Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Fluvial Geomorphology Modeling below Watana Dam Study
Study Plan Section 6.6

Initial Study Report
Part C: Executive Summary and Section 7

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

Tetra Tech
Watershed GeoDynamics

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EXECUTIVE SUMMARY

Fluvial Geomorphology Modeling below Watana Dam Study 6.6	
Purpose	The overall goal of this study is to model the potential effects of the proposed Project on the fluvial geomorphology of the Susitna River and to assist in predicting the magnitude of geomorphic response. Data collected include (1) bed and bank material samples; (2) observations of channel, bank, island, and floodplain surfaces including erosional, depositional, and other features; (3) various types of surveys of channel bathymetry and floodplain geometry; and (4) measurements of discharge, velocity, and water surface elevations. These data were collected along the Susitna River, lateral channels and features, major tributaries, and smaller tributaries. The models in the Fluvial Geomorphology Modeling below Watana Dam Study include hydraulic and sediment transport models of (1) sediment processes at selected tributaries to evaluate sediment supplies and tributary delta effects, (2) reach-scale processes of the Susitna River system below Watana Dam including major tributaries, and (3) local-scale processes at selected Focus Areas in the Middle Susitna River.
Status	The data listed above were collected throughout the Susitna River between PRM 29.9 and PRM 146.1 in 2013 to supplement data collected in 2012. These data also include approximately 10 miles of the Chulitna River, 4 miles of the Talkeetna River, and 11 smaller tributaries. Detailed data were collected at 7 Focus Areas. Additional data will be collected in in 2014 and 2015. Models have been developed in 2013 of the 11 smaller tributaries. The data are currently being used to develop the 1-D reach-scale model of the Susitna River below Watana Dam and 2-D local-scale models of 7 Focus Areas in the Middle Susitna River. Initial 2-D Hydraulic Models have been calibrated for 2 Focus Areas. Results of the 2-D Focus Hydraulic Model for FA-128 (Slough 8A) along with its integration with other studies was demonstrated at the proof-of-concept meeting held April 15-17, 2014. (Note: Corrected information from the February 3, 2014 Draft ISR is provided in Part B: Supplemental Information (and Errata) to February 3, 2014 Draft Initial Study Report)
Study Components	1) **Bed Evolution Model Development, Coordination, and Calibration** includes coordination with other Project studies and stakeholders, data collection, and development of numerical models to accurately simulate river and floodplain fluvial geomorphic processes below Watana Dam. 2) **Model Existing and with-Project Conditions** applies the numerical models to simulate existing conditions and with-Project scenarios. 3) **Coordination and Interpretation of Model Results** integrates the Fluvial Geomorphology Modeling below Watana Dam Study with the

<table>
<tr><th colspan="2">Fluvial Geomorphology Modeling below Watana Dam Study 6.6</th></tr>
<tr><td></td><td>Geomorphology Study and other studies to understand key processes, provide needed information, and make valid comparisons of model results.</td></tr>
<tr><td>2013 Variances</td><td>There were no variances to the 2013 Study Plan. While land access was not available for portions of the river and tributaries adjacent to Cook Inlet Regional Working Group (CIRWG) lands, this was not considered a variance because this study was designed to collect data over multiple years.</td></tr>
<tr><td>Steps to Complete the Study</td><td>AEA’s plan for completing this study are included in ISR Study 6.6 Section 7.2 with 2014 activities listed in Section 7.2.1 and 2015 activities in Section 7.2.2. Major activities are summarized below:

<u>Planned 2014 Activities</u>

• 1-D model field data collection
o Observations of bed roughness PRM 147 to PRM 187
o Water surface elevation measurements in the Middle and Lower River
o Bed and bank sampling PRM 147 to PRM 187

• 2-D model field data collection
o Geomorphic mapping in remaining 3 Focus Areas (FA-151 (Portage Creek), FA-173 (Stephan Lake Complex) and FA-184 (Watana Dam))
o Bed and bank material sampling in remaining 3 Focus Areas
o Level logger installation in selected Focus Areas to provide water surface elevations for model calibration/validation
o Spot water surface elevations for model calibration/validation
o Roughness observations in the remaining 3 Focus Areas
o Support Groundwater (Study 7.5) and Fish and Aquatics Instream Flow (IFS) (Study 8.5) in characterization of groundwater inflows to lateral habitats

• Tributary delta (fan) field data collection
o Cross section surveys, bed material sampling and fan profiles at 10 Middle River tributaries (Tsusena, Fog, Unnamed 174.3, Unnamed 173.8, Chinook (if safe access is possible), Portage, 4th of July, Sherman, 5th of July and Deadhorse creeks)
o Cross section surveys and bed material samples for 3 Lower River tributaries (Birch [or alternate if not accessible], Sheep and Caswell creeks)

• LiDAR data
o Collect high-density LiDAR for Middle River floodplain, PRM 107 to PRM 187</td></tr>
</table>

Fluvial Geomorphology Modeling below Watana Dam Study 6.6	
	o Process LiDAR and perform verification of accuracy • 1-D modeling o Complete calibration and validation of 1-D model (PRM 30 to PRM 187) o Complete initial estimates of tributary water and sediment inflows o Initial 50-year 1-D model runs for existing-conditions and maximum load-following scenario o Perform demonstration run of 1-D model with width adjustment for maximum load-following scenario o Make decision on potential 1-D model extension below PRM 30 based on results of initial 50-year model runs o Prepare Technical Memorandum on 1-D model development • 2-D Modeling o Complete initial hydraulic model calibration for FA-113 (Oxbow 1) and FA-115 (Slough 6A) (Note: FA-104 (Whiskers Creek) and FA-128 (Slough 8A) have already been calibrated) o Perform demonstration representative wet year runs of the 2-D Bed Evolution Model for FA-128 (Slough 8A) with geometry adjustment for year 25 and year 50 (if 1-D model results indicate adjustment is necessary) • Model integration o Collaborate with Riparian IFS (Study 8.6) on floodplain sediment accretion rates o Collaborate with Fish and Aquatics IFS (Study 8.5) on hydraulic parameters to provide for determination of habitat metrics and incorporation of groundwater into 2-D model lateral habitats o Collaborate with Groundwater (Study 7.5) on incorporation of groundwater into 2-D hydraulic model lateral habitats o Collaborate with Ice Processes (Study 7.6) on sediment transport and hydraulic modeling during break up jam conditions o Collaborate with Water Quality Modeling (Study 5.6) on reservoir trap efficiency and sediment outflow from Watana Dam o Collaborate with Fish Barriers (Study 9.12) on tributary delta modeling and assessment <u>Planned 2015 Activities</u> • 1-D field data collection - 1-D model field data collection is planned to be completed in 2014 with the following possible exceptions

Fluvial Geomorphology Modeling below Watana Dam Study 6.6	
	o Collect any data that was not collected in 2014 due to access, funding or field conditions o Collect any data needed to fill data gaps identified during model development and calibration efforts • 2-D field data collection o Perform breaching surveys in Focus Areas in conjunction with Fish and Aquatics IFS (Study 8.5) o Collect any data that was not collected in 2014 due to access, funding or field conditions o Collect any data needed to fill data gaps identified during model development and calibration efforts • Tributary delta (fan) field data collection - Same as 1-D model field data collection • 1-D modeling o Incorporate 2014 cross sections and bed material into model o Finalize tributary water and sediment inflow o Finalize calibration and validation of model • Perform final existing-conditions run o Perform 1-D with-Project scenario runs as they become available from the Operations Model o Perform sensitivity analysis for key model parameters • 2-D modeling o Finalize 2-D model for the 7 Focus Areas with data collected in 2013 (Focus Areas downstream of PRM 147) o Finalize 2-D models for the remaining 3 Focus Areas (assuming all data collected in 2014) o Perform maximum load-following year 0, year 25 and year 50 2-D modeling for all Focus Areas with complete data collected by 2014 o Perform sensitivity analysis for key model parameters • Model integration o Continue items identified for 2014 o Finalize all parameters to be transferred to and from other studies and file formats o Modifications to the Study Plan proposed for 2014 and 2015 are presented in ISR 6.6 Section 7.1.2 with one modification detailed in section 7.1.2.1 and the other two in Section 7.1.2.2. The first modification addresses the need to incorporate groundwater inflow into the 2-D hydraulic model for the lateral habitats in the Focus Areas. The second modification is a clarification of the parameters involved in the sensitivity analysis for bed material mobilization. The third modification addresses the decision to not account for warm and

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	cool PDO in the modeling of representative wet, average and dry years. The basis of this decision is presented in ISR Study 6.6 Appendix E and summarized in ISR Study 6.6 Section 7.1.1.2.1. The first modification is an important improvement to the modeling approach and will enhance AEA's ability to meet Study Plan objectives. The second modification is minor correction in the stated methods. The third modification will reduce the number of model runs required by eliminating consideration of a factor that was demonstrated to not be of significant influence on the hydrology of the Susitna River during open-water periods. This modification does not influence AEA's ability to meet the Study Plan objectives and will allow for more efficient determination of Project effects.

Highlighted Results and Achievements	The data that have been collected are sufficient to develop, calibrate, and validate the 1-D reach-scale and 2-D local-scale models for the three study components listed above. The models will provide necessary results to identify additional data needs for the next year of study. The initial results and integration of the models with the Fish and Aquatic IFS (Study 8.5) was demonstrated at the proof-of-concept meeting conducted April 15-17, 2014.
	
	To document the model integration and refinements resulting from the proof-of-concept the *Revised Fluvial Geomorphology Modeling Approach Technical Memorandum* (Tetra Tech 2014) was filed with FERC in May 2014.
	
	The following data have been collected and are currently being analyzed:
	
	• 11 Smaller Tributaries
	    o 4 to 10 cross-sections surveyed per tributary
	    o 1 to 8 bed-material samples per tributary
	• Susitna, Chulitna, and Talkeetna rivers
	    o 91 cross-sections surveyed in 2013 (88 surveyed in 2012)
	    o 1 to 3 water surface elevations measurements per surveyed cross-section
	    o Bed-material samples at approximate 2-mile intervals in Middle Susitna, Chulitna and Talkeetna rivers, and at approximate 3-mile intervals in Lower Susitna River
	    o Approximately 60 bank material samples in Middle Susitna River
	    o Sampling of bed material in the deepest portions of the channel by videography collected through holes augered in the ice cover in all Middle River and Lower River Geomorphic Reaches in the 1-D model domain
	• Focus Areas (7 in 2013)

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	o Detailed bathymetric survey o Approximately 20 bed-material samples per Focus Area o Approximately 8 bank-material samples per Focus Area o Approximately 600 water surface elevation measurements per Focus Area collected during bathymetric survey o ADCP velocity and discharge measurements at approximately 7 transects at two different flows (dates) o Approximately 25 water surface elevation measurements collected during ADCP data collection per Focus Area The following models have been developed or are in process: • Hydraulic/sediment transport models of 11 smaller tributaries • 1-D reach-scale hydraulic/sediment transport model of Susitna River below Watana Dam to Susitna Station including the lower 10 miles of the Chulitna River and lower 4 miles of the Talkeetna River • 2-D Hydraulic Models of 7 Focus Areas (2 are initially calibrated) • 2-D Sediment Transport Models of 7 Focus Areas (2 include initial model networks) The 1-D and 2-D Bed Evolution Models have been selected: HEC-RAS version 5.0.0 as the 1-D model dam SRH-2D as the 2-D model. As part of the proof-of-concept, preliminary results of one 2-D Hydraulic Model were provided to the Fish and Aquatics Instream Flow Study (Study 8.5) which developed tools to integrate the studies. Significant coordination has occurred between this study (Study 6.6), Geomorphology (Study 6.5), Fish and Aquatics Instream Flow (Study 8.5), Riparian Instream Flow (Study 8.6), Ice Processes in the Susitna River (Study 7.6), Water Quality Modeling (Study 5.6), and Groundwater (Study 7.5) studies to develop understanding of the physical processes that form and maintain channel and floodplain features and habitats.

7 COMPLETING THE STUDY

7.1 Proposed Methodologies and Modifications

There are 3 study components to the Fluvial Geomorphology Modeling Study below Watana Dam (Fluvial Geomorphology Modeling Study). To complete this study, AEA will implement the methods described for each study component in the Study Plan except as described in Section 7.1.2. These activities include:

1. *Study Component: Bed Evolution Model Development, Coordination, and Calibration* – This study component (RSP Section 6.6.4.1) is comprised of 9 tasks listed below with the overall purpose of developing the models to quantify Project effects on the geomorphology of the Susitna River, provide information to other resource studies to support their quantification of Project effects in their resource areas, and to collect data necessary to develop the study components models. These models include 1-D tributary sediment supply models, 1-D and 2-D bed evolution models, and 2-D hydraulic models. The modeling is being conducted at two scales. The local reach-scale represented by the 1-D tributary and 1-D bed evolution model, and the detailed local scale represented by the 2-D bed evolution and hydraulic models applied in the Focus Area. There are no modifications associated with this study component identified in Section 7.1.2.1. There are two proposed modifications described in Section 7.1.1.1 associated with incorporation of ground water inflows into the 2-D hydraulic model for the Focus Areas. Decision points associated with this study component are presented in Section 7.1.1.1 and include past decisions involving the extension of the 1-D Bed Evolution Model downstream from PRM 79 to PRM 29.9, selection of Focus Areas for the 2-D Bed Evolution Model, and selection of the 1-D and 2-D models that are being applied to support determination of Project effects. One future critical decision point remains to address the potential need to extend the 1-D Bed Evolution Model below PRM 29.9 in the Lower River. In addition to the collection and reduction of field data in 2013 described in ISR Study 6.6 Section 5.1.9, two technical memoranda present the progress made in 2013 and early 2014 in the model development effort that is the focus of this study component (Tetra Tech 2013a and Tetra Tech 2014). The second of these two documents present the contribution of the Geomorphology studies, both Study 6.5 and Study 6.6, conducted to demonstrate successful modeling coordination between studies. One future decision point for this study component is described in Section 7.1.1.1.2 and involves potential extension of the 1-D model downstream study limit. There are no variances from 2013 study efforts and one proposed Study Plan modification for 2014/2015 associated with this study component identified in section 7.1.2.1. The modification involves the incorporation of groundwater inflows in the 2-D Hydraulic Model to enhance the ability to characterize aquatic habitat in the lateral features.

   The 9 tasks of this study component include the following:

   - Development of Bed Evolution Model Approach and Model Selection (RSP Section 6.6.4.1.2.1)
   - Coordination with other Studies (RSP Section 6.6.4.1.2.2)
   - Model Resolution and Mesh Size Considerations (RSP Section 6.6.4.1.2.3)

- Focus Area Selection (RSP Section 6.6.4.1.2.4)
- Model Calibration and Validation (RSP Section 6.6.4.1.2.5)
- Tributary Delta Modeling (RSP Section 6.6.4.1.2.6)
- Large Woody Debris Modeling (RSP Section 6.6.4.1.2.7)
- Wintertime Modeling and Load-Following Operations (RSP Section 6.6.4.1.2.8)
- Field Data Collection Efforts (RSP Section 6.6.4.1.2.9)

2. *Study Component: Model Existing and with-Project Conditions* - This study component (RSP Section 6.6.4.2) is comprised of 4 tasks listed below with the overall goal of providing an existing (pre-Project) and a series of with-Project (post-Project) scenarios of future channel conditions for assessing channel change in the Susitna River. The effort also includes providing hydraulic conditions associated with the combination of flows and channel conditions that exist over the 50-year modeling period. The 1-D model will be executed for a 50-year period and the 2-D model for representative wet, average and dry years at year 0, year 25 and year 50 of the modeling period. The study component also includes identification of uncertainties associated with the model results and synthesis of the reach-scale and local-scale results. An important part of the synthesis is to extrapolate the response identified from the combination of 1-D and 2-D modeling in the Focus Area(s) within a geomorphic reach to other portions of the reach that will be modeled at only the 1-D level. One future decision point is described in Section 7.1.1.2.2 and involves the identification of Focus Areas to run specific 2-D model Scenarios. There are no variances from 2013 study efforts and two proposed Study Plan modifications for 2014/2015 associated with this study component identified in Section 7.1.2.2. The modifications involve the clarification of the parameters to be sued in the sensitivity analysis for bed material mobilization and the decision not to include consideration of warm and cool PDO in the representatives wet, average and dry years. This decision was presented in Section 7.1.1.2.1.

   The 4 tasks of this study component include the following:

   - Existing Conditions / Base Case Modeling (RSP Section 6.6.4.2.2.1)
   - Future Conditions / with-Project Scenarios (RSP Section 6.6.4.2.2.2)
   - Uncertainty (RSP Section 6.6.4.2.2.3)
   - Synthesis of Reach-Scale and Local-Scale Analyses (RSP Section 6.6.4.2.2.4)

3. *Study Component: Coordination and Interpretation of Model Results* - This study component (RSP Section 6.6.4.3) consists of two-way integration between the Fluvial Geomorphology Modeling Study and the Geomorphology Study (Study 6.5). The purpose of the integration is to ensure that results from both studies are used in a coordinated manner to identify, and to the extent possible, quantify the potential influence of the Project on key geomorphic features. The counterpart to this study component in the Geomorphology Study is described in RSP Section 6.5.4.11. The Geomorphology Study will apply its results to help guide the development and application of the various modeling efforts. The Geomorphology Study will assist in interpreting the results of the Fluvial Geomorphology Modeling (Study 6.6) and Ice Processes (Study 7.6) studies in predicting the potential change to key geomorphic features that comprise the aquatic and riparian habitat. In turn, the Fluvial Geomorphology Modeling Study (Study 6.6) will provide information such as frequency of inundation of various surfaces, hydraulic forces, sediment transport rates, bed mobility and predicted bed

aggradation/degradation response to (1) help understand current geomorphic processes and to (2) understand how changes to flow and sediment supply regimes under post-Project scenarios may affect the geomorphic features that constitute the aquatic and riparian habitat of the Susitna River. These activities will be ongoing through study completion. There are no variances or proposed modifications to this study component presented in Section 7.1.2.3. There are also no past or proposed decision points identified in Section 7.1.1.3.

The 2 tasks of this study component include the following:

- Integration of Geomorphology and Fluvial Geomorphology (RSP Section 6.6.4.3.2.1)
- Coordination of Results with Other Resource Studies (RSP Section 6.6.4.3.2.2)

7.1.1 Decision Points from Study Plan

7.1.1.1 Study Component: Bed Evolution Model Development, Coordination, and Calibration

Several decision points have been reached in this study component and one significant decision point remains. The past decision points include: selection of Focus Areas, extension of the downstream study limit for the 1-D model, selection of Middle River tributaries to model, selection of Lower River tributaries to model, and selection of the 1-D and 2-D bed evolution models. The remaining decision point involves the potential need to extend the downstream limit of the 1-D model below Susitna Station (PRM 29.9).

7.1.1.1.1 Past Decision Points

Selection of Focus Areas: The process for selection of the Focus Areas is identified in RSP Section 6.6.4.1.2.4 and RSP Section 8.5.4.2. The initial selection was led by the Fish and Aquatics IFS (Study 8.5) with input from the Geomorphology studies (Studies 6.5 and 6.6), Riparian IFS (Study 8.6), Groundwater (Study 7.5), and Characterization and Mapping of Aquatic Habitats (Study 9.9). Through interaction with the licensing participants, the selection of the Focus Areas was refined. The results of this process are detailed in two technical memorandums one filed in Q1 2013 (R2 2013a) and one filed in Q2 2013 (R2 2013b). A total of 10 Focus Areas were selected and presented in R2's (2013a) March technical memorandum, *Selection of Focus Areas and Study Sites in the Middle and Lower Susitna River for Instream Flow and Joint Resource Studies—2013 and 2014*. These selected Focus Areas were modified in May 2013 (R2 2013b) and stand as the working locations for the 10 Focus Areas. Explanation and methods describing the modifications can be found in the aforementioned technical memorandum (R2 2013b) and ISR Study 8.5 Sections 4.1.2.3 and 5.1.3. The results of the Focus Area selection are presented in ISR Study 6.6 Section 5.1.4.

Extension of Downstream Study Limit below PRM 79: The process for determining whether to extend the downstream limit of the Study below PRM 79 in the Lower River and the resulting decision are presented in Section 3.1 above and summarized here. Review of information developed during the 1980s studies and study efforts initiated in 2012 and completed in Q1 2013 (Tetra Tech 2013b through 2013h)—such as sediment transport analyses, hydrologic analysis, assessment of channel change and comparison of habitat mapping from the 1980s with current

2012 conditions in the Geomorphology Study (Study 6.5), and additional 2012 habitat mapping (Study 9.9), operations modeling and the Open-water Flow Routing Model (RSP Section 8.5.4.3)—were used to reassess the extent to which Project operations could potentially influence habitats in the Lower River Segment. Much of the 2012 study effort conducted under the Geomorphology Study (Study 6.5) had been designed to inform this decision. An assessment of the downstream extent of Project effects was completed in Q1 2013 and the results presented in technical memorandums (R2 2013a; R2 2013b) in collaboration with the TWG. This assessment was supported by the results presented in the TMs prepared by the Geomorphology Study (Tetra Tech 2013b through 2013h). The assessment guided the decision to extend studies into the Lower River to PRM 29.9 and to determine which geomorphic reaches should be subject to reach and Focus Area level modeling. Figure 3.1-1, presented in Part A, shows the current limits of the Fluvial Geomorphology Modeling below Watana Dam Study.

Selection of Middle River Tributaries: AEA will implement the methods presented in ISR Study 6.6 Section 4.1.2.6 to complete the tributary delta modeling. There are 19 tributaries selected for delta modeling in the Middle Susitna River Segment (Table 7.1-1); five tributaries to the Lower Susitna River Segment were previously selected (Tables 5.1-3 and 5.1-8). Prior to coordination with the Study of Fish Passage Barriers in the Susitna Tributaries (Study 9.12) and agency staff during the March 19, 2014, Fisheries Technical Meeting, 15 Middle River tributaries were selected for delta modeling. One result of this coordination is the removal of Unnamed Tributary 115.4 from consideration of tributary delta modeling because of the following observations made during the July 2013 reconnaissance: (1) no evidence of a depositional fan at the tributary mouth, (2) no surface flow at the mouth, and (3) the presence of a wetland between the tributary mouth and the Susitna River. Another result of the coordination is that five additional tributaries were selected for modeling because (1) the presence of a delta could create a barrier to upstream fish passage, and (2) the sediment loading will provide needed input to the 1-D Bed Evolution Model. A total of 19 Middle River tributaries are now selected for tributary delta modeling in the Middle River.

The selection criteria included:

1. Contributing drainage area, with greater drainage area being a positive factor influencing selection. Potential for a drainage area to produce sediment and form a delta is greater for larger drainage areas.
2. The location of the tributary mouth relative to Focus Areas, with location in a Focus Area being a basis for selection.
3. The presence of lakes in the drainage area, with presence of large lakes near the mouth of the tributary being a negative factor in selection because the lakes would trap sediment that would otherwise be transported to the mouth of the tributary.
4. The presence and number of resident fish species and salmon species observed during the field efforts for the 2012/2013 Fish Distribution and Abundance in the Middle and Lower Susitna River Study (Study 9.6), with the presence being a positive factor and greater numbers being a positive factor.
5. Whether the tributary is selected for evaluation of fish passage barriers (Study 9.12), with selection being a positive factor for tributary delta modeling.

6. Evidence of an active depositional fan at the mouth of the creek being a positive factor, because an existing fan indicates conditions conducive to development and maintenance of a delta.

Upon evaluation of the criteria, selection was based on the following considerations:

1. If a tributary mouth is located within a Focus Area, then the tributary sediment supply will be modeled to quantify an input for the Bed Evolution Models (1-D and 2-D). If there was no evidence of an active fan at the tributary mouth and if the tributary was not selected for evaluation of fish passage barriers (Study 9.12), the tributary delta will not be modeled; otherwise, the tributary delta will be modeled. If a tributary was not selected for evaluation of fish passage barriers (Study 9.12), the delta modeling will occur as part of the 2-D bed evolution modeling of the Focus Areas.
2. If a tributary mouth is located outside of a Focus Area, if there is evidence of an active fan at the tributary mouth, and if the tributary is selected for evaluation of fish passage barriers (Study 9.12), the tributary sediment supply and the delta will be modeled. If the tributary was selected for evaluation of fish passage barriers (Study 9.12), but there was no evidence of an active fan, the tributary sediment supply and delta will not be modeled (i.e., Devil Creek, Cheechako Creek, Jack Long Creek, Little Portage Creek, McKenzie Creek, Little McKenzie Creek, and Chase Creek).

The evaluation criteria and the selected tributaries are presented in Table 7.1-1.

Selection of Lower River Tributaries: In addition to the 19 tributaries in the Middle River selected for study, 5 tributaries in the Lower River were initially identified for investigation by the Fluvial Geomorphology Modeling Study (Study 6.6). The primary reason for investigation of the five tributaries is to support investigation of potential changes in geomorphology that might influence adult salmon habitat at their mouths, in particular, holding and ability to access the tributaries (Study 9.12). The initial selection was based on review of 1980s information and is presented in the technical memorandum *Synthesis of 1980s Lower Susitna River Segment Aquatic Habitat Information* (Tetra Tech 2013f). The selection criteria was further detailed and the choice of the 5 lower River tributaries confirmed in the technical memorandum *Selection of Focus Areas and Study Sites in the Middle and Lower Susitna River for Instream Flow and Joint Resource Studies—2013 and 2014* (R2 2013a). The five selected tributaries are Tappers Creek, Birch Creek, Sheep Creek, Caswell Creek and the Deshka River. The Deshka River will not be studied as part of Study 9.12 and will only be studied as a sediment supply source in Study 6.6. The mouth of the Deshka is relatively deep and in the backwater of the Susitna River and therefore has little potential for development of conditions that would create access problems under Project operations. The 1980s study *Assessment of Access by Spawning Salmon into Tributaries of the Lower Susitna River* (R&M Consultants, Inc. and Trihey & Associates. 1985) did not include the Deshka River as one of the Lower River tributaries with potential access issues under post-Project conditions.

Selection of 1-D and 2-D Bed Evolution Models: This decision point involves the selection of both the 1-D and 2-D Bed Evolution Models. This process started in May 2012 with the posting of the technical memorandum titled *Fluvial Geomorphology Modeling* (Tetra Tech 2012). This TM described initial 1-D and 2-D model candidates, initial selection criteria and a summary of the overall modeling approach of integrating the 1-D reach-scale modeling and the 2-D local scale modeling. The Fluvial Geomorphology Modeling Study RSP (Section 6.6.4.1.2.1) further described the candidate models and evaluated four 1-D models and five 2-D models against the selection criteria, though no recommendations on selection were made. In May and then June 2013 the draft and final versions of the technical memorandum titled *Fluvial Geomorphology Modeling Approach* (Tetra Tech 2013a) were posted on the AEA website. This document made an initial 1-D model selection of HEC-6T (Mobile Boundary Hydraulics 2010) and narrowed the 2-D model selection to either SRH-2D (Lai 2008) or River2D (Steffler and Blackburn 2002; Kwan 2009) and indicated the modeling team would test the two models in a Focus Area to finalize the selection. At the November 13-15, 2013 Riverine Modelers meeting, the selection of the 1-D and 2-D models was further discussed with the licensing participants and the recommendation remained HEC-6T for the 1-D model and either SRH-2D or River2D for the 2-D model. However, it was mentioned that a new 4.1.0 version of HEC-RAS (USACE 2010) incorporated unsteady flow routing with sediment transport and was therefore going to be looked into as the inclusion of unsteady flow in the 1-D Bed Evolution Model in order to make the model more complete. Sections 5.1.1.1 above indicates that HEC-RAS ver. 4.1.0 had been chosen as the 1-D Bed Evolution Model after further evaluation. ISR Study 6.6 Section 5.1.1.1.2 above indicates that the evaluation of SRH-2D and River2D were still underway for FA-104 (Whiskers Slough) and FA-128 (Slough 8A). The final selection of both Bed Evolution Models was presented in the technical memorandum titled *Updated Fluvial Geomorphology Modeling Approach* (Tetra Tech 2014). The memorandum included tables documenting the ability of each candidate model to fulfill the selection criteria. The selected 1-D model was HEC-RAS 5.0.0. This is an updated version of the previously identified HEC-RAS version 4.1.0. The SRH-2D model was selected as the 2-D bed evolution and also hydraulic simulation model.

7.1.1.1.2 Future Decision Points

<u>Extension of Study Limits below PRM 29.9:</u> The final decision remaining in the Study Plan will occur in 2014 and involves whether to extend the 1-D Bed Evolution Model downstream of PRM 29.9. This decision point is identified in RSP Section 6.6.3.2. The primary reason to consider extending the fluvial geomorphology modeling below PRM 29.9 is to assist in describing the relationship between river flows, water surface elevation, and Cook Inlet Beluga Whale (CIBW) foraging habitat in the Susitna River, consistent with Objective 3 of the CIBW Modified Revised Study Plan (MRSP) (See MRSP Section 9.17 attached to ISR Study 9.17 as Appendix E).

To determine if the 1-D Bed Evolution Model needs to be extended below PRM 29.9, the results of the 1-D Bed Evolution Model in Geomorphic Reach LR-4 (PRM 44.6 to PRM 32.3) and the portion of LR-5 (PRM 32.3 to PRM 23.9) upstream of PRM 29.9 will be compared for the pre-Project condition and Post-Project condition represented by the maximum load-following scenario. The comparison will be performed to estimate the potential for changes to the geomorphology and hydraulics (depth and velocity) downstream of PRM 29.9 and in particular the lower portions of Geomorphic Reach LR-6, the area of most interest in terms of CIBW habitat. The geomorphic criteria represent the potential for long-term channel change related to alteration in flows and sediment supply due to Project operations that could result in changes to habitat. The hydraulic criteria represent the potential for immediate changes in habitat related to alteration in flows due Project operations. Criteria to be evaluated are:

- Changes in flow at Susitna Station and associated potential for channel width adjustment.
- Change in sediment transport volume over the open water period. The sediment volumes of primary interest are sand and larger materials.
- Difference in modeled bed elevations represented by channel aggradation or degradation.
- Estimated change in flow depth and velocity in the lower portion of Geomorphic Reach LR-6 inferred form changes modeled in the upper portion of LR-5 and LR-4.

To evaluate these criteria, the 1-D Bed Evolution model will be run for the 50-year record for both the pre-Project and maximum load-following scenario. The results will be used to develop annual peak flows and open-water period flow duration curves at Susitna Station. The change in peak flows will be used to estimate the potential for change in width based on the assumption that the change in width is proportional to the square root of the ratio of channel forming discharges. Discharges in the range of the 1.5- to 5-year peaks are often representative of the channel forming or effective discharge to which the bankful channel capacity adjusts in streams such as the Lower Susitna River Segment that have mobile bed material and a substantial sediment supply (Wolman and Leopold 1957, Wolman and Miller 1960, Wolman and Gerson 1978, Williams 1978, Andrews 1980). Numerous researchers have identified hydraulic geometry relationships (i.e., relationships between channel dimensions and discharge) that clearly demonstrate this linkage (Leopold and Wolman 1953, Langbein 1964, Emmett 1972, Parker 1979, Andrews 1984, Hey and Thorne 1986, Julien and Wargadalam 1995). The channel width is typically proportional to about the square-root of the discharge (For example, applying this proportionality, a reduction of the channel forming or effective discharge to 80 percent of its current value would translate into an expected reduction in the width to 89 percent of its current value). This criterion was used in the 2013 decision to extend the 1-D model below PRM 79 (R2 2013a). The flow duration curves will be used to understand the temporal change in flow distribution.

The change in annual sediment volumes over the range of conditions represented in the 50 year record will be determined by integration of the 1-D Bed Evolution Model transport rates at Susitna Station over each of the years of the record. The criterion to extend the model will be based on the pre-Project versus post-Project difference in the annual sediment transport volume in the representative wet, average and dry years and in the average annual sediment transport volume over the 50 year period.

Bed elevation changes in Geomorphic Reaches LR-5 (above PRM 29.9) and LR-4 will be compared between the pre-and post-Project runs. The criterion for extending the 1-D modeling downstream will be based on a reach averaged difference in the bed elevation across the channel at various points in time throughout the 50 year period. Changes at individual cross sections will also be reviewed to assess the variability within the area of comparison.

The final comparison will be in the hydraulic conditions represented by flow depths and velocities. The primary factor that may contribute to flow depth and velocity change would be the change in hydrology resulting from Project operations. The flow depths and velocities over the period of the year of interest for the CIBW will be compared between the pre-Project and post-Project scenarios in the upper portion of LR-5 (above PRM 29.9). The level of change in cross section average depth and velocity for the modeled portion of LR-5 will be determined to estimate the associated change in the area of LR-6 considered of primary importance to the CIBW. The comparison will be made for the representative wet, average and dry year model results.

The magnitude of change in the above metrics that will trigger the extension of the 1-D modeling effort below Susitna Station and into Geomorphic Reach LR-6 will be based on comparison of the pre-Project and post-Project models results relative to the expected range of natural variability. The range of natural variability will be partially assessed based on quantifying the range of temporal and spatial variability in the pre-Project model results. Additionally, the range of variability in the Susitna River hydrologic record will be investigated to help in assessment of natural variability. The results of this investigation will be included in the technical memorandum along with the resulting quantitative criteria for the triggers.

The results of the pre- and post-Project 1-D Bed Evolution Model runs and evaluation of decision criteria described above will be presented in a technical memorandum. The results and evaluation criteria along with the decision as whether to extend the 1-D bed evolution modeling below PRM 29.9 will be presented and discussed at a technical team meeting to be conducted during 2014. If the decision is made to extend the model, the methods associated with the modeling below PRM 29.9 will also be presented in the technical memorandum and discussed at the technical team meeting.

If the 1-D Bed Evolution Model is extended below PRM 29.9, additional cross sections will be surveyed for model development and stage monitoring sites will be established for model input and calibration. The model boundary conditions will also be altered as needed. The results of the extended model will be available to evaluate potential Project effects within the extended model domain.

7.1.1.2 Study Component: Model Existing and with-Project Conditions

7.1.1.2.1 Past Decision Points

Selection of Representative Hydrology: As discussed in Section 5.2.1 above, the hydrologic input for the 1-D Bed Evolution Model includes a 50-year hydrologic record and the 2-D Bed Evolution Model includes representative years and selection of representative wet, dry and average. The selection of the 50-year period and representative years has been coordinated with Fish and Aquatics Instream Flow and Ice Processes in the Susitna River studies. Appendix E of this ISR includes detailed information on this analysis and the recommendations for review by other studies and stakeholders. As part of the Proof of Concept exercise conducted in April 2014, the selection process and recommendations was coordinated with Licensing Participants to finalize the hydrology for this study component and for use by other studies (Tetra Tech et al. 2014). The RSP (Section 6.6.4.2.2.1) indicates the short duration, open-water period runs (~6 months) of the 2-D Bed Evolution Model will be performed for a range of hydrologic conditions including representative wet, average, and dry years with warm and cool PDO. It was determined that open water flows are not significantly affected by PDO (ISR Study 6.6 Appendix E) and separate warm and cool PDO years will not be included in the representative wet, average, and dry annual open-water period hydrographs.

7.1.1.2.2 Future Decision Points

Identification of Focus Areas to Run Specific 2-D Model Scenarios: The execution of the 2-D modeling for a Focus Area is a time intensive exercise that generates large amounts of information that also requires considerable effort to evaluate. For certain scenarios, the 1-D Bed Evolution Model may show that the geomorphic response in a reach is very similar to previous scenarios and that running separate 2-D hydraulic models is not necessary. The output of the previously-developed range of 2–D hydraulic models would be run through the 2-D fish habitat models to evaluate the effects of the alternate flow regimes. If the 1-D Bed Evolution Model is showing a very similar geomorphic response to Project operations as an earlier run scenario, then it would not be necessary to perform separate year 25 and year 50 2-D Bed Evolution Model runs of the new scenario. In this case, the year 25 and year 50 geometry from the earlier scenario may adequately reflect the geometry for the new scenario. Additionally, it may be determined that the response of one Focus Area in a geomorphic reach may be sufficient to characterize the response of the reach. In this case, the 2-D bed evolution and hydraulic models would only be run on the representative Focus Areas. In other cases, the 1-D Bed Evolution Model may show the geomorphic response in a reach is minor and running year 25 and year 50 models is not necessary. The 2-D Bed Evolution Model may not be run and the 2-D hydraulic model for aquatic habitat analysis will only be run for the initial year zero geometry. In other Focus Areas, it may be determined that 1-D modeling is appropriate to evaluate Project effects on the key habitat metrics of interest for that Focus Area. In that case, the 2-D hydraulic model and associated 2-D habitat modeling would not be performed.

In order to evaluate and recommend the level of 2-D modeling to be performed for a specific scenario at the various Focus Areas, the results of the 1-D Bed Evolution Modeling for the scenario would be assessed. The 1-D results, assessment of the results and 2-D modeling recommendations for each Focus Area would be reported on and presented to the Licensing Participants for feedback at Technical Team meetings.

7.1.1.3 Study Component: Coordination and Interpretation of Model Results

There are no past or future decision points from the Study Plan for this study component.

7.1.2 Modifications to Study Plan

7.1.2.1 Study Component: Bed Evolution Model Development, Coordination, and Calibration

There were no variances to the Study Plan identified for this study component for work performed in 2013 that would carry over as modifications. There is one modification to the methods proposed for 2014/2015 2-D hydraulic modeling based on experience gained from performing the Proof of Concept exercise.

Incorporation of Groundwater Inflows in the 2-D Hydraulic Model: From the standpoint of hydraulic modeling, the POC identified the need to account for groundwater (Tetra Tech 2014). To accurately model the habitat in Slough 8A at 30,000 cfs a persistent groundwater source had to be incorporated into the SRH-2D model as a point source. Site specific response functions developed from groundwater wells, surface water stage recorders and other field measurements, and observations, such as time-lapse photographs, were input into the FA-128 (Slough 8A) model to depict groundwater source inputs. The resulting model results demonstrated the ability of the SRH-2D model to depict channel hydraulics, although additional calibration details are expected before development of a calibrated and validated FA-128 (Slough 8A) model (Study 8.5 ISR Appendix N).

For illustration purposes, other simulations shown in Attachment A to the *Revised Fluvial Geomorphology Modeling Approach* TM (Tetra Tech 2014) included point sources at additional locations. This effort demonstrated, that even if subsurface flows of less than 1 cfs are identified for individual habitat areas, flows can be introduced in the SRH-2D model and the local influence on habitat can be addressed. As a finite volume model, SRH-2D is extremely well-suited for this type of analysis as these minor flow contributions can be tracked through the channel network and their local influence on habitat can be incorporated into the model.

The Groundwater Study (Study 7.5) will be the primary source for quantification of groundwater inflows to the 2-D hydraulic models in the Focus Area. Within FA-128 (Slough 8A), response functions were developed for Slough 8A, Half Moon Slough, and other side sloughs and side channels that exhibit upwelling from upland or riverine sources (GW Scientific 2014). In addition to FA-128 (Slough 8A), intensive groundwater data collection efforts are ongoing at FA-138 (Gold Creek), FA-115 (Slough 6A), FA-113 (Oxbow 1), and FA-104 (Whiskers Slough). The intent is to use the results of intensive investigation at select Focus Areas to understand groundwater processes and upscale those efforts to other Focus Areas where groundwater/surface water interactions are less complex (ISR Study 8.5 Appendix N Section 1.3).

The Groundwater Study (Study 7.5) has collected data in Focus Areas to estimate groundwater inflows. Site-specific data collection efforts at the Focus Area scale include groundwater wells, surface water hydrology stations, meteorological stations, time-lapse photography, and aerial and TIR imagery. Measurements include water level, flow, water temperature, and other water quality parameters indicative of groundwater flux. These data and analysis of modeling efforts will be used by the Groundwater Study (Study 7.5) to quantify response functions at Focus Area features exhibiting groundwater/surface water interactions (ISR Study 8.5 Appendix N).

The proposed modification to the Study Plan is for groundwater inflows to be accounted for by introduction of point sources in the 2-D open-water period hydraulic model. The proposed modification includes coordination with the Groundwater Study (Study 7.5) and the Fish and Aquatics IFS (Study 8.5) on identification of groundwater sources that need to be included in each Focus Area. With the proposed modification to account for groundwater inflows into the 2-D open-water hydraulic model, AEA expects to meet the objectives of the Study Plan.

7.1.2.2 Study Component: Model Existing and with-Project Conditions

There are two proposed modifications to the Study Plan for this study component in 2014/2015.

Model Uncertainty: The RSP Section 6.6.4.2.2.3 addressing model uncertainty indicates that there is a wide range of information that can be used to identify and understand uncertainty related to the fluvial geomorphology modeling. ISR Study 6.6 Section 6.2.3 includes additional discussion of the evaluation of fluvial geomorphology modeling uncertainty. Based on selection of the sediment transport equation, dimensionless critical shear may not be available as a parameter for the sensitivity analysis as originally indicated in the RSP. The range of variation in the other parameters will be evaluated based on the field data and model calibration results. The modification will not affect AEA's ability to meet the objectives of the Study Plan. If a sediment transport equation that does not use critical shear is selected, the parameter that it uses to determine bed mobility will be incorporated into the sensitivity analysis.

Representative Hydrology: The second proposed modification in the Study Plan results from the decision point documented in Section 7.1.1.2.1 concerning the selection of representative hydrologic years for the open-water period. The RSP Section 6.6.4.2.2.1 indicates the short duration, open-water period runs (~6 months) of the 2-D Bed Evolution Model will be performed for a range of hydrologic conditions including representative wet, average, and dry years with warm and cool PDO. It was determined that open water flows are not significantly affected by PDO (ISR Study 6.6 Appendix E; Tetra Tech 2014) and separate warm and cool PDO years will not be included in the representative wet, average, and dry annual open-water period hydrographs. The objectives of the Study Plan will be met with the proposed modification as the analysis indicates the PDO is not a significant factor affecting the hydrologic characteristics during the open-water period of the representative years.

7.1.2.3 Study Component: Coordination and Interpretation of Model Results

There are no variances from 2013 or proposed modifications to the Study Plan for 2014/2015 for this study component.

7.2 Schedule

In general, the schedule for completing the FERC-approved Study Plan is dependent upon several factors, including Project funding levels authorized by the Alaska State Legislature, availability of required data inputs from one individual study to another, unexpected weather delays, the short duration of the summer field season in Alaska, and other events outside the reasonable control of AEA. For these reasons, the Study Plan implementation schedule is subject to change, although at this time AEA expects to complete the FERC-approved Study Plan through the filing of the Updated Study Report (USR) by February 1, 2016, in accordance with the ILP schedule issued by FERC on January 28, 2014.

7.2.1 2014 Activities

7.2.1.1 Study Component: Bed Evolution Model Development, Coordination, and Calibration (RSP Section 6.6.4.1)

In addition to model development, activities under this study component include the collection of the data for both the 1-D and 2-D bed evolution model. The methods associated with the nine tasks below are presented in RSP Section 6.6.4.1 with additional information provided in ISR Study 6.6 Section 4.1.2.1 above and the technical memoranda presenting the modeling approach (Tetra Tech 2013a and Tetra Tech 2014). Field data collection to support the Geomorphology Study (Study 6.5) is also performed under this task. A significant portion of the data to be collected for the development of the 1-D and 2-D models is performed by other studies. This includes the Fish and Aquatics IFS (Study 8.5), Riparian IFS (Study 8.6), Groundwater (Study 7.5) and Ice Processes (Study 7.6).

7.2.1.1.1 Development of Bed Evolution Model Approach and Model Selection (RSP Section 6.6.4.1.2.1)

The model selection portion of this task has been completed with the selection of HEC-RAS ver. 5.0.0 as the 1-D Bed Evolution Model and SRH-2D as the 2-D Bed Evolution Model and Hydraulic Simulation Model. Development of the overall modeling approach has also been completed and documented in a technical memorandum (Tetra Tech 2014). The modeling approach will continue to be refined with the main areas for further development being the incorporation of groundwater inflows from the Groundwater Study (Study7.5) and integration with the ice processes (Study 7.6). Development of additional metrics and manipulation of model output for the Fish and Aquatics IFS (Study 8.5) and Riparian IFS (Study 8.6) are expected to continue to evolve as these studies refine their analyses procedures.

7.2.1.1.2 Coordination with other Studies (RSP Section 6.6.4.1.2.2)

Coordination with other studies will be continuous and ongoing as the Fluvial Geomorphology Modeling below Watana Dam Study progresses throughout 2014. Major coordination efforts in 2014 include:

- Incorporation of groundwater inflows into the 2-D hydraulic (habitat) model
- Continued coordination with Ice Processes (Study 7.6) on incorporating ice processes influences into the analysis effort, particularly the building of floodplain surfaces
- Continued coordination with the Riparian IFS (Study 8.6) on the dating of surfaces and sedimentation rates

7.2.1.1.3 Model Resolution and Mesh Size Considerations (RSP Section 6.6.4.1.3)

The resolution for the 2-D model mesh has been set as part of the development of the 2-D modeling approach (Tetra Tech 2014). The results are a mesh size of approximately 6 feet (2m) for the areas where fine spatial resolution habitat analysis will be performed such as lateral habitats or spawning areas, 30 feet (10m) in the larger channels and side channels and up to 100 feet (30m) in the floodplain. No additional work will be performed on this task in 2014.

7.2.1.1.4 Focus Area Selection (RSP Section 6.6.4.1.2.4)

Focus Area selection is complete and no further work will be performed on this task in 2014.

7.2.1.1.5 Model Calibration and Validation (RSP Section 6.6.4.1.2.5)

This task is divided into 1-D and 2-D efforts. Model development, calibration and validation efforts will be documented as the work progresses.

- 1-D Bed Evolution Model: Though the 1-D model will have additional cross section and bed material data collected in 2014, the development of an initial model will be completed in

2014 without this data in order to support the decision on whether to extend the 1-D bed evolution model below PRM 29.9. Specific tasks include:

  - Complete development of the initial tributary sediment and water inflows in the Middle River and the Lower River
  - Incorporate the results of the winter bed material sampling effort into the initial model
  - Complete initial calibration of the hydraulics and sediment transport components of the model to PRM 29.9
  - Perform validation of the initial 1-D model including a 30-year run of existing conditions using the 1983 to 2012 hydrology to support model validation
  - Incorporate data collected in 2014 into the model (primary data will be bed material samples, cross section surveys, and 2014 floodplain LiDAR in the Middle River)

- 2-D Bed Evolution Model: Data were collected in 7 of the 10 Focus Areas in 2013 and planned for collection in the remaining 3 in 2014. Calibration and validation of the 2-D hydraulic model will continue in 2014 in the Focus Areas with available 2013 data. The 2-D modeling efforts include:
  - Complete initial hydraulic calibration and validation of FA-104 (Whiskers Slough)
  - Complete initial calibration and validation of sediment transport models for FA-104 (Whiskers Slough) and FA-128 (Slough 8A)
  - In conjunction with Groundwater (Study 7.5) and Fish and Aquatics IFS (Study 8.5) determine locations and estimate rates of groundwater inflow for the hydraulic model of FA-104 (Whiskers Slough) and FA-128 (Slough 8A)
  - Initiate and complete development, calibration and validation of hydraulic models for FA-113 (Oxbow 1) and FA-115 (Slough 6A)
  - Initiate model development for the remaining 3 FAs with available 2013 data: FA-138 (Gold Creek), FA-141 (Indian River) and FA-144 (Slough 21)

7.2.1.1.6 Tributary Delta Modeling (RSP Section 6.6.4.1.2.6)

Tasks in this effort involve creating the sediment inflow rating curves and performing a demonstration of the process to model fan development at a tributary though the 1-D modeling approach (Note: Tributaries within Focus Area will be modeled in 2-D as part of the SRH-2D Focus Area model domain and only require the sediment rating curves from this task).

- Complete development of tributary sediment rating curves for the 9 Middle River tributaries with data collected in 2014
- Initiate development of sediment rating curves for the 10 Middle River tributaries planned for survey in 2014
- Complete development of tributary sediment rating curves for the 2 Lower River tributaries with data collected in 2013
- Initiate development of sediment rating curves for the 3 Lower River tributaries planned for survey in 2014

- Perform initial assessment of delta/fan development for a single 1-D tributary in the Middle River to demonstrate the process

7.2.1.1.7 Large Woody Debris Modeling (RSP Section 6.6.4.1.2.7)

Efforts in 2014 in this task will include:

- In coordination with the Geomorphology Study (Study 6.5) preform the initial application of the bank energy index (BEI) to FA-128 (Slough 8A) along with the turnover analysis results to refine the procedures for estimating project effects on LWD recruitment from bank erosion
- Initiate the application and refine the procedure for accounting for the hydraulic effects of changes in LWD present in the Focus Areas.

7.2.1.1.8 Wintertime Modeling and Load-Following Operations (RSP Section 6.6.4.1.2.8)

Based on observation from field studies and information on frequency of inundation during open-water periods initial application of the 1-D and 2-D hydraulic models, ice processes play an important role in the development and evolution of the geomorphic features in the Susitna River. For example, based on initial results of the Geomorphology Study (Study 6.5 ISR Section 5.1.3.5.5), it appears an appreciable portion of the sedimentation occurring on floodplain surfaces may be the result of flooding during breakup jams. Further integration with the Ice Processes (Study 7.6) modeling effort will occur, including:

- Coordination on the procedures and models to be used to simulate the inundation and potential sedimentation that can occur during break-up jams.
- Information from the Ice Process Study (Study 7.6) River1D reach-scale River2D Focus Area local-scale models will be used to assess bed-material mobilization to determine if significant channel changes can occur during the winter ice cover period.

7.2.1.1.9 Field Data Collection Efforts (RSP Section 6.6.4.1.2.9)

Field data collection efforts in the locations that they could be conducted were largely adequate for development and preliminary calibration of the models as demonstrated by the POC (Tetra Tech 2014). Data collection in 2014 will concentrate on locations that could not be accessed in 2013. The major components of the data collection efforts in 2014 are identified for the 1-D Model, 2-D model, and tributaries. In addition, the primary data being collected by other studies that will contribute to development of the models in the Fluvial Geomorphology modeling Study (Study 6.6) are identified.

7.2.1.1.9.1 1-D Bed Evolution Model (RSP Section 6.6.4.1.2.9.1)

Data collection efforts planned for 2014 will follow the methods presented in ISR Study 6.6 Section 4.1.2.9.1 and include:

- **Channel Roughness observations:** Characterizations of hydraulic roughness will be made upstream of PRM 146.6 during Q3 of 2014 to develop initial energy loss parameters

(Manning's *n*-values). The roughness observations made in 2013 correlated well to the mapped geomorphic surfaces (ISR 6.5 Section 5.1.3.5.1) along the Middle River downstream of PRM 146.1; it is expected that these relationships will also hold upstream of PRM 146.6. The roughness characterizations conducted in 2014 will be conducted to verify these relationships hold upstream of PRM 146 and to make additional observations if needed.

- **Water Surface Observations:** Collection of water-surface elevation measurements during targeted flows in the Lower River and Middle River upstream of PRM 146.6 to support calibration of the Bed Evolution Models will be continued. Further detail regarding the targeted flows for collecting measurements is provided in Section 7.2.1.1.9.4.
- **Sediment sampling:** Surface and subsurface samples will be performed in the Middle River between PRM 146.6 and PRM 187.1. Bank material sampling will be performed at the 3 Focus Areas not accessible during 2013 (i.e., FA-151 (Portage Creek), FA-173 (Stephan Lake Complex), and FA-184 (Watana Dam)). Additional bank material samples will be collected in areas outside of these Focus Areas if field observations indicate they are needed to characterize any substantial spatial differences in bank materials. (Note: Winter sediment sampling was completed in March/April 2014 to characterize the bed gradations in the deepest potions of the main channel of the Upper, Middle and Lower Susitna River Segments. This effort had originally been planned for two field seasons but was accomplished in one.).

7.2.1.1.9.2 Focus Areas (RSP Section 6.6.4.1.2.9.2)

Following the methods presented in Section 4.1.2.9.2 above, data collection will be performed for the three Focus Areas upstream of PRM 146.6 (FA-151 (Portage Creek), FA-173 (Stephan Lake Complex) and FA-184 (Watana Dam)) that could not be accessed during 2013. Additional calibration/validation data will be collected in the other 7 Focus Areas. Specific data to be collected under this study include:

- Water surface elevation observations (Additional water surface elevation will be collected at the remaining seven Focus Areas on an opportunistic basis)
- Installation of level Loggers in selected Focus Area that have not been studied extensively by the Groundwater (Study 7.5) in order to further develop information for calibration of the hydraulic model
- Roughness observations in the remaining three Focus Areas
- Sediment sampling in the remaining three Focus Areas (bed surface, bed subsurface and bank)
- Geomorphic mapping in the remaining three Focus Areas including geomorphic surfaces, erosional and depositional features, bank erosion, geologic controls, beaver ponds,
- LWD survey in the remaining three Focus Areas

7.2.1.1.9.3 Tributary Deltas (RSP Section 6.6.4.1.2.9.3)

Surveys of 10 tributaries in the Middle River are planned for 2014 (Table 7.1-1); five of these tributaries are located upstream of PRM 146.6 and were inaccessible during 2013, and the remaining three tributaries were added after coordination with the Barriers Study (Study 9.12) (ISR Study 6.6 Section 7.1.1.1.1). The Middle River tributaries to be surveyed are Tsusena Creek, Fog Creek, Unnamed Tributary 174.3, Unnamed Tributary 173.8, Chinook Creek (if safe access can be achieved), Portage Creek, Fourth of July Creek, Sherman Creek, Fifth of July Creek, and Deadhorse Creek. In the Lower River, three tributaries are to be surveyed: Birch Creek, Sheep Creek and Caswell Creek. One of the Lower River tributaries, Birch Creek, was not accessible in 2013 and access will be requested again in 2014 or alternate portion of the tributary may be surveyed to develop sediment loading. If neither of these options is feasible, an alternative tributary will be selected for survey, possibly Montana Creek. The data collection at these tributaries will follow the methods presented in Section 4.1.2.9.3.

7.2.1.1.9.4 Field Data from Other Studies (RSP Section 6.6.4.1.2.9.4)

The plans for 2014 field data collection will be closely coordinated with other studies, and integrated to the extent possible.

- **Cross section surveys:** In the Middle River, 13 cross sections not accessible during 2013 are planned for survey in 2014. Eleven cross sections have been identified for survey in the Middle River downstream of Devils Canyon. In the Lower River, 6 cross sections have been selected for survey in 2014. These surveys will be performed by the Fish and Aquatics Instream Flow Study (ISR Study 8.5).
- **Bathymetric surveys within Focus Areas:** Depending on the cost of the other survey efforts, one or all three of the remaining Focus Areas will be surveyed for bathymetry and topography. Work not performed in 2014 will be performed in 2015. These surveys will be performed by the Fish and Aquatics Instream Flow Study (ISR Study 8.5).
- **Water-surface elevation (WSE) measurements:** Additional WSE measurements will be performed in the Middle River and Lower River, respectively, to flows measured at Gold Creek in excess of about 27,000 cfs and at Sunshine in excess of about 70,000 cfs. These measurements will be performed by the Fish and Aquatics Instream Flow Study (ISR Study 8.5).
- **Substrate mapping:** Bed-material mapping may be performed by the Fish and Aquatics IFS (Study 8.5) in 2014 for one or all of the three Focus Areas upstream of PRM 146.6 if adequate funds are available. Work not performed in 2014 will be performed in 2015. This mapping will be performed by the Fish and Aquatics Instream Flow Study (ISR Study 8.5).
- **Acoustic Doppler Current Profiler (ADCP) measurements:** ADCP measurements may be performed by the Fish and Aquatics IFS (Study 8.5) in 2014 for one or all of the three Focus Areas upstream of PRM 146.6 if adequate funds are available. Work not performed in 2014 will be performed in 2015. These measurements will be performed by the Fish and Aquatics Instream Flow Study (ISR Study 8.5).
- **Sediment transport measurements:** The USGS will continue to collect another year of sediment transport measurements in 2014 (See ISR Study 6.5 Section 7.2).

- **Characterization of groundwater inflows in the lateral habitats within Focus Areas:** These measurements will be performed by the Groundwater Study (ISR Study 7.5).

7.2.1.1.9.5 LiDAR Verification and Acquisition (Study 6.6 ISR Section 4.1.2.9.5)

LiDAR will be collected in the Middle River from approximately PRM 107 to PRM 187.1. This will provide for complete high density LiDAR coverage for the entire floodplain of the Middle River. No additional LiDAR will be collected in the Lower River. Ground points will be collected for verification of the 2014 Middle River LiDAR by the Fish and Aquatics IFS (Study 8.5) survey team.

7.2.1.2 Study Component: Model Existing and with-Project Conditions (RSP Section 6.6.4.2)

7.2.1.2.1 Existing Conditions – Base Case Modeling (RSP Section 6.6.4.2.2.1)

In 2014, existing conditions runs will be directed toward a continuation of the POC and supporting the decision on whether to extend the downstream 1-D model study limit below PRM 29.9. For the existing conditions the following efforts will occur:

- Initial Bed Evolution Model run from PRM 187.1 to PRM 29.9 for the selected 50 year open-water hydrology
- Initial 2-D hydraulic model runs at FA-104 (Whiskers Slough), FA-113 (Oxbow 1) and FA-115 (Slough 6A)
- Initial 2-D Bed Evolution Model runs at FA-128 (Slough 8A) for the representative wet year at year 0
- The results will be reported in a technical memorandum that will be presented at the Technical Team meeting in 2014. The 1-D results will be used to support the decision on whether to continue the 1-D Bed Evolution Model below PRM 29.9. The initial model runs will not include the cross section data or the LiDAR data collected in 2014.

7.2.1.2.2 Future Conditions – With-Project Scenarios

Parallel efforts to those performed for the existing-condition, including documentation, will be conducted for the with-Project condition. In addition, the following efforts will be conducted to demonstrate the process to adjust the geometry in the 1-D and 2-D Bed Evolution Models:

- Perform a demonstration 50-year 1-D Bed Evolution Model run with potential width adjustment at two selected intermediate points in the 50 year period
- Perform a demonstration run of the 2-D Bed Evolution Model at FA-128 (Slough 8A) for the representative wet year at year 0, year 25 and year 50 accounting for channel adjustment at years 25 and 50 if necessary

7.2.1.2.3 Uncertainty

Sensitivity analysis of the 1-D and 2-D models will be initiated in 2014. The preliminary results of the 1-D sensitivity analysis will be reported in the technical memorandum identified in Sections 7.2.1.2.1 and 7.2.1.2.2 above.

7.2.1.2.4 Synthesis of Reach-Scale and Local –Scale Analyses

This task will be initiated in 2014 with the demonstration run of the with-Project scenario. This effort will require transferring the information from the 1-D model on sediment inflow, downstream water surface elevations as boundary conditions for the 2-D Bed Evolutions Model. In addition, the two models will be further linked through the incorporation of channel geometry and bed material adjustment from the 1-D modeling effort to the 2-D modeling effort. If adjusts are not indicated as necessary from the 1-D model, artificial adjustments may be made to demonstrate the procedures that could be used.

7.2.1.3 Study Component: Coordination and Interpretation of Model Results (RSP Section 6.6.4.3)

For this Study Component, the following tasks will be performed in 2014 and are consistent with the Study Plan as described in ISR Study 6.6 Section 4.3.2.

7.2.1.3.1 Integration of Geomorphology and Fluvial Geomorphology Modeling below Watana Dam Study (RSP Section 6.6.4.3.2.1)

The integration of the Fluvial Geomorphology with Modeling below Watana Dam Study Geomorphology Study (Study 6.5) the will continue throughout 2014.

- Results of the initial pre-Project 1-D model run in the Middle River will be reviewed and interpreted in terms of the geomorphic response. This will include further refinement as necessary of the conceptual models describing the system.
- Results from the initial 1-D Bed Evolution Model run of post-Project OS-1 scenario will be reviewed and interpreted in terms of the geomorphic response.

7.2.1.3.2 Coordination of Results with other Resource Studies (RSP Section 6.6.4.3.2.2)

Coordination and feedback between the Geomorphology (Study 6.5), Fluvial Geomorphology Modeling below Watana Dam (Study 6.6), Groundwater (Study 7.5), Ice Processes in the Susitna River (Study 7.6), Fish and Aquatics IFS (Study 8.5), Riparian IFS (Study 8.6), Water Quality Modeling (Study 5.6), and Characterization and Mapping of Aquatic Habitats (Study 9.9) studies will be on-going through 2014.

As presented in Section 5.3, coordination with other studies was ongoing in 2013 and early 2014, and will continue through the remainder of the Study. Interpretation of model results was demonstrated in the Proof of Concept presented in 2014. The products of this component of the modeling study will include summarized results from the 1-D and 2-D Bed Evolution modeling in an appropriate format. This will include the values of variables that are taken directly from the models (ISR Study 6.6 Table 4.3-1) and variables or indicators that are computed from a combination of the direct model output and other available information using appropriate relationships outside the direct context of the model (ISR Study 6.6 Table 4.3-2). Additional information on the transfer of model output between studies was developed as part of the POC and presented in Tetra Tech (2014).

7.2.2 2015 Activities

The following activities will be performed in 2015. In addition, any planned 2014 activities that are delayed or only partially completed in 2014 due to field conditions, access, or funding will be completed in 2015.

7.2.2.1 Study Component: Bed Evolution Model Development, Coordination, and Calibration (RSP Section 6.6.4.1)

Of the nine tasks included in this study component, two were completed by Q1 2014, Model Resolution and Mesh Size Considerations (Section 7.2.1.1.3) and Focus Area Selection (Section 7.2.1.1.4. The other seven tasks in this study component will continue into 2015. This work will be conducted per the Study Plan and the modification identified in Section 7.1.2.1.

7.2.2.1.1 Development of Bed Evolution Model Approach and Model Selection (RSP Section 6.6.4.1.2.1)

The model selection portion of this task was completed in 2014 (Tetra Tech 2014). The development of the modeling approach portion of this task is planned to be completed per the Study Plan in 2014 with the exception of minor refinements that may occur as the result of information derived in this study and interaction with the other studies being the only work conducted in 2015.

7.2.2.1.2 Coordination with other Studies (RSP Section 6.6.4.1.2.2)

Coordination with other studies is essential to achieving the objectives of the Study Plan and will continue throughout 2015. Major coordination efforts in 2015 include:

- Continued planning for the 2015 field season
- Complete the incorporation of groundwater inflows into the 2-D hydraulic (habitat) model
- Complete coordination with Ice Processes (Study 7.6) on incorporating ice processes influences into the analysis effort, particularly the building of floodplain surfaces
- Complete coordination with the Riparian IFS (Study 8.6) on the dating of surfaces and sediment accretion rates

7.2.2.1.3 Model Resolution and Mesh Size Considerations (RSP Section 6.6.4.1.3)

The resolution for the 2-D model mesh was set through the POC process (Tetra Tech 2014) and no further work on this task is planned for 2015.

7.2.2.1.4 Focus Area Selection (RSP Section 6.6.4.1.2.4)

Focus Area selection was completed in 2013 and no further work will be performed on this task in 2014.

7.2.2.1.5 Model Calibration and Validation (RSP Section 6.6.4.1.2.5)

This task is divided in 1-D and 2-D efforts. Specific task to be completed in 2015 include:

- 1-D Bed Evolution Model: Data collection for the 1-D model is a priority and planned to be completed in 2014. The tasks below reflect that a substantial amount of effort will have been conducted in 2014 toward development of the 1-D Bed Evolution Model. Tasks remaining for 2015 are:
  - Complete the incorporation of data collected in 2014 into the model (primary data will be bed material samples, cross section surveys, and 2014 floodplain LiDAR in the Middle River)
  - Finalize tributary water and sediment inflow to the Middle and Lower Susitna River Segments
  - Finalize the calibration and validation of the model from PRM 187.1 to PRM 29.9.
  - If necessary, extend the model below PRM 29.9
- 2-D Bed Evolution Model: It is possible that some data may remain to be collected in the Focus Areas in 2015. Therefore, the completion of model calibration and validation will be completed first for the Focus Areas in which data were collected in 2013 and 2014. Specific tasks to be performed in 2015 include:
  - Complete model calibration and validation for the remaining 3 FAs with available 2013 data: FA-138 (Gold Creek), FA-141 (Indian River) and FA-144 (Slough 21
  - Initiate and complete model development, calibration and validation for the remaining three Focus Areas with data collection in 2014 and possibly 2015 (FA-151 (Portage Creek), FA-173 (Stephan Lake Complex) and FA-184 (Watana Dam))
  - In conjunction with Groundwater (Study 7.5) and Fish and Aquatics IFS (Study 8.5) complete the determination of the locations and estimated rates of groundwater inflow for all 10 Focus Areas
  - Complete development, calibration and validation of the Bed Evolution Model for all seven Focus Areas with data collected in 2013 and any of the three remaining Focus Areas for which data were collected in 2014

7.2.2.1.6 Tributary Delta Modeling (RSP Section 6.6.4.1.2.6)

It is planned that all data for this study component will be collected in 2014 and the development of all tributary models in the Middle and Lower Susitna River Segments will continue into 2015. Specific 2015 efforts include:

- Complete development of sediment rating curves for the 10 Middle River tributaries planned for survey in 2014

- Complete development of sediment rating curves for the 3 Lower River tributaries planned for survey in 2014
- Perform assessment of delta development for all 1-D tributaries in the Middle River and Lower Susitna River Segments

7.2.2.1.7 Large Woody Debris Modeling (RSP Section 6.6.4.1.2.7)

Efforts in 2015 in this task will include:

- In coordination with the Geomorphology Study (Study 6.5) preform the application of the bank energy index (BEI) to all Focus Areas along with the turnover analysis estimate Project effects on LWD recruitment from bank erosion
- Complete the analysis of changes in hydraulics associated with potential changes in LWD present in the Focus Areas due to Project operations.

7.2.2.1.8 Wintertime Modeling and Load-Following Operations (RSP Section 6.6.4.1.2.8)

If analysis performed in 2014 indicates appreciable bed load can be mobilized during the ice-covered period, excluding the break-up period, the Fluvial Geomorphology Modeling (Study 6.6) and Ice Processes (Study 7.7) studies will quantify changes in bed mobility during the ice-covered period resulting from Project operations.

7.2.2.1.9 Field Data Collection Efforts (RSP Section 6.6.4.1.2.9)

It is the goals of the 2014 field studies to complete all field data collection efforts in this Study in 2014, it is possible that all field data, including field data from other studies (See ISR Study 6.6 Section 4.1.2.9.4) will be collected in 2014. Some data may remain to be collected in 2015. The highest data collection priorities are directed toward the completion of the 1-D models so the 1-D models can be run to help inform decisions on which 2-D modeling efforts will be conducted in each Focus Area for each scenario (See ISR Part C Section 7.1.1.2.2). Any data collection efforts identified in Section 7.2.1.1.9 not collected in 2014 will be completed in 2015.

7.2.2.2 Study Component: Model Existing and with-Project Conditions (RSP Section 6.6.4.2)

7.2.2.2.1 Existing Conditions – Base Case Modeling (RSP Section 6.6.4.2.2.1)

Existing-conditions model runs in 2015 will result in the finalization of the existing-conditions (pre-Project) runs for both the 1-D Bed Evolution Model. The 2-D existing-conditions Bed Evolution and Hydraulic (habitat) model runs will be finalized for the 7 Focus Areas in which data were collected in 2013. The runs for any of the three remaining Focus Areas will be completed in 2015 if data collection at the particular Focus Area was essentially completed in 2014.

7.2.2.2.2 Future Conditions – With-Project Scenarios (RSP Section 6.6.4.2.2.2)

Future condition (post-Project) model runs for the 2015 effort will be directed toward completion of the maximum load following scenario for inclusion of Project effects in the USR. The 2-D results will only be available for the seven Focus Areas in which data were collected in 2013 and any of the remaining three Focus Areas in which data were collected in 2014. In addition, the 1-D Bed Evolution Model runs and the associated analysis of results for the maximum load-following, intermediate load-following, base-load and run-of-river scenarios will be completed in 2015.

7.2.2.2.3 Uncertainty (RSP Section 6.6.4.2.2.3)

Sensitivity analysis of the 1-D and 2-D models along with the remainder of the assessment of uncertainty will be completed in 2015 per the Study Plan.

7.2.2.2.4 Synthesis of Reach-Scale and Local –Scale Analyses (RSP Section 6.6.4.2.2.4)

This study component will be performed in 2015 for all model runs that were completed in 2015.

7.2.2.3 Study Component: Coordination and Interpretation of Model Results (RSP Section 6.6.4.3)

This study component will be performed in 2015 for all model runs that are completed in 2015.

7.3 Conclusions

Significant progress has been made in 2012, 2013 and Q1 of 2014 in meeting the objectives of the Fluvial Geomorphology Modeling Study. Major progress has achieved in collecting the data required to parameterize the models, developing the approach for applying and integrating the models within the Fluvial Geomorphology Modeling Study and with the other aquatic resource studies, and in developing the models.

The data collected by the Fluvial Geomorphology Modeling (Study 6.6), Fish and Aquatics IFS (Study 8.5), Riparian IFS (Study 8.6) Groundwater (Study 7.5) and Ice Processes (Study 7.6) are described in ISR Study 6.6 Section 5.1.9, summaries of data presented in Appendices A through D (Part A of ISR Study 6.6) and the link to the electronic data files in Section 5.1.10. Most recently, in early April 2014, the Fluvial Geomorphology Study completed the collection of bed material samples in the Upper, Middle and Lower Susitna River Segments in the deepest portions of the river channel by angering through the ice and lowering video cameras using the procedures developed in 2013 (Field Report – Included as Attachment A to Part A of the Study 6.6 ISR). This was a major achievement as the characterization of the bed material in the deepest portions of the channel is important for accurately modeling the system; however, this data could not be collected during open-water conditions because of high turbidity making visual sampling impossible and the size of the material making physical sampling impractical.

The modeling approach has been presented in three technical memoranda (Tetra Tech 2012, Tetra Tech 2013a and Tetra Tech 2014); each providing more detail on the approach. The most recent provided results of model calibration and validation along with the integration with the aquatic habitat modeling performed in the Fish and Aquatics IFS (Study 8.5). The most current examples of the progress made in the development and application of the analysis in the Fluvial Geomorphology Modeling Study and the other aquatic resource studies was the Proof of Concept (POC) effort conducted April 15 – 17, 2014 and the Riparian IFS Technical Team meeting held

April 29 and 30, 2014. Each of these activities demonstrated the progress being made by the various aquatic resource studies involved and in integration of the studies to develop a comprehensive assessment of potential Project effects. The POC demonstrated the application of the models specific to two key biological metrics (effective salmon spawning/incubation habitat, and juvenile salmonid rearing habitat) at one Middle River Segment Focus Area (FA), FA-128 (Slough 8A) (ISR Study 8.5 Appendix N). At the Riparian IFS Technical Team Meeting, the Fluvial Geomorphology Modeling Study and the Geomorphology Study (Study 6.5) demonstrated how the analytical tools being developed support the analysis of Project effects on the geomorphic processes governing the formation and evolution of floodplain surfaces.

In summary, the extensive efforts conducted in the Fluvial Geomorphology Modeling Study have resulted in significant progress in the collection of data, refinement of the modeling approach, and development and integration of the analysis tools necessary to accomplish the objectives of the Study Plan. Given the combination of 2012, 2013 and early 2014 efforts summarized above, variances (see ISR Study 6.6 Section 4), and the plans for 2014 and 2015 with proposed modifications (see ISR Study 6.6 Section 7.1.2), AEA expect to achieve the approved objectives (ISR Study 6.6 Section 2) for the Fluvial Geomorphology Modeling Study.

7.4 Literature Cited

Andrews E.D. 1980. Effective and bankfull discharges of streams in the Yampa River basin, Colorado and Wyoming. Journal of Hydrology 46: 311–330.

Andrews, E.D. 1984. Bed-material entrainment and hydraulic geometry of gravel-bed rivers in Colorado. Bull. Geol. Soc. Am. 95: 371–378.

Emmett, W.W. 1972. The Hydraulic geometry of some Alaska streams south the Yukon River. U.S. Geological Survey Open-file Report 72-0108: 110 p.

GW Scientific. 2014. Groundwater Modeling and Analysis. PowerPoint Presentation, Riverine Modeling Proof of Concept Meetings on April 15-17, 2014. Prepared for Alaska Energy Authority, Anchorage, Alaska. Susitna-Watana Hydroelectric Project, FERC No. P-14241. http://www.susitna-watanahydro.org/meetings/past-meetings/

Hey, R D., and C.R. Thorne. 1986. Stable channels with mobile gravel beds. J. Hydraul. Eng. 112.8: 671–689.

Julien, P.Y., and J. Wargadalam. 1995. Alluvial channel geometry: Theory and applications. J. Hydraul. Eng. 121.4: 312–325.

Kwan, S. 2009.A Two Dimensional Hydrodynamic River Morphology and Gravel Transport Model. University of British Columbia, Vancouver, CA, 113 p.

Lai, Y.G., 2008. SRH-2D version 2: Theory and User's Manual, Sedimentation and River Hydraulics – Two-Dimensional River Flow Modeling, U.S. Department of Interior, Bureau of Reclamation, November, 113 p.

Langbein, W.B. 1964. Geometry of River Channels. J. Hydraulics Div. ASCE 90, HY2, 301-312.

Leopold, L.B., and T. Maddock. 1953. The hydraulic geometry of stream channels and some physiographic implications. U.S. Geological Survey Professional Paper 252; 57 p.

Leopold, L.B. and Wolman, M.G., 1957. River channel patterns: Braided meandering and straight. U.S. Geological Survey Professional Paper 282-B, 47 p.

Mobile Boundary Hydraulics, 2010. Sedimentation in Stream Networks (HEC-6T) User Manual. 388 p.

Parker, G., 1979. Hydraulic geometry of active gravel rivers. Journal of the Hydraulics Division. v. 105. no. HY9: 1185-1201.

R2 Resource Consultants, Inc. (R2) 2013a. Selection of Focus Areas and Study Sites in the Middle and Lower Susitna River for Instream Flow and Joint Resource Studies—2013 and 2014. Technical Memorandum for Alaska Energy Authority Susitna-Watana Hydroelectric Project. FERC No. 14241.

R2 2013b. Technical Memorandum: Adjustments to the Middle River Focus Areas. Susitna-Watana Hydroelectric Project Prepared for the Alaska Energy Authority. Anchorage, Alaska.

Steffler, P. and Blackburn, J. 2002. Two-Dimensional Depth Averaged Model for River Hydrodynamics and Fish Habitat – Introduction to Depth Averaged Modeling and User's Manual, University of Alberta, CA, 120 p.

Tetra Tech Inc. 2012. Fluvial Geomorphology Modeling. Technical Memorandum for Alaska Energy Authority Susitna-Watana Hydroelectric Project, FERC No. 14241.

Tetra Tech. 2013a. Fluvial Geomorphology Modeling Approach. Technical Memorandum. June 30, 2013. Susitna-Watana Hydroelectric Project. Prepared for the Alaska Energy Authority. Anchorage, Alaska.

Tetra Tech. 2013b. *Development of Sediment Transport Relationships and an Initial Sediment Balance for the Middle and Lower Susitna River Segments.* Susitna-Watana Hydroelectric Project. 2012 Study Technical Memorandum. Prepared for the Alaska Energy Authority. Anchorage, Alaska.

Tetra Tech. 2013c. *Initial Geomorphic Reach Delineation and Characterization, Middle and Lower Susitna River Segments.* Susitna-Watana Hydroelectric Project. 2012 Study Technical Memorandum. Prepared for the Alaska Energy Authority. Anchorage, Alaska.

Tetra Tech. 2013d. *Reconnaissance Level Assessment of Potential Channel Change in the Lower Susitna River Segment.* Susitna-Watana Hydroelectric Project. 2012 Study Technical Memorandum. Prepared for the Alaska Energy Authority. Anchorage, Alaska.

Tetra Tech. 2013e. *Stream Flow Assessment.* Susitna-Watana Hydroelectric Project. 2012 Study Technical Memorandum. Prepared for the Alaska Energy Authority. Anchorage, Alaska.

Tetra Tech. 2013f. *Synthesis of 1980s Aquatic Habitat Information.* Susitna-Watana Hydroelectric Project. 2012 Study Technical Memorandum. Prepared for the Alaska Energy Authority. Anchorage, Alaska.

Tetra Tech. 2013g. *Mapping of Aquatic Macrohabitat Types at Selected Sites in the Middle and Lower Susitna River Segments from 1980s and 2012 Aerials.* Susitna-Watana Hydroelectric Project. 2012 Study Technical Memorandum. Prepared for the Alaska Energy Authority. Anchorage, Alaska.

Tetra Tech. 2013h. *Mapping of Geomorphic Features and Assessment of Channel Change in the Middle and Lower Susitna River Segments from 1980s and 2012 Aerials.* Susitna-Watana Hydroelectric Project. 2012 Study Technical Memorandum. Prepared for the Alaska Energy Authority. Anchorage, Alaska.

Tetra Tech. 2014. *Updated Fluvial Geomorphology Modeling Approach. Technical Memorandum*. May 2014. Prepared for the Alaska Energy Authority. Anchorage, Alaska.

Tetra Tech, R2, and HDR. 2014. Representative Year Selection. PowerPoint Presentation, Riverine Modeling Proof of Concept Meetings on April 15-17, 2014. Prepared for Alaska Energy Authority, Anchorage, Alaska. Susitna-Watana Hydroelectric Project, FERC No. P-14241. http://www.susitna-watanahydro.org/meetings/past-meetings/

USACE, 2010. HEC-RAS, River Analysis System, User's Manual, Version 4.1.0, Hydrologic Engineering Center, Davis, California.

U.S. Geological Survey. 2012. Streamflow Record Extension for Selected Streams in the Susitna River Basin. Alaska. Scientific Investigations Report: 2012–5210.

Williams GP. 1978. Bankfull discharge of rivers. Water Resources Research 14: 1141–1154.

Wolman, M.G., and L.B. Leopold. 1957. River flood plains: some observations on their formation. U.S. Geological Survey Professional Paper 282-C. Washington, D.C: 86–109.

Wolman, M.G., and J.P. Miller. 1960. Magnitude and frequency of forces in geomorphic processes. Journal of Geology 68: 54–74.

Wolman, M.G., and R. Gerson. 1978. Relative scales of time and effectiveness of climate in watershed geomorphology. Earth Surface Processes 3: 189-208.

7.5 Tables

Table 7.1-1 Tributaries Selected for Modeling.

				Lake Presence[2]		2012/2013 Fish Distribution (Study 9.6)					
Tributary Name	PRM[1]	D.A. (mi^2)	Focus Area	Trib. RM[3]	Area[4] (ac)	No. of Resident Species	No. of Salmon Species	Selected by Study 9.12	Evidence of an Active Fan	Year Selected	Delta Modeling
Tsusena Creek	184.6	145.4	184			4	1	Yes	Yes	2013	Yes
Fog Creek	179.3	149.7				4	1	Yes	Yes	2013	Yes
Un. Tributary	174.3	4.4	173	1.0 & 1.8	62.3 & 265				No	2013	No
Un. Tributary	173.8	8.6	173			4			Yes	2013	Yes[5]
Chinook Creek	160.5	24.0				2	1	Yes	Yes	2014	Yes
Portage Creek	152.3	179.1	151			2	5		Yes	2013	Yes[5]
Un. Tributary	144.6	5.0	144						Yes	2013	Yes[5]
Indian River	142.1	81.9	141			9	5		Yes	2013	Yes[5]
Gold Creek	140.1	24.6				1	3	Yes	Yes	2013	Yes
Fourth of July Creek	134.3	23.4				2	5	Yes	Yes	2014	Yes
Sherman Creek	134.1	7.1					1	Yes	Yes	2014	Yes
Skull Creek	128.1	4.3	128			4	4		Yes	2013	Yes[5]
Fifth of July Creek	127.3	7.1				3	4	Yes	Yes	2014	Yes
Deadhorse Creek	124.4	4.7						Yes	Yes	2014	Yes
Lane Creek	117.2	11.4				1	4	Yes	Yes	2013	Yes
Gash Creek	115.0	1.9	113	0.6	19.6	6	1		No	2013	No
Slash Creek	114.9	1.8	113						No	2013	No
Un. Tributary	113.7	2.0	113			4	1		Yes	2013	Yes[5]
Whiskers Creek	105.1	18.2	104			9	5		No	2013	No

Notes: Unnamed Tributary 115.4 was excluded from modeling based on July 2013 observations of the absence of a depositional fan at the tributary mouth, the absence of surface flow at the mouth, and the presence of a wetland between the mouth and the Susitna River.

[1] PRM = Project River Mile

[2] Large lakes near the tributary mouth trap sediment and reduce the potential for formation of a delta at the tributary mouth.

[3] Trib RM = tributary river mile, with RM 0.0 at confluence with Susitna River, corresponding to location of a lake.

[4] Area = surface area of the lake.

[5] Even though the tributary is not selected for evaluation of fish passage barriers (Study 9.12), the tributary delta will be modeled as part of the 2-D bed evolution models of the focus area