6. GEOMORPHOLOGY

6.1. Introduction

Construction and operation of the Susitna-Watana Hydroelectric Project (Project) have the potential to alter river flow, sediment transport and delivery, and large woody debris input and transport in the Susitna River. Changes to these processes may affect channel morphology and aquatic habitat downstream of the Watana Dam site. Operation of the reservoir also has the potential to change the morphology and dynamics of streams and hillsides around the reservoir, as deltas form at the stream/reservoir interface and the sides of the reservoir are exposed to erosion and beach formation. An understanding of existing (i.e., baseline) geomorphic conditions is needed for predicting the likely extent and nature of potential changes to river, hillside, and delta geomorphology that would occur due to Project operations. Specific conditions that must be understood include how hydraulic conditions, bed mobility, bank erosion, and aquatic habitat change over the range of river flows, and the relative stability of the river with respect to lateral erosion, aggradation/degradation, and island and bar formation over recent decades.

This study plan describes the Susitna-Watana Geomorphology Study that will be conducted to characterize and evaluate baseline conditions and potential Project effects. This plan will be subject to revision and refinements as part of the licensing participant review and comment process identified in the Integrated Licensing Process (ILP). In particular, at this stage in its development, the Geomorphology Study has not identified specific focus areas; however, candidate focus areas have been identified. Selection of the focus areas involves close coordination among several studies including the Instream Flow Fish, Instream Flow Riparian, Ice Processes, Groundwater, and Fish studies, and consultation with licensing participants, as part of the continuing study planning process and during study implementation.

The geomorphology effort consists of two studies. The Geomorphology Study (Section 6.5) will investigate historical and current conditions of the Susitna River using available information and additional information collected as part of the licensing effort. This study will identify historical behavior of the Susitna River and key physical processes governing its behavior, and provide initial identification of potential Project effects. The Fluvial Geomorphology Modeling Study (Section 6.6) will apply 1D and 2D bed evolution models to further quantify potential Project effects. An extensive data collection effort will be conducted as part of the Fluvial Geomorphology Modeling study. The understanding of the system and its governing physical processes gained in the Geomorphology Study will be integrated with the results of the Fluvial Geomorphology Modeling study in quantifying potential Project effects. Studies in other resource areas, such as the Instream Flow studies, will consider these changes in quantifying Project effects for their resource areas. A key aspect of the integration between the various physical and biological studies will be the common use of the focus areas to jointly carry out integrated resource analysis.

The geomorphology studies will be subject to revision and refinements in consultation with licensing participants as part of the continuing study program identified in the ILP. The impact assessments will inform development of any necessary protection, mitigation, and enhancement measures to be presented in the draft and final License Applications.

6.2. Nexus Between Project Construction / Existence / Operations and Effects on Resources to be Studied

Construction and operation of the Project have the potential to alter river flow, sediment transport and delivery, and large woody debris (LWD) input and transport in the Susitna River. Changes to these processes may affect channel morphology and aquatic habitat downstream of the Watana Dam site. Operation of the reservoir also has the potential to change the geomorphology of streams and hillsides around the reservoir as deltas form at the stream/reservoir interface and the sides of the reservoir are exposed to erosion and beach formation. Understanding existing, baseline geomorphic conditions, how geomorphic conditions and aquatic habitat change over a range of stream flows, and how stable/unstable the geomorphic conditions have been over recent decades provides baseline information needed for predicting the likely extent and nature of potential changes to the fluvial geomorphology that would occur due to Project operations.

Changes in the channel morphology may alter the presence, physical characteristics, and function of important riverine aquatic habitat types such as side channels and sloughs. Reduction in sediment supply has the potential to cause channel downcutting and coarsening of bed material. In contrast, reduction in peak flow magnitude and changes in timing can result in sediment deposition (also at tributary mouths). The regulated hydrology may affect access to aquatic habitats as well as sediment transport rates and timing that ultimately govern formation and maintenance of dynamic aquatic habitats. Analysis of the complex interaction of water and sediment with the channel and floodplain boundaries to evaluate potential Project effects requires development and application of a sediment transport model.

It was indicated in the AEA Susitna Water Quality and Sediment Transport Data Gap Analysis Report (URS 2011) that further quantification of the sediment supply and transport capacity would help identify the sensitivity of the channel morphology (and associated aquatic habitats) to the effects of the proposed Project. The report indicated that information on sediment continuity could provide a basis for evaluating whether the Susitna River below the Chulitna confluence would be at risk of aggradation, and if so, whether the magnitude would alter aquatic habitats and hydraulic connectivity to these habitats. It also pointed out that side channels and sloughs are of particular importance to fisheries, and changes to the relationships between flow and stage at which the habitats are accessible could affect the fisheries. These relationships can be affected by not only distribution of flows, but also changes in the bed elevations due to sediment transport processes. Other impacts to the sediment transport regime could affect the cleaning of spawning gravels, hyporheic flows through redds, groundwater inflows, and hydraulic connectivity for out-migration to the main channel.

6.3. Resource Management Goals and Objectives

Several natural resources agencies have jurisdiction over aquatic species and their habitats in the Project area. These agencies will be using in part, the results of the Geomorphology studies, Instream Flow studies, and other fish and aquatic studies to satisfy their respective mandates. The following federal and state agencies and Alaska Native entities have identified their resource management goals, or provided comments in the context of FERC licensing, related to geomorphology, instream flow, and riparian resource issues.

6.3.1. National Marine Fisheries Service

The following text is an excerpt of the May 31, 2012, National Marine Fisheries Service (NMFS) letter and Geomorphology Study Request:

> *"NMFS is entrusted with federal jurisdiction over marine, estuarine, and anadromous fishery resources under the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C.§ 1801 et seq, the Anadromous Fish Conservation Act (16 U.S.C. 757a-757g; Pub. L. 89-304, as amended), and the Pacific Salmon Treaty Act (16.U.S.C. §3631, et seq.). Section 305(b) of the MSA requires federal agencies to consult with NMFS on all actions that adversely affect Essential Fish Habitat (EFH). Where, in the judgment of NMFS, the proposed action would adversely affect EFH, NMFS is required to make EFH Conservation Recommendations, Section 10(j) of the Federal Power Act (FPA) authorized NMFS to recommend license terms and conditions necessary to protect, mitigate damage to, and enhance fish and wildlife habitat affected by the project. Section 18 of the FPA provides NMFS authority to issue mandatory fishway prescriptions. In addition, NMFS has the responsibilities related to FERC proceedings derived from the Fish and Wildlife Coordination Act, Endangered Species Act, and the Marine Mammal Protection Act.*
>
> *NMFS resource management objectives derived from these authorities include:*
>
> - *Maintaining native and natural aquatic communities for their intrinsic and ecological value ant their benefits to people. This includes habitat protection and maintenance to ensure the health and survival of all species and natural communities.*
> - *Maintaining stream flow regimes sufficient to sustain native riparian and aquatic habitats in the project-affected stream reaches.*
> - *Maintaining the diversified use of ish and wildlife including commercial, recreational, scientific and educational purposes.*
> - *Protecting, conserving and enhancing native fishes and their habitats by maintaining their access to suitable and fully functioning habitats.*
> - *Identifying and implementing measures to protect, mitigate, or minimize direct, indirect and cumulative impacts to native anadromous fish resources, including related spawning, rearing and migration habitats and adjoining riparian habitats.*
> - *Maintaining riparian resources, channel conditions, and aquatic habitats.*

- *Maintaining stream flow regimes sufficient to sustain desired conditions of native riparian, aquatic, and wetland habitats.*
- *Protecting aquatic systems to which species are uniquely adapted."*

6.3.2. U.S. Fish and Wildlife Service

The following text is an excerpt of the May 31, 2012, U.S. Fish and Wildlife Service (USFWS) Geomorphology Study Request:

> *"The overarching resource management goal of the USFWS is described in our mission:*
>
> > *to conserve, protect, and enhance fish, wildlife, plants, and their habitats for the continuing benefit of the American people.*
>
> *The U.S. Fish and Wildlife Service (USFWS), is providing comments in accordance with provisions of the National Environmental Policy Act (NEPA) of 1969 (83 Stat. 852; 42 U.S.C. 4321 et seq.), Endangered Species Act (ESA) of 1973 (87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.), Bald and Golden Eagle Protection Act (BGEPA) (54 Stat. 250, as amended, 16 U.S.C. 668a-d), Migratory Bird Treaty Act (MBTA) (40 Stat. 755, as amended; 16 U.S.C. 703 et seq.), Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.), and Federal Power Act (16 U.S.C. § 791 et seq.). .).*
>
> *Under Section 18 of the Federal Power Act (FPA), the National Marine Fisheries Service*
>
> *(NMFS) and USFWS have authority to issue mandatory fishway prescriptions for safe, timely, and effective fish passage. Under Section 10(j) of the FPA, NMFS and USFWS are authorized to recommend license conditions necessary to adequately and equitably protect, mitigate damages to, and enhance, fish and wildlife (including related spawning grounds and habitat) affected by the development, operation, and management of hydropower projects. Section 10(a)(1) of the FPA requires the Federal Energy Regulatory Commission to condition hydropower licenses to best improve or develop a waterway or waterways for the adequate protection, mitigation, and enhancement of fish and wildlife (including related spawning grounds and habitat) based on NMFS and USFWS recommendations and plans for affected waterways. Specific management goals are the protection of anadromous, trust fish species and their habitats.*
>
> *Consistent with our mission and with the legal authorities described above, our resource goal in this matter is to conserve existing fish and wildlife resources and their habitats in the Susitna River basin. With regard to fish passage, we will recommend scientifically-based and coordinated studies, collaborate with others, and ensure development of the best information possible to inform potential development of fishway prescriptions for this project pursuant to Section 18 of the Federal Power Act."*

6.3.3. Alaska Department of Fish and Game

The following text is an excerpt of the May 30, 2012, Alaska Department of Fish and Game (ADF&G) letter and Instream Flow Study Request:

> *"The Fish and Game Act requires the Alaska Department of Fish and Game to, among other responsibilities, "…manage, protect, maintain, improve, and extend the fish, game and aquatic plant resources of the state in the interest of the economy and general well-being of the state" (AS 16.05.020)."*

6.3.4. Alaska Native Entities

6.3.4.1. Chickaloon Village Traditional Council

The Chickaloon Native Village provided comments on Project licensing activities in a May 31, 2012, letter to the FERC. Chickaloon Native Village is a federally recognized Alaska Native tribe. Chickaloon Village is an Ahtna Athabascan Indian Tribe governed by the nine-member Chickaloon Village Traditional Council. The Chickaloon Village Traditional Council strives to increase traditional Ahtna Dene' practices for the betterment of all residents in the area. Preserving and restoring the region's natural resources is one way of supporting Ahtna culture and the regional ecosystem. Concerning the potential effects of the Project on the geomorphology of the Susitna River, the Chickaloon Native Village wrote:

> *"The whole sediment transport system of the Susitna River will be changed by the proposed dam. Only the smaller sediment particles will pass downstream, as the dam will trap the larger particles. Since the substrate size for salmon redds varies by salmon species, studies must be conducted to ensure that the appropriate sediment particle sizes will be present for the salmon spawning habitats."*

6.4. Summary of Consultation with Agencies, Alaska Native Entities, and Other Licensing Participants

The geomorphology study plans have been modified in response to comments from various agency reviewers, including NMFS, the Alaska Department of Environmental Conservation (ADEC), and USFWS. Consultation on the study plan occurred during licensing participant meetings on April 6, 2012, and during the June 14, 2012 Water Resources Technical Work Group (TWG) meeting. At the June 2012 TWG meeting, study requests and comments from the various licensing participants were presented and discussed, and refinements were determined to address agreed-upon modifications to the draft study plans.

A summary of consultations relevant to the geomorphology studies is provided in Table 6.4-1.

Table 6.4-1. Summary of consultation on Geomorphology study plans.

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
General					
Memo	08/07/2012		NPS	Limiting downstream scope of this and other studies to Talkeetna is unfounded. Until results of the instream flow, ice, fluvial geomorphology, fish, and other studies are available, cannot say how far downstream project's measurable effects on visual, auditory resources will go. Vehemently disagree w/ this premature decision, which contradicts statements elsewhere in this and other PSPs acknowledging need to rely on the results of other studies.	The Fluvial Geomorphology Modeling Study area downstream limit is currently identified at RM75; however, components of the Geomorphology study extend to RM 0 or to RM 28. The initial determination of the downstream limit was based on based on a bed load sediment balance using USGS data from the 1980s. As additional information and analyses are performed, the downstream limit of the Fluvial Geomorphology Study will be extended further downstream if the studies indicate potential for the Project to affect the of the channel morphology below RM 75. Section 6.6.3.2 discusses the process, criteria and schedule for establishing the downstream limit of the Fluvial Geomorphology Modeling Study.

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
TWG Mtg.	08/17/2012	Matt Cutlip / Betsy McCracken	FERC / USFWS	D/S Limit of study – What is it, how and when will it be determined. Would it be in the ISR if not reached in RSP? Each study needs to identify the D/S extent and put a mechanism in place to modify the boundaries if needed.	The downstream limit of the Fluvial Geomorphology Modeling is proposed at RM 75, which includes the upper 23 miles of the Lower River. Portions of the Geomorphology Study will extend further. The reach delineation and evaluation of historic channel change extend to RM 0. Comparison of 1980s and current aquatic habitat extend to RM 28. The initial extent of the detailed study area was determined based on a bed load sediment balance using USGS data from the 1980s. Additional discussion of the sediment balance and the potential influence of the Project are discussed in Section 6.5. More detailed sediment balance and evaluation, within in a geomorphic framework, of potential Project along with hydraulic routing to determine downstream Project effects on stage and discharge are being performed in 2012 and early 2103 to further evaluate the downstream modeling limits. The results of the 1D sediment transport modeling to RM 75, will be evaluated to determine if the detailed study area needs to be extend further downstream. The process, criteria and schedule for determining the downstream extent of the detailed study area are presented in Section 6.6.3.2

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
TWG Mtg.	08/17/2012	Jeff Davis	ARRI	Is the Eulachon Study tied to Geomorph Study?	In the sense that the geomorphology of the Susitna River helps define the habitat for the eulachon; The Geomorphology Study is tied to the Eulachon Study. Initial evaluation of the potential for the Project to affect the geomorphology of the Lower River has indicated it is unlikely that Project effects will extend into the Lower River downstream of Sunshine (RM 84). To be conservative, the downstream limit for the Fluvial Geomorphology Modeling Study has been initially set at RM 75. If, as the studies progress, additional analysis and information suggest the Project may impact the morphology D/S of RM 75, the study limit will eb extended D/S. Section 6.6.3.2 discusses the process, criteria and schedule for establishing the downstream limit of the Fluvial Geomorphology Modeling Study.

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
Email	08/23/2012	Joseph Klein	ADF&G	For the eulachon and boating studies, similar information is needed on what is the study area.	The currently identified downstream study limit for the Fluvial Geomorphology Modeling Study is RM 75. Initial evaluation of the potential for the Project to affect the geomorphology of the Lower River has indicated it is unlikely that Project effects will extend into the Lower River downstream of Sunshine (RM 84). To be conservative, the downstream limit for the Fluvial Geomorphology Modeling Study has been initially set at RM 75. Therefore, in terms of the potential for boating to be affected by changes in the geomorphology as a result of Project operations and construction will not extend below RM 84. This would be the D/S limit of interaction of the boating Study with the Geomorphology Study. Based on the initial assessment Project effects on geomorphology would not extend downstream into the habitat for eulachon. If, as the studies progress, additional analysis and information suggest the Project may impact the morphology D/S of RM 75, the study limit will be extended D/S Section 6.6.3.2 discusses the process, criteria and schedule for establishing the downstream limit of the Fluvial Geomorphology Modeling Study.

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
Letter	09/07/2012	Betsy McCracken	USFWS	If the physical studies boundary is terminated at river mile 75, there will be no ability to relate or integrate biological data to those studies (e.g., geomorphology, ISF, ice processes, flow routing). Resource agencies management goals would effectively not be addressed below river mile 75, if project effects are not assessed to the mouth of the river.	In terms of the Fluvial Geomorphology Study, the downstream study limit was set at RM 75 because initial evaluation of available sediment transport information indicated that the Project would not affect the morphology fo the Susitna River downstream of Sunshine Station (RM 85). If the Project does not affect the morphology below RM 75, there will be no impact on the resource agencies goals from this aspect of the physical environment. If, as the studies progress, additional analysis and information suggest the Project may impact the morphology D/S of RM 75, the study limit will eb extended D/S. Section 6.6.3.2 discusses the process, criteria and schedule for establishing the downstream limit of the Fluvial Geomorphology Modeling Study.
Email	09/07/2012	Betsy McCracken, Fishery Biologist	USFWS	Instream Flow, Habitat Utilization, Geomorphology PSPs do not fully address USFWS' resource mgmt. concerns. During 3 days of ILP study meetings, sequencing and integration of proposed biological resource studies and physical processes was not described; significant outstanding info needed.	To address USFWS resource management concerns, AEA has expanded the discussion and figures in Section 6.5.6 and 6.6.6 to show the integration and interdependency of the Geomorphology Study and Fluvial Geomorphology Modeling studies with biological resource and other physical process studies.
Email	09/07/2012	Betsy McCracken, Fishery Biologist	USFWS	Necessary to describe the integration of inter-related studies, how that integration will result in a comparison of baseline biological info, resulting effects to biological resources caused by project operations.	AEA has revised Section 6.5.6 and 6.6.6 to provide more detail on how the integration of inter-related studies will address baseline biological information and allow for an assessment of potential project effects.

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
Email	09/07/2012	Betsy McCracken, Fishery Biologist	USFWS	Do not believe current Instream Flow, Habitat Utilization, Geomorphology PSPs will yield sufficient info to allow USFWS to adequately assess proposed SuWa Project impacts to US fish, wildlife resources, and to develop adequate PMEs.	The Geomorphology Studies are integrated with the Instream Flow and Habitat Utilization studies as well as numerous other studies. The Geomorphology Study has been specifically designed to provide the Instream Flow studies with information on potential Project effects to the Geomorphology of the Susitna River that would result in changes to the physical habitat. Section 6.6.4.1.2.1 provides examples of the issues that the Fluvial Geomorphology Modeling Study was designed to address.
E-mail	09/07/2012	Betsy McCracken	USFWS, Anchorage Field Office	USFWS has repeatedly articulated concerns about lack of study sequencing, connectivity, integration between biological studies, other proposed engineering and physical processes studies. Need for collection of adequate temporal and spatial baseline biological, fish habitat data to provide direct input to some of proposed physical modeling efforts. Many USFWS concerns are related to temporal mismatch of biological data collection w/ forward momentum of physical modeling efforts.	To address USFWS resource management concerns, AEA has expanded the discussion and figures in Section 6.5.6 and 6.6.6 to show the integration and interdependency of the Geomorphology Study and Fluvial Geomorphology Modeling Studies with biological resource, other physical process studies and the engineering studies (Operations Modeling and Soils & Geology).

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
E-mail	09/07/2012	Betsy McCracken	USFWS, Anchorage Field Office	Study results must be quantifiable to: assess potential losses to aquatic resources, habitats; review SuWa Project under relevant fish, wildlife resource conservation authorities; inform fishway prescription authority (Sec. 18 FPA); eventually develop recommended protection, mitigation, enhancement.	The Study Plans for the Geomorphology Study (Section 6.5) and Fluvial Geomorphology Study (Section 6.6) have been developed to provide the biological resources and other physical process studies with evaluation of potential changes in the geomorphology of the Susitna River that can be used to support determination of habitat indices under with Project conditions. For instance, the 1D and 2D bed evolution models will identify if the substrate size changes below the dam or if downcutting results in less connectivity to lateral habitats. The 2D modeling at focus areas can identify the potential change in the rate of sedimentation and floodplain building which will provide information for the IFS Riparian study to quantify potential changes to riparian plant communities. of potential changes in channel and floodplain morphology to support their assessments of potential habitat losses.
Geomorphology Study (Section 6.5)					
TWG Mtg.	08/17/2012	Jeff Davis	ARRI	Will the studies be able to identify how sediment passed out of Middle effects the Lower Reach?	Yes. The sediment dynamics between the Middle River and the Lower River will be evaluated in Section 6.5.4.3 as part of the sediment balance calculations as well as in the 1D modeling effort in Section 6.6. The latter effort will include modeling to at least RM 75. The former effort looks at the sediment balance to Susitna Station (RM 28)

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
TWG Mtg.	08/17/2012	Jay Stallman	Stillwater / FERC	It would be useful to further define the stratification system on a local and reach scale.	The first two levels of the stratification system are the river segment and geomorphic reach. These are described in section 6.5.4.1. The remaining 3 levels are described in the Fish Studies. The stratification system includes river segment, geomorphic reach, macroscale habitat (main channel and lateral habitats), mesoscale habitat, and microscale habitat levels. Additional information on the geomorphic reach characterization system has also been provided in Section 6.5.4.1 including an initial reach delineation and identification of geomorphic reach types.
TWG Mtg.	08/17/2012	Eric Rothwell	NMFS	Add proposed sediment measurement stations to map to identify locations where USGS is collecting 2012 Data	Figure 6.5-5 has been added to RSP showing the Susitna River above Tsusena Creek, the Susitna River at Gold Creek/ above Talkeetna, the Susitna River at Sunshine and the Chulitna River near Talkeetna gages.
TWG Mtg.	08/17/2012	Jay Stallman	Stillwater / FERC	Will bank erosion be evaluated?	Yes. Bank erosion will be evaluated using the historical aerial photo analysis and by comparison of the 1980s cross sections with cross sections surveyed in 2012 at the same locations (See Sections 6.5.4.4). The volume of sediment from bank erosion will be included in the sediment balance describe in Section 6.5.4.3.2.2.

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
TWG Mtg.	08/17/2012	Jay Stallman	Stillwater / FERC	Will sediment budget look at sizes?	Yes. The sediment budget will consider sediment in at least three size ranges, fines or wash load (silts and clays), sand, and coarse sediments (gravel and cobble). The balance will also consider in terms of bed material load and suspended load. The RSP includes additional details and clarification of the sediment budget calculations including a distinction of the initial sediment budget developed to support the initial determination of the downstream study limit and a more detailed sediment budget to assist in developing the sediment supply for the fluvial morphology modeling effort. The details of the sediment balance have been revised and are presented in Section 6.5.4.3.
TWG Mtg.	08/17/2012	Jeff Davis	ARRI	Explain the use of effective discharge in the geomorphology study	Effective discharge discussion in Section 6.5.4.3.2.4 was expanded to further describe its use in the overall assessment of potential channel change as a result of Project alterations to sediment transport capacity and discharge. Effective discharge is one means of identifying the potential for increase or decrease in channel dimensions as a result of alteration of flow and sediment transport capacity.
TWG Mtg.	08/17/2012	Jeff Davis	ARRI	Tributaries dump a good amount of sediment during storm events. Are they being accounted for in the Study?	Yes. Tributaries are included in the detailed sediment transport balance described in Section 6.5.4.3.2.2 and as a source of sediment supply in the 1D and 2D modeling efforts. The discussion of determination of tributary sediment supply is described in Section 6.6.6.4.1.2.6.

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
TWG Mtg.	08/17/2012	Jeff Davis	ARRI	Is the scale of the LWD study such that the influence of LWD on aquatic habitat in the sloughs be determined (4th of 4 parts)?	Yes, the scale will be sufficient to assess the influence of LWD on aquatic habitat in the sloughs. The following wording is included in the LWD study component described in Section 6.5.4.9: "Observations and discussion of how large woody debris is currently functioning in the Susitna River, including a discussion of interactions with riparian and aquatic/fish habitat, geomorphic processes (sediment transport/channel forming processes), ice processes, and flows."
TWG Mtg.	08/17/2012	Eric Rothwell	NMFS	Will the reservoir erosion study look at the potential different dam designs (heights)?	Yes. The reservoir geomorphology study component (Section 6.54.8) will consider the reservoir inundation zone and a band 100 feet above the high water and covers all potential reservoir heights being considered.

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
Fluvial Geomorphology Modeling Below Watana Dam Study (Section 6.6)					
TWG Mtg.	08/16/2012	Jay Stallman	Stillwater / FERC	Will the geomorphology effort model different operational scenarios and come up with new channel patterns?	Yes. Both the 1D and 2D sediment transport models will be run to evaluate operational scenarios. Section 6.6.4.2 provides a description of time frame for each model. The 1D model will provide a 50 year simulation of the overall aggradation/ degradation response of the system, including general changes in bed material composition, under both baseline (existing) and project conditions. Due to computational limitations, the 2D model cannot reasonably be run for a 50-year period; however, runs will be made for individual (i.e., seasonal) hydrographs for both baseline and project conditions, and the results will be used to assess how changes in flow and sediment regime under project conditions will affect bed evolution. Although specific, long-term changes in bed topography and channel patterns cannot be made, the trajectory of these changes can be inferred from a combination of the short-term 2D results and the long-term 1D results.

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
TWG Mtg.	08/17/2012	Jeff Davis	ARRI	Can the model look at spawning habitat modification for chum (referring to the specific chum spawning area identified for the Whiskers Slough Site in the 1980s)?	Yes. The 2D sediment transport model is capable of simulating the physical processes at the resolution necessary to identify changes in hydraulic conditions and bed material (substrate) in areas such as the chum spawning site identified in the 1980s study at the Whiskers Slough site. To model these areas, a finer mesh will be used. Specific areas to provide a finer mesh size to investigate specific aspects of local hydraulics, bed material and sedimentation processes will be evaluated and determined for each of the focus areas through coordination with the Instream Flow Study Fish, Instream Flow Study Riparian, Groundwater Study, Ice Processes Study and Fish Study and in collaboration with the relicensing participants. Discussion of varying the mesh site to focus in on specific areas of interest such as spawning areas and lateral habitats has been added to Section 6.6.4.1.2.3

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
TWG Mtg.	08/17/2012	Matt Cutlip	FERC	During the general discussion on site selection, it was indicated that AEA will need to justify use of 6 sites (or whatever number)	The process, schedule and criteria for selection of the focus areas is provided in Section 8.5.4.2 of the Fish Instream Flow study. Section 6.6.4.1.2.4. describes the role of the Geomorphology studies in the selection process. The site selection process is a collaborative effort between the Instream Flow Study Fish, Instream Flow Study Riparian, Groundwater Study, Fish Study and Ice Processes Study and coordinated with the relicensing participants. It is noted that the fluvial geomorphic analysis presented in Section 6.5 and the 1D sediment transport modeling presented in Section 6.6 will be performed for the entire detailed study area (currently proposed as RM 184 to RM 75 excluding Devils Canyon).

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
TWG Mtg.	08/17/2012	Jay Stallman	Stillwater / FERC	Need more detail on specific geomorphic data to be collected at the sites.	AEA has modified to Section 6.6 to describe the field data collection program that will be conducted in 2013. Section 6.6.4.1.2.8 has been added to present the field data collection effort. The field data collection effort described in this section covers the collection of data for both the Geomorphology Study (Section 6.5) and the Fluvial Geomorphology Modeling Study (Section 6.6). Major activities at focus areas will include bed material sampling, bathymetric and cross sectional data collection, mapping of geomorphic features, and characterization of physical process at each focus area. Additional data will be collected outside the focus areas such as cross sections to supplement the 2012 data available for the 1D model, additional bed material samples for the 1D model, and identification and/or verification of controls and other geomorphic features identified from aerial photographs and available mapping. Data will be collected in conjunction with field efforts being performed by the Instream Flow Fish, Instream Flow Riparian, Groundwater, and Ice Processes Study.
TWG Mtg.	08/17/2012	Jay Stallman	Stillwater/ FERC	USFWS and NMFS request pebble counts in their Study Plans. We need to have more detail as to where and when we will do pebble counts	The requested detail on bed material sampling has been included in the description of data collection added to Section 6.6.4.1.2.8. Bed material samples will be collected at both the Focus Areas as well as at other locations in the study area.

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
TWG Mtg.	08/17/2012	Henszey/ Davis / Steele	USFWS/ ARRI / ADNR OPMP	General discussion on the mesh size for the 2D model with questions concerning: what will the size be? Will field results influence it? When will size be selected?	The 2D sediment transport model selected for the focus areas will have a variable mesh size. This will allow a finer mesh to be applied to areas in which the scale of the feature being modeled (for example side or upland sloughs) requires a finer mesh size than other areas of the model. Larger mesh sizes can be used in the main channel to allow for more efficient execution of the model. However, even within the main channel, a finer mesh can be applied to provide higher resolution in areas such as spawning sites. More detail on the use and selection of the 2D model mesh size is provided in Section 6.6.4.1.2.3
TWG Mtg.	08/17/2012	Eric Rothwell	NMFS	Will additional cross section be selected at areas that aren't hydraulic controls and added to the 1D model? This question was brought up since the hydraulic routing model data collection likely concentrated on hydraulic controls, but these may not be the best features for describing sediment transport processes.	Yes. AEA will collect additional cross sections to supplement the cross-sectional data collected in 2012 to support the hydraulic routing model development. Cross section sites will be chosen in conjunction with the Instream Flow Study Fish, Instream Flow Study Riparian, Groundwater Study and Ice Processes Study. These additional cross sections are discussed as part of the field work described in Section 6.6.4.1.2.8
TWG Mtg.	08/17/2012	Jay Stallman	Stillwater / FERC	How will the 2D model be calibrated?	Yes. AEA has included additional discussion of the calibration of the 2D fluvial geomorphology model in Section 6.6.4.1.2.5. This includes discussion of the calibration of hydraulics (velocity, depth and flow distribution) and sediment transport conditions.

Comment Format	Comment Date	Licensing Participant Name	Licensing Participant Affiliation	Comment	Response
Email	08/23/2012	Joseph Klein	ADF&G	Will 2D modeling include side channels and sloughs within study area?	The decision to apply 2D modeling will be evaluated at focus area in coordination with the IFS-Fish, IFS-Riparian and groundwater studies. 2D modeling of side channel and sloughs will be utilized at the focus areas as appropriate when complex hydraulic conditions exist that are more accurately and effectively analyzed with 2D hydraulic and sediment transport modeling. Section 6.6 describes the application of 2D modeling of fluvial geomorphology.
Email	09/11/2012	Bob Henszey	USFWS	RISF-5 Characterize the Role of Sediment Deposition in the Formation of Soils: The proposed soil sampling techniques are included in Section 6.6.4.3.1.5, but based on these techniques it is unclear how the USFWS requested objective to characterize the role of sediment deposition in the formation of floodplain and riparian soils, and how sediment deposition affects the rate and trajectory of plant community succession. This objective should investigate the rate of deposition, depth of sediment, and soil profile development required for natural floodplain plant community succession, and then use the predicted sediment deposition characteristic from the Fluvial Geomorphology Study to predict the effects of Project operation on floodplain plant communities.	The Fluvial Geomorphology Modeling Study will assist the Instream Flow Riparian Study in determining the potential effect of the Project on the rate of sediment deposition in the floodplain. This will include modeling of the sedimentation process at the focus areas for both existing conditions and for various operational scenarios. Information developed from the Instream Flow Study Riparian on existing rates of floodplain deposition will be adjusted based on comparison of the frequency of inundation and alteration of sediment delivery under with Project scenarios. This will provide an assessment of the change in the rate of floodplain building under Project conditions. This aspect of the Fluvial Geomorphology Modeling in discussed in Section 6.6.4.1.2.8.

6.5. Geomorphology Study

6.5.1. General Description of the Proposed Study

6.5.1.1. Study Goals and Objectives

The overall goal of the Geomorphology Study is to characterize the geomorphology of the Susitna River, and to evaluate the effects of the Project on the geomorphology and dynamics of the river by predicting the trend and magnitude of geomorphic response. This will inform the analysis of potential Project-induced impacts to aquatic habitats. The results of this study, along with results of the Fluvial Geomorphology Modeling below Susitna-Watana Dam Study, will be used in combination with geomorphic principles and criteria/thresholds defining probable channel forms to predict the potential for alteration of channel morphology from Project operation. This information will be used to assist in determining whether protection, mitigation, or enhancement measures may be needed, and if so, what those measures may be.

Specific objectives of this study can be summarized as follows:

- Determine how the river system functions under existing conditions.
- Determine how the current system forms and maintains a range of aquatic and channel margin habitats.
- Identify the magnitudes of changes in the controlling variables and how these will affect existing channel morphology in the identified reaches downstream of the dam.
- Determine the likely changes to existing habitats through time and space.

In order to achieve the study objectives, the following analyses are required:

- Geomorphically characterize the Project-affected river channels.
- Collect sediment transport data to supplement historical data to support the characterization of Susitna River sediment supply and transport (to be performed by the U.S. Geological Survey [USGS]).
- Empirically characterize Susitna River sediment supply and transport conditions.
- Assess channel and study site stability/change (1980s versus current conditions).
- Characterize the surface area versus flow relationships for riverine habitat types over a range of flows (e.g., 5,100 to 23,000 cubic feet per second [cfs]) in the middle river.
- Conduct a reconnaissance-level geomorphic assessment of potential Project effects on the lower river channel.
- Conduct a reconnaissance-level riverine habitat assessment of potential Project effects on the lower river channel.
- Characterize the proposed Watana Reservoir geomorphology (changes resulting from conversion of the channel/valley to a reservoir).
- Assess potential issues related to large woody debris transport and recruitment.
- Characterize geomorphic conditions at stream crossings along access road/transmission line alignments.

6.5.2. Existing Information and Need for Additional Information

An analysis of the Middle Susitna River Reach geomorphology and how aquatic habitat conditions change over a range of stream flows was performed in the 1980s using aerial photographic analysis (Trihey & Associates 1985). The AEA Susitna Water Quality and Sediment Transport Data Gap Analysis Report (URS 2011) states that "if additional information is collected, the existing information could provide a reference for evaluating temporal and spatial changes within the various reaches of the Susitna River." The gap analysis emphasizes that it is important to determine if the conditions represented by the data collected in the 1980s are still representative of current conditions and that at least a baseline comparison of current and 1980s-era morphological characteristics in each of the identified sub-reaches is required.

An analysis of the Lower Susitna River Reach and how riverine habitat conditions change over a range of stream flows was performed in the 1980s using aerial photographic analysis (R&M Consultants, Inc. and Trihey & Associates 1985a). This study evaluated the response of riverine aquatic habitat to flows in the lower river reach between the Yentna River confluence (river mile [RM] 28.5) and Talkeetna (RM 98) (measured at Sunshine gage near RM 84) ranging from 13,900 cfs to 75,200 cfs. The study also included an evaluation of the morphologic stability of islands and side channels by comparing aerial photography between 1951 and 1983. As with the middle river information, it is important to determine if the conditions represented by the 1980s data are representative of current conditions. Such a comparison should include not only an identification of change, but should consider if the relative proportions of the various mesohabitat types have remained constant within a reach. If the relative proportions of the various mesohabitat types have remained constant in the various reaches, it provides a reasonable basis for using the 1980s data.

Considerable information is available from a variety of sources that will support the development and execution of the Geomorphology Study. Much of the available information is from the 1980s studies associated with the earlier efforts to develop the Susitna Hydroelectric Project (FERC No. 7114). In some cases, the older information will need to be replaced or supplemented with newer information because the Susitna River is a dynamic system and historical data such as cross-sections and aerial images in many areas will likely have changed considerably since they were collected in the 1980s. However, when compared with current information, these data provide valuable tools to understand the behavior and physical processes driving the geomorphology of the Susitna River. Comparability of the two sets of data will indicate that the fundamental relationships between channel form and fluvial process have remained constant and thus provide a basis for using the historical data. Additional data and analyses are needed to determine if historical data can be used to reflect current conditions and to address some of the data gaps identified in the AEA Susitna Water Quality and Sediment Transport Data Gaps Analysis Report (URS 2011). A more specific description of existing information and the need for additional information for each geomorphology study component are provided in the appropriate sections below.

6.5.3. Study Area

The study area for the Geomorphology Study is the Susitna River from its confluence with the Maclaren River (RM 260) downstream to the mouth at Cook Inlet (RM 0). The study area has been divided into three large-scale river segments:

- Upper river: Maclaren River confluence (RM 260) downstream to the proposed Watana Dam site (RM 184).
- Middle river: Proposed Watana Dam site (RM 184) downstream to the three rivers confluence (RM 98.5).
- Lower river: Three rivers confluence (RM 98.5) downstream to Cook Inlet (RM 0).

Each of the 10 study components that make up the Geomorphology Study has a component-specific study area often related to the three large-scale reaches identified above. The study area and river segments are shown on Figure 6.5-1. Identification of the study area that each study component addresses is provided in the discussion of each study component in Section 6.5.4, Study Methods.

6.5.4. Study Methods

The methods for each of the 10 Geomorphology Study components are presented in this section.

6.5.4.1. Study Component 1: Delineate Geomorphically Similar (Homogeneous) Reaches

The goal of the Delineate Geomorphically Similar (Homogeneous) Reaches study component is to geomorphically characterize the Project-affected river channels. This effort is being performed as part of the 2012 studies and is also described in the study plan for Aquatic Habitat and Geomorphic Mapping of the Middle River Using Aerial Photography. The study area is the length of the Susitna River from its mouth at Cook Inlet (RM 0), upstream to the proposed Watana Dam site (RM 184), and upstream of the proposed Watana Dam site, including the reservoir inundation zone and on upstream to the Maclaren River confluence (RM 260). The tributary mouths along the Susitna River and in the reservoir inundation zone that may be affected by the Project are also included in the study area.

6.5.4.1.1. Existing Information and Need for Additional Information

This effort will support the understanding of the conditions in the Susitna River by applying a geomorphic classification system based on form and process. It will also support efforts by other studies, including the Instream Flow, Instream Flow Riparian, Fish, and Ice Processes studies by providing a basis to stratify the river into reaches based on current morphology and their potential sensitivity to the Project. A delineation of the Susitna River into reaches was performed in the 1980s for the middle river (Trihey & Associates 1985) and the lower river (R&M Consultants, Inc. and Trihey & Associates 1985a).

6.5.4.1.2. Methods

This effort consists of identification of a geomorphic classification system and conducting the delineation of geomorphic reaches based on the identified classification system.

6.5.4.1.2.1. Identification and Development of Geomorphic Classification System

The first step in the geomorphic reach delineation effort will be the identification of the system to be used to classify and delineate the reaches. Classification of the river segments is required to provide a basis for communication among the various disciplines and to identify relatively homogeneous river segments that can then be used as a basis for extrapolation of results and findings from more spatially-limited studies. Numerous river classifications exist (Leopold and Wolman 1957; Schumm 1963, 1968; Mollard 1973; Kellerhals et al. 1976; Brice 1981; Mosley 1987; Rosgen 1994, 1996; Thorne 1997; Montgomery and Buffington 1997; Vandenberghe 2001), but no single classification has been developed that meets the needs of all investigators. Several factors have prevented the achievement of an ideal geomorphic stream classification, and foremost among these has been the variability and complexity of rivers and streams (Mosley 1987; Juracek and Fitzpatrick 2003). Problems associated with the use of existing morphology as a basis for extrapolation (Schumm 1991) further complicates the ability to develop a robust classification (Juracek and Fitzpatrick 2003). For purposes of classifying the Susitna River, available classification systems will be reviewed, and it is anticipated that a specific system will be developed that borrows elements from several classification systems. The classification scheme will consider both form and process. Development of this system will be coordinated with the Instream Flow, Instream Flow Riparian, Ice Processes, and Fish studies so it is consistent with their needs. These studies may require further stratification to identify specific conditions of importance to their efforts, in which case these studies will further divide the river into subreaches. However, the overall reach delineations developed in the Geomorphology Study will be used consistently across all studies requiring geomorphic reach delineations.

6.5.4.1.2.2. Geomorphic Reach Delineation

The lower river (RM 0 to RM 98), the middle river (RM 98 to RM 184), and the upper river to the Maclaren River confluence (RM 184 to RM 260) will be delineated into large-scale geomorphic reaches (a few to many miles) with relatively homogeneous characteristics, including channel width, entrenchment, ratio, sinuosity, slope, geology/bed material, single/multiple channel, braiding index, and hydrology (inflow from major tributaries) for the purpose of stratifying the river into study segments. Stratification of the river into relatively homogeneous reaches will permit extrapolation of the results of sampled data at representative sites within the individual reaches.

Because there are several studies that required reach delineation for planning 2012 field activities, an initial delineation primarily based on readily available information (most recent high-quality aerials, bed profile from the 1980s, geomorphic descriptions from the 1980s, and geologic mapping) was developed in April 2012. As additional information is developed, such as current aerial photographs and transects, the delineation will be refined and the various morphometric parameters will be included in the delineation. Coordination with the River Flow Routing Model Transect Data Collection Study is being conducted to obtain cross-section channel/floodplain data. Coordination with the Instream Flow Study, Instream Flow Riparian Study, Geomorphic Modeling Study, and Ice Processes Study is being conducted to ensure that the river stratification is performed at a scale appropriate for those studies.

A reconnaissance-level site visit of the Susitna River will be conducted that will be coordinated with other studies to take advantage of scheduled boat and helicopter trips as well as opportunities to coordinate with other studies. The Study Lead, Geomorphology Lead, and Sediment Transport Modeling Lead, the Erosion Study Lead, and at least one other senior member of the Geomorphology Study team will participate in the reconnaissance trip. They will be joined by representatives from the Instream Flow Study, Instream Flow Riparian Study, Ice

Processes Study, and Fish Study. The purpose of this site visit will be to provide key team members an overview of the river system. This will be extremely useful for all the Geomorphology Study components because it will permit team members to verify on the ground assessments that have been made from remotely sensed information.

Initial Geomorphic Reach Classification System

Classification of the identified segments of the Susitna River, lower, middle and upper, into reasonably homogeneous reaches is required to provide a basis for extrapolation of the results of process-based analyses of existing conditions and predictions of likely geomorphic changes in response to the Project at selected study locations to those reaches. To support development of study plans for a variety of resource areas, an initial reach classification was performed with the information available in 2012. This classification will be reviewed and updated if necessary as new information from the Geomorphology and Fluvial Geomorphology Modeling Study, as well as several other studies, becomes available.

From a practical viewpoint, Schumm (2005) has suggested that rivers and streams can be divided into two principal types: regime and non-regime. Regime channels, which are defined as those that flow on and in sediments transported by the river during the present hydrologic regime, and whose morphology is controlled primarily by the interactions of the flow regime and the sediment supply (Leopold et al. 1964; Schumm 1977), can be further subdivided on the basis of patterns (straight, meandering, wandering, braided, anastomosing). Non-regime channels can be further subdivided into constrained, where the form of the channel is forced by non-alluvial factors such as bedrock, colluvium, glacial deposits or extreme flood deposits (Montgomery and Buffington 1997; Tinker and Wohl 1998; O’Connor and Grant 2003), or unstable, which can include degrading (Schumm et al. 1984; Darby and Simon 1999), aggrading (Schumm 1977) or avulsing (Schumm et al. 2000) channels.

Based on Schumm’s (2005) classification scheme, the factors used in the initial geomorphic classification of the individual reaches of the Susitna River include the following:

1. Channel planform (single channel: straight, meandering; multiple channels: braided, anastomosing) – identified from topographic mapping, aerial photography
2. Constraints (bedrock, colluvium, moraines, alluvial fans, glaciolacustrine and glaciofluvial sediments) – identified from geologic mapping
3. Confinement (width of the floodplain and modern alluvium in relation to the width of the active channel(s)) – identified from geologic mapping, Light Detection and Ranging (LiDAR) based topography, hydraulic modeling
4. Gradient and bed materials – derived from various sources of survey data, 1980s data

Based on available information, the individual reaches within the three river segments were classified as follows:

Single Channel (SC):
SC1– Laterally confined with no sediment storage in bars, islands, or floodplain
SC2 – Laterally confined with limited sediment storage in mid-channel bars and non-continuous bank-attached floodplain segments

SC3 – Laterally confined with sediment storage in mid-channel bars, vegetated islands, and continuous floodplain segments

Multiple Channels (MC):
MC1 – Moderately wide floodplain with significant sediment storage in braid bars and vegetated islands
MC2 – Wide floodplain with significant sediment storage in braid bars and vegetated islands
MC3 – Wide floodplain width with vegetated floodplain segments separated by anastomosed channels with downstream base level controls
MC4 – Delta distributary channels

Initial Geomorphic Delineation

Application of the classification scheme described above to the three river segments of the study area resulted in the geomorphic reaches and reach types presented in Table 6.5-1. Maps showing the geomorphic reaches are presented on Figure 6.5-2, 6.5-3, and 6.5-4 for the upper, middle, and lower river segments, respectively. The upper river was divided into six reaches, with three reaches identified as SC1 reach type and three reaches identified as SC2 reach type. The middle river was divided into reaches with one reach classified as SC1 (Devils Canyon), five as SC2, one as SC3, and one as MC1/SC2 geomorphic reach types. The latter designation represents the fact that the downstream most geomorphic reach of the middle river, MR-8, is a transition reach from a single channel to multiple channel. The lower river was divided into six reaches with the upper two reaches classified as MC1, the next two reaches classified as MC3, the fifth reach classified as SC2, and the downstream-most reach classified as MC4.

It should be kept in mind that as more information becomes available, the geomorphic reach delineations and classifications will be reevaluated and adjusted if necessary.

6.5.4.1.2.3. Information Required

The following available existing information will be needed to conduct this study:

- Historical aerial photographs
- Information on bed material size
- Location and extent of lateral and vertical geologic controls
- Drainage areas of major tributaries
- Topographic mapping, including USGS survey quadrangle maps and LiDAR

The following additional information will need to be obtained to conduct this study:

- Current high resolution aerial photography
- Field observations made during a site reconnaissance
- Extended flow record for the Susitna River and tributaries being developed by USGS
- Profile of the river (thalweg or water surface)

6.5.4.1.3. Study Products

The results of the Delineate Geomorphically Similar Reaches study component will be included in the Geomorphology Report. Information provided will include the following:

- A geomorphic classification system developed specifically for the Susitna River that considers both form and physical processes.
- A delineation of the Susitna River into reaches of similar geomorphic characteristics, which has been coordinated with other relevant studies (Instream Flow, Riparian Instream Flow, Ice Processes, and Fish studies). The delineation will include broad large-scale reaches and further delineation into sub-reaches.
- Tables of morphometric parameters describing the physical characteristics of each reach developed from the analysis of aerial photographs, LiDAR, bed profiles, bed material samples, geologic mapping, and transect surveys.

In addition, an ArcGIS shapefile will be provided with the following information:

- Mapping of the segments and reaches overlaid on recent aerial photography and topographic mapping.

6.5.4.2. Study Components 2: Bedload and Suspended Load Data Collection at Tsusena Creek, Gold Creek, and Sunshine Gage Stations on the Susitna River and Chulitna River near Talkeetna

The goal of the Bedload and Suspended Load Data Collection at Tsusena Creek (RM 182), Gold Creek (RM 136), and Sunshine gage (RM 84) stations on the Susitna River and the Chulitna River near Talkeetna study component is to empirically characterize the Susitna River sediment supply and transport conditions. This effort is being performed by USGS. The effort described is for 2012 and may be modified in subsequent years based on experience gained from the 2012 work. The study covers the Susitna River from RM 84 (Sunshine Station) upstream to RM 182 (Tsusena Gage) and the Chulitna River near its confluence with the Susitna River. Figure 6.5-5 identifies the location of the study gages and other existing and historical USGS gages in the Susitna River basin.

6.5.4.2.1. Existing Information and Need for Additional Information

The collection of the data described in this study will supplement sediment transport data collected in the 1980s. The additional data are needed to determine if historical data can be used to reflect current conditions or if there have been shifts in the rating curves that might be related to climate change, glacial surges, or other as yet unidentified causes and to address some of the data gaps identified in the Susitna Water Quality and Sediment Transport Data Gaps Analysis Report (URS 2011).

This study will provide information on current transport conditions and support assessment of Project effects on sediment supply. Sediment data derived from the gages will be used to provide sediment inputs at model boundaries. This information will be used by several study components in this study as well as the Fluvial Geomorphology Modeling below Watana Dam Study.

6.5.4.2.2. *Methods*

The following scope of work was provided by USGS:

- Operate and maintain the stream gages.
- Maintain datum at the site;
- Record stage data every 15 minutes.
- Make discharge measurements during visits to maintain the stage-discharge rating curve and to define the winter hydrograph.
- Store the data in USGS databases.
- Collect at least five suspended sediment samples at Susitna River above Tsusena Creek, at Gold Creek, and at Sunshine; and the Chulitna River near Talkeetna during the year for concentration and size analysis.
- Collect at least five bed material samples during the year at Susitna River above Tsusena Creek, at Gold Creek, and at Sunshine; and the Chulitna River near Talkeetna for bedload transport determination and size analysis.
- Collect at least five bedload samples during the year at Susitna River at Gold Creek, Susitna River at Sunshine, Susitna River above Tsusena Creek, and the Chulitna River near Talkeetna for bedload transport determination and size analysis.
- Operate and maintain the stream gages at the Susitna River near Denali and the Chulitna River near Talkeetna.
- Operate a stage-only gage at a site upstream from Deadman Creek. Logistics at this site may preclude continuous operation or telemetry of the information.
- Compile suspended and bedload data, including calculation of sediment transport ratings and daily loads, in a technical memorandum delivered to AEA during federal fiscal year (FFY) 2013, and as early as March 2013, if possible. Provisional results from sampling will be available as soon as lab data are available. Provisional results from sediment load computations will be made available as soon as possible.

The bed load and suspended sediment data will be combined with existing rating curves to identify the differences and similarities between the historical and current data sets. This information will be used to evaluate whether the historical data sets are representative of current conditions in the Susitna River at Gold Creek and the Susitna River at Sunshine.

The sediment transport data available for the Chulitna and Talkeetna rivers will be reviewed. This will be accomplished using the sampling results collected in 2012 to help determine whether or not the historical rating curves are expected to be accurate. Because current data are not being collected on the Chulitna and Talkeetna rivers, this will primarily be accomplished by developing the mass balance of sediment above (Gold Creek data) and below (Sunshine data) three rivers to estimate the contributions from the Chulitna and Talkeetna rivers. The estimate based on the mass balance developed from the current data will be compared against estimates based on the historical Chulitna and Talkeetna sediment transport relationships. In addition, the historical Chulitna and Talkeetna sediment transport relationships and their applicability to current conditions will secondarily be evaluated comparing the historical versus new sediment rating curves at Gold Creek and at Sunshine (two locations where new data are being collected in 2012). Based on the results of the effort, a recommendation on whether or not additional sediment transport sampling is necessary in the Chulitna or Talkeetna rivers will be made.

6.5.4.2.3. Study Products

The results of the Bedload and Suspended Load Data Collection at Tsusena Creek, Gold Creek, and Sunshine gage stations study component will be included in the Geomorphology Report. Information provided will include the following:

- Calculation of discharge, suspended sediment discharge, and bedload discharge.
- Tabulation of all discharge, suspended sediment, bedload, and bed material sampling results.
- Data sheets reflecting field measurements.
- Comparison of historical and 2012 sediment transport measurements to determine if historical sediment transport rating curves can be expected to accurately represent current conditions.
- Narrative on data collection activities including description of methods, any difficulties encountered, and recommendations for potential future data collection in 2013.
- Posting of near real-time stage and discharge data on the USGS web site: http://waterdata.usgs.gov/ak/nwis/.
- Publication of the data in the USGS annual Water-Resources Data for the United States report (http://wdr.water.usgs.gov/).

In addition, an ArcGIS shapefile will be provided with the following information:

- Location of gage stations and measurement transects (if different from gage location).

6.5.4.3. Study Component 3: Sediment Supply and Transport Middle and Lower River

The objective of this task is to empirically characterize the sediment supply and transport conditions in the Susitna River between the proposed Watana Dam site (RM 184) and the Susitna Station gage (RM 28). The three rivers confluence (RM 98) separates the middle river from the lower river. Initial estimates for the Lower River Sediment Balance will be developed in 2012 as part of the Reconnaissance Level Geomorphic and Aquatic Habitat Assessment of Project Effects on Lower River Channel. The remaining efforts, which include refined estimates of the Middle River Sediment Balance, Bed Material Mobilization, and Effective Discharge, will be conducted in 2013. The 2013 effort will provide estimates of sediment supply that will be used in the bed evolution modeling efforts described in Section 6.6.

6.5.4.3.1. Existing Information and Need for Additional Information

The Project will reduce sediment supply to the reach of the Susitna River downstream from the dam, and will also alter the timing and magnitude of the flows that transport the sediment.

Information provided in the Pre-Application Document (PAD) (AEA 2011) suggests that peak flows may be reduced in magnitude and occur later in the season, and the flows will tend to be higher during the non-peak flow season under Project conditions. Sediment transport data are available along the mainstem Susitna River and several of the major tributaries between the proposed Watana Dam site (RM 184) and Susitna Station (RM 28) (URS 2011) that can be used to perform an initial evaluation of the sediment balance along the study reach under existing conditions. The results of this study component will provide the initial basis for assessing the potential for changes to the middle and lower river sediment balance, and the associated changes to geomorphology, because it will permit quantification of the magnitude in the reduction of sediment supply below the dam. The studies will also support the Fluvial Geomorphology Modeling below Watana Dam Study through development of sediment supply information that will be required as input to the model.

6.5.4.3.2. Methods

The methods section is divided into five subsections: (1) Initial Lower River Sediment Balance, (2) Middle River Sediment Balance, (3) Characterization of Bed Material Mobilization, (4) Effective Discharge, and (5) Information Required.

Development of the sediment balance for both the lower river (RM 98 to RM 28) and middle river (RM 184 to RM 98) will consider various techniques to characterize the sediment supply to each reach, the sediment transport capacity through the reaches, and deposition/storage within the reaches. Sources of sediment supply are expected to include the mainstem Susitna River, contributing tributaries, and identified locations of mass wasting. Potential procedures to estimate sediment supply include the use of regional sediment supply relationships (e.g., regression equations based on watershed area) and calculation of differences in sediment loads between gaging stations. While it is recognized that the gages are spatially separated, the comparison of the loads at the gages will permit an assessment of whether there is significant storage or loss of sediment between gages. If the data indicate that there is little difference between the gages, then it can be reasonably concluded that there is sufficient supply of sediment within the reach between gages to support an assumption of transport capacity limitation rather than supply limitation. The sediment transport measurements collected by USGS, both historical and current, will be used to develop bedload and suspended load rating curves to facilitate translation of the periodic instantaneous measurements into yields over longer durations (e.g., monthly, seasonal, and annual). Since gradations of transported material will be available, the data will allow for differentiation of transport by size fraction.

The sediment balance will be quantified by developing sediment load versus water discharge rating curves for each portion of the sediment load (i.e., wash load, total bed material load, bed load) using the available data or transport capacity calculations based on the hydraulic modeling results, as appropriate. The rating curves will then be integrated over the relevant hydrographs to estimate the total sediment load, and the resulting total sediment loads will then be compared to determine if each segment of the reach between the locations represented by the rating curves is net aggradational (i.e., more sediment is delivered to the reach than is carried past the downstream boundary) or degradational (i.e., more sediment is carried out of the reach than is delivered from upstream and lateral sources).

Previous studies have documented the potential for bias in suspended load rating curves due to scatter in the relationship between sediment concentration or load and flow (Walling 1977a). Part of the scatter is often caused by hysteresis in the sediment load versus discharge relationship, where the loads on the rising limb are higher than on the falling limb due to availability of material and coarsening of the surface layer during the high-flow portion of the hydrograph (Topping et al. 2010). Bias is also introduced in performing linear least-squares regressions using logarithmically-transformed data and then back-transforming the predicted sediment loads to their arithmetic values (Walling 1977b; Thomas 1985; Ferguson 1986). The hysteresis effect can be accounted for by applying separate (or perhaps, shifting) rating curves through rising and falling limbs of flood hydrographs (Guy 1964; Walling 1974; Wright et al. 2010). Bias in the regression equations can be removed using the Minimum Variance Unbiased Estimator (MVUE) bias correction for normally distributed errors, or the Smearing Estimator (Duan 1983) when a non-normal error distribution is identified. These methods were recommended by Cohn and Gilroy (1991) and have been endorsed by the USGS Office of Surface Water (1992). Once the sediment measurements are available for review, the potential for bias in the sediment rating curves will be considered and addressed as appropriate.

The rating curves for the mainstem Susitna stations, for gaged tributary stations, and those developed for contributing ungaged areas between stations will be used to develop the sediment balance for the pre-Project hydrology for representative wet, average, and dry years and warm and cold Pacific Decadal Oscillation (PDO) phases. (The inclusion of the warm and cold PDO phases was requested by NOAA-NMFS and USFWS in the May 31, 2012, study requests; the rationale for the request was discussed at the June 14, 2012, Water Resources TWG meeting and it was agreed that the PDO phases would be included in the suite of representative annual hydrologic conditions.) The sediment balance will be calculated based on the assumption that the sediment load in the Susitna River is currently in a state of equilibrium. To develop the sediment balance for the post-Project condition, the historical (pre-Project) sediment rating curve developed for the river immediately below the Watana Dam site (Tsusena Creek) will be reduced by 100 percent for the bedload and 90 percent for the suspended load on a preliminary basis. If the reservoir trap efficiency analysis discussed below indicates that a substantially different amount of sediment will pass through the reservoir, the sediment load curves will be adjusted accordingly.

6.5.4.3.2.1. Initial Sediment Balance (Lower River)

The primary purpose of the Initial Sediment Balance evaluation for the lower river that will be performed in 2012 is to help evaluate the potential for the Project to alter sediment transport conditions and channel response in the lower river. The results of this evaluation will provide the basis for assessing the need to perform additional 1D and 2D modeling and other studies related to potential channel change downstream from RM 75. The Lower River Sediment Balance will depend on the sediment supply from the middle river, the Chulitna and Talkeetna rivers, and other local tributaries along the reach, and the transport capacity along the reach. The total sediment supply to the lower river under pre-Project conditions will be evaluated using the sediment rating curves developed from the historical data (and 2012 data, if available) for the Susitna River at Gold Creek and near Talkeetna gages on the mainstem, and the below canyon near Talkeetna and near Talkeetna gages on the Chulitna and Talkeetna rivers, respectively. The historical rating curves for the Sunshine and Susitna Station gages, updated with any new sediment transport data collected by USGS under the Bedload and Suspended Load Data Collection at Tsusena Creek, Gold Creek, and Sunshine Gage Stations on the Susitna River and

Chulitna River near Talkeetna (Section 6.5.4.2), will be used to estimate the sediment loads in the river in the vicinity of RM 84 and RM 26.

6.5.4.3.2.2. Middle River Sediment Balance

A more detailed sediment balance will also be developed in 2013 for the middle river between the proposed Watana Dam site (RM 184) and the three rivers confluence (RM 98) using the available data, and when available, the hydraulic and sediment transport modeling results for this portion of the study reach. Estimates of the contributions to the sediment supply from the upper river, identified mass wasting locations, bank erosion, and contributing tributaries downstream of the dam will be an important aspect of this analysis. An estimate of the volume of sediment from bank erosion will be made utilizing a comparison of the channel location and area developed in the Assess Geomorphic Change Middle and Lower River study component (see Section 6.5.4.4) and comparison of cross-sections surveyed in the 1980s and in 2012. The cross-sections may also be used to determine if there has been a loss or gain in sediment supply from aggradation or degradation of the bed in the middle river. Tributary sediment loading will be estimated as part of the Fluvial Geomorphology Modeling Study (see Section 6.6.4.1.2.6).

Potential procedures to estimate the middle river sediment supply include the use of watershed area and regional sediment supply relationships and the determination of the differences on a seasonal or annual basis between the sediment loads estimated for the Susitna River at the Tsusena Creek and Gold Creek gage locations. Past USGS sediment data may be available for Indian River and Portage Creek, which could also be used to assist in the estimation of the middle river sediment supply inputs. If data being collected by USGS for the Bedload and Suspended Load Data Collection at Tsusena Creek, Gold Creek, and Sunshine Gage Stations on the Susitna River and Chulitna River near Talkeetna are available in time for this analysis, the 2012 data from Tsusena Creek will be compared to the 2012 Gold Creek data to estimate the sediment inflow between these two locations. This will allow development of a sediment rating curve from the 1985 data for the Susitna River at Tsusena Creek (representative of sediment transport at the Watana Dam site).

6.5.4.3.2.3. Characterization of Bed Material Mobilization

Bedload transport, particularly for the gravel and cobble size-fractions, is the key process that determines the dynamic behavior of the river bed both in the mainstem and in the side channel that is important to fish habitat. In coarse-grained rivers such as the Susitna River, a coarse surface layer is present that is typically not mobile over the full range of flows; thus, significant bedload transport does not occur. An important part of the geomorphology study will involve quantification of the range of flows over which bed mobilization occurs, and the potential change in duration of those flows under Project conditions. The approximate discharge at which bedload mobilization begins in the Susitna River near the proposed dam and at selected locations in the middle and lower rivers will be estimated using the USGS empirical sediment rating curves, incipient motion calculations (i.e., estimates of the critical discharge at which bed material begins to mobilize), and field observations. The resulting estimates of the critical discharge will be used to assess the frequency and duration of bed mobilization under the preand post-Project condition hydrology. This will be performed on both a monthly and annual basis at the selected locations for a range of flow years.

The concept of incipient motion as advanced by Shields (1936) relates the critical shear stress for particle motion (τ_c) to the dimensionless critical shear stress (τ^*_c) and the unit weight of sediment (γ_s), the unit weight of water (γ), and the median particle size of the bed material (D_{50}). One key limitation of this relation is the specification of τ^*_c (often referred to as the Shields parameter), which can range by a factor of three (Buffington and Montgomery 1997). The large range in published values for τ^*_c is caused largely by the difficulty in defining and identifying when bed material motion actually begins. To work around this limitation, Parker (Parker et al. 1982) defined a reference Shields stress (τ^*_r) that corresponds to a dimensionless transport rate $W^* = 0.002$, corresponding to a very low, but measurable transport rate. For this relationship, W^* is a function of the unit bedload and the total boundary shear stress, both of which are relatively simple parameters to calculate from field data if bedload and discharge measurements are included. (In the NOAA-NMFS and USFWS Study Plan Requests, it was proposed that the bed material mobilization analysis be calibrated based on the use of tracers. This topic was discussed at the Water Resources TWG held on June 14, 2012. AEA's consultants indicated that the use of tracers in a large river such as the Susitna would not be practical due to the difficulty in locating the tracers after mobilization. Therefore, the use of tracers is not included in the proposed study plan.)

Bed material mobilization at various locations along the study reach will be characterized using the reference shear approach of Parker, following the methods of Mueller et al. (2005). Data collected by USGS, which will include the necessary series of coupled flow and bedload transport measurements, will be used to formulate a series of bedload rating curves. These curves will then provide a basis for estimating τ^* that corresponds to a dimensionless transport rate $W^* = 0.002$ for bed material mobilization.

6.5.4.3.2.4. Effective Discharge

The concept of effective discharge, as advanced by Wolman and Miller (1960), relates the frequency and magnitude of various discharges to their ability to do geomorphic work by transporting sediment. They concluded that events of moderate magnitude and frequency transport the most sediment over the long-term, and these flows are the most effective in forming and maintaining the planform and geometry of the channel. Andrews (1980) defined the effective discharge as "*the increment of discharge that transports the largest fraction of the annual sediment load over a period of years.*"

Estimates of the potential change in effective discharge between historic and post-Project conditions provides a basis for predicting whether the bankfull channel capacity will change due to the Project, and if so, the likely trajectory and magnitude of the changes. The concept of effective discharge, as advanced by Wolman and Miller (1960), relates the frequency and magnitude of various discharges to their ability to do geomorphic work by transporting sediment. They concluded that events of moderate magnitude and frequency transport the most sediment over the long-term, and these flows are the most effective in forming and maintaining the planform and geometry of the channel.

Alluvial rivers adjust their shape in response to flows that transport sediment. Numerous authors have attempted to relate the effective discharge to the concepts of dominant discharge, channel-forming discharge, and bankfull discharge, and it is often assumed that these discharges are roughly equivalent and correspond to approximately the mean annual flood peak (Benson and Thomas 1966; Pickup 1976; Pickup and Warner 1976; Andrews 1980, 1986; Nolan et al. 1987; Andrews and Nankervis 1995). Quantification of the range of flows that transport the most sediment provides useful information to assess the current state of adjustment of the channel and to evaluate the potential effects of increased discharge and sediment delivery on channel behavior. Although various investigators have used only the suspended sediment load and the total sediment load to compute the effective discharge, the bed material load should generally be used when evaluating the linkage between sediment loads and channel morphology because it is the bed material load that has the most influence on the morphology of the channel (Schumm 1963; Biedenharn et al. 2000).

For purposes of this study, the effective discharge will be computed for the Susitna River below Tsusena Creek, at Gold Creek, and at Sunshine. This will be performed by dividing the full range of flows at each location into at least 30 logarithmic classes (Biedenharn et al. 2000) and then computing the sediment transport capacity at the average discharge within each flow class using the previously described rating curves. The bed material transport in each flow class over the long-term will be determined by multiplying the individual transport rates by the corresponding flow duration, which is derived from mean daily flow duration curves. The effective discharge is the flow, or range of flows, where the incremental bed material transport is greatest. Effective discharges will be determined for both the pre- and post-Project conditions. If the post-Project value is lower than the pre-Project value, it provides an indication that the morphology of the channel will change because there is a reasonably well identified relationship between the effective discharge and the size of the channel.

6.5.4.3.2.5. Information Required

The following available existing information will be needed to conduct this study:

- Current and historical aerial photographs.
- Historical suspended sediment and bedload data for the Susitna River and contributing tributaries.
- Flow records for the Susitna River and contributing tributaries.

The following additional information will need to be obtained to conduct this study:

- Suspended and bedload data for the Susitna River at Tsusena Creek and Gold Creek being performed by USGS.
- Extended flow record for the Susitna River and gaged tributaries within the study area being developed by USGS.
- Estimated flows for the ungaged tributaries within the study area.
- Extended flow records for the Susitna River and tributaries being developed by USGS.
- Collection of bed material samples throughout the middle and lower rivers, as well as contributing tributaries.
- Hydraulic conditions in the Susitna River from the Hydraulic Routing Model.

- Surveys of channel geometry for contributing tributaries to simulate hydraulic conditions.

6.5.4.3.3. Study Products

The results of the Sediment Supply and Transport Middle and Lower River study component will be included in the Geomorphology Report. Information provided will include the following:

- Tabular and graphical summary of available discharge and sediment transport data.
- Description of procedures used to develop sediment transport rating curves from suspended load and bedload data, including development of curves for specific sediment size-classes.
- Graphical and numerical relationships for sediment discharge rating curves.
- Narrative describing procedures used to perform effective discharge and bed mobilization calculations.
- Determination of total sediment load delivered to the Susitna River for pre- and post-Project conditions (the latter based on preliminary assumption that 100 percent bedload and 90 percent of suspended load will be trapped behind the Project dam; this estimate can be refined if the trap efficiency analysis indicates substantially different results).
- Estimate of middle river sediment supply inputs from local tributaries and other sources.
- Tabular and graphical representation and comparison of the duration and frequency of bed material mobilization in the middle and lower Rivers for pre- and post-Project conditions.
- Estimates of the effective discharge for the pre- and post-Project conditions, and the likely effects on channel morphology.
- Estimates of the overall sediment transport balance along the reach and the likely effects on channel morphology, particularly with respect to aggradation/degradation trends and changes in braiding potential. In reaches with net sediment deficit, results from the bed mobilization analysis will also be considered in assessing degradation tendencies.

6.5.4.4. Study Component 4: Assess Geomorphic Change Middle and Lower Rivers

The goal of the Assess Geomorphic Change Middle and Lower Rivers study component is to compare existing and 1980s geomorphic feature data from aerial photo analysis to characterize the relative stability of the 1980s study sites and river morphology under unregulated flow conditions. The effort for the middle river will be conducted in 2012 as part of the Aquatic Habitat and Geomorphic Mapping of the Middle River Using Aerial Photography study and for the lower river as part of the Reconnaissance Level Geomorphic and Aquatic Habitat Assessment of Project Effects on Lower River Channel study. The study area extends from the mouth of the Susitna River (RM 0) at Cook Inlet to the proposed Watana Dam site (RM 184).

6.5.4.4.1. Existing Information and Need for Additional Information

An analysis of the Middle Susitna River Reach geomorphology and how aquatic habitat conditions changed over a range of stream flows was performed in the 1980s using aerial photographic analysis (Trihey & Associates 1985). A similar analysis was performed for the lower river (R&M Consultants, Inc. and Trihey & Associates 1985a). The1980s lower river study also included an evaluation of the morphologic stability of islands and side channels by comparing aerial photography between 1951 and 1983. The AEA Susitna Water Quality and Sediment Transport Data Gap Analysis Report (URS 2011) states that "if additional information is collected, the existing information could provide a reference for evaluating temporal and spatial changes within the various reaches of the Susitna River." The gap analysis emphasizes that it is important to determine if the conditions represented by the data collected in the 1980s are still representative of current conditions and that at least a baseline comparison of current and 1980s-era morphological characteristics in each of the identified sub-reaches is required.

Understanding existing geomorphic conditions and how laterally stable/unstable the channels have been over recent decades provides a baseline set of information needed to provide a context for predicting the likely extent and nature of potential changes that will occur due to the Project. Results of this study may also be used in the Instream Flow Riparian and Ice Processes studies to provide the surface areas of bars likely to become vegetated in the absence of ice-cover formation. This would be accomplished by evaluating the areas of exposed bars within river segments over a range of flows and developing exposed bar area discharge curves that could then be used to assess the impacts of the Project flows on bar inundation by both flows and ice. Increases in areas that would be both inundation- and ice-free are likely to permit vegetation establishment and persistence.

6.5.4.4.2. Methods

This study component has been divided into the middle and lower rivers because the available information differs. The analysis of geomorphic change will be conducted for a single representative discharge.

6.5.4.4.2.1. Middle River

Coordination will occur with AEA's Spatial Data Contractor to digitize the riverine geomorphic features from RM 98 to RM 150 defined in the 1980s from hard copy maps found in the Middle River Assessment Report (Trihey & Associates 1985). The September 6, 1983, aerials flown at a flow of 12,500 cfs will be used for the historical condition. Each feature will be a polygon (without slivers). Geomorphic features that are visible between the 1980s and current images, including the main channel, side channels, the presence and extent of mid-channel bars, vegetated bar areas, and changes at tributary deltas will be digitized for a single representative flow. (*Note: the AEA Spatial Data Contractor will complete the digitizing and develop associated metadata for the 1980s digitizing.)* From RM 98 to RM 184 the geomorphic features at a single representative stream flow, currently identified as 12,500 cfs on the 2012 aerial photographs will also be digitized and delineated using the orthorectified photography and ArcGIS software (each geomorphic feature will be a polygon without slivers. (*Note: the Study Contractor will complete the digitizing and develop associated metadata for the 1980s digitizing.)*

The information developed from digitizing the aerials will be used to analyze and compare the geomorphology for 1980s and current conditions. From RM 98 to RM 150, Geographic Information System (GIS) software will be used to compare the 2012 versus 1980s total surface area associated with each geomorphic feature. Results will be compiled into tables and graphs, as appropriate, to show the difference in surface areas of the feature types between 2012 and the 1980s photography. The lead geomorphologist will provide training to ensure appropriate application of the geomorphic definitions. Since this 34-mile river segment below the proposed Watana Dam site (RM 150 to RM 184) was not analyzed in the 1980s, this portion of the river will undergo a new assessment (2012 photography only) that will not be compared to past studies. However, the methods for analyzing riverine geomorphic features will remain the same.

The change in channel planform over the length of the river (main channel location, side channel location, bars, channel and side channel width, channel and side channel location) will be qualitatively assessed between the 1980s and 2012. Reaches will be identified that are relatively stable versus those that are more dynamic. Reaches that would be most susceptible to channel change (e.g., width or planform change) with changes in the flow or sediment regime resulting from the Project or Project operations will be qualitatively identified because these are currently the most dynamic. Depending upon the results of the riverine geomorphic analysis, additional historical photographic analysis may be requested as part of future geomorphic studies, but this additional analysis is not included at this time. Additional analysis of historical aerial photographs and the corresponding flows that occurred between 1985 and 2012 could be pertinent if substantial changes in the riverine habitat types (surface area, locations, etc.) are identified during comparison of the 2012 and 1980s photography. While the long-term changes in river morphology are the result of a range of flows, if significant changes are identified between pairs of aerial photographs, review of the hydrologic record frequently identifies events that are more than likely to have been morphogenetically significant. This type of additional aerial photo analysis could provide more specific information on the flow magnitude(s) and other conditions (for example, ice formation) that may cause substantial geomorphic channel adjustments. If additional analysis is identified, it will be performed as part of the 2013–2014 studies.

6.5.4.4.2.2. Lower River

The 36,600-cfs September 6, 1983, set of lower river aerial photographs and current satellite images or aerial photographs will be obtained to compare historical and present-day channel planform and pattern from RM 28 to RM 99. Planform shifts of the main channel and side channels will be identified between the 1983 and current aerial photography. The three rivers confluence area is also a part of the analysis (extended to RM 99). Geomorphic features that are visible between the 1983 and current images, including the presence and extent of side channels, vegetated bar areas, and changes at tributary deltas, will be mapped and characterized. In areas where the mainstem channel consists of a dynamic braid plain mostly void of stabilizing vegetation, the effort will be directed at defining the edges of the active channel rather than detailing the myriad of channels within the active area. Major sloughs and side channels along the lower river margins will be included in the digitizing effort.

The rest of the lower river effort will be similar to that for the middle river. The geomorphic change over the length of the river (main channel location, side channel location, bars, channel and side channel width, channel and side channel location) will be qualitatively assessed between the 1980s and current conditions. Reaches will be identified that are relatively stable versus those that are more dynamic. Reaches that would be most susceptible to channel change (e.g., width or planform change) with changes in the flow or sediment regime resulting from the Project or

Project operations will be qualitatively identified. Depending on the results of the riverine geomorphic analysis, additional historical photographic analysis may be requested as part of future geomorphic studies, but this additional analysis is not included at this time. Additional analysis of historical aerial photographs and the corresponding flows that occurred between 1985 and 2012 could be pertinent if substantial changes in the riverine habitat types (surface area, locations, etc.) are identified during comparison of the 2012 and 1980s photography. This type of additional aerial photo analysis could provide more specific information on the flow magnitude(s) and other conditions (for example, ice formation) that may cause substantial geomorphic channel adjustments.

6.5.4.4.2.3. Information Required

The following available existing information will be needed to conduct this study:

- Historical 1980s orthorectified aerial photographs for the middle and lower rivers.

The following additional information will be needed to conduct this study:

- Obtain recent or develop 2012 orthorectified aerial photos (or satellite imagery) in the middle and lower rivers at a flow similar to the historic aerials (12,500 cfs middle river and 36,600 cfs lower river).
- Acquire historic orthorectified aerial photos and digitized geomorphic features from the AEA Spatial Data Contractor (SDC) for the middle and lower rivers for a single discharge.

6.5.4.4.3. Study Products

The results of the Assess Geomorphic Change Middle and Lower Rivers component will be included in the Geomorphology Report. Information provided will include the following:

- Maps showing riverine geomorphic features outlined in the middle and lower river for both the 1980s and 2012 for flows of 12,500 cfs and 36,600 cfs, respectively.
- Maps showing the distribution of all riverine geomorphic features for both dates and for the Middle and Lower Susitna River reaches.
- Overlay map of 1980s and 2102 riverine geomorphic features to assess the level of change in the channel morphology over the past three decades.
- Tabular and graphical representation of the areas for each riverine geomorphic feature type by geomorphic sub-reaches within the Middle and Lower Susitna River reaches.
- Qualitative assessment of the level of geomorphic change for the lengths of the Middle River and Lower Susitna River reaches including identification of stable versus non-stable areas.

In addition, an ArcGIS shapefile will be provided with the following information:

- 1980s orthorectified aerial imagery on GIS layer for the Middle and Lower Susitna River reaches.
- Digitized polygons for each riverine habitat feature type in the Middle and Lower Susitna River reaches.

6.5.4.5. Study Component 5: Riverine Habitat versus Flow Relationship Middle River

The goal of the Riverine Habitat Versus Flow Relationship Middle River study component is to develop existing and 1980s riverine habitat type area data over a range of flows to quantify riverine habitat versus surface area relationships. The study area extends from the three rivers area (RM 98) to the Watana Dam site (RM 184). Up to 20 study sites not exceeding 50 percent of the reach will be studied in the 2012 study, Aquatic Habitat and Geomorphic Mapping of the Middle River Using Aerial Photography. All or part of the remaining portion may be studied in 2013–2014, depending on the outcome and recommendations from the 2012 study as well as the selection of instream flow focus areas.

6.5.4.5.1. Existing Information and Need for Additional Information

Understanding existing geomorphic conditions, how aquatic habitat changes over a range of stream flows, and how stable/unstable the geomorphic conditions have been over recent decades provides a baseline set of information needed to provide a context for predicting the likely extent and nature of potential changes that will occur due to the Project. Results of this study will also provide the basis for macro-habitat mapping to support the Instream Flow Study and will be used in the Ice Processes Study to provide the surface areas of bars likely to become vegetated in the absence of ice-cover formation.

6.5.4.5.2. Methods

New aerial photography obtained in 2012 (and possibly 2013) will be combined with 1980s and other information to create a digital, spatial representation (i.e., GIS database) of riverine habitat. The result will be a quantification of the area of the riverine habitat types for three flow conditions for the historical 1980s condition and the current 2012 condition. The results will be presented as riverine habitat versus area relationships for the middle river, reaches in the middle river, and individual habitat study sites. Comparison between the results from the 1980s and 2012 can be made. The historical information will only be developed for the reach from RM 98 to RM 150 because the delineation of habitat in the Devils Canyon section, RM 150 to RM 184, was not performed.

The methods for this study component have been divided into three tasks: aerial photography, digitize riverine habitat types, and riverine habitat analysis.

6.5.4.5.2.1. Aerial Photography

New color aerial photography of the middle river (RM 98 to RM 184) at stream flows corresponding to those analyzed in the Trihey & Associates study (1985) (stream flow at the Gold Creek gage [15292000]) will be obtained to provide the foundation for the aquatic habitat and geomorphic mapping of the middle river, as well as to provide a resource for other studies.

It was the intent of the study plan to obtain three sets of aerial photography in 2012 at the following approximate discharges: 23,000 cfs; 12,500 cfs; and 5,100 cfs. (Note: seven sets of aerial photographs were flown and evaluated in the 1985 study at the stream flows of 5,100 cfs; 7,400 cfs; 10,600 cfs; 12,500 cfs; 16,000 cfs; 18,000 cfs; and 23,000 cfs). The combination of weather conditions and river flows only allowed the 23,000 cfs set of aerials to be collected in 2012. In order to provide a complete set of current aerial imagery, the 23,000 cfs aerials were collected for the entire study are from RM 0 to RM 260.. The aerial photography was collected in 2012 at a scale of 1:12,000 and with a pixel resolution of 1 foot or better. Images to be collected in 2013 will be flown at the same scale and resolution. The flow levels intended to be collected in 2013 will be the 12,500 cfs and 5,100 cfs. If weather and discharge conditions have not occurred that allowed for collection of the aerials at the specified discharges by September 1 of 2013, a more opportunistic approach to obtaining the aerials will be instituted and alternate flows may be substituted for the 12,500 cfs and 5,100 cfs discharges to insure that a medium and low flow set of images are collected by the end of 2013.

6.5.4.5.2.2. Digitize Riverine Habitat Types

For the 2012 effort, 16 study sites totaling 25.8 river miles were selected from the 1980s effort The 16 sites represent approximately 50 percent of the 49 miles (RM 100 to RM 149) of the Middle River with aquatic habitat delineated in the 1980s. The selected sites are listed in Table 6.5-2. Selection of the sites was based on consideration of habitat and geomorphic characteristics of the reach and a visual qualitative side-by-side comparison of the aerials to ensure that the selected reaches were also representative of the level of change that has occurred over the period of comparison. Aerial photography for both 1980s and present condition was obtained for the entire reach so that additional areas may be digitized in the future if warranted.

Coordination has occurred and will continue to occur with AEA's Spatial Data Contractor to digitize (within the aerial photography analysis study reaches) the riverine habitat types from RM 98 to RM 150 defined in the 1980s from hard copy maps found in the Middle River Assessment Report (Trihey & Associates 1985). Each habitat type is a polygon (without slivers). The habitat types were classified into the following categories: main channel, side channel, side sloughs, upland sloughs, and tributary mouths.

Riverine habitat types for the identified study sites are being delineated and digitized from the 2012 aerials at each of the three stream flows used for the 1980s digitizing effort. Sites include those identified for the 1980s digitization effort as well as up to six additional sites between RM 150 and RM 184, identified in coordination with the Instream Flow Study, the Riparian Instream Flow Study, Ice Processes Study, and other pertinent studies. The habitat types are being digitized from the orthorectified photography using ArcGIS software (each habitat type must be a polygon without slivers). Riverine habitat will be classified using the same classification categories used in the Trihey & Associates study (1985) main channel, side channel, side sloughs, upland sloughs, and tributary mouths.

6.5.4.5.2.3. Riverine Habitat Analysis

The information developed in the previous task will be used to develop relationships for riverine habitat versus flow for the specified reaches and habitat study sites. The relationships will be developed for both 1980s and 2012 aerials. The riverine habitat type surface area versus flow relationships between the 1980s and current conditions will be compared at both a site and reach scale to determine if changes in the relationships have occurred. The comparison can only be performed for a portion of the reach, since the 1980s study did not cover the entire middle river.

From RM 98 to RM 150, GIS software will be used to compare the 2012 versus 1980s total surface area associated with each delineated riverine habitat type at each measured flow. Results will be compiled into tables and graphs, as appropriate, to show the difference in surfaces area of the feature types between 2012 and the 1980s photography and to show the change in riverine habitat types versus flow. To ensure accurate comparison to the 1980s data set, not only will the same approximate flows be compared, but the same definitions will be used for each of the riverine habitat features that are delineated (see above). The Lead Geomorphologist will provide training to ensure appropriate application of the habitat definitions.

Since the 34-mile river segment below the proposed Watana Dam site (RM 150 to RM 184) was not analyzed in the 1980s, this portion of the river will be a new assessment (2012 photography only) that will not be compared to past studies. However, the methods for analyzing riverine habitat types over the range of flows will remain the same as for the downstream reach (23,000 cfs; 12,500 cfs; and 5,100 cfs). Because this reach has a high level of lateral and vertical control, the areas associated with riverine habitat types have likely experienced little change. Results of the study component Assess Geomorphic Change will determine whether there has been change in geomorphic features in this portion of the middle river.

Habitat features will be compared and contrasted quantitatively and a qualitative assessment will be made of the similarity of the sites in 2012 compared to the 1980s in order to assess the stability of the study sites. A decision will also be made as to whether the remaining portions of the Middle River, beyond the original selected study sites analyzed in 2012, will be digitized and analyzed in 2013–2014.

6.5.4.5.2.4. Information Required

The following available existing information will be needed to conduct this study:

- Historical 1980s orthorectified aerial photographs for the middle river.
- USGS flow records for the past 10 years for the Susitna River at Gold Creek.

The following additional information will be needed to conduct this study:

- Obtain (fly) 2012 orthorectified aerial photos in the middle river at 5,100; 12,500; and 23,000 cfs (corresponds to 1980s flow).
- Acquire historical 1980s digitized riverine habitat features from the AEA Spatial Data Contractor (SDC) for the middle river for flows of 5,100; 12,500; and 23,000 cfs.

6.5.4.5.3. Study Products

The results of the Riverine Habitat Versus Flow Relationship Middle River component will be included in the Geomorphology Report. Information provided will include the following:

- Tabulation of the riverine habitat types versus flow on a reach and individual site basis for the 1980s and 2012 conditions.
- Graphical representation of the riverine habitat type area versus flow relationships by reaches for both the 1980s and 2012 data.
- Assessment of the change and similarity in riverine habitat types between the 1980s and 2012 and conclusions on site stability to aid the Instream Flow Study in site selection and determination of the applicability of the 1980s data to represent current conditions.

In addition, an ArcGIS shapefile will be provided with the following information:

- Orthorectified aerial imagery of the middle river at 5,100 cfs; 12,500 cfs; and 23,000 cfs.
- Digitized polygons representing the 1980s riverine habitat types for the middle river at 5,100 cfs; 12,600 cfs; and 23,000 cfs from RM 98 to RM 150 (middle river below Devils Canyon).
- Digitized polygons representing the current (2012) riverine habitat types for the middle river at 5,100 cfs; 12,500 cfs; and 23,000 cfs from RM 98 to RM 150 (middle river below Devils Canyon) and RM 150 to 184 (middle river in Devils Canyon and above Devils Canyon).

6.5.4.6. Study Component 6: Reconnaissance-Level Assessment of Project Effects on Lower River Channel

The goal of the Reconnaissance-Level Assessment of Project Effects on Lower River Channel study component is to utilize comparison of pre- and post-Project flows and sediment transport conditions to estimate the likelihood for potential post-Project channel change in the lower river. The study area for this effort is the Lower River from RM 98 to RM 0. This effort was started in 2012 and will be completed in early 2013 as part the Reconnaissance-Level Geomorphic and Aquatic Habitat Assessment of Project Effects on Lower River Channel. The results of this effort will help determine what additional analysis of Project effects may be warranted in the lower river for the 2013–2014 studies.

6.5.4.6.1. Existing Information and Need for Additional Information

An analysis of the lower river reach and how riverine habitat conditions change over a range of stream flows was performed in the 1980s using aerial photographic analysis (R&M Consultants, Inc. and Trihey and Associates 1985a). This study evaluated the response of riverine aquatic habitat to flows in the lower river reach between the Yentna River confluence (RM 28.5) and Talkeetna (RM 98) (measured at Sunshine gage [approximately RM 84]) ranging from 13,900 cfs to 75,200 cfs. The study also included an evaluation of the morphologic stability of islands and side channels by comparing aerial photography between 1951 and 1983.

In another study, 13 tributaries to the lower Susitna River were evaluated for access by spawning salmon under existing and with proposed stream flows for the original hydroelectric project (R&M Consultants, Inc. and Trihey and Associates 1985b). The study contains information regarding fish run timing, mainstem and tributary hydrology, and morphology. Based on the results of this study, it was concluded that passage for adult salmon was not restricted under natural flow conditions nor was it expected to become restricted under the proposed Project operations.

The AEA Susitna Water Quality and Sediment Transport Data Gap Analysis Report (URS 2011) states that "if additional information is collected, the existing information could provide a reference for evaluating temporal and spatial changes within the various reaches of the Susitna River." The gap analysis emphasizes that it is important to determine if the conditions represented by the data collected in the 1980s are still representative of current conditions, and that at least a baseline comparison of current and 1980s morphological characteristics in each of the identified subreaches is required.

Results of this study will provide the initial basis for assessing the potential for changes to the lower river reach morphology due to the Project. Additional studies will be planned for 2013–2014 if the results of this study identify a potential for important aquatic habitat and channel adjustments in response to the Project.

Issues associated with geomorphic resources in the lower river reach for which information appears to be insufficient were identified in the PAD (AEA 2011), including the following:

- G16: Potential effects of reduced sediment load and changes to sediment transport as a result of Project operations within the lower river.
- F19: The degree to which Project operations affect flow regimes, sediment transport, temperature, and water quality that result in changes to seasonal availability and quality of aquatic habitats, including primary and secondary productivity.

6.5.4.6.2. Methods

6.5.4.6.2.1. Stream Flow Assessment

Pre-Project and available post-Project hydrologic data will be compared. This will include a comparison of the monthly and annual flow duration curves (exceedance plots) and plots/tables of flows by month (maximum, average, median, minimum) for the Susitna River at the Sunshine and Susitna Station gaging stations. Additional hydrologic indicators may be used to further illustrate and quantify the comparison between pre- and post-Project stream flows. The pre-Project data analysis will include the extended record being prepared by USGS.

Using the extended record currently being prepared by USGS, a flood-frequency and flood-duration analysis for pre- and post-Project annual peak flows will be performed. The flood-frequency analysis will be performed using standard hydrologic practices and guidelines as recommended by USGS (1982).

6.5.4.6.2.2. Sediment Transport Assessment

As described above, the sediment transport data collected by USGS will be used to develop bedload, total bed material, and wash load rating curves to facilitate translation of the periodic instantaneous measurements into yields over longer durations (e.g., monthly, seasonal, and annual). This information will be used to perform an overall sediment balance for each component of the sediment load. This information will be developed as part of the Sediment Supply and Transport Middle and Lower River study (see Section 6.5.4.3).

6.5.4.6.2.3. Integrate Sediment Transport and Flow Results into Conceptual Framework

Prediction of Project-induced changes to river morphology in an alluvial river is fundamentally based on the magnitudes and directions of change in the driving variables, hydrology, and sediment supply. Initial, qualitative assessment of change can be based on Lane's (1957) equality:

$Q_w.S \sim Q_s.D_{50}$,

where Q_w is the flow, S is the slope, Q_s is the sediment transport and D_{50} is the median size of the bed material. A change in any one of the variables will require a change in the others to maintain the balance.

Use of the expansion of Lane's relation by Schumm (1977) allows the response to the changes in driving variables to be expressed in terms of channel morphometric parameters such as channel width (b), depth (d), slope (S), meander wavelength (λ), width-depth ratio (F) and sinuosity (P). For example, a potential range of changes in response to the Project in the vicinity of the three rivers confluence where flows will be reduced and sediment supply could be effectively increased could be expressed as follows:

$Q_w^-, Q_s^+ \sim b^{\pm}, d^-, \lambda^{\pm}, S^+, P^-, F^+$

where + represents an increase, – represents a decrease and ± represents indeterminacy.

Application of these qualitative relations assumes that the river is alluvial and that the form and characteristics of the channel are the result only of the interaction of the flows and the sediment load. Where non-fluvial factors such as bedrock outcrop or coarse-grained paleo-flood deposits limit the adjustability of the channel, the ability to predict the direction and magnitude of channel change in response to changes in the water and sediment load below dams is reduced (Miller 1995; Grant and Swanson 1995; Grant et al. 2003).

Using the data developed for the pre- and post-Project flood frequency, flood duration, and sediment load, the geomorphic response of the Susitna River in a conceptual framework along the longitudinal profile of the river system from the three rivers confluence through lower river reach will be predicted. The conceptual framework developed by Grant et al. (2003) that relies on the dimensionless variables of the ratio of sediment supply below the dam to that above the dam and the fractional change in frequency of sediment transporting flows will be used to predict the nature and magnitude of the lower river geomorphic response. Other analytical approaches may be considered to evaluate potential for geomorphic adjustments in the river reaches due to the Project. These may include an evaluation of morphologic changes based on changes to the degree and intensity of braiding using Germanoski's (1989) modified braiding index (MBI) that has been used to predict channel responses to anthropomorphically-induced changes in Alaskan, glacial-fed rivers including the Toklat, Robertson, and Gerstle Rivers (Germanoski 2001). As demonstrated by Germanoski and Schumm (1993), Germanoski and Harvey (1993), and Harvey and Trabant (2006), the following are the expected directions of responses in the MBI values to significant changes in bed material gradation and sediment supply:

- If the D50 increases and there is a supply of sediment, then MBI increases.
- If the D50 increases and there is a significant decrease in the supply of sediment, then MBI decreases.
- If the bed aggrades, then MBI increases.
- If the bed degrades, then MBI decreases.

Specific MBI values for braided reaches of the Susitna River under existing conditions will be developed from aerial photography, and the likely changes in values in response to the Project will be assessed. Prediction of the direction, if not the magnitude of changes, will provide useful information for assessing likely Project impacts on instream habitats.

6.5.4.6.2.4. Information Required

The following available existing information will be needed to conduct this study:

- Historical suspended sediment and bedload data for the Susitna River.
- Flow records for the Susitna River.
- Characterization of bed material from previous studies.

The following additional information will need to be obtained to conduct this study:

- Suspended and bedload data for the Susitna River at Tsusena Creek and Gold Creek being performed by USGS.
- Extended flow record for the Susitna River and gaged tributaries within the study area being developed by USGS.
- Channel morphologic data for existing conditions including, width, depth, width/depth ratios, and MBIs.

6.5.4.6.3. Study Products

The results of the Reconnaissance-Level Assessment of Project Effects on Lower River Channel Sediment component will be included in the Geomorphology Report. Information provided will include the following:

- Pre- and post-Project comparison of hydrologic parameters for the Susitna River at Sunshine and at Susitna Station, including:
  - Monthly and annual flow duration curves
  - Annual peak flow frequency
  - Monthly flow statistics (maximum, average, median, minimum)
- Summary of changes in sediment transport for pre- and post-Project conditions in the lower river.
- Results of the assessment of anticipated Project effects on the lower river based on the analytical framework in Grant et al. (2003) and other indicators of potential channel change such as the MBI by Germanoski (1989).

6.5.4.7. Study Component 7: Riverine Habitat Area versus Flow Lower River

The objective of the Riverine Habitat Area versus Flow Lower River study component is to conduct a reconnaissance-level assessment of the potential for Project effects associated with changes in stage to alter lower river riverine habitat. This effort will be conducted in 2012.

6.5.4.7.1. Existing Information and Need for Additional Information

An analysis of the lower river reach and how riverine habitat conditions change over a range of stream flows was performed in the 1980s using aerial photographic analysis (R&M Consultants, Inc. and Trihey and Associates 1985a). This study evaluated the response of riverine aquatic habitat to flows in the lower river reach between the Yentna River confluence (RM 28.5) and Talkeetna (RM 98) (measured at Sunshine gage at approximately RM 84) ranging from 13,900 cfs to 75,200 cfs. Results of this study will provide the initial basis for assessing the potential for changes to the lower river reach morphology due to the Project. Additional studies will be planned for 2013–2014 if the results of this study and other studies identify a potential for important aquatic habitat and channel adjustments in response to the Project.

6.5.4.7.2. Methods

This study component is divided into three tasks: Riverine Habitat-Flow Relationship Assessment, Synthesis of the 1980s Aquatic Habitat Information, and Contingency Analysis to Compare Wetted Channel Area. The third task is optional and dependent on a determination if comparison of riverine habitat in the lower river under pre- and post-Project flows is warranted for additional flow conditions.

6.5.4.7.2.1. Change in River Stage Assessment

A tabular and graphical comparison of the change in water surface elevations associated with the results of the pre- and post-Project stream flow assessment (described above) will be developed using the stage-discharge relationships (rating curves) for the Sunshine and Susitna Station gaging stations. This comparison will include monthly and annual stage duration curves (exceedance plots) and plots/tables of stage by month (maximum, average, median, minimum). Additional parameters to describe and compare the pre- and post-Project water surface elevations may be performed. A graphical plot of a representative cross-section at each gaging station will be developed with a summary of the changes in stage (water surface elevation) for the two flow regimes. If possible, the location of the active channel and the floodplain will also be identified on the cross-section. Changes in stage will be related to exposure of bars through the previously developed bar area discharge curves, thereby providing the link between both vegetation and ice impact assessments. The stage change information will also be used to estimate and compare the areas of the various riverine habitat types for the existing and with-Project conditions over a range of flow frequencies.

The availability of USGS winter gage data with respect to discharge and ice elevation/thickness will be investigated. Coordination with the Documentation of Susitna River Ice Break-up and Formation Study will occur to obtain information on ice elevation/thickness, as appropriate. The potential need for an analysis of discharge effects on ice elevation will be identified and conducted, if feasible.

6.5.4.7.2.2. Synthesis of the 1980s Aquatic Habitat Information

A synthesis/summary of the 1980s Response of Aquatic Habitat Surface Area to Mainstem Discharge Relationships in the Yentna to Talkeetna Reach of the Susitna River (R&M Consultants, Inc. and Trihey & Associates 1985a) will be provided. A synthesis/summary of the Assessment of Access by Spawning Salmon into Tributaries of the Lower Susitna River (R&M Consultants, Inc. and Trihey & Associates, 1985b) will also be provided. Data will be summarized with respect to the anticipated pre- and post-Project flow changes, where applicable (see Stream Flow Assessment section above).

6.5.4.7.2.3. Site Selection and Stability Assessment

Five sites in the Lower River were selected from the Yentna to Talkeetna reach map book (R&M Consultants, Inc. and Trihey and Associates 1985a) at the approximately 36,600 cfs flow at

Sunshine Gage to study in 2012. These sites were selected in coordination with the Instream Flow Study and the Instream Flow Riparian Study. A side-by-side comparison of the sites using the 1983 36,600-cfs aerials and the 2011 aerials from the Mat-Su Borough LiDAR project were used to qualitatively assess site stability. Only sites that had been relatively stable during the period from the 1980s to present were selected. The five sites selected were: Side Channel IV-4 (SC IV-4), Willow Creek (SC III-1), Goose Creek (SC II-4), Montana Creek (SC II-1) and Sunshine Slough (SC I-5).

6.5.4.7.2.4. Aerial Photography Analysis, Riverine Habitat Study Sites (RM 28 to RM 98)

Using GIS and the September 6, 1983, aerials for the 36,600-cfs flow, mainstem and side channel riverine habitat will be digitized from the 1985 map book (R&M Consultants, Inc. and Trihey & Associates 1985a) for the selected sites. Each area associated with a habitat type will be a polygon (without slivers). To provide a comparison with current conditions, either recent satellite imagery at a flow similar to 36,600 cfs or aerials obtained in 2012 (if appropriate satellite imagery is not available) will be used to delineate the current wetted areas within the riverine and side channel habitats for the selected sites.

The difference in wetted surface area of the main channel and side channel riverine habitats (as defined in R&M Consultants, Inc. and Trihey & Associates 1985a) will be compared between the 1983 and current conditions. The areas of the riverine habitat types, along with the Geomorphic Assessment of Channel Change subtask (see below), will be compared and contrasted quantitatively, and a qualitative assessment will be made of the similarity of the 1980s sites compared to the 2012 sites. The assessment of site stability will help determine the applicability of lower river riverine habitat information developed in the 1980s to supplement information being developed in the current Project studies.

6.5.4.7.2.5. Optional: Additional Aerial Photography Analysis, Riverine Habitat Study Sites (RM 28 to RM 98)

Based on the results of the comparison of riverine habitat areas at the selected study sites for the lower river and results of the Geomorphic Assessment of Channel Change subtask (see below), a determination of whether to perform a similar effort and comparison for up to two additional discharges will be made (discharges corresponding to the analysis of wetted habitat areas in the lower river include 75,200 cfs; 59,100 cfs; 36,600 cfs; 21,100 cfs; and 13,900 cfs). This decision will be made in coordination with the Instream Flow Study, Instream Flow Riparian Study, Ice Processes Study, Fish Study, and licensing participants. If the decision is made to analyze riverine habitat at two additional discharges, the flows will be selected and the associated habitat areas digitized from the 1985 map book. Satellite imagery at similar discharges or new aerial photographs will be obtained (if appropriate satellite imagery is not available). The riverine habitat types will be delineated and digitized on these images to represent the current condition. The difference in wetted surface area of the main channel and side channel riverine habitats will be compared between the 1983 and current conditions for the two additional discharges. (The USFWS Study Plan Request included digitizing the riverine habitat types for three flows in the lower river. This topic was discussed at the Water Resources TWG meeting held on June 14, 2012. It was explained that the current proposal by AEA is to digitize riverine habitat for a single flow in 2012, then based on decisions on whether to continue focus area studies into the lower river and how far those studies would be carried downstream, the optional aerial photo analysis identified in this task would be performed in 2013. USFWS agreed at the meeting that this approach was appropriate.)

6.5.4.7.2.6. Information Required

The following available existing information will be needed to conduct this study:

- Historical 1980s orthorectified aerial photographs for the lower river.
- USGS flow record for the Sunshine and Susitna Station gages including measurement notes, rating curves, stage shifts, cross-sections, and information on ice thickness.

The following additional information will need to be obtained to conduct this study:

- Results of Study Component 4, Assess Geomorphic Change Middle and Lower Rivers.

6.5.4.7.3. Study Products

The results of the Riverine Habitat Area versus Flow Lower River component will be included in the Geomorphology Report. Information provided will include the following:

- Comparison of pre- and post-Project stage at the Susitna River at Sunshine and the Susitna Station gages associated with the flow duration curves (monthly and annual) and monthly statistics.
- Summary of available USGS measurements of ice elevation/thickness to identify the need to perform analysis of the discharge effect on ice elevation.
- Narrative describing the synthesis of the 1980s aquatic habitat versus flow relationships and the anticipated post-Project flow changes.
- Identification, based on site stability, of up to eight sites in the lower river for analysis of changes in riverine habitat area from the 1980s to the current condition at the selected flow.
- Results for the selected flow of the comparison of the riverine habitat areas, by type, for the selected sites for 1980s and current aerial imagery.

In addition, an ArcGIS shapefile will be provided with the following information:

- Digitized polygons of the 1980s and current riverine habitat surface areas at the selected sites.

6.5.4.8. Study Component 8: Reservoir Geomorphology

The goal of the Reservoir Geomorphology study component is to characterize changes resulting from conversion of the channel and portions of the river valley to a reservoir. The study area extends from the proposed Watana Dam site (RM 184) upstream to include the reservoir inundation zone and the portion of the river potentially affected by backwater and delta formation in the river, which is currently assumed to correspond to approximately five miles above the reservoir maximum pool (at approximately RM 238). The proposed study area is shown in Figure 6.5-6. Specific objectives of this study component include the following:

- Estimate reservoir sediment trap efficiency and reservoir longevity.
- Estimate the Susitna River and inflow tributary delta formation with respect to potential effects on upstream fish passage.
- Estimate erosion and beach formation in the Watana Reservoir drawdown zone and shoreline area.

6.5.4.8.1. Existing Information and Need for Additional Information

Construction and operation of the proposed Project will impound a reservoir for approximately 39 miles upstream from the dam. The reservoir will likely trap essentially all of the coarse sediment load and much of the fine sediment load that enters the impoundment from the upstream Susitna River. The coarse sediment load will form a delta at the head of the reservoir that will be re-worked by seasonal fluctuations of the reservoir elevation.

Similar to the mainstem Susitna River delta at the head of the reservoir, deltas of varying size will likely form where tributaries enter the reservoir. The amount and distribution of sediment deposits may affect the connectivity of the surface flows between the reservoir and the tributary channels, which may, in turn, block fish passage into the tributaries. The available information does not contain data describing the magnitude and size distribution of the annual sediment loads from the tributaries that enter the reservoir, a potentially significant data gap.

Operation of the Project would result in seasonal and daily water-level fluctuations in Watana Reservoir, which will result in beach formation and erosion and/or mass wasting of soils within the impoundment. The results of the erosion potential portion of this study will provide information on the extent of these processes and the potential for alterations to Project operations or erosion control measures to reduce erosion and mass wasting.

6.5.4.8.2. Methods

The methods are divided into three areas: reservoir trap efficiency and sediment accumulation rates, delta formation, and reservoir erosion. (In the Study Plan comments, NOAA-NMFS and USFWS requested that a description of reservoir sediment removal procedures be included in the Geomorphology effort. At the Water Resources TWG meeting held June 14, 2012, AEA’s consultants indicated that there are no plans for removal of sediment deposited in the reservoir because no feasible procedures for accomplishing this on a large reservoir with a substantial permanent pool currently exist. The reservoir will have a finite life as a result of sedimentation and this will be estimated as part of the Reservoir Geomorphology study component.)

6.5.4.8.2.1. Reservoir Trap Efficiency and Sediment Accumulation Rates

Inflowing sediment loads from the mainstem Susitna River will be determined by integrating the bedload and suspended load equations developed for the Susitna River at Tsusena Creek over the extended hydrologic record for the Susitna River. Due to the short record at this station, the information collected at Vee Canyon and the bedload and suspended load data collected at Gold Creek will be used to further refine Tsusena sediment rating curves. The methods described in the Empirically Characterize Susitna River Sediment Supply and Transport study component will be used to develop the incoming sediment load.

Sediment loading from the significant tributaries within the reservoir may also affect reservoir life. The reservoir tributary loading will be accounted for in the sediment load data collected for the Susitna River at Tsusena Creek. Similarly, if the sediment loading from the reservoir perimeter is substantial, it will be incorporated into the analysis. Potential additional sediment loading resulting from glacial surge will be investigated in the Glacier and Runoff Changes Study (Section 7.7.4.4, Analyze Potential Changes in Sediment Delivery to Watana Reservoir). If this investigation indicates that the increased sediment load can actually be delivered in substantial quantities to Watana Reservoir, more detailed analyses of the increased loading will be performed and a sediment loading scenario accounting for glacial surge will be added to the reservoir trap efficiency and sediment accumulation analysis. This would include an estimate of the reduction in reservoir life that could result from sediment loading associated with periodic glacial surges.

Due to the relatively large storage capacity of the proposed reservoir, it is reasonable to assume that all sand and coarser sediment size fractions delivered to the reservoir will be trapped, while a substantial amount of the fine-grained, colloidal sediments associated primarily with glacial outwash will pass through the reservoir into the downstream river. When applied over a long-term horizon, the amount of trapped sediment can be used to evaluate the impacts of sedimentation on reservoir storage capacity. If the analysis indicates that a substantial amount of fine sediment will deposit in the reservoir, consolidation of the deposits will also be considered in the analysis. (Note that consolidation of sands and gravels is minimal.) Potential methods for estimating the trap efficiency of the fine sediment include the relationships from Einstein (1965) and Li and Shen (1975). The latter method may be the most appropriate because it accounts for the tendency of suspended particles to be carried upward in the water column due to turbulence. Estimates of the trap efficiency for the fine sediment will be made using the Brune (1953) method. The Brune (1953) method that was recommended by Strand and Pemberton (1987) for use in large or normally-ponded reservoirs (Morris et al. 2007) can be used to check the reasonableness of results obtained from the other methods, although this method does not provide a means of separating the behavior of different particle sizes in the inflowing load. Chen (1975) may also be another method to check the reasonableness of the trap efficiency determination. The Churchill (1948) method is also commonly used to estimate reservoir trap efficiency; however, this method is more applicable for settling basins, small reservoirs, and flood-retarding structures and should probably not be used for this study. The proposed methods will provide a basis for estimating the quantity of the various size fractions that either pass through or are trapped in the reservoir. If the initial analyses indicate that a more sophisticated approach is necessary to obtain reasonable trap efficiencies, consideration will be given to using a numerical model such as Environmental Fluid Dynamics Code (EFDC) (Hamrick 1992) model to refine the estimates.

6.5.4.8.2.2. Delta Formation

Estimation of the formation of deltas on the mainstem Susitna River and its tributaries as they enter the proposed Watana Reservoir will require estimation of sediment load. Although the USGS measurements in the Bedload and Suspended Load Data Collection at Tsusena Creek, Gold Creek, and Sunshine Gage Stations study component target three locations along the Susitna River, sediment transport estimates will be needed at additional locations, including ungaged tributaries. Because of the potential impacts on fish movement into the tributaries, ungaged tributaries that require study will be identified in coordination with the Fish studies. In these locations, reconnaissance will be performed to characterize the sediment transport regime and to identify appropriate methods of calculating yields. In cases where bed material delivery to the proposed reservoir could produce deltas with the potential to affect upstream fish migration, surveys of tributary channel geometry and bed material gradations based on samples collected during the reconnaissance will be coupled with selected bed material transport functions to calculate sediment yield rating curves. Long-term flow hydrographs synthesized for the ungaged tributaries will be needed from other studies for each of the selected tributaries to calculate sediment yields. Alternate approaches to quantifying sediment yield, such as previous studies of regional sediment yields (Guymon 1974) may also be considered.

To estimate the development of the deltas, the sediment yield results can be coupled with the physical constraints imposed by Project operations (i.e., variation in lake levels) on the topset and foreset slopes of the deltas to simulate growth and development of deltas throughout the period of the license (USBR 1987; Morris and Fan 1998). The volume of sediments deposited will be distributed within the topographic constraints of the reservoir fluctuation zone identified for the period when mainstem and tributaries are delivering significant sediment load. Consideration will be given to which portion of the sediment load would form the delta deposits based on settling characteristics.

6.5.4.8.2.3. Reservoir Erosion

Erosion and mass wasting potential will be assessed within the reservoir fluctuation zone and along the shoreline for 100 vertical feet above the proposed full pool elevation. The following potential erosion processes will be evaluated:

- Mass wasting.
- Surface erosion from sheetwash.
- Wave erosion (wind and boat wakes if motorized boat recreation is permitted).
- Solifluction, freeze-thaw, and melting of permafrost.
- Beach/bank development at full pool.
- Erosion by ice movement on the reservoir surface.

The following existing spatial data will be collected:

- Topography (LiDAR as available).
- Geo-rectified aerial photography and recent stereo pairs to evaluate existing mass wasting sites.
- Geologic and soil mapping, including work done for the Susitna Hydroelectric Project (Acres 1982) and subsequent mapping by USGS and the Alaska Division of Geologic and Geophysical Surveys. This task will be coordinated with the Geology and Soils Study.
- Vegetation mapping; this task will be coordinated with the Botanical Resources Study.

In addition, the following information will be obtained from other resource study leads:

- Expected reservoir surface elevation fluctuations (seasonal, daily, maximum hourly lowering rate) from the Project Operation Study.
- Expected motorized watercraft recreational use data (if any, from the Recreation and Aesthetic Resources Study).
- Daily air temperature (maximum/minimum) and wind (speed, direction) data from the Water Quality Study.
- Expected ice development and movement within the reservoir from the Ice Processes study.

The existing spatial data will be evaluated to determine if sufficient geologic and soil data are available to evaluate erosion and mass wasting potential. The mass wasting work will be coordinated with the Geology and Soils Study and geotechnical investigations of the dam site and reservoir area that are planned under the geotechnical exploration and testing program. The geotechnical investigations for the dam site and reservoir will cover large, deep rotational and block failures; the Reservoir Erosion Study will cover shallow translational slides (added in response to the FERC comment letter dated May 31, 2012). The initial investigation will be completed by spring 2013. If additional soil/geologic mapping or data on soil characteristics are needed, field mapping and sample collection will occur during summer 2013 in coordination with the Geology and Soils, and Geotechnical studies. This work could include mapping or collection of soil properties of interest in representative areas, including soil texture, depth, permafrost presence/absence, infiltration capacity, and cohesion.

The spatial data (topography, geology, soils, vegetation) will be used to prepare an erosion and mass wasting hazard map of the reservoir shoreline and inundation area. Areas with similar slope, soil, aspect, and potential wave fetch will be delineated. Areas above and below the full pool elevation will be mapped separately.

The erosion potential for representative erosion/mass wasting hazard polygons will be evaluated as follows:

- Mass wasting – evaluate potential for mass wasting based on slope gradient, soil properties, and anticipated pore pressures/fluctuations. This work will be carried out in coordination with the geotechnical investigation of the dam site and reservoir area. A GIS-based model such as SHALSTAB may be used to analyze shallow translational slides if sufficient data exist.
- Surface erosion from sheetwash – estimate surface erosion potential using WEPP and/or RUSLE.
- Wind (aeolian) erosion from exposed reservoir and delta surfaces and the floodplain downstream of Watana Dam – evaluate using the USDA-NRCS WEQ (Wind Erosion Equation) or WEPS (Wind Erosion Production System) to provide information on dust production for the recreation and aesthetics studies (in response to request by USDOI-NPS in a letter dated May 24, 2012).
- Wave erosion (wind and boat wakes if motorized boat recreation is permitted) – estimate erosive energy of waves based on methods in Finlayson (2006) and Sherwood (2006).

- Solifluction, freeze-thaw, and melting of permafrost – evaluate potential based on soil properties, seasonal reservoir water elevations, and daily maximum/minimum temperatures.
- Beach/bank development at full pool – use the beach development model in Penner (Penner 1993; Penner and Boals 2000).
- Erosion by ice movement on the reservoir surface – evaluate potential for ice erosion based on reservoir elevation and coordination with the Ice Processes Study.

6.5.4.8.2.3.1. Bank and Boat Wave Erosion downstream of Watana Dam

It has been suggested that Project operations may cause increased bank erosion, i.e., cumulative to ongoing erosion associated with boat waves, particularly during load-following operations. (This effort was added based on requests from the agencies at the Water Resources TWG meeting on June 14, 2012.) Load-following will primarily occur during the winter months when flows are relatively low (in the range of 5,000 cfs to 14,500 cfs). Boat activity is relatively infrequent (or not present due to ice conditions) during this period; thus, cumulative impacts of these two processes are very unlikely. Based on preliminary information, it appears that the lower portion of the bank that would be affected by the load-following operations is well armored with cobble-sized material; thus, additional erosion due to the load-following alone is unlikely. The Project may reduce flows and the associated river stage during the runoff period in late spring and summer. During the initial phases of the study, data will be collected to assess the amount of armoring of the portion of the banks that will be affected by load-following to assess whether or not bank erosion in this zone is likely. In addition, the bank material characteristics in the range of stages during the periods of frequent boat activity will be assessed under existing conditions and Project operations to determine if changes associated with the Project could cause an increase in bank erosion. If the information indicates the lower portion of the bank is not sufficiently armored and/or boat activity may cause an increase in erosion of the upper part of the bank, the magnitude of the potential effects will be investigated. Factors that may be considered include the following:

- The potential effects of rapid changes in stage, and the associated pore-water pressures on bank stability during the load-following period.
- The typical wave climate and frequency of use of the types of boats that operate in the reach (it is assumed that the boat types and frequency of use will be available from the Recreation studies).
- The change in erosion potential associated with the boat waves due to the change in stage under Project operations during the period of primary boat activity.

6.5.4.8.3. Study Products

The results of the Reservoir Geomorphology component will be included in the Geomorphology Report. Information provided will include the following:

- Determination of average annual trap efficiencies for sediment by general size characterization (clays, silts, sands, and gravels).

- Estimate of average annual sediment loading to the reservoir from the potential primary sources including the upstream Susitna River, reservoir tributaries, and shoreline erosion.
- Estimate of reservoir life based on extrapolation of the sedimentation rate.
- Sediment outflow rating curves to serve as downstream supply for the Fluvial Geomorphology Modeling Study.
- Discussion of the tributary delta formation processes and characterization of the estimated size, vertical extent, and morphology (topset and foreset slopes) of the deltas at the selected tributary mouths.
- Discussion of potential erosion areas within the proposed reservoir, including erosion type, relative erosion potential, Project-related factors affecting erosion, and potential mitigation measures.
- Map showing reservoir erosion hazard areas (completed in coordination with the Geology and Soils and Geotechnical studies).

In addition, an ArcGIS shapefile will be provided with the following information:

- Identification of all tributaries studied for potential tributary delta formation.
- Estimated footprint of delta formation for the selected tributaries.
- Reservoir erosion hazard map units.

6.5.4.9. Study Component 9: Large Woody Debris

The goal of the Large Woody Debris study component is to assess the potential for Project construction and operations to affect the input, transport, and storage of large woody debris in the Susitna River. Specific objectives include the following:

- Evaluation of large woody debris recruitment in the middle and lower river channels (including upstream of Watana Reservoir).
- Characterization of the presence, extent, and function of large woody debris downstream of the Watana Dam site.
- Estimation of the amount of large woody debris that will be captured in the reservoir and potential downstream effects of Project operation.

The study area for the Large Woody Debris study component includes the Susitna River from the mouth (RM 0) upstream to the confluence with the Maclaren River (RM 260).

6.5.4.9.1. Existing Information and Need for Additional Information

The role of large woody debris in the development of channel morphology and aquatic habitat has been widely studied in meandering and anastomosing channels. Large wood and wood jams can create pool habitat, affect mid-channel island and bar development, and create and maintain anastomosing channel patterns and side channels (Abbe and Montgomery 1996, 2003; Fetherston et al. 1995; Montgomery et al. 2003; Dudley et al. 1998). In addition, large wood can provide cover and holding habitat for fish and help create habitat and hydraulic diversity (summary in Durst and Ferguson 2000). Despite the wealth of large woody debris research, little is known of the role of large woody debris in the morphology and aquatic biology of braided, glacial rivers. Large woody debris may play a role in island formation and stabilization, as well as side channel and slough avulsion and bank erosion, although the role of large woody debris in altering hydraulics in the lower Susitna River may be limited due to the size of the river (J. Mouw, ADF&G, personal communication, May 14, 2012).

Construction and operation of the Project has the potential to change the input, transport, stability, and storage of large woody debris downstream of the Watana Dam site by changes to the flow regime, ice processes, and riparian stand development, and interruption of wood transport through the reservoir. An assessment of the source, transport, and storage of large woody debris in the Susitna River and the role of large woody debris in channel form and aquatic habitat is needed to evaluate the magnitude of these effects. Construction and operation of the Project will likely alter large woody debris input and transport downstream of the Watana Dam site. An assessment of the source, transport, and storage of large woody debris in the Susitna River and the role of large woody debris in channel form and aquatic habitat would provide data on the current status of large wood in the river which, in conjunction with data from the studies of hydrology, geomorphology, riparian and aquatic habitat, and ice processes, would be used to determine the potential effects of Project operations on large wood resources. The information can also be used to determine whether protection, mitigation and enhancement (PM&E) measures are necessary, such as a large woody debris management plan and handling of wood that accumulates in the reservoir.

6.5.4.9.2. Methods

Available recent and historic high-resolution aerial photography will be used to assess large woody debris characteristics in the Susitna River between the mouth and the Maclaren River. It is anticipated that large woody debris input, transport, and storage characteristics will vary along the length of the river. Four reaches have been initially delineated with distinct characteristics: downstream of the three rivers confluence; between the three rivers confluence and Devils Canyon; Devils Canyon; and upstream of Devils Canyon. However, the Geomorphically Similar River Segments delineated by the Aquatic Habitat and Geomorphic Mapping study will be used as a basis for final reach determination.

Large woody debris will be inventoried to the extent practical on the aerial photographs. Information regarding the sources of large woody debris, locations of large woody debris in the river channel, and the relationship of large woody debris to channel or slough habitat will be collected and correlated with bank erosion and riparian vegetation mapping from the geomorphology mapping and riparian habitat mapping studies to identify potential recruitment methods (Mouw 2011; Ott et al. 2001). If adequate historic aerial photographs are available, the stability of large wood pieces and jams between photo years will be assessed in representative areas of the river.

It is likely not possible to identify all wood on the aerial photographs. As a supplement to large woody debris information obtained from aerial photographs, a reconnaissance assessment of large woody debris in the Susitna River between the proposed Watana Dam Site and Willow was made in coordination with aquatic/riparian habitat mapping June 2012. This assessment suggested that the primary large woody debris input mechanisms in the Middle Susitna River are wind throw, wind snap, ice snap, and bank erosion. Wood was observed in association with scour pool, islands heads, side channels, and channel margins. The Chulitna River appears to provide a large amount of woody debris to the Susitna River downstream from Three Rivers, where the Susitna becomes braided with both stable, racked log jams and single non-stable piece of wood.

The objective of the 2013–2014 field studies will be to verify the large wood data collected from the aerial photographs and to provide more detailed field information on large wood input, stable/key piece size, large wood/aquatic habitat function, and large wood stability in the river. It is anticipated that the following types of large woody debris data will be collected as part of a field inventory of large wood in 2013–2014:

- GPS location (to correlate with geomorphology, aquatic, and riparian habitat mapping from other studies).
- Wood size class (based on diameter, length).
- Root wad status of attachment.
- Single piece, accumulation, or log jam.
- Decay class.
- Species if known.
- Input mechanism if known (windthrow, bank erosion, ice processes, etc.).
- Channel location (side; mid channel; side channel inlet, middle, outlet; associated with island or bar – and where on island or bar, etc.).
- In wetted or bankfull channel or potential input (leaning over bankfull channel).
- Function (scour pool, bar forming, island forming, side channel inlet protection, bank protection, aquatic cover, etc.).
- For log accumulations and jams: key piece size.

The aerial photograph and field inventories of large wood will be used to determine large wood input processes, large wood transport and storage, and how large wood is functioning in the Susitna River to influence geomorphic, riparian, and aquatic habitat processes. Based on estimated large wood input and transport upstream of the Watana Dam site, the potential effects of reservoir operation on trapping upstream large wood will be assessed. In addition, the potential for operation of the Project to alter large wood input and transport downstream of the dam site will be analyzed. The analysis will require coordination with other geomorphology component studies, and the sediment transport, ice processes, riparian habitat, aquatic habitat, and instream flow studies.

6.5.4.9.3. Study Products

The results of the large woody debris component will be included in the Geomorphology Report. Information provided will include the following:

- Existing large woody debris input mechanisms and source areas.
- Existing large woody debris loading by geomorphic zone.

- Observations and discussion of how large woody debris is currently functioning in the Susitna River, including a discussion of interactions with riparian and aquatic/fish habitat, geomorphic processes (sediment transport/channel forming processes), ice processes, and flows.
- Discussion of potential for Project construction and operation to affect large woody debris input and transport in the Susitna River.
- Map showing current large woody debris loading.

In addition, an ArcGIS shapefile will be provided with the following information:

- Location of large woody debris mapped from aerial photographs and during field visits.

6.5.4.10. Study Component 10: Geomorphology of Stream Crossings along Transmission Lines and Access Alignments

The goals of the Geomorphology of Stream Crossings along Transmission Lines and Access Alignments study are to characterize the existing geomorphic conditions at stream crossings along access road/transmission line alignments and to determine potential geomorphic changes resulting from construction, operation, and maintenance of the roads and stream crossing structures.

6.5.4.10.1. Existing Information and Need for Additional Information

Development of the Watana Dam will require road transportation from either the Denali Highway or the railroad near Gold Creek or Chulitna to the dam site as well as a transmission line from the powerhouse to an existing transmission line intertie. Construction, use, and maintenance of the roads and transmission lines have the potential to affect stream geomorphology if stream crossing structures constrict flow or alter transport of sediment or large wood, or if sediment is delivered to the streams from erosion of the road prism.

Three different access/transmission alignments are currently being considered (Figure 6.5-7). Work currently underway may refine or change the number of alignments that are finally considered for the project, and may include upgrades to existing road systems (e.g., Denali Highway). The Geomorphology of Stream Crossings along Transmission Lines and Access Alignments study area will include the corridors that are under consideration at the beginning of the study work in 2013.

The three alignments currently under consideration are designated as Denali, Chulitna, and Gold Creek. The Alaska Department of Transportation and Public Facilities (ADOT&PF) evaluated potential access corridors, including the Denali and Chulitna options (HDR 2011). The analysis considered the number of stream crossings as one criterion, among many others, during the screening process, but a detailed analysis of the geomorphic effects of the stream crossings on bedload transport, large woody debris, and channel functions was not conducted.

A road in the Denali alignment would cross Seattle Creek and Brushkana Creek, two major drainages within the Nenana River watershed, and Deadman Creek within the Susitna River watershed. A road in this alignment would require a total of 15 stream crossings. A Gold Creek access alignment would require 23 stream crossings. The major streams that would be crossed by the Gold Creek access alignment include Gold Creek, Fog Creek, and Cheechako Creek.

Smaller streams crossed include tributaries to Prairee and Jack Long creeks, and a number of unnamed tributaries to the Susitna River. A road in the Chulitna alignment would require about 30 stream crossings including the Indian River, and Thoroughfare, Portage, Devils, Tsusena, and Deadman creeks. The Chulitna alignment would also cross 10 small, unnamed tributaries of Portage Creek, three small tributaries of Devils Creek, seven smaller tributaries to the upper Susitna River, and two tributaries of Tsusena Creek. Construction of Project access roads and transmission lines would require stream crossing structures. Stream crossing structures have the potential to affect stream geomorphology in the following ways:

- Altering hydraulics upstream and downstream of the crossing if flow is constricted. This can lead to sediment deposition upstream of the crossing or bank erosion/channel incision downstream.
- Altering migration of streams across a floodplain.
- Inhibiting movement of large woody debris.
- Increasing sediment delivered to a stream if road erosion is occurring near stream crossings.

Data collected during this study will help determine the potential for proposed stream crossings to affect stream hydraulics, morphology, sediment transport, and large woody debris transport. This analysis will also provide data needed for design of appropriate stream crossing structures and PM&E measures to minimize effects.

6.5.4.10.2. Methods

The following data would be obtained from existing sources:

- Topography at stream crossings.
- Aerial photography of stream crossings.
- Crossing design – information on the culvert or bridge characteristics planned at each crossing will be obtained from Project engineering designs (HDR 2011 and subsequent reports).
- Road design – information on the proposed road prism in the vicinity of stream crossings will be obtained from Project engineering designs, including surfacing, gradient, expected traffic levels, and road prism width.

A field assessment of each stream crossing along routes being considered will be made during the summer of 2013. Fieldwork will be carried out in conjunction with the Aquatic Resources Study (Access Alignment, Transmission Alignment and Construction Area component), if possible. The following geomorphic information will be collected for each stream crossing:

- Stream characteristics – gradient, wetted and bankfull width, and depth.
- Substrate characteristics – existing substrate size and description of relative sediment loading (based on field evidence of fresh deposits, large gravel bars, etc.).
- Existing large woody debris size and loading.
- Geomorphic channel type (Rosgen classification is recommended by USFS in its study request dated May 31, 2012) and confinement.

- Existing and potential for bank erosion will be measured or evaluated for a minimum of 100 feet upstream and downstream of each proposed crossing.
- Potential for channel migration will be evaluated from aerial photographs if available, supplemented by field/aerial observations.

The potential effects of stream crossings on geomorphology will be analyzed based on stream characteristics and the proposed design of crossing structures. The evaluation will include the following:

- Channel morphology, sediment dynamics – the hydraulic characteristics and bedload transport capacity of existing channel and of proposed crossing structures will be estimated and compared. Guidelines in the existing stream crossing design Memorandum of Agreement (MOU) will be considered (ADOT&PF 2001).
- Channel migration zone – the existing channel migration zone will be mapped for alluvial channels that show evidence of migration across the floodplain. Effects of proposed crossing structures on channel migration will be analyzed.
- Large woody debris transport – potential effects on large woody debris transport will be evaluated based on channel crossing type and width. The potential for culvert plugging will be ranked based on observed large woody debris size in the stream and proposed culvert size.
- Erosion and delivery of road sediment to stream – erosion from any unpaved roads will be estimated using the WEPP or SEDMODL algorithms. Wind (aeolian) erosion from unsurfaced areas (roads, parking areas, airstrip, etc.) will be evaluated using the U.S. Environmental Protection Agency (EPA) methodology (AP-42) to provide information on dust production for the recreation and aesthetics studies. (This effort was added in response to a request by USDOI-NPS in a letter dated May 24, 2012.)

6.5.4.10.3. Study Products

The results of the Geomorphology of Stream Crossings along Transmission Lines and Access Alignments component will be included in the Geomorphology Report. This will include a discussion of the potential effects of road/transmission alignments on the following:

- Channel migration zones (potential effects of crossings on stream and vice versa)
- Channel aggradation/erosion upstream and downstream of crossing
- Blocking large woody debris transport
- Increased turbidity/sediment input to streams

6.5.5. Consistency with Generally Accepted Scientific Practice

The methods described for geomorphology are similar to those used for other recent hydroelectric project licensing procedures and follow current scientific literature (see Literature Cited, Section 6.5.8).

- The Geomorphic Classification component will use a combination of the numerous river classifications that currently exist (Leopold and Wolman 1957; Schumm 1963, 1968;

Mollard 1973; Kellerhals et al. 1976; Brice 1981; Mosley 1987; Rosgen 1994, 1996; Thorne 1997; Montgomery and Buffington 1997; Vandenberghe 2001).

- The Bedload and Suspended Load Data Collection component will be conducted by USGS using its currently accepted field methods.
- The Sediment Supply and Transport in the Middle and Lower River component will use published USGS sediment and flow data and USGS-endorsed correction factors to develop rating curves (Cohn and Gilroy 1992; Duan 1983). Bed mobilization and effective discharge will be computed using currently recognized methods (Mueller et al. 2005; Biedenharn et al. 2000).
- The Geomorphic Change Analysis and Habitat versus Flow components will use geo-rectified aerial and satellite images to compare the river between years and flows. These methods are widely used to compare changes in river systems.
- The Reconnaissance-Level Assessment of Geomorphic Change in the Lower River will utilize published USGS flow and sediment data and the analytical framework developed by Grant et al. (2003).
- The Reservoir Geomorphology Study will use several widely-accepted methods to calculate sediment trap efficiency (Churchill 1948; Brune 1953; Einstein 1965; Miller 1953; Lara and Pemberton 1965; Chen 1975). The delta formation study will use methods developed and applied at similar projects (e.g., Boundary Hydroelectric Project, FERC 2144) to analyze delta formation. Reservoir erosion will use models and analysis methods developed and widely used for either general erosion (e.g., SHALSTAB, WEPP/RUSLE) or for reservoir-based beach development (Penner 1993; Penner and Boals 2000).
- The Large Woody Debris Study component and large wood inventory will be based on widely used methods (Shuett-Hames et al. 1999).
- The Geomorphology of Stream Crossings along Transmission and Access Alignments component will use guidelines from the existing stream crossing design MOU (ADOT&PF 2001) along with site-specific analyses of channel dynamics.

6.5.6. Schedule

The primary field effort is the USGS data collection effort (Study Component 2). It was conducted in the late spring and summer of 2012. A total of five sets of sediment transport data were collected at the Susitna River above Tsusena Creek, Susitna River near Talkeetna (substituted for Gold Creek), and the Susitna River at Sunshine and four sets on the Chulitna River below canyon. Provisional results of the data collection effort will be delivered to the other studies as soon as they are available from the lab during fall 2012. Suspended and bedload data, including calculation of sediment transport ratings and daily loads, will be compiled in a technical memorandum delivered early in 2013.

Performing the digitization of the 2012 aerial photography was dependent on the AEA SDC being able to fly the aerials at the appropriate discharge. Due to the combination of weather and flow conditions during 2012, only the 23,00cfs aerial photography was acquired in 2012. The remainder of the effort—12,500 cfs and 5,100 cfs aerial photography—will be completed in 2013. The schedule for conducting the Geomorphology Study is presented in Table 6.5-2.

A flow chart describing study interdependencies (Figure 6.5-8) outlines the information and products required from other studies and the timing of delivery to successfully complete the Geomorphology Study on schedule. The chart indicates which components of the Geomorphology Study require the information. The chart also shows products and information the Geomorphology Study will provide to other studies and the timing of their delivery. [*Additional Text describing the study interdependencies will be provided in the next version of the RSP*].

6.5.7. Level of Effort and Cost

Initial planning level estimates of the costs to perform the components of the Geomorphology Study are provided in Table 6.5-4. The total effort for the Geomorphology Study, including Component 2, Sediment Data Collection, to be performed by the USGS, is estimated to cost between approximately $1.5 and $2.0 million.

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6.5.9. Tables

Table 6.5-1. Initial geomorphic reach classifications

Reach Designation	Upstream Limit RM)	Down- stream Limit (RM)	Reach Classifi-cation	Slope (ft/mi)	Lateral Constraints
Upper River Segment (UR)					
UR-1	260	248	SC2	NA	Quaternary Basin Fill
UR-2	248	233	SC1	NA	Quaternary Basin Fill
UR-3	233	223	SC1	NA	Quaternary Basin Fill
UR-4	223	206	SC2	NA	Granodiorite
UR-5	206	201	SC1	NA	Quaternary Basin Fill
UR-6	201	184	SC2	NA	Quaternary Basin Fill
Middle River Segment (MR)					
MR-1	184	182	SC2	9	Gneiss
MR-2	182	166.5	SC2	10	Quaternary Basin Fill
MR-3	166.5	163	SC2	17	Granites
MR-4	163	150	SC1	30	Granites
MR-5	150	145	SC2	12	Moraine and Turbidites
MR-6	145	119	SC3	10	Moraines
MR-7	119	104	SC2	8	Moraines
MR-8	104	98.5	MC1/SC2	8	Holocene Lacustrine and Alluvial Terrace deposits
Lower River Segment (LR)					
LR-1	98.5	84	MC1	5	Upper Pleistocene Outwash, Moraine and Lacustrine deposits
LR-2	84	61	MC1	5	Upper Pleistocene Outwash, Moraine and Lacustrine deposits
LR-3	61	40.5	MC3	4	Glaciolacustrine and Moraine deposits
LR-4	40.5	28	MC3	2	Glaciolacustrine and Moraine deposits
LR-5	28	20	SC2	2	Glaciolacustrine and Moraine deposits
LR-6	20	0	MC4	1.4	Glaciolacustrine and Holocene Estuarine deposits

Table 6.5-2. Middle River aquatic habitat from 1980s to be digitized.

Site Name	River Mile (RM)		Length (Miles)
	Downstream RM	Upstream RM	
Whiskers Slough	100.7	102.0	1.3
Slough 4	105.0	106.5	1.5
Slough 5	107.0	108.5	1.5
Slough 6A	112.0	113.0	1.0
Slough 8	113.4	115.4	2.0
Oxbow II	118.5	120.5	2.0
Slough 8A	124.3	126.6	2.3
Slough 9	128.0	129.5	1.5
Side Channel 10A	131.0	132.8	1.8
Side Channel 10	133..0	134.3	1.3
Slough 11	134.3	136.8	2.5
Gold Creek	136.8	138.3	1.5
Indian River	138.5	139.5	1.0
Slough 21	140.0	142.6	2.6
Slough 22	144.0	145.0	1.0
Fat Canoe Island	146.5	147.5	1.0
TOTAL LENGTH	-	-	25.8

Table 6.5-3. Schedule for implementation of the Geomorphology Study.

Activity	2012				2013				2014				2015	
	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1Q	2Q
Develop Geomorphic Classification System / Finalize Classification System		—	—	—	—●									
Initial Geomorphic Reach Delineation / Finalize Delineation			—●			—	—●							
Identify and Map Paleo Geomorphic Features and Geology / Field Verify			—	—	—	/	—●							
Determine Morphometric Parameters (sinuosity, slope, topwidth, etc…)			—	—	—	—	—●							
Identify Key Governing Geomorphic Processes			—	—	—	—	—●							
Acquire Aerial Photo / Complete Aerial Acquisition (if not Completed in 2012)			—	—	/	—	—	—						
Digitize 1980s Habitat and Geomorphic Features			—	—										
Digitize 2012 Habitat and Geomorphic Features / Complete Habitat Effort				—	—	/	—	—						
Assess Habitat Area Change 1980s to 2012				—	—●			—	—●					
Assess Channel Change 1980s to 2012				—	—●			—	—●					
Initial Flow Assessment / Final Flow Assessment				—	—● /	—	—●							
Determine Effective Discharge and Characterization of Bed Mobilization						—	—●							
Initial Sediment Balance / Detailed Sediment Balance for Modeling				—	—● /	—	—	●						
Recon. Level Assessment of Potential Lower River Channel Change				—	—●									
Large Woody Debris						—	—	—	—	—	—			
Reservoir Geomorphology						—	—	—	—	—	—			
Geomorphology of Stream X-ings along Access & Transmission Line Corridor						—	—	—	—	—	—			
Integration with & Support of Interpreting Fluv. Geomorph. Modeling Results					—	—	—	—	—	—	—	—		
Initial Study Report /Updated Study Report									—Δ			—	—▲	

Legend:
— Planned Activity
● Technical Memorandum or Interim Product
Δ Initial Study Report
▲ Updated Study Report

Table 6.5-4. Geomorphology Study costs

Study Component	Estimated Cost Range
1 Geomorphic River Segment Delineation	$60k to $80k
2 Sediment Data Collection	$400k to $550k
3 Sediment Supply and Transport Assessment	$60k to $90k
4 Geomorphic Change Middle and Lower River	$80k to $120k[1]
5 Riverine Habitat Middle River	$200k to $300k[1]
6 Recon Assessment Lower River Project Effects	$40k to $60k
7 Riverine Habitat Lower River	$100k to $150k[1]
8 Reservoir Geomorphology	$140k to $180k
9 Large Woody Debris	$80k to $120k
10 Geomorphology of Stream Crossings	$80k to $140k

[1] Includes acquisition of orthorectified aerial imagery

6.5.10. Figures

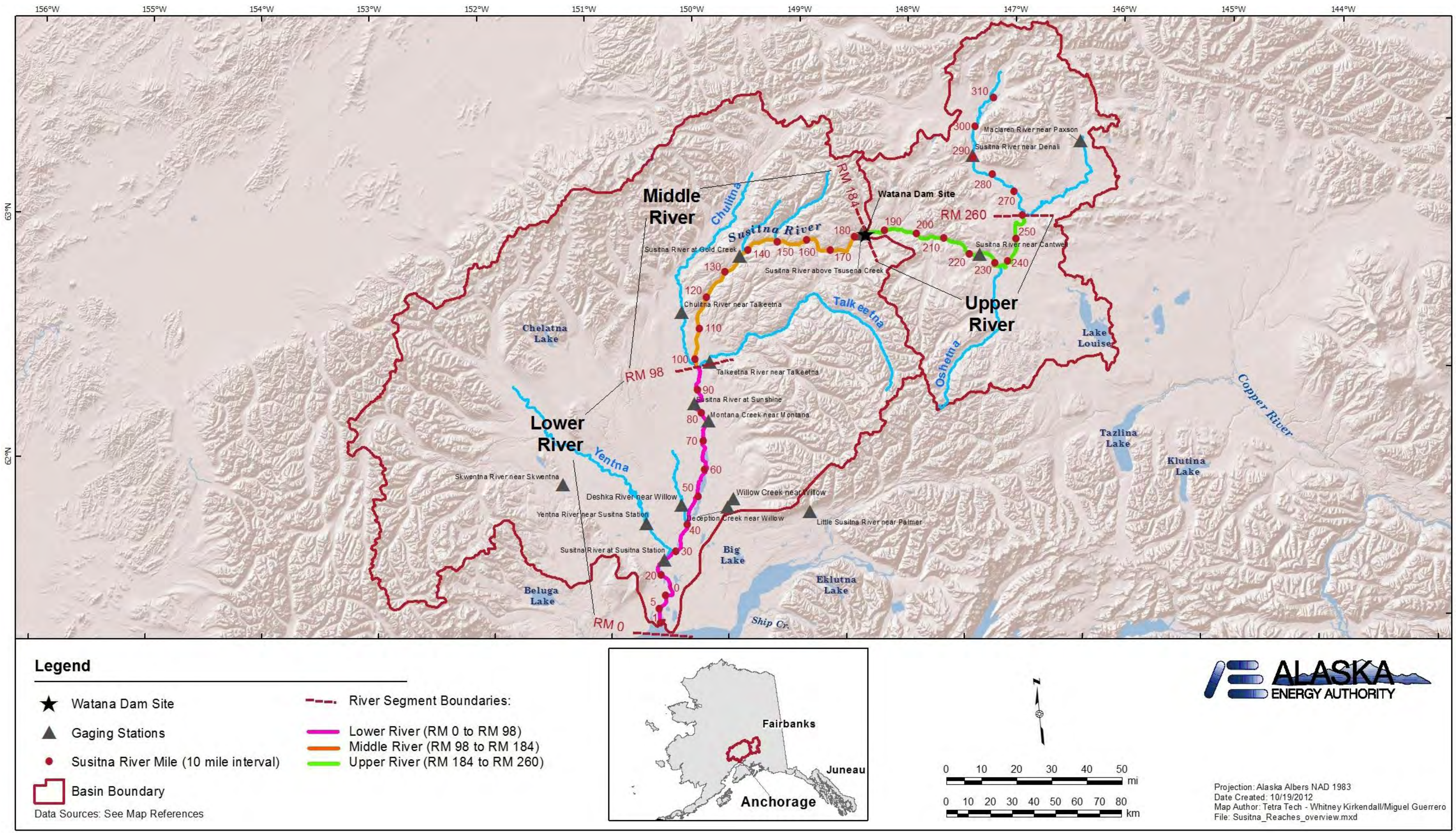

Figure 6.5-1. Susitna River Geomorphology study area and large-scale river segments.

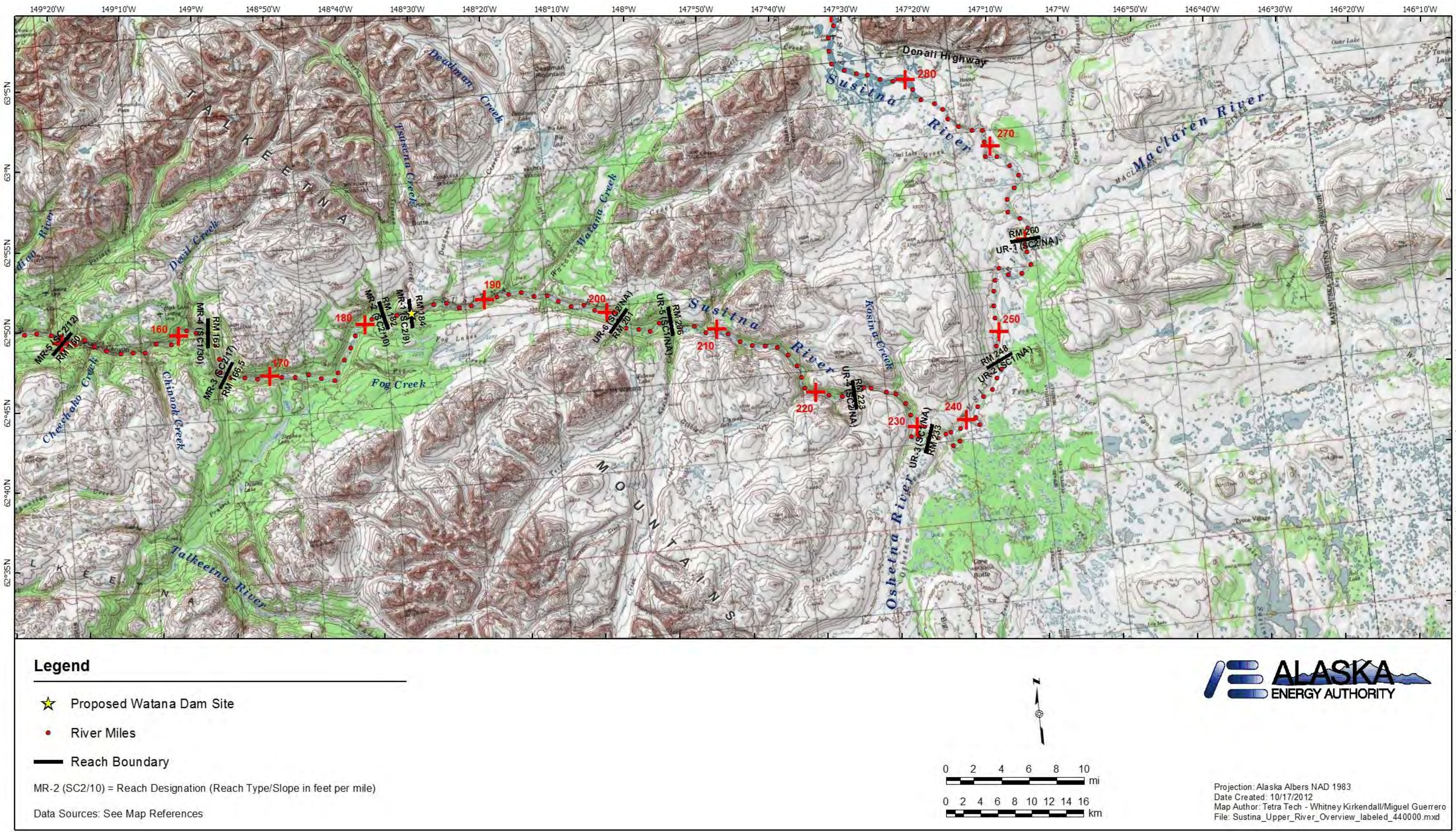

Figure 6.5-2. Upper River Geomorphic reaches.

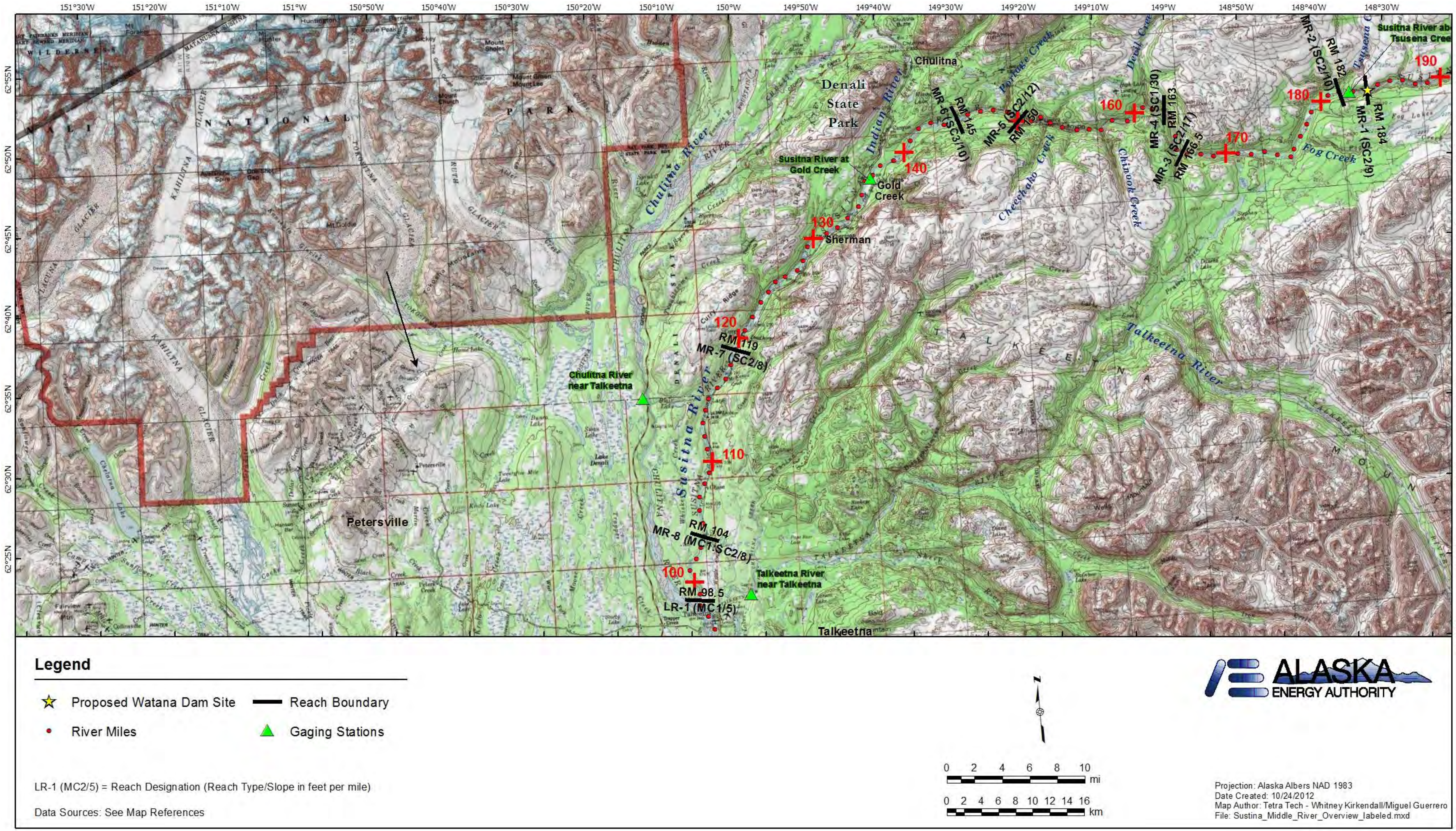

Figure 6.5-3. Middle River Geomorphic reaches.

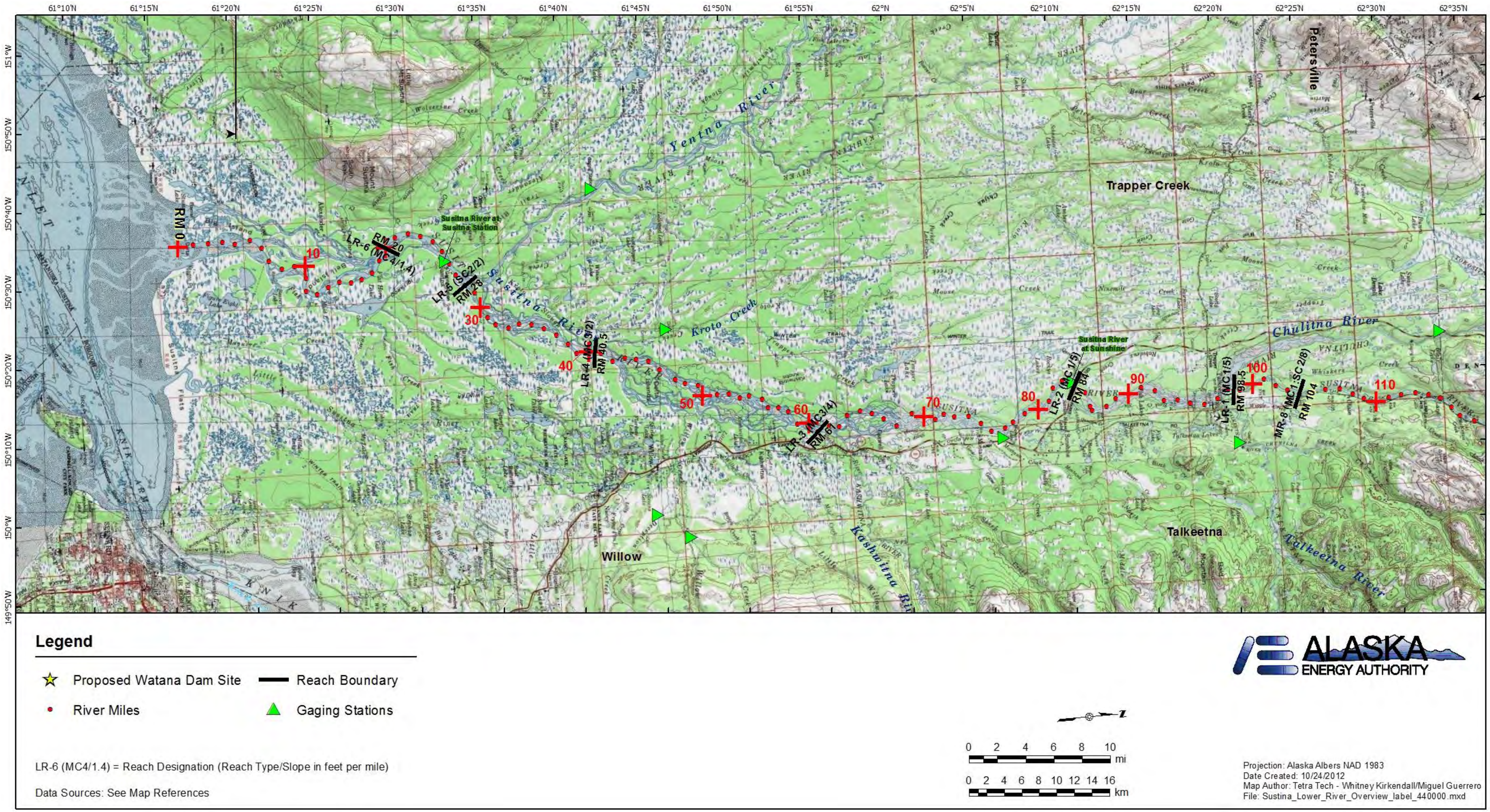

Figure 6.5-4. Lower River Geomorphic reaches.

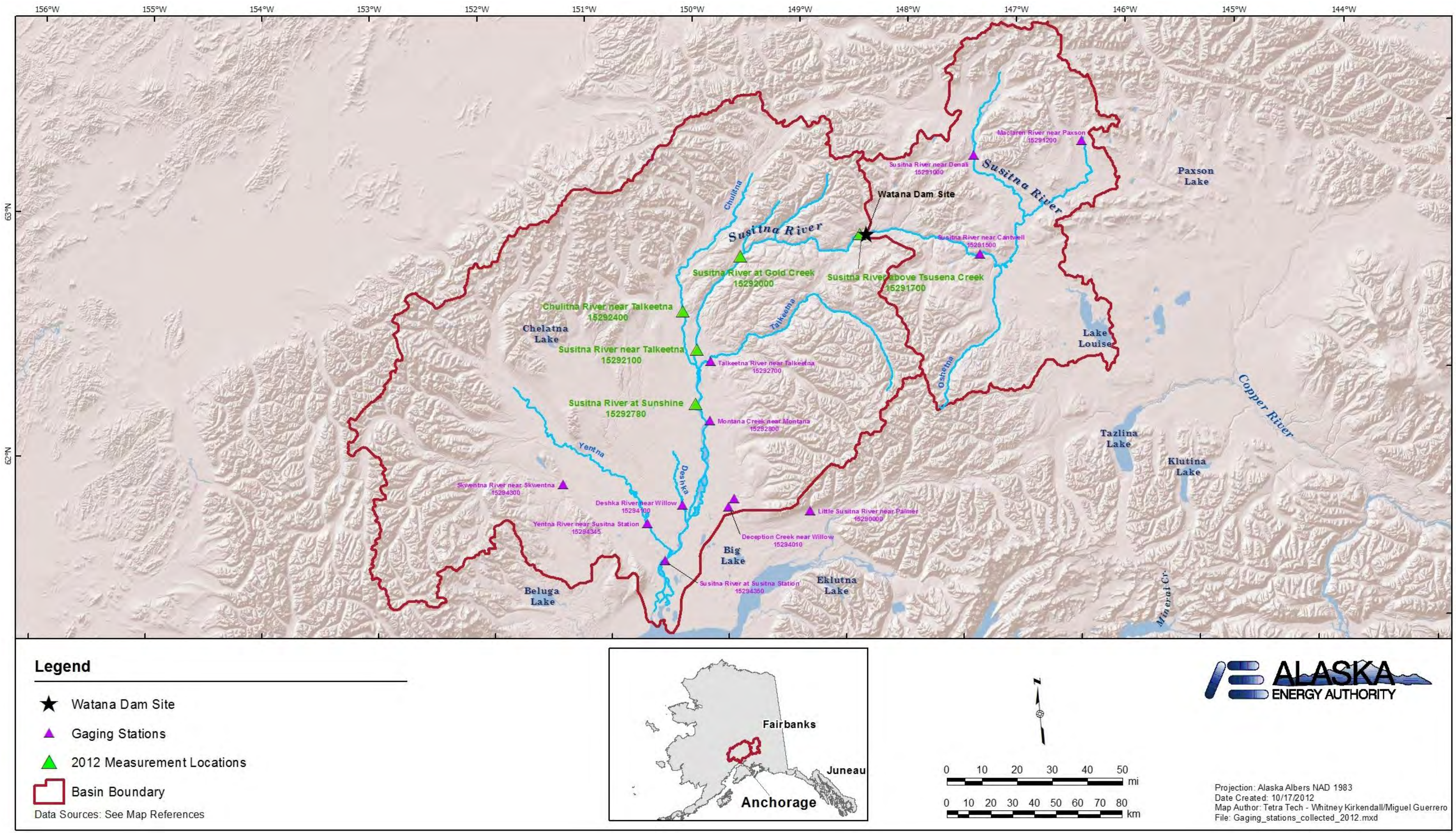

Figure 6.5-5. USGS Susitna River basin gaging stations and 2012 measurement locations.

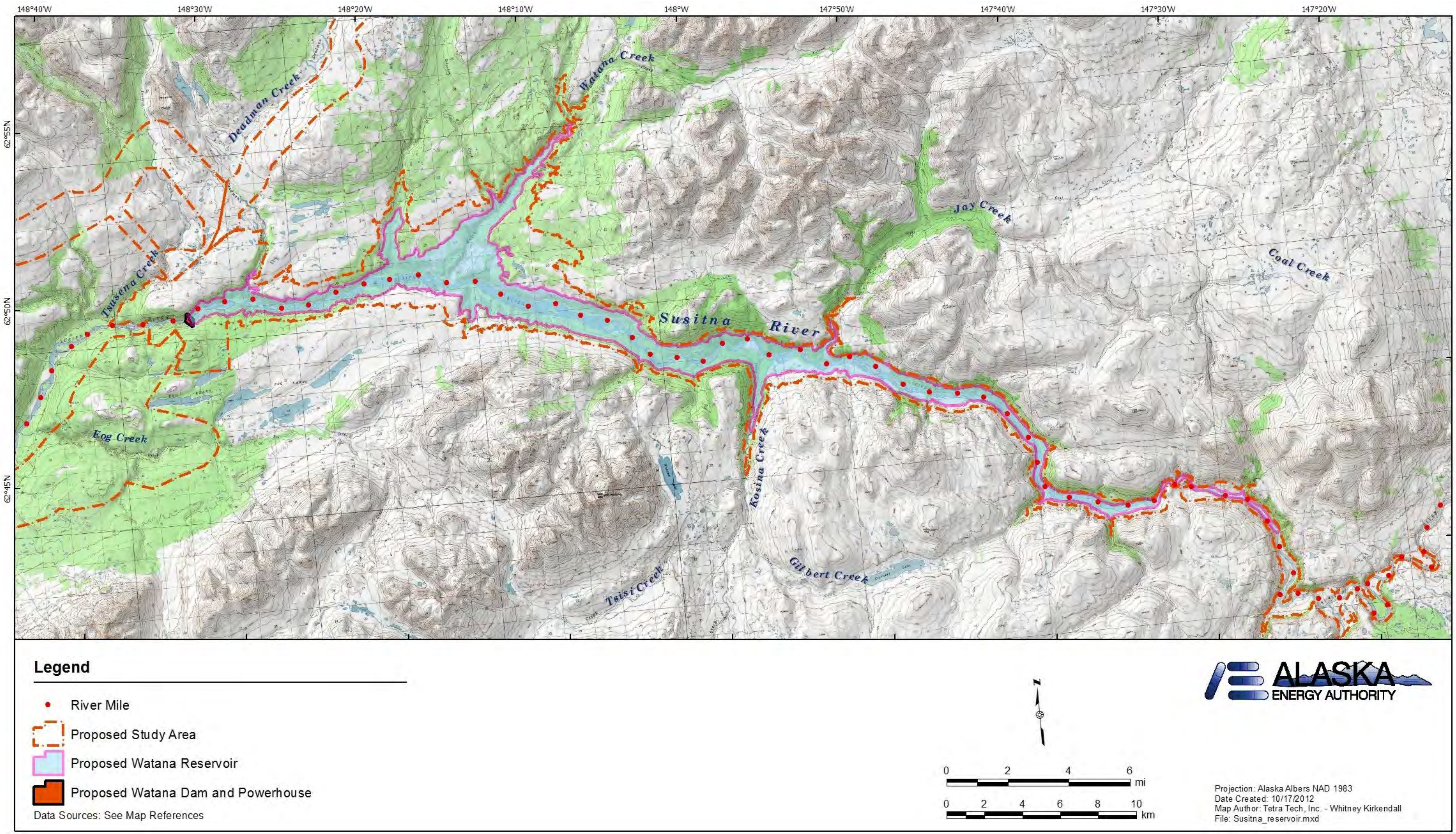

Figure 6.5-6. Susitna-Watana Geomorphology Study reservoir geomorphology study area.

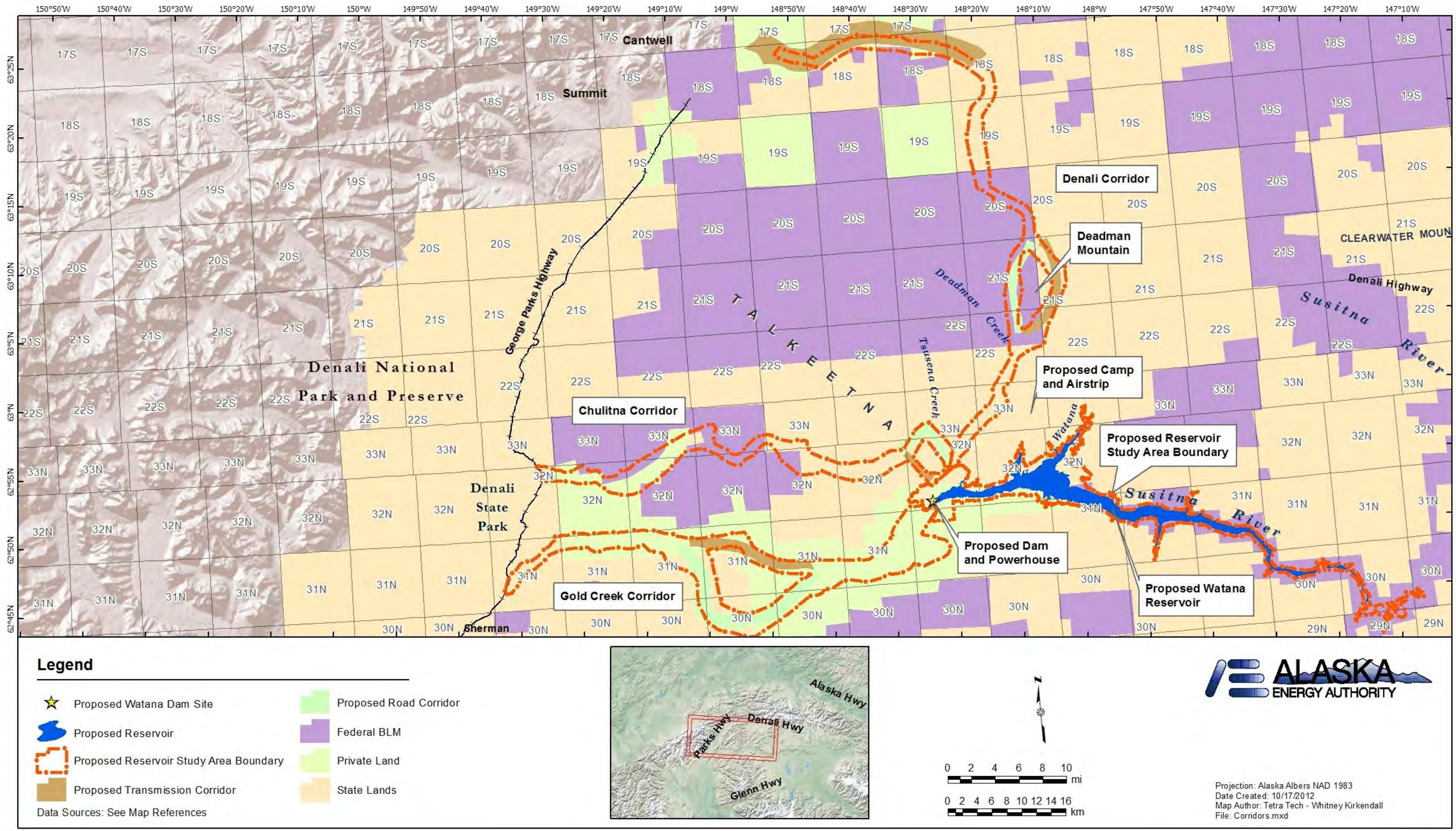

Figure 6.5-7. Susitna-Watana access corridors.

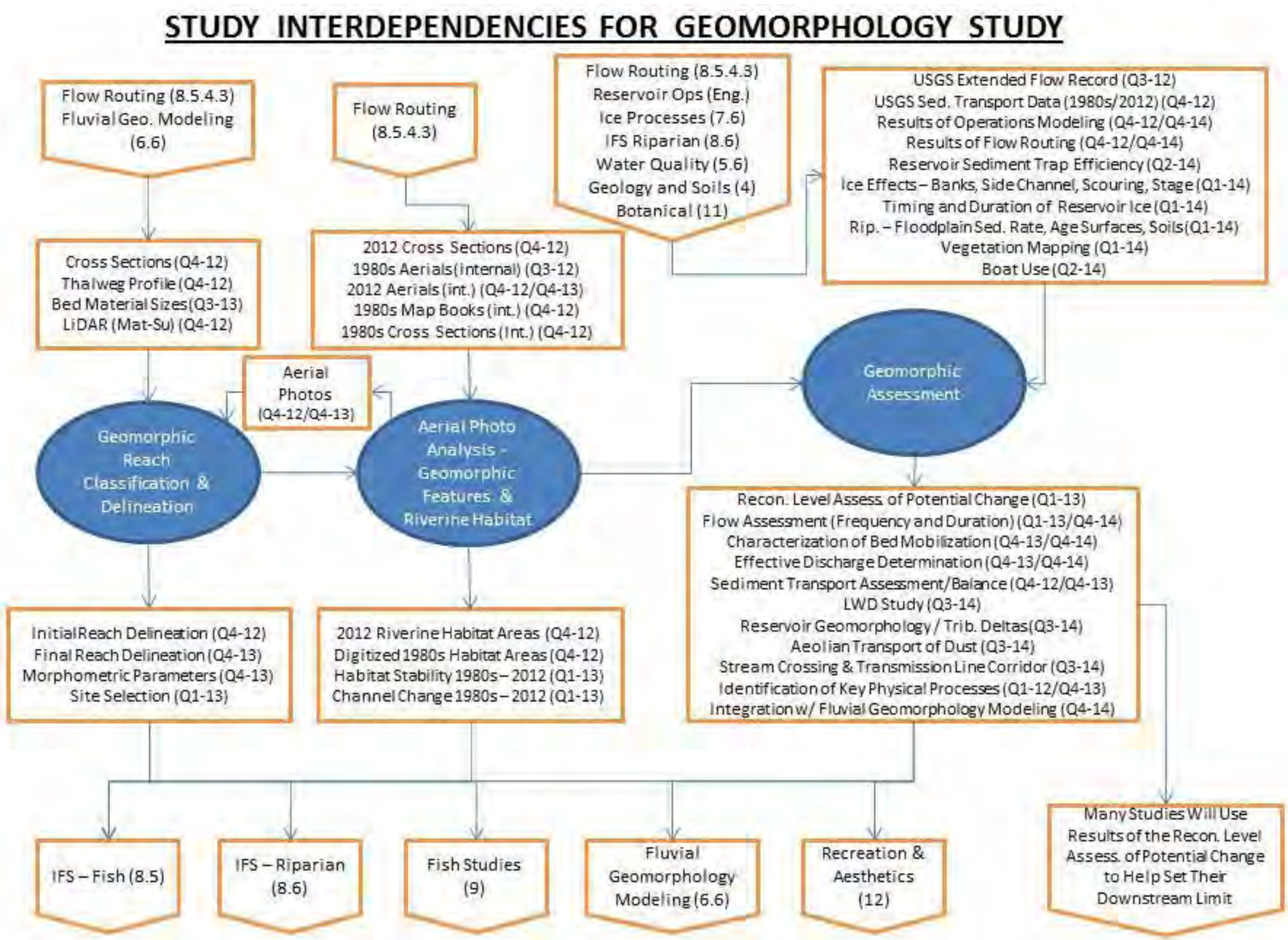

Figure 6.5-8. Study interdependencies for the Geomorphology Study.

6.6. Fluvial Geomorphology Modeling below Watana Dam Study

6.6.1. General Description of the Proposed Study

The overall goal of the Fluvial Geomorphology Modeling below Watana Dam Study is to model the effects of the proposed Project on the fluvial geomorphology of the Susitna River to assist in predicting the trend and magnitude of geomorphic response. More specifically, the purpose of the modeling study, along with the Geomorphology Study (Section 6.5), is to assess the potential impact of the Project on the behavior of the river downstream of the proposed dam, with particular focus on potential changes in instream and riparian habitat. Whether the existing channel morphology will remain the same or at least be in "dynamic equilibrium" under post-Project conditions is a significant question in any instream flow study (i.e., Is the channel morphology in a state of dynamic equilibrium such that the distribution of habitat conditions will be reflected by existing channel morphology, or will changes in morphology occur that will influence the relative distribution or characteristics of aquatic habitat over the term of the license? [Bovee 1982]). This key issue prompts four overall questions that must be addressed by the two geomorphology studies:

- Is the system currently in a state of dynamic equilibrium?
- If the system is not currently in a state of dynamic equilibrium, what is the expected evolution over the term of the license?
- Will the Project affect the morphologic evolution of the Susitna River compared to pre-Project conditions?
- If the Project will alter the morphology of the river, what are the expected changes over the term of the license?

The methods and results from the Geomorphology Study and the Fluvial Geomorphology Modeling Study will address these questions.

Specific objectives of this study are as follows:

- Develop calibrated models to predict the magnitude and trend of geomorphic response to the Project.
- Apply the developed models to estimate the potential for channel change for with-Project operations compared to existing conditions.
- Coordinate with other studies to provide channel output data to support the evaluation of Project effects in their resource areas.

6.6.2. Existing Information and Need for Additional Information

Sediment transport issues downstream of Watana Dam are expected to stem from the influences of the regulated outflows and the deficit of sediment supply due to trapping of sediments in the reservoir. These issues are particularly important because fish resources have the greatest potential to be affected by the Project, and most of the potential impacts would occur downstream of the Project (AEA 2010). The effect of altered flows on anadromous and resident fish habitats and their associated populations was the major focus of studies conducted in the 1980s (APA 1984). The major fish habitats are located in the Susitna River, side channels, side sloughs, upland sloughs, and tributary mouths (APA 1984).

Modeling of the hydraulics of the Susitna River below the previously proposed project, a necessary step in developing a sediment transport model, was performed in the 1980s. This work included development and application of one-dimensional HEC-2 hydraulic models to support the calculation of water-surface profiles and channel hydraulics (Acres 1983). The models represented the reach between Devils Canyon (Susitna RM 186.8) and Talkeetna (RM 99), excluding Devils Canyon (Susitna RM 162.1 to RM 150.2). The Aquatic Resources Data Gap Analysis (HDR 2011) indicates that sediment transport modeling of a portion of the Susitna River was also undertaken. Realizing the complexity of the sediment transport problem at the Chulitna River confluence, APA commissioned the Iowa Institute of Hydraulic Research to develop a quasi-steady, one-dimensional numerical model of sediment transport for the 14-mile reach of the Susitna River from the Chulitna confluence downstream to Sunshine Station (Holly et al. 1985). The model was based on sediment transport data from 1981 and 1982, as the following years of data collection had not yet been completed. The topography was derived from 28 cross-sections (approximately 1 every ½ mile) measured by R&M Consultants and aerial photography (Ashton and R&M 1985). The model was still in development as of the writing of the 1985 report; however, the companion report, referenced in Holly et al. (1985), was not found in the Susitna documentation.

The Aquatic Resources Data Gap Analysis (HDR 2011) indicates that channel equilibrium, an important macrohabitat variable, was not addressed in the APA Project instream flow study. The question of whether the existing channel morphology will remain the same, or at least be in "dynamic equilibrium" once the proposed action is implemented is a significant question in an instream flow study. Instream flow versus habitat relationships developed for today's river assume that similar relationships will persist for the duration of the project, within a reasonably defined range of variability. In the case of the proposed Project's instream flow study, the question is whether the river is currently in a state of equilibrium or disequilibrium. If it is in a state of disequilibrium, will the state be exacerbated or reversed as a result of the Project? If it is exacerbated or reversed, the impact of the Project cannot be assessed without estimating a post-Project channel configuration (Bovee et al. 1998). The same holds true if the river is currently in a state of equilibrium and shifts to disequilibrium for a significant period of time with the Project in place.

The AEA Susitna Water Quality and Sediment Transport Data Gap Analysis Report (URS 2011) concluded: "Numerical modeling of the sediment transport dynamics would provide a basis for comparing the changes in channel morphology and aquatic habitat associated with the proposed Project and the proposed operations." The Fluvial Geomorphology Modeling below Watana Dam Study addresses the need to develop a sediment transport model of the Susitna River. It was also indicated in the Data Gap Analysis Report (URS 2011) that further quantification of the sediment supply and transport capacity would help identify the sensitivity of the channel morphology (and associated aquatic habitats) to the effects of the proposed Project. The report indicated that information on sediment continuity could provide a basis for evaluating whether the Susitna River below the Chulitna confluence would be at risk of aggradation, and if so, whether the magnitude would alter aquatic habitats and hydraulic connectivity to these habitats. URS (2011) also pointed out that side channels and sloughs are of particular importance to fisheries, and changes to the relationships between flow and stage at which the habitats are accessible could affect the fisheries. These relationships can be affected by not only flow distribution, but also changes in the bed elevations due to sediment transport processes. Other impacts to the sediment transport regime could affect the cleaning of spawning gravels, hyporheic flows through redds, groundwater inflows, and hydraulic connectivity for out-migration to the main channel.

6.6.3. Study Area

The potential study area is the portion of the Susitna River from Watana Dam (RM 184) downstream to its mouth at the Cook Inlet (RM 0). The downstream limit of the modeling effort will be initially determined based on results of the Geomorphology Study concerning the potential for the Project to affect channel morphology in the lower river, and in coordination with other studies and the agencies. As a minimum, the study area for this effort includes the entire middle river from the Watana Dam site (RM 184) downstream to the three rivers confluence area (RM 98). (Note: Modeling of Devils Canyon will not be performed because this reach is considered too dangerous to perform cross-section and other surveys needed to develop the model. Devils Canyon will be assumed to be a stable, pass-through reach in terms of sediment transport due to the high level of bedrock control and steep gradient present in this reach.)

6.6.3.1. Focus Areas

The bed evolution modeling approach calls for the application of a 1D bed evolution model to predict the geomorphic response of the Susitna River to the Project for the entire study area (excluding Devils Canyon). To provide a higher level of detail and to model physical processes not adequately represented in a 1D bed evolution model, a 2D bed evolution model will be applied in to some or all of the "focus areas" (in some instances, it may be appropriate to apply a more detailed 1D bed evolution model or series of 1D models than a 2D bed evolution model). Focus areas will involve portions of the Susitna River and its floodplain where detailed study efforts will be jointly conducted by several study teams including the Fish Instream Flow, Riparian Instream Flow, Geomorphology, Ice Processes, Groundwater, and Fish studies. The focus areas will allow for a highly integrated, multidisciplinary effort to be conducted, evaluating potential Project effects for key resource areas across a range of representative sites.

The 2D models will be used to evaluate the detailed hydraulic and sediment transport characteristics on smaller, more local scales where it is necessary to consider the more complex flow patterns to understand and quantify the issue(s). The 2D models may be applied to specific focus areas, within the selected 1D modeling study area, that are representative of important habitat conditions and the various geomorphic reach types. If site conditions at a particular focus area do not warrant 2D bed evolution and associated hydraulic modeling, 1D modeling will be applied at that focus site. The decision on what type of modeling to apply to each focus area will be made as part of the site selection process conducted in collaboration with the stakeholders. In addition, the focus areas will be chosen jointly by the Instream Flow, Riparian Instream Flow, Geomorphology, Ice Processes, and Fish studies to facilitate maximum integration of available information among the studies. Sites will be chosen such that there is at least one focus area for each geomorphic reach (except reaches MR-3 and MR-4 where there are safety concerns associated with Devils Canyon) and the sites will cover the range of riverine aquatic habitat types. At least one unstable site, likely representative of a braided channel reach, will be included in the focus areas. If focus sites involve primary tributary deltas, 2D modeling will also be considered based on screening that considers the importance to the existing fishery and the potential for adverse project effects. The 2D hydraulic modeling could include the three rivers confluence area, though application of a 2D bed evolution model would likely be infeasible. (The distribution of the 2D sites is based on the study requests submitted by NOAA-NMFS and USFWS on May 31, 2012, and discussions during the June 14, 2012 Water Resources TWG meeting.)

6.6.3.2. Determination of Downstream Study Limit

The final spatial extent of the lower river modeling effort has not been determined; however, as a minimum, the 1D modeling will be continued downstream into the lower river to at least RM 75 approximately nine miles downstream of Sunshine Station (RM 84) (NOAA-NMFS and USFWS requested as a minimum the 1D modeling extend to Sunshine Station [study requests dated May 31, 2012]). The decision on whether to continue the 1D modeling further downstream in the lower river and whether detailed focus areas will be included in the lower river below RM 75 will be made based on an assessment of the potential for the Project to affect channel morphology in this portion of the reach as well as results of the summer flow routing, winter flow routing, and water quality modeling. An initial assessment of potential Project effects on channel morphology is being conducted in 2012 as part of the Geomorphology Study (Section 6.5.4.6 Reconnaissance-Level Assessment of Project Effects on the Lower Channel). The results of this assessment will be available by January 2013.

The technical memorandum detailing the results of the Reconnaissance-Level Assessment of Project Effects on the Lower River will be presented to and reviewed by the licensing participants as part of the first check-in on the proposed downstream study limit of RM 75. Discussions of the results and conclusion regarding the extent of Project effects on the geomorphology of the lower river and the decision on finalizing the downstream study limit for the 2013 efforts will occur at Technical Work Group Meetings to be held in February and/or March 2013. These discussions will include establishing the criteria for identifying whether Project effects potentially extend downstream of RM 75. It is an objective of the process to finalize the decision on the downstream study limit by the end of March 2013 to allow for planning of the 2013 field season.

The second check-in, from the geomorphology studies, on the downstream study extent will be based on the results of the 1D bed evolution model. If the results of the 1D modeling effort show differences between the modeled existing and the modeled with-Project conditions that are beyond the range of natural variability, the 1D modeling will be continued farther downstream in the lower river in 2014. The criteria for determining what constitutes natural variability will be made in collaboration with the licensing participants. As part of the process, a technical memorandum documenting the 1D modeling effort and its results will be prepared and distributed for review by the licensing participants in January 2014. A Technical Work Group meeting(s) will be held in February and/or March 2014. If it is determined that the results of the 1D modeling warrant extending the study limits farther downstream, the need for adding focus areas in the lower river will also be determined through consultation with the licensing participants and pertinent study leads at the February and March 2014 Technical Work Group meetings. Table 6.6-1 provides a summary of the steps and dates involved in the process that will be used to initially identify, reevaluate, adjust if necessary, and finalize the downstream study limit for the Fluvial Geomorphology Modeling Study.

It is noted that a variety of resource areas require determination of their downstream study limits. The determination for downstream study limits may also depend on the outcome of 2013 efforts being conducted for the Water Quality Modeling Study, the summer flow routing model (part of the Fish Instream Flow Study), and the winter flow routing model (part of the Ice Processes Study). Whether there is need to integrate Fluvial Geomorphology Modeling Study results with certain studies also depends on the final downstream limit for the modeling effort. Specifically, the Eulachon Study (Section 9.16) is limited to the downstream-most portions of the lower river and will not require input from the Fluvial Geomorphology Modeling Study if the modeling effort is not extended downstream of RM 75.

6.6.4. Study Methods

The Fluvial Geomorphology Modeling below Watana Dam is divided into three study components:

- Bed Evolution Model Development, Coordination, and Calibration
- Model Existing and with-Project Conditions
- Coordination on Model Output

Each of these components is explained further in the following subsections.

6.6.4.1. Study Component: Bed Evolution Model Development, Coordination, and Calibration

The overall goal of the Bed Evolution Model Development, Coordination, and Calibration study component is to develop a model that can simulate channel formation processes in the Susitna River downstream of Watana Dam.

6.6.4.1.1. Existing Information and Need for Additional Information

Modeling of hydraulics of the Susitna River below the proposed Project, a necessary step in developing a sediment transport model, was performed in the 1980s. One-dimensional HEC-2 hydraulic models were developed in the 1980s to support the calculation of water-surface profiles and channel hydraulics (Acres 1983). However, the 1980s effort did not include sediment transport modeling. Both 1D and 2D sediment transport models are required to characterize the bed evolution for both the existing and with-Project conditions in the Susitna River. This study component involves selection and development of the sediment transport models.

6.6.4.1.2. Methods

The Bed Evolution Model Development, Coordination, and Calibration study component is divided into three tasks:

- Development of Bed Evolution Modeling Approach and Model
- Coordination with other Studies on Processes Modeled
- Calibration/Validation of the Model

6.6.4.1.2.1. Development of Bed Evolution Model Approach and Model Selection

Development of the bed evolution model for a dynamic system such as the Susitna River is a complex undertaking that requires considerable investigation and coordination. The work in the lower and middle river contained in the Geomorphology Study provides a considerable part of the required investigation. Based on the study results and input from the Reservoir Operations and Flow Routing Model Development, Instream Flow, Instream Flow Riparian, Ice Processes, and Fish studies, models will be developed that represent the physical processes that control the dynamic nature of the Susitna River, and that will provide other studies with the required information on the potential changes in the channel and floodplain for their analyses.

Some of the important steps in the development of the modeling approach and model are as follows:

- Review and understand available data.
- Develop an understanding of the dominant physical processes and governing physical conditions in the study reach.
- Coordinate with other studies to understand their perspective on system dynamics, and the physical features and processes that are important to their studies.
- Identify an overall modeling approach that is consistent with the study goals, the constraints on information that is currently available or can practically be obtained, and the needs of the other studies.
- Identify a modeling approach that is consistent with the spatial and temporal scale of the area to be investigated.
- Determine the spatial limits of the modeling effort.
- Determine the time scales for the various models.
- Review potential models and select a model(s) that meets the previously-determined needs and conditions.
- Identify data needs and data gaps for the specific model and study area being investigated.
- Collect the required data to fill data gaps.
- Develop the model input.
- Identify information to be used to calibrate and validate the model.
- Perform initial runs and check basic information such as continuity for water and sediment, hydraulic conditions, magnitude of sediment transport, and flow distributions.
- Collaborate with other studies on initial model results.
- Refine model inputs.
- Perform calibration and validation efforts, to include comparison of modeled water-surface elevations, in-channel hydraulic conditions (e.g., velocity and depth), sediment transport rates, and aggradation/degradation rates with available measured data.
- Perform model runs for existing conditions to provide a baseline for comparison of with-Project scenarios.
- Work with other studies to develop scenarios to evaluate the potential Project effects, and apply the model to those scenarios.

- Coordinate with other studies to evaluate and define the appropriate format for presentation of the model results.
- Develop and run additional scenarios, as necessary, based on results from the initial scenarios and identified Project needs.

The following subsections outline the identified issues to be considered and summarize the development of the modeling approach, the model selection, and the model development.

Issues to be Considered: To develop the modeling approach, specific issues that need to be addressed have been identified. These specific issues have been further differentiated into reach-scale and local-scale issues because the scale influences the proposed approach.

Reach-Scale Issues: Reach-scale issues refer to aspects of the system that involve the overall behavior and general characteristics of the Susitna River over many miles. Each reach represents a spatial extent of the Susitna River that has a consistent set of fluvial geomorphic characteristics. Reach-scale issues include the following:

- Historical changes in the system and the existing status with respect to dynamic equilibrium.
- Changes in both the bed material (sand and coarser sizes) and wash (fine sediment) load sediment supply to the system due to trapping in Watana Reservoir.
- Long-term balance between sediment supply and transport capacity and the resulting aggradation/degradation response of the system for pre- and post-Project conditions.
- Changes in bed material mobility in terms of size and frequency of substrate mobilized due to alteration of the magnitude and duration of peak flows by the Project.
- Project-induced changes in supply and transport of finer sediments that influence turbidity.
- Potential for changes in channel dimensions (i.e., width and depth) and channel pattern (i.e., braiding versus single-thread or multiple-thread with static islands) due to the Project and the magnitude of the potential change.
- Project-induced changes in river stage due to reach-scale changes in bed profile, channel dimensions, and potentially hydraulic roughness.

Local-Scale Issues: Local-scale issues refer to aspects of the system that involve the specific behavior and characteristics of the Susitna River at a scale associated with specific geomorphic and habitat features. Local-scale issues are addressed using a more detailed assessment over a smaller spatial area; however, these analyses must draw from and build upon the understanding and characterization of the system behavior as determined at the reach scale. Local-scale issues include the following:

- Processes responsible for formation and maintenance of the individual geomorphic features and associated habitat types.
- Potential changes in geomorphic features and associated aquatic habitat types that may result from effects of Project operation on riparian vegetation and ice processes.

- Effects of changes in flow regime and sediment supply on substrate characteristics in lateral habitat units.
- Changes in upstream connectivity (breaching) of lateral habitats due to alteration of flow regime and possibly channel aggradation/degradation. These changes may induce further changes in the morphology of lateral habitats, including the following:
  - Potential for accumulation of sediments at the mouth.
  - Potential for accumulation of fines supplied during backwater connection with the mainstem.
  - Potential for changes in riparian vegetation that could alter the width of lateral habitat units.
- Project effects at representative sites on the magnitude, frequency, and spatial distribution of hydraulic conditions that control bed mobilization, sediment transport, sediment deposition, and bank erosion.
- Potential for change in patterns of bedload deposits at tributary mouths that may alter tributary access or tributary confluence habitat, as discussed below.

Tributary confluences are areas of interest for determining the potential Project effects on sediment transport and morphology. Modeling of tributary deltas is discussed as a topic separate from the mainstem.

Synthesis of Reach-Scale and Local-Scale Analyses: The final step in the effort will be the synthesis of the reach-scale and local-scale analyses to identify potential Project-induced changes in the relative occurrence of aquatic habitat types and associated surface area versus flow relationships. In addition to the results of the hydraulic and sediment transport modeling, this synthesis will require application of fluvial geomorphic relationships to develop a comprehensive and defensible assessment of potential Project effects. This type of integrated analysis has been performed in the past by the study team on several projects including: instream flow, habitat, and recreation flow assessments to support relicensing of Slab Creek Dam in California; a broad range of integrated geomorphic assessments and modeling to assist the Platte River Recovery Implementation Program in Central Nebraska; and ongoing work to support the California Department of Water Resources and Bureau of Reclamation to design restoration measures for the San Joaquin River in the Central Valley of California downstream of Friant Dam.

Development of Modeling Approach: The proposed modeling approach considers the need to address both reach-scale and local-scale assessments and the practicality of developing and applying various models based on data collection needs, computational time, analysis effort, and model limitations. Based on these considerations, an approach that uses 1D models to address reach-scale issues and 2D models to address local-scale issues is proposed. Considering the broad physical expanse of the Susitna River system, the general hydraulic and sediment transport characteristics of the various sub-reaches that make up the overall study area will be evaluated using 1D computer models and/or established hydraulic relationships. The 2D models will be used to evaluate the detailed hydraulic and sediment transport characteristics on smaller, more local scales where it is necessary to consider the more complex flow patterns to understand and quantify the issues. The 2D models will be applied to specific focus areas that are representative of important habitat conditions—the various channel classification types and selected primary tributaries. These sites will be chosen in coordination with the licensing participants and the Instream Flow, Riparian Instream Flow, Ice Processes, and Fish studies to facilitate maximum integration of available information between the studies.

The proposed approach to integrating 1D modeling at the reach-scale and 2D modeling at the local-scale will provide the following advantages:

- 1D modeling will allow for efficient assessment of the hydraulic conditions and sediment transport balance over the length of the study reach downstream of Watana Dam.
- The 1D model uses cross-sectional data that are being obtained as part of the Flow Routing and Instream Flow studies. (Note that some supplemental cross-sections may be required for the 1D sediment transport model.)
- The 1D model will provide the boundary conditions for the 2D model, including starting water-surface elevations and upstream sediment supply.
- 2D modeling applied at the focus areas that are also chosen for the Ice Processes and Riparian Instream Flow studies will allow for the fullest level of integration of these efforts, particularly as they relate to assessments of potential changes in channel width and pattern for this study.
- 2D modeling at the focus area will provide an understanding of the hydraulic conditions and sediment transport processes that contribute to formation of individual habitat types.
- 2D modeling provides a much more detailed and accurate representation of the complex hydraulic interaction between the main channel and the lateral habitats than is possible with a 1D model.

Model Selection: Many computer programs are available for performing movable boundary sediment-transport simulations. The choice of an appropriate model for this study depends on a number of factors, including (1) the level of detail required to meet the overall project objective(s); (2) the class, type, and regime of flows that are expected to be modeled; and (3) the availability of necessary data for model development and calibration. While 2D modeling would provide the most comprehensive assessment of hydraulic and sediment transport conditions in the study reach, the extent of required data, effort required for model development, and computational time required for execution to model the entire system make this impractical. Considering the very broad physical expanse of the overall Susitna River system, a one-dimensional (1D) computer model and/or engineering relationships that can be applied in a spreadsheet application is the most practical approach to modeling overall system behavior at the scale of the study reach. 2D modeling will then be used for evaluating the detailed hydraulic and sediment-transport characteristics that control the complex geomorphic features and habitat at the local scale. A variety of candidate models will be evaluated for application on the Susitna River. Potential candidate models for the 1D and 2D portions of the study are discussed below.

<u>General Discussion of 1D Models:</u> Most 1D movable boundary sediment-transport models are designed to simulate changes in the cross-sectional geometry and river profile due to scour and deposition over relatively long periods of time. In general, the flow record of interest is discretized into a quasi-unsteady sequence of steady flows of variable discharge and duration. For each model time-step and corresponding discharge, the water-surface profile is calculated

using the step-backwater method to compute the energy slope, velocity, depth, and other hydraulic variables at each cross-section in the network. The sediment-transport capacity is then calculated at each cross-section based on input bed material information and the computed hydraulics, and the aggradation or degradation volume is computed by comparing the transport capacity with the upstream sediment supply (i.e., the supply from the next upstream cross-section for locations not identified as an upstream boundary condition). The resulting aggradation/degradation volume is then applied over the cross-section control volume (i.e., the sub-channel concept), and the shape of the cross-section is adjusted accordingly. Because the sediment-transport calculations are performed by size fraction, the models are capable of simulating bed material sorting and armoring. The computations proceed from time-step to time-step, using the updated cross-sectional and bed material gradations from the previous time-step.

1D sediment-transport models should not be applied to situations where 2- and 3-dimensional flow conditions control the sediment-transport characteristics because they do not consider secondary currents, transverse movement and variation, turbulence, and lateral diffusion; thus, the models cannot simulate such phenomena as point bar formation, pool-riffle formation, and planform changes such as river meandering or local bank erosion. 1D models typically distribute the volume of aggradation or degradation across the entire wetted portion of the channel cross-section after each time-step; thus, the effects of channel braiding are also not directly considered. 1D models are, however, useful in evaluating the general sediment-transport characteristics and overall sediment balance of a given reach, and they are also useful in providing boundary conditions for localized 2D models.

<u>Potential 1D Models:</u> 1D models that are being considered for this study include the U.S. Army Corps of Engineers HEC-RAS (version 4.1; USACE 2010a), the U.S. Bureau of Reclamation's SRH-1D (version 2.8; Huang and Greimann 2011), DHI's MIKE 11 (version 2011; DHI 2011a), and Mobile Boundary Hydraulics' HEC-6T (version 5.13.22_08; MBH 2008). Each of these models, including potential benefits and limitations, is summarized in the following sections.

- **HEC-RAS:** HEC-RAS, version 4.1.0 (USACE 2010a) is a publicly available software package developed by the U.S. Army Corps of Engineers (USACE) to perform steady flow water surface profile computations, unsteady flow simulations, movable boundary sediment transport computations, and water quality analysis. HEC-RAS includes a Windows-based graphical user interface that provides functionality for file management, data entry and editing, river analyses, tabulation and graphical displays of input/output data, and reporting facilities. The sediment-transport module is capable of performing sediment-transport and movable boundary calculations resulting from scour and deposition over moderate time periods, and uses the same general computational procedures that were the basis of HEC-6 and HEC-6T (USACE 1993; MBH 2010). In HEC-RAS, the sediment transport potential is estimated by grain size fraction, which allows for simulation of hydraulic sorting and armoring. This model is designed to simulate long-term trends of scour and deposition in streams and river channels that could result from modifying the frequency and duration of the water discharge and stage, sediment supply, or direct modifications to channel geometry. Benefits of the HEC-RAS software include widespread industry acceptance, public availability, and ease of use. Potential limitations of the program include excessive computer run-times, file size output limitations, and the inherent problems associated with 1D modeling of aggradation and degradation by equal adjustment of the wetted portion of the bed that can result in unrealistic channel geometries.

- **SRH-1D:** SRH-1D (Huang and Greimann 2011) is a publicly-available, mobile boundary hydraulic and sediment transport computer model for open channels that is capable of simulating steady or unsteady flow conditions, internal boundary conditions, looped river networks, cohesive and non-cohesive sediment transport (Ruark et al. 2011), and lateral inflows. The hydraulic and sediment transport algorithms in SRH-1D are similar to those in HEC-RAS 4.1 and HEC-6T except that it also includes the capability to perform fully-unsteady sediment transport simulations. Advantages of SRH-1D include robust algorithms for hydraulic conditions and sediment routing, including sediment sorting. Potential disadvantages include limited testing under a broad range of conditions outside the U.S. Bureau of Reclamation and the lack of graphical user interface that complicates data input and manipulation and display of output.
- **MIKE 11:** Danish Hydraulic Institute's (DHI) MIKE 11 is a proprietary software package developed for 1D dynamic modeling of rivers, watersheds, morphology, and water quality. The model has the ability to solve the complete non-linear St. Venant equations (in only the streamwise direction) for open channel flow, so the model can be applied to any flow regime. MIKE 11 provides the choice of diffusive and kinematic wave approximation and performs simplified channel routing using either the Muskingum or Muskingum-Cunge methods. The program includes a module for simulating erosion and deposition of non-cohesive sediments. Advantages of MIKE 11 include its robust hydrodynamic capabilities (though not necessarily better than HEC-RAS), the user-friendly graphical interface, and the reporting and presentation capabilities. Disadvantages primarily stem from the proprietary nature of this model and high cost of the software license.
- **HEC-6T:** HEC-6T was written by William A. Thomas, former Chief of the Research Branch at the USACE Hydrologic Engineering Center (HEC). Mr. Thomas planned, designed, wrote, and applied the publically available version of HEC-6; HEC-6T is a proprietary enhancement of the original version. HEC-6T is a DOS-based program that includes a Windows-based graphical user interface for input data manipulation and post-processing of simulation results. Limitations of this program include reduced capabilities for modeling numerous ineffective flow areas as compared to HEC-RAS 4.1 and limited capabilities of the graphical user interface. This software is relatively inexpensive; the fact that it is proprietary is not a significant limitation.

<u>1D Model Selection Process and Initial Evaluation:</u> Based on the information provided above and experience with these models, the Geomorphology Study team tentatively proposes to use HEC-6T for the reach-scale sediment transport analysis. This proposal is based on confidence gained that HEC-6T is capable of effectively and efficiently modeling the processes that are important for this scale of geomorphic analysis. The selection of the 1D (as well as the 2D) model will be coordinated with the other pertinent studies and the licensing participants. As part of the coordination process, a technical memorandum titled *Fluvial Geomorphology Modeling* (Tetra Tech 2012) was posted on the AEA website in May 2012. Specific model-selection criteria are identified in Table 6.6-2 along with an evaluation of each candidate model relative to the criteria.

Potential 2D Models: Potential 2D models that are being considered for this study include the U.S. Bureau of Reclamation's SRH2-D version 3 (Lai 2008; Greimann and Lai 2008), USACE's Adaptive Hydraulics ADH version 3.3 (USACE 2010b), the U.S. Geological Survey's (USGS) MD_SWMS suite (McDonald et al. 2005; Nelson et al. 2010), DHI's MIKE 21 version 2011 (DHI 2011b), and the River2D modeling suite (University of Alberta 2002; University of British Columbia 2009).

- **SRH-2D:** The U.S. Bureau of Reclamation's SRH-2D (Lai 2008) is a finite-volume, hydrodynamic model that computes water-surface elevations and horizontal velocity components by solving the depth-averaged St. Venant equations for free-surface flows in 2D flow fields. SRH-2D is a well-tested 2D model that can effectively simulate steady or unsteady flows and is capable of modeling subcritical, transcritical, and supercritical flow conditions. The model uses an unstructured arbitrarily-shaped mesh composed of a combination of triangular and quadrilateral elements. SRH-2D incorporates very robust and stable numerical schemes with a seamless wetting-drying algorithm that results in minimal requirements by the user to adjust input parameters during the solution process. A potential limitation of this software is that the mobile bed sediment transport module is currently not publically available; however, Tetra Tech has gained permission to use the sediment transport module on a number of other projects. Preliminary contact with the model developers indicates that permission would be granted for use in this study. This version of the model (Greimann and Lai 2008) includes a "Morphology" module that calculates bedload transport capacities at each model node based on user-defined bed material sediment gradations, but does not simulate routing of that sediment and related adjustments to the channel bed. SRH-2D also includes a second module that uses the capacities from the Morphology module to perform sediment-routing calculations and associated bed adjustments. Based on guidance from the model developers and confirmed by Tetra Tech's use of the model for other studies, the maximum practical model size is about 16,000 elements, which could be a potential limitation in applying the model to larger-scale areas.
- **ADH:** The USACE ADH program was developed by the Coastal and Hydraulics Laboratory (Engineer Research Development Center) to model saturated and unsaturated groundwater, overland flow, 3D Navier-Stokes flow, and 2D or 3D shallow-water, open-channel flow conditions. ADH is a depth-averaged, finite-element hydrodynamic model that has the ability to compute water-surface elevations, horizontal velocity components, and sediment transport characteristics (including simulations to predict aggradation and degradation) for subcritical and supercritical free-surface flows in 2D flow fields. The ADH mesh is composed of triangular elements with corner nodes that represent the geometry of the modeled reach with the channel topography represented by bed elevations assigned to each node in the mesh. A particular advantage of the ADH mesh is the ability to increase the resolution of the mesh—and thereby the model accuracy—by decreasing the size of the elements during a simulation in order to better predict the hydraulic conditions in areas of high hydraulic variability. However, use of the adaptive mesh option often results in excessively long simulation run times (several days per run) that could be impractical for this study. Additionally, the wetting and drying algorithm in this model has significant numerical stability limitations when applied to shallow, near-shore flows that occur in rivers like the Susitna River. The model is publically available.

- **MD_SWMS Modeling Suite (FaSTMECH/SToRM):** The USGS Multi-Dimensional Surface-Water Modeling System (MD_SWMS; McDonald et al. 2005) is a pre- and post-processing application for computational models of surface-water hydraulics. This system has recently been incorporated into iRIC, a public-domain software interface for river modeling distributed by the International River Interface Cooperative (iRIC) (Nelson et al. 2010). iRIC is an informal organization made up of academic faculty and government scientists whose goal is to develop, distribute, and provide education for the software. iRIC consists of a graphical user interface (GUI) that allows the modeler to build and edit data sets, and provides a framework that links the GUI with a range of modeling applications. The GUI is an interactive 1D, 2D, and 3D tool that can be used to build and visualize all aspects of computational surface-water applications, including grid building, development of boundary conditions, simulation execution, and post-processing of the simulation results. The models that are currently included in iRIC include FaSTMECH (Flow and Sediment Transport with Morphologic Evolution of Channels) and SToRM (System for Transport and River Modeling) that were part of the MD-SWMS package, as well as NAYS, MORPHO2D, and a Habitat Calculator for assessing fish habitat under 2D conditions. Of these models, SToRM appears to be the most relevant for modeling the Susitna River for purposes of this Project, primarily because it uses an unstructured triangular mesh (in contrast to the structured, curvilinear mesh required for FaSTMECH) and provides both steady-flow and unsteady-flow capability. NAYS is a fully unsteady, 2D model designed for a general, non-orthogonal coordinate system with sophisticated turbulence methods that can evaluate the unsteady aspects of the turbulence, and MORPHO2D is 2D model capable of analyzing the interactions between sediment transport and vegetation and between surface water and groundwater. Both NAYS and MORPHO2D were developed in Japan, and have not been widely used or tested in the U.S. The SToRM model blends some of the features of finite volumes and finite elements, and uses multi-dimensional streamline upwinding methods and a dynamic wetting and drying algorithm that allows for the computation of flooding. Subcritical, supercritical, and transcritical flow regimes (including hydraulic jumps) can be simulated. The program includes advanced turbulence models and an automatic mesh refinement tool to better predict the hydraulic conditions in areas of high hydraulic variability. The most recent version of the SToRM model does not include the capability to model sediment-transport, but the program authors are currently working on implementing sediment-transport algorithms that may be available for use in this study (pers. Comm., Jonathon Nelson, USGS, June 18, 2012). MD_SWMS has been successfully applied to a number of rivers in Alaska, including the Tanana River near Tok (Conaway and Moran 2004) and the Copper River near Cordova (Brabets 1997); some of the modules are currently being validated using high-resolution scour data from the Knik River near Palmer.

- **MIKE 21:** Developed by DHI, MIKE 21 is a proprietary modeling system for 2D free-surface flows that can be applied in rivers, lakes, coastal, and ocean environments. It has the ability to simulate sediment transport and associated erosion and deposition patterns. The software includes a Windows-based GUI as well as pre- and post-processing modules for use in data preparation and analysis of simulation results, and reporting modules that have graphical presentation capabilities. MIKE 21 has the ability to model a range of 2D mesh types that include Single Grid, Multiple Grid, Flexible Mesh, and

Curvilinear Grid. The primary limitation to MIKE-21 is that it is proprietary software and is relatively expensive compared to other available software.

- **River2D Modeling Suite:** River2D is a two-dimensional, depth-averaged finite-element hydrodynamic model developed at the University of Alberta and is publically available from the university. The River2D suite consists of four programs: R2D_Mesh, R2D_Bed, River2D, and R2D_Ice, each of which contains a GUI. The R2D_Mesh program is a pre-processor that is used to develop the unstructured triangular mesh. R2D_Bed is used for editing the bed topography data and R2D_Ice is used to develop the ice thickness topography at each node for simulating ice-covered rivers. Following mesh development, the hydrodynamic simulations are run using the River2D program, which also includes a post-processor for visualizing the model output. River2D is a very robust model capable of simulating complex, transcritical flow conditions using algorithms originally developed in the aerospace industry to analyze the transitions between subsonic and supersonic conditions (transonic flow). Many 2D models become numerically unstable due to wetting and drying of elements; however, River2D uniquely handles these conditions by changing the surface flow equations to groundwater flow equations in these areas. The model computes a continuous free surface with positive (above ground) and negative (below ground) water depths, which allows the simulation to continue without changing or updating the boundary conditions, increasing model stability. River2D also has the capability to assess fish habitat using the PHABSIM weighted-usable area approach (Bovee 1982). Habitat suitability indices are input to the model and integrated with the hydraulic output to compute a weighted useable area at each node in the model domain. River2D Morphology (R2DM) is a depth-averaged, two-dimensional hydrodynamic-morphological and gravel transport model developed at the University of British Columbia. The model was developed based on the River2D program, and is capable of simulating flow hydraulics and computing sediment transport for uni-size and mixed-size sediment using the Wilcock-Crowe (2003) equation over the duration of a hydrograph. R2DM can be used to evaluate the changes in grain size distributions, including fractions of sand in sediment deposits and on the bed surface. The sediment-transport module has been verified using experimental data, and was successfully applied to the Seymour River in North Vancouver, British Columbia (Smiarowski 2010). River2D is available in the most recent version of iRIC (Version 2.0).

<u>2D Model Selection Process and Initial Evaluation:</u> The selection of the 2D model will be coordinated with the other pertinent studies and the licensing participants. Specific model selection criteria are identified in Table 6.6-3, along with an evaluation of each candidate model relative to the criteria.

Model Development: The manner in which the models are developed will depend on the model software programs that are ultimately selected for use. Regardless of the selected modeling software, the models will be developed in accordance with the software developers' guidance and recommendations.

6.6.4.1.2.2. Coordination with other Studies

As previously discussed, it is envisioned that a combination of 1D and 2D sediment transport models will be used to assess potential changes in the aggradation/degradation behavior and related processes in the Susitna River downstream from Watana Dam due to the potential size and complexity of the system to be modeled. As a result, the current vision for the modeling approach is to use a reach-scale 1D model to evaluate the potential effects of the Project on the overall aggradation/degradation behavior of the study reach, and then use a series of representative, local-scale 2D models at key locations where the dynamic behavior of the channel and habitat cannot be adequately assessed using the 1D modeling approach. The 1D model will provide boundary conditions for the individual 2D models. Because of this modeling approach, it will be very important to coordinate with other studies because results from the detailed 2D model will only be available at specified locations that will be selected from the key locations (e.g. focus areas) identified by the Instream Flow, Instream Flow Riparian, Ice Processes, and Fish study teams and in consultation with the licensing participants. It is anticipated that a minimum of four to six detailed mainstem 2D study sites will be identified, with each representing a length of river on the order of one to several miles that includes a representation of each geomorphic reach (excluding Devils Canyon) and one unstable reach (likely a braided reach). The 2D sites will also include selected primary tributary confluences. Coordination among the studies will also be necessary to ensure efficient collection of field data, because it is likely that a considerable amount of the data necessary for development and calibration of the 1D and 2D models will either be required for the other studies, or will be easily obtained along with data that will be required for those studies. For example, the Instream Flow Study will likely obtain velocity magnitude and direction, flow depth, and discharge measurements, the data from which would be very useful for calibration of the 2D models. It may also be possible to obtain subaqueous bed material data for the modeling by lowering a laser/video through the ice thickness transect holes that will be bored as part of the Ice Study when turbidity levels are expected to be low.

The temporal resolution for model execution will be selected to ensure model stability and proper representation of important variability in flow conditions (e.g., daily fluctuations associated with load-following). The overall time-scale for model execution will also be an important factor. Because a key purpose of the 1D model will be to assess the long-term sediment balance in the study reach, this model will likely be executed for a continuous period of 50 years to represent the length of a FERC license. On the other hand, due to the computational requirements of the 2D model, much shorter time-periods will be evaluated.

Close coordination between the study leads and key study team members will be required throughout the model development process. It is important that all the study teams have an understanding of the capabilities and limitations of the models, the information that will be provided by the model, and the selection of the focus areas. This will be accomplished through frequent informal communication and more formal Technical Workgroup meetings. The study leads and other key participants will spend time together in the field to develop a practical understanding of each study's needs.

6.6.4.1.2.3. Model Resolution and Mesh Size Considerations

Selection of the appropriate mesh size for the 2D bed evolution mode is dictated by several factors including the following:

1. The size and complexity of the site features of primary interest.
2. The overall area of the site.

3. The desired resolution of output information such as velocity, depth, and bed material gradation.
4. Limitations on the maximum number of elements that the model can simulate.
5. Model execution time.

The identification of an appropriate mesh size often involves balancing the need to provide a high level of spatial resolution to satisfy items 1, 2, and 3 versus the limitations imposed by items 4 and 5. One approach to reduce the trade-offs between model complexity and physical limitations of the 2D model is to utilize a variable mesh (also referred to as flexible mesh). A variable mesh allows a finer mesh to be used in areas where either the information desired or the condition being modeled requires higher spatial resolution (finer mesh). The 2D models being considered for this study are formulated with a flexible mesh, allowing the size of the model element to be varied. Figure 6.1-1 and Figure 6.6-2 provide examples of a relatively coarse and relatively fine mesh applied to the potential focus area at Whiskers Slough in the Middle River Geomorphic Reach 8.

Areas that will require finer mesh sizes include the following:

- Side sloughs
- Upland sloughs
- Smaller side channels
- Spawning areas
- Tributary mouths
- Locations where circulation is of interest such as eddies between the main channel and backwater areas
- Other specific habitat features of interest

Areas where lower spatial resolution may be appropriate include the following:

- Main channel
- Floodplains
- Large side channels

In the areas of higher resolution, the mesh size will be on the order of several feet to 25 feet. In areas where lower spatial resolution is appropriate, the mesh size may be in the range of 25 to 100 feet.

At some focus areas, two model meshes may need to be developed. One mesh would be for executing the bed evolution model which, due to the sediment routing and moveable aspects of the model, requires orders of magnitude more time to execute than the 2D model without the moveable bed options running. This would be the coarser mesh to keep the number of elements within the moveable bed limitations and the execution time down. The other mesh would be associated with a fixed bed representation of the site that would be used to output the hydraulic conditions at a finer resolution for development of aquatic habitat indices.

6.6.4.1.2.4. <u>Focus Area Selection</u>

The use of "focus areas" to conduct concentrated interdisciplinary studies at selected areas within the study area was introduced in Section 6.6.3.1. Focus areas will involve portions of the Susitna River and its floodplain where detailed study efforts will be jointly conducted by the Fish Instream Flow, Riparian Instream Flow, Geomorphology, Ice Processes, Groundwater, and Fish studies. The focus areas will allow for a highly integrated, multidisciplinary effort to be conducted evaluating potential Project effects on key resource areas across a range of representative sites. The process for identifying candidate focus areas and selecting the specific portions of the study area to conduct the focus area studies is detailed in Section 8.5.4.2 of the Instream Flow Study.

The Geomorphology Study has provided input on identifying sites and providing input on the selection of potential focus areas. The geomorphic reach classification system and resulting reach delineation were utilized in the selection process. At least one focus area for each geomorphic reach (except reaches MR-3 and MR-4 where there are safety concerns associated with Devils Canyon) has been identified. Since several of the geomorphic reach types are represented by several reaches in the study area, there is duplication of reach sites within the candidate sites. Table 6.6-4 lists the candidate sites, the associated geomorphic reach, and the geomorphic reach type. The potential focus areas represent five areas within the SC2 reach type, four within the SC3 reach type, and two within the MC1 reach type. The locations of the middle river candidate focus areas are shown on Figure 6.6-3.

The Geomorphology Study also helped establish the limits of the focus study areas. The upstream and downstream boundaries as well as the lateral extents of the focus areas have been chosen so that appropriate boundary conditions can be established for the hydraulic and bed evolution modeling. Considerations included encompassing potential inflow and outflow points to preserve the mass balance and minimize difficulties and assumptions associated with inflow points. Potential upstream connections for side channels, side sloughs, and upland sloughs were also identified and included in the modeling domain. The upstream and downstream limits on the main channel were identified to either provide relatively uniform flow conditions or sufficient distance upstream and downstream from areas of interest so that flow conditions in the area of interest are not significantly affected by the flow directions at the boundary.

The Geomorphology Study will also collaborate on the selection of the modeling approach for each focus area. In some instances, it may be appropriate to utilize a 1D model rather than a 2D model. The 1D model could be appropriate when there are not numerous flow splits and junctions, flow paths are primarily linear, and specific habitat features do not have the streamwise and lateral resolution of the 2D model.

6.6.4.1.2.5. Model Calibration and Validation

Calibration and validation of the models will be a stepwise process. First, the hydraulic components of the models will be calibrated by adjusting roughness and loss coefficients to achieve reasonable agreement between measured and modeled water-surface elevations, and to measured and modeled velocities. Discharges along the study reach will be obtained from the three USGS gages. These gages will also provide a continuous record of stages and water-surface elevations at the gage locations. These data will be supplemented with stage data from at least 10 pressure-transducer type water-level loggers that have been or will be installed as part of various studies being conducted in the Middle and Lower Susitna River reaches. Water-levels measured during the cross-section and bathymetric surveys will also be used to calibrate the models. In addition to water-surface elevations, the depths and velocities predicted by the 2D model should be compared with measured data from ADCP measurements at the focus areas. Depending on the range of conditions and spatial coverage of the depth and velocity data from the Instream Flow Study, additional data may be needed for calibration specifically for this study. Specific calibration criteria will be established for both the 1D and 2D models during the model selection phase. The 2D water surface elevations will also be compared against water surface elevations generated by the 1D model and the Flow Routing Model to ensure that the models are producing consistent results.

The sediment transport portions of both the 1D and 2D model will be first calibrated based on the available measured sediment transport data and the associated sediment rating curves for both bedload and suspended load. For coarse-grained rivers such as the Susitna River, the bed material load transport is dominant with respect to channel forming processes; however, the fine-grained suspended load (i.e., wash load) may be important in evaluating the changes to other features including turbidity, instream habitat, side channels, sloughs and floodplains. The sediment transport model will also be validated, to the extent that available information allows, by comparing modeled and measured (or if necessary, qualitatively observed) changes in bed elevations and bed material gradations from the Geomorphology Study, by making model runs for specific time-periods. This effort will include comparison of 1980s and current 2012 transect data if sufficient data are available.

6.6.4.1.2.6. Tributary Delta Modeling

Tributary confluences are areas of interest for determining the potential Project effects on sediment transport and morphology. Alteration of the mainstem flow regime has the potential to change the elevation at which tributary sediments are initially deposited because the main stem may be at a different stage when the tributaries are at peak flow. Additionally, the ability to mobilize and transport bedload delivered by tributaries may also be altered. Changes in the configuration of sediments deposited at the tributary confluences can affect the ability of fish to access the tributaries and the extent of clear water habitat associated with some tributary confluences. Modeling sediment transport and deposition processes at select tributary mouths will therefore be necessary.

The tributaries to be modeled will be determined in conjunction with the Instream Flow and Fish studies and the licensing participants based on fish use and the potential for Project effects. The Geomorphology Study will model a subset of tributary confluences with the Susitna River that represent the range of conditions among all the tributaries. The selection of primary tributary deltas for 2D modeling will be based on screening that considers the importance of the existing fishery and potential adverse Project effects. Based on the discussion at the June 14, 2012 Water Resources TWG meeting, it is likely that the effort will include the three rivers confluence area (Susitna, Talkeetna, and Chulitna confluence). The selection of the tributary delta sites for 2D modeling will be coordinated with the other pertinent studies and in consultation with the licensing participants.

It is currently proposed that a model will be created for the tributary deltas that uses estimated bedload transport from the tributary, the topography and the bathymetry of the confluence, measurements of the characteristics of the tributary deposits, and the ability of the mainstem in the area of the confluence to mobilize and transport those deposits. The approach will include field observations to characterize the sediment transport regime that will be used to identify appropriate methods of estimating bedload transport. Surveys of tributary channel geometry and sampling of bed material gradations will be coupled with an appropriate bed material transport function to calculate sediment yield rating curves. Hydrology synthesized for ungaged tributaries will be needed from other studies for each of the selected tributaries for this purpose as well as for the purpose of the flow routing models (summer ice-free model and winter ice-covered model). The yield and topography in the area of the expected delta, along with the ability of the mainstem to mobilize and transport the bed material, will provide a basis for characterizing how Project operations would affect the formation of tributary deposits. At this time, it is envisioned that a relatively detailed 1D hydraulic model of the mainstem in the vicinity of each tributary will provide sufficient hydraulic information to evaluate the potential for, and likely extent of, additional growth of the tributary deposits into the mainstem. For complex tributary confluences that are of particular interest to the Instream Flow studies, local-scale 2D models can be developed and applied to support the analysis.

6.6.4.1.2.7. Wintertime Modeling and Load-Following Operations

It is currently not proposed to execute the sediment transport models—either 1D or 2D—during the winter period when flows are low and the bed material is not mobilized. However, if the Characterization of Bed Material Mobility component of the Geomorphology Study indicates that the bed material is mobilized during winter-time flows, including higher than existing flows due to load following, the sediment transport modeling will be extended to include the winter flow period. One winter operational issue of potential importance is the resuspension of fine sediments during load-following that could result in increased turbidity during the early portion of the otherwise clear water conditions during the winter months. To address this, an effort to model the resuspension of fines can be undertaken for the 1D model and the 2D model for the early portion of the winter period. This effort would include investigation of a controlled release to flush the fines from the system prior to commencement of winter load-following operations. Decisions on continuing the 1D and 2D modeling into the winter period will be made in consultation with the licensing participants and in coordination with the Instream Flow, Instream Flow Riparian, Ice Processes, and Fish studies. (This section on Wintertime Modeling and Load-Following Operations was added based on a study comment supplied by NOAA-NMFS in its May 31, 2012, study request; the Natural Resources Defense Council May 30, 2012, study request; and discussions on load-following and turbidity during the June 14, 2012 Water Resources TWG meeting.

6.6.4.1.2.8. Field Data Collection Efforts

The field data collection effort to support both the Geomorphology Study and the Fluvial Geomorphology Modeling Study are presented in this section. The majority of this effort will be conducted in the 2013 field season. If the subsequent need for additional data is identified during the model development process, more focus areas are added, or the downstream limit of the 1D model is extended, additional data will be collected during the 2014 field season.

Much of the data collection performed in this task will be shared with and used by other studies including Instream Flow Fish, Instream Flow Riparian, Groundwater, and Ice Processes studies. The exchange of data between these studies will be highest at the focus areas.

At the start of the summer 2013 field season, a reconnaissance of the entire Fluvial Geomorphology Modeling study area (RM 184 to RM 75) as well as the remainder of the lower river (RM 75 to RM 0) will be conducted. This site reconnaissance will be carried out to observe and characterize the following:

- Hydraulic and geomorphic controls (natural and man-made) that will influence sediment-transport conditions.
- Verification of mapping of geologic and geomorphic features performed in the Geomorphology Study.
- Hydraulic roughness conditions along the main channel and in the overbanks.
- Variations in bed material size.
- The sediment-transport regime, and areas that appear to be in equilibrium, or are aggradational or degradational.
- In areas that are not in equilibrium, qualitative assessment of the degree of erosion or deposition.

To support the site reconnaissance as well as all other field data collection activities, maps of the study area will be developed to assist crews during field activities. The mapping will include topography (from available LiDAR), aerial photo base layer, geologic units and controls, geomorphic features, aquatic habitat types, geomorphic reach boundaries, existing cross-section locations, proposed supplemental cross-section locations, survey control points, focus site locations, location of installed instrumentation, and safety related information.

Beyond the general site reconnaissance, detailed information will be collected to support the development of the 1D model for the entire study area and the focus areas where 2D and possibly 1D modeling will be applied. Additional data will also be collected for the tributary confluences that are identified for modeling. The field data to be collected for each of these study components are provided below.

1D Bed Evolution Model

The primary field data to be collected in support of the 1D bed evolution model include the following:

1. Supplemental cross-sections
2. Bed material samples
    a. Surface pebble count (Wolman count) or photo grid
    b. Subsurface bulk or photo grid samples
3. Bank material samples
4. Spot elevations to verify LiDAR in the area of the supplemental cross-sections (LiDAR will be used to provide the floodplain portion of the cross-sections)
5. Estimation of n-values at supplemental cross-sections
6. Observations on depositional or erosional features at the supplemental cross-sections

Supplemental cross-sections will be required to provide the level of detail in the hydraulic model necessary to properly model sediment transport conditions. The cross-sections collected in 2012 for the Flow Routing Model will be used in development of the 1D model; however, their spacing is such that additional cross-sections will need to be collected in 2013 to complete the 1D sediment transport model. There were 88 cross-sections collected between RM 75 and 184 (excluding the 12-mile length of river in the Devils Canyon area) with an average spacing of just over 1 mile. The minimum and maximum spacing between the cross-sections was 0.1 and 3 miles, respectively. It is estimated that on the order of 80 to 100 supplemental cross-sections will need to be surveyed to complete the cross-sectional database for the 1D sediment transport model. The transects and bathymetric data to be collected at the focus sites will meet a portion of this requirement, likely reducing the number of supplemental sections to be surveyed by 20 to 25 percent. Supplemental cross-sections collected for the Instream Flow Study may also fulfill part of the 1D model supplemental cross-section needs.

Bed material samples will be collected using pebble count, photographic grid, or bulk sampling procedures. Approximately 50 bed material samples will be collected to support the 1D model development. A similar number of subsurface and bank material samples will be obtained. These samples will be supplemented by similar samples collected at the focus areas. The sampling will be performed at low flow to allow as much of the bed to be sampled as possible. In addition, the Geomorphology Study will work with the Ice Processes Study in the winter of 2013 to determine whether video bed material samples can be collected using a camera equipped with two lasers to provide scale. The winter period is when the Susitna River is sufficiently clear to support this type of effort.

Focus Areas

The primary field data to be collected at the focus areas by the Geomorphology Study include the following:

1. A combination of bathymetry (single and multi-beam), cross-section data, and spot elevations necessary to develop a digital terrain model for the portion of the site for which LiDAR is not available. (These will be the main channel, side channels, side sloughs, upland sloughs, tributaries, and open water areas that were inundated at the time the LiDAR was acquired.)
2. All obstructions in the lateral habitats such as beaver dams and debris jams will be surveyed.
3. Large woody debris survey and characterization of its influence on the geomorphology of the channels, side channels and sloughs.
4. Bed material samples in the main channel, sloughs, and side channels
    a. Surface pebble count (Wolman count) or photo grid
    b. Subsurface bulk or photo grid samples
    c. Possible winter sampling in conjunction with the Ice Processes Study (see 1D Bed Evolution Model field data section)
5. Bank material samples.
6. Spot elevations to verify LiDAR in the focus area (LiDAR will be used to provide the floodplain portion of the cross-sections).
7. Estimation of n-values in the channels, side channels, sloughs, and tributaries.
8. Observations on depositional or erosional features at the supplemental cross-sections.
9. Field verification, and correction and/or mapping if necessary, of the geomorphic features, geologic controls, and terraces previously identified from available information for the focus area.
10. ADCP measurements to calibrate and determine the accuracy of the 2D hydraulic model velocities.
11. Installation of level loggers and associated readings to support calibration of water surface elevations produced by the 2D model.
12. Current meter measurements of velocity for areas where the ADCP cannot be used.
13. Mapping of depositional and erosional features.

14. Identification and mapping of evidence of ice processes at the site along with observations of their potential influence on the geomorphology of the focus area.
15. Any evidence of past extreme events.
16. Overall narrative description and assessment of the geomorphology of the focus area including identification of key physical processes and controls.

If it is determined that ID modeling is appropriate for a focus area, rather than collecting bathymetric, cross-sectional and topographic information queried to build a digital terrain model (DTM) to support 2D mesh development, cross-sectional data will be collected on the hydraulic features to be modeled.

Bed material sampling will be performed in a manner similar to the efforts described for the 1D Bed Evolution Model field data. For each focus area, 10 to 30 samples will be collected depending on the complexity of the site. Similar numbers of subsurface and bank material samples will be collected. Supplemental cross-sections will be required to provide the level of detail in the hydraulic model necessary to properly model sediment transport conditions.

Tributary Deltas

A site reconnaissance and data collection effort will also be necessary for each of the key tributaries that have the potential to deliver significant quantities of sediment to the reach and/or are important to other study teams. The reconnaissance to these sites will be relatively detailed, because specific data will need to be collected, in addition to the general observations, to facilitate the modeling at the tributary mouths. Cross-sectional surveys of approximately six transects over a representative reach above the confluence will be necessary, with a spacing of about three- to five-times the active channel width. Surface and sub-surface bed material samples will be collected to characterize the gradation of the sediments along the reach, and will include at least two representative samples of the surface material on the fan. Observations and photographs of erosional and depositional features will be taken.

Field Data from Other Studies

In addition to the above field data collected as part of the Geomorphology Study, the following data collected by the Instream Flow Fish, Instream Flow Riparian, Ice Processes, and Groundwater studies will need to be obtained to support the Geomorphology Study:

- Flow Routing Model cross-sections collected in 2012.
- Instream Flow Study supplemental transects collected in 2013.
- Hydraulic calibration information used in the development of the Flow Routing Model (water surface elevations and associated discharges).
- Information describing the influence of ice processes on channel and floodplain morphology.
- Information describing the influence of riparian vegetation on channel and floodplain morphology.
- Soil classification and gradation from Riparian Instream Flow test pits in the floodplain and on island.
- Thickness and aging of floodplain and island deposits from the Riparian Instream Flow Study.

- Mapping of vegetation and associated age classes from the Riparian Instream Flow Study.
- Information developed in the Geomorphology Study on channel changes that have occurred since the 1980s.
- Information developed in the Geomorphology Study on the physical processes most important to accurately modeling the study reach.
- The velocity and depth measurements collected by the Instream Flow Study to characterize habitat for calibrating the hydraulic model(s).
- Data collected on the distribution of flow between the main channel and lateral habitat to help calibrate the hydraulic portion of the 2D model.

6.6.4.1.2.9. Information Required

In addition to the field data collection effort described in the previous section, the following existing information will be needed to conduct this study:

- Historical and current aerial photographs.
- Historical channel cross-sections.
- LiDAR to develop sub-aerial topography and extend surveyed transects across the floodplain.
- Extended flow records from USGS mainstem and tributary gages.
- Estimated flows from key ungaged tributaries that will be accounted for in the water and sediment inflows, and where potential development of tributary fans is to be evaluated.
- Historical bed material sample data.

6.6.4.1.3. Study Products

The products of this component of the modeling study will include the following:

- 1D hydraulic models that will be used to estimate sediment loading from each of the tributaries that supply significant volumes of bedload along the modeled reach.
- A single, calibrated, 1D mobile-boundary sediment-transport model, or a series of models, that extend from the proposed dam to a yet-to-be determined downstream limit.
- A number of calibrated 2D sediment-transport models for selected focus areas.
- Model calibration data and documentation.
- A report describing model calibration and application to existing conditions.

6.6.4.2. Study Component: Model Existing and with-Project Conditions

The goal of the Model Existing and with-Project Conditions study component is to provide a baseline and series of with-Project scenarios of future channel conditions for assessing channel change. The extent of the study area is the Susitna River downstream of Watana Dam, the specific downstream boundary of which will be determined in study component Bed Evolution Model Development, Coordination, and Calibration.

6.6.4.2.1. Existing Information and Need for Additional Information

Once the 1D and 2D bed evolution models are developed in the previous study component, the model will be run for the existing condition (the Susitna River without Watana Dam in place) in order to establish a baseline for comparison with Project model runs. The model will also be run for various Project scenarios to determine the potential effects of the Project on the fluvial geomorphology of the Susitna River.

6.6.4.2.2. Methods

6.6.4.2.2.1. Existing Conditions – Base Case Modeling

The time period and representative hydrologic conditions to be assessed with the bed evolution model will be determined through coordination with the Technical Workgroup, based on the availability of data, study objectives, and model limitations. The hydrologic inputs for the various with-Project scenarios will be obtained from the Reservoir and Flow Routing Study and the model run for flows representative of each scenario. It is currently envisioned that a 50-year, continuous period of record that represents the length of the FERC licensing period will be used for the 1D modeling, and shorter modeling periods will be used for the 2D model due to computational limitations. As previously indicated, the 1D model will be applied to address the analysis of reach-scale issues and the 2D model to address local-scale issues.

The shorter periods for the 2D model will include specific years or portions of annual hydrographs for selected years of wet, average, and dry hydrologic conditions and warm and cold Pacific Decadal Oscillation (PDO) phases. Therefore, up to six annual hydrologic conditions will be considered. (The inclusion of the warm and cold PDO phases was requested by NOAA-NMFS and USFWS in the May 31, 2012, study requests; the rationale for the request was discussed at the June 14, 2012 Water Resources TWG meeting and it was agreed that the PDO phases would be included in the suite of representative annual hydrologic conditions.) Other scenarios might include rapid release of flows from an ice jam or larger flood events that are not contained in the period of the hydrologic record chosen for simulation.

Each run will be subjected to a quality control process to ensure that the appropriate data were used and model outputs are reasonable. Naming conventions for the model input and output files for the various scenario files will be applied so that files can be easily archived and retrieved in the future.

6.6.4.2.2.2. Future Conditions - with-Project Scenarios

In coordination with the other studies and licensing participants, the with-Project scenarios will be identified. Similar to the existing conditions, the with-Project scenarios will be modeled with both the 1D model to determine the reach-scale Project effect and the 2D model to determine the local-scale Project effects. The with-Project scenarios will be evaluated over the same time period as the existing conditions base case.

6.6.4.2.2.3. Synthesis of Reach-Scale and Local-Scale Analyses

In addition to the raw model output, the model results will be interpreted, and additional analysis applied as necessary to represent channel processes that are not directly represented in the modeling. The last step in the analysis effort involves the synthesis of the reach-scale and local-scale analyses to identify potential Project-induced changes in the relative occurrence of aquatic habitat types and associated surface area versus flow relationships. In addition to the results of the hydraulic and sediment transport modeling, this synthesis will require application of fluvial geomorphic relationships to develop a comprehensive and defensible assessment of potential Project effects.

6.6.4.2.2.4. Interaction with Other Studies

The Fluvial Geomorphology Modeling Study team will interact extensively with the Flow Routing, Instream Flow, Riparian Instream Flow, Ice Processes, and Fish study teams. The types of interaction will vary depending on the specific study, but a considerable amount of physical data describing the system, including transects, topography/bathymetry, substrate characterization, aerial photography, and pre- and post-Project flows generally will be shared. Selection of joint focus areas for detailed studies will be an important aspect of the collaboration. By selecting common sites, the potential for exchange of information between the study teams will be maximized and ensure that the most effective and extensive use of focus area data will occur.

Flow Routing Study: It is anticipated that the Flow Routing Study will provide the pre- and post-Project hydrology information for all studies, including the Fluvial Geomorphology Modeling Study. This hydrology information will include mainstem pre- and post-Project flows at various points along the study area and inflows for gaged and ungaged tributaries. This information is expected to be provided for the 50-year, extended flow record.

For the Fluvial Geomorphology Modeling effort, the upstream boundary condition at RM 184 will be the existing condition or pre-Project daily flows from the extended flow record. For the post-Project condition, the upstream boundary condition will be the average daily releases from Watana Dam unless load-following scenarios are evaluated. In the latter case, the Project outflows will need to be on an hourly or possibly finer time increment. Estimated daily inflows from tributaries provided by the Flow Routing Study will be input along the length of the 1D sediment transport model and may be inputs to the localized 2D models depending on the location and specific issues to be addressed.

Instream Flow Study: For the Instream Flow Study, an assessment of whether the current channel geometry and substrate characterization used in evaluation of habitats will remain relatively unchanged over the period of the license under both the pre- and post-Project conditions will be important. The Geomorphology Study will determine whether the channel morphology is in a state of dynamic equilibrium such that the distribution of habitat conditions over the timeframe of the license (assumed to be 50 years, corresponding to the maximum FERC licensing period) will be adequately reflected by existing channel morphology. If it is determined that the river is not in a state of dynamic equilibrium, the Geomorphology Study will provide projections of the direction and magnitude of the changes. Changes in the relative occurrence of aquatic habitat types and the associated surface area versus flow relationships that may occur as a result of the Project will be an important outcome of these studies. As part of this evaluation, pre- and post-Project changes in channel dimensions (width and depth) and the proportion and distribution of geomorphic features and habitat types will be estimated for each of the reach types delineated using the channel classification system to be developed for the Susitna River. This will provide the Instream Flow Study with an important part of the information required to evaluate the post-Project effects on aquatic habitat. Other important information to be provided by the Fluvial Geomorphology Modeling study for the Instream Flow Study includes the following:

- Identification of zones of substrate mobilization, deposition, and scour at the reach scale for pre- and post-Project flow regimes.
- Potential changes in lateral habitat connectivity due to aggradation and degradation.
- Pre- and post-Project changes in spatial and seasonal patterns of the fine sediment (wash load) transport and the associated Project effects on turbidity.
- Changes in substrate composition in both the main channel and lateral habitats.
- Pre- and post-Project large woody debris (LWD) recruitment and transport.

Riparian Instream Flow Study: Riparian vegetation plays a large role in the development of islands and lateral habitats, primarily by protecting surfaces from erosion and promoting sediment deposition. Vegetation can also contribute to channel narrowing by encroaching onto bars and islands and riverward growth of banks through trapping of sediments. Conversely, changes in the flow regime and/or ice processes can alter riparian vegetation patterns, including the extent, species composition, and age-classes; thus, there is a feedback mechanism between the two processes. As a result, the influence of riparian vegetation on the morphology of the Susitna River is an important consideration in these studies. The Riparian Instream Flow and Geomorphology studies need to be closely coordinated because of the interaction described above. The collaboration will begin with coordinated selection of the focus area among the Riparian Instream Flow, Ice Processes, and Geomorphology study teams. By working on the focus areas together, the teams will develop an understanding of the interaction between the processes that are responsible for creation and maintenance of the islands and lateral habitats. Estimates of the ages of island and floodplain surfaces from the Riparian Instream Flow Study based on dendrochronology, combined with the inundation results from the 2D modeling, will greatly facilitate this effort by helping to identify rates of sediment deposition and reworking of these surfaces. Similarly, profiling of deposited sediments in the riparian corridor to identify the types of sediments that make up the floodplain will also contribute to the understanding of the physical processes and development of the functional model for linkage of the geomorphology, riparian vegetation, and ice processes.

The results of the fluvial geomorphology model along with applicable geomorphic principles will be applied to interpret model results. An understanding of the geomorphology of the system will also be used to provide a reality check on the extent of changes indicated by the modeling.

Examples of the linkage between the Riparian Instream Flow Study and the fluvial geomorphology model include the following:

- Altering Manning's n-values to represent establishment (increased n) or removal (decreased n) of vegetation.
- Application of shear stress parameter to determine the erodibility of banks and potential influence of vegetation.
- Interpretation of flow and sediment transport patterns to determine areas of sediment deposition within and adjacent to vegetation.
- More accurate water surface elevations from the local-scale 2D models than is provided by the 1D models for periods when the flows only partially inundate the riparian corridor.

- Estimation of the change in the rate of floodplain and island building under the with-Project condition and between various operational scenarios. This can be accomplished by scaling the historical rates of sedimentation developed from the Riparian Instream Flow Study by the ratio of the with-Project rate of sediment delivery to the floodplain surfaces to the existing rate. The 2D model will be applied to simulate sediment delivery to the floodplains and islands.
- Use of geomorphic threshold relationships to understand the potential for removal of vegetation by the flows and the potential for additional channel narrowing due to changes in the vegetation patterns.

Ice Processes Study: Ice processes influence both the channel morphology and riparian vegetation. For example, ice can prevent vegetation from establishing on bars by annually shearing off or uprooting young vegetation. Similarly, ice can scour vegetation from the banks, increasing their susceptibility to erosion. In both examples these influences affect channel morphology. Ice jams can also directly influence the channel morphology by diverting flows onto floodplains where new channels can form, particularly when the downstream water surface elevations are low, allowing the return flows to headcut back into the floodplain. Ice can also move bed material that would normally not be mobilized by rafting large cobbles and boulders.

There will be close collaboration between the Geomorphology and Ice Process studies to identify the key physical processes that interact between the two. Working together to analyze the conditions at the focus areas will be a key part of this collaboration. A significant portion of the influences of ice processes on morphology are directly related to their effects on riparian vegetation. Additionally, influences of ice processes beyond the riparian vegetation issues that may be incorporated directly into the fluvial geomorphology modeling may include the following:

- Simulating the effects of surges from ice jam breakup on hydraulics, sediment transport, and erosive forces using unsteady-flow 2D modeling with estimates of breach hydrographs.
- Simulating the effect of channel blockage by ice on the hydraulic and erosion conditions resulting from diversion of flow onto islands and the floodplain.
- Use of the detailed 2D model output to assess shear stress magnitudes and patterns in vegetated areas, and the likelihood of removal or scouring.
- Use of the detailed 2D model output to assess shear stress magnitudes and patterns in unvegetated areas, and the likelihood of direct scour of the boundary materials.
- Application of the 2D model to investigate whether ice jams are a significant contributor to floodplain and island deposition as a result of ice jams inundating these features and causing sedimentation.

Fish Study: The primary interaction with the Fish Study will be in the selection of the focus areas for detailed study. Part of the selection process will consider the use of the specific sites as well as the types of habitat present at the site by target fish species. The local-scale 2D models can be used to evaluate instream habitat quality on a spatially-distributed basis rather than the cross-sectionally-based approach used in traditional Instream Flow Incremental Methodology (IFIM) studies.

Water Quality: The Fluvial Geomorphology Modeling Study will have two primary areas of interaction with the Water Quality Modeling Study. The first involves the determination of reservoir sediment trap efficiency. The EFDC model that is being used for studying the water quality of the reservoir, Middle River and Lower River segments will be used to perform a determination the final determination of reservoir sediment traps efficiency. This will provide a more accurate determination of the fine sediment settling than use us the empirical equations that are described in section 6.5.4.8.2.1 that will be used for the initial estimate of trap efficiency. The Geomorphology Study will provide the Water Quality Modeling study with the sediment inflow to the reservoir based on the sediment supply analysis conducted in Section 6.5.4.3. The second are of interaction is the routing of fine sediment, silt and clay, downstream. Both the 1D bed evolution model form this study and the EFDC model from the water quality will route fine sediments in the Middle River and upper portion of the Lower River. The water quality models interested in the fine sediment in order to estimate the Project effects on turbidity, while the Fluvial Geomorphology Modeling Study is primarily interested in fine sediment in terms of the Project effects on areas of deposition in the main channel, off-channel and floodplain areas. The results of each model in terms of fine sediment transport results will be compared to insure consistency.

6.6.4.2.2.5. Information Required

The following available existing information will be needed to conduct this study:

- The calibrated existing conditions model(s) developed in the previous tasks, including the data used to develop them.
- Extended flow records for mainstem gages and major tributaries for existing conditions.
- With-Project mainstem flows corresponding to the periods and locations in the extended flow record.
- The with-Project sediment outflow rating curve from Watana Dam.

6.6.4.2.2.6. Study Products

The products of this component of the modeling study will include the following:

- Results from the 1D mobile boundary sediment-transport model(s) that extend from the location of the proposed dam to a yet-to-be determined downstream limit.
- Results from the 2D sediment-transport models for selected focus areas.
- A report describing the model runs, and interpreting the model results.

6.6.4.3. Study Component: Coordination on Model Output

The goal of the Coordination on Model Output is to provide necessary output to the various studies that will require determination of potential channel changes associated with the Project. The extent of the study area is the Susitna River downstream of Watana Dam, the specific downstream boundary of which will be determined in Bed Evolution Model Development, Coordination, and Calibration study component.

6.6.4.3.1. Existing Information and Need for Additional Information

Several studies require the results of the Fluvial Geomorphology Modeling Study to conduct their efforts. These include the Instream Flow, Riparian Instream Flow, and Ice Processes Studies. The primary concern is whether the Project will affect aspects of the channel morphology including, but not limited to, substrate characteristics, cross-sectional geometry, and connectivity with lateral habitats.

6.6.4.3.2. Methods

Coordination with Instream Flow, Instream Flow Riparian, Ice Processes, Productivity, and Fish studies will be conducted to confirm information they will need with respect to potential impacts of the Project on bed evolution in-channel conditions under the various Project scenarios. Because of the detailed spatial nature of the information produced by the models, GIS will likely be an important tool for visually illustrating and conveying model results for use in the other studies.

The plan for transferring results in a manner that will facilitate efficient and effective use by other studies will require considerable effort. The details of the plan will be worked out as the overall modeling approach is developed in the Technical Workgroup meetings and through informal coordination with the respective study teams.

6.6.4.3.2.1. Information Required

The following available existing information will be needed to conduct this component of the modeling study:

- Study plans for other studies

The following additional information will need to be obtained to conduct this component of the modeling study:

- Locations of sites for other studies
- Lists of output required for other studies
- Output formats required for other studies
- Schedule dates for providing output

6.6.4.3.3. Study Products

The products of this component of the modeling study will include summarized results from the 1D and 2D sediment-transport modeling in an appropriate format. Although the desired format is not known at this time, the formatted products could include the following:

- Spreadsheets summarizing predicted hydraulic conditions (main channel velocity, hydraulic depth, energy gradient, shear stress, etc.) at various times during the 1D mobile boundary sediment-transport simulations.
- Spreadsheets summarizing the sediment-transport results (bed profiles, aggradation/degradation volumes, changes in mean bed elevation, changes in the active (surface) and inactive (subsurface) gradation, etc.) at various times during the 1D mobile boundary sediment-transport simulations.
- ArcGIS shapefiles representing the predicted hydraulic conditions (velocity magnitude and direction, water depth, shear stress magnitude and direction, etc.) at various times during the 2D modeling simulation at each of the focus areas.

- ArcGIS shapefiles representing the sediment-transport results (predicted change in bed elevation, sediment size, etc.) at various times during the 2D modeling simulation at each of the focus areas.

6.6.5. Consistency with Generally Accepted Scientific Practice

A wide range of temporal scale processes, unknown initial and forcing conditions, unresolved heterogeneities, and unanticipated mechanisms make geomorphic prediction challenging and problems of scale important (Wilcock and Iverson 2003). Fluvial geomorphologic analyses typically involve focusing on a variety of spatial scales at which landforms have characteristic features (Grant et al. 1990; Rosgen 1996; Thomson et al. 2001). These scales generally reference the river channel width (W) due to the similarity of forms among systems of different absolute size that are governed by the same underlying processes (Pasternack 2011). For example, the analysis could include an assessment at the watershed scale, river segment scale (10^3-10^4 W), morphologic or reach scale (10^0-10^1 W), and intensive local scale (10^{-1}-10^0 W). As discussed in more detail below, the Geomorphology Modeling Study will require both reach-scale (1D modeling) and intensive local-scale (2D modeling) analyses. Synthesis of the reach-scale and local scale analyses will therefore be necessary to identify potential Project-induced changes in the relative occurrence of aquatic habitat types and associated surface area versus flow relationships. In addition to the results of the hydraulic and sediment transport modeling, this synthesis will require application of fluvial geomorphic relationships to develop a comprehensive and defensible assessment of potential Project effects. Examples of this type of integrated analysis that have been successfully performed by the Project team include instream flow, habitat, and recreation flow assessments to support relicensing of Slab Creek Dam in California; a broad range of integrated geomorphic assessments and modeling to assist the Platte River Recovery Implementation Program in Central Nebraska; and ongoing work to support the California Department of Water Resources and Bureau of Reclamation to design restoration measures for the San Joaquin River in the Central Valley of California downstream of Friant Dam.

1D and 2D models are commonly used tools to assess hydraulic and sediment transport conditions in rivers[1]. The potential models that are described in the model selection section have been in use by the engineering and geomorphic community for many years (in some cases, many decades) for evaluating both existing/baseline conditions and predicting the likely effects of proposed changes in flow regime, sediment supply, and other natural and anthropogenic factors. All of the proposed models have been developed using scientifically-sound relationships to describe the physical processes that are important to the analysis. The proposed modeling steps, that include initial reconnaissance to understand the study reach, field data collection to obtain quantitative information necessary to build the model inputs files, calibration steps to ensure model results are consistent with field conditions, and modifications to the model input to represent the range of potential future conditions, are commonly employed by practitioners and researchers. Results from the application of these types of models have provided significant technical basis for FERC licensing of numerous projects through the U.S. and similar licensing throughout the world.

[1] The March 2008 Edition of the American Society of Civil Engineers *Journal of Hydraulic Engineering* was entirely dedicated to the practice and challenges associated with sediment transport modeling.

<u>1D Modeling at the Reach Scale</u>: Potential 1D models that are being considered` for this study include the U.S. Army Corps of Engineers HEC-RAS (version 4.1; USACE 2010a), the Bureau of Reclamation's SRH-1D (version 2.8; Huang and Greimann 2011), DHI's MIKE 11 (version 2011; DHI 2011a), and Mobile Boundary Hydraulics' HEC-6T (version 5.13.22_08; MBH 2008). Based on the information above and experience with these models, the Geomorphology Study team tentatively proposes to use HEC-6T for the reach-scale sediment transport analysis. This proposal is based on confidence gained that HEC-6T is capable of effectively and efficiently modeling the processes that are important for this scale of geomorphic analysis. HEC-6T has been successfully applied to model the sediment-transport conditions in a wide range of river systems for a variety of studies. The study team is currently using the model to evaluate sediment augmentation for habitat restoration purposes in the Central Platte River in Nebraska (Tetra Tech 2010). It was successfully used to evaluate the effects of seismic retrofit options for San Clemente Dam on sediment-transport through the reservoir and in the downstream Carmel River (Mussetter Engineering, Inc. 2008).

<u>2D Modeling at the Local Scale:</u> Potential 2D models that are being considered for this study include the U.S. Bureau of Reclamation's SRH2-D version 3 (Lai 2008; Greimann and Lai 2008), USACE's Adaptive Hydraulics (ADH) version 3.3 (USACE 2010b), USGS's MD_SWMS modeling suite (McDonald et al. 2005; Nelson et al. 2010), and DHI's MIKE 21 version 2011 (DHI 2011b) River2D modeling suite (University of Alberta 2002; University of British Columbia 2009). The selection of the 2D model will be coordinated with the other pertinent studies and the licensing participants. In addition to the User's Manuals that are available with each of the potential models, a number of standalone references are also available that provide guidance for development and application of the 2D models, or highlight successful application of 2D geomorphologic modeling. For example, Pasternack (2011) includes an entire chapter that provides instruction for 2D model development, and separate chapters for SRH-2D model execution and interpretation of SRH-2D model results. Conaway and Moran (2004) present successful application of MD_SWMS to modeling sediment-transport conditions in Alaskan rivers. MD_SWMS has also been successfully used to model sediment-transport and Island formation in a gravel bed portion of the Snake River (McDonald et al. 2005).

6.6.6. Schedule

A schedule has been developed, and indicates the Model Development, Coordination, and Calibration study component will be completed by the end of the second quarter 2014; the Model Existing and with-Project Conditions study component will be completed by the end of the third quarter 2014; and Coordination on Model Output study component will be completed by the end of the fourth quarter 2014. A more specific breakdown of the anticipated schedule is presented in Table 6.6-5.

The Initial Study Report (ISR) and the Updated Study Report (USR) explaining the actions taken and data collected to date will be due within one and two years, respectively, of FERC's Study Plan Determination.

A flow chart describing study interdependencies (Figure 6.6-4) outlines the information and products required from other studies and the timing of delivery to successfully complete the Fluvial Geomorphology Modeling Study on schedule. The chart indicates which components of the Fluvial Geomorphology Modeling Study require the information. The chart also shows products and information the Fluvial Geomorphology Modeling Study will provide to other studies and the timing of their delivery. In addition to the flow chart, a discussion of the interactions between the Fluvial Geomorphology Modeling Study and the primary interrelated studies is provided in Section 6.6.4.2.2.4, Interaction with Other Studies. These studies include the Fish Instream Flow Study, Riparian Instream Flow Study, Ice Processes Study, and the Fish Study. Much of this interaction is the result of efforts conducted at the focus areas (see Section 6.6.3.1 for a discussion of the "focus area" concept). [*Additional Text describing the study interdependencies will be provided in the next version of the RSP*]

6.6.7. Level of Effort and Cost

Initial estimates of the costs to perform the components of the Fluvial Geomorphology Modeling Study are provided in Table 6.6-6. The total effort for the Geomorphology Modeling Study is estimated to cost between approximately $2.1 million and $2.7 million.

6.6.8. Literature Cited

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6.6.9. Tables

Table 6.6-1. Schedule for the downstream study limit determination process for the Fluvial Geomorphology Modeling Study

Step in Downstream Geomorphology Study Limit Determination	Date
RM 75 downstream geomorphology modeling limit proposal in RSP	December 2012
Reconnaissance level assessment of Project effects in the lower river and flow routing model results	January 2013
Technical memorandum on reconnaissance level assessment of Project effects in the lower river	January 2013
TWG meeting for confirmation of downstream geomorphology modeling limit	Feb / Mar 2013
1D bed evolution modeling and 2013 Geomorphology Study results and tech memo	January 2014
TWG meeting(s) to reevaluate and confirm or adjust downstream modeling limits	Feb / Mar 2014
Collect additional data if need identified (Summer 2014)	Summer 2014

Table 6.6-2. Evaluation of potential 1D models

Evaluation Criteria	Models			
	HEC-RAS	**SRH-1D**	**MIKE 11**	**HEC-6T**
General				
Proprietary/cost (if applicable)	○	○	● / $8K	● / $3K
Full or quasi unsteady for sediment transport simulation	Quasi	Both	Full	Quasi
Ice for fixed bed	●	○	○	○
Ice for moveable bed	●	○	○	○
# of transport equations supported	7	13	10	18
Supports user defined transport equation	○	○	○	●
Closed loop capability	○[1]	●	●	●
Experience with model: High (H); Moderate (M); Low (L)	H	L	M	H
Model Size Limitations				
# of cross sections	NL	NL	NL	5,000
# of hydrograph ordinates	40,000	NL	NL	NL
# of sediment sizes	20	8	NL	20
Sediment Sizes Supported				
Wash load (silts, clays)	●	●	●	●
Considers settling and resuspension	●	●	●	●
Sand	●	●	●	●
Gravel and cobble	●	●	●	●

Notes: ● = Yes; ○ = No; NL = No Limit
[1] Not currently available, but in development.

Table 6.6-3. Evaluation of 2D models

Evaluation Criteria	Model				
	SRH-2D	ADH	SToRM	MIKE 21	River2D
General					
Proprietary/cost (if applicable)	○	○	○	● / $20K	○
Unsteady flow capability	●	●	●	●	●
Ice for fixed bed	○	○	○	●	●
Ice for moveable bed	○	○	○	●	●
Number of transport equations supported	4	2	○[1]	10	2
Supports user defined transport equation	○	●	○[1]	●	○
Relative execution speed: Fast (F), Slow (S)	F	S	F	F	S
Model stability: High (H), Moderate (M), Low (L)	H	M	M	H	H
Experience with model: High (H), Moderate (M), Low (L)	H	M	L	L	M
Moveable boundary simulation	●	●	○[1]	●	●
Grid Structure/Model Formulation					
Finite element (FE)/ Finite Volume (FV)	FV	FE	FV/FE	FV/FE	FE
Grid structure: Flexible Mesh (FM)	FM	FM	FM	FM	FM
Model Size Limitations					
# of grid elements	16,000	Unlimited	Unlimited	Unlimited	>100,000
Sediment Sizes Supported					
Wash load (silts, clays)	○	●	○[1]	●	○
Considers settling	○	●	○[1]	●	○
Sand	●	●	○[1]	●	●
Gravel and cobble	●	●	○[1]	●	●

Notes: ● = Yes; ○ = No; U = Unknown, currently investigating capabilities; NL = No Limit
[1] Not currently available, but in development.

Table 6.6-4. Potential Focus Area Sites in the Middle and Lower River Segments

Feature	Downstream RM	Upstream RM	Geomorphic Reach	Reach Type
Below Dam	182.0	183.0	MR-1	SC2
MR2-wide	170.7	172.5	MR-2	SC2
MR2-narrow	168.5	170.0	MR-2	SC2
Portage Cr	148.3	148.8	MR-5	SC2
Slough 21	141.0	142.1	MR-6	SC3
Indian R	138.4	140.0	MR-6	SC3
Slough 11	135.3	136.6	MR-6	SC3
Slough 8A	124.2	126.1	MR-6	SC3
Slough 6A	111.8	113.0	MR-7	SC2
Whiskers Slough	101.0	102.2	MR-8	MC1
To be determined	NA	NA	LR-1	MC1

Table 6.6-5. Schedule for implementation of the Fluvial Geomorphology Modeling Study.

Activity	2012				2013				2014				2015	
	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1Q	2Q
Selection of 1D and 2D Models		—	—	—	—	●								
Selection of Focus Areas			—	—	●									
Coordination w/ Other Studies on Modeling Needs Including Focus Areas				—	—	—	—	—	—	—	●			
2013 Field Data Collection / Supplemental Field Data Collection 2014						—	—	●	/	—	●			
Coordinate with Other Studies on Processes Modeled				—	—	—	●							
1D Model Development and Calibration						—	—	—						
Perform 1D Modeling of Existing Conditions and Initial Project Run								—	●					
Reevaluate Downstream Study Limits Based on 1D Results									—	●				
2D Model Development and Calibration							—	—	—	—				
Perform 2D Modeling of Existing Conditions										—	●			
Perform 1D Modeling of Alternative Scenarios									—	—	—	●		
Perform 2D Modeling of Alternative Scenarios											—	●		
Post Process and Provide Model Results to Other Studies										—	—	●		
Interpretation of Channel Change and Integration with Other Studies										—	—	●		
Initial Study Report /Updated Study Report								—	Δ			—	▲	

Legend:
- —— Planned Activity
- ● Technical Memorandum or Interim Product
- Δ Initial Study Report
- ▲ Updated Study Report

Table 6.6-6. Fluvial Geomorphology Modeling Study costs.

Component	Task/Subtask		Estimated Cost Range
Bed Evolution Model Development, Coordination and Calibration	Development of Bed Evolution Modeling Approach and Model	Develop Approach	$50k
		Develop Model	$400k to $500k
		Field Data Collection	$900k to $1,100k
	Coordination with other Studies on Processes Modeled		$50k
	Calibration/Validation of Model		$200k to $300k
Model Existing and with-Project Conditions	Model Existing Conditions		$200k to $300k
	Model with-Project Conditions		$200k to $300k
Coordination on Model Output			$100k to $150k

6.6.10. Figures

Figure 6.6-1. Example of coarse mesh applied to the Whiskers Slough potential focus area, Middle River Reach 8

Figure 6.6-2. Example of fine mesh applied to the Whiskers Slough potential focus area, Middle River Reach 8

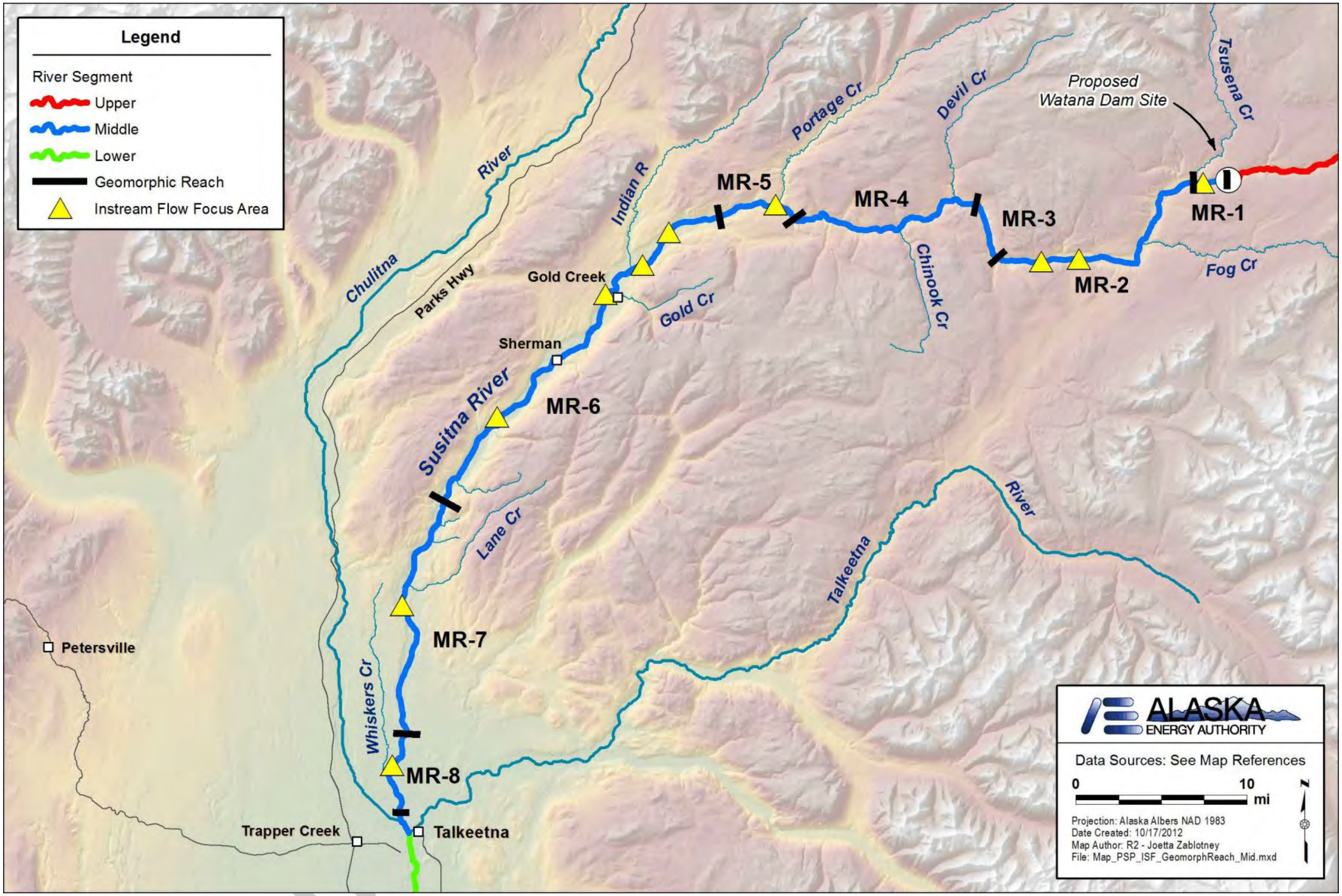

Figure 6.6-3. Locations of candidate Middle River focus areas.

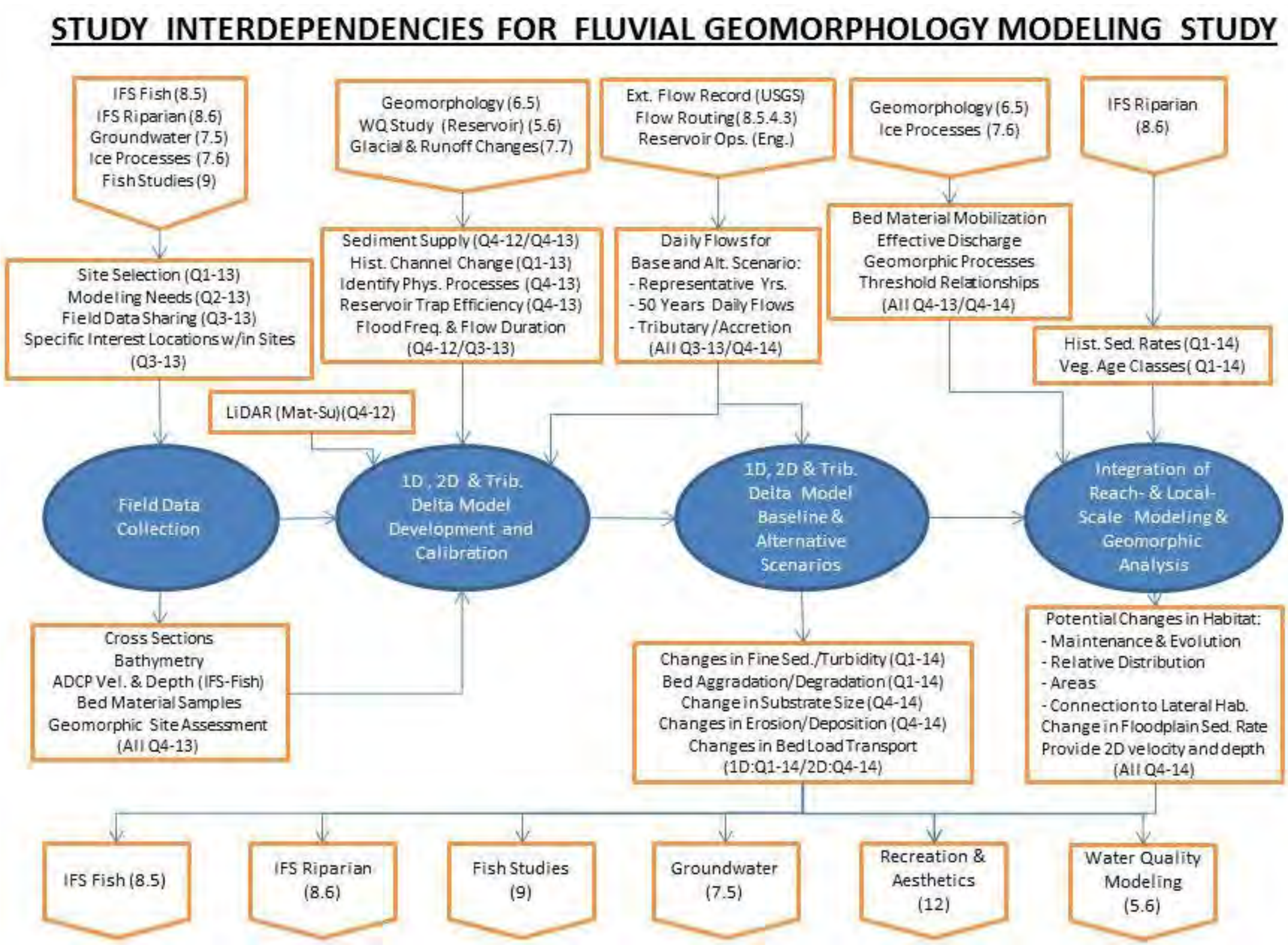

Figure 6.6-4. Study interdependencies for the Fluvial Geomorphology Modeling Study.

6.7. Attachments

ATTACHMENT 6-1. DOCUMENTATION OF CONSULTATION ON GEOMORPHOLOGY STUDY PLAN