Real Time Water Quality Report

Labrador Iron Mines
Schefferville Network

Annual Deployment Report 2011

2011-06-04 to 2011-10-16

Government of Newfoundland & Labrador
Department of Environment and Conservation
Water Resources Management Division
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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), Bob Picco (ENVC), Linda Wrong (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, safety, and field assistance. LIM also provided equipment storage, information on LIM mining operations, station checks when water quality events arise, as well as cleaned instruments when biofouling was suspected of impacting data quality. LIM employees involved in carrying out these activities included Corey McLister, Leah Butler, Shawn Duquet, Derek Parks[1], and Rich Schmidt[2].

EC plays an essential role in the data logging/communication aspect of the network. In particular, EC staff of the Meteorological Service of Canada Division, 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, during the winter of 2011-2012, will be conducted by Tara Clinton.

[1] Parks Environmental Inc. (consultant)
[2] WESA group (consultant)

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).

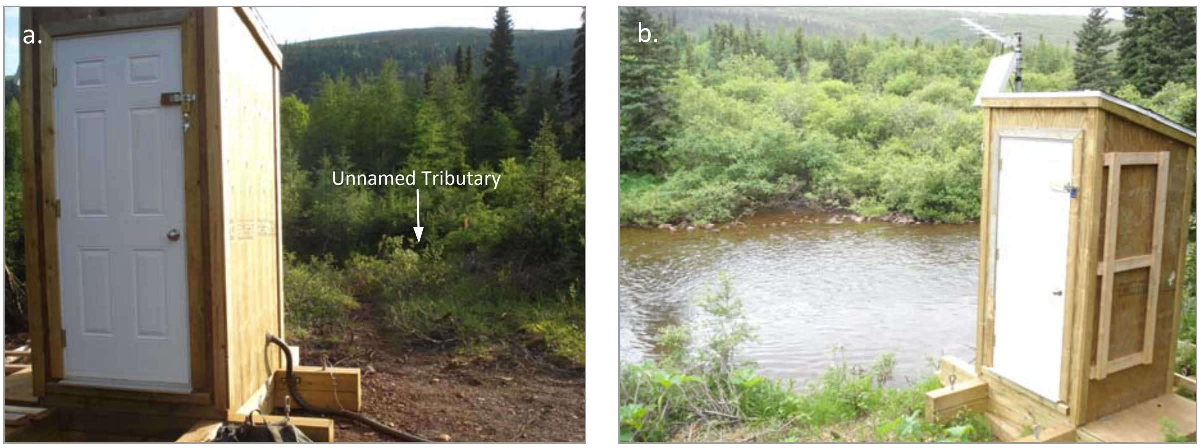

Figure 1. RTWQ stations are located alongside (a) the Unnamed Tributary and (b) James Creek.

- The Unnamed Tributary station monitors water outflow from a series of multi-cell retention and settling ponds, while the James Creek station monitors water outflow from the same multi-cell retention and settling pond system, as well as monitors outflow from Ruth Pit (Figure 2).
- 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. 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.

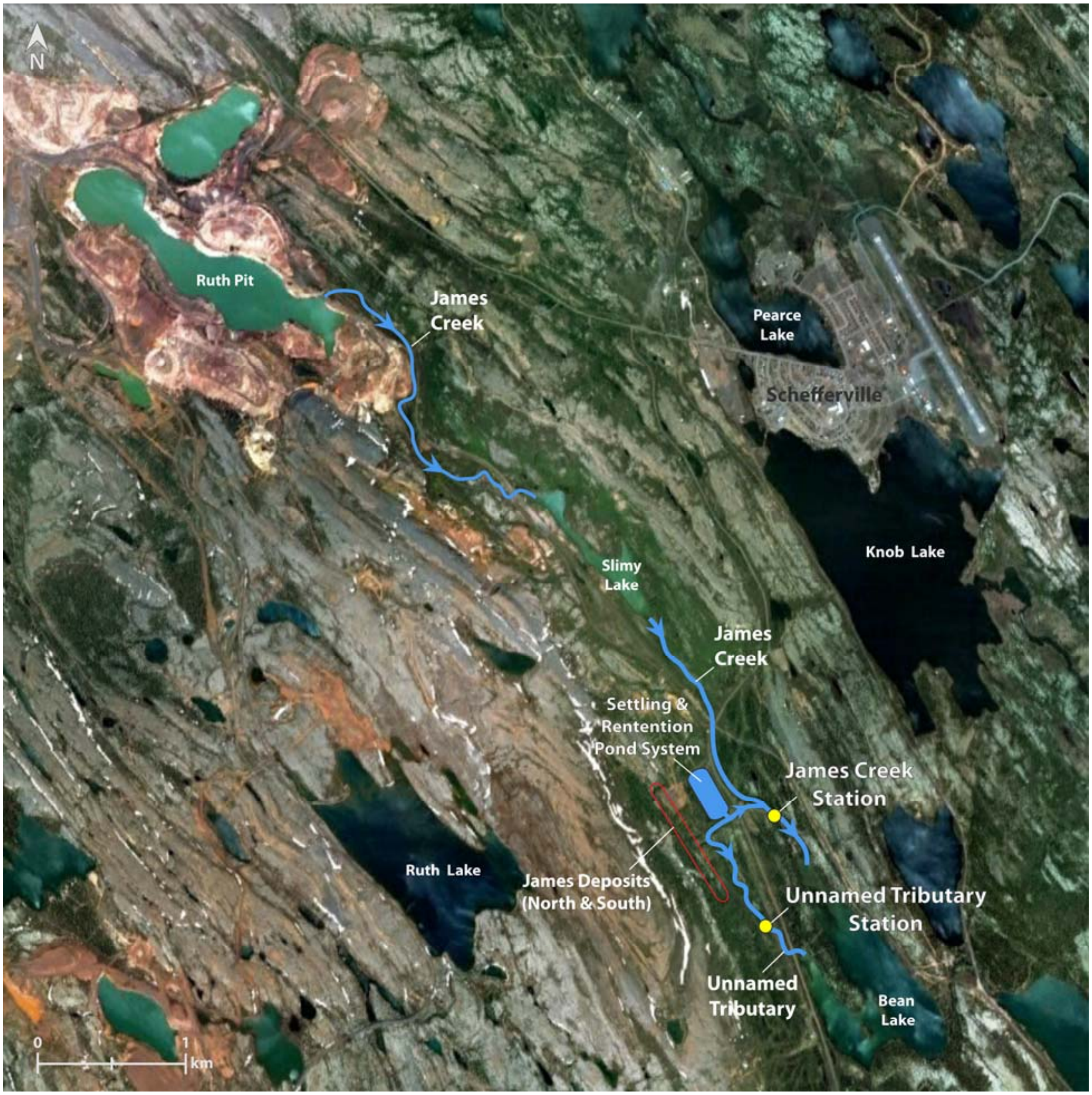

Image © 2012 DigitalGlobe & © 2012 Google

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 and by monthly and annual deployment reports.
- This annual deployment report, presents water quality and water quantity data recorded at the James Creek and Unnamed Tributary stations from June 4, 2011 to October 16, 2011.

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 30-40 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 2011 at James Creek and the Unnamed Tributary.

Station	Start date	End date	Duration (days)	Instrument
James Creek	2011-06-04	2011-07-15	42	49199
	2011-07-16	2011-08-13	30	49199
	2011-08-13	2011-09-19	38	49199
	2011-09-19	2011-10-16	28	49199
Unnamed Tributary	2011-06-04	2011-07-15	42	49200
	2011-07-16	2011-08-13	30	49200
	2011-08-13	2011-09-19	38	49200
	2011-09-19	2011-10-16	28	49200

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

- 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 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 (ºC)	pH	Specific conductivity (µS/cm)	Dissolved oxygen (mg/L)	Turbidity (NTU)
James Creek	Start	2011-06-04	49199	Good	Good	Excellent	Fair	Excellent
	End	2011-07-15	49199	Excellent	Good	Good	Excellent	Good
	Start	2011-07-16	49199	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2011-08-13	49199	Excellent	Good	Excellent	Excellent	Good
	Start	2011-08-13	49199	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2011-09-19	49199	Excellent	Good	Excellent	Excellent	Poor
	Start	2011-09-19	49199	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2011-10-16	49199	Excellent	Excellent	Excellent	Good	Excellent
Unnamed Tributary	Start	2011-06-04	49200	Good	Excellent	Excellent	Good	Excellent
	End	2011-07-15	49200	Excellent	Excellent	Excellent	Excellent	Poor
	Start	2011-07-16	49200	Excellent	Good	Excellent	Excellent	Excellent
	End	2011-08-13	49200	Excellent	Good	Excellent	Excellent	Excellent
	Start	2011-08-13	49200	Excellent	Excellent	Excellent	Excellent	Fair
	End	2011-09-19	49200	Excellent	Excellent	Excellent	Good	Excellent
	Start	2011-09-19	49200	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2011-10-16	49200	Excellent	Excellent	Fair	Good	Excellent

- Instrument sensor performance was rated *poor* on two occasions (Table 2).
- The first *poor* performance rating occurred with the turbidity sensor at the Unnamed Tributary on July 15, 2011, at the end of the 1st deployment period. This poor performance rating was considered inaccurate, due to an inaccurate quality control instrument reading. A laboratory analyzed water sample indicated that turbidity at the Unnamed Tributary at this time was 1.9 NTU; a result that aligned more with the field instrument reading (0.0 NTU) versus the quality control instrument reading (12.0 NTU). Based on the laboratory result, the field instrument should have been given an *excellent* performance rating and the quality control instrument a *poor* performance rating.
- The second *poor* performance rating occurred with the turbidity sensor at James Creek on September 19, 2011, at the end of the deployment period. This poor performance rating was attributed to biofouling (Figure 4), which was suspected of affecting turbidity readings at James Creek between the dates of September 13, 2011 and September 19, 2011.
- With the exception of these two poor performance ratings, the performances of all sensors were rated fair-to-excellent at the beginning and end of deployment at both stations (Table 2).

Figure 4. Algae were found on the instrument's sensors at the James Creek station on September 19, 2011, which resulted in poor performance of the turbidity sensor.

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.
- There were several data disruptions that occurred during the deployment season. Three data disruptions occurred at each station during maintenance and calibration work. Maintenance and calibration procedures are scheduled at the start of each deployment period (Table 1), and took between 7 to 17 hours to perform. An additional data disruption occurred at the James Creek station on October 1, 2011. This disruption had resulted from a transmission error that lasted eight hours, from 04:00 ADT to 11:00 ADT. Water quality data saved to the instrument's internal log file was used to fill-in this data gap. Unfortunately, stage values are not recorded to this log file and are missing for the time of the outage.

Stage

- Figure 5 displays stage values recorded at both stations from June 4, 2011 to October 16, 2011. These values are provisional. Quality assured and quality controlled stage values are available through EC (http://www.ec.gc.ca/rhc-wsc/default.asp).
- Stage values ranged from 0.75 m to 0.85 m at James Creek and from 1.12 m to 1.17 m at Unnamed Tributary from June 4, 2011 to October 16, 2011 (Figure 5).
- 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.
- Weekly trends in stage at the James Creek station corresponded well with spring thaw (decrease in stage in 1st deployment period) and rainfall events (Figure 5 inset).
- Weekly trends in stage were not apparent at the Unnamed Tributary station, since this stream has its flow 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.

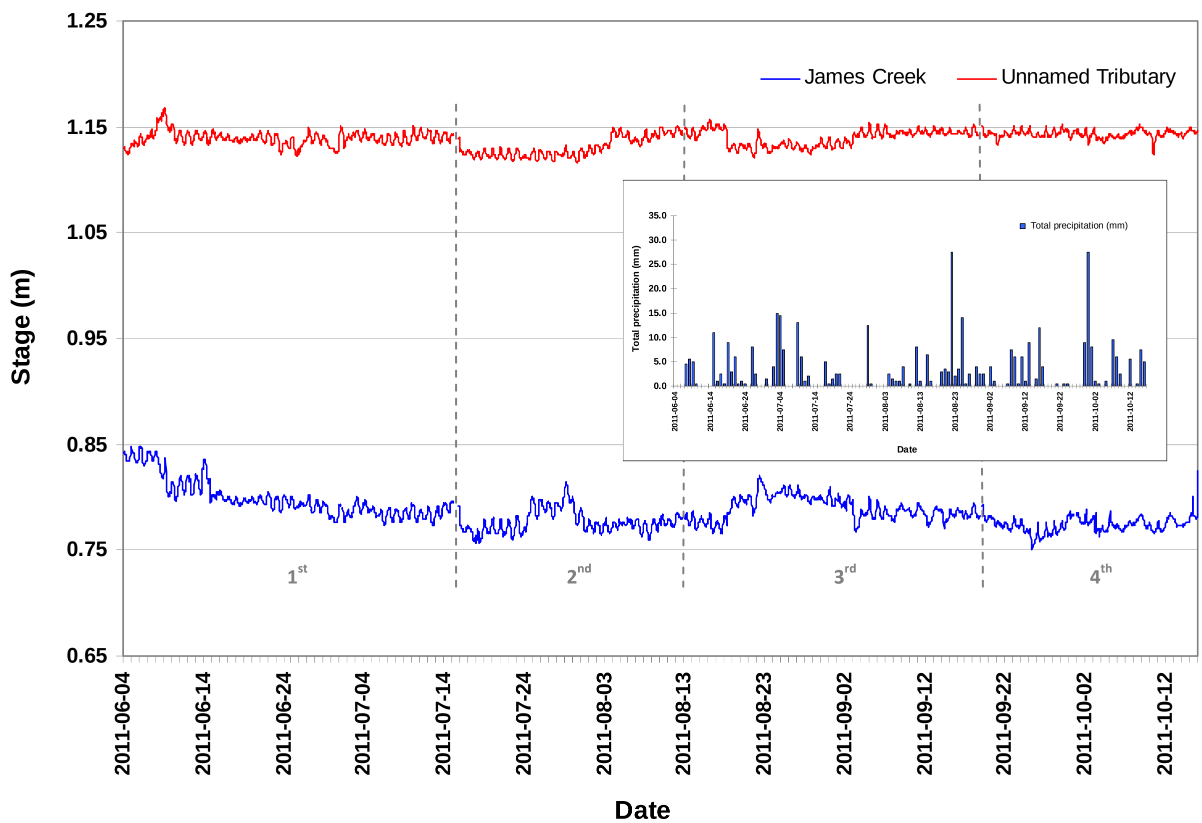

Figure 5. Hourly stage (m) values recorded at James Creek and Unnamed Tributary from June 4, 2011 to October 16, 2011. The inset chart shows total precipitation (mm) recorded at the Schefferville weather station during the same time period. All data was provided by Environment Canada. The four deployment periods are demarcated with dashed lines.

Temperature

- Water temperature ranged from 0.9˚C to 16.9˚C at James Creek and from 0.2˚C to 11.4˚C at Unnamed Tributary from June 4, 2011 to October 16, 2011 (Figure 6).
- 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 also corresponded well with ambient air temperatures recorded by Environment Canada at the Schefferville weather station (Figure 6 inset, Appendix C).
- Water temperatures at the Unnamed Tributary were on average 4.1°C colder than water temperatures at James Creek. Indeed, water flowing into the Unnamed Tributary is close to its groundwater source, and has less exposure to ambient air temperatures, as compared to the surface water source that primarily feeds into James Creek.

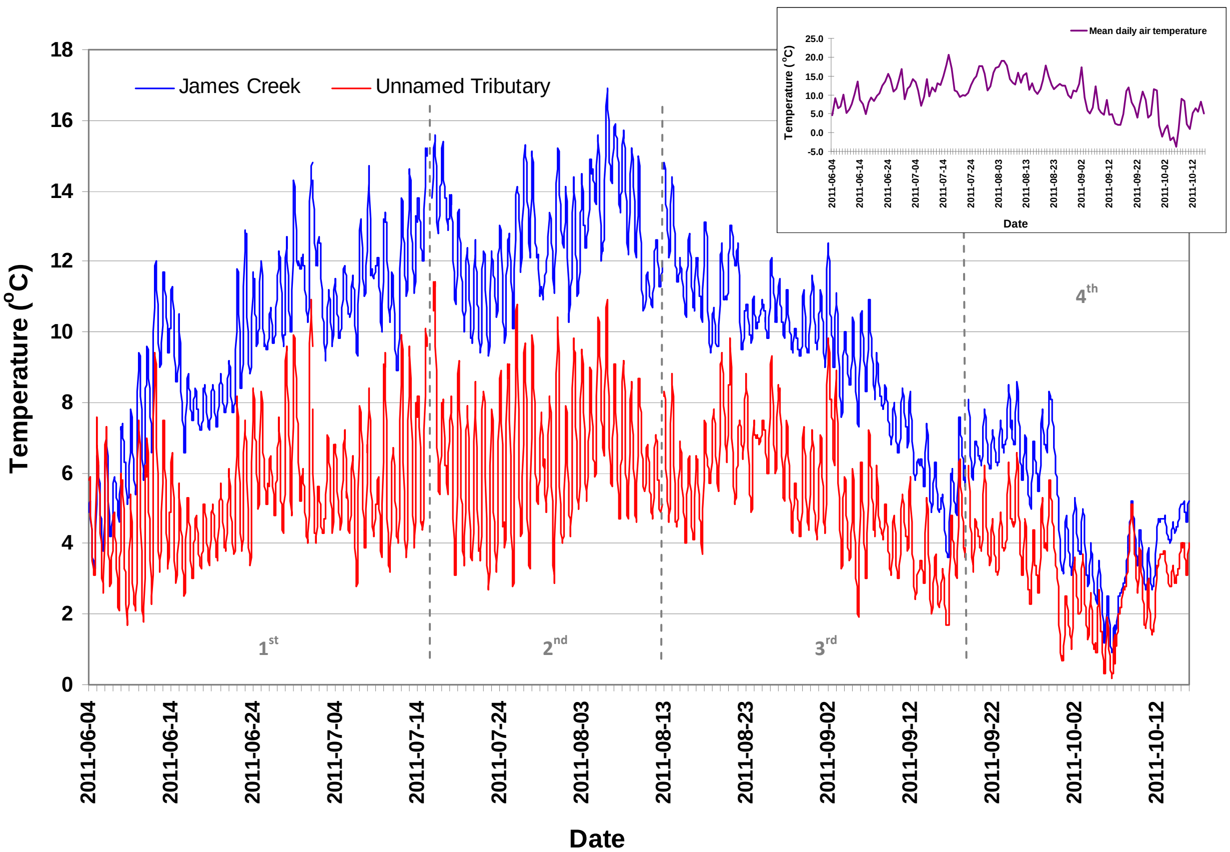

Figure 6. Hourly water temperature (°C) values recorded at James Creek and Unnamed Tributary from June 4, 2011 to October 16, 2011. Inset chart shows air temperature during the same period, as recorded by Environment Canada at the Schefferville weather station. The four deployment periods are demarcated with dashed lines.

pH

- pH values ranged from 6.61 units to 8.53 units at James Creek and from 6.53 units to 7.57 units at Unnamed Tributary from June 4, 2011 to October 16, 2011 (Figure 7).
- 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 1st and 3rd deployment periods. In the 1st period, James Creek saw a slight decrease in pH and the Unnamed Tributary saw a slight increase in pH. Biofouling and/or instrument drift were suspected of affecting pH at this time, since pH levels did not continue these weekly trends after instrument cleaning and recalibration on July 16, 2011. During the 3rd deployment period, there was a slight decrease in pH observed at both stations after September 3-4, 2011. The onset of this decrease coincided with high winds on September 3, 2011 (average wind speeds were 30.8 km/hr with maximum wind gusts of 80 km/hr). Biofouling associated with high winds and blowing debris may have caused this drift in pH at both stations. After cleaning and recalibration of the instruments on September 19, 2011, pH readings were back within the range that is typical and expected at these sites.
- A sudden drop in pH at the James Creek station on September 16, 2011, coincided with high turbidity values (~1000 NTU) and missing data values for specific conductivity, TDS, and stage. Problems with the monitoring equipment were suspected of causing this drop in pH.
- On average, pH was 0.87 units higher at James Creek than at Unnamed Tributary. This difference could be attributed to the mining effluent discharged into Ruth Pit and detected at the James Creek station.

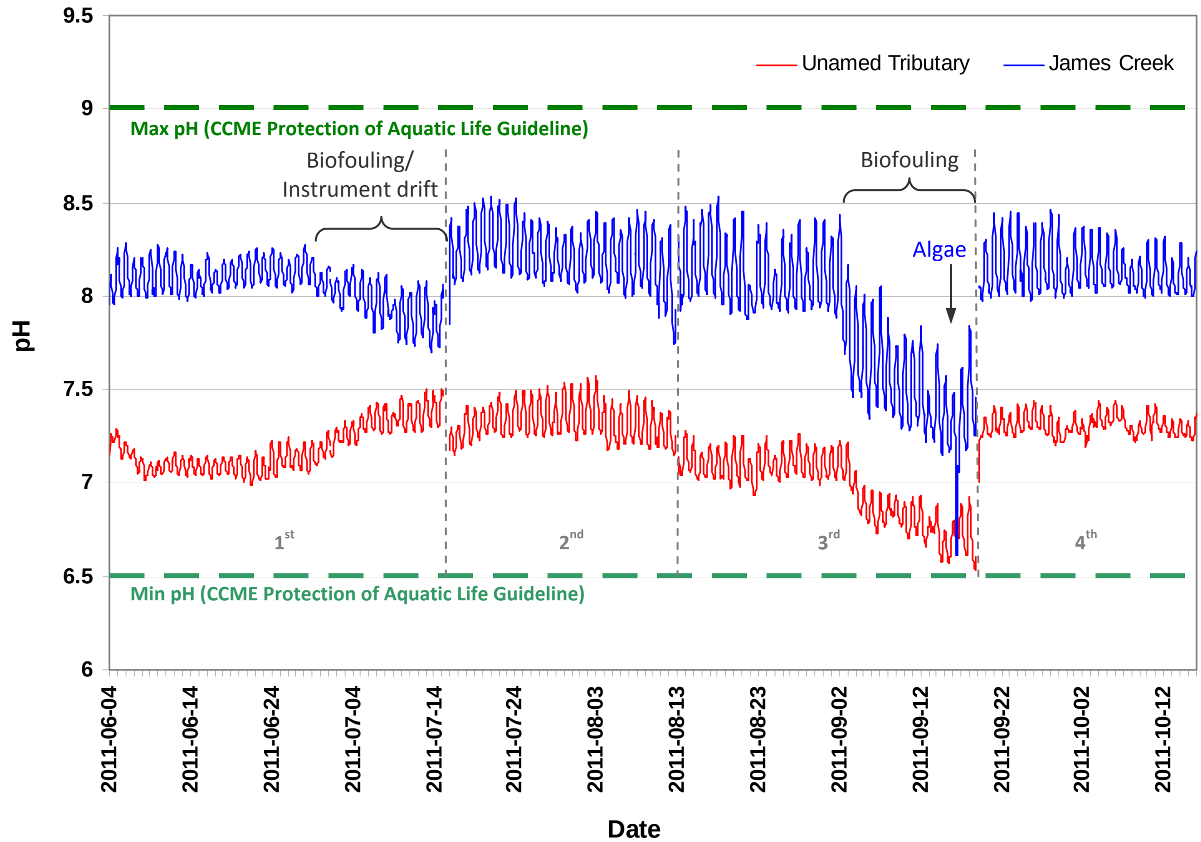

Figure 7. Hourly pH values recorded at James Creek and Unnamed Tributary from June 4, 2011 to October 16, 2011. The four deployment periods are demarcated with dashed lines.

Specific Conductivity

- Specific Conductivity ranged from 126.3 μs/cm to 161.3 μs/cm at James Creek and from 30.4 μs/cm to 72.7 μs/cm at Unnamed Tributary from June 4, 2011 to October 16, 2011 (Figure 8).
- There was a small increase in specific conductivity at James Creek during the 1st deployment period. This increase could be attributed to an increased concentration of dissolved solids, resulting from a decrease in stage (Figure 5).
- There was a sudden increase in specific conductivity at Unnamed Tributary on July 1, 2011. This date coincident with Labrador Iron Mines commencement of full mining operations in the area.
- Specific conductivity increased at the Unnamed Tributary between the dates of July 31, 2011 and August 10, 2011. Surface runoff from the mining site after a rainfall event on July 29, 2011 (12.5m) was thought to have caused this increase. A similar increase was not observed at James Creek, since James Creek is a larger river system with the majority of its water flowing from Ruth Pit, which is situated at a higher elevation than the mining site.
- Specific conductivity decreased slightly and abruptly at James Creek on August 18, 2011. This decrease could have been attributed to a dilution of dissolved solids resulting from an increase in stage.
- Specific conductivity decreased at the Unnamed Tributary between the dates of September 4, 2011 and September 6, 2011. This decrease was attributed to biofouling; leaves were found trapped in and around the instrument probe and when removed, specific conductance returned to normal levels.
- A small decrease in specific conductivity was observed at the James Creek station on September 30, 2011. This decrease corresponded with a large rainfall event (27.5mm) on September 30, 2011 (Appendix C).
- On average, specific conductivity was 97.9 μS/cm higher at James Creek than at Unnamed Tributary. This difference could be attributed to the increased concentration of dissolved solids from the iron ore tailings deposited into Ruth Pit, which feeds into James Creek.

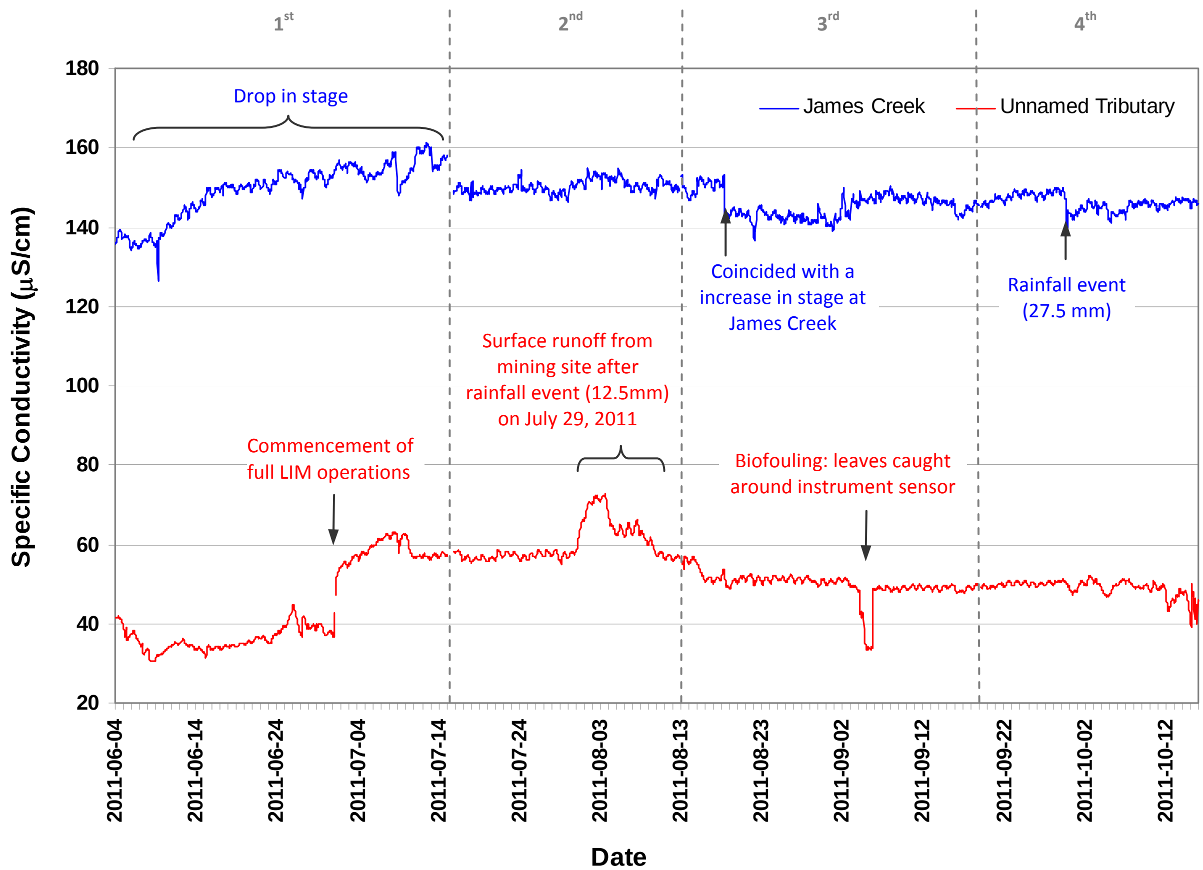

Figure 8. Hourly specific conductivity (µS/cm) values recorded at James Creek and Unnamed Tributary from June 4, 2011 to October 16, 2011. The four deployment periods are demarcated with dashed lines.

Total Dissolved Solids

- Total Dissolved Solids (TDS) values ranged from 0.0808 g/l to 0.1032 g/l at James Creek and from 0.0194 g/l to 0.0465 g/l at Unnamed Tributary from June 4, 2011 to October 16, 2011 (Figure 9).
- TDS is calculated directly from specific conductance and temperature, and as a result TDS values show a similar trend to specific conductance (Figure 8).
- TDS values were on average 0.06266 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.

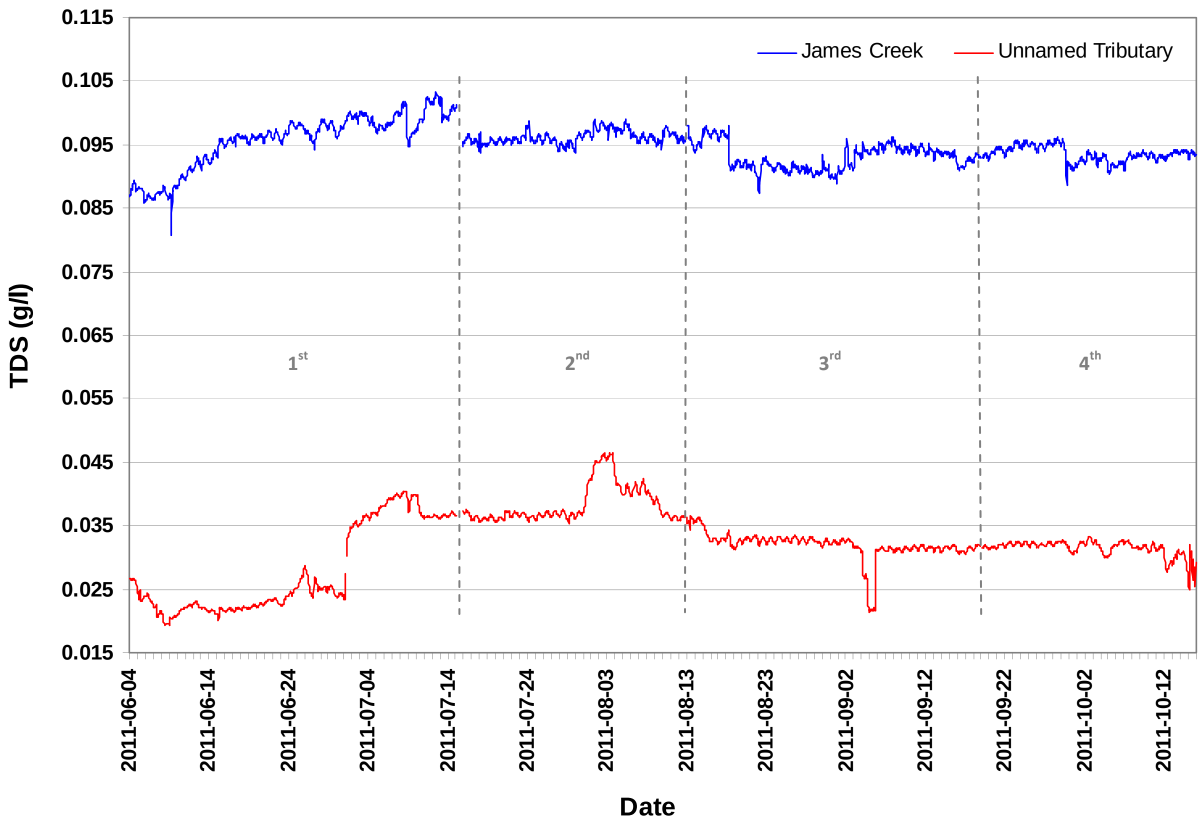

Figure 9. Hourly TDS (g/l) values recorded at James Creek and Unnamed Tributary from June 4, 2011 to October 16, 2011. The four deployment periods are demarcated with dashed lines.

Dissolved Oxygen

- Dissolved Oxygen [DO] values ranged from 9.01 mg/l to 13.81 mg/l at James Creek and from 9.69 mg/l to 14.02 mg/l at Unnamed Tributary from June 4, 2011 to October 16, 2011 (Figure 10).
- DO values 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 (mg/l) 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 (mg/l) corresponded well with the inverse of water temperature (Figure 6), since colder water has a greater potential to dissolve oxygen compared to warmer water.
- On average, DO values were 0.91 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 6).

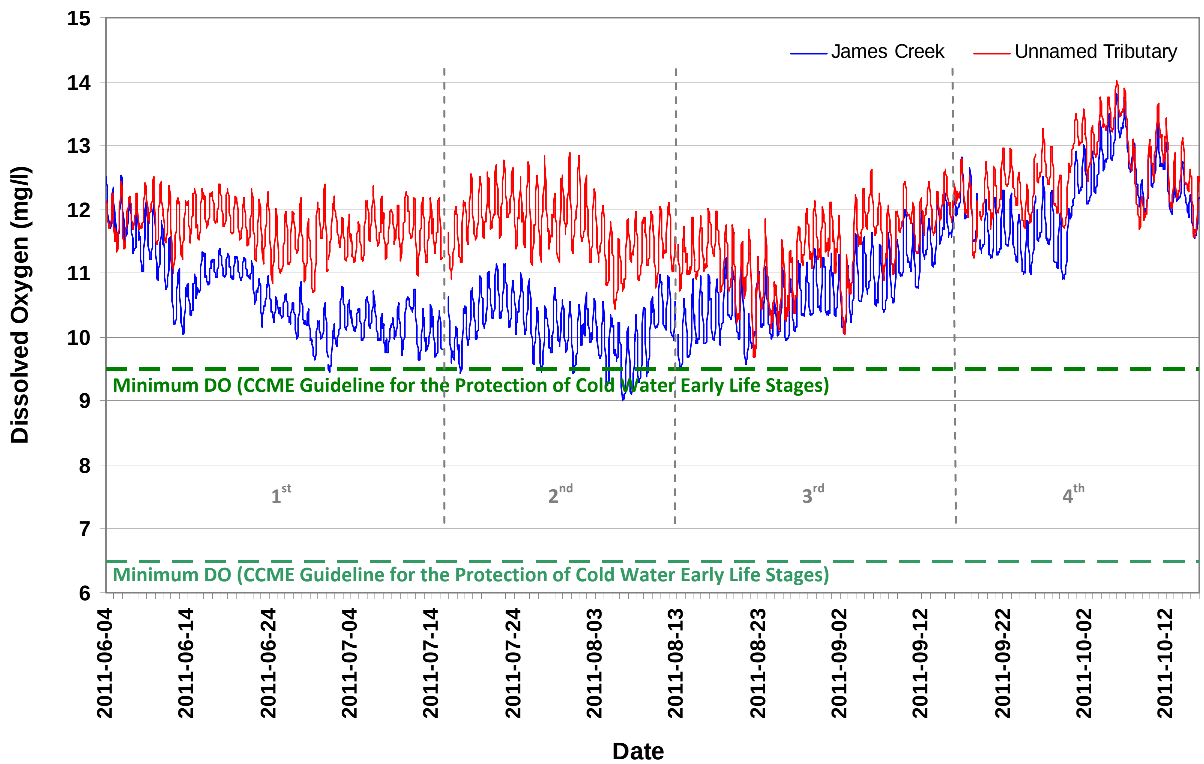

Figure 10. Hourly dissolved oxygen (mg/l) values recorded at James Creek and Unnamed Tributary from June 4, 2011 to October 16, 2011. The four deployment periods are demarcated with dashed lines.

Turbidity

- Turbidity values ranged from 0.0 NTU to 2588.0 NTU at James Creek and from 0.0 NTU to 3000.0 NTU at Unnamed Tributary from June 4, 2011 to October 16, 2011 (Figure 11).
- Turbidity events were numerous at both stations, resulting from various noted sources, including: (i) biofouling (e.g., algae, leaves, etc.); (ii) rainfall events; (iii) spawning fish; (iv) dewatering test discharges; and (v) increased flow rates during the spring freshet. Compounding the effects of these events is the presence of historical silt sediment in both streams that easily gets re-suspended, resulting in turbidity spikes. The historical silt sediment in the watercourses originated from past mining activities in the area.
- A *poor* performance rating was assigned to the turbidity sensor at James Creek on September 19, 2011, at the end of the 3rd deployment period. This poor performance rating was attributed to biofouling, which was suspected of affecting turbidity readings at James Creek between the dates of September 13, 2011 and September 19, 2011.

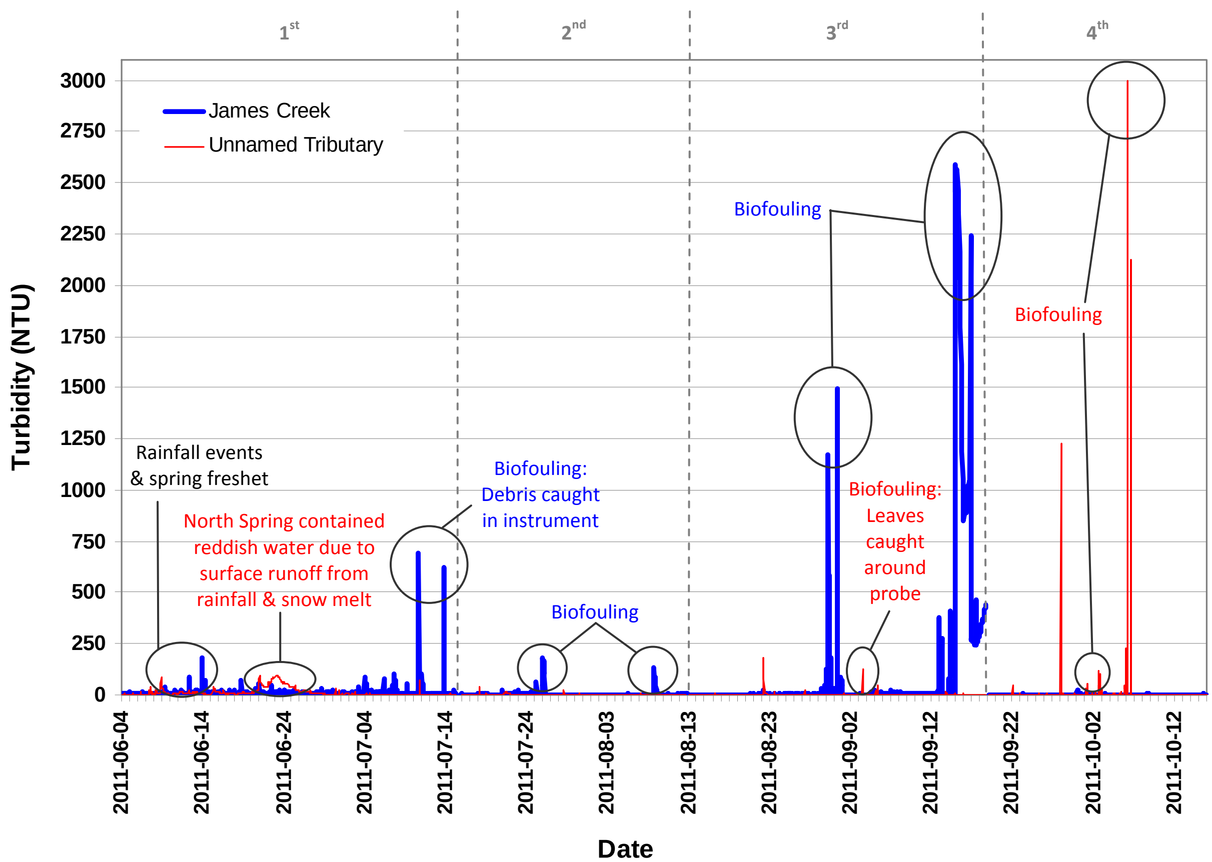

Figure 11. Hourly turbidity (NTU) values recorded at James Creek and Unnamed Tributary from June 4, 2011 to October 16, 2011. The four deployment periods are demarcated with dashed lines.

Conclusions

- Water quality monitoring instruments were deployed at two stations near the James Deposit between June 4, 2011 and October 16, 2011. The stations are located on James Creek and the Unnamed Tributary.
- With the exception of the turbidity sensor, the performances of all sensors were rated *fair*-to-*excellent* at the beginning and end of deployment at both stations
- The turbidity sensor received two *poor* performance ratings, the first *poor* performance rating was found to be unwarranted and the second *poor* performance rating occurred at James Creek on September 19, 2011. This poor performance rating was attributed to biofouling (i.e., algae was found caught around the sensor).
- Variations in water quality/quantity values recorded at each station are summarized below:
  - Daily variations in stage were attributed to temperature-related atmospheric pressure changes. Stage levels displayed no weekly trends at the Unnamed Tributary, but small weekly trends at James Creek, which were related to snow melt and/or rainfall.
  - Daily and weekly trends in water temperature could be attributed to fluctuations in ambient air temperature.
  - 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 varied with most changes attributed to instrument drift and/or biofouling.
  - Fluctuations in specific conductivity and TDS were influenced by rainfall, biofouling, changes in stage, and for the James Creek station, iron ore tailings deposited into Ruth Pit.
  - DO values at both stations were above cold water minimum guidelines set for aquatic life during other life stages, 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.
  - Larger peaks in turbidity recorded at both stations were attributed mostly to biofouling and rainfall.

Path Forward

- Field instruments for both stations will undergo Proficiency, Testing, and Evaluation during the winter of 2011-2012. ENVC will inform LIM of any instrument performance issues.
- ENVC staff will redeploy RTWQ instruments at James Creek and the Unnamed Tributary in spring 2012, when ice conditions allow, and perform regular site visits throughout the 2012 deployment season, for calibration and maintenance of the instruments.
- 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.
- ENVC will begin development of models using RTWQ monitoring data and grab sample data to estimate a variety of additional water quality parameters (e.g., TSS and major ions).
- 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.

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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 (°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 4, 2011 to October 16, 2011)

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
2011-06-04	8.3	0.8	4.6	13.4	0	0	11.2	114.2
2011-06-05	16.3	2.1	9.2	8.8	0	0	18.6	200.0
2011-06-06	11.8	0.9	6.4	11.6	0	0	10.6	248.8
2011-06-07	12	1.9	7	11	0	4.5	13.5	174.2
2011-06-08	16.3	3.8	10.1	7.9	0	5.5	9.3	179.6
2011-06-09	10.3	0.1	5.2	12.8	0	5	19.3	341.7
2011-06-10	13	-0.7	6.2	11.8	0	0.5	13.9	285.4
2011-06-11	15.7	-0.7	7.5	10.5	0	0	10.8	202.9
2011-06-12	17.9	2.6	10.3	7.7	0	0	9.6	202.5
2011-06-13	21.9	5.1	13.5	4.5	0	0	9.3	226.7
2011-06-14	14	3.4	8.7	9.3	0	0	11.2	262.9
2011-06-15	12.8	2.1	7.5	10.5	0	11	12.1	166.7
2011-06-16	8.9	0.9	4.9	13.1	0	1	11.4	194.6
2011-06-17	10.5	5.6	8.1	9.9	0	2.5	12.5	153.8
2011-06-18	11.5	7	9.3	8.7	0	0.5	16.2	114.6
2011-06-19	10	6.5	8.3	9.7	0	9	15.4	87.9
2011-06-20	11.7	7.7	9.7	8.3	0	3	9.0	146.3
2011-06-21	12.2	8.6	10.4	7.6	0	6	6.4	119.6
2011-06-22	17.5	7.4	12.5	5.5	0	0.5	5.3	156.7
2011-06-23	19.7	7.2	13.5	4.5	0	1	6.2	84.6
2011-06-24	23.3	7.8	15.6	2.4	0	0.5	13.1	172.5
2011-06-25	18.3	9.9	14.1	3.9	0	0	14.4	187.9
2011-06-26	12.7	8.8	10.8	7.2	0	8	9.3	141.7
2011-06-27	14.7	8.5	11.6	6.4	0	2.5	10.0	132.9
2011-06-28	19.4	8.2	13.8	4.2	0	0	12.1	152.1
2011-06-29	23	10.6	16.8	1.2	0	0	9.8	180.4
2011-06-30	12.1	5.6	8.9	9.1	0	1.5	17.7	303.3
2011-07-01	17.7	5.4	11.6	6.4	0	0	10.7	163.3
2011-07-02	14.7	9.8	12.3	5.7	0	4	10.2	197.9
2011-07-03	18	10.3	14.2	3.8	0	15	16.0	135.8
2011-07-04	17.5	9.2	13.4	4.6	0	14.5	10.0	162.9
2011-07-05	13.5	8.8	11.2	6.8	0	7.5	16.9	262.1
2011-07-06	10.4	3.7	7.1	10.9	0	0	11.3	272.9
2011-07-07	16.2	2.7	9.5	8.5	0	0	5.7	164.2
2011-07-08	18.6	9.5	14.1	3.9	0	0	4.3	110.4
2011-07-09	12.1	7.1	9.6	8.4	0	13	11.8	236.3
2011-07-10	17.6	6.1	11.9	6.1	0	6	7.9	181.7
2011-07-11	15.4	6.1	10.8	7.2	0	1	11.6	144.6
2011-07-12	17	9	13	5	0	2	13.0	101.3

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
2011-07-13	18	7.2	12.6	5.4	0	0	12.8	320.8
2011-07-14	21.5	8.3	14.9	3.1	0	0	11.5	252.5
2011-07-15	23.7	12.3	18	0	0	0	10.1	248.8
2011-07-16	28	13.2	20.6	0	2.6	0	13.3	204.6
2011-07-17	21.8	12.1	17	1	0	5	10.5	200.8
2011-07-18	15.7	6.6	11.2	6.8	0	0.5	18.5	318.3
2011-07-19	15.6	6	10.8	7.2	0	1.5	18.8	258.3
2011-07-20	13.6	5.4	9.5	8.5	0	2.5	13.3	280.0
2011-07-21	14.5	5.4	10	8	0	2.5	17.9	300.8
2011-07-22	14.1	5.4	9.8	8.2	0	0	17.0	255.0
2011-07-23	17	4	10.5	7.5	0	0	5.0	147.5
2011-07-24	19.5	5.7	12.6	5.4	0	0	16.1	321.3
2011-07-25	20.9	7.4	14.2	3.8	0	0	11.0	275.0
2011-07-26	24.6	5.4	15	3	0	M	8.1	217.1
2011-07-27	24.9	10.2	17.6	0.4	0	0	8.8	248.8
2011-07-28	26.3	8.8	17.6	0.4	0	0	8.2	145.8
2011-07-29	19.2	11.8	15.5	2.5	0	12.5	19.3	205.0
2011-07-30	16.3	5.8	11.1	6.9	0	0.5	15.4	303.8
2011-07-31	20.2	4.1	12.2	5.8	0	0	6.6	167.9
2011-08-01	20.9	10.8	15.9	2.1	0	0	11.8	147.9
2011-08-02	22.9	11.5	17.2	0.8	0	0	11.9	150.0
2011-08-03	22.9	12	17.5	0.5	0	0	12.5	183.8
2011-08-04	23.7	14.4	19.1	0	1.1	2.5	9.5	197.1
2011-08-05	24.3	13.8	19.1	0	1.1	1.5	15.7	192.9
2011-08-06	22.7	12.8	17.8	0.2	0	1	10.7	243.8
2011-08-07	17.8	10.6	14.2	3.8	0	1	8.1	192.1
2011-08-08	18.4	7.9	13.2	4.8	0	4	8.8	251.3
2011-08-09	19.5	5.9	12.7	5.3	0	0	5.5	156.7
2011-08-10	21.6	10.2	15.9	2.1	0	0.5	16.0	145.0
2011-08-11	14.6	11.7	13.2	4.8	0	0	17.8	147.9
2011-08-12	18.6	11.5	15.1	2.9	0	8	9.2	140.0
2011-08-13	20.3	11.1	15.7	2.3	0	1	10.0	247.5
2011-08-14	16.1	6.6	11.4	6.6	0	0	13.1	265.8
2011-08-15	17	9	13	5	0	6.5	17.0	203.8
2011-08-16	15.1	7.1	11.1	6.9	0	1	13.1	300.4
2011-08-17	13	7.3	10.2	7.8	0	0	14.5	300.0
2011-08-18	17.3	5.7	11.5	6.5	0	0	8.0	120.4
2011-08-19	17.6	10	13.8	4.2	0	3	11.8	137.1
2011-08-20	22.3	13.2	17.8	0.2	0	3.5	10.0	193.8
2011-08-21	20.5	9.5	15	3	0	3	6.2	186.3
2011-08-22	16.6	8.5	12.6	5.4	0	27.5	14.4	177.1
2011-08-23	14.5	8.5	11.5	6.5	0	2	19.0	222.1
2011-08-24	16.9	7.5	12.2	5.8	0	3.5	21.5	196.3
2011-08-25	16.9	8.8	12.9	5.1	0	14	19.3	209.6

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
2011-08-26	17.3	7.7	12.5	5.5	0	0.5	20.1	273.8
2011-08-27	16.7	8.3	12.5	5.5	0	2.5	21.5	227.5
2011-08-28	12.6	7.1	9.9	8.1	0	0	11.8	241.7
2011-08-29	11.8	6.5	9.2	8.8	0	4	10.5	130.4
2011-08-30	15.2	7.1	11.2	6.8	0	2.5	6.3	183.3
2011-08-31	15.4	6.4	10.9	7.1	0	2.5	6.7	252.1
2011-09-01	18.4	7.4	12.9	5.1	0	0	13.2	215.4
2011-09-02	22.6	11.9	17.3	0.7	0	4	23.6	214.6
2011-09-03	15	3.5	9.3	8.7	0	1	30.8	280.8
2011-09-04	9.2	2.3	5.8	12.2	0	0	11.8	230.4
2011-09-05	10.7	-0.7	5	13	0	0	9.1	108.8
2011-09-06	15	-1.7	6.7	11.3	0	0	8.0	159.2
2011-09-07	17.8	6.6	12.2	5.8	0	0.5	21.8	243.3
2011-09-08	9.8	2.8	6.3	11.7	0	7.5	23.1	268.8
2011-09-09	8.3	2.4	5.4	12.6	0	6	15.2	235.8
2011-09-10	7.3	2	4.7	13.3	0	0.5	12.8	300.0
2011-09-11	13.8	3.4	8.6	9.4	0	6	21.1	224.6
2011-09-12	8.2	1.4	4.8	13.2	0	1	18.9	285.4
2011-09-13	9.4	0.3	4.9	13.1	0	9	19.7	183.3
2011-09-14	7.6	-2.8	2.4	15.6	0	0	19.7	271.3
2011-09-15	7.2	-3.1	2.1	15.9	0	1.5	7.8	144.6
2011-09-16	3.9	0.1	2	16	0	12	22.1	316.3
2011-09-17	9.3	0.5	4.9	13.1	0	4	23.7	298.8
2011-09-18	15	7	11	7	0	0	19.5	261.3
2011-09-19	17.3	6.4	11.9	6.1	0	0	18.6	233.3
2011-09-20	11.6	4.5	8.1	9.9	0	0	16.1	184.6
2011-09-21	10.7	2.6	6.7	11.3	0	0.5	17.5	292.5
2011-09-22	6.2	1.6	3.9	14.1	0	0	6.6	180.0
2011-09-23	12.8	2.4	7.6	10.4	0	0.5	8.0	192.1
2011-09-24	12.8	9	10.9	7.1	0	0.5	19.6	266.3
2011-09-25	12.8	4.3	8.6	9.4	0	0	28.5	305.4
2011-09-26	6.6	1.2	3.9	14.1	0	0	23.5	319.6
2011-09-27	9	0.4	4.7	13.3	0	0	12.0	266.3
2011-09-28	17.2	5.8	11.5	6.5	0	0	16.2	238.8
2011-09-29	17.7	4.7	11.2	6.8	0	9	11.7	267.1
2011-09-30	4.7	-1	1.9	16.1	0	27.5	23.0	198.8
2011-10-01	1.2	-3.4	-1.1	19.1	0	8	16.6	326.7
2011-10-02	5.6	-3.8	0.9	17.1	0	1	13.9	201.3
2011-10-03	5.2	-1.5	1.9	16.1	0	0.5	21.2	305.8
2011-10-04	1	-5	-2	20	0	0	10.1	239.6
2011-10-05	2.7	-5	-1.2	19.2	0	1	16.1	248.8
2011-10-06	-0.6	-6.8	-3.7	21.7	0	0	17.5	284.2
2011-10-07	8.5	-6.8	0.9	17.1	0	9.5	12.8	260.4
2011-10-08	13.6	4.3	9	9	0	6	13.0	187.1

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
2011-10-09	13.8	2.9	8.4	9.6	0	2.5	22.2	274.2
2011-10-10	5.1	-0.7	2.2	15.8	0	0	25.3	307.5
2011-10-11	3.8	-2.1	0.9	17.1	0	0	13.0	269.2
2011-10-12	11	-0.6	5.2	12.8	0	5.5	16.8	197.9
2011-10-13	10.5	2.5	6.5	11.5	0	0	10.8	179.6
2011-10-14	8.5	2.7	5.6	12.4	0	0.5	13.8	146.3
2011-10-15	9.3	7	8.2	9.8	0	7.5	22.4	135.0
2011-10-16	8.3	1.6	5	13	0	5	16.8	163.8

APPENDIX C (continued...)
Environment Canada Weather Data - Schefferville (June 4, 2011 to October 16, 2011)

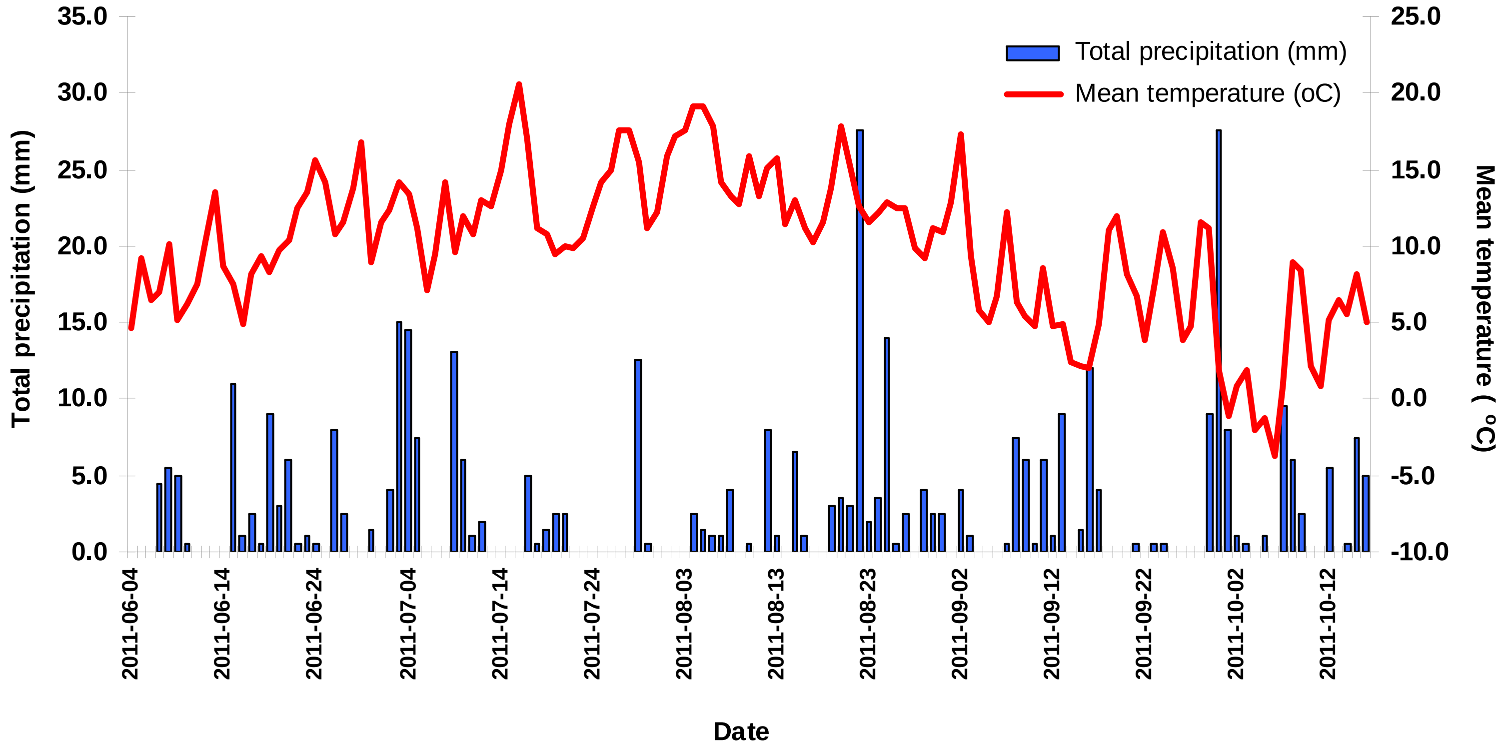

Figure 1. Daily precipitation and mean temperature recorded at the Schefferville Weather Station by Environment Canada from June 4, 2011 to October 16, 2011.

APPENDIX C (continued...)
Environment Canada Weather Data – Schefferville (June 4, 2011 to October 16, 2011)

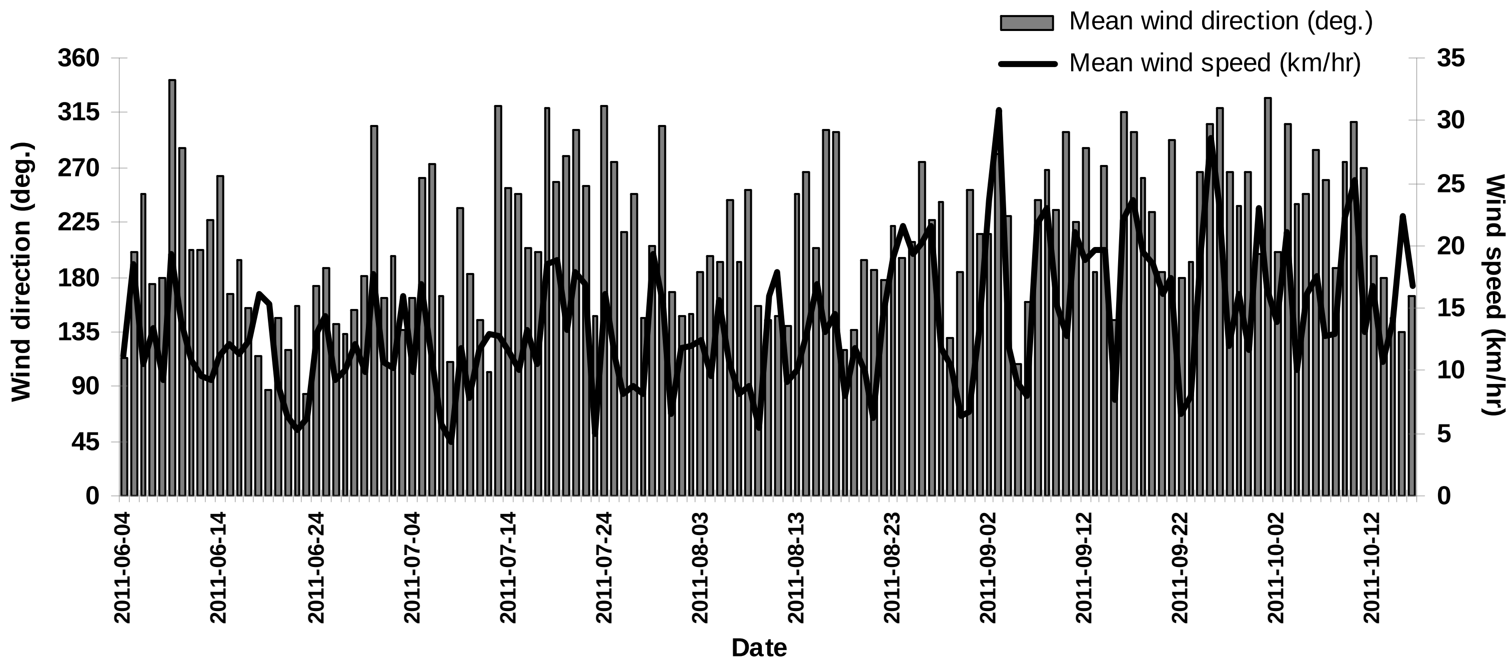

Figure 2. Mean daily wind direction and wind speed recorded at the Schefferville Weather Station by Environment Canada from June 4, 2011 to October 16, 2011.