9. FISH AND AQUATIC RESOURCES

9.9 Characterization and Mapping of Aquatic Habitats in the Susitna River with Potential to be Affected by the Susitna-Watana Project

9.9.1 General Description of the Proposed Study

This Revised Study Plan (RSP) describes a Susitna River-specific hierarchical and nested classification system currently under development by the Fish and Aquatics TWG. The system described in this RSP includes some modifications of the PSP. These include modifications based on "lessons learned" during implementation of initial ground surveys in 2012; evolving needs of other dependent studies; completion of the aerial video in 2012; and, inclusion of stakeholder's comments to the PSP.

In its current draft form, the classification system has two main components: one for the mainstem Susitna River (from the Oshetna River confluence at RM 233.5 downstream to RM 28) and one for tributaries (Upper River tributaries and Middle River tributaries up to the limit of hydrologic influence) (Figure 7.9-1). The Susitna River classification system combines the historic approach to mainstem habitat classification and a modified version of the mesohabitat classification system from the USFS Aquatic Habitat Surveys Protocol (USFS 2001). This hybrid classification system will describe habitats that are defined by the unique hydrology of this river system, yet are significant to the day-to-day function and behavior of fish and aquatic organisms.

This study will be valuable for gathering baseline habitat data that can be used along with other data being gathered (e.g. fish distribution and abundance, water surface elevation and discharge relationships, instream flow modeling, flow routing) to assess potential impacts associated with Project operations.

9.9.2 Study Goals and Objectives

Construction and operation of the Project will modify the aquatic habitat in the area inundated by the Project reservoir and has the potential to alter aquatic habitats in the mainstem channel of the Susitna River downstream from the Project dam, including along channel margins, at tributary confluences, at the inlets and outlets to side channels sloughs, and off-channel water bodies in the zone of hydrologic influence. The goal of this study is to characterize and map all aquatic habitats with the potential to be altered and/or lost as the result of reservoir filling, hydropower operations, and associated changes in flow, water surface elevation, sediment regime, and temperature. Study objectives for collecting baseline data vary depending on the nature of the potential Project effects and where in the study area the effects may occur. Study methods will, therefore, also vary within the study area. Objectives are described below according to the following breakdown.

Upper River Tributaries:

- **a.** Characterize and map Upper River tributary and lake habitat for the purpose of evaluating the potential loss or gain in available fluvial habitat that may result from dam emplacement and inundation by the reservoir.
- **b.** Characterize and map Upper River tributary and lake habitat for the purposes of informing other studies including fish distribution and abundance and river productivity.

Susitna Mainstem: Objectives for the mainstem Susitna vary depending on the river segment.

- **c.** Upper River Mainstem (RM 184 – RM 233.5)
  - **i.** Characterize and map the Upper River mainstem habitat to provide baseline data for the purpose of evaluating the potential loss or gain in accessible available fluvial habitat that may result from dam emplacement and inundation by the reservoir.
  - **ii.** Characterize and map the Upper River mainstem habitat for the purpose of informing other studies including fish distribution and abundance and river productivity.
- **d.** Middle Mainstem – (RM 98 – RM 184)
  - **i.** Characterize and map the Middle River mainstem habitat to provide baseline data for the purpose of evaluating the potential loss or gain in accessible available fluvial habitat that may result from flow regulation below the proposed Watana Dam.
  - **ii.** Characterize and map Middle River mainstem habitat for the purpose of informing other studies including instream flow, fish distribution and abundance, and river productivity.
- **e.** Lower Mainstem (RM 98 – RM 28)
  - **i.** Characterize and map the Lower River mainstem habitat to provide baseline data for the purpose of evaluating the potential loss or gain in available fluvial habitat that may result from flow regulation below the proposed Watana Dam.
  - **ii.** Characterize and map Lower River mainstem habitat for the purpose of informing other studies including instream flow, fish distribution and abundance, and river productivity.

9.9.3 Existing Information and Need for Additional Information

During the 1980s study efforts, habitat characterization and mapping in the middle reach of the mainstem Susitna River was conducted at a relatively coarse scale; mainstem habitat types that were representative of distinct functional hydrology and channel morphology were identified. Under this system, the Susitna River was classified into seven mainstem habitat types: mainstem channel, side channel, side slough, upland slough, tributary mouth, tributary, and lakes, defined by source water and hydrologic connectivity (Trihey 1982, ADF&G 1983a). For example, side channels were described as side channels that carried less than 10 percent of the mainstem flow, whereas sloughs were identified as having a water source derived from some combination of groundwater, tributaries, and/or local runoff. Upland sloughs, unlike side sloughs, were those that were disconnected from mainstem flows at their heads. These seven mainstem habitat types were mapped in the middle river based on aerial photography and were given individual alpha-numeric identifiers such as "Slough 22" (ADF&G 1983a). Subsequent sampling of fish populations and collection of water quality and habitat suitability data were conducted in subsets of the mapped habitats. Additional habitat characterization and mapping efforts developed during the 1980s defined unique categories of river habitat based on clear or turbid water conditions under specific flows, in combination with presence or absence of open water leads during winter (Steward and Trihey 1984) or hydrologic zones (ADF&G 1983a, ADF&G 1983b). The habitat categories were focused on main channel and side channel habitats in intensively studied areas in an attempt to scale the information up to the entire Middle Susitna River Reach for simulating the relationship between habitat and flow.

Very little habitat information has been collected in the upper Susitna River. In the early 2000s, ADF&G conducted sampling in the upper Susitna River sub-basin as part of its Alaska Freshwater Fish Inventory (AFFI) program (Buckwalter 2011a). These surveys were focused on documenting fish presence and collecting reach-level habitat data in medium and large tributary drainages (Buckwalter 2011b). The AFFI habitat studies were conducted at a scale that is not necessarily informative for understanding impacts to fish use or productivity. Because the upper river surveys were focused on fish inventory, they applied a dispersed sampling design that covered 60 streams; however, habitat data were collected at only one transect per stream. The scale of these historic data collection efforts limits their applicability for evaluating fish-habitat relationships and the potential for changes in fish habitat use throughout the Susitna River as a result of hydropower facility development and operation.

To augment the historic habitat data, this study will characterize and map aquatic habitat at finer scales than did the 1980's studies, including to the mesohabitat level in the main channel and tributaries. Mapping of off-channel habitats will include refinements to the typing of off-channel habitats, quantification of edge habitat in off-channel habitats, and typing and habitat metric sub-sampling in sloughs.

Characterization and mapping of mesohabitats is important in assessing potential impacts to fish populations because it is at this level that fish selectively use different habitats (Hardy and Addley 2001) to support different life stages and life functions. A full complement of meso-habitat types is required to sustain multiple life stages, support a diverse fish community, and furthermore, the distribution of these habitats throughout the river will influence fish distributions. Fine scale habitat attributes, such as those found at the mesohabitat level are thought to be particularly relevant to aquatic organisms. Organisms interact with their environment at different scales depending on their size and mobility (Parasiewicz 2007), both of which change with growth and development. Parasiewicz (2007) further suggested that mesohabitats are habitats within which an organism can be observed for a significant portion of its daily routine, similar to functional habitat discussed by Kemp (1999). For this study, information will be collected to support the development of habitat descriptions at more ecologically significant scales by considering several attributes that are biologically important to fishes (Harper et al. 1992, Maddock 1999). The higher mainstem habitat classifications used in the 1980s will be retained to allow for some level of comparison over time.

In addition to considering the scale of habitat classification, it is also important to consider the use of an objective classification approach that not only captures existing site-specific characteristics, but also can be used for comparisons across space and time. Mesohabitat assessments based on river morphology and ecologically significant habitat attributes should be consistent and reproducible. The USFS Aquatic Habitat Surveys Protocol (USFS 2001) is an example of a standardized protocol that was developed in Alaska to facilitate creation of a regional stream habitat database as well as one that allows for aggregation of habitat data at multiple scales. The USFS 2001 protocol is integrated into the habitat mapping study design described in this RSP.

Sources of existing information that will directly support habitat mapping are outlined in Table 9.9-1.

Table 9.9-1. Primary sources of existing information supporting Study 9.9

River Segment or Tributaries	Existing Information Available for Habitat Mapping
Upper River Tributaries	IFSAR 20 foot contour topographic data Low altitude aerial video
Upper River Mainstem	IFSAR 20 foot contour topographic data Low altitude aerial video Matanuska-Susitna Borough LiDAR and Imagery River cross sectional profiles of depth and velocity 2012 geomorphic mapping of channel types
Middle River Mainstem	IFSAR 20 foot contour topographic data Low altitude aerial video Matanuska-Susitna Borough LiDAR and Imagery River cross sectional profiles of depth and velocity 2012 geomorphic mapping of channel types 1980's geomorphic mapping of channel types
Lower River Mainstem	IFSAR 20 foot contour topographic data Matanuska-Susitna Borough LiDAR and Imagery River cross sectional profiles of depth and velocity 2012 partial geomorphic mapping of channel types

Existing fish, habitat, and aquatic resource information appears insufficient to address the following issues that were identified in the PAD (AEA 2011).

- **F1:** Effect of change from riverine to reservoir lacustrine habitats resulting from Project development on aquatic habitats, fish distribution, composition, and abundance, including primary and secondary productivity.
- **F2:** Potential effect of fluctuating reservoir surface elevations on fish access and movement between the reservoir and its tributaries and habitats.

- **F4:** Effect of Project operations on 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. The effect of Project-induced changes include stream flow, stream ice processes, and channel morphology (streambed coarsening) on anadromous fish spawning and incubation habitat availability and suitability in the mainstem and side channels and sloughs in the Middle River above and below Devils Canyon.
- **F7:** Influence of Project-induced changes to mainstem water surface elevations from July through September on adult salmon access to upland sloughs, side sloughs, and side channels.
- **F9:** The degree to which Project operations affect flow regimes, sediment transport, temperature, water quality that result in changes to seasonal availability and quality of aquatic habitats, including primary and secondary productivity.

The information collected during this study will be essential to understanding fish habitat distribution and will provide information relevant to addressing the five potential fisheries issues listed above.

9.9.4 Study Area

10. 9.9.4 Study Area

The study area for Study 9.9 encompasses the mainstem Susitna River from the Oshetna River confluence at RM 233.5 downstream to the upper extent of tidal influence at approximately RM 28. As described above, the mainstem study area is further divided according to geomorphic/hydrologic river segments; the Upper River, Middle River, and Lower River (see Figure 7.5-1). The study area also encompasses tributaries in the Upper River (98.0 to 184.0) and Middle River segments (RM 184.0 to RM 233.5). The study area for tributaries is described as follows.

- The study area for Upper River tributaries extends up to 3,000 feet elevation, unless a permanent impassable barrier exists between 2,200 and 3,000 feet elevation. If a barrier exists within this range surveys will stop at the barrier.
- The study area for Middle River tributaries extends from the confluence with the mainstem up to the upper limit of hydrologic influence.

9.9.5 Study Methods

9.9.5.1 Overview

Given the linear extent and remoteness of the river, an approach that combines analysis of aerial imagery with ground-based collection of habitat data will be used. This combination of methods will allow for maximizing coverage of river habitats in concert with efficient collection of detailed data at selected habitats suitable for ground surveys. Furthermore, the habitat characterization methods can be tailored to accommodate variations in channel size and overall stream length. Habitat data collected in this study will be consistent with the Susitna-Watana

Project habitat classification system being developed in this study planning process and with modifications of standard protocols outlined in the USFS Aquatic Habitat Surveys Protocol (USFS 2001).

Because of the major differences in channel morphology and hydrology between tributaries and the mainstem river and because Project effects are different in different geomorphic segments of the river, habitat mapping methods are differentiated within the study area as follows.

- Tributaries
    - Tributaries in the Upper River
    - Tributary segments in the Middle Mainstem influenced by mainstem flow
- Mainstem
    - Upper River Mainstem
    - Middle River Mainstem
    - Lower River Mainstem

9.9.5.2 Overview of Aerial Video for Habitat Mapping

Low altitude aerial video can be an excellent tool when mapping mesohabitats over long distances in remote and challenging topography. Low altitude aerial video combined with ground sub-sampling for habitat mapping studies has been used in numerous FERC hydro project relicensings in Washington, California, Texas, North and South Carolina. When shot with a professional HD camera from a helicopter at a slow speed (15 to 40 mph, depending on stream size), low height (75-300 feet), under good lighting conditions, good water clarity, and a fairly open canopy, the video provides an up-close and panoramic view of all the stream's features. To maximize the quality of the video it is shot in an upstream direction from the right rear of a helicopter with its cabin door removed. A narrator/navigator is positioned in the left front next to the pilot. From this low elevation, the viewer can clearly discern mesohabitat types, channel character, dominant substrate classes, woody debris, and riparian vegetation. Figure 9.9-1 is a screen capture from an aerial video of an Upper River tributary.

Aerial video collected in early September 2012 (before the mid September flood) included the 12 primary tributaries in the Upper River (Table 9.9-2), the Upper River mainstem, and the Middle River mainstem. While glare and swirling winds were a problem on a few tributaries, conditions were excellent overall. In addition, test video was shot of the Lower River between RM 65 and RM 81 to determine the practical and technical application of aerial video for habitat characterization in the wide and highly braided Lower River. Use of video in the Lower River is discussed further in Section 9.9.5.4.3. The final video product will include live narration, on-screen continuous GPS position, rivermile to the tenth of a mile, and running time to the tenth of a second.

The digital video file is playable using standard media player software. An excellent media player software is VLC. It supports many useful player controls including screen capture and can be downloaded as freeware at http://www.videolan.org/vlc/download-windows.html. Digital video files will be made available to stakeholders through AEA.

9.9.5.3 Upper River Tributary Habitat Mapping

Upper River tributaries will be mapped using results of the AEA 2012 low-altitude aerial video and in-river habitat ground survey sub-sampling. Low-altitude video surveys will only be used to type mesohabitats where they are clearly visible. Whether aerial video is also used to describe other habitat variables such as woody debris or dominant substrate size will be determined on a stream-by-stream basis and once such application is determined necessary and valid. Aerial video will not be used to directly estimate channel dimensions.

Table 9.9-2. Tributaries in the Upper River conducive to aerial video mapping and mapped in 2012.

Tributary Name	Entering	Elevation and Rivermile of Anadromous Barrier	Ending Elevation and Total Length of Proposed Study Area
Oshetna	Susitna RM 233.5	None	3,000ft/ xx miles
Black River	Oshetna RM Xx	None	3,000ft/ xx miles
Goose Creek	Susitna RM 231.0	None	3,000ft/ xx miles
Jay Creek	Susitna RM 208.6	None	3,000ft/ xx miles
Jay Creek Tributary	Jay Creek RM xx.	None	3,000ft/ xx miles
Kosina Creek	Susitna RM 206.8	None	3,000ft/ xx miles
Tsisi Creek	Kosina RM xx	None	3,000ft/ xx miles
Watana Creek	Susitna RM194.1	None	3,000ft/ xx miles
Deadman Creek	Susitna RM 186.6	xx	3,000ft/ xx miles
Tsusena Creek	Susitna RM 181.8	None	3,000ft/ xx miles
Tributary 181.2	Susitna RM 181.2	xx	Xx RM xx
Devils Creek	Susitna RM 161.5	xx	Xx RM xx
Chinook Creek	Susitna RM xx	None	3,000ft/ xx miles
Cheechako Creek	Susitna RM 152.4	None	3,000ft/ xx miles

9.9.5.3.1 Application of Aerial Video for Mapping Upper River Tributaries

Habitat in primary tributaries will be typed to the mesohabitat level shown in Table 9.9-3 using a video sampling method. Smaller and shorter tributaries that are not conducive to aerial video mapping will be mapped using ground methods only. The need and method for mapping lower order tributaries than those listed in Table 9.9-2 will be determined in collaboration with the Technical Work Group prior to the 2013 field season. Smaller tributaries may not require mapping, or, if they are mapped, a smaller number could be selected by a randomized method.

In video sampling, first a string is stretched horizontally across the computer monitor at about the center. The video is then played from the beginning at normal or slow speed and paused at a predetermined time interval. When paused, the mesohabitat type that is directly crossed by the line is classified and entered into an excel spreadsheet with the corresponding running time, e.g. 00hrs:12mins:3secs_riffle. This is repeated at a set interval of between 3 and 5 seconds, depending on the stream width and mesohabitat length, e.g., geomorphic reaches with short habitat units will have 3-second intervals, while reaches with long habitat units may have 5 second intervals. At an average speed of 18 mph and a recommended 3 second interval for tributaries, a sample is taken approximately every 80 feet or 66 samples per mile. Study area tributaries in the Upper River (Kosina, Watana, Fog, etc) are over ten miles long, resulting in over 600 mesohabitat samples in each tributary.

A library of aerial video screen captures (mesohabitat type-index) will be built that includes several variants of each mesohabitat type Figures 9.9-2 through Figure 9.9-15. The video “mapper” will constantly refer to the library of image captures to assure accuracy and consistency in mesohabitat typing. Ideally the type-index images would be ground verified prior to use in the video mapping. However, ground sub-sampling of all tributaries will not be completed until 2013. Therefore, for some streams, the completed video frequency analysis will need to be reviewed and checked against ground mapping later in 2013 and revised if needed. Given the low altitude perspective and clarity of the video, most mesohabitat types will be easily and accurately classifiable without ground verification.

The primary result of the video mapping is a mesohabitat frequency of 100% of the tributary study area. This frequency analysis can also be subdivided by geomorphic reach. Histograms and tables of mesohabitat type frequency will be produced. The metadata can also be used for other studies such as selection of random mesohabitat units for fish population surveys.

The method proposed above is a random sampling and replicable method. It's random for several reasons: a) the speed of the helicopter is changing by a few tenths to a few miles per hour several times per minute; b) since the camera is handheld and the attitude of the helicopter is constantly changing the angle of the lens relative to the ground is constantly changing; c) the height above the ground is constantly changing by a few to tens of feet; and, d) the sequence and lengths of mesohabitat types is highly variable in mountain streams. All these factors contribute to a constantly varying ground distance between sample points, even though the sample time interval is constant. The video sampling method has also been tested for "replicability", as described below.

To be certain mesohabitat typing using video is a reliable tool and the results are replicable, an analysis of the replicability of results was conducted in a California hydro relicensing. To check the general replicability of the habitat type identification, an independent reviewer conducted video mapping of randomly selected ground verified segments representing 20 percent or more of three PHABSIM reaches. Because ground truthing is an essential component of video mapping, the independent reviewer had also participated in the habitat mapping ground surveys, but not on the test stream segment. The three PHABSIM reaches selected represented a variety of channel and habitat types: wide, open canopy; variable gradient and canopy coverage; and a smaller, higher-gradient channel. The test concluded that the aerial video habitat mapping method is a reliable tool and that differences between replicates would be minimal; and, therefore differences between one investigator and another would be minimal, as long as the investigators were involved with the ground mapping and were given clear definitions and type-index images of the various mesohabitat types. An added value of the video record is the ability to check a habitat typing call with another researcher, if in doubt.

Within each geomorphic reach, habitats will be typed to the mesohabitat level according to a nested hierarchical classification system developed in part with input from the Fish and Aquatic TWG and from stakeholder comments to the PSP (Table 9.9-3). Note that the mesohabitat categories have been nested and expanded in this RSP to accommodate the high diversity of habitat types found in the tributaries during 2012 video and ground surveys.

Table 9.9-3. Upper Susitna River Tributary Mesohabitat Types and Descriptions.

Channel Type (# of channels)	Hydraulic Type	Mesohabitat Type	Definition
Single (1) Split (2) Channel Complex (3 or > channels)	Fast Water	Falls	Steep near vertical drop in water surface elevation greater than approximately 5 feet over a permanent feature, generally bedrock.
		Cascade	A fast water habitat with turbulent flow; many hydraulic jumps, strong chutes, and eddies and between 30-80% white water. High gradient; usually greater than 4% slope. Much of the exposed substrate composed of boulders organized into clusters, partial bars, or step-pool sequences. [3]
		Chute	An area where most of the flow is constricted to a channel much narrower than the average channel width. Laterally concentrated flow is generally created by a channel impingement or a laterally asymmetric bathymetric profile. Flow is fast and turbulent.
		Rapid	Swift, turbulent flow including small chutes and some hydraulic jumps swirling around boulders. Exposed substrate composed of individual boulders, boulder clusters, and partial bars. Lower gradient and less dense concentration of boulders and white water than Cascade. Moderate gradient; usually 2.0-4.0% slope, occasionally 7.0-8.0%. [3]
		Boulder Riffle	Same flow and gradient as Riffle but with numerous boulders that can create sub-unit sized pools or pocket water created by scour.
		Riffle	A fast water habitat with turbulent, shallow flow over submerged or partially submerged gravel and cobble substrates. [3] Gradients are approximately 2 to less than 4%.
		Run/Glide	A habitat area with minimal surface turbulence with generally uniform depth that is greater than the maximum substrate size. [3] Velocities are on border of fast and slow water. Gradients are approximately 0 to less than 2%. Generally deeper than riffles with few major flow obstructions and low habitat complexity. [3]
	Slow Water	Pool	A slow water habitat with a flat surface slope and low water velocity that is deeper than the average channel depth. Substrate is highly variable. [3]
		Pool subtypes	**Straight Scour Pool**: Formed by mid-channel scour. Generally with a broad scour hole and symmetrical cross section. [3]
			Plunge Pool: Formed by scour below a complete or nearly complete channel obstruction (logs, boulders, or bedrock). Pool must be Substrate is highly variable. Frequently, but not always, shorter than the active channel width. [3]
			Lateral Scour Pool: Formed by flow impinging against one stream bank or partial obstruction (logs, root wad, or bedrock). Asymmetrical cross section. Includes corner pools in meandering lowland or valley bottom streams. [3]

			Backwater Pool: Found along channel margins; created by eddies around obstructions such as boulders, root wads, or woody debris. Part of active channel at most flows; scoured at high flow. Substrate typically sand, gravel, and cobble. Generally not as long as the full channel width. [3]
		Beaver Pond	Water impounded by the creation of a beaver dam. Maybe within main, side, or off-channel habitats. [3]
		Alcove	An off-channel habitat that is laterally displaced from the general bounds of the active channel and formed during extreme flow events or by beaver activity; not scoured during typical high flows. Substrate is typically sand and organic matter. Generally not as long as the full channel width. [3]

[3] *Source*: Adapted from Moore et al. 2006.

9.9.5.3.2 Ground Mapping Upper River Tributaries

Because of the general inaccessibility, very rugged terrain, and mostly non-wadeable stream channels, near census mapping (100% coverage) would be very challenging and in some cases unsafe or impossible. For this reason AEA proposes to ground habitat map the Upper River Susitna tributaries listed in Table 9.9-2 using a combination of video, as described above, and on-the-ground sub-sampling described below. How many and which smaller independent tributaries, and how many and which smaller tributaries to the primary tributaries, need to be mapped will be determined in collaboration with the TWG.

Using desk-top tools including IFSAR topographic contour data, USGS topographic maps, aerial video, and information from reconnaissance flights, tributaries will first be segmented into geomorphic reaches where the channel is relatively homogeneous in stream gradient, confinement, and hydrology. Major breaks in each of these parameters will constitute a geomorphic/hydrologic reach boundary. Hydrologic reach breaks will be established at tributaries that appear to contribute more than approximately 10% of total flow to the parent tributary. A segment boundary will not be placed where downstream channel characteristics are primarily controlled by bedrock rather than fluvial processes. Bedrock channels are generally insensitive to short-term changes in sediment supply or discharge. Only a persistent decrease in discharge and/or an increase in sediment supply sufficient to convert the channel to an alluvial morphology would significantly alter fluvial bedrock channels (Montgomery and Buffington 1993). For this reason, flow accretion will only be used as a factor for segmentation at locations where channel characteristic below the contribution point are controlled by fluvial processes.

Within each geomorphic reach type, continuous habitat surveys will be conducted over a distance equivalent to at least 20 channel widths with the goal of sampling at least 5 units of each of the primary mesohabitat types occurring in the geomorphic reach. Primary is defined as mesohabitat types with a frequency in the geomorphic reach type of greater than 10%. Survey distance will be extended, either contiguously or at another location in the geomorphic reach, until the requisite number of replicates is obtained. If accessible by foot or helicopter, e.g. not in the bottom of a gorge, habitats with a frequency lower than 10% will be also surveyed but with fewer than 5 replicates.

Because helicopter landing zones in the uplands near the tributaries are extremely limited, a randomized approach for selecting mapping sections is impractical. A high percentage of randomly selected sites would likely not be accessible, and, when one was accessible, in-channel accessibility over a distance of 20 or more channel widths would likely also be a problem. Instead, subsample sites within each geomorphic reach will be selected based first on access to the site by helicopter and foot and second on the availability of multiple and varied mesohabitat types within safe and reasonable hiking/wading access. The concept of segmenting the stream into geomorphic reaches assumes that mesohabitat types within the segment are generally similar.

Channel metrics to be sub-sampled on the ground will be collected using a modified USFS Tier I and Tier III stream habitat survey protocol (2001). Note that some of the variables listed in the USFS protocol assume the stream being surveyed is wadeable.

Ground surveys in 2012 were not able to effectively or safely collect some of the Tier I or Tier III variables that were proposed for collection in the PSP. In many of the primary tributaries in the upper Susitna, habitat variables that involved crossing the streams were very difficult to collect given the difficult wading conditions in most reaches. Flows, even during late summer seasonal lows, were too fast and deep to negotiate at most points along the streams. Wading factors were typically above 8-9 (product of depth x velocity) over predominantly boulder substrate. Depths of 2.5 – 3 feet in combination with velocities of 3 to 4 feet per second around boulder substrates were very common in the Upper Susitna tributaries. Crossings with lesser wading factors were few and far between. As a result, some variables that were included for collection in the PSP have either been eliminated or the collection method or frequency of collection has been modified in this RSP.

Aquatic habitat surveys will be conducted by two-person survey crews. Each survey crew will consist of a fish biologist and qualified fisheries technician. Survey sections will begin at a predetermined location based on the survey section selection process described above and will progress in an upstream direction. If a permanent impassable barrier is encountered within the 2,200 elevation point, the barriers will be documented and surveys will continue upstream to the survey end. If a permanent impassable barrier is encountered above the 2,200 elevation point ground sub-sampling surveys will not be conducted beyond that point.

In stream sections with complex channel morphology (e.g. 3 or more parallel channels), the primary and one secondary channel will be designated and will be fully mapped. The remaining secondary channels will be identified and typed using the aerial video. In a highly complex channel type (Figure 9.9-15) the unit will be more characterized than mapped, e.g. length, width, number, type of sub-channels, and the general mesohabitat type present.

Habitat data will be recorded on the stream survey field data form. Separate stream survey data sheet(s) will be completed for each geomorphic reach. Habitat parameters to be measured for this component of the study include the following.

9.9.5.3.2.1 Tier I Data Collection

The following habitat metrics will be collected for each geomorphic reach.

- Geomorphic Reach Type (confined, similar gradient, similar hydrology)
- Channel type (primarily single thread, primarily split, primarily braid, or combination with estimated percent of each type)
- Measured bankfull width;
- Measured or estimated bankfull maximum depth;
- Measured gradient;
- Estimated dominant substrate composition;
- GPS location of channel measurements;

Note that incision depth was eliminated at Tier I in the RSP because collection generally requires crossing the stream.

9.9.5.3.2.1 Tier III Data Collection

The following habitat metrics will be collected for each mesohabitat unit.

- Habitat unit type;
- Measured unit length;
- Measured average wetted width (3 measurements per unit);
- If pool, estimated or measured maximum depth;
- If pool, estimated or measured pool crest depth;
- Estimated average maximum depth of unit;
- Measured width of unit;
- Woody debris count in unit;
- Estimated percent substrate composition in unit;
- Estimated percent undercut, each bank in unit;
- Estimated percent erosion, each bank in unit
- Estimated percent riparian vegetation cover in unit;
- Dominant riparian vegetation type for each unit;
- Estimated percent instream cover in unit;
- Photograph of each unit;
- GPS location of each unit;

Habitat units within the survey section will be sequentially numbered as they are encountered during each survey, and data will be recorded for each habitat unit. Data collected for all habitat units will include the unit length, the mesohabitat type according to Table 9.9-3, three measurements of wetted width from which an average wetted width will be calculated, percent substrate composition, percent eroding bank on each side of the channel, percent undercut bank on each side of the channel, dominant riparian vegetation type, cover type, and cover percent.

Additional data will be recorded for pool habitat units. The maximum pool depth and depth at the pool tail crest will be measured to the nearest 0.1 foot, whenever possible. These data will be used to calculate residual pool depth. The structural feature responsible for forming the pool will be identified (e.g., boulder, undercut bank, large or small wood).

Split channels are defined as separate flow paths located within the bankfull channel and separated from each other by gravel bars that are barren or support only annual vegetation. When split flow is encountered, each split will be surveyed and the proportion of flow conveyed by the split will be estimated, recorded, and used to classify each channel as primary (majority of the flow) or secondary (minority of the flow). Habitat units in the split that convey the most flow will be designated primary units and will continue to be numbered sequentially as part of the main channel survey. Where more than 2 split channels exist, only the primary and secondary splits will be numbered. The data form will note the total number of split channels.

Side channels are defined as features with a fluvially-sorted mineral bed that are separated from the main channel by an island that is at least as long as the main channel bankfull width and that supports permanent vegetation. At a minimum, the inlet and outlet of each side channel will be documented by collecting a GPS waypoint and taking a photograph looking upstream from the outlet and downstream from the inlet. The side channel will be identified as entering from the left or right bank (looking downstream) and classified as wet or dry. Habitat data will be collected in wetted side channels according to the methodology described above. Where more than 2 side channels exist, only the primary and secondary channels will be numbered. The data form will note the total number of split channels.

Relative flow levels on the day of the survey will be estimated according to the following:

- **Dry**
- **Puddled:** Series of isolated pools connected by surface trickle or subsurface flow.
- **Low Flow:** Surface water flowing across 50 to 75 percent of the active channel surface. Consider general indications of low flow conditions.
- **Moderate Flow:** Surface water flowing across 75 to 90 percent of the active channel surface.
- **High Flow:** Stream flowing completely across active channel surface but not at bankfull.
- **Bankfull Flow:** Stream flowing at the upper level of the active channel bank.
- **Flood Flow:** Stream flowing over banks onto low terraces or flood plain.

In addition, Susitna River mean daily discharge will be obtained from the nearest downstream USGS stream gauge and entered onto each day's survey forms.

Special Habitat Features

Special habitat features include tributary channels, seeps and springs that contribute groundwater to the mainstem, and temporary (e.g. subsurface flow) or permanent barriers to upstream fish migration. A separate data sheet will be maintained for each reach listing the type, location, and a description of special habitat features.

For features classified as stream barriers, the following information will be recorded in the comments section. Only cursory information will be collected under the Habitat Mapping study as most of the following barrier data is being collected under the Fish Passage Barrier Study Plan (RSP Section 9.13).

- Barrier type (beaver dam, debris dam, vertical falls, chute/cascade, boulder, other);
- Temporal nature (ephemeral or permanent);
- Maximum height of falls or biggest single step if cascading;
- Maximum depth of plunge pool;
- Chute/cascade gradient and length; and
- Length of feature.

A GPS waypoint and a photograph will be taken of each special feature. Additional photographs will be taken of representative channel conditions throughout each reach. The photo number, waypoint, date, and associated habitat unit or feature number will be recorded for each photograph.

9.9.5.5 Mainstem Habitat Mapping

The mainstem Susitna River from the Oshetna River to the upper extent of tidal influence includes approximately 200 miles of river and many times more than that distance when the lengths of side channels, braided channels, and sloughs, are included. An approach that includes the use of aerial imagery and collection of ground-based habitat data is required given the linear extent of this large river, its channel complexity, and its remoteness. This combination of methods will allow for maximizing coverage of river habitats in concert with ground sub-sampling at selected habitat areas. Furthermore, this combination allows habitat characterization and mapping methods to be tailored to accommodate different study objectives, different mapping tools available, and different methods, depending on the specific river segment.

9.9.5.4.1 Upper River Mainstem

The Upper River will be mapped using hierarchically-nested habitat typing adapted to feasible identification levels based on the use of aerial still imagery, LIDAR, and aerial videography. A linear network will be created in GIS by drawing lines through the middle of the stream channel as viewed by aerial imagery or LIDAR. The reference imagery was collected at river flows generally ranging from 10,000 to 12,000 cfs, which will be considered a representative mid-flow to conduct mapping. Divided channels will have multiple lines representing that stream section. Main-channel and off-channel habitat will be delineated. The length of the lines will be based on mesohabitat classification for the main-channel and macrohabitat classification for off-channel habitat. Each individual vector line will have a length and a hierarchical-tiered habitat classification organized in 'Levels'.

The habitat classification hierarchy will be composed of five levels representing: 1) major hydraulic segment; 2) geomorphic reach; 3) mainstem habitat type; 4) main channel mesohabitat; and 5) edge habitat (Table 9.9-4). Level 1 will generally identify the upper, middle, and lower rivers from each other. Level 2 will identify one of six unique reaches established from the channel's geomorphic characteristics (established from the Geomorphology Mapping Study). Level 3 will classify the mainstem habitat type of main, off-channel, and tributary habitat using a similar approach to the 1980's historical habitat mapping definitions (ADF&G 1983a). All off-channel habitat will be classified to level 3 and all main-channel habitat will be identified to Level 4 mesohabitat type (i.e. riffle, pool, run, etc.). The final Level 5, edge habitat, will be a calculated length of shoreline based on habitat linear units and classification from levels 1 through 4. Off-channel habitat will also have this calculation conducted based on Level 3 habitat lengths. Edge habitat typing is further described below.

Identifying small-scale habitat features from aerial imagery (i.e. still or video) can be difficult. In contrast, limiting habitat typing to only broader levels may insufficiently represent the amount of nearshore habitat available in more complex, divided, or backwater habitat units of larger rivers. Beechie et al. (2005) suggested that the shoreline edges of banks and bars provided excellent habitat for juvenile salmonids in large river systems and should be a focus of stream sampling. Beechie et al. (2005) conducted a ground-based fish sampling and habitat identification effort, but principles from this study can be applied to aerial habitat typing. Level 5 edge habitat typing will be a quantification of shoreline habitat based on the length of each habitat unit. The type of sub-mesohabitat will be based on prior hierarchical tier classification (i.e. levels 1 through 4). For example, a 100m confined (level 1), mainstem (level 2), single channel (level 3), glide (Level 4) will have 200 meters (i.e. two shorelines of 100m) of edge-type shoreline habitat. Off-channel habitat length will be determined by the Level 3 classification, because Level 4 mesohabitat typing only will occur in the main-channel and tributary habitat. Using the prior levels and identifying the quantity of edge habitat will help to identify complexity, inform fish sampling effort, and interpret fish relative abundance results.

A series of tables and figures were created to illustrate the habitat mapping approach and also the analyses that will be conducted from the data. Figure 9.9-16 shows an example of how habitat will be visually mapped from a GIS layer. An example of the raw database is shown in Table 9.9-5. The GIS database will create a hierarchical table that will be used to summarize the proportion of habitat by mapped unit of length (Table 9.9-6). The tiered approach will allow for summaries at all 5 levels to support resource study planning. The table will also provide individual identification of all unique habitat types. Also, edge-length will be calculated to identify sections of river with relatively higher complexity (i.e. more channels result in more shoreline habitat). This information will be important to understand how to best represent the Upper River.

Several controls will be established to ensure that the habitat mapping effort is both precise and accurate. Habitat typing will be conducted by no more than two unique GIS technicians to ensure typed habitat is consistent. Examples of specific aerial images of habitat as related to the levels will be created. These examples will be reviewed and confirmed by the technical lead and provide a voucher reference to help identify habitat types. Also, all typed data will be identified as having clear or turbid water to better identify slough habitat and correct any habitat typing errors. Final habitat typing will be reviewed by the technical lead to ensure consistency and accurate habitat mapping.

In addition to the remote mapping, on-the-ground truthing and refinement will occur. In 2013, a subset of off channel and main channel habitat units will be ground mapped and will include metrics described for tributaries, e.g. depth, width, wood, cover, etc, as appropriate for off-channel and main channel habitats. [THE FOLLOWING TEXT DESCRIBING MESOHABITAT SAMPLING WILL BE REFINED IN RSP] Five to ten main channel mesohabitat units and five to ten off-channel habitats units of each type will be randomly selected for sub-sampling. If there are fewer than the selected number all units of that habitat type all will be sub-sampled.

9.9.5.4.2 Middle River Mainstem

The Middle River mainstem will be mapped in similar fashion to the Upper River. The hierarchical tiered classification system will be implemented to identify habitat from aerial still imagery, LIDAR, and aerial videography. The Middle River habitat data will also be used by the Instream Flow study to establish habitat complexity and frequency. All habitat segments will be identified using a mid-channel line, which will provide habitat length; however, off-channel slough habitat will separately be drawn in an area (polygon) in the Middle River to identify the size of each slough and better characterize slough diversity for Instream Flow study needs. Area mapping will be reported separately from the linear database.

Table 9.9-4. Nested and tiered habitat mapping units and categories.

Level	Unit	Category	Definitions
1	Major Hydrologic Segment	Upper, Middle, Lower River	**<u>Defined Reach Breaks</u>** ***Upper River*** - RM184-248 (*Note Mapping only extends to RM 233*) ***Middle River*** - RM 98.5-184 ***Lower River*** - RM 0-98.5
2	Geomorphic Reach	Upper River Reaches 1-6 Middle River Reaches 1-8 Lower River Reaches 1-4	Geomorphic reaches that uniquely divide major hydraulic segments for the upper, middle and lower river based on geomorphic characteristics
3	Mainstem Habitat	Main Channel Habitat Off-Channel Habitat Types[1] Tributary Habitat	**<u>Main Channel Habitat:</u>** ***Main Channel*** **–** Single dominant main channel ***Split Main Channel*** **–** Less than 3 distributed dominant channels ***Braided Main Channel*** **–** Greater than 3 distributed dominant channels ***Side Channel*** **–** Channel that is turbid and connected to the active main channel but represents non-dominant proportion of flow ***Tributary Mouth*** - Clear water areas that exist where tributaries flow into Susitna River main channel or side channel habitats (upstream Tributary habitat will be mapped as a separate effort) **<u>Off-Channel Habitat:</u>** ***Side Slough:*** Overflow channel contained in the floodplain, but disconnected from the main channel. Has clear water.[2] ***Upland Slough:*** Similar to a side slough, but contains a vegetated bar and is rarely overtopped by mainstem flow. Has clear water. [2] ***Backwater:*** Found along channel margins and generally within the influence of the active mainchannel. Water is not clear. ***Beaver Complex*** **–** Complex ponded waterbody created by beaver dams **<u>Tributary Habitat:</u>** Tributaries will be mapped to the upper hydrological influence of the mainstem

4	Main Channel Mesohabitat	Main Channel and Tributary Habitat	**<u>Main Channel and Tributary Mesohabitat:</u>** ***Cascades* –** A fast water habitat with turbulent flow and hydraulic steps ***Riffle* –** fast turbulent water with shallow flow ***Pool* –** slow water habitat with minimal turbulence and deeper in depth due to a hydraulic control ***Run* –** fast water with minimal to moderate turbulence ***Glide* –** slower water with minimal turbulence
5	Edge Habitat	Length of Shoreline Habitat	***Calculation***- will be determined by doubling the length of the mapped habitat unit

[1] All habitat within this designation will receive an additional designation of whether water was clear or turbid within the database.
[2] All slough habitat will have an associated area created during the mapping process to better classify size.

Table 9.9-5. Example of raw data from mapping displayed in Figure 9.9-16.

Map ID	Level 1	Level 2	Level 3	Level 4	Turbid	Unit Length	Level 5 Edge Length
1	Middle	MR-7[1]	Main Channel	Glide	Yes	2,819	5,638
2	Middle	MR-7	Main Channel	Glide	Yes	2,339	4,678
3	Middle	MR-7	Side Channel	Run	Yes	2,101	4,202
4	Middle	MR-7	Main Channel	Glide	Yes	1,503	3,006
5	Middle	MR-7	Side Slough	Side Slough	No	824	1,648
6	Middle	MR-7	Side Channel	Run	Yes	978	1,956
7	Middle	MR-7	Side Channel	Glide	Yes	1,356	2,712
8	Middle	MR-7	Main Channel	Riffle	Yes	954	1,908

[1] MR-7 represents Middle Reach 7 of the geomorphic reaches

Table 9.9-6. Example data summarizing percent composition of unique habitat types.

Level 1	Level 2	Level 3	Level 4	Segment Count	Total Length (ft)	% of MR-7
Middle	MR-7[1]	Main Channel	Glide	3	6,661	51.7%
			Riffle	1	954	7.4%
		Side Channel	Glide	1	1,356	10.5%
			Run	2	3,079	23.9%
		Side Slough	Side Slough	1	824	6.4%
			Total	**8**	**12,874**	**100.0%**

[1] MR-7 represents Middle Reach 7 of the geomorphic reaches

Table 9.9-7. Example data summarizing length and percent composition of general habitat units by main channel and off-channel habitat.

Main Channel Mesohabitat	Total Length (ft)	%	Off-Channel Habitat	Total Length (ft)	%
Glide	8,017	66.5%	Main Channel	7,615	59.2%
Riffle	954	7.9%	Side Channel	4,435	34.4%
Run	3,079	25.6%	Side Slough	824	6.4%
Total	**12,050**	**100.0%**	**Total**	**12,874**	**100.0%**

Tributary segments in the Middle Mainstem that are within the zone of hydrologic influence will be mapped according to the methods described in Section 9.9.5.3 - Upper River Tributary Habitat Mapping. The extent to which aerial video is used versus ground mapping will depend on the length of the segment hydrologically influenced by the mainstem, accessibility, and canopy cover of the tributary segments. The need and method for mapping Middle River tributary segments will be determined in collaboration with the Technical Work Group prior to the 2013 field season. Smaller tributaries may not require mapping, or, if they are mapped, a smaller number could be selected by a randomized method.

As in the Upper River segment, in addition to the remote mapping, on-the-ground truthing and refinement will occur in the Middle River segment. In 2013, a subset of off-channel and main channel habitat units will be ground mapped and will include metrics described for tributaries, e.g. depth, width, wood, cover, etc, as appropriate. [THE FOLLOWING TEXT ON

SAMPLING IN FOCUS SITES MAY BE REFINED IN THE RSP] Separate from Focus Sites, five to 10 main channel mesohabitat units and five to 10 off-channel habitat units or each type will be randomly selected for sub-sampling. If there are fewer than the selected number of units of a habitat type than all will be sub-sampled. Main channel and off-channel habitats in Focus Sites will be 100% mapped to the mesohabitat level. Ground mapping will include metrics described for tributaries, e.g. depth, width, wood, cover, etc, as appropriate for off-channel and main channel habitats.

9.9.5.4.3 Lower River Mainstem

Because of the very large size and channel complexity of the Lower River (Figure 9.9-17) it is impractical to map the entire river segment beyond Level 3 (Mainstem Habitat Type). Of the five mesohabitat types in Level 4, the Lower River appears to primarily differentiate into only glides and riffles. The low gradient and aggraded gravel bed of the Lower River is generally not conducive to the formation of other mesohabitat types, such as pools or runs, although likely present in very low numbers.

Whether the Lower River is mapped to Level 3 depends on the extent of mapping to be conducted under the Geomorphic Mapping Study, which will use existing LiDAR and aerial imagery from the Matanuska-Susitna Borough LiDAR and Imagery Project.

In early September 2012, AEA conducted a test to determine the possible application of aerial video for habitat mapping the Lower River. A one mile wide segment was selected between RM 65 and RM 81. The test section was flown at three different heights above ground (AG). The number of parallel flight paths necessary to cover the river width at the three different elevations was: one path at 2,650 feet AG; two paths at 1,700 feet AG; and four paths at 400 feet AG. The test showed that a height of 400 feet or lower with 3-5 paths in a mile wide section would be necessary to visually differentiate mesohabitat types of riffle, glide, pool, or run, if they did occur. Further, several parallel paths would be extremely difficult to track even with GPS and would be very difficult to follow in the video.

In summary, Study 9.9 will rely on the Geomorphic Mapping Study to map the Lower River to Level 3. Development of mapping methods beyond Level 3 should wait until results of the 2012 interim studies, particularly the hydrologic study, are reviewed and analyzed by the technical work groups. The habitat characterization objectives for the Lower River will then be more clearly identified and defined.

9.9.5.4.4 Study Coordination and Updates

Multiple studies will be collecting field data in 2013 to better refine habitat mapping databases. Instream flow studies will be mesohabitat typing focus site off-channel habitat. This mesohabitat data may provide additional resolution to select areas of off-channel habitat. Also, the Geomorphology study will be area mapping focus areas in 2013 that could provide more refine area habitat units, where available. All relevant collected data from other studies will be reviewed and assessed to determine if updating or modifying the habitat mapping database with the additional information will be beneficial and supportive to the overall study goals.

9.9.5.4.5 Consistency with Generally Accepted Scientific Practices

Studies to map and characterize aquatic habitats are commonly conducted during water resource development projects, including for hydroelectric projects as part of FERC licensing. Field studies will use protocols developed in consultation with agency representatives and modified from standard federal protocols developed for use in Alaska (USFS 2001) and be consistent with the ISF analysis. Remote mapping will utilize protocols similar to those performed at other hydroelectric projects.

9.9.6 Schedule

Habitat characterization of the upper Susitna River will begin in 2012. Ground-based surveys will be conducted from July through September in 2012 and 2013. Flights for video data collection will be conducted in mid- to late-September 2012. Analysis of the video and habitat typing will occur simultaneously with data management for field survey data from October through December 2012 and 2013. The ISR and USR will be filed within one and two years, respectively, of FERC's Study Plan Determination (i.e., February 1, 2013).

Table 9.9-8. Schedule for implementation of the Habitat Characterization and Mapping 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	1 Q
Data Collection		—	—			—	—						
Initial Study Report								—	Δ				
Follow up Data Collection										—	—		
Updated Study Report												—	▲

Legend:

—— Planned Activity
----- Follow up activity (as needed)
Δ Initial Study Report
▲ Updated Study Report

9.9.7 Interdependency with Other Studies

In addition to providing baseline information about aquatic resources in the Project Area, aspects of the Habitat Characterization and Mapping Study are designed to complement and support other AEA studies (Figure 9.9–18. In addition to a review of background information that will aid in study planning and design, five study components will provide the necessary precursor or input information. Inputs from the Geomorphology Study (Section 6.0), Aerial Video Study, GIS Mapping and Aerial Imagery, Fish Distribution and Abundance in the Upper (Section 9.5) and Middle and Lower Susitna River (Section 9.6) will aid in the physical and biological delineation and mapping of habitat. The characterization of aquatic habitat will then provide useful output or feedback to understanding five AEA studies. The mapping of aquatic habitat will aid in understanding the behavior, movements, and spatial use of fish in the Fish Distribution and Abundance in the Upper (Section 9.5) and Middle and Lower Susitna River (Section 9.6). Habitat characterization will help better understand the potential project effects of the flow regime in the Instream Flow Study (Section 8). The characterization of aquatic habitat will allow for the identification of habitat impacted by the Project reservoir and this may affect the future reservoir fish community (Section 9.10). Finally, the River Productivity Study (9.08) will use the habitat mapping for identification of study site selection and quantification of habitat types for interpolation.

9.9.8. Consultation and Correspondence

Table 9.4-1 presents stakeholder comments to all of the fish and aquatics study plans, including the 9.9 Preliminary Habitat Characterization and Mapping Study Plan.

9.9.9 Level of Effort and Cost

The total estimated cost of the study for 2013 and 2014 is $1,000,000 including remote mapping, field surveys, data analysis and technical report preparation.

9.9.10 Literature Cited

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9.9.11 Figures

Figure 9.9-1. Video frame capture of a tributary mid-channel scour pool in a confined channel with boulder and cobble substrate and no stream wood visible. ***(For a closer inspection the image can be zoomed to 250%).***

Figure 9.9-2. Aerial video tributary habitat mapping type-index - Falls

Figure 9.9-3. Aerial video tributary habitat mapping type-index - Cascade

Figure 9.9-4. Aerial video tributary habitat mapping type-index - Chute

Figure 9.9-5. Aerial video tributary habitat mapping type-index- Rapid

Figure 9.9-6. Aerial video tributary habitat mapping type-index - Run

Figure 9.9-7. Aerial video tributary habitat mapping type-index - Boulder Riffle

Figure 9.9-8. Aerial video tributary habitat mapping type-index - Cobble/Gravel Riffle - Spit Channel

Figure 9.9-9. Aerial video tributary habitat mapping type-index - Glide

Figure 9.9-10. Aerial video tributary habitat mapping type-index - Mid Channel Scour Pool

Figure 9.9-11. Aerial video tributary habitat mapping type-index - Lateral Scour Pool - Braided Channel

Figure 9.9-12. Aerial video tributary habitat mapping type-index – Alcove – Special Habitat Feature.

Figure 9.9-13. Aerial video tributary habitat mapping type-index – Beaver Comples – Special Habitat Feature.

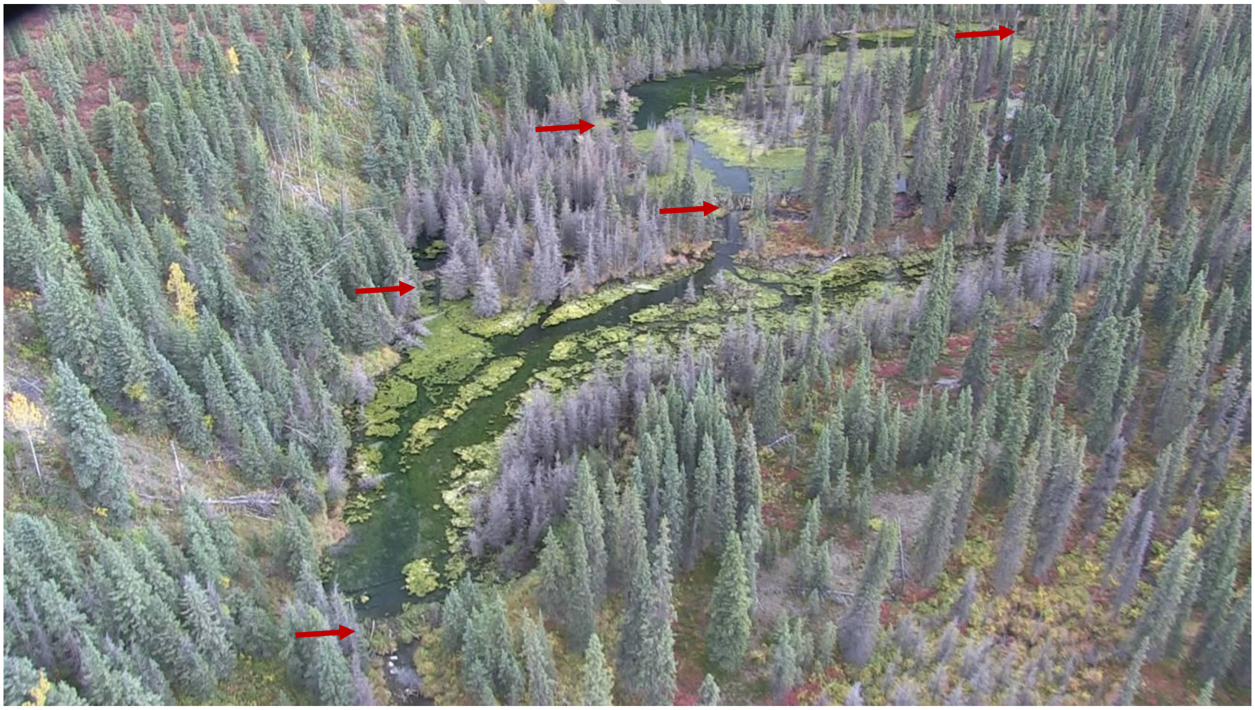

Figure 9.9-14. Aerial video tributary habitat mapping type-index - Unclassified - Boulder Riffle?

Figure 9.9-15. Aerial video tributary habitat mapping type-index - Unclassified – Braided Channel?

Figure 9.9-16. Example of mapping using the tiered habitat classification system in GIS.

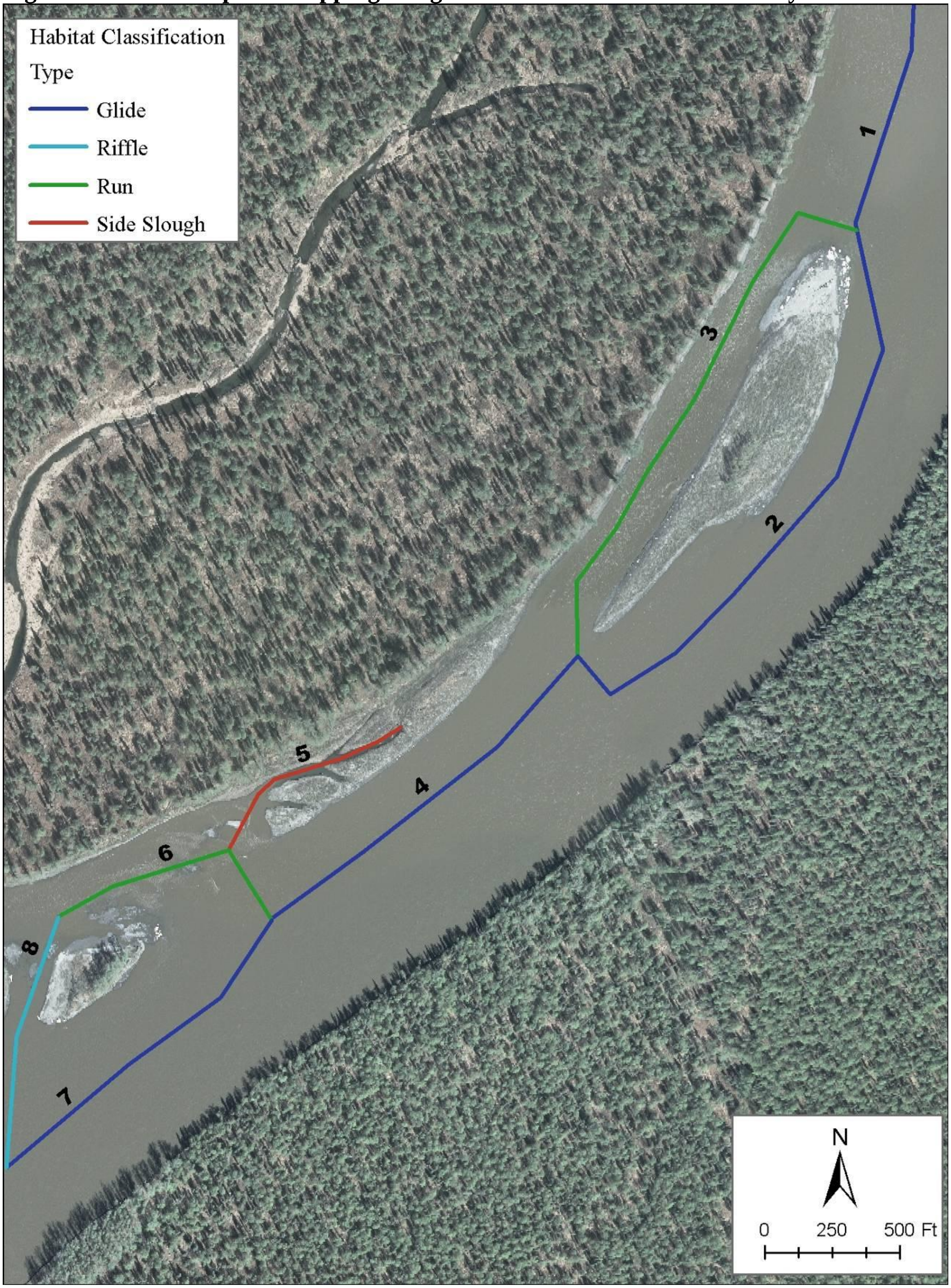

Figure 9.9-17. Aerial video capture of the Lower River mainstem.

Figure 9.9-18. Interdependencies for Characterization and Mapping of Aquatic Habitats