## Real Time Water Quality Report

# Tata Steel Minerals Canada Elross Lake Network

## Annual Deployment Report 2012

## 2012-06-05 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 Network in the vicinity of the Elross Lake Iron Ore Mine in western Labrador is fully funded by Tata Steel Minerals Canada Limited (TSMC) and its success is dependent on a joint partnership between TSMC, Environment Canada (EC), and the Newfoundland & Labrador Department of Environment & Conservation (ENVC). Managers and program leads from each organization, namely Loic Didillon (TSMC), Renee Paterson (ENVC), and Howie Wills (EC), are committed to the operation of this network and ensuring that it provides meaningful and accurate water quality/quantity data.

In addition to funding this program, TSMC also assisted ENVC and EC staff with fieldwork operations, transportation, food, accommodations, and equipment storage. TSMC employees who were helpful in this regard included Loic Didillon, Donna O'Quinn, Sabrina Penney, Louis-David Sansoucy, Arindam Sarkar, Henry Simpson, and William Zinn.

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 Elross Lake Mine, 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, were conducted in-house by Ryan Pugh.

## Introduction

- An agreement was signed on April 18, 2011, between the Newfoundland & Labrador Department of Environment & Conservation (ENVC) and Tata Steel Minerals Canada Limited (TSMC), to establish two real-time water quality/quantity stations in the vicinity of Elross Lake Iron Ore Mine in western Labrador, near Schefferville, QC.
- The official name of each station is ELROSS CREEK BELOW PINETTE LAKE INFLOW and GOODREAM CREEK 2KM NORTHWEST OF TIMMINS 6, hereafter referred to as the *Elross Creek Station* and the *Goodream Creek Station*, respectively (Figure 1).

a. Elross Creek Station b. Goodream Creek Station

Figure 1. RTWQ stations are located alongside (a) Elross Creek and (b) Goodream Creek.

- Table 1 lists the geographic coordinates of each station, including the location of the water quality instrument, gauge house, and helicopter pad.

Table 1. Geographic coordinates of the Elross Creek Station and Goodream Creek Station components.

| | Elross Creek Station | | Goodream Creek Station | |
|---|---|---|---|---|
| | Latitude | Longitude | Latitude | Longitude |
| Instrument | 54.877757 | -67.099728 | 54.917549 | -67.124027 |
| Gauge house | 54.877698 | -67.099848 | 54.917564 | -67.123939 |
| Helicopter pad | 54.877604 | -67.100014 | 54.917699 | -67.123763 |

- Station sites were selected to monitor all surface water outflows from the Elross Lake mining site (Figure 2).
- The Elross Creek Station monitors surface water downstream of the Timmins 1 pit, and downstream of Pinette Lake.
- The Goodream Creek Station monitors potential impacts from groundwater flowing from Timmins 6 pit into the surface water of Goodream Creek.
- The stations went into operation October 17-18, 2011, recording only stage values for the first 7 months until June 5, 2012, when water quality instruments were first deployed.
- Six parameters are measured at each station during ice-free months, 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 TSMC, 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 TSMC 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 Elross Creek and Goodream Creek stations from June 5, 2012 to October 25, 2012.

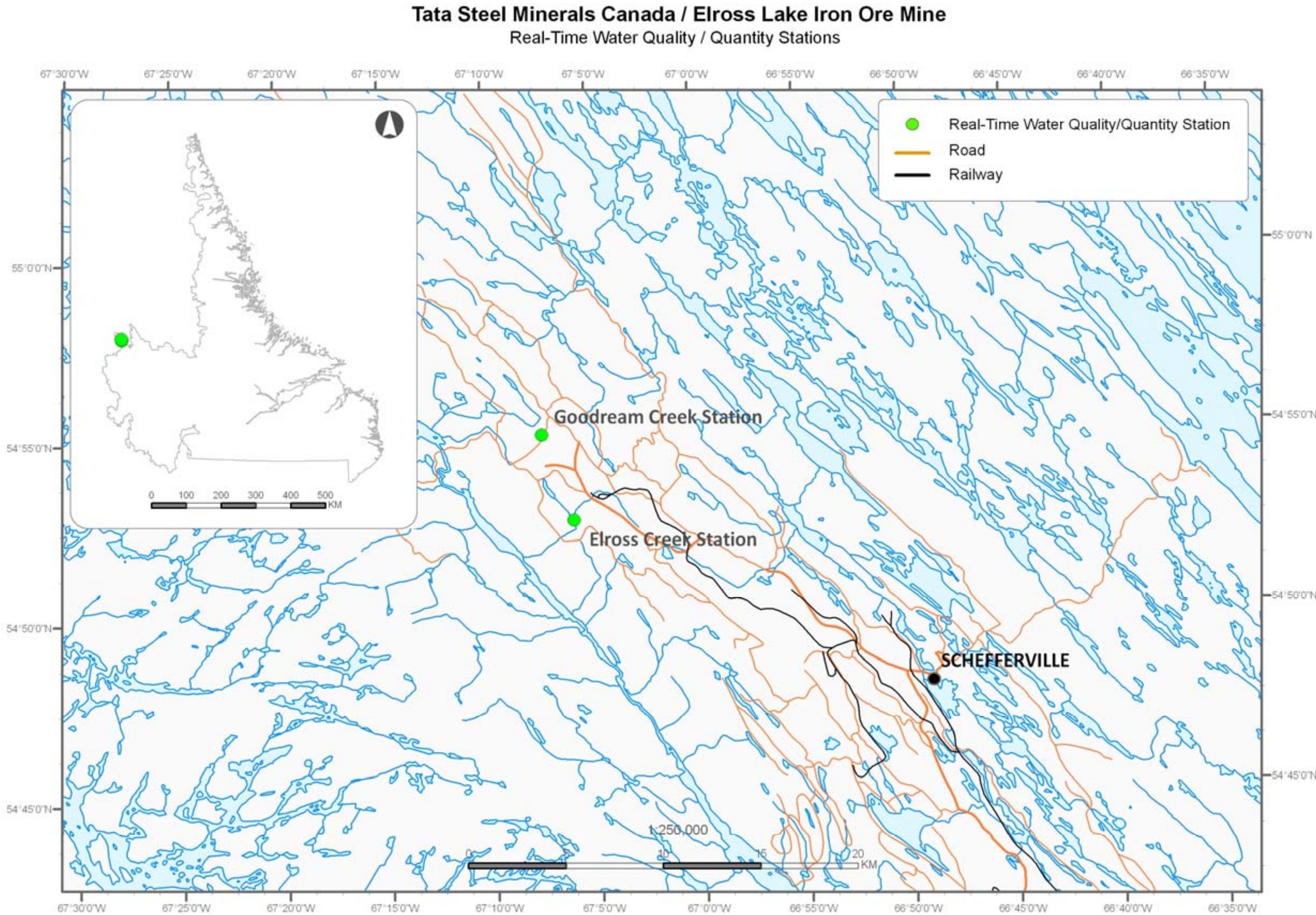


Figure 2. Map of real-time water quality/quantity stations in the vicinity of Elross Lake Iron Ore Mine in Western Labrador.

## 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 28-40 days, before the start of a new deployment period. Deployment start and end dates are summarized in Table 2.

Table 2. Water quality instrument deployment start and end dates for 2012 at Elross Creek and Goodream Creek.

| Station | Start date | End date | Duration (days) | Instrument |
|---|---|---|---|---|
| Elross Creek | 2012-06-05 | 2012-07-15 | 40 | 62069 |
| | 2012-07-15 | 2012-08-22 | 38 | 62065 |
| | 2012-08-23 | 2012-09-27 | 35 | 62065 |
| | 2012-09-27 | 2012-10-25 | 28 | 62065 |
| Goodream Creek | 2012-06-05 | 2012-07-14 | 39 | 62065 |
| | 2012-07-14 | 2012-08-22 | 39 | 62068 |
| | 2012-08-23 | 2012-09-27 | 35 | 62068 |
| | 2012-09-27 | 2012-10-25 | 28 | 62068 |

[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 3 shows the performance ratings of the instrument sensors (i.e., temperature, pH, conductivity, dissolved oxygen and turbidity) deployed at Elross Creek and Goodream Creek. Based on quality control procedures, instrument sensor performance ranged from poor-to-excellent in 2012.

Table 3. Instrument sensor performance at the start and end of each deployment period for the Elross Creek and Goodream Creek RTWQ stations.

| Station | Stage of deployment | Date (yyyy-mm-dd) | Instrument | Temperature (°C) | pH | Specific conductivity (µS/cm) | Dissolved oxygen (mg/L) | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|---|
| Elross Creek | Start | 2012-06-05 | 62069 | Good | Excellent | Excellent | Excellent | Excellent |
| | End | 2012-07-15 | | Excellent | Excellent | Excellent | Excellent | Excellent |
| | Start | 2012-07-15 | 62065 | Excellent | Excellent | Excellent | Excellent | Good |
| | End | 2012-08-22 | | Excellent | Good | Excellent | Excellent | Fair |
| | Start | 2012-08-23 | 62065 | Excellent | Excellent | Excellent | Excellent | Excellent |
| | End | 2012-09-27 | | Excellent | Excellent | Excellent | Good | Excellent |
| | Start | 2012-09-27 | 62065 | Excellent | Good | Excellent | Excellent | Excellent |
| | End | 2012-10-25 | | Excellent | Excellent | Excellent | Fair | Excellent |
| Goodream Creek | Start | 2012-06-05 | 62065 | Excellent | Good | Excellent | Excellent | Excellent |
| | End | 2012-07-14 | | Excellent | Excellent | Excellent | Excellent | Excellent |
| | Start | 2012-07-14 | 62068 | Excellent | Excellent | Excellent | Excellent | Excellent |
| | End | 2012-08-22 | | Excellent | Excellent | Excellent | Excellent | Poor |
| | Start | 2012-08-23 | 62068 | Excellent | Good | Excellent | Excellent | Excellent |
| | End | 2012-09-27 | | Excellent | Good | Excellent | Good | Excellent |
| | Start | 2012-09-27 | 62068 | Excellent | Good | Excellent | Excellent | Excellent |
| | End | 2012-10-25 | | Excellent | Good | Good | Fair | Excellent |

- The turbidity sensor at the Elross Creek station was given a fair performance rating at the end of second deployment. It was noted during the field visit on August 22, 2012 that there was a heavy silt build-up inside the protective casing of the field instrument, which may have influenced turbidity readings. To remedy this problem, the instrument was redeployed on a rocky substrate, to prevent silt settling in and around instrument sensors.
- The turbidity sensor at Goodream Creek was given a poor performance rating at the end of second deployment period. It was determined that the turbidity sensor wiper had repositioned itself over the sensor window shortly after the start of the second deployment. This repositioning of the wiper affected sensor readings, resulting in invalid data being collected at Goodream Creek for the entire second deployment period. This data was removed from the dataset and omitted from this report.

- Dissolved oxygen sensors at both stations received fair performance ratings at the end of the fourth deployment season. Although these performance ratings were not of great concern, it should be noted that the QA/QC instrument used to rate performance was found to have a malfunctioning dissolved oxygen sensor. Any performance ratings based on this malfunctioning QA/QC sensor are nullified.
- Bath tests were also conducted in February and March of 2013, to further test sensor performance. During these bath tests, sensor readings were logged in 15 minute intervals while immersed in a relatively stable aquatic environment. Results from the bath test showed that all sensors performed well for all instruments.

## Deployment Notes

- Mining operations were halted on June 29, 2012 and resumed around September 5, 2012.
- Transmission errors occurred sporadically during the first, second and third deployment periods at the Goodream Creek station, resulting in the loss of 375 hourly transmission records. The timing of the data losses primarily coincided with rainfall events. 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.
- Water quality monitoring stopped at Goodream Creek on October 12, 2012 at 3:30 am. Both the data logger inside the streamside hut, as well as the internal log file within the instrument, did not acquire any data from October 12-25, 2012. The portion of stream where the instrument was located was completely ice covered on October 25, 2012. The instrument regained its connection and started logging water quality data after it was removed from the icy stream and had its battery chamber dried of any water droplets. It was suspected that freezing temperatures and ice formation caused water to come in contact with the instrument's electrical components, resulting in an electrical short and the instrument to malfunction. This data gap is apparent in all water quality graphs shown in this report.

## 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 ($^oC$)
  (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 4 displays stage values recorded at both stations from June 5, 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).
- Stage values ranged from 1.061 m to 1.385 m at Elross Creek and from 1.786 m to 2.202 m at Goodream Creek from June 5, 2012 to October 25, 2012.
- Fluctuations in stage corresponded well with rainfall events (Figure 4 inset). Some minor disturbances in stage occurring near the end of the deployment season coincided with freezing air temperatures, and possible ice formation, which was present at the Goodream Creek station.
- 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.

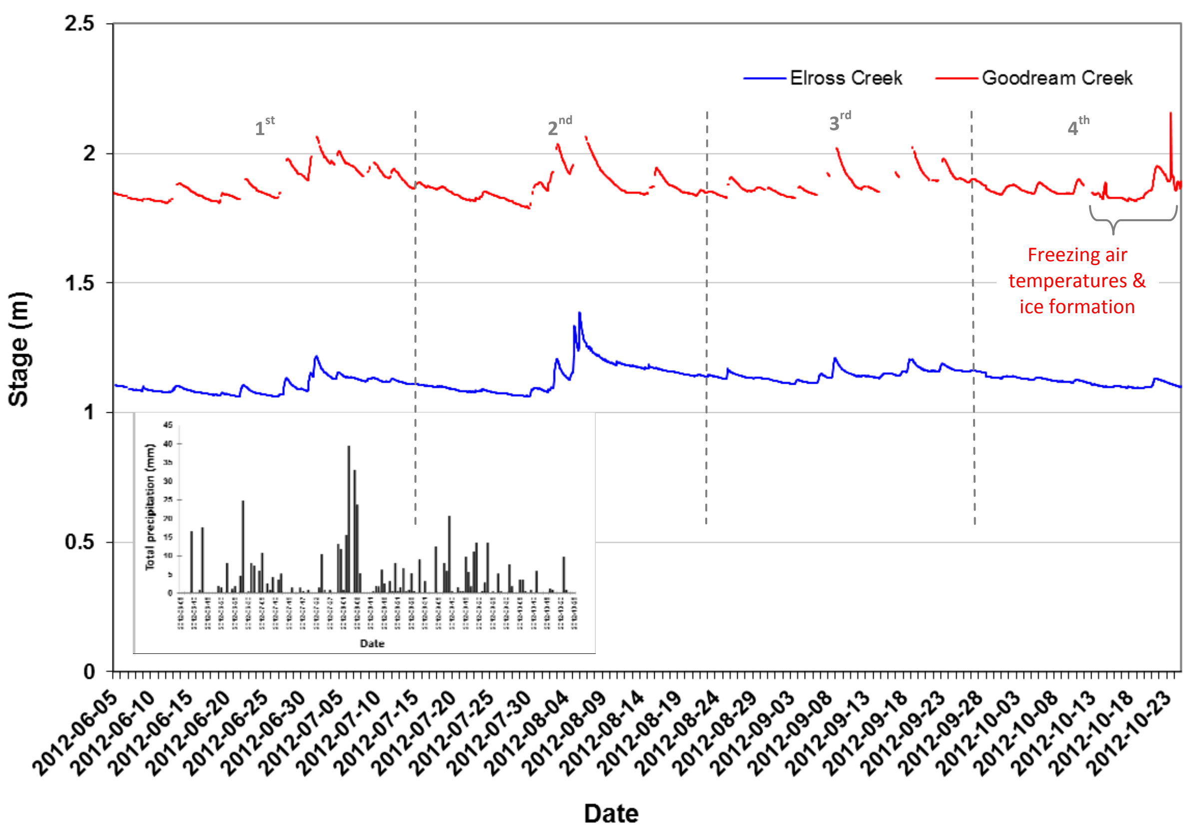


Figure 4. Hourly stage (m) values recorded at Elross Creek and Goodream Creek from June 5, 2012 to October 25, 2012. The inset chart shows total precipitation (mm) recorded at the Schefferville weather station during the same time period. All data was recorded by Environment Canada. The four deployment periods are demarcated with dashed lines.

## Temperature

- Water temperature ranged from 0.20˚C to 16.10˚C at Elross Creek and from 1.50˚C to 19.93˚C at Goodream Creek from June 5, 2012 to October 25, 2012 (Figure 5).
- 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. Diurnal variations were larger at Goodream Creek compared to Elross Creek, since Goodream Creek is a shallower stream, and as a result, more responsive to diurnal changes in air temperatures.
- Weekly trends in water temperature corresponded well with hourly air temperatures recorded by Environment Canada at the Schefferville weather station (Figure 5 inset, Appendix C).
- Water temperatures at Elross Creek were on average 0.87$^{o}$C colder than water temperatures at Goodream Creek. This difference was most noticeable during the first two deployment periods, and it was suspected that the smaller, shallower Goodream Creek was more responsive to the warming summer temperatures, compared to the slightly larger Elross Creek.

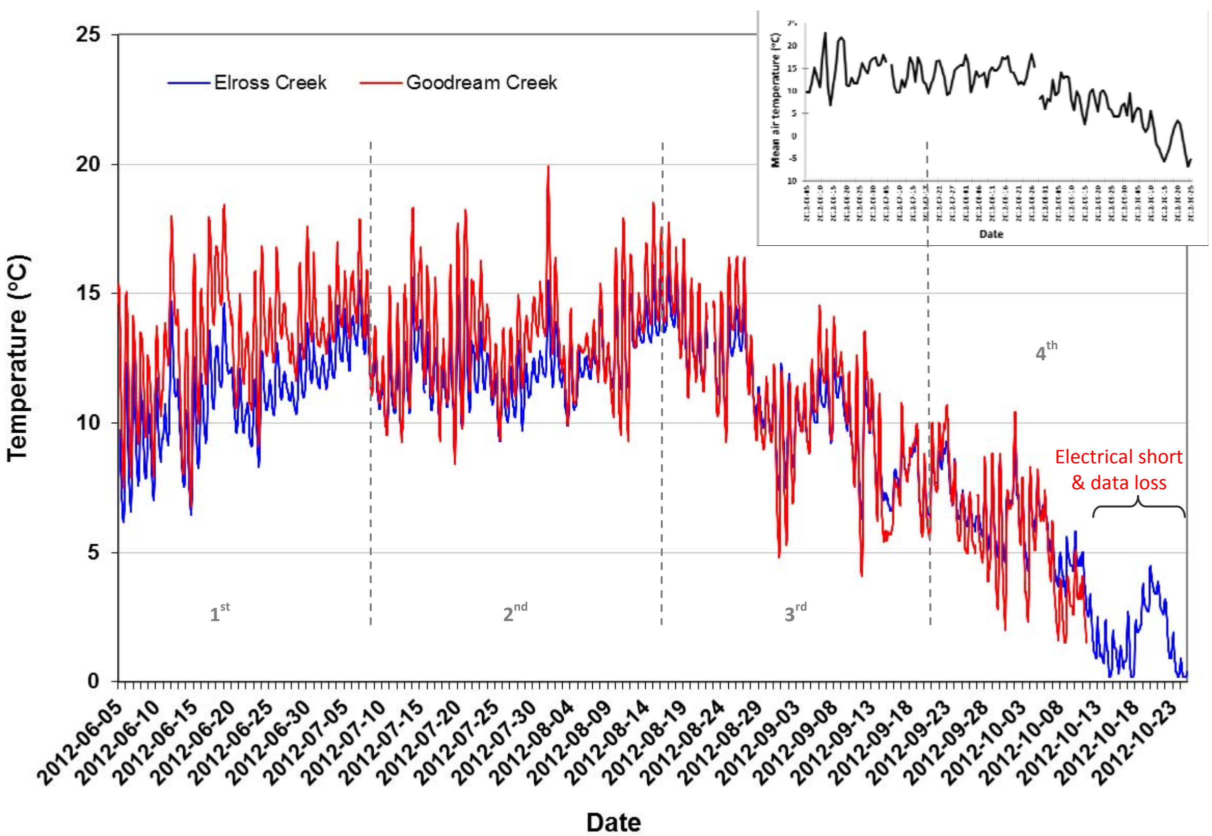


Figure 5. Hourly water temperature ($^{o}$C) values recorded at Elross Creek and Goodream Creek from June 5, 2012 to October 25, 2012. Inset chart shows air temperature during the same period, as recorded by Environment Canada at the Schefferville weather station. The four deployment periods are demarcated with dashed lines.

## pH

- pH values ranged from 5.56 units to 6.87 units at Elross Creek and from 5.18 units to 6.53 units at Goodream Creek from June 5, 2012 to October 25, 2012 (Figure 6).

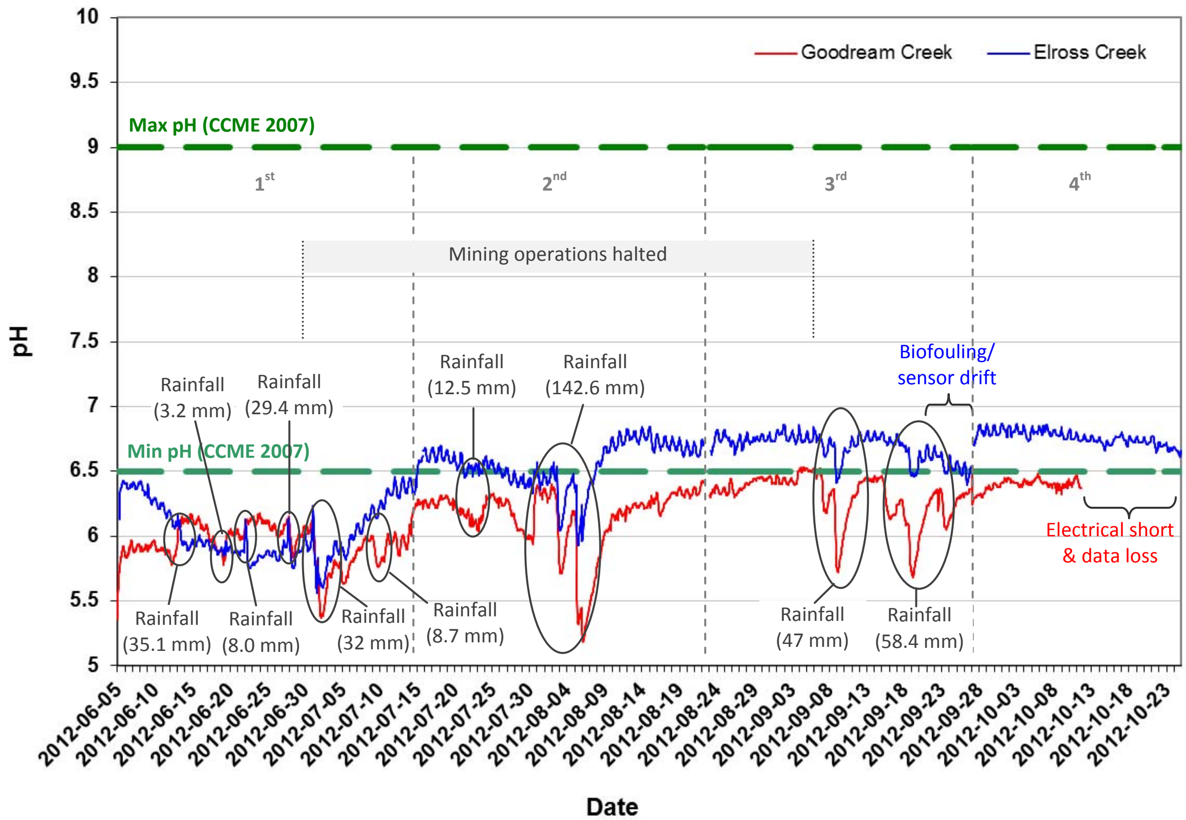


Figure 6. Hourly pH values recorded at Elross Creek and Goodream Creek from June 5, 2012 to October 25, 2012. The four deployment periods are demarcated with dashed lines.

- 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 corresponded well with changes in stage (Figure 4), and were primarily attributed to rainfall activity and surface runoff.
- The increase in pH from the first to the second deployment period could have been attributed to an increase in the photosynthetic cycling of $CO_2$ by aquatic organisms, which typically occurs during the warmer summer months (Appendix C).
- The work stoppage in mining operations from June 29, 2012 to September 5, 2012 did not appear to have any noticeable impact on pH levels.

- Biofouling and/or sensor drift may have influenced pH readings at the Elross Creek at the end of the third deployment period. Indeed, there was a marked increase in pH at Elross Creek during the transition from the third to the fourth deployment period, during which time the field instrument underwent a cleaning and calibration to abate any issues related to biofouling or sensor drift.
- Most pH values recorded at Elross Creek fluctuated above the minimum pH guideline set for the protection of aquatic life (i.e., 6.5 units), as defined by the Canadian Council of Ministers of the Environment (2007), while most pH values recorded at Goodream Creek fell below this minimum guideline. Low pH levels were considered normal for this area, based on baseline data collected around July 17-19, 2008 and September 10-12, 2008 (AMEC 2009, as cited in NML 2009). Indeed, baseline data was highly variable and acidic at times at the DSO3-15 sampling site (5.8-7.78 units) that is in close proximity to the Elross Creek station, as well as at sampling sites DSO3-11 and DSO3-14 (5.6-7.2 units) that are upstream from the Goodream Creek station.
- On average, pH was 0.30 units higher at Elross Creek than at Goodream Creek. This difference could be attributed to the past and present deposit of mining debris in the vicinity of Timmins 1 pit that drains into Elross Creek.

## Specific Conductivity

- Specific Conductivity ranged from 6.7 μs/cm to 20.4 μs/cm at Elross Creek and from 3.7 μs/cm to 7.0 μs/cm at Goodream Creek from June 5, 2012 to October 25, 2012 (Figure 7).
- 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.
- Weekly trends in specific conductivity were primarily influenced by rainfall events and surface runoff. The trends were more pronounced at the Elross Creek station, where the concentration of dissolved solids was expected to be more varied due to flow contribution from Timmins 1 mine site.
- The pause in mining operations, from June 29, 2012 to September 5, 2012, did not appear to have any noticeable impact on specific conductivity levels.
- On average, specific conductivity was 10.1 μS/cm higher at Elross Creek than at Goodream Creek. This difference could be attributed to the past and present deposit of mining debris in the vicinity of Timmins 1 pit that drains into Elross Creek.

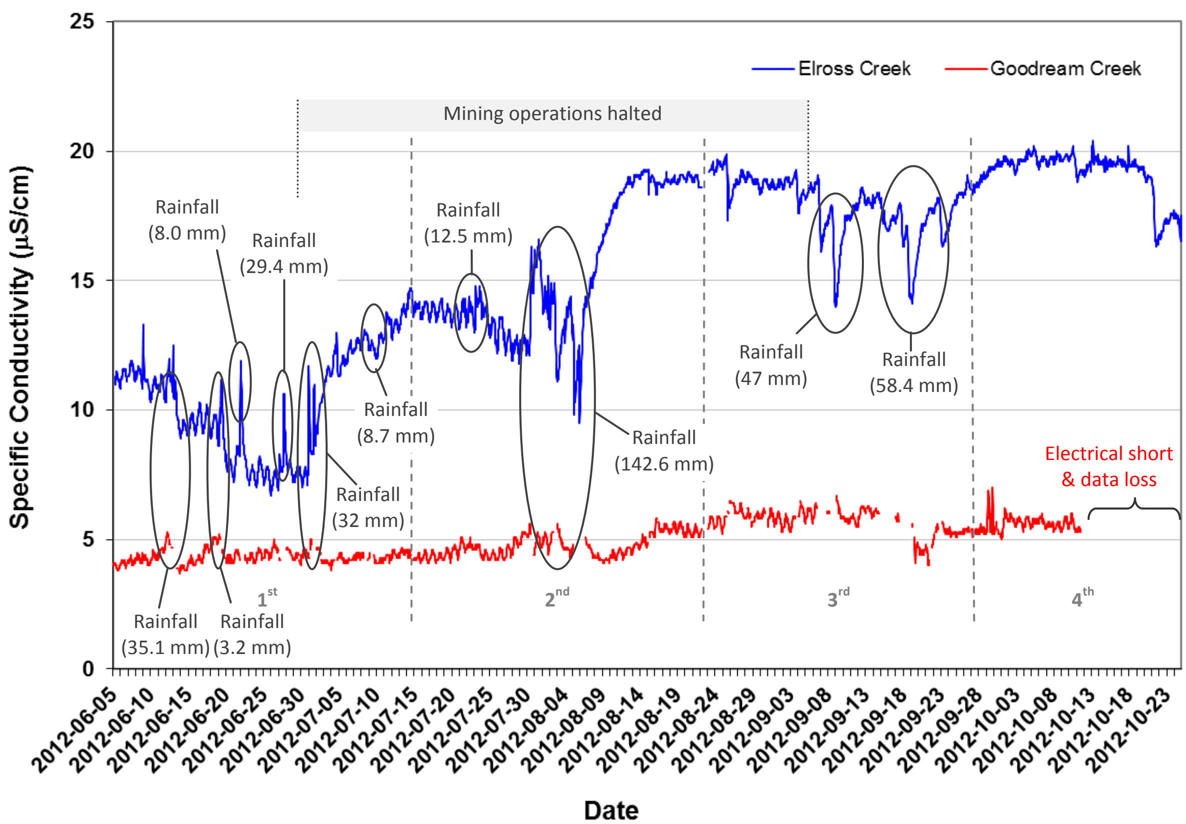


Figure 7. Hourly specific conductivity (μS/cm) values recorded at Elross Creek and Goodream Creek from June 5, 2012 to October 25, 2012. The four deployment periods are demarcated with dashed lines.

## Total Dissolved Solids

- Total Dissolved Solids (TDS) values ranged from 0.0043 g/l to 0.0130 g/l at Elross Creek and from 0.0024 g/l to 0.0045 g/l at Goodream Creek from June 5, 2012 to October 25, 2012 (Figure 8).
- TDS is calculated directly from specific conductance and temperature, and as a result TDS values show a similar trend to specific conductivity (Figure 7).
- The pause in mining operations, from June 29, 2012 to September 5, 2012, did not appear to have any noticeable impact on TDS levels.
- TDS values were on average 0.0064 g/l higher at Elross Creek compared to Goodream Creek. This difference could be attributed to the past and present deposit of mining debris in the vicinity of Timmins 1 pit that drains into Elross Creek.

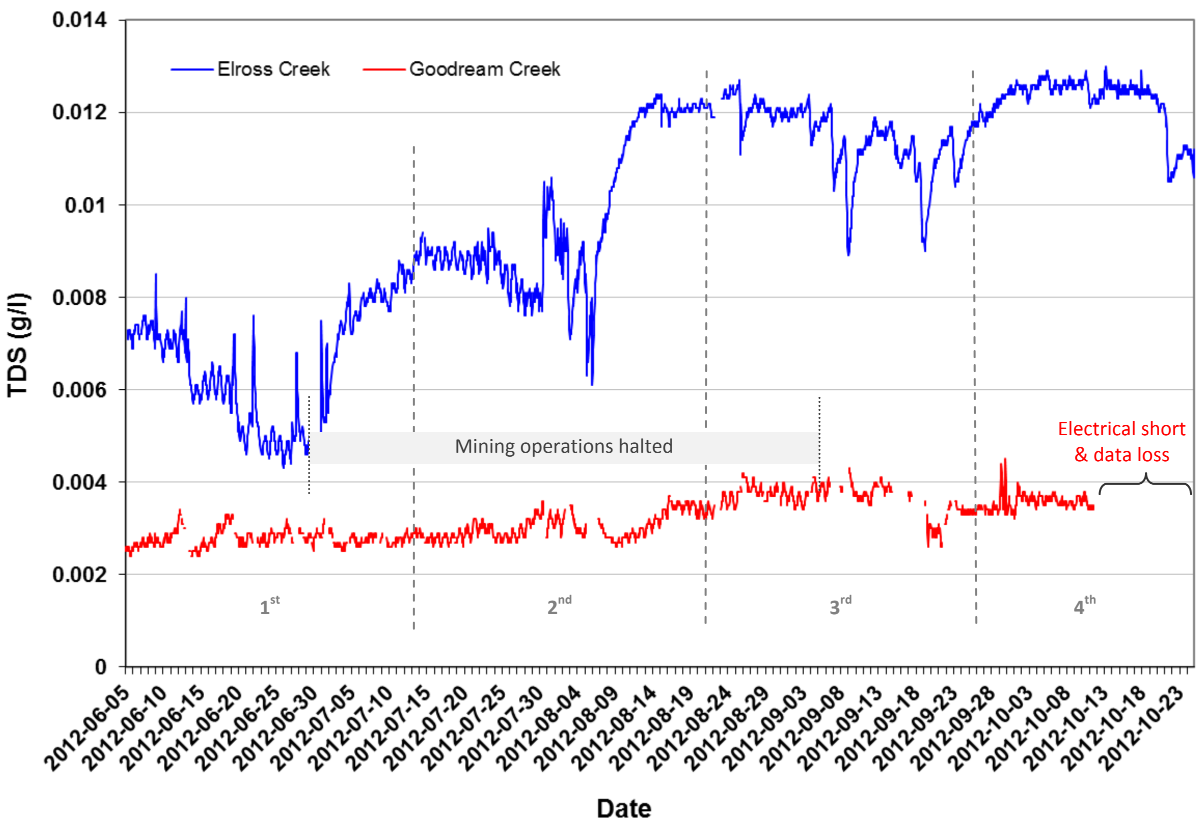


Figure 8. Hourly TDS (g/l) values recorded at Elross Creek and Goodream Creek from June 5, 2012 to October 25, 2012. The four deployment periods are demarcated with dashed lines.

## Dissolved Oxygen

- Dissolved Oxygen (DO) values ranged from 8.88 mg/l to 13.37 mg/l at Elross Creek and from 6.34 mg/l to 12.93 mg/l at Goodream Creek from June 5, 2012 to October 25, 2012 (Figure 9).
- 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 5), since colder water has a greater potential to dissolve oxygen compared to warmer water.
- On average, DO values were 0.12 mg/l higher at Elross Creek compared to Goodream Creek. This difference can be attributed to average water temperatures being colder at Elross Creek compared to Goodream Creek (Figure 5).
- DO values at both stations fell below cold water minimum guidelines set for aquatic life during early life stages (9.5 mg/l), but were generally above minimum guidelines set for other life stages (6.5 mg/l), as determined by the Canadian Council of Ministers of the Environment (2007). The one exception where DO values fell below the 6.5 mg/l guideline was on July 30, 2012, at which time low stage and high water temperatures contributed to this decrease.

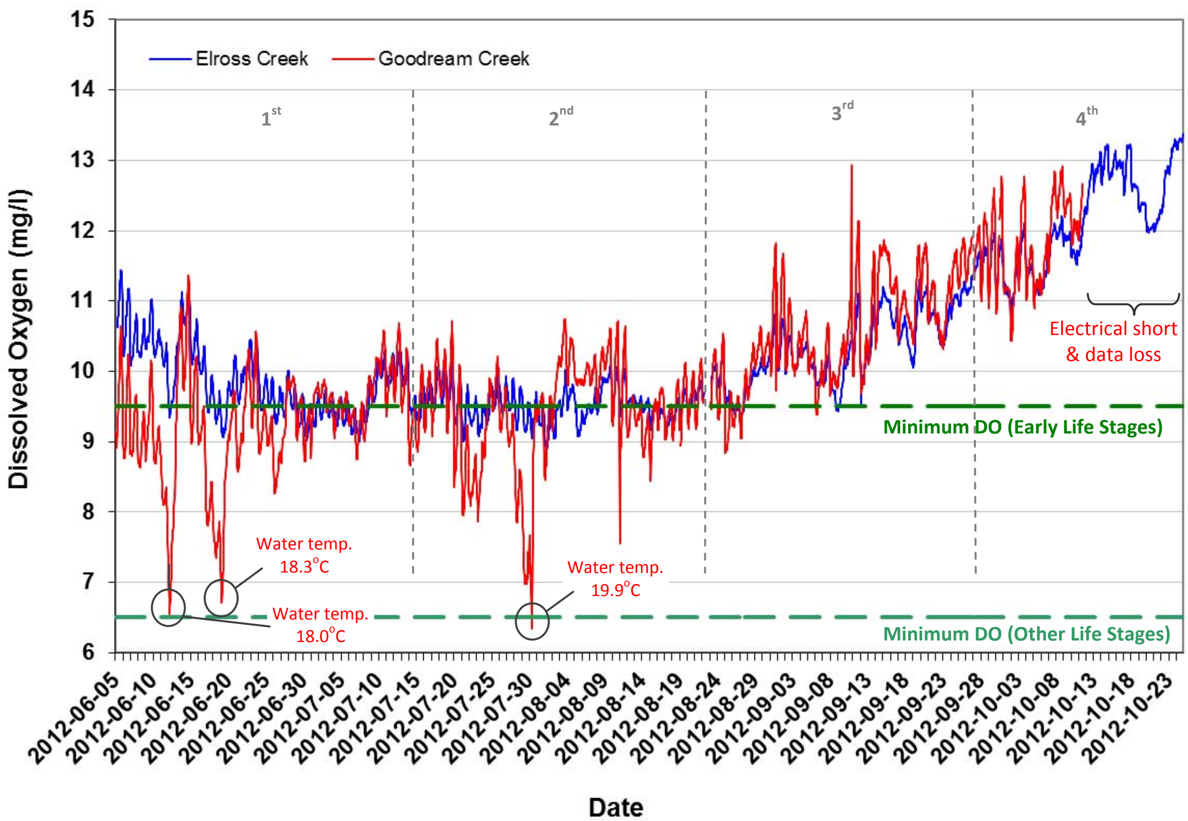


Figure 9. Hourly dissolved oxygen (mg/l) values recorded at Elross Creek and Goodream Creek from June 5, 2012 to October 25, 2012. The four deployment periods are demarcated with dashed lines.

## Turbidity

- Turbidity values ranged from 0.0 NTU to 2988.0 NTU at Elross Creek and 0.0 NTU to 472.0 NTU at Goodream Creek from June 5, 2012 to October 25, 2012 (Figure 10).

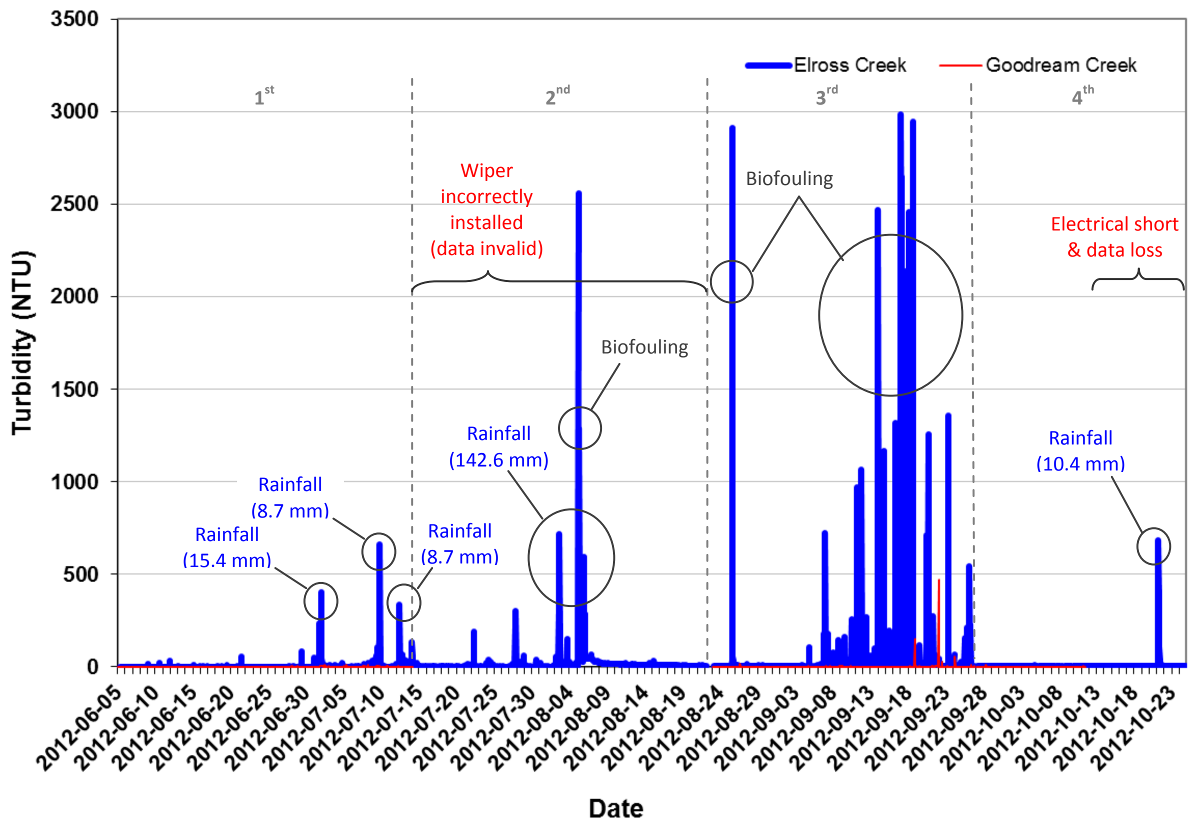


Figure 10. Hourly turbidity (NTU) values recorded at Elross Creek and Goodream Creek from June 5, 2012 to October 25, 2012. The four deployment periods are demarcated with dashed lines.

- Turbidity data collected during the second deployment period at the Goodream Creek station was invalid and omitted from Figure 10. The problem was with the turbidity wiper, which had repositioned itself over the sensor window shortly after the start of the second deployment. This repositioning of the wiper affected sensor readings, resulting in invalid data being collected for the entire second deployment period.
- There were both relatively moderate (e.g., 100-1000 NTU) and large (e.g., 1000-3000 NTU) turbidity events measured at both stations. The moderate events typically coincided with rainfall activity (Appendix C) and increases in stage (Figure 4), whereas the large turbidity events were attributed to biofouling.

- Instances of biofouling occurred during the second and third deployment periods.
  - At the end of the second deployment period, silt sediment was found inside the Elross Creek water quality instrument casing, which may have triggered the large turbidity event on August 5-6, 2012. Rainfall amounts were high during that week of July 30, 2012 to August 7, 2012 (i.e., 142.6 mm), which would have increased stream flow rates and stream sediment loads. Historical silt sediment found on the bottom substrate of Elross Creek, may have become suspended at this time, causing the large increase in turbidity. To prevent silt from lodging inside the instrument casing, the instrument was redeployed on a rocky substrate before the start of the third deployment period.
  - Biofouling was thought to be responsible for causing large spikes in turbidity during the third deployment period. Figure 11 shows a mix of leaves and sediment that was found interspersed in and around the instrument sensors at both stations on September 27, 2012. To prevent leaves and other debris from interfering with the sensors, station instruments were wrapped in a nylon mesh before their redeployment on September 27, 2012.

a. Elross Creek b. Goodream Creek

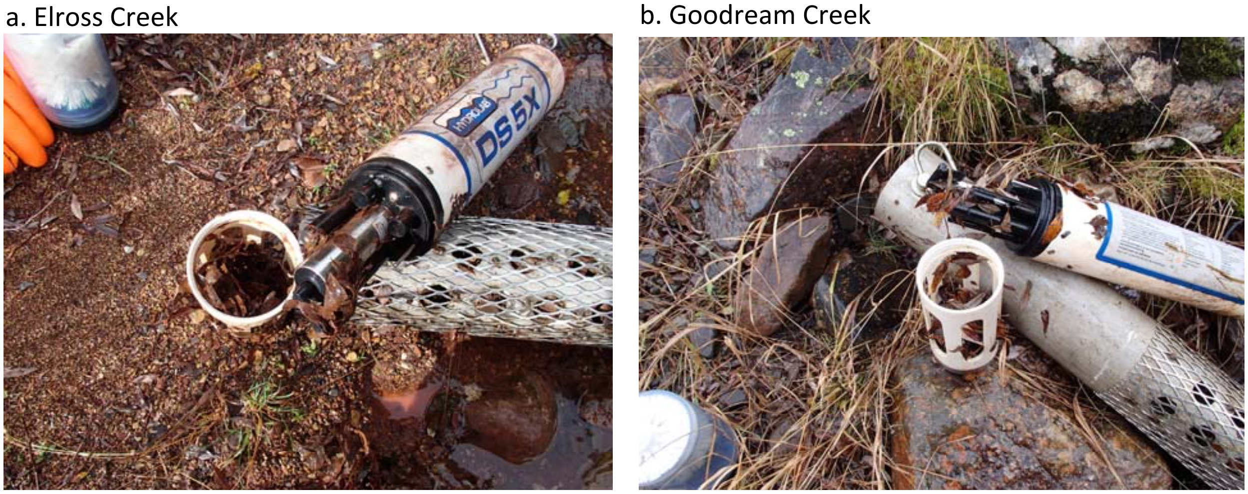


Figure 11. A mix of leaves and sediment were found tangled in and around the instrument sensors at (a) Elross Creek and (b) Goodream Creek on September 27, 2012.

## Conclusions

- Water quality monitoring instruments were deployed at two stations near the Elross Lake, Iron Ore Mine between June 5, 2012 and October 25, 2012. The stations are located on Elross Creek and Goodream Creek.
- The performance ratings of all instrument sensors ranged between *poor*-to-*excellent* at the beginning and end of each of the four deployment periods.
- The turbidity sensor at the Elross Creek station was given a fair performance rating at the end of second deployment, which was attributed to biofouling in the form of silt build-up inside the protective casing of the field instrument.
- The turbidity sensor at the Goodream Creek station was given a poor performance rating at the end of second deployment period, which was caused by the incorrect placement of the turbidity wiper over its sensor window. Turbidity data collected during this period was removed from the dataset and omitted from this report.
- Dissolved oxygen sensors at both stations received fair performance ratings at the end of the fourth deployment season. The fair performance was attributed to a malfunctioning QA/QC sensor used to rate field sensor performance at that time.
- Transmission errors occurred sporadically during the first, second and third deployment periods at the Goodream Creek station, resulting in the loss of 375 hourly data records. The timing of the data losses primarily coincided with rainfall events. EC was notified of this issue.
- Water quality monitoring stopped at Goodream Creek from October 12, 2012 to October 25, 2012. It was suspected that freezing temperatures and ice formation caused water to come in contact with the instrument's electrical components, resulting in an electrical short and the instrument to malfunction.
- Mining operations were halted on June 29, 2012 and resumed around September 5, 2012.
- Variations in water quality/quantity values recorded at each station are summarized below:
  - STAGE: Daily variations in stage were negligible, however weekly variations coincident with rainfall events, and in the case of the Goodream Creek station, to ice formation during the end of the fourth deployment period.
  - WATER TEMPERATURE: Daily and weekly trends in water temperature were attributed to fluctuations in ambient air temperature.
  - pH: Most pH values recorded at Elross Creek fluctuated above the minimum pH guideline set for the protection of aquatic life, while most pH values recorded at Goodream Creek fell below this minimum guideline. Daily trends in pH were attributed to the photosynthetic cycling of $CO_2$ by aquatic organisms and weekly trends corresponded well with changes in stage, and were primarily influenced by rainfall activity and surface runoff.
  - SPECIFIC CONDUCTIVITY & TDS: Daily fluctuations in specific conductivity and TDS were attributed to the photosynthetic cycling of $CO_2$ by aquatic organisms. Weekly fluctuations coincident with rainfall activity and surface runoff.

- DISSOLVED OXYGEN: DO values at both stations were generally 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: Relatively moderate turbidity events (e.g., 100-1000 NTU) typically coincided with rainfall activity and increases in stage, whereas large turbidity events (e.g., 1000-3000 NTU) were attributed to biofouling.

## Path Forward

- ENVC staff will redeploy RTWQ instruments at Elross Creek and Goodream Creek in spring 2013, when ice conditions allow, and perform regular site visits throughout the 2013 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 TSMC 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.
- Parameter alerts will be set prior to the 2013 deployment season to notify ENVC staff by email of any emerging water quality issues.
- TSMC 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. TSMC will also receive an annual report, summarizing the events of the deployment season.
- 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 TSMC 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).

AMEC, 2009, Fish and Fish Habitat Investigation for the Direct-Shipping Ore Project. Report No. TF 8165902. Submitted to Groupe Hémisphères for New Millennium Capital Corp.

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).

NML, 2009, Elross Lake Area Iron Ore Mine, Environmental Impact Statement, submitted to Government of Newfoundland and Labrador, December 2009. Online: http://www.env.gov.nl.ca/env/env_assessment/projects/Y2010/1380/nml_pfwa_eis_for_gnl_december_2009.pdf (accessed October 12, 2012).

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<br>yyyy-mm-dd | Max Temp<br>°C | Min Temp<br>°C | Mean Temp<br>°C | Heat Deg Days<br>°C | Cool Deg Days<br>°C | Total Precip<br>mm | Avg Wind Spd<br>Km/hr | Avg Wind Dir<br>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<br>yyyy-mm-dd | Max Temp<br>°C | Min Temp<br>°C | Mean Temp<br>°C | Heat Deg Days<br>°C | Cool Deg Days<br>°C | Total Precip<br>mm | Avg Wind Spd<br>Km/hr | Avg Wind Dir<br>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)

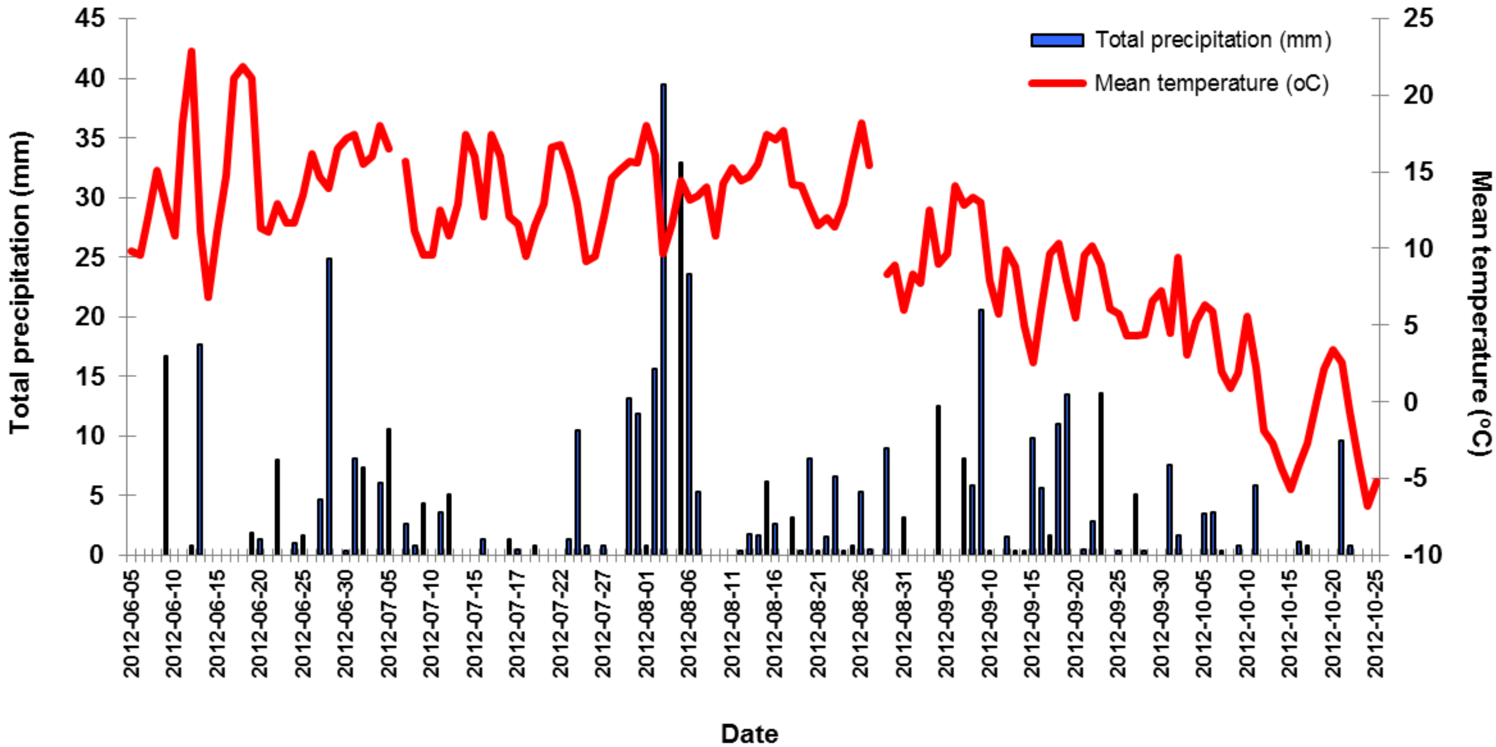


Figure 1. Daily precipitation and mean temperature recorded at the Schefferville Weather Station by Environment Canada from June 5, 2012 to October 25, 2012.

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

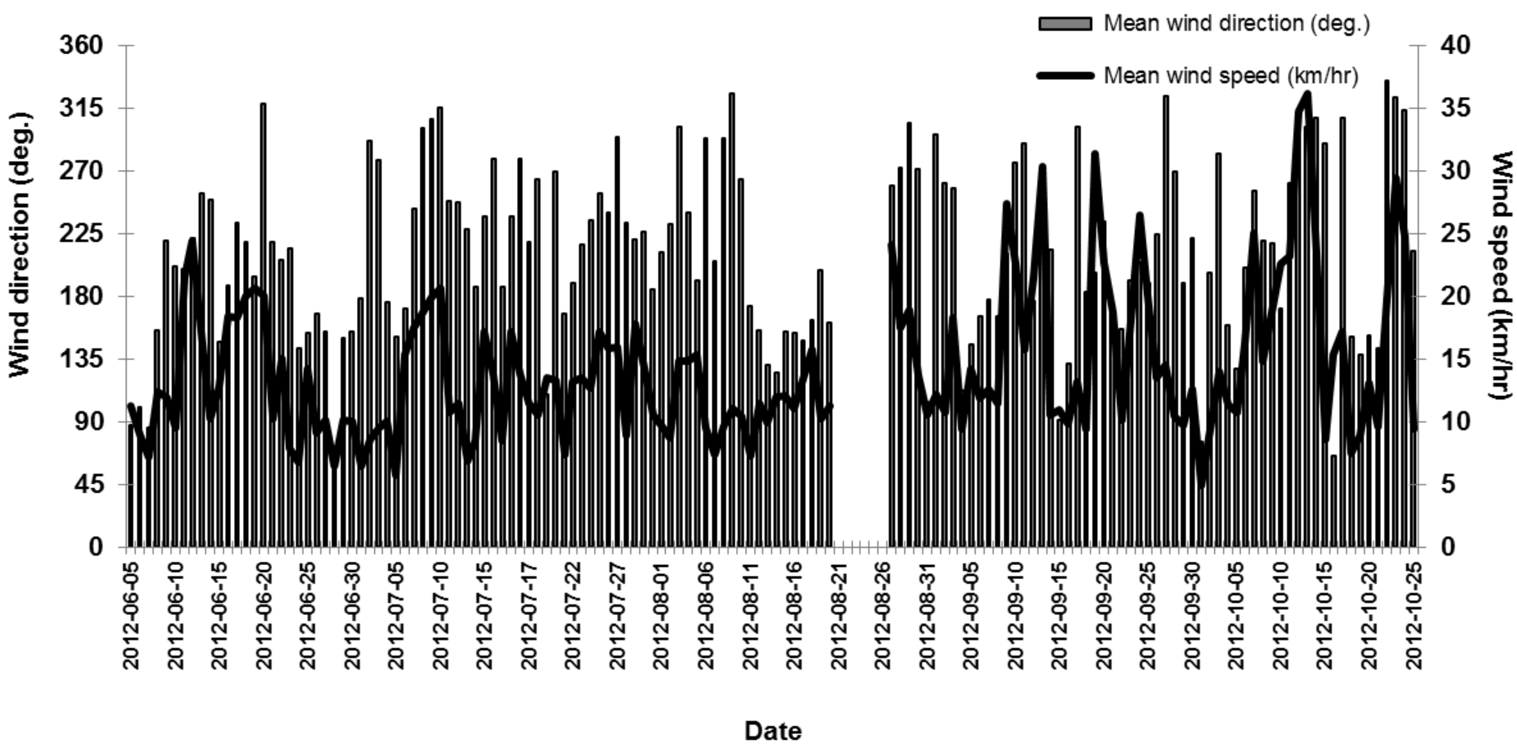


Figure 2. Mean daily wind direction and wind speed recorded at the Schefferville Weather Station by Environment Canada from June 5, 2012 to October 25, 2012.