Duncan Dam Project Water Use Plan

2013 Lower Duncan River Kokanee Spawning Monitoring

Implementation Year: Year 6 Data Report

Reference: DDMMON-4

Study Period: September – October 2013

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EXECUTIVE SUMMARY

The Duncan Dam (DDM) Water Use Planning (WUP) process attempted to address flow management issues related to local resources such as Lower Duncan River (LDR) Kokanee populations. Monitoring of the abundance of Kokanee spawning in this area was initiated by BC Hydro in 2008 as part of its Water License Requirements (WLR) DDMMON#4 program. Year 2013, represented the sixth year of this ten year monitoring program. As in the previous five years, Kokanee spawner counts were carried out from a helicopter. In addition to aerial counts, features of the preferred spawning habitats and observer efficiency verification were determined on the ground. Year 6, represents the continuation of the work carried out by AMEC from 2008–2012 (AMEC 2009, AMEC 2010, AMEC 2011, AMEC 2012, AMEC 2013). To achieve consistency between the successful surveys carried out by AMEC from 2008–2012 and the 2013 surveys carried out by Okanagan Nation Alliance (ONA), previously established methods were applied whenever possible and improved where necessary. None of the changes made in 2013 affected the comparability of 2013 results with results obtained in previous years.

Based on an Area Under the Curve (AUC) calculation, the 2013 Kokanee spawning population in the Lower Duncan River was estimated to be 20,300 fish, with a lower 95% Confidence Interval (CI) of 900 fish and an upper 95% CI of 62,000 fish. In comparison to previous years, the 2013 estimate can be categorized as low but comparable to 2009 (19,600 spawners) and 2010 (19,000 spawners) levels but much lower than the highest estimate of 75,600 spawners in 2012.

Specific management questions defined in the DDMMON#4 Terms of Reference (TOR) and the progress made in addressing them is summarized in **Error! Reference source not found.**.

Table 1. Management questions and the status of the answers to them based on field work and data analysis carried out as part of the BC Hydro project DDMMON-4.

Management Question	Status
What is the spawn run timing, fry emergence timing, and relative intensity of kokanee spawning in the Lower Duncan River? What potential operational/environmental cues affect this variable?	<u>Spawn Run Timing:</u> Based on AMEC (2013), between 2008 and 2012 Kokanee spawned in the LDR from late August to late October and peak spawning occurred from September 20 –October 10. In 2013, the peak of Kokanee spawning activity was observed on October 4, 2013 within the range of peaks observed from 2008–2012. Changes in LDR flow and decreasing seasonal trend in water temperature did not trigger changes in spawning migration or the distribution pattern of Kokanee spawners in the LDR. <u>Fry Emergence Timing:</u> In general, fry emergence timing is dependent on the Accumulated Thermal Units or ATUs of fish eggs during incubation and early development. Based on observations in AMEC (2013), the DDM low level outlets (LLOs) discharge water may be warmer than surface waters in the winter, resulting in emergence timing that is earlier for LDR kokanee than seen in adjacent systems such as Meadow Creek and Lardeau River. Temperature profiles during the incubation period have not been explicitly collected to determine the effect of operations on emergence timing. <u>Relative Intensity of Spawning in the LDR in Comparison to Lardeau</u>

	<u>River and Meadow Creek:</u> From 2008–2013 the majority of Kokanee in the Duncan River watershed spawned in Meadow Creek (52%) and the Lardeau River (45%) while only a small portion of the fish spawned in the LDR (3%). <u>DDM operational Effects:</u> According to AMEC (2013), the regulated flow through DDM may have led to substrate compaction and thus reduced the amount of Kokanee spawning habitat when compared with the amount of historical spawning habitat.
What are the timing/cues of Kokanee spawners in Meadow Creek and Lardeau River systems?	<u>Spawn Timing Cues:</u> Kokanee spawning in Meadow Creek occurs from mid-August to late October with peak spawning from end of September (AMEC 2013) to first week of October(this study). In this context, water temperature does not appear to either influence the arrival of Kokanee in the LDR or their spawn timing. In 2013, water release through DDM was kept constant throughout most of the spawning period and therefore neither water temperature nor discharge, fluctuated enough to act as a possible cue for spawn timing or river entry. It is known that Kokanee spawning in the Lardeau River occurs from early September to mid-October but it is unknown which environmental cues trigger river entry or spawning in the Lardeau River (AMEC 2013).
What are the relative distribution of Kokanee spawners in the Lower Duncan River, Meadow Creek and Lardeau River? What potential operation/ environmental/ physical cues (e.g., temperature, velocity, depth, cover, substrate) affect this variable?	<u>Kokanee Spawner Distribution in the LDR:</u> In 2013 and in all earlier years (AMEC 2013) of DDMMON-4, Kokanee spawning has been limited to the upper 9 km of the 12 Km study area (LDR Kms 1-9), where gravel suitability is highest. Gravel suitability is lowest in the reaches proximal to the confluence with Kootenay Lake due to sediment deposition that occurs each freshet (NHC 2010). In 2013 and from 2008–2012 (AMEC 2013), early Kokanee holding and initial spawning starts in side channels but then spreads to the main channel during the peak of spawning. Kokanee may initially move into side channels to seek out low velocity and cooler holding habitat with cover to minimize energy expenditure and avoid predation as has been observed for Kokanee in Meadow Creek (AMEC 2013). <u>Kokanee Spawner Distribution Meadow Creek:</u> In Meadow Creek, the majority of spawning occurs in the 3 km of Meadow Creek Spawning Channel (located approximately 4 km upstream of the confluence with the Lower Duncan River) with idealized conditions for Kokanee egg incubation. Areas outside of the spawning channel are mainly used when the spawning channel itself is filled to capacity with Kokanee spawners (AMEC 2013). The bottom substrate of the lower section of Meadow Creek has a high percentage of silt and fewer spawning gravels and is therefore limited in suitability for Kokanee spawning (Quamme 2008). <u>Kokanee Spawner Distribution Lardeau River:</u> Kokanee spawning in the

	Lardeau River has been observed along its whole length with the highest densities found in the upriver side channels. Based on its natural hydrograph, the Lardeau River experiences typical spring flush flows that aid in removing fines (AMEC 2013). As a general comment, genetic analysis of Kokanee spawning in the LDR, Lardeau River and Meadow Creek revealed that Kokanee spawners from the three locations are not genetically different. They are therefore considered to belong to the same Kokanee stock (AMEC 2012, Lemay and Russello 2011).
What physical works or operational constraints could be implemented to minimize operational conflicts associated with recommended Kokanee spawning operations?	A primary goal of this study is to identify opportunities to limit the potential stranding impact associated with kokanee spawning protection flows defined in the WUP. Due to the multiple factors limiting the ability to manipulate flows during the late September – early October period, and the limited feasibility of physical works to minimize access/impact to sidechannels affected by the spawning flows (AMEC 2012), any regime that can minimize flow reductions during peak spawning, and maintain incubation flows close to spawning flows will reduce conflicts with existing spawning operations. In 2013, kokanee spawning flows were reduced four days earlier (September 27^{th} vs October 1^{st}) and the minimum flow was increased from 73 to 97cms for the duration of the spawning period. This ensured that sidechannel 6.9R and potentially 3.5R remained wetted

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LGL Limited

Thanks to Lucia Ferreira and Julio Novoa of LGL Limited who prepared all maps for this study and estimated wetted widths and areas based on mapping data.

Poisson Consulting

Dr. Joe Thorley of Poisson Consulting calculated the Area Under the Curve (AUC) estimate of abundance for Kokanee spawners and adjusted all calculations by observer efficiency. Dr. Thorley was effective and responsive to the request and was chosen to maintain consistency in the analysis methods with previous years.

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IMPORTANT NOTICE

This report was prepared exclusively for BC Hydro by the Okanagan Nation Alliance (ONA) in collaboration with LGL Consulting. The quality of information, conclusions and estimates contained herein is consistent with the level of effort involved in ONA and LGL services and based on: i) information available at the time of preparation, ii) data supplied by outside sources, and iii) the assumptions, conditions and qualifications set forth in this report. This report is intended to be used by BC Hydro only, subject to the terms and conditions of its contract with the ONA and LGL. Any other use of, or reliance on, this report by any third party is at that party's sole risk.

1.0 INTRODUCTION

The Duncan Dam (DDM) was constructed from 1965 to 1967 for water storage under the Columbia River Treaty (CRT). Since 1967 the Lower Duncan River has been managed as a regulated river and is operated by BC Hydro for flood control purposes. The dam, which is situated 13 kilometers upstream of the north end of Kootenay Lake, regulates water levels in the Lower Duncan River (LDR) through daily, seasonal and annual operations (Figure 1) (AMEC 2013). The complexity of up and downstream ecological function, and social and economic interests of the many users of the LDR and Kootenay Lake, poses many challenges for the operation of DDM. Therefore a Water Use Planning, or WUP, consultation process was initiated in 2001 and completed in 2004 to address flow management issues with respect to impacts on competing resources in the area (BC Hydro 2004; AMEC 2013). The DDM WUP Consultative Committee (CC) identified Kokanee (*Oncorhynchus nerka*) spawning success in the LDR as a valuable ecosystem component that could be impacted by DDM operations (BC Hydro 2007).

Based on recommendations from a review of stranding mitigation options in 2013 (AMEC 2013a), DDM Operations implemented a test flow variation, which set minimum water flow targets of 73 m^3/s from August 1–September 20 followed by slight increase to 80 m^3/s for the period September 21–26 and another slight increase to 97 m^3/s for the key spawning period of September 27 to October 21, followed by a slight reduction to a minimum of 80 m^3/s from October 22–February 28 (Table 2). In summary, overall flows are held fairly consistent throughout the spawning and incubation period for Kokanee which reduced the potential for redd desiccation.

Table 2. Proposed BC Hydro flow regime change test for 2013, as measured at the confluence of the Lardeau and Duncan Rivers (BC Hydro data, September 3, 2013), compared to data from Water Survey Of Canada Station No 08NH118 (2013-2014).

Dates	**WUP Flow Variation (Proposed, m^3/s)**		**Hydrometric Data (WSC STN. 08NH118, m^3/s)**	
	Min	**Max**	**Min**	**Max**
August 1- 24	73	400	167	259
August 25 - September 20	73	250	205	240
September 21-23	**80**	**200**	**193**	**203**
September 24-26	**80**	**150**	**134**	**153**
September 27-October 21	**97**	**103**	**91.8**	**105**
October 22-December 21	**80**	**110**	**102**	**111**
December 22-February 28	**80**	**110**	**160**	**252**
March 1-April 9	73	250	32*	164
April 10-May 15	73	120	83	239**
May 16-July 31	73	400	171	315

*April 9, 2014 for 20 min from 114 m^3/s

** May 15, 2014

1.1 Objectives

DDMMON-4 is a 10 year project with the following specific objectives. Bolded objectives were addressed in Year 6 or this study and all other objectives were addressed from 2008–2012 (AMEC 2009-2013):

1. **Document the annual Kokanee escapement to the Lower Duncan River**, Lardeau River, Meadow Creek, and Meadow Creek Spawning Channel;
2. **Document Kokanee spawning in the Lower Duncan River within and outside of operational constraints**; and;
3. Define Kokanee spawning habitat preferences, timing and Kokanee morphology between spawning runs in the Lower Duncan River, Lardeau River and Meadow Creek for consideration of future decisions.

DDMMON-4 has the following management questions based on the terms of reference (BC Hydro 2008) and scope of services (BC Hydro 2013). Bolded management questions were addressed in Year 6 or this study and all other objectives were addressed from 2008–2012 (AMEC 2009-2013):

1. **What is the spawn run timing**, fry emergence timing, and relative intensity of K**okanee spawning in the Lower Duncan River**? What potential operational/environmental cues affect this variable?
2. What are the timing/cues of Kokanee spawners in Meadow Creek and Lardeau River systems?
3. **What are the relative distribution of Kokanee spawners in the Lower Duncan River**, Meadow Creek and Lardeau River? What potential operation/environmental/physical cues (e.g., temperature, velocity, depth, cover, substrate) affect this variable?; and
4. What physical works or operational constraints could be implemented to minimize operational conflicts associated with recommended Kokanee spawning operations?

1.2 Purpose

Currently, five years of monitoring have been completed (AMEC 2009-2013) with 2013 and 2014 designated as Year 6 and Year 7 respectively within the total of 10 years of the DDMMON-4 program. This report fulfills the ONA and LGL's commitment to provide BC Hydro with a data report for the 2013 (Year 6) monitoring of Kokanee spawning in the LDR.

2.0 METHODS

2.1 Study Area

The LDR is fed by DDM at its upstream end and flows over a distance of approximately 12.4 km into the northern end of Kootenay Lake, which is located north of Nelson in southeastern British Columbia. The Duncan River watershed above DDM receives input from the Selkirk and Purcell mountains. The 2013 study covered the entire 12.4 km of LDR from DDM (River Km 0.0) to Kootenay Lake (Km 12.4) and its side channels (Figure 1).

2.2 Environmental Parameters

Since discharge was a factor that needed to be related to Kokanee spawning onset, abundance, distribution and potential desiccation of eggs hourly discharge through DDM and water temperature records for LDR were obtained from the Water Survey of Canada (WSC) gauge (No: 08N118) below the Lardeau and Duncan rivers confluence from BC Hydro's Access database.

2.3 Sample Timing

A summary of Kokanee spawning monitoring dates and methods for 2013 is summarized in Table 3. Sampling methods included visual Kokanee counts out of a helicopter and simultaneous redd mapping. In addition, a stream walk was carried out on a selected side-channel to assess observer efficiency for the helicopter counts. The selected-side-channel had low and clear water and was shaded and thus offered optimum fish viewing conditions from the ground. During the ground count, counters also double and triple counted each section to get the best possible count for validation of their own and the helicopter observer efficiency.

During aerial counts, the helicopter flew at an altitude of 20–40 m above the river (AMEC 2012) at a low speed. Therefore all aerial surveys conformed with low level, low speed flight planning requirements of BC Hydro. Data collection methods for each type of survey are provided below.

Table 3.Sample timing and survey type for DDMMON-4 Lower Duncan River Kokanee spawner monitoring, 2013.

Date	Survey Type	Helicopter Type
Sept 19, 2013	**Aerial enumeration survey, ground enumeration validation (failed)**	**BO105LS, Dam Helicopters (Twin Rotor), Castlegar, BC**
September 27, 2013	**Aerial enumeration survey**	
October 2, 2013	**Aerial enumeration survey, ground enumeration validation, redd survey (successful)**	
October 9, 2013	**Aerial enumeration survey**	

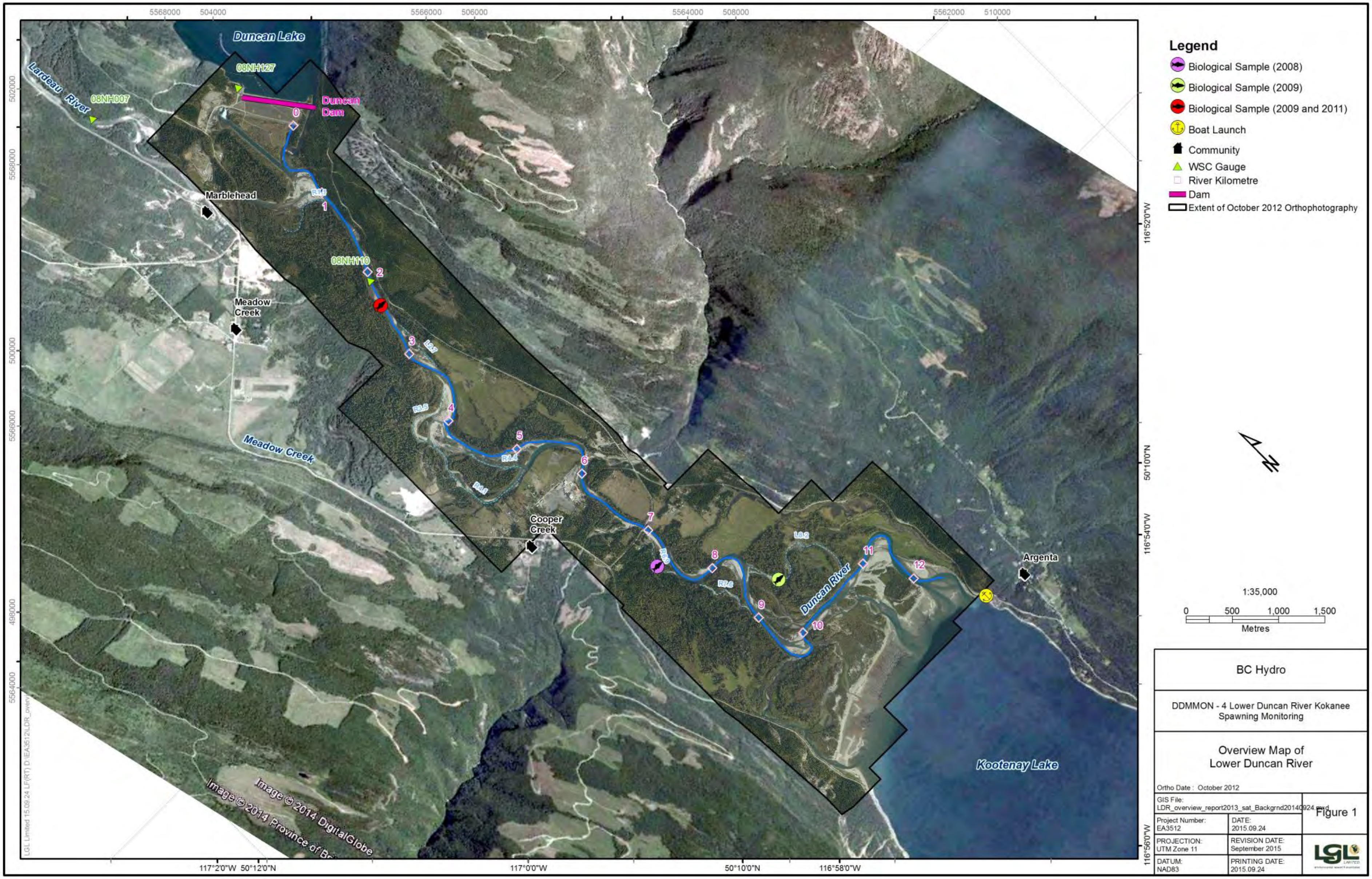

Figure 1. Lower Duncan River (LDR) study area for DDMMON 4 Kokanee enumeration and redd surveys.

2.4 Helicopter Enumeration Surveys

All helicopter aerial surveys covered the entire length of LDR from the delta in Kootenay Lake flying upstream to approximately 600 m below DDM and also covered all LDR side channels following the protocol that was used from 2008–2012 (AMEC 2009-2013). In 2013, all surveys were carried out using a BO105LS twin engine helicopter operated by Dam Helicopters (Castlegar, BC) and piloted by Duncan Wassick, who had operated the helicopter in previous surveys for DDMMON-4.

During the surveys, fish were visually counted and their numbers were recorded with tally counters by the lead fish counter in the front of the helicopter. The lead counter had an approximately 180^{o} view of the river because the helicopter was flying upstream at a 45^{o} angle to the direction of the current. The position, number and the extent of the area that Kokanee were using to hold or spawn was then manually drawn on a detailed 1:4,000 orthophoto and later geo-referenced as a polygon layer on a map. On the orthophotos of the main stem and the side-channels 100 m orientation markings helped to describe the exact location of the fish over all four surveys. Each side channel and main stem reach was named and the naming conventions conformed to the conventions established in the 2008-2012 studies (AMEC 2009–2013). In addition to the number of fish and extent of the area the main counter categorized Kokanee behaviour as follows:

- **Holding** – Kokanee observed in a school that were holding stationary and did not appear to be spawning;
- **Migrating** – Kokanee observed in a school that were moving in an upstream direction and did not appear to be spawning;
- **Spawning** – Kokanee observed stationary and paired up and distributed evenly throughout an area (sometimes redd digging was observed); and
- **Dead** – Kokanee observed drifting at the surface belly up without any volitional movement.

All flights were conducted at approximately 20–40 m above the ground at a speed of 10–18 km/hr upstream. Depending on the terrain, safety hazards, and weather conditions the helicopter had to increase elevation or speed at times. During each survey the main stem of the LDR was surveyed first followed by individual side channels to ensure the surveys could be carried out in a systematic and consistent manner (AMEC 2013). For all surveys, Clint Tarala was the lead counter in the front of the helicopter. Clint Tarala had carried out the aerial surveys during the five previous years of DDMMON-4 and was therefore contracted to maintain consistency of observer efficiency between years. In addition to Clint Tarala, different ONA Fisheries Department biologists and technicians joined the survey crew to familiarize themselves with counting methods in general and to benefit from Clint Tarala's previous experience. The methods used in 2013 followed the standards set for salmonid aerial counts throughout the Pacific Northwest (Jones et al. 2007).

2.5 Data Analyses

2.5.1 Area Under the Curve (AUC) Abundance Estimates

Repeated spawner counts can be converted into abundance estimates by dividing the area under the spawner curve (AUC) by the observer efficiency and residence time (English et al. 1992) where the residence time is the number of days fish spend on the spawning grounds. With the inclusion of an arrival time model the method provides a basis for statistically describing uncertainty (Hilborn et al. 1999) and estimating spawn timing. When data is sparse hierarchical methods allow "borrowing strength" from years with informative data to improve estimates for years with uninformative data (Su et al. 2001). Here we use hierarchical Bayesian AUC methods with a normal arrival time model to estimate spawn timing and spawner abundance with credible intervals.

Hierarchical Bayesian models were fitted to the LDR Kokanee enumeration data using R version 3.0.2 (Team 2013) and JAGS 3.3.0 (Plummer, 2012) which interfaced with each other via Jaggernaut 1.6 (Thorley 2014). For additional information on hierarchical Bayesian modelling in the BUGS language, of which JAGS uses a dialect, the reader is referred to Kéry and Schaub (2011, pp. 41-44).

Unless specified, the models assumed vague (low information) prior distributions (Kéry and Schaub, 2011, p. 36). The posterior distributions were estimated from a minimum of 1,000 Markov Chain Monte Carlo (MCMC) samples thinned from the second halves of three chains (Kéry and Schaub 2011, pp. 38-40). Model convergence was confirmed by ensuring that Rhat (Kéry and Schaub 2011, p. 40) was less than 1.1 for each of the parameters in the model (Kéry and Schaub, 2011 p. 61). Model adequacy was confirmed by examination of residual plots.

The posterior distributions of the *fixed* (Kéry and Schaub 2011, p. 75) parameters are summarized in terms of a *point* estimate (mean), *lower* and *upper* 95% credible limits (2.5th and 97.5th percentiles), the standard deviation (*SD*), percent relative *error* (half the 95% credible interval as a percent of the point estimate) and *significance* (Kéry and Schaub 2011, p. 37,42).

The results are displayed graphically by plotting the modeled relationships between particular variables and the response with 95% credible intervals (CRIs) with the remaining variables held constant. In general, continuous and discrete fixed variables are held constant at their mean and first level values respectively while random variables are held constant at their typical values (expected values of the underlying hyperdistributions) (Kéry and Schaub 2011, pp. 77-82). Where informative the influence of particular variables is expressed in terms of the *effect size* (i.e., percent change in the response variable) with 95% credible intervals (Bradford et al. 2005). Plots were produced using the ggplot2 R package (Wickham 2009).

2.5.2 Observer Efficiency

Observer efficiency was based on a comparison between fish counts provided by ground counters with fish counts provided by aerial counters. Surveys were attempted on September 19 and October 2 at known side channel locations (i.e., SC 3.5 and SC 8.2) in the LDR. The ground surveys were conducted on the same day as the aerial surveys, immediately prior or past the fly-over, coordinated via radio communication. Of the three observer efficiency surveys attempted only one survey was successful in adequately comparing ground and aerial counts. Ratios of ground counts to aerial counts were calculated by Poisson and compared to observer efficiency calculated from 2008-2012.

2.5.3 Relative Intensity of Spawning

Kokanee enumeration counts for the four surveys conducted in 2013 were used by Poisson to generate an estimate of the relative intensity of spawning run timing in the LDR as part of the AUC analysis.

Spawning run abundance estimates for Meadow Creek and the upper Lardeau River were provided by MFLNRO (M. Neufeld, unpublished data 2013). Enumeration data provided by MFLNRO were based on single, aerial surveys conducted on October 3, 2013. Clint Tarala was also a lead enumerator on all MFLNRO aerial Kokanee enumerations.

2.5.4 Potential Egg Deposition and Losses

Potential egg deposition (PED) and loss calculations followed methods and assumptions on dewatering effects, spawn timing/superposition/predation, multiple-redd construction, and sex ratios employed by AMEC (2012, 2013), where peak counts were used to estimate female numbers, and where egg deposition for LDR Kokanee = avg fecundity (225) – avg egg retention(4). Only one redd mapping exercise was conducted on October 2, due to low numbers and high turbidity on September 19, turbulent winds and safety concerns on September 27, and no change in flows from October 2 and helicopter time limitations on October 9. Egg loses where calculated separately for sidechannel and mainstem redds observed to be dewatered throughout the duration of the study period (September 19 to October 9, 2013).

The 1:500 orthophotos with redd locations were scanned and digitized by GIS and areas of redds measured. Comparisons were then made between observed redd locations (area, m^2) in side channels and mainstem to calculate PED.

3.0 RESULTS

Environmental Parameters

3.1 Lower Duncan River Discharge and Temperature

Based on data collected from Lower Duncan River Water Survey Canada (WSC) hydrometric station 08NH118 (Figure 2), the Kokanee spawning period in September and October 2013 was characterized by lower flows than in the summer period and a decrease in flow at the beginning of the spawning period in mid-September in accordance with the Water Use Plan variance approved earlier that year described in the introduction. Summer flows were stepped down from 240 m^3/s on September 18, 2013 in three steps to 90 m^3/s on October 1, 2013 (Figure 3. Duncan River (Stn 08NH118) discharge (m3/s) and temperature, September 15 - October 21, 2013. (Source: Environment Canada). Dashed lines indicate survey dates.

The third flow reduction of three between September 19 to 27) lowered the water level in the LDR from 1.99 m to 1.73 m (Figure 4. Duncan River (Stn 08NH118) water level elevation (m) and temperature, September 27 - October 11, 2013. (source: Environment Canada; direct discharge measurement data not provided here). Dashed lines indicate survey dates. Dashed line on October 2 indicates first and only redd survey. as compared to 2012 and prior levels which displayed slightly larger water level changes during this period.

Water temperature data was summarized from the WSC station (Figure 2) to determine any correlations to timing of spawning and to predict incubation and emergence timing. Temperatures during spawning and through the duration of the field investigations followed decreasing seasonal trends, from 13°C on September 19 to 11°C on October 9, 2013 (Figure 3).

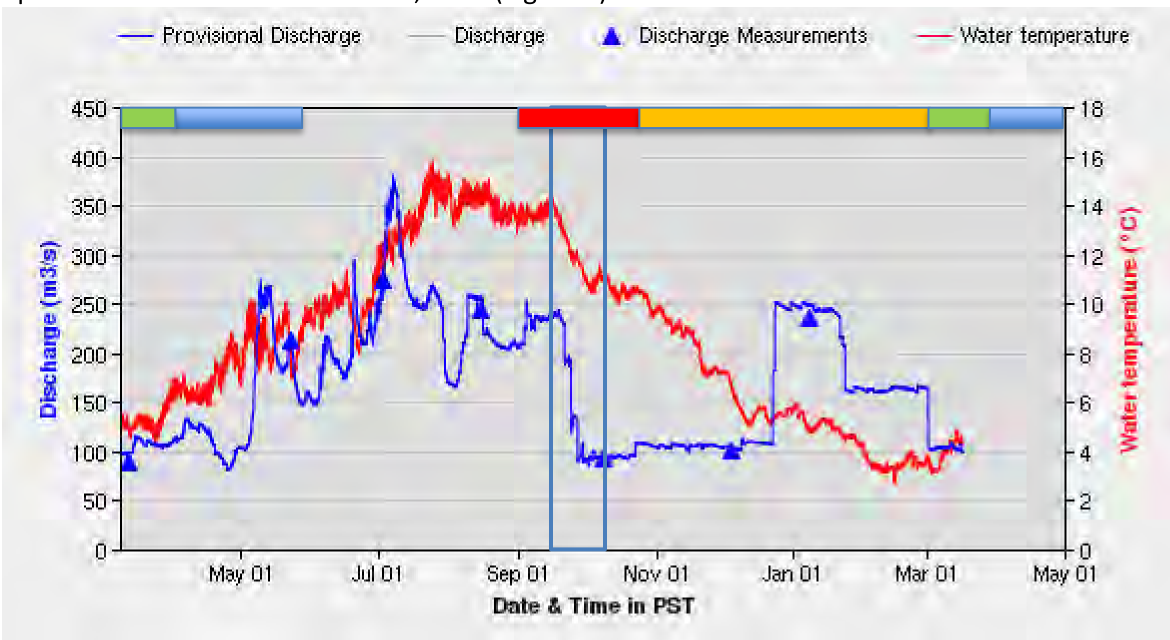

Figure 2. Discharge and temperature for Duncan River at Lardeau River confluence for 2013-2014. Blue line box indicates Kokanee enumeration study period for DDMMON 4 (Source: Water Survey of Canada Stn. 08NH118). Solid colour boxes indicate kokanee life history in the Lower Duncan River: Red – Spawning (migration, holding, redd construction); Orange – Incubation; Green – Emergence; Blue – Ponding and out-migration (to Kootenay Lake) (Source: AMEC 2010).

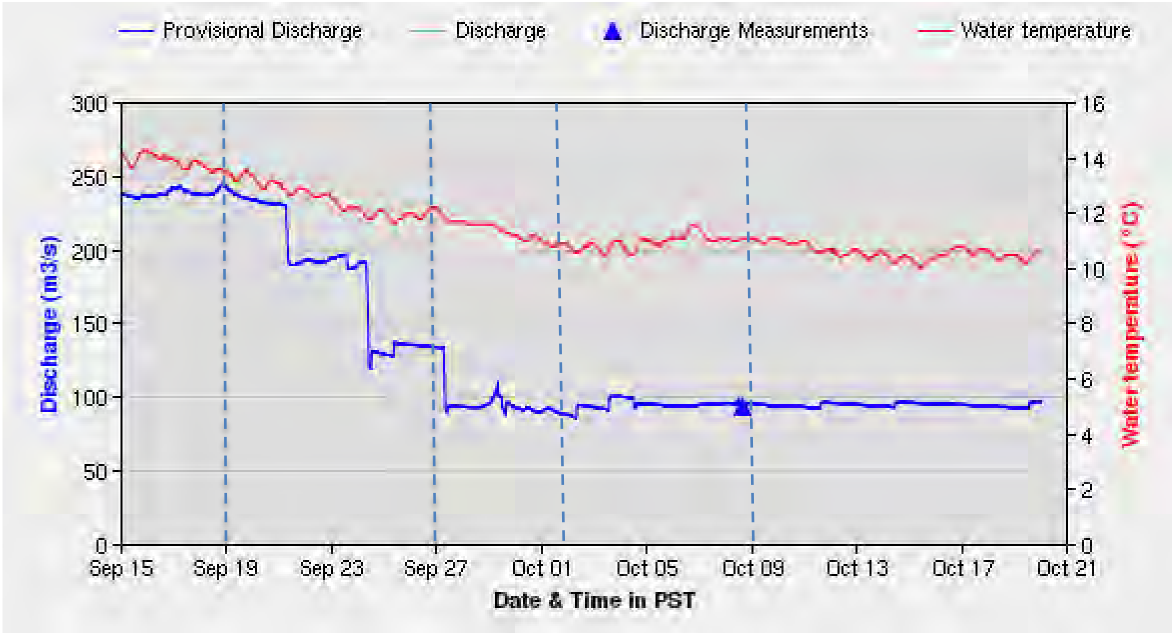

Figure 3. Duncan River (Stn 08NH118) discharge (m^3/s) and temperature, September 15 - October 21, 2013. (Source: Environment Canada). Dashed lines indicate survey dates.

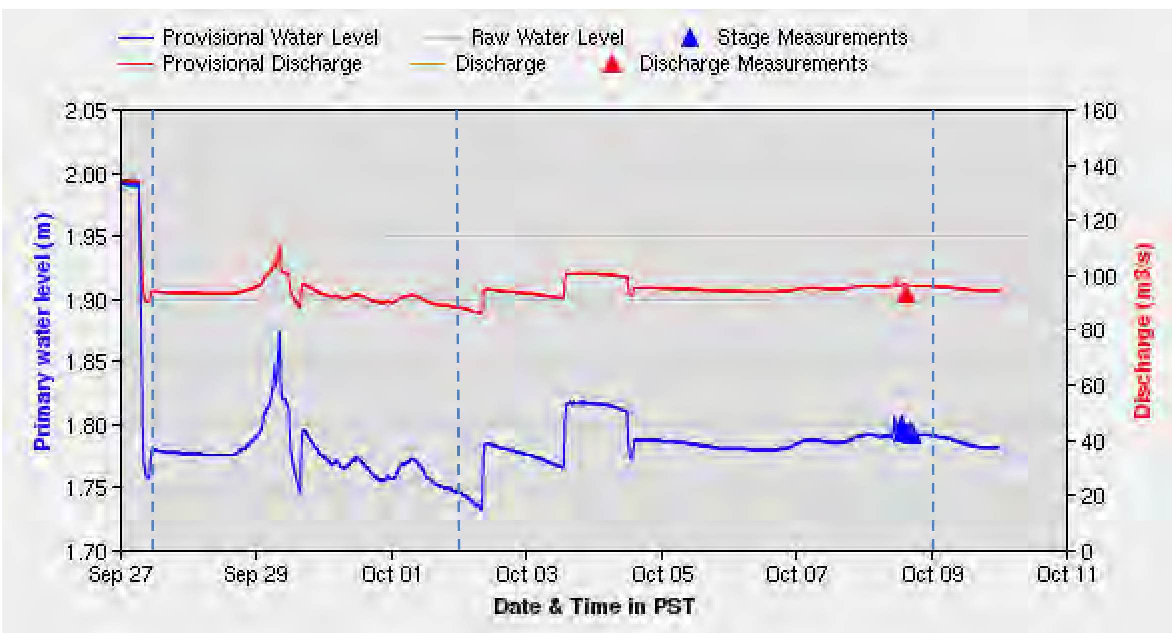

Figure 4. Duncan River (Stn 08NH118) water level elevation (m) and temperature, September 27 - October 11, 2013. (source: Environment Canada; direct discharge measurement data not provided here). Dashed lines indicate survey dates. Dashed line on October 2 indicates first and only redd survey.

3.2 Kokanee Peak Count Timing

The estimated peak spawn timing for Kokanee in 2013 and throughout the rest of the DDMMON-4 project period from 2008–2012 is shown in Figure 5 and a tabular summary for the peak spawn timing from 2008–2013 is shown in Table 4. Peak spawning was predicted for October 4 in 2013 (Figure 6). The 2013 peak fell within the range of peaks from September 26–October 7 observed in previous years. The peak timing estimate for 2013 was less certain than in previous years because the counts did not decline, i.e., they do not provide information on when most fish had spawned.

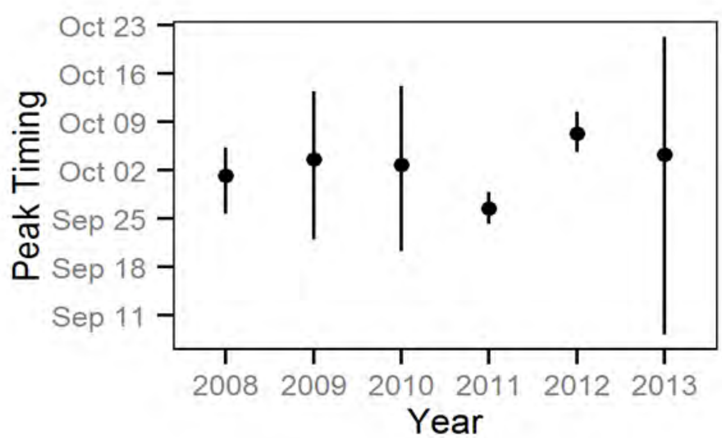

Figure 5. Predicted Kokanee peak spawn timing by year with 95% CIs

Table 4. Annual peak counts of Kokanee spawners in the LDR study area, 2002-2013

Year	Date of Peak Spawning	Lower 95% CI	Upper 95% CI
2008	Oct 1	Sep 25	Oct 5
2009	Oct 3	Sep 21	Oct 13
2010	Oct 2	Sep 20	Oct 14
2011	Sep 26	Sep 24	Sep 28
2012	Oct 7	Oct 4	Oct 10
2013	Oct 4	Sep 8	Oct 21

3.3 Area Under the Curve Estimates

Figure 6, shows the Area Under the Curve (AUC) estimate of abundance for 2013 (bottom right panel) based on four aerial counts (dots) in comparison to the last five years from 2008–2012. The plot also shows the daily spawner abundance estimates calculated by the hierarchical Bayesian AUC model. In Figure 7, the total 2013 spawner abundance estimate is shown in comparison to the five previous years. The 2013 Kokanee AUC estimate of abundance (20,300 fish) represents one of the lowest estimates since 2008.

AUC estimates, their 95% confidence intervals, their Standard Deviation (SD) and the number of surveys undertaken are summarized in Table 5.

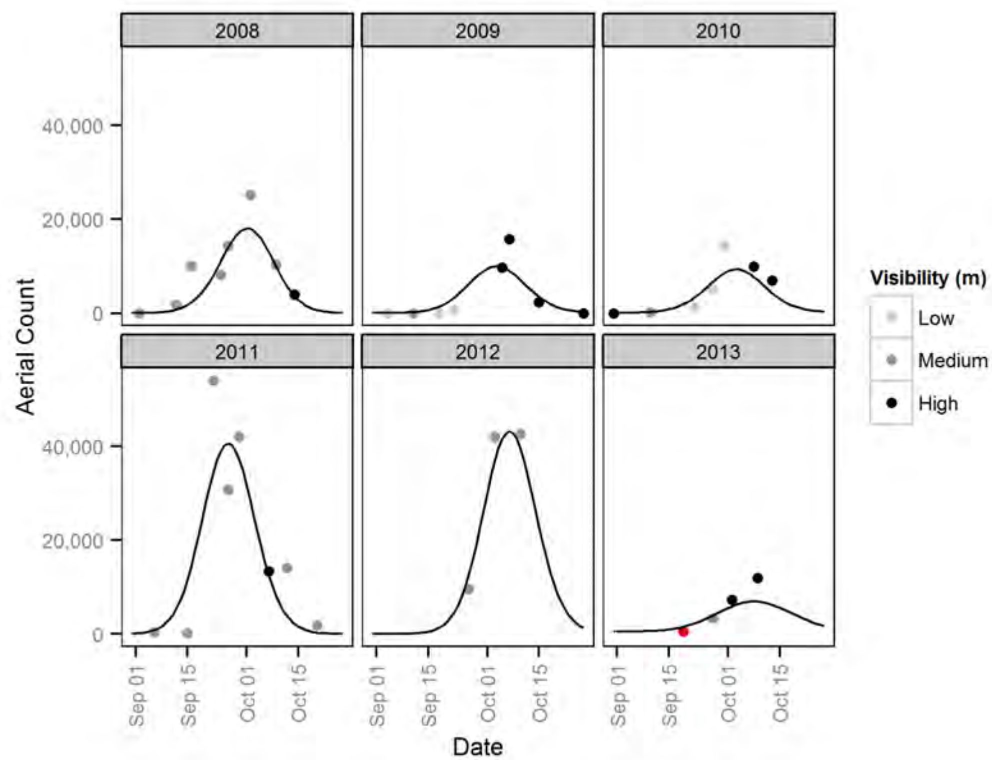

Figure 6. Kokanee spawner aerial counts with predicted aerial counts by date and year.

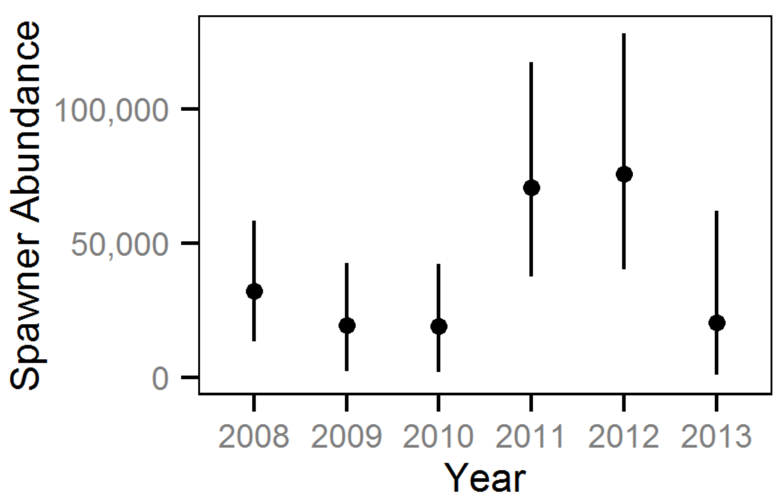

Figure 7. Predicted total Kokanee spawner abundance by year with 95% CIs.

Table 5. Kokanee spawner abundance estimates in the LDR from 2008–2013.

Year	Spawner Abundance	Lower 95% CI	Upper 95% CI	SD	# of Counts
2008	32,300	13,300	58,300	11,770	8
2009	19,600	2,400	42,500	10,745	8
2010	19,000	2,100	42,300	12,305	7
2011	70,700	37,700	117,300	21,141	8
2012	75,600	40,100	128,200	23,784	3
2013	20,300	900	62,000	25,617	4

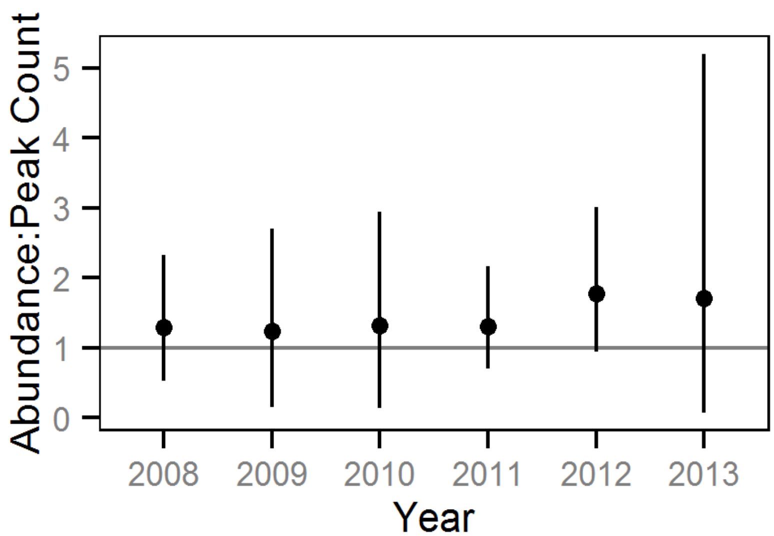

Figure 8. Ratio of estimated annual spawner abundance to peak counts by year for Kokanee in the LDR

As another measure to estimate total spawner abundance, the ratio of peak count to total spawner abundance was calculated and the results are shown in Figure 8. The ratio was 1.7 for 2013 and within the range of 1.3–1.8 observed between 2008–2012 (Table 6).

Table 6. Summary of ratios between annual spawner estimate and peak count for Kokanee in the LDR from 2008–2013.

Year	Estimate	Peak Count	Ratio Estimate to Peak Count
2008	32,300	25,100	1.3
2009	19,600	15,700	1.3

2010	19,000	14,400	1.3
2011	70,700	54,000	1.3
2012	75,600	42,600	1.8
2013	20,300	11,900	1.7

3.4 Relative Intensity of Kokanee Spawning in the Duncan River System

The Lardeau River accounted for 52% of the observed total escapement within the Duncan River system in 2013, followed by Meadow Creek (45%) and the Lower Duncan River (3%) (Figure 9)

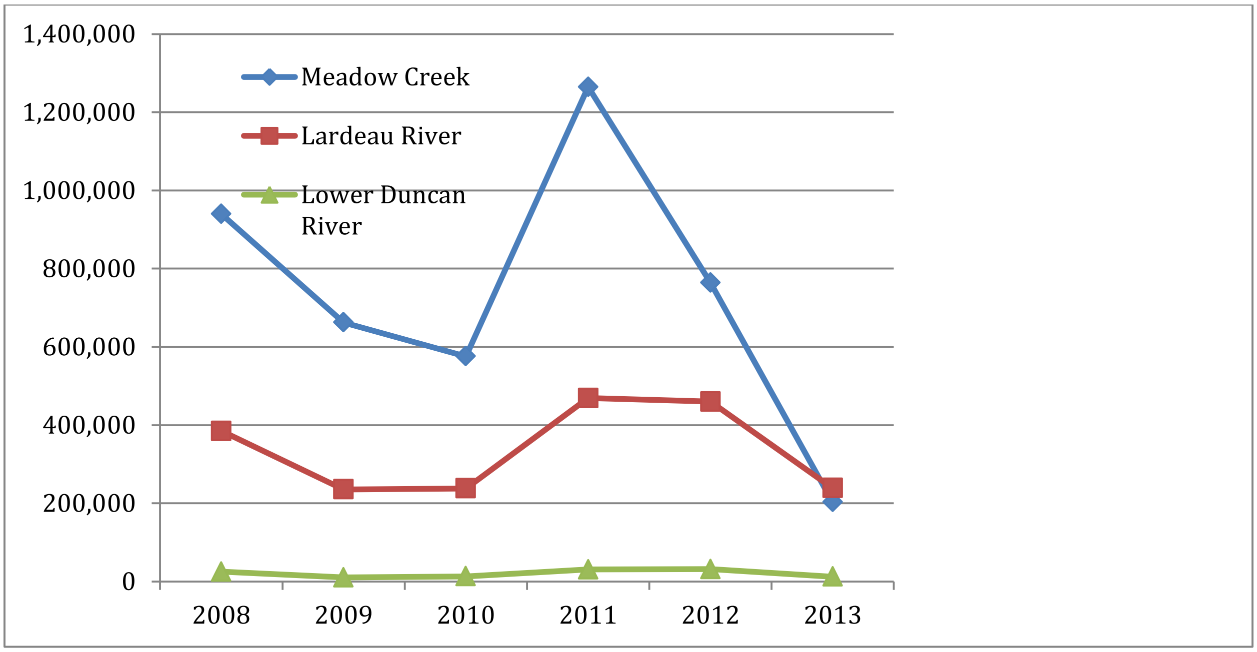

Figure 9. Estimated abundance of Kokanee spawning in Meadow Creek, Lardeau River, and the Lower Duncan River, 2008-2013. (source: Meadow Creek and Lardeau River MFLNRO (M. Neufeld pers comm/unpublished data); Lower Duncan River AMEC (2013))

3.5 Migration, Holding and Spawning Behaviour

The initial survey conducted on September 19 showed low numbers of Kokanee in the LDR, which were equally displaying migrating, holding and spawning behaviors (Figure 10). As the season progressed, surveys indicated a higher proportion of spawning behaviour. The trend continued through to the last survey on October 9, where the behaviour pattern observed was almost exclusively spawning.

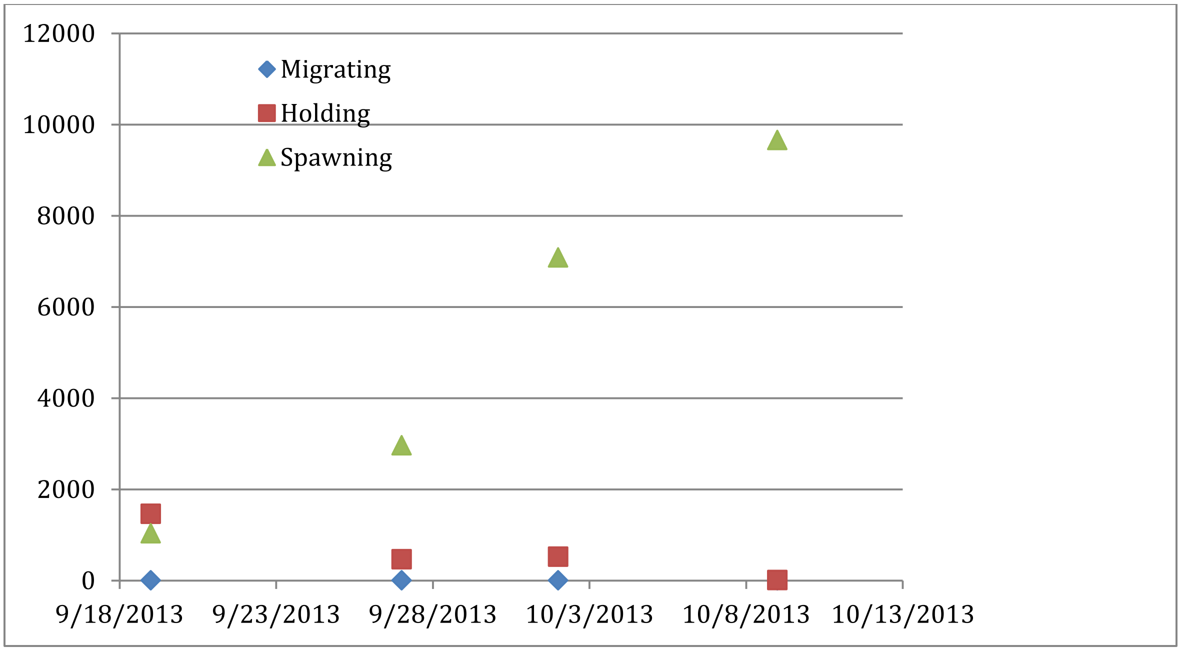

Figure 10. Number of migrating, holding and spawning Kokanee enumerated in the Lower Duncan River for 2013.

3.6 Spawner Distribution and Habitat Use in the LDR

As in previous years, Kokanee were observed to spawn in the upper nine kilometers of the study area with main concentrations of redds observed between Kilometers 1.0 and 9.3 (See Appendix A). No redds were observed upstream of Kilometer 1 (Duncan Dam discharge channel, upstream end of the study reach), or from Kootenay Lake to Km 9.3 (downstream end of the study reach). Most notable concentrations were around km 3.0 and 4.0, within the upper third of the study reach. Side channel use was also evident prior to implementing the Kokanee Protection Flows (September 19), particularly SC 3.5R, 4.1R, 6.9R and heavy use of 8.2L (See Appendix A).

Table 7. Number of spawning Kokanee distributed in the side channels and mainstem Lower Duncan River for 2013.

Date	Mainstem	Side Channels
September 19, 2013	970	1526
September 27, 2013	3085	342
October 2, 2013	7025	578
October 9, 2013	9283	379

3.7 Kokanee Spawn Mapping, PED & Egg Losses

The locations of the 2013 Kokanee spawning were mapped on the series of six maps attached as Appendix A. Redd mapping was based on the redd survey conducted October 2, 2013. Redds were not surveyed on October 9 due to no observed significant difference in discharge since October 2, and helicopter time constraints. Discharge observed in the study area indicated water levels did not decrease between October 2 and October 9, but increased slightly (Figure 4) as a result of test Kokanee Protection Flows. However, some inferences were made by the lead enumerator regarding areas of likely redd dewatering, exclusively in Side Channels 3.5R and 6.9R. These inferences were based on his interpretation of higher flows on September 19, and probable (based on his experience) spawning areas dewatered after the onset of test Kokanee Protection Flows on September 27. Potential egg deposition and egg losses were calculated from area calculations based on the comparative redd distributions between Side Channel and Mainstem habitats. These observations of likely dewatered redds occurred only in Side Channel habitats.

The total area used by spawning Kokanee in the LDR side channels and mainstem was approximately 2,817.16 m^2, estimating 1,194,394 eggs were deposited in 2013 (Table 8; as per AMEC 2013). As previously described, only one detailed redd survey was completed on October 2, with inferences made by the lead enumerator (C. Tarala pers com.) on redds that had become dewatered in Side Channel habits (no redds were dewatered in the Mainstem). No egg losses were calculated for Mainstem habitat as flows were kept constant during the Kokanee Protection Flows from September 27 to October 9, or through the period of the 2nd, 3rd and 4th Kokanee enumeration survey.

3.8 Effectiveness of the 2013 Kokanee Flow Trial

Total spawning area in sidechannels is summarized in Table 8 below. Of all the sidechannels, only two side channels showed dewatered redds (SC6.9R and SC3.5R), where historically impacts of the Kokanee protection flows have been most prominent. The monitoring showed that dewatering was slightly reduced, with 13.2 % of redds dewatered in 2013 compared to 16.1% in 2012. However, there is large variability in area of redds dewatered compared to earlier years (i.e., 14.5% in 2011, and 6.4% in 2010). Further measurement of sidechannel dewatering would be required to assess flow trial effectiveness in the future.

Table 8. Total spawning area, area dewatered (difference), Potential Egg Deposition (PED), number of eggs dewatered and spawning success for side channel (SC) and mainstem areas (MS) within the LDR study area before (Pre) and after (Post) Kokanee Protection Flows, 2009 to 2013 (adapted from AMEC 2013).

Year	Period	Area (m^2)		PED	
		SC	MS	SC	MS
2013	Pre[a]	1,078	1,739	168,623	1,025,771
	Post	936	1,739	146,449	1,025,771
	Difference	142	0	22,173	0
2012	Pre[b]	4,734	N/A	473,172	2,713,272
	Post[c]	3,973	20,922	397,156	2,713,272
	Difference	760	0	76,016	0
2011	Pre	6,902	88,172	3,253,621	2,372,672
	Post	5,902	88,172	2,781,955	2,372,672
	Difference	1,000	0	471,666	0

2010	Pre	4,041	8,055	830,540	642,948
	Post	3,784	8,632	777,601	640,852
	Difference	258	-577	52,939	2,096
2009	Pre	399	0	48,732	-
	Post[d]	267	4219	32,667	-
	Difference	132	-	16,065	-

[a] Based on backcalculating areas based on observed watered and dewatered sidechannel and mainstem redds on one survey – October 2, 2013

[b] Mainstem mapping was not conducted prior to the flow reduction. However, no dewatered redds were observed in the mainstem during post-reduction mapping.

[c] Additional spawning areas were observed post-reduction (3556 m^2) because Kokanee moved into side channels but the information presented reflects the original spawning area dewatered and changes to PED.

[d] Larger area was observed post-reduction because Kokanee moved into side channels to spawn. Only 132 m^2 of area was dewatered from the original pre-reduction mapping, which is reflected in PED.

- Spawning was not observed pre-reduction. It was assumed that post-reduction spawning areas were not dewatered.

3.9 Estimate of Observer Efficiency

The observer efficiency for 2013 was solely estimated using a comparison of aerial and ground counts in side channel L 8.2 in 2013. The ratio of aerial count to ground count was 0.86 (Table 9), which was well within the range of previous observer efficiencies (Figure 11, Figure 12).

Table 9. Ratios of aerial and ground Kokanee calibration counts for standardized locations in the LDR.

Year	Average of Aerial Counts for Calibration Locations	Average of Ground Count for Calibration Locations	Average Ratio of Aerial to Ground Count for Calibration Sections (# of surveys with data)
2008	1580	1410	1.12 (1)
2009	51	51	1.00 (5)
2010	300	284	1.06 (1)
2011	2665	1461	1.82 (2)
2012*	-	-	- (0)
2013	100	116	0.86 (1)

*Not reported (AMEC 2013)

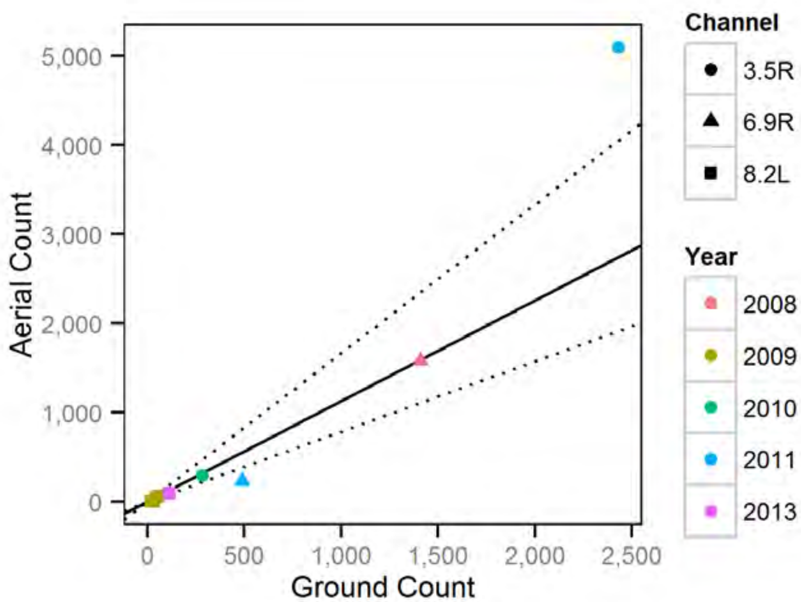

Figure 11. Aerial versus ground Kokanee spawner counts and predicted ground count (with 95% CRIs) by year and channel.

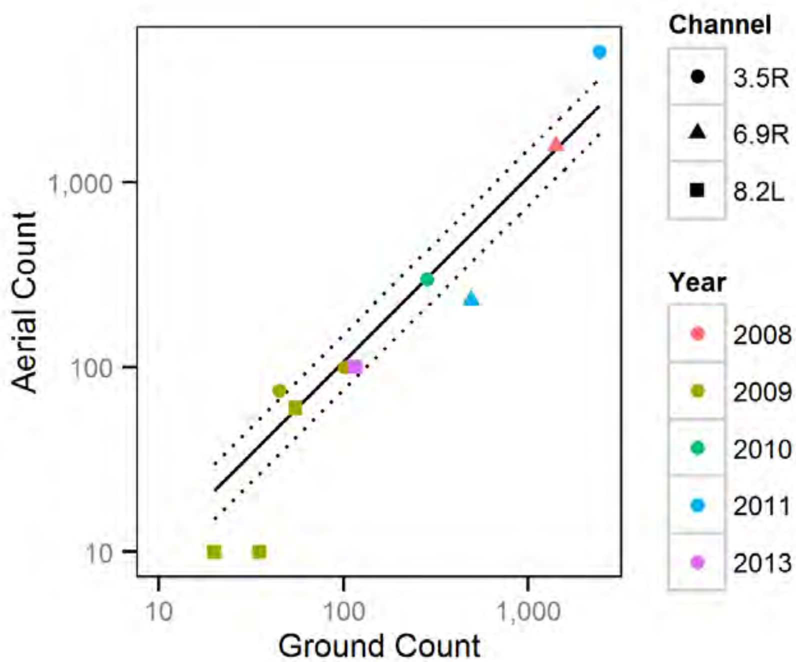

Figure 12. Aerial versus ground Kokanee spawner counts (on log10 scales) and predicted ground count (with 95% CRIs) by year and channel.

4.0 DISCUSSION

The following discussion is structured along the management questions that were applicable to Year 6 of DDMMON-4.

4.1 Lower Duncan River Environmental Parameters: Temperature and Discharge

Water temperature (as measured by Environment Canada at WSC Station No. 08NH118) decreased steadily throughout the spawning period in the LDR in 2013. The temperature was measured (Environment Canada 2013) at 13 °C for the first enumeration survey (Sept 19, 2013) and steadily decreased to 10°C at the final survey of October 9, 2013, which was similar to the trend observed in 2012, decreasing from 12.5 to 9.0 °C over the LDR Kokanee spawning enumeration period (AMEC 2013). Similar trends of decreasing water temperatures were observed since 2009, and ranged from 16 °C to 8 °C (AMEC 2012, no data recorded in 2008). Temperature reductions are primarily due to reductions in DDM discharge, which draws flows from a warmer reservoir during this period than that of the Lardeau. It is believed that reducing the proportion of DDM discharge to the Lower Duncan River therefore reduces the temperature (AMEC and Poisson 2012). Further monitoring of Duncan Reservoir temperatures, contrasting surface with Low Level Outlet depth temperatures would be required to understand the effects of dam releases on incubation and emergence timing of kokanee.

Discharge (as measured by Environment Canada at WSC Station No. 08NH118) was regulated through DDM in September and October 2013 to manage for protection of Kokanee spawning in the LDR. In comparison with previous years, the 2013 discharge in the LDR showed little fluctuation around 100 m^3/s (105 -90.7 m^3/s) for the period September 27 to October 9. In past years (2008-2012), discharge varied from highs of approximately 202 m^3/s to lows of 69.8 m^3/s, with intermittent spikes within this range in some years (Environment Canada, 2013 unpublished data).

4.2 Spawn Run Timing

The initial spawning survey took place on September 19, 2013 with 2,496 Kokanee observed throughout the study area side channels and mainstem. Kokanee presence at the initial visit indicates onset of spawning migration behaviours before this date. The September 19 survey was also concurrent with higher Duncan Dam discharges preceding the initiation of a discharge reduction to test Kokanee Protection Flows from September 27 to October 21, 2013. The highest (peak) count (9,662) was observed on the last enumeration flight on October 9, 2013, which is similar to 2012 (Peak October 10; AMEC 2013), but much later than previous years' peak counts (ranged from September 19 to October 7, from 2002 to 2011; AMEC 2013). Similarly, 2013 spawning run timing in adjacent watercourses (i.e., Meadow Creek) tributary to Kootenay Lake and Arrow Lakes tributaries was also delayed (later than usual) according to discussions with MFLNRO staff (M. Pearson and M. Neufeld pers comm.), indicating delayed run timing in the LDR was not unique in 2013.

4.3 Relative Intensity of Kokanee Spawning in the LDR

Continued surveys indicated a successive increase in the numbers of Kokanee, culminating in the peak count, on the last survey date on October 9. MFLNRO also indicated a similar trend in their annual Kokanee enumerations conducted throughout the Kootenay and Arrow Lakes regions. It is unknown based on field observations whether numbers increased beyond October 9, but based on the peak count analysis and Area Under the Curve estimates, a peak spawning time of October 4 was derived. This period also coincides with the test Kokanee Protection Flow window.

4.4 Area Under the Curve Estimates

Kokanee spawner abundance and peak estimates for 2013 were the third lowest within the six years of observation from 2008–2013 However, the largest Standard Deviation (SD) in estimating abundance was calculated for the 2013 data. This high SD can be attributed to the low number of four surveys carried out in 2013 compared with the eight surveys carried out in 2008, 2009 and 2011. It is likely than the low spawner abundance, very wide confidence limits and larger SD are a result of the low numbers of observed escapement.

Similarly, the ratio of peak count to total spawner abundance estimate in 2013 was the second highest observed under DDMMON 4 and since 2008. From 2008–2011 when either seven or eight surveys were carried out, the ratio was a constant 1.3 while in the two years with less surveys (three in 2012 and 4 in 2013) the ratio increased to 1.7–1.8. In conclusion and as expected, small numbers of surveys appear to increase the SD around the mean and the ratio of peak count to total abundance estimate.

4.5 Relative distribution of Kokanee spawners in the Lower Duncan River

Kokanee habitat occupation was higher in the side channels during the initial survey on September 19, which coincided with higher flows in the LDR mainstem. As flows were reduced after September 27 at the commencement of the Kokanee Protection Flows, Kokanee distribution shifted to higher numbers in mainstem locations. This shift of spawning locations from side channels to mainstem is likely related to flow-related side channel exclusion, and the subsequent availability of suitable habitat and velocity reduction in the mainstem.

4.6 Kokanee Spawn Mapping, PED and Egg Losses

For the 2013 field data collection program the cumulative area for all Kokanee spawner locations was to be calculated from geo-referenced 1:5,000 mapping of water levels and kokanee use prior to and proceeding the implementation of the Kokanee Protection Flows. However, the study team was unable to provide mapping prior to protection flow reductions scheduled September 20-27th(see Table 2). The experimental Kokanee Protection Flows initiated on September 27, 2013 appeared to minimize dewatering effects on mainstem redds with no difference in spawning area and subsequent potential egg deposition between pre and post flow regulation. Subsequently egg losses in mainstem redds were calculated to be zero as a result of Kokanee Protection Flows that remained at or above those observed on October 9 for the duration of the incubation and emergence period.

The lack of mapping limits the ability to calculate sidechannel losses, but observations during field surveys concluded that of the five sidechannels used by kokanee prior to the September 27th flow reduction (R3.5, R4.1, R7.6, L8.2 and R6.9), only side channels R 3.5 and R 6.9 were dewatered by the flow reduction (see Appendix A) and had measurable egg losses. Examining 2013 operations changes and comparing results to previous years with comparable effort and conditions (e.g., 2009-2012), it is expected that there may have been a proportionate loss on spawning habitat during the 2013 flow reduction as it was the second lowest potential egg loss since 2009.

4.7 Estimates of Observer Efficiency

The observer efficiency in 2013 was well within the range of observer efficiencies calculated from 2008–2013. The ratio of aerial counts to ground counts for the same calibration section of the river had an average of 1.00–1.82 from 2008–2012. In 2013, the ratio was slightly lower with 0.86 but based on this value the aerial counts would predict the ground counts well and within the range of predictions in previous years. Different from other years, the 2013 ratio was below 1 for the first time since aerial counts started in 2008. This means that until 2013, aerial counts were always higher than ground counts although the slow and thorough ground counts in the selected river sections should be higher than the fast overview counts from a helicopter, as they were in 2013.

5.0 RECOMMENDATIONS

1. Test Kokanee Protection Flows (i.e., proposed 97-103 m^3/s for the period September 27 to October 21) that covered the peak spawning timing period of October 2-9 appeared to have a slightly positive effective in minimizing stranding and redd dewatering. Opportunities should be explored to initiate protection flows sooner, to capture the onset of known Kokanee spawning in the LDR (September 7).

2. Updated orthophoto maps (2012) provided by contractors for DDMMON 3 were very useful for enumeration and redd survey data collection. Since the Lower Duncan River is an active, alluvial channel, we recommend using regularly updated orthophotos as base-maps for enumeration and redd surveys when available.

3. Current methods for spawner enumeration and redd surveys should be continued, including low elevation flights (~20 m). Enumerations should be conducted over a minimum of four surveys during the period September 19 to October 9. However, more strategic scheduling of the counts will be implemented in future years to better capture the full spawning period. Furthermore, future enumerations will aim be completed by the same study team, replicating to the furthest degree possible, the most experienced core of the teams used in prior surveys.

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Appendix A – Kokanee Spawner Mapping for the Lower Duncan River 2013 (6 maps)


MAP 1
Legend
River Kilometre
Side Channel Kilometre
Kokanee Spawning Use
Kokanee Spawning Use - Area Lost
1:5,000
0 100 200 300
Metres
BC Hydro
DDMMON - 4 Lower Duncan River Kokanee Spawning Monitoring
2013 Kokanee Spawning Areas and Areas Dewatered in the LDR
Ortho Date : October 2012
GIS File: LDR_5000_report_20150924.mxd
Project Number: EA3512
DATE: 2015.09.24
PROJECTION: UTM Zone 11
REVISION DATE: September 2015
DATUM: NAD83
PRINTING DATE: 2015.09.24
R1.1

5564000
5563000
503000
50°14'0"N
116°58'0"W
L2.7
R3.5
MAP 2
R 1.1
L 2.7
R 3.5
R 4.1
R 4.4
R 6.9
R 7.6
L 8.2
Legend
River Kilometre
Side Channel Kilometre
Kokanee Spawning Use
Kokanee Spawning Use - Area Lost
1:5,000
0 100 200 300
Metres
BC Hydro
DDMMON - 4 Lower Duncan River Kokanee Spawning Monitoring
2013 Kokanee Spawning Areas and Areas Dewatered in the LDR
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REVISION DATE: September 2015
DATUM: NAD83
PRINTING DATE: 2015.09.24


Legend
River Kilometre
Side Channel Kilometre
Kokanee Spawning Use
Kokanee Spawning Use - Area Lost
MAP 3
1:5,000
0 100 200 300
Metres
BC Hydro
DDMMON - 4 Lower Duncan River Kokanee Spawning Monitoring
2013 Kokanee Spawning Areas and Areas Dewatered in the LDR
Ortho Date : October 2012
GIS File: LDR_5000_report_20150924.mxd
Project Number: EA3512
DATE: 2015.09.24
PROJECTION: UTM Zone 11
REVISION DATE: September 2015
DATUM: NAD83
PRINTING DATE: 2015.09.24
R3.5
R4.4
R4.1
50°13'0"N
116°58'0"W
116°57'0"W

MAP 4
Legend
River Kilometre
Side Channel Kilometre
Kokanee Spawning Use
Kokanee Spawning Use - Area Lost
1:5,000
0 100 200 300
Metres
BC Hydro
DDMMON - 4 Lower Duncan River Kokanee Spawning Monitoring
2013 Kokanee Spawning Areas and Areas Dewatered in the LDR
Ortho Date : October 2012
GIS File: LDR_5000_report_20150924.mxd
Project Number: EA3512
DATE: 2015.09.24
PROJECTION: UTM Zone 11
REVISION DATE: September 2015
DATUM: NAD83
PRINTING DATE: 2015.09.24
R6.9

R6.9
R7.6
L8.2
MAP 5
Legend
River Kilometre
Side Channel Kilometre
Kokanee Spawning Use
Kokanee Spawning Use - Area Lost
1:5,000
0 100 200 300
Metres
BC Hydro
DDMMON - 4 Lower Duncan River Kokanee Spawning Monitoring
2013 Kokanee Spawning Areas and Areas Dewatered in the LDR
Ortho Date : October 2012
GIS File: LDR_5000_report_20150924.mxd
Project Number: EA3512
DATE: 2015.09.24
PROJECTION: UTM Zone 11
REVISION DATE: September 2015
DATUM: NAD83
PRINTING DATE: 2015.09.24
50°11'0"N
116°57'0"W

L8.2
MAP 6
Legend
River Kilometre
Side Channel Kilometre
Kokanee Spawning Use
Kokanee Spawning Use - Area Lost
1:5,000
0
100
200
300
Metres
BC Hydro
DDMMON - 4 Lower Duncan River Kokanee Spawning Monitoring
2013 Kokanee Spawning Areas and Areas Dewatered in the LDR
Ortho Date : October 2012
GIS File: LDR_5000_report_20150924.mxd
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PROJECTION: UTM Zone 11
REVISION DATE: September 2015
DATUM: NAD83
PRINTING DATE: 2015.09.24
116°56'0"W
5559000
505000