Bridge River Project Water Use Plan

Lower Bridge River Aquatic Monitoring

Implementation Year 4

Reference: BRGMON-1

2015 Annual Data Report

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EXECUTIVE SUMMARY

The main objectives of the BRGMON-1 Lower Bridge River Aquatic Monitoring program in 2015 were to: 1) reduce uncertainty regarding the effects of the flow releases on the aquatic productivity of the Lower Bridge River (LBR); 2) inform a summer and fall ramp down strategy that reduces the risk of fish stranding while meeting environmental objectives and to salvage fish during river ramping; and 3) inform the adaptive management of the LBR.

This program was designed to compare the aquatic productivity of the LBR during two flow releases (Trials 1 and 2) against a zero-flow baseline scenario (Pre-Flow), with flow for each trial released from Terzaghi Dam according to prescribed hydrograph shapes. The Pre-Flow release represented baseline productivity monitoring. Trial 1 was a 3 $m^3 \cdot s^{-1}$ mean annual flow (2000-2010) based on a hydrograph that ranged from a minimum of 2 $m^3 s^{-1}$ to a maximum of 5 $m^3 \cdot s^{-1}$. Trial 2 was a 6 $m^3 \cdot s^{-1}$ mean annual flow (2011-2015) that ranged from a minimum of 1.5 $m^3 \cdot s^{-1}$ to a target peak flow of 15 $m^3 \cdot s^{-1}$. In 2015, the flow release deviated from the prescribed Trial 2 hydrograph during mid-July and early August (referred hereinafter as the 'spill' event) and a mean annual flow of 6.6 $m^3 \cdot s^{-1}$ was released from the dam with a peak flow of 20.7 $m^3 \cdot s^{-1}$.

Five monitoring activities were conducted as part of the program in 2015: 1) water temperature and river stage; 2) water chemistry, aquatic invertebrate abundance and diversity, and periphyton accrual; 3) habitat surveys; 4) juvenile salmonid growth sampling; and 5) fall standing stock assessment. In addition, a rampdown monitoring component was conducted during the summer and fall seasons to minimize fish stranding risk, salvage fish and to collect information in order to inform an optimal strategy for ramping down discharge on the LBR.

Stage ranged from a low winter flow of 1.5 $m^3 \cdot s^{-1}$ and peaked at a discharge of 20.7 $m^3 \cdot s^{-1}$, before returning to target WUP target flows in late July. Fall temperatures were on average 3°C to 6°C warmer during 2015, compared to the Pre-Flow period. Temperature differences were greatest in the upper reaches (reaches 3 and 4) and lowest in Reach 2. The warmer temperatures may have had implications for the life-cycle of Chinook salmon by causing early emergence and decreasing winter survival of juveniles. Benthic invertebrate abundance and diversity remained high in 2015. Higher peak flows in 2015 during the summer juvenile salmon rearing period (June and July) increased the amount of wetted area in the river, which corresponded with an increase in the cascade/ rapid habitat type throughout the study area. The suitability and availability of rearing habitat for juvenile salmon could have been reduced in this habitat as flow velocities may have increased to above optimal thresholds. The total abundance of juvenile salmonids declined substantially across the Lower Bridge River in 2015, and was lower than any other annual estimate since the flow release was initiated in 2000. Coho fry and rainbow/steelhead fry populations were low in 2015, particularly in Reach 4, while Chinook populations remained similar to recent years. Higher summer flows in 2015 may have displaced coho fry and rainbow fry downstream, and potentially impeded successful steelhead reproduction or rearing during the spring and summer. Overall, while the long-term influence of high flows on fish productivity remains uncertain at this time, higher peak flows in 2015 likely impacted juvenile populations of coho fry and rainbow/ steelhead fry and likely contributed to a reduction in aquatic productivity within the Lower Bridge River in 2015.

Limited other productivity data outside of WUP target flows were available to make definitive conclusions regarding whether high flows or low flows benefit the ecosystem more, or precisely how much influence the 2015 hydrograph may have had on the productivity of the aquatic ecosystem. More high flow data greater than 15 $m^3 \cdot s^{-1}$ are expected in 2016 to continue to reduce uncertainty surrounding the study objectives, and further support or refute interpretations of program hypotheses.

BRGMON-1 STATUS of OBJECTIVES, MANAGEMENT QUESTIONS, and HYPOTHESES after Year 5

Study Objectives	Management Questions	Study Hypotheses	Implementation Year 4 (2015) Status
To reduce uncertainty about the relationship between the magnitude of flow release from the dam and the relative productivity of the Lower Bridge River aquatic and riparian ecosystem. To provide comprehensive documentation of the response of key physical and biological indicators to alternative flow regimes (Trials 1 and 2) to better inform decisions on the long-term flow regime for the Lower Bridge River. The scope of this program is limited to monitoring the changes in key physical, chemical, and biological productivity indicators of the Lower Bridge River aquatic ecosystem.	1) How does the instream flow regime alter the physical conditions in aquatic habitats of the Lower Bridge River ecosystem?	H_0: "High flow is better" H_A: "Low flow is better"	**<u>Physical Conditions:</u>** • H_0 is not rejected • H_A is not rejected **Temperature Rationale:** Flows across Trial 1, Trial 2 and 2015 appeared to cause similar temperature effects on the physical conditions of the aquatic habitat. Fall water temperatures were on average 2°C to 4°C warmer and were sustained longer into the fall than the Pre-flow period. The higher the flow release the further downstream the temperature effects extended. The Null hypothesis cannot be rejected at this stage from temperature inferences alone. We are on track to answering this management question and more data are expected under higher flows in 2016 to further reduce this uncertainty. **Habitat Rationale:** Higher peak flows in 2015 increased the amount of wetted area in the river, which corresponded with an increase in the cascade/ rapid habitat type. This may have reduced the availability of suitability of rearing habitat, as flow velocities may have been increased to above optimal thresholds. The Null hypothesis cannot be rejected at this stage as more data would be beneficial at higher flows, however low flows appear to provide greater availability of suitable rearing habitat. We are on track to answering this management question and are expecting more high flow data in 2016.

Study Objectives	Management Questions	Study Hypotheses	Implementation Year 4 (2015) Status
Same as above	2) How do differences in physical conditions in aquatic habitat resulting from the instream flow regime influence community composition and productivity of primary and secondary producers in the Lower Bridge River?	H_0: "High flow is better" H_A: "Low flow is better"	**Community Composition and Productivity of Benthic Invertebrates** • H_0 is not rejected • H_A is not rejected **Primary production Rationale:** Periphyton accrual data do not appear to be different across the flow trials. Differences in trends appear to be more closely associated with deposition and accumulation of nutrients from pink salmon spawning years in pink (odd years) and non-pink (even years) than flow regime. Null hypothesis cannot be rejected at this stage from primary productivity data alone.
			Secondary production Rationale: The rewetting of Reach 4 benefited the benthic invertebrate community after the initiation of the flow trials. During Trials 1 and 2, no significant differences were observed in response to flow changes. Higher peak flows in 2015 did not significantly increase the benthic invertebrate community abundance, or change the community composition. In 2015 abundance and diversity remained high. Null hypothesis cannot be rejected at this stage, and more data are needed under high flows to further test the hypothesis. .

Study Objectives	Management Questions	Study Hypotheses	Implementation Year 4 (2015) Status
Same as above	3) How do changes in physical conditions and trophic productivity resulting from flow changes together influence the recruitment of fish populations in the Lower Bridge River?	H_0: “High flow is better” H_A: “Low flow is better”	**Fish:** • H_0 is not rejected • H_A is not rejected Juvenile Rainbow Trout and Coho salmon abundance increased significantly from pre-flow levels in Trial 1 due to the rewetting of Reach 4. However, the abundance of these species in Trial 2 did not differ from the Pre-Flow Trial. In contrast, Chinook fry production declined across Trials 1 and 2 and in 2015 remained similar to previous years. Rainbow Trout and Coho salmon fry abundance was low in 2015 – possibly in response to the summer spill event. More data under flows >15 $m^3 \cdot s^{-1}$ are needed, and the null hypothesis cannot be rejected at this stage.
To inform a summer and fall rampdown strategy that reduces the risk of fish stranding while meeting environmental objectives and to salvage fish during river ramping.	4) Question 4: What is the appropriate 'shape' of the descending limb of the 6 $m^3 \cdot s^{-1}$ hydrograph, particularly from 15 $m^3 \cdot s^{-1}$ to 3 $m^3 \cdot s^{-1}$?	N/A	**Stranding Risk:** According to the BC Hydro LBR Fish Stranding Protocol, stage changes with the lowest fish stranding potential occurred between 15 and 9 $m^3 \cdot s^{-1}$. In 2015, data further supported these conclusions; stranding risk was lowest between 11.0-$m^3 \cdot s^{-1}$ and 9.3 $m^3 \cdot s^{-1}$. As flows were further reduced, stranding risk increased. We are on track to answering this management question, however stranding risk may change annually with high flows and more data are needed to continue to further reduce this uncertainty.

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1.0 INTRODUCTION

The Bridge River, a tributary of the middle Fraser River, is an important fish-bearing river in Southern Interior British Columbia. While it was used historically as a major food source for St'at'imc fishing, today it is used for a variety of purposes including hydroelectric power. Traditionally, fish comprised 60% of the local diet (Kennedy and Bouchard, 1992) some of which originated in the Bridge River. However, the benefits to society from this fish resource extended much farther than just as a source of food. This fishery was also integral to a complex trading network where salmon and salmon oil were highly prized and considered the foundation of commerce in the region. The health and productivity of the Bridge River aquatic ecosystem contributed to the rich fish resource and culture in St'át'imc territory. Overall, this resource generated significant benefits towards the health and well-being of the St'át'imc Nation and trading partners.

In 1960, the Bridge River was fully impounded by Terzaghi Dam (formerly called Mission Dam), which was built at the head of a long, narrow canyon approximately 40 km upstream of the confluence with the Fraser River. This impoundment created Carpenter Reservoir, which serves as a water source for hydroelectric production in the Seton watershed, and fragmented the Bridge River, creating a controlled lower section called the Lower Bridge River (LBR). Initially, all flow was diverted to Seton Lake for hydroelectricity, with the exception of infrequent high-water spill over events. Consequently, 4kms of river directly below the dam were dewatered for 40 years (1960-2000). Downstream of the dewatered reach, and upstream of the confluence with the Yalakom River, groundwater and tributary influence created a flow less than 1% of the historic mean annual discharge (Longe and Higgins, 2002).

Concerns were raised and discussed over the lack of water flowing in the LBR by the St'át'imc, federal and provincial regulatory agencies, and the public. After discussions in the 1980s, an agreement was reached to continuously release water to provide fish habitat downstream of Terzaghi Dam. Under the Water Use Plan (WUP), an adaptive management approach was recommended by the WUP Consultative Committee along with an environmental monitoring program, which was designed to test two main flow releases (Trials 1 and 2) against a zero-flow baseline scenario (Pre-Flow), which represented the previous 40 years. As part of a structured decision-making process (Failing et al., 2004; Failing et al., 2013) key benefits from the aquatic ecosystem were identified, and parameters were chosen and monitored during 2015 as they have been historically over the course of the Flow Trial experiment. The focus of the LBR WUP includes the physical conditions in the aquatic and riparian habitats, biomass and growth of juvenile salmonids, periphyton and benthic invertebrate abundance and diversity as a proxy for river health. This program gathers empirical data to inform the flow management of the LBR, and aims to generate a better understanding of the effects of the introduction of water from Carpenter Reservoir on the aquatic ecosystem productivity and the ecosystem services, or benefits which the river generates, below the dam.

An average 3.0 $m^3 \cdot s^{-1}$ annualized interim water budget (Trial 1), based on a hydrograph that ranged from a minimum of 2 $m^3 \cdot s^{-1}$ to a maximum 5 $m^3 \cdot s^{-1}$ was initially allocated for in-stream flow releases into the LBR. Water was released on August 1, 2000 and continued at this level until spring 2011. Prior to this release, data were collected from 1996-2000 (Pre-Flow), to provide baseline information on the pre-release ecosystem and the ecological services the river provided, and to facilitate measuring and comparing the response of the aquatic environment to different flow trials. Between 2011 and 2014 (Trial 2) the LBR annual hydrograph target was 6 $m^3 \cdot s^{-1}$, and ranged from a minimum of 1.5 $m^3 \cdot s^{-1}$ to a maximum of approximately 15 $m^3 \cdot s^{-1}$.

The 2015 hydrograph average was 6.6 $m^3 \cdot s^{-1}$, with a summer peak flow of 20.7 $m^3 \cdot s^{-1}$ and a winter low flow of 1.5 $m^3 \cdot s^{-1}$.

This report describes the results of the Year 4 (2015) of a ten-year study of the LBR in accordance with the WUP Order to release water and monitor the environmental benefits and impacts of the flow release on the aquatic ecosystem. Data from this monitoring program will be used to inform the management of the LBR flow regime. Presently, the St'át'imc Nation, the Bridge River Band, BC Hydro, regulatory agencies and other stakeholders work together to determine a long-term flow release strategy for the LBR. The implementation of this aquatic monitoring program is part of the Bridge-Seton WUP. St'át'imc Eco- Resources (SER), an incorporated company owned by the St'át'imc Chiefs Council, has been contracted by BC Hydro to undertake this work. Subsequently, Coldstream Ecology, Ltd. has been subcontracted to implement the monitoring program. Detailed descriptions of past monitoring activities and results of past years can be found in McHugh and Soverel (2013 - 2015), Riley et al. (1997, 1998), Higgins and Korman (2000), Longe and Higgins (2002), Sneep and Higgins (2003, 2004), and Sneep and Hall (2005 - 2012).

1.1 Management Questions

The goal of this ecological monitoring program is to utilize an adaptive management framework to reduce uncertainty about the expected benefits of releasing water from Carpenter Reservoir downstream of Terzaghi Dam. Past studies have been unable to provide scientifically defensible predictions of the ecological benefits of the flow releases, and this lack of certainty constitutes a major challenge for decision-making regarding valued ecological resources and energy management. Consequently, the long-term monitoring program was designed to provide defensible data defining the functional relationship between the magnitude of flow releases, and physical and biological responses in the LBR. As identified in the WUP Terms of Reference (BC Hydro, 2012) for this monitoring program, four key management questions that directly describe the uncertainties and the learning objectives include:

1) How does the in-stream flow regime alter the physical conditions in aquatic and riparian habitats of the Lower Bridge River ecosystem?

2) How do differences in physical conditions in aquatic habitat resulting from the in-stream flow regime influence community composition and productivity of primary and secondary producers in the Lower Bridge River?

3) How do changes in physical conditions and trophic productivity resulting from flow changes together influence the recruitment of fish populations in the Lower Bridge River?

4) What is the appropriate 'shape' of the descending limb of the 6 $m^3 \cdot s^{-1}$ hydrograph, particularly from 15 $m^3 \cdot s^{-1}$ to 3 $m^3 \cdot s^{-1}$?

Juvenile salmonid biomass is used as a primary criterion to compare performances of different flow levels because salmon represent a highly valued ecological component of the aquatic ecosystem. In addition, juvenile salmonid biomass integrates the effects of flow on trophic productivity and habitat conditions in the LBR. The monitoring program was designed to test the following hypotheses regarding the ecological benefits and the effects of flow on the fish populations in the LBR:

H_0: "High flow is better"
H_A: "Low flow is better"

The data provided in this annual data report summarize the 2015 program. These data are part of a larger dataset (1996-2015), which will address management questions 1-3 (above) to inform long-term water use planning in 2016 and beyond. The fourth management question (above) is being addressed by a rampdown monitoring component that was integrated into this WUP monitoring in 2012. Information collected from this component will help to mitigate the risk of fish stranding and inform the optimal “shape” of the hydrograph throughout annual rampdown activities.

1.2 Objectives and Scope

The primary objectives of this monitoring program are to: 1) to reduce uncertainty regarding the effects of the flow releases on the aquatic productivity of the ecosystem; and 2) to inform a summer and fall rampdown strategy that reduces the risk of fish stranding while meeting environmental objectives and to salvage fish during river ramping. Specifically, monitoring program activities in 2015 continued to focus on:

1) Water temperature, dam discharge, and river stage;
2) Water chemistry parameters, periphyton accrual and diversity, and the relative abundance and diversity of aquatic invertebrates during the fall field ecology series;
3) Growth, distribution, and relative abundance of juvenile salmonids including coho salmon (*Oncorhynchus kisutch*), chinook salmon (*O. tshawytscha*), steelhead and rainbow trout (*O. mykiss*), within the study area;
4) Summer and fall rampdown monitoring and salvage activities; and
5) Aquatic habitat assessment.

1.3 Study Area

The Bridge River lies within St’át’imc Territory, in Southern Interior British Columbia. The Lower Bridge River is the section between the confluence of the Fraser River and Terzaghi Dam. It is divided into four reaches, which are defined in Table 1 and illustrated in Figure 1. This monitoring program focuses on Reach 2 – 4.

Table 1: Reach break designations and descriptions for the Lower Bridge River

Reach	Boundary (Rkm) Downstream	Upstream	Description
1	0.0	20.0	Fraser River confluence to Camoo Creek
2	20.0	25.5	Camoo Creek to Yalakom River confluence
3	25.5	36.8	Yalakom River confluence to upper extent of groundwater in-flow
4	36.8	40.9	Upper extent of groundwater in-flow to Terzaghi Dam

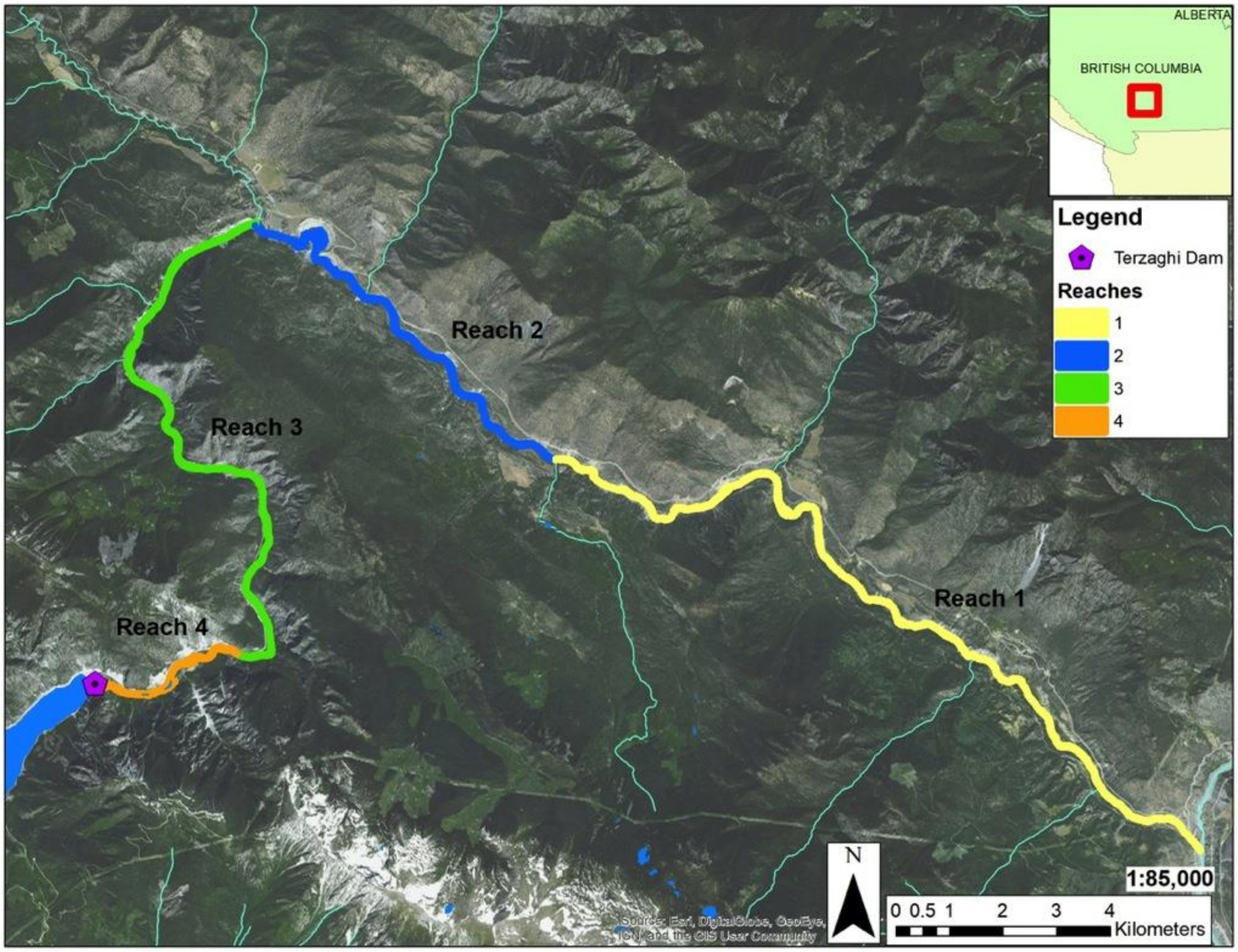


Figure 1: Overview map of the 2015 Lower Bridge River Aquatic Monitoring Program study area

1.4 Study Period

Aquatic monitoring occurred during nine sampling sessions in 2015. A general description of the activities and sampling timing are presented in Table 2.

Table 2: Schedule of sampling sessions in 2015

Sample Session	2015 Dates	Activities
Spring	19 March 11 to 14 April	Water temperature logger downloads; Salmonid juvenile growth sampling
Summer	14 to 21 August	Salmonid juvenile growth sampling
Summer	21 August to 28 September	Aquatic habitat surveys (3 m^3s^{-1} flow)
Summer Rampdown	29 to 30 July; 1 to 20 August; 29 and 30 September	Flow rampdown surveys: fish salvage and staff stage, temperature and turbidity data collection; Electrofishing
Fall Stock Assessment	1 to 28 September	Fall standing stock assessment
Early Fall	1 to 5 October	Deploying primary and secondary productivity samplers; Water chemistry and nutrient sampling
Late Fall	30 November	Retrieving primary and secondary productivity samplers
Late Fall	25 to 27 November; 30 November	Salmonid juvenile growth sampling; Water chemistry and nutrient sampling
Early Winter	16 September	Temperature logger downloads

2.0 METHODS

2.1 The Aquatic Monitoring Program

2.1.1 *Overview*

Monitoring methods and protocols utilized in 2015 were standardized to facilitate comparisons across the Trials. These methods and protocols originated from a general template of monitoring initiated at the start of the baseline flow-monitoring phase (1996 – 2000) and have since undergone adaptations through Trials 1 and 2.

- Water temperature,
- River stage,
- Flow release,
- Water nutrient/chemistry,
- Primary productivity (periphyton),
- Secondary productivity (macroinvertebrate),
- Juvenile salmonid growth,
- Fall standing stock,
- Habitat surveys, and
- Rampdown and salvage surveys.

Data collection in 2015 occurred at seven index sites located at 3 km intervals along the LBR, 49 standing stock assessment sites within reaches 2, 3 and 4, and water quality tributary locations (Figure 2). In descending order from Terzaghi Dam, these include the following river kilometers: 39.9, 36.8, 36.5, 33.3, 30.4, 26.4, 26.1, 23.6, and 20.0. The timing and frequency of data collection were similar to historic LBR data collection within the program.

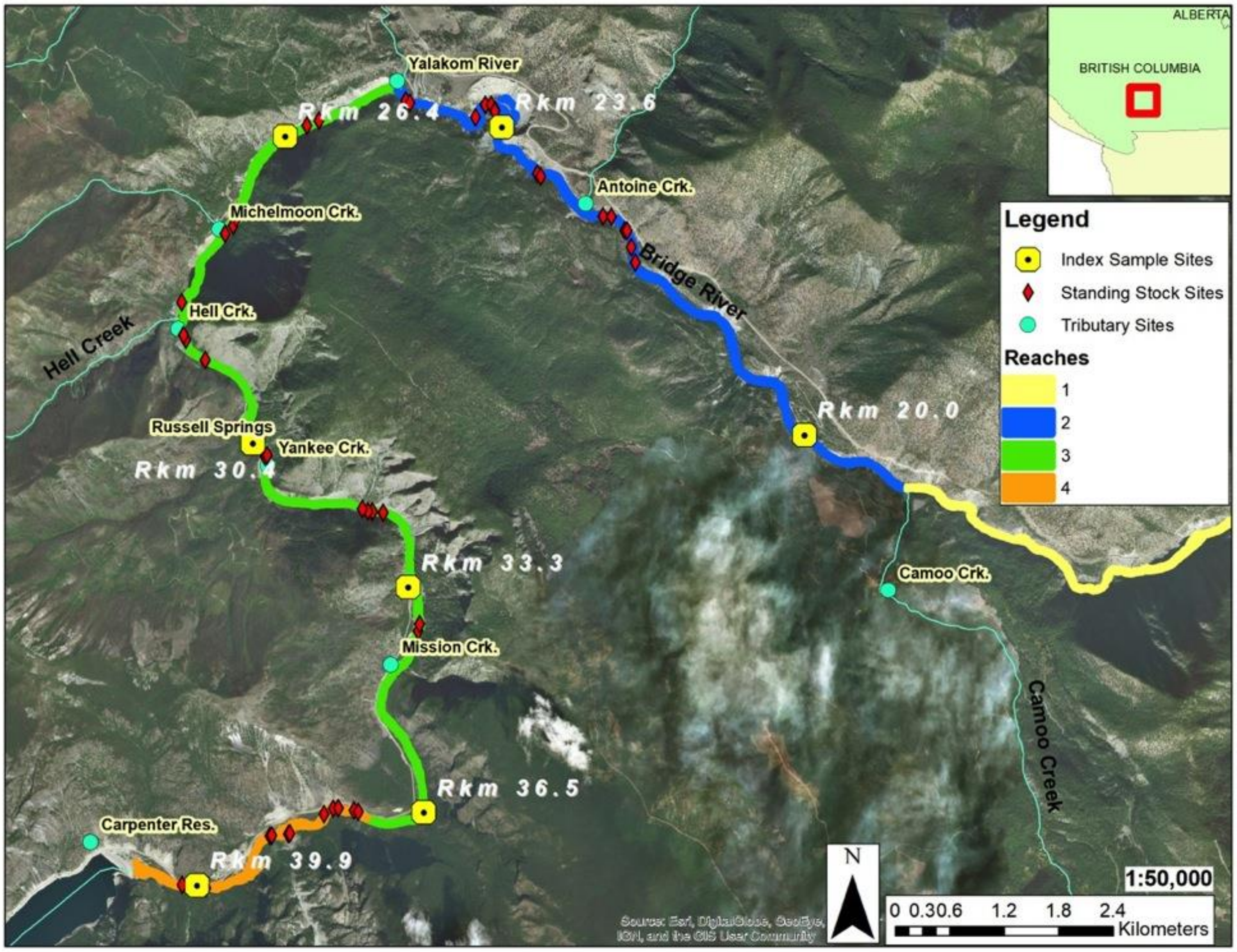


Figure 2: The Lower Bridge River Aquatic Monitoring Program study area (reaches 2, 3 and 4) index sample site locations, tributaries, and standing stock assessment site locations

2.1.2 *Temperature, Stage and Flow Release*

Water temperature was recorded at an hourly rate on every day of 2015 using UTBI-001 data loggers manufactured by the Onset Computer Corporation (Bourne, MA). These data loggers were located at the seven site index locations as well as an additional logger located in the Yalakom River approximately 100 meters upstream of its confluence with the LBR. Temperature loggers were housed in a protective cover, anchored at locations and submerged to the river bed at a depth of 0 cm. They were both checked and downloaded for data every 3 to 5 months to ensure data quality. Temperature data in reaches 2 and 3 and the Yalakom River were irretrievable between 18 August and 03 December due to a logger malfunction.

Relative river stage was recorded by PS9000 submersible pressure transducers (Instrumentation Northwest, Inc.), which were coupled with Lakewood 310-UL-16 data recorders. Data were collected at three Rkm locations: 20.0, 26.1, and 36.8. River stage was recorded every 15 minutes per day every day of the year.

Data on flow release were provided by BC Hydro Power Records and are maintained by BC Hydro. These data represent hourly discharge from the Lower Level Outlet (LLO) gates at Terzaghi Dam.

Chinook emergence calculations within the report utilized water temperature data collected using the field methods described above. However, detailed information related to the exact calculations and workflow employed for chinook emergence date predictions can be found in Sneep & Korman (in prep).

2.1.3 *Water Chemistry and Nutrients*

Water chemistry and nutrient data collection occurred in the early fall session on 5 October and 30 November 2015 for the late fall session. During both fall sampling periods, water samples were taken from all seven LBR index locations, as well as Carpenter Reservoir, and the following LBR tributaries: Antoine Creek, Camoo Creek, Hell Creek, Michelmoon Creek, Mission Creek, Russell Springs, Yalakom River, and Yankee Creek (refer to Figure 2). These water samples were submitted to ALS Environmental and analyzed for the following nutrient levels: NH_4 (Ammonium$_)$, NO_2/NO_3 (Nitrate/Nitrite), soluble reactive phosphorus (SRP), total dissolved phosphorous (TDP), and total phosphorus (TP); the chemical parameters included total alkalinity and pH. Turbidity (NTU) was also included within in the ALS Environmental analysis. When manual recordings of water were taken they were measured at each site using a WTW handheld field meter (Hanna Instruments, Laval, Quebec) and these included conductivity, pH, and spot water temperature.

2.1.4 *Primary and Secondary Productivity Sampling*

Data were collected in order to assist in the characterization of both spatial (between reaches) and inter-annual variations of primary and secondary productivity. Productivity refers to the rate of generation of biomass in an ecosystem. Primary productivity was monitored using periphyton accrual (chlorophyll-a) as the main indicator parameter. Macroinvertebrate abundance and diversity were the main indicators of secondary productivity. Abundance, when discussed in this report relates to the overall number or count of individuals within a given population (i.e. sampling basket at a specific location in the river). Diversity is defined as the number of taxa (in this case, families) in that population. At each of the seven index site locations, both periphyton and macroinvertebrate samplers were installed on 1 October, and data were collected weekly at three replicate subplot locations spaced approximately 20 m apart.

The medium used to accrue periphyton consisted of a 30 x 30 x 1 cm cell Styrofoam sheet that was rubber banded to a plywood backing which was bolted to a 30 x 30 x 10 cm concrete block. At each site index, periphyton accrual samplers were placed at each replicate in areas relatively similar in water depth and velocity. Periphyton accrual data were collected approximately every week at all the replicate subplots and for all seven site index locations between 7 October and 27 November, 2015. Each weekly sample involved the removal of a core of Styrofoam using the open end of a 7-dram plastic vial (8.5 cm^2 core area). These samples were then sent to ALS

Environmental for measurement of Chlorophyll-a concentration and Limnotek for periphyton density and biovolume assessment.

The medium used to measure macro-invertebrate abundance and diversity included a standardized metal basket filled with river gravel and substrate collected at each site. These prepared baskets were placed at similar water depths and velocities at each of the site locations and proximal to the periphyton accrual samplers. The baskets were left undisturbed for the duration of the eight-week fall field ecology sampling series at which point they were carefully lifted out of the water and placed into buckets. The contained substrates were carefully removed from the baskets and were hand scrubbed in order to remove all attached material. This material was filtered through a mesh sieve (Nitex), and placed into a sample jar that contained 10% formalin solution. As was done in previous years, the sample jars were sent to Mike Stamford at Stamford Environmental to be sorted, identified to family, and enumerated.

Several benthic invertebrate performance metrics were compared in order to determine differences between the flow trial periods and between the LBR reaches (Stamford 2017). Results were produced utilizing standardized methods and procedural statistical compilation methods outlined in detail in Stamford (2016, 2017). These procedural statistics included: mean total abundance, % and number of EPT, (the percentage and total number of families belonging to the mayflies, stoneflies, and caddisflies, EPT taxa), and the Simpsons Diversity Index. The EPT index is generally based on the premise that higher water quality will have a higher % EPT. The Simpsons' Diversity Index is a measure of biodiversity, and incorporates the number of species present and the abundance of each species.

2.1.5 *Sampling for Juvenile Salmonid Growth Data*

In 2015 juvenile salmon were collected for growth data at each index site four times (April, August, September, and November) in order to characterize temporal and spatial patterns of fish growth. The intent of this sampling was to collect a target of approximately 30 salmonids within each age/species class. Live fish were collected using backpack electrofishing. Fish were anaesthetized and identified to species. Forklength (mm) and weight (g) measurements were recorded. Following a brief recovery, all fish were released close to their initial collection area.

2.1.6 *Fall Standing Stock Assessment*

The objective of the fall standing stock assessment is to estimate the abundance and distribution of juvenile salmon in reaches 2, 3, and 4. Relative to the fish growth sampling, the standing stock assessment employs a more intensive level of effort, spanning 49 sites along the LBR. The fall stock assessment was conducted during the 3 $m^3 \cdot s^{-1}$fall flow, a similar season and water flow as sampled in previous years.
Upon arrival to each site, the standing stock survey area was enclosed with three ¼-inch mesh stop nets in size ranging from 50 to 150 m^2. Perpendicular to the bank, two shorter panels were used as stop nets upstream and downstream of the bank while a longer net was used parallel to the bank. Stop nets were attached to bipods and anchored down to the shore so that they were fixed during sampling. As crews changed over the years and the river changed, net placement deviated slightly between crews and depended on site conditions at the time of sampling. This is minimized to ensure that no sampling biases occur.

A four-pass depletion method using LR-24 electrofishers (Smith-Root, Vancouver, WA) was executed within the netted enclosure by using a 400 volts DC. Live fish were collected using backpack electrofishing. Fish were anaesthetized and identified to species, and fork length (mm) and weight (g) measurements were recorded. Fish were kept in a live basket in the stream until the sampling was complete and fish were then released near the original electrofishing location.

Physical (abiotic) data of the site was measured and recorded. Three length and width measurements of the netted enclosure were recorded. The length and width measurements were taken in order to calculate the area sampled. After the net enclosure was removed, water depth and flow velocity was recorded via three transects at upstream, mid, and downstream locations. At each transect five depths and five velocities were measured at equidistant intervals from bank to the offshore extent of the sampled area. Water velocity was measured with an E-230-Model 2100 current meter (Swoffer Instruments, Burnaby BC) at 0.6 of depth. Maximum depth and velocity were also noted at each site. Supplementary site data included sampling effort (electrofishing seconds), date, dominant habitat type, D90, substrate composition, and mean particle size.

Data were compiled and analyzed according to Hierarchical Bayesian Model (HBM) outputs (Korman, 2017; Sneep and Korman, in prep). The HBM was developed for BRGMON-1 to estimate reach-wide standing crop and account for differences in catchability among flow treatments (see Bradford et al. 2011, BCH, 2012):

$$Fij = \mu + \_T + Sj + Yi(T) + eij$$

where, Fij = standing crop biomass in year i at site j; μ is the mean density; _ is the treatment coefficient, T is the fixed treatment effect (dam release), and Yi and Sj are random year and site effects, respectively. Outputs were presented across the years for this report; however, significance testing was not conducted due to program and budgetary constraints.

2.1.7 *2015 Aquatic Habitat Assessment Methods*

2.1.7.1 Overview

A single habitat survey was conducted in 2015 during the fall flow of 3 $m^3 \cdot s^{-1}$. Work took place in the period of 21 August through 28 September. The geographic extent of this aquatic habitat survey included reaches 3 and 4. Due to the limited time available during target survey flows, no field data were collected for reach 2.

2.1.8 *Remote sensing and digitization methods*

The main objective of the 2015 aquatic habitat assessment was to construct a geodatabase that classified aquatic habitat at the 3 $m^3 \cdot s^{-1}$ flow. The principal remote sensing dataset utilized as a reference to this work were orthophotos supplied by BC Hydro. These orthophoto images were captured via airplane in mid-September, 2013.

Initial heads-up digitization of aquatic mesohabitats was employed on the orthophotography in order to map the habitat types. Heads-up digitization is a widely accepted approach to aquatic habitat classification (Northwest Hydraulic Consultants, 2009; Thomson et al., 2001) whereby one uses background imagery (orthophotos) and its characteristics (e.g., a river and its associated habitat types) to trace relevant features. Aquatic features were digitized directly from the aerial photos using ArcMap 10.3.1 (ESRI, 2015). Heads-up digitization of habitat classes was achieved through visual interpretation at an approximate scale of 1:1,000 using a combination of features that included water colour, visible white-water and apparent water flow, substrate, river shape, and riparian vegetation. The remote sensing digitizer used the aforementioned combination of visible aquatic features to determine the proper mesohabitat size, shape and classification which would take the form of a habitat unit or subunit. A habitat unit consisted of a mesohabitat that was characterised by similar aquatic characteristics. A habitat subunit was defined as small areas of habitat within the larger habitat unit but with distinct physical characteristics. These habitat subunits were classified as part of the main habitat unit but were given their own unique identifier. Different habitat unit and subunit classes with their descriptions are outlined in Table 3. Aquatic mesohabitat class types were taken from historical field methods utilized in the LBR (Sneep, 2012) as a means for data consistency and comparability across annual LBR habitat surveys. The final spatial product includes a geodatabase representing the LBR classified by aquatic habitat types with an emphasis on habitat types important to salmonid species and the size and shape of each habitat unit applicable subunit.

Table 3: Outline of descriptions and definitions utilized to identify habitat types

Habitat Type	Depth	Velocity	Gradient	Instream Cover	Comments
Run	Mod. to High	Mod.	Low to Mod.	Mod.	Moderate, laminar flow; little surface agitation
Riffle	Low to Mod.	High	Mod. to High	Mod. to High	Swift, turbulent flow; some partially exposed substrate
Pool	High	Low	Low	Low to High	Variety of forms; can be either 1^{o} or 2^{o} units
Cascade	Mod	High	High	Low	Very steep riffle habitat; Substrate is usually boulders
Rapid	Mod. to High	High	Mod.	Low	Very fast flowing runs, flooded riffles; Around constrictions
Side-channel	Low to Mod.	Low to Mod.	Low to Mod.	High	2^{o} habitat type; productive but limited quantity in LBR
Bar	N/A	N/A	N/A	N/A	Can be wetted or dry and usually lacks vegetation
Island	N/A	N/A	N/A	N/A	Always dry and normally have annual and perennial vegetation.

2.1.9 *Flow Rampdown Surveys*

Flow rampdown and stranding risk surveys were conducted for all stage reductions from 20-$m^3 \cdot s^{-1}$ to 1.5 $m^3 \cdot s^{-1}$**.** The focus study area of the LBR rampdown occurred between Terzaghi Dam and the confluence of the Yalakom River, a river length of 16 km. At the start of each rampdown day, a preliminary baseline reconnaissance of the entire 16 km was conducted. The physical progress of the flow reduction was monitored according to the BCH LBR Fish Stranding Protocol (Sneep, 2016) and close attention was paid to those areas with historically high fish stranding potential.

Based on historical data, reporting, and stage levels for the rampdown component, potential areas with risk were identified daily, and salvage crews were dispatched to those areas. Upon arrival, these crews documented the physical attribute characteristics of the area; and if necessary, crews began fish salvage. At the start of the work day, fish salvage efforts started closest to Terzaghi Dam and highest priority was given to the following river habitats: sidechannels, low gradient edge habitats, and 'potholes' from historical gold mining endeavours.

2.1.10 *Fish Salvage*

When crews arrived to an identified fish salvage site, physical habitat attribute information was recorded as noted. These notes included:

- Date, time, full name of crew members, operational changes being assessed,
- General site description (i.e. reach #, river km, bank location, proximity to landmarks, etc.),
- NAD 1983 UTM Zone 10 North coordinates,
- Estimated dewatering time for the site, and
- Additional comments.

Upon arrival at each site, crews assessed the area for presence of fish, and estimated the size of habitat that would likely dewater. A strategy for moving fish out of the affected area and back into the main river was determined. During active salvage, fish were categorized according to the following categories:

- Incidental - fish habitats that were not yet isolated, and fish still had the opportunity to move to deeper areas on their own;
- Isolated – fish in wetted areas that were isolated from the main flow of the river (i.e. strand pools)
- Stranded – fish that were found in habitats that had completely dewatered, but were still alive when salvaged;
- Mortality – fish that were found dead in habitats that were isolated or completely dewatered.

Fish that were salvaged from shallow waters within potential stranding areas prior to complete isolation from the main channel were considered 'incidental' captures. Crews counted and recorded the total number of incidental captures within this category. When sites were completely isolated from the main channel and fish could not be captured in an incidental manner, they were captured by backpack electrofisher. All captured fish were categorized, counted and identified to species before returning them back to the main channel. A subset of the captured fish were measured for forklength (to the nearest mm).

At the end of each ramp-down event, an update was provided to BC Hydro regarding the environmental monitoring conducted on the LBR, including: rampdown stages, flow reduction, fish salvage crew numbers, the number and location of sites used for salvage and the total number of fish salvaged in relation to salvage category.

3.0 AQUATIC MONITORING RESULTS

3.1 Physical Conditions

3.1.1 *River Stage*

The mean annual discharge from Terzaghi Dam in 2015 was ~6.58 $m^3 \cdot s^{-1}$. The hydrograph ranged from a spring and summer peak of approximately 20.7 $m^3 \cdot s^{-1}$ during June and July to a fall and winter low of approximately 1.5 $m^3 \cdot s^{-1}$ (Figure 3).

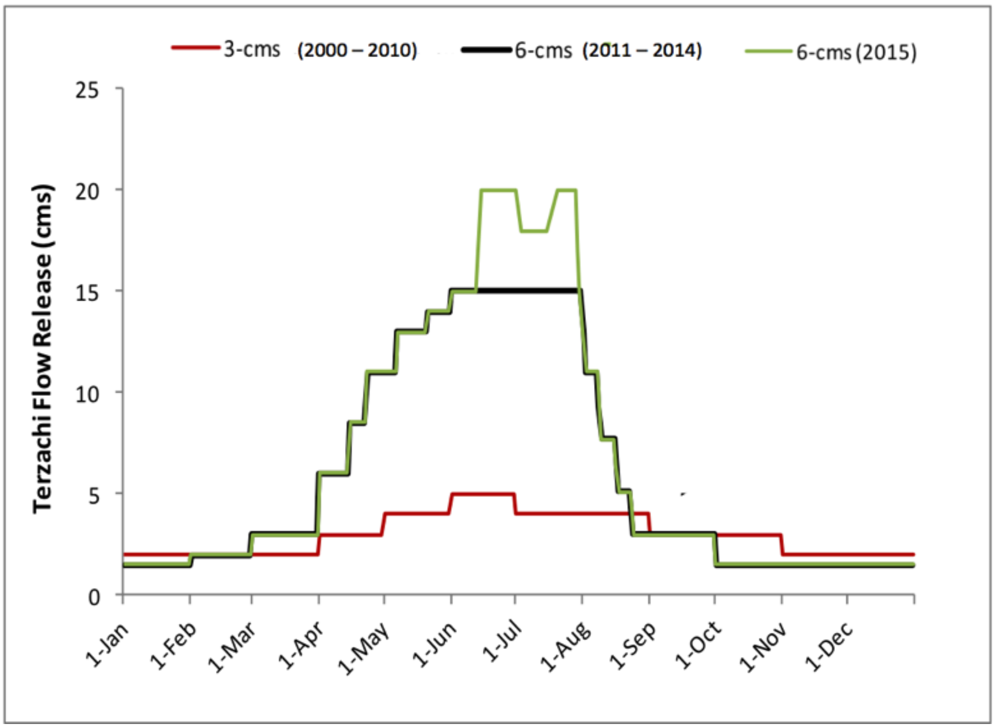


Figure 3: Lower Bridge River hydrographs during the 3 $m^3 \cdot s^{-1}$ Trial 1 period (2000-2010), the 6 $m^3 \cdot s^{-1}$ Trial 2 period (2011 – 2014), and 6.6 $m^3 \cdot s^{-1}$ in 2015

Staged ramp-up from 3 $m^3 \cdot s^{-1}$ to 15 $m^3 \cdot s^{-1}$ began on 01 April and progressed within WUP target values. In mid-June, a spill scenario occurred which required an additional 5 m^3s^{-1} to be released through Terzaghi Dam. The spill peak discharge of approximately 20.7 $m^3 \cdot s^{-1}$ was maintained until 01 July 1, when there was a decline in discharge from Terzaghi Dam starting at approximately 12:00 PM. The discharge declined from approximately 20.7 m^3s^{-1} to 17.8 m^3s^{-1} over several hours. A decline in stage of approximately 5.5 cm was observed over the afternoon/evening on 01 July at the BC Hydro compliance point (36.8 Rkm). Discharge stabilized at approximately 17.8 m^3s^{-1}. Flows were restored to 20 m^3s^{-1} on approximately July 15th (Figure 3). Between 29 July and 20 August, ten rampdown events took place to reduce flow in stages from approximately 20 $m^3 \cdot s^{-1}$ to the fall WUP target of 3 $m^3 \cdot s^{-1}$. These stages occurred across multiple weeks due to a flow change of approximately 17 $m^3 \cdot s^{-1}$. Between 29 and 30 September the LBR was further ramped down from 3 $m^3 \cdot s^{-1}$ to 1.5 $m^3 \cdot s^{-1}$.

3.1.2 *Water Temperature*

3.1.2.1 2015 Water Temperature Results

Annual mean daily water temperatures during 2015 for reaches 2, 3, 4 and the Yalakom River are presented in Figure 4. Trial 2 mean daily temperature data between 18 August and 03 December were used for Figure 4 as these provide a surrogate for data that were irretrievable.

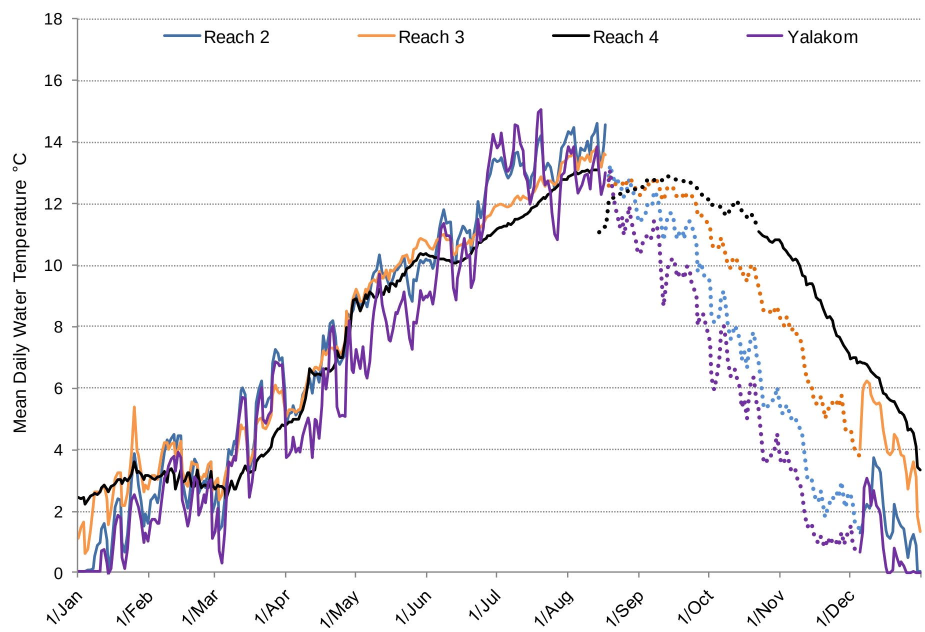
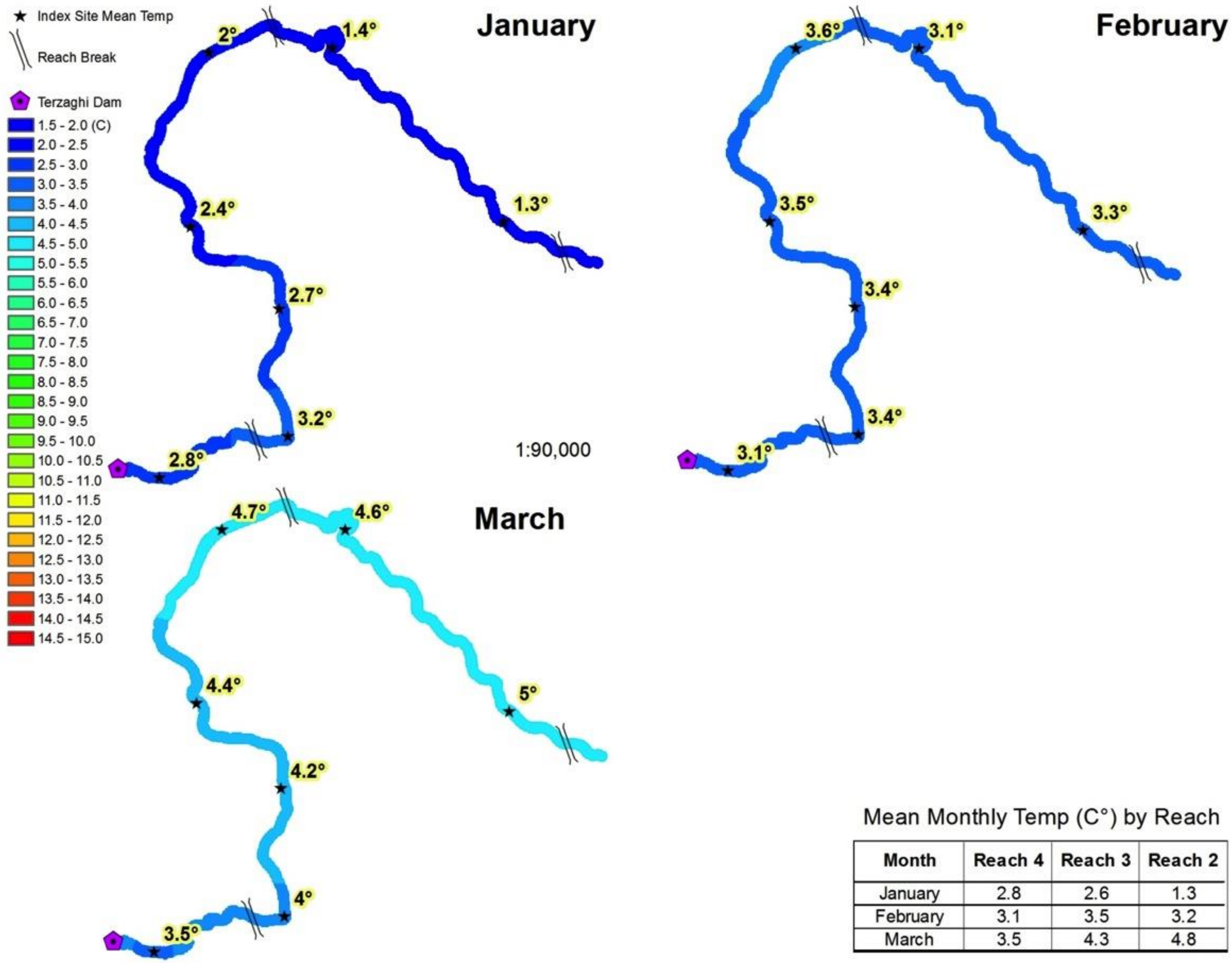


Figure 4: Lower Bridge River reaches 2, 3, 4 and Yalakom River mean daily temperatures between 1 January and 31 December 2015. Dotted coloured lines within this figure represent Trial 2 (2011-2014) mean daily temperatures between the dates of 18 August and 03 December

Seasonal temperature trends for 2015 in reaches 2 – 4 of the Lower Bridge River were similar to those observed throughout Trials 1 and 2 (McHugh & Soverel, 2015; 2014; 2013). The thermal effects of the release exhibit an upstream to downstream gradient that varies by season. Figure 5 and Figure 6 geographically display a colour ramp indicating mean monthly temperature, by reach, during the winter and spring seasons.

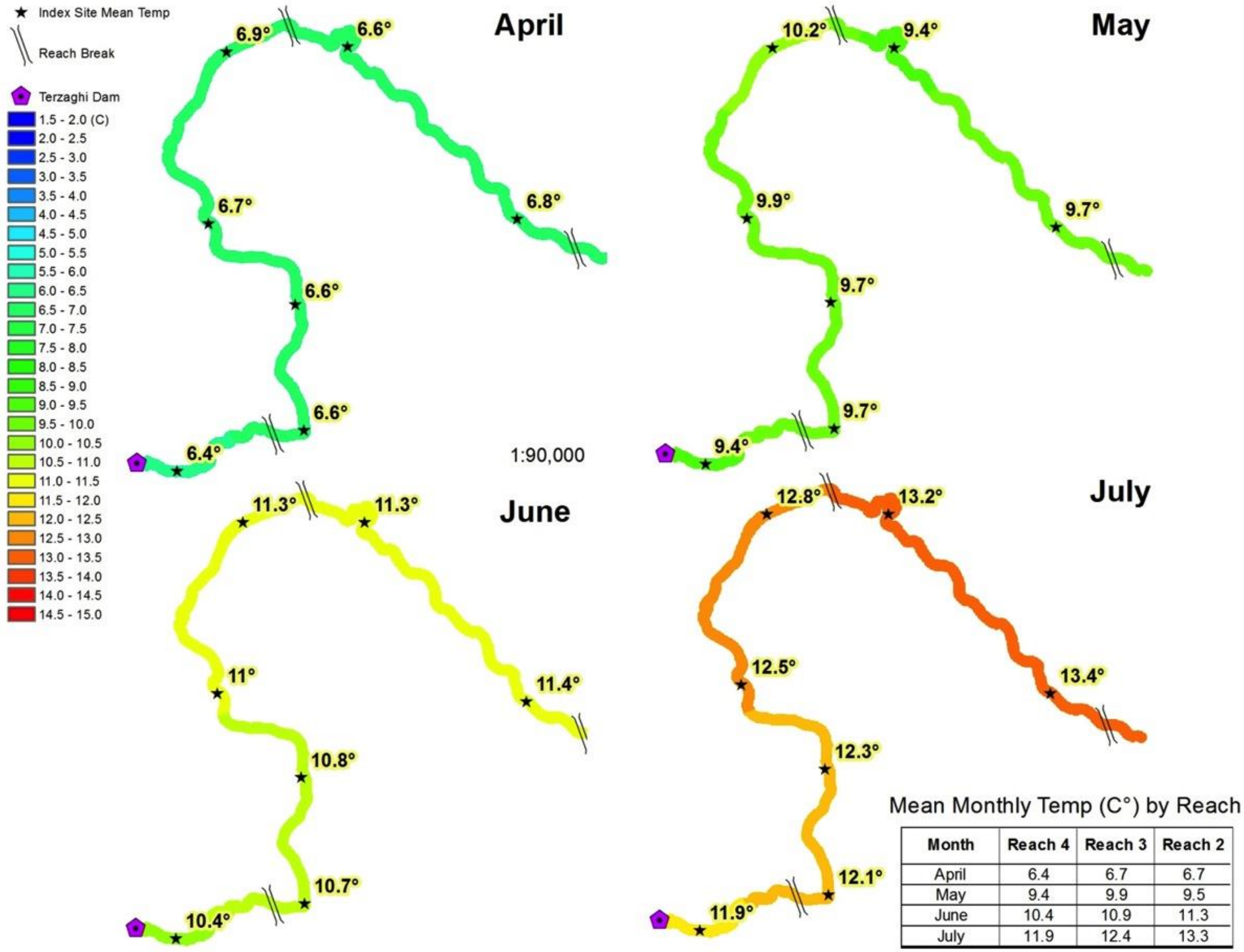
The contributing factors that set up the thermal profile of the LBR are the temperature of the reservoir, volume of the release, time of exposure to ambient influence (distance from the dam), and attenuation of tributary inflows. Patterns in 2015 were similar to 2014, and other years in Trial 2 (Figure 7). In general, temperatures in reaches 3 and 4 were warmer in the fall and early winter compared to the Pre-Flow thermal regime (Figure 7). Across the fall period, temperatures in Reach 4 were on average 3 - 6 °C warmer than Reach 2 (Figure 4). Temperature reflected the principal influence of the hypolimnetic flow from the reservoir through reaches 2, 3 and 4, with effects that extended farther downstream during the June and July high flow periods (Figure 6). In addition to distance from Terzaghi Dam, temperatures in Reach 2 were also moderated by the influence of the unregulated Yalakom River and other tributaries, groundwater influences (Figure 4 and Figure 7) and differing channel morphology such as steep shaded canyon walls and a steeper gradient.



Mean Monthly Temp (C°) by Reach

Month	Reach 4	Reach 3	Reach 2
January	2.8	2.6	1.3
February	3.1	3.5	3.2
March	3.5	4.3	4.8

Figure 5: Temperature schematic of mean monthly water temperature (C°) recorded at each site index location along the Lower Bridge River in January, February, and March of 2015. Site indices on the map are in order from upstream to downstream (Rkm): 39.9, 36.5, 33.3, 30.4, 26.4, 23.6 and 20.0 The colour ramp represents warmest water temperatures with shades of red and decreasing water temperatures progressing into orange and yellow, followed by green and finally the dark blue colour represents the coldest temperatures



Mean Monthly Temp (C°) by Reach

Month	Reach 4	Reach 3	Reach 2
April	6.4	6.7	6.7
May	9.4	9.9	9.5
June	10.4	10.9	11.3
July	11.9	12.4	13.3

Figure 6: Temperature schematic of mean monthly water temperature (C°) recorded at each site index location along the Lower Bridge River in April, May, June and July of 2015. Site indices on the map are in order from upstream to downstream (Rkm): 39.9, 36.5, 33.3, 30.4, 26.4, 23.6 and 20.0. The colour ramp represents warmest water temperatures with shades of red and decreasing water temperatures progressing into orange and yellow, followed by green and finally the dark blue colour represents the coldest temperatures. Data were unavailable between 18 August and 03 December

3.1.2.2 Water Temperature: Trial Comparison

Annual mean daily temperature trends during Pre-Flow (1996-2000) Trial 1 (2000-2010), Trial 2 (2011-2014) and 2015 are presented in Figure 7. In 2015, Trial 1 and Trial 2, spring and fall temperatures were distinctly warmer, and summer temperatures were consistently cooler than observed in the Pre-Flow period. Like 2015, across the trials, these effects were strongest in the upper reaches (reaches 3 and 4) and weakest in Reach 2, reflecting the primary influence of the hypolimnetic flow from Terzaghi Dam (Figure 7).

The Trial 2 thermal regime produced increased fall temperatures of approximately 2 – 4°C relative to the Pre-Flow baseline, particularly in reaches 3 and 4 (Figure 4, Figure 7). This time period coincided with the annual LBR chinook egg incubation period. Implications of the altered thermal regime on the emergence and subsequent survival of chinook fry are discussed in Section 3.3.2.4. Temperatures changes in other seasons were minimal, and were not observed to impact juvenile salmon life cycles.

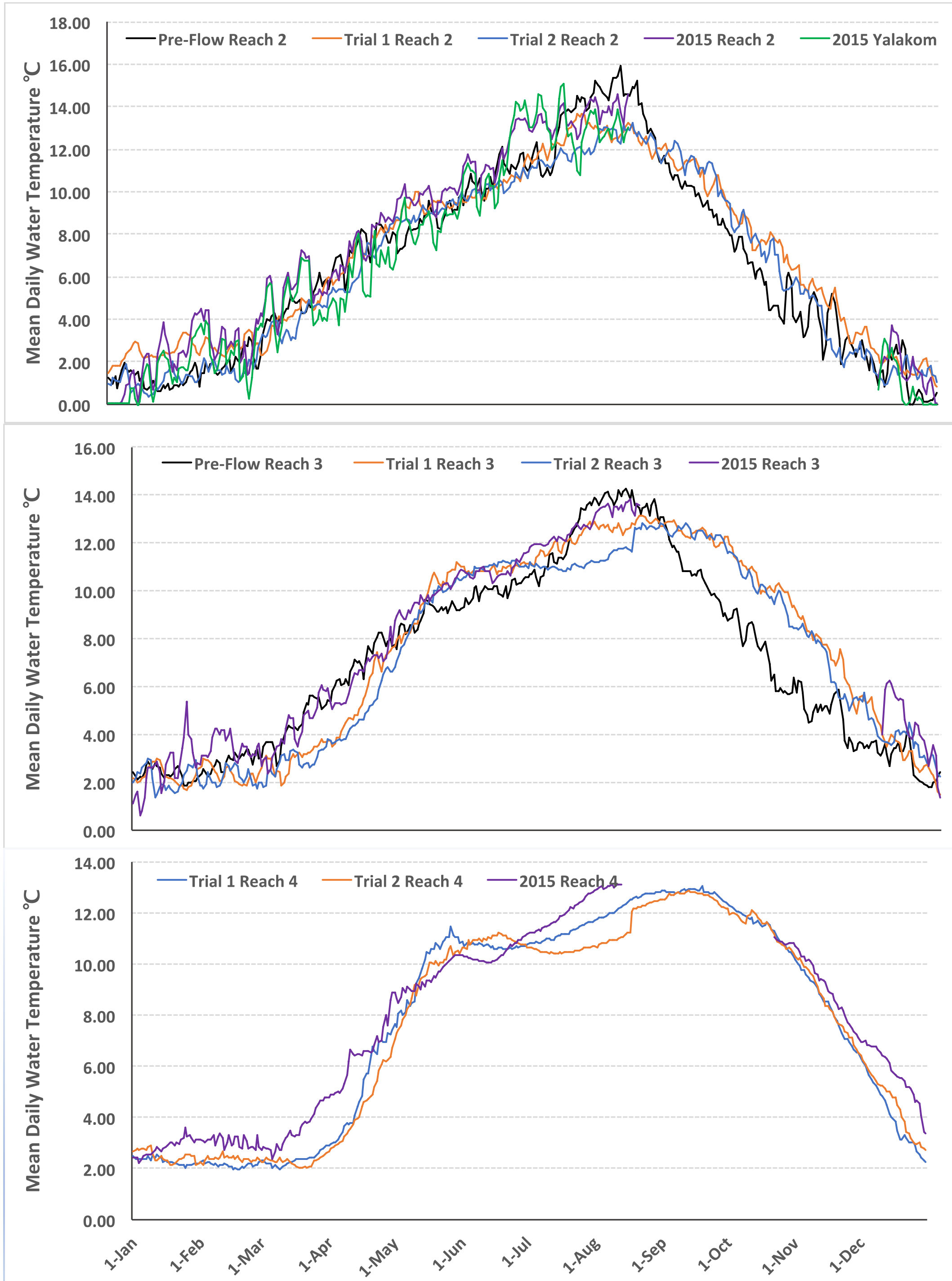


Figure 7: Pre-Flow, Trial 1, Trial 2, and 2015 comparisons for Lower Bridge River reaches 2 (top), 3 (middle) and 4 (bottom) figures. No Pre-Flow data are presented in Reach 4 because there was no water during that time period (1996 – 2000). Data were unavailable from 18 August to 03 December

3.1.3 *Water Chemistry*

Water chemistry samples were collected from the LBR, Carpenter Reservoir, and tributaries within the study area during 05 October and 30 November, 2015. The water chemistry parameters observed in 2015 were similar to those reported in previous pink salmon spawning years, and differences were minimal. All levels of parameters measured were within the normal range and within British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife and Agriculture (Ministry of Environment 2017). The Lower Bridge River is an alkaline environment. The levels of pH in the main stem remained in the optimal category for most organisms and ranged from 7.62 to 8.12. Tributary levels ranged from 8.01 - 8.33, and Carpenter Reservoir pH remained consistent at 7.55 (late fall) and 7.63 (early fall).

Turbidity levels in the LBR ranged from 2.7 to 29.4 NTUs, with Carpenter Reservoir measuring 2.8 (early fall) and 11.3 NTUs (late fall). Turbidity levels in the tributaries ranged from 0.2 to 1.9 NTUs. Concentrations of nitrates and phosphate levels were within the British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife and Agriculture, and remained relatively stable through 2015, and since the Flow Trials began. In early fall sampling, results showed a decline or stabilization in all parameters, with the exception or a rise in turbidity, within all reaches of the main stem compared to Pre-Flow, Trials 1 and 2. In late fall sampling there was also a general decline and stabilization of all parameters comparable to Pre-Flow, Trial 1 and Trial 2. As such, these differences cannot be easily distinguished from natural variations between years using descriptive graphical comparison. A more rigorous statistical comparison should be conducted in future years to determine if water quality should continue to monitored twice annually during the fall field ecology series, or if monitoring during other seasons, like high summer freshet, would be more beneficial for reducing uncertainties in the management questions.

3.1.4 *Aquatic Habitat Assessment Results*

Total wetted area across reaches 3 and 4 at the 3 $m^3 \cdot s^{-1}$ flow in 2015 was approximately 290,900 m^2. Overall, results for the 2015 3 m^3s^{-1} habitat survey were comparable to the previous 3 m^3s^{-1} habitat survey conducted in 2006 (Table 4, Figure 8). The 2015 habitat survey results showed that at 3 m^3s^{-1} riffles were most common habitat type (50%), followed by runs (33%), pools (12%), sidechannels (3%) and cascades/ rapids (1%) (Figure 8). Proportion of habitat type and total area were similar across the lowest flows (1.5 $m^3 \cdot s^{-1}$, 3 $m^3 \cdot s^{-1}$) suggesting they contained a similar amount of wetted rearing habitat area for juvenile salmon (Figure 8). In general, the 5 m^3s^{-1}, 8 m^3s^{-1}, and 15 m^3s^{-1} flows provided the highest amount of wetted area in the river, but contained increased proportions of cascade and rapid habitat classifications. As flow increased, some of the pool, riffle and sidechannel habitat was replaced by cascades and rapids, most notably in Reach 4. In general, sidechannel habitat appeared to be minimal across the reaches, regardless of flow. Reach 2 contained very little pool habitat, while Reach 4 contained the most. While variable, run habitat appeared to be similar across the flow levels in Reaches 3 and 4. Overall riffle habitat area appeared to be similar, but variable, across the low to mid flow-level ranges, with less overall area evident during the 15 m^3s^{-1} flow in Reach 4. Results demonstrated that higher flows may provide more wetted area; however, it is unknown if the additional wetted habitat area provided more suitable rearing habitat for juvenile salmon.

Table 4: Aquatic habitat survey results, depicted as total area, 100 m^2, conducted between 1996 and 2015 for various flows in the Lower Bridge River. A dash indicates data were unavailable

Reach	Habitat Type	Sep-96	Jul-00	Oct-13	Oct-14	Oct-06	Sep-15	Aug-00	Jun-07	Jul-07	Jul-14
		0 m3·s-1	0 m3·s-1	1.5 m3·s-1	1.5 m3·s-1	3 m3·s-1	3 m3·s-1	4 m3·s-1	5 m3·s-1	8 m3·s-1	15 m3·s-1
4	Run	-	-	140	195	149	168	145	83	141	146
	Riffle	-	-	247	286	310	227	489	363	346	230
	Pool	-	-	190	186	223	205	120	222	260	196
	Ca/Rapid	-	-	-	2	-	39	-	55	61	213
	SC	-	-	41	29	37	41	37	55	72	35
	Subtotal	**-**	**-**	**618**	**697**	**718**	**680**	**792**	**778**	**880**	**821**
3	Run	618	581	630	798	543	784	818	730	838	771
	Riffle	1004	1211	1296	1278	1569	1236	1186	1449	1297	1288
	Pool	52	54	176	114	183	147	71	174	124	3
	Ca/Rapid	89	93	-	11	23	11	30	442	482	344
	SC	-	-	39	70	2	50	2	45	48	109
	Subtotal	**1,763**	**1,939**	**2,141**	**2,272**	**2,319**	**2,229**	**2,107**	**2,839**	**2,789**	**2,514**
2	Run	541	208	-	752	605	-	555	580	-	557
	Riffle	1093	1581	-	975	917	-	1288	591	-	1282
	Pool	18	18	-	8	12	-	6	15	-	13
	Ca/Rapid	87	105	-	95	254	-	76	901	-	195
	SC	71	71	-	94	87	-	87	124	-	33
	Subtotal	**1,809**	**1,983**	**-**	**1,924**	**1,876**	**-**	**2,013**	**2,211**	**-**	**2,079**
1	Run	-	-	-	-	-	-	-	-	-	-
	Riffle	-	-	-	-	-	-	-	-	-	-
	Pool	-	-	-	-	-	-	-	-	-	-
	Ca/Rapid	-	-	-	-	-	-	-	-	-	-
	SC	-	-	-	-	-	-	-	-	-	-
	Subtotal	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

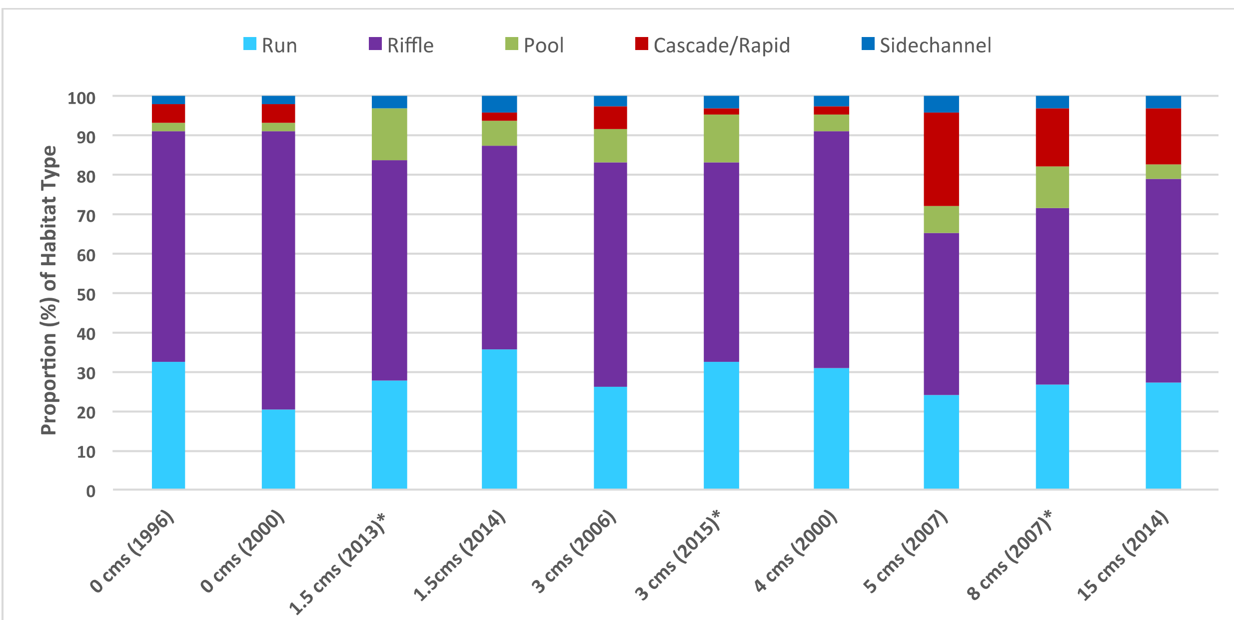


Figure 8: Proportion of habitat types within the Lower Bridge River in reaches 2, 3 and 4 for each studied flow discharge, by year and habitat survey. An * indicates that no data were available for Reach 2 during that survey year

3.1.4.1 Geospatial Depiction of Habitat Across Flows

Figure 9 is included in this report in order to demonstrate the interpretative ability of displaying aquatic habitat in a spatial context. Figure 9 depicts habitat type and area, mid-channel water velocity and repeat photographs by habitat unit at the same location of the LBR but at two different flow magnitudes. By spatially comparing these two areas of the LBR the viewer can see that the habitat unit shape, area and type changes as well as water velocity and other qualitative qualities in particular areas of interest.

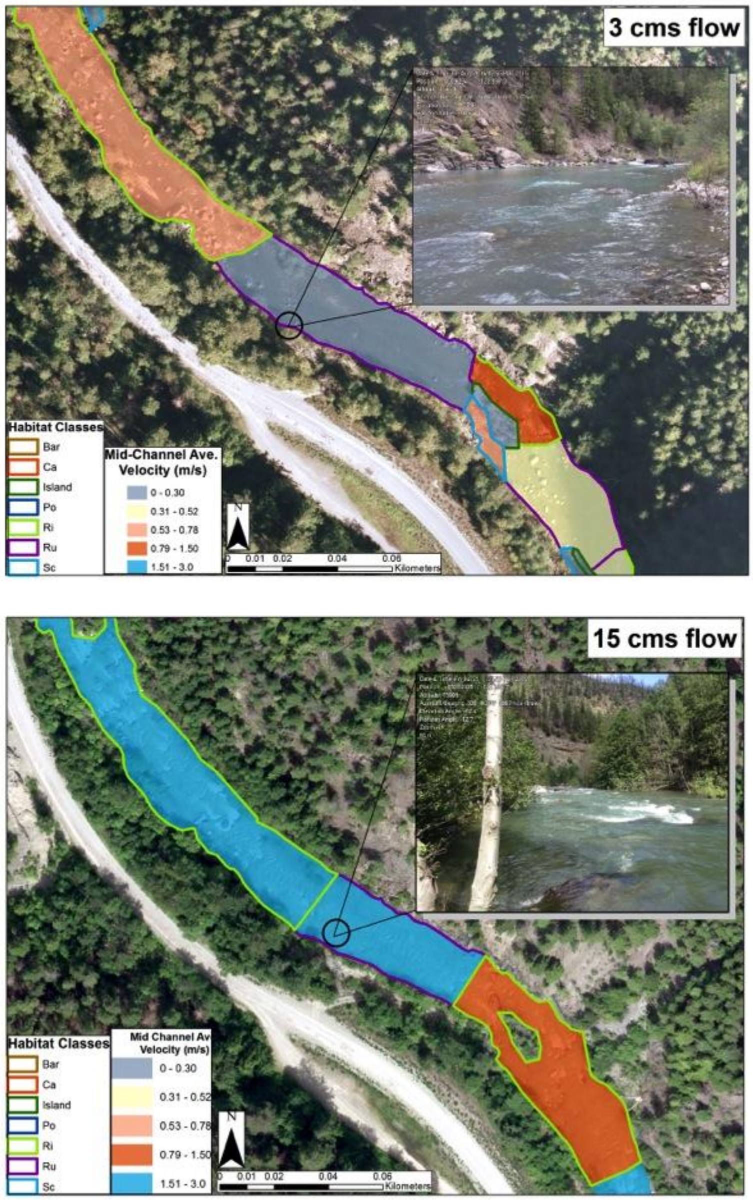


Figure 9: The top figure depicts the Lower Bridge River at 3 m^3s^{-1} flow and the bottom figure depicts the river at 15 m^3s^{-1} flow as assessed as part of the habitat analysis and at the same location. These figures portray habitat type and area, water velocity and repeat photographs at the same location within each digitized habitat unit

3.2 **Periphyton and Macroinvertebrates**

3.2.1 *2015 and Trial comparison of Periphyton Results*

Mean periphyton accrual rates (measured as cumulative concentration of chlorophyll-a) for the entire fall sampling period in Trials 1, 2 and 2015 are depicted in Figure 10. Data depict pink salmon years (odd years) as historical trends of periphyton accrual. Trends, which were demonstrated in even and odd years in previous LBR reports, relate strongly with spawning fish deposition and subsequent accumulation of nutrients (McHugh & Soverel, 2015; Sneep & Hall, 2012).

Results in 2015 showed a similar overall accrual trend that was observed through both Trials 1 and 2 (Figure 10). This trend typically showed reaches 3 and 4 increased through sample week 8 with Reach 3 accruing more periphyton than Reach 4 and Reach 2 (Figure 10). The trend for Reach 2 during pink years has been very gradual accrual and consistently lower than reaches 3 and 4 throughout the samples weeks.

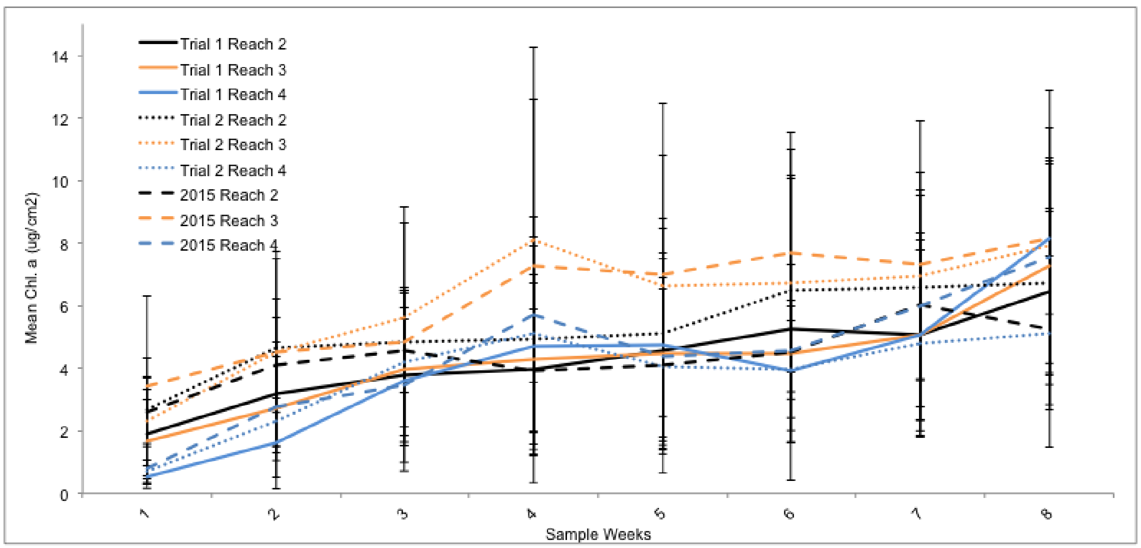


Figure 10: Mean periphyton accrual (measured as chlorophyll-a) on artificial substrates in the Lower Bridge River, during the fall series sampling in odd years in Trials 1 and 2 and 2015. Each point represents an average accrual for all stations within a reach; error bars represent (+/-) standard deviation. Samples weeks (1-8) represent weeks between early October and late November in ascending order

3.2.2 *2015 and Trial Comparison of Benthic Invertebrate Results*

Invertebrate abundance and biodiversity were the primary metrics used to measure benthic invertebrate health and production within the LBR over the last 20 years. These metrics were compared across differing time periods, including 2015 (6.8 $m^3 \cdot s^{-1}$), Pre-Flow (0-$m^3 s^{-1}$), Trial 1 (3 $m^3 \cdot s^{-1}$) and Trial 2 (6 $m^3 \cdot s^{-1}$) and between the reaches.

Total benthic invertebrate abundance and diversity initially increased following the flow release in 2000 as the benthic invertebrate community across reaches 2 and 3 adjusted to the flow release or became established in Reach 4 (Stamford, 2017). Once the ecosystem stabilized, invertebrate abundance and diversity were similar under Trial 1 and Trial 2 (Figure 11, Stamford 2017).

Invertebrate abundance in 2015 was similar to abundance estimates observed during the other years in Trial 2 (Table 5); no differences were apparent in between 2015 and other Trial 1 and 2 years (Table 5: Micro and macro portions of mean total abundance and mean taxonomic richness among Lower Bridge River aquatic invertebrate taxa (family level and higher) that colonized basket samples within reaches 2, 3, and 4 and among years in Trial 2 (2011 – 2015). A 2mm sieve differentiated between Micro and Macro sizes. The ranges from CV (coefficient of variation) and SD (standard deviation) are shown in parentheses. Table adapted from Stamford (2015)

Year	Trial	Mean Total Abundance (CV)		Mean Taxonomic Richness (SD)	
		Micro	Macro	Micro	Macro
2011	2	5233 (0.6)	732 (0.71)	15.0 (3.4)	24.2 (5.6)
2012	2	2098 (1.1)	475 (1.0)	20.1 (3.7)	22.3 (5.5)
2013	2	3305 (0.8)	225 (0.9)	13.8 (3.6)	15.6 (4.1)
2014	2	1707 (0.9)	215 (0.7)	14.3 (3.6)	16.4 (6.6)
2015	2	3476 (0.8)	525 (0.96)	13.4 (3.2)	19.5 (6.5)

Table 6, Table 6, Figure 11). Diversity remained high in the LBR invertebrate community in 2015. The total number of EPT families and total number of families were similar in Trial 2 (Table 5, Table 6) compared to Trial 1. EPT % did not appear to change in Reaches 3 and 4 across the trials and through 2015 (Table 6, Figure 12), with the exception of the increase that occurred following the initial flow release at the start of Trial 1. Higher relative abundances of mayflies (e.g. Heptageniidae, Ephemerellidae) may have lowered the Simpsons index (increased evenness) and increased %EPT in Reach 3 (Table 6, Figure 13), although data were highly variable. An overall stabilization of abundance with minimal changes to diversity may suggest the complexity of aquatic habitat did not decline in 2015 and through Trial 2, compared to Trial 1. In summary, results indicated that following the changes that occurred at the start of Trial 1 in response to the initial continuous release of water from Terzaghi Dam, the benthic invertebrate community did not appear to be different between Trials 1 and 2 in response to the flow changes (Stamford and Vidmanic 2016). Continued monitoring at high flows would help to reduce this uncertainty.

Table 5: Micro and macro portions of mean total abundance and mean taxonomic richness among Lower Bridge River aquatic invertebrate taxa (family level and higher) that colonized basket samples within reaches 2, 3, and 4 and among years in Trial 2 (2011 – 2015). A 2mm sieve differentiated between Micro and Macro sizes. The ranges from CV (coefficient of variation) and SD (standard deviation) are shown in parentheses. Table adapted from Stamford (2015)

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2013	2	3305 (0.8)	225 (0.9)	13.8 (3.6)	15.6 (4.1)
2014	2	1707 (0.9)	215 (0.7)	14.3 (3.6)	16.4 (6.6)
2015	2	3476 (0.8)	525 (0.96)	13.4 (3.2)	19.5 (6.5)

Table 6: Mean abundance and diversity indices among Lower Bridge River aquatic invertebrate taxa (family level and higher) that colonized basket samples within reaches 2, 3, and 4 and between flow trials. The ranges from 95% confidence intervals are shown in parentheses. Table adapted from Stamford (2017)

Reach	Trial	Mean Total Abundance		Mean %EPT		Mean #EPT Families		Mean Simpon's Index	
2	0	922	(181-1436)	66	(55-78)	7.9	(6.7-9.2)	0.28	(0.23-0.32)
	3	5277	(3943-6402)	41	(36-47)	12.7	(12.0-13.4)	0.31	(0.27-0.34)
	6	4357	(3028-5520)	46	(41-52)	13.2	(12.5-13.9)	0.29	(0.24-0.32)
3	0	4842	(2381-6832)	41	(33-49)	9.1	(8.6-9.6)	0.45	(0.38-0.51)
	3	3237	(2659-3762)	60	(56-64)	10.1	(9.7-10.6)	0.32	(0.30-0.35)
	6	3049	(2356-3680)	56	(49-63)	10.9	(10.3-11.6)	0.31	(0.28-0.33)
4	0	-	-	-	-	-	-	-	-
	3	2968	(2348-3528)	52	(45-58)	8.8	(8.2-9.4)	0.41	(0.35-0.46)
	6	3910	(2283-5262)	47	(34-60)	8.1	(7.1-9.5)	0.41	(0.31-0.50)

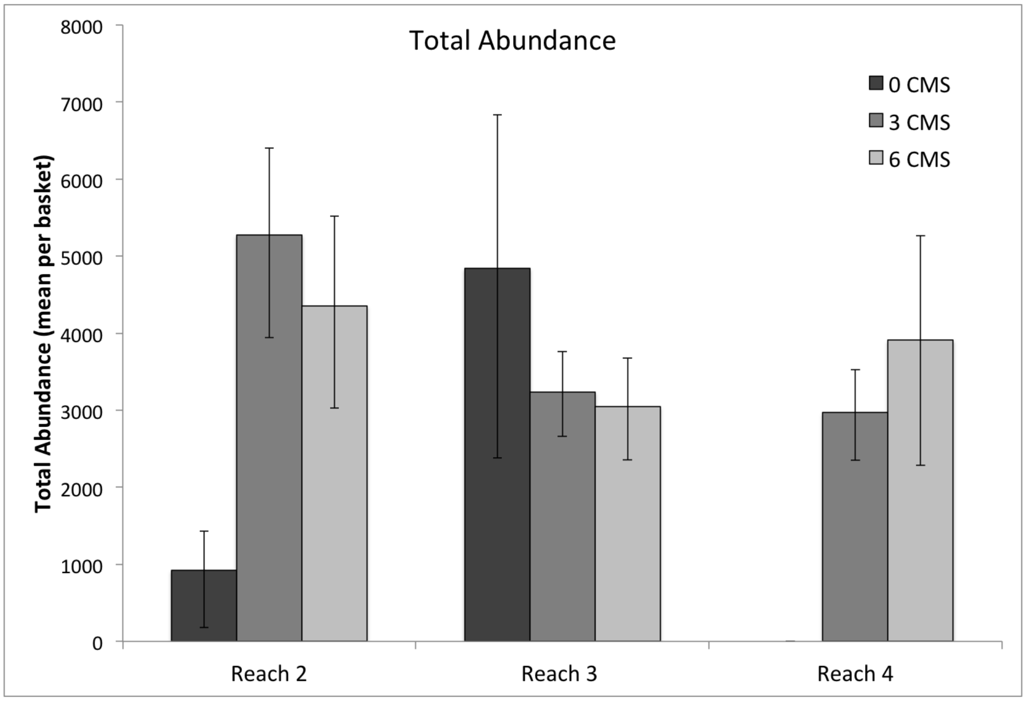

Figure 11: Total Abundance (all taxa combined) of benthic invertebrates in fall baskets in the Lower Bridge River within reaches 2, 3, and 4 and between flow trials. 95% confidence intervals determined from simple bootstrap procedure. Figure adapted from Stamford (2017)

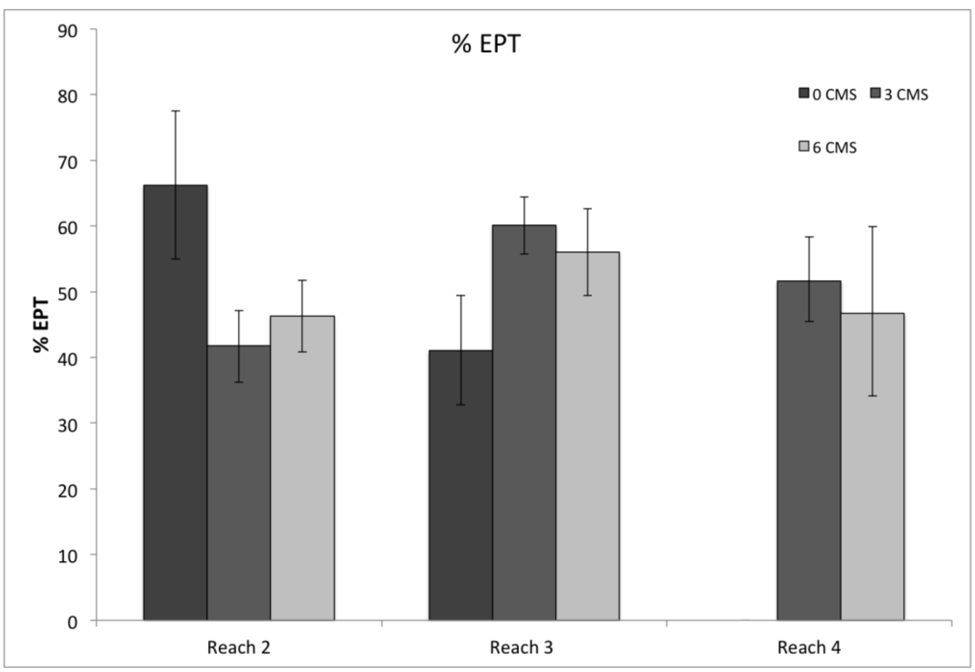

Figure 12: Percent abundance of Ephemeroptera, Plecoptera, and Trichoptera orders combined, relative to total invertebrate abundance (% EPT) among Lower Bridge River basket samples within reaches 2, 3, and 4 and between flow trials. Error bars are 95% confidence intervals determined from a simple bootstrap procedure. Figure adapted from Stamford (2017)

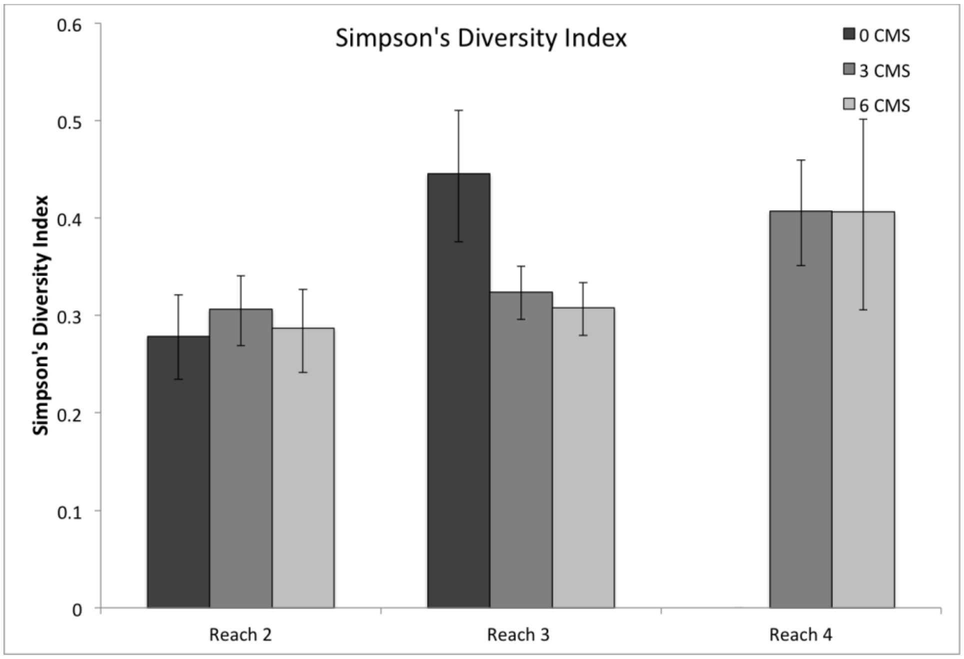

Figure 13: Simpsons diversity index (with 95% bootstrap CI) among fall basket samples in the Lower Bridge River within reaches 2, 3, and 4 and between flow trials. Figure adapted from Stamford (2017)

3.3 Fish Sampling for Abundance and Growth Assessments

A total of 2,015 fish were sampled during backpack electrofishing during the annual fall standing stock assessment (Reach 2, *n* =448; Reach 3, *n*=1,141; and Reach 4, *n*=426), which was conducted between 1 to 28 September 2015. During juvenile growth sessions, which occurred in April, August, September and November a total of 1,829 fish were caught during the sessions (Reach 4, *n*=762; Reach 3, *n*=2,077; Reach 2, *n*=1,005). River stage was too high to carry out growth sampling during the months of May, June, and July. Water temperatures were less than 5° C throughout the study area during the scheduled December fish growth sampling session which prohibited fish sampling according to the permit conditions. Consequently, winter juvenile growth data were not collected.

3.3.1 *2015 Seasonal Fish Size Index (Fish Growth) Results*

During 2015, a total of 3,844 fish were measured in all growth sessions (Table 7). Rainbow trout made up most of the samples. A total of 472 chinook were caught and measured in total across 2015 (Reach 2, *n*=225; Reach 3, *n*=208; Reach 4, *n*=39). Chinook fry capture peaked with a total of 190 during April sampling, and dropped to 59 in November. One Age-1 chinook and zero Age-1 coho were caught throughout the entire year. A total of 1,055 coho fry (Reach 4, *n*=239; Reach 3, *n*=588; Reach 2, *n*=228) and 2,317 rainbow trout (Reach 4, *n* =484; Reach 3, *n* =1,281; Reach 2, *n* =552) were caught in 2015, with most caught in September.

Table 7: Mean fish weight (g), sample size (n) and standard deviation for each species and age-class of salmonids within reaches 2, 3 and 4 captured in the Lower Bridge River for growth information, April to November, 2015. The bold and italicized numbers indicate those species/age classes that were insufficient in achieving their target sampling size minimum threshold per reach

Species &	Sampling	Reach 2			Reach 3			Reach 4		
Age Class	Month	Mean	n	SD	Mean	n	SD	Mean	n	SD
CH - 0+	April	0.8	60	0.2	0.6	121	0.2	0.6	***9***	0.2
CH - 0+	August	4.9	***55***	1.9	7.3	***21***	2.5	8.6	***7***	2.4
CH - 0+	September[a]	7.2	84	2.3	8.2	***42***	2.0	7.6	***13***	2.2
CH - 0+	November	7.0	***26***	1.4	9.4	***23***	1.4	9.8	***10***	2.3
CH - 1	April	-	-	-	6.5	***1***	-	-	-	-
CH - 1	August	-	-	-	-	-	-	-	-	-
CH - 1	September[a]	-	-	-	-	-	-	-	-	-
CH - 1	November	-	-	-	-	-	-	-	-	-
CO - 0+	April	0.3	***54***	0.1	0.3	***89***	0.1	0.2	***20***	0.1
CO - 0+	August	2.4	60	1.1	2.6	***91***	1.1	3.6	57	1.3
CO - 0+	September[a]	3.7	***33***	1.2	3.4	269	1.1	3.8	98	1.1
CO - 0+	November	5.1	***40***	1.4	5.4	***73***	1.8	6.9	38	2.5
CO - 1	April	5.1	***41***	1.8	4.4	***66***	1.6	5.6	***23***	1.2
CO - 1	August	-	-	-	-	-	-	8.2	***1***	-
CO - 1	September[a]	-	-	-	-	-	-	-	-	-
CO - 1	November	-	-	-	-	-	-	15.5	***2***	-
RB - 0+	April	4.6	***57***	1.9	3.5	***113***	1.5	4.6	***22***	2.2
RB - 0+	August	1.2	***55***	0.6	1.1	***90***	0.6	1.2	56	0.5
RB - 0+	September[a]	2.3	310	1.0	1.8	704	0.8	2.1	262	0.9
RB - 0+	November	3.0	62	1.2	3.8	***88***	1.5	4.2	32	1.8
RB - 1	April	20.1	***10***	5.8	18.1	***45***	5.9	24.8	***4***	7.2
RB - 1	August	13.0	***19***	6.5	13.6	***45***	4.9	14.8	***24***	5.3
RB - 1	September[a]	16.1	***18***	6.4	16.2	***116***	5.7	16.4	45	6.2
RB - 1	November	23.3	***13***	9.7	24.7	***48***	9.1	17.4	***24***	7.3
RB - 2	April	48.9	***4***	12.5	54.6	***8***	19.9	46.7	***3***	19.8
RB - 2	August	-	-	-	34.6	***3***	1.8	36.2	***1***	-
RB - 2	September[a]	39.7	***3***	8.7	40.3	***9***	6.7	41.0	***7***	4.5
RB - 2	November	64.4	***1***	-	57.6	***11***	12.6	57.4	***3***	3.2
RB - 3	April	-	-	-	-	-	-	-	-	-
RB - 3	August	-	-	-	-	-	-	-	-	-
RB - 3	September[a]	-	-	-	89.6	***1***	-	98.0	***1***	-
RB - 3	November	-	-	-	-	-	-	-	-	-

[a] Growth data for September were derived from fish sampled during the annual stock assessment.
(-) indicates that no fish were caught within that species and age-class.
Species are abbreviated as RB for rainbow trout, CO for coho and CH for Chinook. Age classes are denoted as 0+, 1, 2, and 3.

Cells italicized and in bold (Table 7) demonstrate where the target number of fish per species and age-class (target of *n*=30 per site/reach; therefore, *n*=60 for Reach 2, *n*=120 Reach 3 and *n* =30 Reach 4) was not achieved for that reach. Overall, sampling occurred in 32 sessions; fish were caught in 25 sessions. Results indicated that Reach 2 achieved targeted sampling approximately16% of the time, Reach 3, 9% of the time and Reach 4, 22% of the time. More effort (electrofishing time) was put into electrofishing during the sessions in April, August and November, 2015 to increase the sample size to attempt to meet or exceed target numbers consistently in these specific months, however fish abundance limited catch. Due to insufficient sampling numbers, data were compiled; however, interpretation was limited.

3.3.2 *Standing Stock Assessment Results*

3.3.2.1 2015 Abundance Estimates and Trial Comparison

Total fish abundance across the reaches in 2015 was estimated at 179,000 fish (Table 8). Juvenile rainbow trout totalled 128,000 fish and represented 71% of the total estimated abundance of fish (Table 8). Total 2015 coho fry abundance was 37,000, or 21% of the total abundance in 2015. Total 2015 Chinook fry abundance was estimated at 14,000 or 8% of the total (Table 8).

Rainbow fry numbered 109,000 and represented 61% of the total estimated abundance of juvenile fish in 2015. This value was higher than most of the Pre-flow estimates for this species/age class, but was similar to the lowest estimates in Trials 1 and 2 (i.e., 2004 and 2012). Among the reaches, differences in the rainbow trout fry abundance in Reach 4 accounted for most of the drop; the 2015 estimates for reaches 2 and 3 were similar to some of the previous annual estimates for these reaches.

Table 8: 2015 abundance estimates for all species-age classes for reaches 2, 3 and 4 of the Lower Bridge River for rainbow trout fry (RB-0+), rainbow trout parr (RB-1+), coho fry (CO-0+), and Chinook fry (CH-0+). No error estimate was available for these data at the time of publication

Abundance (Number of fish in thousands)			
Species-Age Class	**Reach 2**	**Reach 3**	**Reach 4**
CH - 0+	7	6	1
CO - 0+	3	29	5
RB - 0+	21	75	13
RB - 1+	2	15	2
Total	**33**	**125**	**21**

Total coho abundance was 37,000, or 21% of the total abundance in 2015. Coho abundance was higher than the abundances observed in the Pre-Flow period (mean = 25,000) (Table 8), but lower than all of the previous estimates for both Trial 1 (mean = 81,000) and Trial 2 (mean = 77,000). Estimates in 2015 resulted in a drop in the Trial 2 mean abundance of 10,000 fish (i.e., a change of 11.5% from approximately 87,000 to 77,000). The majority of the decrease in abundance for coho fry could be accounted for by changes in the estimates for reaches 3 and 4. Coho fry abundance in Reach 2 was lower than the other Trial 2 estimates, but similar to many of the Trial 1 and Pre-flow estimates for that reach (Figure 14).

Overall Chinook fry abundance decreased since the start of monitoring in 1996. While the Chinook fry numbers were low relative to many of the earlier years, the abundance appears to have stabilized across Trial 2 (Figure 14). The 2015 estimate (14,000) was similar to all of the other Trial 2 years (10,000 - 14,000) and contributed about 8% to the total estimate. By reach, the Chinook fry estimates were higher in reaches 2 and 4 than the other Trial 2 years, and similar in Reach 3. By river length, the densities of Chinook fry were highest in Reach 2 (96 fry/100 m), followed by Reach 3 (52 fry/100 m), and then Reach 4 (32 fry/100 m).

Rainbow parr (1+) abundance measured roughly 19,000 fish (or about 10% of the total 2015 abundance estimate). This value was lower than the other Trial 2 years and reduced the Trial 2 average by about 3,000 fish overall (or about 10%) relative to the average from 2011 to 2014. The 2015 estimate was lower than most of the other flow trial years, and most of this was due to the decrease in abundance in Reach 4 (Figure 14). Abundance in reaches 2 and 3 was similar to the Trial 2 averages. It should be noted that estimates of rainbow parr abundance tended to be more uncertain than for fry due to higher catch variability and reduced capture probability for this age class (Sneep and Korman 2015). The issues related to catch variability and reduced capture probability made interpretations of abundance estimates more difficult.

The 2015 abundance estimate of approximately 179,000 fish was roughly 63% of the abundance (286,000) during Trial 2 (2011–2015); 57% of the abundance during Trial 1 (313,000; 2000–2010); and 93% of the abundance during the Pre-Flow period (191,000; 1996–1999). Overall, the 2015 abundance estimate was lower than any other annual estimate since the flow release was initiated, and was in the range of the Pre-flow estimates before Reach 4 was wetted (Table 9).

Table 9: Estimated total abundance of salmonids in the Lower Bridge River in 2015 and by flow trials for rainbow trout fry (RB-0+), rainbow trout parr (RB-1+), coho fry (CO-0+), and Chinook fry (CH-0+). No error estimate was available for these data at the time of publication

	Abundance (Number of fish in thousands)			
Species-Age Class	**Pre-Flow** (0 $m^3 \cdot s^{-1}$)	**Trial 1** (3 $m^3 \cdot s^{-1}$)	**Trial 2** (6 $m^3 \cdot s^{-1}$)	**2015** (6.6 $m^3 \cdot s^{-1}$)
CH - 0+	39	22	13	14
CO - 0+	25	81	77	37
RB - 0+	91	175	163	109
RB – 1+	36	34	33	19
Total	**191**	**313**	**286**	**179**

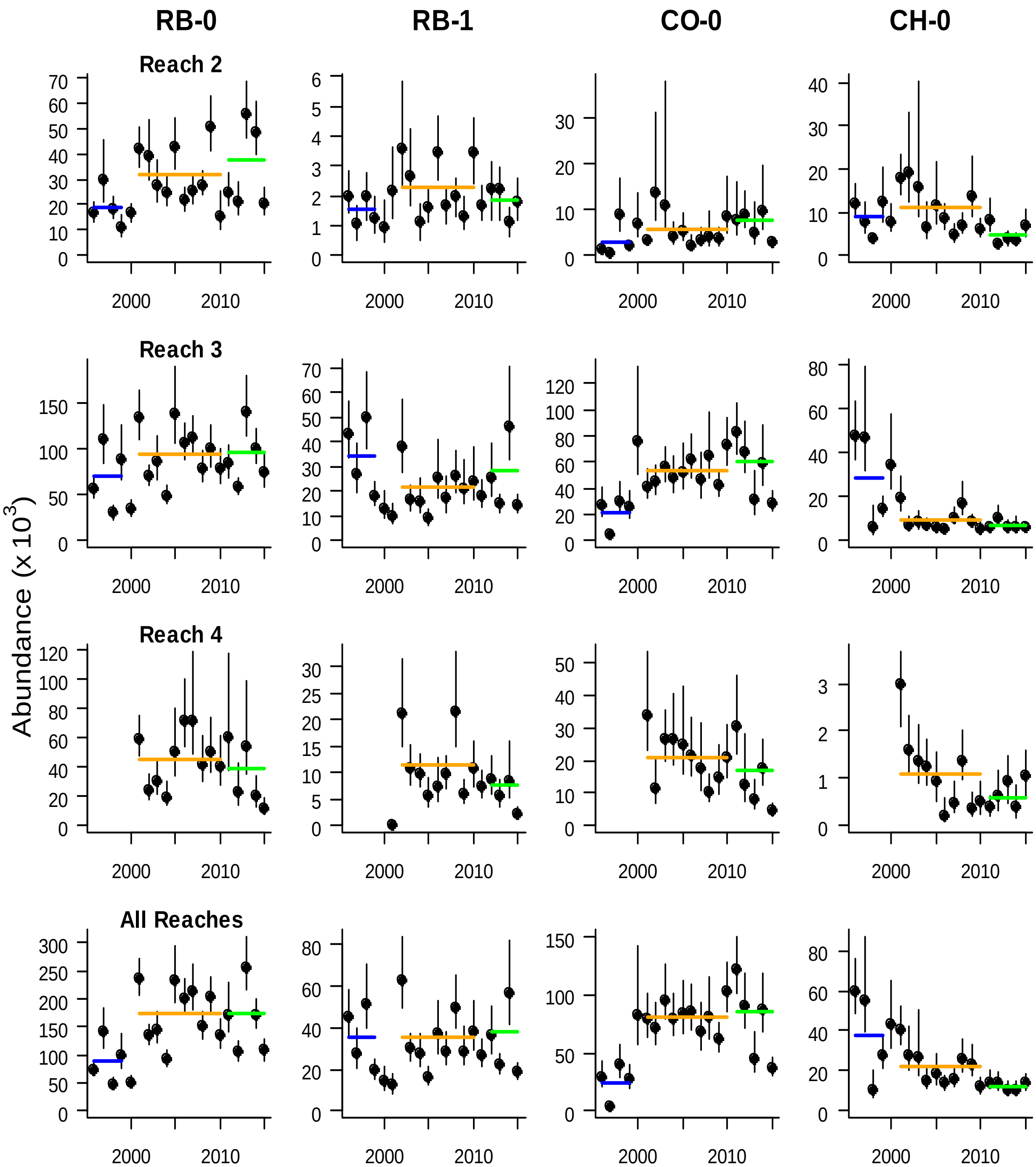

Figure 14: Annual median estimates of abundance (points) and 95% credible intervals in the Lower Bridge River across reaches 2, 3 and 4 by flow trials for rainbow trout fry (RB-0), rainbow trout parr (RB-1), coho fry (CO-0), and Chinook fry (CH-0). Horizontal lines show the average of annual median estimates across years for each flow trial period (blue=Pre-Flow, orange=Trial 1, green=Trial 2) (Sneep and Korman, in prep)

3.3.2.2 2015 Total Mean Biomass Estimates and Trial Comparison

Fish biomass across the reaches in 2015 was estimated at 746 kg (Table 10). Total rainbow trout biomass was 512 kg representing 69% of the total biomass (Table 10). Total coho fry biomass was 132 kg, or 18% of the total biomass in 2015. Total 2015 Chinook fry biomass was estimated at 102 kg or 14%.

Table 10: 2015 total mean biomass of salmonids in the Lower Bridge River across reaches 2, 3 and 4 for rainbow trout fry (RB-0+), rainbow trout parr (RB-1+), coho fry (CO-0+), and Chinook fry (CH-0+). No error estimate was available for these data at the time of publication

	Biomass (Kilograms)		
Species-Age Class	**Reach 2**	**Reach 3**	**Reach 4**
CH - 0+	43	51	8
CO - 0+	11	103	18
RB - 0+	52	139	28
RB – 1+	28	223	42
Total	**134**	**516**	**96**

Biomass in 2015 was observed to be the lowest since the year 2000, (the beginning of Trial 1) at 746 kg (Table 11, Figure 14). In comparison, the biomass between 2011 – 2014 was 1,223 kg; the mean biomass between 2000 – 2010 (Trial 1) was 1,341 kg (Table 11, Figure 14). Declines were evident across Reaches 3 and 4; while Reach 2 appeared relatively stable, compared to Trial 1, Trial 2 and the Pre-Flow period. Biomass in Reach 3 was estimated at 516 kg, which was the lowest level recorded since the start of the Pre-Flow period for that reach. Similarly, Reach 4 was also the lowest estimated biomass since the start of Trial 1, with a total value of 96 kg. Coho fry biomass declined across all the Reaches in 2015. Coho fry biomass was estimated at 132 kg, which was approximately 50% less than the estimated biomass across the years in Trials 1 and 2. Rainbow fry biomass was estimated at 219 kg, which was lower than average trial estimates from 1996 – 2014 during the Pre-Flow (mean = 249 kg), Trial 1 (mean = 305 kg) and Trial 2 (mean = 311 kg). Overall, Chinook fry biomass remained notably low at approximately 102 kg in 2015, which was comparable to the other years in Trial 2 (Table 11, Figure 14).

Table 11: Estimated total mean biomass of salmonids in the Lower Bridge River in 2015 and by flow treatment for rainbow trout fry (RB-0+), rainbow trout parr (RB-1+), coho fry (CO-0+), and Chinook fry (CH-0+). No error estimate was available for these data at the time of publication

	Biomass (Kilograms)			
Species-Age Class	**Pre-Flow** (0 $m^3 \cdot s^{-1}$)	**Trial 1** (3 $m^3 \cdot s^{-1}$)	**Trial 2** (6 $m^3 \cdot s^{-1}$)	**2015** (6.6 $m^3 \cdot s^{-1}$)
CH - 0+	228	134	92	102
CO - 0+	108	281	286	132
RB - 0+	249	305	311	219
RB – 1+	690	621	534	293
Total	**1275**	**1341**	**1223**	**746**

Populations of coho and rainbow fry in the LBR in 2015 may have been impacted by the hydrograph as abundance and biomass estimates were among the lowest since the flow release was initiated (Figure 14), although trends of declining abundance observed through Trial 2 continued in reaches 3 and 4. Juvenile Chinook populations were already very low and it is unclear if they were further impacted by the 2015 flows. Similar patterns of apparent population declines for coho and rainbow fry were observed following previous spill scenarios within the LBR in 1997, which was an ~25 $m^3 \cdot s^{-1}$ spill, (Figure 14; McHugh et al. 2015b), following a spill in 1991 (Triton Environmental 1992), and recently after a small spill event and stage fluctuation in 2015 which peaked around 20 $m^3 \cdot s^{-1}$ (McHugh, et. al 2015b). It is uncertain how the hydrographs contributed to the declines, and more data are needed at high flows greater than 15 $m^3 \cdot s^{-1}$ to increase resolution of findings. The Discussion outlines several flow related factors that may have contributed to the low abundance and biomass estimates in 2015. Additional factors unrelated to higher flows from Terzaghi Dam, such as a change in adult stock recruitment (spawner numbers across species) in the LBR, or elevated water temperatures during the fall and winter Chinook egg incubation period, may have also influenced juvenile fish populations and are discussed in the following sections.

3.3.2.3 LBR Stock and Recruitment Relationships

The relationship between escapement and juvenile production has been documented extensively in the literature for rivers where these parameters are well monitored (Sneep and Korman, in prep). In order to make interpretations regarding the effects of the increased flows on juvenile abundance, it is assumed that escapement did not affect the number of juveniles present during sampling. This assumption required that escapement exceeded levels needed to fully seed the available habitat. As part of the LBR Synthesis Assessment (Sneep and Korman, in prep), the available stock recruitment information was assessed for Chinook and coho in Reach 3 and 4 to determine if abundance of juvenile salmon could have been influenced by LBR escapement during the flow trial periods. Data from each LBR flow trial period indicated relatively consistent fry production across a fairly broad range of adult escapement levels. In 12 out of 15 years where data were available, spawner density estimates for coho exceeded the numbers required to fully seed reaches 3 and 4 through Trial 1 and Trial 2 (Sneep and Korman, in prep). Analysis indicated that juvenile abundance estimates during Trial 1 and 2 (2000 – 2015) were likely not impacted by the number of parental spawners (up to and including 2014 escapements). For the 2014 brood year (2015 productivity) BCH found in their preliminary assessment that the 2015 productivity for Chinook and coho was lower than expected after taking into consideration the effects of spawner abundance (Martins 2017). This was more apparent during the 2015 brood year of coho, but was also been evident for Chinook.

Stock and recruitment relationships for Chinook have not been extensively documented in the literature. Based on the recommended DFO habitat seeding requirements of 51-80 spawners/km for mid Fraser River populations (Sneep and Korman, in prep) and LBR spawner estimates provided by BRGMON-3, the number of Chinook spawners may not have exceeded the DFO seeding recommendations since 2004. However, estimates for LBR Chinook and coho were potentially underestimated based on comparison with the more robust resistivity counter data available starting in 2014 (Sneep and Korman, in prep). Limitations regarding the historical reconstruction of LBR Chinook and coho escapement are discussed in more detail in Sneep and Korman (in prep). Accurate Chinook estimates from the resistivity counter in 2014 indicated that Reach 3 and 4 exceeded the DFO recommendation that year (with 63 spawners/ km). For this brood year in particular, no spawner limitation occurred that would have influenced juvenile production. However, very few Chinook fry were captured during the standing stock assessment in the fall of 2015. These data demonstrated that the decline in Chinook fry abundance over Trial 1 and Trial 2 was not likely caused by adult escapement limitations alone (Sneep and Korman, in prep). Going forward, the collection of annual adult escapement data for coho and Chinook under BRGMON-3 will further support the development of LBR-specific stock-recruitment curves for these species.

3.3.2.4 Implications of Altered Thermal Regime for Chinook Emergence Timing

The thermal regime evident across Trials 1, 2 and 2015 (Figure 7) produced increased fall temperatures of approximately 2 – 6 C° during the Chinook egg incubation period, relative to the Pre-Flow baseline. This was documented within the LBR during Trial 1 to cause acceleration in the development of eggs and alevin, leading to early emergence of Chinook fry in the LBR (Sneep and Korman, in prep; Sneep and Hall, 2012). Coho and rainbow were likely not impacted by the elevated temperatures, as egg development occurs before and after the elevated fall temperatures. While emergence timing is not likely determined by temperature alone, Table 12 (from Sneep and Korman, in prep) shows predicted dates of emergence, across the Pre-Flow, Trial 1 and Trial 2 periods, based on river temperature and accumulated thermal units in the LBR. Flows during the fall and winter were similar between Trial 1 and Trial 2; therefore predicted emergence dates were also similar.

Table 12: Predicted Chinook emergence date summary in the Lower Bridge River based on the Pre-Flow, Trial 1 and Trial 2 thermal regimes during the incubation period. Early to mid-winter emergence dates are highlighted in red; late winter dates are highlighted in yellow; and 'normal' dates are not highlighted (from Sneep and Korman, in prep)

Site	Pre-Flow		Trial 1 (3 $m^3 \cdot s^{-1}$)		0 to 3 $m^3 \cdot s^{-1}$ Diff	Trial 2 (6 $m^3 \cdot s^{-1}$)		0 to 6 $m^3 \cdot s^{-1}$ Diff
	Est. Emerge. Date	Incub. (# days)	Est. Emerge. Date	Incub. (# days)		Est. Emerge. Date	Incub. (# days)	
39.9			26-Nov	80		26-Nov	80	
36.5	15-Jan[a]	130	15-Dec	99	-31	16-Dec	100	-30
33.3	20-Apr	225	26-Jan	141	-84	2-Feb	148	-77
30.4	27-Apr	232	16-Feb	162	-70	2-Mar	176	-56
26.4	28-Apr	233	3-Mar	177	-56	18-Mar	192	-41
23.6	5-May	240	30-Mar	204	-36	25-Apr	230	-10
20.0	6-May	241	18-Apr	223	-18	24-Apr	229	-12

Survival was likely poor for fry that emerged in winter or early spring, and this was one of several probable causes of low fry abundance in reaches 3 and 4 following the initiation of the flow release from Terzaghi Dam and through Trial 1 and 2 (Sneep and Korman, in prep). Three proposed fall flow alternatives (1 $m^3 \cdot s^{-1}$; 0.5 $m^3 \cdot s^{-1}$ and 0.25 $m^3 \cdot s^{-1}$) were modelled during the LBR Synthesis Assessment (Sneep and Korman, in prep) to conceptualize the level of flows required to restore a more natural thermal regime. Thermal regime restoration was predicted to reduce early emergence and benefit CH survival (Sneep and Korman, in prep). A more detailed discussion regarding predicted CH emergence timing, subsequent survival, and results from the modelling exercise to restore the thermal regime are available in the LBR Synthesis Assessment (Sneep and Korman, in prep).

3.3.3 *Flow Rampdown Survey Results*

3.3.3.1 Terzaghi Dam Flow Release and River Stage Results

The initial rampdown events transitioned the river from approximately 20 $m^3 \cdot s^{-1}$ to 3 $m^3 \cdot s^{-1}$. In the subsequent September rampdown, flow from the lower-level outlet gates was reduced from 3 $m^3 \cdot s^{-1}$ to 1.5 $m^3 \cdot s^{-1}$ as per the Trial 2 WUP hydrograph. According to terms within the Bridge River Power Development WUP (2011), the maximum rates of stage change should not exceed 2.5 cm/h or a total of 15 cm/d within Reach 4 of the Lower Bridge River. At the BCH compliance point, Rkm 36.8, the total maximum change per day limit (15 cm/d) was not exceeded during any of the 10 rampdowns (Table 13). Table 13 summarizes the total changes in river stage elevation and the flow release volume at the estimated stage change compliance point for each ramping date in July, August and September. During the summer rampdown events, the relative stage data decreased across all sites in correspondence with the decrease in flow coming from the LLO gates at Terzaghi Dam. By being on site, crews successfully salvaged fish regardless of hourly stage change rates.

Table 13: Stage change at the compliance point (Rkm 36.8) during each rampdown event

Rampdown Dates	TRZ m3·s-1 (Start)	TRZ m3·s-1 (End)	Stage Change (cm)
29-Jul-15	20.7	15.0	5.7
30-Jul-15	15.0	11.0	4.0
11-Aug-15	11.0	9.3	1.7
12-Aug-15	9.3	7.7	1.6
13-Aug-15	7.7	6.4	1.3
18-Aug-15	6.4	5.1	1.3
19-Aug-15	5.1	4.1	1.0
20-Aug-15	4.1	3.0	1.1
29-Sep-15	3.0	2.2	0.8
30-Sep-15	2.2	1.6	0.6

3.3.3.2 Stranding Risk

Due to morphological characteristics and predominately coarse in-stream substrate, the Lower Bridge River is sensitive to juvenile fish stranding. Stranding risk has historically been associated with the ramping rate, particularly within higher risk stage elevation ranges (Sneep, 2016, Crane Creek Enterprises, 2012). In general, the slower the river was ramped down, the lower the risk for adverse effects on fish. The cross-sectional channel shape was also influential; as the river volume dropped, the effect of each 1 cm flow reduction on river stage elevation increases.

Historically, flow ranges associated with the lowest fish stranding potential occurred between 15 and 9 $m^3 \cdot s^{-1}$. During stage reductions below 11 $m^3 \cdot s^{-1}$, the fish stranding impact increased and remained high for each subsequent ramping step (Sneep, 2016). In 2015, data followed similar patterns (Table 14). Stranding risk with the lowest stranding potential occurred between 11.0 $m^3 \cdot s^{-1}$ and 9.3 $m^3 \cdot s^{-1}$ and stranding risk increased and remained medium to high throughout the duration of the stage reductions (Table 14). Stranding risk was also elevated from 20.7 $m^3 \cdot s^{-1}$ to 11 $m^3 \cdot s^{-1}$. Sites were ranked risk ranked according to the number of fish salvaged, per site, per stage reduction. Sites where the number of fish salvaged on a given day was > 100 were ranked as high risk, and color-coded red. Yellow cells represent where the number of fish captured was between 10 and 99; sites were ranked as medium risk. Low risk sites, where < 10 fish were captured were shaded green (Table 14).

Table 14: Strand-risk ratings for stranding sites on the Lower Bridge River based on the numbers of fish salvaged per site, during each stage reduction. Red = High Risk; Yellow = Moderate Risk; Green = Low Risk, as defined above

Salvage Site		39.7	39.6	Eagle	Bluenose	37.0	36.9	36.6	35.9	Cobra	Upper Russell	Russell Springs	28.4	Hell Bar	Grizzly Bar	House Rock	Hippy Pool	Yalakom Confluence
Ca. Area (m^2)		75	30	3900	140	525	45	150	680	50	120	210	280	625	2050	75	120	80
Start Flow	End Flow	Total Number of Salvaged Fish Per Site																
20.7	15.0		14		314	110										28	10	
15.0	11.0	42		133	96	2					145							
11.0	9.3		20	32	17	71		95										58
9.3	7.7			73	5				329								4	
7.7	6.4	13		9	88	1			322				125					
6.4	5.1				66	34			328			12				30		
5.1	4.1							164	316	40		227	131	7				
4.1	3.0							60	132	32		78	52			3		
3.0	2.2		93			498		92				129	48					
2.2	1.6		21			246	13			18					384			

3.3.3.3 Physical Habitat Attributes

Crews were on site to implement salvage at all required sites from the BCH LBR Fish Stranding Protocol (Sneep, 2016) as well as any sites newly identified to pose a stranding risk when areas dewatered or isolated. Due to access issues and safety considerations related to high river stage, it was not possible to survey much of the river-right side of the channel on most of the July and August rampdown dates. Reach 1 and 2 were also not salvaged, as they are not included in the LBR Fish Stranding Protocol.

Elevated flows in 2015 required salvage to be conducted at one additional site in 2015. A new sidechannel adjacent to the existing Bluenose site in Reach 4 was found when flows exceeded 15 $m^3 \cdot s^{-1}$ and measured approximately 50 m^2. This sidechannel is depicted in Figure 5 of the LBR Spill Memo Report (McHugh et al., 2015b). The sidechannel was isolated due to a water fall at the bottom and an elevation gradient; however, water was flowing into the sidechannel throughout the duration of the spill and numerous juvenile salmonids were observed. Juvenile fish were possibly displaced from their mainstem habitat and monitoring sites and were observed in the sidechannel during the spill. This site was salvaged during the spill rampdown monitoring and 474 fish were documented using the newly wetted area. Fish were salvaged and returned to the river at this location in July.

3.3.3.4 Fish Salvage

The BCH LBR Fish Stranding Protocol (Sneep 2016), which focuses on reaches 3 and 4 and omits reaches 1 and 2, guided the overall strategy for rampdown operations and monitoring in 2015. Fish salvage crews monitored the stranding and conducted salvage where necessary, over the duration of all of the rampdown events. Overall, data demonstrated a successful transition throughout the rampdown events on the LBR in 2015. Consequently, the majority of fish observed at identified salvage sites were successfully salvaged prior to stranding.

Most of the fish salvaged during the rampdown event were rainbow and coho fry (Table 15). Most of these juvenile fish prefer shallow, grassy, protected habitat for rearing, and this habitat type is likely to dewater when flows are ramped down in the Lower Bridge River. Table 15 summarizes the number of fish salvaged by species for each day of the rampdown. Rainbow fry made up the majority of the fish salvaged; coho made up most of the remainder; and Chinook numbers were minimal. Table 16 summarizes the number of fish salvaged by date, type of activity (e.g. incidental "push" or active salvage), species and reach. In total, approximately 5,400 fish were salvaged during all the rampdown events. This is comparable to the average number of fish salvaged during Trial 2 (Sneep 2016, McHugh and Soverel 2015, McHugh and Soverel 2014). Fish that were still in wetted habitat but were isolated from the main channel made up about 50% of all salvage types, with the majority of the remaining proportion being incidental capture (fish were occupying habitat that was still connected to the main flow, and were "pushed" or encouraged to vacate habitat areas that would isolate or dewater as the rampdown continued). Very few fish mortalities were observed (15), and even fewer (14) were found stranded in dewatered habitat.

Table 15: Number of fish salvaged in reach 3 and 4, by species for each day of the rampdown, July, August and September, 2015

Species	Jul 29	Jul 30	Aug 11	Aug 12	Aug 13	Aug 18	Aug 19	Aug 20	Sep 29	Sep 30	Total
Reaches 3, 4											
Chinook	1	1	1	2	3	2	5	1	12	3	31
Coho	177	151	139	134	246	120	300	70	215	140	1692
Steelhead/RB	298	264	153	275	308	355	573	286	633	539	3684
Bull Trout					1						1
Red Sided Shiner		2									2
Total	476	418	293	411	558	477	878	357	860	682	5410

Table 16: Number of fish salvaged by reach, species and salvage category, July, August and September, 2015

Month	Reach	Species	Incidental	Isolated	Mortality	Stranded	Total
July	3	Bull Trout	–	–	–	–	0
		Chinook	–	1	–	–	1
		Coho	11	30	–	–	41
		Stteelhead/RB	17	124	–	–	141
		Red Sided Shiner	–	–	–	–	–
	4	Bull Trout	–	–	–	–	0
		Chinook	1	–	–	–	1
		Coho	116	170	–	1	287
		Stteelhead/RB	60	359	–	2	421
		Red Sided Shiner	2	–	–	–	2
August	3	Bull Trout		1	–	–	1
		Chinook	7	–	–	–	7
		Coho	339	204	–	–	543
		Stteelhead/RB	724	487	–	4	1215
		Red Sided Shiner	–	–	–	–	0
	4	Bull Trout	–	–	–	–	0
		Chinook	6	1	–	–	7
		Coho	329	125	7	5	466
		Stteelhead/RB	462	264	7	2	735
		Red Sided Shiner	–	–	–	–	0
September	3	Bull Trout	–	–	–	–	0
		Chinook	3	1	–	–	4
		Coho	55	123	–	–	178
		Stteelhead/RB	89	308	–	–	397
		Red Sided Shiner	–	–	–	–	0
	4	Bull Trout	–	–	–	–	0
		Chinook	3	8	–	–	11
		Coho	97	80	–	–	177
		Stteelhead/RB	489	285	1	–	775
		Red Sided Shiner	–	–	–	–	0

4.0 DISCUSSION

4.1.1 *Answering the Management Questions and Current Challenges*

This report summarized data collected in Year 4 (2015) for BRGMON-1 in the Bridge-Seton WUP. It also presents data from previous years and compares and contrasts data from separate trials wherever this is feasible. Data from this report will help to inform flow management decisions in the LBR.

The management questions, listed below, drive the program. They are intended to directly describe and reduce uncertainties about the effects of flow on the LBR aquatic ecosystem:

1) How does the in-stream flow regime alter the physical conditions in aquatic and riparian habitats of the Lower Bridge River ecosystem?
2) How do differences in physical conditions in aquatic habitat resulting from the in-stream flow regime influence community composition and productivity of primary and secondary producers in the Lower Bridge River?
3) How do changes in physical conditions and trophic productivity resulting from flow changes together influence the recruitment of fish populations in the Lower Bridge River?
4) What is the appropriate 'shape' of the descending limb of the 6 m^3s^{-1} hydrograph, particularly from 15 m^3s^{-1} to 3 m^3s^{-1}?

Due to the nature of an adaptive management program such as the LBR and the importance of integrating new knowledge and information into assessments as time progresses, it is important to annually evaluate if the program is on track to answering these questions and address any challenges. Towards this effort, the discussion below attempts to summarize how the flow regime influenced the physical conditions and habitat, the primary and secondary benthic invertebrate response, and ultimately how these factors influenced the recruitment of juvenile fish populations in the LBR.

4.2 Question 1: How does the instream flow regime alter the physical conditions in aquatic and riparian habitats of the Lower Bridge River ecosystem?

4.2.1 *Thermal Regime*

Throughout 2015, Trial 1 and Trial 2, spring and fall temperatures were distinctly warmer, and summer temperatures were consistently cooler than observed in the Pre-Flow data. These effects were strongest in the upper reaches (Reach 3 and 4) and weakest in Reach 2, reflecting the primary influence of the hypolimnetic flow from the Low Level Outlet Gates of Terzaghi Dam. During higher flow periods in both Trial 1 and Trial 2, effects extended further downstream. The unregulated, Yalakom River flow helped buffer the impacts of the hypolimnetic flow release on the aquatic ecosystem during WUP flows, and aided in thermal recovery and mitigation of impacts, particularly in Reach 2.

Thermal regimes have distinct ecological relevance and differ in their variability, predictability of annual temperatures and monthly temperatures, and thermal events (the magnitude, frequency, duration time and rate of change in event). Fish and invertebrates are influenced by individual and interactive effects of flow and thermal modification (Olden and Naiman 2010) and depend on certain temperatures as environmental cues to complete their life cycle. In addition to physiological responses, behavioral responses have also been observed in other river systems. At elevated temperatures, Kuehne et al. (2012) found multiple and cumulative stressors changed juvenile behavior and these responses ultimately influenced development and reproduction, and the overall growth of organisms within the aquatic community. In the LBR, increased fall temperatures of approximately 2 - 6 C° relative to the Pre-Flow baseline influenced the reproduction of Chinook over 2015, Trial 1 and Trial 2, and caused accelerated egg development and early emergence of fry during the winter months. Survival of fry that emerged early was likely low, particularly in reaches 3 and 4. A more natural thermal regime would mitigate this issue. This could potentially be achieved by a reduction in fall and winter flows from Terzaghi Dam, or dam modifications that would facilitate releasing water with cooler temperatures. The elevated temperatures may not have accelerated coho egg development, but this requires more data to reduce this uncertainty.

Temperature data show that the program is on track to answering the management question. More data under higher flows in 2016 will provide further resolution of trends during high flows to help answer this question.

4.2.2 *Changes to Aquatic Habitat Depending on flow*

The largest benefits to aquatic habitat since the implementation of flow trials has been the rewetting of reach 4 and increasing the wetted widths in reach 2 and 3. Higher flows in 2015 and in Trial 2 increased the amount of wetted area in the LBR; however, results indicated that cascade/rapid habitat made up a greater relative proportion of the habitat throughout reaches 2, 3 and 4. This may have reduced the availability and suitability of rearing habitat as flow velocities may have increased to above optimal thresholds throughout the reaches. In summary, increased velocity during high flows may have impacted juvenile fish behavior, migration or movement patterns and may help explain the decline in fish abundance and biomass observed across the reaches in 2015.

Data from this monitoring component currently aid in the understanding of how different flows influence aquatic habitat characteristics. To further answer this management question, future years of data collection would benefit from focusing on the habitat suitability during flows equal to or greater than 15 m^3s^{-1}, and validating and refining the predicted flow thresholds for rearing habitat.

4.3 **Question 2: How do differences in physical conditions in aquatic habitat resulting from the in-stream flow regime influence community composition and productivity of primary and secondary producers in the Lower Bridge River?**

4.3.1 *Primary producers' conclusion*

Periphyton accrual rates were similar between 2015, Trials 1 and 2. Differences in trends appear to be more closely associated with deposition and accumulation of nutrients from pink salmon spawning years in pink (odd years) and non-pink (even years) than flow regime. This natural trend may influence the availability of nutrients for juvenile growth.

4.3.2 *Secondary producers' conclusion*

The rewetting of Reach 4 significantly benefited the benthic invertebrate community in general by increasing total abundance and diversity within reaches 2, 3 and 4 of the LBR. During Trials 1 and 2, no significant differences were observed in response to flow changes. Abundance and diversity remained high in the invertebrate communities in 2015, but higher flows under Trial 2 did not significantly increase the benthic invertebrate community abundance, or benefit the community composition.

Data from these monitoring components show that the program is on track to answering this management question. However continued monitoring is recommended to improve resolution at the high flows.

4.4 Question 3: How do changes in physical conditions and trophic productivity resulting from flow changes together influence the recruitment of fish populations in the Lower Bridge River?

Juvenile fish productivity increased by greater than 100,000 fish across Trial 1 and Trial 2, relative to the Pre-Flow period. This was mainly attributed to continuously wetting all of Reach 4 and increasing the wetted widths in reaches 2 and 3. In general, productivity changes in Trial 1 were similar to Trial 2. In other words, increases in flows under Trial 2 did not provide any additional benefit for juvenile production. Rainbow and coho fry both benefited significantly from the flow release in Trial 1 and Trial 2. In contrast, Chinook production declined after the initiation of flow in 2000 and estimates were low, but similar across Trial 1 and Trial 2.

Total estimates of abundance and biomass of juvenile fish populations during high flows in 2015 were the lowest recorded since the initiation of Terzaghi Dam flow release in 2000. In 2015, rainbow fry and coho fry abundance and biomass estimates were among the lowest recorded values since the start of Trial 1. Chinook fry populations remained low, but stable. The most notable patterns were observed (according to species) in reaches 3 and 4, which suggested that the higher peak flows in 2015 may have been a driving factor of the low estimates.

While the long-term impact of high flows on fish productivity is uncertain at this time, several flow-related factors related to the spill event in 2015 potentially contributed to the decline in abundance and biomass within the study area. They included, but were not limited to: 1) juvenile fish were displaced from their normal habitat downstream; 2) velocities within the cascade/rapid habitat type during the June and July spill event likely limited rearing habitat availability and use; 3) unknown stranding risk throughout the LBR may have caused fish mortality in areas not actively monitored during stage fluctuations immediately following the Terzaghi Dam LLOG malfunctions, as well as through fish salvage operations; and 4) successful reproduction for rainbow trout and steelhead was potentially impeded by factors including migration challenges or habitat availability for spawners during high flows, or potential redd disturbance (scouring, smothering, or dewatering during high flows and subsequent stage fluctuations and reduction). Additional factors unrelated to higher flows from Terzaghi Dam, such as a change in adult stock recruitment (spawner numbers across species) in the LBR, or elevated water temperatures during the fall and winter egg incubation period also influenced juvenile fish populations. More years of data collection under higher flows as well as the collection of annual adult escapement data under BRGMON-3 will reduce this uncertainty.

Data demonstrate the program is on track to answering this management question. Since the abundance and biomass of coho fry and rainbow fry were reduced following increased peak flows in 2015, the relationship between higher flows and juvenile salmon production should continue to be monitored in the LBR. The adaptive management of the LBR would also benefit from more refined information regarding the relationship between optimal flow thresholds and 1) rearing habitat quantity and quality, and 2) substrate movement, egg development and emergence timing.

4.5 Question 4: What is the appropriate 'shape' of the descending limb of the 6 $m^3 \cdot s^{-1}$ hydrograph, particularly from 15 $m^3 \cdot s^{-1}$ to 3 $m^3 \cdot s^{-1}$?

The LBR Fish Stranding Protocol (Sneep, 2016) was effective in guiding the overall strategy and facilitating the rampdown in 2015 in Reach 3 and 4, and mainly on river left. Fish salvage site results from 2015 illustrated the dynamic nature of the riverbed following high flows; new sites were actively salvaged, where historical salvage was not conducted and stranding was not observed. Flow ranges associated with the lowest fish stranding potential occurred between 11 and 9 $m^3 \cdot s^{-1}$. Based on available data, Sneep (2016) determined that at flows below 9 $m^3 \cdot s^{-1}$, the fish stranding impact increased and remained high for each subsequent ramping step (Sneep 2016). Data from 2015 support these conclusions, however in 2015, stranding risk was also elevated from 20.7 $m^3 \cdot s^{-1}$ to 11 $m^3 \cdot s^{-1}$. The data show that the program is on track to answering this management question, in the specific and limited geographic area that is the current focus of the protocol. However continued monitoring is recommended to improve resolution of savage results at high flows and expand the geographic focus of the salvage effort.

4.5.1 *Future Research and Monitoring*

Ecosystems are complex, and have multiple interactive and cumulative factors and linkages. Adaptive management success is predicated on being able to accurately predict the response of the aquatic ecosystem to flow changes, and then acting on that information. This report provides information regarding the predicted and observed benefits and ecosystem response to the instream flow release. However, uncertainties still confound questions regarding the long-term ecological benefits and costs from the release of instream flow from Carpenter Reservoir, and the effects on the aquatic productivity of the Lower Bridge River ecosystem. More years of data collection will continue to reduce this uncertainty.

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6.0 APPLICABLE LITERATURE AND IN-TEXT CITATIONS

Angilletta, M., Steel, A., Bartz, K., Kingsolver, J., Scheuerell, M., Beckman, B., and L. Crozier. (2008). Big dams and salmon evolution: changes in thermal regimes and their potential evolutionary consequences. Evolutionary Applications. 2008: 286-299.

BC Hydro. (2011). Bridge River Power Development Water Use Plan; Revised for Acceptance for the Comptroller of Water Rights, March 17, 2011.

BC Hydro. (2012). Bridge-Seton Water Use Plan, Monitoring Program Terms of Reference, BRGMON-1 Lower Bridge River Aquatic Monitoring. Website: https://www.bchydro.com/content/dam/hydro/medialib/internet/documents/planning_regulatory/wup/lower_mainland/2012q2/brgmon-1_tor_2012-01-23.pdf (Last accessed: May, 2016).

Bradford, M.J. and Taylor, G.D. (1997). Individual variation in dispersal behaviour of newly emerged Chinook salmon (*Oncorhynchus tshawytscha*) from the Upper Fraser River, British Columbia. Can. J. Fish. Aquat. Sci. 54: 1585-1592.

Bradford, M.J. and P.S. Higgins. (2001). Habitat-, season-, and size-specific variation in diel activity patterns of juvenile Chinook salmon (*Oncorhynchus tsawytscha)* ans steelhead trout (*Oncorhynchus mykiss)*. Can. J. Fish. Aquat. Sci. 58: 365 -374.

Bradford, M.J., Higgins, P., Korman, J., and J. Sneep. (2011). Test of an environmental flow release in a British Columbia River: does more water mean more fish? Freshwater Biology. 1-16.

Clark, A., King, N., and K. Telmer. (2014). Use of otolith microchemistry to examine Chinook salmon life-history in the Lower Bridge River. Bridge Seton Water Use Plan. Prepared for Coldstream Ecology, Ltd., St'at'imc Eco Resources, Ltd. and BC Hydro for submission to the Deputy Comptroller of Water Rights, August 2013.

Connor, W. P. and H. L. Burge. (2003). Influence of Flow and Temperature on Survival of Wild Subyearling Fall Chinook Salmon in the Snake River. North American Journal of Fisheries Management. 23: 362-375.

Crane Creek Enterprises. (2012). Lower Bridge River 2011 Flow Ramping Report. Draft report prepared for BC Hydro, Bridge River Generation. 25 p. + 2 app.

Decker, S., Bradford, M., and P. Higgins. (2008). Rate of biotic colonization following flow restoration below a diversion dam in the Bridge River, British Columbia. River. Res. Applic. 24: 876-883.

ESRI. (2015). ESRI ArcMap 10.3.1. http://www.esri/com

Failing, L., Horn, G, and P. Higgins. (2004). Using expert judgment and stakeholder values to evaluate adaptive management options. Ecology and Society. 9(1): 13.

Failing, L. R. Gregory, and P. Higgins. (2013). Science, uncertainty, and values in ecological restoration: a case study in structured decision-making and adaptive management. Restoration Ecology. 21(4): 422-430.

Geist, D. R., Abernethy, S., Hand, K., Cullinan, V., Chandler, J., and P. Groves. (2006). Surivival, development and growth of fall Chinook salmon embyos, alevins, and fry exposed to variable thermal and dissolved oxygen regimes. Transactions of the American Fisheries Society 135:1462-1477.

Golder Associates Ltd. (2010). Upper Duncan Bull Trout Migration Monitoring--Final Report March 2010. Report Prepared for BC Hydro, Castlegar BC. Golder Report No. 09-1480-0051: 49 p. + 8 app.

Higgins P. and J. Korman. (2000). Abundance, growth, standing stock, and components of variation of juvenile salmonids in the Bridge River: An analysis to define ‘baseline conditions’ and optimal sampling design. B.C. Hydro Power Supply Environment Burnaby, B.C.

Kennedy, I.D. and R. Bouchard. (1992). Stl’atl’imx (Fraser River Lillooet) Fishing. A complex culture of the British Columbia Plateau. Traditional Stl’atl’imx Resource Use. UBC Press p 266-354.

Instrumentation Northwest. http://inwusa.com/#&panel1-3 (website last accessed: July, 2016)

Korman, Josh. (2017). Population Estimates 1996 – 2016. Unpublished briefing and data compilation prepared for BRGMON-1 of the Bridge-Seton WUP, April 2017.

Kuehne, L. M., Olden, J, and J. Duda (2012). Costs of living for juvenile Chinook salmon (*Oncorhynchus tshawytscha*) in an increasingly warming and invaded world. Canadian Journal of Fisheries and Aquatic Sciences, 2012, 69 (10): 1621-1630.

Longe, R., and P. Higgins. (2002). Lower Bridge River Aquatic Monitoring: Year 2001 Data Report. Unpublished report prepared for the Deputy Comptroller of Water Rights, April 2002.

Maloney, K.O., Talbert, C.B., Cole, J.C., Galbraith, H.S., Blakeslee, C.J., Hanson, L., and C.L. Holmquist-Johnson. (2015). Fundamental and Applied Limnology, Volume 186: 171-192.

Martins, E. (2017). Bridge River salmon productivity. Unpublished briefing prepared by BC Hydro for the Technical Scientific Committee as part of the Bridge-Seton Water Operations Group, May 2017.

McHugh, A.E., and D. O'Farrell. 2017. Applepsrings Effectiveness Monitoring Program. Project No. COA-F17-F-1354. Prepared for the Fish and Wildlife Compensation Program. March 2017.

McHugh, A. and N. O. Soverel. (2013). Lower Bridge River Aquatic Monitoring. Year 2012 Data Report. Bridge Seton Water Use Plan. Prepared for St'at'imc EcoResources, Ltd. and BC Hydro for submission to the Deputy Comptroller of Water Rights, August 2013.

McHugh, A. and N.O. Soverel. (2014). Lower Bridge River Aquatic Monitoring. Year 2013 Data Report. Bridge Seton Water Use Plan. Prepared for St'át'imc EcoResources, Ltd. and BC Hydro for submission to the Deputy Comptroller of Water Rights, August 2014.

McHugh, A. and N.O. Soverel. (2015a). Lower Bridge River Aquatic Monitoring. Year 2014 Data Report. Bridge Seton Water Use Plan. Prepared for St'át'imc EcoResources, Ltd. and BC Hydro for submission to the Deputy Comptroller of Water Rights, September 2015.

McHugh, A.E., Soverel, N.O., and G.E. Michel. (2015b). Lower Bridge River Spill Monitoring. 2015 Report Memo. Prepared for St'át'imc Eco Resources, Ltd. and BC Hydro for submission to the Deputy Comptroller of Water Rights, August 2015.

McHugh, A.E., Soverel, N.O., Michel, G.E., and D. O'Farrell. 2017. Selection and prioritization of potential enhancement sites to act as refugia habitat for rearing juvenile salmon at high flows within the Lower Bridge River in 2017. Unpublished report prepared for the St'atimc Nation Subcommittee, January 2017.

McHugh, A.E., Soverel, N.O., and D. O'Farrell. 2017. Lower Bridge River (LBR) Aquatic Monitoring (2016 High Flow). Unpublished report by Coldstream Ecology, Ltd., Lillooet, BC, for BC Hydro Generation, Water License Requirements, Castlegar, BC. 48 pp. + Apps.

Ministry of Environment (2017). British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture, Summary Report. Water Protection & Sustainability Branch, Ministry of Environment, January 2017.

Northwest Hydraulic Consultants (2009). Cheakamus Project Water Use Plan: Cheakamus River Channel Morphology (Year 1) Reference: CMSMON-8.

Olden J., and R. Naiman. (2010). Incorporating thermal regimes into environmental flows assessments: modifying dam operations to restore freshwater ecosystem integrity. Freshwater Biology, 55: 86–107.

Pommen, Nagpal, and Swain. (1995). Approved and Working Criteria for Water Quality – 1995. B.C. Environment – Water Quality Branch.

Riley, S.C., P.S. Higgins, and T. Nevin. (1997). Bridge River stream ecology and stock assessment: 1996 data report. Unpublished report prepared for B.C. Hydro, Strategic Fisheries, Burnaby, B.C.

Riley, S.C., P.S. Higgins, and T. Nevin. (1998). Bridge River stream ecology and stock assessment: 1997 report. Unpublished report prepared for B.C. Hydro, Strategic Fisheries, Burnaby, B.C.

Shrimpton, J.M., K. Rezansoff, K.H. Telmer, G.J. Glova, and N.L. Todd. (2009). Linking Freshwater Migration and Rearing Habitats Through LA-ICPMS of Interior Fraser Chinook and Coho Salmon Juveniles (Year 2). Report prepared for Pacific Salmon Commission. 64 p.

Sneep, Jeff. 2016. Fish Stranding Protocol for BC Hydro's Bridge-Seton Generation Area. Prepared for BC Hydro. March 2016.

Sneep, J. and J. Korman. (In Prep). Draft Lower Bridge River Aquatic Monitoring Program Synthesis Analysis: Study Results from 1996 to 2014. Prepared for St’at’imc Eco-Resources Ltd.

Sneep, Jeff. (2012). Proposal to Provide Biological Services for Monitoring No. BRGMON-1: Lower Bridge River Adaptive Management Program: Aquatic Ecosystem Productivity Monitoring, Study Years 1 to 3. Submitted by: St’át’imc Eco-Resources

Sneep, J. and S. Hall. (2012). Lower Bridge River Aquatic Monitoring: Year 2011 Data Report. Unpublished report prepared for the Deputy Comptroller of Water Rights, August 2012.

Sneep, J. and S. Hall. (2011). Lower Bridge River Aquatic Monitoring: Year 2010 Data Report. Unpublished report prepared for the Deputy Comptroller of Water Rights, August 2011.

Sneep, J., and S. Hall. (2010). Lower Bridge River Aquatic Monitoring: Year 2009 Data Report. Unpublished report prepared for the Deputy Comptroller of Water Rights, August 2010.

Sneep, J., and S. Hall. (2009). Lower Bridge River Aquatic Monitoring: Year 2008 Data Report. Unpublished report prepared for the Deputy Comptroller of Water Rights, July 2009.

Sneep, J., and S. Hall. (2008). Lower Bridge River Aquatic Monitoring: Year 2007 Data Report. Unpublished report prepared for the Deputy Comptroller of Water Rights, July 2008.

Sneep, J., and S. Hall. (2007). Lower Bridge River Aquatic Monitoring: Year 2006 Data Report. Unpublished report prepared for the Deputy Comptroller of Water Rights, July 2007.

Sneep, J., and S. Hall. (2006). Lower Bridge River Aquatic Monitoring: Year 2005 Data Report. Unpublished report prepared for the Deputy Comptroller of Water Rights, July 2006.

Sneep, J., and S. Hall. (2005). Lower Bridge River Aquatic Monitoring: Year 2004 Data Report. Unpublished report prepared for the Deputy Comptroller of Water Rights, May 2005.

Sneep, J., and P.S. Higgins. (2004). Lower Bridge River Aquatic Monitoring: Year 2003 Data Report. Unpublished report prepared for the Deputy Comptroller of Water Rights, April 2004.

Sneep, J., and P.S. Higgins. (2003). Lower Bridge River Aquatic Monitoring: Year 2002 Data Report. Unpublished report prepared for the Deputy Comptroller of Water Rights, April 2003.

Stamford, M. and L. Vidmanic. (2016). Lower Bridge River Fall 2008 through 2015 Benthic Invertebrates: an analysis of temporal and spatial patterns of benthic invertebrate abundance and diversity. Unpublished report prepared for BRGMON-1 of the Bridge-Seton WUP, July 2016.

Stamford, Mike. (2017). Lower Bridge River Benthic Invertebrate Diversity Metrics Summary: Unpublished memo briefing prepared for BRGMON-1 of the Bridge-Seton WUP, July 2017.

Thomson, J.R., Taylor, M.P., Fryirs, K.A., and G.J. Brierley. A geomorphological framework for river characterization and habitat assessment. Aquatic Conservation: Marine and Freshwater Ecosystems, 11: 373-389.

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