Cheakamus Project Water Use Plan

Monitoring Program Terms of Reference

- **Cheakamus River Juvenile Salmonid Outmigrant Enumeration Monitoring**

November 2006

Terms of Reference for the Cheakamus Water Use Plan Effectiveness Monitoring Program

Overview

The ten (10) effectiveness monitoring programs for the Cheakamus Water Use Plan (WUP) will monitor outcomes of the recommended operational changes, and provide information on which to base future operating decisions.

This document provides detailed Terms of Reference for the Cheakamus River Juvenile salmonid outmigrant enumeration monitoring, a five-year monitoring program to enumerate juvenile salmonid outmigration from the Cheakamus River mainstem and key side channels.

The remaining monitoring programs for the Cheakamus Water Use Plan (WUP) will be submitted to the Comptroller of Water Rights on or before 17 February 2007 as per the Cheakamus Order, dated 17 February 2006. The following is an overview of the remaining monitoring programs.

1b) Cheakamus River chum salmon escapement monitoring and mainstem spawning groundwater survey: A five-year monitoring program to enumerate chum spawning escapement and examine groundwater in mainstem spawning areas

2) Trout abundance monitor in Cheakamus River (Daisy Lake Dam to Chekamus canyon): A five-year monitoring program for rainbow trout in the non-anadromous section of the Cheakamus River.

3) Cheakamus River steelhead adult abundance, fry emergence-timing, and juvenile habitat use and abundance monitoring: A five-year monitoring program to examine the effects of mainstem flows on steelhead production.

4) Monitoring stranding downstream of Cheakamus generating station: A three-year monitoring program to examine stranding downstream of the Cheakamus generating station tailrace on the Squamish River.

5) Monitoring stranding downstream of Daisy Lake Dam: A one-year monitoring program to monitor fish stranding downstream of Daisy Dam.

6) Monitoring groundwater in side channels of the Cheakamus River: A five-year program to monitor the effect of Cheakamus mainstem flows on groundwater-fed side channels.

7) Cheakamus River benthic community monitoring: A three-year monitoring program and modelling exercise to examine the effects of mainstem flows on the benthic community.

8) Monitoring channel morphology in Cheakamus River: A five-year monitoring program to examine the effects of flows on channel morphology in the Cheakamus River mainstem.

9) Cheakamus River recreational angling access monitoring: A two-year monitoring program to examine the benefits to recreational angling access (available angling locations) of the 1 January to 31 March 5.0 $m^3 \cdot s^{-1}$ minimum flow release from Daisy Lake Dam.

Description of Facility

The Cheakamus generating system consists of the Daisy Lake Dam and Reservoir and the Cheakamus Powerhouse in the Squamish Valley connected by a tunnel through Cloudburst Mountain. The Daisy Lake Dam and Reservoir are located on the Cheakamus River about 40 km north of Squamish. The generating station is located about 40km north of Squamish along the upper Squamish River. Water flows from Daisy Lake Reservior to Shadow Lake Reservoir where a tunnel and two penstocks carry the water 11km to the two-unit powerhouse located on the Squamish River.

The location and general layout of the project is illustrated in Figure 1.

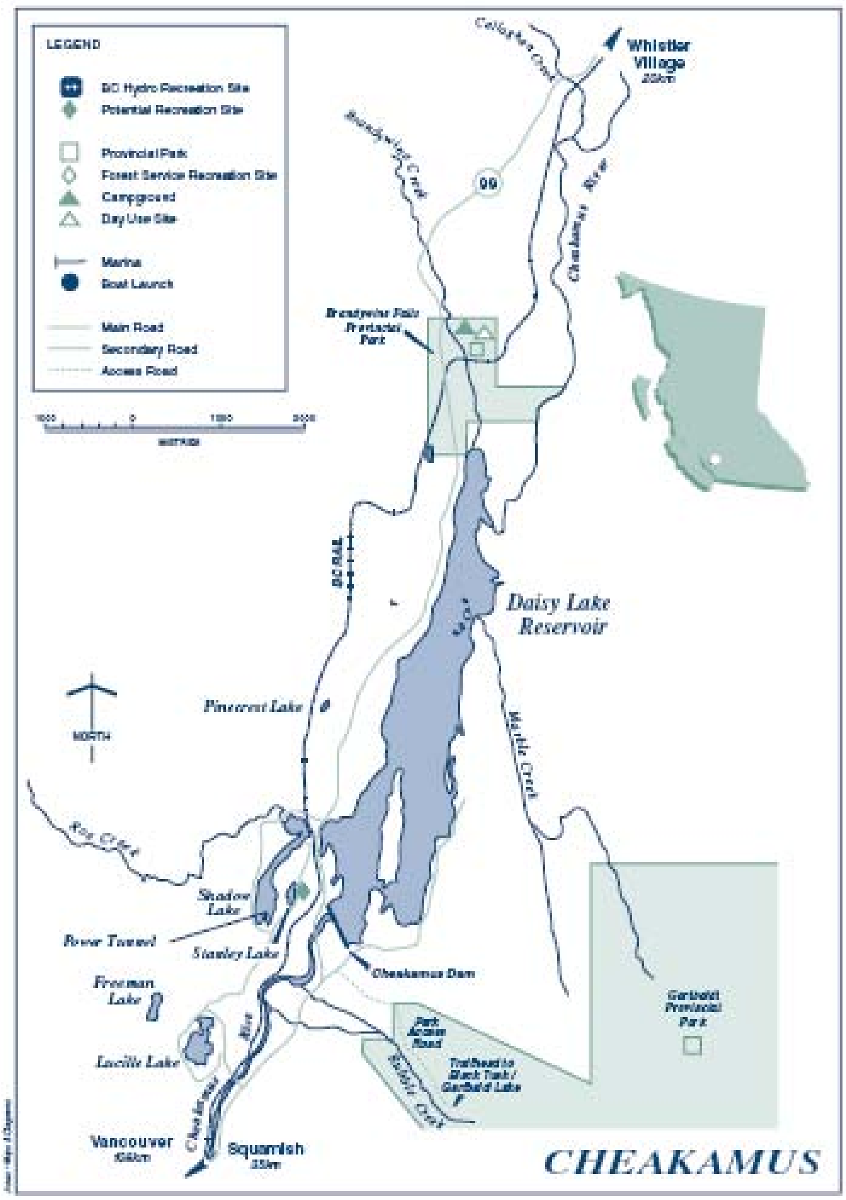

Figure 1: Map of Cheakamus Project

Cheakamus River Juvenile Salmonid Outmigrant Enumeration Monitoring

1.1 Monitoring Program Rationale

1.1.1 Background

The Water Use Plan (WUP) for the Cheakamus River (BC Hydro 2005) includes a flow regime for the Cheakamus River designed to balance environmental, social and economic values. One of the fundamental objectives of the Cheakamus River WUP was to maximize wild fish populations, and the WUP recommended an operating alternative and associated river flow regime based in part on expected benefits to wild fish populations. However, the benefits to fish populations from the new river flows were uncertain because benefits were modelled based on uncertain relationships between fish habitat and flow, and assumed relationships between fish habitat and fish production (Marmorek and Parnell 2002). To help reduce this uncertainty and help determine the impacts of the new flow regime on salmon populations, the WUP Fisheries Technical Committee recommended that the outmigration of juvenile salmon be monitored.

The monitoring program outlined in this Terms of Reference has been developed to examine the effects of the WUP flow regime on the production of juvenile salmonids from the mainstem of the Cheakamus River and major side channels. The program is a continuation and expansion of a program initiated during the consultative process to monitor juvenile outmigration. Operation of two Rotary Screw Traps (RSTs) at River Kilometre 5.5 commenced in the Spring of 2000 and is ongoing. This Terms of Reference (TOR) outlines the study plan that has been developed and refined over six years of operation, and includes a number of refinements to increase the precision and accuracy of outmigration estimates, and improve crew safety and fish catches during high water operation. Data from this study will be used in conjunction with data from other monitoring programs to develop stock-recruitment relationships that are critical for separating effects of spawning escapement from flow-related changes in survival during incubation and freshwater rearing (Bradford et al. 2005).

1.1.2 Management Questions

Important management concerns are the effects of discharge on:

i) The production of juvenile salmonids, defined as the total smolt outmigration.

ii) Productivity, defined as the number of smolts per adult spawner at low spawner abundance (i.e., slope of stock-recruitment relationship).

iii) Habitat capacity, defined as the maximum production (outmigration) that the habitat can produce (i.e., asymptote of a stock-recruitment relationship).

The new flow regime is expected to affect habitat capacity and productivity, and hence affect juvenile production. Thus, the key management questions addressed by this monitor are:

1) What is the relation between discharge and juvenile salmonid production, productivity, and habitat capacity of the mainstem and major side channels of the Cheakamus River?

2) Does juvenile salmonid production, productivity, or habitat capacity change following implementation of the WUP flow regime?

1.1.3 Hypotheses

The key ecological null hypotheses examined by this monitor are:

H_1: Flow does not affect smolt production.

$H_{1.1}$: Flow does not affect productivity

$H_{1.2}$: Flow does not affect habitat capacity

H_2: Smolt production does not change following implementation of the WUP operations.

$H_{2.1}$: Productivity does not change following implementation of the WUP operations

$H_{2.2}$: Habitat capacity does not change following implementation of the WUP operations

Discharge can affect many components of salmonid lifehistory in freshwater, such as the quantity and quality of spawning and incubation habitat, and the availability of food and space for rearing. Thus, the new flow regime can affect all species of anadromous salmonids in the Cheakamus River. These hypotheses will be examined for each species for which sufficient data are available (Table 1a-1).

Table 1a-1: Data Sources Available to Examine Hypotheses #1 and 2.

Lifestage	Expect a reasonably precise mainstem estimate?	Expect a reasonably precise side-channel estimate?	Data source
Chum fry	Yes, outmigrants	Yes, outmigrants	This program
Chum spawners	Perhaps, spawners	Perhaps, spawners	Chum escapement, program #1b
Chinook fry	Yes, outmigrants	N/A	This program
Coho smolt	Yes, outmigrants	Yes, outmigrants	This program
Pink fry	Yes if abundant, outmigrants	Yes, outmigrants	This program
Chinook smolt	No, outmigrants	N/A	This program
Steelhead smolt	No, outmigrants	N/A	This program
Steelhead parr (index of late-freshwater production)	Perhaps, spring 'pre-migrants'	N/A	Steelhead abundance, program #3
Steelhead adults	Yes, spawners	N/A	Steelhead abundance, program #3

This juvenile outmigration program is expected to provide reasonably precise mainstem estimates of the chum fry, Chinook fry (age 0 spring outmigrants), pink fry, and coho smolt outmigrations; it has been a challenge to obtain precise estimates of Chinook smolt (age 1 or older spring outmigrants), and steelhead smolt outmigrations (Table 1a-1; Melville and McCubbing 2005). Thus, using the data from this program it should be possible to examine the hypotheses for mainstem juvenile production and habitat capacity for chum fry, Chinook fry, pink fry, and coho smolts, as well as the hypotheses for chum productivity ($H_{1.1}$) using spawner escapement data from the "Cheakamus River chum salmon escapement monitoring and mainstem spawning groundwater survey (#1b)". There may not be sufficient data from the mainstem to examine hypotheses for the other species and lifestages, though the "Cheakamus River steelhead adult abundance, fry emergence-timing, and juvenile habitat use and abundance monitoring (#3)" will examine flow effects on steelhead stock recruitment. Information on steelhead outmigrants from this outmirgration program will provide companion data to support the steelhead program (#3). As such, estimates of steelhead smolt outmigrants will be provided annually to program #3 for use in subsequent analyses.

1.1.4 Key Water Use Decision Affected

The key water use decision that would be informed by the results of the monitoring program would be the flow release from the Daisy Lake Dam. Such changes would affect social and environmental values, and power production in the system.

1.2 Monitoring Program Proposal

1.2.1 Objective and Scope

The objective of this monitor is to collect the data necessary to estimate the annual outmigration of juvenile salmonids from the Cheakamus River mainstem and key side channels. The species of interest are: chum and pink fry, and coho, steelhead and Chinook smolts, though it can be a challenge to obtain precise mainstem estimates for each species (Table 1a-1). In-stream movement of other species and life-stages captured will also be documented, including steelhead parr, coho fry, coast range sculpin (*Cottus aleuticus*) and the Pacific lamprey (*Entophenus tridentatus*).

Juvenile outmigration for all salmonid species will be enumerated with traps and counters at the outlets of key side channels. To provide data to test the hypotheses for Program #6 (Monitoring groundwater in side channels of the Cheakamus River), juvenile outmigration will also be enumerated from groundwater-only fed channels (which for some channels can be considered "tributaries" to larger channel complexes; Figure 1a-2). Based on the species use of individual channels, the outmigration of either fry, smolts or both will be enumerated from select channels.

Fry migration will be monitored as individual estimates at two groundwater channels (Upper Paradise, Kisutch) in order to meet the objectives of Program #6. As well, the entire Upper Paradise/Kisutch/Gorbushca complex will be assessed for fry production. This will be accomplished by using a series of fyke nets and mark-recapture methodology in the side channels to obtain and estimate the contribution to fry production in the Cheakamus.

Juvenile smolt outmigration from side channels will be monitored using manual traps or traps equipped with automated counters at five locations. Juvenile outmigration will be monitored at four ground water only fed channels; Kisutch, BC Rail channels and Tenderfoot channels by automated counter as well a manual trap which will be operated at a new site on Upper Paradise channel upstream of the confluence with Farpoint (which is flow through). This assessment of productivity in groundwater-only channels will meet objectives Program #6. In addition a manual trap will be operated at a new location downstream of the confluence of all channels in the Upper Paradise/Gorbushca area of restoration. This trap has a dual purpose: to monitor production from all channels that enter the Upper Paradise outflow above the RST site (Gorbuschca complex, Kisutch, Upper Paradise, Sue's and Far Point complex) and to provide coho smolts for marking groups required to provide recaptures at the RST site and a subsequent coho smolt production estimate for all the watershed area above the RST site.

The scope of the monitoring, based on the objectives outlined above, is as follows:

- The geographic scope of the monitoring includes the Cheakamus River mainsteam and key side channel habitats upstream from river Kilometre 5.5. RSTs will be operated at the site currently being utilized, 5.5 km upstream of the confluence with the Squamish River (Melville and McCubbing 2004) due to various logistics that make this site the most feasible, and for comparison with the previous data available at this location.

- RSTs will attempt to obtain mainstem population estimates (i.e., total outmigration) for: chum fry, pink fry, coho smolts, steelhead smolts, and Chinook smolts. As such, data collection at RSTs will occur during the juvenile outmigration, which occurs from approximately 15 February and 15 June based on historic run timing (as defined by Melville and McCubbing 2000). Total outmigration will be estimated using the mark recapture methodology as developed by Melville and McCubbing 2005 and appropriate analytical methods. It is expected that improvement to the marking and sampling techniques (noted in section 1.2.3) relative , and associated analytical methods (see Task 4 of section 1.2.3) will be explored to attempt to improve population estimates, while ensuring that estimates can be compared with those from previous years.

- Side channel traps will enumerate the same species and life-stages as RSTs. As such, data collection at the side channels will occur from approximately 15 February to 15 June. Total outmigration from each channel will be estimated based on estimates of fence and counter efficiency.

- All species captured in the RSTs and in side channel traps will be documented.

- Monitoring is scheduled to occur annually for five years.

1.2.2 Approach

The monitoring approach is to annually estimate the total juvenile outmigration for each salmon species using downstream trapping methods. This time series of data will be used to examine the effects of flow on juvenile production, productivity, and habitat capacity by comparing variation in juvenile production and discharge. It is anticipated that both differences in the pre-WUP and WUP flow regime, as well as the natural annual variation in seasonal discharge will provide good contrast in flow to examine the effects of discharge on spawning, egg incubation, juvenile rearing, and ultimately juvenile production. Juvenile production is a useful measure that integrates the effects of flow over these many life stages.

The monitoring approach is based on sampling methodologies developed and refined on the Cheakamus River (i.e., Melville and McCubbing 2005), as well as recommendations from quantitative reviews of the program sampling design (Parnell et al. 2003, Bradford et al. 2005).

Separate estimates of production from the Cheakamus River mainstem and key side channels will be used to compare relative production between mainstem and side channel habitats, as well as variation in production between these habitats that may be related to mainstem discharge.

1.2.3 Methods

Task 1: Project Coordination

Project coordination involves the general administrative and technical oversight of the program. This will include but not be limited to:

1) Budget management.

2) Staff selection.

3) Logistic coordination.

4) Technical oversight in field and analysis components.

5) Liaison with regulatory agencies and other stakeholders.

Coordination with WUP Monitoring and Other Monitoring Programs

To help answer high-level questions regarding the relation between Cheakamus River discharge and fish production, data from this juvenile downstream migrant program will ultimately be used in combination with data from the adult chum escapement program (Program #1b), the steelhead monitoring program (#3), the groundwater in side channels monitoring program (#6), and possibly other WUP monitoring programs. Therefore, it is critical that data collection is coordinated among programs.

To ensure that data collection is coordinated among the inter-related monitoring programs for the Cheakamus WUP, an important task for this program is to develop and maintain communication with project leads for the other monitoring programs.

This communication could involve a workshop at the start of the field season to ensure that the trapping locations and methodologies will meet the data requirements of the other programs, and vice-versa. Logistical changes within the scope of the monitoring program may be required.

To help distinguish between natural and hatchery production, the proponent will maintain communication with hatchery staff (i.e., Tenderfoot hatchery, North Vancouver Outdoor School hatchery) to determine and coordinate with the location and timing of hatchery releases, and determine if modifications to the trapping methodology are needed distinguish downstream migration of hatchery and naturally produced fish. At a minimum, annual reporting will summarize data on hatchery releases, the ability to distinguish hatchery and wild juveniles, and the influence of these releases, if any, on catches and abundance estimates for wild fish. To date, hatchery releases have not affected outmigration estimates for the key species of interest noted in Table 1a-1 (Melville and McCubbing 2005).

Task 2: Mainstem RST Trapping

RST Installation and Removal

To date temporary cableways and winch systems have been installed attached to large cottonwoods on the right bank and a fairly mature cedar on the left bank. A breakaway on the left bank is part of the cable system as a safety in case of cable failure. At the present discharge curve traps can be operated safely at a maximum of 70 $m^3 \cdot s^{-1}$. As well there is the risk of the mature cottonwoods failing. Therefore, permanent mooring points to operate three RSTs and with larger cable to withstand higher discharge will be designed and installed. This mooring will increase operation safety as well as the ability to fish in higher flows (>50 $m^3 \cdot s^{-1}$), thus improve the accuracy and precision of population estimates. Design and installation of the moorings is a priority and should commence in the first year of the monitor.

Two RSTs have previously been fished in this program and the minimum use of two RSTs will continue under this TOR. In addition, to increase capture efficiency during higher discharge, and thus confidence in population estimation, a third RST will be installed and operated when the flows and wetted width permit. This would increase the number of fish caught (for marking Steelhead/Chinook) and recaptured.

Note: The bank full width (~40m) would preclude the operation of more than three RSTs at this site.

Annual RST installation at the North Vancouver Outdoor School Site will commence on approximately 10 February in order for trapping to commence on 15 February. This will include installing the cable systems and replacing any worn components to ensure they are sound and assembly of all traps. Two RST will be installed at the start of trapping and the third will be added as warranted when discharge increases. Annual removal of all traps and cable ways would be completed by 30 June.

RST Operation

The RSTs will be positioned in the channel to maximize fish capture, as in previous years (e.g., Melville and McCubbing 2005). Particular emphasis is placed on sampling locations and velocities for steelhead smolt capture during their migration.

The RSTs will be monitored every day throughout the sample period. All fish will be counted, marked (where appropriate, see Task #4 below) and biological data collected. Each trap will be checked again in the late afternoon/evening for debris build up, if warranted. Further checks or continuous monitoring will be undertaken during high water events this requirement being determined by the onsite supervisor. Sampling and marking of juvenile salmonids at the RST site will be undertaken as per previous study years. Debris will be removed on all checks.

A temperature logger will be installed at the RST site from 15 February to 15 June, as well as a permanent manual water gauge to assist with monitoring discharge instantaneously for operational decisions. Hourly discharge measurements from the Water Survey of Canada (WSC) for the Cheakamus River at Brackendale (WSC 08GA043), located 100 m upstream of the trap site will be utilized for data analysis.

A set of drums for the RSTs with a larger mesh size than previously used (Melville and McCubbing 2005) will be installed at higher discharges to reduce water resistance, thus increasing the ability to operate the traps during the peak of smolt migration. These drums would be exchanged with the existing drums on or about 30 April when the majority of the fry migration (chum, pink and chinook) is complete and the smolt migration is beginning to increase (run-timing information from 2000-2005 reports). This will increase smolt capture as discharges increase (Figure 1a-1) by reducing the effects of algal blooms that typically clog small meshed drums, reducing attractive flow and fish capture.

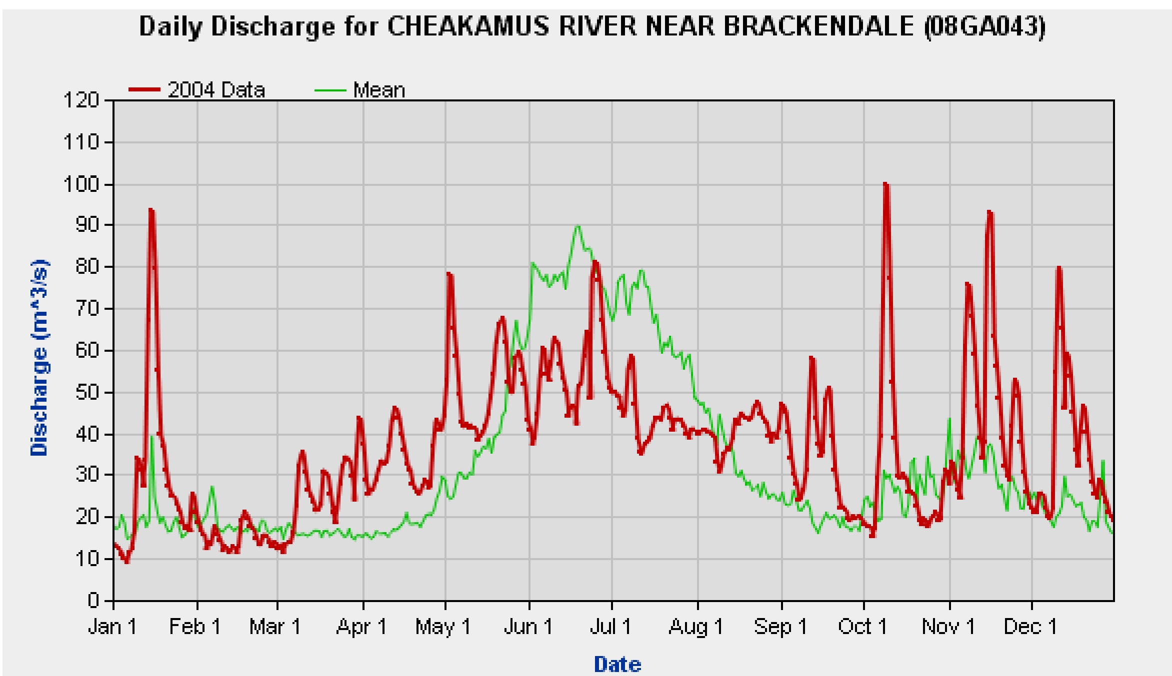

Figure 1a-1: Daily Discharge for the Cheakamus River near Brackendale in 2004, and the Average Over the Period of Record

Task 3: Side Channel Trapping

Fry Trapping, Installation and Removal

Based on historic outmigration timing of chum, pink and chinook fry, fyke nets will be installed in Upper Paradise, Kisutch. and Gorbushca such that they can begin operation 15 February to enumerate fry outmigrations.

To provide data for Program #6 (Monitoring groundwater in side channels of the Cheakamus River) enumeration of fry from groundwater-only side channels (Upper Paradise, and Kisutch) will be undertaken. Two fyke nets will be installed in each of these channels (fyke net sites a to d in Figure 1a-2) in order to estimate fry production utilizing mark-recapture methodology as described in Melville and McCubbing 2004. Briefly; an upstream fyke net and trap box will be used to capture fish for marking using Neutral Red dye, these fish will then be released for recapture in the downstream trap on each groundwater channel and a mark-recapture population estimate will be calculated for each channel (Figure 1a-2).

To enumerate total fry production of the Upper Paradise/Gorbushca channel complex two additional fyke nets (e and f in Figure 1a-2) will be installed; one in Gorbushca channel and one at the new diversion weir. The Gorbushca fyke will be used to obtain fry for marking as described above and the fyke located just upstream of the new Upper Paradise/Gorbushca diversion weir will be used to estimate total fry production from the entire side channel complex (Figure 1a-2).

Fry species will be determined manually at each trap site where fish are being processed by field personnel. The fry enumeration in side channels will continue until numbers drop to near zero, normally 30 April 30.

Tenderfoot Creek will not be enumerated for fry as confounding factors from hatchery influences and logistical issues (higher flows, hatchery releases) are likely not conducive to successful fry enumeration.

1. Smolt Trapping Installation and Removal:

Side channel full span diversion weirs will be operated to enumerate smolt outmigrations from the Upper Paradise/Gorbushca, BC Rail and Tenderfoot channels. Based on historic run timing (Melville and McCubbing, 2005) traps will be installed such that enumeration of smolts can commence on 1 April. As part of Program #6 groundwater-fed sections of the Kisutch channel and Upper Paradise channel will also be monitored, for a total of five smolt trapping locations (Figure 1a-2).

Trap designs will be site specific (Table 1a-2) but will consist of a full span diversion weir that directs all smolts to a holding box for subsequent manual counting and or passive electronic enumeration. Fence and trap box efficiency will be periodically checked by release of marked fish upstream of the trap location (McCubbing and

Ward 2004). Counter efficiency will be assessed through video validation with digital video equipment (Galesloot 2004). Species identification will be conducted manually for smolts at Upper Paradise and Upper Paradise/Gorbushca Channels, and by video and sub sampling at Kisutch, BC Rail and Tenderfoot Channels.

Site 1: Upper Paradise/Gorbushca

The new trapping site on the Upper Paradise/Gorbushca Restoration Channel will be located below the confluence of all the channels that exit via Upper Paradise (Figure 1a-2) and would also be utilized by the adult Chum enumeration monitor (Chum Escapement Program #1b). The location will facilitate the enumeration of all juvenile species form this large network of channels and increase fish numbers available for marking for the RST efficiency estimate of coho smolts (see Melville and McCubbing 2005), and a similar opportunity will be explored for steelhead smolts. It will consist of a concrete sill and full span diversion weir into a trap box.

Site 2: New Upper Paradise

This site will be located upstream of the confluence of Farpoint channel and Upper Paradise, and upstream of the new 'Emerson' channel proposal. Data collection will be linked to Program #6 (Ground water side channel study). This trap will also be a secondary marking location for smolts, mitigating the loss of fish available to mark by the occasional backwatering of Site 1 (occurs at ~100 $m^3 \bullet s^{-1}$ see Figure 1a-1). It will consist of a sill and full span diversion weir into a trap box.

Sites 3, 4 and 5: Kisutch, BC Rail, and Tenderfoot Creek

At Kisutch, BC Rail and Tenderfoot Channel automated counters (Logie 2100C, Aquantic Ltd. or comparable counter) will be used for the enumeration of coho and other (few previously observed <0.1% total production) smolts. Counter efficiency will be validated using digital VCR. The diversion design will incorporate the option to trap and mark a portion of the smolt outmigration if required for RST monitoring and/or species partitioning. The Tenderfoot trap will not be operated during smolt hatchery releases. Resistivity tube counters have been proven to accurately assess fish migrations within acceptable efficiencies, >90% accuracy (Galesloot 2004, McCubbing et al. 1999). The counter infrastructure required will be the same as used in adult chum monitoring program (program 1b), except for the "leads" tube sensors and trap boxes, which will be of a size suitable to pass chum fry but divert smolts. Four tubes will be utilized to enumerate coho and other smolts at each site, with sub-sampling or video utilized to separate species. All side channel traps will be removed commencing 15 June.

Table 1a-2: Summary of Trap Sites and Methods for Juvenile Salmonids on the Cheakamus River Mainstem and Side Channels. Trap numbers correspond to Figure 1a-2.

Trap	Design	Target Species	Enumeration Method	Channel Type	Data Requirement
Upper Paradise/ Gorbushca	Full span diversion and trap	Coho smolts and other smolts (few)	Total count manual (trap efficiency check)	Groundwater and mainstem intake	Side channel production and RST marking site
Smolts and fry (#1 and e-f)	Partial Fry Trap utilizing fyke nets	All fry	Mark recapture estimate		
Upper Paradise	Full span diversion and trap	Coho smolts and other smolts (few)	Total count manual (trap efficiency check)	Groundwater	Ground water side channel production and back-up for smolt mark-groups
Smolts and fry (#2 and a-b)	Partial Fry Trap utilizing fyke nets	All fry	Mark recapture estimate		
Kisutch Smolts and fry (#3 and c-d)	Diversion fence box and counter tubes	Coho smolts and other smolts (few)	Total count manual (trap efficiency check)	Groundwater	Side channel production and Ground water
	Partial Fry Trap utilizing fyke nets	All fry	Mark recapture estimate		
BC Rail Smolts only (#4)	Diversion fence box and counter tubes	Coho smolts and other smolts (few)	Total count corrected for efficiency	Groundwater	Side channel production and Ground water
Tenderfoot Smolts only (#5)	Diversion fence box and counter tubes Partial Fry Trap utilizing fyke nets	Coho smolts and other smolts (few)	Total count corrected for efficiency	Groundwater (and other source?)	Side channel production and Ground water but hatchery influence
RST Site All species and age	RST (3)	All smolts and fry	Mark recapture estimate	Not applicable	Mainstem estimator

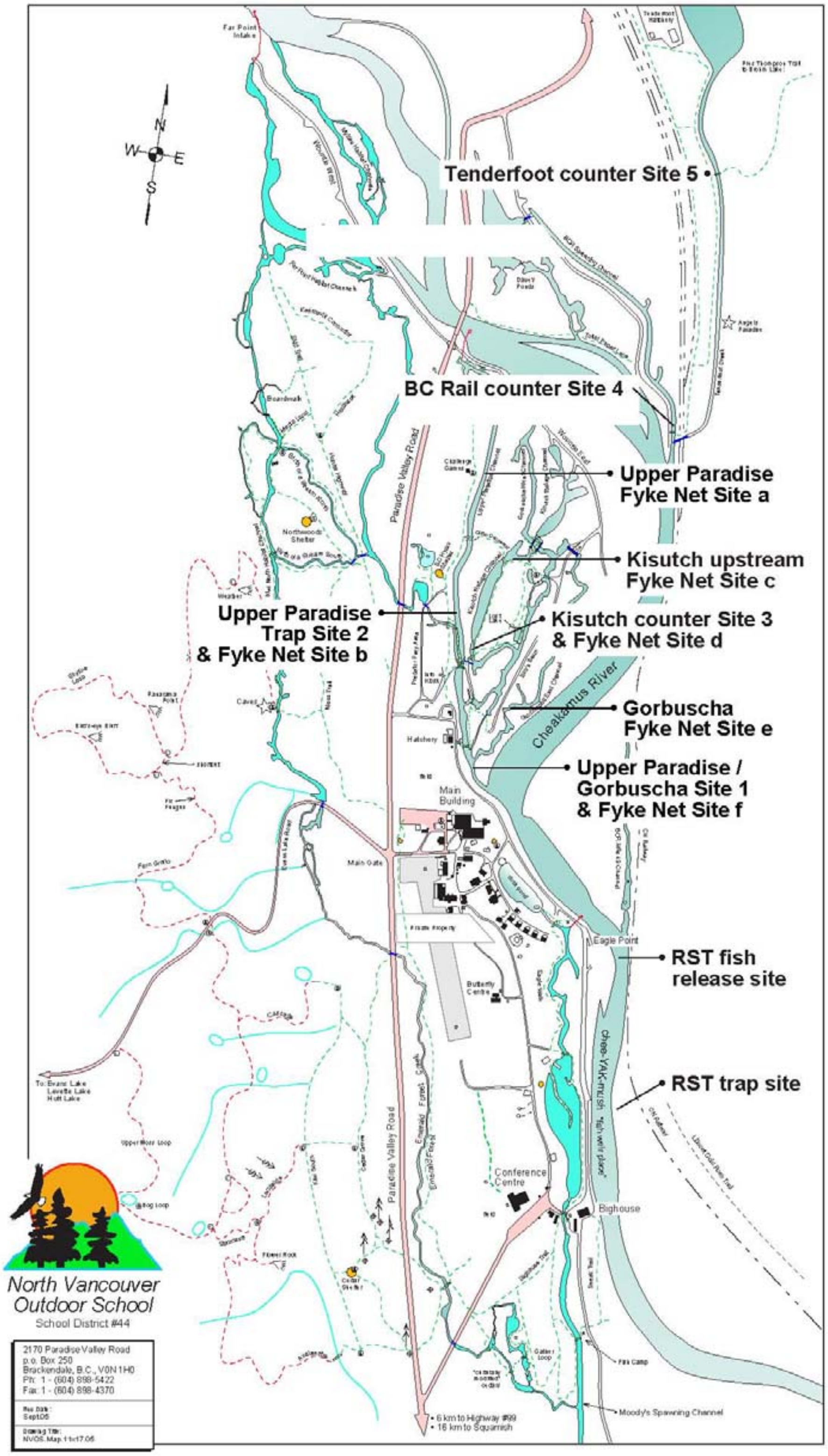

Figure 1a-2: Trapping and Release Sites for the Cheakamus River Juvenile Monitoring Program

Task 4: Trap Operation, Mark Group Methodology and Biosampling

Methodologies for developing mark groups for population estimation are site specific to the Cheakamus and have been developed over six years of operation (Melville and McCubbing 2005), and these methods are outlined briefly below. These methods are assessed as the best methods available taking into account, fish health, site logistics/access, crew safety and to full-fill the assumptions of mark-recapture methodology as outlined in Seber (1982).

Fry

Based on observations of fry mortality and recapture the following method of marking and release is utilized.

In order to assess catch efficiency of salmonid fry at the RST site a percentage of fish captured in each trap will be marked in the late afternoon/early evening and released immediately ~500 m upstream of the capture site. The percentage marked is based on sampling logistics and in-season professional opinion. Pink, chum and chinook fry will be marked for four consecutive days each week by immersion in aerated Bismark Brown Y dye at a concentration 1:100,000, for one to two hours depending on the number of fry and the water temperature. In order to separate release groups into weekly marking strata (Melville and McCubbing 2005), a three-day period with no marking and releases will follow the four consecutive days of marking and release.

Estimates of side channel fry production will be calculated using the methods prescribed in McCubbing and Melville 2004. Briefly, fry will be captured in upstream fyke nets and will be marked in the late afternoon/early evening and released immediately at the upstream fyke net site (a minimum of 100+ m upstream of downstream recapture site). Pink, chum and chinook fry will be marked as described for RST fry, except the dye utilized will be Neutral Red. The ratio of marked to unmarked fry at the downstream fyke nets will be used through statistical analysis to estimate total fry yield for each channel as described in Section 2.3.3.

Smolts

Capture efficiency for smolts at the RSTs will be assessed using smolts from two sites. The first will be unmarked smolts captured at the RST site, these smolts will be marked (please see below for marking procedure) at the morning trap check. The RST marked fish will then be transported upstream ~500 m to a holding box and released at dusk. The second group will be captured at the Upper Paradise/Gorbushca trap, marked as above, with a different distinguishing mark that will differentiate side channel marked fish from RST marked fish. These fish will be held in a holding box until dusk and released. Smolt marking will be undertaken on a minimum of six groups of fish stratified by run time and strength. Marking of smolts will occur seven days per week. Recaptures and fish not used for mark groups will be recorded and released ~300 m downstream of each RST trap and immediately downstream of side channel traps.

Smolt marks (unique to each release group) refer to a combination of caudal fin mark(s) and the subdermal injection of a coloured dye using a jet inoculator (Hart and Pritcher, 1969). Prior to dye marking, smolts will be anaesthetized. Caudal fin clips will be of two types: upper caudal (UC) and lower caudal (LC). The caudal fin will be cut dorso-ventrally at a point approximately one-fourth the distance from the tip of the lobe to the caudal peduncle. Coloured dye will be applied either to the upper or lower caudal peduncle, or the pectoral fin with a jet inoculator. The mark is a line on the fin ray approximately 3–4 mm long. Coho and steelhead parr and smolts along with all age classes of chinook will be marked individually, using this method.

Rotary Trap Efficiencies and Population Estimate Calculations

A key challenge in estimating outmigration from the Cheakamus river is the decreasing catchability as flows increase during the spring, often at the same time as outmigration for some species is expected to peak. Historical estimates of run size from Cheakamus River outmigrant data have been calculated using the unstratified Petersen or the temporally-stratified Darroche methods as implemented in SPAS (Arnason et. al. 1996). The unstratified estimates of population size are likely quite biased because capture efficiency can change dramatically over the sampling period. The stratified estimator can be difficult to implement using data from the Cheakamus because there are sometimes very low or zero recaptures in some strata when trap efficiency is low and/or the amount of fish available to mark within a stratum is small. Reducing the number of strata through pooling may alleviate this problem but can lead to the same biases and uncertainty associated with the unstratified estimator. A new statistical methodology is being developed which the proponent will use for estimating run size and timing from stratified mark-recapture data. The new method will assume that the numbers of fish migrating past a trapping location over successive strata are not independent, but instead exhibit a temporal pattern in abundance determined by a run-timing curve. This assumption can be supported from a meta-analysis of outmigrant data derived from downstream weirs where the numbers of migrating fish are reliably determined. The new method will fit a run-timing curve to the mark-recapture data using bayesian estimation with priors for run timing and process variation in the run-timing curve developed from the meta-analysis.

Discharge data required for these calculations can be obtained from BC Hydro, WSC gauges, and the inflow monitoring component of the channel morphology monitoring program (#8).

Note: Minor changes in marking methodology outlined above (i.e., the number of mark groups/strata) may be warranted as an improved estimation methodology is developed.

Bio-sampling

For chum, pink, chinook and coho fry a maximum of 25 of each species will be sampled for length and weight bi-weekly at the RST site and Upper Paradise/Gorbushca site.

For coho, chinook and steelhead parr and smolts approximately twenty per cent of the day's catch up to 25 per day of each will be sampled for length to the nearest millimetre. Twice weekly each species will also be sampled for weight to the nearest tenth of a gram. Scale samples will be taken stratified by migration timing and size for each species (Ward et al. 1989), and aged. Bio sampling will be undertaken at the RST site and the Upper Paradise/Gorbushca trap site.

Modifications to sampling regime in consultation with the contract monitor may be made in-season based on numbers of fish captured.

Task 5: Temperature Logging

A need to have annual temperature logger stations on the Cheakamus River to meet the needs of the various ongoing environmental studies has been identified. As the juvenile downstream migrant study has a large daily field component it has been decided to include the collection and distribution of annual river temperature data within the TOR.

Five sites will be monitored for temperature:

1) Between Daisy Dam and Rubble Creek.
2) Between Rubble Creek and the Cheakamus Canyon.
3) Downstream of the Cheakamus Canyon and upstream of Culliton Creek.
4) Rotary Screw Trap Site.
5) Downstream of Cheekye River.

Two loggers will be installed at each site (as back up) and temperature will be logged hourly, 365 days per year. The loggers will be downloaded bimonthly. Data will be made available to the Project Biologist for all other BC Hydro monitoring studies.

Task 6: Data Analysis and Reporting

Different analytical models with different assumptions are available to calculate the total outmigration. In addition, new analytical tools are being developed (see Task 4) that may be more suitable for challenging conditions on the Cheakamus River of decreasing catchability with increasing discharge. Hence, a component of the data analysis in Year 1 will be to hold a workshop with regulatory agencies and interested parties to review the analytical methods, discuss the assumptions for each method, and ultimately determine the most appropriate analytical method to use for this program.

A report will be prepared annually that:

a) Re-iterate the objective and scope of the monitor.
b) Presents the methods used for data collection.
c) Describes the compiled data set and presents the results of all analyses, including;
    - Biophysical data.
    - Biological data – length, weight, age, condition, length at age.
    - Run timing data – capture through time.

- Fry and smolt yield estimate– Peterson estimates, and associated precision. Also a comparison with previous data collection.
- Mainstem and side channel production.
- Hatchery vs. wild production.
- Operational difficulties.

d) Discusses the consequences of these results as they pertain to the current WUP operation.

A key deliverable of the project each year will be the raw data complied in a standardized database.

In addition, the raw data, data summaries and data analyses from the groundwater-fed channels will be provided annually and in a timely manner to the implementers of the "Groundwater in side channels" monitoring program (#6).

1.2.4 Interpretation of Monitoring Results

The management questions and hypotheses in Sections 1.2 and 1.3 will be examined for each species and life stage for which reasonably precise outmigration estimates can be obtained (see Table 1a-1). Management Question 1 and Hypothesis 1 address specific relations between seasonal discharge and smolt production. As such, ecologically relevant metrics of discharge (i.e., peak discharge during chum egg incubation, minimum weekly discharge during the coho growing season) will be calculated for use in subsequent correlation analyses with smolt outmigration. Such analyses may provide a useful diagnostic tool to examine flow effects. Management Question 2 and Hypothesis 2 address the more general trends in smolt production following implementation of the WUP flow regime, and as such analyses will follow a general before-after approach using the outmigration data collected prior to implementation of the WUP flow regime.

The sampling and subsequent analytical challenges outlined above for obtaining precise outmigrant estimates for some species (Table 1a-1) in the Cheakamus River may limit the strength of the inferences that can be drawn from the monitoring data, or increase the duration of monitoring required to determine the effect of flow (Bradford et al. 2005). Refinements to the sampling and analytical techniques outlined in these Terms of Reference should help to address these challenges. Despite these challenges, a quantitative review (Parnell et al. 2003) of the sampling for the analytical components that involve a general before-after approach found that the program had reasonable statistical power to detect large-scale changes in the order of a 50% decrease in coho production or a 100% increase in chum production, given the relatively precise outmigration estimates for these species (Melville and McCubbing 2005).

Information from this program will also be used in combination with data from other monitoring programs to help answer high-level questions regarding the relation between Cheakamus River discharge and fish production (see the "Project Coordination" section above). Data from each program will provide multiple lines of evidence with which to evaluate ecological hypotheses and contribute to continued quantitative and qualitative learning on the response of fish to flow in the Cheakamus River.

Analyses and interpretations from the side channel data will consider any physical alterations or expansions of these channels that may occur in the future.

1.2.5 Schedule

Data will be collected annually for five years. Trapping is scheduled to occur from 15 February to 15 June. Water temperature in the Cheakamus River will be logged year-round and downloaded every second month. The specific timing for individual tasks is described in the Methods section above.

1.2.6 Budget

Table 1a-3 outlines the estimated cost for the monitoring program. The budget assumes that the two RSTs currently (2006) used in the program will be available for use.

Table 1a-3: Cost Estimate for the Cheakamus River Juvenile Salmonid Outmigrant Enumeration Monitoring

Task	Labour	Daily rate	Units Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total Cost
Project Coordination	Project Biologist	$600	10	10	10	10	10	$30,000
Installation & removal of cables	Rigging Technicians	$600	10	10	10	10	10	$30,000
Trap installation	Project Biologist	$600	4	4	4	4	4	$12,000
(RST and side channel)	Technician 1	$300	4	4	4	4	4	$6,000
	Technician 2	$300	4	4	4	4	4	$6,000
	Technician 3	$300	4	4	4	4	4	$6,000
	Technician 4	$300	4	4	4	4	4	$6,000
RST & side channel trap operation	Project Biologist	$600	90	90	90	90	90	$270,000
(Feb 15 to Jun 15)	Technician 1	$300	100	100	100	100	100	$150,000
	Technician 2	$300	100	100	100	100	100	$150,000
	Technician 3	$300	70	70	70	70	70	$105,000
	Technician 4	$300	70	70	70	70	70	$105,000
Trap removal	Project Biologist	$600	2	2	2	2	2	$6,000
	Technician 1	$300	2	2	2	2	2	$3,000
	Technician 2	$300	2	2	2	2	2	$3,000
	Technician 3	$300	2	2	2	2	2	$3,000
	Technician 4	$300	2	2	2	2	2	$3,000
Temperature logger downloads	Project Biologist	$600	4	4	4	4	4	$12,000
	Technician 1	$300	4	4	4	4	4	$6,000
Data entry	Project Biologist	$600	15	15	15	15	15	$45,000
	Technician 1	$300	10	10	10	10	10	$15,000
Data analysis and reporting	Analyst	$750	15	5	5	5	5	$26,250
	Project Biologist	$600	15	15	15	15	15	$45,000
	Technician 1	$300	3	3	3	3	3	$4,500
	Contingency	10%	$45,971	$23,121	$24,621	$25,871	$24,621	$144,205
		Subtotal	*$261,521*	*$231,171*	*$232,671*	*$233,921*	*$232,671*	*$1,191,955*
	Expenses	Unit Price						
	Construction of new RST moorings	$50,000	1					$50,000
	Large mesh drums for RST	$7,000	3					$21,000
	RST purchase / replacement	$20,000	1			1		$40,000
	RST maintenance & re-screening	$5,000	2		3		3	$40,000
	Side channel traps	$9,500	5					$47,500
	Side channel trap maintenance	$500		5	5	5	5	$10,000
	Automated counters	$20,000	3					$60,000
	VCR validation equipment	$2,500	3					$7,500
	Fyke net purchase / replacement	$2,000	3			3		$12,000
	Temp loggers & accessories	$1,500	1			1		$3,000
	Field supplies	$4,000	1	1	1	1	1	$20,000
	Mileage	$0.56	11000	11000	11000	11000	11000	$30,800
	Lodging and meals (month)	$2,500	4	4	4	4	4	$50,000
	Report preparation	$500	1	1	1	1	1	$2,500
		Subtotal	*$244,160*	*$23,160*	*$38,160*	*$50,660*	*$38,160*	*$394,300*
	Future Inflation	2%	$10,114	$10,275	$16,577	$23,459	$28,188	$88,613
		Total	**$515,795**	**$264,606**	**$287,408**	**$308,040**	**$299,019**	**$1,674,868**

1.2.7 References

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