (Figure 11). Bank seepage flow at side channel sites SSC-20 and SC8A-15 was characterized by warmer temperature than adjacent surface water, whereas in upper Slough 8A (SL8A-50) bank seepage was very similar to the main water body in terms of temperature and specific conductance (Figure 11). Specific conductance measurements at FA-128 ranged from 168.2 µS/cm at main channel Site MC-50, 137.0 – 162.3 µS/cm at Skull Side Channel (SSC) sites, 109.0 – 150.6 µS/cm at Side Channel 8A (SC8A) sites, 90.0 – 123.3 µS/cm among Slough 8A (SL8A) sites, 125.0 – 149.0 µS/cm at Upland Slough 2 (US2) sites, and 144.5 – 168.2 µS/cm at Half Moon Slough (HMSL) sites (Table 1).

Intergravel dissolved oxygen recorded at approximately 20 cm below the substrate surface at Site SL8A-15 in FA-128 was generally stable at approximately 5.2 mg/L through late March and April 2013 (Figure 12). Water temperature recorded by the dissolved oxygen logger was 2.7°C during the measurement period and was similarly stable with minimal daily fluctuation (Figure 12). Intergravel dissolved oxygen recorded at FA-104 Site SL3B-10 was measured to be near 0 mg/L for much of the measurement period but fluctuated frequently and substantially (range: 0.0 – 6.0 mg/L) near the end of the deployment period. The highly erratic nature of the intergravel dissolved oxygen data at Site SL3B-10 suggested the logger may have been fouled and because values were not validated with instantaneous measurements, the intergravel dissolved oxygen data are not reported. The intergravel water temperature data recorded by the dissolved oxygen logger at FA-104 Site SL3B-10 closely reflected temperature values measured at a similar depth by an intergravel temperature logger at the site.

5.3. Fish Observations

Underwater observations of fish and fish capture efforts during the February – April 2013 study period indicated that juvenile fish were active during both day and night periods in both FA-104 and FA-128. Fish activity was observed during day and nighttime opportunistic underwater surveys of ice-covered side channel, side slough, and upland slough habitats in FA-104 (Whiskers Slough) and FA-128 (Slough 8A) (9 total sites) in which optical video cameras were used to actively scan the channel from one or more fixed positions under the ice (see AEA 2012, Section 9.6). Juvenile Chinook and coho salmon (< 150 mm fork length), adult rainbow trout (> 150 mm fork length), adult round whitefish (> 150 mm fork length), and sculpin species were observed during underwater video surveys. No distinct difference in fish activity was apparent during day and night surveys during optical video camera surveys, however, DIDSON sonar surveys in FA-104 near Site WS-70 identified directional movements of juvenile fish (approximately 100 – 200 mm total length) at dusk and at dawn that were not apparent at other times. The crepuscular fish movements detected during the DIDSON survey were in an upstream direction at dusk and downstream at dawn; the species of fish detected by the DIDSON could not be discerned (R2 2014). Day and nighttime electrofishing surveys of eight open water sites also indicated potential differences in diurnal fish behavior, with more fish captured during the night. Overall, total fish capture at night was higher than daytime at all sites sampled during both diurnal periods in FA-104 (SL3A-71) and FA-128 (SSC-20, SC8A-28, SL8A-10, US2-10), except Site 128-SSC-20 at which no fish were caught (Table 2). A total of four juvenile Chinook salmon (size range: 65 – 72 mm fork length) were caught during daytime electrofishing surveys, while 23 Chinook salmon (size range: 55 – 110 mm fork length) and three coho salmon (size range: 46 – 65 mm fork length) were captured during nighttime (Table 2). Composition of fish captured during IFS electrofishing surveys consisted of Chinook and coho salmon and sculpin species.

A total of 29 HSC observations of juvenile Chinook and coho habitat utilization were recorded during 14 electrofish sampling surveys of four open water sites in each of FA-104 and FA-128 in March and April 2013 (Table 3). Of this total, 26 observations were recorded for juvenile Chinook and three for juvenile coho salmon (Table 3). No HSC data were recorded in ice covered areas in association with underwater optical video surveys.

6. DISCUSSION AND CONCLUSION

Winter is a critical period for various life stages of Susitna River fish species and aquatic habitat conditions can be severe. Susitna River areas that support spawning and egg incubation, juvenile fish rearing and adult holding are critical winter habitats and may be altered by proposed Project operations. The 2012-2013 winter study was a pilot effort to test methods, instruments and approaches 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.

The 2012-2013 winter pilot study was conducted at two Focus Areas, FA-104 (Whiskers Slough) and FA-128 (Slough 8A), that supported salmon spawning in 2012 and contained a diversity of main channel and off-channel habitats. The close proximity of FA-104 to Talkeetna allowed greater focus on field data collection relative to logistic support demands (e.g., remote camp construction and travel). Future winter data collection will incorporate additional study sites to help evaluate potential Project effects on winter habitat conditions within the Middle River Segment of the Susitna River (see Section 7).

6.1. Water Surface Elevation

The stage data collected from this initial study provided for some insight into how different macrohabitat types may respond to main channel flows during winter periods. Comparison of stage records at FA-104 during February – April 2013 indicated a direct relationship between Susitna main channel Site MC-50 and the proximal side channel Site WSC-30 suggesting that either the side channel had been breached enabling a surface flow connection throughout the period or that shallow groundwater flow from the main channel was still being provided and was subject to main channel stage changes. However, these relationships were less apparent between main channel stage and off-channel monitoring sites suggesting that either these areas had not been breached or groundwater sources may have an influence on water levels for these areas. More insight into this will be made as part of the groundwater studies (AEA 2012, Section 7.5). The importance of local groundwater sources for maintaining flow and habitat conditions in off-channel habitats was documented during 1980s Susitna River studies, although the relationship between main channel and off-channel stage and groundwater upwelling was not completely understood (Quane et al. 1984, Aaserude et al. 1985, Keklak and Withrow 1985, Vining et al. 1985). Studies conducted during the 1980s indicated that Susitna River main channel discharge volumes and corresponding stage levels affected discharge in off-channel habitats via intergravel flow through islands and gravel bars even if the inlet was not breached by main channel streamflow (Harza-Ebasco and R&M 1984, Trihey & Associates and Entrix 1985). It was estimated that one-foot reductions in main channel stage resulted in changes of 0.3 – 0.6 cfs in side slough flow, depending on the slough (Harza-Ebasco and R&M 1984, Trihey & Associates and Entrix 1985). This relationship was believed to be similar between winter and summer based on similar Susitna River main channel stage levels between seasons (Harza-Ebasco and R&M 1984, Trihey & Associates and Entrix 1985). A better understanding of breaching flows (i.e., flows at which surface flows from the main channel Susitna River begin to enter side channel and off-channel habitats) and relationships between under-ice stage and main channel flows within each of the Focus Areas will be possible once the open water and under ice 2-D hydraulic models are fully developed (AEA 2012, Sections 6.6 and 7.6).

6.2. Water Quality

Continuous surface and intergravel water temperature monitoring during the pilot 2012-2013 effort indicated that surface and intergravel temperatures were generally warmer in off-channel areas relative to the main channel and diurnal temperature fluctuations were more evident at some sites (e.g., WS-40) relative to others (WSC-30). Researchers during 1980s Susitna River studies similarly identified off-channel areas with warmer water temperatures relative to the main channel that were of particular importance for winter fish use (Keklak and Withrow 1985, Vining et al. 1985, Stratton 1986). Temperature data collected during 1984-1985 indicated that intergravel water temperature in the Susitna River main channel and tributaries were closely associated with surface water temperature, while surface and intergravel temperatures in side sloughs was generally warmer than the main channel due to groundwater input (Vining et al. 1985). Continuous monitoring sites with pronounced diurnal patterns in surface and intergravel temperatures in 2013 may represent areas of downwelling (negative hydraulic gradient) in which surface flows that are susceptible to diurnal changes in temperature are moving into the groundwater, while sites with warm intergravel temperature (3-4°C) and minimal diurnal temperature oscillation (e.g., WSC-30 and CFSL-10) likely represent areas of groundwater upwelling (positive hydraulic gradient) (Constantz et al. 2008).

The surface and intergravel water temperature data, when analyzed in conjunction with the stage data also provide some insight into the thermal influence of main channel flows on off-channel habitats. For example, the effect of Susitna River main channel water level fluctuations during February – April 2013 on intergravel temperatures at FA-104 sites that were known to support salmon spawning in 2012 was negligible (Figure 9). At side channel site WSC-30, intergravel temperature was stable throughout the measurement period, despite variations of 0.2 – 0.3 feet in water level (Figure 9). Warm intergravel temperatures (3-4°C) at WSC-30 likely reflect a strong groundwater influence and contrast with near-zero surface temperature (Figure 9). However, as noted above, it was not known whether breaching had occurred during any of the monitoring period. Stage changes induced by hydrostatic pressure under ice may result in breaching flows that bring in cold surface water from the main channel into these off-channel habitats which can result in intergravel temperature changes. Results of 2013-2014 winter studies coupled with the groundwater and ice processes studies should provide more information concerning this. During 1980s studies, intergravel water temperatures in areas of off-channel upwelling were observed to be insensitive to surface water temperature when the inlet to the slough was not breached by main channel streamflow (Trihey & Associates and Entrix 1985). However, when the slough inlet was breached, intergravel water temperature was affected by surface water and such effects were most evident during the freeze-up period in early winter (Trihey & Associates and Entrix 1985). Monitoring of water level and surface and intergravel temperature in habitats that support critical fish life stages, including adult spawning, egg incubation and juvenile rearing will help evaluate the relationship between Susitna River stage and winter habitat conditions.

Instantaneous measurements of surface water temperature and specific conductance during February – April 2013 supported the general trend indicated by continuous temperature data of warmer surface water in off-channel areas relative to the main channel. Instantaneous measurements recorded in April 2013 in FA-104 indicated that side slough and upland slough habitats typically exhibited higher temperature and lower conductance than main channel and side channel areas. A similar pattern was apparent in FA-128, though the degree of difference in water temperature and conductance between mainstem and off-channel sites was not as distinct as that observed at FA-104. Instantaneous water quality, in conjunction with continuous temperature and water level data, will be helpful to discern the relative influence of varied groundwater and surface water sources in critical aquatic habitats.

Intergravel dissolved oxygen concentrations recorded at FA-128 (Slough 8A) were stable throughout the March – April 2013 measurement period. Recorded values of dissolved oxygen (5.2 mg/L) and temperature (2.7°C) correspond to approximately 35% saturation, which could be below the ideal level for anadromous salmon egg incubation, but may represent adequate conditions for egg development depending on intergravel flow, substrate permeability and other factors (Bjornn and Reiser 1991, Quinn 2005, USGS 2011). Similarly low levels of dissolved oxygen were recorded during 1980s studies, particularly in off-channel habitats (Vining et al. 1985). Mean intergravel dissolved oxygen at FA-128 (Slough 8A) in April 1983 was 4.6 mg/L, which was the lowest mean value among the four off-channel sites sampled during that period (Slough 8A, Slough 9, Slough 11 and Slough 21) (Hoffman et al. 1983). At FA-104 (Whiskers Slough), continuous dissolved oxygen measurements recorded during February-April 2013 appeared erroneous and were not reported, though the cause of the unusually low and highly erratic measurements was not clear. It is possible that measurements by the probe were affected by fouling and/or sedimentation. For future studies, field calibration of the dissolved oxygen loggers will be performed to minimize these concerns.

6.3. Fish Observations

Fish presence was recorded in day and night periods in ice covered areas during underwater video monitoring, while underwater sonar observations and fish capture totals indicated that some species may exhibit diel shifts in activity. Upstream and downstream crepuscular movements of juvenile fish recorded during underwater sonar monitoring suggest shifts in habitat utilization between day and night periods, while greater fish capture totals during night electrofish surveys may indicate increased overall activity during nighttime. Diel differences in fish behavior are common among fish species, particularly during winter, but information specific to the Susitna River is sparse. In general, when day length is short and water temperatures are low, fish activity often shifts from diurnal to nocturnal periods, such that individuals become inactive and/or hide during the day to minimize energy expenditure and reduce predation risk (Roni and Fayram 2000, Quinn 2005, Reeves et al. 2009). The presence of ice cover, however, may mitigate such behavioral shifts. During a winter study of the effect of ice cover on fish behavior, greater fish activity and foraging was observed in the presence of ice cover relative to its absence (Watz 2013). Monitoring of fish activity and behavior during future day and nighttime winter surveys using underwater video, sonar and fish capture techniques will help elucidate potential winter behavioral patterns exhibited by fish species in the Susitna River.

7. PLANS FOR 2014

The 2013-2014 IFS Winter Studies will expand on the pilot studies conducted during winter 2012-2013 and will be performed in conjunction with winter work by FDA and groundwater resource disciplines. Data collection by IFS, FDA and groundwater groups will be coordinated with IFS-riparian, river productivity, geomorphology, water quality and ice processes resource disciplines.

The goals of the 2013-2014 IFS winter studies remain the same as stated above and are 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 and HSI development. Objectives for the 2013-2014 work are identified in Section 2. The general approach of the 2013-2014 IFS winter study will be similar to the 2012-2013 pilot effort (see Section 4), except that the level of effort will be increased and the study areas will be expanded to three Focus Areas: FA-104 (Whiskers Slough), FA-128 (Slough 8A), and FA-138 (Gold Creek) (Figure 13). Specific tasks include:

- Continuous stage and water quality (temperature and dissolved oxygen) monitoring will occur at FA-104, FA-128 and FA-138 through the period of salmon egg incubation (September 2013 – April 2014) (Figure 13).
- Stage and water temperature data (surface and intergravel) will be continuously monitored at main channel and off-channel sites in each of FA-104, FA-128 and FA-138. Monitoring sites within each FA will be distributed among habitat types, at locations of known salmon spawning, and at sites with and without groundwater influence (Figure 14, Figure 15, and Figure 16).
- Intergravel dissolved oxygen will be continuously recorded at known salmon spawning locations in FA-128 and FA-138.
- Fish observation and capture efforts will be performed at available habitat types in each of FA-104, FA-128 and FA-138; additional sites outside of these FAs will be sampled based on observed fish distribution, site access, weather conditions and personnel safety.
- Fish activity and behavior will be monitored using underwater video equipment to discern potential patterns in activity related to diurnal and seasonal periodicity and/or habitat (e.g., side channel, side slough).
- Site-specific habitat suitability criteria (HSC) for juvenile and adult fish will be recorded using electrofish capture methods in open water areas and underwater video in ice covered habitats.
- Instantaneous surface water quality measurements (temperature, dissolved oxygen, specific conductance) will be recorded in association with maintenance of continuous stage and water quality monitoring sites and fish observation and capture efforts.

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9. TABLES

Table 1. Instantaneous surface water temperature and specific conductance recorded at mid-column depth at sites within FA-104 (Whiskers Creek) and FA-128 (Slough 8A).

Focus Area	Site	Water Body	Habitat Type[1]	Date	Temperature (°C)	Specific Conductance (µS/cm)
104	CFSL-40	Chicken Foot slough	Side Slough	4/12/13	2.2	120.3
	MC-50	Susitna River	Main channel	4/12/13	0.1	149.8
	SL3A-70	Slough 3A	Upland Slough	3/25/13	1.0	57.9
	SL3A-70	Slough 3A	Upland Slough	4/12/13	2.5	61.6
	SL3A-75*	Seepage; Slough 3A	Upland Slough	3/25/13	2.5	56.5
	SL3B-10	Slough 3B	Side Channel	3/25/13	1.1	55.9
	WC-10	Whiskers Creek	Tributary	4/13/13	0.8	20.0
	WSC-10	Whiskers Side Channel	Side Channel	3/25/13	0.2	149.2
	WSL-15	Whiskers Slough	Side Slough	2/6/13	0.5	23.0
	WSL-18	Whiskers Slough	Side Slough	3/25/13	0.8	25.2
	WSL-20	Whiskers Slough	Side Slough	2/6/13	0.4	23.0
	WSL-35	Whiskers Slough	Side Slough	2/6/13	1.8	43.0
	WSL-40	Whiskers Slough	Side Slough	2/6/13	2.7	45.0
	WSL-40	Whiskers Slough	Side Slough	4/13/13	3.3	49.9
128	HMSL-20	Half Moon Slough	Upland Slough	4/10/13	1.4	144.5
	HMSL-25	Half Moon Slough	Upland Slough	4/10/13	2.8	168.2
	MC-50	Susitna River	Main Channel	4/10/13	0.1	168.2
	SC8A-15	Side Channel 8A	Side Channel	4/10/13	2.3	124.6
	SC8A-15*	Seepage; Side Channel 8A	Side Channel	4/10/13	4.2	147.4
	SC8A-20	Side Channel 8A	Side Channel	3/22/13	0.6	109.0
	SC8A-28	Side Channel 8A	Side Channel	4/9/13	3.1	124.5
	SC8A-30	Side Channel 8A	Side Channel	3/22/13	1.7	149.0
	SC8A-30	Side Channel 8A	Side Channel	4/9/13	1.5	149.9
	SL8A-10	Slough 8A	Side Slough	3/22/13	1.0	114.0
	SL8A-10	Slough 8A	Side Slough	4/9/13	4.3	113.4
	SL8A-15	Slough 8A	Side Slough	4/10/13	1.5	99.0
	SL8A-44	Slough 8A	Side Slough	4/9/13	1.9	95.9
	SL8A-50	Slough 8A	Side Slough	3/22/13	3.0	104.0
	SL8A-50	Slough 8A	Side Slough	4/9/13	3.3	105.8
	SL8A-50*	Seepage; Slough 8A	Side Slough	4/9/13	3.3	105.2
	SL8A-52	Slough 8A	Side Slough	4/9/13	1.7	123.3
	SSC-20	Skull Side Channel	Side Channel	4/10/13	0.2	162.3
	SSC-20	Seepage; Skull Side Channel	Side Channel	4/10/13	1.9	137.0
	SSC-30	Skull Side Channel	Side Channel	4/10/13	0.3	161.4
	US2-10	Upland Slough 2	Upland Slough	3/22/13	2.7	149.0
	US2-10	Upland Slough 2	Upland Slough	4/10/13	2.9	148.0
	US2-11	Upland Slough 2	Upland Slough	4/10/13	2.0	140.4

Notes:

1 Habitat designations are based on 2012 Middle Susitna River remote line habitat mapping (HDR 2013).

Table 2. Total number of fish captured by species and lifestage during daytime and nighttime electrofishing surveys conducted in FA-104 and FA-128 in March and April 2013.

Site	Survey Date	Habitat Type[1]	Area Surveyed (sq. ft.)	Capture totals, by species: Chinook, Juvenile	Coho, Juvenile	Sculpin sp., Juvenile, adult	Total Count
104-WSL-20	24-Mar	SS	12502	0	0	8	*8*
104-WSC-10	24-Mar	SC	4256	0	0	0	*0*
104-SL3B-10	24-Mar	SC	3432	1	0	4	*5*
104-SL3A-71	24-Mar	US	4455	1	0	35	*36*
	25-Mar[2]		4455	12	3	35	*50*
128-SL8A-10	22-Mar	SS	14850	0	0	1	*1*
	22-Mar[2]		14850	3	0	0	*3*
	9-Apr		18150	2	0	8	*10*
128-SC8A-28	9-Apr	SC	4356	0	0	0	*0*
	9-Apr[2]		4356	7	0	6	*13*
128-SSC-20	10-Apr	SC	5610	0	0	0	*0*
	10-Apr[2]		5610	0	0	0	*0*
128-US2-10	22-Mar	US	240	0	0	0	*0*
	22-Mar[2]		240	1	0	0	*1*

Notes:

1 SS = Side slough, SC = Side Channel, US = Upland Slough; habitat designations are based on 2012 Middle Susitna River remote line habitat mapping (HDR 2013).

2 Survey was conducted at night.

Table 3. Total number of HSC observations recorded during electrofish sampling in March and April 2013 by species and lifestage.

Species	Lifestage	Whiskers Slough, FA-104	Slough 8A, FA-128	Total
Chinook salmon	Juvenile	14	12	26
Coho salmon	Juvenile	3	0	3

10. FIGURES

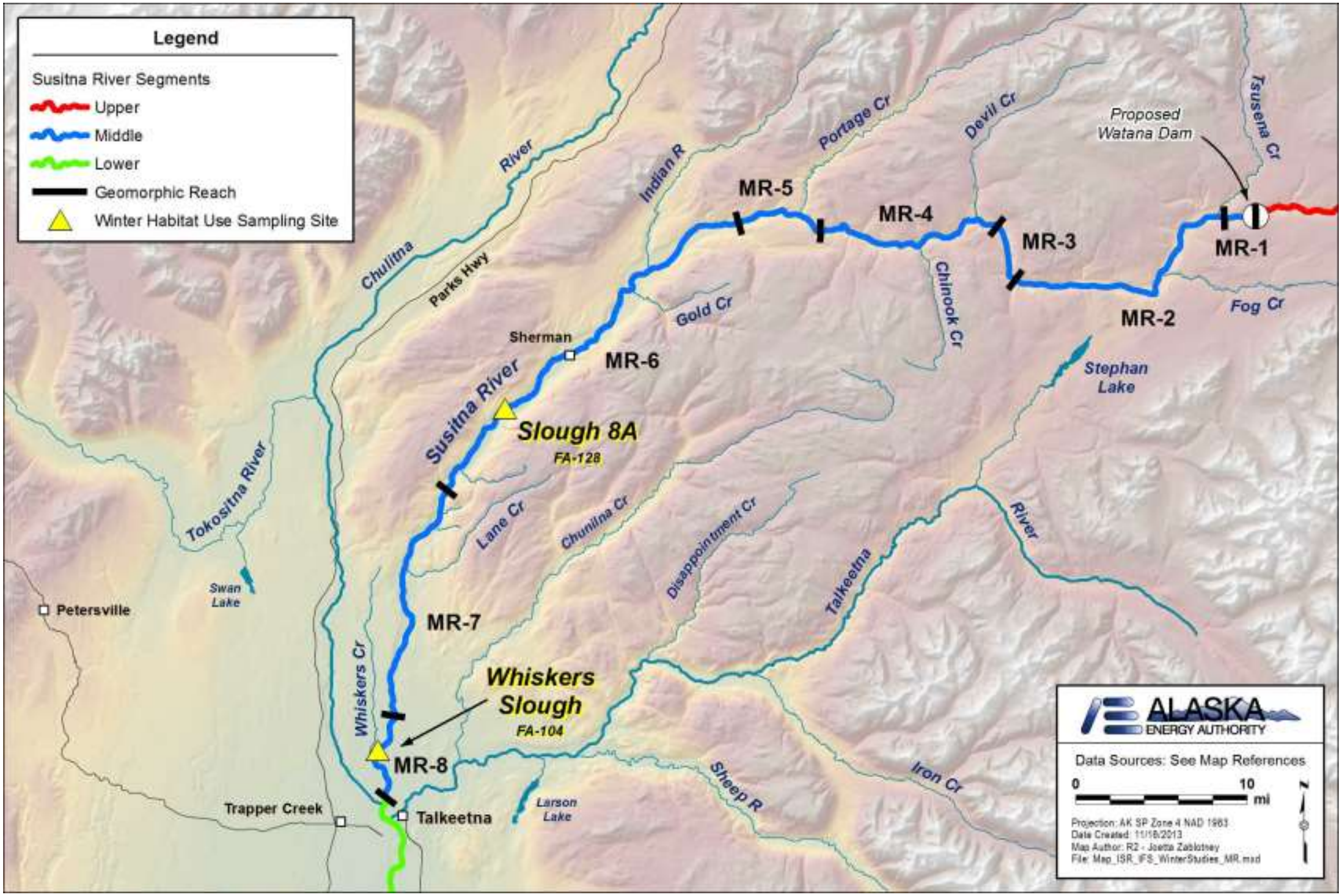

Figure 1. Location of Focus Areas used for 2012-2013 winter data collection.

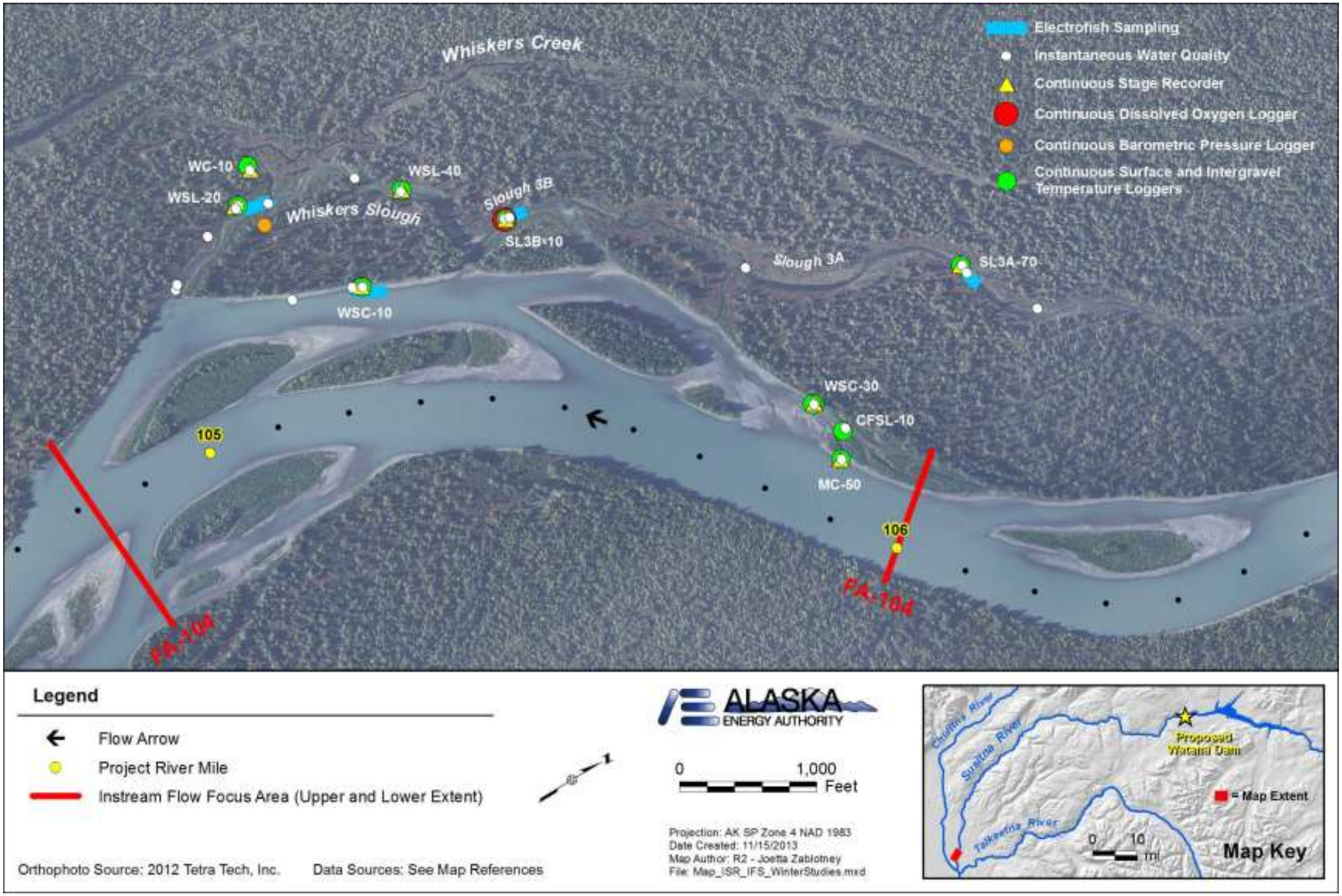

Figure 2. Locations of 2012-2013 winter sites for continuous and instantaneous water quality monitoring, water level monitoring, and fish sampling in FA-104.

Figure 3. Locations of 2012-2013 winter sites for continuous and instantaneous water quality monitoring, water level monitoring, and fish sampling in FA-128.

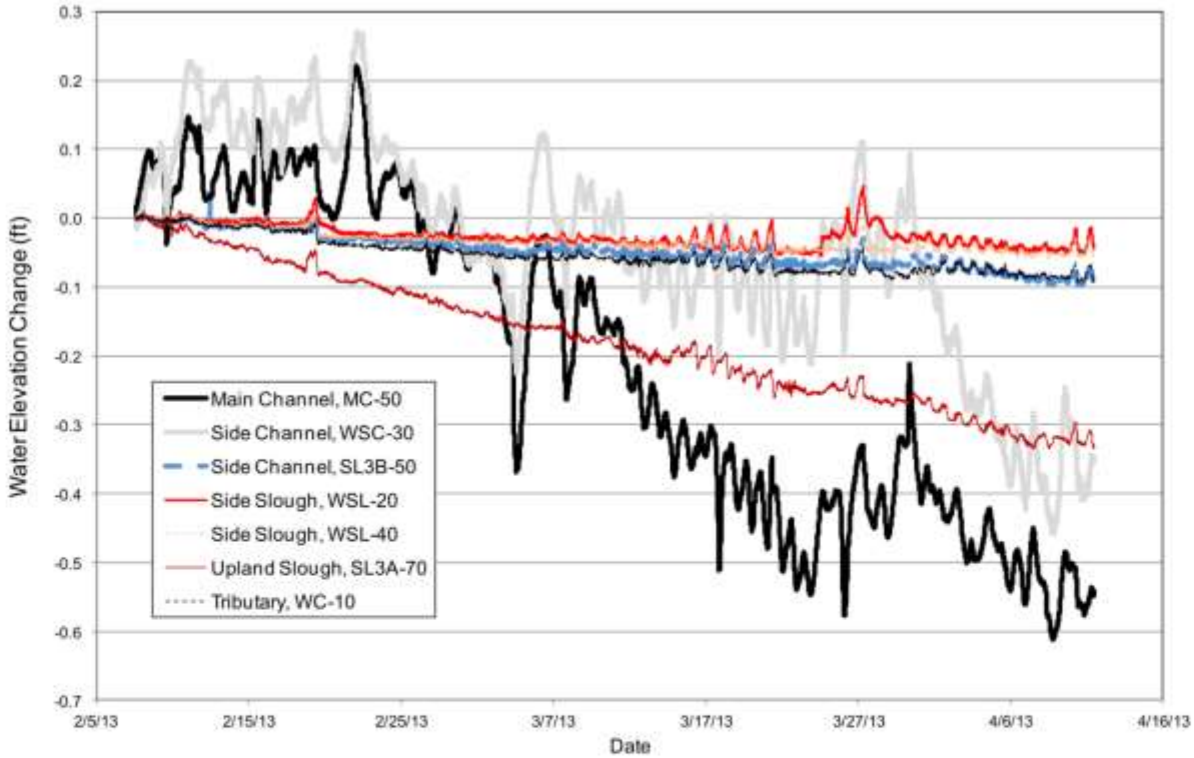

Figure 4. Comparison of change in normalized water surface elevation among continuous monitoring sites in FA-104 during February through April 2013. Elevations were normalized to zero at the start of main channel stage data collection on February 7.

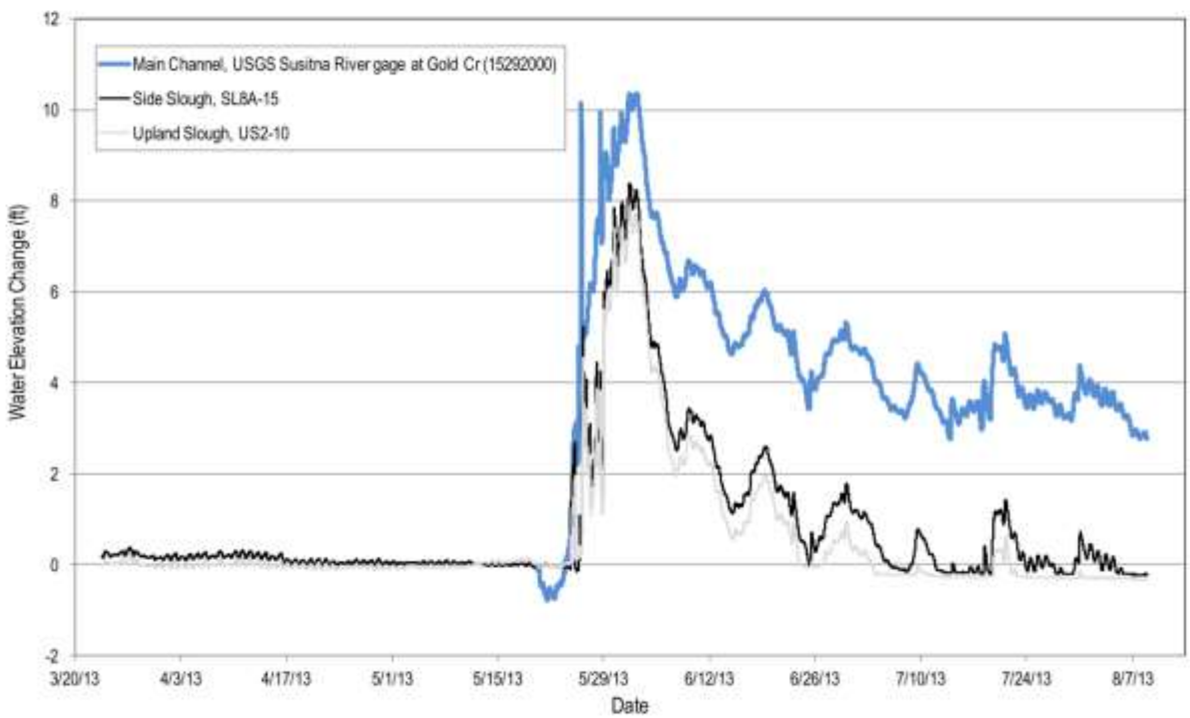

Figure 5. Comparison of change in normalized water surface elevation among continuous monitoring sites in FA-128 and the USGS Susitna River gage at Gold Creek (#15292000) during March through early August 2013. Elevations were normalized to zero at time of ice-free main channel stage data collection at the USGS gage on May 20.

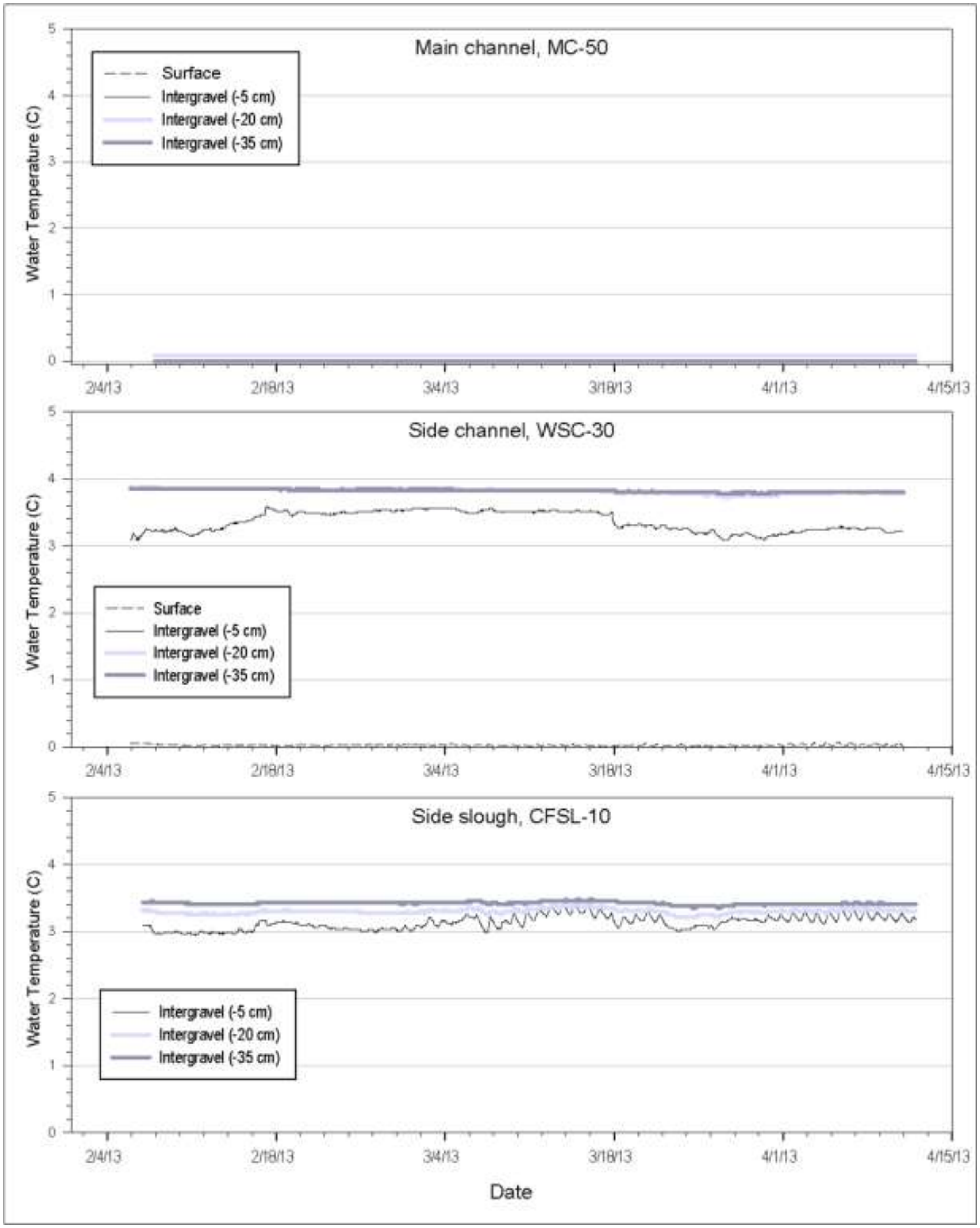

Figure 6. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) at main channel (MC-50), side channel (WSC-30) and side slough (CFSL-10) continuous monitoring sites in FA-104 during February - April 2013.

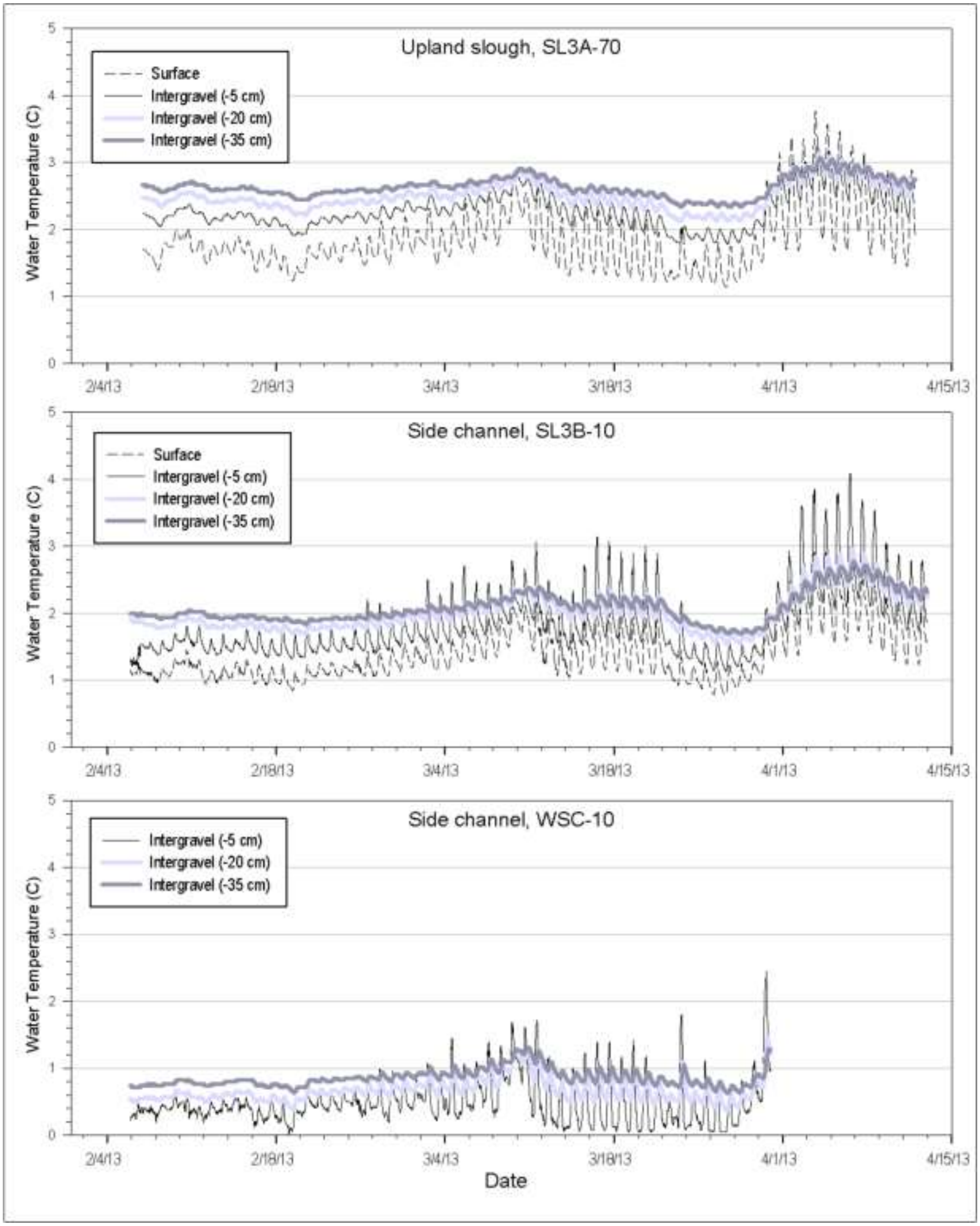

Figure 7. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) at upland slough (SL3A-70) and side channel (SL3B-10, WSC-10) continuous monitoring sites in FA-104 during February - April 2013.

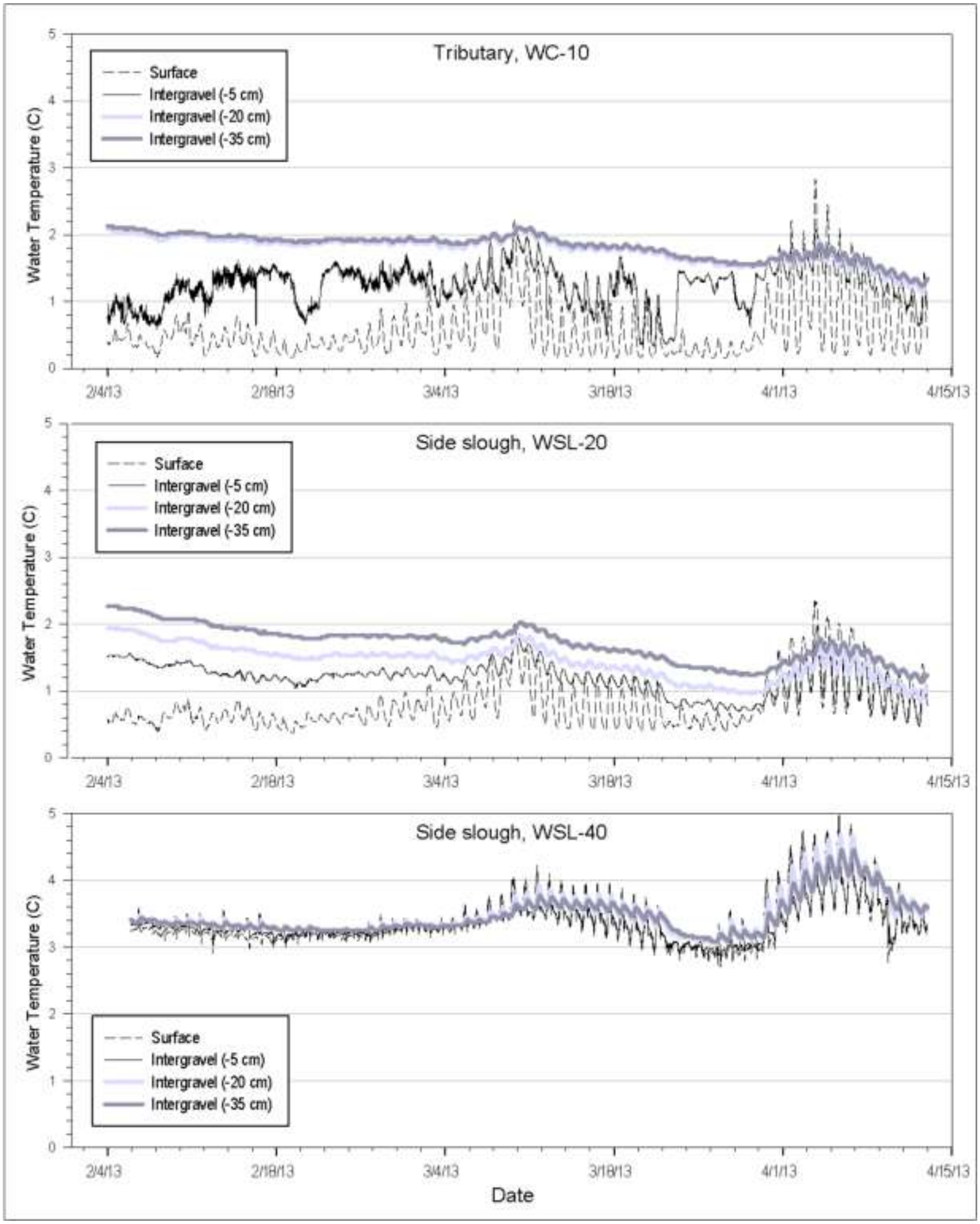

Figure 8. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) at tributary (WC-10) and side slough (WS-20, WS-40) continuous monitoring sites in FA-104 during February - April 2013.

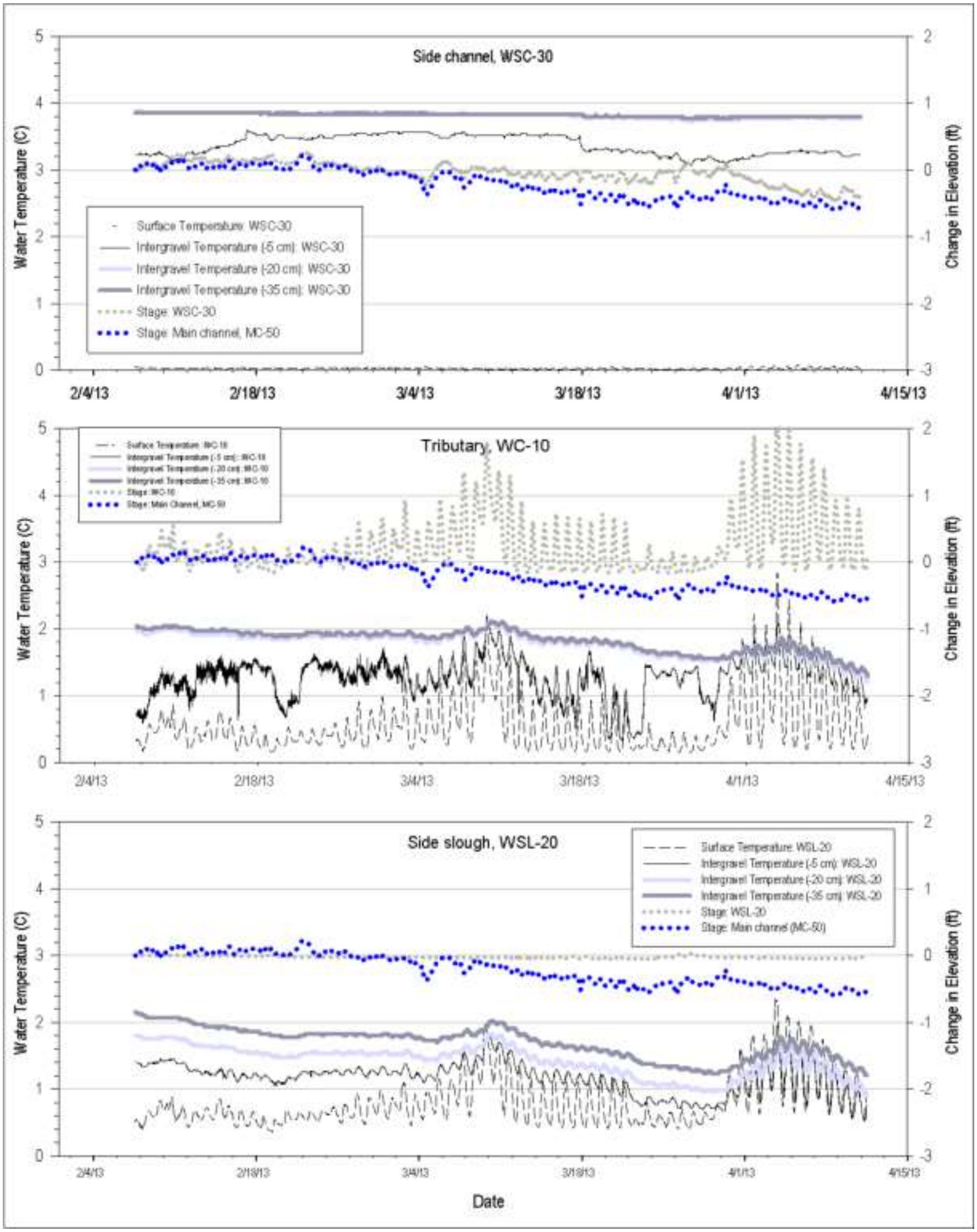

Figure 9. Comparison of continuous surface and intergravel water temperatures recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) at side channel (WSC-30), tributary (WC-10) and side slough (WSL-20) sites relative to change in normalized water surface elevation at each site and at main channel site MC-50. Water elevations were normalized to zero at the start of main channel stage data collection on February 7.

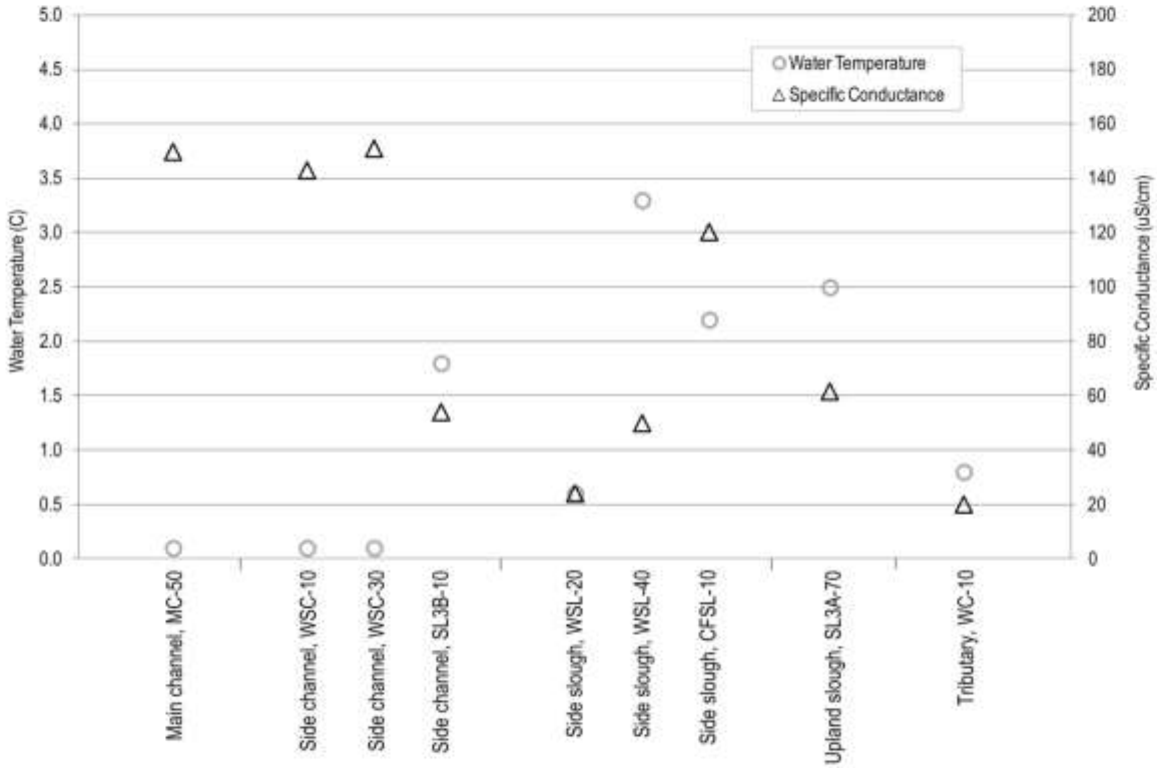

Figure 10. Instantaneous measurements of surface water temperature and specific conductance recorded at sites in FA-104 during April 2013, by habitat type.

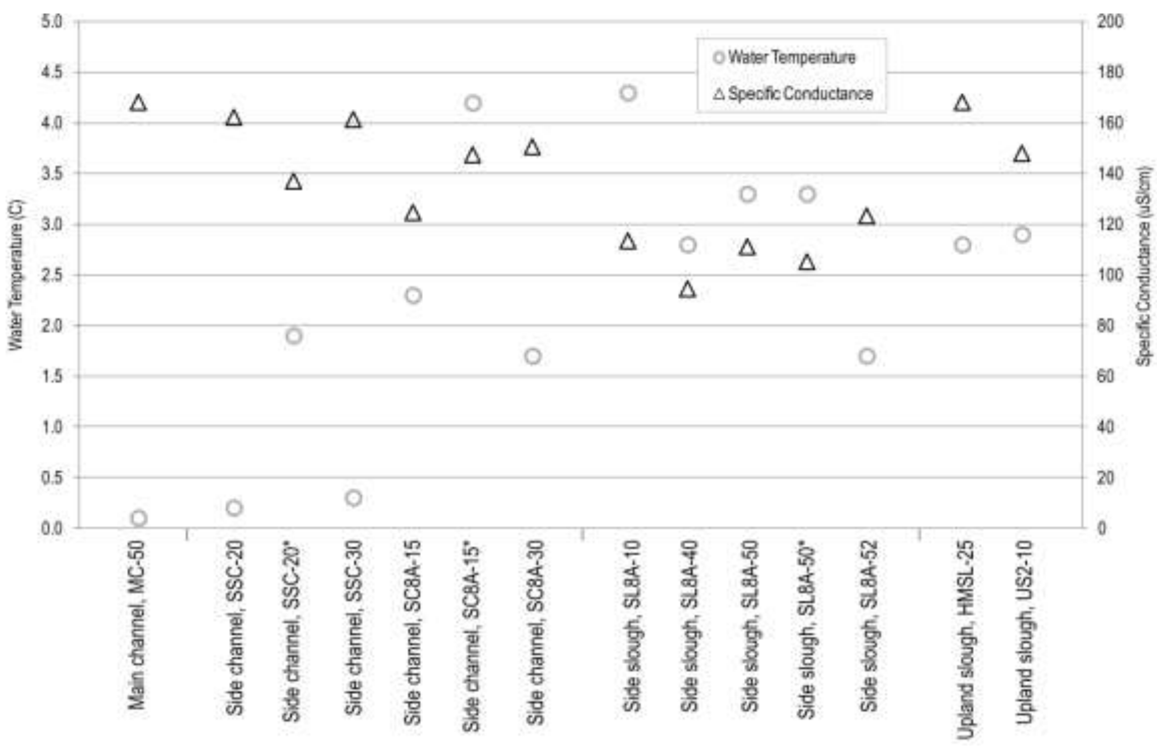

Figure 11. Instantaneous measurements of surface water temperature and specific conductance recorded at sites in FA-128 during April 2013, by habitat type. Asterisks represent measurements of bank seepage.

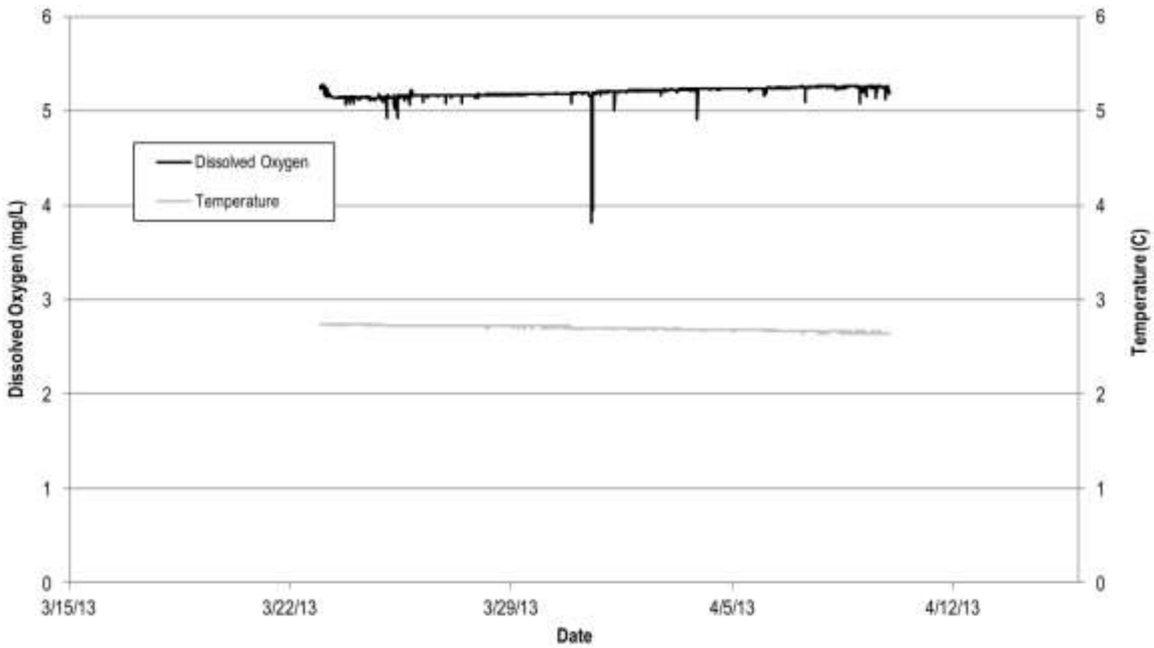

Figure 12. Dissolved oxygen concentration and water temperature recorded approximately 20 cm (7.9 in) below the substrate surface at Site SL8A-15 in FA-128 during March and April 2013.

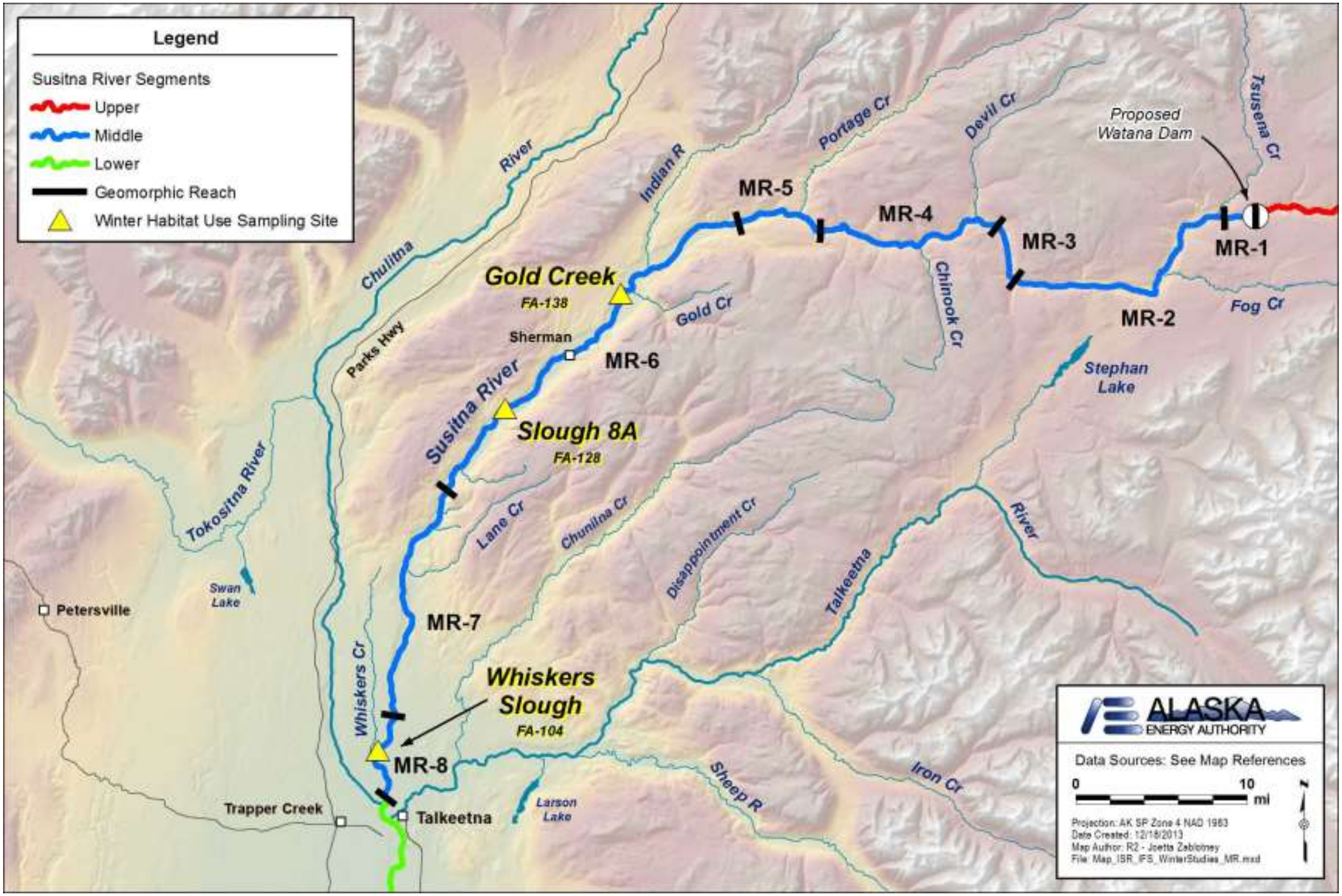

Figure 13. Location of Focus Areas to be used for 2013-2014 winter data collection.

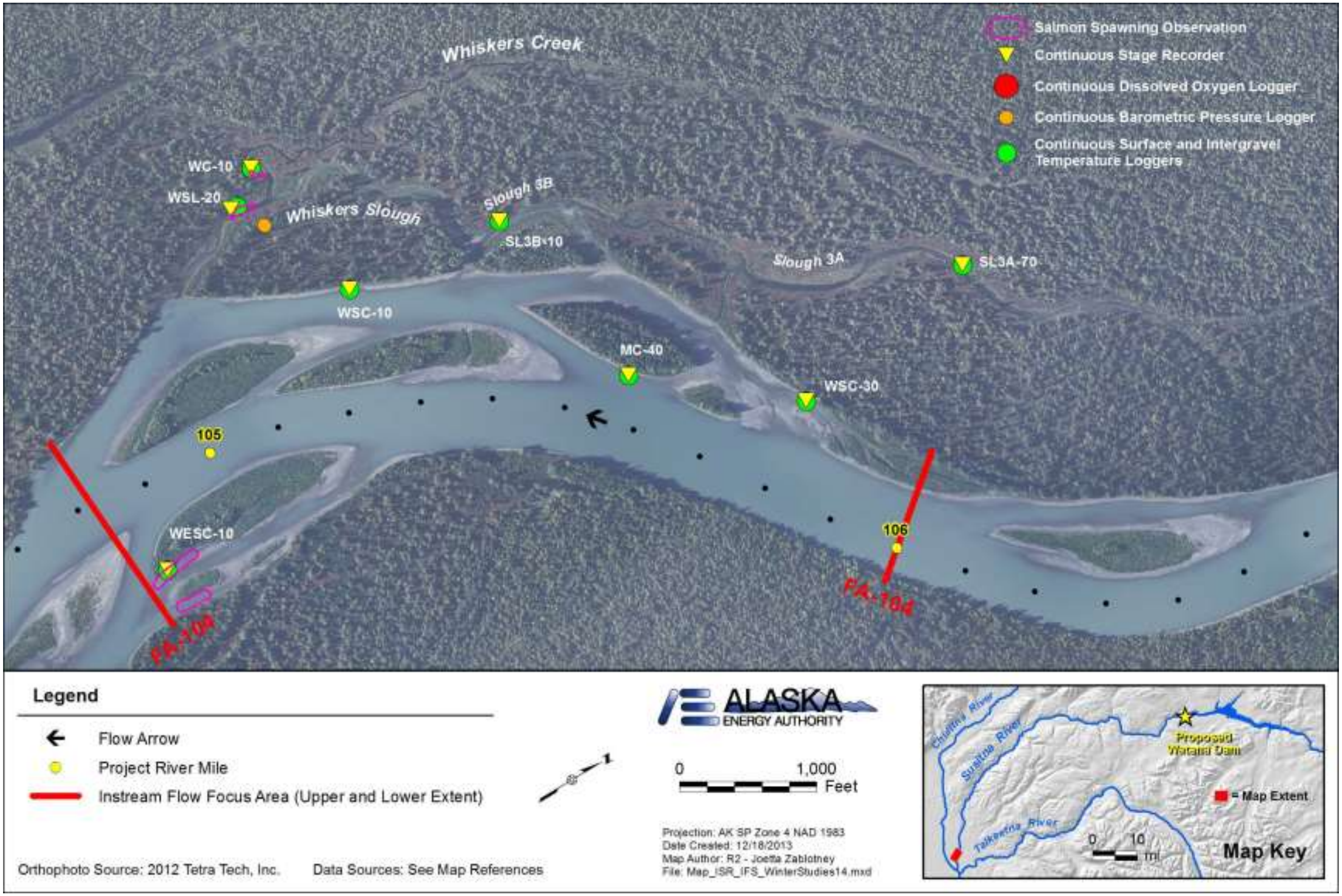

Figure 14. Locations of 2013-2014 winter sites for continuous water level and water quality monitoring relative to observed 2013 salmon spawning areas in FA-104.

Figure 15. Locations of 2013-2014 winter sites for continuous water level and water quality monitoring relative to observed 2013 salmon spawning areas in FA-128.

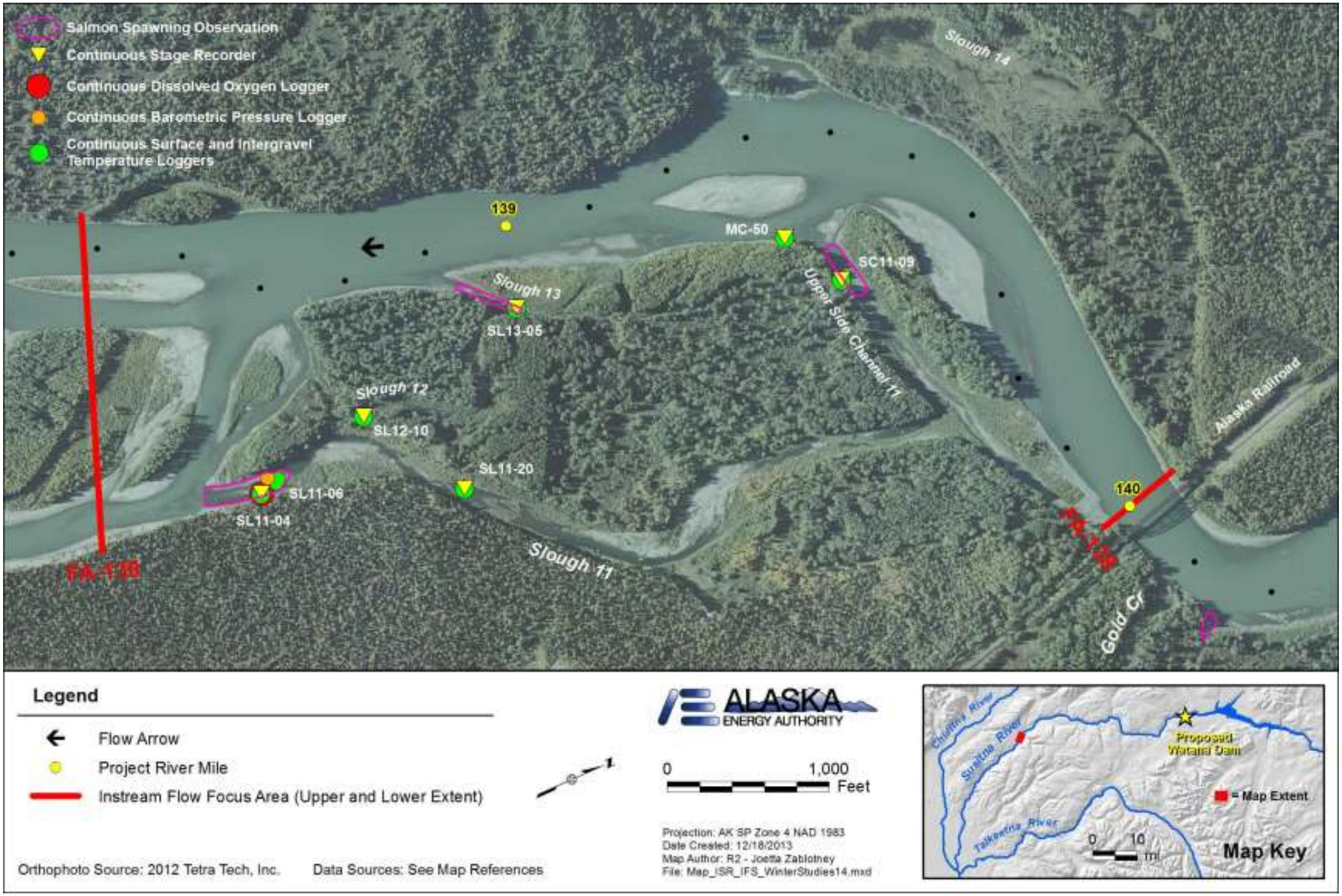

Figure 16. Locations of 2013-2014 winter sites for continuous water level and water quality monitoring relative to observed 2013 salmon spawning areas in FA-138.