Real-Time Water Quality 2017 Annual Report

Churchill River Network

May 31 to November 2, 2017

Newfoundland Labrador

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

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Acknowledgements

The Real-Time Water Quality (RTWQ) monitoring network on the Churchill River is successful in tracking emerging water quality issues, as well as creating a database of baseline water quality data due to the hard work and diligence of certain individuals. The management and staff of Nalcor work in cooperation with the management and staff of the Department of Municipal Affairs and Environment (MAE) as well as Environment and Climate Change Canada (ECCC) to ensure the protection of ambient water resources in the Churchill River.

Employees with the Water Resources Management Division of the Department of MAE were integral in ensuring the smooth operation of such a technologically advanced network. In 2017, WRMD Environmental Scientist Brenda Greene was responsible for deployment and removal of instruments including cleaning, calibration, and maintenance, as well as preparation of monthly deployment reports. Maria Murphy is acknowledged for her contribution to deployment and removal procedures throughout the 2017 season.

Water Survey of Canada staff with ECCC played an essential role in the data logging/communication aspect of the network. These individuals visited the site regularly to ensure the data logging equipment was operating properly and transmitting data efficiently. Finally, they played the lead role in dealing with hydrological quantity and flow issues.

Managers from each agency (Peter Madden/David Haley – Nalcor; Renee Paterson/Melissa McComiskey – MAE; and Howie Wills – ECCC) are fully committed to improving this network and ensuring it provides meaningful and accurate water quality/quantity data that can be used in decision-making processes. Throughout the summer and fall months of 2017, there was continued communication in the form of small meetings and email correspondence between MAE and Nalcor. This network is continually successful due to the participation and collaboration of all three agencies.

Abbreviations

ECCC	Environment and Climate Change Canada
MAE	NL Department of Municipal Affairs and Environment
CRbelowMR	Station at Churchill River below Metchin River
CRaboveGR	Station at Churchill River above Grizzle Rapids
CRbelowMF	Station at Churchill River below Muskrat Falls
CRatEngPt	Station at Churchill River at English Point
DO	Dissolved Oxygen
NL	Newfoundland and Labrador
QA/QC	Quality Assurance and Quality Control
RTWQ	Real-Time Water Quality
WRMD	Water Resources Management Division
%Sat	Percent Saturation

History

- The RTWQ monitoring network on the Lower Churchill River was successfully established by MAE and ECCC in cooperation with Nalcor Energy in September 2008.
- The objective of the network is to identify and track emerging water quality or quantity management issues and ensure protection of ambient water resources along the Lower Churchill River. The information being collected will serve as a baseline from which changes throughout the several phases of the Lower Churchill Hydroelectric Generation Project can be monitored.
- The original network, established in 2008, consisted of 4 water quality/quantity monitoring stations along the Lower Churchill River from just below the confluence with Metchin River to just below Muskrat Falls. In addition, there were two water quantity monitoring stations on the Churchill River below the Tailrace and above Grizzle Rapids, which strictly recorded stage level continuously. There were also hydrometric stations on select tributaries to the Churchill River (ie. East Metchin River, Pinus River, Minipi River (Figure 1).
- In 2011, MAE in cooperation with ECCC established another water quality/quantity monitoring station at the mouth of the Churchill River (Churchill River at English Point). This station is included in this annual report for comparison purposes (Figure 1). A water quantity station was also established at Lake Melville east of Little River in 2011.
- During the 2014 deployment year, one water quality/quantity monitoring station (Churchill River below Metchin River) and three water quantity monitoring stations (Churchill River above Churchill Falls Tailrace, East Metchin River below Highway Bridge and Minipi River below Minipi Lake) were discontinued as per changes to the Memorandum of Agreement between MAE and Nalcor. An additional water quantity monitoring station (Churchill River at Mid Pool) was added to the agreement in 2014.
- Continuous monitoring at four water quality/quantity monitoring stations in the Lower Churchill River Network recommenced in spring 2017. This annual deployment report illustrates, discusses and summarizes water quality related events from May 31 to November 2, 2017. Due to challenging site conditions, only one RTWQ station (Churchill River below Muskrat Falls) was monitored for the entire season. Instruments were generally deployed for 30-50 day intervals referred to as deployment periods.
- Issues were encountered at a few of the stations during the deployment season. Due to the presence of an ice wall at below Grizzle Rapids and damage to the landing pad at English Point, these stations were not deployed until the end of June. Further, the station at below Grizzle Rapids had to be relocated to above Grizzle Rapids due to a landslide that occurred in 2016. The stations at above Muskrat Falls and Mid Pool were not deployed during the 2017 due to inaccessibility and safety concerns. The station at Churchill River below Metchin River was reactivated towards the end of the 2017 season, and an instrument was deployed at this site from September through November.
- During the 2017 deployment season, several stations were reactivated or added to the Churchill River network. Stations at Churchill River below Metchin River and Churchill River above Churchill Falls Tailrace were reactivated. New stations at Churchill River below Churchill Falls Tailrace, Churchill River at Happy Valley, and Mud Lake at Mud Lake were installed. With the exception of Churchill River below Metchin River, these reactivated and new stations collect water quantity data only.
- Construction at the Muskrat Falls Hydroelectric Generation site began in 2013. In 2017, construction continued on the worksite with progress on the powerhouse, and north and south dams. Construction is scheduled to continue through 2018.

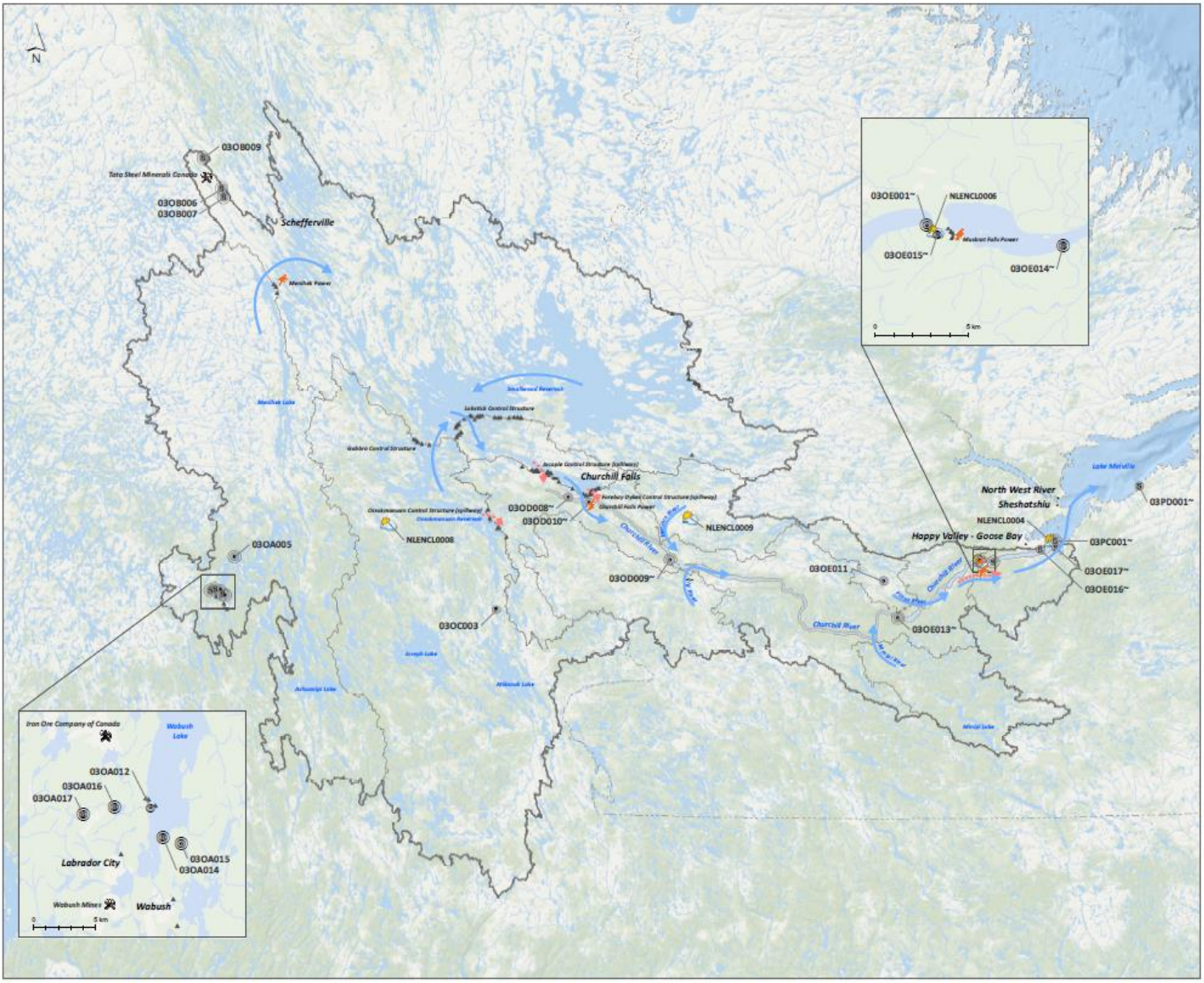


Figure 1: Churchill River Station Network Map

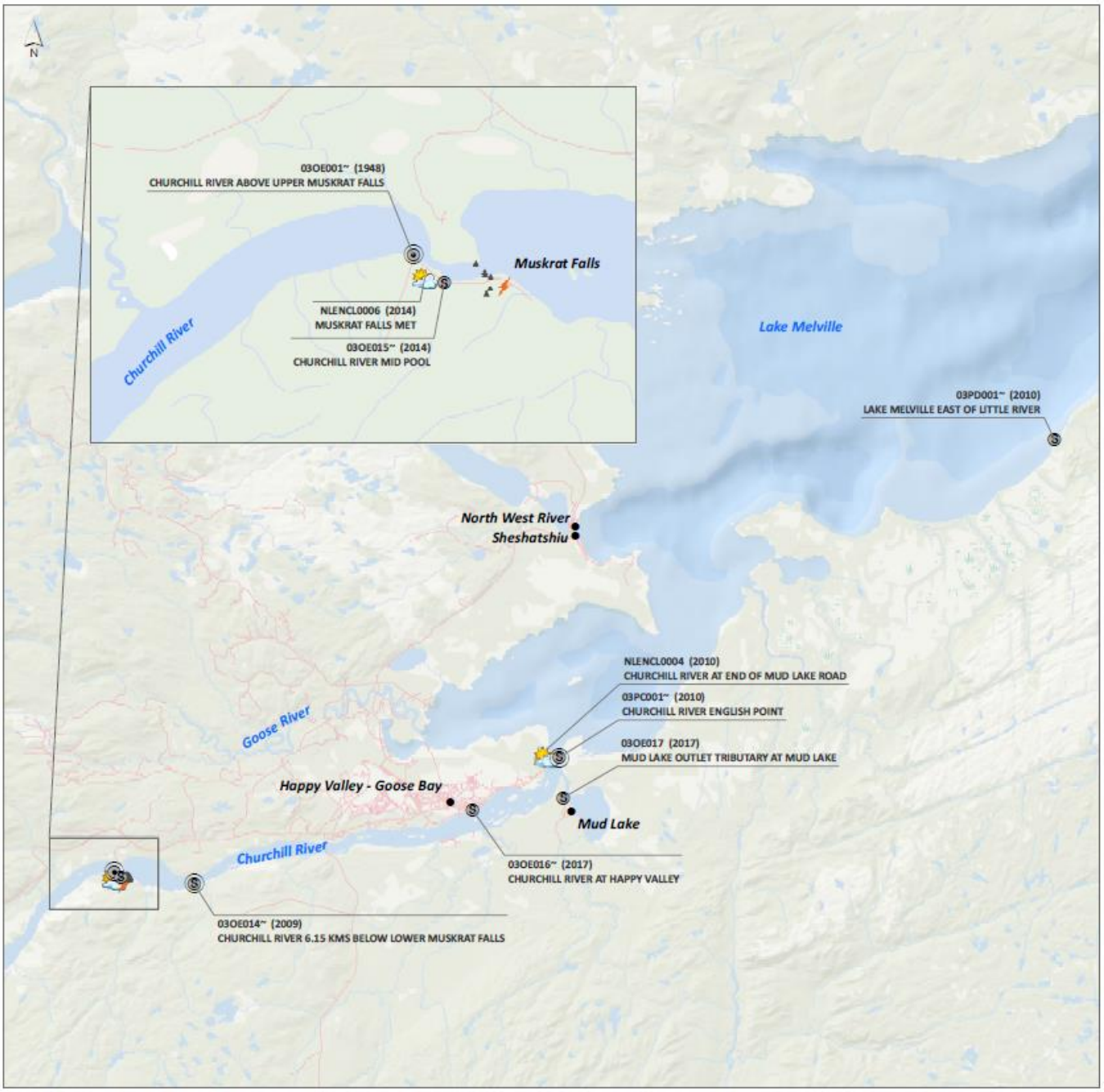


Figure 2: Lower Churchill River Network Station Map

Maintenance and Calibration

- Regular maintenance and calibration of the instruments is required to ensure data accuracy. This procedure is the responsibility of MAE staff and is performed generally every 30-50 days.
- Maintenance includes a thorough cleaning of the instrument and replacement of any small sensor parts that are damaged or unsuitable for reuse. Once the instrument is cleaned, MAE staff carefully calibrate each sensor attachment for pH, specific conductivity, dissolved oxygen and turbidity.
- Installation and removal dates for each station during the 2017 deployment season are summarized in Table 1.

Table 1: Installation and removal dates for 2017 deployment season

Station	Initial Installation	Removal	Deployment Periods (days)
Churchill River below Metchin River	September 29	November 2	34
Churchill River above Grizzle Rapids	July 12	November 1	29, 50, 33
Churchill River below Muskrat Falls	May 31	November 1	36, 36, 48, 35
Churchill River at English Point	July 6	November 1	35, 48, 35

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. The procedure is based on the approach used by the United States Geological Survey (USGS).
  - ► 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 2).

Table 2: 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 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.

- Comparison rankings for the Lower Churchill River stations during the 2017 deployment season are summarized in Table 3.
- For additional information and explanations of rankings including "N/A" rankings, please refer to the monthly deployment reports.

Table 3: Comparison rankings for Lower Churchill River stations, 2017 deployment season

Station	Date	Action	Temperature	pH	Specific Conductivity	Dissolved Oxygen	Turbidity
Churchill River below Metchin River		Deployment	Instrument not deployed				
		Removal					
		Deployment	Instrument not deployed				
		Removal					
		Deployment	Instrument not deployed				
		Removal					
	September 29	Deployment	Good	Excellent	Excellent	Excellent	Excellent
	November 2	Removal	Good	Excellent	Excellent	Good	Excellent
Churchill River above Grizzle Rapids		Deployment	Instrument not deployed				
		Removal					
	July 12	Deployment	Good	Good	Excellent	Excellent	Excellent
	August 10	Removal	Good	Good	Excellent	Good	Excellent
	August 10	Deployment	Good	Good	Excellent	Good	Excellent
	September 29	Removal	Good	Excellent	Excellent	Poor	Poor
	September 29	Deployment	Good	Good	Excellent	Excellent	Poor
	November 1	Removal	N/A	N/A	N/A	N/A	N/A
Churchill River below Muskrat Falls	May 31	Deployment	Good	Poor	Excellent	Poor	Fair
	July 5	Removal	Excellent	Good	Excellent	Excellent	Excellent
	July 5	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
	August 10	Removal	Excellent	Good	Excellent	Fair	Excellent
	August 10	Deployment	Excellent	Excellent	Excellent	Good	Poor
	September 27	Removal	Excellent	Excellent	Excellent	Excellent	Excellent
	September 27	Deployment	Good	Fair	Excellent	Excellent	Poor
	November 1	Removal	Fair	Good	Excellent	Good	Fair
Churchill River at English Point		Deployment	Instrument not deployed				
		Removal					
	July 6	Deployment	Fair	Good	Good	Excellent	Poor
	August 10	Removal	Good	Excellent	Fair	Fair	Excellent
	August 10	Deployment	Marginal	Excellent	Good	Excellent	Excellent
	September 27	Removal	Good	Excellent	Poor	Excellent	Fair
	September 27	Deployment	Good	Good	Marginal	Excellent	Poor
	November 1	Removal	Good	Excellent	Excellent	Excellent	Poor

Data Interpretation and Review

- The following graphs and discussions illustrate significant water quality-related trends from May 31 to November 2 throughout the Churchill River network. In this summary of all 2017 deployment periods, general patterns will be discussed. For more detailed analysis and discussion of specific events, please refer to the monthly deployment reports.
- With the exception of water quantity data (stage), all data used in the preparation of the graphs and subsequent discussion below adhere to stringent QA/QC protocol.
- Water Survey of Canada (ECCC) is responsible for QA/QC of water quantity data (stage). Corrected data can be obtained upon request.
- For a general comparison, 2015 and 2016 data have been included (where available) to show trends in water quality on the Churchill River over the past 3 years.
- Summary statistics are calculated using the entire data set. This means that the number of values used to calculate the median, minimum, and maximum vary from year to year, and from station to station, depending on the length of the deployment season.

Churchill River below Metchin River

Temperature

- Water temperature ranged from 2.9°C to 8.9°C during the 2017 deployment season, with a median value of 5.4°C (Figure 3).
- Since this station was not deployed until late September, the observed decreasing temperature trend is expected into the fall months.
- Comparison data from 2016 and 2015 is not available for this station.

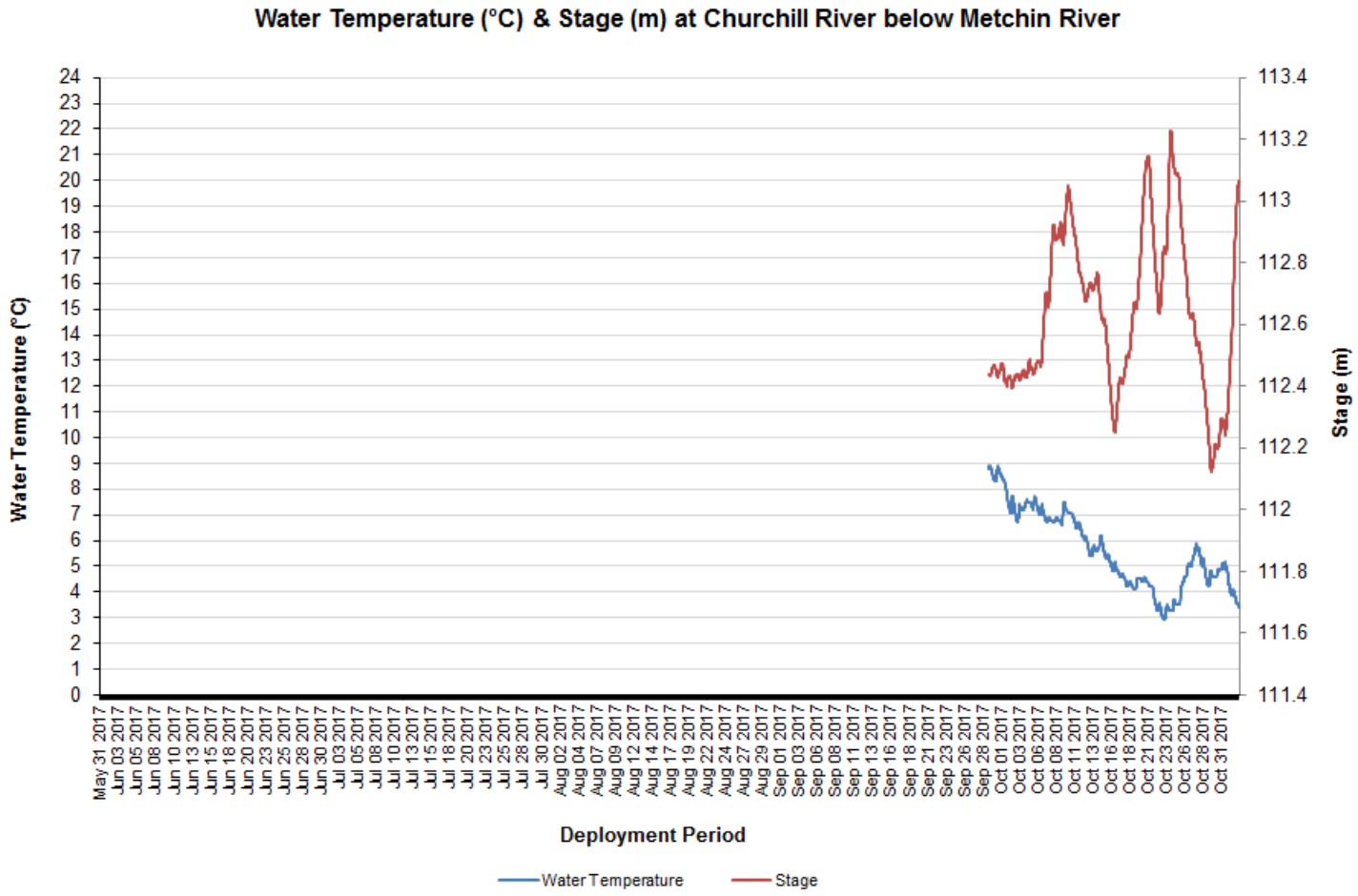


Figure 3: Water Temperature & Stage at Churchill River below Metchin River

Temperature	2017	2016	2015
Min	2.9	-	-
Max	8.9	-	-
Median	5.4	-	-

- Water temperature values showed a typical seasonal trend (Figure 4). Water and air temperatures both decreased through the fall months.

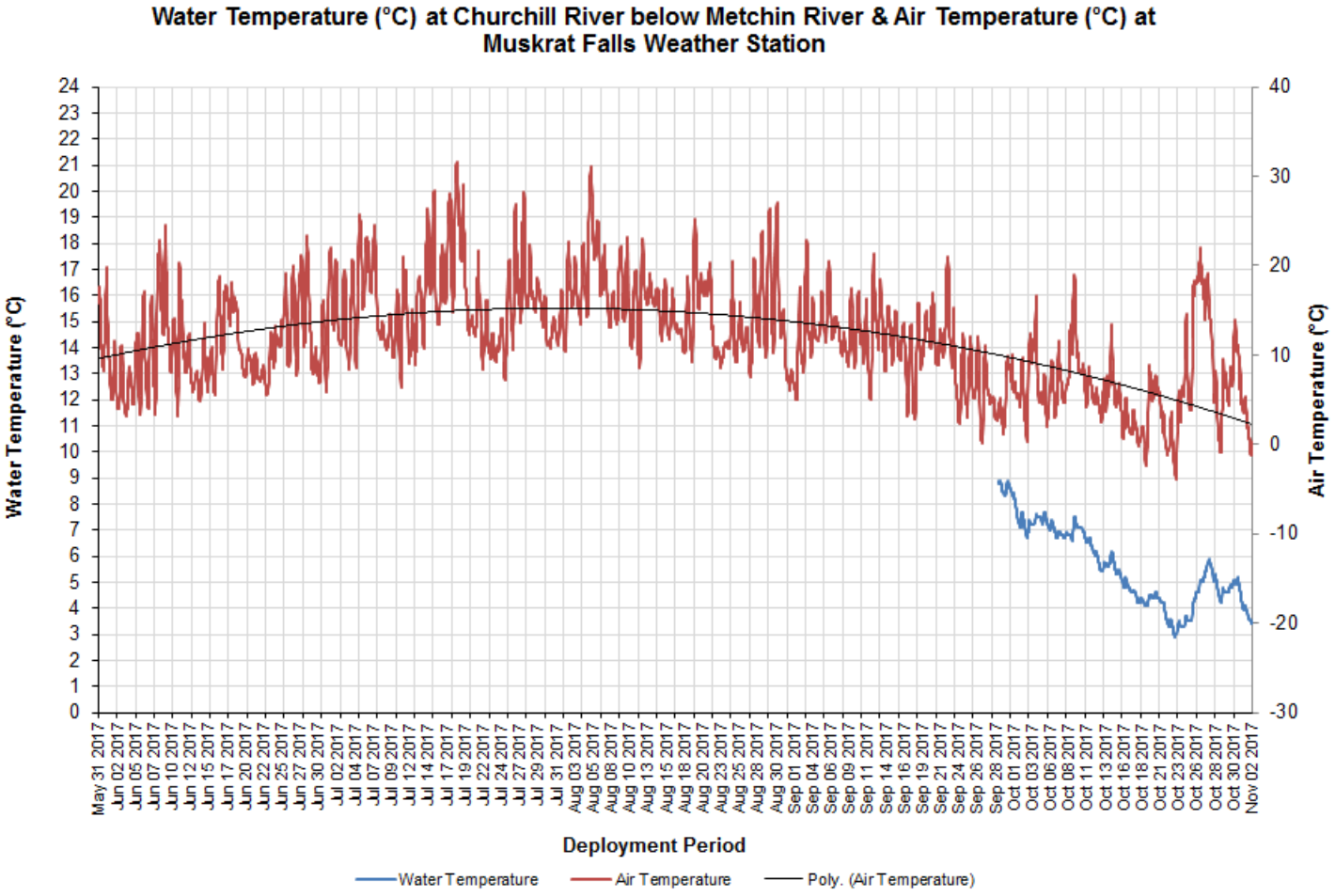


Figure 4: Water Temperature at Churchill River below Metchin River & Air Temperature at Muskrat Falls MET

pH

- pH ranged from 6.58 to 6.95 pH units during the 2017 deployment season, with a median value of 6.75 pH units (Figure 5).
- pH values were consistent throughout the deployment season, with clear diurnal fluctuation.
- pH values during the 2017 deployment season were within the CCME Guidelines for the Protection of Aquatic Life (>6.5 and <9.0 pH units). The guidelines are indicated in red on Figure 5.
- Comparison data for 2016 and 2015 is not available for this station.

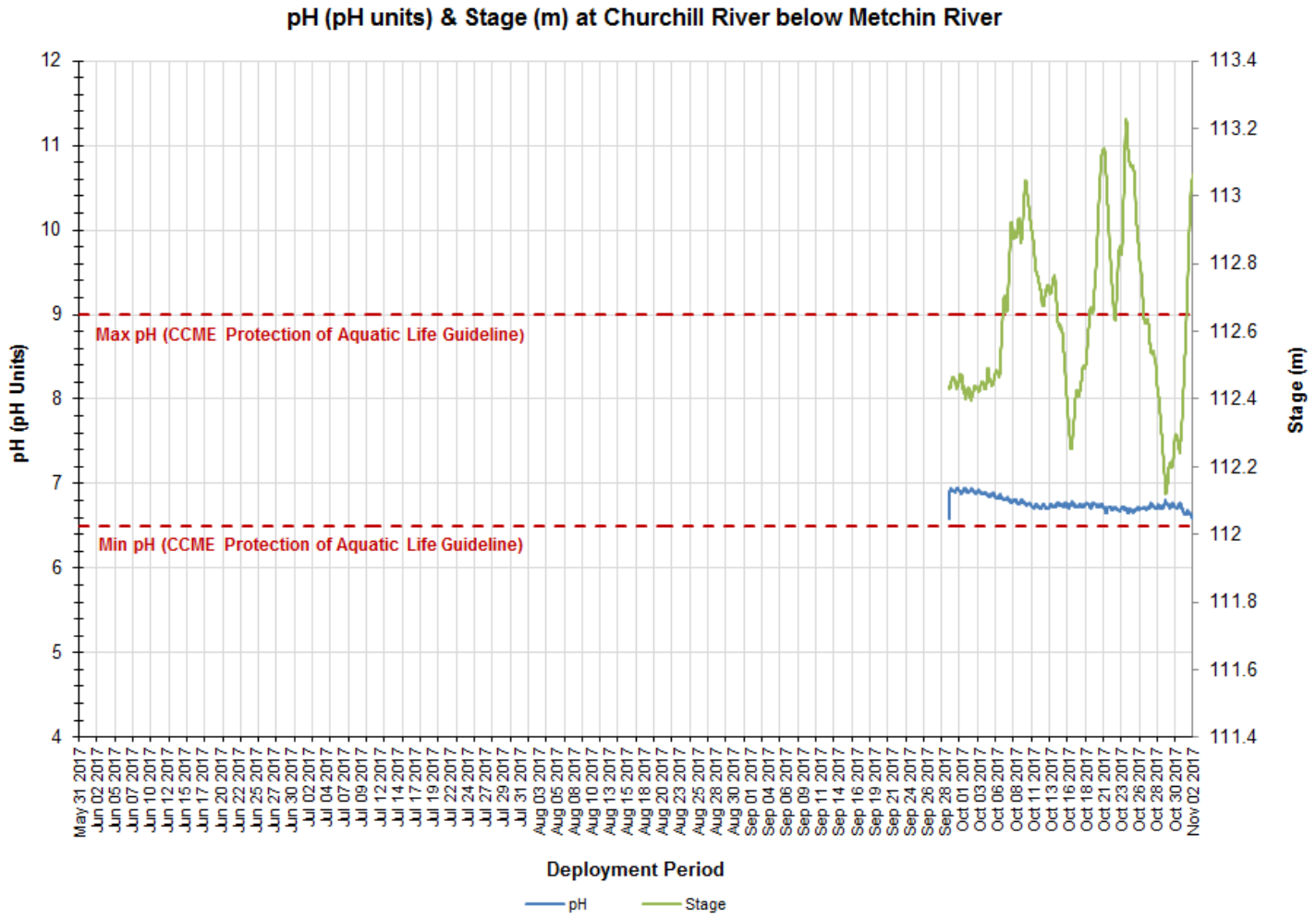


Figure 5: pH & Stage at Churchill River below Metchin River

pH (units)	2017	2016	2015
Min	6.58	-	-
Max	6.95	-	-
Median	6.75	-	-

Specific Conductivity

- Specific conductivity ranged from 18.7µS/cm to 21.5µS/cm during the 2017 deployment season, with a median value of 19.9µS/cm (Figure 6).
- Specific conductivity was consistent at this station for the duration of deployment, with only slight fluctuations.
- Increases and decreases in specific conductivity are generally related to fluctuations in stage. As stage decreases, specific conductivity usually increases as the concentration of dissolved solids increases. Inversely, when stage increases due to precipitation events, specific conductivity usually decreases due to the dilution of dissolved solids.
- Comparison data for 2016 and 2015 is not available for this station.

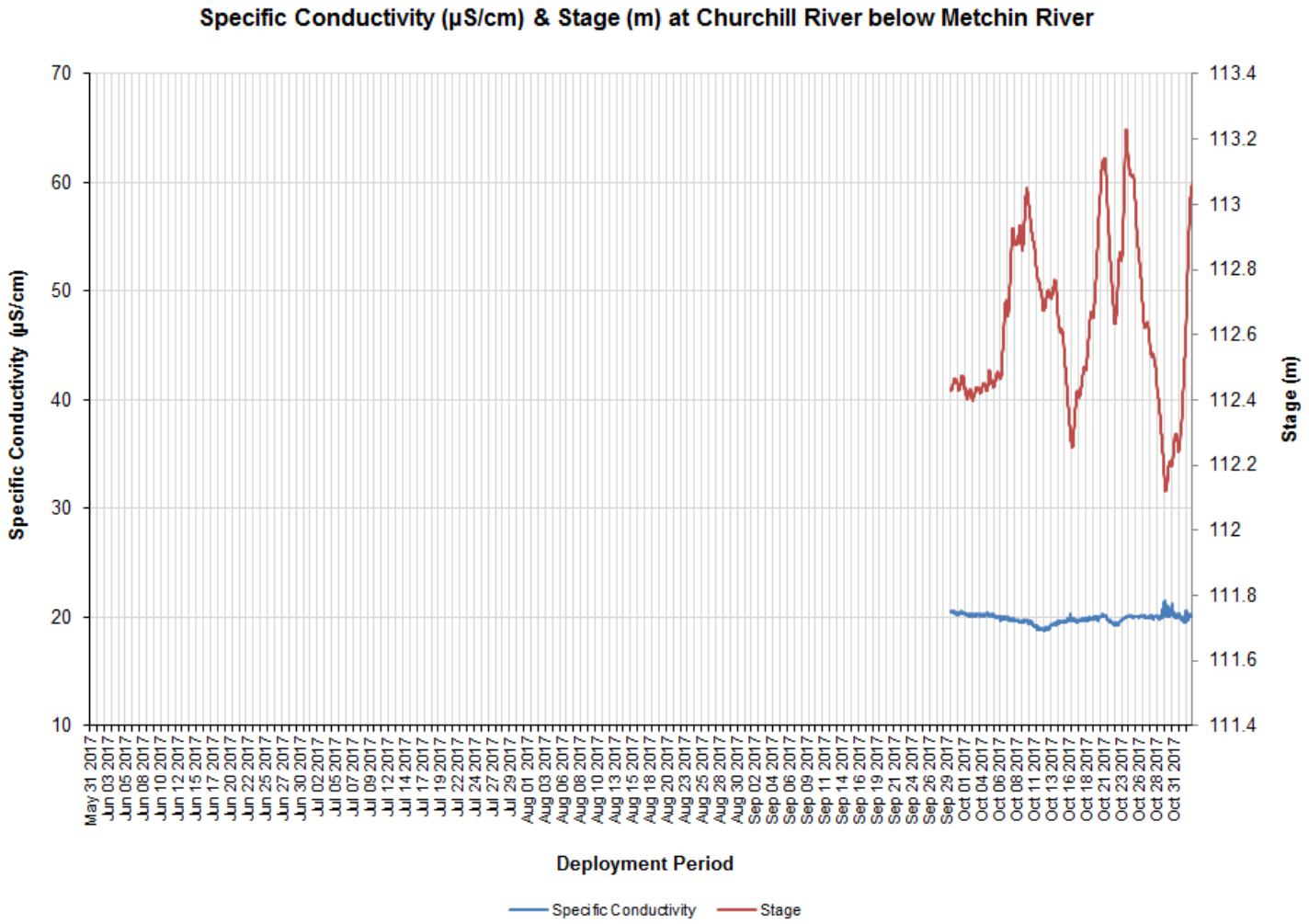


Figure 6: Specific Conductivity & Stage at Churchill River below Metchin River

Specific Conductivity (µS/cm)	2017	2016	2015
Min	18.7	-	-
Max	21.5	-	-
Median	19.9	-	-

Dissolved Oxygen

- Dissolved oxygen ranged from 10.67mg/L to 12.48mg/L during the 2017 deployment season, with a median value of 11.87mg/L (Figure 7).
- Percent saturation ranged from 90.8% to 95.5%, with a median value of 92.4% (Figure 7).
- Dissolved oxygen content fluctuates regularly on a daily basis. Percent saturation is generally consistent throughout the deployment season. As temperatures decreased into the fall, dissolved oxygen content steadily increased.
- Dissolved oxygen values were above the minimum CCME Guidelines for the Protection of Early and Other Life Stages (6.5mg/L and 9.5mg/L respectively). The guidelines are indicated in red on Figure 7.
- Comparison data for 2016 and 2015 is not available for this station.

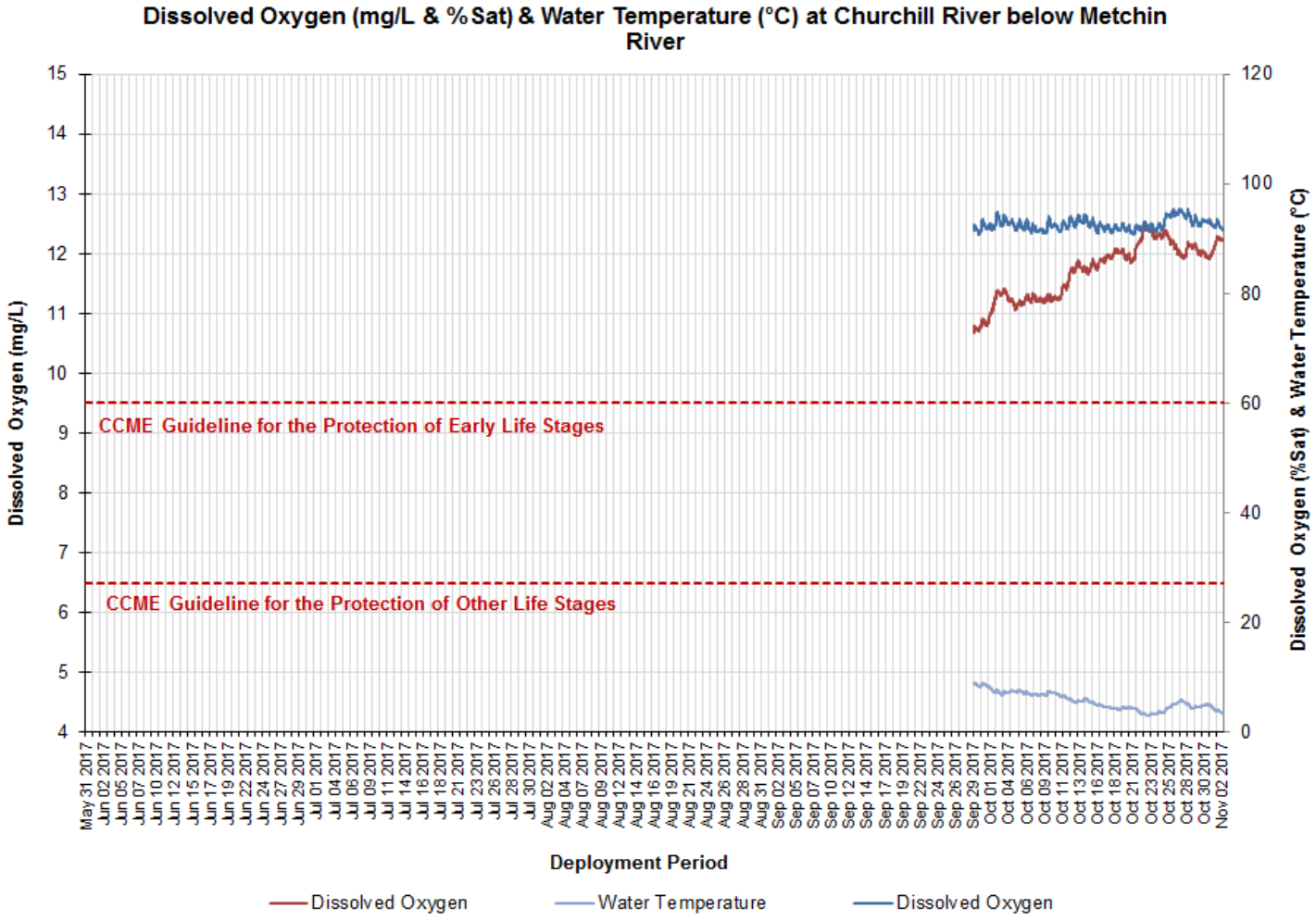


Figure 7: Dissolved Oxygen (mg/L and %Sat) & Water Temperature at Churchill River below Metchin River

Dissolved Oxygen (mg/L)	2017	2016	2015		Dissolved Oxygen (%Sat)	2017	2016	2015
Min	10.67	-	-		**Min**	90.8	-	-
Max	12.48	-	-		**Max**	95.5	-	-
Median	11.87	-	-		**Median**	92.4	-	-

Turbidity

- Turbidity ranged from 0NTU to 59.2 NTU during the 2017 deployment season, with a median value of 0NTU (Figure 8). A median value of 0 NTU indicates there is no natural background turbidity at this station. Turbidity fluctuated only slightly at this station throughout October.
- Comparison data for 2016 and 2015 is not available for this station.

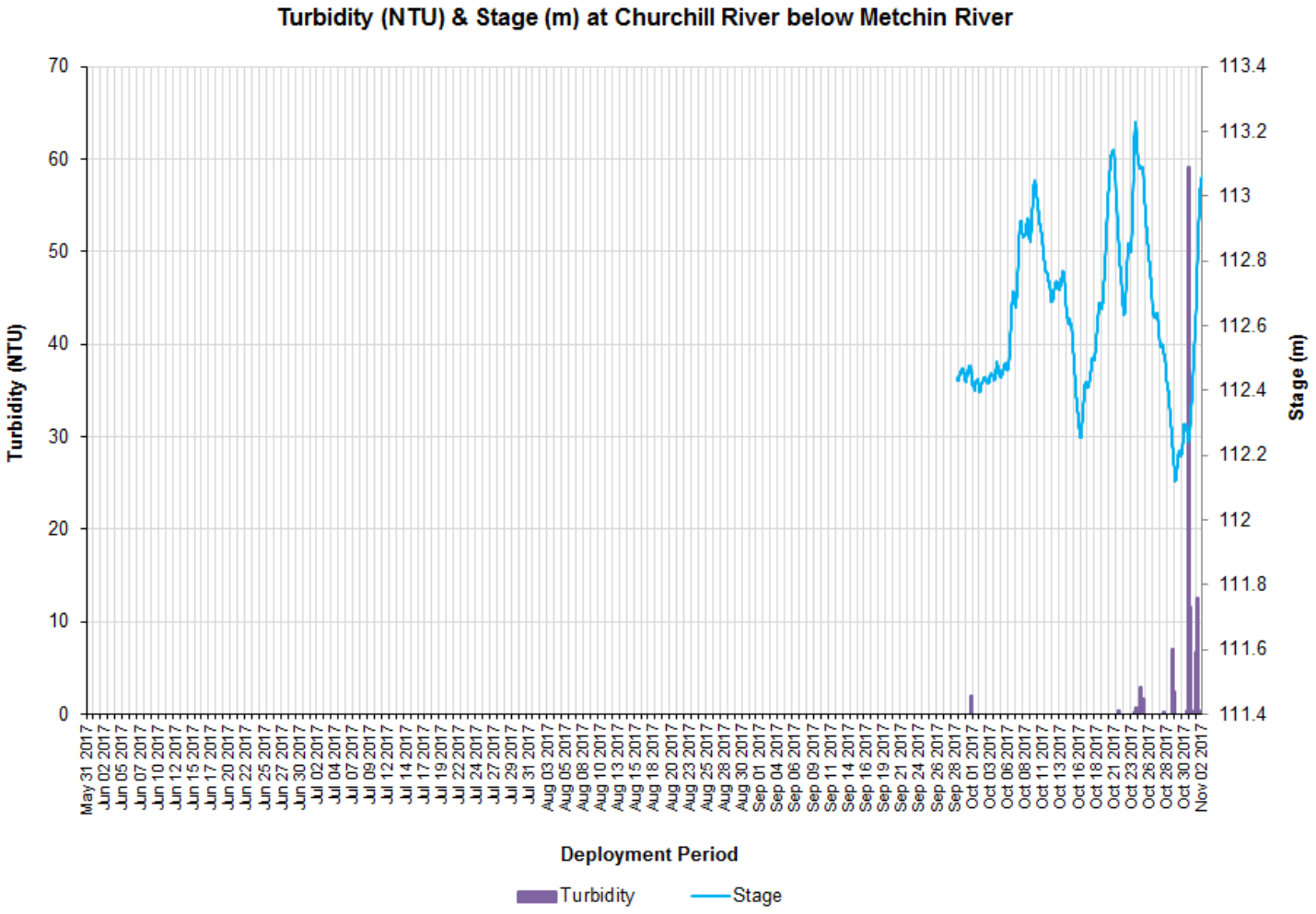


Figure 8: Turbidity & Stage at Churchill River below Metchin River

Turbidity (NTU)	2017	2016	2015
Min	0	-	-
Max	59.2	-	-
Median	0	-	-

Stage

- Stage ranged from 112.121m to 113.228m during the 2017 deployment season, with a median value of 112.623m (Figure 9). Stage remained relatively stable throughout the fall season.
- Comparison data for 2016 and 2015 is not available for this station.
- Water Survey of Canada (ECCC) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

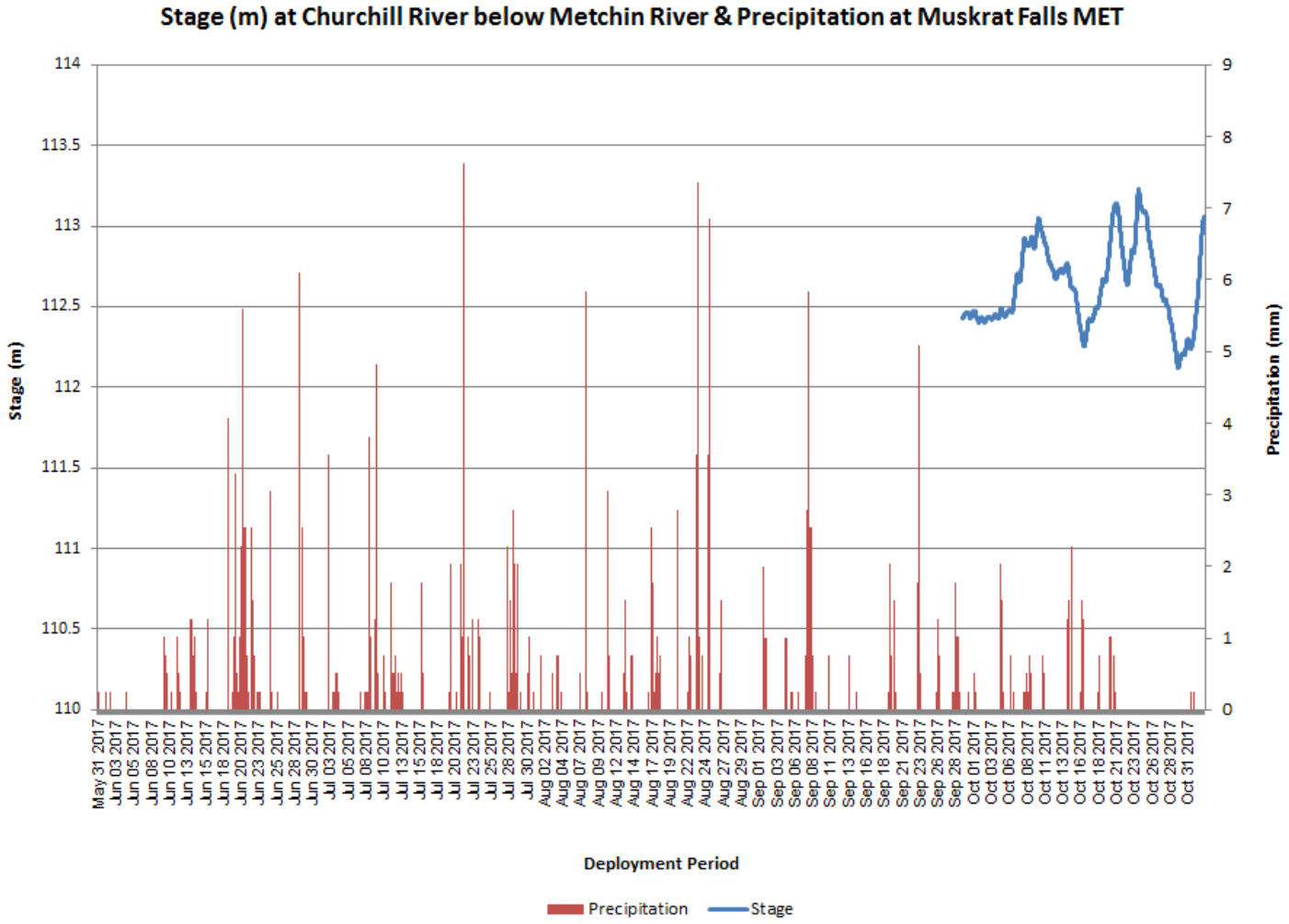


Figure 9: Stage at Churchill River below Metchin River & Precipitation at Muskrat Falls MET

Stage (m)	2017	2016	2015
Min	112.121	-	-
Max	113.228	-	-
Median	112.623	-	-

Churchill River above Grizzle Rapids

Temperature

- Water temperature ranged from 5.58°C to 17.57°C during the 2017 deployment season, with a median value of 13.98°C (Figure 10).
- Water temperatures peaked during August, and then steadily declined through late summer and fall.
- Comparison data for 2016 and 2015 is not available for this station.

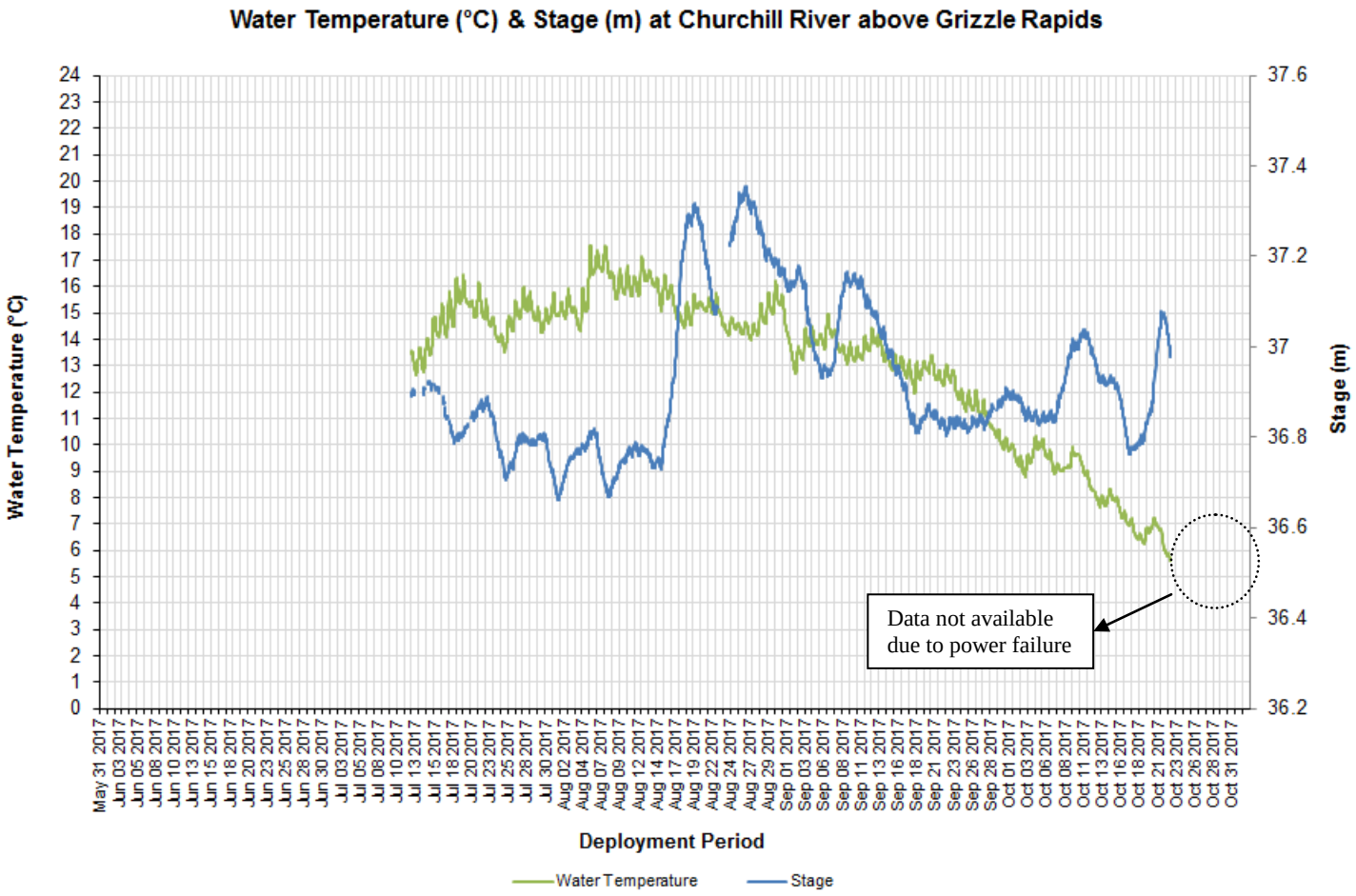


Figure 2: Water Temperature & Stage at Churchill River above Grizzle Rapids

Temperature	2017	2016	2015
Min	5.58	-	-
Max	17.57	-	-
Median	13.98	-	-

- Water temperature showed a typical seasonal trend (Figure 11), where both water and air temperatures increased throughout the spring and early summer before gradually declining again into the fall season.

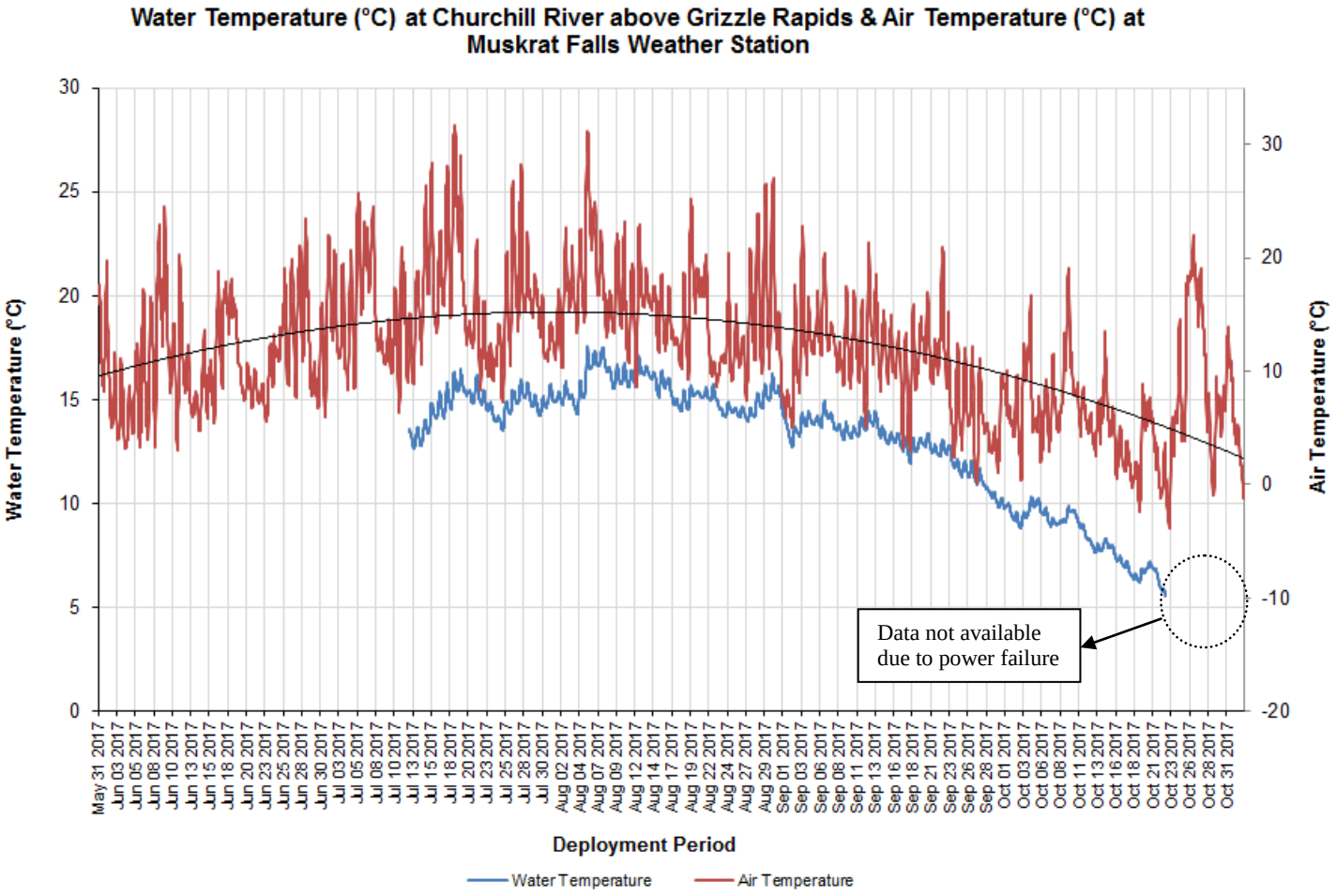


Figure 3: Water Temperature at Churchill River above Grizzle Rapids & Air Temperature at Muskrat Falls MET

pH

- pH ranged from 6.45 to 7.16 pH units during the 2017 deployment season, with a median value of 6.91 pH units (Figure 12).
- pH values were relatively consistent throughout the deployment period.
- pH values during the 2017 deployment season remained within the CCME Guidelines for the Protection of Aquatic Life (>6.5 and <9.0 pH units), except at the very end of data collection on October 22. After this, the instrument experienced a power failure and no more data was collected.
- Comparison data for 2016 and 2015 is not available for this station.

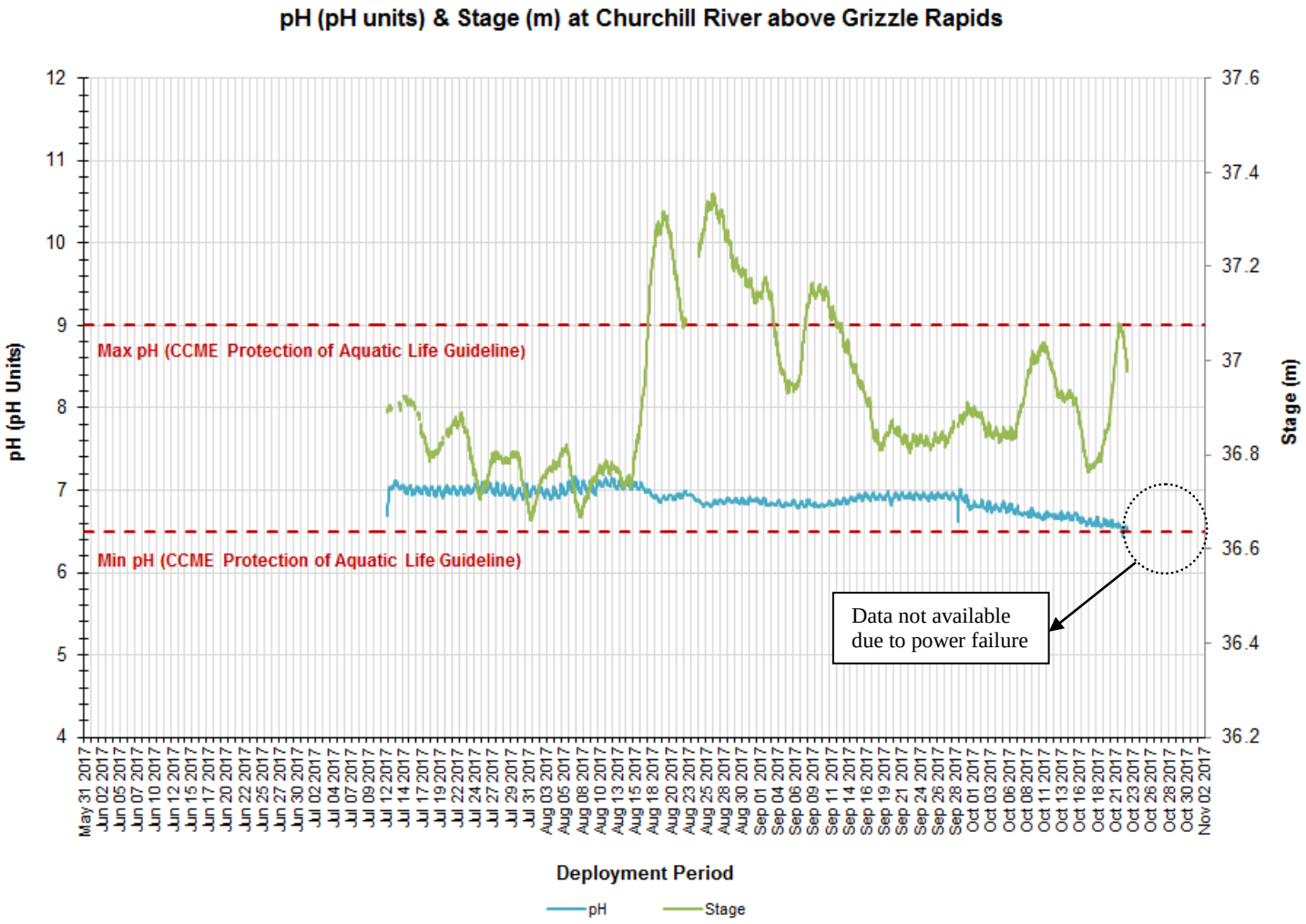


Figure 4: pH & Stage at Churchill River above Grizzle Rapids

pH (units)	2017	2016	2015
Min	6.45	-	-
Max	7.16	-	-
Median	6.91	-	-

Specific Conductivity

- Specific conductivity ranged from 15µS/cm to 19µS/cm during the 2017 deployment season, with a median value of 17µS/cm (Figure 13).
- Specific conductivity was relatively consistent throughout the deployment season.
- Increases and decreases in specific conductivity are generally related to fluctuations in stage. As stage decreases, specific conductivity usually increases as the concentration of dissolved solids increases. Inversely, when stage increases, specific conductivity decreases due to the dilution of dissolved solids in the water column. These slight fluctuations are difficult to see from the graph below, since specific conductivity was recorded as integers as opposed to decimal values.
- Comparison data for 2016 and 2015 is not available for this station.

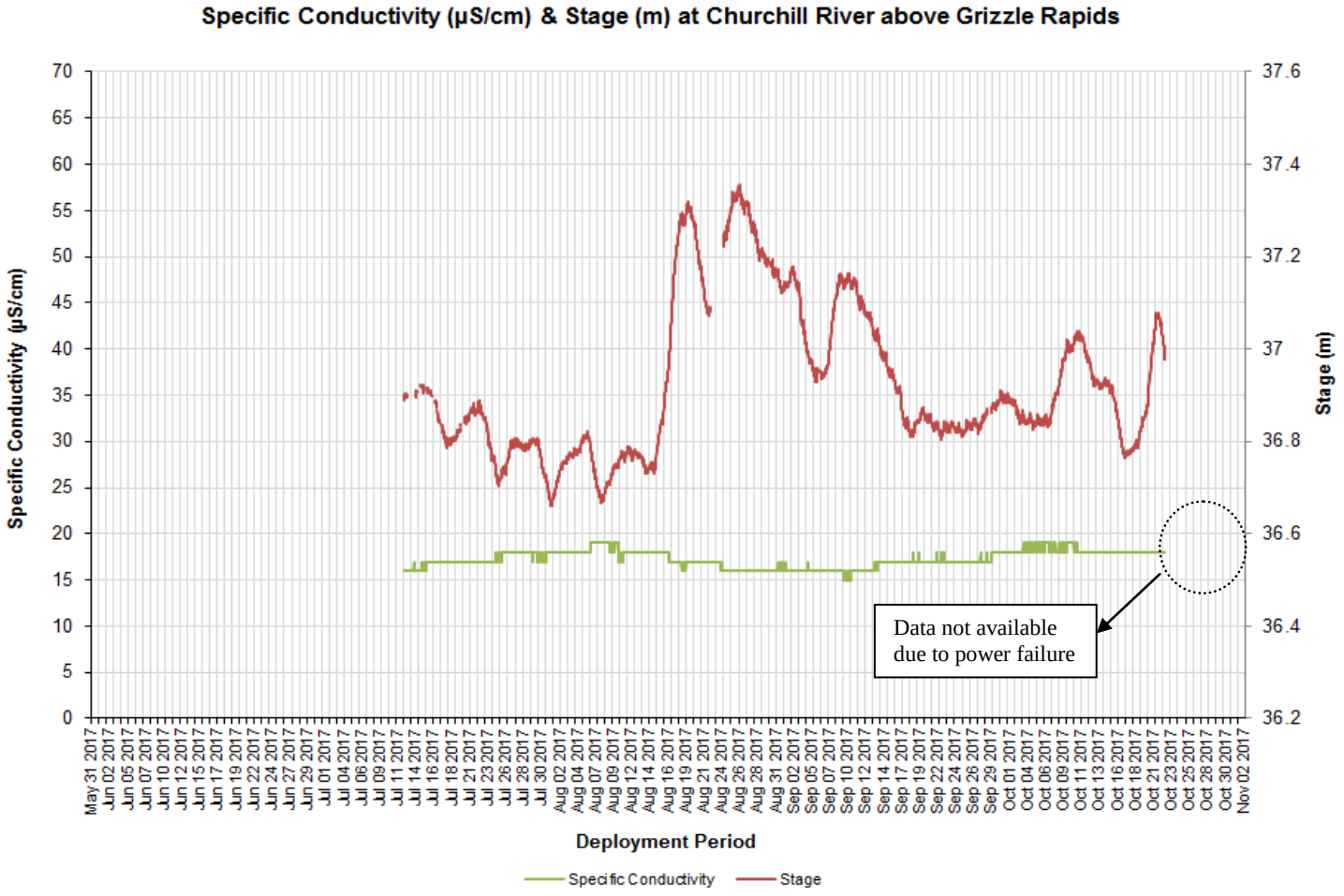


Figure 5: Specific Conductivity & Stage at Churchill River above Grizzle Rapids

Specific Conductivity (µS/cm)	2017	2016	2015
Min	15	-	-
Max	19	-	-
Median	17	-	-

Dissolved Oxygen

- Dissolved oxygen ranged from 9.27mg/L to 11.81mg/L during the 2017 deployment season, with a median value of 9.94mg/L (Figure 14).
- Percent saturation ranged from 91.9% to 101.2%, with a median value of 95.5% (Figure 14).
- Dissolved oxygen content displayed a typical seasonal trend, where levels were lowest during the summer months (July-August) and then increased through the fall (September-October). Warmer temperatures decrease the amount of oxygen present in the water, and vice versa. Percent saturation remained fairly consistent throughout the season.
- Dissolved oxygen values remained above the minimum CCME Guideline for the Protection of Early and Other Life Stages (6.5mg/L and 9.5mg/L respectively), with the exception of several instances during August when water temperatures were warmest.
- Comparison data for 2016 and 2015 is not available for this station.

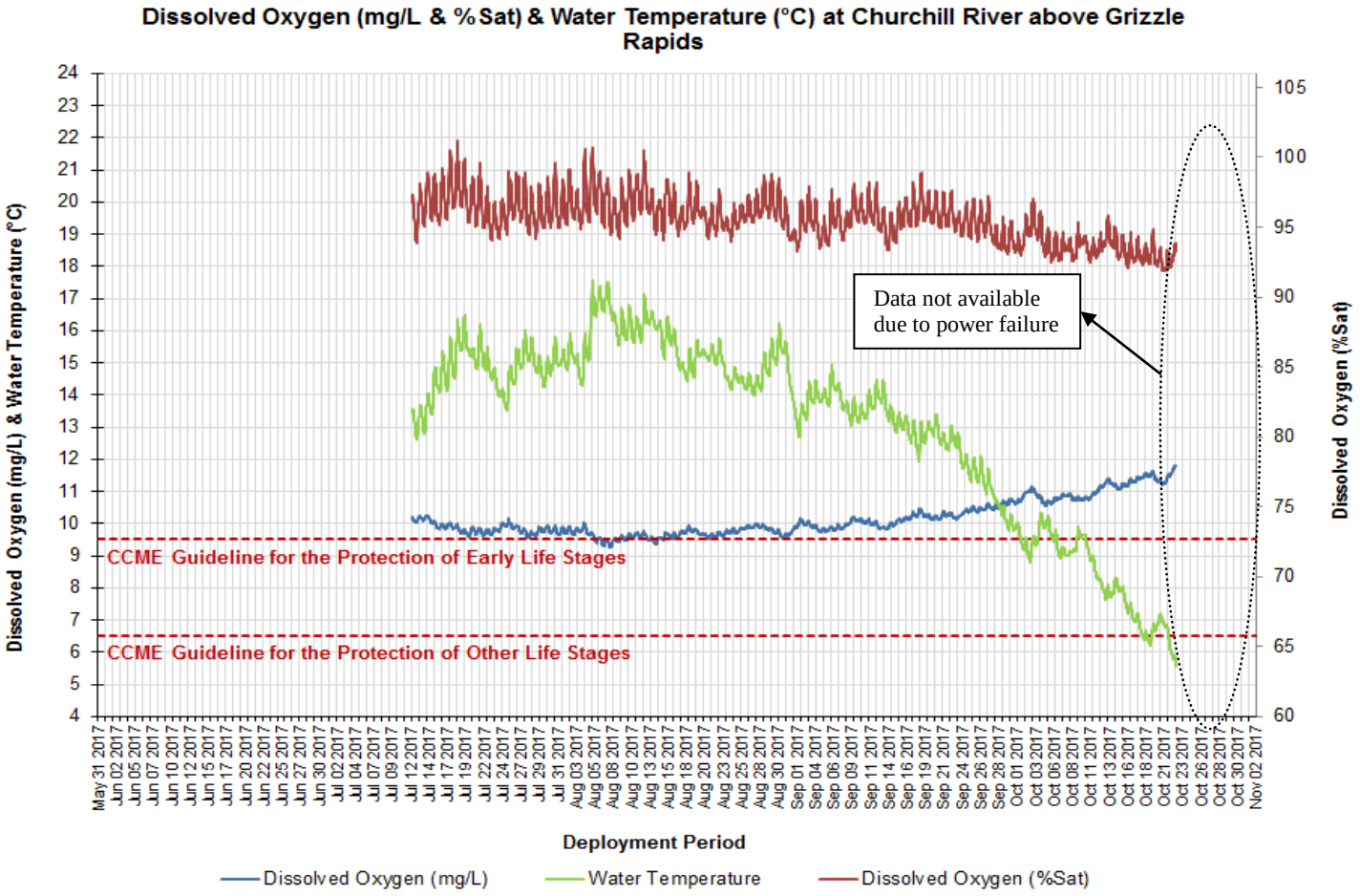


Figure 6: Dissolved Oxygen (mg/L and %Sat) & Water Temperature at Churchill River above Grizzle Rapids

Dissolved Oxygen (mg/L)	2017	2016	2015		Dissolved Oxygen (% Sat)	2017	2016	2015
Min	9.27	-	-		**Min**	91.9	-	-
Max	11.81	-	-		**Max**	101.2	-	-
Median	9.94	-	-		**Median**	95.5	-	-

Turbidity

- Turbidity ranged from 0NTU to 19.3NTU during the 2017 deployment season, with a median value of 0NTU (Figure 15). While a median value of 0NTU would normally indicate that there is no natural background turbidity at a station, in this case it is more likely indicative of a sensor failure. The natural aquatic conditions at this station do not support a median turbidity value of 0NTU.
- Turbidity spikes generally correlate with increases in stage, which often correlate with precipitation events. Turbidity levels returned to background levels following each observed increase.
- Comparison data for 2016 and 2015 is not available for this station.

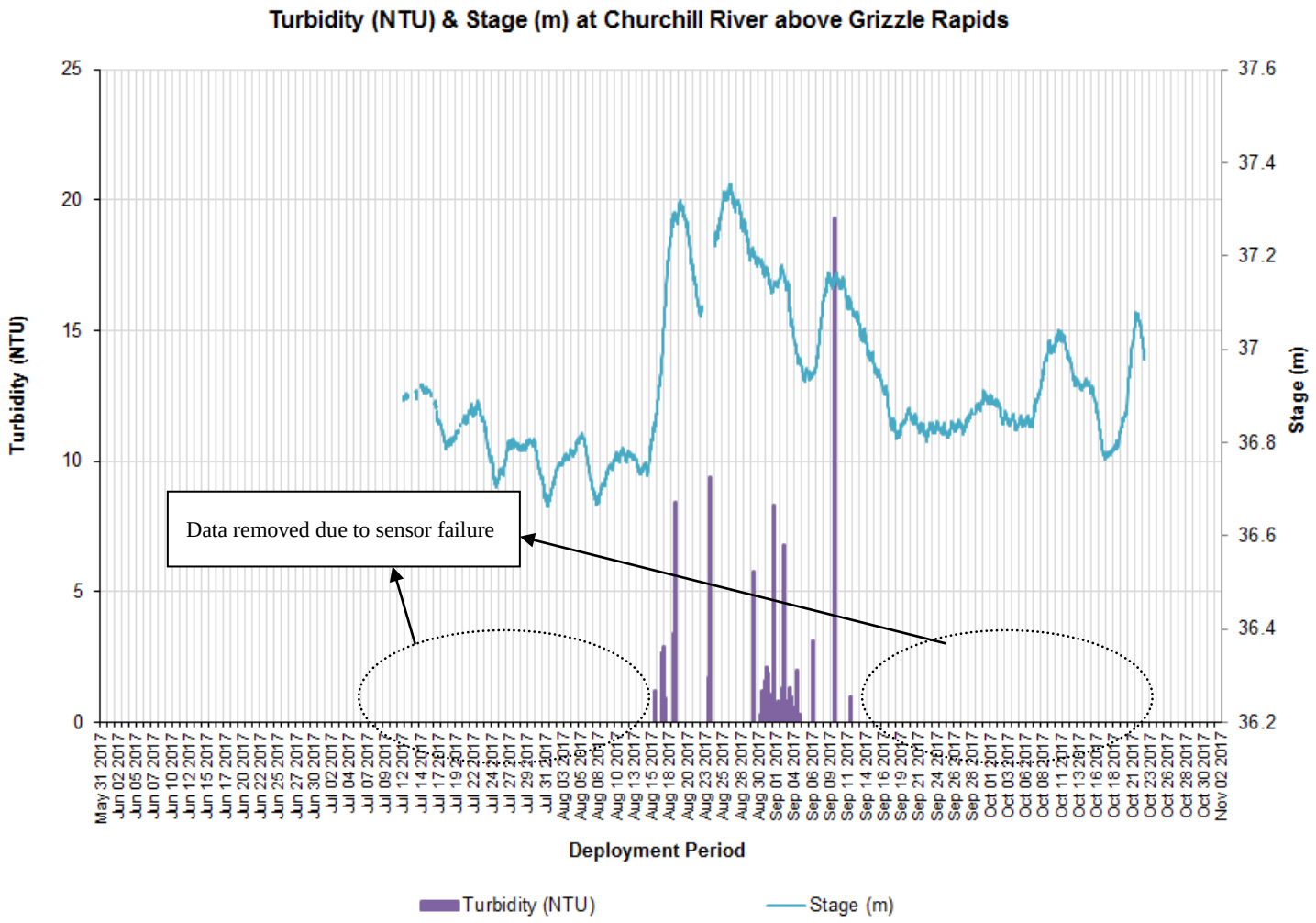


Figure 7: Turbidity & Stage at Churchill River above Grizzle Rapids

Turbidity (NTU)	2017	2016	2015
Min	0	-	-
Max	19.3	-	-
Median	0	-	-

Stage

- Stage ranged from 36.661m to 37.355m during the 2017 deployment season, with a median value of 36.866m (Figure 16).
- Increases in stage frequently correlate with precipitation events (Figure 16).
- Comparison data for 2016 and 2015 is not available for this station.
- Water Survey of Canada (ECCC) is responsible for QA/QC of water quantity data (stage and flow). Corrected data can be obtained upon request.

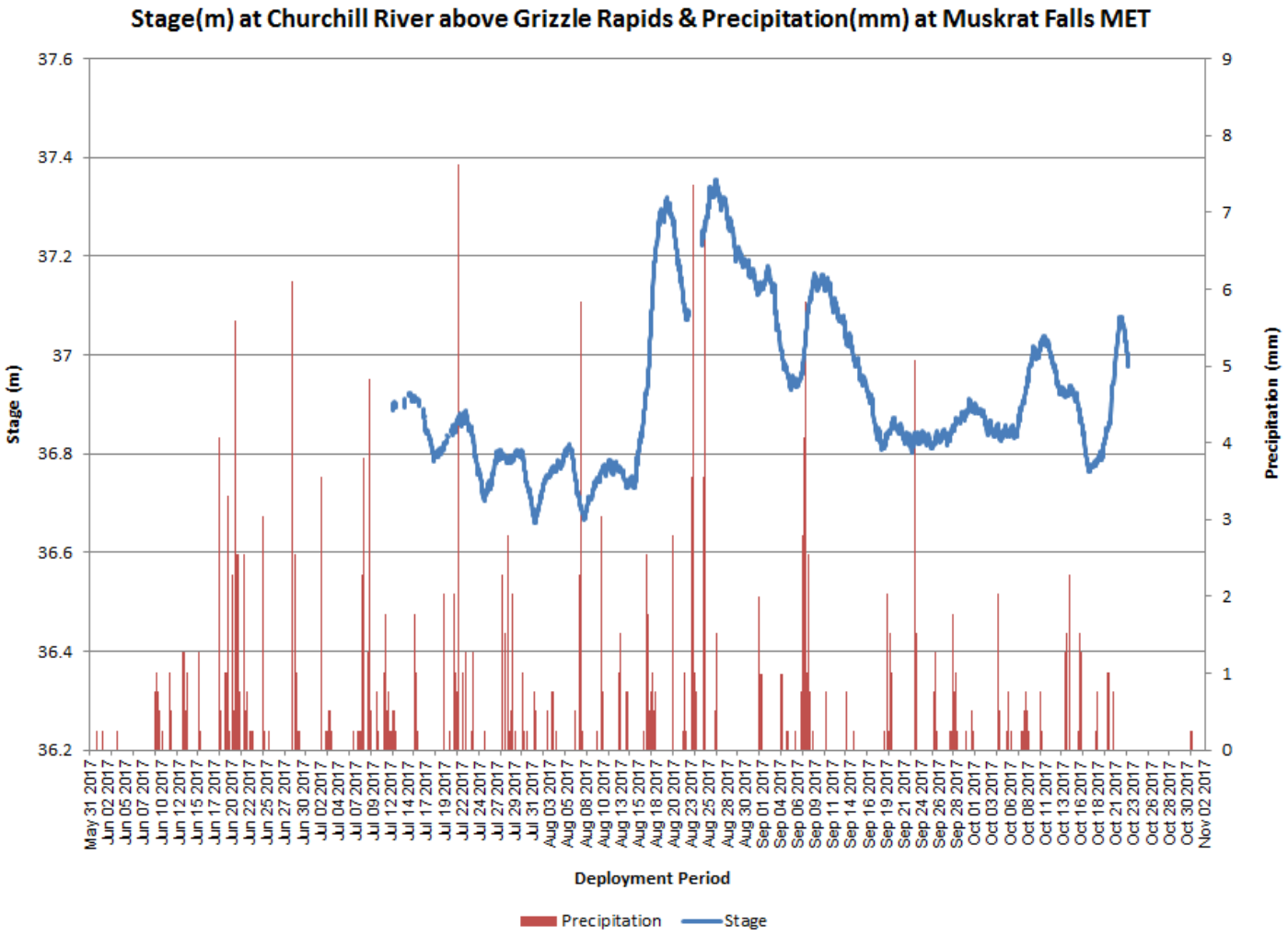


Figure 8: Stage & Precipitation at Churchill River above Grizzle Rapids

Stage (m)	2017	2016	2015
Min	36.661	-	-
Max	37.355	-	-
Median	36.866	-	-

Churchill River below Muskrat Falls

Temperature

- Water temperature ranged from 3.2°C to 18.2°C during the 2017 deployment season, with a median value of 13.0°C (Figure 17).
- Water temperatures in 2017 were comparable to those in 2016.
- Significant data was missing from the 2015 deployment season and so it is difficult to make comparisons to the 2015 season.

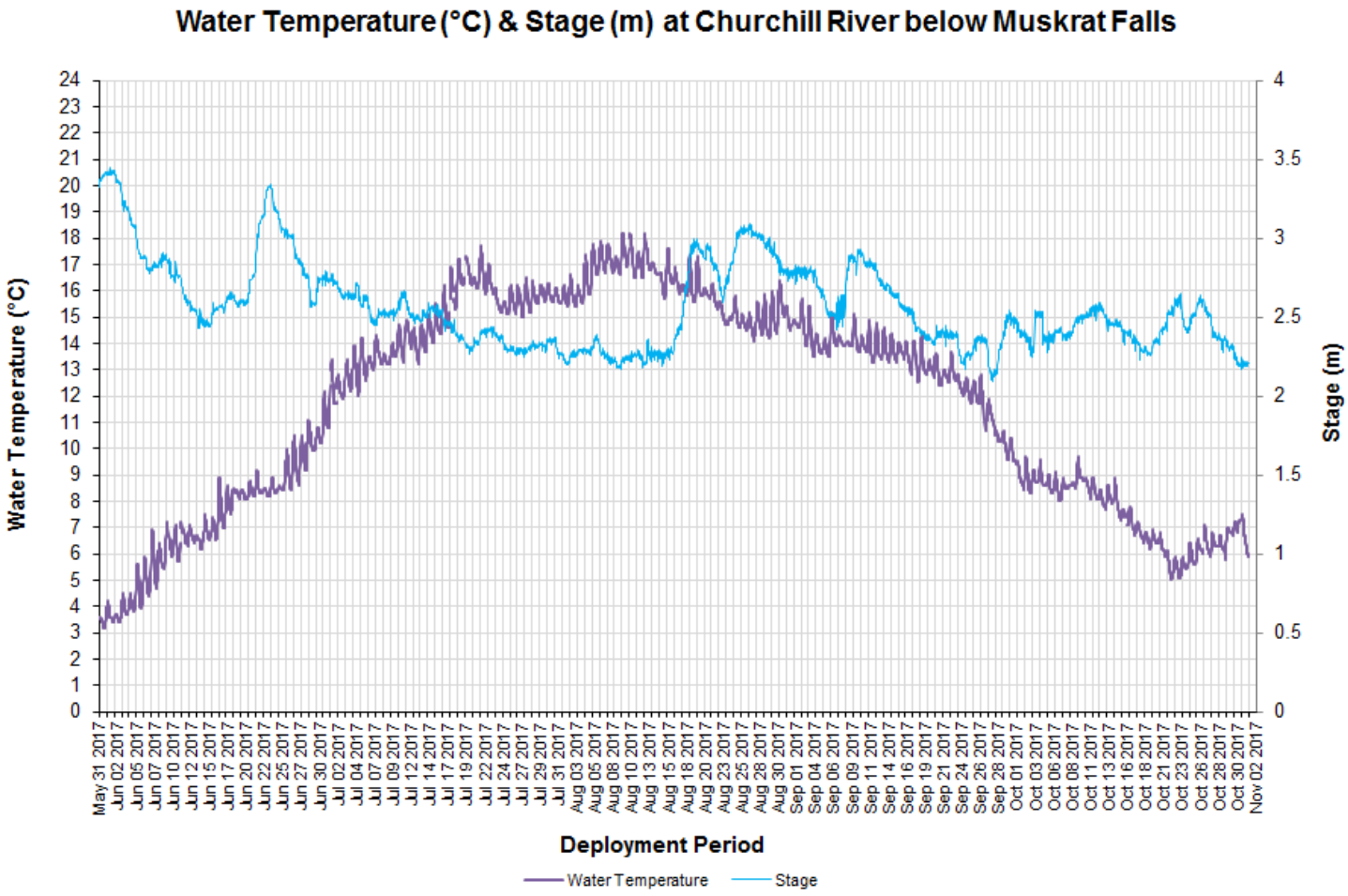


Figure 17: Water Temperature & Stage at Churchill River below Muskrat Falls

Temperature	2017	2016	*2015
Min	3.2	2.9	2.6
Max	18.2	19.9	16.4
Median	13.0	13.1	10.4

***data set not complete**

- Water temperature values displayed a typical seasonal trend (Figure 18), where both water and air temperatures increased through the summer months and then gradually decreased again into the fall season.

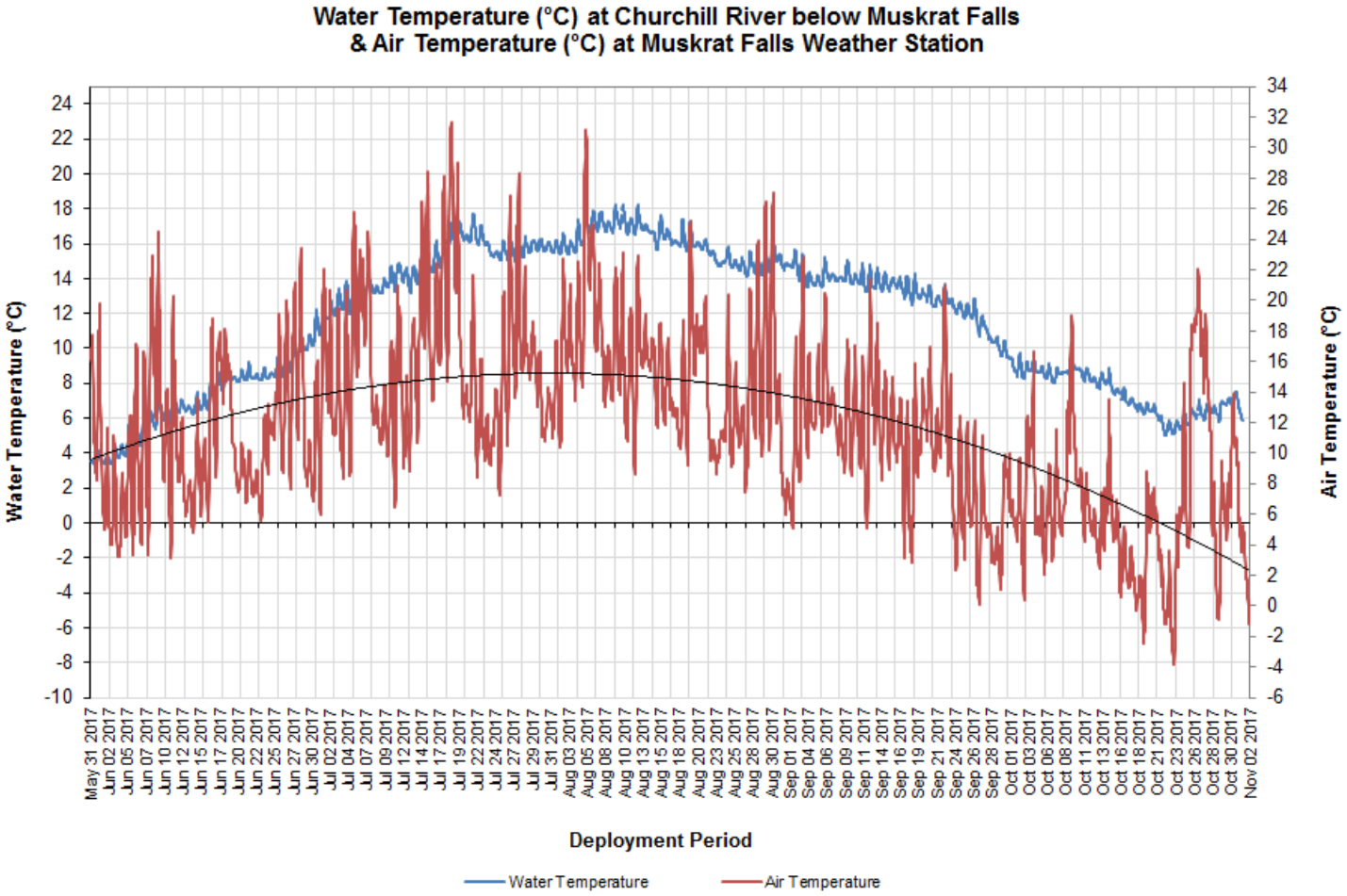


Figure 18: Water Temperatures at Churchill River below Muskrat Falls & Air Temperature at Muskrat Falls MET

pH

- pH ranged from 6.01 to 7.19 pH units during the 2017 deployment season, with a median value of 6.67 pH units (Figure 19), which is comparable to the 2016 season.
- There were several notable drops in pH, which generally corresponded to large precipitation events. pH was relatively stable throughout June and July, before starting a downward trend July 21. A similar downward trend started around September 10, again likely the result of heavy precipitation.
- With a median value of 6.67 pH units, more than half of the pH values recorded during the 2017 deployment season were within the CCME Guidelines for the Protection of Aquatic Life (>6.5 and <9.0 pH units). The other half of the data drops below the minimum pH guideline, likely due to the influence of large precipitation events.

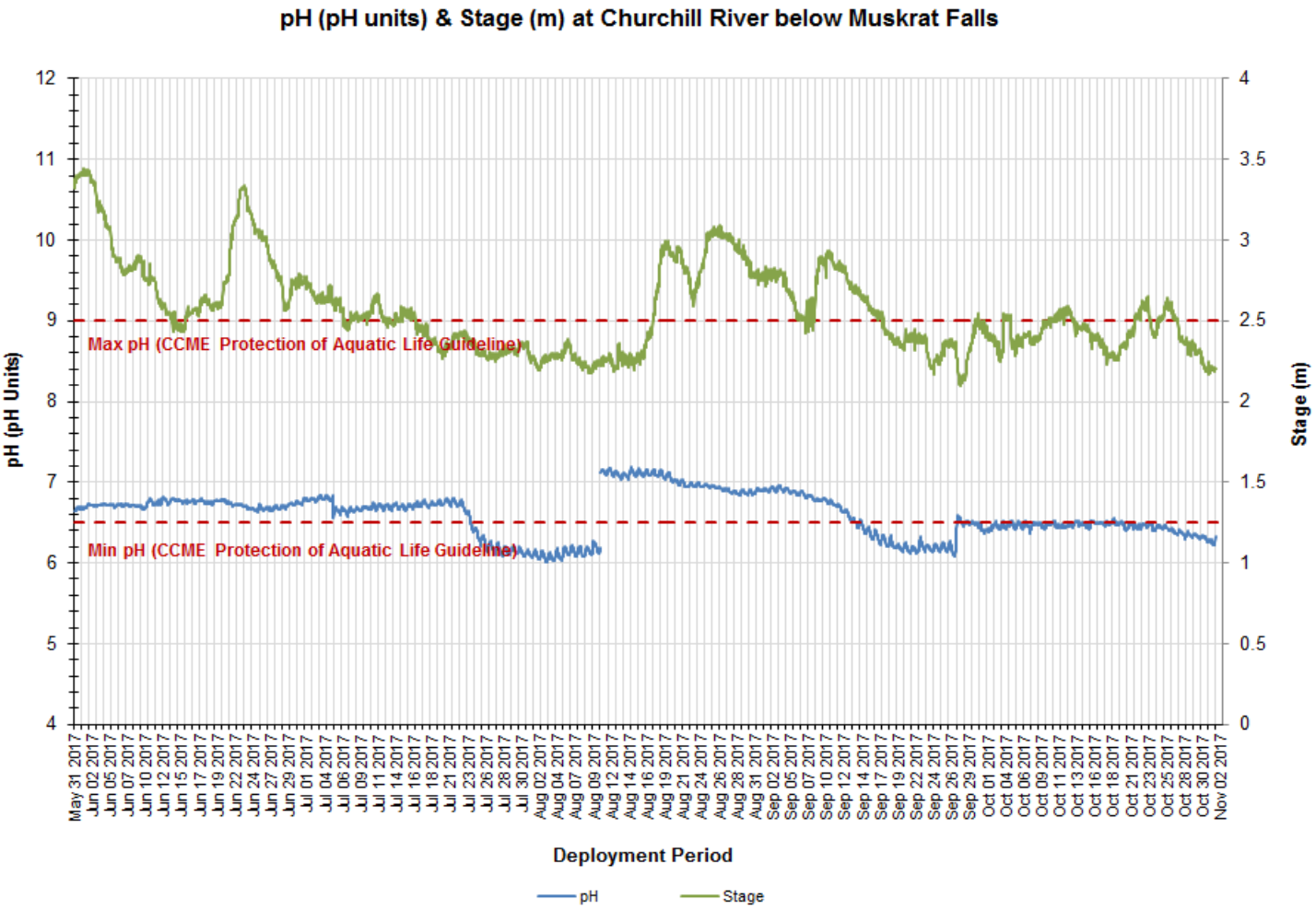


Figure 19: pH & Stage at Churchill River below Muskrat Falls

pH (units)	2017	2016	*2015
Min	6.01	5.08	6.80
Max	7.19	7.26	7.29
Median	6.67	6.54	7.13

***data set not complete**

Specific Conductivity

- Specific conductivity ranged from 11.0µS/cm to 20.0µS/cm during the 2017 deployment season, with a median value of 18.1µS/cm (Figure 20), which is comparable to the 2016 season.
- Specific conductivity gradually increased throughout the spring and summer months. Generally, specific conductivity does not vary greatly in the Lower Churchill River, which is evidenced in the graph below.
- Increases and decreases in specific conductivity are generally related to fluctuations in stage. As stage decreases, specific conductivity usually increases as the concentration of dissolved solids increases. Inversely, when stage increases, specific conductivity decreases due to the dilution of dissolved solids in the water column.
- Significant data was missing from the 2015 deployment season and so it is difficult to make comparisons.

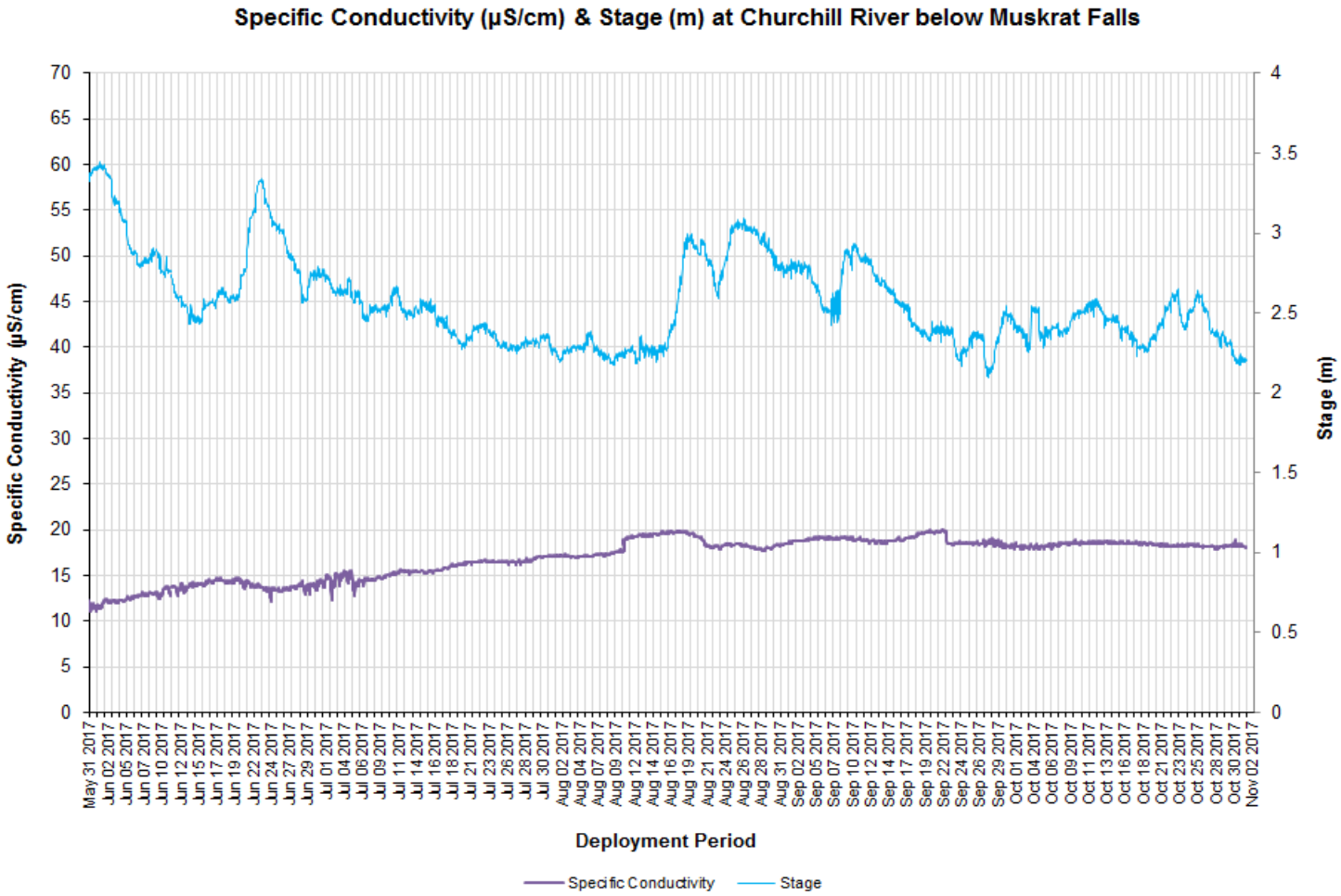


Figure 20: Specific Conductivity at Churchill River below Muskrat Falls

Specific Conductivity (µS/cm)	2017	2016	*2015
Min	11.0	14	14
Max	20.0	20.7	20.1
Median	18.1	17.3	18.9

***data set not complete**

Dissolved Oxygen

- Dissolved oxygen ranged from 9.54mg/L to 14.82mg/L during the 2017 deployment season, with a median value of 11.40mg/L, which was comparable to the 2016 season (Figure 21).
- Percent saturation ranged from 96.3% to 114.2%, with a median value of 106.4%, which was less than during the 2016 season (Figure 21).
- Significant data was missing from the 2015 deployment season and so it is difficult to make comparisons.
- Dissolved oxygen displayed a typical seasonal trend throughout 2017, with the lowest values observed during the summer months (July-August). Warmer temperatures decrease the amount of oxygen present in the water, and vice versa. Percent saturation remained fairly consistent throughout the season.
- Dissolved oxygen remained above the minimum CCME Guidelines for the Protection of Early and Other Life Stages for the duration of the 2017 deployment season (Figure 21).

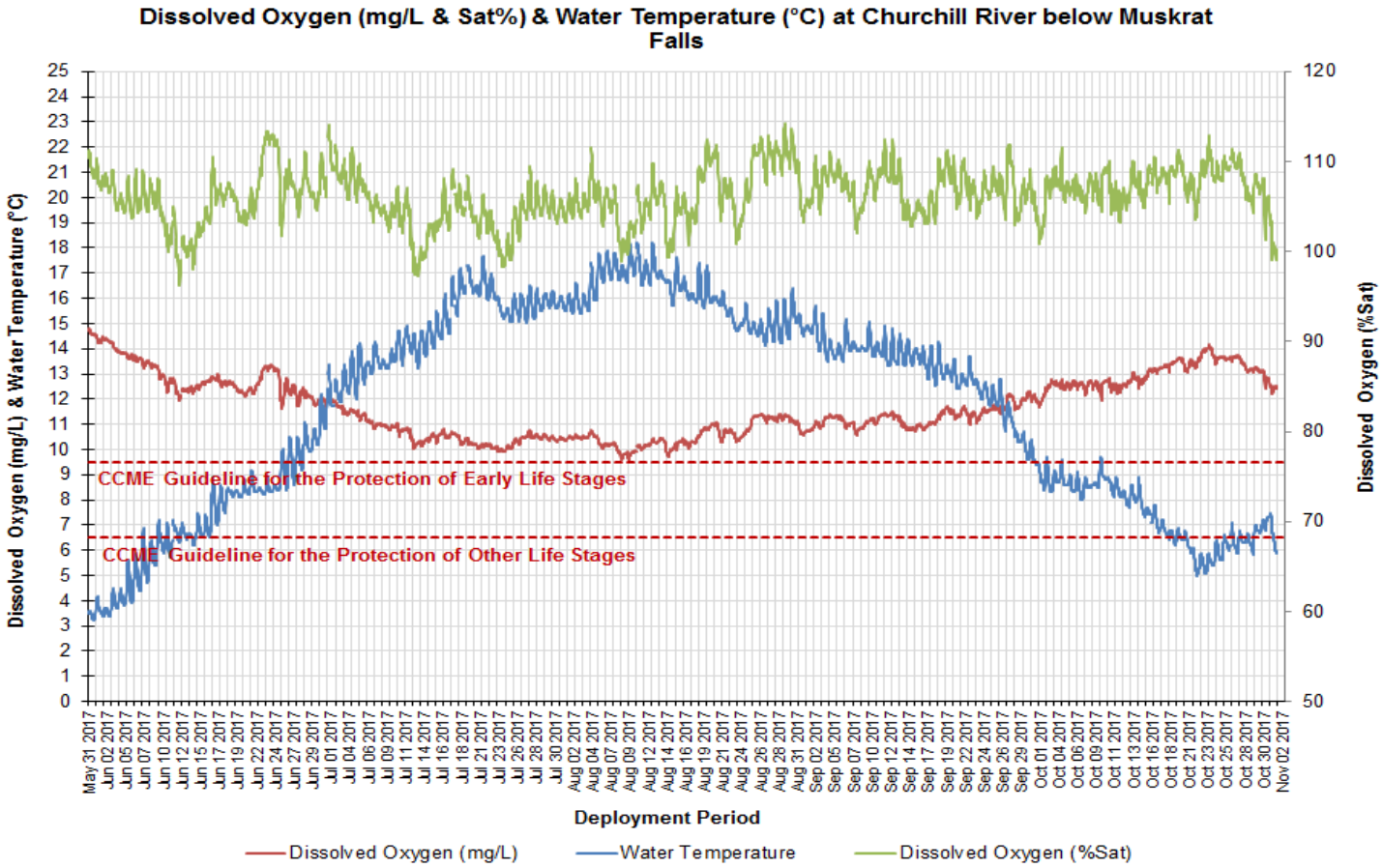


Figure 21: Dissolved Oxygen (mg/L and %Sat) & Water Temperature at Churchill River below Muskrat Falls

Dissolved Oxygen (mg/L)	2017	2016	*2015		Dissolved Oxygen (% Sat)	2017	2016	*2015
Min	9.54	9.78	10.21		Min	96.3	101.2	98.6
Max	14.82	14.99	14.46		Max	114.2	123.3	113.2
Median	11.40	11.85	11.92		Median	106.4	112.3	106.4

***data set not complete**

Turbidity

- Turbidity ranged from 0NTU to 105.5 NTU during the 2017 deployment season, with a median value of 1.5NTU. (Figure 22). A median value of 1.5NTU indicates that there is natural background turbidity at this station.
- Turbidity data from August 10 through September 27 have been removed from the dataset due to a sensor failure. Turbidity values for 2017 are comparable to, albeit less than, turbidity values observed in 2016.
- Significant data was missing from the 2015 deployment season and so it is difficult to make comparisons.
- Turbidity events throughout the 2017 deployment season generally correlated with increases in stage, which were further linked to precipitation events.

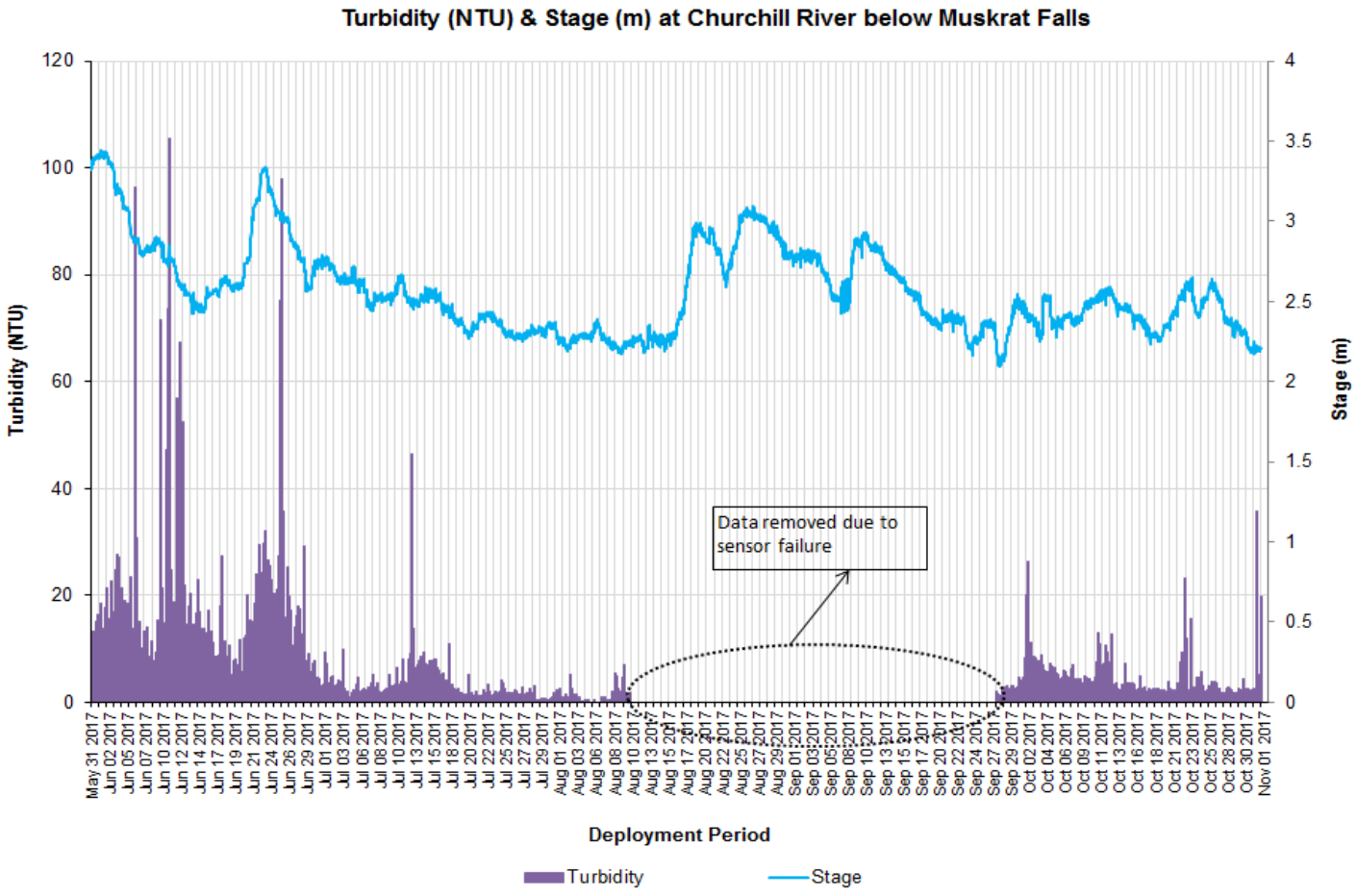


Figure 22: Turbidity & Stage at Churchill River below Muskrat Falls

Turbidity (NTU)	2017	2016	*2015
Min	0	0	0
Max	105.5	241.7	492
Median	1.5	4.3	4.9

***data set not complete**

Stage

- Stage ranged from 2.096m to 3.446m during the 2017 deployment season, with a median value of 2.517m (Figure 23), which was comparable to, but slightly lower than, the 2016 season.
- Stage increases were generally associated with precipitation events through the 2017 season (Figure 23).
- Significant data was missing from the 2015 deployment season and so it is difficult to make comparisons.
- Water Survey of Canada (ECCC) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

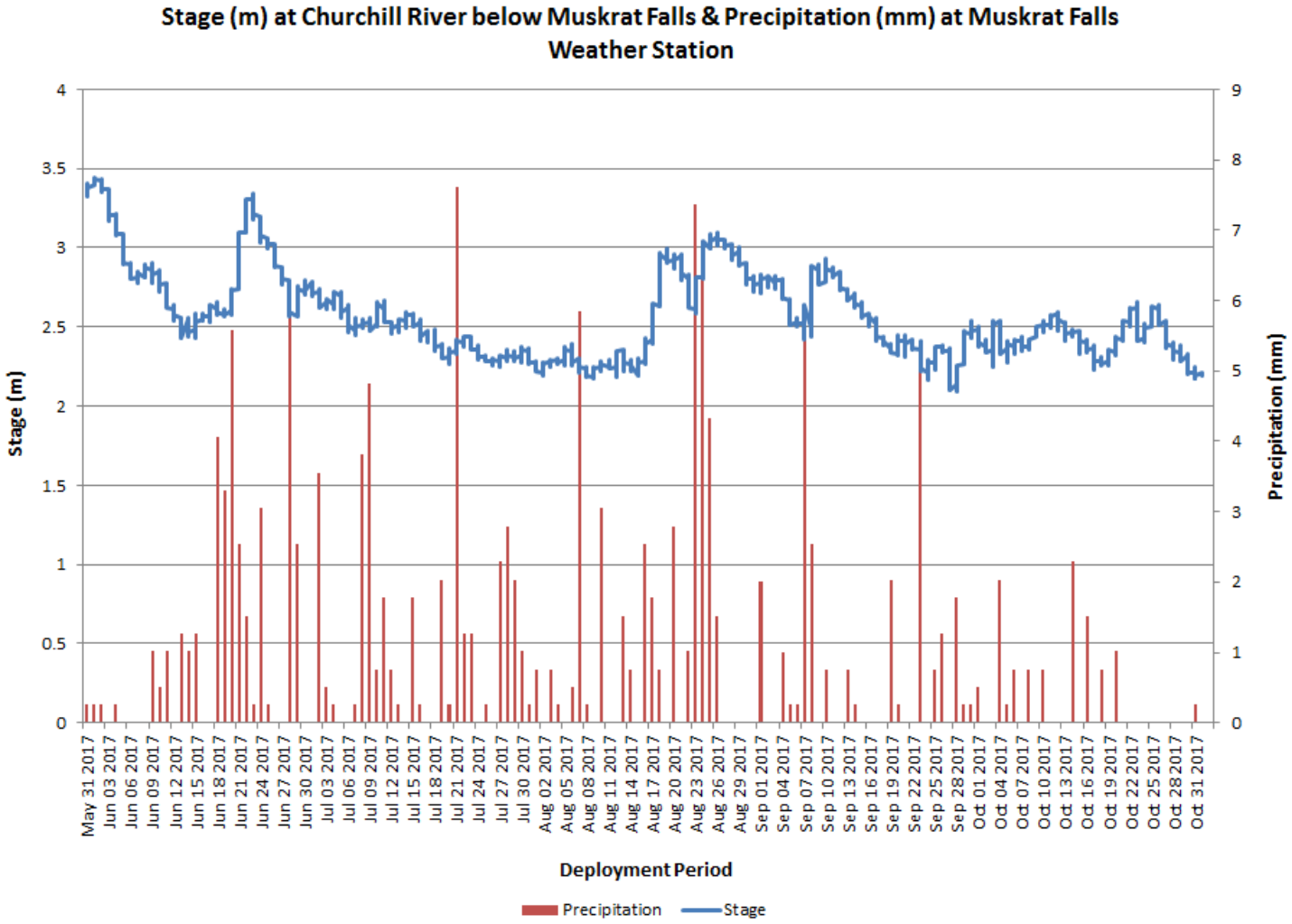


Figure 23: Stage at Churchill River below Muskrat Falls & Precipitation at Muskrat Falls MET

Stage (m)	2017	2016	2015
Min	2.096	2.291	2.106
Max	3.446	4.331	4.521
Median	2.517	2.762	2.566

Churchill River at English Point

Temperature

- Water temperature ranged from 4.2°C to 20.6°C during the 2017 deployment season, with a median value of 13.8°C (Figure 24), which was comparable to the previous two seasons.
- Daily fluctuations at this station are far greater compared to the other stations in the Churchill River network due to tidal influences from the Atlantic Ocean and Lake Melville.

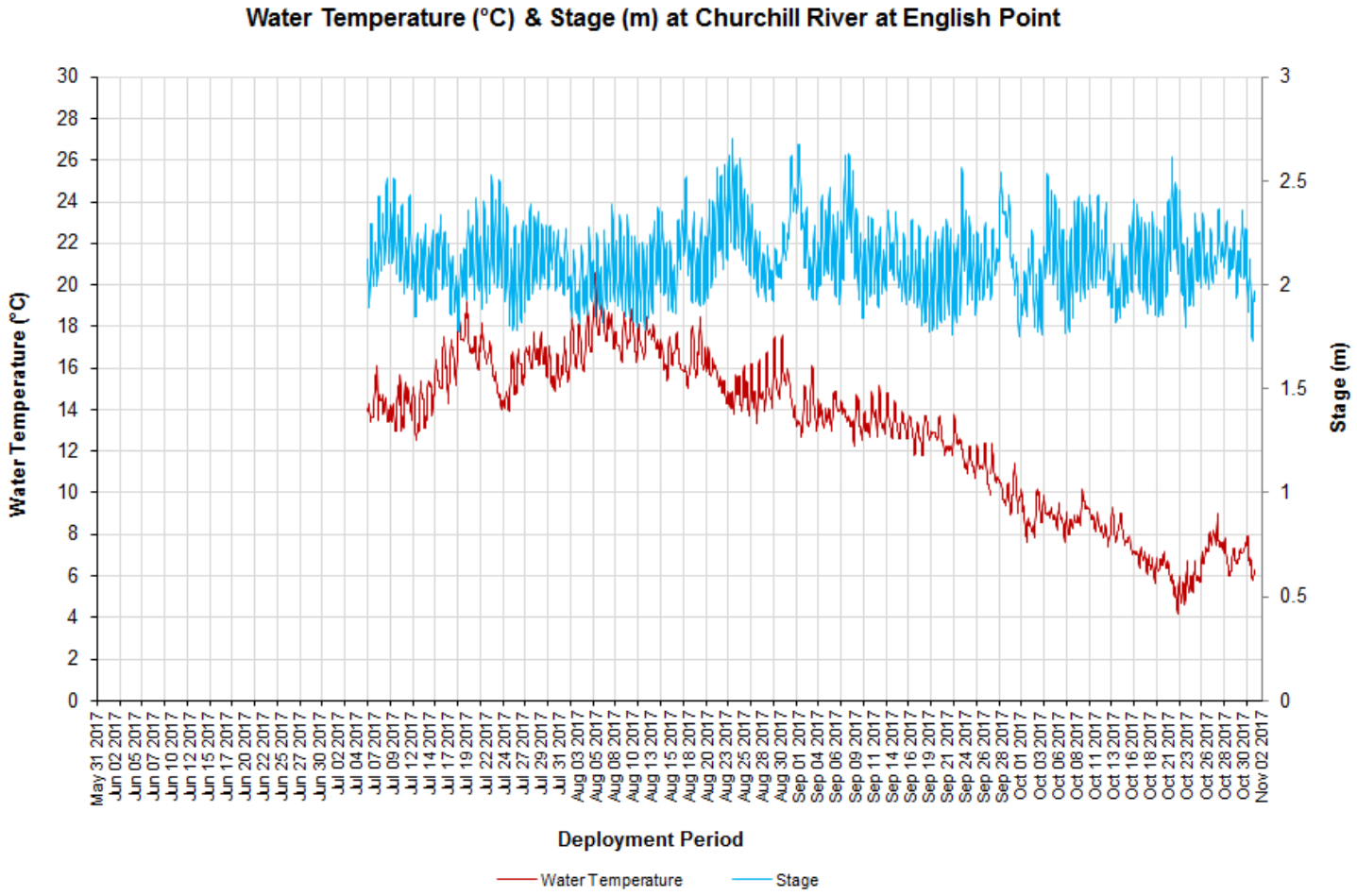


Figure 24: Water Temperature & Stage at Churchill River at English Point

Temperature (°C)	2017	2016	2015
Min	4.2	1.60	1.50
Max	20.6	21.70	20.20
Median	13.8	12.10	13.60

- Water temperature followed a typical seasonal trend (Figure 25), where both water and air temperatures increased throughout the spring and early summer with water temperatures peaking in early August. Water and air temperatures decreased steadily from mid-August onwards.

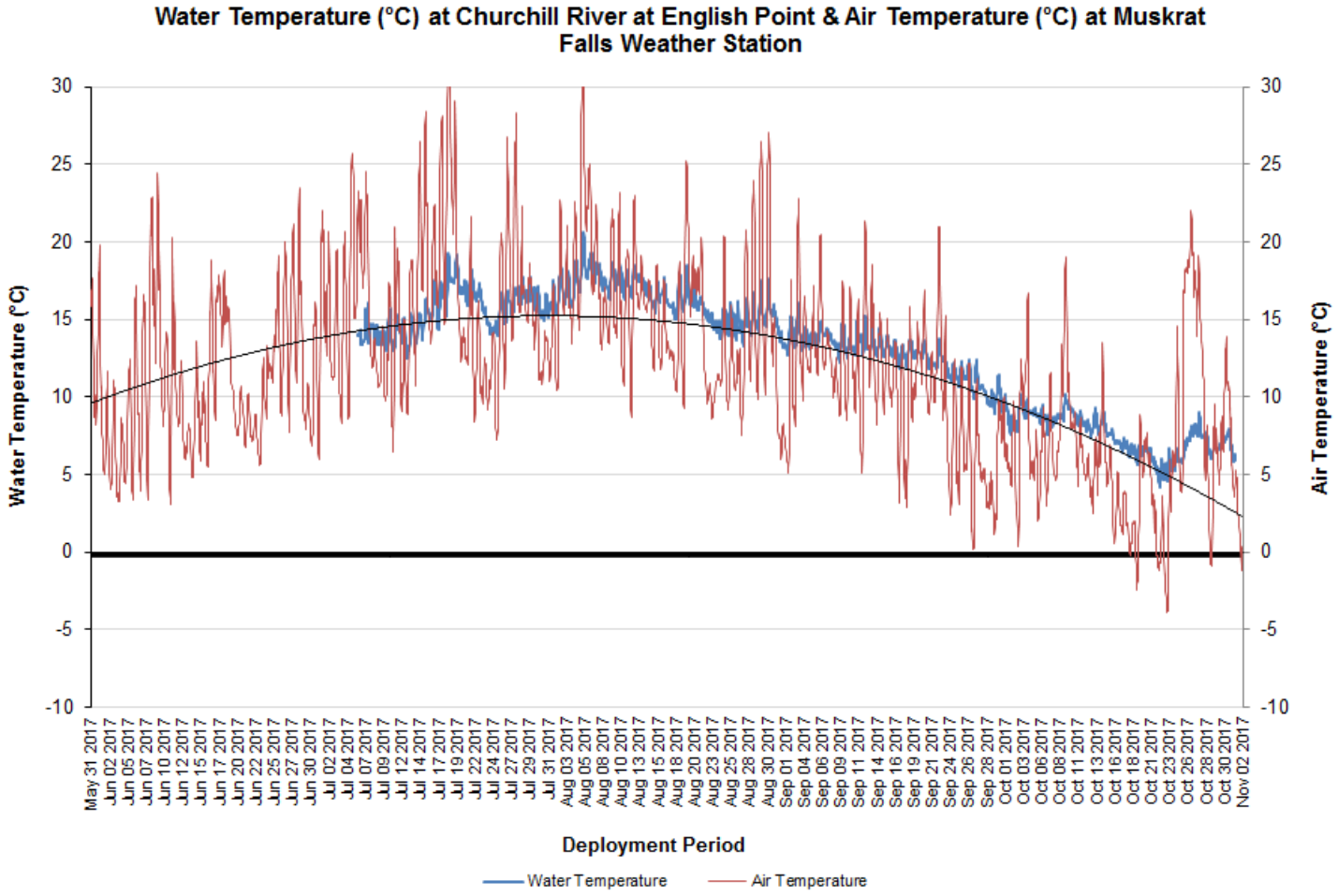


Figure 25: Water Temperature at Churchill River at English Point & Air Temperature at Muskrat Falls MET

pH

- pH ranged from 6.14 and 7.34 pH units during the 2017 deployment season, with a median value of 6.79 pH units (Figure 26), which was very similar to the 2016 season.
- pH values generally remained within the CCME Guidelines for the Protection of Aquatic Life (>6.5 and <9.0 pH units), with only a few exceptions that are likely linked to precipitation events. CCME Guidelines are indicated in red on Figure 26.

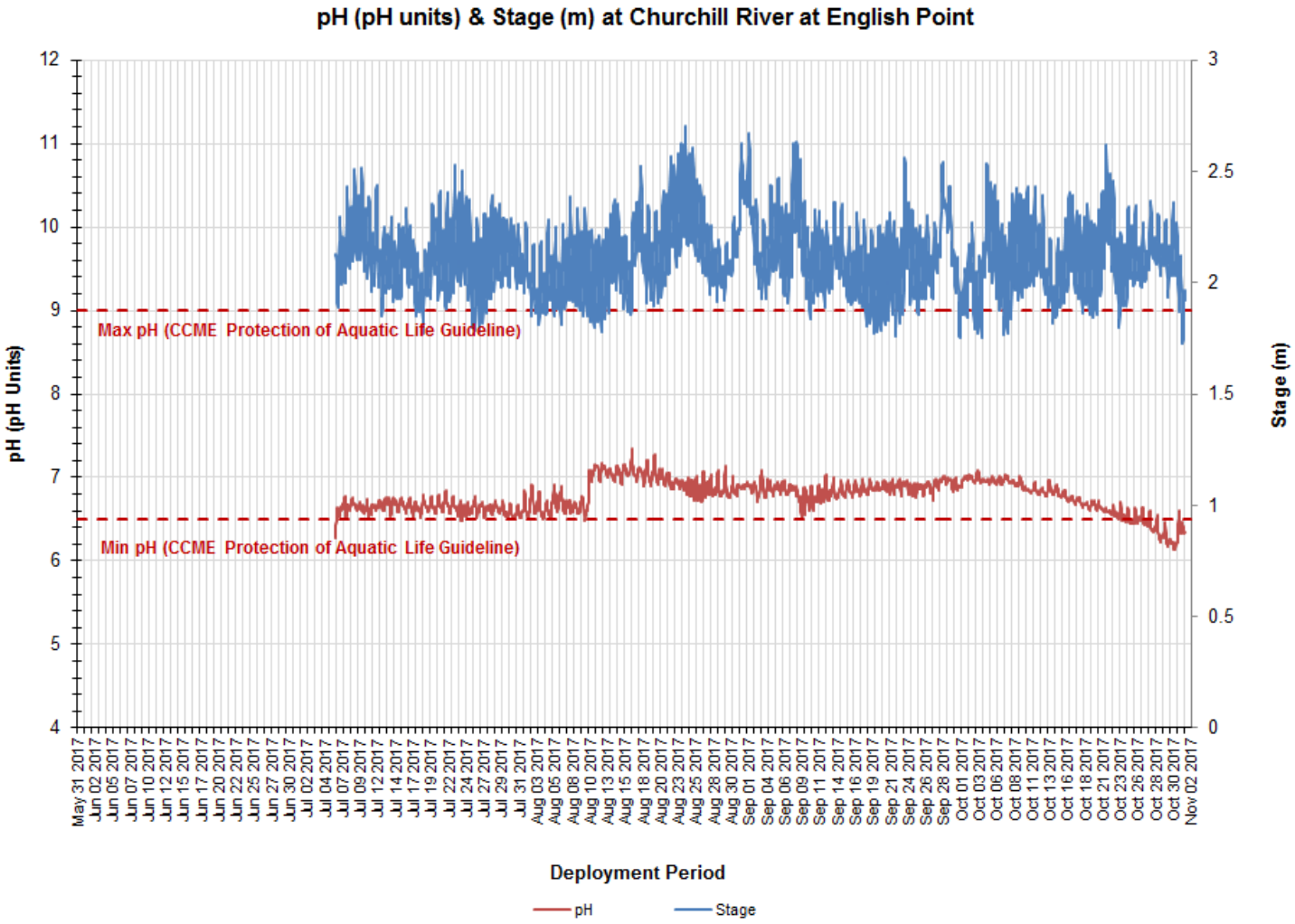


Figure 26: pH & Stage at Churchill River at English Point

pH (units)	2017	2016	2015
Min	6.14	6.20	6.09
Max	7.34	7.32	7.43
Median	6.79	6.69	7.00

Specific Conductivity

- Specific conductivity ranged from 16.1µS/cm to 60.9µS/cm during the 2017 deployment season, with a median value of 29.6µS/cm, which was very similar to the previous two seasons (Figure 27).
- Specific conductivity is highly variable at this station, fluctuating significantly every day due to tidal influences from the Atlantic Ocean. As the tide comes in, specific conductivity increases as dissolved solids and salinity increase. Similarly, when the tide goes out, specific conductivity decreases as dissolved solids and salinity decrease. This increase and decrease in specific conductivity and stage occurs twice daily.

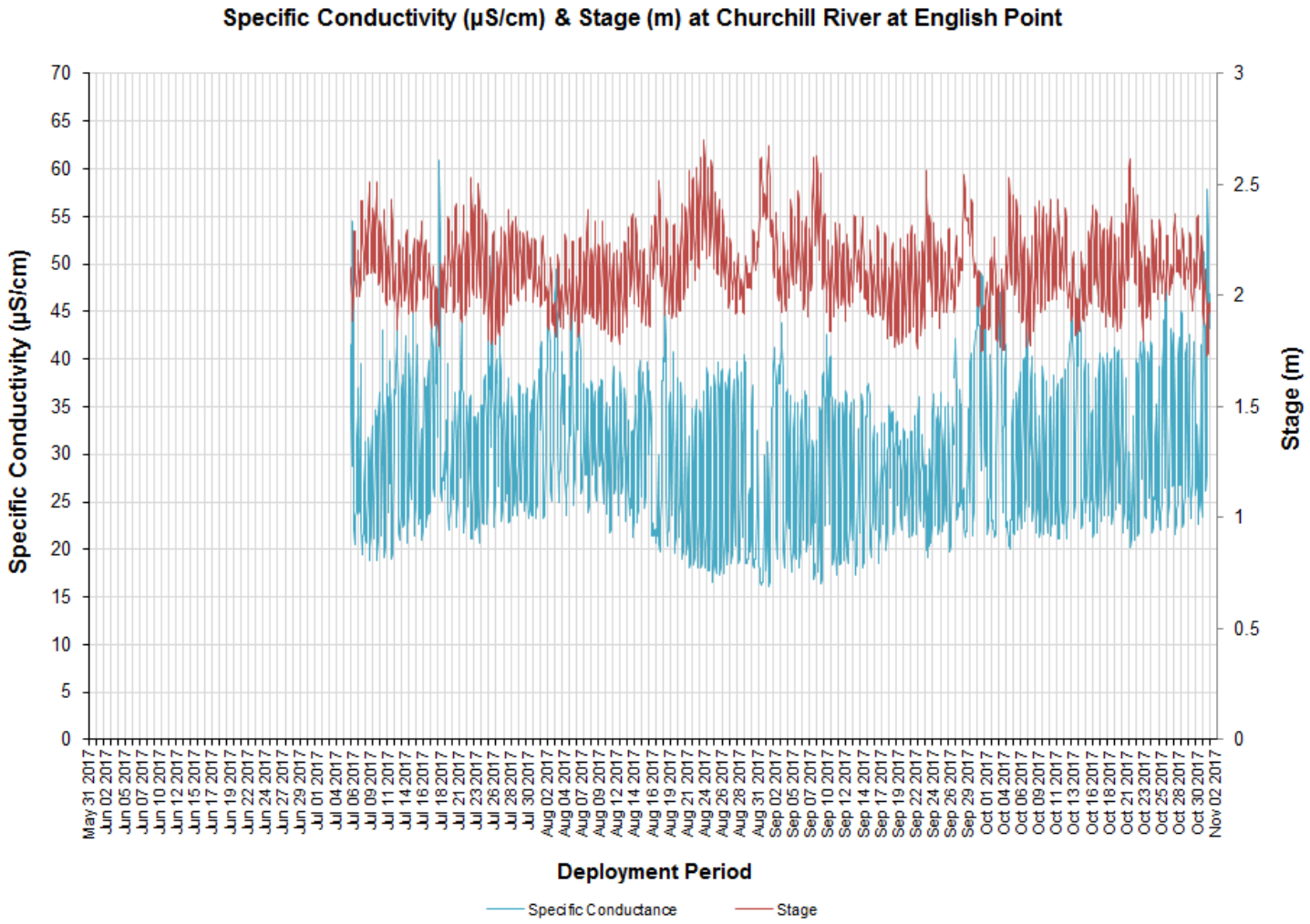


Figure 27: Specific Conductivity & Stage at Churchill River at English Point

Specific Conductivity (µS/cm)	2017	2016	2015
Min	16.1	12.2	10.3
Max	60.9	72.0	59.8
Median	29.6	30.1	29.9

Dissolved Oxygen

- Dissolved oxygen ranged from 8.7mg/L to 13.31mg/L during the 2017 deployment season, with a median value of 10.35mg/L (Figure 28), which was comparable to previous seasons.
- Percent saturation ranged from 86.9% to 112.1%, with a median value of 98.5% (Figure 28), which was also comparable to previous seasons.
- Dissolved oxygen content displayed typical daily and seasonal fluctuations. Percent saturation was generally consistent throughout the deployment season.
- Dissolved oxygen values were above the minimum CCME Guideline for the Protection of Other & Early Life Stages (6.5mg/L and 9.5mg/L respectively) for the majority of the deployment season. An obvious exception was from mid-July to mid-August when water temperatures were highest. CCME Guidelines are indicated in red on Figure 28.

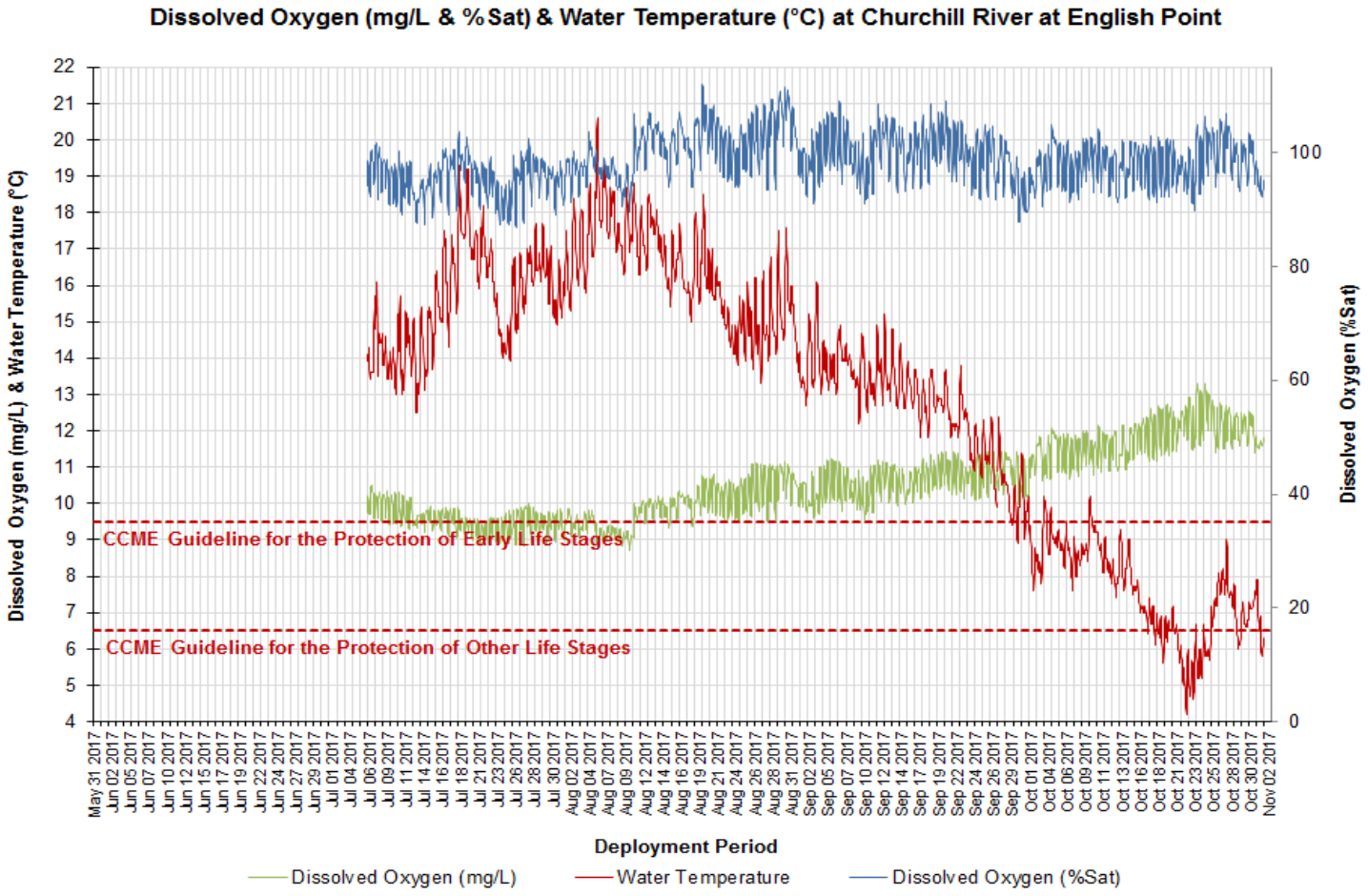


Figure 28: Dissolved Oxygen (mg/L and %Sat) & Water Temperature at Churchill River at English Point

Dissolved Oxygen (mg/L)	2017	2016	2015		Dissolved Oxygen (% Sat)	2017	2016	2015
Min	8.7	9.04	8.48		**Min**	86.9	86.3	73.80
Max	13.31	14.14	13.66		**Max**	112.1	115.2	112.60
Median	10.35	10.94	10.42		**Median**	98.5	100.7	99.00

Turbidity

- Turbidity ranged from 0NTU to 117.9NTU during the 2017 deployment season, with a median value of 5.0NTU (Figure 29). A median value of 5.0NTU indicates that there is significant natural background turbidity at this station.
- Turbidity levels were lower throughout the 2017 deployment season as compared to the previous two seasons.

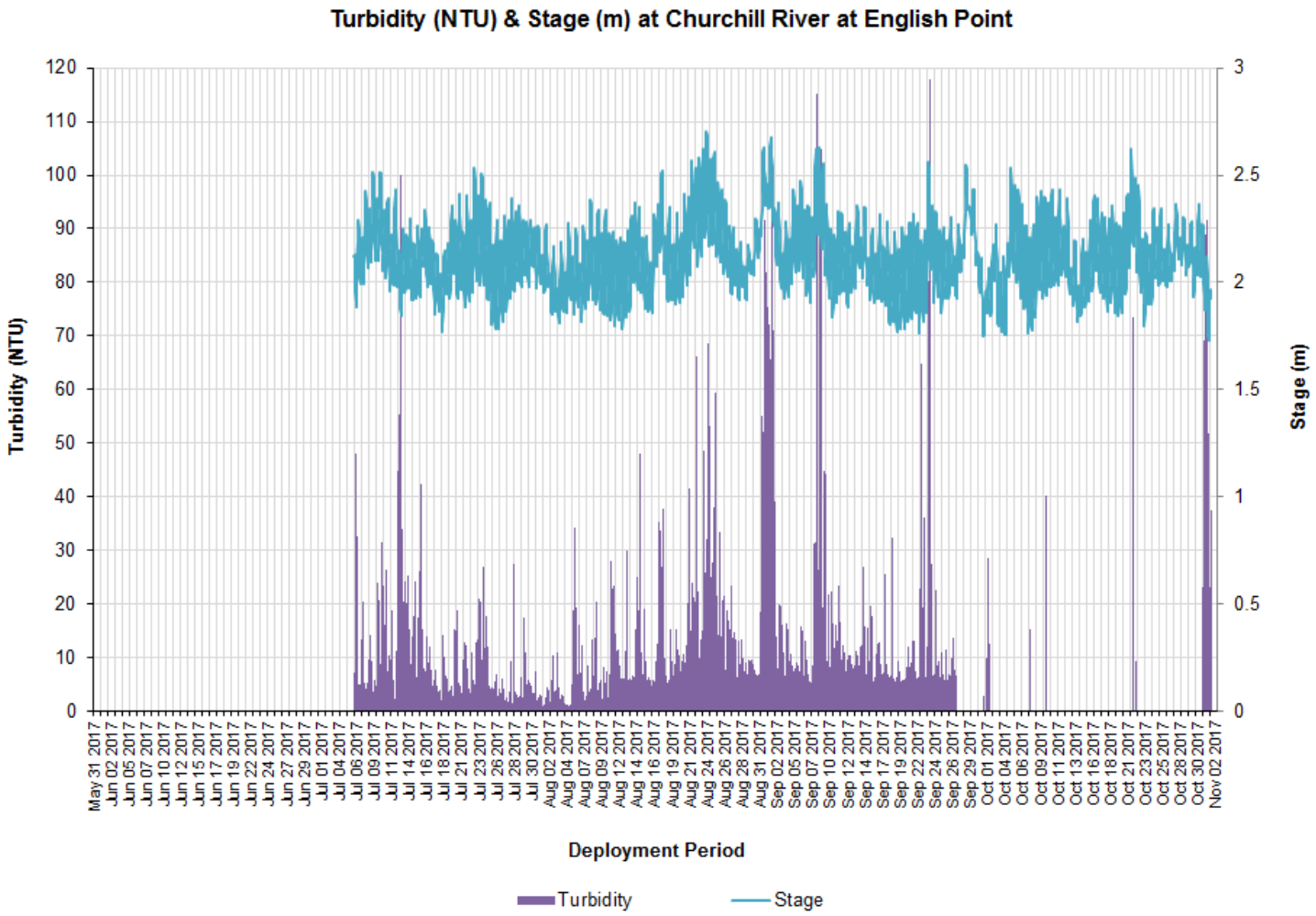


Figure 29: Turbidity & Stage at Churchill River at English Point

Turbidity (NTU)	2017	2016	2015
Min	0.0	0.0	0.0
Max	117.9	322.9	541.1
Median	5.0	10.5	13.3

Stage

- Stage ranged from 1.728m to 2.701m during the 2017 deployment season, with a median value of 2.113m (Figure 30), which is comparable to the previous two seasons.
- While stage is relatively consistent over the course of the deployment season, stage values at this station do fluctuate considerably on a daily basis due to tidal influences from the Atlantic Ocean.
- Water Survey of Canada (ECCC) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

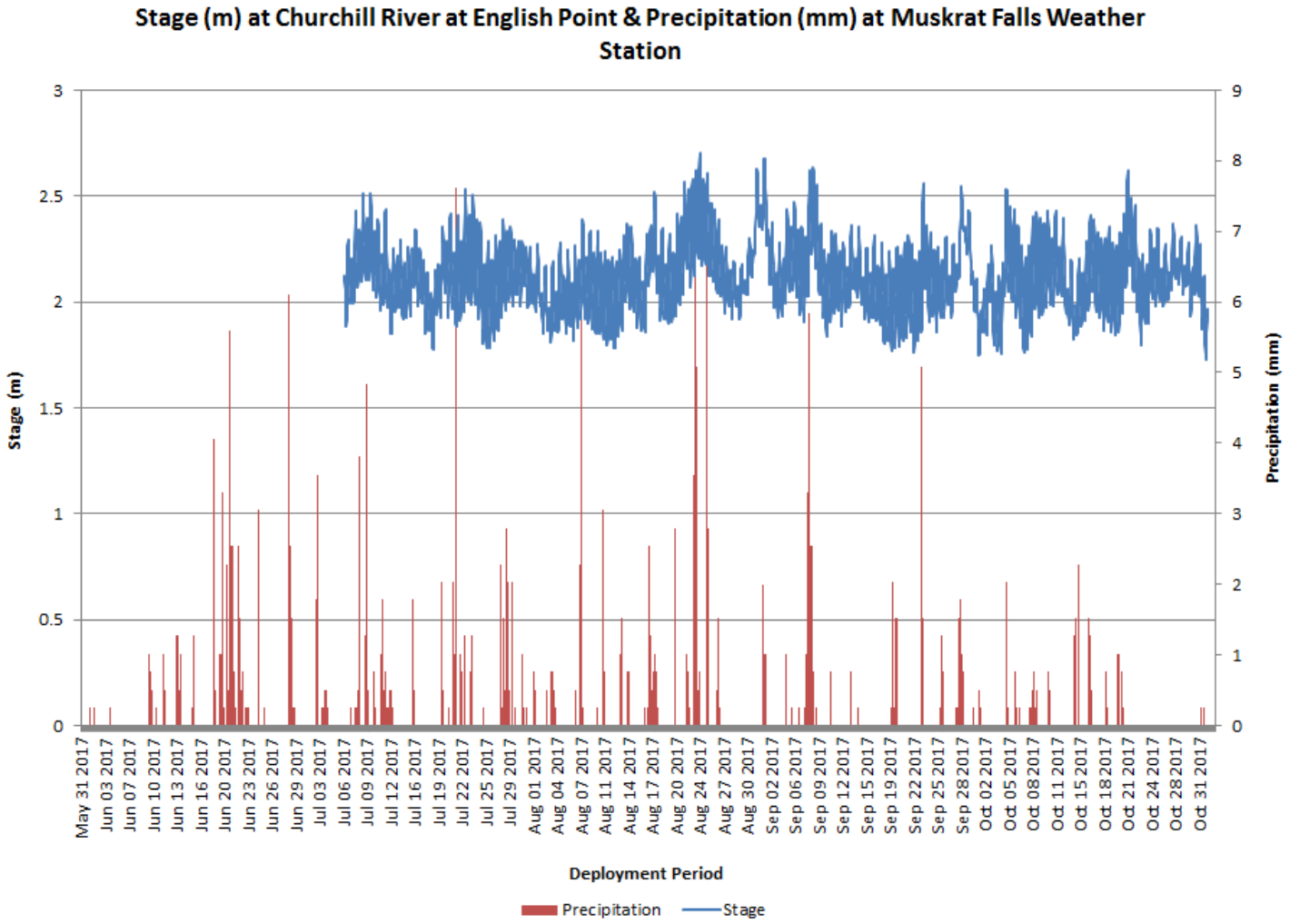


Figure 30: Stage at Churchill River at English Point & Precipitation at Muskrat Falls MET

Stage (m)	2017	2016	2015
Min	1.728	1.70	1.63
Max	2.701	3.06	2.77
Median	2.113	2.16	2.09

Station Comparison

Temperature

- Water temperatures at each of the four stations on the Churchill River displayed a similar trend throughout the 2017 deployment season (Figure 31). Overall, increases and decreases occurred at all stations around the same time, though to different degrees.
- Water temperature was generally warmest at English Point, while this station also had the greatest diurnal fluctuations. Into the summer months, the coolest water temperatures were recorded above Grizzle Rapids, while the warmest were recorded at English Point. Median water temperature values typically show a decrease in temperature as you move downstream through the river, from below Metchin River to English Point; however, since instruments were deployed at different times during the 2017 season, this trend is not observed.

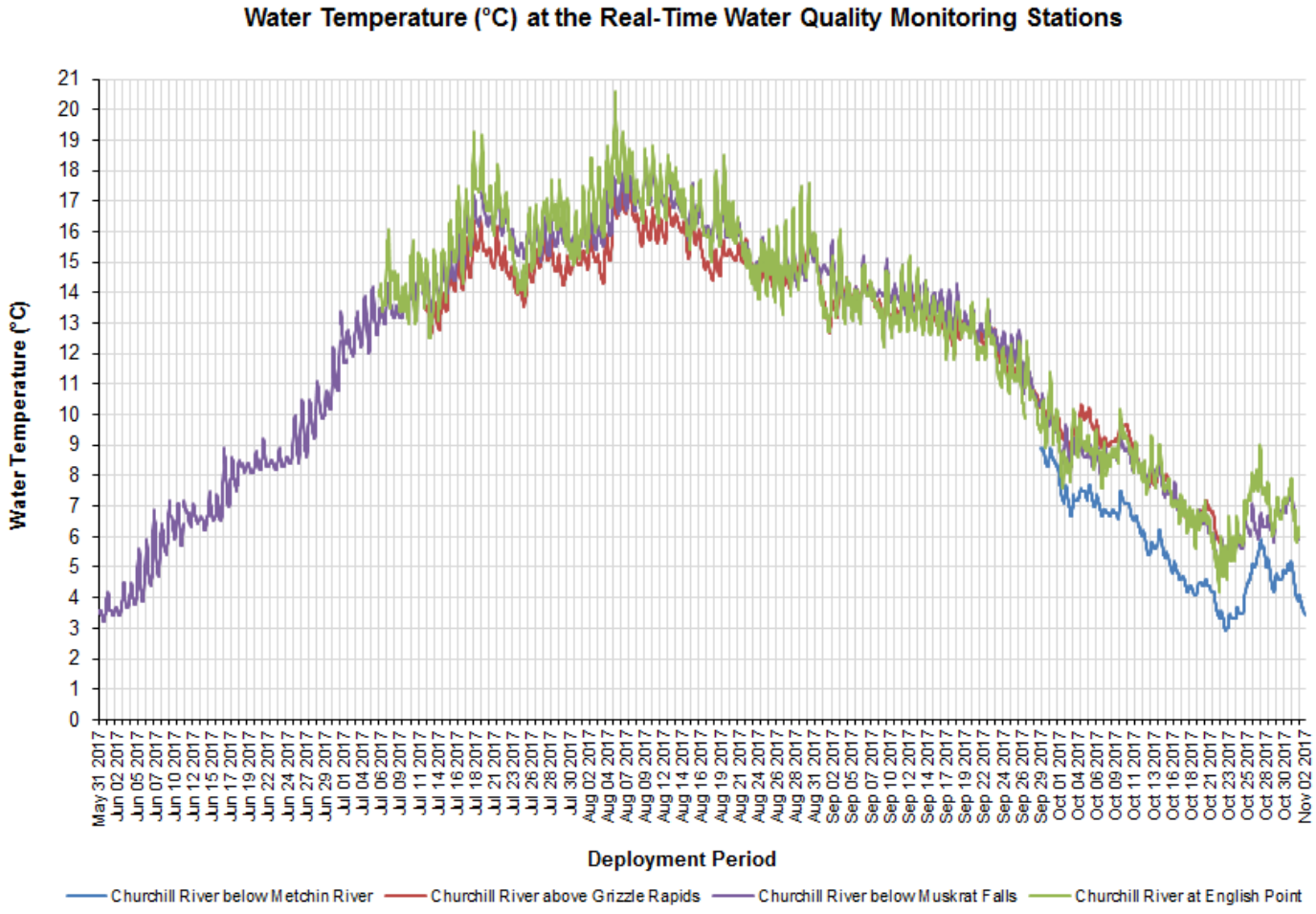


Figure 31: Water Temperature at all Stations on the Churchill River in 2017

Temperature	CRbelowMR	CRaboveGR	CRbelowMF	CRatEngPt
Min	2.9	5.58	3.2	4.2
Max	8.9	17.57	18.2	20.6
Median	5.4	13.98	13.0	13.8

- Water temperatures at each of the four stations on the Churchill River displayed clear seasonal trends in response to changes in ambient air temperatures throughout the deployment season (Figure 32).

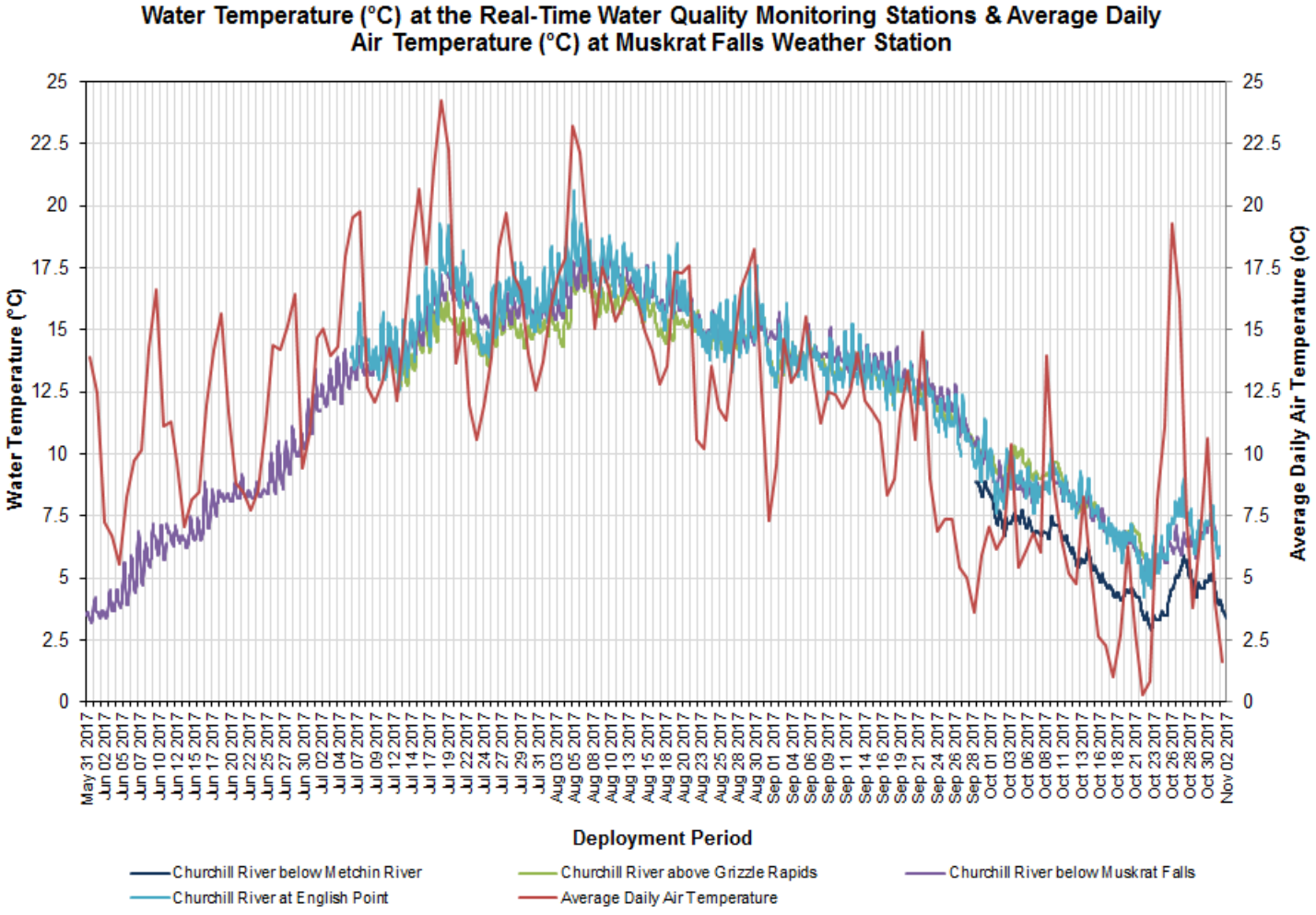


Figure 32: Water Temperature at all Stations on the Churchill River in 2017 & Average Daily Air Temperature

pH

- pH values at each of the four stations on the Churchill River displayed similar trends throughout the 2017 deployment season (Figure 33). An obvious exception is at the station below Muskrat Falls, which displayed a much lower pH at certain times during the season as compared to the other three stations.
- Median values for below Metchin River and at English Point were very similar, while the median value for above Grizzle Rapids was slightly higher and the median value for below Muskrat Falls was slightly lower.
- pH values at English Point showed the greatest daily variation throughout the deployment season due to the position of this station at the mouth of the Churchill River and tidal influences from the Atlantic Ocean.

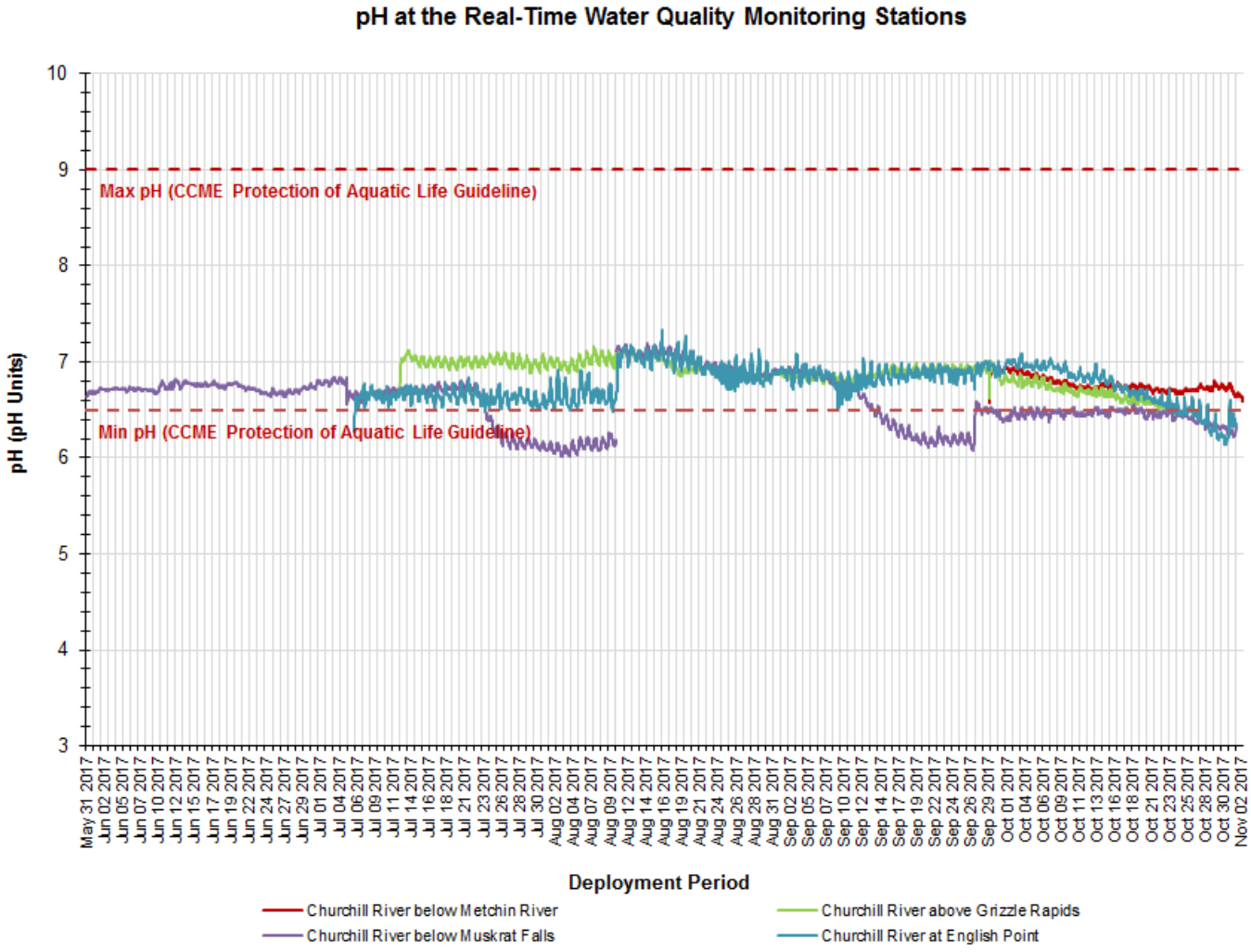


Figure 33: pH at all Stations on the Churchill River in 2017

pH	CRbelowMR	CRaboveGR	CRbelowMF	CRatEngPt
Min	6.58	6.45	6.01	6.14
Max	6.95	7.16	7.19	7.34
Median	6.75	6.91	6.67	6.79

Specific Conductivity

- Specific conductivity values at each of the four stations on the Churchill River displayed similar trends throughout the 2017 deployment season, with the exception of the station at English Point (Figure 34).
- Specific conductivity is generally very stable on the Churchill River (above English Point), fluctuating very little over the course of a deployment period. In contrast, at the station at English Point, specific conductivity is highly variable, fluctuating significantly twice daily due to the tidal influences of the Atlantic Ocean.

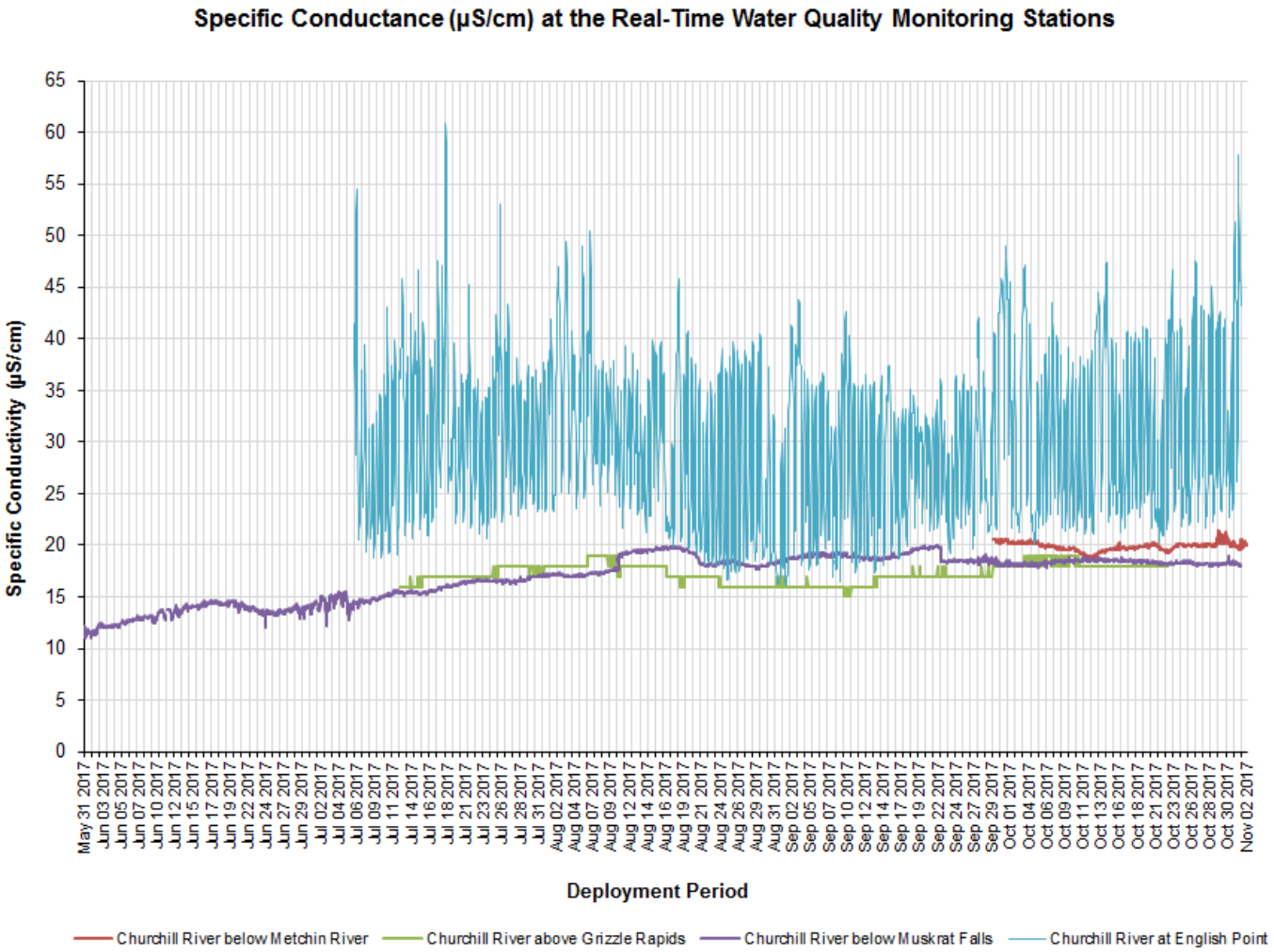


Figure 34: Specific Conductivity at all Stations on the Churchill River in 2017

Specific Conductivity (µS/cm)	CRbelowMR	CRaboveGR	CRbelowMF	CRatEngPt
Min	18.7	15	11.0	16.1
Max	21.5	19	20.0	60.9
Median	19.9	17	18.1	29.6

Dissolved Oxygen

- Dissolved oxygen content and percent saturation values at each of the four stations on the Churchill River were very similar throughout the 2017 deployment season (Figure 35a and 35b), with median values ranging from 9.94mg/L above Grizzle Rapids to 11.87mg/L below Metchin River.
- Dissolved oxygen (mg/L) displayed a very clear inverse relationship with water temperature, and followed a distinct seasonal trend whereby values decreased through spring and early summer, then increased through late summer into fall (Figure 35a). In contrast, dissolved oxygen (% Sat) remained relatively stable across the deployment season at all stations (Figure 35b).
- Generally, dissolved oxygen content is highest at the station below Muskrat Falls compared to all other stations due to its downstream proximity to Muskrat Falls. Dissolved oxygen content at below Muskrat Falls remained above the CCME Guidelines for the Protection of Early Life Stages (9.5mg/L) for the duration of the 2017 deployment season, whereas values at above Grizzle Rapids and at English Point dipped below the CCME Guidelines during the warmer summer months.

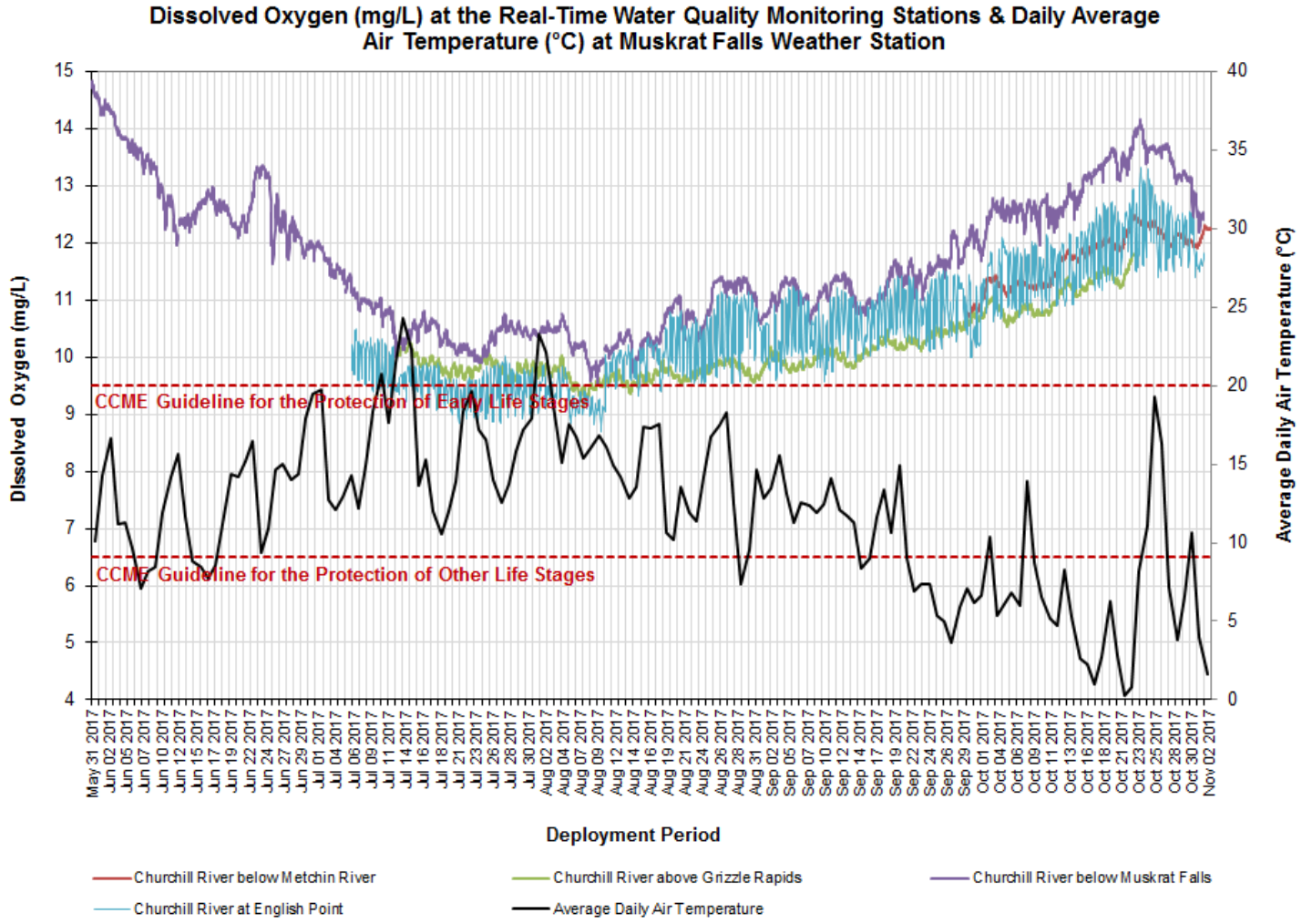


Figure 35a: Dissolved Oxygen (mg/L) at all Stations on the Churchill River in 2017

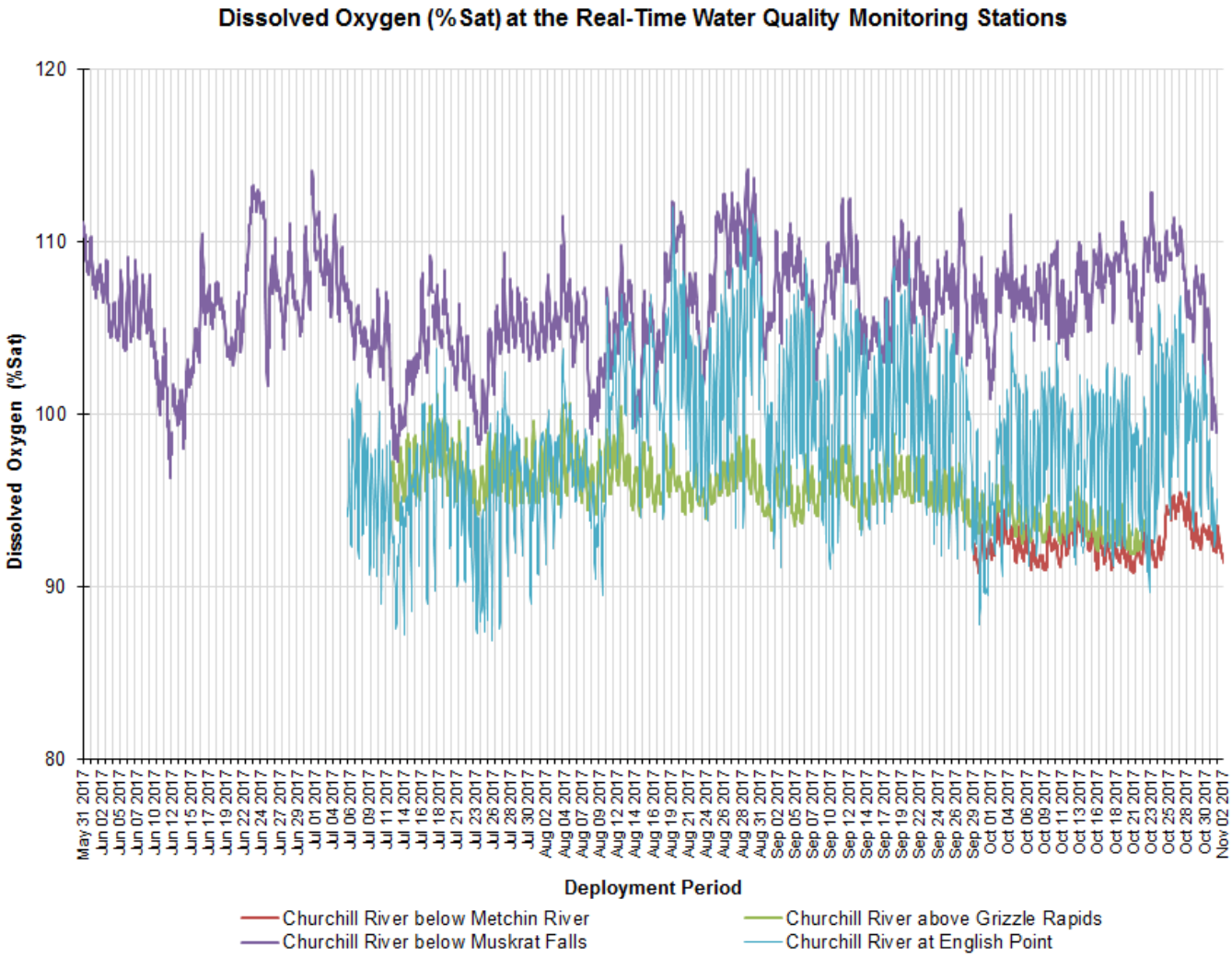


Figure 35b: Dissolved Oxygen (%Sat) at all Stations on the Churchill River in 2017

	Dissolved Oxygen (mg/L)					Dissolved Oxygen (% Sat)			
	CRbelowMR	CRaboveGR	CRbelowMF	CRatEngPt		CRbelowMR	CRaboveGR	CRbelowMF	CRatEngPt
Min	10.67	9.27	9.54	8.70		90.8	91.9	96.3	86.9
Max	12.48	11.81	14.82	13.31		95.5	101.2	114.2	112.1
Median	11.87	9.94	11.40	10.35		92.4	95.5	106.4	98.5

Turbidity

- Turbidity values at each of the four stations on the Churchill River were somewhat similar during the 2017 deployment season (Figure 36), with median values ranging from 0NTU to 5NTU.
- Turbidity values showed the most variation at below Muskrat Falls and at English Point, where values ranged from 0NTU to 105.5NTU and from 0NTU to 117.9NTU, respectively. Traditionally, variable turbidity would also be observed at Grizzle Rapids; however, sensor failures hindered the collection of turbidity data at this station during the 2017 deployment season.
- English Point showed a higher range of turbidity values and more frequent increases throughout 2017, likely due to tidal influences at this location as sediment is stirred up by wave action.

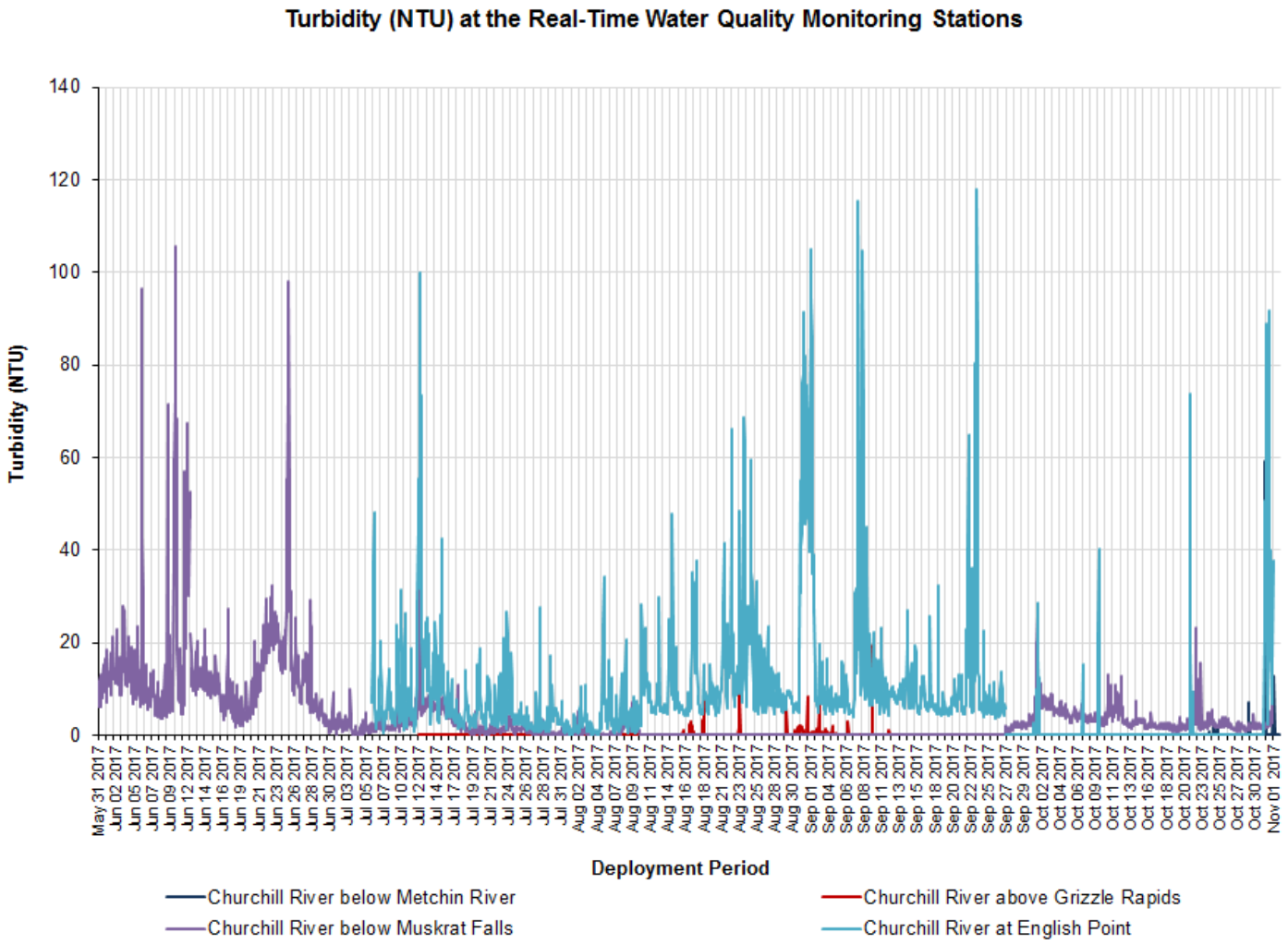


Figure 36: Turbidity at all Stations on the Churchill River in 2017

Turbidity (NTU)	CRbelowMR	CRaboveGR	CRbelowMF	CRatEngPt
Min	0.0	0.0	0.0	0.0
Max	59.2	19.3	105.5	117.9
Median	0.0	0.0	1.5	5.0

Stage

- Stage values on the Churchill River varied significantly from one station to the next during the 2017 deployment season (Figure 37), with the exception of at the below Muskrat Falls and at English Point stations.
- Stage was generally quite stable at each station across the deployment season. The greatest variability in stage was observed at English Point, where values are greatly affected by tidal influences from the Atlantic Ocean.
- Stage generally decreases as you move downstream through the Churchill River network, with the highest values being observed below Metchin River and the lowest values being observed at English Point.
- Water Survey of Canada (ECCC) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

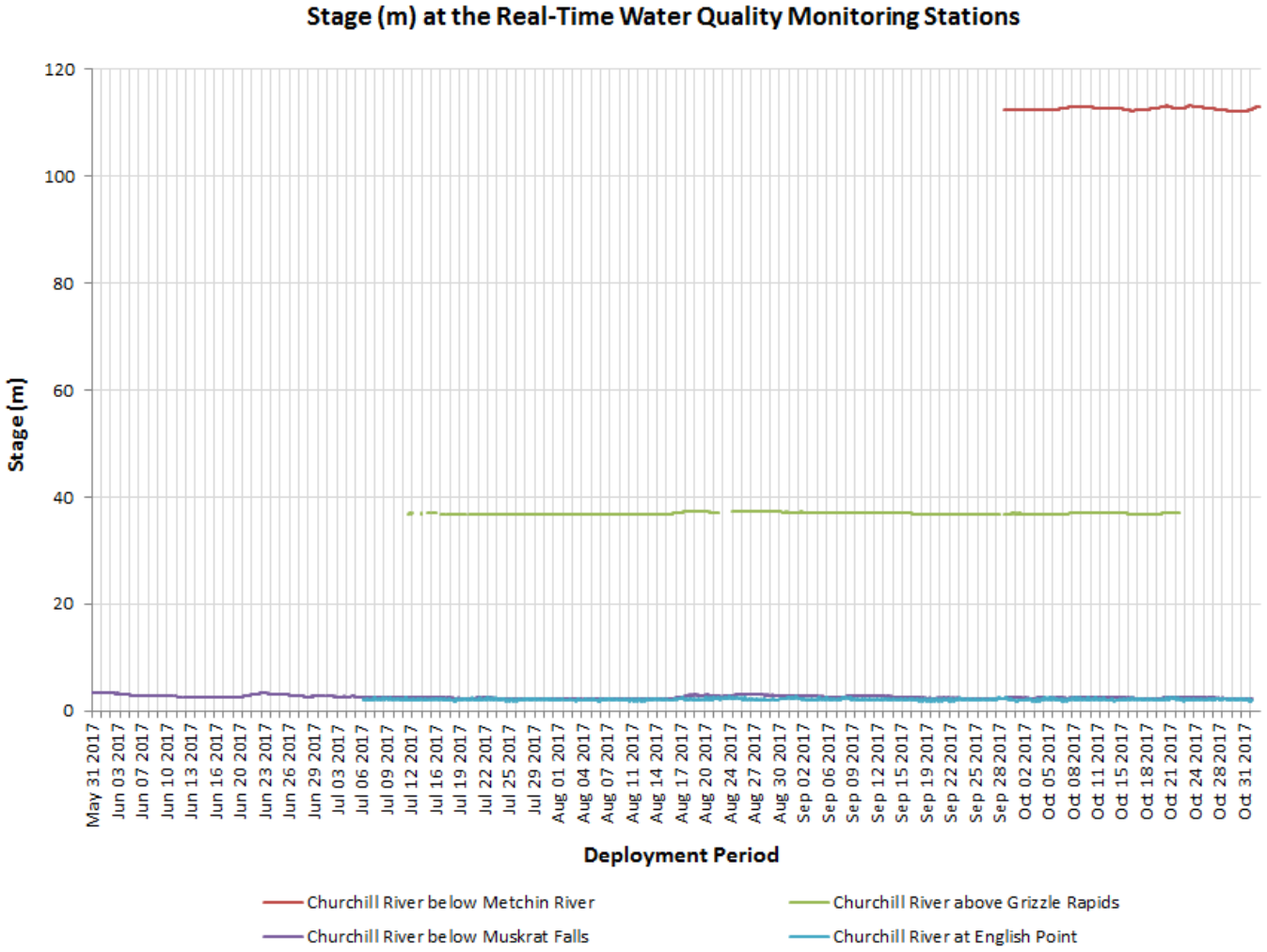


Figure 37: Stage at all Stations on the Churchill River in 2017

Stage (m)	CRbelowMR	CRaboveGR	CRbelowMF	CRatEngPt
Min	112.121	36.661	2.096	1.728
Max	113.228	37.355	3.446	2.701
Median	112.623	36.866	2.517	2.113

Conclusions

- Water quality monitoring instruments were successfully deployed on the Churchill River for different lengths of time during the spring, summer, and fall of 2017. The station below Metchin River was not deployed until September. The station above Grizzle Rapids was not deployed until July due to the presence of an ice wall blocking accessibility to that site. The station at English Point was not deployed until July due to ice damage to the helicopter landing pad preventing access to that site. The station above Muskrat Falls was not deployed at all in 2017 due to safety concerns that hindered access to that site.
- In most cases, weather related events can explain fluctuations in water levels. The deployed stations continue to perform well at capturing water quality baseline data along different reaches of the river. The English Point station provides a last measurement of water quality in the Lower Churchill River before entering Lake Melville. This station is affected by tidal influences from the Atlantic Ocean.
- Regular visits on a 30-50 day deployment schedule were adhered to for the 2017 deployment season. This has provided good quality data with limited drift. The effects of bio fouling rarely impact the instruments due to the cold pristine nature of the river and regular monthly maintenance.
- Instruments performed well for much of the deployment season with only limited disruptions to data collection.
- Data collected in 2017 was comparable with datasets from previous years; however, the reactivation of the station below Metchin River and the relocation of the station below Grizzle Rapids prevented some comparisons. Generally speaking, water quality parameters do not tend to vary significantly from year to year.
- Water temperatures followed a typical seasonal trend at all stations in the network, whereby temperatures increased through the spring and early summer, then decreased through late summer into fall.
- The majority of recorded pH values were within the CCME Guidelines for the Protection of Aquatic Life, with the exception of several periods of time at the station below Muskrat Falls.
- During the warmer summer months, dissolved oxygen at two stations (above Grizzle Rapids and at English Point) fell below the minimum CCME Guideline for the Protection of Early Life Stages (9.5mg/L). All dissolved oxygen values at all stations remained above the CCME Guideline for the Protection of Other Life Stages (6.5mg/L) for the duration of deployment.
- Specific conductivity is generally stable on the Churchill River (above English Point), experiencing only minor fluctuations during deployment. In contrast, specific conductivity at English Point is highly variable, experiencing significant daily fluctuations due to tidal influences from the Atlantic Ocean. As the tide comes in, specific conductivity increases as dissolved solids and salinity increase; the opposite is true as the tide goes out.
- Turbidity was variable along the Churchill River in 2017, with median values ranging from 0NTU to 5.0NTU. The stations below Muskrat Falls and at English Point showed frequent turbidity events as expected. Normally the station above Grizzle Rapids would be expected to show similar turbidity trends; however, sensor failures impeded the collection of turbidity data at this station.

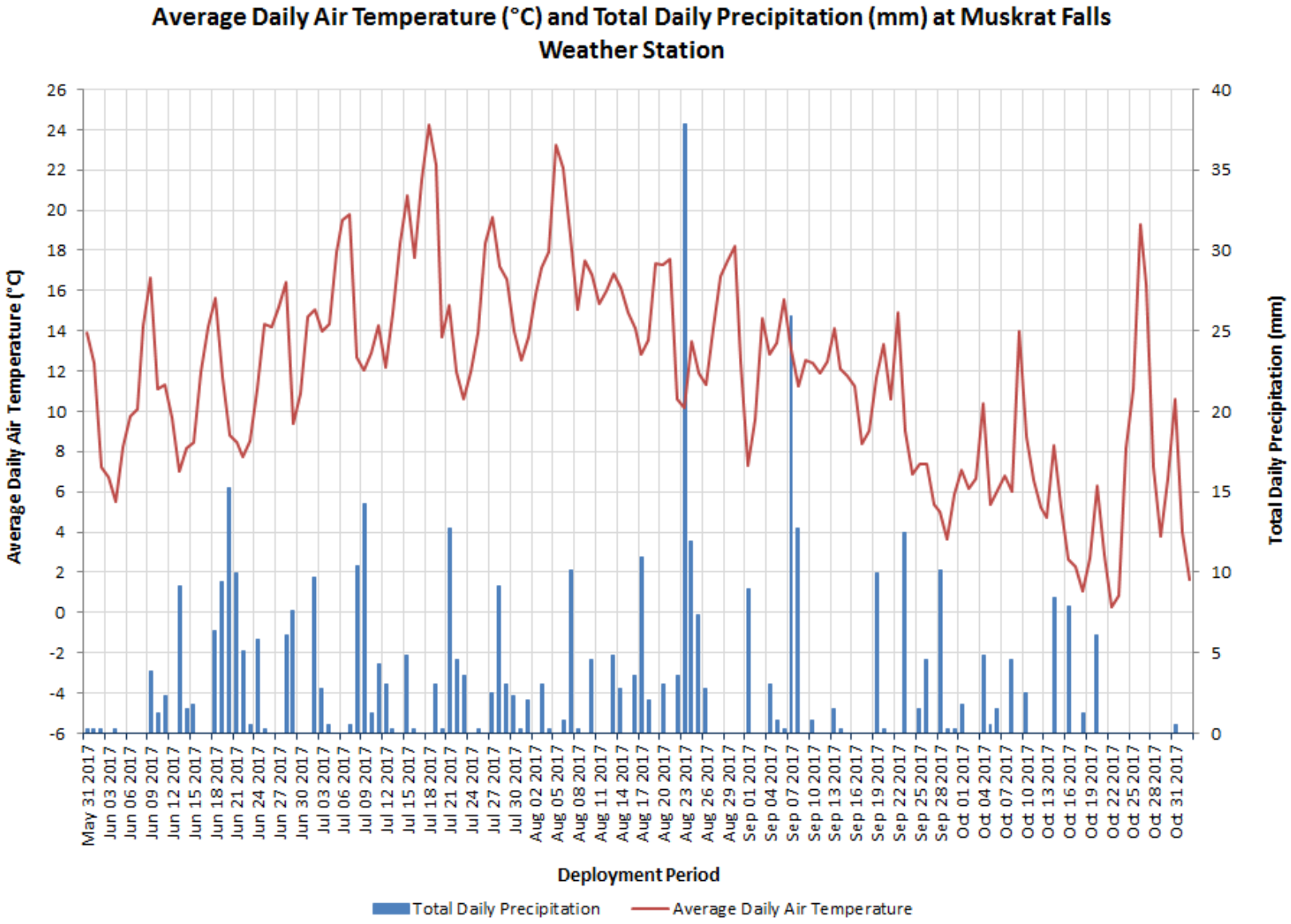
Path Forward

In order for this agreement to be successful, it is essential to continually evaluate and move forward. The 2017 deployment season was successful in providing water quality data for the Churchill River. The following is a list of planned activities to be carried out in the upcoming year. This list also includes some multi-year activities planned in previous years that are still in progress.

- MAE staff will deploy RTWQ instruments in spring 2018 when ice conditions allow and perform regular site visits throughout the 2018 deployment season for calibration and maintenance of the instruments.
- ECCC staff will perform regular site visits to ensure water quantity instrumentation is correctly calibrated and providing accurate measurements.
- Nalcor will continue to be informed of data trends and any significant water quality events in the form of a monthly deployment report when the deployment season begins. Nalcor will also receive an annual report summarizing the events of the deployment season.
- Nalcor will continue to receive batch datasets of all RTWQ data. Raw data will be provided if requested.
- Open communication lines will continue to be maintained between MAE, ECCC and Nalcor employees involved with the agreement in order to respond to emerging issues on a proactive basis.
- MAE will continuously update the TSS-Turbidity model for the stations above and below Muskrat Falls as new grab sample data becomes available. The model will then be tested and validated in consultation with Nalcor or their consultants as necessary.
- Research into the use of remote sensing (using satellite imagery) to predict/map water quality parameters (i.e. turbidity and TSS) will continue in 2018. Satellite imagery will be acquired by MAE to further this area of research.
- The Lake Melville station remains a water quantity station. RTWQ monitoring was stopped in 2012 following continued damage to the deployed instrument.
- MAE purchased a NexSens CB-450 data buoy that was deployed in Lake Melville in August 2015. However, due to heavy ice at the end of the season, significant damage was sustained. The buoy was not deployed during the 2017 season; however, the buoy will be deployed again in 2018 as Lake Melville is very important to assessing the water quality of the Lower Churchill River ecosystem.

Prepared by:
Brenda Greene – Environmental Scientist
Department of Municipal Affairs & Environment
Water Resources Management Division
Email: brendagreene@gov.nl.ca

Appendix 1


Average Daily Air Temperature (°C) and Total Daily Precipitation (mm) at Muskrat Falls Weather Station
Average Daily Air Temperature (°C)
Total Daily Precipitation (mm)
Deployment Period
Total Daily Precipitation
Average Daily Air Temperature