LOTIC ENVIRONMENTAL LTD
2193 MAZUR ROAD
CRANBROOK BC, V1C 6V9
P. 250.421.7802
WWW.LOTIC.CO

Arrow Lake Environmental Stewardship Society
Box 52, Burton, BC
V0G1E0
c/o Ian Greig (iangreig@outlook.com)

June 16, 2017

**Subject: Columbia Basin Water Quality Monitoring Program, 2015/2016 McDonald Creek - Data Review**

Lotic Environmental Ltd. (Lotic Environmental) has completed the review of data collected by the Arrow Lake Environmental Stewardship Society (ALESS) at McDonald Creek (NEMCD01), through the Columbia Basin Water Quality Monitoring Project (CBWQMP). This review included analysis of data collected in 2015 and 2016 for the four components of the project: 1) water quality data, 2) continual temperature data, 3) hydrometric data (velocity and flow), and 4) Canadian Aquatic Biomonitoring Network (CABIN) data. All data and initial analyses for these components were summarized by the ALESS. Lotic Environmental's objective was to conduct a quality assurance/quality control review (QA/QC) 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 ALESS (See Excel attachment). The following data were collected in 2015/2016:

a. Monthly (spring through fall) – orthophosphate and total phosphorus, total suspended solids (TSS), and *in situ* (field measured) data. *In situ data* were dissolved oxygen (DO), temperature, specific conductivity, pH, turbidity, and air temperature.
b. Annually, in the fall (coinciding with CABIN monitoring) - in addition to above parameters, nitrate and nitrite, total nitrogen, dissolved chloride, inorganics, and metals.
c. Once in 2016 - 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.

Duplicate samples were only collected for two parameters, conductivity and turbidity. Typically the full suite of parameters are analysed for both samples, to provide an indication of the degree of precision in data collection and lab procedures. The relative percent difference (RPD) could only be determined for conductivity and turbidity. Turbidity exceeded the concern level of 50%, however, a field measured and lab analysed sample were compared. Greater than normal variability would be expected when comparing these two different techniques; particularly for turbidity which can be influenced by agitation/settling. Natural variability in turbidity in the water column is also likely.

Water quality field blanks were 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 parameters analyzed were below the alert level, indicating that the sample was 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 streamlining 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 met all but three aquatic life and/or drinking water guidelines for the parameters assessed. Details are as follows:

**Dissolved oxygen (DO):** The BC Approved water quality guideline for DO for the protection of aquatic life identifies 8 mg/L as the minimum concentration for all stages of fish other than buried embryo. At NEMCD01, DO ranged from 7-13 mg/L, and the guideline was not met once. Because there was only an isolated occurrence of low DO, there is little cause for concern. Sometimes DO readings in the field can be low if samples are collected in standing water, as some probes consume DO at the membrane and need to be ‘gently’ swayed through the water while a reading is attained.

**pH**: The BC approved water quality guideline for the protection of aquatic life for pH allows for an unrestricted change within the range of 6.5-9.0 (BC Ministry of Environment [BC MoE] 2017). The pH at NEMCD01 ranged from 6.39 - 7.59 pH units. The lower guideline was not met once. This low value is not concerning if it reflects background conditions and was not influence by a particular anthropogenic influence/discharge to the watercourse. However, if there is a discharge into the systems, then pH should be monitored more thoroughly in accordance with the BC guidelines to ensure guidelines are met and there are no impacts on the aquatic environment. The stewardship group should also ensure that their field meter is properly calibrated daily during sampling.

**Total phosphorus:** The total phosphorus guideline for the protection of aquatic life was not met in 1 out of the 9 samples collected. Total phosphorus follows a framework-based approach where concentrations should not (i) exceed predefined ‘trigger ranges’; and (ii) increase more than 50% over the baseline (reference) levels (CCME 2004). The trigger ranges are based on the range of phosphorus concentrations in water that define the reference productivity or trophic status[1] for the site (CCME 2004). Total phosphorus ranged from <0.005 - 0.0218 mg/L at NEMCD01. Based on this data, the baseline range for total phosphorus was determined to be 0.004 - 0.010 mg/L, representing oligotrophic conditions. This is typical of unimpacted areas and generally supports diverse and abundant aquatic life and is self-sustaining (CCME 2004). Data were evaluated against the site specific guideline, calculated as 1.5 x the upper end of the baseline range, which is equivalent to 0.015 mg/L. The guideline was exceeded on May 26, 2015. Nutrient loading into a watercourse is anticipated during the spring, as a result of melting snow and rain events causing overland runoff. Since the exceedance was not prolonged, aquatic life impacts are not expected. This data provides a valuable baseline for assessing long-term changes resulting from anthropogenic influences.

# 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 be present in McDonald Creek include (BC MoE 2017a):

- Bull Trout (*Salvelinus confluentus*)
- Rainbow Trout (*Oncorhynchus mykiss*)
- Kokanee (*Oncorhynchus nerka*)

[1] Trophic status refers to the productivity of a waterbody, with eutrophic systems having high productivity and oligotrophic having low. Nutrient addition, primarily phosphorus, contributes to eutrophication, which is when the waterbody’s productivity is accelerated from natural (Wetzel 2001).

The special guidelines for streams with Bull Trout were used for reviewing the temperature data. In general, stream temperature did not exceed the maximum daily temperature of 15 ºC for Bull Trout in 2015 (Figure 1). The maximum daily temperature guideline reflects the optimal rearing temperatures for Bull Trout (6.0 ºC – 14 ºC).

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 McDonald Creek did exceed optimal spawning temperature guidelines (i.e. a max daily temperature of 10 ºC) in the early fall; however, this occurred likely before spawning was initiated by declines in temperatures below 9 ºC. Furthermore, 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 McDonald Creek did meet this guideline during the period that temperatures were measured in the spring and fall. No data exists for the winter when eggs are incubating in the gravel.

The stream temperatures did not exceed the drinking water temperature guideline of 15 ºC.

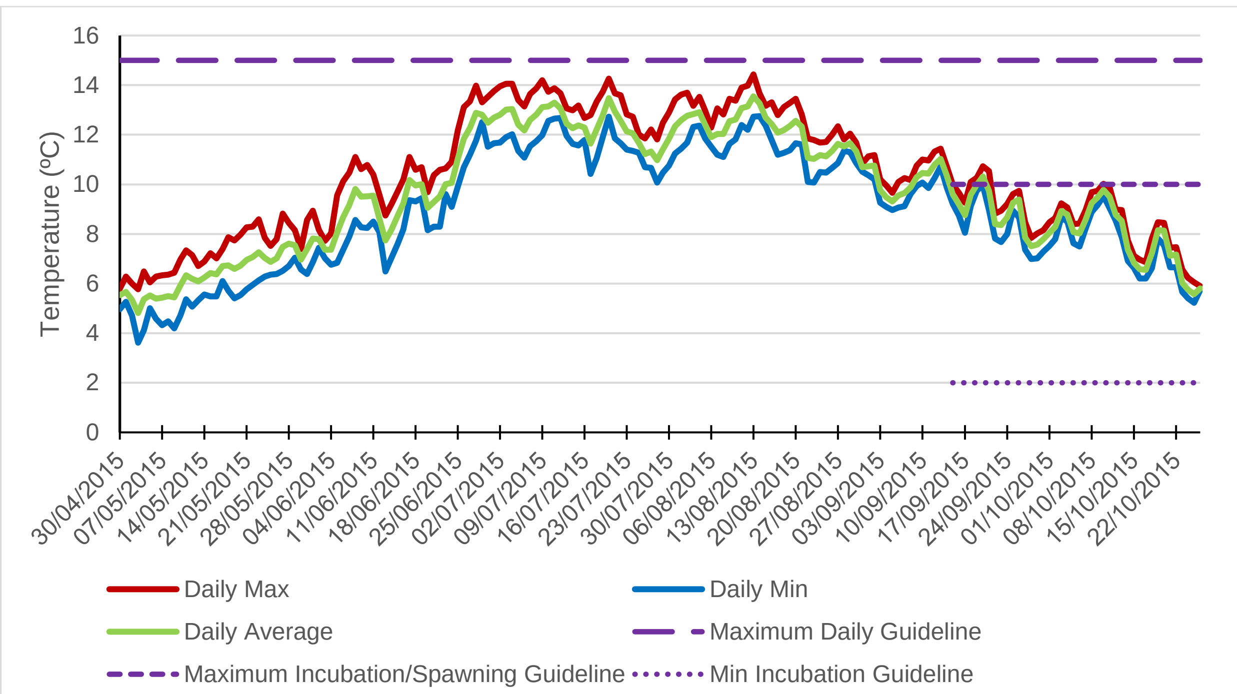


**Figure 1. Stream water temperatures in McDonald Creek from April 30 to October 26, 2015. The long dashed purple line indicates the BC MoE guideline for aquatic life for streams with Bull Trout present. The short dashes indicate maximum daily temperature during spawning, and the dotted line indicates 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 McDonald 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.

Hydrometric data in McDonald Creek is limited in 2016, as measurements were not taken in April and May due to safety concerns during high flows, and in August due to equipment issues. Results for 2015 (Figure 2, Figure 3) show steady flows and velocity after freshet (i.e. high flows due to snowmelt and/or heavy rain), which were similar to pre-freshet flows/velocity in April. The velocity/flow data from late June 2016 was substantially higher than for the same time in 2015. With the gap in freshet data for both years, the true significance is unknown (perhaps the 2016 freshet just occurred later than in 2015). By July 2016, there was a large drop, with values at summer-fall base levels through to October, similar to 2015. Although hydrometric data was not collected in August, the creek was visually similar to August 2015 (Ian Greig, personal communication).

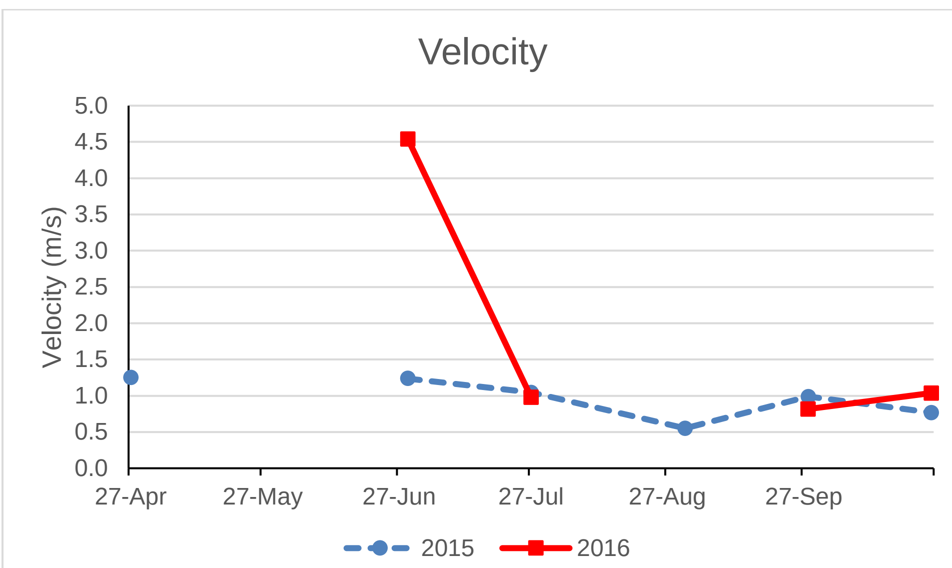


**Figure 2. Water velocity at McDonald Creek (NEMCD01) in 2015 and 2016. No measurements were taken in May for both years due to safety concerns during high flows, and in August 2016 due to an equipment issue.**

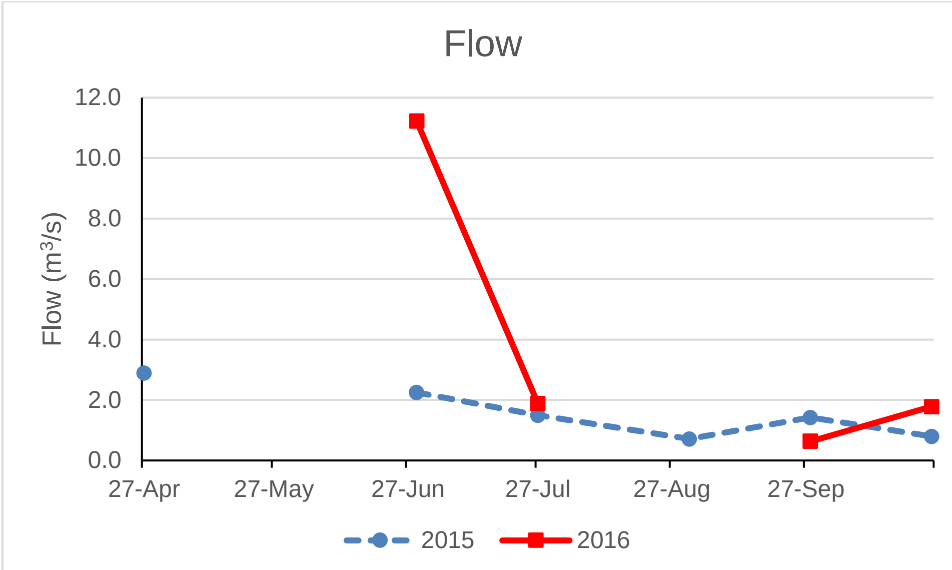


**Figure 3. Water flow at McDonald Creek (NEMCD01) in 2015 and 2016. No measurements were taken in May for both years due to safety concerns during high flows and in August 2016 due to an equipment issue.**

# 4 CABIN

CABIN data was collected following standard methods in the CABIN Field Protocols Manual (Environment Canada 2012) at NEMCD01 in the fall of 2015 and 2016. The ALESS 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 NEMCD01, CABIN BEAST analysis determined the highest probability of reference group membership was to Group 4 in both 2015 and 2016 (probabilities found in Table 1). The site was thus compared with Reference Group 4, which includes 12 streams, mostly from the Columbia Mountain and Highlands Ecoregion. The average channel depth of Reference Group 4 is 23.6 ± 11.1 cm (SD - standard deviation), which is similar to the test sites' average depth of 21.8 cm and 17.1 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 NEMCD01, as unstressed in 2015 and potentially stressed 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 |
|---|---|---|---|
| NEMCD01 | McDonald Creek, Site 1 | **Unstressed**<br>Group 4; 62.8% | **Potentially stressed**<br>Group 4; 61.6% |

## 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 NEMCD01 was 0.99 in 2015 and 0.96 in 2016. In both years there was one family not present at the test site that was expected.

## 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 here (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 4 (Mean +/- SD) | NEMCD01 | |
|---|---|---|---|
| | | 2015 | 2016 |
| Total abundance | 587.4 ± 299.1 | 1167 | 1850 |
| % EPT taxa | 87.7 ± 7.4 | 70.2 | 64.7 |
| % Chironomidae | 7.4 ± 6.4 | 8.0 | 2.1 |
| % of 2 dominant taxa | 57.9 ± 14.2 | 46.9 | 36.0 |
| Total number of taxa | 19.3 ± 3.7 | 24 | 23 |

Total abundance of organisms 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 NEMCD01 (1167 and 1850 organisms, respectively in 2015 and 2016) was higher than the reference group mean (587.4 ± 299.1 organisms), in particular during 2016. There was no evidence of nutrient enrichment in the water quality results at the site to influence these results.

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. The percent EPT was slightly higher in 2015 than 2016 at the test site (70.2 % versus 64.7 %). The 2015 value was also more similar to the reference group (87.7 ± 7.4 %), than the 2016 result. This may have contributed to the potentially stressed CABIN model outcome in 2016.

Chironomidae (non-biting midges), are generally tolerant of pollution. % Chironomidae was low at the test site in both 2015 and 2016 (8.0 % and 2.1 %, respectively), and similar to the reference group mean (7.4 ± 6.4 %). The lower 2016 value indicates improved conditions, although it is different than the reference mean.

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 the test site, the percent of the two dominant taxa in 2015 (46.9 %) was similar to the reference group (57.9 ± 14.2 %).

Again, although the 2016 tests site value (36.0 %) was lower the reference mean, a lower value indicates potentially improved conditions.

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 in both years at the test site (24 and 23 taxa, respectively), were similar to the reference sites (19.3 ±3.7 count).

Overall, the metrics do not clearly support the CABIN model analysis of the site transitioning from unstressed to potentially stressed between 2015 and 2016. Some of the differences from the reference group mean indicate healthier conditions (such as lower percent Chironomidae, and percent of 2 dominant taxa). However, increased total abundance and decreased percent EPT in 2016 were also contributors, worthwhile of continued monitoring.

# 5 Conclusions

Overall, the water quality was good at this site, exceeding three aquatic life guidelines for only a short period (pH one monthly sample in 2015), pH (one monthly sample in 2016), and phosphorus (one sample in 2015). As outlined in the results, the guideline exceedances should only be reviewed further if there is concern of anthropogenic influences relating to them in the watershed. Otherwise they may simply represent normal background conditions. Temperature data was taken from spring to fall of 2015 and did not exceed guidelines for the protection of aquatic life or drinking water. Hydrometric data from 2015 and 2016 showed similar steady flows, following the spring freshet period.

The CABIN model determination of the site being unstressed in 2015 and potentially stressed in 2016, did not appear to be a cause for concern, because the deviations from the reference group were not necessarily seen as negative when investigated more closely. In addition to the data reviews above, habitat variables reported in the CABIN outputs, such as velocity (taken at the time of CABIN sampling) and substrate were also looked over, with no major differences noted between the years. The higher and more variable flows from spring through fall of 2016 may have potentially contributed the potentially stressed CABIN result for 2016. The benthic invertebrate changes could also simply be the result of natural variability in the community.

# 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.

One project specific recommendation for the Arrow Lake Environmental Stewardship Society is to:

- Ensure the field meter is properly calibrated daily during water quality sampling, using a standard calibration solution for pH.

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 Arrow Lake Environmental Stewardship 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,

Sherri McPherson
Senior Aquatic Ecologist (BSc, RPBio)
250.464.4564
sherri.mcpherson@lotic.co

Kamila Baranowska
Aquatic Biologist, (MSc, RPBio)
705.977.0306
kamila.baranowska@lotic.co

# 8 References

BC Ministry of Environment (BC MoE). 2015. British Columbia Working Water Quality Guidelines. Government of BC. Accessed at: http://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/wqgs-wqos/bc_env_working_water_quality_guidelines.pdf

BC Ministry of Environment (BC MoE). 2016. *Environmental Management Act* Authorizations, Technical Guidance 4: Annual Reporting Under the Environmental Management Act. Version 1.3. Accessed at: http://www2.gov.bc.ca/assets/gov/environment/waste-management/industrial-waste/industrial-waste/mining-smelt-energy/annual_reporting_guidance_for_mines.pdf

BC Ministry of Environment (BC MoE). 2017. British Columbia Approved Water Quality Guidelines. Accessed at: http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-guidelines/approved-water-quality-guidelines

BC Ministry of Environment (BC MoE). 2017a. Habitat Wizard mapping tool. Available: http://maps.gov.bc.ca/ess/sv/habwiz/.

Canadian Council of Ministers of the Environment (CCME). 2017. Canadian Water and Sediment Quality Guidelines for the Protection of Aquatic Life – Summary Table. Accessed at: http://st-ts.ccme.ca/en/index.html .

CCME. 2004. Canadian water quality guidelines for the protection of aquatic life: Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems. In: Canadian environmental quality guidelines, 2004, Canadian Council of Ministers of the Environment, Winnipeg.

Environment Canada. 2012. Canadian Aquatic Biomonitoring Network: Wadeable Streams Field Manual. Accessed at: http://ec.gc.ca/Publications/default.asp?lang=En&xml=C183563B-CF3E-42E3-9A9E-F7CC856219E1

Environment Canada 2012b. CABIN Module 3 – sample processing and introduction to taxonomy and benthic macroinvertebrates.

Health Canada. 2017. Guidelines for Canadian Drinking Water Quality. Accessed at: http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/sum_guide-res_recom/index-eng.php .

McPhail, J.D. 2007. The freshwater fishes of British Columbia. The University of Alberta Press. Edmonton, Alberta. 620 p.

Oliver G.G., and L.E. Fidler. 2001. Towards a Water Quality Guideline for Temperature in the Province of British Columbia. Prepared by Aspen Applied Sciences Ltd. for the B.C. Ministry of Environment, Lands, and Parks. 54 pp + appendices.

Province of BC. 2003. British Columbia field sampling manual: 2003- for continuous monitoring and collection of air, air emission, water, wastewater, soil sediment and biological samples. Available at: http://www2.gov.bc.ca/assets/gov/environment/research-monitoring-and-reporting/monitoring/emre/field_sample_man2013.pdf.

Rosenberg, D.M. and Resh, V.H. 1993. Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman and Hall, New York. pp.199

Rosenberg, D.M., T.B. Reynoldson and V.H. Resh. 1999. Establishing reference conditions for benthic invertebrate monitoring in the Fraser River Catchment British Columbia, Canada. Fraser River Action Plan, Environment Canada, Vancouver BC Accessed at: http://www.rem. sfu.ca/FRAP/9832.pdf

Wetzel, R.G. 2001. Limnology – Lake and River Ecosystems (third edition). Academic Press, San Diego, USA. 1006 pp.