# Joseph Creek
# Water Quality Monitoring Report
# 2007 – 2012

A Columbia Basin Water Quality Monitoring Project

## Final Report

L. Duncan and J. Duncan,
Mainstreams Environmental Society

Lotic Environmental

Columbia Basin Watershed Network

Columbia Basin Trust
a legacy for the people

2014

## Acknowledgements

We are grateful for the volunteers who helped with field data collection, including .

We wish to acknowledge Lotic Environmental Ltd. staff Ryan MacDonald, Sherri McPherson, and Kathryn Kuchapski, who provided substantive technical support throughout the data compilation, analysis, and reporting stages of this project. GranDuke Geomatics staff Guy Duke, Kevin Grant, and Tom Rutherford created valuable tools to aid in water quality guideline presentation and review. Katie Burles provided additional hydrologic analysis support.

## Contact Information

Mainstreams Environmental Society
Laura Duncan
gardenlaura@shaw.ca

Columbia Basin Water Quality Monitoring Project Coordinators:
Jim and Laura Duncan
gardenlaura@shaw.ca or jim.duncan9@icloud.com

Columbia Basin Trust Coordinator
Tim Hicks, Manager Water and Environment
thicks@cbt.org

The Water Quality Monitoring Project is part of the Columbia Basin Watershed Network. The Columbia Basin Watershed Network Database is located at: www.cbwn.ca

## Suggested Citation

Duncan, L and J. Duncan. 2013. Joseph Creek Water Quality Monitoring Report 2007-2012. A Columbia Basin Water Quality Monitoring Project.

**Cover photo** of Joseph Creek, taken by Laura Duncan.

## Project Highlights

- The health of Joseph Creek, which runs through the City of Cranbrook was reviewed using the results of benthic invertebrate and water quality monitoring from 2007 to 2012. This study reviewed three sites in the watershed: 1) NGJOS01, an upstream site which represented undeveloped conditions; 2) NGJOS02, a mid stream site, representing urban conditions, and; 3) a NGJOS03, a downstream site, representing semi-rural conditions.

- Overall, the study determined that Joseph Creek became increasingly impacted progressing downstream. The site in the upper watershed (NGJOS01) was found to be unstressed in all years when the benthic macro-invertebrate communities from test sites were compared to reference condition sites. NGJOS02 was found to be unstresssed in one year (2011), all other years were either potentially stressed or stressed. NGJOS03 was stressed in all but one year, when it was potentially stressed.

- The CABIN assessments were supported by other macro-invertebrate analyses and metrics, including: ratios of observed to expected taxa, presence of pollution intolerant taxa (Ephemeroptera, Plecoptera, and Trichoptera), presence of pollution tolerant taxa (Chironomidae), and proportions of dominant and first two dominant taxa.

- Water quality analysis showed few guideline exceedances but the majority of these occurred at the site furthest downstream (NGJOS03). Guidelines were exceeded for total phosphorus, dissolved oxygen, aluminum, and turbidity. Turbidity levels were elevated compared to guidelines at NGJOS03 at both clear flow and turbid flow times of the year.

- Differences in the thermal conditions were observed between sites, with little inter-annual variation. The greatest difference was found to be between NGJOS01 (upstream site) and the other two sites. Temperatures at both NGJSO02 and NGJOS03 were above the optimal temperature for westslope cutthroat trout and bull trout rearing during the warmer portions of the year.

# Contents

## Table of Tables



## Table of Figures

## Table of Appendices

# 1 Introduction

Community-based water quality monitoring in the Columbia River basin plays an important role in preserving watershed function for sustainable communities and ecosystems. 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 landuse and climate pose the greatest threat to both water quality and water quantity in the Columbia River basin. 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 landuses of the Columbia River basin, including: recreational and industrial development, streamflow 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 Watershed Network (CBWN) is an environmental stewardship project funded by the Columbia Basin Trust (CBWN 2012). The CBWN provides support to organizations, individuals and local water stewardship groups that undertake activities to conserve and monitor rivers and lakes throughout the Canadian Columbia River Basin (CBWN 2009). In response to local support, the CBWN has developed a long-term Water Quality Monitoring Project (WQMP), with the following goals (CBWN 2009):

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.

In order to meet these goals the Mainstreams Environmental Society has been conducting water quality monitoring in the Joseph Creek watershed from 2007 to 2013. Monitoring has included benthic macro-invertebrate assessment, water and sediment quality assessment and continual temperature monitoring (Table 1).

## *1.1 Study location and background*

Four studies completed by the BC Ministry of Environment (BCMoE), and by GG Oliver and Associates Environmental Science (Oliver) pointed out the numerous water quality problems on Joseph Creek, many of which were the result of urbanization. As a way of bringing the attention of Joseph Creek to the citizens of Cranbrook, Mainstreams became involved with a restoration project in Kinsmen Park in Cranbrook, with the intention of using the restoration project as a focal point of interest, as well as a living classroom for school groups. When the CBWN began a water quality monitoring project, Joseph Creek was chosen for monitoring to provide additional information to the citizens and local government. Three sites were chosen for monitoring (Table 1):

1) upstream of the city and reservoir;

2) in Kinsmen Park due to past activity; and
3) downstream of the City, but upstream of the confluence with the St. Mary River.

Joseph Creek has been influenced by numerous anthropogenic activities. The upper watershed has experienced logging, recreational activities, ranching, and mining (rock quarry). The middle watershed has been influenced by urban activities such as storm sewer input, run-off from roads & private residences, commercial effluents, riparian vegetation removal, channelization of the stream bed, and improper culvert installation. In addition, small agricultural developments have influenced the lower watershed.

Historically, Joseph Creek was considered the most important juvenile fish recruitment stream in the lower St. Mary River drainage due to its low gradient, warm temperatures and high background nutrient regime. Westslope cutthroat trout (*Oncorynchus clarkii lewisi)*, a blue-listed species in British Columbia (BC Conservation Data Centre (BC CDC) 2013), were known to spawn in large numbers in the middle reaches of Joseph Creek. Today, access from the St. Mary River is impeded by migration barriers and sediment deposition, manipulation of the annual flow regime, and changes to the annual temperature regime; all of which are believed to have negatively impacted juvenile fish survival. An additional pressure on fish populations in Joseph Creek is the introduced species, eastern brook trout *(Salvenlinus fontinales),* which, have been found to outnumber westslope cutthroat trout in fish community surveys (Oliver 1994). Bull trout *(Salvelinus confluentus*), also a blue listed species (BC CDC 2013), have been identified in Joseph Creek (BC MoE 2012). Historical information indicates that there was once a healthy population of bull trout in Joseph Creek; however, habitat changes (e.g., temperature increases) in the middle and lower reaches are also believed to have affected this species. Other fish species known to inhabit Joseph Creek include slimy sculpin *(cottus cognatus),* a native fish species; and largemouth bass (Micropterus salmoides) and rainbow trout *(Oncorhynchus mykiss),* which are introduced species (BC MoE 2012).

See Appendix A for location (latitude/longitude) and overview maps and photos of Joseph Creek sampling sites.

**Table 1. Summary of sites monitored in 2007-2013**

| Site Code | Site name, general location | Development Pressures | CABIN | Year Monitored Water / sediment quality | Temperature* |
|---|---|---|---|---|---|
| NGJOS01 | Joseph Ck Site 1, Upper Joseph Ck | Logging, ranching, mining (quarry), recreational activities | 2007-2012 | Annual Water: 2007-2012 | 2007-2013 |
| NGJOS02 | Joseph Ck Site 2, Kinsmen Park | Urban residential pressures, storm sewers, lack riparian vegetation, hard surfaces | 2007-2012 | Annual Water: 2007-2012 | 2007-2013 |
| NGJOS03 | Joseph Ck Site 3, Lower Joseph Ck | Downstream of residential, commercial, industrial urban influences and small scale agricultural properties | 2007-2012 | - Monthly Water 2007-2013<br>- Annual Metals in water: 2007-2009<br>- Annual Metals in sediment: 2010-2012 | 2007-2013 |

Legend:
*Hourly temperature, partial year 2007-2013

## *1.2 Objectives*

The objectives of this water quality monitoring report are as follows:

1. Present CABIN, sediment and water quality and continual temperature data collected to date in a format that can be used for analysis and ongoing assessment.
2. Analyse biological monitoring data (CABIN). Complete the analysis using the analytical tools in the CABIN database by classifying benthic invertebrate community stress at sampling sites according to the Reference Condition Approach and calculating invertebrate community metrics.
3. Analyse water and sediment quality data to identify if there were any parameters of potential concern in the study area. Complete this review by comparing monitoring results to applicable federal and provincial guidelines for the protection of aquatic life and drinking water, where available.
4. Analyse temperature data obtained from the continual data logger(s).
5. Relate biological results to water/sediment quality and temperature findings.
6. Provide recommendations for future stream health data collection including applicable data to be collected, locations to be sampled and procedures.

# 2 Methods

## 2.1 General data collection

Canadian Aquatic Biomonitoring Network (CABIN) techniques were used to collect data on benthic macro-invertebrates, habitat and water quality. Data were collected following the CABIN Field Procedures for Wadeable Streams (Environment Canada 2012a) and the CBWQMP Operating Procedures (CBWQMP 2012). CABIN sampling was conducted once a year in the fall at sites indicated in Table 1. Invertebrate samples were analysed by EcoAnalysts, Inc., Aquatic Bioassessment Services following CABIN laboratory methods (Environment Canada 2012b). All data were entered into the online CABIN database which were then used to analyse findings and provide site reports.

In addition to water quality sampling collected during annual CABIN data collection, water quality data was also collected monthly at the site NGJOS03 following CBWQMP Operating Procedures (CBWQMP 2012). Water quality parameters measured in the field (*in situ*) included turbidity, pH, specific conductivity, dissolved oxygen, water temperature and air temperature. Parameters analysed in the laboratory included inorganics, nutrients and metals. Sediment chemistry sampling (i.e., metals) was conducted at NGJOS03 in 2010-2012. Maxxam Analytics (Burnaby, BC) completed laboratory water and sediment quality analysis.

HOBO Pro V2 temperature loggers were installed at sites NGJOS01, NGJOS02, and NGJOS03 to record hourly stream temperature. Recordings were primarily from just after freshet to late fall but some loggers were recording throughout the winter in some years. Temperature loggers have been deployed from 2007-2012.

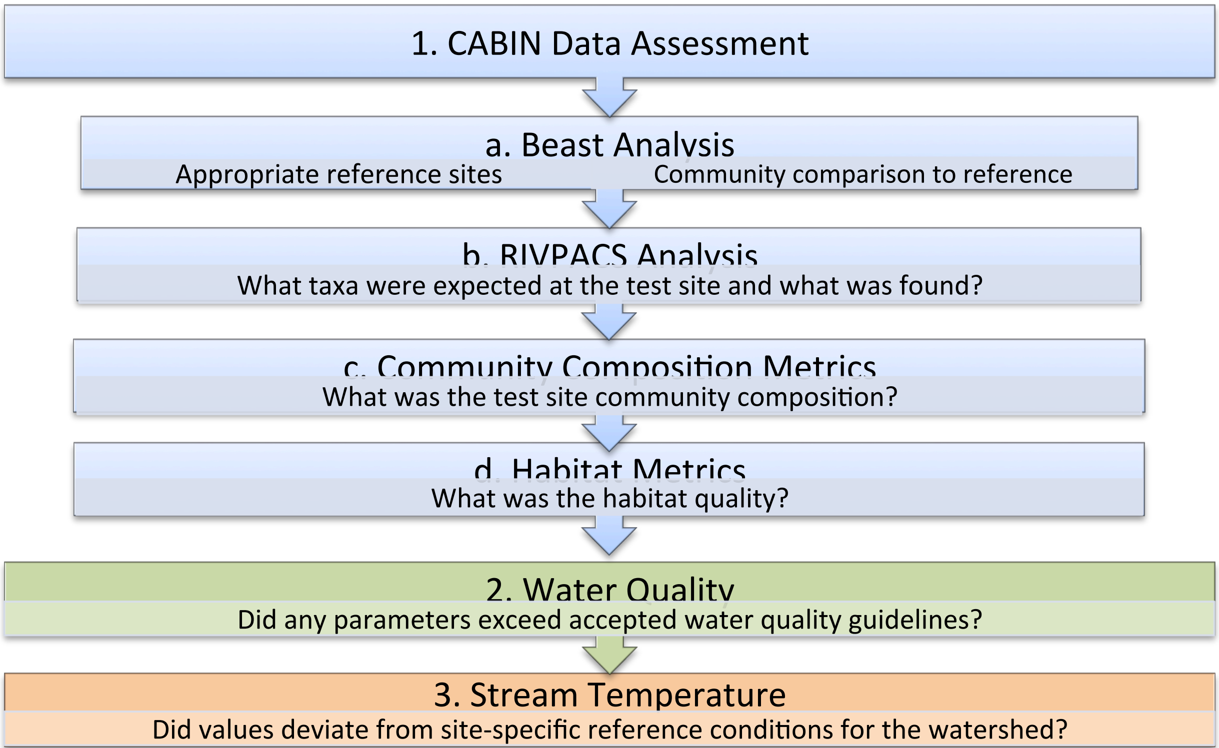
## 2.2 General data analysis

The Reference Condition Approach (RCA) in CABIN was used to determine the condition of the benthic invertebrate community at the test sites by comparing each test site to a group of reference sites with similar environmental characteristics.

Using the Analytical Tools in the CABIN database, four analyses were used to review invertebrate test site data (Steps 1a – 1d in Figure 1): BEnthic Assessment of SedimenT (BEAST), River Invertebrate Prediction and Classification System (RIVPACS), community composition metrics and habitat metrics. Water quality (Step 2) and stream temperature (Step 3) 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 1c). Furthermore, it was important that all subsequent analyses (Steps 2 and 3) were conducted.

**Figure 1. 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 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 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 (similar to reference) to severely stressed (highly divergent). In the ordination assessment, sites that are unstressed fall within the 90% confidence ellipse around the cloud of reference sites indicating that their communities are similar or equivalent to reference (Rosenberg *et al.* 1999). Potentially stressed, stressed and severely stressed sites fall outside of the 90%, 99% and 99.9% confidence ellipses and 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 relies on presence/absence data for individual taxa. The RIVPACS ratio determines 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 indicates that a site is in good condition as all taxa expected to be present 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.

### 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 sediment and 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 1. For duplicate values at or greater than five times the MDL, a RPD values >20% indicates a possible problem, and > 50% indicates a definite problem, most likely either contamination or lack of sample representativeness (BC MoE 2003). An RPD value greater than or equal to 30% was considered an alert level (Horvath pers. comm.). Where RPD values were greater than 30%, 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 1: Duplicate sample quality control**

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

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

Field blank data were collected to monitor possible contamination prior to receipt at the laboratory. Field blanks were compared using Equation 2. 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; as well other data on that day were compared to historical data to identify if there were anomalies possibly related to contamination.

**Equation 2: 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, sediment or biota, which in order to prevent specified detrimental effects from occurring, should not be exceeded (Nagpal 2001). Water quality results were compared to the applicable provincial and federal guidelines for the protection of aquatic life and drinking water (Table 2). Sediment quality results were also compared to the applicable British Columbia and Canadian guidelines for the protection of aquatic life.

**Table 2. Provincial and federal guidelines applicable to the protection of aquatic life (sediment and water quality) and drinking water (water quality only).**

| Document | Sediment Quality – Aquatic Life | Water Quality – Aquatic Life | Water Quality – Drinking Water |
|---|---|---|---|
| Federal | | | |
| Canadian Water Quality Guidelines (CCME 1999a) | | X | |
| Guideline for Canadian Drinking water quality (Health Canada 2012) | | | X |
| Canadian Sediment Quality Guidelines (CCME 1999b) | X | | |
| Provincial | | | |
| Approved Water Quality Guidelines (Government of BC 2013) | X | X | X |
| Working Water Quality Guidelines for BC (Nagpal et al. 2006) | X | X | X |

* CCME - Canadian Council of Ministers of the Environment

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. As well, to characterize water and sediment quality, all guideline thresholds were considered in this review. An exceedance of any of the thresholds was flagged to provide an understanding of the potential risks to aquatic organisms.

The transpose add-in tool created by GranDuke Geomatics (2013a) was used to automate the addition of new water quality data from Maxxam into existing CBWN datasets. Using Visual Basic for Applications (VBA) users opened MS Excel files from Maxxam and chose which MS Excel file to append the new data into. The add-in matches parameter names between files and converts units (e.g., between µm and mg) flagging the data cells that were successfully transferred. The Automated Guideline Assessment Tool for High-speed Analysis (AGATHA), also developed by GranDuke Geomatics (2013b) was then used to compare measured water and sediment quality values to the applicable published guidelines. The interface to AGATHA for the CBWQMP was provided through Microsoft Excel. AGATHA highlighted values that were above or below published guidelines and provided links to guidelines where further information could be attained. AGATHA automatically monitors the national and provincial guidelines for changes, ensuring guideline checks are up-to-date into the future.

## 2.5 Stream temperature analysis

HOBOware was used to process the data and Microsoft Excel was used for the stream temperature analysis. Daily stream temperature data were analyzed using descriptive statistics (average, standard deviation). Monthly averages of daily average and standard deviations were derived for each year and site. Months were removed if more than two consecutive days were missing from the dataset. The monthly average of daily average stream temperature values were compared against the optimal thermal ranges for the rearing life history stage of westslope cutthroat trout and bull trout.

# 3 Results

## 3.1 CABIN results

### 3.1.1 Reference Condition Approach: BEAST analysis and site assessment

For sites sampled at Joseph Creek, CABIN BEAST analysis determined the highest probability of reference group membership for all sites in all years, except one, was to reference group 3 (probabilities found in Table 3). Site NGJOS03 was predicted to group 2 in 2012.

Reference group 3, includes 21 sites located in the Northern Continental Divide, Columbia Mountains and Highlands and Western Continental Range eco-regions. These eco-regions surround the Joseph Creek sites which are found in the Columbia Mountains and Highlands and Southern Rocky Mountain Trench regions (Demarchi 2011). Shared eco-region membership and proximity indicate that the Joseph Creek test sites are similar in location (latitude and longitude) as well as in biogeography and climate to the reference sites with which they are being compared. The mean average channel depth of reference group 3 is 21.2 cm and is also similar to the test sites' average depth range of 8.3-22.6 cm.

The probability of NGJOS03 being predicted to reference group 2 was between 45.2% and 48.2% over the sampled period, except for in 2012 when the prediction to group 2 was 51.0%. This is only slightly greater than the probability of group 3 membership in 2012 of 47.8%.

Reference group 2 consists of 64 sites, of which, over half are located in the Okanagan Range and Thompson-Okanagan Plateau eco-regions which are distinct in terms of location, biogeography and climate from the eco-regions of reference group 3 near Joseph Creek (Demarchi 2011). This similarity between reference group 3 sites and NGJOS03, as well as similar prediction probabilities between the two groups, provides support for group 3 prediction. Therefore, NGJOS03 2012 was assigned to group 3 for analysis (Table 3). Further comparison of individual test site habitat attributes with the reference group 2 and 3 means can be done from the information provided in Site Assessment Reports in Appendix A.

CABIN models assessed NGJOS01 as unstressed over the period from 2007-2012 (Table 3). Community stress at NGJOS02 decreased from an assessment of stressed in 2007 to potentially stressed from 2008-2010 and unstressed in 2011, but again increased to stressed in 2012. NGJOS03 was assessed as stressed from 2007-2010 but community divergence from reference condition decreased in 2011 when the site's status was evaluated as potentially stressed, but again increased to stressed in 2012. Site assessment ordination plots are included in the Site Assessment Reports in Appendix A.

**Table 3. CABIN model assessment of Joseph Creek test sites against reference condition as defined by the preliminary Okanagan-Columbia reference model; assessment, prediction of reference group and probability of group membership.**

| Site Code | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | |
|---|---|---|---|---|---|---|---|
| NGJOS01 | **Unstressed**<br>Group 3;<br>76.1% | **Unstressed**<br>Group 3;<br>75.6% | **Unstressed**<br>Group 3;<br>75.7% | **Unstressed**<br>Group 3;<br>76.2% | **Unstressed**<br>Group 3;<br>75.7% | **Unstressed**<br>Group 3;<br>76.3% | |
| NGJOS02 | **Stressed**<br>Group 3;<br>60.8% | **Potentially Stressed**<br>Group 3;<br>60.2% | **Potentially Stressed**<br>Group 3;<br>61.1% | **Potentially Stressed**<br>Group 3;<br>62.5% | **Unstressed**<br>Group 3;<br>61.6% | **Stressed**<br>Group3;<br>62.5% | Group 3; |
| NGJOS03 | **Stressed**<br>Group 3;<br>50.3% | **Stressed**<br>Group 3;<br>50.8% | **Stressed**<br>Group 3;<br>53.1% | **Stressed**<br>Group 3;<br>51.1% | **Potentially Stressed**<br>Group 3;<br>50.7% | **Stressed**<br>Group 3 ;<br>47.8% | |

The classification of NGJSO01 as unstressed over the entire sampling period indicates that the benthic community at this site is similar or equivalent to reference and that this site provides baseline data for good biological health in the stream. Changes in classification from stressed to unstressed over the sampling period at NGJOS02 provide strong evidence of improving biological health and, potentially, water quality over time at this site. NGJOS03 was consistently assessed as stressed over the sampling period with only one year where it was classified as potentially stressed (2011).

### *3.1.2 RIVPACS analysis*

RIVPACS O:E ratios for test sites are summarized in Table 4. The RIVPACS ratios at site NGJOS01 were high in all years, indicating similarity to reference sites in terms of the presence and absence of families of macro-invertebrate organisms. The RIVPACS ratios at NGJOS02 were lower than NGJOS01 in all years (<0.80) indicating a greater difference in family composition from reference sites. The RIVPACS ratios at NGJOS03 were low in all years except 2012 and were lower than the other sites in most years, indicating the most frequent absence of expected families of the three sites over the sampled years.

**Table 4. RIVPACS Observed:Expected Ratios of taxa at test sites. Taxa were included in the analysis if their probability of occurrence at reference sites was >0.70. CABIN model assessment indicated as shaded background**.**

| Site | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| NGJOS01 | **1.06** | **0.97** PSYC | **1.06** | **0.97** TAEN | **1.06** | **0.96** PSYC |
| NGJOS02 | **0.59** BAET, NEMO, PERLO, RHYA | **0.78** PSYC, RHYA, TAEN | **0.78** PERLO, RHYA, TAEN | **0.88** PERLO, TAEN | **0.78** HYDR, RHYA, TAEN | **0.88** HYDR, TAEN |
| NGJOS03 | **0.50** CHLO, HYDR, PERLO, PSYC, RHYA, TAEN | **0.59** CHLO, HYDR, PERLO, PSYC, RHYA, TAEN | 0.49 CHLO, HEPT, NEMO, PSYC, RHYA, TAEN | **0.69** CHLO, PERLO, PSYC, TAEN | **0.79** CHLO, PSYC, TAEN | **0.89** CHLO, TAEN |

*Macroinvertebrate family abbreviations:

**Order Ephemeroptera:** BAET – Baetidae, HEPT-Heptageniidae
**Order Plecoptera:** CHLO-Chloroperlidae, NEMO – Nemouridae, PERLO-Perlodidae, TAEN-Taeniopterygidae
**Order Trichoptera**: HYDR-Hydropsychidae, RHYA-Rhyacophilidae
**Order Diptera**: CERA-Ceratopogonidae, PSYC-Psychodidae

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

The taxa that were expected to be present with probability > 0.70 that were not observed in the three Joseph Creek sites are also identified in Table 4. Taxa are listed at the family level of taxonomic resolution. Probability of occurrence is the probability that a family of organisms will be present at a test site based on its presence at reference sites. As the sites move downstream, there were an increasing number of taxa that were predicted to be present at the site but not present in the collected samples. The results indicate that most families absent but expected were from the EPT (Ephemeroptera, Plecoptera, Trichoptera) orders. Many families in these orders are considered to be sensitive to habitat disturbance (Environment Canada 2012b). Community composition metrics

The benthic macro-invertebrate community found in a stream can give an indication of the health of that waterbody. Several different metrics are used to summarize the abundance and diversity of benthic invertebrates found in a standard collection protocol. The definitions and significance of these metrics can be found in Appendix C (Table C-2). Analysis of the benthic macro-invertebrate communities at the three Joseph Creek sites shows variability, both between sites and between years.

The total abundance of organisms varied from year to year. The total number of organisms in a stream can be influenced in different ways by disturbance. Nutrient enrichment can result in high abundance while toxic effects from changes in water quality (pH, metals, dissolved oxygen, conductivity, etc.) can cause declines in total abundance (Environment Canada 2013b).

Abundance was lowest at NGJOS01 in 4 out of 6 sampling years, while NGJOS02 and NGJOS03 experienced two years each with the highest abundance (Figure 2). NGJOS02 showed a very large spike in abundance in 2012 when the total abundance of organisms was 48,160.

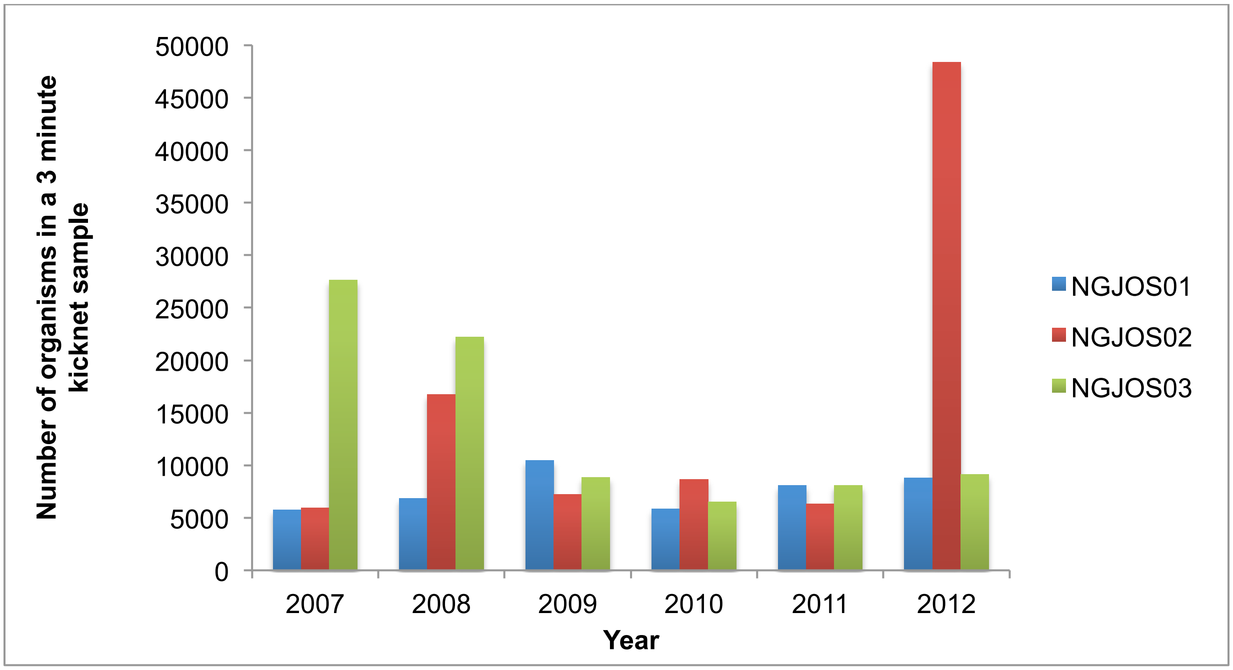



**Figure 2 Total Abundance of benthic invertebrates in 3 min kicknet samples collected at NGJOS01, NGJOS02 and NGJOS03 between 2007 and 2012.**

The total number of taxa is a measure of the diversity of benthic macro-invertebrates found at a site where greater diversity generally indicates better stream health (Environment Canada 2012b). While there was variability from year to year, diversity at NGJOS03 increased by 40% over 5 years from a low of 13 in 2008 to a high of 22 in 2012. Alternatively, NGJOS01 and NGJOS02 had high numbers of taxa in 2008 but decreased between 2008 and 2012. The number of taxa found at NGJOS01 decreased by 28%, from 23 to 19, between 2007 and 2012. NGJOS02 had a similar number of taxa in 2007 and 2012 (15 and 16 respectively) having reached a maximum of 20 in 2008 (Figure 3).

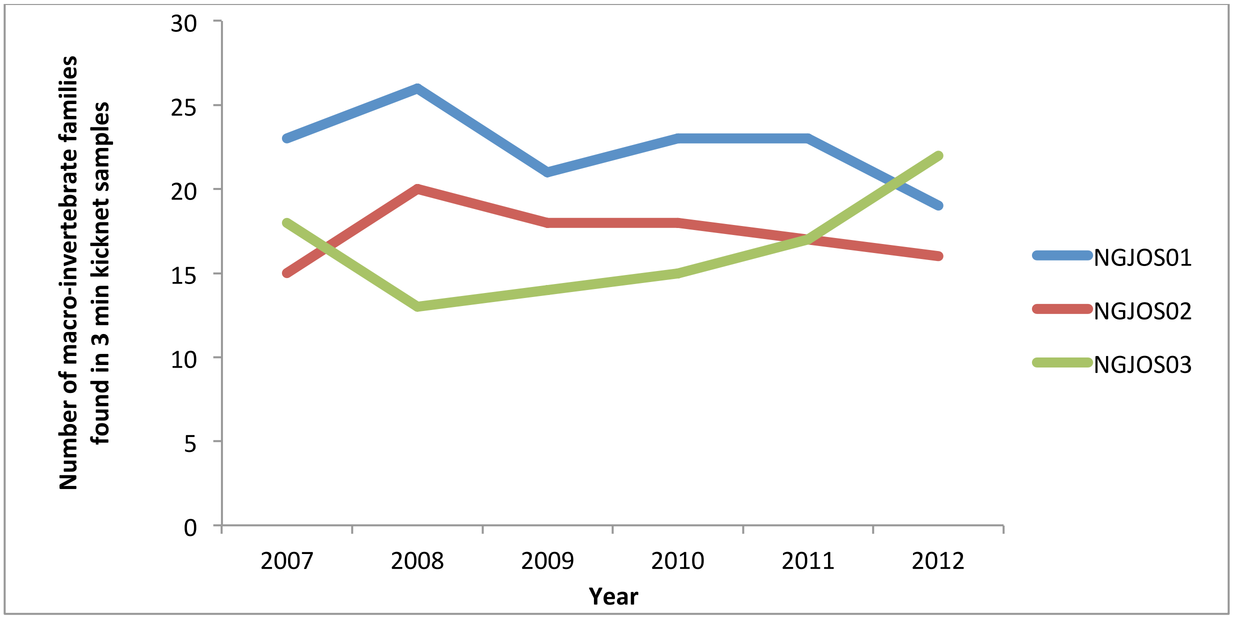



**Figure 3 Total number of families found in 3 min kicknet samples collected at NGJOS01, NGJOS02 and NGJOS03 between 2007 and 2012.**

High numbers of the EPT taxa generally indicate good water quality as these taxa are sensitive to pollution and/or low oxygen levels (Environment Canada 2012b). Ephemeroptera are intolerant of pollution and are also sensitive to low levels of oxygen. Plecoptera indicate an ample supply of oxygen and Trichoptera are generally sensitive to moderately tolerant of pollution. NGJOS01 had consistently higher numbers of EPT taxa than NGJOS02 and NGJOS03, which were relatively similar in number of EPT taxa found (Figure 4).

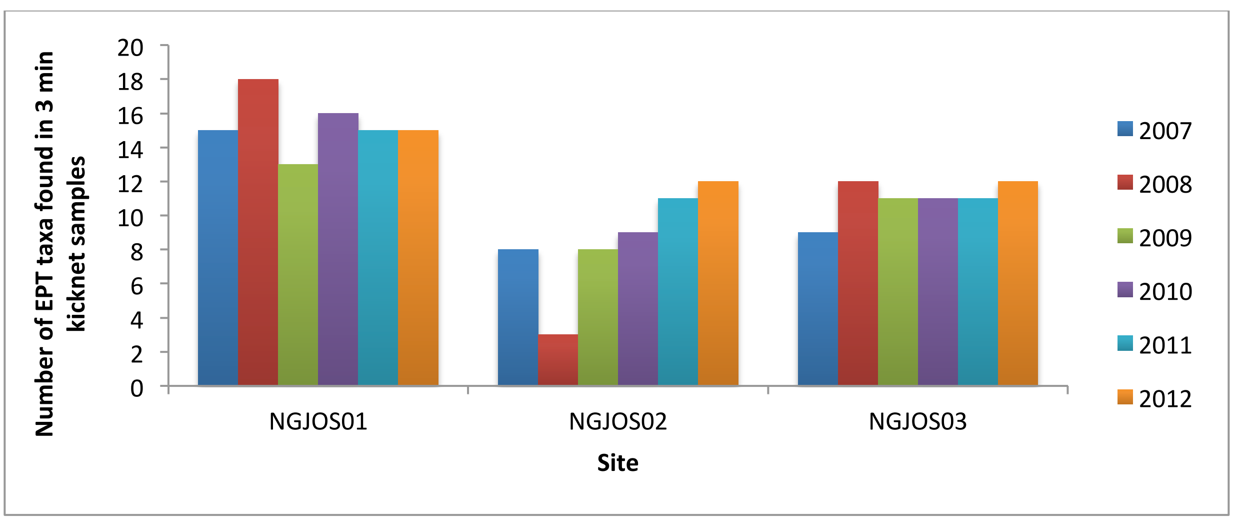



**Figure 4 Total number of EPT taxa found in 3 min kicknet samples taken at NGJOS01, NGJOS02 and NGJOS03 between 2007 and 2012.**

Percentage of organisms in kicknet samples that were of the orders Ephemeroptera, Plecoptera, and Trichoptera (%EPT) were quite stable at NGJOS01 and more variable at NGJOS02 and NGJOS03 (Figure 5).

Chironomidae are more tolerant of pollution than the EPT taxa are and therefore the relative percentages of EPT organisms and Chironomidae at a site can be an indication of the health of the benthic community. Sampling at Joseph Creek found that the percentage of Chironomidae relative to EPT was very low except for at NGJOS03 in 2007 when the sample was comprised of 43% Chironomids and of only 29% EPT organisms (Figure 5, Figure 6, and Figure 7).

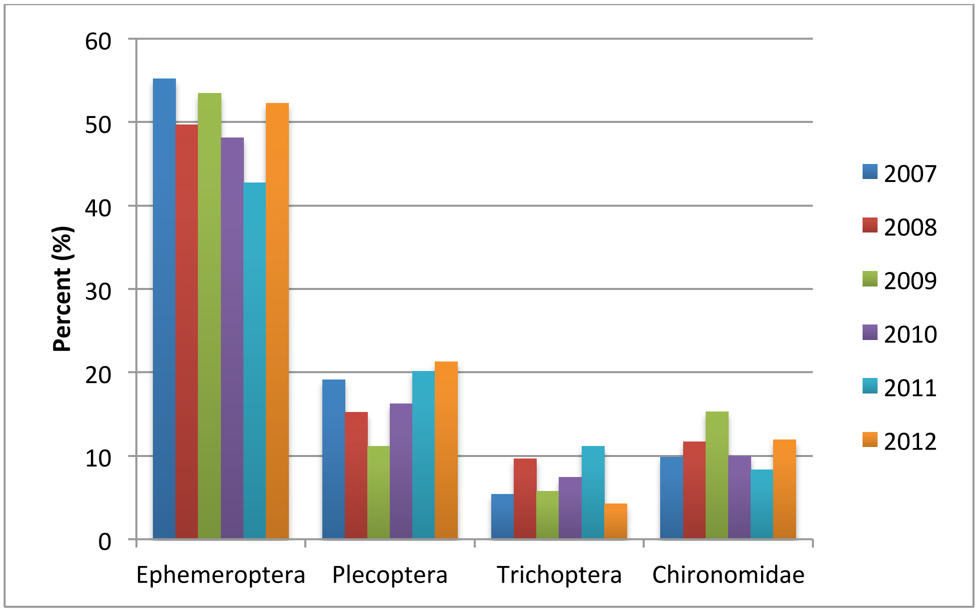



**Figure 5. Percentage of Ephemeroptera, Plecoptera, Trichoptera & Chironomidae organisms in 3 min kicknet samples taken at NGJOS01 between 2007 and 2012.**

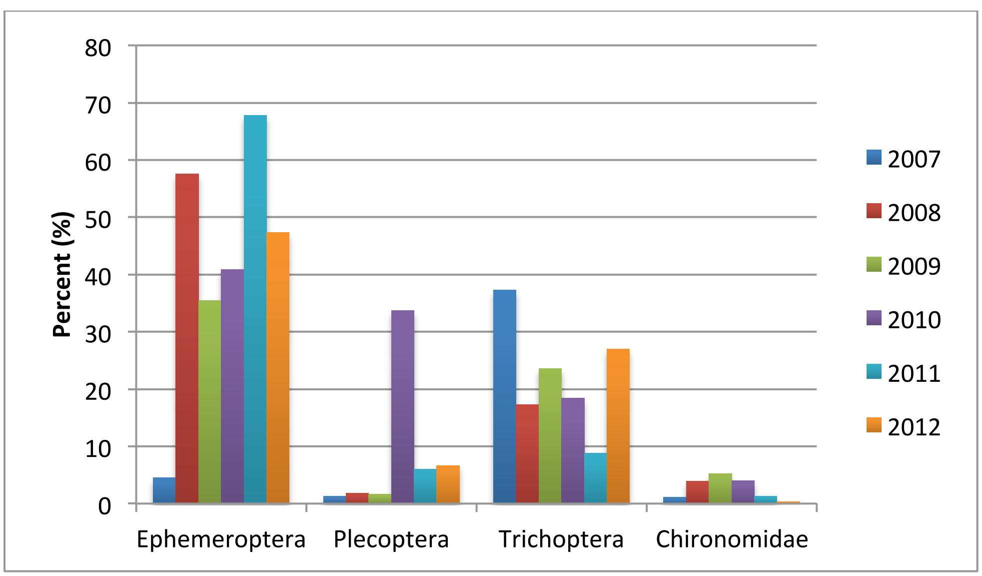



**Figure 6 Percentage of Ephemeroptera, Plecoptera, Tricoptera & Chironomidae organisms in 3 min kicknet samples taken at NGJOS02 between 2007 and 2012.**

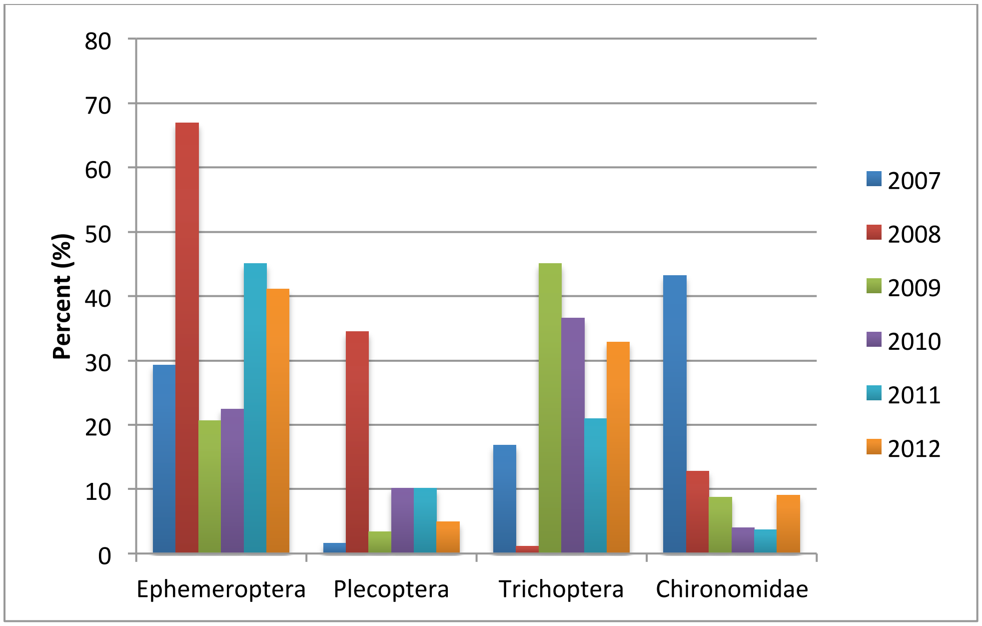



**Figure 7. Percentage of Ephemeroptera, Plecoptera, Trichoptera & Chironomidae organisms in 3 min kicknet samples taken at NGJOS03 between 2007 and 2012.**

Biodiversity in a stream generally declines with disturbance to the system. As the diversity decreases, taxa with less specific ecological needs can replace taxa with more specific needs, therefore a few taxa often end up dominating the community (Environment Canada 2012b). The percentage of dominant taxa (percentage of the total sample represented by the most abundant taxa) and the percentage of the 2 dominant taxa (percentage of the total sample represented by the two most abundant taxa) are one measure of the diversity of the stream. An upward trend in either of these measures indicates that a few taxa may be dominating the community. Along with the total number of taxa found at a site, this gives an indication of whether biodiversity is increasing or decreasing.

The % dominant taxa and the % 2 dominant taxa remained relatively stable at NGJOS01 between 2007 and 2012 where the % dominant taxa never exceeded 33% (Figure 8). There was however, a slight decrease in the total number of taxa at NGJOS01 (Figure 3). Dominance by one or two taxa decreased at NGJOS02 between 2007 (54% and 84%, respectively) and 2008 (49% and 26%, respectively) then remained below 40% dominant taxa and 60% 2 dominant taxa for the remainder of the monitoring period (Figure 9). NGJOS03 indicated greater dominance by one or two taxa throughout the sampling period with a maximum 67% dominant taxa in 2008 and a minimum 29% dominant taxa in 2010(Figure 10).

In general, the % 2 dominant taxa followed the trend of the % dominant taxa at all sites over the sampling period indicating that in most cases a single taxa drives dominance of the invertebrate community at these sites. The exception is at NGJOS03 in 2010 where the 2nd dominant taxa, Lepidostomatidae (25%), made up almost the same proportion of the benthic community as the dominant taxa, Heptageniidae (29%) (Figure 10 and Appendix C).

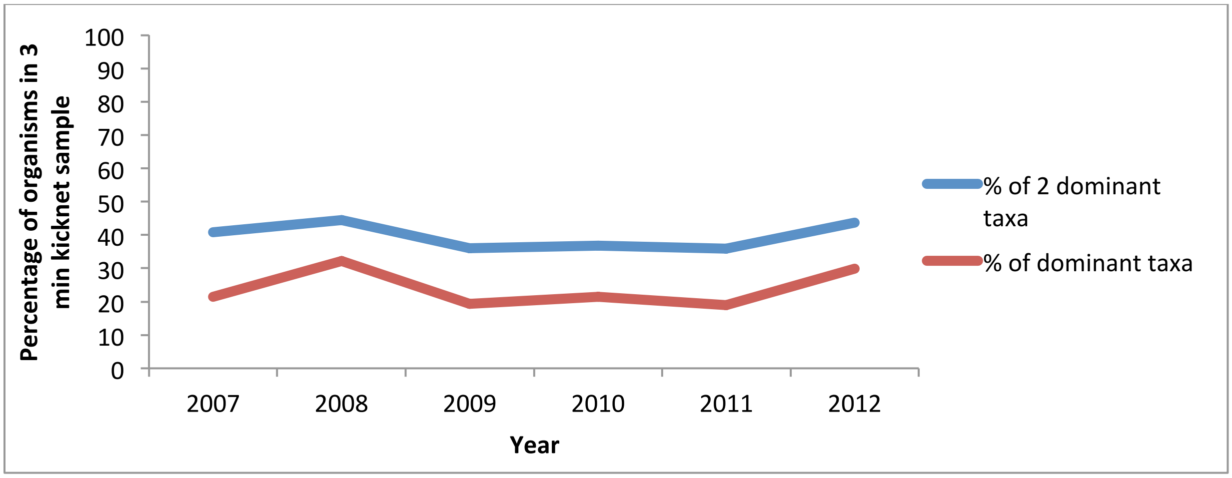



**Figure 8 Percentage of organisms belonging to the dominant taxon and the 2 dominant taxa in 3 min kicknet samples taken at NGJOS01 between 2007 and 2012.**

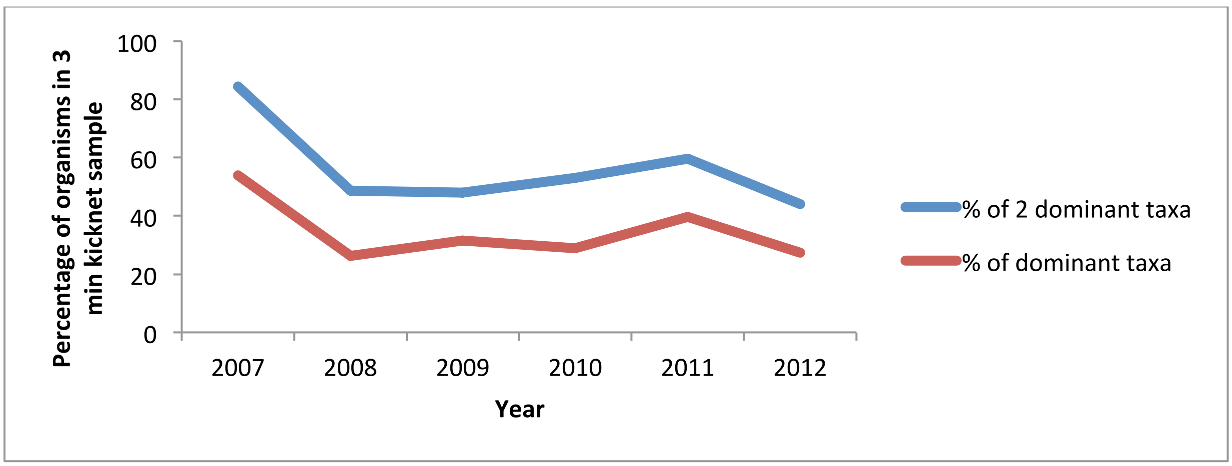



**Figure 9. Percentage of organisms belonging to the dominant taxon and the 2 dominant taxa in 3 min kicknet samples taken at NGJOS02 between 2007 and 2012.**

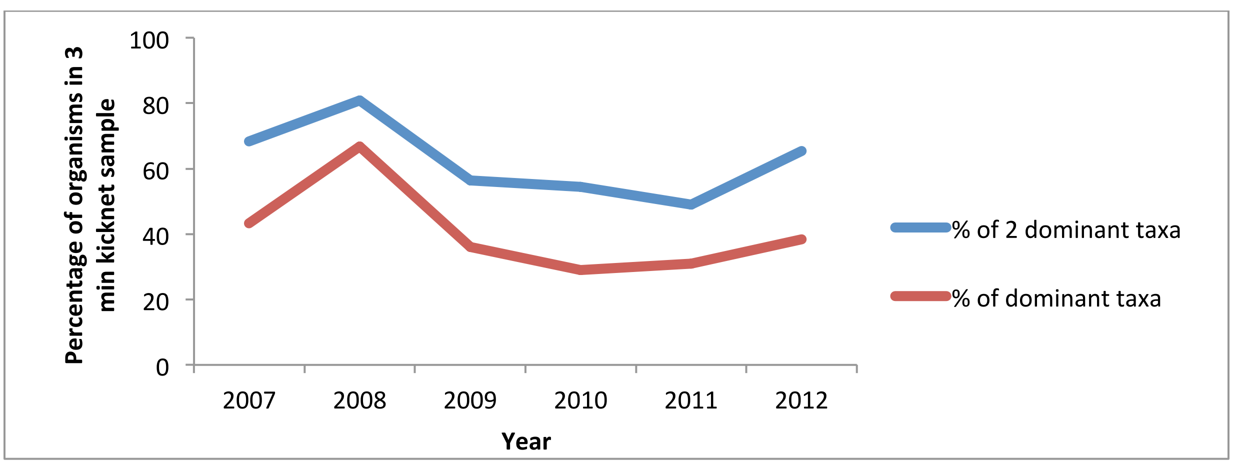



**Figure 10. Percentage of organisms belonging to the dominant taxon and the 2 dominant taxa in 3 min kicknet samples taken at NGJOS03 between 2007 and 2012.**

## 3.2 Water quality results

### 3.2.1 Water quality QA/QC

All laboratory quality control results were reviewed and confirmed to meet standard criteria (Maxxam 2012) prior to proceeding with processing of field samples (T. Rudkin Pers. Comm.). Field duplicates and field blanks of water samples were submitted to the laboratory for site NGJOS03 at a frequency of once per year (Appendix B-1). RPD values from field duplicate sample comparison indicated two values exceeding the Alert Criteria of 30%. This included one turbidity and one pH value. Field blank data revealed that only one parameter, bicarbonate exceeded Alert Criteria (2x detection limit). These results indicated minimal field sampling error and/or environmental variance. All subsequent water quality analyses included only the first of the duplicate samples, typed as “Regular”.

### 3.2.2 Non-metal water quality

Non-metal data collected at Joseph Creek had a few parameters of potential concern when compared to the guidelines for the protection of aquatic life (Appendix B-2). The main parameter with elevated levels was the nutrient, total phosphorus. The phosphorous guideline 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 a site (CCME 2004). Based on a preliminary evaluation of available data, the baseline range for total phosphorus was approximated as a mechanism for review of this parameter. At NGJOS01 and NGJOS02, the total phosphorus baseline was estimated to be 4-10 µg/L, indicating that the creek was oligotrophic. This is typical of unimpacted areas and typically supports diverse and abundant aquatic life and is self-sustaining (CCME 2004). Downstream at NGJOS03, the baseline was estimated to be higher (10-20 µg/L and meso-eutrophic). Using the CCME approach, data were evaluated against the site specific guideline, calculated as 1.5x the upper end of the baseline range. The guideline was thus determined to be 15 µg/L for NGJOS01 and NGJOS02 and 30 µg/L for NGJOS03. The guideline was not exceeded in NGJOS01 and NGJOS02; however the sampling frequency was low at 1 to 2 times sampled per year. NGJOS03, sampled 12 times between 2007 and 2009, exhibited guideline exceedances in 50% of samples. Total phosphorus increased on a downstream gradient, with the average values determined to be 2.5 µg/L (n=3) at NGJOS01, 8.3 µg/L (n=4) at NGJOS02, and 57.8 µg/L (n=12) at NGJOS03[2]. The maximum value was 301 µg/L and occurred at NGJOS03 in March 2009.

[1] Trophic status refers to the productivity of a waterbody, with eutrophic systems having high productivity
[2] Measurements <RDL were valued at half their RDL for statistical analyses

**Table 5 Summary of guideline exceedances for water and sediment quality data for the protection of aquatic life.**

| Parameter Type | Site | Years assessed* | Exceedance (source**): date |
|---|---|---|---|
| Water, non metals | NGJOS01 | 2007, 2008, 2009, 2010 (2X), 2011 | None |
| | NGJOS02 | 2007, 2008, 2009 (2X), 2010 (4X), 2011 (2X) | Total Phosphorus (CCME): Oct 2007 |
| | | | Total Phosphorus (CCME): May, Jun, Jul 2008; Aug 2009 |
| | NGJOS03 | 2007, 2008 (3X), 2009 (8X), 2010 (10X), 2011 (10X), 2012 (8X), 2013 (6) | Total Phosphorus (CCME): May 2009, Oct 2010, |
| | | | Turbidity (BC Appr.) – see text<br>Dissolved Oxygen (BC Appr): All life stages - April 2010 and June 2013. Buried embryo – 13 occasions |
| Water, metals | NGJOS03 | 2007, 2008 | Total Aluminum (CCME): Sep 2007, Oct 2008 |
| Sediment, metals | NGJOS03 | 2010, 2011, 2012 | none |

**Legend:**

*Data collected 1 time per year unless otherwise indicated and data typically collected only 1 time per month.

**Source:

BC Appr. = BC Approved Water Quality Guidelines (Government of BC 2013)
BC Work = BC Working Water Quality Guidelines (Nagpal et al. 2006)
CCME (ISQG or PEL) = Canadian Sediment Quality Guidelines (CCME 1999b)
CCME = Canadian Water Quality Guidelines (CCME 1999a)
HC = Drinking Water Quality Guidelines (Health Canada 2012)

Turbidity is a measure of the lack of clarity or transparency of water. Turbidity increases as the amount of suspended or dissolved material in the water increases. Turbidity in Joseph Creek increased in a downstream gradient. NGJOS01 is the most upstream site and given that it has received the least anthropogenic activity, likely represents natural background turbidity levels for the watercourse.

The BC guideline for the protection of aquatic life during the clear flow period (which is typically July through April in the East Kootenay) are such that induced turbidity should not exceed a change of (Caux *et al*. 1997):

- 8 NTU from background for a duration of 24 hours during clear flow period, and/or
- 2 NTU from background for a 30 day period.

During the period of naturally turbid waters or high flow period (typically May and June), the guideline indicates the maximum increase from background levels at any one time to be 5 NTU when background is between 8 and 50 NTU.

In order to determine if there was a true guideline exceedance, more readings should be collected to verify background values, and data should be collected more regularly. However, using the currently available average for NGJOS01, the estimated guideline would be 3 NTU during the 30 day clear flow period (Figure 11) and 15 NTU during the turbid flow period (Figure 12). Site 3 was measured to often exceed these estimated guidelines.

Although higher than NGJOS01, NGJOS02 turbidity levels during the clear flow period values have remained relatively stable, ranging from an annual average of 3 to 6 NTU. The annual average for NGJOS03 was highest in 2012 (54 NTU). This was marked by very high measurements during August and September monthly sampling (120 NTU and 317 NTU, respectively). 2013 data collected to July have been similar to 2011 (17 NTU) (Figure 11).

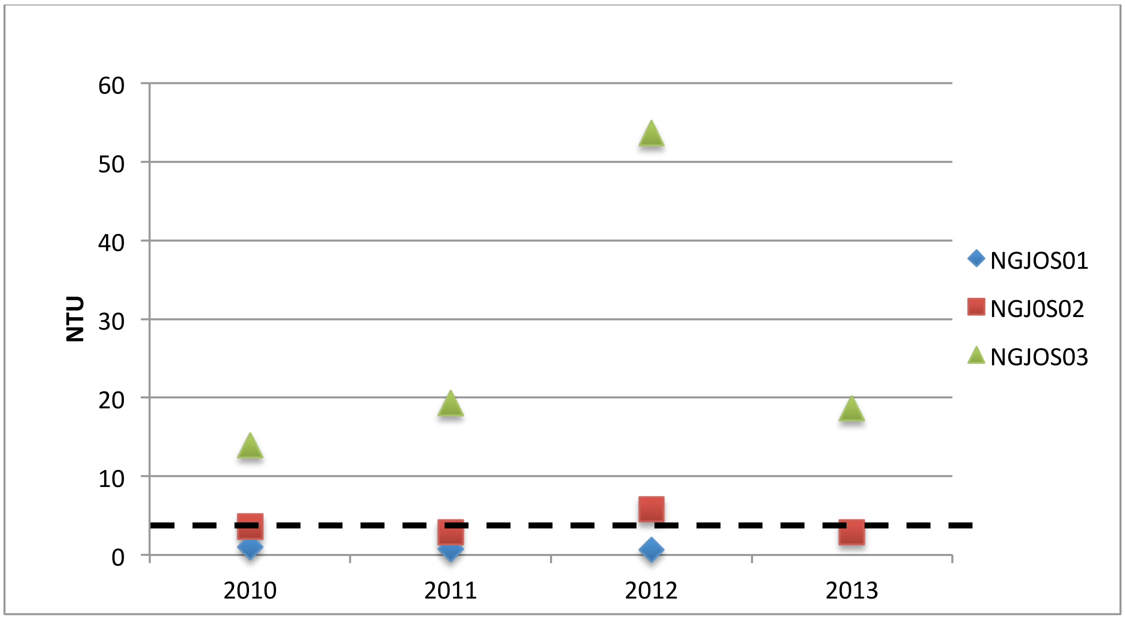



**Figure 11 Average turbidity at NGJOS01, NGJOS02, and NGJOS03 during clear flow period (July-May), 2010-2013. Guideline for the protection of aquatic life is estimated to be 3 NTU, as indicated by the dashed line.**

During the turbid flow period, data for NGJOS01 and NGJOS02 was limited to only 2012, thus not allowing for a comparison between the years. NGJOS03, however, has shown increasing turbidity with time, starting with an average of 13 NTU in 2010 climbing to 42 NTU in 2013 (Figure 12).

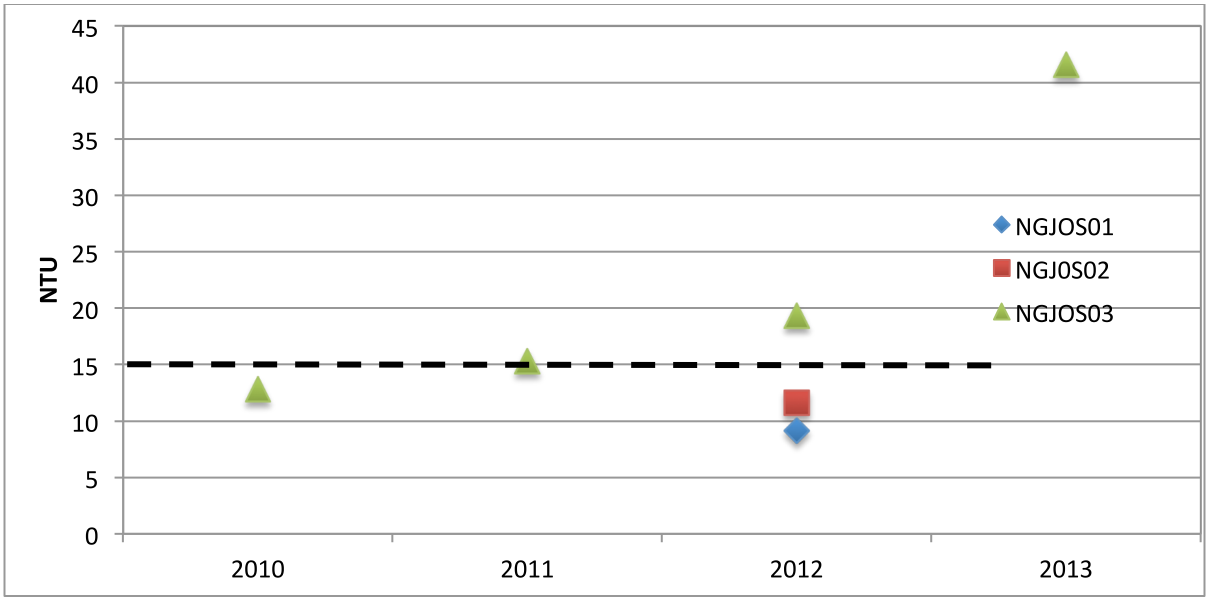



**Figure 12. Average turbidity at NGJOS01, NGJOS02, and NGJOS03 during turbid flow period (May and June), 2010-2013. Guideline for the protection of aquatic life is estimated to be 15 NTU as indicated by the dashed line.**

Dissolved oxygen (DO) is the concentration of oxygen dissolved in water, expressed as mg/l. The minimum guidelines for the protection of aquatic life were not met occasionally throughout the monitoring period. The BC approved guideline for all life stages of fish other than buried embryo and alevin is 8 mg/L (minimum). This guideline for all life stages was not met at NGJOS03 during monthly sampling on April 2010 (5 mg/L) and June 2013 (7 mg/L). The DO guideline for when there are buried embryo in the sediment is 11 mg/L (minimum). This guideline was not met during 13 sampling events at NGJOS03, which included times in June through to mid July, when westslope cutthroat trout would be expected to have eggs in the gravel.

On six occasions, DO levels were measured above those normally recorded in flowing streams (greater than 15 mg/L). These were all recorded at site NGJOS03 in the period from Feb 23, 2010 to January 25, 2011. Given that DO levels have been within normally expected levels at all other times, it is assumed that these high results were due to sampler or instrument error.

### *3.2.3 Metal water quality*

Analysis of metals in the water column was carried out at NGJOS03 once a year in 2007, 2008 and 2009. Samples were taken in the fall when water levels in the creek are quite low. The only parameter shown to exceed Canadian Water Quality Guidelines of 100 μg/L was total aluminum on two occasions. The September 2007 sample measured total aluminum at 115 μ/L while the October 2008 sample measured 163 μ/L. In contrast, the September 2009 sample measured only 55μ/L. It is not known what caused the high levels in 2007 and 2008. All other metals tested were within water quality guidelines.

### 3.2.4 Sediment quality

Analysis of metals in stream sediment was undertaken once a year in 2010, 2011 and 2012. All metal levels were within water quality guidelines.

## 3.3 Stream temperature results

Monthly average stream temperature values at NGJOS01 were lower during the spring, summer, and fall, and warmer during early winter relative to NGJOS02 and NGJOS03 (Figures 13, 14, and 15). The inter-annual variation in average monthly stream temperature was low, with the exception of October (Figures 13, 14, and 15). Monthly average stream temperature values were within the optimal range for westslope cutthroat trout and bull trout rearing (7°C to 16°C and 6°C to 14°C, respectively; Nagpal *et al*. 2006) at NGJOS01. However, monthly average stream temperature values did reach and exceed optimal westslope cutthroat trout and bull trout rearing conditions in July and August at NGJOS02 and NGJOS03 (Figures 13, 14, and 15).

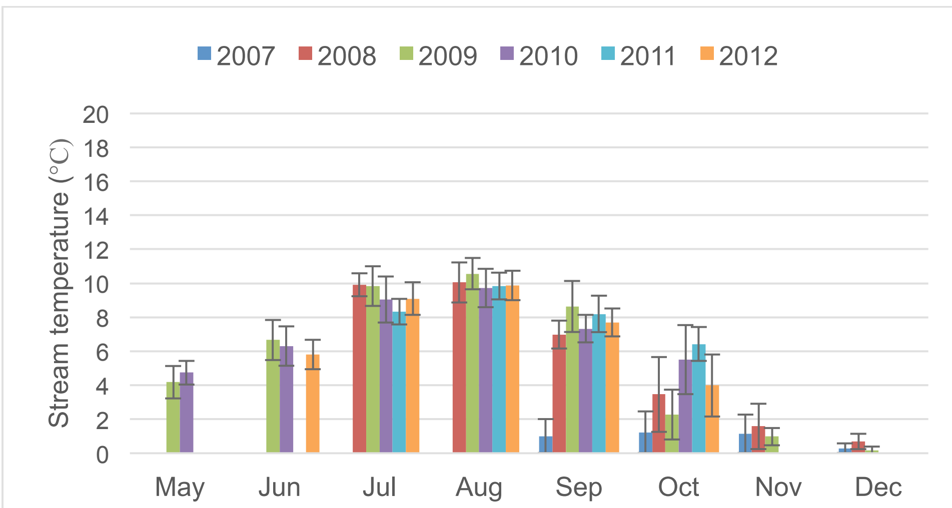



**Figure 13. Monthly average stream temperature for May to December from 2007 to 2012 at NGJOS01. The error bars represent +- 1 standard deviation. Note, not all years are included in this analysis due to missing data.**

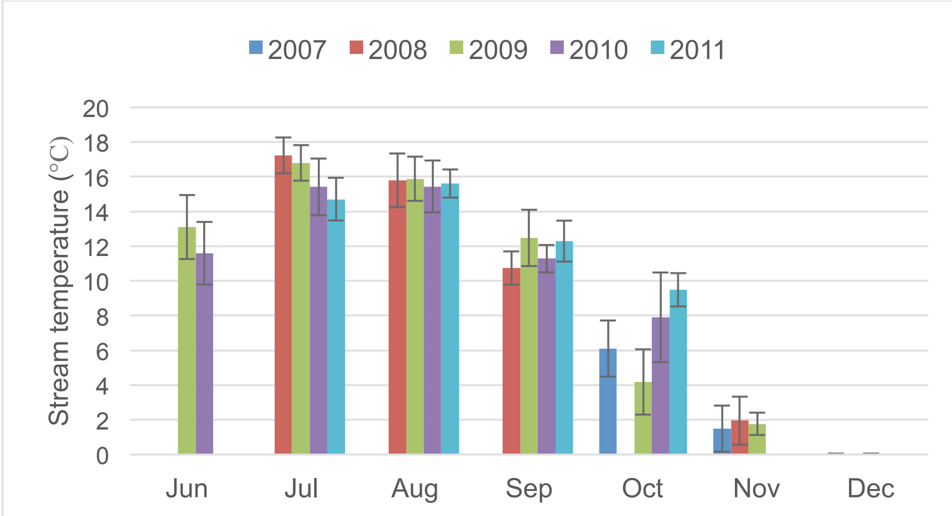



**Figure 14. Monthly average stream temperature for June to December from 2007 to 2011 at NGJOS02. The error bars represent +- 1 standard deviation. Note, not all years are included in this analysis due to missing data.**

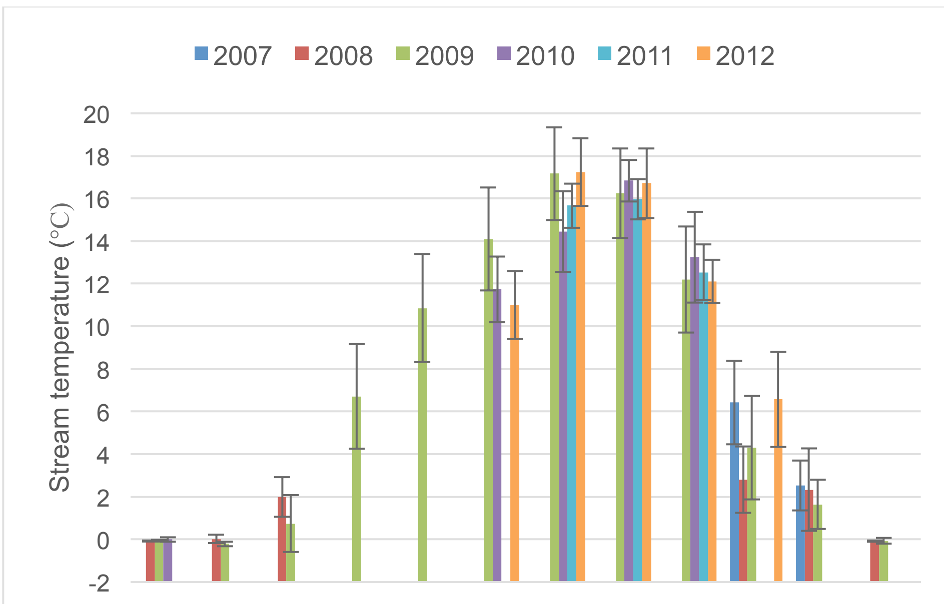



**Figure 15. Monthly average stream temperature for January to December from 2007 to 2012 at NGJOS03. The error bars represent +- 1 standard deviation. Note, not all years are included in this analysis due to missing data.**

# 4 Discussion

Results from the CABIN assessments varied considerably between the three sites in Joseph Creek monitored for the CBWN project. NGJOS01 was assessed as being Unstressed in all years. NGJOS02 was found to be Unstressed in 2011 but was Potentially Stressed in 2008, 2009, and 2010 and was Stressed in both 2007 and 2012. NGJOS03 was assessed as being Stressed in all years except for 2011 when it was found to be Potentially Stressed. These results indicate that Joseph Creek becomes increasingly impacted as it flows from the upper watershed through the urban area of Cranbrook and then through a semi-rural area before reaching the St. Mary River.

The CABIN assessments were corroborated by other macro-invertebrate analyses and metrics. The RIVPACS Ratios, taxa expected with a probability <70%, biodiversity (number of taxa), number of EPT taxa and percentage of dominant and 2 dominant taxa all indicate increasing impact to Joseph Creek as it moves downstream.

At NGJOS01, there has been a stable total abundance of organisms and high total number of taxa throughout the monitoring period relative to the other test sites. These are indications of good benthic community health as stable total abundance reflects a lack of nutrient enrichment or toxicity effects while high total number of taxa reflects valuable biodiversity. High numbers of EPT taxa and % of EPT organisms show a diversity and abundance of the organisms which are typically the most sensitive to pollution and habitat disturbance. The Unstressed condition of NGJOS01 throughout the monitoring period also indicates that this site reflects good quality baseline conditions for Joseph Creek and comparison of other test sites to this baseline can be used to help identify invertebrate metrics that vary from reference condition.

At NGJOS02, the total number of taxa and the total number of EPT taxa were lower in all sampling years than at NGJOS01 reflecting lower overall diversity and lower diversity of sensitive taxa. In 2007, when NGJOS02 was assessed as stressed, it had a low RIVPACS ratio, extremely low % of Ephemeroptera organisms (4.5%) and a high % of the dominant and 2 dominant taxa. Therefore, organisms that were expected to be present under reference conditions were absent, Ephemeroptera which are typically sensitive to disturbance were only present in low numbers, and the community was dominated by one or two taxa (low diversity). In 2012, NGJOS02 was also assessed as stressed which was likely largely due to an extreme spike in total abundance of more than 5 times the number of organisms found in other years.

NGJOS03 was assessed as stressed in all but one sampling year. Between 2007 and 2009, RIVPACS ratios and total number of taxa were lower than at other test sites and total abundance and % of dominant taxa between were higher. High abundance can be an indication of nutrient enrichment while low diversity (total number of taxa and % dominant taxa) can be an indication of site disturbance. Between 2010 and 2012, these metrics of invertebrate community composition improved at NGJOS03 but the improvement was only reflected in the CABIN assessments in 2011 when the site was assessed as potentially stressed. Further CABIN monitoring will help confirm if benthic community health is improving at this test site.

While macroinvertebrate community analyses supported CABIN assessments of stress at Joseph Creek sites, water and sediment chemistry showed few parameters of concern. Total phosphorus was the main parameter exceeding Aquatic Life guidelines. Exceedances were found only at NGJOS03. Since sources of phosphorus are often anthropogenic in nature, it is not surprising to find increasing levels in Joseph Creek after it flows through the urban and rural residential areas of the City of Cranbrook.

Metals analysis showed only aluminum exceeded CCME water quality guidelines and only in two years (2007 and 2008). However, since metal monitoring ceased after 2009, it may be of interest to repeat this analysis to determine if there is an increasing trend in aluminum levels or if guideline exceedences in 2007 and 2008 were anomalies. No guideline exceedances of metals in sediment were found in 2010, 2011 and 2012.

A greater number of and more frequent turbidity readings are needed to verify background levels and exceedances during clear flow times of the year, but clear flow period turbidity levels at NGJOS03 were above the estimated guideline and trending trend towards increasing turbidity levels during turbid flow times are reason for concern. Some potential mechanisms for increased turbidity in the watershed may be: input from storm sewers, run-off from streets or the landscape, lack of riparian vegetation, and erosion of streambanks. Because increased levels of turbidity are one of the only water quality parameters of concern in Joseph Creek, they may be an important factor affecting the benthic invertebrate community and resulting in stressed assessments (Caux *et al*. 1997).

Dissolved oxygen was another parameter that periodically did not meet the minimum guidelines at NGJOS03. Low DO values have the potential to impact fish embryo developing in the gravel. A more focused assessment of areas where fish have selected to spawn and DO values during the incubation period would aid in better understanding the likelihood of DO impacting the aquatic community.

The low inter-annual variation in stream temperature suggests there is likely consistent streamflow regime in Joseph Creek (MacDonald *et al*., 2013), likely due to regulation from Phillips Reservoir and Idlewild Lake. Stream temperature results show that Joseph Creek increases in temperature as it flows downstream, with temperatures exceeding optimum temperature for westslope cutthroat trout and bull trout rearing at NGJOS02 and NGJOS03 in July and August. Streams typically warm in a downstream direction as they gain more energy. However, some potential mechanisms for increased temperature may be: lack of vegetation shading the Gold Creek diversion, lack of riparian vegetation at many places through the City of Cranbrook, and run-off from heated roads or other non-permeable surfaces. These increased temperatures may be affecting the westslope cutthroat trout and bull trout populations in Joseph Creek (BC MoE. 1999, Oliver 2000 and Oliver 2001).

# 5 Conclusions and Recommendations

The results of the CABIN analysis, water chemistry, and stream temperature data show that Joseph Creek is increasingly impacted as it flows downstream to meet the St. Mary River. Of particular note is the change noted in the benthic macro-invertebrate communities and turbidity levels, suggesting a deterioration in water quality. Since water chemistry showed few concerns other than Total Phosphorus, it may be that increased turbidity plays a larger role in the impact to the macro-invertebrate community. Taking more frequent turbidity readings at more sites would help to identify where sediment is entering the stream and since sediment deposition has been noted at some storm sewer outfalls, monitoring of outfalls should be considered.

Elevated stream temperatures are a potential concern for aquatic life. It is recommended that temperature loggers remain in-stream year-round to enable long-term trend analysis. Along with stream temperature data collection, the mitigation of radiation effects on stream temperature through riparian planting at locations such as the Gold Creek diversion upstream of Phillips reservoir and other areas where there is little riparian vegetation should be considered.

Previous studies have identified areas of disturbed in-stream habitats, which likely also contribute to the stressed macro-invertebrate populations (Oliver. 2001). Therefore, in-stream restoration combined with riparian restoration should be considered.

This study did not include analysis of microbial indicators, but concerns have been expressed about potential seepage from the sewage lagoons located adjacent to Hwy 95A by residents further downstream along Joseph Creek. It is therefore recommended that such sampling take place to determine if Joseph Creek is being affected.

# 6 References

Barnett, T., D.W. Price, H.G. Hidalgo., C. Bonfils, B.D. Santer, T. Das, G. Bala, A.W. Wood, T. Nozawa, A.A. Mirin, D.R. Cayan., and M.D. Dettinger. 2008. Human-induced changes in the hydrology of the western United States, Science 319: 1080-1803.

BC Ministry of Environment (BC MoE). 2003. Water quality field sampling manual. Government of British Columbia

B.C. Conservation Data Centre. 2013. BC Species and Ecosystems Explorer. B.C. Ministry of Environment. Available: http://a100.gov.bc.ca/pub/eswp/.

Burger, G., J. Schulla, and T. Werner. 2011. Estimates of future flow, including extremes, of the Columbia River headwaters. Water Resources Research, 47: W10520, doi:10.1029/2010WR009716.

Caux, P.Y., D.R.J. Moore and D. MacDonald. 1997. Ambient Water Quality Guidelines (Criteria) for Turbidity, Suspended and Benthic Sediments, Technical Appendix. Prepared for BC Ministry of Environment, Lands and Parks.

CCME (Canadian Council of Ministers of the Environment). 2001. Canadian sediment quality guidelines for the protection of aquatic life: Introduction. Updated. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

CCME. 1999a. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Introduction. Updated 2001. Cited in Canadian Environmental Quality Guidelines,1999 (plus updates), Canadian Council of Ministers of the Environment, Winnipeg. Accessed at: http://ceqg-rcqe.ccme.ca/

CCME. 1999b. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: In Canadian Environmental Quality Guidelines. 1999 (plus updates). Canadian Council of Ministers of the Environment. Winnipeg. Accessed at: http://ceqg-rcqe.ccme.ca/

CBWQMP (Columbia Basin Water Quality Monitoring Program). 2012. Operating Procedures

Demarchi. 2011. The British Columbia Ecoregion Classification. Ministry of Environment, Victoria BC. Accessed at: http://www.env.gov.bc.ca/ecology/ecoregions/index.html

EcoAnalysts Inc. 2012. Standard metric output guidance document. Moscow, Idaho.

Environment Canada. 2012a. 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. Canadian Aquatic Biomonitoring Network Laboratory Methods: Processing, Taxonomy and Quality Control of benthic Macroinvertebrate Samples. Accessed at: http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=CDC2A655-A527-41F0-9E61-824BD4288B98

Government of British Columbia. 2013. British Columbia Approved Water Quality Guidelines. Accessed at: http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html

GranDuke Geomatics. 2013a. Microsoft Excel add-in to transpose Maxxam water quality data into CBWN Excel format. Version 1.2 (Beta Release).

Granduke Geomatics 2013b. AGATHA- Automated guideline assessment tool for high speed analysis. Version 0.9.0 (Beta Release).

Health Canada. 2012. Guideline for Canadian Drinking Water Quality. Accessed at: http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/2012-sum_guide-res_recom/index-eng.php.

Jost, G., R.D. Moore, D. Gluns, and R.S. Smith. 2012. Quantifying the contribution of glacier runoff to streamflow in the upper Columbia River basin, Canada. Hydrology and Earth Systems Science 16: 849-860, doi:10.5194/hess-16-1-2012.

MacDonald, R.J., S. Boon, J.M. Byrne, and U. Silins. 2013. A comparison of surface and sub-surface controls on summer temperature in a headwater stream. Hydrological Processes. DOI: 10.1002/hyp.9756.

Maxxam Analytics. 2012. Environmental QA/QC Interpretation Guide (COR FCD-00097/5).

Nagpal, N.K., L. W. Pommen and L. G. Swain. 2006. A Compendium of Working Water Quality Guidelines for British Columbia. Environmental Protection Division, Ministry of Environment, Government of BC.

Nagpal, N.K. 2001. Ambient Water Quality Guidelines for Selenium. Water Protection Branch, Ministry of Water, Land and Air Protection, Victoria, BC.

Oliver, G.G. 2000. Towards a Strategy for Fish habitat Restoration in the Joseph Creek Watershed.

Oliver, G.G. 2001. Joseph Creek Restoration Phase 2: Water Use Planning and Implementation.

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

Quilty, E.J., and L.E. McDonald. 1996. Urban Impacts on Lower Joseph Creek: A Preliminary Investigation, Environmental Protection, BC Environment, Cranbrook.

## Personal Communications

Horvath, Steve. Senior lab officer. Water and air monitoring & reporting section, BC Ministry of Environment, Surrey.

## Appendix A. Site Locations

| Site Code | Description of Site | Latitude | Longitude | Elevation |
|---|---|---|---|---|
| NGJOS01 | Upper Joseph Creek | 49° 27' 6" | -115° 41' 12" | 1116m |
| NGJOS02 | Kinsmen Park | 49° 30' 7'" | -115° 45' 17" | 940m |
| NGJOS03 | Lower Joseph Creek | 49° 34' 38" | -115° 45' 31" | 866m |

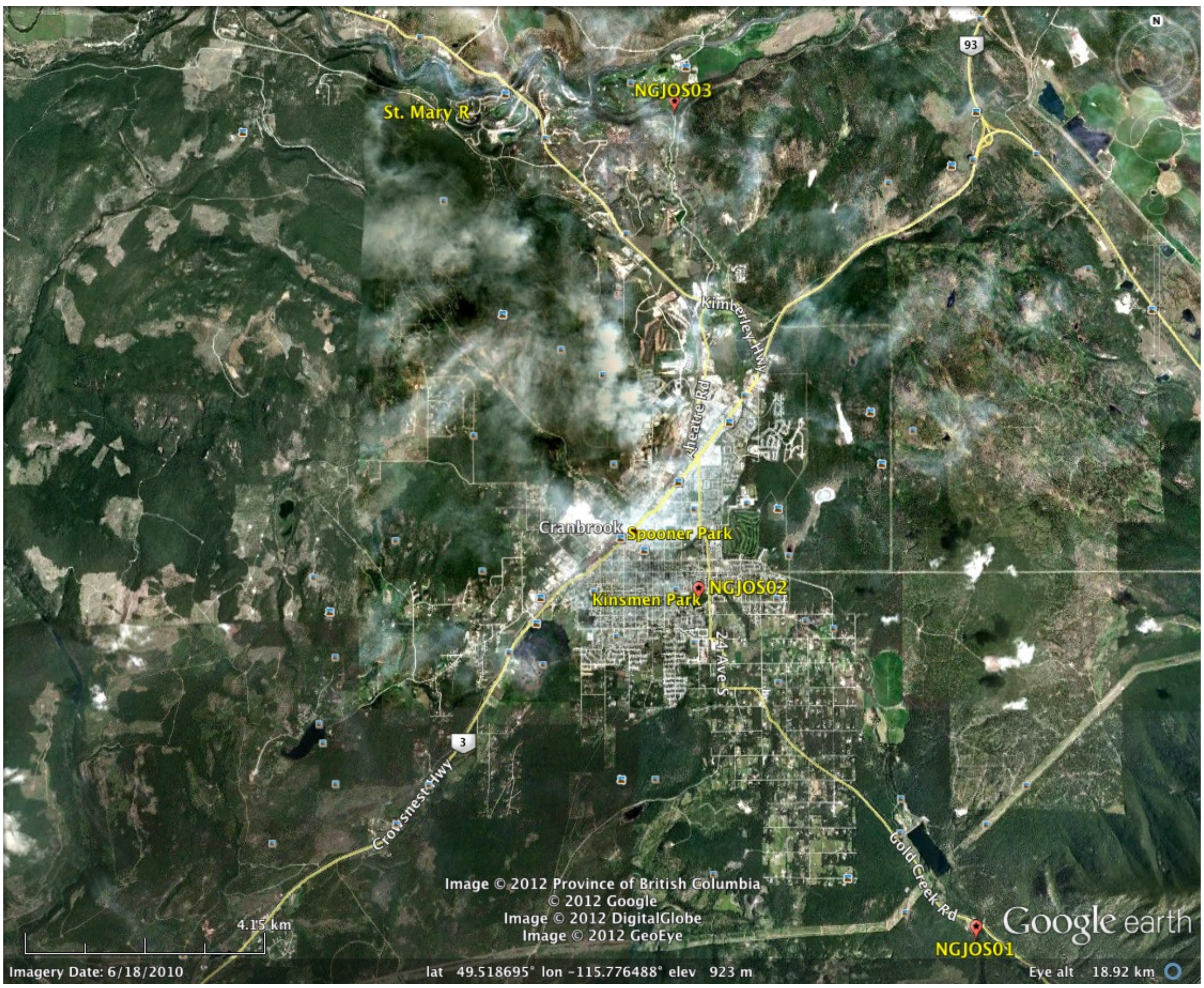



**Figure 14. Map of Joseph Cr sites**

## Appendix B. CABIN data