Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Fish and Aquatics Instream Flow Study (8.5)
2014-2015 Study Implementation Report

Appendix C
2014 Moving Boat Acoustic Doppler Current Profiler (ADCP) Measurements

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

Brailey Hydrologic

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LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	Definition
1-D	One Dimensional
2-D	Two Dimensional
ADCP	Acoustic Doppler Current Profiler
AEA	Alaska Energy Authority
BT	Bottom-tracking
cfs	cubic feet per second
C/N	Constant/No-slip Fit
DEM	Digital Elevation Model
DMG	Distance Made Good
FA	Focus Area
FERC	Federal Energy Regulatory Commission
GPS	Global Positioning System
IFS	Fish and Aquatics Instream Flow Study
OSW	U.S. Geological Survey Office of Surface Water
P/P	Power/power fit
PRM	Project River Mile
Project	Susitna-Watana Hydroelectric Project
QC	Quality Control
RSP	Revised Study Plan
USGS	U.S. Geological Survey
VMT	Velocity Mapping Software
VTG	National Marine Electronics Association – 0183 VTG data sentence

1. INTRODUCTION

On December 14, 2012, Alaska Energy Authority (AEA) filed with the Federal Energy Regulatory Commission (FERC) its Revised Study Plan (RSP), which included 58 individual study plans (AEA 2012). Included within the RSP was the Fish and Aquatics Instream Flow Study (IFS) Study 8.5. RSP Section 8.5 focused on establishing an understanding of important biological communities and associated habitats, and of the hydrologic, physical, and chemical processes in the Susitna River that directly influence those resources. RSP Section 8.5 also described the study methods that would be used to evaluate Project effects, including the selection of study sites, collection of field data, data analysis, and modeling.

This report provides results of 2014 moving-boat Acoustic Doppler Current Profiler (ADCP) measurements performed as part of the IFS (Study 8.5) and Fluvial Geomorphology Modeling (Study 6.6) studies for the Susitna-Watana Hydroelectric Project (Project).

2. STUDY OBJECTIVES

The goals of the IFS and Fluvial Geomorphology Modeling studies include using hydraulic models to quantify changes in instream and riparian habitats resulting from the proposed Project. The 2014 ADCP measurements were intended for calibration and verification of 1- and 2-dimensional (1-D and 2-D) hydraulic, bed evolution, and fish habitat models as part of AEA's Revised Study Plan (AEA 2012).

3. STUDY AREA

The Susitna River was divided into Upper, Middle, and Lower River segments (ISR Study 8.5, Part A, Section 4.2.1.1 [AEA 2014]) separated by the proposed Dam Site (Project River Mile [PRM] 187.1) and the Three Rivers Confluence (PRM 102.4) (Figure 1). During 2014, moving-boat ADCP measurements were performed at six tributary gages, eight mainstem gages, and at fourteen 1-D model cross sections (Figure 1). All of the 1-D model flow measurements were located in the Middle River Segment, with repeated measurements at four of the fourteen cross sections. In addition, two sets of 2-D model calibration transects were measured at Focus Area FA-151 (Portage Creek), and one set of velocity mapping transects was measured at the proposed Dam Site (PRM 187.1).

4. METHODS

Discharge measurements were conducted following current U.S. Geological Survey (USGS) guidance for moving-boat ADCP measurements (Mueller et al. 2013). Deviations from current USGS guidance are identified in Section 4.1.

4.1. Deviations from the Study Plan

Deviations from current USGS guidance included aspects of compass calibration and moving bed tests. These topics are addressed in Sections 4.5.2 and 4.5.3, respectively.

4.2. Instrument Selection

For consistency with 2012 and 2013 flow data, the SonTek M9 was selected for 2014 ADCP measurements. This was despite compass calibration issues that resulted in the November, 2014 factory recall and replacement of all original SonTek M9 compasses. USGS and factory testing indicates that the original compass was affected by both electronic interference and calibration errors. Although the replacement compass was found to be accurate to within ±2 degrees, small heading errors persist (Mueller 2015).

In 2012, the SonTek M9 was selected because of its shallow measurement depth (0.5 feet) and good performance under variable measurement conditions. Although compass performance issues were identified in 2012 (*Open-water HEC-RAS Flow Routing Model*, Technical Memo submitted to FERC: January 31, 2013 [R2 et al. 2013]), their impact was minimized by using bottom-track positioning with loop corrections during moving bed conditions. Compass errors resulted in about 20% invalid loop tests during 2012. However, the close spacing of main-channel flow measurements (about 1 mile apart) allowed interpolation between valid loop test locations. Because many of the invalid loops occurred during stationary bed conditions, the overall effect was relatively minor.

Despite its known compass issues, the SonTek M9 was again selected in 2013 to support the development of 1-dimensional mainstem fish habitat and 2-dimensional hydraulic models. Of the available instruments, the SonTek M9 was the best suited for the shallow and swift flows characteristic of the Middle Susitna River. To avoid compass errors, the 2013 flow measurements used bottom tracking with loop corrections for moving bed conditions. Despite potential compass errors, valid loop tests were obtained by maintaining a constant heading during the tests (Section 4.5.3). To assess the impact of bad bottom-tracking, repeated loop tests were performed where bad bottom-tracking exceeded 5 percent and comparison measurements were performed at USGS gages.

4.3. Measurement Platform

The 2014 ADCP measurements were performed from a 12-foot solo cataraft powered by an outboard motor (Figure 2). The ADCP was mounted in the center hull of an M9 trimaran at the forward end of the cataraft. A pivoting mount limits lateral roll to that of the cataraft, but allows fore-aft pitch to vary independently. The cataraft's light weight permits a small (10-horsepower) motor that can be raised in shallow water. The cataraft's shallow draft and floorless design allow it to be walked or held stationary with the operator's feet in shallow water. These features allow measurements in water less than 1 foot deep, resulting in small edge estimates. An on-board computer avoids shore-based communication issues, and allows the boat operator to simultaneously monitor boat navigation and ADCP data quality.

4.4. Pre-Field Instrument Preparation

Although a backup M9 was maintained throughout the field program, all of the 2014 discharge measurements were made using the same instrument used in 2013 (serial no. 3936). Both units had current M9 firmware installed (v. 3.5), had their custom beam transformation matrices re-loaded, and passed factory beam alignment tests (Thompson 2014).

4.5. Field Procedures

4.5.1. Site Selection

Except for measurements at active USGS gages, all ADCP measurements were accompanied by water surface elevation measurements at their associated cross sections or gage locations. However, the locations of some ADCP measurements were changed to provide better measurement quality. On tributaries, for example, better measurements were usually obtained at nearby pools than at gage locations selected for protection of the gaging equipment (e.g., Portage Creek and the Oshetna River). Similarly, measurement locations for several mainstem transects were adjusted to avoid areas of high turbulence or shear stress resulting in excessive bedload transport. In all cases where measurement locations were modified, care was taken to ensure that the resulting discharge was representative of the intended measurement location.

4.5.2. Compass Calibration

Compass calibrations were performed daily in accordance with the USGS *Best Practice for Calibrating RiverSurveyor S5/M9* (USGS OSW 2012a). Although occasional passing scores were obtained, most of the compass calibrations failed. These results are discussed further in Section 5.1.1.

4.5.3. Moving Bed Tests

Except where low velocities (< 0.8 ft/s) resulted in loop test error messages, loop moving bed tests were performed at all mainstem and tributary flow measurement locations. This was done despite predominantly unsuccessful compass calibrations. Valid loop tests were obtained by maintaining a nearly-constant boat orientation, either by walking the boat or dragging an oar (Figure 3). These techniques were successful at all but one measurement location (Kosina Creek on June 18, 2014), where the discharge was estimated using the GPS tracking method of the ADCP instead of the bottom-tracking method.

For the velocity mapping and 2-D model calibration transects, loop tests were limited to representative locations within each study area. Again, valid loop test closures were obtained by maintaining a nearly-constant boat orientation.

4.5.4. Mainstem and Tributary Flow Measurements

Mainstem and tributary flow measurements were performed at locations requested by the IFS and Geomorphology Modeling teams. These measurements included at least four reciprocal transects with a combined exposure time of at least 720 seconds (12 minutes). Except where low velocities resulted in loop test error messages, loop tests were performed at each measurement location. Edge estimates included at least 10 seconds of valid velocity data from at least two good bins.

4.5.5. 2-D Model Calibration Transects and Velocity Mapping

Two sets of 2-D model calibration transects were measured at FA-151 (Portage Creek), on June 22 and September 15, 2014 (Figure 4). Measurement procedures followed those established in 2013 for seven other Middle River Segment Focus Areas (AEA 2014). These procedures required that all of the 2-D calibration measurements for each Focus Area be completed on the same day. Because the 2013 Focus Areas included 10 to 14 2-D calibration transects, this timeframe did not allow moving bed tests and 720 seconds of exposure time at each location. Instead, moving bed tests were performed at representative main channel locations, and each measurement consisted of at least two reciprocal transects.

Similar procedures were used for the 2014 2-D calibration transects at FA-151 (Portage Creek), although complete measurements (including moving bed tests and 720 seconds of exposure time) were possible at three of the eight measurement locations. A 2-D calibration transect planned for the downstream end of FA-151 (Portage Creek) (T1 on Figure 4) could not be measured due to flow velocities over 15 ft/s and associated standing waves.

On August 15, 2014, seven velocity mapping transects were measured at PRM 187.1, spaced about 80 feet apart. Moving bed tests were performed at three locations, indicating stationary bed conditions at the two uppermost transects, moving bed conditions at four downstream transects, and no moving bed correction at the lowermost transect. Although insufficient passes were made for “complete” measurements at each transect, adjacent transects were combined to provide acceptable discharge measurements for the two uppermost transects and the four downstream transects.

4.6. Data Review and Post-Processing

4.6.1. Field Data Review

Upon completion of each measurement, the results were reviewed to ensure that:

- System settings were correct;
- Valid moving bed tests were completed;
- An even number of reciprocal transects were recorded;
- The transects did not show significant bottom tracking errors;
- The velocity profiles did not include missing or corrupted data;
- At least 12 minutes of exposure time were recorded;
- Measurement precision was acceptable; and
- Directional bias was acceptable.

The field review identified additional issues related to compass calibration, moving bed tests, and bottom-tracking errors. These issues are described in Sections 5.1, 5.2, and 5.4.

4.6.2. Data Post-Processing

4.6.2.1. Data Reprocessing

ADCP data reprocessing was performed to verify system settings, to check for data quality issues, and to evaluate velocity profile extrapolation settings. After the initial Quality Control (QC) field data review (QC1), QC2 reprocessing was performed by Brailey Hydrologic, followed by QC3 reprocessing by R2 Resource Consultants.

4.6.3. Review and Rating of ADCP Measurements

After reprocessing, an accuracy evaluation was performed by comparing field measurements against flows at nearby USGS gages. These results, together with other precision and data quality indicators, were used to rate each measurement as Excellent, Good, Fair, or Poor. Results are described in Section 5.5.

5. RESULTS

5.1. Compass Calibrations

Based on prior indications of compass interference (R2 et al. 2013, AEA 2014), all 2014 compass calibrations were considered suspect, regardless of the calibration score. Compass calibrations were performed daily, but were not repeated at each transect. Instead, all measurements relied on bottom-track positioning with loop corrections for moving bed conditions. Loop corrections were obtained using an approach designed to minimize compass errors, and bad bottom-tracking was evaluated using repeated loop tests and results of USGS comparison measurements (Sections 5.2 and 5.4).

5.2. Loop Moving Bed Tests

Due to compass calibration issues, 2012 USGS guidance recommends stationary rather than loop moving bed tests for the SonTek M9 (USGS OSW 2012a). However, swift current at most mainstem Susitna measurement locations makes stationary moving bed tests impractical. In addition, previous results (AEA 2014) indicate that the impact of compass errors on loop test results can be minimized by maintaining a constant boat orientation. This conclusion is supported by analysis of heading errors for the SonTek M9's replacement compass (Mueller 2015), which indicates one-cycle errors of up to ±2 degrees. By definition, one-cycle errors vary solely with boat orientation. If the boat orientation remains constant, so does the heading error. Constant heading errors, such as entering the wrong magnetic declination, do not affect loop test results (Mueller and Wagner 2006).

Results of 2014 loop tests are provided on Table 1. Except where repeated loops yielded similar results, the difference in flow direction between the outgoing and return legs of each loop was less than 5 degrees. This was accomplished by maintaining a nearly-constant boat orientation, either by walking the boat in shallow water or by dragging an oar (Figure 3). Results of repeated loop tests indicate that the variation in out-back difference has little effect on measurement precision (Figure 5). Similarly, USGS comparison measurements (Figure 6) indicate that the variation in out-back difference has little effect on measurement accuracy. As a result, the 2014 loop tests do not appear to be compromised by compass errors.

In addition to compass errors, loop tests can also be compromised by bad bottom tracking. For this reason, repeated loop tests were performed where bad bottom-tracking exceeded 5 percent. Results indicate that for measurements with less than 15% bad bottom-tracking, the proportion of bad bottom tracking has little effect on loop test precision (Figure 7). Similarly, USGS comparison measurements with less than 15% bad bottom tracking show little relation between bad bottom-tracking and measurement accuracy (Figure 8). This is due in part to the low boat velocities required for constant-heading loop tests, as indicated by 2014 loop test durations (Table 1; average = 376 seconds). Constant boat orientations were usually maintained by dragging an oar, resulting in slow lateral progress across the stream. Because the data acquisition software substitutes the last valid boat velocity for each 1-second sample with bad bottom-tracking, and the boat velocity changes little over short periods (e.g., 5-10 seconds), the velocity substitutions had little effect on data quality. Although USGS comparison measurements suggest that this conclusion also holds for measurements with over 15% bad bottom tracking (Figure 8), the small sample size (n=2) makes this conclusion premature.

Fast current in narrow channels required an additional loop test modification. Maintaining a uniform lateral boat speed, slow enough to achieve the minimum loop test duration (5 minutes), can be difficult in narrow channels with fast current. In these cases, a more uniform boat speed was accomplished by navigating multiple complete loops. Where multi-loop tests were performed, a single loop was also measured to demonstrate an acceptable out-back flow direction difference. Results are summarized on Table 1.

5.3. Velocity Profile Extrapolation Settings

Because ADCPs cannot measure velocities near the surface or the riverbed, discharge is calculated by extrapolating measured velocities in those regions. By default, RiverSurveyorLive uses the 1/6 power law for velocity profile extrapolation. Current guidance recommends reprocessing all measurements with the USGS Extrap program to identify best-fit extrapolation settings, but only implementing those settings if they cause more than 1% change in discharge (USGS OSW 2012b).

Upon reprocessing with a screening distance equal to the transducer depth plus 0.52 feet, two of the 2014 ADCP measurements indicated a change in discharge over 1 percent using best-fit power law extrapolation settings (Table 2). These measurements were modified to use empirical power law extrapolation settings, and the remaining measurements used the default 1/6 power law.

5.4. Comparison Measurements at USGS Gages

During 2012 through 2014, comparison measurements at USGS gages were performed whenever possible. Because the field measurements spanned nearly 200 miles of river corridor, however, only 20 measurements were located in close proximity to USGS gages. For additional comparison measurements, transects within 3 miles of the Gold Creek and Tsusena Creek gages were used (Figure 9). The additional transects were limited to single-channel measurements without intervening tributaries between their locations and respective USGS gages. Travel times between the USGS gages and the additional measurements were computed using results from

Version 2 of the flow routing model (AEA 2014). The travel time shift was used to identify corresponding measured flows at respective USGS gages. A comparison of measured flows vs. approved final discharge values at USGS gages is provided on Table 3.

5.4.1. Accuracy of Vertical-Beam vs. 4-Beam Discharges

As shown on Figure 10, comparison measurements indicate that vertical-beam flow measurements are biased an average of 2.1 percent low relative to approved final discharge values at USGS gages. However, the rating measurements at USGS gages were made with ADCPs that measure only 4-beam depths (Morse, personal communication 2014). Because a potential bias has been noted with other ADCPs using vertical-beam depths (Mueller 2014), comparison measurement discharges were also calculated using 4-beam depths. When all 35 comparison measurements are included, results indicate that 4-beam discharges are not significantly biased at the 95 percent confidence level. However, when two field measurements with the highest percent difference from USGS discharge values are eliminated, the 4-beam discharges are biased an average of 1.3 percent low. These results are similar to those reported by Mueller (2013) for the SonTek M9. Based on these results, a negative bias of 1 percent is inferred for 4-beam discharges, and a negative bias of 2.1 percent is inferred for vertical-beam discharges measured during the 2014 field program.

5.4.2. Accuracy of Bottom-track vs. Loop Corrected Discharges

Figure 11 compares the accuracy of bottom-track vs. loop-corrected comparison measurements at USGS gages. Although the mean percent difference is lower for loop-corrected than bottom-track discharge measurements, the difference between the two means is not statistically significant at the 95 percent confidence level. As a result, loop-corrected discharge measurements do not appear to be biased relative to bottom-track discharge measurements.

5.4.3. Effect of Bad Bottom-Tracking

Figure 8 compares accuracy vs. percent bad bottom tracking for comparison measurements at USGS gages. Results indicate that for measurements with less than 15 percent bad bottom-tracking, the proportion of bad bottom tracking has little effect on measurement accuracy. Although measurements with more than 15 percent bad bottom tracking were equally accurate, the small sample size (n=2) makes this conclusion tenuous. As a result, additional uncertainty was added for measurements with more than 15 percent bad bottom-tracking (Section 5.5).

5.5. Rating of Mainstem and Tributary Flow Measurements

USGS discharge measurements are rated as Excellent, Good, Fair or Poor corresponding to levels of uncertainty ranging from 0-2%, 2-5%, 5-8%, and over 8%, respectively. Current guidance (USGS OSW 2012c), approximates 95% uncertainty as 0.5% for systematic errors plus the variation between repeated transects multiplied by a coefficient related to the number of transects. If known, other uncertainties can be added to obtain the 95% uncertainty.

Based on results shown on Figure 10, discharges calculated using 4-beam depths are recommended over those calculated using vertical-beam depths. Following procedures outlined in USGS OSW (2012c), ratings were calculated to include the following additional uncertainties:

- 1% uncertainty for "SonTek M9 bias" (all 4-beam discharge values)
- 1% uncertainty for more than 15% bad bottom-tracking
- 2% uncertainty for more than 30% bad bottom-tracking
- 1% for more than 9 seconds of consecutive bad bottom-tracking
- 1% for measurement durations less than 720 seconds
- 5% for GPS reference with known compass interference

The resulting 95% uncertainties and ratings are shown on Table 2. Of the 80 mainstem and tributary flow measurements, 2% are rated Excellent, 84% are rated Good, 10% are rated Fair, and 4% are rated Poor.

5.6. Rating of 2-D Model Calibration Measurements

As explained in Section 4.5.5, the methodology for 2-D model calibration measurements differed from mainstem and tributary flow measurements. Instead of recording at least 12 minutes of reciprocal passes at each transect, a minimum of two reciprocal passes were recorded. Moving bed tests were limited to representative main-channel locations, and data quality was evaluated by comparing the total discharge at streamwise locations where discharge could be summed across all channels. The combined flows are provided on Tables 4 and 5, and are graphed on Figures 12 and 13. Using the USGS methodology (USGS OSW 2012c), 95% uncertainties were calculated for deviations from the average and the best fit line. Results indicate 95% uncertainties ranging from 1.4 to 1.9%. Adding 1% of additional uncertainty for "SonTek M9 bias", the quality of the 2-D calibration transects is rated "Good," with 95% uncertainties ranging from 2.4 to 2.7%.

5.7. Velocity Mapping Results

On August 15, 2014, seven velocity mapping transects were measured at PRM 187.1, spaced about 80 feet apart. The transects were intended to characterize the velocity field near two sonar counters installed as part of AEA's Salmon Escapement Study (AEA 2014). The transects were intended for use with the USGS Velocity Mapping Toolbox (VMT) software, which averages repeated transects and provides cross sectional and plan-view plots. However, the spatial averaging and plotting routines in VMT rely on GPS coordinates. PRM 187.1 is located in a canyon at the proposed Dam Site, where GPS reception is poor. As shown on Figure 14, the SonTek GPS receiver yielded erratic GPS positions for transects T4-T7, and no GPS reception for transects T1-T3. As a result, the VMT software could not be used.

Because it provides tools for navigating planned lines, the velocity mapping transects were navigated using the HYPACK data acquisition system, with continuous input from a TopCon GPS receiver. Although the SonTek GPS receiver yielded erratic GPS positions, the TopCon receiver provided smooth positions that varied only a few feet from the planned lines (Figure 14). As a result, additional bathymetry data were collected using the HYPACK system and results were used to prepare a digital elevation model (DEM) of the site. Velocity cross sections were superimposed on the DEM to provide an oblique view of the 3-dimensional velocity field (Figure 15).

The velocities shown on Figure 15 reflect bottom-track positioning with loop corrections for transects T2 through T5. Loop tests indicated stationary bed conditions at transects T6 and T7, and the loop correction was below the recommended minimum (<1%) at transect T1. Although the 95% uncertainty of discharge calculated by combining transects T2-T5 and T6-T7 is within 3 percent (Table 2), the uncertainty of velocity measurements for individual transects is likely higher, and may be on the order of 5-10 percent.

5.8. Summary of Data Quality

Overall, field procedures and data processing ensured the ADCP measurements collected in 2014 met project data quality objectives. Although compass performance was compromised by hardware and software issues, these problems were avoided by relying on bottom-track positioning for all but one measurement. Moving bed bias was quantified using constant-heading loop tests, which eliminate the effect of variable heading (compass) errors. Bad bottom-tracking represents another concern, but results of 35 comparison measurements at USGS gages indicate that bad bottom tracking had no discernible effect on measurement accuracy. Because only two of the comparison measurements had more than 15% bad bottom tracking, additional uncertainty was added for measurements exceeding 15% bad bottom tracking. Uncertainties computed from the variation between repeated transects were added to those resulting from bad bottom tracking, short exposure durations, use of GPS positioning (1 measurement), instrument bias, and systematic errors. Following current USGS guidance, the resulting uncertainties were used to rate each measurement as Excellent, Good, Fair or Poor. Despite challenging measurement conditions and the added uncertainties identified above, 86% of the measurements performed in 2014 were rated either Good or Excellent.

6. NEXT STEPS

The 2014 ADCP measurements were intended for calibration and verification of 1- and 2-dimensional (1-D and 2-D) hydraulic, bed evolution, and fish habitat models that will be used in evaluating potential Project operational effects. Once these models are fully developed, it is possible that supplemental ADCP measurements may be needed for further verification purposes. However, at this time there are no plans for conducting any additional ADCP measurements.

7. 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/

Morse, J.R. 2014. Personal communication with Josh Morse, Hydrologist, U.S. Geological Survey, Anchorage, Alaska.

Mueller, D.S. 2013. Status of testing of hydroacoustic instruments. USGS Hydroacoustics webinar, February 2013. https://hydroacoustics.usgs.gov/training/webinars.shtml.

Mueller, D.S. 2014. What's new in hydroacoustics? USGS Hydroacoustics webinar, November 2014. https://hydroacoustics.usgs.gov/training/webinars.shtml.

Mueller, D.S. 2015. RiverSurveyor M9/S5 compass upgrade and new features. USGS Hydroacoustics webinar, February 2015. https://hydroacoustics.usgs.gov/training/webinars.shtml.

Mueller, D.S. and C.R. Wagner. 2006. Application of the Loop Method for Correcting Acoustic Doppler Current Profiler Discharge Measurements Biased by Sediment Transport. U.S. Geological Survey Scientific Investigations Report 2006-5079, 18 p.

Mueller, D.S., C.R. Wagner, M.S. Rehmel., K.A. Oberg, and F. Rainville. 2013. Measuring discharge with acoustic Doppler current profilers from a moving boat. U.S. Geological Survey Techniques and Methods 3A-22, 95 p.

R2 Resource Consultants, Inc. (R2), Geo-Watersheds Scientific (GWS), Brailey Hydrologic, and Geovera. 2013. Open-water HEC-RAS Flow Routing Model. Susitna-Watana Hydroelectric Project, FERC No. P-14241 Submittal: January 31, 2013, Attachment A, Technical Memorandum. Prepared for Alaska Energy Authority, Anchorage, Alaska. http://www.susitna-watanahydro.org/wp-content/uploads/2013/02/Att-A-Flow-Routing-Model.pdf.

Thompson, T. 2014. Personal communication re: SonTek M9 Serial No. 3061. TTT Environmental, Anchorage, Alaska.

U.S. Geological Survey (USGS), Office of Surface Water (OSW). 2012a. Best practice for calibrating SonTek RiverSurveyor M9/S5 compass. USGS Best Practice Recommendation, August 30, 2012.

U.S. Geological Survey (USGS), Office of Surface Water (OSW). 2012b. Introduction to Extrap 3.X. OSW Hydroacoustics Podcast, September 2012.

U.S. Geological Survey (USGS), Office of Surface Water (OSW). 2012c. Review and rating of moving-boat ADCP Q measurements. OSW Hydroacoustics Webinar, October 4, 2012.

8. TABLES

Table 1. 2014 Acoustic Doppler Current Profiler (ADCP) loop test results completed on the Susitna River in 2014.

					Velocity, ft/s		Direction, deg			Loop test % correction							
Site	Date	Start time	DMG[3] ft	Duration, s	Bed	Flow	Bed	Flow	Difference	Estimated percent correction	Standard deviation	Actual percent correction	Standard deviation	Estimated - actual difference	% bad bottom-tracking	out-back difference[4]	Added uncertainty
ESS80	6/17/14	1252	73.17	349	0.21	7.04	58.6	209.5	150.9	2.98		NA-bad BT			34.1	0.3	
ESS80	***6/17/14***	***1316***	***61.06***	***314***	***0.19***	***7.30***	***32.2***	***209.2***	***177.0***	***2.77***	0.57	***NA-bad BT***			***26.4***	***0.2***	***1% - bad BT***
ESS80	6/17/14	1323	35.66	305	0.12	7.02	54.2	209.7	155.5	1.67		NA-bad BT			26.2	6.9	
Oshetna	6/18/14	1036	1.9	192	0.01	4.47	178.5	350.3	171.8	0.00		NA			0.5	1.4	
Oshetna	***6/18/14***	***1039***	***16.76***	***337***	***0.05***	***4.56***	***209.9***	***350.2***	***140.4***	***1.09***		***1.42***		***0.33***	***0.9***	***2.5***	
ESS70	6/19/14	1447	72.59	342	0.21	7.81	97.1	274.2	177.1	2.72		NA-bad BT			23.7	1.7	
ESS70	6/19/14	1453	88.79	341	0.26	7.59	88.4	272.2	183.7	3.43	0.30	NA-bad BT			26.7	0.9	
ESS70	***6/19/14***	***1459***	***69.94***	***307***	***0.23***	***7.91***	***89.0***	***272.2***	***183.2***	***2.88***		***NA-bad BT***			***25.1***	***2.4***	***1% - bad BT***
PRM 186.7	6/19/14	1553	72.95	413	0.18	7.17	113.1	273.0	159.9	2.46		NA-bad BT			26.0	4.2	
PRM 186.7	***6/19/14***	***1601***	***77.54***	***396***	***0.20***	***7.42***	***79.5***	***274.8***	***195.3***	***2.64***	0.49	***NA-bad BT***			***25.0***	***5.0***	***2% - bad BT***
PRM 186.7	6/19/14	1609	38.91	352	0.11	7.29	86.5	276.1	189.6	1.52		NA-bad BT			23.0	1.9	
PRM 184.7	6/20/14	1050	36.84	302	0.12	7.62	110.5	276.9	166.4	1.60		1.91		0.31	12.6	2.7	
PRM 184.7	***6/20/14***	***1055***	***38.54***	***305***	***0.13***	***7.67***	***115.2***	***278.9***	***163.7***	***1.64***	***0.75***	***1.98***	***0.85***	***0.34***	***14.4***	***3.3***	
PRM 184.7	6/20/14	1107	72.61	304	0.24	7.44	118.7	277.9	159.2	3.21		3.74		0.53	14.5	2.6	
ESS65	6/20/14	1337	65.9	374	0.18	7.14	113.3	298.0	184.8	2.47		2.78		0.31	11.0	3.3	
ESS65	***6/20/14***	***1344***	***65.89***	***393***	***0.17***	***7.12***	***123.6***	***297.6***	***174.0***	***2.36***	***0.31***	***2.64***	***0.35***	***0.28***	***10.7***	***1.3***	
ESS65	6/20/14	1350	45.05	361	0.12	7.10	116.5	300.0	183.5	1.76		1.97		0.21	10.5	2.5	
PRM 173.6	6/20/14	1500	63.41	407	0.16	6.73	88.4	278.6	190.2	2.31		2.54		0.23	7.1	1.2	
PRM 173.6	6/20/14	1508	44.92	377	0.12	6.72	97.9	278.5	180.7	1.77	0.24	1.94	0.27	0.17	8.5	0.3	
PRM 173.6	***6/20/14***	***1514***	***47.57***	***311***	***0.15***	***6.87***	***101.4***	***278.3***	***176.9***	***2.23***		***2.49***		***0.26***	***8.4***	***0.7***	
Portage Ck	6/21/14	1555	7.95	125	0.06	6.85	336.5	201.9	-134.6	0.93		NA			3.2	1.4	
Portage Ck	***6/21/14***	***1602***	***11.03***	***353***	***0.03***	***6.88***	***345.6***	***201.6***	***-144.0***	***0.00***		***NA-£0.04***[2]			***1.7***	***2.9***	
Portage Ck	6/22/14	1159	5.28	116	0.05	6.93	41.0	200.9	159.9	0.66		NA			3.5	0.1	
Portage Ck	***6/22/14***	***1201***	***14.04***	***305***	***0.05***	***6.79***	***59.4***	***201.4***	***141.9***	***0.68***		NA-<1%[2]			***3.6***	***1.2***	
ESS55	6/22/14	1307	53.75	444	0.12	7.67	119.6	282.9	163.3	1.58		1.93		0.35	11.3	1.5	
ESS55	***6/22/14***	***1315***	***49.29***	***402***	***0.12***	***7.55***	***118.2***	***281.4***	***163.2***	***1.62***	***0.20***	***1.95***	***0.19***	***0.33***	***12.9***	***1.3***	
ESS55	6/22/14	1322	64.64	420	0.15	7.58	106.1	281.7	175.5	2.03		2.34		0.31	9.3	0.1	
FA151_T6	6/22/14	1400	63.4	380	0.17	7.45	117.7	308.3	190.6	2.24		2.55		0.31	18.4	3.5	
FA151_T6	***6/22/14***	***1407***	***67.74***	***341***	***0.20***	***7.41***	***137.7***	***307.2***	***169.5***	***2.68***	***0.29***	***3.04***	***0.32***	***0.36***	***15.6***	***2.3***	***1% - bad BT***
FA151_T6	6/22/14	1413	80.21	370	0.22	7.36	132.7	306.6	173.8	2.94		3.31		0.37	16.5	3.6	
PRM 151.8	***6/23/14***	***1250***	***36.66***	***344***	***0.11***	***7.31***	***92.1***	***285.4***	***193.3***	***1.46***		***1.72***		***0.26***	***2.9***	***0.8***	
PRM 151.8	6/23/14	1303	42.48	389	0.11	7.26	95.1	285.3	190.2	1.50	0.17	1.76	0.19	0.26	4.6	1.1	
PRM 151.8	6/23/14	1309	31.98	388	0.08	7.29	75.9	285.4	209.5	1.13		1.33		0.20	4.9	1.0	
PRM 139.0	6/23/14	1617	52.83	436	0.12	6.19	17.0	190.5	173.5	1.96		2.24		0.28	8.5	1.3	
PRM 139.0	***6/23/14***	***1625***	***46.06***	***354***	***0.13***	***6.18***	***2.8***	***190.5***	***187.7***	***2.11***	***0.26***	***2.41***	***0.29***	***0.30***	***5.1***	***2.7***	
PRM 139.0	6/23/14	1631	31.63	338	0.09	6.23	3.7	190.5	186.8	1.49		1.73		0.24	8.3	2.1	
PRM138.4_C2	6/24/14	1126	15.82	302	0.05	8.44	36.3	199.5	163.2	0.62		NA-<1%[2]			9.6	3.5	
PRM138.4_C2	6/24/14	1133	14.68	327	0.04	8.54	137.7	199.9	62.2	0.52	0.04	NA-£0.04[2]			11.9	2.4	
PRM138.4_C2	***6/24/14***	***1139***	***15.61***	***341***	***0.05***	***8.47***	***341.2***	***201.0***	***-140.2***	***0.54***		***NA-<1%***[2]			***9.7***	***4.6***	
PRM138.4_C1	***6/24/14***	***1258***	***30.52***	***346***	***0.09***	***3.88***	***43.2***	***221.5***	***178.3***	***2.27***		***3.35***		***1.08***	***4.9***	***3.0***	
PRM138.4_C1	6/24/14	1304	25.84	372	0.07	3.93	78.5	223.3	144.9	1.77	0.40	2.63	0.56	0.86	10.2	2.7	

Site	Date	Start time	DMG[3] ft	Duration, s	Velocity, ft/s		Direction, deg			Loop test % correction					% bad bottom-tracking	out-back difference[4]	Added uncertainty
					Bed	Flow	Bed	Flow	Difference	Estimated percent correction	Standard deviation	Actual percent correction	Standard deviation	Estimated - actual difference			
PRM138.4_C1	6/24/14	1311	38.22	361	0.11	3.85	44.0	222.6	178.5	2.75		4.01		1.26	11.4	4.1	
Tsusena Ck	6/29/14	1228	13.78	107	0.13	4.99	161.3	243.7	82.4	2.57		NA			13.1	4.0	
Tsusena Ck	6/29/14	1233	9.4	297	0.03	4.69	83.5	250.8	167.4	0.00		NA-£0.04[2]			17.5	3.5	
Tsusena Ck	6/29/14	1244	4.47	300	0.01	4.75	80.3	251.1	170.8	0.00		NA-£0.04[2]			20.0	5.2	
Tsusena Ck	6/29/14	1252	8.47	332	0.03	4.95	108.6	254.1	145.5	0.00		NA-£0.04[2]			12.7	1.5	1% - bad BT
ESS40	7/3/14	1222	33.15	380	0.09	8.81	326.1	173.3	-152.8	0.99		NA-<1%[2]			19.2	3.2	
ESS40	7/3/14	1232	43.23	496	0.09	8.76	11.9	172.8	161.0	1.00	0.02	NA-<1%[2]			21.0	3.2	
ESS40	7/3/14	1241	40.88	495	0.08	8.71	357.9	172.7	-185.2	0.95		NA-<1%[2]			13.1	0.7	
PRM 104.7_C2	7/3/14	1413	35.52	301	0.12	9.09	333.7	154.0	-179.8	1.29		1.61		0.32	15.0	0.1	
PRM 104.7_C2	7/3/14	1427	34.79	312	0.11	9.15	314.5	154.1	-160.5	1.21		1.52		0.31	17.3	2.9	
PRM 104.7_C2	7/3/14	1451	61.28	308	0.20	9.22	319.4	153.1	-166.3	2.16	0.36	NA-bad BT	0.24		23.4	1.3	
PRM 104.7_C2	7/3/14	1458	46.59	302	0.15	9.16	327.0	153.2	-173.8	1.68		2.10		0.42	16.6	2.9	2% - bad BT
PRM 104.7_C2	7/3/14	1509	34.27	302	0.11	8.96	352.8	152.3	-200.4	1.26		1.54		0.28	17.2	3.5	
PRM 104.7_C1	7/3/14	1613	40.74	332	0.12	6.57	291.6	154.6	-137.0	1.87		NA-bad BT			21.7	1.4	
PRM 104.7_C1	7/3/14	1626	78.16	302	0.26	6.51	311.8	155.5	-156.4	3.98	0.90	NA-bad BT			25.6	0.1	
PRM 104.7_C1	7/3/14	1632	44.82	294	0.15	6.50	298.0	153.9	-144.1	2.35		NA-bad BT			21.8	3.1	3% - misc.
ESS30_C1	7/4/14	1101	129.11	594	0.22	7.85	357.3	180.8	-176.5	2.77		NA-bad BT			18.5	4.4	1% - bad BT
ESS30_C1	7/4/14	1119	173.84	511	0.34	7.83	345.7	182.0	-163.8	4.34	0.75	NA-bad BT			24.3	5.1	
ESS30_C1	7/4/14	1130	105.36	490	0.22	7.92	7.1	181.7	174.6	2.72		NA-bad BT			25.9	4.5	
ESS30_C2	7/4/14	1247	83.93	369	0.23	3.49	19.9	203.5	183.6	6.51		7.20		0.69	6.2	5.2	
ESS30_C2	7/4/14	1300	69.34	311	0.22	3.82	28.7	202.1	173.3	5.83	0.53	7.05	0.46	1.22	7.7	5.6	1% - out/back
ESS30_C2	7/4/14	1308	63.06	324	0.19	3.74	17.3	201.8	184.5	5.20		6.16		0.96	7.4	6.0	
ESS30_C3	7/4/14	1408	38.21	360	0.11	4.63	348.2	182.1	-166.1	2.29		2.60		0.31	2.8	2.9	
ESS30_C4	7/4/14	1446	8.85	227	0.04	2.25	354.7	181.5	-173.2	0.00		NA			3.5	5.9	
Sunshine	7/4/14	1629	70.55	435	0.16	8.19	70.0	215.3	145.3	1.98		NA-bad BT			28.5	4.9	
Sunshine	7/4/14	1639	146.69	635	0.23	7.99	4.6	214.7	210.1	2.89	0.39	NA-bad BT			33.4	1.7	
Sunshine	7/4/14	1701	116.01	538	0.22	8.11	23.8	210.6	186.8	2.66		NA-bad BT			37.6	0.4	3% - bad BT
Deshka	7/5/14	1425	6.79	315	0.02	2.00	324.2	161.7	-162.6	0.00		NA-£0.04[2]			1.3	4.3	
ESS55	7/6/14	1407	48.12	366	0.13	8.07	120.3	287.4	167.1	1.63		1.92		0.29	3.8	4.3	
Portage Ck	8/12/14	1608	3.38	114	0.03	3.73	341.8	197.8	-144.0	0.00		NA			0.9	1.5	
Portage Ck	8/12/14	1610	5.42	314	0.02	3.60	41.2	198.6	157.4	0.00		NA-£0.04[2]			0.6	2.2	
PRM 151.8	8/12/14	1702	7.36	379	0.02	6.36	113.3	279.4	166.1	0.00		NA-£0.04[2]			1.3	0	
PRM 144.3 C2	8/13/14	1223	7.28	330	0.02	7.59	20.2	193.9	173.8	0.00		NA-£0.04[2]			3.3	0.6	
PRM 144.3 C1	8/13/14	1331	18.94	310	0.06	2.38	33.2	216.4	183.1	2.57		3.20		0.63	1.0	4.2	
PRM 141.9	8/13/14	1434	25.71	512	0.05	5.35	40.1	232.8	192.7	0.94		NA-<1%[2]			1.8	1	
PRM 139.0	8/13/14	1616	40.29	494	0.08	5.27	11.6	192.2	180.6	1.56		1.70		0.14	2.4	2.5	
Tsusena Ck	8/14/14	1200	4.57	104	0.04	2.94	118.2	254.2	136.1	1.50		NA			3.9	4.1	
Tsusena Ck	8/14/14	1208	0.23	312	0.00	2.88	31.2	252.5	221.3	0.00		NA-£0.04[2]			4.5	0.8	
PRM 184.9	8/14/14	1415	30.62	431	0.07	6.48	93.2	263.0	169.9	1.10		1.19		0.09	3.5	0.6	
LGL T6&7	8/15/14	1352	4.05	345	0.01	7.63	118.8	272.0	153.2	0.00		NA-£0.04[2]			4.9	1	
LGL T2-T5	8/15/14	1437	36.41	329	0.11	6.99	84.5	265.0	180.6	1.58		2.04		0.46	5.2	2.8	

					Velocity, ft/s		Direction, deg			Loop test % correction							
Site	Date	Start time	DMG[3] ft	Duration, s	Bed	Flow	Bed	Flow	Difference	Estimated percent correction	Standard deviation	Actual percent correction	Standard deviation	Estimated - actual difference	% bad bottom-tracking	out-back difference[4]	Added uncertainty
PRM 184.7	8/16/14	1614	39.86	433	0.09	6.61	73.4	271.6	198.2	1.39		1.51		0.12	3.5	0	
PRM 176.5	8/17/14	1054	62.13	461	0.13	6.38	120.0	293.2	173.2	2.11		2.30		0.19	5.0	1.7	
PRM 173.6	8/17/14	1203	32.17	516	0.06	6.28	100.3	278.0	177.7	0.99		NA-<1%[2]			4.1	1.8	
PRM 138.4 C2	8/18/14	1022	31.66	480	0.07	8.12	335.5	198.6	-136.9	0.81		NA-<1%[2]			3.8	1.1	
PRM 138.4 C1	8/18/2014	1124	27.63	365	0.08	3.60	37.0	223.5	186.6	2.11		2.92		0.81	4.93	1.5	
PRM 128.1 C2	8/18/2014	1338	28.82	338	0.09	7.52	7.8	208.1	200.3	1.13		1.23		0.10	4.14	0.7	
PRM 128.1 C1	8/18/14	1436	59.82	300	0.20	4.21	35.9	231.2	195.4	4.74		6.23		1.49	3.7	4.2	
PRM 104.7 C2	8/18/14	1722	13.15	358	0.04	7.01	74.4	160.4	86.1	0.00		NA-£0.04[2]			3.9	2.5	
PRM 104.7 C1	8/18/14	1848	19.36	364	0.05	3.57	311.6	132.5	-179.1	1.49		2.38		0.89	0.8	2.6	
Oshetna	9/10/14	1503	6.3	180	0.03	4.82	33.1	349.5	316.4	0.00		NA			4.4	0.7	
Oshetna	9/10/14	1507	10.64	343	0.03	4.56	173.2	347.7	174.4	0.00		NA-£0.04[2]			0.9	0.0	
Kosina	9/11/14	1207	6.43	185	0.03	4.13	9.3	331.2	322.0	0.00		NA			13.0	0.5	
Kosina	9/11/14	1211	15.86	311	0.05	4.05	124.8	330.2	205.4	1.26	0.06	1.25	0.09	-0.01	13.2	4.6	
Kosina	9/11/14	1228	18.44	329	0.06	4.05	176.8	330.4	153.6	1.38		1.44		0.06	14.6	4.8	
Tsusena	9/12/14	1220	14.03	176	0.08	2.83	98.5	250.6	151.4	2.82		NA			9.1	3.7	
Tsusena	9/12/14	1241	6.35	305	0.02	3.35	145.7	246.9	100.9	0.00		NA-£0.04[2]			5.3	5.3	
Tsusena	9/12/14	1253	6.82	336	0.02	3.12	109.9	253.2	142.9	0.00		NA-£0.04[2]			8.7	2.3	
Tsusena	9/12/14	1300	5.98	365	0.02	3.18	103.9	248.6	144.3	0.00		NA-£0.04[2]			8.5	0.7	
PRM 184.9	9/12/14	1500	41.96	470	0.09	6.08	83.7	270.4	186.7	1.47		1.59		0.12	1.7	1.7	
PRM 184.7	9/13/14	1115	20.33	377	0.05	6.04	98.6	265.2	166.7	0.89		NA-<1%[2]			2.1	0.4	
PRM 180.7	9/13/14	1309	14.09	540	0.03	5.26	49.9	208.3	158.4	0.00		NA-£0.04[2]			0.9	0.4	
PRM 177.3	9/13/14	1442	25.72	424	0.06	6.61	119.3	290.7	171.4	0.91		NA-<1%[2]			3.1	3.1	
PRM 173.6	9/14/14	1142	40.8	477	0.09	5.64	101.3	282.8	181.6	1.52		1.82		0.30	2.3	2.7	
PRM 168.8	9/14/14	1308	11.04	448	0.02	6.23	175.0	356.1	181.2	0.00		NA-£0.04[2]			2.2	0.6	
Portage	9/15/14	1147	7.14	126	0.06	4.46	19.7	198.3	178.5	1.27		NA			0.0	2.5	
Portage	9/15/14	1152	11.24	312	0.04	4.45	308.7	199.7	-109.0	0.00		NA-£0.04[2]			2.9	0.8	
FA151 T6	9/15/14	1300	9.66	380	0.03	6.52	139.4	309.8	170.4	0.00		NA-£0.04[2]			1.8	2.9	
FA151 T3	9/15/14	1413	17.03	345	0.05	6.44	85.5	281.9	196.4	0.77		NA-<1%[2]			2.0	1.1	
FA151 T2	9/15/14	1504	9.67	334	0.03	7.15	332.2	268.1	-64.1	0.00		NA-£0.04[2]			3.0	0.4	
PRM 151.8	9/16/14	1101	13.18	373	0.04	6.53	63.0	279.7	216.8	0.00		NA-£0.04[2]			2.7	1.6	
PRM 150.1	9/16/14	1253	9.61	307	0.03	7.82	160.1	273.7	113.6	0.00		NA-£0.04[2]			3.6	1.2	
PRM 147.5 C1	9/16/14	1422	2.51	392	0.01	5.68	158.8	270.0	111.2	0.00		NA-£0.04[2]			2.0	3.3	
PRM 147.5 C2	9/16/14	1527	2.95	312	0.01	5.08	267.9	253.3	-14.6	0.00		NA-£0.04[2]			1.6	0.6	
PRM 139.0	9/17/14	1053	33.81	403	0.08	5.82	13.3	187.9	174.6	1.44		1.60		0.16	2.7	0.3	
PRM 138.4 C2	9/17/14	1204	14.69	309	0.05	8.31	12.2	195.7	183.5	0.57		NA-<1%[2]			3.2	1.5	
PRM 138.4 C1	9/17/14	1333	27.58	351	0.08	3.52	35.5	223.0	187.5	2.24		2.96		0.72	2.9	4.0	
PRM 124.1	9/17/14	1523	57.29	394	0.15	6.16	37.3	216.5	179.2	2.36		3.03		0.67	5.1	3.5	
ESS30 C1	9/18/14	1245	106.17	421	0.25	6.98	349.0	177.2	-171.8	3.61		4.71		1.10	10.9	1.5	
ESS30 C1	9/18/14	1252	126.80	442	0.29	6.88	338.7	177.6	-161.1	4.17	0.36	5.36		1.19	13.8	0.5	
ESS30 C1	9/18/14	1300	99.49	444	0.22	6.82	351.7	174.2	-177.6	3.29		4.19		0.90	13.3	3.1	

Site	Date	Start time	DMG[3] ft	Duration, s	Velocity, ft/s		Direction, deg			Loop test % correction					% bad bottom-tracking	out-back difference[4]	Added uncertainty
					Bed	Flow	Bed	Flow	Difference	Estimated percent correction	Standard deviation	Actual percent correction	Standard deviation	Estimated - actual difference			
ESS30 C2	9/18/14	1501	45.66	216	0.21	3.60	7.3	176.3	169.0	5.87		NA			5.1	1.4	
ESS30 C2	**9/18/14**	**1522**	**81.23**	**416**	**0.20**	**3.51**	**356.4**	**177.8**	**-178.6**	**5.57**		**6.21**		**0.64**	**2.6**	**3.7**	
Kosina	9/24/14	1449	8.44	387	0.02	2.96	311.9	333.0	21.2	0.00		NA-£0.04[2]			12.4	1.1	
Kosina	9/24/14	1455	11.18	373	0.03	3.03	328.4	332.0	3.6	0.00		NA-£0.04[2]			13.4	1.4	
Kosina	**9/24/14**	**1518**	**5.78**	**379**	**0.02**	**3.05**	**200.4**	**333.3**	**132.9**	**0.00**		**NA-£0.04[2]**			**13.7**	**0.9**	
Kosina	9/24/14	1524	1.69	140	0.01	2.81	28.0	330.9	302.9	0.00		NA			13.6	2.1	
Oshetna	9/25/14	1128	6.32	208	0.03	3.47	347.7	352.6	4.9	0.00		NA			0.5	3.4	
Oshetna	**9/25/14**	**1139**	**9.96**	**415**	**0.02**	**3.67**	**316.7**	**349.3**	**32.6**	**0.00**		**NA-£0.04[2]**			**0.5**	**3.2**	
PRM 184.9	**9/26/14**	**1040**	**13.95**	**409**	**0.03**	**5.42**	**132.3**	**269.3**	**137.0**	**0.00**		**NA-£0.04[2]**			**3.2**	**1.4**	
Fog Creek	**9/26/14**	**1405**	**12.11**	**303**	**0.04**	**4.12**	**43.8**	**238.0**	**194.2**	**0.97**		**NA-<1%[2]**			**4.6**	**1.1**	
Portage	9/27/14	1043	3.66	119	0.03	3.95	189.8	197.8	-8.0	0.00		NA			2.5	3.4	
Portage	**9/27/14**	**1051**	**6.39**	**313**	**0.02**	**3.90**	**1.9**	**200.0**	**-198.1**	**0.00**		**NA-£0.04[2]**			**3.2**	**1.3**	
PRM 139.0	**9/27/14**	**1352**	**4.65**	**419**	**0.01**	**4.15**	**233.0**	**194.9**	**-38.0**	**0.00**		**NA-£0.04[2]**			**1.91**	**0.6**	
Sunshine	**9/28/14**	**1020**	**88.72**	**556**	**0.16**	**4.90**	**15.1**	**197.0**	**181.8**	**3.26**		**3.93**			**3.42**	**1.5**	
Average				**376[5]**						**1.52**	**0.37**	**2.75**	**0.35**	**0.46**	**9.62**	**2.27**	

Notes:

1 Bolded loop tests used for discharge computations.

2 NA-£0.04: stationary bed (bed v £ 0.04 ft/s), NA-<1%: bed v <1% of mean v - no correction recommended.

3 DMG = distance made good.

4 Difference in flow direction between the outgoing and return legs of the loop.

5 Excluding single loops used to demonstrate acceptable out-back difference.

Values accepted for stationary bed conditions (bed v £ 0.04), or for single loops used to demonstrate acceptable out-back difference.

Values contributing to added uncertainty.

Table 2. Details of Acoustic Doppler Current Profiler discharge measurements completed on the Susitna River in 2014.

Date	Mid-point time	Site	Transect or Channel	Loop Test Results See Table 5.1-1		Mmt duration, s	No. of Passes	Mean velocity, ft/s	Max. velocity, ft/s	Hydraulic depth, ft	Best-fit extrap. % change[1]		% Top & Bottom Est's.	% Edge Est's.	Discharge, cfs		COV[2]	% bad bottom-tracking	Max. consec[3]. bad BT, s	95% Uncer-tainty	Added Uncert. (%)	Rating
				Time	% corr						P/P	C/N			vertical beam	4-beam						
6/17/14	13:40	ESS80	C1	1316	2.77	772	4	7.03	12.75	5.75	-0.79	-1.64	32.32	0.035	14,440	14,694	0.018	28.9	4	5.4	2.0	Fair
6/18/14	10:57	Oshetna	C1	1039	1.09	816	8	3.98	8.34	2.94	-0.25	-2.02	43.78	1.007	1,453	1,476	0.028	0.9	1	3.7	1.0	Good
6/18/14	16:38	Kosina	C1	none	invalid	1566	18	3.87	8.84	3.22	-0.60	-0.94	46.75	0.755	1,296	1,305	0.034	VTG w/ compass error		8.5	6.0	Poor
6/19/14	15:14	ESS70	C1	1459	2.88	808	4	7.72	14.85	7.91	-0.77	-1.76	32.94	0.029	20,342	20,537	0.026	25.2	4	6.7	2.0	Fair
6/19/14	16:29	PRM 186.7	C1	1601	2.64	776	4	6.99	14.02	8.01	-0.91	-2.57	31.56	0.046	20,726	21,001	0.035	24.7	15	9.1	3.0	Poor
6/20/14	11:23	PRM 184.7	C1	1055	1.64	888	4	6.56	12.32	5.47	-0.11	-0.71	34.24	0.324	19,304	19,584	0.007	13.8	3	2.6	1.0	Good
6/20/14	14:07	ESS65	C1	1344	2.36	836	4	6.63	11.55	6.13	-0.43	-1.53	30.93	0.067	21,560	21,950	0.015	10.7	4	3.9	1.0	Good
6/20/14	15:28	PRM 173.6	C1	1514	2.23	788	4	6.57	10.87	6.16	-0.41	-1.41	31.66	0.030	21,663	21,964	0.010	8.0	3	3.1	1.0	Good
6/21/14	16:19	Portage Ck	C1	1602	0.00	850	10	6.08	12.80	3.42	-0.41	-0.85	42.30	0.540	1,465	1,499	0.042	2.5	1	4.4	1.0	Good
6/22/14	12:23	Portage Ck	C1	1201	0.68	790	10	6.24	12.00	3.38	-0.24	-0.75	42.86	0.683	1,510	1,544	0.047	3.5	1	4.8	1.0	Good
6/22/14	13:36	ESS55	C1	1315	1.62	792	4	7.27	15.59	6.73	-0.35	-1.53	33.59	0.037	24,642	24,953	0.007	11.2	8	2.6	1.0	Good
6/22/14	14:27	FA151	T6	1407	2.68	832	4	6.94	12.89	6.20	-0.87	-1.68	30.25	0.021	23,632	24,079	0.011	16.8	4	4.3	2.0	Good
6/23/14	13:22	PRM 151.8	C1	1250	1.46	724	4	6.96	12.53	6.13	-0.49	-1.06	33.71	0.039	21,744	22,121	0.012	4.1	2	3.4	1.0	Good
6/23/14	16:57	PRM 139.0	C1	1625	2.11	744	4	5.74	10.73	7.49	-0.67	-1.61	33.17	0.119	22,334	22,503	0.017	7.3	1	4.2	1.0	Good
6/24/14	11:55	PRM 138.4	C2	1139	0.54	840	4	7.15	12.88	4.63	-0.28	-1.00	35.40	0.114	18,169	18,515	0.011	10.4	3	3.3	1.0	Good
6/24/14	13:25	PRM 138.4	C1	1258	2.27	896	4	3.11	6.93	2.15	0.08	-2.00	49.88	0.728	2,708	2,727	0.006	8.8	2	2.5	1.0	Good
6/29/14	13:28	Tsusena Ck	C1	1252	0.00	832	8	3.54	9.87	2.88	0.33	1.97	44.48	0.831	1,151	1,162	0.032	15.8	2	5.1	2.0	Fair
7/3/14	12:59	ESS40	C1	1222	0.99	832	4	7.89	14.03	8.31	-0.52	-1.28	32.64	0.029	41,657	42,112	0.015	17.8	5	4.9	2.0	Good
7/3/14	15:33	PRM 104.7	C2	1458	1.68	756	4	8.42	13.10	7.18	-0.42	-1.44	31.20	0.036	33,510	33,804	0.008	17.9	14	4.8	3.0	Good
7/3/14	16:45	PRM 104.7	C1	1632	2.35	668	4	6.45	10.84	2.99	-0.28	-1.97	43.37	0.085	7,999	8,085	0.029	23.0	20	9.1	4.0	Poor
7/4/14	11:51	ESS30	C1	1101	2.77	764	4	7.34	13.84	9.67	-0.13	-0.84	28.57	0.008	64,353	64,479	0.008	22.9	7	3.8	2.0	Good
7/4/14	13:21	ESS30	C2	1300	5.83	648	6	3.62	7.98	5.74	-0.87	1.05	34.50	0.114	4,135	4,137	0.028	7.1	2	5.3	2.0	Fair
7/4/14	14:23	ESS30	C3	1408	2.29	630	6	4.48	8.43	4.13	0.24	-0.90	37.95	0.103	4,818	4,842	0.009	2.8	1	3.4	2.0	Good
7/4/14	15:00	ESS30	C4	1446	0.00	558	6	1.72	5.28	3.50	0.58	-0.48	32.15	-0.054	1,286	1,287	0.019	3.5	1	4.4	2.0	Good
7/4/14	17:26	Sunshine	C1	1701	2.66	796	4	7.10	15.63	10.12	0.10	-0.83	27.72	0.007	70,889	71,051	0.006	33.2	14	5.5	4.0	Fair
7/5/14	14:42	Deshka	C1	1425	0.00	850	10	1.99	3.80	2.49	0.16	-1.80	44.20	0.608	714	724	0.012	1.3	1	2.3	1.0	Good
7/6/14	14:21	ESS55	C1	1407	1.63	816	6	7.82	13.98	6.94	-0.42	-1.32	32.70	0.038	28,513	28,976	0.013	3.8	1	2.8	1.0	Good
8/12/14	16:34	Portage Ck	C1	1608	0.00	720	8	3.15	7.40	2.84	-0.17	-0.45	43.29	2.083	572	583	0.015	0.8	1	2.7	1.0	Good
8/12/14	17:29	PRM 151.8	C1	1702	0.00	1056	6	6.08	10.93	5.50	-0.37	-2.06	34.44	0.070	16,423	16,687	0.006	1.3	1	2.1	1.0	Good
8/13/14	12:40	PRM 144.3	C2	1223	0.00	1026	6	7.16	12.48	5.01	-0.66	-1.46	32.17	0.079	16,442	16,830	0.013	3.3	2	2.8	1.0	Good
8/13/14	13:45	PRM 144.3	C1	1331	2.55	816	6	2.03	4.49	1.94	0.27	-1.19	53.55	1.183	689	699	0.025	1.0	1	4.0	1.0	Good
8/13/14	14:49	PRM 141.9	C1	1434	0.93	744	4	5.16	8.53	6.82	-0.03	-1.24	34.20	0.078	17,441	17,596	0.005	1.8	1	2.3	1.0	Good
8/13/14	16:35	PRM 139.0	C1	1616	1.56	1116	6	5.03	9.08	6.83	-0.32	-1.14	32.18	0.057	17,614	17,838	0.007	2.4	1	2.2	1.0	Good
8/14/14	12:35	Tsusena Ck	C1	1200	1.50	864	8	2.05	5.29	2.00	-0.10	-1.76	43.10	8.397	414	420	0.025	4.2	1	3.5	1.0	Good
8/14/14	14:32	PRM 184.9	C1	1415	1.09	1164	6	6.27	10.89	5.16	-0.50	-1.28	31.38	0.160	14,533	14,784	0.011	3.5	1	2.6	1.0	Good
8/15/14	14:31	LGL sonar	T6&7	1352	0.00	828	4	6.89	13.30	6.61	-0.76	-1.46	33.82	0.022	14,981	15,220	0.002	4.9	3	1.8	1.0	Excellent
8/15/14	16:23	LGL sonar	T2-T5	1437	1.58	1472	8	6.26	11.10	7.78	-0.79	-1.26	32.69	0.081	14,946	15,194	0.014	5.2	8	2.6	1.0	Good
8/16/14	16:31	PRM 184.7	C1	1614	1.39	600	4	6.41	11.03	5.49	-0.58	-1.75	30.40	0.060	16,375	16,673	0.002	3.5	2	2.8	2.0	Good
8/17/14	11:10	PRM 176.5	C1	1054	2.11	720	4	6.15	11.88	5.68	-0.48	-1.33	29.69	0.062	18,664	18,997	0.006	5.0	3	2.5	1.0	Good
8/17/14	12:25	PRM 173.6	C1	1203	0.99	1068	6	6.09	10.79	6.11	-0.53	-1.72	30.19	0.143	18,152	18,421	0.006	4.1	3	2.1	1.0	Good
8/18/14	10:38	PRM 138.4	C2	1022	0.81	1020	6	6.88	12.67	4.80	-0.32	-1.88	33.43	0.074	18,291	18,660	0.011	3.8	3	2.6	1.0	Good
8/18/14	11:39	PRM 138.4	C1	1124	2.11	972	6	3.03	6.82	2.26	0.01	-2.52	51.51	0.707	2,787	2,810	0.014	4.9	3	2.9	1.0	Good
8/18/14	13:54	PRM 128.1	C2	1338	1.13	966	6	7.20	12.00	5.28	-0.20	-1.39	33.53	0.122	14,413	14,612	0.010	4.1	3	2.5	1.0	Good
8/18/14	14:50	PRM 128.1	C1	1436	4.74	846	6	3.73	7.31	5.76	-0.27	-1.85	34.28	0.110	7,226	7,243	0.015	3.7	1	3.0	1.0	Good
8/18/14	17:53	PRM 104.7	C2	1722	0.00	984	6	6.56	11.15	5.26	-0.29	-0.22	34.60	0.230	18,756	18,996	0.015	3.9	1	3.0	1.0	Good
8/18/14	19:02	PRM 104.7	C1	1848	1.49	966	6	2.49	6.93	2.57	-0.27	-1.85	40.53	1.578	2,956	2,976	0.012	0.8	1	2.7	1.0	Good

Date	Mid-point time	Site	Transect or Channel	Loop Test Results See Table 5.1-1		Mmt duration, s	No. of Passes	Mean velocity, ft/s	Max. velocity, ft/s	Hydraulic depth, ft	Best-fit extrap. % change[1]		% Top & Bottom Est's.	% Edge Est's.	Discharge, cfs		COV[2]	% bad bottom-tracking	Max. consec[3]. bad BT, s	95% Uncer-tainty	Added Uncert. (%)	Rating
				Time	% corr						P/P	C/N			vertical beam	4-beam						
9/10/14	15:30	Oshetna	C1	1507	0.00	872	8	4.16	8.71	2.85	-0.36	-1.69	45.42	0.974	1,466	1,473	0.016	2.7	1	2.8	1.0	Good
9/11/14	12:54	Kosina	C1	1211	1.26	920	8	3.84	8.40	2.58	-0.43	-1.48	57.54	1.876	1,057	1,058	0.031	13.6	4	4.0	1.0	Good
9/12/14	13:30	Tsusena Ck	C1	1253	0.00	848	8	2.42	6.30	2.22	-0.07	-1.95	43.99	3.370	579	586	0.046	7.9	2	5.2	1.0	Fair
9/12/14	15:22	PRM 184.9	C1	1500	1.47	1128	6	5.91	10.76	4.88	-0.52	-2.01	32.96	0.168	12,763	13,011	0.014	1.7	1	2.9	1.0	Good
9/13/14	11:36	PRM 184.7	C1	1115	0.89	1068	6	5.86	10.57	4.84	-0.61	-1.80	32.86	0.158	12,340	12,580	0.012	2.1	1	2.7	1.0	Good
9/13/14	13:30	PRM 180.7	C1	1309	0.00	1080	6	5.10	9.58	3.84	-0.27	-1.06	38.79	0.205	13,080	13,339	0.005	0.9	1	2.0	1.0	Good
9/13/14	14:59	PRM 177.3	C1	1442	0.91	1050	6	6.02	11.20	4.36	-0.36	-1.24	35.46	0.145	13,534	13,790	0.010	3.1	1	2.5	1.0	Good
9/14/14	12:03	PRM 173.6	C1	1142	1.52	930	6	5.37	10.12	5.55	-0.42	-1.42	29.97	0.029	14,508	14,727	0.014	2.3	1	2.9	1.0	Good
9/14/14	13:28	PRM 168.8	C1	1308	0.00	1050	6	5.92	10.53	4.94	-0.58	-1.99	31.65	0.242	14,372	14,665	0.012	2.2	1	2.7	1.0	Good
9/15/14	12:13	Portage Ck	C1	1152	0.00	800	10	4.06	8.52	3.16	-0.42	-1.38	43.97	0.829	809	825	0.015	2.9	1	2.6	1.0	Good
9/15/14	13:13	FA151	T6	1300	0.00	788	4	6.49	11.38	4.87	-0.54	-1.87	34.61	0.030	16,568	16,943	0.009	1.8	1	2.9	1.0	Good
9/15/14	13:33	FA151	T5	1300	0.00	588	4	5.74	10.52	7.62	-0.43	-1.47	31.55	0.008	16,605	16,813	0.019	1.8	2	5.5	2.0	Fair
9/15/14	13:50	FA151	T4	1300	0.00	560	4	7.18	13.59	6.89	-1.25	-1.68	32.19	0.032	17,510	17,837	0.011	1.8	2	4.3	2.0	Good
9/15/14	14:30	FA151	T3	1413	0.77	1020	6	6.00	10.73	5.99	-0.41	-1.88	34.02	0.087	17,465	17,763	0.011	2.0	2	2.6	1.0	Good
9/15/14	15:15	FA151	T2	1504	0.00	712	4	6.74	12.58	4.94	-0.62	-1.99	34.74	0.033	17,597	18,018	0.008	3.0	1	3.8	2.0	Good
9/16/14	11:20	PRM 151.8	C1	1101	0.00	1050	6	6.49	11.53	5.61	-0.47	-2.12	31.69	0.029	19,021	19,442	0.010	2.7	1	2.5	1.0	Good
9/16/14	13:14	PRM 150.1	C1	1253	0.00	1002	6	7.22	12.21	5.12	-0.41	-1.43	34.22	0.106	19,167	19,611	0.010	3.6	1	2.5	1.0	Good
9/16/14	14:41	PRM 147.5	C1	1422	0.00	852	6	5.59	10.67	5.27	-0.16	-1.60	32.09	0.065	13,202	13,386	0.009	2.0	1	2.4	1.0	Good
9/16/14	15:42	PRM 147.5	C2	1527	0.00	840	6	4.80	8.67	3.75	-0.25	-1.69	37.23	0.381	5,956	6,064	0.006	1.6	1	2.1	1.0	Good
9/17/14	11:15	PRM 139.0	C1	1053	1.44	1008	6	5.60	9.59	7.15	-0.33	-1.05	32.74	0.098	21,009	21,287	0.012	2.7	1	2.7	1.0	Good
9/17/14	12:20	PRM 138.4	C2	1204	0.57	966	6	6.68	13.00	4.94	-0.51	-1.78	34.43	0.036	18,066	18,409	0.011	3.2	2	2.6	1.0	Good
9/17/14	13:48	PRM 138.4	C1	1333	2.24	1014	6	2.97	6.28	2.19	0.01	-2.75	51.59	0.878	2,651	2,677	0.017	2.9	1	3.2	1.0	Good
9/17/14	15:39	PRM 124.1	C1	1523	2.36	900	6	5.67	10.27	9.32	0.07	-1.36	30.19	0.029	21,287	21,417	0.005	5.1	1	2.0	1.0	Good
9/18/14	13:27	ESS30	C1	1245	3.61	784	4	6.34	12.64	7.77	-0.03	-0.78	30.87	0.020	45,918	46,135	0.005	12.7	6	2.3	1.0	Good
9/18/14	15:46	ESS30	C2	1522	5.57	832	8	3.38	7.35	3.50	0.04	-0.12	43.13	0.391	2,434	2,440	0.020	3.9	2	3.1	1.0	Good
9/18/14	16:54	ESS30	C3	1522	5.57	984	8	2.25	5.35	3.30	0.08	-1.77	38.11	0.484	2,042	2,052	0.013	3.9	2	2.5	1.0	Good
9/18/14	17:24	ESS30	C4	not recommended[4]		820	10	0.42	2.53	2.59	1.30	1.69	35.41	-0.603	161	162	0.075	NA	NA	6.8	1.0	Fair
9/24/14	15:41	Kosina	C1	1518	0.00	744	8	2.82	8.19	3.20	-0.65	-1.95	46.96	1.327	817	827	0.023	13.3	3	3.3	1.0	Good
9/25/14	12:03	Oshetna	C1	1139	0.00	736	8	3.33	6.79	2.60	-0.13	-0.61	48.01	0.913	1,028	1,034	0.014	0.5	1	2.6	1.0	Good
9/26/14	11:09	PRM 184.9	C1	1040	0.00	954	6	5.16	9.20	4.41	-0.51	-1.70	36.77	0.084	9,642	9,828	0.006	3.2	2	2.1	1.0	Good
9/26/14	14:48	Fog Creek	C1	1405	0.97	904	8	2.74	8.61	1.71	0.00	-2.54	62.63	2.232	272	274	0.031	4.6	1	4.0	1.0	Good
9/27/14	11:10	Portage Ck	C1	1051	0.00	730	10	3.58	7.73	3.02	-0.30	-0.07	45.05	0.969	687	701	0.032	2.9	1	3.7	1.0	Good
9/27/14	14:11	PRM 139.0	C1	1352	0.00	1184	8	3.96	7.67	6.12	-0.43	-2.22	30.08	0.073	11,996	12,147	0.005	1.9	1	1.9	1.0	Excellent
9/28/14	10:50	Sunshine	C1	1020	3.26	1284	6	4.55	8.44	6.79	0.14	-1.00	33.20	0.085	27,151	27,193	0.006	3.4	1	2.1	1.0	Good
Average					**1.33**	**885.23**	**6.15**	**5.28**	**10.14**	**5.02**	**-0.31**	**-1.36**	**36.97**	**0.47**			**0.016**	**6.6**	**2.76**	**3.48**	**1.35**	

Notes:

1 Percent change using best-fit extrapolation settings; P/P = power/power, C/N = constant/no-slip best fit.

2 COV = coefficient of variation.

3 Maximum consecutive bad bottom-tracking, seconds.

4 Loop tests not recommended for velocities < 0.8 ft/s (Mueller et al. 2013).

(yellow) Values contributing to added uncertainty: 1% for "SonTek M9 bias" (all measurements); 1% for > 15% bad bottom-tracking; 2% for >30% bad bottom-tracking; 1% for >9 s consecutive bad bottom track; 1% for durations < 720 s; 5% for GPS reference with known compass interference.

(orange) Power/power best-fit extrapolation settings applied due to >1% change in discharge.

Table 3. Comparison measurements at USGS Gage.

Date	Project River Mile (PRM)	Start time	End time	Distance u/s of USGS gage, mi	Corresponding start and end times at gage		Average USGS Q[1], cfs	No. of transects	Loop test results		Bad bottom-tracking		Vertical Beam			4-Beam			Same-day USGS mmts		
					Start	End			% correction	out-back difference	% bad BT	Con-secutive[2]	Q, cfs	COV[3]	USGS % diff	Q, cfs	USGS % diff	95% Uncert[4].	time	Q, cfs	4-beam % diff
6/18/2012	185.5	16:01	16:23	0.6	16:06	16:28	25,600	4	3.80	5.9	3.9	8	25,745	0.009	0.57	26,028	1.67	2.94			
6/18/2012	186.2	14:05	14:27	1.3	14:16	14:38	26,267	4	1.64	2.7	10.4	3	24,885	0.018	-5.26	25,136	-4.31	4.38			
6/29/2012	139.8	16:13	16:40	-0.2	16:10	16:37	32,133	4	0.00	2.2	5.2	2	29,540	0.010	-8.07	30,336	-5.59	3.10			
6/29/2012	140.0	14:44	14:58	0.0	14:44	14:58	32,300	4	1.08	0.6	5.4	3	31,249	0.006	-3.25	31,759	-1.67	2.46			
8/6/2012	184.9	18:18	18:34	0.0	18:18	18:34	14,550	4	0.00	NA	1.2	2	14,447	0.011	-0.71	14,659	0.75	3.26			
8/6/2012	186.2	16:59	17:15	1.3	17:10	17:26	14,667	4	0.00	NA	0.9	1	14,776	0.015	0.74	14,989	2.20	3.90	15:21	16,000	6.74
8/13/2012	137.6	16:07	16:24	-2.4	15:35	15:52	16,600	4	0.00	NA	0.7	1	16,701	0.002	0.61	16,905	1.84	1.82			
8/13/2012	138.7	14:43	14:57	-1.3	14:26	14:39	16,700	4	0.00	NA	0.3	1	16,696	0.007	-0.02	16,915	1.29	2.62			
8/13/2012	139.0	13:51	14:07	-1.0	13:37	13:53	16,700	4	0.00	NA	2.8	1	16,853	0.014	0.92	17,051	2.10	3.74			
8/13/2012	140.0	12:49	13:04	0.0	12:49	13:04	16,700	4	0.00	NA	0.5	1	16,666	0.010	-0.20	16,946	1.47	3.10			
9/15/2012	186.2	13:59	14:15	1.3	14:10	14:26	8,327	4	0.00	NA	2.1	1	7,776	0.011	-6.62	7,897	-5.16	3.26			
9/15/2012	187.1	13:11	13:26	2.3	13:30	13:45	8,340	4	0.00	NA	2.3	1	8,000	0.011	-4.08	8,207	-1.59	3.26			
9/30/2012	137.6	14:50	15:07	-2.4	14:18	14:35	16,700	4	0.00	NA	0.0	1	17,630	0.007	5.57	17,904	7.21	2.62			
9/30/2012	140.0	13:51	14:04	0.0	13:51	14:04	16,700	4	0.00	NA	2.3	1	17,828	0.005	6.75	18,160	8.74	2.30			
7/1/2013	139.0	13:46	14:00	-1.0	13:32	13:46	27,050	4	1.92	3.6	2.9	1	25,396	0.016	-6.11	25,708	-4.96	4.06			
8/3/2013	87.7	16:17	16:33	0.0	16:17	16:33	53,933	4	2.79	3.3	9.2	9	53,224	0.006	-1.31	53,245	-1.28	2.46			
8/10/2013	137.6	16:44	17:01	-2.4	16:12	16:29	16,900	4	0.58	0.1	1.5	1	16,033	0.005	-5.13	16,255	-3.82	2.30			
8/10/2013	139.0	15:35	15:50	-1.0	15:21	15:36	16,900	4	0.87	0.2	3.9	2	16,286	0.003	-3.63	16,548	-2.08	1.98			
8/15/2013	139.0	12:48	13:03	-1.0	12:34	12:49	19,900	4	1.46	0.2	1.2	1	19,029	0.012	-4.38	19,247	-3.28	3.42	13:49	18,800	-2.32
9/9/2013	139.0	13:05	13:18	-1.0	12:51	13:04	30,667	4	1.55	3.5	5.2	1	29,070	0.006	-5.21	29,471	-3.90	2.46			
6/19/2014	186.7	16:22	16:41	1.8	16:37	16:56	20,933	4	2.64	5.0	24.7	15	20,726	0.035	-0.99	21,001	0.32	7.10			
6/20/2014	184.7	11:16	11:33	-0.2	11:15	11:31	19,800	4	1.64	3.3	13.8	3	19,304	0.007	-2.51	19,584	-1.09	2.62			
6/23/2014	139.0	16:39	17:11	-1.0	16:25	16:58	22,933	4	1.96	1.3	7.3	1	22,334	0.017	-2.61	22,503	-1.88	4.22			
7/4/2014	87.7	17:18	17:38	0.0	17:18	17:38	74,000	4	2.66	0.4	33.2	14	70,889	0.006	-4.20	71,050	-3.99	2.46			
8/15/2014	187.1	14:08	15:03	2.2	14:26	15:21	14,950	4	0.00	NA	4.9	3	14,981	0.002	0.20	15,220	1.81	1.82			
8/16/2014	184.7	16:21	16:45	-0.2	16:20	16:43	16,667	4	1.39	0.0	3.5	2	16,375	0.002	-1.75	16,673	0.04	1.82			
8/13/2014	139.0	16:25	16:48	-1.0	16:12	16:35	17,600	6	1.56	2.5	2.4	1	17,614	0.007	0.08	17,838	1.35	2.20			
8/14/2014	184.9	14:23	14:46	0.0	14:23	14:46	14,800	6	1.09	3.5	3.5	1	14,533	0.011	-1.80	14,784	-0.11	2.60			
9/12/2014	184.9	15:13	15:34	0.0	15:13	15:34	13,450	6	1.47	1.7	1.7	1	12,763	0.014	-5.11	13,011	-3.26	2.90			
9/13/2014	184.7	11:28	11:47	-0.2	11:26	11:46	13,200	6	0.89	0.4	2.1	1	12,340	0.012	-6.52	12,580	-4.70	2.70			
9/17/2014	139.0	11:00	11:28	-1.0	10:47	11:15	21,367	6	1.44	0.3	2.7	1	21,009	0.012	-1.68	21,287	-0.37	2.70	14:22	21,600	1.47
9/26/2014	184.9	10:51	11:36	0.0	10:51	11:36	9,890	6	2.00	1.4	3.2	3	9,642	0.006	-2.51	9,828	-0.63	2.10			
9/28/2014	87.7	10:31	11:05	0.0	10:31	11:05	27,867	6	3.26	1.5	3.4	1	27,151	0.006	-2.57	27,193	-2.42	2.10			
8/15/2014	187.1	15:19	17:06	2.2	15:37	17:24	14,878	8	1.58	1.0	5.2	8	14,946	0.014	0.46	15,194	2.12	2.62			
9/27/2014	139.0	13:59	14:27	-1.0	13:46	14:14	12,567	8	0.00	0.6	1.9	1	11,996	0.005	-4.54	12,147	-3.34	1.90			
Average															-2.14		-0.76				
Median															-2.51		-1.09				

Notes:

1 Average of published final 15-minute discharge values.

2 Maximum consecutive bad bottom-tracking, seconds.

3 Coefficient of variation.

4 95 percent uncertainty, calculated as per USGS OSW 2012b.

Table 4. Discharge at 2-D Model Calibration Transects, FA-151 (Portage Creek) June 22, 2014. Times listed for main channel transects.

June 22, 2014					Measured 4-beam flow (or sum), cfs			Constant average line Q = 25,381 (cfs)	
Date	Time	Transect	Pass	Duration, seconds	Left	Right	Total	Flow - cfs	Error
6/22/2014	14:20	T6	R-L	305	23,691	1,477	25,167	25,381	-214
6/22/2014	14:25	T6	L-R	255	24,056	1,574	25,630	25,381	248
6/22/2014	14:29	T6	R-L	307	24,128	1,600	25,728	25,381	347
6/22/2014	14:33	T6	L-R	274	24,442	1,523	25,965	25,381	584
6/22/2014	14:43	T5	L-R	214	24,578	1,574	26,152	25,381	771
6/22/2014	14:46	T5	R-L	236	23,585	1,523	25,107	25,381	-274
6/22/2014	14:51	T4	R-L	160		"Right" channel is Portage Creek	26,818	25,381	1,437
6/22/2014	14:54	T4	L-R	168			27,215	25,381	1,834
6/22/2014	13:30	T3 (ESS55)	R-L	247			25,099	25,381	-282
6/22/2014	13:34	T3 (ESS55)	L-R	178			24,532	25,381	-850
6/22/2014	13:38	T3 (ESS55)	R-L	194			25,002	25,381	-380
6/22/2014	13:41	T3 (ESS55)	L-R	174			25,181	25,381	-200
6/22/2014	15:01	T2	R-L	194			24,950	25,381	-432
6/22/2014	15:07	T2	L-R	165			26,062	25,381	681
mean	14:24		total duration	3071		T4 excluded	25,381	25,381	
COV						due to high bias	0.019		0.019
95%U							1.85		1.85

Notes:

1 Date and time in serial number format (datum = 1/0/1900).

Table 5. Discharge at 2-D Model Calibration Transects, FA-151 (Portage Creek) September 15, 2014. Times listed for main channel transects.

September 15, 2014					Measured 4-beam flow (or sum), cfs			Best fit line Q = 3115*date[1] + 1.30e8	
Date	Time	Transect	Pass	Duration, seconds	Left	Right	Total	Flow (cfs)	Error
9/15/14	13:08	T6	R-L	199	16,746	845	17,591	17,685	-94
9/15/14	13:12	T6	L-R	177	17,017	831	17,848	17,692	156
9/15/14	13:15	T6	R-L	210	17,118	802	17,919	17,699	220
9/15/14	13:19	T6	L-R	202	16,893	831	17,724	17,707	17
9/15/14	13:29	T5	L-R	155	17,164	845	18,009	17,729	280
9/15/14	13:31	T5	R-L	161	16,553	831	17,383	17,735	-351
9/15/14	13:34	T5	L-R	142	17,098	802	17,900	17,741	159
9/15/14	13:37	T5	R-L	130	16,439	831	17,270	17,746	-477
9/15/14	13:45	T4	L-R	151	17,832	"Right" channel is Portage Creek	17,832	17,765	68
9/15/14	13:49	T4	R-L	144	17,804		17,804	17,772	32
9/15/14	13:52	T4	L-R	135	18,182		18,182	17,778	404
9/15/14	13:54	T4	R-L	130	17,530		17,530	17,784	-254
9/15/14	14:20	T3 (ESS55)	R-L	193	17,671		17,671	17,841	-170
9/15/14	14:24	T3 (ESS55)	L-R	159	17,951		17,951	17,848	103
9/15/14	14:27	T3 (ESS55)	R-L	182	17,891		17,891	17,854	36
9/15/14	14:33	T3 (ESS55)	L-R	164	17,540		17,540	17,868	-328
9/15/14	14:36	T3 (ESS55)	R-L	169	17,570		17,570	17,874	-304
9/15/14	14:41	T3 (ESS55)	L-R	151	17,957		17,957	17,885	72
9/15/14	15:10	T2	R-L	192	18,153		18,153	17,949	205
9/15/14	15:14	T2	L-R	183	18,018		18,018	17,956	62
9/15/14	15:17	T2	R-L	184	17,798		17,798	17,963	-165
9/15/14	15:20	T2	L-R	154	18,103		18,103	17,970	133
mean	14:07		total duration	3667			17,802	17,811	
COV							0.013		0.013
95%U							1.44		1.38

Notes:

1 Date and time in serial number format (datum = 1/0/1900).

9. FIGURES

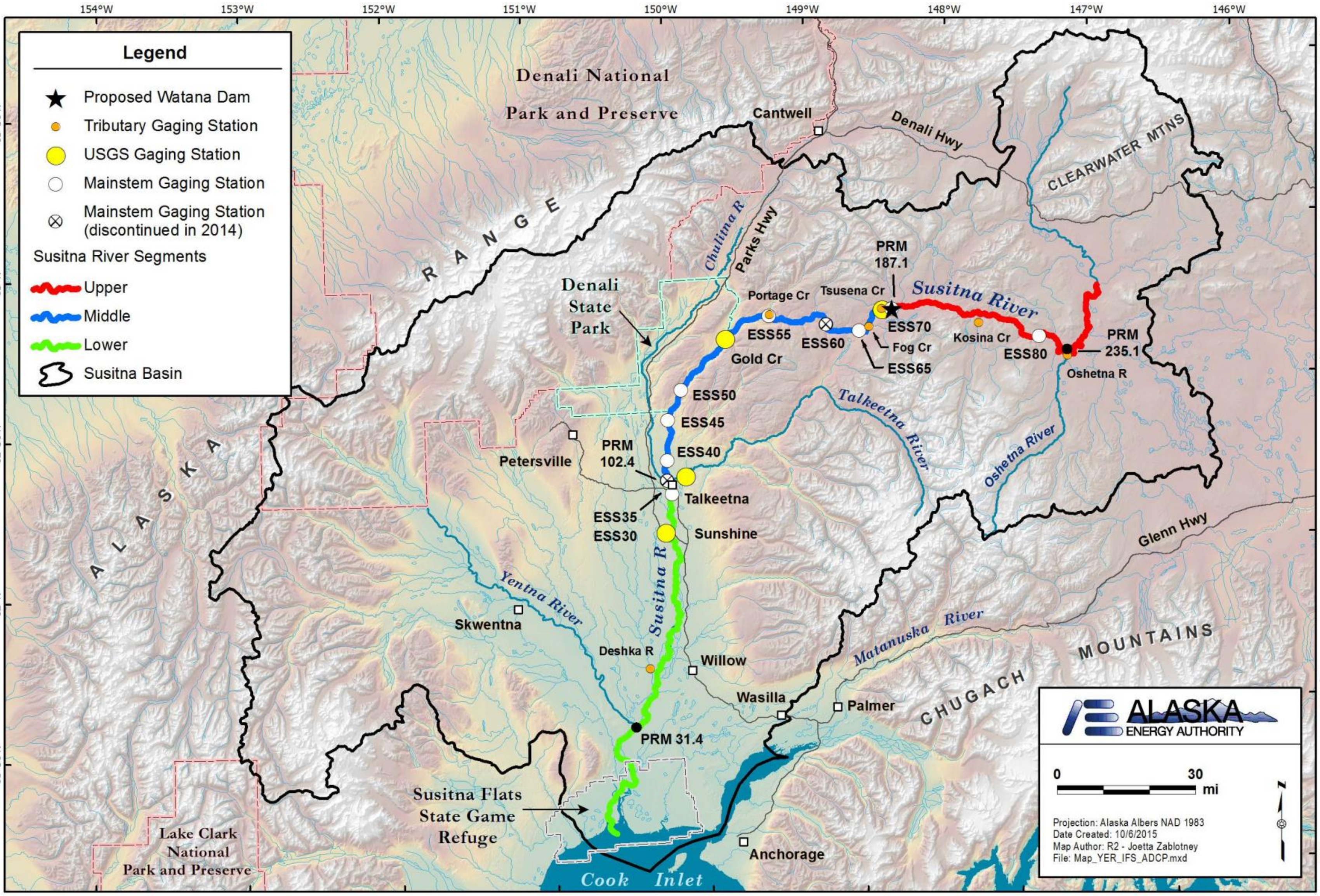

Figure 1. Susitna River watershed showing mainstem and tributary gaging stations.

Figure 2. ADCP measurement platform.

Figure 3. Techniques for maintaining a constant boat orientation.

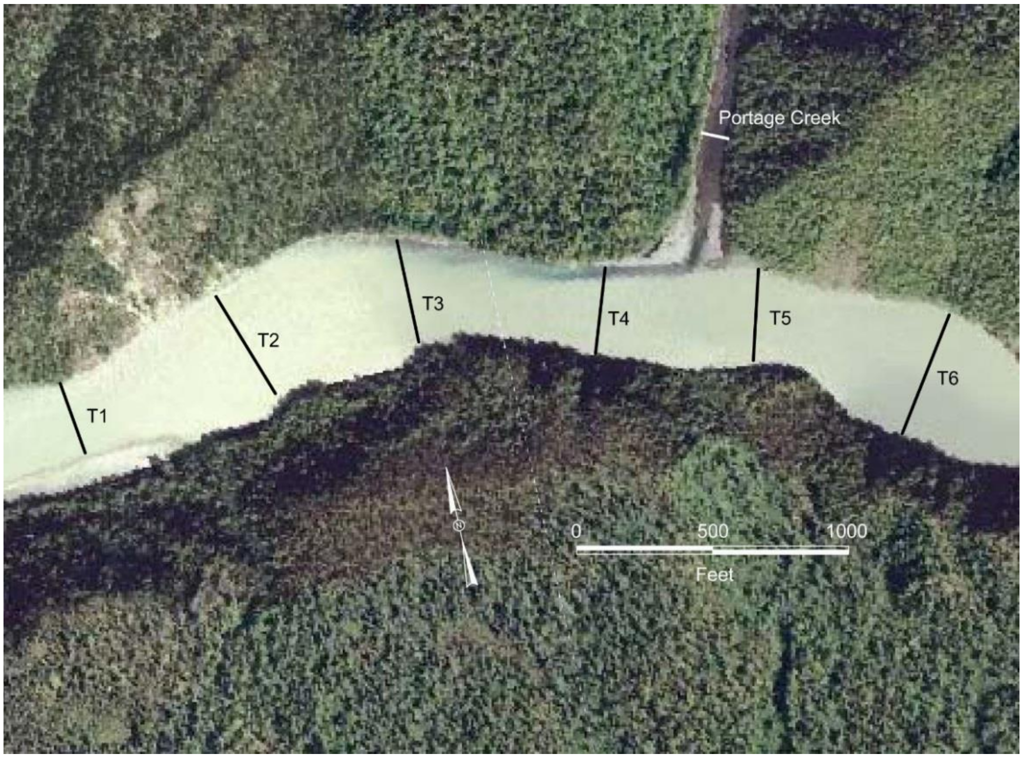

Figure 4. 2-D Model calibration transects at FA-151 (Portage Creek).

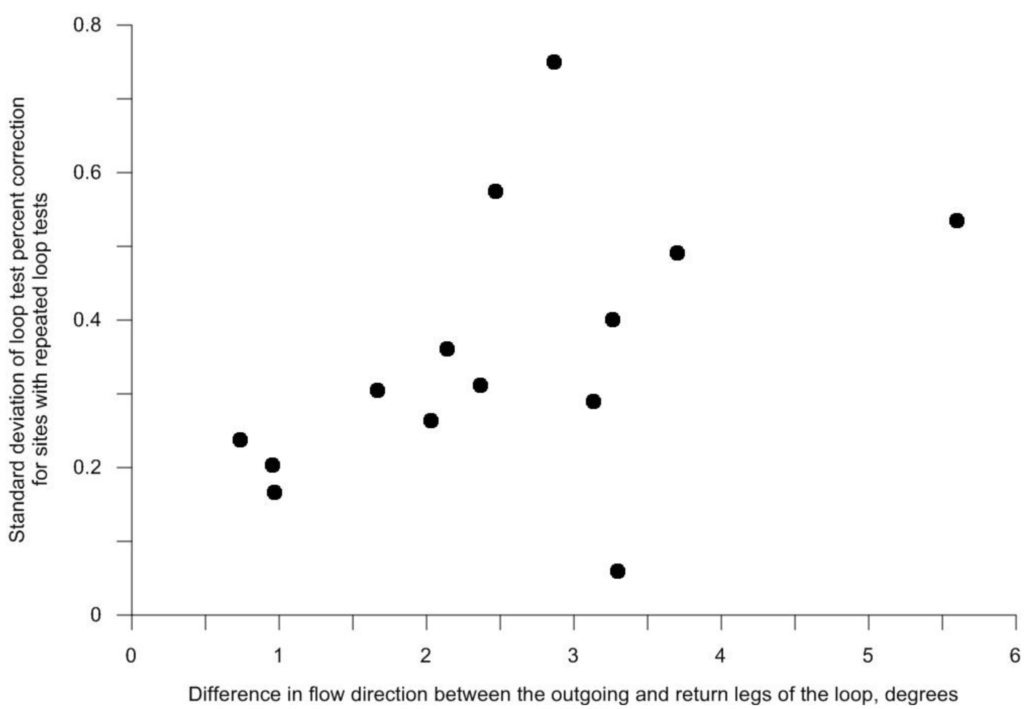

Figure 5. Loop test precision vs. out-back difference test results completed on the Susitna River as part of Acoustic Doppler Current Profiler measurements in 2014.

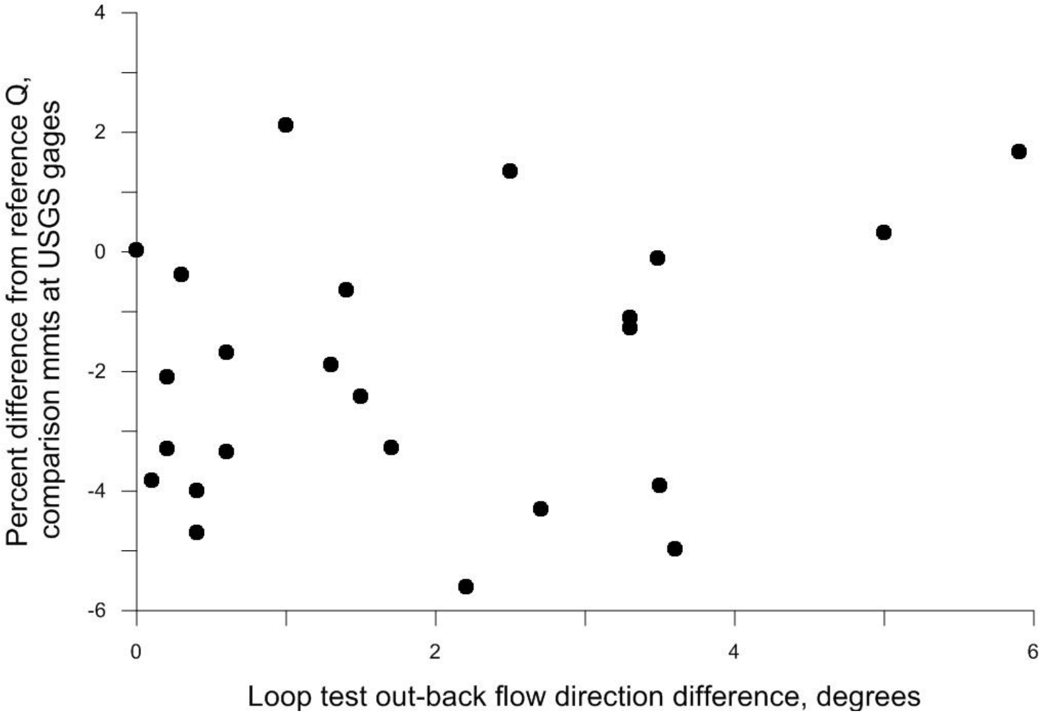

Figure 6. USGS comparisons measurement accuracy vs. out-back difference completed on the Susitna River as part of Acoustic Doppler Current Profiler measurements in 2014.

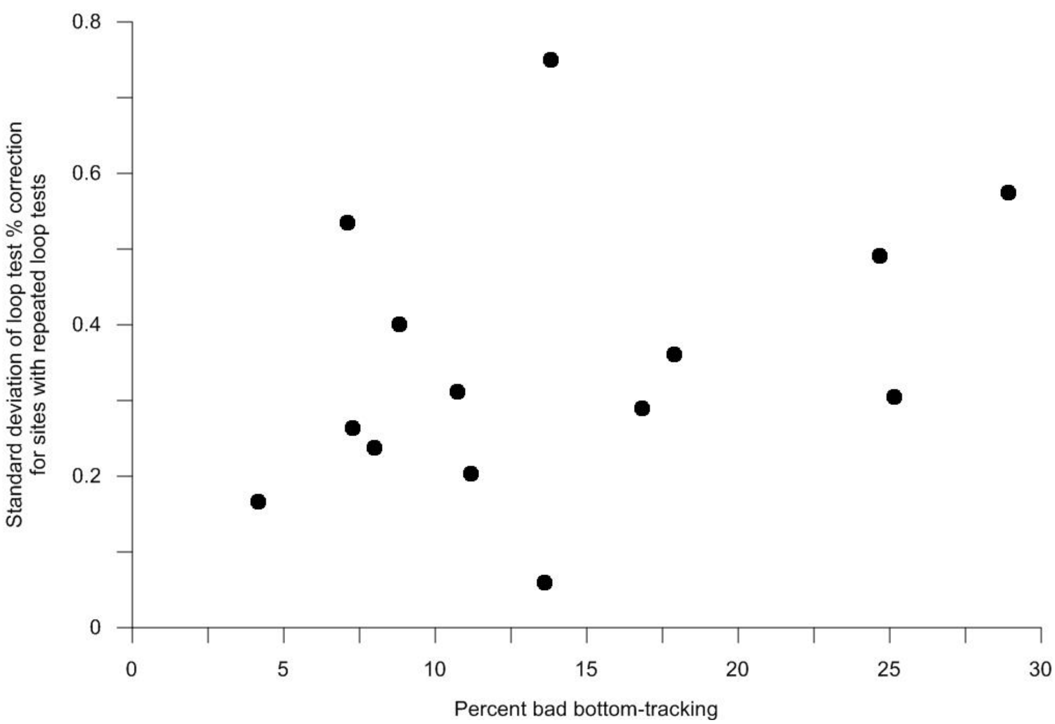

Figure 7. Results of loop test precision vs. percent bad bottom-tracking, completed on the Susitna River as part of Acoustic Doppler Current Profiler measurements in 2014.

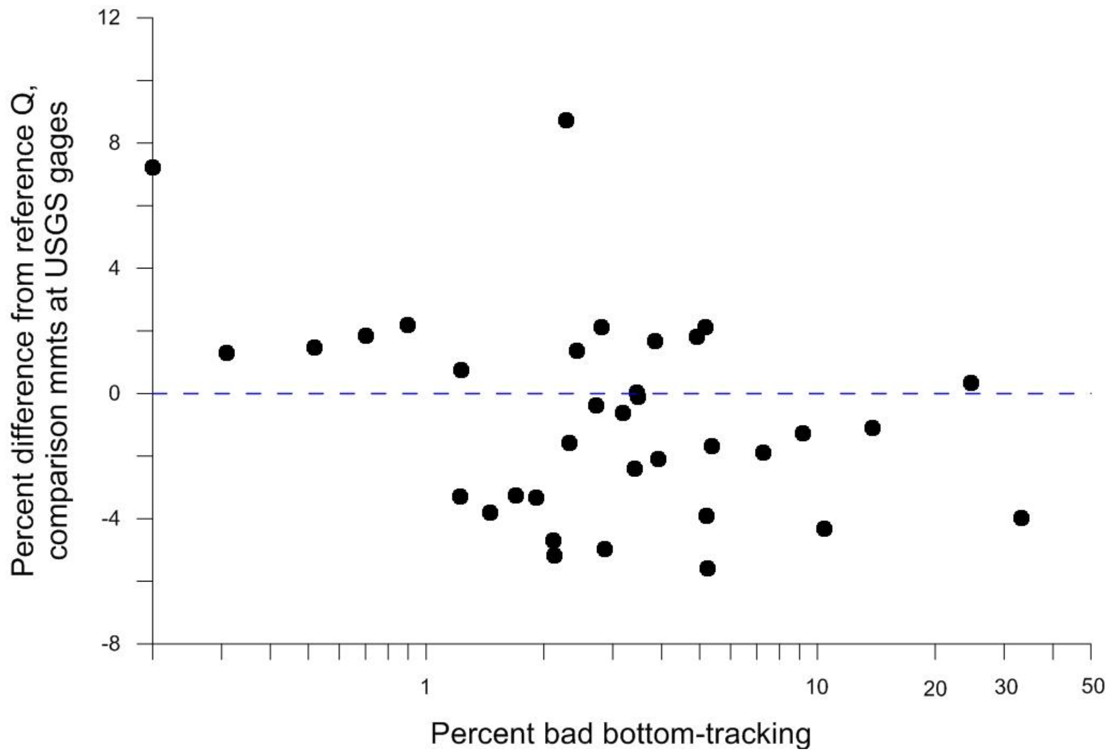

Figure 8. USGS comparison measurement accuracy vs. percent bad bottom-tracking, completed on the Susitna River as part of Acoustic Doppler Current Profiler measurements in 2014.

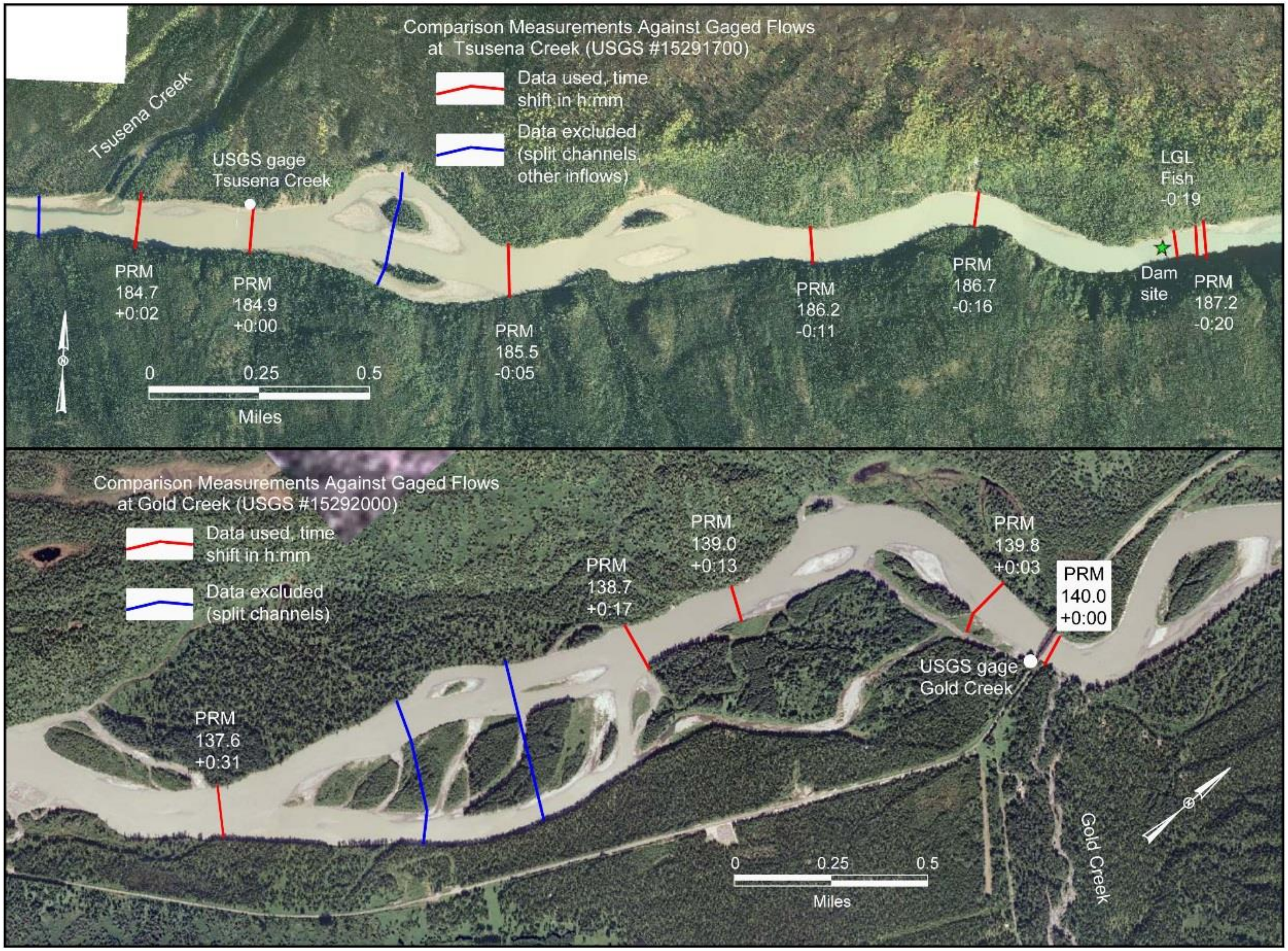

Figure 9. Comparison measurement locations on the Susitna River near USGS Tsusena Gage (USGS No. 15291700) (upper) and the Gold Creek Gage (USGS No. 15292000) (lower).

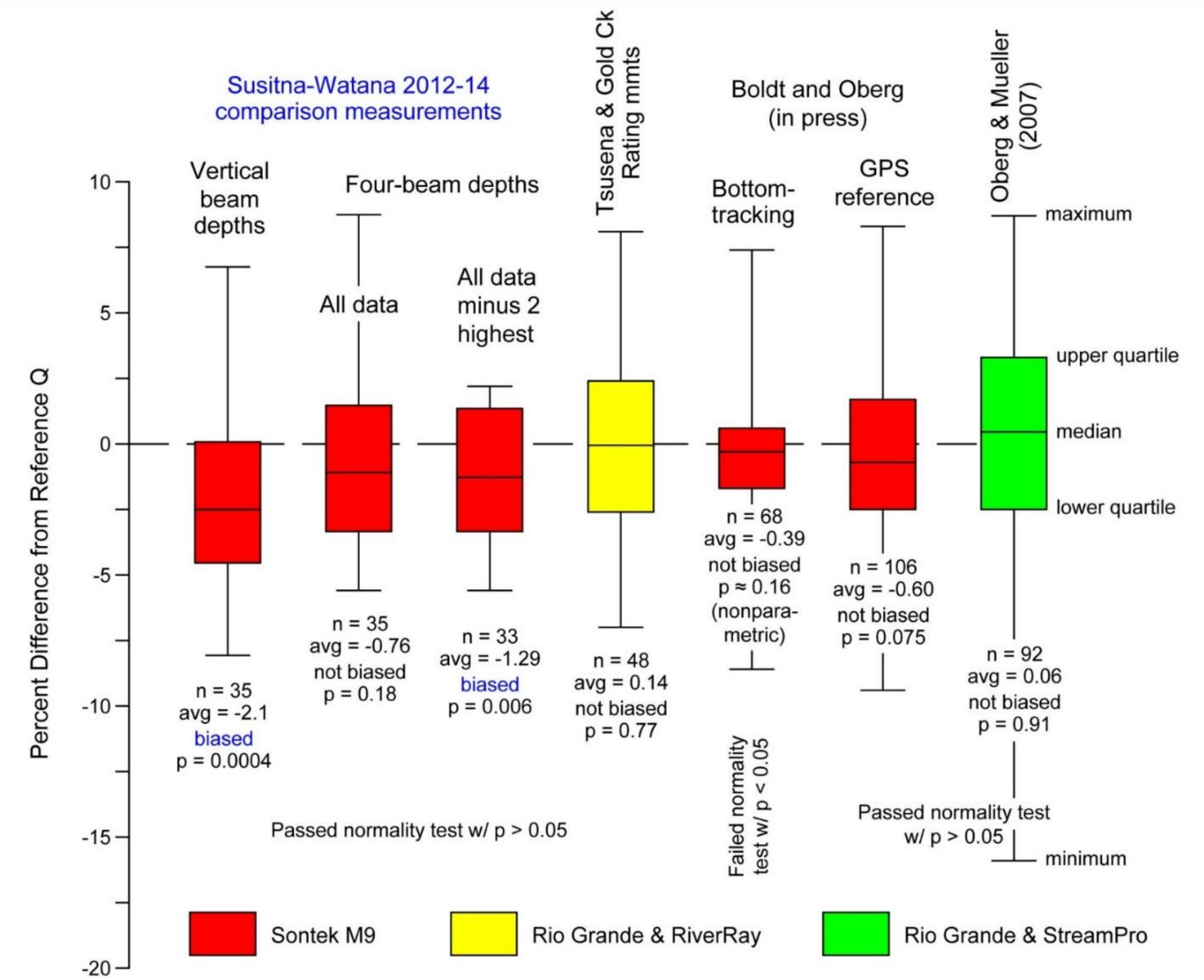

Figure 10. Comparison measurements, rating measurements, and published Acoustic Doppler Current Profiler accuracy data.

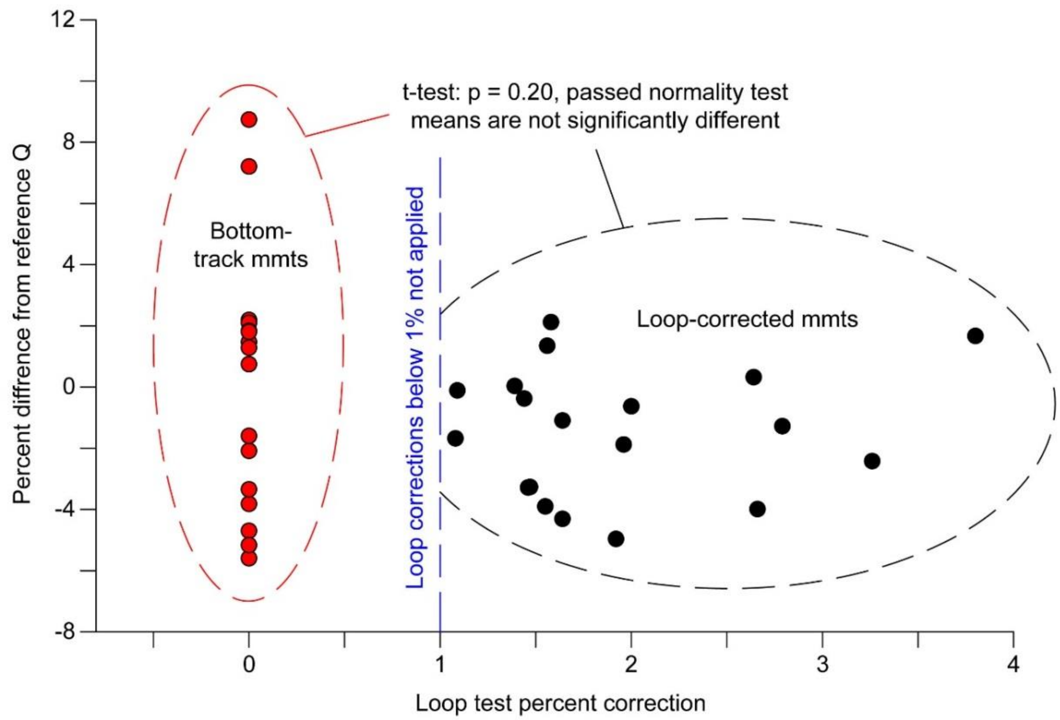

Figure 11. Accuracy of bottom-track vs. loop corrected comparison measurements at USGS gages in the Susitna River.

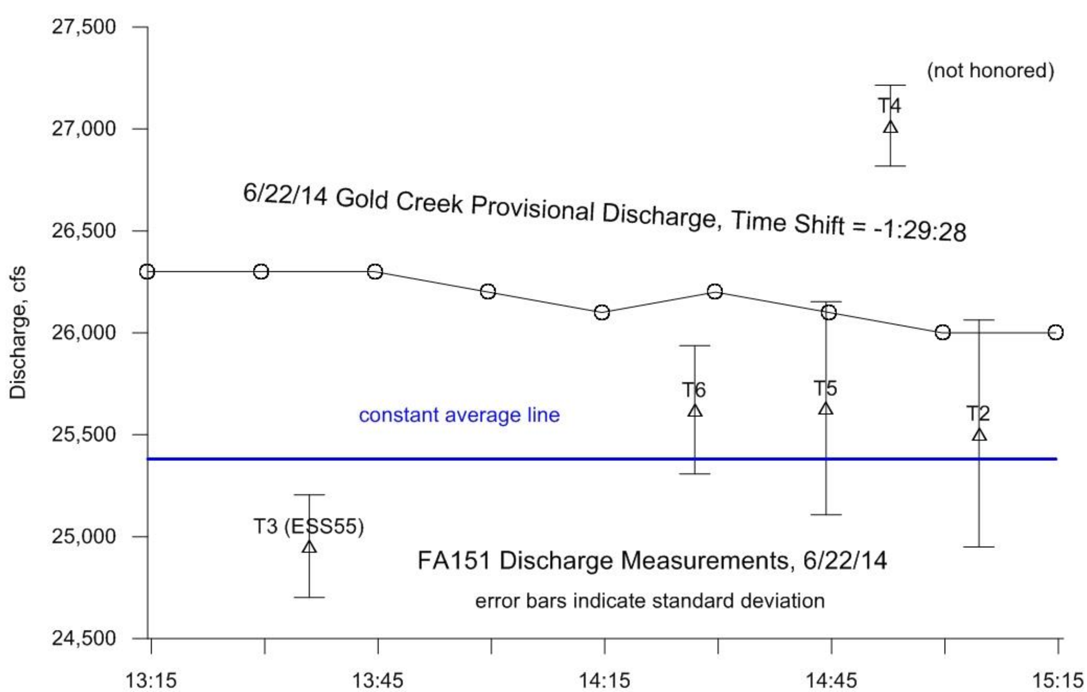

Figure 12. Discharge for 2-D model calibration transects at FA-151 (Portage Creek), June 22, 2014.

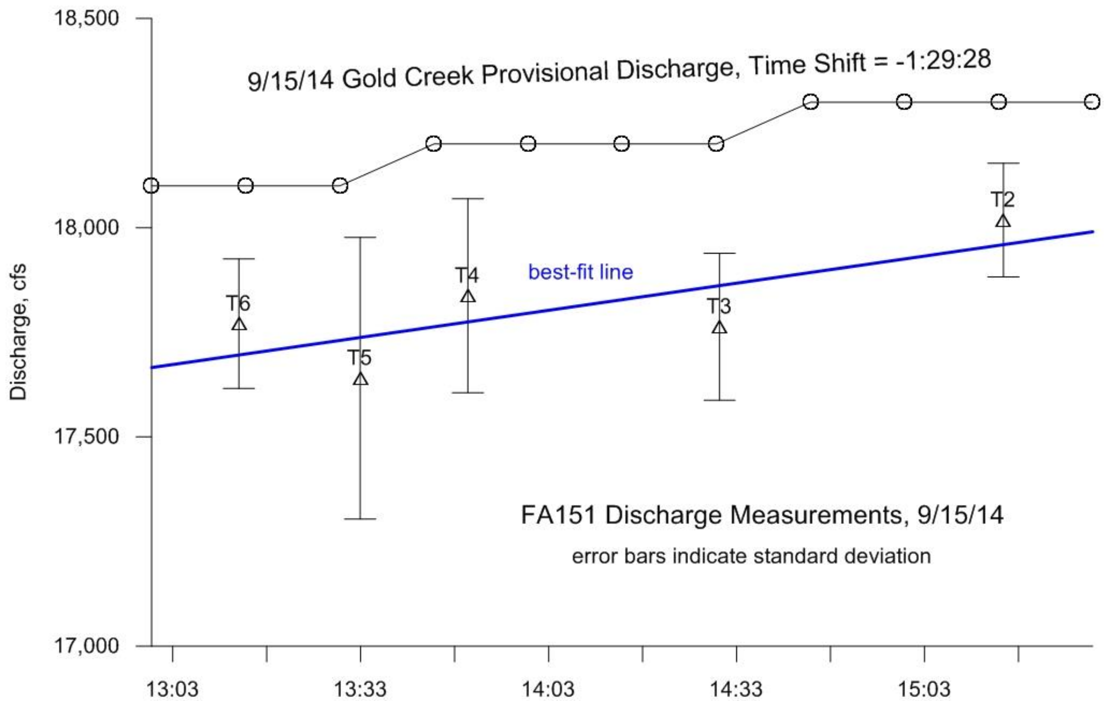

Figure 13. Discharge for 2-D model calibration transects at FA-151 (Portage Creek), September 15, 2014.

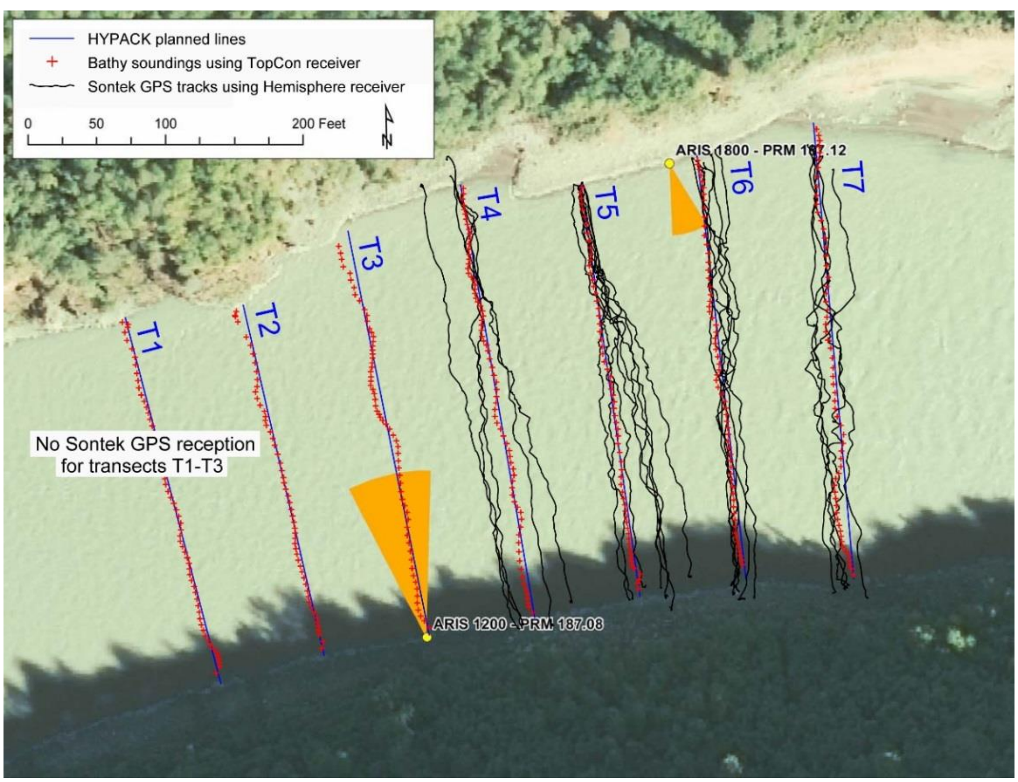

Figure 14. SonTek vs. TopCon GPS tracks at PRM 187.2 in the Susitna River.

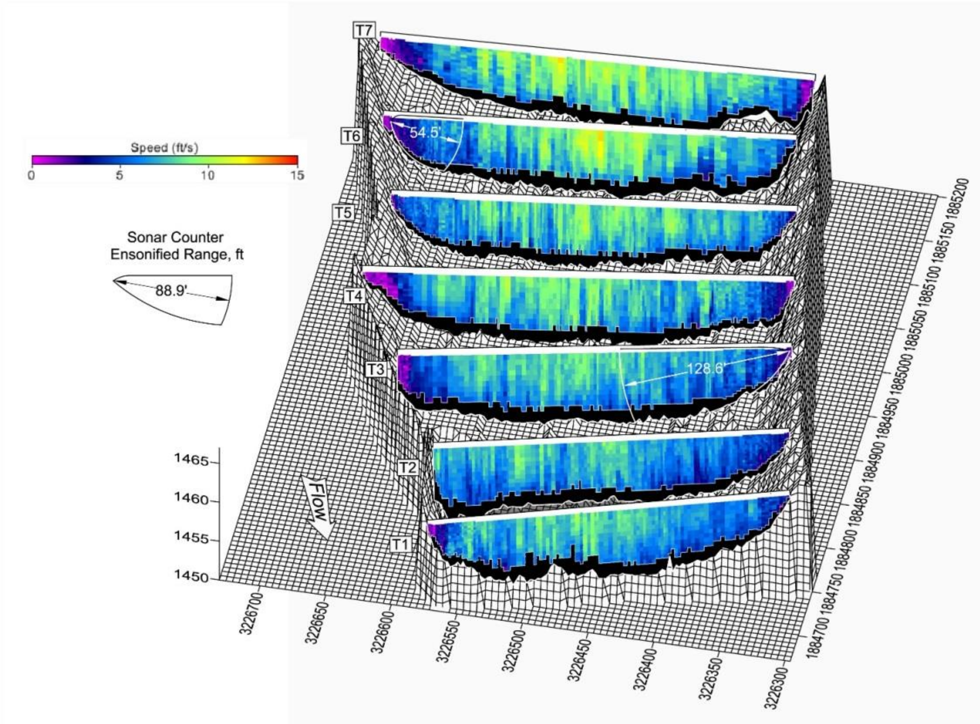

Figure 15. Velocity field at PRM 187.1, August 15, 2014 (15,000 cfs) in the Susitna River.