

***Preliminary Evaluation of Entrainment in Cooper Lake
Cooper Lake Project (FERC No. 2170)***

Final Report

**Prepared by
Long View Associates, Inc.
and
Northern Ecological Services**

**Prepared for
Chugach Electric Association, Inc.**

June 2004

TABLE OF CONTENTS

1.0	Introduction and Background	1
2.0	Project Description	1
2.1	Project Setting and Facilities	1
2.1.1	Intake and Intake Channel	2
2.1.2	Tunnel/Penstock System	3
2.1.3	Powerhouse and Tailrace	3
2.2	Project Operations	3
2.2.1	General Description of Project Operations	3
2.2.2	Reservoir Operations	4
3.0	General Study Approach and Methods	5
4.0	Fish Populations and Management Species in Cooper Lake	6
4.1	Cooper Lake Fish Populations	6
4.2	Characteristics of Management Species	7
4.2.1	Arctic Char	7
4.2.2	Rainbow Trout	9
5.0	Cooper Lake Project Entrainment Assessment	11
5.1	Characterization and Analysis of Entrainment Risk Factors at the Cooper Lake Project	11
5.1.1	Location of the Intake Relative to the Shoreline and Littoral Zone	11
5.1.2	Substrate/Habitat Conditions in the Vicinity of the Intake	12
5.1.3	Distribution and Habitat Use of Fish Species of Interest	13
5.1.4	Hydraulic Capacity and Entrance Velocity of the Intake	15
5.1.5	Approach Velocity	16
5.1.6	Water Quality with Depth in the Reservoir	23
5.2	Summary of Entrainment Risk at the Cooper Lake Project based on Project-Specific Factors	24
6.0	Cooper Lake Project Entrainment Survival Assessment	26
7.0	Conclusions	29
7.1	Entrainment Risk	29
7.1.1	Arctic Char	29
7.1.2	Rainbow Trout	29
7.2	Entrainment Survival	30

7.3 Implications of Entrainment Analysis Regarding Project Effects30

8.0 Literature Cited.....31

LIST OF TABLES

Table 1. Typical operational day for the Cooper Lake Project powerhouse.....3

Table 2. Fish species currently present and/or reportedly present historically in Cooper Lake.6

Table 3. Maximum flow velocities at transects A–A', B–B' and C–C', for the upper and lower portions of the water column1, and combined average flow velocity for each transect.22

Table 4. Summary of the presence (Yes) or absence (No) of specific entrainment risk factors as they relate to the species of interest in Cooper Lake, and conclusions regarding overall entrainment risk.25

Table 5. Summary of the specific facility factors relevant to entrainment survival at the Cooper Lake Project.28

Table 6. Fish entrainment survival rates (immediate) by fish size class for radial-flow (Francis) type runners with hydraulic capacities of 275–695 cfs and turbine speeds greater than 250 rpm (after Winchell et al. 2000).....28

LIST OF FIGURES

Figure 1. Cooper Lake Powerhouse flow duration curve (2002–2003).4

Figure 2. Site Map at Intake on Cooper Lake with Track Line Overlay, Current Velocity Delineation, Cooper Landing, Alaska.18

Figure 3. Acoustic Doppler Current Profile A-A' Current Velocity Delineation Cooper Landing, Alaska.19

Figure 4. Acoustic Doppler Current Profile B-B' Current Velocity Delineation Cooper Landing, Alaska.20

Figure 5. Acoustic Doppler Current Profile C-C' Current Velocity Delineation Cooper Landing, Alaska.21

APPENDIX

Appendix A. Final Report for Geophysical Services: Current Velocity Delineation, Cooper Landing, Alaska Report prepared by B.E.S.T. Resource, January 2004

Appendix B. Summary of Responses to Comments on the Draft Report, June 2004

Final Report: Preliminary Evaluation of Entrainment in Cooper Lake Cooper Lake Project (FERC No. 2170)

1.0 INTRODUCTION AND BACKGROUND

The Cooper Lake Hydroelectric Project (Project), Federal Energy Regulatory Commission (FERC) Project No. 2170, is owned and operated by Chugach Electric Association, Inc. (Chugach). Located near Cooper Landing on the Kenai Peninsula, the Project provides power in southcentral Alaska as part of Chugach's electric generation and transmission system. The Project was originally licensed by FERC in May 1957, and the current license term expires at the end of April 2007.

The purpose of the study described in this report is to evaluate risk factors for fish entrainment at the Project. Questions regarding the possibility that rainbow trout and Arctic char may be entrained into the Project's generation water intake in Cooper Lake and passed through the powerhouse turbines were raised as a resource issue during development of the relicensing studies program. To address this issue, Chugach proposed an analysis of risk factors related to entrainment, and after further consultation with agencies, added field measurements to the study plan, to obtain site-specific information.

This report describes literature review and field studies conducted according to the Preliminary Evaluation of Entrainment in Cooper Lake Final 2003 Study Plan (April 2003). To the extent that study activities deviated from the study plan, these modifications are described in the relevant sections of this report. The review of existing information contained in this report was conducted by Long View Associates, Inc., in summer and fall 2003. The field studies were conducted by Northern Ecological Services and B.E.S.T. Resource during the period of May through November 2003.

This report provides a qualitative assessment of the potential for entrainment at the Project. The findings from this analysis will be considered together with information being developed on the current status of rainbow trout and Arctic char populations in Cooper Lake to evaluate the overall significance to these populations of any entrainment that may be occurring at the Project intake.

2.0 PROJECT DESCRIPTION

2.1 Project Setting and Facilities

The Project facilities pertinent to this entrainment risk evaluation are located within the Kenai Peninsula Borough, southcentral Alaska, approximately 55 miles south of Anchorage.¹ The

¹ The Project transmission line between the Quartz Creek substation (near Cooper Landing) and Anchorage crosses land located in both the Kenai Peninsula and Anchorage boroughs.

closest community to the Project dam and powerhouse is Cooper Landing, approximately 4 miles north of Cooper Lake Dam. Project facilities are located on Cooper Creek, Cooper Lake, and Kenai Lake.

Cooper Lake Dam was constructed on Cooper Creek, approximately 4.3 river miles from the mouth of the creek at the outlet of Cooper Lake, raising the natural elevation of Cooper Lake. Storage below the base of the dam is provided by the natural lake. The reservoir created by the dam covers approximately 2,900 acres and has a mean depth of 187 feet. The maximum normal operating elevation of Cooper Lake is 1,194 feet above mean sea level (MSL).

The Project diverts water at the intake on Cooper Lake through the tunnel/penstock to the powerhouse on Kenai Lake. The Project powerhouse is located on the southwest shore of Kenai Lake, approximately 7 miles from the outlet of the lake. Cooper Creek and Kenai Lake both flow into the Kenai River. Approximately 1/4 mile below the dam is a series of natural barrier falls (impassable to fish), each 10–40 feet in height, with a combined total vertical drop of approximately 160 feet. These barrier falls historically prevented anadromous fish from reaching Cooper Lake.

The primary Project components that factor into the entrainment analysis are briefly described below.

2.1.1 Intake and Intake Channel

The intake structure is located on the eastern shore of Cooper Lake, approximately 5 miles from the dam. The intake has two openings, separated from each other by a 3-foot-wide divider. Each intake opening is 10.5 feet wide and 11.5 feet high. The invert (bottom of the opening) for the tunnel intake is at elevation 1,151 feet MSL. The intake structure has a sloping upstream face with removable trashracks. The intake leads to an 11-foot-diameter horseshoe-shaped tunnel, which can be closed off for inspection or maintenance by lowering a steel slide gate at the intake structure.

There is no low-level outlet at the dam; all outflow from Cooper Lake is withdrawn through the generation water intake. The intake can be used to drain the reservoir to a level approximately 17 feet below the base of the dam.

Based on recent measurements, the channel leading to the intake opening is approximately 50 feet long. The channel width at the surface and varies from about 60 feet wide at the intake structure to about 160 feet wide where it intersects the reservoir shoreline. The sides of the channel slope irregularly inward toward the center of the channel, and at the bottom of the channel ranges from about 15 to 20 feet wide. The channel depth, for example, at a reservoir elevation of 1,188 feet MSL, is generally in the 30–35 feet range. (Project survey drawings were not used to describe the intake channel bathymetry as planned [see study plan], because the channel is occasionally dredged and because measurements of the existing depth profile were taken during the field studies.)

2.1.2 Tunnel/Penstock System

Cooper Lake water drawn into the intake enters a nearly horizontal tunnel connected to a penstock that provides generation flows to the powerhouse on Kenai Lake. The tunnel is 4,797 feet long from the intake gate shaft to the downstream portal structure. The majority of the tunnel length is unlined and is approximately 12 feet in diameter. At the downstream portal, the tunnel is 11 feet in diameter and steel lined and bifurcates into two 7-foot-diameter steel branches. Just downstream of the bifurcation, there is an 84-inch butterfly valve on the main branch of the penstock. The other branch is blocked off with a dished head. The branch of the penstock extending to the powerhouse is 5,890 feet long and is buried.

2.1.3 Powerhouse and Tailrace

The penstock ends at the Cooper Lake Powerhouse, located on the southwest shore of Kenai Lake. Inside the powerhouse, the water is diverted to either or both of two vertical-shaft Francis turbine/generator units, each rated 9.69 MW. The powerhouse tailrace discharges directly into Kenai Lake. The tailwater elevation is the water surface level of Kenai Lake (normal elevation of 436 MSL).

2.2 Project Operations

2.2.1 General Description of Project Operations

The Project raises the level of the naturally occurring lake to provide additional storage and increased head for power generation. All inflow to Cooper Lake is diverted from the intake structure through the tunnel/penstock and to the powerhouse on Kenai Lake. The net elevation drop between the intake and powerhouse is approximately 750 feet. The powerhouse typically operates 10 to 12 hours each day, but daily generation patterns vary widely. A generally typical day would result in operation approximately as depicted in Table 1; however, a number of factors can affect the operation. Peak hours are normally fairly constant, but the partially loaded hours may be affected by a number of system requirements.

Table 1. Typical operational day for the Cooper Lake Project powerhouse.

Time	Load Condition	Approximate Output (MW)	Approximate Discharge (cfs)
6:00 A.M. to 9:00 A.M.	Fully loaded – morning peak	19.6	380
9:00 A.M. to 4:00 P.M.	Partially loaded – carrying spin	4	75
4:00 P.M. to 7:00 P.M.	Fully loaded – evening peak	19.6	380
7:00 P.M. to midnight	Partially loaded – carrying spin	4	75
Midnight to 6:00 A.M.	Shut Down	0	0

Average annual generation is approximately 50,500 MWh. Average outflow through the powerhouse is approximately 100 cubic feet per second (cfs), based on the average annual inflow to the reservoir (72,500 acre-feet/year). Maximum powerhouse discharge at any time is 380 cfs,

and the minimum discharge is 0 cfs. Figure 1 shows a flow-duration curve for powerhouse discharge, based on hourly powerhouse flow data for 2002–2003. This figure depicts the percentage of time that a given volume of discharge occurred at the powerhouse during that time period.

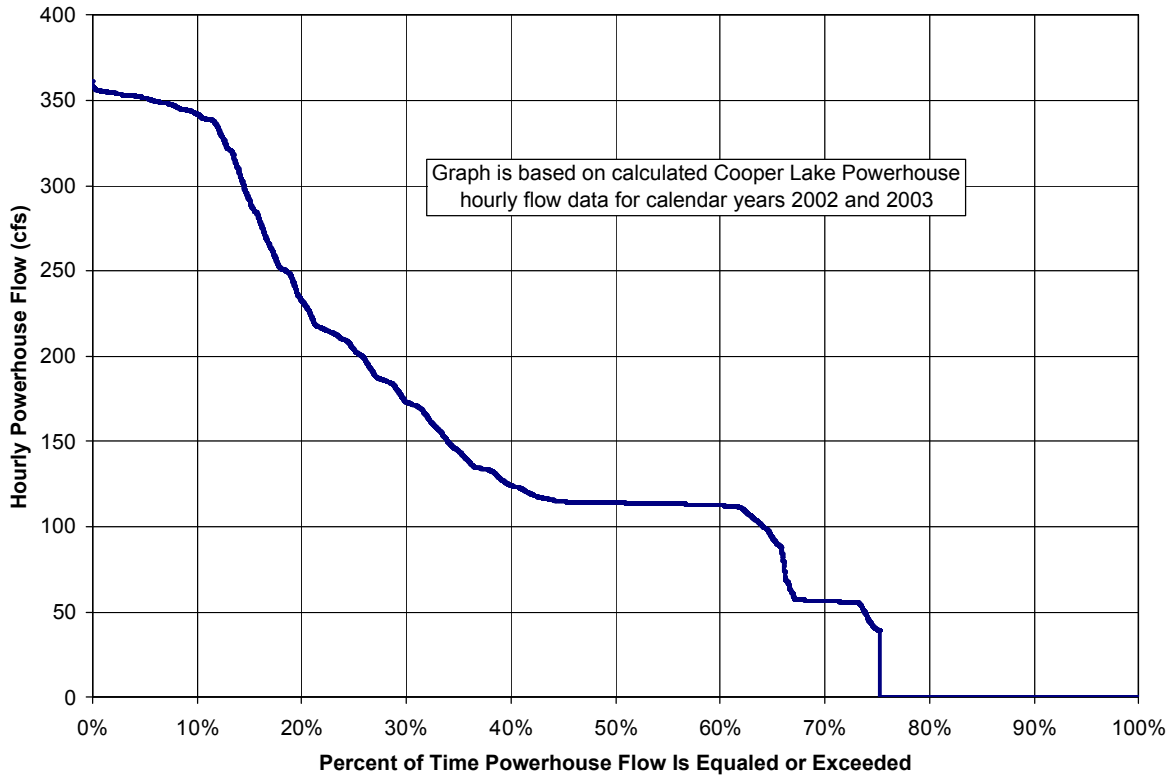


Figure 1. Cooper Lake Powerhouse flow duration curve (2002–2003).

2.2.2 Reservoir Operations

Power generated by the Project is dispatched according to system need, which varies relatively little on a seasonal basis. The reservoir typically is drawn down during late fall through early spring, experiences its most rapid refilling during the period of late spring and summer snowmelt runoff, and continues to fill through early fall. Thus, reservoir levels are typically at their lowest in April–May and at their highest in August–October. Within any given year, the reservoir typically fluctuates (on average) within a zone of about 15 feet. The water level typically varies 1 to 2 feet within any month, with a maximum monthly variation of about 8 feet. The absolute range of reservoir operations varies from year to year, but generally remains within a relatively consistent band of about 15 feet.

3.0 GENERAL STUDY APPROACH AND METHODS

This assessment of entrainment potential at the Project is based on review of existing information and evaluation of site-specific data. The existing information considered for this evaluation includes the following:

- Project engineering information regarding the physical characteristics of the intake, including depth and dimensions of the intake opening.
- Information on power generation and reservoir operations for Cooper Lake.
- Scientific literature regarding life history, habitat preferences, and other characteristics of rainbow trout and Arctic char.
- Pre-Project and more recent reports and agency documents characterizing fish populations in Cooper Lake.
- Documented observations of the characteristics of the shoreline and substrate in the vicinity of the intake.
- Documented observations of fish presence and spawning locations in Cooper Lake.
- Published analyses quantifying entrainment risk factors associated with comparable hydroelectric facilities.

Relevant site-specific information developed in conjunction with other relicensing studies is also incorporated into this entrainment risk evaluation. This information includes preliminary population estimates developed from tagging/recapture studies of the Arctic char and rainbow trout populations in the reservoir, and systematic identification of spawning areas in the reservoir and its tributaries.

In addition to the review of existing information and use of information from related studies, site-specific field data were obtained for this study. Specifically, flow velocities were measured near the intake while the Project was operating at near maximum generation (336–341 cfs) and at an intermediate level of generation (86–107 cfs). The purpose of the velocity measurements was to define the zone in which withdrawal through the intake could be affecting fish. In addition, seasonal underwater observations were made of fish presence in the vicinity of the intake. Methods for these field studies are described in sections 5.1.3 and 5.1.5 of this report, and the velocity measurement methods are described in detail in Appendix A.

Together, the existing information and field data are used as the basis for analyzing known risk factors to make a qualitative assessment of the potential for entrainment at the Project for both species of interest.

Finally, the survival potential for any fish entrained into the Project intake is briefly evaluated. This evaluation relies on relevant findings from published, quantitative analyses of other hydropower projects.

4.0 FISH POPULATIONS AND MANAGEMENT SPECIES IN COOPER LAKE

4.1 Cooper Lake Fish Populations

Cooper Lake supports naturally reproducing populations of Arctic char, rainbow trout, and slimy sculpin. Of these three species, Arctic char and rainbow trout have been identified by relicensing participants as species of interest for management purposes. Therefore, this entrainment analysis focuses on these two species.

The Arctic char and slimy sculpin currently present in the reservoir are believed to be native to Cooper Lake. Other species that have been documented or reported in Cooper Lake have been introduced, such as through stocking programs conducted by ADFG. Fish stocking programs were conducted in Cooper Lake at least as early as 1984, and possibly earlier, but were evidently discontinued after 1994. Stocking efforts have included rainbow trout and chinook salmon, and possibly other species, including whitefish, lake trout, and burbot (Lazar and Van Hatten 1994). However, results of sampling conducted in Cooper Lake during the past several years indicate that, of the previously stocked species, only rainbow trout are still present in the reservoir.

Chinook salmon is one of the previously stocked species of which there are no remaining individuals or progeny in Cooper Lake. In 1984, approximately 125,600 chinook salmon fry were stocked in Cooper Lake (Nelson 1985a) (a density of approximately 65 fry per acre). Shortly after this stocking effort, intensive sampling was conducted to measure growth rates of these fish and study their migration patterns within the lake; capture rates were low, but the fish captured exhibited good growth rates (Nelson 1985a, 1985b). Subsequent sampling has not located any surviving chinook salmon, and it has been speculated that the fingerlings of this anadromous species may have sought a downstream outlet from the reservoir through the intake tunnels in an attempt to migrate downstream (Dean 2002).

Fish species that are present or have reportedly been present in Cooper Lake, based on historical records or agency reports referencing stocking in the reservoir, are listed in Table 2. The Cooper Lake Arctic char and rainbow trout populations are discussed in more detail below.

Table 2. Fish species currently present and/or reportedly present historically in Cooper Lake.

Species (Common Name)	Species (Scientific Name)	Presumed Origin	Confirmed Population in Cooper Lake as of 2002
Arctic char	<i>Salvelinus alpinus taranetzi</i>	Native	Yes
Rainbow trout	<i>Oncorhynchus mykiss</i>	Introduced	Yes
Slimy sculpin ²	<i>Leptocottus armatus</i>	Native	Yes
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	Introduced	No
Burbot	<i>Lota lota</i>	Introduced	No
Grayling	<i>Thymallus arcticus (Pallus)</i>	Introduced	No
Lake trout	<i>Salvelinus namaycush</i>	Introduced	No

² The species of sculpin in Cooper Lake was originally thought to be Coastrange sculpin; however more recently it has been suggested that the sculpin are most likely slimy sculpin.

4.2 Characteristics of Management Species

4.2.1 Arctic Char

4.2.1.1 General

Arctic char are a typically non-anadromous, primarily lake-dwelling salmonid (although some anadromous populations of Arctic char exist). Arctic char have a circumpolar distribution in the northern hemisphere and occur farther north than other species of freshwater fish. Of the five recognized subspecies, *Salvelinus alpinus taranetzi* is most likely the variety found in southcentral Alaska (Dean 2002).

Arctic char often exist in two or more different morphologic forms in the same lake. Two general forms are described as “dwarf” and “normal,” both of which may occur in Cooper Lake. The different morphologic forms show differences in habitat and food selection, resulting in different growth rates, size at maturity, and average size. The two morphological types may spawn in different locations, but may also interbreed and are commonly from the same gene pool (Nordeng 1983, cited in Willson 1997). Studies of two forms of landlocked Arctic char in Norway indicate that in those lakes, the dwarf char are bottom feeders in the littoral zone whereas the normal form predominantly occupies a pelagic niche (Klemetsen and Otsbye 1967; Klemetsen *et al.* 1972; and Klemetsen and Grotnes 1975, cited in Balon 1980).

Dean (2002) notes that the ability of Arctic char to develop alternate morphologies is a successful strategy for utilizing available habitats and food resources of nutrient poor coldwater lakes. Large, deep lakes such as Cooper Lake offer the best conditions for more than one form of a single char species. Arctic char’s greater preference for cold water relative to other species results in “niche compression” with Arctic char typically occupying deeper waters.

Arctic char are generally considered to be lake spawners. After reaching sexual maturity at an age of 6 to 9 years, Arctic char may spawn every other year. Spawning typically occurs from August through October, probably over steep, broken substrates or gravel shoals at sufficient depth to be protected from winter ice. In some lakes, prespawning Arctic char congregate near inlet streams or waterways connecting lakes, but move back into the lake to spawn. Growth and maximum size may vary greatly, depending on the productivity of the particular lake and the presence of other fish species. Arctic char over 10 pounds are not uncommon in some Alaska lakes, while other lakes may not produce Arctic char over 2 pounds even though the fish may reach great age (DeCicco 1994).

4.2.1.2 Cooper Lake Population

Dolly Varden were identified in Cooper Lake before construction of the Project (e.g., McKernan 1956). However, it is now generally accepted that the char reported in the lake were misidentified as Dolly Varden until 2000, when genetic testing confirmed them to be Arctic char (which bear a close resemblance to Dolly Varden). Arctic char are assumed to be native to Cooper Lake based on the fact that there are no records of ADFG stocking of this species in this lake, and because Arctic char were identified in nearby Char Lake well before ADFG bred this

species at any of the State fish hatcheries, beginning in the 1980s (J. Dean, retired USFWS biologist, personal communication, as cited in Chugach 2002).

Surveys conducted periodically in Cooper Lake by ADFG (primarily using gill nets and minnow traps) between 1973 and 2001 documented the presence of char in most years (Winter and Williams 1992; Lazar and Van Hatten 1994; ADFG fish sampling data sheets; Rappoport 2000; J. Dean, retired USFWS biologist, personal communication, cited in Chugach 2002). The char captured in the ADFG surveys generally ranged from about 50 mm to 500 mm in length (ADFG fish sampling data sheets) and were captured at depths of up to 200 feet (J. Dean, retired USFWS biologist, personal communication, Chugach 2002).

Research conducted since 1999 has indicated the possibility of two distinct types of Arctic char in Cooper Lake — a “dwarf” variety and a “normal” variety; in addition, within the “normal” morphological type there are two distinct color phases. Although they differ morphologically, genetic testing has indicated that the two morphological types of Arctic char are indistinguishable on a genetic basis. The dwarf variety has not been identified anywhere else in southcentral Alaska (J. Dean, personal communication, as cited in Chugach 2002).

As part of its relicensing studies program, Chugach is conducting research in Cooper Lake to develop information regarding Arctic char in the reservoir. Analysis of data from 2002 and 2003 tagging/recapture efforts that are part of this research has provided a preliminary population estimate of 109,000 larger-size Arctic char in the reservoir (estimate includes only fish at least 180 mm in length (Northern Ecological Services and HDR 2004).

Trap netting and radiotracking data from this study indicate that Cooper Lake Arctic char ≥ 180 mm spend much time at depths of less than 40 feet throughout the open-water season, and Arctic char of all size classes have been observed to occupy shoal-type habitats along the shoreline (at shallow depths down to approximately 10 feet) during this season. However, Arctic char have been captured at depths of up to 210 feet in this reservoir (Northern Ecological Services and HDR 2004; ADFG fish sampling data sheets). Observations and capture data for 2003 also indicate that Arctic char are more abundant in the northern portion of the reservoir than in the southern portion (Northern Ecological Services and HDR 2004).

The field surveys for this study are also intended to provide information on the depth and location of Arctic char spawning areas in Cooper Lake. Observations in October and November 2002 identified two definite Arctic char spawning areas in Cooper Lake, one of which was within the excavated channel immediately in front of the Project intake structure. Using underwater video camera equipment, researchers observed Arctic char exhibiting spawning behavior at mounds of gravel and rubble present in the intake channel. The fish were observed at a variety of depths from near the intake trashrack to the outer edges of the excavated channel area. Observations of suspected spawning behavior extended from the trash boom (about 15 feet from the face of the intake structure) outward for about 100 feet. Observations in 2003 using a remotely operated vehicle in conjunction with radiotelemetry also indicated the presence of at least ten spawning areas in addition to the one near the intake. Spawning by Arctic char in the intake channel was again observed in October and November 2003, through underwater videography, scuba diving survey, and radiotelemetry conducted as part of the Cooper Lake Fish Resources Study. Timing of spawning of Arctic char in Cooper Lake appears to be consistent with typical spawning behavior for this species. Spawning by Arctic char in Cooper Lake

typically occurs in the late fall, when the reservoir is at its highest stage, and incubation occurs over the winter as the reservoir level recedes.

4.2.2 Rainbow Trout

4.2.2.1 General

Rainbow trout are a freshwater salmonid and are found in a variety of settings, including lakes, rivers, and streams. They typically spawn in smaller tributaries, in shallow riffles with small gravel substrate. They do not spawn successfully on beaches of lakes (Scott and Crossman 1973). The typical spawning period for rainbow trout is from about mid-April to late June (Lindsey et al. 1959, Hartman et al. 1962).

The name “rainbow trout” is used for the non-anadromous life history of *O. mykiss*, while the name “steelhead” refers to the anadromous life history of this species. Anadromous forms of the trout can convert to resident populations when conditions (such as drought or blockage to ocean access) make this change favorable for continued survival. Conversely, resident trout populations can become anadromous if local food sources are limiting survival and ocean access becomes available (McEwan and Jackson 1996).

Hatching normally takes place from a few weeks to as much as four months after spawning, depending upon the water temperature. A few more weeks may be required for the fry to emerge from the gravel. Upon emergence, the fry assemble in groups and seek shelter along the stream margins or protected lakeshore areas, feeding on crustaceans, plant material, and aquatic insects and their larvae. Rainbow trout rear in this type of habitat for the first two or three years then move into deeper water of lakes and streams. Adult rainbow trout most often feed at or near the water surface, and mainly target insects, but also feed on plankton, fish eggs, small fish, and crustaceans (ADFG 2003).

Rainbow trout are native to the Kenai River and its tributaries. The upper Kenai River supports a major segment of the basin’s trout population. Rainbow trout spawning occurs in the spring in this system and has been documented in the mainstem Kenai River between Skilak and Kenai lakes, and at the outlet of Skilak Lake. Reproducing populations of rainbow trout also occur in the drainages of Beaver Creek, Soldotna Creek, Moose River, Russian River, and streams tributary to Kenai and Trail lakes (ADNR 1998).

4.2.2.2 Cooper Lake Population

Available records of pre-Project Cooper Lake and subsequent records documenting fisheries resources in the reservoir after construction of the dam do not conclusively indicate the presence of native rainbow trout. Edwards (1940) noted a lack of rainbow trout in Cooper Lake and attributed the absence of this species to the fact that passage into the lake from the Kenai River system was blocked by the large barrier falls in Cooper Creek. The rainbow trout population currently in the reservoir is assumed to have originated from past hatchery stocking programs.

There is no record of when rainbow trout stocking began in Cooper Lake, although stocking is known to have occurred between 1987 and 1994 (Lazar and Van Hatten 1994). Beginning in

1989, a five-year stocking plan was developed that called for the annual stocking of about 250,000 fingerling-size rainbow trout in the reservoir; however, ADFG discontinued stocking in Cooper Lake after 1994 because of the generally low rate of survival of rainbow trout and minimal sport fishing activity in the reservoir (USFS 1995).

ADFG fish surveys in Cooper Lake (conducted during various years between 1973 and 2001) documented the presence of rainbow trout in the reservoir at least as early as 1990. Numbers captured most years were low relative to numbers of Arctic char captured; however, during the August 1994 survey, nearly all (75 of 77) of the fish captured were rainbow trout. The reason for the significantly greater proportion of rainbow trout in this catch compared to the catch for previous years was not clear (Lazar and Van Hatten 1994). Rainbow trout captured during the surveys ranged from about 40 mm to 390 mm in length.

Although apparently of hatchery origin, the rainbow trout population in Cooper Lake now reproduces naturally, rearing in the reservoir and migrating to tributary streams for spawning. This population of rainbow trout is estimated to number approximately 6,000 (≥ 180 mm), based on 2002 and 2003 tagging/recapture data (Northern Ecological Services and HDR 2004).

During late spring 2000, approximately 45 rainbow trout were observed spawning in a tributary on the southwest end of Cooper Lake (Blanchet 2000). Surveys conducted in 2002 and 2003 as part of the Cooper Lake Fish Resources Study confirmed the presence of tributary spawning by rainbow trout during the late-May to mid-June timeframe, and documented spawning locations. Findings to date indicate that most rainbow trout spawning occurs in a tributary at the southwest end of Cooper Lake, approximately 1.5–2 miles from the intake structure. One tributary to the reservoir (SE-1) is in the general vicinity (within approximately 1/4 mile) of the intake, and spawning surveys in 2003 indicated that a small tributary to this stream is used at least in some years for spawning by rainbow trout.

Time of emergence of rainbow trout fry from the spawning gravels most likely varies from year to year, but has been observed to occur as early as mid-July and may extend from mid-July to mid-August. Some trout probably stay in the tributaries for years after emergence, while others move into the reservoir at varying ages. Age 0+ fry probably do not enter the reservoir until at least late summer (J. Morsell, personal communication 2004).

Observations and surveys during 2003 found that rainbow trout make extensive use of the littoral zone habitat (particularly the fluctuation zone) along the reservoir shoreline, including rearing for juveniles. Very small fry (< 45 mm) were not observed in the reservoir, and sampling conducted using a fine-mesh beach seine in early August 2003 did not catch any rainbow trout. However, fry in the 45–50 mm length range were captured in the trap nets throughout the summer, indicating that some small age 1+ rainbow trout are present in the shoreline areas during the open-water season (J. Morsell, personal communication 2004).

Rainbow trout have also been observed at depths somewhat greater than the immediate shoreline area in Cooper Lake. During observations at the intake channel in October 2002, one rainbow trout was observed near the intake, and two others also were observed at similar depths (approximately 20–30 feet) at other locations in the reservoir (Morsell 2003). During 2003, two

rainbow trout were captured in a gill net set at a depth of approximately 95 feet; these were the only rainbow trout captured in deep water.

5.0 COOPER LAKE PROJECT ENTRAINMENT ASSESSMENT

The following general assessment for entrainment risk at the Project focuses on rainbow trout and Arctic char, which, as noted above, have been identified by relicensing participants as the management species of interest in Cooper Lake. The assessment draws from a review of risk factors considered by the Electric Power Research Institute (EPRI 1997) and subsequent analysis by Winchell et al. (2000). The EPRI review considered data from over 100 hydropower projects over the past decade and compiled the data from 43 of those projects into a database for assessing fish entrainment risk and survival probabilities. Identified risk factors for entrainment include the following:

- Location of the intake relative to the shoreline and littoral zone (taking into consideration intake depth and reservoir operations).
- Substrate/habitat conditions in the vicinity of the intake.
- Habitat use and distribution of fish in the reservoir.
- Hydraulic capacity of the intake.
- Approach velocities in the vicinity of the intake.
- Water quality (e.g., temperature and dissolved oxygen) with depth in the reservoir.

Existing site-specific data from the Cooper Lake Project does not lend itself to the sort of predictive modeling that the EPRI database may be used for in other cases. However, trends identified through development of the database provide a useful benchmark for assessing risk factors at the Project.

In the following subsections, entrainment risk factors at the Cooper Lake Project are characterized based on existing information (literature review, Project engineering drawings, etc.) along with information from field data collection conducted to date for relicensing studies. Based on these characteristics, the presence or absence of each identified risk factor is determined, and a qualitative assessment is made of the overall risk of entrainment to each of the two species of interest in Cooper Lake.

5.1 Characterization and Analysis of Entrainment Risk Factors at the Cooper Lake Project

5.1.1 Location of the Intake Relative to the Shoreline and Littoral Zone

5.1.1.1 Characteristics

The littoral zone comprises the shallow marginal area of a lake or reservoir, and is generally defined as the portion of the shoreline area that is less than 15 feet in depth. The littoral zone is

typically where the majority of the aquatic plants and invertebrates are found and therefore is a primary area used by young fish of many species. For some fish species, the littoral zone also provides essential spawning habitat. Given the importance of the littoral zone as fish habitat, the location of the intake relative to the littoral zone is an important entrainment risk factor to consider.

The Project intake structure is located adjacent to the shoreline of Cooper Lake, and at some reservoir levels the intake is within the range of depths that can be considered to be in the littoral zone. The maximum normal operating elevation of the reservoir is 1,194 feet MSL, and the reservoir level generally has been maintained above about 1,170 feet MSL. The invert of the intake opening is located at 1,151 feet MSL (43 feet below the maximum normal operating level and 19 feet below the normal minimum operating level), and the top of the opening is approximately 11 feet higher, at 1,162 feet MSL (32 feet below the maximum normal operating level and 8 feet above the normal minimum operating level).

5.1.1.2 Analysis

Based on the above considerations, the Cooper Lake Project intake is located within the littoral zone of the reservoir in some years, during periods when the reservoir is drawn down below about 1,177 feet MSL. The depth of the intake relative to the water surface is the least during the April–May period of maximum annual drawdown.

Of the two species of interest in this analysis, rainbow trout can be considered to be primarily a littoral zone species, making extensive use of the reservoir shoreline for rearing and generally not frequenting deeper zones in the reservoir in significant numbers; however, they have been observed at depths of up to about 30 feet in Cooper Lake, including in the immediate vicinity of the intake. Arctic char of all lifestages also appear to use the littoral zone for feeding, but unlike rainbow trout, they are present in significant numbers in deeper portions of the reservoir, as well.

Based on these general characteristics, the location of the intake relative to the littoral zone represents an entrainment risk for Arctic char at all reservoir levels. The intake location also represents a risk for rainbow trout, particularly at certain reservoir levels within the normal range of operations; however the risk is probably lower than for Arctic char, based on observations that rainbow trout do not appear to be present in great numbers below the shallower shoreline areas.

5.1.2 Substrate/Habitat Conditions in the Vicinity of the Intake

5.1.2.1 Characteristics

The littoral zone of Cooper Lake consists of three primary habitat categories: 1) stream/lake interface (productive fish usage); 2) wetland/marshy habitat (primarily at the south end of the reservoir); and 3) rocky steep slope habitat (comprises much of the reservoir shoreline area) (HDR 2003). The habitat in vicinity of the intake generally fits into the third category of rocky steep slope, which, of the three habitat types, as a function of its steepness provides the narrowest zone along the shoreline for food productivity in terms macroinvertebrate density.

In the intake channel itself, substrate characteristics are unique to this location. The intake channel was excavated from bedrock, and the current substrate conditions reflect both the excavation process and subsequent deposition of fine sediments, woody debris, and other organics. The bedrock sidewalls of the channel are nearly vertical with some jagged irregularities. Based on observations in October 2002 (J. Morsell, personal communication 2003), the bottom substrate within the excavated portion of the channel consists primarily of angular rock rubble ranging from gravel size to boulder size. The rubble is irregularly distributed in piles and banked along the margins. At the time of the observations in October 2002, a thin film of deposited fine sediment covered most of the rubble area. Large woody debris was observed to have accumulated immediately in front of the intake trashracks, and leaves and other organic materials were present between rubble piles. This type of debris routinely accumulates over time in the intake channel and is removed periodically for maintenance purposes.³ With distance from the excavated channel, the rubble becomes sparser and is gradually replaced by a featureless silt substrate with some bacterial growth (J. Morsell, personal communication 2003; Chugach 2001).

5.1.2.2 Analysis

Based on its characteristic steepness, the substrate along the shoreline in the vicinity of the intake would provide a relatively limited zone of food production compared with other types of shoreline habitat in the reservoir. This conclusion is consistent with capture data from the Cooper Lake Fish Resources Study, which suggest that rainbow trout are not particularly attracted to the shoreline zone in the vicinity of the intake structure. In addition, because they are stream spawners, the shoreline habitat does not serve as spawning habitat for rainbow trout. Therefore, the substrate/habitat conditions at the location of the intake do not represent a significant entrainment risk for rainbow trout.

The shoreline substrate in the vicinity of the intake channel also would not be expected to provide a particularly attractive area for Arctic char feeding, relative to other areas of the reservoir. However, Arctic char appear to find the construction rubble in the intake channel highly suitable for spawning. As noted above, this location has been the site of substantial spawning activity during 2002 and 2003 spawning surveys. Therefore, substrate/habitat conditions near the intake represent a risk of entrainment for Arctic char.

5.1.3 *Distribution and Habitat Use of Fish Species of Interest*

5.1.3.1 Characteristics

General Distribution and Abundance

As discussed above, rainbow trout in the reservoir primarily utilize the littoral zone habitat along the shoreline and migrate into tributaries (mostly at the southwest end of the reservoir) to spawn. Fry begin emerging from the spawning gravels by about mid-July, but likely remain in the

³ The intake channel was most recently cleared in September 2003; the sediment and woody debris in the channel were cleared from the intake channel using a suction dredge and were then re-deposited further out in the reservoir (B. Wick, Plant O&M Supervisor, Chugach, personal communication 2003).

tributaries for most of their first summer. Some fry may enter the reservoir late in their first year while others may stay in tributary streams for several years. By contrast, Arctic char of all size classes in Cooper Lake make extensive use of the littoral zone of the reservoir but also utilize deeper portions of the reservoir (to depths of up to 210 feet, based on available capture data), including for spawning. Preliminary population estimates from 2002/2003 mark-recapture data indicate the Cooper Lake Arctic char population is significantly larger than the rainbow trout population (approximately 109,000 Arctic char vs. approximately 6,000 rainbow trout). Arctic char spawning was observed to occur within the intake channel during both the 2002 and the 2003 spawning seasons. In addition, at least ten other spawning areas have been identified throughout the reservoir during the 2002/2003 field studies.

Observations at the Intake

The excavated channel in front of the intake openings was identified as a spawning area for Arctic char in 2002 (Morsell 2003). To further evaluate the presence of fish near the intake, a series of visual observations were made in 2003 using direct observation by SCUBA diving and/or underwater videography. Observations of the intake channel were conducted with the aid of a remotely operated underwater vehicle (ROV) on May 28, July 30, October 1, and November 5. On the latter two dates a diver survey was also conducted following the ROV survey.⁴

The ROV surveys consisted of several passes along the length of the channel from the intake trashracks outward for about 75 feet. Generally both sides of the excavated channel were observed, along with the shelf immediately above the vertical walls that mark the outer edge of the excavated area. Underwater conditions (including fish presence) were observed by the ROV operator on a monitor screen. The observation sessions were recorded on videotape, and the videotapes were reviewed after each session to confirm operator observations. Dive surveys were conducted by a single diver and covered approximately the same area as the ROV surveys.

No fish were observed in the survey area during the May, July, or October 2003 observation sessions. However, the November 5 observations confirmed the use of the intake channel as a spawning area for Arctic char. Approximately 40 sexually mature Arctic char were present in the intake channel area on this date (based on visual estimate during the dive survey), and the observations confirmed the use of the channel as a spawning area for these fish. One pair of char had established a spawning territory on the bottom of the channel about 8 feet from the intake trashracks. Most of the spawning areas were located 20–40 feet from the intake on gravel and rubble slopes at the sides of the intake channel. The depth of these locations on November 5 ranged from 32 feet to 38 feet. A few char were spawning on the shelf just over the edge of the channel wall at a depth of about 12 feet.

In addition to the Arctic char, one adult rainbow trout was observed in the intake channel during the November 5 observation session. No spawning behavior was exhibited by this fish. Incidental observations over the course of the Cooper Lake Fish Resources Study indicate that rainbow trout also are at least occasionally present in the immediate vicinity of the intake during

⁴ During the October 1 survey period, water in Cooper Lake was turbid from glacial melt and visibility was limited to about 5 feet. Water clarity was better during the other survey periods and ranged from 10–40 feet. Diver observations were similar to observations made using the ROV monitor, which suggested that the use of the ROV for observations in the defined area of the intake channel was a reasonable technique.

summer months. In mid-summer 2003, anglers were observed catching rainbow trout from the intake area, and two juvenile rainbow trout were observed from the surface at this location.

No juvenile fish were observed near the intake on November 5, 2003.

5.1.3.2 Analysis

Observations to date suggest that rainbow trout are not present in large numbers at the depth or location of the intake in Cooper Lake. As discussed above, rainbow trout would generally not be expected to make extensive use of the area in front of intake at times when the reservoir elevation is higher than approximately 1,177 feet MSL (15 feet above the top of the intake opening). More importantly, rainbow trout appear to spawn exclusively in the tributaries to Cooper Lake, and thus the smallest juveniles would not be present in the reservoir until after emergence from the gravel and initial rearing period within the tributaries. Rainbow trout as small as age 1+ fry have been observed in Cooper Lake, but only in the shallowest shoreline areas. There is no evidence (nor would there be any reason to expect) that Cooper Lake rainbow trout are actively seeking a downstream outlet. Considering these factors, it can be concluded that rainbow trout in Cooper Lake are at relatively low risk of becoming entrained during any lifestage.

Arctic char are more abundant in Cooper Lake than are rainbow trout, are present in large numbers in the littoral zone throughout the open-water season, and significant numbers have been documented at the depth and location of the intake. Spawning has been observed to occur as close as about 15 feet from the intake, in the coarse substrate within the intake channel. Therefore, Arctic char (in particular, fry emerging from the spawning redds near the intake) may be susceptible to entrainment.

As described in the study plan, the intent was to make observations at full powerhouse flow when significant numbers of fish were present in the intake channel, with the primary purpose of observing how the flows affected the behavior of small fish. However, small fish were not observed in the channel and the powerhouse was not operating at the time of the October 2002 or November 5, 2003, observations. It is possible that flows would have affected the large Arctic char spawners and rainbow trout that were present in the channel during the observations. Based on calculations and measurements of approach and intake velocities, however, this is very unlikely (see sections 5.1.4 and 5.1.5, below).

5.1.4 Hydraulic Capacity and Entrance Velocity of the Intake

5.1.4.1 Characteristics

The maximum hydraulic capacity of the intake, tunnel/penstock, and powerhouse is 380 cubic feet per second (cfs); this flow rate is achieved when the powerhouse is operated with both turbines generating at full load and with the reservoir at the normal maximum operating elevation of 1,194 feet MSL. However, flows through this system are often much lower than the maximum hydraulic capacity (down to 0 cfs during times when the powerhouse is not operating); average annual discharge through the powerhouse is approximately 100 cfs.

For evaluation of potential fish entrainment into the intake tunnel, the velocity at the intake was calculated for the situation in which the powerhouse is operating at full capacity. In this situation, the maximum velocity at the face of the intake entrance (trashracks) is calculated to be 1.57 feet per second (fps), as follows:

$$380 \text{ cfs} \div (10.5 \text{ feet} \times 11.5 \text{ feet} \times 2) = 1.57 \text{ fps}$$

For comparison, operation at a generation flow of 100 cfs corresponds to a calculated water velocity at the intake entrance of 0.41 fps, as follows:

$$100 \text{ cfs} \div (10.5 \text{ feet} \times 11.5 \text{ feet} \times 2) = 0.41 \text{ fps}$$

5.1.4.2 Analysis

As a point of reference, the NOAA Fisheries juvenile fish screening criteria for salmonid fry (<60 mm) specify a maximum velocity of ≤ 0.4 fps perpendicular to a screen. This velocity criterion takes into consideration the swimming ability of salmonid fry and is intended to ensure that fry can swim away from the screen. Similarly, the NOAA Fisheries juvenile fish screening criteria for salmonid fingerlings (≥ 60 mm in length) specify a maximum velocity perpendicular to the screen of ≤ 0.8 fps.

The velocity at the intake entrance at the average annual powerhouse flow (100 cfs) is approximately the same as the NOAA fry screening criterion. Thus, although the NOAA Fisheries screening criteria were not developed for this type of analysis, it can be concluded that at average or below-average powerhouse generation flows, Arctic char juveniles (fry and fingerlings) at the entrance of the intake would be able to swim away from the entrance without becoming entrained. At powerhouse flows greater than 100 cfs, however, the flow velocity directly at the intake entrance may exceed the swimming ability of Arctic char juveniles, thus creating the potential for entrainment at these powerhouse flows.

5.1.5 Approach Velocity

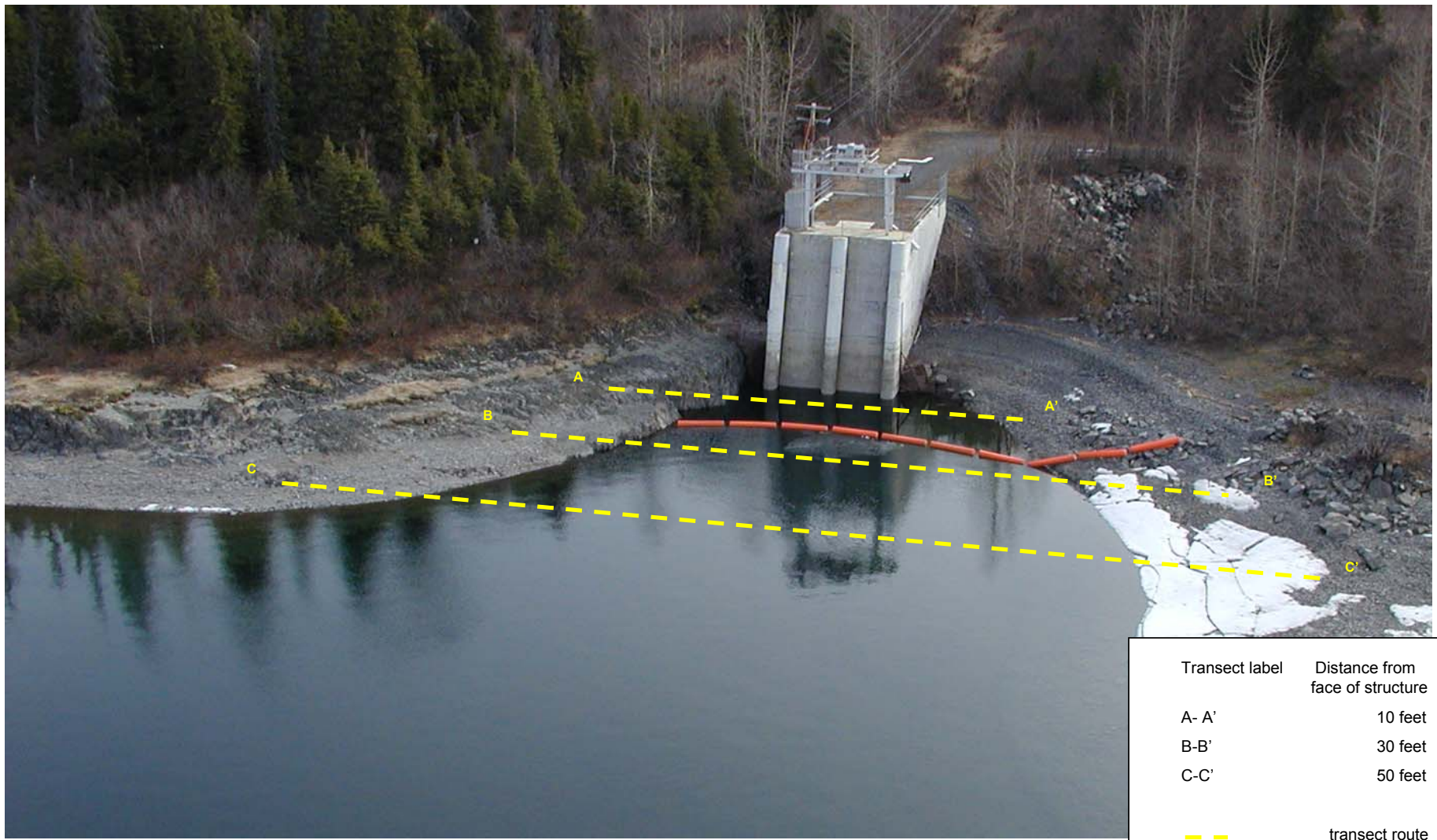
5.1.5.1 Characteristics

Water velocity profiles were measured within the intake channel to describe the potential area of influence of water withdrawal into the intake at different powerhouse flows (B.E.S.T., 2004; provided as Appendix A). Measurements were conducted on November 10 and 19, 2003,⁵ using a boat-mounted Acoustic Doppler Current Profiler (ADCP). The instrument used was the RD Instruments 1200 kHz “Rio Grande,” which provides a velocity resolution of up to approximately 0.1 fps. Velocity measurements from the surface to the bottom of the intake

⁵ The ADCP measurements were not taken in summer 2003 as indicated in the study plan because of a series of equipment-related problems.

channel⁶ were made along a series of three transects perpendicular to the intake flow positioned at distances of 10 feet, 30 feet, and 50 feet from the intake trashrack, respectively (Figure 2). Complete sets of velocity measurements were made at two powerhouse operation levels: near maximum flow (approximately 336–341 cfs) and near average annual flow (approximately 86–107 cfs). From these data, a two-dimensional plot of flow velocities corresponding to each transect was developed for the outfall area at each of these two powerhouse flows (Figures 3–5).

⁶ The Rio Grande measures approximately 92% of the water column. The unmeasured area in the water column is due to the immersion depth of the ADCP, the blanking distance at the top of the water column, unmeasured near-shore discharge and side lobe interference at the bottom.



Transect label	Distance from face of structure
A- A'	10 feet
B-B'	30 feet
C-C'	50 feet

- - - transect route

↑
N

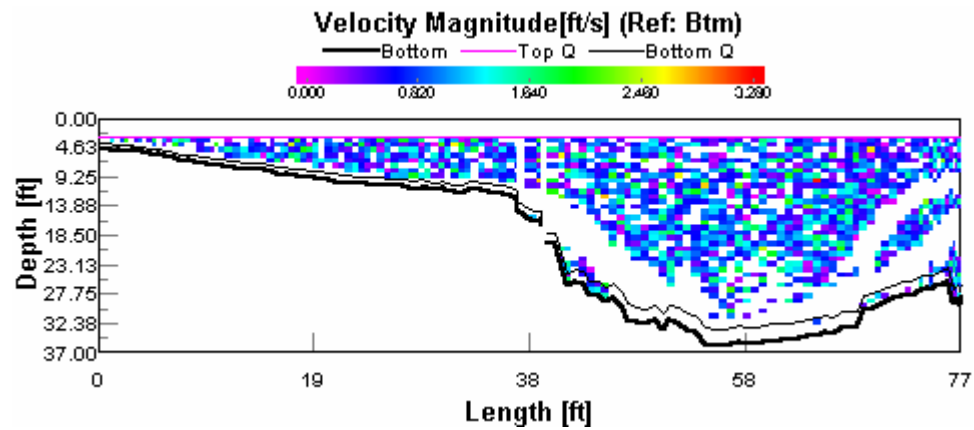


Site Map at Intake on Cooper Lake with Track Line Overlay
 Current Velocity Delineation
 Cooper Landing, Alaska
 HDR Alaska, Inc

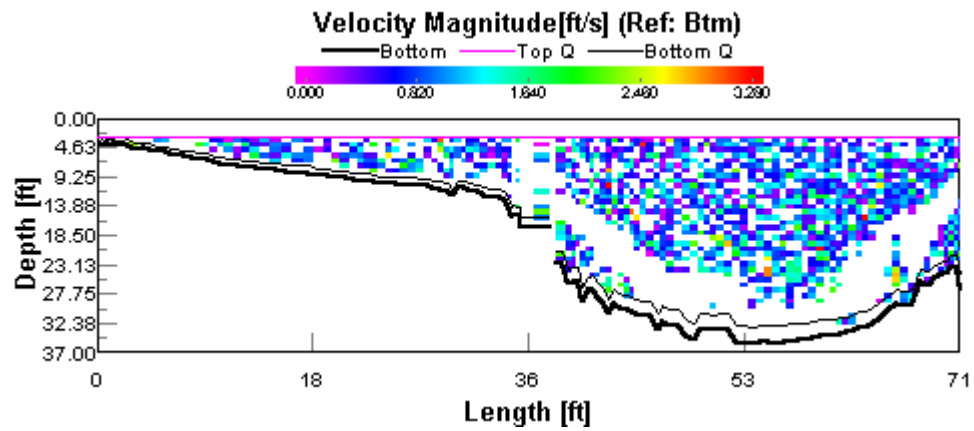
B.E.S.T. Resource

By: CLB	Date: 11/30/03	Project No: 03-0153
Checked: MAB	Date: 11/30/03	
Scale: N/A	Figure 2	File Path: C:\BEST Resource\projects\03-0153\fig1.ppt

LOW FLOW



HIGH FLOW



Acoustic Doppler Current Profile A-A'
 Current Velocity Delineation
 Cooper Landing, Alaska
 HDR Alaska, Inc

B.E.S.T. Resource

By:

CLB

Date:

02/05/04

Project

No: 03-0153

Checked:

MAB

Date:

02/05/04

File Path:

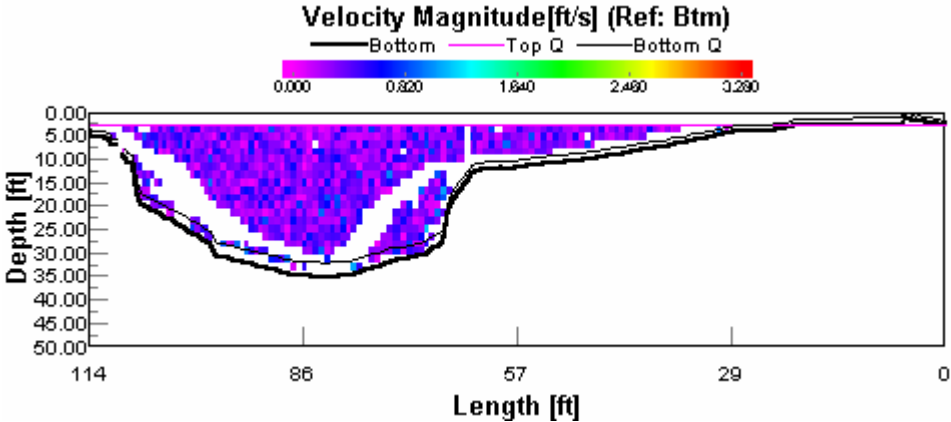
C:\BEST Resource\
 projects\03-0153\fig4.ppt

Scale:

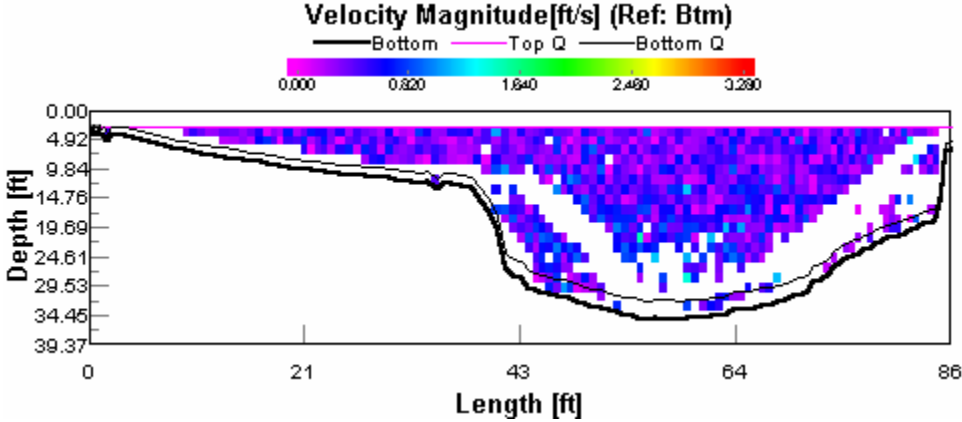
N/A

Figure 3

LOW FLOW



HIGH FLOW

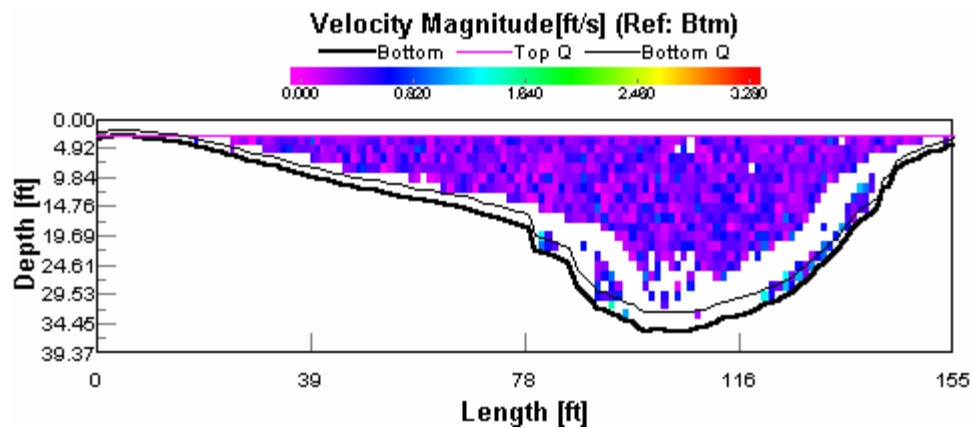


Acoustic Doppler Current Profile B-B'
 Current Velocity Delineation
 Cooper Landing, Alaska
 HDR Alaska, Inc

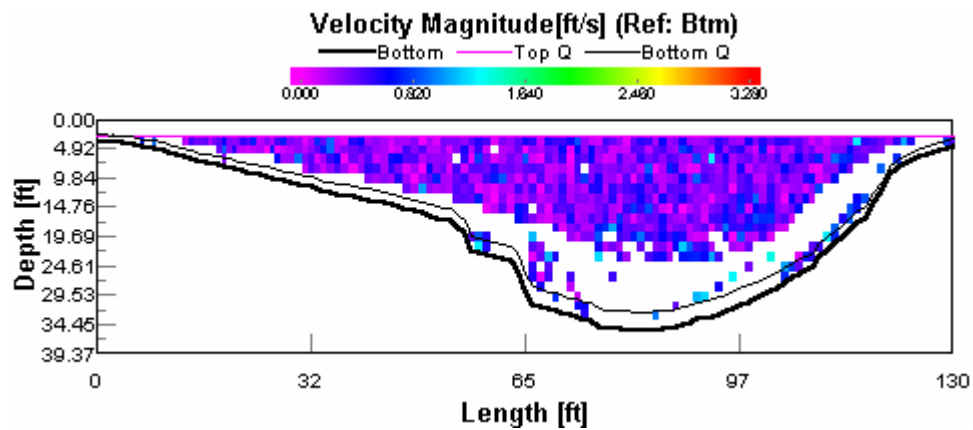
B.E.S.T. Resource

By: CLB	Date: 02/05/04	Project No: 03-0153
Checked: MAB	Date: 02/05/04	
Scale: N/A	Figure 4	File Path: C:\BEST Resource\projects\03-0153\fig5.ppt

LOW FLOW



HIGH FLOW



Acoustic Doppler Current Profile C-C'
 Current Velocity Delineation
 Cooper Landing, Alaska
 HDR Alaska, Inc

B.E.S.T. Resource

By: CLB	Date: 02/05/04	Project No: 03-0153
Checked: MAB	Date: 02/05/04	
Scale: N/A	Figure 5	File Path: C:\BEST Resource\projects\03-0153\fig6.ppt

For the purpose of analysis, the ADCP data were subdivided according to relative depth in the water column in the vicinity of the intake. At the time of the ADCP measurements, the upper layer of the water column, which had slightly lower velocities on average, extended from the surface to a depth of 15 feet, and the lower layer extended from a depth of 15 feet to the channel bed (total depth of approximately 37 feet).⁷ The total average velocity across each transect, along with the maximum water velocities for the upper and lower layers, as measured during the higher (near-full) and lower (near annual average) intake flows are summarized in Table 3.

Table 3. Maximum flow velocities at transects A–A', B–B' and C–C' (see Figure 2), for the upper and lower portions of the water column¹, and combined average flow velocity for each transect.

Transect, distance from intake opening	Transect length (feet)	Lower Powerhouse Intake Flow (86–107 cfs)			Higher Powerhouse Intake Flow (336–341 cfs)		
		Max. flow velocity (fps) in upper and lower parts of water column		Average velocity for transect (cfs)	Max. flow velocity (fps) in upper and lower parts of water column		Average velocity for transect (cfs)
		Upper	Lower		Upper	Lower	
A–A', 10 ft.	63	1.0	1.1	0.05	1.1	1.2	0.2
B–B', 30 ft.	96	0.4	0.7	0.06	0.5	0.7	0.2
C–C', 50 ft.	147	0.2	0.3	0.03	0.3	0.3	0.1

Note:

1. Upper and lower portions of the water column are located above and below a depth of 15 feet, respectively.

As shown in Table 3, at a distance of 10 feet from the intake trashrack (transect A–A') flow velocities toward the intake averaged approximately 0.05 fps under the lower powerhouse flow (86–107 cfs), and approximately 0.2 fps with higher powerhouse flow (336–341 cfs). At a distance of 30 feet (transect B–B'), average velocity toward the intake increased slightly to 0.06 cfs for the lower flow and stayed the same at 0.2 cfs for the higher flow. At a distance of 50 feet from the intake (transect C–C') average flow velocities dropped to 0.03 fps at the lower flow and 0.1 fps at the higher flow. Maximum velocities measured at any one velocity cell ranged from 1.1 fps at the lower flow to 1.2 fps at the higher flow (in the lower layer at transect A–A' in both cases).

Because transect C–C' was located approximately at the reservoir entrance to the intake channel, a velocity transect was not established at a distance farther than 50 feet from the intake to attempt to identify the maximum distance of the intake's influence on flow, as described in the study plan. However, although there was a low but measurable current at a distance of 50 feet (reservoir end of the channel) under both powerhouse flows, the flow vectors at this distance were not oriented directly toward the intake (see Table 1 in Appendix A). In addition, the average velocities at transect C–C' were not much different than the average velocity of 0.07 fps measured for calibration purposes across a background transect.

⁷ Reservoir elevations were 1,188.5 MSL on November 10 and 1,187.9 on November 19.

5.1.5.2 Analysis

The results of the ADCP measurements suggest that average velocities approaching the intake at distances of 10 feet and greater from the intake are very low and thus unlikely to entrain juvenile fish, even at full powerhouse flow. Again using the NOAA Fisheries screening criteria as a point of reference, the ADCP results may be interpreted as indicating that at distances as close as 10 feet, average flow velocities toward the intake are on the order of one-half or less of the 0.4 fps NOAA Fisheries screening criterion for fry-size salmonids with full powerhouse flow, and roughly an order of magnitude lower than this criterion under the average annual powerhouse flow.

5.1.6 Water Quality with Depth in the Reservoir

5.1.6.1 Characteristics

Water temperature profiles are being collected in Cooper Lake to provide data for relicensing studies, and other physical and chemical water quality data for the reservoir have been collected previously by ADFG and more recently (2002–2003) by Chugach as part of the relicensing studies program. Based on the existing information, Cooper Lake is clear, cold, and well oxygenated, and shows no signs of nutrient enrichment (ADFG unpublished data sheets; ADFG 1999 as summarized in USFS 2002; HDR 2004a, 2004b). Temperatures in the upper layer of the reservoir (upper 30–40 feet) warm by a few degrees (°C) over the summer, but the reservoir becomes uniformly cooler in the fall when surface temperatures cool, allowing the reservoir to mix, or “turn over” (HDR 2004a).

Among the specific water quality parameters that could affect whether fish in Cooper Lake are able to swim and spawn successfully at the depth of the intake are the characteristics of the reservoir’s euphotic zone (zone with minimum 1 percent light penetration, and thus conducive to food production and successful feeding) and dissolved oxygen content with depth. Specific findings regarding these parameters are as follows:

- Measurements at various depths within the water column indicate that Cooper Lake’s euphotic zone has a maximum depth of approximately 43–75 feet (ADFG 1999, as summarized in USFS 2002).
- Dissolved oxygen measured in Cooper Lake in August 1998 was relatively high (slightly oversaturated in the reservoir’s upper 50 feet, and slightly undersaturated below this level); these oxygen levels are likely beneficial for fish (ADFG 1999, as summarized in USFS 2002).
- Physical water quality parameters measured in Cooper Lake in 2003 showed similar average DO concentrations among sampling stations. These data and other observations in 2003 indicate that winds in the area mix the surface waters of Cooper Lake, which, coupled with relatively cool temperatures, keep the waters well oxygenated (HDR 2004b).

5.1.6.2 Analysis

Neither productivity (in terms of potential for photosynthesis) nor dissolved oxygen characteristics described for Cooper Lake would appear to pose any deterrent to fish utilizing depths of the reservoir in the vicinity of the intake. In addition, no other physical or chemical characteristic of the water column have been described that would appear to be a barrier to the presence of either rainbow trout or Arctic char at the depth of the intake. Based on this assessment, water quality in the reservoir does not limit the entrainment potential at the intake (nor does it create any conditions that would tend to concentrate fish in the vicinity of the intake).

5.2 Summary of Entrainment Risk at the Cooper Lake Project based on Project-Specific Factors

The entrainment-related risk factors discussed above indicate that some, though not all, of the factors at the Cooper Lake Project present the potential for entrainment into the generation water intake. Overall, this evaluation of potential entrainment risk factors suggests that rainbow trout in Cooper Lake are at relatively low risk of being entrained into the intake, while Arctic char in the reservoir are subject to a somewhat higher but still low to moderate risk of entrainment. A summary of findings regarding the various entrainment risk factors and specific conclusions regarding entrainment risk to rainbow trout and Arctic char in Cooper Lake is presented in Table 4.

Table 4. Summary of the presence (Yes) or absence (No) of specific entrainment risk factors as they relate to the species of interest in Cooper Lake, and conclusions regarding overall entrainment risk.

Entrainment Factor	Rainbow Trout	Arctic Char
Intake location relative to littoral zone:		
• Intake adjacent to shoreline	Yes	Yes
• Intake depth at normal maximum operating level of reservoir	No	Yes
• Intake depth at reservoir elevations less than about 1,177 feet MSL	Yes	Yes
Substrate/habitat suitability		
	No	Yes
Distribution in vicinity of intake:		
• Life history (anadromy)	No	No
• Spawning	No	Yes
• Other observed presence in vicinity of intake	Yes (very few fish – adults and fingerling-size juveniles)	No
Entrance velocity (fps):		
• Average annual operation (100 cfs)	No; entrance flow velocity does not exceed swimming ability of fry-size juvenile salmonids. ¹	No; entrance flow velocity does not exceed swimming ability of fry-size juvenile salmonids. ¹
• Full powerhouse generation (380 cfs)	Yes; entrance flow velocity exceeds swimming ability of fry-size and fingerling-size juvenile salmonids. ¹	Yes; entrance flow velocity exceeds swimming ability of fry-size and fingerling-size juvenile salmonids. ¹
Approach velocity (cfs), at all powerhouse flows up to full generation (380 cfs)		
	No; entrance flow velocity does not exceed swimming ability of fry-size juvenile salmonids. ¹	No; entrance flow velocity does not exceed swimming ability of fry-size juvenile salmonids. ¹
Water quality		
	Yes	Yes
Summary:		
Relative risk of entrainment:	Low	Low to Moderate
Rationale:	<u>Mitigating factors:</u> <ul style="list-style-type: none"> • Very few rainbow trout have been observed in the vicinity of the intake. • Spawning occurs in tributaries distant from this location, and thus fry are unlikely to be present near the intake. • Rainbow trout are more likely to frequent shoreline areas than deeper areas, and do not appear to be present in large numbers at greater depths. 	<u>Risk factors:</u> <ul style="list-style-type: none"> • Extensive use of habitat at the depth of the intake. • Fry emerging from spawning sites in the intake channel are potentially at risk of being entrained. <u>Mitigating factors:</u> <ul style="list-style-type: none"> • Presence of many other spawning sites throughout Cooper Lake reduces the overall proportion of fry exposed to entrainment risk. • Absence of strong current at all powerhouse flows minimizes the entrainment risk for fish of all sizes.

¹ Interpretation based on comparison to NOAA Fisheries juvenile fish screening criteria (NMFS 1995), as a point of reference.

6.0 COOPER LAKE PROJECT ENTRAINMENT SURVIVAL ASSESSMENT

The potential for survival of any fish that may become entrained at the Project intake is briefly examined in this section of the report. Survival of any entrained fish is a resource consideration in part because of the theoretical implications of having non-native stocks of rainbow trout exit Cooper Lake and enter the Kenai River to potentially interbreed with the river's native rainbow trout, which is one of the region's most renowned game fish.

Winchell *et al.* (2000) summarized entrainment survival trends using data parsed out from EPRI's Turbine Entrainment and Survival Database (1997). Data were examined from 51 turbines tested through paired releases of treatment and control fish to estimate immediate and delayed survival. Two trends are apparent among the reviewed studies: (1) survival was higher for small fish and for all fish passing through Kaplan turbines with relatively low rotational speed (<250 rpm); and (2) survival does not appear to be species dependent (Franke *et al.* 1997; Winchell *et al.* 2000).

For purposes of the qualitative assessment of potential entrainment survival at the Cooper Lake Project, the following factors are considered:

- *Distribution of fish size classes* — For any given turbine, small fish tend to survive turbine passage at a higher rate than do fish larger than 8 inches. The relatively low velocities at the entrance to the intake and immediately surrounding area (even with the powerhouse generating at full capacity) suggests that primarily small fish in the immediate vicinity of the Project intake would become entrained, although larger fish are also present in this vicinity and could enter the intake volitionally.
- *Depth of intake* — High hydrostatic pressure caused by deep intakes at high-head sites may cause decompression trauma in entrained fish as pressure is rapidly released in the fish when they pass through the turbines into the tailrace. The intake at Cooper Lake is at a relatively shallow depth and therefore, the difference between hydrostatic pressure at the intake and in the tailrace is not likely to be a significant contributor to mortality of any fish that become entrained.
- *Turbine type* — The size of water passage spaces relative to fish size influences susceptibility to contact with the runners. Francis-type (radial-flow) runners, which are present in the Project, have more closely spaced blades than do Kaplan-type (axial-flow) runners and have been found to have lower rates of survival for fish passed through Francis-type turbines. However, turbine operation — including net head, turbine settings, and blade speeds of the particular turbine (Kaplan or Francis) — may be the primary factors related to fish mortality, rather than runner type (Eicher and Associates 1987, Cramer and Oligher 1964, as cited in CH2M Hill 2003).
- *Turbine speed and peripheral runner blade speed* — Higher rotational speed (in rotations per minute [rpm]) increases the chance that entrained fish will come into contact with the turbine blades. Turbines at the Cooper Lake Project operate at a relatively high speed (maximum of 720 rpm), thus lowering the chance for survival of

any fish passing through the turbines. In addition to rotational speed, peripheral blade speed on Francis-type turbines has been found to correlate ($r=0.73$) with fish mortality. For the Project turbines (51.5-inch runner diameter at 720 rpm), the peripheral runner speed is about 160 fps. Extrapolating from existing data that plots the relation between peripheral runner speed (up to 120 fps) and fish mortality (Eicher et al. 1987) suggests that turbine mortality for the Project turbines may be roughly on the order of 50% to 75% mortality.

- *Turbine efficiency.* Operation of turbines at peak efficiency may be associated with decreased turbine mortality. The two turbine/generator units in the Project powerhouse were upgraded in 2000, which included rewinding the generators' stator coils and replacing the turbine runners. This modernization of the equipment increased the efficiency of the turbines. In addition, Project operations personnel strive to manage generation at the Project such that the turbines are operating at maximum efficiency. For these reasons, there is no indication that efficiency of operations is a factor that would increase the risk of mortality for any fish passed through the Project turbines.
- *Net head and hydrostatic pressure.* Net head alone does not appear to correlate with fish turbine mortality; rather, the higher hydrostatic pressures and turbine speeds that are associated with higher net heads are the primary factors that contribute to the increased fish mortality that has been found to be associated with higher net head. Among the effects on fish of hydrostatic pressure associated with turbine passage are fatal gas bubbles in the bloodstream or heart, and hemorrhaging or explosion of the swim bladder; these effects are associated with rapid changes in pressure. For the Cooper Lake Project, the static gross head (i.e., with no water flowing in the penstock) is 758 feet, or 330 pounds per square inch (psi).⁸ Because the tunnel from the intake is nearly horizontal, hydrostatic pressure would be relatively low in that portion of the system (estimated to be in the range of 30 psi). Pressure in the penstock would be the same as in the tunnel at its upslope end and would increase with distance (drop) up to a maximum of 330 psi just upstream of the turbines, then almost instantaneously decrease to pressures likely in the range of 7–14 psi (Becker et al. 2003). This increase and subsequent decrease would occur over a very brief time period. At full powerhouse flow (380 cfs), total transit time for water through the 7-foot-diameter, 5,890-foot-long penstock would be approximately 10 minutes. At a lower flow of 100 cfs, transit time would increase to about 38 minutes. Based on biological effects documented in testing of this type of rapid pressure change (Becker et al. 2003), these relatively rapid and large pressure changes appear to have the potential to cause mortality to a fish passing through the Project turbines.

Specific facility factors that are relevant to the assessment of potential survival of entrained fish at the Project are summarized in Table 5.

⁸ In reality, pressure in the penstock decreases slightly with increased flow (because of head losses in the pipe) and decreases progressively with elevation above the turbines.

Table 5. Summary of the specific facility factors relevant to entrainment survival at the Cooper Lake Project.

Facility Factor	Corresponding Factor at the Cooper Lake Project	Associated Entrainment Survival Potential
Fish size	All size classes	Higher for smaller fish; lower for larger fish (see Table 6)
Pressurized intake tunnel	No	High
Turbine type	Francis (radial-flow)	Low
High turbine speed / high peripheral blade speed	720 rpm / 160 fps	Low
Turbine efficiency	Efficient operations	High
Net head / hydrostatic pressure	Rapid and large pressure changes	Low

Winchell et al. (2000) estimated average survival of all species from the EPRI database using the following information: turbine type, runner speed, hydraulic capacity, and fish size. Table 6 (after Winchell et al. 2000) presents the relative likelihood of survival of entrained fish of different size class into radial-flow (Francis) type runners operating at hydraulic capacities between 275 cfs and 695 cfs and at speeds in excess of 250 rpm. The Cooper Lake Powerhouse turbines match these criteria, and therefore the findings shown in Table 6 are assumed to be applicable to the Project. The finding that there is low survival potential for any fish entrained into turbines with these characteristics (see Table 5) corroborates the assessment above that survival rates for any fish entrained into the Project turbines would be low.

Table 6. Fish entrainment survival rates (immediate) by fish size class for radial-flow (Francis) type runners with hydraulic capacities of 275–695 cfs and turbine speeds greater than 250 rpm (after Winchell et al. 2000).

Size Class (mm)	Average Immediate Survival (all species)				Survival Potential
	N (studies)	Minimum	Maximum	Mean	
<100	6 %	31.0 %	97.6 %	70.1 %	Low
100–199	7 %	34.3 %	82.7 %	60.0 %	Low
200–299	7 %	22.8 %	82.9 %	39.3 %	Low
> 300	3 %	3.5 %	35.4 %	19.1 %	Low

7.0 CONCLUSIONS

7.1 Entrainment Risk

7.1.1 Arctic Char

Arctic char in Cooper Lake have an overall relatively low-to-moderate risk of entrainment into the intake, considering the factors that create entrainment risk together with the factors that minimize that risk, as summarized below.

- Entrainment is a potential risk for Arctic char in Cooper Lake because of the following characteristics:
 - Extensive use of habitat at the depths of the intake.
 - Observed spawning in the intake channel.
 - Presence of currents directly at the intake opening that are potentially strong enough when the powerhouse is generating at full capacity to entrain emerging fry (<2.36 inches [60 mm] in length) that swim very close (<10 feet) to the entrance.
- The following mitigating factors reduce the potential entrainment risk for Cooper Lake Arctic char:
 - Relatively low approach and entrance velocities at the intake, at all powerhouse flows. Based on comparison to NOAA Fisheries screening criteria, velocities do not exceed the swimming ability of fingerling-size juveniles (i.e., greater than 2.36 inches [60 mm]), even directly at the intake opening at full powerhouse flows. Velocities do not exceed the swimming ability of fry-size salmonids (<2.36 inches [60 mm] in length) at distances of 10 feet or more from the intake, at any generation flow.
 - To date, the spawning surveys conducted for the Cooper Lake Fish Resource Study have documented many spawning sites used by Arctic char in the reservoir, including the spawning area in the intake channel. Because the highest risk of entrainment exists for Arctic char fry that emerge from spawning gravels located within the intake channel, the overall proportion of Cooper Lake Arctic char fry exposed to entrainment risk is presumed to be small.

7.1.2 Rainbow Trout

Rainbow trout in Cooper Lake are overall at relatively low risk of entrainment because of several factors that limit the presence of potentially susceptible fish near the intake, as summarized below.

- The documented distribution and habitat use of Cooper Lake rainbow trout, as well as characteristic behavior described in the literature reviewed, greatly limits the entrainment risk for these fish. This conclusion is based on the following pertinent characteristics:

- Observed spawning exclusively in tributaries to the reservoir, and primarily in tributaries located more than 1 mile from the intake structure.
- Early rearing (fry stage) in tributaries or protected areas of the reservoir shoreline, according to literature reviewed and observations in Cooper Lake.
- Apparent preference of all size classes for shallow shoreline areas, which are typically above the depth of the intake, especially during the months when the smallest juveniles would be present in the reservoir (based on literature, Cooper Lake trapping data, and historical reservoir operations).
- Very low numbers of rainbow trout of any size in the immediate vicinity of the intake, based on ROV videography and diver observations.
- As described above for Arctic char, rainbow trout of all sizes are unlikely to be entrained at any powerhouse flow, based on site-specific approach and entrance velocities relative to established criteria.

7.2 Entrainment Survival

The potential for survival of any fish entrained through the intake into the tunnel, penstocks and turbines is low, primarily as a function of turbine type (Francis / radial-flow) and turbine speed (relatively high), and possibly also as a function of the net head and associated hydrostatic pressure changes during passage through the penstock and turbines.

7.3 Implications of Entrainment Analysis Regarding Project Effects

The results of this preliminary evaluation of entrainment in Cooper Lake suggest that the risk of entrainment is probably not a significant Project effect. Moreover, taken together with documented fish abundance and successful spawning by Arctic char and rainbow trout in the reservoir, there is also no indication of a significant Project effect on these populations due to entrainment.

The findings from this qualitative analysis will be evaluated in conjunction with results of other pertinent relicensing studies as part of the Project effects analysis presented in the FERC license application. Other study results that relate to the entrainment analysis include data on population size and size-class distributions for Cooper Lake Arctic char and rainbow trout and conclusions regarding limiting factors for population size. This additional information will allow a more definitive overall assessment as to whether the possible Project effect of entrainment is impacting these two fish populations.

8.0 LITERATURE CITED

- Alaska Department of Fish and Game (ADFG). 1999. Letter and report from Jim A. Edmundson, Limnologist to USFS biologist, Eric Johansen summarizing data and limnological characteristics of Cooper Reservoir. ADFG Division of Commercial Fisheries, July 27, 1999.
- Alaska Department of Fish and Game (ADFG). 2003. Wildlife notebook series: Rainbow trout. <http://www.adfg.state.ak.us/pubs/notebook/fish/rainbow.php>
- Balon, E.K. [ed.]. 1980. Charrs: Salmonid Fishes of the Genus *Salvelinus*. Dr. W. Junk bv Publishers, the Hague.
- Becker, J.M., C.S. Abernethy, and D.D. Dauble. 2003. Identifying the effects on fish of changes in water pressure during turbine passage. Hydro Review. September 2003.
- Blanchet, D. 2000. USFS memorandum to D. Palmer (USFWS) regarding Cooper Lake gill net sampling, dated June 15, 2000.
- CH2M Hill. 1984. Cooper Lake Probable Maximum Flood Study. Prepared for Chugach Electric Association. May 194.
- CH2M Hill. 2003. Literature Based Characterization of Resident Fish Entrainment and Turbine-Induced Mortality, Klamath Hydroelectric Project (FERC No. 2082). Draft Technical Memorandum. Prepared for PacifiCorp. September 2003.
- Chugach Electric Association. 2001. Cooper Lake Field Survey Bathymetry, Biology, and Habitats. Prepared for Chugach by LGL Alaska Research Associates, Inc. Anchorage, Alaska. June 30, 2001.
- Chugach Electric Association. 2002. Initial Consultation Package for the Cooper Lake Hydroelectric Project FERC No. 2170
- Cramer, F.K., and R.C. Olighter. 1964. "Passing Fish through Hydraulic Turbines." Transactions of the American Fisheries Society, Volume 93, No. 3, 1964, pp. 243–259.
- Dean, J. 2002. Arctic char in south-central Alaska, a status report. Self-Published, Soldotna, Alaska.
- Edwards, O.T. 1940. Russian River fish catch report. USDA, Forest Service, Chugach National Forest, Kenai Division.
- Eicher and Associates, Inc. 1987. Turbine-related fish mortality: review and evaluation of studies. Research Project 2694-4. Electric Power Research Institute, Palo Alto, California.

- Electric Power Research Institute (EPRI). 1997. Guidelines for hydro turbine fish entrainment and survival studies. EPRI Report TR- 107299. Prepared by Alden Research Laboratory, Inc., Holden, MA.
- Federal Energy Regulatory Commission (FERC). 1995. Preliminary assessment of fish entrainment at hydropower projects; a report on studies and protective measures. Volume 1. Federal Energy Regulatory Commission, Washington, DC.
- Federal Energy Regulatory Commission (FERC). 2001. Hydroelectric Project Licensing Handbook. Federal Energy Regulatory Commission, Washington, D.C. April 2001.
- Hartman, G.F., T.G. Northcote, and C.C. Lindsey. 1962. Comparison of inlet and outlet spawning runs of rainbow trout in Loon Lake, British Columbia. *Journal Fisheries Research Board Canada* 19(2): 173-200.
- HDR Alaska, Inc. (HDR). 2003. Cooper Lake Macroinvertebrates Study, Final 2003 Study Plan, Cooper Lake Project (FERC No. 2170). Prepared for Chugach Electric Company. April 2003.
- HDR Alaska, Inc. (HDR). 2004a. Stream Flow and Water Quality Study, Draft Report, Cooper Lake Project (FERC No. 2170). Prepared for Chugach Electric Company. February 2004.
- HDR Alaska, Inc. (HDR). 2004b. Stream Flow and Water Quality Study, Draft Report, Cooper Lake Project (FERC No. 2170). Prepared for Chugach Electric Company. February 2004.
- Lazar, J. and G. Van Hatten. 1994. Cooper Lake survey, August 16-18, 1994. Alaska Department of Fish and Game.
- Lindsey, C.C., T.G. Northcote, and G.F. Hartman. 1959. Homing of rainbow trout to inlet and outlet spawning streams at Loon Lake, British Columbia. *Journal Fisheries Research Board Canada* 16(5): 695-719.
- McEwan, D., and T.A. Jackson. 1996. Steelhead restoration and management plan for California. California Department of Fish and Game. February 1996.
- Morsell, J. 2003. Cooper Lake Fish Resources Study, Final 2003 Study Plan, Cooper Lake Project (FERC No. 2170). Northern Ecological Services. Prepared for Chugach Electric Association. April 2003.
- Northern Ecological Services and HDR Alaska, Inc. 2004. Cooper Lake Fish Resources Study, Draft Report, Cooper Lake Project (FERC No. 2170). Prepared for Chugach Electric Association. April 2003.
- National Marine Fisheries Service (NMFS). 1995. Juvenile Fish Screen Criteria. National Marine Fisheries Service Environmental & Technical Services Division, Portland, OR.

- Nelson, K.J. 1985a. USFS internal fisheries planning memorandum regarding 1986 work plans for Cooper Lake, Grant Lake, Summit Lakes, and Sixmile Creek. January 24, 1985.
- Northern Ecological Services and Long View Associates, Inc. 2003. Preliminary Evaluation of Entrainment in Cooper Lake, Final 2003 Study Plan, Cooper Lake Project (FERC No. 2170). April 2003.
- Rappoport, A.G. 2000. Memorandum to D. Boergers (FERC) regarding new biological information: arctic char in Cooper Lake. U.S. Fish and Wildlife Service. 24 January 2000.
- Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board Canada. Bulletin 184.
- Stone and Webster Engineering Corp. 1988. Supplementary Study, Fifth Periodic Safety Inspection, Stability Evaluation. Cooper Lake Hydroelectric Project. December 1988
- USDA Forest Service (USFS). 1995. Forest Plan Monitoring and Evaluation Report (Fiscal Year 1995), Chugach National Forest.
- USDA Forest Service (USFS). 2002. Cooper Creek Watershed Analysis. USDA Forest Service. Chugach National Forest. April 2002.
- Winter and Williams. 1992. Cooper Lake survey, July 9–10, 1992. Alaska Department of Fish and Game.
- DeCicco, 1994. ADF&W Wildlife Notebook Series (Website <http://www.state.ak.us/adfg/notebook/fish/a%5Echar.htm>)
- Willson, M.F. 1997. Variation in Salmonid Life Histories: Patterns and Perspectives. Research Paper PNW-RP-498. USDA Forest Service, Pacific Northwest Research Station. February 1997.
- Winchell, F., S. Amaral, and D. Dixon. 2000. Hydroelectric turbine entrainment and survival database: an alternative to field studies. HydroVision Conference, Charlotte, NC. August 2000.

Appendix A

**Final Report for Geophysical Services:
Current Velocity Delineation, Cooper Landing, Alaska
Report prepared by B.E.S.T. Resource**

January 2004

**Technical Memorandum for Geophysical Services
Current Velocity Delineation
Cooper Lake Hydroelectric Project**

1.0 Introduction

B.E.S.T. Resource (BEST) provided geophysical services in support of HDR Alaska, Inc.'s (HDR) desire to delineate current velocities in Cooper Lake and Kenai Lake related to the inlet and outlet of Chugach Electric Association's (Chugach) Cooper Lake powerhouse tunnels on November 10-11 and 19, 2003. In accordance with our scope of services for this project, the following are included in this document:

- Time and events summary of our geophysical survey and
- Representative post-processed records of current velocities for low and high flow regimes in both survey areas

2.0 Study Area

BEST's geophysical survey investigated two sites in an effort to delineate the current velocity under low (approximately 4 mega watts of output) and high (approximately 20 mega watts of output) flow regimes. The inlet to the powerhouse tunnels is in Cooper Lake (Figure 1) and the outlet of the powerhouse tunnels is in Kenai Lake (Figure 2). The survey included a set of transects consisting of ~3000' lineal feet, while ensonifying to a maximum depth of forty feet.

3.0 Methods

ADCP survey was performed on November 10, 11 & 19, 2003. Equipment was calibrated upon arrival at the site. Calibration consists of initializing a software communication program and setting data collection parameters. The BBTalk program (Broad Band ADCP) communicates with the ADCP to verify it is functioning properly. The 'Configuration Wizard' assists the operator in creating a configuration file that consists of information needed for data collection and display during Acquire mode. BEST conducted all geophysical survey operations employing a RD Instruments 1200 kHz Rio Grande ADCP on a gin pole rigged on our survey vessel. Data were collected digitally and recorded on a laptop computer.

The face of the inlet tunnel structure and the second tunnel gate from the east on the tail race's super structure were used as survey reference points. Our geophysical survey was oriented parallel to the face of the super structure and perpendicular to the current flow (Figure 2). The maximum depth of investigation was approximately 40 feet and the minimum depth of investigation was approximately five

feet or as close to shore as possible. At the inlet on Cooper Lake, transects were surveyed at 10', 30' and 50' distances from the face of the tunnel structure and labeled as A-A' through C-C' on Figure 1. The survey lines at the tail race on Kenai Lake were stationed 10', 25', 50', 100' and 130' from the face of the second tunnel gate on the east and labeled as D-D' through H-H' on Figure 2. The F-F', G-G' and H-H' transects were curved instead of parallel to the face of the powerhouse. This method was employed to ensure that the survey direction was perpendicular to flow. All lines were duplicated for low and high flows at both sites. An operation summary is presented below.

**Summary of Survey Operations
Inlet and Tail Race of Chugach Electric Association's
Cooper Lake Powerhouse Tunnels**

	From (hours)	To (hours)	Task/Equipment
November 10, 2003	10:30	12:15	Establish survey grid, assemble, calibrate equipment at Cooper Lake
	12:25	16:45	ADCP & Saturation / surveys
November 11, 2003	09:30	11:00	Establish survey grid, assemble & calibrate equipment at Kenai Lake
	11:30	16:00	ADCP & Saturation / surveys
November 19, 2003	09:00	10:00	Establish survey grid, assemble & calibrate equipment at Kenai Lake
	10:15	12:45	ADCP & Saturation / surveys
November 19, 2003	13:45	14:45	Establish survey grid, assemble & calibrate equipment at Cooper Lake
	15:00	16:15	ADCP survey

3.1 ADCP Data Acquisition

Rio Grande 1200kHz Acoustic Doppler Current Profiler

The equipment employed during this program consisted of a RD Instruments 1200 kHz Rio Grande ADCP on a gin pole rigged on our survey vessel. This instrument consists of a 4-beam transducer head, input/output communication cable, laptop and RDI's Windows-based WinRiver data acquisition, display and post-processing software. This instrument measures river discharge and surveys river current structure. The Rio Grande ADCP can collect results approaching 0.05 m/s current velocity provided environmental surroundings do not compromise the quality of data collection. Approximately thirty-five centimeters (16") of water are required for an acceptable return signal. The Rio Grande measures approximately 92% of the river's water column. The unmeasured area in the water column is due to the immersion depth of the ADCP, the blanking distance at the top of the water column, unmeasured near-shore discharge and side lobe interference at the bottom.

The blanking distance and the immersion depth of the ADCP account for approximately 2% of the unmeasured area at the top water column. The blanking distance allows the ADCP to ring down and become acoustically quiet before receiving the return signal. The same transducer is used to receive the acoustic energy after transmitting a pulse. A short time (or a short sound travel distance) must pass before reception is possible. This delay is the blanking distance (Figure 3).

Side lobe interference causes a shallow layer of water near the bottom to be unmeasured. Discharge is not computed for this layer. When the ADCP sends out an acoustic pulse, a small amount of energy is transmitted in side lobes rather than in the direction of the ADCP beam. Side lobe reflection from the bottom can interfere with the water echoes. This gives erroneous velocities for the water near the bottom. WinRiver post-processing software does not use data in the region because it may be affected by side lobe interference. The ADCP has beams oriented at 20 degrees from the vertical. The thickness of the side lobe is 6% of the distance from the transducers to the bottom (Figure 3).

3.2 ADCP Survey

The survey plan was developed prior to field work and where possible was flagged on site for relocation of transects if necessary. BEST surveyed a series of 8 transects; three at the inlet and five at the tail race. Each transect was run a minimum of 4 times to ensure quality data to post-process. Data along all transects were collected with optimal water and bottom mode ensonification settings with the ADCP. Data were collected at high and low flows regulated by Chugach.

“Cultural features” such as abrupt steep slopes, wind-driven surface chop and concentrations of air bubbles can degrade the resolution of the data. Concentration of air bubbles created by the water exiting the tunnels can form on or under the transducer. This acts as a shield which can inhibit the transmission of sound and reduce the profiling range and ability.

3.3 ADCP Data Processing

The raw ADCP data was processed to enhance the signal-to-noise ratio. The resulting analysis of processed ADCP records leads to considerably higher confidence in the identification of current velocity anomalies.

4.0 ADCP Survey Results

4.1 Inlet

The data collected in Cooper Lake suggested that the current structure separates into two layers. The two layers were from 0' to 15' (top) and 15' to the channel bed ~35' (bottom). The maximum and average velocities and discharge measurements reported in Table 1 correspond to transects A-A', B-B' and C-C' (Figure 1). No distinct variation in velocity with depth was apparent along the background transect. A background transect recorded average values of 0.07 ft/sec.

4.2 Tail Race

The data collected in Kenai Lake suggested a lateral separation in the water column, due to the flows that emanated from the east and west tunnels. The maximum and average velocities and discharge measurements reported in Table 1 correspond to transects D-D', E-E', F-F', G-G' and H-H' (Figure 2). No distinct variation in velocity with depth was apparent along the background transect. A background transect recorded average values of 0.13 ft/sec.

5.0 ADCP Survey Conclusions

5.1 Inlet

Water entering the tunnels affected the velocity structure of the water column within fifty feet of the tunnel face. The velocity structure within the affected water column was divided in a top and bottom layer. Fifty feet from the tunnel face, the velocities degraded to levels approaching ambient measurements of the lake and within the margin of error of the ADCP. Water moved in two distinct layers along the A-A' transect. These layers coalesced into one flow and became indistinguishable from ambient lake measurements along transect C-C' during both flow regimes (Figure 1). Top layer maximum velocities along transect A-A' during low and high flows were 0.96 ft/sec and 1.14 ft/sec, respectively (Table 1, Figure 4). Maximum velocities of 0.40 ft/sec and 0.45 ft/sec were recorded during low and high flows, respectively along B-B' (Table 1, Figure 5). The maximum velocities dropped to 0.24 ft/sec during low flow and 0.26 ft/sec during high flow along C-C' (Table 1, Figure 6). The maximum velocity in the top layer decreased by 75% from A-A' to C-C'. The bottom layer moved faster than the top layer under both flow regimes. The maximum velocities of the bottom layer along the A-A' transect flow were 1.05 ft/sec and 1.20 ft/sec during low and high flows, respectively (Table 1, Figure 4). Maximum velocities along B-B' were 0.68 ft/sec during low flow and 0.72 ft/sec during high flow (Table 1, Figure 5). Maximum velocities continued to decrease as the distance increased from the tunnel

structure. Along C-C' low flow velocities were measured at 0.27 ft/sec and high flow velocities were 0.31 ft/sec (Table 1, Figure 6). The maximum velocity of the bottom layer decreased by 75% from A-A' to C-C'.

Averaging the velocity over the entire water column provides a comprehensive illustration of each profile and reduces measurement uncertainty. On the A-A' transect the average velocities were 0.05 ft/sec during low flow and 0.21 ft/sec during high flow. The average velocities on B-B' transect were 0.06 ft/sec during low flow and 0.18 ft/sec during high flow. The average velocities on the C-C' transect were a nominal 0.03 ft/sec during low flow and 0.11 ft/sec during high flow.

5.2 Tail Race

Water exiting the tunnels affected the velocity structure of the water column in Kenai Lake at the tailrace. The effects were limited to 50' from the tunnel face during low flow and at 130' during high flow. At these distances the velocities degraded to levels below ambient lake measurements and within the margin of error of the ADCP. The water exiting from the east and west tunnels appeared as two distinct bodies of faster moving water that eventually merged into one flow at 50' during low flow and at 100' during high flow. The tunnel output velocities became indistinguishable from the lake at 100' during low flow and at 130' during high flow. During low flow the difference in maximum water velocities of east and west output ranged from 0.01 to 0.14 ft/sec (Table 1). During high flow the difference in maximum water velocities of east and west output ranged from 0.01 to 0.3 ft/sec (Table 1).

At low flow, individual tunnel output was distinguishable along transect D-D' and started to coalesce into one zone at E-E' (Figure 7, 8). The influenced portion of the water column was approximately thirty feet wide and ten feet deep (Figure 8). Along transect E-E', the average velocity measured 0.17 ft/sec. Current trended 336.5°. Discharge measured was approximately 96.18 ft³/sec. Along the F-F' transect individual flows were ostensibly indistinguishable (Figure 9). Average velocity was 0.12 ft/sec. Current trended 358.9°. Discharge measured was approximately 84.87 ft³/sec. Along the G-G' and H-H' transects the flow was indistinguishable from the background measurements of Kenai Lake. An average velocity of 0.03 ft/sec was measured along the G-G' profile (Figure 10). Current trended 322.0°. Discharge measured was approximately 97.27 ft³/sec. An average velocity of 0.01 ft/sec was

measured along the profile H-H' (Figure 11). Current trended 315.0°. Discharge measured was approximately 80.84 ft³/sec.

At high flow individual tunnel output was prominent along the F-F' transect. Maximum velocities of 1.84 ft/sec and 1.76 ft/sec emanated from the east and west tunnels, respectively (Figure 9). The average velocity was 0.32 ft/sec. Current trended 18.2°. Discharge measured was approximately 345.23 ft³/sec. The portion of the water column influenced by the tunnel output coalesced into one broad zone approximately 40 feet wide and 10 feet deep at G-G' (Figure 10). The average velocity was 0.39 ft/sec. Current trended 21.9°. Discharge measured was approximately 377.29 ft³/sec. Along H-H' the average velocity was 0.06 ft/sec, well below the average background velocity. Current trended 24.4°. Discharge measured was approximately 343.91 ft³/sec (Figure 11).

TABLE 1**Inlet Flows**

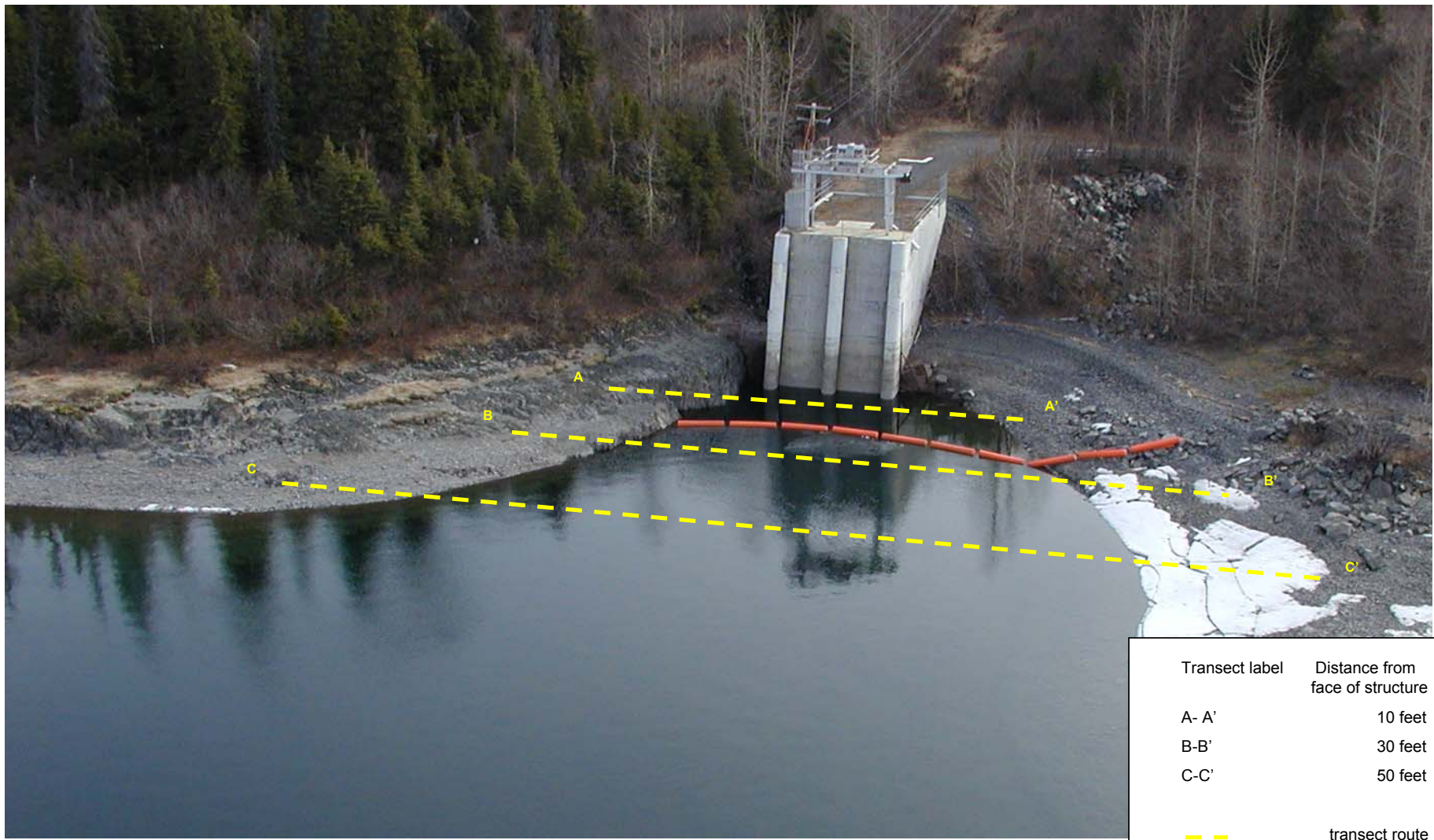
Transect & distance from reference point	Date & Time Surveyed	Low Velocity in water column				High Velocity in water column						
		Average	Top	Bottom	Trend	Total Discharge	Date & Time Surveyed	Average	Top	Bottom	Trend	Total Discharge
A-A' 10'	11/19/03 @ 1400	0.05ft/sec	0.96ft/sec	1.05ft/sec	22.4°	86.16ft3/sec	11/19/03 @ 1530	0.21ft/sec	1.14ft/sec	1.20ft/sec	71.5°	335.76ft3/sec
B-B' 30'	11/10/03 @ 1230	0.06ft/sec	0.40ft/sec	0.68ft/sec	23.5°	107.25ft3/sec	11/10/03 @ 1540	0.18ft/sec	0.45ft/sec	0.72ft/sec	42.3°	340.82ft3/sec
C-C' 50'	11/10/03 @ 1445	0.03ft/sec	0.24ft/sec	0.27ft/sec	56.4°	95.29ft3/sec	11/10/03 @ 1605	0.11ft/sec	0.26ft/sec	0.31ft/sec	62.7°	340.14ft3/sec

Tail Race Flows

Transect & distance from reference point	Date & Time Surveyed	Low Velocity in water column				High Velocity in water column						
		Average	East	West	Trend	Total Discharge	Date & Time Surveyed	Average	East	West	Trend	Total Discharge
D-D' 10'	11/11/03 @ 1525	0.36ft/sec	1.41ft/sec	1.42ft/sec	346.7°	264.60ft3/sec	11/19/03 @ 11033	0.47ft/sec	2.27ft/sec	2.26ft/sec	21.5°	324.67ft3/sec
E-E' 25'	11/11/03 @ 1145	0.17ft/sec	1.15ft/sec	1.16ft/sec	336.6°	96.18ft3/sec	11/19/03 @ 1050	0.47ft/sec	1.89ft/sec	2.19ft/sec	10.5°	368.89ft3/sec

TABLE 1

F-F' 50'	11/11/03 @1205	0.12ft/sec	0.76ft/sec	0.62ft/sec	358.9°	84.87ft3/sec	11/19/03 @ 1110	0.32ft/sec	1.84ft/sec	1.76ft/sec	18.2°	345.23ft3/sec
G-G' 100'	11/11/03 @1310	0.03ft/sec	< 0.50ft/sec		322.0°	97.27ft3/sec	11/19/03 @ 1135	0.39ft/sec	1.68ft/sec		21.9°	377.29ft3/sec
H-H' 130'	11/11/03 @1440	0.01ft/sec	<0.25ft/sec		315.3°	80.84ft3/sec	11/19/03 @ 1210	0.06ft/sec	1.26ft/sec		24.5°	343.91ft3/sec



Transect label	Distance from face of structure
A- A'	10 feet
B-B'	30 feet
C-C'	50 feet

- - - transect route

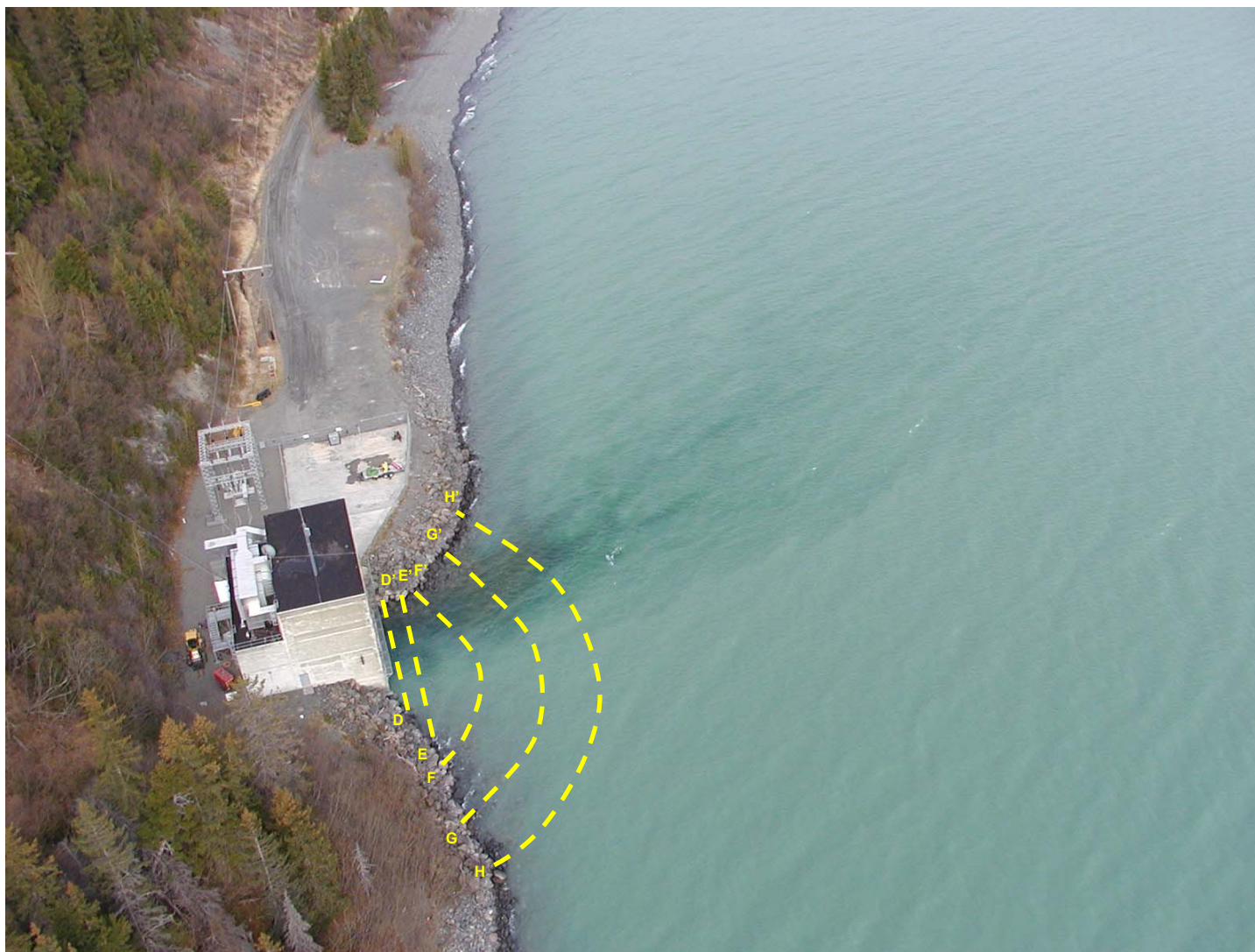
↑
N





Site Map at Intake on Cooper Lake with Track Line Overlay
 Current Velocity Delineation
 Cooper Landing, Alaska
 HDR Alaska, Inc

B.E.S.T. Resource

By: CLB	Date: 11/30/03	Project No: 03-0153
Checked: MAB	Date: 11/30/03	
Scale: N/A	Figure 1	File Path: C:\BEST Resource\projects\03-0153\fig1.ppt



Transect label	Distance from face of 2 nd tunnel
D - D'	10 feet
E - E'	25 feet
F - F'	50 feet
G - G'	100 feet
H - H'	130 feet

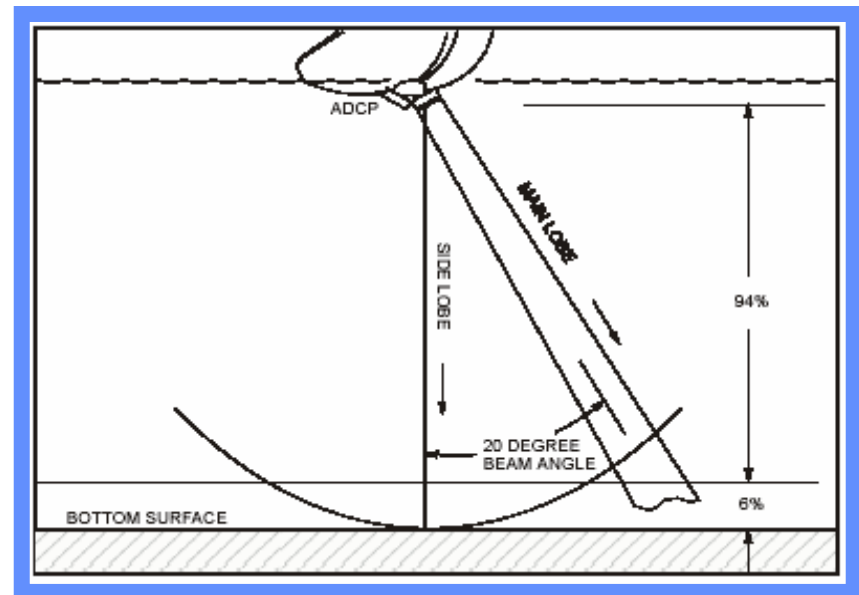
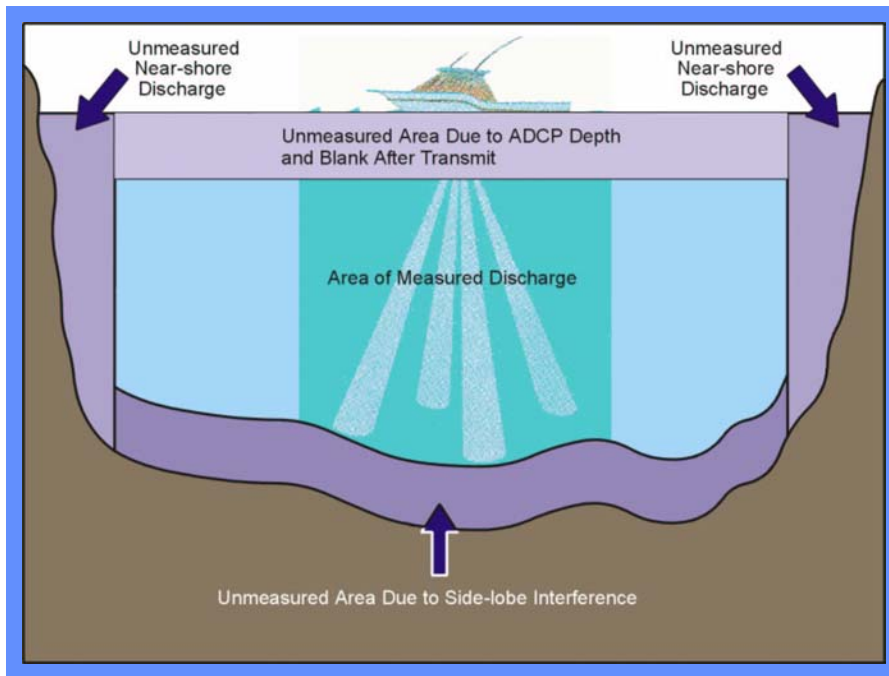
 transect route




Site Map at Tail Race on Kenai Lake with Track Line Overlay
 Current Velocity Delineation
 Cooper Landing, Alaska
 HDR Alaska, Inc

B.E.S.T. Resource

By: CLB	Date: 11/30/03	Project No: 03-0153
Checked: MAB	Date: 11/30/03	
Scale: N/A	Figure 2	File Path: C:\BEST Resource\projects\03-0153\fig2.ppt

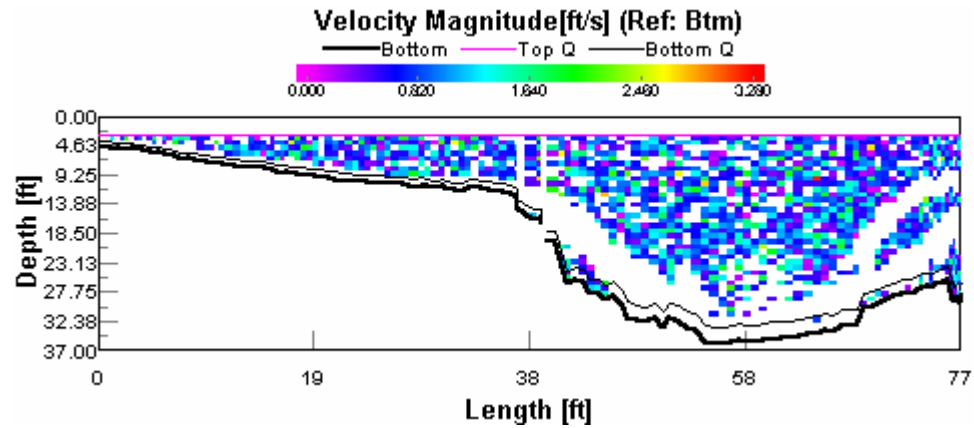


Acoustic Doppler Current Profiler Operations
 Current Velocity Delineation
 Cooper Landing, Alaska
 HDR Alaska, Inc

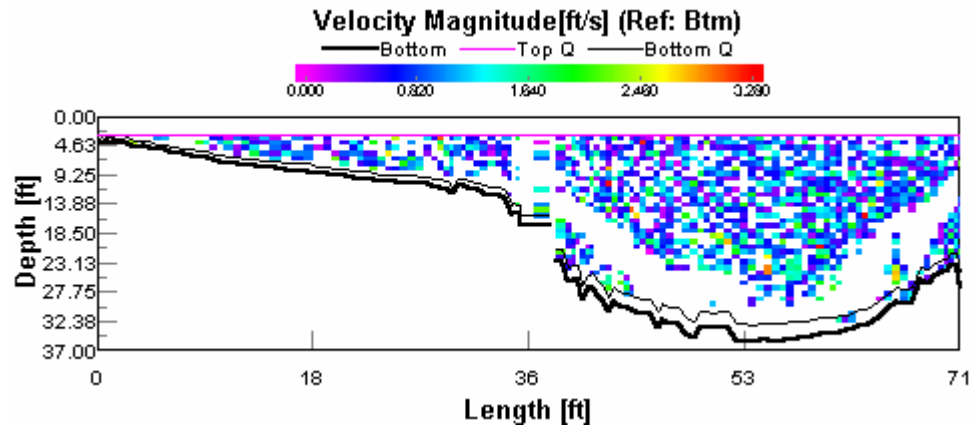
B.E.S.T. Resource

By: CLB	Date: 11/30/03	Project No: 03-0153
Checked: MAB	Date: 11/30/03	
Scale: N/A	Figure 3	File Path: C:\BEST Resource\projects\03-0153\fig3.ppt

LOW FLOW



HIGH FLOW

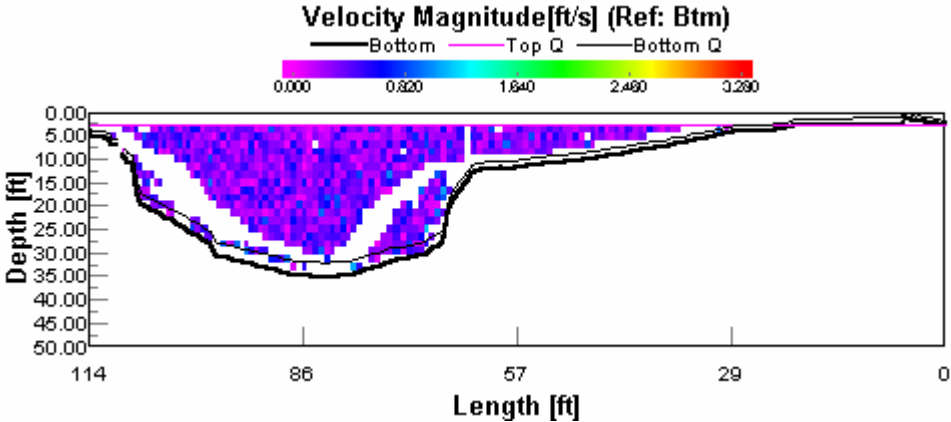


Acoustic Doppler Current Profile A-A'
 Current Velocity Delineation
 Cooper Landing, Alaska
 HDR Alaska, Inc

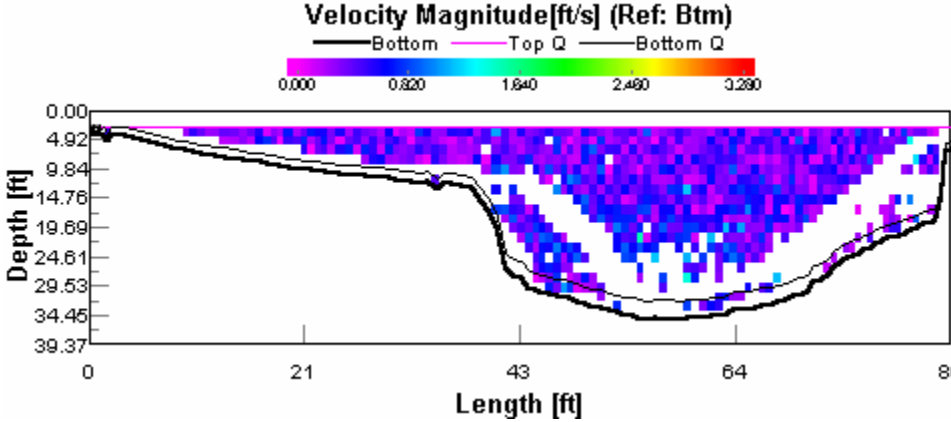
B.E.S.T. Resource

By: CLB	Date: 02/05/04	Project No: 03-0153
Checked: MAB	Date: 02/05/04	
Scale: N/A	Figure 4	File Path: C:\BEST Resource\projects\03-0153\fig4.ppt

LOW FLOW



HIGH FLOW

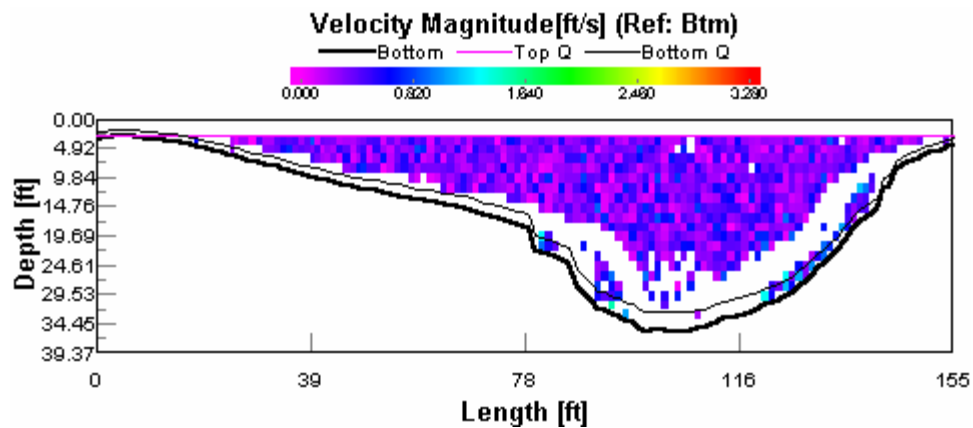


Acoustic Doppler Current Profile B-B'
 Current Velocity Delineation
 Cooper Landing, Alaska
 HDR Alaska, Inc

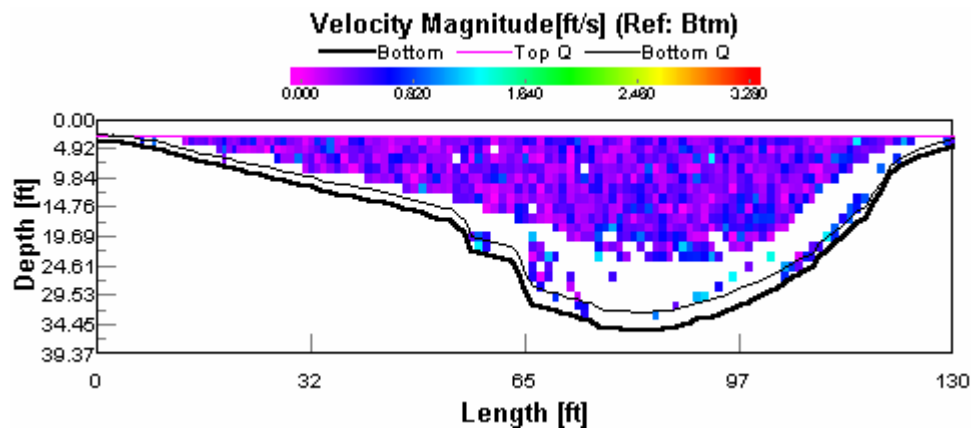
B.E.S.T. Resource

By: CLB	Date: 02/05/04	Project No: 03-0153
Checked: MAB	Date: 02/05/04	
Scale: N/A	Figure 5	File Path: C:\BEST Resource\projects\03-0153\fig5.ppt

LOW FLOW



HIGH FLOW

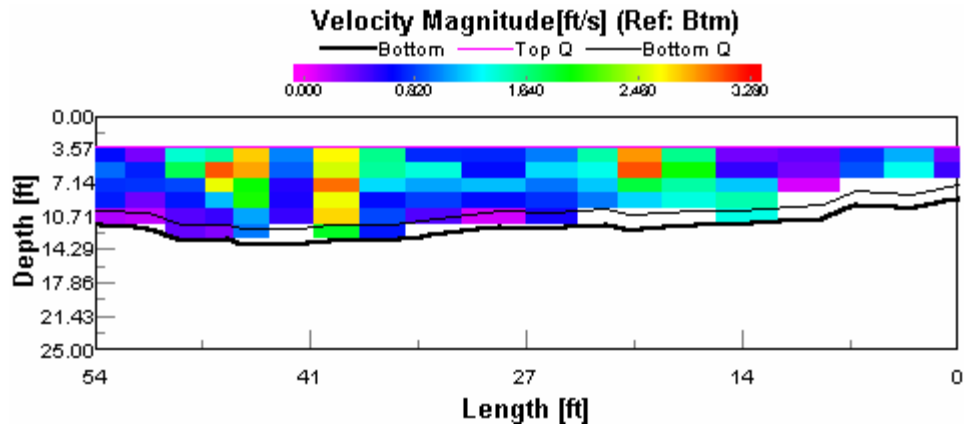


Acoustic Doppler Current Profile C-C'
Current Velocity Delineation
Cooper Landing, Alaska
HDR Alaska, Inc

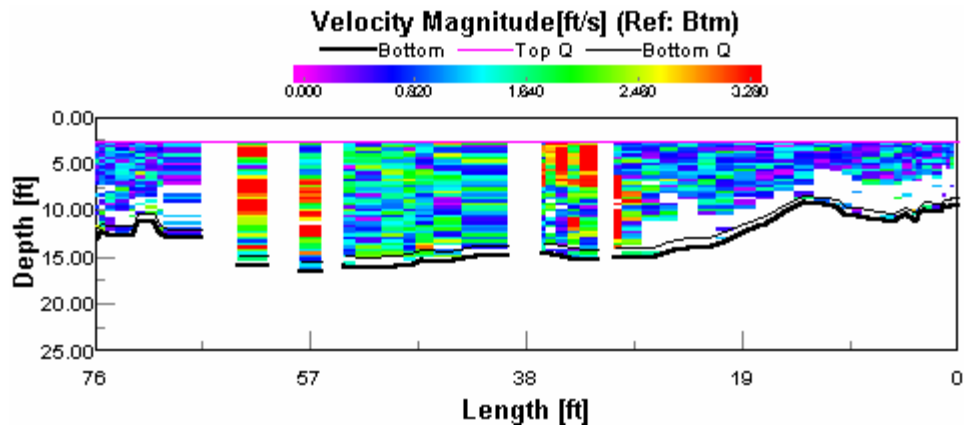
B.E.S.T. Resource

By: CLB	Date: 02/05/04	Project No: 03-0153
Checked: MAB	Date: 02/05/04	
Scale: N/A	Figure 6	File Path: C:\BEST Resource\ projects\03-0153\fig6.ppt

LOW FLOW



HIGH FLOW

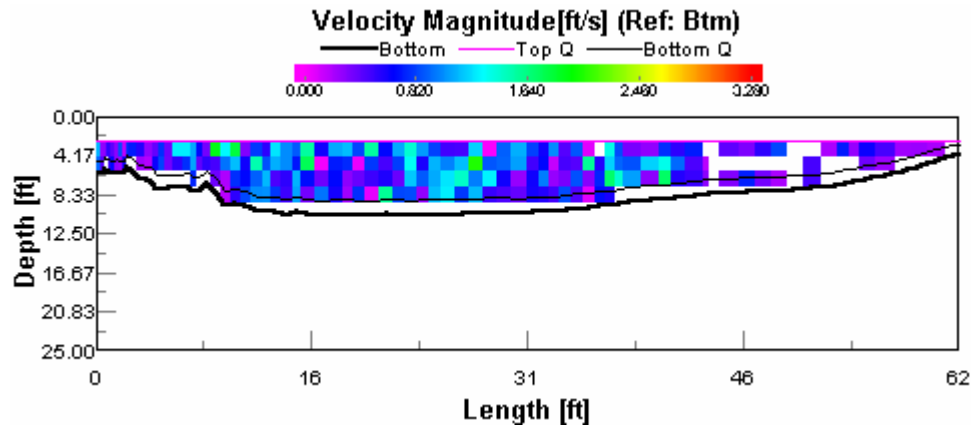


Acoustic Doppler Current Profile D-D'
 Current Velocity Delineation
 Cooper Landing, Alaska
 HDR Alaska, Inc

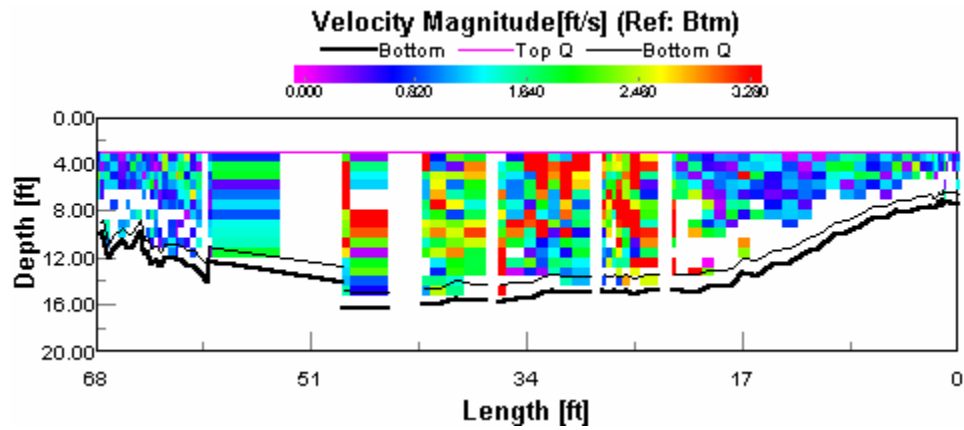
B.E.S.T. Resource

By:	CLB	Date:	02/05/04	Project No:	03-0153
Checked:	MAB	Date:	02/05/04	File Path:	C:\BEST Resource\projects\03-0153\fig7.ppt
Scale:	N/A		Figure 7		

LOW FLOW



HIGH FLOW

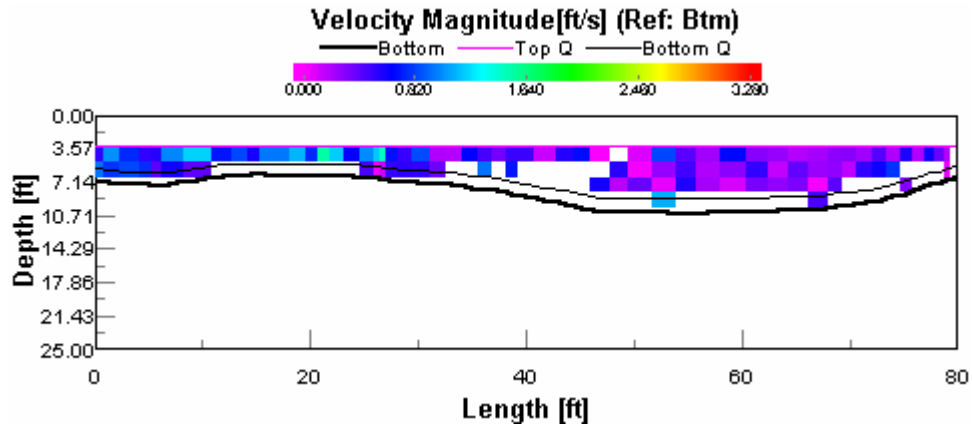


Acoustic Doppler Current Profile E-E'
 Current Velocity Delineation
 Cooper Landing, Alaska
 HDR Alaska, Inc

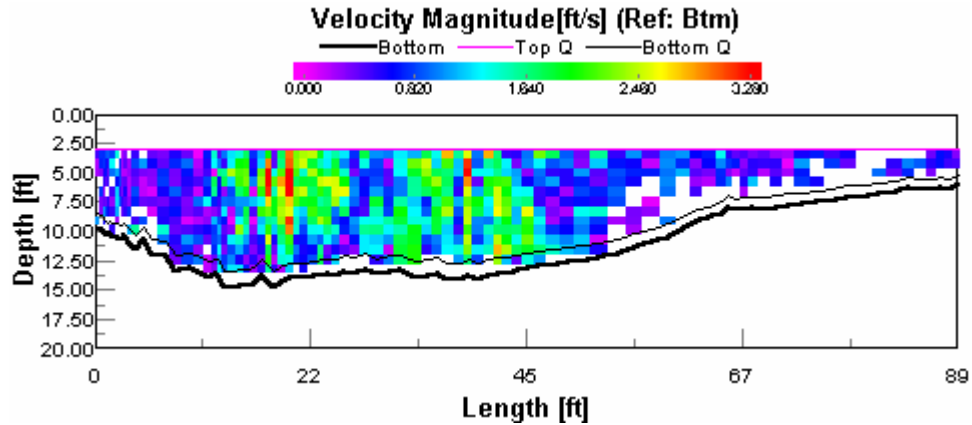
B.E.S.T. Resource

By:	CLB	Date:	02/05/04	Project No:	03-0153
Checked:	MAB	Date:	02/05/04	File Path:	C:\BEST Resource\projects\03-0153\fig8.ppt
Scale:	N/A		Figure 8		

LOW FLOW



HIGH FLOW

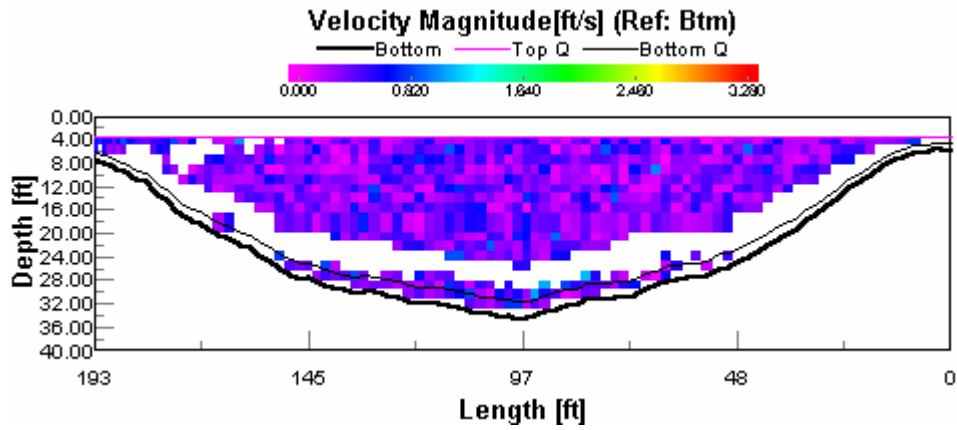


Acoustic Doppler Current Profile F-F'
Current Velocity Delineation
Cooper Landing, Alaska
HDR Alaska, Inc

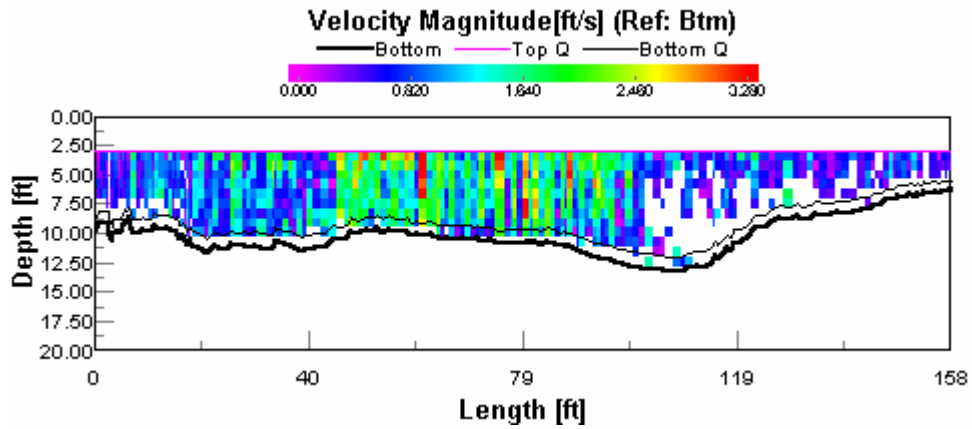
B.E.S.T. Resource

By:	CLB	Date:	02/05/04	Project No:	03-0153
Checked:	MAB	Date:	02/05/04	File Path:	C:\BEST Resource\projects\03-0153\fig9.ppt
Scale:	N/A		Figure 9		

LOW FLOW



HIGH FLOW

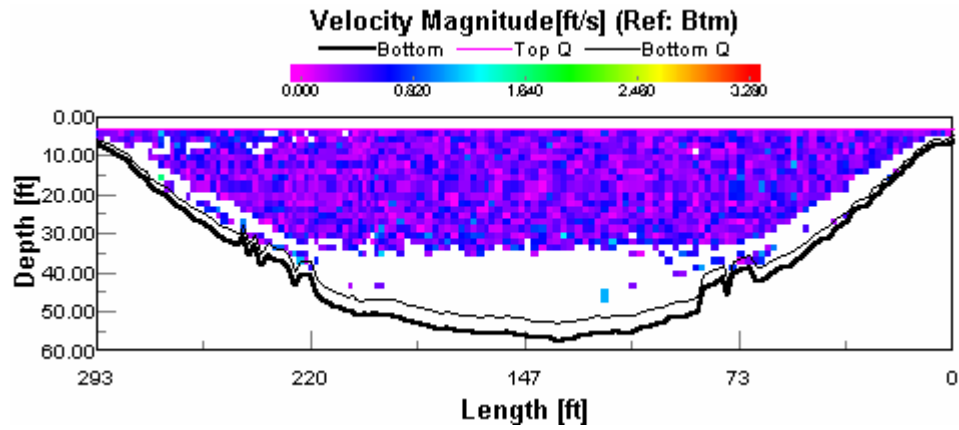


Acoustic Doppler Current Profile G-G'
 Current Velocity Delineation
 Cooper Landing, Alaska
 HDR Alaska, Inc

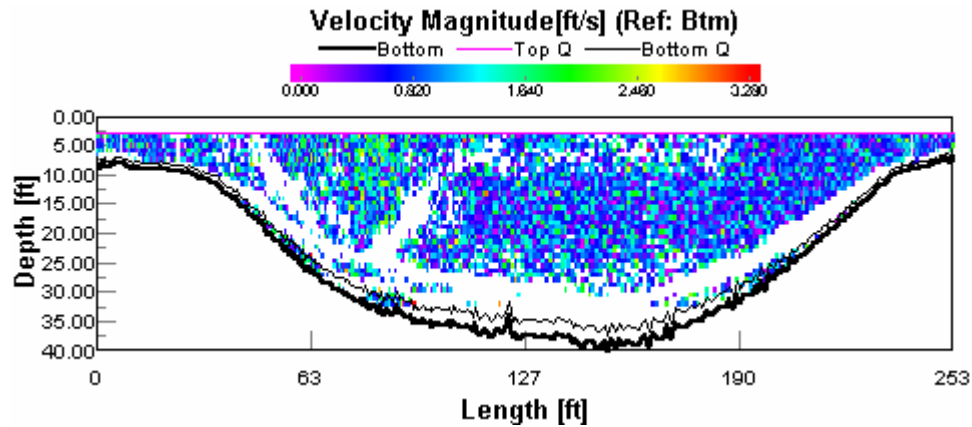
B.E.S.T. Resource

By:	CLB	Date:	02/05/04	Project No:	03-0153
Checked:	MAB	Date:	02/05/04	File Path:	C:\BEST Resource\projects\03-0153\fig10.ppt
Scale:	N/A		Figure 10		

LOW FLOW



HIGH FLOW



Acoustic Doppler Current Profile H-H'
Current Velocity Delineation
Cooper Landing, Alaska
HDR Alaska, Inc

B.E.S.T. Resource

By:	CLB	Date:	02/05/04	Project No:	03-0153
Checked:	MAB	Date:	02/05/04	File Path:	C:\BEST Resource\projects\03-0153\fig11.ppt
Scale:	N/A		Figure 11		

Appendix B

Summary of Responses to Comments on the Draft Report

June 2004

Summary of responses to comments on the draft report for the Preliminary Evaluation of Entrainment in Cooper Lake.

Date of Letter / Email	Commenting Party ¹	Comment	Chugach Response / Report Changes
4/30/04	ADFG	<u>Page 30 last paragraph.</u> It is stated, in a rather long sentence, that a more definitive assessment of whether entrainment is impacting these two fish populations is needed. In the preceding paragraph it is stated: “there is no indication of a significant project effect on these populations due to entrainment.” These two statements contradict each other and further clarification or analysis is needed.	The text has been clarified (p.30, last paragraph). Chugach’s intent in this reference to a “more definitive analysis” is the synthesis of all available data (i.e., Cooper Lake fish population data, plus the entrainment analysis) for discussion in Project effects analysis in the license application. [Text modified at p. 30, last paragraph.]
4/30/04	USFS	No comments.	Noted.

Note:

1. ADFG = Alaska Department of Fish and Game. USFS = USDA Forest Service (Chugach National Forest).