Cheakamus Project Water Use Plan

Monitoring Program Terms of Reference

- Cheakamus River Benthic Community Monitoring

Revision 1: February 2007
1st Submission: November 2006

22 February 2007
Terms of Reference for the Cheakamus Water Use Plan
Effectiveness Monitoring Program

Overview

This document presents Terms of Reference (TOR) for the effectiveness monitoring programs for the Cheakamus Water Use Plan (WUP). These programs will monitor outcomes of the recommended operational changes, and provide information on which to base future operating decisions.

The first submission of the TOR was in November 2006 for the Cheakamus River Juvenile salmonid outmigrant enumeration monitoring program. This document is Revision 1 and provides detailed Terms of Reference for the following programs:

1a) 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. Previously submitted to the Comptroller of Water Rights on 20 November 2006; leave to commence was received 28 November 2006.

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 Cheakamus 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 one-year monitoring program to examine the benefits to recreational angling access (available angling locations) of the 1 January to 31 March 5.0 m³·s⁻¹ minimum flow release from Daisy Lake Dam.
Cheakamus Water Use Plan
Monitoring Program Terms of Reference 22 February 2007

Cheakamus River Monitoring Program #7: Cheakamus River Benthic Community Monitoring

1.1 Monitoring Program Rationale

1.1.1 Background

The consultative process for the Cheakamus River Water Use Plan (WUP, Marmorek and Parnell 2002) considered operating alternatives to achieve objectives for water demand for power production, heritage and cultural values by First Nations, recreation, fish production, integrity of the aquatic ecosystem that supports the river food web and water quality, and flood control. The effects of flow regulation on the benthic community was an important uncertainty during this process. To reduce uncertainties, the CC unanimously endorsed implementation of a monitoring plan to fill in data gaps, reduce scientific uncertainty, and provide information to better inform the CC members during future planning processes (see BC Hydro 2005). One component of the monitoring plan was updated modelling to examine the importance of Cheakamus River flow on the abundance and composition of benthic communities that indicate “ecosystem health” and are fish food organisms. This document is a Terms of Reference (TOR) pertaining to the monitoring of benthic communities and habitat attributes that determine the composition and abundance of those communities in the Cheakamus River.

Benthic invertebrates are good indicators of water quality (Rosenberg and Resh 1993) and ecosystem health (Norris and Hawkins 2000), where the term “health” is useful for defining river condition that can be understood by the general public and resource managers (i.e., properly functioning condition). Good condition of the Cheakamus River can be defined by the presence of clean water and a functioning food web having a diversity of organisms that can support highly valued endemic fish species (mainly salmonids). Poorer condition following implementation of the new flow regime might include relatively low diversity and abundance of benthic organisms caused by an effect of altered release of water from the Daisy Dam that may modify the water chemistry, the availability of physical habitat, or hydrological regime. Because of continuous exposure to water flow, benthic biota provide an integrated record of physical and chemical environmental quality. They are ubiquitous, largely sedentary, and there are large numbers of species that can provide an integrated measure of response to stress. Their characteristics allow effective spatial and temporal analyses of disturbance among river reaches. The invertebrates act as a major food supply for fish, particularly salmonids that are sentinel species of the Cheakamus River, and provide an indication of food availability for fish populations through time and space. The result is that monitoring of benthic invertebrates can provide a sensitive indication of change in the chemical and physical attributes of the Cheakamus River.

The CC recognized this importance of the benthic community as an indicator of ecosystem function and endorsed a plan to build on earlier monitoring of the Cheakamus River (Perrin 2001). Biological and habitat data collected by Perrin (2001) in 1996 and again in 1999-2000 was used to examine the importance and effect of several hydrological variables on benthic invertebrate endpoints as indicators of “river health”. A predictive model, hereafter referred to as the Cheakamus Benthos Model (CBM), was developed as part of this process. That model was later used to examine
the effect of change in nutrient discharges from the Whistler Wastewater Treatment Plant that may be expected from future plant upgrades and water withdrawal scenarios on periphyton biomass in the Cheakamus River upstream of Daisy Reservoir.

The present monitoring design will focus on further development of the CBM to improve insight into effects of change in hydrological attributes on benthic invertebrate and periphyton composition and abundance. This TOR outlines the monitoring approach that will be required for continued development of the CBM to make it ready for application in the next WUP review.

1.1.2 Management Questions

The present CBM (Perrin 2001) showed that flow, variation in velocity, soluble phosphorus concentration, and distance from the dam were important predictors of benthic invertebrate biomass in the Cheakamus River. This model suggests that flow management can be an important driver of benthic invertebrate biomass. These predictors were found from only two years of monitoring in different seasons and can be considered preliminary due to a relatively small sample size (42 observations) that was used to identify the predictor variables. The WUP monitoring will provide approximately 80 new observations to be collected over four seasons to supplement the existing data and answer two management questions:

1) What habitat and flow attributes best determines the composition, abundance, and biomass of benthic invertebrates in the Cheakamus River?

2) Among all habitat and flow attributes, what is the relative importance and magnitude of effect of water release from the Daisy Dam in determining the composition, abundance, and biomass of benthic communities in the Cheakamus River?

The monitoring will be required over a wide range of flows and environmental conditions, among different seasons. Following data collection, various statistical modelling procedures including multiple regression analysis that is the basis of the present CBM and any supplemental analyses that are considered necessary by the project’s lead biologist will be run. All statistical procedures will support development of a final predictive model that will be produced following the completion of data collection. That model will be used in future planning processes to explore the potential effects of water release alternatives on benthic indicators of ecosystem health and food availability for fish.

1.1.3 Summary of Alternative Hypotheses

The primary hypotheses (and sub-hypotheses) associated with these management questions and stated as if they were true (alternate hypotheses) are:

\( H_1: \) Flow and related hydrologic variables are important predictors of benthic community attributes.

\( H_{1.1}: \) Variation in flow and related hydrological variables are important predictors of benthic community attributes.
H₂: Benthic invertebrate community diversity increases with increasing distance from the Daisy Dam.

H₂.₁ Distance from the dam is an important predictor of benthic invertebrate community diversity.

H₃: Benthic invertebrate abundance increases with increasing distance from the Daisy Dam.

H₃.₁ Distance from the dam is an important predictor of benthic invertebrate abundance.

H₄: Soluble phosphorus concentration is an important predictor of epilithic (i.e., on the surface of rocks) algae biomass in the Cheakamus River.

H₅: Soluble phosphorus concentration is an important predictor of benthic invertebrate biomass in the Cheakamus River.

H₆: Habitat attributes other than those described in H₁ to H₃ are not important predictors of benthic invertebrate composition.

H₇: Habitat attributes other than those described in H₁ to H₃ are not important predictors of benthic invertebrate abundance.

H₈: There is close similarity between the composition of prey that is ingested by fish in the Cheakamus River and composition of benthos that is produced in the Cheakamus River.

Each of these hypotheses will be examined as part of the main goal of further developing the CBM for use in future planning processes.

1.1.4 Key Water Use Decision Affected

The key water use decision that would potentially be affected by the results of the monitoring is the seasonal flow release from the Daisy Dam. The CBM will be a tool used to calculate various ecological performance measures, for use by technical committees to explore the potential consequences of change in strategies to release water from the Daisy Dam on indicators of river health and food availability for fish. The CBM will be regarded as a decision support tool, not a decision making tool. Use of the CBM for this purpose will contribute to future decisions on allocation of water for power production, heritage and cultural values by First Nations, recreation, fish production, integrity of the aquatic ecosystem that supports the river food web and water quality, and flood control. As part of this decision-making process in future planning, the CBM will quantify the importance of flow and flow related attributes in supporting a healthy river for multiple uses.
1.2 Monitoring Program Proposal

1.2.1 Objective and Scope

The objective of the benthos monitoring is to continue development of the CBM for use in evaluating river health among flow alternatives. River health will be indicated by attributes of the benthic invertebrate and periphyton communities. The model will be a decision support tool for future planning initiatives.

The geographic scope of the monitoring is the Cheakamus River mainstem downstream of Daisy Dam (Figure 7-1). The monitoring will occur at five sites that were sampled by Perrin (2001) in previous activities that supported initial water use planning and are located downstream of the Daisy Dam on the Cheakamus River (Figure 7-1). Those sites are called CH4 (approximately 200 m downstream of the Daisy Dam), CH5 (adjacent to highway sand sheds), CH6 (upstream of the Culliton Creek confluence), CH7 (downstream of the Culliton Creek confluence), and CH8 (downstream of the Cheekye Creek confluence). A wide range of environmental conditions will be captured in the sampling to facilitate development of the CBM using all possible physical and chemical conditions in the Cheakamus River. To meet this goal, data will be collected once during each season of the year. One sampling session will occur during each season of the year, for a total of four sampling sessions. This data collection is scheduled to occur over two calendar years (two separate seasons per year; see proposed schedule in Section 1.2.5). The resulting data will be appended to existing physical, chemical, and biological data that was used for preliminary model development by Perrin (2001). The final model will be compiled along with all statistical analyses in the year following completion of data collection.

The scope of work in this TOR is limited to provide the information needed to assess the effects of flow regulation on the aquatic ecosystem in the Cheakamus River downstream of the Daisy Dam. However, application of the CBM should be adaptable to consider other anthropogenic impacts in the watershed, should such data collection and analyses be requested as separate projects with additional funding, outside the scope of this TOR. For example, the model development should be sufficiently flexible to support additional monitoring at sites upstream of the reservoir that may be necessary to support interests of the Resort Municipality of Whistler, Whistler wastewater treatment plant. Such data would not be needed to assess flow effects downstream of Daisy Dam, of interest to the present TOR.
Figure 7-1: Cheakamus River Monitoring Sites as Defined from Previous Sampling by Perrin (2001). Sites CH-4, 5, 6, 7, and 8 are recommended for this TOR.
1.2.2 Approach

The monitoring approach is to collect physical and biological data from the river to add to an existing database of collected data, and use this expanded dataset to refine a model that predicts various benthic endpoints from the physical variables. The effect of flow variables on these benthic endpoints will be a key relationship examined.

The river monitoring will focus on benthic invertebrates and attributes of benthic habitats that support the invertebrates, including flow and related hydrological variables. Periphyton biomass and composition will be monitored for potential use as a predictor in the invertebrate modelling (as was found by Perrin 2001) but it will also to be available for any alternative modelling in which algal biomass and composition may form endpoints of interest. Perrin (2001) used benthic invertebrate biomass as the endpoint in the existing linear regression model but the project’s lead biologist should not hesitate in running other endpoints (e.g., a diversity metric, abundance metrics, other measurement) to potentially produce more than one linear model corresponding to each endpoint of interest. Tools such as multidimensional scaling may assist in defining taxa or groups of taxa that are most important in discriminating between effects of location and time or other defined groups of samples. Combinations of those taxa may be most useful as final endpoints. In addition, consultation with members of the Cheakamus Water Use Plan monitoring committee may be useful to guide selection of endpoints that are most relevant to management of flows on the Cheakamus River. Effort should be made to limit analyses to not more than three regression equations. Any more may add complexity to eventual interpretations and potentially make results difficult to understand.

Analyses need not be restricted to application of regression modelling techniques. The compiled data will in fact be amenable to multivariate analysis and modelling that may also be suitable for addressing the hypotheses. Analyses and model selection will trade-off the increased predictive capability of more complex models with i) the ability to communicate the model and results to technical committees, and ii) the utility to managers and decisions makers who will ultimately use the model results.

Artificial substrata will be used for all measurements of periphyton and benthic invertebrate community composition, abundance, and biomass using hardware and procedures outlined by Perrin (2001). This approach will be consistent with the previous sampling methods, thus allowing data sets to be combined without confounding by method of collection. Because the samplers have a standardized substrate, particle size will be eliminated as a variable affecting benthic communities over space and time. The artificial substrata will facilitate sampling at wide ranging depths that is not possible with conventional samplers such as a Hess or Surber type of sampler. Use of artificial samplers requires installation of the hardware, a six to eight week period of incubation during which time a variety of physical and chemical measurements are made at each sampler or site as biological communities develop in the samplers, followed by harvest of the communities. The physical and chemical measurements will include but are not limited to several forms of nitrogen and phosphorus, water velocity, water depth, dissolved oxygen, conductivity, total dissolved solids, pH, turbidity, flow, continuous measurement of temperature, coding of ambient particle size distribution, and descriptions of other habitat conditions.
Laboratory work will follow to enumerate the benthic invertebrates, by genus, and the epilithic algae, by species, and to determine the biomass of the invertebrates and algae. The advantage of this approach is that it integrates community development processes over the time of installation of the samplers. The data are not strongly affected by episodic events that can introduce large variation in data from measurements made at discrete points in time.

In each of year of data collection, data will be compiled into a master file. To ensure that the data collected will be suitable for the extensive modelling exercise, and ensure that all data is formatted correctly and error free, it is recommended that following the first year of data collection, the data be read into statistical software, and that the CBM model be updated and re-run with the updated dataset. This exercise is not for application of the model, but to facilitate a quality check of the data and data collection. Final model development and reporting will occur in the year following the completion of data collection. No field sampling will be required in that year.

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.

Coordination with WUP Monitoring and Other Monitoring Programs

To help answer high-level questions regarding the relation between Cheakamus River discharge and aquatic production at different trophic levels, data from this monitoring program will ultimately be used in combination with data from the fish monitoring programs (Programs #1, 2, and 3), the channel morphology and hydrology monitoring program (#8), 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 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. For example, Task 4 of this program requires that juvenile fish be obtained from one of the fish monitoring programs (Programs #1 to 3). Logistical changes within the scope of the program may be required.
Task 2: Site Selection and Field Preparation

Five sites in the Cheakamus River (CH4 to CH8 as shown in Figure 7-1) that were previously sampled by (Perrin 2001) will be sampled annually within a 40 – 50 day time series such that one sampling series in each season is completed. The result will be observations spanning a wide range of biological characteristics and habitat conditions from which the CBM will be developed. A field data sheet will be prepared in advance of each field session to ensure that all data needs are met. The form will contain the following data fields:

1. Survey information including date/time, predominant weather conditions, crew members, site name and number,

2. Installation details: georeferenced location for each site, site identification and configuration (photograph reference, sketch and/or description of site), details regarding the invertebrate collection baskets dimensions, installed substrate size, specifications of the periphyton plates, temperature logger identification,

3. Habitat descriptions and measurements that are consistent with modelling requirements and include but are not limited to flow, depth and velocity at each sampler, photosynthetically active radiation at the water surface and at each sampler, temperature, and check boxes to indicate the collection of samples for analysis of soluble reactive P (SRP), total phosphorus (TP), total dissolved P (TDP), ammonium (NH4+), nitrate (NO3-), total nitrogen (TN), total alkalinity, total dissolved solids, conductivity, pH, and turbidity (e.g. all potential predictor variables must be included),

4. Sampler removal data including date/time, predominant weather and site conditions, notes describing any sampler disturbance or movement, etc.

Task 3: Field Sampling and Analysis in Laboratories

Benthic invertebrates and periphyton will be sampled from artificial substrata installed over a time series of 40 – 50 days at each site in a different season within a scheduled two year period (see Section 1.2.5 for a proposed schedule). Four replicate benthos samplers and three replicate periphyton samplers will be installed and sampled at each site.

A periphyton sampler will consist of open-cell sheet Styrofoam mounted on a concrete patio block that is submerged in water depths of 8 – 50 cm in riffle or run habitat at each site. Once per week for at least six weeks a 2 cm diameter core of the Styrofoam and the adhered biomass will be removed using the open end of a 7 dram plastic vial and analyzed for chlorophyll-a concentration. Algal accrual on the plate is a function of cell settlement during a colonization phase, actual growth, and losses associated with insect grazing, scour from suspended particulates and sloughing. Colonization largely determines biomass in the first week of accrual but thereafter colonization is insignificant relative to growth. In this project, periphyton biomass is of particular interest because it is biomass that is available to higher trophic levels. Peak biomass (PB) measured during the accrual series is a function of actual growth and can be used in place of growth for spatial and temporal comparisons. PB will be the highest average concentration of chlorophyll-a attained on the replicate substrata on a given day during an accrual series. On the final
sampling day of each series, one additional core will be removed from each substrate and preserved in Lugol's solution for taxonomic identification and enumeration.

Four replicate invertebrate substrata will be installed at each site at the same time that the periphyton substrata are installed. The substrata will be wire baskets (30 cm long x 14 cm wide x 14 cm deep) filled with gravel having a standard diameter of 2.5 – 3.5 cm. They will be placed in riffles or runs at each site in water depths of approximately 15 – 50 cm. The baskets will be embedded with the top surface flush with the top of the natural gravel. At the same time of final periphyton sampling, the baskets will be retrieved by placing a 250 μm mesh Nitex net around the basket and lifting the basket and net assembly out of the water and into a collection bucket. This retrieval method will prevent loss of animals. In the collection bucket, the baskets will be opened; the invertebrates will be brushed from the gravel and preserved in 10 per cent formalin. In the laboratory, all organisms retained on a 250 μm sieve will be identified to the lowest reliable taxonomic level, and counted. After enumeration, invertebrate biomass will be determined for each sample either using destructive procedures of drying and weighing or preferably with the use of length – weight regressions.

The installed colonization plates and baskets will be placed such that they will remain wetted under all flow conditions. Minimum flow conditions during the sampling period can be estimated based on the minimum flows outlined in Section 1.1.1 (above).

One water sample will be collected from each site at the start and finish of the sampler incubation period. All water samples will be analysed in the lab for a suite of parameters including soluble reactive P (SRP), total phosphorus (TP), total dissolved P (TDP), ammonium (NH₄⁺), nitrate (NO₃⁻), total N (TN), and alkalinity. The N:P ratio will be determined from molar concentrations of DIN and SRP, which are the forms of N and P that are considered biologically available.

On one day each week during the sampler incubation period, selected physical and chemical measurements will be made. Current velocity and water depth will be measured at each sampler using a velocity meter and meter stick respectively. Photosynthetically active radiation (PAR) will be measured at the water surface and at the sampler depth preferably using an irradiance meter that specifically measures PAR and is equipped with an underwater quantum sensor. Other weekly measurements will include total dissolved solids (TDS), conductivity, turbidity, dissolved oxygen, and pH using a water quality Sonde.

Temperature will be logged in hourly intervals over the complete sampling time series each year using a submersible temperature logger installed at each station.

The determination of flow for each sampling site will not simply be water released from the dam but must be specific to a given site. Flow metrics for use as predictors in the CBM may be average, maximum, or minimum flow for the period of sampler installation. Coefficient of variation of flow may also be a useful predictor. Power Records at BC Hydro can run calculations to provide daily mean flow at given locations in the river along with QAQC. There would be a fee billed to the project for this service. Alternatively the project's lead biologist can run the calculations independently. Which ever way this is done, the project implementers must include a fee in their cost estimate for determination of site-specific flow metrics. Inflows from major tributaries will also be logged continuously under the Cheakamus River.
Channel Morphology monitoring program (Program #8), and data may be obtained from this program.

All data that is acquired in the field will be compiled on site forms that are described in Section 1.2.3.1. It is recommended that photos be taken on at least one visit to each sampling site during the sampling time series to illustrate the layout of samplers and ambient habitat characteristics. Any replacement baskets or plates required due to disturbance over the survey period must be documented on the field forms, as would any other changes to the sampling protocol.

**Task 4: Fish Sampling and Analysis of Fish Diet**

Composition of food that is ingested by fish in the Cheakamus River is needed to assist with the interpretation of the link between production of benthic invertebrates and food that is actually ingested by the fish. It is recommended that stomach samples from 15 juvenile salmonids be collected for each stream rearing salmonid species of interest (i.e., 15 samples per species in each of the years of benthic sampling, Years 2 and 3). Subject to sampling permit approval and conservation concerns, these species would include rainbow trout/steelhead, coho salmon, Chinook salmon and bull trout.

To enable cost efficiency, it is recommended that fish stomach samples be collected under the fish sampling Programs #2 (Trout abundance) and #3 (Steelhead production) and provided to this benthic program for lab analyses. Samples would be collected “opportunistically” from near the benthic sampling sites over the same timing window as the colonization baskets are in place. The samples must be enumerated to the lowest reliable taxonomic level in the laboratory.

**Task 5: Analytical Methods**

The present Cheakamus Benthos Model is a regression equation that can be used to predict benthic invertebrate biomass as a function of several habitat variables and to show the most important habitat attributes that determine the invertebrate biomass. As the new data are compiled from monitoring each year, the regression analysis should be run again using forward and backward stepping procedures. The result may be an annual change in predictor variables and statistics that indicate fit of the equation to the data and error rates as sample size is increased.

It is recommended that multivariate tools be run to reveal benthic indicators or metrics based on count data that may supplement the biomass model. For example, multidimensional scaling (MDS) may be used to identify groups of samples based on the Bray Curtis similarity of community groups. These groups may correspond to gradients downstream of the dam, time course change in composition and abundance of invertebrates, or both. A subsequent analysis in MDS that is also based on the Bray Curtis similarity measure may reveal what taxa are most important in contributing to those sample groups. Those taxa may be considered indicators of spatial and temporal variation in the Cheakamus River. Alternatively, combinations of taxa (e.g., all mayflies or mayflies plus stoneflies plus caddisflies) may be found to be good indicators. It is recommended that no more than three of these indicators be selected as supplemental endpoints for additional regression equations. These models in addition to the biomass model will then be available to support exploration of effects of water release strategies on biomass and on important metrics that are
sensitive to flow manipulation during the subsequent Water Use Planning. All regression modelling must be accompanied by statistics showing variation in the dependent variable that is explained by the predictor variables, error rates, significance levels, distribution of residuals, etc., as diagnostic tools to decide on acceptance or rejection of the equations.

The project’s lead biologist is encouraged to explore other modelling alternatives. For example, multivariate modelling may be found to be more revealing and useful with fewer constraints than are found in multiple regression approaches. These approaches should be run and contrasted with application of the present CBM to eventually arrive at a final recommended model or group of models for future use in planning processes.

As in previous investigations (Perrin 2001), to control for Type I error rates, consideration should be given to the number of statistical test performed and should be limited to those required in the analysis.

**Task 6: Performance Measure Development**

Once data collection is concluded, appropriate performance measures (i.e., measures of the benthic community) can be selected, and the model will be finalized. The model can then be used during planning (outside the scope of this TOR) to calculate performance measures that can be used to examine the effect of flow on these benthic invertebrate endpoints. A final CBM will be the one supplied to an assigned technical committee to support future decisions on flows in the Cheakamus River.

**Task 7: Reporting**

Following the first year of data collection, a data report will provide the background, methods, and results date. Reports will include an Executive Summary outlining the data collected to date, the status of selected benthic invertebrate metrics across all sites, and the status of the CBM.

Once final analytical work has been completed in Year 4, a final report will be prepared that will include:

a) An executive summary of the entire project.

b) A data summary.

c) The analytical procedures.

d) A detailed summary of the findings as they relate to the ecological hypothesis and the key management questions.

e) The final recommended model or models for use in subsequent planning

All reports will be provided in Microsoft Word and Adobe Acrobat (*.pdf) and all maps and figures will be provided in their native format either as embedded objects in the Word file or as separate files. All data collected will be submitted annually in a Microsoft Access Database. The raw data is a key deliverable of this project.
1.2.4 Interpretation of Monitoring Results

The analytical methods and modelling exercise under Task 5 will inherently test Hypotheses 1 to 7, and address the two management questions. Hypothesis 8 will be examined under Task 4.

The final model(s) will provide value for future flow management decisions on the Cheakamus River by allowing users to explore ecological responses to various changes in flow that may be considered in future planning exercises.

All data that are collected during the years of monitoring and appended to existing data will also be available for other applications. The data will be a wealth of descriptive information for examining the ecological structure and function of the Cheakamus River.

1.2.5 Schedule

Field data is scheduled to be collected over two years, with final model development and reporting completed in the following year.

Table 7-1: Example Schedule for the Benthic Community Monitoring Program.

'Year' refers to the year following implementation of the Cheakamus monitoring programs, which is estimated to begin in 2007. Data collection during each season = 40-50 day sampling session. Winter = Jan-Mar, spring = Apr-Jun, summer = Jul-Sept, and fall = Oct-Dec.

<table>
<thead>
<tr>
<th>Year</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 2 (2008)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 3 (2009)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 4 (2010)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data collection is scheduled to begin in Year 2 after approval of the Cheakamus WUP monitoring programs, and the modelling and reporting completed in Year 4 following approval (Table 7-1). There is flexibility in the exact sequence in which the seasons are sampled. However, one constraint is that in order to sample a broad range of physical conditions, consecutive seasons should not be sampled (e.g., spring and summer in the same year).

1.2.6 Budget

Total Program Cost: $266,218.
1.2.7 References


