AQUATIC RESOURCE STUDIES

CASCADE CREEK HYDROELECTRIC PROJECT

FERC NO. 12495-002

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ACRONYMS AND ABBREVIATIONS

ADFG	Alaska Department of Fish and Game
ADT	Alaska daylight time
AST	Alaska standard time
AUV	Automated underwater vehicle
CCLLC	Cascade Creek LLC
cfs	Cubic feet per second
Ck	Creek
CPUE	Catch per unit effort
CS	Coast range sculpin
D_{50}	Median particle size
Dbkfl	Bankfull depth
DO	Dissolved oxygen
dr	Drainage
DV	Dolly Varden
El.	Elevation
FP	Primary pool
fps	Feet per second
GL	Glide
GPS	Global Positioning System
HDOP	Horizontal dilution of precision
HN	Hoop net
LBB	Bottom of left bank
LBF	Left bankfull
LBP	Left bank pin
LEW	Left edge of water
Lk	Lake
LTB	Top left bank
LWD	Large woody debris
M-R	Mark-recapture
msl	Mean sea level
MT	Minnow trap
MW	Megawatts

NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NSO	Natural sequence order
PAD	Pre-Application Document
PL	Pool
PL SPC	Pool spacing
PLNGTH/M	Pool length per meter
POOL/KM	Pools per kilometer
POOL_SIZE	Pool size
Project	Cascade Creek Hydroelectric Project
RBB	Bottom of right bank
RBF	Right bankfull
RBP	Right bank pin
RBT	Rainbow trout
REL_SUBMERGE	Relative submergence
REW	Right edge of water
RF	Riffle
RHMO	Riparian habitat management objectives
RK	River kilometer
RPD	Residual pool depth
RPD/CBW	Residual pool depth divided by channel bed width
RTB	Top right bank
TIN	Triangulated Irregular Network
TKWD/M	Total key pieces large wood per meter
TL	Total length
TLWD/M	Total large wood pieces per meter
USFS	US Forest Service
USFWS	US Fish and Wildlife Service
VIE	Visible implant elastomer
Wbkfl	Bankfull width
WD	Width-to-depth ratio
WGS84	World Geodetic System of 1984
YOY	Young of the year

1. INTRODUCTION

The proposed Cascade Creek Hydroelectric Project (Project) is located on Swan Lake, Cascade Creek, and Thomas Bay, approximately 15 miles northeast of Petersburg, Alaska in the US Forest Service (USFS) managed by the Tongass National Forest (Figure 1-1). Cascade Creek LLC (CCLLC) proposes to construct an intake structure, penstock, and powerhouse, which will accommodate three turbine-generator units for a total capacity of approximately 70MW. CCLLC proposes to operate the proposed Project within the normal, seasonal fluctuations of Swan Lake. The Project would not require the construction of a dam for operational storage purposes, but would incorporate a modest outlet control structure to aid in the management of lake levels.

1.1. PROPOSED STRUCTURES

The major proposed features of the Project include an intake structure, penstock, outlet control structure, powerhouse, tailrace, service roads, transmission line, and appurtenant equipment. Flow to the powerhouse will be drawn from Swan Lake through a lake siphon. The lake siphon, equipped with fish screens and placed at an approximate depth of 40 ft, will be housed in a 46-foot-long, 34-foot-wide, and 25-foot-high concrete intake control structure (gatehouse) with a valve system to control water flow.

An outlet control structure is included as part of the proposed Project. This structure would consist of a very small, low-head weir approximately 4-6 ft high above the lowest elevation of the lake outlet. The structure would serve several purposes: minimize outflow leakage through the shallow substrata, provide for minimum in-stream flow contribution if required; facilitate lake level management by adding the ability to store or release water as necessary in drought or flood conditions to help maintain the desired lake level; and allow for emergency overflow discharge to the stream outlet of Swan Lake. The outlet control structure would be designed to allow fish to emigrate from the lake as has occurred naturally.

Water would be delivered to the powerhouse from the lake siphon via a drilled and excavated 12-ft-diameter mostly unlined rock power tunnel that originates at the gatehouse at El. 1,430 ft and extends 13,100 ft at a slope of approximately 1 percent. From this point, it would drop into a 1,290-ft-long vertical shaft/vent. The vertical shaft would be connected at the bottom end to another 1,624-ft-long tunnel at a slope of approximately 1 percent that would terminate at the penstock at an elevation of approximately 265 ft mean sea level (msl). The penstock would consist of a 600-ft-long, 9-ft-diameter buried steel pipe that would connect to the powerhouse at an elevation of approximately 50 ft msl at tidewater on Thomas Bay.


Powerhouse
Scow Bay Substation
Figure 1. Project Area Map
Cascade Creek
Hydroelectric Project
Legend
Infrastructure
138-kV Overhead Transmission Line
138-kV Submarine Transmission Line
Powerhouse Power Conduit Tunnel & Penstock
Swan Lake Power Conduit Tunnel
Swan lake
Cascade Creek
N
0 0.5 1 2 Miles
Thomas Bay
Frederick Sound
Petersburg
Petersburg Mountain
Cosmos Range
Patterson Pks
Porter Pk
Cosmos Peak
Sukoi Islets
McDonald Is
Horn Mtn
Brown Cove
Icy Cove
Frederick Pt
Scow Bay
Pt Agassiz
Ruth I
Spray
Vandeput
Wood Pt
Muddy
Patterson River

The powerhouse, located at tidewater on Thomas Bay, would consist of a concrete and metal building, approximately 140 ft by 80 ft, embanked by rock fill on the north and east sides. Its foundation would be cast-in-place concrete, founded on bedrock. The north and east walls would be concrete and act as a retaining wall for the proposed tunnel exit. The superstructure would be a metal building with a sloped metal roof. CCLLC proposes to site the structure at least 200 ft off the shoreline to provide an aesthetic vegetative buffer and avoid effect to the coastal zone. Inside the powerhouse, an overhead crane would provide access to place and maintain the turbine generating units. The turbine housings would be cast in the concrete substructure. It would house three generating units, and water would drop vertically from the units to the tailrace below.

The Project tailrace is proposed as a low gradient open stream channel lined with natural rock/cobble/boulder materials approximately 450 ft long and 40 ft wide, discharging as a new outlet to Thomas Bay. It would exit the powerhouse in a southern direction for approximately 300 ft and then turn west to Thomas Bay for approximately 100 ft in order to provide a tree screen to visually hide the powerhouse from Thomas Bay. The tailrace would be designed to deter use by anadromous fish.

1.2. AQUATIC RESOURCES STUDY OBJECTIVES

Studies of the aquatic resources were initiated to provide pre-development baseline data, which could be used to examine potential effects of hydro development associated with the run-of-the-river operation approach of the proposed Cascade Creek Hydroelectric Project. Objectives of the proposed studies are to provide information suitable to: 1) Establish baseline aquatic resources data in areas potentially affected by the Project; and; 2) Evaluate the effects of Project construction and operation in those areas.

1.2.1. STUDY SCOPE

The study plan encompasses the fishery resources in the Cascade Creek drainage as well as water quality and aquatic invertebrates in these water bodies. Swan Lake contains a self sustaining population of rainbow trout (RBT) stocked in the late 1950's (ADFG 1975).

In the following sections, we define specific studies undertaken in the various study areas. The individual studies reflect study requests made by respective resource agencies with oversight on aquatic resources. The Alaska Department of Fish and Game (ADFG) provided written comments on SD1 and subsequent comments submitted on March 5th, 2010 on the initial Draft Aquatic Resources Study Plan. CCLLC distributed Version 2 of the Draft Aquatic Resources Study Plan for review in July 2010. On August 12th, 2010 and again on September 28th, 2010, CCLLC hosted a meeting to review Version 2 of the Draft Aquatic Resources Study Plan. Agency staff provided comments during that meeting as well as written and verbal comments. The 2010 Aquatic Resource Studies included the following individual study components:

- Stock Assessment and Seasonal Fisheries Inventory;

- Fish Habitat Survey;
- Fish Passage Survey
- Geomorphic Study of Swan Lake Inlet;
- Bathymetry Study;
- Limnology Study of Swan Lake at the Penstock Intake; and
- Aquatic Macroinvertebrate Study on Falls Lake and Lower Cascade Creek.

Table 1-1: Schedule for Aquatic Resource Study components.

Study	Study Area	Study Year	Study period
Stock Assessment &Seasonal Fisheries Inventory	Falls Lk	2010	August/September/ November
	Lower Cascade dr	2010	August/September/ November
Habitat Survey	Upper Cascade dr	2010	August
Geomorphic Investigation In Area Of Swan Lake Major Inlet	Swan Lk	2010	August
Bathymetric Mapping	Falls Lk	2010	August
	Swan Lake Inlet	2010	August
	Tidewater	2010	August
Limnology Study of Swan Lake @ Penstock Intake	Swan Lk (at siphon depths)	2010	August / September
Aquatic Invertebrate Inventory	Falls Lk	2010	August
	Lower Cascade dr	2010	August

1.3. RAINBOW TROUT FISHERY BACKGROUND

Swan Lake was originally stocked with RBT (*Oncorhynchus mykiss*) in 1957 and 1958 by the ADFG. Rainbow trout are a popular trout species of targeted by anglers nationwide. Trout occur naturally in cold water stream habitats but because of their adaptability in diet and habitat use, in addition to their general hardiness, the stocking of this species into lakes and reservoirs is widespread throughout North America and the world where their presence supports major sport fisheries.
The RBT used to stock Swan Lake 50 years ago have thrived and spread into the adjacent water bodies including Cascade Creek (which both feeds and drains Swan Lake) and Falls Lake (downstream of Swan Lake). Current population and distribution information for this isolated and self-sustaining population of trout is unknown. However, although unverified, their occurrence has been described as abundant in Swan Lake. Rainbow trout populations in Lower Cascade Creek, Falls Lake and the Pond are uncertain.

1.3.1. RAINBOW TROUT LIFE HISTORY BACKGROUND

Rainbow trout mature between the age of 3 and 7 years and are capable of reproducing annually for many seasons. This reproductive pattern is called iteroparity (Quinn 2005) and is markedly different from salmon which spawn once and then die (semelparity). Rainbow trout spawn in the spring and early summer beginning in May and ending in July. Fry emerge in late spring or early summer (Quinn 2005) depending on water temperature, with warmer water accelerating embryonic development. As with other salmons the female constructs a nest or "redd" by excavating gravel with their caudal fin. Eggs are laid in the resulting depression and subsequently fertilized by a male RBT. This spawning strategy renders the availability of relatively loose and suitably sized gravel substrate, which is paramount in importance for reproductive success. Rainbow trout, as well as other salmon, are also sensitive to temperature, flow and dissolved oxygen variations that are present in areas of connectivity between surface water and groundwater. These water exchange processes are collectively known as "upwelling" and occasionally "downwelling" when the direction of water movement is reversed. Zones of stream or lake bottom habitats where vertical gradients occur are preferentially selected for spawning by trout and other salmonids. The above observations of RBT are general to the population and not specific to the trout at Cascade Creek or Swan Lake project area. The RBT found in Cascade Creek and Swan Lake could have irregularities not mentioned here, which will be documented during the study and summarized in the final report.

1.4. AQUATIC RESOURCES STUDY AREA

The study area for the Aquatic Resource Study encompassed Cascade Creek from its mouth at Thomas Bay to the portion of Cascade Creek that flows from a natural fish barrier, approximately 1.5 miles upstream of Swan Lake (Figure 1-2). Cascade Creek was divided into three reaches, Reach 1, Reach 2, and Reach 3. In addition to these primary stream reaches, Falls Lake, the Pond, Swan Lake and the Spring Creek received intensive study as part of the Aquatic Resource Studies. The section of Cascade Creek from Thomas Bay to the Swan Lake outlet was referred to as Lower Cascade Creek. The section of Cascade Creek upstream of the Swan Lake inlet was referred to as Upper Cascade Creek.

Reach 1 contained the stretch of stream from Thomas Bay to the outlet of Falls Lake. This reach was further divided into Reach 1A, tidewater to the first barrier falls, and Reach 1B, the barrier falls to the outlet of Falls Lake.

Reach 2 started at the Falls Lake inlet and ended at the outlet of Swan Lake. Reach 2 was divided into two sub-sections, 2A and 2B. Reach 2A runs from Falls Lake inlet to the Pond outlet and Reach 2B runs from the Pond inlet to Swan Lake outlet. Reach 3 is the portion of Cascade Creek from Swan Lake inlet and above, to the barrier falls.

Reach 3, located on Upper Cascade Creek, started at the Swan Lake inlet and terminated at the barrier falls approximately 3,500 m upstream from Swan Lake. The Spring Creek drained the valley bottom in Upper Cascade Creek flowing just north and parallel to Reach 3 for approximately half its length.

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FIGURE 1-2

CASCADE CREEK STREAM REACHES

CASCADE CREEK DRAINAGE
18 Miles NW of Petersburg, Alaska

DATE: NOV. 2010
CHKD: J.G.
DRWN: C.L.H.
PROJ. No.: 637-004

825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880

J:\Projects\637_001_Cascade_Creek\mxd\Field_Site_Layout_Reaches

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2. UPPER CASCADE CREEK GEOMORPHIC AND AQUATIC HABITAT SURVEY

The following section presents the results of the geomorphic and aquatic habitat surveys completed for Upper Cascade Creek and the adjacent Spring Creek, a physical survey of the delta at the inlet to Swan Lake and select portions of Lower Cascade Creek.

2.1. INTRODUCTION

CCLLC's Pre-Application Document (PAD) identified issue(s) associated with Upper Cascade Creek and the adjacent Spring Creek for which the existing, relevant, and reasonably available information were insufficient to address. During subsequent consultation with agency staff, the following information needs were identified:

- Baseline information on the aquatic habitat and geomorphic characteristics of Upper Cascade and Spring creeks, both of which flow into Swan Lake; and
- Geomorphic characteristics of the river delta formed at the confluence of the two creeks with Swan Lake

As a result, CCLLC, in consultation with the agency representatives including the National Marine Fisheries Service, U.S. Fish and Wildlife Service (USFWS) and Alaska Department of Fish and Game (ADFG), developed an aquatic habitat mapping study as a viable and reasonable method to obtain the information necessary to assess the identified resource issue(s).

The primary goal of this study was to characterize existing fish habitat and geomorphic conditions in Upper Cascade Creek and the adjacent Spring Creek, both of which flow into Swan Lake, in sufficient detail to provide the licensing participants a sound understanding of current (i.e., baseline) conditions and the watershed context in which they occur. The delta area formed by the confluence of these creeks with Swan Lake was also characterized as to its form. The rationale for this study was previously described in the study plan, submitted and approved by the agencies involved in the licensing process.

The specific objectives for Upper Cascade Creek included:

1. Inventory geomorphic characteristics and processes in both stream systems and the delta at their confluence with Swan Lake.
2. Characterize existing fish habitat conditions, using USFS R10 survey methods for both Upper Cascade Creek and Spring Creek, as appropriate.

Stream habitat surveys were considered for Lower Cascade Creek in the development of the study plan below the outlet to Swan Lake. After examination of topographic maps aerial photos and a reconnaissance of the reach, it was determined that the extreme steepness of the stream posed unreasonable risk to safety. Furthermore, the consistent steep gradient resulted in a fairly homogenous pattern of cascades and plunge pools, affording little aquatic habitat other than small pools and infrequent riffles. Enumerating these habitats would seem to provide little basis to make judgments about how the project might affect the fisheries resource. Consequently, quantitative stream habitat surveys were not conducted in Lower Cascade Creek. Aerial video footage depicting the habitat characteristics of Lower Cascade Creek are available online at www.thomasbayhydro.com. Aerial footage of reach 3 and the Spring Creek are also posted at the same site. In September 2010, the National Marine Fisheries Service (NMFS) requested a qualitative stream habitat survey in the portion of Lower Cascade Creek accessible to anadromous fish. This 200 meter reach, referred to as reach 1A, was added to the stream habitat study plan.

2.2. UPPER CASCADE CREEK GEOMORPHIC AND HABITAT SURVEY METHODS

This section describes the field methods and data analysis associated with the geomorphic study and stream habitat survey in Upper Cascade Creek and the adjacent Spring Creek.

2.2.1. STUDY AREA

The study area included approximately 2000 meters of the main channel of Upper Cascade Creek above its confluence with Swan Lake to the impassible falls. Additionally, a survey of the Spring Creek adjacent to Upper Cascade Creek was completed for a length of about 600 m (2000 ft). For Upper Cascade Creek, the initiation point was from the pool below the impassable falls (~ 2.0 RK ["river kilometer"]). All side channels and tributary junctions were noted, and GPS coordinates were recorded.

The study also included a topographic survey of the delta at the confluence of Cascade Creek and Swan Lake to a depth of about 1–1.5 m (depending on lake level) that defines the present topographic surface and the overall distribution of sediment sizes across that surface.

2.2.2. GEOMORPHIC SURVEY METHODS

For Cascade Creek, the USFS "Tier Two" survey parameters and methods were applied to develop consistent, replicable data for use in subsequent analyses and provide a baseline for future data-collection efforts. The purpose of this level of data collection is

> "…to provide consistent, quantitative estimates of habitat parameters necessary to evaluate the condition of a stream relative to Tongass National Forest riparian habitat management objectives (RHMO). The Tier Two survey protocol identifies variables that can be measured efficiently by a two-person survey crew. Habitat units are defined and discrete categories established to minimize observer bias, reduce measurement error, and enable replication and comparison of data across time and space. These habitat objectives will help define the natural variation for key indices of channel condition and fish habitat, and are the basis for describing the desired condition of healthy, fully functioning stream

ecosystems." (FSH 2090.21 – Aquatic Habitat Management Handbook, Chapter 20, 2001)

Methods used for the following channel morphology elements of the survey are described below:

1. Station (distance) relative to a known geographical point
2. Channel incision and entrenchment
3. Bankfull and channel-bed width
4. Bankfull depth
5. Channel substrate
6. Channel gradient
7. Channel pattern and sinuosity

These data were collected using a three-pass approach. The first, a traverse of the entire study reach, was used to gain an overall impression of the river's key attributes, to make a preliminary assignment of the primary geomorphic reach breaks and to identify representative locations for geomorphic cross-sections within each reach. The second pass focused on quantitative data collection at the cross-sections (elements 2–5 above); the third constituted a systematic longitudinal survey, not required under Tier Two protocols but yielding an invaluable data set for any future analyses (as well as providing the framework for element 1 and the optimal data for elements 6 and 7).

Based on air photo review, the first field traverse, and the requirements of the Tier Two survey, Cascade Creek was subdivided in to five geomorphic reaches with a cross-section location sited in each one (see element #3 below). For Spring Creek, a single geomorphic reach was judged appropriate for the limited degree of observed geomorphic variability. The methods used for collecting data needed for each element are as follows:

1. Station (distance) relative to a known geographical point. Stationing for all geomorphic measurements (reach breaks and cross-sections) were defined during the survey of the longitudinal profile. Owing to differences in overall length, size, and complexity, we used different methods for the two channels. In Cascade Creek, horizontal position and bed elevation was determined by a survey autolevel and stadia rod; water depth on the day of measurement was read directly off the rod. Both vertical measurements have a precision of ~0.03 m (0.1 ft); over the typical distances of individual segments, the horizontal precision is typically about 1 m (3 ft). Instrument stations, cross-sections, and several benchmarks were also recorded using both recreation-grade (7-m horizontal precision) and non-differential survey-grade (2-m precision) GPS units. Over the length of the study reach and at individual locations, measurement precision is well within the normal temporal variation in the position and bed elevation of an alluvial channel, and so this geographic framework should provide a suitable basis for any future measurements of channel stability or change. Semi-permanent benchmarks "UCC1-4" were established with rebar and surveyed with GPS. The geomorphic and gradient surveys are tied in to these benchmarks.

For Spring Creek, overhanging vegetation precluded the use of an autolevel but distances were sufficiently short to track horizontal location using a 100' tape. Location of individual habitat units, and the one cross-section, was stationed with respect to the taped position. Measurements were later converted to metric equivalents for presentation in this report.

2. Channel incision and entrenchment. Along the entire study reach of both channels, there was no evidence of any significant channel incision, undoubtedly a consequence of the extensive floodplain everywhere present on at least one side of the channel and, where adjacent to the channel, very stable bedrock valley walls. Thus, these measurements (and those of "flood-prone width" and side slope angle) were not recorded.

3. Bankfull and channel-bed width. The most precise measurements of channel dimensions were made at the geomorphic cross-sections (five for Cascade Creek and one for Spring Creek), located in the middle part of each geomorphic reach at sites that most closely met the criteria for suitability as expressed in FSH 2090.21 (USFS, 2001):

> "Channel cross-section sites should occur at riffle sections. Select a straight and narrow section of riffle, free of undercut banks and obstructions such as large woody debris accumulations. The tape should be stretched across the channel to a point well beyond the bankfull point. The objective is to capture not only the bankfull stage, but also the lower angle. On wide channels, a stadia rod and survey instrument should be used to obtain accurate measurements. On narrow channels, it may be possible to obtain accurate measurements by measuring from the stream bottom to a tape stretched parallel to the water surface."

For both Cascade Creek and Spring Creek, a horizontally stretched tape was used to determine horizontal station. On Cascade Creek, an autolevel and stadia rod established accurate bed elevation while on Spring Creek a horizontal tape served as reference for measuring channel cross-section elevations. Measurement precision was 0.03 m (0.1 ft) in all cases.

For each cross-section, the following attributes were recorded:

Left bank pin	LBP
Left bankfull	LBF
Top left bank	LTB
Bottom of left bank	LBB
Left edge of water	LEW
Right edge of water	REW
Bottom of right bank	RBB
Top right bank	RTB
Right bankfull	RBF
Right bank pin	RBP

In addition to station/elevation measurements at each of these points, between 8 and 18 additional measurements were recorded between LBB to RBB (a minimum of 4 are required by the Tier Two method). Given the detail of the cross-channel survey, the thalweg (i.e., the deepest point in the channel) was subsequently identified from the data (although the best field-determined location was always a measured point on the cross-section).

The upper edge of the bankfull channel was field-identified using the normal indicators of vegetation change and bank/floodplain geometry commonly applied on rivers in humid-region around the world. Both Cascade Creek and Spring Creek have exceptionally well-defined bankfull channels, with excellent correspondence of vegetation, sediment, and topographic indicators. These points on the cross-sections, namely at points LBF and RBF, provided the basis for determining values for both the maximum and average bankfull width at each cross-section by extraction of the resulting data.

The location of the edges of the active bed in these channels corresponded almost precisely to the base of the topographic break in bank slope (i.e., at LBB and RBB), and these were identified visually at the time of measurement. Many additional measurements of active bed width were made elsewhere throughout the study reach in the process of conducting the survey of habitat units, and these were made with a hand-held 100' tape. Their precision is somewhat lower than those made at the cross-sections (~1 m) but was judged entirely adequate for the purposes of that survey.

4. Bankfull depth. As noted above, the upper edge of the bankfull channel was prominently expressed in the field at each cross-section, and so the bankfull depth was readily defined from the resulting cross-section elevation data. As is common in moderately to very wide channels, however, the elevations of the right- and left-bank bankfull indicators do not always match precisely, owing to variations in the meander history, scour patterns, and floodplain aggradation that can vary from one side of the river to the other. Thus, observations were made in the field at the time of measurement to evaluate which bank appeared to express a more consistent, and more reach-representative, elevation of "the" bankfull depth. Depending on the reach, one or the other top-of-bank elevation, or an intermediate value, was identified as the most representative one. In most all cases this introduced a judgmental consideration of no more than about 0.2 m (i.e., less than a foot) and never more than 0.6 m (2 feet).

5. Channel substrate. Surface pebble counts of ≥100 individual clasts were made at each cross-section using the standard "first-touch" method of Wolman (1954). We took sampling transects as specified in FSH 2090.21 (2001), to wit:

> "Establish 5 pebble count transects at each morphology survey site. Take 20 boot-tip samples along each transect for a total of 100 particle samples. Transects should be perpendicular to the stream (parallel to the cross-section), and extend across the channel bed to the point coinciding with the bottom-of-bank...The objective is to sample proportionately across the

entire channel bed (not just the wetted bottom), and to capture within-site variability along the longitudinal profile."

Transects bracketed the cross-section locations up- and downstream within ~10 m, spanning the full active bed width. Grains were measured with a ruler and binned into ½-phi categories, with 4 mm the minimum recorded size (i.e., categories of <4, 5.6, 8, 11, 16, 22, 32 mm, etc.). Data were entered into USFS-supplied Excel spreadsheets to ensure standard methods for analysis and display.

6. Channel gradient. Channel gradient was extracted from the data collected under element #1 above ("Station [distance] relative to a known geographical point"), because it was determined that a systematic survey of the longitudinal profile would provide more accurate data than up/downstream shots with a hand-held clinometer. The survey methods should be capable of detecting vertical changes less than 0.1 m per 100 m (i.e., one foot per thousand feet), and data were reported to the 1/100th of a percent.

7. Channel pattern and sinuosity. These attributes were determined by calculating the ratio of the channel distance (measured from the longitudinal profile) and the straight-line valley distance as measured from high-quality aerial photographs from 2006. Such ratios are commonly reported with two-digit precision (e.g., 1.5). The data under the methods used in this report were at least one order of magnitude more precise.

2.2.3. FISH HABITAT SURVEY METHODS

In the following section we provide a description of the survey methods to characterize aquatic habitats in the study area, including the specific metrics. Deviations from standard protocols were necessary for part of the survey, and these are also described.

2.2.3.1. CASCADE CREEK

To characterize aquatic habitat conditions in upper Cascade Creek, we used the USFS Region 10 (2001) Tier Two sampling protocols, as described in the Aquatic Resources Study Plan approved by the agencies. To survey the adjacent Spring Creek, we used a slightly modified approach to characterize existing geomorphic and habitat conditions. All distinct stream channel "types" were characterized using the USFS Region 10 channel classification scheme. A complete census of habitat types in both streams was completed during the study period. Side channels and off-channel features relative to the main Cascade Creek were also noted and their features inventoried, according to the survey protocol. For each stream, the survey proceeded in an upstream to downstream direction, and each unique habitat unit was identified to the macro type (pool, riffle, glide, etc.) using the habitat feature code assigned in the protocol. Each habitat unit was further assigned a sequential number ("NSO," or natural sequence order) to show its position in the channel Secondary habitat units that occurred in the main channel (e.g., a pool that occupied <50% of the wetted width) were labeled as such. Because of the scale of side channels and off-channel features, and as a way to distinguish them from main channel units, all habitat units that occurred in these areas were labeled as secondary units, even though they occupied virtually the entire wetted width vs. secondary units that constituted side channels and tributary junctions.

Survey data was compiled on Rite-in-the-Rain® survey forms fashioned after the standard forms used in the USFS Tier Two survey and subsequently transferred to an Excel spreadsheet for archiving and analysis. A data column was added to the standard USFS survey form to allow recording of average wetted width of each habitat unit. Standard survey tools (laser rangefinder and 100-ft survey tape) were used to take measurements of habitat unit length and widths. All measurements were recorded in English standard units and later converted to metric units.

The following metrics were included in the survey of Upper Cascade Creek:

1. Total length of stream surveyed
2. Complete inventory of habitat units, categorized by type, length and their relative position in the channel network
3. Average habitat unit (channel bed) width
4. Pool characteristics; including number of "qualifying" pools, max depth, depth of crest outlet, and residual pool depth
5. Large wood loading (number of pieces per channel width); key pieces and vertical location (zone) within the channel
6. Side channel measurements as above including location, width and total length, if water is present and flowing; number of qualifying macro pools; number of qualifying pieces of large wood and key pieces scaled to the average channel bed width; and maximum pool depth and pool tail crest depth.

2.2.3.2. SPRING CREEK

After an initial reconnaissance of this stream system and associated wetlands, we determined that use of the standard Tier Two stream survey protocol would not be very useful, considering the homogeneity of this spring-fed system. The habitat type in this entire system was primarily slow-moving glide, with little velocity. The channel was inset in a broad wetland complex, with extensive vegetated areas only navigable by foot with considerable difficulty. When the lake level is high, water backs-up into the lower reaches of the creek creating more slow-water habitat. Thus, we opted to use a simplified approach that divided the stream (and its many channels) into ~30-m survey segments. In this way, we inventoried the entire accessible length of the stream. Surveyed features included overall length, substrate characterization, wetted width, dominant habitat feature, and notes on riparian vegetation. Streamflow was primarily attributable to hyporheic upwelling, seeps and springs from the upstream wetlands and adjacent hillslopes. Some locations in the channel showed active upwelling of flow from hydrostatic pressure. No sign of beaver activity was seen in either Spring Creek or the larger Upper Cascade Creek.

2.3. RESULTS

The results from both the geomorphic survey and the habitat survey are provided below. The entire length of the study area was included in the survey, essentially providing a complete, linear census of geomorphic conditions and habitat characteristics for the area of interest. Where practical, results are presented in tabular or graphic form. Full survey field notes are provided as appendices at the end of the report.

2.3.1. GEOMORPHIC SURVEY RESULTS

Upper Cascade Creek is a broad, sinuous, low-gradient alluvial channel with an extensively developed floodplain and a generally stable pattern. Using the classification of USFS Report R10-TP-26 (1992), it is an FP4 channel ("wide low gradient flood plain channel"). Its gradient is relatively well-anchored by likely near-surface bedrock at the head of the study reach and at several points farther downstream, and by the level of Swan Lake (under whatever degree of fluctuation it experiences). The channel has an ample supply of sand and gravel available for erosion from the adjacent floodplain and supplied from upstream over the reach-bounding waterfall; a paucity of LWD along the channel suggests that landslide delivery from the adjacent valley walls is not a significant source (of either logs or sediment). The substrate is loose and well-graded, suggesting frequent mobility; but the floodplain vegetation is dense, and both field observations and reference to historic aerial photos suggest that channel migration is limited. No evidence of vertical incision was observed or suggested by the channel data.

For purposes of organizing the geomorphic data, the ~2-km study section for Upper Cascade Creek was subdivided into five reaches, hereafter referred to as "Geo-Reaches" (Table 2-1). The basic attributes of the respective Geo-Reaches are described below.

Table 2-1: Upper Cascade Creek longitudinal profile reach lengths.

Geo-Reach	Length (m)
1	233.2
2	561.4
3	395.0
4	240.8
5	709.3
Total Survey Length	**2139.7**

Geo-Reach 1 begins at the base of the impassable waterfall at RK 2.0 (Figure 2-1a). Flow direction is from the bottom right to the upper left in the photo. The impassible falls is seen as a white area in the shadows at the bottom right corner. The uppermost 10-20 m is a chaotic, turbulent pool where the water dropping off the falls moves in all directions before organizing into a steep boulder cascade with a number of large immobile clasts, delivered over the falls but unable to be transported through this reach by any but the highest discharges. The channel has deposited a broad left-bank bar at the inside of the first broad meander bend that lies unconstrained at the head of the valley.

The cross-section for this reach was located about 80 m downstream of the base of the waterfall, traversing the upper part of the left-bank bar that was partly submerged even at low flow and which was bounded on its right side by the free-flowing channel. The bottom of this reach lies at the transition between the broad meander bend that constitutes most of its length and a sharp right bend imposed by flow impinging on the bedrock valley wall. This reach includes habitat units NSO 1–4 ("Natural Sequence Order").

Geo-Reach 2 was characterized by bedrock control along the left bank at its upstream and downstream ends. Between these two segments of the reach, the channel has developed a prominent meander bend, the second such bend downstream of the falls that swings well into the middle of the widening valley and with a sediment-rich, well-developed point bar. The channel was thus confined by bedrock on one bank at both the upstream and downstream ends of this reach; gravel bars immediately upstream of both bedrock banks suggest backwater effects at high discharge. The cross-section for this reach was located midway between the apex of the main meander bend and the downstream bedrock control, in a short straight segment of the low-flow channel that began a few meters below the downstream end of the (left-bank) point bar. The end of this reach was immediately downstream of the left-bank bedrock control that constrained the southerly migration of the channel. Starting at NSO 7, this reach stretched downstream to the end of NSO 17. NSO 5 (a riffle in a side channel) and NSO 6 (a pool nested within NSO 7) were secondary units coincident with NSO 7 (Figure 2-1a).

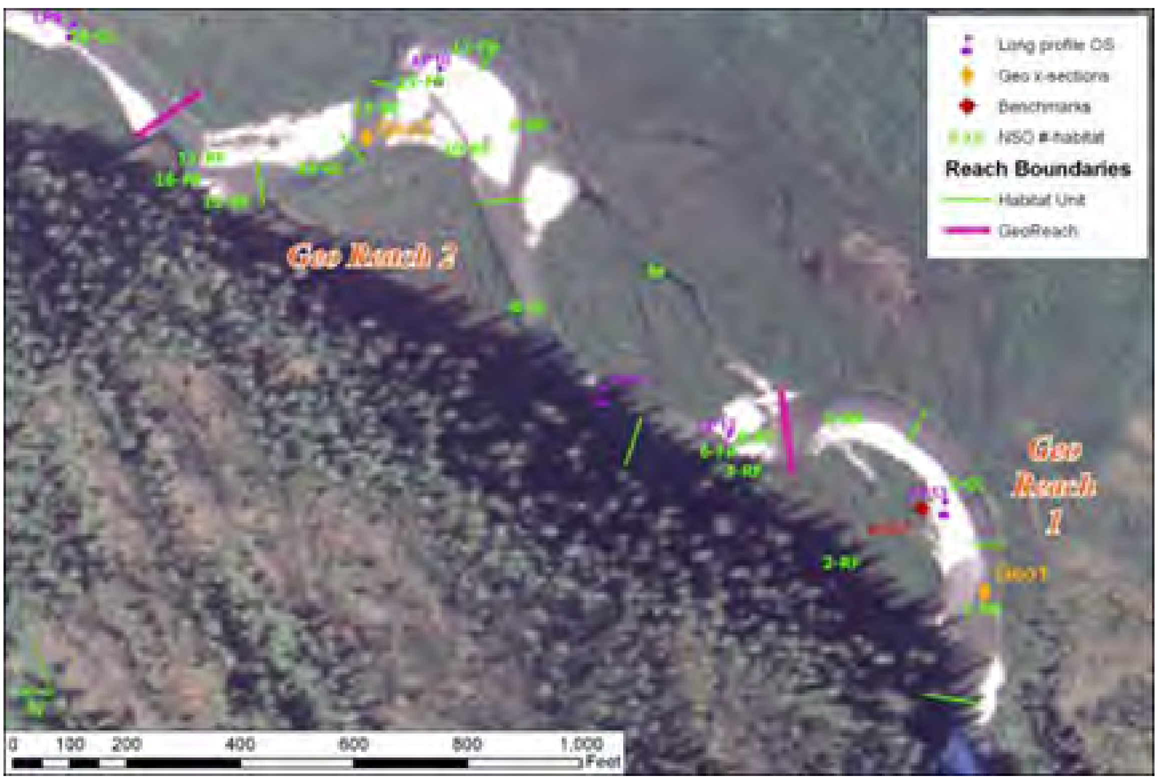

Figure 2-1a: Geo-Reaches 1 and 2 in Upper Cascade Creek.

Habitat codes: *RF (riffle), GL (glide), FP (primary pool), PL (pool)*

Geo-Reach 3 was an entirely alluvial reach, composed of one wavelength (about 400 m long) of a broad, open meander bend with an amplitude of 80 m with weakly developed point bars (Figure 2-1b). The channel was entirely unconfined. The cross-section was located almost exactly midway between the apexes of the two meander bends, in a uniform straight riffle that was characteristic of most of the reach. The end of this reach lies immediately upstream of the extensive point-bar deposition on the left bank associated with the next meander bend downstream. This reach starts at NSO 18 and proceeds downstream to the end of NSO 21.

Geo-Reach 4 was also entirely alluvial, encompassing the single largest meander bend of the study area. This bend had a tight radius of curvature resulting in both an extensive point bar deposit and several neck cutoff channels that have degraded the point bar but not yet led to its abandonment (i.e., the majority of low to moderate flows continue to follow a sinuous course around it). The cross-section was located just past the downstream end of the point-bar sediments, analogous to the location of the cross-section in Reach 2. The bottom of this reach was defined by the return of the channel against the bedrock of the south valley wall, constraining further development of its prior sinuous pattern. This reach starts at NSO 23 and proceeded downstream to the end of NSO 26. NSO 22, also nested within this reach, was a relict side channel with an outlet to the main channel but with no direct upstream inlet connection to the main channel.

Figure 2-1b: Geo-Reaches 3 and 4 in Upper Cascade Creek.

Habitat codes: *RF (riffle), GL (glide), FP (primary pool), PL (pool)*

Geo-Reach 5 was a nearly straight reach, bounded by bedrock along the left bank and the broad floodplain of the alluvial valley on the right, and continued almost uniformly to the inlet to Swan Lake (Figure 3-1c). Several alternate gravel bars with wavelengths of 200–400 m suggest an incipient migrating pattern, but bedrock along the left bank and dense willows along the right bank have apparently impeded any significant bank erosion and resulting migration. The cross-section was located 87 m upstream of the left-bank gage, in a uniform straight riffle that exemplified the channel characteristics through this reach (the form and position was analogous to that of the cross-section in Reach 3). The bottom of this reach graded into a well-developed delta constructed into the head of Swan Lake; a discrete channel form was identifiable up to and beyond the confluence with Spring Creek, but at moderate discharge (or high lake level) the flow begins spreading out over the left bank across the delta and into the lake about 100 m farther upstream. Starting at NSO 27 this reach extends downstream to NSO 41, which terminates at the delta confluence at the lake. NSO 28 was an off-channel backwater pool feature associated with a small tributary, and was coincident with NSO 27 (Appendix 2-1).

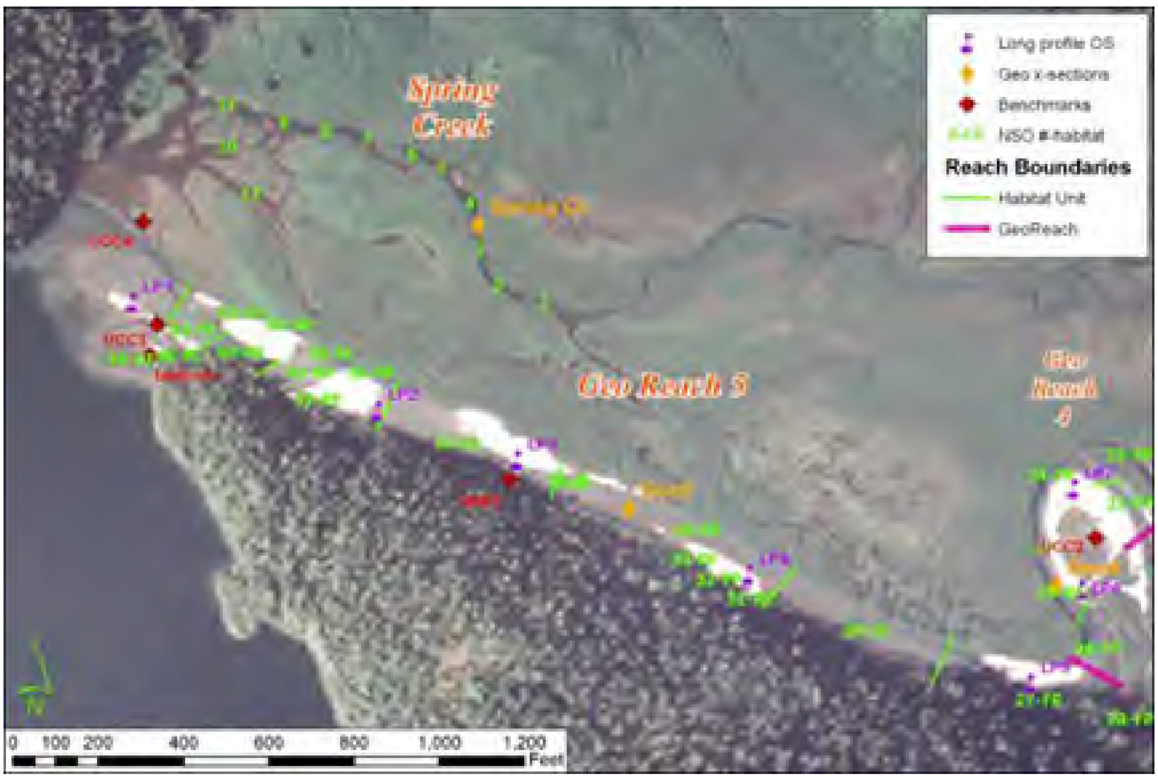

Figure 2-1c: Geo-Reach 5 in Upper Cascade Creek, Spring Creek and Swan Lake

Habitat codes: *RF (riffle), GL (glide), FP (primary pool), PL (pool).*

Cross-sectional plots and grain-size data at each of the five cross-sections are provided in Appendix 2-4; the summary data are as follows:

Table 2-2: Summary geomorphic statistics for Upper Cascade Creek

	GEO 1	GEO 2	GEO 3	GEO 4	GEO 5
Wbkfl--mean (m)	32.5	23.1	19.3	18.5	23.7
Wbkfl--maximum (m)	33.4	28.7	20.6	20.4	24.8
Dbkfl--mean (m)	0.6	1.0	1.1	1.1	0.9
Dbkfl--maximum (m)	1.1	1.2	1.3	1.5	1.0
Bed width (m)	30.2	21.3	16.3	18.4	22.5
D_{50} (mm)	63	39	38	30	32
D_{84} (mm)	150	77	70	55	62
Water-surface slope	1.76%	0.40%	0.40%	0.63%	0.22%
Reach Sinuosity	1.31	1.55	1.29	1.66	1.04

Wbkfl means bankfull width; Dbkfl means bankfull depth

The systematic and relatively monotonic changes in channel character were evident from the summary data. For example, at the head of the reach, it is steep, wide and shallow, coarse-bedded, and sinuous to meandering in character. As the channel approaches its entrance to Swan Lake, its gradient is flat, sediments are finer grained, width is both narrower and deeper, and the channel is nearly straight. Overall sinuosity across the five reaches (i.e., from waterfall base to Swan Lake) was a modestly sinuous 1.38.

The longitudinal profile of Cascade Creek exhibited a generally concave-up profile of the channel (Figure 2-2). The bed topography was entirely alluvial (i.e., no bare bedrock was observed) and was developed almost entirely as a result of either forced (i.e., impingement of flow against the bedrock valley wall) or free (fully unconstrained) meanders. Boulders and large woody debris were almost entirely absent, providing minimal opportunities for more localized bed heterogeneity.

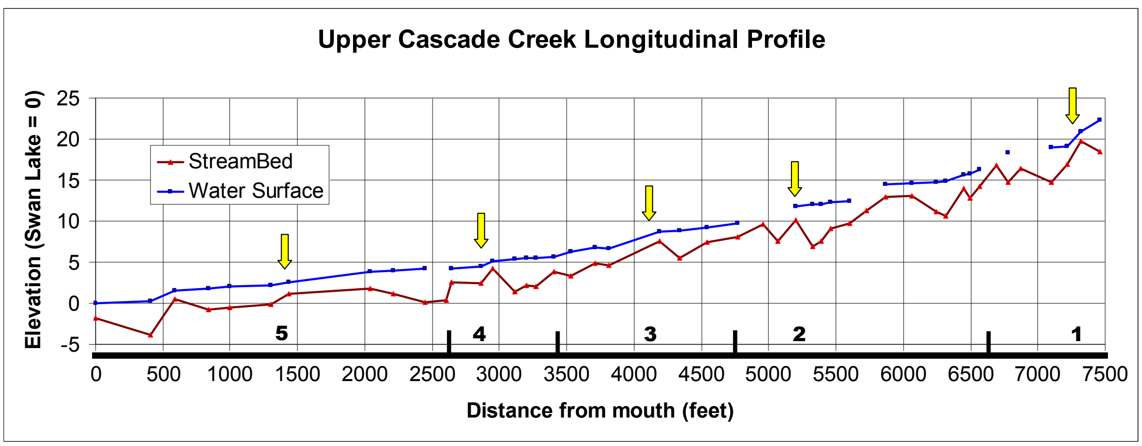

Figure 2-2: Longitudinal profile of Upper Cascade Creek.

The yellow arrows in Figure 2-2 mark the location of the five cross-sections. Geo-Reach boundaries are denoted by short vertical lines along the horizontal axis. The 0 point was located in the field-identified (and somewhat diffuse) boundary between “stream” and “lake” and would surely vary in its presumed location under different discharges and lake levels.

Spring Creek had an entirely different character than Upper Cascade Creek, reflecting its small drainage area and limited sources of water and sediment. It was quite homogeneous in character; hence, no overlay of geomorphic "reaches" was applied, as it would lend little to its description. The channel was fed by avalanche chutes from the steep north valley wall, but the flow paths were disconnected from Spring Creek. Subsurface flow through the broad debris cones flanking the base of the mountainsides delivered water more uniformly to Spring Creek through groundwater upwelling. Consequently, sediment sources were limited. The channel gradient was determined by the relatively flat valley gradient (rather than the other way around). The channel itself was fine-bedded and only modestly sinuous. Summary data for the Spring Creek are listed in Table 2-3.

Table 2-3: Summary geomorphic statistics for Spring Creek.

	Spring Ck.
W_{bkfl}--mean (m)	6.9
W_{bkfl}--maximum (m)	8.0
D_{bkfl}--mean (m)	0.6
D_{bkfl}--maximum (m)	0.8
Bed width (m)	5.8
D_{50} (mm)	18
D_{84} (mm)	36
Water-surface slope	0.17%
Reach Sinuosity	1.09

The morphology of the delta formed by the Spring Creek–Upper Cascade Creek confluence reflected the flows and sediment contributions of each respective source area, coupled with the influence of Swan Lake. Directly upstream of the confluence, Spring Creek flowed over a broad silt-bottom shelf most likely deposited from sediment suspended in Swan Lake backwaters during high flow events. As lake levels declined, discharge in Spring Creek was not competent to remove much of the material deposited. In contrast, Upper Cascade Creek was fully competent to erode deposited material to whatever depth was determined by the geometry of channel and lake levels. At the time of this survey (August 2010), Upper Cascade Creek flowed north almost perpendicular across the "mouth" of Spring Creek. The result was a scarp with over 1 m of relief where the alcove of Spring Creek was incised by the flow of Upper Cascade Creek. At other times, past or future, when the primary channel of Upper Cascade Creek enters Swan Lake more directly to the south, this abrupt subaqueous topography is probably not as pronounced, and the transition from Spring Creek into Swan Lake is likely more gradual.

A topographic map of the confluence and delta, to the limits of safe wading, was made to provide baseline data for future analyses (Figure 2-3). The surface sediment was predominantly sand, but areas dominated by gravel and silt were noted during the survey as well and are indicated on the map. Substrate composition was delineated by areas of open circles for gravel-dominated at the surface while areas with short lines depict silt-dominated.

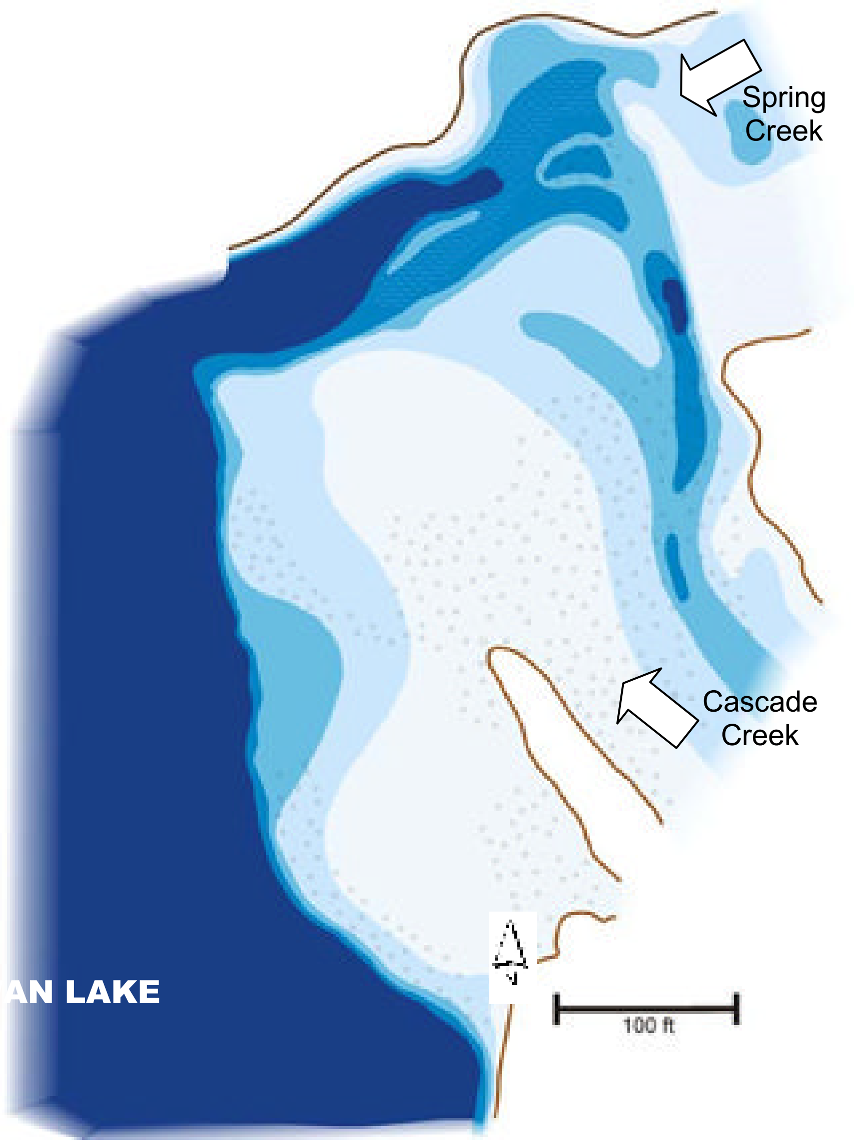

Figure 2-3: Swan Lake inlet delta bathymetry, August 2010.

Color boundaries delineate 0.3-m (1-ft) intervals with the maximum depths (darkest blue) of >1.2 m. The brown lines indicate areas above water level.

The results of the pebble counts showed an even pattern in Upper Cascade Creek (only one such measurement was made in Spring Creek) (see Table 2-2 above). The coarsest sediment fraction at the base of the falls (in Geo-Reach 1) is quickly rendered immobile, and the channel maintains a relatively uniform sediment-size distribution almost to the mouth of the creek with only modest additional downstream fining.

2.3.2. HABITAT SURVEY RESULTS

Results of the habitat survey are presented below for both Upper Cascade Creek and Spring Creek. Habitats are delineated as to their type (i.e. pool – riffle – glide), their location sequentially and within a given Geo-Reach, and their dimensions are provided (i.e. length, width and for pools, residual depth). Conditions in Spring Creek necessitated use of a modified survey approach that included characterization of habitat types, woody debris and substrate within continuous 30 m survey reaches, as described below. Photos were taken for a majority of the surveyed habitat units (Appendix 2-3).

2.3.2.1. UPPER CASCADE CREEK HABITAT CENSUS

The census results of contiguous habitat units (referred to here as “NSO” or “Natural Sequence Order”) are provided in Appendix 2-1. There were 26 primary main-channel habitat units and 19 side-channel habitat units documented in the survey. Figures 2-1a through 2-1c comprise three annotated maps showing the relative locations of identified habitat units (NSO) for Upper Cascade Creek and survey segments for Spring Creek. For Upper Cascade Creek, the total length of the main channel habitat units encountered was approximately 2,183 m (7,160 ft) with an additional 846 m (2,777 ft) of side channels. Note that the total lengths in the habitat and longitudinal profile surveys were not in complete agreement, an consequence of using different methods to measure lengths of individual units and the longitudinal profile segments. The length measurements from the longitudinal profile survey (see Table 2-1) were most reliable because all survey “legs” were contiguous, were completed with an autolevel and survey rod, and were completed in one complete temporal sequence. In contrast, boundaries between habitat units were sufficiently arbitrary to introduce a certain level of approximation in the unit length measurements. The two sets of numbers were equal within about 1%, however, so the divergence was not significant. Consequently, the habitat survey lengths are used in this analysis for consistency. In addition, one tributary stream was noted during the survey.

Of the main channel habitats encountered, seven were primary pools, while another three primary pools were seen in side channels. The remaining habitat units were made up of glides and riffles (Figure. 2-4).

Throughout the survey, riffle habitat was the most abundant type, followed by glide habitat. Although pools were fairly abundant in Geo-Reach 4 and 5, they were generally less abundant than glides in the entire survey area. Because of the relatively low gradient, many glides exhibited pool characteristics, with a very long, relatively deep thalweg that transitioned into riffles where gravels accumulated at point bars and meander bends.

Geo-Reach 1 included three main channel habitat units that form just downstream of the turbulent plunge pool below the approximately 30-m-tall falls (~100 ft). These three habitat units (NSO 1, 3 and 4) formed the uppermost 233 m (765 ft) of habitat that formed the first meander bend in the channel. These habitat units included a high-gradient riffle (NSO 1) that transitioned into a fast glide (NSO 3), and then a high gradient riffle (NSO 4) just above a point where the river struck a bedrock wall and graded into NSO7 (Figure 2-1a) where Geo-Reach 2 began. A side channel inlet (NSO 2) was located on the left bank of NSO1, and the fast riffle ran approximately 128 m (422 ft) to the confluence with the lower end of NSO 4. An additional side channel (NSO 5) formed at the transition between NSO 4 and NSO 7, where the channel branched. The only key piece of wood encountered in this survey was in NSO 1 (right bank), embedded in the channel perpendicular to the direction of flow.

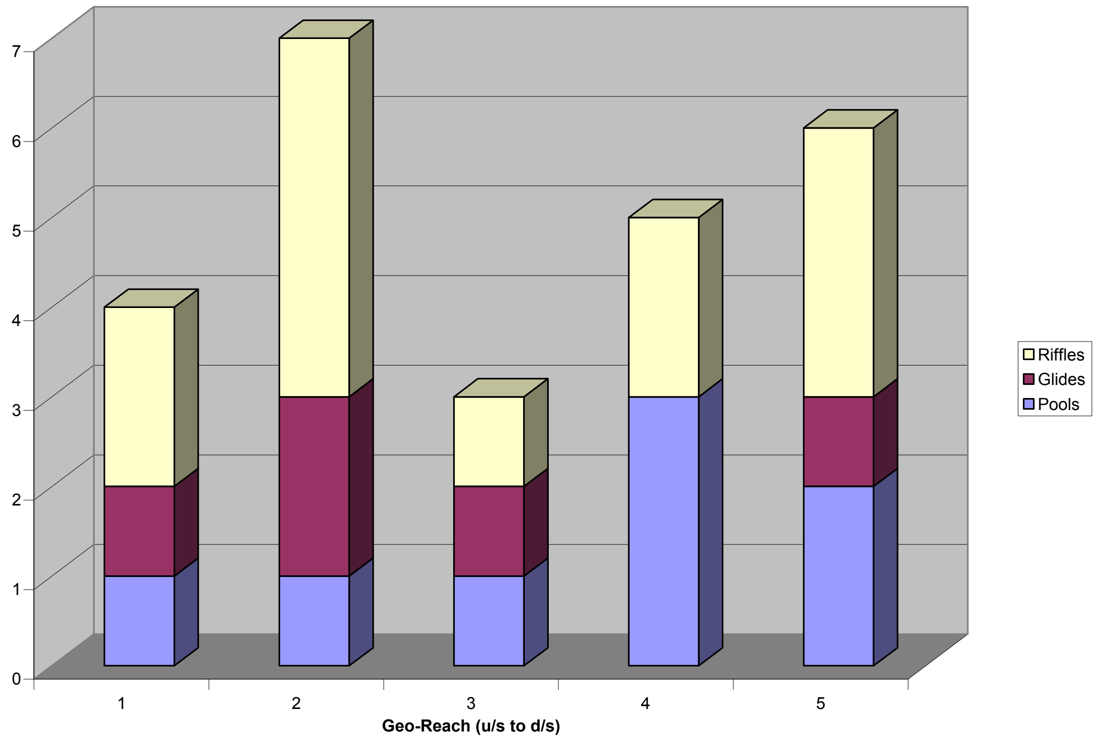

Figure 2-4: Upper Cascade Creek main channel habitat distributions by Geo-Reach.

Geo-Reach 2 was bounded on its upper end by the head of NSO 7 (and side channel NSO 5) and the lower end by the terminus of NSO 17. As shown in Figure 2-1a, the reach contained seven primary main channel habitat units constituting 561 meters of main channel length. The main channel units on the reach included riffles (NSO 7, 9 13, and 17), glides (NSO 8, 14), and one long pool (NSO 12). This pool unit had a residual depth exceeding 0.75m (2.5 ft.), although the exact maximum depth was > 1.2 m (~4 ft) and beyond the limits of the survey equipment. NSO 6 was a secondary pool within NSO 7. A long off-channel feature "4A" branched off the right bank in this section. Another side channel on the left bank (NSO 10-11) terminated in a pool on the inside of the meander bend.

Geo-Reach 3 began at NSO 18 and extended downstream 395 m through NSO 21. It included a series of riffle-glide habitat sequences. NSO 18 began just below the bedrock knob that protruded from the left bank (see photo in Appendix 2-3). It contains a long riffle, glide and pool habitat unit (with a residual pool depth of ~ 0.4 m (1.5 ft). A left bank side channel (NSO 19) also occurred in this reach.

Geo-Reach 4 began at NSO 23 (with an associated side channel NSO 22) that extended around a tight meander sequence to the end of NSO 26, a total main channel distance of 241 meters. It contained two long riffles and three large pools. One of the pools (NSO 26) had a residual pool depth of >1 m (3.3 ft).

Geo-Reach 5 was characterized by a relatively straight channel becoming braided near the delta, which split into several side channels that, for purposes of this study, were assigned individual habitat designations. A total of 11 side channel or secondary habitats were counted, while main channel habitat units numbered 7 and included 3 riffles, 2 glides and 2 pools. The pools were quite deep, with residual pool depths of 0.4 m (1.5 ft) and 1.12 m (3.7 ft), respectively. The main channel ran 709 meters from the top of NSO 27 to the bottom of NSO 41 at the delta.

2.3.2.2. HABITATS IN SIDE CHANNELS AND OFF-CHANNELS

A total of 19 side channels were noted during the Upper Cascade Creek survey, with a combined length of ~ 846 m (2777 ft), mostly in the form of shallow riffles and glides (Figure 2-5). A total of 3 pools were counted in these side channels, and, combined, these had a total length of 75 m (247 ft). A few of these side channels were relict features that had no direct connection to the surface flows in the main channel, and were thus labeled as OC for off channel, and most appeared to be wet by virtue of upwelling from hyporheic flow and spring creeks flowing from the adjacent wetland valley. In most cases, these dead-ended side channels did reconnect with the main channel at their lower end. There were only 3 of these features. Other "side channels" reflected localized channel bifurcation within a given Geo-Reach. For example, only one side channel occurred in Geo-Reach 1 (NSO 2), and Geo-Reach 3 (NSO 19), while the braided lower section of the river in Geo-Reach 5 exhibited multiple side channels.

2.3.2.3. RESIDUAL POOL DEPTH

Residual pool depth (RPD), measured for each pool encountered, was stratified in the sequential Geo-Reaches. Pools were reasonably well distributed across the five Geo-reaches and within individual Geo-reaches (Figure 2-6). RPDs generally exceeded 0.4 m. Determination of RPD was often ambiguous given the nature of the bottom topography that yielded a gradually sloping outlet to pools associated with glides.

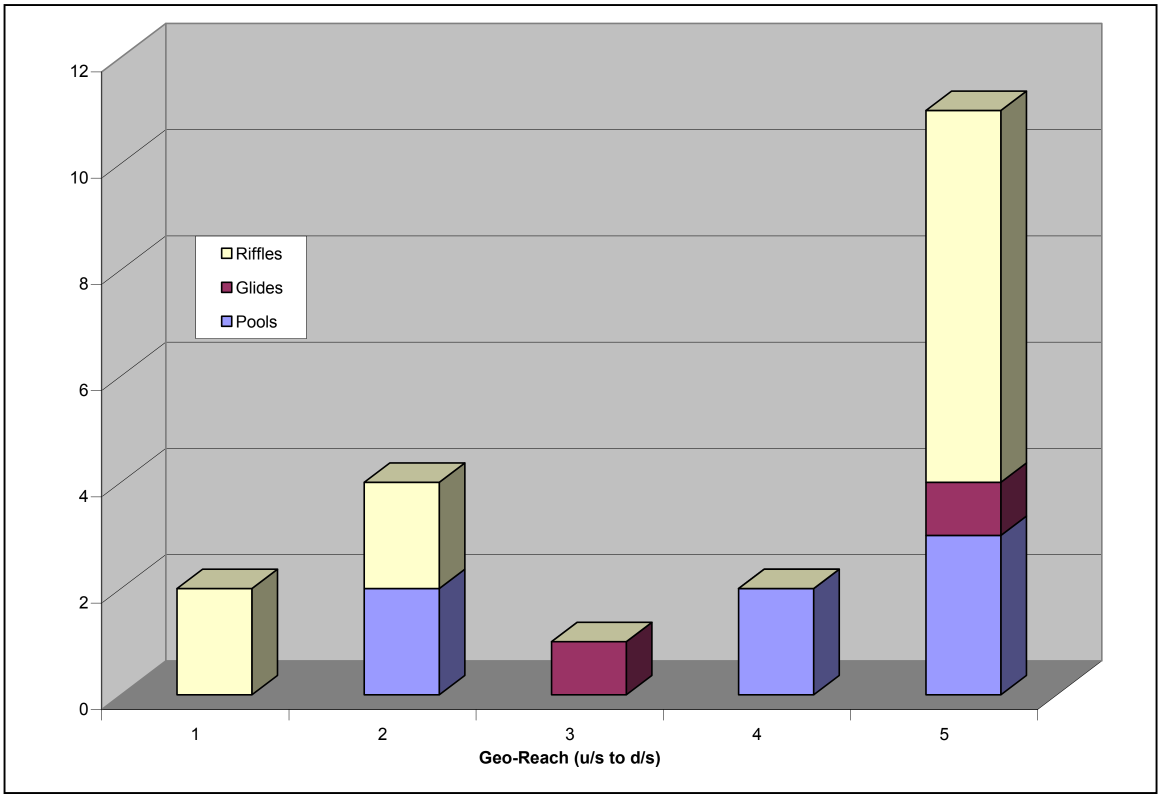

Figure 2-5. Habitat types in side channels to Upper Cascade Creek by Geo-Reaches.

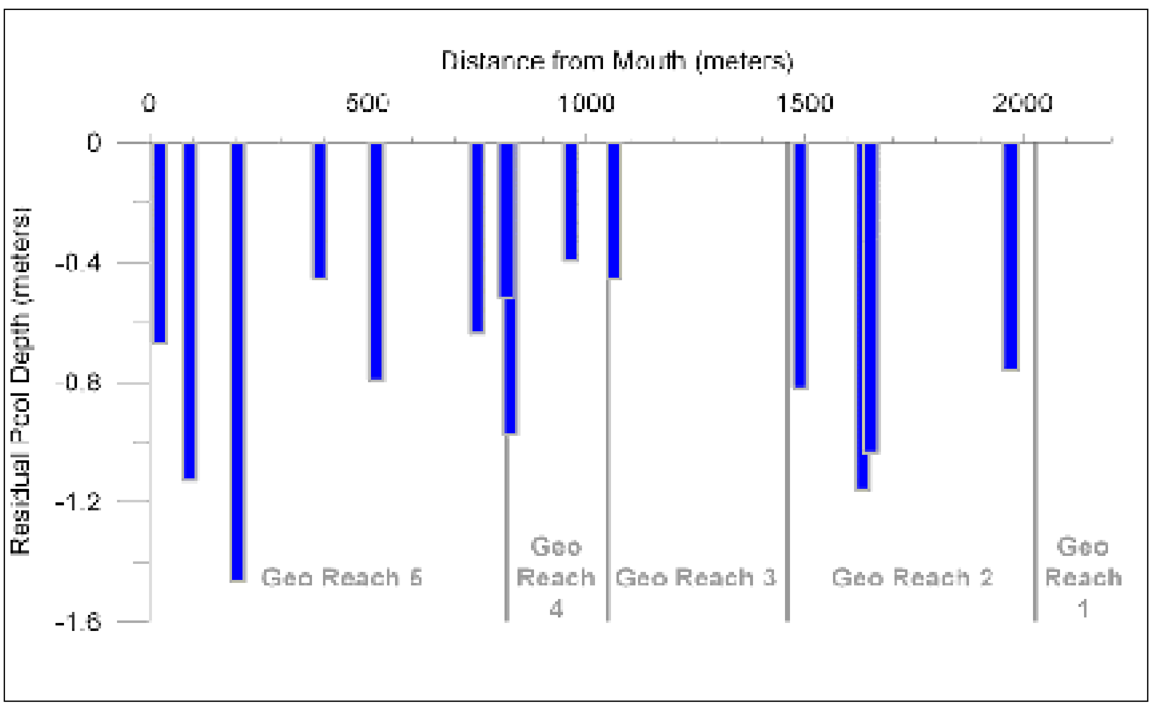

Figure 2-6: Residual pool depths for 5 Geo-Reaches in Upper Cascade Creek.

2.3.2.4. LWD DISTRIBUTION AND ABUNDANCE

The total count of all wood (including side channels) was quite low (Figure 2-7), as compared to reference streams throughout the Pacific Northwest (Fox 2003). Overall, large wood in the channel was very limited. A total of 10 of pieces of LWD were encountered and only one of these met the size criteria for a “key” piece. Geo-Reach 4 clearly had the most wood, and, coincidentally, also had an abundance of pools. In contrast, Geo-Reach 2 had no apparent wood at all.

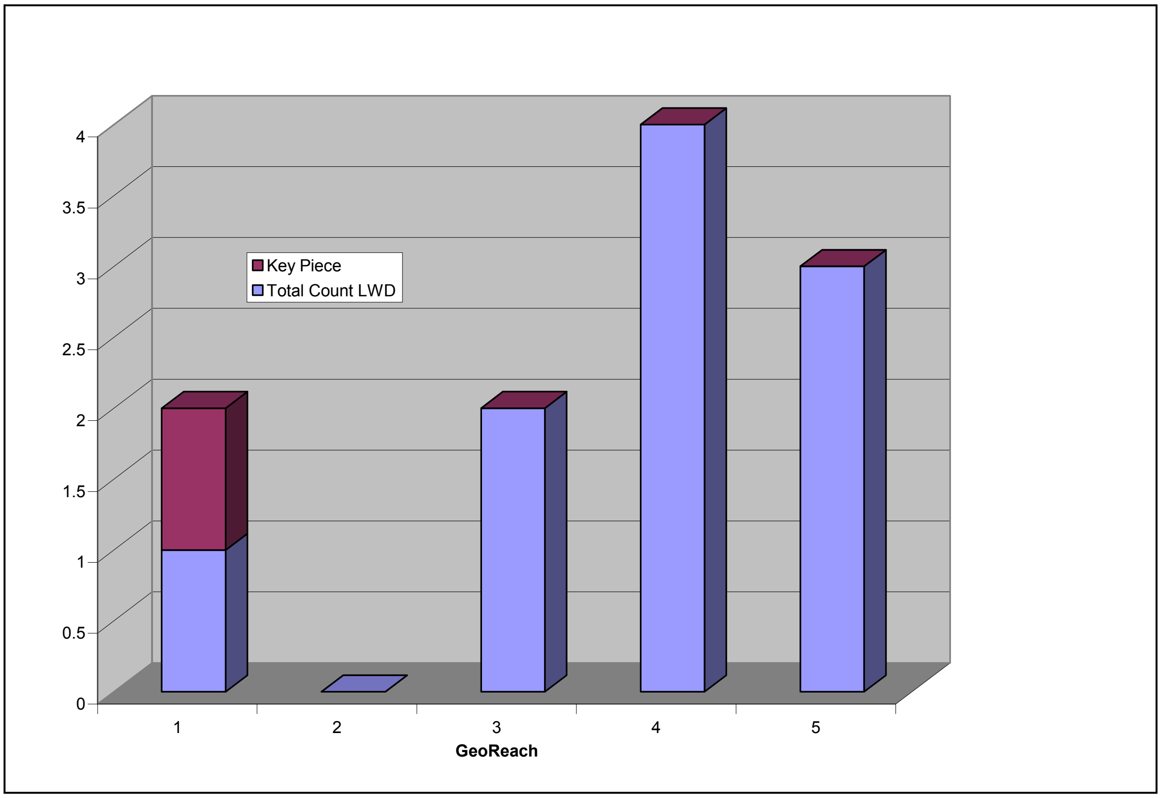

Figure 2-7: Total LWD count for 5 Geo-Reaches in Upper Cascade Creek.

2.3.2.5. SUMMARY STATISTICS

The USFS Regional stream survey protocol specifies a variety of summary statistics (Table 2-5) applied for the 2.0 RK (1.2 mi) of Upper Cascade Creek.

Table 2-4. Summary statistics and methods for USFS stream survey protocol.

Habitat response variable	Equation	Data Collection Methods	Survey Results
1. Width-to-depth ratio (WD)	Bankfull width / mean bankfull depth	Bankfull width ÷ Bankfull depth (∑ depths within bankfull / n+1) averaged for the reach	17–25 (Geo-Reaches 2–5); 51 (Geo-Reach 1)
2. Total Large Wood pieces / meter (TLWD/M)	Total Pieces / meters surveyed	Total count of large wood pieces >1 m long and 0.1m in diameter ÷ Total length of stream surveyed	10/1940 m = 0.005 pieces per meter (1 piece per 200 m)
3. Total Key pieces Large Wood/meter (TKWD/M)	Total Key pieces / meters surveyed	Total count of key large wood pieces Key piece size based on avg channel bed width surveyed ÷ Total length	1/1940 = 0.0005 key pieces per meter (1 piece per 2000 m)
4. Pool/km (POOL/KM)	Total number of Pools / meters surveyed * 1000	Total count of pools ÷ Total length of stream surveyed	10/ 1940 = 1000= 5.2 pools per km
5. Pool Spacing (PL SPC)	Length of stream surveyed / channel bed width / total number of pools	Total length of stream surveyed Average channel bed width (width of active channel bed from bottom of bank to bottom of bank averaged for the reach) ÷ Total number of pools	1940 ÷ 23 ÷ 10 = 8.4 channel widths
6. Residual Pool Depth/Channel Bed width (RPD/CBW)	Average of all pool residual depth / average channel bed width	Residual Pool depth = maximum pool depth – pool tail depth ÷ Average channel bed width	0.78 ÷ 23 = 0.03 channel widths
7. D_{50}	Median particle size	Measure intermediate diameter of 100 pebbles	See Table 2; average for whole study reach = 40 mm
8. Pool Length/meter (PLNGTH/M)	Total pool length / total length of stream surveyed	Sum of all pool lengths ÷ Total length surveyed	478 ÷ 1940 = 0.25
9. Relative Submergence (REL_SUBMERGE)	Mean bankfull depth / D_{50}	Bankfull depth (∑ depths within bankfull / n+1) averaged for the reach Measure intermediate diameter of 100 pebbles	avg D_{bkfl} ÷ D_{50} = 17 (Geo-Reach 1); 37 (Geo-Reach 2–5)
10. Pool Size (POOL_SIZE)	Average residual pool depth / average bankfull depth	Residual pool depth = max. depth – pool tail depth reach average ÷ Bankfull depth (å depths within bankfull / n+1) averaged for the reach	0.78 ÷ avg D_{bkfl} = 0.87

2.3.3. SPRING CREEK SURVEY RESULTS

The upstream extent of the survey was approximately 600 m (2000 ft), including surveys of the several parallel side channels that can be seen in Figure 2-1c. The upstream extent of the survey was halted 30 m (100 ft) below the major channel split observable in the aerial photo. Substrate conditions in this reach, and the one below, had become such that walking in the channel was impractical. Mud and silt deposits up to >0.6 m (2 ft deep) made it nearly impossible to walk upstream. A narrative account of the 30 m (100 ft) survey segments, from upstream to downstream is provided below and summarized in Table 2-6.

Segment 1 - Starting at ~ 30 m (100 ft) below the major channel split visible in the aerial photo, the first segment was characterized by deep mud, up to 0.6 m (2 ft), overlying gravel substrate (presumed but not visible). Patches of gravel and rooted vegetation were also present, but sparse in the overall area. Water depths in this segment were from 0.3 m to 0.45 m (1 to 1.5 ft) during the survey. Channel width was ~ 7 m (23 ft), but narrowed to as little as 4.3 m (14 ft) in places (see photos in Appendix 2-3). An abundance of willows in the riparian zone provided shade to the stream channel. At 5°C (42ºF), water temperatures in the stream overall were ~ -12°C (10°F) less than in Cascade Creek during the survey.

Segment 2 - Substrate in this 30 m (100 ft) reach was dominated by gravel, with fewer patches of silts, but still showing some occurrence of rooted vegetation. Habitat was consistently glide in character. Water depths in this reach varied from 0.3 to 0.4 m (1 to 1.4 ft). Current was estimated to be ~ 0.5 fps, with an estimated flow of around 5 to 7 cfs. Channel width averaged 5.5 m (18 ft). Willows and sedges dominated the riparian vegetation.

Segment 3 - In this 30 m (100 ft) segment, water depths averaged 0.2 m (0.7 ft), and more gravel patches were evident, bedded in substantial amounts of sand. There was less silt (detritus) and less rooted vegetation evident. The channel averaged 5.8 m (19 ft) in width. Water velocities were estimated at ~ 0.7 fps.

Segment 4 -The fourth segment of 30 m (100 ft) in length was dominated by a large pool (~1.1 m (3.6 ft) maximum depth) that occupied most of the channel width, with a hydraulic control downstream that was 0.3 m (1 ft) deep. The pool occupied approximately 12.5 m (41 ft) of the length of this segment. The channel width averaged about 7 m (23 ft) in this segment.

Segment 5 - Substrate in the fifth 30 m (100 ft) segment was predominantly sands and gravels, with little rooted aquatic vegetation. The riparian zone was dense with native willows and understory shrubs. Water depths averaged > 0.45 m (1.5 ft), with a maximum depth recorded of 0.76 m (2.5 ft). One cross-over bar in the channel marked the first riffle and an obvious increase in local gradient. A small branch on the right bank formed an alcove habitat. The channel averaged about 9 m (30 ft) in width throughout the segment.

Segment 6 - Midway through this 30 m (100 ft) segment (at the 48 ft mark) there was a significant channel split with a 0.85 m (2.8 ft) deep pool (and a hydraulic control at 0.06 m (0.2 ft) deep. At 5.8 m (19 ft) wide, the left bank channel was the main channel, with a riffle habitat unit that coursed over a substrate of suitable sized spawning gravels. Some disturbance of the detritus layer suggested recent spawning activity, but this could not be determined definitively given the disturbance attendant with walking the channel.

Segment 7 - This 30 m (100 ft) segment provided the first LWD encountered in Spring Creek, with a total wood count of 13 pieces, all > 0.1 m (4 in) diameter and 3 m (10 ft) in length, all within the wetted channel (i.e. Zone 1). One piece was 0.2 m (8 in) diameter and 6 m (20 ft) long. Substrate here was primarily sands and gravels, with an estimated D50 of ~ 30 mm. Water depth averaged 0.3 m (1 ft), and water velocity was more evident through riffle habitat, indicating a localized increase in bed gradient. A short channel entered on the right bank, and had a few pieces of scattered LWD. A few boulders were seen in the channel, and created localized scour holes. Some rooted vegetation punctuated the predominately sand and gravel substrate. The channel averaged 11.3 m (37 ft) in width. Some tadpoles were seen on the channel margins in slow moving water). One juvenile fish of ~ 50 mm in length was seen.

Segment 8 - This segment of 30 m (100 ft) also contained a scattering of LWD (5 pieces, all submerged within the channel). Backwater from the elevated lake level created predominantly slack-water glide habitat. Fine silt and detritus overlaid the gravel substrate and submerged boulders. Depths from the backwater ranged from ~0.5 to 0.7 m (1.5 to 2.2 ft), with an average of 0.6 m (1.9 ft). Channel width varied from 8.5 – 9.4 m (28 ft to 31 ft).

Segment 9 - Because of the occurrence of islands that bifurcated the channel, this segment was 20.7 m (68 ft) in length. These islands split the channel into three lobes. This segment ended at the island that splits the channel, and was 9 m (30 ft) in width, with an average of 0.5 m (1.7 ft) in depth. Gravel was the dominant substrate, but was again overlain by a thin mantle of detritus that was easily disturbed when trod upon. There were two pieces of submerged LWD, but neither met the key piece size criteria.

Segment 10 - This segment was 36.5 m (120 ft) long, and terminated at the end of the island referred to in the description of Segment 9 above. The substrate was predominantly gravel covered with detritus, with some rooted vegetation. Channel width was 12.5 m (41 ft.). Five pieces of LWD were submerged in the channel. Again, this was primarily a slack-water glide in terms of habitat characteristics.

Segment 11 - This 62.5 m (205 ft) long segment was another lobe of the channel trifurcated by the islands mentioned above (see photos, Appendix 2-3). Gravels were the dominant substrate and showed less coverage with detritus than seen elsewhere, perhaps reflecting higher velocities present when lake levels are lower. Channel width was 10 m (38 ft.). Two pieces of LWD were seen, both in zone one and not meeting the key piece criteria.

Segment 12 - This was the last surveyed segment and was composed of primarily backwater glides, grading into the lake delta making its terminus indistinct. The average width was 31 ft and the length was ~159 m (520 ft). Substrate was homogenous gravels with an overlay of detritus and silt.

Table 2-5: Spring Creek habitat characteristics.

Segment	Length/Width (ft)	Primary Substrate	# LWD	Habitat Type
Segment 1	30 m (100 ft)/ 7.0– 4.3 m (23-14 ft)	Deep mud and silt with rooted vegetation	0	Glide
Segment 2	30 m (100 ft)/ 5.5 m (18 ft)	Gravels with rooted vegetation	0	Glide
Segment 3	30 m (100 ft)/ 5.8 m(19 ft)	Gravels with sand	0	Glide
Segment 4	30 m (100 ft)/ 7 m (23 ft)	Gravels with sand	0	Pool with glides
Segment 5	30 m (100 ft)/ 9 m (30 ft)	Sands and gravels, with little rooted vegetation	0	Glides and riffle
Segment 6	30 m (100 ft)/ 5.8 m (19 ft)	Gravels with detritus and silt	0	Glide with large pool
Segment 7	30 m (100 ft)/ 11.3 (37 ft)	Sands and gravels	13	Glide
Segment 8	30 m (100 ft)/ 8.5 – 9.4 m (28 - 31 ft)	Gravels smothered in detritus and silt	5	Glide
Segment 9	30 m (100 ft)/ 9.1 m (30 ft)		2	Glide
Segment 10	36.6m (120 ft)/ 12.5 (41 ft)	Gravels with detritus	5	Glide
Segment 11	62.5m (205ft)/ 11.6 m (38 ft)	Gravels	2	Glide
Segment 12	159m (520 ft)/ 9m (31ft)	Gravels with detritus and silt	0	Backwater

2.3.4. LOWER CASCADE CREEK AT TIDEWATER

Reach 1A, located between Thomas Bay tidewater and the first barrier falls on Lower Cascade Creek was approximately 200-meters in length. Because the combination of steep gradient and high discharge made wading unsafe, water depths and channel widths were estimated from shore. Flows at the time of the qualitative survey on October 27th, 2010 were approximately 400 cfs on Lower Cascade Creek.

The stream habitat in reach 1A was primarily cascades with a large pool located directly below the barrier falls (Appendix 2-5). The slope from the barrier falls to Thomas Bay was steep (estimated ≥10%). Water velocity was swift and cascading in most places with occasional breaks occurring along the banks and behind large boulders where there were limited pockets of calm water. Substrate near the mouth of the Tidewaters ranged from sub-angular and rounded cobbles to boulders with few gravels present. Limited small pockets of sand and silt were located near the mouth of the stream and close to or below the tidewater influence. The average water depth was approximately 0.5 feet in the riffles and cascade habitats and estimated to be up to 1.5-meters in the pool below the barrier falls. The channel had an average width of 10.5-meters.

Comparatively, the stream reach above the barrier falls contains larger pools and drops, relatively fewer boulders and cobbles, and appears to be influenced by bedrock controls to a greater degree than the lower Reach 1A.

A limited amount of large woody debris overhung and was submerged along the banks of Lower Cascade Creek but relatively little to no vegetative cover existed in the channel on this section of the stream; however, thick over-hanging vegetation existed along the banks a short distance from the wetted perimeter (e.g. alders and devil's club). Boulders and cobble substrate provided the most habitat variation and pools for fish to utilize.

2.4. DISCUSSION

Overall, habitat diversity was relatively limited in the low-gradient channel of Upper Cascade Creek. The watershed was completely unaffected by human development or resource extraction. Habitat units were large, and boundaries between one unit to the next were often indistinct. The lack of obstructions to flow (large woody debris and boulders) resulted in relatively few micro habitat features. Wood loading was relatively low when compared to literature values but was likely typical for streams in recently deglaciated landscapes at elevations that do not support rapid growth of large trees. Gravels suitable for spawning were abundant, but the lack of large cobble and boulders suggests that juvenile *O. mykiss* may not find abundant rearing habitats. Still, the existing habitats were sufficiently diverse to provide what appears to be ideal spawning and adult feeding habitats. Pools were reasonably abundant, although few were formed by major obstructions to flow such as boulders or large wood accumulations. Although not widely abundant, overbank cover was provided by the ample riparian vegetation consisting of native willows and conifers.

Habitat diversity in Spring Creek was considerably more limited, but the predominantly glide/pool habitat and low velocity refuge water was ideal for juvenile salmonid rearing. Temperature in Spring Creek was about -12.2°C (10°F) colder than Upper Cascade Creek, and the relatively colder temperatures may reduce growth if food supplies were limited. Spawning habitat may be located upstream of the reach surveyed on Spring Creek, but difficulty with access prevented identification of this area. Given the preponderance of silts and mud overlaying the reach, it seems unlikely that such spawning habitat occurs in great abundance upstream of the point surveyed.

The delta at the lower confluence of the two creeks and Swan Lake was a product of ongoing sediment transport down Upper Cascade Creek, modified by natural variability in lake levels. Although no sediment cores were taken, the substrate composition was likely primarily composed of sand, with silt moving into deeper water by suspension (or re-suspension during storms). Gravel can be moved fairly efficiently over the delta surface, but its observed distribution suggests that it is a secondary component of the bulk composition of the delta. Shifting of the primary flow path of Cascade Creek over time, as a result of storm-deposited gravel bars in the upstream part of the delta, undoubtedly scours different parts of this feature over time and gave rise to a complex internal stratigraphy and a moderately varying extent. The broad geometry and topography of the delta, however, have probably been relatively stable for a long period and presumably reflects a long-term balance of sediment input from up-valley, very slow growth into the deep water of the lake, and transport of finer sediment by episodic storm waves and high stream flow.

Lower Cascade Creek is a high energy, low sediment supply stream system that is mostly bedrock or structurally controlled (boulders/colluvial deposition) in an entrenched and confined channel associated with faults, scarps, joints, and other structural controls in a deep canyon. Accordingly, spawning size substrate was virtually non-existent in Lower Cascade Creek, including the reach between the last downstream barrier falls and Thomas Bay. Pool spacing was irregular with relatively low sinuosity. Some large woody debris overhung and was submerged along the banks of Lower Cascade Creek but. little to no vegetative cover was present in the wetted channel on this subreach of the stream. However, thick over-hanging vegetation did exist along the banks above the wetted perimeter (e.g. spruce, alders and devil's club). Boulders and cobble substrate provided the most habitat variation and pools for fish to utilize.

At best, Lower Cascade Creek might provide transitory habitat for fish being flushed downstream. Even at periods of low flow, these lower areas are impassible in terms of migration upstream to areas with more suitable spawning and rearing habitats, and therefore, provide little benefit to overall fish productivity or contribute to sustaining the population in Swan Lake.

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3. BATHYMETRY

The following section presents the results of the bathymetry surveys completed for the Swan Lake Delta, Falls Lake, and an area of tidal waters in Thomas Bay.

3.1. INTRODUCTION

In 2008, CCLLC conducted a bathymetric study of Swan Lake in response to agency requests for baseline information on the basin shape (BioSonics, Inc. 2008). After reviewing the 2008 bathymetric study, Agency staff requested additional study of the Upper Cascade Creek Delta at the inlet to Swan Lake. Specifically, agency staff were interested in higher resolution surveys of the delta area in order to better assess the potential for channel erosion and headcutting in the delta area for respective Swan Lake pool elevations.

In their comments on the January 2010 Draft Aquatic Resources Study Plan, ADFG requested high quality bathymetric mapping of the delta area in Swan Lake as well as Falls Lake. Mapping of the latter waterbody should contain sufficient resolution to afford evaluation of the aquatic habitat area currently dewatered during seasonal changes in Cascade Creek discharge.

Lastly, at the August 12, 2010 agency meeting in Petersburg, agency staff expressed an interest in bathymetry data for the near shore environment of Thomas Bay where the powerhouse, tailrace and dock were proposed for construction.

During subsequent consultation with agency staff, the following study objectives were identified for Swan Lake, Falls Lake and Thomas Bay:

- Develop a 1-foot vertical elevation bathymetric model of key areas in the watershed potentially affected by the proposed Cascade Creek hydroelectric project.
- Complete a bathymetric survey of the Swan Lake delta where Upper Cascade Creek flows into Swan Lake to examine the interaction of lake drawdowns from power operations and inflow hydrology to better understand potential for channel erosion and headcutting in the delta area.
- Complete a bathymetric survey of Falls Lake allowing quantification of the loss in fish habitat area dewatered by seasonal changes in pool elevations under natural discharge conditions.
- Complete a bathymetric survey of 1000 feet of the nearshore ocean floor of Thomas Bay where the powerhouse, tailrace and dock are proposed for construction.

3.2. BATHYMETRY SURVEY METHODS

The bathymetry survey was conducted using an Automated Underwater Vehicle (AUV). The accuracy and precision of the AUV are described below as well as the survey methods. The bathymetry field work focused on the near shore ocean bed in Thomas Bay, Falls Lake and the inlet delta on Swan Lake (Figure 3-1).

3.2.1. AUTOMATED UNDERWATER VEHICLE EQUIPMENT

Bathymetric lake and ocean bottom depth soundings were collected using an AUV designed and operated by YSI Inc. The AUV navigates along pre-planned mission transects orienting itself using a combination of GPS and internal dead-reckoning systems. The AUV collects sonar depth soundings at one-second intervals while recording horizontal GPS positions as it moves along its mission course.

AUV bathymetric survey instrument specifications:

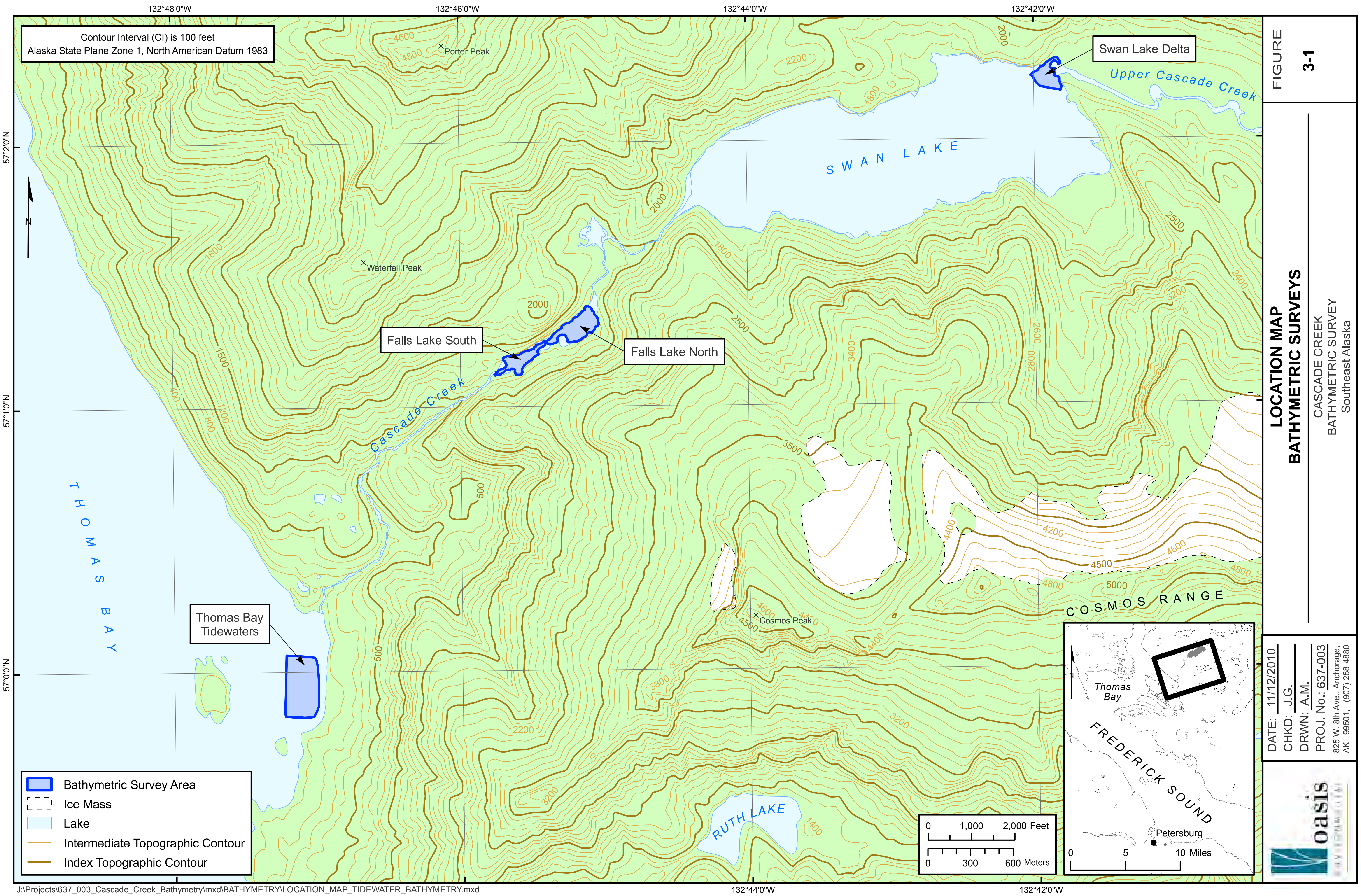
- Depth: Range: 0-200 m
- Resolution: 0.001 m
- Accuracy: +/- 0.3 m
- Altimeter: Range: 0.06-80m
- Accuracy: +/- 0.2 cm/s
- Resolution: 0.001 m/s

The data was processed by a licensed surveyor using Hypack Processing Package and was reviewed for quality assurance using Fledermaus Visualization Software. Digital data products including elevation models, subsurface contours and cartographic renderings were developed using ArcGIS 9.3.1 Spatial Analyst.

3.2.2. SURVEY PROCEDURES

The AUV was calibrated prior to each survey event to set internal compass, GPS lock, and system stability. Surveys were typically conducted in a phased approach starting with an initial preliminary survey followed by the full detailed survey. Custom mission planning software called VectorMap was used with the AUV to set the vehicle on a preliminary survey of the water feature’s perimeter and general subsurface layout. This information was used to plan the detailed survey transects. At times, the deep canyon relief of the project area would create GPS signal interference, also known as multi-path error, which would disrupt the preliminary survey. During these episodes, the survey crews would tow the vehicle behind a row-boat to provide a rough survey of the water feature.

The preliminary surveys were used to provide the boundary of the planned detailed surveys as well as provide insight into potential areas requiring additional attention, for instance a steep drop, hole, or rocky bottom. VectorMap was used to develop transects



Contour Interval (CI) is 100 feet
Alaska State Plane Zone 1, North American Datum 1983
132°48'0"W
132°46'0"W
132°44'0"W
132°42'0"W
57°2'0"N
57°1'0"N
57°0'0"N
Porter Peak
Waterfall Peak
Cosmos Peak
Swan Lake Delta
Upper Cascade Creek
SWAN LAKE
Falls Lake South
Falls Lake North
Cascade Creek
THOMAS BAY
Thomas Bay Tidewaters
COSMOS RANGE
RUTH LAKE
Bathymetric Survey Area
Ice Mass
Lake
Intermediate Topographic Contour
Index Topographic Contour
0 1,000 2,000 Feet
0 300 600 Meters
Thomas Bay
FREDERICK SOUND
Petersburg
0 5 10 Miles
FIGURE
3-1
LOCATION MAP
BATHYMETRIC SURVEYS
CASCADE CREEK
BATHYMETRIC SURVEY
Southeast Alaska
DATE: 11/12/2010
CHKD: J.G.
DRWN: A.M.
PROJ. No.: 637-003
825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880
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spaced appropriately to derive the required vertical precision. The AUV was deployed on the detailed missions targeting GPS waypoints and using internal navigation systems to focus along its planned course. In areas with dramatic lake or ocean bottom relief, the AUV was submerged in a deep dive pattern to maintain proximity to the bottom. In these instances the AUV relied exclusively on its internal doppler velocity instruments for navigation as GPS lock becomes impossible at depths. Survey missions typically lasted between 30 minutes and one hour with some lasting just over two hours.

Data files were relayed daily to licensed surveyor Joshua Hazen (TerraSond Inc. FL Professional Surveyor 6681) via web link for preliminary inspection and data review, with the exception of the Swan Lake data due to time constraints. Upon initial inspection, a few concerns were noted and discussed. In certain data sets it was apparent that the depth sounder was losing bottom tracking and was creating false soundings. After further investigation, it was determined that a part of the standard programming in the AUV creates a doppler velocity altitude value of 32.77 feet whenever the sounder does not get a valid return from the bottom. See Section 3.2.3.4 for how this was resolved in processing.

Another issue that became apparent was the loss of GPS satellites in specific areas – most notably in the Falls Lake project site. The acquired data did not record the Horizontal Dilution of Precision (HDOP) data but did contain information indicating the number of satellites that were being tracked during acquisition. This was valuable information in estimating the reliability of the AUV position and was the only information available that could be used in estimating the horizontal accuracy of the AUV as it directly influenced the accuracy of bathymetric data.

Due to adverse site conditions such as cross-currents and limited view of GPS satellites, the AUV was not able to maintain course for the entire duration of a few planned transect lines. This created some areas where there were significant gaps, some greater than 70 feet, where no data were collected. Weather conditions and time constraints did not allow subsequent visits to acquire data in these areas. These areas were few and relatively small compared to the overall survey areas. Interpolation was used to account for any gaps in survey coverage.

3.2.4. DATA PROCESSING

Raw data was downloaded nightly and reviewed for quality and completeness. A full review and processing of the data was performed by Joshua Hazen of TerraSond Inc. after field efforts were concluded.

3.2.4.1. RAW DATA FORMAT

The data were delivered to TerraSond Inc. in ASCII formatted *.LOG files as the native format downloaded directly from the AUV. These files contained numerous columns of useful data. Of most importance for processing were the columns containing Latitude, Longitude, Time, Number of Satellites, DFS Depth, DTB Height, Total Water Column, DVL Depth, DVL Altitude, DVL Water Column, Pitch, and Roll. The Total Water Column values were used as the soundings for processing while all other aforementioned values were used, at least in some part, as a form of quality check or quality control.

3.2.4.2. VERTICAL REFERENCE DATUM

The bathymetric data are not referenced to any existing geodetic or tidal vertical datum. All soundings are relative to the water surface elevation at the time of data acquisition and are either reduced to water stage elevations as provided by gauge station readings or reduced to a value of 0.0 feet - referring to the lowest observed water level at the time of acquisition. Each survey area – Falls Lake, Swan Lake, and Thomas Bay tidewaters – has an independent vertical reference for a value of 0.0 and special consideration should be taken regarding this particular aberration. For example, an elevation of -10.0 feet in Swan Lake is not at the same absolute elevation as a point at -10.0 feet in Falls Lake. No elevation data presented in this survey can be referenced to mean sea level without further ground verification.

3.2.4.3. TIDAL AND WATER ELEVATION DATA

Tidal and water surface measurements were collected by the field crew and were approximated in the Thomas Bay tidewater area. The tide data for Thomas Bay was measured in reference to the features below:

- Tidewater Tide Marker 1 (Lat: 56° 59' 59.692" N, Long: 132° 47' 0.104" W) Aug 21 1455 11.2 in
- Tidewater Tide Marker 2 (Lat: 56° 59' 58.761" N, Long: 132° 47' 0.538" W) Aug 21 1648 6.5 in

Two markers were approximately 3.5 ft apart in elevation (Photo 3-1). The measurement is from a noticeable vein on the rock to the surface of the water. With no other information to work from besides a very general tide chart, the approximate values shown above were used to determine the tide corrections for the tidewaters area. By holding the 3.5 ft separation between the two reference points and adjusting for the measured down values from reference points to the water surface at the specified times, the tidal range between 14:55 (local time) and 16:48 was calculated to be 3.11 feet with the tide dropping during data acquisition. The time range of data acquisition was from 14:37 (at the beginning of the first usable line) to 18:03 (the end of the last usable line). The survey technician was only able to use the two aforementioned tide observations, so extrapolation was required in order to best approximate the tidal range throughout the acquisition.

A drop of 3.11 feet over the time range of 113 minutes translates into a tidal change of 0.0275 feet per minute. Extrapolating this to the beginning and end of the data collection over a range of 206 minutes generates an approximated tide drop of 5.7 feet over the 3 hour and 26 minute acquisition period. These tide corrections were applied to the raw data on a per-second basis, that is – each recorded measurement was adjusted at each one-second collection interval.

In Falls Lake, water stage data was provided by field hydrologists in a spreadsheet format. The data contained a date, timestamp in Alaska Daylight Time (ADT), and water stage elevation (in feet). The elevations were provided in 15-minute intervals. The total range of this data during the Falls Lake survey was 3.95 feet, with a maximum value of 41.80 feet at 16:45 (ADT) on 8/19/2010 and a minimum value of 37.85 feet at 18:45 (ADT) on 8/23/2010.

It is important to note that the elevation of the water surface may vary between the northern portion of Falls Lake and the southern portion of Falls Lake, as there are some obstructions between the two lake halves that may influence the flow of the water. Any separation between the water surfaces, if it exists, has not been accounted for in this analysis. However, the difference in elevation between the upper and lower pool at the water surface elevations during this field work are believed to be minor (<0.1 ft) and not likely to affect the overall bathymetry results.

Of all the data acquired in this area, only five of the transect lines spanned two or more water stage epochs (30 minutes or greater). The water elevations in this area, in sharp contrast to the changes observed in the tidewater area, changed rather slowly over the duration of the project. After comparing the stage data to the start and stop times of each line, it was determined that the water stage did not change more than 0.02 feet during any one transect line. In order to expedite processing while maintaining the highest possible accuracy, it was decided that the transect line files would be adjusted individually to the stage data as a single shift by a value that would be determined by the stage elevation closest to the time at the start of each line. This eliminated the need for excessive interpolation of the elevation data and allowed for a quicker processing method. The final processed soundings were referenced to the arbitrary datum that was referenced by the stage data. All soundings for the Falls Lake areas were in the same datum as the stage information.

In the Swan Lake delta area, water stage data was provided in a similar format as stated above for Falls Lake, with the exception of the timestamp. The Swan Lake times were provided in Alaska Standard Time (AST). The timestamps were converted to ADT for uniformity. The total range of this data during the Swan Lake survey was 0.07 feet, with a maximum value of 10.54 feet at 11:15 (ADT) on 8/26/10 and a minimum value of 10.47 feet at 17:45 on 8/26/10. The Swan Lake area was processed in the same manner as described in the Falls Lake Area subsection, above.

The final processed soundings were referenced to the arbitrary datum that was referenced by the Swan Lake stage data. All soundings for the Swan Lake area were in the same datum as the stage information.

Photo 3-1: Benchmarks used to quantify elevation differences in tide during survey

3.2.4.4. REMOVAL OF INVALID SOUNDINGS

It was observed in certain survey areas, and even sometimes sporadically, that the sounder hardware on the AUV would lose its ability to track the bottom and would return an invalid depth. After discussions with YSI personnel, it was determined that the AUV was programmed to return a value of exactly 32.77 feet when the sounder depth was invalid.

The maximum range of the AUV could also have been exceeded, although the depths in this area were within the manufacturer's specifications for depth limitations. The example above is only one example of where the 32.77 feet soundings were recorded, and it is important to note that in every survey area there were several locations where soundings were lost. Thomas Bay tidewater was the only area where depth or steepness of slope would have been the most likely explanation of invalid readings.

Each raw file was inspected individually and any invalid soundings were removed. The data that contained these sounding values were not recoverable.

3.2.4.5. EXCESSIVE ROLL

Once the tide corrections were made and the invalid soundings were removed, the remaining data were inspected for any excessive attitude motion. It was noticed in the preliminary data checks that the roll value fluctuated drastically in some areas during acquisition. Many times this was in areas near the beginning or end of each mission transect line, but there were other areas where the roll value occasionally exceeded 50º even in the middle of a line. The roll angle becomes an issue as the AUV rotates around its longitudinal axis because the sonar transducer begins to point in the opposite direction of the roll. This can create significant changes in the depth readings of the sounder and errors caused by sound velocity changes and inaccuracies in roll angle detection become magnified at an increasing level. The roll factor is being compensated for by the AUV and it is correcting the roll depth (hypotenuse length) to nadir depth (vertical length) in real time. Taking that into consideration, it would seem lower roll values should still present relatively reliable sounding data. Any areas where the roll value was outside the range of approximately +/- 30º were subsequently removed from the data sets. This resulted in a loss of approximately 3% of the overall data, and very few gaps were created due to roll filtering.

3.2.4.6. COORDINATE TRANSFORMATION

The cleaned sonar files were reduced to contain only the Latitude, Longitude, and Total Water Column (depth) fields. These coordinates were recorded in the World Geodetic System of 1984 (WGS84) datum. They were imported into Hypack processing software individually, and converted to U.S. State Plane Grid coordinates utilizing the "Text to XYZ" datum conversion program.

The final data set was delivered in U.S. State Plane Grid, North American Datum of 1983, Alaskan Zone 1, in U.S. Survey Feet.

3.2.4.7. TRANSDUCER OFFSET

Field tests and calibration procedures performed by YSI, Inc. while on the project site confirmed that a transducer phase center offset will need to be applied to the soundings during processing. Field measurements based on monitoring sonar data and comparing it to physical depth measurements in shallow waters concluded that a value of 0.10 meters (0.33 feet) will need to be added to the soundings throughout the project site to account for this transducer offset. This was performed by adding the offset through the Hypack software package.

3.2.4.8. OUTLIERS

After the data sets were cleaned and filtered to remove known issues of concern, the individual transect lines were combined and viewed simultaneously in Hypack's "Cloud" program. This allowed us to view and interpret the data in a 3-D viewer and enabled us to easily identify any outliers or random soundings that do not correlate to what appears to be the realistic surface.

This program was used for all the survey areas and very few points were found with this method that needed to be removed.

3.2.4.9. SURFACE SMOOTHING AND CELL AVERAGING

Analysis of the data showed that the sonar ping spacing between echosounder returns was typically between 1-3 feet. The transducer utilized for this project created a vertical spread of the sounding data that is wider than what would typically be created with a hydrographic survey transducer. The examination of the sonar over various areas showed that this "spread" increased as a function of depth.

Modeling of the data by using all the points with such a vertical spread would not be possible, or would create extremely rough surfaces in the areas where soundings were collected that would not create a realistic interpretation of the true lake beds. Therefore, to create a more realistic and smoother model of the soundings, a sounding reduction was performed on the data set by creating a 5 foot grid for each survey site. The raw soundings were then imported into this grid and an average value was generated for each cell that contained data. The gridded and averaged data were then used as the basis for the Triangulated Irregular Networks that became the final surfaces for the areas.

3.2.4.10. TIN MODEL CREATION

A Triangulated Irregular Network (TIN) model was created for each project area based on the 5 foot smoothed data mentioned above. The TIN model was required in this process because it allowed the data to be interpolated through areas where data was missing. As previously mentioned, there were gaps between survey lines that were as large as 70 feet. The TIN model allowed a triangulated surface to be created by connecting these soundings across those gaps and to generate surfaces in between. The TIN model created a continuous and solid surface for each of the survey areas.

The TIN models were closely examined and edited to remove any possible triangles that were created outside the areas where soundings existed and to prevent excessive data extrapolation. Once the TIN models were verified for consistency, they were examined in a 3-D environment a final time to look for any possible outliers or unusual "spikes" that may have been generated. The TIN models were then used to generate the required Digital Terrain Models.

3.2.4.11. DTM CREATION

Utilizing the final smoothed surface that was created from the TIN model, a final gridded surface was created on a 1-foot by 1-foot grid. This was performed by utilizing Hypack's "TIN Model Export" routine and by overlaying a 1-foot gridded matrix on top of the TIN surface. The matrix was populated with the depth value that was calculated to be the average depth in the center of each 1-foot cell. These final cell-centered values were exported to an ASCII XYZ format (Easting, Northing, Elevation) for final deliverables.

3.2.5. DATA CHECKS AND QUALITY CONTROL

In addition to daily reviews of raw survey data, several techniques were used in the office after the surveys were complete to enhance data quality and reliability.

3.2.5.1. CROSSING LINES

As a standard quality control check in hydrographic projects, areas where different survey lines intersect create a unique opportunity to verify sonar accuracy and consistency. Crossing lines can be examined and estimations can be made on accuracy by comparing the depths of one line to the other at or near the locations where they cross.

However, as previously mentioned, the potential errors caused by the spread of the soundings increases with depth. These errors were not isolated to one particular line being offset in a certain direction or one particular segment being more noticeable than the rest. The errors appear to be random and scattered throughout each survey site. It is estimated that the crossing lines had an average error of roughly 1 foot, with several locations matching within acceptable limits and others with as much as 5 foot difference.

The application of the smoothing and averaging grids that were discussed in Section 3.2.3.9 was the best possible method of dealing with this difference. The averaging system utilized will create the most reasonable surface with the least amount of uncertainty possible.

3.2.5.2. TIDES AND STAGE DATA

Tide data for the Thomas Bay tidal area was discussed in Section 3.2.3.3. The accuracy of the tidal information for this site was questionable due to the assumed relative distance between the two reference points (rocks). With only an approximate distance noted between reference points, it was possible that the tidal error in this section could be on the order of +/- 2 feet throughout the duration of the survey. The Thomas Bay tidewater survey dataset can be made subsequently more accurate by ground surveying the two tidewater markers described above.

For the lake study areas, the water stage data appears to be more accurate. The stage data provided by a field hydrologist were retrieved from a WaterLog H-350-XL vented pressure transducer. The water surfaces changed very little throughout the survey duration and were averaged over 15 minute intervals. The elevation changes between survey transect lines were minimal – usually less than 0.02 feet. Even throughout the period of a day, the changes were mostly insignificant – around 0.10 feet or less, with the exception of the change on 8/20/2010 which saw a drop of around 0.40 feet. It was estimated that the errors caused by the stage data would be less than 0.10 ft.

3.2.5.3. DATA DENSITY

After the data was cleaned and filtered, the final soundings were examined for areas where the density and spacing of the data may create a loss of accuracy on the final surface.

In the northern portion of Falls Lake, survey lines were planned on a much tighter grid than in the Thomas Bay tidewaters area. Effort was made to survey lines on a 5 meter (16.4’) grid. However, currents and turbulence created by the waterfall at Falls Lake forced pressure on the AUV making it difficult to maintain its planned course along transects near the waterfall. Other factors that contributed to navigation difficulties were the rugged shoreline, obstructions in the waters (boulders), and the turning rate and radius of the AUV. On average, the resulting coverage created gaps of approximately 25’ x 50’. There were areas, as highlighted above, that exceeded these numbers and created areas where very little data was acquired. These areas needed excessive interpolation in the processing phase and the uncertainty in the final results should be considered higher in these locations.

The southern portion of Falls Lake had the same issues with cross-currents as the northern portion, but with less of an impact on the survey lines. The data coverage was sufficient with the exception of areas that were difficult to obtain navigation data and had limited space where the AUV could maneuver properly. There were also significant amounts of positional errors in these areas which required several soundings to be removed from the data set.

The Swan Lake project site had one area of concern in the shallower water near the northern end of the site. Data was collected in this area, but a majority of the data had invalid soundings and were removed in processing. The shallow water in this area was less than the usable range of the sonar system.

3.3. BATHYMETRY RESULTS AND DISCUSSION

Bathymetric surveys were conducted by a two-person field crew over a one week period ranging from August 19 to August 26, 2010. Falls Lake was surveyed in its entirety (approximately 740,000 meters2) and separated by surveys of the upper and lower portions of the Lake. The delta of Swan Lake (approximately 26,000 meters2) was surveyed at the inflow of Upper Cascade Creek. A portion of the tidewaters of Thomas Bay (96,000 meters2) was surveyed south of the Cascade Creek ocean outflow. XYZ data for the respective study sites are available online at www.thomasbayhydro.com. Bathymetric maps for the respective water bodies are provided below (Figures 3-2, 3-3, 3-4, and 3-5). Falls Lake was divided into two separate maps; Upper and Lower Falls Lake.

The data collected at Falls Lake and Swan Lake achieved the targeted 1-foot vertical accuracy elevation model. The less precise Thomas Bay tidewater data can be improved markedly by surveying the tide markers using traditional survey equipment. Accuracy estimates of the sonar data vary significantly between survey areas and also vary depending on depth. The accuracy ranges include estimates based on analyzing sources of error including sound velocities (travel time measurement of a sonar pulse); sonar variations as beam widths expand and contract over different depths; and low GPS precision due to natural impediments.

The accuracy estimates are the professional opinion of a licensed surveyor with extensive background and training in the field of hydrography. It should be noted that the estimates reported here refer only to the soundings and positions that were actually collected and used in processing. Areas where interpolation was required between soundings will have a significantly higher uncertainty level. Comparisons to known values, either horizontal or vertical, were not made to verify accuracies because the required field checks were outside the scope and target of this effort which was principally to establish a relative elevation model capable of determining fish habitat and calculating water feature volumes. If absolute elevations are required in the future, it is recommended that additional ground surveys be performed to tie these data into verified tidal surveys using traditional survey methods and control monumentation.

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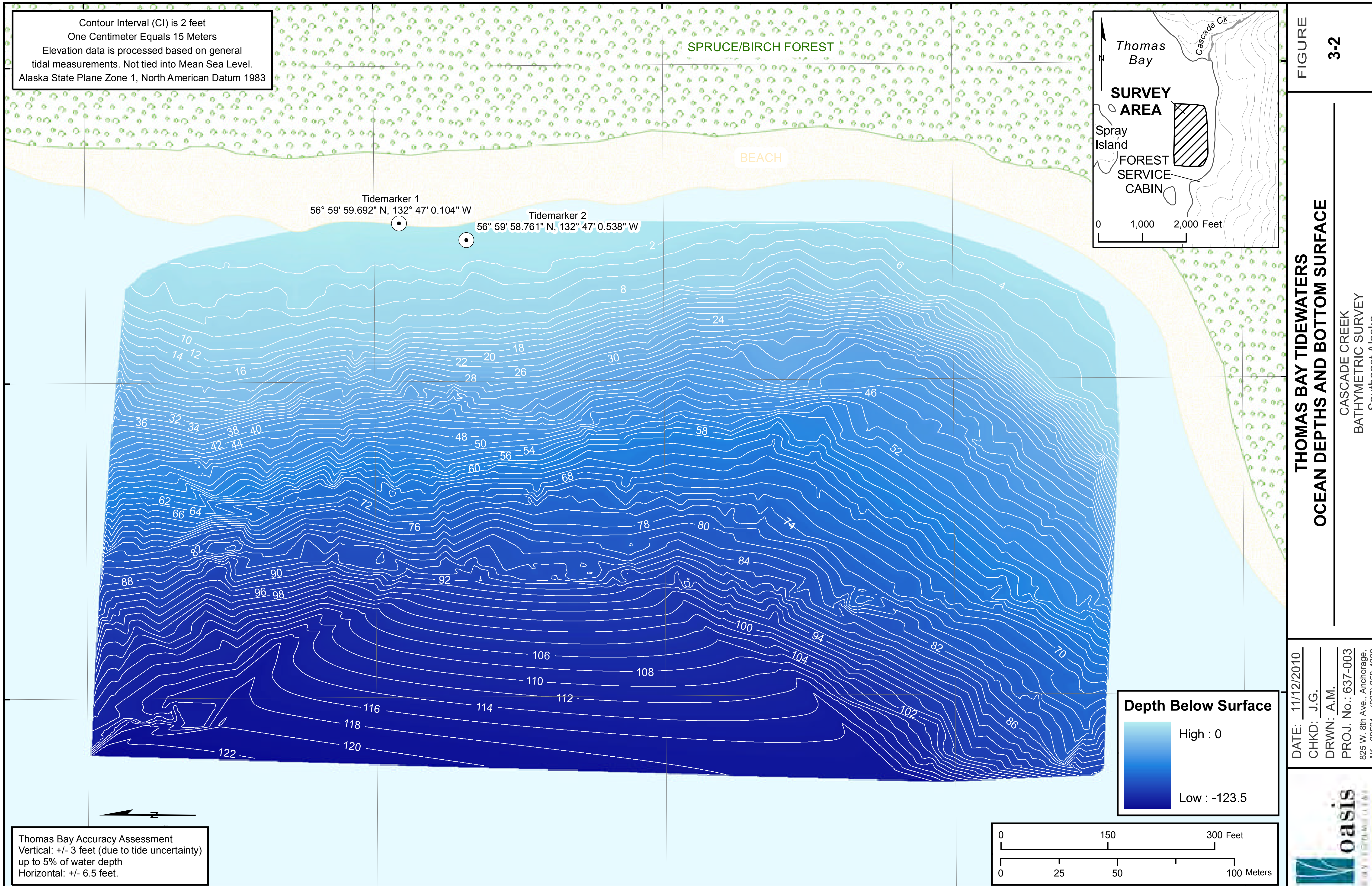

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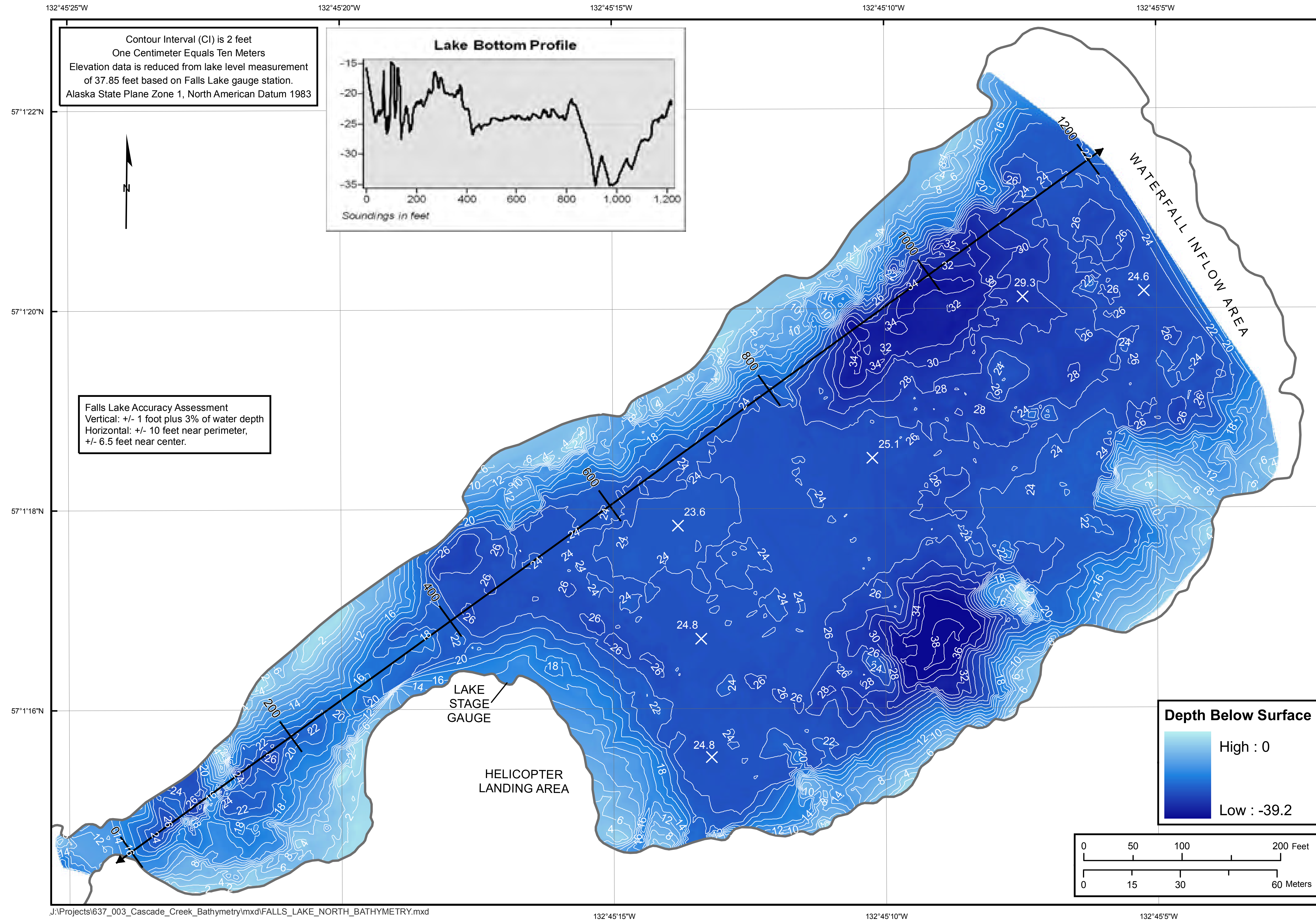

FIGURE 3-3

UPPER FALLS UPPER LAKE DEPTHS AND BOTTOM SURFACE CONTOURS

CASCADE CREEK
BATHYMETRIC SURVEY
Southeast, Alaska

DATE: 11/12/2010
CHKD: J.G.
DRWN: A.M.
PROJ. No.: 637-003

oasis
825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880

J:\Projects\637_003_Cascade_Creek_Bathymetry\mxd\FALLS_LAKE_NORTH_BATHYMETRY.mxd

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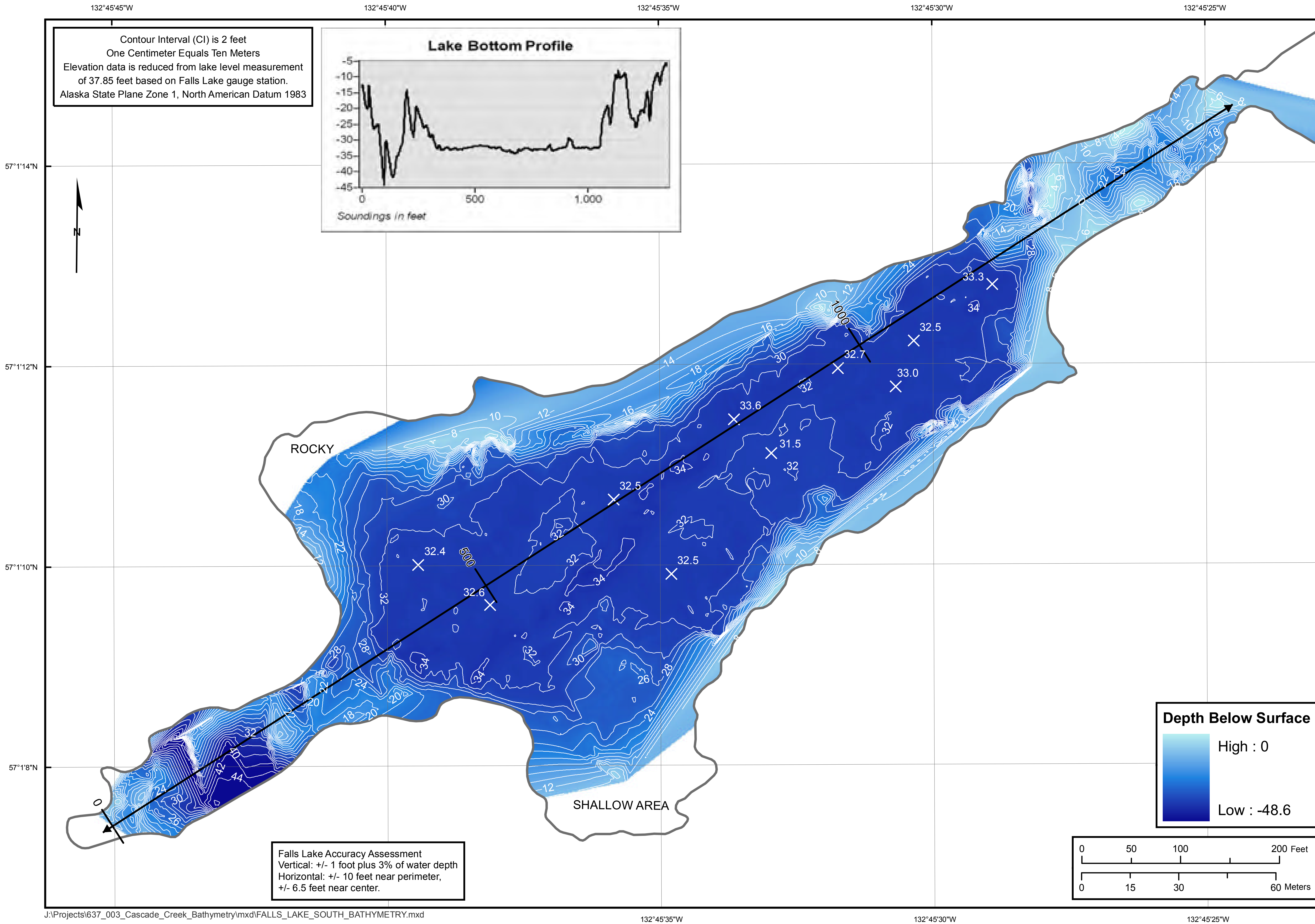

FIGURE 3-4

FALLS LAKE LOWER
LAKE DEPTHS AND BOTTOM SURFACE CONTOURS

CASCADE CREEK
BATHYMETRIC SURVEY
Southeast, Alaska

DATE: 11/12/2010
CHKD: J.G.
DRWN: A.M.
PROJ. No.: 637-003

825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880

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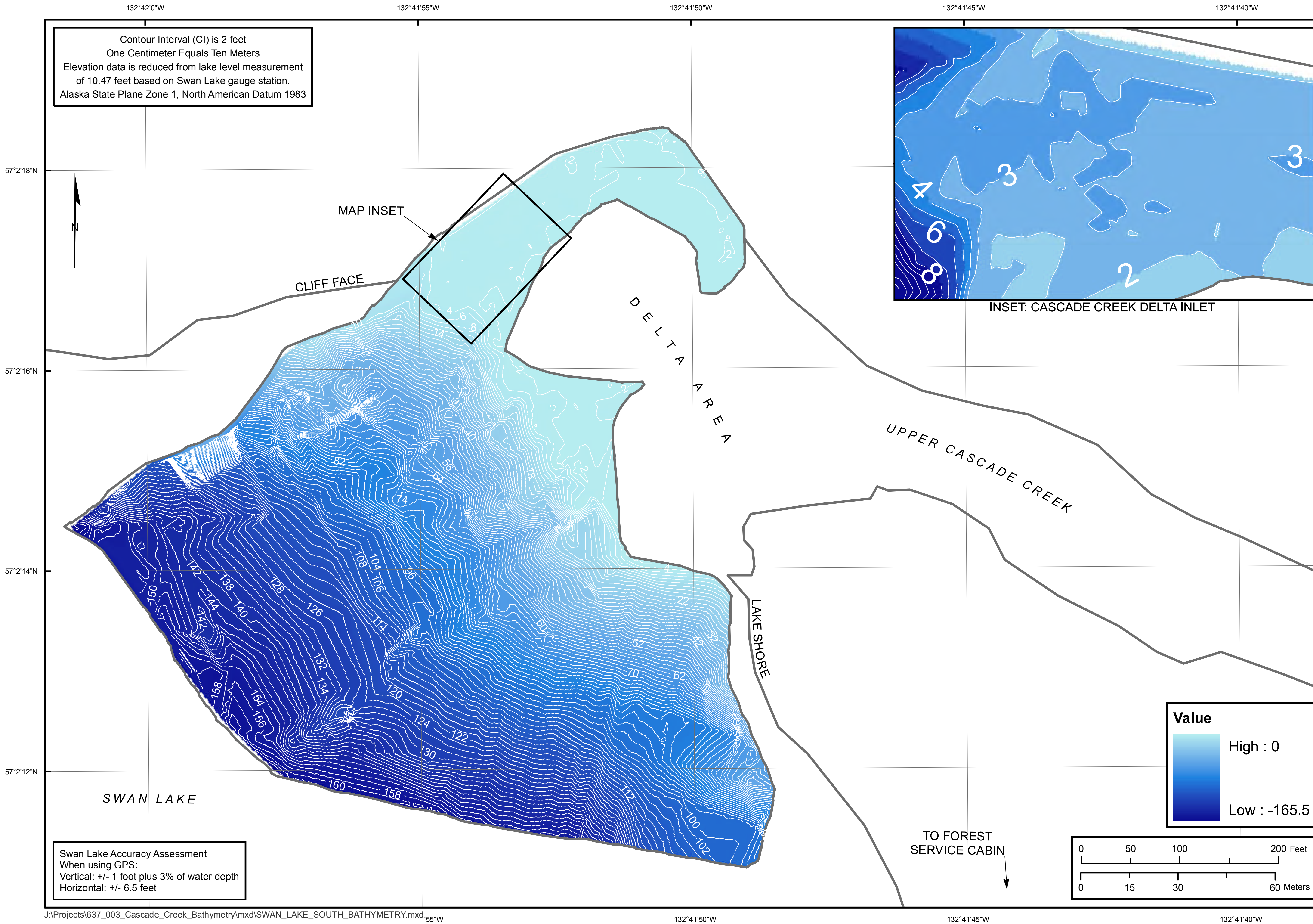

FIGURE 3-5

SWAN LAKE DELTA
LAKE DEPTHS AND BOTTOM SURFACE CONTOURS

CASCADE CREEK
BATHYMETRIC SURVEY
Southeast, Alaska

DATE: 11/12/2010
CHKD: J.G.
DRWN: A.M.
PROJ. No.: 637-003

825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880

oasis

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4. LIMNOLOGY

This section describes the limnological profiles recorded in Swan Lake in 2010 in the vicinity of the proposed intake structure. In addition, an analysis of the potential for changes in the limnology of Thomas Bay resulting from project operations is addressed.

4.1. INTRODUCTION

4.1.1. SWAN LAKE

The limnology investigation focused on the physical and chemical conditions in the water column of Swan Lake in August and September, within the immediate vicinity of the proposed intake (Figure 4-1). The proposed run-of-the-river hydroelectric project would siphon water at a depth of approximately 12 m (40 ft) from Swan Lake, and agency managers are tasked with assessing the potential effects of this intake on the physical and chemical conditions of the lake.

Deep, cold lakes at this latitude and elevation typically exhibit two periods of thermal stratification, during winter and summer, driven by temperature-dependent density gradients that exist within the water column. The summer thermal stratification of interest to this study is caused when solar radiation heats the lake surface, raising the water temperature and in turn decreasing water density. As water density decreases, greater amounts of wind energy are required to cause enough turbulence to mix the upper, warmer layer with the lower, cooler layers. Thus, the lake begins to stratify into an upper layer called the epilimnion, underlain by the metalimnion and hypolimnion layers, which are comprised of cooler, denser water. Limnologists also refer to the metalimnion as the "thermocline." The thermocline is a distinct layer of water between the epilimnion and hypolimnion that exhibits a distinct temperature gradient.

The objectives of the limnology investigation were to (1) describe the baseline conditions of temperature, dissolved oxygen (DO), pH, and conductivity within Swan Lake near the proposed intake, including any thermal stratification of the water column and (2) if thermal stratification is observed, identify the depths at which the summer epilimnion and thermocline exist, with regards to thermal stratification, and the associated DO profile.

4.1.2. THOMAS BAY

ADFG expressed concern about the possible effects of the hydropower plant water discharges on the oceanography and marine fauna in Thomas Bay. These concerns were primarily based on the results of a 1985 pre-feasibility assessment report commissioned by the city of Petersburg that discusses potential oceanographic impacts of hydroelectric development on Swan Lake, Scenery Lake and Ruth Lake (Hosey & Associates, 1985). This report mentions three main concerns related to changes in the timing and volume of water discharged into Thomas Bay.

1. Changes in water temperature, salinity and water density in Thomas Bay.

2. Changes in circulation and stratification of the water column in Thomas Bay.
3. Changes in ice formation in Thomas Bay.

The pre-feasibility report was based on possible hydropower operations of three drainage basins. From north to south these drainage systems are Scenery Creek (Scenery Lake), Cascade Creek (Swan Lake and Falls Lake), and Delta Creek (Ruth Lake). The calculations and associated concerns summarized in the Hosey & Associates Report were based on a constant water intake for hydropower.

The Cascade Creek hydropower project is proposed to operate in a run-of-the-river mode where levels of Swan Lake would be maintained close to natural seasonal lake levels. The water intake amount from Swan Lake for hydropower generation will not exceed the water inflow into Swan Lake from upper Cascade Creek. Based on the context of the proposed run-of-the-river operation mode, the three concerns listed above will be addressed in the sections below.

4.2. LIMNOLOGY METHODS AND STUDY AREA

4.2.1. SWAN LAKE INTAKE

Swan Lake is approximately two miles long and 500 ft deep, situated in a steep mountainous basin at roughly 1,514 ft elevation. It is a highly oligotrophic lake (low in nutrient inputs and organic production), given its high mountain setting, inflow of cold glacial streams, and steep shoreline with a general lack of littoral zone.

OASIS conducted limnology measurements on Swan Lake during two sampling events, on August 15th and September 24th, 2010. Staff used a YSI 556 multi-parameter meter to simultaneously measure four parameters in the vicinity of the proposed intake (Photo 4-1): temperature (˚C), dissolved oxygen (DO) (mg/l), pH, and conductivity (µS/cm). During the August sampling event, parameters were measured at 1 ft (0.3 m) intervals from the lake surface, down to a depth of 30 ft (9.14 m), and then at 5 ft (1.52 m) intervals from 30 ft to 65 ft (19.81 m) (total n=38). During the September sampling event, parameters were sampled at 1 ft intervals down to a depth of 50 ft (15.24 m), then at 5 ft intervals to 60 ft, with the September depth profile ending at 63 ft (19.2 m) (total n=53). Staff calibrated the YSI daily using known standards for each parameter measured. All calibration measurements were recorded in instrument logbooks. The YSI DO probe was also calibrated in-situ account for local barometric pressure.

Data analysis included summary statistics (minimum and maximum) and a qualitative assessment of temperature, DO, pH and conductivity along the depth continuum. Results of each parameter were plotted against depth to identify any patterns present in the water column, including the presence of a thermocline. The thermocline is described as the area of maximum rate of decrease in temperature with respect to depth, which can be difficult to determine graphically. Therefore, Wetzel (1983) quantified the thermocline as a change of greater than 1°C per meter, which must occur over a reasonable range of depth

FIGURE 4-1

LOCATION OF LIMNOLOGY SAMPLING AT PROPOSED INTAKE STRUCTURE ON SWAN LAKE

THOMAS BAY
18 Miles NW of Petersburg, Alaska

DATE: DEC. 2010
CHKD: J.G.
DRWN: C.L.H.
PROJ. No.: 637-004

825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880

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Photo 4-1: Aerial view of proposed location for intake structure on Swan Lake

within a lake. Temperature change per meter was therefore calculated for August and September, in an effort to quantify the presence of a thermocline.

4.2.2. THOMAS BAY

Thomas Bay is part of Frederick Sound, located in southeast Alaska at 57.0000° N, 132.7833° W and situated northeast of Petersburg. Baird Glacier drains into the bay through several drainage basins. The Cascade Creek project is located in the south arm of Thomas Bay. The main river and creeks that discharge into that part of the bay from north to south are Scenery Creek, Cascade Creek, Delta Creek, and Patterson River.

The project consists of a lake siphon taking water from Swan Lake at about 12 m (40 ft) water depth. The water will run through a gatehouse and valve entry to an approximately three-mile long 11' diameter tunnel complex of horizontal and vertical shafts. This tunnel leads to a powerhouse at tidewater on Thomas Bay, where the water will eventually be discharged. The tailrace is proposed as a low gradient open stream channel lined with natural rock/cobble/boulder materials approximately 300-400 feet long discharging as a new outlet to Thomas Bay, approximately ¼ mile south of the mouth of Cascade Creek. Combined tailrace and Cascade Creek post development discharge volumes will closely resemble the pre-development discharge of Cascade Creek's natural regime on a seasonal and weekly basis. The hydropower plant will be in a nonoperational mode under circumstances where the water flow into Swan Lake is too low. This can be expected to occur during the winter months.

The calculations summarized in the section below are based on information presented in the pre-feasibility report (Hosey & Associates, 1985) and from field data collected during 2009 and 2010. It should be noted that the available data were not collected to specifically address the concerns summarized earlier. The calculations and associated conclusions are therefore, in part, based on several assumptions summarized in the result section.

4.3. LIMNOLOGY RESULTS

The results section includes analysis of the limnology data collected at Swan Lake in August and September 2010 as well as volumetric modeling of potential impacts on Thomas Bay limnology resulting from diversion of Cascade Creek to the hydroelectric powerhouse discharge point.

4.3.1. SWAN LAKE INTAKE

Weather during the August sampling event was clear and warm, 23.5˚C, with light winds 5-10 mph. During the September sampling event it was overcast and rainy, 8.5˚C, with no wind recorded. Table 4-1 presents the minimum and maximum values for temperature, pH, conductivity and DO for the two sampling events. Parameters for the August and September sampling events are plotted along the depth continuum in Figure 4-2, with the depth of the proposed intake just below 12 m (40 ft), depicted on the map as a horizontal dashed line for reference. Results for each parameter are discussed separately below with a focus on the temperature profile.

Table 4-1: Swan Lake temperature, pH, conductivity and dissolved oxygen

Parameter	August		September	
	Min	Max	Min	Max
Temperature (˚C)	5.44	14.47	6.27	9.80
Dissolved Oxygen (mg/l)	10.11	11.92	10.44	11.04
pH	5.14	8.11	6.21	6.51
Conductivity (µS/cm)	11	183	10	157

Temperature in August ranged from 14.47 °C at the lake surface to 5.44 °C at 20 m, while September temperatures ranged from 6.27-9.8 °C (Table 4-1). Although August temperatures were higher near the lake surface and decreased with depth, the temperature profile was relatively smooth, and no distinct temperature gradient was identified. Table 4-2 presents the temperature change per meter in August and September, within the first 9 m (30 ft) of the surface. Changes of greater than 1°C per meter were identified at three locations in August: between 1-2 m, at ~4.5 m, and between 6-7.5 m. This gradient was observed at approximately 7.5 m in September, which corresponded to the depth at which the water transitioned from isothermal, to slightly more varied temperature (Table 4-2 and Figure 4-1).

Dissolved oxygen ranged from 10.1-11.9 mg/l in August, and 10 to 11 mg/l in September. In August, DO was lowest at the lake surface and generally increased with depth, increasing slightly from ~11 to 11.9 mg/l at approximately 6.5 m, and returning to 11 mg/l just below 7 m. This pattern was not as distinct in September with a narrower range of DO values.

In August, pH exhibited a wider range (5.14-8.11) than in September (6.21-6.51). August pH values were lowest near the lake surface and generally increased with depth, with the greatest increase occurring between 6-8 m. Conductivity ranged from 11-183 µS/cm in August and from 10-157 µS/cm in September. Conductivity values varied throughout the water column, with the greatest variability occurring between 4-9 m in August.

4.3.2. THOMAS BAY

Cascade Creek is one of the four main sources of freshwater influence in south Thomas Bay. Most freshwater influence originates from the Patterson River, located in the southern end of the southern Thomas Bay arm. Table 4-3 shows the contribution of freshwater discharge into south Thomas Bay from Cascade Creek and the hydropower plant relative to other freshwater sources during pre- and post-development phases. The data is summarized for summer and winter period, representing the four months with the highest and lowest discharge, respectively. The main assumption for this calculation is that the minimum allowable level in Cascade Creek will be 20 cubic feet per second (cfs). This number is based on a 90-day annual minimum derived from Hosey & Associates (1985; page IV-4). Note that changes in this number will not have any influence on the combined Cascade Creek and hydropower plant discharge volume, only on the relative contribution between these two sources. Under these assumptions discharge from Cascade Creek post development will be about 1% during summer and 9% during winter. The remaining 14% and 19% will be discharged through the tailrace from the hydropower plant. The contribution of combined Cascade Creek and Power Plant discharge in Thomas Bay will remain similar to pre-development values under the assumption that operations will be conducted under a run-of-the-river flow scenario. Changes in ice formation due to increased freshwater discharge during winter will therefore not occur under the proposed operations.

The surface area and water volume of south Thomas Bay were calculated by OASIS through a GIS exercise using sub-sea contour data of NOAA Chart #317367, Scale 1:40,000. The calculated surface area of south Thomas Bay was 11,119,850 square meters (4.3 square miles) and water volume 219,930,524 cubic meters.

Table 4-2: Temperature change in the first 9.14 m (30 ft) in Swan Lake.

Depth (m)	Temp ˚C Aug	Aug Temp ˚C change/m	Temp ˚C Sept	Sept Temp ˚C change/m
0.00	14.47	NA	NA	NA
0.30	14.47	0.00	9.79	NA
0.61	14.42	0.16	9.79	0.00
0.91	14.28	0.46	9.79	0.00
1.22	14.03	0.82	9.79	0.00
1.52	13.7	**1.08**	9.79	0.00
1.83	13.34	**1.18**	9.79	0.00
2.13	13.15	0.62	9.79	0.00
2.44	13.12	0.10	9.79	0.00
2.74	13.01	0.36	9.79	0.00
3.05	12.92	0.30	9.79	0.00
3.35	12.67	0.82	9.79	0.00
3.66	12.53	0.46	9.79	0.00
3.96	12.38	0.49	9.79	0.00
4.27	12.13	0.82	9.8	-0.03
4.57	11.78	**1.15**	9.78	0.07
4.88	11.58	0.66	9.78	0.00
5.18	11.4	0.59	9.78	0.00
5.49	11.1	0.98	9.78	0.00
5.79	10.89	0.69	9.79	-0.03
6.10	10.76	0.43	9.79	0.00
6.40	10.34	**1.38**	9.79	0.00
6.71	10.07	0.89	9.79	0.00
7.01	10.06	0.03	9.78	0.03
7.32	9.81	**2.59**	9.78	0.00
7.62	9.61	0.66	9.47	**1.02**
7.92	9.59	0.07	9.27	0.66
8.23	9.57	0.07	9.15	0.39
8.53	9.38	0.62	8.92	0.75
8.84	9.29	0.30	8.86	0.20
9.14	9.08	0.69	8.8	0.20

bold print signifies temperature changes >1°C per meter

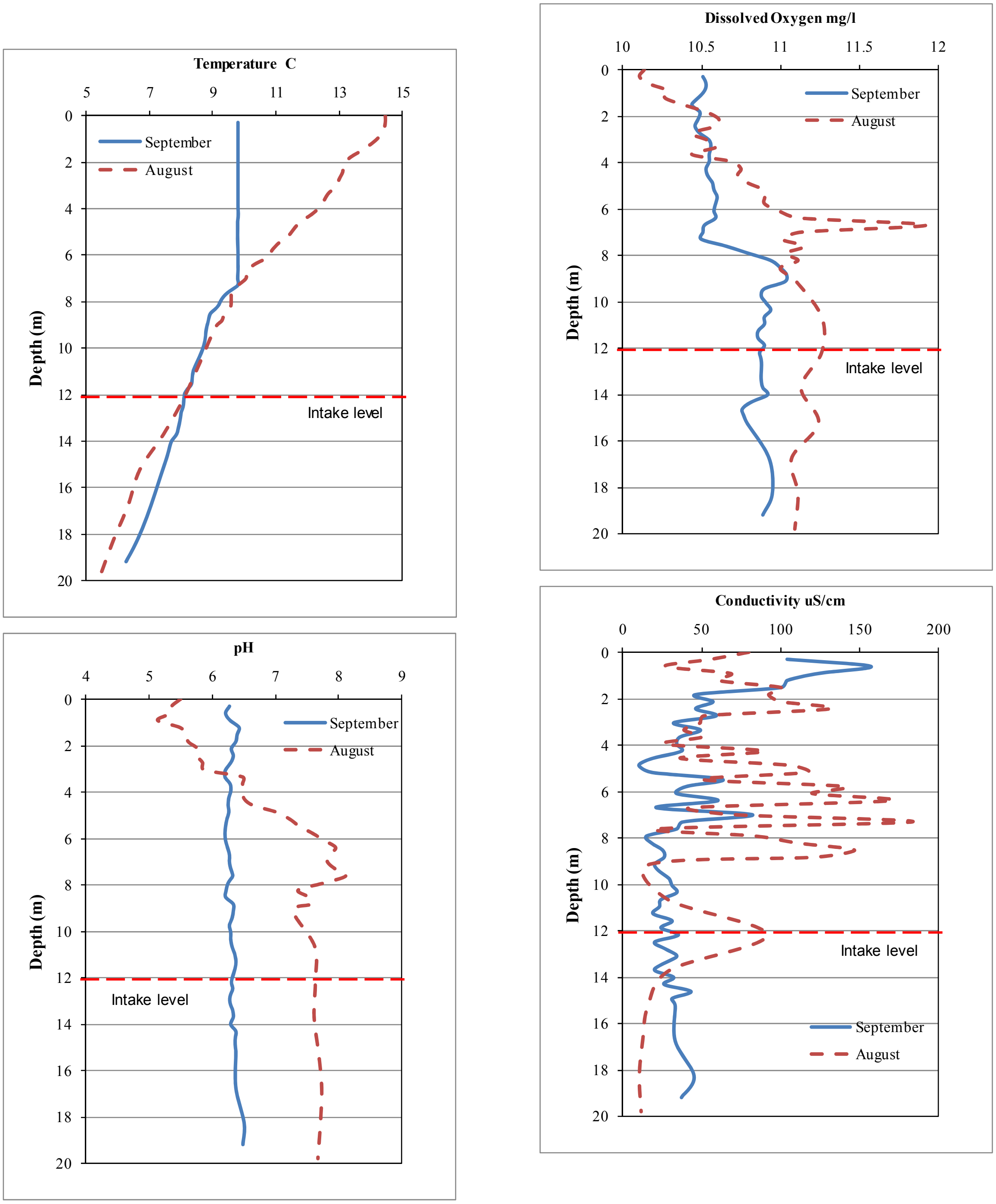

Figure 4-2: Temperature, DO, pH and conductivity in Swan Lake

Table 4.3: Analysis of discharge inputs to Thomas Bay

FRESHWATER DISCHARGE (cfs)	Pre-development		Post-development	
	SUMMER (Jun-Sep)	WINTER (Jan-Apr)	SUMMER (Jun-Sep)	WINTER (Jan-Apr)
Lower Cascade Creek [1]	474	61	20	20
Patterson River [2]	2084	80	2084	80
Delta Creek [3]	142	18	142	18
Scenery Creek [4]	474	61	474	61
Hydropower plant	0	0	454	41
TOTAL discharge on south Thomas Bay	3174.2	220.3	3174.2	220.3
% contribution Cascade Creek	15%	28%	1%	9%
% contribution hydropower plant	0%	0%	14%	19%
% contribution combined	15%	28%	15%	28%

[1] Average cfs 1918-28 and 1947-73 (Hosey & Associates 1985). Minimum post development discharge values based on 90-day cfs minimum of 1918-28 and 1947-73 (Hosey & Associates 1985, page IV-4).

[2] Table V-A, page V-9 Hosey & Associates 1985)

[3] cfs 30% of Cascade Creek, page V-7 Hosey & Associates 1985)

[4] cfs similar to Cascade Creek, page IV-7 Hosey & Associates 1985).

Table 4-4 shows that under the proposed run-of-the-river flow scenario and the assumed discharge values from Table 4-3, the freshwater discharge from the hydropower plant relative to the total volume of south Thomas Bay is 0.5% (summer) and 0.05% (winter). The discharge volume of all freshwater sources combined (Scenery Creek, Cascade Creek and hydropower plant, Delta Creek, and Patterson River) relative to south Thomas Bay is provided for reference.

Table 4.4: Discharge from hydropower plant verses tributaries to Thomas Bay.

	SUMMER (Jun-Sep)	WINTER (Jan-Apr)
Freshwater discharge in cubic meters per day		
from hydropower plant	1,098,317	99,187
from all main freshwater sources	7,679,025	532,950
% discharge relative to south Thomas Bay volume		
from hydropower plant	0.50%	0.05%
from all main freshwater sources	3.49%	0.24%

Temperature changes in the south arm of Thomas Bay due to a shift in discharge source from Cascade Creek to the hydropower plant are expected to be negligible. Hosey & Associates (1985) report temperature data profiles from Swan Lake taken in summer of 1961 and 1962 and winter of 1984. OASIS measured depth profile temperature data of Swan Lake in August and September of 2010 (Table 4-2). The available data show that summer temperature in Swan Lake varied from 10.0 to 14.5oC at the surface and from 6.1 to 10.2oC at the intake level (12 m or 40 ft). On average the difference in temperature between the intake location at Swan Lake and Lower Cascade Creek water surface during summer is about 3oC. During winter months the temperature of the water intake at Swan Lake might be somewhat warmer than Cascade Creek surface water. No apparent temperature changes are expected during the three-mile tunnel transport. The contribution of hydropower plant discharge relative to Thomas Bay water volume and other freshwater sources is relatively small, especially in winter. No appreciable influence on Thomas Bay water temperature is therefore expected to occur from a shift in water discharge from Cascade Creek to the hydropower plant.

Differences in water salinity, pH and dissolved oxygen between the intake location at Swan Lake and surface water are generally very small, especially in winter when biological productivity is low. Any differences that might exist will not change during the passage through the three-mile rock tunnel system. Once the water exits the powerhouse to the tailrace, consisting of a 300-400 feet long open stream channel, it will be exposed to natural atmospheric conditions before entering Thomas Bay. This channel is too short to substantially change any water characteristics, but mitigates for the potential of gas supersaturation of discharge water. Most importantly, the discharge volume of the hydropower plant will not exceed natural values and as such will have no measurable effect on the water quality of Thomas Bay. If the hydropower plant will operate under a different regime than the run-of-the-river flow scenario, the results mentioned here need to be re-assessed.

4.4. LIMNOLOGY DISCUSSION

4.4.1. SWAN LAKE INTAKE

Based on the August and September sampling events, all of the significant variability in the vertical profiles of temperature, dissolved oxygen, pH and conductivity in Swan Lake appears to occur above 10 m, which is above the level of the 12 m proposed intake. However, it should be recognized that this data represents a very limited spatial and temporal view of Swan Lake, and not the annual late summer/fall distribution of temperature, DO, pH and conductivity in Swan Lake. Vertical distributions of each of the four parameters are discussed below.

No distinct thermal stratification was observed in Swan Lake during the 2010 sampling events. Although a temperature gradient greater than 1°C per meter was identified at three depths in August, these areas of increased gradient were very narrow (0.3 m to 1.5 m) and were not considered thick enough for distinction of a thermocline in the temperature profile. The lack of thermal stratification could be a result of the flow-through dynamics of Swan Lake, which is fed by glacial streams. Wetzel (1983) notes that "…in reservoirs, high inflow from stream discharge, often cooler than the water of the epilimnion, can cause much turbulence and reduce the thermal gradient appreciably. A similar phenomenon is observed frequently in alpine and northern lakes that receive large flows of glacial or snow meltwater during the later portions of the summer stratification." As the surface of Swan Lake begins to warm during the summer, the influx of colder, denser water likely reduces surface temperatures and facilitates mixing of the water column, in turn creating a smoother temperature profile that lacks distinct temperature gradients.

In September, the isothermal temperatures observed from the surface down to approximately 7 m were expected for that time of year. The cooler, denser surface water resulting from cooler fall air temperatures begins to cause vertical turbulence and mixing, until the entire water column is isothermal.

In both August and September, Swan Lake exhibited an orthograde oxygen profile typical of oligotrophic lakes (Wetzel 1983), with dissolved oxygen generally increasing with depth, as a function of decreasing temperature. The exception to this orthograde profile was observed at approximately 7 m in August, where DO temporarily spiked. This spike was considered relatively minor given the magnitude (1 mg/l over a span of 1.2 m), but is interesting in that it corresponded to the depth of spikes observed in the pH and conductivity profiles.

The August pH profile corresponded roughly with the DO profile, with lower pH values at the surface, spiking slightly at 7 m, and becoming relatively homogenous below 10 m. This profile was rather unexpected for an oligotrophic lake, where the pH vertical distribution is generally homogenous with depth, as seen in the September profile (Wetzel 1983). It is common for the pH profile to mirror the DO profile in highly productive eutrophic lakes where pH is driven by vertical fluctuations of carbon dioxide (CO_2), which is in turn related to biologically mediated reactions, namely metabolic respiration and photosynthetic uptake. Because pH is inversely proportional to CO_2, water becomes more acidic or basic in response to respective increases or decreases in CO_2. In contrast, oligotrophic lakes generally experience only slight changes in the vertical profile of CO2, resulting in minimal pH variability throughout the water column. It is possible that the warm weather during the August sampling event could have resulted in increased biological activity near the surface, increasing CO2 production and in turn decreasing pH. However, additional profiles of pH and other water chemistry parameters would have been required to determine whether or not this was the case.

Conductivity values were within the range of natural variability for oligotrophic lakes, with the greatest variability observed in August. However, additional sampling of conductivity and other water chemistry parameters would be necessary to explain the large swings in conductivity. August conductivity in Swan Lake roughly mirrored the pH profile, which is typical given that alkalinity-related ions also increase the electrical conductance of water (Wetzel 1983).

All four of the parameters exhibit a distinct layer of water at approximately 7 m where DO, pH and conductivity temporarily increase. This could potentially be the result of the inlet stream water sitting at this depth. As the cooler inlet stream water enters the lake it is denser than the surface water, causing the stream water to sink until it encounters cooler lake water of equivalent density. The inlet stream water is likely more aerated with higher mineral concentrations, resulting in elevated DO, pH, and conductivity levels at that depth.

In conclusion, no distinct thermocline was noted, and most of the vertical variability in temperature, dissolved oxygen, pH and conductivity in Swan Lake appears to occur above the level of the 12 m proposed intake. However, this data is limited to two sampling events in a single year, and should be treated as a snapshot in space and time rather than the annual late summer/fall distribution of physical and chemical parameters in Swan Lake.

4.4.2. THOMAS BAY

The Cascade Creek hydropower project is proposed to operate in a run-of-the-river flow scenario. This means that levels of Swan Lake would be maintained close to natural seasonal lake levels and that the combined discharge volume of lower Cascade Creek and the hydropower plant discharge will not exceed the natural discharge volume of Cascade Creek. Based on this major assumption, the contribution of hydropower discharge relative to the existing freshwater discharge and to the volume of Thomas Bay is limited and will have no impacts on the oceanographic conditions of Thomas Bay. It is important to note that this conclusion is based on a run-of-the-river operation. Changes to this operating regime would require a re-assessment of the volumetric modeling and associated conclusions provided in this report.

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5. CASCADE CREEK FISHERY INVESTIGATIONS

Fisheries investigations during the summer and fall of 2010 were focused on two areas of study: 1) a mark and recapture and seasonal distribution study to determine the abundance of the RBT stock in Falls Lake and the Pond and inventory other species of fish that may be present in the lake and Lower Cascade Creek system; and 2) a limited rainbow spawning survey focusing on creeks that enter Swan Lake.

5.1. INTRODUCTION

Swan Lake contains a population of RBT stocked in the late 1950's (ADFG 1975). No stocking has occurred in Swan Lake since the initial releases in 1957 and 1958. RBT have spread throughout the Cascade Creek drainage since the initial stocking event. Distribution in the upstream end is limited by an impassable barrier falls approximately 1.5 miles upstream from Swan Lake. At present, the RBT inhabiting the Swan Lake-Cascade Creek-Falls lake-system represent a fragmented stock separated by physical barriers (waterfalls and cascades) that limits the possibility of upstream movement within specific reaches of Cascade Creek. Seasonal movement occurs from Swan Lake upstream to known and unknown stream spawning areas in Upper Cascade Creek and, potentially, other Swan Lake inflow tributaries. In Lower Cascade Creek, upstream movement from Falls Lake to the Pond is restricted by several waterfalls and cascades. Upstream movement between the Pond and Swan Lake is also deemed to be restricted.

The RBT of the Swan Lake-Cascade Creek system are likely a genetically distinct, isolated, and self sustaining stock. Some individuals sampled in past years have appeared visually distinct and identifiable from other trout in the region by their unique pink-red background coloration (pers. comm. D. Fleming). This fishery resource is believed to be a monoculture.

Due to the fact that the RBT stock in the system appear fragmented by the one or more upstream physical barriers, for the purposes of this study each discrete portion of the watershed was considered individually. This project assessed the RBT stock for Falls Lake and the Pond upstream of Falls Lake only and a seasonal fishery inventory for Lower Cascade Creek only.

Other terms to be defined that are pertinent to the ongoing investigation are stock structure and stock assessment. Stock structure is the proportional distribution of sizes, ages, or genders in a stock resulting from processes of recruitment, growth, and mortality (Murphy and Willis 1996). Stock assessment studies the status of a fish stock as well as the possible outcomes of different management alternatives. The present study plan deviates from this "classical" definition of stock assessment because "length-based" stock assessments and management are more commonly used in Southeast Alaska largely owing to the direct application to length-based regulations. Moreover, the determination of accurate age, and in many cases sex, of RBT and other game fish often requires confirmation using lethal sampling means. Non-lethal ageing of scales is possible but problematic (i.e. scale annuli are very small and close together in slow growing, coldwater fish) and must be verified through more destructive sampling techniques (e.g. otolith interpretation) or with known aged fish through longer-term studies. In addition, for RBT, the results of the recruitment, growth and mortality portions of a stock assessment may be obfuscated by the reality of adult trout predation on juvenile trout. For the purpose of this project the planned stock assessment focuses on size (length and weight) and stock abundance (estimate of the number of individual RBT in Falls Lake and estimate of the number of individual RBT in the Pond).

A RBT spawning survey was conducted during May 2010 in the tributaries to Swan Lake. This was the only trip to the project site that was specifically designed to observe spawning fish. Further observations of spawning activity in Swan Lake tributaries and other areas of the Cascade Creek drainage were made during the Stock Assessment and Seasonal Fish Inventory field trips. Results of these observations are presented below.

5.2. RAINBOW TROUT STOCK ASSESSMENT AND SEASONAL FISH INVENTORY STUDY OBJECTIVES

The RBT stock assessment and seasonal fish inventory study was designed to evaluate and document the status of the RBT stock of Falls Lake and Lower Cascade Creek during the pre-development phase of the Cascade Creek Hydroelectric Project. The specific objectives were:

1. Estimate the abundance of the RBT stock of Falls Lake through mark-recapture (M-R) sampling (all sizes vulnerable to sampling gear) during summer and fall, 2010.
2. Estimate the abundance of the RBT stock in the Pond through mark-recapture sampling (all sizes vulnerable to sampling gear) during summer and fall, 2010.
3. Assess the size structure and of the RBT stocks in Falls Lake and the Pond through length-frequency analysis.
4. Determine sex of captured RBT, when and if possible.
5. Perform a seasonal fishery inventory to determine presence/absence of RBT and other fish inhabiting Lower Cascade Creek (to include M-R sampling which will allow for estimation of abundance).

5.3. METHODS AND STUDY AREA

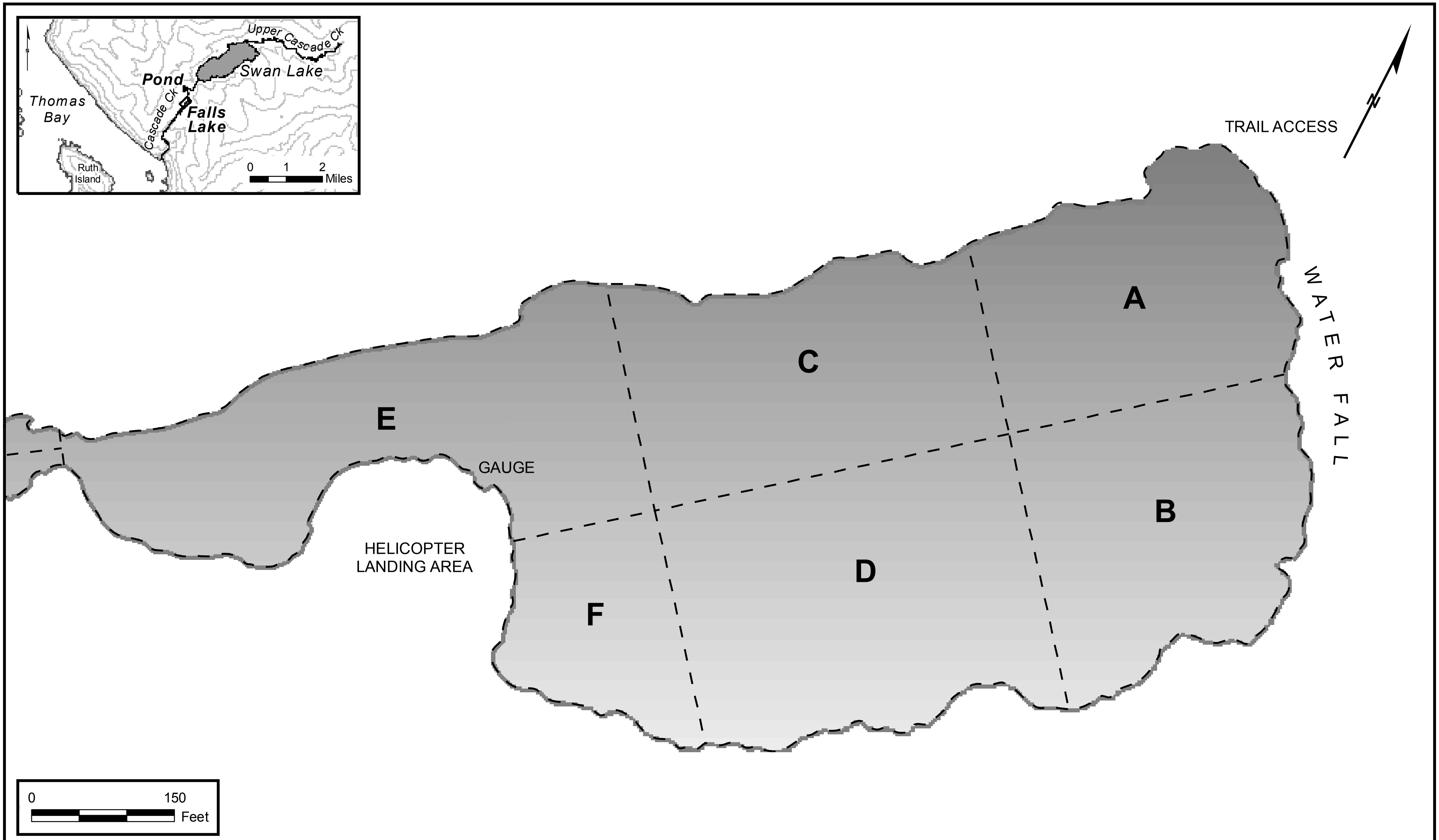
The study area and methods used for the mark and recapture study and the seasonal fish inventory are presented below.

5.3.1. MARK-RECAPTURE STUDY METHODS

The stock assessment (hereafter referred to as the Mark-Recapture Study) was limited to Reach 2 (2A and 2B) in Lower Cascade Creek, Falls Lake and the Pond. Rainbow trout were captured in Falls Lake and the Pond using a combination of baited minnow traps and baited hoop nets fished independently and at varying depths. All trap sites were assigned an identification number and marked with flagging and identification tag, including collection permit and contact information. Rainbow trout were captured in lower Cascade Creek (Reach 2) with baited minnow traps. Minnow traps were made of 0.32 cm size galvanized wire mesh and had two, 1.9 cm diameter funnel openings. Hoop nets were 1.4 m long and consisted of four 0.6 m-diameter hoops with 9 cm diameter throats attached to the first and third hoops. All minnow traps and hoop nets were baited with betadine-treated salmon eggs.

Due to the size and shape of Falls Lake it was divided into two parts (Upper Falls Lake and Lower Falls Lake) to ensure adequate sampling effort. Upper Falls Lake, Lower Falls Lake and the Pond were further divided into cells in a grid pattern (Figures 5-1, 5-2 and 5-3). Each cell contained at least one minnow trap and hoop net combination. Minnow traps were set close to shore in shallow water to target juvenile and small-sized trout. Hoop nets were set further from shore in deep water to target adult trout (Photo 5-1). Lower Cascade Creek was sampled with minnow traps only. This was due to shallow water depth and high water velocity which precluded the use of hoop nets. Trap depth was directly measured where possible and trap location was recorded with GPS. Trap depth, water temperature, location coordinates and set and pick times were recorded. In Lower Falls Lake and Lower Cascade Creek, trap depth was not measured for all traps due to sampling difficulties (i.e. hazardous terrain on land and in the stream channel). All fish traps (minnow traps and hoop nets) were allowed to soak overnight.

Minnow traps and hoop nets were retrieved and checked within approximately 24 hours of the set time. Captured fish were sedated (clove oil-ethanol solution), identified, measured (total length to the nearest mm), marked, and released after a recovery period. The August 16 to August 20, 2010 capture and marking event utilized upper or lower caudal partial fin clips (Table 5-1) depending on the capture location. The September 20 to September 24 capture and marking event utilized visual implant elastomer (VIE) tags that were color coded according to capture location. The elastomer is a 2-part polymer that produces a brightly colored liquid which hardens into a flexible, color-coded tag when injected subcutaneously (Photo 5-2). Rainbow trout captured in September were examined for partial fin clip marks.



oasis	DATE: DEC. 2010 CHKD: J.O. DRWN: A.M. PROJ. No.: 637-003 825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880	**UPPER FALLS LAKE SAMPLING GRID** CASCADE CREEK, LLC. RAINBOW TROUT STOCK ASSESSMENT AND SEASONAL FISHERY INVENTORY Southeast Alaska	FIGURE **5-1**

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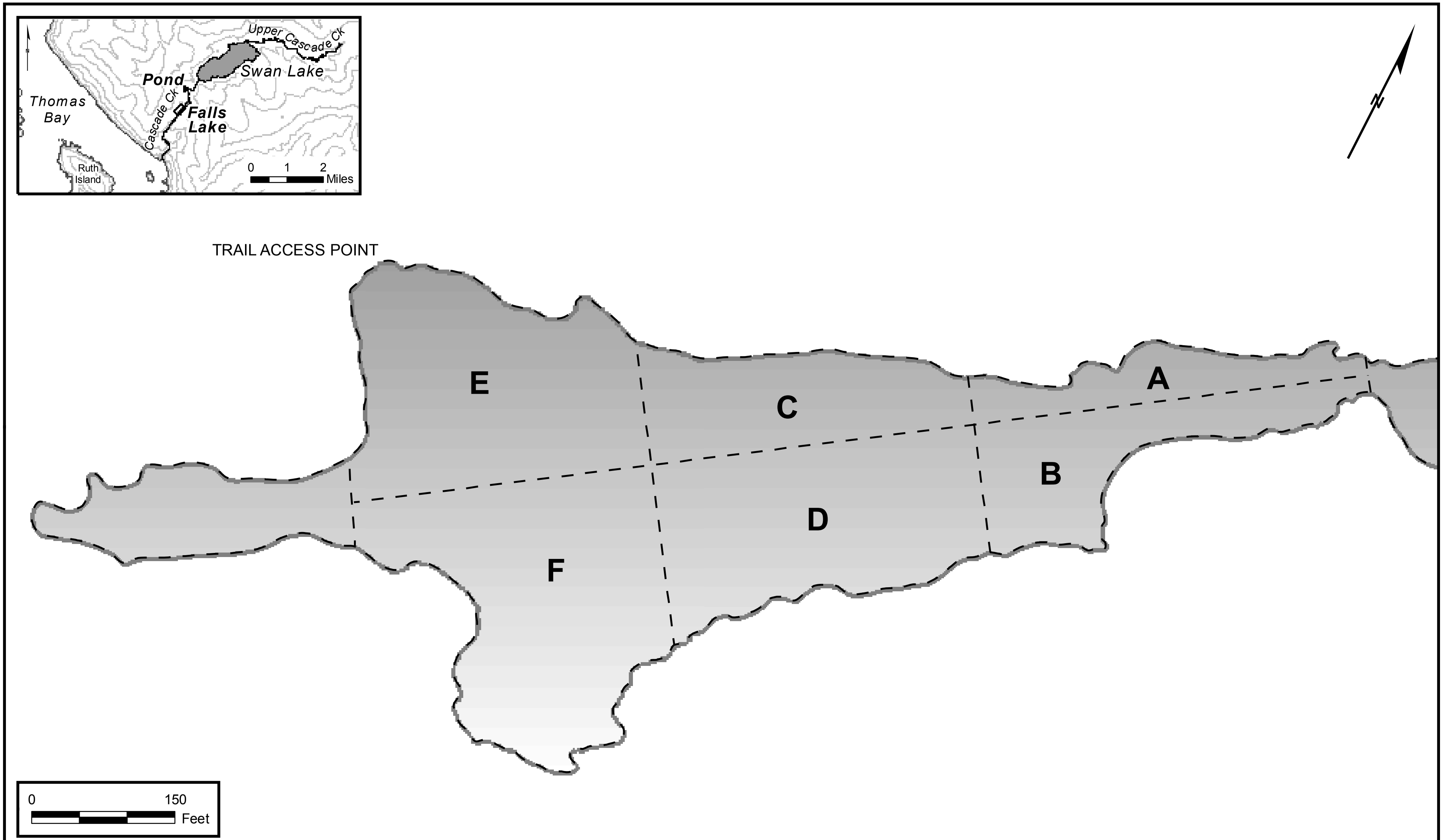

DATE: DEC. 2010	LOWER FALLS LAKE SAMPLING GRID	FIGURE
CHKD: J.O.		
DRWN: A.M.	CASCADE CREEK, LLC.	5-2
PROJ. No.: 637-003	RAINBOW TROUT STOCK ASSESSMENT AND SEASONAL FISHERY INVENTORY	
825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880	Southeast Alaska	

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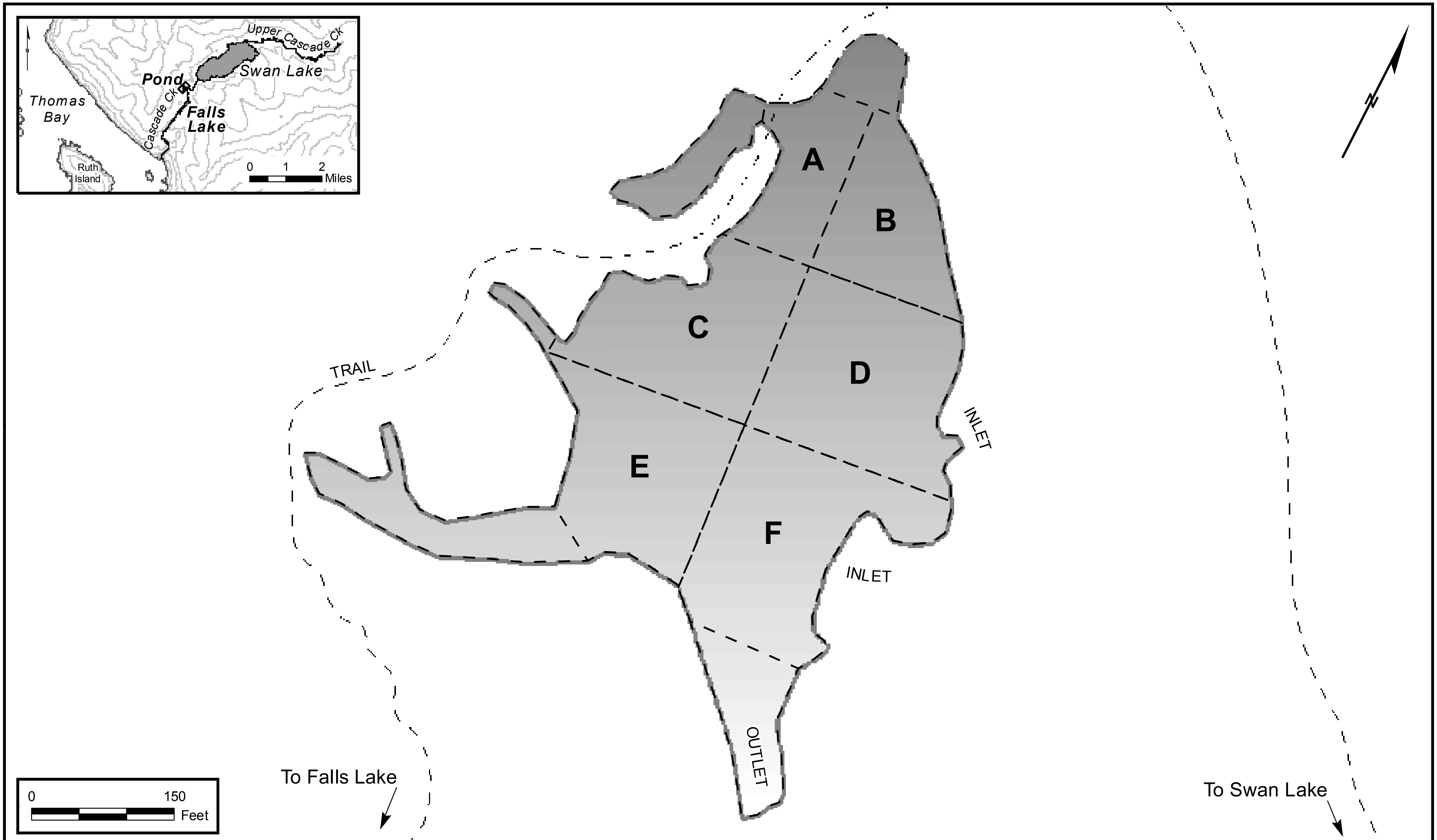

DATE: DEC. 2010
CHKD: J.O.
DRWN: A.M.
PROJ. No.: 637-003
825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880

POND SAMPLING GRID

CASCADE CREEK, LLC.
RAINBOW TROUT STOCK ASSESSMENT AND SEASONAL FISHERY INVENTORY
Southeast Alaska

FIGURE 5-3

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Photo 5-1: Hoop net deployment in Upper Falls Lake, September 2010.

Catch per unit effort (CPUE) was used to compare and evaluate the effectiveness of capture sampling. Length-frequency analysis was employed to establish baseline size information for trout present in the respective water bodies. Size structure of the RBT populations living in various segments of the Cascade Creek drainage will substitute for fish age because ageing of RBT in the system is not practical except through destructive sampling (i.e. otolith analysis).

Photo 5-2: Typical rainbow trout marked with visual implant elastomer (VIE).

In addition to checking fish for partial caudal fin clips, captured individuals were examined for external morphological characteristics indicative of sex. Specifically, anatomy of the urogenital (vent) opening was noted.

Table 5-1: Fin clips and VIE marks according to capture location.

2010	Pond	Upper Falls Lake	Lower Falls Lake	Lower Cascade Creek Reach 2
August	lower caudal fin clip	upper caudal fin clip	no captures	no captures
September	◆ Pink VIE	◆ Red VIE	◆ Blue VIE	◆ Orange VIE

5.3.2. SEASONAL FISHERY INVENTORY METHODS

The seasonal fisheries inventory focused on Reach 1 in Lower Cascade Creek. Reach 1 was further divided into Reach 1A, tidewater to first barrier falls and Reach 1B, barrier falls to Falls Lake outlet. Ten baited minnow traps were set in Reach 1A and ten traps in Reach 1B (Figure 5-4). Traps were placed in areas with a relatively low velocity and ample cover if available. For the most part, these locations were in eddies behind large boulders or pocket water along the banks. Traps were soaked overnight and checked the following day. GPS locations were recorded as well as marked on maps.

Representative photographs were taken of each trap location and each captured fish. Additionally, fish were identified, total length was measured to the nearest millimeter, and presence/absence of fin clips or VIE tags was checked and recorded. After identification and measurement were completed, the fish were returned to the stream location from which they were collected. No anesthetic was used on the fish and all data was recorded in an all-weather notebook. The purpose of this sampling was to establish presence/absence of RBT and/or other species; therefore, CPUE was not analyzed.

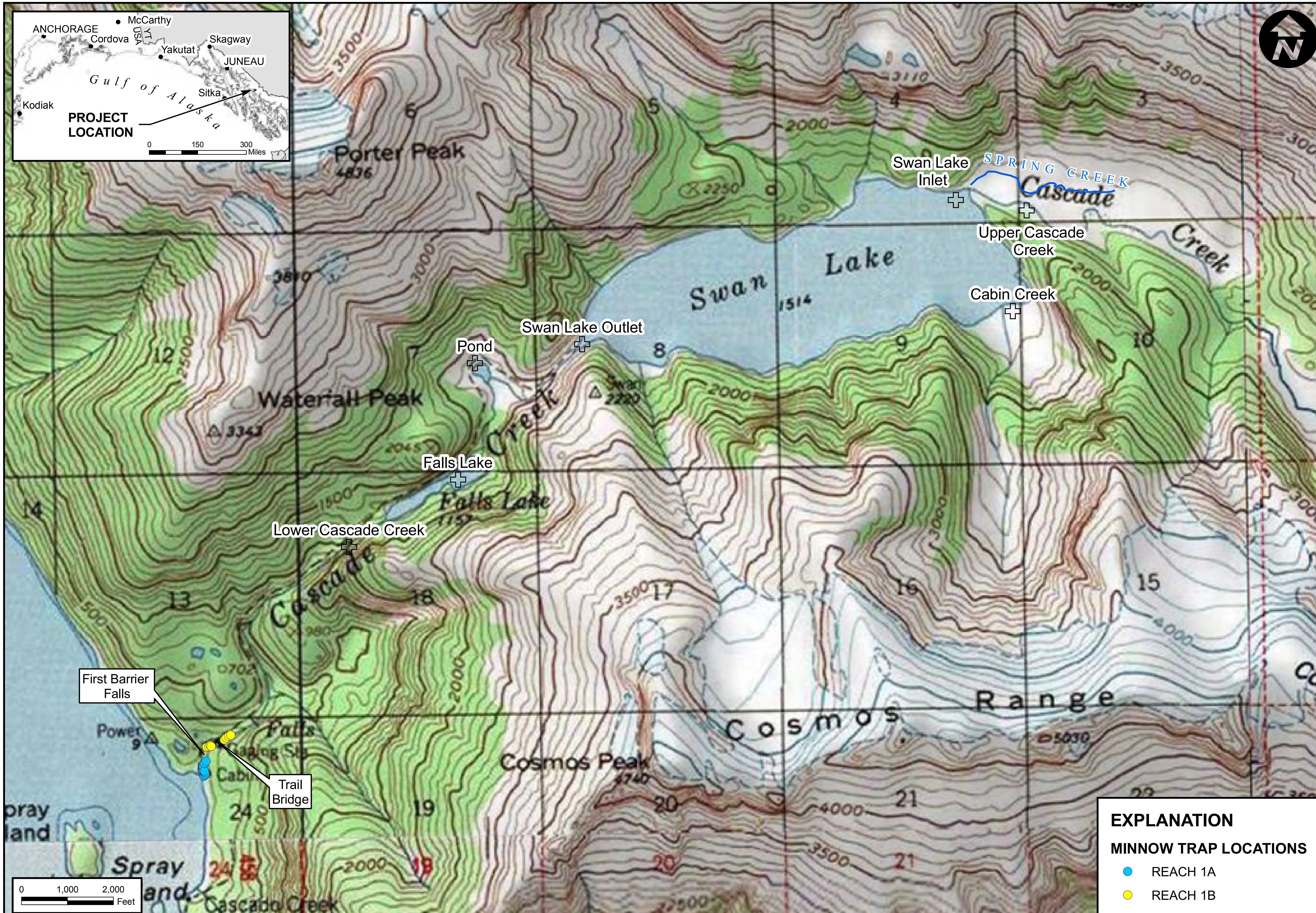

FIGURE 5-4

MINNOW TRAP LOCATION IN REACH 1A AND 1B FOR SEASONAL FISH INVENTORY

CASCADE CREEK DRAINAGE
18 Miles NW of Petersburg, Alaska

DATE: NOV. 2010
CHKD: J.G.
DRWN: C.L.H.
PROJ. No.: 637-003

825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880

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5.4. RESULTS

In an effort to gather information on the RBT population potentially affected by construction and operation of the Cascade Creek Hydroelectric Project, fish investigations were undertaken in August, September and October 2010 in specific reaches and water bodies in Lower Cascade Creek downstream of Swan Lake. The mark and recapture study was limited to August and September sampling events using a combination of hoop nets and minnow traps in the Pond and Falls Lake. The seasonal fisheries inventory sampled for the presence/absence in four distinct reaches of Lower Cascade Creek (1A, 1B, 2A, and 2B) plus the Pond and Falls Lake. The spawning survey was limited to a single reconnaissance effort on Upper Cascade Creek associated with deployment of temperature probes. Potential barriers to upstream fish passage were documented for each reach in Lower Cascade Creek as well as Upper Cascade Creek. In addition, fishery biologists performed reconnaissance investigations on tributaries to Swan Lake and Lower Cascade Creek noting fish passage barriers, presence of spawning habitat, and presence/absence of fish, in particular, searching for YOY fish indicating presence of spawning habitat in the tributary. The results are organized below by each specific study.

5.4.1. MARK-RECAPTURE STUDY

Sixty (60) RBT were captured and marked during two sampling events August 16 to August 20, 2010 and September 20 to September 24, 2010 in Falls Lake, the Pond and reaches 2A and 2B of Lower Cascade Creek. No other fish species was captured or observed. Only 9 fish were captured in August and none of these fin-clipped RBT was were recaptured in September. Due to the low numbers of fish captured and lack of recaptures, abundance estimation is not possible at this time.

5.4.1.1. THE POND

Total catch in September (n=11) was more than double the total catch in August (n=5). Out of a total of 10 hoop nets deployed in August, 3 successfully captured fish. In September, 4 out of 10 hoop nets captured fish. Out of a total of 10 minnow traps deployed in August, 1 successfully captured fish. In September, 2 out of 9 minnow traps captured fish. Hoop nets caught more RBT in both months. Catch per unit effort (CPUE) is a measure of the number of fish caught per hour. Table 5-2 displays CPUE for the pond during the August and September sampling.

The total length (TL) of RBT captured in the pond ranged from 86 to 275 mm and 148 mm (5.8”) was the average TL (Figure 5-5). Fish caught by minnow trap caught fish ranged from 105 to 138 mm TL with a mean average of 120 mm TL. Fish caught by hoop net ranged from 86 to 275 mm TL with a mean average of 165 mm TL. Hoop nets caught the largest and smallest RBT which suggests that traps were not size selective.

Trap depth (hoop nets and minnow traps) ranged from 0.15 to 3.05 m (0.5 to 10 ft.) but only traps in the .61 to 1.8 m (2 to 6 ft.) depth range captured fish in the pond. Trap depths with the highest and 2nd second highest CPUE were 1.5 and 0.61 m (5 and 2 ft.) respectively in August 2010 and 0.8 to 1.5 m (2.7 and 5 ft.) respectively, in September 2010.

Table 5-2: CPUE for the Pond in August and September, 2010.

Trap ID no.	Aug 16 and 17			Sept 20 and 21		
	Depth (m)	Catch	CPUE	Depth (m)	Catch	CPUE
A-1H	1.5	1	0.05	1.9	0	0
A-2H	0.8	0	0	1.5	3	0.15
B-1H	3.0	0	0	1.7	0	0
B-2H	3.0	0	0	1.1	0	0
C-1H	1.5	2	0.10	1.1	1	0.05
C-2H	2.0	0	0	1.4	0	0
D-1H	1.5	0	0	1.9	0	0
D-2H	1.8	1	0.05	1.5	1	0.05
E-1H	0.6	0	0	1.7	1	0.05
F-1H	0.9	0	0	1.2	0	0
	HN Catch	**4**			**6**	
A-1M	0.5	0	0	1.5	0	0
B-1M	0.9	0	0	1.5	0	0
B-2M	0.3	0	0	1.4	0	0
C-1M	0.9	0	0	1.1	0	0
C-2M	0.6	1	0.05	*	*	*
D-1M	1.2	0	0	0.7	0	0
D-2M	*	*	*	1.5	0	0
E-1M	0.6	0	0	0.2	0	0
E-2M	0.9	0	0	*	*	*
F-1M	0.5	0	0	1.3	1	0.05
F-2M	0.8	0	0	0.8	4	0.19
	MT Catch	**1**			**5**	
	Total Catch	**5**			**11**	

*HN=Hoop Net, MT=Minnow Trap, *=not sampled.*

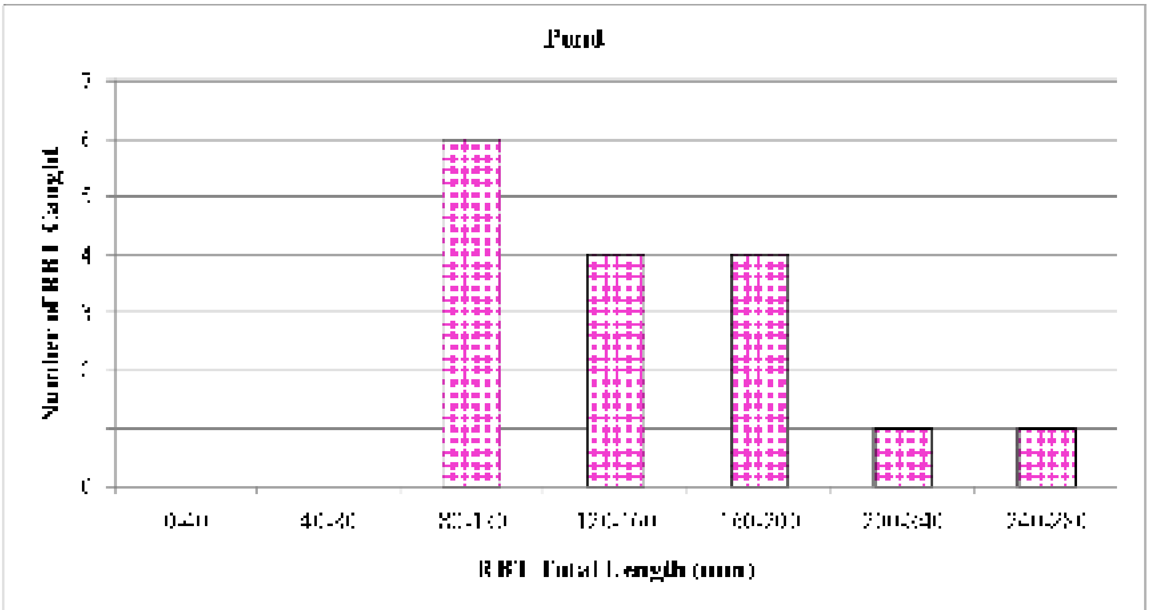

Figure 5-5: Length frequency histogram of RBT captured in the Pond

5.4.1.2. UPPER FALLS LAKE

Total catch in September (n=30) was six times greater than the total catch in August (n=5). Out of a total of 10 hoop nets deployed in August, 1 successfully captured fish. In September, 4 out of 10 hoop nets successfully captured fish. Out of a total of 10 minnow traps deployed in August, 3 captured fish. In September, 6 out of 10 minnow traps successfully captured fish. Minnow traps caught more RBT in August. Hoop nets caught more RBT in September. Table 5-3 displays CPUE for Upper Falls Lake during the August and September sampling events.

The total length (TL) of RBT captured in Upper Falls Lake ranged from 48 to 361 mm and 155 mm (6.1 in”) was the average TL (Figure 5-6). Fish caught by minnow trap ranged from 48 to 130 mm TL with a mean average of 95 mm TL. Fish caught by hoop net ranged in size from 97 to 361 mm TL with a mean average of 194 mm TL. Hoop nets caught the largest RBT and minnow traps caught the smallest RBT suggesting that traps were size selective.

Trap depth (hoop nets and minnow traps) ranged from 0.61 to 7.6 m (2 to 25 ft) but only traps in the 0.61 to 4.6 m (2 to 15 ft) depth range captured fish in Upper Falls Lake. Trap depths of traps with the highest and 2nd second highest CPUE were 2.4 and 1.8 m (8 and 6 ft) respectively in August 2010 and 3.05 and 0.61 m (10 and 2 ft) respectively, in September 2010.

Table 5-3: CPUE for Upper Falls Lake in August and September, 2010.

Trap ID no.	Aug 18 and 19			Sept 22 and 23		
	Depth (m)	Catch	CPUE	Depth (m)	Catch	CPUE
A-1H	7.6	0	0	1.5	0	0
A-2H	1.8	1	0.04	3.0	16	0.76
B-1H	3.0	0	0	3.0	2	0.09
B-2H	3.7	0	0	3.7	1	0.05
C-1H	1.8	0	0	3.0	0	0
C-2H	7.6	0	0	3.7	0	0
D-1H	4.6	0	0	3.7	0	0
D-2H	4.6	0	0	1.8	0	0
E-1H	4.6	0	0	6.1	0	0
F-1H	1.8	0	0	4.6	1	0.05
	HN Catch	**1**			**20**	
A-1M	1.8	1	0.04	1.8	2	0.09
B-1M	1.2	0	0	0.6	3	0.13
B-2M	2.4	2	0.08	*	*	*
C-1M	1.5	0	0	1.2	0	0
C-2M	1.5	0	0	1.2	2	0.09
D-1M	1.5	0	0	0.9	0	0
D-2M	2.4	0	0	1.2	0	0
E-1M	0.6	1	0.04	0.8	1	0.04
E-2M	0.9	0	0	0.9	1	0.04
F-1M	0.9	0	0	0.9	0	0
F-2M	*	*	*	0.6	1	0.04
	MT Catch	**4**			**10**	
	Total Catch	**5**			**30**	

*HN=Hoop Net, MT=Minnow Trap, *=not sampled.*

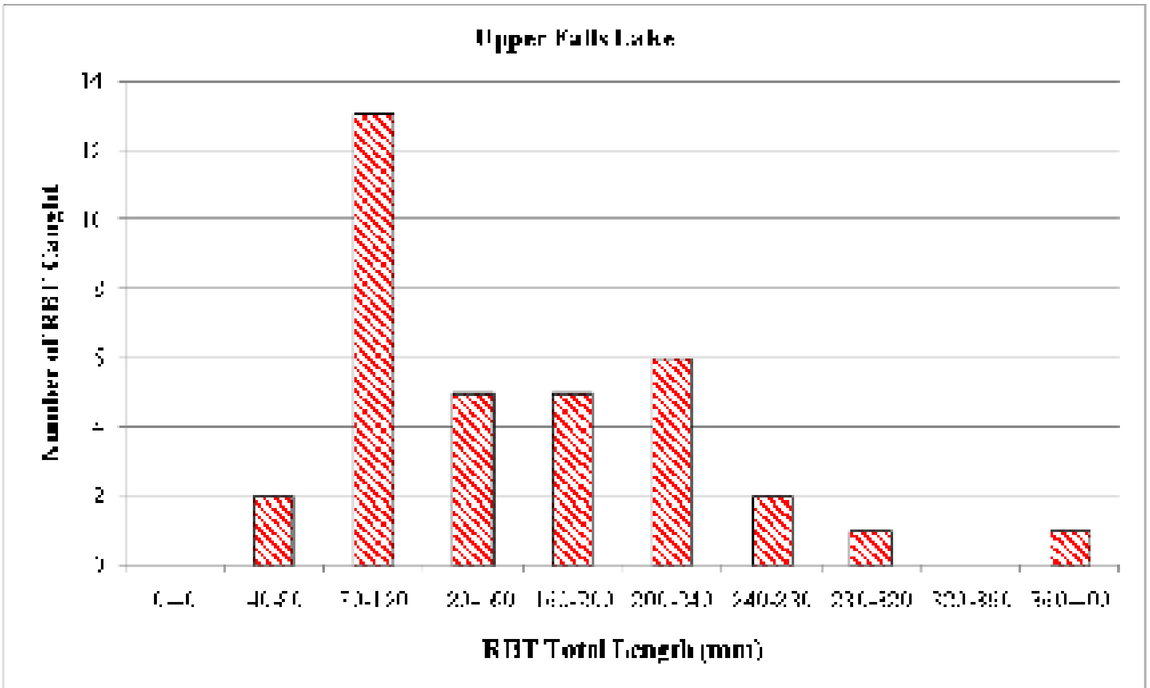

Figure 5-6: Length-frequency histogram of RBT captured in Upper Falls Lake

5.4.1.3. LOWER FALLS LAKE

Total catch in September (n=6) was six times greater than the total catch in August (n=0). In August, 10 hoop nets were deployed but none successfully captured fish. In September, 1 out of 10 hoop nets successfully captured fish. Lower Falls Lake was not sampled by minnow trap in August. In September, 3 out of 10 minnow traps captured fish. Minnow traps caught more RBT in September in Lower Falls Lake. Table 5-4 displays CPUE for Lower Falls Lake during the August and September sampling events.

The total length (TL) of RBT captured in Lower Falls Lake ranged from 55 to 320 mm and 193 mm (7.6 in”) was the average TL (Figure 5-7). Fish caught by minnow trap ranged from 55 to 230 mm TL with a mean average of 135 mm TL. Fish caught by hoop net (n=2) were 297 and 320 mm TL. Hoop nets caught the largest RBT but the presence of a 230 mm TL (9.05 in”) and a 196 mm TL (7.7 in”) RBT in a single minnow trap is notable because minnow traps seldom capture fish greater than 6 in” in total length. This suggests a lack of size selectivity of the minnow traps and is unusual since identically baited hoop nets were nearby (in September).

Table 5-4: CPUE for Lower Falls Lake in August and September, 2010.

Trap ID no.	Aug 19 and 20			Sept 23 and 24		
	Depth (m)	Catch	CPUE	Depth (m)	Catch	CPUE
A-1H	*	0	0	1.8	0	0
A-2H	1.8	0	0	3.4	0	0
B-1H	3	0	0	3.0	0	0
B-2H	*	0	0	3.7	0	0
C-1H	*	0	0	1.5	0	0
C-2H	*	0	0	3.7	0	0
D-1H	4.6	0	0	4.0	2	0.09
D-2H	*	0	0	4.6	0	0
E-1H	*	0	0	7.3	0	0
E-2H	*	0	0	*	*	*
F-1H	*	*	*	3.0	0	0
	HN Catch	**0**			**2**	
A-1M	*	*	*	0.9	1	0.05
B-1M	*	*	*	*	0	0
C-1M	*	*	*	1.5	1	0.05
C-2M	*	*	*	1.2	0	0
D-1M	*	*	*	*	0	0
D-2M	*	*	*	*	0	0
E-1M	*	*	*	*	0	0
E-2M	*	*	*	*	2	0.09
F-1M	*	*	*	*	0	0
F-2M	*	*	*	*	0	0
	MT Catch	**0**			**4**	
	Total Catch	**0**			**6**	

*HN=Hoop Net, MT=Minnow Trap, *=not sampled.*

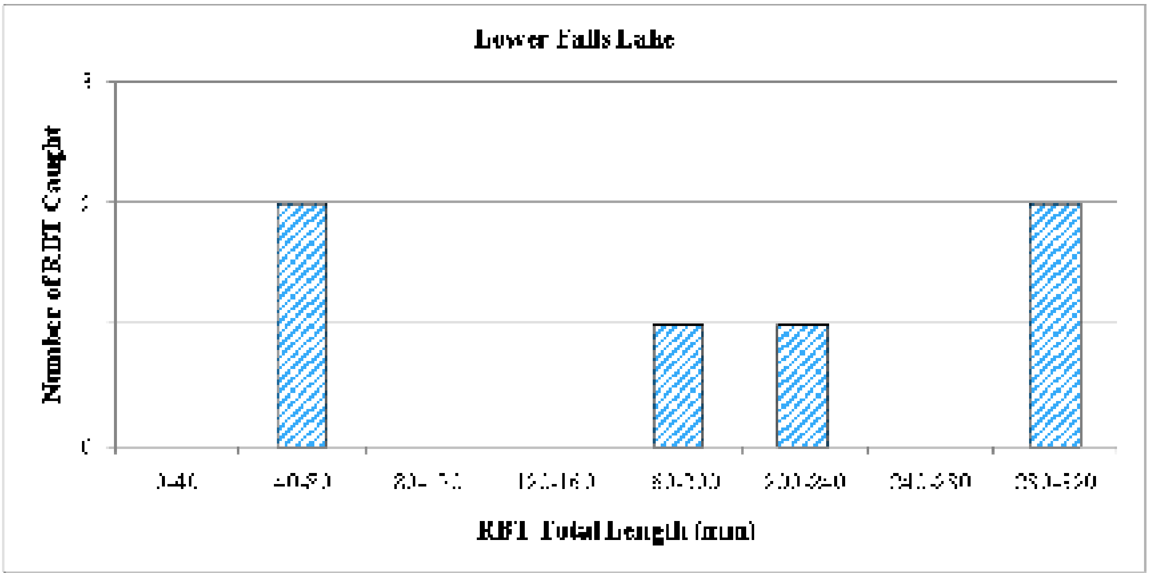

Figure 5-7: RBT length-frequency histogram, Lower Falls Lake, Sep. 2010.

5.4.1.4. LOWER CASCADE CREEK REACH 2

Lower Cascade Creek was only sampled in September and only by minnow traps. Two segments of Reach 2 (2A and 2B) were sampled. Five minnow traps were deployed at each site but only three (n=3) RBT were captured in Reach 2A and none (n=0) were captured in Reach 2B

Table 5-5: CPUE for Lower Cascade Creek, Reach 2 in September, 2010.

Reach no.	Sept 20 and 22			
	Trap ID no.	Depth (m)	Catch	CPUE
2A	LC-1	1.2	1	0.05
2A	LC-2	*	1	0.05
2A	LC-3	0.5	0	0
2A	LC-4	0.9	1	0.05
2A	LC-5	*	0	0
2B	LC-6	0.9	0	0
2B	LC-7	0.6	0	0
2B	LC-8	1.5	0	0
2B	LC-9	2.1	0	0
2B	LC-10	1.2	0	0
		MT Catch	3	

*MT=Minnow Trap. *=not sampled.*

The total length (TL) of RBT captured in Lower Cascade Creek ranged from 50 to 116 mm and 73 mm (2.9 in") was the average TL (Figure 5-8). An overall Length-Frequency histogram (Figure 5-9) is provided to compare TL of captured fish between water bodies.

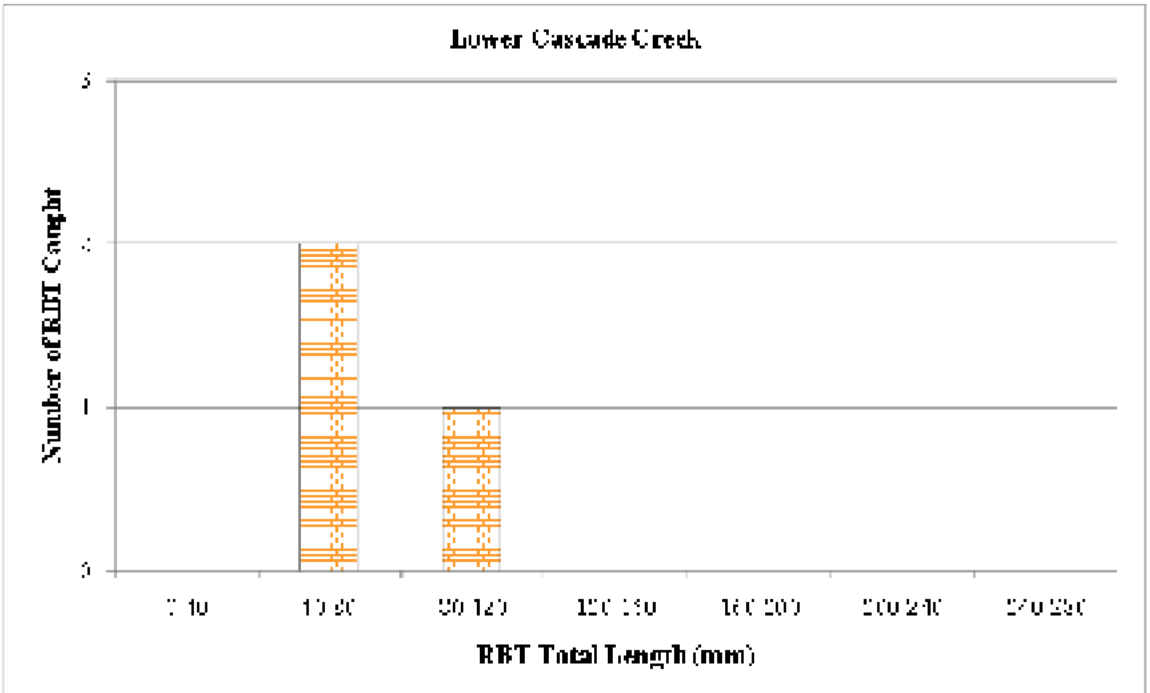

Figure 5-8: RBT Length-frequency, Reach 2A Lower Cascade Creek, Sept. 2010.

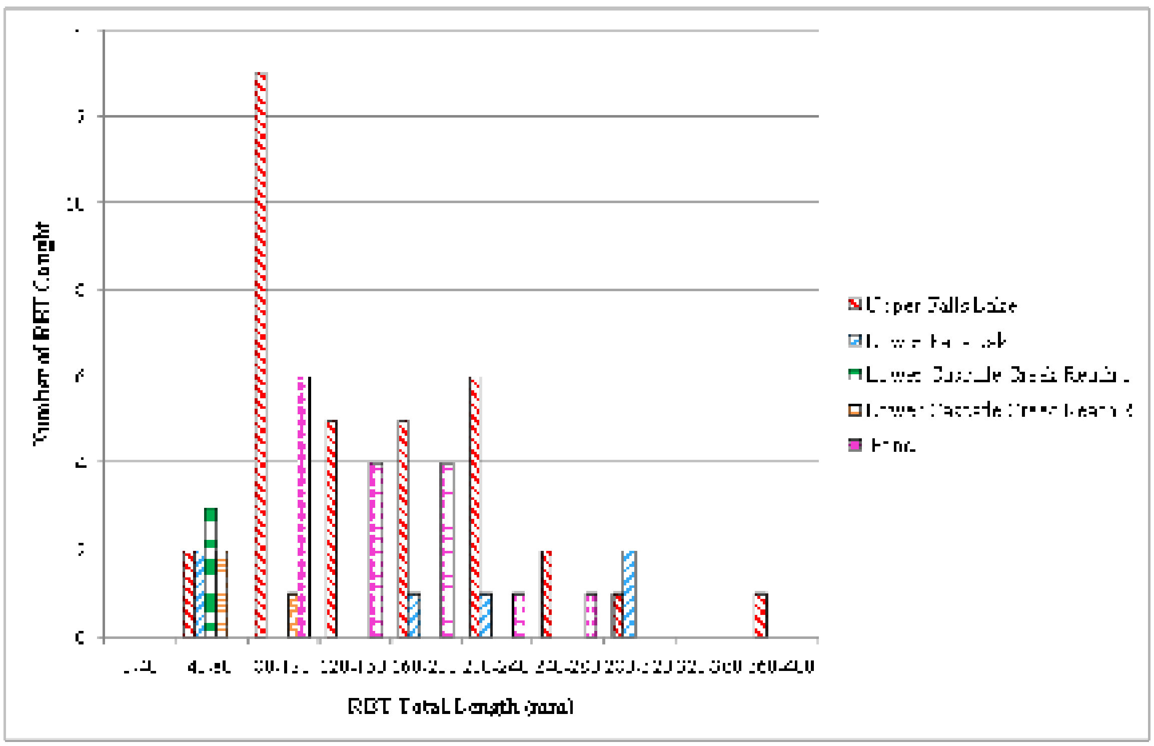

Figure 5-9: Comparative length-frequency of all RBT collected in 2010.

Two forms of vent anatomy were noted in September 2010: "keyhole shaped" and "ellipsoid" (Photo 5-3). Most captured RBT (49 out of 51) were placed in one of the two categories; observations on the remaining three were inconclusive. Trout with a keyhole-shaped vent (n=21) were possible females and RBT with ellipsoid-shaped vents (n=28) were possible males but no effort was made to verify this through destructive sampling.

Photo 5-3: RBT with ellipsoid-shaped vent on left; keyhole-shaped vent on right.

5.4.2. LOWER CASCADE CREEK SEASONAL FISHERIES INVENTORY REACH 1

The seasonal fish inventory scheduled during the August and September sampling events in Reach 1 were not completed due to heavy precipitation events raising discharge levels in Lower Cascade Creek to levels that made it impractical to sample with minnow traps as well as unsafe for biologists to access stream habitats. Sampling in Reach 1A and 1B was completed on October 27 and October 28, 2010.

In Reach 1A, two (n=2) juvenile RBT (TL 63 and 65 mm); three (n=3) Dolly Varden, (DV) (*Salvelinus malma)* (DV: TL 135, 155 and 171 mm); and one (n=1) coast range sculpin, (*Cottus aleuticus*) (90 mm TL) were captured (Table 5-6).

In Reach 1B, one (n=1) juvenile RBT (73 mm TL) and one (n=1) DV (165 mm TL) (Photo 5-4) were captured. None of the RBT captured in Reach 1 were previously VIE-marked or fin clipped.

5.4.3. FISH PASSAGE

Barriers to upstream fish passage were mapped in Reaches 1A, 1B, 2A, 2B and 3 (Figure 5-10). A total of nine potential barriers to upstream fish passage were observed in Cascade Creek (Table 5-7). All observed barriers were photo documented (Appendix 5-1). Eight of these barriers were located in Lower Cascade Creek between Swan Lake outlet and Thomas Bay. The ninth barrier was located in Upper Cascade Creek upstream of Swan Lake. Obvious barriers were designated with a B such as the falls at Falls Lake inlet whereas cascades that appeared to present barriers to upstream movement were designated PB to signify a potential barrier.

Table 5-6: Seasonal Fishery Inventory, Reach 1, Lower Cascade Creek. Oct., 2010.

Reach no.	October 27 and 28				
	Trap ID no.	Depth (m)	Catch	Species	TL mm
1A	A-1M	0.25	1	RBT	64
1A	A-2M	0.15	0		
1A	A-3M	0.35	2	DV	135
1A				RBT	63
1A	A-4M	0.46	0		
1A	A-5M	0.5	1	CS	90
1A	A-6M	0.3	1	DV	171
1A	A-7M	0.25	0		
1A	A-8M	0.9	0		
1A	A-9M	0.2	0		
1A	A-10M	0.46	1	DV	155
		MT Catch	**6**		
1B	B-1M	0.35	1	RBT	73
1B	B-2M	0.61	0		
1B	B-3M	0.35	0		
1B	B-4M	0.61	0		
1B	B-5M	0.5	0		
1B	B-6M	0.35	1	DV	165
1B	B-7M	0.5	0		
1B	B-8M	0.56	0		
1B	B-9M	0.56	0		
1B	B-10M	0.25	0		
		MT Catch	**2**		
		Total Catch	**8**		

MT=Minnow Trap; DV=Dolly Varden; CS=coast range sculpin.

Two barriers located in reaches 2A and 2B respectively, were surveyed using a stadia rod and survey level to quantify the height of the barrier. Barrier B-5 was located a short distance upstream from the USFS lean-to structure on Cascade Creek. The surveyed height of the barrier B-5 was 30 feet. Barrier PB-6 was located in reach 2B just upstream from the Pond. Barrier PB-6 was a stepped cascade. Discharge during the survey on September 21, 2010 was 72 cfs. Under these flow conditions upstream passage appeared to be obstructed. Under higher flow conditions, upstream passage may be possible at barrier PB-6.

Barrier PB-7, located directly upstream of PB-6, was a 300 foot reach of giant boulders with numerous falls ranging in height from 5 to 10 feet. This reach likely presents an upstream barrier to fish passage.

FIGURE 5-10

BARRIERS TO UPSTREAM FISH PASSAGE OBSERVED IN CASCADE CREEK

CASCADE CREEK DRAINAGE
18 Miles NW of Petersburg, Alaska

DATE: DEC. 2010
CHKD: J.G.
DRWN: C.L.H.
PROJ. No.: 637-004

825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880

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Photo 5-4: Dolly Varden (165 mm) captured at 1B-6M (above barrier falls)

Barrier PB-8 was a seasonal barrier evident when discharge was insufficient in Lower Cascade Creek for surface flow. Cascade Creek flowed subsurface in this section just downstream from Swan Lake outlet. The length of the dry channel expanded and contracted with changes in discharge disconnecting the large pool approximately 300 meters downstream from Swan Lake. A short section of dewatered channel (<2 meters) was first observed on August 13, 2010 when discharge was 236 cfs. Warm weather throughout the sampling week increased runoff from the glaciers upstream, causing discharge to increase and reconnecting surface flow in Lower Cascade Creek. On September 21, 2010 the length of dry stream channel at this location was approximately 100 meters. Discharge was 72 cfs at Swan Lake outlet.

Barrier B-9, approximately 100 feet in height, was located in Upper Cascade Creek approximately 1.5 miles upstream from the inlet to Swan Lake. Based on communication with ADFG fisheries biologist (Doug Flemming, personal communication) coupled with review of stocking records, Upper Cascade Creek upstream of barrier B-9 was considered fishless.

5.4.4. RAINBOW TROUT SPAWNING SURVEY RESULTS

The RBT spawning survey was limited a single reconnaissance event in Upper Cascade Creek, the inlet delta to Swan Lake and Cabin Creek coinciding with the deployment of temperature probes in Cascade Creek on May 23, 2010. No RBT spawners were observed in Upper Cascade Creek, Swan Lake inlet delta or Cabin Creek. The water clarity was exceptionally clear allowing fisheries biologists to easily observe redds had they been present. Fisheries staff also performed spawning survey reconnaissance on tributaries to the Pond on May 23, 2004 but did not observe any spawning RBT or redds.

Table 5-7: Observed and potential upstream fish passage barriers in Cascade Creek

Barrier No.	Reach No.	Description	Height (ft)	Appendix 5.1 Photo No.
B-1	Reach 1a	Cascade Ck Falls	~45	Photo 5.1-1
B-2	Reach 1b	Unnamed Falls	~35	Photo 5.1-2- aerial
B-3	Reach 1b	Falls Lake Outlet	~100	Photo 5.1-2
B-4	Reach 2a	Falls Lake Inlet	~45	Photo 5.1-3
B-5	Reach 2a	Cascade/Falls	~30	Photo 5.1-4
PB-6	Reach 2b	Cascade/Falls	~22	Photo 5.1-5
PB-7	Reach 2b	Boulder Cascade	~5-10	Photo 5.1-6
PB-8	Reach 2b	subsurface channel	na	Photo 5.1-7
B-9	Reach 3	Barrier Falls 1.5 miles above Swan Lake	~100	Photo 5.1-8

Spawning surveys were not conducted in the adjacent Spring Creek on May 23. However, during habitat mapping surveys in the Spring Creek in August 2010 up to 49 potential redds were observed in the first 200 meters of Spring Creek directly upstream from Swan Lake. Newly emerged YOY fish were observed in the gravel depressions of these redds at the time.

Two unnamed tributary streams flowing directly into Swan Lake were surveyed on August 15th 2010 for spawning habitat and potential redds. The gradients of the remaining tributary streams to Swan Lake were too steep to provide suitable spawning habitat.

The first Swan Lake tributary investigated drains a glacier in the Cosmos Range flowing into Swan Lake near the outlet in the vicinity of the proposed intake structure. The substrate in the initial 150 meters of this tributary consisted largely of gravels and sand suitable for spawning. However, the heavily braided channel suggested a dynamic system that shifted annually. Furthermore, the maximum stream temperatures were 5 C at 1300 hours on a clear day with near record air temperatures of XX C. Above this point, the gradient steepened dramatically with numerous impassable falls across bedrock. No redds were observed in the initial 150 meters. The delta at this creek mouth was small dropping off to deep water habitats quickly. No redds were observed in this area either.

The second Swan Lake tributary stream drains from the basin below Fighting John peak entering Swan Lake in the southwest quarter of section 4. A potential barrier to upstream fish passage exists within 50 meters of Swan Lake. This barrier is likely passable during years when Swan Lake reaches near record full pool events. The stream was mostly bedrock cascades and plunge pools. The substrate was dominated by boulders and bedrock with extremely limited spawning areas containing suitable spawning gravels for RBT. Several upstream passage barriers were observed the most notable of which was a 50 foot overhanging falls approximately 800 meters from the confluence with Swan Lake. No redds or fish were observed beyond the pool at the base of the first barrier 50 meters upstream from Swan Lake.

5.5. DISCUSSION

Rainbow trout were introduced to Swan Lake in the late 1950s to provide a sport fishery. Previous introductions of Eastern brook trout in the 1930's were unsuccessful. The RBT population is self-sustaining. ADF&G regulations allow a daily bag and possession limit of 2 RBT between 11 and 22 inches (279-559 mm) in length. The Southeast Alaska Recreational Cabin Survey is conducted every few years to gauge fishing pressure on lakes throughout Southeast serviced by USFS cabins. In 2006 (the last year Swan Lake was surveyed), Swan Lake was subject to 69 days of fishing during which 45 fish (between 11 and 22 inches in length) were caught and retained by anglers and 285 fish were caught and released. Sport fishing is expected to exert low mortality on RBT populations in the sampled areas due to their remote locality (fly-in or hike-in only). Osprey, bald eagle, loon and black bear are other sources of natural trout mortality. Large RBT predating small-sized and juvenile RBT is suspected but the extent of piscivory by large trout is not known.

The RBT in the Cascade Creek-Swan Lake Drainage exist in several fragmented, isolated populations of unknown proportion. Initial trapping efforts in August 2010 only marked a small number of trout in 2 out of the 4 water bodies (4 RBT in the Pond and 5 in Upper Falls Lake). None of these fish were recaptured in the September 2010 trapping effort. Due to the small capture in August and failure to re-capture any fish in September a population estimate was not possible for any of the water bodies.

Assumptions included in basic mark and recapture studies are 1) the population is geographically closed with no fish entering or leaving the system, 2) the population is demographically closed (no births or deaths), 3) no marks are lost or missed, 4) marking does not change fish behavior or vulnerability to capture, 5) marked fish mix at random with unmarked fish and, 6) all fish have an equal probability of capture that does not change over time (Hayes, et al. 2007). Various formulae for mark-recapture abundance estimates yield similar results provided that a sufficient number of marked fish are recaptured (e.g., at least 2-4 preferably greater than 10) (Chapman 1951; Robison and Regier 1964). Due to the fact that no RBT that had been marked in August were recaptured in September an estimate of absolute abundance cannot be made at this time. If marked RBT are recaptured in future sampling events, an abundance estimate of the population can then be calculated using Chapman's modifications of the Peterson estimator (Seber 1982) which among many similar formulae has a strong theoretical basis and is widely used in fisheries studies (Hayes et al. 2007):

$$N = \frac{(n_1 + 1)(n_2 + 1)}{\left(m_2 + 1\right)} - 1$$

Where n1 = number caught and marked in the first sampling period; n2 = number caught in second sampling period; and m2 = number of marked fish in second sampling period.

Direct comparisons of abundance estimates from one lake to another can be misleading due to large differences in lake size or other factors (Bangs 2007). Comparisons of fish density (i.e. RBT catch divided by water body surface area) may provide a more meaningful measure for comparison (Bangs 2007). Catch per unit effort with passive gear (such as minnow traps and hoop nets) can be used as an index of population density (Murphy and Willis 1996). Identical items of gear fished in a similar manner and time of year can provide reasonable indices of change in stock abundance (Murphy and Willis 1996). The theoretical underpinnings of this method are based upon the assumption that CPUE is proportional to stock density. True density is unknown as is the value of the proportionality constant. If the proportionality can be assumed to be constant, changes in CPUE will indicate corresponding changes (positive or negative) in the species' abundance (Murphy and Willis 1996). To use CPUE in this manner, care must be taken to reduce the variability by standardizing gear, methods and sampling design.

Despite the inability to quantify the RBT population from the mark and recapture results, the low numbers of fish trapped given the level of effort suggests a small population of RBT in Falls Lake and even smaller residing in the Pond. In September, the RBT population in Falls Lake appeared to increase compared to August whereas the catch numbers were so limited in the Pond that it was not possible to detect differences. Seasonality and the associated changes in discharge may explain, in part, the population changes. Multiple barriers to upstream fish passage also likely play a role. Re-captures are anticipated during future sampling events since more RBT were captured and VIE marked in the September trapping effort. At that time, the ratio of the marked to unmarked fish can be used to estimate the total population.

The trapping results associated with the mark and recapture effort can be applied to the Seasonal Fisheries Inventory providing valuable information on fish distribution and habitat use. For example, during the September M-R field operations, several small trout were captured, marked and released in pools in Reach 2A. These were estimated to be 1-year old RBT. In Reach 2B, in some pools previously inaccessible due to high water during the spring and summer RBT were observed up to 250 mm (10 inches) total length (TL) although none of these fish were successfully captured or marked there. The habitat in both these reaches was marginal to fair and fragmented. Connectivity between more favorable habitats was limited to downstream passage only due to multiple upstream barriers in Reaches 2A and 2B in the form of waterfalls, high gradient riffles, cascades and subsurface flow disconnecting stream habitat units.

Fish habitat in the Pond appeared to be poor in approximately one half of its area due to shallow water depth, mud/organic and fine particulate substrate coupled with a lack of cover. The other half of the Pond was marginal to fair fish habitat with water depths to 3.6 m (12 ft). Active upwelling was observed on the northern edge of the Pond where a small tributary enters. This portion of the Pond has potential as rearing habitat for YOY RBT but none were observed in this location despite concerted search efforts.

Catch in Upper Falls Lake was highest at the inlet directly below the falls. Turbulence associated with an influx of drifting macroinvertebrates and other food particles likely make this an excellent feeding area for RBT. Lower Falls Lake (connected to Upper Falls Lake by a rocky narrows) was also good RBT habitat and contained abundant cover for small-sized RBT. One individual captured and marked had a torn lower maxilla which is was presumed to be a hook scar.

No YOY RBT were observed or captured in Lower Cascade Creek, the Pond, Falls Lake or tributaries below Swan Lake. This suggests that no spawning occurs below Swan Lake. Field staff searched tributaries to the Pond with potential habitat for spawning and rearing but failed to observe YOY or larger RBT. YOY were observed in Spring Creek above Swan Lake but none were observed in Lower Cascade Creek or tributaries. The lack of YOY observations below Swan Lake suggests RBT either emigrate or are involuntarily swept downstream from Swan Lake via the Lower Cascade Creek outlet. The ability to regain Swan Lake at this body size or as adults by moving upstream in Lower Cascade Creek is unlikely due to high gradient riffles, rapids and cascades, which collectively represent a barrier to upstream movement (Appendix 5-1). This pattern of voluntary and involuntary downstream movement coupled with upstream fish passage barriers was also evident at the Pond, Falls Lake and the remainder of Lower Cascade Creek. In some reaches, multiple barriers existed. Consequently the RBT population in Lower Cascade Creek, including the Pond and Falls Lake, is fragmented with limited access, if any, to spawning habitat. RBT in Lower Cascade Creek likely have low densities and do not contribute to sustaining the population in Swan Lake due to upstream passage barriers.

The size structure of the RBT populations in the four water bodies studied appeared to be different although this cannot be confirmed without larger sample sizes. Some of these differences may be variations associated with seasonality or trap selectivity. Size structures obtained from samples are often different from the true size structure of the fish population due to sampling gear, time of year and trap location (Neumann and Allen 2007). All captured fish appeared to be in good condition with several in notably robust condition.

Sex ratio of captured RBT could not be reliably determined based on our observations. Sexual identification of RBT may be possible during spring spawning when captured RBT may express eggs or milt when handled. In the case of cutthroat trout, a close relative of RBT (same genus Oncorhynchus), the ovipositor of female trout may protrude slightly from the vent during the spawning period. Others have used maxillary bone length as a non-lethal method of determining sex of trout (the maxillary bone in males is often longer) however the accuracy of this method is questionable. Bangs (2008) suggested that researchers refrain from relying on external, morphological characteristics for determining the sex and reproductive status of trout. Although two external forms of vent anatomy were observed and noted on captured RBT a review of the literature failed to indicate a simple, reliable, and non-lethal method of sexing RBT in the field.

The habitat requirements of trout in streams and lakes vary seasonally and according to life stage (Bjornn and Reiser 1991). The growth and development of trout, from eggs incubating in gravel to the reproductive spawning years to senescence, is driven and dependent upon the thermal aspects of their aqueous environment. Optimal growth temperature for juvenile RBT is 13.1 to-13.6 °C (McMahon, et al. 2006). Overall thermal preference for adult RBT is 14.8-14.9 °C when tested in a thermal gradient of 11-17 °C.

Although RBT are generally regarded as a "coldwater" fish species, streams can be too cold as well as too warm for upstream migration. Cutthroat trout and RBT have been observed waiting for tributaries to warm up before entering them to spawn (Bjornn and Reiser 1991). December and January spawning has produced viable eggs at water temperatures of 0.3 to 2.0 °C g (Raleigh et al. 1984). However, eggs exposed to long periods of 0 to 4 °C suffered high mortalities and abnormalities.

Trout (and salmon) stocks have evolved to respond to temperature cues for upstream migration for the purposes of spawning. Innate adaptability permits survival in conditions and temperatures beyond a "preferred" range which may vary with latitude, stock and physiographic region. However, stream discharge, stream temperature, and water quality must be suitable for at least a portion of the migration season (Bjornn and Reiser 1991). If thermal regimes that trout and other fish species have adapted to is abruptly changed or altered through human-caused actions the ability to survive through reproduction is reduced.

Unsuitable temperatures can precede the outbreak of disease in migrating or spawning fish, altered timing of migration, and accelerated or stunted maturation (Bjornn and Reiser 1991). Transplanted fish, such as the RBT stocks in the present study, may face even greater survival challenges than native stocks if they lack flexibility in migration timing in their new environment (Bjornn and Reiser 1991).

Just as potential physical barriers may prevent RBT upstream movement between water bodies in the Swan Lake-Cascade Creek system, thermal barriers may prevent the use of some tributary streams for spawning. Preliminary analyses of water temperature data (Table 5-8) suggest that Upper Cascade Creek and Cabin Creek may be too cold for successful RBT spawning. This is corroborated by recent observations of RBT spawning redds and YOY RBT in Spring Creek whose daily minima is approximately 2 °C warmer than both Cabin Creek and Upper Cascade Creek.

Table 5-8: Min/max temperatures at 7 sites on Cascade Ck. (June-Sept 2010).

Site	Min Temp (°C)	Max Temp (°C)
Upper Cascade Creek	1.9	13.1
Spring Creek	4.2	12.4
Cabin Creek	1.8	11.7
Swan Lake Inlet	3.4	16.7
Swan Lake Outlet	3.5	14.8
Falls Lake	4.1	14.2
Lower Cascade at Tidewater	5.1	14.6

The RBT population in Cascade Creek appears to be fragmented due to multiple barriers to upstream fish passage in each study of the three study reaches. Although spawning surveys were not exhaustive in 2010, spawning does appear to be limited to the Spring Creek at the inlet to Swan Lake. This conclusion is based on the fact that limited spawning habitat was observed in Lower Cascade Creek and associated tributaries as well as the lack of YOY fish observe d anywhere but the Spring Creek. If, in fact, spawning does not occur or is severely limited in Lower Cascade Creek, then the RBT population in Lower Cascade Creek is sustained entirely by outmigrants from Swan Lake. Spawning surveys in 2011 will help confirm the timing and distribution of spawning in the Cascade Creek drainage and implications on the sustainability of the population within respective reaches.

The presence of DV above the initial fish passage barrier in Lower Cascade Creek may be explained through examination of the geologic record. During prehistoric time periods ocean levels or the presence of ice may have rendered a portion of Lower Cascade Creek accessible to anadromous DV. As these conditions changed over time, access to upstream areas was again restricted leaving small, isolated populations of stream resident DV. Human transport of DV above the barrier falls in an attempt to create additional sport fishing opportunities is another possible mechanism explaining current DV distribution.

The fact that DV were captured above the Lower Cascade Creek barrier Falls separating Reach 1A from Reach 1B suggests a small self-sustaining population of DV is present in this stream reach. This phenomenon of long-term persistence of isolated populations of DV and cutthroat trout has been well-documented in many other southeast coastal streams (Hastings 2005; Leder 2001; Blackett 1973). In some cases, these populations are capable of existing in isolation for thousands of years if stream habitats remain intact (Hastings 2005).

Dolly varden populations in Alaska exist in two distinct forms: anadromous and resident (Ihlenfeldt 2005). The resident form is commonly found upstream of natural barriers (e.g. falls, dams) that prevent the upstream migration of the anadromous form (Ihlenfeldt

2005). Some of the characteristics of the resident form are small body size, reduced fecundity and early maturation.

The fact that DV were captured below the Lower Cascade Creek barrier falls in Reach 1A suggests out-migrants from the upstream population, a separate stream resident population or possible use of Lower Cascade Creek Reach 1A by anadromous DV.

Coast range sculpin is a marine-derived species which spends most of its life in fresh water but spawns in salt water or brackish water estuaries (a life history strategy known as catadromy). This fish is widely distributed from southern California to Bristol Bay, Alaska where it commonly occurs in small coastal streams. A single specimen was captured in October, 2010 downstream of the first barrier falls in Lower Cascade Creek Reach 1A.

6. BENTHIC MACROINVERTEBRATE COMMUNITY

Benthic macroinvertebrates (BMI) are an essential component in the ecological processes of an aquatic ecosystem, due to their position as consumers and intermediate trophic level of lotic food webs (Hynes 1970; Wallace and Webster 1996). BMI are included in many state and federal agency biological monitoring programs because of their significant functional roles coupled with their vulnerability to flow regulations and water quality perturbations (Barbour et. al. 1999). BMI are advantageous for biological monitoring because they are ubiquitous, have a high species diversity offering a spectrum of responses to environmental stress, and their life cycles offer analysis of effects from stochastic and intermittent disturbances (Rosenberg and Resh 1993).

6.1. BENTHIC MACROINVERTEBRATE STUDY OBJECTIVES

The study is designed to document BMI composition in lower Cascade Creek. The specific objectives of the Benthic Macroinvertebrate Study include:

1. BMI community composition
2. BMI density longitudinally in Lower Cascade Creek

6.2. BENTHIC MACROINVERTEBRATE METHODS AND STUDY AREA

This section describes the methods used to investigate BMI in lower Cascade Creek. BMI will be sampled at four locations on Cascade Creek (Figure 6-1).

BMI Sample Sites from downstream to upstream:

- BMI 1. Lower Cascade at RM 1.25;
- BMI 2. Pelagic zone of Falls lake;
- BMI 3. Cascade Creek directly upstream of the Pond; and
- BMI 4. Outlet to Swan Lake;

These sample locations are representative of the BMI community in Cascade Creek across the elevation gradient and water features. Sample sites were selected, in part, based on availability of safe sampling locations in Cascade Creek.

Riffle habitats are the preferred stream habitat for comparative studies of benthic macroinvertebrates. Riffle habitats typically have the highest densities and diversity of benthic macroinvertebrates. Most benthic macroinvertebrate sampling devices are designed for riffle habitats relying on the transport of organisms by the current velocity into a net after disturbance by field staff. Accordingly, three of the sites were located in riffle habitats. BMI sampling in Falls Lake was requested by ADFG to assess food resources for the RBT population.

Three replicate BMI samples were collected in riffle habitats with boulder and cobble substrate at respective sample sites using a surber sampler with 500 µm mesh in August 2010. The surber sampler covers a 20 cm square area of the stream. The substrate was disturbed to a depth of 10 cm. Individual substrate was scrubbed clean of attached material and organisms. Samples were preserved in 90 percent isopropyl alcohol.

Sampling in the Falls Lake pelagic zone was done using a zooplankton net measuring 0.3 m diameter by 1.2 m long with a 64 µm mesh. Three vertical tows were done in the estimated deepest point in Falls Lake. The length of each vertical tow was measured in order to calculate the volume of lake water filtered. The sample was rinsed with deionized water from the removable bucket end of the net, immersed in carbonated water then preserved in 90% isopropyl alcohol.

Identification and enumeration of BMI samples was performed by Northern Ecological Services in Bellingham, Washington. Species densities were expressed as the number of organisms per square meter in the case of the surber sampler and the number per liter for samples collected in Falls Lake. The data required electronic truncation of some taxonomic groups (e.g., chironomid midges and oligochaetes) before metrics were calculated. The final product of the laboratory analyses was a table of the raw taxonomic data and a list of all macroinvertebrate taxa and the abundance per sample for all samples. Metrics were calculated to assess taxonomic abundance in terms of function in the ecology of the system.

6.3. BENTHIC MACROINVERTEBRATE RESULTS

The BMI sampling took place on August 13, 2010. Three replicate samples were taken at each of the four BMI sample sites. Data analysis was limited to descriptive statistics (average of replicate samples per site) for BMI density and taxa richness as well as relative community composition and functional feeding group composition. Between site comparisons were not appropriate due to the elevation gradient between sites, single sampling event in time and differences in site characteristics.

The three replicate samples in Falls Lake did not contain any BMI organisms. Three vertical tows were performed in the center of Upper Falls Lake. The depth in Falls Lake at this location was 8.9 meters. Vertical tows were from a depth of 5.5 meters to the lake surface. Total volume of water sampled was 401.3 liters for each replicate. Each replicate sample contained abundant numbers of *cladocera*, *copepoda* and *rotifera*. The samples were archived for identification and enumeration at a later date if requested but are not included in this report.

The 2010 BMI sampling effort yielded thirty-five taxa collected from three sites in Lower Cascade Creek (Appendix 6-1). The 2010 BMI taxa were distributed among eight orders: *Ephemeroptera* (5); *Plecoptera* (7); *Trichoptera* (4); *Diptera* (14); *Bivalvia* (1); *Crustacea* (2); *Arachnidea* (1) and *Annelida* (1). *Diptera* comprised nearly half of the total taxa list. Within the *Diptera* order the family *Chironomidae* dominated the taxa list with a total of twelve taxa. The list of taxa was relatively consistent spatially throughout the elevation gradient on Lower Cascade Creek.

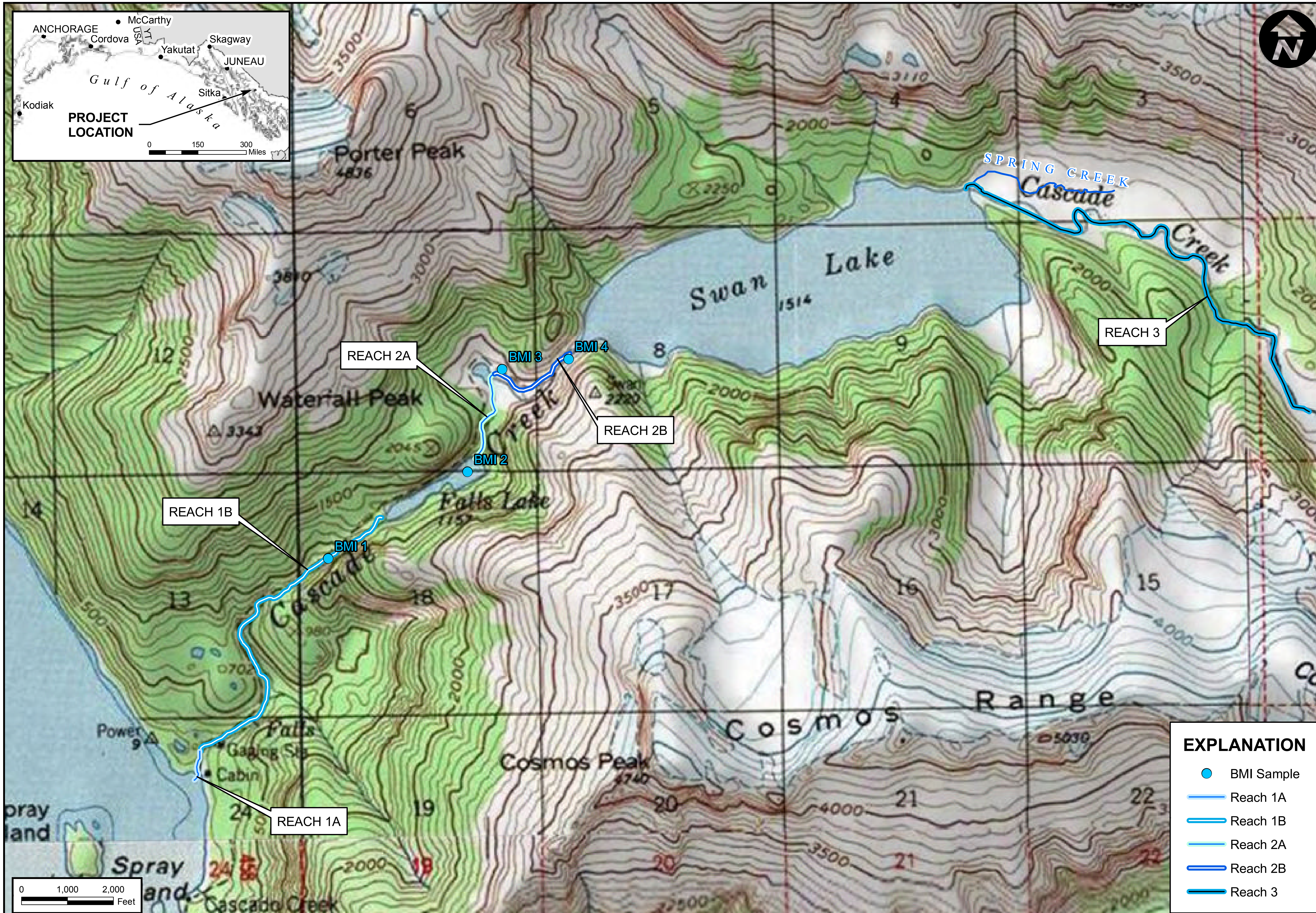

FIGURE 6-1

CASCADE CREEK BMI SAMPLE LOCATIONS

CASCADE CREEK DRAINAGE
18 Miles NW of Petersburg, Alaska

DATE: NOV. 2010
CHKD: J.G.
DRWN: A.C.M.
PROJ. No.: 637-003

oasis
825 W. 8th Ave., Anchorage, AK 99501, (907) 258-4880

J:\Projects\637_001_Cascade_Creek\mxd\Field_Site_Layout_BMI.mxd

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The average BMI density at Swan Lake outlet was double the density observed above the Pond and at Lower Cascade Creek RM 1.25; 6,677 orgs/m^2 compared to 3,059 and 2,867 orgs/m^2 respectively (Figure 6-2). The average *Ephemeroptera-Plecoptera-Trichoptera* (EPT) density was also substantially greater at Swan Lake outlet (4,288 orgs/m^2) compared to Lower Cascade RM1.25 (1,683 orgs/m^2) and the site above the Pond (628 orgs/m^2). Despite the density differences between sites EPT comprised 63.5% and 62.0% of the BMI community composition at Swan Lake outlet and Lower Cascade Creek RM 1.25 respectively (Table 6-1). In contrast, EPT comprised only 19.8% at the site above the Pond.

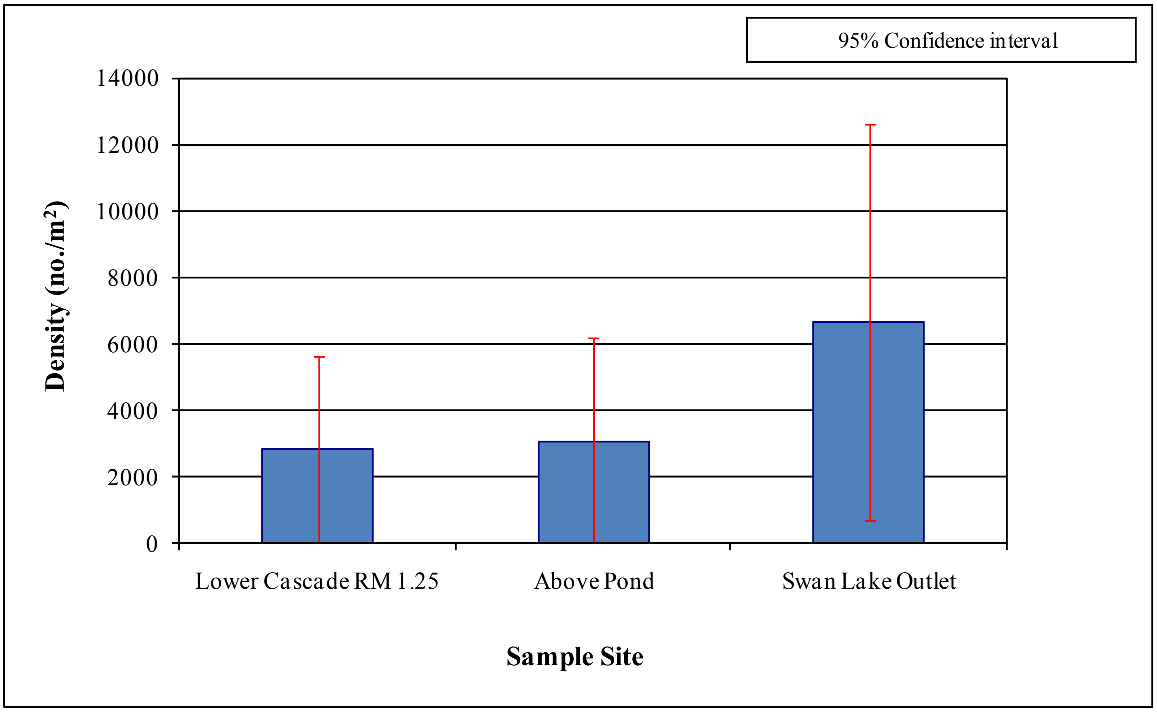

Figure 6-2: BMI density at three sites on Lower Cascade Creek

At Swan Lake outlet, *Plecoptera* comprised 63.2% of the community composition (Figure 6-3). The dominant *Plecoptera* taxa at this site was *Triznaka sp*., a member of the *chloroperlidae* family, comprising (53.8%) of the community composition. *Diptera* was the second largest group comprising 21.5% of the community composition. *Ephemeroptera* and *Trichoptera* comprised less than 1% of the community composition at Swan Lake outlet.

Table 6-1: BMI density at three sites on Lower Cascade Creek

Sample Site	Reach No.	BMI Density No. orgs/m^2	EPT Density No. orgs/m^2	Community Composition							
				EPT	Ephemer-optera	Plec-optera	Trich-optera	Total Diptera	Chirono-midae	Other	Domimant Taxa
Lower Cascade RM 1.25	1B	2867	1683	62.0%	24.5%	35.7%	1.8%	30.4%	27.7%	7.6%	36.6%
Above Pond	2B	3057	628	19.8%	8.5%	10.4%	0.8%	71.8%	68.6%	8.4%	34.7%
Swan Lake Outlet	2B	6677	4288	63.5%	0.1%	63.2%	0.2%	21.5%	18.8%	15.0%	53.8%

At site BMI3, located above the Pond, *Diptera* comprised the largest percentage of the community composition (71.8%) of which *chironomidae* comprised 68.6%. The dominant taxon was *Eukiefferiella sp*., a chironomid, comprising 34.7% of the BMI community. *Plecoptera* and *Ephemeroptera* were the second and third largest groups, 10.4% and 8.5% respectively.

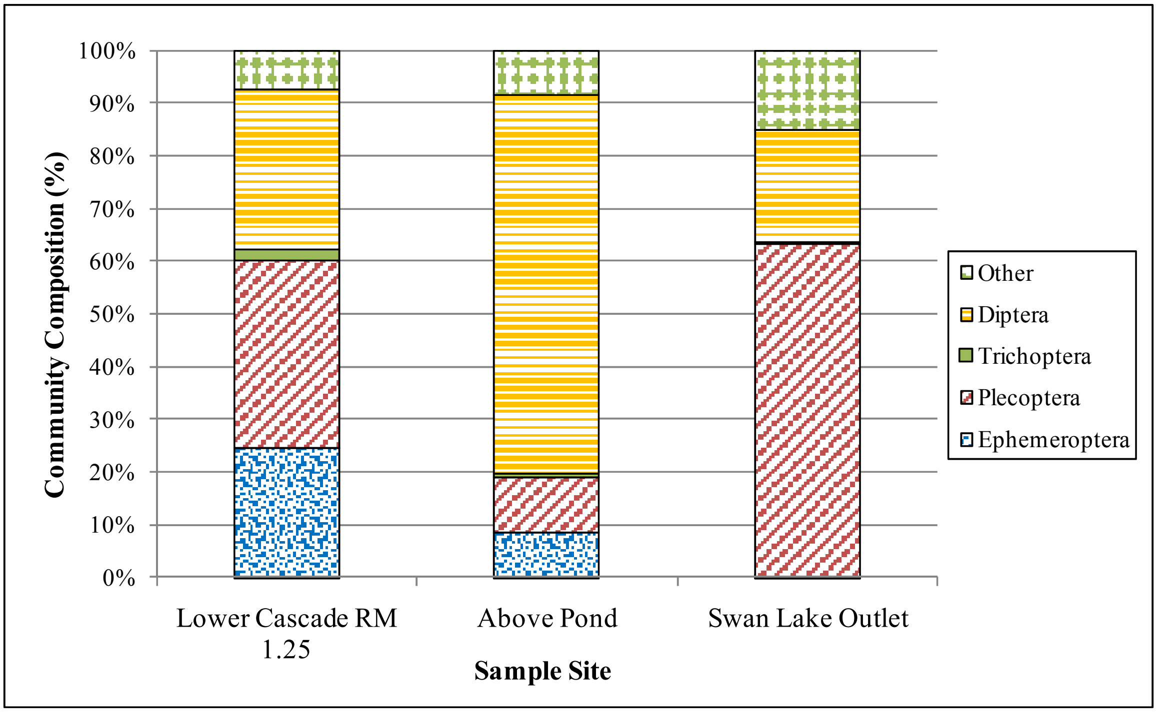

Figure 6-3: BMI community composition at three sites on Lower Cascade Creek

The BMI Community sampled at Lower Cascade Creek RM 1.25 was fairly evenly distributed between Plecoptera (35.7%), Diptera (30.4%) and Ephemeroptera (24.5%). The dominant taxon was the *Plecoptera* genus, *Zapada sp*., in two replicate samples and the chironomid, *Tvetenia sp*. in the third replicate.

Taxa richness was similar at the three sites ranging from 15 to 16 taxa (Figure 6-4). At the Lower Cascade RM 1.25 site, the average *Ephemeroptera* taxa was 3.7 (Table 6-2). *Chironomidae* also had an average of 3.7 taxa at this site. *Plecoptera* and *Trichoptera* taxa richness was 2 and 1.7 respectively. The site located above the Pond contained an average of 5.7 *Chironomidae* taxa, 2.7 *Plecoptera* taxa, 1.7 *Ephemeroptera* taxa and 1 *Trichoptera* taxa. At Swan Lake outlet, there was an average of 5 *Chironomidae* taxa, 4 *Plecoptera* taxa, 0.7 *Ephemeroptera* taxa and 0.7 *Trichoptera* taxa.

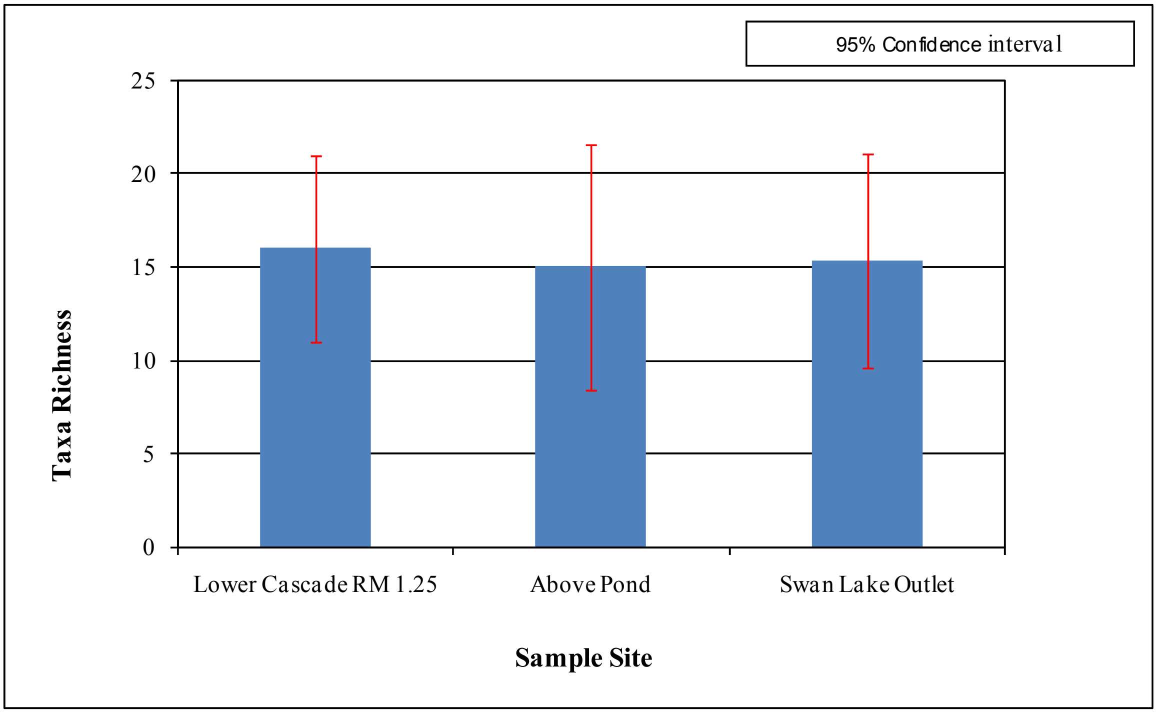

Figure 6-4: BMI taxa richness at three sites on Lower Cascade Creek

The BMI community at the three sample sites was classified into five functional feeding groups (Barbour et al. 1999; Merrit and Cummins. 1996). Gatherers were the dominant functional feeding group at the Lower Cascade Creek RM 1.25 site and the site above the Pond, 51.8% and 84.6% respectively (Figure 6-5). Shredders were the second largest functional feeding group at the Lower Cascade RM 1.25 site, 31.4% (Table 6-3). In contrast, shredders were only 7.7% of the functional feeding group composition at the site above the Pond. At Swan Lake outlet, predators comprised 58.8% of the functional feeding group composition. Gatherers comprised 33.9% at Swan Lake outlet. Surprisingly, filter feeders comprised only 0.2% of the community at Swan Lake outlet.

Table 6-2: BMI taxa richness at three sites on Lower Cascade Creek

Sample Site	Reach No.	Taxa Richness					
		All Taxa	EPT	Ephemeroptera	Plecoptera	Trichoptera	Chronomidae
Lower Cascade RM 1.25	1B	16.0	7.3	3.7	2.0	1.7	3.7
Above Pond	2B	15.0	5.3	1.7	2.7	1.0	5.7
Swan Lake Outlet	2B	15.3	5.3	0.7	4.0	0.7	5.0

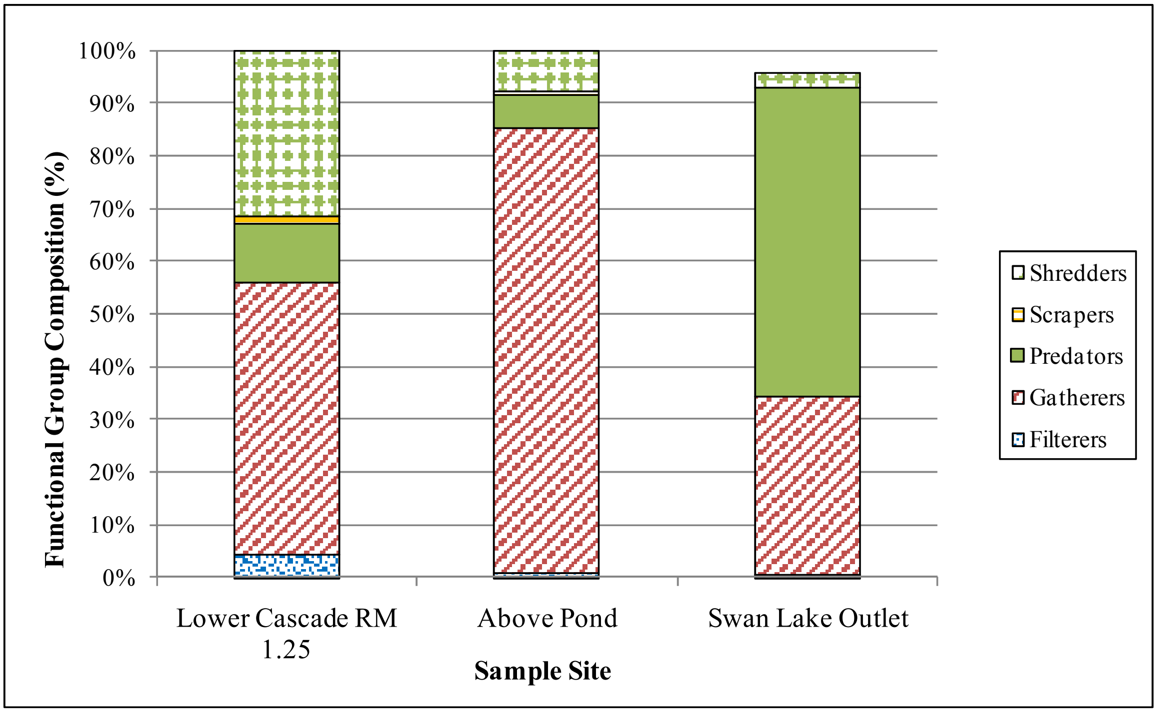

Figure 6-5: BMI functional feeding group composition on Lower Cascade Creek

Table 6-3: BMI functional feeding group composition on Lower Cascade Creek

Sample Site	Reach No.	Functional Group Composition				
		Filterers	Gatherers	Predators	Scrapers	Shredders
Lower Cascade RM 1.25	1B	4.2%	51.8%	10.9%	1.4%	31.4%
Above Pond	2B	0.7%	84.6%	6.0%	1.0%	7.7%
Swan Lake Outlet	2B	0.2%	33.9%	58.8%	0.0%	2.5%

6.4. BENTHIC MACROINVERTEBRATE DISCUSSION

Swan Lake outlet had the highest BMI density of the three sites sampled in Lower Cascade Creek. The BMI community likely capitalizes on the food resources available in the surface water outflows from Swan Lake. Other researchers have found higher BMI densities at lake outlets (Valett and Stanford 1985). Surface water lake outlets tend to contain higher quality food resources in the form of phytoplankton, zooplankton and seasonal nutrient fluxes relative to adjacent lotic environments. Phytoplankton and zooplankton, entrained in the waters at the lake outlet, are transported downstream. The concentration of this higher quality food decreases progressively with distance from the lake outlet. Accordingly, BMI densities decrease progressively downstream as food quality declines. The BMI density at the two downstream sites was less than half the density observed at Swan Lake outlet.

Typically, filter feeders are the most abundant functional feeding group at lake outlets. In this study, filter feeders were less than 1% of the composition at Swan Lake outlet. Predators and gatherers were the dominant groups. The lack of filter feeders is somewhat of a mystery. Most filter feeders have a one-year life history and may have emerged prior to the August sampling event. Additional sampling during the early summer and fall periods may collect filter feeders missed in August.

The number of taxa collected at the three sites on Lower Cascade Creek was low relative to taxa lists for studies elsewhere in Alaska and specifically in the Alexander Archipelago in southeast Alaska (Oswood 1989). The lack of BMI diversity may be due to the high gradient nature of Lower Cascade Creek resulting in coarse substrate (mostly boulders with little fine grained material) and return interval of scouring flows. The Diptera taxa more common to Alaska streams (Oswood 1989) tend to burrow into finer grained materials. The high gradient character of Lower Cascade Creek results in intense scour of the streambed on a regular basis. Scouring flows were observed in 2010 on a nearly monthly basis triggered by snowmelt in the spring, above normal air temperatures in August resulting in increased glacial melt, and during normal precipitation events in August, September and October. Additional sampling events in the spring and fall periods would likely result in collection of additional BMI taxa.

Falls Lake was not conducive to bottom sampling using an Ekman or Ponar grab type device due to the angular boulder substrate. Instead, three replicate tows were taken with a zooplankton net in the pelagic zone of Falls Lake. No BMI were collected in these samples despite filtering 400 liters of lake column in each tow. Field staff did collect numerous BMI (*Plecoptera* and *Trichoptera*) in the minnow traps and hoop nets deployed in Upper Falls Lake near the inlet falls. These traps also had the highest CPUE. Traps located elsewhere in Falls Lake contained few if any BMI. BMI likely drift from upstream into Falls Lake where RBT take advantage of the food inputs in an otherwise food limited system. Few RBT were caught in Lower Falls Lake likely due to the lack of available food resources. The highest trapping success in Lower Falls Lake was in the area closest to the tributary inflow suggesting that inflows provide the necessary food resources for the RBT population. Examination of RBT stomach contents in future sampling would identify and quantify importance of available food resources in Falls Lake and other portions of Lower Cascade Creek.

Field staff observed distinct differences in the BMI and algal communities between Upper Cascade Creek and Lower Cascade Creek. The substrate in shallower gradient sections of Lower Cascade Creek was covered with thick mats of filamentous green algae (*Cladophora glommerata*). The mats were particularly evident in the lower gradient sections just upstream of the Pond but lacking in the higher gradient sections exposed to more intense scour. The mats of algae indicate higher nutrient concentrations relative to adjacent tributary streams lacking similar algal growth. Numerous *Plecoptera* and *Trichoptera* were observed in. minnow traps in Lower Cascade Creek.

Upper Cascade Creek, in contrast, was void of filamentous algae and periphyton on the stream substrate. Field staff found very few BMI (Ephemeroptera) and only after turning over numerous rocks. BMI density in Upper Cascade Creek appeared to be a fraction of that observed in Lower Cascade Creek. Upper Cascade Creek appears to contain an extremely low BMI density providing little in the form of food resources to the RBT community.

The adjacent Spring Creek appears to have a higher BMI density relative to Upper Cascade Creek based on field observations. Nutrients associated with hyporheic upwellings coupled with biological productivity in the wetlands and stable substrate likely contribute to the increase in BMI density. YOY and juvenile RBT likely rely on the BMI and zooplankton food resources in the Spring Creek. ADFG determined that BMI sampling was not necessary in Upper Cascade Creek or the adjacent Spring Creek based on the natural lake level operation regime.

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APPENDIX 2-1

UPPER CASCADE CREEK STREAM HABITAT DATA

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Stream Name: Cascade Creek (NE of Petersburg, AK) — **Date:** 8/15-20/2010

Crew: Steve Ralph, Derek Booth & Eric Edlund — **Units:** meters _X_ feet ___

5 channel bed width measurements; see geomorph data

Minimum residual pool depth (rpd) [(avCBW x 0.01) + 0.15m] = see individual NSO measurements

Survey proceeds from upstream below the falls in d/s direction; all units in meters; refer to report for codes

					HABITAT UNIT LENGTH/WIDTH				POOL CHARACTERISTICS			LARGE WOOD		
Geo Reach	NSO	LOC MC/ SC/ OC	Habitat Feature Code	Primary or Secondary Unit	unit length (m)	*running MC length (m)*	Hab Unit Avg Width (m)	Habitat Unit Area (sq. meters)	Max. Pool depth	Pool Tail Crest depth	Res Pool Depth (m)	LWD total count	LWD KEY pieces	Remarks
1	**1**	MC	RF	1°	**84.4**	*84.4*	**28.0**	2368				1	1	Survey begins d/s of falls; high grad riffle w/cobble and boulders; LWD on RB buried; size=9ftx2ft diam.
1	**2**	OC	RF	2°	**128.6**	*84.4*	**3.0**	392						LB inlet; captures ~25% of flow
1	**3**	MC	GL	1°	**76.2**	*160.6*	**16.2**	1231						Extension of HGRiffle; overhanging veg
1	**4**	MC	RF	1°	**72.5**	*233.2*	**24.1**	1747						
2	**4a**	OC	GL	2°	**198.1**	*233.2*	**2.4**	483						Off channel habitat with no physical flow u/s connection
2	**5**	SC	RF	2°	**38.4**	*233.2*	**2.4**	94						channel splits at gravel bar into side-channel; wdith was estimated after the fact from notes
2	**6**	MC	FP	2°	**22.6**	*233.2*	**5.5**	124	>1.2	0.5	0.8			parallel to NSO7; pool occur in main channel but occupies <50% of area
2	**7**	MC	RF	1°	**106.4**	*339.5*	**21.6**	2302						meander bend Hi Grad Riffle
2	**8**	MC	GL	1°	**147.8**	*487.4*	**17.1**	2523						long glide w/ deep >4ft pool of variable depth
2	**9**	MC	RF	1°	**100.0**	*587.3*	**11.6**	1158						long meander bend riffle
2	**10**	SC	RF	2°	**77.1**	*587.3*	**8.7**	670						variable width riffle
2	**11**	SC	FP	2°	**14.0**	*587.3*	**11.9**	167	1.3	0.1	1.2			pool at end of NSO 10
2	**12**	MC	FP	1°	**60.7**	*648.0*	**11.3**	684	>1.5	0.5	1.0			deep, lateral scour pool;relic inlet to faint sc pm RB; very narrow <2ft wide
2	**13**	MC	RF	1°	**34.7**	*682.8*	**22.9**	794						
2	**14**	MC	GL	1°	**47.5**	*730.3*	**16.2**	768						end of glide, have channel split=1MC &1 SC; on RB is a small inlet <2 ft wide
2	**15**	SC	RF	2°	**20.7**	*730.3*	**4.6**	95						lateral scour pool nested; 32 ft long
2	**16**	SC	FP	2°	**39.6**	*730.3*	**11.6**	459	>1.4	0.6	0.8			pool at end of NSO 15; pool forced by bedrock; see sketch
2	**17**	MC	RF	1°	**64.3**	*794.6*	**12.8**	823						
3	**18**	MC	GL	1°	**169.8**	*964.4*	**13.1**	2225						
3	**19**	OC	GL	2°	**125.0**	*964.4*	**1.8**	229						long, shallow off-channel with no surface flow; 4inches deep
3	**20**	MC	RF	1°	**202.1**	*1166.5*	**16.2**	3265				2		LWD zone 1; on LB is backwater with no surface velocity; <3 in deep
3	**21**	MC	FP	1°	**23.2**	*1189.6*	**14.3**	332	1.0		0.5			
4	**22**	OC	GL	2°	**96.6**	*1189.6*	**3.4**	324						d/s ends in shallow outlet to MC at pool; no inlet connection to MC (see picture of SR at inlet)
4	**23**	MC	RF	1°	**45.7**	*1235.4*	**10.1**	460				1		LWD= 6in x 10ft; zone 1
4	**24**	MC	FP	1°	**101.5**	*1336.9*	**16.8**	1702	>1.6	1.2	0.4			lateral scour pool along entire meanderbend; no LWD; Hydraulic control indistinct
4	**25**	MC	RF	1°	**55.2**	*1392.0*	**16.2**	891						
4	**26**	MC	FP	1°	**38.4**	*1430.4*	**28.0**	1077	>1.5	0.5	1.0			big meander pool
5	**27**	MC	FP	1°	**123.1**	*1553.6*	**9.8**	1201	>1.5	0.9	0.6			
5	**28**	OC	FP	2°	**49.1**	*1553.6*	**14.3**	703	>0.6	0.1	0.5	3		Off-channel backwater with tributary junction; zone1
5	**29**	MC	GL	1°	**121.9**	*1675.5*	**23.8**	2899						length from gps
5	**30**	MC	RF	1°	**176.8**	*1852.3*	**21.9**	3880						pool on RB
5	**31**	SC	RF	2°	**16.5**	*1852.3*	**4.0**	65						NSO 31,32,33 are contiguous
5	**32**	SC	FP	2°	**21.6**	*1852.3*	**3.7**	79	0.9	0.1	0.8	1		lwd 4in x 12 ft zone 1
5	**33**	SC	RF	2°	**38.1**	*1852.3*	**4.6**	174						
5	**34**	MC	PL	2°	**21.0**	*1852.3*	**9.1**	192	0.8	0.4	0.5			Associated with NSO 30; on RB, formed by bank slough
5	**35**	MC	GL	1°	**121.6**	*1973.9*	**15.8**	1928				1		lwd 6in x 14ft; zone 1; gage site
5	**36**	SC	RF	2°	**50.9**	*1973.9*	**12.2**	621						channel splits; this is RB branch
5	**37**	MC	RF	1°	**95.1**	*2069.0*	**9.8**	928						Channel splits; this is LB branch
5	**38**	SC	PL	2°	**61.3**	*2069.0*	**9.4**	579	>1.7	0.2	1.5			very long deep lateral scour pool
5	**39**	SC	RF	2°	**34.1**	*2069.0*	**10.1**	343						
5	**40**	MC	RF	1°	**37.8**	*2106.8*	**9.8**	369						LB; continuation of SC NSO 37 & crossover bar; RB side channel starts as RF, becomes GL (NSO42)
5	**41**	MC	FP	1°	**32.9**	*2139.7*	**7.0**	231	1.5	0.3	1.1			last main channel habitat unit before confluence with Lake
5	**42**	SC	GL	2°	**29.3**	*2139.7*	**8.2**	241				1	0	1 piece LWD; zone 1; RB; pool is d/s of NSO 37 & NSO 40
5	**43**	SC	RF	2°	**25.9**	*2139.7*	**25.0**	648						located as a cross-over riffle into NSO 37
5	**44**	SC	RF	2°	**12.2**	*2139.7*	**6.1**	74						These last three units are in sequence; on Left Bank, and terminate in the lake
5	**45**	SC	PL	2°	**22.9**	*2139.7*	**6.1**	139	0.8	0.1	0.7			
5	**46**	SC	RF	2°	**10.7**	*2139.7*	**5.8**	62						

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APPENDIX 2-2

UPPER CASCADE CREEK GEO-REACH PHOTOS

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GeoReach 1, upstream view

GeoReach 1, downstream view

GeoReach 2, upstream view

GeoReach 2, downstream view

GeoReach 3, upstream view

GeoReach 3, downstream view

GeoReach 4, upstream view

GeoReach 4, downstream view

GeoReach 5, upstream view

GeoReach 5, downstream view

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APPENDIX 2-3

UPPER CASCADE CREEK AND SPRING CREEK STREAM HABITAT UNIT (NSO'S) PHOTOS

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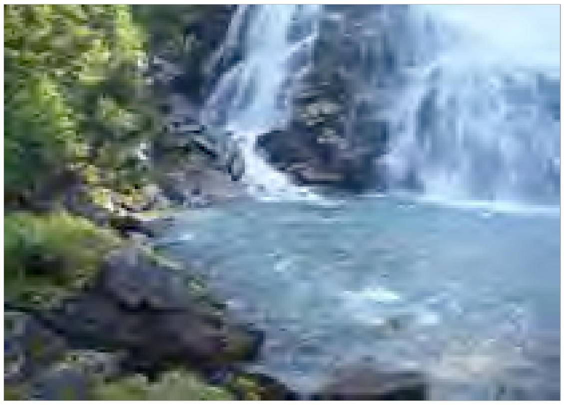
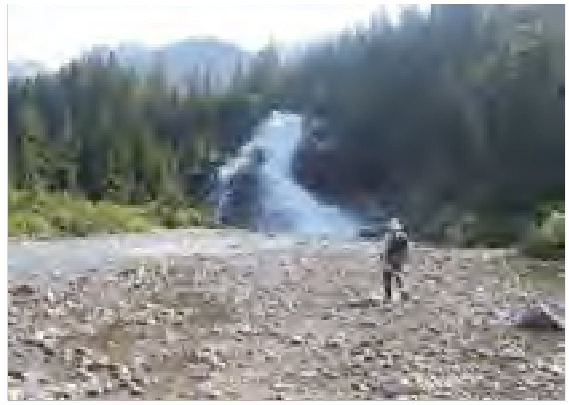
1 (IMGP3004a) Oblique aerial view of Upper Cascade Creek Falls and Geo Reaches 1-2

2 (IMGP3006a) Oblique aerial view of Upper Cascade Creek Geo Reaches 2-5

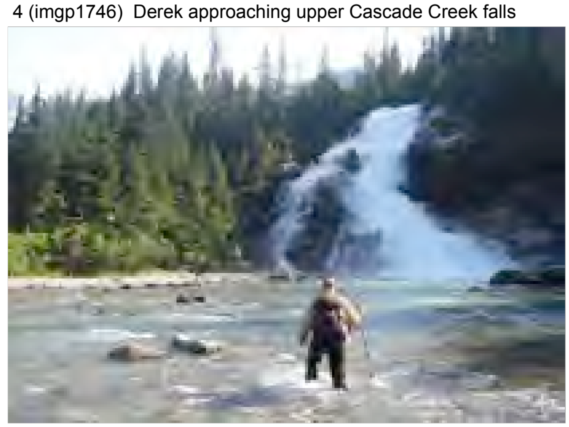
Note: Digital versions of original photographs are available on request.

Upper Cascade Creek


3 (imgp1754) large pool with gyro below falls


4 (imgp1746) Derek approaching upper Cascade Creek falls

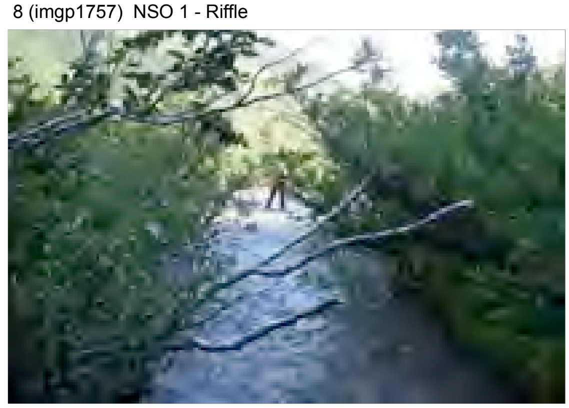

5 (imgp1755) Top of NSO 1

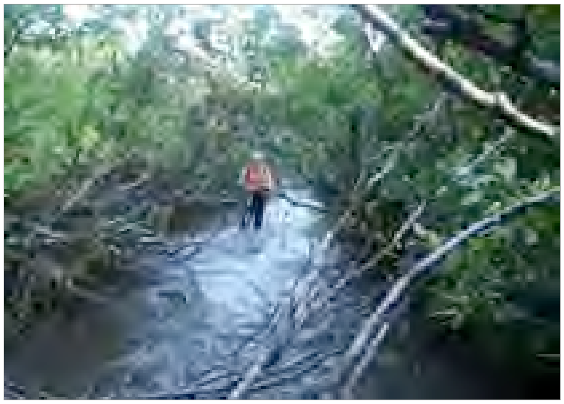

6 (imgp1749) Habitat Survey (NSO1) begins in this riffle unit


7 (imgp1756) Head of NSO 1 Riffle (high gradient)


8 (imgp1757) NSO 1 - Riffle

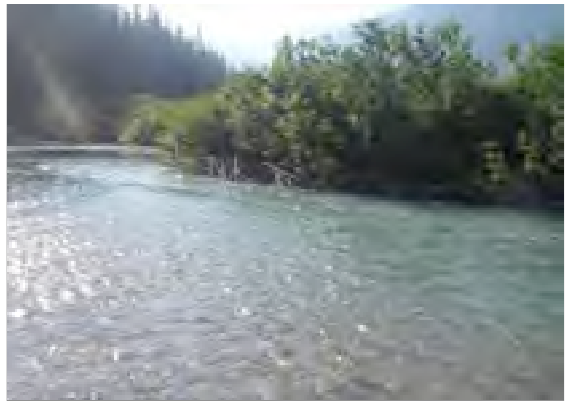

9 (imgp1758) NSO 1 - note submerged log at lower left bank of channel

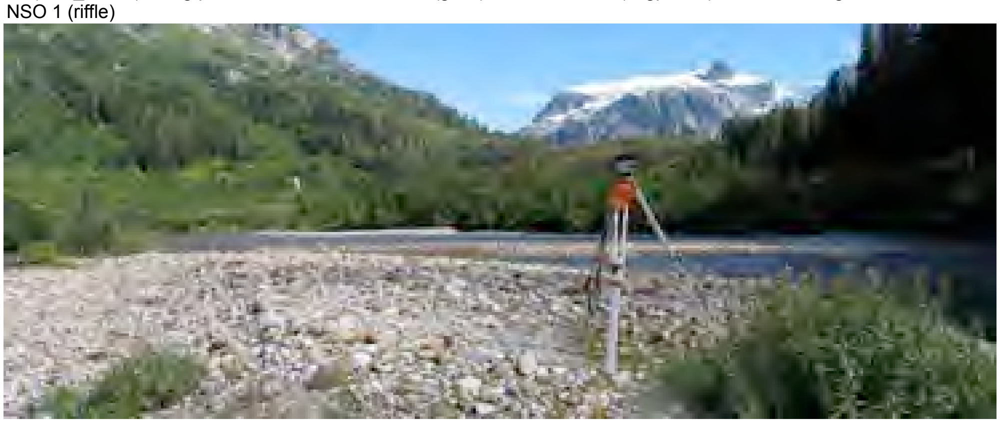

10 (imgp1759) Side Channel (NSO2) on LB of NSO1


11 (imgp1762) NSO 2 Side Channel


12 (imgp1766) NSO 3 MC Glide begins


13 (IMG_3168c) Long profile station OS13, NSO 3 (glide) and NSO 1 (riffle)


14 (imgp1773) NSO 3 Glide grades into riffle NSO4

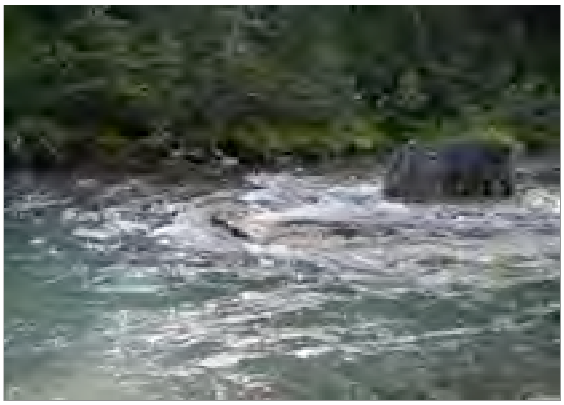

15 (IMG_3165pc) Long profile station OS12, NSO 4-5-7


16 (imgp1829) NSO 5-7 and outlet of sidechannel NSO 2

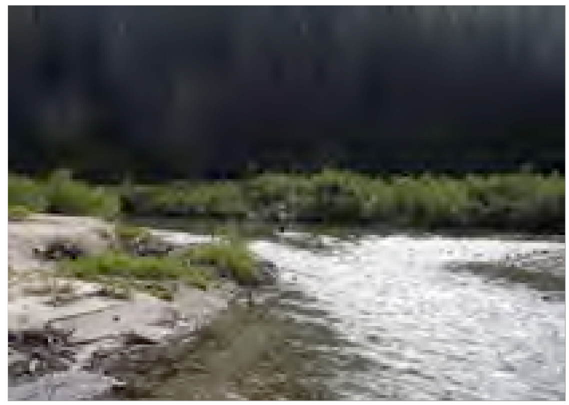

17 (imgp1778) Eric at top of S bend of NSO 4

18 (imgp1774) Channel splits at NSO 4

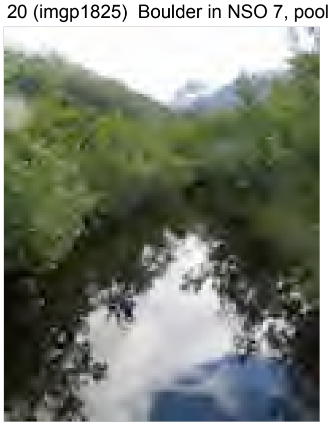
19 (imgp1824) NSO 7



20 (imgp1825) Boulder in NSO 7, pool NSO 6 to left (u/s)

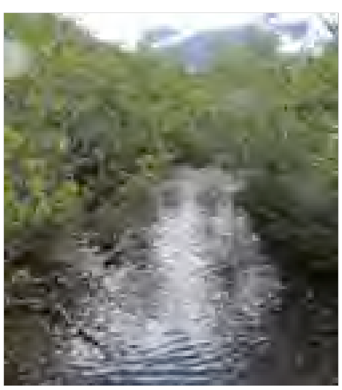


21 (imgp1822) View of NSO 8 from NSO 9

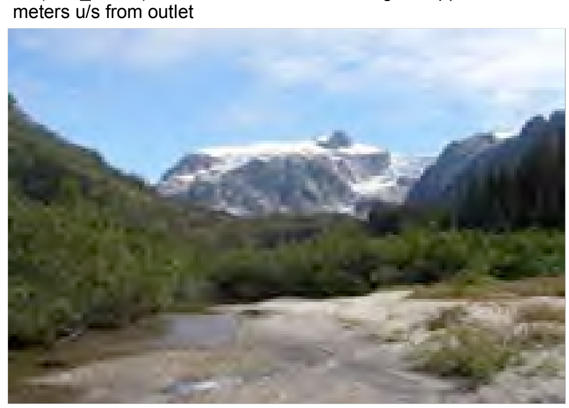


22 (IMG_3256c) NSO 4a, facing u/s near head of sidechannel

23 (IMG_3255c) Sidechannel NSO 4a, facing u/s approx. 40 meters u/s from outlet



24 (IMG_3253c) NSO 4a, facing u/s near sidechannel outlet

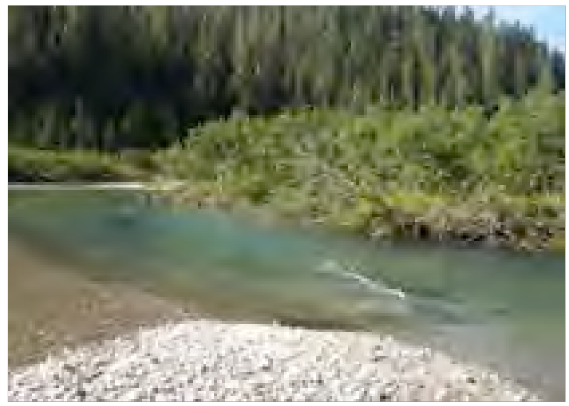


25 (imgp1820) Terminus of sidechannel NSO 4a

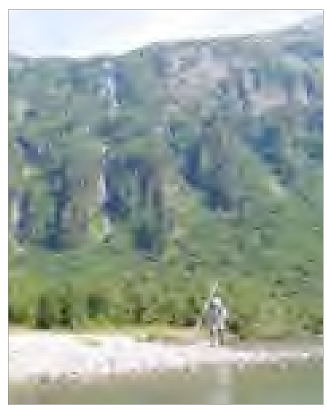

26 (IMG_3123c) Transition from NSO 9 riffle to NSO 12 pool; SC pool NSO 11 forms left edge of bar


27 (imgp1782) Facing u/s, NSO 12 (left) and NSO 9 (right)


28 (imgp1781) Sidechannel NSO 11 Pool, facing u/s to NSO 9 Riffle


29 (imgp1783) Pool NSO 12, sidechannel pool NSO 11 on left


30 (imgp1784) Sidechannel NSO 11 joining NSO 12 on right


31 (IMG_3126c) Right bank of NSO 13 at Geo XS 2


32 (imgp1785) NSO 15-16

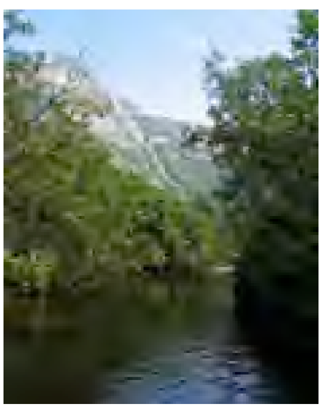

33 (IMG_3252c) Sidechannel NSO16, small tributary on steep left bank


34 (IMG_3127c) Sidechannel pool NSO16


35 (IMG_3128c) NSO 18 Glide grades into NSO 20 Riffle


36 (IMG_3129c) NSO 20 Riffle

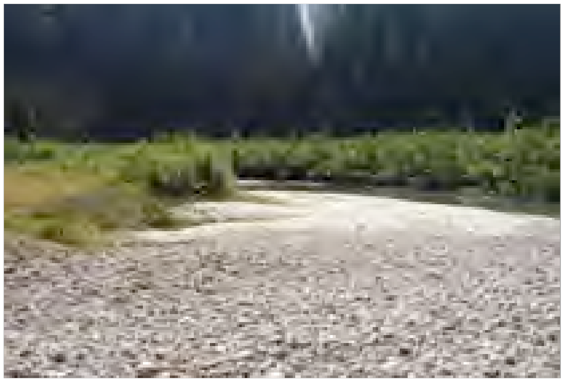

37 (IMG_3130c) NSO 23 Riffle, facing dewatered inlet to sidechannel NSO 22

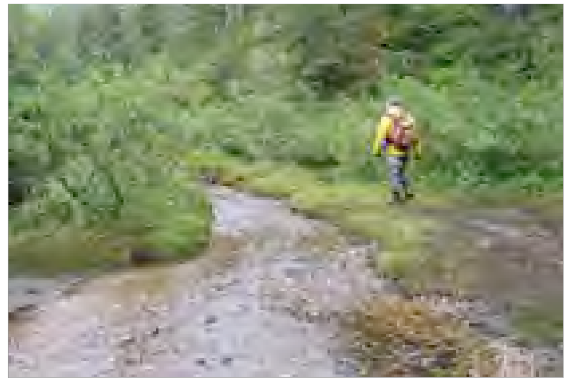

38 (IMG_3133c) Sidechannel NSO 22, facing u/s

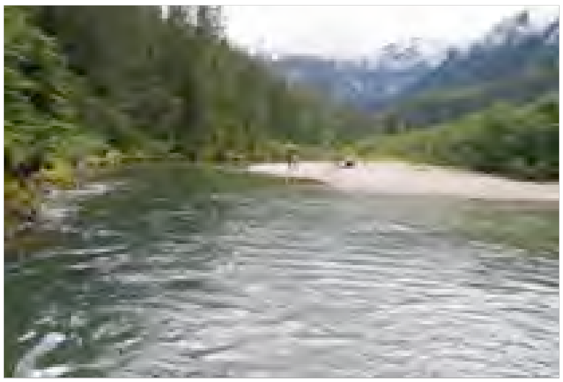

39 (IMG_3131c) Sidechannel NSO 22, substrate with frog

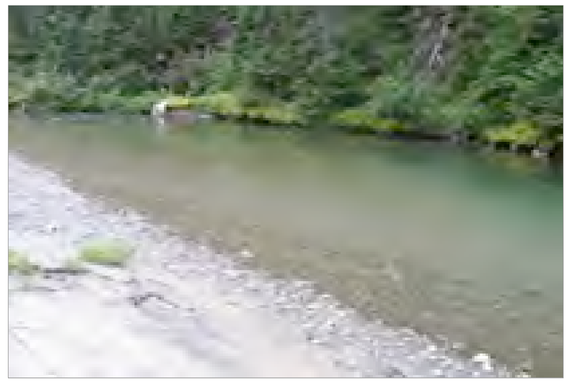

40 (IMG_3134c) NSO 24 Pool, facing outlet of sidechannel NSO 22


41 (imgp1790) NSO 24 Pool

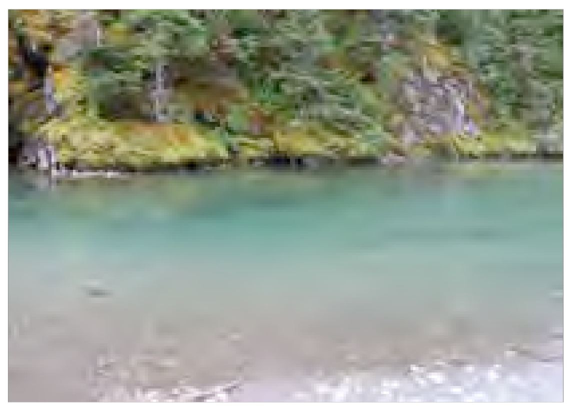

42 (imgp1793) NSO 24 Glide grades into NSO 25 Riffle


43 (IMG_3292c) Tributary from south side of valley, flows into NSO 28


44 (IMG_3297c) View of NSO 27 Pool from mouth of tributary/backwater NSO28

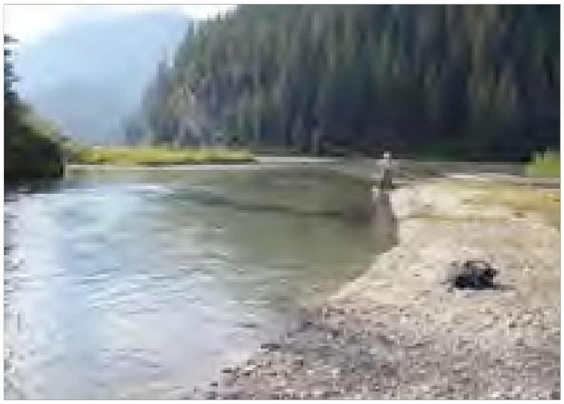

45 (IMG_3245c) NSO 27 Pool, view 1/4 from long profile OS5


46 (IMG_3246c) NSO 27 Pool, view 2/4 from long profile OS5


47 (IMG_3247c) NSO 27 Pool, view 3/4 from long profile OS5

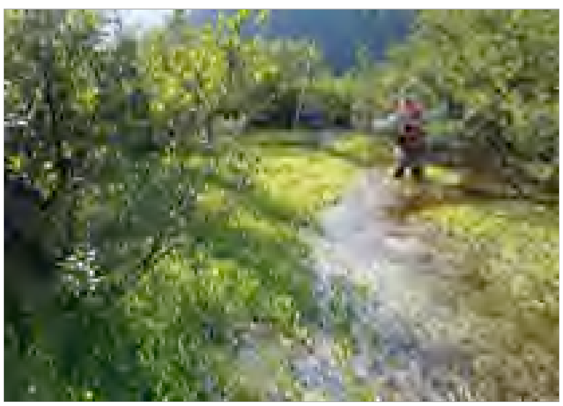

48 (IMG_3248c) NSO 27 Pool grading to NSO 29 Riffle, view 4/4 from long profile OS5

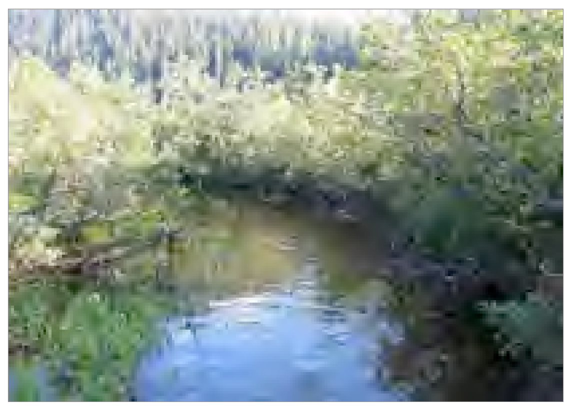

49 (imgp1799) Side channel habitat units NSO 38, 43

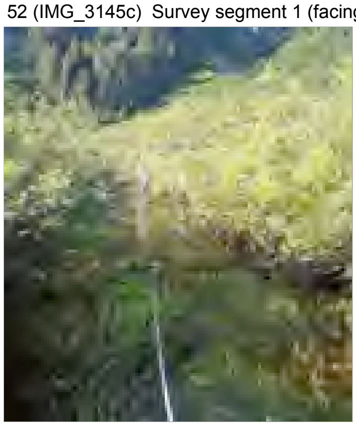

50 (imgp1803) Main channel NSOs 40-41 just u/s of delta


51 (IMG_3174c) d/s end of sidechannel NSO 46 at Swan Lake

Spring Creek Habitat Photos


52 (IMG_3145c) Survey segment 1 (facing d/s)


53 (IMG_3146c) Survey segment 2 (facing u/s from bottom)


54 (IMG_3148c) Survey segment 3 (facing d/s from top)


55 (imgp1953) Survey segment 3 @ Geo X-S


56 (imgp1955) Survey segment 3 @ Geo X-S

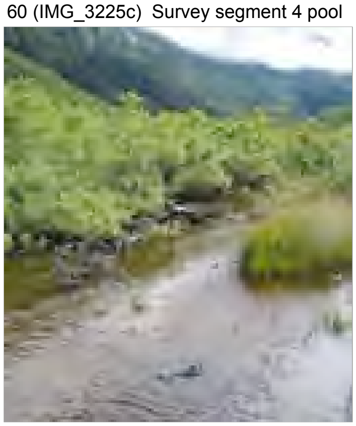

57 (imgp1951) gravels suitable for spawning?


58 (imgp1952) Survey segment 3, overhanging bank


59 (IMG_3149c) Survey segment 4 pool (facing d/s)

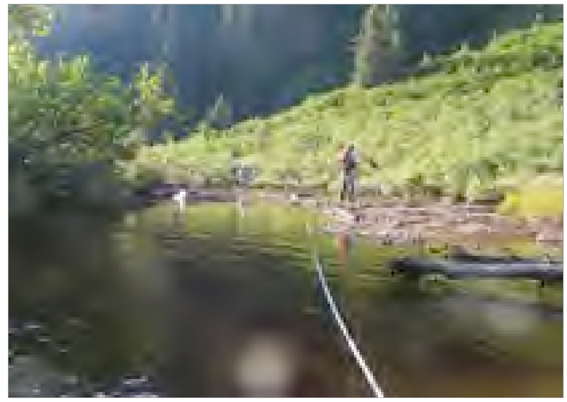

60 (IMG_3225c) Survey segment 4 pool


61 (IMG_3150c) Survey segment 5


62 (IMG_3226c) Survey segment 5 joined by tributary from north side of valley


63 (imgp1960) Survey segment 5: typical Spring Creek glide/riffle habitat types


64 (IMG_3151c) Survey segment 6 (facing u/s)


65 (IMG_3152c) Survey segment 7 (facing d/s)


66 (imgp1961) Survey segment 7, facing u/s

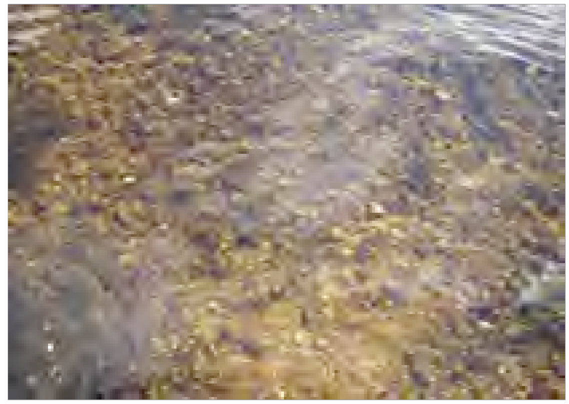

67 (imgp1962) Survey segment 7 (facing u/s), glide habitat


68 (IMG_3153cp) Survey segment 7


69 (imgp1963) Survey segment 8 showing rip vegetation and occasional LWD


70 (imgp1964) Survey segment 8 with backwater from lake

71 (IMG_3227c) Survey segment 8



72 (imgp1946) gravel substrate with detritus overlay

73 (imgp1947) gravel with detritus

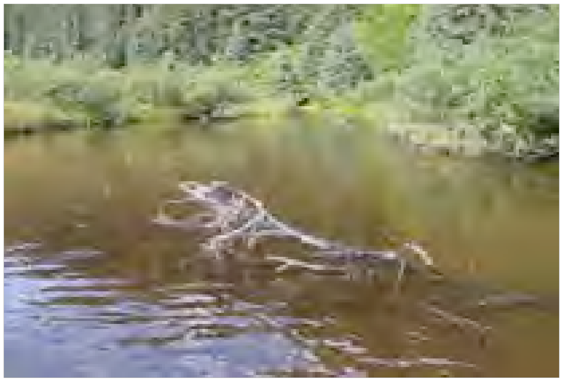
74 (imgp1949) rooted veg and gravels

75 (imgp1950) gravels and detritus

76 (IMG_3231c) Survey segment 9, overhanging bank

77 (IMG_3232c) Survey segment 9

78 (IMG_3233c) Survey segment 11, Salix cover


79 (IMG_3234c) Survey segment 11


80 (IMG_3235c) Survey segment 11

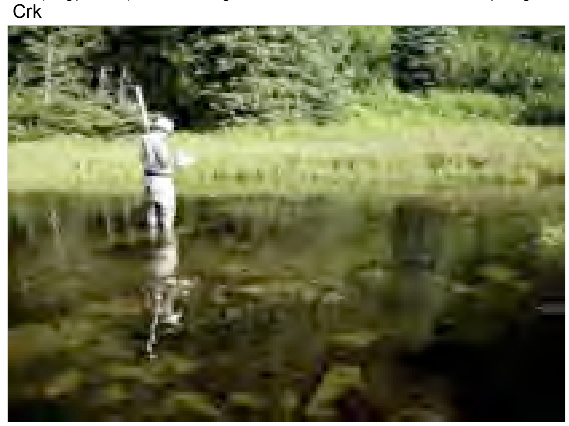

81 (IMG_3237c) Survey segment 10, facing d/s to delta


82 (IMG_3238c) Survey segment 12

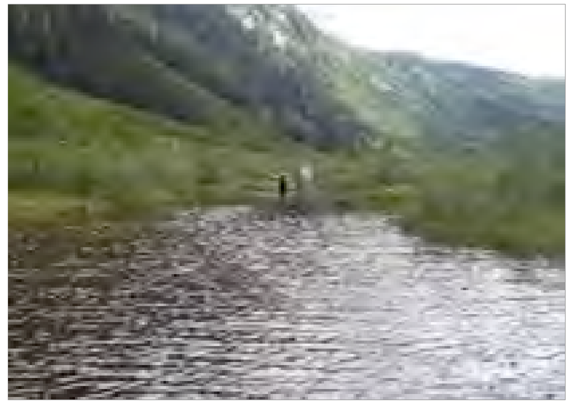

83 (IMG_3240c) swale southeast of Survey segment 12


84 (imgp1942) rooted veg and boulders at lower end of Spring Crk

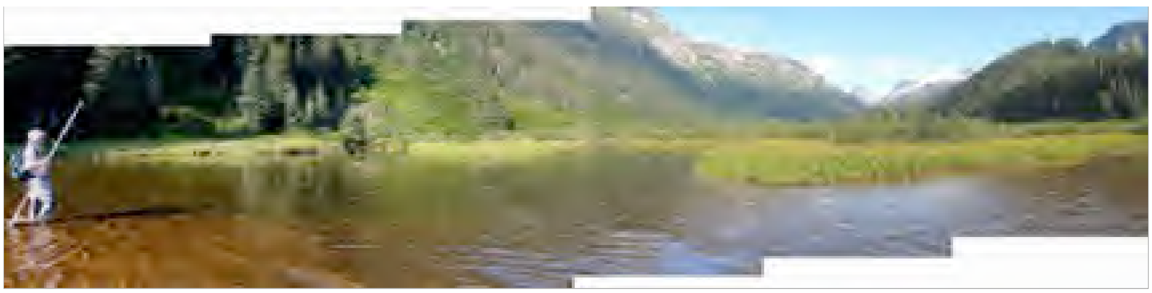

85 (imgp1943) boulders at terminus of Spring Creek: size ~ 1.5 ft x 1.5 ft


86 (imgp1944) Derek amidst boulders in delta

87 (imgp1939) delta view u/s showing islands

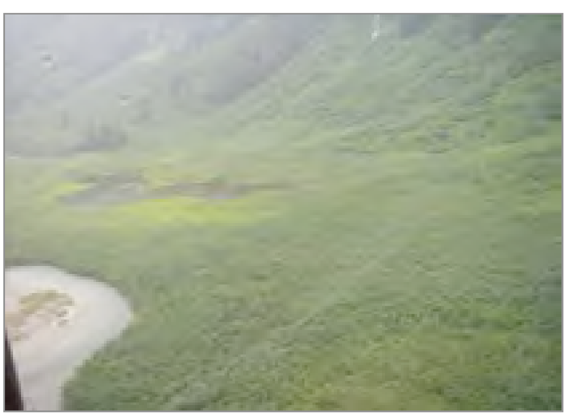


88 (imgp1968) View from delta into survey segment 10



89 (IMG_3138cp) Panorama view from delta facing Spring Creek mouth

Spring Creek Aerial Photos



90 (imgp1860) Helicopter view -- Lake feature u/s of Spring Creek (Upper Cascade Cr in foreground)

91 (IMG_3190c) Helicopter view -- u/s wetland complex, connected to Spring Cr & Cascade Cr by hyporrheic flow

92 (IMG_3191c) Helicopter view -- wetlands u/s from Spring Creek

93 (imgp1862) Helicopter view -- wetland complex u/s from Spring Creek

94 (IMG_3192c) Helicopter view -- Spring Creek u/s wetlands

95 (imgp1869) more wetland complex at head of Spring Creek

96 (IMG_3197c) Helicopter view -- wetlands @ head of Spring Creek

97 (imgp1873) main channel of Spring Creek

98 (IMG_3201c) Helicopter view -- Spring Creek confluence above survey segment 1

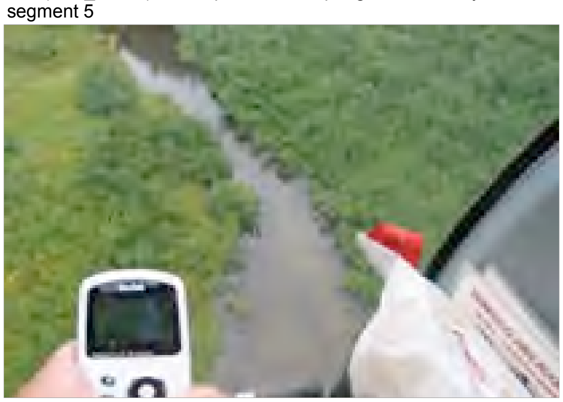
99 (IMG_3202c) Helicopter view -- Spring Creek survey segments 1-2

100 (IMG_3203c) Helicopter view -- Spring Creek survey segments 3-4

101 (imgp1876) Helicopter view -- main channel of Spring Creek in surveyed segments 4-5-6

102 (IMG_3204c) Helicopter view -- Spring Creek survey segment 5

103 (IMG_3205c) Helicopter view -- Spring Creek survey segment 6



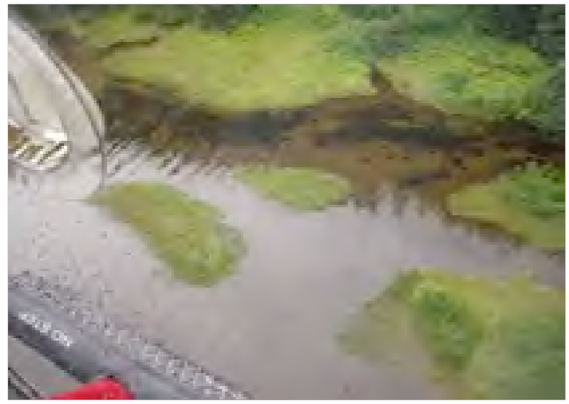
104 (IMG_3206c) Helicopter view -- Spring Creek survey segments 7-8

105 (IMG_3207c) Helicopter view -- Spring Creek approaching Swan Lake delta

106 (IMG_3208c) Helicopter view -- Spring Creek at Swan Lake delta

107 (imgp1880) lower end of Spring Crk as it approaches delta; note islands and channel split

108 (imgp1884) Spring Creek near delta confluence



109 (imgp1881) islands at lower Spring Creek

110 (imgp1889) delta confluence with islands at lower Spring Creek

111 (IMGP3003.jpg) Oblique aerial view of delta formed at the outlets of Upper Cascade Creek and Spring Creek to Swan Lake

APPENDIX 2-4

UPPER CASCADE CREEK SURVEY DATA

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Longitudinal profile survey of Upper Cascade Creek, August 17, 2010.
Derek Booth, Steve Ralph, Eric Edlund
Two stadia rods in use, one metric (Derek), one feet (Steve).
Data have been carefully reviewed to ensure there were no problems related to units of measurement.
Original data are available on request.

Streambed Points Along Longitudinal Profile

LP point	Distance from mouth (feet)	Streambed Height (feet above Swan Lk surface)	Stream Water Surface (feet)
0	0	-1.77	0.00
1	411	-3.82	0.28
2	592	0.54	1.54
4	842	-0.79	1.81
5	999	-0.47	2.09
8	1299	-0.12	2.21
9	1434	1.13	2.53
11	2042	1.84	3.84
13	2214	1.15	4.05
14	2447	0.15	4.22
15	2605	0.39	
17	2642	2.61	4.29
18	2861	2.46	4.56
19	2949	4.20	5.11
21	3115	1.42	5.42
22	3199	2.20	5.55
23	3271	2.10	5.60
24	3402	3.78	5.62
26	3533	3.34	6.36
28	3709	4.89	6.79
29	3816	4.62	6.65
30	4192	7.62	8.74
31	4336	5.45	8.85
33	4543	7.44	9.24
34	4767	8.06	9.83
35	4956	9.63	
37	5069	7.62	
38	5205	10.15	11.79
39	5324	6.98	12.08
40	5389	7.58	12.04
41	5463	9.09	12.39
42	5601	9.76	12.51
43	5726	11.27	
44	5869	13.01	14.52
45	6061	13.11	14.69
47	6245	11.16	14.81
48	6314	10.61	14.91
50	6447	13.92	15.62
51	6494	12.82	15.81
52	6569	14.23	16.27
53	6694	16.84	
54	6776	14.78	18.39
55	6875	16.45	
57	7103	14.78	18.94
58	7219	16.92	19.12
59	7322	19.71	20.93
60	7461	18.51	22.33

Control Points

LP point	Description	Approx. distance from mouth (feet)	Height (feet above Swan Lake surface)
na	BM_UCC3 (*)	245	1.46 (**)
7	stream gage lag bolt	1148	6.63
25	BM_UCC2	3300	9.76
61	BM_UCC1	7060	21.55

Notes

* Benchmarks set with rebar and flagged; height measurements to ground surface directly behind rebar marker as viewed from occ. stn.

** approximate height only; BM UCC3 was established on Aug. 18th, the day after LP survey, and the original LP occ. stn. was reoccupied +/- 0.1 ft.

Swan Lake Delta bathymetric survey, August 18, 2010. Survey crew: Derek Booth, Steve Ralph, Eric Edlund

Setup autolevel @ long profile OS LP1. Position is just a few hundredths of a foot below waterline at 10:00 a.m. Inst. ht. 4.7 ft.

Zero ("BS") on long profile shot 0 from previous day. FS to new benchmark BM UCC3. Sideshot to BM UCC4 on Cascade Creek right bank.

Two stadia rods in use, one metric, one feet! Data have been carefully reviewed to ensure against problems related to units.

Auto-level data					Notes			Intermediate data				Data in Local Coordinates (feet)		
Shot	Rod Height	Top Hair	Bottom Hair	Azimuth	Remarks	Substrate (s=sand, g=gravel)	Water depth (obs.)	upper minus middle	middle minus lower	units	distance feet	**easting**	**northing**	**depth**
0	6.66	7.6	5.72	0	to start of LP survey		1.96	0.94	0.94	f	188.1	**0.0**	**188.1**	**2.0**
1	1.05	1.16	0.94	151.1	BM UCC3, ground			0.11	0.11	m	74.8	**36.2**	**-65.5**	**-3.7**
2	0.87	1.05	0.82	151.1	BM top of pin			0.18	0.05	m	74.8	**36.2**	**-65.5**	
3	8.01	9.16	*6.86*	190.3	3.9 feet to rock wall		3.3	1.15	1.15	f	230.0	**-41.1**	**-226.3**	**3.3**
4	1.83	2.14	1.53	190.4	2.3 meters to rock wall; lower hair estimated		1.3	0.31	0.3	m	200.1	**-36.1**	**-196.8**	**-2.9**
5	9.17	10.25	8.11	192.3		sand w minor g	4.6	1.08	1.06	f	213.5	**-45.5**	**-208.6**	**4.5**
6	1.87	2.17	1.57	192				0.3	0.3	m	197.5	**-41.1**	**-193.2**	**-2.8**
7	9.36	10.36	8.36	195.6			4.62	1	1	f	199.5	**-53.6**	**-192.2**	**4.7**
8	1.85	2.13	1.57	195.2	against log	g	1.35	0.28	0.28	m	183.7	**-48.2**	**-177.3**	**-2.9**
9	8.14	9.11	7.18	196.9	5.5 ft from end of log		3.42	0.97	0.96	f	192.7	**-56.0**	**-184.4**	**3.4**
10	1.7	1.93	1.47	190	end of log		0.85	0.23	0.23	m	151.6	**-26.3**	**-149.3**	**-3.0**
11	9.39	10.37	8.43	204.6		s		0.98	0.97	f	194.5	**-81.0**	**-176.8**	**4.7**
12	1.88	2.15	1.61	203		gravel w minor s		0.27	0.27	m	177.2	**-69.2**	**-163.1**	**-2.8**
13	9.45	10.42	8.49	212		s		0.97	0.97	f	193.5	**-102.5**	**-164.1**	**4.8**
14	1.86	2.13	1.59	212		gravel w minor s		0.27	0.27	m	176.5	**-93.5**	**-149.7**	**-2.8**
15	9.33	10.3	8.39	217.7				0.97	0.95	f	191.0	**-116.8**	**-151.1**	**4.6**
16	1.88	2.15	1.62	218				0.27	0.26	m	173.2	**-106.7**	**-136.5**	**-2.8**
17	9.31	10.27	8.34	222.8				0.96	0.98	f	193.5	**-131.5**	**-142.0**	**4.6**
18	1.97	2.24	1.7	225.5				0.27	0.27	m	177.5	**-126.6**	**-124.4**	**-2.7**
19	9.53	10.5	8.56	228.9				0.97	0.97	f	193.5	**-145.8**	**-127.2**	**4.8**
20	1.95	2.22	1.68	230.3				0.27	0.27	m	177.8	**-136.8**	**-113.6**	**-2.7**
21	9.39	10.35	8.43	234.9				0.96	0.96	f	192.0	**-157.1**	**-110.4**	**4.7**
22	1.86	2.11	1.58	234.7				0.26	0.28	m	175.5	**-143.3**	**-101.4**	**-2.8**
23	9.37	10.31	8.43	241.6			4.61	0.94	0.94	f	188.0	**-165.4**	**-89.4**	**4.7**
24	1.89	2.15	1.62	241.9				0.26	0.26	m	171.9	**-151.7**	**-81.0**	**-2.8**
25	9.38	10.31	8.46	248.2				0.93	0.93	f	185.5	**-172.2**	**-68.9**	**4.7**
26	2.19	2.43	1.96	252.4		g		0.24	0.24	m	155.8	**-148.5**	**-47.1**	**-2.5**
27	9.34	10.26	8.42	255.6				0.92	0.92	f	184.0	**-178.2**	**-45.8**	**4.6**
28	2.26	2.52	2	256.9				0.26	0.26	m	168.6	**-164.2**	**-38.2**	**-2.4**
29	9.43	10.32	8.54	262.9				0.89	0.89	f	177.5	**-176.1**	**-21.9**	**4.7**
30	2.27	2.52	2.03	263.8				0.25	0.25	m	162.7	**-161.8**	**-17.6**	**-2.4**
31	9.14	10.03	8.26	269.7				0.89	0.88	f	177.0	**-177.0**	**-0.9**	**4.4**
32	2.13	2.37	1.88	272.5				0.24	0.24	m	159.4	**-159.3**	**7.0**	**-2.6**
33	9.17	10.07	8.28	276.8				0.9	0.9	f	179.5	**-178.2**	**21.3**	**4.5**
34	7.11	7.94	6.28	277.8	begin Derek = sole rodman, Steve = notetaker			0.83	0.83	f	165.5	**-164.0**	**22.5**	**2.4**
35	9.38	10.31	8.44	281.7				0.94	0.94	f	187.5	**-183.6**	**38.0**	**4.7**
36	7.45	8.35	6.56	282				0.9	0.89	f	178.5	**-174.6**	**37.1**	**2.8**
37	9.24	10.25	8.24	287.5				1.01	1.01	f	201.0	**-191.7**	**60.4**	**4.5**
38	6.78	7.71	5.85	287.6				0.93	0.93	f	185.5	**-176.8**	**56.1**	**2.1**
39	9.21	10.29	8.18	293.3				1.08	1.03	f	211.0	**-193.8**	**83.5**	**4.5**
40	6.17	7.15	5.19	294		g		0.98	0.99	f	196.5	**-179.5**	**79.9**	**1.5**
41	9.06	10.16	7.98	298.2		g		1.1	1.09	f	218.0	**-192.1**	**103.0**	**4.4**
42	6.49	7.51	5.47	298.5		g edge		1.03	1.02	f	204.5	**-179.7**	**97.6**	**1.8**
43	9.22	10.37	8.07	303.8				1.15	1.16	f	230.0	**-191.1**	**127.9**	**4.5**
44	6.87	7.99	5.76	304.3				1.12	1.11	f	223.0	**-184.2**	**125.7**	**2.2**
45	8.91	10.17	7.65	306.8				1.26	1.26	f	252.0	**-201.8**	**151.0**	**4.2**
46	6.73	7.9	5.55	308		very soft silty sand		1.18	1.18	f	235.5	**-185.6**	**145.0**	**2.0**
47	8.72	10.08	7.35	311				1.36	1.37	f	273.0	**-206.0**	**179.1**	**4.0**
48	6.26	7.46	5.06	311.2				1.21	1.2	f	240.0	**-180.6**	**158.1**	**1.6**
49	8.09	9.32	6.87	317.1				1.23	1.23	f	245.5	**-167.1**	**179.8**	**3.4**
50	6.02	7.18	4.86	316.9				1.16	1.16	f	231.5	**-158.2**	**169.0**	**1.3**
51	8.04	9.2	6.87	324				1.16	1.17	f	233.0	**-137.0**	**188.5**	**3.3**
52	5.66	6.77	4.54	324				1.12	1.12	f	223.0	**-131.1**	**180.4**	**1.0**
53	8	9.15	6.85	333				1.15	1.15	f	230.0	**-104.4**	**204.9**	**3.3**
54	6.12	7.21	5.03	333.1				1.09	1.1	f	218.5	**-98.9**	**194.9**	**1.4**
55	8.43	9.61	7.24	341.4				1.19	1.19	f	237.0	**-75.6**	**224.6**	**3.7**
56	6.97	8.13	5.84	341.8				1.16	1.14	f	229.0	**-71.5**	**217.5**	**2.3**
57	8.05	9.28	6.82	349				1.23	1.23	f	246.0	**-46.9**	**241.5**	**3.4**
58	6.29	7.44	5.14	349.6				1.15	1.16	f	230.5	**-41.6**	**226.7**	**1.6**
59	7.94	9.31	6.59	352.4				1.37	1.35	f	272.0	**-36.0**	**269.6**	**3.2**
60	7.97	9.36	6.59	-1.6				1.39	1.38	f	277.0	**-7.7**	**276.9**	**3.3**

Auto-level data					Notes			Intermediate data				Data in Local Coordinates (feet)		
Shot	Rod Height	Top Hair	Bottom Hair	Azimuth	Remarks	Substrate (s=sand, g=gravel)	Water depth (obs.)	upper minus middle	middle minus lower	units	distance feet	**easting**	**northing**	**depth**
61	6.56	7.83	5.29	0				1.27	1.28	f	254.5	0.0	254.5	1.9
62	7.97	9.49	6.48	-1.7		g		1.52	1.5	f	301.5	-8.9	301.4	3.3
63	6.05	7.48	4.62	-1.2		g		1.43	1.43	f	286.0	-6.0	285.9	1.3
64	7.91	9.46	6.34	3.3		g		1.56	1.57	f	312.5	18.0	312.0	3.2
65	6.33	7.83	4.83	3.6				1.5	1.5	f	300.0	18.8	299.4	1.6
66	7.31	8.8	5.82	8.1				1.5	1.49	f	298.0	42.0	295.0	2.6
67	6.3	8	4.61	10.4	top of shelf			1.7	1.69	f	339.0	61.2	333.4	1.6
68	5.9	7.58	4.24	5.8	bottom hair estimated in field; revised downward by .015 avg.			1.68	1.67	f	334.0	33.8	332.3	1.2
69	5.57	7.12	4.02	8.2				1.56	1.55	f	310.5	44.3	307.3	0.9
70	5.21	6.6	3.83	13.6				1.39	1.38	f	276.5	65.0	268.7	0.5
71	4.97	6.12	3.82	20	edge of grass			1.15	1.15	f	229.5	78.5	215.7	0.3
72	6.08	7.15	5.04	20.2	edge of grass			1.07	1.04	f	210.5	72.7	197.6	1.4
73	8.4	9.41	7.39	20.5				1.01	1.01	f	202.0	70.7	189.2	3.7
74	8.97	10.06	7.89	18.3	deep hole			1.09	1.08	f	217.0	68.1	206.0	4.3
75	8.81	9.98	7.65	15.7		g		1.17	1.16	f	233.0	63.0	224.3	4.1
76	7.33	8.62	6.04	10.3		s		1.29	1.29	f	257.5	46.0	253.4	2.6
77	6.59	7.67	5.51	9.7		sg mix		1.08	1.08	f	216.0	36.4	212.9	1.9
78	6.37	7.13	5.6	11.2		g		0.77	0.77	f	153.0	29.7	150.1	1.7
79	5.51	5.9	5.12	11		g		0.39	0.39	f	78.1	14.9	76.7	0.8
BMx	3.43			151.1				-3.43	3.43	f	74.8	36.2	-65.5	-1.3
80	5.7	5.93	5.46	63.2		g		0.23	0.23	f	46.4	41.4	20.9	1.0
81	6.47	6.85	6.11	63.2		g		0.38	0.37	f	74.0	66.1	33.4	1.8
82	7.26	7.69	6.82	62.2		s+g		0.43	0.43	f	86.3	76.3	40.2	2.6
83	5.76	6.29	5.23	60.5		g		0.53	0.53	f	105.8	92.1	52.1	1.1
84	5.85	6.47	5.23	61.2	1 ft from edge	s		0.62	0.62	f	123.7	108.4	59.6	1.1
85	5.81	6.5	5.11	37.3		g		0.69	0.69	f	138.7	84.1	110.3	1.1
86	6.36	7.2	5.52	36.3	1 ft from edge	s		0.84	0.85	f	168.5	99.8	135.8	1.7
87	3.62	4.61	2.62	28	BM UCC4, ground			0.99	0.99	f	198.4	93.1	175.2	-1.1
88				20.5	reoccupy edge of grass; failed to record rod data									
89	4.93	6.34	3.52	26	grassy pt	silt		1.41	1.41	f	282.0	123.6	253.5	0.2
90	6.96	8.55	5.37	19.6	grassy pt	silt		1.59	1.59	f	318.0	106.7	299.6	2.3
91	6.11	8.06	4.18	17.4	side channel inlet			1.95	1.94	f	388.5	116.2	370.7	1.4
92	5.58	7.43	3.73	10	2 ft from bank	silt		1.85	1.85	f	369.5	64.2	363.9	0.9
93	6.15	7.82	4.47	11		silt		1.68	1.68	f	335.0	63.9	328.8	1.4
94	7.57	9.31	5.83	6.3	16 ft from bank			1.74	1.74	f	348.0	38.2	345.9	2.9
95	6.68	8.48	4.89	1.2	15 ft from bank	silt		1.8	1.8	f	359.0	7.5	358.9	2.0
96	7.79	9.48	6.12	1		silt/gravel		1.69	1.68	f	336.5	5.9	336.4	3.1
97	7.76	9.31	6.23	0.2		silt		1.55	1.54	f	308.0	1.1	308.0	3.1
98	8.03	9.48	6.59	356		silt		1.45	1.44	f	289.0	-20.2	288.3	3.3
99	7.77	9.39	6.16	355.5		silt		1.62	1.62	f	323.5	-25.4	322.5	3.1
100	6.91	8.73	5.11	354.9	12 ft from bank	silt		1.82	1.81	f	362.5	-32.2	361.1	2.2
101	5.67	7.18	4.16	346.9	3 ft from bank	silt		1.51	1.51	f	302.0	-68.4	294.1	1.0
102	7.92	9.38	6.46	347.1	15 ft from bank			1.46	1.46	f	292.0	-65.2	284.6	3.2
103	7.79	9.04	6.55	347.4				1.25	1.25	f	249.5	-54.4	243.5	3.1
104	7.42	8.77	6.08	342.8		silt		1.35	1.35	f	269.5	-79.7	257.4	2.7
105	9.19	10.56	7.83	342.3	17 ft from bank	s+g		1.37	1.36	f	273.0	-83.0	260.1	4.5
106	8.46	9.65	7.28	341.4		silt		1.19	1.18	f	236.5	-75.4	224.1	3.8
107	6.66	7.78	5.55	341.2		silty sand		1.13	1.11	f	223.0	-71.9	211.1	2.0
108	5.56	6.37	4.75	341.9		sand w minor g		0.81	0.81	f	162.0	-50.3	154.0	0.9
109	5.13	5.48	4.78	343.8		gravel w minor s		0.35	0.35	f	69.5	-19.4	66.7	0.4
110	4.37	4.57	4.16	300.4		crest of gravel bar, D50=25mm		0.2	0.21	f	40.9	-35.3	20.7	-0.3
111	5.3	5.94	4.64	318.2		g E, s W		0.65	0.65	f	130.0	-86.6	96.9	0.6
112	5.48	6.39	4.56	325.3				0.92	0.92	f	183.3	-104.3	150.7	0.8
113	5.97	7.11	4.84	324.3	delta lip	s		1.14	1.14	f	227.5	-132.8	184.7	1.3
114	5.97	7.08	4.87	314		s		1.11	1.1	f	220.5	-158.6	153.2	1.3
115	6.44	7.42	5.46	303.9		s		0.98	0.98	f	195.5	-162.3	109.0	1.7
116	6	6.72	5.28	303.2		minor g		0.72	0.72	f	144.3	-120.7	79.0	1.3
117	5.29	5.76	4.82	301.6		g/s		0.47	0.48	f	94.8	-80.7	49.7	0.6
118	5.72	6.14	5.3	282.3		sand w minor g		0.42	0.42	f	84.1	-82.2	17.9	1.0
119	6.88	7.53	6.23	279		s		0.65	0.65	f	130.0	-128.4	20.3	2.2
120	7.06	7.78	6.31	256		sand w minor g		0.73	0.74	f	146.9	-142.5	-35.5	2.4
121	5.64	6.12	5.16	254.2		sand w minor g		0.49	0.48	f	96.3	-92.7	-26.2	0.9
122	5.03	5.31	4.75	252.5		gravel w minor s		0.28	0.28	f	55.6	-53.0	-16.7	0.3

Auto-level data					Notes			Intermediate data				Data in Local Coordinates (feet)		
Shot	Rod Height	Top Hair	Bottom Hair	Azimuth	Remarks	Substrate (s=sand, g=gravel)	Water depth (obs.)	upper minus middle	middle minus lower	units	distance feet	**easting**	**northing**	**depth**
123	5.52	5.97	5.08	237.4		sand w minor g		0.44	0.44	f	88.4	**-74.5**	**-47.6**	**0.8**
124	5.59	6.26	4.92	238		s		0.67	0.67	f	134.3	**-113.9**	**-71.2**	**0.9**
125	5.68	6.52	4.85	228.2		gravel w minor s		0.84	0.83	f	167.0	**-124.5**	**-111.3**	**1.0**
126	5.56	6.17	4.94	218.1		s		0.62	0.62	f	123.5	**-76.2**	**-97.2**	**0.9**
127	4.45	4.91	3.99	200	upper end of unvegetated bar	gravel w minor s		0.46	0.46	f	92.3	**-31.6**	**-86.7**	**-0.3**
128	4.9	5.24	4.57	188.2	middle of side channel	g+s		0.33	0.33	f	66.6	**-9.5**	**-65.9**	**0.2**
129	4.44	4.6	4.28	176.2	bare bar	g		0.16	0.16	f	32.0	**2.1**	**-31.9**	**-0.3**
130	4.49	4.93	4.05	166.4	top edge unveg bar	s+g		0.44	0.44	f	88.0	**20.7**	**-85.5**	**-0.2**
131	5.16	5.65	4.67	172.4	center of side channel			0.49	0.49	f	98.0	**13.0**	**-97.1**	**0.5**
132	4.24	4.77	3.72	184.3	top of veg bar 15' wide 32' long			0.53	0.52	f	104.5	**-7.8**	**-104.2**	**-0.5**
133	4.46	5.17	3.77	175.7	SE corner of delta	s+g		0.7	0.69	f	139.4	**10.5**	**-139.0**	**-0.2**
134	5.22	5.9	4.54	185.4	3 ft from bank	g		0.68	0.68	f	135.2	**-12.7**	**-134.6**	**0.5**
135	5.36	6.19	4.52	203		g		0.83	0.84	f	166.4	**-65.0**	**-153.2**	**0.7**
136	5.51	6.31	4.7	219		g		0.81	0.81	f	161.5	**-101.6**	**-125.5**	**0.8**
137	5.66	6.32	4.99	226		s		0.67	0.66	f	132.9	**-95.6**	**-92.3**	**1.0**
138	5.44	6.06	4.81	241.2		s		0.63	0.63	f	125.1	**-109.6**	**-60.3**	**0.7**
139	6.22	6.78	5.65	261.6		sand w minor g		0.56	0.57	f	113.4	**-112.2**	**-16.6**	**1.5**
140	6.29	6.84	5.74	272		s		0.55	0.55	f	109.3	**-109.2**	**3.8**	**1.6**
141	6.16	6.73	5.59	287				0.57	0.57	f	113.2	**-108.3**	**33.1**	**1.5**
142	6	6.7	5.31	305.1		s		0.7	0.7	f	139.5	**-114.1**	**80.2**	**1.3**
143	5.03	5.67	4.39	314.2		gravel w minor s		0.64	0.64	f	128.2	**-91.9**	**89.4**	**0.3**
144	5.4	6.07	4.73	339.6		sand w minor g		0.67	0.67	f	134.0	**-46.7**	**125.6**	**0.7**
145	5.54	6.14	4.93	355.8		g+s		0.6	0.61	f	121.1	**-8.9**	**120.8**	**0.8**
146	5.73	6.3	5.17	10.7				0.56	0.56	f	112.8	**20.9**	**110.8**	**1.0**
147	6.67	7.22	6.11	26.7		g		0.55	0.56	f	111.0	**49.9**	**99.2**	**2.0**
148	7.44	8.01	6.87	37.5		g+s		0.57	0.57	f	114.0	**69.4**	**90.4**	**2.7**
149	5.35	5.97	4.74	48		g		0.62	0.61	f	122.6	**91.1**	**82.0**	**0.7**
150	6.19	6.84	5.54	55.2	5 ft from bank	s		0.65	0.65	f	129.2	**106.1**	**73.7**	**1.5**
151	5.69	6.25	5.14	55		g		0.56	0.55	f	111.3	**91.2**	**63.8**	**1.0**
152	7.11	7.57	6.64	52.3				0.46	0.46	f	92.4	**73.1**	**56.5**	**2.4**
153	7.65	8.09	7.22	53		sand w minor g		0.44	0.43	f	86.6	**69.2**	**52.1**	**3.0**
154	5.79	6.08	5.5	52				0.29	0.29	f	57.8	**45.5**	**35.6**	**1.1**
155	5.41	5.8	5.03	3.1				0.39	0.38	f	76.8	**4.2**	**76.7**	**0.7**
156	6.1	6.82	5.37	8.4		g		0.73	0.73	f	145.0	**21.2**	**143.4**	**1.4**
157	5.39	5.92	4.86	342.7		gravel w minor s		0.53	0.53	f	105.5	**-31.4**	**100.7**	**0.7**
158	5.37	5.67	5.09	279.5		gravel w minor s		0.29	0.28	f	57.8	**-57.0**	**9.5**	**0.7**
159	5.09	5.32	4.84	233		sand w minor g		0.24	0.24	f	48.0	**-38.3**	**-28.9**	**0.4**
160	4.47	4.64	4.31	158	upper edge	g		0.17	0.16	f	33.1	**12.4**	**-30.7**	**-0.2**

Upper Cascade Creek and Spring Creek GPS survey data, August 20, 2010.
GPS operator: Eric Edlund
Benchmarks are semi-permanent, 1.5-foot rebar with flagging; survey measurements to solid ground next to peg.

Point Name	Max PDOP	GPS_Date	GPS Time	Unfilt Pos	Std Dev	GPS Height	Horiz Prec	Vert Prec	Latitude	Longitude
bm-bedrock	2.5	8/20/2010	06:43:18PM	31	0.59	464.94	64.44	121.46	-132.696939917	57.037391407
bm-ucc1	3.2	8/20/2010	01:31:59PM	43	2.57	467.65	65.32	103.60	-132.672832050	57.033327372
bm-ucc1b	3.6	8/20/2010	05:21:12PM	66	4.42	463.60	63.01	105.23	-132.672762654	57.033320295
bm-ucc2	4.0	8/20/2010	05:48:05PM	46	4.12	443.62	84.08	157.81	-132.685821897	57.036131903
bm-ucc3	2.2	8/20/2010	09:32:14AM	15	1.91	464.80	76.84	99.89	-132.696851093	57.037595751
bm-ucc3b	4.3	8/20/2010	09:32:49AM	27	3.25	464.19	64.38	97.01	-132.696861834	57.037607591
bm-ucc3c	2.9	8/20/2010	12:01:12PM	61	0.26	464.25	57.91	87.65	-132.696845672	57.037586231
bm-ucc4	4.7	8/20/2010	09:40:02AM	23	4.71	464.03	104.28	135.56	-132.697001112	57.038258873
bm-ucc4b	2.9	8/20/2010	11:58:13AM	31	2.47	455.94	63.56	86.18	-132.696975036	57.038246654
bm-ucc4d	2.5	8/20/2010	06:44:24PM	51	2.74	468.94	62.71	101.62	-132.696803607	57.037655332
xs-SpgCr	1.4	8/20/2010	10:58:06AM	62	0.74	459.75	46.92	73.94	-132.693058286	57.038205501

Datum NAD83, units = meters

Note: GPS positions were recorded with a handheld Trimble Pathfinder GPS with post-processed differential capability.
Differential correction failed to provide accurate positions because of problems with nearby CORS reference station parameters.
With corrected basestation data, it should be possible to correct the existing Upper Cascade Creek GPS positions to accuracies of +/- a few meters.
Original GPS data are available on request.

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APPENDIX 2-5

LOWER CASCADE CREEK REACH 1A STREAM HABITAT PHOTOS

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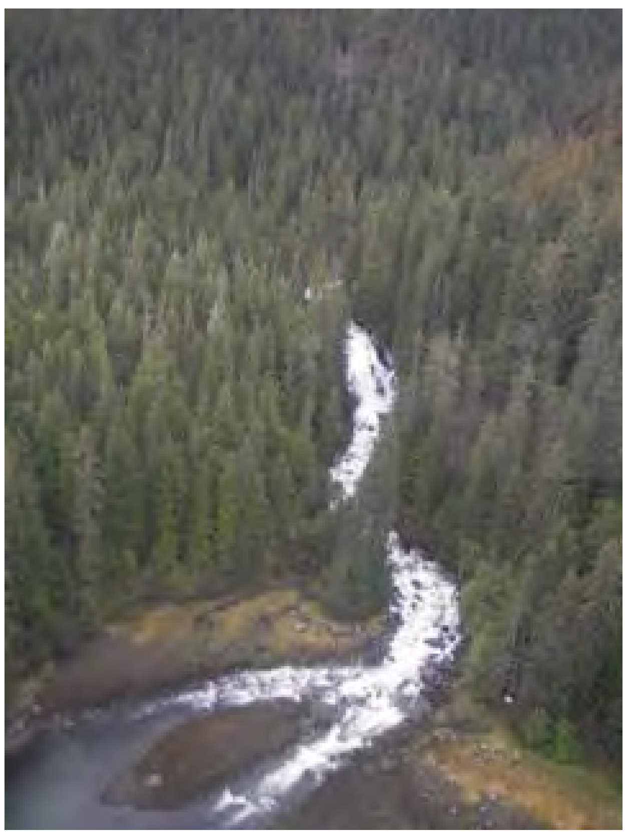
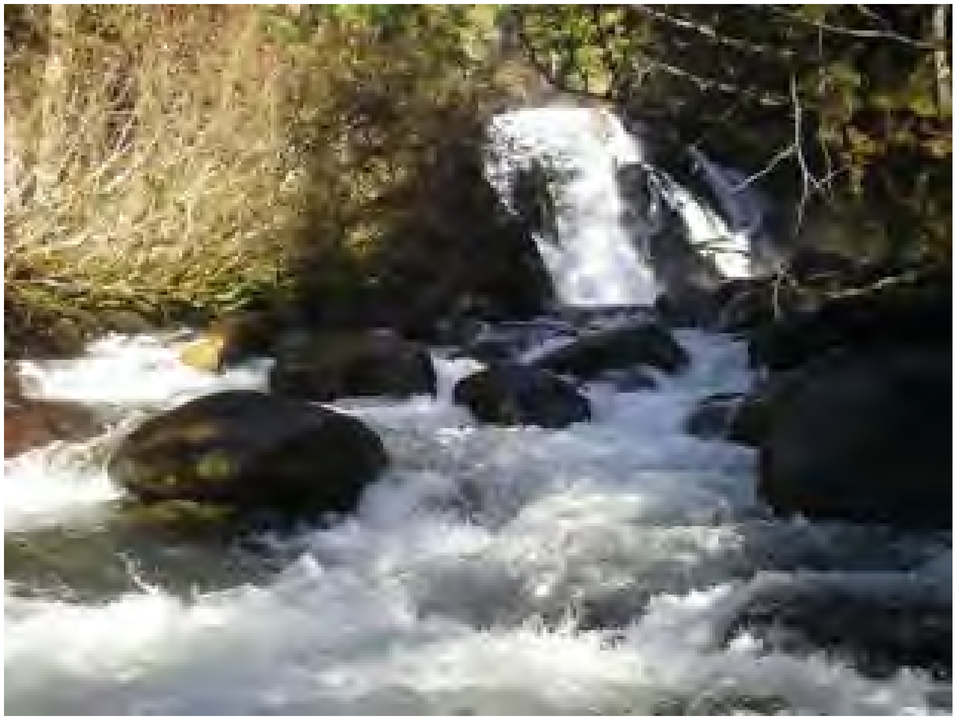


Photos 1 and 2: First barrier falls upstream from Thomas Bay on Lower Cascade Creek (top photo) and aerial view of Lower Cascade Creek below, and including, barrier falls.



Photos 3 and 4: Barrier falls and upstream view of Reach 1A showing steep gradient and large substrate in main flow/current (top photo) and minnow trap location 1A-7M showing stream substrate along banks of this reach.

Photos 5 and 6: View from trail along left bank of upper section of Reach 1A (both photos). The bottom photo is downstream of the upper photo. NOTE: Half of the large boulder in center of top photo on left bank is visible in the far right hand side of the lower photo for reference.

Photos 8 and 9: Lowest section of Reach 1A in Lower Cascade Creek with view from left bank looking downstream (top photo) and upstream view at the mouth of the stream, also taken from the left bank.

APPENDIX 5-1

CASCADE CREEK FISH PASSAGE BARRIER PHOTOS

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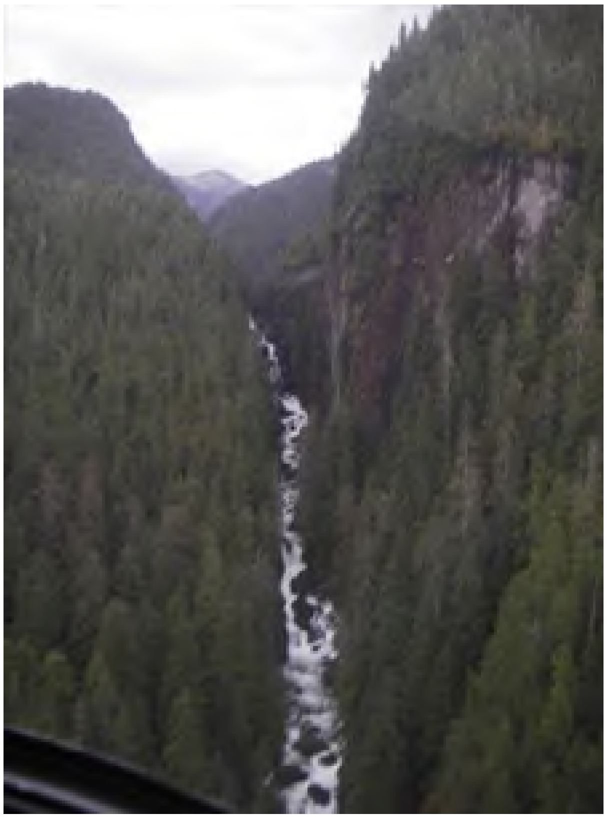
Photo 5-1.1: Upstream Fish Barrier B-1, also known as Cascade Creek Falls, located 150 meters upstream from Thomas Bay, Reach 1A. Photo Date: 10/26/2010 and 9/26/2010 respectively; Discharge was 302 cfs on 10/22/2010 and 438 cfs on 9/26/2010 at the Lower Cascade Creek gauge.

Reach 1B aerial view 9/26/2010

Barriers B-2 and B-3



Falls Lake outlet downstream 8/20/2010

Barrier B-3

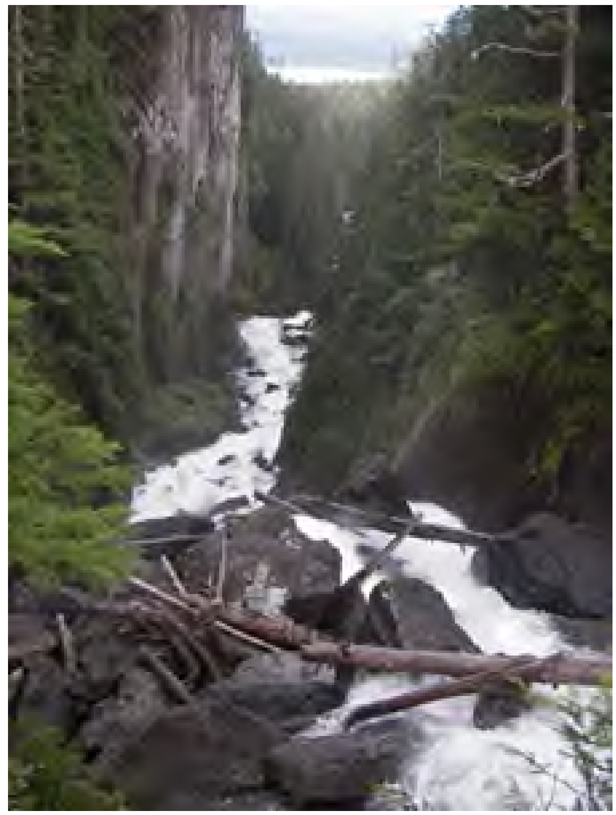


Photo 5-1.2: Barriers to upstream fish passage in Reach 1B. Barrier B-2 located in middle of aerial photo on left. Barrier B-3 at Falls Lake outlet. Discharge 577 cfs on 8/20/2010 and 438 cfs on 9/26/2010 at the Lower Cascade Creek gauge.

Photo 5-1.3: Barrier B-4 located at Falls Lake inlet in Reach 2A. Photo Date 9/21/2010 and 9/23/2010; Discharge 72 cfs on 9/21/2010 and 63 cfs on 9/23/2010 at the Swan Lake outlet gauge.

Photo 5-1.4: Barrier B-5 located in Reach 2A directly upstream of lean-to structure. Elevation difference surveyed on 9/21/2010. Photo Date: 9/21/2010; Discharge 72 cfs at the Swan Lake outlet gauge.

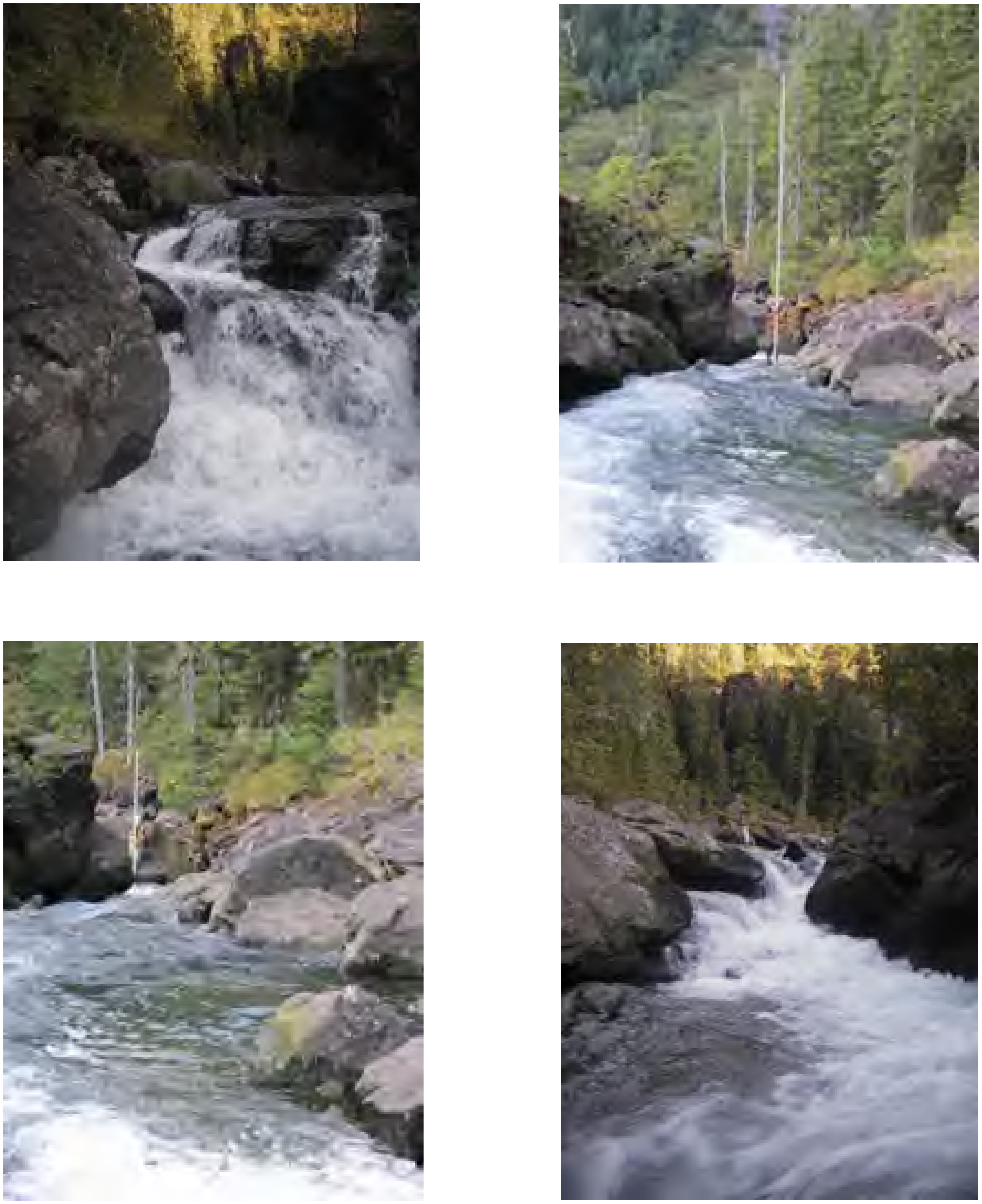


Photo 5-1.5: Potential Barrier PB-6 located 150 meters upstream from the Pond in Reach 2B. Elevation difference surveyed on 9/21/2010. Photo Date: 9/21/2010; Discharge 72 cfs at the Swan Lake outlet gauge.

Photo 5-1.6: Potential barrier PB-7 located equidistant between the Pond and Swan Lake outlet in Reach 2B. Boulder cascade with multiple 1.5 to 3 meter drops over 100 meter section. Photo Date: 8/14/2010; Discharge 238 cfs at the Swan Lake outlet gauge.

Photo 5-1.7: Bottom end of potential barrier PB-8 in Reach 2B. Cascade Creek went subsurface for approximately 100 meters at this discharge disconnecting large pool from Swan Lake. Pool was mostly non-existent. Photo Date: 9/21/2010; Discharge 72 cfs at the Swan Lake outlet gauge (view upstream).

Photo 5-1.8: Middle of potential barrier PB-8 in dewatered section in Reach 2B below Swan Lake outlet. Photo Date: 9/21/2010; Discharge 72 cfs at the Swan Lake outlet gauge (view downstream).

Photo 5-1.9: Start of potential barrier PB-8 in dewatered section in Reach 2B below Swan Lake outlet. Photo Date: 9/21/2010; Discharge 72 cfs at the Swan Lake outlet gauge (view upstream).

Photo 5-1.10: Barrier B-9 located at the end of Reach 3 in Upper Cascade Creek. Photo Date: 8/15/2010; Discharge 178 cfs at the Swan Lake inlet gauge.

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APPENDIX 6-1

LIST OF BMI TAXA FOR THREE SITES ON LOWER CASCADE CREEK

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Order	Sample Site	Lower Cascade RM 1.25	Lower Cascade RM 1.25	Lower Cascade RM 1.25	Above Pond	Above Pond	Above Pond	Below Swan Lake	Below Swan Lake	Below Swan Lake
	Reach	Reach 1	Reach 1	Reach 1	Reach 2	Reach 2	Reach 2	Reach 2	Reach 2	Reach 2
	Replicate	1	2	3	1	2	3	1	2	3
	Device	Surber	Surber	Surber	Surber	Surber	Surber	Surber	Surber	Surber
	Collection Date	8/13/2010	8/13/2010	8/13/2010	8/13/2010	8/13/2010	8/13/2010	8/13/2010	8/13/2010	8/13/2010
	Genus/Species									
Ephemeroptera	Ameletus	+			+	+				
	Baetis	+		+	+	+	+			+
	Cinygmula	+	+							
	Drunella	+	+	+				+		
	Serratella	+	+	+						
Plecoptera	Capnia				+		+	+	+	+
	Isoperla							+	+	+
	Triznaka				+		+	+	+	+
	Zapada	+	+	+	+	+	+	+	+	+
	Megarcys					+				
	Hesperoperla	+	+	+						
	unid		+					+	+	+
Trichoptera	Ecclisomyia				+					+
	Moselyana					+			+	
	Neothrema	+	+	+						
	Rhyacophila	+		+			+			
Diptera-Chironomidae	Pagastia		+	+	+	+	+			
	Pseudodiamesa				+			+	+	+
	Corynoneura		+							
	Diplocladius									+
	Eukiefferiella	+	+	+	+	+	+	+		
	Hydrobaenus				+					
	Orthocladius		+		+	+	+	+	+	+
	Parakiefferiella		+							+
	Psilometriocnemus				+		+	+	+	+
	Thienemanniella					+				
	Tvetenia	+	+	+	+	+	+	+	+	+
	Micropsectra			+				+	+	+
Diptera	Clinocera	+	+	+	+	+	+	+	+	+
	Prosimulium	+	+		+	+				+
Bivalvia	Sphaeriidae	+	+	+					+	+
Annelida	Oligochaeta	+	+				+	+	+	+
Arachnida	Hydracarina	+	+	+	+					
Crustacea	Copapoda				+	+		+	+	+
	Ostracoda			+	+		+		+	