Susitna-Watana Hydroelectric Project

(FERC No. 14241)

Fish and Aquatics Instream Flow Study

Study Plan Section 8.5

2014-2015 Study Implementation Report

Appendix B

Open-water Hydrology Data Collection and Open-water Flow Routing Model (Version 2.8)

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ATTACHMENTS

LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	Definition
2-D	Two Dimensional
ADCP	Acoustic Doppler Current Profiler
AEA	Alaska Energy Authority
AIC	Akaike's Information Criteria
Chulitna River Gage	USGS No. 15292400
cfs	Cubic Feet Per Second
ESS	ESS stations are continuously monitored surface water stations; see ISR Study 7.5 Part A Figure 4.5-1 for Geo-Watersheds Scientific's short naming convention used for continuously monitored stations.
FERC	Federal Energy Regulatory Commission
GWS	Geo-Watersheds Scientific
IFS	Fish and Aquatics Instream Flow, Study 8.5
ILF	Intermediate Load Following
ISR	Initial Study Report
LiDAR	Light Detection and Ranging
OWFRM	Open-water Flow Routing Model
OS	Operating Scenario
PRM	Project River Mile
Q	Flow
QA/QC	Quality Assurance/Quality Control
RSP	Revised Study Plan
SIR	Study Implementation Report
Susitna River Gage above Tsusena	USGS No. 15291700 at PRM 184.9
Susitna River Gage at Cantwell	USGS No. 15291500 at PRM 225.0
Susitna River Gage at Gold Creek	USGS No. 15292000 at PRM 140.0
Susitna River Gage at Sunshine	USGS No. 15292780 at PRM 87.9,
Susitna River Gage at Susitna Station	USGS No. 15294350 at PRM 29.9
Talkeetna River Gage	USGS No. 15292700
TIN	Triangulated Irregular Network
USGS	United States Geological Survey
UTC	Coordinated Universal Time
WSE	Water Surface Elevation
Yentna River Gage	USGS No. 15294345

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.

The purpose of this report is to document the hydrologic field data collected since the June 2014 Initial Study Report (ISR), additional work that has been conducted on the Open-water Flow Routing Model (OWFRM) since Version 2 was described in ISR Study 8.5, Part C, Appendix K (*Hydrology and Version 2 Open-water Flow Routing Model*, submitted to the FERC June 3, 2014 [R2 2014a]), and the necessary files and background information needed to run the OWFRM and to conduct future modeling efforts.

Results and documentation of Version 1 of the OWFRM were completed in January 2013 (*Open-water HEC-RAS Flow Routing Model*, Technical Memorandum submitted to the FERC on January 31, 2013 [R2 et al. 2013]). The January 2013 version of the model extended from the proposed Dam Site at Project River Mile (PRM) 187.1 downstream to PRM 80.0 (about 23 miles downstream from the confluence with the Chulitna River). Version 1 of the model relied on data collected during the 2012 summer field season and included data from 88 surveyed river cross-sections. Version 2 of the Open-water Flow Routing Model was completed in 2014 and was developed using 167 river cross-sections surveyed in 2012 and 2013, 383 flow/water surface elevation pairs, and Light Detection and Ranging (LiDAR) surveys of the floodplain in 2011. The Version 2 model extended from the proposed Dam Site at PRM 187.1 downstream to PRM 29.9.

As described in the FERC-approved study plan, the final Version 3 of the OWFRM was anticipated for completion as part of the Updated Study Report. However an intermediate version of the model was completed that represents an update from Version 2, but is not the final version that will be presented as Version 3. This intermediate version of the model is documented herein and is termed Version 2.8. Based on the differences in data collection and model completion, the Susitna River has been separated into two reaches, above and below the U.S. Geological Survey (USGS) gage Susitna River at Sunshine (USGS No. 15292780) at PRM 87.9.

Version 2.8 of the OWFRM includes a revision of the reach between the proposed Dam Site at PRM 187.1 downstream to PRM 87.9 (USGS No. 15292780 Susitna River at Sunshine), while the model from PRM 87.9 downstream to PRM 29.9 (USGS No. 15294350 Susitna River at Susitna Station) has not changed from Version 2. The reach from the Proposed Dam Site to Sunshine incorporates the additional transect and Q (flow) and Water Surface Elevation (WSE) pair data collected in 2014, the revised LiDAR data collected in 2013, diurnal fluctuations, and adjustments of tributary estimates based on gage data collected in 2013 and 2014. In order to simulate the lower Sunshine to Susitna Station reach of the model, the results of the upper reach (Dam Site to Sunshine reach) are used as input to the lower reach and represent a boundary condition for the Sunshine to Susitna Station reach. The electronic files needed to run the OWFRM for each reach are provided separately.

The reach of the model from Sunshine to Susitna Station uses the data and calibration provided in Version 2 and documented in ISR Study 8.5, Part C, Appendix K (R2 2014a). The final Version 3 of the OWFRM will include validation of the upper Susitna River portion and revisions to the lower Susitna River portion with additional cross-section and hydrologic data. Table 1 summarizes the four versions of the model and their similarities and differences. Since it is anticipated that additional data will be collected between the Sunshine and Susitna Station gages, Version 2.8 of the OWFRM was not re-calibrated for this reach. Version 3 of the OWFRM will extend from the proposed Dam Site at PRM 187.1 downstream to PRM 29.9.

2. PREVIOUS REPORTS

There are a number of reports and supporting hydrologic documents that pertain to the development of the OWFRM that have been previously distributed. These reports are cited below and are frequently referenced in this document, especially as they pertain to methods and information sources common to all versions of the OWFRM. Background information available in these documents is not repeated in the present document.

- Revised Study Plan: Susitna–Watana Hydroelectric Project, FERC Project No. 14241 (AEA 2012)
    - Section 8.5.4.3 Hydraulic Routing and Operations Modeling
    - Section 8.5.4.4 Hydrologic Data Analysis
- *Stream Flow Assessment* (submitted to the FERC March 1, 2013 [Tetra Tech 2013])
- *Open-water HEC-RAS Flow Routing Model* (R2 et al. 2013)
- Initial Study Report: Susitna-Watana Hydroelectric Project FERC No. 14241
    - ISR Study 8.5, Part A, Section 4.3: Hydrologic Data Analysis (AEA 2014)
    - ISR Study 8.5, Part A, Section 4.4: Reservoir Operations Model and Open-water Flow Routing Model (AEA 2014)
    - ISR Study 8.5, Part A, Appendix A: *Hydrologic Data Collection Methods* (submitted to the FERC June 3, 2014 [R2 2014b])
    - ISR Study 8.5, Part A, Appendix C: *2013 Moving Boat ADCP Measurements* (Submitted to the FERC June 3, 2014 [R2 2014c])
    - ISR Study 8.5, Part C, Appendix J: *Representative Years* (submitted to the FERC June 3, 2014 [R2 2014d])
    - ISR Study 8.5, Part C, Appendix K: *Hydrology and Version 2 Open-water Flow Routing Model* (R2 2014a)

3. MAINSTEM DATA COLLECTION AND RESULTS

Additional mainstem Susitna River data were collected in 2014. Similar to previous years, the data collection was divided into distinct groups:

1. ESS Transects and Stage Recording Measurements
2. Bathymetry Transects
3. Q-WSE-Bathymetry Transects
4. Focus Area Stage Measurements

The methods for these field efforts are similar to previous years and can be found in the documents cited above in Section 2. The detailed methodologies are not repeated, but any modifications are described, and the type of data is briefly summarized.

3.1. ESS Transects and Stage Recording Measurements

The number of ESS[1] stations maintained in 2014 was modified from the RSP as described in ISR Study 8.5, Part A, Section 4.4: Reservoir Operations Model and Open-water Flow Routing Model (AEA 2014). Station ESS60 (PRM 168.1) was removed in 2013 and not re-installed in 2014 due to poor site conditions affecting rating curve development and the availability of data from ESS65 (PRM 176.5). ESS35 (PRM 102.1) was discontinued since it was located in an unstable channel that was not conducive for rating curve development. ESS stations were maintained and data Quality Control (QC) checked to QC Level 3 by Geo-Watersheds Scientific (GWS). Brailey Hydrologic also collected discharge measurements at select ESS stations during the 2014 field season. The final discharges are included in Table 2 which summarizes all mainstem transect data collected between 2012 and 2014. The Technical Memorandum prepared by Brailey Hydrologic provided in Study Implementation Report (SIR) Study 8.5, Appendix C (2014 Moving Boat Acoustic Doppler Current Profiler [ADCP] Measurements, submitted to the FERC November 2015 [Brailey 2015]) summarizes both the ADCP methodologies used to collect the measurements and computation and correction challenges that were encountered.

3.2. Q-WSE-Bathymetry Transects

Streamflow, water surface elevation (WSE), and bathymetry data were collected again on mainstem transects in 2014. Data were collected at eight new sites to provide better definition of channel conditions within Focus Areas and at twelve existing sites to fill low, medium, or high flow data gaps from previous field efforts. Methods for collecting the 2014 streamflow field data are described in SIR Study 8.5, Appendix C (Brailey 2015). The WSE and bathymetry data collection followed similar methods as those described in 2012 and 2013. The Q-WSE pairs collected in 2014 summarized by PRM are provided in Table 2. The Q-WSE pairs categorized by low, medium, and high flows are provided in Table 3. The OWFRM relied on the Q-WSE surveys at the river cross-sections for calibration purposes.

[1] ESS stations are continuously monitored surface water stations; see ISR Study 7.5 Part A Figure 4.5-1 for Geo-Watersheds Scientific's short naming convention used for continuously monitored stations.

3.3. Bathymetry-WSE Transects

Additional bathymetry-WSE only transects were requested by the Fluvial Geomorphology Modeling Study (Study 6.6) to better define channels for the sediment transport model. Bathymetry-WSE data were collected at an additional 49 transects in 2014 (Table 2). Data were collected following methods similar to those used in 2012 and 2013.

3.4. Focus Areas

Data were collected at Focus Areas for different study efforts during the 2014 field season. Discharge measurements collected within Focus Areas are described in SIR Study 8.5, Appendix C (Brailey 2015). In addition, mainstem stage data were collected at the upstream and downstream ends of the eight Focus Areas below Devils Canyon to support the Fluvial Geomorphology Modeling Study (Study 6.6). For this, Solinst levelogger pressure transducers were installed at 11 locations along the mainstem of the Susitna River (Table 4). The leveloggers were set to record in 15-minute increments, installed on July 22 and 23, 2014 and removed in mid-September. During installation, either temporary benchmarks were installed and surveyed in to the existing Project datum, or existing benchmarks were used from which to base the location of the leveloggers and measurements of WSE. Barometric pressure data were obtained from previously installed dataloggers used for the tributary gaging task. The recorded pressure transducer and barometric pressure data and the surveyed WSE during field visits were used to create an hourly estimate of WSEs throughout the period of installation. Hourly stage data were QC checked and comparisons were made for consistency with other available mainstem stage data (USGS and ESS stations).

4. TRIBUTARY GAGING DATA COLLECTION AND RESULTS

Tributary gaging stations installed in 2013 were maintained in 2014. Data collected in 2013 are described in ISR Study 8.5, Part C, Appendix K, Section 5.2: Tributary Gaging Data Collection (R2 2014a). In addition, six more gaging stations were installed in June 2014, two with mainstem companion gages that recorded stage. There were also select "spot" measurement locations where site conditions prevented the establishment of rating curves and only flow measurements were collected. About half of the sites were removed in September 2014, but six continuous gage sites (Deshka River, Sheep Creek, Tsusena Creek, Portage Creek, Indian River, and Gold Creek), two spot measurement sites (Fog Creek and Caswell Creek), and two companion sites (Susitna River at Sheep Creek and Susitna River at Caswell Creek) were retained over the 2014 winter and are scheduled for removal in September 2015. Table 5 summarizes all of the tributary gage site information; locations are shown in Figure 1. Similar procedures for installation and maintenance were applied as described in ISR Study 8.5, Part A, Appendix A (*Hydrologic Data Collection Methods* [R2 2014b]). Tributary gage site schematics are provided in Attachment 1 to this report.

The general activities associated with each of the tributary gages included the installation and maintenance of Solinst levelogger pressure transducers and barologgers, collection of streamflow measurements, recording of staff gage readings, and surveying of WSEs. Measured tributary gage data are provided in Attachment 2 to this report. These data were used to create a rating curve for each site with a continuous logger and to produce hourly flow records. The data from the tributary gaging will be used in the development of the accretion estimates for the 61-year period of record.

4.1. Rating Curve Development

For the continuous monitoring sites, pressure data collected over the period of installation for each tributary site were converted to hourly streamflow values using a rating curve developed for each site. Rating curves were developed using a standardized Excel template established for this project. This template follows standard USGS procedures to determine the relationship between staff gage measurements (S) and streamflows (Q) (Kennedy 1984). All rating curve graphics and calculations were performed in the spreadsheet. First, the discharge data were plotted against the measured stage minus the stage of zero flow (S_o) in log-log space. Any outlier points were reviewed to determine whether environmental conditions or sampling equipment used were the cause and to determine if any data should be removed from the analysis for a specific reason. The data were reviewed to assess whether there were any changes in slope between low, medium, and high streamflows. If the data appeared to plot linearly in log-log space, the measured staff gage and streamflow data were fitted to the following relationship:

$$\text{Log}(Q) = a * \text{Log}(S-S_o) + b$$

Which is equivalent to the equation:

$$Q = 10^b(S- S_o)^a$$

Where a, b, and S_o are constants,

S_o is the stage of zero flow.

Constants *a* and *b* can be determined using a linear least square regression equation for the data included in the analysis. S_o was varied, and constants *a* and *b* were recalculated. Several factors were considered when selecting an S_o value. Foremost, the S_o was selected to generate a high r^2 value and visually fit the data over the range of flows. Secondly, the conditions of the cross-section were evaluated to ensure that the S_o made physical sense. In addition, the range of measured stage and the bulk of the stage measurements were evaluated to determine if and how far the rating curve would need to be extrapolated to be used to predict flows and which part of the curve should be targeted for the highest level of accuracy. For example, if 80 percent of the measurements were collected in the low flow range the S_o was selected to fit the low-flow measured data to a greater degree than other magnitudes. Lastly, if these factors did not identify an appropriate value, S_o was selected to maintain constant *a* at less than 2. Rating curves for each of the continuous tributary gage sites and their corresponding measurements are provided in Attachment 3.

4.2. Hourly Records

Once the rating curves were established, the hourly streamflow values were compiled. To do this, the 15-minute pressure data were adjusted for the change in barometric pressure using the data downloaded from the barologgers and then converted to a streamflow using the staff gage data collected and the rating curves developed. The data recorded on the hour was used for the hourly estimates. These calculations were performed in a separate file from the rating curve. A summary of the hourly hydrograph period of record available for each of the continuous gaging sites is presented in Table 6. The minimum and maximum values used to create the rating curves are provided in Table 7. Values outside this range are extrapolated using the rating curve. An example of the data provided is included in Attachment 4. All data were converted into the time reference of Coordinated Universal Time (UTC) minus nine hours (Alaska Standard Time). The significant digits used to report hourly and measured streamflow and WSE values followed USGS protocols. WSE were reported to the nearest hundredth of a foot. Streamflow values were reported as shown in Table 8. Gage sites retained over winter 2014 and summer 2015 will be analyzed in Fall 2015 and gage rating curves and records will be updated accordingly.

4.3. Quality Assurance/Quality Control (QA/QC)

All data were QA/QC'd for accuracy. In addition to summarizing the field data and the rating curve regression information, the rating curve template includes a QA/QC form. The QA/QC forms were used to track the development of the rating curve and document the logic for any changes. This QA/QC form includes specific details on when changes/additions were made to the file, what review was conducted and in what format, the comments and suggested changes, and the action taken to address the comment. Hourly calculation files also had similar QA/QC forms. Both the rating curve development and hourly calculations were QC'd by a technical reviewer. Notes from the technical reviewer were included in the QA/QC form in each file. In some cases, changes were made as a result of the review. Additional steps were also conducted to ensure derived hydrograph values were accurate including a comparison with available USGS gage data, review of temperature data, and comparison of WSE between tributary and companion gages.

Hourly streamflow values at each tributary were compared with available gage data from the USGS. These included comparisons with either Susitna River at Gold Creek (USGS No. 15292000), Susitna River near Sunshine (USGS No. 15292780), Talkeetna River (USGS No. 15292700), Chulitna River near Talkeetna (USGS No. 15292400), and Deshka River (USGS No. 15294100). The two sets of records were compared for any overlapping periods to identify any abnormalities and potential calculation errors. The data were plotted for visual comparisons with specific review of the magnitude and timing of peak flow events. If any irregularities were identified, WSE values and flow calculations were reviewed to ensure records produced were accurate representations of streamflow. No overlapping data were available for the Deshka River gage. Instead, typical baseflow and peak values were compared to identify irregularities.

The temperature data collected by the levelogger and barologgers were reviewed to identify periods of ice cover. Ice was considered probable during conditions with water temperatures at or below 0°C. Streamflows before, during, and after frozen conditions were compared and ice cover periods identified. Streamflows were removed for these periods since rating curves are not applicable. The WSE of the five tributary gage sites with companion gages were compared to the WSE in the Susitna River at the companion gage. Data were reviewed to verify consistency and the magnitude and timing of peaks were compared to ensure backwater from the mainstem did not influence the WSE at the tributary gage.

Based on the review above, derived hourly data were flagged using qualifiers when necessary. Qualifiers were used to identify specific conditions or the accuracy limits of the values reported and are summarized in Table 9.

5. WINTER GAGING DATA COLLECTION

Winter gaging data are summarized in the ISR Study 8.5, Part C, Appendix K, Section 5.3: Winter Gaging Data Collection (R2 2014a). No additional winter gaging field data have been collected since the release of that report; however, recording equipment installed at tributary gaging sites collected measurements during the 2014-2015 winter season and were downloaded and removed in September 2015. The stage and water temperature records may be useful in understanding winter streamflow conditions.

6. HYDROLOGIC RECORDS FOR MODEL DEVELOPMENT AND PROJECT EVALUATION

Version 2.8 of the OWFRM has been developed for the Susitna River for the open-water period from the proposed Dam Site at PRM 187.1 downstream to PRM 29.9. The model was developed in HEC-RAS and will be used to route pre-project and post-project streamflow estimates from the Dam Site to downstream locations. The model was developed using transect data collected in 2012-2014 and is described in further detail below. To simulate conditions using the OWFRM, inputs to the model at the upstream end (i.e., Dam Site) and estimates of tributary accretion are necessary. Other resource studies also need estimates of tributary hydrology for their evaluation and modeling purposes. This section outlines the methods used to develop the hydrologic records needed for modeling purposes, describes the previous work conducted to develop the period of record and identify representative years, and outlines methodologies used to incorporate diurnal fluctuations, produce input records for the Susitna River at the Dam Site, and develop tributary accretion streamflow estimates.

6.1. Hydrologic Record and Representative Years

Previous efforts have established the 61-year period extending from Water Years 1950 through 2010 (October 1, 1949 to September 30, 2010) as the hydrologic period of record for the Project. The HEC-RAS model was set up to simulate conditions over this same period. Other work was also completed to identify representative years to reflect wet/warm (1981), average (1985), and dry/cold conditions (1976). This work can be found in ISR Study 8.5, Part C, Appendix J: *Representative Years* (R2 2014d).

6.2. Daily Flow Adjustments

The USGS conducted a record extension study for USGS gages within the Susitna River basin (Curran 2012). This study used index gages and the correlation between gages to develop a complete record for 11 USGS gages within the basin for the 61-year period of record (i.e., 1950-2010). During the extension process, daily streamflow values were estimated sometimes for several months. In some cases, the daily flows were estimated as the same value for a series of days and then would jump or drop to a new value for another series of days creating a stair-step like hydrograph. This stair-step hydrograph preserves the overall mass balance when flows are estimated from an index gage, but is not necessarily illustrative of natural processes. In reality, the change from one flow to the next would be more gradual. In addition, this stair-step function causes unrealistic flow predictions when synthesizing the hourly flows from the daily flows. To counteract this consequence, the mean daily flow values predicted by the USGS were adjusted to smooth out periods when flows followed a stair-step pattern. This smoothing process preserved the monthly average, but changed the daily values. This adjustment was only applied to data when the same flow is repeated from one day to the next. An example figure comparing the mean daily value estimated in Curran (2012) and the adjusted mean daily values is shown in Figure 2. This adjustment was applied to all mean daily USGS gage data used in the OWFRM (i.e., 8 gages listed in Table 1).

6.3. Diurnal Fluctuations

Daily hydrology is available for the 61-year period of record at select USGS gages in the Susitna River and its tributaries from analysis conducted by the USGS on record extension for gages in the basin (Curran 2012). However, the Susitna basin experiences pronounced diurnal patterns during the summer months as a result of the dominance of glacier meltwater over precipitation. To accurately represent hourly streamflow and stage changes, diurnal fluctuations need to be incorporated to these hydrologic records. Diurnal fluctuations were incorporated by using measured hourly streamflow data to develop a statistical model to predict the magnitude and timing of these fluctuations.

The 15-minute streamflow data collected by the USGS in 2012 and 2013 were used to estimate diurnal patterns in the Susitna River and its tributaries. Diurnal fluctuation analysis was conducted at the following seven USGS gage sites:

- Susitna River above Tsusena (USGS No. 15291700)
- Susitna River at Gold Creek (USGS No. 15292000)
- Chulitna River (USGS No. 15292400)
- Talkeetna River (USGS No. 15292700)
- Susitna River at Sunshine (USGS No. 15294250)
- Yentna River (USGS No. 15294345)
- Susitna River at Susitna Station (USGS No. 15294350)

The Susitna River above Tsusena gage data were used to develop the diurnal patterns for the Dam Site. Diurnal patterns were incorporated into other gage data for use in developing the tributary inflows.

A different model was developed for each location, but the same methodology was applied. Residuals were calculated between the measured flow on 15-minute intervals and the smoothed average daily flow for the data available in 2012 or 2013. Each daily set of 15-minute residuals were fit with a Fourier series assuming one periodic cycle. A Fourier series with one period is a linear combination of sine and cosine curves. The coefficients of the linear combination are estimated using least squares regression. It was clear that not all daily patterns represented diurnal fluctuations. For example, high flow changes would supersede a typical diurnal flow. Since the objective of the analysis is to predict diurnal fluctuations, the data set used for this model were restricted to data representing diurnal fluctuations. Therefore, the fit models showing distinct diurnal fluctuation patterns were identified for use in further model development and days with patterns that did not fit the diurnal pattern were excluded.

Days with a distinct diurnal pattern typical of glacial meltwater hydrology were identified by reviewing the pattern of flow fluctuations within a day as well as between sequential days. Days were excluded if there were an inconsistent pattern of flow fluctuation or fluctuation patterns that might be caused by rainfall events or significant changes in air temperature. In order to be considered a “diurnal fluctuation” a flow pattern had to have a single peak/trough per day and consistent timing of the peaks from one day to the next. The seven locations, their measured hourly flow period of record available, the total number of days during this period, and the number of days selected with clear diurnal fluctuation patterns are presented in Table 10.

After the days with distinct diurnal patterns were isolated, the relationships between available hydrologic and environmental predictors and the magnitude (amplitude) and timing (represented by phi) of these fluctuations were examined using linear regression. The objective was to develop a relationship between known parameters over the 61-year period of record and the magnitude and timing of diurnal fluctuations during measured periods so that the magnitude and timing can be predicted during unmeasured periods (i.e., the 61-year period of record). The magnitude and timing are functions of the estimated regression parameters for the Fourier series fit to each daily series.

Predictor variables were limited to parameters that were available for the entire 61-year period of record. Parameters evaluated included average daily flow (Q, cubic feet per second [cfs]), average daily air temperature (T, °C), change in average flow from the previous day (Delta Q), and the proportion of daylight (E, is calculated as a cosine function with the peak of 1 at the summer solstice on June 21st, and the low of -1 occurring on December 21st), or Julian day (JD). The phi for days past the last date of available data (September 21) were calculated using the daylight proportion on this date. So the phi on all days between September 21 and October 28 were calculated as the proportion of daylight (E) for September 21.

Exploratory data analysis was used to determine whether non-linear relationships existed or data transformations should be used in each case, and also whether there were outliers that were exerting undue influence and should not be included in regressions. Air temperature, the proportion of solstice daylight, and Julian day are highly correlated variables and were not included in any models together. Rather, the one variable providing the strongest fit was retained. To ensure continuity from one day to the next, it was necessary to include either Julian day or proportion of solstice daylight in the model estimating phi, regardless of strength of relationship.

Akaike’s Information Criteria (AIC) was used to select models with better fit than others. In general, models within absolute AIC of 2 of the best model have strong evidence of being the correct model (Burnham and Anderson 2002). The simplest model that fit the criteria that was within this low AIC group of models was generally selected for predictions. These regression parameters were then used to predict diurnal deviations from the daily average flow available for the 61-year period of record. The selected model for each location and the application to the daily flow values are summarized in Table 11. Note that in order to limit the extraneous addition of diurnal fluctuations, application criteria were developed for each location. In general, diurnal fluctuations were only applied to days with average daily flow values less than the smoothed daily median (daily median values were smoothed using a Lowess function). The fluctuations were applied to days with flows above the smoothed daily median, but only if the average daily temperature was in the top quartile for days that exhibited diurnal fluctuations.

The range of predictor variables used in the amplitude and phi predictions by site is summarized in Table 12. In some cases, the models were applied to days with values of predictor variables outside of these ranges (i.e., extrapolation), but were reviewed to ensure they were hydrologically realistic.

The Susitna River at Susitna Station regression was developed using data from June to September 2013 which represented a high flow period. As a result, the prediction was developed using the available flow data between 85,000 cfs and 173,000 cfs. Extrapolating the regression below or beyond this range produced unrealistic estimates and had to be adjusted. The amplitude for flow less than 85,000 cfs was set to 0.012 times the flow, and the amplitude for flow greater than 173,000 cfs was set to the amplitude predicted for 173,000 cfs. While flows above 173,000 cfs are rare, flows less than 85,000 cfs are frequent given the median flow for the Susitna River near Susitna Station is 19,000 cfs (Tetra Tech 2013). Future hydrology revisions will reassess diurnal fluctuations for flows less than 85,000 cfs.

Once the amplitude and phi were determined, the hourly flows were estimated as a function of the average daily flow as:

$$Qt = Qhourly + Amplitude * \sin(2\pi t + \varphi)$$

Where:

Qt – hourly flow at the location of interest (with diurnal fluctuations)

Qhourly – hourly flow at the location of interest (without diurnal fluctuations)

Amplitude – magnitude of the daily flow fluctuation as predicted using the equation for the location of interest in Table 11

t – fraction of the 24 hour day

φ – phi, timing of the flow peak as predicted using the equation for the location of interest in Table 11

An example application of the diurnal fluctuations for the Susitna River at the Dam Site location is shown in Figure 3. This figure shows the average daily flow values from the USGS in the dashed line, the conversion of the daily flow values into an hourly flow estimate as used in Version 1 and 2 of the OWFRM in the thick solid line, and the hourly flow estimates with the diurnal fluctuations in the thin blue line. The incorporation of diurnal fluctuation varies depending on whether or not the criteria conditions have been met; the amplitude and timing of the diurnal fluctuations varies depending on the values predicted from the statistical models developed.

6.4. Flows in the Susitna River at the Dam Site

In order to run and simulate conditions in the Susitna River using the OWFRM, input flows were necessary for the Dam Site location. This section summarizes how the hourly streamflow record for this location was developed.

6.4.1. Pre-project Conditions

Daily flows in the Susitna River at the Dam Site were estimated for the 61-year period of record from daily flows in the Susitna River at Gold Creek (USGS No. 15292000 at PRM 140.0, drainage Area = 6,160 square miles) and from daily flows in the Susitna River at Cantwell (USGS No. 15291500 at PRM 225.0, drainage Area = 4,140 square miles) available from the USGS (Curran 2012). Of these two gages, the Susitna River at Gold Creek gage is considered to be more reliable since it has a longer period of record.

The estimation of the daily flows involved the following steps:

1. Adjust Susitna River at Cantwell for stair-step estimates.
2. Convert mean daily discharge estimates to hourly estimates.
3. Shift hourly streamflows from the Susitna River at Cantwell location to the Susitna River at Gold location.
4. Reaggregate to mean daily flows for Susitna River at Cantwell shifted to Gold location.
5. Calculate daily accretion estimates between the Cantwell and Gold Creek locations.
6. Make adjustments to the accretion to account for negative flows.
7. Recalculate Susitna River at Cantwell flows to account for changes to accretion estimates.
8. Change the streamflow estimates for the Susitna River at Cantwell to the Susitna River at the Dam Site using a drainage area adjustment.
9. Shift the recalculated daily Susitna River at Dam Site flows back upstream to the Dam Site location.
10. Perform diurnal fluctuation analysis to convert from mean daily to hourly.

In Step 1, the daily flows at Cantwell were adjusted for the unrealistic stair-step estimates as described in Section 6.2 above. In Step 2, the adjusted daily flows were then converted to hourly flows using previously developed methodologies (ISR Study 8.5, Part C, Appendix K, Section 5.4.1.2.3, Figure 5.4-6 [R2 2014a]). With this methodology, the daily average was preserved each day and the hourly flow hydrograph was smooth and continuous. The diurnal fluctuations were not yet incorporated at this step. In Step 3, the hourly flows for Susitna River at Cantwell were then shifted to the Susitna River at Gold Creek location using a 12.3 hour travel time. This travel time was calculated using the travel velocity between the two gages as determined by comparing peak flow events. In Step 4, the hourly flows calculated at the Gold Creek location are reaggregated into mean daily values. In Step 5, the daily accretion between Susitna River at Cantwell and Susitna River at Gold Creek is calculated as:

$$Q_{ungaged\ accretion} = Q_{Gold\ Creek} - Q_{Cantwell,shifted}$$

In some cases, this accretion is negative due to measured gage error, and/or error resulting from the prediction of the mean daily flows. Negative accretion flows are unrealistic, so in Step 6 the ungaged accretion estimates were adjusted. To do this, an exceedance curve was developed for the ratio of the ungaged accretion to the flow at Gold Creek. Because the ungaged accretion flows are negative, this ratio is also negative at high exceedances. The negative ratios at the high end of the curve were truncated, and to counteract the removal of the negative values, the values at the low end of the curve were also truncated such that the total was preserved. The values were then redistributed over the 0-100 percent exceedance range and the daily ratio's recalculated accordingly.

In Step 7, the daily flows for the Susitna River at Cantwell were recalculated using the adjusted accretion estimates as:

$$Q_{Cantwell} = Q_{Gold\ Creek} - Q_{adjusted\ accretion}$$

Where $Q_{Cantwell}$ accounts for the flow at the Susitna River at Cantwell location shifted downstream to Gold Creek, then adjusted for changes in the accretion. Streamflow estimates were needed at the Dam Site location, not the Cantwell location, so in Step 8 the streamflows at the Dam Site were calculated using drainage area interpolation (Susitna River at Cantwell drainage area = 4,140 square miles and Susitna River at the Dam Site drainage area = 5,180 square miles). Note that the flows in steps 4-8 are all calculated in terms of the Susitna River at Gold Creek location. Therefore, in Step 9, the hourly flows for the Susitna River at the Dam Site were adjusted back upstream from the Gold Creek location to the Dam Site location using a shift of 6.83 hours. Finally in Step 10, hourly streamflows were again recalculated for the Susitna River at Dam Site, but this time incorporating diurnal fluctuations using the methodologies described above in Section 6.3.

6.4.2. Post Project Operational Scenarios

A HEC-ResSim model was developed to simulate operations of the reservoir and the Watana Dam site and simulate flow releases from the Dam under Post-Project operations. Originally, post-project conditions were developed under operations referred to as the Maximum Load Following Operations Scenario 1b (OS-1b) (ISR Study 8.5, Part A, Section 4.1.2.2 [AEA 2014]). Operating Scenario (OS)-1b was based on the assumption that the entire load fluctuation of the entire Railbelt would be provided by the Susitna-Watana Hydroelectric Project, and that all other sources of electrical power in the Railbelt would be running at base load. This assumed condition is not realistic for an entire year, and as a result, an additional operational scenario is in development. This scenario is termed Intermediate Load Following or ILF-1, and is intended to provide a more realistic operating regime from which to evaluate Project effects.

6.5. Tributary Hydrology

The tributary accretion calculations are split into three reaches based on the location of major USGS gages. The three reaches include the Dam Site to Gold Creek, Gold Creek to Sunshine, and Sunshine to Susitna Station. Version 1 of the tributary hydrology was developed in January 2013 for each subbasin from the proposed Dam site at PRM 187.1 downstream to PRM 80 (R2 et al. 2013). Version 1 of the hydrology distributed flows to each subbasin using drainage area and did not account for diurnal fluctuations.

Version 2 of the tributary hydrology was completed for the reach of the Susitna River from the Dam Site to Gold Creek in June 2014 and incorporates diurnal fluctuations ISR Study 8.5, Part C, Appendix K (*Hydrology and Version 2 Open-water Flow Routing Model* [R2 2014a]). The tributary hydrology was updated in spring 2015 for the Dam Site to Sunshine location and incorporated both diurnal fluctuations and adjustments made based on measured gage data. Tributary hydrology for the Sunshine to Susitna Station reach was also developed and was based on drainage area distribution.

Additional adjustments to the tributary hydrology between the Dam Site and Sunshine are anticipated based on gage data collected in 2015. Currently, these adjustments are scheduled to occur in the Fall/Winter of 2015. However, the changes are not anticipated to be significant since the hydrology was already adjusted based on data collected in 2013 and 2014. No adjustments to tributary hydrology were made to the Sunshine to Susitna Station reach based on measured gage data. Instead, the tributary hydrology for this reach is proportioned based on drainage area. Adjustments based on measured gage data for this reach are also scheduled to occur in the Fall/Winter of 2015. In addition, the hydrology in the reach from Sunshine to Susitna Station needs to be improved with regard to diurnal fluctuations. Further improvements can be achieved through modifications to diurnal fluctuations in the tributaries to the Susitna River between Sunshine and Susitna Station. Once complete, it is assumed that these adjustments will constitute the final Version of the Hydrology for each of the reaches and will be Hydrology used in the OWFRM. However, additional revisions for tributaries located in Focus Areas may be appropriate for use in two-dimension (2-D) modeling of Focus Areas. The need for such revisions will be evaluated on a tributary by tributary basis and will only be revised for Focus Area 2-D modeling efforts.

6.5.1. Tributaries between the Dam Site and Gold Creek

Total accretion calculations for the Dam Site to Gold Creek location are described above in Section 6.4.1 on Pre-project Conditions. This section describes pre-project hydrology calculations for the 61-year period of record. The methodology for the total accretion calculations was provided in steps 5 and 6 in Section 6.4.1. The total accretion is used and distributed to each of the 19 subbasins within the Dam Site to Gold Creek reach. Originally in previous versions, accretion was distributed solely on drainage area and was the same for the open-water and wintertime conditions. However, in the current version, two distributions are used, one for the open-water (June 1st to September 30th) and one for the ice period (November 1st to April 30th). The month of May was treated as a transition from the ice period to the open-water period. The month of October was treated as a transition from the open-water period to the ice period. May 1st through 31st was linearly interpolated between the winter percentage and the summer percentage and vice versa for the October 1st through 31st period. Measured gage data from the tributary gaging task and the winter gaging task were used to make adjustments to the distributions. In order to determine distributions during the measured periods and make subsequent adjustments, total accretion calculations also had to be conducted for the 2013 through 2014 period. These were completed using similar methods as applied for the 61-year period of record.

Measured gage data during the summer are available from the tributary gaging task (Section 4) for five of the 19 subbasins accounting for 59 percent of the drainage area. These included Tsusena Creek (14.8%), Fog Creek (15.3%), Portage Creek (18.3%), Indian River (8.4%), and Gold Creek (2.5%). The percentage of flow from each of these tributaries to the total accretion was calculated for each day and reviewed over the period of record available. These values were compared to the percentage based on drainage area only and a single percentage (typically the average) was recommended for each of the five measured subbasins for the open-water period. The percentages for the remaining 14 subbasins were redistributed based on drainage area using the total percentage of flow remaining.

Measured gage data during the winter are available from the winter gaging task (ISR Study 8.5, Part C, Appendix K, Section 5.3: Winter Gaging Data Collection [R2 2014a]). In the Dam Site to Gold Creek reach, the only wintertime tributary data available was for Indian River for two dates, one in January and one in March of 2014. The average accretion was calculated for these two dates and used to update the percentage for that subbasin. The percentages for the remaining 18 subbasins were redistributed using the total remaining flow based on the summertime percentage. It should be noted that the summertime distribution was used instead of the drainage area distribution since the measured gage data provides some indication of variations in basin productivity even though measurements were not collected during the winter. In the case of Indian River, the wintertime distribution and summertime distribution were not substantially different so the percentages are similar.

A comparison of the percentage by subbasin based on drainage area and the recommended and redistributed open-water and ice-period percentages is provided in Table 13. The following procedures were used to develop the hourly tributary flows for the 61-year period of record for the subbasins between the Dam Site and Gold Creek.

1. The hourly flows for the tributary/subbasin of interest were calculated using the distributions provided in Table 13. This process produces the hourly tributary flows at the Susitna River at Gold Creek Gage location.
2. The hourly flows for the tributary/subbasin of interest were shifted from the Gold Creek location back to the tributary or subbasin midpoint location; travel time was estimated at 6.91 miles per hour.
3. The hourly flows were re-aggregated to daily flows.
4. Diurnal fluctuations were incorporated into the analysis based on methodologies outlined above in Section 6.3 Diurnal Fluctuations.

5. The hourly estimates were QA/QC reviewed for consistency. This step consisted of comparing the daily and hourly minimum and maximum statistics and plotting select years from the period of record.

6.5.2. Tributaries between Gold Creek and Sunshine

Tributary inflows to the Susitna River between the USGS Gage on the Susitna River at Gold Creek (USGS No. 15292000) and the USGS Gage on the Susitna River at Sunshine (USGS No. 15292780) were developed for the 61-year period from October 1949 to September 2010. Two of the major tributaries include the Chulitna River and the Talkeetna River. Daily measured or synthesized flows are available for both of these tributaries from the USGS Gage on the Chulitna River near Talkeetna (USGS No. 15292400) and from the USGS Gage on the Talkeetna River (USGS No. 15292700).

Flow records from these two gage locations were shifted to account for travel time between each gage and the corresponding confluence with the Susitna River. The travel time in the Chulitna River between USGS No. 15292400 and the confluence with the Susitna River was estimated to be four hours. The travel time in the Talkeetna River between USGS No. 15292700 and the confluence with the Susitna River was estimated to be one hour. These shifted hydrographs can be used as input to the OWFRM.

Procedures were developed to estimate inflows from the remaining tributaries to the Susitna River between Gold Creek and Sunshine. The total tributary inflow was developed, and then portioned out to each tributary based on drainage area and/or recent tributary gage records.

Flow records from upstream USGS gage locations (Susitna at Gold Creek, Chulitna, and Talkeetna) were shifted forward to account for travel time between each gage and the USGS Gage on the Susitna River at Sunshine (USGS No. 15292780). The travel time from the USGS Gage on the Susitna River at Gold Creek to the USGS Gage on the Susitna River at Sunshine was estimated to be 13.5 hours. The travel time from the USGS Gage on the Chulitna River near Talkeetna to the USGS Gage on the Susitna River at Sunshine was estimated to be 9.25 hours. The travel time from the USGS Gage on the Talkeetna River near Talkeetna to the USGS Gage on the Susitna River at Sunshine was estimated to be 5.5 hours.

Using the flows routed to Sunshine, the following equation was developed and initially used to estimate total tributary inflow:

$$Q_{Total} = Q_{Sunshine} - Q_{Gold\ Creek} - Q_{Chulitna} - Q_{Talkeetna}$$

However, the total tributary inflows calculated from this equation were often negative. An example of when this occurs is shown in Figure 4 for a period in July 1967. The combined flows from the three upstream gages (Gold Creek, Chulitna, and Talkeetna) exceed the flow at the downstream gage (Sunshine) by as much as 10,000 cfs in this example.

To avoid negative tributary inflows, a different procedure was used to synthesize these flows. Monthly average flows were calculated from the 61-year period of record for the Susitna River at Gold Creek, the Chulitna River near Talkeetna, the Talkeetna River near Talkeetna, and the

Susitna River at Sunshine. When the equation shown above was applied using monthly average flows, no negative tributary inflows were found for all 12 months of the year.

Results of these calculations are shown in Table 14. The total tributary inflow was derived on a monthly basis as a percentage of the sum of the flows in the Susitna River at Gold Creek, the Chulitna River near Talkeetna, and the Talkeetna River near Talkeetna. These percentages were then used to synthesize total tributary inflow for the 61-year period of record. To avoid flow discontinuities from the end of one month to the beginning of the next month, daily percentages were estimated from the monthly percentages as shown in Figure 5.

The net result of this process is that no negative tributary inflows were generated over the 61-year period of record, synthesized flows in the Susitna River at Sunshine differ slightly from the original set of flows, and flows in the Chulitna River near Talkeetna and the Talkeetna River near Talkeetna match the original set of flows which was deemed important for the Fluvial Geomorphology Modeling Study (Study 6.6).

The flows shown in Figure 4 were replotted using the adjusted flows at Sunshine (adjusted to remove negative tributary inflows). The new hydrograph at Sunshine is shown in Figure 6. The adjusted flows at Sunshine are greater than the sum of the flows from the three upstream gages, and the tributary inflows are not negative.

The 61-year average from the original (unadjusted) set of flows for the Susitna River at Sunshine is 24,100 cfs. After adjusting the flows to remove negative tributary inflows, the average flow is the same (24,100 cfs). Flow duration curves were derived from the unadjusted and adjusted flows for the Susitna River at Sunshine. These flow duration curves are shown in Figure 7. The two curves are virtually identical except at the low end of the flows where the adjusted flows are slightly higher than the unadjusted flows.

The 61-year average tributary inflow to the Susitna River between Gold Creek and Sunshine based on unadjusted conditions (with negative flows) is 1,680 cfs. After adjusting the flows to remove negative tributary inflows, the average flow is the same (1,680 cfs). Flow duration curves were derived from the unadjusted and adjusted tributary inflows to the Susitna River between Gold Creek and Sunshine. These flow duration curves are shown in Figure 8. Although the curves are substantially different, none of the tributary flows are negative.

Once the total tributary inflow was determined, it was distributed into each of the other 13 subbasins. Distributions are provided in Table 15. This table shows a comparison of the percentage by subbasin based on drainage area and the recommended and redistributed open-water and ice-period percentages. The following procedures were used to develop the hourly tributary flows for the 61-year period of record for the subbasins between Gold Creek and the Sunshine gage.

1. The hourly flows for the tributary/subbasin of interest were calculated using the distributions provided in Table 15. This process produces the hourly tributary flows at the Susitna River at Sunshine Gage location.

2. The hourly flows for the tributary/subbasin of interest were shifted from the Sunshine location back to the tributary or subbasin midpoint location; travel time was estimated at 3.86 miles per hour.
3. The hourly flows were re-aggregated to daily flows.
4. Diurnal fluctuations were incorporated into the analysis based on methodologies outlined above in Section 6.3 Diurnal Fluctuations.
5. The hourly estimates were QA/QC reviewed for consistency. This step consisted of comparing the daily and hourly minimum and maximum statistics and plotting select years from the period of record.

6.5.3. Tributaries between Sunshine and Susitna Station

Tributary inflows to the Susitna River between the USGS Gage on the Susitna River at Sunshine (USGS No. 15292780) and the USGS Gage on the Susitna River at Susitna Station (USGS No. 15294350) were developed for the 61-year period from October 1949 to September 2010. A major tributary is the Yentna River. Daily measured or synthesized flows are available for the Yentna River from the USGS Gage (USGS No. 15294345).

The Open-water Flow Routing Model was split into two reaches: The upstream reach extends from the Dam Site to the USGS Gage at Sunshine. The downstream reach extends from the USGS Gage at Sunshine to the USGS Gage at Susitna Station. Simulated flows from the upstream model at Sunshine were used as input to the downstream reach.

Flows in the Susitna River at Sunshine were routed to Susitna Station using a travel time assumed to be 26.25 hours. Flows in the Yentna River at the USGS Gage were routed to Susitna Station using a travel time assumed to be 5.75 hours.

Using the flows routed to Susitna Station, the following equation was developed and initially used to estimate total tributary inflow:

$$Q_{Total} = Q_{Susitna\ Station} - Q_{Sunshine} - Q_{Yentna}$$

However, the total tributary inflows calculated from this equation were often negative. An example of when this occurs is shown in Figure 9 for a period in June 1964. The combined flows from the two upstream gages (Sunshine and Yentna) exceed the flow at the downstream gage (Susitna Station) by as much as 40,000 cfs in this example.

Procedures were developed to estimate inflows from the Yentna River and remaining tributaries to the Susitna River between Sunshine and Susitna Station. Inflows from the Yentna River were adjusted to ensure that flows from the remaining tributaries remained positive. The total tributary inflow from the remaining tributaries was developed, and then portioned out to each tributary based on drainage area. After additional Lower River tributary data have been collected, the distribution to each subbasin will be adjusted based on available measured tributary gage data.

Average monthly flows from the 61-year period of record were determined for the Susitna River at Susitna Station and Sunshine, and for the Yentna River. The difference in monthly flow between the Susitna River at Susitna Station and Sunshine was calculated and the average monthly flow in the Yentna River was determined as a percentage of the difference between Susitna Station and Sunshine. Results of these analyses are list in Table 16, and shown in Figure 10. The monthly ratios were then converted to daily ratios (Figure 10). These daily ratios were then used to adjust the flows in the Yentna River.

Results of these adjustments are shown in Figure 11 during the period in June 1964. The sum of the flows from the two upstream gages (Sunshine and Yentna Adjusted) does not exceed the flows at Susitna Station. Total tributary inflows from the remaining tributaries were then determined from the following equation:

$$Q_{Total} = Q_{Susitna\ Station} - Q_{Sunshine} - Q_{Yentna\ Adjusted}$$

The 61-year average from the original (unadjusted) set of flows for the Yentna River is 19,470 cfs. After adjusting the flows in the Yentna to remove negative inflows from the other tributaries, the average flow is the same (19,470 cfs). Flow duration curves were derived from the unadjusted and adjusted flows for the Yentna River. These flow duration curves are shown in Figure 12. The two curves are very similar.

The 61-year average tributary inflow to the Susitna River between Sunshine and Susitna Station based on unadjusted conditions (with negative flows) is 5,040 cfs. After adjusting the flows at Yentna to remove negative inflows from the other tributaries, the average flow is the same (5,040 cfs). Flow duration curves were derived from the unadjusted and adjusted tributary inflows to the Susitna River between Sunshine and Susitna Station. These flow duration curves are shown in Figure 13. Although the curves are substantially different, none of the adjusted tributary flows are negative.

Once the total tributary inflow was determined, it was distributed into each of the other 24 subbasins. Distributions are provided in Table 17. The flow was distributed based on a drainage area percentage. Additional adjustments will be made to account for measured tributary gage data after data collection and measured hourly flows are complete in the Fall of 2015. The following procedures were used to develop the hourly tributary flows for the 61-year period of record for the subbasins between the Sunshine and Susitna at Susitna Station Gages.

1. The hourly flows for the tributary/subbasin of interest were calculated using the distributions provided in Table 17. This process produces the hourly tributary flows at the Susitna River at Susitna Station Gage location.
2. The hourly flows for the tributary/subbasin of interest were shifted from the Susitna Station location back to the tributary or subbasin midpoint location; travel time was estimated at 2.21 miles per hour.
3. The hourly flows were re-aggregated to daily flows.
4. Diurnal fluctuations were incorporated into the analysis based on methodologies outlined above in Section 6.3 Diurnal Fluctuations.

The hourly estimates were QA/QC reviewed for consistency. This step consisted of comparing the daily and hourly minimum and maximum statistics and plotting select years from the period of record.

The calculations described in this section for the tributary hydrology between Sunshine and Susitna Station differ from what was developed and documented in Version 2 (ISR Section 8.5, Part C, Appendix K [R2 2014a). The main difference is that in the current version an adjusted estimate of the flows for the Susitna River at Sunshine were developed and used in the tributary accretion calculations instead of basing the calculations on the actual measured flows at the Sunshine gage as was done previously.

7. OPEN-WATER FLOW ROUTING MODEL

7.1. Model Inputs

7.1.1. Cross-sections

Combinations of data sources were utilized to construct cross-sections for the OWFRM. In general, cross-sections consist of "in-channel" and "overbank" portions. The in-channel cross-sectional geometry consists of the wetted river channel plus the adjacent riverbanks, just extending into the floodplain. Overbank geometry generally refers to the river floodplain, extending up the valley walls far beyond any potential flood elevations.

7.1.1.1. In-Channel Geometry

The in-channel geometry was derived from data collected by Brailey Hydrologic and Geovera during the 2012, 2013, and 2014 field seasons. Methods for producing and adjusting in channel cross-sections followed those documented in the ISR Study 8.5, Part A, Section 5.4.1.1.1: In-Channel Geometry (AEA 2014). Of the 216 total cross-sections, 92 transects required a shift to the wetted bathymetry of the side channel(s), 33 required shifting to both wetted bathymetry and dry topography, and 91 required no shifting.

7.1.1.2. Overbank Geometry

Depending on availability, the overbank geometry was derived from either the 2013 and 2014 LiDAR mapping (preferred), or the Matanuska-Susitna (MatSu) LiDAR mapping collected in 2011 and indexed to the NAVD88 (feet) in 2013 (*Updated Fluvial Geomorphology Modeling Approach* TM filed with the FERC May 27, 2014 [Tetra Tech 2014]). In some cases, the overbank geometry was a combination of the three sources. The overbank geometry data were merged with the field-surveyed geometry following the same techniques documented in the ISR Study 8.5, Part A, Section 5.4.1.1.2 Overbank Geometry (AEA 2014).

7.1.1.3. Devils Canyon

For reasons of safety, no mainstem transect data were collected in the Devils Canyon reach (PRM 154.6-166.1). Instead, cross-sectional profiles were estimated using the LiDAR topography data and a rectangular conveyance channel developed by Study 7.6 (Ice Processes).

The channels are similar to those used in Version 2 and documented in the ISR Study 8.5, Part C, Appendix K: *Hydrology and Version 2 Open-water Flow Routing Model* (R2 2014a). A total of 29 estimated cross-sections were included in the Devils Canyon reach.

7.1.2. Roughness Coefficients

Manning's *n* roughness coefficients were specified for each cross-section. Site photographs as well as other field data were used to select appropriate *n* values for the cross-sections. The selection of Manning's *n* differed from the previous versions of the model. In previous versions, each cross-section had only three Manning's *n*'s that were adjusted, which included the main channel, left overbank, and right overbank. To make the model more representative of varying channel and vegetation types, multiple Manning's *n*'s were used both within the main channel and within the overbank. As a result, many channels had six different manning's *n*'s. In some cases (for less than half of the transects) it was necessary to vary Manning's *n* by flow magnitude. However, the magnitude of Manning's *n*'s did not vary significantly from those presented in the ISR for Version 2 of the OWFRM (Figure 5.4-16 of ISR Study 8.5, Part C, Appendix K [R2 2014a]).

7.1.3. Boundary Conditions

The upstream boundary condition at PRM 187.7 was represented by the streamflows (pre-project or with project) at the proposed Dam Site. The stage discharge rating curve at the Susitna River at Sunshine gage was used as the downstream boundary condition at PRM 87.9 for the upper reach of the OWFRM. The output from this model is used as the upstream boundary condition for the Susitna River at Sunshine (PRM 87.9) to Susitna River at Susitna Station (PRM 29.9) reach. The stage discharge rating curve at the Susitna River at Susitna Station gage was used as the downstream boundary condition at PRM 29.9.

7.1.4. Tributary Inflows

There are 59 subbasins between the Dam Site and Susitna River at Susitna Station. Similar to efforts described in ISR Study 8.5, Part C, Appendix K: *Hydrology and Version 2 Open-water Flow Routing Model* (R2 2014a), in order to reduce the effort of incorporating the lateral inflows from all 59 subbasins into the HEC-RAS model, the hourly flow records were combined and reduced to 13 reaches. No changes were made to these reaches from the previous versions (ISR Study 8.5, Part C. Appendix K, Table 5.4-2 [R2 2014a]). Importantly, the streamflow estimates for these reaches have changed, as described above in Section 6.5 Tributary Hydrology, but not how they were combined into reaches.

7.1.5. Expansion/Contraction Loss Coefficients

The Manning's *n* roughness coefficient is used by HEC-RAS to account for frictional loss coefficients. Another form of energy loss is associated with expansion or contraction. The default values for expansion and contraction in HEC-RAS are 0.3 and 0.1, respectively. The default values for expansion and contraction were accepted for Version 2.8 of the OWFRM.

7.2. Model Calibration

As stated previously in Section 1, Version 2.8 of the OWFRM model is applicable to the length of the Susitna River between the Dam Site and the Sunshine Gage. It is anticipated that additional data will be collected between the Sunshine and Susitna Station gages in support of Version 3.0. As such, Version 2.8 of the model was only calibrated between the Dam Site and Sunshine Gage and Version 2.0 of the OWFRM was not modified for the lower reach of the river that extends from the Sunshine Gage to Susitna Station (PRM 29.9). The Susitna River OWFRM was calibrated under both steady-state and unsteady conditions for the Dam Site (PRM 187.1) to Sunshine Gage (PRM 87.9).

A longitudinal thalweg profile of the Susitna River was developed from the 216 cross-sections that were surveyed in 2012, 2013, and 2014 (Figure 14). The channel gradient was steepest through Devils Canyon (0.57%) and becomes gradually reduced in a downstream direction.

7.2.1. Steady-State Model Calibration

The OWFRM was first calibrated under steady-state conditions using over 500 pairs of flow/water surface elevation measurements/estimates obtained at the 216 transects collected in 2012, 2013, and 2014. The relative magnitude of these flow measurements was assessed by using the concurrent flows in the Susitna River at Gold Creek (USGS No. 15292000) and Susitna River at Sunshine (USGS No. 15292780) as a common reference point (Figures 15 and 16). Transects upstream of PRM 102.5 were assessed using the Susitna River at Gold Creek gage as shown in Figure 15 while transects downstream of PRM 102.5 were assessed using the Susitna River at Sunshine gage as shown in Figure 16. Similar to the previous work, flows at transects compared to the Susitna River at Gold Creek were considered high if the flow was greater than 24,000 cfs, medium if they were between 17,700 cfs and 24,000 cfs, and low if they were less than 17,700 cfs. Flows at transects compared to the Susitna River at Sunshine Gage were considered high if the flow was greater than 60,600 cfs, medium if they were between 45,500 cfs and 60,600 cfs, and low if they were less than 45,500 cfs.

Similar to Version 2, there was good coverage at low, medium, and high flows for the transects measured. Additional detail on the coverage of collected data in 2012 and 2013 and the flow conditions during those years can be found in the ISR Study 8.5, Part C, Appendix K [R2 2014a]. The purpose of data collection in 2014 was two-fold: the first goal was to collect additional bathymetry data at transects identified by the riverine modelers study team for the Middle Susitna River and the second was to collect any additional bathymetry and Q-WSE pairs needed to define the upstream and downstream ends of Focus Areas. Although the transects collected in 2014 did not have good coverage of the low, medium, and high flows, they were included in the OWFRM to provide additional bathymetry definition at transect locations. All ten of the Focus Areas have transects at or near both their downstream and upstream ends; total transects = 20. Of the resulting 20 transects, 17 have all three measurements collected corresponding to a low, medium, and high flow condition, and only three were missing one of those due to overlap of a similar measured flow condition.

Calibration procedures generally followed those applied to previous versions of the model with a few exceptions. No changes were made to the downstream boundary condition or the cross-sections or calibration in the Devils Canyon reach. Changes were made to both the roughness coefficients and interpolated cross-sections. Changes to the roughness coefficients (i.e., Manning's *n*) are described above in Section 7.1.2 Roughness Coefficients and changes to the interpolated cross-sections are described below.

As described in Version 2, a QA/QC feature in HEC-RAS requires the addition of interpolated cross-sections when the change in velocity head is too large to accurately determine the change in energy gradient which is necessary to accurately model friction losses (U.S. Army Corps of Engineers [USACE] 2010a; USACE 2010b). Interpolated cross-sections were necessary in Version 2 and were also interpolated in this version. During this process, no modifications were made to the actual surveyed cross-sections. Version 2 of the OWFRM interpolated cross-sections every 1,000 feet and the width of the cross-section may have changed from the HEC-RAS default. In Version 2.8, interpolated cross-sections were included only downstream of measured cross-sections and the HEC-RAS default for the width of the interpolated cross-section was always retained. These interpolated cross-sections were included approximately 1,000 feet downstream of a measured cross-section. The purpose of these cross sections is to match measured WSEs at known cross sections under different flow conditions. In some cases, an interpolated cross-section was not necessary since the WSE was calibrated to within 0.1 feet of the measured WSE. Approximately 90 percent of the transects required an interpolated cross-section downstream. There were a total of 156 interpolated cross-sections included in Version 2.8. In Focus Areas where a triangulated irregular network (TIN) model was developed from topographic and bathymetric surveys, elevations were extracted from these models using a cutline in one foot increments.

The HEC-RAS model was calibrated under steady-state conditions to calculate water surface elevations to within plus or minus 0.2 feet of the observed water surface elevation for the transects upstream of the Three Rivers Confluence and 0.25 feet of the observed water surface elevation for the transects downstream of the confluence. Almost all of the calculated water surface elevations fell within this target range. However, a few were slightly outside of this range. A summary of the Manning's "*n*" coefficients that were used for model calibration is presented in Figure 17. The Manning's "*n*" coefficients ranged from 0.03 to 0.04. These values are similar to those from Version 2 of the OWFRM.

Similar to Version 2, measured and modeled stage values were compared for high flow events at the Susitna River at Gold Creek gage (PRM 140) within the project area. This comparison found consistent results between predictions with the model and recorded measurements indicating the model is performing as anticipated in this range. Note that this discussion of steady state calibration only applies to the Dam Site to Sunshine reach. No additional model changes have been conducted for the Sunshine to Susitna Station reach. The reader should refer to Version 2 documentation for a description of calibration procedures for the Sunshine to Susitna Station reach.

7.2.2. Unsteady-State Model Calibration

Version 2.8 of the model was calibrated under unsteady-state conditions using the data available between 2012 and 2014. Accretion estimates were included in the model using either a tributary point source or uniform lateral inflow as described in ISR Study 8.5, Part C, Appendix K, Section 5.4.2.2: Unsteady-State Model Calibration (R2 2014a). Excellent agreement was found between the measured and simulated flows for Susitna River at Gold Creek, but because of the different approach to hydrology calculations for the Gold Creek to Sunshine Reach, the measured and simulated flows for the Susitna River at Sunshine are different. In some cases the USGS gage data have conflicting measurements and mass balance cannot be maintained between the Gold Creek Gage, Chulitna Gage, Talkeetna Gage, and Sunshine Gage. In these cases, the priority is given to the Gold Creek, Chulitna, and Talkeetna gages.

Unsteady model calibration results comparing measured and simulated hydrographs for the July 28 – August 4 2013 period and the entire 2013 open water period in the Susitna River at Gold Creek (USGS No. 15292000) are shown in Figures 18 and 19, respectively. These figures show good agreement between the hourly measured USGS streamflow and the simulated hourly streamflow. The comparison of the measured and simulated streamflow at the Susitna River at Sunshine (USGS No. 15292780) is shown in Figures 20 and 21, respectively. These figures show similar magnitudes and shape of the hydrographs, but in some periods, there are distinct differences between the measured and simulated hydrographs. The previous two versions of the model and hydrology placed a higher priority on the Susitna River at Sunshine gage and used adjusted values for the Talkeetna and Chulitna River values. In discussion with other riverine modelers (e.g., Study 6.6 [Fluvial Geomorphology Modeling] Study 7.6 [Ice Processes]), a higher priority is placed on the Talkeetna and Chulitna River gages due to the robustness of data at those gage sites. As a result the model does not always closely match flows at the Susitna River at Sunshine gage. This approach was a conscious decision among the multiple study groups to work within the constraints of the data available while also meeting the needs of each individual study's goals.

No changes have been made to the OWFRM for the section from Sunshine to Susitna Station since Version 2 which is documented in the ISR Section 8.5, Part C, Appendix K (R2 2014a). However, the hydrology approach and tributary calculations have changed. The new version of the tributary hydrology is described above in Section 6.5.3. As a result, the model calibration period was re-run using the new tributary inputs. The results from this simulation for the Susitna River at Susitna Station for the July 28 – August 4, 2013 period and the entire 2013 open-water period are shown in Figures 22 and 23, respectively.

7.3. Model Validation

No model validation was conducted for the OWFRM Version 2.8. Model validation against data collected at the mainstem Susitna River ESS stations will be conducted during development of Version 3.0.

8. NEXT STEPS

8.1. Tributary Gaging and Hydrology

Completion of the tributary gaging task is expected in the Fall of 2015. Rating Curves and hourly flow data will be revised and extended through the period of record available. These data will be used to revise the percentage of flow distributed to each subbasin in the tributary hydrology calculations. Major changes from the revisions and new data are not expected for the Dam Site to Sunshine reach since the distributions have already been adjusted based on data collected in 2013 and 2014. However, changes for the Sunshine to Susitna Station reach are anticipated since this tributary hydrology was distributed based on drainage area only. The revisions to the tributary hydrology are expected to be complete by the end of 2015. In addition, simulated tributary estimates will be developed for the 2013 to 2015 period using the methods described in Section 6.5 above. These estimates will be compared to measured tributary gage data to evaluate how well simulated flows are reproducing actual.

In addition, the hydrology in the reach from Sunshine to Susitna Station needs to be improved with regard to diurnal fluctuations. Further improvements can be achieved through modifications to diurnal fluctuations in the tributaries to the Susitna River between Sunshine and Susitna Station.

Once these steps are complete, no additional tributary gaging data will be incorporated into the OWFRM for the reach between the proposed Dam site at PRM 187.1 and the Susitna River at Sunshine (PRM 87.9). Additional tributary field data will be available as a result of data collection associated with 2-D models in Focus Areas above Devils Canyon or other riverine modeling field activities. Those additional tributary gage data will be used to refine hourly flow records for tributaries of interest. The tributary data available would be used to support Study 6.6 (Fluvial Geomorphology Modeling below Watana Dam Study), fish habitat modeling within Focus Areas (Study 8.5 Fish and Aquatics Instream Flow Study) and/or Study 9.12 (Study of Fish Passage Barriers in the Middle and Upper Susitna River.

8.2. Lower River Transects

Data collection in 2014 focused on collecting all necessary transect data in the reach from the proposed dam site (PRM 187.1) downstream to the Susitna River at Sunshine (PRM 87.9). Additional transect data are needed to describe the reach between the Susitna River at Sunshine (PRM 87.9) and the Susitna River at Susitna Station (PRM 29.9). These data will be used to develop Version 3 of the OWFRM.

8.3. ESS Stations and Mainstem Flow Measurements

Mainstem ESS stations will be evaluated for removal on a case by case basis. Some stations will be removed, while others will be minimally maintained by AEA in the interim while other federal agencies develop plans to take over ownership. Stations that could potentially be maintained include ESS80, ESS70, ESS55, ESS45, ESS40, and ESS20.

Rating curve development and processing of the continuous flow data for the mainstem ESS stations are not yet complete. This work will need to consider and address measurement issues that came up during field data collection over the course of the three year data collection effort. All mainstem streamflow data were collected using the Sontek M9 ADCP. Following extensive testing by the USGS to investigate known compass problems, in November 2014 there was a factory recall to replace all original Sontek M9 compasses. In response to this long known issue, all M9 ADCP data was collected using bottom tracking (as opposed to GPS) and incorporated methods to minimize compass heading errors (USGS, OSW 2012). Additionally, after the 2014 field season, Brailey Hydrologic has preliminarily identified a bias in utilizing vertical-beam to track depth, and has recommended utilizing slant-beam depths instead (SIR Study 8.5, Appendix C: 2014 Moving Boat ADCP Measurements [R2 2015]). As such, all of the 2014 data are processed in this manner. However, all of the 2012 and 2013 data have been processed using the vertical-beam depth method and at the time of QC review, USGS had not yet provided a formal recommendation for the Sontek M9 data. The ADCP measurement concerns were discussed between the Geomorphology and IFS modeling teams. Since there was no clear guidelines from the USGS on how to approach the M9 processing issues and the data collected in 2012 and 2013 had been finalized and distributed, no adjustments were applied to these data. However, if rating curves are developed in the future for the mainstem ESS stations, the differences in ADCP processing methods between the different years should be reviewed.

8.4. Open-water Flow Routing Model

Several tasks remain before the OWFRM is complete. These include:

- Validation of the OWFRM using 2014 USGS data.
- Validation of the OWFRM using 2012-2014 ESS station data. This task will require completion of tasks identified above in Section 8.3 regarding ESS data and rating curves.
- Completion and calibration of the OWFRM for the Sunshine to Susitna Station Reach. This task will require review and agreement on mainstem data collection needs for the lower river reach (Sunshine to Susitna Station).
- Simulation of the 61-year period of record.

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10. TABLES

Table 1. Summary of the four versions of the Open-water Flow Routing Model.

Model Component	Version 1	Version 2	Version 2.8	
Reach	NA	NA	Dam Site to Sunshine	Sunshine to Susitna Station
Extent	PRM 80-187.1	PRM 29.9-187.1	PRM 87.9-187.1	PRM 29.9-87.9
Number of measured Cross-sections	88	167	169	47
WSE/Q Pairs	120	387	194 Measured 204 Estimated	13 Measured, 99 Estimated
Accretion	Hourly	Hourly	Hourly	Hourly
Diurnal Fluctuations	None	Measured where and when available, not estimated for missing gaps	Complete	Complete
Floodplain coverage	None	Extended using 2011 and 2013 LiDAR	Extended using 2011, 2013, and 2014 LiDAR	Extended using 2011 and 2013 LiDAR
Calibration/Validation Data	6 gages 15291500 15291700 15292000 15292780 15292400 15292700	8 gages 15291500 15291700 15292000 15292780 15294350 15292400 15292700 15294345	8 gages 15291500 15291700 15292000 15292780 15294350 15292400 15292700 15294345	8 gages 15291500 15291700 15292000 15292780 15294350 15292400 15292700 15294345

Table 2. Master Mainstem Transect Data Summary Table.

UPPER RIVER (PRM 261.3 - 187.1)

Project River Mile (PRM)	XS Profile /Bathy Date	XS Profile /Bathy Date 2	June/July 2012					August 2012					September/October 2012					June/July 2013					August 2013					September/October 2013					June/July 2014					August 2014					September 2014				
			Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]
225.0	NA		6/14/2012	17:57	26,900	Good	NA	8/9/2012	15:03	11,300	Excellent	NA	10/18/2012	NA	WSE only[5]		1906.26						8/8/2013	15:05	11,900	Excellent	NA	9/3/2013	13:32	14,700	Good	NA	6/17/2014	13:40	14,400	Fair	NA										
187.2	6/17/2012		6/17/2012	16:30	27,700	Poor	1466.42	8/6/2012	16:13	14,700	Good	1464.09	9/15/2012	13:17	7,840	Good	1461.81																6/19/2014	15:14	20,300	Fair	1465.63										

MIDDLE RIVER (PRM 187.1 - 102.4)

Project River Mile (PRM)	XS Profile /Bathy Date	XS Profile /Bathy Date 2	June/July 2012					August 2012					September/October 2012					June/July 2013					August 2013					September/October 2013					June/July 2014					August 2014					September 2014				
			Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]
186.6	6/17/2014																																6/17/2014 6/19/2014	17:41 16:29	WSE only[5] 20,700	 Poor	1460.50 1460.74										
186.2	6/18/2012		6/18/2012	14:13	24,500	Good	1458.50	8/6/2012	17:05	14,400	Good	1457.07	9/15/2012	14:05	7,630	Excellent	1455.36																														
185.5	6/18/2012		6/18/2012	16:10	25,400	Good	1452.14	8/6/2012	17:17	WSE only[5]		1450.52	9/15/2012	14:28	WSE only[5]		1449.17																														
185.2	6/19/2012		6/19/2012	13:00	26,700	Good	1449.28	8/6/2012	17:43	WSE only[5]		1447.37	9/15/2012	14:57	WSE only[5]		1445.92																														
184.9	6/19/2012		6/19/2012	15:49	27,600	Good	1446.04	8/6/2012	18:24	14,200	Excellent	1443.72	9/15/2012	14:57	7,710	Excellent	1442.10																					8/14/2014	14:32	14,500	Good	NA	9/12/2014 9/26/2014	15:22 14:48	12,800 9,600	Good Good	NA NA
184.7	6/18/2014																																6/18/2014 6/20/2014	12:35 11:23	WSE only[5] 19,300	 Good	1441.86 1442.10	8/16/2014	16:31	16,400	Good	1441.16	9/13/2014	11:36	12,300	Good	1440.09
184.4	6/19/2012		6/19/2012	16:51	27,900	Fair	1440.48	8/7/2012	12:38	14,800	Good	1437.43	9/15/2012	15:52	8,350	Good	1435.55																														
183.8	6/18/2014																																6/18/2014	13:27	WSE only[5]		1429.84										
183.3	6/20/2012		6/20/2012	13:19	29,400	Fair	1424.86	8/7/2012	13:35	14,200	Excellent	1422.91	9/15/2012	16:41	8,310	Excellent	1421.75																														
182.9	6/20/2012		6/20/2012	16:01	29,200	Good	1418.25	8/7/2012	13:40	WSE only[5]		1416.49	9/15/2012	17:10	WSE only[5]		1415.30																														
182.2	6/18/2014																																6/18/2014	14:19	WSE only[5]		1408.89										
181.6	6/20/2012		6/20/2012	17:56	29,600	Excellent	1402.27	8/7/2012	14:44	14,700	Good	1400.11	9/15/2012	17:55	8,690	Good	1398.98																														
180.7	6/18/2014																																6/18/2014	19:11	WSE only[5]		1390.70						9/13/2014	13:30	13,100	Good	1389.73
180.1	6/19/2014																																6/19/2014	13:43	WSE only[5]		1385.28										
179.5	6/21/2012		6/21/2012	12:28	30,900	Fair	1381.40	8/7/2012	15:41	14,300	Excellent	1377.74	9/14/2012	17:05	8,360	Good	1375.79																														
179.0	6/19/2014																																6/19/2014	15:04	WSE only[5]		1375.23										
178.5	6/16/2012		6/16/2012	18:35	29,800	Good	1370.75	8/7/2012	16:37	14,800	Excellent	1367.82	9/14/2012	17:47	8,740	Good	1366.14																														
177.8	6/19/2014																																6/19/2014	16:37	WSE only[5]		1361.73										
177.3	6/19/2014																																6/19/2014	17:30	WSE only[5]		1354.38						9/13/2014	14:59	13,500	Good	1352.73
176.5	6/21/2012		6/21/2012	14:40	31,200	Excellent	1346.56	8/8/2012	12:07	14,600	Excellent	1344.03	9/16/2012	14:50	10,800	Excellent	1343.18																6/20/2014	14:07	21,600	Good	1345.20	8/17/2014	11:10	18,700	Good	1344.69					
175.9	6/19/2014																																6/19/2014	18:07	WSE only[5]		1339.06										
174.9	6/21/2012		6/21/2012	16:12	31,200	Good	1329.91	8/8/2012	13:22	WSE only[5]		1327.53	9/16/2012	16:00	WSE only[5]		1326.88																														
173.5	6/20/2014																																6/20/2014	15:28	21,700	Good	1314.04	8/17/2014	12:25	18,200	Good	1313.89	9/14/2014	12:03	14,500	Good	1313.13
173.4	6/20/2014																																6/20/2014	13:43	WSE only[5]		1312.93										
173.1	6/21/2012		6/21/2012	17:39	30,600	Good	1310.65	8/8/2012	14:28	WSE only[5]		1307.89	9/16/2012	16:29	11,100	Excellent	1306.82																														
172.3	6/20/2014																																6/20/2014	14:38	WSE only[5]		1302.63										
171.6	6/20/2014																																6/20/2014	15:26	WSE only[5]		1296.50										
170.8	6/20/2014																																6/20/2014	16:22	WSE only[5]		1289.03										
170.1	6/22/2012		6/22/2012	12:56	31,100	Good	1285.05	8/8/2012	15:16	14,600	Excellent	1282.38	9/16/2012	17:33	11,100	Excellent	1281.59																														
169.6	6/21/2014																																6/21/2014	11:53	WSE only[5]		1277.73										
168.8	6/21/2014																																6/21/2014	13:29	WSE only[5]		1266.24						9/14/2014	13:28	14,400	Good	1264.47
168.1	6/22/2012		6/22/2012	14:33	32,300	Good	1259.50	8/8/2012	16:03	14,700	Excellent	1256.43	9/17/2012	15:19	14,600	Good	1256.46																														
167.4	6/21/2014																																6/21/2014	14:47	WSE only[5]		1250.43										
166.3	6/21/2014																																6/21/2014	17:01	WSE only[5]		1239.72										
153.7	6/25/2012		6/25/2012	17:15	32,200	Good	862.57	8/10/2012	15:03	14,600	Excellent	858.93																																			
153.3	6/27/2014, 7/6/2014																																6/27/2014	12:54	WSE only[5]		859.93										
152.9	6/26/2012		6/26/2012	13:43	30,500	Fair	853.72	8/10/2012	15:14	WSE only[5]		850.17																																			
152.1	6/26/2012	9/29/2012	6/26/2012	15:38	30,000	Good	843.65	8/10/2012	16:07	15,400	Good	840.96	9/29/2012	15:20	18,500	Good	841.61																6/22/2014 7/6/2014	13:36 14:21	24,600 28,500	Good Good	842.35 NA										
151.8	6/27/2014																																6/23/2014 6/27/2014	13:22 15:58	21,700 WSE only[5]	Good	837.35 839.99	8/12/2014	17:29	16,400	Good	836.59	9/16/2014	11:20	19,000	Good	837.08
151.5	6/27/2014																																6/27/2014	16:26	WSE only[5]		836.57										
151.1	6/25/2012		6/25/2012	14:00	33,200	Good	832.09	8/10/2012	17:32	WSE only[5]		827.79	9/29/2012	15:59	WSE only[5]		829.13																														
150.6	6/28/2014																																6/28/2014	12:25	WSE only[5]		825.07										
150.1	6/28/2014																																6/28/2014	14:14	WSE only[5]		818.17						9/16/2014	13:14	19,200	Good	816.87
149.3	6/28/2014																																6/28/2014	15:08	WSE only[5]		807.59										
148.8	6/28/2014																																6/28/2014	15:39	WSE only[5]		803.19										
148.3	6/26/2012		6/26/2012	18:24	32,100	Good	796.39	8/10/2012	18:03	14,900	Excellent	793.54	9/29/2012	NA	WSE only[5]		794.00																														
147.9	6/28/2014																																6/28/2014	16:55	WSE only[5]		793.65										
147.5	6/28/2014																																6/28/2014	17:20	WSE only[5]		787.27						9/16/2014	15:13	19,200	Good[4]	786.39
147.0	6/29/2014																																6/29/2014	11:04	WSE only[5]		777.88										
146.6	6/27/2012		6/27/2012	12:24	31,000	Fair	773.49	8/12/2012	12:54	WSE only[5]		771.94	9/29/2012	16:36	WSE only[5]		772.02																														
146.1	8/3/2013																						8/3/2013	12:30	WSE only[5]		766.45	9/5/2013	13:09	WSE only[5]		767.62															
145.7	6/27/2012	9/29/2012	6/27/2012	13:51	31,400	Fair	761.96	8/12/2012	13:12	17,400	Excellent	759.65	9/29/2012	16:51	18,100	Good	759.86	6/20/2013	14:42	WSE only[5]		761.43						9/7/2013	13:18	WSE only[5]		760.93															
145.5	6/27/2012		6/27/2012	14:40	31,900	Fair	760.04	8/12/2012	13:53	WSE only[5]		757.93						6/20/2013	12:10	WSE only[5]		758.22	8/3/2013	9:38	WSE only[5]		758.57	9/5/2013	13:33	WSE only[5]		760.03															
144.9	6/27/2012		6/27/2012	17:01	31,900	Fair	751.50	8/12/2012	14:11	WSE only[5]		749.46	9/29/2012	17:15	WSE only[5]		749.80	6/20/2013	16:12	WSE only[5]		751.24																									
144.3	6/27/2012		6/27/2012	18:50	31,100	Good	742.52	8/12/2012	14:32	WSE only[5]		740.68											8/3/2013 8/15/2013	16:25 15:28	WSE only[5] WSE only[5]		740.93 740.77	9/5/2013	9:21	WSE only[5]		742.36						8/13/2014	13:12	17,100	Good[4]	740.43					
143.9	8/3/2013																						8/3/2013	15:44	WSE only[5]		736.31	9/5/2013	14:16	WSE only[5]		737.47															
143.5	6/28/2012		6/28/2012	12:17	30,300	Excellent	732.35	8/12/2012	14:58	17,000	Excellent	730.64	9/29/2012	17:26	WSE only[5]		730.72	7/30/2013	16:16	WSE only[5]		730.63																									
143.0	6/28/2012		6/28/2012	13:53	29,500	Good	725.04	8/12/2012	15:40	WSE only[5]		723.49						6/23/2013	14:30	WSE only[5]		725.33	8/4/2013	14:34	WSE only[5]		725.07	9/5/2013	15:16	WSE only[5]		726.11															
142.2	6/28/2012	9/29/2012	6/28/2012	15:15	29,800	Good	716.41	8/12/2012	16:29	16,800	Excellent	714.51	9/29/2012	17:45	18,300	Excellent	714.78											9/8/2013	14:53	WSE only[5]		716.21															

MIDDLE RIVER (PRM 187.1 - 102.4)

Project River Mile (PRM)	XS Profile /Bathy Date	XS Profile /Bathy Date 2	June/July 2012					August 2012				
			Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]
141.9	6/28/2012		6/28/2012	16:27	30,600	Good	712.88	8/12/2012	17:13	16,800	Excellent	710.84
141.7	6/28/2012		6/28/2012	17:41	30,600	Excellent	711.43	8/12/2012	17:13	WSE only[5]		709.09
141.4	6/29/2014											
141.2	8/4/2013											
140.8	8/4/2013											
140.5	8/5/2013											
140.2	6/30/2014											
140.0	6/29/2012	9/30/2012	6/29/2012	14:48	30,400	Excellent	693.77	8/13/2012	12:54	16,400	Excellent	691.69
139.8	6/29/2012		6/29/2012	16:21	29,100	Excellent	691.34	8/13/2012	13:10	WSE only[5]		689.07
139.0	6/30/2012		6/30/2012	13:56	28,000	Good	679.92	8/13/2012	13:58	16,400	Good	678.26
138.7	6/30/2012		6/30/2012	14:51	28,200	Excellent	678.08	8/13/2012	14:48	16,300	Excellent	677.07
138.4	8/5/2013											
138.1	6/30/2012		6/30/2012	16:33	28,200	Good	670.43	8/13/2012	15:07	WSE only[5]		669.00
137.7	6/25/2014											
137.6	6/30/2012	9/30/2012	6/30/2012	18:13	27,900	Good	664.17	8/13/2012	16:14	16,400	Excellent	662.67
137.2	8/5/2013											
136.8	6/25/2014											
136.7	7/1/2012		7/1/2012	13:35	26,800	Good	654.82	8/13/2012	16:34	WSE only[5]		653.46
136.2	7/1/2012		7/1/2012	16:06	26,900	Good	648.86	8/13/2012	17:06	WSE only[5]		648.12
135.6	8/6/2013											
135.4	6/30/2014											
135.2	6/30/14, 7/1/14											
135.0	7/1/2012		7/1/2012	18:33	26,500	Excellent	634.86	8/13/2012	17:41	15,600	Excellent	632.97
134.7	8/6/2013											
134.3	7/2/2012	10/1/2012	7/2/2012	12:16	25,500	Good	627.51	8/13/2012	18:21	WSE only[5]		625.41
134.1	7/2/2012		7/2/2012	13:18	26,200	Good	625.74	8/14/2012	13:14	16,500	Excellent	624.10
133.8	7/2/2012		7/2/2012	14:30	25,700	Good	623.51	8/14/2012	14:05	16,300	Excellent	622.22
133.3	7/2/2012		7/2/2012	16:22	25,700	Excellent	618.46	8/14/2012	14:41	WSE only[5]		617.34
132.6	7/2/2012		7/2/2012	17:57	25,000	Excellent	609.97	8/14/2012	15:17	16,000	Good	608.67
132.0	8/7/2013											
131.4	7/3/2012		7/3/2012	15:27	28,600	Good	598.37	8/14/2012	16:05	WSE only[5]		597.82
130.9	8/8/2013											
130.4	8/9/2013											
130.1	7/1/2014											
129.7	7/3/2012	10/1/2012	7/3/2012	17:33	28,200	Good	580.58	8/14/2012	17:00	16,300	Excellent	578.98
128.1	7/4/2012		7/4/2012	15:40	26,700	Good	564.50	8/15/2012	12:50	15,900	Excellent	563.54
127.8	8/9/2013											
127.4	7/1/2014											
126.8	7/4/2012	10/1/2012	7/4/2012	17:22	27,600	Excellent	552.41	8/15/2012	13:40	16,100	Excellent	550.87
126.4	8/10/2013											
126.1	7/5/2012		7/5/2012	14:24	27,200	Good	546.88	8/15/2012	13:41	WSE only[5]		545.26
125.9	7/2/2014											
125.8	8/11/2013											
125.4	7/5/2012		7/5/2012	16:38	26,400	Excellent	541.32	8/15/2012	14:12	WSE only[5]		540.09
124.9	8/11/2013											
124.6	6/30/2014											
124.5	8/11/2013											
124.1	7/5/2012	10/1/2012	7/5/2012	18:11	26,100	Good	530.43	8/15/2012	14:27	16,200	Excellent	529.24
123.9	6/30/2014											
123.7	7/6/2012		7/6/2012	12:18	23,900	Excellent	527.93	8/15/2012	15:54	WSE only[5]		527.43
123.2	8/12/2013											
122.7	7/6/2012		7/6/2012	14:23	23,300	Excellent	518.91	8/15/2012	17:15	WSE only[5]		517.91
122.6	7/6/2012		7/6/2012	15:59	22,900	Good	517.85	8/15/2012	16:13	16,300	Excellent	516.97
122.1	8/12/2013											
121.4	8/12/2013											
120.7	7/6/2012		7/6/2012	17:19	22,700	Good	502.03	8/15/2012	17:27	WSE only[5]		501.13
120.3	8/12/2013											
119.9	7/7/2012	10/3/2012	7/7/2012	12:19	20,700	Excellent	495.29	8/16/2012	12:54	16,000	Excellent	494.37
119.5	7/1/2014											
118.9	8/14/2013											
118.3	7/7/2012		7/7/2012	14:06	20,700	Excellent	485.32	8/16/2012	13:04	WSE only[5]		484.18
118.1	7/1/2014											
117.9	8/14/2013											
117.4	7/7/2012		7/7/2012	16:15	20,700	Excellent	477.82	8/16/2012	13:39	WSE only[5]		477.21
117.0	8/14/2013											

Project River Mile (PRM)	September/October 2012					June/July 2013					August 2013				
	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]
141.9						6/22/2013	17:50	WSE only[5]		712.34	8/4/2013	15:21	WSE only[5]		711.25
141.7											8/4/2013	15:44	WSE only[5]		710.00
141.4															
141.2											8/4/2013	17:16	WSE only[5]		703.48
140.8											8/4/2013	18:41	WSE only[5]		700.72
140.5											8/5/2013	10:55	WSE only[5]		696.94
140.2															
140.0	9/30/2012	13:56	17,600	Good	691.94						8/5/2013	12:08	WSE only[5]		692.12
139.8											8/5/2013 8/10/2013	12:30 15:03	WSE only[5] WSE only[5]		689.52 688.92
139.0	9/30/2012	14:26	WSE only[5]		678.50	6/7/2013 6/25/2013 7/28/2013	11:39 11:11 14:59	WSE only[5] WSE only[5] WSE only[5]		680.77 678.93 678.28	8/10/2013	15:40	15,900	Excellent	678.03
138.7											8/5/2013 8/10/2013	12:50 15:48	WSE only[5] WSE only[5]		677.46 677.06
138.4											8/5/2013	15:34	WSE only[5]		673.21
138.1	9/30/2012	14:52	WSE only[5]		669.36						8/5/2013 8/10/2013	13:21 16:12	WSE only[5] WSE only[5]		669.70 669.46
137.7															
137.6	9/30/2012	15:00	17,400	Excellent	662.58						8/10/2013	16:51	15,700	Excellent	662.13
137.2											8/5/2013	17:22	WSE only[5]		658.44
136.8															
136.7											8/5/2013	17:54	WSE only[5]		653.47
136.2											8/6/2013	11:24	WSE only[5]		648.21
135.6											8/6/2013	12:54	WSE only[5]		640.17
135.4															
135.2															
135.0											8/6/2013	13:39	WSE only[5]		633.09
134.7											8/6/2013	15:31	WSE only[5]		631.40
134.3	10/1/2012	13:40	15,600	Excellent	625.68						8/6/2013	14:45	WSE only[5]		625.99
134.1											8/7/2013	10:45	WSE only[5]		623.64
133.8											8/7/2013	11:01	WSE only[5]		622.05
133.3											8/7/2013	5:45	WSE only[5]		618.23
132.6											8/7/2013	12:00	WSE only[5]		608.61
132.0											8/7/2013	13:18	WSE only[5]		601.78
131.4											8/7/2013	14:34	WSE only[5]		597.89
130.9											8/8/2013	13:27	WSE only[5]		592.37
130.4											8/9/2013	6:49	WSE only[5]		585.67
130.1															
129.7	10/1/2012	16:16	15,700	Excellent	579.02	6/27/2013	11:38	WSE only[5]		580.28					
128.1											8/9/2013	15:02	WSE only[5]		562.69
127.8											8/9/2013	15:44	WSE only[5]		560.66
127.4															
126.8	10/1/2012	17:02	15,600	Excellent	551.04	7/9/2013	13:24	23,100	Good	552.15	8/11/2013	12:26	16,200	Excellent	550.96
126.4											8/10/2013	13:58	WSE only[5]		547.78
126.1											8/11/2013	12:48	WSE only[5]		544.76
125.9															
125.8											8/11/2013	14:10	WSE only[5]		543.45
125.4											8/10/2013	15:15	WSE only[5]		540.55
124.9											8/11/2013	12:56	WSE only[5]		535.81
124.6															
124.5											8/11/2013	14:57	WSE only[5]		531.40
124.1	10/1/2012	17:42	15,600	Good	529.40	7/9/2013	14:14	22,500	Good	530.21	8/11/2013	13:32	16,600	Excellent	529.32
123.9															
123.7											8/11/2013	16:15	WSE only[5]		528.09
123.2											8/12/2013	12:45	WSE only[5]		521.89
122.7											8/12/2013	1:09	WSE only[5]		518.85
122.6											8/12/2013	12:26	WSE only[5]		517.56
122.1											8/12/2013	6:30	WSE only[5]		512.92
121.4											8/12/2013	15:04	WSE only[5]		508.79
120.7											8/12/2013	16:34	WSE only[5]		502.32
120.3											8/12/2013	8:40	WSE only[5]		498.48
119.9	10/3/2012	14:47	14,000	Excellent	493.97	7/9/2013	17:10	22,700	Excellent	495.34	8/14/2013	11:38	WSE only[5]		494.54
119.5															
118.9											8/14/2013	12:06	WSE only[5]		489.01
118.3	10/3/2012	14:39	WSE only[5]		484.62						8/14/2013	13:27	WSE only[5]		484.58
118.1															
117.9											8/14/2013	14:11	WSE only[5]		481.58
117.4											8/14/2013	16:10	WSE only[5]		477.65
117.0											8/14/2013	14:37	WSE only[5]		471.85

Project River Mile (PRM)	September/October 2013					June/July 2014					August 2014					September 2014				
	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]
141.9	9/5/2013	15:39	WSE only[5]		712.73						8/13/2014	14:49	17,400	Good	710.73					
141.7	9/5/2013	15:53	WSE only[5]		711.76															
141.4						6/29/2014	14:17	WSE only[5]		706.46										
141.2	9/6/2013	11:27	WSE only[5]		705.26															
140.8	9/6/2013	11:39	WSE only[5]		702.23															
140.5	9/6/2013	12:31	WSE only[5]		698.50															
140.2						6/30/2014	10:22	WSE only[5]		694.52										
140.0	9/6/2013	12:29	WSE only[5]		693.56															
139.8	9/6/2013	12:39	WSE only[5]		691.01															
139.0	9/6/2013	12:50	WSE only[5]		679.90	6/23/2014	16:57	22,300	Good	678.89	8/13/2014	16:35	17,600	Good	678.19	9/17/2014 9/27/2014	11:15 14:11	21,000 12,000	Good Excellent	678.75 NA
138.7	9/6/2013	13:15	WSE only[5]		678.55															
138.4	9/6/2013	13:27	WSE only[5]		674.41	6/24/2014	12:40	20,900	Good[4]	673.61	8/18/2014	11:08	21,100	Good[4]	673.55	9/17/2014	13:04	20,700	Good[4]	673.47
138.1	9/6/2013	9:10	WSE only[5]		670.74															
137.7						6/25/2014	12:49	WSE only[5]		664.64										
137.6	9/6/2013	14:20	WSE only[5]		663.95															
137.2	9/6/2013	17:07	WSE only[5]		659.83															
136.8						6/25/2014	14:55	WSE only[5]		655.62										
136.7	9/6/2013	17:21	WSE only[5]		654.78															
136.2	9/6/2013	17:36	WSE only[5]		649.06															
135.6	9/6/2013	17:51	WSE only[5]		641.23															
135.4						6/30/2014	11:47	WSE only[5]		639.33										
135.2						7/1/2014	12:56	WSE only[5]		637.15										
135.0	9/6/2013	18:04	WSE only[5]		635.01															
134.7	9/6/2013	18:14	WSE only[5]		632.73															
134.3	9/6/2013	18:24	WSE only[5]		628.13															
134.1	9/12/2013	13:24	WSE only[5]		626.31															
133.8	9/12/2013	13:35	WSE only[5]		624.06															
133.3	9/12/2013	13:52	WSE only[5]		618.70															
132.6	9/12/2013	14:09	WSE only[5]		610.90															
132.0	9/12/2013	14:25	WSE only[5]		604.41															
131.4	9/10/2013	14:29	WSE only[5]		598.97															
130.9	9/10/2013	13:57	WSE only[5]		592.97															
130.4	9/10/2013	13:11	WSE only[5]		587.41															
130.1						7/1/2014	15:23	WSE only[5]		583.92										
129.7	9/10/2013	11:43	WSE only[5]		580.53															
128.1											8/18/2014	14:22	21,600	Good[4]	562.47					
127.8																				
127.4						7/1/2014	16:20	WSE only[5]		558.37										
126.8	9/12/2013	16:52	31,100	Good	552.79															
126.4																				
126.1																				
125.9						7/2/2014	14:25	WSE only[5]		546.78										
125.8																				
125.4																				
124.9																				
124.6						6/30/2014	12:48	WSE only[5]		533.64										
124.5																				
124.1	9/10/2013 9/12/2013	13:51 17:41	WSE only[5] 30,600	 Good	530.81 531.16											9/17/2014	15:39	21,300	Good	529.81
123.9						6/30/2014	15:06	WSE only[5]		529.84										
123.7	9/10/2013	11:38	WSE only[5]		528.61															
123.2																				
122.7	9/9/2013	15:48	WSE only[5]		520.10															
122.6	9/9/2013	15:33	WSE only[5]		518.69															
122.1																				
121.4																				
120.7	9/9/2013	15:18	WSE only[5]		503.32															
120.3																				
119.9	9/9/2013	9:59	WSE only[5]		496.49															
119.5						7/1/2014	13:13	WSE only[5]		492.91										
118.9																				
118.3	9/9/2013	13:45	WSE only[5]		486.42															
118.1						7/1/2014	14:03	WSE only[5]		484.17										
117.9																				
117.4	9/9/2013	13:18	WSE only[5]		478.57															
117.0																				

MIDDLE RIVER (PRM 187.1 - 102.4)

Project River Mile (PRM)	XS Profile /Bathy Date	XS Profile /Bathy Date 2	June/July 2012 Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	August 2012 Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	September/October 2012 Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]
116.9	7/2/2014																
116.6	7/7/2012		7/7/2012	17:36	20,700	Excellent	468.98	8/16/2012	14:15	16,100	Excellent	468.16	10/3/2012	15:53	14,300	Excellent	467.97
116.3	7/8/2012		7/8/2012	12:42	23,800	Excellent	467.39	8/16/2012	14:49	WSE only[5]		466.24					
115.7	7/8/2012		7/8/2012	14:05	25,000	Excellent	461.95	8/16/2012	15:17	WSE only[5]		461.01					
115.4	7/8/2012		7/8/2012	16:13	26,000	Excellent	458.41	8/16/2012	15:44	WSE only[5]		456.99					
114.4	7/8/2012		7/8/2012	18:29	25,900	Excellent	450.21	8/16/2012	16:07	WSE only[5]		448.97					
113.6	7/9/2012	10/3/2012	7/9/2012	14:23	28,300	Excellent	444.75	8/16/2012	16:38	16,300	Excellent	443.10	10/3/2012	16:41	13,500	Excellent	442.90
113.1	8/15/2013																
112.5	8/15/2013																
111.9	7/9/2012		7/9/2012	15:23	28,300	Good	429.73	8/17/2012	14:02	WSE only[5]		427.98					
111.2	7/2/2014																
110.5	7/9/2012	10/3/2012	7/9/2012	16:46	28,800	Good	417.55	8/17/2012	14:57	15,300	Excellent	415.70	10/3/2012	17:33	14,200	Excellent	415.49
109.7	7/3/2014																
109.0	8/15/2013																
108.3	8/18/2012							8/17/2012	17:55	16,400	Good	396.50					
107.8	8/15/2013																
107.4	7/3/2014																
107.1	7/9/2012		7/9/2012	18:26	28,400	Good	387.63	8/18/2012	13:12	15,500	Excellent	385.44	10/4/2012	14:10	14,600	Excellent	385.12
106.9	7/3/2014																
106.6	8/15/2013																
106.1	8/18/2012							8/18/2012	14:22	15,300	Excellent	377.95	10/4/2012	14:26	WSE only[5]		377.75
105.3	8/18/2012							8/18/2012	15:52	15,400	Excellent	372.01					
104.7	8/18/2012							8/18/2012	17:48	15,400	Excellent	367.05	10/4/2012	14:58	WSE only[5]		366.93
104.1	8/19/2012							8/19/2012	12:49	15,300	Excellent	364.79					
103.5	10/1/2012												10/4/2012	16:49	14,600	Excellent	359.89
102.7	7/10/2012		7/10/2012	13:53	26,600	Good	352.87	8/19/2012	15:05	WSE only[5]		351.70					

Project River Mile (PRM)	June/July 2013 Date	Time	Q, cfs	Q Rating[2]	WSE[3]	August 2013 Date	Time	Q, cfs	Q Rating[2]	WSE[3]	September/October 2013 Date	Time	Q, cfs	Q Rating[2]	WSE[3]
116.9															
116.6	7/9/2013	15:55	22,900	Excellent	469.33	8/14/2013	14:00	18,100	Excellent	468.71	9/9/2013 9/13/2013	12:31 12:05	WSE only[5] 30,800	 Good	470.52 470.62
116.3	7/23/2013	10:40	WSE only[5]		466.98	8/14/2013	12:50	WSE only[5]		466.79					
115.7						8/14/2013	12:30	WSE only[5]		461.83					
115.4	7/5/2013 7/23/2013	15:46 15:20	WSE only[5] WSE only[5]		457.29 457.50	8/14/2013	12:17	WSE only[5]		457.30					
114.4						8/13/2013 8/14/2013	16:01 16:25	WSE only[5] WSE only[5]		449.42 449.39					
113.6						8/14/2013 8/14/2013	12:48 16:12	WSE only[5] 18,100	 Excellent	443.28 443.45					
113.1						8/14/2013 8/15/2013	17:30 11:00	WSE only[5] WSE only[5]		439.27 438.67					
112.5						8/15/2013	13:07	WSE only[5]		432.60					
111.9						8/15/2013	14:05	WSE only[5]		428.51					
111.2															
110.5						8/15/2013	14:32	WSE only[5]		416.25					
109.7															
109.0						8/15/2013	14:13	WSE only[5]		403.26					
108.3						8/15/2013	13:23	WSE only[5]		397.46	9/7/2013	13:51	WSE only[5]		398.01
107.8						8/15/2013	12:56	WSE only[5]		391.77					
107.4															
107.1	7/11/2013	16:50	19,700	Excellent	385.92	8/15/2013	15:53	18,900	Excellent	385.64	9/7/2013 9/15/2013	12:57 12:09	WSE only[5] 21,700	 Excellent	387.46 386.36
106.9															
106.6						8/15/2013	10:49	WSE only[5]		382.41					
106.1						8/15/2013	10:08	WSE only[5]		378.31	9/7/2013	12:40	WSE only[5]		380.10
105.3						8/16/2013	10:05	WSE only[5]		372.44	9/7/2013	23:05	WSE only[5]		374.10
104.7						8/16/2013	10:29	WSE only[5]		367.15					
104.1						8/16/2013	10:56	WSE only[5]		365.31	9/6/2013	12:10	WSE only[5]		366.38
103.5						8/16/2013	11:24	WSE only[5]		359.88	9/6/2013	11:54	WSE only[5]		361.21
102.7						8/16/2013	10:32	WSE only[5]		352.66					

Project River Mile (PRM)	June/July 2014 Date	Time	Q, cfs	Q Rating[2]	WSE[3]	August 2014 Date	Time	Q, cfs	Q Rating[2]	WSE[3]	September 2014 Date	Time	Q, cfs	Q Rating[2]	WSE[3]
116.9	7/2/2014	16:58	WSE only[5]		472.94										
116.6															
116.3															
115.7															
115.4															
114.4															
113.6															
113.1															
112.5															
111.9															
111.2	7/2/2014	18:20	WSE only[5]		423.99										
110.5															
109.7	7/3/2014	12:08	WSE only[5]		412.49										
109.0															
108.3															
107.8															
107.4	7/3/2014	12:48	WSE only[5]		390.69										
107.1	7/3/2014	12:59	41,700	Good	389.00										
106.9	7/3/2014	13:31	WSE only[5]		387.77										
106.6															
106.1															
105.3															
104.7	7/3/2014	16:09	41,500	Fair [4]	369.85	8/18/2014	18:27	21,700	Good [4]	367.75					
104.1															
103.5															
102.7															

LOWER RIVER (PRM 102.4 - 3.3)

Project River Mile (PRM)	XS Profile /Bathy Date	XS Profile /Bathy Date 2	June/July 2012 Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	August 2012 Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	September/October 2012 Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]
102.1	8/16/2013																
101.4	7/10/2012	10/15/2012	7/10/2012	16:28	WSE only[5]		346.09	8/19/2012	15:54	WSE only[5]		344.82	10/15/2012	15:31	WSE only[5]		344.68
100.7	6/10/13 - 6/11/13, 7/17/2013																
99.9	6/10/13 - 6/11/13, 7/17/2013																
98.4	7/11/2012	10/5/2012	7/11/2012	14:09	46,500	Good	326.86	8/20/2012	14:51	40,600	Good	326.37	10/5/2012	14:37	39,100	Excellent	326.08
97.0	7/11/2012		7/11/2012	18:27	45,100	Good	318.49	8/20/2012	17:03	40,300	Excellent	318.38	10/5/2012	15:18	WSE only[5]		318.21
96.2	6/12/2013																
95.3	7/4/2014,7/5/2014																
94.8	6/12/2013, 7/18/2013																
94.0	6/13/2013																
93.2	6/13/2013																
92.3	6/13/2013, 7/18/2013																
91.6	8/21/2012							8/21/2012	14:55	46,300	Excellent	285.74					
91.0	7/12/2012		7/12/2012	15:39	43,900	Good	282.34	8/21/2012	16:51	46,200	Excellent	282.34					
90.2	6/14/2013																
89.5	6/14/2013																
88.4	8/22/2012							8/22/2012	15:01	41,700	Excellent	268.25					
88.0	6/15/2013																
87.6	6/15/2013																
87.1	7/12/2012		7/12/2012	18:00	42,600	Excellent	263.24	8/22/2012	17:33	WSE only[5]		262.89					
86.3	7/13/2012		7/13/2012	13:13	41,900	Excellent	258.59	8/22/2012	17:54	WSE only[5]		258.39					
85.4	8/22/2012							8/22/2012	18:01	40,500	Excellent	255.18					
84.4	8/23/2012							8/23/2012	15:16	37,000	Good	251.19					
83.0	7/13/2012		7/13/2012	16:09	42,000	Excellent	245.29	8/23/2012	16:33	WSE only[5]		244.93					
82.3	8/23/2012							8/23/2012	17:52	37,900	Good	241.19					
81.4	6/16/2013																
80.7	6/16/2013																
80.0	8/24/2012							8/24/2012	15:07	36,600	Excellent	229.51					

Project River Mile (PRM)	June/July 2013 Date	Time	Q, cfs	Q Rating[2]	WSE[3]	August 2013 Date	Time	Q, cfs	Q Rating[2]	WSE[3]	September/October 2013 Date	Time	Q, cfs	Q Rating[2]	WSE[3]
102.1						8/16/2013	14:11	WSE only[5]		348.19					
101.4															
100.7	6/10/2013 7/17/2013	6:10 14:28	WSE only[5] WSE only[5]		341.09 342.11	8/1/2013	14:00	WSE only[5]		341.54					
99.9	6/10/2013 6/11/2013	15:53 11:57	WSE only[5] WSE only[5]		337.43 338.15	8/1/2013	14:55	WSE only[5]		336.51					
98.4						8/1/2013	15:15	WSE only[5]		327.62					
97.0						8/1/2013	15:55	WSE only[5]		319.19					
96.2	6/12/2013	11:06	WSE only[5]		315.50	8/1/2013	16:23	WSE only[5]		315.28					
95.3															
94.8	6/12/2013 7/18/2013	12:29 10:30	WSE only[5] WSE only[5]		307.57 305.77	8/1/2013 8/2/2013	15:40 11:49	53,800 WSE only[5]	Good [4]	306.38 306.16					
94.0	6/13/2013 7/18/2013	13:02 10:58	WSE only[5] WSE only[5]		301.54 300.72										
93.2	6/13/2013	15:42	WSE only[5]		297.59	8/2/2013	12:21	WSE only[5]		296.23					
92.3	6/13/2013 7/18/2013	5:36 7:01	WSE only[5] WSE only[5]		292.79 291.17	8/2/2013	14:08	WSE only[5]		291.73					
91.6						8/2/2013	16:27	WSE only[5]		286.54					
91.0						8/2/2013	16:40	WSE only[5]		283.58					
90.2	6/14/2013	13:24	WSE only[5]		280.51	8/3/2013	13:00	51,900	Good [4]	279.73					
89.5	6/14/2013 7/18/2013	7:30 15:36	WSE only[5] WSE only[5]		276.16 274.24	8/2/2013	17:01	WSE only[5]		275.58					
88.4						8/3/2013	11:00	WSE only[5]		269.39					
88.0	6/15/2013	11:18	WSE only[5]		268.19	8/3/2013	13:20	WSE only[5]		266.71					
87.6	6/15/2013	13:29	WSE only[5]		267.00	8/3/2013	16:23	52,700	Excellent	265.99					
87.1						8/3/2013	14:17	WSE only[5]		264.23					
86.3						8/3/2013	16:33	WSE only[5]		259.92					
85.4						8/3/2013	17:10	WSE only[5]		256.22					
84.4						8/3/2013	17:00	WSE only[5]		252.05					
83.0						8/4/2013	14:30	WSE only[5]		245.63					
82.3						8/4/2013	14:00	WSE only[5]		242.01					
81.4	6/16/2013	11:47	WSE only[5]		238.57	8/4/2013	13:33	WSE only[5]		237.22					
80.7	6/16/2013	13:44	WSE only[5]		235.84	8/4/2013	11:02	WSE only[5]		234.64					
80.0						8/4/2013	12:56	WSE only[5]		230.55					

Project River Mile (PRM)	June/July 2014 Date	Time	Q, cfs	Q Rating[2]	WSE[3]	August 2014 Date	Time	Q, cfs	Q Rating[2]	WSE[3]	September 2014 Date	Time	Q, cfs	Q Rating[2]	WSE[3]
102.1															
101.4															
100.7															
99.9															
98.4	7/4/2014	13:39	74,600	Good [4]	328.46						9/18/2014	15:53	50,600	Good [4]	326.97
97.0															
96.2															
95.3	7/4/2014, 7/5/2014	over 2 days	WSE only[5]		309.73										
94.8															
94.0															
93.2															
92.3															
91.6															
91.0															
90.2															
89.5															
88.4															
88.0															
87.6															
87.1															
86.3															
85.4															
84.4															
83.0															
82.3															
81.4															
80.7															
80.0															

LOWER RIVER (PRM 102.4 - 3.3)

Project River	XS Profile	XS Profile	June/July 2012					August 2012					September/October 2012				
Mile (PRM)	/Bathy Date	/Bathy Date 2	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]
79.0	6/17/2013																
78.0	6/17/2013																
77.0	6/18/2013																
75.9	6/18/2013, 8/20/2013																
75.0	6/19/2013																
74.1	6/19/2013, 8/20/2013																
73.1	6/20/2013																
71.0	6/20-6/22, 8/26/2013																
69.2	6/23/2013																
68.2	6/24/2013- 6/25/2013																
67.2	6/25/2013																
66.1	6/25/2013- 6/26/2013																
64.6	6/26/2013																
62.7	6/27/2013																
60.3	6/27/2013																
59.1	6/28/2013																
57.8	6/28/2013																
55.4	6/29/2013																
54.2	6/30/2013																
52.1	7/2/2013 - 7/3/2013																
49.0	7/4/2013, 7/6/2013																
47.9	7/4/2013, 7/6/2013																
47.1	7/5/2013																
46.3	7/5/2013, 7/7/2013																
45.6	7/7/2013																
44.5	7/7/2013																
41.3	7/8/2013																
40.4	7/8/13 - 7/10/2013																
39.5	7/10/13 - 7/12/2013																
38.3	7/11/13 - 7/13/2013																
36.4	7/11/2013 - 7/13/2013																
34.8	7/14/2013																
33.7	7/14/2013																
32.4	7/15/2013																
31.6	7/15/2013																
30.8	7/14/2014																
29.9	7/15/2013												9/11/2012	15:05	WSE only[5]		40.16

Project River	June/July 2013					August 2013				
Mile (PRM)	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]
79.0	6/17/2013	12:21	WSE only[5]		226.66	8/4/2013	12:33	WSE only[5]		225.93
78.0	6/17/2013	13:38	WSE only[5]		221.54	8/4/2013	12:32	52,100	Good [4]	220.90
77.0	6/18/2013	10:08	WSE only[5]		215.46					
75.9	6/18/2013	8:33	WSE only[5]		209.14	8/5/2013 8/20/2013	12:40 6:05	WSE only[5] WSE only[5]		207.19 208.22
75.0	6/19/2013	12:07	WSE only[5]		205.04					
74.1	6/19/2013	14:29	WSE only[5]		200.98	8/5/2013 8/20/2013	13:12 13:02	WSE only[5] WSE only[5]		199.62 199.48
73.1	6/20/2013	13:54	WSE only[5]		194.77	8/5/2013	13:28	51,100	Good [4]	193.41
71.0	6/20/2013 6/21/2013	15:12 13:41	WSE only[5] WSE only[5]		182.36 182.89	8/26/2013	16:06	WSE only[5]		181.26
69.2	6/23/2013	12:38	WSE only[5]		171.39	8/5/2013	16:09	WSE only[5]		170.71
68.2	6/25/2013	0:48	WSE only[5]		166.79	8/5/2013	16:54	WSE only[5]		166.43
67.2	6/25/2013	13:02	WSE only[5]		161.48	8/6&7/2013	NA	45,400	Fair [4]	160.18
66.1	6/25/2013	15:09	WSE only[5]		155.90	8/6/2013	12:46	WSE only[5]		155.12
64.6	6/27/2013	13:41	WSE only[5]		150.46	8/6/2013	13:30	WSE only[5]		149.75
62.7	6/27/2013	12:17	WSE only[5]		141.33	8/6/2013	13:57	WSE only[5]		141.07
60.3	6/27/2013	13:39	WSE only[5]		131.89	8/6/2013	14:51	WSE only[5]		130.95
59.1	6/28/2013	11:35	WSE only[5]		126.07					
57.8	6/28/2013	9:55	WSE only[5]		120.33	8/6/2013 8/27/2013	15:19 13:40	WSE only[5] WSE only[5]		119.04 119.21
55.4	6/29/2013	12:48	WSE only[5]		110.65	8/27/2013	14:37	WSE only[5]		109.84
54.2	6/30/2013	8:51	WSE only[5]		104.51	8/27/2013	15:54	WSE only[5]		102.80
52.1	7/2/2013 7/3/2013	16:39 12:52	WSE only[5] WSE only[5]		96.88 98.97	8/28/2013	16:14	WSE only[5]		94.06
49.0	7/4/2013	12:26	WSE only[5]		83.55	8/28/2013	14:49	WSE only[5]		82.58
47.9	7/4/2013	14:34	WSE only[5]		79.97	8/28/2013	14:27	WSE only[5]		79.22
47.1	7/5/2013	12:38	WSE only[5]		77.10	8/28/2013	14:12	WSE only[5]		76.06
46.3	7/5/2013 7/7/2013	11:21 11:02	WSE only[5] WSE only[5]		72.84 72.15	8/28/2013	17:01	WSE only[5]		72.16
45.6	7/7/2013	12:13	WSE only[5]		71.35	8/29/2013	12:25	WSE only[5]		71.59
44.5	7/7/2013	13:42	WSE only[5]		68.30	8/29/2013	13:00	WSE only[5]		68.73
41.3	7/8/2013	12:41	WSE only[5]		61.84	8/29/2013	14:40	WSE only[5]		62.10
40.4	7/8/2013	13:07	WSE only[5]		60.14	8/29/2013	14:20	WSE only[5]		60.76
39.5	7/10/2013	15:10	WSE only[5]		58.48	8/29/2013	14:55	WSE only[5]		58.71
38.3	7/12/2013 7/18/2013	12:46 15:43	WSE only[5] WSE only[5]		55.34 55.56	8/29/2013	15:15	WSE only[5]		55.49
36.4	7/13/2013	2:18	WSE only[5]		50.82	8/30/2013	14:30	WSE only[5]		51.05
34.8	7/14/2013	12:57	WSE only[5]		47.35					
33.7	7/14/2013	14:13	WSE only[5]		46.41	8/30/2013	13:30	WSE only[5]		46.17
32.4	7/15/2013	10:58	WSE only[5]		45.33	8/30/2013	12:56	WSE only[5]		45.03
31.6	7/15/2013	13:24	WSE only[5]		44.64					
30.8										
29.9	7/15/2013	13:18	WSE only[5]		42.42	8/30/2013	12:31	WSE only[5]		41.43

Project River	September/October 2013				
Mile (PRM)	Date	Time	Q, cfs	Q Rating[2]	WSE[3]
79.0					
78.0	9/20/2013	16:59	WSE only[5]		219.48
77.0					
75.9	9/20/2013	15:49	WSE only[5]		206.23
75.0					
74.1					
73.1	9/20/2013	14:43	WSE only[5]		192.32
71.0	9/20/2013	9:14	WSE only[5]		180.38
69.2	9/20/2013	13:07	WSE only[5]		170.12
68.2					
67.2	9/20/2013	12:42	WSE only[5]		159.69
66.1					
64.6	9/20/2013	11:51	WSE only[5]		148.97
62.7	9/20/2013	11:31	WSE only[5]		139.84
60.3	9/18/2013	12:28	WSE only[5]		130.98
59.1					
57.8	9/18/2013	8:56	WSE only[5]		118.63
55.4	9/18/2013	13:52	WSE only[5]		109.09
54.2	9/16&17/2013 9/18/2013	NA 9:26	50,600 WSE only[5]	Fair [4]	103.00 102.48
52.1					
49.0	9/12/2013 9/18/2013	14:08 12:26	WSE only[5] 44,100	Good [4]	84.95 82.72
47.9					
47.1					
46.3	9/12/2013 9/18/2013	14:46 11:07	WSE only[5] WSE only[5]		76.91 71.93
45.6					
44.5	9/12/2013 9/18/2013	15:28 11:24	WSE only[5] WSE only[5]		72.70 68.28
41.3					
40.4	9/19/2013	12:34	44,500	Good [4]	60.03
39.5	9/12/2013 9/19/2013	15:55 8:37	WSE only[5] WSE only[5]		61.22 58.11
38.3					
36.4	9/20/2013	13:17	40,900	Good [4]	50.05
34.8	9/12/2013 9/15/2013 9/19/2013 9/21/2013	16:24 14:58 13:00 12:18	WSE only[5] WSE only[5] WSE only[5] 38,100	Excellent [4]	52.09 47.76 46.79 46.15
33.7					
32.4					
31.6					
30.8					
29.9	9/9/2013 9/19/2013	17:19 9:42	WSE only[5] WSE only[5]		46.03 40.65

Project River	June/July 2014					August 2014					September 2014				
Mile (PRM)	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]
79.0															
78.0															
77.0															
75.9															
75.0															
74.1															
73.1															
71.0															
69.2															
68.2															
67.2															
66.1															
64.6															
62.7															
60.3															
59.1															
57.8															
55.4															
54.2															
52.1															
49.0															
47.9															
47.1															
46.3															
45.6															
44.5															
41.3															
40.4															
39.5															
38.3															
36.4															
34.8															
33.7															
32.4															
31.6															
30.8	7/14/2014	14:34	WSE only[5]		46.11										
29.9															

extra Q mmt at Sunshine (beneath June/July 2014)

extra Q mmt at Sunshine and at FA151 (beneath September 2014)

[1] Data approved by HDR Alaska, Inc. (See HDR, 2013)

[2] Q measurement rated according to guidance of U.S. Geological Survey, Office of Surface Water (see USGS OSW, 2012)

[3] WSE = water surface elevation (feet, NAVD 88). WSE was measured during, or within 2 hours of, the flow measurement, typically at left and right banks of all channels . The average WSE of the main channel is reported here.

[4] 2013/2014 multiple channel measurement. Q rating methodology adapted for summing multiple channel Q measurements (see ISR Section 8.5, Appendix C)

[5] Only water surface elevation (WSE) was measured at these cross sections. Flows to be estimated by interpolating/synthesizing from nearby stations.

Not measured concurrently with Q (or reasonably close in time). Pairing of Q and WSE may not be appropriate.

Known channel change affects WSE measurements.

In post processing transects for calibration, the designation of the main channel was changed. Therefore, by the new designation, these WSE measurements are on a side channel.

Following the 2012 flood, measurements show noteworthy change in the channel cross section. The post flood bathymetry has been adopted, therefore these measurements **might not** reflect the current channel geometry.

NA WSE not provided.

Table3. Summary of low, medium, and high flow measurements collected between 2012 and 2014 on mainstem transects of the Susitna River.

PRM	Low	Medium	High	PRM	Low	Medium	High
187.2		✓✓	✓✓	118.3	✓✓	✓✓	✓
186.6				117.9		✓✓	
186.2	✓✓	✓✓	✓✓	117.4	✓✓	✓✓	✓
185.5	✓✓	✓✓	✓✓	117		✓✓	
185.2	✓✓	✓✓	✓✓	116.6	✓✓	✓✓	✓✓
184.9	✓✓	✓✓	✓✓	116.3	✓✓	✓✓	✓✓
184.7	✓✓	✓✓	✓✓	115.7	✓✓	✓✓	✓✓
184.4	✓✓		✓✓	115.4	✓✓	✓✓	✓✓
183.3	✓✓		✓✓	114.4	✓✓	✓✓	✓✓
182.9	✓✓		✓✓	113.6	✓✓	✓✓	✓✓
181.6	✓✓		✓✓	113.1		✓✓	
180.7	✓✓			112.5		✓	
179.5	✓✓		✓✓	111.9	✓✓	✓	✓✓
178.5	✓✓		✓✓	110.5	✓✓	✓	✓✓
177.3	✓✓			109		✓✓	
176.5	✓✓	✓✓	✓✓	108.3		✓✓	✓
174.9	✓✓		✓✓	107.8		✓✓	
173.5	✓✓	✓✓	✓✓	107.1	✓✓	✓✓	✓✓
173.1	✓✓		✓✓	106.6		✓✓	
170.1	✓✓		✓✓	106.1	✓✓	✓✓	✓
168.8	✓✓			105.3	✓✓	✓	✓
168.1	✓✓	✓✓	✓✓	104.7	✓✓	✓✓	✓✓
153.7	✓✓		✓✓	104.1	✓✓	✓	✓
152.9	✓✓		✓✓	103.5	✓✓	✓	✓
152.1	✓✓	✓✓	✓✓	102.7	✓✓	✓	✓✓
151.8	✓✓	✓✓		102.1		✓	
151.1	✓✓	✓✓	✓✓	101.4	✓	✓	
150.1		✓✓		100.7		✓	✓
148.3	✓✓	✓✓	✓✓	99.9		✓✓	✓
147.5		✓✓		98.4	✓✓	✓✓	✓✓
146.6	✓	✓✓	✓✓	97	✓	✓✓	
146.1		✓	✓	96.2		✓✓	✓
145.7	✓✓	✓✓	✓✓	94.8		✓✓	✓
145.5	✓✓	✓	✓✓	94		✓	✓
144.9	✓✓	✓✓	✓✓	93.2		✓	✓
144.3	✓✓	✓	✓✓	92.3		✓	✓
143.9		✓	✓	91.6	✓✓	✓	
143.5	✓✓	✓✓	✓✓	91	✓✓	✓	
143	✓✓	✓	✓✓	90.2		✓✓	✓
142.2	✓✓	✓✓	✓✓	89.5		✓	✓

PRM	Low	Medium	High	PRM	Low	Medium	High
141.9	✓✓	✓	✓✓	88.4	✓✓	✓✓	
141.7	✓✓	✓	✓✓	88		✓✓	✓
141.2		✓	✓	87.6		✓✓	✓
140.8		✓	✓	87.1	✓✓	✓✓	
140.5		✓	✓	86.3	✓	✓✓	
140	✓✓	✓	✓✓	85.4	✓✓	✓	
139.8	✓✓	✓	✓✓	84.4	✓✓	✓	
139	✓✓	✓✓	✓✓	83	✓✓	✓	
138.7	✓✓	✓	✓✓	82.3	✓✓	✓	
138.4		✓✓	✓	81.4		✓	✓
138.1	✓✓	✓	✓✓	80.7		✓	✓
137.6	✓✓	✓	✓✓	80	✓✓	✓✓	
137.2		✓	✓	79		✓✓	✓
136.7	✓✓	✓✓	✓✓	78	✓	✓✓	✓
136.2	✓✓	✓✓	✓✓	77			✓
135.6	✓	✓	✓	75.9	✓	✓✓	✓
135	✓✓	✓✓	✓✓	75			✓
134.7	✓	✓	✓	74.1		✓✓	✓
134.3	✓✓	✓	✓✓	73.1	✓	✓✓	✓
134.1	✓✓	✓	✓✓	71	✓	✓✓	✓
133.8	✓✓	✓	✓✓	69.2	✓	✓	✓
133.3	✓✓	✓	✓✓	68.2		✓	
132.6	✓✓	✓	✓✓	67.2	✓	✓✓	
132	✓	✓	✓	66.1		✓✓	
131.4	✓✓	✓	✓✓	64.6	✓	✓	✓
130.9	✓	✓	✓	62.7	✓	✓	✓
130.4	✓	✓	✓	60.3	✓	✓	✓
129.7	✓✓		✓✓	59.1			✓
128.1	✓✓	✓✓	✓✓	57.8	✓	✓	✓
127.8	✓			55.4	✓	✓	✓
126.8	✓✓	✓✓	✓✓	54.2	✓	✓✓	✓
126.4	✓			52.1			✓
126.1	✓✓	✓	✓✓	49	✓✓	✓	✓
125.8	✓✓			47.9		✓	
125.4	✓✓	✓	✓✓	47.1		✓	
124.9	✓✓			46.3	✓	✓	✓
124.5	✓✓			45.6	✓	✓	
124.1	✓✓	✓✓	✓✓	44.5	✓	✓	✓
123.7	✓✓	✓✓	✓	41.3	✓	✓	
123.2		✓		40.4	✓✓	✓	
122.7	✓✓	✓✓	✓	39.5	✓✓	✓	✓
122.6	✓✓	✓✓	✓	38.3		✓	
122.1		✓		36.4	✓✓	✓	

PRM	Low	Medium	High	PRM	Low	Medium	High
121.4		✓		34.8	✓✓	✓	✓
120.7	✓✓	✓✓	✓	33.7		✓	
120.3		✓		32.4		✓	
119.9	✓✓	✓✓	✓	31.6		✓	
118.9		✓		29.9	✓	✓	✓

Notes:

1 ✓WSE and estimated streamflow ✓✓WSE and measured streamflow.

Table 4. Focus Area pressure transducer site locations.

Focus Area	Name	PRM	Latitude	Longitude
151	Portage Creek – downstream	151.8	62.829458	-149.395588
144	Slough 21 – upstream	145.7	62.818930	-149.576018
144	Slough 21 – downstream	144.3	62.803036	-149.601279
141	Indian River – downstream	141.9	62.784096	-149.662469
138	Gold Creek - downstream	138.5	62.753528	-149.719407
128	Slough 8A – Upstream	129.7	62.671285	-149.901254
128	Slough 8 A - downstream	128.2	62.660587	-149.939926
115	Slough 6A - Downstream	115.4	62.507323	-150.113471
113	Oxbow 1 - Downstream	113.6	62.485240	-150.098638
104	Whiskers Slough – upstream	106	62.383478	-150.142623
104	Whiskers Slough – downstream	104.8	62.370041	-150.165218

Table 5. Tributary gaging site information.

Tributary Name	Susitna PRM	Gage Site Type	Data Collection Years	Latitude	Longitude
Oshetna River [1]	235.1	Continuous	2013-2014	62.628520	-147.369830
Kosina Creek [1]	209.1	Continuous with barologger	2013-2014	62.755970	-147.955150
Tsusena Creek [1]	184.6	Continuous	2014	62.825689	-148.609891
Fog Creek [1]	179.3	Spot	2014	62.774199	-148.705479
Unnamed Tributary 174.3	174.3	Spot	2014	62.765622	-148.842813
Unnamed Tributary 173.8	173.8	Spot	2014	62.767920	-148.857384
Portage Creek [1]	152.3	Continuous	2014	62.833177	-149.378048
Unnamed Tributary 144.6	144.6	Spot	2013-2014	62.803980	-149.591350
Indian River [1]	142.1	Continuous	2013-2014	62.800881	-149.664233
Gold Creek [1]	140.1	Continuous	2014	62.762437	-149.676828
Skull Creek [1]	128.1	Continuous with barologger	2013-2014	62.657530	-149.932540
Unnamed Tributary 115.4	115.4	Spot	2013-2014	62.508178	-150.114503
Gash Creek [1]	115	Spot	2013-2014	62.504288	-150.104018
Slash Creek	114.9	Spot	2013-2014	62.503202	-150.103737
Unnamed Tributary 113.7 [1]	113.7	Spot	2013-2014	62.486316	-150.093785
Whiskers Creek [1]	105.1	Continuous with barologger	2013-2014	62.378096	-150.170806
Trapper Creek [1]	95.4	Continuous	2013-2014	62.257540	-150.172762
Susitna River at Trapper Creek	95.4	Continuous stage only	2013-2014	62.253622	-150.168375
Birch Creek [1]	93.3	Continuous	2013-2014	62.250468	-150.089622
Susitna River at Birch Creek Slough	92.6	Continuous stage only	2013-2014	62.223373	-150.116821
Sheep Creek [1]	71.7	Continuous	2014	61.996301	-150.052516
Susitna River at Sheep Creek [1]	68.3	Continuous stage only	2014	61.979015	-150.072249
Caswell Creek [1]	67.3	Spot	2014	61.947736	-150.056148
Susitna River at Caswell Creek [1]	67.3	Continuous stage only	2014	61.940156	-150.081047
Deshka River [1]	44.9	Continuous with barologger	2013-2014	61.754522	-150.328552
Susitna River at Deshka River	44.9	Continuous stage only	2013-2014	61.696491	-150.313659

Note:

1 Site schematic located in Attachment 1.

Table 6. Susitna Tributary continuous gaging summary.

Site	Period of Record	Data Gaps	Reason
Oshetna River	7/13/2013-9/18/2014	10/26/2013-5/8/2014	Ice
Kosina Creek	7/13/2013-9/18/2014	10/22/2013-5/6/2014	Ice
Tsusena Creek	6/11/2014-9/19/2014	None	
Portage Creek	6/12/2014-9/18/2014	None	
Indian River	7/11/2013-9/20/2014	10/7/2013-4/19/2014	Ice
Gold Creek	6/13/2014-9/20/2014	None	
Skull Creek	7/12/2013-9/21/2014	11/6/2013-5/2/2014	Ice
Whiskers Creek	6/22/2013-9/23/2014	11/22/2013-12/11/2013 5/3/2014-5/7/2014	Gage backwatered
Trapper Creek	6/17/2013-9/22/2014	11/7/2013-4/25/2014	Ice
Susitna at Trapper Companion gage	6/17/2013-9/22/2014	9/17/2013-6/16/2014	Removed for winter
Birch Creek	7/14/2013-9/24/2014	None	
Susitna at Birch Companion gage	7/14/2013-9/22/2014	9/30/2013-6/16/2014	Removed for winter
Sheep Creek	6/15/2014-9/25/2014	None	
Susitna at Sheep Companion gage	6/18/2014-9/24/2014	None	
Caswell Creek	6/15/2014-9/24/2014	WSE Only; None	
Susitna at Caswell Companion gage	6/18/2014-9/24/2014	None	
Deshka River	7/15/2013-9/25/2014	11/9/2013-5/1/2014	Ice
Susitna at Deshka Companion gage	7/15/2013-8/10/2014	9/27/2013-6/17/2014 8/10/2014-9/25/2014	Removed for winter Out of water

Table 7. Minimum and maximum measured values used in development of rating curves.

Site	Minimum Flow (cfs)	Maximum Flow (cfs)
Oshetna River	614.3	1,472
Kosina Creek	610.0	1,307
Tsusena Creek	405.0	1,151
Portage Creek	571.9	1,506
Indian River	136.8	618.2
Gold Creek	62.2	153.0
Skull Creek	2.49	48.5
Whiskers Creek	5.7	147.7
Trapper Creek	10.8	124.7
Birch Creek	23.9	82.3
Sheep Creek	317.5	432.4
Deshka River	245.0	1,145.4

Table 8. Summary of streamflow reporting levels.

Flow level (cfs)	Hourly Reporting Level	Measured Values Level
<1 cfs	0.01 cfs	0.01 cfs
1-10 cfs	0.1 cfs	0.01 cfs
10-1,000 cfs	1 cfs	0.1 cfs
1,000-10,000 cfs	10 cfs	1 cfs

Table 9. Tributary gaging data qualifiers used to flag hourly hydrograph values.

Qualifier Abbreviation	Qualifier Type	Qualifier Description
I	Ice	Ice in channel or margins affecting stage measurement
E1	Estimated Category 1	The reported flow value is an estimate - gage stilling well was slightly bent.
E2	Estimated Category 2	The reported flow value is an estimate - the rating curve was extrapolated significantly beyond the range of measured flows
R	Removed	Likely or possible inundation from backwater from the Susitna, rating curve not applicable, data removed.
NI	Not Installed	Pressure transducer was removed for the winter season
DI	Downstream Influence	WSE at gage is influenced by downstream beaver activity

Table 10. Summary of days identified with diurnal fluctuation at USGS gages.

Location	Period of Record	Total Number of Days	Number of days selected with diurnal patterns
Susitna River above Tsusena (15291700)	2013-2014	271	120
Susitna River at Gold Creek (15292000)	2013-2014	280	139
Chulitna River (15292400)	2013-2014	256	99
Talkeetna River (15292700)	2013-2014	313	169
Susitna River at Sunshine (15294250)	2013-2014	286	113
Yentna River (15294345)	2013	91	44
Susitna River at Susitna Station (15294350)	2013	111	55

Table 11. Summary of diurnal model equations and application.

Location	Amplitude Equation	Phi Equation	Model Application
Susitna River above Tsusena (15291700)	$e^{(-6.20+0.0243*T + 1.26*LQ)}$	$-15.9+0.0894*JD-0.000194*JD^2+0.564*LQ$	• Air Temperature > 2°C • Q_{daily} < Smoothed median • Q_{daily} > Smoothed median if Air Temp > 11°C
Susitna River at Gold Creek (15292000)	$e^{(-3.63+0.951*LQ + 0.0406*T)}$	$15.9-0.113*JD+0.000245*JD^2-0.489*LQ$	• Air Temperature > 2°C • Q_{daily} < Smoothed median • Q_{daily} > Smoothed median if Air Temp > 11°C
Chulitna River (15292400)	$e^{(-5.34+1.17*LQ)}$	$-12.4+0.111*JD-0.000256*JD^2-0.0000792*JD$	• Air Temperature > 2°C • Q_{daily} < Smoothed median • Q_{daily} > Smoothed median if Air Temp > 13°C
Talkeetna River (15292700)	$e^{(-7.07+1.38*LQ + 0.0598*T)}$	$4.98-0.0594*JD+0.000146*JD^2$	• Air Temperature > 2°C • Q_{daily} < Smoothed median • Q_{daily} > Smoothed median if Air Temp > 11°C
Susitna River at Sunshine (15294250)	$e^{(-6.07+1.17*LQ + 0.0180*T)}$	$-2.76+0.675*E-1.11*E^2+0.105*LD$	• Air Temperature > 2°C • Q_{daily} < Smoothed median • Q_{daily} > Smoothed median if Air Temp > 11°C
Yentna River (15294345)	82.7+83.1T	0.650+0.392*E	• Air Temperature > 2°C • Q_{daily} < Smoothed median • Q_{daily} > Smoothed median if Air Temp > 14°C
Susitna River at Susitna Station (15294350)	$-8813+0.167*Q-0.000000606*Q^2$	$-6.71+15.0*E-9.74*E^2+0.0000134*Q$	• Air Temperature > 2°C • Q_{daily} < Smoothed median • Q_{daily} > Smoothed median if Air Temp > 14°C

Notes:
T – Average daily air temperature (°C)
LQ – Natural log of average daily flow (flow in cfs)
JD – Julian Day
D – Delta Flow (i.e., Current average daily flow minus previous day average daily flow in cfs)
LD – natural log-transformed absolute value of D
E – Proportion of Solstice daylight
Q – Average Daily Streamflow
NOTE: Predictions for the Susitna River at Susitna Station were modified for low and high flows outside the range of predictor values

Table 12. Ranges of predictor variables observed and utilized for amplitude and phi predictions by site.

Location	Range	Flow (cfs)	Air Temp (°C)	Prop Solstice	Delta (cfs)	ABS(Delta)	JDAY
Susitna River above Tsusena (15291700)	Min	8030	-0.3	-0.38	-9500	27.1	136
	Max	72800	24.5	1	32100	32100	287
Susitna River at Gold Creek (15292000)	Min	6290	-1.35	-0.38	-19200	9.38	128
	Max	86800	20.9	1	34200	34200	287
Chulitna River (15292400)	Min	14590	8.35	0.193	-5309	15.6	152
	Max	39010	24.5	1	6275	6275	253
Talkeetna River	Min	1730	-1.35	-0.38	-6750	1.98	127
	Max	27800	24.5	1	7430	7430	275
Susitna River at Sunshine (15294250)	Min	15600	-4.45	-0.5488	-18800	10.4	134
	Max	140000	24.5	1	25500	25500	298
Yentna River (15294345)	Min	29100	8.05	0.056	-11100	49	152
	Max	83000	24.5	1	15100	15100	261
Susitna River at Susitna Station (15294350)	Min	85310	8.35	0.1586	-13200	430	154
	Max	172900	20.8	1	14200	14200	255

Table 13. Subbasins and percent distributions for the Dam Site to Gold Creek reach.

Location	Name	Drainage Area %	Summertime %	Wintertime %
PRM 187.1-184.6	NA	1.186%	0.873%	0.875%
PRM 184.6	Tsusena Creek	14.838%	21.000%	21.036%
PRM 184.6-184	NA	0.289%	0.213%	0.213%
PRM 184.0	Unnamed Tributary 184	4.511%	3.322%	3.327%
PRM 184.0-179.3	NA	2.266%	1.668%	1.671%
PRM 179.3	Fog Creek	15.270%	9.000%	9.015%
PRM 179.3-164.8	NA	6.990%	5.147%	5.155%
PRM 164.8	Devil Creek	7.591%	5.589%	5.599%
PRM 164.8-160.5	NA	2.073%	1.526%	1.529%
PRM 160.5	Chinook Creek	2.449%	1.804%	1.807%
PRM 160.5-155.8	NA	2.217%	1.633%	1.635%
PRM 155.9	Cheechako Creek	3.512%	2.586%	2.590%
PRM 155.9-152.3	NA	1.735%	1.278%	1.280%
PRM 152.3	Portage Creek	18.280%	28.000%	28.048%
PRM 152.3-142.1	NA	4.917%	3.620%	3.627%
PRM 142.1	Indian River	8.361%	10.000%	9.846%
PRM 142.1-140.1	NA	0.964%	0.710%	0.711%
PRM 140.1	Gold Creek	2.509%	2.000%	2.003%
PRM 140.1-140.0	NA	0.043%	0.032%	0.032%

Table 14. Total tributary inflow to the Susitna River between Gold Creek and Sunshine as a percentage of the sum of the flows in the Susitna River at Gold Creek, the Chulitna River near Talkeetna, and the Talkeetna River near Talkeetna.

	Average Monthly Flow (cfs)		
Month	Gold Creek + Chulitna + Talkeetna	Total Tributary	Percentage
October	15,120	790	5.2%
November	6,150	348	5.7%
December	4,260	237	5.6%
January	3,560	162.4	4.6%
February	3,120	138.7	4.4%
March	2,860	95.1	3.3%
April	3,710	315	8.5%
May	28,600	4,560	15.9%
June	58,400	5,260	9.0%
July	57,500	3,010	5.2%
August	51,400	2,790	5.4%
September	32,500	2,330	7.2%

Table 15. Subbasins and percent distributions of total tributary inflow for the Gold Creek to Sunshine reach.

Location	Name	Drainage Area %	Summertime %	Wintertime %
PRM 140-128.1	NA	17.12%	21.33%	19.26%
PRM 128.1	Skull Creek	1.25%	0.45%	0.24%
PRM 128.1-105.1	NA	33.05%	41.2%	37.2%
PRM 105.1	Whiskers Creek	5.28%	0.84%	3.87%
PRM 105.1-102.5	NA	3.74%	4.66%	4.21%
PRM 102.4	Chulitna River	41.72%	NA – Calculated from measured USGS data	
PRM 102.4-100.3	NA	2.59%	3.22%	2.91%
PRM 100.3	Talkeetna River	32.40%	NA – Calculated from measured USGS data	
PRM 100.3-95.4	NA	7.62%	9.49%	8.57%
PRM 95.4	Trapper Creek	7.77%	1.44%	3.45%
PRM 95.4-93.3	NA	3.02%	3.76%	3.4%
PRM 93.3	Birch Creek	1.16%	1.3%	5.53%
PRM 93.3-88.0	NA	7.62%	9.49%	8.57%
PRM 88.0	Sunshine Creek	9.60%	2.58%	2.58%
PRM 88.0-87.9	NA	0.19%	0.23%	0.21%

Table 16. Inflow from the Yentna River to the Susitna River between Gold Creek and Sunshine as a percentage of the difference in flow in the Susitna River between Susitna Station and Sunshine.

Month	Average Monthly Flow (cfs)		Percentage
	Susitna Station minus Sunshine	Yentna River	
October	19,890	13,410	67%
November	7,890	5,350	68%
December	5,020	3,640	73%
January	4,180	3,020	72%
February	3,820	2,650	69%
March	3,550	2,400	68%
April	4,780	3,470	73%
May	32,600	27,000	83%
June	56,700	50,600	89%
July	61,200	49,900	82%
August	55,000	43,100	78%
September	37,900	27,900	74%

Table 17. Subbasins and percent distributions of total tributary inflow for the Sunshine tot Susitna Station reach.

Location	Name	Drainage Area %
PRM 88.0-87.2	NA	0.05%
PRM 87.2	Rabideux Creek	0.53%
PRM 87.2-81.0	NA	0.45%
PRM 81.0	Montana Creek	2.01%
PRM 81.0-76.8	NA	0.31%
PRM 76.8	Goose Creek	0.33%
PRM 76.8-71.7	NA	0.37%
PRM 71.7	Sheep Creek	1.70%
PRM 71.7-67.3	NA	0.32%
PRM 67.3	Caswell Creek	0.23%
PRM 67.3-64.7	NA	0.19%
PRM 64.7	Kashwitna River	4.28%
PRM 64.7-63.4	NA	0.10%
PRM 63.4	197 ½ Mile Creek	0.39%
PRM 63.4-54.5	NA	0.65%
PRM 54.5	Little Willow Creek	1.92%
PRM 54.5-52.1	NA	0.18%
PRM 52.1	Willow Creek	2.00%
PRM 52.1-44.9	NA	0.53%
PRM 44.9	Deshka River	7.67%
PRM 44.9-43.3	NA	0.12%
PRM 43.3	Rolly Creek	0.23%
PRM 43.3-31.4	NA	0.87%
PRM 31.4	Yentna River	74.46%
PRM 31.4-29.9	NA	0.11%

11. FIGURES

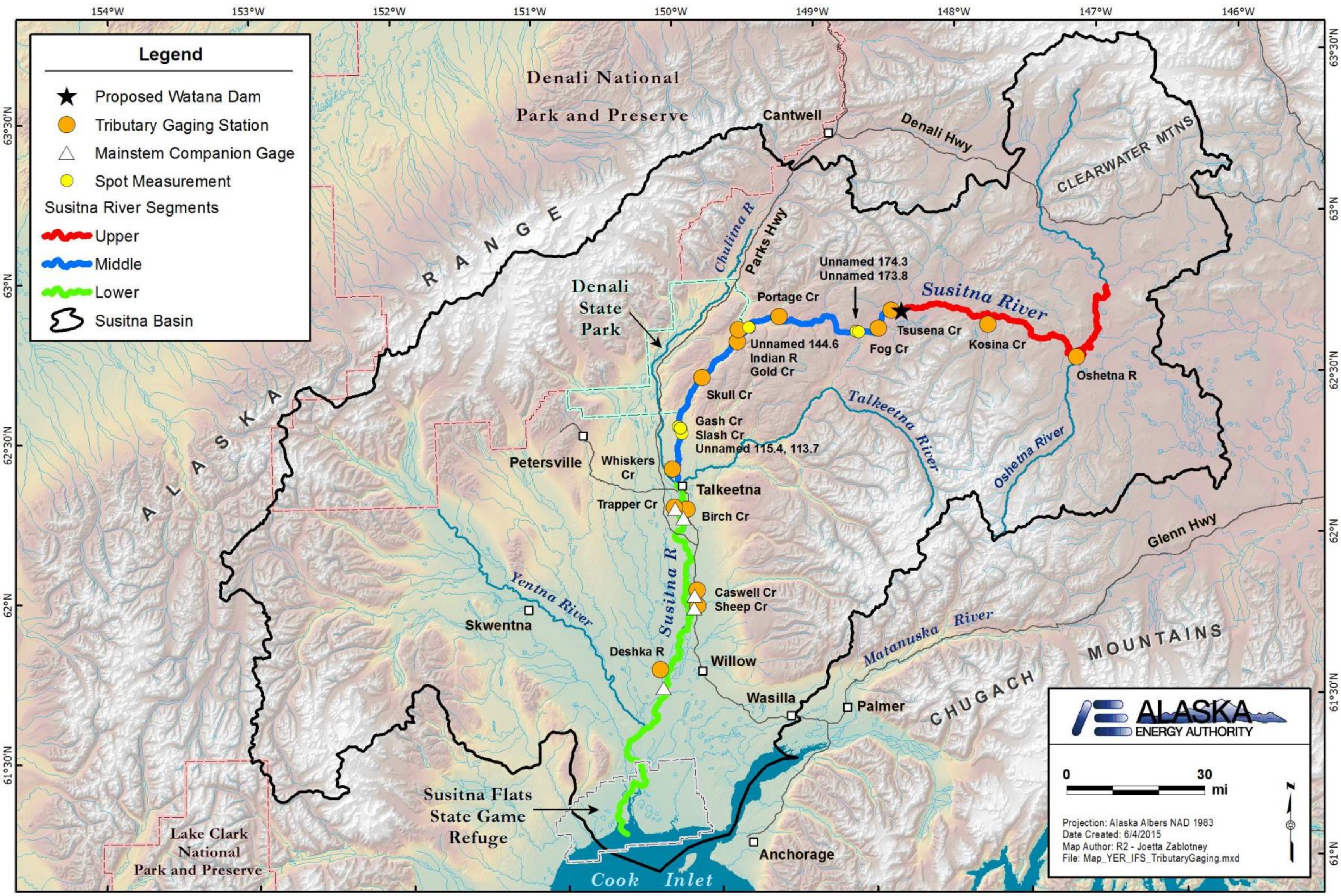


Figure 1. Locations of tributary gage sites.

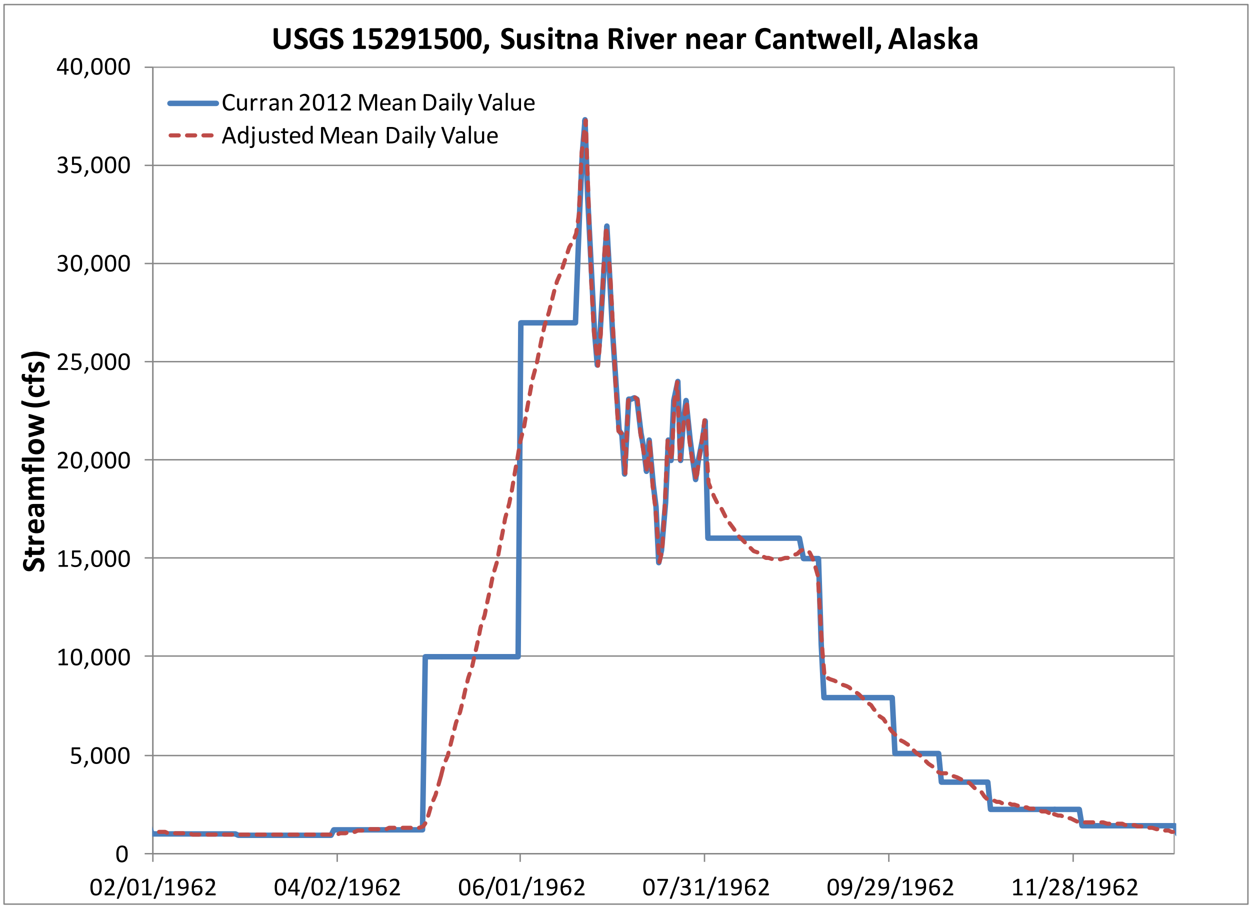
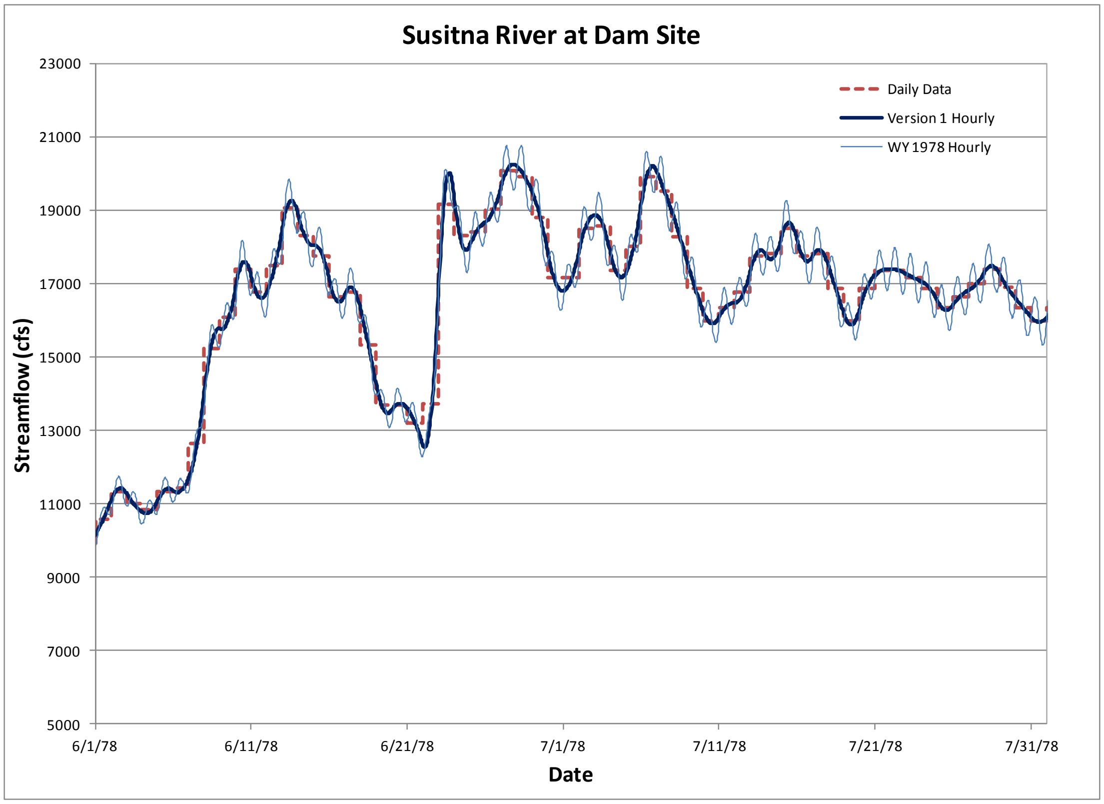


Figure 2. Example adjustment of mean daily flows for the Susitna River near Cantwell, Alaska.



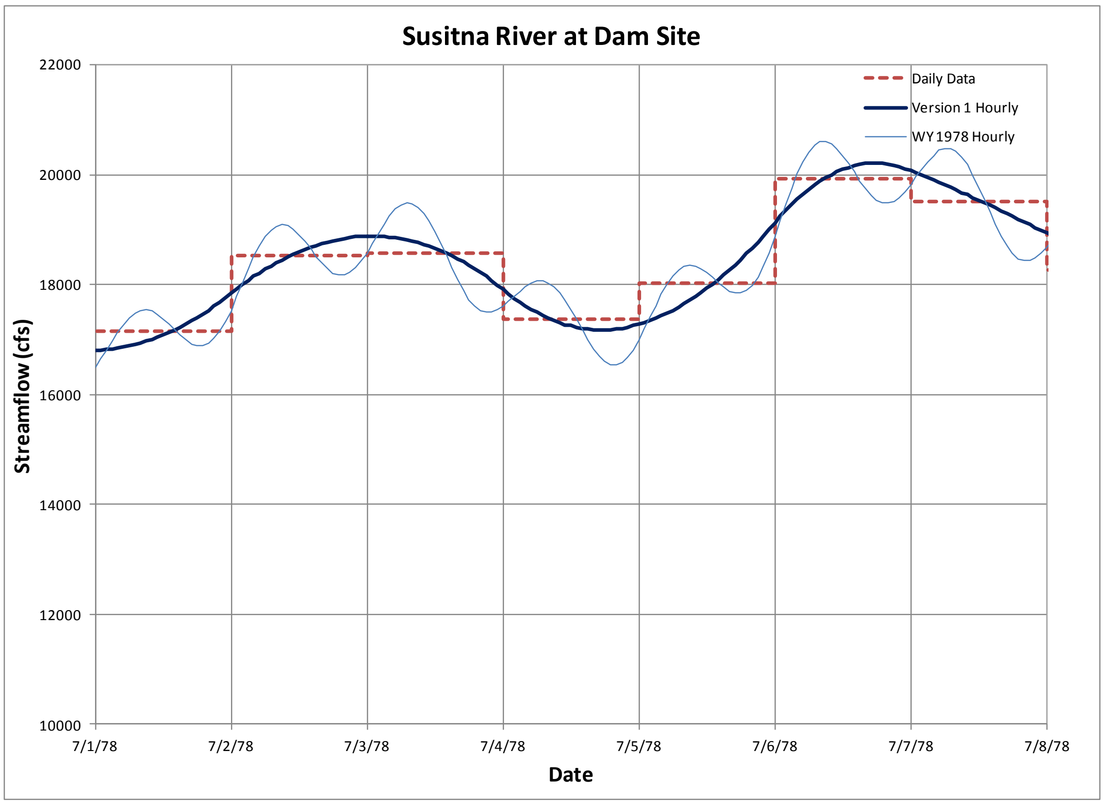


Figure 3. Example application of diurnal fluctuations to the historical record of the Susitna River at the Dam Site for a two month period (top) and a one week period (bottom).

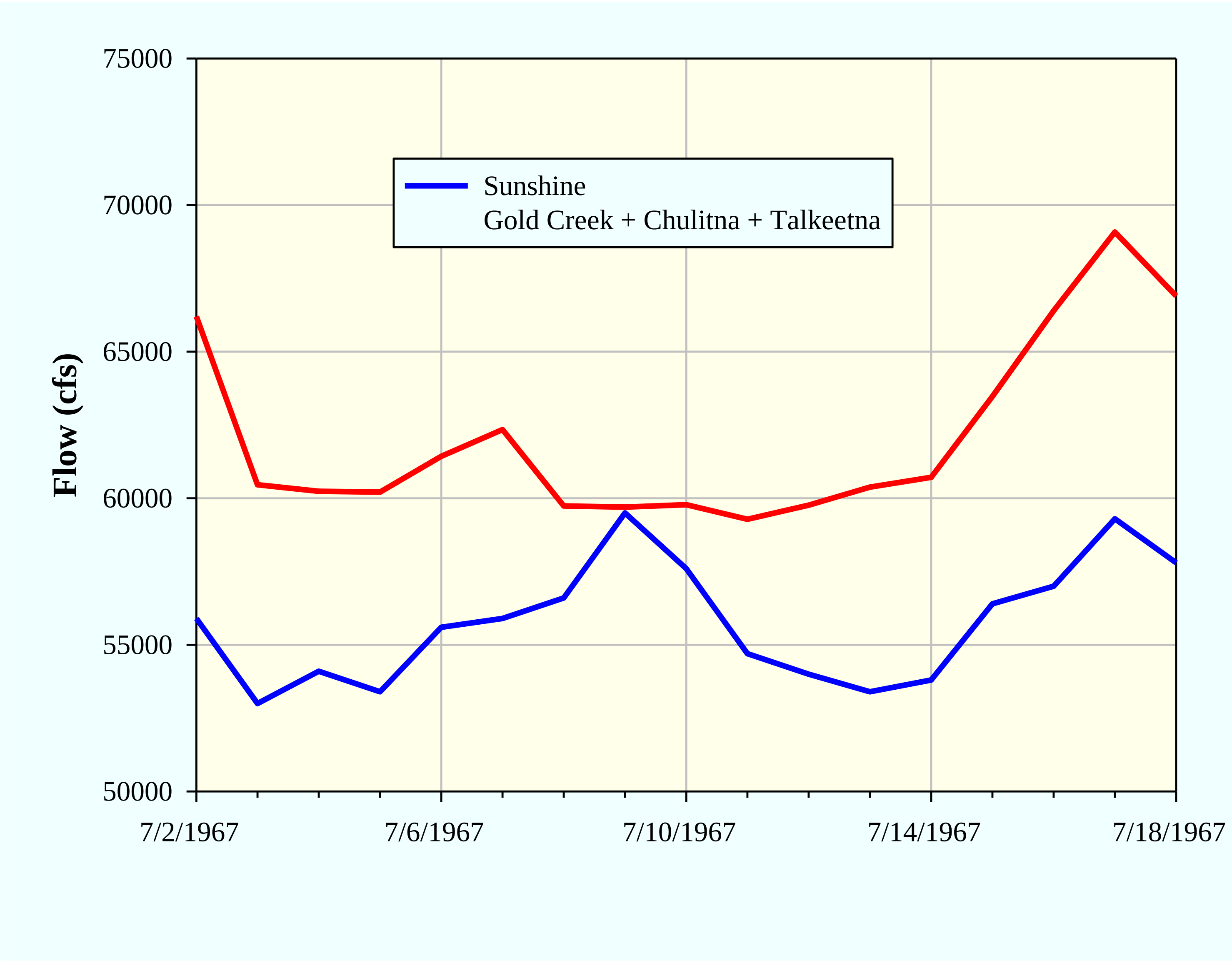


Figure 4. Flow at Sunshine Gage versus the combined flows from Gold Creek, Chulitna, and Talkeetna gages in July 1967. The combined flows from the three upstream gages exceed the flow at Sunshine Gage.

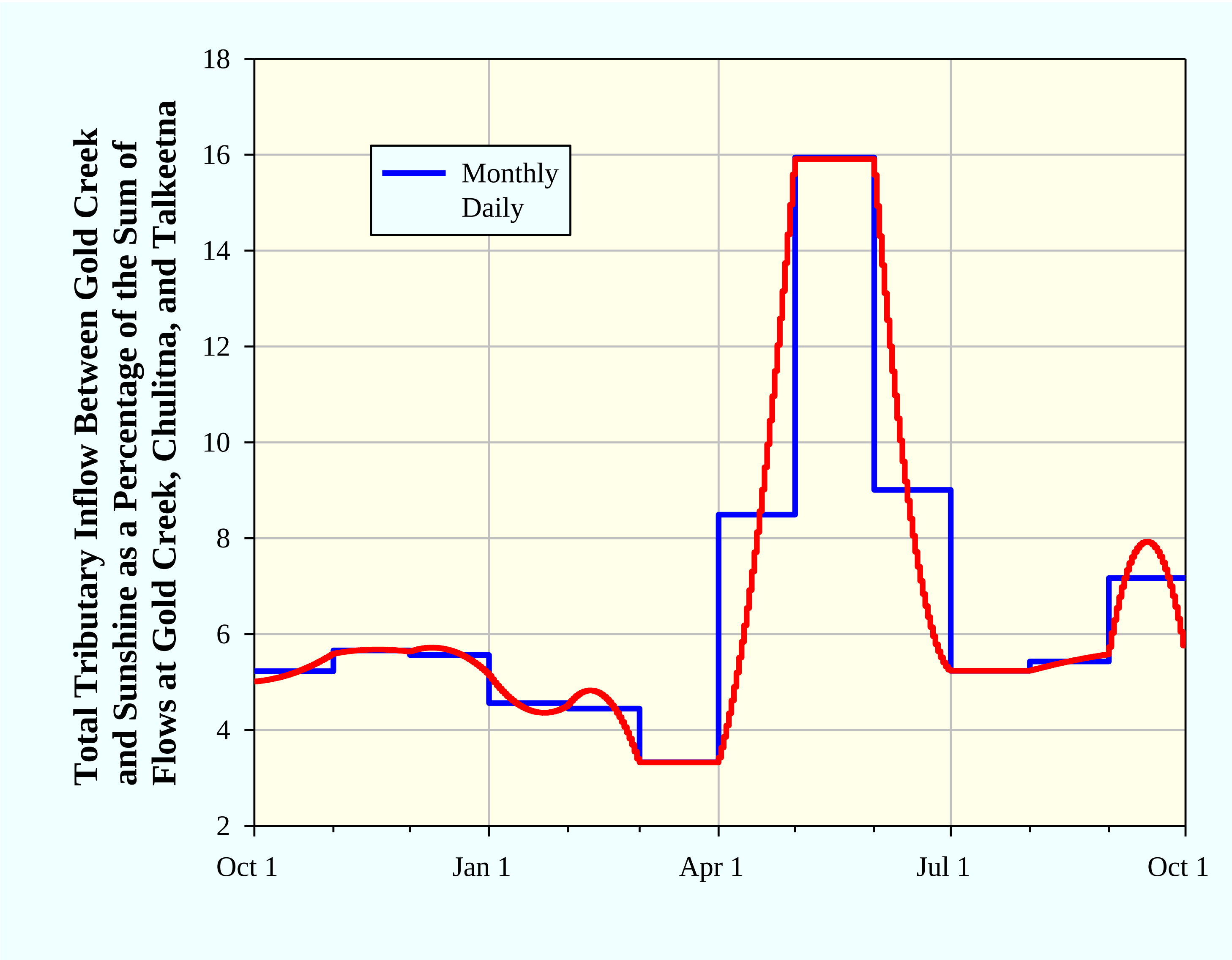


Figure 5. Total tributary inflow to the Susitna River between Gold Creek and Sunshine, expressed as a percentage of the sum of flows from the Susitna River at Gold Creek, the Chulitna River near Talkeetna, and the Talkeetna River near Talkeetna.

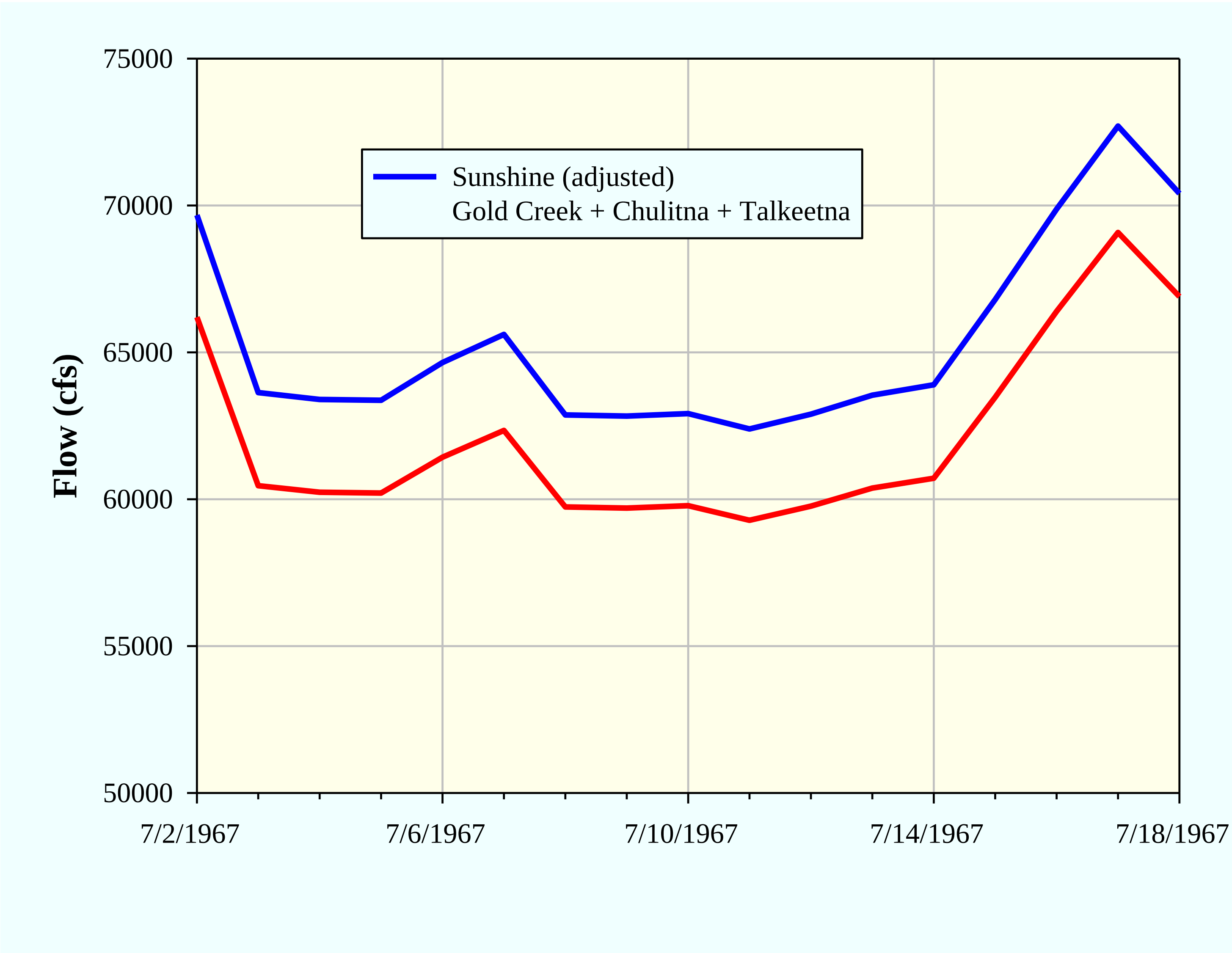


Figure 6. Flow at Sunshine Gage (after adjustments to remove negative tributary inflows) versus the combined flows from Gold Creek, Chulitna, and Talkeetna gages in July 1967. The combined flows from the three upstream gages are less than the flow at Sunshine Gage.

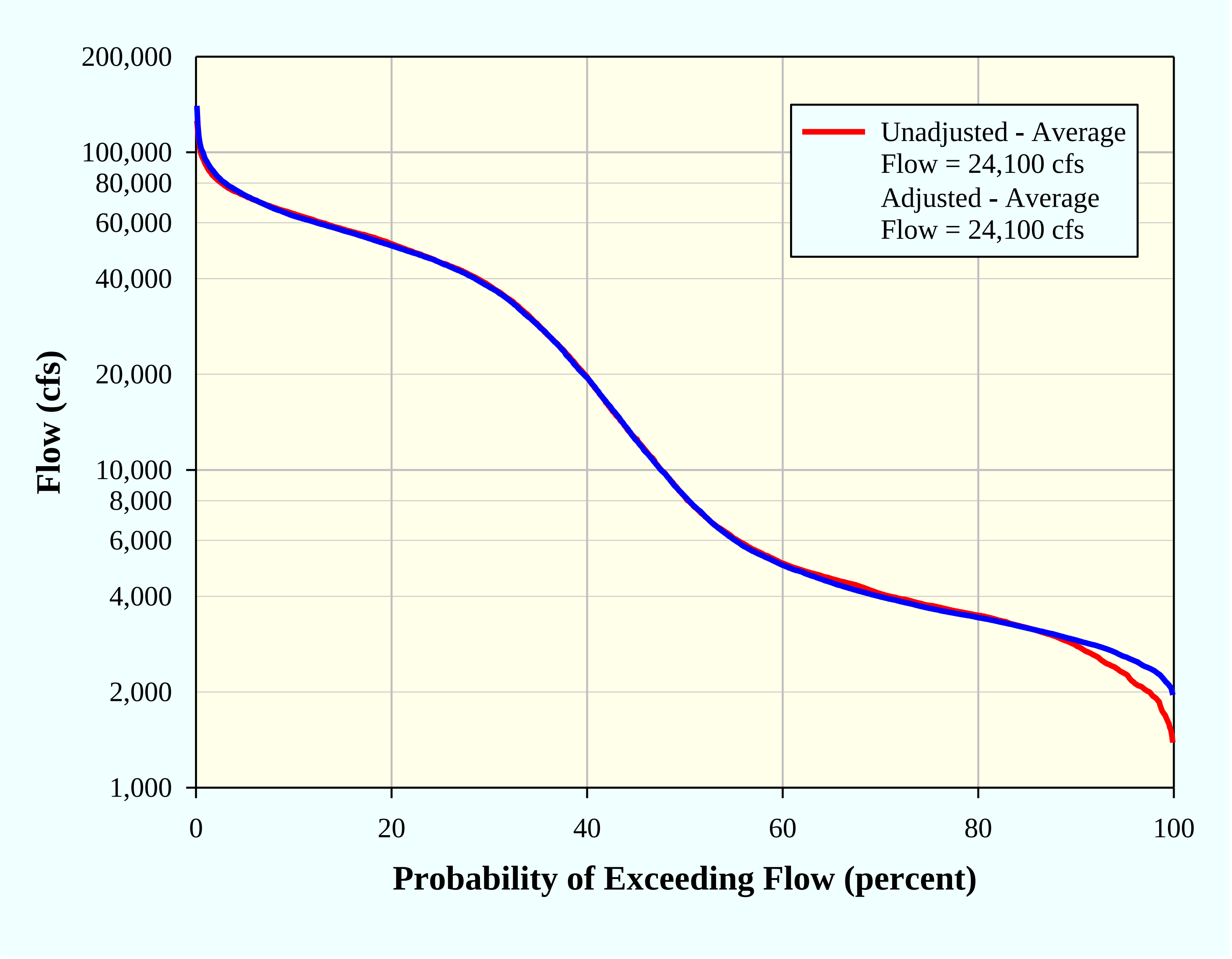


Figure 7. Flow duration curves for the Susitna River at Sunshine based on unadjusted conditions (with negative tributary inflows) and on adjusted conditions (without negative tributary inflows.

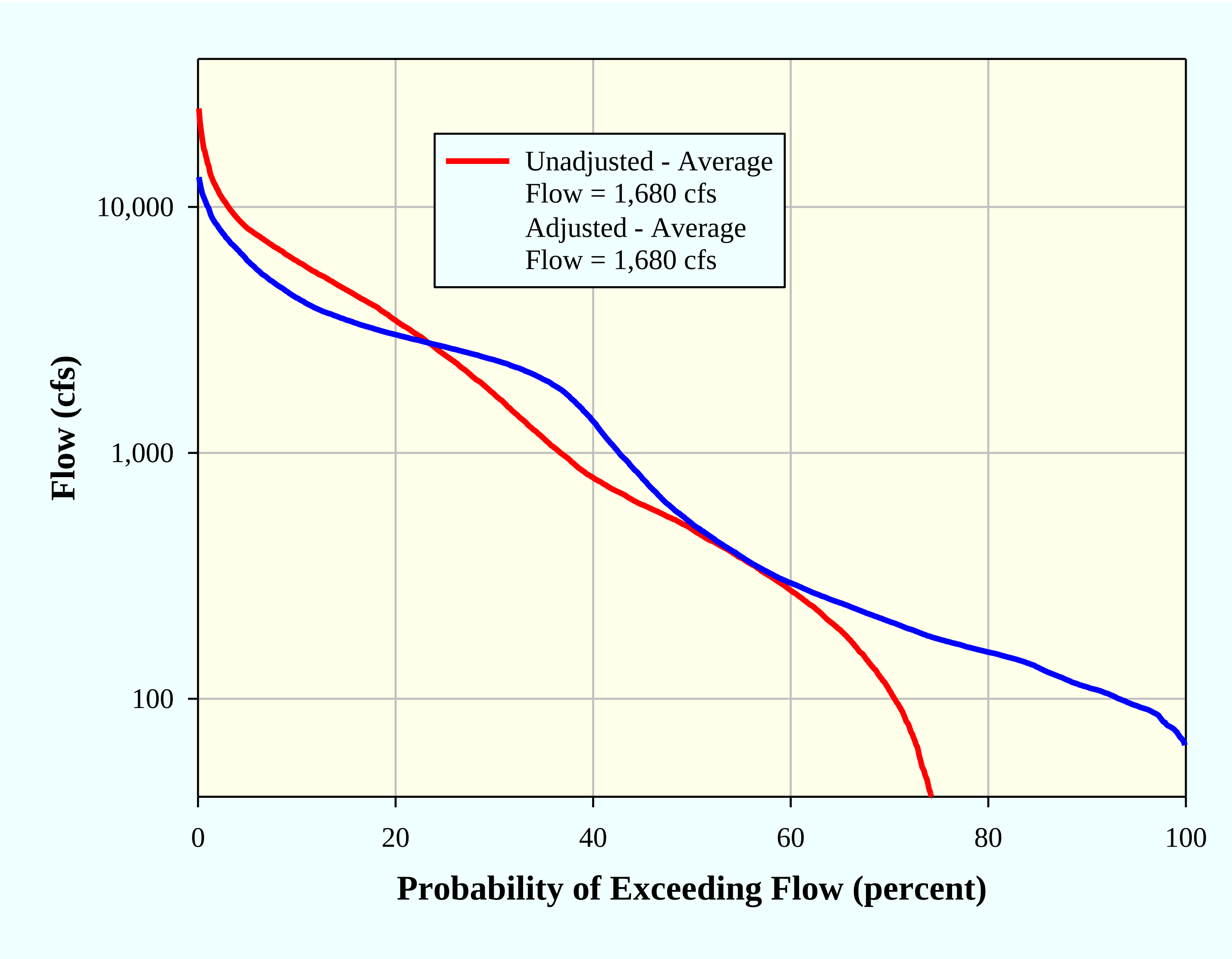


Figure 8. Flow duration curves for tributary inflow to the Susitna River between Gold Creek and Sunshine based on unadjusted conditions (with negative tributary inflows) and on adjusted conditions (without negative tributary inflows. Negative tributary inflows cannot be shown with a logarithmic scale.

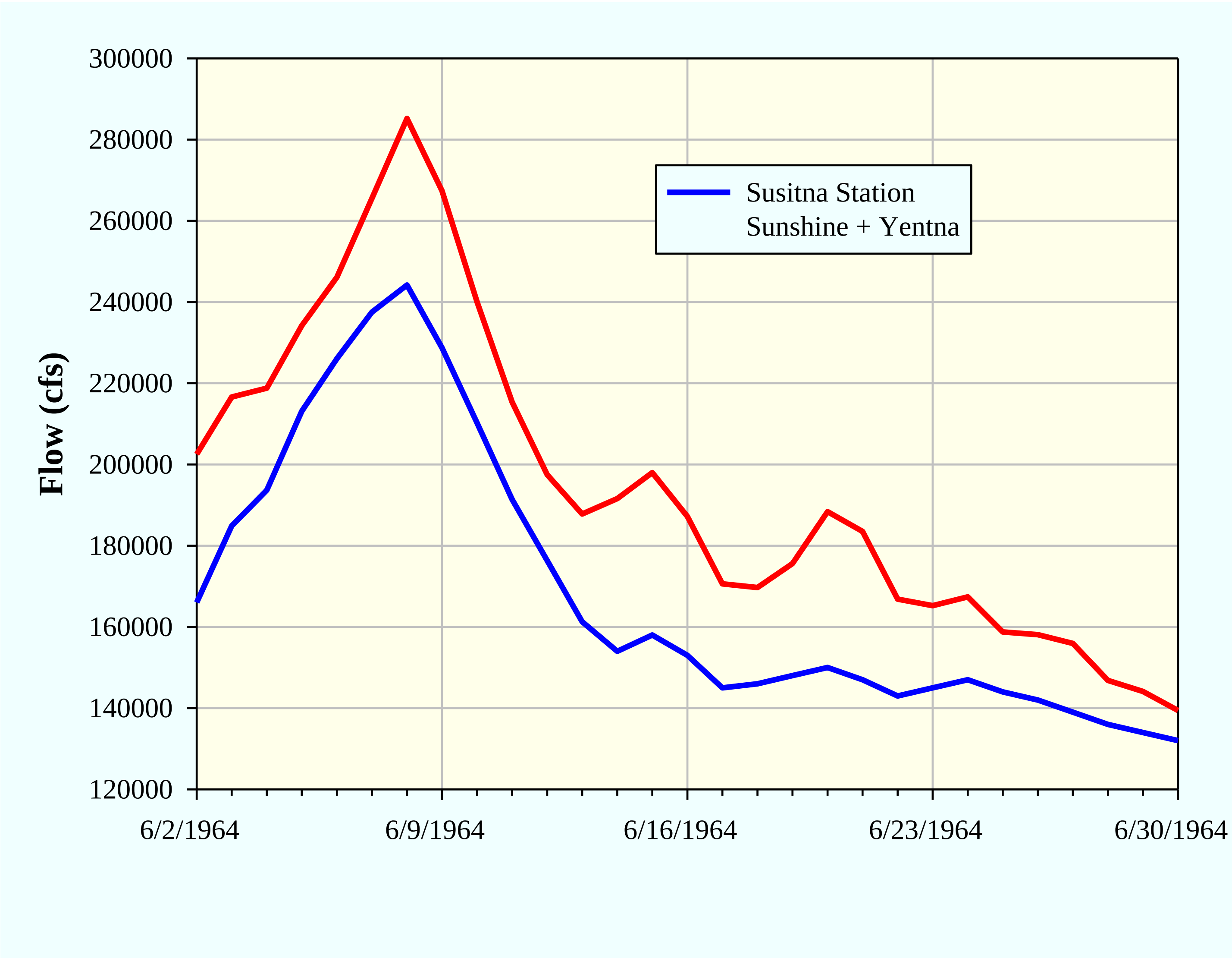


Figure 9. Flow at Susitna Station Gage versus the combined flows from Sunshine and Yentna gages in June 1964. The combined flows from the two upstream gages exceed the flow at Susitna Station Gage.

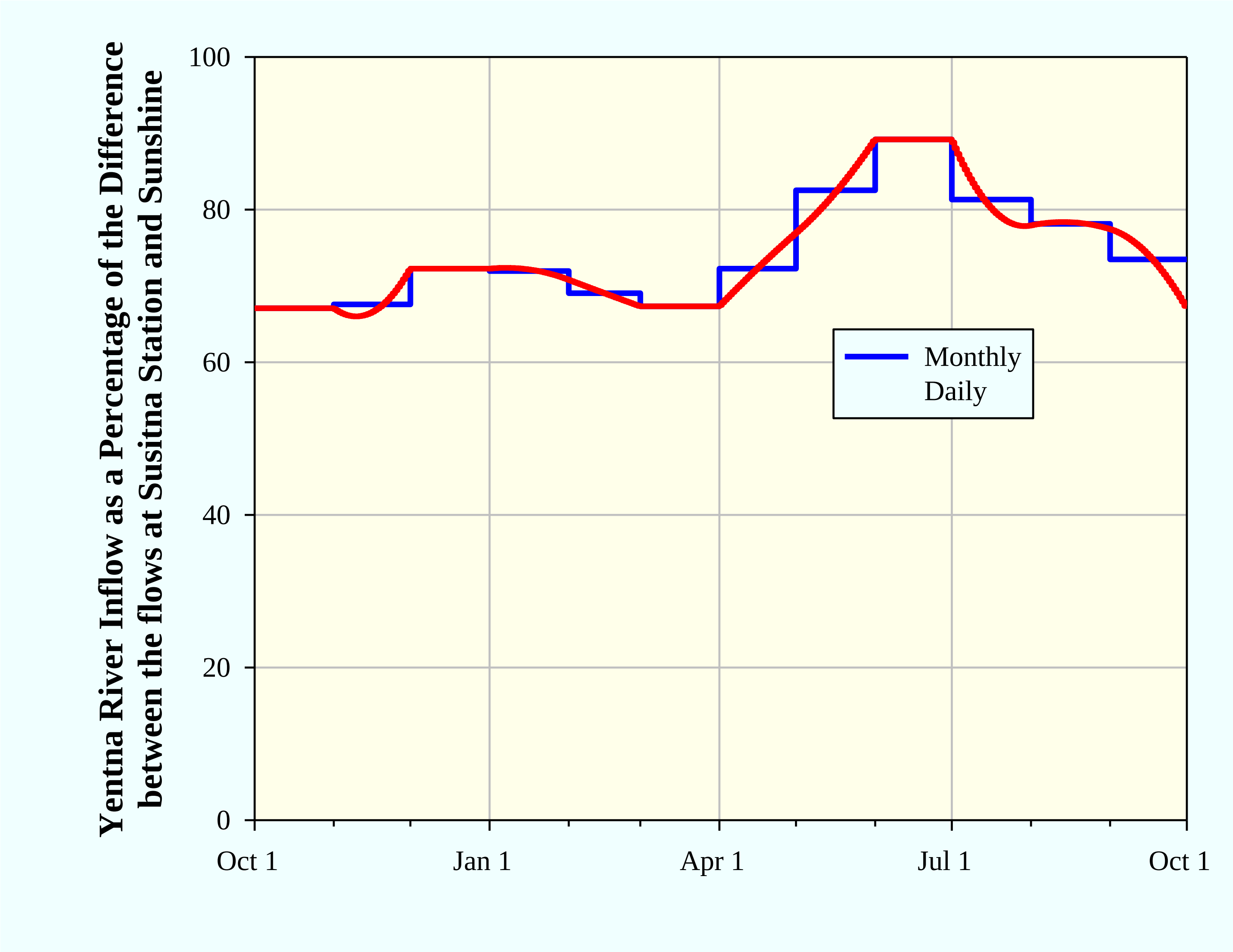


Figure 10. Inflow to the Susitna River from the Yentna River, expressed as a percentage of the difference in flows in the Susitna River between Susitna Station and Sunshine gages.

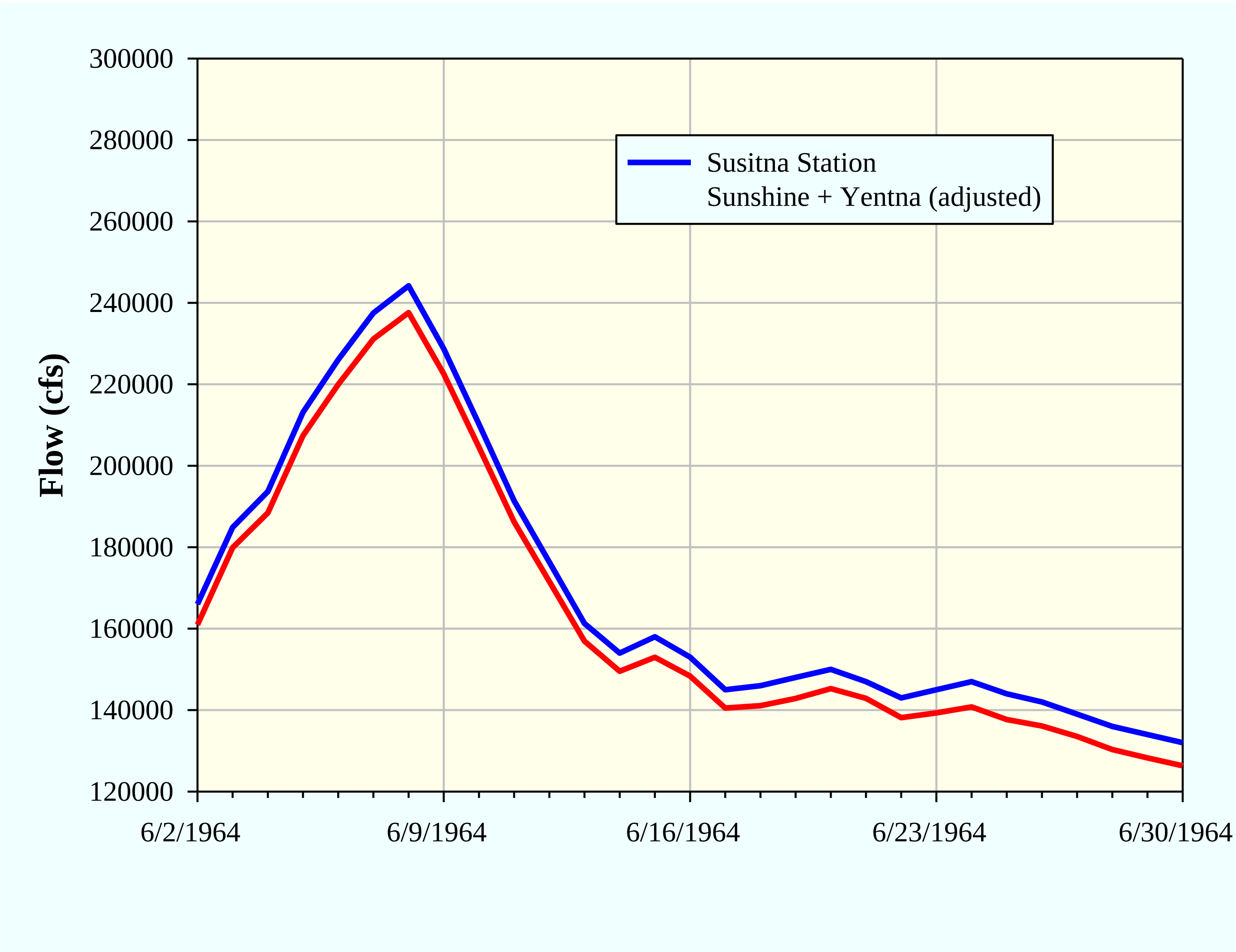


Figure 11. Flow at Susitna Station Gage versus the combined flows from Sunshine and the Yentna River (adjusted) gages in June 1964. The combined flows from the two upstream gages are less than the flow at Susitna Station Gage.

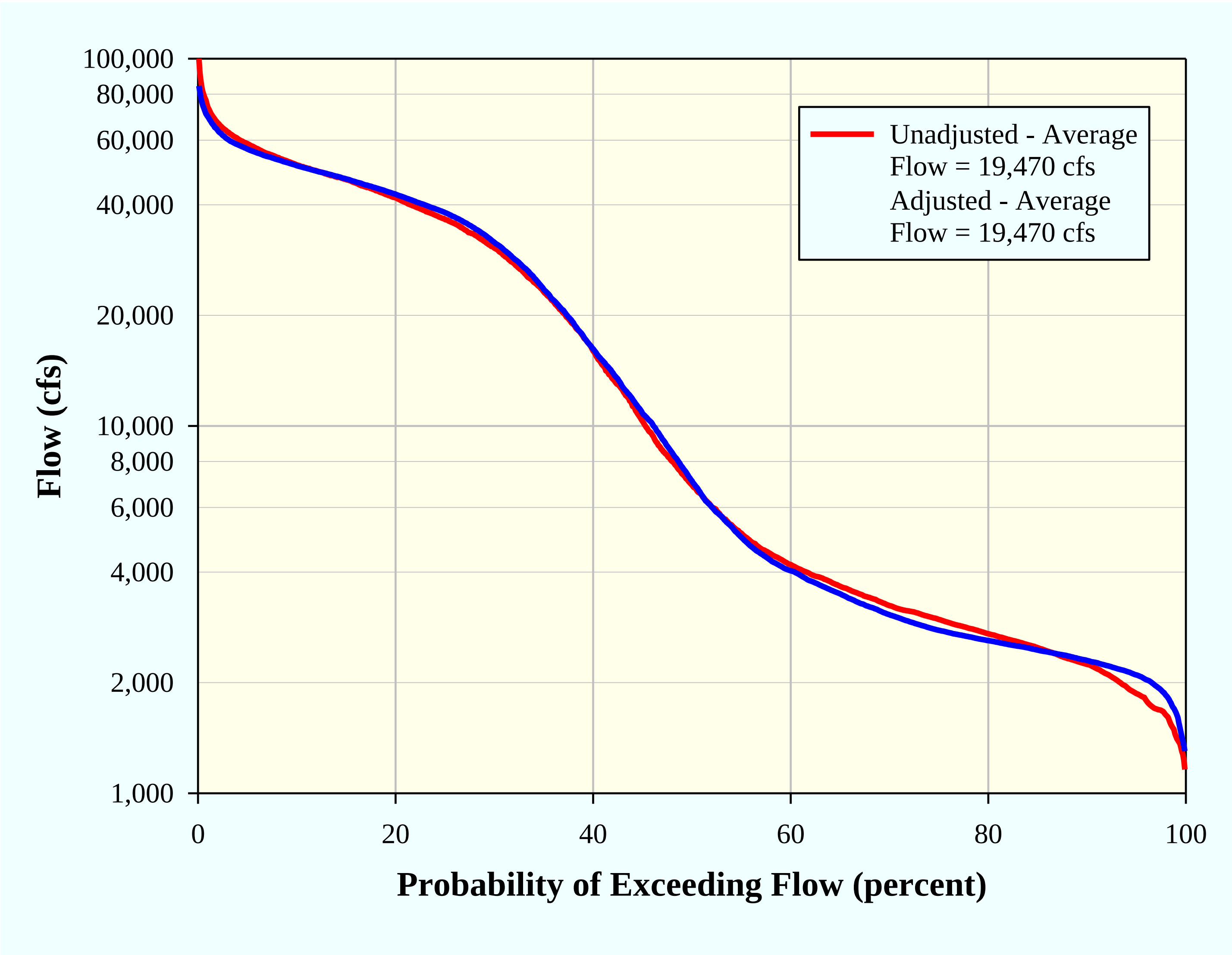


Figure 12. Flow duration curves for the Yentna River based on unadjusted conditions (with negative inflows from other tributaries) and on adjusted conditions (without negative tributary inflows from other tributaries).

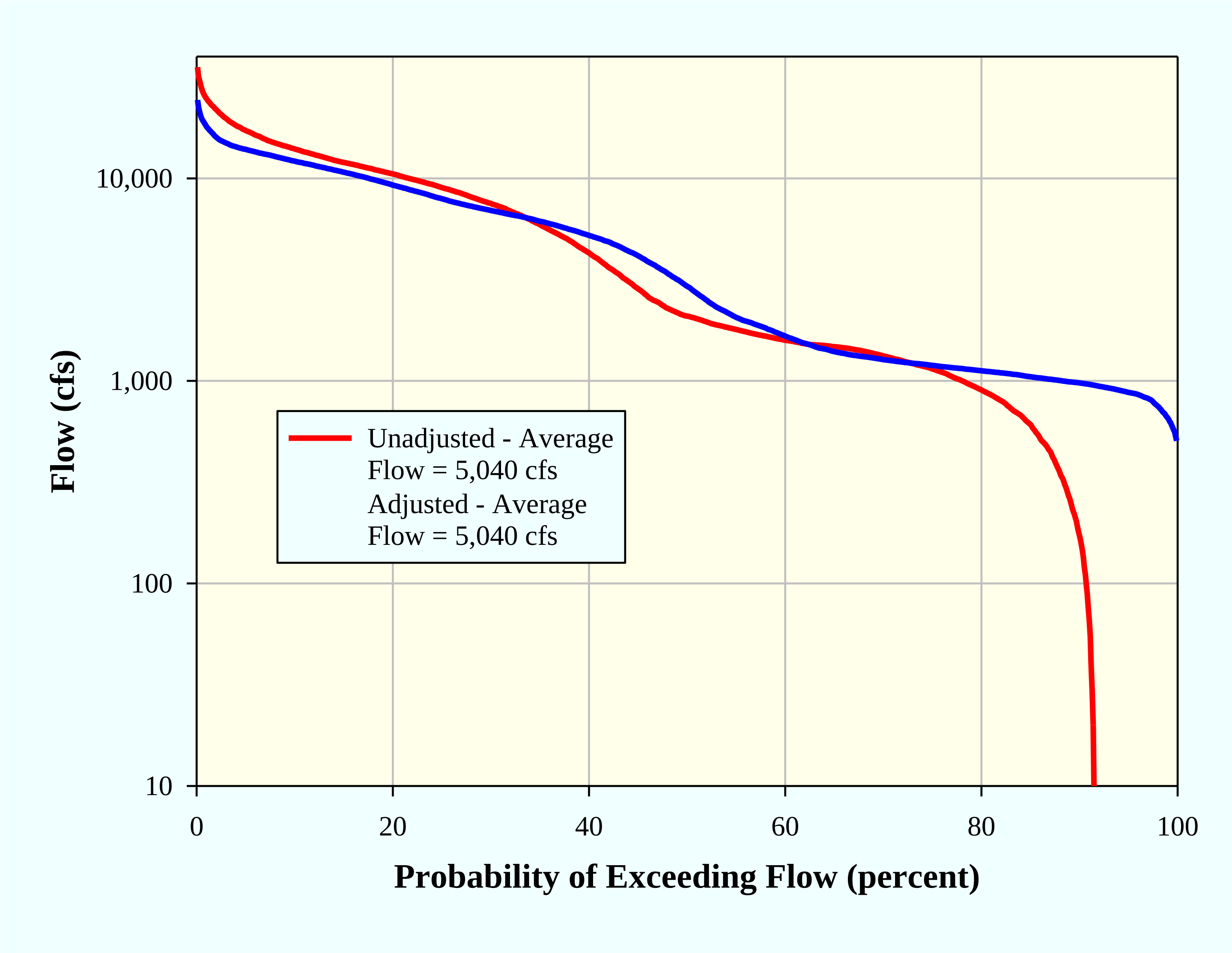


Figure 13. Flow duration curves for tributary inflow to the Susitna River between Sunshine and Susitna Station based on unadjusted conditions (with negative tributary inflows) and on adjusted conditions (without negative tributary inflows). Negative tributary inflows cannot be shown with a logarithmic scale.

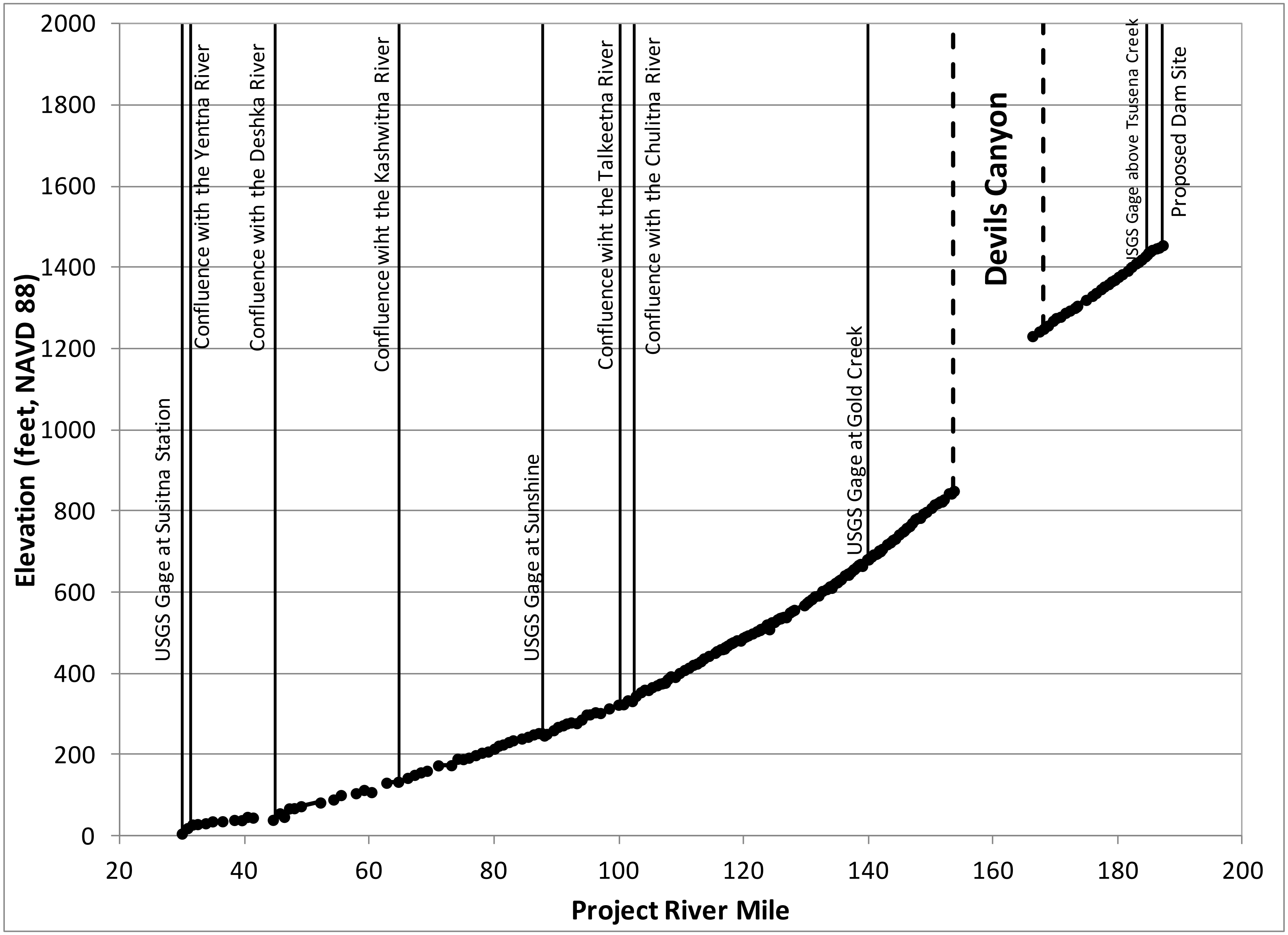


Figure 14. Longitudinal thalweg profile of the Susitna River extending from PRM 29.9 to PRM 187.1.

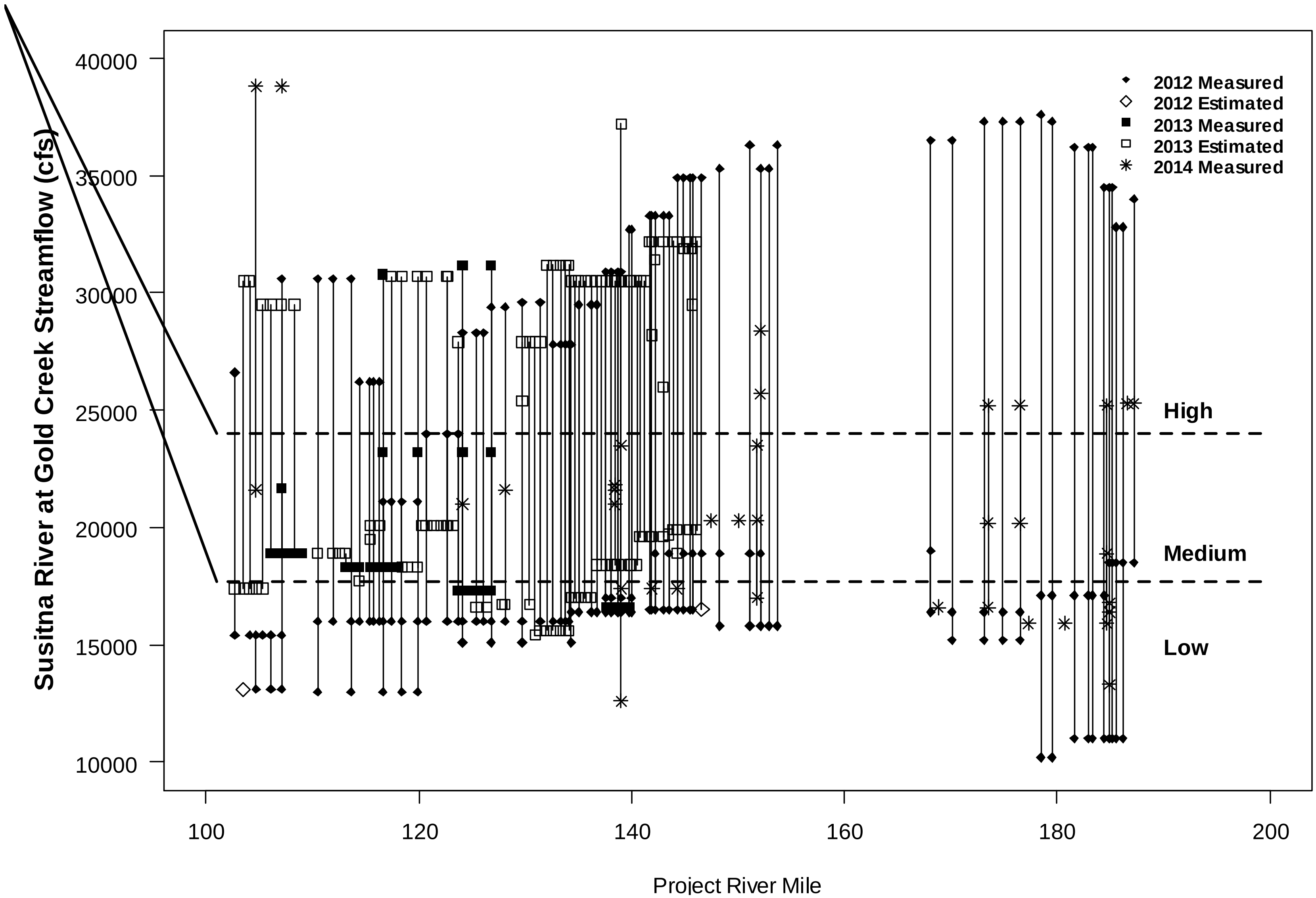


Figure 15. Locations of flow measurements in the upper Susitna River in 2012-2014, and classification of flows as low, medium, or high based on concurrent measurements in the Susitna River at Gold Creek (USGS No. 15292000).

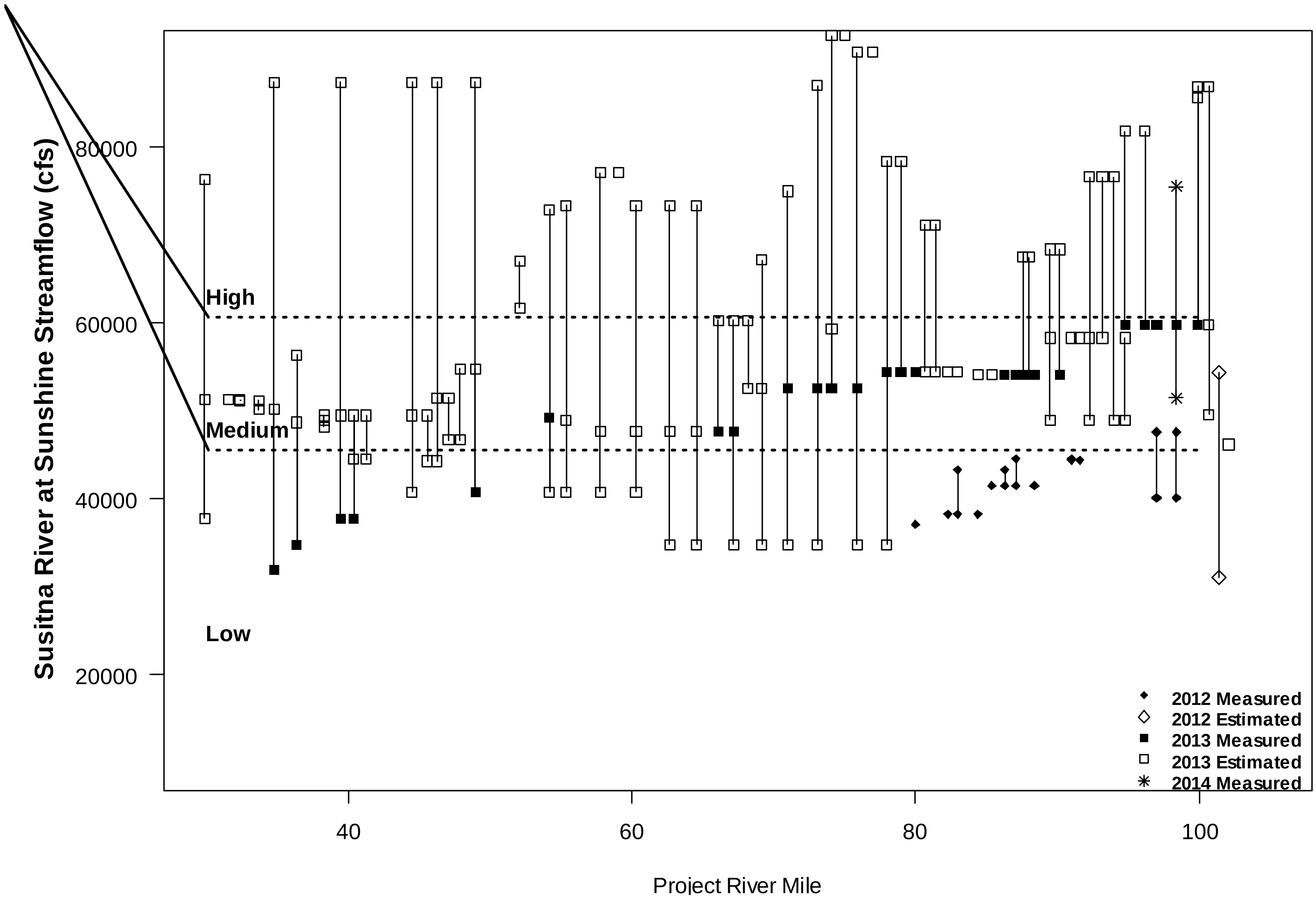


Figure 16. Locations of flow measurements in the lower Susitna River in 2012-2014, and classification of flows as low, medium, or high based on concurrent measurements in the Susitna River at Sunshine gage (USGS No. 15292780).

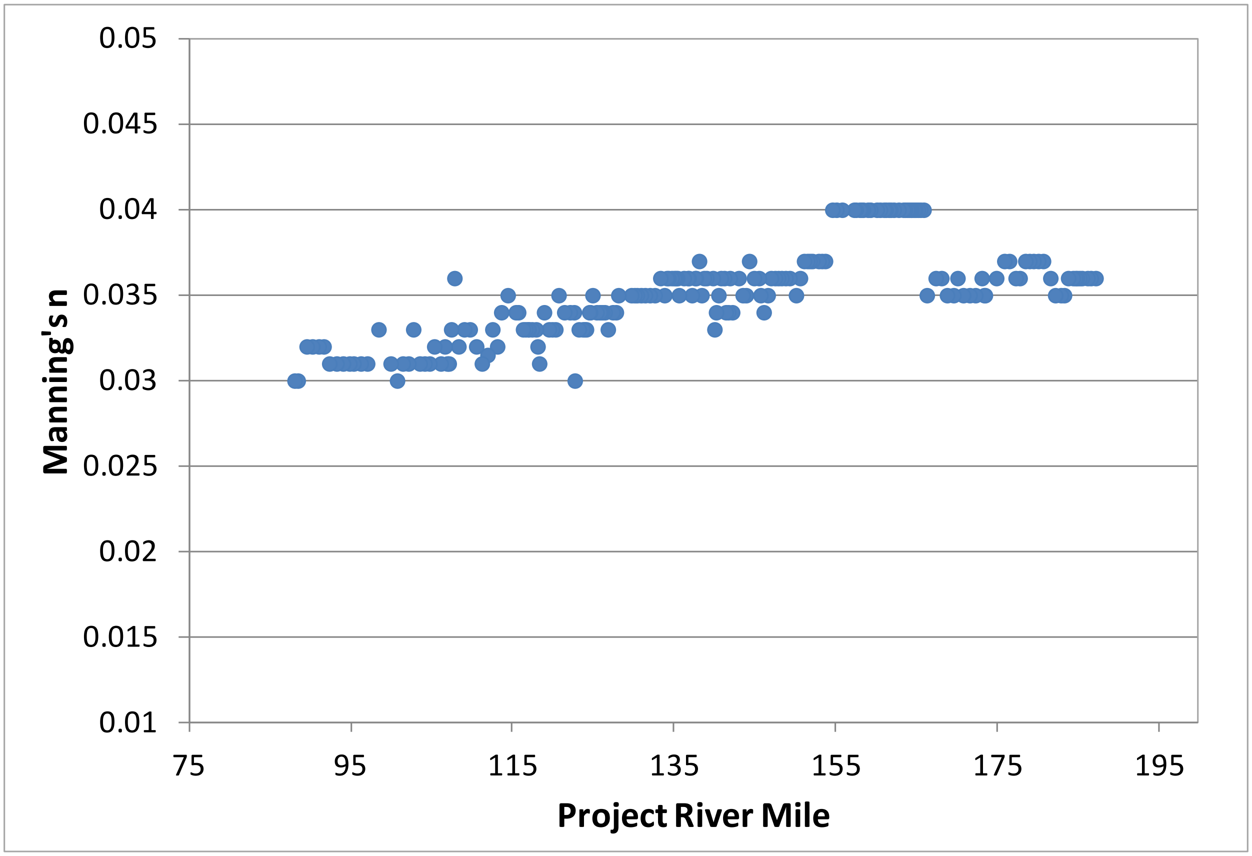


Figure 17. Manning's *n* channel roughness coefficients derived from steady-state calibration of flow routing model for 216 cross-sections of the Susitna River surveyed between 2012-2014.

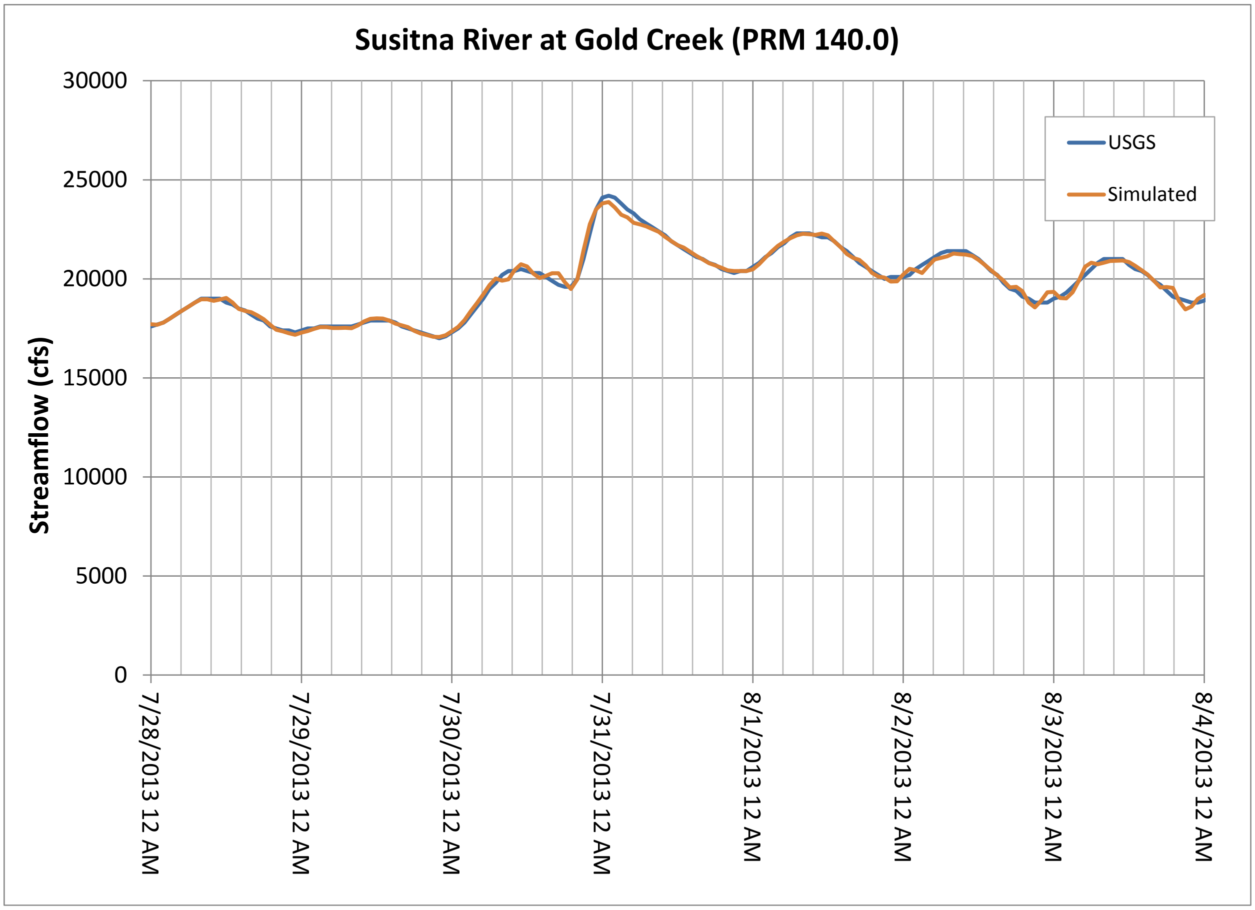


Figure 18. Comparison of measured versus simulated flow hydrographs in the Susitna River at Gold Creek (USGS No. 15292000) during the period from July 28 to August 3, 2013.

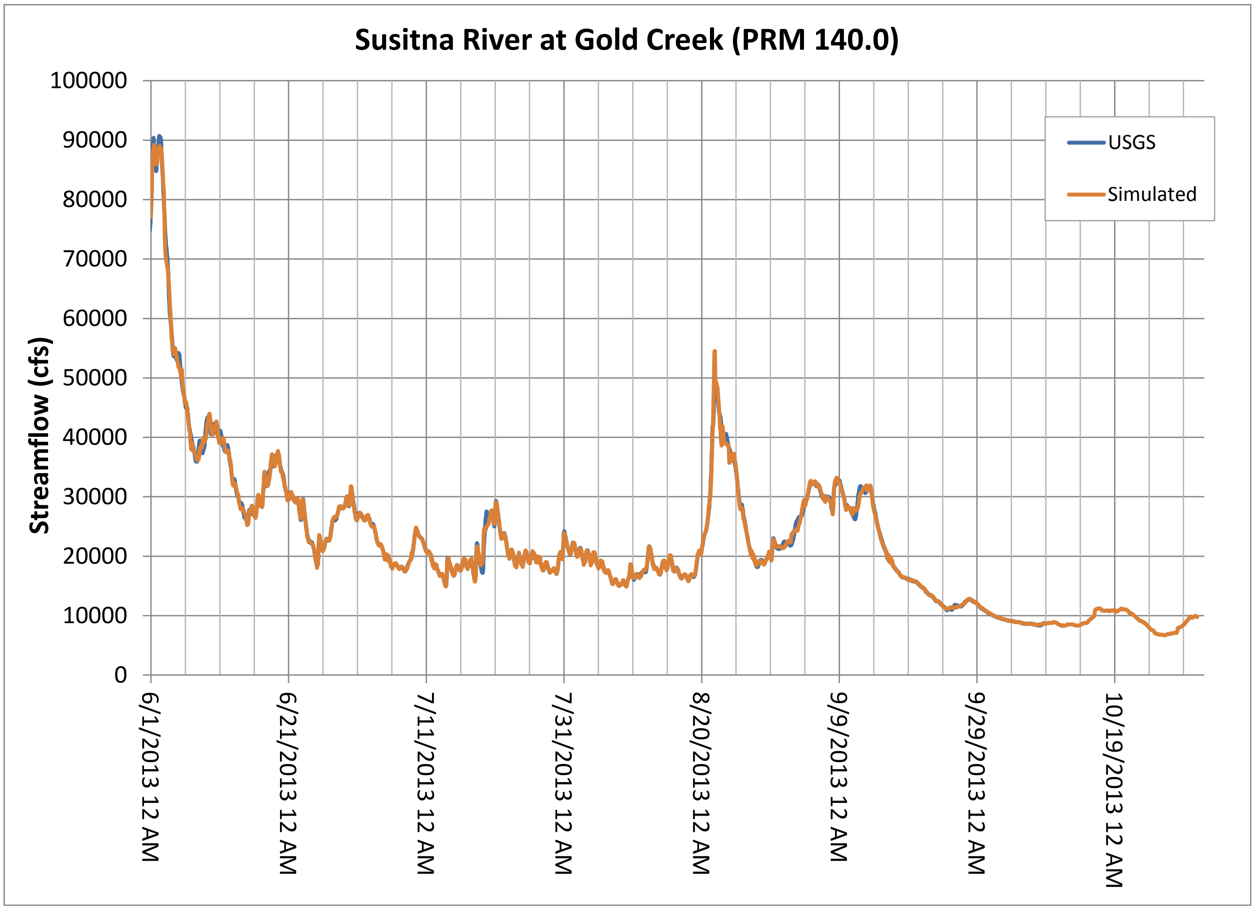


Figure 19. Comparison of measured versus simulated flow hydrographs in the Susitna River at Gold Creek (USGS No. 15292000) during the 2013 open water period.

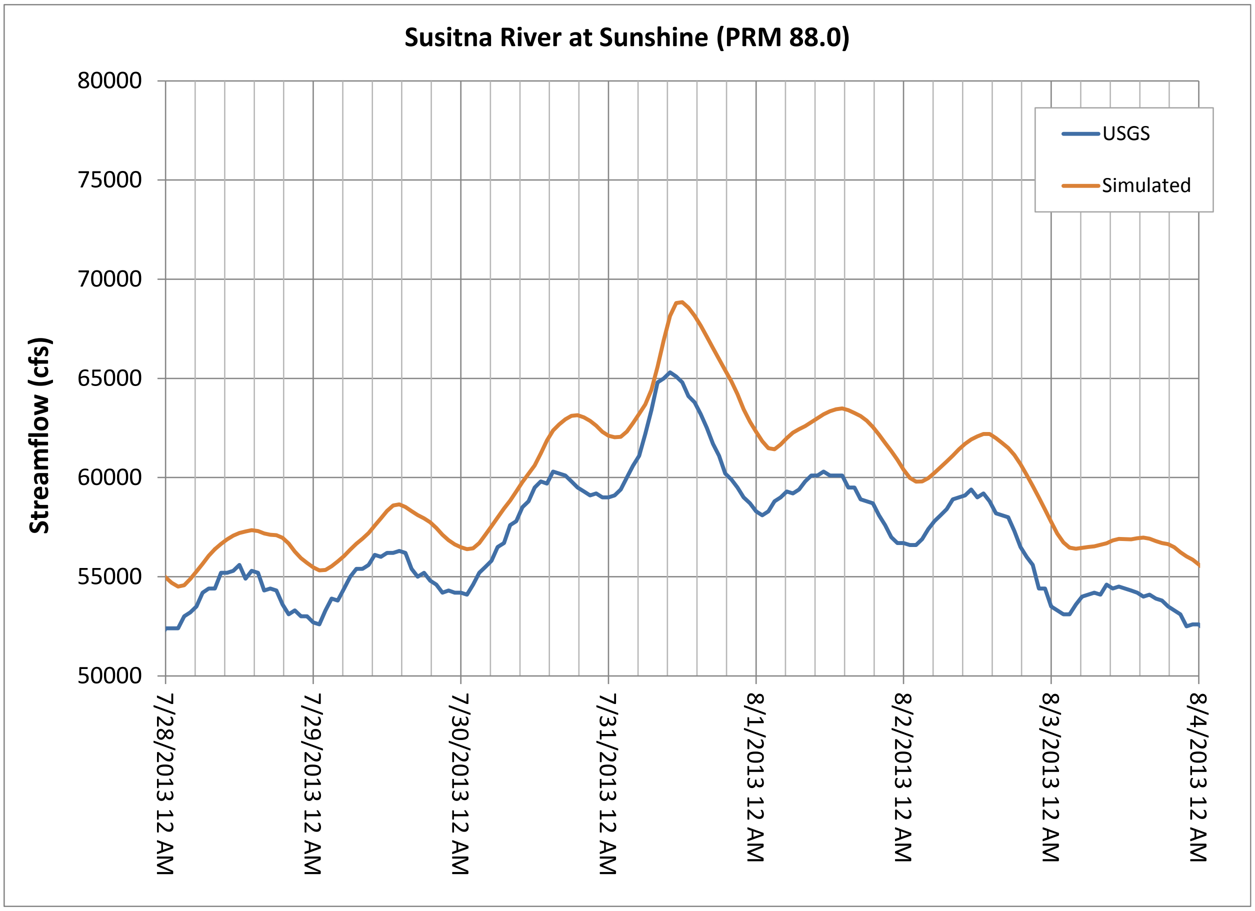


Figure 20. Comparison of measured versus simulated flow hydrographs in the Susitna River at Sunshine (USGS No. 15292780) during the period from July 28 to August 3, 2013.

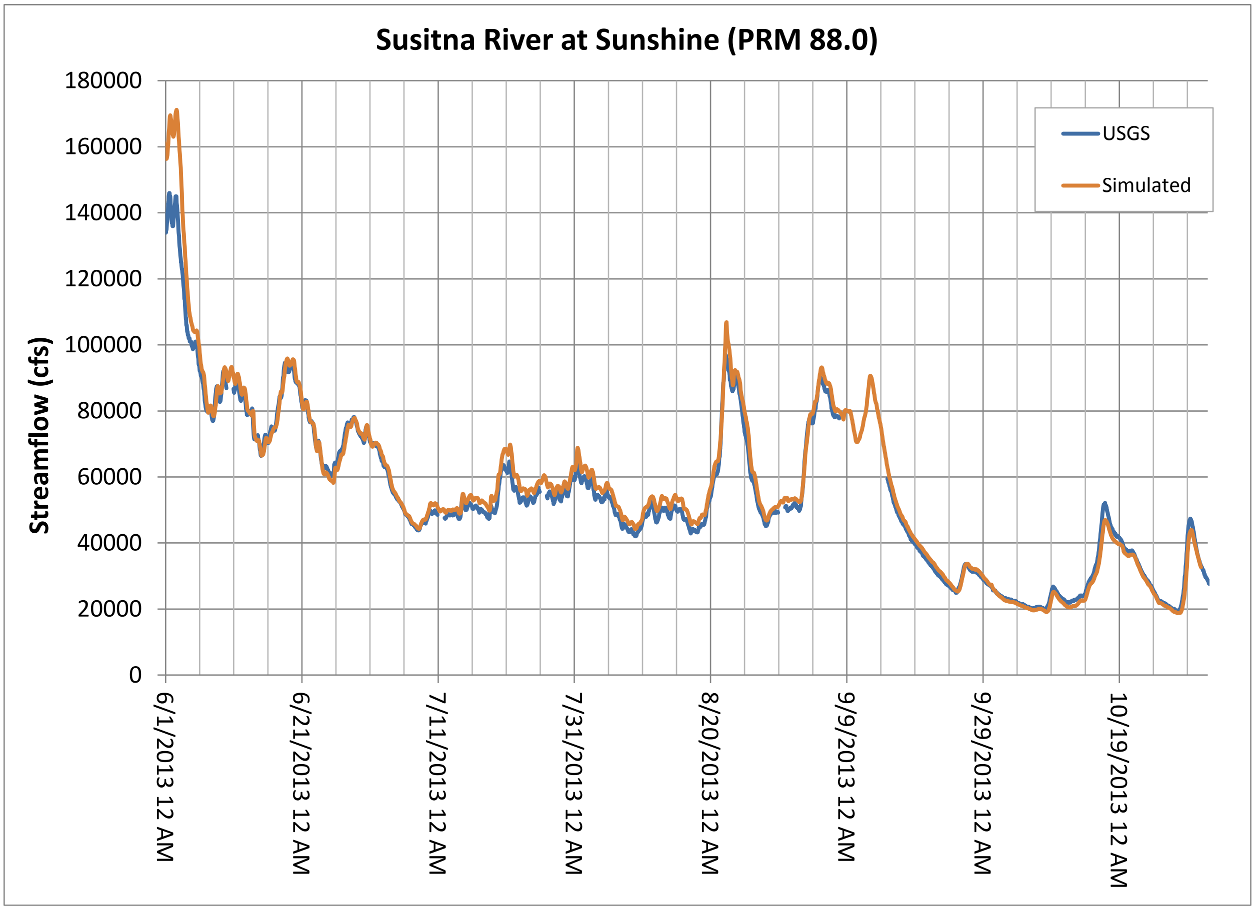


Figure 21. Comparison of measured versus simulated flow hydrographs in the Susitna River at Sunshine (USGS No. 15292780) during the 2013 open water period.

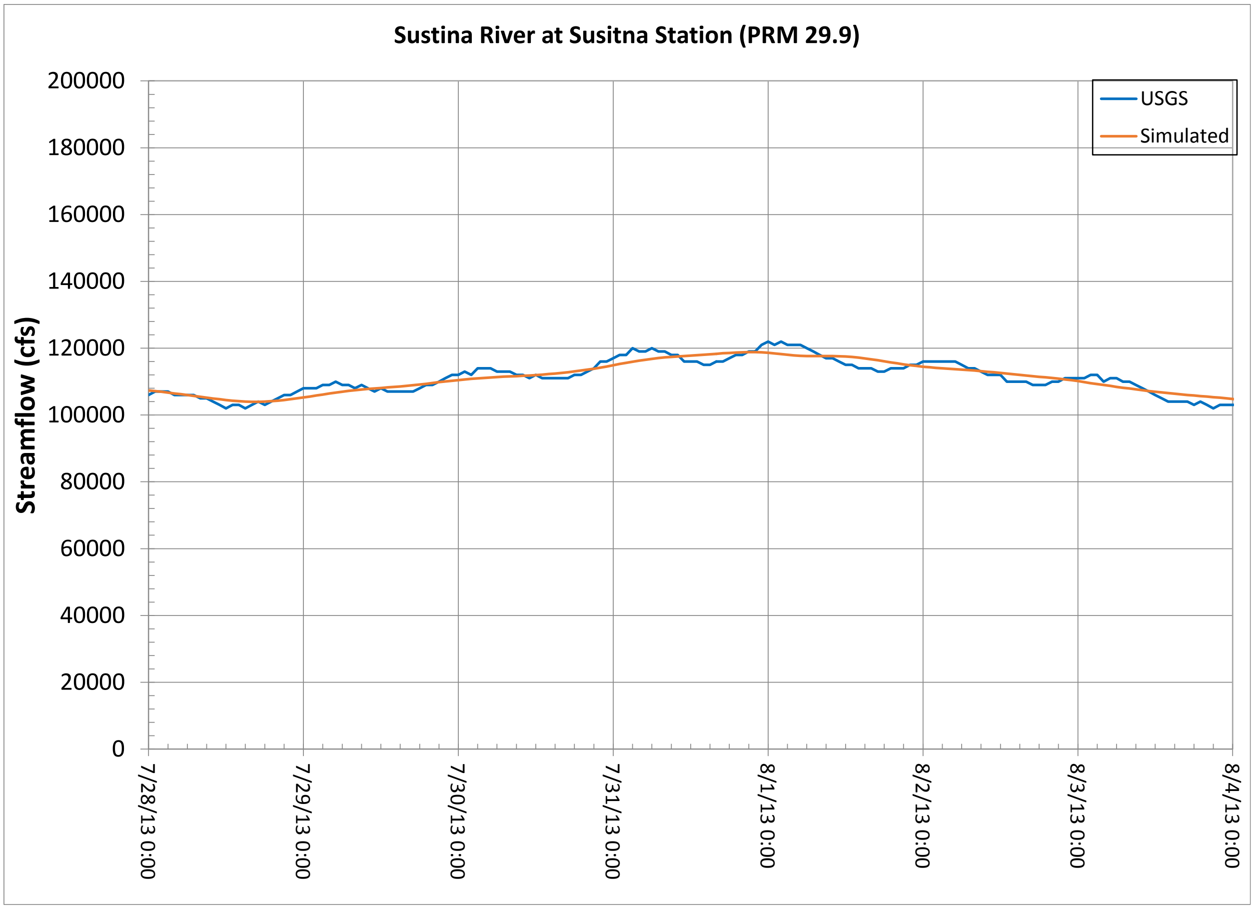


Figure 22. Comparison of measured versus simulated flow hydrographs in the Susitna River at Susitna Station (USGS No. 15294350) during the period from July 28 to August 3, 2013.

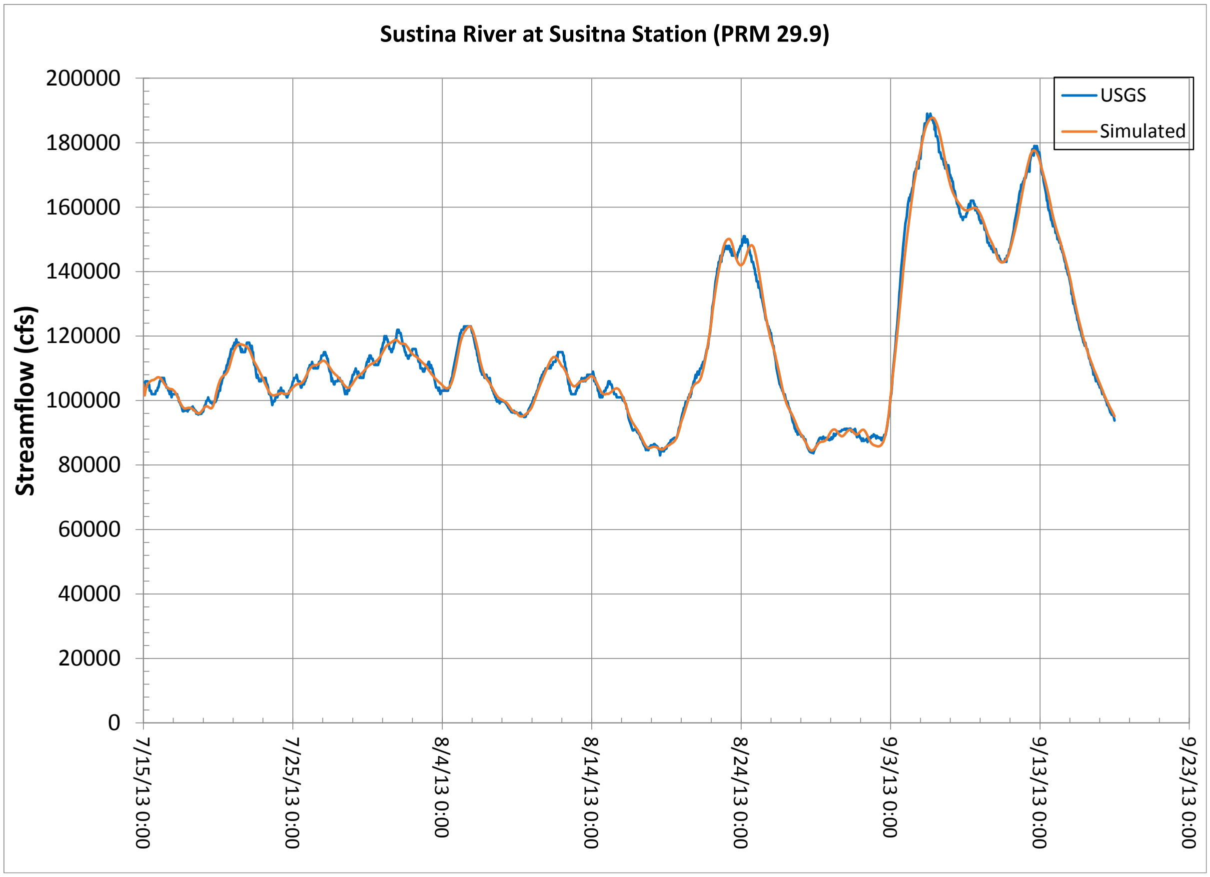


Figure 23. Comparison of measured versus simulated flow hydrographs in the Susitna River at Susitna Station (USGS No. 15294350) during the 2013 open water period.

ATTACHMENT 1: TRIBUTARY GAGE SITE SCHEMATICS

Susitna-Watana Hydroelectric Project

(FERC No. 14241)

Fish and Aquatics Instream Flow Study (8.5)

2014-2015 Study Implementation Report

Appendix B Attachment 1

Tributary Gage Site Schematics

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

R2 Resource Consultants, Inc.

November 2015

LIST OF FIGURES

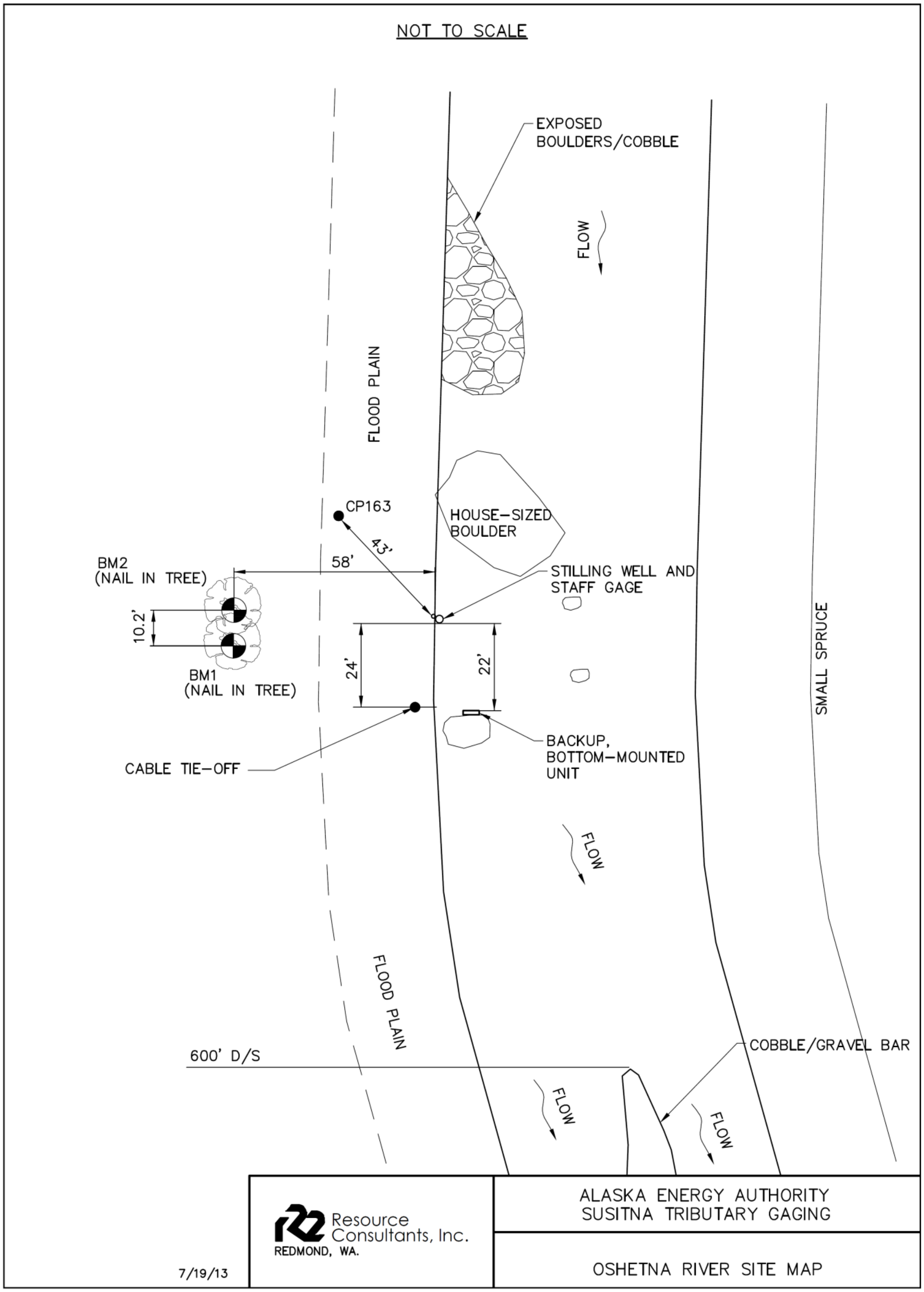


Figure B1-1. Site schematic for tributary gage at Oshetna River (Upper River).

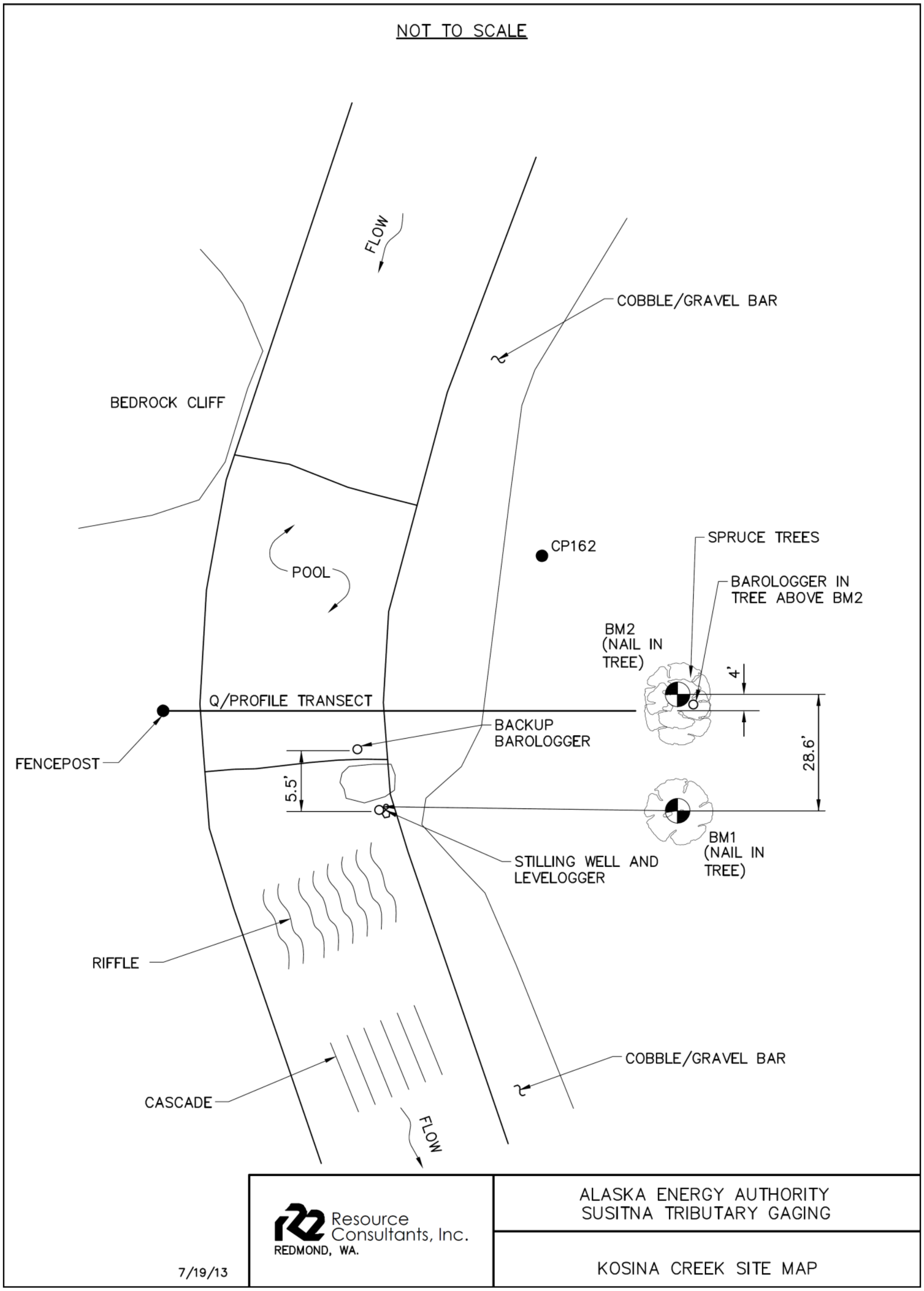


Figure B1-2. Site schematic for tributary gage at Kosina Creek (Upper River).

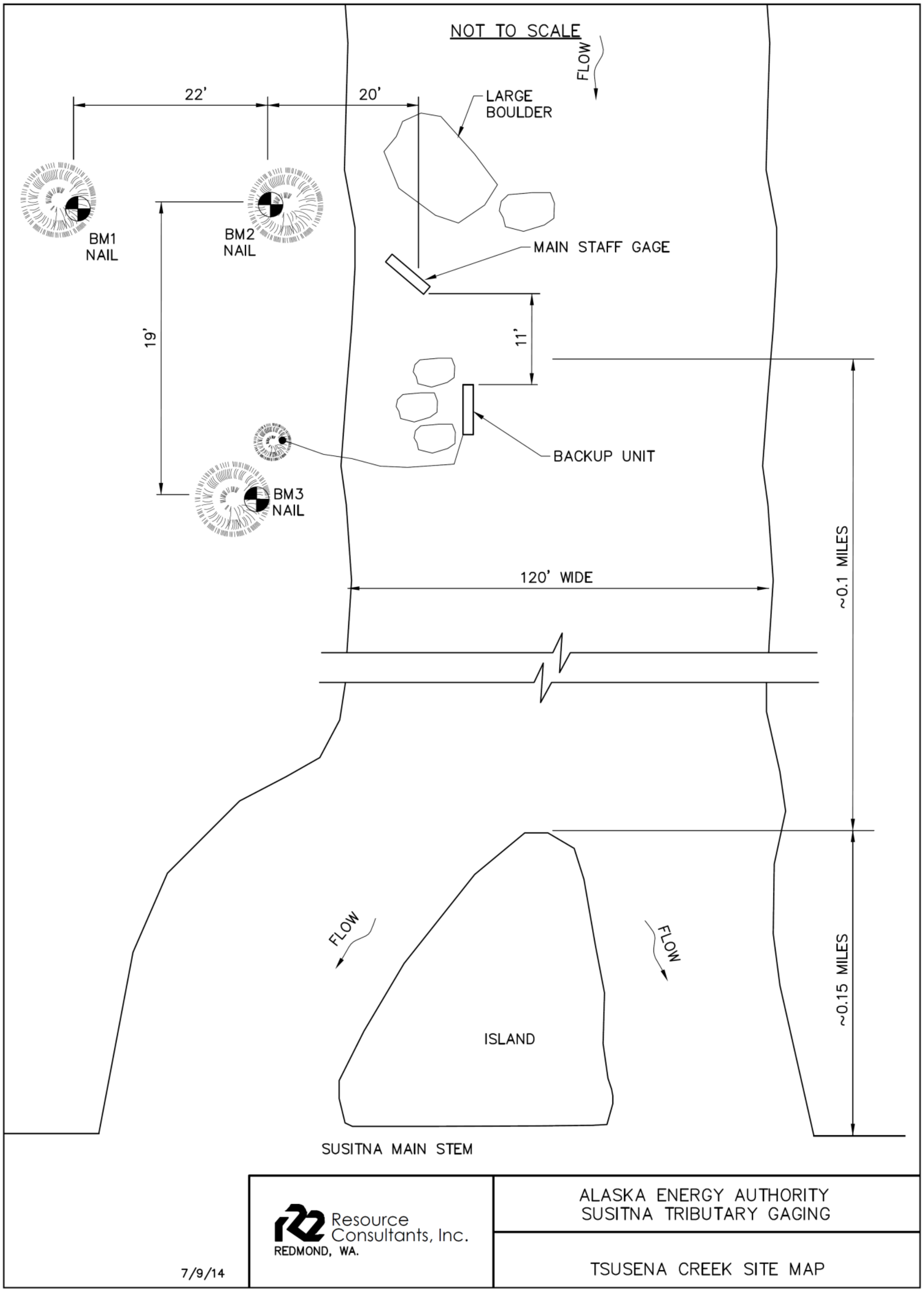


Figure B1-3. Site schematic for tributary gage at Tsusena Creek (Upper River).

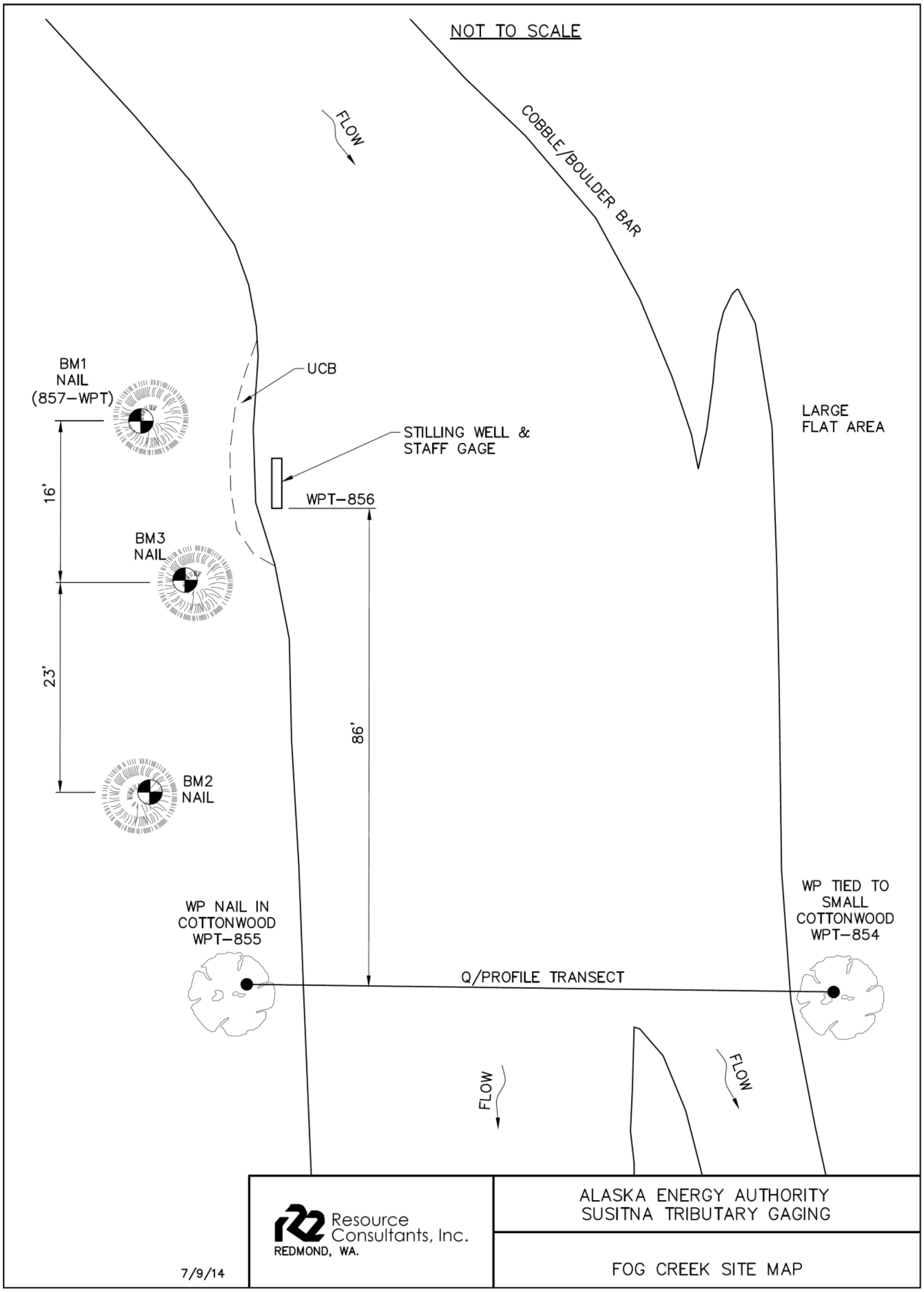


Figure B1-4. Site schematic for tributary gage at Fog Creek (Upper River).

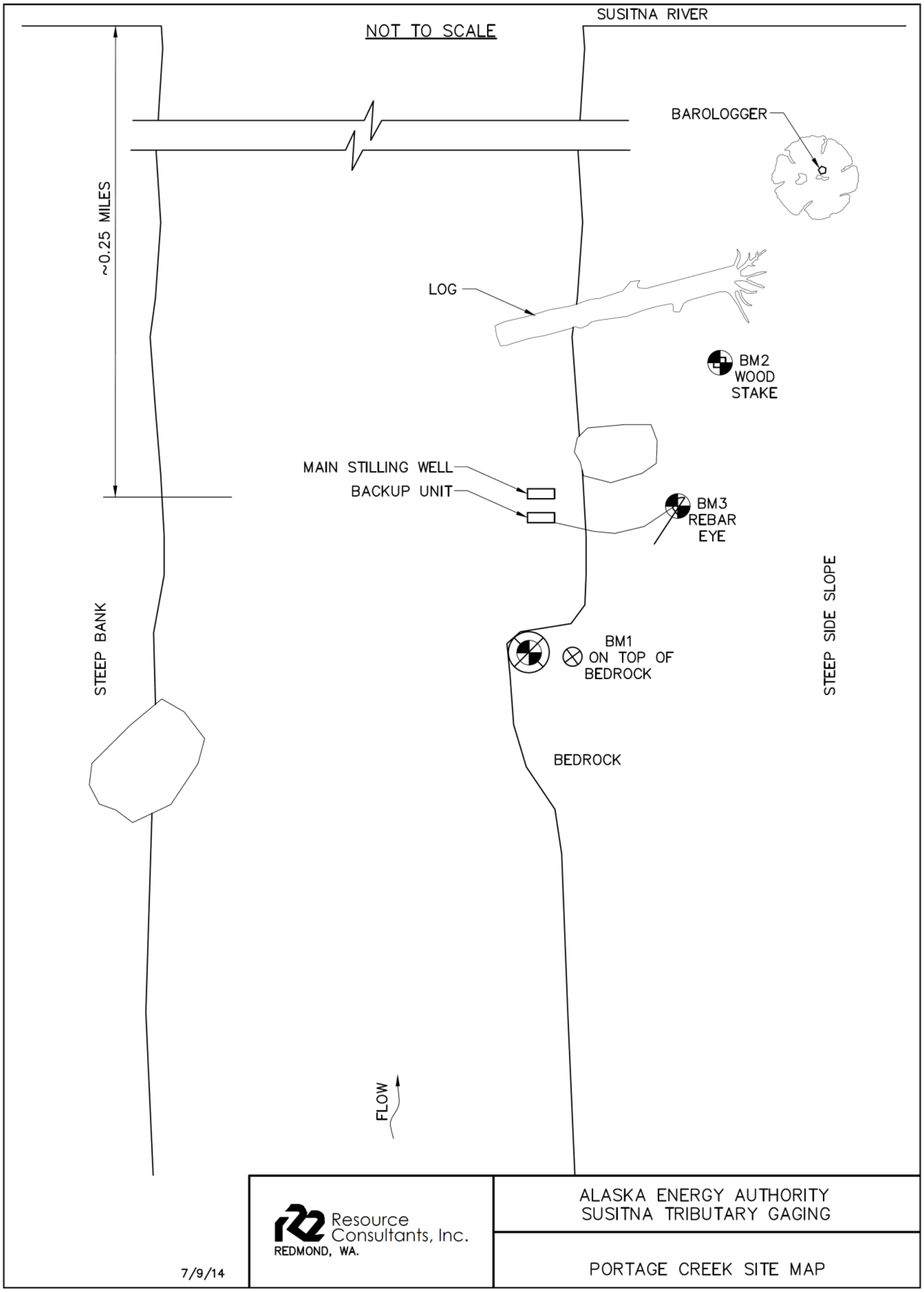


Figure B1-5. Site schematic for tributary gage at Portage Creek (Middle River, FA-151 [Portage Creek]).

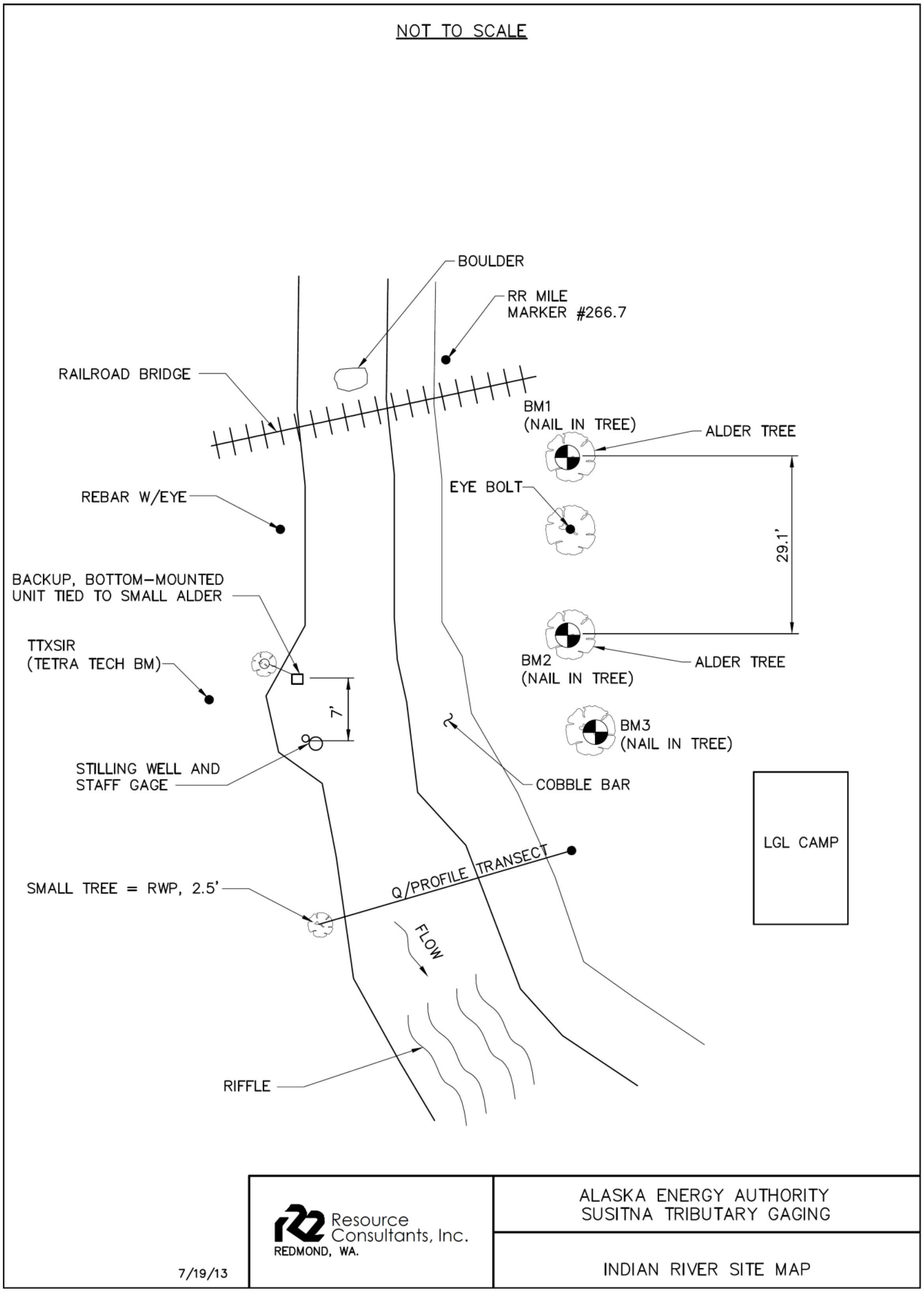


Figure B1-6. Site schematic for tributary gage at Indian River (Middle River, FA-141 [Indian River]).

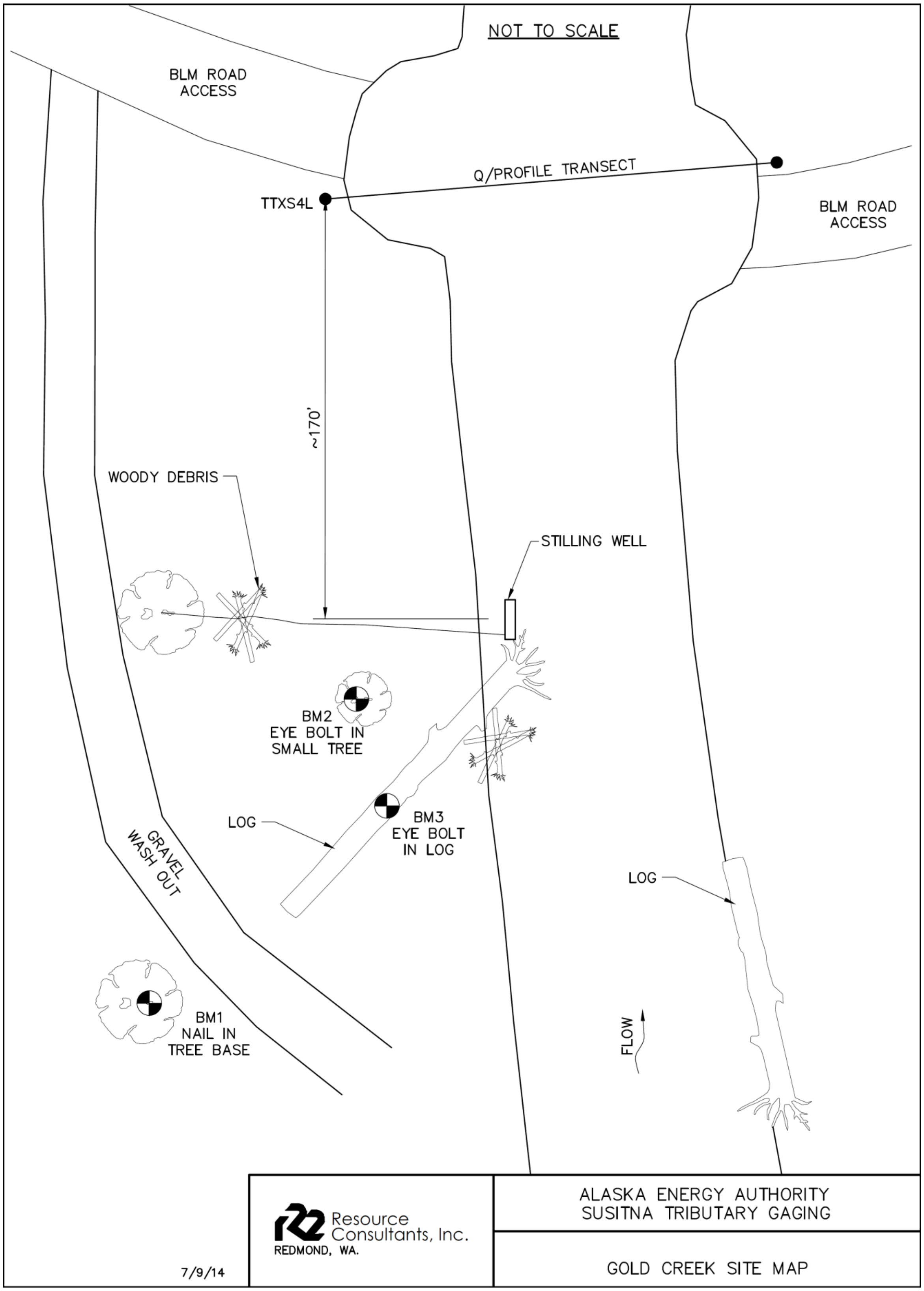


Figure B1-7. Site schematic for tributary gage at Gold Creek (Middle River, FA-138 [Gold Creek]).

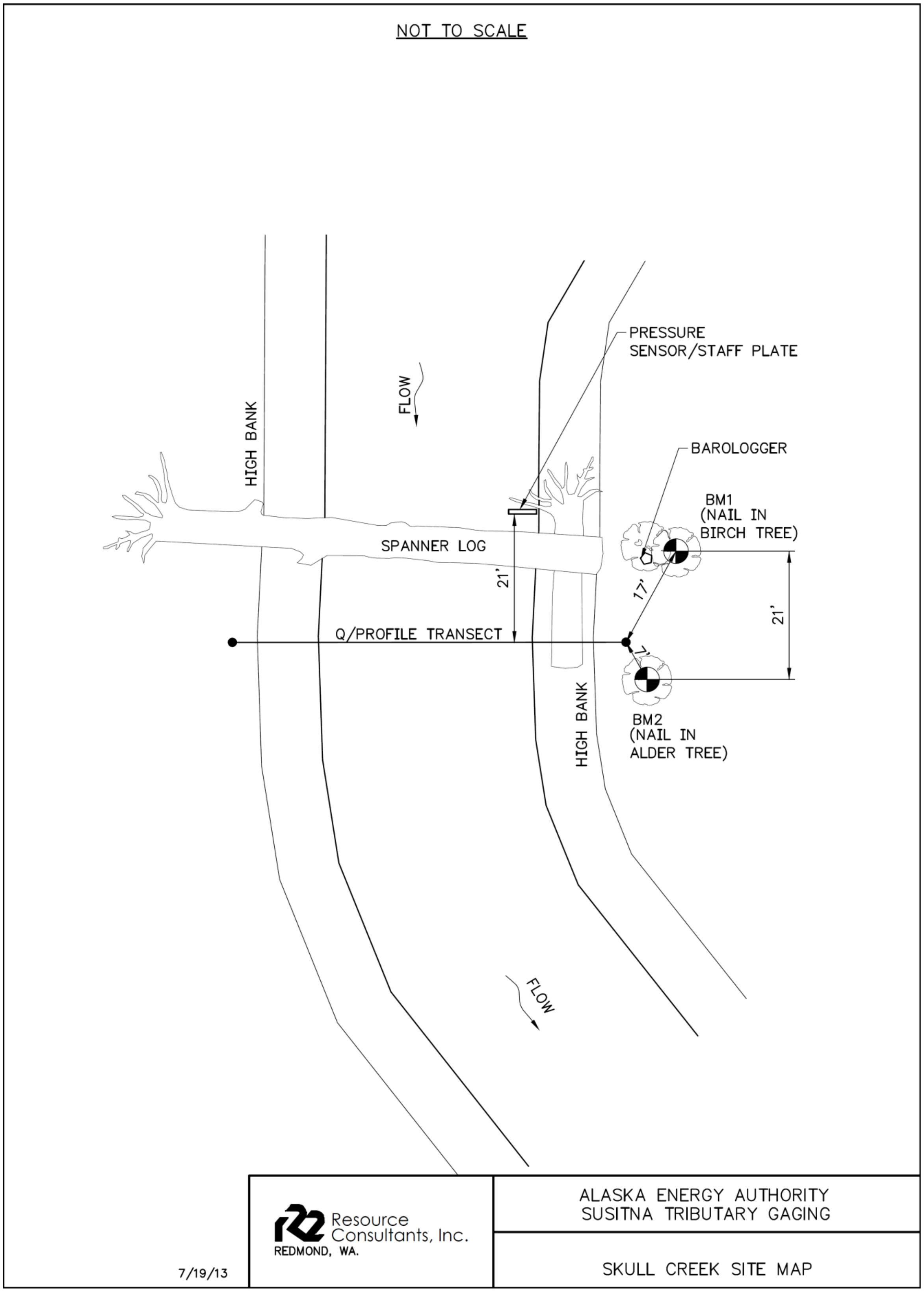


Figure B1-8. Site schematic for tributary gage at Skull Creek (Middle River, FA-128 [Slough 8A]).

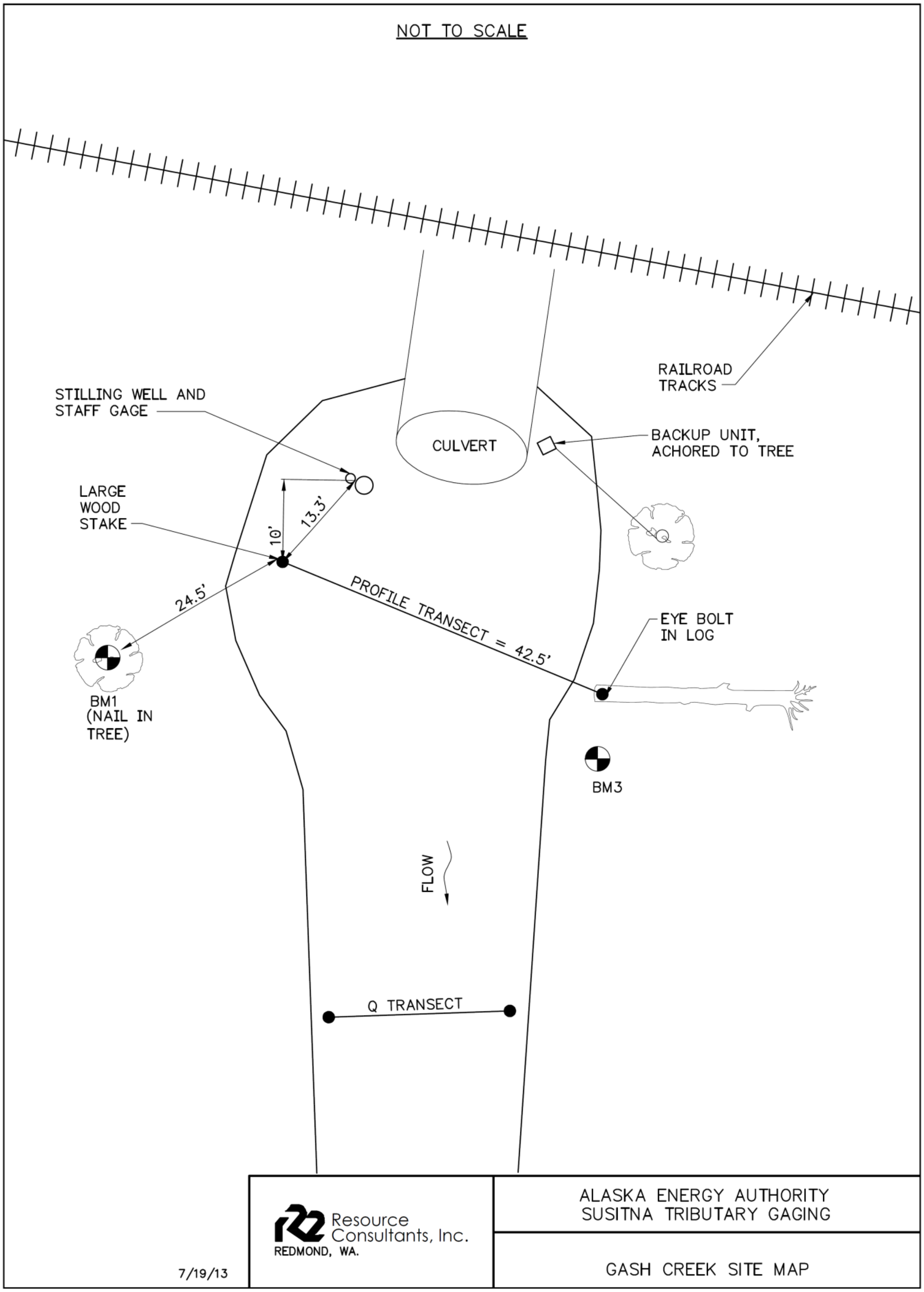


Figure B1-9. Site schematic for tributary gage at Gash Creek (Middle River, FA-113 [Oxbow 1]).

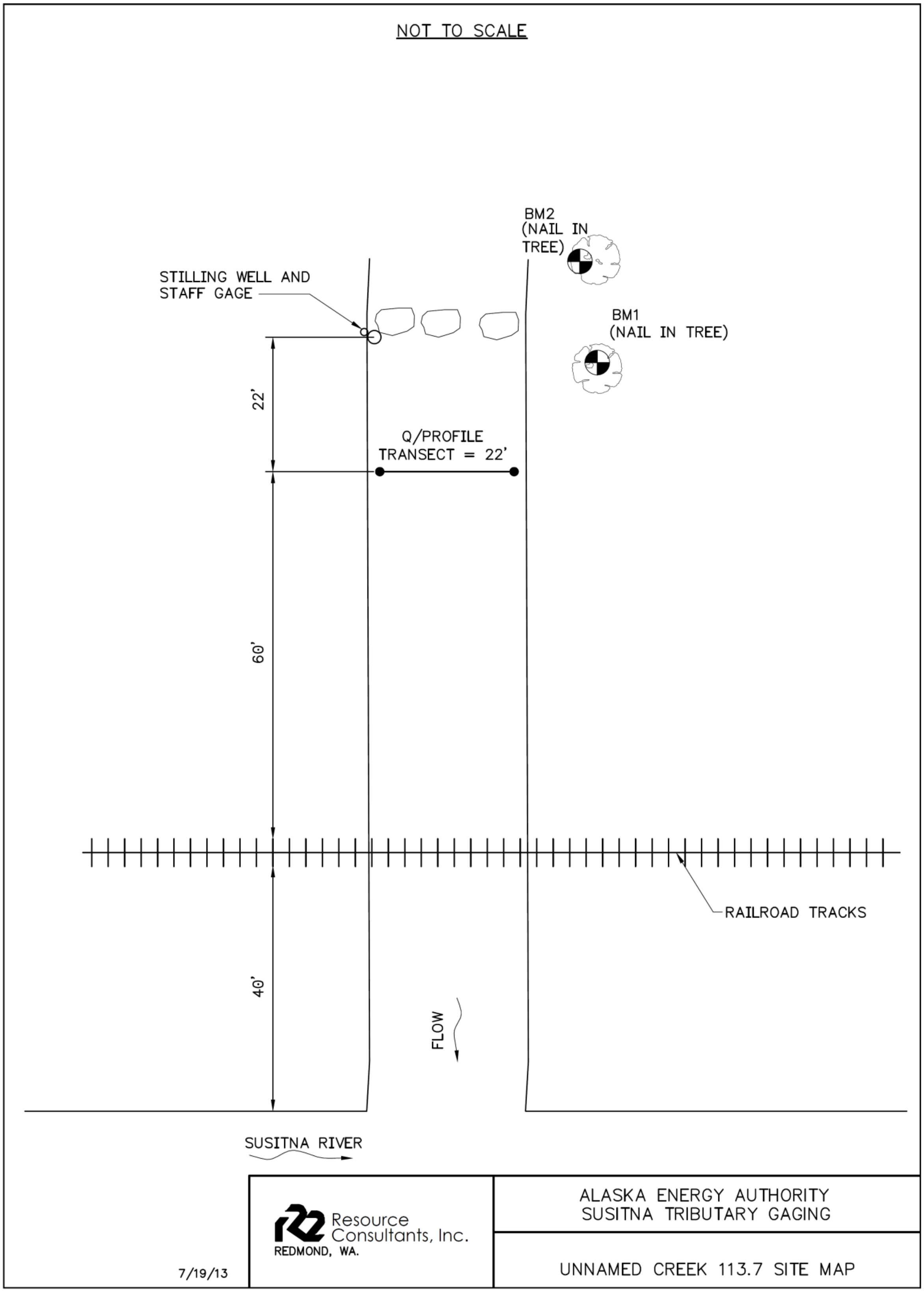


Figure B1-10. Site schematic for tributary gage at Unnamed Creek 113.7 (Middle River, FA-113 [Oxbow 1]).

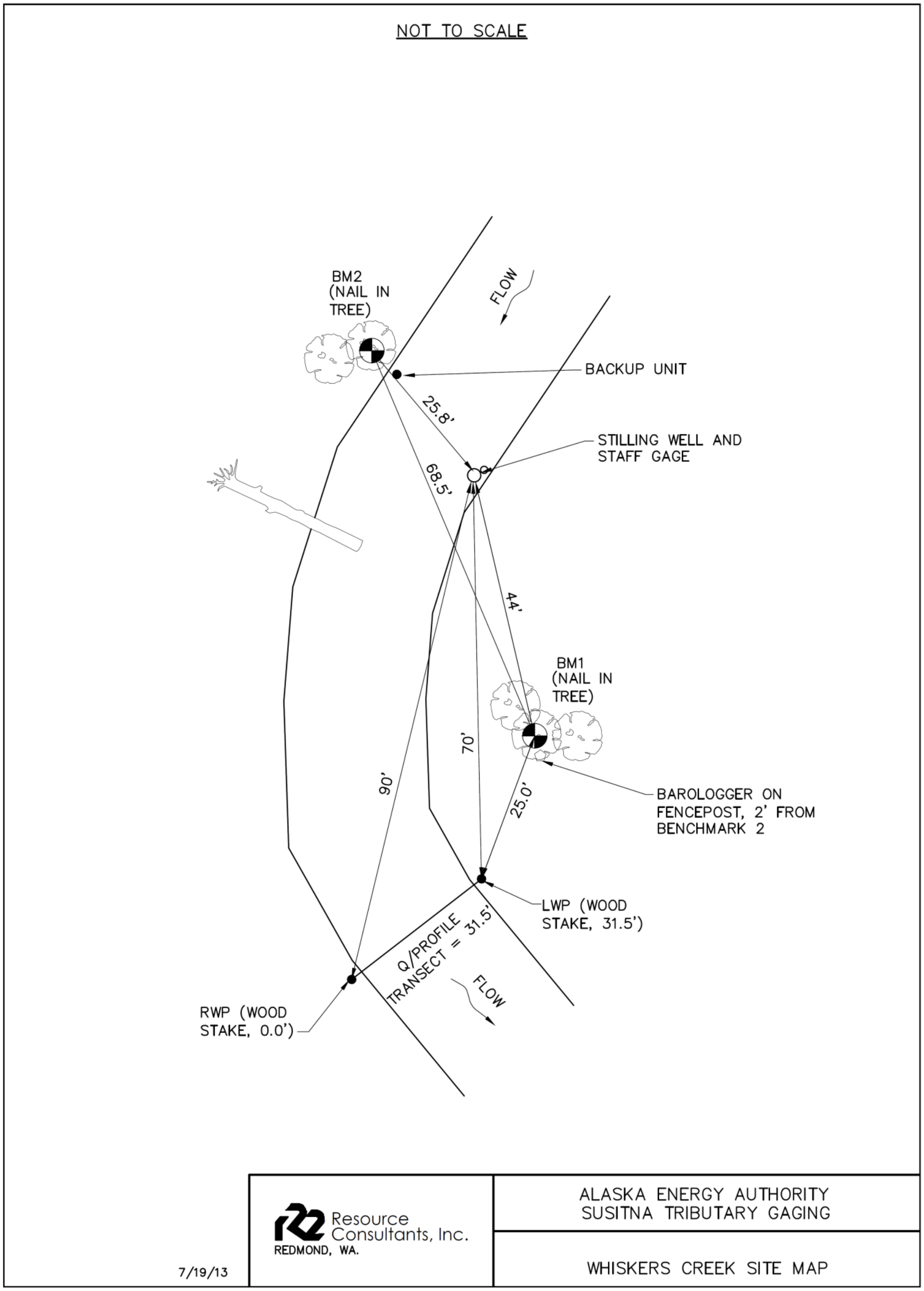


Figure B1-11. Site schematic for tributary gage at Whiskers Creek (Middle River, FA-104 [Whiskers Slough]).

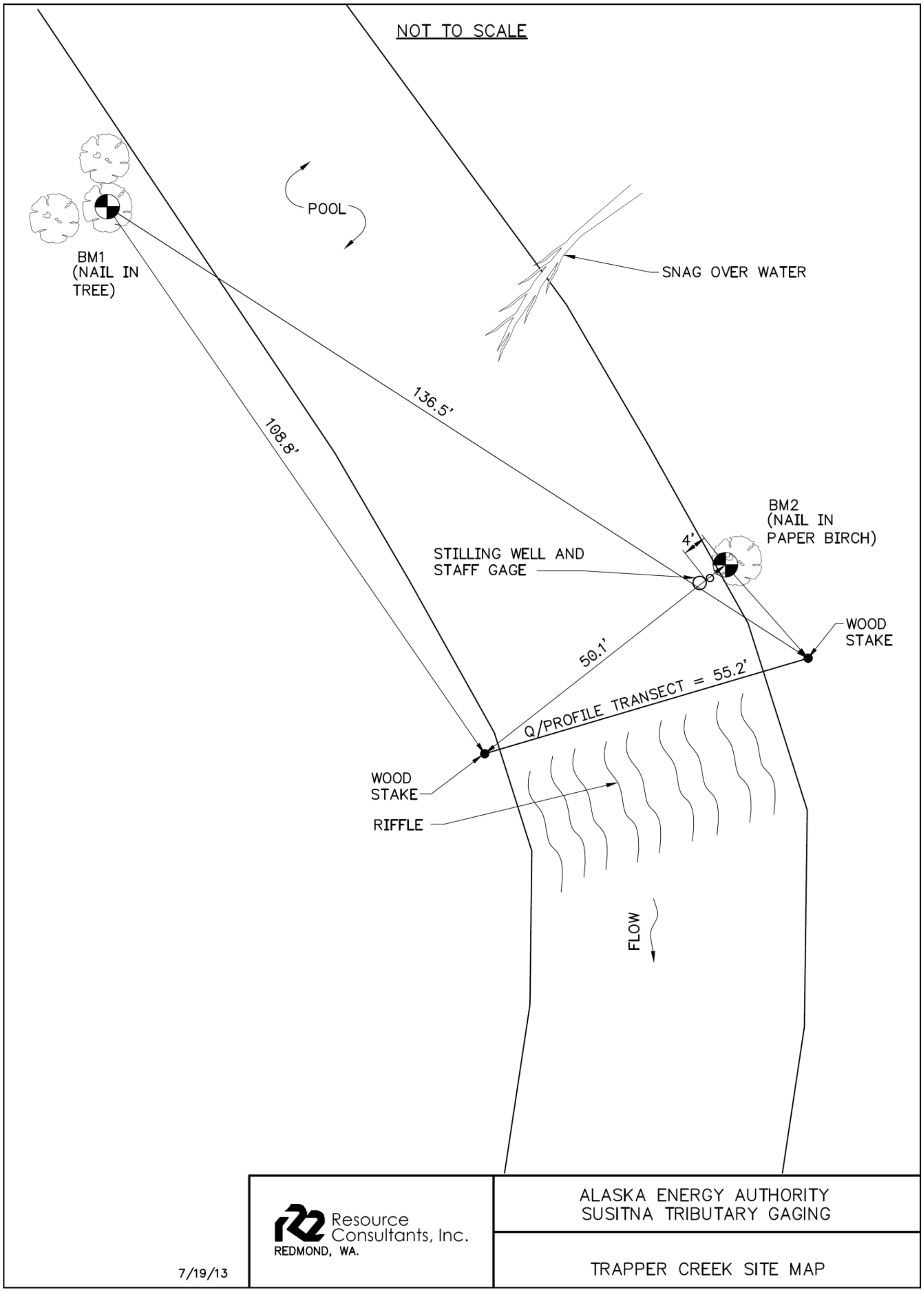


Figure B1-12. Site schematic for tributary gage at Trapper Creek (Lower River).

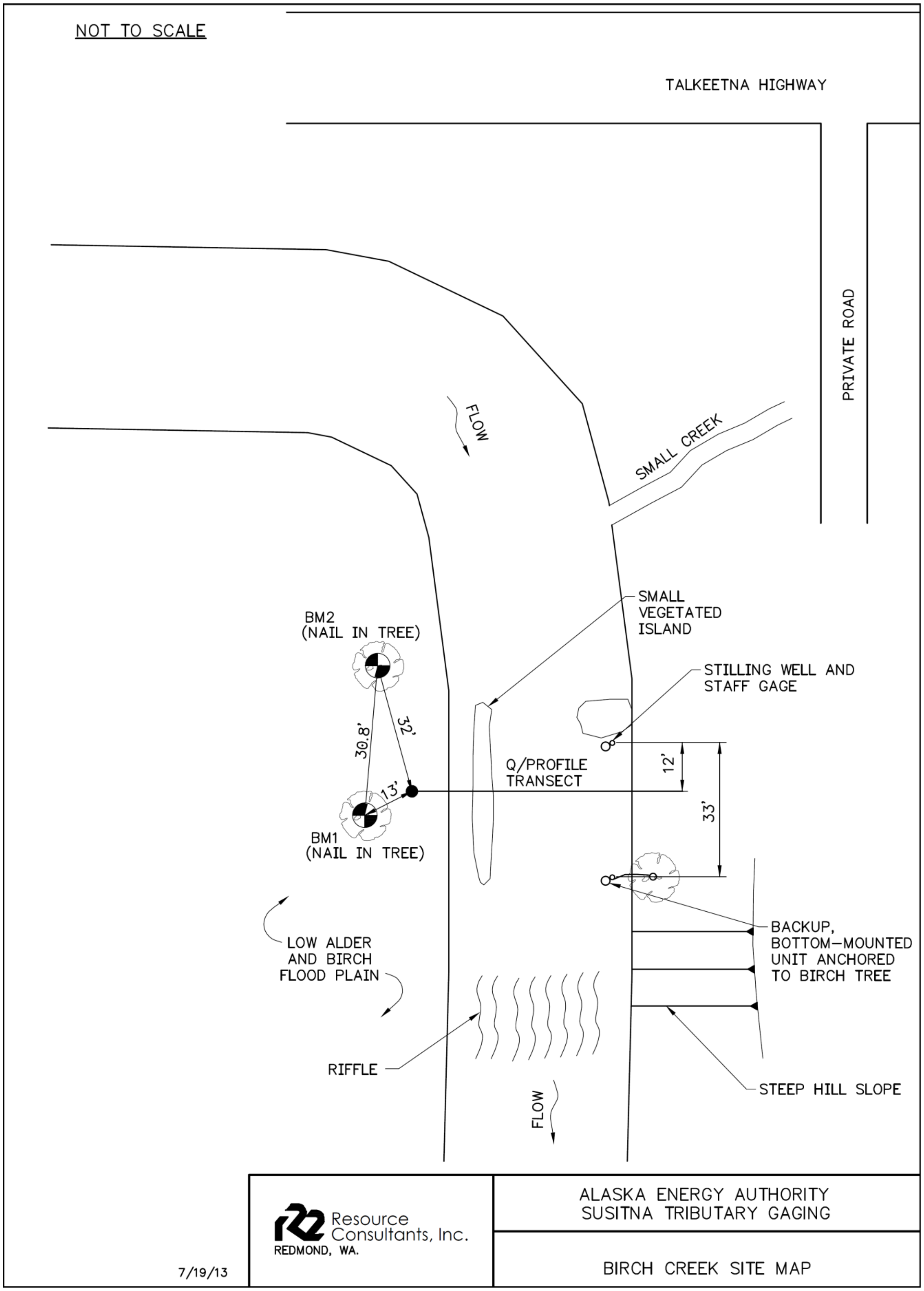


Figure B1-13. Site schematic for tributary gage at Birch Creek (Lower River).

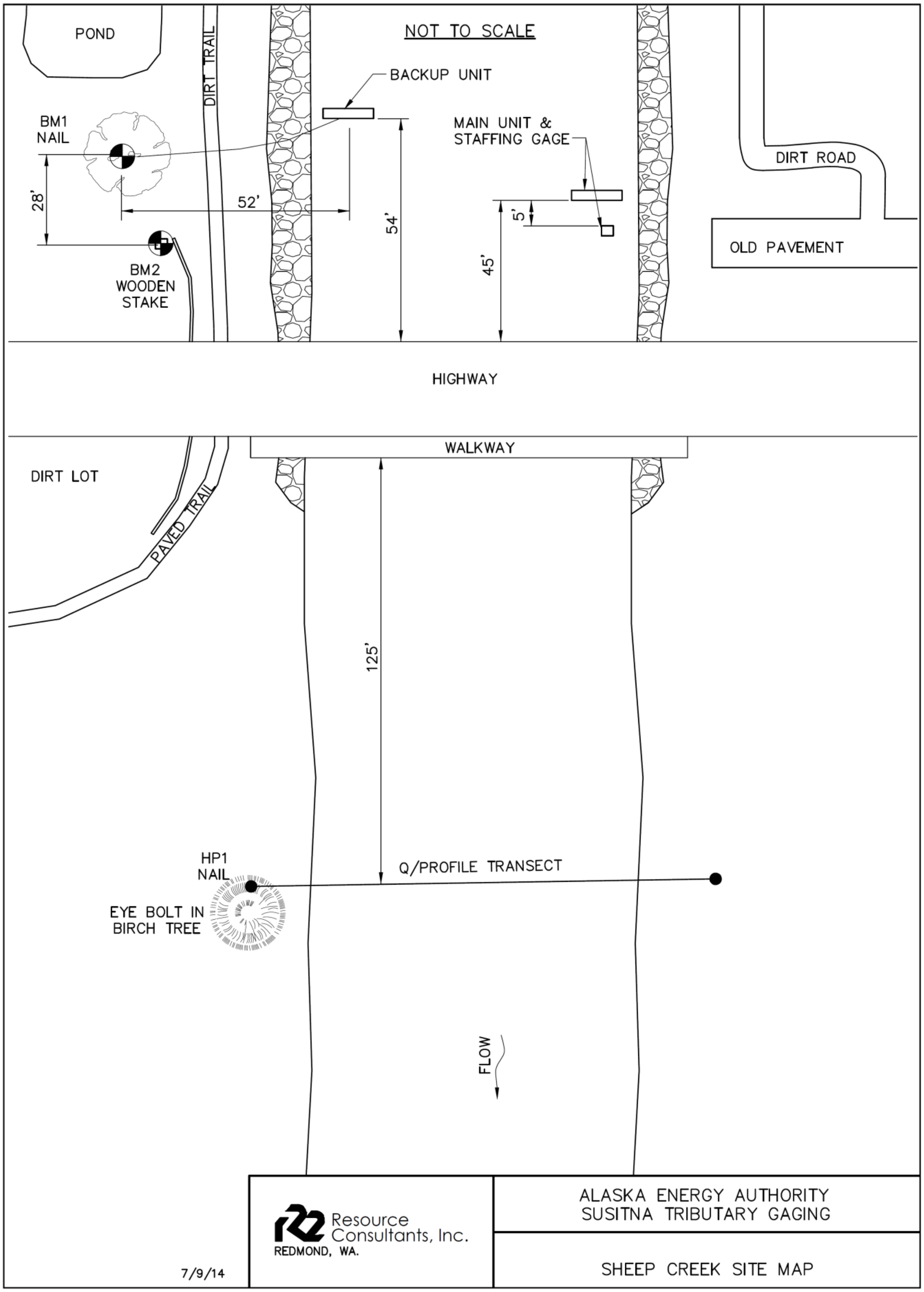


Figure B1-14. Site schematic for tributary gage at Sheep Creek (Lower River).

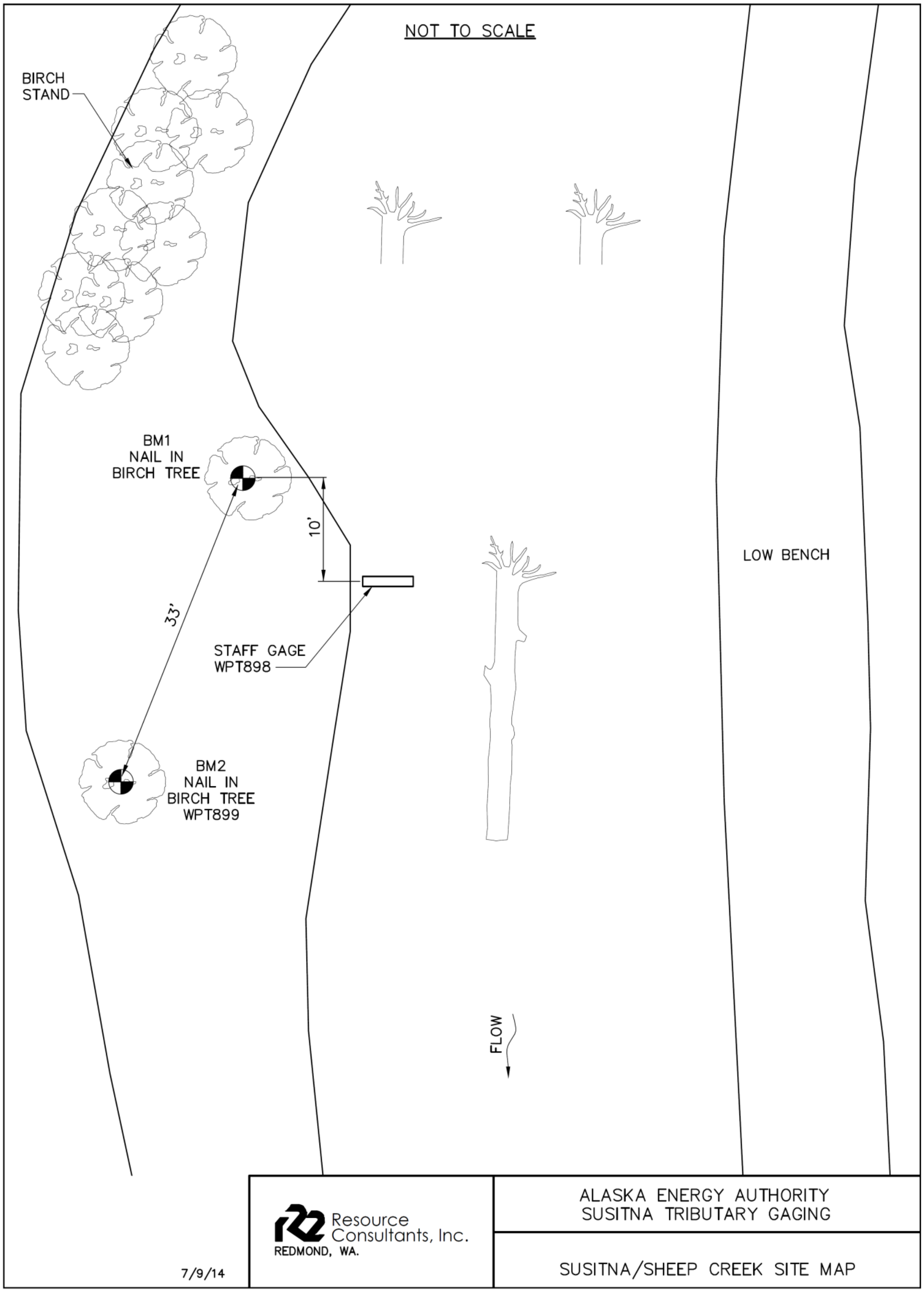


Figure B1-15. Site schematic for tributary gage at Susitna River at Sheep Creek (Lower River).

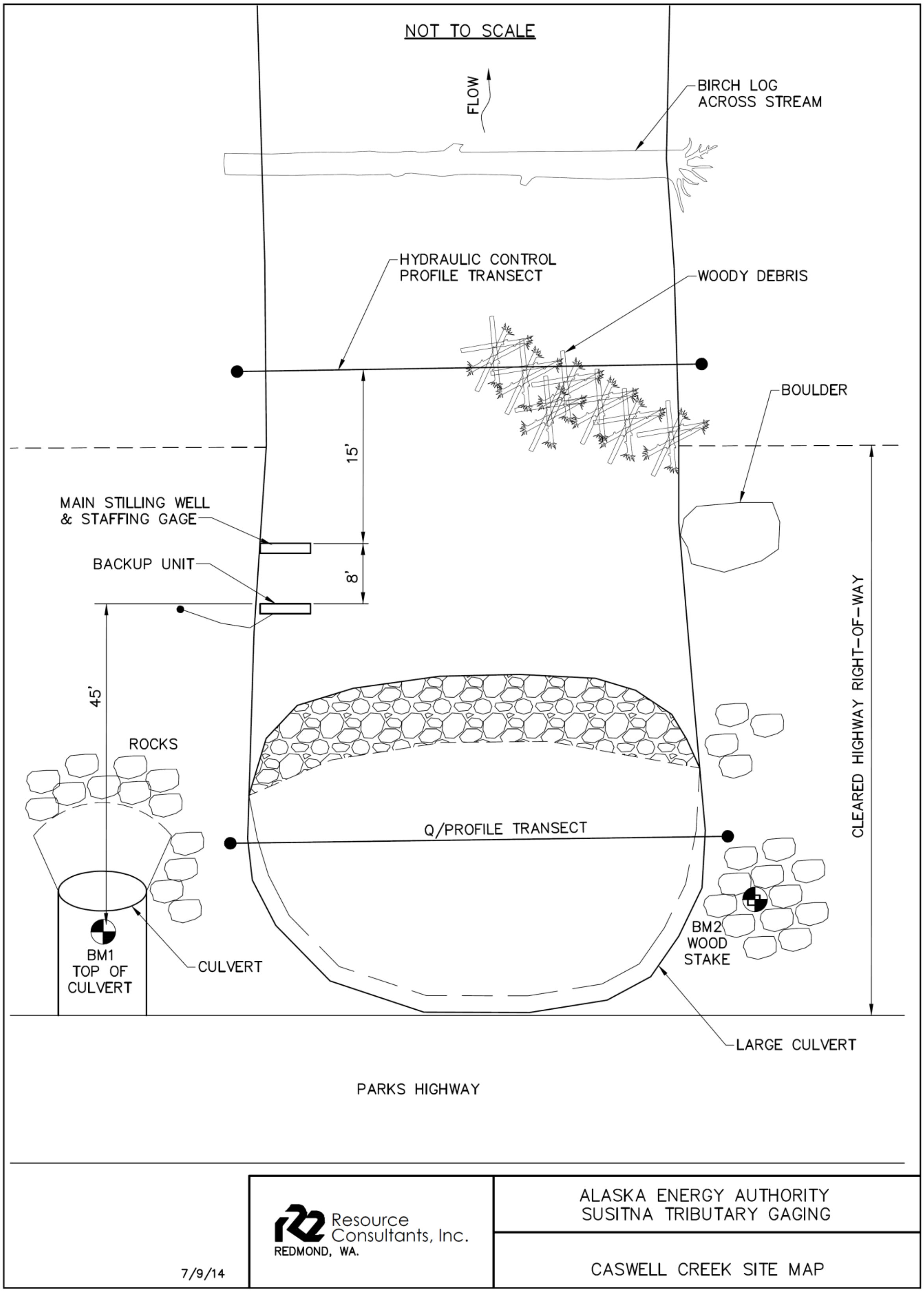


Figure B1-16. Site schematic for tributary gage at Caswell Creek (Lower River).

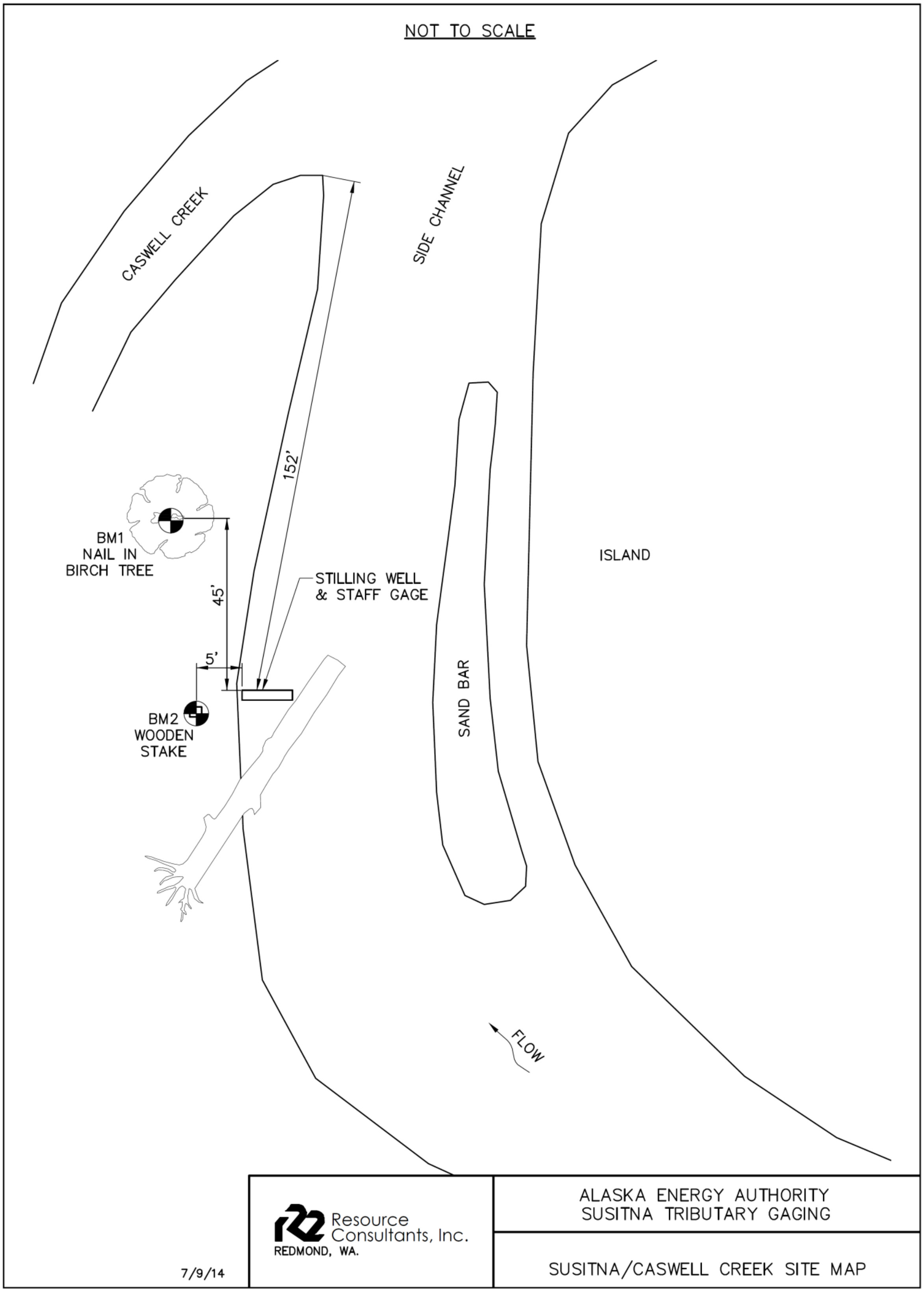


Figure B1-17. Site schematic for tributary gage at Susitna River at Caswell Creek (Lower River).

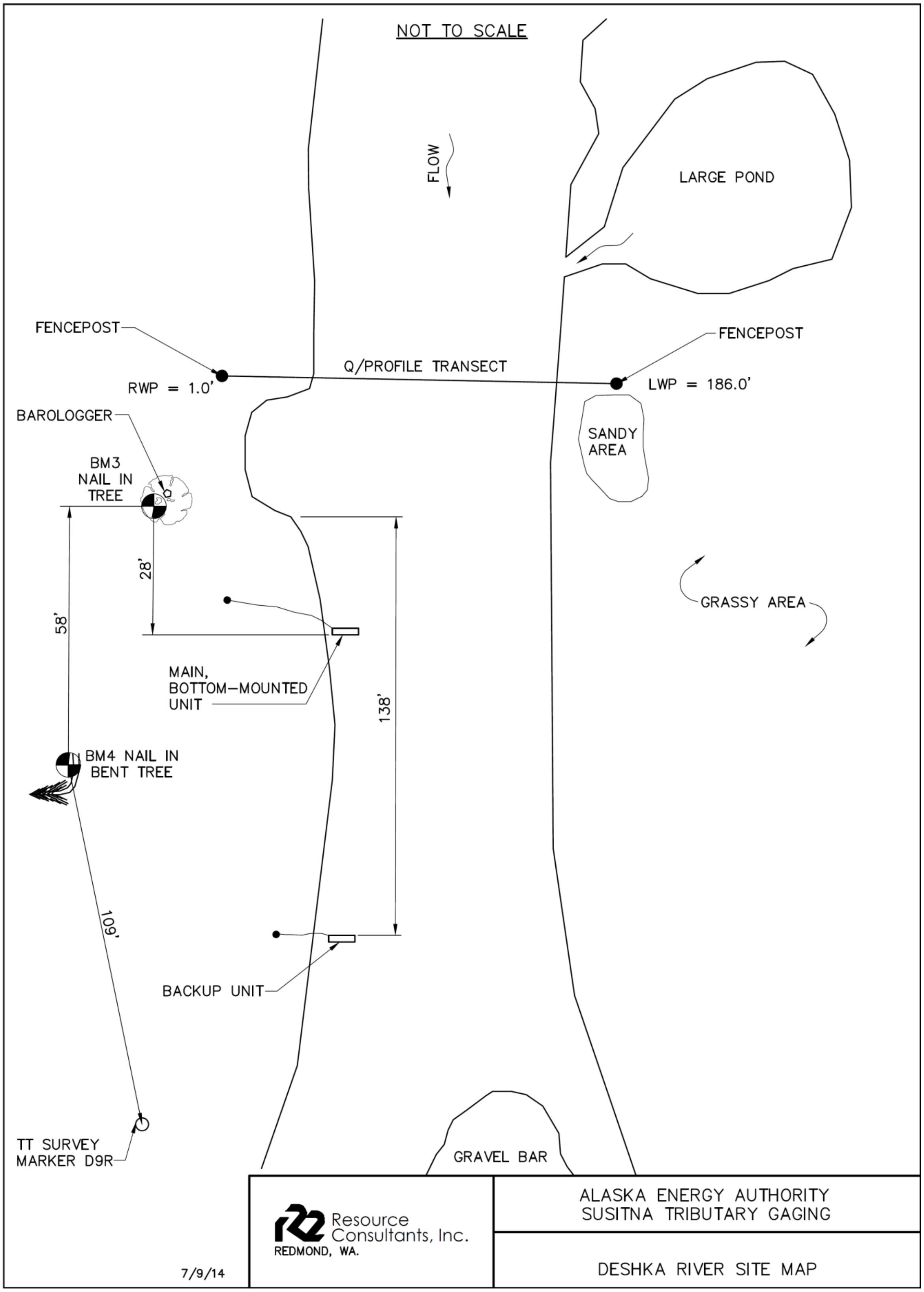


Figure B1-18. Site schematic for tributary gage at Deshka River (Lower River).

ATTACHMENT 2: MEASURED TRIBUTARY GAGE DATA

Susitna-Watana Hydroelectric Project

(FERC No. 14241)

Fish and Aquatics Instream Flow Study (8.5)

2014-2015 Study Implementation Report

Appendix B Attachment 2

Measured Tributary Gage Data

Prepared for

Alaska Energy Authority

Prepared by

R2 Resource Consultants, Inc.

November 2015

Table B2-1. Measured Susitna River Tributary Gage Data.

Tributary Gage Site	Date	Streamflow (cfs)	SG1 (ft, SG1 datum)	SG2 (ft, SG2 datum)	WSE (ft)	Comment
Oshetna River	7/13/2013	NM	1.55	1.23	2160.75	SG2 is calculated
Oshetna River	8/7/2013	NM	1.54	1.22	2160.74	SG2 is calculated
Oshetna River	8/9/2013	614.3	1.42	1.10	NM	SG2 is calculated
Oshetna River	9/3/2013	1107	2.17	1.85	NM	SG2 is calculated
Oshetna River	9/26/2013	NM	1.44	1.12	2160.62	SG2 is calculated
Oshetna River	6/10/2014	NM	2.16	1.84	2161.38	SG1 is calculated
Oshetna River	6/18/2014	1450	2.37	2.05	NM	SG1 is calculated
Oshetna River	9/10/2014	1472	2.48	2.16	NM	SG1 is calculated
Oshetna River	9/18/2014	NM	2.13	1.81	2161.33	SG1 is calculated
Oshetna River	9/25/2014	1028	1.97	1.65	2161.19	SG1 is calculated
Kosina Creek	7/13/2013	620.1	1.44	1.25	1904.63	SG2 is calculated
Kosina Creek	8/7/2013	610.0	1.38	1.19	1904.58	SG2 is calculated
Kosina Creek	9/26/2013	NM	1.53	1.34	1904.73	SG2 is calculated
Kosina Creek	6/10/2014	NM	1.64	1.45	1904.86	SG1 is calculated
Kosina Creek	6/18/2014	1307	2.19	2.00	NM	SG1 is calculated
Kosina Creek	9/11/2014	1044	2.04	1.85	NM	SG1 is calculated
Kosina Creek	9/18/2014	NM	1.85	1.66	1905.09	SG1 is calculated
Kosina Creek	9/24/2014	816.8	1.74	1.55	NM	SG1 is calculated
Tsusena Creek	6/11/2014	NM	1.99	NA	1455.61	
Tsusena Creek	6/29/2014	1151	2.28	NA	NM	
Tsusena Creek	7/30/2014	NM	1.48	NA	1455.13	
Tsusena Creek	8/14/2014	405.0	1.11	NA	NM	
Tsusena Creek	9/12/2014	578.6	1.49	NA	NM	
Tsusena Creek	9/19/2014	NM	1.48	NA	1455.1	
Fog Creek	6/11/2014	339	1.99	1.01	1410.25	SG1 is calculated, WSE at original levelogger
Fog Creek	7/30/2014	375	NA	1.00	1410.35	WSE at original levelogger
Fog Creek	9/19/2014	303.4	NA	1.37	1410.15	WSE at relocated levelogger
Unnamed Tributary 174.2	6/12/2014	2.71	NA	NA	NA	
Unnamed Tributary 173.8	6/12/2014	13.3	NA	NA	NA	
Unnamed Tributary 173.8	9/19/2014	13.4	NA	NA	NA	
Portage Creek	6/12/2014	NA	2.00	NA	852.68	
Portage Creek	6/21/2014	1459	2.43	NA	NM	
Portage Creek	6/22/2014	1506	2.48	NA	NM	
Portage Creek	7/29/2014	NA	1.85	NA	852.53	

Tributary Gage Site	Date	Streamflow (cfs)	SG1 (ft, SG1 datum)	SG2 (ft, SG2 datum)	WSE (ft)	Comment
Portage Creek	8/12/2014	571.9	1.25	NA	NM	
Portage Creek	9/15/2014	809	1.65	NA	NM	
Portage Creek	9/18/2014	NA	1.82	NA	852.49	
Portage Creek	9/27/2014	687.3	1.45	NA	NM	
Gold Creek	6/13/2014	153.0	1.95	NA	776.91	
Gold Creek	7/29/2014	62.2	1.41	NA	776.41	
Gold Creek	9/20/2014	143.5	1.90	NA	776.86	
Unnamed Tributary 144.6	7/12/2013	0.33	NA	NA	NA	
Unnamed Tributary 144.6	8/7/2013	0	NA	NA	NA	
Unnamed Tributary 144.6	9/15/2013	17.9	NA	NA	NA	
Unnamed Tributary 144.6	9/26/2013	12.2	NA	NA	NA	
Unnamed Tributary 144.6	6/10/2014	23.3	NA	NA	NA	
Unnamed Tributary 144.6	9/19/2014	20.8	NA	NA	NA	
Indian River	7/11/2013	231.5	1.61	NM	771.96	
Indian River	8/9/2013	136.8	1.28	NM	771.66	
Indian River	9/28/2013	286.3	1.69	NM	772.01	
Indian River	6/13/2014	435.0	2.06	1.98	772.32	SG1 is calculated
Indian River	9/20/2014	618.2	2.39	2.31	772.63	SG1 is calculated
Skull Creek	7/12/2013	7.40	0.96	NA	592.74	
Skull Creek	8/8/2013	2.49	0.75	NA	592.56	
Skull Creek	9/13/2013	48.5	1.6	NA	NM	
Skull Creek	9/29/2013	13.7	1.15	NA	592.92	
Skull Creek	6/14/2014	18.5	1.18	NA	593.01	
Skull Creek	9/21/2014	48.3	1.62	NA	593.42	
Unnamed Tributary 115.4	9/17/2013	0.83	NA	NA	NA	
Unnamed Tributary 115.4	6/14/2014	0.29	NA	NA	NA	
Unnamed Tributary 115.4	9/21/2014	0.41	NA	NA	NA	
Unnamed Tributary 115.4	9/23/2014	7.2	NA	NA	NA	
Gash Creek	6/16/2013	2.37	1.12	NA	NA	
Gash Creek	8/8/2013	2.86	1	NA	NA	
Gash Creek	9/29/2103	5.32	1.13	NA	NA	
Gash Creek	6/14/2014	3.92	1.05	NA	NA	
Gash Creek	9/21/2014	9.24	NA	NA	NA	
Gash Creek	9/23/2014	0.45	NA	NA	NA	
Slash Creek	6/16/2013	0.17	NA	NA	NA	
Slash Creek	8/8/2013	0.03	NA	NA	NA	
Slash Creek	9/29/2013	0.28	NA	NA	NA	

Tributary Gage Site	Date	Streamflow (cfs)	SG1 (ft, SG1 datum)	SG2 (ft, SG2 datum)	WSE (ft)	Comment
Slash Creek	6/14/2014	0.12	NA	NA	NA	
Slash Creek	9/21/2014	0.35	NA	NA	NA	
Slash Creek	9/23/2014	0.24	NA	NA	NA	
Unnamed Tributary 113.7	6/16/2013	2.31	1.26	NA	NA	
Unnamed Tributary 113.7	8/8/2013	0.32	1.00	NA	NA	
Unnamed Tributary 113.7	9/29/2013	4.92	1.42	NA	NA	
Unnamed Tributary 113.7	6/14/2014	2.01	NA	NA	NA	
Unnamed Tributary 113.7	9/23/2014	5.22	NA	NA	NA	
Whiskers Creek	6/22/2013	17.6	1.99	NA	371.85	
Whiskers Creek	8/6/2013	5.68	1.75	NA	371.62	
Whiskers Creek	9/11/2013	147.7	3.59	NA	NM	
Whiskers Creek	9/30/2013	39.3	2.41	NA	372.26	
Whiskers Creek	6/9/2014	12.1	1.89	1.42	371.74	SG1 is calculated
Whiskers Creek	9/23/2014	28.7	2.3	1.83	372.17	SG1 is calculated
Trapper Creek	6/17/2013	31.7	1.26	NA	305.43	
Trapper Creek	8/6/2013	10.8	1.01	NA	305.19	
Trapper Creek	9/30/2013	89.7	1.7	NA	305.91	
Trapper Creek	6/16/2014	31.4	1.23	1.34	305.44	
Trapper Creek	9/22/2014	124.7	2.13	2.22	306.31	
Mainstem Trapper Companion Gage	6/17/2013	NA	2.06	NA	304.56	
Mainstem Trapper Companion Gage	8/6/2013	NA	0.04	NA	302.54	
Mainstem Trapper Companion Gage	9/30/2013	NA	NA	NA	300.25	SG is dry
Mainstem Trapper Companion Gage	6/16/2014	NA	0.39	2.02	302.88	SG1 is calculated
Mainstem Trapper Companion Gage	9/22/2014	NA	0.53	2.16	303.03	SG1 is calculated
Birch Creek	7/14/2013	35.1	1.85	NA	304.33	
Birch Creek	8/9/2013	23.9	1.76	NA	304.25	
Birch Creek	9/27/2013	82.3	2.33	NA	304.80	
Birch Creek	6/17/2014	37.2	1.9	NA	304.37	
Birch Creek	9/24/2014	43.3	1.97	NA	304.46	
Mainstem Birch Companion Gage	7/14/2013	NA	1.89	NA	289.57	
Mainstem Birch Companion Gage	8/6/2013	NA	1.77	NA	289.45	
Mainstem Birch Companion Gage	9/30/2013	NA	0.50	NA	288.16	
Mainstem Birch Companion Gage	6/16/2014	NA	1.93	1.98	289.62	SG1 is calculated
Mainstem Birch Companion Gage	9/22/2014	NA	2.1	2.15	289.79	SG1 is calculated
Sheep Creek	6/15/2014	432.4	1.98	NA	201.16	
Sheep Creek	7/21/2014	NM	1.89	NA	NM	
Sheep Creek	7/31/2014	333.3	1.78	NA	200.98	

Tributary Gage Site	Date	Streamflow (cfs)	SG1 (ft, SG1 datum)	SG2 (ft, SG2 datum)	WSE (ft)	Comment
Sheep Creek	9/25/2014	317.5	1.75	NA	200.93	
Mainstem Sheep Companion Gage	6/18/2014	NA	2.25	NA	175.31	
Mainstem Sheep Companion Gage	9/24/2014	NA	1.63	NA	174.72	
Caswell Creek	6/15/2014	28.5	1.88	NA	96.26	
Caswell Creek	7/31/2014	21.6	2.57	NA	96.93	
Caswell Creek	9/24/2014	30.9	2.94	NA	97.33	
Mainstem Caswell Companion Gage	6/18/2014	NA	2.05	NA	159.79	
Mainstem Caswell Companion Gage	9/24/2014	NA	0.89	NA	158.65	
Deshka River	7/15/2013	317.4	NA	NA	76.29	No SG installed
Deshka River	8/10/2013	245	NA	NA	76.13	No SG installed
Deshka River	9/27/2013	NM	NA	NA	79.25	No SG installed
Deshka River	6/17/2014	481.7	NA	NA	76.51	No SG installed
Deshka River	7/5/2014	714.9	NA	NA	76.82	No SG installed
Deshka River	7/31/2014	606.9	NA	NA	76.74	No SG installed
Deshka River	9/25/2014	1145.4	NA	NA	77.47	No SG installed
Mainstem Deshka Companion Gage	7/15/2013	NA	1.64	NA	69.98	
Mainstem Deshka Companion Gage	8/10/2013	NA	1.31	NA	69.58	
Mainstem Deshka Companion Gage	9/27/2013	NA	0.11	NA	68.38	
Mainstem Deshka Companion Gage	6/17/2014	NA	2.45	1.98	70.71	SG1 is calculated
Mainstem Deshka Companion Gage	7/31/2014	NA	1.49	1.02	69.79	SG1 is calculated
Mainstem Deshka Companion Gage	9/25/2014	NA	-0.13	-0.6	68.2	SG1 is calculated

Notes:

1 NA = Not Applicable

2 NM = Not Measured

ATTACHMENT 3: TRIBUTARY GAGE RATING CURVES

Susitna-Watana Hydroelectric Project

(FERC No. 14241)

Fish and Aquatics Instream Flow Study (8.5)

2014-2015 Study Implementation Report

Appendix B Attachment 3

Tributary Gage Rating Curves

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

R2 Resource Consultants, Inc.

November 2015

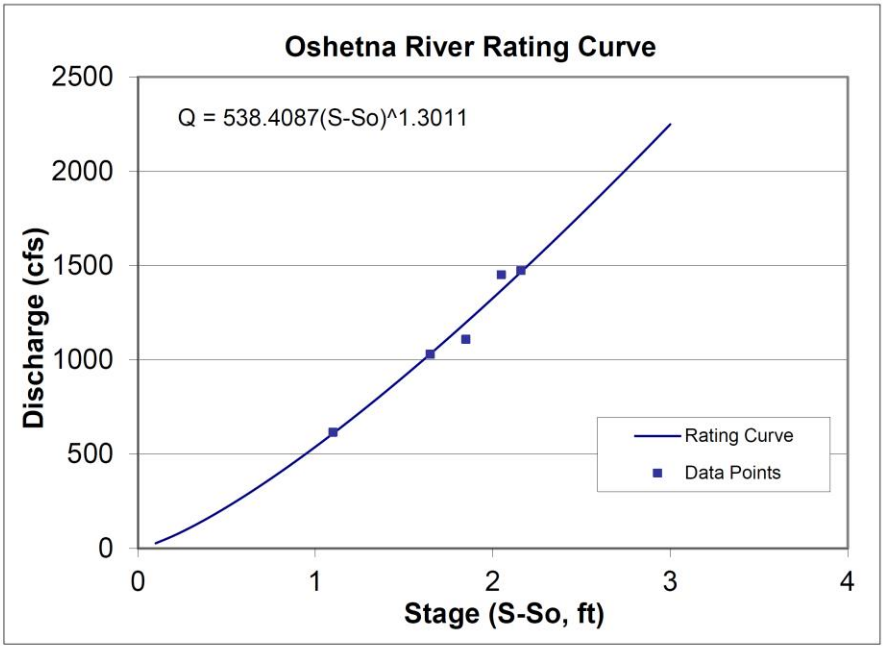
LIST OF FIGURES

Oshetna River Rating Curve

a	1.301119	b	2.731112
So	0		
Equation	Q = 10^(1.3011log(S- 0)+2.7311)		
	Q = 538.4087(S-So)^1.3011		

Rating Curve

S (ft)	S-So (ft)	Q (cfs)
0.1	0.1	26.9
0.2	0.2	66.3
0.3	0.3	112.4
0.4	0.4	163.4
0.5	0.5	218.5
0.6	0.6	277.0
0.7	0.7	338.5
0.8	0.8	402.7
0.9	0.9	469.4
1	1	538.4
1.1	1.1	609.5
1.2	1.2	682.6
1.3	1.3	757.5
1.4	1.4	834.1
1.5	1.5	912.5
1.6	1.6	992.4
1.7	1.7	1073.9
1.8	1.8	1156.8
1.9	1.9	1241.1
2	2	1326.7
2.1	2.1	1413.7
2.2	2.2	1501.9
2.3	2.3	1591.3
2.4	2.4	1681.9
2.5	2.5	1773.7
2.6	2.6	1866.6
2.7	2.7	1960.5
2.8	2.8	2055.5
2.9	2.9	2151.5
3	3	2248.6



Data Points

S (ft)	S-So (ft)	Q (cfs)
1.1	1.1	614.3
1.85	1.85	1107.0
2.05	2.05	1450.0
2.16	2.16	1472.0
1.65	1.65	1028.0

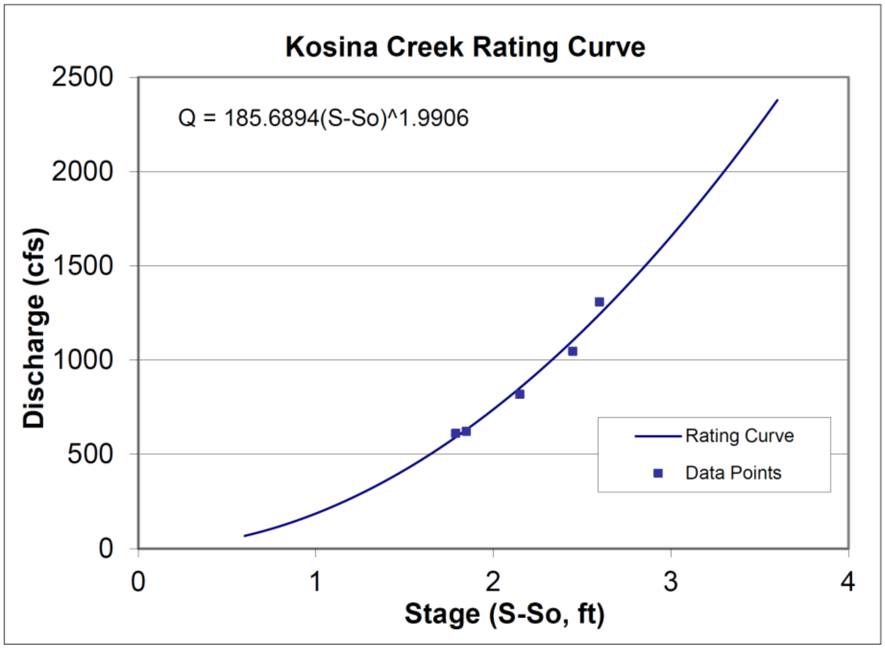
Figure B3-1. Oshetna River rating curve.

Kosina Creek Rating Curve

a	1.990599	b	2.268787
So	-0.6		
Equation	Q = 10^(1.9906log(S- -0.6)+2.2688)		
	Q = 185.6894(S-So)^1.9906		

Rating Curve

S (ft)	S-So (ft)	Q (cfs)
0	0.6	67.2
0.1	0.7	91.3
0.2	0.8	119.1
0.3	0.9	150.6
0.4	1	185.7
0.5	1.1	224.5
0.6	1.2	266.9
0.7	1.3	313.0
0.8	1.4	362.8
0.9	1.5	416.2
1	1.6	473.3
1.1	1.7	534.0
1.2	1.8	598.3
1.3	1.9	666.3
1.4	2	737.9
1.5	2.1	813.2
1.6	2.2	892.1
1.7	2.3	974.6
1.8	2.4	1060.8
1.9	2.5	1150.6
2	2.6	1244.0
2.1	2.7	1341.1
2.2	2.8	1441.8
2.3	2.9	1546.1
2.4	3	1654.0
2.5	3.1	1765.6
2.6	3.2	1880.8
2.7	3.3	1999.6
2.8	3.4	2122.0
2.9	3.5	2248.1
3	3.6	2377.7



Data Points

S (ft)	S-So (ft)	Q (cfs)
1.25	1.85	620.1
1.19	1.79	610.0
2	2.6	1307.0
1.85	2.45	1044.0
1.55	2.15	816.8

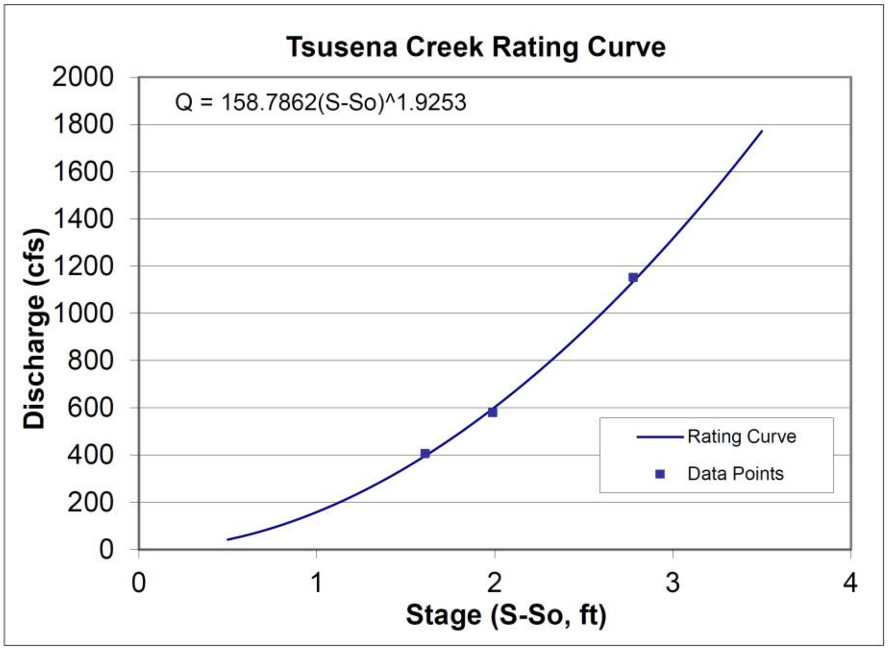
Figure B3-2. Kosina Creek rating curve.

Tsusena Creek Rating Curve

a 1.925259 b 2.200813
So -0.5
Equation Q = 10^(1.9253log(S- -0.5)+2.2008)
Q = 158.7862(S-So)^1.9253

Rating Curve

S (ft)	S-So (ft)	Q (cfs)
0	0.5	41.8
0.1	0.6	59.4
0.2	0.7	79.9
0.3	0.8	103.3
0.4	0.9	129.6
0.5	1	158.8
0.6	1.1	190.8
0.7	1.2	225.6
0.8	1.3	263.1
0.9	1.4	303.5
1	1.5	346.6
1.1	1.6	392.5
1.2	1.7	441.0
1.3	1.8	492.4
1.4	1.9	546.4
1.5	2	603.1
1.6	2.1	662.5
1.7	2.2	724.5
1.8	2.3	789.3
1.9	2.4	856.7
2	2.5	926.7
2.1	2.6	999.4
2.2	2.7	1074.7
2.3	2.8	1152.7
2.4	2.9	1233.2
2.5	3	1316.4
2.6	3.1	1402.2
2.7	3.2	1490.6
2.8	3.3	1581.6
2.9	3.4	1675.1
3	3.5	1771.3



Data Points

S (ft)	S-So (ft)	Q (cfs)
2.28	2.78	1151.0
1.11	1.61	405.0
1.49	1.99	578.6

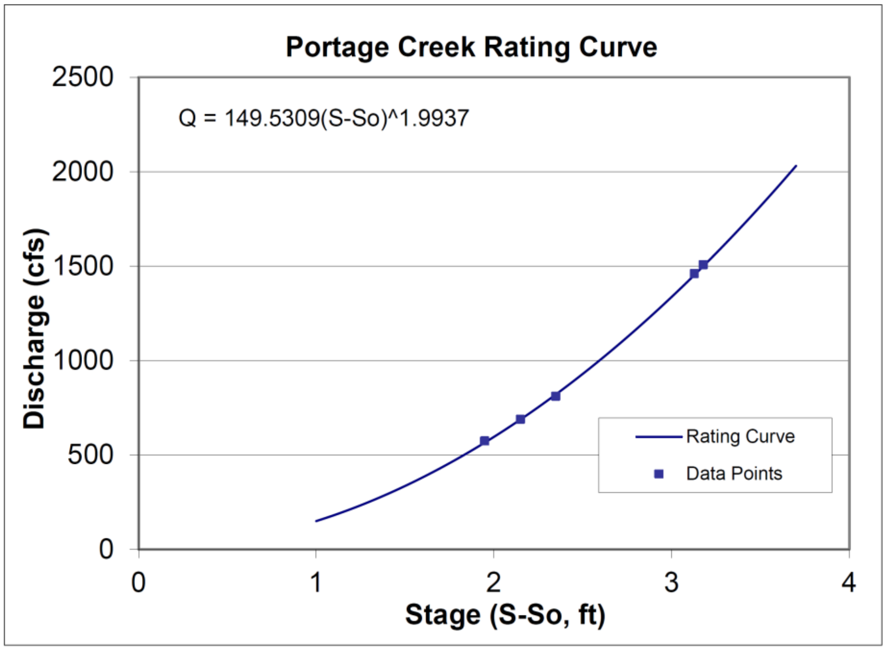
Figure B3-3. Tsusena Creek rating curve.

Portage Creek Rating Curve

a	1.993734	b	2.174731
So	-0.7		
Equation	Q = 10^(1.9937log(S- -0.7)+2.1747)		
	Q = 149.5309(S-So)^1.9937		

Rating Curve

S (ft)	S-So (ft)	Q (cfs)
0.3	1	149.5
0.4	1.1	180.8
0.5	1.2	215.1
0.6	1.3	252.3
0.7	1.4	292.5
0.8	1.5	335.6
0.9	1.6	381.7
1	1.7	430.7
1.1	1.8	482.7
1.2	1.9	537.6
1.3	2	595.5
1.4	2.1	656.4
1.5	2.2	720.2
1.6	2.3	786.9
1.7	2.4	856.6
1.8	2.5	929.2
1.9	2.6	1004.8
2	2.7	1083.3
2.1	2.8	1164.8
2.2	2.9	1249.2
2.3	3	1336.5
2.4	3.1	1426.8
2.5	3.2	1520.1
2.6	3.3	1616.3
2.7	3.4	1715.4
2.8	3.5	1817.4
2.9	3.6	1922.4
3	3.7	2030.4



Data Points

S (ft)	S-So (ft)	Q (cfs)
2.43	3.13	1459.0
2.48	3.18	1506.0
1.25	1.95	571.9
1.65	2.35	809.0
1.45	2.15	687.3

Figure B3-4. Portage Creek rating curve.

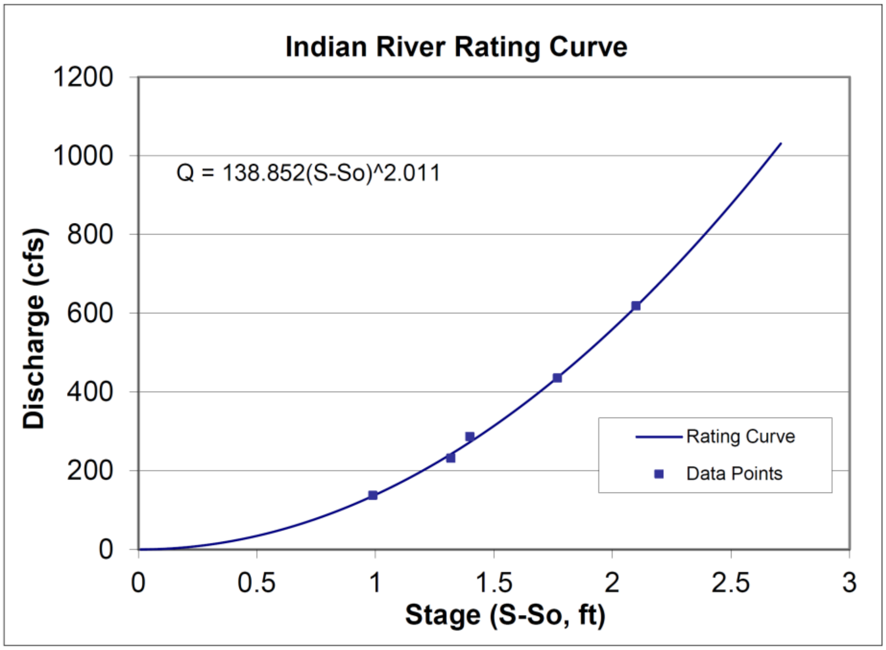
Indian River Rating Curve

a	2.011	b	2.142552
So	0.29		

Equation Q = 10^(2.011log(S- 0.29)+2.1426)
Q = 138.852(S-So)^2.011

Rating Curve

S (ft)	S-So (ft)	Q (cfs)
0.3	0.01	0.0
0.4	0.11	1.6
0.5	0.21	6.0
0.6	0.31	13.2
0.7	0.41	23.1
0.8	0.51	35.8
0.9	0.61	51.4
1	0.71	69.7
1.1	0.81	90.9
1.2	0.91	114.9
1.3	1.01	141.7
1.4	1.11	171.3
1.5	1.21	203.7
1.6	1.31	239.0
1.7	1.41	277.1
1.8	1.51	318.0
1.9	1.61	361.8
2	1.71	408.4
2.1	1.81	457.9
2.2	1.91	510.2
2.3	2.01	565.3
2.4	2.11	623.3
2.5	2.21	684.1
2.6	2.31	747.8
2.7	2.41	814.3
2.8	2.51	883.7
2.9	2.61	955.9
3	2.71	1031.0



Data Points

S (ft)	S-So (ft)	Q (cfs)
1.61	1.32	231.5
1.28	0.99	136.8
1.69	1.4	286.3
2.06	1.77	435.0
2.39	2.1	618.2

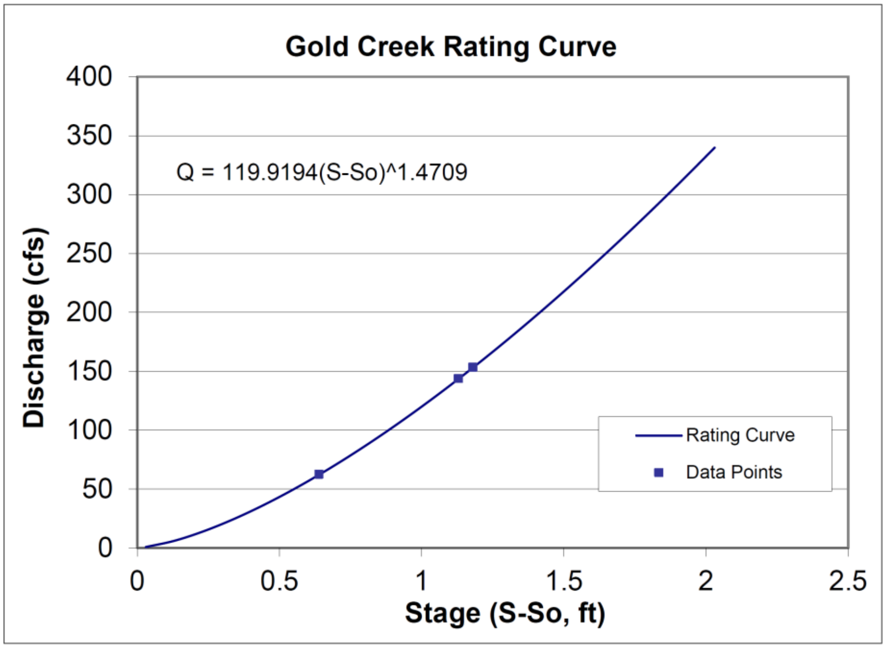
Figure B3-5. Indian River rating curve.

Gold Creek Rating Curve

a 1.47094 b 2.078889
So 0.77
Equation Q = 10^(1.4709log(S- 0.77)+2.0789)
Q = 119.9194(S-So)^1.4709

Rating Curve

S (ft)	S-So (ft)	Q (cfs)
0.8	0.03	0.7
0.9	0.13	6.0
1	0.23	13.8
1.1	0.33	23.5
1.2	0.43	34.7
1.3	0.53	47.1
1.4	0.63	60.8
1.5	0.73	75.5
1.6	0.83	91.2
1.7	0.93	107.8
1.8	1.03	125.2
1.9	1.13	143.5
2	1.23	162.6
2.1	1.33	182.4
2.2	1.43	202.9
2.3	1.53	224.2
2.4	1.63	246.0
2.5	1.73	268.6
2.6	1.83	291.7
2.7	1.93	315.4
2.8	2.03	339.8
2.9	2.13	364.7
3	2.23	390.1



Data Points

S (ft)	S-So (ft)	Q (cfs)
1.95	1.18	153.0
1.41	0.64	62.2
1.9	1.13	143.5

Figure B3-6. Gold Creek rating curve.

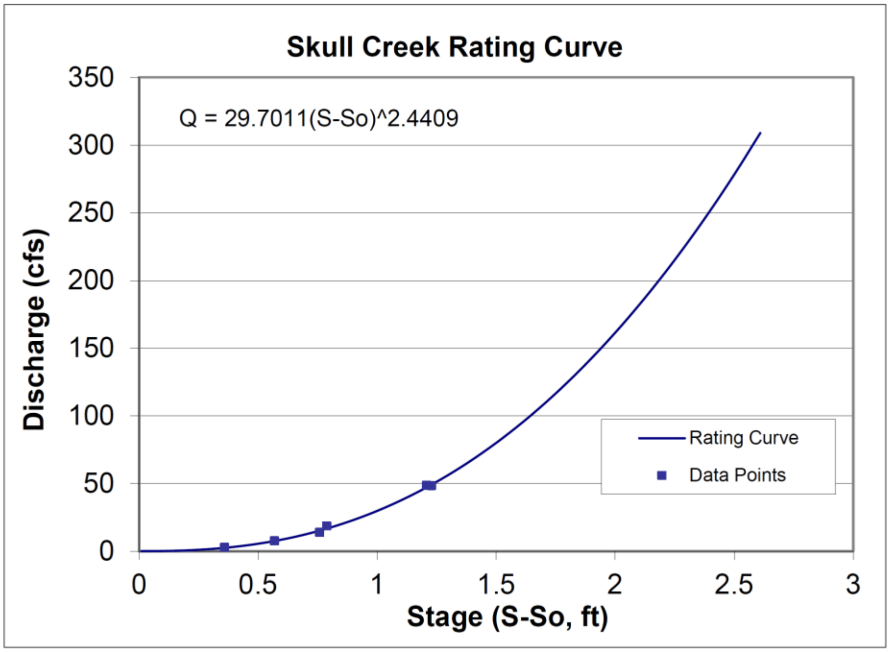
Skull Creek Rating Curve

a	2.44094	b	1.472773
So	0.39		

Equation Q = 10^(2.4409log(S- 0.39)+1.4728)
Q = 29.7011(S-So)^2.4409

Rating Curve

S (ft)	S-So (ft)	Q (cfs)
0.4	0.01	0.0
0.5	0.11	0.1
0.6	0.21	0.7
0.7	0.31	1.7
0.8	0.41	3.4
0.9	0.51	5.7
1	0.61	8.9
1.1	0.71	12.9
1.2	0.81	17.8
1.3	0.91	23.6
1.4	1.01	30.4
1.5	1.11	38.3
1.6	1.21	47.3
1.7	1.31	57.4
1.8	1.41	68.7
1.9	1.51	81.2
2	1.61	95.0
2.1	1.71	110.0
2.2	1.81	126.4
2.3	1.91	144.1
2.4	2.01	163.3
2.5	2.11	183.8
2.6	2.21	205.8
2.7	2.31	229.3
2.8	2.41	254.2
2.9	2.51	280.8
3	2.61	308.9



Data Points

S (ft)	S-So (ft)	Q (cfs)
0.96	0.57	7.4
0.75	0.36	2.5
1.6	1.21	48.5
1.15	0.76	13.7
1.18	0.79	18.5
1.62	1.23	48.3

Figure B3-7. Skull Creek rating curve.

Whiskers Creek Rating Curve

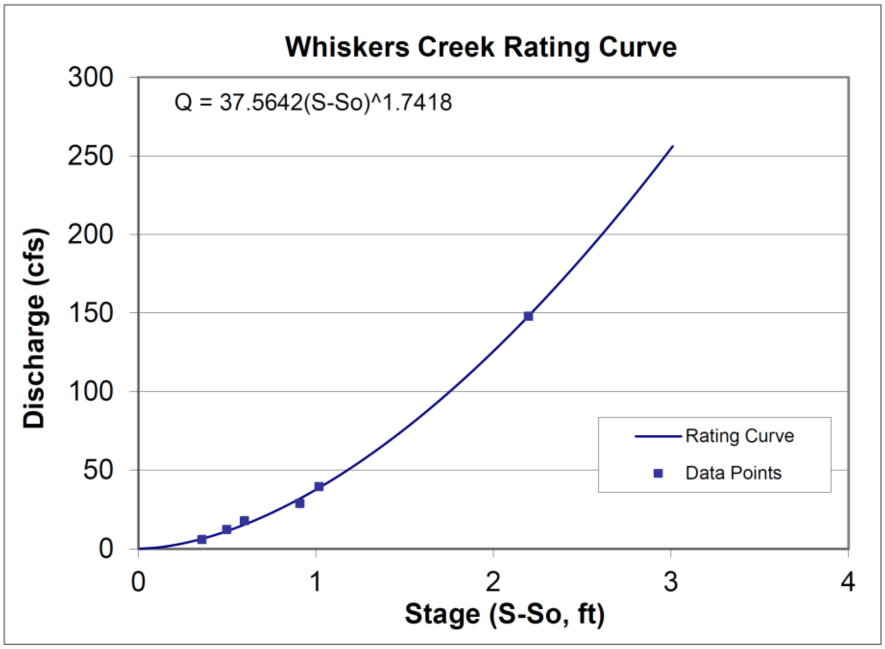
a	1.741829	b	1.574774
So	1.39		

Equation $Q = 10^{(1.7418\log(S - 1.39)+1.5748)}$

$Q = 37.5642(S-So)^{1.7418}$

Rating Curve

S (ft)	S-So (ft)	Q (cfs)
1.4	0.01	0.0
1.5	0.11	0.8
1.6	0.21	2.5
1.7	0.31	4.9
1.8	0.41	7.9
1.9	0.51	11.6
2	0.61	15.9
2.1	0.71	20.7
2.2	0.81	26.0
2.3	0.91	31.9
2.4	1.01	38.2
2.5	1.11	45.1
2.6	1.21	52.4
2.7	1.31	60.1
2.8	1.41	68.3
2.9	1.51	77.0
3	1.61	86.1
3.1	1.71	95.6
3.2	1.81	105.6
3.3	1.91	116.0
3.4	2.01	126.7
3.5	2.11	137.9
3.6	2.21	149.5
3.7	2.31	161.5
3.8	2.41	173.9
3.9	2.51	186.6
4	2.61	199.8
4.1	2.71	213.3
4.2	2.81	227.2
4.3	2.91	241.4
4.4	3.01	256.1



Data Points

S (ft)	S-So (ft)	Q (cfs)
1.99	0.6	17.6
1.75	0.36	5.7
3.59	2.2	147.7
2.41	1.02	39.3
1.89	0.5	12.1
2.3	0.91	28.7

Figure B3-8. Whiskers Creek rating curve.

Trapper Creek Rating Curve

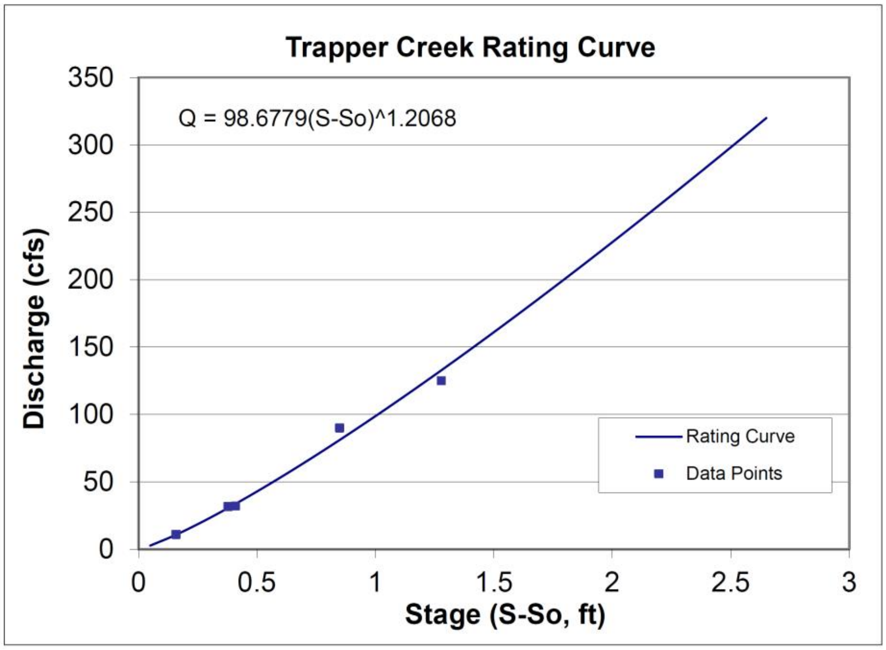
a	1.206785	b	1.99422
So	0.85		

Equation $Q = 10^{(1.2068\log(S-0.85)+1.9942)}$

$Q = 98.6779(S-So)^{1.2068}$

Rating Curve

S (ft)	S-So (ft)	Q (cfs)
0.9	0.05	2.7
1	0.15	10.0
1.1	0.25	18.5
1.2	0.35	27.8
1.3	0.45	37.6
1.4	0.55	48.0
1.5	0.65	58.7
1.6	0.75	69.7
1.7	0.85	81.1
1.8	0.95	92.8
1.9	1.05	104.7
2	1.15	116.8
2.1	1.25	129.2
2.2	1.35	141.7
2.3	1.45	154.5
2.4	1.55	167.5
2.5	1.65	180.6
2.6	1.75	193.9
2.7	1.85	207.3
2.8	1.95	220.9
2.9	2.05	234.7
3	2.15	248.5
3.1	2.25	262.6
3.2	2.35	276.7
3.3	2.45	291.0
3.4	2.55	305.4
3.5	2.65	319.9



Data Points

S (ft)	S-So (ft)	Q (cfs)
1.26	0.41	31.7
1.01	0.16	10.8
1.7	0.85	89.7
1.23	0.38	31.4
2.13	1.28	124.7

Figure B3-9. Trapper Creek rating curve.

Birch Creek Rating Curve

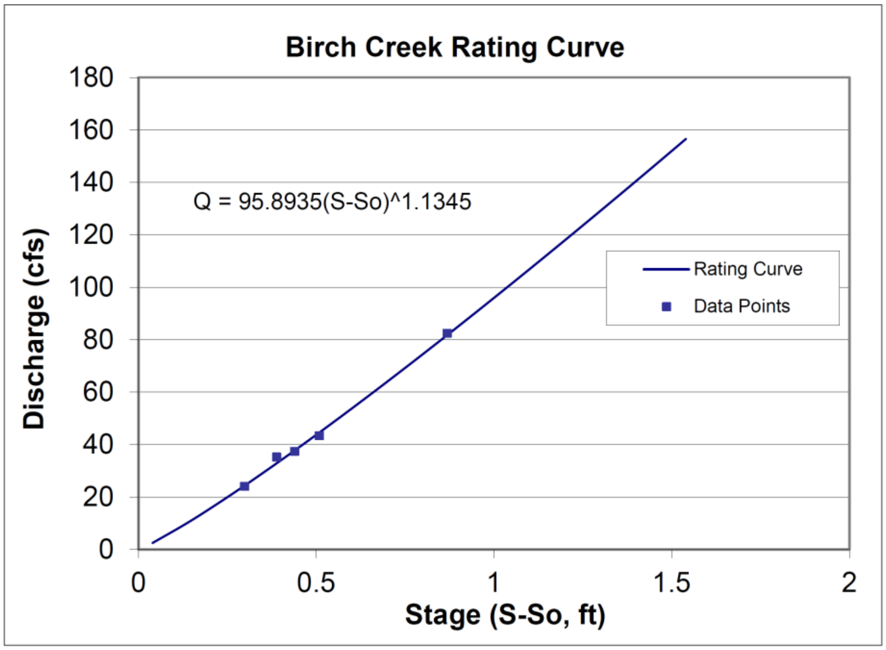
a	1.134489	b	1.981789
So	1.46		

Equation $Q = 10^{(1.1345\log(S - 1.46) + 1.9818)}$

$Q = 95.8935(S-So)^{1.1345}$

Rating Curve

S (ft)	S-So (ft)	Q (cfs)
1.5	0.04	2.5
1.6	0.14	10.3
1.7	0.24	19.0
1.8	0.34	28.2
1.9	0.44	37.8
2	0.54	47.7
2.1	0.64	57.8
2.2	0.74	68.1
2.3	0.84	78.7
2.4	0.94	89.4
2.5	1.04	100.3
2.6	1.14	111.3
2.7	1.24	122.4
2.8	1.34	133.7
2.9	1.44	145.0
3	1.54	156.5



Data Points

S (ft)	S-So (ft)	Q (cfs)
1.85	0.39	35.1
1.76	0.3	23.9
2.33	0.87	82.3
1.9	0.44	37.2
1.97	0.51	43.3

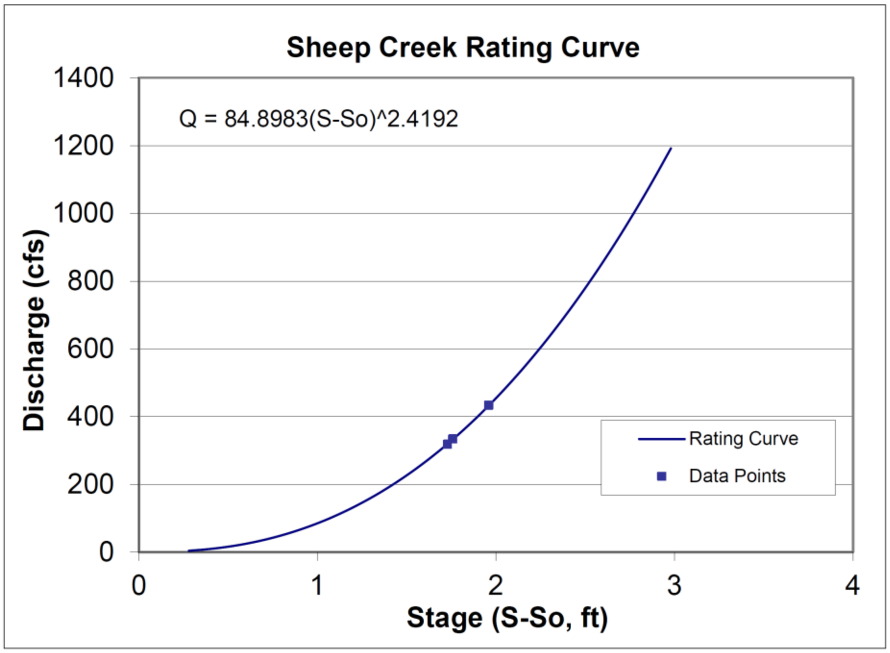
Figure B3-10. Birch Creek rating curve.

Sheep Creek Rating Curve

a	2.419168	b	1.928899
So	0.02		
Equation	Q = 10^(2.4192log(S- 0.02)+1.9289)		
	Q = 84.8983(S-So)^2.4192		

Rating Curve

S (ft)	S-So (ft)	Q (cfs)
0.3	0.28	3.9
0.4	0.38	8.2
0.5	0.48	14.4
0.6	0.58	22.7
0.7	0.68	33.4
0.8	0.78	46.5
0.9	0.88	62.3
1	0.98	80.8
1.1	1.08	102.3
1.2	1.18	126.7
1.3	1.28	154.3
1.4	1.38	185.1
1.5	1.48	219.2
1.6	1.58	256.7
1.7	1.68	297.8
1.8	1.78	342.5
1.9	1.88	391.0
2	1.98	443.2
2.1	2.08	499.3
2.2	2.18	559.3
2.3	2.28	623.5
2.4	2.38	691.7
2.5	2.48	764.1
2.6	2.58	840.8
2.7	2.68	921.8
2.8	2.78	1007.2
2.9	2.88	1097.1
3	2.98	1191.5



Data Points

S (ft)	S-So (ft)	Q (cfs)
1.98	1.96	432.4
1.78	1.76	333.3
1.75	1.73	317.5

Figure B3-11. Sheep Creek rating curve.

Deshka River Rating Curve

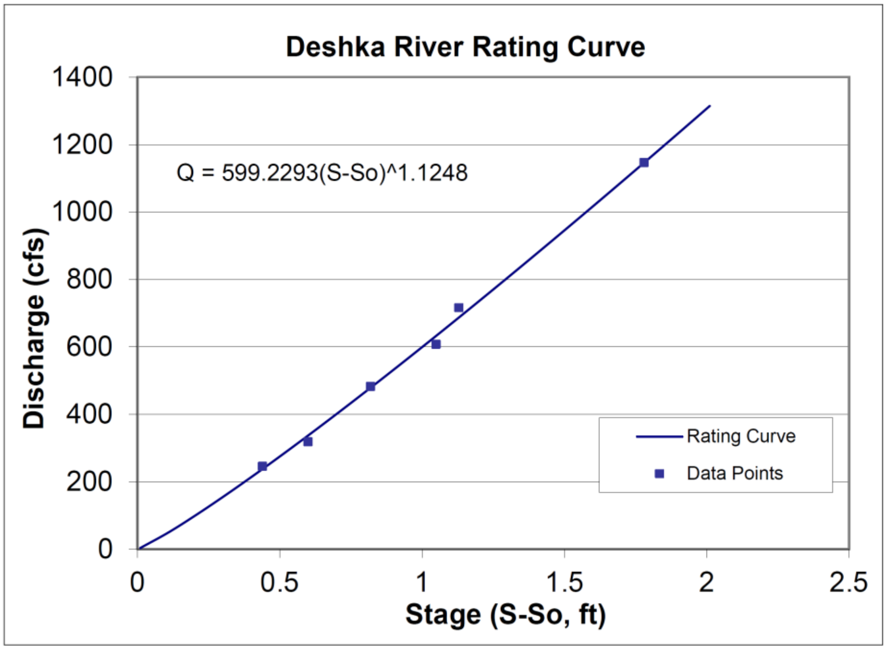
a	1.12483	b	2.777593
So	75.69		

Equation $Q = 10^{(1.1248\log(S - 75.69)+2.7776)}$

$Q = 599.2293(S-So)^{1.1248}$

Rating Curve

S (ft)	S-So (ft)	Q (cfs)
75.7	0.01	3.4
75.8	0.11	50.0
75.9	0.21	103.6
76	0.31	160.5
76.1	0.41	219.8
76.2	0.51	281.0
76.3	0.61	343.7
76.4	0.71	407.6
76.5	0.81	472.8
76.6	0.91	538.9
76.7	1.01	606.0
76.8	1.11	673.9
76.9	1.21	742.5
77	1.31	811.9
77.1	1.41	881.9
77.2	1.51	952.6
77.3	1.61	1023.9
77.4	1.71	1095.7
77.5	1.81	1168.0
77.6	1.91	1240.8
77.7	2.01	1314.1
77.8	2.11	1387.9
77.9	2.21	1462.1
78	2.31	1536.7



Data Points

S (ft)	S-So (ft)	Q (cfs)
76.29	0.6	317.4
76.13	0.44	245.0
76.51	0.82	481.7
76.82	1.13	714.9
76.74	1.05	606.9
77.47	1.78	1145.4

Figure B3-12. Deshka River rating curve.

ATTACHMENT 4: EXAMPLE HOURLY TRIBUTARY DATA

Susitna-Watana Hydroelectric Project

(FERC No. 14241)

Fish and Aquatics Instream Flow Study (8.5)

2014-2015 Study Implementation Report

Appendix B Attachment 4

Example Hourly Tributary Data

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

R2 Resource Consultants, Inc.

November 2015

Table B4-1. Example hourly tributary data.

Date/Time	Time Reference	Kosina Creek WSE (ft, NAVD 88)	Kosina Creek Streamflow (cfs)	Kosina Creek Qualifier
10/10/13 0:00	UTC-9 hours	1904.29	415	
10/10/13 1:00	UTC-9 hours	1904.27	406	
10/10/13 2:00	UTC-9 hours	1904.23	385	
10/10/13 3:00	UTC-9 hours	1904.20	369	
10/10/13 4:00	UTC-9 hours	1904.11	322	
10/10/13 5:00	UTC-9 hours	1904.04	291	
10/10/13 6:00	UTC-9 hours	1903.97	256	
10/10/13 7:00	UTC-9 hours	1903.88	222	E2
10/10/13 8:00	UTC-9 hours	1903.85	207	E2
10/10/13 9:00	UTC-9 hours	1903.84	206	E2
10/10/13 10:00	UTC-9 hours	1903.83	201	E2
10/10/13 11:00	UTC-9 hours	1903.87	217	E2
10/10/13 12:00	UTC-9 hours	1903.93	242	
10/10/13 13:00	UTC-9 hours	1904.00	271	
10/10/13 14:00	UTC-9 hours	1904.11	322	
10/10/13 15:00	UTC-9 hours	1904.24	388	
10/10/13 16:00	UTC-9 hours	1904.26	400	
10/10/13 17:00	UTC-9 hours	1904.28	410	
10/10/13 18:00	UTC-9 hours	1904.30	424	
10/10/13 19:00	UTC-9 hours	1904.27	405	
10/10/13 20:00	UTC-9 hours	1904.27	407	
10/10/13 21:00	UTC-9 hours	1904.31	427	
10/10/13 22:00	UTC-9 hours	1904.34	444	
10/10/13 23:00	UTC-9 hours	1904.35	449	
10/11/13 0:00	UTC-9 hours	1904.36	453	
10/11/13 1:00	UTC-9 hours	1904.34	446	
10/11/13 2:00	UTC-9 hours	1904.33	436	
10/11/13 3:00	UTC-9 hours	1904.32	435	
10/11/13 4:00	UTC-9 hours	1904.31	428	
10/11/13 5:00	UTC-9 hours	1904.30	422	
10/11/13 6:00	UTC-9 hours	1904.28	412	
10/11/13 7:00	UTC-9 hours	1904.28	410	
10/11/13 8:00	UTC-9 hours	1904.26	402	
10/11/13 9:00	UTC-9 hours	1904.26	398	
10/11/13 10:00	UTC-9 hours	1904.25	393	
10/11/13 11:00	UTC-9 hours	1904.24	390	
10/11/13 12:00	UTC-9 hours	1904.25	396	
10/11/13 13:00	UTC-9 hours	1904.25	397	
10/11/13 14:00	UTC-9 hours	1904.29	417	
10/11/13 15:00	UTC-9 hours	1904.28	410	