BC Hydro

Alouette Water Use Plan

Monitoring Program Synthesis Report

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

Draft Report

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Executive Summary

This document describes the second Alouette Project Water Use Plan (ALU WUP) that was initiated in 2005 and finalized in 2006. In 2009, the Comptroller of Water Rights (CWR) issued Orders in response to the ALU WUP under the Water Act, which included implementing seven monitoring projects to assess effects of operations on fish, fish habitat and archaeological resources. These seven monitoring projects were conducted over the years 2008 – 2014. The Alouette system is connected to the Stave/Ruskin system through a diversion tunnel at the north end of Alouette Lake Reservoir. Information on the Stave WUP monitoring program information can be found in a separate synthesis document. Out of the seven studies, the first five were conducted on the Alouette River below Alouette Dam and above the confluence with the North Alouette River. The remaining two studies focused on the reservoir area examining Kokanee age structure (ALUMON-5) and archaeology monitoring (ALUMON-7). Throughout the duration of the study period, the Alouette Fertilization Program has been adding nutrients to the reservoir and has provided data for ALUMON-5. The seven Alouette WUP studies were completed by 2014 and all attempted to answer their management questions and determined benefits if any, achieved by WUP operations and have provided information that will be used to make future operational changes and WUP Order review decisions. This document was prepared as part of the WUP Order Review process, and summarizes results from the seven monitors, and outlines whether benefits anticipated by the WUP Consultative Committee (CC) are being realized under the current operation constraints.

The seven studies were as follows:

Alouette River Programs:

- **ALUMON-1: Smolt Enumeration**: The objective of this seven year study was to determine out migration numbers of salmon and trout fry and smolts in the Alouette River.
- **ALUMON-2: Kokanee Out Migration**: The objective of this seven year study was to identify the initiation, duration, and peak of the Kokanee smolt out migration in the Alouette River.
- **ALUMON-3: Substrate Quality**: The objective of this seven year study was to quantify relative sediment distribution within the Alouette River to identify the need for a directed flushing flow.
- **ALUMON-4: Sockeye Adult Enumeration**: The objective of this seven year study was to determine the run timing and enumeration of the return of successfully re-andromised adult Kokanee and stray Sockeye from other watersheds in the Alouette River and compare ocean survival rates of returning re-anadromised Kokanee to other BC populations.
- **ALUMON-5: Water Temperature**: the objective of this seven year study was to quantify the frequency, duration and magnitude of warm water temperatures within the Alouette River to assess the need and feasibility of operational actions that can be implemented to mitigate potential impacts.

- **ALUMON-6: Kokanee Age Class Structure**. The objective of this seven year study was to determine the nature of the relationship between reservoir operations and recruitment potential of Kokanee in Alouette Lake Reservoir.

- **ALUMON-7: Archaeological Monitoring**. The objective of this three-year program was to inventory and conduct a qualitative assessment of the nature and extent of the impacts to archaeological sites as a result of reservoir operations in the Alouette River Watershed.

Table E1 below summarizes the objectives, management questions, results and operational implications of each monitor

Table E1. Summary of objectives, management questions, outcomes, and operational implications for the Alouette WUP monitoring programs.

Study name	Objectives	Management Questions	Response	Implications
ALUMON-1 Smolt Enumeration	Determine out migration of salmon and trout fry and smolts in the South Alouette River using downstream trapping methods and mark recapture analysis.	1. Is the average base flow release of 2.6 m^3/s from the Alouette Dam (obtained by fully opening the low level outlet) adequate to sustain or improve current levels of salmonid smolt production downstream of the dam? The species of interest include Chum, Pink, Chinook, and Coho salmon as well as Steelhead and Cutthroat trout. 2. Following their migration out of Alouette Lake, do the Kokanee smolts immediately continue their migration out of the Alouette River or do they delay their seaward migration for a period of time? 3. Using Chum salmon counts at the Allco Park Hatchery as an indicator of run strength and the results of the substrate quality monitor, is there evidence of a persistent, declining trend in egg to smolt survival that would suggest a degrading condition in spawning substrate quality.	1. Ordered increased minimum flows have continued to support stable or increasing levels of smolt productivity in all salmon species. Furthermore, using the spillway gates to attract outmigration in the spring was seen as an effective downstream passage alternative to the low level outlets. Monitoring also confirmed that the “pulse” flows tested during the monitoring program do not improve Kokanee smolt downstream passage success. 2. There was a clear indication from results of both rotary screw trap (RST) trapping sites that Sockeye smolts do not delay leaving the Alouette system. 3. Based on study observations, there was no evidence of declining trends in egg to fry survival in Chum. Results of ALUMON-6 indicate that substrate quality was stable through the monitoring period. Variable survival was only seen during high escapement years, likely due to density dependent interactions (over-spawning).	Ordered outlet gate operations are adequate to support targeted salmonid productivity. Current base flow targets and timing support Sockeye smolt outmigration Base flows support Chum egg to fry survival.

Study name	Objectives	Management Questions	Response	Implications
ALUMON-2 Kokanee Out-Migration	Test the effectiveness of surface flow releases, test the effectiveness of pulse flows and determine the duration of smolt outmigration.	1. Is the surface release of at least 3 m^3/s from the Alouette Dam (obtained through the spillway gate) adequate to promote the downstream migration of Kokanee smolts out of the Alouette Reservoir? 2. Does a post surface release flush of 6-9 m^3/s, lasting 7 days following the tail end of the out migration period, encourage more smolts to leave the system? 3. How long should the surface release last to ensure out migration of all smolts prepared to leave the system?	1. This study confirmed that the spillway releases of at least 3 m^3/s were adequate to promote downstream migration of Sockeye smolts out of Alouette Reservoir. 2. It was determined that the post surface release flush (pulse flows) did not encourage any additional smolts to leave the system. 3. Smolt migration occurs in the south coast region during freshet or slight warming of the lake outlet typically from April to mid-June	Spillway surface flow releases are effective at attracting volitional Kokanee migrants during the out-migration timing window. April 15-June 14 is the appropriate timing for surface flow releases. Pulse flow releases mid-June are not effective. However, earlier pulse flow releases have only recently been implemented and their effectiveness is still under review.
ALUMON-3 Substrate Quality	Evaluate the long term transport of fine sediments in the Alouette River and assess effectiveness of flushing flows.	1. Do the results of the Toe-Pebble count (Wolman) procedure reflect the general composition of bed materials within the channel downstream of the Alouette Dam? 2. Is the <20% fines threshold adequate to distinguish a state in substrate quality that would require a prescribed flushing event? 3. Is an alternative methodology required to qualify/calibrate the results of the pebble count procedure? 4. For each year of the monitor, is a prescribed flushing flow necessary given the current state of substrate quality?	1. Yes. The sampling results observed during this study were consistent with other observations of substrate condition and the methodology has been successful in other systems. 2. Yes. Based on ALUMON-1 results, there is no indication that chum fry production are affected by gravel quality below 20% fines. The 20% level was only significantly exceeded once in the Alouette River prior to the implementation of the Minimum Flow Agreement. 3. No. Wolman's pebble count method has provided an efficient and adequate measure of substrate	As Wolman's pebble count methodology is an effective long-term indicator of substrate quality, natural frequency of flushing flows has proved to be effective in moving fine sediments with no further need for prescribed flushing flows.

Study name	Objectives	Management Questions	Response	Implications
			quality change; therefore, alternative methodologies are not required to qualify or calibrate the monitor's results. 4. Directed flushing flow could benefit certain sections of the river, but only on a localized basis. Observations indicated gravel quality issues were caused by natural occurrences and not always permanent (i.e., fallen tree, land slide increasing sediment load).	
ALUMON-4 Sockeye Adult Enumeration	Determine the run timing of successfully re-anadromised Kokanee and compare ocean survival rates of returning re-anadromized Kokanee to other BC populations.	1. Are the Alouette Lake Kokanee smolts successfully adapting to an anadromous existence by returning from the ocean environment to spawn in Alouette Lake? 2. What is the run timing of adult Sockeye returns so that an appropriate enumeration study can be carried out? 3. Are adult Sockeye caught during the monitor members of the 'Alouette stock' or are they strays from other nearby coastal systems? 4. Are ocean survival rates of returning re-anadromised Kokanee comparable to that of Sockeye stocks found elsewhere?	1. Many returning adults have been genetically identified as Alouette stock indicating migrating smolts had successfully adapted to an anadromous existence. 2. Run time was consistently during summer months (July and August) while a few fish were captured in the fall (September and October). 3. As above, many returning adults have been genetically identified as Alouette stock, with the majority of these fish arriving mid-July to mid-August. The majority of fish arriving late August through to October are strays from other systems. 4. Ocean survival rates of Alouette River Sockeye are extremely low and a significant factor in limiting the success of a re-anadromization program. Survival rates were generally lower than other Fraser River stocks, but within the ranges	There is little evidence to suggest that current trap and truck and fencing operations should be modified from its current mid-June to October operating window.

Study name	Objectives	Management Questions	Response	Implications
			recently observed during this period of poor ocean survival.	
ALUMON-5 Water Temperature	Quantify the frequency, duration and magnitude of warm water temperatures within the Alouette River to assess the need and feasibility of operational actions that could be implemented to mitigate potential impacts.	1. How often are water temperatures ≥25°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)? 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? 5. Given the extent of thermal stratification in the reservoir and the location of the Low Level Outlet (LLO), is there an operational change that can be implemented to mitigate the occurrence of warm water events.	1. Since 1999, daily average water temperatures did not approach the 25°C threshold; water temperatures rarely exceeded the upper salmonid tolerance limit of 21°C. 2. Generally, warm water events (≥21°C) occurred for a short time period; 91% of the occurrences lasted less than a day. Two warm water events lasted an entire day and one event lasted two consecutive days. 3. Warm water events were not observed consistently through the entire river. Only 9 of the 35 warm water events measured at the dam's plunge pool were also observed at all sampling sites within the same day. Typically, warm water within the plunge pool was cooled while distributing downstream. 4. A shift in fish community structure from a hypothesized persistent warming was not observed and is considered unlikely. 5. Since water temperatures are generally below the upper salmonid tolerance limit (21°C), and any events exceeding this threshold are rare and short in duration, operational changes were not investigated.	No mitigation measures for cooling water temperatures within the Alouette River are required. Temperatures do not exceed salmonid tolerance thresholds.
ALUMON-6	Determine the nature	1. Is the existing Kokanee population in the	1. Size-at-age analysis showed a slight	Two Water Use Plan

Study name	Objectives	Management Questions	Response	Implications
Kokanee Age Class Structure	of the relationship between reservoir operations and recruitment potential of Kokanee in Alouette Lake reservoir.	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?	size decline in age-3 Kokanee since 2003, which indicates that the population is unlikely to be recruitment limited. Increased size at age usually indicates low densities which can be attributed to low spawning success. 2. The stock recruitment model indicated that annual variability in fry recruitment was not correlated with the extent of reservoir fluctuations during the spawning and incubation period. 3. The spawner-recruitment model predicted that daily reservoir elevation changes could potentially limit recruitment and the reproductive success of Kokanee; however, the relationship was not considered significant and demonstrated substantial uncertainty.	Ordered operations were hypothesized to potentially affect the productive capacity of Alouette Reservoir: reservoir operations (effect on spawning success) and smolt outmigration operations (effect on spawner abundance). While reservoir operations were modeled to have no effect on fry production, smolt outmigration effects remain uncertain as they were not part of the model.
ALUMON-7 Archaeological Monitoring	Maximize the protection of cultural resources within the Alouette System.	1. Where are the archaeological sites in the reservoir? 2. What are the relative heritage values of identified sites? 3. What is the nature and extent of the impacts to archaeological sites that are caused by reservoir operations? 4. Are there archaeological resources that are impacted by river flows? 5. Would an operation change potentially minimize those impacts?	1. Eight sites were identified. All sites are located on the southwest shore of the reservoir between Gold Creek and the Dam, with the exception of one site located at the narrows on the northwest shore. 2. Sites were rated from low to moderate scientific significance. All sites have high cultural and ethnic significance. 3. Combined effects of multiple years of scouring and erosion and accretion. 4. No sites were identified along the river. 5. No operational changes were recommended.	The study provided an assessment of effects to archaeological sites directly related to reservoir operations and concluded that further surveying and testing was required. Recommendations for archaeological site management were provided to BC Hydro's Reservoir Archaeology Program as these activities fall under the purview of the Heritage

Study name	**Objectives**	**Management Questions**	**Response**	**Implications**
				Conservation Act and are outside the jurisdiction of the Comptroller of Water Rights.

Acknowledgements

This document and related monitoring programs were funded by BC Hydro's Water License Requirements program for the Alouette Project Water Use Plan. BC Hydro would like to thank the Alouette River Management Society, Creekside Aquatic Sciences, Greenbank Environmental Inc., Katzie Development Corporation, LGL Limited, Poisson Consulting Ltd., Redfish Consulting Ltd., Ross Davies, and Westslope Fisheries Ltd for their contributions to the program.

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Glossary of Terms

Smolt	A juvenile salmonid that undergoes a chemical transformation in preparation for its migration from freshwater to saltwater.
Volitional	Voluntary
Spawning success	Degree of successful redd development, egg deposition, fertilization and incubation prior to emergence.
(Re-) anadromization	The process of incorporating ocean rearing into a salmonid life history. For Kokanee, the process where juveniles volitionally migrate out of their natal habitat to the ocean and return as Sockeye adults.
O. nerka	Binomial name *(Oncorhynchus nerka)* for Sockeye salmon

Alouette Water Use Plan
Monitoring Programs Synthesis Report

1. INTRODUCTION

The Alouette Water Use Plan (ALU WUP) was initiated in 1996 and reviewed in 2005. The Consultative Committee determined that there were still remaining uncertainties that needed to be addressed regarding the effects of BC Hydro operations on aquatic resources downstream of Alouette Dam on the South Alouette River (herein referred to as the Alouette River). In 2009, the Comptroller of Water Rights (CWR) issued Orders in response to the review of the ALU WUP under the Water Act that included the undertaking of seven monitoring projects to assess for anticipated benefits to fish, fish habitat, and water quality (CWR 2009). The seven monitoring projects included:

1. A study to quantify salmon and trout fry and smolt out migration in the Alouette River;
2. A study to identify the initiation, duration, and peak of Kokanee smolt out migration in the Alouette River;
3. An assessment of relative sediment distribution within the Alouette River;
4. A study to determine the run timing and enumeration of re-anadromised adult Kokanee and stray Sockeye in the Alouette River;
5. A monitor to investigate the frequency, duration and magnitude of warm water temperatures in the Alouette River;
6. An assessment of Kokanee recruitment potential in Alouette Lake reservoir; and
7. A study to inventory, assess, and mitigate impacts to archaeological remains in the Alouette River Watershed.

These monitoring projects were conducted over the years 2008 to 2014.

With these projects now complete, BC Hydro has scheduled a Water Use Plan Order Review to occur for the Alouette and Stave Watersheds in 2019. The review responds to the Alouette WUP Consultative Committee recommendation to undertake a review upon completion of the monitoring programs.

This document was prepared as part of the Order Review process. It summarizes results from the above seven monitors and outlines whether benefits anticipated by the Consultative Committee are being realized under the current operating constraints. The specific objectives of this report are to:

- Provide a summary of the objectives, activities, and results for each of the seven monitors;
- Relate monitor findings to the objectives of the Alouette WUP;
- Describe any data gaps, particularly those that affect the ability of a monitor to address the WUP objectives and the Orders issued in response to the WUP;
- Provide recommendations to address any of the above data gaps; and
- Provide a list of potential operational implications.

2. BACKGROUND

2.1 Hydroelectric Facilities

The Alouette-Stave Falls-Ruskin generating complex includes four dams, a 1090m long diversion tunnel and three powerhouses (Figure I-1 – Blind Slough Dam adjacent to Stave Falls Dam, and Ruskin Dam downstream of Hayward Lake, are missing from the figure). These facilities are located approximately 64 km east of Vancouver, north of the Fraser River between Haney and Mission. The Alouette Dam is located at the south end of the 17 km long reservoir (Table I-1). Approximately 24 km downstream of the dam, Alouette River discharges into Pitt River. The intake for the diversion tunnel to the Alouette Powerhouse (9.0 MW) is located at the north east end of the reservoir discharging into Stave Lake Reservoir. The ALU Powerhouse has been out of service since February 5, 2010 and is awaiting redevelopment. The proposed conditions for the operation of Stave Falls and Ruskin hydroelectric facilities are covered in the Stave River Water Use Plan (BC Hydro 2003).

Table 1. Alouette Project general information. Referenced from BC Hydro website (August 2017) and BC Hydro (2003).

Dam Name	Alouette Dam
Year of Completion	1936; rebuilt 1983
Dam Type	Earthfill embankment
Dam Use	Storage
Dam Height	21.5 m
Spillway Type	Gated sluice way and free overflow
Max. Discharge Capacity of Spillway	1257 m^3/s (Probable Maximum Flood)
Generating Station	Alouette
Nameplate Capacity	9 MW
Storage	198.6 million m^3
Reservoir Name	Alouette Lake Reservoir
Reservoir Area at Max. Normal Level	1600 ha
Water Course	Alouette River
Drainage Area	202 km^2
Reservoir Operating Range	12.9 m
Upstream Project	n/a
Downstream Project	Stave Falls and Ruskin Dam
Nearest City	Maple Ridge, BC

Figure I-1. Site map of Alouette Dam, Alouette GS, and Stave Lake Reservoir and Stave Falls New GS.

3. Alouette WUP Process

The first Alouette Project WUP was initiated in 1996 accordance with Condition #14 of the Stave Falls Powerplant Replacement Energy Project certificate Disposition Order that required BC Hydro to develop a Water Use Plan (BC HYDRO ALU WUP 1996). The second Alouette Project Water Use Plan (ALU WUP) was implemented over a four year process starting in 2005 which followed the Water Use Guidelines developed by the province (Province of British Columbia 1998). The ALU WUP involved a review of all data collected since implementation of the 1996 WUP, an assessment of new knowledge in the basin, including changes in resource values, and a refinement in proposed conditions for the operation of the Alouette Project. The process created the following outputs (in chronological order):

Previous ALU WUP:

- The Alouette Stakeholder Committee: Process, Analysis and Recommendations (February - July 1996)
- Alouette Generating Station - Water Use Plan (September 25, 1996)

Current ALU WUP:

- Alouette Project Water Use Plan: Report of the Consultative Committee (BC Hydro 2006) – documentation of the structured decision making process which evaluated operating alternatives against objectives represented by the Consultative Committee (CC), and documented uncertainties that would define the study program for implementation following WUP approval.
- ALU WUP (BC Hydro 2009a) – submitted by BC Hydro to the CWR as the summary of operating constraints and implementation commitments (monitoring studies) to be appended to its Water Licenses.
- Alouette Hydroelectric System Order (CWR 2009) – the Water Act Order issued by the CWR (CWR) to implement the WUP as a condition of the 3 licenses associated with the Alouette project.
- Water License Requirements (WLR) Terms of Reference (monitoring; BC Hydro 2009b) – for monitoring studies ordered by the CWR; management questions and methodologies were prepared to address uncertainties defined in the WUP consultative process and submitted to the CWR for Leave to Commence.
- Study progress and annual watershed reports – reports summarizing annual data collection results for ordered studies were prepared and watershed activities were summarized each year in a watershed report and submitted to the CWR. All reports are available on BC Hydro’s WUP website:

  (https://www.bchydro.com/about/sustainability/conservation/water_use_planning/lower_mainland/alouette.html).

The operating conditions for the Alouette Hydroelectric System ordered by the CWR are shown in Table I-2. In addition, the CC felt there was uncertainty of the benefits associated with the following operating conditions (BC hydro 2009a):

- Spring surface release starting April 15 and ending June 14;

- A higher reservoir elevation (122.5 m) during the peak recreation season starting June 15 and ending Labour Day (September 5);
- Short recreation shoulder season ending September 15 when water levels are above 121.25 m; and
- Reconsidering the potential requirement for a prescribed flushing flow to clear fine sediments.

Table I-2. Operating conditions ordered by the Comptroller of Water Rights (CWR) for the Alouette Hydroelectric system (from BC Hydro 2009a).

System Component	Constraint	Time of Year	Purpose
Alouette Dam Outlet	▪ Base flow LLO release between 1.52 and 2.97 m^3/s	All year	Enhance downstream fisheries habitat
	▪ Crest gate target release of ≥ 3.0 m^3/s by maintaining a target reservoir level of about ≥ 121.85 m	April 15 to June 14	Kokanee out-migration
	▪ Increase discharge from the crest gate between 6 and 9 m^3/s for seven days to create a 'freshet pulse'.[1]	April 15 to June 14 (four out of every eight years)	Kokanee out-migration cue
	▪		
	▪ Ramping up rate will not exceed 6.3 m^3/s ± 15 % every 40 minutes	All Year	Public safety
	▪ Ramping down rate will be such that change in plunge pool stage elevation does not decrease by more than 5 cm/hour	All Year	Prevent fish stranding
	▪ Ramp rates are not applicable when free spilling over the free crest weir or when flows measured on the South Alouette River (WSC gauge #08MH005) exceed 25.0 m^3/s	All Year	
Alouette Lake Reservoir	▪ Maintain flood buffer limit of 122.60 m, by opening the adit gate to manage the flood buffer, up to the capacity of the power tunnel	October 1 to March 31	Flood mitigation
	▪ Maintain flood buffer limit of 124.70 m, by opening the adit gate to manage the flood buffer, up to the capacity of the power tunnel	April 1 to September 30	Flood mitigation
	▪ Target reservoir level of 121.85 m	April 15 to June 14	Sufficient head for release to manage outmigration of Kokanee and increase recreational benefits.
	▪ Target reservoir level ≥ 122.0 m	June 15 to July 15	Recreational benefits
	▪ Target reservoir level ≥ 122.5 m	July 16 to September 5	Recreational benefits
	▪ Target reservoir level ≥ 121.25 m	September 6 to September 15	Recreational benefits
	▪ Keep the adit gate fully open, and adjust the crest gate to between 31.9 and 53.1 m3/s when the reservoir is between El. 124.7 m and 125.87 m	All Year	
	▪ Leave the adit gate fully open, close the crest gate, and manage the reservoir level using the free crest weir when the reservoir is above El. 125.87 m	All Year	

[1] Note that the requirement to provide pulse flows was removed the Order in 2018

	▪ Changes to the adit or crest gate must be initiated within 24 hours	All Year

To address the above data gaps and uncertainties in the Alouette WUP the following monitoring programs were ordered by the CWR to assess whether anticipated benefits from changes to operation were actually achieved. Results from these monitors were to be reviewed upon completion, and results used to provide information needed to determine whether the Alouette WUP needed further changes. The required studies were implemented under BC Hydro's Water License Requirements program according to the following terms of references:

ALUMON-1 – Smolt Enumeration: A seven year study to determine out migration numbers of salmon and trout fry and smolts in the Alouette River.

ALUMON-2 – Kokanee Out Migration: A seven year study to identify the initiation, duration, and peak of the Kokanee smolt out migration in the Alouette River.

ALUMON-3 – Substrate Quality: A seven year study to quantify relative sediment distribution within the Alouette River to identify the need for a directed flushing flow.

ALUMON-4 – Sockeye Adult Enumeration: A seven year study to determine the run timing and enumeration of the return of successfully re-anadromised adult Kokanee and stray Sockeye from other watersheds in the Alouette River and compare ocean survival rates of returning re-anadromised Kokanee to other BC populations.

ALUMON-5 – Water Temperature: A seven year monitor to quantify the frequency, duration and magnitude of warm water temperatures within the Alouette River to assess the need and feasibility of operational actions that can be implemented to mitigate potential impacts.

ALUMON-6 – Kokanee Age Class Structure: A seven year monitor to determine the nature of the relationship between reservoir operations and recruitment potential of Kokanee in Alouette Lake reservoir.

ALUMON-7 – Archaeological Monitoring: A one-year program to inventory, assess, and mitigate impacts to archaeological remains in the Alouette River Watershed.

4. ORDERED PROGRAMS SUMMARY

4.1 ALUMON-1 Smolt Enumeration

4.1.1 Summary

The Alouette salmonid smolt enumeration program was initiated in 1998 based on recommendations from the first WUP CC committee in 1996. Terms of reference were developed for the smolt enumeration program as a condition of the 1996 and 2006 WUPs. For the seventeen consecutive years of both WUPs, the smolt outmigration study has been consistently collecting data, ending in 2014. Both WUP monitoring periods used very similar TORs to guide the study. Over the monitoring period, the increased minimum flows in the Alouette River below Alouette Dam, as well as stocking and rehabilitation efforts, have resulted in:

- a maximum capacity run of Chum salmon;
- the return of Pink salmon after being determined extirpated prior to 1985;
- the return of Chinook salmon;
- an increased Coho population and wild Steelhead; and
- the return of Alouette Sockeye after being considered extirpated prior to 2007.

4.1.2 Management Questions

Three management questions were to be addressed through the smolt enumeration monitor (BC Hydro 2009, pp. 8):

1. Is the average base-flow release of 2.6 m^3/s from the Alouette Dam (obtained by fully opening the low level outlet) adequate to sustain or improve current levels of salmonid smolt production downstream of the dam? The species of interest include Chum, Pink, Chinook, and Coho salmon as well as Steelhead and Cutthroat trout.

2. Following their migration out of Alouette Lake, do the Kokanee smolts immediately continue their migration out of the Alouette River or do they delay their seaward migration for a period of time?

3. Using Chum salmon counts at the Allco Park Hatchery as an indicator of run strength and the results of the substrate quality monitor, is there evidence of a persistent, declining trend in egg to smolt survival that would suggest a degrading condition in spawning substrate quality.

4.1.3 Objectives and Scope

The goal of this project was to determine out-migration numbers of salmon and trout fry and smolts in the Alouette River using downstream trapping methods and mark-recapture analysis (Cope 2015). Specifically, the project was to:

- Obtain abundance estimates of emigrant fry and smolts (by species);
- Determine the migration timing and biological characteristics of emigrant fry and smolts, and document general environmental conditions throughout the migration period; and
- Examine assumptions inherent within the mark-recapture procedure to determine possible sampling bias of incline-plane traps, rotary screw traps, and marking methodology.

4.1.4 Approach and Methods

The Contractor for all 17 years of this study was Scott Cope of Westslope Fisheries Ltd., with fisheries technicians from Katzie First Nation assisting with smolt and fry enumeration, and field operations for the duration of the project. All works were carried out in accordance with the objectives outlined in the terms of reference in 2009 (below) and were also consistent with the original WUP TOR in 1996.

The field methods described below have not changed since the first Alouette WUP 1996 (BC HYDRO ALU TOR 2009, pg.12, 13). Field methods below are described in Cope (2005) all data are consistent with those in prior years of monitoring (1998 to 2005). This includes the following elements:

1. Use of two incline plane traps located just upstream of the 224th St bridge. These are to be fished continuously from the last week of February until the end of the chum out-migration period (usually the first week of May).

2. Use of a single rotary screw (1.5m drum until April 15 and a 1.8 m drum afterwards) trap located just downstream of the 224th St bridge. Installation is to include the appropriate use of sand bags and screens to improve volume and direction of flow to the trap. It will be fished continuously from the last week of February to the first week of June which is typically the end of the smolt outmigration period.

3. The traps will be maintained and adjusted as required to ensure consistent trapping conditions through time.

4. Gear efficiency will be determined twice weekly for both fry (0+ fish < 70 mm FL) and smolts (fish > 70 mm FL that have over-wintered at least 1 year). Fry will be marked using Bismark Brown dye (1-2 hour immersion in 10 ppm solution) while smolts will be caudal fin clipped. Fry and smolts will be released at the 232 St bridge. If possible, the frequency of measurement will be reduced to once a week if it is determined that precision and accuracy will not be compromised by the action.

6. Captured fish will be sub-sampled for measurement of fork length (mm FL) and wet weight (g). Sub-sampling will be done daily to ensure an even distribution of effort through time. Intensity of sub-sampling will be at the discretion of the crew (e.g., at least a minimum of 10 individuals/day) but must be based on a standard sub-sampling protocol (e.g., every xth individual or be evenly distributed among the catch, etc.) and be consistent through time to minimise error.

7. All incidental catches from upstream studies will be noted, including the presence and type of marks.

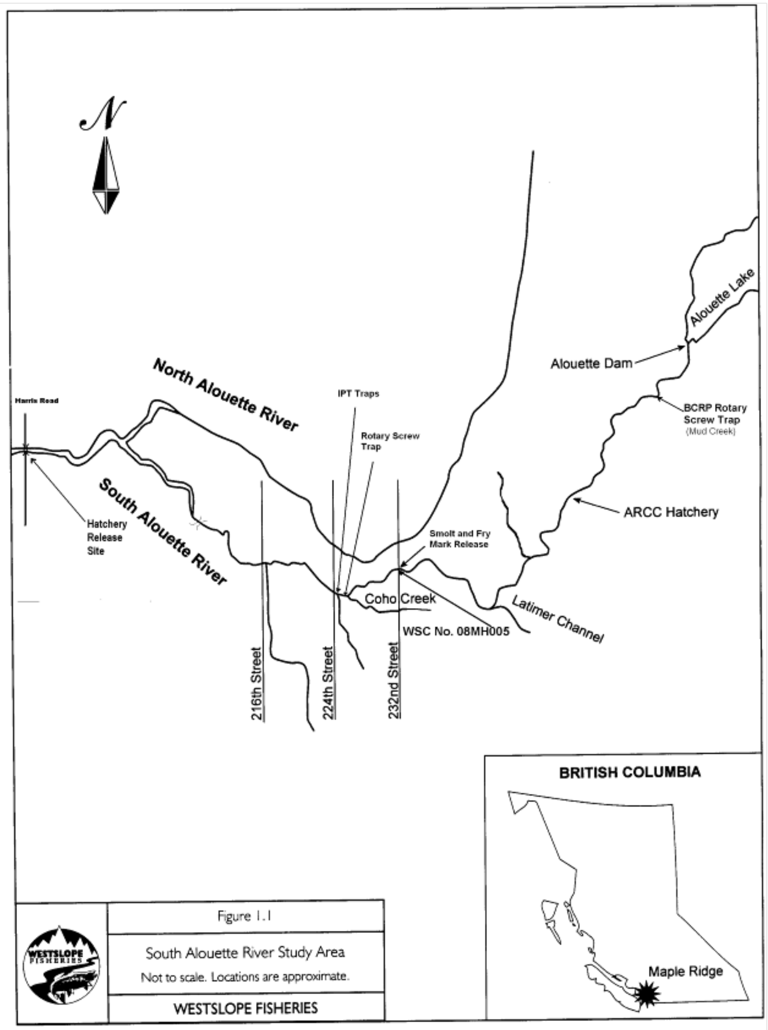

Figure 1-1 Smolt outmigration study area (Cope 2015).

Daily monitoring of water levels at the 224th St. Bridge, as well as daily water temperature from Tidbit™ temperature data loggers was collected at each trap location. Daily discharge data was used from the Water Survey of Canada gauging station at the 232nd St. Bridge (Station No. 08MH005) throughout the duration of the study.

Two incline plane traps were installed directly upstream of the 224th St. Bridge from 1998-2014. The Rotary Screw traps were originally located at the 216th St. Bridge from 1998-2001, with slight variations in start timing and trap configuration 2001-2007. In 2008, the rotary screw traps were relocated to the 224th St. Bridge location and reconfigured to maximize trapping efficiency and increase public safety; they remained at this location for the duration of the study. Trap relocation was necessary due to backwatering impacts from the Pitt River.

4.1.5 **Results**

Over the course of the program (1998-2014), 28 fish species have been confirmed. Chinook, Pink and Sockeye salmon were considered extirpated in 1985. Since 1998, out-migrant fry or smolts of all three species have been captured and confirmed. Returning Chinook, Pink and

Sockeye salmon (*i.e.,* mature spawners) have been confirmed at the FRCC-ARMS hatchery broodstock fence (Cope 2014).

4.1.6 Management Questions and Answers (Cope 2015 pp. 68-70):

1. Q: Is the average base flow release of 2.6 m^3/s from the Alouette Dam (obtained by fully opening the low level outlet) adequate to sustain or improve current levels of salmonid smolt production downstream of the dam? The species of interest include Chum, Pink, Chinook, and Coho salmon as well as Steelhead and Cutthroat trout.

   A: Ordered increased minimum flows have continued to support stable or increasing levels of smolt productivity in all salmon species.

2. Q: Following their migration out of Alouette Lake, do the Kokanee smolts immediately continue their migration out of the Alouette River or do they delay their seaward migration for a period of time?

   A: There was clear indication from results of both RST trapping sites that Sockeye smolts do not delay leaving the Alouette system. Furthermore, using the spillway gates to attract outmigration in the spring was seen as an effective downstream passage alternative to the low level outlets. Monitoring also confirmed that the “pulse” flows tested during the monitoring program do not improve Kokanee smolt downstream passage success.

3. Q: Using Chum salmon counts at the Allco Park Hatchery as an indicator of run strength and the results of the substrate quality monitor, is there evidence of a persistent, declining trend in egg to smolt survival that would suggest a degrading condition in spawning substrate quality.

   A: There was no evidence found of declining trends in egg to fry survival in Chum. In fact escapements of Chum in some years has exceeded capacity resulting in variable survival due to density dependent interactions.

Other Results

The project captured some introduced species of note in the Alouette River that appear to be from more than one life stage possibly indicating that they are successfully reproducing.

The Alouette Chum Salmon stock has been continually rebuilding and is now to the point where egg-to-fry survival appears to be variable indicating the Alouette River has reached a point of significant density-dependent mortality during high escapement years (Cope 2015).

Pink salmon was considered extirpated but have returned to the Alouette River within the timeframe of this study.

Chinook salmon appear to be responding to stocking efforts with increasing out-migrants documented annually (Cope 2015).

Previously extirpated Alouette Sockeye salmon have returned to the Alouette River almost annually since 2007.

Although the monitoring results for this study (and for ALUMON-02) confirmed that June pulse flow releases did not increase the number of outmigrating kokanee/sockeye smolts observed in the enumeration program, post-ALUMON-01 study results (Matthews et al 2018) indicate that earlier pulse flow events may influence outmigration.

4.1.7 Implications

The ordered average base flow releases on the Alouette River below Alouette Dam have continued to sustain or improve salmonid smolt production through this latest WUP monitoring period. Between the two WUP monitoring phases, this study has collected data continuously for 17 years, initiated under the first Alouette WUP in 1996 and continued during the development and fulfillment of the second Alouette WUP 2009 - 2015. This study also found that Sockeye smolts did not delay moving from the upper to lower RST monitoring sites indicating surface release timing and ordered base flows are effective and are supporting Chum egg to fry survival.

Based on these study results, Ordered outlet gate operations are adequate to support targeted salmonid productivity.

4.2 ALUMON-2 Kokanee Out-Migration

4.2.1 Summary

The Mud Creek RST smolt trapping program was used as a method to assess the feasibility of anadromous Sockeye re-introduction into the Alouette Reservoir in conjunction with other studies throughout the watershed. In order to specifically test surface flow releases from Alouette Dam, the Fish and Wildlife Restoration program (FWCP - formerly called the Bridge-Coastal Restoration program - BCRP) funded a study in 2005 that used hatchery Coho smolts to see if they would cue to the surface currents and migrate out of the reservoir.

An unexpected result of this test was the outmigration of Kokanee smolts, which prompted the Alouette WUP Consultative Committee (CC) to recommend that surface releases be done annually with the expectation that this could aid in the re-establishment of Sockeye to the Alouette River. A downstream smolt collection monitoring program was recommended to determine the start timing of surface releases from the reservoir. Initial surface flow releases were scheduled for 8 weeks with the monitoring program being responsible for identifying the start of the out-migration, duration, peak and end in order to reduce or adjust the release duration as needed. The fisheries technical committee (FTC) requested investigations into the magnitude of the surface flow release to determine if a 6-9 m^3/s flush[2] for 7 days at the end of the surface release would promote any additional smolts to leave the reservoir. This additional operation test was scheduled to occur every second year, but the 7 day pulse was not to exceed the total 8 week duration of the scheduled surface

[2] Flush flows are referred to in this document, operationally these are referred to as pulse flows.

flows. Smolt outmigration counts were monitored at the Mud Creek location located 1.5 km downstream from Alouette Dam. This location was used for the duration of the study.

The Mud Creek smolt trapping program was operational for 10 years under the Alouette WUP until 2015 when the WUP studies were completed.

4.2.2 Management Questions

Three management questions were to be addressed through the Kokanee out-migration monitor (BC Hydro ALU TOR 2009, pg. 20-21):

1. Is the surface release of at least 3 m^3/s from the Alouette Dam (obtained through the spillway gate) adequate to promote the downstream migration of Kokanee smolts out of the Alouette Reservoir?
2. Does a post-surface release flush of 6-9 m^3/s, lasting 7 days following the tail end of the out migration period, encourage more smolts to leave the system?
3. How long should the surface release last to ensure out migration of all smolts prepared to leave the system?

4.2.3 Objectives and Scope

Test the effectiveness of surface flow releases, test the effectiveness of pulse flows and determine the duration of smolt outmigration.

1. Operate the Alouette Dam spillway to allow ~3.0–4.5 m^3/s of flow from 15 April to 14 June; flows through the low level outlet will be held near 0.0 m^3/s for the study period.
2. Monitor natural and scheduled pulse flows throughout the outmigration period.
3. Install and operate a RST at the Mud Creek site, located 1.5 km downstream of the Alouette Dam, from 15 April to 14 June (or earlier if the migration ceases) to monitor the migration of Kokanee from the reservoir.
4. Capture Kokanee from the Alouette Reservoir in the Mud Creek RST.
5. Mark all and re-capture these same marked Kokanee in the Mud Creek RST to estimate total migration.
6. Determine the abundance, timing and biological characteristics of Kokanee migrating from the Alouette Reservoir.
7. Collect genetic tissue from 100 individuals of Kokanee to determine stock identification; and Record incidental catches of all other species.

4.2.4 Approach and Methods

Annual reports were compiled for each study year and the 7th year report finalized the results and addressed all management questions listed above. All reports are available on BC Hydro's WUP website:

https://www.bchydro.com/about/sustainability/conservation/water_use_planning/lower_mainland/alouette.html

The Mud Creek RST is located just below the confluence of the Alouette River and Mud Creek, approximately 1.5 km downstream from the Alouette Dam on the mainstem of the Alouette River. The RST was installed and operated every year from April 15 to approximately May 27th of each year, with a range of 39-51 days. The end date varies annually depending on the smolt migration timing. The first smolts were caught in the trap only two days after the surface flow releases began in 2014 but this was not always the case. The trap is checked twice daily, all fish processing was completed after the morning check; the afternoon check was to remove debris and ensure fish health. During the past 10 years run timing was slightly different depending on the year but the start date of mid-April to mid-June captured most of the variation. The RST is removed when the Sockeye smolts migration is finished, the surface flow releases at Alouette Dam are also stopped when the migration has finished based on recommendations from the RST information. All sockeye captured were distinctively marked (caudal clipped) and released below the dam to determine recapture rates at the RST. A portion of the unmarked smolts that were captured were bio-sampled for fork length, weight and fin clipped for genetic stock identification. Another smaller portion of the bio-sampled smolts had scale samples taken for age analysis. Fin clips were sent to the DFO Pacific Biological Station for genetic analysis to confirm Alouette stock.

The FTC had remaining uncertainties around the amount of surface flows (3.5-4.9 m^3/s) so they recommended testing a post surface-release flush of (9.5 m^3/s). These flushes were thought to be a way to encourage any additional smolts to leave the reservoir if the surface flows themselves were not enough.

4.2.5 **Results**

The Mud Creek smolt trapping program was operational for 10 years under the Alouette Water Use Plan until 2015 when the Water Use Plan studies were completed. These results summarize the 10 years of study completed though WUP funding. Throughout all years the program documented a distinctive start, peak and end to the smolt outmigration which is a commonly documented pattern for Sockeye smolts (Mathews et al 2014 ALU WUPMON 2). This monitoring program revealed that a post-surface release pulse of 6–9 m^3/s, lasting seven days following the tail end of the out-migration period, did not encourage more smolts to leave the system. Natural pulse events in 2009, 2010, 2011 did not increase smolts outmigration and neither did scheduled pulse flows events that were tested in 2014 (four events).

Answers to Management Questions

Three management questions were addressed through the Kokanee out-migration monitor:

1. Q: Is the surface release of at least 3 m^3/s from the Alouette Dam (obtained through the spillway gate) adequate to promote the downstream migration of Kokanee smolts out of the Alouette Reservoir?
   A: Yes, this study confirmed that the surface spillway releases of at least 3 m^3/s were adequate to promote outmigration of Sockeye smolts out of Alouette Reservoir and into the Alouette River.
2. Q: Does a post-surface release flush of 6-9 m^3/s, lasting 7 days following the tail end of

the out migration period, encourage more smolts to leave the system?
A: No, the post-surface release (natural or scheduled) did not encourage additional smolts to leave the system.

3. Q: How long should the surface release last to ensure out migration of all smolts prepared to leave the system?
   A: The current operating window of April 15-June 14 is adequate to provide opportunity to all volitional migrants from the system.

4.2.6 Implications

Spillway surface flow releases are effective at attracting volitional Kokanee migrants during the out-migration timing window. April 15-June 14 is the appropriate timing for surface flow releases.

A post surface release flush of 6–9 m^3/s, lasting seven days following the tail end of the out-migration period, did not encourage more smolts to leave the system. Pulse flow releases in 2009, 2010, 2011, and 2014 (four events) did not increase smolts outmigration). The Order was amended in 2018 to remove the requirement to provide pulse flows. An evaluation of an alternative pulse flow operation was conducted in 2018 under a Fish and Wildlife Compensation Program study, but results were not available for consideration in this report.

4.3 ALUMON-3 Substrate Quality

4.3.1 Background

This monitor was a continuation of the study established in 1996 (BC Hydro 1996) where a Wolman's Pebble Count (Wolman 1954) procedure was used to quantify distribution of sediments through the Alouette River in years 2008 through 2014. A monitoring plan TOR was drafted based on the recommendations of the ALU WUP CC (refer to BC Hydro 2009 for details).

4.3.2 Management Questions

Four management questions were to be addressed through the substrate quality monitor:

1. Do the results of Wolman's Pebble count procedure reflect the general composition of bed materials within the channel downstream of the Alouette Dam?
2. Is the <20% fines threshold adequate to distinguish a state in substrate quality that would require a prescribed flushing event?
3. Is an alternative methodology required to qualify/calibrate the results of the Wolman pebble count procedure?
4. For each year of the monitor, is a prescribed flushing flow necessary given the current state of substrate quality?

(BC Hydro 2009, pp. 29)

4.3.3 Objectives and Scope

The objective of this monitor was to quantify relative sediment distribution of the Alouette River to identify the need for a directed flushing flow. The following aspects define the scope of the study:

a) The study area consisted primarily of the riverine habitat located downstream of the Alouette Dam to the 216th St. Bridge.
b) All sites were the same as those used for monitoring during the last 10 years (1996 WUP). To minimize the effect of observer bias, the same survey crew was used to collect the data.
c) Year 1 of the monitor included an assessment of the pebble count procedure based on a review of published literature.
d) The monitor was carried out annually for 7 years (2008 – 2014).

4.3.4 Approach and Methods

The Substrate Quality Monitor was continued under the ALU WUP in 2008 from the study established in 1996 (BC Hydro 1996). The extension of the monitor was conducted over 7 years from 2008 to 2014 by Westslope Fisheries. Annual reports were compiled for each study year and the 7th year report finalized the results and addressed all management questions listed above. All reports are available on BC Hydro's WUP website:

https://www.bchydro.com/about/sustainability/conservation/water_use_planning/lower_mainland/alouette.html

The modified pebble count methodology was continued (Higgins 2005) but with more frequent and regularly scheduled sampling intervals instead of sampling opportunistically as done prior to 2008. This adjusted sampling schedule was implemented to improve the determination of the effects of flow events on the condition of the substrate and avoid confounding effects of season variations. Further, in year 1, a literature review was completed to review the uncertainties of the pebble count methodology.

Sampling was conducted at 23 sites on the Alouette River each year during mid-summer during low water levels and no incubating eggs or alevins in the substrate (Figure 3-1). A minimum of 100 samples per transect were collected and each assigned a size class (Wentworth 1922). The percentage of fines (<2 mm diameter; impairing salmonid production) and gravels (16-128 mm; suitable salmonid spawning habitat) were analyzed.

Fry enumeration results from ALUMON-1 were analysed for correlation with percentages of fine sediment and gravel, separately. Substrate condition was also compared to discharge.

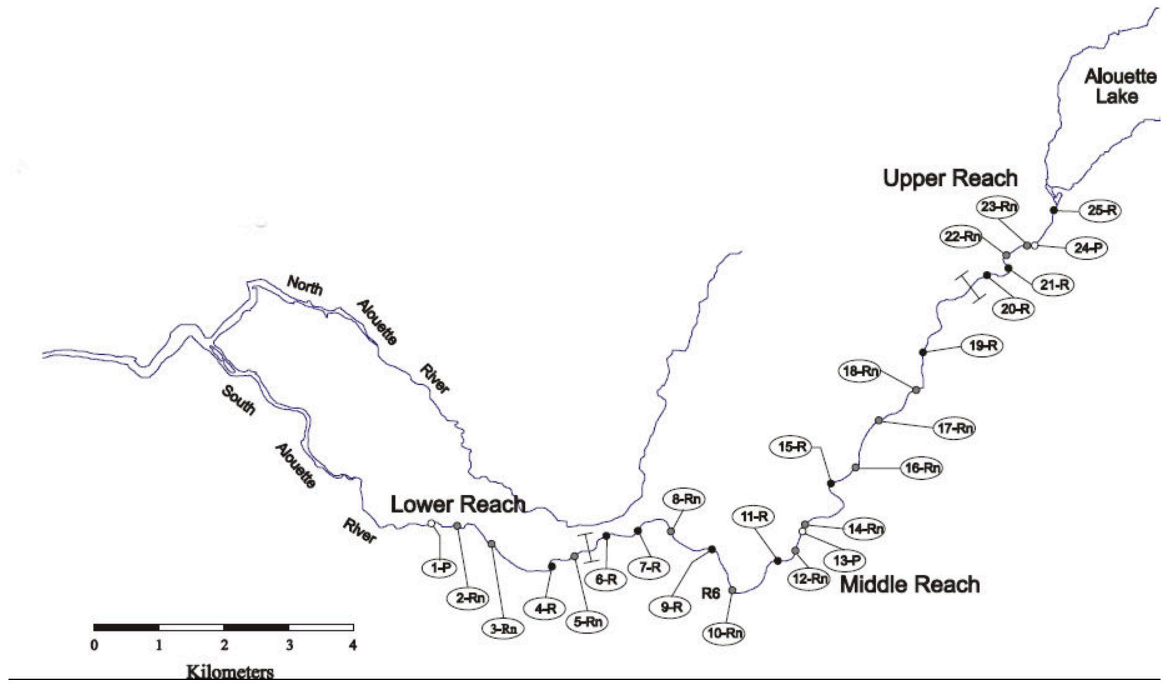

Figure 3-1. ALUMON-3 Substrate Quality Monitor study area on the Alouette River.

4.3.5 **Results**

Since the implementation of the 1996 Minimum Flow Agreement, fine sediment levels have remained relatively stable with no evidence of increasing sedimentation or substrate compaction occurring in the Alouette River. Direct flush flow could benefit certain sites; however, localized affects (i.e., increase sedimentation) do not have a negative effect on salmonid habitat or their food sources when considering the river as a whole. Spawning prevention by sediment compaction was never observed.

Answers to the Management Questions

1. Q: Do the results of the Wolman pebble count procedure reflect the general composition of bed materials within the channel downstream of the Alouette Dam?

   A: This question was not specifically tested; however, the sampling results during this study have been consistent with other observations of substrate condition. Further, the pebble count methodology has been successful in other systems (Potyondy and Hardy 1994).

2. Q: Is the <20% fines threshold adequate to distinguish a state in substrate quality that would require a prescribed flushing event?

   A: Observations of this monitor and other studies (Kondolf 2000; Cover and Resh 2006) support the <20% fines as an adequate threshold in determining the requirement of a prescribed flushing event. This level has only been significantly exceeded once in the Alouette River (31%, 1995) prior to the implementation of the Minimum Flow Agreement (Figure 3-2).

3. Q: Is an alternative methodology required to qualify/calibrate the results of the Wolman pebble count procedure?

   A: Wolman's pebble count procedure has proven over time to be a suitable method for assessing changes in substrate condition in the Alouette River. To avoid sampling bias, particle selection and measurement was conducted by the same technician at permanent sites and same time of year across years. This method has provided an efficient and adequate measure of substrate quality change; therefore, alternative methodologies are not required to qualify or calibrate the monitor's results.

4. A: For each year of the monitor, is a prescribed flushing flow necessary given the current state of substrate quality?

   Q: Results of the monitor suggest a directed flushing flow could benefit certain sections of the river, but only on a localized basis. Observations indicated instream changes were caused by natural occurrences and not always permanent (i.e., fallen tree, land slide increasing sediment load).

Other results

Although the substrate condition is an important indicator of overall habitat performance, there is no conclusive correlation in the data between substrate condition and chum fry abundance.

The overall percentage of fine sediments remained relative stable at <20% throughout the monitor and consistently dropped following high water events. The 20% fines threshold was exceeded in 1995, prior to the Minimum Flow Agreement, and again in 2014 (Figure 3-2). Given this result, no further monitoring is required.

In 2000, 460 tons of spawning gravel was deposited at two locations in the upper Alouette River. An increase of gravel percentage was observed following the project with deposited gravel distributing as far as 10 km downstream of the release site (Figure 3-3).

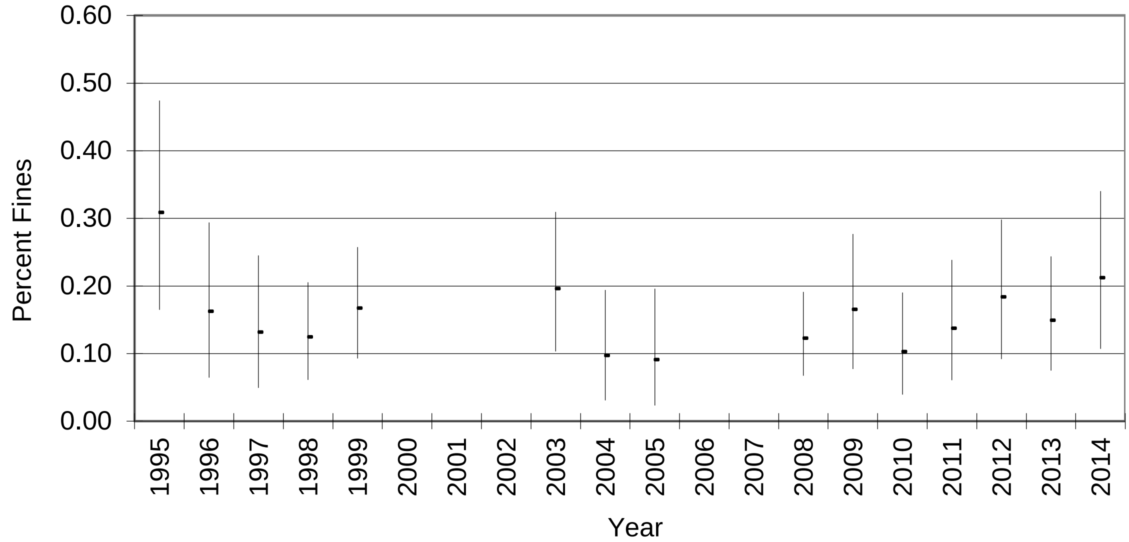

Figure 3-2. Percentages of fine sediments measured in the Alouette River from 1995 to 2014. Alouette Water Use Plan was initiated in 2008. Controlled Alouette Dam releases did not occur from 2010 to 2014.

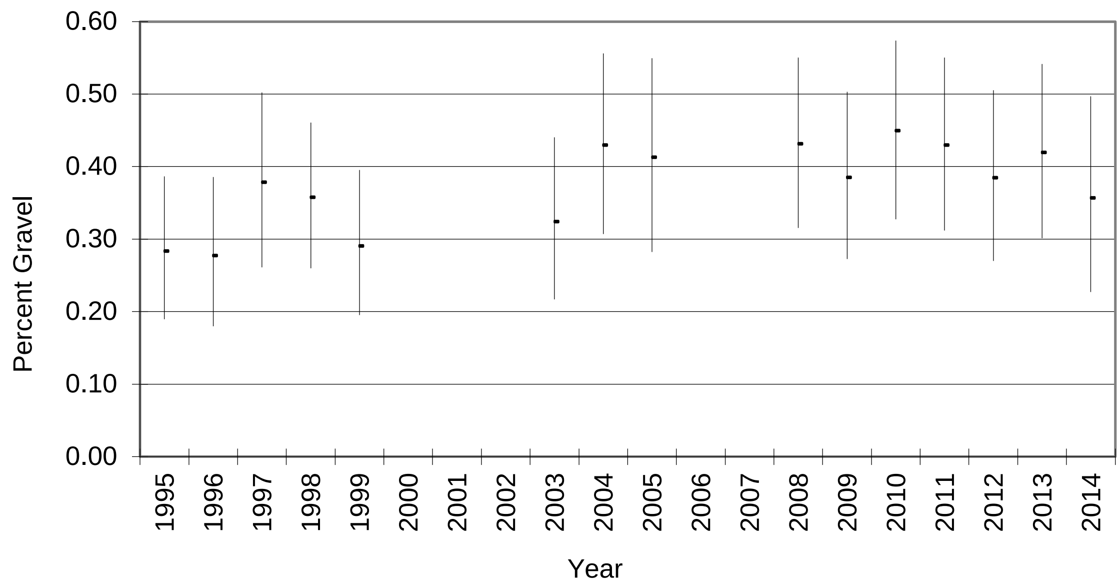

Figure 3-3. Percentages of gravel measured in the Alouette River from 1995 to 2014. Alouette Water Use Plan was initiated in 2008. Controlled Alouette Dam releases did not occur from 2010 to 2014.

4.3.6 Implications

The modified Wolman pebble counts have been used since 1996 as an effective indicator of substrate quality. During the study period, there has been no evidence of increasing sedimentation, or impacts to spawning success/egg-to-fry survival. As such, sedimentation does not appear to be a factor limiting the production of fry and smolts in the Alouette River. Natural frequency of flushing flows has proved to be effective in moving fine sediments, with no need for prescribed flushing flows. Results of this monitor indicate that natural flushing flows which are significant enough to transport fine sediment occur on a frequent enough basis to maintain the percent fines below the 20% threshold (Davies 2014).

4.4 ALUMON-4 Sockeye Adult Enumeration

4.4.1 Background

Operations to allow the passage of Kokanee smolts through the spillway gate were integrated into the ALU WUP to allow Kokanee the opportunity to migrate to the ocean. Since 2005, smolts have successfully migrated through the spillway gate during spring release (April to June; annual range of 728 to 72,923 smolts). A key assumption of this operation was that Kokanee are capable of successfully 're-anadromising' to ocean rearing conditions. This monitor was designed to assess the benefit of this operation and determine whether to continue in the future. A monitoring plan Terms of Reference was drafted based on the recommendations of the ALU WUP CC (refer to BC Hydro 2009, for details).

4.4.2 Management Questions

Four management questions were to be answered by the Sockeye adult enumeration monitor:

1. Are the Alouette Lake Reservoir, Kokanee smolts successfully adapting to an anadromous existence by returning from the ocean environment to spawn in Alouette Lake?

This question could not be answered without first addressing the following three critical data gaps:

2. What is the run timing of adult Sockeye returns so that an appropriate enumeration study can be carried out?
3. Are adult Sockeye caught during the monitor, members of the 'Alouette stock' or are they strays from other nearby coastal systems?
4. Are ocean survival rates of returning re-anadromised Kokanee comparable to that of Sockeye stocks found elsewhere?

(BC Hydro 2009, pp. 36 – 37)

4.4.3 Objectives and Scope

The objective of this monitor was to determine the run timing and enumeration of the return of successfully re-anadromised adult Kokanee and stray Sockeye from another watershed and compare ocean survival rates of returning re-anadromised Kokanee to other BC populations. The following aspects define the scope of the study:

1. The study area consisted primarily of the riverine habitat located downstream of the Alouette Lake Reservoir, and particularly the brood stock collection fence operated by the Allco Hatchery.
2. The monitor was an addition to the current brood stock collection operation conducted annually by the Allco Hatchery which will consist of the following:
   - **a.** Year round fence operations (2008-2017).

   b. Extended fence operations to cover the Sockeye adult return period once the run timing has been established.
3. Genetic analysis of a minimum of 100 randomly selected adult returns per year for three years, and include the development/construction of a Sockeye adult holding facility outside of the perimeter of the hatchery.
4. The monitor was carried out annually for 7 years.

4.4.4 Approach and Methods

The Sockeye Adult Enumeration Monitor was conducted over 7 years from 2008 to 2014 by Alouette River Management Society. Annual reports were compiled each study year and the 7th year report finalized the results and addressed all management questions listed above. All reports are available on BC Hydro's WUP website:

https://www.bchydro.com/about/sustainability/conservation/water_use_planning/lower_mainland/alouette.html

Adult Sockeye were enumerated at the Allco Hatchery fish fence approximately 8 km downstream from the Alouette Reservoir (Figure 4-1). During the first three years of the program (2008-2010), the fish fence was operated from April to December to determine the timing and volume of the run. Based on the results of these efforts, the following four years (2011-2014) involved a shorter operation period of mid-June though October.

Captured fish were measured for fork length, and scale and tissue samples were collected for age and genetic analyses, respectively. Fish were transferred by trailer and released in Alouette Reservoir. In 2011 and 2012, returning Sockeye were also tagged with motion sensitive MAP tags to track migration in the Alouette Reservoir (see Plate and Bocking 2010, 2011, 2013 for details). Smolt to spawner survival was calculated for each returning age class.

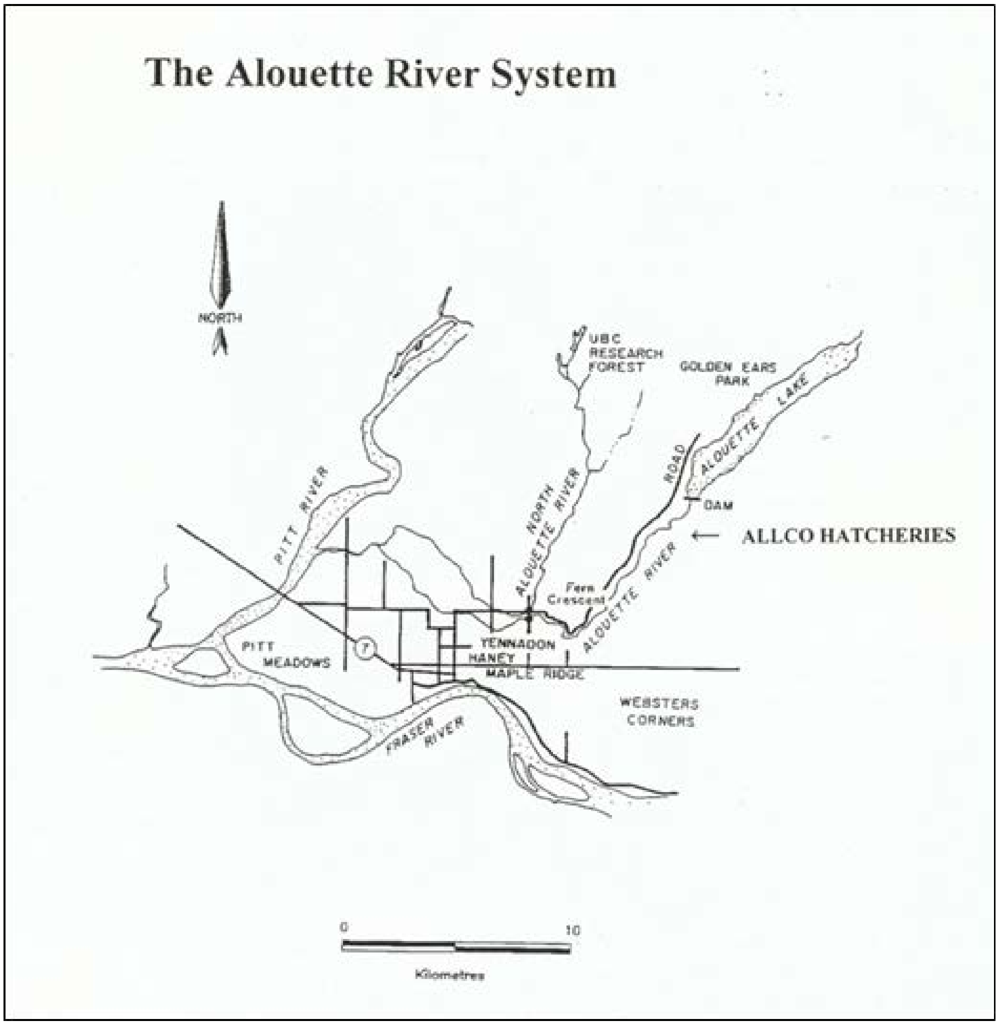

Figure 4-1. Map of Alouette Watershed with location of Allco Hatchery where returning adult Sockeye were enumerated.

4.4.5 Results

From 2007 - 2014, 308 adult Sockeye returned to Alouette Watershed during the "summer run" period with a few late fall exceptions (Figure 4-2). Through an adult transfer program, 262 were released alive back into the reservoir. Annual returns ranged from a peak return 115 in 2010 to the lowest return (0) in 2014. The return of adults show that re-anadromization of Kokanee/Sockeye to the Alouette watershed is possible, but the low numbers of adults surviving the ocean makes restoration of Sockeye unlikely under re-anadromization alone.

Answers to the Management Questions

1. Q: Are Alouette Lake Kokanee smolts successfully adapting to an anadromous existence by returning from the ocean environment to spawn in Alouette Lake?

   A: Returning adult were genetically identified as Alouette stock (Candy 2009; Godbout et al. 2011) indicating migrating smolts had successfully adapted to an anadromous existence. Due to the low abundance, it is unknown if returned adults successfully spawn or if the returning Sockeye are spawning as pairs.

2. Q: What is the run timing of adult Sockeye returns so that an appropriate enumeration study can be carried out?

   A: Run time was consistently during summer months (July and August) while a few fish were captured in the fall (September and October; Figure 4-2). Peak abundance typically occurred from the last week of July to the second week of August.

3. Q: Are adult Sockeye caught during the monitor members of the 'Alouette stock' or are they strays from other nearby coastal systems?

   A: The majority of summer run returns were determined genetically to be of Alouette stock. Fish captured during the fall months were in most cases genetically identified as strays from a nearby system (e.g. Weaver Creek).

4. Q: Are ocean survival rates of returning re-anadromised Kokanee comparable to that of Sockeye stocks found elsewhere?

   A: From 2005 – 2012, smolt to spawner survival ranged from 0.084% to 1.344%, which are extremely low for Sockeye as compared to other Fraser River and nearby Sockeye systems. (CSAS 2010; Plate et al. 2014; Rensel et al. 2010). These low ocean survival rates make Sockeye restoration unlikely without supplementation (e.g. hatchery releases).

Other Results

The age of returning Sockeye adults ranged from 4.2 to 6.4 (Gilbert Rich Scale; i.e., 4.2 age class migrated from the reservoir at age 2 and spent 2 years in the marine environment until returning to Alouette River). The majority of fish were aged 4.2 and 5.3.

Telemetry tracking has identified possible spawning locations within Alouette Reservoir (Plate and Bocking 2010, 2011, 2013).

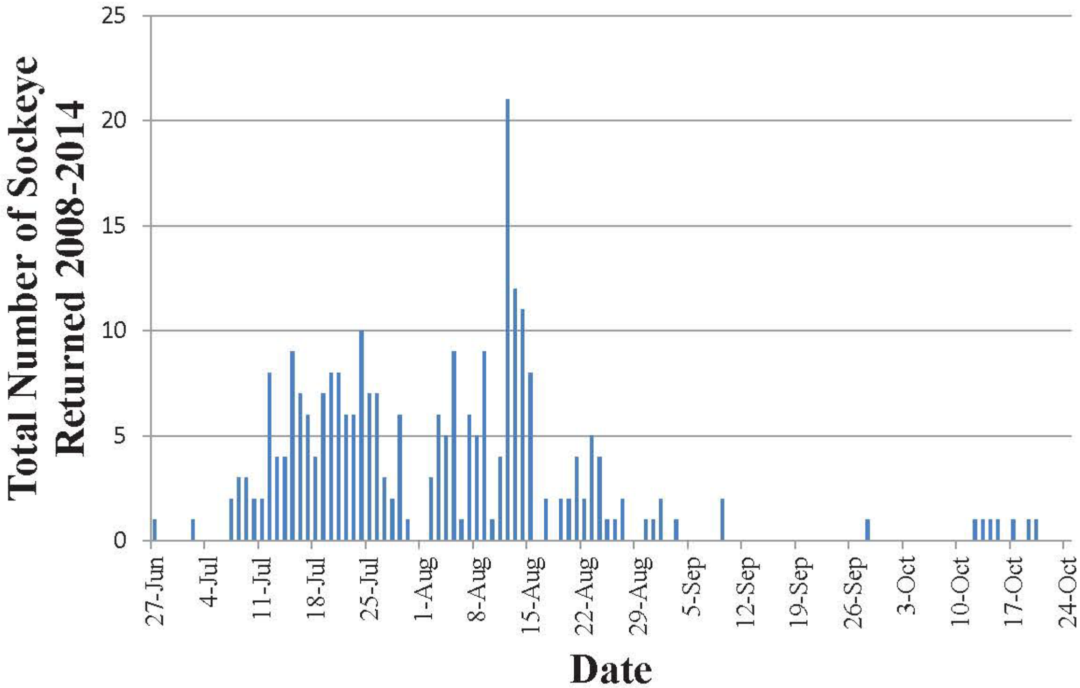

Figure 4-2. Number of adult Sockeye returned by date to the Allco Hatchery fish fence from 2008-2014. No fish returned in 2014.

Table 4-1. Alouette Sockeye smolt to spawner survival for 2005 – 2012 (B. Bocking, pers. comm.).

Year of Smolt Migration	Survival (smolt:TRS)
2005	0.532%
2006	0.750%
2007	0.084%
2008	1.344%
2009	0.171%
2010	0.282%
2011[1]	0.028%
2012[1]	0%

[1]Survival estimate for 2011 and 2012 is preliminary based on unreported data at time of report publication for age classes that had yet to return.

4.4.6 Implications

Results of this monitor have shown that Kokanee juveniles that out-migrate to the ocean can return as Sockeye adults (re-anadromization). Furthermore, the study suggests that the timing of juvenile outmigration and returning adult migrations are consistent with the timing of spring Ordered operations and summer trap and truck operations, respectively. There is no information to suggest either operation would require additional consideration in the upcoming Order Review. The Alouette River Sockeye Re-anadromization Program (ARSRP) is implementing a multi-year plan to assess the feasibility of Sockeye restoration to the Alouette. The ARSRP applies for funding for its feasibility studies annually, from the Fish and Wildlife Compensation Program, according to BC Hydro’s Fish Passage Decision

Framework. As per the Framework, should the FWCP provide endorsement of the ARSRP's Sockeye restoration plan, BC Hydro will consider funding fish passage at Alouette Dam.

4.5 ALUMON-5 Water Temperature

4.5.1 Background

Water temperatures ≥ 25°C can impact growth and survival of rearing salmonids, as well as shift community structure if persistent through time. This monitor was implemented to address uncertainties of water temperature in the Alouette River downstream of the Alouette Dam and if further mitigation can be applied through reservoir operations. A monitoring plan Terms of Reference was drafted based on the recommendations of the ALU WUP CC (please refer to BC Hydro 2009, for details).

Results determined river and reservoir temperatures were generally within the range of historical values with the exception of mid-September to mid-November when daily average temperatures exceeded historical maximum values at the plunge pool (mean +0.4°C) and Allco Hatchery (mean +0.6°C).

4.5.2 Management Questions

Five management questions were to be answered by the water temperature monitor:

1. How often are water temperatures ≥ 25°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 Low Level Outlet (LLO), is there an operational change that can be implemented to mitigate the occurrence of warm water events.

(BC Hydro 2009, pp.43-44)

4.5.3 Objectives and Scope

The objective of this monitor was to quantify the frequency, duration and magnitude of warm water temperatures within the Alouette River to assess the need and feasibility of operational actions that can be implemented to mitigate potential impacts. The following aspects define the scope of the study:

1. The study area consisted of Alouette Lake reservoir (at the LLO inlet) and the river downstream of the dam to 244th St. Bridge.
2. A literature search was completed to determine threshold water temperatures and exposure levels for rearing salmonids.
3. A simple model was developed to evaluate the range of possible operations that may mitigate the impact.
4. The monitor was carried out annually for 7 years.

4.5.4 Approach and Methods

The Water Temperature Monitor was conducted over 7 years from 2008 to 2014 by Creekside Aquatic Sciences and Greenbank Environmental Inc. Annual reports were compiled each study year and the 7th year report finalized the results and addressed all management questions listed above. All reports are available on BC Hydro's WUP website:

https://www.bchydro.com/about/sustainability/conservation/water_use_planning/lower_mainland/alouette.html

Temperature loggers (TidbiT V2 Temp Logger) were installed at 5 locations throughout the Alouette River and Alouette Lake reservoir (Figure 5-1). A vertical temperature logger array was installed to monitor the thermal stratification process in the reservoir near the entrance to the LLO. Loggers recorded hourly temperatures and were downloaded every 4 months.

Data from the current monitor (2008-2014) were analyzed for daily average (T_{avg}), maximum (T_{max}) and minimum (T_{min}) values. Data from earlier years (1999-2007) were provided by BC Hydro in daily mean, maximum and minimum values (no hourly data). Summary statistics were used to compare between-site and between-year/seasons. Bivariate density and time series plots were used to compare temperature frequencies and seasonal trends occurring among sites.

Warm water temperature events were defined in the Terms of Reference (BC hydro 2009) as ≥ 25°C; the upper incipient lethal temperature of most Pacific Northwest salmonids (Jobling 1981; Sullivan et al. 2000). A secondary threshold was established at ≥ 21°C; the upper sustained temperature limit of most salmonids (Brett 1952). An event was considered short term if T_{max} > 21°C but T_{avg} < 21°C, indicating the threshold was only exceeded for a short period (e.g., a few hours) in a given day. A long term event was defined by T_{avg} > 21°C with a duration of one or more consecutive days.

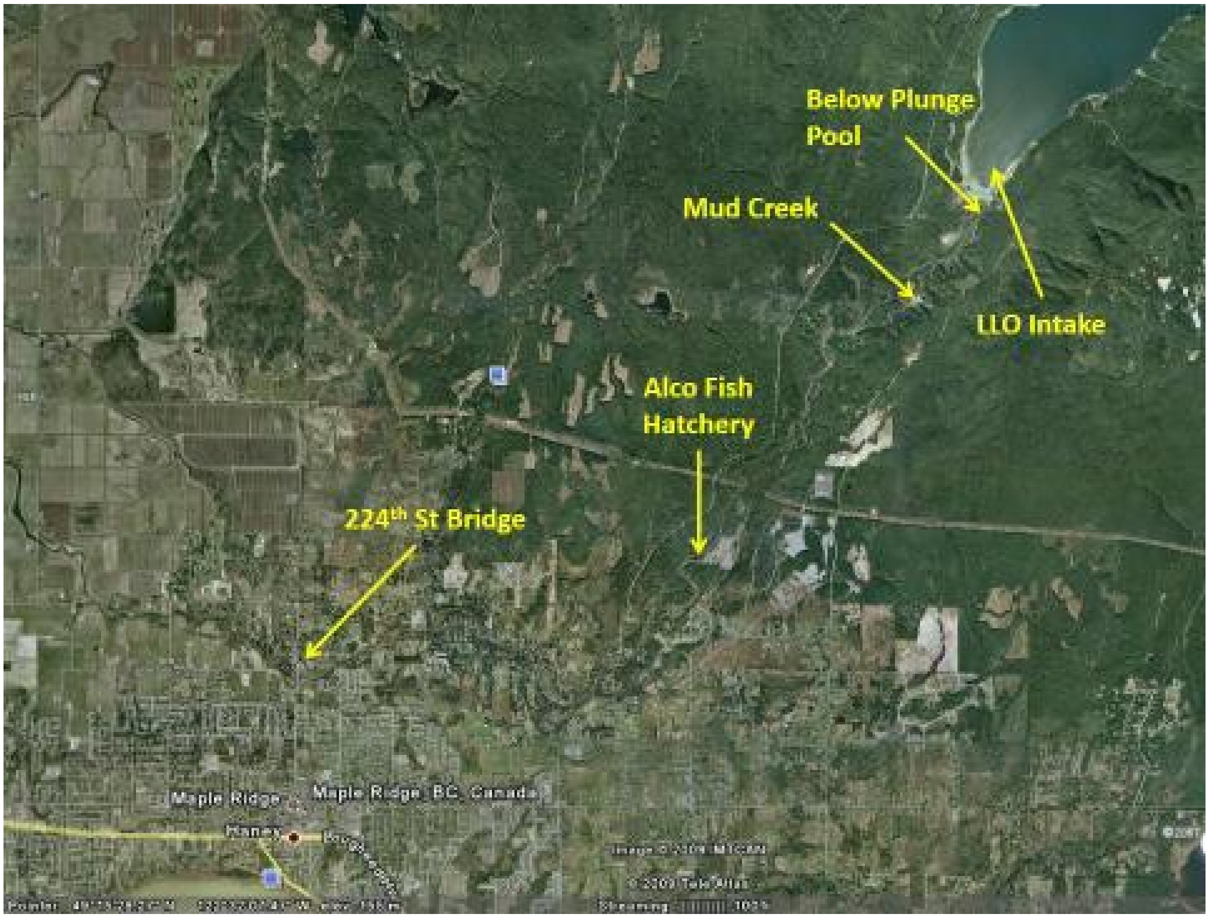

Figure 5-1. Air photo of Alouette River indicating the five water temperature sampling locations.

4.5.5 Results

Daily average water temperature at the plunge pool was 17.5°C (range of 13.5 to 20.5°C) while temperatures cooled with distance downstream (Allco Hatchery, 17.1°C; range of 14.1 to 19.3°C; Figure 5-2). Maximum daily average temperature recorded at the plunge pool was 20.8°C. In 2014, five warm water events (> 21°C; T_{max} 21.27°C) occurred in late August lasting no more than a few hours.

Answers to the Management Questions

1. Q: How often are water temperatures ≥ 25°C, the incipient lethal temperature of most stream rearing salmonid species, including the duration of each event and the frequency of occurrence?

   A: Since 1999, T_{avg} in Alouette River did not approach or exceed the ≥25°C threshold at any of the sampling sites (Figure 5-2). During this Monitor, water temperatures rarely exceeded the upper salmonid tolerance temperature limit of 21°C. Over the 7 years of this Monitor, the highest recorded T_{max} and instantaneous temperature was 21.58°C (Mud Creek; August 28, 2013) and 22.9°C (plunge pool; August 8, 2004), respectively.

2. Q: Is the duration of observed warm water events less than 1 day, thus limiting exposure to warm waters and therefore thermal stress impacts?

   A: Generally, warm water events (≥ 21°C) occurred for a short period of time. Since 1999, 35 occurrences when the maximum instantaneous water temperatures exceeded 21°C were recorded at the plunge pool; however, 91% lasted less than a day. Two warm water events lasted an entire day and one event lasted two consecutive days. Warm water events at all other downstream locations lasted less than 1 day (Mud Creek, 23 events; Allco Hatchery, 30 events; 224th St. Bridge, 29 events). There were no measurements of water temperatures exceeding the lethal threshold (≥ 25°C) at any of the sampling sites.

3. Q: Are warm temperature events restricted to certain sections of river, indicating the inflow of cooler waters into system (most likely ground water)?

   A: Warm water events were not observed consistently through the entire river. Only 9 of the 35 warm water events measured at the dam's plunge pool were also observed at all sampling sites within the same day. Typically, warm water within the plunge pool was cooled while distributing downstream. Additionally, thermal conditions unique to each site created short term, localized warm water events that may or may not cool as it travelled downstream.

4. Q: 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?

   A: No evidence of a thermal regime shift over the course of the monitoring period was found (Figure 5-3). A shift in fish community structure from a hypothesized persistent warming was considered unlikely. This could not be directly tested as abundance data for summer rearing salmonids was confounded by changes in methodology over time (ALUMON-1).

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

   A: Increasing the reservoir water level so the LLO intake can extract cooler water deeper in the thermocline would mitigate occurrence of warm water; however, this would increase flooding risks later in the year. Since Alouette River water temperature is generally below the upper salmonid tolerance limits (21°C), and if exceeded events are rare and short in duration, implementation of operational changes are not recommended.

Other results

A comparison of water temperatures in the plunge pool and LLO entrance found a high degree of correlation (variance of ±0.8°C) when the LLO was in use. LLO temperatures were up to 0.5°C cooler when plunge pool temperatures were > 15°C suggesting there were localized heating at the plunge pool site (i.e., solar heating). During surface release period (April 15 – June 15), plunge pool temperatures were closely related to surface temperatures, which tended to be slightly warmer than the LLO entrance (typically 1.5°C but varies among years; Figure 5-4). These results indicate that the mitigation measure of LLO release operation has improved Alouette River temperature conditions.

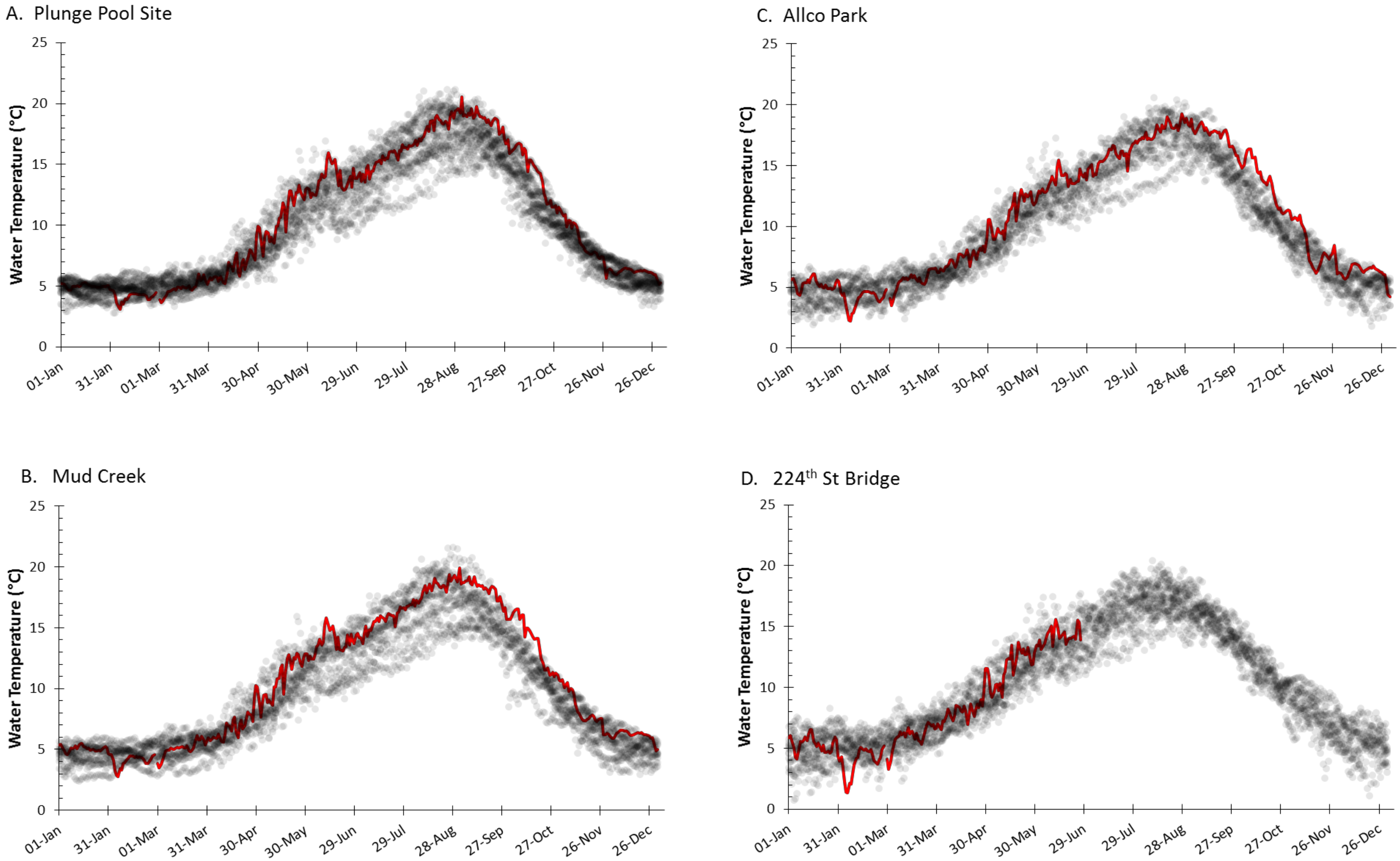

Figure 5-2. Alouette River water temperature at four locations downstream of Alouette Dam. Data includes average daily temperatures from 2000 through 2014 (red line). Darker areas indicate higher observed frequency of values.

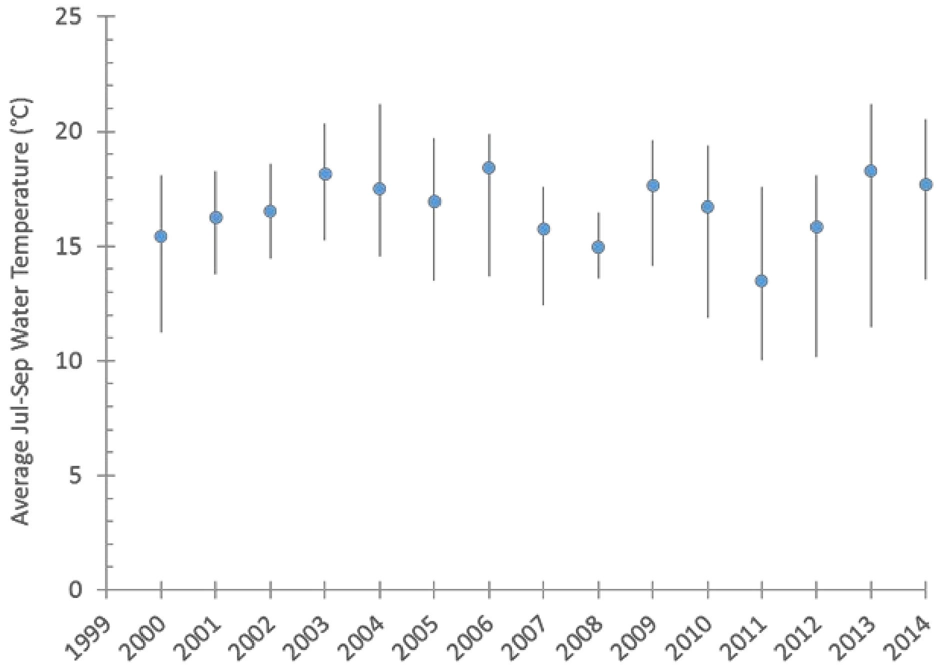

Figure 5-3. Average water temperature at the Alouette Dam plunge pool from July to the end of September. Data were provided by BC Hydro (1999 to 2007) and collected through this monitor (2008 to 2014). Vertical lines denote range of average daily water temperatures.

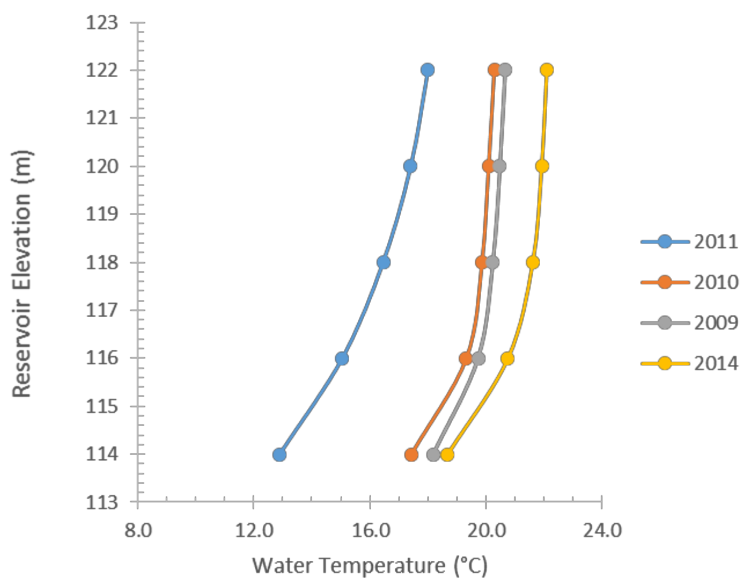

Figure 5-4. Average late summer water temperature of epilimnion immediately above the LLO intake at the southern end of Alouette Lake Reservoir.

4.5.6 Implications

Water temperatures within the Alouette River did not exceed the salmonid lethal threshold (≥25°C) and rarely exceeded the upper tolerance limit (21°C). Therefore, no mitigation measures for changes to the current WUP flow regime to provide cooling water temperatures within the Alouette River are required.

4.6 ALUMON-6 Kokanee Age Structure Analysis

4.6.1 Background

The Kokanee Age Structure Analysis Monitor was designed to address concerns of reservoir operational impacts on Kokanee spawning success. The population of Kokanee has increased dramatically (3 to 38 times) with the initiation of the fertilization program; however, it was uncertain whether the current level of production represents the full potential of the reservoir or if further increases in reproductive success is limited by reservoir operations. A monitoring plan Terms of Reference to address these uncertainties was drafted based on the recommendations of the ALU WUP CC (refer to BC Hydro 2009, for details).

Size-at-age analysis showed a slight decline in age-3 Kokanee since 2003, which indicates that the population is unlikely to be recruitment limited. Increased size at age usually indicates low densities which can be attributed to low spawning success.

4.6.2 Management Questions

Three management questions were to be answered in the Kokanee age structure analysis 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?

(BC Hydro 2009, pp. 54)

4.6.3 Objectives and Scope

The objective of this monitor was to determine the nature of the relationship between reservoir operations and recruitment potential of Kokanee in Alouette Lake reservoir. The following aspects define the scope of the study:

1. The study area included Alouette Lake Reservoir and relied on annual hydro acoustic work completed as part of the fertilization program monitor.
2. A fish sampling program similar to that used in the Stave Reservoir Fish Biomass Monitor (SFLMON-03) was carried out for the first two years and every second year thereafter.
3. The monitor was carried out annually for 7 years.

4.6.4 Approach and Methods

The Kokanee Age Structure Analysis Monitor was conducted from 2008 to 2014 by Redfish Consulting and Poisson Consulting. Annual reports were compiled for each study year and the 7th year report finalized the results and addressed all management questions listed above. All reports are available on BC Hydro's WUP website:

https://www.bchydro.com/about/sustainability/conservation/water_use_planning/lower_mainland/alouette.html

Hydrologic and nutrient loading information, fish biometrics, gillnet catches, daily reservoir elevations and hydro acoustic estimates were provided by the Ministry of Environment and the Ministry of Forests, Lands and Natural Resource Operations.

Hydro acoustic data (2001 – 2014; Simrad model EK60 120 KHz split beam system; see Harris et al. 2013 for details) collected at 12 transects provided the limnetic abundance of Kokanee (Figure 6-1). Data from depth layer > 10 m (years 2001-2011, 2013-2014) was considered less confounded by species distribution overlap and was used for analyses. Data from depth layer > 5 m was used in 2012 due to summer sampling (vs. fall) when Kokanee are higher in the water column (verified by gillnet surveys). Hydro acoustic data collected prior to 2001 was not used due to inconsistencies in methodology.

Littoral gillnetting (1998-2009) and pelagic gillnetting (2008-2014) was conducted to corroborate hydro acoustic data (Figure 6-1; see Harris et al. 2013 for details). Kokanee scale samples were collected for aging (n = >1,300); analyzed data excluded 4+ and 5+ aged fish due to small sample sizes (n = 94 and 3, respectively).

Hierarchical Bayesian models were fitted to size-at-age data from gillnet sampling and stock recruitment data from hydro acoustic sampling using R version 3.0.2 (R Core Development Team 2013). Size-at-age was analyzed using a generalized mixed effects model to determine if the population's size-at-age was stable or decreasing with optimized reservoir productivity. A loading coefficient was modeled to assess size-at-age in relation to nutrient loading and reservoir productivity. Nutrient data prior to 1999, when the fertilization program was initiated, was excluded. Stock recruitment was analyzed using a Bayesian Beverton-Holt model to interpret the effect of reservoir fluctuations during spawning and incubation on subsequent fry and adult abundance. Sex of fish, sampling season and location were also accounted for in each model.

Uncertainties in analyses were confounded by: 1) Temporal and spatial distribution of other species in the pelagic zone; 2) Losses of a proportion of the population due to entrainment; 3) inability of hydro acoustics to separate older Kokanee age classes (e.g., 2+ vs. 3+); 4) limited ability of trawling to obtain accurate species compositional estimates under low densities; 5) lack of information on Kokanee spawning population distribution and abundance; and 6) deliberate release of nerkids from the reservoir through water withdrawals at the dam spillway and the planned re-introduction of anadromized Kokanee/sockeye (Plate et al. 2014).

In the absence of Kokanee spawner biological, distribution, and abundance data, several assumptions were made:

- age at maturity as derived from the hydro acoustic data was defined as age 2+ and age 3+ fish; age at maturity from the gillnet data was defined as age 3+ fish;
- spawning habitat was assumed not to be limiting;
- gillnet data are representative of the actual proportions of age 1-3 fish but does not account for the bias of this method (i.e., selectivity in size);
- inherent limitations in the equipment/software and inadequate size separation between older age classes of Kokaneeaffected the ability to accurately estimate age structure for larger (1, 2, and 3+) Kokanee using hydro acoustic data alone potentially effecting the reliability of the estimates; and
- out-migrating Kokanee at the dam spillway are representative of age structure in the reservoir in early spring before young-of-year fry emerge.

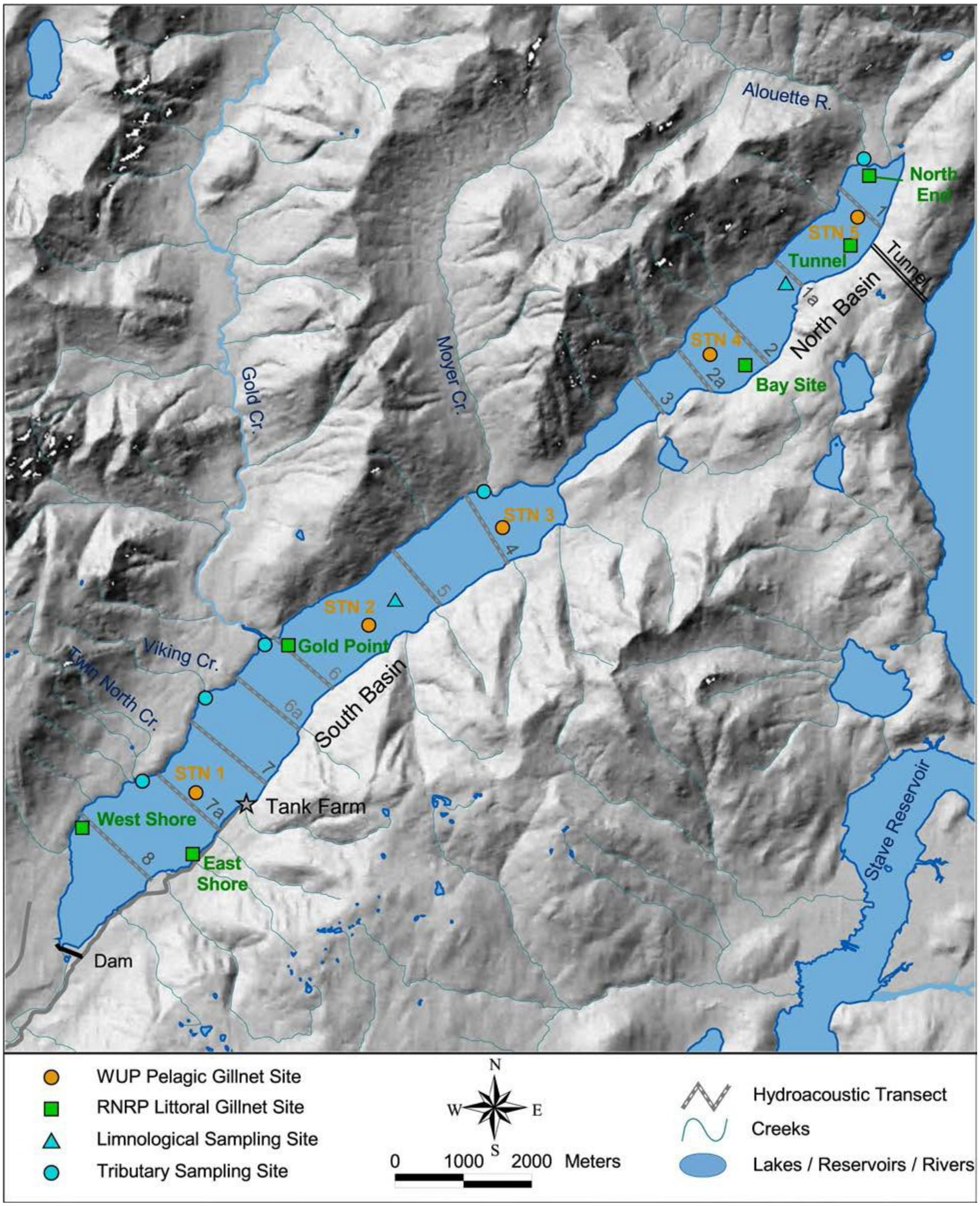

Figure 6-1. Locations for pelagic gillnetting (WUP; 2008-2013), littoral gillnetting (RNPR;1988-2009), reservoir water sampling, and tributary water sampling on the Alouette Lake Reservoir.

4.6.5 **Results**

The Kokanee population substantially increased since 2000, while the average Kokanee size from 2000 – 2003 has subsequently declined before stabilizing at the present level around which there are inter-annual fluctuations (Figure 6-2;Figure 6-3). However, the relation between abundance and size of Kokanee in the reservoir is relatively weak and not significant suggesting other factors related to reservoir food productivity and/or food quality maybe influencing the compensatory mechanisms.

Stock recruitment models analyzing the contribution of spawning stock (age 2+ and 3+) to the age-0 population predicted the average carrying capacity of fry of 153,990 (95% CRI 128,720 – 181,150). Model also predicted severe reservoir drawdown may limit recruitment and reproductive success; however relationship was insignificant and demonstrated substantial uncertainty. In contrast, a second model analyzing age 0 (fry) and age 1+ (recruits) predicted a peak recruitment of 44,770 (95% CRI 34,950 – 58,260) age 1+ and indicated elevation changes during Kokanee spawning and rearing period does not limit recruitment of Kokanee at the age 1+ stage. Estimated age 0+ and 1+ numbers are considered conservative since separation of age classes from hydro acoustic data may not be reliable. Both models indicated that density dependent factors likely regulate population abundance of age-0 and age-1 fish.

Answers to the Management Questions

1. Q: Is the existing Kokanee population in the Alouette Lake Reservoir, recruitment limited?

   A: Size-at-age analysis showed a slight decline in age-3 Kokanee since 2003, which indicates that the population is unlikely to be recruitment limited. Increased size at age usually indicates low densities which can be attributed to low spawning success.

2. Q: 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)?

   A: The stock recruitment model indicated that annual variability in fry recruitment was not correlated with the extent of reservoir fluctuations during the spawning and incubation period. However, the model did predict that extensive reservoir drawdowns outside of ordered Water Use Plan operations could potentially limit recruitment and the reproductive success of the Alouette Lake Reservoir Kokanee population.

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

   A: The stock recruitment model results indicated that annual variations in fry abundance does not impact the cohort's future reproductive potential. The spawner-recruitment model predicted that daily reservoir elevation changes (October 15 – February 28) could potentially limit recruitment and the reproductive success of the Alouette Lake Reservoir Kokanee population; however, the relationship was not considered significant and demonstrated substantial uncertainty.

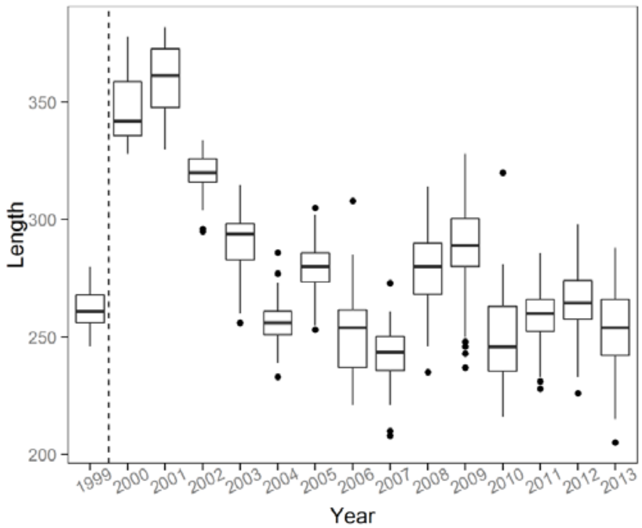

Figure 6-2. Observed length of age-3 Kokanee captured with gillnets on Alouette Lake Reservoir from 1998-2013. The fertilization period began in 1999 (dashed line). A change in sampling technique occurred in 2008. The larger size of Kokanee from 2000 – 2002 corresponds to when abundance was considerably lower than current estimates.

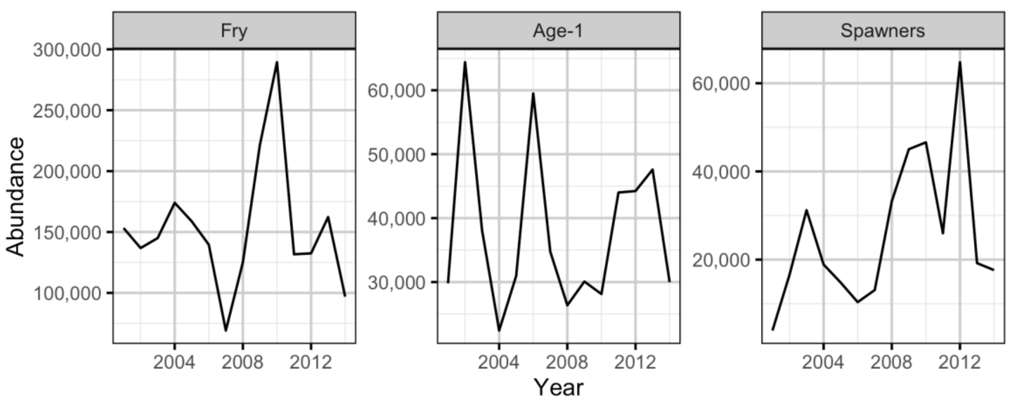

Figure 6-3. Abundance of fry, age-1 and age-3 (spawners) Kokanee from 2002 – 2014 as assessed from hydro acoustic data. Note: 2001 data from split beam not included.

4.6.6 Implications

Two WUP activities were hypothesized to potentially affect the productive capacity of Alouette Reservoir: reservoir operations (effect on spawning success) and smolt outmigration operations (effect on spawner abundance). While reservoir operations were modeled to have little to no effect on fry production, smolt outmigration effects remain uncertain as it was not modeled. No implications are associated with ALUMON-6.

4.7 ALUMON-7 Archaeological Monitoring

4.7.1 Summary/ background

This study was intended, in part, to address a knowledge gap regarding the number, location, elevation, condition, susceptibility to erosion and relative importance of archaeological sites within the Alouette Reservoir and Alouette River study area. It was also intended to maximize the protection of cultural resources within the Alouette system. The study was planned to be 1 year in duration, but was extended to 3 years to accommodate challenges conducting assessments during low-reservoir conditions.

An archaeological monitoring plan was recommended by the WUP Committee to provide a more accurate assessment of the impacts of BC Hydro operations on archaeological sites and to inform the evaluation of operating alternatives. The WUP Committee recommended a program consisting of an archaeological inventory and impact assessment, including an erosion-monitoring component, of the Alouette Reservoir draw down zone and the Alouette River.

This monitoring program is comprised of several non-intrusive study components involving field survey of the Alouette Reservoir drawdown zone and Alouette River as well as an archival literature review.

4.7.2 Objective and Management Questions

The objective of this monitor was to maximize the protection of cultural resources within the Alouette System. There were five management questions:

1. Where are the archaeological sites in the reservoir?
2. What are the relative heritage values of identified sites?
3. What is the nature and extent of the impacts to archaeological sites that are caused by reservoir operations?
4. Are there archaeological resources that are impacted by river flows?
5. Would an operation change potentially minimize those impacts?

4.7.3 Approach and Methods

Prior to conducting fieldwork, the study team engaged in an extensive background research program designed to assess existing documentary information pertaining to past uses of the study area. During the early planning stages of this project, representatives from the Katzie First Nation, Kwantlen First Nation, and the Stó:lō Research and Resource Management Centre were contacted. The Katzie First Nation was involved through the employment of field crew and direction from the Katzie Development Corporation (KDC) for the Alouette Reservoir fieldwork. Katzie members have been involved in the background research for this project. A field assistant was also employed from the Kwantlen First Nation for the Alouette River part of the fieldwork, though no one was available for the Alouette Reservoir fieldwork.

An Archaeological Potential Assessment was completed prior to fieldwork. Areas of the Alouette Reservoir were judged to have high archaeological potential due to the presence of suitable landforms and the proximity of available water and fish resources, a southern aspect, and locations along trail systems that carry possible associations with mountain goat hunting expeditions into the alpine surrounding the Alouette Reservoir. Three previously identified sites (DiRo-1, DhRo-7, and DhRo-8) had been recorded in the drawdown zone of the Alouette Reservoir. All three sites are located on fairly level land surfaces which are in close proximity to water and fishing resources. Two (DiRo-1 and DhRo-8) of the three identified sites have a southern aspect. One previously identified site (DhRo-7) is now considered to be destroyed by Alouette Dam construction and improvements. There are no previously recorded archaeological sites along the 16 km of the Alouette River from the south side of the Dam to 216th Street. The Alouette River had not been surveyed by archaeologists; however, the Water Use Planning Consultative Committee felt that areas with archaeological potential exist along the river because this waterway was traditionally and presumably in pre-contact times used by Katzie people and their ancestors.

A Preliminary Field Reconnaissance (PFR) was completed in 2009 and 2011 for the reservoir drawdown zone and the river. In the drawdown zone, the PFR included both a pedestrian and boat survey. Exposures (e.g., drawdown zone, game trails, tree throws, sparsely vegetated areas, rocky outcrops, and creek banks) were examined for the presence of cultural materials and other evidence of past human settlement and land use. Bedrock exposures and large boulders were examined for rock shelters, seams of flakable lithic raw materials, and pictographs and petroglyphs. Trees, including stumps, of various species were examined for the presence of cultural modification.

In the river, the PFR consisted of a boat survey. The banks of the river and adjacent riparian areas were assessed for their archaeological potential as the rafts navigated down the River from the Alouette Dam to 216th Street in Maple Ridge. Due to private property access issues, survey was constrained to the river channel and cutbanks. Where possible, bedrock exposures and large boulders were examined for seams of workable lithic raw materials, and pictographs and petroglyphs. Cutbanks were also examined for changes in sediment that might be indicative of anthropogenic soils. Trees of various species were observed for potential for the presence of cultural modification.

4.7.4 **Results**

At the conclusion of the monitoring program, there were eight archaeological sites located within the drawdown zone of Alouette Reservoir. All sites are located on the southwest shore of the reservoir, with the exception of one site located on the northwest shore. This study concluded that impacts to sites within the Alouette Reservoir drawdown zone may result from mechanical processes such as fluctuating water levels, outflow erosion, rainfall erosion, siltation, saturation and slumping. Human impacts may include unauthorized collection of artifacts, damage through recreational use (e.g., the creation of temporary use fire pits) and damage caused by park maintenance projects. At the north end of the Alouette Lake reservoir, the roots systems of some stumps have been exposed demonstrating that the ground surface has been eroded by up to 2 metres, whereas other nearby stumps are almost completely buried by silt. These extremes in aggradation and erosion have probably affected the integrity of most archaeological sites in the Alouette Lake reservoir drawdown zone. It is likely that archaeological remains located at most sites within the Alouette Lake reservoir are not in situ.

There were no archaeological sites recorded along the banks of the Alouette River. One archaeological site was identified near the river, but from a potentially disturbed context as a result of historic activities. The section of river between 232nd street and 216th street is considered to have high archaeological potential. Recommendations were made to conduct periodic surface surveys in the high potential areas following periods of high water or similar erosional events.

Based on the results of the study, scientific significance ratings were calculated based on the Archaeology Branch Site Assessment Guideline (1996). While the sites score fairly low based solely on the guidelines, the sites were rated from low moderate scientific significance due to a variety of other variables. Katzie First Nation considers all the sites to have high cultural and ethnic significance.

Recommendations for the drawdown zone of Alouette Reservoir included implementation of an archaeological testing program to be carried out in areas above the high pool to both determine the inland extent of known or previously unrecorded sites and to determine appropriate management schemes for each site recorded during the inventory. The study also recommends that the inventory include culturally significant resources and resource areas (e.g., plant resources, areas appropriate for ceremonial activities and inland and alpine access points and trails).

Recommendations for the Alouette River included conducting periodic surface surveys in the high potential areas following periods of high water or similar erosional events.

No recommendations were provided in regard to changing operations. However, four management strategies were recommended. These recommendations for archaeological site management were provided to BC Hydro's Reservoir Archaeology Program (RAP), as these activities fall under the purview of the Heritage Conservation Act and are outside the jurisdiction of the Comptroller of Water Rights.

Answers to management questions:

1. Q: Where are the archaeological sites in the reservoir?
   A: Eight sites were identified. All sites are located on the southwest shore of the reservoir between Gold Creek and the Alouette Dam, with the exception of one site located on the northwest shore.

2. Q: What are the relative heritage values of identified sites?
   A: Sites were rated from low to moderate scientific significance. All sites have high cultural and ethnic significance.

3. Q: What is the nature and extent of the impacts to archaeological sites that are caused by reservoir operations?
   A: Combined effects of multiple years of scouring, and erosion and accretion.

4. Q: Are there archaeological resources that are impacted by river flows?
   A: No sites were identified along the river.

5. Q: Would an operation change potentially minimize those impacts?
   A: mThe study provided an assessment of effects to archaeological sites directly related to reservoir operations, and concluded that further surveying and testing was required. This was completed under the RAP.

5. Overall Operational Implications

Out of the six aquatic monitoring studies completed, only two studies have implications for operational changes; with the first study indicating that the pulse flows tested during spillway surface flow releases are ineffective at moving additional smolts out of the reservoir (ALUMON-2) and secondly the requirement for river wide flushing flows was provided by natural inflows for the majority of years sampled (ALUMON-3) therefore additional flows were not required. Ordered minimum flows for the Alouette River were tested and monitoring indicated that the flows are supporting smolt survival, productivity and transport out of the system without delay (ALUMON-1). Spring surface flows from mid-April to mid-June proved to be successful at enabling smolts to leave the reservoir (ALUMON2). over the period of the monitor, the data has shown that re-anadromization of Kokanee/Sockeye to the Alouette watershed is possible in the watershed (ALUMON4). Water temperatures in the Alouette River remained within acceptable levels for salmonids throughout the study period therefore no operational changes required (ALUMON-5). Throughout the duration of the study period the Alouette Fertilization Program has supported reservoir nutrient supplementation and has provided data for ALUMON-5. No operation implications are associated with ALUMON-5. No recommendations were provided in regard to changing operations as a result of ALUMON-7.

Table E2. Summary of operational implications for the Alouette WUP monitoring programs

Study name	Implications
ALUMON-1 Smolt Enumeration	1. Ordered outlet gate operations are adequate to support targeted salmonid productivity. 2. No clear evidence that current base flow targets and timing should be revised. 3. Base flows are supporting Chum egg to fry survival.
ALUMON-2 Kokanee Out-Migration	Spillway surface flow releases are effective at attracting volitional Kokanee migrants during the out-migration timing window. April 15-June 14 is the appropriate timing for surface flow releases.Pulse flow releases mid-June are not effective and the requirement to continue providing them was removed from the Order in 2018.
ALUMON-3 Substrate Quality	As the Wolman pebble count methodology is an effective long-term indicator of substrate quality, natural frequency of flushing flows has proved to be effective in moving fine sediments with no further need for prescribed flushing flows.
ALUMON-4 Sockeye Adult Enumeration	There is little evidence to suggest that current trap and truck and fencing operations should be modified from its current mid-June to October operating window.
ALUMON-5 Water Temperature	No mitigation measures for cooling of water temperatures within the Alouette River are recommended.
ALUMON-6 Kokanee Age Class Structure	Two Water Use Plan activities were hypothesized to potentially affect the productive capacity of Alouette Reservoir: reservoir operations (effect on spawning success) and smolt outmigration operations (effect on spawner abundance). While reservoir operations were modeled to have no effect on fry production, smolt outmigration effects remain uncertain as they were not part of the model.
ALUMON-7 Archaeological Monitoring	No recommendations were provided in regard to changing operations.

6. Conclusion

Overall, the six aquatic studies (ALUMON-1 to ALUMON-6) have sufficiently answered their management questions and have provided information to be used in discussions regarding operational implications and WUP Order review decisions. Of these six studies, two suggest flow changes:

- ALUMON-2 suggests that pulse flows for moving smolts out of the system are not effective and that BC Hydro be relieved of the current Order requirement. According to those results, this ordered requirement was removed in 2018; and
- ALUMON-3 indicated that natural inflows provide adequate substrate maintenance in the Alouette River and that prescriptive flushing flow releases from Alouette Dam are not required.

Under ALUMON-6, two activities were hypothesized to potentially affect the productive capacity of Alouette Reservoir – reservoir operations and smolt outmigration operations. While reservoir operations were modeled to have no effect on fry production, smolt outmigration effects remain uncertain as they were not part of the model. Regardless, all studies have concluded with Management Questions answered and no further study is recommended. With the exception of the Kokanee pulse flows (Order #4) all Fish Flow Releases Ordered under this Water Use Plan have proven to be beneficial to the aquatic environment. Whereas outcomes of the ALUMON-01 and 02 study programs identified no benefit to outmigration from June pulse flows, it should be noted that follow up studies under the Fish and Wildlife Compensation Program has shown that earlier pulse flows (April and May) may influence outmigration.

The remaining study, ALUMON-7, was an archaeological monitoring program. Recommendations from this study have been provided to BC Hydro's Reservoir Archaeology Program, as these activities fall under the Purview of the *Heritage Conservation Act*.

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