Bridge-Seton Water Use Plan

Monitoring Program Terms of Reference

- BRGMON-1 Lower Bridge River Aquatic Monitoring
1 Monitoring Program Rationale

1.1 Background

The lack of continuous flow releases from the Terzaghi Dam into the Lower Bridge River has been a long standing concern of the public, First Nations, and regulatory agencies and the resolution of instream flow management is an important component of the Bridge-Seton Water Use Plan. In 1998, an agreement between BC Hydro and regulatory agencies (associated with litigation regarding 1991-92 dam operations) specified that an instream flow test release and monitoring program be developed and implemented in an attempt to resolve uncertainty about response of the aquatic ecosystem to reservoir releases. The agreement specified that an experimental flow release program was to continue until a Water Use Plan was developed for the Bridge-Seton watershed. Continuous instream flow releases for the purpose of testing the response of the aquatic ecosystem to flow changes were initiated with a water budget of 3 cms on August 1, 2000. Instream flow assessment studies (1993-1995) and baseline ecological monitoring (1996-present) have improved scientific understanding about baseline conditions in the Lower Bridge aquatic ecosystem, however, they have not provided sufficient scientific understanding needed to provide reliable predictions about the impacts of instream flow releases on the productivity of the aquatic or riparian components of the ecosystem. Accordingly, the Bridge-Seton Consultative Committee (BRG WUP CC) and more recent Bridge River Technical Working Group (TWG) recommended that as part of the Water Use Plan the current flow testing program now underway at Terzaghi Dam be continued and expanded to a second flow level to empirically document the response of the ecosystem to instream flow changes in Lower Bridge River.

A long term test flow release program was recommended to empirically measure the environmental benefits that could arise from two alternative instream flow release regimes considered by the Bridge River Technical working group. The flow regimes differ in the relative shape of the delivered hydrograph and the annual water budget delivered (referred to as: 3 cms/y, 6 cms/y treatments). The hydrographs are detailed in the Water Use Plan (dated March 17 2011). The test flow monitoring will be used to evaluate functional relationship between flow release from the dam and key physical and ecological indicator variables. This approach will provide the scientifically defensible data to quantify response of the ecosystem and fish population response to instream flows. The Consultative Committee recommended three general monitoring activities be undertaken: 1) Aquatic Ecosystem Productivity Monitoring; 2) Adult Salmonid Spawning Habitat Monitoring and Population Enumeration; 3) Riparian Vegetation Monitoring. This proposal is addressing required studies for the Aquatic Ecosystem Productivity Monitoring.

The 3 cms/y treatment has been evaluated since 2000. The 6 cms/y treatment commenced 1 May 2011 based on the WUP Water Licence Order issued March 31,
2011. After April 2015, BC Hydro will work with regulatory agencies, St’at’imc and stakeholders to determine a long term flow release strategy for the Terzaghi Dam based upon existing information and data from the flow treatments. A decision on a long term flow release strategy is expected to be complete and implemented by May 1, 2015.

1.2 Management Questions

The fundamental goal of the adaptive management program is to reduce uncertainty about the expected long term ecological benefits from releasing instream flow from Terzaghi Dam, as past studies have been unable to provide scientifically defensible prediction of the ecological benefits of flow releases. This lack of certainty was deemed to be a major impediment for decision making because incorrect decisions about long term flow regime will have significant consequences for the energy production and could have significant consequences to the highly valued ecological resources in Lower Bridge River. The three specifically linked learning objectives identified by the BRG WUP CC for the adaptive management program as the related to understanding the influence of flow regime on aquatic ecosystem productivity are:

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

Changes in the physical conditions regulate the quantity and quality of habitats for aquatic and riparian organisms. Documenting the functional relationships between river flow and physical conditions in the habitat is fundamental for identifying and developing hypotheses about how physical habitat factors regulate, limit or control trophic productivity and influence habitat conditions in the ecosystem.

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

Changes in the flow regime are expected to alter the composition and productivity of periphyton and invertebrate communities. Understanding how these physical changes influence aquatic community structure and productivity are important as they act as indicators to evaluate “ecosystem health” and the trophic status of the aquatic ecosystem in relation to provision of food resources for fish populations.

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

Changes in flow regime can have significant effects on the physical habitat and trophic productivity of the aquatic ecosystem and these two factors are critical determinants of the productive capacity of the aquatic ecosystem for fish. Understanding how instream flow regime influences abundance, growth, physiological condition, behavior, and survival of stream fish populations helps to explain observations of changes in abundance and diversity of stream fish related to flow alteration.

4) What is the appropriate ‘shape’ of the descending limb of the 6 cms hydrograph, particularly from 15 cms to 3 cms?
The 'shape' of the 6 cms hydrograph was developed following the principles (described in Bradford et al. *in press*) of a bottom-up approach to create a down-sized, naturalized hydrograph to meet a range of environmental objectives. The TWG followed a Structured Decision Making process to evaluate alternative 6 cms hydrograph shapes to meet performance measures for: Chinook salmon emergence timing (temperature during egg incubation), fish overwinter habitat, riparian development, risk of redd dewatering or fish stranding, flows during juvenile stock assessment in September, and potential for scour. The selected hydrograph and associated monthly flow targets was top ranked among the alternatives for each of these performance measures.

The exact configuration of the recommended hydrograph was not laid-out in detail by the TWG, other than the monthly flow targets, with the expectation that seasonal adjustments would be worked out prior to and during implementation. A more detailed configuration of the hydrograph, including the transitions between monthly targets, was proposed following and outside of the TWG process. The detailed hydrograph, when it was designed following the TWG process, included relatively rapid transitions between monthly targets (on the order of several days and following the ramping rates) in or around the first day of each month. Subsequently, some TWG members recommended that extending these transitions throughout each month during the descending limb of the hydrograph would better meet the 'naturalized' intent of the hydrograph and hence the environmental performance measures. For instance, the risk of fish stranding during the descending limb of the hydrograph (Aug to Oct) was deemed to be low, based on the conservative ramp-down rates required under the Water Use Plan. As well, the number of fish found to be at risk of stranding during previous ramp-downs (Higgins et al. 1994; Tisdale 2011a, 2011b) relative to known fish abundance estimates from the aquatic monitoring program (e.g., Sneep and Hall 2010, Bradford et al. *in press*) was very small. However, there is some uncertainty as to the risk of fish stranding given the relative magnitude of ramp-downs in the monthly transitions under the detailed hydrograph. In addition, while the risk of fish stranding between 8.5 and 2 cms has been documented (Tisdale 2011a, 2011b) there was limited existing information on fish stranding in the discharge range from (15 cms to 8.5 cms) and the types of habitats in this flow range. Some risk of fish stranding in this flow range was documented during a ramp-down in Aug 1992 (see Fig. 2 in Higgins and Bradford 1996). Additional information on will be available once the assessment of the 2011 ramp down is complete (Sneep and Hall in prep).

1.3 Detailed Hypotheses about the Impacts of Carpenter Reservoir Releases on the Lower Bridge River Ecosystem

Juvenile salmonid biomass was selected as a primary measure to assess the productivity of the aquatic ecosystem because it serves as a measure that integrates the effects of flow on the trophic productivity and habitat conditions in the Lower Bridge River ecosystem and reflects a highly valued ecological component. Two competing hypotheses about the effects of flow on the fish populations in Lower Bridge River have been developed:

Ho: “High flow is better”

H_A: “Low flow is better”
Both hypotheses are cast in terms of the effects of flow on the overall quality and quantity of fish habitat and each acknowledges significant gain in wetted habitat area will be obtained from rewatering of the 4 km long reach immediately below Terzaghi Dam that is usually dry. The hypotheses differ on how increased flow will impact habitat quality in the rest of the river and ultimately how fish populations will respond to altered habitat conditions. The null hypothesis (Ho) reflects the view that higher flow will provide a greater quantity of wetted channel area, and will not reduce the quality of juvenile rearing habitats. Higher flows are believed to have additional benefits for cueing migrations of anadromous fish, provide increase opportunities for spawning, and providing some habitat maintenance functions such as scouring fine sediments from riffles. The alternative hypothesis (H_a) reflects a view that lower flow releases (i.e., <3 cms/y water budget) from the dam will optimize fish production because gain in wetted habitat area is made through the rewatering of the reach immediately below the dam without appreciable reduction in habitat quality in the other reaches of the river. The experimental flow testing program was recommended to test the hypotheses and give more certain estimates of the biological benefits

1.4 Key Water Use Decision Affected

The key water use plan decision affected by this result of the monitoring program is the magnitude of the long term flow release regime from Carpenter Reservoir into the Lower Bridge River. This decision has implications that are significant for ecological as well as power generating values in the Bridge-Seton system. The Lower Bridge River is viewed as an important fish (salmon and steelhead) producing stream, and the opportunities to enhance productivity in this river are highly valued. On the other hand, the cost of releasing water at LBR is relatively high and the financial costs of incorrectly assuming a strongly positive fish response to higher flows could be high. The results from the program are to provide scientifically defensible information needed to reliably arbitrate between the completing hypotheses described above and aid in the selection of long term flow regime for the river. Results of this assessment will inform decisions on the appropriate ‘shape’ of the descending limb of the 6 cms hydrograph, particularly from 15 cms to 3 cms.

2 Monitoring Program Proposal

2.1 Objective and Scope

The objective of the test flow program is 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. The objective of the Aquatic Ecosystem Monitoring Program is to provide comprehensive documentation of the response of key physical and biological indicators to alternative flow regimes to better inform decision on the long term flow regime for 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.

The objectives of the ramp-down assessment are to reduce uncertainty about the effect of the 15 cms to 3 cms ramp-down on the aquatic productivity of the lower Bridge River and complement the information collected under other components of this program. The
scope of the ramp down assessment is limited to the 15 cms to 3 cms ramp-down and within the primary zone of influence of Terzaghi flow releases: from the Terzaghi Dam to the confluence with the Yalakom River. In addition, known off-channel habitats a short distance downstream of the Yalakom confluence near the Horseshoe Bend will be surveyed at a lower level of intensity (since these habitats are influenced by the natural hydrology and receding flows from the Yalakom River). The assessment will focus habitats with higher potential stranding risk, such as the de-watering of habitats isolated from the main channel (pothole or side-channel entrapment stranding\textsuperscript{1}, as per Higgins and Bradford 1996).

2.2 Approach

The approach to the Lower Bridge River Aquatic Monitoring program will be to follow the standardized protocols for ecological sampling and data collection established and refined during its implementation of monitoring in Lower Bridge River from 1996 through to 2011. The approach for the rampdown assessment will be to follow the general protocols for ramp down assessments in other WLR programs (e.g., Coquitlam #2 Anon 2006; Puntledge #4 Anon 2005), and that implemented on the Lower Bridge River in 2011. These include stage and discharge monitoring, establishing index sites that have higher potential stranding risk, and carrying-out ramp-down assessments at these sites during key stage changes.

2.3 Methods

2.3.1 Task 1 Project Coordination

Project coordination involves the general administrative and technical oversight of the program. This will include but not be limited to: 1) budget management, 2) staff selection, 3) logistic coordination, 4) technical oversight in field and analysis components; and 5) liaison with regulatory and first nations groups.

2.3.2 Task 2 Field Sampling

The proposed aquatic ecology monitoring program follows the methods and protocol established during the implementation of Lower Bridge River Aquatic Ecology Monitoring implemented during the baseflow evaluation period (1996-2000) and the initiation of the 3 cms/y flow treatment during 2000-2010. Below is a brief description of each component of the field monitoring program. Also refer to Table 1 for information about sampling frequency and location.

\textit{Ecology Sampling: Nutrients and Water Quality}

At seven monitoring locations, the six tributaries to the river (Mission, Yankee, Hell, Russell, Michelmoon, Yalakom, Antoine) and in Carpenter Lake Reservoir near to the dam water samples and in situ measurement of pH, conductivity and temperature will be

\textsuperscript{1} “Pothole or side-channel entrapment stranding occurs when surface flow is cut off from the main channel and fish become trapped within an impoundment formed by a depression on the floodplain or within side-channel areas.” Higgins and Bradford (1996)
collected in September and November. Water samples will be analyzed to estimate total
dissolve phosphorous, total phosphorous, soluble reactive phosphorous, nitrate, nitrite,
ammonium and total alkalinity. The methodology employed for water sampling, as well
as techniques used for laboratory analysis of nutrients are described by Riley et al.
(1997). To ensure consistency the DFO Cultus Lake Laboratory will process all nutrient
samples based on ongoing collaborative agreement with BC Hydro.

Water and sediment sample collection may be required to support BRGMON-9 Metals
and Contaminants. A detailed sampling design and sampling protocols will be provided
BRGMON-12.

Ecology Sampling: Primary Productivity

To provide an index of primary productivity, the accrual of periphyton will be measured at
seven monitoring locations three artificial samplers will be installed in the river to
estimate periphyton accrual. At each site, three stations located approximately 20
meters apart provided sample replication for periphyton data. One foot square Styrofoam
samplers will be sampled on 7 day intervals for each 6-8 week long series conducted
during Fall (~September 1 - ~November 1). Chlorophyll concentration will be used to
index primary productivity. At the end of each series samples will be taken and
preserved for quantitative analyses of periphyton community species composition and
cell counts per unit area.

Ecology Sampling: Secondary Productivity

To provide an index of secondary productivity benthic invertebrate density will be
estimated at each monitoring site by the placement of three gravel filled colonization
baskets at each monitoring site during the fall (~September 1 - ~November 1). At each
site, three stations located approximately 20 meters apart provided sample replication
for invertebrate data.

Fish Species Composition, Growth and Abundance

Fish growth rate is a key requirement of the monitoring programs, as it provides a
measure to integrate many factors that control relative quality of conditions that the fish
is living. Juvenile fish will be collected at monthly intervals from each of the seven
sampling locations using electrofishing to track season patterns of size in different parts
of the river. Approximately 50-100 fish of each species age class present at each site will
be collected, measured for length and weight and immediately returned to the point of
collection. All sampling will occur outside of the general boundaries (i.e., 100 m section
of river) of each of the monitoring sites.

Non-lethal biopsy will be obtained from a sub-sample of these fish to support
investigations under BRGMON-12 Metals and Contaminants. A detailed sampling design
and sampling protocols will be provided BRGMON-12.

Fall Standing Stock Assessment

Fall standing stock has been conducted in Bridge River in 1993, 1994, and 1996 - 2011.
These data represent the most complete systematically collected database to quantify
the abundance of stream salmonids before the test flow release and have apriori identified as the key measurement variable for judging ecosystem response to the proposed flow treatments. To assess relative changes in fish productivity we propose to repeat the 50 site standing stock program following the protocol first established in 1993 and then followed by BC Hydro in 1996-present to allow a before-after comparison of the relative abundance/biomass of fish in the study area. Four pass closed section sampling is employed to derive depletion type population estimates by species and age class. All fish captured are weighed and measured and then returned to the stream at the point of capture after completing the site.

**Physical sampling: Discharge, Stage, Photographs, Habitat Inventory and Temperature**

Continuous measurements of physical habitat parameters will be implemented. Discharge will be monitored by continuous recording pressure sensors at the Camoo Creek Bridge (km ~20) lower spawning platforms (km ~25) and at the point 50 m downstream of where groundwater enters the channel (km 36.8). Temperature will be monitored by pressure transducer recorders at eight locations (mainstem monitoring sites + Yalakom River) and all data recorders will be downloaded at 3 to 4 month intervals. Reference photographs of the river will be taken at each flow stage (~monthly) at established photopoints each year.

To support the analysis of otolith microchemistry (task below), water chemistry (metals) will be collected seasonally for two years. Water chemistry will be collected with sufficient spatial resolution to quantify juvenile Chinook rearing habitats, and would include all 4 reaches of the Bridge River, major tributaries, and the Fraser River near the Bridge River confluence.

Following the methods described in Riley et al (1997, 1998) and Higgins (2001) field surveys will be conducted to capture habitat inventory data at each flow level within each water budget treatment (estimated at 2 surveys per year). The objective of the field surveys will be to quantify the area of wetted channel, to determine the relative proportion of riffles, runs, and pools, and to estimate basic hydraulic conditions of habitat in Reach 2, 3 and 4 under the test flow conditions. Similar baseline habitat inventory surveys were under baseline (0 flow) during 1996 and 1997, and conducted for the 3 cms flow regime in 2000 - 2009. These data are needed to draw inferences about the seasonal changes in the wetted area of the aquatic habitats under the proposed 3 cms/y, and 6 cms/y flow treatments.

**Rampdown Assessment**

Ramp-down assessments will occur during each of the site-specific critical discharge ranges, identified during field reconnaissance and information from previous years. The timing of assessments at each site will therefore depend on the ramp-down schedule. Assessments will generally follow previous methods (e.g., Tisdale 2011a) to document physical characteristics of the site, estimate the number of fish in habitats at risk of dewatering, and move fish out of these habitats. Electrofishing is estimated to be the primary fish sampling method employed.
A data collection sheet will be prepared and the following information will be documented:

- Date, time, number and names of personnel, and operation assessed;
- Brief site description (reach, site number, river km, bank location, proximity to landmarks);
- Location in UTM coordinates;
- Estimated dewatered area for the site;
- Fish enumeration by species and size class; and
- Qualitative comments regarding the mechanism for stranding (e.g., pool isolation; high water refugia subsequently dewatered, etc.), and the limitations to the methods employed.

**Chinook Salmon Life History**

Juvenile Chinook salmon undertake seasonal movements and can have diverse life histories (see Bradford and Taylor 1997 for a description for Fraser River tributaries). A better understanding of the life history of juvenile Chinook salmon in the Bridge would help to interpret the time-series of the juvenile abundance. Further, hypothesized flow and temperature mediated changes in juvenile life history may be an important impact of the flow releases, that to date has only been documented indirectly (e.g., under this program, Sneep and Hall 2009). Bradford et al. (2011) state:

“Only for Chinook salmon did juvenile density decrease as predicted by habitat modeling. While the change in physical habitat may have contributed to decreasing Chinook salmon abundance, we believe that the change in the thermal regime could be a contributing factor. As has been observed in other regulated streams in temperate environments, the hypolimnetic release caused water temperatures in the fall months to be 2-3 °C higher than the baseline period over in Reach 3, similar to what has been observed in other regulated systems (Bradford, 1994; Angilletta et al., 2008). In the Bridge River, Chinook salmon spawning occurs in early September, and increased fall temperatures will accelerate the development of eggs and alevins. After the flow release field crews began to observe newly emerged fry in December during electrofishing surveys conducted in Reaches 3 and 4, whereas prior to 2000 the first fry were observed in March (JS, unpublished data). Survival of fry that emerge in mid-winter may be poor and could be a contributing factor to the low abundance of juveniles in our surveys. While changes in stream temperatures after the flow release were predicted for the Bridge River (Failing et al., 2004), the impact on emergence timing was not considered in the design of the winter flow regime. The temperature effect can be mitigated by reducing fall flows, as low air temperatures will cool the river at this time of year. A variety of engineering solutions are also potentially available (Olden & Naiman 2010).”

The early life history and dispersal of Chinook salmon from the Bridge River will be examined using otolith microchemistry. This approach has been used to identify the rearing locations and movements of juvenile Chinook salmon in nearby watersheds (Shrimpton et al. 2009; see also Bacon et al. 2011 for another example for Chinook salmon). A model to discriminate the rearing habitats inhabited during the juvenile phase
will be developed using otoliths of juvenile and adult Chinook salmon, and water chemistry (similar to Golder and Associates 2010). Further, some portion of the Chinook salmon that emerge from the Bridge River will likely rear in the Fraser River, based on similar life history patterns documented for Chinook salmon from other Fraser River tributaries (Bradford 1994, Mike Bradford, pers. Comm.). Therefore, some water chemistry and otoliths from juvenile Chinook salmon will also be collected in the Fraser River, in proximity to the Bridge River confluence.

Otoliths from juvenile Chinook salmon will be collected under the Fish Species Composition, Growth and Abundance and Fall Standing Stock Assessment task (above), using a reach- and size-stratified design for all four reaches of the lower Bridge River. Additional juveniles will be collected from the Fraser River, in proximity to the confluence of the Bridge River. Field crews from the Lower Bridge River Adult Salmon and Steelhead Enumeration program (BRGMON-3) will collect otoliths from Chinook salmon carcasses, following a reach- and fish size- (age) stratified design. Otoliths from adults will be collected for first 5 years in order to sample adults returns that incubated and reared under the 3 cms / y and 6 cms / y regimes, and the natural variation in water temperature across those years. Concurrent water chemistry samples will be collected using a reach- and season-stratified design from the lower Bridge River and Fraser River.

**2.3.3 Task 3 Reporting**

Data will be managed in the Access database that has been developed for this program. A detailed technical report will be prepared annually that outlines the findings from the program as they relate to the primary components described above. A synthesis report will be prepared prior to the flow decision in 2015.

**2.4 Schedule**

The program will be implemented each year during the experimental flow release program. The seasonal timing of the proposed components of the work is presented in Table 1 below.

**2.5 Interpretation of Monitoring Program Results**

The overall strategy of the Aquatic Ecosystem Monitoring Program is collect the data needed to make a scientifically defensible linkage between key physical habitat changes, changes in aquatic productivity (i.e., primary and secondary productivity), and to link both of those to impacts to response of fish populations. The approach for interpreting the monitoring program is to use juvenile salmonid biomass as the leading indicator of the influence of flow on aquatic productivity to accept or refute the null hypotheses associated with the influence of dam releases on aquatic productivity. Because past sampling has involved use of index locations that are sampled each year it is proposed that a repeated measure design using a 3 factorial mixed-model Analysis of Variance be used. The form of the proposed statistical model is:

\[ F_{ij} = \mu + T + S_l + Y_i(T) + e_{ij}, \]
where, $F_{ij}$ = standing crop biomass in year $i$ at site $j$; $\mu$ is the mean density; $T_i$ is the treatment coefficient, $T$ is the fixed treatment effect (dam release), and $Y_i$ and $S_j$ are random year and site effects, respectively. Statistical power analysis was conducted to examine the power of statistical model under different sampling designs (Higgins et al. 1999). These analysis suggested that the experiment, under the observed levels of natural variation and measurement precision will provide a 50% (worst case) to 75% (best case) probability of correctly detecting statistical differences in standing crop biomass between the proposed flow treatments under the originally proposed experimental design of the adaptive management program (4 treatments each conducted for four years).

A hierarchical Bayesian model has been developed to estimate reach-wide estimates of standing crop and account for differences in catchability among flow treatments (see Bradford et al. 2011). This model will be used to estimate reach-wide standing crop.

Results from the rampdown assessment will be interpreted in the context of the standing crop estimates to understand the effects of the rampdown.

Additional inferential power will be achieved by analysis of the information provided by the adult escapement (BRGMON-3). The key interpretation of the adult escapement results will occur under this program, to address the Management Questions and associated Hypotheses. Since the true capacity of the rearing environment is not known, adult escapement data will be used to support professional judgments about the level of seeding that has been achieved in each year. In addition to experience from other river systems, this professional judgment will rely in using site specific auxiliary data collected in the Bridge River about juvenile salmonid abundance, growth rate and condition to support conclusions about this issue.

Additional inferential power will be achieved by analysis of secondary indicators and physical habitat data. Monitoring data will be used to identify key linkages between flow magnitude and physical habitat variables, productivity of lower trophic levels (periphyton, benthic food organisms), and fish productivity. Analysis of these relationships should provide deeper understanding of the relative importance of flow on ecological linkages, and where statistical inferences are weak, can be used to help support interpretation of the results.

2.6 Schedule

The program will be implemented each year during the experimental flow release program. The seasonal timing for each task is detailed in the methods section.

2.7 Budget

Total Program Cost: $2,033,317.
3 References Cited


