Final Report:
Cooper Creek Instream Flow Study and Preliminary Evaluation of Potential Aquatic Habitat Benefits

Cooper Lake Project (FERC No. 2170)

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ACKNOWLEDGMENTS

The Chugach/HDR/Northern Ecological Services team would like to thank the members of the Instream Flow Review Team for their crucial involvement in this project. This instream flow study took more than two years, included several different academic disciplines, and involved several subconsultants. The Instream Flow Review Team played a major role in supporting the coordination and direction of the study. Key members of the Instream Flow Review Team included Margaret Beilharz, Dave Blanchet, Phil Brna, Tom Cappiello, Eric Johansen, Jason Kent, Joe Klein, Paul McLarnon, John Morsell, Sally Morsell, Larry Peltz, Gary Prokosch, Dudley Reiser, Rob Spangler, and Burke Wick.

We would also like to thank Stuart Beck, Chi-Ming Huang, and Dudley Reiser of R2 Resource Consultants for providing essential and timely technical review of the PHABSIM and SNTEMP computer models. Their review of the draft and final models was critical in strengthening the technical merits and defensibility of the models.

EXECUTIVE SUMMARY

As a component of environmental studies for relicensing of the Cooper Lake Dam (FERC Project No. 2170), Chugach Electric Association (Chugach) has conducted an instream flow study of Cooper Creek, with the purpose of identifying the potential effects on stream habitat and temperature by theoretical alternative flow regimes. To determine the potential effects, the study team commenced three investigations; a habitat-flow relationship study, a water temperature study, and a sediment transport study. The final report for the sediment transport study was issued in June 2003, and is only briefly summarized in this report. Components of other studies associated with the relicensing efforts were utilized in the instream flow study, including habitat mapping from the Cooper Creek Aquatic Habitat Study, fish use and attainability data from the Cooper Creek Fish Resources Study, and water temperatures from the Cooper Creek Water Quality Study.

Chugach approached the instream flow study pursuant to the protocol described in the Instream Flow Incremental Methodology, or IFIM. An important task that was immediately undertaken was the formation of an Instream Flow Review Team comprised of hydrologists and fisheries biologists representing resource agencies and Chugach's consulting experts. All major decisions in the instream flow study were made by the Instream Flow Review Team, either in group meetings or by email communication. The instream flow study included a problem identification and study scoping phase. The study objectives were formed and agreed upon in this phase, and the technical investigations sought to answer the questions put forward in this phase of the study.

The flow-habitat component of the instream flow study required measured input data to determine quantity of physical microhabitat available for certain species and life stages of fish. PHABSIM, a suite of hydraulic and habitat models, was selected by the Instream Flow Review Team as the program to drive the flow-habitat modeling. Numbers and locations of study sites in Cooper Creek were determined by the review team, and a Chugach field crew collected data from the study sites five times in the summer of 2003 and early 2004. Continuous monitoring gages were also established in Cooper Creek. The data were collected and entered into the PHABSIM model for calibration. The draft model was reviewed by members of the Instream Flow Review Team and R2 Resource Consultants and revised accordingly, and the final model was calibrated. Alternative scenarios were agreed upon by the Instream Flow Review Team and analyzed using the final model.

The temperature study also required measured input data to determine water temperatures throughout Cooper Creek under different input flow and water temperature conditions. The deterministic water temperature model SNTEMP was selected by the Instream Flow Review Team to model the water temperatures in Cooper Creek. Monitoring points were established at three locations in Cooper Creek; these data, along with meteorological data gathered from nearby weather stations, comprised the daily input data for the model. The draft model was reviewed by members of the Instream Flow Review Team and R2 Resource Consultants and revised accordingly; the final model was calibrated and the same alternative flow scenarios modeled in the flow-habitat study were analyzed in the water temperature model.

The products of the flow-habitat and temperature models were "snapshots" of daily average available stream habitat in Cooper Creek with its associated water temperature in May through October 2003. Four potential alternative flow regimes were investigated, each assuming

diversions of cold water out of Stetson Creek, the major tributary to Cooper Creek, and an associated inflow of surface-warmed water from Cooper Lake at the head of Cooper Creek. The flow-habitat models suggested that these alternatives would modestly increase the quantity of spawning habitat, while providing minor decreases in quantities of fry and juvenile rearing habitat. The increases in temperatures, particularly for the alternatives that include the larger inflow of warm water from Cooper Lake and larger diversions of cold water out of Stetson Creek, would likely increase water temperatures, which are currently colder than the optimal temperatures for chinook salmon and rainbow trout, into the range of optimal temperatures for these species.

All the output from the flow-habitat and temperature models reflects data collected in 2003. Analysis of long-term meteorological and flow stations on the Kenai Peninsula revealed that average air temperatures in May through October 2003 were above average, and flows in Cooper Creek were likely below average. As such, the results of the flow-habitat and temperature models should be considered within this hydrologic context. Compared to the results for the 2003 modeling period, incremental increases in water temperature would likely be less pronounced in cooler years with greater inflows of cold tributary water.

The PHABSIM and SNTEMP analyses provide an indication of the suitability of physical habitats for various fish species and life history stages, but do not directly address the changes to species composition and abundance that might occur under mitigated conditions. Model results were integrated with knowledge of the resource and professional judgment to provide an indication of the kinds of changes that might result from an "optimal" mitigation scenario (diversion of water from Stetson Creek into Cooper Lake and release of up to 30 cfs from Cooper Lake into upper Cooper Creek).

Cooper Creek would be expected to experience a shift in fish population presence and interaction, an increase in total biomass, and an increase in genetic diversity. A resident population of rainbow trout might populate the short, upstream reaches between the Cooper Creek Dam and the barrier waterfalls, depending on the effectiveness of outfall screening. Resident and migratory populations of rainbow trout would also likely develop in the Stetson, Canyon, and Alluvial Reaches. Coho and chinook salmon would be expected to utilize the Alluvial and Canyon Reaches for spawning more frequently, and coho likely would also utilize the Stetson Reach for spawning. Chinook and coho fry would utilize the available habitat for rearing before outmigrating to the Kenai River.

The number of juvenile Dolly Varden using the Stetson Reach for rearing would likely be reduced from current numbers because of competition and predation. Changes to Stetson Creek outflow and Cooper Creek temperature might reduce the numbers of adult Dolly Varden that currently spawn in the upper Canyon Reach. Resident adult Dolly Varden feeding in Cooper Creek would likely increase. Overall changes to stream productivity would depend heavily on whether salmon were able to occupy the stream in significant numbers because of nutrients brought to the system by eggs and carcasses.

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). The Project was originally licensed by FERC in May 1957, and the current license term expires at the end of April 2007. Chugach is conducting studies to develop information needed to determine the effects of the Project on environmental resources. Information from the resource studies will be used to help evaluate potential protection, mitigation, and enhancement measures for possible inclusion in Chugach's final application to relicense the Project, which must be filed with FERC no later than April 30, 2005.

This report describes and analyzes the results of aquatic habitat modeling. Habitat was modeled for five flow scenarios, comparing the existing condition with four theoretical alternative flow regimes. This report also synthesizes the results of the habitat modeling with the results of the Cooper Creek temperature modeling and provides an overall interpretation of the effects of flow and temperature changes on fish use potential.

The analyses in this report draw on information obtained through several other study programs associated with the relicensing process including: the Cooper Creek Aquatic Habitat Analysis, the Cooper Creek Fish Resources Study, the Cooper Creek Sediment and Geomorphology Investigation, the Cooper Creek Water Quality Study, and the Cooper Creek Temperature Model Study. Draft and/or final reports of these studies have been released and are currently available on Chugach's website.

The work of the Instream Flow Review Team[1] has been instrumental in developing a model that includes mutually agreed-upon methodology, study locations, and suitability criteria. The series of Instream Flow Review Team meeting notes are available on the Chugach website. Members of the Instream Flow Review Team have been involved in technical review of the habitat and temperature models. This team-oriented technical review approach has been very effective in strengthening the technical merits and defensibility of the models.

This report first describes the existing technical information that has been developed, including Cooper Creek habitat inventory, Cooper Creek sediment transport and geomorphology study, Cooper Creek temperature modeling, and meetings of the Instream Flow Review Team. The report then describes the results of the habitat and temperature models, followed by an integrated analysis of the habitat and temperature model results. This report concludes with an interpretation of the analysis in terms of implications for fish in Cooper Creek.

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[1] The members of the Instream Flow Review Team are as follows: Doug Palmer, Gary Sonnevil, and Phil Brna (U.S. Fish and Wildlife Service); Bill Shuster, Dave Blanchet, Eric Johansen, Margaret Beilharz, and Rob Spangler (U.S. Forest Service); Larry Peltz (National Marine Fisheries Service); Bruce King, Jason Mouw, Jeff Breakfield, Joe Klein, Lee McKinley, and Tom Cappiello (Alaska Department of Fish & Game); David Katz and Gary Prokosch (Alaska Department of Natural Resources); Dudley Reiser and Mike Ramey (R2 Resource Consultants); John Morsell (Northern Ecological Services); Jason Kent, Paul McLarnon, and Sally Morsell (HDR Alaska); and Burke Wick (Chugach Electric Association).

Description of the Project

The Project dam and powerhouse are located within the Kenai Peninsula Borough, southcentral Alaska, approximately 55 miles south of Anchorage. The closest community to the Project dam and powerhouse is Cooper Landing, approximately 4 miles north of Cooper Lake. Project facilities are located on Cooper Creek, Cooper Lake, and Kenai Lake. In addition, the 90-mile-long Project transmission line between the Quartz Creek Substation (near Cooper Landing) and Anchorage crosses land located in both the Kenai Peninsula and Anchorage boroughs. Lands occupied by the Project are owned and/or managed by the USDA Forest Service (USFS), Alaska Department of Natural Resources, and private landowners. The Project area is shown in Figure 1.

Cooper Lake Dam was constructed in 1957–1959 on Cooper Creek, approximately 4.8 river miles from the mouth of the creek at the outlet of Cooper Lake. The dam raised the elevation of Cooper Lake to provide increased storage capacity for hydroelectric generation. Storage below the base of the dam (at elevation 1,168 feet above mean sea level [MSL]) is provided by the natural lake; storage above that level to the top of the Cooper Lake Dam spillway (elevation 1,210 feet MSL) is created by the dam. At its licensed normal maximum operating level of 1,210 feet MSL, Cooper Lake covers approximately 3,100 acres and has a mean depth of 187 feet.

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.

The Project stores all inflow to Cooper Lake and diverts the entire outflow from the reservoir through the tunnel/penstock to the powerhouse, which discharges into 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. For the period 1985–2002, the diverted natural flow ranged on average from around 20 cfs during late winter / early spring to about 260 cfs during early summer snowmelt, based on calculated inflows to Cooper Lake. Average annual inflow to / discharge from the reservoir for the same period was approximately 74,000 acre-feet (Chugach 2002).

The licensed maximum normal operating elevation of Cooper Lake is 1,210 feet MSL. However, since the mid-1980s, the reservoir has been operated at a normal maximum level of 1,194 feet MSL; the upper 16 feet of licensed reservoir storage is reserved for flood surcharge to ensure that the theoretical probable maximum flood (PMF) can be passed through the spillway without overtopping the dam. The reservoir typically is drawn down during late fall – early spring, experiences its most rapid refilling during the period of late spring – summer snowmelt runoff, and continues to fill through early fall. Within any given year, the reservoir typically fluctuates (on average) within a zone of about 15 feet (Chugach 2002).

Project-Related Resource Issues Addressed by this Study

Under existing operations of the Project, all inflow to Cooper Lake is diverted through the intake structure to the powerhouse on Kenai Lake, reducing flows and temperatures in Cooper Creek relative to the condition that would exist with outflows from the lake going into the creek. The objective of the instream flow study, as stated in the Instream Flow Study Plan (April 2003), was to determine the potential effects of a range of alternative flows on fish habitat, water temperature, and sediment transport in Cooper Creek. The results of this report are intended to provide an indication of the changes in quantity of fish habitat that could be expected under a range of potential mitigation scenarios, encompassing specific scenarios that have been investigated and that are analyzed in the license application. This report does not, however, address the feasibility and costs associated with altering the project necessary to produce the alternative flows studied in this report; such engineering analyses are set forth in the Draft Potential Cooper Creek Protection, Mitigation, Enhancement Measures Report, dated August 2004.

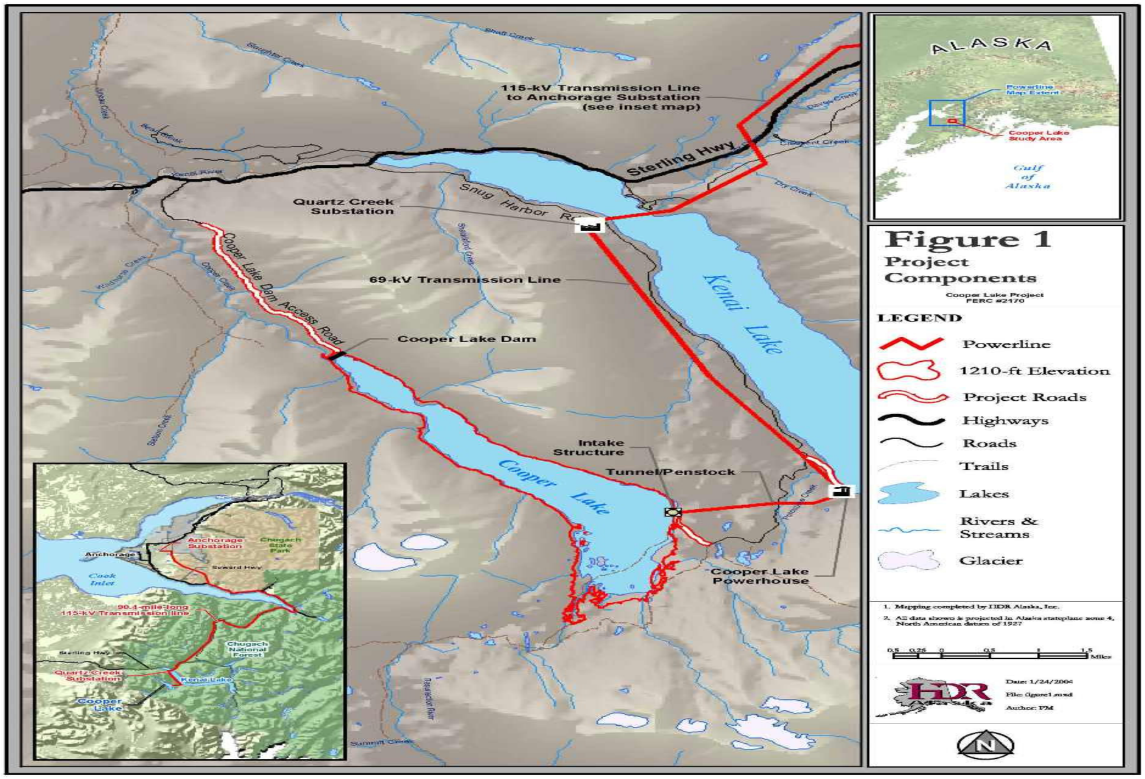
This report describes the process and results of the data collection, modeling, and analysis that were undertaken to meet the study objective. Major tasks include:

- Selection of study sites, target species/lifestage pairs, and target macro- and mesohabitats
- Development of Cooper Creek-specific Habitat Suitability Criteria
- Development and calibration of Cooper Creek habitat model based on 2003 data
- Development and calibration of Cooper Creek water temperature model based on 2003 data
- Application of a series of plausible, theoretical mitigation scenarios to the calibrated habitat and temperature models
- Analysis of habitat and temperature effects on fish populations
- Analysis of sediment transport on fish populations.

The tasks listed above are addressed in detail in this report, with the exception of the sediment transport question. A sediment and geomorphology investigation in Cooper Creek was undertaken in 2003; the results are detailed in the Cooper Creek Sediment and Geomorphology Investigation – Final Report, available on Chugach's relicensing website.

Study Area

The study area included Cooper Creek from the Cooper Lake Dam to the mouth of Cooper Creek near the Sterling Highway (Figure 2). Sampling and data collection locations for fish, sediment, and aquatic habitat were located throughout the creek, while fish habitat study locations were concentrated in the three reaches downstream of the lower barrier falls, a natural feature that is the upstream limit of anadromous and fluvial fish migration. Flow and temperature gages were established in the anadromous/fluvial reaches of Cooper Creek. In addition, a water temperature profile station was established in the north bay of Cooper Lake to collect information on temperature stratification of Cooper Lake in the ice-free months.



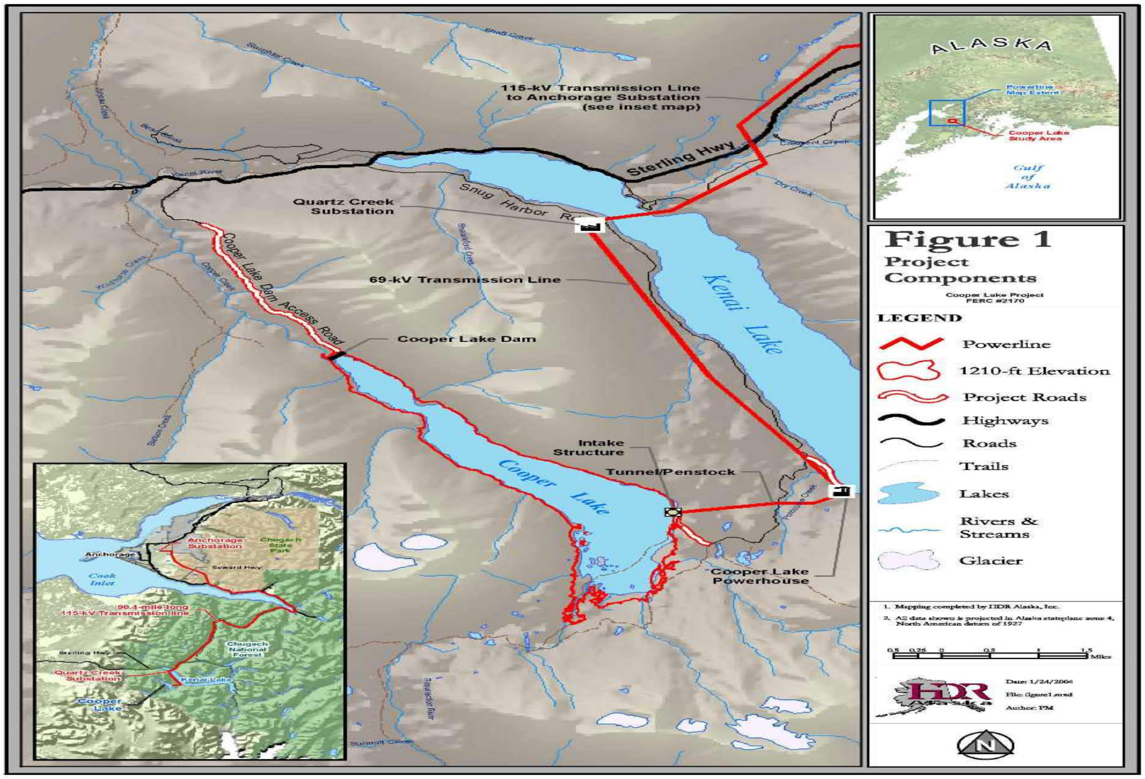


Figure 1. Cooper Lake Project Area

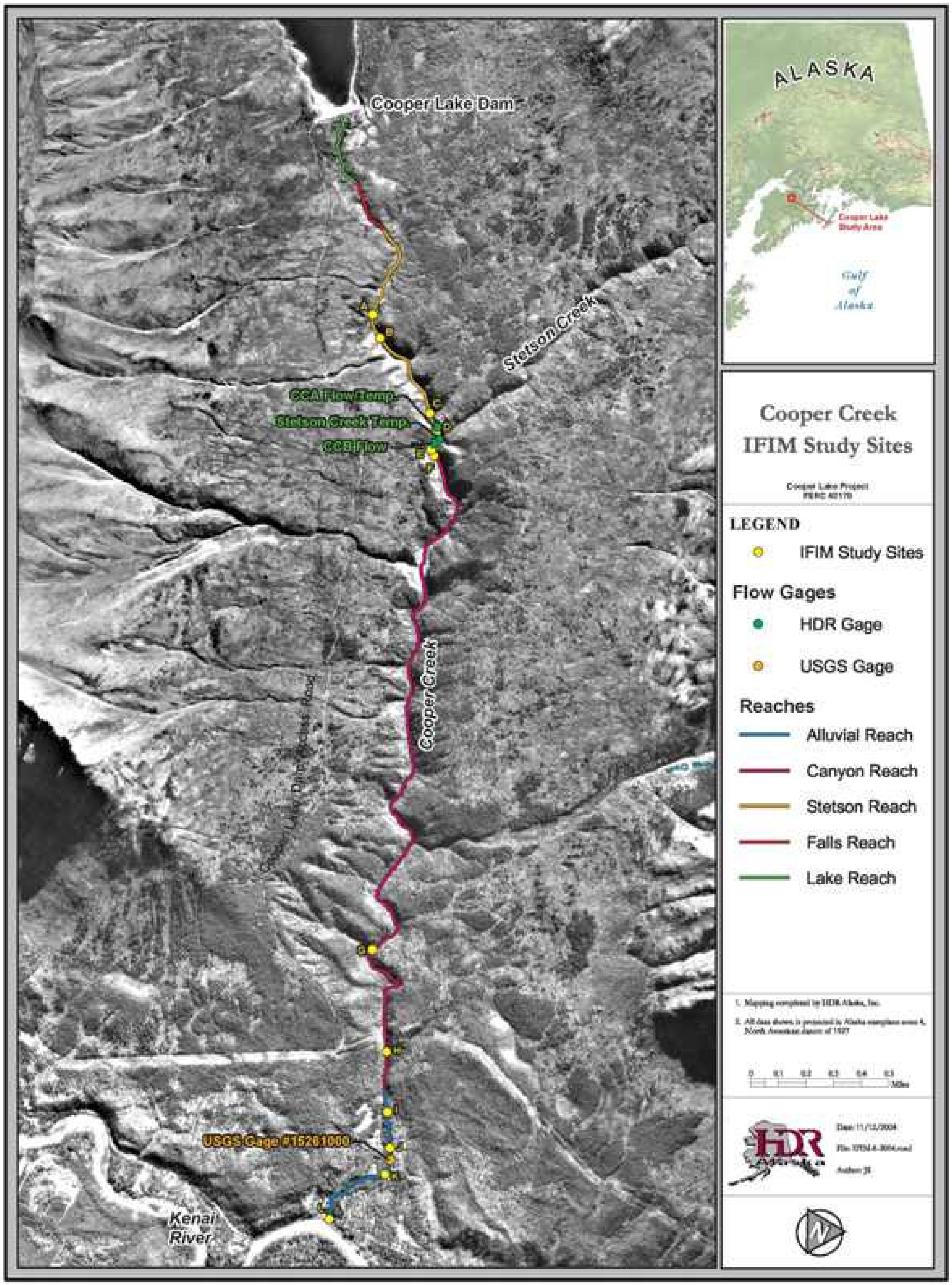


Figure 2. Cooper Lake Study Area Map

TECHNICAL INFORMATION

This section includes summaries of the studies and models that were developed as components of the Cooper Creek instream flow study. The technical information is divided into three sections: previous work that is documented in reports, notes, and technical memoranda; habitat model results; and temperature model results.

Previous Work

Instream Flow Study Plan

A scope of work and study plan was developed based on the items discussed in the December 5, 2002 Instream Flow Review Team meeting. The final study plan, issued April 2003, is available on the relicensing website.

Cooper Creek Aquatic Habitat Inventory

Data collection for the Cooper Creek aquatic habitat inventory (HDR Alaska, Inc., 2004a) was performed in the summer of 2002 and completed in the spring of 2003. The main purpose of the study was to quantify the aquatic habitat in the entire creek using protocol described in the USFS FSH 2090–Aquatic Habitat Management Handbook (R-10 Amendment 2090.21-2001-1), Chapter 20–Fish and Aquatic Stream Habitat Survey, which establishes standard techniques for fish biologists, hydrologists, and aquatic ecologists conducting fish and aquatic stream habitat surveys in coastal Alaska (USDA Forest Service, 2001). A secondary study purpose was to identify barriers to fish passage; a large waterfall at the upstream limit of the Stetson Reach was identified as the upstream barrier for migration of anadromous and fluvial fish.

Prior to conducting the aquatic habitat survey, five reaches were identified as containing general features unique to each reach. Figure 2 shows the locations of these unique mesohabitat types in Cooper Creek. The three lower reaches, namely the Alluvial, Canyon, and Stetson Reaches, are open to anadromous and fluvial fish. The Alluvial Reach is characterized by its alluvial material and pre-development fan-like qualities, and is heavily disturbed and channelized by historic mining activity. The Canyon Reach is characterized by its steeper gradient and steep canyon walls. The Stetson Reach has a much lower average flow than the Alluvial and Canyon Reaches as it is upstream of Cooper Creek's major tributary, Stetson Creek.

Upstream of the Stetson Reach, the Falls Reach is characterized by a series of large waterfalls that are impassible to fish. The upstream-most reach, the Lake Reach, is a short, disturbed reach of stream that has been altered by the construction of the Cooper Lake Dam, by the cutoff of historical flow in the reach, and by the presence of an abundance of beaver dams.

The Aquatic Habitat Analysis Report described in detail the habitat in each reach. Of particular importance to the instream flow study are the total areas of various mesohabitat types in the lower three reaches. The main fast water mesohabitat types present in the lower three reaches of Cooper Creek are riffle-cobble, riffle-boulder, cascade/step-pool, and run/glide. The main slow water mesohabitat types are main channel scour pools and plunge pools. Figure 3 illustrates the estimated available area in square meters for each of the above mesohabitat types in each of the three downstream reaches.

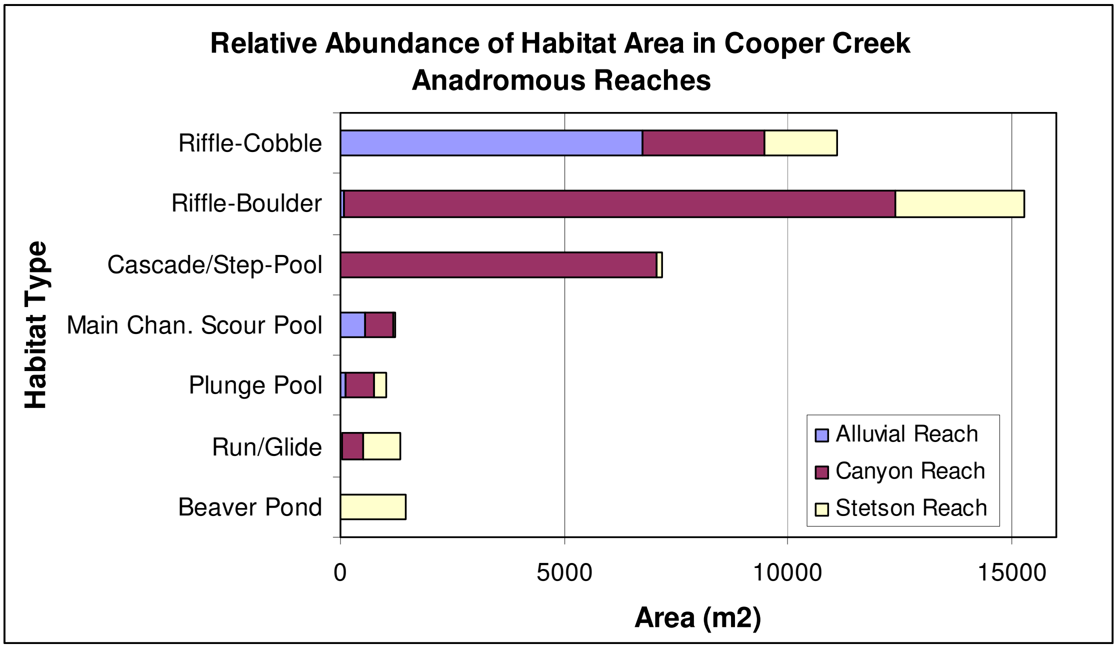


Figure 3. Relative Abundance of Habitat Area in Cooper Creek Anadromous Reaches

The results of the habitat analysis show that the most abundant mesohabitats in the Alluvial and Stetson Reaches are fast water riffle-cobble and riffle-boulder. In the Canyon Reach large substrate riffle-boulder and cascade/step-pool mesohabitats are most abundant. Pool mesohabitats are less abundant in the Alluvial and Stetson Reaches. The Stetson reach has the most diverse habitat with a mix of riffle-cobble, riffle-boulder, pool, run/glide, and beaver pond mesohabitats.

The Cooper Creek Aquatic Habitat Inventory Final Report is available on Chugach's relicensing website.

Cooper Creek Sediment/Geomorphology Report

Two major purposes of the sediment/geomorphology report (Inter-Fluve, Inc., 2004) were to determine the current sediment transport regime of Cooper Creek and to determine the existing morphological condition of the creek.

Sediment embedment analyses revealed that stream gravels in Cooper Creek are slightly to moderately embedded and would be considered by biological criteria to be suitable for spawning habitat for salmonids. Grain size distribution analyses indicated that the amounts of fine-grained material within the stream gravels are near or less than the levels that would reduce the survival of salmonids eggs to hatching and emergence of fry from the gravel. Incipient motion particle size analyses indicated that the existing hydrologic regime fosters retention and scour frequencies of spawning sized gravels that create conditions appropriate for salmonid use.

Geomorphic investigations found that Cooper Creek above the Stetson Creek confluence has adjusted to the reduced flow regime by variously filling the narrow valley floor with material delivered primarily from upslope colluvial sources. In the Canyon Reach, upslope sources of material have also been delivered, however these materials appeared to be relatively mobile under the current hydrologic regime. The Alluvial Reach morphology appeared to be more a legacy of past mining disturbance and diminished large wood recruitment than hydrologic regime. Overall, the lower three reaches of Cooper Creek appeared to be roughly in equilibrium with the current hydrologic and sediment delivery regimes.

The Cooper Creek Sediment/Geomorphology report is available on the Chugach relicensing website, and will not be discussed further in this report.

Cooper Creek Draft Temperature Model Technical Memorandum[2]

A baseline SNTEMP (Theurer, et al. 1984) water temperature model was developed and calibrated for Cooper Creek for the modeling period May 1, 2003 to October 30, 2003. The model was based on water temperature and flow data collected on Cooper Creek and meteorological data collected in the vicinity of the Cooper Creek basin. The calibration of the model concentrated on the period in which model simulations would be run, May to October 2003. This model includes the sampling period for the fish species investigated in the instream flow study: rainbow trout, chinook salmon, coho salmon, and Dolly Varden.

The preliminary model simulations indicate that a warm water input at the head of Cooper Creek (from release at the dam of surface water from the reservoir) would increase monthly average water temperatures for, at least, the months of June–September, with certain scenarios predicting increases in water temperature in May and October as well. Greater increases in water temperatures over the baseline temperatures were generally predicted at the upstream gage in Cooper Creek, located immediately upstream of the Stetson Creek confluence, compared to the downstream gage, located near the mouth of Cooper Creek. In general, model simulations that included the diversion of Stetson Creek flows away from Cooper Creek and into Cooper Lake resulted in higher water temperatures at the downstream gage. These models were run using water temperature, flow, and meteorological data measured at or near the study site in May–October, 2003.

Cooper Creek Fish Resources Study

The Cooper Creek Fish Resources Study (Northern Ecological Services and HDR Alaska, Inc., 2004) describes detailed field studies and analysis of fish populations in Cooper Creek. The report discusses distribution, abundance, and density of species and life classes of fish, and

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[2] A separate Draft Temperature Model Technical Memorandum was developed for the preliminary temperature model. Only three of the preliminary temperature model scenarios described in the Technical Memorandum were similar to the scenarios run in the habitat model: the existing conditions, “10 in, 10 out,” and “30 in, 30 out” scenarios. The remaining temperature model scenarios were run after the draft memorandum was issued. In the interest of brevity, the Draft Temperature Model Technical Memorandum will not be updated. The output of the final temperature models are instead described in this document.

relates use to microhabitat and macrohabitat scales. The habitat use data for Dolly Varden was used by the Instream Flow Review Team to develop site-specific Habitat Suitability Criteria.

Cooper Creek Streamflow and Water Quality Study

The Cooper Creek Streamflow and Water Quality Study (HDR Alaska, Inc., 2004b) developed baseline nitrogen gas conditions and evaluated impacts of watershed uses. Flow data were collected in Cooper Creek and temperature data were collected in Stetson Creek, Cooper Lake, and Cooper Creek. The flow and temperature data were used as existing conditions data for the instream flow study.

Instream Flow Review Team Meeting Notes

The Instream Flow Review Team met on several occasions to determine model selection, study site selection, target species, and habitat suitability criteria selection. Meeting minutes are published on the Chugach website. Meeting dates and topics are provided below:

December 5, 2002 – Kickoff Meeting

This meeting outlined the responsibilities of the Instream Flow Review Team and the study timeline. Model selection, habitat type selection, and target species/lifestage selection were two major issues that were covered.

March 26, 2003 – Transect Selection Meeting

The main purpose of this meeting was to select the number and general locations of mesohabitat types that would be measured in the creek.

May 9 and 12, 2003 – Transect Selection Field Trip

This two-day meeting involved members of the Instream Flow Review Team working in the field to select study sites based on the mesohabitat types and locations selected in the March 26, 2003 meeting. The locations of the selected study sites are shown in Figure 2.

June 11, 2003 – Status Meeting

This meeting emphasized a summary of the transect selection process and discussion of data collection methods. The sediment and geomorphology study team was introduced and general methods for the study program were discussed.

December 10, 2003 – Status Meeting

Results of the 2003 study effort were summarized. Additional data needs were discussed along with strategies for acquiring the needed information.

March 11-12, 2004 – Habitat Suitability Criteria Selection Meeting

In this two-day meeting, members of the Instream Flow Review Team reviewed Cooper Creek data and habitat suitability criteria (HSC) from other systems, and discussed and selected HSC specific to Cooper Creek for the target species and lifestages.

Cooper Creek-specific temperature criteria were also discussed for the target species and lifestages. It was decided that more research and was needed, and draft criteria would be sent to the group for review. The final Cooper Creek temperature criteria were adopted in August 2004.

October 12, 2004 – Status Meeting

This meeting focused on review of the Draft Interim Instream Flow Report, of the habitat and temperature models, of the discussion of model interpretation and synthesis relative to estimation of potential fish populations, and on requests for additional information to be included in the Draft Final Instream Flow Report.

Fish Species Periodicity

Alaska Department of Fish and Game (ADF&G) developed stream-specific periodicity tables for the selected target species and lifestages that would be likely to use Cooper Creek based on likely periods of the year in which the species/lifestage would be likely to use Cooper Creek. The Cooper Creek periodicities of selected species and lifestages are presented in Table 1.

Table 1. Selected Cooper Creek Species/Lifestage Periodicity Chart.

Species/Lifestage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chinook Salmon												
Spawning							??	????	??			
Rearing	????	????	????	????	????	????	????	????	????	????	????	????
Coho Salmon												
Spawning									??	????	????	
Rearing	????	????	????	????	????	????	XXXX	XXXX	????	????	????	????
Dolly Varden												
Spawning									??XX	XXXX	?	
Rearing	????	????	????	????	????	XXXX	XXXX	XXXX	XXXX	XXXX	????	????
Adult Passage						????	XXXX	XXXX	XXXX	XXX?	?	
Rainbow Trout												
Spawning				?	????	????						
Rearing	????	????	????	????	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	????	????
Adult Passage				??	????	????	??XX	XXXX	XXXX	XXXX		

Notes: All periodicity charts are based on professional judgment of ADF&G biologists
Adult passage - for salmon species is immigration, for RBT and DV, immigration and emigration
? - Data not available or timing is incomplete

METHODS

Habitat Modeling

This section documents the methodology development, data collection, model development, calibration, and analysis of the Cooper Creek habitat model.

Selection of Methodology

On December 5, 2002, the Instream Flow Review Team met for the first time and, among other items, selected a methodology to use for the Cooper Creek Instream Flow Study (the details of this meeting are given in the Meeting Summary notes in Appendix A). The selected methodology was the Instream Flow Incremental Methodology, or IFIM (Bovee, et al. 1998), including the models PHABSIM (Milhous, et al. 1989) for habitat modeling and SNTEMP for water temperature modeling. In this meeting, the team also expressed its interest in a sediment and geomorphology study, the results of which were summarized in a previous section of this report.

Stream habitat modeling was limited to the Alluvial, Canyon, and Stetson Reaches as agreed upon at the Instream Flow Workshop.

The Instream Flow Review Team also selected the species and lifestages to be considered in the instream flow study. These species and lifestages are as follows:

- Rainbow Trout (*Oncorhynchus mykiss*)
    - Spawning
    - Juvenile rearing
    - Adult rearing
- Dolly Varden (*Salvelinus malma*)
    - Spawning
    - Juvenile rearing
    - Adult rearing
- Chinook Salmon (*O. tshawytscha*)
    - Spawning
    - Juvenile rearing
- Coho Salmon (*O. kisutch*)
    - Spawning
    - Juvenile rearing

Description of Habitat Model

The Physical Habitat Simulation System Reference Manual, Information Paper 26 (Milhous, et al., 1989), states "the purpose of the Physical Habitat Simulation System is to simulate a relationship between streamflow and physical habitat for various life stages of a species of fish or a recreational activity." PHABSIM is a suite of models that combine stream flow hydraulics with fish biological parameters to create an index of habitat available to a species or lifestage of fish in a user-specified reach of stream. The "virtual stream" in the PHABSIM environment uses cross-sections that were measured at specific locations and include multiple stream habitat types and/or stream reaches.

PHABSIM includes three modules: hydraulic simulation, habitat suitability curve building, and habitat simulation. These modules are described in more detail below. Details of the habitat suitability module are also provided in the March 11-12 Habitat Suitability Criteria Selection Meeting of the Instream Flow Review Team Meeting Notes in Appendix A.

In PHABSIM, a river reach is defined by a number of cross-sections spaced a sufficient distance apart to capture the hydraulic characteristics of the reach. This distance can range from a few meters to hundreds of meters, depending on the lengths of continuous habitat types within the reach. The purpose is to develop a set of depths, water surface elevations, and cross-section-averaged velocities for all cross-sections in the reach at a range of discharges. The user begins this process by entering the cross-section bed geometries and water surface elevations (stages) for the calibration discharges. PHABSIM then develops a relationship between stage and discharge for the reach. Once this relationship is determined, depth at any point along the channel cross-section can be determined by subtracting the bed elevation from the stage. Three approaches exist to determine stage-discharge relationships; hydraulic models within the PHABSIM software: a log-log linear regression (IFG4), use of Manning's equation (MANSQ), and a standard step-backwater calculation (Water Surface Profile; WSP). Either one or all three approaches can be used in a reach for different discharges, depending on which approach(es) provide the best calibration of modeled and observed parameters (water surface elevation and velocity). Once a stage-discharge relationship has been determined using IFG4, MANSQ, and/or WSP, the IFG4 approach is used to determine a stage-velocity relationship. An important output of hydraulic modeling in PHABSIM is the calculation of the area of flow at each cross-section in the study reach. The areas are calculated by adding the areas of a number of user-specified vertical cells that are determined by the number of points used to create the cross-section geometry. The corresponding depths and velocities of each of the cells are also calculated and forwarded to the habitat modeling module of PHABSIM.

The habitat models in PHABSIM combine the output from the hydraulic simulation and the HSC curves to develop a measure of available habitat as a function of discharge. In doing so, PHABSIM assumes that the individual fish will select the most desirable habitat condition first, and when those most desirable locations are filled, will select a less desirable condition nearby. Each cell in a cross-section is evaluated independently. Several approaches exist in PHABSIM for habitat simulation: the HABTAE program calculates weighted usable area (WUA) for each reach and cross-section; the HABTAM program simulates conditions in which fish can migrate laterally within a cross-section in order to make use of the available WUA when there is a change in discharge; and the HABEF program calculates the physical habitat considering the conditions at two stream flows and/or for two lifestages or species of fish. The HABTAE program was utilized in this study.

The output from PHABSIM is an index of WUA for a number of flows and flow regimes. Care must be taken not to interpret PHABSIM output as hard and fast numbers, rather as a simulated index of probable trends in available habitat as a function of flow and flow regimes.

The primary limitations of PHABSIM are its reliance on habitat suitability criteria that, except in the case of Dolly Varden, were not developed from data specific to Cooper Creek fish. Another limitation is the inevitable loss of richness that comes from breaking a 7.5-km creek that contains extremely varied microhabitat throughout its length into tens of cross-sections to represent a few habitats. The most effective way to reduce the magnitude of these limitations is to carefully plan and wisely choose HSC and cross-sections that best represent the fish and physical habitat, respectively, of Cooper Creek.

It should be noted that the PHABSIM model predicts a relationship between available habitat conditions under a range of discharges. It does not, however, "make the leap" to providing estimates of fish population abundance or biomass, or relationships of fish use as a function of discharge. In later sections, this report discusses the potential changes to fish populations that might occur as a result of some possible mitigation alternatives for Cooper Creek. This discussion is based on analysis of water temperature and habitat modeling of the alternatives, and not direct output from the models.

Data Collection

The Cooper Creek Instream Flow Study required a great deal of data collection, including field data and hydrologic data that had already been collected by the USGS. The data collection process started with mesohabitat level mapping of the creek. Study sites were selected based on the quantity and locations of mesohabitat types, and cross-sections were set within each study site. Continuous hydrology gages were set and monitored in the system, and hydraulic measurements were taken on multiple occasions at each study site.

Aquatic Habitat Analysis

An aquatic habitat analysis was conducted in 2002 and 2003 to determine the types, distribution, and quantity of aquatic habitats in Cooper Creek. This analysis led to habitat mapping of the three anadromous macrohabitat reaches of Cooper Creek – the Alluvial, Canyon, and Stetson Reaches – and was crucial in the selection of Instream Flow study sites. Two additional reaches with distinct macrohabitats, the Falls and Lake Reaches, were identified upstream of the Alluvial, Canyon, and Stetson Reaches; these reaches were not considered available to anadromous and fluvial fish because of a major waterfall (Figure 4) that acts as a barrier to upstream migration. The locations of the five macrohabitat reaches in Cooper Creek are shown in Figure 2, and a summary of the anadromous macrohabitat reaches is provided in Table 2.

Stream habitat survey methods for Cooper Creek were adapted from the USFS FSH 2090-Aquatic Habitat Management Handbook (R-10 Amendment 2090.21-2001-1), Chapter 20-Fish and Aquatic Stream Habitat Survey, which establishes standard techniques for fish biologists, hydrologists, and aquatic ecologists conducting fish and aquatic stream habitat surveys in coastal Alaska (USDA Forest Service, 2001). Method protocols are described in detail in the USFS handbook.

HDR staff conducted a Tier III analysis of the Alluvial and Stetson Reaches and about 70% of the Canyon Reach; the remaining Canyon reach was surveyed using a Tier II level of effort. The detailed methods of the aquatic habitat mapping procedures are given in the Aquatic Habitat Analysis Final Report, available on the relicensing website.

Figure 4. Lower Barrier Falls, the Upstream Limit of Anadromous Fish in Cooper Creek.

Table 2. Macrohabitat Description of Cooper Creek Anadromous Reaches

Reach	Length	Gradient	Dominant Habitat Type	Dominant Substrate
Alluvial	0.70 mi	1.5%	MM2 – single, moderately sinuous channel with moderate gradient	Large gravel to boulder (32-512 mm)
Canyon	2.70 mi	2-6%	HC3 – single, linear channel with high gradient	Small cobble to large boulder (90-4096 mm)
Stetson	0.89 mi	2-3%	MC2 – single, linear channel with moderate gradient	Medium gravel to small cobble (16-90 mm)

The Tier III habitat mapping method included the visual and measurement-based identification of all river habitats into mesohabitat units. The major mesohabitats are listed and described in Table 3.

One of the results of the aquatic habitat analysis was a series of habitat maps for Cooper Creek that identified the Tier III mesohabitat types throughout the creek. The maps of the anadromous reaches are provided in Appendix B. These maps and those for the remaining reaches of Cooper Creek are also available on Chugach's relicensing website.

Study Site Selection

The process for study site and transect selection began in the Instream Flow Review Team meeting on March 26, 2003. The team based its guidance for the selection of study sites on the aquatic habitat data collected in 2002. The recommendations of the team are given in Table 4.

Members of the Instream Flow Review Team walked portions of the anadromous reaches of Cooper Creek on May 9 and 12, 2003 (the meeting notes are given in Appendix A). Using the guidance provided in Table 4, the group selected eleven study sites and transects for each site. A twelfth study site, representing the run-glide mesohabitat type, was added by HDR. The locations of the study sites are shown in Figure 2 and detailed below. Photos of each study site are given in Appendix C. A summary of the study site parameters is provided in Table 5.

Table 3. Description of Major Cooper Creek Mesohabitats

Mesohabitat Type	Abbreviation	Length in Anadromous Reaches (ft)	Description
Riffle-Cobble (upstream)	Rf-cb-up	1693	Cobble (64-256 mm)-dominated riffles in the Stetson Reach
Riffle-Cobble (downstream)	Rf-cb-down	5151	Cobble (64-256 mm)-dominated riffles in the Canyon and Alluvial Reaches
Riffle-Cobble (with side channel)	Rf-cb-sc	1414	Cobble (64-256 mm)-dominated riffles in the Alluvial Reach with side channel habitat
Riffle-Boulder (upstream)	Rf-bd-up	2018	Boulder (>256 mm)-dominated riffles in the Stetson Reach
Riffle-Boulder (downstream)	Rf-bd-down	7959	Boulder (>256 mm)-dominated riffles in the Canyon and Alluvial Reaches
Dam/Plunge Pool	Pl-dm + Pl-pp	925	Pool caused by backwater and scour, all three reaches
Main Channel Scour Pool	Pl-mcs	1192	Scour-dominated pool, all three reaches
Cascade/Step-Pool	Cs-sp	3153	Fastwater habitat, series of short drops and high turbulence, may include exposed bedrock
Run/Glide	Gl-gl	699	Fastwater habitat with little surface agitation and no major obstructions

Table 4. Mesohabitat Type Study Recommendations, March 2003.

Segment	Mesohabitat Type	# of Study Sites	# of Transects
Alluvial Reach	Rf-cb	3[a]	[b]
		1	[b]
Canyon Reach	Cs-sp	1	[b]
	Pl-mcs	1	[b]
	Rf-bd	1	[b]
	Rf-cb	[c]	[c]
Stetson Reach	Pl-dm + Pl-pp	1	[b]
	Gl-gl	1	[b]
	Rf-bd	1	[b]
	Rf-cb	1	[b]

[a] – 2 of the 3 study sites describe side channels.

[b] – Approximately 3-5 per study site.

[c] – If necessary.

Each study site has unique properties and habitat types:

- **Study Site A** – Stetson Reach. Riffle-cobble habitat, upstream of Stetson Creek. This is the upstream-most study site. Cross-section locations were selected considering the presence of gravel bars. The downstream cross-section transects a hydraulic control formed by a narrowing of the stream channel.
- **Study Site B** – Stetson Reach. Plunge pool habitat, upstream of Stetson Creek. One cross-section transects the deepest part of a plunge pool formed by a bedrock outcrop in

the channel. The remaining cross-sections were located by setting equal distances between them. The downstream cross-section transects the head of a riffle.

- **Study Site C** – Stetson Reach. Riffle-boulder habitat, upstream of Stetson Creek. Reach confined by steep canyon walls. Cross-section locations were set by breaks in bank cover. The downstream cross-section transects the head of a cascade reach.
- **Study Site D** – Stetson Reach. Run-glide habitat, immediately upstream of the Stetson Creek confluence. Reach confined by steep canyon walls. Rather homogeneous habitat, hydraulics likely affected by Stetson Creek flow, primarily during periods of high discharge. Cross-section locations were set by breaks in bank cover. The downstream cross-section transects the head of a plunge pool created by the Stetson Creek inflow.
- **Study Site E** – Canyon Reach. Riffle-boulder habitat, a few hundred feet downstream of the Stetson Creek confluence and immediately upstream of Study Site F. Study Sites E and F share vertical control benchmarks. Very turbulent reach with much higher flows than Study Sites A-D. Reach confined by steep canyon walls. Cross-section locations were set by breaks in bank cover. The downstream cross-section transects the head of a cascade reach.
- **Study Site F** – Canyon Reach. Cascade/step-pool habitat, a few hundred feet downstream of the Stetson Creek confluence and immediately downstream of Study Site E. Extremely turbulent reach, confined by vertical wall on left side and steep canyon wall on right side. Cross-section locations were set by equal intervals, and with the intention to avoid areas of significant tangential velocity. The downstream cross-section transects the head of a waterfall.
- **Study Site G** – Canyon Reach. Riffle-cobble habitat, in the lower half of the Canyon Reach. Fairly turbulent reach. Cross-section locations were set by breaks in cover. The downstream cross-section transects gravel bar created by the inflow of a small tributary on the right side of the creek.
- **Study Site H** – Canyon Reach. Main channel scour pool habitat, several hundred feet upstream of the "transition zone" of the Canyon Reach. Recent recreational mining disturbance directly upstream of this site. Cross-section locations were set by equal intervals, and with the intention to avoid areas of significant tangential velocity. The downstream cross-section transects the tail crest of the pool.
- **Study Site I** – Alluvial Reach. Main channel scour pool habitat, several hundred feet downstream of the end of the Canyon Reach and immediately upstream of Study Site J. Cross-section locations were set by equal intervals, and with the intention to avoid areas of significant tangential velocity. The downstream cross-section transects the tail crest of the pool.
- **Study Site J** – Alluvial Reach. Riffle-cobble habitat, several hundred feet downstream of the end of the Canyon Reach and immediately downstream of Study Site I. Cross-section locations were set by equal intervals. The downstream cross-section transects the head of a historical rock weir.
- **Study Site K** – Alluvial Reach. Riffle-cobble habitat with side channels. This study site has the longest distance between the cross-sections of the twelve study sites. The cross-section locations were set by breaks in cover and the presence of a side channel; cross-sections were set at the inlet and the outlet of the side channel. The downstream cross-section transects a hydraulic control formed by a narrowing of the stream channel.
- **Study Site L** – Alluvial Reach. Riffle-cobble habitat with side channels, located immediately upstream of the Kenai River confluence and the Sterling Highway bridge.

The hydraulics of this reach are likely affected by the stage of the Kenai River. The cross-section locations were set by breaks in cover and the presence of a side channel; cross-sections were set at the inlet and the outlet of the side channel. The downstream cross-section transects a low terrace upstream of the Kenai River confluence.

Hydraulic Data Collection Procedures

Site-specific hydraulic data were collected by HDR field crews on five occasions:

1. **Trip 1** – May 10-11 and 13-15, 2003
2. **Trip 2** – June 24-25, 2003
3. **Trip 3** – September 17-19, 2003
4. **Trip 4** – October 8 and 10, 2003
5. **Trip 5** – May 4-6, 2004

Table 5. Descriptions of Selected Cooper Creek Study Sites.

Study Site Desig.	Reach	Mesohabitat Type	# X-Secs	Transect Selection Basis
A	Stetson	Rf-cb	5	Presence of island
B	Stetson	Pl-dm + Pl-pp	4	Equal intervals
C	Stetson	Rf-bd	4	Breaks in cover
D	Stetson	Gl-gl	3	Breaks in cover
E	Canyon	Rf-bd	4	Breaks in cover
F	Canyon	Cs-sp	3	Equal intervals and tangential velocity
G	Canyon	Rf-cb	4	Breaks in cover
H	Canyon	Pl-mcs	4	Equal intervals and tangential velocity
I	Alluvial	Pl-mcs	4	Equal intervals and tangential velocity
J	Alluvial	Rf-cb	3	Equal intervals
K	Alluvial	Rf-cb	4	Presence of side channel and breaks in cover
L	Alluvial	Rf-cb	5	Presence of side channel and breaks in cover

Each field trip involved the surveyed observation for check of vertical and the associated horizontal control (headpin and tailpin) for each study site. Water surface elevations were also observed and recorded on the day of survey at each study site. Field trips 1 and 5 included collection of velocity and depth data. Trip 3 included collection of substrate and cover information. Trip 1 also included the survey of existing ground profile for each study site between headpin and tailpin using accepted engineering survey methods.

Vertical elevation control and horizontal profile data were obtained through utilization of standard differential engineering survey methods. A Lietze/Sokkisha BC2 Automatic Level was employed for differential observation and collection.

Due to a lack of a published vertical control datum in the Cooper Creek valley, temporary benchmarks (TBM) were set for vertical control with an assumed elevation of 100.00 feet at each study site. Two benchmarks were set at each study site; study sites E and F shared vertical benchmarks due to their proximity to each other, as did sites I and J. At study site L, located near the Sterling Highway bridge, a BLM monument (No. 57286) was recovered and used as a benchmark reference point for the study site. The only TBM that was observed to have moved from its reference position during the study period was TBM "K-A". This temporary benchmark was set in the trunk of a tree using a small spike. The creek bank adjacent to the tree was subjected to natural erosion during the study period, and a drop in the elevation of the benchmark was observed between Trips 2 and 3.

Headpin (bank right facing downstream) and tailpin (bank left facing downstream) locations for each study site were set well above bankfull flow elevation to describe the primary floodplain, and created a cross-section line perpendicular to the dominant stream flow direction. A fiberglass survey tape ("rag tape") was attached and pulled taut between headpin and tailpin to create a chord, as shown in Figure 5. In the floodplain, a survey rod was traversed along the rag tape manually to vertical inflection points. The horizontal distance and vertical elevation was observed and recorded at these points. In the active stream channel, all inflection points were surveyed with a maximum horizontal distance of 2 feet. Boulders and large rocks were represented in the survey as described in Bovee (1997). The distances between each cross-section in a study site was measured from the center of channel using a rag tape, and included "doglegs" if the cross-section locations followed around a bend in the stream (this was the case for Study Site K).

Figure 5. Cross-Section Survey at Study Site F.

Water surface elevations were collected also using protocol described in Bovee (1997). On most occasions, three water surface elevations were collected at left, center, and right side; more water surface elevations were collected when the flow was very turbulent, and water surface elevations were not collected in areas of zero flow or low terraces. Average water surface elevations for each cross-section at each trip were calculated by averaging the measured water surface elevations after outliers had been omitted from the data set.

Hydraulic slope was determined for each study site using the known distances between the cross-sections and the average upstream and downstream water surface elevations.

Stream flow was estimated using depth and velocity measurements for each cross-section. Depth at each vertical cell was measured to the nearest 0.1 foot using a top-setting wading rod with 0.1 foot increments. Velocities were recorded using a Marsh-McBirney electromagnetic flow meter to the nearest 0.1 foot/second. The velocity meters were calibrated in the factory prior to Trip 1.

Substrate measurements were made for each vertical cell. A Wolman Pebble Meter, also known as a "gravelometer," was provided for the study by the U.S. Forest Service. Shown in action in Figure 6, the gravelometer includes square punched holes with known diagonal measurements made to indicate the upper length of the intermediate axis of a sample of substrate. The diagonal length of the smallest hole the substrate could fit through was recorded and converted to a conventional Modified Wentworth Scale substrate coding system as described in Wilson and Underwood (1991). Additional codes were recorded for substrate sizes not measurable using the gravelometer; these include organic, silt, sand, and bedrock codes. These substrate types were measured and recorded using ocular scale. The available diagonal lengths of the gravelometer and the conversion to the Modified Wentworth Scale are given in Table 6.

Figure 6. Substrate Sizing Using Wolman Pebble Meter, or "Gravelometer."

Table 6. Gravelometer Sizes and Conversions to Modified Wentworth Scale.

Gravelometer Measurement	Modified Wentworth Scale	Code	Description
(mm)	**(mm)**		
Organic	Organic	0	Organic
Silt	< 2	1	Silt/Sand
Sand	< 2	1	" "
2.0	2-8	2	Small Gravel
2.8	2-8	2	" "
4.0	2-8	2	" "
5.6	2-8	2	" "
8	2-8	2	" "
11	8-32	3	Medium Gravel
16	8-32	3	" "
22.6	8-32	3	" "
32	8-32	3	" "
45	32-64	4	Large Gravel
64	32-64	4	" "
90	64-128	5	Small Cobble
128	64-128	5	" "
180	128-256	6	Large Cobble
256	128-256	6	" "
512	> 256	7	Boulder
1024	> 256	7	" "
2048	> 256	7	" "
Bedrock	Bedrock	8	Bedrock

Cover descriptions were also noted for each vertical cell, although they were not used in the subsequent habitat analysis. Observations were made for each vertical cell exhibiting overhanging vegetation 0-1 foot above the water surface, overhanging vegetation 1-4 feet above the water surface, undercut banks, and boulders likely to create velocity refugia.

Hydrology Data Collection Procedures

Two temporary flow gages were set in Cooper Creek: gage "CCA" was set about 150 feet upstream of the Stetson Creek confluence and immediately upstream of the upstream cross-section in Study Site D, and gage "CCB" was set about 250 feet downstream of the Stetson Creek confluence. The locations of these sites are shown in Figure 2. The following text from the Cooper Lake Stream Flow and Water Quality Final Report describes the process for stream gage flow and temperature measurements:

> "Stream flow and temperature monitoring stations were installed on Cooper Creek above (CCA) and below (CCB) the confluence with Stetson Creek on September 5, 2002. Extreme high-water, beginning around October 22, 2002, caused the pressure transducer installed at CCB just below the confluence with Stetson Creek to wash out. It was reset on November 21, 2002, after high flows subsided. Each Cooper Creek monitoring station's instrumentation includes a Dryden Instrumentation R2 data logger with a pressure transducer to measure water level or stage (accuracy 0.01 ft.) and a thermistor temperature sensor (accuracy 0.1° C). Pressure transducers were calibrated against a dead weight tester by manufacturer, checked for accuracy before installation by measuring water depth in a graduated cylinder, and in the field by direct measurement of water depth at the tip of the sensor. Thermistors were tested by the

> manufacturer and were ice bath tested for accuracy before installation. The station on Cooper Creek above Stetson Creek, CCA, also measures air temperature for use in the stream temperature model. The monitoring stations on Cooper Creek continuously record data at 1-hour intervals.
>
> "Flow measurements (used to create a stream flow-rating curve for each station) were made at control sections at CCA and CCB when water samples were collected. At least 10 water depth and velocity measurements across the control section were recorded on a standard field data form. Stream flows at CCB, below the confluence with Stetson Creek, were on occasion too high to allow a measurement to be taken. Winter stream flow measurements were made at CCB during the 2002/2003 winter on February 19 and March 5. Measurable water flow could not be located at CCA on either winter field trip. Flow measurements will continue through the 2004 water year to document a range of flow conditions and refine the rating curves. A Marsh-McBirney Flow meter and wading rod were used to collect water velocity and depth measurements. Flow meters were calibrated by the manufacturer prior to use in spring 2003. The USGS supplied flow and temperature data collected at the gaging station on lower Cooper Creek."

Due to the close proximity of the two gages to the confluence, Stetson Creek flows could be back-calculated by subtracting the CCA flow from the CCB flow. Stetson Creek flows were used in the SNTEMP model hydrology files and in development of habitat time series. The CCA data were directly entered into the SNTEMP hydrology files, and the CCA and CCB data were considered in the hydraulic model calibration and estimation of flows at each study site.

The USGS has established and maintained a long term gaging station near the mouth of Cooper Creek. This station, "USGS 15261000 COOPER C AT MOUTH NR COOPER LANDING AK," is located near the Cooper Creek South Campground and between study sites J and K, and continuously records gage height, stream flow, and water temperature, and possesses "real time" telemetry capabilities. The gage was established in 1957 and has collected flow information for water years 1958-1964 and 1999-present. Water temperature has been collected for water years 1999-present. The measured flow and temperature data were used in the SNTEMP hydrology file, and measured flow was used in development of habitat time series.

Habitat Suitability Criteria Development

The process of selecting Habitat Suitability Criteria (HSC) for the Cooper Creek Instream Flow Study was initiated in an Instream Flow Review Team meeting March 11-12, 2004. As described in Bovee et al. (1998), Category II HSC were developed based on measured frequency distributions for Dolly Varden adults and juveniles (Appendix D includes figures that show the locations of observed fish, observed redds, and fish resources study areas. These figures are taken from Appendix I of the Cooper Creek Fish Resources Study). These criteria were modified in group discussion (the details of this meeting are provided in Appendix A). As no other species of fish are resident in Cooper Creek, Category I criteria for rainbow trout, chinook salmon, and coho salmon were developed based on discussion and review of HSC developed in other streams in Alaska and the Pacific Northwest.

Draft HSC and draft temperature criteria were forwarded to meeting attendees for review. The reviewers made minor revisions to the draft HSC and to the upper lethal temperature limits. The HSC and temperature criteria were then finalized and forwarded to the Instream Flow Review Team, and used in habitat modeling and synthesis of habitat and temperature model results. Final Cooper Creek HSC are attached in Appendix E, and temperature criteria are given in Table 7.

It should be noted that optimal temperatures presented in Table 7 are not experimental optimums but are based on temperatures within southcentral Alaska water bodies where the target species have healthy populations. Alaskan fish have adapted to a wide range of conditions and are not necessarily confined to the optimum range.

Table 7. Cooper Creek Temperature Criteria.

		Lower Lethal	Lower Limiting	Optimal	Upper Limiting	Upper Lethal
		Degrees Celcius (°C)				
Dolly Varden	Spawning	0	< 2	3-4	13	25
	Incubation	0	< 2	3-4	13	> 16*
	Emergence CTU	NA	NA	475	NA	NA
	Juvenile Rearing	0	< 2	8 - 10	14	25
Rainbow Trout	Spawning	0	< 5.5	5.5 - 11	14	25
	Incubation	0	< 5.5	5.5 -12	14	> 16*
	Emergence CTU	NA	NA	500-580	NA	NA
	Juvenile Rearing	0	< 2.7	6 - 12	14	25
Coho Salmon	Spawning	0	< 3	3 - 8	10	25.5
	Incubation	0	< 3	3 - 8	14	> 16*
	Emergence CTU	NA	NA	700-800	NA	NA
	Juvenile Rearing	0	< 2	7 - 12	16	25
Chinook Salmon	Spawning	0	< 5	8 - 10.5	16	25.1
	Incubation	0	< 5	8 - 10.5	16	> 16*
	Emergence CTU	NA	NA	900-1000	NA	NA
	Juvenile Rearing	0	< 2	7 - 11	16	25.1

Lower Limiting/Upper Limiting = the point at which growth is less than optimal but not lethal

Dolly Varden CTUs are based on arctic char emergence at Fort Richardson Hatchery. Optimal temperatures are based on temperature regimes used at the hatchery (telephone conversation with Chuck Prat, Fish Culturist, Fort Richardson Hatchery, ADF&G Division of Sport Fish 2/9/04) and those observed in Cooper and Crescent Creeks. Little to no information was found on upper limiting and upper lethal temperature limits for Dolly Varden but are assumed to be similar to salmon and trout and are based on professional judgment.

Rainbow Trout CTUs are from ADF&G Division of Sport Fish; optimal temperatures are based on literature review information referencing rainbow trout spawning activity May through June in the Kenai and Russian Rivers (Palmer, D. E. 1998. Migratory Behavior and Seasonal Distribution of Radio Tagged Rainbow Trout in the Kenai River, Alaska. U.S. Fish and Wildlife Service, Alaska Fisheries Technical Report Number 46, Kenai, Alaska) and observed temperatures in the Russian River and Quartz Creek during the same time period. Upper lethal and lower lethal temperatures are based on Raleigh, R.F., T. Hickman, R.C. Solomon, and P. C. Nelson. 1984. Habitat Suitability Information: Rainbow trout. U.S. Fish and Wildl. Serv. FWS/OBS-82/10.60. 64pp. Upper lethal temperature for juvenile rearing is based on professional judgment.

Coho Salmon CTUs are from ADF&G Division of Sport Fish; optimal temps are based on temperatures observed in Crescent Creek during estimated spawning and incubation periods (see Periodicity Graphs). Upper limiting and upper lethal temperatures are based on comments provided by ADF&G, USFWS, R2 Resource Consultants and McMahon, T.E. 1983. Habitat Suitability Index Models: Coho Salmon. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.49. 29 pp. Lower limits are the same as chinook salmon and are based on professional judgment.

Chinook Salmon CTUs are from ADF&G Division of Sport Fish; optimal temps are based on temperatures observed in Crescent Creek during estimated spawning and incubation periods (see Periodicity Graphs). Upper lethal temperatures are based on comments provided by ADF&G, USFWS, R2 Resource Consultants and the "Marine and Coastal Species Information System" (MACSIS) prepared for the Corps of Engineers by the Fish and Wildlife Information Exchange (http://fwie.fw.vt.edu/WWW/macsis/index.htm) and Armour, Carl L. 1991. Guidance for Evaluating and Recommending Temperature Regimes to Protect Fish. U.S. Fish and Wildl. Serv., Biol. Rep. 90(22). 13pp.

Periodicity Graphs are based on periodicity information presented by ADF&G at the IFIM workshop. Temperature data were provided by ADF&G Division of Sport Fish.

* A literature review for upper lethal temperatures for all of the species listed above found only an incubation tolerance for chinook salmon (Wilson et al. 1987) found in: Armour, Carl L. 1991. Guidance for Evaluating and Recommending Temperature Regimes to Protect Fish. U.S. Fish and Wildl. Serv., Biol. Rep. 90(22). 13pp. Incubation for other species listed above is presumed to be the same and is based on professional judgment.

Model Production and Calibration

PHABSIM model calibration consisted of a multi-faceted process that included data reduction, data checking and error analysis, data entry, water surface elevation calibration, velocity calibration, and habitat modeling.

Water surface elevations were closely analyzed before they were entered into the final hydraulic model. As described above, all collected water surface elevations were averaged unless there was an outlier or improperly placed elevation point (i.e. top of a wave, on a low terrace). Professional judgment was used to identify and eliminate these data points.

Calibration discharges were estimated for the trips in which flows were not directly measured using a combination of linear regression based on stage and known discharges (Trips 1 and 5) and use of known discharges at CCA, CCB, and the USGS gages.

Water surface elevations were calibrated to the measured discharges in Trips 1 and 5 for most study sites; calibration was based on Trip 1 water surface elevations only for study sites F, G, H, and L. For all study sites, water surface elevations at the downstream cross-sections at simulation discharges were developed using the MANSQ program, and upstream cross-sections were usually modeled using the WSP program linked to the MANSQ-determined elevations.

The next step was to produce velocity profiles based on the predicted water surface elevations for the simulation discharges. Velocity simulation was accomplished using the IFG4 program, and the models were calibrated to the Trip 1 profiles and validated by the Trip 5 profiles when available. Velocity modeling was accomplished using the procedures set forth in the PHABSIM Reference Manual (Milhous et al., 1989).

Velocity Adjustment Factors – VAFs – are products of the velocity simulations and were used to verify the reasonableness of the simulations. Comparably, other model output including Froude number and Manning's n values were inspected. Appendix F[3] includes the detailed calibration results for each study site.

The program selected for habitat modeling was HABTAE, which calculates weighted usable area for a cross-section or a reach. The option for multiplicative composite suitability was selected; this means that for a particular cross-section at a particular flow, the values of the depth, velocity, and substrate HSC for a selected species/lifestage pair were multiplied, and the resulting product was multiplied by the total available habitat to find the WUA for that species/lifestage pair at that particular cross-section.

The result of habitat modeling is flow vs. WUA tables (often displayed as curves) for each study site and for each species/lifestage pair. The tables were used in development of the habitat time series, described in the next section. The flow vs. WUA curves for Cooper Creek are included in Appendix G.

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[3] HDR/Chugach responses to the draft model reviews and descriptions of changes made in the final models are given in Appendix K.

Model Post-Processing

The ultimate product of the PHABSIM modeling is the production of habitat time series. The time series combines the flow-habitat relationship developed by the PHABSIM model and the hydrologic record to calculate and display the available habitat for each species/lifestage pair at a moment in time. This is effective in comparing and quantifying the available habitat in the existing condition to the available habitat in any number of potential alternative hydrologic regimes.

The Instream Flow Review Team agreed to evaluate five preliminary scenarios proposed by Chugach for the purposes of developing the models: the existing (2003) condition and four alternatives[4]. Each of these five conditions was modeled for water temperature and had a habitat time series developed. The habitat time series, with the critical time period specific to each species/lifestage pair transposed on the graphs, are given in Appendix H.

Alternative Scenarios

Model runs were made for the following five sets of conditions:

1. Existing conditions.
2. Existing conditions with a 10 cfs diversion from Stetson Creek to Cooper Lake (with the caveat that no less than 6 cfs would be left in Stetson Creek) and a 10 cfs diversion from the upper 2 meters of Cooper Lake to the upper part of the Cooper Creek Lake Reach. This scenario is titled "10 in, 10 out."
3. Existing conditions with a 30 cfs diversion from Stetson Creek to Cooper Lake (same caveat as 10 in, 10 out) and a 30 cfs diversion from the upper 2 meters of Cooper Lake to Cooper Creek ("30 in, 30 out").
4. Existing conditions with a 30 cfs diversion from Stetson Creek to Cooper Lake (same caveat as 10 in, 10 out) and a 10 cfs diversion from the upper 2 meters of Cooper Lake to Cooper Creek ("30 in, 10 out").
5. Existing conditions with a diversion from Stetson Creek to Cooper Lake equal to the historical monthly average flow in Stetson Creek for that particular month (with the caveat that no less than 6 cfs would be left in Stetson Creek) and a 30 cfs diversion from the upper 2 meters of Cooper Lake to Cooper Creek ("Monthly Average in, 30 out").

Habitat Time Series

The habitat time series were calculated in a spreadsheet. WUA output from different reaches was combined for similar mesohabitat types; for example, study sites I and H were combined as they both describe main channel scour pool mesohabitats. The hydrology for each alternative was developed, and the flow for each time period selected the appropriate WUA for each species/lifestage pair at each mesohabitat. This led to a series of tables for each alternative. WUA output from the PHABSIM model is given in units of ft^2/1000 ft, so the values were converted based on the linear feet of each mesohabitat unit in the anadromous reaches of stream (measured in the Aquatic Habitat Study). This was done for each alternative and for each

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[4] Additional modeling, as requested by the Settlement Working Group, is being conducted in support of the settlement negotiation efforts.

mesohabitat type. The resulting table is the habitat time series. The habitat time series are displayed for each species/lifestage pair and each mesohabitat type in Appendix H. Each chart includes all five conditions for ease of comparison between the existing condition and the four alternatives.

Example problem for determining one value in a habitat time series:

Problem: How much main channel scour pool habitat was available for adult Dolly Varden during the week of July 10-16, 2003?

Solution:

1. July 10-16 is Week 11 (Table H-1 in Appendix H). Study Sites H and I, located in the lower Canyon and Alluvial Reaches, describe main channel scour pool habitat. Therefore, using the table of daily flows for the Existing Conditions model at Cooper Creek mouth (Appendix I), the average flow during this period was 95.1 cfs.
2. From the WUA curves in Appendix G, the WUA relationship for adult Dolly Varden at site H is 6245 ft^2/1000 ft for 95 cfs and 6239 ft^2/1000 ft for 100 cfs. For site I, the WUA value for 95 cfs is 2238 ft^2/1000 ft and 2180 ft^2/1000 ft for 100 cfs.
3. The weighted average of the main channel scour pool habitat is 4178 ft^2/1000 ft for 95 cfs and 4145 ft^2/1000 ft for 100 cfs. The weighted average calculation used study site reach lengths; site H reach length was 45.9 feet and site I reach length was 48.9 feet (Appendix F).
4. Linear interpolation of 95.1 cfs between the 95 and 100 cfs WUA values produces a WUA relationship for 95.1 cfs of 4177 ft^2/1000 ft.
5. 1192 feet of main channel scour pool habitat is available in the anadromous reaches of Cooper Creek (Table 3).
6. (4177 ft^2)/(1000 ft)*(1192 ft) = **4979 ft^2** average main channel scour pool habitat area available for adult Dolly Varden the week of July 10-16, 2003.

Temperature Modeling

Selection of Methodology

As described in the Habitat Modeling section, the SNTEMP model was selected by the Instream Flow Review Team in its December 5, 2002 meeting as the model for simulating Cooper Creek water temperatures.

Description of Temperature Model

The Stream Network Temperature Model, SNTEMP, models temperatures in a stream as a function of hydrologic conditions, riparian and topographic shading, and meteorological conditions. The one-dimensional model assumes steady flow, complete mixing, and requires daily mean temperatures for input variables. SNTEMP is a stream network model with a spatial grid as fine as 100 meters, and references output from companion programs, SSSOLAR and SSSHADE, to provide data on short-wave radiation and shading percentages. SNTEMP has a text interface and is a public domain model.

SNTEMP, a DOS-based program, uses an energy balance equation to calculate mean water temperature as a function of measured input variables. Maximum temperatures are calculated from the modeled mean temperatures using an algorithm; this means calculated maximum temperatures are not physically based.

The SNTEMP model utilizes six input files that include measured data and two system control files. The **Study File** includes the locations and types of nodes that define the stream network system, as well as locations in the network where output is required. The **Geometry File** provides a network definition of the modeled stream, the site location and the stream geometry (e.g. channel width, depth, and gradient). The **Shade File** includes data for parameters that contribute to the shading of the stream due to topographic and vegetative conditions. The **Time Period Data File** is primarily used by SNTEMP as a system file but includes two parameters that are used in the determination of incoming solar radiation: the dust coefficient and ground reflectivity. The **Meteorology Data File** includes all remaining meteorological data for the study reach for each day in the study period. The **Hydrology Data File** provides the mean daily stream flows and temperatures for the modeled streams and all tributaries to the stream network for each day in the study period. The **Hydrology Node File** is a system control file that contains information needed by the program on where hydrology data are required. The **Job Control File** is another system control file that contains information required by the program that defines the size of the network, the extent of output desired, years of data simulated, node counts, calibration factors, and file names.

Daily mean and maximum instream temperatures were collected at three locations in the study reach during the modeling period for use in model calibration and validation. Unknown tributary water temperatures were assumed in the model calibration process. The output from the SNTEMP model is a table of average and maximum modeled water temperatures for each day in the modeling period at user-requested locations in the model stream network.

Water temperatures were modeled for all five reaches of Cooper Creek for all alternatives. For the Lake reach, the assumption was made to not include the beaver dams in the stream geometries for the model scenarios. The geometries of the remainder of the reaches were not changed between the existing condition and the alternatives.

Data Collection

Data requirements for the SNTEMP model include Cooper Creek and tributary inflow hydrology, meteorological parameters including air temperature and relative humidity, and geometric factors such as stream length, azimuth, and topographic altitude.

Hydrology Data

2003 water temperature data were collected at three locations: at the CCA gage immediately upstream of the Stetson Creek confluence, at the mouth of Stetson Creek, and at the USGS station. The locations of these stations are shown in Figure 2, and the measured data are given in Appendix I.

Temperature data were collected at 15-minute intervals at the two upstream sites as described in a previous section. The temperature data were reduced to daily averages for entry into the temperature model. USGS temperature data were also collected from the real-time website in 15-minute intervals and reduced to daily averages. These measured data are given in Appendix I.

The collection of Cooper and Stetson Creek flow data was described in a previous section of this report.

The inflow rates of ungaged tributaries are unknown. Knowing the daily average flows at the CCA, CCB, and USGS gages, inflow rates were calculated using linear regression to achieve a mass balance. Inflow temperatures were likewise unknown, and were manipulated in model development to calibrate Cooper Creek simulated temperatures.

A thermister string with probes at 0.2, 0.5, 1.5, 3, 10, and 15 meters in depth was suspended from a buoy in the center of the south end of Cooper Lake to measure the water temperature profile in 15-minute intervals. This information was reduced to daily averages. The average of the upper three measurements (at 0.2, 0.5, and 1.5 meters) was calculated to represent the average daily inflow temperature to the Lake Reach of Cooper Creek from a hypothetical lake surface intake structure. These inflow temperatures were used as the inflow temperature, from Cooper Lake to Cooper Creek, for all four model alternatives.

In the four alternatives, inflow rates at only two locations were changed: the head of Cooper Creek and the mouth of Stetson Creek. The hydrology for the four alternatives was based on the hypothetical mitigation scenarios that were described:

- “10 in, 10 out” – the inflow at the upstream-most Cooper Creek reach was increased by 10 cfs. The Stetson Creek discharge into Cooper Creek was reduced by either 10 cfs or, if the resulting discharge would be less than 6 cfs, the difference between the measured Stetson Creek flow and 6 cfs.
- “30 in, 30 out” – the Cooper Creek inflow was increased by 30 cfs. The Stetson Creek discharge was decreased by either 30 cfs or the difference between the Stetson Creek discharge and 6 cfs.
- “30 in, 10 out” – the Cooper Creek inflow was increased by 10 cfs. The Stetson Creek discharge was decreased by either 30 cfs or the difference between the Stetson Creek discharge and 6 cfs.
- “MA in, 30 out” – the Cooper Creek inflow was increased by 30 cfs. The Stetson Creek discharge was decreased by either the monthly average Stetson Creek discharge (May–33 cfs, June–50 cfs, July–51 cfs, August–34 cfs, September–23 cfs, October–30 cfs) or the difference between the daily Stetson Creek discharge and 6 cfs.

While the flow rates at the two inflow points changed in the four alternatives, the flow rates of all other minor tributaries remained the same in the four alternatives and the existing condition models. The inflow temperatures at all points, described above, were also the same in the four alternative models.

Meteorology Data

SNTEMP requires the latitude and elevation data for only one meteorological data station in the model. This station was the USFS SNOTEL station near the Cooper Lake Intake. Two input parameters were selected from this station; average annual air temperature and daily mean air temperature. Daily average wind speed and daily average relative humidity were collected at a BLM/Alaska Fire Service Remote Automated Weather Station (RAWS) near Kenai Lake. Relative humidity data is directly dependent on air temperature and indirectly dependent on elevation, so the lapse rate equation described in Part II of the Instream Water Temperature Model documentation (Theurer et al., 1984) was applied to the Kenai Lake data to convert it to the model meteorological station. Percent sunshine data was retrieved from the nearest reporting station, the Soldotna Airport. All these data are provided in Appendix I.

The dust coefficient and ground reflectivity coefficients used in the model were based on suggested values given in Theurer et al. (1984).

Geometry Data

Stream spatial and geometric data, including latitude, elevation, topographic altitude, and stream reach azimuth were obtained from GIS databases and paper maps. Stream width equations were developed from survey measurements. Vegetative shading parameters were estimated from site photography.

Model Production and Calibration

The existing conditions model was calibrated before the hydrology modifications, described above, were made to the four alternative models. Existing conditions model calibration was accomplished by parameter perturbation of the minor tributary inflow temperatures until the average difference between measured and predicted temperatures was zero at both the CCA and USGS stations. Figures 7 and 8 show the results of the existing condition model compared to measured water temperatures at the Stetson Creek confluence and at Cooper Creek mouth, respectively. The detailed calibration notes are given in Appendix J[5].

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[5] HDR/Chugach responses to the draft model reviews and descriptions of changes made in the final models are given in Appendix K.

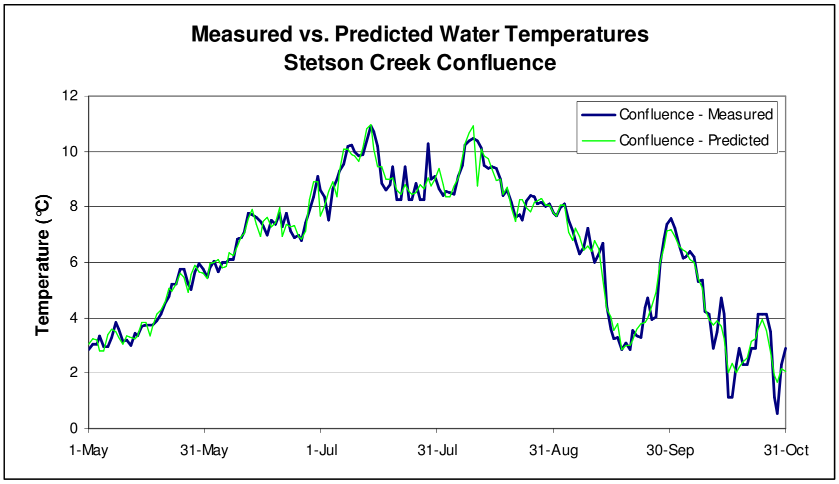

Figure 7. Measured vs. Predicted Water Temperatures at Stetson Creek Confluence

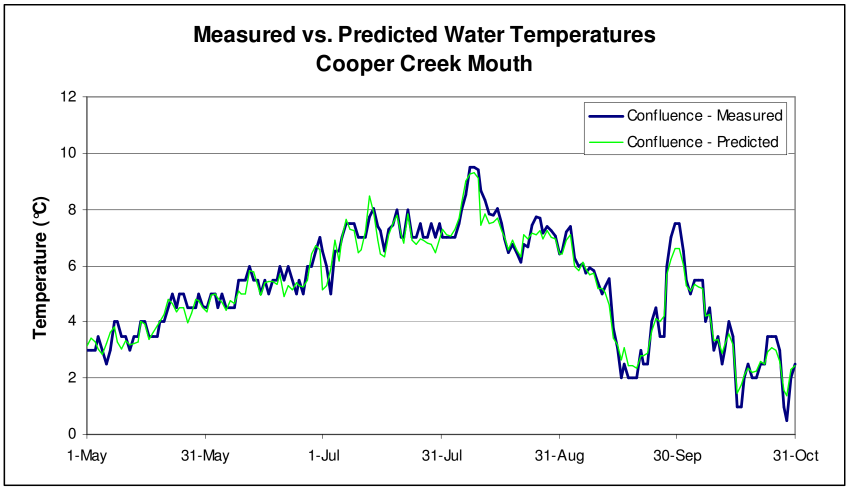

Figure 8. Measured vs. Predicted Water Temperatures at Cooper Creek Mouth

Keeping the same minor tributary flows and temperatures as the existing conditions model, the alternative-specific hydrology files were applied to the four alternative models to predict water temperatures under the different potential mitigation hydrologic regimes.

RESULTS

Flow-Habitat Modeling

For each species and lifestage, the PHABSIM habitat model produces a relationship of available habitat area as a function of stream discharge. These relationships are known as flow-habitat curves, and are developed individually for each mesohabitat type, species and lifestage. The flow-habitat curves developed in the PHABSIM model for Cooper Creek are given in Appendix G.

In post-processing of this model output, habitat time series were developed for each species/lifestage pair specific to each mesohabitat for all scenarios. The habitat time series charts for Cooper Creek are provided in Appendix H.

For the Cooper Creek preliminary habitat model, the model output was broken into seven stream mesohabitat types – riffle-cobble, riffle-cobble with side channel habitat, riffle-boulder, plunge pool, main channel scour pool, cascade/step-pool, and run/glide. The riffle-cobble and riffle-boulder habitat types were further divided into sections upstream of Stetson Creek (Stetson Reach) and downstream of Stetson Creek (Alluvial and Canyon Reaches) because of the marked differences in stream morphology and flows between these two areas of Cooper Creek.

Total available area was calculated for the Alluvial, Canyon, and Stetson Reaches. Table 8 shows the average total WUA over the modeling period for each mesohabitat type by reach. This table illustrates model output only and does not specify WUA during the critical time periods identified by ADF&G. These time periods are highlighted in the habitat time series, given for each species and lifestage, separated by week and by model scenario, in Appendix H. Table 9 is provided for easy comparison of model period average WUA for the five scenarios.

Table 8. Cooper Cr. Average WUA for Model Period

	CHINOOK SALMON		COHO SALMON			DOLLY VARDEN				RAINBOW TROUT			
	Spawning	Fry	Spawning	Juvenile	Fry	Spawning	Adult	Juvenile	Fry	Spawning	Adult	Juvenile	Fry
EXISTING CONDITIONS MODEL													
Riffle-Cobble U/S	273	7,984	2,849	11,292	6,328	3,801	1,288	9,559	6,328	3,554	1,287	10,319	6,328
Riffle-Cobble D/S	48,621	15,961	44,303	30,404	10,177	36,391	11,791	25,367	10,177	35,221	11,572	31,101	10,177
Riffle-Cobble D/S with Side Channel	22,035	6,599	22,051	12,935	4,851	17,149	8,771	10,834	4,851	16,950	8,696	12,877	4,851
Riffle-Boulder U/S	435	9,026	3,849	15,215	6,120	5,059	951	14,105	6,120	4,641	949	14,659	6,120
Riffle-Boulder D/S	76,282	26,175	68,312	55,209	18,657	61,402	26,783	47,754	18,657	60,226	26,373	57,146	18,657
Dam/Plunge Pool	1,339	4,110	2,664	6,377	2,898	3,419	1,224	5,866	2,898	3,316	1,223	6,106	2,898
Main Channel Scour Pool	11,786	5,494	9,982	8,930	3,875	8,463	5,975	7,947	3,875	8,377	5,914	8,881	3,875
Cascade/Step-Pool	21,632	8,920	18,387	15,166	5,228	15,141	10,853	13,138	5,228	14,965	10,665	15,105	5,228
Run/Glide	700	4,078	1,801	6,560	2,434	2,544	908	6,467	2,434	2,437	908	6,588	2,434
Sum	183,103	88,348	174,197	162,089	60,569	153,370	68,543	141,038	60,569	149,688	67,588	162,782	60,569
10 IN, 10 OUT MODEL													
Riffle-Cobble U/S	3,936	5,612	7,373	8,377	4,646	7,706	2,180	7,083	4,646	7,522	2,165	8,171	4,646
Riffle-Cobble D/S	48,378	15,946	44,519	30,487	10,152	36,569	11,822	25,432	10,152	35,392	11,602	31,192	10,152
Riffle-Cobble D/S with Side Channel	22,015	6,546	22,097	12,839	4,829	17,160	8,773	10,700	4,829	16,962	8,700	12,761	4,829
Riffle-Boulder U/S	4,211	6,257	8,705	11,690	5,321	9,250	2,171	9,737	5,321	8,802	2,159	11,283	5,321
Riffle-Boulder D/S	76,346	25,961	68,747	55,686	18,626	61,910	26,903	48,143	18,626	60,716	26,498	57,650	18,626
Dam/Plunge Pool	4,232	3,603	5,297	5,734	2,605	5,693	2,403	4,997	2,605	5,625	2,393	5,504	2,605
Main Channel Scour Pool	11,780	5,494	10,058	8,908	3,870	8,512	6,006	7,916	3,870	8,426	5,945	8,864	3,870
Cascade/Step-Pool	21,745	8,733	18,513	14,868	5,151	15,168	10,860	12,820	5,151	14,997	10,671	14,805	5,151
Run/Glide	2,625	2,456	4,212	5,564	1,653	4,554	1,868	5,176	1,653	4,467	1,867	5,759	1,653
Sum	195,268	80,606	189,520	154,153	56,852	166,522	72,985	132,005	56,852	162,909	72,000	155,989	56,852
30 IN, 30 OUT MODEL													
Riffle-Cobble U/S	11,193	9,045	8,321	10,746	7,354	8,069	2,858	9,668	7,354	8,039	2,797	10,250	7,354
Riffle-Cobble D/S	56,077	15,788	46,398	29,196	10,155	38,198	11,876	24,145	10,155	37,003	11,610	29,830	10,155
Riffle-Cobble D/S with Side Channel	24,270	6,482	23,506	12,114	4,937	18,255	9,669	9,918	4,937	18,059	9,579	12,016	4,937
Riffle-Boulder U/S	9,166	9,068	9,299	10,543	7,477	9,424	2,333	9,166	7,477	9,257	2,300	10,003	7,477
Riffle-Boulder D/S	84,410	26,063	71,280	55,452	19,183	63,801	27,738	47,826	19,183	62,665	27,242	57,599	19,183
Dam/Plunge Pool	6,329	3,079	4,508	4,196	2,231	4,888	2,395	3,927	2,231	4,873	2,368	4,235	2,231
Main Channel Scour Pool	12,906	5,329	10,178	8,445	3,827	8,701	5,811	7,545	3,827	8,627	5,734	8,400	3,827
Cascade/Step-Pool	23,815	9,400	19,012	14,113	5,587	16,326	11,170	12,149	5,587	16,164	10,960	13,983	5,587
Run/Glide	5,453	2,366	5,239	3,983	1,287	5,363	1,763	3,527	1,287	5,304	1,732	4,087	1,287
Sum	233,620	86,619	197,742	148,789	62,040	173,025	75,613	127,871	62,040	169,992	74,323	150,403	62,040
30 IN, 10 OUT MODEL													
Riffle-Cobble U/S	4,104	5,710	7,581	8,411	4,737	7,884	2,251	7,101	4,737	7,706	2,236	8,189	4,737
Riffle-Cobble D/S	40,982	15,655	43,676	31,534	10,057	35,702	11,772	26,324	10,057	34,492	11,585	32,367	10,057
Riffle-Cobble D/S with Side Channel	19,744	6,253	21,373	13,195	4,412	16,565	8,307	10,984	4,412	16,356	8,262	13,215	4,412
Riffle-Boulder U/S	4,388	6,145	8,883	11,478	5,293	9,396	2,214	9,490	5,293	8,947	2,202	11,072	5,293
Riffle-Boulder D/S	66,644	25,866	67,188	56,548	17,517	60,999	26,123	49,127	17,517	59,689	25,806	59,001	17,517
Dam/Plunge Pool	4,346	3,583	5,390	5,690	2,592	5,770	2,451	4,948	2,592	5,705	2,440	5,462	2,592
Main Channel Scour Pool	10,930	5,628	10,550	9,404	3,953	8,836	6,292	8,304	3,953	8,741	6,237	9,353	3,953
Cascade/Step-Pool	19,936	7,369	18,379	14,140	4,510	13,857	10,606	11,926	4,510	13,689	10,444	14,221	4,510
Run/Glide	2,704	2,394	4,302	5,489	1,626	4,619	1,907	5,088	1,626	4,533	1,905	5,692	1,626
Sum	173,779	78,603	187,320	155,888	54,696	163,628	71,922	133,292	54,696	159,858	71,118	158,572	54,696
MONTHLY AVERAGE IN, 30 OUT MODEL													
Riffle-Cobble U/S	11,193	9,045	8,321	10,746	7,354	8,069	2,858	9,668	7,354	8,039	2,797	10,250	7,354
Riffle-Cobble D/S	55,597	15,801	46,529	29,505	10,161	38,352	11,886	24,354	10,161	37,116	11,621	30,201	10,161
Riffle-Cobble D/S with Side Channel	24,034	6,347	23,640	12,048	4,823	18,328	9,718	9,806	4,823	18,129	9,633	11,940	4,823
Riffle-Boulder U/S	9,166	9,068	9,299	10,543	7,477	9,424	2,333	9,166	7,477	9,257	2,300	10,003	7,477
Riffle-Boulder D/S	83,452	26,026	71,518	55,756	18,962	64,157	27,757	48,022	18,962	62,995	27,272	58,098	18,962
Dam/Plunge Pool	6,329	3,079	4,508	4,196	2,231	4,888	2,395	3,927	2,231	4,873	2,368	4,235	2,231
Main Channel Scour Pool	12,914	5,335	10,346	8,452	3,833	8,827	5,826	7,539	3,833	8,753	5,748	8,407	3,833
Cascade/Step-Pool	23,700	9,310	19,049	13,871	5,508	16,159	11,089	11,874	5,508	15,991	10,882	13,761	5,508
Run/Glide	5,453	2,366	5,239	3,983	1,287	5,363	1,763	3,527	1,287	5,304	1,732	4,087	1,287
Sum	231,839	86,377	198,450	149,101	61,636	173,568	75,625	127,883	61,636	170,458	74,352	150,981	61,636

Table 9. Summary of Cooper Creek Average WUA for Model Period.

	Existing	"10 in, 10 out"	"30 in, 30 out"	"30 in, 10 out"	"MA in, 30 out"
CHINOOK SALMON					
Spawning	183,103	195,268	233,620	173,779	231,839
Fry	88,348	80,606	86,619	78,603	86,377
COHO SALMON					
Spawning	174,197	189,520	197,742	187,320	198,450
Juvenile	162,089	154,153	148,789	155,888	149,101
Fry	60,569	56,852	62,040	54,696	61,636
DOLLY VARDEN					
Spawning	153,370	166,522	173,025	163,628	173,568
Adult	68,543	72,985	75,613	71,922	75,625
Juvenile	141,038	132,005	127,871	133,292	127,883
Fry	60,569	56,852	62,040	54,696	61,636
RAINBOW TROUT					
Spawning	149,688	162,909	169,992	159,858	170,458
Adult	67,588	72,000	74,323	71,118	74,352
Juvenile	162,782	155,989	150,403	158,572	150,981
Fry	60,569	56,852	62,040	54,696	61,636

Additionally, aggregate habitat curves have been developed that combine all mesohabitat types. The data for these curves are shown in Table 10, and the curves are displayed in Appendix G.

Table 10. Aggregate Cooper Creek Flow-WUA Table

Cooper Creek Aggregate Total WUA
Units: ft^2/1000 ft
Total Length: 22,638 ft

Reaches	CHINOOK SALMON Q (cfs)	Spawning	Fry
Stetson	2	2	7,362
	4	159	5,381
	6	460	3,786
	8	801	3,667
	10	1,210	3,432
	14	2,345	3,211
	16	2,992	3,287
	18	3,659	3,418
Stetson Canyon Alluvial	20	4,811	4,096
	25	6,509	3,994
	30	7,819	3,933
	35	8,969	4,149
	40	9,806	4,281
	45	10,456	4,359
	50	11,041	4,524
	55	11,607	4,705
	60	12,061	4,833
	65	12,507	5,049
	70	12,915	5,254
	75	13,140	5,381
Canyon Alluvial	80	15,697	4,110
	85	15,986	4,227
	90	16,323	4,339
	95	16,736	4,458
	100	17,130	4,580
	105	17,494	4,747
	110	17,865	4,946
	112	17,974	5,026
Alluvial	120	20,104	5,914
	130	20,324	6,863
	140	20,368	7,780
	150	20,310	8,315

COHO SALMON Q (cfs)	Spawning	Juvenile	Fry
2	715	8,013	5,419
4	1,367	7,937	3,611
6	2,065	7,034	2,582
8	2,886	7,213	2,608
10	3,603	6,828	2,528
14	4,663	5,896	2,541
16	5,035	5,760	2,676
18	5,327	5,631	2,802
20	7,647	8,615	2,637
25	8,795	8,484	2,654
30	9,517	7,944	2,716
35	10,137	7,736	2,801
40	10,529	7,911	2,946
45	10,772	7,894	3,087
50	10,906	7,837	3,266
55	11,006	7,778	3,425
60	11,025	7,814	3,565
65	11,007	7,942	3,720
70	10,968	8,125	3,856
75	10,779	8,188	3,923
80	13,200	7,092	3,180
85	13,036	7,124	3,298
90	12,851	7,120	3,441
95	12,635	7,101	3,567
100	12,429	7,061	3,650
105	12,277	7,074	3,741
110	12,154	7,166	3,858
112	12,077	7,229	3,907
120	13,306	7,982	4,899
130	12,584	8,627	5,589
140	11,985	9,782	6,318
150	11,372	10,407	7,003

DOLLY VARDEN Q (cfs)	Spawning	Adult	Juvenile	Fry
2	1,247	709	7,079	5,419
4	2,269	648	7,333	3,611
6	2,846	682	6,541	2,582
8	3,581	969	6,631	2,608
10	4,154	1,208	6,151	2,528
14	5,002	1,612	5,057	2,541
16	5,305	1,752	4,907	2,676
18	5,540	1,838	4,781	2,802
20	6,621	2,752	7,806	2,637
25	7,416	3,206	7,519	2,654
30	7,893	3,476	6,859	2,716
35	8,308	3,776	6,554	2,801
40	8,591	4,059	6,687	2,946
45	8,792	4,219	6,689	3,087
50	8,905	4,331	6,652	3,266
55	8,965	4,416	6,623	3,425
60	8,972	4,467	6,672	3,565
65	8,948	4,511	6,828	3,720
70	8,911	4,552	7,019	3,856
75	8,765	4,479	7,127	3,923
80	10,553	5,207	5,886	3,180
85	10,448	5,148	5,967	3,298
90	10,326	5,070	6,035	3,441
95	10,178	5,013	6,100	3,567
100	10,034	4,966	6,150	3,650
105	9,932	4,939	6,245	3,741
110	9,853	4,968	6,395	3,858
112	9,798	4,976	6,468	3,907
120	10,634	5,415	7,202	4,899
130	10,065	5,309	7,770	5,589
140	9,589	5,268	8,852	6,318
150	9,105	5,276	9,647	7,003

RAINBOW TROUT Q (cfs)	Spawning	Adult	Juvenile	Fry
2	1,143	709	7,085	5,419
4	2,112	648	7,487	3,611
6	2,664	682	6,889	2,582
8	3,394	969	7,109	2,608
10	3,975	1,207	6,764	2,528
14	4,840	1,607	5,784	2,541
16	5,162	1,745	5,611	2,676
18	5,415	1,829	5,465	2,802
20	6,453	2,746	8,804	2,637
25	7,259	3,195	8,627	2,654
30	7,752	3,459	8,028	2,716
35	8,172	3,754	7,766	2,801
40	8,449	4,032	7,896	2,946
45	8,628	4,187	7,860	3,087
50	8,757	4,294	7,829	3,266
55	8,832	4,374	7,798	3,425
60	8,838	4,419	7,806	3,565
65	8,825	4,459	7,899	3,720
70	8,794	4,497	8,031	3,856
75	8,656	4,419	8,099	3,923
80	10,427	5,130	6,984	3,180
85	10,330	5,065	7,009	3,298
90	10,216	4,982	7,022	3,441
95	10,080	4,920	7,010	3,567
100	9,948	4,869	7,008	3,650
105	9,856	4,837	7,051	3,741
110	9,780	4,861	7,167	3,858
112	9,728	4,868	7,229	3,907
120	10,572	5,291	7,983	4,899
130	10,015	5,182	8,515	5,589
140	9,550	5,136	9,528	6,318
150	9,075	5,144	10,273	7,003

Appendix H displays the results of the habitat analyses for each species and lifestage at applicable mesohabitat types. For the riffle-cobble and riffle-boulder mesohabitats, figures for "upstream" (Stetson Reach) and "downstream" (Canyon and Alluvial Reaches) of the Stetson Creek confluence are given. This is due to the difference in stream character (i.e. flow, depth, velocity, and geomorphology) between the segments of Cooper Creek upstream and downstream of the confluence.

Each time series graph has a unique y-axis scale. This maximizes the plot on the graph and highlights the difference in available habitat area between the existing condition and the four mitigation scenarios. Because the scales are different, care must be taken in comparing one figure to another.

The following section summarizes the habitat model results by lifestage.

Spawning

The Instream Flow Review Team selected spawning substrate size categories for the target species in Cooper Creek during the March 11-12, 2004 meeting. Spawning optimally occurs in medium gravel to small cobble (8-128 mm) for chinook salmon, Dolly Varden, and rainbow trout, and medium to large gravel (8-64 mm) for coho salmon. For chinook salmon, Dolly Varden, and rainbow trout the maximum range of gravel sizes for spawning is 2 mm to 256 mm, and for coho salmon the range is 2 mm to 128 mm.

In Cooper Creek, these gravel sizes are typically found in the riffle-cobble and riffle-boulder habitats. Figure 3 shows the relative abundance of these habitat types in each of the three downstream reaches. The availability of spawning habitat on a weekly basis during the modeling period of May through October, 2003, is illustrated for each species in Figures H1-H20 in Appendix H.

Fry Rearing

For all four target species in Cooper Creek, fry rearing potentially occurs year-round (Table 1). Rearing habitat is primarily determined by depth and velocity (and also is affected by proximity to food availability and cover). For coho salmon, ADF&G has identified June and July as key months for rearing in Cooper Creek. For Dolly Varden, the key months are June through October, and for rainbow trout, the key months are May through October. ADF&G did not determine key rearing months for chinook salmon in Cooper Creek.

Potential rearing areas are found in the riffle-cobble, riffle-boulder, pool, and run/glide habitats of Cooper Creek. Figure 3 shows the relative abundance of these habitat types in each of the three downstream reaches. The availability of fry rearing habitat on a weekly basis during the modeling period of May through October, 2003, is illustrated for each species in Figures H21-H52 in Appendix H.

Adult Rearing

Adult rearing habitat was modeled for Dolly Varden and rainbow trout species only, as these are the only two of the target species that would have a resident population in the creek. Like juvenile fry, depth and cover are the primary components of adult rearing habitat. According to ADF&G, key months for adult rearing are July through mid-October for Dolly Varden and mid-July through October for rainbow trout.

In Cooper Creek, potential adult rearing areas are found in all habitats: riffle-cobble, riffle-boulder, pool, cascade/step-pool, and run/glide habitats. Figure 3 shows the relative abundance of these habitat types in each of the three downstream reaches. The availability of adult rearing habitat on a weekly basis during the modeling period of May through October, 2003, is illustrated for Dolly Varden and rainbow trout in Figures H53-H70 in Appendix H.

Temperature Modeling

The Cooper Creek temperature models were developed using the SNTEMP program developed by the U.S. Fish and Wildlife Service. The models have been developed, revised based on Instream Flow Review Team review, and calibrated, and five mitigation scenarios were simulated. This section describes the results of the final temperature model.

Model output was analyzed at two locations on Cooper Creek: immediately upstream of the Stetson Creek confluence and at the mouth of the creek. The SNTEMP model predicted that all the creek diversion scenarios would result in higher temperatures at the confluence (Figure 9) and at the mouth (Figure 10). It should be noted that only three curves are apparent in Figure 9; this is because the two “10 out” mitigation scenarios have identical water temperatures at the gage immediately upstream of the Stetson Creek confluence, as do the two “30 out” mitigation scenarios.

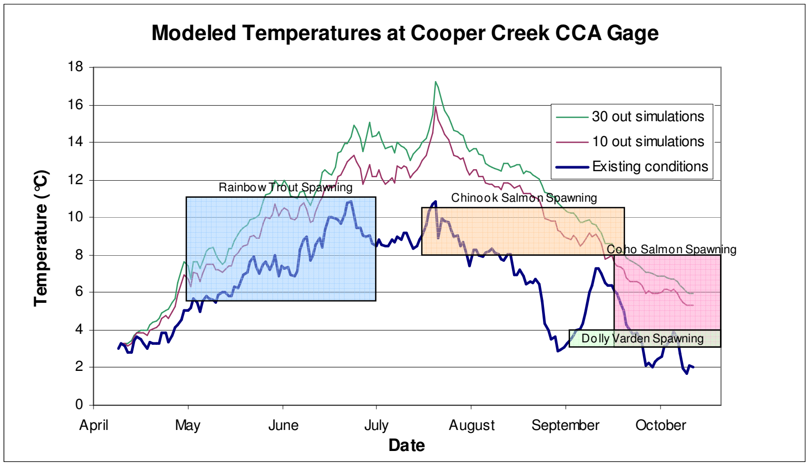

Figure 9. Simulated Cooper Creek Temperatures at Stetson Creek Confluence

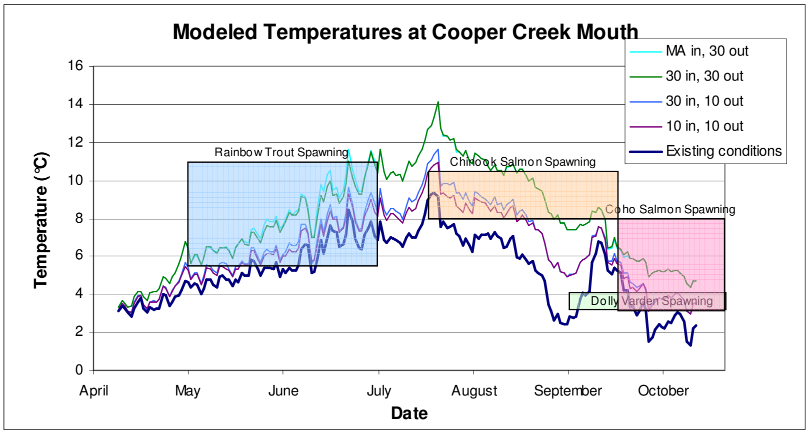

Figure 10. Simulated Temperatures at Cooper Creek Mouth

The curves in Figures 9 and 10 are shown against the target species spawning periodicity on the horizontal axis (Table 1) and species-specific optimal spawning temperature on the vertical axis (Table 7).

The monthly average temperature increases for each scenario over the existing condition are shown at Cooper Creek's confluence with Stetson Creek (Figure 11) and at the mouth (Figure 12).

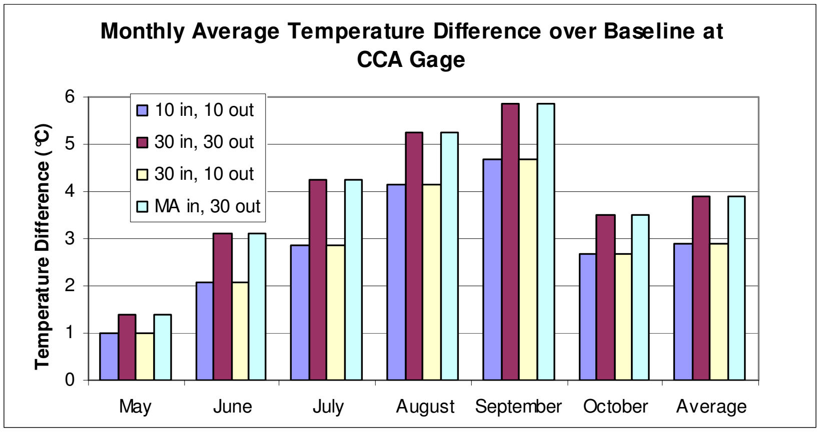

Figure 11. Monthly Average Temperature Increases Over the Existing Condition at Stetson Creek Confluence

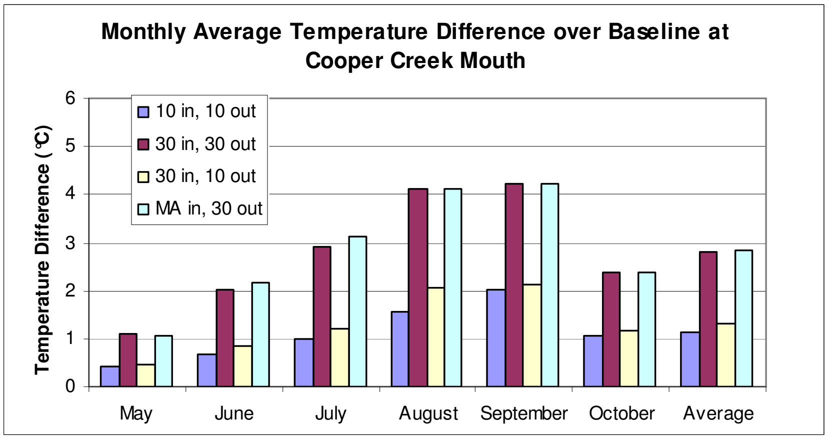

Figure 12. Monthly Average Temperature Increases Over the Existing Condition at Cooper Creek Mouth

INTERPRETATION OF RESULTS

Historical Climatology Perspective

The flow and temperature modeling is based on 2003 measured data. This means the model is effectively a “snapshot” of a period of time that does not necessarily represent the average or median values of environmental conditions.

Several factors influence stream and river discharges, including snowfall and snowpack depth, precipitation, air temperature, cloud cover and solar radiation conditions and, especially, the timing of all the above. It is extremely difficult to estimate the values of any of those parameters before they actually occur. As such, researchers are relegated to analyzing past conditions and comparing the time period in which they are interested to the historical record.

Two parameters were investigated in this manner for the May-October 2003 period: stream flow and air temperature. Precipitation, while very important in determining stream flow and water temperatures, was not investigated because the parameter is too dependent on timing and microclimates to be useful in comparison of the study time period to the historical record.

Air temperature data were recorded at two long term gages near the study site – a National Weather Service (NWS) cooperative weather station on Kenai Lake near the Cooper Lake Powerhouse with a 43-year period of record, and the City of Kenai Airport with a 55-year period of record (Figure 13). The average of the 2003 July-October[6] monthly average air temperatures at the NWS cooperative weather station at the Cooper Creek Powerhouse was 51.8°F, the third warmest period in the 43-year period of record and 2.8°F warmer than the long-term average for the same monthly period (Figure 13). The Kenai Airport data revealed a similar pattern; the average of 2003 May-October monthly average air temperatures was 49.6°F, the sixth warmest period in the 55-year period of record and 2.1°F warmer than the long-term average for the same monthly period (Figure 13).

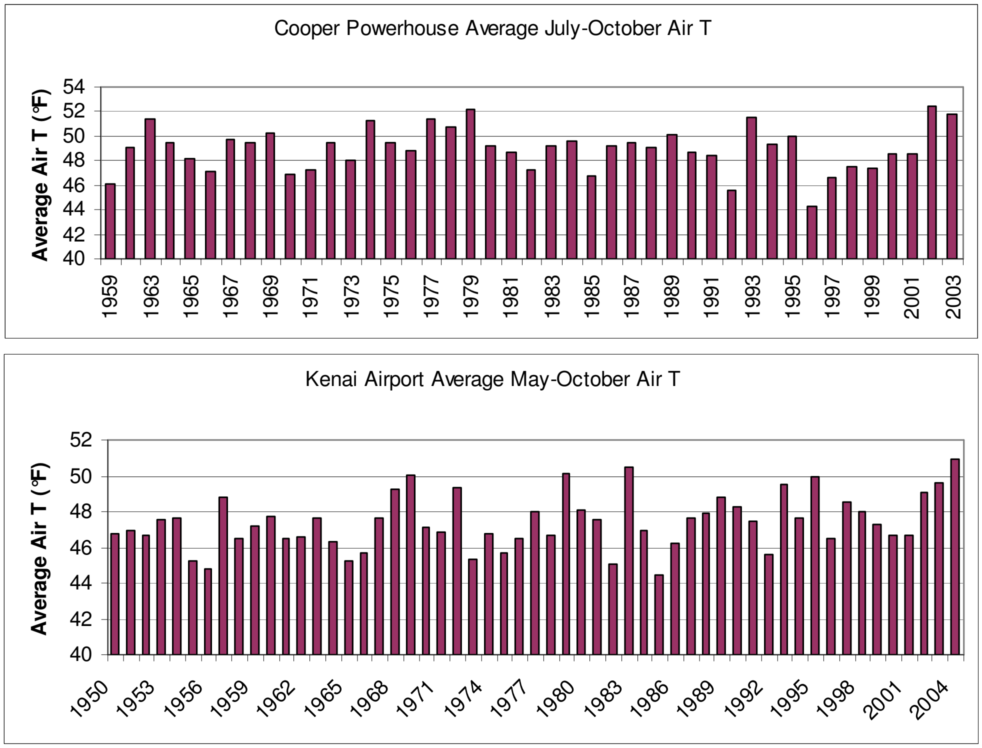

Figure 13. May-October Air Temperature Records at Two Kenai Peninsula Weather Stations.

These measurements lead to the conclusion that 2003 was an above-average year for air temperature in the study months of May-October. Previous reports have shown that air temperature is an extremely important factor in the dynamics of water temperature, and the SNTEMP program is most sensitive to this parameter over other input parameters (HDR Engineering, 2002). Therefore, it is important to consider the results of the temperature model

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[6] July-October temperatures were analyzed at this station because May and June 2003 data were not available at the time this analysis was performed.

with the understanding that in a typical year, air temperatures would likely be lower than in 2003, possibly resulting in generally lower water temperatures. This has implications for the potential increases in water temperature the mitigation scenarios would produce.

A similar analysis was conducted for stream flow. The Cooper Creek gage (USGS #15261000) was analyzed (Figure 14); the results of this analysis should be considered with caution because of its short period of record. The gage was established in 1957 and data were collected for water years 1958-1964 and 1999-2003. The first year of record with the Cooper Lake Dam in place was 1963, leaving only seven years of post-dam hydrologic record. The average 2003 June-September flow at the USGS gage was 61 cfs, the second lowest and about 11 cfs less than the average flow in this short, 7-year post-dam period of record. Monthly median flows in 2003 were lower than the 7-year period of record median flows in June, July, and September, and about equal to the median flows in August. Again, caution must be taken in analyzing these results because of the short period of record.

As is the case in most basins in Alaska, summer flows are closely linked with precipitation and temperature in the winter and spring. The winter of 2002-2003 was unseasonably warm, and a portion of the precipitation came in the form of rain instead of snow and thus ran off immediately instead of storing water as snowpack. Additionally, warm early spring temperatures melted much of the low snowpack. These factors potentially contributed to lower than average summer flows in Cooper Creek.

The flow record for Sixmile Creek near Hope, AK (USGS #15271000) was also analyzed (Figure 14). This site has a 17-year period of record (water years 1980 to 1990 and 1998 to 2003) and is located in the northeast part of the Kenai Peninsula. The average flow for the June-September 2003 period was the second lowest recorded in the 17-year period of record at the Sixmile gage. The close proximity of Sixmile Creek to Cooper Creek makes this analysis of interest, but the utility of comparing these results is minimal because of the difference in watershed character, particularly considering the presence of Cooper Lake Dam.

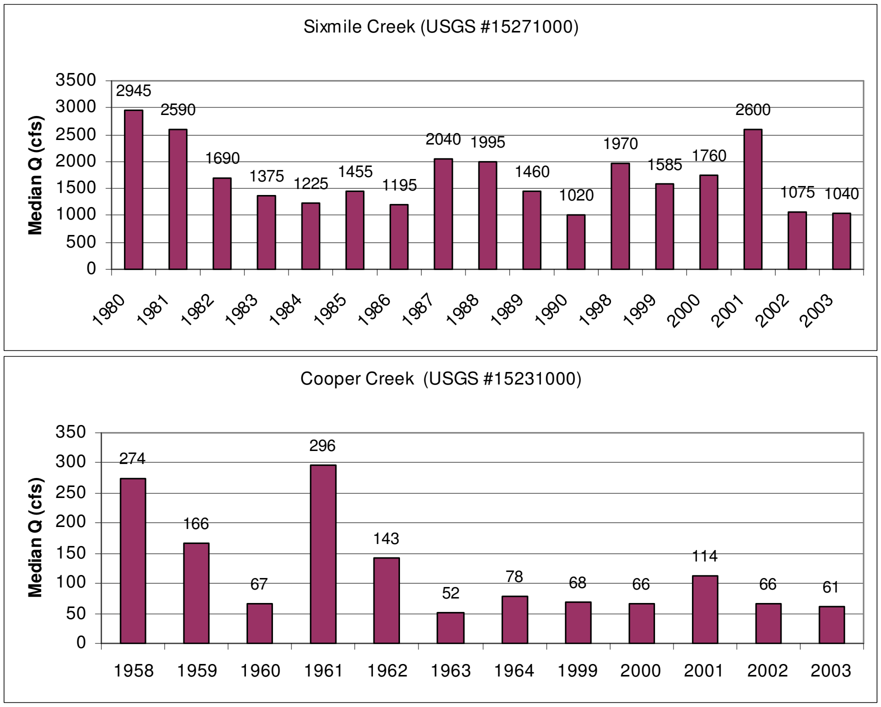

Figure 14. June-September Stream Flow Records at Sixmile Creek and Cooper Creek Flow Gages

David Meyer of the USGS-Water Resources Division in Anchorage analyzed the surface water conditions throughout Alaska for the 2003 water year, and believes the flows in the Kenai Peninsula were generally average (Meyer, personal communication). However, the large variation in climate and hydrology throughout the peninsula precludes the use of generalized region-wide estimates when data specific to the basin of interest exists.

Care must be taken in interpreting only seven years of recorded data. Weighing this analysis against the Sixmile Creek analysis on one hand and David Meyer's analysis on the other, it is reasonable to consider the 2003 flows in Cooper Creek during the June-September period were at some level below normal. This conclusion, paired with the observation of higher air temperatures, should be kept in mind when considering the results of the Cooper Creek habitat and temperature models, and caution should be taken in assessing the model results for the alternative flow regimes. A below-average stream flow means that less cold water enters Cooper Creek from Stetson Creek, the smaller tributaries, and groundwater. A 10 cfs or 30 cfs inflow of warm, epilimnetic Cooper Lake water would produce a greater increase over baseline temperatures in years with lower base flows. This relationship is a simple mass balance of water temperatures; in above average flow years, increased cold water base flow would "wash out" the high temperatures of the Cooper Lake inflow. Concurrently lower than normal air temperatures would contribute in two ways: the temperature of the Cooper Lake epilimnion could possibly be lower than was measured in 2003, and the rate of temperature increase would be lower as the water flows in Cooper Creek.

The amount of flow in Cooper Creek also affects the quantity of habitat available for fish in Cooper Creek. The flow-habitat relationships for targeted fish species and lifestages in Cooper

Creek are provided in Appendix G, and the impacts of increased flows in the mitigation alternatives on fish habitat are discussed later in this report.

The Cooper Creek habitat and temperature models only describe the conditions in May-October 2003. It appears that this period was characterized by above average air temperatures and below average flows in the Cooper Creek basin. Any analysis that involves transferring the results of the habitat and temperature model to other time periods, including future time periods, should use caution and keep in perspective the hydrology and meteorological conditions of the study period.

General Habitat Analysis

Although different species have different preferences for habitat parameters, primarily depth, velocity, and substrate, many of the total available habitat area relationships were similar between species. This is likely a function of both the small size (i.e., width) of Cooper Creek and the similarity of the habitat suitability criteria (HSC). This section discusses general trends for major lifestages.

It should be noted that restoration of mechanically altered stream reaches (such as the Alluvial Reach of Cooper Creek) can effectively increase physical microhabitat for one or more target lifestages. Stream restoration is a tool that can be used alone or in combination with other mitigation alternatives to increase available instream habitat. Stream restoration was not addressed in habitat modeling.

Spawning

Within the study area, spawning for all species most likely occurs primarily in the riffle-cobble and riffle-boulder habitats because of their favorable microhabitat features of depth, velocity, and substrate. Model output was broken down into upstream and downstream locations for these habitats, and the downstream riffle-cobble habitat was additionally broken into two units; those with side channel habitat, and those without side channel habitat.

The existing condition provides little spawning area in riffle-cobble habitat upstream of the Stetson Creek confluence. The model predicted available spawning habitat area would increase over the existing condition in the “10 out” scenarios, and would increase substantially in the “30 out” scenarios. This pattern is not repeated for the riffle-cobble habitat downstream of the confluence. Model output indicates that substantial spawning habitat is currently available in the Canyon and Alluvial Reaches under the existing flow regime. Total available spawning habitat would decrease slightly in the “30 in, 10 out” scenario compared to the current condition, would increase slightly in the “MA in, 30 out” scenario, and would be about the same in the remaining scenarios. This relationship is consistent for riffle-cobble habitats both with and without side channel habitat. The riffle-cobble habitat type provides substantially more spawning area in the Canyon and Alluvial Reaches than riffle-boulder habitat, even though more riffle-boulder habitat is present in these reaches (Figure 3).

The same flow-habitat relationships observed for riffle-cobble habitat hold true for riffle-boulder habitat. Upstream of the confluence, it appears that higher flows in all four mitigation scenarios would increase the spawning habitat upstream of Stetson Creek, which is scarce under the current condition. The majority of the riffle-boulder habitat in Cooper Creek is found in the Canyon Reach, where riffle-boulder habitat accounts for almost 75% of the habitat in the reach (Figure 3). Like riffle-cobble habitat downstream of the Stetson Creek confluence, available riffle-boulder habitat area increases only modestly in the "MA in, 30 out" scenario, decreases in the "30 in, 10 out" scenario, and is similar to the existing condition for the remaining scenarios.

Fry Rearing

Fry rearing likely occurs to some extent in all the major measured habitats in Cooper Creek except cascade/step pools. Model output was calculated for the same habitats described above for spawning, as well as for the dam/plunge and main channel scour pool habitats and the run/glide habitat.

In the first half of the modeling period, May through July, more habitat is available in the "30 out" scenarios than the existing condition for the fry rearing lifestage in riffle-cobble habitat upstream of the Stetson Creek confluence. However in the second half of the modeling period, August through October, fry rearing habitat area increases dramatically above the scenarios in existing condition. The "10 out" scenarios provide consistently less fry rearing habitat within the riffle-cobble habitat than the "30 out" scenarios. Downstream of Stetson Creek, the model predicts fry rearing habitat areas nearly identical to the existing condition for three of the four mitigation scenarios; the "30 in, 10 out" model predicts slightly less available rearing habitat for fry. This pattern is consistent for the downstream habitat with side channels. The side channel habitat provides a greater area for fry rearing than any other habitat type.

Upstream of Stetson Creek, the flow-habitat pattern for the riffle-boulder habitat type is similar to that of the riffle-cobble habitat for fry, however the model predicts habitat area would decrease for fry in the mitigation scenarios, primarily in the "10 out" scenarios. Downstream of the confluence, the model predicts the existing condition as having roughly the same habitat as the mitigation scenarios.

For the dam/plunge pool and run/glide habitats, PHABSIM predicted the existing condition provides more fry rearing habitat than the four mitigation scenarios. In main channel scour pool habitat, the scenarios provided as much rearing habitat area as the existing condition except the "MA in, 30 out" scenario, which provided slightly less. This indicates neither a positive nor a negative flow-habitat correlation for these two habitat types. Either increasing or decreasing flow in the creek would not increase habitat available to fry in pools in Cooper Creek, and the same relationship could be true for run/glides.

Adult Rearing

For Dolly Varden and rainbow trout, rearing of the adult lifestage could likely occur throughout all three anadromous reaches of Cooper Creek. Chinook and coho salmon adults do not rear in Cooper Creek. Model output was calculated for the same habitats as for fry rearing plus the cascade/step pool habitat.

In the Stetson Reach, this lifestage exhibits a positive flow-habitat correlation. As flow increases in Cooper Creek, more surface area is available for use by adult fish. This relationship would be expected, as adults can utilize areas with higher velocities than fry, and prefer deeper depths than fry.

Downstream of the Stetson Creek confluence, however, the mitigation scenarios provided very little additional available rearing area compared to the existing condition for most of the habitat types. Only slight increases in area were generally predicted for the "30 out" scenarios in the major riffle-boulder and cascade/step-pool habitat types. The model predicted increased area for the scenarios in the dam/plunge pool and run/glide habitat types, but the total area for these habitats is very small compared to the other habitat types downstream of the confluence.

General Temperature Analysis

The temperature analysis compares model output to model output. In this case, the existing conditions model output, to which the scenario outputs are compared, is comprised of simulated water temperatures rather than actual temperatures. One of the reasons for this is to keep the comparison of "apples to apples;" that is, to highlight the results of the differences the deterministic SNTEMP model calculated, based on the physical input. The water temperature model was calibrated to very closely represent the measured water temperatures at the Stetson Creek confluence and at the mouth of Cooper Creek. The average difference between predicted and measured water temperatures was 0.0°C at the confluence and 0.1°C at the mouth. Figures 7 and 8 show the measured and predicted water temperatures at the confluence and at the mouth, respectively.

Figures 9 and 10 show the water temperatures of the existing condition and the four mitigation scenarios at a point just upstream of the Stetson Creek confluence and at the mouth of Cooper Creek, respectively. The temperatures in the scenarios are usually higher at the Stetson Creek confluence than those at the Cooper Creek mouth. This is due to the influence of warmed Cooper Lake water upstream of the confluence with the cooler water from Stetson Creek. Stetson Creek is the major tributary to Cooper Creek, and its cold water input, as well as smaller downstream tributaries, would lower the Cooper Creek water temperatures at the mouth as compared to upstream of the Stetson Creek confluence.

Just upstream of the Stetson Creek confluence, the two scenarios with a 30 cfs inflow showed the highest increase in temperature, followed by the two scenarios with a 10 cfs inflow. This is due to the inflow rate of the higher temperature water (Figure 9).

At the mouth, the temperatures of each scenario diverged relative to the inflow rate of Stetson Creek. The scenarios with the greatest diversion of cold water from Stetson Creek out of the system, the "30 in, 30 out" and "monthly average in, 30 out" scenarios, resulted in the highest water temperatures at the mouth (Figure 10). The "10 in, 10 out" scenario resulted in the lowest increase in water temperatures because of the volume of cold water that was left in Stetson Creek to flow into Cooper Creek.

Figure 11 shows the monthly average change in water temperature of each scenario over the existing condition just upstream of the confluence of Stetson Creek with Cooper Creek. This chart highlights two points: first, that the two "10 out" scenarios have identical water temperature outputs at the Stetson Creek confluence, as do the two "30 out" scenarios, and second, that the "30 out" scenarios have a substantially greater warming effect on Cooper Creek water temperature at the confluence than the "10 out" scenarios. The month with the greatest average water temperature increase is September, and the smallest average temperature increase is predicted in May.

The water temperature increases over the existing condition at the mouth of Cooper Creek are shown for the four scenarios in Figure 12. The greatest temperature increases are seen in the months of August and September, due to the high air temperatures that warm both Cooper Creek and the epilimnion (surface) of Cooper Lake that feeds the upper reaches of the creek. The "30 in, 30 out" and "monthly average in, 30 out" scenarios both have monthly average temperature increases above 4.0°C for the months of August and September, and the average increase over the modeling period is slightly less than 3.0°C. For the "10 in, 10 out" and "30 in, 10 out" scenarios, the average increase over the modeling period is 1.1°C and 1.3°C respectively.

The warm inflow from the epilimnion of Cooper Lake undoubtedly contributed to the increased water temperatures throughout the creek that were predicted by the SNTEMP model. The scenarios that include the greater diversions from Stetson Creek (monthly average and 30 cfs "in" scenarios) resulted in higher temperatures, in part because of the diversion of cold Stetson Creek water. The "30 in, 10 out" scenario resulted in a net decrease in Cooper Creek flow and typically produced higher temperatures than the existing condition, but it appears that the inflow rate of warm, epilimnetic Cooper Lake water to the creek is the most important factor as the "30 in, 30 out" and "monthly average in, 30 out" scenarios were predicted as generating the highest temperatures of all the scenarios.

HABITAT/TEMPERATURE SYNTHESIS

A key component of analyzing the habitat and temperature model output relative to the target species in Cooper Creek is understanding the life histories of the species. Life history information has been developed for the target species and lifestages in Cooper Creek: the Instream Flow Review Team developed Cooper Creek-specific Habitat Suitability Criteria, and ADF&G developed a Cooper Creek-specific periodicity chart. Both these items are useful in evaluating the effects of potential changes of flow regime on stocks of fish that currently exist in the creek and those that do not.

The habitat suitability criteria were utilized in the PHABSIM habitat model. As described in an earlier section of this report, the available habitat areas were calculated by mathematically associating the criteria with the output of the PHABSIM hydraulic models. The result is an index of usable area as a function of flow, which is then associated with the hydrologic record to develop a habitat time series. The habitat time series are provided in Appendix H.

Periodicity indicates the general time of the year that a species is most likely to use Cooper Creek for each stage in its life history. The Cooper Creek periodicity table, developed by ADF&G, is displayed in Table 1. The periodicities within the modeling period, May through

October, for each species and lifestage are shown in the figures in Appendix H with the light tan-colored box. Periodicities presented in Table 1 represent the full range of timing for a life stage. Primary periods are encompassed within the full range and may vary from area to area and year to year.

When analyzing the habitat model output, it is important to consider the timing of the availability of habitat. Is habitat available to a species/lifestage at the time it is needed? Would potential changes in flow regime improve the habitat availability for a species/lifestage? Would potential changes in flow regime attract a species of fish that does not currently use Cooper Creek? While factors other than habitat may be involved, insight into these questions can be gained by looking at habitat availability and the modeled scenarios.

The temperature model output can then be included in the analysis. What does the temperature model tell us about the current conditions in Cooper Creek? Do potentially increased water temperatures coincide with essential species/lifestage periodicity? How can the potential changes in the temperature regime improve the attractiveness of Cooper Creek to certain species? The following integration of water temperature and habitat availability is intended to help describe the effectiveness of the hypothetical mitigation scenarios.

Chinook Salmon

Spawning

The likely period that chinook salmon would be spawning in Cooper Creek is mid-July through mid-September (Table 1). The first month of this period is probably the most crucial, as the early Kenai River runs of chinook tend to spawn in the tributaries. During this period, the temperature model predicts the largest increase in water temperatures of the modeling period for all four mitigation scenarios. The average increase at the mouth during this two-month period was 1.6°C for the "10 in, 10 out" simulation, 2.0°C for the "30 in, 10 out" simulation, and 4.0°C for the two "30 out" simulations. The highest daily average difference in water temperature was estimated as 5.4°C at the Stetson Creek confluence on September 16, 2003 in both the "30 in, 30 out" and "monthly average in, 30 out" simulations.

The Habitat Suitability Criteria selected by the Instream Flow Review Team indicated that the optimal water temperature range for chinook salmon spawning is 8-10.5°C (Table 7). During the 62 days in the period from July 16 to September 15, 2003, measured water temperatures were only greater than 8°C for 5 days. The temperature model predicts the water temperatures would be greater than 8°C for 46 of the 62 days in the "10 in, 10 out" scenario, for 51 days in the "30 in, 10 out" scenario, and for all 62 days in the two "30 out" scenarios. It should be noted that modeled water temperatures exceed the 10.5°C optimal limit more than 40 of 62 days in the two "30 out" scenarios, 4 days in the "30 in, 10 out" scenario, and 3 days in the "10 in, 10 out" scenario.

This initial analysis indicates that potential Cooper Lake epilimnetic water diversions into Cooper Creek may warm creek temperatures at the mouth to levels optimal for chinook salmon spawning. The optimal water temperature was rarely observed in Cooper Creek in 2003.

Chinook salmon spawning would likely occur in riffle-cobble habitat and in pocket gravels in riffle-boulder habitat in the Alluvial and Canyon Reaches. Riffle-cobble habitat is well distributed throughout the Alluvial Reach, and riffle-boulder habitat is well distributed throughout the Canyon Reach. Figures H-2, H-3, and H-5 show the habitat model output for downstream riffle-cobble habitat, downstream riffle-cobble with side channel habitat, and downstream riffle-boulder habitat, respectively. The figures indicate that spawning habitat currently exists for chinook salmon in Cooper Creek during the critical time period. The models predict that the two “30 out” scenarios would provide more habitat, the “30 in, 10 out” scenario would provide less habitat, and the “10 in, 10 out” scenario would provide roughly equal habitat as the existing condition during the critical period.

The availability of habitat is a moot point, however, if water temperatures are too low for chinook salmon spawning. The alternative scenarios indicate that water temperatures would increase enough to allow use of the available microhabitat for spawning chinook salmon.

Fry Rearing

Chinook fry and juveniles would possibly utilize Cooper Creek for rearing year-round, but the exact periodicity is not known (Table 1). Thus, the entire model period was analyzed for temperature compatibility and habitat availability.

The presence of chinook salmon fry in Cooper Creek is primarily dependent on spawning in the creek rather than water temperature (however, since spawning itself is dependent on temperature, temperature is an indirect determining factor). Temperature is important, however, as temperatures in the optimal range foster the highest rate of growth for juveniles and is likely a major factor in determining the downstream migration period. The optimal temperature range for chinook salmon fry is 7-11°C (Table 7).

The SNTEMP model indicated that during the May-October modeling period, the current condition daily average temperatures only met the optimal fry rearing temperature range (above 7°C) at the mouth of Cooper Creek in 36 of 182 days in the modeling period. The “10 out” models predicted 78 days above 7°C, and the “30 out” models predicted 112 days above 7°C.

The average temperatures in the existing condition and the “10 in, 10 out” models did not exceed the upper optimal limit for chinook fry lifestage of 11°C. The “30 in, 10 out” model exceeded this threshold on 3 days, the “30 in, 30 out” model exceeded the limit on 24 days, and the “monthly average in, 30 out” model exceeded the limit on 27 days.

Chinook salmon fry would likely utilize all habitat types that exist in the Canyon and Alluvial Reaches. Inspection of the habitat time series reveals the existing condition provides as much or more rearing habitat for fry during the modeling period than the four mitigation scenarios. The only exception is that the “30 out” scenarios provide more rearing habitat in upstream riffle-cobble habitat than the existing condition in the May-July period only. Riffle-cobble habitat is abundant, but does not comprise the majority of habitat upstream in the Stetson Reach.

The initial analysis suggests that while optimal water temperatures are not necessary to attract chinook salmon fry, all four scenarios would produce substantially more time than the existing condition for water temperatures to be within the optimal range for the fry rearing lifestage. The scenarios do not substantially increase habitat area for chinook salmon fry, but neither do they substantially decrease available area in the dominant downstream habitats.

Coho Salmon

Spawning

The likely period of time that coho salmon would spawn in Cooper Creek is mid-September through November (Table 1). The analysis addresses the mid-September through October modeling period. During this period, the temperature model predicted increased temperatures in all four scenarios over the existing condition; however, the increase is not as pronounced for the early autumn period as it is for mid-summer. The average temperature increase over this period ranges from 1.3°C in the "10 in, 10 out" scenario to 2.9°C in the "30 out" scenarios.

The average current condition water temperature at the Cooper Creek mouth during the mid-September through October period is 3.5°C. Optimal coho salmon spawning water temperatures are 3-8°C (Table 7). The existing condition is within the optimal temperature range for coho, albeit on the low end of the optimal range, and the mitigation scenarios would occasionally increase temperatures above the optimal range. The model predicts the 8°C limit would be exceeded 5 of 46 days in the "30 out" scenarios, and not at all in the "10 out" scenarios. Modeled average water temperatures during the coho salmon spawning period do not exceed 8°C under the current condition.

Coho salmon likely spawn in downstream riffle-cobble habitat. During the coho spawning period, habitat currently exists under the existing condition. The two "30 out" scenarios would provide approximately 25% more spawning habitat than the existing condition mid-September through October. The two "10 out" scenarios would provide approximately 5% more spawning habitat over the same period.

Small numbers of coho salmon exhibiting spawning behavior were observed in the Alluvial Reach and downstream "transition zone" of the Canyon Reach of Cooper Creek in September and October of both 2002 and 2003, but not in 2004.

Fry Rearing

ADF&G has identified July and August as the critical period for the coho salmon fry rearing lifestage, while acknowledging that all other months might be critical for coho fry (Table 1). The optimal temperature range for coho fry in Cooper Creek is 7-12°C, with the lower limiting temperature being less than 2°C (Table 7).

Water temperatures in the current condition are regularly below the optimal range for coho fry. In the 62 days in July and August, average temperatures were below the optimal range for 26 days. The mitigation scenarios improved this situation substantially, reducing the number to 0 in the "MA in, 30 out" scenario, 1 day in the "30 in, 30 out" scenario and to 3 days in the "10 out" scenarios. While the existing condition average water temperature dipped below 2°C in the mid-

September through October period, water temperatures stayed well above this threshold in the mitigation scenarios.

Coho salmon fry currently rear in the downstream transition zone of the Canyon Reach and in the Alluvial Reach, particularly near the mouth of Cooper Creek. If, under future conditions, coho salmon were to spawn in the Stetson Reach, then rearing would also likely occur in the Stetson Reach. Riffle-cobble is the dominant habitat in the Alluvial Reach and comprises a major portion of the Stetson Reach; therefore analysis will focus on this habitat type.

The habitat model predicts the scenarios would provide roughly the same habitat area as the existing condition except the “30 in, 10 out” scenario, which provides about 4% less. These small levels of change indicate that rearing habitat is currently available in Cooper Creek for coho fry and changing the flow regimes by those modeled in the scenarios would have little effect on total habitat availability.

The initial analysis suggests that habitat is currently available for both spawning and rearing lifestages of coho salmon, and that water temperature is already within the optimal range for spawning. Water temperature is currently lower than optimal for fry rearing, and the model predicts the scenarios would greatly improve conditions for fry in the mid-September through October period (November is unknown as it is outside the model time period).

This result seemingly contradicts the fact that coho salmon are currently present in Cooper Creek in only very small numbers. Existing temperatures are at the low end of the optimal spawning range. It is possible that warm fall temperatures may be more important to coho salmon than suggested by the above analysis, both in terms of attracting spawners to Cooper Creek and providing optimal incubation conditions. Cool incubation temperatures, especially during the period immediately following spawning, could cause delayed emergence and poor survival of coho salmon fry in Cooper Creek.

Dolly Varden

Of the four target species in this study, only Dolly Varden currently utilize Cooper Creek as resident fish. Intensive fish resources studies have been undertaken for the Cooper Lake Project relicensing process and have documented Dolly Varden presence, population, and utilization within the creek. The periodicity tables and habitat suitability criteria for Dolly Varden were based in part on these studies.

Dolly Varden utilize habitat both upstream and downstream of the Stetson Creek confluence. Both sections of Cooper Creek will be analyzed in the following sections.

Spawning

Dolly Varden typically spawn in riffle-cobble and riffle-boulder habitats, primarily mid-September through October (Table 1). Upstream of the Stetson Creek confluence, the two “10 out” scenarios have identical hydrology and thus identical model water temperature output. The same applies to the two “30 out” scenarios. The “10 out” and “30 out” scenarios predict higher water temperatures in both of the potentially utilized spawning habitat types upstream of the confluence. Just above the confluence, the average increase in water temperature during the critical mid-September through October period was 3.4°C for the “10 out” scenarios and 4.3°C for the “30 out” scenarios.

Dolly Varden prefer relatively cold water for spawning, optimally 3-4°C (Table 7). During the critical mid-September through October period, the existing conditions model predicted water temperatures in this narrow range in the existing condition 15 days out of 46. Of the remaining days, 16 were above this range and 13 were below the range. All four scenarios predicted water temperatures just above the confluence well above the optimal range for Dolly Varden spawning.

At the mouth of Cooper Creek, the current condition temperature model predicts the optimal 3-4°C temperature range for spawning Dolly Varden is met 7 days in the modeling period, exceeded 14 days and colder than the optimal range 23 days. The optimal range is exceeded in all days in the “30 out” scenarios; the “10 out” scenarios meet this narrow range 14 days of 46, and the remaining days exceed the range. At the mouth, the average water temperature during the mid-September-October range for the current condition is 3.5°C; for the scenarios the average temperatures range from 4.8°C (“10 in, 10 out”) to 6.4°C (both “30 out” scenarios). These temperatures, while above the optimal range, are well below the upper limiting temperature for this lifestage of 13°C (Table 7).

It should be mentioned that these calculations only include daily average water temperatures and do not include instantaneous measurements. For example, it is normal for water temperatures to exceed criteria during the hottest part of the day, and then meet them at night. Because daily average water temperatures are used, this analysis does not necessarily reflect whether the criteria are not met throughout the entire day or just for a certain period of time.

The temperature models suggest the optimal temperature range is not currently achieved during the Dolly Varden spawning period lower in the Cooper Creek system but probably is met higher in the system. This is verified by the fish resources work, which documented significant numbers of adult Dolly Varden near the confluence of Stetson Creek during the spawning period. Cooper Creek is kept cool in its upper reaches by the dominant cold groundwater upwelling sources and the shading of the Falls Reach. Stetson Creek provides the majority of the Cooper Creek flow downstream of the confluence; its water is typically very cold as well. The scenarios would add warmer water to the upstream end of Cooper Creek, simultaneously decreasing the cold water inflow from Stetson Creek. This would result in a substantial net increase in water temperatures throughout the creek.

Upstream of the confluence, some spawning habitat currently exists for Dolly Varden spawning activity, an average of about 8,900 ft^2 total in the riffle-cobble and riffle-boulder habitat types. The higher flows in the “10 out” scenarios contribute to an average spawning area of 17,000 ft^2 total. The “30 out” scenarios produced an average of 17,500 ft^2 of available habitat for Dolly Varden spawning in the upstream riffle-cobble and riffle-boulder habitats.

Downstream of the confluence, the patterns of Dolly Varden spawning habitat availability in riffle-cobble and riffle-boulder habitat are similar to those for coho salmon. The periodicity is similar as well: coho salmon likely spawn mid-September through November, and Dolly Varden spawn mid-September through October. The spawning periods for both species are identical within the model, which ends on October 31. While the total downstream spawning habitat area available for these species is not the same, they are close, and the patterns are identical.

Similar to coho salmon, Dolly Varden likely spawn in downstream riffle-cobble habitat. During the spawning period, the two “30 out” scenarios would provide approximately 15% more spawning habitat than the existing condition mid-September through October. The “30 in, 10 out” scenario provides approximately 2% less spawning habitat over the same period. The “10 in, 10 out” provides about the same area as the existing condition.

The flow-habitat relationship for the Dolly Varden spawning lifestage is positively correlated. The increased discharge in the two “30 out” scenarios results in increased spawning habitat for Dolly Varden throughout the anadromous reaches of Cooper Creek. The “10 in, 10 out” scenario results in increased habitat area upstream of the confluence, and the “30 in, 10 out” scenario results in increased habitat area upstream of the confluence and decreased area downstream. The scenarios result in increased water temperatures, however, that are well above the optimal range for Dolly Varden spawning. It is possible that on some days the positive results of increasing spawning area in Cooper Creek would be negated by the increase in water temperature.

Fry Rearing

Since Dolly Varden is a resident species, fry rearing occurs in Cooper Creek year-round. ADF&G has identified the months of June through October as the critical period for fry rearing. The optimal temperature for the Dolly Varden juvenile rearing lifestage is 8-10°C (Table 7).

The model predicts average temperature increases at both the Stetson Creek confluence and at the mouth of Cooper Creek for the scenarios in June through October over the existing condition. Table 11 summarizes the average monthly water temperatures for the existing condition and the four mitigation scenarios for the critical Dolly Varden fry rearing period.

The current conditions in the creek provide 51 of the 153 days in the critical June-October fry rearing period within the optimal temperature range at the Stetson Creek confluence, and only 6 days within the optimal range at the mouth of Cooper Creek. At the confluence, a majority of the days within the optimal temperature range occur in July and August, the warmest period of the summer.

Table 11. Temperatures in Cooper Creek during Dolly Varden Fry Rearing Critical Period

	Stetson Creek Confluence						**Cooper Creek Mouth**					
	Avg. Temp (°C) (# days in optimal range)						Avg. Temp (°C) (# days in optimal range)					
Scenario	June	July	Aug	Sept	Oct	Avg	June	July	Aug	Sept	Oct	Avg
Existing Condition	7.1 (3)	9.2 (24)	8.8 (22)	5.4 (2)	3.9 (0)	6.4 (51)	5.3 (0)	6.9 (1)	7.4 (5)	4.6 (0)	3.3 (0)	5.2 (6)
10 in, 10 out	9.1 (13)	12.0 (2)	13.0 (0)	10.1 (16)	6.6 (4)	9.3 (35)	6.0 (0)	7.9 (14)	9.0 (27)	6.6 (4)	4.4 (0)	6.4 (45)
30 in, 30 out	10.2 (11)	13.4 (0)	14.1 (0)	11.3 (5)	7.4 (10)	10.3 (28)	7.3 (6)	9.8 (16)	11.6 (0)	8.8 (10)	5.7 (2)	8.0 (34)
30 in, 10 out	9.1 (13)	12.0 (2)	13.0 (0)	10.1 (16)	6.6 (4)	9.3 (35)	6.1 (0)	8.1 (20)	9.5 (26)	6.7 (8)	4.5 (0)	6.5 (54)
Monthly average in, 30 out	10.2 (11)	13.4 (0)	14.1 (0)	11.3 (5)	7.4 (10)	10.3 (28)	7.4 (7)	10.0 (13)	11.6 (0)	8.8 (10)	5.7 (2)	8.1 (32)

The four mitigation scenarios greatly increase the number of days that meet the optimal temperatures at the mouth, while slightly reducing the number of days that meet the optimal temperatures at the Stetson Creek confluence. The "30 out" scenarios meet the 8-10°C optimal range at the mouth 32-34 days, and the "10 out" scenarios meet the range 45-54 days, compared to the 6 days for which the optimal temperature range is currently met. At the confluence, the scenario models predict average temperatures within the 8-10°C range 28-35 days in the 153-day critical period, compared to 51 days in the current condition.

The scenarios also shift the time period in which the optimal temperatures are met. Currently most of the optimal temperatures at the confluence are met in the months of July and August; the water temperatures in all four of the mitigation scenarios are higher than the optimal range throughout August, so optimal temperatures are instead met in June, September and October.

Since Dolly Varden spawning could occur throughout the lower three reaches of Cooper Creek, fry could rear in all habitat types. Upstream of the confluence, the model predicts about 6,000-9,000 square feet of Dolly Varden fry rearing habitat are available May through July, though the available area increases to as much as 20,000 square feet in the August-October period. The "30 out" mitigation scenarios would result in a substantial 44% habitat increase in the May-July period, but would provide about 14% less habitat in the August-October period. The "10 out" scenarios would provide a 20% increase in habitat area May-July, and about 43% less habitat area than the existing condition August-October. Both riffle-cobble and riffle-boulder habitat are abundant upstream of the confluence.

Downstream of the confluence, habitat area is currently available in the riffle-cobble and riffle-boulder habitat types. The scenarios would largely neither increase nor decrease this total area, as the range of total habitat area differences is -5% ("30 in, 10 out" scenario) to 4% ("30 in, 30 out" scenario). This relationship is identical for the cascade/step-pool habitat type, a habitat type abundant in the Canyon Reach.

Of the less abundant habitat types, the models predict essentially the same availability of habitat area for all scenarios and the current condition for the main channel scour pool habitat type. Slightly more habitat would be available in the current condition than in any of the four scenarios for the dam/plunge pool habitat type.

All the scenarios predict tradeoffs in terms of both temperature and habitat availability. While the scenarios substantially improve temperature conditions for rearing Dolly Varden at the mouth of Cooper Creek, they could impart a negative impact at the Stetson Creek confluence. For any increase in rearing area that a scenario creates in one habitat type, there is a decrease in area for another habitat type. For example, the cascade/step-pool habitat, the riffle-boulder habitat in the Canyon Reach, and the riffle-cobble habitat in the Alluvial Reach are the dominant substrates in the creek due to their abundances. The existing condition provides more area in these habitat types than any of the four mitigation scenarios. However, temperature increases associated with the mitigation scenarios would benefit rearing Dolly Varden fry. The impacts of a mitigation scenario to habitat and temperature for the fry lifestage would have to be weighed against those to the spawning lifestage and the adult rearing lifestage, while considering other species as well.

Adult Rearing

ADF&G has identified the period July through the third week in October as critical for rearing and passage of adult Dolly Varden. In the Aquatic Habitat Analysis Report, it was determined there are no barriers to upstream passage of adult Dolly Varden between the mouth and the upstream end of the Stetson Reach.

The Instream Flow Review Team did not select temperature criteria for the adult rearing lifestage of Dolly Varden. Effects of scenario temperatures will not be analyzed for this lifestage.

Little adult rearing habitat area currently exists in the upstream riffle-cobble and riffle-boulder habitat types during the critical time period for Dolly Varden. The scenarios substantially increase the habitat area for adult rearing upstream of Stetson Creek, the two “30 out” scenarios slightly outperforming the two “10 out” scenarios. Downstream of the confluence, all four scenarios provide essentially the same habitat area in the riffle-cobble and riffle-boulder habitat types as the current condition.

The habitat model predicts the scenarios have essentially the same area of cascade/step-pool habitat as the existing condition. The cascade/step-pool habitat is common in the Canyon Reach.

In the dam/plunge pool and run/glide habitat types, the models predict a major increase in habitat area over the existing condition for all four scenarios, although the total area for these two habitat types is very small. The two “30 out” scenarios provide slightly more habitat than the two “10 out” scenarios. In the main channel scour pool habitat type, the scenarios provide essentially the same area as the existing condition.

Rainbow Trout

Rainbow trout do not currently utilize Cooper Creek to a significant degree. Anecdotal evidence suggests that some rainbow trout use occurred in the creek prior to operation of the Cooper Lake Project.

Spawning

The exact periodicity of spawning use of Cooper Creek by rainbow trout is not known. The timing of trout spawning is keyed to water temperature and varies from stream to stream depending on temperature regime. ADF&G has estimated that rainbow trout would likely spawn in the creek sometime between the last week of April and the end of June (Table 1). Rainbow trout would enter Cooper Creek from the Kenai River and likely utilize the downstream segments, including the Alluvial Reach and the transition zone of the Canyon Reach. If conditions were favorable in the Stetson Reach, spawning could possibly occur there as well.

Water temperature during the post-breakup period in May and early June is critical for rainbow trout spawning success. The average May temperature in lower Cooper Creek is 3.8° C and average June temperature is 5.3° C. These temperatures are below the optimal range designated in Table 7 and, thus, under existing conditions temperatures in Cooper Creek may be too low for rainbow trout spawning.

In order to get a better idea of the temperatures that rainbow trout prefer, or at least tolerate, on the Kenai Peninsula, temperature records for nearby streams with trout runs have been graphed along with periodicity information for rainbow trout spawning and incubation (Figure 15). The important thing to note about Figure 15 is the rise in temperature that occurs in Crescent Creek, Quartz Creek, and the Russian River during the mid-May to late June period, in contrast to the very slow warming in Cooper Creek during this same time. Rainbow trout generally move into spawning streams when temperatures reach 4-5°C then remain until temperature increases to 7-8°C, at which time they spawn. The temperature increase is essential to trigger spawning, and the warm temperatures also speed up incubation. Figure 15 suggests that Cooper Creek does not reach the critical temperature until too late. Under either of the "30 out" scenarios, Cooper Creek temperatures would increase more rapidly in the spring and likely reach critical spawning temperature by mid-May or early June. It is probably reasonable to conclude from this information that rainbow trout from Kenai River populations would resume use of Cooper Creek for spawning under these circumstances.

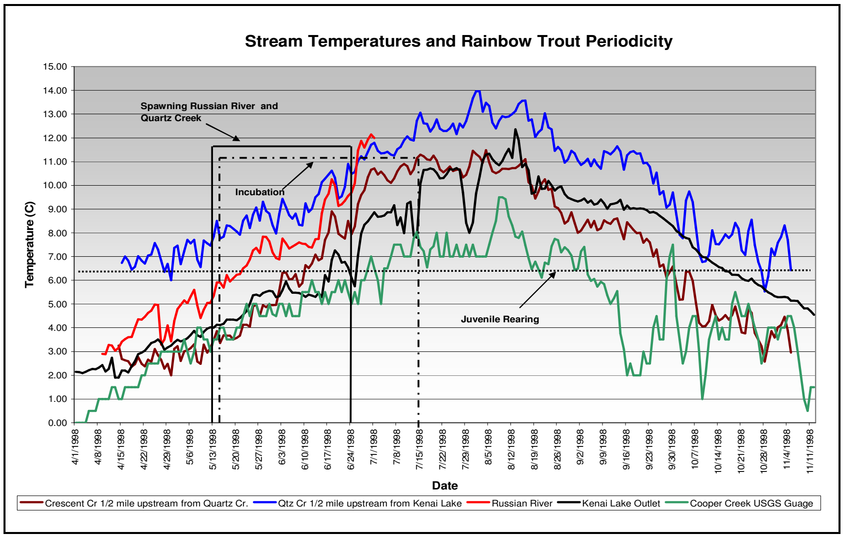

Figure 15. Kenai Peninsula Stream Temperatures with Rainbow Trout Periodicity

Rainbow trout would largely utilize riffle-cobble and riffle-boulder habitat for spawning. Riffle-cobble is the dominant habitat type in the Alluvial Reach and one of the primary habitats in the Stetson Reach. The habitat model predicted roughly similar habitat areas for the existing condition and all four scenarios in these habitat types, with only modest increases over the existing condition in the "30 in, 10 out" scenario.

It should be emphasized that while existing spawning habitat is available, the temperatures in Cooper Creek during the critical spawning period are substantially below the optimal spawning temperatures for rainbow trout, and conceivably cause the available habitat to become unavailable. The water temperatures at the mouth in the "30 out" scenarios could be increased into the optimal range for rainbow trout spawning during the critical period, thereby effectively "opening up" the physical microhabitat for spawning adults.

Fry Rearing

ADF&G has identified the period May-October as the critical rearing period for the rainbow trout fry lifestage (Table 1). Since rainbow trout have the ability to populate Cooper Creek as a resident species, rainbow trout fry could utilize the creek year-round. This analysis focuses on the critical May-October period for temperature and habitat area relationships.

The Instream Flow Review Team determined the optimal rearing temperature for rainbow trout fry is 6-12°C (Table 7). During the 184-day period of May-October, the daily average water temperature at the Cooper Creek mouth in the current condition model was within the optimal range for 70 days. The scenario models predicted the average temperatures would fall within the range 96-128 days, with water temperatures in the "30 out" scenarios exceeding the range 10 days in the model period.

Rainbow trout fry would likely utilize the rearing habitat in the Alluvial Reach. The riffle-cobble habitat type is by far the most abundant habitat in this reach, followed by main channel scour pool. There is a very small amount of riffle-boulder and plunge pool habitat in the reach.

The model predicts all scenarios, except the "30 in, 10 out" scenario, provide roughly similar habitat areas in the riffle-cobble habitat type, both with and without side channels; the "30 in, 10 out" scenario provides slightly less. The scenarios also provide roughly the same habitat area as the existing conditions in the main channel scour pool habitat type. In the small amount of riffle-boulder habitat in the Alluvial Reach, the scenarios produce no substantial differences in habitat area from the existing condition.

Cooper Creek water temperatures currently meet the 6-12°C optimal temperature range for rearing rainbow trout fry 71 of 184 days in the critical period, or approximately 39% of the time. The scenarios would improve this record to meeting the optimal temperature range about 52-70% of the time. This limited improvement is probably not crucial to the development of rainbow trout fry. The habitat area results are similar; the models predict no improvement in available habitat for fry rearing in the scenarios. The models predict the "30 in, 10 out" scenario would see a modest increase in habitat area in the riffle-cobble habitat type, but this increase would probably not lead to a substantial improvement in rainbow trout fry rearing conditions.

Adult Rearing

ADF&G has identified the period mid-July through October as critical for rearing and passage of adult rainbow trout. As stated earlier, it was determined there are no barriers to upstream passage of adult rainbow trout between the mouth and the upstream end of the Stetson Reach.

The Instream Flow Review Team did not select temperature criteria for the adult rearing lifestage of rainbow trout. Effects of scenario temperatures will not be analyzed for this lifestage.

Rainbow trout adults would likely rear in the Alluvial Reach and the transition zone of the Canyon Reach, and could also establish a resident population in the Stetson Reach and upper segments of the Canyon Reach. The dominant mesohabitat in the downstream segments of Cooper Creek, riffle-cobble, could support adult rainbow trout rearing under the existing flow regime. The "30 out" scenarios would produce a modest 4-5% increase in available habitat within these reaches, while the "30 in, 10 out" scenario would produce a 2% decrease in available habitat. All four scenarios would provide a significant increase in available habitat within the Stetson Reach. Overall, the models predict the "30 out" scenarios will produce a 10% increase in rearing area for adult rainbow trout, the "10 in, 10 out" scenario will produce a 7% increase in rearing area, and the "30 in, 10 out" scenario is predicted to result in a 5% increase in rearing area.

Emergence Analysis

An analysis of egg hatching and emergence using cumulative temperature units (CTU) from temperature model output was performed to determine when emergence would likely occur under the various mitigation alternatives compared to the existing condition. This analysis should be considered as an approximation only, because other variables, such as genetic composition of specific stocks and other direct or indirect environmental factors, also influence spawning and subsequent emergence timing.

The emergence analysis utilized the following assumptions:

- The analysis referenced temperatures at the mouth of Cooper Creek, thus the analysis reflects conditions at the mouth.
- Spawning redds are located in areas of Cooper Creek that do not freeze solid and adequate flow is maintained during winter conditions to allow egg development.
- Intra-gravel water temperatures do not fall below 0.5°C (33°F). Actual measurements from Cooper Creek USGS gage included many temperature readings of 0°C which would be lethal to the incubation process. In the actual "measured" data set from Cooper Creek (USGS 2003), temperature readings of 0 to 0.4°C were increased to 0.5°C based on the assumption that redds do not freeze and are maintained at a minimum temperature of 0.5°C.
- Winter temperatures for the modeled scenarios would increase by 1°C over the existing condition.
- Chinook salmon spawning periodicity would be similar to Crescent and Quartz Creeks.
- Rainbow trout spawning periodicity would be the similar to the Russian River and Quartz Creek.
- Coho salmon and Dolly Varden spawning periodicity would remain as it presently occurs in Cooper Creek.

Emergence timing for each species was established by starting temperature unit accumulation at both the beginning and end of the spawning period for each species during each of the five temperature scenarios. This emergence periodicity "window" is the time between when a fish could emerge once adequate temperature units accumulate, taking into account eggs spawned early in the run and late in the run and the overall CTU emergence range specific to each species. The CTUs needed to induce emergence for salmon species in Alaska were provided by Alaska Department of Fish and Game (ADFG 2001).

An example situation follows: In the "10 in, 10 out" scenario, a chinook salmon egg spawned on July 30 would begin accumulating TUs 31 days before an egg spawned on August 31 with the "July 30 brood" having already accumulated 303 TUs by August 31. By April 20 of the following year, the "July 30 brood" would have 900 CTUs and could emerge from the gravel as free swimming fish anytime after April 20 or typically up to about 1000 CTUs which would occur by mid-May. However, eggs spawned on August 31 (at the end of the run) would reach 900 CTUs by about June 23 or approximately 64 days later and would reach 1000 CTUs by July 7 or about 80 days behind the "July 30 brood". The emergence window shown in the attached graphs is the duration between when fish could emerge at the earliest and at the latest. The chinook salmon emergence analysis results are shown in Figure 16; results for coho salmon, Dolly Varden, and rainbow trout are given in Figures 17, 18, and 19, respectively.

It is important to note that because of the genetic traits of specific salmon stocks, fish spawned at the beginning of the run may emerge at higher CTUs (i.e. later) and fish spawned at the end of the run could emerge at lower CTUs (i.e. sooner), thus compressing the overall emergence periodicity. Based on this fact, actual emergence would probably occur somewhere towards the middle of each emergence periodicity window shown in the attached figures.

Table 12 shows the potential emergence periodicity windows based on CTU calculations for the five mitigation scenarios.

Table 12. Cooper Creek Emergence Periodicity Model

		Emergence Periodicity				
Species	Spawning Timing	Existing Conditions	10 in, 10 out	30 in, 30 out	30 in, 10 out	MA in, 30 out
Rainbow Trout	1-May – 30-Jun	13-Aug - 20-Sep	7-Aug - 2-Sep	29-Jul - 19-Aug	6-Aug -30-Aug	27-Jul - 18-Aug
Dolly Varden	1-Sep – 31-Oct	16-Jun - 20-Jul	10-May - 28-Jun	28-Apr - 19-Jun	9-May -27-Jun	29-Apr - 20-Jun
Chinook Salmon	16-Jul – 15-Sep	30-Jun - 12-Aug	20-Apr - 7-Jul	8-Dec - 17-Jun	10-Apr -6-Jul	10-Dec - 15-Jun
Coho Salmon	16-Sep – 30-Nov	10-Jun - 19-Aug	26-Mar - 27-Jul	10-Dec - 11-Jul	7-Mar -21-Jul	11-Dec - 14-Jul

For spring spawning fish (rainbow trout) the "30 in, 30 out" and "MA in, 30 out" scenarios could provide emergence timing similar to natural conditions generally observed on the Kenai Peninsula. Based on TU accumulation, these two scenarios could produce emergence for rainbow trout during the mid to late-summer season with water temperatures generally in the 10-11°C range.

For fall spawning fish (chinook salmon, coho salmon, and Dolly Varden) the "10 in, 10 out" and "30 in, 10 out" scenarios would provide emergence timing similar to natural conditions generally observed on the Kenai Peninsula. Based on TU accumulations, these two scenarios could produce emergence for chinook salmon from early spring to the early-summer season with water temperatures generally in the 2-6°C range over the duration of emergence. Emergence for coho salmon could range from early spring to mid-summer season with water temperatures generally in the 1-8°C range.

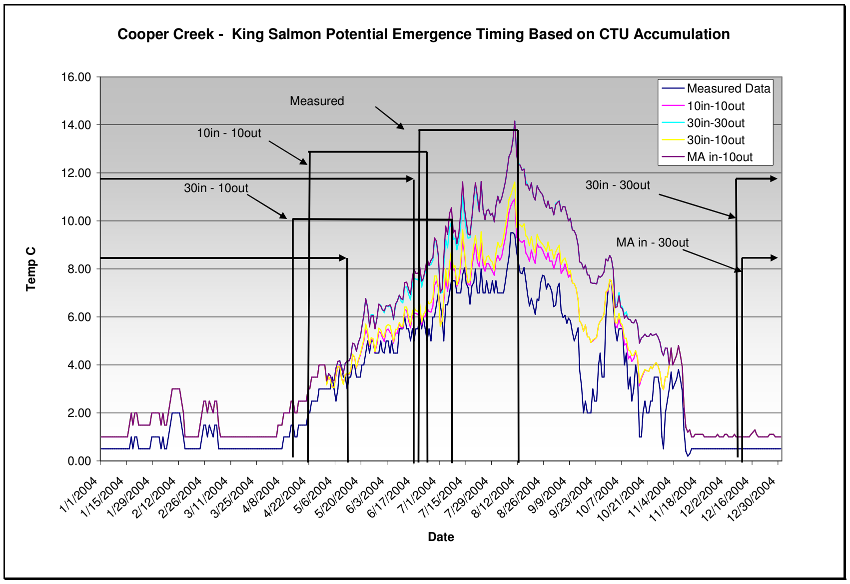

Figure 16. Chinook Salmon Potential Emergence Timing for Model Scenarios.

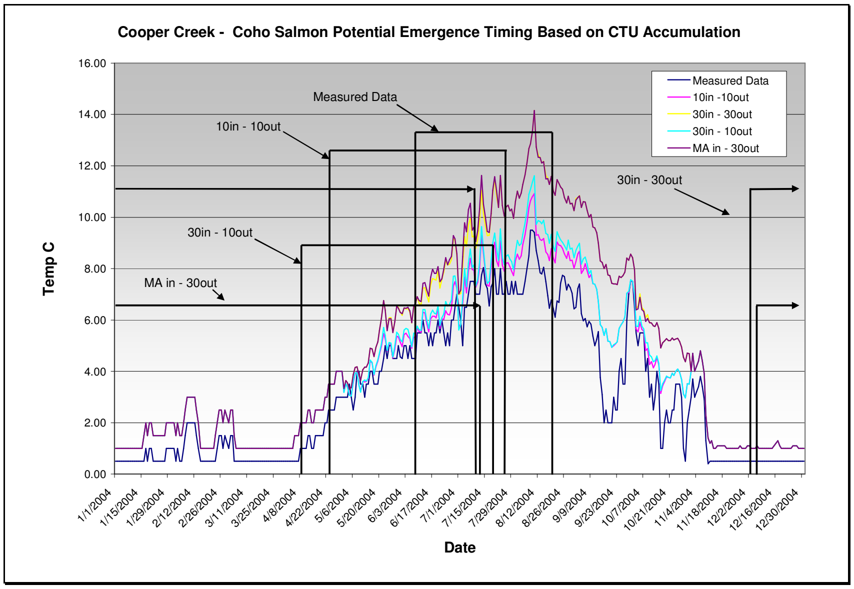

Figure 17. Coho Salmon Potential Emergence Timing for Model Scenarios.

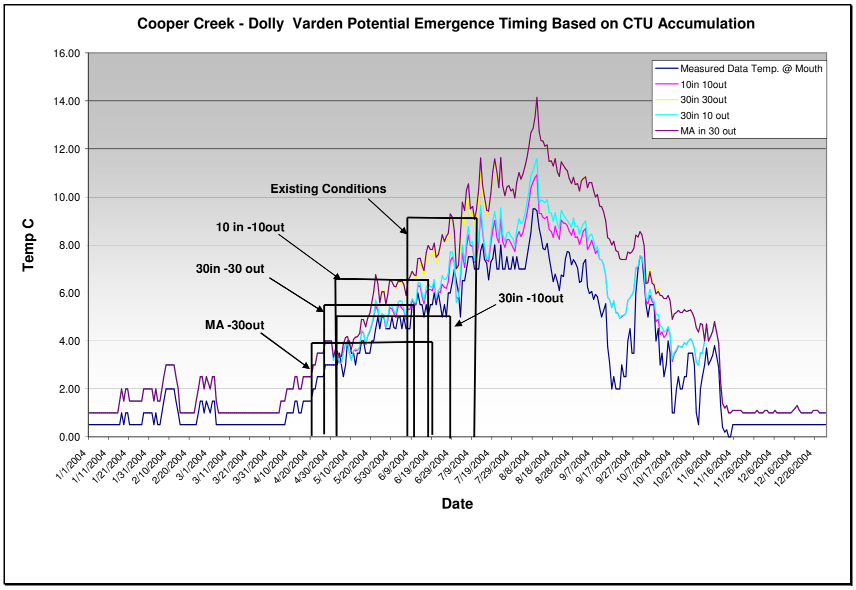

Figure 18. Dolly Varden Potential Emergence Timing for Model Scenarios.

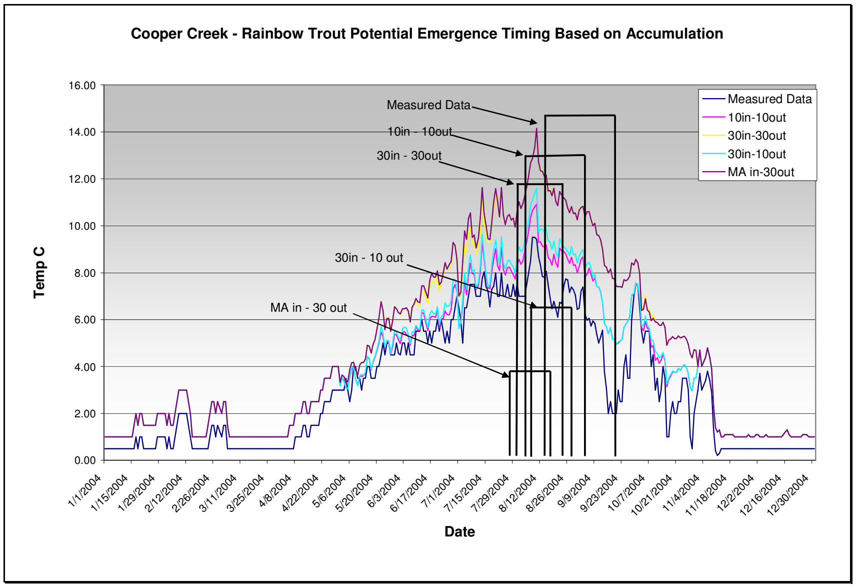

Figure 19. Rainbow Trout Potential Emergence Timing for Model Scenarios.

POTENTIAL CHANGES TO AQUATIC HABITATS AND FISH POPULATIONS

As discussed above, the PHABSIM model can only predict available habitat under different flow conditions, and the temperature model only provides an indication of whether temperature conditions are within known tolerance limits. Neither of these models directly addresses how fish species composition or fish numbers would respond to stream changes.

The following analysis goes beyond the modeling and attempts to integrate the model results with knowledge of the resource and professional judgment to provide an indication of the kinds of changes, in terms of fish use, Cooper Creek might actually be subjected to under an "optimal" mitigation strategy. It is readily acknowledged that any two biologists would likely develop different interpretations of the available information. However, it is hoped that there will be sufficient common ground such that the following discussion can provide a useful starting point for future discussions.

The discussion below emphasizes changes to species composition and numbers of fish. It is acknowledged that there may be other values to habitat enhancement that are important but much more difficult to quantify. Such values may include ecological diversity and stability, genetic diversity within the Kenai River drainage, and wildlife food availability. Presentations of fish use trends or numbers are expressed on an annual basis. It is also acknowledged that potential changes to fish populations could extend into the indefinite future, thus, "value" has a future use component.

The analysis in this section only addresses what might be considered a generic "optimal" mitigation scenario (however, this does not imply that one mitigation scenario is superior to another), the essential features of which are as follows:

1. Diversion of all but 6 cfs from Stetson Creek into Cooper Lake (up to 70 cfs maximum) during the open water season (Cooper Lake ice breakup through November 15).
2. Regulated flow release from the dam of up to 30 cfs during the same period. (Releases from the dam would be seasonally regulated to optimize temperature and flow conditions for selected fish species. Releases would not necessarily be equal to input from the Stetson diversion during any given week, but total release over an open water period would not exceed total input from the Stetson diversion.)
3. Release of a continuous 5 cfs from the Cooper Lake dam throughout the winter. A flow of 5 cfs was arbitrarily selected to provide minimum incubation conditions and to provide a basis for engineering analysis. For purposes of this scenario, it is understood that the winter release amount could be adjusted, if desirable, within the constraints of power generation requirements.
4. Screening of the dam outlet structures was not considered as part of the engineering analysis, but regulatory agencies have suggested that screening might be required to prevent movement of Cooper Lake fish into other portions of the Kenai River drainage. The following discussions will consider both screened and unscreened options. It should be noted that fish screens are often not totally effective.

The preliminary habitat and temperature modeling described in previous sections of this report along with professional judgment suggests that the above scenario would cause the following physical alterations to Cooper Creek, which may be beneficial to fish:

1. Stream temperatures in most of Cooper Creek would be increased during the May through October period, probably extending into late November (November time period was not modeled).
2. Significant summer flow would be established in extreme upper Cooper Creek (dam to falls) where little or no flow currently exists.
3. Summer flow would be increased in the Stetson Reach by more than 300 percent.

4. A minimum winter flow of 5 cfs would be guaranteed in the reach from the dam to the mouth of Stetson Creek.
5. Winter flow downstream from Stetson Creek would be increased by 20-30 percent.
6. Winter water temperature may be slightly higher throughout the creek especially in the upper reaches, because water tapped from near the lake bottom by the proposed winter bypass pipe will have a slightly higher temperature than surface water.
7. The potential would exist to regulate flow during the open water season to optimize temperature and/or flow effects.
8. Water quality within Cooper Creek would change with the addition of water from Cooper Lake. Slightly higher conductivity of Cooper Lake water combined with the presence of plankton suggests that overall productivity could be increased as a result of greater nutrient availability.

Analysis by Stream Reach

Lake and Falls Reaches

These reaches currently contain no fish because of low winter flow and inaccessibility to fish from both downstream and upstream. The Lake and Falls Reaches were not considered in the habitat or temperature modeling. The mitigation scenario described above would cause greatly enhanced summer flow, guaranteed winter flow, and possibly access to Cooper Lake fish carried downstream through the dam release structure. In the absence of dam outlet screening, this set of circumstances would likely cause rainbow trout to become established as residents in this reach. There is no evidence that Cooper Lake Arctic char inhabit tributary streams; consequently it is unlikely that char would become established as resident species (char accidentally moving downstream through the dam structure would likely continue downstream into the Kenai River).

If dam outlets were successfully screened, then the Lake and Falls Reaches would continue to be devoid of fish. A more likely outcome of screening is that fish would become established in these reaches more slowly. Escapement of fish through or around the screens would likely occur eventually. Short length and inaccessibility to fish from downstream (because of the falls) obviously limits the fisheries value of this reach regardless of its accessibility from upstream.

There would be a period of scouring of fine sediments and channel stabilization following the introduction of flow to this reach, which might lead to downstream siltation and temporary adverse impact. Some existing beaver ponds would likely become scoured out and new stream channel would be created in some areas. Beaver activity may continue in this reach but the resulting stream and pond configuration would likely be altered. Adverse downstream effects would be temporary. Because of the fine nature of the sediment and the generally high gradient of Cooper Creek, most scoured material would likely pass through the system without impacting long term fish production.

In the absence of screening, a small population of year-round resident rainbow trout would likely become established in the reach within a period of about 10 years. Very short stream length and blocked fish passage from downstream would ensure that fish numbers remained small, probably less than 50 adult fish. Without screening, some trout, originating from Cooper Lake stocks, would likely proceed downstream into the Kenai River.

Stetson Reach

The Stetson Reach would be altered by both increased flow and increased temperature. Of the two changes, flow would be the most significant. Flow in the Stetson Reach during the 2003 open water period averaged 8.2 cfs and ranged from 2.2-35.3 cfs (excluding the October floods). The addition of 30 cfs (dam release) would make the average flow about 40 cfs, or four times the existing flow. Such a change would obviously increase surface area and stream depth significantly. Average stream velocity would increase, but, at the same time, slow stream margin habitats such as backwaters would also likely increase. The aquatic habitat modeling described above indicates that spawning and adult rearing habitat would increase substantially under a "30 out" scenario. Such a major change in flow would definitely cause a net increase in the availability of various kinds of fish habitats including spawning, overwintering, and adult feeding habitats, which do not now exist.

Temperature changes in the Stetson Reach would be 1-2° C higher than in the downstream reaches. This increase in temperature would be less dramatic in the Stetson Reach, however, because the portion of the stream above the confluence of Stetson Creek is already warmer than lower Cooper Creek by about 2° C in mid-summer. Warming in early summer would occur more quickly under the Stetson diversion scenario. As discussed above, this temperature increase during the late May to mid-June period is a critical factor relative to rainbow trout spawning and incubation. Mid-summer temperatures would be somewhat warmer (possibly too warm). More significantly, fall temperatures would be significantly warmer and fall cooling would occur more slowly. This temperature regime would potentially open up opportunity for coho salmon spawning with good early winter incubation conditions.

Warmer summer temperatures could be disadvantageous to juvenile Dolly Varden, either through direct avoidance of warm water or as a result of competition with juvenile salmon and rainbow trout. The potential response of resident Dolly Varden to habitat changes in the Stetson Reach might be complex. The Stetson Reach currently supports an unusually high density of juvenile Dolly Varden during the open water season (see the Cooper Creek Fish Resources Study Report for supporting discussion). No other species are currently present. In the absence of other species, altered conditions per the modeled mitigation scenarios would increase the area of rearing habitat somewhat and would increase the area of spawning and adult rearing habitat substantially. Stream temperatures, while warmer than now exist, would mostly still be within the tolerable range, and overall Dolly Varden use might increase. However, if other species begin to utilize the Stetson Reach, then the situation becomes substantially different. Resources and feeding niches would become partitioned and each species would become more of a specialist with the productivity of each species adjusted to match the available food source. Various studies have shown that when Dolly Varden are the only species, they tend to exploit a variety of food sources and feeding niches, but, when they exist along with other species, their niche contracts and they become more specialized (interactive segregation) with resources divided between the species (Andrusak 1970). Additionally, Dolly Varden (and other members of the char family) are generally less aggressive than other salmonids when it comes to defending feeding niches (Behnke 2002;

Griffith 1972; Newman 1960). Most often the Dolly Varden assume a behavior that favors feeding on the stream or lake bottom as opposed to within the water column where the other species have an edge. The addition of rainbow trout or juvenile salmon would very likely reduce juvenile Dolly Varden density in the Stetson Reach through both competition and predation and might also limit the numbers of adult Dolly Varden that the area could support.

Considerations of productivity might become more complicated if salmon begin to spawn in the Stetson Reach in significant numbers. Salmon eggs and carcasses provide a readily useable source of organic carbon and other nutrients to stream ecosystems. If salmon became established in the Stetson reach, then the stream could become substantially more productive over the long term. Higher productivity would increase carrying capacity for the total species assemblage including Dolly Varden. However, the refuge-like habitat that now exists for juvenile Dolly Varden would no longer be present, and the density of juveniles could end up reduced in spite of the increased overall productivity.

Since the Stetson Reach currently contains an unusually high density of juvenile Dolly Varden on a stream area basis (see Cooper Creek Fish Resources Study), it seems reasonable to conclude that the addition of competing species would likely reduce the carrying capacity for juvenile Dolly Varden.

There is no way of knowing for sure the progression of changes in fish use that would occur in the Stetson Reach under Stetson diversion conditions. Fish use could occur naturally through colonization from the Kenai River or Cooper Lake, or it could be artificially enhanced by initial stocking. Considering the natural colonization scenario first, a possible sequence of events that might occur during the first ten years is as follows:

1. A year-round resident rainbow trout population would develop either from upstream movement of Kenai River fish or downstream movement of Cooper Lake fish or both.
2. Small numbers of migratory rainbow trout from the Kenai River would spawn and feed in the Stetson Reach.
3. Substantial numbers of juvenile rainbows would use the reach.
4. The number and density of juvenile Dolly Varden would decrease from existing conditions because of competitive interaction with juvenile trout and coho salmon.
5. Because of favorable substrate, depth, velocity, and fall temperature conditions, coho salmon would begin using the reach for spawning. Successful spawning would lead to use of the area by juvenile coho in the summer and winter.
6. Sporadic spawning by sockeye salmon would occur. Most fry would leave Cooper Creek after emergence and rear downstream.
7. Chinook salmon spawning may occur but at a low density because of lack of suitable spawning habitats.
8. Juvenile chinook salmon may rear in the reach, but at a much lower density than coho salmon.
9. If salmon become established in the reach, then overall productivity would likely increase because of increased nutrient availability.

Artificial introduction of fish to the Stetson Reach (or lower Cooper Creek) could obviously change the equation. The most likely introductions might be coho and/or chinook salmon. These fish would likely be introduced as smolts in the spring. The smolts would become imprinted on Cooper Creek stream chemistry and would outmigrate to the sea, returning to Cooper Creek 1.5-5 years later as adults. Assuming the environment is compatible, this kind of introduction would likely produce salmon populations in a short time. If then allowed to reproduce naturally, an equilibrium would be reached where average fish numbers would reflect the carrying capacity of the habitat. Limiting factors could be either availability of spawning habitat or rearing habitat.

Canyon and Alluvial Reaches

The canyon and alluvial reaches are physically somewhat different from each other, but under the Stetson diversion scenario they would have the same temperature and flow regime and thus will be discussed together. Since mean annual flow would remain roughly the same as it is currently, water temperature changes would be the dominant influence driving changes to fish populations. However, increased winter flow may have a significant influence on incubation potential and changes to seasonal flows could occur. For example, a 30 cfs discharge from the dam during late summer could result in a flow that would be higher than currently exists in some years. The diversion of Stetson Creek into Cooper Lake would attenuate flood flows to some extent since dam release would likely remain constant regardless of precipitation. However, this ability to attenuate flood flows would be limited to the capacity of the pipeline to the lake. Flows greater than 70 cfs would pass over the Stetson weir and enter Cooper Creek as now occurs.

At present, juvenile Dolly Varden are the primary resident species inhabiting the Canyon and Alluvial Reaches. It is expected that colonization by additional species would have a less dramatic effect on juvenile Dolly Varden in the canyon than in the Stetson Reach because the density is lower and the habitats used by Dolly Varden are more marginal. Interactive segregation would likely occur within the better habitats, such as large pools.

The well-documented Dolly Varden spawning area in the vicinity of the Stetson Creek mouth presents another special situation where Cooper Creek currently provides specific conditions required for a crucial life stage. Studies to date suggest that Dolly Varden in the upper Kenai River have a complex life history with predictable movements to specific spawning and seasonal feeding locations. There is some evidence that the fish that spawn in Cooper Creek are a unique subpopulation with a specific life history (King, personal communication). It is not known which factors cause this group of Dolly Varden to choose upper Cooper Creek as a spawning location, although cool water temperature is likely a contributing factor. These fish may be responding directly to preferred environmental characteristics or they may be using the area because of lack of competition with other species. Regardless of the exact reason for preference, it seems reasonable to assume that substantially altering this set of presumably preferred conditions could have negative consequences. The magnitude of change that might have deleterious effects would be difficult to predict.

As with the Stetson Reach, there is no way to accurately predict the sequence of fish use. Under natural colonization, the following events might occur in the first ten years:

1. Small numbers of rainbow trout from the Kenai River would begin to use portions of the Canyon and Alluvial Reaches for spawning. The availability of suitable spawning habitats would likely be a major limiting factor. Spawning would likely occur in the lower canyon area, in short segments of the middle Alluvial Reach, and in small pockets of fine gravel scattered throughout the Canyon Reach.
2. Adult rainbow trout would begin to use the area for feeding, but abundance would be limited by the scarcity of pool habitats and the generally high gradient.
3. Juvenile rainbow trout would expand use areas to the entire stream, but abundance in the Canyon and Alluvial Reaches would be severely limited by lack of slow water habitats and juvenile fish passage blocks within the middle canyon.
4. Coho salmon would use the Canyon and Alluvial Reaches to a greater degree than they do now. Suitable spawning habitats would probably be more limited in these reaches than in the Stetson Reach. Spawning would likely occur in pocket habitat areas throughout the canyon, in the lower canyon transitional area, and at a few sites in the Alluvial Reach.
5. If coho salmon spawning occurred in the upper canyon or in the Stetson Reach then coho salmon juveniles would likely inhabit slow water habitats throughout the stream. Slow water habitats are very limited in the canyon.
6. Chinook salmon would likely begin using the Canyon Reach and, to a lesser extent, the Alluvial Reach for spawning. Chinooks generally prefer faster water and coarser substrate than the other salmon species. Pockets of gravel and cobble at the edges of step pools and lateral scour areas would likely be used for spawning. Similar areas in other high gradient streams like the Bradley River are utilized to a significant degree.
7. Juvenile chinook salmon would expand their range throughout the stream but moderate velocity stream bank habitats preferred by juvenile chinooks are not common in Cooper Creek and density would be low.
8. Sporadic spawning by sockeye salmon, as currently exists, would continue. Most fry would leave Cooper Creek after emergence and rear downstream.
9. If the Stetson Creek diversion continued into the fall during the Dolly Varden spawning period, then spawning by Dolly Varden would likely be reduced.
10. A low density of juvenile Dolly Varden, as currently exists, would likely continue.
11. If salmon become established in the reach, then overall productivity would likely increase because of increased nutrient availability.

As with the Stetson Reach, artificial introduction of chinook or coho salmon would likely jump-start fish populations but might not affect equilibrium fish numbers over the long term.

Potential Numbers of Fish Within the Anadromous Portion of Cooper Creek

Species most likely to be affected by any Cooper Creek flow and temperature changes include chinook salmon, coho salmon, rainbow trout, and Dolly Varden. Each of these will be discussed separately.

Chinook Salmon

As the Pacific salmon species largest in body size, chinook salmon are normally present in relatively low density throughout their range. At best, the number of chinook salmon that would utilize Cooper Creek under optimal conditions would be small. Historical information suggests that up to 35 adult chinooks were observed in the Alluvial Reach of Cooper Creek prior to dam construction (U.S. Forest Service, 1992). A foot survey of nearby Juneau Creek counted 50 adult chinook salmon in early August of 1985 (Burger et al., 1987). Additional sporadic surveys of lower Juneau Creek conducted in eight years during the 1976-2000 time period observed 0-90 chinooks with an average count of 40 fish (ADF&G file information). Most of these Juneau Creek surveys observed a length of stream roughly comparable to the Cooper Creek Alluvial Reach combined with a portion of the lower Canyon Reach. Another nearby stream with some similarities to Cooper Creek is Crescent Creek. Three surveys of Crescent Creek during the 1979-1984 time period counted 79-141 chinooks with an average of 100 fish. It should be noted that one-time foot surveys often underestimate fish numbers and do not represent total escapement but only the number of fish present at the time of the survey. Actual numbers of fish using a stream in a given year would be expected to be substantially higher. The length of stream potentially available to chinook spawners on Cooper Creek is up to four times longer than the useable portions of either Juneau or Crescent Creeks.

One case study that might shed some light on the number of chinook salmon that could utilize Cooper Creek under ideal conditions is the long term study of the Bradley River on the southern Kenai Peninsula (Morsell, 2000). The Bradley River has some similarities to Cooper Creek in that the fish-usable area is short and includes similar canyon-type habitats. However, spawning habitat is generally more consistent and favorable in the Bradley River than in Cooper Creek. The flow regime in the Bradley River was radically changed due to the Bradley Lake Hydroelectric Facility. In the eight-year period following flow regulation, chinook salmon established a small, relatively stable population whose numbers ranged from 50 to 600 fish with an average of about 200 spawners per year. The Bradley River chinooks spawned in traditional riffle areas as well as in pocket habitats within steep portions of the river. Taking into account the shorter length of accessible habitat in the Bradley River and different spawning potential of the areas, it might be reasonable to suggest that the full length of Cooper Creek could support similar numbers of chinook salmon.

Summary Assessment – The number of adult chinook salmon potentially spawning in Cooper Creek under mitigated conditions might range from 50 to 600 fish, possibly averaging several hundred fish over a period of years.

Coho Salmon

The modeling results suggest that spawning and rearing habitats exist under current conditions and that temperatures during the fall spawning period are within the low end of the optimal spawning range. In spite of these apparently favorable conditions, very small numbers of coho salmon currently spawn in Cooper Creek. It is suspected that warm fall temperature could play a larger role than indicated by the model both in attracting spawners and in providing optimal conditions for incubation. It is also suspected that the addition of the Stetson Reach as spawning and rearing habitat might be especially important for cohos because of the tendency of this species to spawn in headwaters areas, often associated with groundwater inflow. Increases in Stetson Reach spawning habitat might have a greater benefit to coho salmon than to chinook salmon because cohos are more tolerant of shallow water and slower velocities than are chinooks.

Comparative data for other upper Kenai River tributary streams are sparse since coho salmon spawn later in the year than the other salmon species. Weir data for Quartz Creek during 1982-84 counted 1220-2596 (average = 1688) cohos entering the stream (ADF&G file data). Quartz Creek is at least four times longer than Cooper Creek and the weir data includes fish entering two major tributaries. Consequently, the Quartz Creek data may not be very useful as an indicator of the potential of Cooper Creek. At the very least, the numbers suggest an upper limit of coho salmon spawning potential. If the Quartz Creek numbers are divided by a factor of six to compensate for the greater habitat length, then the numbers suggest that perhaps 200-400 coho spawners might use Cooper Creek with improved temperature and upstream flow conditions.

Summary Assessment – The number of adult coho salmon potentially spawning in Cooper Creek under mitigated conditions would be unlikely to exceed 1000 fish and would be more likely to be in the low hundreds in an average year.

Sockeye Salmon

Sockeye salmon were not initially identified as an evaluation species and sockeye habitats were not modeled in the PHABSIM analysis. However, sockeye salmon currently utilize lower Cooper Creek for spawning, and, in some years, may be the most abundant salmon in the creek. The limited study period suggests that numbers are highly variable from year-to-year. Only a few sockeyes were observed in September 2003, whereas 209 were observed in September 2004. Sockeye salmon are extremely abundant in the Kenai River system and it seems reasonable to assume that some of the fish in Cooper Creek are strays from the main river or other tributaries. The results of the foot survey in 2004 suggested that much of the available spawning habitat in the Alluvial Reach and the lower Canyon Reach was utilized. This portion of Cooper Creek may not be able to support many more than the 200 fish observed. It is not known why the relatively abundant sockeyes in 2004 did not exploit areas that were further upstream, although gradient increases above the canyon transitional area and suitable spawning habitats become less common.

It is unknown whether altered temperature conditions would encourage more sockeyes to use Cooper Creek and whether such conditions would encourage the fish to expand their spawning area upstream. Increased availability of suitable spawning habitat in the Stetson Reach due to increased flow might open up new potential spawning area for sockeyes. The modeled increases in spawning habitat for coho salmon can likely be applied to sockeyes as well because of similar requirements. However, the fish would have to pass through the high gradient upper canyon area to reach desirable spawning habitat in the Stetson Reach. If it is assumed that the Stetson Reach could support the same density of sockeye salmon observed in lower Cooper Creek in 2004, then habitat for an additional 250 fish might become available based on number of fish per lineal stream distance.

Kenai River tributaries without accessible lake systems usually do not attract many sockeyes. Juneau Creek surveys have counted from 0 to176 sockeyes in the late summer and fall, numbers that are similar to the lower Cooper Creek counts.

Summary Assessment – The number of sockeye salmon potentially spawning in Cooper Creek under mitigated conditions would likely be variable from year-to-year, possibly ranging from very low numbers up to 1000 fish. Existing use suggests that 500 fish might be a reasonable expectation if sockeye became established in the Stetson Reach.

Dolly Varden

The 1999 ADF&G weir study on Cooper Creek estimated that 400-500 adult Dolly Varden were present in Cooper Creek in the late summer and fall. This estimate includes a correction factor for fish that may have bypassed the weir. Most of these fish probably entered the stream to spawn. Significant warming of the water in the fall and loss of Stetson Creek flow could put some or all of these fish at risk and could remove a major Dolly Varden spawning area contributing to a possibly unique upper Kenai River Dolly Varden stock. However, reduced dam releases and release of water from Stetson Creek during the spawning period could potentially avoid this problem by cooling the water below the Stetson confluence. Regulating the water in this way would involve a tradeoff between optimizing coho salmon spawning and rearing in the Stetson Reach and optimizing Dolly Varden spawning downstream from Stetson Creek. Under a compromise dam release scenario where less water is released from the dam and less water is diverted from Stetson Creek, coho salmon spawning conditions could probably still be favorable in the Stetson Reach of Cooper Creek while maintaining suitable conditions for Dolly Varden spawning downstream from the Stetson confluence.

The approximate number of juvenile Dolly Varden inhabiting Cooper Creek is documented in the Cooper Creek Fish Resources Study. If juvenile coho and/or chinook salmon and rainbow trout become established throughout the creek, then the number of juvenile Dolly Varden could be reduced through competition, interactive segregation, and/or predation, especially in the Stetson Reach where density is high and habitats are favorable to rearing. The Cooper Creek study estimated about 2100 juvenile Dolly Varden present in the Stetson Reach. Interaction between species could reduce this number by some fraction, resulting in a loss of rearing opportunity. If, for example, carrying capacity were reduced by 50 percent, then the Stetson Reach would support 1000 fewer juvenile Dolly Varden than currently exist. While this sort of impact is speculation, the outer boundary is limited by the total estimated number of fish, and, thus, the order of magnitude is reasonable. Use of Cooper Creek by subadult and adult Dolly Varden for feeding would likely increase as a result of increased habitat area in the Stetson Reach and possibly increased overall productivity due to the presence of salmon eggs or carcasses.

Summary Assessment – The number of Dolly Varden spawning in Cooper Creek could be reduced from that which occurs under the existing conditions with the potential of affecting up to about 500 adult fish from a possibly unique subpopulation. Manipulation of Stetson Creek releases during the Dolly Varden spawning period could minimize this effect. The number of juvenile Dolly Varden using Cooper Creek rearing habitats could be reduced by some fraction of the total, up to about 2000 fish. Use by feeding adults could increase.

Rainbow Trout

Rainbow trout do not currently use Cooper Creek to a significant extent. The Stetson diversion scenario would alter the water temperature regime so that temperatures would likely become suitable for spawning, rearing, and adult feeding. Additionally, increased flow in the Stetson Reach would increase the availability of spawning and adult feeding habitat. These habitat changes would be expected to cause the numbers of adult and juvenile trout to increase in Cooper Creek. The number of spawners would be limited by the availability of spawning habitat and its accessibility, while the number of adults and juveniles present in feeding habitats would be limited by the availability of suitable physical habitats, especially pools and runs, as well as availability of food. Little information is available regarding trout density in southcentral Alaska stream habitats; consequently it is particularly difficult to predict the number of trout that might utilize Cooper Creek under optimal conditions. Additionally, feeding and rearing uses of Kenai River tributaries are dependent on seasonal food availability. Adult and juvenile trout tend to follow spawning salmon to take advantage of salmon eggs and salmon carcasses as a food source, and, thus, presence of rainbow trout is often driven by the presence of salmon (Palmer, personal communication). Long term decay of salmon carcasses also adds to overall stream productivity, providing another link between trout and salmon.

Some indication of potential spawner numbers can be derived from spawner counts conducted on the lower Russian River below Lower Russian Lake during the time period 1991-2003. This reach of the Russian River includes about 3.5 river miles and is comparable in length to the portion of Cooper Creek from the mouth to the Stetson Creek confluence. Peak spawner counts in the lower Russian River have ranged from 204 to 606 fish with an average of 377 (ADF&G file information). As is the case for all visual counts, the numbers are probably an underestimate of actual number present. Portions of the Russian River (especially between the power line and the Kenai River confluence) contain consistently favorable rainbow trout spawning habitat, and radiotracking studies indicate that the Russian River is an important spawning area for Kenai River trout. Potential Cooper Creek spawning habitat accessible to Kenai River fish is likely limited primarily to sections of the Alluvial and lower Canyon Reaches. It is not known whether rainbow trout originating in the Kenai River would traverse the more difficult sections of the canyon to access spawning areas in the Stetson Reach. It seems more likely that the Stetson Reach might support resident trout isolated from the main Kenai River population, similar to the situation suspected to occur in the Russian River where use by Kenai River fish is likely limited to the area below the falls, while fish spawning above the falls may be part of a separate population (Marsh, personal communication). Rainbow trout spawner numbers for the lower Russian River probably suggest an extreme upper limit of Cooper Creek potential spawner use. Russian River spawning habitats are more favorable than those in Cooper Creek, and numbers using Cooper Creek would likely be significantly lower, even if temperature and flow conditions were optimal.

A series of population estimates of large rainbow trout (greater than 300 mm) in a 10 mile section of the upper Kenai River between Jim's Landing and the Russian River in 1986 and 1987 indicated that 2600-5000 fish were present in the section (Lafferty, 1989). The Kenai River cannot be compared to Cooper Creek because of difference in size and habitat characteristics. However, these numbers provide a context for tributary contribution. Unless Cooper Creek were to provide an essential life history element for Kenai River rainbow trout, it seems unlikely that Cooper Creek would contribute significantly to overall numbers in the Kenai River.

As suggested above, adult and juvenile rearing may well be limited first by habitat availability and secondarily by food availability, especially salmon eggs and carcasses. Most Russian River rainbow trout spawners leave the Russian River after spawning and move to the Kenai River where feeding conditions are presumably more favorable (Palmer, personal communication). High gradient, relatively infrequent pools, and difficult juvenile fish passage in the canyon would likely put an upper limit on the abundance and distribution of rainbow trout in Cooper Creek regardless of food availability. The presence of significant numbers of spawning salmon would provide an incentive for trout to enter or remain in Cooper Creek but density would likely not approach that of the Kenai River where conditions are known to be highly favorable to trout, especially during the sockeye salmon run.

Summary Assessment – Lower Cooper Creek would provide additional spawning habitat for rainbow trout originating in the Kenai River. Numbers would likely be less than 500. Upper Cooper Creek, including the Stetson Reach, could provide spawning habitat but would most likely be used by resident trout. The number of rearing juvenile and feeding adult rainbow trout in Cooper Creek would increase from present use. The extent to which Cooper Creek is used as feeding habitat would likely depend significantly on future use by spawning salmon.

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APPENDIX A

Instream Flow Review Team Meeting Summaries

APPENDIX B

Mesohabitat Type Maps

APPENDIX C

Study Site Photographs

APPENDIX D

Fish Resource Study Maps

APPENDIX E

Cooper Creek Habitat Suitability Criteria

APPENDIX F

Hydraulic Model Calibration Details

APPENDIX G

Flow vs. WUA Curves

APPENDIX H

Habitat Time Series

APPENDIX I

Stream Flow, Temperature, and Meteorological Data

APPENDIX J

Temperature Model Calibration Details

APPENDIX K

Draft Model Review Comments and Responses