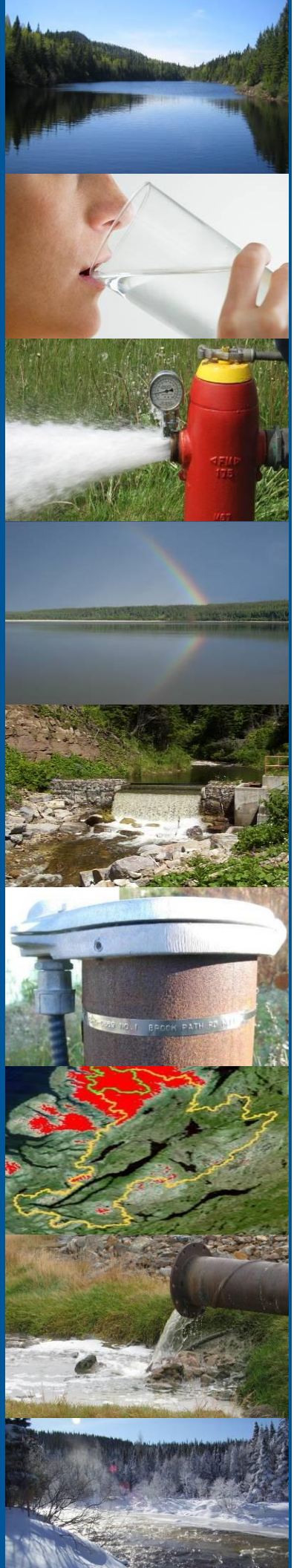

Real-Time Water Quality Report

Waterford River
@
Kilbride

NF02ZM0009

Deployment Period
April 29, 2014 to June 16, 2014

Newfoundland Labrador

Government of Newfoundland & Labrador
Department of Environment and Conservation
Water Resources Management Division

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General

- The Water Resources Management Division monitors real-time water quality data on a daily basis.
- The instrument used for the deployment period of April 29, 2014 to June 16, 2014 was a YSI 6600 series multi-probe, which continuously measured water temperature, pH, dissolved oxygen, specific conductivity and turbidity.
- The instrument was deployed for 49 days.

Quality Assurance and Quality Control

- As part of the Quality Assurance and Quality Control (QA/QC), an assessment of the reliability of data recorded by the instrument is made at the beginning and end of the deployment period.
- This procedure is based on the approach used by the United States Geological Survey and is outlined in Appendix A.
- At deployment and removal, a QA/QC Sonde is temporarily deployed alongside the Field Sonde
- Values for temperature, pH, conductivity, dissolved oxygen and turbidity are compared between the two instruments.
- Based on the difference between the parameters measured on the Field Sonde and the QA/QC Sonde at deployment and removal, a qualitative statement is made on the data quality (Table 1).

Table 1: Instrument Performance Ranking classifications for deployment and removal

	Rank				
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 (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) (% Sat)	<=+/-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 (%)	<=+/-5	>+/-5 to 10	>+/-10 to 15	>+/-15 to 20	>+/-20

- It should be noted that the temperature sensor on any sonde is the most important. All other parameters can be divided into subgroups of: temperature dependant, temperature compensated and temperature independent.
- Due to the importance of this parameter it is necessary for temperature to stabilize first, if a reading is taken too soon it may not accurately portray the water body.
- Deployment and removal instrument performance rankings for the station at Waterford River at Kilbride for the period of April 29, 2014 to June 16, 2014 are summarized in Table 2.

Table 2: Instrument performance rankings for Waterford River at Kilbride

Station	Date	Action	Comparison Ranking				
			Temperature	pH	Conductivity	Dissolved Oxygen	Turbidity
Waterford River	April 29, 2014	Deployment	Good	Excellent	Good	Excellent	Excellent
	June 16, 2014	Removal	Good	Good	Good	Poor	Poor

- During the deployment at Waterford River at Kilbride Station, pH, dissolved oxygen, and turbidity all ranked as 'excellent'. With temperature and conductivity ranking as 'good'.
- At removal, water temperature, pH, and conductivity ranked as 'good'. Dissolved oxygen and turbidity ranked as 'poor'. The poor ranking is likely a result of a large amount of debris and mud clogging the sensors which was noted when the Field Sonde was removed.

Data Interpretation

- Performance issues and data records were interpreted, for each station during the deployment period, for the following eight parameters:
  - Temperature (oC)
  - pH
  - Stage (m)
  - Flow (m^3/s)
  - Specific conductivity (µS/cm)
  - Total dissolved solids (g/l)
  - Dissolved oxygen (mg/l or % saturation)
  - Turbidity (NTU)
- With the exception of water quantity data (stage & flow), all data in the preparation of the graphs and subsequent discussions below adhere to this QAQC protocol. Water Survey of Canada is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.
- A brief description of each parameter is provided in Appendix B.
- The Waterford River at Kilbride instrument stopped transferring water quality data to its datalogger on May 11, 12, and June 7 for short periods of time (less than 10 hours). The data was not logged directly to the instruments log file resulting in brief periods of no data recorded.

Water Temperature

Water temperature ranged from 1.34 °C to 17.26 °C during this deployment period (Figure 1). There are noticeable increases and decreases in the water temperature during the deployment period. This is consistent with ambient air temperatures recorded by Environment Canada at the St. John's International Airport weather station over this time period, generally increasing during daylight hours and cooling overnight (Appendix C).

The higher water temperatures indicated on the graph also correspond with higher averaged daily air temperatures. Dips in water temperatures can indicate rainfall events; rainfall can lower the water temperature slightly over a short period of time.

A drop in ambient air temperature and a large precipitation event (~70 mm) resulted in lower water temperature from May 26 to May 31, 2014.

The water temperatures at this station display diurnal variations. Shallow streams and ponds are highly influenced by natural diurnal variations in the surrounding air temperatures.

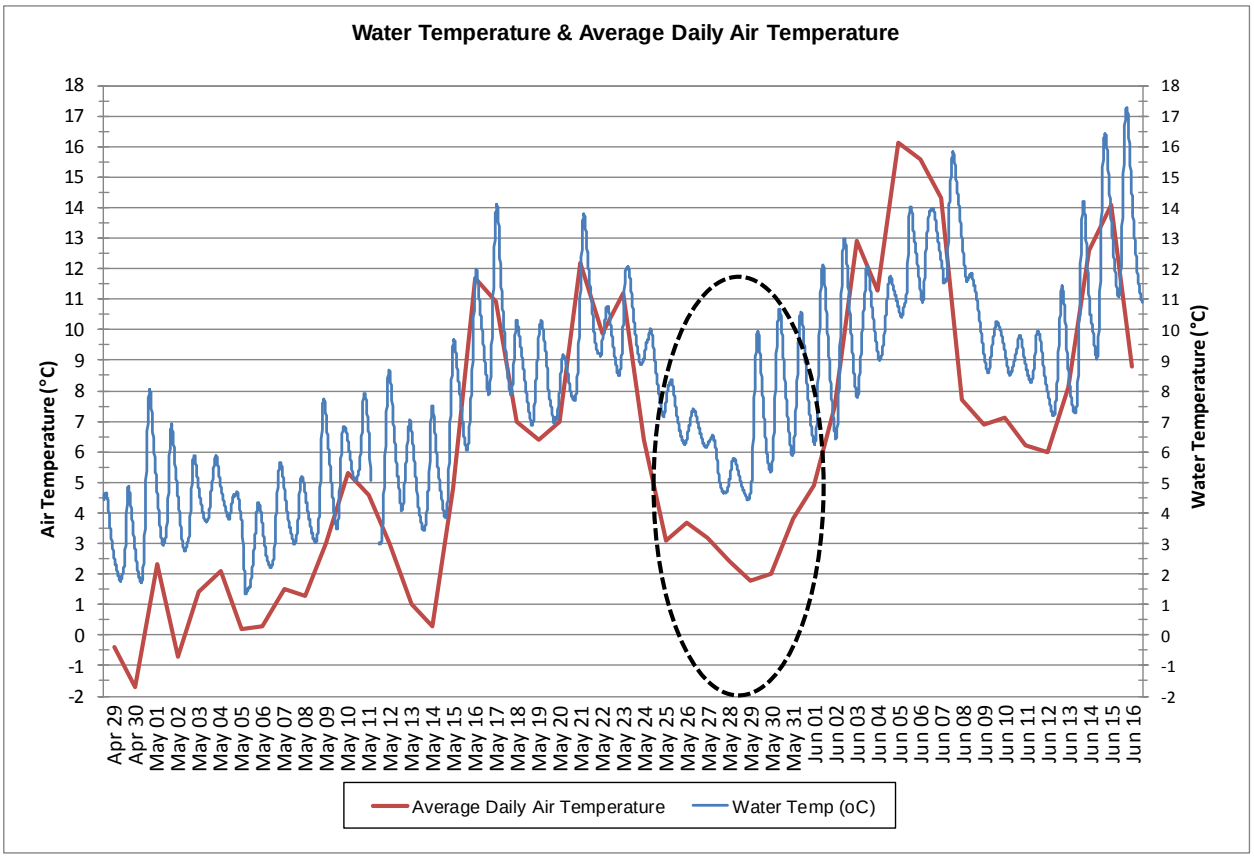

Figure 1: Water temperature (°C) values at Waterford River at Kilbride Station and daily air temperature at St. John's International Airport

pH

Throughout this deployment period pH values ranged between 6.55 pH units and 7.41 pH units (Figure 2).

The CCME guideline for the Protection of Aquatic Life provides a basis by which to judge the overall health of the river. The pH at the station remained between the CCME guidelines of 6.5 to 9.0 with a median value of 7.07 over the deployment period.

The pH dipped on May 31st, 2014, close to the lower limit of the CCME guideline (6.55 pH units). This drop in pH corresponded with an increase in stage level during a significant rainfall event that occurred in the days preceding the pH dip (~70 mm).

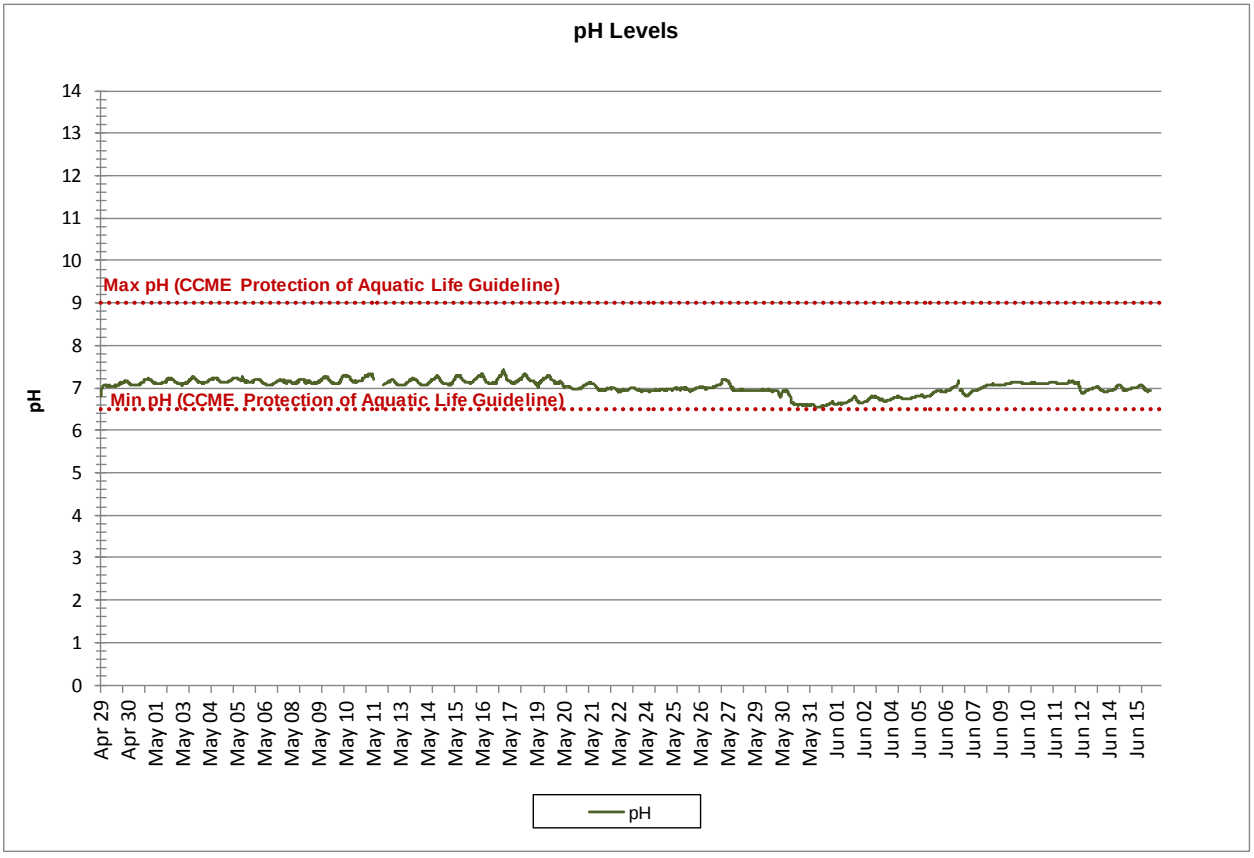

Figure 2: pH levels at Waterford River at Kilbride Station

Specific Conductivity & TDS

The conductivity levels were between 200.0µS/cm and 1007.0µS/cm and the Total Dissolved Solids (TDS) ranged from 0.1300 g/L to 0.655 g/L during the deployment period.

When stage levels rise, the specific conductance levels drop in response as the increased amount of water in the river system dilutes the solids that are present.

On May 6th and 7th, there are several peaks in conductivity which can likely be attributed to the application of road salt. A mixed precipitation event (rain and snow) occurred on May 5th, 2014 (Figure 3). With daily average air temperature hovering around the freezing point on the days surrounding the spike in conductivity it is likely that a mixture of road salt and precipitation melt ran off into the river (Appendix C).

TDS, is a parameter that the instrument calculates by an algothrim that utilizes the data from specific conductivity and water temperature to produce a TDS value. TDS generally always mirrors specific conductivity.

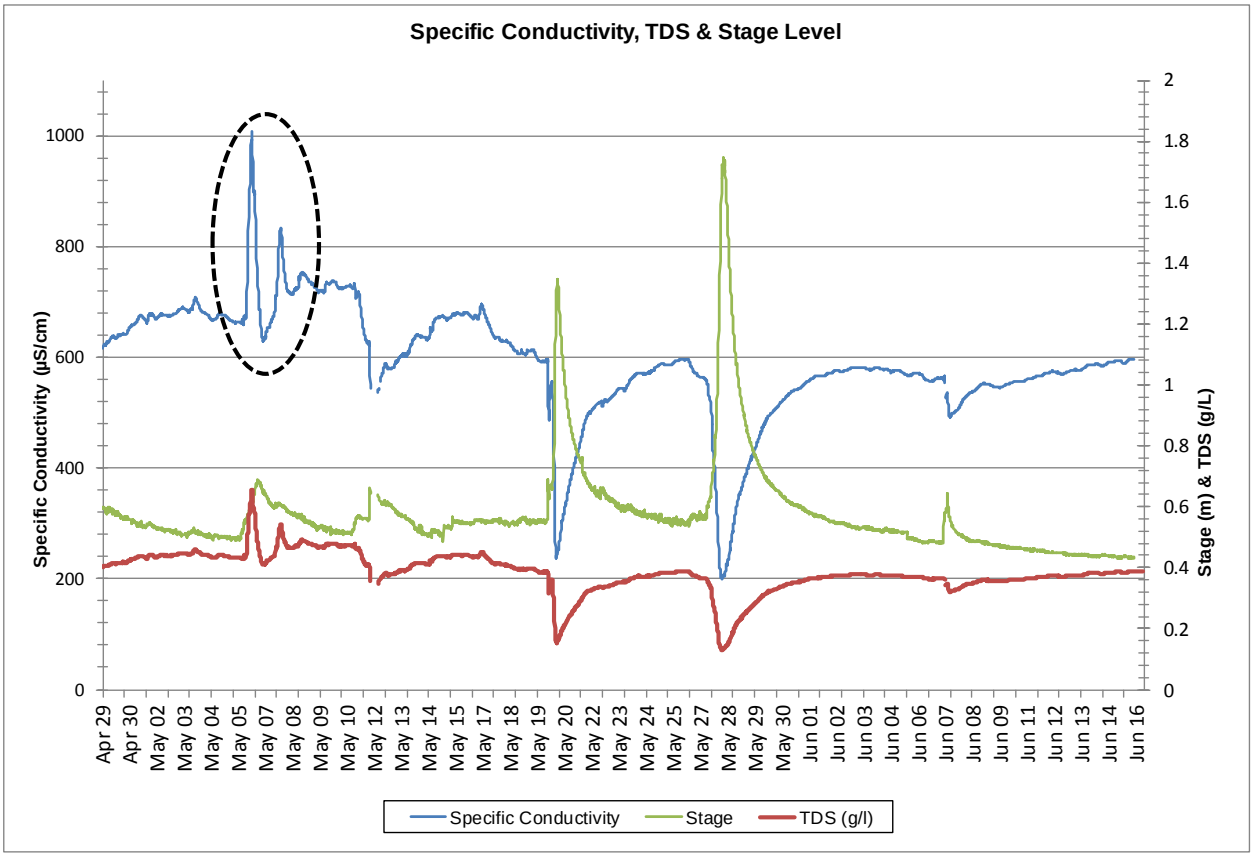

Figure 3: Specific conductivity (uS/cm), TDS (g/L) and stage (m) values for Waterford River at Kilbride Station

Dissolved Oxygen

The water quality instrument measures dissolved oxygen (mg/L) with the dissolved oxygen probe and then the instrument calculates percent saturation (% Sat) with water temperature.

The Dissolved Oxygen % Sat levels ranged from 37.1% Sat to 108.1% Sat and dissolved oxygen measured between 4.07 mg/L to 13.30 mg/L.

During this deployment the dissolved oxygen levels showed initial diurnal fluctuation with water temperature and air temperature (Figure 2). As water temperature increases the level of dissolved oxygen consumed increases, which means there is less dissolved oxygen in the river during the day when air temperature and water temperature rise.

The dissolved oxygen data after May 17th until the end of the deployment period on June 16th indicate that the DO sensor failed to operate properly. Upon removal of the sonde it was noted that the DO sensor had failed due to the presence of mud/silt around the sensor (Figure 4). As shown in the QA/QC procedure DO was given a poor ranking due to mud/silt covering the sensor. This data should not be used as valid readings or included in any statistical analysis.

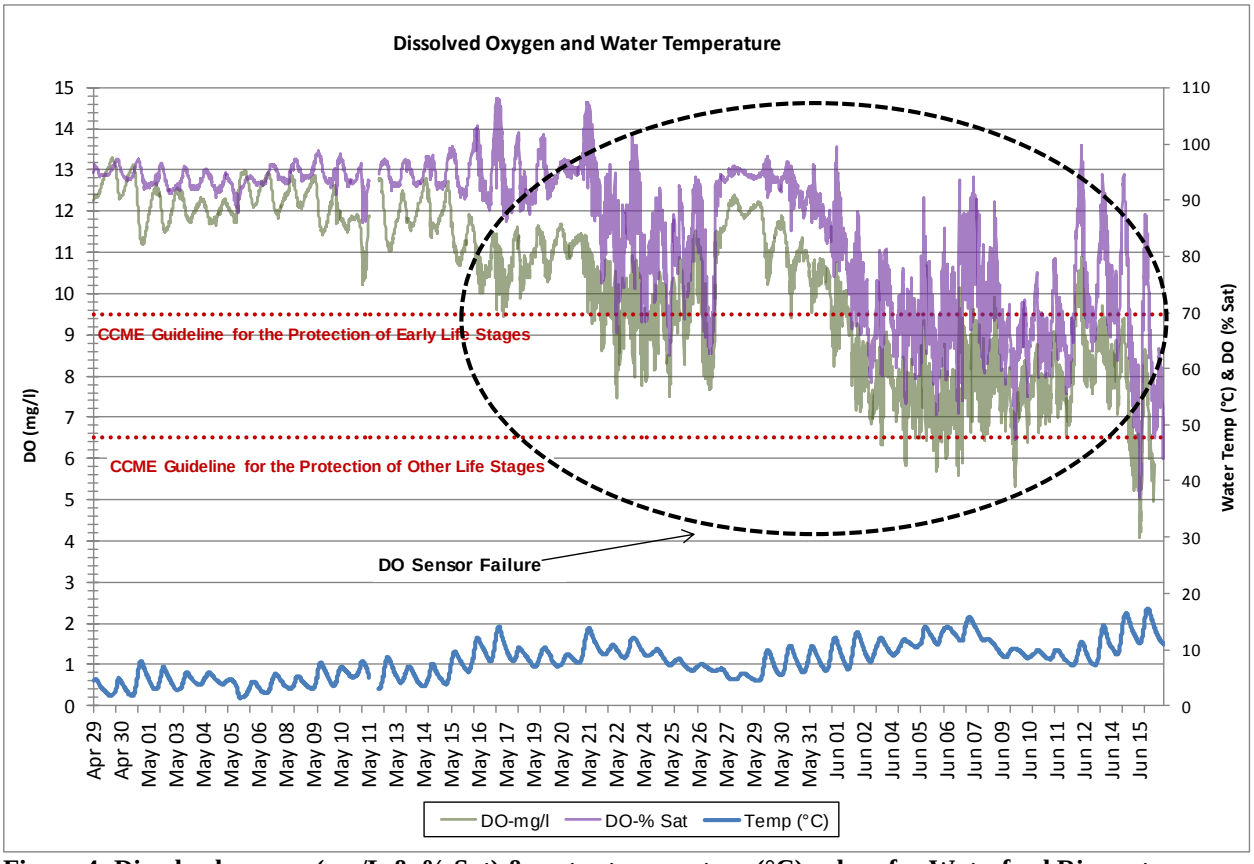

Figure 4: Dissolved oxygen (mg/L & % Sat) & water temperature (°C) values for Waterford River at Kilbride Station

Turbidity

Turbidity levels during this deployment period ranged within 0.9 NTU and 949.3 NTU (Figure 5). The median turbidity during the deployment period was 7.3 NTU.

The turbidity sensor on this instrument can read turbidity values between 0 NTU and 3000 NTU. However a turbidity reading of 3000 NTU is always identified as an error reading and should not be used as a valid reading or included in any statistical analysis.

Most of the turbidity events in the deployment period correlate with increases in stage from precipitation events (Figure 5). Precipitation can increase the presence of suspended material in water as seen clearly on May 5th, 20th, and 27th.

Upon removal the QA/QC ranking for turbidity was poor. It is possibly that after the significant rainfall event (May 27th, 2014) the sensor calibration was disrupted. It was also noted that the sonde was covered in mud/silt upon removal from the river.

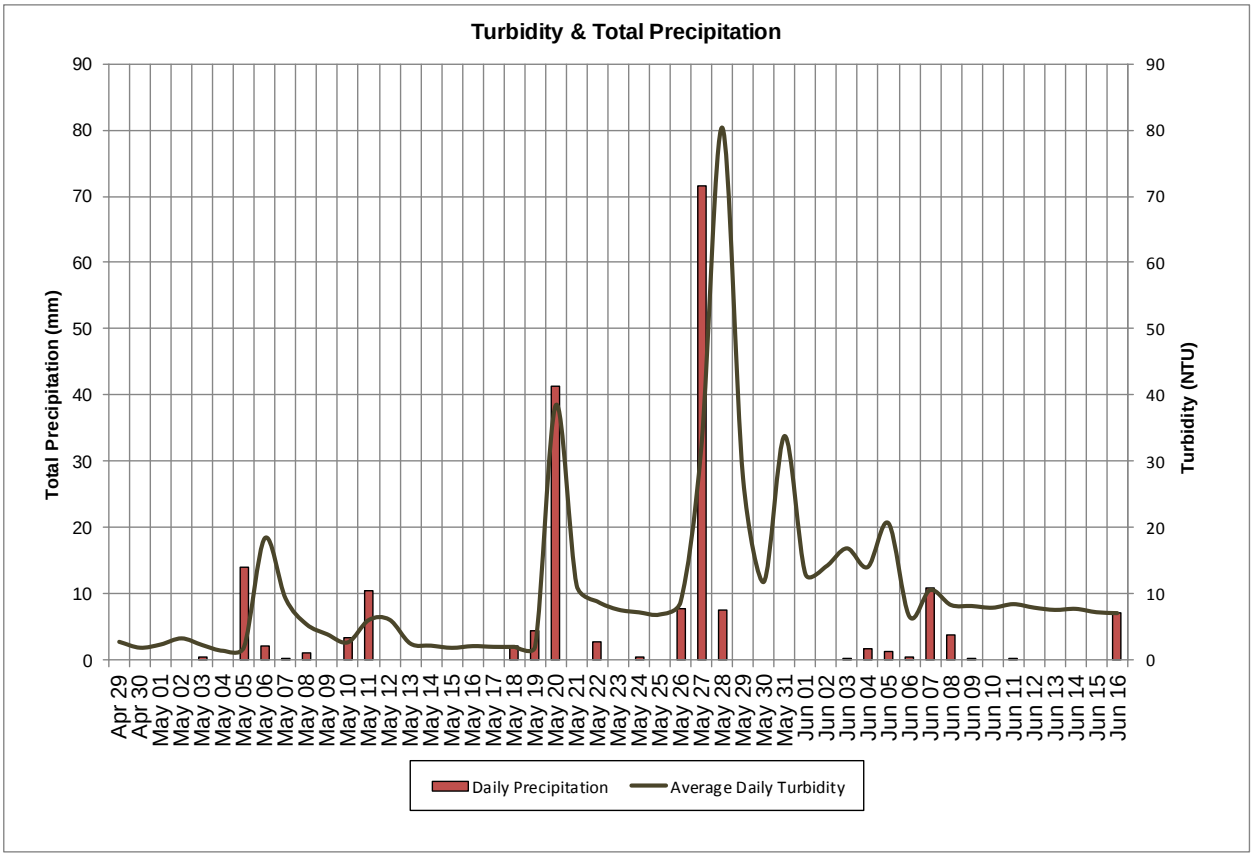

Figure 5: Turbidity (NTU) at Waterford River at Kilbride Station and Daily Precipitation (mm) at St. John's International Airport

Stage & Stream Flow

Stage can be defined as the height or elevation of the stream's water surface above a reference elevation (sea level, gage level)**.** Stage is important to display as it provides an estimation of water level at the station and can explain some of the events that are occurring with other parameters (i.e. Specific Conductivity, DO, turbidity).

Stream flow can be defined as the volume of water in a river at a specific location and time. It is measured in cubic meters per second.

Stage and Stream flow will increase during rainfall events and during any surrounding snow or ice melt as runoff will collect in the river. However, direct snowfall will not cause them to rise significantly. During the deployment period, the stage values ranged from 0.43m to 1.75m. The stream flow values ranges from 0.64m^3/s to 35.90m^3/s .The larger peaks in stage and stream flow do correspond with substantial rainfall events as noted on Figure 5.

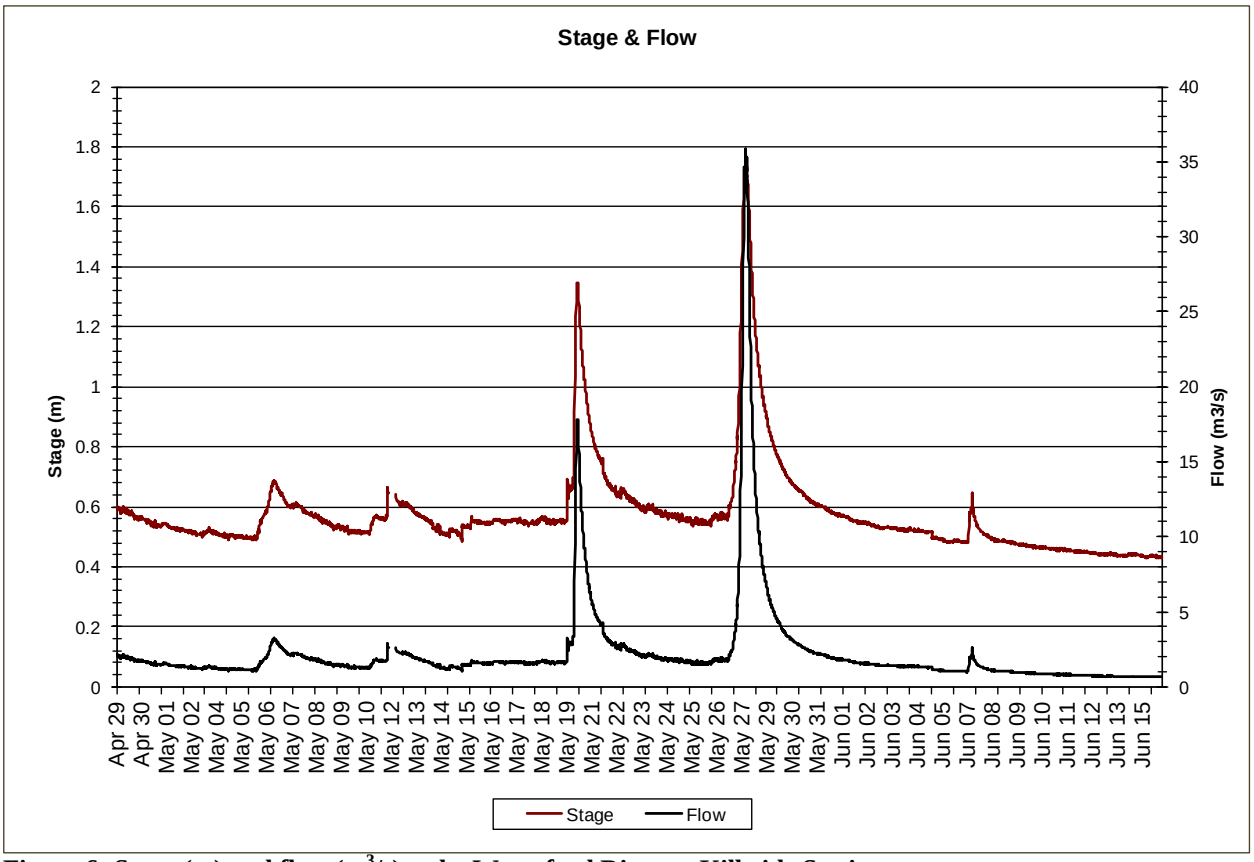

Figure 6: Stage (m) and flow (m^3/s)at the Waterford River at Kilbride Station

Conclusion

- The data shows evidence that large spikes in stage level were a result of several rainfall events as displayed in Figure 5 & 6. Rainfall events can also influence changes in water temperatures, conductivity, pH, DO and turbidity in the water column.
- As ambient air temperatures increase with the seasonal changes it is reflected in the water temperature. Diurnal water temperature patterns are also noted with the increasing temperatures during sunlight hours.
- This river flows through significantly developed areas, including residential, commercial, and industrial zones within the boundaries of heavily used road ways, which can influence the water quality parameters in the areas of turbidity increases or conductivity increases when runoff from residential areas is a factor.
- On May 6th and 7th, there are several peaks in conductivity which can likely be attributed to the application of road salt. A mixed precipitation event (rain and snow) occurred on May 5th, 2014 (Figure 3). With daily average air temperature hovering around the freezing point on the days surrounding the spike in conductivity it is likely that a mixture of road salt and precipitation melt ran off into the river (Appendix C).
- The dissolved oxygen data after May 17th until the end of the deployment period on June 16th indicate that the DO sensor failed to operate properly (Figure 4). This data should not be used as valid readings or included in any statistical analysis.

References

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.
Online: http://st-ts.ccme.ca/en/index.html?chems=154,162&chapters=1

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 beginning 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 beginning of the deployment period, a newly calibrated QA/QC water quality instrument (i.e., QA/QC Sonde) is temporarily deployed *in-situ* and along side the newly calibrated Field Sonde. A grab sample is also taken from the water body at this time and sent away to a laboratory for analysis. Field Sonde performance ratings for *temperature (^oC)* and *Dissolved Oxygen (% saturation)* are based on differences recorded by the Field Sonde and QA/QC Sonde. Field Sonde performance ratings for *specific conductivity (µS/cm)*, *pH (unit)* and *turbidity (NTU)* are based on differences between Field Sonde readings and grab sample results.
- At the end of the deployment period, water quality parameters are recorded by the Field Sonde before and after a thorough cleaning of its probes. Error caused by *bio-fouling* (E_f) is assessed by comparing these readings with readings made by a newly calibrated QA/QC Sonde, which is temporarily deployed *in-situ* and along side the Field Sonde. An assessment of *instrument drift error* (E_d) is made during laboratory calibration of the Field Sonde, and the two error values are added to give an estimate of total error ($E_t = E_f + E_d$). If E_t exceeds a predetermined data correction criterion, a correction factor is applied to the dataset based on linear interpolation of E_t. The Field Sonde performance is also rated at the end of the deployment period, based on the E_t value.
- Performance ratings are based on differences listed in the table below.

	Rating				
Parameter	**Excellent**	**Good**	**Fair**	**Marginal**	**Poor**
Temperature (^oC)	≤ ±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 (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) (% Sat)	≤ ±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 (%)	≤ ±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 or % saturation) 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).

Flow – Flow (m3/s) is a measure of how quickly a volume of water is displaced in streams, rivers, and other channels.

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 (oC) 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 – St. John's International Airport (April 29 to June 16, 2014)

Date yyyy-mm-dd	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days °C	Cool Deg Days °C	Total Rain mm	Total Snow cm	Total Precip mm
2014-04-29	1.2	-2	-0.4	18.4	0	0	0.2	0
2014-04-30	2.3	-5.7	-1.7	19.7	0	0	0	0
2014-05-01	8.4	-3.8	2.3	15.7	0	0	0	0
2014-05-02	3.1	-4.5	-0.7	18.7	0	0	0	0
2014-05-03	7	-4.3	1.4	16.6	0	0	0.4	0.4
2014-05-04	4.4	-0.2	2.1	15.9	0	0	0	0
2014-05-05	1.4	-1	0.2	17.8	0	5.5	8.5	14
2014-05-06	1.5	-1	0.3	17.7	0	1	1	2
2014-05-07	3.9	-0.9	1.5	16.5	0	0.2	0.2	0.2
2014-05-08	3.7	-1.1	1.3	16.7	0	0.2	0.8	1
2014-05-09	6.8	-0.9	3	15	0	0	0	0
2014-05-10	9.9	0.7	5.3	12.7	0	3.4	0	3.4
2014-05-11	10.9	-1.8	4.6	13.4	0	9.8	1	10.4
2014-05-12	7.6	-1.6	3	15	0	0	0	0
2014-05-13	5.6	-3.6	1	17	0	0	0	0
2014-05-14	3.7	-3.1	0.3	17.7	0	0	0	0
2014-05-15	11.5	-2	4.8	13.2	0	0	0	0
2014-05-16	19.7	3.6	11.7	6.3	0	0	0	0
2014-05-17	18.8	3	10.9	7.1	0	0	0	0
2014-05-18	10.8	3.1	7	11	0	2	0	2
2014-05-19	10.1	2.7	6.4	11.6	0	4.4	0	4.4
2014-05-20	10.7	3.2	7	11	0	41.4	0	41.4
2014-05-21	18.5	5.9	12.2	5.8	0	0	0	0
2014-05-22	14.7	5.1	9.9	8.1	0	2.8	0	2.8
2014-05-23	15.8	6.5	11.2	6.8	0	0	0	0
2014-05-24	10.5	2.2	6.4	11.6	0	0.4	0	0.4
2014-05-25	4.3	1.8	3.1	14.9	0	0	0	0
2014-05-26	5	2.4	3.7	14.3	0	7.8	0	7.8
2014-05-27	3.8	2.5	3.2	14.8	0	71.6	0	71.6
2014-05-28	3.5	1.2	2.4	15.6	0	7.4	0	7.4
2014-05-29	5.7	-2.1	1.8	16.2	0	0	0	0

2014-05-30	5.8	-1.9	2	16	0	0	0	0
2014-05-31	8.4	-0.8	3.8	14.2	0	0	0	0
2014-06-01	10.6	-0.8	4.9	13.1	0	0	0	0
2014-06-02	15.2	-0.3	7.5	10.5	0	0	0	0
2014-06-03	21.4	4.4	12.9	5.1	0	0.2	0	0.2
2014-06-04	17.4	5.2	11.3	6.7	0	1.6	0	1.6
2014-06-05	22.5	9.7	16.1	1.9	0	1.2	0	1.2
2014-06-06	21.1	10.1	15.6	2.4	0	0.4	0	0.4
2014-06-07	20.3	8.3	14.3	3.7	0	10.9	0	10.9
2014-06-08	11.1	4.2	7.7	10.3	0	3.8	0	3.8
2014-06-09	9.7	4.1	6.9	11.1	0	0.2	0	0.2
2014-06-10	9.7	4.4	7.1	10.9	0	0	0	0
2014-06-11	9.1	3.3	6.2	11.8	0	0.2	0	0.2
2014-06-12	9.4	2.6	6	12	0	0	0	0
2014-06-13	12.9	3.2	8.1	9.9	0	0	0	0
2014-06-14	19.5	5.6	12.6	5.4	0	0	0	0
2014-06-15	20.2	8	14.1	3.9	0	0	0	0
2014-06-16	11.1	6.4	8.8	9.2	0	7	0	7