2012 River Flow Routing Model Data Collection

Introduction

The Alaska Energy Authority (AEA) is preparing a License Application that will be submitted to the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project (Project) using the Integrated Licensing Process (ILP). The Project is located on the Susitna River, which drains a 20,000 square-mile watershed in Southcentral Alaska (Figure 1). The Project's dam site (Watana Dam) will be located at river mile (RM) 184. The results of this study and of other proposed studies will provide information needed to support the FERC's National Environmental Policy Act (NEPA) analysis for the Project license.

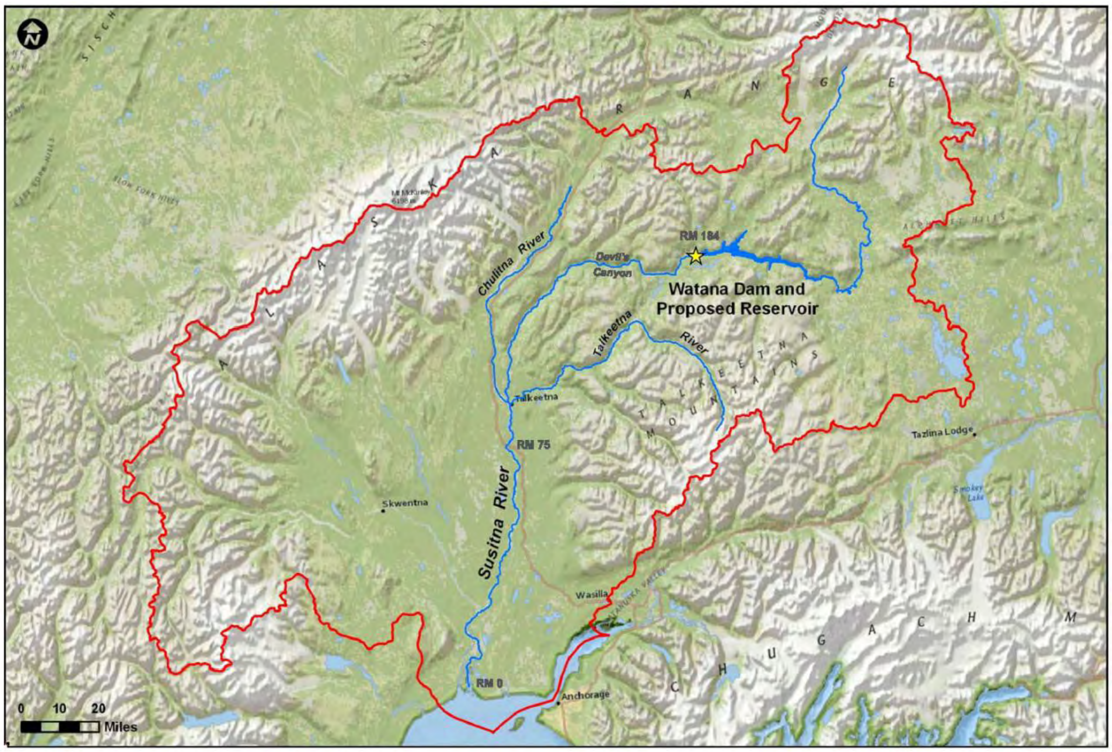

Figure 1. Project Location, Southcentral Alaska

A variety of models will be needed to assess the Project's impact on river hydraulics, temperatures, ice processes, sediment transport, aquatic resources, and terrestrial resources. A hydraulic flow routing model of the Susitna River downstream of Watana Dam will be required for the Project impact assessment. U.S. Army Corps of Engineers' (USACE) HEC-RAS (River Analysis System) model is being considered for this purpose because of its ability to simulate hourly fluctuations in water surface elevation caused by load-following operations. Results of the routing model will be used as input for other models needed to simulate various physical and biological processes.

This study plan describes the 2012 field data collection required for developing a river flow routing model. Unsteady-state routing models require flow, roughness, and topographic input data, and water surface elevations at known discharges for model calibration and verification. Channel topography and roughness data will be collected at transects spaced down the river to define the channel's cross-sectional shape and gradient. Roughness estimates will be developed based on visual assessments and by solving Manning's equation using measurements of discharge, surface slope, and cross sectional area. Calibration data will be calculated though rating curves (stage versus discharge) at selected cross sections. Model verification will be performed using stage measurements during natural flow events throughout a network of gauging and water surface elevation monitoring stations.

STUDY OBJECTIVES

The study objective for the 2012 field effort is to provide input, calibration, and verification data for a river flow routing model extending from the proposed dam site to RM 75. Specific objectives are as follows:

- Survey cross sections to define channel topography and hydraulic controls between RM 75 and RM 184, excluding Devil's Canyon (for safety reasons);
- Measure stage and discharge at each cross section during high and low flows, with the potential addition of an intermediate flow measurement;
- Measure the water surface slope during discharge measurements, and document the substrate type, groundcover, habitat type, and woody debris in the flood-prone area for the purposes of developing roughness estimates; and
- Install and operate approximately 8 to 10 water-level recording stations in collaboration with other studies.

STUDY AREA

The primary study area includes the Susitna River mainstem channel between RM 75 and RM 184 (Figure 2). Additional measurements will be performed at inactive U.S. Geological Survey (USGS) stations at RM 26 (Susitna Station), RM 223 (Susitna R. near Cantwell), and in the Susitna delta (Figure 3) to help support other studies taking place in these regions. In the lower Susitna Basin, cross-section and discharge measurements will only be taken at the Susitna River at Susitna Station gauging station. The two stations downstream will focus on water level measurements to help characterize tidal influences in the lower river. The locations of these stations are preliminary at this time and will be finalized after permitting conditions are identified for the lower river.

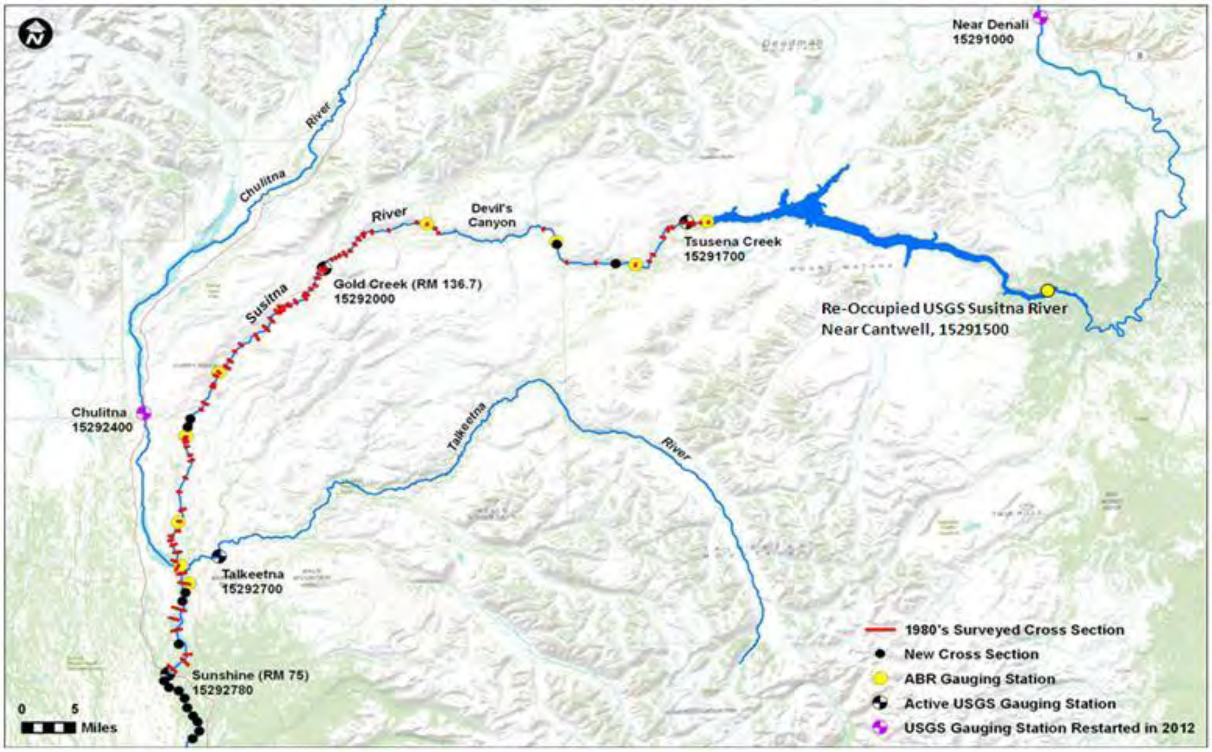

Figure 2. Middle Basin Study Areas

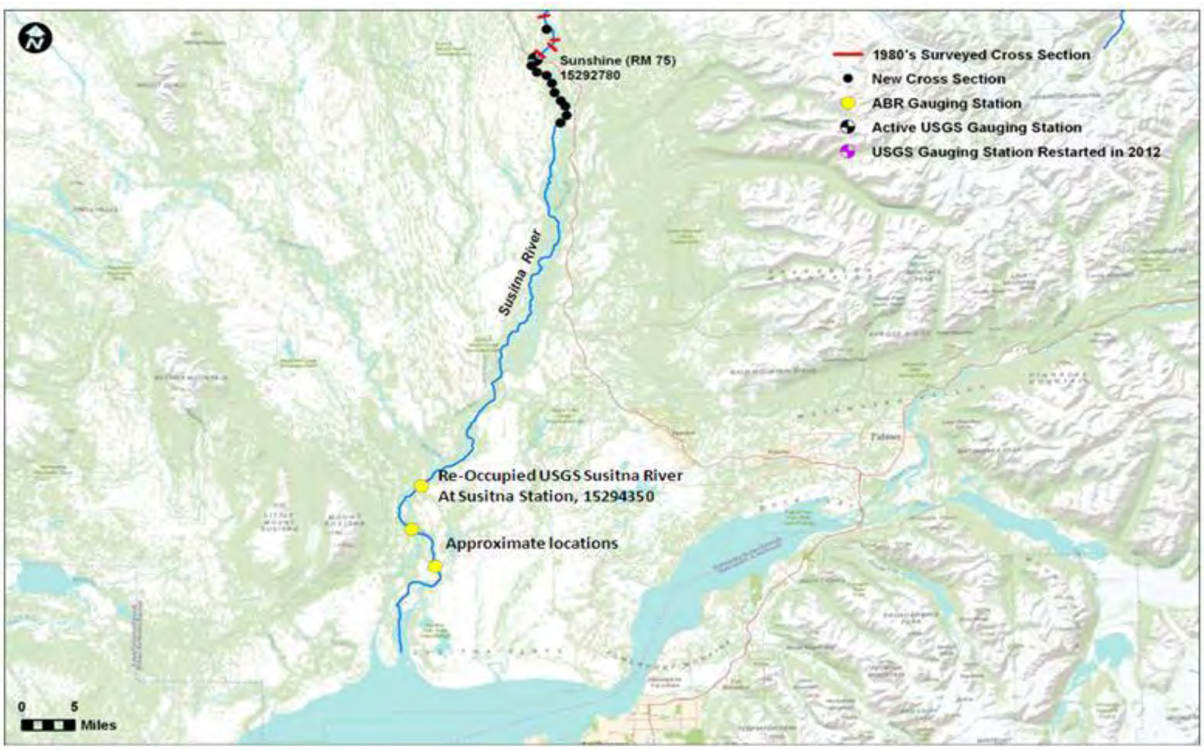

Figure 3. Lower Basin Study Area, showing locations of cross section locations and lower river gauging and water level stations.

EXISTING INFORMATION

A river flow routing model was developed in the 1980s using HEC-2, USACE's predecessor to HEC-RAS. As documented in the 1980s HEC-2 reports (R&M 1982; Harza 1984a; 1984b), a total of 91 cross sections were surveyed in 1981 and 33 cross sections were surveyed in 1982. The cross sections were located in the Susitna River above Devil's Canyon from RM 162 to RM 187and below Devil's Canyon from RM 85 to RM 150 (Figure 2). The cross sections are located on line drawings included in the 1983 HEC-2 modeling report (Harza 1984a). The 1980s modeling reports also include roughness information, riverbed and water surface profiles, computed rating curves for each cross section, and a summary of HEC-2 modeling results.

Existing hydrologic data for the Susitna Watershed has been summarized by MWH (2011), including results from fourteen gauging stations operated by the USGS. Together with data from the adjoining Little Susitna watershed, the USGS is using intermittent records from the fourteen stations to generate a combination of measured and synthetic streamflows for the 63-year period from 1949 through 2011 (Curran, in preparation). During the 1980s, additional hydrologic data was collected by the Alaska Department of Fish and Game as part of instream flow studies (Estes, Chalkboard Inc., personal communication, March 2012).

Existing topographic data includes the 1980s cross sections, USGS topographic maps (1:63,360), and Light Detection and Ranging (LiDAR) data throughout the Project corridor (Aerometric, in preparation).

METHODS

Cross Section Surveys

- Approximately 100 cross sections will be surveyed at the locations identified in Table 1. A minimum of 50 cross sections will be surveyed in 2012 and, if needed, the remaining cross sections will be surveyed in 2013. Where the new cross sections are in the vicinity of historic cross sections, an attempt will be made to survey approximately the old cross section alignment if it is also an appropriate alignment for the current channel. This will be done to provide ancillary information on channel change.
- About 80 percent of the cross sections are located where previous transects were surveyed in the 1980s. The locations of the 1980s transects will be determined by transferring their positions on 1980s line drawings to the aerial photographs from which the drawings were produced. The aerial photographs will be georeferenced using recent aerial photography and satellite imagery, and geodetic coordinates will be established for each cross section. A reconnaissance of the cross section locations will be conducted prior to surveying to ensure the resulting locations are appropriate.
- The cross section survey will be overseen by a licensed engineer or land surveyor and conducted by individuals familiar with river cross-sectioning protocol and safety considerations. The licensed engineer or land surveyor is not required to be on the field.
- The onshore and shallow-water portion of each cross section and associated endpoints will be surveyed using real-time kinematic (RTK) global positioning system (GPS) methods. Prior to surveying, a static control network will be established to provide RTK GPS coverage

throughout the Project corridor. The precision of the onshore survey will be ±0.1 foot vertical and ±1.0 foot horizontal.

- The submerged portion of each cross section will be surveyed using a 0.5 megahertz (MHz), vertical-beam depth sounder deployed from a motorized cataraft. The vertical-beam depth sounder is part of Sontek's M9 acoustic Doppler current profiler (ADCP) which includes an internal GPS receiver that receives RTK corrections from a base station on shore. By recording the positions of temporary reference points (RPs, typically rebar) installed on both banks, the bathymetric surveys will be referenced to the shore-based control network.
- Because it is impractical to maintain a perfectly straight course, the bathymetric surveys will include multiple transects along the line of section. As part of post-processing, a digital terrain model will be generated and the cross section elevations will be computed along the line of section.
- Based on the 1982 HEC-2 results (R&M 1982), the maximum water depth at the 15 percent exceedance discharge ranged from 8.5 to 24.1 feet, and the average depth was 6.6 feet across the 89 surveyed cross sections. The accuracy of the Sontek 0.5 MHz depth sounder is rated at 1 percent of total depth, corresponding to a minimum accuracy of 0.24 feet at the deepest cross section and an average accuracy of 0.066 feet at the 15 percent exceedance discharge. Considering that the bathymetric accuracy will be improved by repeating each transect 4 to 8 times, this level of resolution is considered adequate.
- The cross sections will extend to elevations corresponding to the 10-percent exceedance discharge, as determined from the 1980s HEC-2 modeling results. If woody vegetation interferes with GPS reception, then LiDAR data will be used to complete the upper limits of each section. As permitted by GPS reception, additional control points will be surveyed to confirm LiDAR data for cross sections where the upper limits cannot be surveyed using RTK GPS methods.
- The endpoints of each transect will be marked with rebar or rock bolt monuments, and vegetation will be cleared so that the endpoints are easily visible from air and ground. Vegetation will be flagged so that the transects are visible from the water, and if the headpins are not easily visible from shore, a supplemental benchmark will be installed to facilitate water surface elevation measurements.

Table 1. Proposed Cross Section Locations

Sequence Number	Current Cross-Section Number	1980's Cross-Section Number (LRX or URX #)	River Mile	Report Reference
1	75.0	-----	75.0	None - new
2	76.0	-----	76.0	None - new
3	77.0	-----	77.0	None - new
4	78.0	-----	78.0	None - new
5	79.0	-----	79.0	None - new
6	80.0	-----	80.0	None - new
7	81.0	-----	81.0	None - new
8	82.0	-----	82.0	None - new
9	83.0	-----	83.0	None - new
10	84.6	84.6	84.6	R&M 1985
11	86.3	86.3	86.3	R&M 1985
12	87.7	87.7	87.7	R&M 1985
13	89.0	-----	89.0	None - new
14	90.6	90.6	90.6	R&M 1985
15	91.8	91.8	91.8	R&M 1985
16	93.1	93.1	93.1	R&M 1985
17	94.0	-----	94.0	None - new
18	95.0	-----	95.0	None - new
19	95.9	95.9	95.9	R&M 1985
20	97.1	97.1	97.1	R&M 1985
21	98.0	98.0	98.0	R&M 1985
22	98.59	3	98.59	R&M 1981a,b
23	99.58	4	99.58	R&M 1981a,b
24	100.36	5	100.36	R&M 1981a,b
25	100.96	6	100.96	R&M 1981a,b
26	101.52	7	101.52	R&M 1981a,b
27	102.38	8	102.38	R&M 1981a,b
28	103.22	9	103.22	R&M 1981a,b
29	104.75	10	104.75	R&M 1981a,b
30	106.68	11	106.68	R&M 1981a,b
31	108.41	12	108.41	R&M 1981a,b
32	110.36	13	110.36	R&M 1981a,b
33	110.89	14	110.89	R&M 1981a,b
34	111.83	15	111.83	R&M 1981a,b
35	112.34	16	112.34	R&M 1981a,b
36	112.69	17	112.69	R&M 1981a,b
37	113.02	18	113.02	R&M 1981a,b
38	114.0	-----	114.0	None - new
39	115.0	-----	115.0	None - new
40	116.44	19	116.44	R&M 1981a,b
41	117.19	20	117.19	R&M 1981a,b
42	119.15	21	119.15	R&M 1981a,b
43	119.32	22	119.32	R&M 1981a,b
44	120.26	23	120.26	R&M 1981a,b
45	120.66	24	120.66	R&M 1981a,b
46	121.63	25	121.63	R&M 1981a,b
47	122.57	26	122.57	R&M 1981a,b
48	123.31	27	123.31	R&M 1981a,b
49	124.41	28	124.41	R&M 1981a,b
50	126.11	29	126.11	R&M 1981a,b
51	127.50	30	127.5	R&M 1981a,b
52	128.66	31	128.66	R&M 1981a,b
53	129.67	32	129.67	R&M 1981a,b
54	130.12	33	130.12	R&M 1981a,b
55	130.47	34	130.47	R&M 1981a,b
56	130.87	35	130.87	R&M 1981a,b
57	131.19	36	131.19	R&M 1981a,b
58	131.80	37	131.8	R&M 1981a,b
59	132.90	38	132.9	R&M 1981a,b
60	133.33	39	133.33	R&M 1981a,b
61	134.28	40	134.28	R&M 1981a,b
62	134.72	41	134.72	R&M 1981a,b
63	135.36	42	135.36	R&M 1981a,b
64	135.72	43	135.72	R&M 1981a,b
65	136.40	44	136.4	R&M 1981a,b
66	136.68	45	136.68	R&M 1981a,b
67	138.23	49	138.23	R&M 1981a,b
68	138.48	50	138.48	R&M 1981a,b
69	138.89	51	138.89	R&M 1981a,b
70	139.44	52	139.44	R&M 1981a,b
71	140.15	53	140.15	R&M 1981a,b
72	140.83	54	140.83	R&M 1981a,b
73	141.49	55	141.49	R&M 1981a,b
74	142.13	56	142.13	R&M 1981a,b
75	142.34	57	142.34	R&M 1981a,b
76	143.18	58	143.18	R&M 1981a,b
77	144.83	59	144.83	R&M 1981a,b
78	147.56	60	147.56	R&M 1981a,b
79	148.73	61	148.73	R&M 1981a,b
80	149.51	66	149.51	R&M 1981a,b
81	150.19	68	150.19	R&M 1981a,b
82	162.1	121	162.1 (a)	R&M 1981a,b
83	164.5	-----	164.5	None - new
84	167.0	120	167 (a)	R&M 1981a,b
85	170.0	119	170 (a)	R&M 1981a,b
86	172.0	-----	172.0	None - new
87	173.9	118	173.9 (a)	R&M 1981a,b
88	176.1	117	176.1 (a)	R&M 1981a,b
89	176.8	116	176.8 (a)	R&M 1981a,b
90	178.9	115	178.9 (a)	R&M 1981a,b
91	179.8	114	179.8 (a)	R&M 1981a,b
92	180.3	113	180.3 (a)	R&M 1981a,b
93	181.7	112	181.7(a)	R&M 1981a,b
94	182.2	111	182.2 (a)	R&M 1981a,b
95	182.6	110	182.6 (a)	R&M 1981a,b
96	182.8	109	182.8 (a)	R&M 1981a,b
97	183.4	208	183.4 (a)	R&M 1981a,b
98	184.1	207	184.1 (a)	R&M 1981a,b

Note: (a) denotes an approximate river mile

Water Level, Surface Slope, and Discharge Measurements

- At each cross section, water level, surface slope, and discharge measurements will be performed concurrently with bathymetric surveys. Before and after each survey, water levels will be recorded at temporary RPs installed on both banks. A pressure transducer (Campbell Scientific - CS450-L-7 Pressure Transducer SDI-12, 0-7.25psig (50kPa), Stainless Steel) affixed to one RP will provide a continuous record of water level changes during each survey.
- Discharge measurements will be performed using a Sontek M9 ADCP, which uses multiple frequencies (1.0 and 3.0 MHz) and ping types to accommodate variable water depths and flow conditions. Multiple transects will be used to assess the precision of each measurement, and comparison of bottom-track vs. GPS positioning can be used to help quantify bedload movement during high flow events. Quality control procedures will be outlined in a detailed workplan based on current USGS guidance (Mueller and Wagner 2009; OSW 2012).
- Discharge and stage measurements will be conducted during two to three field trips between June 10 and September 30, 2012 (Figure 4). The goal of the discharge and stage measurements is to provide rating measurements at high and low flows (and potentially intermediate flows).
- An initial discharge measurement will be performed at each cross section during the June-July field trip. Results from the initial field trip will be used to identify reaches with relatively constant discharge among cross sections, and locations will be selected to provide discharge measurements representative of the whole reach. In this manner, it is estimated that discharge measurements will be required at approximately two-thirds of the cross sections during the August -September field trip(s).
- Following each discharge measurement, the water surface slope within 300 feet (upstream and downstream) of each cross section will be measured using conventional level-loop methods.
- Water surface elevations at each cross section will be surveyed to develop stage-discharge relationships. Water surface elevations will be surveyed from the established benchmarks to the nearest 0.01 ft on both banks for all major channels at the cross section. Times will be recorded for all discharge and water surface elevation measurements.
- Discharge measurements will also be performed at two inactive USGS gauging stations: Susitna River at Sunshine (USGS No. 15294350), and Susitna River near Cantwell (USGS No. 15291500). The discharge measurements will be performed using the equipment and techniques outlined above. Water surface elevations will be measured or surveyed before and after each discharge measurement.

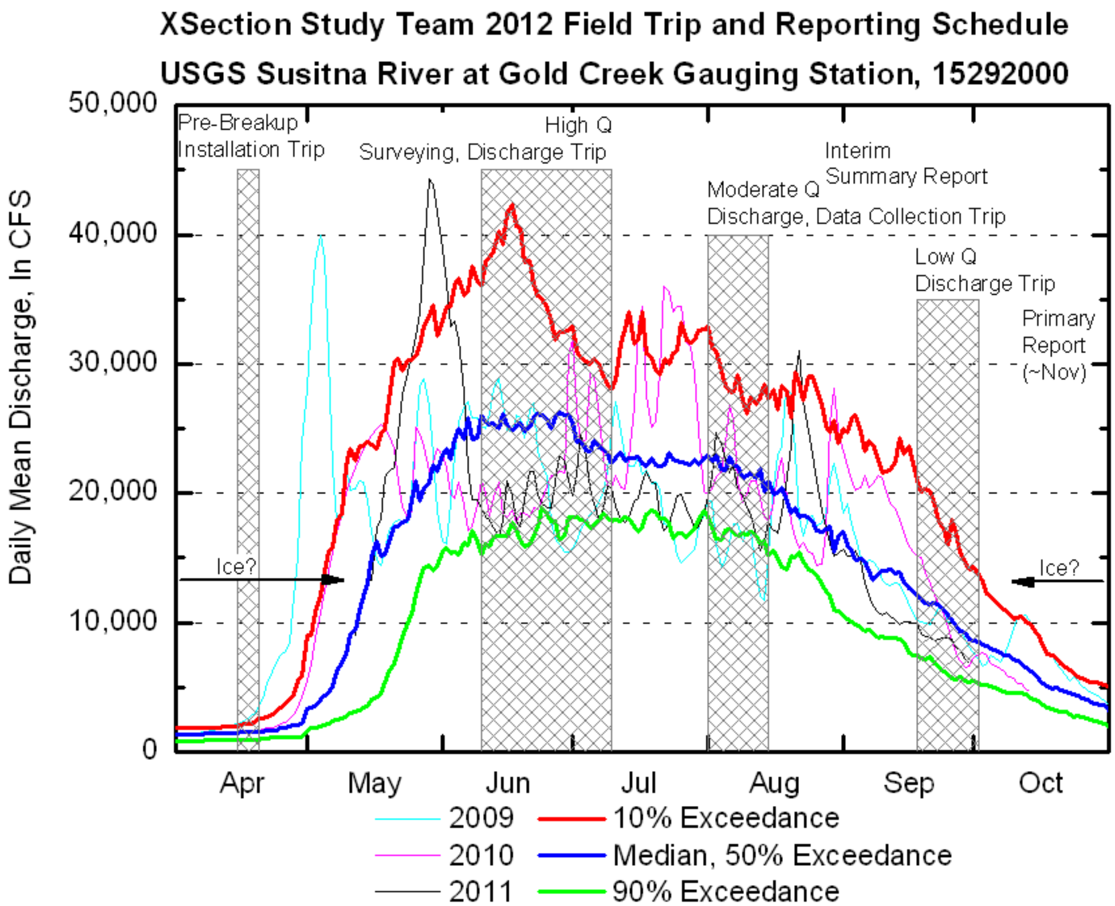

Figure 4. Project Schedule and Historic Flows at Gold Creek. The August field trip is optional depending on June 2012 measurement results and August 2012 flow conditions.

Floodplain Roughness Estimates and Temperature Measurements

- At each cross section, the survey team will record the main channel and overbank locations, substrate and vegetation descriptions, water temperature, the estimated D_{84} substrate size, and field roughness estimates following USGS guidance.
- Georeferenced photographs will be taken at each cross section to document the general transect locations, endpoint monuments, elevation benchmarks, river flow conditions, substrate, habitat type, and woody debris in the floodplain.
- Upon completion of each site visit, the lead field hydrologist will perform an on-site data review and will record ambient air and water temperatures.

Installation and Operation of Water Surface Monitoring Stations

- Gauging (water-level) monitoring stations will be installed at the approximate locations as shown on Figures 2 and 3. Each gauging station will include two unvented or vented pressure transducers with dataloggers. If the pressure transducers are unvented (e.g., Solinist Leveloggers), a nearby MET station or a barometric pressure sensor will be used to correct the pressure readings. Where vented pressure transducers are used (e.g., Campbell Scientific - CS450-L-7 Pressure Transducer SDI-12, 0-7.25psig [50kPa], Stainless Steel), barometric pressure correction will not be required. The two pressure transducers will provide redundant data for quality assurance and backup in the event of a sensor failure.

- The transducers will be housed in short sections of steel pipe, and where cables are needed, the cables will be protected by flexible metallic conduit. The transducers will be installed at different depths and locations so that sensor movements can be identified by comparing stage records.
- Each gauging (water-level) monitoring station will be positioned to measure the water level at a surveyed cross section.
- The pressure transducers will include temperature sensors. Logging intervals and metadata standards for the pressure and temperature sensors are provided in Appendix A.
- Selected gauging stations are anticipated to include digital cameras (Campbell Scientific CC5MPX cameras), air temperature sensors (GWS-YSI-3), and Internet reporting via a radio telemetry network. The placement of cameras, meteorological sensors, and telemetry network components will be addressed in other study plans.
- At least three benchmarks will be installed for elevation control at each section. Benchmark elevations will be established to within 0.1 ft (vertical) using RTK GPS methods.
- Water surface elevations will be surveyed relative to the on-site benchmarks using conventional level-loop methods. Water surface elevations will be surveyed during each of the field trips.
- Staff gages will be installed at selected cross sections, and their elevations will be surveyed relative to the on-site benchmarks.

NEXUS BETWEEN PROJECT AND RESOURCE TO BE STUDIED AND HOW THE RESULTS WILL BE USED

Understanding how Project flows will affect the downstream hydraulics is important to predict further effects on river temperature, ice processes, sediment transport, aquatic resources, and terrestrial resources. While the effects of Project operations on flows and stage will be attenuated downstream due to channel routing effects, tributary inflows, and channel size, it is important to understand how and when these changes will be realized under different Project operation scenarios.

Routing model input, calibration, and verification data are needed to predict hourly flow and stage levels downstream, which in turn are used as inputs to model river temperatures, ice processes, sediment transport, and for a variety of geomorphic, instream flow, aquatic habitat and riparian vegetation assessments. The cross section survey data will be used by others to define baseline conditions, forecast anticipated Project effects and/or development prevention, mitigation and enhancements (PM&Es) concepts for the Susitna-Watana Project. The following issue has been identified in the PAD (AEA 2011):

- **WR1:** Project operations will affect flow timing and magnitude compared to current conditions in Susitna River reaches below the proposed dam, which in turn can affect fish and riparian habitats and fish movement.

PRODUCTS

Work products will include:

Summary of Interim Results. Interim reports will be prepared and presented to the Work Group to provide study progress. Reports will include up-to-date compilation and analysis of the data and ArcGIS spatial data products.

ArcGIS Spatial Products. Work products will include annotated ArcGIS maps including coordinates and elevations for local benchmarks, cross section endpoints, and staff gages. Cross section data will be provided in digital and graphic forms including the survey date, measured discharge values, the corresponding discharge at Gold Creek, and water surface elevations on both banks.

Relational Database. Field measurements of water surface elevations, air and water temperatures, field roughness data, and ADCP measurement notes will be recorded in field books, scanned, and photographed. The resulting electronic files will be linked together with recent and historic survey data, digital photographs, and ADCP measurement files into a geospatially-referenced relational database. This database will be used for additional data collection in 2013-2014.

Final 2012 Technical Memo. A Technical Memo summarizing the 2012 results will be prepared and presented to resource agency personnel and other licensing participants, along with spatial data products. All spatial products will be in the NAD 83 AK Albers projection.

SCHEDULE

Figure 4 illustrates the proposed 2012 study schedule. Key milestones are as follows:

- Summary of Interim Results – July 30, 2012
    - Brief summary
    - Geospatially-referenced relational database
    - ArcGIS map products
    - Graphic summary of cross-sections
- Quality Assurance/Quality Control data and geospatially-referenced relational database – October 30, 2012
- Final Technical Memorandum on 2012 Activity – November 15, 2012.

LEVEL OF EFFORT AND COST

This study will provide a variety of basic data and information that will be used by a number of other studies. The scope of the study may change as the study plan is further developed. The level of effort and cost of the study will developed at a future date.

REFERENCES CITED

AEA (Alaska Energy Authority). 2011. Pre-Application Document: Susitna-Watana Hydroelectric Project, FERC Project No. 14241. December 2011. Prepared for the Federal Energy Regulatory Commission by the Alaska Energy Authority, Anchorage, Alaska.

Estes, Christopher. 2012. Personal communication with Christopher Estes, Chalkboard Inc., Anchorage, Alaska. March 2012.

Harza (Harza-Ebasco). 1984a. Water Surface Profiles and Discharge Rating Curves for the Middle and Lower Susitna River, Volume I. Alaska Power Authority Document No. 481. Harza-Ebasco Susitna Joint Venture. January 1984.

___________ 1984b. Water Surface Profiles and Discharge Rating Curves for the Middle and Lower Susitna River, Volume II (Appendices). Alaska Power Authority Document No. 482. Harza-Ebasco Susitna Joint Venture. January 1984.

Mueller, D.S. and Wagner, C.R. 2009. Measuring Discharge with Acoustic Doppler Current Profilers from a Moving Boat. U. S. Geological Survey Techniques and Methods 3A-22, 72 p.

MWH. 2011. Watana Hydroelectric Project: Susitna Watershed Historical Hydrology. Technical Memorandum No. 3, Alaska Railbelt Large Hydro Engineering Services. Prepared for Alaska Energy Authority by MWH, Bellevue Washington. June 1, 2011.

U.S. Geological Survey, Office of Surface Water (OSW) 2012. OSW Hydroacoustics Home Page, online at http://hydroacoustics.usgs.gov/

R & M (R&M Consultants). 1981a. Hydrographic Surveys, Susitna Hydroelectric Project. Alaska Power Authority Document No. 1. Prepared for Acres American by R&M Consultants, Anchorage Alaska. October 1981.

___________ 1981b. Hydrographic Surveys: Task 2 – Surveys and Site Facilities, Final Draft. Alaska Power Authority Document No. 13. Prepared for Acres American by R&M Consultants, Anchorage Alaska, October 1981.

___________ 1982. Hydraulic and Ice Studies: Task 3 – Hydrology. Alaska Power Authority Document No. 442. Prepared for Acres American by R&M Consultants, Anchorage Alaska, March 1982.

___________ 1985. Lower Susitna Aggradation Study: Field Data. Alaska Power Authority Document No. 2719. Prepared for Harza-Ebasco by R&M Consultants, Anchorage Alaska, June 1985.

APPENDIX A - EXAMPLE DATA MEASUREMENT AND RECORDING STANDARDS

Surface-Water Monitoring Stations

Data-Collection Objectives: Reservoir and river flow routing model transect.
Time Recording Standard: **Always** Alaska Standard Time (UTC – 9).
Datalogger Scan Interval Standard: 60 seconds.
Time Measurement Standards:

- Hourly readings are recorded at the end of the hour; therefore, the hourly average water temperature, for example, with a 60-second scan interval and a time stamp of 14:00 is measured from 13:01 to 14:00:00. For a 60-second scan interval, the hourly average would be the average of 60 min = 60 values.
- Quarter-hourly readings are recorded every fifteen minutes starting at the top of the hour.
- Instantaneous (Sample) readings are taken at the time specified by the time stamp.
- A day begins at midnight (00:00:00) and ends at midnight (23:59:55). All daily data are from the day prior to the date of the time stamp. For example, if the time stamp reads 09/09/2007 00:00 or 09/09/2007 12:00:00 AM, the data are from 09/08/2007.

Data Retrieval Interval: Data will be retrieved hourly.
Data Reporting Interval: Hourly

Images

Cameras: CC640 digital camera.
Memory Card: 2G Flash Memory Card
Flash Card Capacity: ~20,000 Images or over 2 years.
Images Taken: Triggered from external trigger (Logger control port. Allows images to be taken as needed.)
Images Saved on Datalogger: Five.
Image Trigger Interval: 60-minutes.
Data Retrieval Interval: One image every hour.
Connection: Direct for single camera

Air Temperature: Cold Range

Sensor: Triplicate YSI Series 44033 thermistors
Operating Range: -80°C to +75°C
Installation: In 6-gill radiation shield, non-aspirated.
Height: 2 meters
Output Units: kΩ, °C.
Scan Interval: 60 seconds
Output to Tables:

- Hourly Atmospheric Table:
  - Hourly Sample Air Temperature: Recorded at the top of each hour. (three values, one for each thermistor)
  - Hourly Average Air Temperature: 60 readings from the beginning of the hour to the end of the hour, averaged and recorded at the end of the hour. (three values, one for each thermistor)
- Daily Table:
  - Daily Average Air Temperature: Average of all temperature readings for the previous day ending at midnight AST. (three values, one for each thermistor)
  - Daily Maximum Air Temperature: the highest reading taken during the previous day. (three values, one for each thermistor)
  - Daily Minimum Air Temperature: the lowest reading taken during the previous day. (three values, one for each thermistor)
- Hourly Raw Table:

- Hourly Sample Sensor Resistance: Recorded at the top of each hour. "Raw" data in kΩ. (three values, one for each thermistor)
- Hourly Average Sensor Resistance: 60 readings from the beginning of the hour to the end of the hour, averaged and recorded at the end of the hour. "Raw" data in kΩ. (three values, one for each thermistor)

Water Height

Sensor: Two CS450 (Campbell Scientific, inc) SDI-12 Sensors
Pressure Measurement Range: 0-3 psi
Output Units: cm, ft (water height above sensor)
Scan Interval: 60 seconds
Output to Tables:

- Fifteen-Minute Water Height Table:
  - Fifteen-Minute Sample Water Height: Fifteen minute sample (point) reading recorded at the top of the hour, 15, 30, and 45 minutes past the hour.
  - Fifteen-Minute Average Water Height: Fifteen minute average of all 15 readings recorded at the top of the hour, 15, 30, and 45 minutes past the hour.
  - Fifteen-Minute Maximum Water Height: Fifteen minute maximum of all 15 readings recorded at the top of the hour, 15, 30, and 45 minutes past the hour.
  - Fifteen-Minute Minimum Water Height: Fifteen minute minimum of all 15 readings recorded at the top of the hour, 15, 30, and 45 minutes past the hour.
- Daily Table:
  - Daily Average Water Height: Average of all readings for the previous day.
  - Daily Maximum Water Height: Maximum water height for the previous day.
  - Daily Minimum Water Height: Minimum water height for the previous day.

Surface-Water Temperature

Sensor: Two CS450 (Campbell Scientific, inc) SDI-12 Sensors
Operating Range: -10°C to 80°C
Output Units: °C
Scan Interval: 60 seconds
Output to Tables:

- Fifteen-Minute Water Level Table:
  - Fifteen-Minute Average Water Temperature: Fifteen minute average of all 15 readings recorded at the top of the hour, 15, 30, and 45 minutes past the hour.
  - Fifteen-Minute Maximum Water Temperature: The highest reading taken during the previous fifteen minutes.
  - Fifteen-Minute Minimum Water Temperature: The lowest reading taken during the previous fifteen minutes.
- Daily Table:
  - Daily Average Water Temperature: Average of all readings for the previous day.
  - Daily Maximum Water Temperature: the highest reading taken during the previous day.
  - Daily Minimum Water Temperature: the lowest reading taken during the previous day.

Surface-Water Temperature

Sensor: Triplicate YSI Series 44033 thermistors
Operating Range: -80°C to 75°C
Output Units: kΩ, °C
Scan Interval: 60 seconds
Output to Tables:

- Fifteen-Minute Water Level Table:

    - Fifteen-Minute Average Water Temperature: Fifteen minute average of all 15 readings recorded at the top of the hour, 15, 30, and 45 minutes past the hour.
    - Fifteen-Minute Maximum Water Temperature: The highest reading taken during the previous fifteen minutes.
    - Fifteen-Minute Minimum Water Temperature: The lowest reading taken during the previous fifteen minutes.
- Hourly Raw Table:
    - Hourly Sample Sensor Resistance: Recorded at the top of each hour. "Raw" data in kΩ.
    - Hourly Average Sensor Resistance: 60 readings from the beginning of the hour to the end of the hour, averaged and recorded at the end of the hour. "Raw" data in kΩ.
- Daily Table:
    - Daily Average Water Temperature: Average of all readings for the previous day.
    - Daily Maximum Water Temperature: the highest reading taken during the previous day.
    - Daily Minimum Water Temperature: the lowest reading taken during the previous day.

CR1000 Battery Voltage

Sensor: CR1000
Output Units: V.
Scan Interval: 60 seconds
Output to Tables:

- Hourly Diagnostics Table:
    - Hourly Sample CR1000 Battery Voltage: Measured at the top of the hour.
    - Hourly Average CR1000 Battery Voltage: Average of the 60 one-minute readings for the previous hour.
    - Hourly Maximum CR1000 Battery Voltage: The highest reading taken during the previous hour.
    - Hourly Minimum CR1000 Battery Voltage: The lowest reading taken during the previous hour.

CR1000 Solar Panel Voltage

Sensor: GWS Wiring Harness, CR1000
Output Units: V.
Scan Interval: 60 seconds
Output to Tables:

- Hourly Diagnostics Table:
    - Hourly Sample Solar Panel Voltage: Hourly reading at the top of the hour.
    - Hourly Average Solar Panel Voltage: Average of the 60 one-minute readings for the previous hour.
    - Hourly Maximum Solar Panel Voltage: The highest reading taken during the previous hour.
    - Hourly Minimum Solar Panel Voltage: The lowest reading taken during the previous hour.

Datalogger (CR1000) Panel Temperature

Sensor: CR1000 Internal thermistor
Output Units: °C.
Scan Interval: 60 seconds
Output to Tables:

- Hourly Diagnostics Table:
    - Hourly Average CR1000 Panel Temperature: Average of one-minute readings for the previous hour.

Resulting Final Storage Data Tables:

See Datalogger Output Files Excel Document

Notes

Definitions:
Scan interval = sampling duration = scan rate
Time of maximum or minimum values is not recorded
Sample reading = instantaneous reading
Beginning of the hour = top of the hour