Crawford Creek
Water Quality Monitoring Report
2015 – 2017

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Cover photo

Upstream view of Crawford Creek from monitoring site NJCRA01, September 2017.

Project Highlights

The Columbia Basin Water Quality Monitoring Project (CBWQ) is an environmental stewardship project funded by Columbia Basin Trust. Under the CBWQ, the East Shore Freshwater Habitat Society conducted water quality monitoring in Crawford Creek from 2015 to 2017. Monitoring was conducted downstream of the community of Crawford Bay, at site NJCRA01. The site was selected because it was near the mouth of the creek, and thus downstream of most uses that could influence creek health (e.g., residential, commercial, agricultural, and forestry activities). Four components were monitored: benthic macro-invertebrate community using Canadian Aquatic Biomonitoring Network (CABIN), water quality, water temperature, and hydrologic characteristics (i.e., velocity and streamflow).

CABIN monitoring determined NJCRA01 to be unstressed in 2015 and 2017, and potentially stressed in 2016. The potentially stressed characterization was evident through slightly poorer outcomes for benthic macro-invertebrate community composition metrics relative to the reference group mean. Specifically, total invertebrate abundance was higher; proportion of Ephemeroptera, Plecoptera, and Trichoptera orders of taxa (EPT) was lower; proportion of Chironomidae was higher; and the proportion of two dominant taxa was higher. Deeper water conditions was the one habitat variable that was evident to possibly contribute to the potentially stressed outcome in 2016. It may also have been due to natural variability.

The water quality was good at this site. Although there were three guidelines for the protection of aquatic life not met, exceedances occurred only incidentally. Zinc was exceeded once in 2015, pH was exceeded once in 2016, and total phosphorus was exceeded once 2017. *Escherichia coli (E. coli)* regularly exceeded the drinking water guideline, and as a result, it is recommended that water be disinfected prior to consumption. The source of *E. coli* was unknown; however, it could be influenced by domestic livestock, wildlife, or potentially septic systems.

Monthly average water temperatures at NJCRA01 did not show a notable difference amongst the years sampled. Water temperature guidelines for Bull Trout rearing, spawning, and incubating were often not met. It is unknown if Bull Trout utilize the area where temperature data were collected. However, based on temperature results, they would likely seek suitable waters elsewhere in the watershed. Instantaneous streamflow data indicated similar hydrologic conditions amongst the three years sampled.

The three-year baseline monitoring program provides some understanding of natural conditions and variation. This baseline will be valuable help to assess changes over time.

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1 Introduction

Community-based water quality monitoring in the Columbia River Basin plays an important role in gathering baseline information to understand watershed function and potential influences of concern. This information can help inform management decisions, to ensure that aquatic ecosystems are preserved, which in turn will contribute to maintaining sustainable communities. It is imperative that current and future water quality and quantity concerns be assessed in the Columbia River Basin as environmental change poses substantial risk to ecosystem and societal health. Changes in land use and climate change have the potential to substantially alter water quality and quantity in the Columbia River Basin (Carver 2017). Current and future reductions in snow accumulation (Barnett et al. 2008) and glacial ice (Jost et al. 2012) have been shown to result in reduced water supply in the Columbia Basin, particularly for the low flow summer periods (Burger et al. 2011). Lower streamflow leads to a reduced ability for streams to dilute pollution, potentially resulting in substantial water quality issues. In addition to climate change, the diverse land uses of the Columbia River Basin, including: recreational and industrial development, stream flow regulation, municipal and industrial waste water, and non-point source pollution present a challenge for community-based water quality management.

A first step in addressing present and future water quality and quantity issues is developing community awareness and involvement. The Columbia Basin Water Quality Monitoring Project (CBWQ) had its beginnings at a 2005 Watershed Stewardship Symposium sponsored by Columbia Basin Trust (CBT), where the Columbia Basin Watershed Network was born. A key resolution from that meeting was for CBT to build capacity for watershed groups to monitor water quality in their watersheds. Consequently, on a sunny weekend in June 2006, reps from watershed groups from across the Columbia Basin met in Kimberley to attend a monitoring workshop with Dr. Hans Schreier and Dr. Ken Hall from UBC. At the end of the workshop Mainstreams agreed to coordinate the Columbia Basin Water Quality Monitoring Project and four groups began water quality monitoring in September 2007 with the following goals:

1. Develop a science-based model for community-based water quality monitoring;
2. Establish online accessibility to water quality data; and,
3. Link the monitoring project with community awareness activities.

All told, twelve watershed stewardship groups have participated in the project. Data collected by these groups can be found at the CBWQ website www.cbwq.ca.

As a part of the CBWQ, the East Shore Freshwater Habitat Society (ESHS or the stewardship group) conducted water quality monitoring in Crawford Creek from 2015 to 2017. The following four components were monitored: benthic macro-invertebrate community using Canadian Aquatic Biomonitoring Network (CABIN) methods, water quality, water temperature, and hydrologic characteristics (i.e., velocity and streamflow). This report presents the data, analyses the results, relates biological results to physical monitoring findings, and provides recommendations for future stream health monitoring.

Ongoing funding from CBT has been and continues to be key to keeping this unique project, guided and administered by community watershed groups operating until June 2018.

1.1 Crawford Creek background

The ESFHS is a public organization formed in 2014, engaged in the enhancement of the watershed systems along the east shore of Kootenay Lake. The ESFHS's mandate is to promote responsible use of fish and wildlife resources, and to enhance fish populations in the Kootenay Lake ecosystem. The ESFHS also provides education to residents, tourists, and students who interface with the environment in the Kootenay Lake region.

The organization's initial activities centered around reviewing the condition of several of the streams along the east shore, from Tam O' Shanter Creek in the north to the Goat River in the south. From this, it was determined that initial monitoring efforts would focus on Crawford Creek, as it was central to numerous facilities and had historically provided habitat for a large spawning run of Kokanee. Crawford Creek is also an important stream locally for Bull Trout, which utilize the upper reaches, away from the residential, agricultural, and commercial disturbances associated with the community of Crawford Bay.

Crawford Creek is located at the northern extreme of the South Arm of Kootenay Lake. It is at the head of Crawford Bay, the largest sheltered bay on Kootenay Lake. The Crawford Creek watershed area is 187 km^2. The watershed has been subject to extreme flood events, the largest and most recent being the 2012 flood. This was caused by heavy precipitation during the normal June freshet (upper elevation melt water runoff).

Crawford Creek forms a sandy delta at the head of Crawford Bay. The community of Crawford Bay formed around this area, as it provides a relatively extensive area of low lying flat terrain, amenable to development. The lower 2 km of Crawford Creek flows through residential, commercial and agricultural development. The upper portions of Crawford Creek have been subjected to ongoing forestry activities. As a result of vegetation clearing, it has appeared to the ESFHS that overland runoff has increased in the spring, resulting in heightened stream channel erosion. The ESFHS is working on repairing riparian disturbance in the downstream 2 km of Crawford Creek, to improve spawning and rearing habitat for Kokanee.

Monitoring was conducted downstream of the community of Crawford Bay, at site NJCRA01 (Figure 2, Figure 1). The site was selected because it was near the mouth of the creek and thus downstream of most uses that could influence creek health.

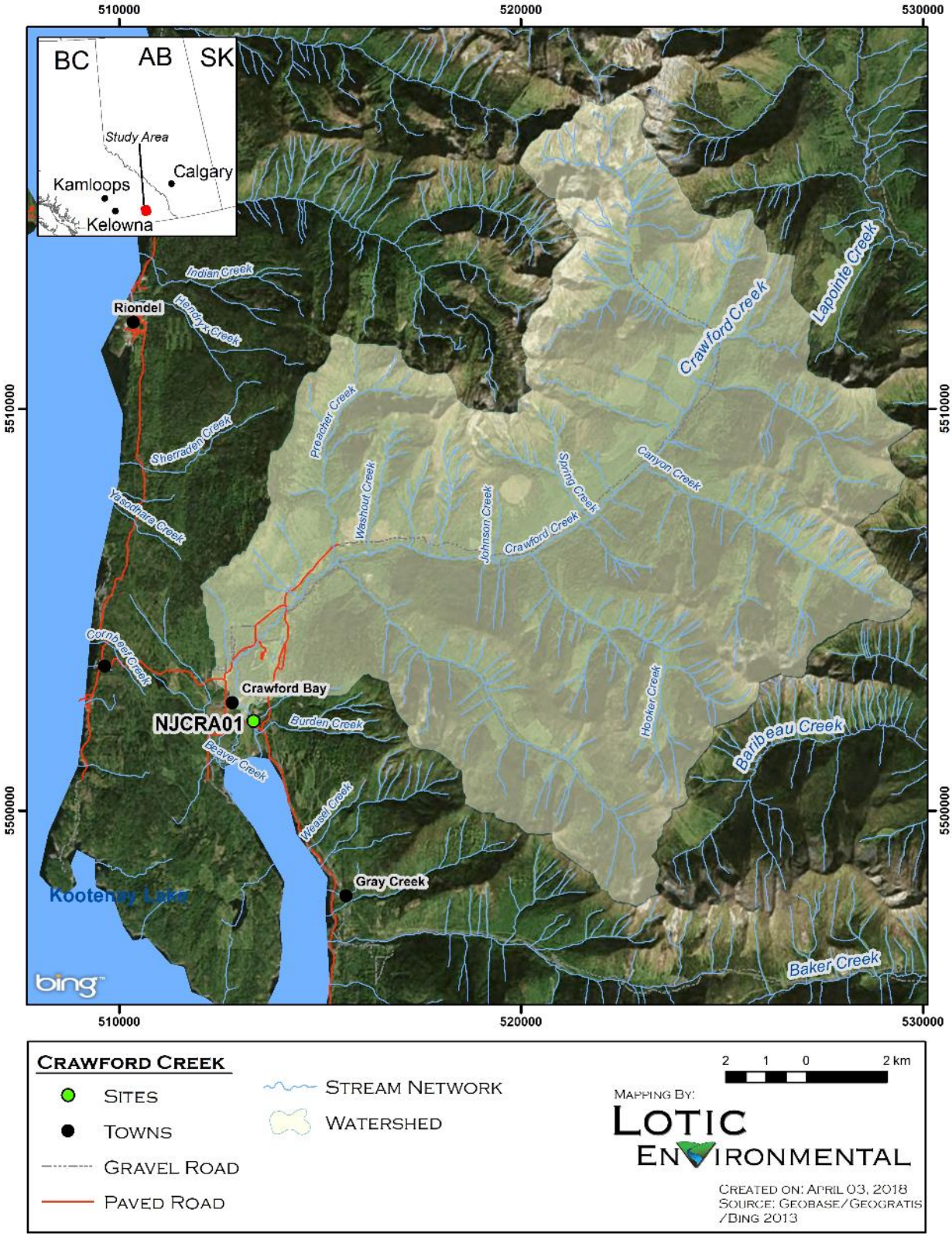

Figure 1. Crawford Creek monitoring location

Figure 2. Downstream view of site NJCRA01, Sept 12, 2017.

1.2 Fish community

The fish community in Crawford Creek is comprised of five native species (Table 1).

Table 1. Fish species documented in Crawford Creek (BC MoE 2018a).

Species - common name	Scientific name
Bull Trout	*Salvelinus confluentus*
Kokanee	*Oncorhynchus nerka*
Rainbow Trout	*Oncorhynchus mykiss*
Mountain Whitefish	*Prosopium williamsoni*
Prickly Sculpin	*Cottus asper*

Bull Trout (interior lineage*)* is a species of conservation concern. Bull Trout is recognized as a species of Special Concern in BC and by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; BC Conservation Data Center [BC CDC] 2018). Locals often observe Bull trout migrating upstream in the fall, beyond the 2 km point from the stream mouth, where habitat conditions are presumed to be more suitable for spawning and rearing. The monitoring site is downstream of the area used by Bull Trout.

2 Methods

2.1 Data collection, data entry, and initial data presentation, completed by CBWQ stewardship group

Overall, data were collected following the CBWQ Operating Procedures (CBWQ 2012) and the CABIN Field Procedures for Wadeable Streams (Environment Canada 2012a). The CBWQ stewardship group completed all the field work, downloaded data into standard spreadsheets, and as applicable, conducted initial analyses (i.e., summary graphs, CABIN site reports) (Figure 3).

Figure 3. East Shore Freshwater Habitat Society field crew, Garth Norris (left); and Fred Green, Brian Zytaruk, and Tom Lang (right).

Benthic macro-invertebrates

CABIN sampling was conducted once a year in the fall. Invertebrate samples were analysed by Pina Viola Taxonomy following CABIN laboratory methods (Environment Canada 2012b). Data were entered into the online CABIN database and site reports were prepared using the CABIN analysis tools.

Water quality

Water quality laboratory analysis was completed by Maxxam (Burnaby, BC). The following water quality data were collected at NJCRA01:

a. Monthly (spring through fall 2015 - 2017) - nutrients, total suspended solids (TSS), dissolved chloride, *Escherichia coli,* and *in situ* (field measured) data. *In situ data* were dissolved oxygen (DO), water and air temperature, specific conductivity, pH, and turbidity.

b. Annually, in the fall (coinciding with CABIN monitoring) - in addition to data above, inorganics, and metals. However, metals were also collected in June in 2016 and 2017.

c. Once in 2016 - a duplicate and blank sample.

The transpose add-in tool created by Devin Cairns (Blue Geosimulation) was used to automate the addition of new water quality data from Maxxam into the existing CBWQ datasets. Using the add-in tool, users opened MS Excel files from Maxxam and chose which MS Excel file to append the new data into. The add-in matched parameter names in the files and converted units (e.g., between µm and mg), flagging the data cells that were successfully transferred.

Stream temperature

Hourly stream temperature (°C) was measured using a HOBO Pro V2 temperature logger. Measurements were taken for the period from April 12, 2015 – April 22, 2017. The data were downloaded into a spreadsheet, and descriptive statistics (daily maximum, minimum, and average) were calculated. Monthly averages were also calculated.

Hydrometric data

Monthly streamflow and velocity data were collected. Velocity is the speed of water and is measured as a unit of distance per time (m/s). Streamflow, also known as discharge, is a measure of the volume of water moving through a stream channel in a given amount of time (m^3/s).

Depth (m) and velocity were measured using a Swoffer 3000 flow meter. Measurements were collected at regular length intervals across the stream. Streamflow was calculated using Equation 1, where the Wetted Stream Width (m) and Average Depth were determined in the stream profile.

Equation 1: Stream flow (Q)

Q = Wetted Stream Width (m) x Average Depth (m) x Average Velocity (m/s).

2.2 Analysis overview

Following the data collection preparation described above completed by the CBWQ, Lotic Environmental Ltd. completed analyses and reporting. This included completing a quality assurance/quality control review (QA/QC) of data, comparing results to applicable guidelines, interpreting results, and providing recommendations.

The Reference Condition Approach (RCA) in CABIN was used to determine the condition of the benthic macro-invertebrate community at the test site (as sampled by the CBWQ group), by comparing the test site results to a group of reference sites with similar environmental characteristics. The Analytical Tools function in the CABIN database was used to run four analyses to review invertebrate test site data (Steps 1a – 1d in Figure 4): BEnthic Assessment of SedimenT (BEAST), River Invertebrate Prediction and Classification System (RIVPACS), community composition metrics, and habitat metrics. Water quality (Step 2), stream temperature (Step 3) and hydrometric (Step 4) analyses followed to provide an overall understanding of stream condition.

The reference model used in the RCA analysis was the Preliminary Okanagan-Columbia Reference Model (2010) provided in the online CABIN database. Because the model was still considered preliminary, with some potential data gaps, caution was exercised when interpreting RCA results (obtained from Steps 1a to 1d). Furthermore, it was important that all subsequent analyses (Steps 2 – 4) were conducted.

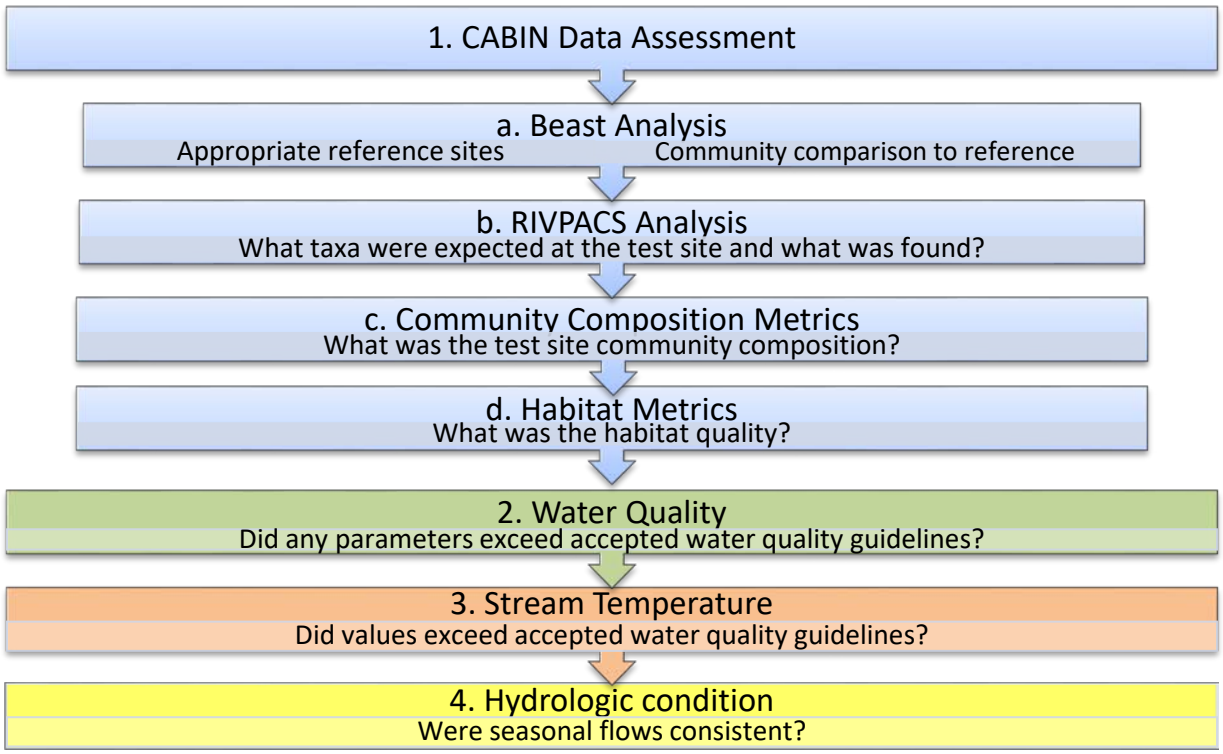

Figure 4. Stream condition analysis steps.

2.3 CABIN data analysis

2.3.1 Reference Condition Approach: BEAST analysis and site assessment

BEAST analysis was used to predict test sites to a reference group from the Preliminary Okanagan-Columbia Reference Model provided by Environment Canada through the CABIN database. BEAST used a classification analysis that determined 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 were latitude, longitude, percent area of watershed with a gradient <30%, percent area of watershed with permanent ice cover, and average channel depth.

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

2.3.2 RIVPACS analysis

RIVPACS ratios were calculated in the Analytical tools section of the CABIN database. RIVPACS analysis relied on presence/absence data for individual taxa. The RIVPACS ratio determined the

ratio of observed taxa at test sites to taxa expected to be present at the test site based on their presence at reference sites. A RIVPACS ratio close to 1.00 indicated that a site was in good condition, as all taxa expected to be present were found at the test site. A RIVPACS ratio >1.00 could indicate community enrichment, while a ratio <1.00 could indicate that the benthic community was in poor condition.

2.3.3 Community composition metrics

Benthic community composition metrics were calculated in the CABIN database using the Metrics section of the Analytical Tools menu. A collection of relevant measures of community richness, abundance, diversity, and composition were selected to describe the test site communities. Using metrics, indicator attributes were used to interpret the response to environmental disturbances. Metrics are complimentary to an RCA analysis.

2.4 Water quality data analysis

2.4.1 Water quality QA/QC

Raw data were first subjected to a quality control evaluation to assess the accuracy and precision of the laboratory and field methods. For all water samples analysed, the laboratory assessed accuracy through the use of matrix spike, spiked blank, and method blank samples. As well, the laboratory measured precision through duplicate sample analysis. As per standard practice, all laboratory quality control results were reviewed and confirmed to meet standard criteria prior to proceeding with processing of field samples (Maxxam 2012).

Field duplicates were submitted to the laboratory to measure both field sampling error plus local environmental variance. Duplicate review was based on relative percent difference (RPD) as determined by Equation 2. For duplicate values at or greater than five times the Reportable Detection Limit (RDL), RPD values >50% indicated a problem, most likely either contamination or lack of sample representativeness (BC MoE 2003). Where RPD values were greater than 50%, the source of the problem was determined, and the impact upon the sample data ascertained (BC MoE 2003). If data were found to be within acceptable ranges, subsequent analyses included only the first of the duplicate samples.

Equation 2: Duplicate sample quality control

Relative Percent Difference = (Absolute difference of duplicate 1 and 2/average of duplicate 1 and 2)*100

$$\text{RPD} = \left(\frac{\text{Duplicate 1} - \text{Duplicate 2}}{(\text{Duplicate 1} + \text{Duplicate 2})/2} \right) \text{X } 100$$

Field blank data were collected to monitor possible contamination prior to receipt at the laboratory. Field blanks were collected using laboratory issued de-ionized water. Field blank results were analysed using Equation 3. Field blank values that were 2 times greater than the reportable detection limit were considered levels of alert (Maxxam 2012, Horvath pers. comm.). Field blank values that exceeded the alert level were reviewed in more detail to identify the potential source(s) for contamination; additionally, other data collected on that day were compared to historical data to identify if there were anomalies possibly related to contamination.

Equation 3: Field Blank sample quality control

$$\text{Blank x difference} = \frac{\text{Field Blank Value}}{\text{Reportable Detection Limit (RDL)}}$$

2.4.2 Guideline review

A guideline is a maximum and/or a minimum value for a characteristic of water, which in order to prevent specified detrimental effects from occurring, should not be exceeded (BC MoE 2018). Water quality results were compared to the applicable provincial and federal guidelines for the protection of aquatic life and drinking water. Exceedances of guidelines were flagged to provide an understanding of the potential impacts to aquatic life or drinking water.

When there was more than one guideline for a parameter, the following hierarchy was applied to determine the guideline that would apply (BC MoE 2016):

a. BC Approved Water Quality Guidelines (BC MoE 2018b)
b. BC Working Water Quality Guidelines (BC MoE 2017)
c. The Canadian Environmental Quality Guidelines (Canadian Council of Ministers of the Environment [CCME] 2017), or Health Canada (2017).

When both long-term and short-term exposure guidelines were available, the long-term guideline was used in the review, since sampling was assumed to have occurred under ‘normal’ conditions.

2.5 Stream temperature analysis

Stream temperature statistics (daily maximum, minimum, and average) were graphed. The results were reviewed against the BC stream temperature guidelines for the protection of aquatic life and drinking water that were most applicable to the monitored site. The aquatic life guidelines are dependent on the fish species (mostly salmonids) found in the stream for different life stages (rearing, spawning, and incubation) (BC MoE 2018b).

2.6 Hydrometric data analysis

Hydrometric data were reviewed for consistency and anomalies. Streamflow results were graphed, with seasonal patterns compared qualitatively among the years.

3 Results

3.1 CABIN results

3.1.1 Reference Condition Approach: BEAST analysis and site assessment

For NJCRA01, CABIN BEAST analysis determined the highest probability of reference group membership was to Group 4 in 2015 - 2017 (Table 2). 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 27.4 cm. 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 (Appendix A). The CABIN model assessed NJCRA01, as unstressed in 2015 and 2017, and potentially stressed in 2016.

Table 2. 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	2015	2016	2017
NJCRA01	**Unstressed** Group 4; 73.6%	**Potentially stressed** Group 4; 74.8%	**Unstressed** Group 4; 72.2%

3.1.2 RIVPACS analysis

The RIVPACS ratio at NJCRA01 was 0.80 in all years (Table 3). This indicates that most families expected to be present, based on the reference group, were found at the test site. In all years the same three families were not present at the test site that were expected.

Table 3. RIVPACS Observed:Expected Ratios of taxa at test sites. Taxa listed had a probability of occurrence >0.70 at reference sites and were not observed at the test site. Condition indicated as shaded background*.

Site	2015	2016	2017
NJCRA01	0.80 Capniidae, Chloroperlidae, Perlidae	0.80 Capniidae, Chloroperlidae, Perlidae	0.97 Capniidae, Chloroperlidae, Perlidae

*CABIN model condition: unstressed, potentially stressed, stressed, severely stressed.

3.1.3 Community composition metrics

Key benthic macro-invertebrate metrics that were reviewed in detail (Table 4) include: total abundance; percent composition of Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) orders (EPT); percent composition of Chironomidae (non-biting midges) taxa; percent composition of the two dominant taxa; and total number of taxa.

Table 4. Benthic macro-invertebrate community composition metrics measured in 3 min kicknet samples at NJCRA01, 2015-2017. Condition indicated as shaded background*

Metric	Reference Group 4 (Mean ± std dev)	NGMAT01		
		2015	2016	2017
Total abundance	933.4 ± 922.0	1282.1	2087.5	1522.7
% EPT taxa	83.0 ± 13.5	73.0	48.3	75.5
% Chironomidae	11.7 ± 12.7	7.8	39.6	14.0
% of 2 dominant taxa	57.3 ± 13.7	52.9	75.4	70.1
Total number of taxa	20.0 ± 4.8	21.0	21.0	21

*__CABIN model condition:__ unstressed, potentially stressed, stressed, severely stressed.

Overall, there were several community metrics at NJCRA01 that were slightly different than the reference group mean in 2016. While in 2015 and 2017, all metrics reviewed were within the reference group mean. These results support the CABIN model assessment of the site being potentially stressed in 2016 and unstressed in 2015 and 2017.

In 2016, NJCRA01 had a total abundance of 2087.5 organisms, while the reference group mean was 933.4 ± 922 organisms. Total abundance of organisms can be dependent on many factors including type of stress and the organisms involved (Rosenberg and Resh 1984). Although abundance may increase due to nutrient enrichment (Environment Canada 2012c), there was no evidence of nutrient enrichment in the water quality results at the site (Section 2.4).

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 % EPT in 2016 was 48.3 %, which was lower than the reference group mean (83.0 ± 13.5 %). Chironomidae (non-biting midges) are generally tolerant of pollution. In 2016, the percentage of Chironomidae at the test site (39.6 %), was higher than the reference group mean (11.7 ± 12.7 %).

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 (Environment Canada 2012c). Opportunistic taxa that are less particular about where they live replace taxa that require special foods or particular types of physical habitat (Environment Canada 2012c). In 2016, the percent of the community represented by the two dominant taxa (75.4 %) was higher than the reference group mean (57.3 ± 13.7), also indicating the potentially stressed benthic macro-invertebrate community.

Overall, there were several benthic macro-invertebrate community metrics that indicated why NJCRA01 was assessed to be potentially stressed in 2016, relative to being unstressed the other two years sampled. The reason for the shift to a slightly poorer community was unconfirmed. General water quality, water temperature, and stream flow were relatively stable amongst the years. The one evident difference was that water was 10 to 18 cm deeper in 2016 relative to the other years sampled (see below). This may have contributed to the change in community.

3.1.4 Habitat Conditions

Key physical habitat conditions that could influence benthic macro-invertebrate community health were provided for comparison amongst the sampling years (Table 5). Average stream depth in 2016 (36.3 cm), was one characteristic that was higher than both the reference group mean (23.6 ± 11.1 cm), and the other years sampled. Stream depth may have influenced the invertebrate community. While stream depth was different than the reference group mean, substrate composition at NJCRA01 was similar in all years.

Table 5. Select physical habitat characteristics for the predicted reference group, and NJCRA01 during CABIN sampling.

Parameter	Reference group mean ± std dev	2015	2016	2017
Average depth (cm)	23.6 ± 11.1	26.3	36.3	18.3
Average velocity (m/s)	0.48 ± 0.22	0.41	0.44	0.17
% Cobble (6.4 - 25.6 cm)	51 ± 15	89	92	93
% Pebble (1.6 – 6.4 cm)	37 ± 20	5	3	5
% Gravel (0.2 – 1.6 cm)	3 ± 3	0	0	2
% Sand (0.1 – 0.2 cm)	0 ± 0	0	0	0
% silt and clay (<0.1 cm)	0 ± 0	0	0	0

3.2 Water quality results

3.2.1 Water quality QA/QC

The relative percent difference for the 2016 parameters sampled in duplicate, indicated that all but one parameter was below the concern level of 50%, indicating a high degree of precision (94%) in data collection and lab procedures (Appendix B1). Also, all but one field blank parameter analyzed was below the alert level, indicating that 94% of the sample was contaminant free and analysed with precision.

3.2.2 Guideline review

Water quality results met all but three aquatic life and/or drinking water guidelines for the non-metal parameters (Appendix B2). There was one metal parameter guideline that was not met (Appendix B3). Exceedance details are as follows:

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] 2018b). The pH ranged from 6.1 to 7.91 pH units and was below the guideline in one sample (May 2016). This value is not concerning as 95% of samples had a pH within the normal range, and the mean was 7.2, also within the normal range. Also, low pH can occur naturally, and is only a concern if it is influenced by a particular anthropogenic discharge to the watercourse, in which case pH should be monitored more thoroughly in accordance with the BC guidelines. This low value could have also been due to the field meter not being calibrated.

Total phosphorus: The total phosphorus guideline for the protection of aquatic life was not met in 1 out of the 14 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 was below detectable limits (<0.005 mg/L) in all but two samples; both occurred in May (0.0065 and 0.0161 mg/L in 2016 and 2017, respectively). Based on these data, the baseline range for total phosphorus was determined to be 0.004 - 0.010 mg/L, representing oligotrophic conditions (CCME 2004). 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 exceedance thus occurred on May 2017. 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 were not expected. These data provide a valuable baseline for assessing long-term changes resulting from anthropogenic influences.

E coli: The *E coli* drinking water guideline for raw untreated drinking water is 0 CFU/100 mL (BC MoE 2001, Health Canada 2017). *E. coli* values ranged from <1 to 48 CFU/100 mL, with the guideline exceeded in 74% of samples. *E. coli* is a bacteria found in human and animal feces, which can cause intestinal infection if present in untreated drinking water (BC MoE 2001). The source of *E. coli* at NJCRA01 was unknown; however, it could be influenced by domestic livestock, wildlife, or potentially septic systems.

Amongst all results from 2015-17, 13 of the 19 samples had *E. coli* values between 1 and 10 CFU/100 ml, with values below 10 indicating a low level for concern (Yeow pers. comm.). One sample was greater than 20 CFU/100 ml, which is considered more serious (Yeow pers. comm.). Drinking water derived from surface water and shallow groundwater sources should receive disinfection as a minimum treatment before human consumption (BC MoE 2001). Boiling for at least one minute would be recommended as an effective treatment (HealthLink BC 2018).

Total zinc: Zinc ranks fourth among metals of the world in annual consumption and is found in an array of products (BC MoE 2018b). Zinc is an essential element in trace amounts for plants and animals, but can be toxic in high concentrations (BC MoE 2018b). Total zinc was 14.7 µg/L on September 28, 2015, exceeding the long-term (average) aquatic life guideline of 7.5 µg/L. However, this value was considerably lower than the short term (maximum) guideline of 33 µg/L, and the two subsequent samples collected in 2016 and 2017 were less than detectable levels.

3.3 Stream temperature results

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.
- Increased oxygen demand, while the dissolved oxygen content of water decreases.
- Reduced ability to cope with swimming demands, which is compounded by biological stresses such as predation and disease.

[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).

- In waters where dissolved gases are supersaturated, elevated water temperatures may worsen the effects of gas bubble trauma in fish.

Monthly average water temperatures for the three years sampled at NJCRA01 were not notably different between the years (Table 6); at least not in a manner that might explain why the benthic macro-invertebrate community was potentially stressed in 2016 and unstressed in 2015 and 2017. Monitoring over a longer time period would be required to determine trends.

Table 6. Monthly average (Avg) and standard deviation (Std Dev) in daily average stream temperature (°C) from 2015 – 2017 at NJCRA01.

Month	2015		2016		2017	
	Avg	Std Dev	Avg	Std Dev	Avg	Std Dev
January	-	-	1.79	0.87	0.77	0.88
February	-	-	2.94	0.70	1.10	0.85
March	-	-	4.36	0.95	2.94	0.87
April	5.55	0.63	4.36	0.38	4.76	0.52
May	7.02	0.76	10.26	0.55	-	-
June	10.77	2.06	8.95	1.17	-	-
July	15.05	0.96	7.49	1.36	-	-
August	10.06	1.42	14.31	0.71	-	-
September	10.06	1.06	10.73	0.75	-	-
October	7.84	1.52	6.99	1.28	-	-
November	2.91	1.77	5.03	1.04	-	-
December	1.86	1.04	0.95	0.94	-	-

*Data were collected for only part of the month

Because of Bull Trout's presence in Crawford Creek, stream temperature data were compared to the guidelines for Bull Trout. In general, summer stream temperatures regularly exceeded the maximum daily Bull Trout rearing temperature of 15ºC (Figure 5). These fish likely seek out deeper cooler waters (e.g., in Kootenay Lake) during the warm summer months.

Bull Trout spawning generally occurs from mid-September to late October and often is initiated when water temperatures drop below 9ºC (McPhail 2007). The maximum daily temperatures at the monitoring location in Crawford Creek exceeded the optimal spawning temperature guideline of 10ºC through to mid-October in 2015, and to early October in 2016. However, it is unknown if fish spawn in the location of the temperature logger, as monitoring of spawning or potential for spawning (based on habitat characteristics such as gravel size, flows, and depths) were not part of this study. If spawning occurs in Crawford Creek, it may occur in other locations, like where groundwater-surface water interactions are high (Baxter and Hauer 2000), as these areas provide consistent year-round water temperatures (i.e., approximately 5ºC) (Meisner *et al.* 1988). If spawning had occurred, the minimum temperature guideline during egg incubation is 2ºC. Temperatures at the location measured in Crawford Creek were below the minimum guideline regularly in the winter. Again, this may be a site-specific condition related to the temperature logger location, and does not preclude the potential for successful Bull Trout incubation elsewhere in the creek, particularly areas with groundwater upwelling.

The stream temperatures exceeded the drinking water temperature guideline of 15 ºC in the summer. 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).

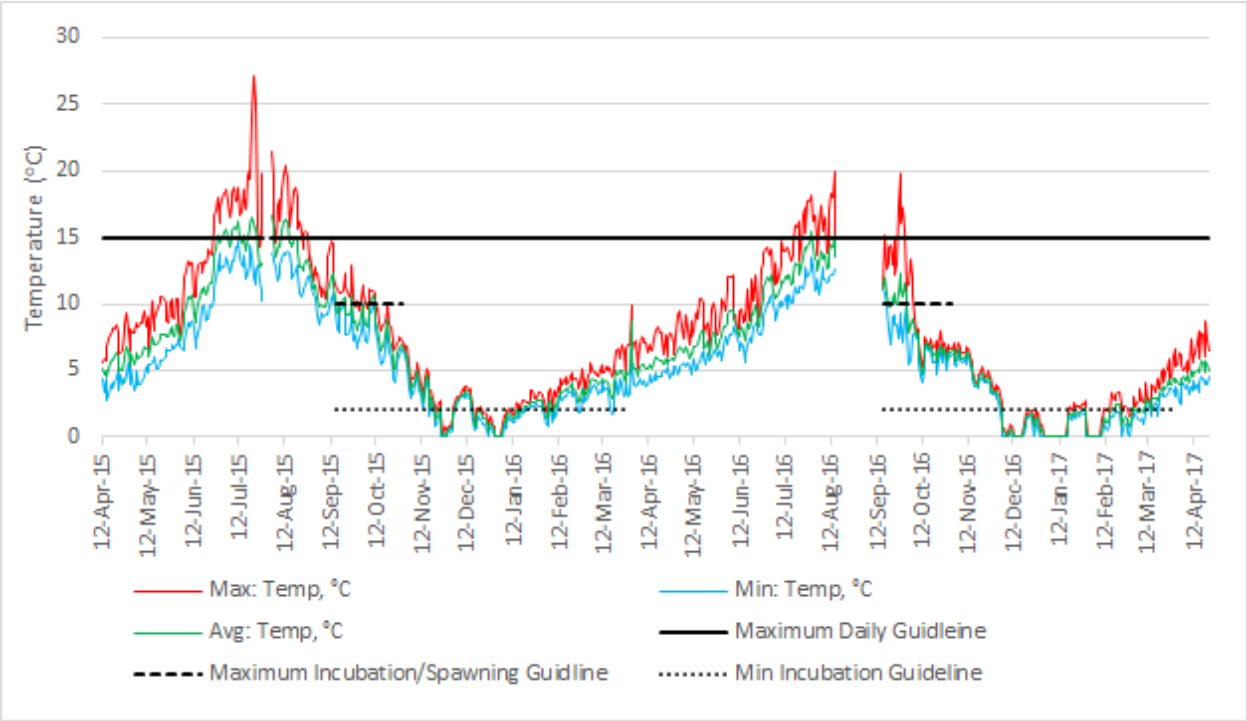

Figure 5. Average daily stream water temperatures in Crawford Creek (NJCRA01) from April 12, 2015 to April 22, 2017. The guidelines presented are for the protection of aquatic life for streams with Bull Trout present (BC MoE 2018b).

3.4 Hydrometric results

Streamflow plays 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).

Instantaneous streamflow data were collected on a monthly basis from spring through fall in 2015-2017, with the exception of during the highest flows when it was unsafe to wade in the stream (Figure 6). Spring freshet (i.e., high flows due to snowmelt and/or heavy rain) started as early as April and extended through to June. Streamflow decreased through the summer reaching baseflow that was consistent into the fall. Baseflow was lowest in 2017, with the lowest flow being 1.08 m^3/s on September 12.

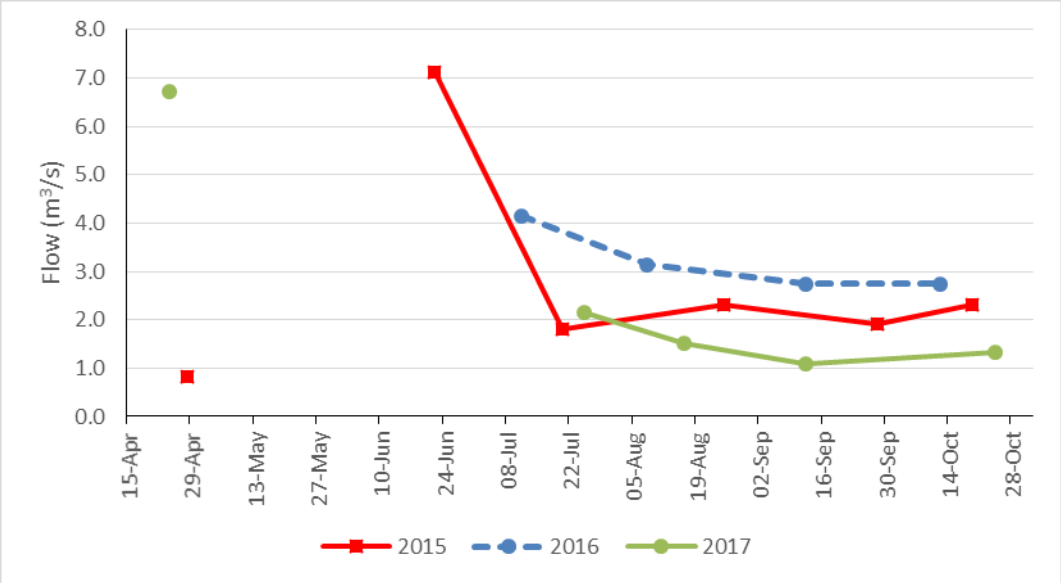

Figure 6. Streamflow in Crawford Creek (NJCRA01), 2015-2017.

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 described using a long-term dataset. This would be best achieved using continuous level loggers and developing level-streamflow 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 are still important as they can be used to evaluate changes in streamflow patterns with time.

4 Conclusions

The CABIN model determined NJCRA01 to be unstressed in 2015 and 2017, and potentially stressed in 2016. The potentially stressed characterization was evident through slightly poorer outcomes for invertebrate community composition metrics relative to the reference group mean. Specifically, total abundance was higher, proportion of EPT taxa was lower, proportion of Chironomidae was higher, and the proportion of two dominant taxa was higher. Greater stream depth in 2016 was the one habitat variable that was found to be different amongst the years, and may have contributed to the change in invertebrate community. The change may have also been the result of natural variability.

The water quality was good at this site. Although there were three guidelines for the protection of aquatic life not met, exceedances occurred only incidentally. Zinc was exceeded once in 2015, pH was exceeded once in 2016, and total phosphorus was exceeded once 2017. E. coli regularly exceeded the drinking water guideline, and as a result, it is recommended that water be disinfected prior to consumption.

Monthly average water temperatures at NJCRA01 did not show a notable difference amongst the years sampled. Water temperature guidelines for Bull Trout rearing, spawning, and incubating were often not met. It is unknown if Bull Trout utilize the stream where the temperature logger

was located. However, based on these results, they would likely seek suitable waters elsewhere in the watershed. Instantaneous streamflow data indicated a similar flow pattern amongst the three years sampled.

5 Recommendations

The existing monitoring program was good for developing a baseline. Three years of monitoring provide a good picture of benthic macro-invertebrate health and water quality, assuming that the years captured were relatively representative of general conditions in the watershed and there were no changes in land-use during the years monitored. This information can be used in the future to identify if there are any water quality or invertebrate changes caused by increased disturbance. Obtaining data over a longer period, of course, would help provide a greater understanding of natural variability in the system over time, but we recognize that resources are limited and a three-year period is realistic and achievable. Now that baseline data have been attained, sampling should focus on other locations experiencing ongoing development pressures.

There is a variety of other information, outside of the scope of this monitoring project that could be potentially collected to support a baseline understanding of a watershed. This may include, but not be limited to: 1) determining the hydrologic regime of the stream, using continuous level loggers, 2) conducting fish habitat assessments, 3) conducting fish population assessments (e.g., composition, abundance, and use by life-history stage such as spawning). To determine the assessments required, the stewardship group should review existing data available and determine where there are information gaps needing to be filled. Also, a hydrologic assessment should be conducted to determine if forestry-related development is having an effect on Crawford Creek given that forestry appears to be a land use of concern to the stewardship group.

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Appendix A. CABIN data

Site Description

Study Name	CBWQ-East Shore
Site	NJCRA01
Sampling Date	Sep 28 2015
Know Your Watershed Basin	Lower Kootenay
Province / Territory	British Columbia
Terrestrial Ecological Classification	Montane Cordillera EcoZone Columbia Mountains and Highlands EcoRegion
Coordinates (decimal degrees)	49.67244 N, 116.81500 W
Altitude	1653
Local Basin Name	Crawford Creek
	Kootenay
Stream Order	4

Figure 1. Location Map

Across Reach
Aerial (No image found)

Up Stream

Cabin Assessment Results

Reference Model Summary	
Model	Columbia-Okanagan Preliminary March 2010
Analysis Date	May 15, 2018
Taxonomic Level	Family
Predictive Model Variables	Depth-Avg Latitude Longitude Reg-Ice Reg-SlopeLT30%

Reference Groups	**1**	**2**	**3**	**4**	**5**
Number of Reference Sites	9	43	17	12	33
Group Error Rate	22.2%	24.5%	22.2%	25.0%	32.4%
Overall Model Error Rate	26.4%				
Probability of Group Membership	0.2%	1.6%	15.6%	73.6%	9.1%
CABIN Assessment of NJCRA01 on Sep 28, 2015	Similar to Reference				

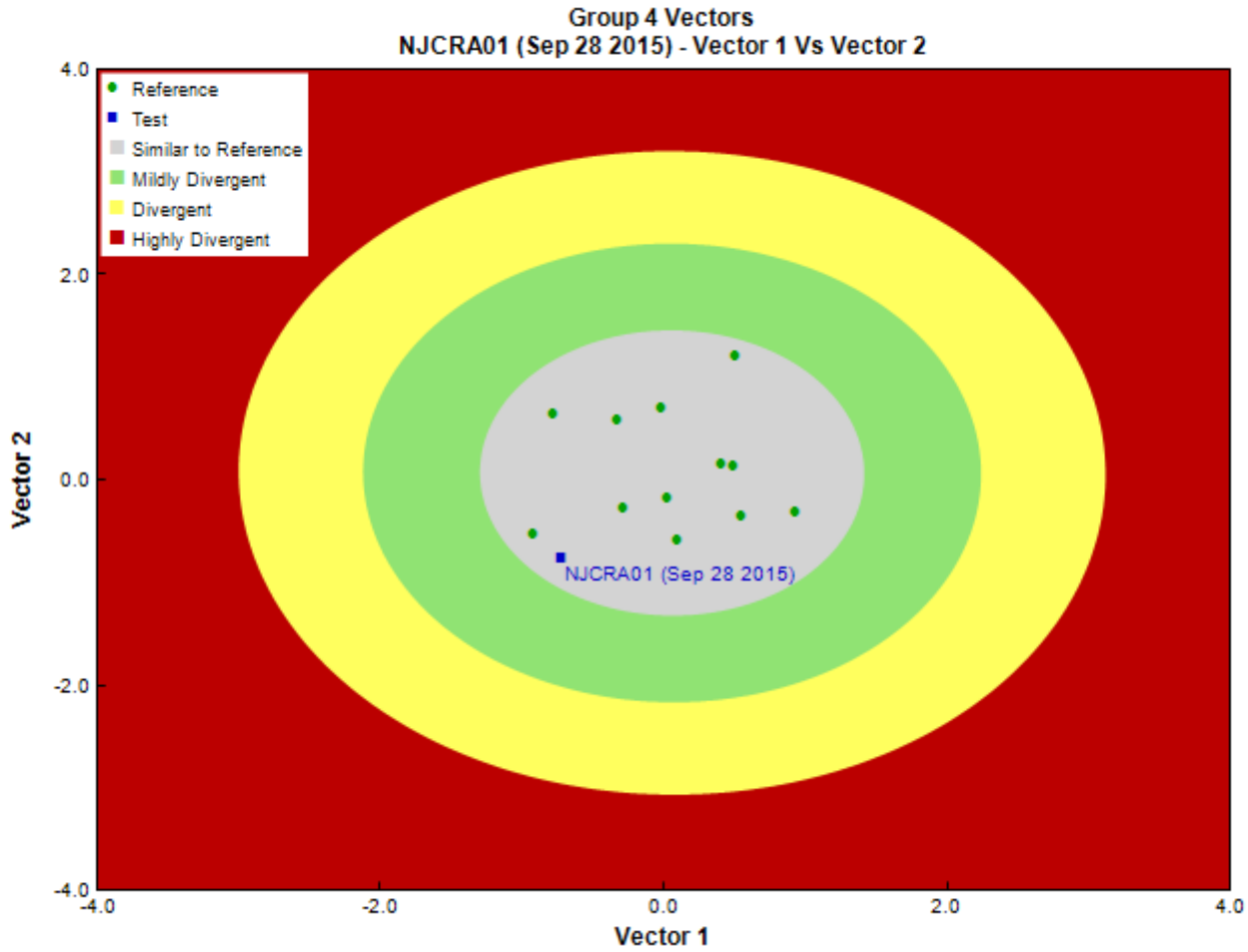

Figure 3. CABIN ordination assessment of the test site with the predicted group of reference sites. Each axis represents the relative abundance of the entire benthic invertebrate community with different organisms weighted differently on each axis.

Sample Information

Sampling Device	Kick Net
Mesh Size	400
Sampling Time	3
Taxonomist	Pina Viola, Consultant
Date Taxonomy Completed	January 04, 2016
	Marchant Box
Sub-Sample Proportion	28/100

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
Annelida	Clitellata	Tubificida	Naididae	40	142.9
Arthropoda	Arachnida	Trombidiformes	Lebertiidae	2	7.1
			Sperchontidae	3	10.7
			Torrenticolidae	4	14.2
	Insecta	Coleoptera	Elmidae	1	3.6
		Diptera	Chironomidae	28	100.0
			Empididae	10	35.7
			Psychodidae	2	7.1
			Simuliidae	4	14.3
			Tipulidae	3	10.7
		Ephemeroptera	Baetidae	139	496.5
			Ephemerellidae	7	25.0
			Heptageniidae	51	182.1
			Leptophlebiidae	10	35.7
		Plecoptera	Nemouridae	31	110.8

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
			Perlodidae	4	14.2
			Taeniopterygidae	4	14.3
		Trichoptera	Apataniidae	1	3.6
			Glossosomatidae	5	17.9
			Hydropsychidae	4	14.3
			Rhyacophilidae	6	21.4
			Total	359	1,282.1

Metrics

Name	NJCRA01	Predicted Group Reference Mean ±SD
Bray-Curtis Distance	0.57	0.4 ± 0.1
Biotic Indices		
Hilsenhoff Family index (North-West)	3.8	3.3 ± 0.4
Intolerant taxa	--	
Long-lived taxa	1.0	2.1 ± 1.1
Tolerant individuals (%)	--	0.8 ± 0.3
Functional Measures		
% Filterers	--	
% Gatherers	37.3	41.1 ± 16.0
% Predatores	18.1	20.7 ± 14.1
% Scrapers	58.2	55.8 ± 22.6
% Shredder	11.1	27.1 ± 15.4
No. Clinger Taxa	22.0	23.6 ± 7.2
Number Of Individuals		
% Chironomidae	7.8	11.7 ± 12.7
% Coleoptera	0.3	1.4 ± 3.6
% Diptera + Non-insects	26.7	15.6 ± 14.0
% Ephemeroptera	57.7	47.7 ± 20.1
% Ephemeroptera that are Baetidae	67.2	38.7 ± 28.0
% EPT Individuals	73.0	83.0 ± 13.5
% Odonata	--	0.0 ± 0.0
% of 2 dominant taxa	52.9	57.3 ± 13.7
% of 5 dominant taxa	80.5	81.2 ± 8.1
% of dominant taxa	38.7	39.3 ± 14.3
% Plecoptera	10.9	30.3 ± 15.6
% Tribe Tanyatarisini	--	
% Trichoptera that are Hydropsychida	25.0	29.4 ± 27.7
% Tricoptera	4.5	5.0 ± 2.9
No. EPT individuals/Chironomids+EPT Individuals	0.9	0.9 ± 0.1
Total Abundance	1282.1	933.4 ± 922.0
Richness		
Chironomidae taxa (genus level only)	1.0	1.0 ± 0.0
Coleoptera taxa	1.0	0.5 ± 0.6
Diptera taxa	5.0	3.3 ± 1.3
Ephemeroptera taxa	4.0	4.0 ± 0.8
EPT Individuals (Sum)	935.7	693.9 ± 519.8
EPT taxa (no)	11.0	13.5 ± 2.9
Odonata taxa	--	0.0 ± 0.0
Pielou's Evenness	0.7	0.7 ± 0.1
Plecoptera taxa	3.0	6.3 ± 1.3
Shannon-Wiener Diversity	2.1	2.0 ± 0.4
Simpson's Diversity	0.8	0.8 ± 0.1
Simpson's Evenness	0.2	0.3 ± 0.1
Total No. of Taxa	21.0	20.0 ± 4.8
Trichoptera taxa	4.0	3.3 ± 1.5

Frequency and Probability of Taxa Occurrence

Reference Model Taxa	Frequency of Occurrence in Reference Sites					Probability Of Occurrence at NJCRA01
	Group 1	Group 2	Group 3	Group 4	Group 5	
Baetidae	100%	100%	100%	100%	97%	1.00

Frequency and Probability of Taxa Occurrence

Reference Model Taxa	Frequency of Occurrence in Reference Sites					Probability Of Occurrence at NJCRA01
	Group 1	Group 2	Group 3	Group 4	Group 5	
Capniidae	78%	55%	50%	92%	68%	0.82
Chironomidae	100%	100%	100%	100%	95%	1.00
Chloroperlidae	78%	88%	94%	100%	100%	0.99
Ephemerellidae	78%	100%	100%	100%	100%	1.00
Heptageniidae	100%	100%	100%	100%	100%	1.00
Hydropsychidae	11%	92%	78%	92%	86%	0.89
Nemouridae	100%	100%	100%	100%	100%	1.00
Perlidae	11%	84%	33%	100%	3%	0.80
Perlodidae	78%	78%	89%	92%	81%	0.90
Rhyacophilidae	100%	92%	100%	100%	95%	0.99
Taeniopterygidae	89%	49%	100%	92%	97%	0.93

RIVPACS Ratios

RIVPACS : Expected taxa P>0.50	13.67
RIVPACS : Observed taxa P>0.50	12.00
RIVPACS : O:E (p > 0.5)	0.88
RIVPACS : Expected taxa P>0.70	11.32
RIVPACS : Observed taxa P>0.70	9.00
RIVPACS : O:E (p > 0.7)	0.80

Habitat Description

Variable	NJCRA01	Predicted Group Reference Mean ±SD
Channel		
Depth-Avg (cm)	26.3	23.6 ± 11.1
Depth-BankfullMinusWetted (cm)	64.00	51.38 ± 29.42
Depth-Max (cm)	45.5	34.6 ± 12.3
Discharge (m^3/s)	1.600	0.000 ± 0.000
Macrophyte (PercentRange)	1	0 ± 0
Reach-%CanopyCoverage (PercentRange)	1.00	1.33 ± 0.78
Reach-Pools (Binary)	1	1 ± 0
Reach-Rapids (Binary)	0	0 ± 0
Reach-Riffles (Binary)	1	1 ± 0
Reach-StraightRun (Binary)	1	1 ± 1
Slope (m/m)	0.0100000	0.0546683 ± 0.0376269
Veg-Coniferous (Binary)	1	1 ± 0
Veg-Deciduous (Binary)	1	1 ± 0
Veg-GrassesFerns (Binary)	1	1 ± 0
Veg-Shrubs (Binary)	1	1 ± 0
Velocity-Avg (m/s)	0.41	0.48 ± 0.22
Velocity-Max (m/s)	0.63	0.76 ± 0.36
Width-Bankfull (m)	20.0	13.4 ± 9.9
Width-Wetted (m)	11.4	8.5 ± 5.8
XSEC-VelMethod (Category(1-3))	1	1 ± 0
Landcover		
Reg-Ice (%)	0.00000	0.02487 ± 0.06034
Substrate Data		
%Bedrock (%)	0	0 ± 0
%Boulder (%)	6	9 ± 9
%Cobble (%)	89	51 ± 15
%Gravel (%)	0	3 ± 3
%Pebble (%)	5	37 ± 20
%Sand (%)	0	0 ± 0
%Silt+Clay (%)	0	0 ± 0
D50 (cm)	13.15	15.12 ± 14.26
Dg (cm)	13.0	8.2 ± 2.8
Dominant-1st (Category(0-9))	7	7 ± 1
Dominant-2nd (Category(0-9))	6	7 ± 1
Embeddedness (Category(1-5))	4	5 ± 1
PeriphytonCoverage (Category(1-5))	2	1 ± 0

Habitat Description

Variable	NJCRA01	Predicted Group Reference Mean ±SD
SurroundingMaterial (Category(0-9))	2	4 ± 1
Topography		
Reg-SlopeLT30% (%)	15.66263	18.88386 ± 9.29866
Water Chemistry		
Ag (mg/L)	0.0000100	0.0000050
Al (mg/L)	0.0165000	0.0049000
As (mg/L)	0.0002100	0.0002700
B (mg/L)	0.0250000	0.0500000
Ba (mg/L)	0.0204000	0.0682000
Be (mg/L)	0.0005000	0.0000100
Bi (mg/L)	0.0005000	0.0000050
Ca (mg/L)	16.9000000	21.1083333 ± 16.8005659
Cd (mg/L)	0.0000050	0.0000050
Chloride-Dissolved (mg/L)	0.2500000	0.9750000 ± 2.6309780
Co (mg/L)	0.0002500	0.0000100
CO3 (mg/L)	0.2500000	0.0000000 ± 0.0000000
Cr (mg/L)	0.0005000	0.0001000
Cu (mg/L)	0.0002500	0.0001000
Fe (mg/L)	0.0250000	0.0080000
General-Alkalinity (mg/L)	52.8000000	71.7000000 ± 53.9231440
General-DO (mg/L)	13.0000000	11.4175000 ± 0.7986708
General-Hardness (mg/L)	63.7000000	84.2750000 ± 70.6251066
General-pH (pH)	7.0	7.9 ± 0.4
General-SolidsTSS (mg/L)	2.0000000	0.8849836 ± 1.2378575
General-SpCond (µS/cm)	93.4000000	168.9833333 ± 123.7858182
General-TempAir (Degrees Celsius)	9.9	26.0
General-TempWater (Degrees Celsius)	6.8000000	7.3183333 ± 2.7240839
General-Turbidity (NTU)	0.5800000	0.2020000
HCO3 (mg/L)	64.5000000	0.0000000 ± 0.0000000
Hg (ng/L)	10.0000000	0.0000000 ± 0.0000000
K (mg/L)	0.4920000	0.6141667 ± 0.4056971
Li (mg/L)	0.0002500	0.0011000
Mg (mg/L)	5.2300000	7.6666667 ± 7.9748848
Mn (mg/L)	0.0023000	0.0006100
Mo (mg/L)	0.0005000	0.0006900
Na (mg/L)	1.5500000	1.5383333 ± 1.2751459
Ni (mg/L)	0.0005000	0.0003000
Nitrogen-NH3 (mg/L)	0.0120000	0.0024545 ± 0.0025045
Nitrogen-NO2 (mg/L)	0.0025000	0.0027500 ± 0.0062831
Nitrogen-NO2+NO3 (mg/L)	0.0390000	0.0690000
Nitrogen-NO3 (mg/L)	0.0390000	0.0546667 ± 0.0498148
Nitrogen-TN (mg/L)	0.0120000	0.0883333 ± 0.0521943
Pb (mg/L)	0.0010000	0.0000520
Phosphorus-OrthoP (mg/L)	0.0025000	0.0002727 ± 0.0004671
Phosphorus-TP (mg/L)	0.0025000	0.0045833 ± 0.0049992
S (mg/L)	1.5000000	5.0000000
Sb (mg/L)	0.0002500	0.0000700
Se (mg/L)	0.0000500	0.0001200
Si (mg/L)	2.4700000	3.1516667 ± 1.2277017
Sn (mg/L)	0.0025000	0.0000100
SO4 (mg/L)	11.3000000	17.2250000 ± 25.9966125
Sr (mg/L)	0.0651000	0.0443000
Ti (mg/L)	0.0025000	0.0005000
Tl (mg/L)	0.0000250	0.0000020
U (mg/L)	0.0002400	0.0011700
V (mg/L)	0.0025000	0.0002000
Zn (mg/L)	0.0147000	0.0010000
Zr (mg/L)	0.0002500	0.0000000 ± 0.0000000

Site Description

Study Name	CBWQ-East Shore
Site	NJCRA01
Sampling Date	Sep 12 2016
Know Your Watershed Basin	Lower Kootenay
Province / Territory	British Columbia
Terrestrial Ecological Classification	Montane Cordillera EcoZone Columbia Mountains and Highlands EcoRegion
Coordinates (decimal degrees)	49.67244 N, 116.81494 W
Altitude	1653
Local Basin Name	Crawford Creek
	Kootenay
Stream Order	4

Figure 1. Location Map

Across Reach
Aerial (No image found)

Cabin Assessment Results

Predictive Model Variables	Depth-Avg Latitude Longitude Reg-Ice Reg-SlopeLT30%

Reference Groups	**1**	**2**	**3**	**4**	**5**
Number of Reference Sites	9	43	17	12	33
Group Error Rate	22.2%	24.5%	22.2%	25.0%	32.4%
Overall Model Error Rate	26.4%				
Probability of Group Membership	0.9%	1.3%	14.7%	74.8%	8.3%
CABIN Assessment of NJCRA01 on Sep 12, 2016	Mildly Divergent				

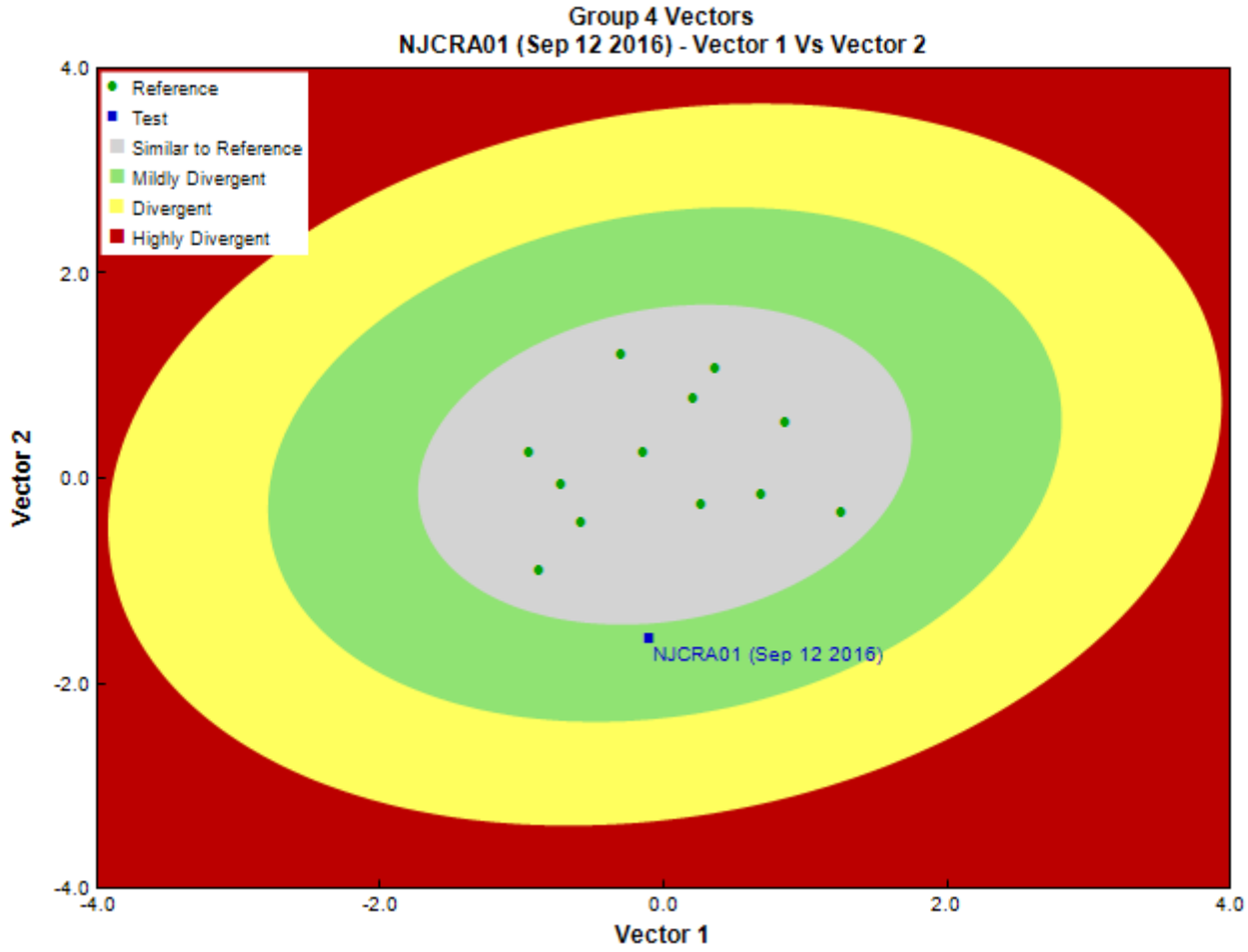

Figure 3. CABIN ordination assessment of the test site with the predicted group of reference sites. Each axis represents the relative abundance of the entire benthic invertebrate community with different organisms weighted differently on each axis.

Sample Information

Sampling Device	Kick Net
Mesh Size	400
Sampling Time	3
Taxonomist	Pina Viola, Consultant
Date Taxonomy Completed	September 12, 2016
	Marchant Box
Sub-Sample Proportion	16/100

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
Annelida	Clitellata	Tubificida	Naididae	6	37.5
Arthropoda	Arachnida	Trombidiformes		1	6.3
			Lebertiidae	2	12.5
			Sperchontidae	3	18.8
			Torrenticolidae	14	87.6
	Insecta	Diptera	Chironomidae	132	825.0
			Empididae	4	25.0
			Psychodidae	1	6.3
			Tipulidae	10	62.5
		Ephemeroptera	Baetidae	119	743.8
			Ephemerellidae	10	62.6
			Heptageniidae	12	75.1
			Leptophlebiidae	4	25.0
		Plecoptera	Nemouridae	3	18.8
			Perlodidae	2	12.5
			Taeniopterygidae	2	12.5
		Trichoptera	Apataniidae	2	12.5
			Brachycentridae	1	6.3
			Glossosomatidae	1	6.3
			Hydropsychidae	2	12.5
			Rhyacophilidae	2	12.5
			Uenoidae	1	6.3
			Total	334	2,088.2

Metrics

Name	NJCRA01	Predicted Group Reference Mean ±SD
Bray-Curtis Distance	0.76	0.4 ± 0.1
Biotic Indices		
Hilsenhoff Family index (North-West)	4.7	3.3 ± 0.4
Intolerant taxa	--	
Long-lived taxa	--	2.1 ± 1.1
Tolerant individuals (%)	--	0.8 ± 0.3
Functional Measures		
% Filterers	--	
% Gatherers	51.5	41.1 ± 16.0
% Predatores	48.5	20.7 ± 14.1
% Scrapers	41.6	55.8 ± 22.6
% Shredder	5.4	27.1 ± 15.4
No. Clinger Taxa	20.0	23.6 ± 7.2
Number Of Individuals		
% Chironomidae	39.6	11.7 ± 12.7
% Coleoptera	0.0	1.4 ± 3.6
% Diptera + Non-insects	51.7	15.6 ± 14.0
% Ephemeroptera	43.5	47.7 ± 20.1
% Ephemeroptera that are Baetidae	82.1	38.7 ± 28.0
% EPT Individuals	48.3	83.0 ± 13.5
% Odonata	--	0.0 ± 0.0
% of 2 dominant taxa	75.4	57.3 ± 13.7
% of 5 dominant taxa	86.2	81.2 ± 8.1
% of dominant taxa	39.6	39.3 ± 14.3
% Plecoptera	2.1	30.3 ± 15.6
% Tribe Tanyatarisini	--	
% Trichoptera that are Hydropsychida	22.2	29.4 ± 27.7
% Tricoptera	2.7	5.0 ± 2.9
No. EPT individuals/Chironomids+EPT Individuals	0.5	0.9 ± 0.1
Total Abundance	2087.5	933.4 ± 922.0
Richness		
Chironomidae taxa (genus level only)	1.0	1.0 ± 0.0
Coleoptera taxa	0.0	0.5 ± 0.6
Diptera taxa	4.0	3.3 ± 1.3
Ephemeroptera taxa	4.0	4.0 ± 0.8

Metrics

Name	NJCRA01	Predicted Group Reference Mean ±SD
EPT Individuals (Sum)	1006.3	693.9 ± 519.8
EPT taxa (no)	13.0	13.5 ± 2.9
Odonata taxa	--	0.0 ± 0.0
Pielou's Evenness	0.6	0.7 ± 0.1
Plecoptera taxa	3.0	6.3 ± 1.3
Shannon-Wiener Diversity	1.7	2.0 ± 0.4
Simpson's Diversity	0.7	0.8 ± 0.1
Simpson's Evenness	0.2	0.3 ± 0.1
Total No. of Taxa	21.0	20.0 ± 4.8
Trichoptera taxa	6.0	3.3 ± 1.5

Frequency and Probability of Taxa Occurrence

Reference Model Taxa	Frequency of Occurrence in Reference Sites					Probability Of Occurrence at NJCRA01
	Group 1	Group 2	Group 3	Group 4	Group 5	
Baetidae	100%	100%	100%	100%	97%	1.00
Capniidae	78%	55%	50%	92%	68%	0.83
Chironomidae	100%	100%	100%	100%	95%	1.00
Chloroperlidae	78%	88%	94%	100%	100%	0.99
Ephemerellidae	78%	100%	100%	100%	100%	1.00
Heptageniidae	100%	100%	100%	100%	100%	1.00
Hydropsychidae	11%	92%	78%	92%	86%	0.88
Nemouridae	100%	100%	100%	100%	100%	1.00
Perlidae	11%	84%	33%	100%	3%	0.81
Perlodidae	78%	78%	89%	92%	81%	0.90
Rhyacophilidae	100%	92%	100%	100%	95%	0.99
Taeniopterygidae	89%	49%	100%	92%	97%	0.93

RIVPACS Ratios

RIVPACS : Expected taxa P>0.50	13.69
RIVPACS : Observed taxa P>0.50	12.00
RIVPACS : O:E (p > 0.5)	0.88
RIVPACS : Expected taxa P>0.70	11.33
RIVPACS : Observed taxa P>0.70	9.00
RIVPACS : O:E (p > 0.7)	0.79

Habitat Description

Variable	NJCRA01	Predicted Group Reference Mean ±SD
Channel		
Depth-Avg (cm)	36.3	23.6 ± 11.1
Depth-BankfullMinusWetted (cm)	64.00	51.38 ± 29.42
Depth-Max (cm)	49.0	34.6 ± 12.3
Discharge (m^3/s)	2.740	0.000 ± 0.000
Macrophyte (PercentRange)	1	0 ± 0
Reach-%CanopyCoverage (PercentRange)	1.00	1.33 ± 0.78
Reach-%Logging (PercentRange)	0	0 ± 0
Reach-DomStreamsideVeg (Category(1-4))	2	4 ± 1
Reach-Pools (Binary)	1	1 ± 0
Reach-Riffles (Binary)	1	1 ± 0
Reach-StraightRun (Binary)	1	1 ± 1
Slope (m/m)	0.0150000	0.0546683 ± 0.0376269
Veg-Coniferous (Binary)	1	1 ± 0
Veg-Deciduous (Binary)	1	1 ± 0
Veg-GrassesFerns (Binary)	1	1 ± 0
Veg-Shrubs (Binary)	1	1 ± 0
Velocity-Avg (m/s)	0.44	0.48 ± 0.22
Velocity-Max (m/s)	0.75	0.76 ± 0.36
Width-Bankfull (m)	20.0	13.4 ± 9.9
Width-Wetted (m)	15.5	8.5 ± 5.8

Habitat Description

Variable	NJCRA01	Predicted Group Reference Mean ±SD
XSEC-VelInstrumentDirect (Category(1-3))	3	0 ± 0
XSEC-VelMethod (Category(1-3))	3	1 ± 0
Landcover		
Reg-Ice (%)	0.00000	0.02487 ± 0.06034
Substrate Data		
%Bedrock (%)	0	0 ± 0
%Boulder (%)	5	9 ± 9
%Cobble (%)	92	51 ± 15
%Gravel (%)	0	3 ± 3
%Pebble (%)	3	37 ± 20
%Sand (%)	0	0 ± 0
%Silt+Clay (%)	0	0 ± 0
D50 (cm)	13.50	15.12 ± 14.26
Dg (cm)	13.2	8.2 ± 2.8
Dominant-1st (Category(0-9))	7	7 ± 1
Dominant-2nd (Category(0-9))	6	7 ± 1
Embeddedness (Category(1-5))	4	5 ± 1
PeriphytonCoverage (Category(1-5))	2	1 ± 0
SurroundingMaterial (Category(0-9))	2	4 ± 1
Topography		
Reg-SlopeLT30% (%)	15.66263	18.88386 ± 9.29866
Water Chemistry		
Ag (mg/L)	0.0000100	0.0000050
Al (mg/L)	0.0054000	0.0049000
As (mg/L)	0.0001300	0.0002700
B (mg/L)	0.0250000	0.0500000
Ba (mg/L)	0.0215000	0.0682000
Be (mg/L)	0.0000500	0.0000100
Bi (mg/L)	0.0000500	0.0000050
Ca (mg/L)	0.0182000	21.1083333 ± 16.8005659
Cd (mg/L)	0.0000050	0.0000050
Chloride-Dissolved (mg/L)	0.2500000	0.9750000 ± 2.6309780
Co (mg/L)	0.0025000	0.0000100
CO3 (mg/L)	0.2500000	0.0000000 ± 0.0000000
Cr (mg/L)	0.0005000	0.0001000
Cu (mg/L)	0.0025000	0.0001000
Fe (mg/L)	0.0120000	0.0080000
General-Alkalinity (mg/L)	60.9000000	71.7000000 ± 53.9231440
General-Conductivity (µS/cm)	74.0000000	121.8083333 ± 87.6800844
General-DO (mg/L)	13.0000000	11.4175000 ± 0.7986708
General-Hardness (mg/L)	63.5000000	84.2750000 ± 70.6251066
General-pH (pH)	13.0	7.9 ± 0.4
General-SolidsTSS (mg/L)	2.0000000	0.8849836 ± 1.2378575
General-SpCond (µS/cm)	107.0000000	168.9833333 ± 123.7858182
General-TempAir (Degrees Celsius)	10.0	26.0
General-TempWater (Degrees Celsius)	8.5000000	7.3183333 ± 2.7240839
General-Turbidity (NTU)	0.2400000	0.2020000
HCO3 (mg/L)	74.3000000	0.0000000 ± 0.0000000
Hg (ng/L)	5.0000000	0.0000000 ± 0.0000000
K (mg/L)	0.0005290	0.6141667 ± 0.4056971
Li (mg/L)	0.0025000	0.0011000
Mg (mg/L)	0.0044000	7.6666667 ± 7.9748848
Mn (mg/L)	0.0011000	0.0006100
Mo (mg/L)	0.0005000	0.0006900
Na (mg/L)	0.0011200	1.5383333 ± 1.2751459
Ni (mg/L)	0.0005000	0.0003000
Nitrogen-NH4+ (mg/L)	0.0990000	0.0000000 ± 0.0000000
Nitrogen-NO2 (mg/L)	0.0025000	0.0027500 ± 0.0062831
Nitrogen-NO3 (mg/L)	0.0310000	0.0546667 ± 0.0498148
Nitrogen-TN (mg/L)	0.1030000	0.0883333 ± 0.0521943
Pb (mg/L)	0.0001000	0.0000520
Phosphorus-OrthoP (mg/L)	0.0025000	0.0002727 ± 0.0004671

Habitat Description

Variable	NJCRA01	Predicted Group Reference Mean ±SD
Phosphorus-TP (mg/L)	0.0025000	0.0045833 ± 0.0049992
S (mg/L)	0.0015000	5.0000000
Sb (mg/L)	0.0002500	0.0000700
Se (mg/L)	0.0000500	0.0001200
Si (mg/L)	2.9100000	3.1516667 ± 1.2277017
Sn (mg/L)	0.0025000	0.0000100
SO4 (mg/L)	8.4100000	17.2250000 ± 25.9966125
Sr (mg/L)	0.0659000	0.0443000
Ti (mg/L)	0.0025000	0.0005000
Tl (mg/L)	0.0000250	0.0000020
U (mg/L)	0.0002100	0.0011700
V (mg/L)	0.0025000	0.0002000
Zn (mg/L)	0.0025000	0.0010000
Zr (mg/L)	0.0025000	0.0000000 ± 0.0000000

Site Description

Study Name	CBWQ-East Shore
Site	NJCRA01
Sampling Date	Sep 12 2017
Know Your Watershed Basin	Lower Kootenay
Province / Territory	British Columbia
Terrestrial Ecological Classification	Montane Cordillera EcoZone Columbia Mountains and Highlands EcoRegion
Coordinates (decimal degrees)	49.67244 N, 116.81500 W
Altitude	1653
Local Basin Name	Crawford Creek
	Kootenay
Stream Order	4

Figure 1. Location Map

Across Reach
Aerial (No image found)

Substrate

Up Stream

Cabin Assessment Results

Reference Model Summary	
Model	Columbia-Okanagan Preliminary March 2010
Analysis Date	April 18, 2018
Taxonomic Level	Family
Predictive Model Variables	Depth-Avg Latitude Longitude Reg-Ice Reg-SlopeLT30%

Reference Groups	**1**	**2**	**3**	**4**	**5**
Number of Reference Sites	9	43	17	12	33
Group Error Rate	22.2%	24.5%	22.2%	25.0%	32.4%
Overall Model Error Rate	26.4%				
Probability of Group Membership	0.0%	1.9%	16.2%	72.2%	9.7%
CABIN Assessment of NJCRA01 on Sep 12, 2017	Similar to Reference				

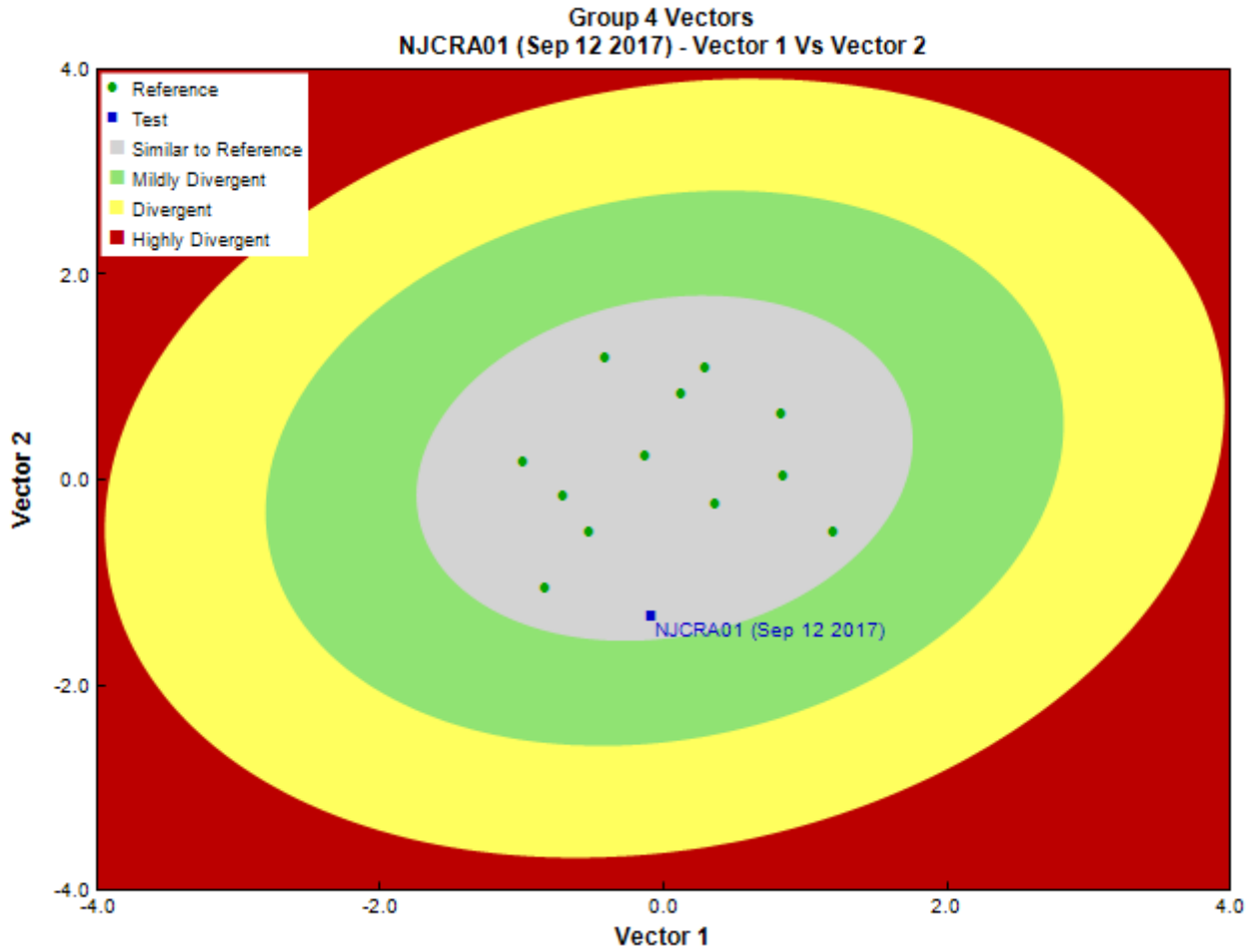

Figure 3. CABIN ordination assessment of the test site with the predicted group of reference sites. Each axis represents the relative abundance of the entire benthic invertebrate community with different organisms weighted differently on each axis.

Sample Information

Sampling Device	Kick Net
Mesh Size	400
Sampling Time	3
Taxonomist	Pina Viola, Consultant
Date Taxonomy Completed	December 20, 2017
	Marchant Box
Sub-Sample Proportion	22/100

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
Annelida	Clitellata	Tubificida	Naididae	10	45.5
Arthropoda	Arachnida	Trombidiformes	Hygrobatidae	1	4.5
			Lebertiidae	4	18.2
			Sperchontidae	1	4.5
			Torrenticolidae	7	31.8
	Insecta	Coleoptera	Elmidae	2	9.0
		Diptera	Chironomidae	47	213.6
			Empididae	6	27.2
			Simuliidae	2	9.0
			Tipulidae	2	9.1
		Ephemeroptera	Baetidae	188	854.5
			Ephemerellidae	8	36.2
			Heptageniidae	28	127.3
			Leptophlebiidae	4	18.1
		Plecoptera	Nemouridae	15	68.2

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
			Perlodidae	2	9.2
			Taeniopterygidae	2	9.1
		Trichoptera	Apataniidae	2	9.1
			Glossosomatidae	1	4.5
			Hydropsychidae	2	9.1
			Rhyacophilidae	1	4.5
			Total	335	1,522.2

Metrics

Name	NJCRA01	Predicted Group Reference Mean ±SD
Bray-Curtis Distance	0.64	0.4 ± 0.1
Biotic Indices		
Hilsenhoff Family index (North-West)	4.2	3.3 ± 0.4
Intolerant taxa	--	
Long-lived taxa	2.0	2.1 ± 1.1
Tolerant individuals (%)	--	0.8 ± 0.3
Functional Measures		
% Filterers	--	
% Gatherers	28.1	41.1 ± 16.0
% Predatores	21.8	20.7 ± 14.1
% Scrapers	67.8	55.8 ± 22.6
% Shredder	6.9	27.1 ± 15.4
No. Clinger Taxa	26.0	23.6 ± 7.2
Number Of Individuals		
% Chironomidae	14.0	11.7 ± 12.7
% Coleoptera	0.6	1.4 ± 3.6
% Diptera + Non-insects	23.9	15.6 ± 14.0
% Ephemeroptera	68.1	47.7 ± 20.1
% Ephemeroptera that are Baetidae	82.5	38.7 ± 28.0
% EPT Individuals	75.5	83.0 ± 13.5
% Odonata	--	0.0 ± 0.0
% of 2 dominant taxa	70.1	57.3 ± 13.7
% of 5 dominant taxa	86.0	81.2 ± 8.1
% of dominant taxa	56.1	39.3 ± 14.3
% Plecoptera	5.7	30.3 ± 15.6
% Tribe Tanyatarisini	--	
% Trichoptera that are Hydropsychida	33.3	29.4 ± 27.7
% Tricoptera	1.8	5.0 ± 2.9
No. EPT individuals/Chironomids+EPT Individuals	0.8	0.9 ± 0.1
Total Abundance	1522.7	933.4 ± 922.0
Richness		
Chironomidae taxa (genus level only)	1.0	1.0 ± 0.0
Coleoptera taxa	1.0	0.5 ± 0.6
Diptera taxa	4.0	3.3 ± 1.3
Ephemeroptera taxa	4.0	4.0 ± 0.8
EPT Individuals (Sum)	1150.0	693.9 ± 519.8
EPT taxa (no)	11.0	13.5 ± 2.9
Odonata taxa	--	0.0 ± 0.0
Pielou's Evenness	0.6	0.7 ± 0.1
Plecoptera taxa	3.0	6.3 ± 1.3
Shannon-Wiener Diversity	1.7	2.0 ± 0.4
Simpson's Diversity	0.7	0.8 ± 0.1
Simpson's Evenness	0.1	0.3 ± 0.1
Total No. of Taxa	21.0	20.0 ± 4.8
Trichoptera taxa	4.0	3.3 ± 1.5

Frequency and Probability of Taxa Occurrence

Reference Model Taxa	Frequency of Occurrence in Reference Sites					Probability Of Occurrence at NJCRA01
	Group 1	Group 2	Group 3	Group 4	Group 5	
Baetidae	100%	100%	100%	100%	97%	1.00

Frequency and Probability of Taxa Occurrence

Reference Model Taxa	Frequency of Occurrence in Reference Sites					Probability Of Occurrence at NJCRA01
	Group 1	Group 2	Group 3	Group 4	Group 5	
Capniidae	78%	55%	50%	92%	68%	0.82
Chironomidae	100%	100%	100%	100%	95%	0.99
Chloroperlidae	78%	88%	94%	100%	100%	0.99
Ephemerellidae	78%	100%	100%	100%	100%	1.00
Heptageniidae	100%	100%	100%	100%	100%	1.00
Hydropsychidae	11%	92%	78%	92%	86%	0.89
Nemouridae	100%	100%	100%	100%	100%	1.00
Perlidae	11%	84%	33%	100%	3%	0.79
Perlodidae	78%	78%	89%	92%	81%	0.90
Rhyacophilidae	100%	92%	100%	100%	95%	0.99
Taeniopterygidae	89%	49%	100%	92%	97%	0.93

RIVPACS Ratios

RIVPACS : Expected taxa P>0.50	13.64
RIVPACS : Observed taxa P>0.50	12.00
RIVPACS : O:E (p > 0.5)	0.88
RIVPACS : Expected taxa P>0.70	11.30
RIVPACS : Observed taxa P>0.70	9.00
RIVPACS : O:E (p > 0.7)	0.80

Habitat Description

Variable	NJCRA01	Predicted Group Reference Mean ±SD
Channel		
Depth-Avg (cm)	18.3	23.6 ± 11.1
Depth-BankfullMinusWetted (cm)	64.00	51.38 ± 29.42
Depth-Max (cm)	35.0	34.6 ± 12.3
Discharge (m^3/s)	1.080	0.000 ± 0.000
Macrophyte (PercentRange)	1	0 ± 0
Reach-%CanopyCoverage (PercentRange)	1.00	1.33 ± 0.78
Reach-%Logging (PercentRange)	0	0 ± 0
Reach-DomStreamsideVeg (Category(1-4))	2	4 ± 1
Reach-Pools (Binary)	1	1 ± 0
Reach-Riffles (Binary)	1	1 ± 0
Reach-StraightRun (Binary)	1	1 ± 1
Slope (m/m)	0.0140000	0.0546683 ± 0.0376269
Veg-Coniferous (Binary)	1	1 ± 0
Veg-Deciduous (Binary)	1	1 ± 0
Veg-GrassesFerns (Binary)	1	1 ± 0
Veg-Shrubs (Binary)	1	1 ± 0
Velocity-Avg (m/s)	0.17	0.48 ± 0.22
Velocity-Max (m/s)	0.44	0.76 ± 0.36
Width-Bankfull (m)	29.0	13.4 ± 9.9
Width-Wetted (m)	18.0	8.5 ± 5.8
XSEC-VelInstrumentDirect (Category(1-3))	3	0 ± 0
XSEC-VelMethod (Category(1-3))	3	1 ± 0
Landcover		
Reg-Ice (%)	0.00000	0.02487 ± 0.06034
Substrate Data		
%Bedrock (%)	0	0 ± 0
%Boulder (%)	0	9 ± 9
%Cobble (%)	93	51 ± 15
%Gravel (%)	2	3 ± 3
%Pebble (%)	5	37 ± 20
%Sand (%)	0	0 ± 0
%Silt+Clay (%)	0	0 ± 0
D50 (cm)	12.00	15.12 ± 14.26
Dg (cm)	11.0	8.2 ± 2.8
Dominant-1st (Category(0-9))	6	7 ± 1
Dominant-2nd (Category(0-9))	7	7 ± 1

Habitat Description

Variable	NJCRA01	Predicted Group Reference Mean ±SD
Embeddedness (Category(1-5))	4	5 ± 1
PeriphytonCoverage (Category(1-5))	2	1 ± 0
SurroundingMaterial (Category(0-9))	2	4 ± 1
Topography		
Reg-SlopeLT30% (%)	15.66263	18.88386 ± 9.29866
Water Chemistry		
Ag (mg/L)	0.0000200	0.0000050
Al (mg/L)	0.0074000	0.0049000
As (mg/L)	0.0001200	0.0002700
B (mg/L)	0.0500000	0.0500000
Ba (mg/L)	0.0237000	0.0682000
Be (mg/L)	0.0001000	0.0000100
Bi (mg/L)	0.0010000	0.0000050
Ca (mg/L)	19.2000000	21.1083333 ± 16.8005659
Cd (mg/L)	0.0000100	0.0000050
Chloride-Dissolved (mg/L)	1.0000000	0.9750000 ± 2.6309780
Co (mg/L)	0.0002000	0.0000100
CO3 (mg/L)	1.0000000	0.0000000 ± 0.0000000
Cr (mg/L)	0.0010000	0.0001000
Cu (mg/L)	0.0005000	0.0001000
Fe (mg/L)	0.0130000	0.0080000
General-Alkalinity (mg/L)	64.8000000	71.7000000 ± 53.9231440
General-Conductivity (µS/cm)	90.0000000	121.8083333 ± 87.6800844
General-DO (mg/L)	11.0000000	11.4175000 ± 0.7986708
General-pH (pH)	8.0	7.9 ± 0.4
General-SolidsTSS (mg/L)	4.0000000	0.8849836 ± 1.2378575
General-SpCond (µS/cm)	120.0000000	168.9833333 ± 123.7858182
General-TempAir (Degrees Celsius)	12.0	26.0
General-TempWater (Degrees Celsius)	11.1000000	7.3183333 ± 2.7240839
General-Turbidity (NTU)	0.4800000	0.2020000
HCO3 (mg/L)	79.0000000	0.0000000 ± 0.0000000
Hg (ng/L)	0.0000100	0.0000000 ± 0.0000000
K (mg/L)	0.5920000	0.6141667 ± 0.4056971
Li (mg/L)	0.0020000	0.0011000
Mg (mg/L)	5.0500000	7.6666667 ± 7.9748848
Mn (mg/L)	0.0160000	0.0006100
Mo (mg/L)	0.0010000	0.0006900
Na (mg/L)	1.4000000	1.5383333 ± 1.2751459
Ni (mg/L)	0.0010000	0.0003000
Nitrogen-NO2 (mg/L)	0.0050000	0.0027500 ± 0.0062831
Nitrogen-NO2+NO3 (mg/L)	0.0390000	0.0690000
Nitrogen-NO3 (mg/L)	0.0390000	0.0546667 ± 0.0498148
Nitrogen-TN (mg/L)	0.0630000	0.0883333 ± 0.0521943
Pb (mg/L)	0.0002000	0.0000520
Phosphorus-OrthoP (mg/L)	0.0050000	0.0002727 ± 0.0004671
Phosphorus-TP (mg/L)	0.0050000	0.0045833 ± 0.0049992
S (mg/L)	3.3000000	5.0000000
Sb (mg/L)	0.0005000	0.0000700
Se (mg/L)	0.0010000	0.0001200
Si (mg/L)	2.6800000	3.1516667 ± 1.2277017
Sn (mg/L)	0.0050000	0.0000100
SO4 (mg/L)	9.8000000	17.2250000 ± 25.9966125
Sr (mg/L)	0.0698000	0.0443000
Ti (mg/L)	0.0000100	0.0005000
U (mg/L)	0.0002600	0.0011700
V (mg/L)	0.0050000	0.0002000
Zn (mg/L)	0.0050000	0.0010000
Zr (mg/L)	0.0001000	0.0000000 ± 0.0000000

Appendix B. Water quality data

B1 – Water quality, QA/QC

B2 – Water quality, non-metals

B3 – Water quality, metals

Water quality legend:

Abbreviation/ symbol	Description
QA/QC table/criteria	Duplicate (or REP for replicate): review based on relative percent difference (RPD). Concern level if RPD >50% for general chemistry, if one of a set of duplicate values ≥ 5 times the RDL. Relative percent difference limit (RPD) = [(Result 2 - Result 1) / mean] x 100.
	Field Blank (BLK): recommended alert = 2X reporting limit (RDL)
	Grey highlight: exceedance of QA/QC criteria
1	Guidelines relevant to background not assessed, as they are intended to be monitored during construction/discharge activity.
(1)	RDL raised due to matrix effects.
AO	Aesthetic objective.
BC App	BC approved water quality guidelines (BC MoE 2018b).
BC Work	BC working water quality guidelines (BC MoE 2017).
CCME	Canadian environmental quality guidelines (CCME 2018).
HC	Health Canada drinking water guidelines (Health Canada 2017).
Red font	Field collected data.
Green highlight	Exceedance of guideline for the protection of aquatic life.
Blue highlight	Exceedance of drinking water guideline.

Appendix B1 - Water quality, QA/QC

Stewardship Group	Sample Date (yy/mm/dd)	Site Code	Site Name	Nitrite (N)	Nitrate (N)	Alkalinity (Total as CaCO3)	Alkalinity (PP as CaCO3)	Bicarbonate (HCO3)	Carbonate (CO3)	Hydroxide (OH)	Orthophosphate (P)	Nitrate plus Nitrite (N)	Turbidity
			Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**µg/L**	**mg/L**	**NTU**
			Detection Limit (RDL)	**0.005**	**0.02**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**5**	**0.02**	**0.1**
East Shore Fresh Water Habitat Society	16-09-12	NJCRA01	Crawford Cr	<0.0050	0.031	60.9	<0.50	74.3	<0.50	<0.50	<5	0.031	0.24
East Shore Fresh Water Habitat Society	16-09-12	NJCRA01 DUP	Crawford Cr	<0.0050	0.029	59.7	<0.50	72.8	<0.50	<0.50	<5	0.029	0.15
		Duplicate QC	**Calculated RPD (%)**	**0.0**	**6.7**	**2.0**	**0.0**	**2.0**	**0.0**	**0.0**	**0.0**	**6.7**	**46.2**
East Shore Fresh Water Habitat Society	16-09-12	NJCRA01 BLK	Crawford Cr	<0.0050	<0.020	<0.50	<0.50	<0.50	<0.50	<0.50	<5	<0.020	<0.10
		Blank QC	**X times > than RDL**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**

Appendix B1 - Water quality, QA/QC

Sample Date (yy/mm/dd)	Site Code	Total Phosphorus (P)	Total Nitrogen (N)	Conductivity	Total Suspended Solids	Dissolved Sulphate (SO4)	Dissolved Chloride (Cl)	Total Ammonia (N)	E. coli
		mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	mg/L	CFU
		0.005	**0.02**	**1**	**4**	**0.5**	**0.5**	**0.005**	**1**
16-09-12	NJCRA01	<0.0050	0.103		<4.0	8.41	<0.50	0.099	2
16-09-12	NJCRA01 DUP	<0.0050	0.115	127	<4.0	8.45	0.5	0.029	2
	Duplicate QC	**0.0**	**-11.0**	**-**	**0.0**	**-0.5**	**0.0**	**109.4**	**0.0**
16-09-12	NJCRA01 BLK	<0.0050	0.06	<1.0	<4.0	0.71	<0.50	<0.0050	<1
	Blank QC	**1.0**	**3.0**	**1.0**	**1.0**	**1.4**	**1.0**	**1.0**	**1.0**

Stewardship Group	Sample Date (yy/mm/dd)	Site Code	Site Name	Nitrite (N)	Nitrate (N)
			Units	mg/L	mg/L
			Guideline for protection of aquatic life^{avg}	BC App: 0.02 when chloride <2 mg/L (or see Guideline Table)	BC App: 3
			Guideline for drinking water^{max}	HC: 1	HC: 10
East Shore Fresh Water Habitat Society	15-04-28	NJCRA01	Crawford Cr	<0.0050	0.194
East Shore Fresh Water Habitat Society	15-05-20	NICRA01	Crawford Cr	<0.0050	0.108
East Shore Fresh Water Habitat Society	15-06-22	NJCRA01	Crawford Cr	<0.0050	0.032
East Shore Fresh Water Habitat Society	15-07-20	NICRA01	Crawford Cr	<0.0050	0.035
East Shore Fresh Water Habitat Society	15-09-28	NJCRA01	Crawford Cr	<0.0050	0.039
East Shore Fresh Water Habitat Society	15-10-19	NJCRA01	Crawford Cr	<0.0050	0.054
East Shore Fresh Water Habitat Society	15-10-19	NJCRA01	Crawford Cr	<0.0050	0.054
East Shore Fresh Water Habitat Society	16-04-11	NJCRA01	Crawford Cr	<0.0050	0.229
East Shore Fresh Water Habitat Society	16-05-09	NJCRA01	Crawford Cr	<0.0050	0.119
East Shore Fresh Water Habitat Society	16-06-14	NJCRA01	Crawford Cr	<0.0050	0.038
East Shore Fresh Water Habitat Society	16-07-11	NJCRA01	Crawford Cr	-	-
East Shore Fresh Water Habitat Society	16-08-08	NJCRA01	Crawford Cr	<0.0050	0.033
East Shore Fresh Water Habitat Society	16-09-12	NJCRA01	Crawford Cr	<0.0050	0.031
East Shore Fresh Water Habitat Society	16-10-12	NJCRA01	Crawford Cr	<0.0050	0.104
East Shore Fresh Water Habitat Society	17-04-24	NJCRA01	Crawford Cr	<0.0050	0.113
East Shore Fresh Water Habitat Society	17-05-23	NJCRA01	Crawford Cr	<0.0050	0.134
East Shore Fresh Water Habitat Society	17-06-20	NJCRA01	Crawford Cr	<0.0050	0.026
East Shore Fresh Water Habitat Society	17-07-25	NJCRA01	Crawford Cr	<0.0050	0.021
East Shore Fresh Water Habitat Society	17-08-16	NJCRA01	Crawford Cr	<0.0050	<0.020
East Shore Fresh Water Habitat Society	17-09-12	NJCRA01	Crawford Cr	<0.0050	0.039
East Shore Fresh Water Habitat Society	17-10-24	NJCRA01	Crawford Cr	<0.0050	0.039

Appendix B2 - Water quality, non-metals

Sample Date (yy/mm/dd)	Alkalinity (Total as CaCO3)	Alkalinity (PP as CaCO3)	Bicarbonate (HCO3)	Carbonate (CO3)	Hydroxide (OH)	Orthophosphate (P)	Nitrate plus Nitrite (N)
	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L
	-	-	-	-	-	-	BC App: 3
	-	-	-	-	-	-	BC App: 10
15-04-28	-	-	-	-	-	-	0.194
15-05-20	-	-	-	-	-	<5	0.108
15-06-22	-	-	-	-	-	<5	0.032
15-07-20	-	-	-	-	-	<5	0.035
15-09-28	52.8	<0.50	64.5	<0.50	<0.50	<5	0.039
15-10-19	-	-	-	-	-	-	0.054
15-10-19	-	-	-	-	-	-	0.054
16-04-11	-	-	-	-	-	-	0.229
16-05-09	-	-	-	-	-	<5	0.119
16-06-14	-	-	-	-	-	<5	0.038
16-07-11	-	-	-	-	-	<5	-
16-08-08	-	-	-	-	-	<5	0.033
16-09-12	60.9	<0.50	74.3	<0.50	<0.50	<5	0.031
16-10-12	-	-	-	-	-	-	0.104
17-04-24	-	-	-	-	-	-	0.113
17-05-23	-	-	-	-	-	<5	0.134
17-06-20	-	-	-	-	-	<5	0.026
17-07-25	-	-	-	-	-	7.4	0.021
17-08-16	-	-	-	-	-	<5	<0.020
17-09-12	64.8	<1.0	79	<1.0	<1.0	<5	0.039
17-10-24	-	-	-	-	-	-	0.039

Appendix B2 - Water quality, non-metals

Sample Date (yy/mm/dd)	Dissolved Oxygen	Specific Conductivity	pH	Turbidity
	mg/L	uS/cm		NTU
	BC App (**minimum**): 8 all stages other than buried embryo. 11 buried embryo not assessed, as spawning confirmation required.	-	BC App: 6.5-9.0.	BC App[1]: Change from background of 8 during clear flow period, and change of 5 during turbid flows
	-	-	HC: 7-10.5	BC App[1]: Change of 1 when background is <5 NTU; change of 5 when background is >5 and <50; change of 10% when background is >50.
15-04-28	*11*	*0.1*	*7.02*	*0.44*
15-05-20	*11*	*127*	*7.07*	*0.58*
15-06-22	*12*	*140.7*	*7.16*	*0.59*
15-07-20	*10*	*124.9*	*7.01*	*0.58*
15-09-28	*13*	*93.4*	*7.01*	*0.67*
15-10-19	*14*	*101.3*	*7.1*	*1.27*
15-10-19	*13*	*72.1*	*7.1*	*1.73*
16-04-11	*11*	*88.1*	*7.1*	*2.48*
16-05-09	*16*	*68.3*	*6.1*	*4.3*
16-06-14	*12*	*80.2*	*7.5*	*1.9*
16-07-11	*13*	*96.5*	*6.9*	*0.53*
16-08-08	*12*	*115.9*	*7.91*	*0.47*
16-09-12	*13*	*107*	*7.23*	*0.24*
16-10-12	*15*	*79*	*7.1*	*1.69*
17-04-24	*12.6*	*49*	*7.29*	*4.2*
17-05-23	*12*	*41*	*7.4*	*12.9*
17-06-20	*10.95*	*50*	*7.14*	*5.28*
17-07-25	*9.63*	*83*	*6.95*	*0.33*
17-08-16	*8.38*	*76*	*7.55*	*0.28*
17-09-12	*13*	*90*	*7.98*	*0.48*
17-10-24	*14*	*102*	*7.77*	*1.91*

Appendix B2 - Water quality, non-metals

Sample Date (yy/mm/dd)	Water Temperature	Air Temperature	Total Hardness (CaCO3)	Dissolved Hardness (CaCO3)	Total Phosphorus (P)	Total Nitrogen (N)
	C	C	mg/L	mg/L	mg/L	mg/L
	BC App: 19 max. See continuous temperature results for site specific fish species and lifestage guidelines.	-	-	-	CCME: Based on this data, the site is oligotrophic (0.004-0.01); exceedances of 1.5 times the upper value (or 0.015) indicates a potential problem.	-
	BC App[AO]: 15	-	-	-	-	-
15-04-28	*7*	*10*	0.5	2.3	-	0.215
15-05-20	*6.8*	*9.9*	0.5	1.9	<0.0050	0.153
15-06-22	*10*	*11*	0.5	2.3	<0.0050	0.083
15-07-20	*14.6*	*20.5*	0.48	1.8	<0.0050	0.091
15-09-28	*9*	*15*	0.76	7.1	<0.0050	0.096
15-10-19	*5.7*	*8*	0.11	0.81	-	<0.020
15-10-19	*5.8*	*14*	-	-	-	<0.020
16-04-11	*4.3*	*10*	-	-	-	0.303
16-05-09	*4.5*	*9*	-	-	0.0065	0.212
16-06-14	*7.5*	*9.5*	36.9	-	<0.0050	0.076
16-07-11	*9.5*	*17*	-	-	<0.0050	-
16-08-08	*12*	*20*	-	-	<0.0050	0.09
16-09-12	*8.5*	*10*	63.5	-	<0.0050	0.103
16-10-12	*4*	*8*	-	-	-	0.231
17-04-24	*4.59*	*8*	-	-	-	0.199
17-05-23	*5.5*	*17*	-	-	0.0161	0.273
17-06-20	*7.68*	*21*	37.6	-	<0.0050	0.098
17-07-25	*10.7*	*14*	-	-	<0.0050	0.082
17-08-16	*11.5*	*11*	-	-	<0.0050	0.127
17-09-12	*11.1*	*12*	68.8	-	<0.0050	0.063
17-10-24	*4.66*	*11*	-	-	-	0.102

Appendix B2 - Water quality, non-metals

Sample Date (yy/mm/dd)	Total Suspended Solids	Dissolved Sulphate (SO4)	Dissolved Chloride (Cl)	Total Ammonia (N)	E. coli
	mg/L	mg/L	mg/L	mg/L	CFU
	BC App[1]: Change from background of: ≤ 25 for 24 hr during clear flow, or 10 for 24 hr during turbid period (when natural water is 25-100)	BC App (total): hardness 0-3 = 128, hardness 31-75 = 218, hardness 76-180 = 309, hardness 181-250 = 429	BC App (total): 150	BC App: 1.12 to 1.97 based on daily pH and temp, using guideline table.	-
	-	HC[AO]: 500	BC App[AO]: 250	-	BC App: 0
15-04-28	<4.0	-	<0.50	0.015	<1
15-05-20	<4.0	-	<0.50	0.0099	1
15-06-22	<4.0	-	<0.50	0.79	1
15-07-20	<4.0	-	<0.50	0.0076	9
15-09-28	<4.0	11.3	<0.50	0.012	-
15-10-19	<4.0	-	<0.50	0.019	4
15-10-19	<4.0	-	<0.50	0.019	4
16-04-11	4.8	-	1.1	0.013	<1
16-05-09	7.5	-	0.79	0.0064	2
16-06-14	<4.0	4.06	<0.50	0.041	48
16-07-11	<4.0	-	<0.50	0.017	-
16-08-08	<4.0	-	0.62	0.02	9
16-09-12	<4.0	8.41	<0.50	0.099	2
16-10-12	<4.0	-	<1.0	<0.0050	<1
17-04-24	<4.0	-	<0.50	0.022	6
17-05-23	24	-	<0.50	0.015	<1
17-06-20	<4.0	4.32	<0.50	0.017	6
17-07-25	<4.0	-	29	0.058	<1
17-08-16	<4.0	-	<1.0	0.025	7
17-09-12	<4.0	9.8	<1.0	0.022	2
17-10-24	<4.0	-	<1.0	0.097	1

Stewardship Group	Sample Date (yy/mm/dd))	Site Code	Site Name	Total Hardness (CaCO3)	Total Aluminum (Al)	Total Antimony (Sb)	Total Arsenic (As)	Total Barium (Ba)
			Units	mg/L	µg/L	µg/L	µg/L	µg/L
			Guideline for protection of aquatic life[avg]	-	BC App (**dissolved Al**): when pH is <6.5 = e[1.6-3.327 (median pH) + 0.402 (median pH)^2]. When pH ≥ 6.5 = 50.	BC Work: 9 (**antimony III**).	BC App: 5 (max)	BC Work: 1000
			Calculated aquatic life guideline (where required)	-	50	-	-	-
			Guideline for drinking water[max]	-	BC App[AO]: 9500	HC: 6	BC App: 10	HC: 1000
East Shore Fresh Water Habitat Society	2015-09-28	NJCRA01	Crawford Cr	63.7	16.5	<0.50	0.21	20.4
East Shore Fresh Water Habitat Society	2016-06-14	NJCRA01	Crawford Cr	36.9	23.8	<0.50	0.11	13.5
East Shore Fresh Water Habitat Society	2016-09-12	NJCRA01	Crawford Cr	63.5	5.4	<0.50	0.13	21.5
East Shore Fresh Water Habitat Society	2017-06-20	NJCRA01	Crawford Cr	37.6	37.3	<0.50	<0.10	12.4
East Shore Fresh Water Habitat Society	2017-09-12	NJCRA01	Crawford Cr	68.8	7.4	<0.50	0.12	23.7

Total Beryllium (Be)	**Total Bismuth (Bi)**	**Total Boron (B)**	**Total Cadmium (Cd)**	**Total Calcium (Ca)**	**Total Chromium (Cr)**	**Total Cobalt (Co)**	**Total Copper (Cu)**	**Total Iron (Fe)**	**Total Lead (Pb)**	**Total Lithium (Li)**	**Total Magnesium (Mg)**
µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L
BC Work: 0.13	-	BC App: 1200	CCME: 10{0.83(log[hardness]) – 2.46}	-	BC Work: 8.9 (**chromium III**)	BC App: 4.0	BC App: when hardness <50 = 2. Hardness >50 = (0.04 x hardness)	BC App^{max}: 1000	BC App: when hardness >8 = (3.31 + e(1.273 In [hardness] - 4.704).	-	-
-	-	-	0.10	-	-	-	2.164	-	4.77	-	-
-		BC App: 5000	HC: 5	-	HC: 50	-	BC App^{AO}: 1000	BC App^{AO}: 300	BC App: 10	-	-
<0.10	<1.0	<50	<0.010	16.9	<1.0	<0.50	<0.50	25	<0.20	<5.0	5.23
<0.10	<1.0	<50	0.017	10.6	<1.0	<0.50	<0.50	19	<0.20	<5.0	2.54
<0.10	<1.0	<50	<0.010	18.2	<1.0	<0.50	<0.50	12	<0.20	<5.0	4.4
<0.10	<1.0	<50	<0.010	10.9	<1.0	<0.20	<0.50	37	<0.20	<2.0	2.54
<0.10	<1.0	<50	<0.010	19.2	<1.0	<0.20	<0.50	13	<0.20	<2.0	5.05

Total Manganese (Mn)	Total Mercury (Hg)	Total Molybdenum (Mo)	Total Nickel (Ni)	Total Potassium (K)	Total Selenium (Se)	Total Silicon (Si)	Total Silver (Ag)	Total Sodium (Na)	Total Strontium (Sr)	Total Sulphur (S)	Total Thallium (Tl)
µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	mg/L	µg/L	mg/L	µg/L
BC App: (0.0044 x hardness + 0.605)x1000	CCME 0.026	BC App: 1000	CCME: when hardness 0 to ≤ 60 = 25. Hardness > 60 to ≤ 180 = e{0.76[ln(hardness)]+1.06}. Hardness >180 = 150.	-	BC App. 2.0	-	BC App: when hardness <100 = 0.05. Hardness >100 = 1.5.	-	-	-	BC Work: 0.8
605.24	-	-	25.00	-	-	-	0.05	-	-	-	-
BC App[AO]: 50	BC App: 1	BC App: 250	-	-	BC App: 10	-	-	HC[AO]: 200	-	-	-
2.3	<0.010	<1.0	<1.0	0.492	<0.10	2470	<0.020	1.55	65.1	<3.0	<0.050
1.7	<0.010	<1.0	<1.0	0.314	<0.10	2160	<0.020	0.606	35.4	<3.0	<0.050
1.1	<0.010	<1.0	<1.0	0.529	<0.10	2910	<0.020	1.12	65.9	<3.0	<0.050
2.2	<0.010	<1.0	<1.0	0.351	<0.10	2390	<0.020	0.549	32.7	<3.0	<0.010
1.6	<0.010	<1.0	<1.0	0.592	<0.10	2680	<0.020	1.4	69.8	3.3	<0.010

Appendix B3 - Water quality, metals

Total Tin (Sn)	Total Titanium (Ti)	Total Uranium (U)	Total Vanadium (V)	Total Zinc (Zn)	Total Zirconium (Zr)
µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
-	-	BC Work: 8.5	-	BC App: hardness <90 = 7.5. Hardness 90 - 330 = 7.5 + 0.75 x (hardness - 90)	-
-	-	-	-	7.5	-
-	-	HC: 20	-	BC App[AO]: 5000	-
<5.0	<5.0	0.24	<5.0	14.7	<0.50
<5.0	<5.0	<0.10	<5.0	<5.0	<0.50
<5.0	<5.0	0.21	<5.0	<5.0	<0.50
<5.0	<5.0	<0.10	<5.0	<5.0	<0.10
<5.0	<5.0	0.26	<5.0	<5.0	<0.10