Real-Time Water Quality Deployment Report

Lower Churchill River Network

August 10 to September 27/29, 2017

Newfoundland Labrador

Government of Newfoundland & Labrador
Department of Municipal Affairs & Environment
Water Resources Management Division

Contents

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Real Time Water Quality Monitoring

- Staff with the Department of Municipal Affairs & Environment monitor real-time water quality data on a regular basis.
- This deployment report discusses water quality related events occurring at three stations on the Lower Churchill River: Churchill River above Grizzle Rapids, Churchill River below Muskrat Falls and Churchill River at English Point.
- Real-time water quality monitoring instruments were deployed at all three stations on the Lower Churchill River on August 10th. Instruments were removed from Churchill River below Muskrat Falls and Churchill River at English Point on September 27th for a deployment period of 48 days. The instrument was removed from Churchill River above Grizzle Rapids on September 29th for a deployment period of 50 days.
- The station at above Muskrat Falls was not able to be deployed during this deployment period. This station was relocated in October 2016 as it was situated in the flood zone of the Muskrat Falls Reservoir and needed to be moved back to ensure the station did not flood as the reservoir water levels were raised (as was planned in the fall of 2016). However, due to unforeseen issues, water levels were raised and decreased again. As a result, the newly located above Muskrat Falls station is now situated approximately 650 feet from the edge of the reservoir (i.e. at current water levels) making it impractical to install monitoring equipment. Additionally, safety requirements with regards to working in and around the reservoir for the Muskrat Falls project further hindered the ability to deploy the instrument at this station.

Quality Assurance and Quality Control

- As part of the Quality Assurance and Quality Control protocol (QA/QC), an assessment of the reliability of data recorded by an 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.
- At deployment and removal, a QA/QC instrument is temporarily deployed alongside the field instrument. Values for temperature, pH, conductivity, dissolved oxygen and turbidity are compared between the two instruments**.** Based on the degree of difference between parameters recorded by the field instrument and QA/QC instrument at deployment and at 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 > 35µS/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 instrument is the most important. All other parameters can be broken down into three groups: temperature dependent, temperature compensated and temperature independent. Because the temperature sensor is not isolated from the rest of the instrument, the entire instrument must be at the same temperature before the sensor will stabilize. The values may take some time to climb to the appropriate reading; if a reading is taken too soon it may not accurately portray the water body.

- Deployment and removal comparison rankings for the Lower Churchill River stations deployed from August 10 to September 27/29, 2017 are summarized in Table 2.

Table 2: Comparison rankings for Lower Churchill River stations August 10 to September 27/29, 2017

Churchill River Station	Date	Action	Comparison Ranking				
			Temperature	pH	Conductivity	Dissolved Oxygen	Turbidity
Above Grizzle Rapids	August 10, 2017	Deployment	Good	Good	Excellent	Good	Excellent
	Sept 29, 2017	Removal	Good	Excellent	Excellent	Poor	Poor
Above Muskrat Falls	Not deployed	Deployment	N/A	N/A	N/A	N/A	N/A
	Not deployed	Removal	N/A	N/A	N/A	N/A	N/A
Below Muskrat Falls	August 10, 2017	Deployment	Excellent	Excellent	Excellent	Good	Poor
	Sept 27, 2017	Removal	Excellent	Excellent	Excellent	Excellent	Excellent
At English Point	August 10, 2017	Deployment	Marginal	Excellent	Good	Excellent	Excellent
	Sept 27, 2017	Removal	Good	Excellent	Poor	Excellent	Fair

- **Churchill River above Grizzle Rapids**
    - At deployment, conductivity and turbidity were 'excellent', while temperature, pH and dissolved oxygen were all 'good'.
    - At removal, pH and conductivity were 'excellent', temperature was 'good', while dissolved oxygen and turbidity ranked as 'poor'. The QA/QC ranking for both dissolved oxygen and turbidity is attributed to a sensor failure on the QA/QC sonde.
- **Churchill River below Muskrat Falls**
    - At deployment, temperature, pH and conductivity ranked as 'excellent', dissolved oxygen was 'good', while turbidity was 'poor'. For turbidity, the QA/QC sonde recorded a value of 1.0NTU, the grab sample gave a value of 3.6NTU, while the field sonde read 24.1NTU. This discrepancy is likely due to the placement of the field sonde as it could have disturbed sediment that in turn impacted the recorded turbidity value.
    - At removal, all parameters ranked as 'excellent'.

- **Churchill River at English Point**
    - At deployment, pH, dissolved oxygen and turbidity were all 'excellent', specific conductivity was 'good', while temperature was 'marginal'. This discrepancy could be due to the QA/QC instrument not being placed in close enough proximity to the field instrument.
    - At removal, pH and dissolved oxygen were 'excellent', temperature was 'good', turbidity was 'fair' and specific conductivity was 'poor'. These discrepancies could be due to the QA/QC instrument not being placed in close enough proximity to the field instrument.

Data Interpretation

- The following graphs and discussion illustrate water quality related events occurring from August 10 to September 27/29, 2017 on the Lower Churchill River Network.
- With the exception of water quantity data (stage & flow), all data used in the preparation of the graphs and subsequent discussion below adhere to this stringent QA/QC protocol. Water Survey of Canada is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.
- The station at Churchill River above Grizzle Rapids was deployed on July 12th, 2017. Since an area near the below Grizzle Rapids station (which contained both water quality and quantity monitoring capabilities) experienced a landslide in September 2016, a decision was made to relocate the water quality component of this station to the existing above Grizzle Rapids hydrometric station. Unforeseen power issues prevented transmission of data from this station; however, internal log file data is available for analysis in this report.
- The above Muskrat Falls station was inaccessible due to having been moved a significant distance from the water (i.e. outside of flood zone) and due to safety concerns associated with working in and around the reservoir.

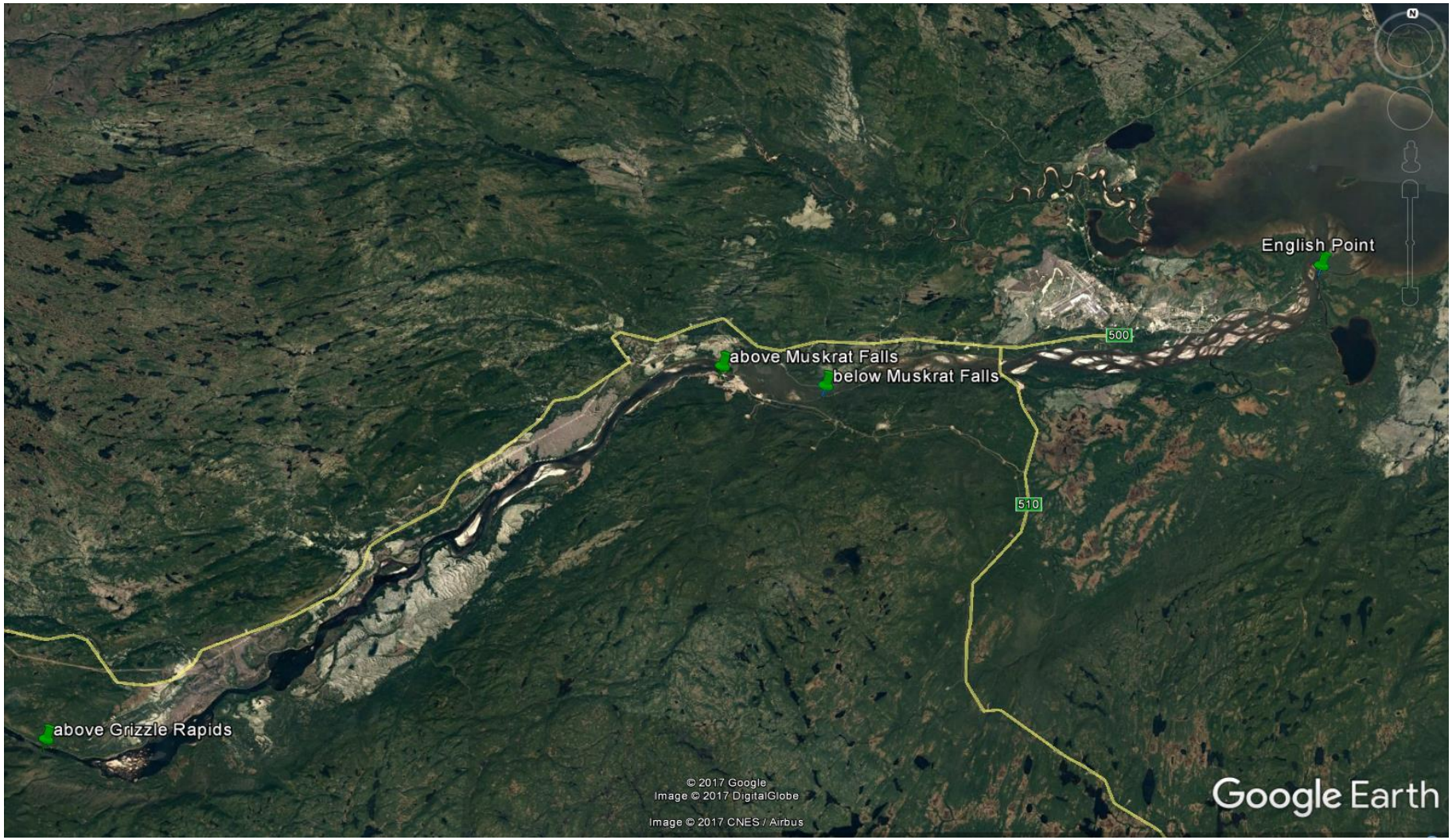

Figure 1: Lower Churchill Network of Real-Time Water Quality Stations

Churchill River above Grizzle Rapids

Water Temperature

- Water temperature ranged from 10.25°C to 17.12°C, with a median value of 14.06°C (Figure 2).
- Water temperature slowly decreased over the course of this deployment – a trend that is expected as air temperatures cool as summer transitioned to fall. Water temperature data exhibits a diurnal pattern as expected, and closely correlates with ambient air temperatures.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

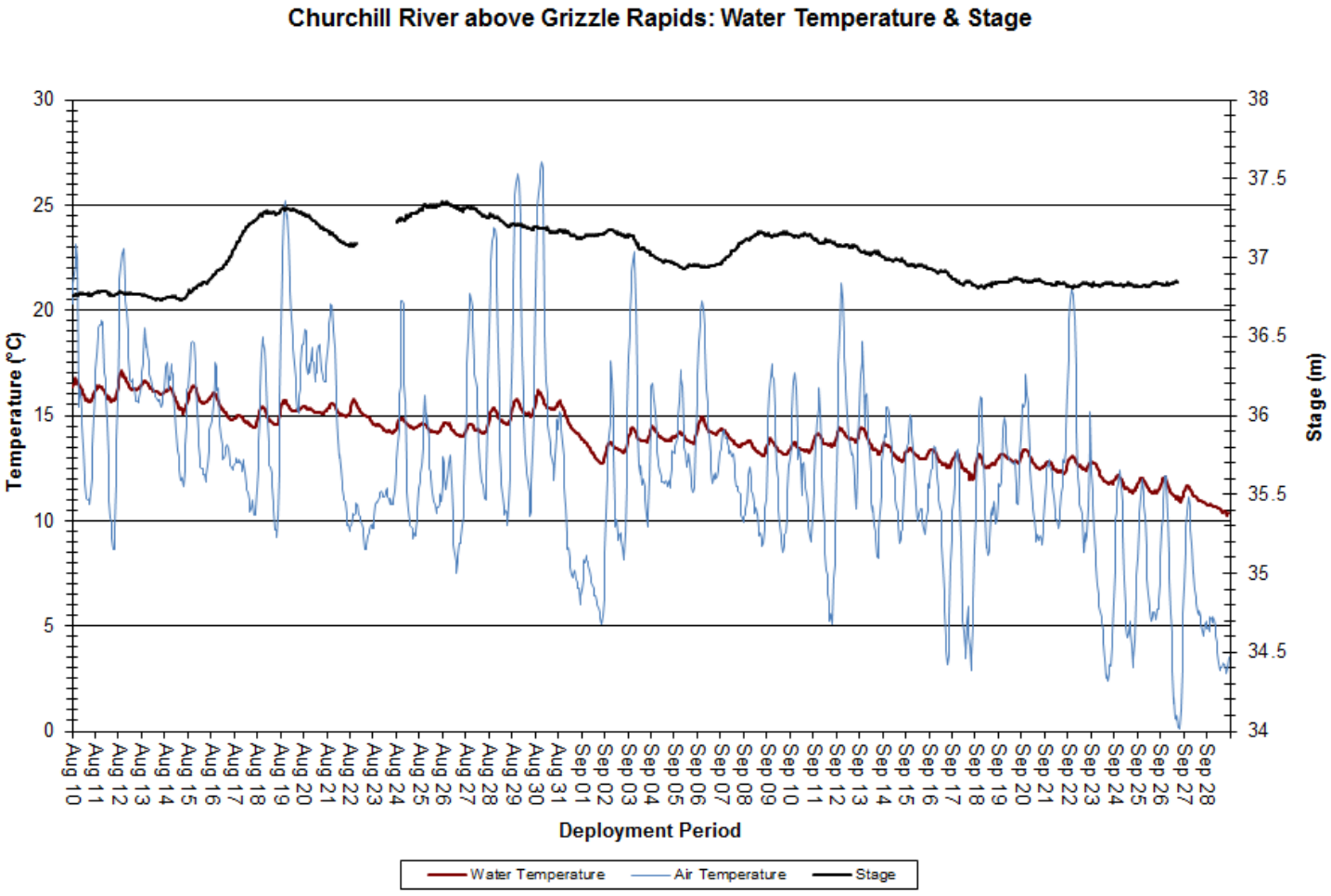

Figure 2: Water & Air Temperature (Muskrat Falls Weather Station) and Stage at Churchill River above Grizzle Rapids

pH

- pH values ranged from 6.77 to 7.15 pH units, with a median value of 6.90 (Figure 3).
- pH values are stable over the deployment period and fall within the CCME Protection of Aquatic Life Guidelines.
- Photosynthesis uses up hydrogen molecules; this causes the concentration of hydrogen ions to decrease, which in turn causes pH to increase. For this reason, pH may be higher during daylight hours and during the growing season when photosynthesis is at a maximum. This is illustrated by the diurnal fluctuations in pH values (Figure 3).
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

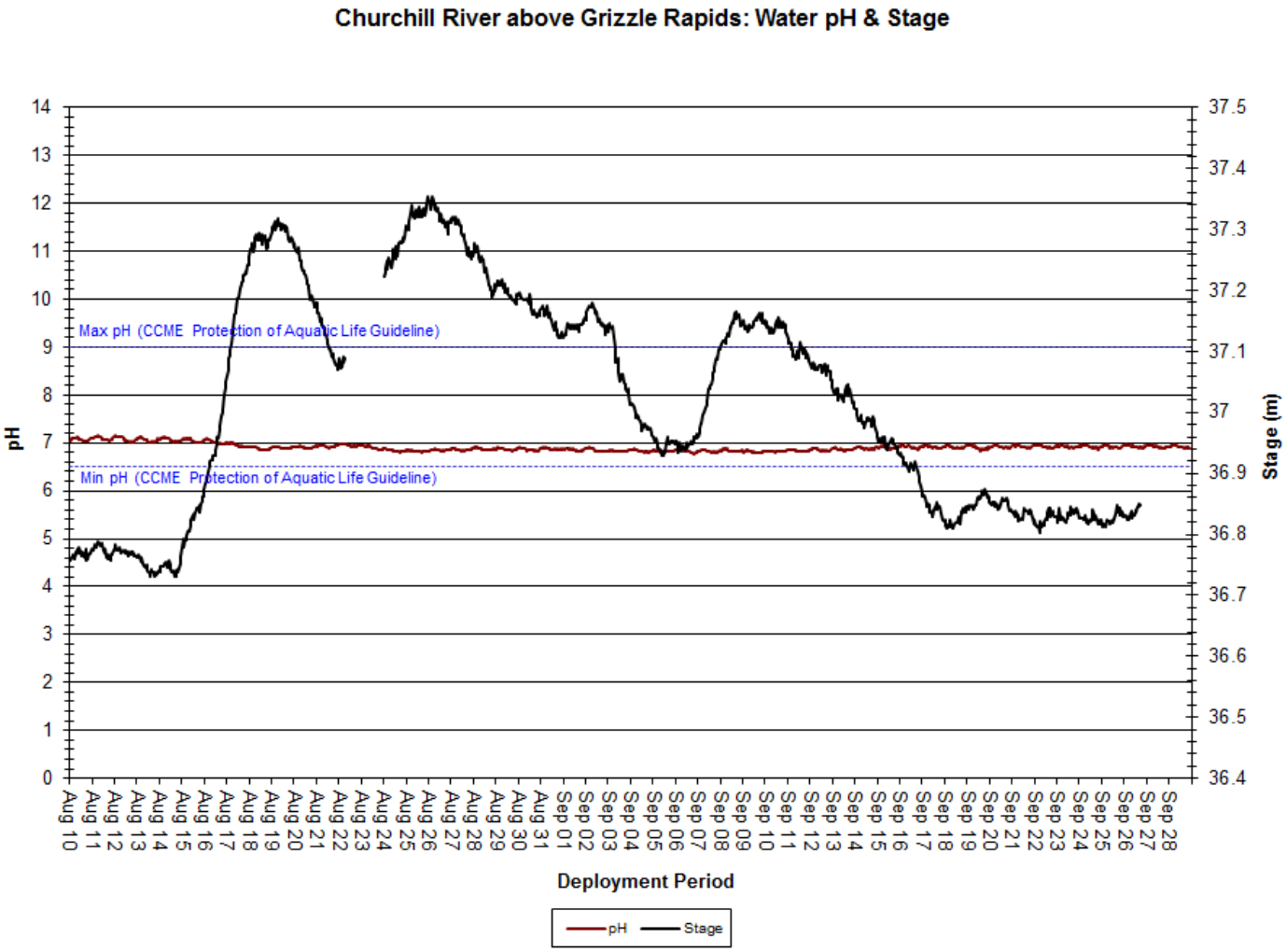

Figure 3: pH & Stage at Churchill River above Grizzle Rapids

Specific Conductivity

- Specific conductivity ranges from 15µS/cm to 18µS/cm, with a median of 17µS/cm (Figure 4).
- The relationship between conductivity and stage is inversed. When stage levels increase, specific conductance levels decrease as the increased amount of water in the river system dilutes solids that are present. This relationship is difficult to see in the graph below due to specific conductivity values in the internal log file being recorded as integers as opposed to decimals.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

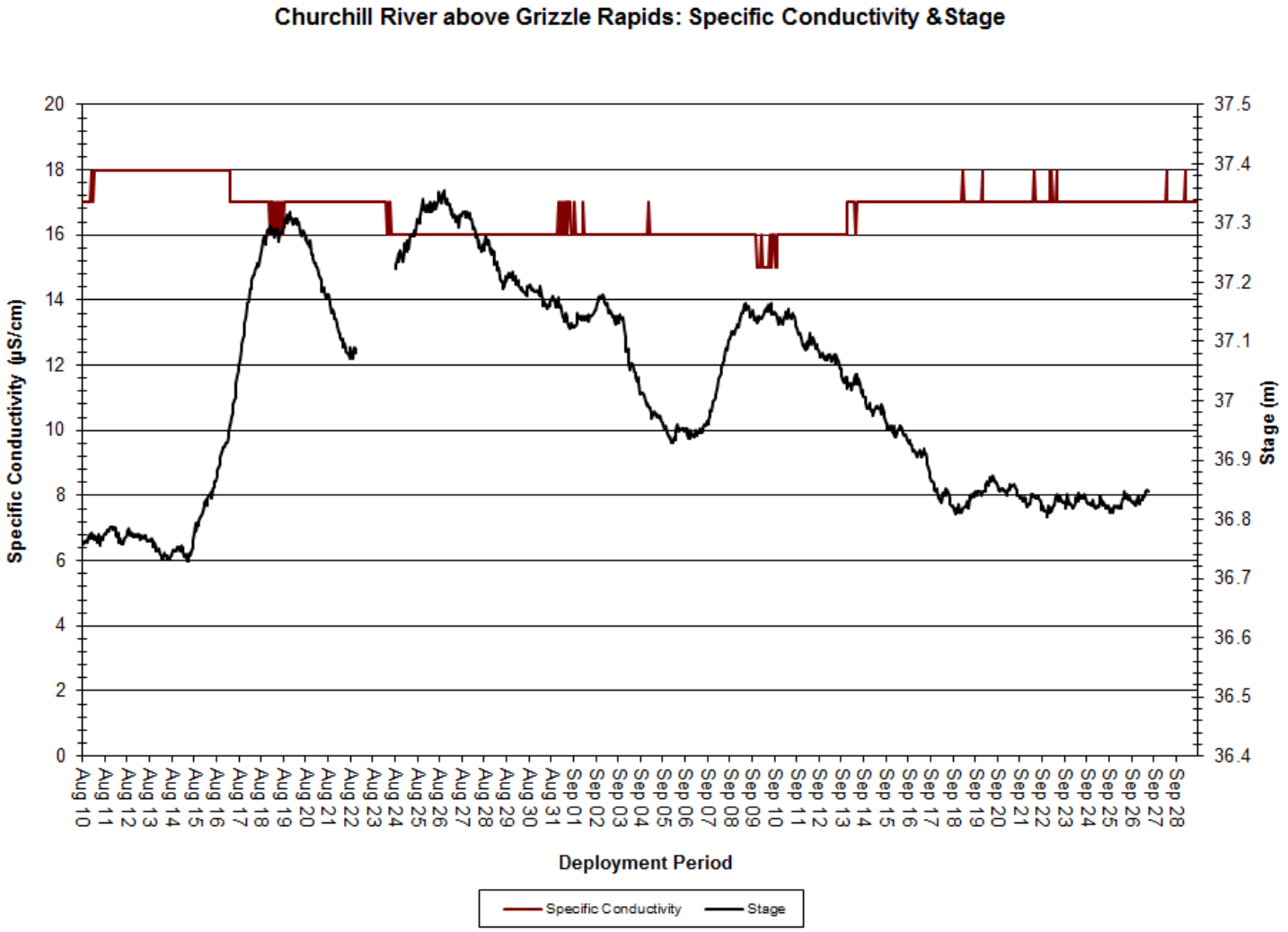

Figure 4: Specific Conductivity & Stage at Churchill River above Grizzle Rapids

Dissolved Oxygen

- Dissolved oxygen content ranged from 9.36mg/L to 10.63mg/L, with a median value of 9.88mg/L. The saturation of dissolved oxygen ranged from 93.3% to 100.5%, with a median value of 95.7% (Figure 5).
- There is an evident relationship between water temperature and dissolved oxygen. Over the deployment period, dissolved oxygen levels are gradually increasing as temperatures decrease as summer transitions to autumn. Dissolved oxygen also follows a diurnal pattern as water temperatures rise and fall under the influence of ambient air temperatures. Generally, dissolved oxygen levels are higher in a waterbody during cooler temperatures.
- Dissolved oxygen levels remained above the CCME Guideline for the Protection of Early Life Stages for the majority of the deployment period, with the exception of a few instances early in the deployment period.

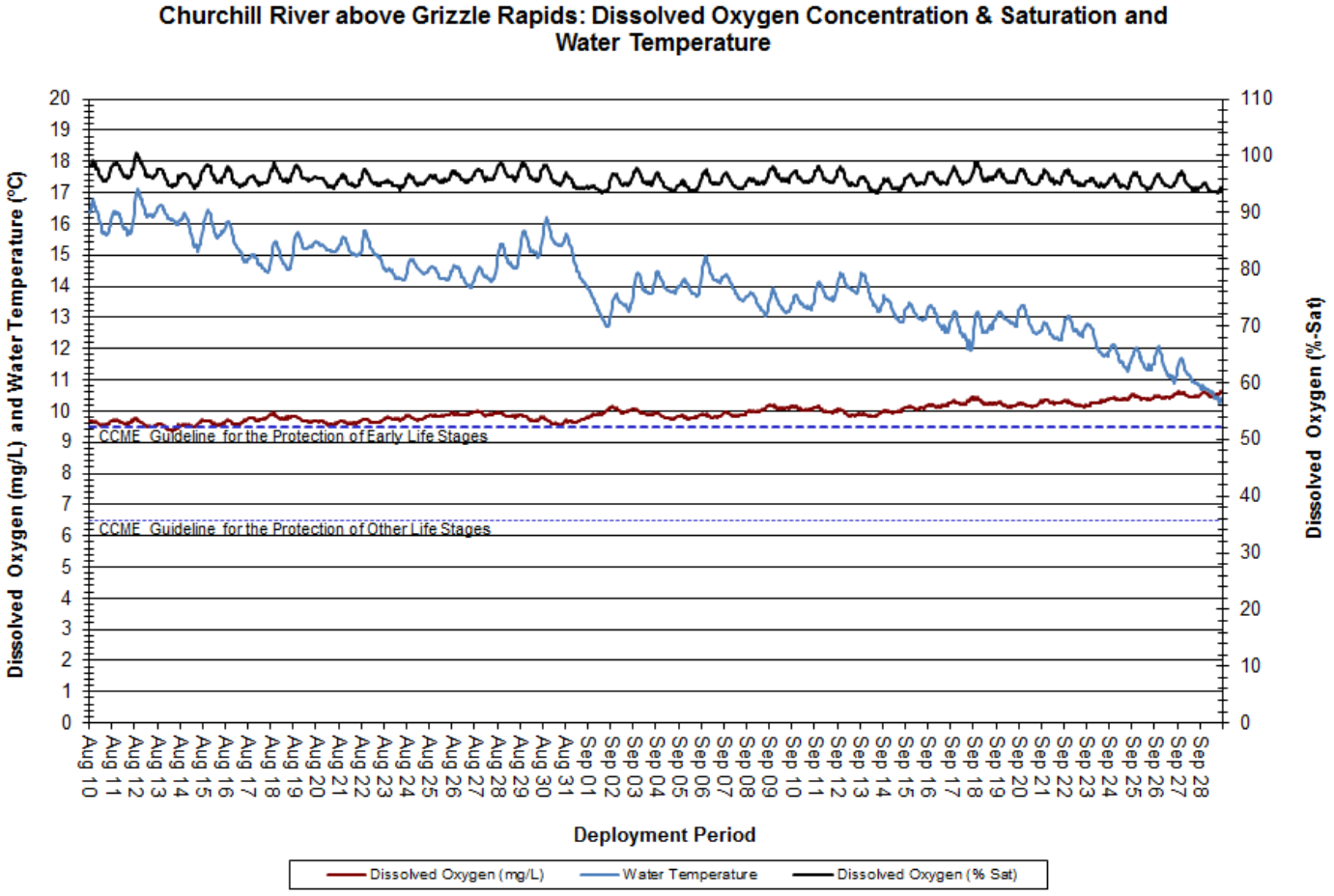

Figure 5: Dissolved Oxygen & Water Temperature at Churchill River above Grizzle Rapids

Turbidity

- Turbidity ranged from 0.0NTU to 19.3 NTU, with a median value of 0.0NTU (Figure 6). A median value of 0.0NTU indicates a very low level of natural background turbidity in the waterbody.
- Many of the larger turbidity spikes correlate with increases in stage, which further correlate with precipitation events (Figure 7).Turbidity levels returned to background levels following each observed increase.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

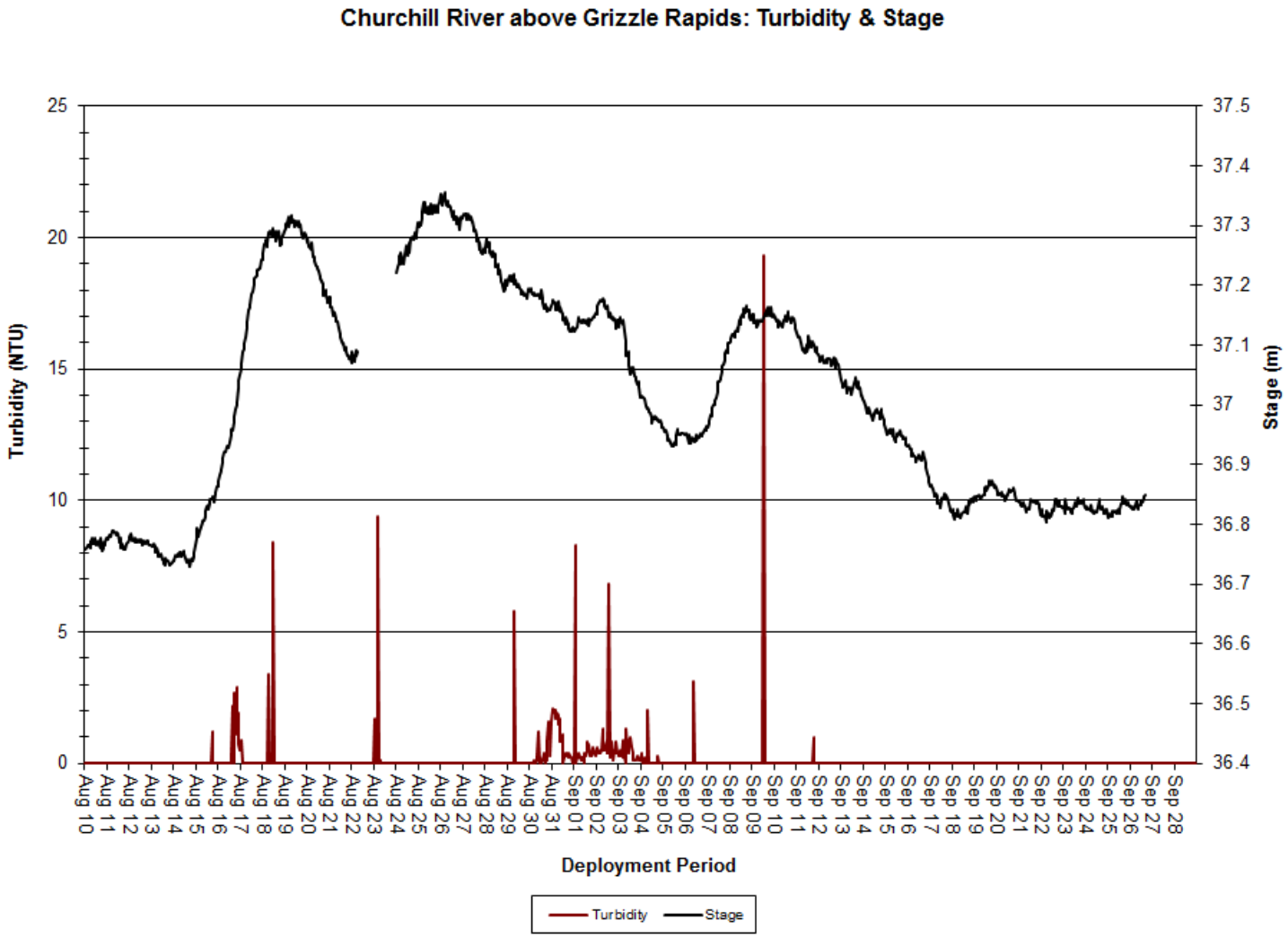

Figure 6: Turbidity & Stage at Churchill River above Grizzle Rapids

Stage

- Stage levels ranged from 36.73m to 37.36m, with a median value of 37.01m (Figure 7).
- Stage was variable across the course of deployment, with precipitation events often correlating with temporary increases in stage.
- Precipitation data was obtained from the Muskrat Falls Weather Station.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

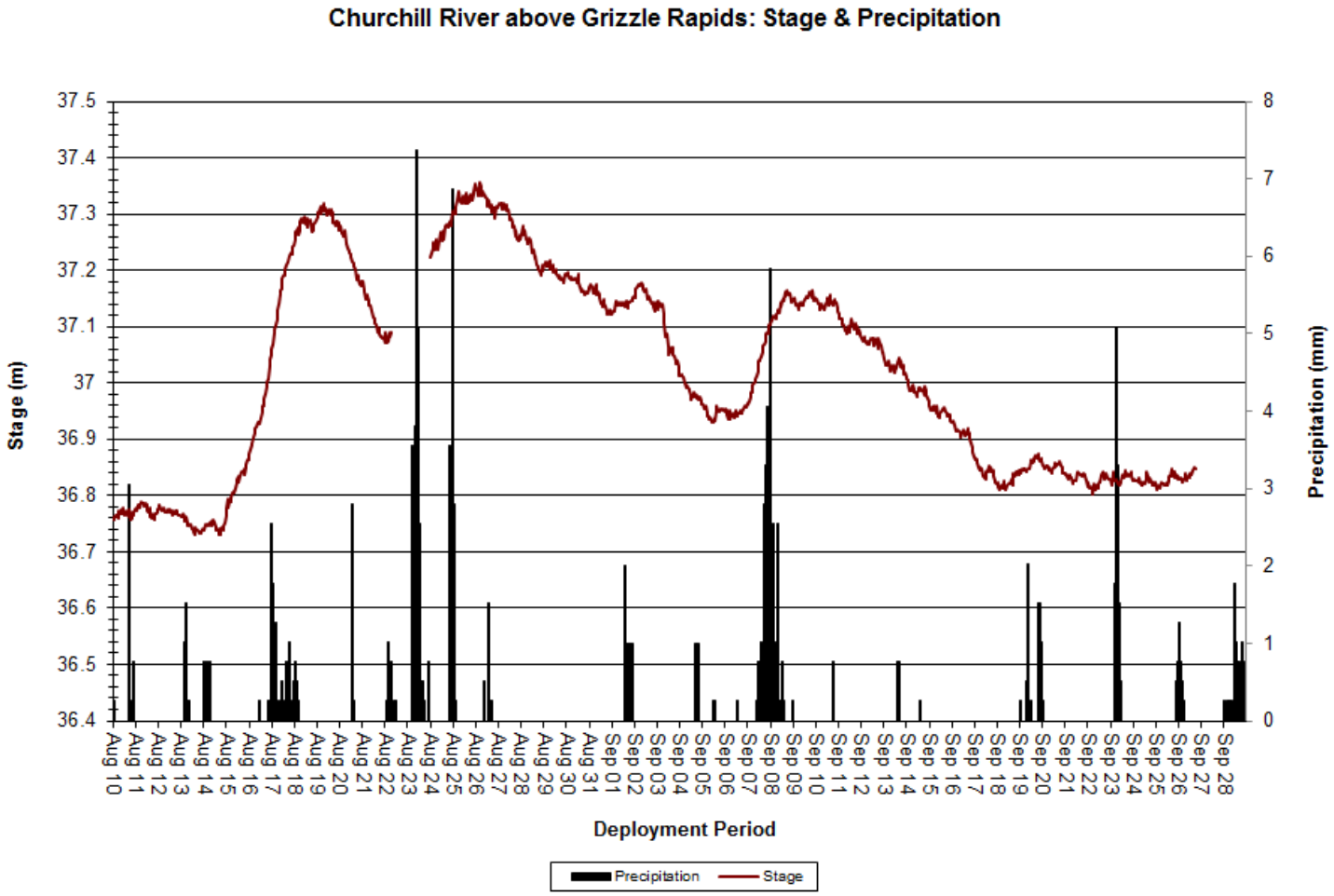

Figure 7: Stage & Precipitation (Muskrat Falls Weather Station) at Churchill River above Grizzle Rapids

Churchill River below Muskrat Falls

Water Temperature

- Water temperature ranged from 10.70°C to 18.20°C, with a median value of 14.50°C (Figure 8).
- Water temperature gradually decreases across the deployment period - a trend that is expected as air temperatures also decrease. Water temperatures closely correlate with ambient air temperatures (Muskrat Falls Weather Station).
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

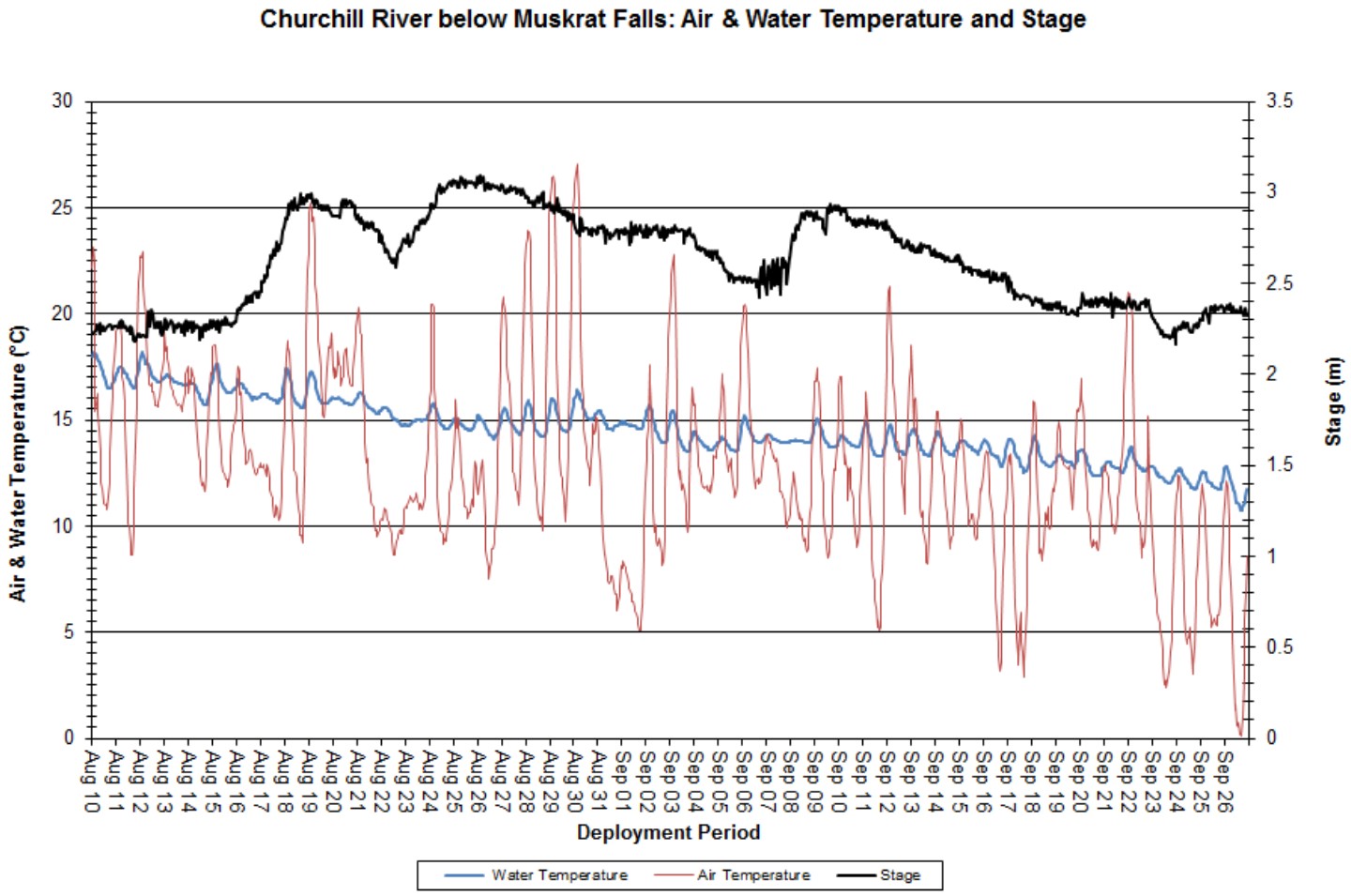

Figure 8: Water & Air Temperature (Muskrat Falls Weather Station) and Stage at Churchill River below Muskrat Falls

pH

- pH ranged from 6.08 to 7.19 pH units, with a median value of 6.88 (Figure 9).
- pH values are relatively stable and within the CCME Protection of Aquatic Life Guidelines until around September 10th, after which time they decrease quickly and stay below the CCME Guidelines for the remainder of deployment. This decrease in pH values is likely the result of heavy precipitation around September 8th and 9th.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

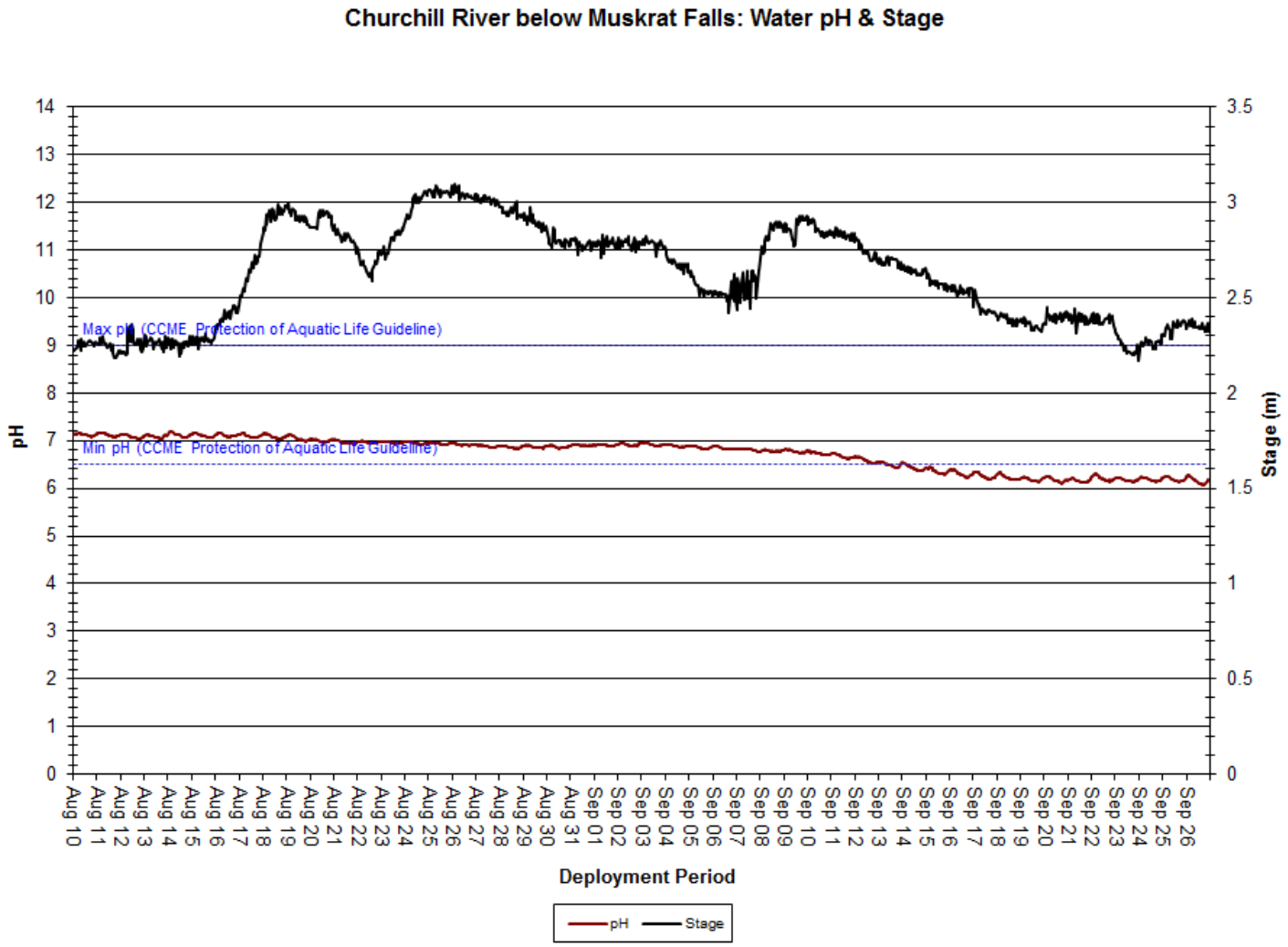

Figure 9: pH & Stage at Churchill River below Muskrat Falls

Specific Conductivity

- Specific conductivity ranged from 17.7µS/cm to 20.0µS/cm, with a median value of 18.9µS/cm (Figure 10).
- The relationship between conductivity and stage is inversed. When stage levels decrease, specific conductance levels increase as the decreased amount of water in the river system concentrates solids that are present.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

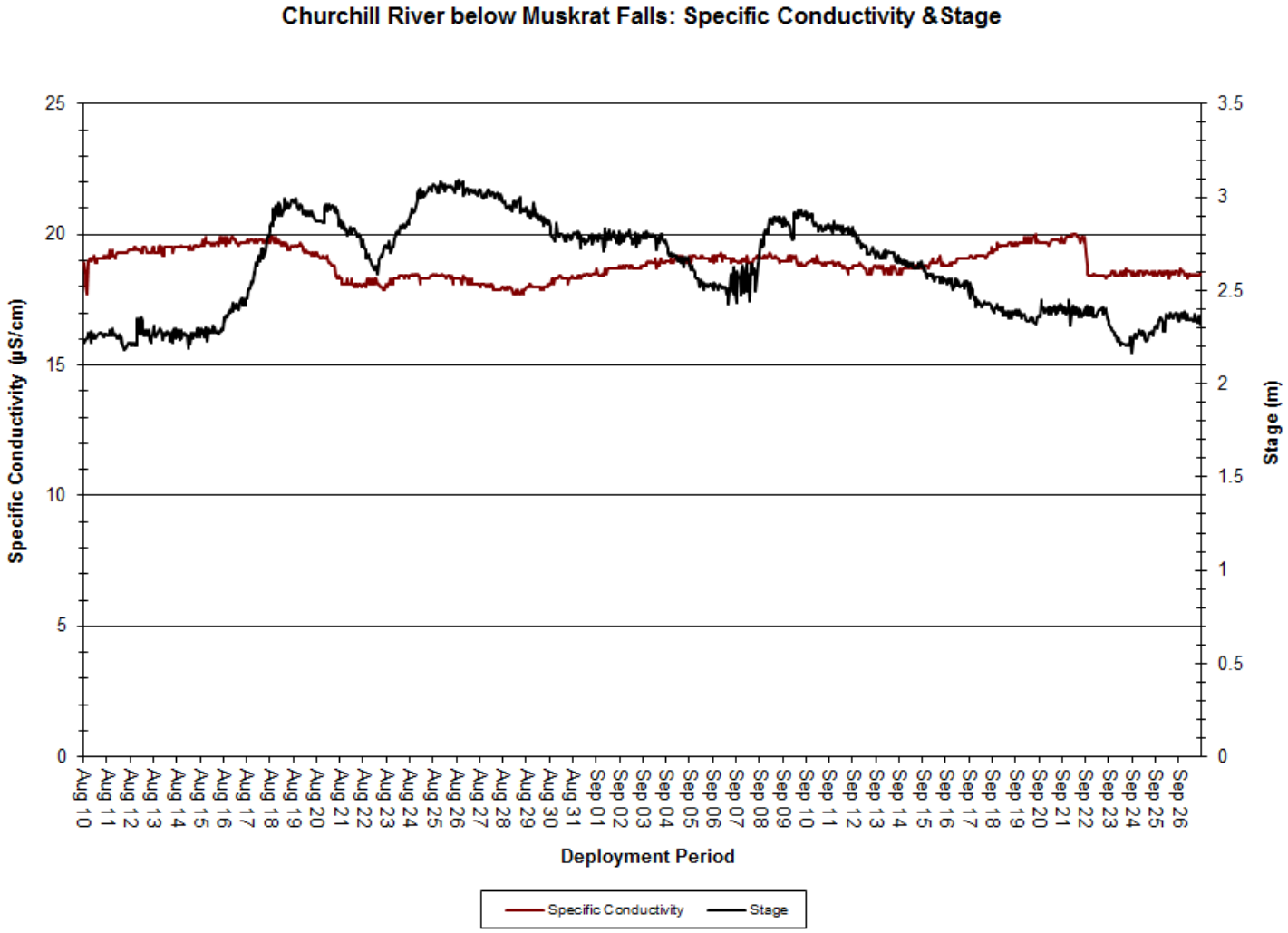

Figure 10: Specific Conductivity & Stage at Churchill River below Muskrat Falls

Dissolved Oxygen

- Dissolved oxygen concentration ranged from 9.71mg/L to 11.77mg/L, with a median value of 11.04mg/L. The saturation of dissolved oxygen ranged from 99.3% to 114.2%, with a median value of 107.1% (Figure 11).
- There is an evident relationship between water temperature and dissolved oxygen. Over the deployment period, dissolved oxygen levels are slowly increasing as temperatures decrease into the Fall season. Dissolved oxygen also follows a diurnal pattern as water temperatures rise and fall under the influence of ambient air temperatures. Generally, dissolved oxygen levels are higher in a waterbody during cooler temperatures.
- Dissolved oxygen levels remained above the CCME Guidelines for the Protection of Other Life Stages and the CCME Guidelines for the Protection of Early Stages for the duration of deployment.

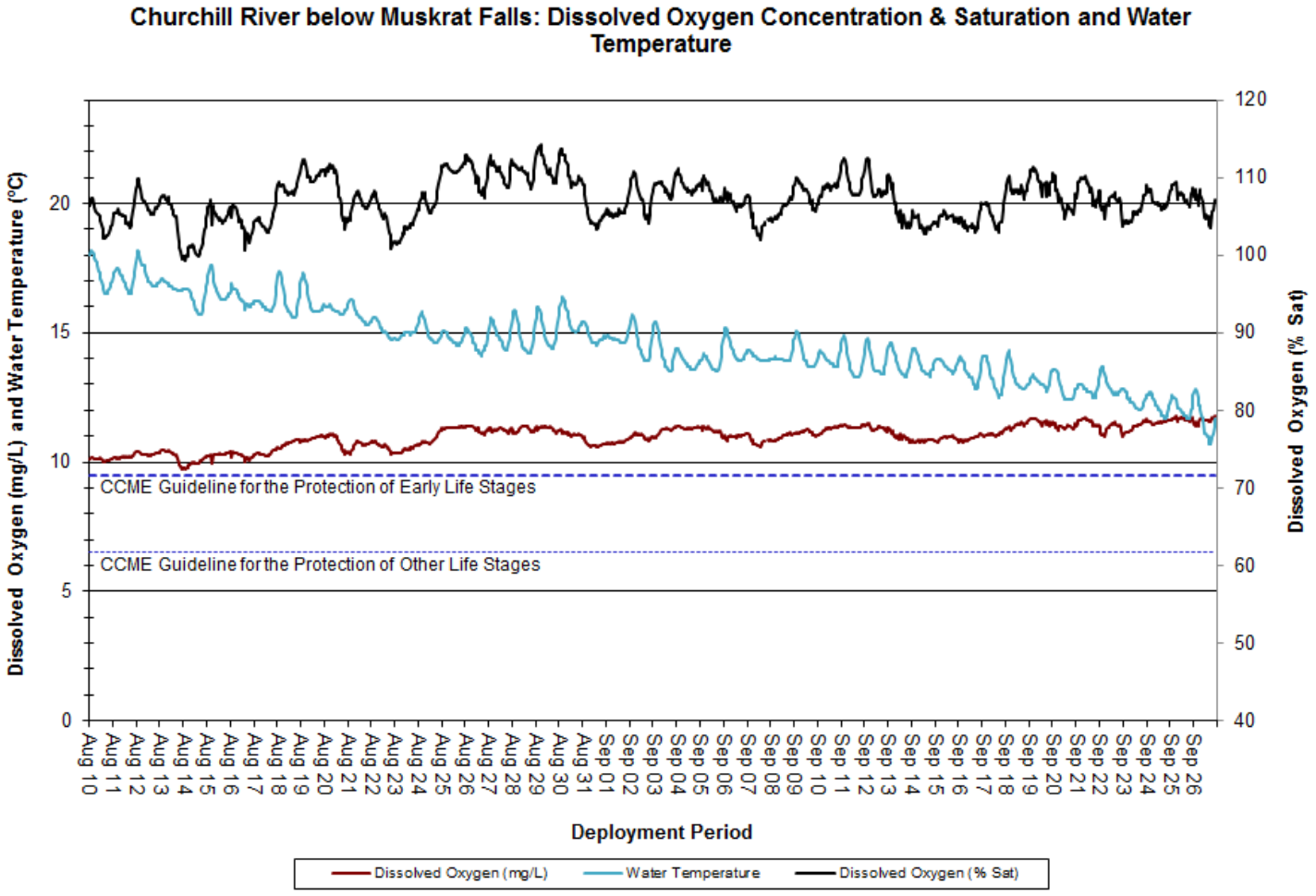

Figure 11: Dissolved Oxygen & Water Temperature at Churchill River below Muskrat Falls

Turbidity

- Turbidity remained constant at 0.0NTU for the duration of deployment. Given the natural aquatic conditions at this station, this likely indicates a sensor failure and so turbidity data has been removed from the dataset.

Stage

- Stage ranged from 2.17m to 3.09m, with a median value of 2.66m (Figure 12).
- Stage remained relatively consistent over the course of deployment, with precipitation events often correlating with temporary increases in stage.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

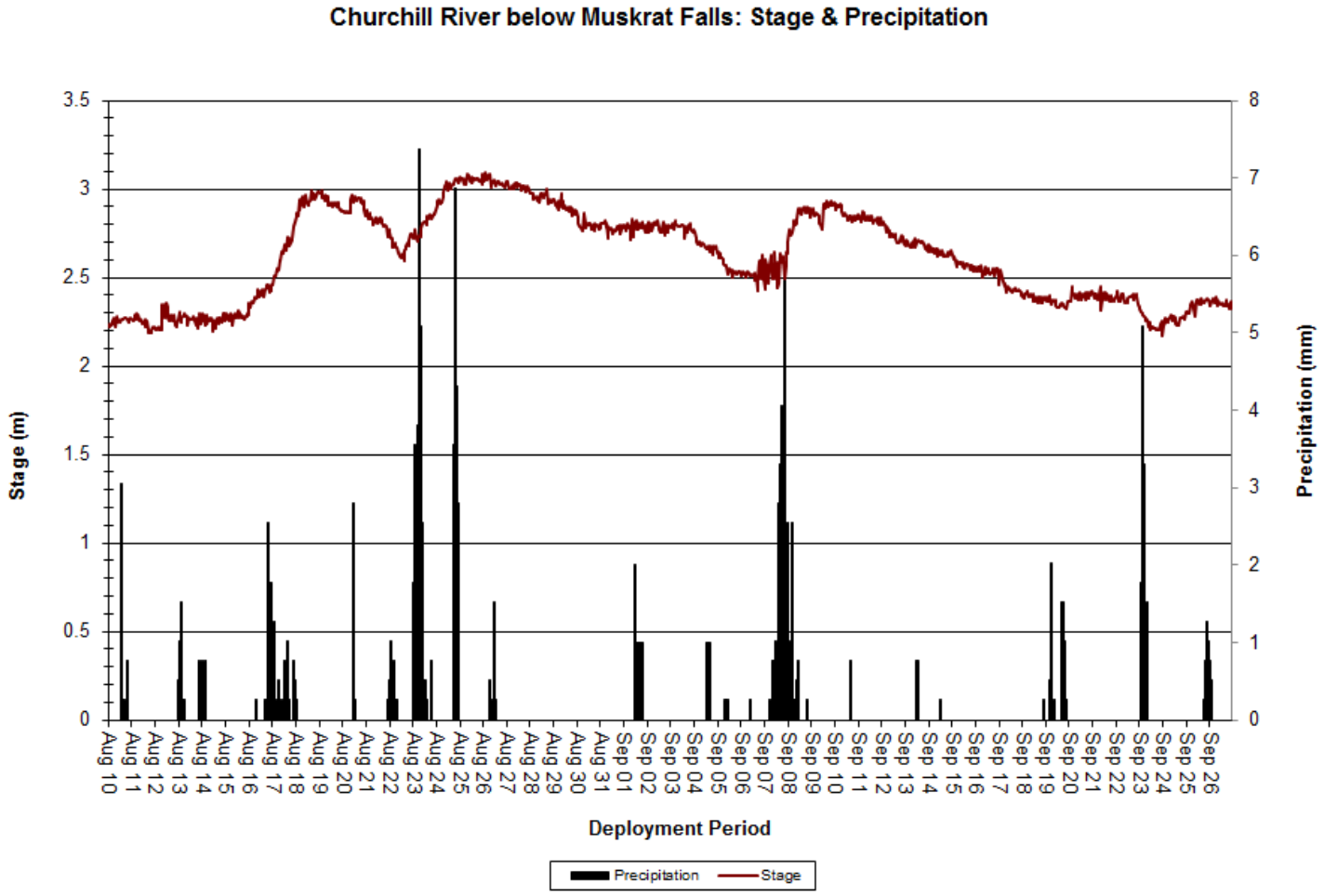

Figure 12: Stage & Precipitation (Muskrat Falls Weather Station) at Churchill River below Muskrat Falls

Chlorophyll

- Chlorophyll ranged from 1.92ug/L to 3.72ug/L, with a median value of 2.74ug/L (Figure 13).
- Chlorophyll is found within living cells of photosynthetic organisms like phytoplankton and cyanobacteria. The amount of chlorophyll found in water can be used to understand the general biological health of an ecosystem. Chlorophyll can also be used to identify algal bloom events and is an indicator of nutrient loading in ecosystems.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

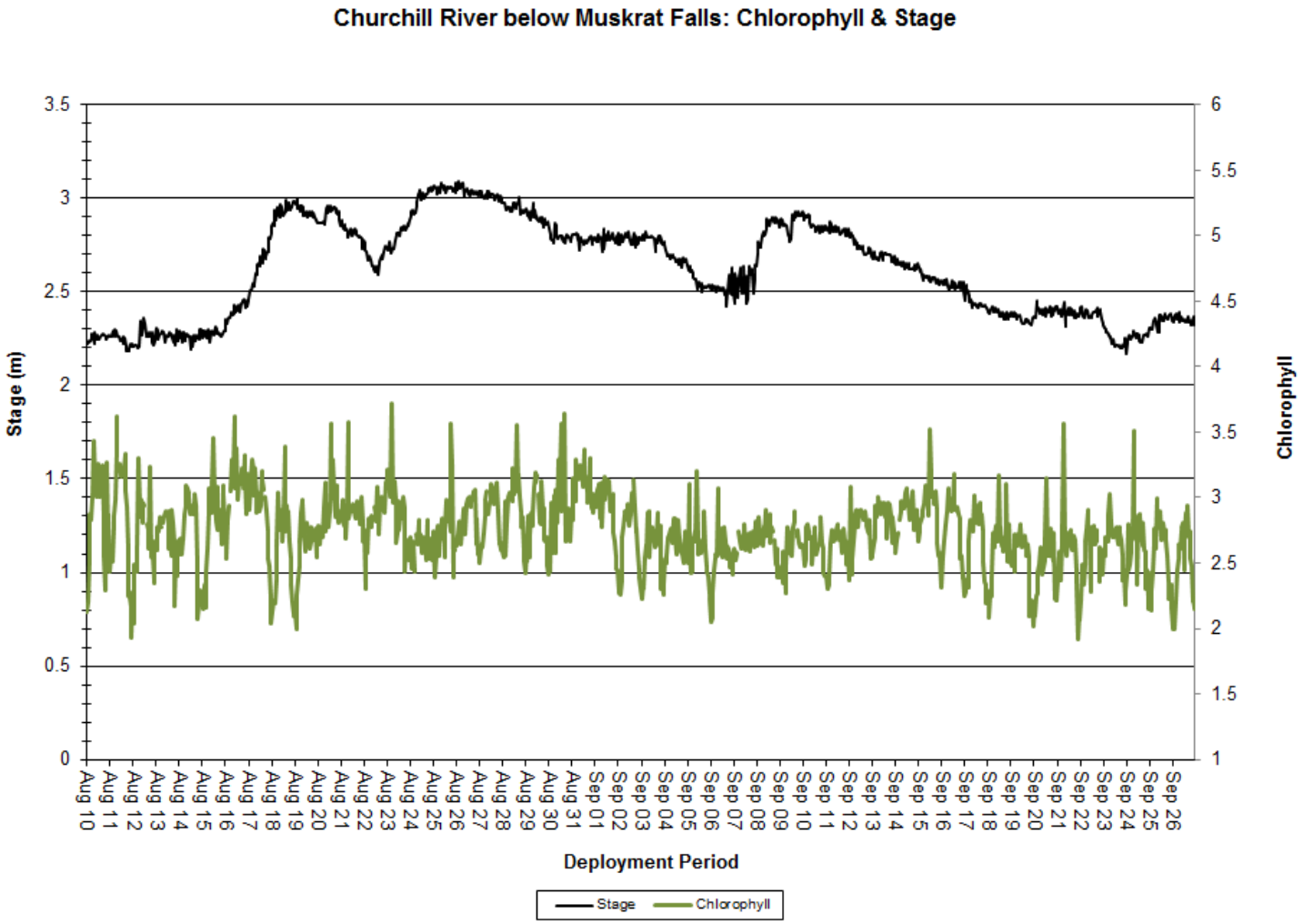

Figure 13: Chlorophyll & Stage at Churchill River below Muskrat Falls

Churchill River at English Point

Water Temperature

- Water temperature ranged from 9.90°C to 18.80°C, with a median value of 14.10°C (Figure 14).
- Water temperature gradually decreases over the course of deployment, a trend that is expected as air temperatures fall after the summer months. Water temperatures closely correlate with ambient air temperatures (Mud Lake Weather Station).
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

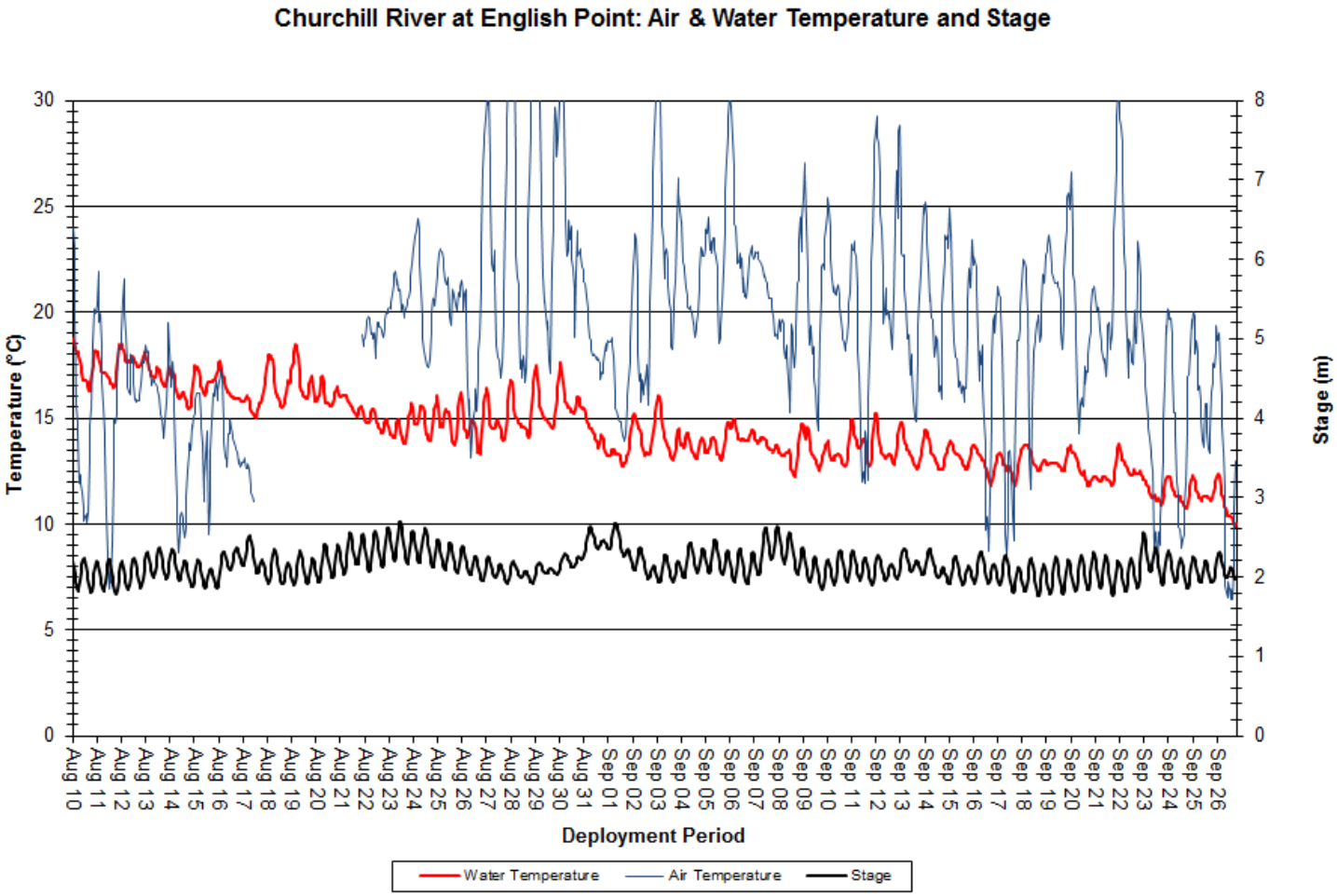

Figure 14: Water & Air Temperature (Mud Lake Weather Station) and Stage at Churchill River at English Point

pH

- pH ranged from 6.51 to 7.34 pH units, with a median value of 6.90 (Figure 15).
- pH values remained within the CCME Guidelines for Protection of Aquatic Life for the duration of deployment.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

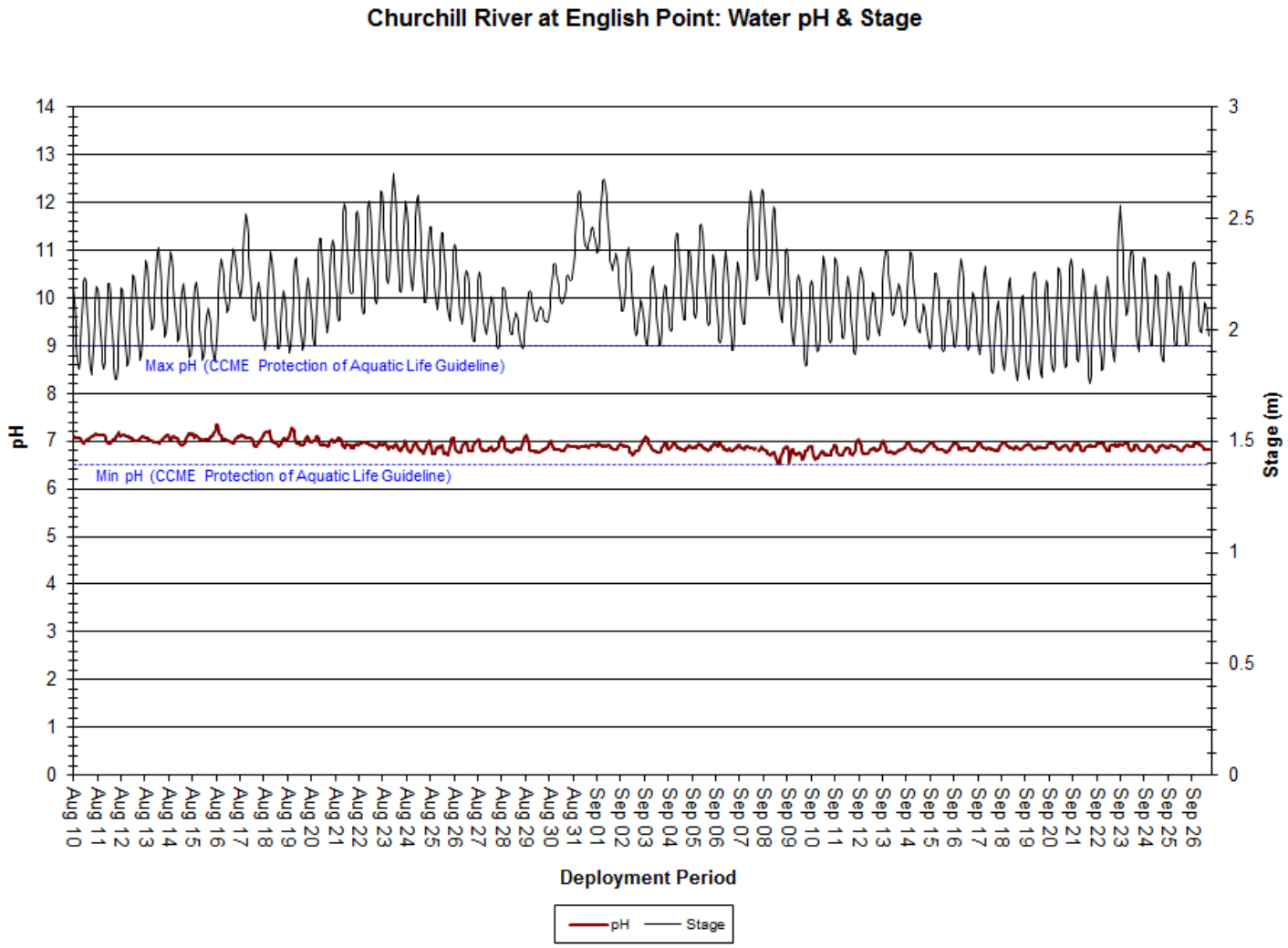

Figure 15: pH & Stage at Churchill River at English Point

Specific Conductivity

- Specific conductivity ranged from 16.1µS/cm to 45.9µs/cm, with a median value of 28.2µS/cm (Figure 16).
- Specific conductivity fluctuates considerably at this location due to the tidal influences of the Atlantic Ocean on Lake Melville. As the tide comes in, specific conductivity increases as dissolved solids and salinity increase, and vice versa as the tide goes out. This increase and decrease in specific conductivity and stage occurs twice daily. This pattern is generally consistent throughout the deployment period (Figure 16).
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

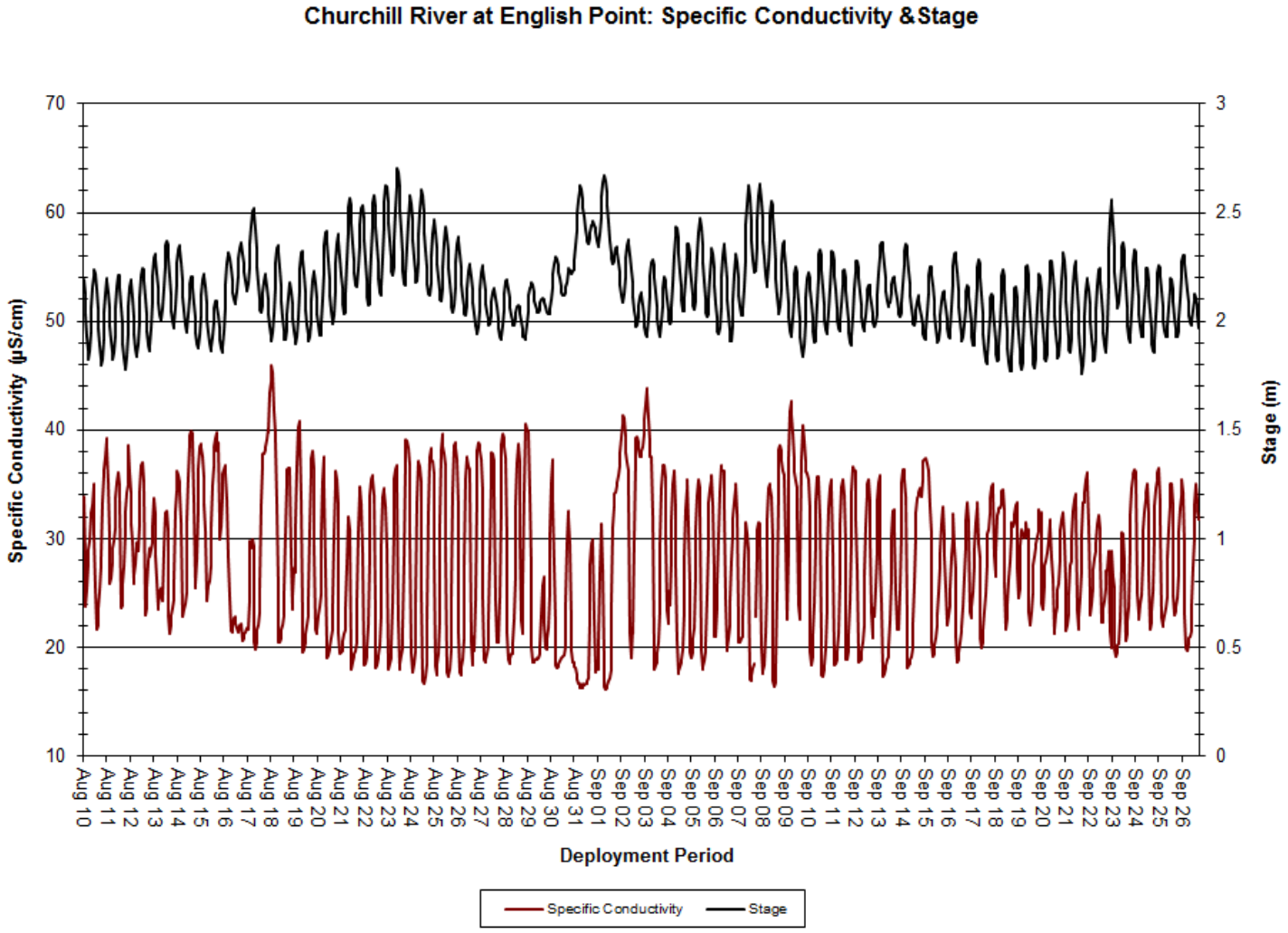

Figure 16: Specific Conductivity & Stage at Churchill River at English Point

Dissolved Oxygen

- Dissolved oxygen concentration ranged from 9.31mg/L to 11.51mg/L, with a median value of 10.39mg/L. The saturation of dissolved oxygen ranged from 91.0% to 112.1% saturation, with a median value of 101.5% (Figure 17).
- There is an evident relationship between water temperature and dissolved oxygen. As water temperatures decrease over the deployment period, dissolved oxygen levels slowly increase. Dissolved oxygen levels also follow a diurnal pattern as water temperatures rise and fall under the influence of ambient air temperatures. Generally, dissolved oxygen levels are higher in a waterbody during cooler temperatures.
- Dissolved oxygen levels remained above the CCME Guidelines for the Protection of Other Life Stages for the duration of deployment; however, dissolved oxygen levels continuously crossed over the CCME Guideline for the Protection of Early Life Stages until around August 18th, after which dissolved oxygen levels remained above the CCME Guideline for the remainder of deployment (Figure 17). This is to be expected considering decreasing water temperatures.

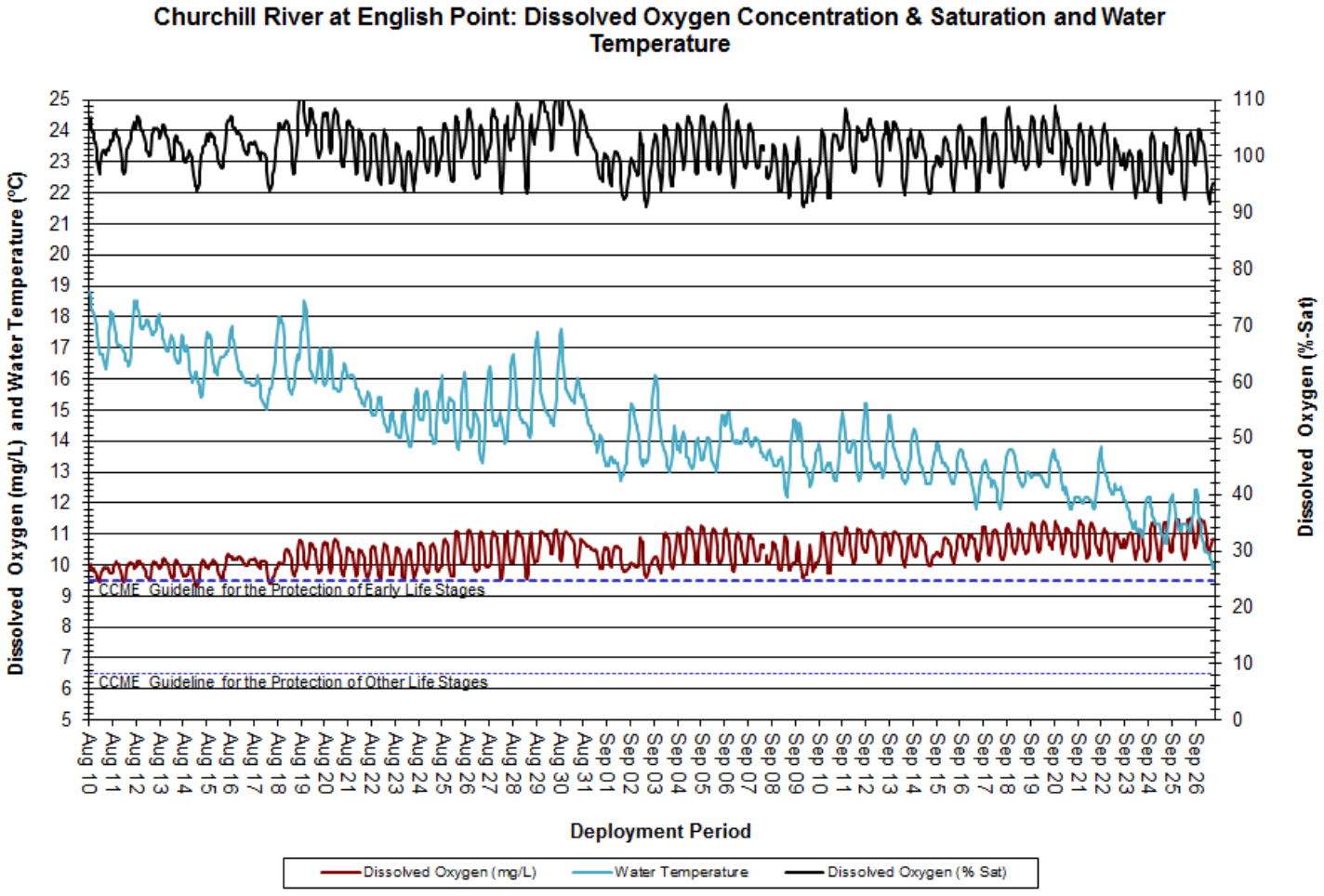

Figure 17: Dissolved Oxygen & Water Temperature at Churchill River at English Point

Turbidity

- Turbidity ranged from 3.7NTU to 117.9NTU, with a median value of 8.2NTU (Figure 18).
- Turbidity events often correlate with increases in stage and precipitation events. Precipitation can increase the presence of suspended material in water (Figure 19).
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

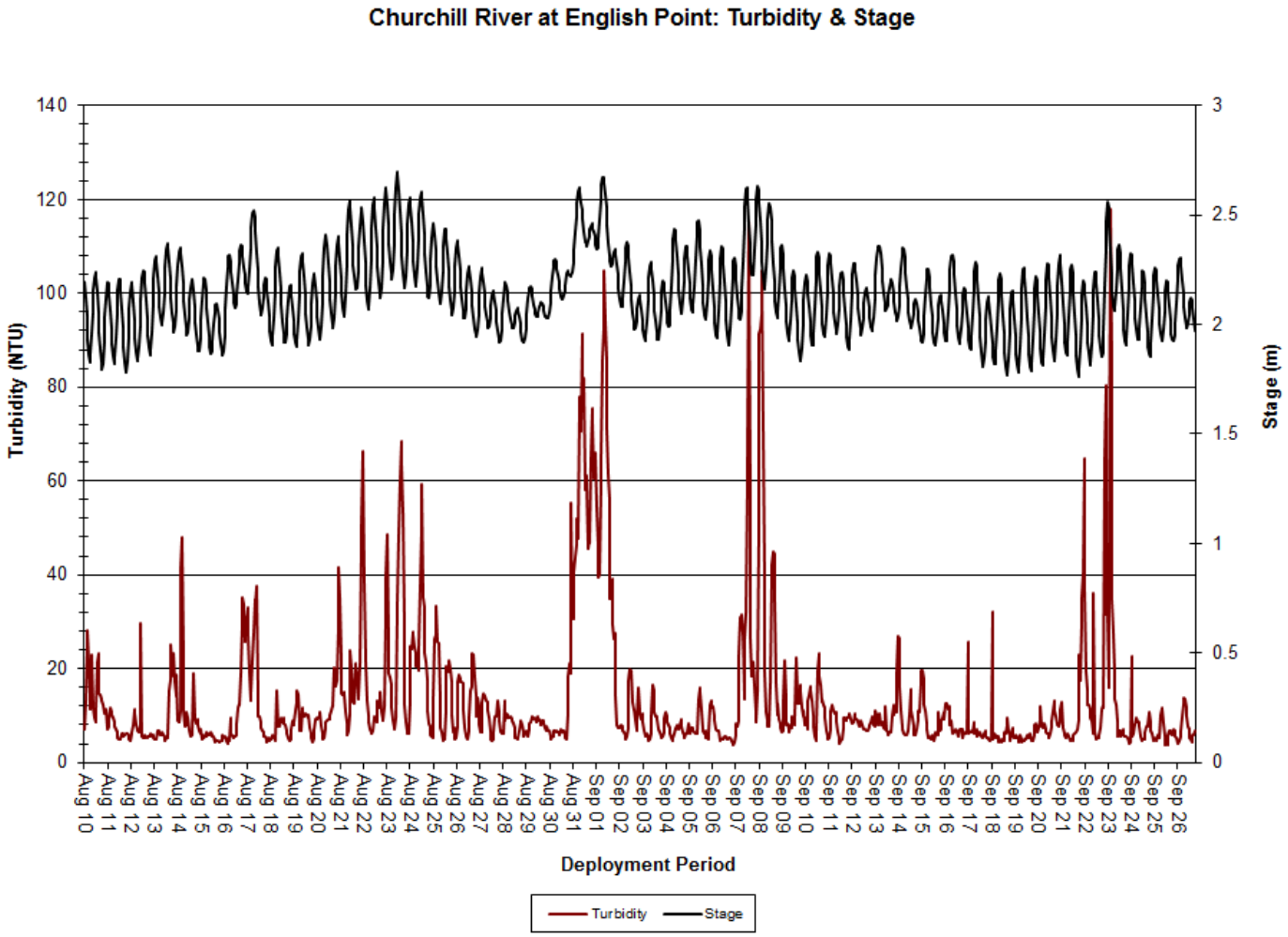

Figure 18: Turbidity & Stage at Churchill River at English Point

Stage

- Stage ranged from 1.76m to 2.70m, with a median value of 2.13m (Figure 19).
- Stage fluctuates at this location due to the tidal influences of the Atlantic Ocean. As the tide comes in, stage increases causing tide-related turbidity events, and vice versa as the tide goes out. This pattern is generally consistent throughout the deployment period (Figure 19). Tidal action may also suspend material in the water column, causing spikes in turbidity unrelated to precipitation events.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

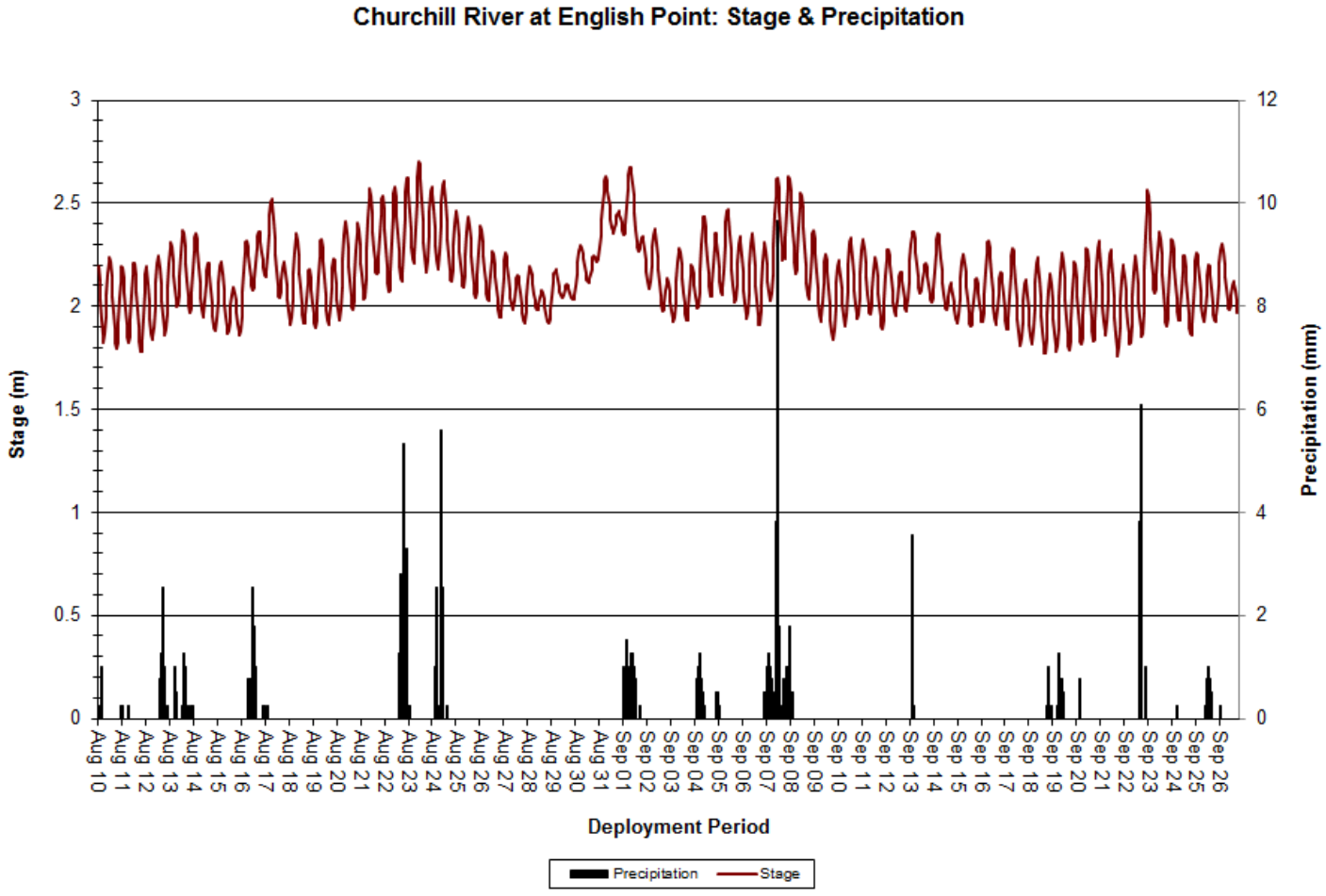

Figure 19: Stage & Precipitation (Mud Lake Weather Station) at Churchill River at English Point

Conclusions

- Instruments at three water quality monitoring stations on the Lower Churchill River were deployed from August 10 to September 27/29, 2017 for periods of 48-50 days.
- Water temperature decreased at all stations throughout the deployment period due to decreasing ambient air temperatures in the region. Water temperature ranged from 9.90°C to 18.80°C across all stations.
- pH was generally neutral and stable at stations along the Lower Churchill River, ranging from 6.08 at Churchill River below Muskrat Falls to 7.34 at Churchill River at English Point. pH values at all stations were within the recommended CCME Guidelines for the Protection of Aquatic Life for the majority of the time, except during the last two weeks of deployment at Churchill River below Muskrat Falls.
- Specific conductivity was relatively stable at the above Grizzle Rapids and below Muskrat Falls stations, ranging from 15.0 to 20.0µS/cm. Since English Point is influenced by tides in Lake Melville, specific conductivity values at the Churchill River at English Point station had a much wider range between 16.1µS/cm and 45.9µS/cm. This is comparable to other deployments at this location.
- Dissolved oxygen increased slightly throughout the deployment period at all stations as water temperatures decreased following the summer months. Dissolved oxygen levels are generally higher in a waterbody at cooler temperatures. Dissolved oxygen values ranged from 9.31mg/L to 11.77mg/L, and remained above the CCME Guideline for the Protection of Early Life Stages for the duration of deployment at Churchill River below Muskrat Falls. Dissolved oxygen levels at the other two stations remained above the CCME Guideline for the Protection of Other Life Stages for the duration of deployment and were above the CCME Guidelines for the Protection of Early Life Stages for much of the deployment period.
- Turbidity events occurred at two stations and were mainly related to precipitation events. At all stations, median turbidity values ranged from 0.0NTU to 8.2NTU, which indicate low background turbidity levels. Turbidity at all stations ranged from 0.0 to 117.9NTU.

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APPENDIX A

Station Comparisons

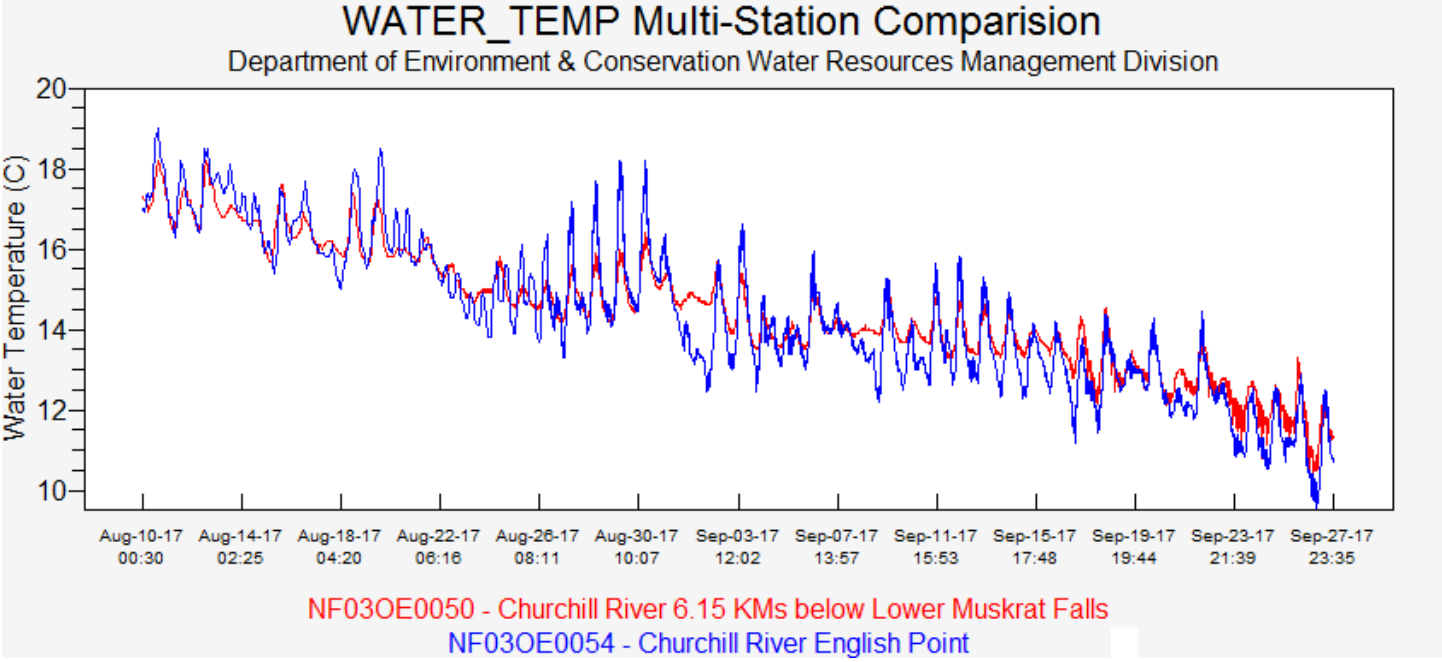

Figure A1: Comparison of Water Temperature at the Real-Time Stations on Churchill River

(Note: Grizzle Rapids station not included due to transmission issues)

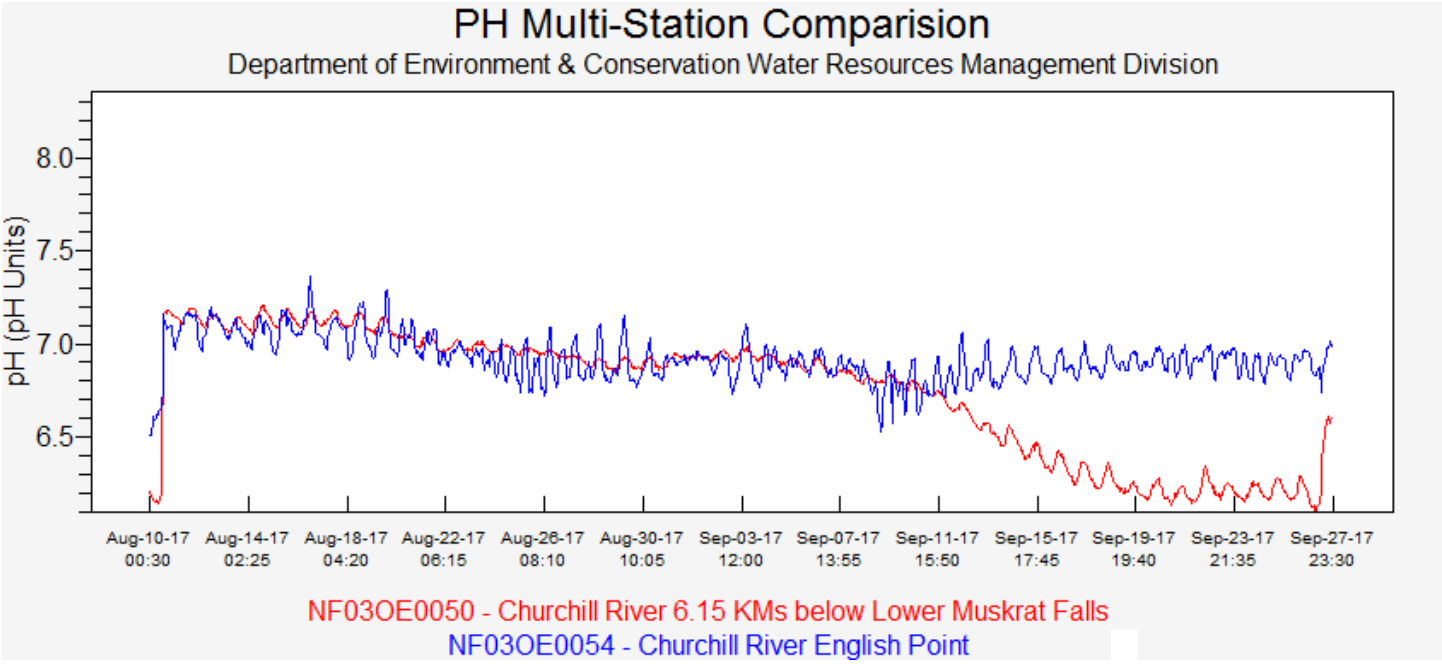

Figure A2: Comparison of pH at the Real-Time Stations on Churchill River

(Note: Grizzle Rapids station not included due to transmission issues)

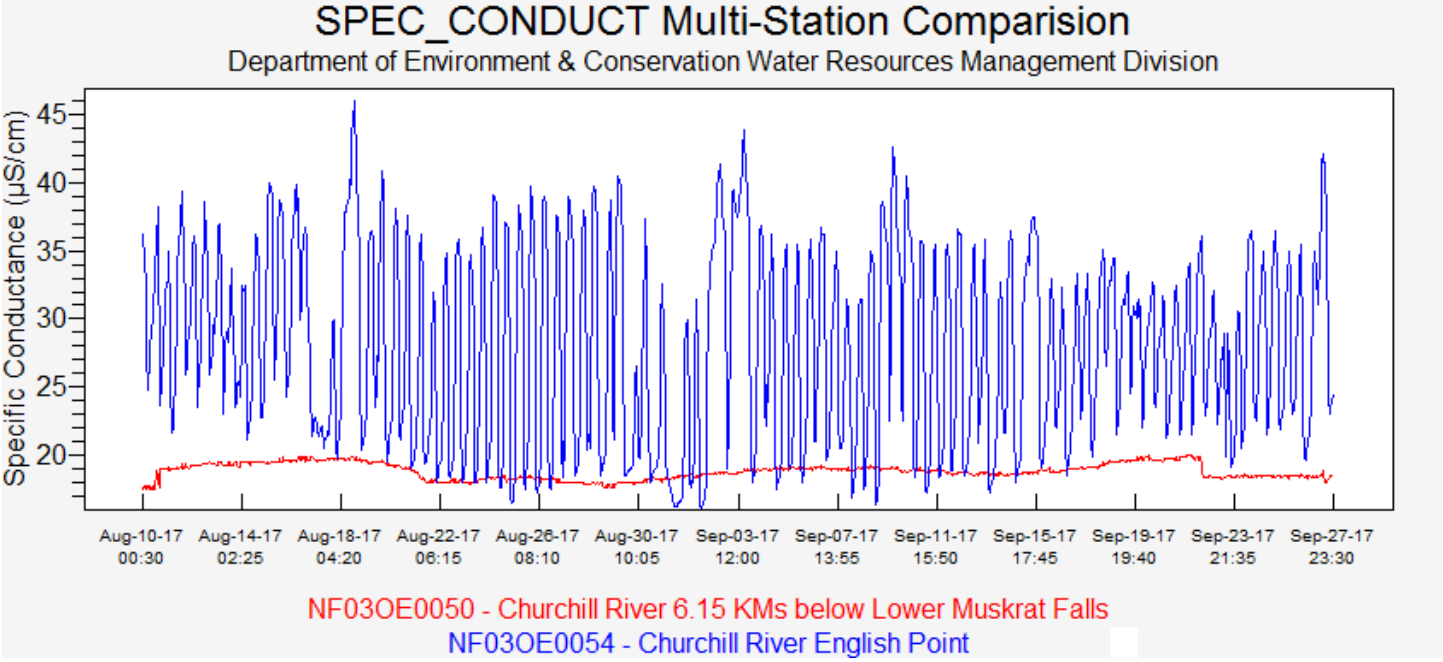

Figure A3: Comparison of Specific Conductivity at the Real-Time Stations on Churchill River

(Note: Grizzle Rapids station not included due to transmission issues)

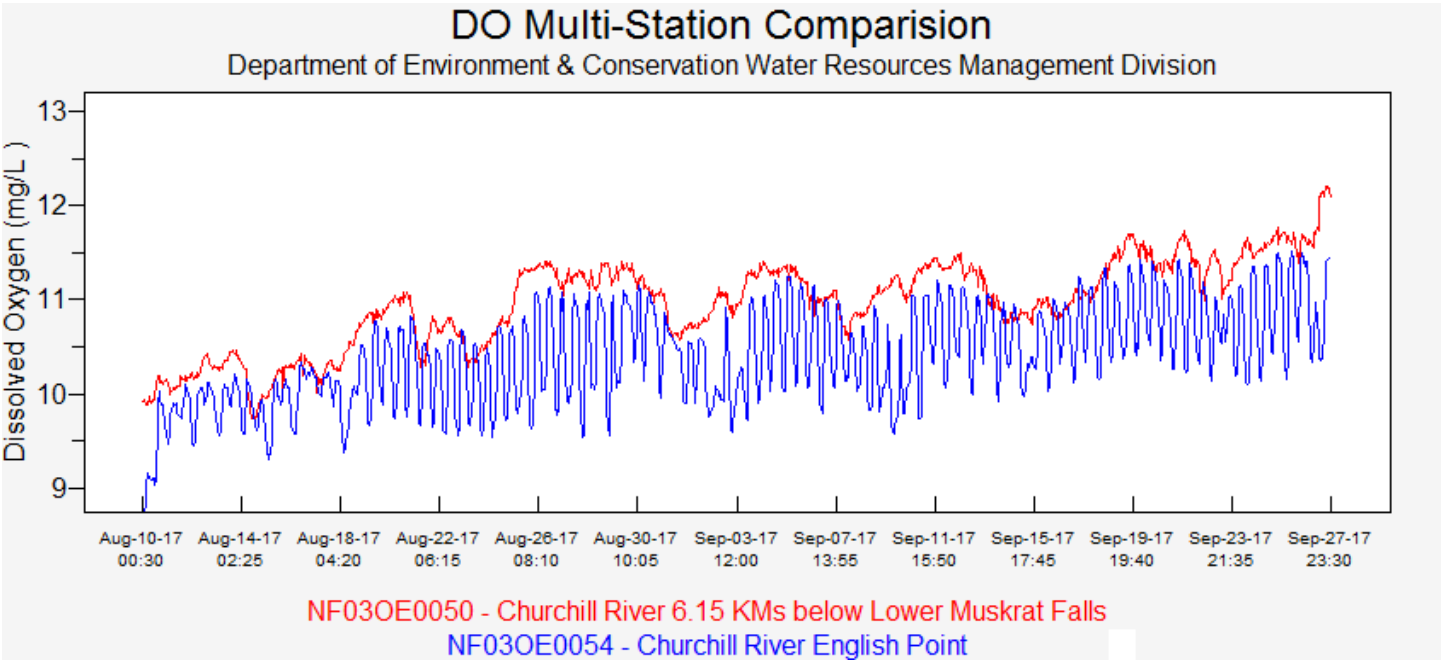

Figure A4: Comparison of Dissolved Oxygen at the Real-Time Stations on Churchill River

(Note: Grizzle Rapids station not included due to transmission issues)

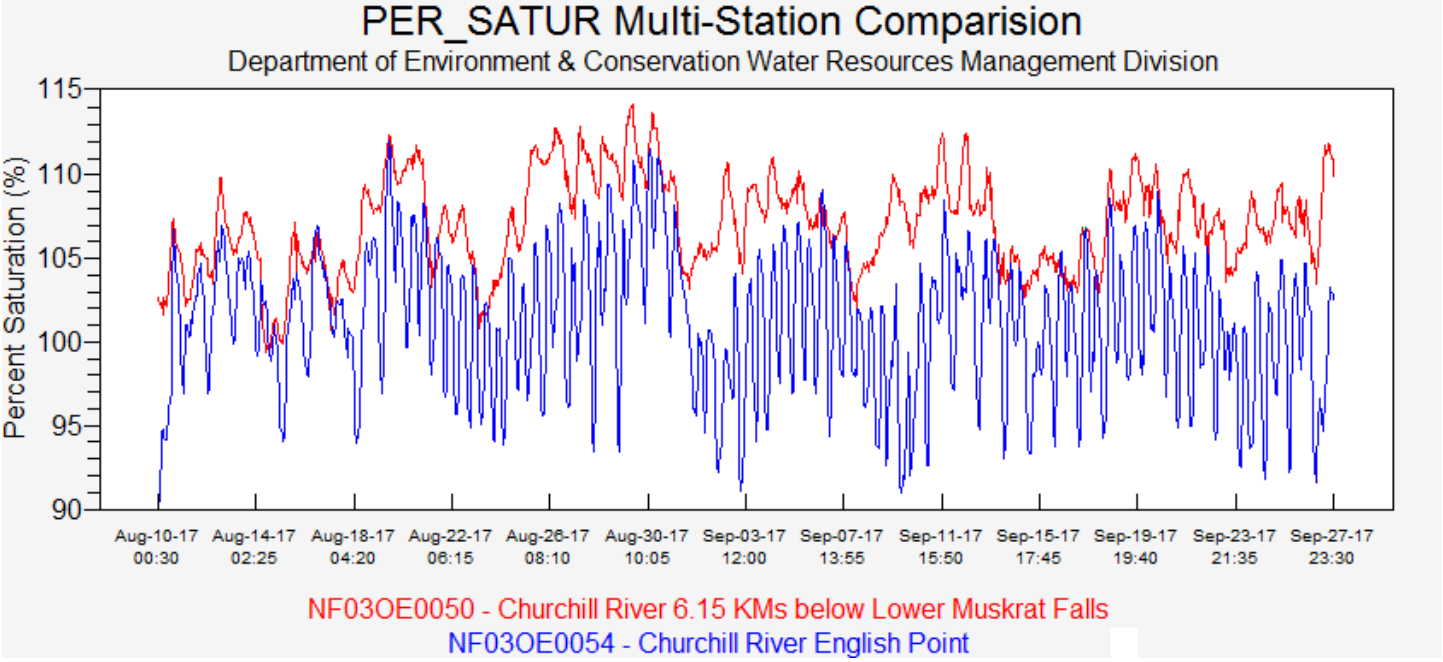

Figure A5: Comparison of Dissolved Oxygen (% Sat) at the Real-Time Stations on Churchill River

(Note: Grizzle Rapids station not included due to transmission issues)

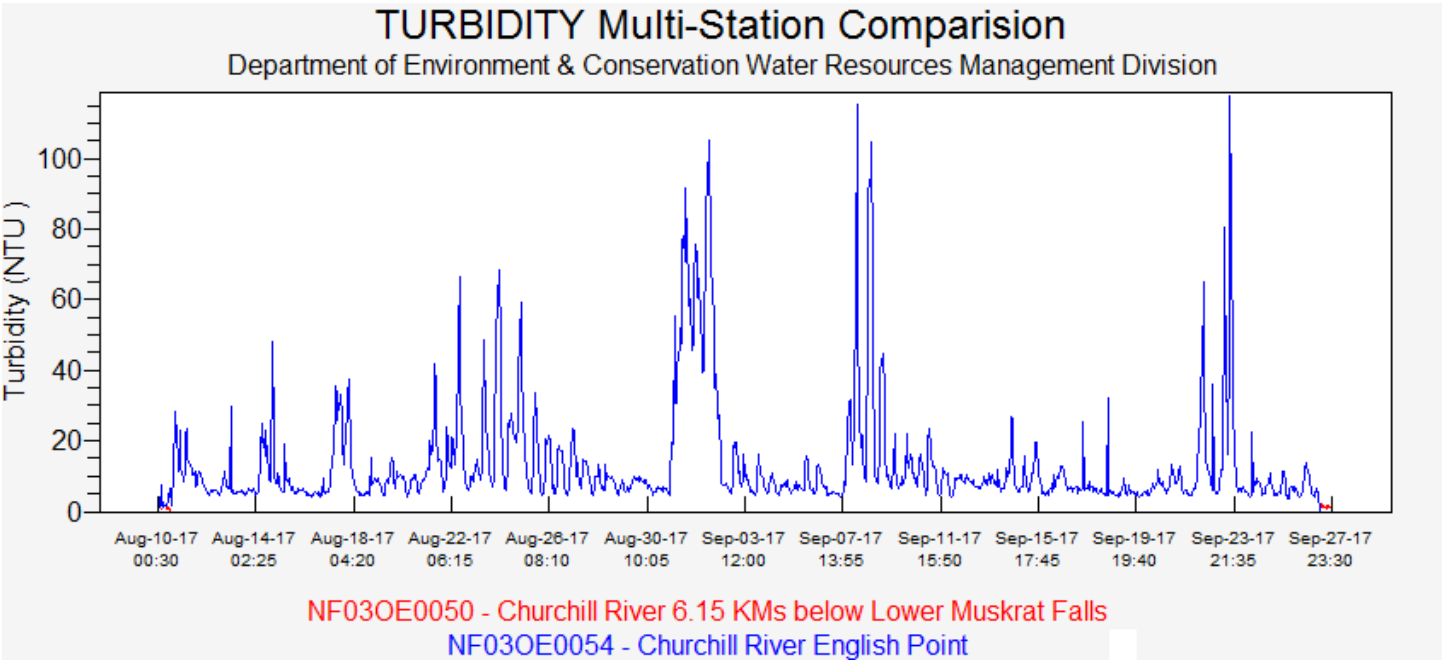

Figure A6: Comparison of Turbidity at the Real-Time Stations on Churchill River. Turbidity data for Churchill River below Muskrat Falls has been removed from the dataset for QA/QC purposes.

(Note: Grizzle Rapids station not included due to transmission issues)

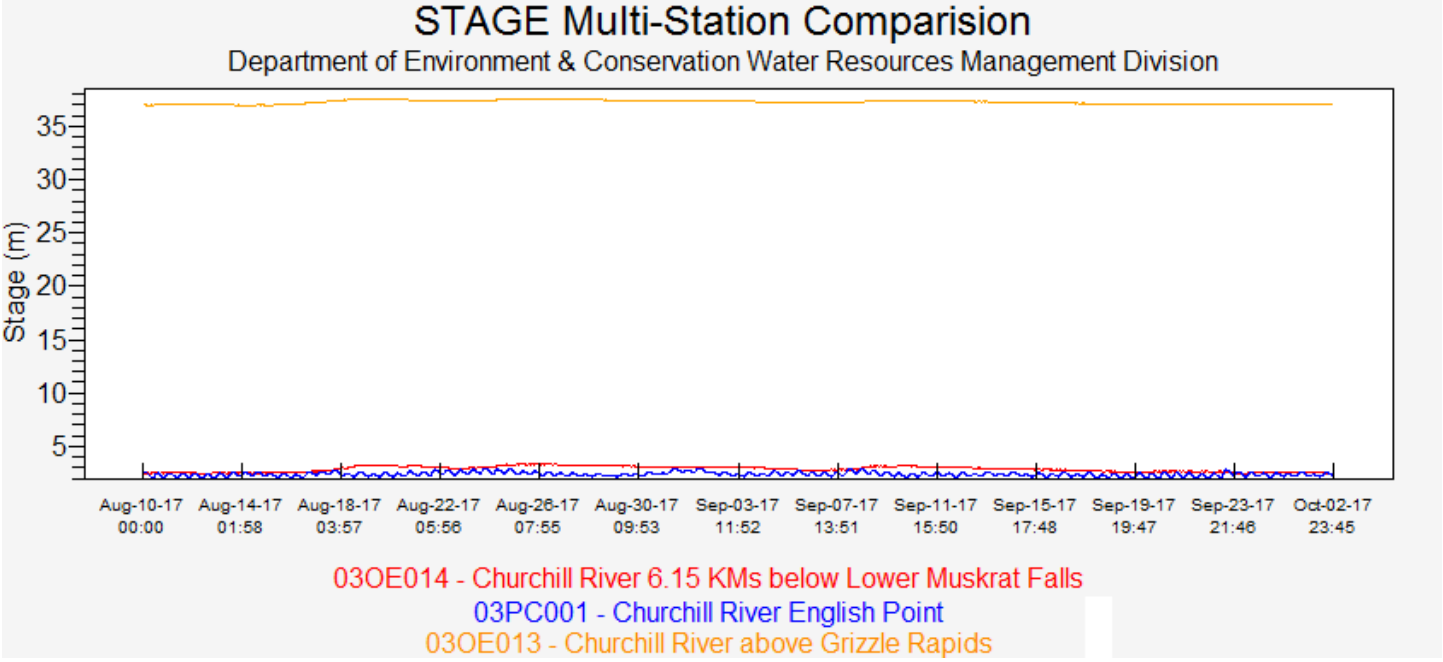

Figure A7: Comparison of Stage at the Real-Time Stations on Churchill River

APPENDIX B

Water Parameter Description

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 (USGS, 2017).

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 a measure of the relative amount of free hydrogen and hydroxyl ions in water. pH is an important indicator of chemically changing water, and determines the solubility and biological availability of nutrients and heavy metals in the water (USGS, 2017).

Specific conductivity - Specific conductivity (µs/cm) is a measure of water's ability to conduct electricity, with values normalized to a water temperature of 25°C. 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 (Fondriest Environmental Inc, 2016).

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 (°C) controls most aquatic processes. 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. In turn, water temperature has an influence on the metabolic rates and biological activity of aquatic organisms (Fondriest Environmental Inc, 2016b).

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 (Swenson 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 (Swenson and Baldwin 1965).

APPENDIX C

Grab Sample Results

Maxxam Job #: B7H4171
Report Date: 2017/08/23

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER
Your P.O. #: 2115062145-2
Sampler Initials: BG

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
EXZ300 CR above GR								
Sampling Date 2017/08/10 10:30								
Matrix W								
Sample # 2017-6319-00-SI-SP								
Registration # WS-S-0000								
RESULTS OF ANALYSES OF WATER								
Calculated Parameters								
Calculated TDS	12	1.0	mg/L	N/A	2017/08/22	2017/08/22		5119022
Hardness (CaCO3)	8.5	1.0	mg/L	N/A	2017/08/18	2017/08/18		5119015
Nitrate (N)	<0.050	0.050	mg/L	N/A	2017/08/21	2017/08/21		5119018
Inorganics								
Conductivity	19	1.0	uS/cm	N/A	2017/08/17	2017/08/17	JMV	5122980
Bromide (Br-)	<1.0	1.0	mg/L	N/A	2017/08/21	2017/08/21	FD	5125811
Total Alkalinity (Total as CaCO3)	9.6	5.0	mg/L	N/A	2017/08/21	2017/08/21	NRG	5125726
Dissolved Chloride (Cl)	<1.0	1.0	mg/L	N/A	2017/08/22	2017/08/22	NRG	5125730
Colour	25	5.0	TCU	N/A	2017/08/21	2017/08/21	NRG	5125739
Dissolved Fluoride (F-)	<0.10	0.10	mg/L	N/A	2017/08/17	2017/08/17	JMV	5122981
Total Kjeldahl Nitrogen (TKN)	<0.10	0.10	mg/L	N/A	2017/08/17	2017/08/18	BMO	5123892
Nitrite (N)	<0.010	0.010	mg/L	N/A	2017/08/21	2017/08/21	NRG	5125751
Nitrogen (Ammonia Nitrogen)	<0.050	0.050	mg/L	N/A	2017/08/21	2017/08/21	NRG	5125443
Dissolved Organic Carbon (C)	4.0	0.50	mg/L	N/A	2017/08/21	2017/08/21	SMT	5128392
Total Organic Carbon (C)	4.2	0.50	mg/L	N/A	2017/08/21	2017/08/21	SMT	5128400
pH	7.21	N/A	pH	N/A	2017/08/17	2017/08/17	JMV	5122979
Total Phosphorus	0.006	0.004	mg/L	+/- 0.004	2017/08/17	2017/08/18	ASP	5124209
Dissolved Sulphate (SO4)	<2.0	2.0	mg/L	N/A	2017/08/21	2017/08/21	NRG	5125731
Turbidity	1.1	0.10	NTU	N/A	2017/08/17	2017/08/17	JMV	5123019
MERCURY BY COLD VAPOUR AA (WATER)								
Metals								
Total Mercury (Hg)	<0.000013	0.000013	mg/L	N/A	2017/08/21	2017/08/22	AYN	5128081
ELEMENTS BY ICP/MS (WATER)								
Metals								
Total Aluminum (Al)	0.051	0.0050	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Antimony (Sb)	<0.0010	0.0010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Arsenic (As)	<0.0010	0.0010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Barium (Ba)	0.0077	0.0010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Boron (B)	<0.050	0.050	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Cadmium (Cd)	<0.000010	0.000010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Calcium (Ca)	2.2	0.10	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Chromium (Cr)	<0.0010	0.0010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Copper (Cu)	<0.0020	0.0020	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Iron (Fe)	0.12	0.050	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Lead (Pb)	<0.00050	0.00050	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Magnesium (Mg)	0.72	0.10	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Manganese (Mn)	0.0088	0.0020	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Nickel (Ni)	<0.0020	0.0020	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Potassium (K)	0.28	0.10	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067

Maxxam Analytics International Corporation o/a Maxxam Analytics 200 Bluewater Rd, Suite 105, Bedford, Nova Scotia Canada B4B 1G9 Tel: 902-420-0203 Toll-free: 800-565-7227 Fax: 902-420-8612 www.maxxamanalytics.com

Maxxam Job #: B7H4171
Report Date: 2017/08/23

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER
Your P.O. #: 2115062145-2
Sampler Initials: BG

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
EXZ300 CR above GR Sampling Date 2017/08/10 10:30 Matrix W Sample # 2017-6319-00-SI-SP Registration # WS-S-0000								
ELEMENTS BY ICP/MS (WATER)								
Metals								
Total Selenium (Se)	<0.0010	0.0010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Sodium (Na)	0.56	0.10	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Strontium (Sr)	0.012	0.0020	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Uranium (U)	<0.00010	0.00010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Zinc (Zn)	<0.0050	0.0050	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067

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Maxxam Job #: B7H4165
Report Date: 2017/08/21

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER
Your P.O. #: 216009736
Sampler Initials: BG

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
EXZ278 CR above GR Sampling Date 2017/08/10 10:30 Matrix W Sample # 2017-6319-00-SI-SP Registration # WS-S-0000 **RESULTS OF ANALYSES OF WATER** **Inorganics**								
Total Suspended Solids	2.0	1.0	mg/L	N/A	2017/08/16	2017/08/18	AM6	5121364

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Maxxam Job #: B7H4171
Report Date: 2017/08/23

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER
Your P.O. #: 2115062145-2
Sampler Initials: BG

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
EXZ301 CR below MF								
Sampling Date 2017/08/10 12:55								
Matrix W								
Sample # 2017-6320-00-SI-SP								
Registration # WS-S-0000								
RESULTS OF ANALYSES OF WATER								
Calculated Parameters								
Calculated TDS	14	1.0	mg/L	N/A	2017/08/22	2017/08/22		5119022
Hardness (CaCO3)	8.7	1.0	mg/L	N/A	2017/08/18	2017/08/18		5119015
Nitrate (N)	<0.050	0.050	mg/L	N/A	2017/08/21	2017/08/21		5119018
Inorganics								
Conductivity	19	1.0	uS/cm	N/A	2017/08/17	2017/08/17	JMV	5122980
Bromide (Br-)	<1.0	1.0	mg/L	N/A	2017/08/21	2017/08/21	FD	5125811
Total Alkalinity (Total as CaCO3)	10	5.0	mg/L	N/A	2017/08/21	2017/08/21	NRG	5125726
Dissolved Chloride (Cl)	1.3	1.0	mg/L	N/A	2017/08/22	2017/08/22	NRG	5125730
Colour	27	5.0	TCU	N/A	2017/08/21	2017/08/21	NRG	5125739
Dissolved Fluoride (F-)	<0.10	0.10	mg/L	N/A	2017/08/17	2017/08/17	JMV	5122981
Total Kjeldahl Nitrogen (TKN)	<0.10	0.10	mg/L	N/A	2017/08/17	2017/08/18	BMO	5123892
Nitrite (N)	<0.010	0.010	mg/L	N/A	2017/08/21	2017/08/21	NRG	5125751
Nitrogen (Ammonia Nitrogen)	<0.050	0.050	mg/L	N/A	2017/08/21	2017/08/21	NRG	5125443
Dissolved Organic Carbon (C)	4.3	0.50	mg/L	N/A	2017/08/21	2017/08/21	SMT	5128392
Total Organic Carbon (C)	4.2	0.50	mg/L	N/A	2017/08/21	2017/08/21	SMT	5128400
pH	7.11	N/A	pH	N/A	2017/08/17	2017/08/17	JMV	5122979
Total Phosphorus	0.008	0.004	mg/L	+/- 0.004	2017/08/17	2017/08/18	ASP	5124209
Dissolved Sulphate (SO4)	<2.0	2.0	mg/L	N/A	2017/08/21	2017/08/21	NRG	5125731
Turbidity	3.6	0.10	NTU	N/A	2017/08/17	2017/08/17	JMV	5123019
MERCURY BY COLD VAPOUR AA (WATER)								
Metals								
Total Mercury (Hg)	<0.000013	0.000013	mg/L	N/A	2017/08/21	2017/08/22	AYN	5128081
ELEMENTS BY ICP/MS (WATER)								
Metals								
Total Aluminum (Al)	0.16	0.0050	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Antimony (Sb)	<0.0010	0.0010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Arsenic (As)	<0.0010	0.0010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Barium (Ba)	0.0090	0.0010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Boron (B)	<0.050	0.050	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Cadmium (Cd)	<0.000010	0.000010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Calcium (Ca)	2.2	0.10	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Chromium (Cr)	<0.0010	0.0010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Copper (Cu)	<0.0020	0.0020	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Iron (Fe)	0.21	0.050	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Lead (Pb)	<0.00050	0.00050	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Magnesium (Mg)	0.75	0.10	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Manganese (Mn)	0.0088	0.0020	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Nickel (Ni)	<0.0020	0.0020	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Potassium (K)	0.37	0.10	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067

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Maxxam Job #: B7H4171
Report Date: 2017/08/23

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER
Your P.O. #: 2115062145-2
Sampler Initials: BG

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
EXZ301 CR below MF Sampling Date 2017/08/10 12:55 Matrix W Sample # 2017-6320-00-SI-SP Registration # WS-S-0000								
ELEMENTS BY ICP/MS (WATER)								
Metals								
Total Selenium (Se)	<0.0010	0.0010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Sodium (Na)	0.68	0.10	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Strontium (Sr)	0.012	0.0020	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Uranium (U)	<0.00010	0.00010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Zinc (Zn)	<0.0050	0.0050	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067

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Maxxam Job #: B7H4165
Report Date: 2017/08/21

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER
Your P.O. #: 216009736
Sampler Initials: BG

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
EXZ279 CR below MF Sampling Date 2017/08/10 12:55 Matrix W Sample # 2017-6320-00-SI-SP Registration # WS-S-0000 **RESULTS OF ANALYSES OF WATER** **Inorganics**								
Total Suspended Solids	4.6	1.0	mg/L	N/A	2017/08/16	2017/08/18	AM6	5121364

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Maxxam Job #: B7H4171
Report Date: 2017/08/23

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER
Your P.O. #: 2115062145-2
Sampler Initials: BG

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
EXZ303 CR @ EP								
Sampling Date 2017/08/10 14:40								
Matrix W								
Sample # 2017-6322-00-SI-SP								
Registration # WS-S-0000								
RESULTS OF ANALYSES OF WATER								
Calculated Parameters								
Calculated TDS	24	1.0	mg/L	N/A	2017/08/22	2017/08/22		5119022
Hardness (CaCO3)	9.6	1.0	mg/L	N/A	2017/08/18	2017/08/18		5119015
Nitrate (N)	<0.050	0.050	mg/L	N/A	2017/08/21	2017/08/21		5119018
Inorganics								
Conductivity	38	1.0	uS/cm	N/A	2017/08/17	2017/08/17	JMV	5122983
Bromide (Br-)	<1.0	1.0	mg/L	N/A	2017/08/21	2017/08/21	FD	5125811
Total Alkalinity (Total as CaCO3)	9.4	5.0	mg/L	N/A	2017/08/21	2017/08/21	NRG	5125726
Dissolved Chloride (Cl)	6.2	1.0	mg/L	N/A	2017/08/22	2017/08/22	NRG	5125730
Colour	54(1)	25	TCU	N/A	2017/08/21	2017/08/21	NRG	5125739
Dissolved Fluoride (F-)	<0.10	0.10	mg/L	N/A	2017/08/17	2017/08/17	JMV	5122984
Total Kjeldahl Nitrogen (TKN)	<0.10	0.10	mg/L	N/A	2017/08/17	2017/08/18	BMO	5123892
Nitrite (N)	<0.010	0.010	mg/L	N/A	2017/08/21	2017/08/21	NRG	5125751
Nitrogen (Ammonia Nitrogen)	<0.050	0.050	mg/L	N/A	2017/08/21	2017/08/21	NRG	5125443
Dissolved Organic Carbon (C)	5.9	0.50	mg/L	N/A	2017/08/21	2017/08/21	SMT	5128392
Total Organic Carbon (C)	5.9	0.50	mg/L	N/A	2017/08/21	2017/08/21	SMT	5128400
pH	7.19	N/A	pH	N/A	2017/08/17	2017/08/17	JMV	5122982
Total Phosphorus	0.017	0.004	mg/L	+/- 0.005	2017/08/17	2017/08/18	ASP	5124209
Dissolved Sulphate (SO4)	<2.0	2.0	mg/L	N/A	2017/08/21	2017/08/21	NRG	5125731
Turbidity	8.4	0.10	NTU	N/A	2017/08/17	2017/08/17	JMV	5123019
MERCURY BY COLD VAPOUR AA (WATER)								
Metals								
Total Mercury (Hg)	<0.000013	0.000013	mg/L	N/A	2017/08/21	2017/08/22	AYN	5128081
ELEMENTS BY ICP/MS (WATER)								
Metals								
Total Aluminum (Al)	0.29	0.0050	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Antimony (Sb)	<0.0010	0.0010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Arsenic (As)	<0.0010	0.0010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Barium (Ba)	0.0097	0.0010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Boron (B)	<0.050	0.050	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Cadmium (Cd)	<0.000010	0.000010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Calcium (Ca)	2.1	0.10	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Chromium (Cr)	<0.0010	0.0010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Copper (Cu)	<0.0020	0.0020	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Iron (Fe)	0.56	0.050	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Lead (Pb)	<0.00050	0.00050	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Magnesium (Mg)	1.1	0.10	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Manganese (Mn)	0.012	0.0020	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Nickel (Ni)	<0.0020	0.0020	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067

(1) Elevated reporting limit due to sample matrix.

Maxxam Analytics International Corporation o/a Maxxam Analytics 200 Bluewater Rd, Suite 105, Bedford, Nova Scotia Canada B4B 1G9 Tel: 902-420-0203 Toll-free: 800-565-7227 Fax: 902-420-8612 www.maxxamanalytics.com

Maxxam Job #: B7H4171
Report Date: 2017/08/23

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER
Your P.O. #: 2115062145-2
Sampler Initials: BG

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
EXZ303 CR @ EP Sampling Date 2017/08/10 14:40 Matrix W Sample # 2017-6322-00-SI-SP Registration # WS-S-0000								
ELEMENTS BY ICP/MS (WATER)								
Metals								
Total Potassium (K)	0.56	0.10	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Selenium (Se)	<0.0010	0.0010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Sodium (Na)	4.1	0.10	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Strontium (Sr)	0.017	0.0020	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Uranium (U)	<0.00010	0.00010	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067
Total Zinc (Zn)	<0.0050	0.0050	mg/L	N/A	2017/08/17	2017/08/17	BAN	5123067

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Maxxam Job #: B7H4165
Report Date: 2017/08/21

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER
Your P.O. #: 216009736
Sampler Initials: BG

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
EXZ281 CR @ EP Sampling Date 2017/08/10 14:40 Matrix W Sample # 2017-6322-00-SI-SP Registration # WS-S-0000								
RESULTS OF ANALYSES OF WATER								
Inorganics								
Total Suspended Solids	9.1	2.0	mg/L	N/A	2017/08/16	2017/08/18	AM6	5121364

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