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-6

Kokanee Age-Structured Population Analysis

1.0 PROGRAM RATIONALE

1.1 Background

The FTC expressed some concern about the impacts of reservoir operations on kokanee spawning success. With the fertilization program, the population of kokanee in the reservoir has increased dramatically (anywhere from 3 to 28 times the pre fertilization abundance estimates depending on the year), indicating that the there is sufficient recruitment to fully seed the increased production potential of the reservoir. At issue however, is whether current level of production represents the full potential of the reservoir with the fertilization program in place, or whether further increases are hampered by what may be operations-based limitations to reproductive success. The issue is further complicated by the fact that smolt releases are being planned, which will remove a proportion of the spawning population each year. As well, a re-introduction of anadromised kokanee/sockeye is also planned. The success of both management activities however is uncertain, as are the potential consequences to the existing kokanee population.

Hydro-acoustic assessments of kokanee biomass collected since 1998 suggest that the population has responded well to the addition of fertilizer, and to date has shown no strong indication of a recruitment limitation to production (Greg Wilson, pers comm.). As well, the range of WUP operations being considered by the CC does not change significantly from current practice during the spawning and incubation period; as a result no incremental impact is expected from implementation of WUP operations. Furthermore, modelling done to date for the WUP process suggests that there may limited opportunities to alter operations during the spawning/incubation period because it occurs during a period of high flood risk.

Given the confounding effects of smolt out-migration and sockeye re-introduction, the uncertainty that reproductive success is indeed limiting, and the fact that operations are unlikely to change with WUP implementation, the FTC recommended that the year to year variability in reservoir operations (both since 1998 and post WUP implementation) be examined for correlations with the ongoing hydro-acoustic kokanee population monitor. Specifically, the FTC recommended the following analysis:

1. Correlation analysis between the extent of reservoir fluctuation during the spawning and incubation period and age structure of the kokanee population.

   Should an impact arise due to reservoir fluctuation, it is assumed that it will show up as a drop in the number of age 1 fish in the following year. It should be noted *that there are likely to be compensatory mechanisms at play that may dampen the response over time and that the impact may not be carried over between years to create measurable response on the number of spawners. Because of this, the analysis should involve all cohorts and include between year comparisons.*

2. Correlation analysis between the extent of reservoir fluctuation during the spawning and incubation period and size at age.

   This analysis takes advantage of the fact that size at age data can provide an indication of whether the population is approaching or moving away from the system's capability. As the size of fish for a given age class increases, it is generally indicative of reduced competition of food resources, and if the availability of food resources remain more or less constant (as one would expect in a fertilized lake system), it is also indicative of a decreasing population of fish. As fish size for a given age class decreases, it is generally indicative of increasing competition for food resources, and therefore increasing fish abundance (again if food resources remain constant through time).

1.2 Management Questions

The FTC identified three management questions to be addressed through the kokanee age structure monitor:

1. Is the existing kokanee population in the Alouette Lake reservoir recruitment limited?

2. If there is evidence of a recruitment constraint to productivity, can it be linked to reservoir operations, in particular the extent of reservoir fluctuation during the spawning and incubation period (deemed to be mid-October to the end of February)?

3. If found linked to reservoir operation, what is the nature of the relationship and can it guide the development of possible mitigative reservoir operations?

1.3 Summary of Hypotheses

The management questions identified in section 1.2 are to be addressed through tests of the following set of three hypotheses. The first hypothesis pertains to Management question 1 while the last two relate to management question 2:

$H_0$1: Once standing crop has stabilised with the annual addition of fertiliser, the size at age of the kokanee population remains stable or decreases with time.

It is critical that standing crop has reached a state of equilibrium with the addition of fertiliser, i.e., the annual biomass of kokanee has hit a plateau following years of increase with the onset of the fertilization program. Once the state has been reached, rejection of $H_0$1 would indicate that the population may be recruitment limited.

$H_0$2: Drops in fry abundance, relative to estimates in previous years and to that predicted by estimates of mature kokanee, are uncorrelated with the extent of reservoir fluctuations during the spawning and incubation period.

One way to integrate reservoir fluctuations through time and there impact on reproductive success is to calculate an effective spawning area over the range of possible reservoir elevations. Effective spawning area is the area that can be spawned in and remain wetted for the duration of the incubation period. This relative statistic has been successfully used in other WUPs to calculate between year differences in relative spawning success. Results of the test will establish a link between reservoir operations and relative spawning success. It should be stressed that this is an index, not an absolute measure of spawning habitat.

$H_0$3: Drops in fry abundance observed in one year do not persist through time to cause an impact on the abundance of mature kokanee.

Test of this hypothesis will establish whether inter annual variability in fry abundance is within the population's capability to absorb with out impact on the cohort's future reproductive potential. Failure to reject the hypothesis will indicate that the impact of reservoir operation may affect spawning success, the magnitude of the impact is insufficient to cause a population impact.

It should be stress that the results of the monitor may be confounded by the release of smolts of the reservoir, as well as the introduction of re-anadromised kokanee and sockeye to the reservoir. Interpretation of the data should take into account these two factors.

Management question 3 will be addressed through inference based on the results of Hypotheses $H_0$1 to $H_0$3.

1.4 Key Water Use Decision

This monitor is designed to address a key uncertainty in the nature of the relationship between reservoir operations and recruitment potential of kokanee in Alouette Lake reservoir. With greater clarity on the issue, particularly in light of the confounding effects of kokanee smolt releases and the re-introduction of the anadromized kokanee spawners, the CC will be better informed to address this issue at the next WUP review period in 2014.

2.0 PROGRAM PROPOSAL

2.1 Approach

The kokanee age-structured population analysis will rely mainly on the ongoing hydro-acoustic program and fish survey data currently being collected as part of the fertilization program monitor. The hydro-acoustic survey follows all of the provincial standards for such work. Though suitable for the needs of the fertilization program, recent results from a similar program on Stave Lake Reservoir have found this to be inadequate for the present monitor. There is insufficient resolution of hydro-acoustic targets to distinguish between different kokanee age classes and the presence of other, similarly sized fish species or larger planktonic organisms. To resolve this poor resolution issue, additional gillnetting will have to be done to better characterise the spatial and temporal distribution of fish in the reservoir. This will give the necessary information to identify hydro-acoustic targets with much greater accuracy. Because this additional gillnetting work is unnecessary for the purposes of the fertilization program, this additional work will have be funded through WUP sources. Funding will also be made available to cover the extra costs of data analysis and report writing needed to satisfy WUP requirements.

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 be restricted to the Alouette Lake Reservoir and rely on the annual hydro-acoustic work currently being done as part of the fertilization program monitor.

2. The monitor will be carried out annually until the next WUP review period (2014)

3. A fish sampling program similar to that used in the Stave Reservoir Fish Biomass monitor (e.g., Stables and Perrin 2007) will be carried out for the first two years of the monitor, and then every second year thereafter.

4. A data report, including a detailed executive summary and short presentation, 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.

5. 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 question in Section 1.2.

2.3 Methods

2.3.1 Field Methods

Though no additional hydro-acoustic work will be required to meet the needs of the present monitor, it will be necessary to collect additional fish survey data to improve the identification of hydro-acoustic targets. Fish capture will primarily be by gillnets and will follow the setting protocols described by Stables and Perrin (2007) for the Stave Reservoir (i.e., floating shoreline sets, sinking shoreline sets, and mid water sets, each with specific gillnet panel arrangements), however, mid water sets will be set to maximize kokanee capture through the entire 1+ through 3 + age structure as per recent Ministry of Environment Alouette Reservoir gillnetting assessments. In the first year, sampling stations will be selected and benchmarked for future reference. Sampling will be repeated at these sites in all subsequent years to ensure consistency in between-year data. In addition, sampling shall be done at roughly the same time each year and is to be carried out within 2 days of the hydro-acoustic survey.

2.3.2 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.

Fish catch and morphometric data will be described using simple descriptive statistics and summary tables. The primary intent of the analysis will be to support interpretation of hydro-acoustic survey data, which will follow the protocols and techniques described by Stables and Perrin (2007). However, because of the consistency in which the data is collected each year, between year comparisons of catch-per-unit-effort and fish morphometry (e.g., condition factor) is possible and should be pursued if the analysis can be done at little or no additional cost to the program.

Hypothesis $H_0 1$ will be tested using a generalized linear mixed effects model. The data will be modeled to represent the two eras of 'pre' and 'post' fertilization as a fixed effect and year will be modeled as a random effect to account for the inter-annual variation in individual lengths that is likely to be present. The response variable will be the length of the age-3 (spawners) kokanee as determined from the gill net sampling.

Tests of $H_0 2$ will involve use a stock recruitment curve (non-linear regression) to determine the relationship between the number of spawners and the response variable of numbers of fry the following year. The number of spawners in each year will be estimated based on the annual acoustic data and the proportions of age-3 fish caught in the gill nets. Simple regression analysis will not be used because the relationship between the number of spawners and subsequent fry abundance is not expected to be linear. The covariates of reservoir variability during the spawning and incubation periods and the fertilizer amounts by year will be incorporated into the model. Several measures of reservoir variability will be considered including a relative effective spawning area index.

Hypothesis $H_0$3 will be addressed through the use of stock-recruitment models where age-0 fish will be the stock and age-1 fish will be considered the recruits. The abundance of age-0 fish in each year will be obtained from the acoustic trawl estimates. The numbers of age-1 fish will be obtained from the acoustic trawl estimates combined with the proportions of age-1 fish caught in the gill nets. The advantages of the stock-recruitment approach are that 1) the carrying capacity of age-1 fish can be estimated 2) the numbers of age-0 fish required to reach this capacity can be estimated and 3) the deviations in the number of stock or recruits required to reach carrying capacity can be modeled in relation to environmental variables or reservoir operations.

2.3.3 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

A significant upward trend in size at age would be considered indicative of a drop in adult recruitment, though it would not provide any information on whether the cause is the result of reservoir operations related spawning failure, the loss of smolts due to the spring surface release operation, or some other factor (e.g., intensive recreational fishing). Inferences on possible causal mechanisms will have to rely on the results of other studies or analyses, including the correlation analysis of operational impacts on fry abundance (test of $H_0$2) and the chi-square analysis of age class structure (test of $H_0$3)

Rejection of $H_0$2 would imply that there is a strong causal link between reservoir operations during the spawning/incubation period of Kokanee salmon and reproductive success. It would imply that significant spawning may be occurring within the drawdown zone area, and that drawdown events have the potential to cause significant egg mortality. Failure to reject $H_0$2 would indicate otherwise, that spawning for the most part lies below the drawdown zone, and that year to year variability in fry abundance is the result of some other factor(s) affecting fry recruitment success.

As noted section 2.3.2, the pattern of significant deviations between age classes as determined from chi-square analyses of annual age class abundance data will serve as the indicator of impact severity. If the recruitment losses are found to persist for one or more generations (i.e., Condition 3 in section 2.3.2), then the impact will be deemed significant. To reject $H_0$3, the persistent age class recruitment loss must begin with a significant drop in fry abundance compared to other years, and that drop must be related to a reservoir operations impact; implying that $H_0$3 cannot be rejected unless $H_0$2 is rejected as well.

Establishing a correlation between some measure of effective spawning area (a statistic to summarise potential reservoir impacts on the spawning and incubation periods of kokanee) and fry abundance would validate the index as a meaningful performance measure for use in future WUP processes. It would provide a means of gauging the impact of alternative operational strategies in simulation exercises, the results of which can be used to devise alternative operational constraints that are less harmful to the reservoir's kokanee population.

2.5 Schedule

The kokanee age-structured population monitor will be carried out annually until the next WUP review period in 2014. Additional Fish surveys will be done in the first two years of the monitor and every second year thereafter. A data report and executive summary of the year's data will be due the 1st week of December the following year based on fall data collection and subsequent data analysis. 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 kokanee age-structured population monitor including 2008 expenditures of $12,248 is estimated to be $77,381 in 2006 dollars. Taking into account an average inflation rate of 2%, the total cost is expected to be closer to $72,145 over the remaining 6-year period. The average annual cost of the monitor, not taking into account inflation, is expected to be $11,054 per year.

2.7 References

Hastings, A. 1997. Population Biology: Concepts and models. Springer-Verlag New York Inc. New York, N.Y. 220 pp.

Stables, T. B., and C. J. Perrin. 2007. Abundance and biomass of fish in Stave Reservoir in September 2006. Report prepared by Limnotek Research and Development Inc. and Shuksan Fisheries Consulting for BC Hydro. 43p

Zar, J.H. 1974. Biostatistical Analysis. Prentice-Hall, Inc. Englewood Cliffs, N.J. 620 pp.