Real Time Water Quality Report

Labrador Iron Mines Schefferville Network

Annual Deployment Report 2012

2012-06-06 to 2012-10-25

Government of Newfoundland & Labrador
Department of Environment and Conservation
Water Resources Management Division
St. John’s, NL, A1B 4J6 Canada

Prepared by:

Keith Abbott
Environmental Scientist

Department of Environment & Conservation
Water Resources Management Division
Government of Newfoundland & Labrador
4th Floor, Confederation Building, West Block
PO Box 8700, St, John's, NL, A1B 4J6

t. 709.729.1331
f. 709.729.0320
e. keithnabbott@gov.nl.ca

Acknowledgements

The Real-Time Water Quality/Quantity Monitoring Program at the James deposit near Schefferville is fully funded by Labrador Iron Mines (LIM) and its success is dependent on a joint partnership between LIM, Environment Canada (EC), and the Newfoundland & Labrador Department of Environment & Conservation (ENVC). Managers and program leads from each organization, namely Renee Paterson (ENVC), Larry Ledrew (LIM), and Howie Wills (EC), are committed to the operation of this network and ensuring that it continually provides meaningful and accurate water quality/quantity data.

In addition to funding this program, LIM also provided support to ENVC and EC staff during site visits, including transportation, food, workspace, tools, and field assistance. LIM also provided storage facilities, information on LIM mining operations, and station checks when water quality events arise. LIM employees involved in carrying out these duties included Leah Butler, Ashley Rieseberg, Corey McLister, and Shawn Duquet.

EC plays an essential role in the data logging/communication aspect of the network. In particular, EC staff of the Water Survey of Canada, including Brent Ruth, Perry Pretty, Roger Ellsworth, Dwayne Ackerman and Mike Ludwicki visited network stations regularly to ensure that the data logging and data transmitting equipment was working properly. EC also plays the lead role in dealing with stage and flow issues.

ENVC is responsible for recording and managing water quality data. Keith Abbott, under the supervision of Renee Paterson, is ENVC's main contact for Real-Time Water Quality Monitoring operations at the James deposit, and was responsible for maintaining and calibrating water quality instruments, as well as grooming, analyzing and reporting on water quality data recorded at the stations. Instrument performance evaluation and repairs, during the winter of 2012-2013, is being conducted in-house by Tara Clinton & Ryan Pugh.

Introduction

- The Newfoundland & Labrador Department of Environment & Conservation (ENVC), in partnership with Labrador Iron Mines (LIM) and Environment Canada (EC), established two real-time water quality/quantity (RTWQ) stations in September 2010 at the James Iron Ore deposit in western Labrador, near Schefferville, QC.
- The official name of each station is *James Creek Above Bridge* and *Unnamed Tributary Below Settling Pond*, hereafter referred to as the *James Creek* station and the *Unnamed Tributary* station, respectively (Figure 1).

a. Unnamed Tributary

b. James Creek

Figure 1. RTWQ stations are located alongside (a) the Unnamed Tributary and (b) James Creek.

- Unnamed Tributary station monitors water outflow from a series of multi-cell retention and settling ponds.
- James Creek station monitors water outflow from the multi-cell retention and settling pond system, as well as monitors outflow from Ruth Pit.
- The retention and settling pond system is comprised of four smaller man-made ponds that receive water primarily from groundwater wells constructed along the periphery of the James Property, in addition to storm water from the beneficiation area, flush water from the reject rock pipeline, and in case of pump failure, reject rock inside the pipeline that was destine to Ruth Pit. Outflow from the retention and settling pond system is directed into the Unnamed

Tributary and James Creek (Figure 2). Priority is given to the outflow leading into the Unnamed Tributary, with surplus water directed into James Creek.

- Ruth Pit is used as a settling pond for reject rock originating from the beneficiation area at the Silver Yard, as well as receives water from pit dewatering pumps. The outflow from Ruth Pit is the start of James Creek (Figure 2).

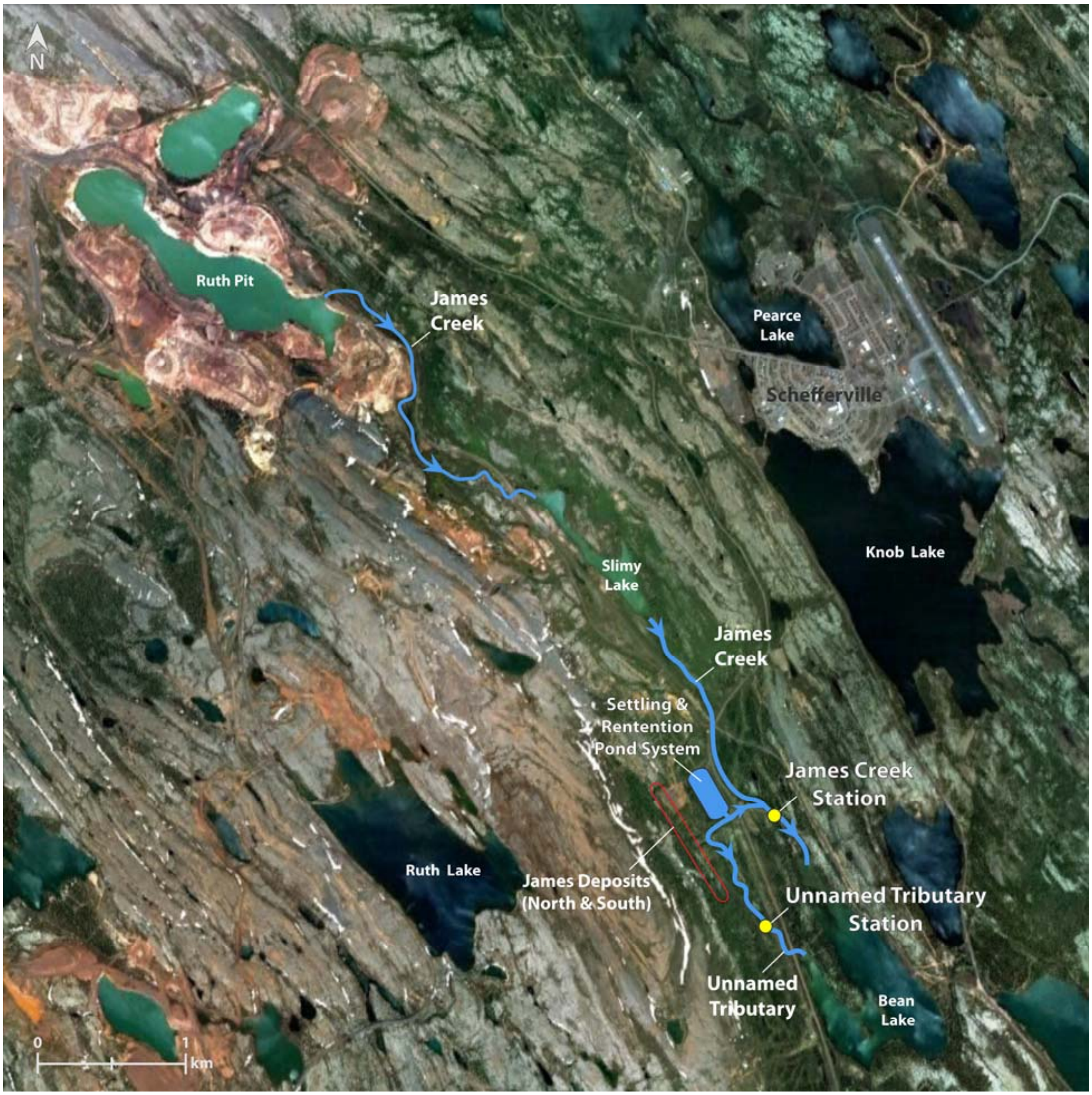

Image © 2012 DigitalGlobe & © 2012 Google

Figure 2. Map of Schefferville Project Area in Western Labrador showing two RTWQ Monitoring Stations at James Creek and Unnamed Tributary. Background image was taken from Google Earth on March 7, 2012.

- Six water parameters are measured at each station, including five water quality parameters (i.e., temperature, pH, specific conductivity, dissolved oxygen and turbidity) and one water quantity parameter (i.e., stage).
- Water quality parameters are recorded on an hourly basis, typically from late-May to mid-October, when streams are ice-free. ENVC is responsible for collecting and managing this dataset.
- Stage is recorded year-round on an hourly basis. EC is responsible for collecting and managing this dataset.
- EC is responsible for logging and transmitting all water quality and water quantity data to a central repository via satellite communications.
- The purpose of the real-time network at these stations is to monitor, process, and distribute water quality and water quantity data to LIM, ENVC, and EC, for assessment and management of water resources, as well as to provide an early warning of any potential or emerging water issues, such that mitigative measures can be implemented in a timely manner.
- ENVC informs LIM of any significant water quality events by email notification. Monthly and annual deployment reports serve to document water parameters measured at these stations.
- This annual deployment report, presents water quality and water quantity data recorded at the James Creek and Unnamed Tributary stations from June 6, 2012 to October 25, 2012.

Quality Assurance & Quality Control

- Water quality parameters are measured at each station using a Hydrolab DataSonde instrument (Figure 3).

Model DS5 © 2005 Hach Company

Figure 3. Hydrolab DataSonde used for monitoring five water quality parameters.

- To ensure accurate data collection, water quality instruments are subjected to quality assurance procedures, in order to mitigate any errors caused by biofouling and/or sensor drift.
- Quality assurance procedures include: (i) a thorough cleaning of the instrument, (ii) replacement of any small sensor parts that are damaged or unsuitable for reuse, and (iii) the calibration of four instrument sensors (i.e., pH, specific conductivity, dissolved oxygen, and turbidity sensors)[1].
- Quality assurance procedures are carried out every 28-38 days, before the start of a new deployment period. Deployment start and end dates are summarized in Table 1.

Table 1. Water quality instrument deployment start and end dates for 2012 at James Creek and the Unnamed Tributary.

Station	Start date	End date	Duration (days)	Instrument
James Creek	2012-06-06	2012-07-14	38	49200
	2012-07-14	2012-08-21	38	49200
	2012-08-22	2012-09-26	35	49199
	2012-09-26	2012-10-25	29	49199
Unnamed Tributary	2012-06-06	2012-07-14	38	49201
	2012-07-14	2012-08-21	38	49201
	2012-08-22	2012-09-26	35	49200
	2012-09-26	2012-10-24	28	49200

- Instrument 49199 was out-of-service for the first and second deployment periods, due to LDO sensor repairs.

[1] By design, the DataSonde temperature sensor cannot be calibrated using Hydras 3LT software; it is a factory calibration.

- Instrument 49201 was taken offline for the third and fourth deployment periods, due to pH sensor issues.
- As part of quality control procedures, instrument performance is tested at the start and end of its deployment period. The process is outlined in Appendix A.
- Instruments are assigned a performance rating (i.e., poor, marginal, fair, good or excellent) for each water quality parameter measured.
- Table 2 shows the performance ratings of the instrument sensors (i.e., temperature, pH, conductivity, dissolved oxygen and turbidity) deployed at James Creek and Unnamed Tributary.

Table 2. Instrument sensor performance at the start and end of each deployment period for the James Creek and Unnamed Tributary RTWQ stations.

Station	Stage of deployment	Date (yyyy-mm-dd)	Instrument	Temperature (^{o}C)	pH	Specific conductivity (µS/cm)	Dissolved oxygen (mg/L)	Turbidity (NTU)
James Creek	Start	2012-06-06	49200	Good	Excellent	Good	Excellent	Excellent
	End	2012-07-14	49200	Excellent	Excellent	Good	Excellent	Excellent
	Start	2012-07-14	49200	Excellent	Fair	Excellent	Good	Excellent
	End	2012-08-21	49200	Excellent	Excellent	Excellent	Excellent	Fair
	Start	2012-08-22	49199	Excellent	Good	Excellent	Excellent	Excellent
	End	2012-09-26	49199	Excellent	Fair	Excellent	Good	Excellent
	Start	2012-09-26	49199	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2012-10-25	49199	Excellent	Good	Excellent	Good	Excellent
Unnamed Tributary	Start	2012-06-06	49201	Excellent	Good	Fair	Excellent	Good
	End	2012-07-14	49201	Excellent	Excellent	Good	Excellent	Excellent
	Start	2012-07-14	49201	Excellent	Good	Excellent	Excellent	Excellent
	End	2012-08-21	49201	Excellent	Excellent	Good	Excellent	Excellent
	Start	2012-08-22	49200	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2012-09-26	49200	Excellent	Excellent	Excellent	Excellent	Good
	Start	2012-09-26	49200	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2012-10-24	49200	Excellent	Good	Excellent	Fair	Excellent

- Based on quality control procedures, instrument sensor performance ranged from fair-to-excellent in 2012 (Table 2).
- Despite receiving favourable ratings, pH sensor performance was often unreliable during the 2012 deployment season. Indeed, all three LIM instruments (i.e., 49199, 49200, and 49201) at some time displayed a decreasing trend in pH of approximately 0.6-1.5 units, starting 10-15 days after instrument deployment. This decreasing drift was attributed to a problem with the sensor itself. Quality control checks failed to detect these decreasing trends as poor instrument performance since the problem would rectified itself during quality control checks; pH levels would return to a normal range within 5-10 minutes after a computer (i.e., archer or laptop) connection was made with the problematic sensor. After consultation with ENVC and Campbell Scientific technical staff on this issue, the reason for this pH dependence on a computer connection is still unclear.

- To test pH sensor performance during deployment, two instruments (i.e., 49200 & 49201) were deployed next to each other at the Unnamed Tributary station, during the third and fourth deployment periods. The pH sensor on instrument 49200 was considered reliable, whereas the pH sensor on instrument 49201 was considered unreliable. Figure 4 displays pH data recorded by both sensors during that two-month period. Data recorded by the reliable sensor (49200) was consistent throughout the deployment, with daily fluctuations coinciding with the photosynthetic cycling of CO_2 by aquatic organisms. In contrast, the unreliable sensor (49201) displayed a 1.5 unit drop in pH starting approximately 15 days after the initial deployment. When the unreliable sensor (49201) was recalibrated on September 26, 2012, it performed as well as the reliable sensor (49200) for the remainder of deployment. The test showed that there was a problem with the 49201 sensor during the third deployment period, and also showed that the problem was not predictably in the time of its occurrence.

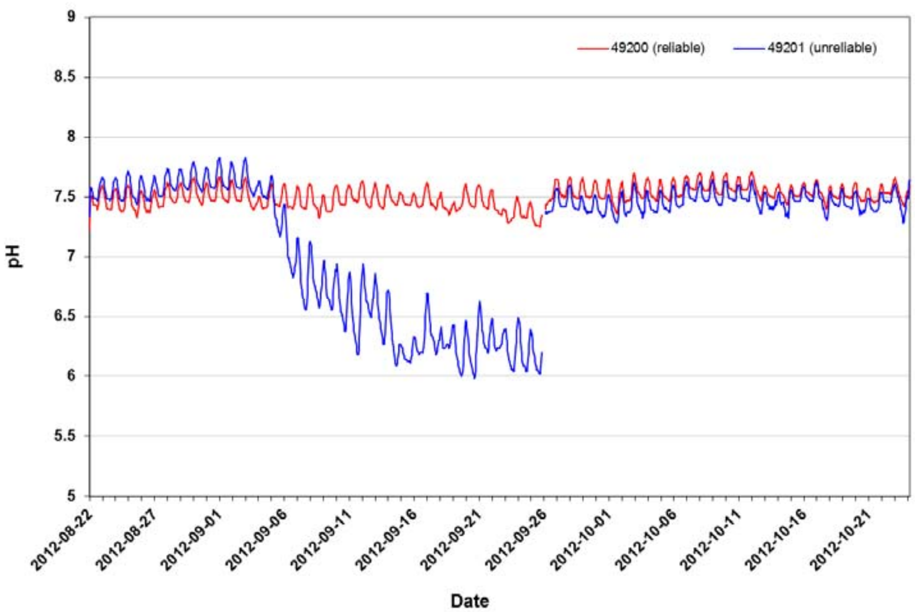

Figure 4. pH data recorded at the Unnamed Tributary station from August 22, 2012 to October 24, 2012, by a presumed reliable instrument (49200) and unreliable instrument (49201).

- Bath tests were also conducted from November 29, 2012 to December 12, 2012, to further test sensor performance. During these bath tests, pH sensor readings were logged in 15 minute intervals while immersed in a relatively stable aquatic environment. Results from the bath test showed that the pH sensors on instruments 49199 and 49201 were not working correctly, and the recommendation was to replace these sensors (Figure 5). This recommendation was also supported by Campbell Scientific technicians, after reviewing both bath test and field data.
- Based on the bath test results, pH data acquired by the failing sensors (i.e., 49199 & 49201) were omitted from this report. Fortunately, the Teflon junction replacement on Instrument 49200, after the 2^{nd} deployment period, appeared to fix pH issues with that instrument, and it performed well in the bath test. The pH data recorded by the 49200 instrument does appear in this report.

- The failing sensors are scheduled to be replaced before the start of the 2013 deployment season. It is expected that sensor replacement will remedy the problem. It is also suspected that this issue will arise again, especially with the aging 49200 pH sensor.

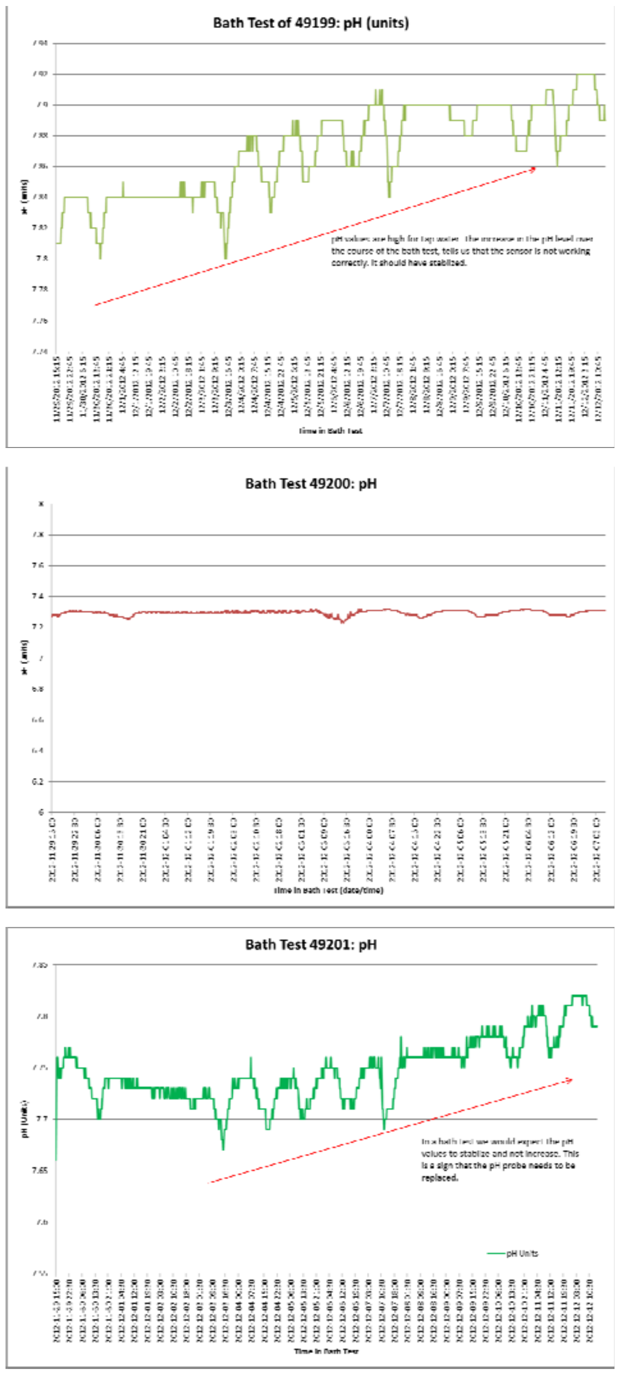

Figure 5. pH data recorded by three instruments during a 14 day bath test, from November 29, 2012 to December 12, 2012. Based on this analysis, it was recommended that pH sensors on instrument 49199 and instrument 49201 be replaced.

Deployment Notes

- Transmission errors occurred sporadically throughout the deployment period at the James Creek station, resulting in the loss of 298 hourly transmissions. It was suspected that the time allotted by the Automated Data Retrieval System (ADRS) for data upload from the station to the satellite was exceeded, causing incomplete data transmissions. EC has been notified of this issue. To obtain a complete dataset for this report, water quality data was extracted from the instrument's internal log file. The only exceptions were the *specific conductivity* and *TDS* datasets, which were extracted from the ADRS, due to the higher precision of the ADRS datasets. Provisional *stage* values were also extracted from the ADRS. Data gaps are apparent in the *specific conductivity*, *TDS*, and *stage* graphs shown in this report.
- Damage caused by winter flooding at the Unnamed Tributary station in early 2012, resulted in an electrical short, which stopped data relay from the water quality field instrument to the data logger during the first deployment period (i.e., June 6, 2012 to July 14, 2012). Fortunately, water quality data for this station was obtained from the water quality instrument's internal log file. The wire suspected of being damaged by the flood was replaced and the problem did not reoccur.
- No tailings were discharged into Ruth Pit after August 16, 2012.

Data Interpretation

- Performance issues and data records were interpreted for each station during the deployment period for the following seven parameters:

  (i.) Stage (m)
  (ii.) Temperature (^{o}C)
  (iii.) pH
  (iv.) Specific conductivity (μS/cm)
  (v.) Total dissolved solids (g/l)
  (vi.) Dissolved oxygen (mg/l)
  (vii.) Turbidity (NTU)

- A description of each parameter is provided in Appendix B.

Stage

- Figure 6 displays stage values recorded at both stations from June 6, 2012 to October 25, 2012. These values are provisional. A complete dataset of quality assured and quality controlled stage values should be available upon request through EC after March 2013 (http://www.ec.gc.ca/rhc-wsc/default.asp).

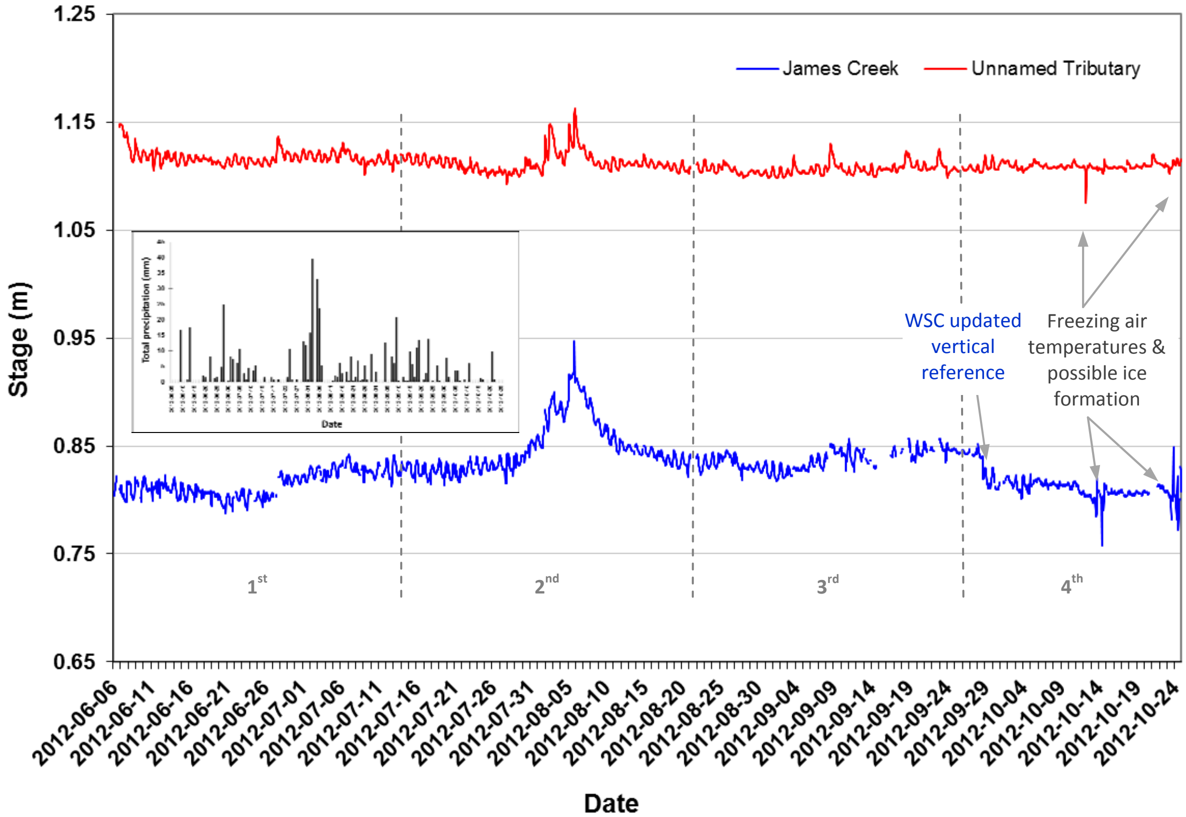

Figure 6. Hourly stage (m) values recorded at James Creek and Unnamed Tributary from June 6, 2012 to October 25, 2012. The inset chart shows total precipitation (mm) recorded at the Schefferville weather station during the same time period. All data was recorded by Environment Canada. The four deployment periods are demarcated with dashed lines.

- Stage values ranged from 0.758 m to 0.947 m at James Creek and from 1.075 m to 1.163 m at Unnamed Tributary from June 6, 2012 to October 25, 2012.
- Daily fluctuations were observed at both stations with increases occurring in the afternoon and decreases occurring at night. These diurnal fluctuations were attributed to temperature-related atmospheric pressure changes. Some minor disturbances in stage occurring near the end of the deployment season coincided with freezing air temperatures (Figure 6).
- Weekly trends in stage at the James Creek station corresponded well with rainfall events (Figure 6 inset).

- The Water Survey of Canada (WSC) updated their vertical reference (i.e., datum) for the James Creek station on September 28, 2012, which resulted in a sudden and slight decrease in stage at that station.
- Weekly trends in stage were not as apparent at the Unnamed Tributary station, since the flow of this stream is highly regulated.
- Stage values are based on a vertical reference that is unique to each station. As a result, absolute values of stage are not comparable between stations, but relative changes in stage are.
- Figure 7 displays stage recorded during the 2011 and 2012 deployment seasons. Water levels were for the majority of time higher at the James Creek station and lower at the Unnamed Tributary station in 2012, compared to 2011 levels.

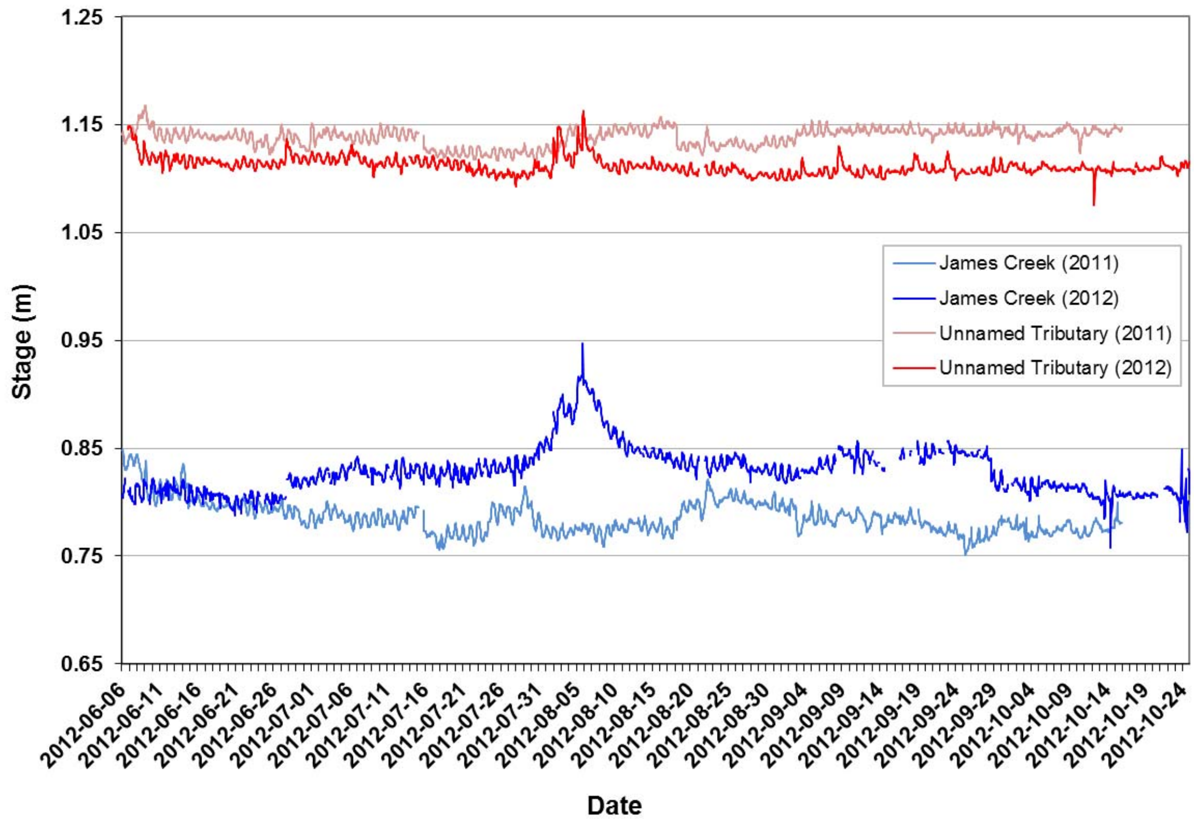

Figure 7. Hourly stage (m) values recorded at James Creek and Unnamed Tributary during the 2011 deployment season (June 4, 2011 to October 16, 2011) and 2012 deployment season (June 6, 2012 to October 25, 2012).

Temperature

- Water temperature ranged from 0.18˚C to 15.69˚C at James Creek and from 0.0˚C to 17.47˚C at Unnamed Tributary from June 6, 2012 to October 25, 2012 (Figure 8).
- Water temperatures at both stations display large diurnal variations. This is typical of shallow water streams and ponds that are highly influenced by diurnal variations in ambient air temperatures.
- Weekly trends in water temperature corresponded well with ambient air temperatures recorded by Environment Canada at the Schefferville weather station (Figure 8 inset, Appendix C).
- Water temperatures at the Unnamed Tributary were on average 1.53°C colder than water temperatures at James Creek. Indeed, water flowing into the Unnamed Tributary is primarily from a groundwater source, and has less exposure to ambient air temperatures, as compared to the surface water source that primarily feeds into James Creek.

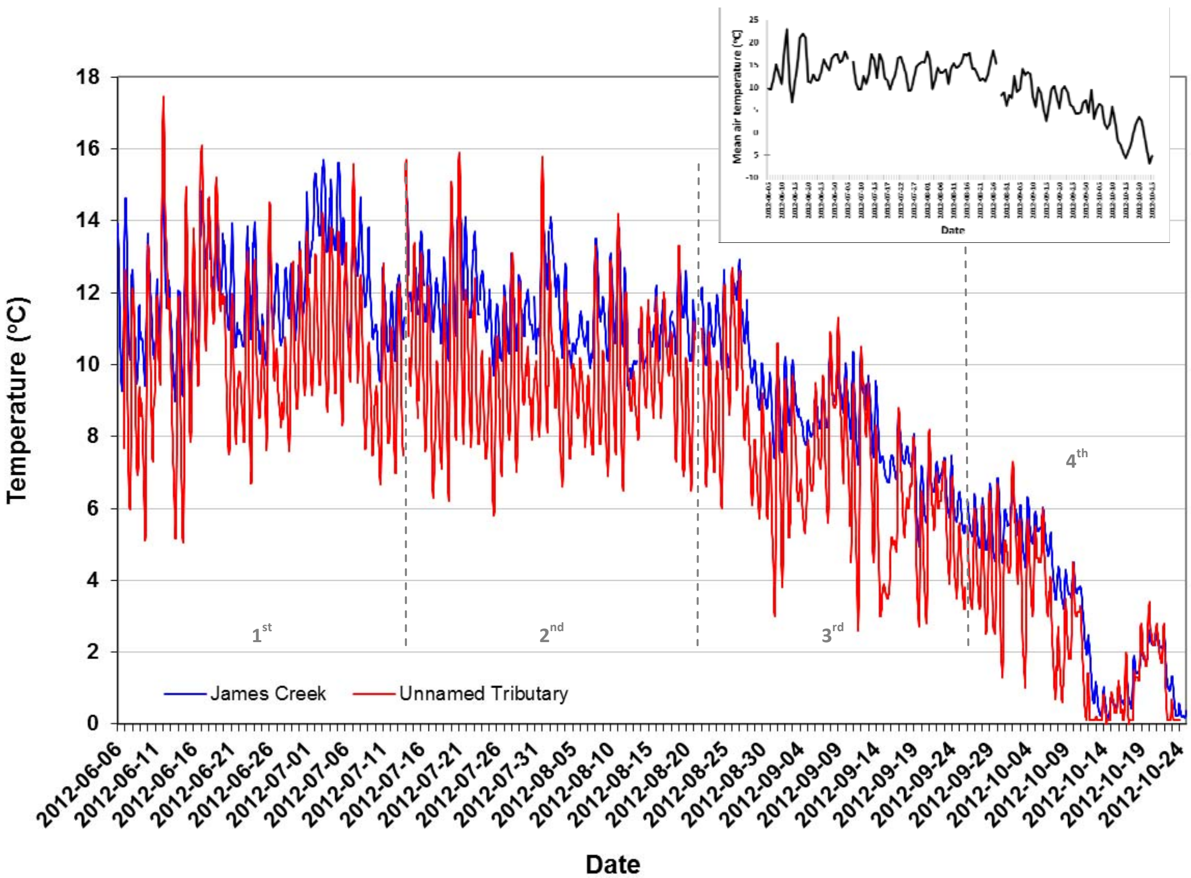

Figure 8. Hourly water temperature (°C) values recorded at James Creek and Unnamed Tributary from June 6, 2012 to October 25, 2012. Inset chart shows air temperature during the same period, as recorded by Environment Canada at the Schefferville weather station. The four deployment periods are demarcated with dashed lines.

- Figure 9 displays water temperatures recorded during the 2011 and 2012 deployment seasons. Water temperatures measured at both stations were more alike in 2012, when compared to water temperatures measured in 2011. This was most apparent midway through the deployment season. It is assumed that water originating from the ground and flowing into Unnamed Tributary in 2011 had a shorter wait time in the retention pond system, and thus had less exposure to ambient air temperatures, which would have increased its temperature.

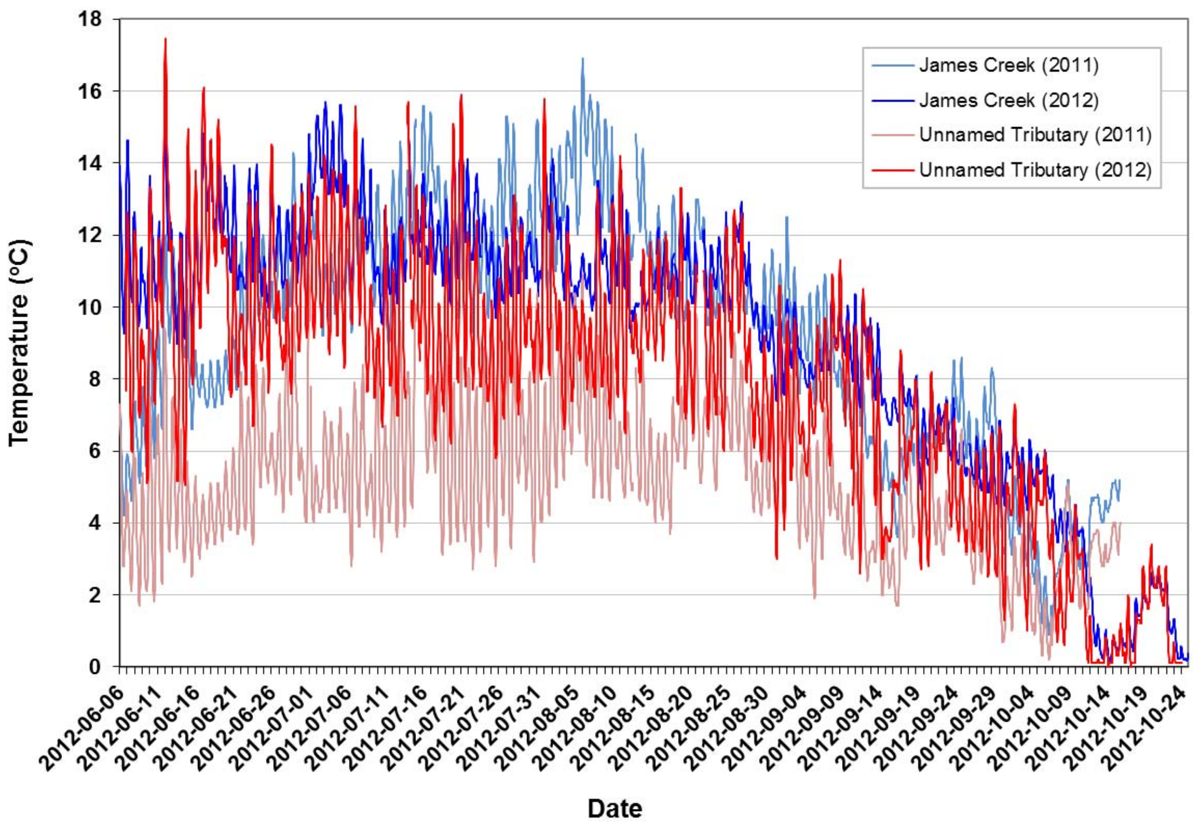

Figure 9. Hourly water temperature (°C) values recorded at James Creek and Unnamed Tributary during the 2011 deployment season (June 4, 2011 to October 16, 2011) and 2012 deployment season (June 6, 2012 to October 25, 2012).

pH

- pH values ranged from 7.07 units to 8.40 units at James Creek and from 7.31 units to 7.71 units at Unnamed Tributary from June 6, 2012 to October 25, 2012 (Figure 10).

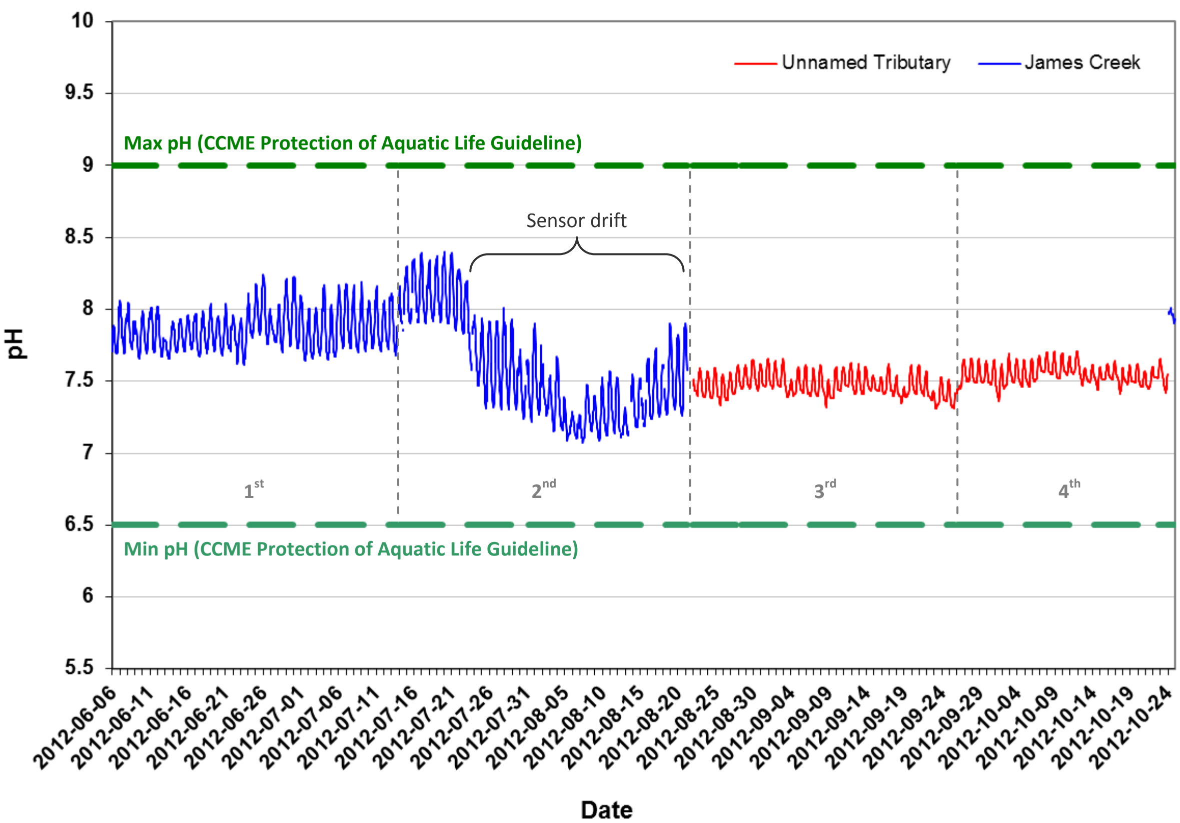

Figure 10. Hourly pH values recorded at James Creek and Unnamed Tributary from June 6, 2012 to October 25, 2012. The four deployment periods are demarcated with dashed lines.

- Only pH data acquired by instrument 49200 is shown in Figure 10, due to pH sensor issues with instruments 49199 and 49201.
- All pH values were within the acceptable range for the protection of aquatic life (i.e., 6.5 to 9.0 units), as defined by the Canadian Council of Ministers of the Environment (2007).
- pH values at both stations fluctuated daily with peaks typically occurring in the late afternoon/ early evening. These variations coincide with the photosynthetic cycling of CO_2 by aquatic organisms.
- Weekly trends in pH were observed during the second deployment period at the James Creek station. Instrument drift was suspected of affecting pH at this time, since pH levels did not continue these weekly trends after instrument cleaning and recalibration on August 21, 2012. The Teflon junction was replaced on the pH reference probe during instrument recalibration on

August 21, 2012, which appeared to fix pH issues with that instrument for the duration of the deployment season.

- The 49200 instrument was deployed at the James Creek station for one day at the end of the 2012 deployment season (Figure 10). pH values recorded during this short deployment showed pH levels at James Creek are typically higher than those recorded at the Unnamed Tributary. Higher pH levels measured at James Creek, compared to Unnamed Tributary, were also observed during the 2011 deployment season (Figure 11). This difference could be attributed to the mining effluent discharged into Ruth Pit and detected at the James Creek station.
- Instrument drifting was also apparent in pH data collected in 2011 (Figure 11). Indeed, instrument 49199 deployed at James Creek in 2011 and instrument 49200 deployed at Unnamed Tributary in 2011 both showed a decreasing drift in pH values during the third deployment period. This sensor issue became more prominent during the 2012 deployment season.

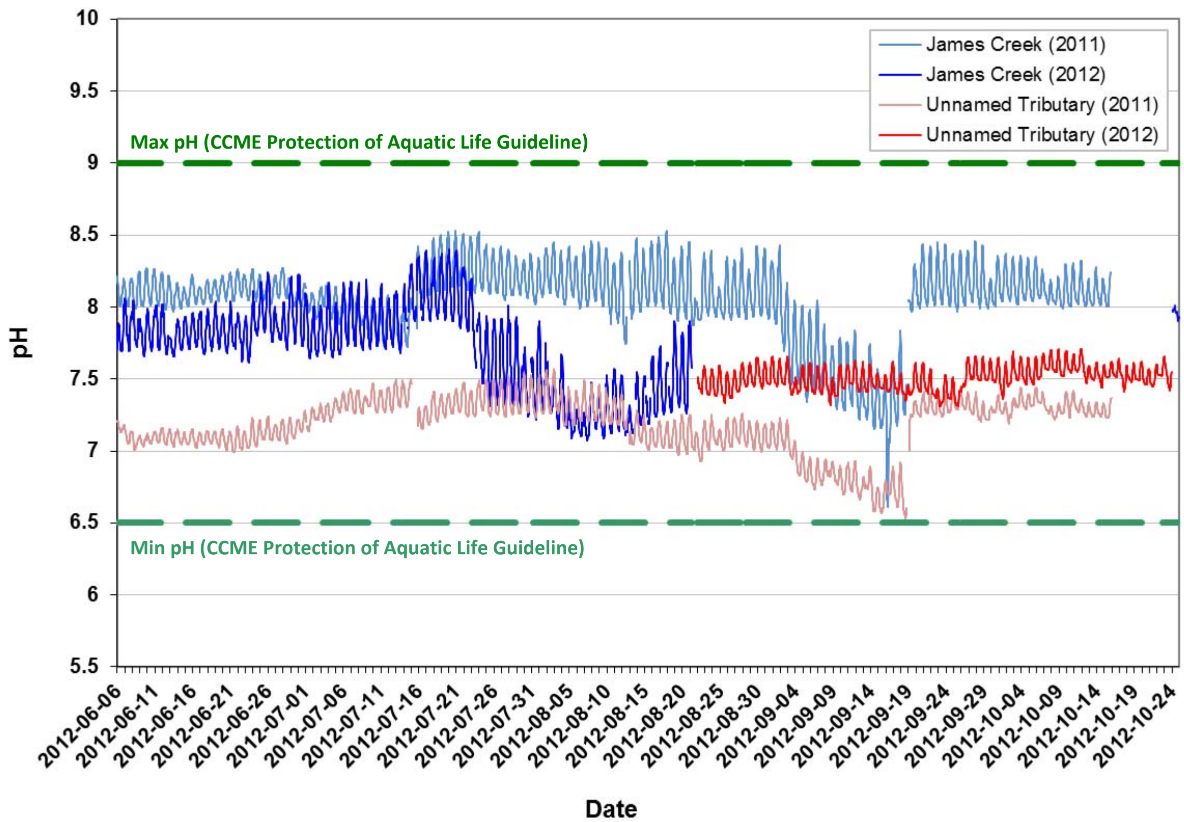

Figure 11. Hourly pH values recorded at James Creek and Unnamed Tributary during the 2011 deployment season (June 4, 2011 to October 16, 2011) and 2012 deployment season (June 6, 2012 to October 25, 2012).

Specific Conductivity

- Specific Conductivity ranged from 130.3 μs/cm to 152.5 μs/cm at James Creek and from 53.0 μs/cm to 66.6 μs/cm at Unnamed Tributary from June 6, 2012 to October 25, 2012 (Figure 12).

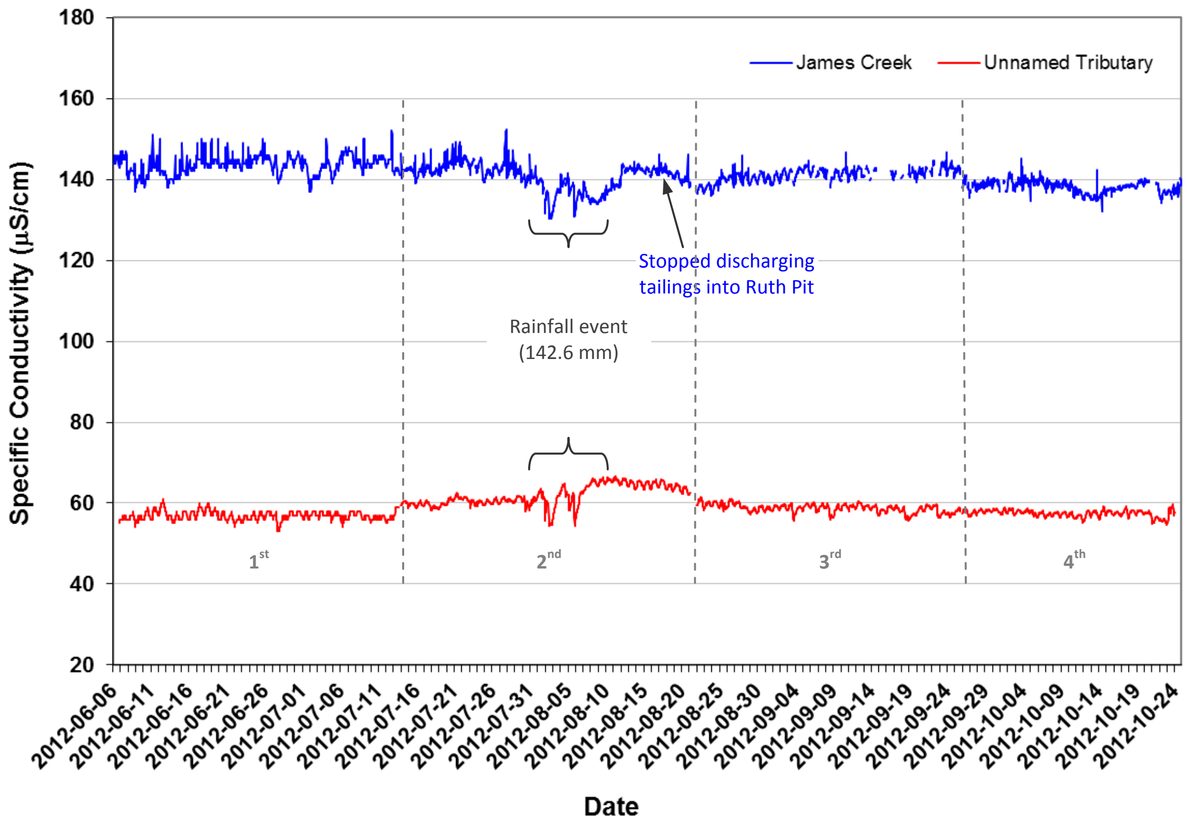

Figure 12. Hourly specific conductivity (μS/cm) values recorded at James Creek and Unnamed Tributary from June 6, 2012 to October 25, 2012. The four deployment periods are demarcated with dashed lines.

- Specific conductivity values at both stations fluctuated daily with peaks typically occurring late evening/early morning. Diurnal fluctuations could be attributed to the photosynthetic cycling of CO_2 by aquatic organisms, with peaks coinciding with a presumed increase in major ions (e.g., HCO_3^-) during the night.
- Daily fluctuations at the James Creek station appeared to be more subdued after August 16, 2012, when there was a stoppage in mining effluent discharged into Ruth Pit.
- Rainfall events, and the resulting increases in stage, caused some variation in specific conductivity values at both stations. For example, rainfall that fell over a 9-day period, from July 30, 2012 to August 7, 2012 (142.6 mm), coincided with a drop in specific conductivity at both stations. The decreased concentration of dissolved solids in the water, caused by the dilution effects of rainfall, was likely responsible for this decrease in specific conductivity.

- On average, specific conductivity was 82.2 μS/cm higher at James Creek than at Unnamed Tributary. This difference could be attributed to the past and present deposit of iron ore tailings into Ruth Pit, upstream of James Creek.
- Figure 13 displays specific conductivity recorded during the 2011 and 2012 deployment seasons. Specific conductivity appeared to be more consistent at each station during the 2012 deployment season, compared to the 2011 season.

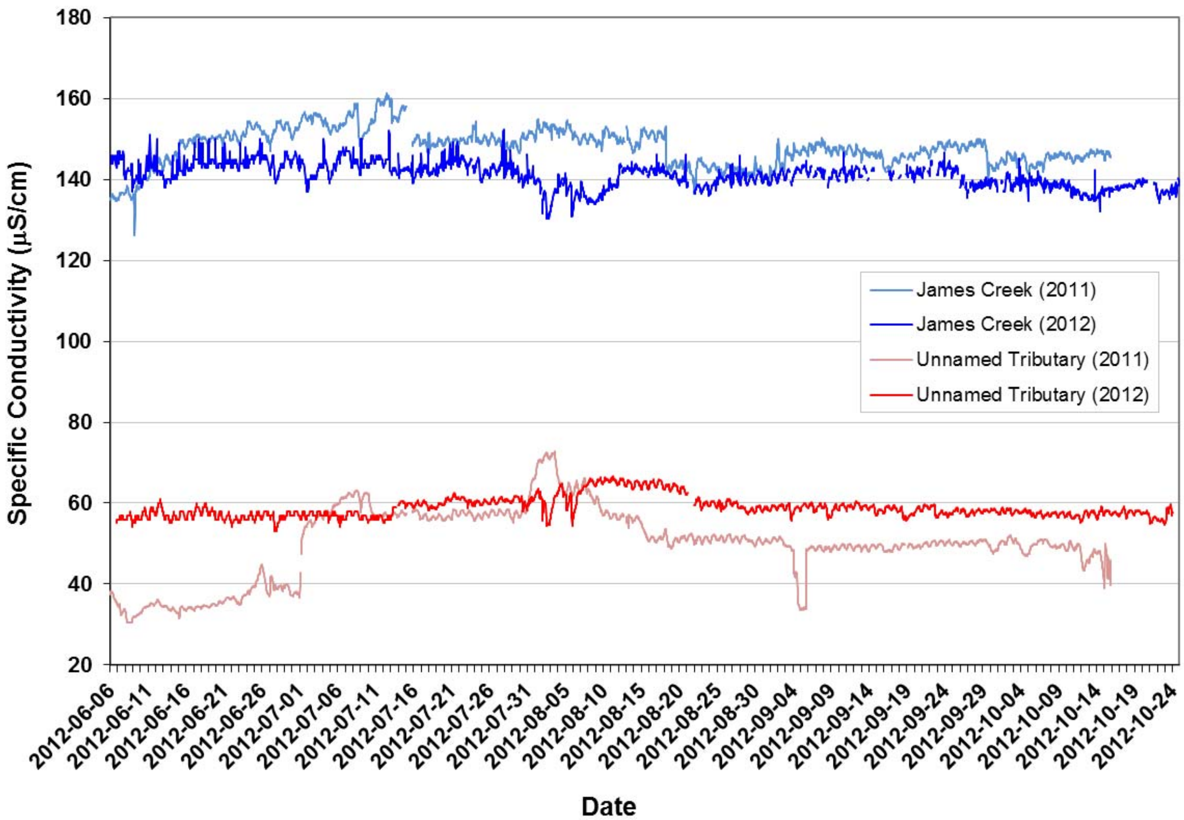

Figure 13. Hourly specific conductivity (μS/cm) values recorded at James Creek and Unnamed Tributary during the 2011 deployment season (June 4, 2011 to October 16, 2011) and 2012 deployment season (June 6, 2012 to October 25, 2012).

Total Dissolved Solids

- Total Dissolved Solids (TDS) values ranged from 0.0834 g/l to 0.0976 g/l at James Creek and from 0.0339 g/l to 0.0426 g/l at Unnamed Tributary from June 6, 2012 to October 25, 2012 (Figure 14).
- TDS is calculated directly from specific conductance and temperature, and as a result TDS values show a similar trend to specific conductance (Figure 12).
- TDS values were on average 0.0526 g/l higher at James Creek compared to Unnamed Tributary. This difference can be attributed to the past and present deposit of iron ore tailings into Ruth Pit, upstream of James Creek.

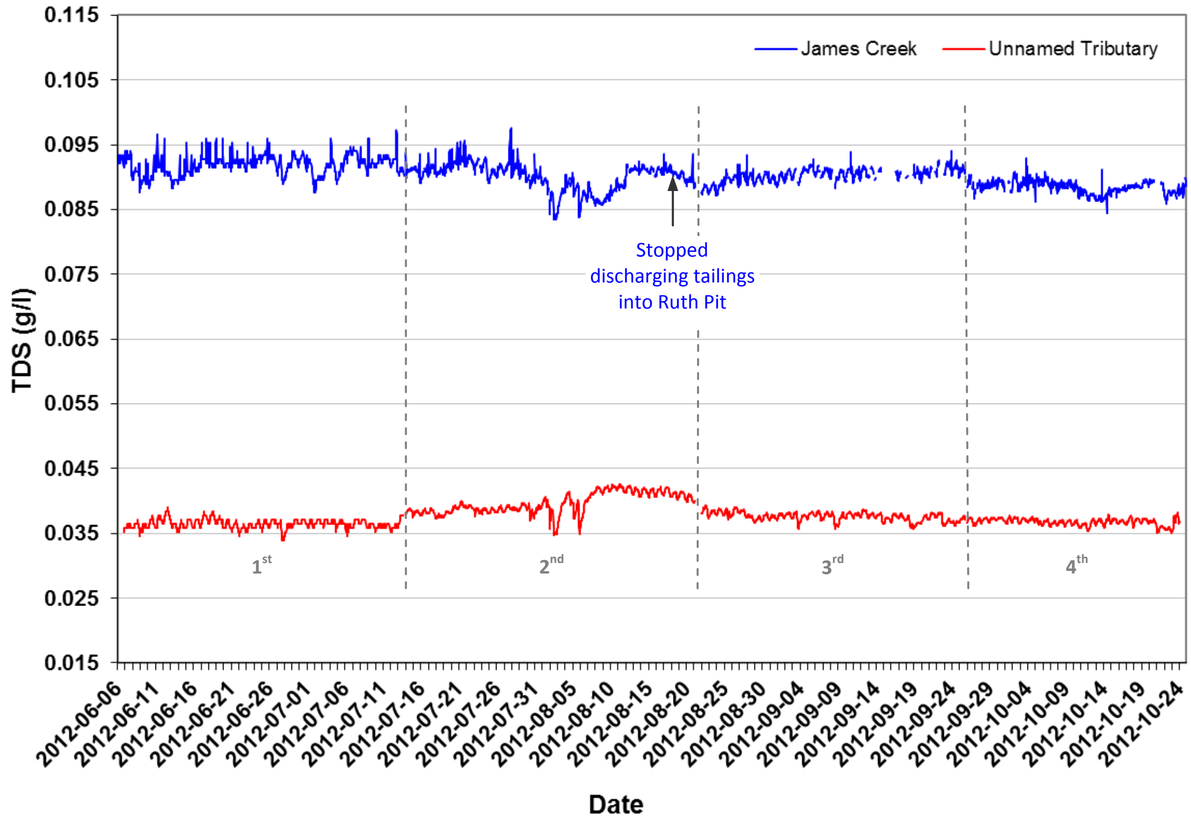

Figure 14. Hourly TDS (g/l) values recorded at James Creek and Unnamed Tributary from June 6, 2012 to October 25, 2012. The four deployment periods are demarcated with dashed lines.

- Figure 15 displays TDS recorded during the 2011 and 2012 deployment seasons. Like specific conductivity, TDS values recorded during the 2012 season appeared to be more consistent at each station when compared to the 2011 season.

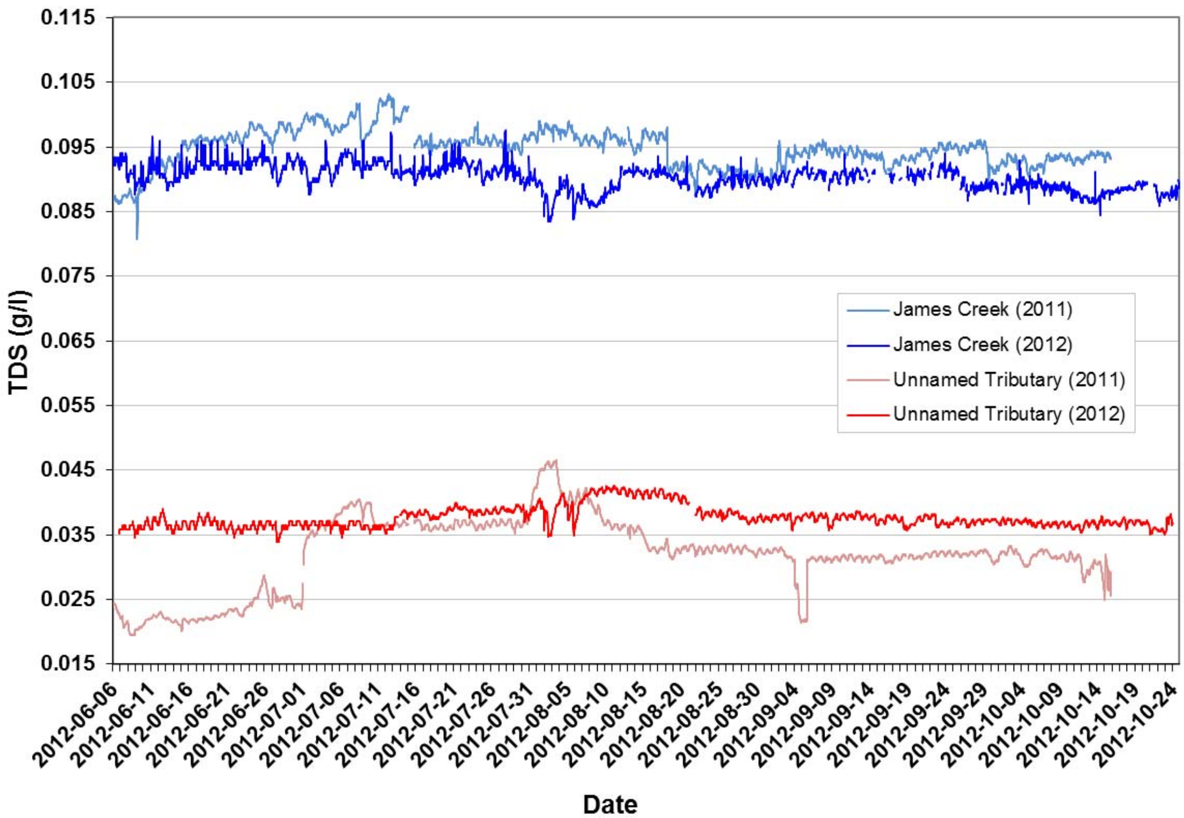

Figure 15. Hourly TDS (g/l) values recorded at James Creek and Unnamed Tributary during the 2011 deployment season (June 4, 2011 to October 16, 2011) and 2012 deployment season (June 6, 2012 to October 25, 2012).

Dissolved Oxygen

- Dissolved Oxygen (DO) values ranged from 9.17 mg/l to 14.51 mg/l at James Creek and from 8.94 mg/l to 14.52 mg/l at Unnamed Tributary from June 6, 2012 to October 25, 2012 (Figure 16).
- DO levels at both stations were, for the majority of time, above cold water minimum guidelines set for aquatic life during early life stages (9.5 mg/l) period, and above minimum guidelines set for other life stages (6.5 mg/l), as determined by the Canadian Council of Ministers of the Environment (2007).
- DO levels fluctuated daily, with increases in DO observed in the afternoon and decreases observed at night. These diurnal variations can be attributed to the photosynthetic activity of aquatic organisms.
- Weekly trends in DO corresponded well with the inverse of water temperature (Figure 8), since colder water has a greater potential to dissolve oxygen compared to warmer water.
- On average, DO values were 0.28 mg/l higher at Unnamed Tributary compared to James Creek. This difference can be attributed to colder water temperatures at Unnamed Tributary than at James Creek (Figure 8).

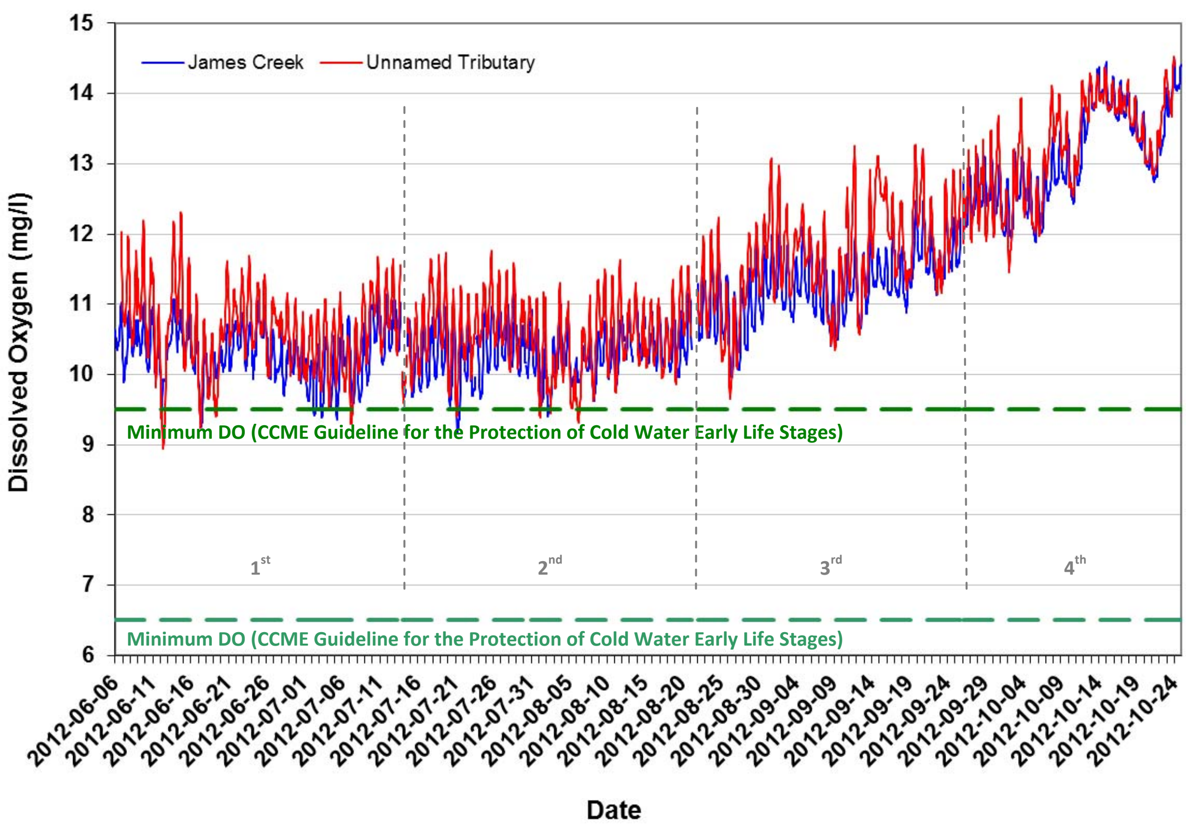

Figure 16. Hourly dissolved oxygen (mg/l) values recorded at James Creek and Unnamed Tributary from June 6, 2012 to October 25, 2012. The four deployment periods are demarcated with dashed lines.

- Bath test results generated in December 2012 detected a problem with the DO sensor on instrument 49200, and instrument 49201. The 49200 instrument was deployed at James Creek during the first and second deployment periods and at the Unnamed Tributary station during the third and fourth deployment periods. The 49201 instrument was deployed at the Unnamed Tributary station during the first and second deployment periods. It is uncertain if or when problems with these sensor affected DO measurements during the 2012 deployment season. Their performance ratings during 2012 were mostly good or excellent, with the exception of instrument 49200, which received a fair rating at the end of the fourth deployment at Unnamed Tributary on October 24, 2012. It should be noted that the quality control instrument used to test performance at the end of the fourth deployment period was the problematic 49201 instrument.
- DO sensors on instruments 49200 and 49201 are scheduled for replacement before the 2013 deployment season.
- Figure 17 displays DO values recorded during the 2011 and 2012 deployment seasons. DO levels were higher at the Unnamed Tributary station in 2011, compared to 2012, due to lower water temperatures in 2011 (Figure 9).

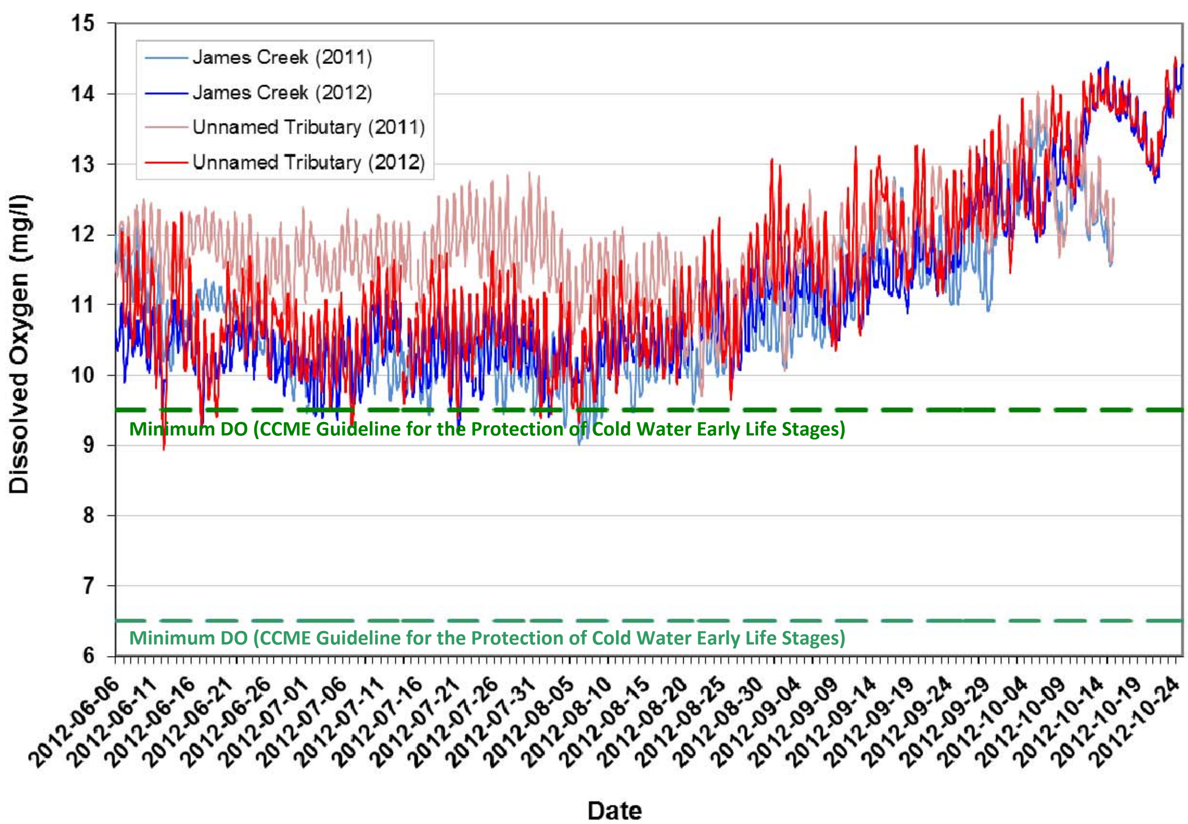

Figure 17. Hourly dissolved oxygen (mg/l) values recorded at James Creek and Unnamed Tributary during the 2011 deployment season (June 4, 2011 to October 16, 2011) and 2012 deployment season (June 6, 2012 to October 25, 2012).

Turbidity

- Turbidity values ranged from 0.0 NTU to 311.9 NTU at James Creek and from 0.0 NTU to 112.3 NTU at Unnamed Tributary from June 6, 2012 to October 25, 2012 (Figure 18).

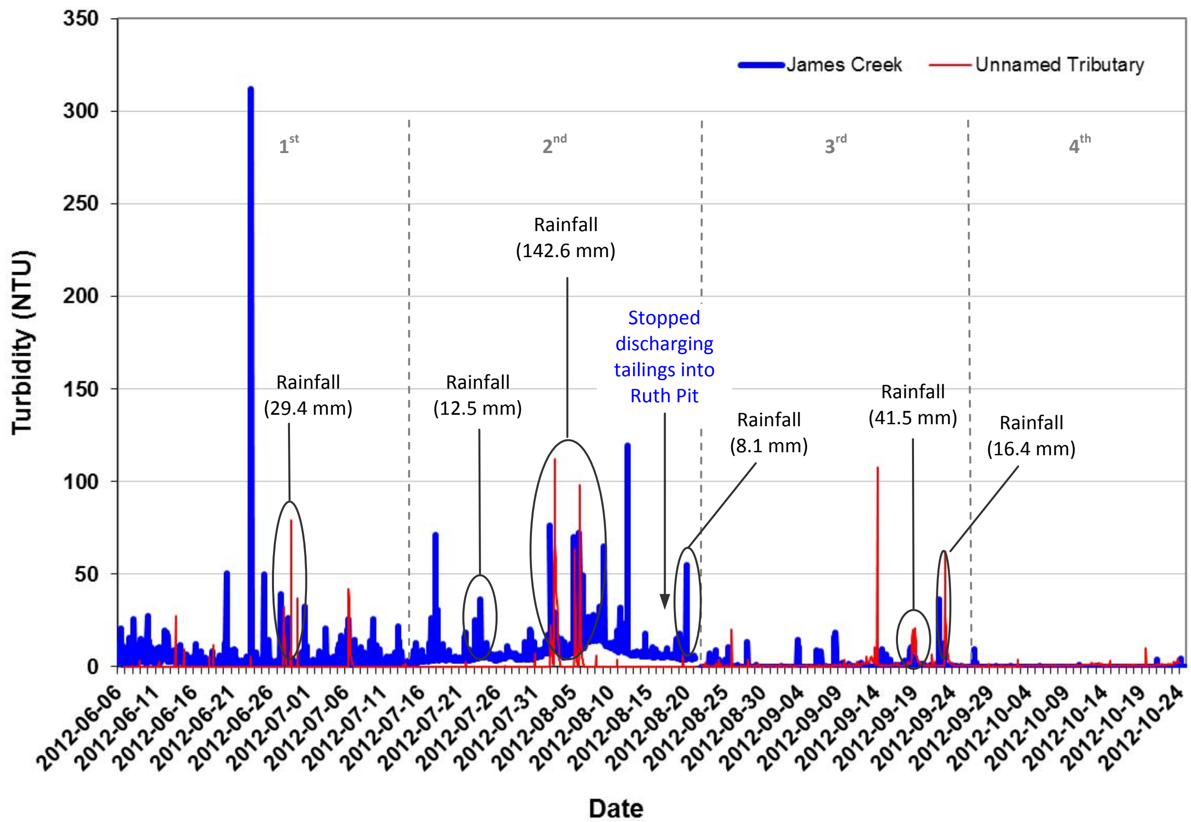

Figure 18. Hourly turbidity (NTU) values recorded at James Creek and Unnamed Tributary from June 6, 2012 to October 25, 2012. The four deployment periods are demarcated with dashed lines.

- There were several turbidity events measured at the James Creek and Unnamed Tributary stations. Most of these events coincided with rainfall activity and increases in stage. This was the case at James Creek, where elevated amounts of turbidity was observed midway through the deployment season corresponded well with increases in stage (Figure 6). Compounding the effects of these events is the presence of historical silt sediment on the stream bottom that easily gets re-suspended, resulting in turbidity spikes. The historical silt sediment in the watercourses originated from past mining activities in the area. Other turbidity events not associated with rainfall and stage were generally short-lived, and as such, were not of any great concern.
- There were fewer turbidity events at James Creek shortly after August 16, 2012, when there was a stoppage in mining effluent discharged into Ruth Pit.

- Bath test results generated in December 2012 detected a problem with the turbidity sensor on instrument 49200, which was deployed at James Creek during the first and second deployment periods and at the Unnamed Tributary during the third and fourth deployment periods. It is uncertain if or when problems with this sensor affected turbidity measurements during the 2012 deployment season. Its performance ratings were mostly good or excellent, with the exception of a fair rating it received at the end of the second deployment at James Creek on August 21, 2012.
- The turbidity sensor on instrument 49200 is scheduled for replacement before the 2013 deployment season.
- Figure 19 displays turbidity values recorded during the 2011 and 2012 deployment seasons. Biofouling caused by algae, leaves, periphyton, and other organic materials produced larger turbidity events in 2011. Instruments at both stations were deployed inside a nylon mesh in 2012, to prevent such biofouling caused turbidity events.

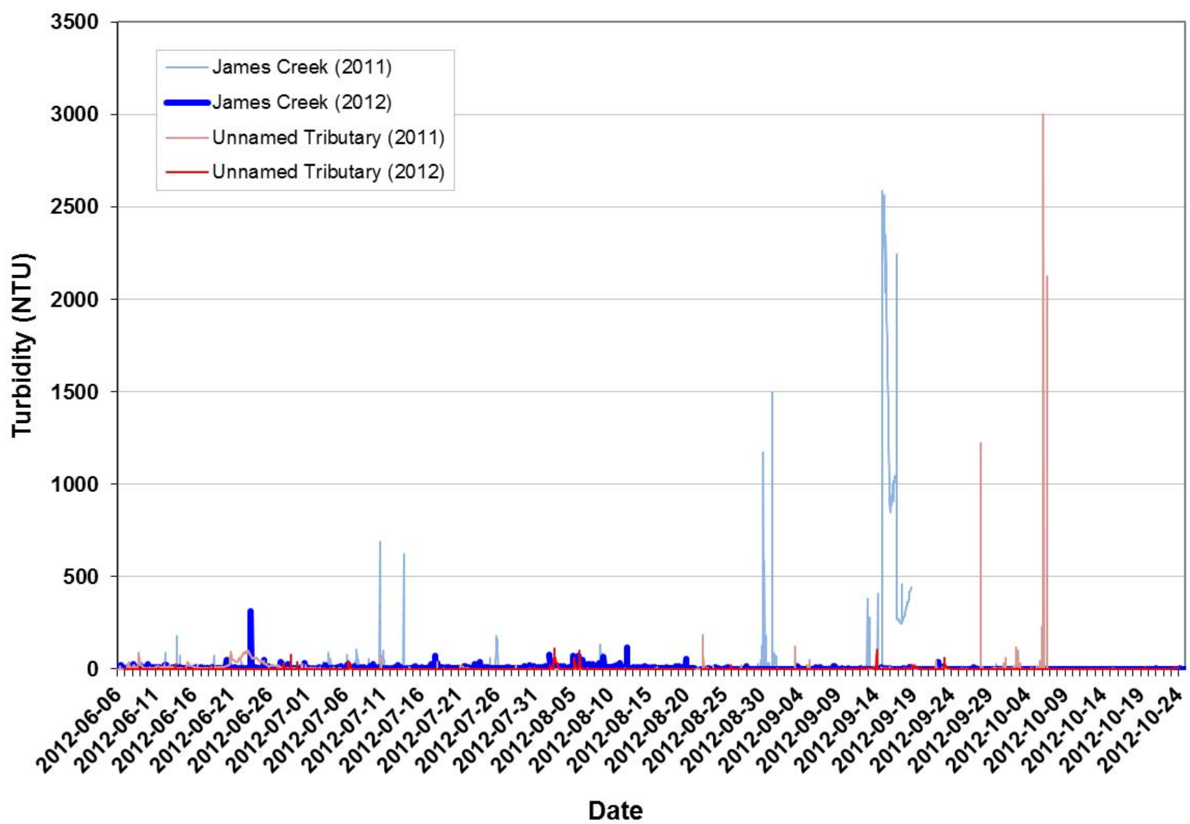

Figure 19. Hourly turbidity (NTU) values recorded at James Creek and Unnamed Tributary during the 2011 deployment season (June 4, 2011 to October 16, 2011) and 2012 deployment season (June 6, 2012 to October 25, 2012).

Conclusions

- Water quality monitoring instruments were deployed at two stations near the James Deposit Iron Ore Mines between June 6, 2012 and October 25, 2012. The stations are located on James Creek and the Unnamed Tributary.
- The performance ratings of all instrument sensors ranged between *fair*-to-*excellent* at the beginning and end of each of the four deployment periods.
- Despite receiving favourable performance ratings, sensor drift was an issue that plagued all pH sensors at some time during the 2012 deployment season. The drift would appear as a decrease in pH of approximately 0.6-1.5 units, starting 10-15 days after instrument deployment. Quality control checks failed to detect pH sensor drift as poor instrument performance, since the problem would rectified itself during performance checks. Indeed, pH levels would return to a normal range within 5-10 minutes after a computer (i.e., archer or laptop) connection was made with the problematic sensor. After consultation with ENVC and Campbell Scientific technical staff on this issue, the reason for pH sensor dependence on a computer connection is still unclear.
- Results from bath tests, conducted from November 29, 2012 to December 12, 2012, showed that two of the three LIM pH sensors were failing and require replacement. pH data recorded by these two failing sensors were omitted from this report.
- Transmission failures occurred sporadically throughout the deployment period at the James Creek station, resulting in the loss of 298 hourly transmission records. It was suspected that the time allotted by the Automated Data Retrieval System (ADRS) for data upload from the station to the satellite was exceeded, causing incomplete data transmissions. EC was informed of this issue. To obtain a complete dataset for this report, water quality data was extracted from the instrument's internal log file. A complete dataset of stage values for the 2012 deployment season should be available upon request through EC after March 2013.
- Damage caused by winter flooding at the Unnamed Tributary station in early 2012, resulted in an electrical short, which stopped data relay from the water quality field instrument to the data logger during the first deployment period (i.e., June 6, 2012 to July 14, 2012). Fortunately, water quality data for this station was obtained from the water quality instrument's internal log file. The wire suspected of being damaged by the flood was replaced and the problem did not reoccur.
- No tailings were discharged into Ruth Pit after August 16, 2012.
- Variations in water quality/quantity values recorded at each station are summarized below:
  - STAGE: Daily variations in stage were primarily attributed to temperature-related atmospheric pressure changes. Some daily variations observed at the end of the deployment season coincided with freezing air temperatures and possible ice formation. Weekly trends in stage were related to rainfall events.
  - WATER TEMPERATURE: Daily and weekly trends in water temperature were attributed to fluctuations in ambient air temperature.

- pH: All pH values were within the acceptable range for the protection of aquatic life. Daily trends in pH were attributed to the photosynthetic cycling of CO_2 by aquatic organisms and weekly trends attributed mostly to sensor drift.
- SPECIFIC CONDUCTIVITY & TDS: Fluctuations in specific conductivity and TDS were influenced by rainfall, changes in stage, and for the James Creek station, past and present iron ore tailings deposited into Ruth Pit.
- DISSOLVED OXYGEN: DO values at both stations were above cold water minimum guidelines set for aquatic life during other life stages (6.5 mg/l), but at times fell below minimum guidelines set for aquatic life during early life stages (9.5 mg/l). Daily and weekly trends in DO were attributed to the photosynthetic activity of aquatic organisms and fluctuations in ambient air temperature, respectively.
- TURBIDITY: Some of the larger peaks in turbidity recorded at both stations coincided with rainfall events and resulting increases in stage, along with the re-suspension of historical silt sediment on the stream bottom.

Path Forward

- The existing Memorandum of Agreement between LIM and ENVC expires in March 2013, thus an extension/amendment letter will be signed by both parties in March 2013 to ensure the real-time water monitoring continues at these stations.
- Field instruments for both stations will undergo repairs during the winter of 2013. The pH sensor will be replaced on instrument 49199 and instrument 49201, the DO sensor will be replaced on instrument 49200 and instrument 49201, and the turbidity sensor will be replaced on instrument 49200.
- ENVC staff will redeploy RTWQ instruments at James Creek and the Unnamed Tributary in spring 2013, when ice conditions allow, and perform regular site visits throughout the 2013 deployment season, for calibration and maintenance of the instruments.
- A new real-time water quality and water quantity station will be installed in spring/summer of 2013, to monitor surface water outflow in the area of the proposed Houston deposit.
- If necessary, deployment techniques will be evaluated and adapted to each site, ensuring secure and suitable conditions for RTWQ monitoring.
- ENVC staff will update LIM staff on any changes to processes and procedures with handling, maintaining and calibrating the real-time instruments.
- EC staff will perform regular site visits to ensure water quantity instrumentation is correctly calibrated and providing accurate measurements.
- LIM will continue to be informed of data trends and any significant water quality events in the form of email and/or monthly deployment reports, when the deployment season begins. LIM will also receive an annual report, summarizing the events of the deployment season.
- Parameter alerts will be set prior to the 2013 deployment season to notify ENVC staff by email of any emerging water quality issues.
- ENVC has begun development of models using water quality monitoring data and grab sample data to estimate a variety of additional water quality parameters (e.g., TSS and major ions). This work will continue with a goal in implementing these models for RTWQ data collected.
- ENVC will continue to work on its Automatic Data Retrieval System, to incorporate new capabilities in data management and data display.
- ENVC will be active in creating new value added products using the RTWQ data and water quality indices.
- Open communication will continue to be maintained between ENVC, EC and LIM employees involved with the agreement, in order to respond to emerging issues on a proactive basis.

References

Allan, D. (2010). Advanced Water Quality Instrumentation Training Manual. Edmonton, AB: Allan Environmental Services Inc. (pp. 160).

Canadian Council of Ministers of the Environment. 2007. Canadian water quality guidelines for the protection of aquatic life: Summary table. Updated December, 2007. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg. (Website: http://ceqg-rcqe.ccme.ca/download/en/222/)

Hach (2006) Important water quality factors - H2O University. Hach Company. Online: http://www.h2ou.com/index.htm (accessed August 24, 2010).

Swanson, H.A., and Baldwin, H.L., 1965. A Primer on Water Quality, U.S. Geological Survey. Online: http://ga.water.usgs.gov/edu/characteristics.html (accessed August 24, 2010)

APPENDIX A
Quality Assurance / Quality Control Procedures

- As part of the Quality Assurance / Quality Control (QA/QC) protocol, the performance of a station's water quality instrument (i.e., Field Sonde) is rated at the start and end of its deployment period. The procedure is based on the approach used by the United States Geological Survey (Wagner *et al.* 2006)[1].
- At the start of the deployment period, a fully cleaned and calibrated QA/QC water quality instrument (i.e., QA/QC Sonde) is placed *in-situ* with the fully cleaned and calibrated Field Sonde. After Sonde readings have stabilized, which may take up to five minutes in some cases, water quality parameters, as measured by both Sondes, are recorded to a field sheet. Field Sonde performance for all parameters is rated based on differences recorded by the Field Sonde and QA/QC Sonde. If the readings from both Sondes are in close agreement, the QA/QC Sonde can be removed from the water. If the readings are not in close agreement, there will be attempts to reconcile the problem on site (e.g., removing air bubbles from sensors, etc.). If no fix is made, the Field Sonde may be removed for recalibration.
- At the end of the deployment period, a fully cleaned and calibrated QA/QC Sonde is once again deployed *in-situ* with the Field Sonde, which has already been deployment for 30-40 days. After Sonde readings have stabilized, water quality parameters, as measured by both Sondes, are recorded to a field sheet. Field Sonde performance for all parameters is rated based on differences recorded by the Field Sonde and QA/QC Sonde.
- Performance ratings are based on differences listed in the table below.

	Rating				
Parameter	**Excellent**	**Good**	**Fair**	**Marginal**	**Poor**
Temperature (^{o}C)	≤ ±0.2	> ±0.2 to 0.5	> ±0.5 to 0.8	> ±0.8 to 1	> ±1
pH (unit)	≤ ±0.2	> ±0.2 to 0.5	> ±0.5 to 0.8	> ±0.8 to 1	> ±1
Sp. Conductance ≤ 35 (µS/cm)	≤ ±3	> ±3 to 10	> ±10 to 15	> ±15 to 20	> ±20
Sp. Conductance > 35 (µS/cm)	≤ ±3	> ±3 to 10	> ±10 to 15	> ±15 to 20	> ±20
Dissolved Oxygen (mg/l)	≤ ±0.3	> ±0.3 to 0.5	> ±0.5 to 0.8	> ±0.8 to 1	> ±1
Turbidity ≤ 40 NTU (NTU)	≤ ±2	> ±2 to 5	> ±5 to 8	> ±8 to 10	> ±10
Turbidity > 40 NTU (NTU)	≤ ±5	> ±5 to 10	> ±10 to 15	> ±15 to 20	> ±20

[1] Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments; accessed April 10, 2006, at *http://pubs.water.usgs.gov/tm1d3*

APPENDIX B
Water Parameter Description

Dissolved Oxygen - The amount of Dissolved Oxygen (DO) (mg/l) in the water is vital to aquatic organisms for their survival. The concentration of DO is affected by such things as water temperature, water depth and flow (e.g., aeration by rapids, riffles etc.), consumption by aerobic organisms, consumption by inorganic chemical reactions, consumption by plants during darkness, and production by plants during the daylight (Allan 2010).

pH - pH is the measure of hydrogen ion activity and affects: (i) the availability of nutrients to aquatic life; (ii) the concentration of biochemical substances dissolved in water; (iii) the efficiency of hemoglobin in the blood of vertebrates; and (iv) the toxicity of pollutants. Changes in pH can be attributed to industrial effluence, saline inflows or aquatic organisms involved in the photosynthetic cycling of CO_2 (Allan 2010).

Specific conductivity - Specific conductivity (μS/cm) is a measure of water's ability to conduct electricity, with values normalized to a water temperature of 25ºC. Specific conductance indicates the concentration of dissolved solids (such as salts) in the water, which can affect the growth and reproduction of aquatic life. Specific conductivity is affected by rainfall events, the composition of inflowing tributaries and their associated geology, saline inflow (e.g., road salt), agricultural run-off and industrial inputs (Allan 2010; Swanson and Baldwin 1965).

Stage – Stage (m) is the elevation of the water surface and is often used as a surrogate for the more difficult to measure flow.

Temperature - Essential to the measurement of most water quality parameters, temperature (^{o}C) controls most processes and dynamics of limnology. Water temperature is influenced by such things as ambient air temperature, solar radiation, meteorological events, industrial effluence, wastewater, inflowing tributaries, as well as water body size and depth (Allan 2010; Hach 2006).

Total Dissolved Solids - Total Dissolved Solids (TDS) (g/l) is a measure of alkaline salts dissolved in water or in fine suspension and can affect the growth and reproduction of aquatic life. It is affected by rainfall events, the composition of inflowing tributaries and their associated geology, saline inflow (e.g., road salt), agricultural run-off and industrial inputs (Allan 2010; Swanson and Baldwin 1965).

Turbidity - Turbidity (NTU) is a measure of the translucence of water and indicates the amount of suspended material in the water. Turbidity is caused by any substance that makes water cloudy (e.g., soil erosion, micro-organisms, vegetation, chemicals, etc.) and can correspond to precipitation events, high stage, and floating debris near the sensor (Allan 2010; Hach 2006; Swanson and Baldwin 1965).

APPENDIX C
Environment Canada Weather Data - Schefferville (June 5, 2012 to October 25, 2012)

Date yyyy-mm-dd	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days °C	Cool Deg Days °C	Total Precip mm	Avg Wind Spd Km/hr	Avg Wind Dir deg
2012-06-05	17.5	2.1	9.8	8.2	0	0	11.3	87.6
2012-06-06	18.7	0.5	9.6	8.4	0	0	9.0	100.5
2012-06-07	21.5	2.5	12	6	0	0	7.1	85.5
2012-06-08	22.1	8	15.1	2.9	0	0	12.4	155.5
2012-06-09	19.6	5.9	12.8	5.2	0	16.7	12.0	219.5
2012-06-10	18	3.5	10.8	7.2	0	0	9.5	201.4
2012-06-11	23.2	13.2	18.2	0	0.2	0	21.4	199.1
2012-06-12	30.1	15.6	22.9	0	4.9	0.8	24.4	221.3
2012-06-13	20.2	2	11.1	6.9	0	17.6	17.2	254.2
2012-06-14	12.3	1.2	6.8	11.2	0	0	10.3	249.0
2012-06-15	19	3.1	11.1	6.9	0	0	12.8	147.5
2012-06-16	22.2	7.3	14.8	3.2	0	0	18.4	187.5
2012-06-17	27.6	14.6	21.1	0	3.1	0	18.3	232.9
2012-06-18	25.8	17.9	21.9	0	3.9	0	20.0	219.2
2012-06-19	26.5	15.6	21.1	0	3.1	1.9	20.7	193.8
2012-06-20	16.1	6.5	11.3	6.7	0	1.3	20.0	318.3
2012-06-21	16.4	5.7	11.1	6.9	0	0	10.3	219.1
2012-06-22	16	9.7	12.9	5.1	0	8	15.0	206.3
2012-06-23	17.4	6	11.7	6.3	0	0	7.9	214.5
2012-06-24	18.5	4.8	11.7	6.3	0	1	6.8	143.0
2012-06-25	16	10.9	13.5	4.5	0	1.6	14.2	153.8
2012-06-26	21.4	10.9	16.2	1.8	0	0	9.1	167.4
2012-06-27	16.9	12.4	14.7	3.3	0	4.6	10.2	154.3
2012-06-28	16.5	11.2	13.9	4.1	0	24.8	6.5	68.2
2012-06-29	21.6	11.4	16.5	1.5	0	0	10.2	149.5
2012-06-30	20.8	13.5	17.2	0.8	0	0.3	10.0	154.5
2012-07-01	20.7	14.1	17.4	0.6	0	8.1	6.5	178.4
2012-07-02	18.1	12.8	15.5	2.5	0	7.3	8.6	291.7
2012-07-03	20	11.9	16	2	0	0	9.5	278.1
2012-07-04	22.4	13.5	18	0	0	6	10.0	175.5
2012-07-05	20.1	12.9	16.5	1.5	0	10.6	5.8	150.9
2012-07-06	-	-	-	-	-	-	15.4	171.3
2012-07-07	20	11.4	15.7	2.3	0	2.6	17.5	242.6
2012-07-08	16.1	6.3	11.2	6.8	0	0.8	18.8	300.8
2012-07-09	13	6.1	9.6	8.4	0	4.3	20.0	307.1

Date yyyy-mm-dd	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days °C	Cool Deg Days °C	Total Precip mm	Avg Wind Spd Km/hr	Avg Wind Dir deg
2012-07-10	13	6.1	9.6	8.4	0	0	20.6	315.4
2012-07-11	17.4	7.6	12.5	5.5	0	3.6	10.7	248.3
2012-07-12	14.2	7.4	10.8	7.2	0	5.1	11.5	247.3
2012-07-13	18.9	6.8	12.9	5.1	0	0	6.8	228.1
2012-07-14	23.9	10.9	17.4	0.6	0	-	8.5	186.5
2012-07-15	21.6	10.3	16	2	0	-	17.1	237.1
2012-07-16	16.3	7.8	12.1	5.9	0	1.3	13.8	278.3
2012-07-14	23.9	10.9	17.4	0.6	0	-	8.5	186.5
2012-07-15	21.6	10.3	16	2	0	-	17.1	237.1
2012-07-16	16.3	7.8	12.1	5.9	0	1.3	13.8	278.3
2012-07-17	15.8	7.3	11.6	6.4	0	0.5	11.4	219.1
2012-07-18	13.3 (E)	5.7 (E)	9.5 (E)	8.5 (E)	0 (E)	-	10.5	263.8
2012-07-19	16.2	6.8	11.5	6.5	0	0.8	13.5	109.2
2012-07-20	20.1	5.6	12.9	5.1	0	-	13.3	269.6
2012-07-21	24.6	8.5	16.6	1.4	0	0	7.4	167.8
2012-07-22	23.1	10.5	16.8	1.2	0	-	13.2	189.2
2012-07-23	18.6	11.4	15	3	0	1.3	13.5	217.1
2012-07-24	16.5	9.2	12.9	5.1	0	10.4	12.7	234.1
2012-07-25	12.6	5.7	9.2	8.8	0	0.8	17.2	253.8
2012-07-26	13.1	5.9	9.5	8.5	0	0	15.9	240.0
2012-07-27	15.5	8.6	12.1	5.9	0	0.8	16.0	294.2
2012-07-28	19.7	9.5	14.6	3.4	0	0	8.9	233.0
2012-07-29	20.5	9.8	15.2	2.8	0	0	17.8	220.4
2012-07-30	18	13.3	15.7	2.3	0	13.1	14.3	225.8
2012-07-31	17.4	13.8	15.6	2.4	0	11.8	10.5	184.8
2012-08-01	23.2	12.8	18	0	0	0.8	9.6	211.3
2012-08-02	19.5	12.6	16.1	1.9	0	15.6	8.7	232.2
2012-08-03	13.1	6.2	9.7	8.3	0	39.5	14.9	301.3
2012-08-04	15.9	7.2	11.6	6.4	0	0	14.9	240.0
2012-08-05	19.2	9.6	14.4	3.6	0	32.9	15.3	191.5
2012-08-06	16.4	10	13.2	4.8	0	23.6	9.5	292.9
2012-08-07	16.6	10.1	13.4	4.6	0	5.3	7.3	205.3
2012-08-08	19.3	8.6	14	4	0	0	9.6	293.5
2012-08-09	13.1	8.5	10.8	7.2	0	0	11.0	325.8
2012-08-10	19.7	8.9	14.3	3.7	0	0	10.4	264.1
2012-08-11	21.6 (E)	8.9 (E)	15.3 (E)	2.7 (E)	0 (E)	0	7.3	172.7
2012-08-12	22.3	6.5	14.4	3.6	0	0.3	11.4	155.5
2012-08-13	16.5	12.9	14.7	3.3	0	1.8	10.0	130.8
2012-08-14	17.2	13.8	15.5	2.5	0	1.6	12.0	125.0

Date yyyy-mm-dd	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days °C	Cool Deg Days °C	Total Precip mm	Avg Wind Spd Km/hr	Avg Wind Dir deg
2012-08-15	21.2	13.5	17.4	0.6	0	6.1	12.0	154.2
2012-08-16	20.2	13.9	17.1	0.9	0	2.6	11.0	153.3
2012-08-17	20.5	14.8	17.7	0.3	0	0	13.4	147.9
2012-08-18	16.8	11.6	14.2	3.8	0	3.1	15.7	162.5
2012-08-19	18	10.1	14.1	3.9	0	0.3	10.2	198.3
2012-08-20	17.2	8.4	12.8	5.2	0	8.1	11.2	160.8
2012-08-21	13.8	9.1	11.5	6.5	0	0.3	-	-
2012-08-22	15.4	8.6	12	6	0	1.5	-	-
2012-08-23	14.6	8.2	11.4	6.6	0	6.6	-	-
2012-08-24	16.4	9.4	12.9	5.1	0	0.3	-	-
2012-08-25	21.7	9.7	15.7	2.3	0	0.8	-	-
2012-08-26	21.8	14.5	18.2	0	0.2	5.3	-	-
2012-08-27	21.1	9.7	15.4	2.6	0	0.5	24.1	259.0
2012-08-28	-	8.6 (E)	-	-	-	-	17.4	271.9
2012-08-29	10.5	6	8.3	9.7	0	8.9	18.9	304.6
2012-08-30	11.2	6.6	8.9	9.1	0	0	13.8	271.7
2012-08-31	10.5	1.5	6	12	0	3.1	10.5	104.1
2012-09-01	15.4	1.2	8.3	9.7	0	0	12.2	296.1
2012-09-02	13.9	1.4	7.7	10.3	0	0	10.8	261.3
2012-09-03	16.8	8.1	12.5	5.5	0	0	18.3	257.8
2012-09-04	9.9	8.1	9	9	0	12.5	9.4	112.6
2012-09-05	12.1	7.3	9.7	8.3	0	0	14.2	145.8
2012-09-06	17.8	10.4	14.1	3.9	0	0	11.9	165.4
2012-09-07	16.2	9.4	12.8	5.2	0	8.1	12.5	177.5
2012-09-08	18	8.6	13.3	4.7	0	5.8	11.5	165.7
2012-09-09	16.5	9.5	13	5	0	20.6	27.3	210.8
2012-09-10	10.5	5.3	7.9	10.1	0	0.3	22.5	276.3
2012-09-11	12	-0.7	5.7	12.3	0	0	15.8	289.6
2012-09-12	20.8	-1	9.9	8.1	0	1.5	21.4	176.3
2012-09-13	14.3	3.2	8.8	9.2	0	0.3	30.3	263.8
2012-09-14	8.5	1.5	5	13	0	0.3	10.5	213.8
2012-09-15	3.8	1.3	2.6	15.4	0	9.8	10.9	91.3
2012-09-16	8.5	3.4	6	12	0	5.6	9.9	131.7
2012-09-17	14.4	5	9.7	8.3	0	1.6	13.2	301.7
2012-09-18	14.2	6.3	10.3	7.7	0	11	9.4	183.3
2012-09-19	14.1	1.7	7.9	10.1	0	13.5	31.3	196.7
2012-09-20	9.8	1.2	5.5	12.5	0	0	22.7	233.8
2012-09-21	15.5	3.6	9.6	8.4	0	0.5	18.7	174.2
2012-09-22	13.2	7.1	10.2	7.8	0	2.8	10.2	156.1

Date yyyy-mm-dd	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days °C	Cool Deg Days °C	Total Precip mm	Avg Wind Spd Km/hr	Avg Wind Dir deg
2012-09-23	13.5	4.2	8.9	9.1	0	13.6	18.1	191.0
2012-09-24	8.4	3.7	6.1	11.9	0	0	26.4	204.2
2012-09-25	8.2	3.1	5.7	12.3	0	0.3	20.1	189.2
2012-09-26	6.4	2.2	4.3	13.7	0	0	13.5	224.8
2012-09-27	6.8	1.8	4.3	13.7	0	5.1	14.5	323.3
2012-09-28	8.2	0.6	4.4	13.6	0	0.3	10.5	269.2
2012-09-29	11.5	1.7	6.6	11.4	0	0	9.8	189.1
2012-09-30	14.1	0.3	7.2	10.8	0	0	12.5	221.7
2012-10-01	10.8	-1.9	4.5	13.5	0	7.6	4.9	75.2
2012-10-02	13	5.7	9.4	8.6	0	1.6	9.5	197.0
2012-10-03	7.2	-1.1	3.1	14.9	0	0	14.0	282.2
2012-10-04	11.5	-1.1	5.2	12.8	0	0	11.3	159.6
2012-10-05	9.1	3.4	6.3	11.7	0	3.5	10.7	128.3
2012-10-06	8.7	3	5.9	12.1	0	3.6	16.3	200.4
2012-10-07	4.4	-0.5	2	16	0	0.3	25.0	255.8
2012-10-08	2.7	-0.9	0.9	17.1	0	0	14.8	220.0
2012-10-09	3.6	0.2	1.9	16.1	0	0.8	18.8	217.9
2012-10-10	8.8	2.3	5.6	12.4	0	0	22.6	171.3
2012-10-11	5.4	-1.1	2.2	15.8	0	5.8	23.2	261.3
2012-10-12	0.2	-4	-1.9	19.9	0	0	34.7	298.8
2012-10-13	-0.2	-5.2	-2.7	20.7	0	0	36.2	301.7
2012-10-14	-1.1	-7.6	-4.4	22.4	0	0	23.4	307.8
2012-10-15	-1.9	-9.5	-5.7	23.7	0	0	8.6	290.0
2012-10-16	-3	-5.3	-4.2	22.2	0	1.1	15.4	65.0
2012-10-17	0.7	-6.1	-2.7	20.7	0	0.8	17.2	307.9
2012-10-18	3.1 (E)	-10 (E)	-3.5 (E)	21.5 (E)	0 (E)	0	7.5	151.3
2012-10-19	4.2	-0.1	2.1	15.9	0	0	9.0	137.7
2012-10-20	5.9	0.9	3.4	14.6	0	0	13.0	152.1
2012-10-21	4.2	0.9	2.6	15.4	0	9.6	9.6	142.3
2012-10-22	1.7	-2.9	-0.6	18.6	0	0.8	19.8	334.2
2012-10-23	-1.9	-5.8	-3.9	21.9	0	0	29.5	322.5
2012-10-24	-5	-8.6	-6.8	24.8	0	0	24.8	313.8
2012-10-25	-0.8	-9.6	-5.2	23.2	0	0	9.4	212.9

- = No data available
M = Missing
E = Estimated
A = Accumulated
C = Precipitation occurred, amount uncertain
L = Precipitation may or may not have occurred
F = Accumulated and estimated
N = Temperature missing but known to be > 0
Y = Temperature missing but known to be < 0
S = More than one occurrence
T = Trace
* = The value displayed is based on incomplete data
† = Data for this day has undergone only preliminary quality checking

APPENDIX C (continued...)
Environment Canada Weather Data - Schefferville (June 5, 2012 to October 25, 2012)

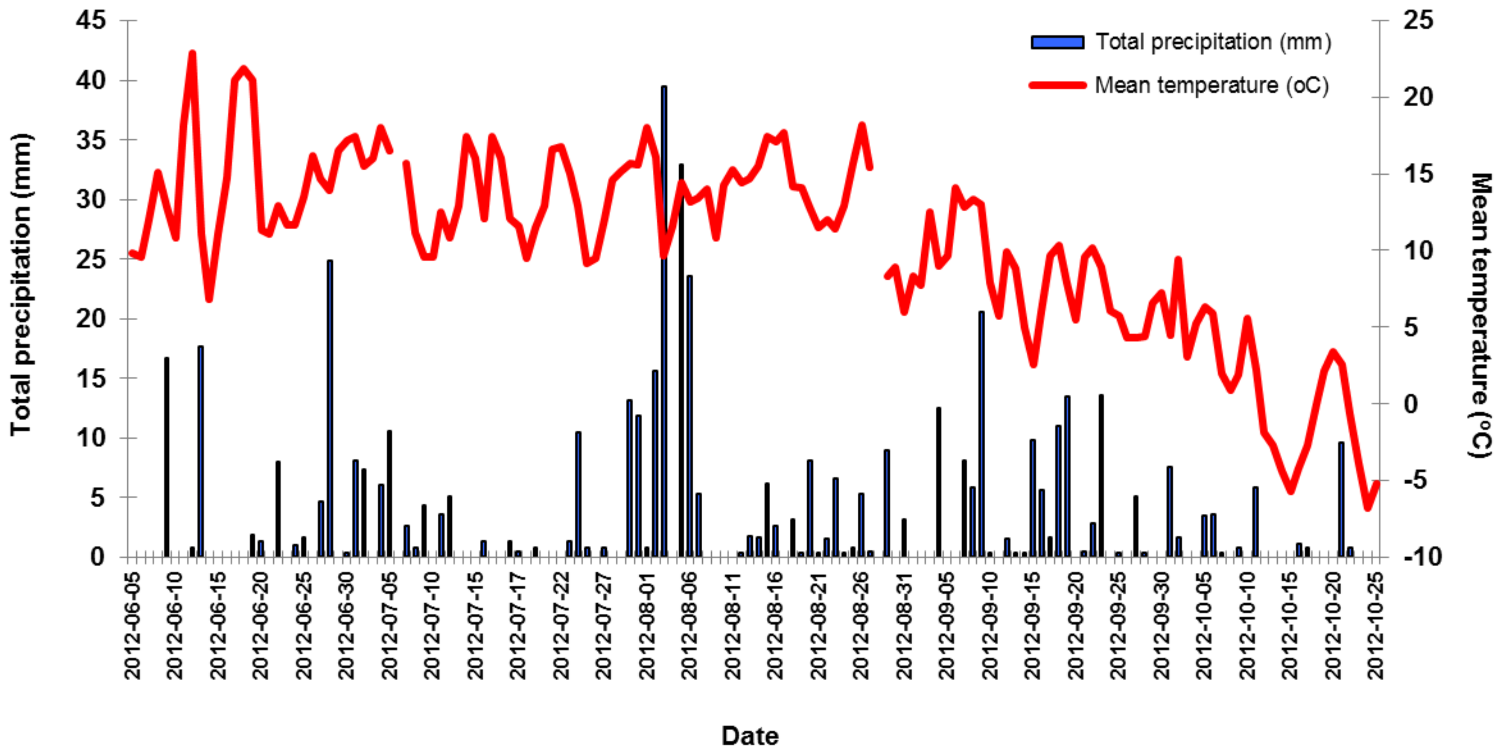

Figure 1. Daily precipitation and mean temperature recorded at the Schefferville Weather Station by Environment Canada from June 5, 2012 to October 25, 2012.

APPENDIX C (continued...)
Environment Canada Weather Data – Schefferville (June 5, 2012 to October 25, 2012)

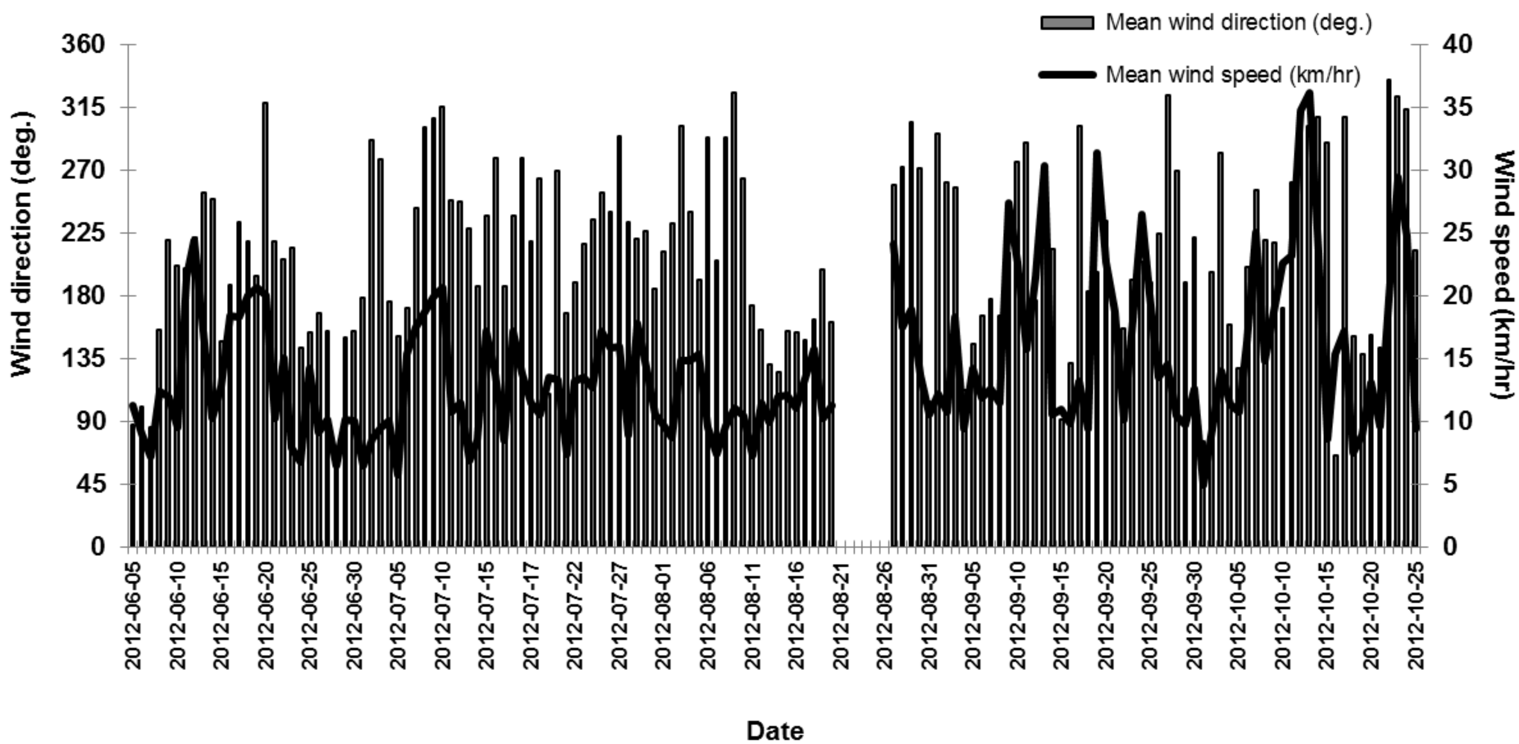

Figure 2. Mean daily wind direction and wind speed recorded at the Schefferville Weather Station by Environment Canada from June 5, 2012 to October 25, 2012.