

Alouette Project Water Use Plan

Monitoring Program Terms of Reference

- **ALUMON#1 Smolt Enumeration**
- **ALUMON#2 Kokanee Out-migration**
- **ALUMON#3 Substrate Quality**
- **ALUMON#4 Sockeye Adult Enumeration**
- **ALUMON#5 Water Temperature**
- **ALUMON#6 Kokanee Age Class Structure**
- **ALUMON#7 Archaeological Monitoring**

October 15, 2009

Alouette Project Monitoring Program Terms of Reference

1.0 OVERVIEW

This document presents Terms of Reference for both the fisheries and archaeological monitoring programs recommended by the Alouette Water Use Plan Consultative Committee and required per the 20 October 2009 Water Act Order issued by the Comptroller of Water Rights (Table 1). These monitoring programs involve effectiveness monitoring to assess the response of the aquatic environment to licenced BC Hydro operations as well as monitoring to assess the effects of BCH operations on archaeological sites situated within the drawdown zone of the Alouette Lake Reservoir and a section of the South Alouette River.

Table 1. Alouette Fisheries and Archaeological Monitoring Plan Terms of Reference Submission Information

Name of Monitoring Program	Order Clause Fulfilled	Submitted with this Package	Previously Submitted To CWR	Submission Date	Leave to Commence
ALUMON#1 Smolt Enumeration	Section 16.a	Yes	No	20 Oct 2009	-
ALUMON#2 Kokanee Out-migration	Section 16.b	Yes	No	20 Oct 2009	-
ALUMON#3 Substrate Quality	Section 16.c	Yes	No	20 Oct 2009	-
ALUMON#4 Sockeye Adult Enumeration	Section 16.d	Yes	No	20 Oct 2009	-
ALUMON#5 Water Temperature	Section 16.e	Yes	No	20 Oct 2009	-
ALUMON#6 Kokanee Age Class Structure	Section 16.f	Yes	No	20 Oct 2009	-
ALUMON#7 Archaeological Monitoring	Section 16.g	Yes	No	20 Oct 2009	-

Fisheries Monitoring Program Terms of Reference

1.0 INTRODUCTION

As the Alouette Lake Water Use Plan (WUP) reached completion, a number of uncertainties were identified regarding the effect of BC Hydro operations on aquatic resources. The primary consequence of these uncertainties was a limited ability to predict the response of fish and wildlife populations to operational changes as a result of WUP implementation. This in turn highlighted the general uncertainty surrounding the likelihood that the expected fish and wildlife benefits of the WUP operation will be realised.

The framework for WUP process requires that it be reviewed on a periodic and ongoing basis. Therefore, in the years subsequent to the implementation the WUP, there will be a need for compliance monitoring and effectiveness monitoring to gain the information necessary to address these uncertainties. Compliance monitoring consists of monitoring activities to ensure that BC Hydro complies with the conditions of its water license. Effectiveness monitoring is more complex. It involves the observation, measurement, and evaluation of streamflows, fish and wildlife habitat, and population changes to test the efficacy of the WUP.

Effectiveness monitoring for the Alouette Lake system will require the collection of data in order to quantify relationships between specific fish population parameters and different aspects of BC Hydro operations. Monitoring will assess whether a predicted biological response to changes in operations actually occurred as predicted, and thereby assess whether the objectives of greater abundance and/or diversity were met.

2.0 OVERVIEW

At the conclusion of the Alouette Lake WUP Review process, the Consultative Committee (CC) recommended several key changes to the way Alouette Dam is operated. They are believed to have at least some impact to the ecology of resident fish species. The proposed changes are in addition to the operational changes made in 1996 as part of the original water license review process:

1. Spring surface release starting April 15 and ending June 14.
2. A higher reservoir elevation (122.5) during the peak recreation season starting June 15 and ending Labour Day (September 5).
3. Short recreation shoulder season ending Sep 15 when water levels are above 121.25m.
4. Removing the need for a prescribed flushing flow to clear fine sediments

When recommending these operational changes, the CC acknowledged that there was a need for additional fish related information that would add greater certainty to their decision making, but could not be collected at the time of the WUP review process or had to be monitored *in situ* to confirm their assumed consequences. In particular, the CC identified the following critical uncertainties:

1. Long term impact on Alouette River smolt output
2. Success of surface release in allowing kokanee to leave to reservoir and begin their seaward migration.
3. Long term impact on the transport of fine sediments in Alouette River.
4. Success of the kokanee re-anadromisation initiative, and hence an evaluation of the need for the surface release.
5. Water temperature impacts on the Alouette River.
6. Long term impact on the kokanee reproductive success.

In addition to the uncertainties above, the CC also recommended that an Alouette Monitoring Review Committee be created to oversee the general progress of the monitor, review all reports before general release, and recommend changes regarding the monitoring program's implementation as deemed necessary. Committee membership is to include representatives from BC Hydro, BC Ministry of Environment, Fisheries and Oceans Canada, Katzie First Nation, District of Maple Ridge, and Alouette River Management Society.

3.0 COST

The total cost of the 7 year monitoring program, including year 1 (2008) and a component of year 2 expenditures through July 2009, is estimated to be roughly \$1,316,879 (in 2006 dollars). When incorporating a future annual inflation rate of 2%, the anticipated cost of the program is expected to be closer to \$1,437,623. Average annual cost for the remaining 5 full implementation years is expected to be \$185,258 (in 2006 dollars), but will vary between \$172,107 and \$203,909 depending on the tasks to be completed or the equipment to be purchased.

ALUMON-5

Water Temperature

1.0 PROGRAM RATIONALE

1.1 Background

Water temperature downstream of the Alouette dam continues to be a concern for FTC members. Though some data has been collected since the LLO was fully opened in 1996, it was considered incomplete and tended to raise more questions than provide answers. There was general agreement among the FTC members that temperature conditions in the river have improved considerably since the 1996 change in LLO operation. However, there remained some uncertainty as to whether conditions improved to the extent that high water temperature impacts were fully mitigated. Two particular impacts were identified;

1. High summer temperatures approaching incipient lethal limits of rearing salmonids that impact survival and growth during the summer critical rearing period.
2. A general increase in stream temperatures that shifts fish community structure from a cold-water, primarily salmonid system to a warm-water primarily cyprinid system.

To address these uncertainties, the FTC recommended that a formal water temperature monitor be implemented that measures water temperature throughout the watershed, including the reservoir, to better assess the possible range of operational actions that can be taken to mitigate measured impacts.

1.2 Management Questions

The FTC identified the following management questions that are to be addressed by the water temperature monitor:

1. How often are water temperatures $\geq 25^{\circ}\text{C}$, the incipient lethal temperature of most stream rearing salmonid species, including the duration of each event and the frequency of occurrence?
2. Is the duration of observed warm water events less than 1 day, thus limiting exposure to warm waters and therefore thermal stress impacts?
3. Are warm temperature events restricted to certain sections of river, indicating the inflow of cooler waters into system (most likely ground water)?

It is assumed that ground water inputs provide thermal refugia, allowing fish to escape periods of excessively warm water.

4. Is the duration and frequency of warm water events such that it would promote a shift in fish community structure and/or reduce summer survival and growth of rearing juvenile salmonids, as indicated by a change in salmonid smolt numbers?

It is assumed that a shift in community structure cannot occur without observing a loss in salmonid rearing capacity.

5. Given the extent of thermal stratification in the reservoir and the location of the LLO, is there an operational change that can be implemented to mitigate the occurrence of warm water events.

1.3 Summary of Hypotheses

Management Question 1 is descriptive in nature and there does not readily lend itself to hypothesis testing. Management questions 2 and 3 lead to the following six testable hypotheses:

- H₀1: The duration of warm water events are greater than the tolerance threshold (maximum temperatures that can be tolerated for periods less than 1 day) for rearing salmonids

A literature search will have to be carried out to determine the length of exposure that salmonid juveniles are able to tolerate with little or no impact. Alternatively, a maximum weekly average temperature statistic can be used (Armour 1991, Eaton et. al. 1995)

- H₀2: Average daily peak water temperatures are similar between sections.

- H₀3: Average daily water temperatures are similar between sections.

- H₀4: Average duration of warm water events is similar between sections.

- H₀5: The frequency of warm water events is similar between sections.

Management Question 4 will require use of the smolt enumeration data collected during Monitor 1 to test for correlations between smolt output and the occurrence of warm water events:

- H₀6: Variability in smolt output, as measured in Monitor 1, is correlated with the occurrence of warm water events.

It is assumed that a persistent loss in smolt enumeration, correlated with a high occurrence of warm water events, would be indicative of a potential shift in fish community structure.

It may be necessary to define 'warm water events' in different ways to fully explore the nature of the relationship. The choice of definition should be accompanied with a clear description of the underlying rationale.

Management question 5, like question 1, is descriptive in nature and does not lend itself to hypothesis testing. Rather, the information will be used in a modeling exercise (conceptual and/or numerical) to determine the range of operational actions, if any, that can be taken to mitigate the occurrence of warm water temperature events.

1.4 Key Water Use Decision

The water temperature monitor is designed to address a number of uncertainties regarding the occurrence of water temperatures $\geq 25^{\circ}\text{C}$ that can impact both the growth and survival of rearing salmonids, as well as create a shift in community structure if persistent through time. There is also uncertainty in whether the impact, if found to occur, could be mitigated by changes in reservoir operations by taking advantage of the reservoirs' thermal structure and the location of the LLO. Results of this monitor would help resolve these uncertainties, and hence provide the information necessary to address the issue during the next WUP review in 2014.

2.0 PROGRAM PROPOSAL

2.1 Approach

The water temperature monitor will consist primarily of temperature data loggers installed at 6 locations along the length of the Alouette River, starting with the plunge pool immediately down stream of the dam, and ending downstream at the 224th St. Bridge. This will break the river into 5 sections to explore the possible mitigating effects of ground water sources and local inflows. In the reservoir near the inlet of the LLO pipe, a vertical array of temperature data loggers will be installed to track the thermal stratification process near the entrance to the LLO. All temperature loggers will be downloaded twice annually, and analysed at the end of each calendar year.

Included in the monitor is a cursory literature review to establish threshold temperatures and durations that define events that may have significant impact to the fish community. This is to build on the work already completed by Bruce (2005).

2.2 Objective and Scope

The objective of this monitor is to collect the data necessary to test the hypotheses outlined in Section 1.3 and hence, address the management questions presented in Section 1.2. The following aspects define the scope of the study:

1. The study area will consist of both the Alouette Lake reservoir (at the LLO inlet) and the river downstream of the dam to 224th St. Bridge.
2. The scope of the monitor will include a literature search of threshold water temperatures and exposure levels for rearing salmonids.
3. The scope of the monitor will include the development of a simple model to evaluate the range of possible operations that may mitigate the impact
4. The monitor will be carried out annually until the next WUP review period (2014)
5. A data report will be prepared annually summarising the data collected to date, as well as discuss inferences and present conclusions as they pertain to the impacts of the WUP over time.
6. A final report will be prepared at the end of the monitor that summarises the results of the entire monitoring program, discusses inferences that can be drawn from the data pertaining to the impacts of the WUP over time, and presents conclusions concerning the hypotheses and the management questions in Section 1.2.

2.3 Methods

2.3.1 Literature review

At the start of the monitor, a cursory literature review will be carried out to establish threshold temperatures and durations that define events that may have significant impact to the fish community during the critical summer growth period (July to September). This is to build on the work already completed by Bruce (2005) and is to include the following temperature criterion in tabular form:

1. Upper Lethal Temperature (ULT)

The maximum temperature that 50% of fish could survive for very short periods for a given acclimation temperature (e.g., 10 min)

2. Short term Maximum Survival Temperature (SMT)

The maximum temperature that 50% of fish could survive for less than a day for a given acclimation temperature (equivalent to the incipient lethal temperature)

3. Ultimate Upper Incipient Lethal Temperature (UUILT)

The maximum temperature that 50% of fish could survive for less than a day irrespective of acclimation temperature

4. Final Thermal Preferendum (FTP)

Temperature selected when given the choice that is independent of acclimation temperature - thought to correspond to the temperature that maximises overall physiological function.

5. Maximum Weekly Average Temperature That Should Not Be Exceeded (MWAT)

A calculated thermal maximum criterion that attempts to account for variable stream temperature conditions (Armour 1991). It is calculated as;

$$MWAT = FTP + \frac{UUILT - FTP}{3}$$

The species of interest are to include the fry and parr life stages of cutthroat trout, steelhead trout, coho salmon, and Chinook salmon.

2.3.2 Field Methods

Reservoir Temperature

The vertical profile of reservoir water temperature will be tracked through time using a vertical array of six temperature data loggers suspended in the vicinity of the inlet structure of the LLO. The data loggers will be spaced 2 m apart, the lowest of which will be placed at an elevation of 114 m (corresponding to the top of the LLO inlet). The top data logger will sit at elevation 124 m.

The data loggers will be programmed to measure water temperature once every hour and will be down loaded four times annually. All temperature loggers will be calibrated for precision and accuracy so that they all measure the same value for a given temperature).

River Temperature

Temperature data loggers will be installed at five locations on the South Alouette River between Alouette Dam and the 216th St Bridge. They are to correspond to those of previous data collection efforts (Bruce 2005) including:

1. At the LLO (to measure water a temperature leaving the Alouette Dam)

2. Immediately downstream of the Alouette Dam plunge pool (approx 50 m downstream of the LLO to evaluate the effect of plunge pool residence time on outflow temperatures)
3. At the confluence of the Mud Creek,
4. At Alco Park Hatchery
5. At 224th St Bridge

The data loggers will be programmed to measure water temperature once every hour and will be down loaded twice annually. All temperature loggers will be calibrated for accuracy (i.e., ensure that they read the same value for a given temperature or provide a correction factor).

2.3.3 Safety Concerns

A safety plan will have to be developed for all aspects of the study in accordance to BCH procedures and guidelines. It is important to note that the installation and downloading of temperature data loggers must always be carried out by at least two crew members and that appropriate daily check-in and checkout procedures must be followed. Installation of the vertical array of temperature data loggers will require prior approval by BH Hydro to ensure that it does not interfere in anyway with the facilities' operation

2.3.4 Data Analysis

All data will be entered into a common database in a standard format for analysis. This will ensure that all data collected over the years on monitoring are compatible and can be analysed with transformation.

Reservoir temperatures

Data analysis will consist primarily of the development of annual depth – time plots of temperature isotherms to identify the elevations that define the reservoirs epilimnion, metalimnion, and hypolimnion (Wetzel 2003), as well as plot annual water temperature at the entrance of the LLO.

River temperatures

Data analysis will consist primarily of summary statistics, including annual plots of daily average, minimum and maximum temperatures for each site, average monthly differences of site temperatures relative to that of the LLO, annual frequency and duration of water temperature events that exceed critical threshold values, and the calculation of 7 day moving averages (i.e., 168 hrs) to prepare annual plots of observed MWAT for comparison with critical threshold values (Section 2.3.1).

Hypothesis H_01 will be tested using a simple z test to determine the proportion of events that lie below the threshold value for the temperature criterion of interest, including ULT, SMT, UUILT and MWAT (Zar 1974). Between section differences will be explored using analysis of variance (ANOVA) and will involve data that are pooled across all years of data collection. Where necessary, the data will be transformed to ensure that assumptions of normality and homoscedasticity are not violated.

Hypotheses H_02 to H_04 will be tested using two way analysis of variance (ANOVA) to explore differences between sections by month (Zar 1974). As in H_01 , the data will be transformed where necessary to ensure that assumptions of normality and homoscedasticity are met.

Because frequency data are being compared in H_05 , this analysis will be done using the Chi Square statistic.

At a minimum, Hypothesis H_06 will be tested through regression analysis using annual smolt abundance data collected in Monitor 1 as the dependent variable. Independent variables can include a number of the summary statistics used above, though care must be taken to avoid the risk of spurious correlations. The analysis may be carried out for each species of interest, or as a group. Because other factors may mask or confound the temperature response, it may be necessary to explore the effect of other possible limiting factors such as average discharge, occurrence of flooding, over-wintering temperatures, and run strength, using multiple regression techniques. Where necessary, data transformations will be used to ensure that assumptions of normality, linearity and homoscedasticity are met.

2.3.5 Reporting

Project reporting will consist of annual data reports and a comprehensive final report at the conclusion of the monitor. The annual data reports will summarise the year's findings and include a short discussion of how the year's data compare to that collected in previous years. It will include a brief description of methods, present the data collected that year, and report on the results of all analyses.

At the conclusion of the monitor, a final comprehensive report will be prepared from all of the annual reports written to date that:

1. Re-iterates the objective and scope of the monitor,
2. Presents the methods of data collection,
3. Describes the compiled data set and presents the results of all analyses, and
4. Discusses the consequences of these results as they pertain to the current WUP operation, and how it may or could factor into future decision making.

All reports will be submitted to regulatory agencies for review and comment prior to being finalised for general release.

2.4 Interpretation of results

Tests of H₀1 will provide the information necessary to assess the occurrence and extent of warm water events and to evaluate the potential risk to rearing salmonid populations. This evaluation however, will be theoretical in nature as it relies on published thermal criterion. Verification of impacts, if any, will be done by testing H₀6, which looks for correlations between summer rearing temperatures and smolt output. A strong correlation would be indicative of a causal link and would trigger investigation into measures that could be taken to mitigate the impact, particularly with respect to operations (Management Question 5).

Hypotheses H₀2 to H₀5 all relate to Management Question 3 which is concerned about spatial differences in temperature response. Rejection of some or all of these hypotheses would suggest that the occurrence of harmful warm water events may be localised, and that impacts may not be so widespread as to affect smolt output if no water temperature correlations are found (i.e. H₀6 is not rejected). It may be inferred that the localised drops in water temperature are the result of cooler groundwater entering the system (at least through an interchange or mixing of hyporheic and surface streamwater, Wetzel 2001), and that in turn, there exists the possibility of thermal refugia.

2.5 Schedule

The water temperature monitor will be carried out annually for the duration of the monitor until the next WUP review period in 2014. A data report and executive summary of the year's data will be due the 1st week of February the following year. The final report will be due just prior to the start of the next UP review process in 2014, though the precise due date will be determined at BC Hydro's discretion.

2.6 Budget

The total cost of the 7-year water temperature monitor enumeration monitor, including February 2008 (year 1) through July 2009 (portion of year 2) expenditures of \$8,586, is estimated to be \$36,669 in 2006 dollars. Taking into account an average inflation rate of 2%, the total cost is expected to be closer to \$31,463 over the remaining 6-year period. The average annual cost of the monitor, not taking into account inflation, is expected to be \$5,818 per year.

2.7 References

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