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June 14, 2017

Subject: Columbia Basin Water Quality Monitoring Program, 2014-2016 Sheep Creek - Data Review

Lotic Environmental Ltd. (Lotic Environmental) has completed the review of data collected by the Salmo Watershed Streamkeepers Society (SWSS) at Sheep Creek Site 1 (NESHP01), Site 2 (NESHP02), and Site 3 (NESHP03) through the Columbia Basin Water Quality Monitoring Project (CBWQMP). This review included analysis of data collected in 2014 - 2016 of the four main components of the project: 1) water quality data, 2) continual temperature data, 3) hydrometric data (velocity and flow), and 4) Canadian Aquatic Bio Monitoring Network (CABIN) data. All data and initial analyses for these components were summarized by the SWSS. Lotic Environmental's objective was to conduct a quality assurance/quality control (QA/QC) review of data, compare water quality results to applicable guidelines, interpret results, and make recommendations.

1 Water Quality

Water quality data had been transposed into the master spreadsheet by the CBWQMP (see Excel attachment). In 2014, all three sites were reviewed in August and September, and in subsequent years only Site 1 (NESHP01) was reviewed (spring through fall). Generally, the following data were collected:

a. Monthly - total suspended solids (TSS), orthophosphate, and *in situ* (field measured) data. *In situ data* were dissolved oxygen (DO), temperature, specific conductivity, pH, turbidity, and air temperature.
b. Once per year (coinciding with CABIN monitoring) - in addition to data above, inorganics, full complement of nutrients, sulphate, and metals.
c. One additional time annually (for a total of two sampling dates each year) – sulphate, total hardness, and metals.
d. Once in 2016 - a duplicate and a blank sample.

1.1 *Water Quality QA/QC*

Water quality data were first subjected to a quality control evaluation to assess the accuracy and precision of the laboratory and field methods.

The relative percent difference (RPD) was determined for the parameters sampled in duplicate (Province of BC 2003). All parameters were below the alert level of 50%, indicating a high degree of precision in data collection and lab procedures.

A water quality field blank was collected using laboratory issued de-ionized water. Field blank values two times greater than the reportable detection limit (RDL) were considered to be an alert level (Province of BC 2003). All field blank data were below the alert level, indicating that samples were contaminant free and analysed with precision.

1.2 *Guideline updates*

A guideline is a maximum and/or a minimum value for a characteristic of water, sediment or biota, which in order to prevent specified detrimental effects from occurring, should not be exceeded (BC MoE 2017). The guidelines for the protection of aquatic life, and drinking water were updated to reflect changes since 2012, when they were last summarized for the CBWQMP. This involved updating threshold values, where applicable, and streamline the review process, by just presenting one guideline per parameter for each use category. This was done by applying the following hierarchy to guideline determination (BC MoE 2016):

a. Use the BC Approved Water Quality Guideline (BC MoE 2017), and if one did not exist then use;
b. BC Working Water Quality Guidelines for British Columbia (BC MoE 2015), and if one did not exist then use;
c. The Canadian Environmental Quality Guidelines (Canadian Council of Ministers of the Environment [CCME] 2017), or Health Canada (2017).

When both a long-term (30- day average or chronic) and short-term (maximum acute) exposure guideline was available, the long-term guideline was used in the review, since sampling was assumed to have occurred under ‘normal’ conditions. Exceedances of these guideline thresholds were flagged to provide an understanding of the potential risks.

1.3 *Water quality results*

Water quality results were generally good for the three sites. The turbidity stood out as indicating a stable environment, since values remained low (<2 NTU) even during the freshet. All but two parameters met the aquatic life and/or drinking water guideline for the parameters assessed. Details are as follows:

Water temperature: Water temperature exceeded the BC Approved drinking water guideline of 15 ^{o}C on September 2, 2014 at both NESHP01 and NESHP02. The guideline is established for aesthetic reasons, as temperature indirectly affects disinfection, corrosion control, and formation of biofilms in distribution systems (Health Canada 2017). The daily maximum of 19 ^{o}C to protect general aquatic life was not exceeded, however fish species and life-stage specific temperature requirements were not included in this review (see Section 2).

Total zinc: Zinc was 8.1 µg/L at NESHP01 in September 2015, exceeding the BC Approved guideline for the protection of aquatic life of 7.5 µg/L. The exceedance may not be cause for concern, as it was only slightly higher than the long term guideline, it was considerably lower than the short term (maximum) guideline of 33 µg/L, and the 2016 value was within the guideline.

Zinc ranks fourth among metals of the world in annual consumption, and is found in an array of products (BC MoE 2017). Zinc is an essential element in trace amounts for plants and animals, but can be toxic in high concentrations (BC MoE 2017). Soluble or dissolved zinc is readily available for biological reactions and therefore considered most toxic (BC MoE 2017). The zinc guideline may thus be interpreted in terms of the dissolved metal fraction when the total zinc concentration in the environment exceeds the guideline (BC MoE 2017). For this reason, future sampling could include dissolved metals to confirm if there is a potential for impact on aquatic life.

2 Stream Temperature

Temperature plays an important role in many biological, chemical, and physical processes. The effects of temperature on aquatic organisms are listed in the technical appendix for the BC MoE approved water quality guideline (Oliver & Fidler 2001), with the following generally occurring in aquatic organisms as water temperatures increase:

- Increased cardiovascular and respiratory functions, which in turn may increase the uptake of chemical toxins.
- Oxygen demand increases, while the dissolved oxygen content of water decreases, making swimming more difficult.
- In waters where dissolved gases are supersaturated, elevated water temperatures may worsen the effects of gas bubble trauma in fish.

The BC MoE stream temperature guidelines are specified by water use (i.e., drinking water, aquatic life, irrigation/livestock, and recreation/aesthetics). The aquatic life guidelines are dependent on the fish species (mostly salmonids) found in the stream for different life stages (rearing, spawning, and incubation). Bull Trout are especially sensitive to temperature changes, therefore streams with Bull Trout present have a separate set of more rigorous guidelines. The BC MoE also sets out temperature guidelines for streams with known fish distributions (mainly salmonids other than Bull Trout), and for streams with unknown fish distributions.

Fish species known to inhabit Sheep Creek include (BC MoE 2017a):

- Bull Trout (*Salvelinus confluentus*)
- Westslope Cutthroat Trout (*Oncorhynchus clarkia lewisi*)
- Rainbow Trout (*Oncorhynchus mykiss*)
- Brook Trout (*Salvelinus fontinalis*)
- Slimy Sculpin (*Cottus cognatus*)
- Longnose Dace (*Rhinichthys cataractae*)

The special guidelines for streams with Bull Trout were used for reviewing the temperature data. In general, stream temperatures regularly exceeded the maximum daily temperature of 15 ºC for Bull Trout during the summer months of both 2015 and 2016 (Figure 1). The number of exceedance days appears to be higher in 2015 than 2016; however, the temperature logger was out of the water from mid-August to mid-September 2016, when temperatures may have still been high. The maximum daily temperature guideline reflects the optimal rearing temperatures for Bull Trout (6.0 ºC – 14 ºC). The water temperatures also exceeded the optimal Westslope cutthroat rearing temperatures (7 ºC – 16 ºC) in the summer months.

Bull Trout spawning generally occurs from mid-September to late October and often is initiated when water temperatures drop below 9 ºC (McPhail 2007). The maximum daily temperatures in

Sheep Creek exceeded optimal spawning temperature guidelines (i.e. a max daily temperature of 10 ºC) in early fall; however, this was likely before spawning was initiated by a drop in temperatures below 9 ºC. Moreover, it is unknown if fish spawn in the area of the temperature logger, as monitoring of spawning or potential for spawning (based on habitat including gravel size, flows, and depths) were not part of this study. If spawning had occurred, the guideline for minimum temperature during incubation is 2 ºC. Temperatures in Sheep Creek did not meet this guideline regularly from late fall through to early spring of 2014/2015, as well as in December 2015, January and March of 2016.

The stream temperatures also regularly exceed the drinking water temperature guideline of 15 ºC during the summer months in both 2015 and 2016. The drinking water guideline is an aesthetic objective. Temperature indirectly affects health and aesthetics through impacts on disinfection, corrosion control and formation of biofilms in the distribution system (Health Canada 2017).

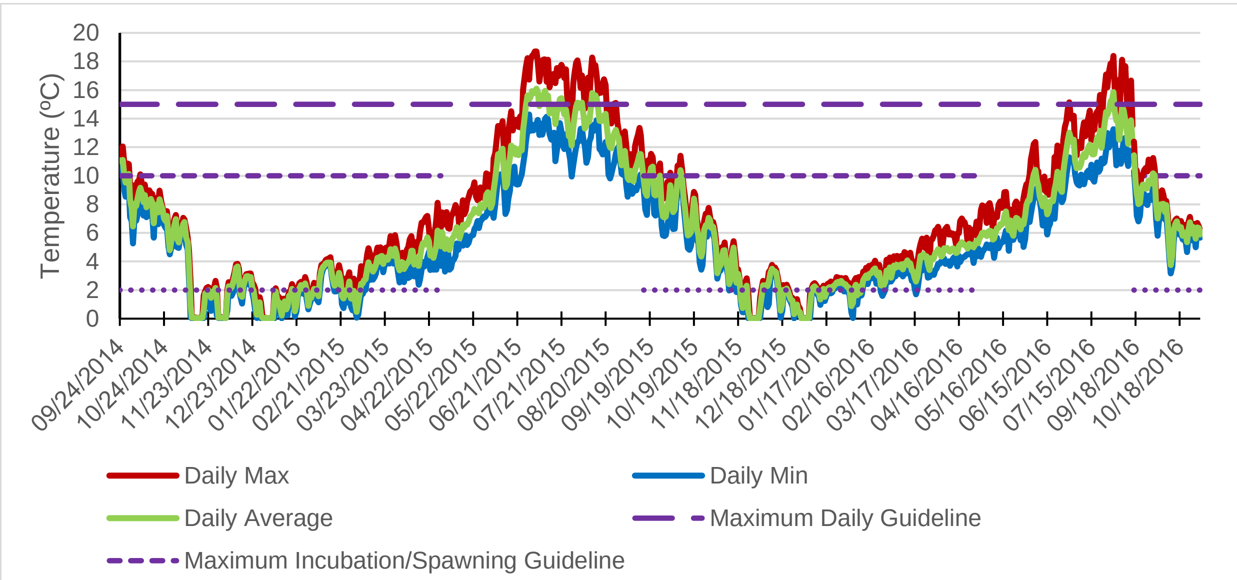

Figure 1. Stream water temperatures in Sheep Creek (site NESHP01) from September 24, 2014 to November 1, 2016. The logger was out of the water from August 13 to September 16, 2016. The long dashed purple line indicates the BC MoE guideline for aquatic life for streams with Bull Trout present. The short dashes indicate maximum daily temperature during spawning, and the dotted line indicates minimum daily water temperature during spawning and incubation.

3 Hydrometric data (velocity and flow)

Stream flows play an important role in stream ecosystems, influencing aquatic species distributions, water quality (especially turbidity, dissolved oxygen content and stream temperature), physical habitat (especially substrate characteristics), and fish life history traits (e.g. spawning time). Hydrometric data on Sheep Creek was collected as both a flow and a velocity. Both measure the amount of water moving past a point. Velocity is the speed of water and is measured as a unit of distance per time. Flow, also known as discharge, measures the volume of water moving through a point in a given amount of time, and is calculated by multiplying water velocity by the cross-sectional area.

The CBWQMP generally aimed to collect instantaneous velocity and flow data monthly from spring through fall. Provincial instream flow guidelines to protect aquatic ecosystems are usually set relative to natural historic flows of each stream. In order to develop these criteria, the annual hydrologic regime of the stream would need to be thoroughly detailed in a long term dataset. This would be best achieved using continuous level loggers and developing level-discharge (flow) relationships. Instantaneous flow measurements at one site cannot be directly related to fish habitat requirements, as water velocity will vary with channel morphology, and fish can swim to more suitable habitats within the stream. Nevertheless, the hydrometric data collected as part of this project is still important as it shows changes in flow patterns with time. This information can also explain changes in water quality (e.g., turbidity can increase during high flows) and biological changes such as fish/invertebrate/periphyton species population distributions.

Velocity measurements in 2015 were limited to data from May and September, with the remaining months having flows too high to be safely measured. From the limited dataset in 2015, it appears that velocity patterns were similar between 2015 and 2016. (i.e. high flows due to snowmelt and/or heavy rain) occurred April – June, followed by decreasing velocity until September, before increasing again in October (Figure 2). Flows (discharge) followed a similar pattern to velocity and were also similar between the years sampled (Figure 3). Flow data in 2015 was collected in July and August when velocity data was not measured. Flow in both years appears to be high in freshet, before decreasing to lows from July to September and increasing again in October. The increase in both flows and velocity in October may have been caused by fall precipitation.

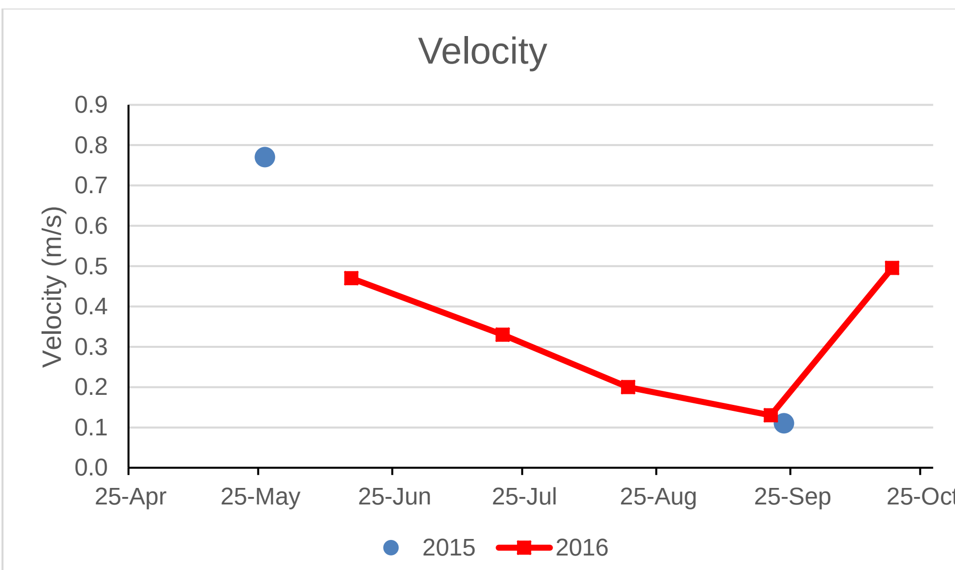

Figure 2. Water velocity at NESHP01 in 2015 and 2016. No measurements were taken in April, June, July, August, and October of 2015, as well as April and May of 2016 due to safety concerns during high flows.

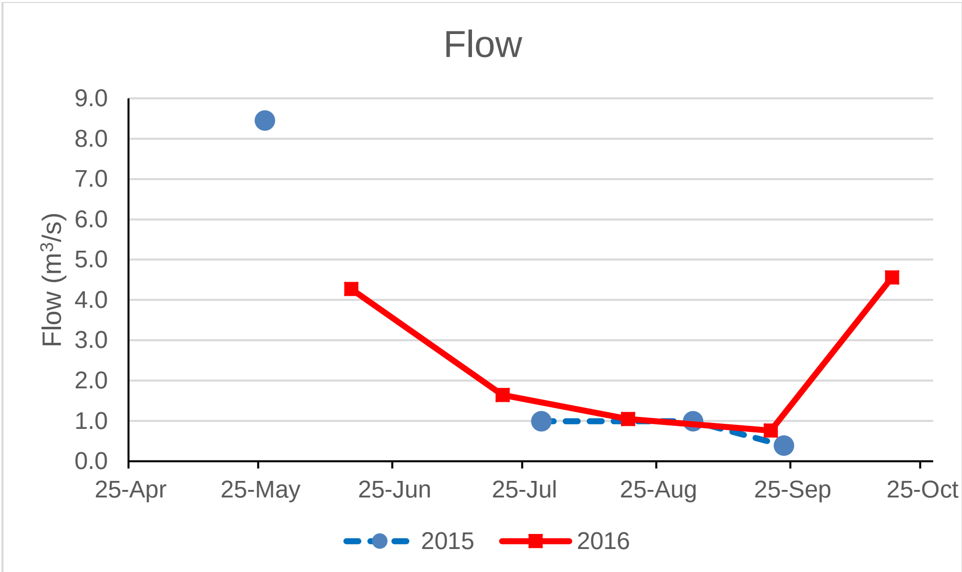

Figure 3. Water flow (discharge) at NESHP01 in 2015 and 2016. No measurements were taken in April for both years, as well as in October of 2015 and May of 2016 due to safety concerns during high flows.

4 CABIN

CABIN data was collected following standard methods in the CABIN Field Protocols Manual (Environment Canada 2012) at NESHP01 in the fall of 2015 and 2016. The SWSS completed a RCA analysis on collected CABIN data using the Analytical tools in the CABIN database. We reviewed the CABIN output, and summarized and interpreted the results.

4.1 *Reference Condition Approach: BEAST Analysis and Site Assessment*

The Reference Condition Approach (RCA) in CABIN is used to determine the condition of the benthic invertebrate community at the test sites (as sampled by CBWQMP groups), by comparing each site to a group of reference sites with similar environmental characteristics. The RCA in CABIN determines whether the benthic community at the test sites falls within the normal range of community variability defined by pristine sites, or sites in “reference condition”.

The Benthic Assessment of Sediment tool (BEAST) was used to predict sites to a reference group from the preliminary Okanagan-Columbia reference model. BEAST uses a classification analysis that determines the probability of test site membership to a reference group based on habitat variables (Rosenberg *et al.* 1999). Habitat variables used to predict group membership in the Okanagan-Columbia reference model include: latitude, longitude, percent of watershed with a gradient <30, percent of watershed with permanent ice cover, and average channel depth (cm).

The reference model used in the RCA analysis was the Preliminary Okanagan-Columbia Reference Model provided in the online CABIN database (Environment Canada 2010). Because the model is still considered preliminary, with some potential data gaps, caution must be exercised when interpreting RCA results. However, CABIN results can be investigated in multiple ways, including by examining the test site's water chemistry, habitat and invertebrate community metrics. These additional assessments are used to supplement ordination assessments, and they provide essential information for evaluating the CABIN model outputs.

CABIN model hybrid multi-dimensional scaling ordination assessment was used to evaluate benthic community stress based on divergence from reference condition. This analysis places test sites into assessment bands corresponding to a stress level ranging from unstressed to severely stressed. The assessment is based on how different the benthic community at the test site is from the reference communities. In the ordination assessment, sites that are unstressed fall within the 90% confidence ellipse around the cloud of reference sites which means that their communities are similar or equivalent to reference (Rosenberg *et al.* 1999). Potentially stressed, stressed and severely stressed sites indicate mild divergence, divergence, or high divergence from reference condition (Rosenberg *et al.* 1999).

For NESHP01, CABIN BEAST analysis determined the highest probability of reference group membership was to Group 2 in both 2015 and 2016 (probabilities found in Table 1). The site was thus compared with Reference Group 2, which includes 43 streams, mostly from the Thompson Okanagan Plateau Ecoregion. The average channel depth of Reference Group 2 is 18.0 +/- 7.8 cm (SD - standard deviation), which is close to the test site's average depth of 22.3 and 25.8 cm, in 2015 and 2016 respectively. A comparison of other individual test site habitat attributes with the reference model means, and the ordination plots are included in the Site Assessment Reports. The CABIN model assessed NESHP01, as potentially stressed in 2015 and unstressed in 2016.

Table 1. CABIN model assessment of the test site against reference condition as defined by the preliminary Okanagan-Columbia reference model; assessment, prediction of reference group and probability of group membership.

Site	Description	2015	2016
NESHP01	Sheep Creek, Site 1	**Potentially stressed** Group 2; 100%	**Unstressed** Group 2; 100%

4.2 *RIVPACS Analysis*

River Invertebrate Prediction and Classification System (RIVPACS) ratios were calculated in the Analytics tools section of the CABIN database. RIVPACS is a measure that describes the presence or absence of specific taxa. The RIVPACS ratio determines the ratio of observed taxa at test sites, relative to taxa expected to be present (at a >70% probability) at reference sites. A RIVPACS ratio close to 1.00 indicates that a site is in good condition as all or most taxa expected were found at the test site. A RIVPACS ratio >1.00 can indicate community enrichment while a ratio <1.00 can indicate that a benthic community is in poor condition.

The RIVPACS ratio at NESHP01 was 0.92 in 2015 and 1.01 in 2016. These values support the model results above, indicating improvement in the invertebrate community from 2015 to 2016. In 2015 there were two families not present at the test site that were expected based on the reference group; while in 2016, all families of taxa were present.

4.3 *Community Composition Metrics*

Benthic community composition metrics were calculated in the CABIN database using the Analytical Tools. A collection of measures (metrics) of community richness, abundance, diversity and composition were selected to describe the test site communities and are summarized in the Site Assessment Reports. The following metrics of special interest were reviewed in further detail (Table 2): total abundance; percent composition of Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) orders (EPT); percent composition of Chironomidae (midges) taxa; percent composition of the two dominant taxa; and total number of taxa.

Table 2. Summary of select metrics of interest for reference and test site

Metric	Reference Group 2 (Mean +/- SD)	NESHP01	
		2015	2016
Total abundance	3018.4 ± 2496.0	3150	4725
% EPT taxa	78.6 ± 14.0	44.8	55.3
% Chironomidae	8.7 ± 10.4	32.7	21.9
% of 2 dominant taxa	49.3 ± 10.6	43.7	43.3
Total number of taxa	21.8 ± 4.8	27	28

Total abundance of organisms found at the test site can be influenced by many factors including type of stress and the organisms involved (Rosenberg and Resh 1984). Abundance may increase due to nutrient enrichment but decrease in response to toxic effects such as metals contamination or changes in pH, conductivity and dissolved oxygen. Total abundance at NESHP01 was lower in 2015 than in 2016 (3150 and 4725 organisms, respectively), with both values falling within the reference group mean (3018.4 ± 2496 organisms), indicating healthy conditions.

The percent of the community made up by individuals of any taxon, either at the family or order level, will vary depending on the taxon's tolerance to pollution, feeding strategy and habitat requirements (Rosenberg and Resh 1984). EPT orders of insects are typically indicators of good water quality. Percent EPT was lower in 2015 than in 2016 at the test site (44.8 and 55.3% respectively), with values slightly lower than that of the reference site mean (78.6 ± 14.0 %). Conversely, Chironomidae (non-biting midges), are generally tolerant of pollution. Percent Chironomidae was higher in 2015 than 2016 (32.7 versus 21.9 %), both of which were higher than the reference mean (8.7 ± 10.4 %). The results of percent EPT and Chironomidae indicated an improvement at the test site over the two years of study.

Relative occurrence of the two most abundant taxon is a metric that can relate to impacted streams, since as diversity declines, a few taxa end up dominating the community. Opportunistic taxa that are less particular about where they live replace taxa that require special foods or particular types of physical habitat (Environment Canada 2012b). At this test site, the percent of the two dominant taxa were similar in 2015 and 2016 (43.7 and 43.3%), and similar to the reference group (49.3 ± 10.6 %) indicating a healthy community.

Taxa richness is the total number of taxa present for a given taxonomic level. There is usually a decrease of intolerant taxa and an increase of tolerant taxa with disturbance (Environment

Canada 2012b). However, overall biodiversity of a stream typically declines with disturbance (Environment Canada 2012b). Taxa richness at the test site was also consistent over the two years (27 and 28 taxa, respectively), and similar to the reference mean (21.6 ±4.8 taxa).

5 Conclusions

Overall, the water quality was good at Sheep Creek. Water temperatures were high in the summer months when they regularly exceeded guidelines for the protection of aquatic life and drinking water. Hydrometric data in both 2015 and 2016 followed a similar pattern of high flows during freshet, followed by steady declines throughout the summer, before increasing again in October. The CABIN results indicated an improvement of the benthic invertebrate community during the study period, with a change from potentially stressed to unstressed. This was primarily evident through increases in percent EPT and Chironomidae. A cursory review of physical habitat metrics (such as velocity, and substrate), did not indicate any substantive changes between the years. Thus, the reason for the improvement is not evident; it could simply be the result of natural variation. The aquatic environment was healthy at Sheep Creek.

6 Recommendations

Overall, the program you are undertaking is really good for developing a baseline. Three years should provide a good picture of aquatic invertebrate health and water quality, assuming relatively representative years are captured, and there are no change in land-use during the 3 year period. This information will identify if there are water quality or benthic invertebrate changes as a result of a major disturbance. Obtaining data over a longer period, of course, would help provide an understanding of natural variance in the system over time, but we recognize that resources are limited, and a three year period is realistic and achievable. Once baseline data has been attained, sampling should be focussed to locations experiencing ongoing development pressures.

A few specific recommendations for the Salmo Watershed Streamkeepers Society are to:

1. Include total phosphorus in the monthly analysis in addition to or instead of orthophosphate, as there is a CCME guideline for phosphorus that helps determine if there are potential impacts on the aquatic environment.
2. Consider including dissolved metals, particularly zinc for Sheep Creek, but also cadmium for the Salmo River (exceeded guideline as evident in water quality table, but outside of this review), to confirm if there is a potential for impact on aquatic life.

Other general recommendations for the CBWQMP to consider, to improve the baseline monitoring program are:

1. The current level of flow monitoring is limited to providing context for CABIN and water quality results. However, continuous hydrologic monitoring would provide much more robust datasets to work with. The effort required for this is low, and would involve adding a pressure transducer and developing a rating curve. Additional ideas regarding flow data collection:
    a. In terms of regional assessment, it would be interesting to tie these sites in with Water Survey of Canada data to develop hydrographs over longer time periods.

This would allow for an assessment of regional trends, and differences in hydrologic regime between larger areas, etc.

b. The Water Sustainability Act has a component that is trying to mirror the Alberta Watershed Planning and Advisory Council approach. This is where stewardship actually plays a role in decision making. Because there is relatively little hydrologic monitoring in the province, water licencing in BC could benefit from these data. It could provide a basis for water allocation and for understanding trends (link with regional analysis above).

2. Sample CABIN in triplicate (three sites) in every third year, to get a sense of spatial variability in the stream.
3. It would be good if the duplicate and blank were collected annually at least once, and for all parameters (during the fall), if funding allowed.

7 Closing

The Salmo Watershed Streamkeepers Society has completed very good monitoring work, which will be a valuable base to measure changes over time. We hope that this review provides useful information to help your organization with understanding the results of your efforts, and planning for future monitoring.

Sincerely,

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