Wahleach Project Water Use Plan

Lower Jones Creek Channel Stability Assessment
Final Report

Reference: WAHMON-2

Study Period: October 2005 – May 2014

Final Report: NHC 300102

Northwest Hydraulic Consultants Ltd.
30 Gostick Place
North Vancouver, BC
V7M 3G3

December 31, 2015

NOTIFICATION

CITATION

NHC. December 31, 2015. Lower Jones Creek Channel Stability Assessment, WAHMON-2 Final Report. Prepared for BC Hydro. 2015.

CERTIFICATION

Report prepared by:

Andre Zimmermann, PhD, PGeo

Report reviewed by:

Barry Chilibeck, MASc, PEng

EXECUTIVE SUMMARY

The assessment of channel stability on lower Jones Creek was established by BC Hydro as part of the Wahleach Water Use Plan monitoring program to investigate the extent to which the physical stability of the channel bed and substrate grain size distribution limit fish productivity. Channel stability and substrate quality are physically evaluated at seven (7) previously established cross sections (XS) through repeat topographic surveys and photogrammetric sampling of the substrate. In addition, during the first 5 years of the program, orthophotos were used to track channel changes at the site.

To quantify salmonid productivity, pink and chum salmon escapement has been monitored in Lower Jones Creek for a number of years (Greenbank and Macnair, 2008, 2012, 2014). In the subsequent spring, fry escapement has been quantified and the egg-to-fry survival for the spawning and incubation period determined. These data, along with substrate and channel morphology information collected as part of this study can be used to examine the following two management questions:

1) Is channel stability in Lower Jones Creek limiting fish productivity; and
2) Is substrate quality in Lower Jones Creek limiting fish productivity?

In order to address the first question, the following hypotheses are to be tested:

H_1 In consideration of improvements to spawning habitat through increased spawning and incubation flows, fish productivity is not correlated to habitat instability in the anadromous reach of lower Jones Creek.

H_{1a} Fish productivity is not correlated to channel instability as measured by cross sectional areas of scour and fill in the anadromous reach.

H_{1b} Fish productivity is not correlated to channel instability as measured by lateral channel migration involving abandonment of spawning habitat in the anadromous reach.

In order to address the second question, the following hypothesis will also be addressed:

H_2 In consideration of improvements to spawning habitat through increased spawning and incubation flows, fish productivity is not correlated to substrate quality as measured by substrate particle size in the anadromous reach of lower Jones Creek.

To address these hypotheses, the assessment and field program extends from mid-October to mid-March during odd (pink spawning) years to coincide with peak spawning and end of incubation dates for pink and chum salmon. This report presents summary results collected over the past 10 years of monitoring.

The hydrology data provided by BC Hydro shows that minimum flow targets were more commonly met during the last five years of the program compared to the first 5 years of the program.

Repeat channel cross section surveys were used to assess the vertical and lateral stability of the channel. On average, Sections 4, 6 and 8 experience more than 15 cm of scour or fill across more than 40% of the wetted channel each year. This is a relatively large amount of change and speaks to the mobility of these sections and the stream channel in general. Sections 9 and 10 are relatively more stable, but still experience some significant scour and fill. Wetted width data from the surveys demonstrates that the wetted width varies more between the sections, than between surveys which further highlights the dynamics of the sections. The orthophotos show that the wetted channel migrates laterally at relatively high rates, which poses a risk to egg survival as the channel may migrate away from where the eggs were buried.

A main physical characteristic related to substrate quality and fish productivity is the fraction of the bed composed of medium and fine gravel, and sand. As a first order approximation, the surface grain size can be used to provide some information about the subsurface distribution. As such the surface grain size distribution has been monitored at each cross section. Results from the study show that the surface grain size distribution has remained relatively constant over the study period.

To assess if fish productivity was related to channel stability, a correlation analysis was completed with egg-to-fry survival data from Greenbank and Macnair (2014) and channel morphology metrics (scour, fill and change within the wetted cross section). No significant correlation was observed related to channel morphological metrics. A similar analysis was completed for both the mean percent of the surface substrate composed of medium gravel and sand, and no correlation was found. Based on the data collected during the study it is not possible to reject any of the null hypothesis at the 0.05 % level.

On initial analysis, these results suggest that physical stability and grain size does not affect egg-to-fry survival; however, the repeat surveys and orthophotos show that the channel morphology and grain size is highly variable during all the study years. There are several potential reasons for the lack of correlation:

1. The observed range in egg-to-fry survival is not sufficient to provide enough statistical power.
2. The current physical measurements are not sufficiently precise or of required spatial and temporal coverage to measure channel instability.
3. The current range of channel instability is above a threshold limit such that there is no underlying correlation to egg-to-fry survivals.
4. There is a combination of both physical and biological factors that pose a more fundamental limit on egg-to-fry survivals that is not captured with the current analyses or monitor.

The most important observation from grain size and morphology studies is that lower Jones Creek is an especially dynamic channel that is modified throughout the spawning and incubation period during most years. These conditions are not ideal for fish production, yet Jones Creek continues to produce a large number of fry. Successful fry production relies on a large number of spawning adults, spawning over a large spatial area, so there is a high probability of some areas not being disturbed each year.

Additional studies examining the spatial variability of intergravel flow, fine sediment loading throughout the spawning and incubation period, as well as the quality of the substrate immediately after spawning would improve our understanding of the factors effecting egg-to-fry survival. These should be incorporated with the ongoing egg-to-fry survival studies using egg baskets at the sites.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

Jones Creek (Wahleach Creek) flows northward into the Fraser River about 16 km west of Hope, BC (**Figure 1**). The channel drains an area of 115 km^2 in the rugged terrain of the Cascade Mountains. The channel is confined until it emerges from a steep valley where gradient declines from 4% to 1.2% (Newbury Hydraulics, 2004), and sediments transported from upstream are deposited on a broad alluvial fan within the Fraser River floodplain. The creek flows across the fan for approximately 900 m before joining the Fraser River. This reach of the creek is commonly referred to as Lower Jones Creek and contains anadromous Pacific salmon and trout.

BC Hydro owns and operates the 64 MW Wahleach Hydroelectric Project (WAH) with a fixed spillway dam on Wahleach Lake about 8 km upstream from the mouth of Jones Creek and a diversion tunnel to the generating station adjacent to Herrling Island on the Fraser River. Approximately 88 km^2 (78%) of the total watershed area drains into Wahleach Lake.

Operation of the hydroelectric project began in 1952, significantly altering the flow regime downstream of the dam and in lower Jones Creek. Peak flows have been reduced by as much as 65% and average annual flow has been reduced by over 80% (MMAL, 1997). Currently, instream flows are derived from tributaries below the dam, though BC Hydro can augment these to meet the Water Use Plan minimum flow target via a siphon on the diversion dam. However, the siphon loses prime and flows cease at lower reservoir elevations.

Compensation measures to reduce fisheries impacts associated with the hydroelectric project began soon after completion of the dam. An artificial spawning and rearing channel was constructed in 1954 adjacent to Lower Jones Creek (Hartman and Miles, 1997) but the channel was plagued by sedimentation problems and has since been abandoned.

More recently, BC Hydro has attempted to restore the physical processes and habitat function by replacing concrete and sheet pile weirs with constructed rock riffles (in 2004) and through placement of an engineered log jam at a side channel entrance (in 2005) to prevent its enlargement (Streamworks Unlimited, 2006). In 2006, several new enhancement projects were completed near the downstream end of Jones Creek, the most significant of which was construction of a new right bank side channel (Streamworks Unlimited, 2006, see Figure 1). Additional recent enhancement projects include flow augmentation of a backwater rearing habitat and revegetation of adjacent banks near Lorenzetta Creek confluence.

BC Hydro's Wahleach Water Use Plan (2005) currently addresses seasonal instream flow targets for pink salmon in Lower Jones Creek via a fish water release siphon on the Wahleach Dam capable of diverting up to 0.85 m^3/s and a fish water release gate on the Boulder Creek Diversion Dam capable of passing up to 1.4 m^3/s of Boulder Creek flow to continue into Jones Creek (BC Hydro, 2004). However, the effectiveness of these flows for maintaining pink salmon productivity are uncertain given the potential effects of channel instability and sedimentation in the creek channel.

The Lower Jones Creek Channel Stability Assessment was initiated in 2005 under the Wahleach WUP Monitoring Program (BC Hydro, 2005) to evaluate the effects of channel instability and sedimentation on pink salmon productivity during the spawning and incubation phases of their life cycle. This report presents the results of data collection efforts during the last 10 years of the monitoring program and provides a comparison with data collected during Years 1 (2005/2006), 3 (2007/2008), 5 (2009/10), 7 (2011/2012) and 9 (2013/2014).

WAHLEACH WATER USE PLAN MONITORING

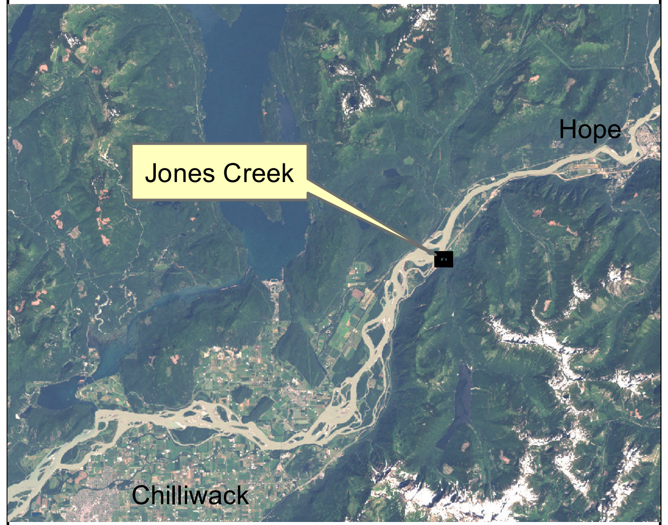
Lower Jones Creek Monitoring Sites

Scale - 1:2,500

50 25 0 50 100 Metres

coord. syst.: UTM Zone 10	horz. datum: NAD 83	horz. units: metres
northwest hydraulic consultants	project no. 300102	August 2014

Reference Map



Legend

⌖ Photo Documentation Point (PDP)

⋀ Cross Section Alignment

NOTES:

1) CROSS SECTION LOCATIONS ESTABLISHED OCTOBER, 2005 AND REVISED IN 2012/13.

2) REFER TO FIGURES FOR PLOTTED CROSS SECTIONS.

3) NINE (9) PHOTO DOCUMENTATION POINTS (PDP) ARE SHOWN ON THE MAP.

4) LOCATION OF SPAWNING REARING CHANNEL FEATURES AFTER 1973, (MMAL, 1997).

5) BACKGROUND ORTHOPHOTO CAPTURED APRIL 2010, PROVIDED BY BC HYDRO

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Figure 1: Jones Creek monitoring sites

1.1 BACKGROUND

The Lower Jones Creek study area extends within the stream channel approximately 900 m from the Laidlaw Road Bridge near the apex of the fan to the Highway 1 Bridge near the mouth of the creek (**Figure 1**). Lorenzetta Creek enters Lower Jones Creek approximately 80 m upstream from the mouth. BC Hydro operates a streamflow gauging station (BCH_LJC) immediately downstream of the Laidlaw Road Bridge. A buried gas pipeline crosses beneath the creek channel approximately 200 m downstream of the Laidlaw Road Bridge.

The creek channel is incised on the upper part of the alluvial fan, from the apex near Laidlaw Road Bridge to a point shortly downstream of the pipeline crossing. In this section, the channel is approximately 10 m in bottom width and is confined within banks 3 to 4 m in height. Exposed tree roots in the banks provide evidence of significant channel downcutting through fan deposits in recent years and there is some recession and ravelling along the steep left bank. There were very large floods in both 1989 and in 1990 (the flood of record; Newbury Hydraulics, 2004) that introduced large volumes of sediment from upstream through which the channel has since incised.

Large rainstorm-generated floods in 1993 and 1995 also introduced large volumes of sediment to the fan (Hartman and Miles, 1997) depositing material up to 3 m thick near the Laidlaw Bridge (Interfor, 1996). The channel bed is comprised mainly of coarse, infrequently mobile material, with pockets of finer material in protected areas between the boulders. Active sediment sources related to logging activities were a primary source of sediment in the past (cf. Hartman and Miles, 1997) while large natural landslides provide the primary source of sediment to the fan at present.

Below the pipeline crossing, the channel widens dramatically to 40 to 50 m width with lower banks (1 to 2 m height, occasionally less). The meandering channel is characterized by frequent point, lateral and mid-channel gravel bars which are inundated during high flow events. The wetted low flow channel occupies less than one-third of the total active flood channel. This part of the fan channel is subject to active sediment deposition and lateral channel movement. Near the downstream end of the fan a recently constructed (2004) rock weir constricts the channel (**Figure 1** – Photo point #2). The weir replaces older concrete and sheet pile weirs that were lowered because they were creating a sediment wedge that raised the bed (Newbury Hydraulics, 2004).

Near the mouth of the creek, Fraser River exerts a seasonal backwater influence on Jones Creek water levels. The Fraser River hydrograph is dominated by snowmelt with maximum water levels occurring between May and July. During this period, the lowermost 200 m of Jones Creek is affected by Fraser River backwater and there can be significant accumulations of sediment on a right bank bar. Jones Creek also experiences a modest spring freshet resulting from snowmelt in the watershed below Wahleach Lake. However, the largest flows typically occur during rainfall and rain-on-snow events in the autumn and winter, typical of small basins in coastal British Columbia.

1.2 OBJECTIVES AND APPROACH

BC Hydro completed a Water Use Plan (WUP) for the Wahleach Project which was submitted to the Comptroller of Water Rights in 2004 and implemented in January, 2005. The Consultative Committee (CC) formed under the WUP, recommended several operational changes as part of the WUP, including the provision of minimum flow targets. A minimum discharge of 1.1 m^3/s is the current target during the spawning period (15 September through 30 November), and a minimum discharge of 0.6 m^3/s is required during the remainder of the year. These instream flow targets can be met pending available Wahleach Dam siphon available at reservoir elevations >636 m and Boulder Diversion augmentation available for flows > 0.14 m^3/s.

The CC could not address whether instream flows or channel instability was limiting spawning success and fish productivity in Lower Jones Creek. Therefore, a comprehensive monitoring program was approved to assess the effectiveness of the minimum flow regime on fish productivity, and to assess channel conditions in Lower Jones Creek as a possible limiting condition for fish productivity.

The channel stability assessment commenced in 2005-2006 and is scheduled to be conducted in alternate years though 2013 corresponding to pink salmon runs. The overall purpose of the lower Jones Creek channel stability assessment is to address two management questions:

1) Is channel stability in Lower Jones Creek limiting fish productivity; and
2) Is substrate quality in Lower Jones Creek limiting fish productivity?

In order to address the first question, the following hypotheses are to be tested:

H_1 In consideration of improvements to spawning habitat through increased spawning and incubation flows, fish productivity is not correlated to habitat instability in the anadromous reach of lower Jones Creek.

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In order to address the second question, the following hypothesis will also be addressed:

H_2 In consideration of improvements to spawning habitat through increased spawning and incubation flows, fish productivity is not correlated to substrate quality as measured by substrate particle size in the anadromous reach of lower Jones Creek.

The approach to addressing these hypotheses was outlined in the original Terms of Reference, but has been subsequently modified to reflect problems encountered with data collection and methodology. Data and analysis presented in this report is based on a proposal originally submitted by NHC in August, 2007 and subsequently agreed to by BC Hydro.

These changes include showing topographic changes over time at discrete cross section locations only rather than attempting to integrate volumetric changes throughout the study reach, and a consistent approach for substrate monitoring using photo sampling. NHC (2010) suggested adding a new section between XS 6 and XS 8 to better reflect the spatial extent of spawning habitat, which has been established and monitored within the Year 9 study.

For each odd year of the monitoring program, topographic surveys, site photography and photographic substrate sampling was completed at six previously established transect locations along Lower Jones Creek (**Figure 1**) and an additional section (XS 8.5) was added between XS 7 and XS 8. Target survey dates were established to coincide with peak spawning (15 October), mid-incubation (1 January), and end of incubation periods (15 March). Repeat topographic surveys and site photos are used to monitor habitat stability, while the repeat photographic substrate samples are used to monitor changes in substrate quality.

This report summarizes the methodology and results from the last ten years of the monitoring program. The data are used to assess if the data display any temporal trends and to assess the management questions. As part of the Year 9 reporting, NHC also conducted an internal review of the approaches being used to analyze the data, and as a result some of the analysis was changed. These changes are described in the Year 9 report (NHC, 2015).

2 DATA COLLECTION

2.1 HABITAT STABILITY MONITORING

Habitat stability monitoring quantifies the magnitude of channel changes during the post-spawning period. Habitat monitoring surveys have been scheduled to correspond with various points in the spawning and incubation life cycle phases for pink salmon (**Table 1**). In practice, the actual dates of channel survey and site photography deviate from the target dates due to poor weather or high flow conditions, and because of scheduling constraints. The lag between the survey target date and the actual survey date is not critical provided there have been no large or sustained peak flows, as these can cause significant changes in channel shape.

Table 1. Topographic survey schedule for Lower Jones Creek.

Target Date	Pink Salmon Periodicity
Oct 15, odd years	Peak spawning
Jan 1, even years	Incubation midpoint
Mar 15, even years	Incubation endpoint

Site photographs were taken from each photo documentation points (PDPs) with roughly the same view orientation used in previous years. The site photographs were initially intended to provide supplementary information for interpreting topographic survey results (presented in annual reports (NHC, 2006, 2008, 2010, 2012, 2015)). Orthophotos taken during low water periods in 2008, 2009 and 2010 also provide a means of interpreting channel stability and are better in some respects as they have identical scaling and orientation, allowing lateral changes to be better quantified. However, they are not collected at the beginning of the spawning period or end of the incubation period, and as such channel changes that occur during the spawning/incubation period cannot be separated from changes occurring outside of the period. Results from the earlier orthophoto mapping are reviewed and updated in the current report.

2.2 SUBSTRATE QUALITY MONITORING

An abundance of fine sediment in stream substrates is thought to be a key indicator of poor quality fish habitat. The *Terms of Reference* specifies the use of grain-size limits from 0.85 mm to 9.5 mm as recommended by Tappel and Bjornn (1983). This study found the fraction of sediment within this range to be a limiting factor for salmonid embryonic survival. These limits do not correspond to conventional physically based thresholds, but rather are based on an artefact of sieves sizes used in earlier work (Kondolf, 2000) and are often rounded to 1 mm and 8 mm.

More recent work has shown that fine sand and silt can also effect survival (Levasseur *et al*., 2006), at much lower concentrations, due to the effectiveness of fine sediment at reducing inter-gravel velocities. The above listed studies are based on sub-surface grain size distributions, which are relatively time consuming to collect in the field, require disturbing gravel which may contain incubating eggs, and have a limited spatial extents.

To provide a simpler approach that covers a wider spatial area, photos of the substrate surface were collected and used to determine the grain size of the surface sediment. The assumption is that the surface grain size distribution will correlate with the sub-surface distribution. Generally this is true, but the ratio can vary over a factor of 4 for the mean grain size (D_{50}; Hassan *et al*., 2006), and will vary even more for fine gravel and sand due to winnowing and low flow fine sediment deposition that can occur. For this reason the surface grain size distribution is best taken as an index of grain size, but the absolute values should not be directly compared to metrics that predict egg survival based on grain size.

The photographic substrate samples are scheduled to correspond with various points in the spawning and incubation life cycle phases for pink salmon, and are hence used to assess changes in fine sediment content over this period. The actual dates of photographic substrate sampling are identical to the cross section dates, eliminating potential bias in surface sediment changes introduced by a large lag period between photo and topographic sampling. Photo sampling is limited by elevated turbidity levels, so field visits are not completed immediately following rain events or when water levels are too high.

Photographic substrate samples were collected at the same five transects as the topographic surveys (Table 2). Samples were taken on each transect near points coinciding with ¼, ½ and ¾ of the measured width of the entire wetted channel at the time of survey. Two photographs are taken at each site immediately to the left and the right of the distance marker (6 samples in total). During low light conditions additional photos are taken from different orientations or with different camera settings and the two sharpest images are retained for analysis.

Photos are taken through the water column using a 65 cm tall, 36 cm diameter aluminum tube adapted from a device developed for work in Alaskan Streams (Whitman *et al*., 2011). The tube is fitted with a clear Plexiglas bottom, and mounted on 5 cm high legs. A darkened, removable lid with camera mount and viewing hole sits on top of the tube. The tube design blocks all light except that which filters in from the bottom.

Table 2. Date of photos and daily mean flow on date photos were collected.

Date of photos	Daily Discharge (BC Hydro)
8-Dec-05	Not available
9-Feb-06	Not available
5-May-06	Not available
5-Nov-07	2.82
25-Jan-08	0.74
19-Mar-08	1.13
28-Oct-09	1.03
3-Feb-10	0.79
18-Mar-10	1.31
1-Nov-11	1.57
23-Feb-12	3.04
26-Sep-13	1.16
27-Feb-14	0.81
2-Apr-14	1.03

By using a digital camera with polarizing filter, sharp, high-resolution images can be acquired in a variety of light conditions. A height-adjustable rod attached to the side allows the device to be used in clear water to depths of roughly 1 meter. The device can be used in moderately turbid water provided the flow depth is small as the base can be placed near the bottom, minimizing the thickness of the water column through which the picture is taken. Results of the substrate analysis are provided in Section 3.

Prior to the Year 9 report the analysis was done using grain size data that was truncated at 64 mm, as this has historically been a common practice in the fisheries biology community and was thought to remove the bias that can occur if larger grains are present, but not adequately sampled. In practice, truncating at larger grain sizes artificially increases the percent fines and can make the habitat appear to have poorer quality than that which actually occurs (Fripp and Diplas, 1993; Zimmermann *et al*., 2005).

3 RESULTS

3.1 HYDROLOGIC ANALYSIS

Daily discharge records have been provided by BC Hydro for the duration of the monitoring program through the fall of 2015. A complete record of the discharge data that NHC has received to date is shown in **Figure 2.** The gaps early on in the record make it difficult to assess some aspects of the project.

The current Water Use Plan indicates that a minimum flow of 1.1 m^3/s is targeted during the spawning cycle (Sept 15 – Nov 30). A year by year presentation of observed flows, IFR requirements, and data gaps is presented in **Figure 3** through **Figure 13**. These data are summarized in **Table 3.**

Figure 2. Discharge record from 2005 to 2015. Data from BC Hydro.

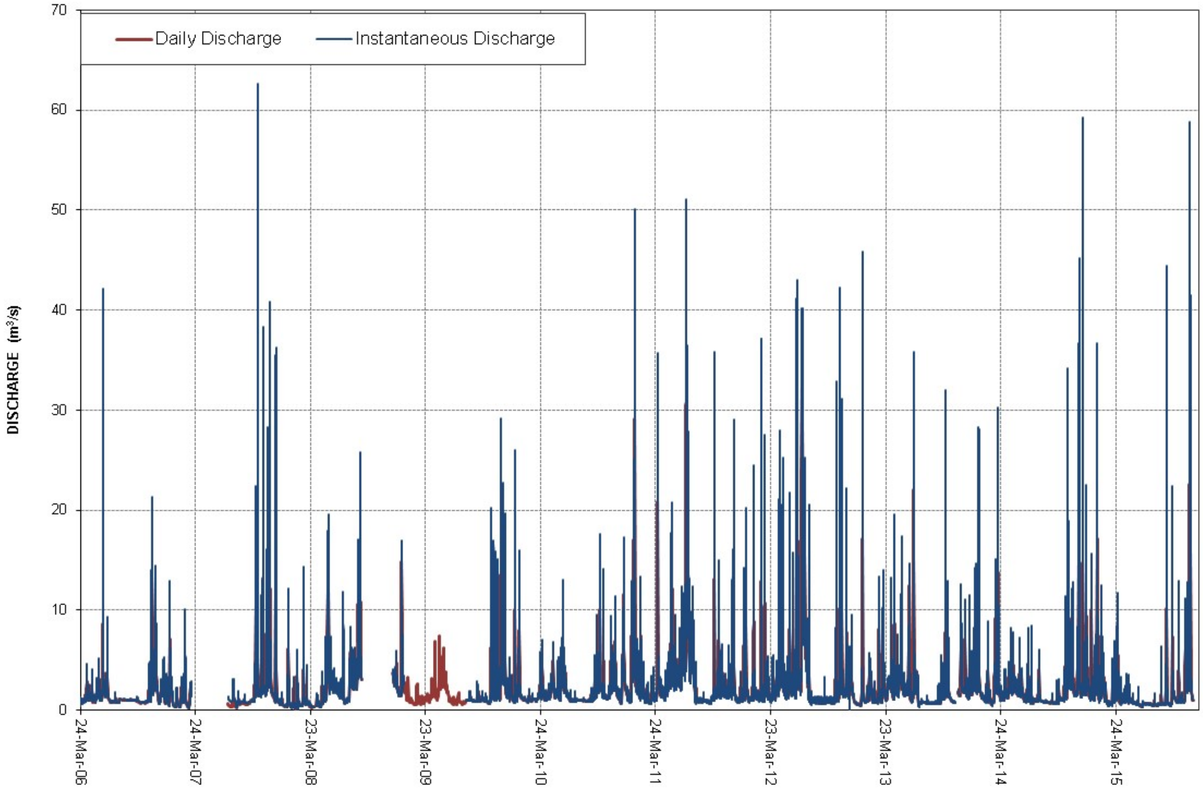


Figure 3. Hydrograph from 2005 illustrating low flow conditions.

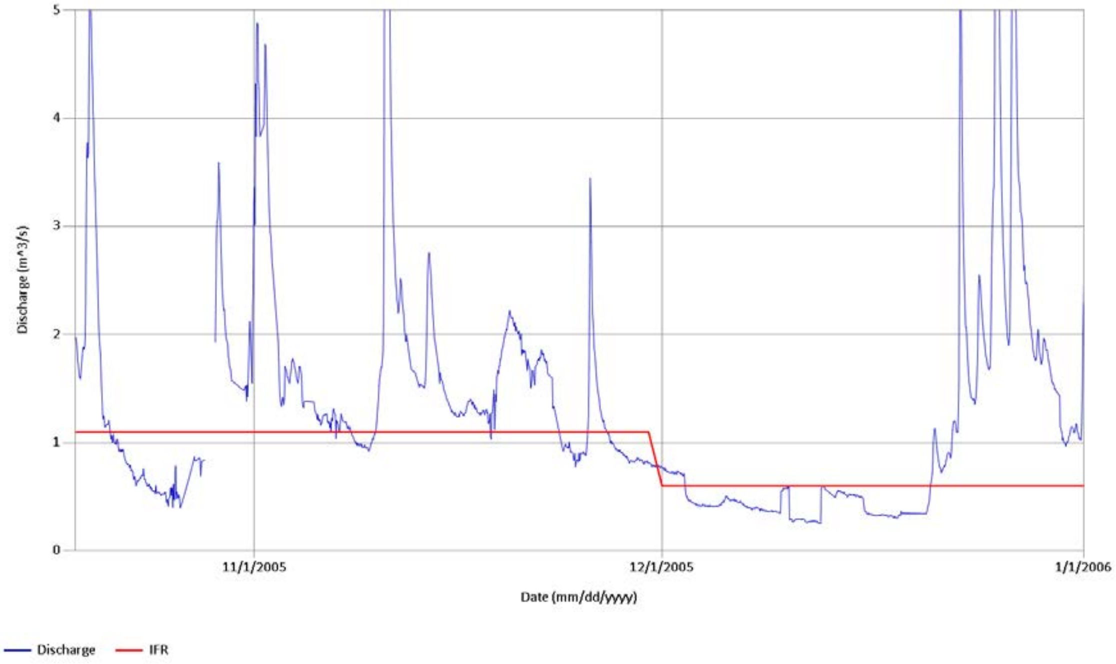


Figure 4. Hydrograph from 2006 illustrating low flow conditions.

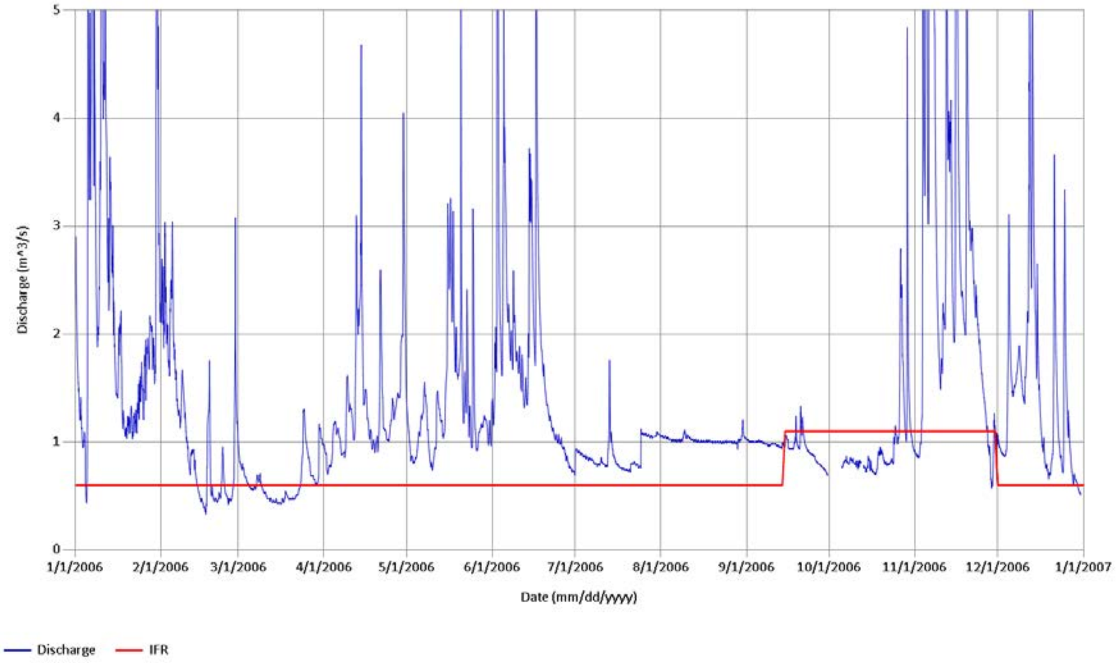


Figure 5. Hydrograph from 2007 illustrating low flow conditions.

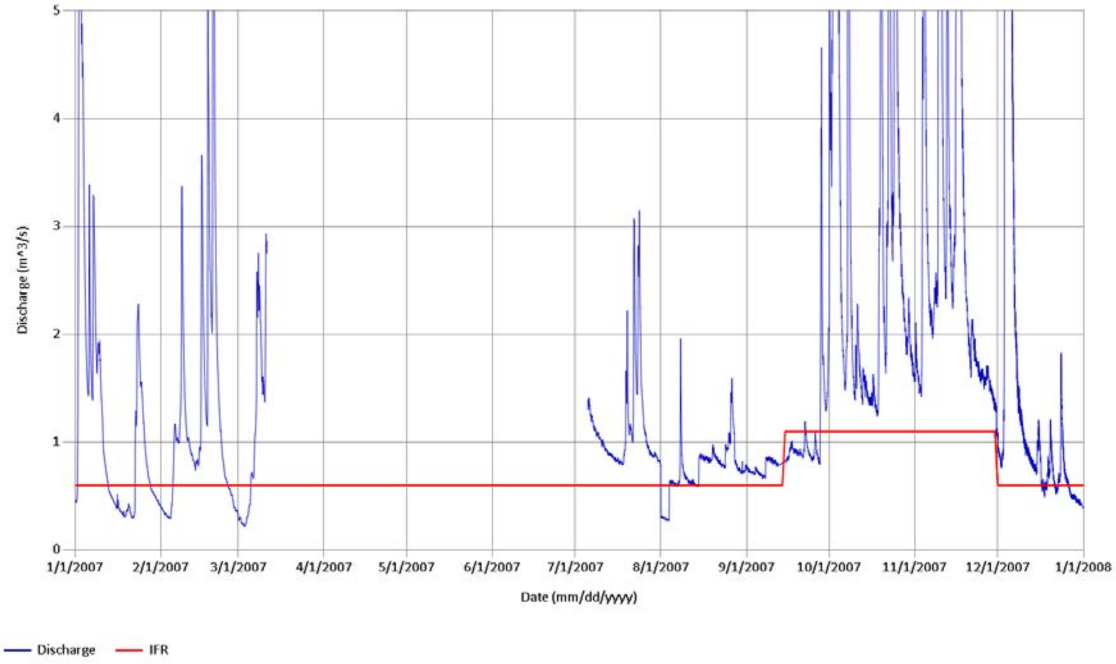


Figure 6. Hydrograph from 2008 illustrating low flow conditions.

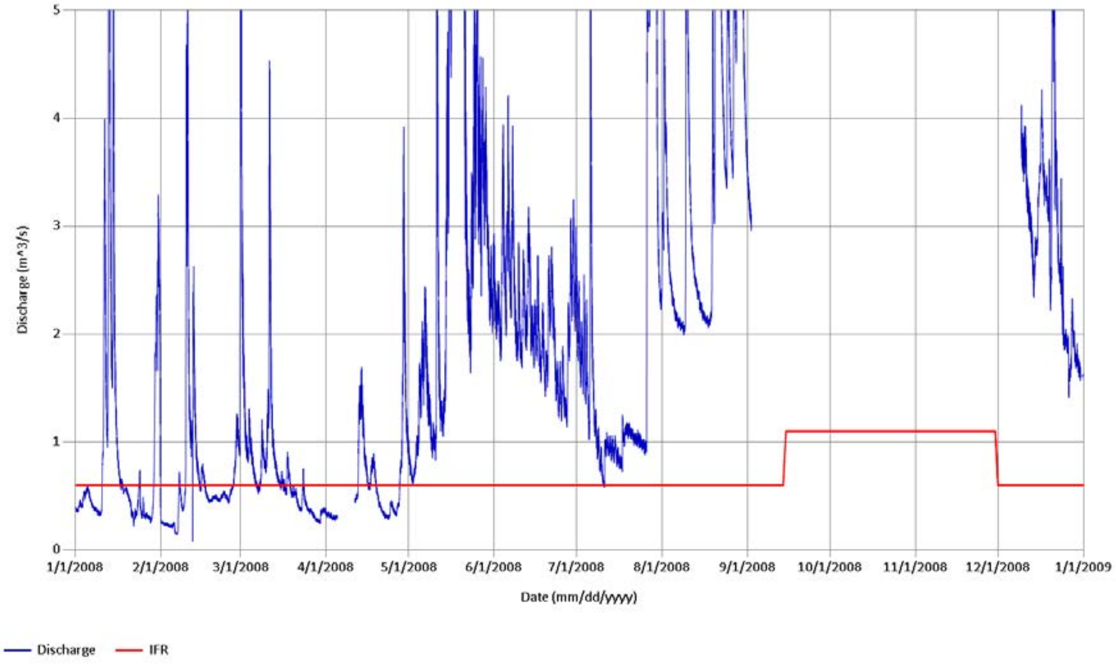


Figure 7. Hydrograph from 2009 illustrating low flow conditions.

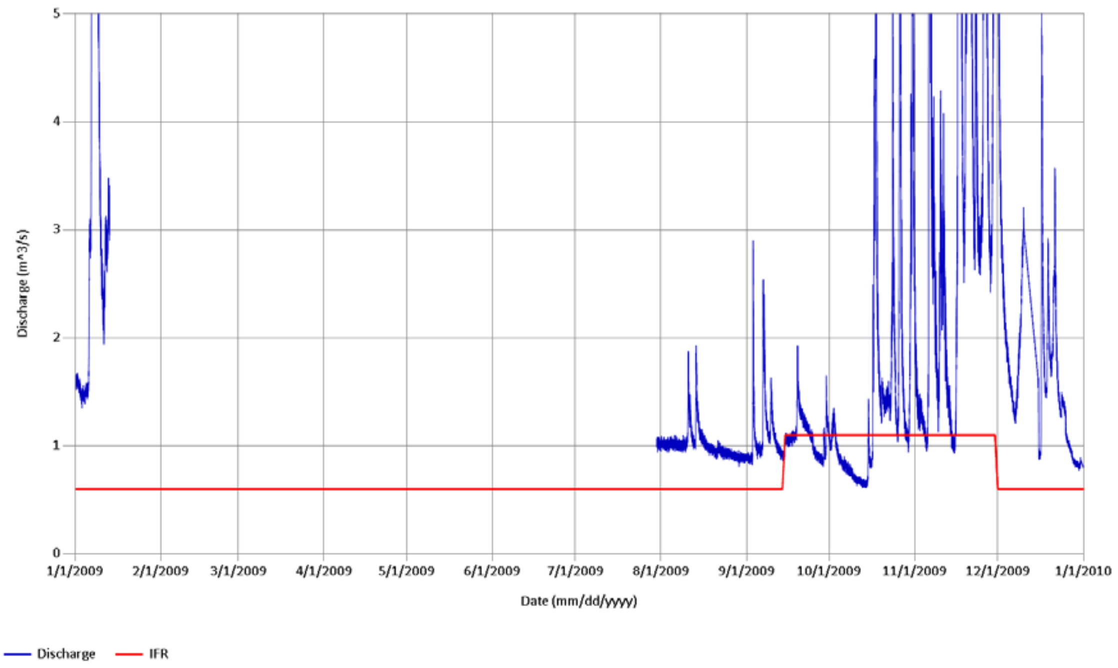


Figure 8. Hydrograph from 2010 illustrating low flow conditions.

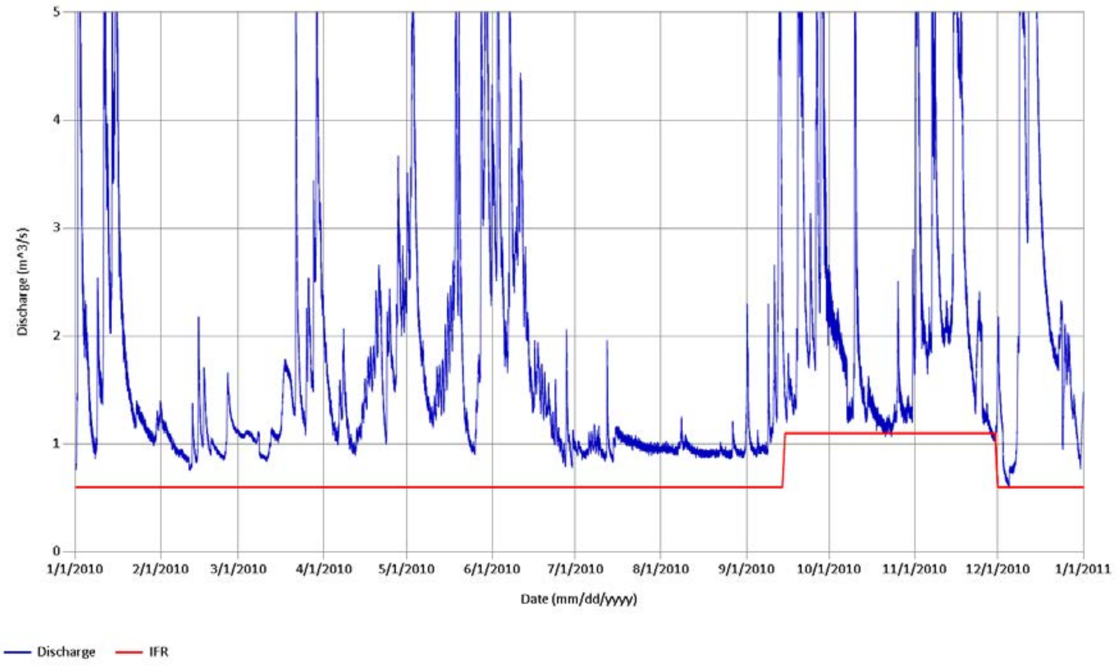


Figure 9. Hydrograph from 2011 illustrating low flow conditions.

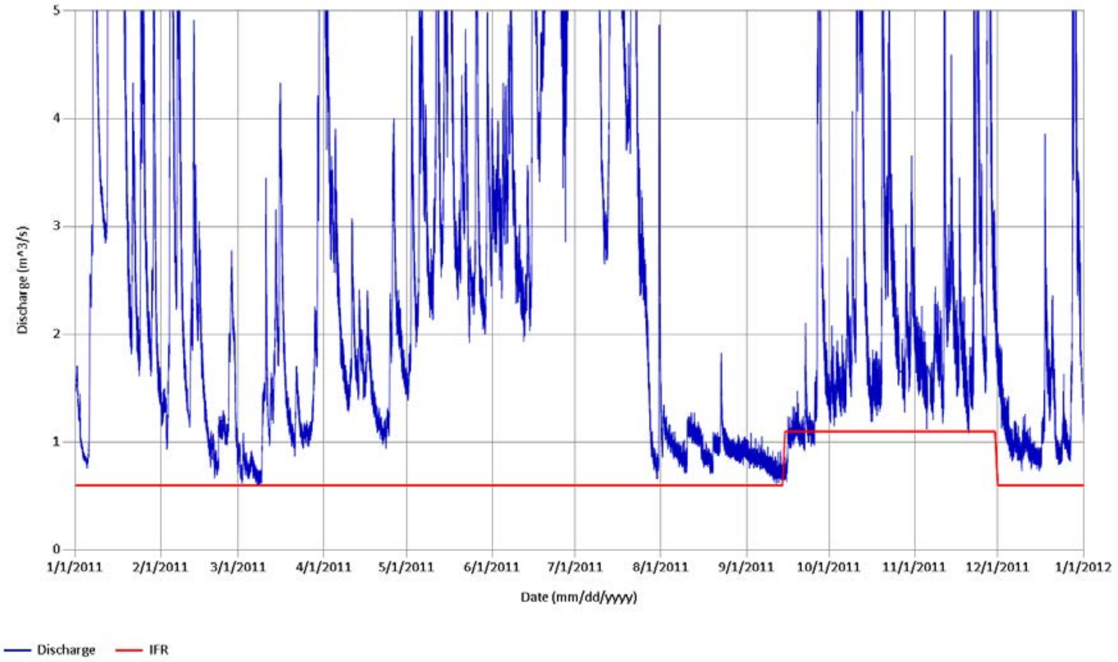


Figure 10. Hydrograph from 2012 illustrating low flow conditions.

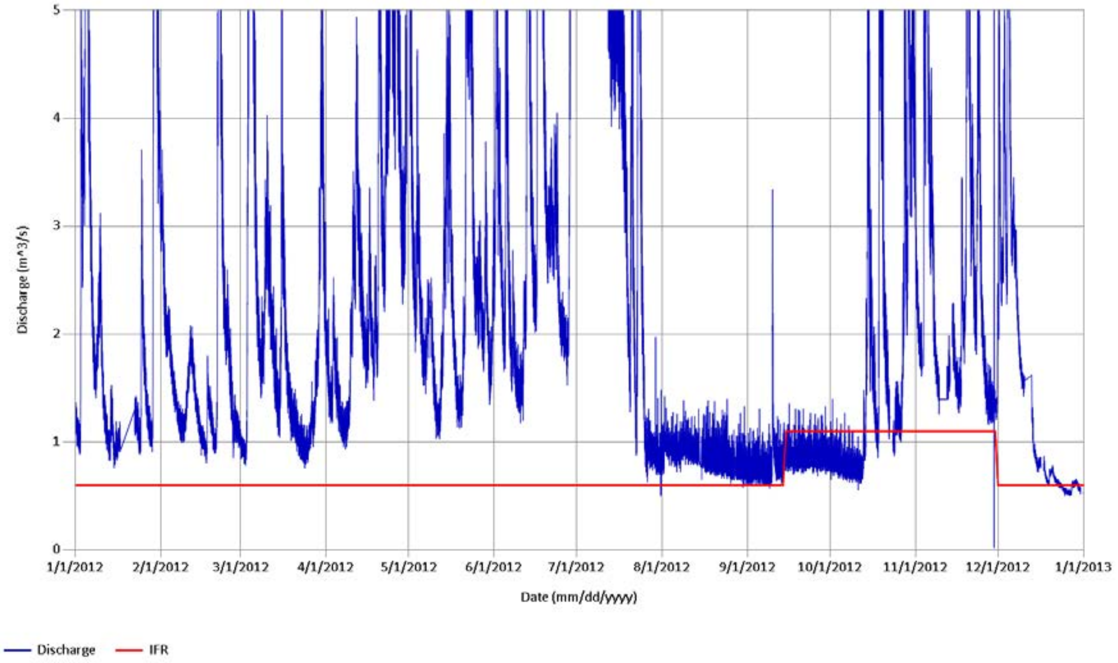


Figure 11. Hydrograph from 2013 illustrating low flow conditions.

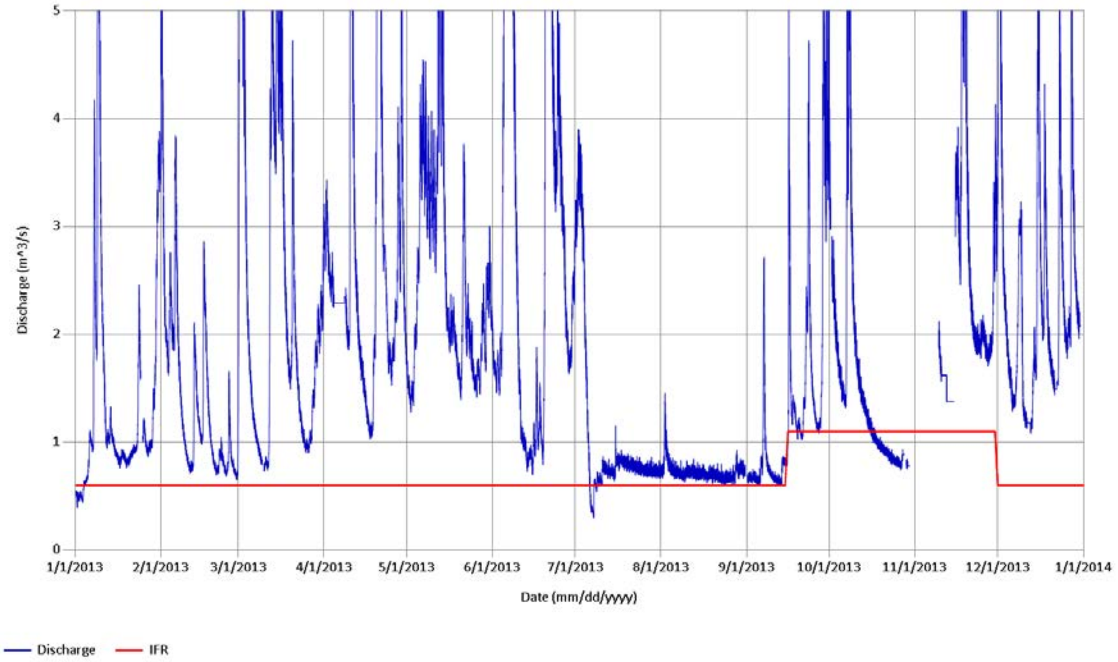


Figure 12. Hydrograph from 2014 illustrating low flow conditions.

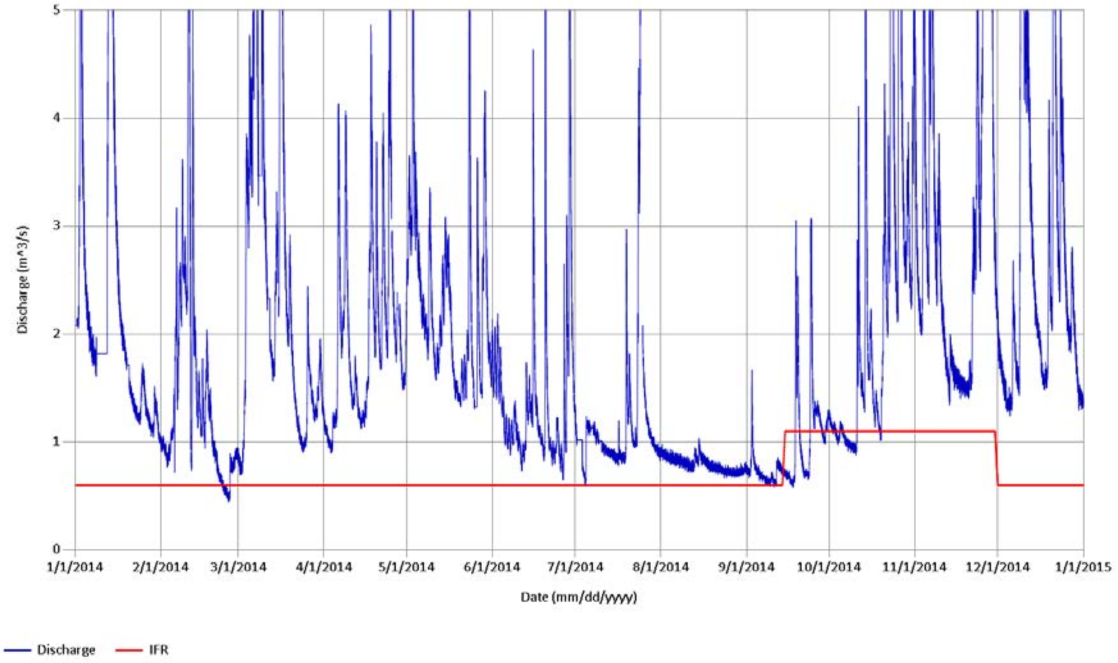


Figure 13. Hydrograph from 2015 illustrating low flow conditions.

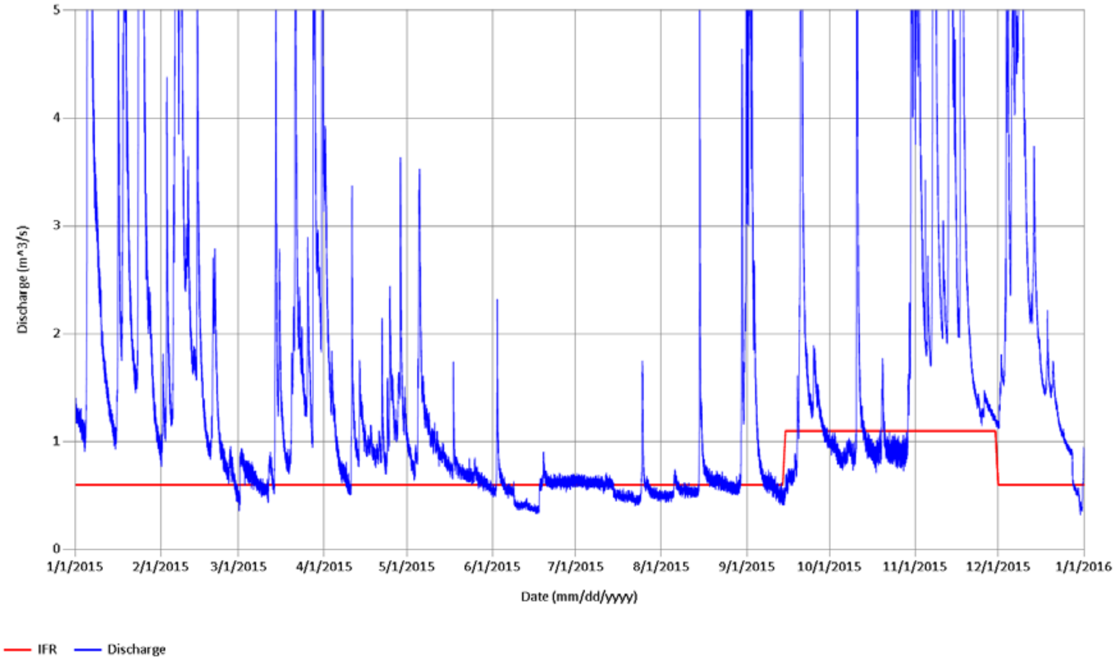


Table 3. Summary of data gaps and flows above instream flow targets (IFT).

Year	Proportion of year with missing data	Proportion of year with flow less than IFT or missing data	Proportion of spawning period with missing data	Proportion of spawning period with flow less than IFT or missing data	Proportion of incubation period with missing data	Proportion of incubation period with flow less than IFT or missing data
2005[1]	2%	46%	4%	37%	0%	58%
2006	2%	21%	8%	61%	1%	22%
2007	32%	46%	0%	16%	4%	38%
2008	29%	48%	100%	100%	8%	48%
2009	54%	62%	0%	35%	59%	59%
2010	0%	0%	0%	2%	0%	0%
2011	0%	2%	0%	8%	0%	0%
2012	1%	11%	3%	42%	2%	7%
2013	5%	10%	16%	35%	3%	6%
2014	1%	6%	0%	20%	1%	3%
2015	0%	28%	0%	40%	0%	9%

[1] 2005 Period: 18 Oct - 31 Dec, 2005.

The data provided by BC Hydro shows that data gaps have become less frequent in the last 5 years and that flows are generally above the minimum flow targets. Inspection of the plots in **Figure 3** through **Figure 13** shows that when the targets are not met, flows are generally close to the target flows.

The occurrence of high flows causes changes in channel morphology and substrate quality. Newbury Hydraulics (2004) estimated bankfull discharge to be roughly 20 m^3/s. The bankfull discharge is often considered to be the discharge that is capable of reshaping alluvial channel dimensions by eroding banks and transporting bed material. Ideally the bankfull discharge should be compared to the instantaneous peak flow, not the daily mean flow. In streams that are rain dominated, like Jones Creek, the daily peak flow can be considerably smaller as is evident in **Table 4**.

Table 4. Timing of surveys and associated peak discharge values between surveys.

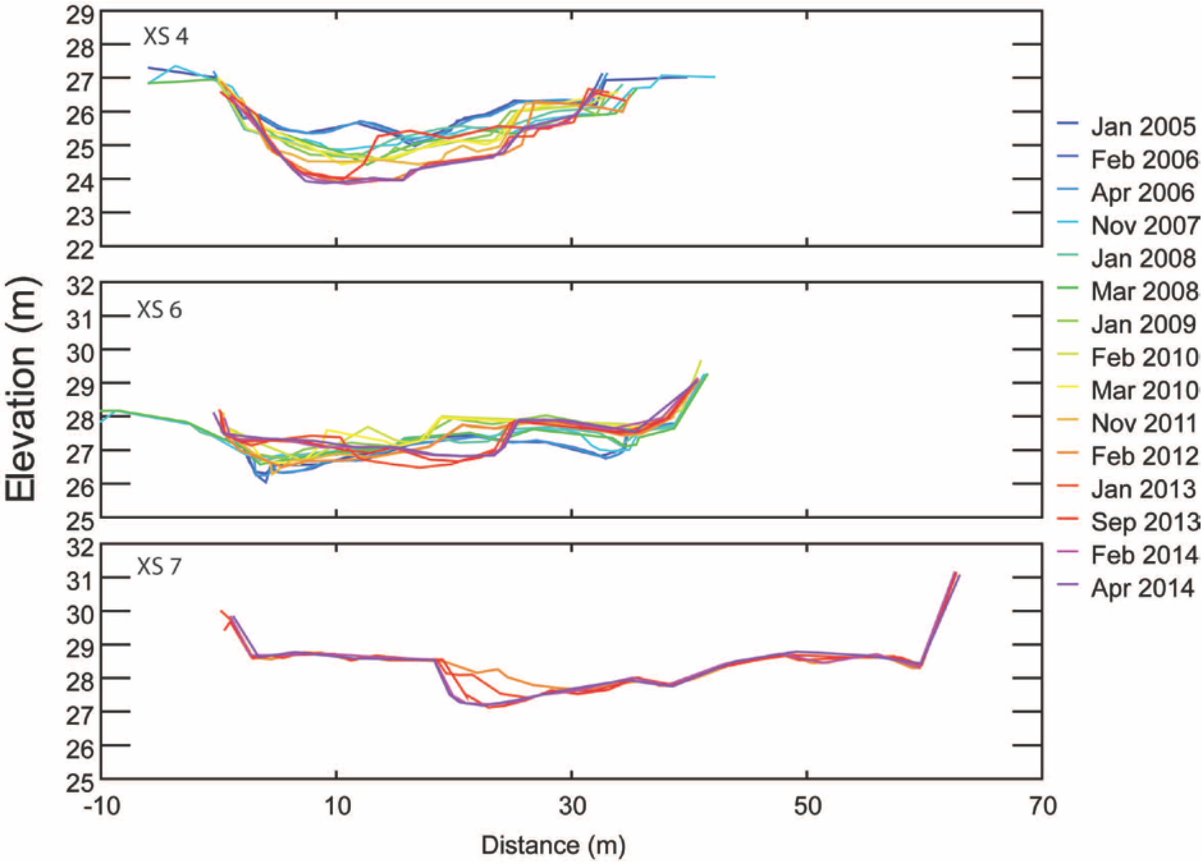
Dates		Max Instantaneous Flow (m^3/s)	% Coverage	Max daily Flow (m^3/s)	% Coverage	Likelihood of missing large event
Start	End					
10/25/2005	2/6/2006	19.965	99%	7.9	97%	Low
2/6/2006	4/5/2006	3.077	100%	1.5	100%	None
4/5/2006	11/15/2007	62.66	80%	13.3	80%	Moderate
11/15/2007	1/25/2008	40.8	100%	17.4	100%	None
1/25/2008	3/19/2008	14.3	100%	4.1	100%	None
3/19/2008	**10/28/2009**	**25.75**	**48%**	**14.8**	**81%**	**High**
10/28/2009	2/3/2010	29.16	100%	8.9	100%	None
2/3/2010	3/18/2010	2.2	100%	1.3	100%	None
3/18/2010	11/1/2011	51.06	100%	10.7	100%	None
11/1/2011	2/23/2012	37.2	100%	12.9	100%	None
2/23/2012	1/31/2013	51.1	100%	33.4	100%	None
1/31/2013	9/26/2013	35.8	100%	22	100%	None
9/26/2013	2/27/2014	32	100%	21.2	100%	None
2/27/2014	4/2/2014	30.2	100%	13.7	100%	None

3.2 HABITAT STABILITY MONITORING

Temporal trends in the cross section morphology are shown in **Figure 14** and **Figure 15** by overlaying sequential plots. Cross sections 4 and 6 (XS 4 and XS 6) have been relatively active over the monitoring period, and change both laterally and vertically (**Figure 14**). The magnitude of these changes is not surprising given the sediment load and fining of the grain size distribution that occurs because of the Fraser River induced backwatering.

XS 7 has been relatively more stable; however, it has progressively incised and eroded the left side of the channel. With the exception of aggradation that occurred after 2007, the channel has remained relatively stable from XS 8 upstream to the Laidlaw Road Bridge across Jones Creek. This is reflected in the cross sectional profiles displayed in **Figure 15** (XS 8, XS 8.5, XS 9, and XS 10). With the exception of XS 8, all of these monitoring sections have remained quite stable in both planform and profile. XS 8 experienced primarily degradation along the lock-block reinforced left bank during the first 6 years of monitoring, and has remained more stable since.

Figure 14. Plots of cross section 4, 6 and 7 from 2005 to 2014. Sections are viewed looking downstream.



The survey data has been used to calculate the magnitude of change at each cross section within the wetted portion of the channel. This is done by determining the bed elevation at fixed locations spaced 0.1 m across the channel. Each point is then compared to the survey from the preceding year to see of bed has scoured or aggraded. Vertical differences in bed elevation of 10 cm or less are considered within the range of survey error due to the irregularity of the channel bed. Minor differences in elevation also occur due to small deviations from the previous survey line during the time of survey. Chainage and elevation values recorded by the total station are exported to a spreadsheet for plotting.

Scour and fill within the wetted portion of the channel are summarized in **Table 5**. A threshold of 15 centimetres was used to define ‘significant’ scour or fill. This threshold was chosen as it is likely that scour of fill of 15 cm is biologically meaningful (likely to scour or entomb eggs) and it exceeds the uncertainty associated with repeat surveys. Figures illustrating temporal changes in the amount of scour and fill are shown in **Figure 16** along with the peak flow that was observed between the two surveys. In general, larger peak flows resulted in a larger proportion of the channel changing by more than 15 cm.

Figure 15. Plots of cross section 8, 8.5, 9 and 10 from 2005 to 2014. Sections are viewed looking downstream.

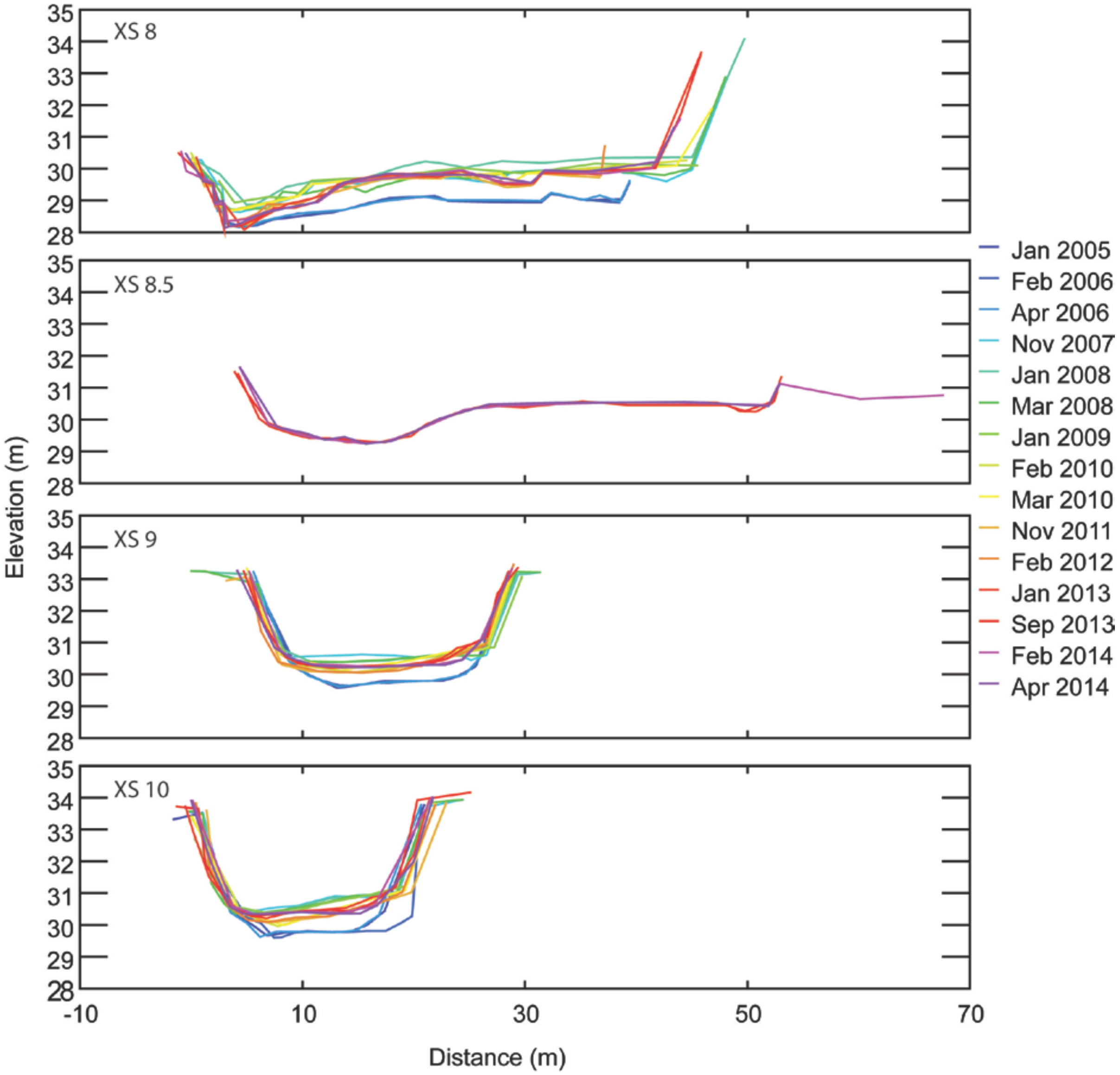
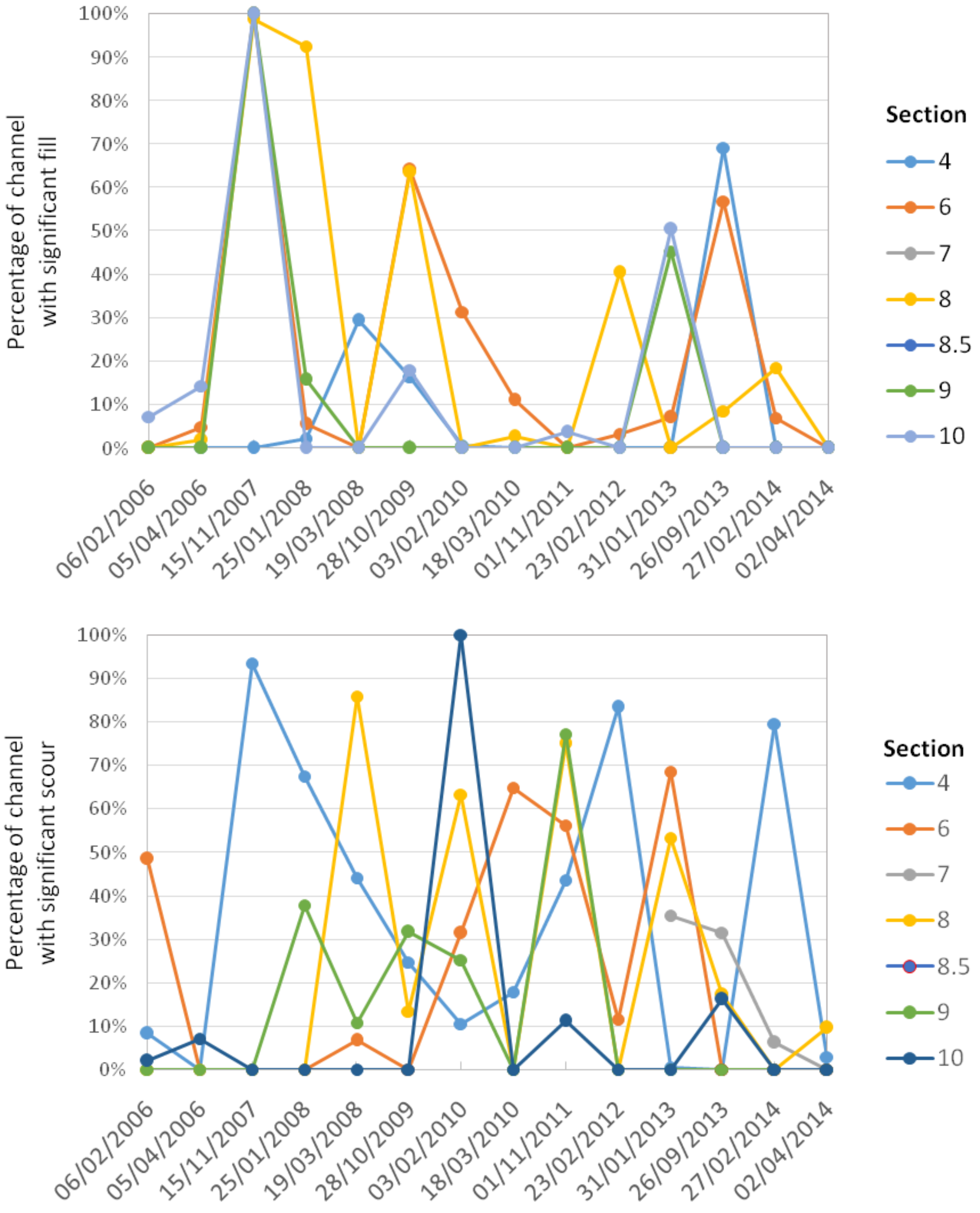
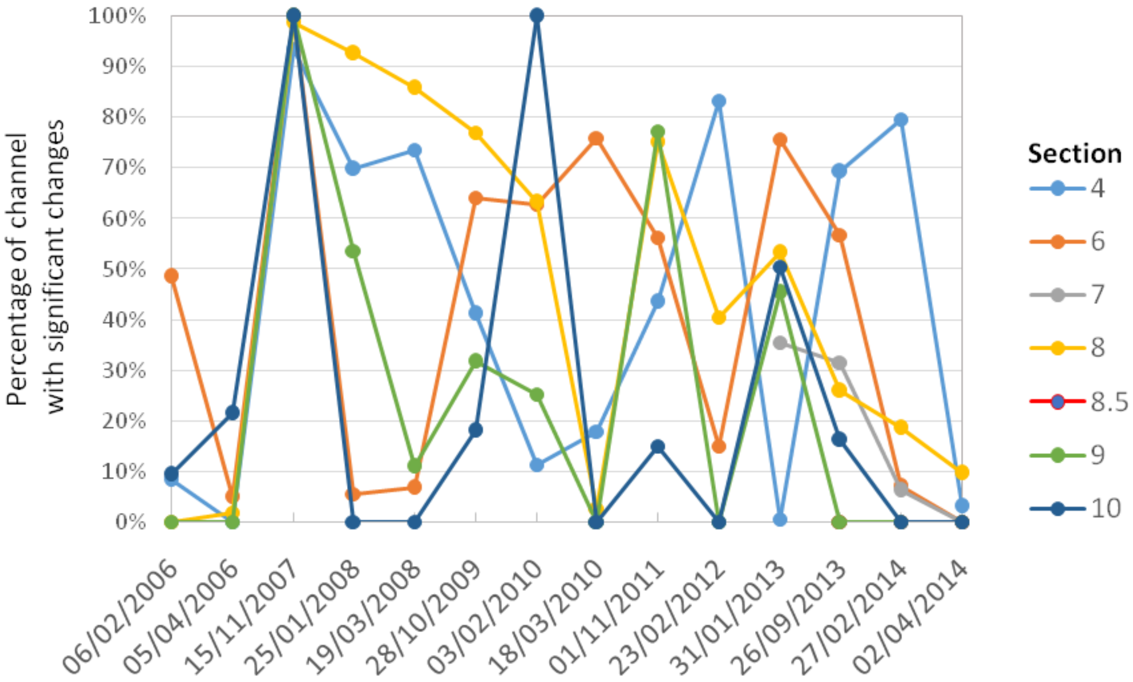


Figure 16 Percentage of channel width that experienced more than 15 cm of fill, scour and total change during each survey. The peak flow that occurred between each survey is also indicated.




Percentage of channel with significant changes
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
06/02/2006
05/04/2006
15/11/2007
25/01/2008
19/03/2008
28/10/2009
03/02/2010
18/03/2010
01/11/2011
23/02/2012
31/01/2013
26/09/2013
27/02/2014
02/04/2014
Section
4
6
7
8
8.5
9
10

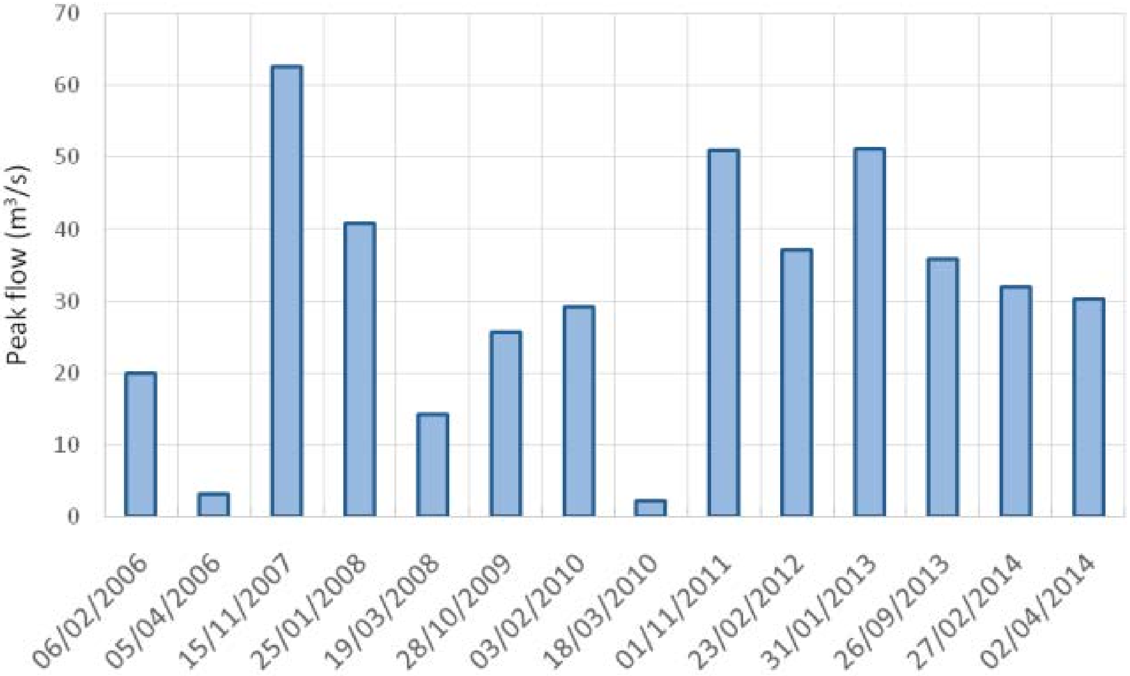

Peak flow (m³/s)
70
60
50
40
30
20
10
0
06/02/2006
05/04/2006
15/11/2007
25/01/2008
19/03/2008
28/10/2009
03/02/2010
18/03/2010
01/11/2011
23/02/2012
31/01/2013
26/09/2013
27/02/2014
02/04/2014

Table 5. **Proportion of wetted channel width that had fill, scour and total change exceeding 15 cm. No changes greater than 15 cm occurred between the 4 surveys at section 8.5, thus it has been excluded from the table. Light shading indicates spawning period, dark shading indicates incubation period.**

Proportion of channel with significant fill

Date		Section						Peak Flow (m^3/s)
Start	End	4	6	7	8	9	10	
25/10/2005	06/02/2006	0%	0%		0%	0%	7%	20.0
06/02/2006	05/04/2006	0%	5%		2%	0%	14%	3.1
05/04/2006	15/11/2007	0%	100%		99%	100%	100%	62.7
15/11/2007	25/01/2008	2%	6%		93%	16%	0%	40.8
25/01/2008	19/03/2008	29%	0%		0%	0%	0%	14.3
19/03/2008	28/10/2009	16%	64%		64%	0%	18%	25.8
28/10/2009	03/02/2010	1%	31%		0%	0%	0%	29.2
03/02/2010	18/03/2010	0%	11%		3%	0%	0%	2.2
18/03/2010	01/11/2011	0%	0%		0%	0%	4%	51.1
01/11/2011	23/02/2012	0%	3%		41%	0%	0%	37.2
23/02/2012	31/01/2013	0%	7%	0%	0%	45%	50%	51.1
31/01/2013	26/09/2013	69%	57%	0%	9%	0%	0%	35.8
26/09/2013	27/02/2014	0%	7%	0%	19%	0%	0%	32.0
27/02/2014	02/04/2014	0%	0%	0%	0%	0%	0%	30.2

Proportion of channel with significant scour

Date		Section						Peak Flow (m^3/s)
Start	End	4	6	7	8	9	10	
25/10/2005	06/02/2006	8%	49%		0%	0%	2%	20.0
06/02/2006	05/04/2006	0%	0%		0%	0%	7%	3.1
05/04/2006	15/11/2007	94%	0%		0%	0%	0%	62.7
15/11/2007	25/01/2008	67%	0%		0%	38%	0%	40.8
25/01/2008	19/03/2008	44%	7%		86%	11%	0%	14.3
19/03/2008	28/10/2009	25%	0%		14%	32%	0%	25.8
28/10/2009	03/02/2010	11%	31%		63%	25%	100%	29.2
03/02/2010	18/03/2010	18%	65%		0%	0%	0%	2.2
18/03/2010	01/11/2011	44%	56%		75%	77%	11%	51.1
01/11/2011	23/02/2012	83%	12%		0%	0%	0%	37.2
23/02/2012	31/01/2013	1%	69%	36%	53%	0%	0%	51.1
31/01/2013	26/09/2013	0%	0%	31%	17%	0%	16%	35.8
26/09/2013	27/02/2014	80%	0%	6%	0%	0%	0%	32.0
27/02/2014	02/04/2014	3%	0%	0%	10%	0%	0%	30.2

Proportion of channel with significant total change								
Date		Section						Peak Flow (m^3/s)
Start	End	4	6	7	8	9	10	
25/10/2005	06/02/2006	8%	49%		0%	0%	9%	20.0
06/02/2006	05/04/2006	0%	5%		2%	0%	21%	3.1
05/04/2006	15/11/2007	94%	100%		99%	100%	100%	62.7
15/11/2007	25/01/2008	70%	6%		93%	54%	0%	40.8
25/01/2008	19/03/2008	74%	7%		86%	11%	0%	14.3
19/03/2008	28/10/2009	41%	64%		77%	32%	18%	25.8
28/10/2009	03/02/2010	11%	63%		63%	25%	100%	29.2
03/02/2010	18/03/2010	18%	76%		3%	0%	0%	2.2
18/03/2010	01/11/2011	44%	56%		75%	77%	15%	51.1
01/11/2011	23/02/2012	83%	15%		41%	0%	0%	37.2
23/02/2012	31/01/2013	1%	76%	36%	53%	45%	50%	51.1
31/01/2013	26/09/2013	69%	57%	31%	26%	0%	16%	35.8
26/09/2013	27/02/2014	80%	7%	6%	19%	0%	0%	32.0
27/02/2014	02/04/2014	3%	0%	0%	10%	0%	0%	30.2

Table 6. Average percent of wetted channel that experienced more than 15 cm of fill, scour or change based on 15 surveys completed between 2005 and 2014.

Section	% wetted channel fill	% wetted channel scour	% wetted channel changed
4	8%	34%	42%
6	21%	21%	41%
8	23%	23%	46%
9	12%	13%	25%
10	14%	10%	24%

Table 6 summarizes the average amount of change for the 5 original sections and demonstrates that on average at Sections 4, 6 and 8 more than 40% of the wetted channel is either scoured or filled by more than 15 cm. This is a relatively large amount of change and speaks to the mobility of these sections.

A plot illustrating the wetted width during each survey is shown in **Figure 17**. Overall the sections show that wetted width varies more between the sections, than between surveys as the width does not consistently change between each survey in response to slight differences in the discharge at which the survey data were collected. This speaks to the overall dynamics of the sections, and how the availability of wetted habitat changes with time. In general, the wetted width varies more at the downstream section than the upstream sections, which is related to the channel geometry changing more at the downstream sites over time.

Figure 17. Wetted width observed during each survey.

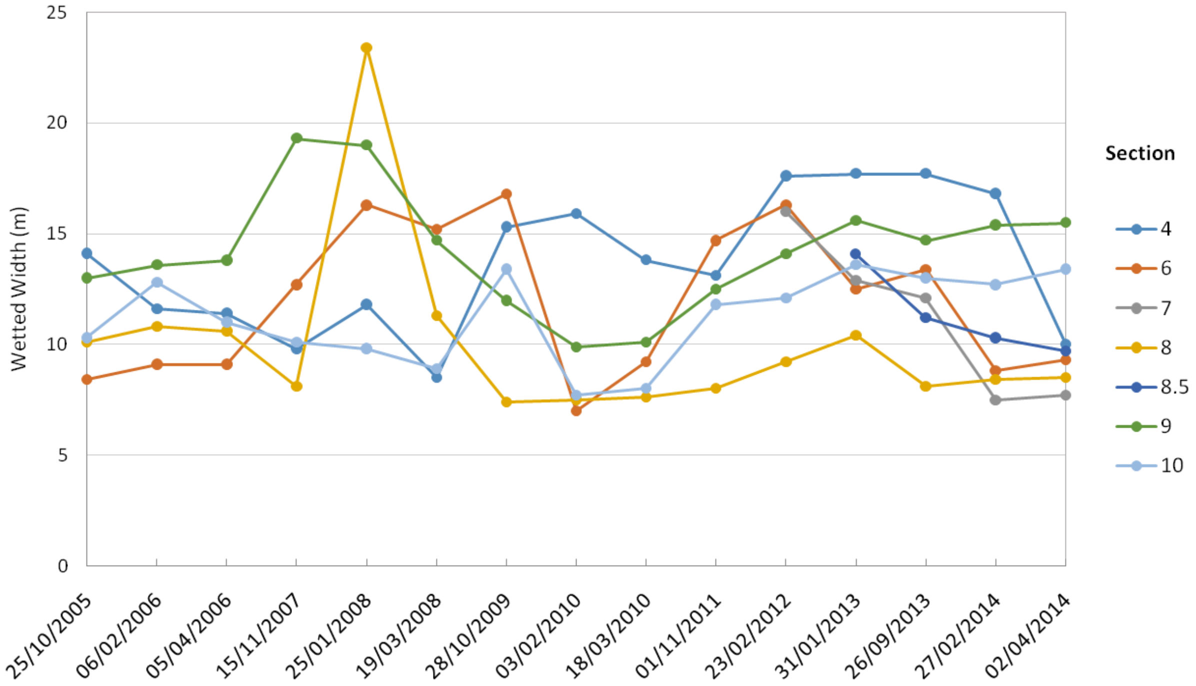


Table 7. Wetted channel width during survey.

Date	Section							Daily Flow (m^3/s)
	4	6	7	8	8.5	9	10	
25/10/2005	14.1	8.4		10.1		10.03	10.3	0.5
06/02/2006	11.6	9.1		10.8		13.6	1.55	1.6
05/04/2006	11.4	9.1		10.6		13.8	1.12	1.1
15/11/2007	9.8	12.7		8.1		19.3	3.66	3.7
25/01/2008	11.8	16.3		23.4		19.0	0.74	0.7
19/03/2008	8.5	15.2		11.3		14.7	1.13	1.1
28/10/2009	15.3	16.8		7.4		12.0	1.03	1.0
03/02/2010	15.9	7.0		7.5		9.9	0.79	0.8
18/03/2010	13.8	9.2		7.6		10.1	1.31	1.3
01/11/2011	13.1	14.7		8.0		12.5	1.57	1.6
23/02/2012	17.6	16.3	16.0	9.2		14.1	3.04	3.0
31/01/2013	17.7	12.5	12.9	10.4	14.1	15.6	3.61	3.6
26/09/2013	17.7	13.4	12.1	8.1	11.2	14.7	1.16	1.2
27/02/2014	16.8	8.8	7.5	8.4	10.3	15.4	0.81	0.8
02/04/2014	10.0	9.3	7.7	8.5	9.7	15.5	1.03	1.0

Table 8. Percent of wetted channel that was not wetted during previous survey.

Date	Section							Daily Flow (m^3/s)
	4	6	7	8	8.5	9	10	
06/02/2006	6.9%	25.3%		6.5%		4.4%	25.0%	1.6
05/04/2006	9.6%	9.9%		0.9%		1.4%	10.9%	1.1
15/11/2007	36.7%	41.7%		3.7%		28.5%	20.8%	3.7
25/01/2008	27.1%	22.1%		65.4%		0.0%	0.0%	0.7
19/03/2008	20.0%	2.0%		0.0%		0.0%	0.0%	1.1
28/10/2009	44.4%	23.8%		0.0%		0.0%	33.6%	1.0
03/02/2010	17.0%	0.0%		9.3%		0.0%	0.0%	0.8
18/03/2010	2.9%	41.3%		1.3%		5.0%	3.8%	1.3
01/11/2011	22.9%	39.5%		5.0%		19.2%	32.2%	1.6
23/02/2012	28.4%	9.8%		14.1%		11.3%	5.0%	3.0
31/01/2013	3.4%	44.0%	17.1%	11.5%		10.9%	11.0%	3.6
26/09/2013	4.5%	6.7%	10.7%	0.0%	0.0%	0.0%	0.0%	1.2
27/02/2014	0.6%	2.3%	14.7%	3.6%	0.0%	8.4%	0.8%	0.8
02/04/2014	0.0%	5.4%	3.9%	2.4%	2.1%	0.6%	5.2%	1.0

3.2.1 SECTION 4

Section 4 (XS 4) is located immediately downstream from a rock weir. The creek channel below the weir is subject to seasonal backwater from the Fraser River during the late spring freshet when bed filling of up to a metre or more can occur.

Over the course of the project, monitoring surveys have shown that this is an active section of channel, with aggradation occurring during the summer when high water on Fraser River creates a backwater effect. This deposited material is then reworked and eroded during high creek flows in the autumn and winter. Between September 2013 and February 2014, 80% of the wetted channel was scoured by more than 15 cm. A further 3% of the channel was scoured by more than 15 cm between February and April (**Table 5**).

As noted in the year 7 monitoring report (NHC, 2012), XS 4 had experienced significant erosion between February 2010 and February 2012. Between February 2013 and September 2013, 70% of the wetted channel had aggraded by more 15 cm. As part of this aggradation, a large right bank bar formed. The majority of this recently deposited sediment was again eroded away by April 2014, such that the channel returned to the shape it had in February 2012.

3.2.2 SECTION 6

The 171 m long channel reach in which XS 6 is located is roughly 100 m upstream of the rock weir and the section is located in a generally widened section of channel characterized by frequent bar deposits. Previous reports (NHC, 2012) have shown the thalweg had remaining relatively fixed in position along the left bank prior to February 2012.

The mid channel bar formations have experienced significant change over the monitoring program, while the small channel along the right bank has remained relatively fixed in location. Between September 2013 and February 2014, 7% of the channel width filled more than 15 cm. No substantial changes occurred during the incubation period (**Table 5**). In most previous years substantially larger changes have occurred at this site.

3.2.3 SECTION 7

Section 7 (XS 7) was established in February 2012 at the widest (~60 m) and most morphologically complex section of channel. The thalweg is bounded by a large point bar on the left bank and mid channel bar near the right bank. A smaller, shallow secondary channel is found adjacent to the right bank (**Figure 1**).

An engineered log jam on the right bank bend immediately downstream of the section protects the right bank from large scale erosion, and helps maintain the channel alignment. The channel is progressively migrating towards the left bank (**Figure 14**) and 31% of the channel scoured more than 15 cm between September 2013 and February 2014. No significant changes occurred during the incubation period (**Table 5**).

3.2.4 SECTION 8

Section 8 is located within a length of channel that exhibits similar morphology to that found at XS 6 downstream. This cross section is representative of a 164 m section of channel, and has lock-blocks protecting the left bank. The morphology at this section has become more complex since 2008-2009 as a minor chute channel has developed and enlarged, bifurcating an existing, extensive point bar deposit, and the main channel thalweg has deepened.

From September 2013 to February 2014, 19% of the wetted width aggraded by more than 15 cm. During the incubation period that followed (February to April 2014), 10% of the wetted width degraded by more than 15 cm. These changes are less than the long term average and suggest fry survival should be higher for the 2013-2014 winter.

3.2.5 SECTION 8.5

Sections 8.5 was established in September 2013 to monitor potential changes to the large right bank lateral bar in this river reach. The left bank at this section is reinforced by lock-blocks, which may result in increased channel incision. The survey of this section was repeated in February and April 2014 and no significant changes were observed during this period.

3.2.6 SECTION 9

Sections 9 (XS 9) is also located within the incised length of channel on the upper fan (Photo Documentation Points 8 and 9) and was initially chosen to be representative of a section of channel which extends 108 m in length (the shortest representative length of all study sections). The section has a trapezoidal channel shape, characterized by a flatbed that gently slopes downward towards the left bank terrace, exposing a minor right bank lateral bar at lower flows. During the fall spawning period and winter incubation period of 2013-2014, no changes greater than 15 cm were observed at this site.

3.2.7 SECTION 10

Section 10 (XS 10) is located in an incised portion of channel below the anadromous barrier. This section represents a portion of the channel extending from the mid-point between XS 9 and XS 10 to the anadromous barrier located 280 m upstream. In previous years it has exhibited a simple morphology characterized by a well-established lateral bar on the right bank that gently slopes towards the left bank thalweg.

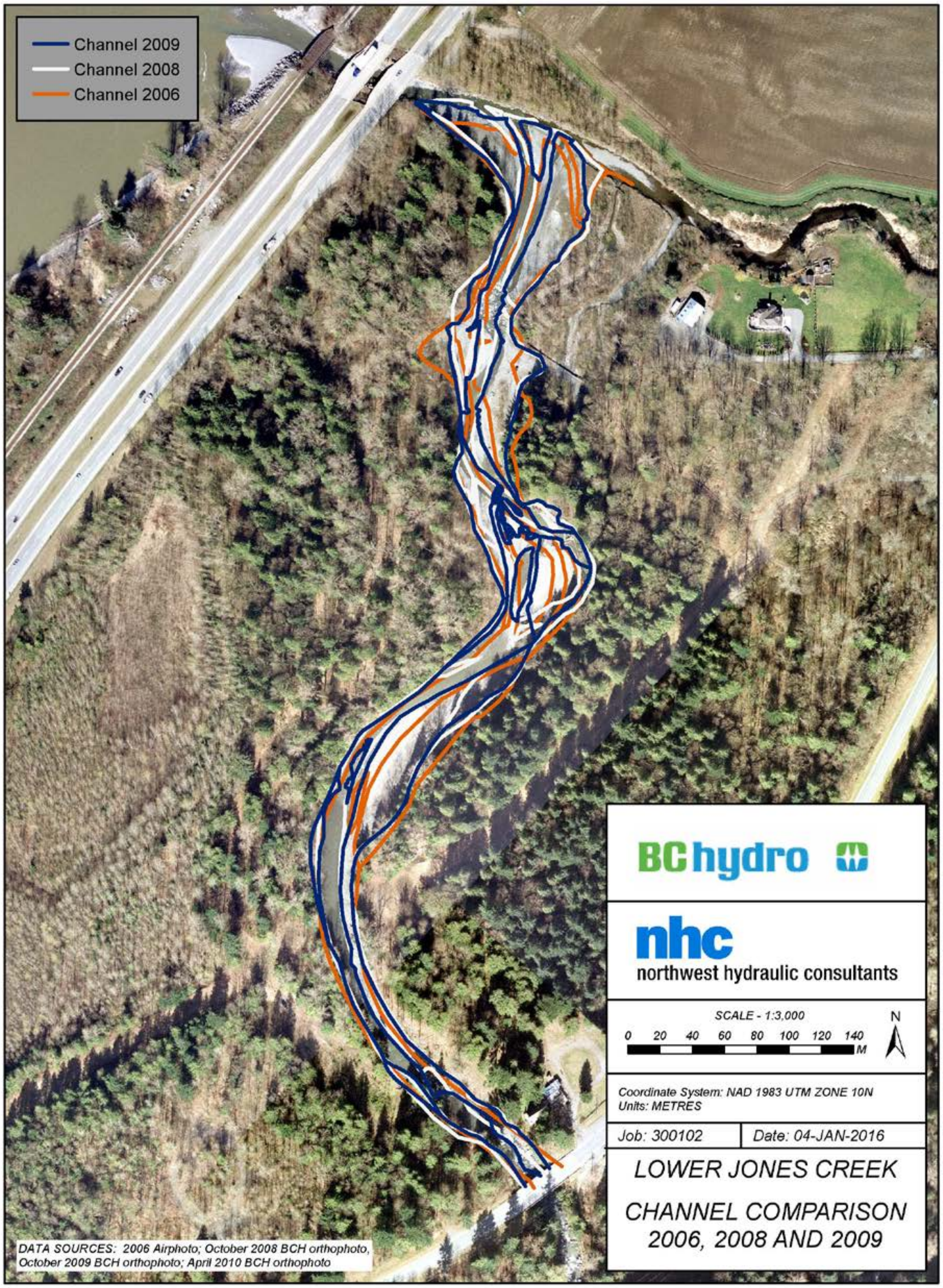
Some erosion of the right side lateral bar within the channel and deposition within the left bank thalweg and against the left bank has recently been measured, creating a more flatbed profile. There are occasional boulders found within the wetted low flow channel that would only move during very high flows. During the fall spawning period and winter incubation period of 2013-2014 no changes larger than 15 cm were observed at this site. Note that during the fall of 2015 a large tree fell across the river near this site, which may cause changes in the future.

3.2.8 ORTHOPHOTO MONITORING

BC Hydro provided October, 2008, October, 2009 and April, 2010 orthophotos to help with the channel change analysis. In addition, a 2006 airphoto was rectified using the orthophoto images. For each of the four sets of images, the edge of the channel and wetted edge were mapped and compared (**Figure 18**).

For the purposes of this study, it is most useful to compare how the location of the wetted channel moved with time, as movement of the wetted channel indicates that the spawning beds could be buried, or dewatered. Between 2006 and 2008, 52% of wetted area remained the same, and between 2008 and 2009 67% of wetted area remained the same. These are relatively low values, as they imply that over a third of the channel was newly wetted between the photo periods. In general the orthophotos and cross-section data show that the channel is very laterally mobile within the active channel margins.

Figure 18. Mapped edge of wetted channel in 2006, 2008 and 2009 overlaid upon the 2010 orthophoto.



DATA SOURCES: 2006 Airphoto; October 2008 BCH orthophoto, October 2009 BCH orthophoto; April 2010 BCH orthophoto

3.3 SUBSTRATE QUALITY MONITORING

Substrate photographs were analysed by measuring the b-axis of each particle underlying a grid node from the digital photographs using GIS software. A metal bar of known dimensions that is placed on the bed when the photos are taken is used to scale each image. A 64 mm x 64 mm ‘digital’ sampling grid was created in the GIS and superimposed on the digital images.

The dimensions of each measured particle are measured to the nearest tenth-millimetre and stored in a database. All clasts smaller than 1 mm (the upper limit for coarse sand) were assigned an arbitrary value of 0.5 mm. The b-axis dimension of particles smaller than 1 mm cannot be reliably measured from the substrate photographs. Size fractions are based on particle counts for different size classes, so it is not necessary to have an accurate measurement of grains less than 1 mm diameter.

The actual number of samples that can be obtained from each photo depends upon the bed material texture, with fewer counts recorded where there are clasts larger than 64 mm. By taking 6 photos along each transect, a total of 100 grains are typically measured. **Table 9** summarizes the number of stones measured each year at each site.

The average D_{84}, D_{50} and D_{16} for the duration of the study, at each site is summarized in **Table 10**, while **Figure 19** through **Figure 21** display the temporal trend in grain size. In **Figure 19** through **Figure 21**, individual photos are treated as individual samples and results are presented as box plots to show the between photo variability as well as general trends. Overall the data show that the channel consistently fines downstream and that the largest grain sizes in the bed are typically cobbles (> 64 mm).

Table 9. Number of sediment clasts sampled at each site.

Date Sampled	Section						
	4	6	7	8	8.5	9	10
06/02/2006	354	332	84		299		211
06/02/2006	304	229	361		341		308
05/04/2006	81	82	81		82		74
15/11/2007	170	185	129		132		167
25/01/2008	322	216	64				104
19/03/2008	278	370	299		390		206
28/10/2009	188	311	109		139		104
03/02/2010	254	250	281		261		146
18/03/2010	106	114	138		124		104
01/11/2011	99	103	102		128		109
23/02/2012	208	230	174	274	200		190
26/09/2013	128	72	88	63	94	71	99
27/02/2014	91	87	96	90	91	81	94
02/04/2014	153	139	146	125	186	123	115

Table 10. Average D_{84}, D_{50}, D_{16} observed at each study site over the period of the study.

D_{84} (mm)							
Date Sampled	4	6	7	8	8.5	9	10
06/02/2006	104	127		73		67	94
06/02/2006	126	162		64		100	107
05/04/2006	118	105		53		106	142
15/11/2007	68	72		43		87	126
25/01/2008	133	116				83	116
19/03/2008	81	54		101		125	118
28/10/2009	60	105		29		88	143
03/02/2010	119	42		14		102	124
18/03/2010	129	30		29		145	125
01/11/2011	78	115		46		132	157
23/02/2012	84	139	85	34		106	125
26/09/2013	75	82	73	57	130	101	164
27/02/2014	159	90	141	61	142	130	102
02/04/2014	161	89	109	47	120	109	151

D_{50} (mm)							
Date Sampled	4	6	7	8	8.5	9	10
06/02/2006	65	72		39		32	40
06/02/2006	62	67		30		36	38
05/04/2006	57	52		26		26	46
15/11/2007	39	39		24		37	54
25/01/2008	44	55				30	51
19/03/2008	36	26		25		46	48
28/10/2009	22	43		14		35	64
03/02/2010	36	17		7		34	48
18/03/2010	74	10		18		47	47
01/11/2011	37	54		25		58	63
23/02/2012	34	86	51	10		48	41
26/09/2013	44	37	34	16	75	32	42
27/02/2014	68	35	75	11	86	53	55
02/04/2014	95	40	50	20	57	50	62

	D16 (mm)						
Date Sampled	4	6	7	8	8.5	9	10
06/02/2006	42	42		18		16	18
06/02/2006	20	25		7		4	6
05/04/2006	13	17		11		8	13
15/11/2007	17	19		13		15	26
25/01/2008	16	25				13	15
19/03/2008	8	8		3		15	15
28/10/2009	8	23		8		14	21
03/02/2010	15	8		4		11	17
18/03/2010	14	5		9		14	18
01/11/2011	11	16		9		15	22
23/02/2012	12	24	12	3		17	15
26/09/2013	12	12	18	4	26	8	13
27/02/2014	17	10	23	2	42	16	27
02/04/2014	25	9	22	13	28	15	22

Figure 19. D84 (mm) measured at each site.

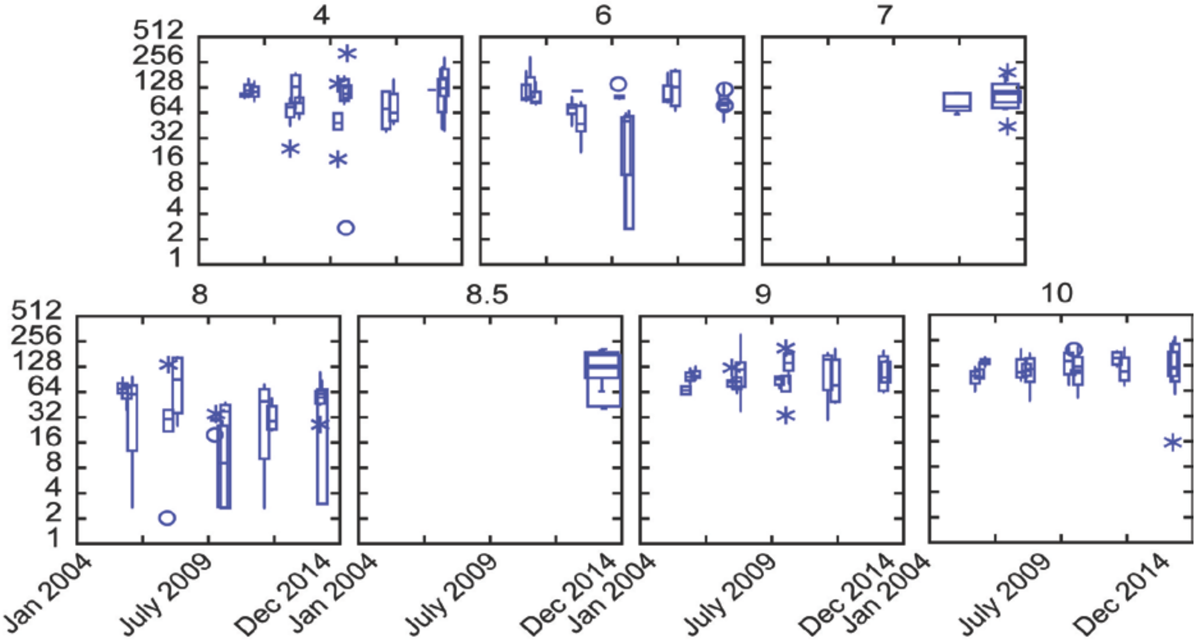


Figure 20. D_{50} (mm) measured at each site.

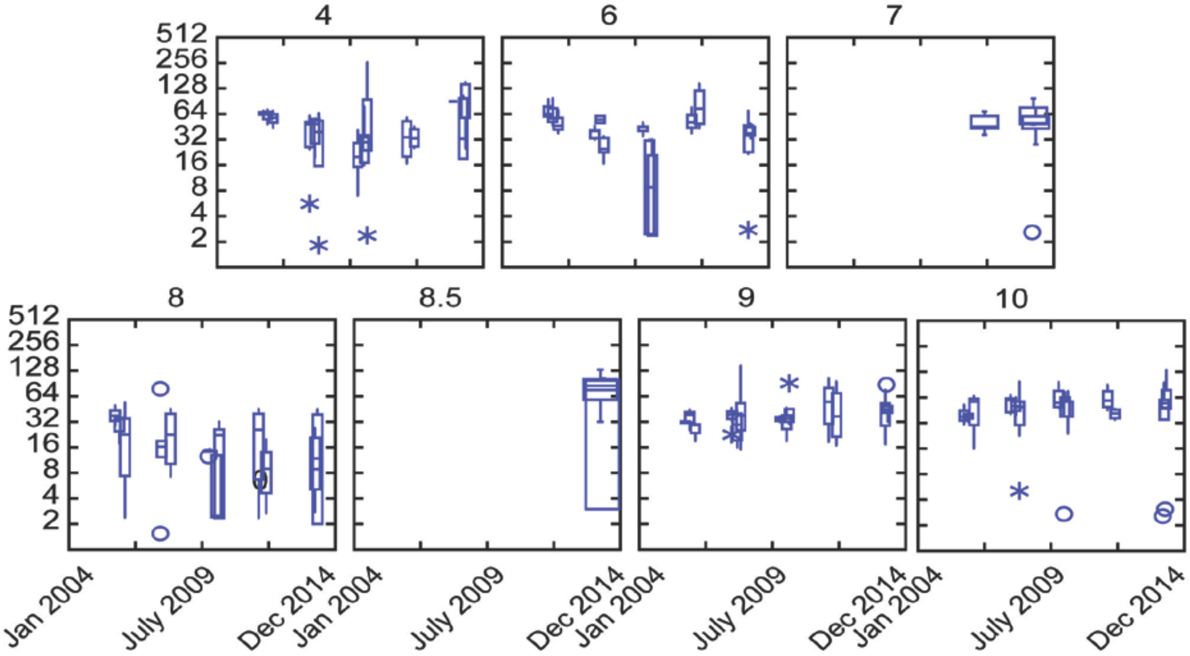


Figure 21. D_{16} (mm) measured at each site.

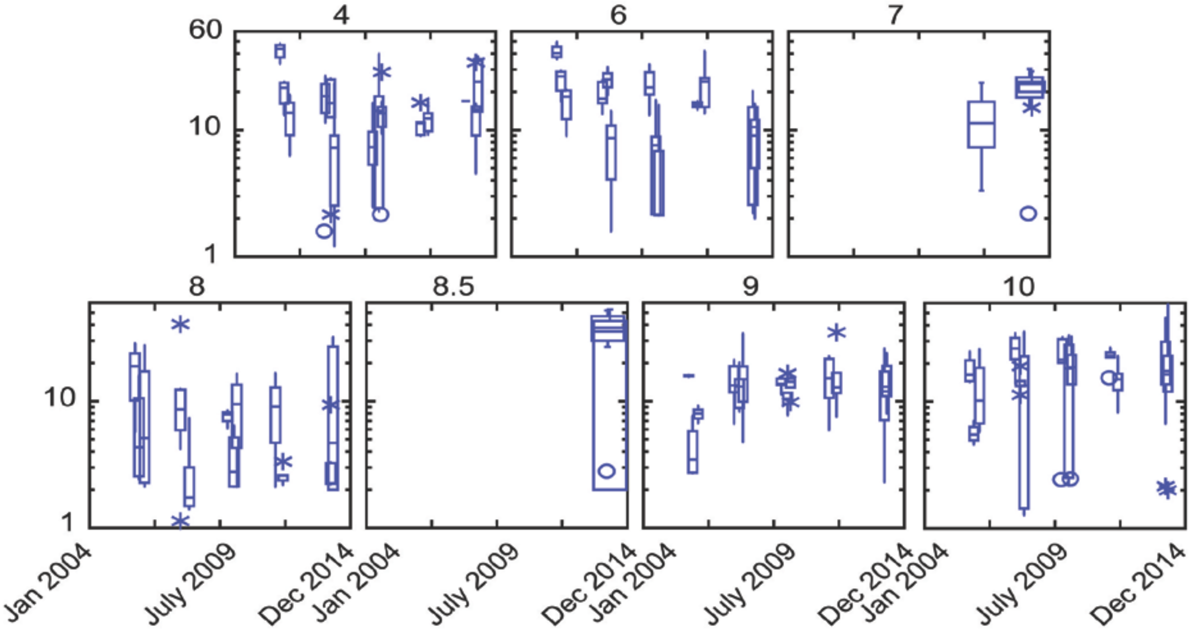


Table 12 illustrates the proportion of the bed that is sand (2 mm or finer). Overall a relatively small amount of the channel is covered with sand. To provide an understanding of the amount of the bed covered by fine gravel, the percent of the bed composed of 8 mm or finer material is summarize in **Table 13**.

Table 11. Percent of surface grain size distribution classified as 1 mm or finer.

Date Sampled	Percentage of the sampling sites covered by sand						
	4	6	7	8	8.5	9	10
08/12/2005	0.0%	0.0%		0.0%		0.0%	0.0%
06/02/2006	0.0%	0.0%		0.0%		0.0%	0.0%
05/04/2006	4.9%	1.2%		36.2%		0.0%	0.0%
15/11/2007	0.0%	0.0%		0.0%		0.0%	0.0%
25/01/2008	0.0%	0.0%				0.0%	0.0%
19/03/2008	0.0%	0.0%		0.0%		0.0%	0.0%
28/10/2009	5.2%	1.8%		2.9%		2.0%	7.7%
03/02/2010	9.8%	16.8%		42.0%		1.8%	9.0%
18/03/2010	16.7%	60.4%		33.3%		2.5%	5.7%
01/11/2011	0.0%	0.0%		28.6%		0.0%	0.0%
23/02/2012	0.0%	0.0%	3.6%	28.6%		2.9%	5.7%
26/09/2013	0.0%	4.3%	24.6%	17.8%	8.2%	12.6%	2.7%
27/02/2014	1.0%	20.0%	2.1%	48.4%	2.6%	4.5%	19.2%
02/04/2014	0.7%	12.7%	0.9%	41.7%	21.5%	0.8%	12.2%

Table 12. Proportion of surface grain size distribution finer than 2 mm.

Date Sampled	Percentage of the sampling sites covered by sand						
	4	6	7	8	8.5	9	10
08/12/2005	0	1		6		6	4
06/02/2006	6	4		18		15	10
05/04/2006	6	2		40		5	1
15/11/2007	8	0		16		1	0
25/01/2008	8	0				4	4
19/03/2008	17	7		24		1	13
28/10/2009	6	2		4		2	8
03/02/2010	14	42		53		2	17
18/03/2010	17	60		33		3	6
01/11/2011	0	1		29		0	0
23/02/2012	3	0	4	31		5	8
26/09/2013	1	7	25	21	8	13	3
27/02/2014	1	21	2	48	3	5	19
02/04/2014	1	13	1	42	21	2	13

Table 13. Proportion of surface grain size distribution finer than 8 mm.

Date Sampled	Percentage of the sampling sites covered by sand						
	4	6	7	8	8.5	9	10
08/12/2005	0	1		9		11	8
06/02/2006	11	9		24		23	26
05/04/2006	13	14		45		26	17
15/11/2007	16	9		38		13	3
25/01/2008	15	1				19	11
19/03/2008	28	18		45		14	19
28/10/2009	30	5		36		11	8
03/02/2010	21	48		71		19	19
18/03/2010	27	65		44		12	9
01/11/2011	18	7		36		10	4
23/02/2012	17	7	16	54		14	16
26/09/2013	15	19	26	40	15	24	13
27/02/2014	11	25	3	50	5	9	19
02/04/2014	4	23	3	46	24	9	19

4 ANALYSIS: RELATION BETWEEN PEAK FLOWS, HABITAT, SUBSTRATE AND EGG-TO-FRY SURVIVAL

To quantify salmonid productivity, pink and chum salmon escapement has been monitored in Lower Jones Creek for a number of years (Greenbank and Macnair, 2008, 2012, 2014). In the subsequent spring, fry escapement has been quantified and the egg-to-fry survival for the spawning and incubation period determined. Summary data from these studies are provided in **Table 14**.

These data can be used to examine the following two management questions:

1) Is channel stability in Lower Jones Creek limiting fish productivity; and
2) Is substrate quality in Lower Jones Creek limiting fish productivity?

In order to address the first question, the following hypotheses are to be tested:

H_1 In consideration of improvements to spawning habitat through increased spawning and incubation flows, fish productivity is not correlated to habitat instability in the anadromous reach of lower Jones Creek.

H_{1a} Fish productivity is not correlated to channel instability as measured by cross sectional areas of scour and fill in the anadromous reach.

H_{1b} Fish productivity is not correlated to channel instability as measured by lateral channel migration involving abandonment of spawning habitat in the anadromous reach.

In order to address the second question, the following hypothesis will also be addressed:

H_2 In consideration of improvements to spawning habitat through increased spawning and incubation flows, fish productivity is not correlated to substrate quality as measured by substrate particle size in the anadromous reach of lower Jones Creek.

In order to test if egg-to-fry survival can be correlated to changes in substrate grain size or channel stability the changes observed at of the geomorphology cross sections were weighted using fish spawning density. Spawning density is broken down into four regions that were assigned to the geomorphology sections as per **Table 15**. The two new sections (7 and 8.5) were not used for this analysis.

Weighted changes in channel morphology and grain size were then calculated for both the spawning and incubation periods. Correlation coefficients were then developed between these metrics and egg-to-fry survival for both pink and chum salmon, and the combined egg-to-fry survival. Each of the hypotheses are examined below.

H_{1a} Fish productivity is not correlated to channel instability as measured by cross sectional areas of scour and fill in the anadromous reach.

The maximum discharge, and weighted scour, fill and change metrics for the spawning and incubation period were also calculated and are provided in **Table 14** and illustrated in **Figure 22**.

These metrics also did not correlate with egg-to-fry survival ratio at the $p = 0.05$ level. As such it is not possible to reject the null hypothesis (H_{1a}) that fish production is not correlated to channel vertical stability or grain size, based on the 5 study years.

H_{1b} Fish productivity is not correlated to channel instability as measured by lateral channel migration involving abandonment of spawning habitat in the anadromous reach.

To assess if channel lateral stability is correlated with egg-to-fry survival (H_{1b}) the proportion of the wetted channel that was not wetted during the previous survey was determined for each cross-section. This was then weighted using the fish use data as per **Table 15**.

The lateral change metrics, summarized in this manner, did not correlate with egg-to-fry survival ratio at the p = 0.05 level. As such it is not possible to reject the null hypothesis (H_{1b}) that fish production is not correlated to channel lateral stability based on the 5 study years. Nevertheless, the lateral change metrics based on the cross-section surveys and orthophoto wetted channel mapping suggest a consistently laterally unstable channel planform. Fish productivity is likely to be reduced as a result.

Figure 24 indicates a weak relationship between pink egg-to-fry survival and percent of channel width that is newly wetted for the incubation period; however, the spawning period data do not show a trend and have a wider range in the percent of the wetted channel that changed.

> H_2 In consideration of improvements to spawning habitat through increased spawning and incubation flows, fish productivity is not correlated to substrate quality as measured by substrate particle size in the anadromous reach of lower Jones Creek.

To assess whether substrate quality is related to egg-to-fry survival, the proportion of the bed that is sand (< 2 mm) and the proportion that is fine gravel or smaller (< 8 mm) was correlated with the egg-to-fry survival. These metrics were specified in the WUP monitoring program based on metrics in Tappel and Bjornn (1983). Tappel and Bjornn relate large amounts of sand and fine gravel in the substrate to poor egg-to-fry survival.

The correlation analysis revealed that none of the grain size metrics (D_{16}, D_{50}, D_{84}, % <1 mm, % < 2 mm, % < 8 mm) were correlated with egg to fry survival.

In **Figure 25** the data from Jones Creek are plotted on top of the Tappel and Bjornn (1983) figure relating egg to fry survival to the percent of the sediment less than 9.5 mm and 0.85 mm. Note that the Jones Creek data are plotted using the percent of the sediment less than 8 mm and 1 mm. More importantly, the Tappel and Bjornn (1983) bioassay is based on subsurface grain size distributions, while the Jones Creek data are based on surface grain size distributions, and as such, they cannot be directly compared.

In general surface grain size distributions are coarser and lack the fine end of the distribution as this material is winnowed away. The surface grain size distribution suggests that egg-to-fry survival should not be limited in Jones Creek, yet the egg-to-fry survival is low. Young *et al.* (1991) also provide relations that related survival to emergences to the subsurface geometric mean of sediment.

Using these relations, the <u>surface grain size distributions</u> suggest that the geometric mean (see D_{50} in **Table 10**) is substantially larger than values that are associated with reduced emergence rates (15 mm and smaller). If the surface to subsurface ratio were 2, which is reasonable for a high sediment supply rain dominated system like Jones Creek (Hassan et al., 2006), the geometric mean would be sufficiently large that it would not be expected to impede emergence and subsequent egg-to-fry survival.

In general, based on the site photos, grain size data and nature of sediment supply and channel mobility it is likely that the subsurface grain size distribution is sufficiently coarse that the overall grain size of the bed is not impeding survival. However, the concentration of finer sand and silt in the subsurface is unknown. Finer sand and silt can have a significant effect on egg survival (Levasseur *et al*., 2006) and site visits show that Jones Creek certainly transports a large quantities of fine sediment at relatively low flows (**Figure 26**). This fine sediment could infiltrate into the subsurface and impact egg survival.

Figure 22. Relationship between egg to fry survival and proportion of channel experiencing more than 15 cm of scour, fill or either change within the wetted channel width.

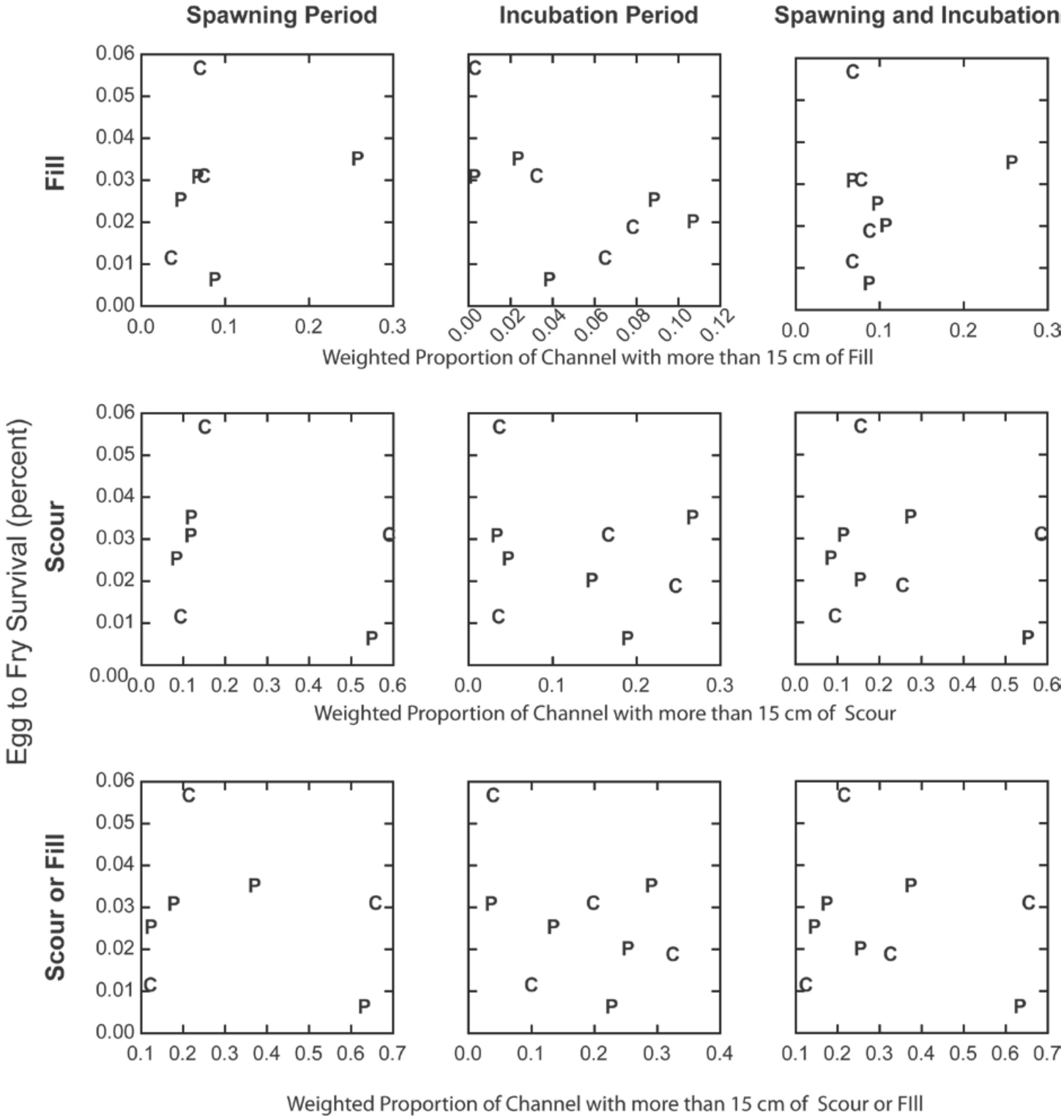


Figure 23. **Relationship between maximum instantaneous discharge and grain size metrics and the egg to fry survival for Pink (P) and Chum (C).**

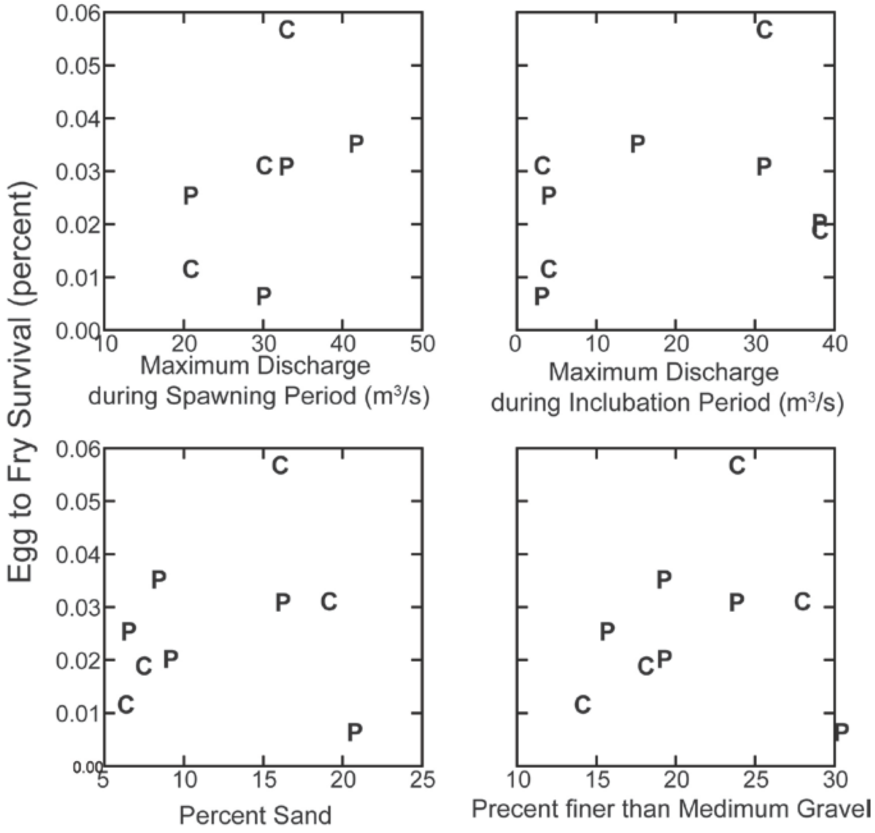


Figure 24. **Relationship between egg to fry survival and the percentage of the wetted channel that was wetted during the survey that was not wetted during the previous survey for Pink (P) and Chum (C) salmon.**

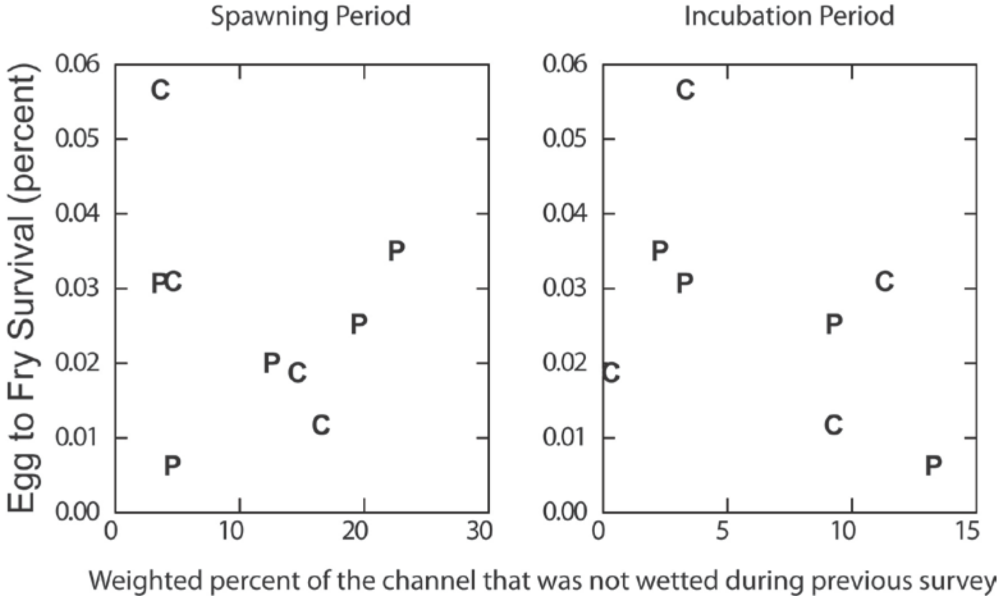


Figure 25. Surface grain size distribution data plotted on Tappel and Bjornn figure showing egg to fry survival for Pink (P) and Chum (C) as a function of percent substrate smaller than 9.5 mm and 0.85 mm.

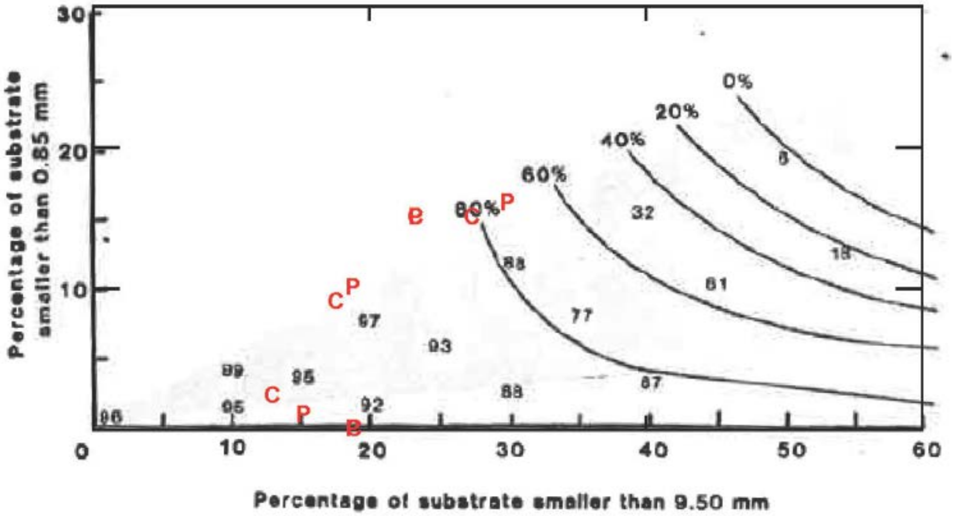


Table 14. Egg-to-fry survival and weighted grain size and channel change metrics, as well as peak flow during spawning and incubation period.

Period	Egg-to-fry survival	Average % of bed covered in sand during surveys	Average % of bed covered in medium gravel or finer sediment during surveys	Instantaneous Peak flow (m^3/s)	Weighted Proportion of channel with significant fill	Weighted Proportion of channel with significant scour	Weighted Proportion of channel with significant change
Chum Salmon							
2005	1.17%	6%	14%	20.0	6%	8%	11%
2007		8%	19%	40.8	21%	29%	41%
2009	3.13%	19%	27%	29.2	7%	57%	64%
2011	1.91%	7%	18%	37.2	8%	24%	31%
2013	5.70%	16%	23%	32.0	6%	14%	20%
Pink Salmon							
2005	2.56%	6%	15%	20.0	9%	7%	13%
2007	3.54%	8%	19%	40.8	25%	26%	36%
2009	0.66%	20%	30%	29.2	8%	54%	62%
2011	2.04%	9%	19%	37.2	10%	14%	24%
2013	3.11%	16%	23%	32.0	6%	10%	16%

Table 15. Division of fish spawning density among the 5 long-term geomorphology sections.

Geomorphology Monitoring Section	Fish spawning regions			
	S1	S2	S3	S4
4	100%	100%	4%	0%
6	0%	0%	30%	0%
8	0%	0%	29%	0%
9	0%	0%	19%	0%
10	0%	0%	18%	100%

Figure 26. Jones Creek on October 30th, 2015. Discharge was 3.3 m^3/s

5 SUMMARY

The assessment of channel stability on lower Jones Creek was established by BC Hydro as part of the Wahleach Water Use Plan monitoring program to investigate the extent to which the physical stability of the channel bed and substrate grain size distribution limit fish productivity. In particular the purpose of the study is to assess the following two management questions:

1) Is channel stability in Lower Jones Creek limiting fish productivity; and

2) Is substrate quality in Lower Jones Creek limiting fish productivity?

In order to address the first question, the following hypotheses were tested:

H_1 In consideration of improvements to spawning habitat through increased spawning and incubation flows, fish productivity is not correlated to habitat instability in the anadromous reach of lower Jones Creek.

H_{1a} Fish productivity is not correlated to channel instability as measured by cross sectional areas of scour and fill in the anadromous reach.

H_{1b} Fish productivity is not correlated to channel instability as measured by lateral channel migration involving abandonment of spawning habitat in the anadromous reach.

In order to address the second question, the following hypothesis was also addressed:

H_2 In consideration of improvements to spawning habitat through increased spawning and incubation flows, fish productivity is not correlated to substrate quality as measured by substrate particle size in the anadromous reach of lower Jones Creek.

Fish productivity was established as the egg-to-fry survival of pink and chum salmon that utilize lower Jones Creek. Channel stability and substrate quality are physically evaluated at seven (7) previously established cross sections through repeat topographic surveys and photogrammetric sampling of the substrate.

The assessment and field program extends from mid-October to mid-March during odd (pink salmon spawning) years to coincide with peak spawning and end of incubation dates for pink and chum salmon.

The data provided by BC Hydro shows that minimum flow targets were met for the majority of the spawning and incubation periods, and have generally been close to the target when flows have dropped below the target. In general flows were above pre-WUP flows, and as a result salmon spawning during the post-WUP period have access to a larger area of spawning substrate (Greenbank and Macnair, 2014).

Repeat channel cross section surveys were used to assess the vertical and lateral stability of the channel. On average, sections 4, 6 and 8 experience more than 15 cm of scour or fill across more than 40% of the wetted channel each year. This is a relatively large amount of change and speaks to the overall mobility of the channel and bank sediments. Sections 9 and 10 are relatively more stable, but still experience some significant scour and fill. Wetted width data from the surveys demonstrates that the wetted width varies more between the sections, than between surveys and this speaks to the overall dynamics of the sections. During Year 9 of the monitoring program the channel morphology was more stable than most of the preceding years.

A main physical characteristic related to substrate quality and fish productivity is the fraction of the bed composed of medium and fine gravel, and sand. As a first order approximation, the surface grain size can be used to provide some information about the subsurface distribution. As such the surface grain size distribution has been monitored at each cross section. Results from the study show that the surface grain size distribution remained relatively constant over a 10 year period.

To assess if fish productivity was related to channel stability (H_{1a} and H_{1b}), a correlation analysis was completed with egg-to-fry survival data from Greenbank and Macnair (2014) and channel morphology metrics (scour, fill and change within the wetted cross section). No significant correlations were observed. A similar analysis was completed for the mean percent of the surface substrate composed of medium gravel and sand (H_2) and no correlation was found. As such it was not possible to reject any of the null hypothesis at the $p= 0.05$ level.

On initial analysis, these results suggest that physical stability and grain size does not affect egg-to-fry survival; however, the repeat surveys show that the channel morphology and grain size is highly variable during all the study years.

There are several potential reasons for the lack of correlation:

1. The observed range in egg-to-fry survival is not sufficient to provide enough statistical power.
2. The current physical measurements are not sufficiently precise or of required spatial and temporal coverage to measure channel instability.
3. The current range of channel instability is above a threshold limit such that there is no underlying correlation to egg-to-fry survivals.
4. There is a combination of both physical and biological factors that pose a more fundamental limit on egg-to-fry survivals that is not captured with the current analyses or monitor.

The most important observation from grain size and morphology studies is that lower Jones Creek is an especially dynamic channel that is modified throughout the spawning and incubation period during most years. These conditions are not ideal for fish production, yet Jones Creek continues to produce a large number of fry. Successful fry production relies on a large number of spawning adults, spawning over a large spatial area, so there is a high probability of some areas not being disturbed each year.

A comparison of the grain size distribution at the sites, based on surface samples, and existing biostandards of egg survival was also completed. This analysis suggested that the grain size of the bed may not be limiting egg survival. However, the biostandards are based on sub-surface grain size distributions, not surface grain size distributions, so the results should not be relied upon. No subsurface samples have been collected at Jones Creek.

Continuing the existing cross-section and grain size sampling is unlikely to significantly improve the statistical power associated with the existing hypothesis as channel mobility is particularly high in Jones Creek and egg-to-fry survival has consistently been low. Instead, should additional studies be undertaken, they should focus on following study questions:

1. The spatial variability of intergravel flow,
2. Fine sediment loading throughout the spawning and incubation period,
3. Quality of the substrate immediately after spawning,

4. Effect of flows less than the Instream Flow Target on egg survival during the periods when instream flows are reduced, and
5. Effects of icing events on egg survival. Midwinter icing events often occur during low flow conditions when high pressure systems dominate and Boulder Creek flows are insufficient for the diversion to supply flow, and the reservoir level drops below 636 m resulting in the syphon loosing prime.

Examining these questions would improve our understanding of the factors effecting egg-to-fry survival. These studies should be incorporated with the ongoing egg survival studies using egg baskets within Jones Creek.

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