Campbell River Water Use Plan

Monitoring Program Terms of Reference

- **JHTMON- 8 Quinsam and Salmon River Smolt and Spawner Abundance Assessments**

September 20, 2013

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1 Program Rationale

1.1 Background

A key question throughout the Water Use Plan (WUP) process has been "what exactly limits fish abundance?" For example, is fish abundance and biomass limited by amount of available habitat (i.e., rearing, spawning, holding, etc.), food (e.g., invertebrate abundance), environmental perturbations (e.g., flood events) or ecological interactions (e.g., predation and competition)? There is no reason to expect that answers will be similar for the different stream components of the Campbell River system, particularly in terms of operational impacts. However, due to time constraints and the paucity of available information, the Fish Technical Committee (FTC) evaluated the impacts of BC Hydro operations based on habitat availability alone (Figure 8.1). As a result, there is a high degree of uncertainty surrounding the expected benefits to fish from WUP-based operations.

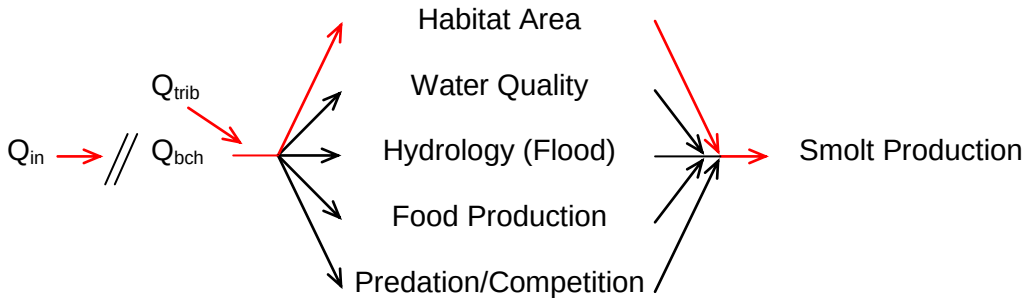

Figure 8.1 Influence-diagram showing the conceptual pathways of BC Hydro operational impacts on smolt production in Campbell River Project streams. The pathway highlighted in red and the items in bold denote the main impact pathway considered during the WUP process.

Precisely because of this uncertainty, the FTC recommended that an effectiveness-monitoring program be implemented to verify whether fish benefits are being fully realized, and to test whether limits to fish production may be further enhanced through future changes to BC Hydro operations. The primary aim of this Monitor will be to assess population status of stream fish populations, and to test for relationships to specific environmental factors. The factors include water quality, flood-related perturbations and food availability. (Fish population status in relation to habitat area will be measured in Monitors 6 and 5). Detailed impact assessment of predation, competition and other types of environmental perturbations were judge by the FTC to be beyond the scope of the present Monitor, though they will be considered at an anecdotal level.

1.2 Management Questions

This Monitor is designed to address the following three management questions.

1) What are the primary factors that limit fish abundance in the Campbell River system and how are these factors influenced by BC Hydro operations?

The streams of interest in this monitor are the Quinsam, and Salmon Rivers[1].

2) Have WUP-based operations changed the influence of these primary factors on fish abundance, allowing carrying capacity to increase?

   During the WUP process, habitat availability was assumed to be the only factor limiting fish abundance in each of the study streams. Other factors were not considered because there was too little information on their relationship with fish abundance, or how they are impacted by BC Hydro operations. As a result, the expected fish benefits arising from what are believed to be improved habitat conditions may not fully occur because other factors mask the response.

3) If the expected gains in fish abundance have not been fully realized, what factors if any are masking the response and are they influenced by BC Hydro operations?

   This analysis may lead to the development of alternative impact hypotheses and performance measures for use in future WUP processes.

1.3 Summary of Impact Hypotheses

The general approach of this Monitor is to first determine whether annual population abundance in each of the study streams (Quinsam River, and Salmon River) has changed through time (the change does not necessarily need to follow a particular trend). If significant changes have been observed through time, then the next step is to determine whether the variability in population abundance can be correlated to variability in environmental factors such as habitat availability, water quality, flood-related perturbations, or changes in food availability/production. The final step in the Monitor will be to confirm that BC Hydro operations, through its impact on discharge, were the primary mechanism of the change in fish abundance. This will require testing the following hypotheses.

$H_0$1: Annual population abundance does not vary with time (i.e., years) over the course of the Monitor.

To test this hypothesis, annual abundance must be accompanied with an estimate of variance, therefore allowing Analysis of Variance (ANOVA) techniques to be used. Failure to reject this hypothesis would suggest that the population has not responded to changes in BC Hydro operations. Rejection of this hypothesis would indicate that there is sufficient inter-annual variance in the abundance data to proceed with further analysis.

Hypothesis $H_0$1 will be tested separately for each study stream, based on the following:

Quinsam River — Population abundance will be reported as a count of outmigrating smolts using the existing Department of Fisheries and Oceans (DFO) fish counting fence at the Quinsam Hatchery. (This fence is currently not in active operation and will require some updating and maintenance.) Species of primary interest include Chinook salmon, coho salmon and steelhead trout. Note that pink smolt outmigration monitoring program has been implemented by DFO

[1] Heber River was originally part of this monitor scope, but since Heber Dam has been decommissioned, it was removed.

over several years (David Ewart pers com.). This data is expected to be made available to this monitoring program by DFO.

Salmon River — Population abundance will be reported as juvenile (fry or parr) abundance estimates at index sites collected by Ministry of Environment (MOE) as part of an ongoing monitor investigating the effects of a stream fertilization program. Species of primary interest include Chinook salmon, coho salmon and steelhead trout

As noted above, rejection of $H_0$1 would indicate sufficient variance in annual abundance to test the next set of hypotheses, testing for correlations with the key environmental parameters noted in Section 1.1;

$H_0$2: Annual population abundance is not correlated with annual habitat availability as measured by Weighted Usable Area (WUA).

The hypothesis will be tested separately for each salmonid species of interest within each study stream. Correlations with habitat availability will be tested at three different life stages (fry, parr, and spawner). WUA data will be collected and summarized as part of Monitors 5 and 11.

$H_0$3: Annual population abundance is not correlated with water quality.

The hypothesis will be tested separately for each salmonid species of interest within each study stream. The water quality parameters of primary interest are water temperature (cumulative thermal units, maximum, minimum and average °C), turbidity (NTU), specific conductance ($\mu S \cdot cm^{-1}$), alkalinity ($mg \cdot L^{-1}$), and phosphorus and nitrogen concentrations ($mg \cdot L^{-1}$).

$H_0$4: Annual population abundance is not correlated with the occurrence of flood events.

The hypothesis will be tested separately for each salmonid species of interest within each study stream. The occurrence of flood events will be quantified in terms of an accumulated flood risk index during the spawning and incubation period.

$H_0$5: Annual population abundance is not correlated with food availability as measured by aquatic invertebrate sampling.

The hypothesis will be tested separately for each salmonid species of interest within each study stream. Invertebrate samples will be collected during the critical summer growth period when salmonid juveniles experience their greatest potential for growth.

For the Quinsam system where escapement and smolt abundance data are collected separately, there is one additional impact hypothesis to be tested;

$H_0$6: Annual smolt abundance is not correlated with the number of adult returns.

Test for this hypothesis should ensure consideration of natural spawn production versus Quinsam Coho outplanting colonization program production to watershed upstream of Lower Quinsam Lake. In some years Chinook are also outplanted to Quinsam River in upstream areas. This hypothesis is a check to determine whether each system was fully seeded and will be carried out for each species of concern. For example, it will be necessary to test whether smolt abundance has responded to BC Hydro

operations, whether it is related to the number of adult spawners, or perhaps both.

It should be noted that the test of these hypotheses will be complicated by a number of factors and will likely require exploratory data analysis, rather than simple tests designed *a priori*. It is likely that a number of potentially confounding variables will require exploration before strong conclusions can be drawn.

1.4 Key Water Use Decision

During the Campbell River WUP, evaluation of alternative operation scenarios relied on the use of performance measures to predict the response of fish (and other resources) to changes in operations, yet the strength of these predictions is unknown. Validation of Performance Measure (PM) predictions is required in order to evaluate the effectiveness of the Campbell River WUP, and to evaluate the reliability of PMs for future assessments of BC Hydro operations.

2 Program Proposal

2.1 Objective and Scope

The objective of this Monitor is to address the management questions presented in Section 1.2 by collecting data necessary to test the impact hypotheses outlined in Section 1.3. The following aspects define the scope of the study:

1) The study area will consist of Quinsam and Salmon Rivers in areas under the influence of BC Hydro operations (downstream of diversion structures).
2) The Monitor will be carried out annually until the next WUP review period (10 years following WUP implementation).
3) Sampling will be carried out in a standardized manner and follow a specified schedule to ensure consistency among years in data quality and collection procedures.
4) A data report will be prepared annually, summarizing the year's findings. All data will be archived according to BC Hydro protocols.
5) An interim summary report will be prepared in Year 5 of the monitor summarizing the data collected to date, discussing inferences and presenting conclusions.
6) A final report will be prepared at the end of the Monitor that summarizes the results of the entire Monitor, discusses inferences that can be drawn pertaining to the impacts of the WUP over time, and presents conclusions concerning the management question in Section 1.2 and the impact hypotheses in Section 1.3.

2.2 Approach

This Monitor has four main components: annual fish population assessments in selected stream sections, annual surveys of water quality and invertebrate abundance, and examination of relationships between fish abundance and physical and biological parameters. These Terms of Reference provides a description of the studies as they are presently conceived, but contractors are encouraged to suggest improvements, provided there is a good rationale for doing so.

1) **Fish population assessments.** Population estimates will be conducted using several techniques. The variable of greatest interest is smolt/junvenile

production. This will be estimated directly in the Quinsam. MOE measured smolt/frey abundance in the Salmon River at several index sites, however. These data are no longer being collected, and hence will be funded through this study, including collation of all historical data. Collectively, these data will be used in this Monitor to assess fish abundance in the Quinsam River and Salmon River.

2) **Water quality monitoring.** Annual monitoring will be completed on the Quinsam River and Salmon River. These surveys will measure physical parameters such as temperature, turbidity, and conductivity, along with spot measurements of alkalinity and nutrients.

3) **Invertebrate sampling.** Annual monitoring will be completed on the Quinsam River and Salmon River. These surveys will measure aquatic invertebrate quantity and community composition, as a direct measure of food availability for juvenile salmonids.

4) **Analyses of abundance patterns.** Detailed analyses will be conducted to see if salmonid abundance patterns are related to physical and biological parameters such as water quality, food availability, habitat availability, and flood patterns. Some of these parameters will be measured as part of this Monitor, whereas others will be extracted from Monitor 6.

2.3 Methods

2.3.1 Data Capture

2.3.1.1 Fish Population Assessments

Fish abundance will be estimated in the Quinsam and Salmon Rivers, using techniques appropriate to each stream. Fish population assessment work already being carried out through funding provided by the MOE in the Salmon River was, at the time of the WUP, considered independent of the WUP. Funding for this program however, has since been cancelled by MOE. This component of the monitor therefore will have to be covered through the present program. Where data collection overlaps or expands on the work already done by MOE, it will be the responsibility of the contractor to contact the principle investigator and field crews of each monitor to collect the information necessary to prepare a detailed description of data collection methods, including the location of study/index sites in each river, the frequency and timing of sampling, an assessment of data consistency in sampling between years and an assessment of the over all quality of the data collected to date.

Quinsam River

Population assessment on the Quinsam River will require upgrading and operating the Quinsam Hatchery counting fence. It is an inclined plane fence with three openings, with traps that operate at 5 to 10% efficiency in its current configuration (D. Ewart, DFO, pers. comm.). The counting fence is currently operable but is not being used every year. Some updating and maintenance will be required both at the start of this project and on an annual basis. The fence currently needs new panels, troughs and traps. The fence will be used to count outmigrating smolts of Chinook, coho, pink and steelhead, and will be operated from March 15 through July 15 (approximately 120 days). All upgrades, maintenance and operations will be done by DFO Quinsam Hatchery staff. Efficiency of the counting fence will have to be

assessed after upgrade work is completed using mark-recapture methods and at least three times per season, using methods approved by DFO staff. As part of their core activities, adult returns to the Quinsam River are estimated annually by DFO at the counting fence.

Salmon River

Population assessment on the Salmon River will utilize data collected by MOE, who have undertaken annual electrofishing studies to assess juvenile abundance at a variety of index sites both above and below the diversion dam. MOE have also conducted occasional snorkel swims to assess adult abundance, but in general, clarity is poor and river conditions are dangerous during times that are appropriate for adult enumeration. As noted above, this work is no longer funded through MOE and will have to be continued as an integral part of the present monitor. DFO also have undertaken Coho Juvenile assessments but funding has been limited. Juvenile assessments are conducted during low water periods in the summer and assess all salmonid species at several index sites – these data have been collected continuously for many years, which will allow comparisons to the pre-WUP implementation period. Juvenile assessments will be combined with adult assessments which were conducted periodically by MOE.

It will be the responsibility of the contractor to contact the principle investigator and field crews of the MOE and DFO population assessment studies to collect the information necessary to:

1) Prepare a detailed description of data collection methods, including the location of study/index sites in each river,
2) The frequency and timing of sampling,
3) An assessment of data consistency in sampling between years, and
4) An assessment of the over all quality of the data collected to date.

For the purposes of the present TOR, a closed-cell, three-pass, multiple-removal procedure using electrofishing gear could be considered as an option. However, the contractor is expected to consult with principal investigators from each agency to ensure that sampling techniques are kept consistent with historical methods used in each stream.

2.3.1.2 Water Quality

A single representative site will be selected on each stream, which will become the site for all measurements of water quality and food availability. These sites will be selected with input from BC Hydro, DFO and MOE, and will consider access, safety and biological conditions. The sites will be briefly described with GPS coordinates and representative photos.

Water quality parameters will be measured in each study stream with either an appropriate monitoring device in situ, or by water sample analysis in a contracting laboratory. The data collected will include: temperature, dissolved oxygen, Ph, conductivity, alkalinity, phosphorus and nitrogen concentrations, total dissolved solids and suspended solids. These samples will be taken in duplicate once a month, at a minimum from May 1 through the end of October, the main growth season of salmonids in these streams. Sampling methods, transportation, and laboratory

analysis will follow standard methods and protocols as directed by the contracting laboratory.

2.3.1.3 Invertebrate Sampling

Macro-invertebrates and their habitats are often considered in instream flow decisions in an effort to preserve food sources for fish, since many fish species depend on drift of invertebrates from upstream areas. Numerous studies have shown changes in invertebrate abundance and distribution in response to flow regulation, although the magnitude of biological response varies among locations and with characteristics of the regulated flow. Taxonomic shifts are common following large changes in flow regime.

Drift samplers will be used to measure density, biomass and invertebrate community composition in the drift. Invertebrate drift peaks at dusk and dawn and is generally higher at night than during the day. However, we assume that fish will be feeding predominantly during the day, or at least that night time feeding is proportional to daytime feeding, so drift samples can be taken during the day, when working conditions are easier and safer. We are assuming that daytime samples will be a good indicator of food availability and consumption, regardless of when fish are actually feeding. Contractors may wish to assess this assumption.

Mundie-style drift samplers will be deployed at a similar time of day to ensure representative sampling of drift organisms. This design (Mundie 1964; Figure 8.1) allows sampling of surface and subsurface drift. Five replicate samples will be collected monthly from 1 site on each of the study streams from May through September (Table 3.1), the main growing season for salmonids. In addition, each year, a different month will be selected for intensive weekly sampling in order to estimate within month variability of drift biomass. This should be considered a minimum frequency of sampling, and a greater frequency would be preferred if resources allow. A minimum of 18 drift (comprised of five replicates per sample) and two kick-net samples will be collected each year.

Drift samplers will be deployed simultaneously across the channel (or in representative habitats where water is too deep or fast) to ensure within-site spatial coverage. Thus, replication will occur both spatially and temporally. Note that unlike Surber samplers, which can be used to gather benthic samples quickly and efficiently at any time of day, drift samplers must be set in the current and left to “fish” for an extended period (at least 4 hours). The sampling effort should be standardized. The drift samplers will utilize a 250 µm mesh as this will retain invertebrates of most importance to fish. The following data are the minimum requirements to calculate the volume of water filtered: water velocity at mid-opening of the sampler at start and end of set, duration of sample set, depth of submerged orifice at start and end of set. The contractor may also wish to explore a means of collecting continuous depth and velocity measurements during drift sampling sets.

Figure 8.1 Photos of Mundie-style drift samplers

Table 8.1 Example of a drift sampling schedule in each of the study streams. There will be five replicate samples per stream at least once a month. Each year, a different month will be sampled at least weekly.

Month	Quinsam	Salmon
May	x x x x x	x x x x x
June	x x x x x	x x x x x
July	x x x x x	x x x x x
August wk1	x x x x x	x x x x x
August wk2	x x x x x	x x x x x
August wk3	x x x x x	x x x x x
August wk4	x x x x x	x x x x x
September	x x x x x	x x x x x
October	x x x x x	x x x x x

Changes to invertebrate community composition will also be measured with comparisons of benthic samples. In addition to the drift data, the information on the inter-annual benthos variation as well as varying levels of resemblance to the regional reference condition are expected to provide a weight-of-evidence approach to quantifying change in the fish food resource. A single, travelling kick-net sample is to be collected from each drift site during September sampling. Benthic invertebrate sample collection must follow published procedures from the Canadian Aquatic Biomonitoring Network[2] (CABIN) for stream sampling to allow for meaningful comparison to the Environment Canada database of Georgia Basin reference sites. Physical habitat and stream channel data will also be collected as required to classify study stream sites to the appropriate CABIN reference stream group using the predictive model developed and tested by Environment Canada for the Fraser and Georgia Basins. The Environment Canada predictive model allows users to select the sub-set of environmental parameters to be used for site group classification, and

[2] Website; http://cabin.cciw.ca/; accessed 17/09/09.

it is critical that the selected parameters do not include those which may change as a result of the project treatments (e.g., changes to flow).

Drift and benthic samples will be preserved for analysis in the lab, where they will be filtered, sorted into size classes, classified as aquatic or terrestrial, and identified to the lowest practical taxonomic level by a suitably certified taxonomist. Care should be taken to select a preservative that will minimize effects to biomass estimates of samples stored for several years. Processed invertebrates drift samples will be enumerated and weighed or digitized for biomass estimation. Biomass should be reported at the Family-level for each taxa. Processing may rely on subsamples depending on the abundance of invertebrates in each sample. Subsampling of bulk samples should provide a representative sample with a minimum of 300 organisms, exclusive of taxa from the following Orders: Nematoda, Ostracoda, Porifera, Copepoda, Cladocera, and Platyhelminthes. Lab processing, including biomass estimation, enumeration and taxonomic identification will be done for the contents of each of the 5 replicates per drift sample collected in Years 1, 3, 5, 7, and 9. In Years 2, 4, 6, 8, and 10, the contents of the five drift nets will be combined to create a single, composite sample for laboratory processing. Samples not processed in the lab will be stored in preservative. Identification will be to the taxonomic level of Genus, where possible and details on the identification quality assurance/quality control program should be provided.

2.3.2 Safety Concerns

A safety plan will have to be developed for all aspects of the study in accordance to WorkSafe BC and BC Hydro OSH standards procedures and guidelines. It is important to note that, because of the remoteness of some of the study areas and the large geographical area that must be covered, all field work must be carried out by a minimum two-person crew and that appropriate check-in and checkout procedures must be followed.

2.3.3 Data Analysis

All data will be entered into a common database in a standard format for subsequent analysis. This will ensure that data collected over the years are compatible and can be extracted and compared without concern regarding differences in file format. BC Hydro will provide direction on data entry and file formats. At the conclusion of the Monitor, the contractor will carry out power analyses to assess the detectable limits of the Monitor, e.g., the magnitude of change in water quality or drift that must occur in order to create a statistically significant response in smolt output. Some adjustment may be required to presentation formats and analyses suggested below, following collection and review of data. Contractors and BC Hydro are expected to make adjustments to ensure that the best methods are used for analysis and presentation.

2.3.3.1 Fish Population Assessments

Population abundance will be analyzed for within-year trends where possible, and will be summarized to allow testing at the end of the Monitor for among-year trends. Abundance data will be used to test all impact hypotheses in this Monitor (i.e., $H_0$1 through $H_0$6). When the WUP is implemented there is an expectation that fish productivity in the target streams will increase as a result of improved spawning and rearing conditions for each of the target species. This would show up initially as a

change in recruitment of younger size classes, and later in abundance of adult salmonids, assuming ocean survival and harvest remain constant. Since adult abundance is determined in part by ocean survival and harvest, a factor over which BC Hydro operations has no control, the test of $H_0$1 will assess the abundance of juvenile salmonids as a trend through time. There are a variety of methods available for trend analysis of animal populations (e.g., Link and Sauer 1997); a simple t-test (e.g., Welch modified two sample t-test) may be appropriate for comparing pooled abundance estimates before and after a selected time threshold. Both of these tests may be weak due to small sample size and small treatment effect, which should be assessed with statistical power analysis. In addition to analysis of abundance, data should be analyzed for within- and among-year trends in smolt condition, based on measurements of body weight and length. Correlation tests will be used to test whether abundance is significantly related to specific environmental factors such as habitat availability ($H_0$2), water quality ($H_0$3), flood events ($H_0$4), food availability ($H_0$5), or number of adult returns ($H_0$6). The following paragraphs describe some of the different analyses that will be required to assess population abundance for each target stream.

Quinsam River

Quinsam River fish abundance will be measured as number of returning adults in the fall and number of smolts out-migrating in the spring and early summer, for chinook, coho and steelhead. For each species the number of returning adults will be taken directly from DFO estimates based on upstream migration through the Quinsam River hatchery. These data will be summarized graphically and in table form, showing the estimated abundance and where appropriate, estimates of variance. Sources of error will be discussed and where possible, quantified.

Smolt abundance will be summarized graphically and in table form. Daily counts for each species will be presented, along with total counts for the period of observation. Total abundance will be estimated based on mark-recapture estimates of capture efficiency. Since mark-recapture estimates will be conducted more than once through the counting period, there is likely to be variance in the estimate of catch efficiency. This variance will be estimated and its effect on total abundance estimates will be clearly provided. Analysts should examine the data for trends in catch efficiency (e.g., relations with time, density, or other factors). In addition to an examination of within-year patterns, among-year patterns will be assessed at five years and at the end of the Monitor. This analysis will assess trends through time in order to formally test Impact Hypothesis $H_0$1.

Salmon River

Salmon River fish abundance will be expressed as juvenile salmonid abundance at index sites above and below the diversion dam. Data will concentrate on coho and steelhead/rainbow trout collected from closed-cell, triple pass electrofishing data collected at index sites that are appropriate for those species or other techniques implemented by MOE/DFO in the past. Data will also be analyzed for all salmonids as a group. These data will be summarized graphically and in table form, showing the estimated abundance and where appropriate estimates of variance. Sources of error will be discussed and where possible quantified. The key variable of interest is juvenile abundance over time, specifically pre- and post-WUP. Juvenile abundance is

expected *a priori* to be related (in some way) to ecological conditions and adult returns. The relation to adult returns will require exploratory analysis since annual counts are unlikely to be available. However, it may be possible to use the MOE snorkel data or an index from adjacent streams to test for relations between juvenile and adult abundance. Trends in juvenile abundance in relation to WUP operations will be used to formally test Impact Hypothesis $H_0$1 for the Salmon River.

2.3.3.2 Water Quality

Water quality data will be analyzed for within- and among-year trends in the parameters measured. Data will be summarized using graphs and tables to demonstrate trends through the sample period in the target streams.

2.3.3.3 Invertebrate Sampling

Drift sample data will be tabulated and graphed for presentation to show seasonal and locational patterns in diversity, abundance and biomass. Taxonomic data will be used to characterize the taxonomic makeup of the drift. Analyses of invertebrate density and biomass will examine within- and among-year trends, using the same or similar techniques as the analysis of fish abundance data. It is expected that the primary measure of invertebrate drift will be biomass and density rather than diversity. Variance in seasonal and locational abundance must be estimated and discussed.

Changes to benthic invertebrate community composition will be compared to the Fraser/Georgia Basin database of Reference Streams provided by the Canadian Aquatic Biomonitoring Network (CABIN) and Environment Canada (Sylvestre, 2004). Benthic invertebrate data and accompanying habitat data will be input into the CABIN website to determine the probability of Reference Group membership, Bray Curtis distance to Reference Group median and site status (i.e., unstressed, stressed or severely stressed). Information on which community taxa or site habitat data were particularly responsible for departures from the Reference Condition should be provided as well as basic community descriptors (e.g., total richness, % dominance of top 3 taxa, diversity).

2.3.3.4 Analyses of Abundance and Biomass Patterns

Analyses will be performed to assess relationships between fish abundance and biomass with several environmental factors. These analyses will be the formal tests of Impact Hypotheses $H_0$2 through $H_0$6, which involve testing for correlations between indicators of fish abundance and biomass with other environmental indicators. The tests will be performed at the end of the Monitor, and will also be performed initially for the 5-year summary.

Indicators of fish abundance will vary among streams, but will likely be similar: a total count of fish by species and life stage. In contrast, it is difficult in advance to predict how each environmental factor should be rolled up into a single indicator. For example, it is not clear how temperature data should be summarized to test for correlations with smolt abundance, and a variety of indicators may require testing (e.g., mean temperature, number of days above a certain threshold, etc.). Although exploratory analysis will be required, it is equally important to avoid spurious correlations through excessive multiple comparisons. Indicators must ultimately make sense both biologically and statistically. All tests of Impact Hypotheses $H_0$2 through $H_0$6 will require use of statistical correlation tests appropriate to the

hypotheses and data, and must be accompanied by statistical power analysis. Care should be exercised in how tests are performed, particularly with respect to the form of the relationships being tested. For example, there is no *a priori* reason to expect relationships to be simple and linear, and in fact many, such as stock-recruit relations, are expected to be non-linear.

2.3.4 Reporting

In general, project reporting will consist of annual data reports, a summary report in Year 5, and a final report at the conclusion of the Monitor.

Annual data reports will summarize the year's findings and include a short discussion of how the year's data compare to that collected in previous years. It will include a brief description of methods, present the data collected that year, and report on the results of all analyses.

The CC have requested that a summary report be prepared in Year 5 that collates all the data collected to date, summarizes all the analyses and presents a discussion of results as they pertain to the impact hypotheses in Section 1.3, and more importantly, to the management questions in Section 1.2. This will provide an early assessment of WUP operations in each study stream, though the implementation interval would likely be too short to determine with certainty whether the WUP was successful in meeting the intended fish benefits.

At the conclusion of each component of the Monitor, a final comprehensive report will be prepared from all of the data and/or annual reports written to date that:

1) Re-iterates the objective and scope of the Monitor,
2) Presents the methods of data collection and analysis,
3) Describes the compiled data set and presents the results of all analyses,
4) Presents the result of all impact hypothesis testing and their consequence in terms of addressing the management questions in Section 1.2, and
5) Discusses the consequences of these results as they pertain to the current BC Hydro operations, and the necessity and/or possibility for future change.

Each report will be due in winter of the year following the data collection period. This should provide sufficient time in integrate findings in those years that multiple study component are simultaneously carried out.

2.4 Interpretation of Results

2.4.1 Impact Hypothesis $H_0$1

This hypothesis will be tested separately for each of the target streams. Rejection of $H_0$1 (one or more of its sub-hypotheses) indicates that salmonid abundance has changed in target streams in the Campbell River system following implementation of the WUP. Since the hypothesis is not specific to a particular mechanism, the reason for the change may be tied to BC Hydro operations or to some other factor. Rejection of the hypothesis provides justification to proceed with tests of other Impact Hypotheses in this Monitor.

Failure to reject $H_0$1 would suggest that operational changes resulting from the WUP's implementation had no measurable impact on salmonid abundance. There may be a number of reasons for such a result:

1) There was only a minimal response to the treatments used,
2) The resolution of the Monitor was too low to detect a change (too small a sample size),
3) The change in reservoir operations was too small to illicit a measurable ecological response (too small a treatment effect),
4) There is some other limiting factor(s) that either masks the ecological response to operational changes, or
5) Some combination of the above.

The statistical resolution of the Monitor will be determined through power analysis at the conclusion of the Monitor when estimates of sampling error can be made. Results of the analysis will indicate the limits of detection for a change in fish population response and will put the results of the Monitor into the proper statistical context.

2.4.2 Impact Hypothesis $H_0$2

This hypothesis will be tested separately for each of the target streams. Measures of habitat availability WUA will be supplied by BC Hydro, and will be based on work completed during the WUP or during other Monitors. Rejection of $H_0$2 indicates that salmonid abundance is significantly related to habitat availability in target streams in the Campbell River system following implementation of the WUP. Rejection of the hypothesis provides reasonably strong inference that BC Hydro operations affect salmonid abundance through their effects on habitat availability, since water quantity (i.e., water releases from dams or generating facilities) has an immediate and measurable effect on the abundance and distribution of fish habitat in streams. This is a fairly general hypothesis, and the exact mechanism may be unknown, and does not exclude the influence of other environmental factors on salmonid productivity. Adequate testing of this hypothesis will require the construction of a good indicator of habitat availability in the target streams.

Failure to reject $H_0$2 would suggest that operational changes resulting from the WUP's implementation had no measurable impact on salmonid abundance. There may be a number of reasons for such a result:

1) There was only a minimal response to the treatments used,
2) The resolution of the Monitor was too low to detect a change (too small a sample size),
3) The change in reservoir operations was too small to illicit a measurable ecological response (too small a treatment effect),
4) The habitat availability indicator is inappropriate,
5) There is some other limiting factor(s) that either that masks the ecological response to operational changes, or
6) Some combination of the above.

The statistical resolution of the Monitor will be determined through power analysis at the conclusion of the Monitor when estimates of sampling error can be made. Results of the analysis will indicate the limits of detection for a change in fish population response and will put the results of the Monitor into the proper statistical context.

2.4.3 Impact Hypothesis $H_0$3

This hypothesis will be tested separately for each of the target streams. Rejection of $H_0$3 indicates that salmonid abundance is significantly related to water quality in target streams in the Campbell River system following implementation of the WUP. Rejection of the hypothesis provides reasonably strong inference that fish abundance is related to water quality, but the link to BC Hydro operations may need to be established to show how operations affect salmonid abundance through their effects on water quality. Because several water quality factors are being measured, this hypothesis has both general and specific aspects. The exact mechanism of water quality's influence on salmonid growth and survival may be unknown, and does not exclude the influence of other environmental factors on salmonid productivity. Adequate testing of this hypothesis will require the construction of a good indicator of water quality in the target streams.

Failure to reject $H_0$3 would suggest that operational changes resulting from the WUP's implementation had no measurable impact on salmonid abundance. There may be a number of reasons for such a result:

1) There was only a minimal response to the treatments used,
2) The resolution of the Monitor was too low to detect a change (too small a sample size),
3) The change in reservoir operations was too small to illicit a measurable ecological response (too small a treatment effect),
4) The water quality indicator is inappropriate,
5) There is some other limiting factor(s) that either that masks the ecological response to operational changes, or
6) Some combination of the above.

The statistical resolution of the Monitor will be determined through power analysis at the conclusion of the Monitor when estimates of sampling error can be made. Results of the analysis will indicate the limits of detection for a change in fish population response and will put the results of the Monitor into the proper statistical context.

2.4.4 Impact Hypothesis $H_0$4

This hypothesis will be tested separately for each of the target streams. Measures of flood events will be supplied by BC Hydro, and will be based on empirically measured (i.e., gauged) flows in each target stream. The flood indicators will be based on work completed during the WUP or during other Monitors. Rejection of $H_0$4 indicates that salmonid abundance is significantly related to flood events in target streams in the Campbell River system following implementation of the WUP. Rejection of the hypothesis provides reasonably strong inference that fish abundance is related to flood events, but the mechanistic link to BC Hydro operations may need

additional study to show how operations affect salmonid abundance through operational effects on flood events. Because flood events may have a variety of impact pathways, this hypothesis is fairly general. The exact mechanism of a flood event's influence on salmonid incubation, growth and survival may be unknown, and does not exclude the influence of other environmental factors on salmonid productivity. Adequate testing of this hypothesis will require the construction of a good indicator of flood events in the target streams.

Failure to reject $H_0$4 would suggest that operational changes resulting from the WUP's implementation had no measurable impact on salmonid abundance. There may be a number of reasons for such a result:

1) There was only a minimal response to the treatments used,
2) The resolution of the Monitor was too low to detect a change (too small a sample size),
3) The change in reservoir operations was too small to illicit a measurable ecological response (too small a treatment effect),
4) The flood indicator is inappropriate,
5) There is some other limiting factor(s) that either that masks the ecological response to operational changes, or
6) Some combination of the above.

The statistical resolution of the Monitor will be determined through power analysis at the conclusion of the Monitor when estimates of sampling error can be made. Results of the analysis will indicate the limits of detection for a change in fish population response and will put the results of the Monitor into the proper statistical context.

2.4.5 Impact Hypothesis $H_0$5

This hypothesis will be tested separately for each of the target streams. An indicator of food availability will be developed, based on invertebrate drift samples in each of the target streams and used to assess relationships with fish productivity. Rejection of $H_0$5 indicates that salmonid abundance is significantly related to food availability in target streams in the Campbell River system following implementation of the WUP. Rejection of the hypothesis provides reasonably strong inference that fish abundance is related to food availability, but the mechanistic link to BC Hydro operations may need additional study to show how operations affect salmonid abundance through operational effects on invertebrate drift. Operations may affect food availability in a variety of ways, so this hypothesis is fairly general. The exact mechanism of operation's influence on salmonid growth and survival may be unknown, and does not exclude the influence of other environmental factors on salmonid productivity. Adequate testing of this hypothesis will require the construction of a good indicator of food availability in the target streams.

Failure to reject $H_0$5 would suggest that operational changes resulting from the WUP's implementation had no measurable impact on salmonid abundance. There may be a number of reasons for such a result:

1) There was only a minimal response to the treatments used,

2) The resolution of the Monitor was too low to detect a change (too small a sample size),

3) The change in reservoir operations was too small to illicit a measurable ecological response (too small a treatment effect),

4) The food availability indicator is inappropriate,

5) There is some other limiting factor(s) that either that masks the ecological response to operational changes, or

6) Some combination of the above.

The statistical resolution of the Monitor will be determined through power analysis at the conclusion of the Monitor when estimates of sampling error can be made. Results of the analysis will indicate the limits of detection for a change in fish population response and will put the results of the Monitor into the proper statistical context.

2.4.6 Impact Hypothesis $H_0$6

This hypothesis will only apply to the Quinsam River. The hypothesis will not be tested for the Heber and Salmon rivers because smolt abundance is calculated directly from adult abundance estimates. Adult abundance estimates will be used to assess relationships with juvenile fish productivity. Rejection of $H_0$6 indicates that smolt abundance is significantly related to adult returns in target streams in the Campbell River system following implementation of the WUP. Rejection of the hypothesis provides reasonably strong inference that smolt abundance is related to adult abundance, but the mechanistic link to BC Hydro operations may need additional study to show how operations affect the relationship through water management practices. Operations may affect adult and smolt abundance in a variety of ways, so this hypothesis is fairly general. The exact mechanism of operation's influence on the abundance of different life stages may be unknown, and does not exclude the influence of other environmental factors.

Failure to reject $H_0$6 would suggest that operational changes resulting from the WUP's implementation had no measurable impact on the relation between adult and smolt abundance. There may be a number of reasons for such a result:

1) There was only a minimal response to the treatments used,

2) The resolution of the Monitor was too low to detect a change (too small a sample size),

3) The change in reservoir operations was too small to illicit a measurable ecological response (too small a treatment effect),

4) Measures of adult and juvenile abundance are inappropriate,

5) There is some other limiting factor(s) that either that masks the ecological response to operational changes, or

6) Some combination of the above.

The statistical resolution of the Monitor will be determined through power analysis at the conclusion of the Monitor when estimates of sampling error can be made. Results of the analysis will indicate the limits of detection for a change in fish

population response and will put the results of the Monitor into the proper statistical context.

2.5 Schedule

The Salmon River diversion canal has been out of service since 2010 due to dam safety deficiency concerns. BC hydro had initiated a project to address the dam safety deficiencies identified on Salmon River diversion structure and the canal. However, no firm timeline has been scheduled for completion of the dam safety project. In the absence of diversion, there is no diversion related- WUP impacts to be monitored for Salmon River section of this monitor. Consequently the implementation of this monitor hinges on whether the canal upgrade project gets implemented in advance of the schedule set in this TOR for implementation of this monitor. Therefore, the schedules designed for this monitor is conditional on and will be driven by the canal upgrade project implementation schedules.

The fish population assessments, water quality monitoring and invertebrate drift sampling are to be carried out annually for the duration of the monitoring period (10 years following implementation of the WUP). WUA data will also be collected annually from Monitors 5 and 11 as they are made available. Trend analyses on the abundance data will be done annually as well, but the level of effort will be kept to a minimum except for Year 5 when a report on the results-to-date is expected and Year 10 (i.e., at the conclusion of the monitor) when sample size would be sufficient to warrant more intensive exploratory analyses . As noted above annual data reports are due each year following data collection.

Two major reports are to be prepared as part of this monitor. The first is due in Year 5 (i.e., winter of Year 6) of the monitor, which is a summary report of all data collected and analyses done to date that provides an early assessment of WUP operations in each stream. The second is a final report due at the conclusion of the monitor in Year 10, as per Section 2.3.5. A summary of the monitor schedule can be found in Table 3.2.

It should be noted that the schedule presented here is different form that presented in the Campbell River WUP CC report. In the CC report, the duration of the monitor was fixed to five years on the assumption that the WUP would be reviewed within that time frame. However, the CC decided to extend the WUP review period to 10 years during the last meeting, and recommended that the monitoring program be similarly extended. This increase in duration is considered beneficial to the monitor as it provides a longer time trend from which to assess WUP impacts, and hence improve the monitor’s statistical power.

2.6 Budget

The total cost of the 10-year Quinsam, and Salmon Rivers smolt and spawner abundance assessment monitor is estimated to be $2,108,678 based on a 2014 start.

3 References

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