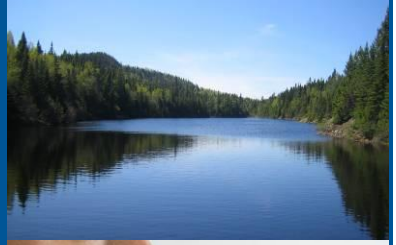







Real-Time Water Quality 2019 Annual Report

Churchill River Network

May 28 to October 30, 2019

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. WRMD staff was responsible for deployment and removal of instruments including cleaning, calibration, and maintenance, as well as preparation of monthly deployment reports for the 2019 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 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 2019, 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 to monitor and assess water quality throughout the several phases of the Lower Churchill Hydroelectric Generation Project.
- 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.
- During the 2017 deployment year, 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.
- Continuous monitoring at four water quality/quantity monitoring stations in the Lower Churchill River Network recommenced in spring 2019. This annual deployment report illustrates, discusses and summarizes water quality related events from May 28 to October 30, 2019. Due to challenging site conditions, only three RTWQ stations (Churchill River below Metchin River, Churchill River below Muskrat Falls and Churchill River at English Point) were 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 above Grizzle Rapids, this station was not deployed until later in the season. The station at above Muskrat Falls was not deployed during the 2019 season due to inaccessibility and safety concerns.
- Construction at the Muskrat Falls Hydroelectric Generation site began in 2013. In 2019, construction continued as the worksite neared completion. Work is scheduled to continue through 2020.

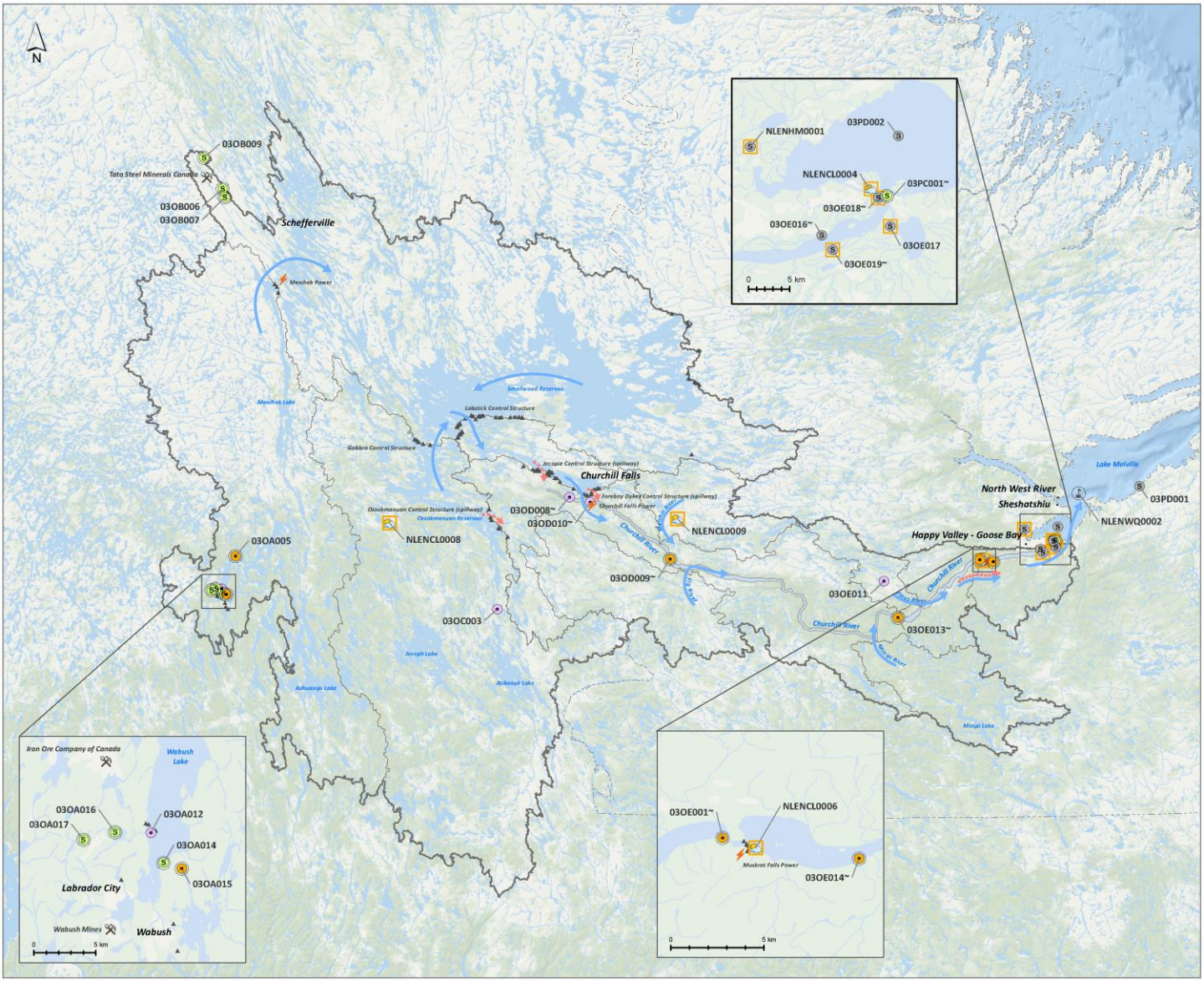

Figure 1: Churchill River Station Network Map

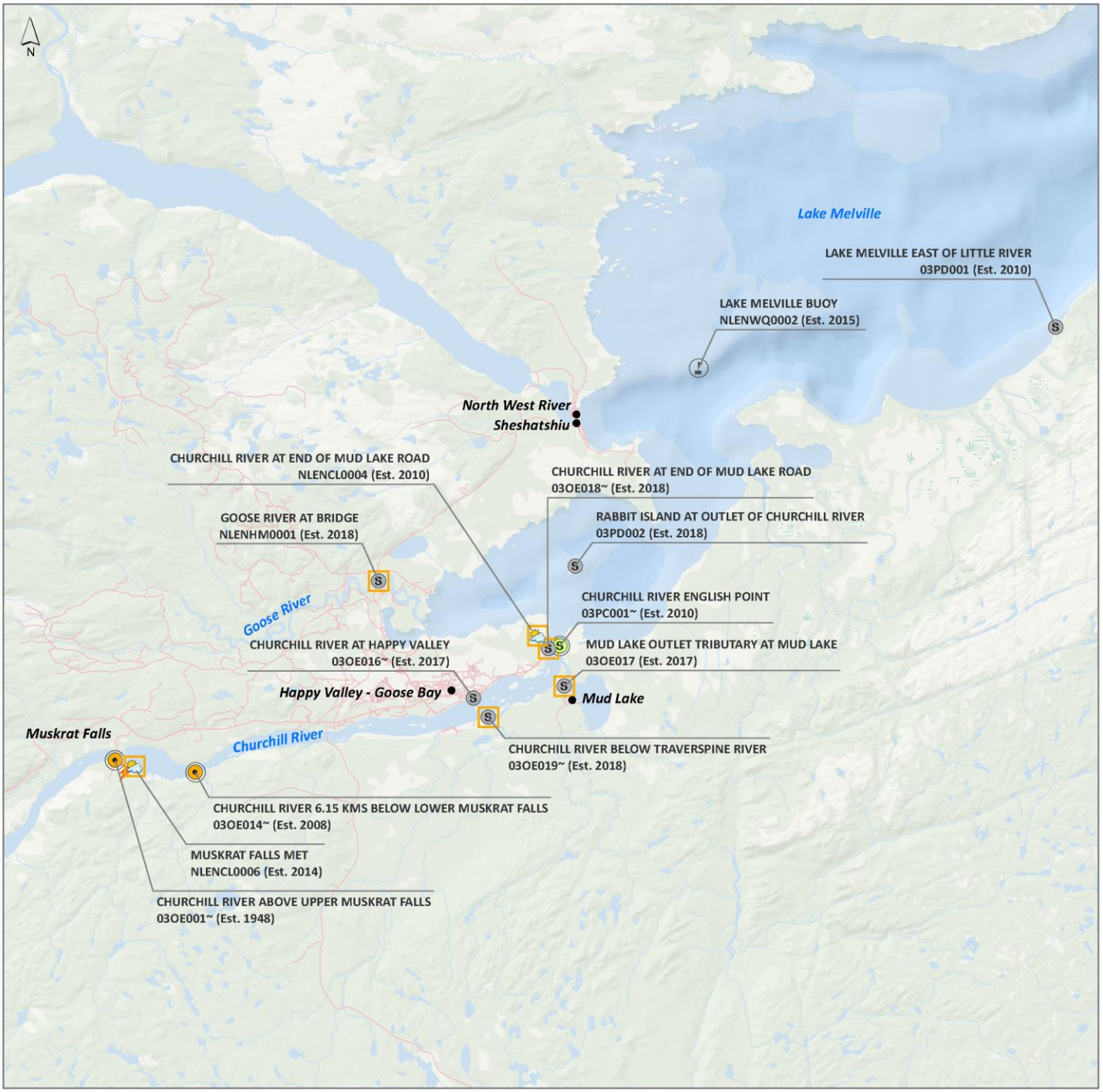

Figure 2: Lower Churchill River Network Station Map

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 2019 deployment season are summarized in Table 1.

Table 1: Installation and removal dates for 2018 deployment season

Station	Initial Installation	Removal	Deployment Periods (days)
Churchill River below Metchin River	June 11	October 29	35, 49, 56
Churchill River above Grizzle Rapids	July 3	October 29	62, 31, 25
Churchill River below Muskrat Falls	May 28	October 30	42, 57, 30, 26
Churchill River at English Point	May 28	October 30	42, 57, 30, 26

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 2019 deployment season are summarized in Table 3.
- For additional information and explanations of rankings, please refer to the monthly deployment reports.

Table 3: Comparison rankings for Lower Churchill River stations, 2019 deployment season

Station	Date	Action	Temperature	pH	Specific Conductivity	Dissolved Oxygen	Turbidity
Churchill River below Metchin River	June 11	Deployment	Excellent	Good	Excellent	Excellent	Good
	July 16	Removal	Fair	Good	Poor	Poor	Excellent
	July 16	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
	September 3	Removal	Good	Excellent	Excellent	Excellent	Excellent
	September 3	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
		Removal	Instrument not removed				
		Deployment					
	October 29	Removal	Good	Good	Excellent	Fair	Good
Churchill River above Grizzle Rapids		Deployment	Instrument not deployed				
		Removal					
	July 3	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
	September 3	Removal	Excellent	Excellent	Excellent	Excellent	Excellent
	September 3	Deployment	Good	Good	Excellent	Excellent	Excellent
	October 4	Removal	Good	Good	Excellent	Good	Excellent
	October 4	Deployment	Excellent	Fair	Excellent	Excellent	Excellent
	October 29	Removal	Good	Good	Excellent	Fair	Excellent
Churchill River below Muskrat Falls	May 28	Deployment	Good	Excellent	Excellent	Fair	Excellent
	July 9	Removal	Good	Good	Excellent	Excellent	Excellent
	July 9	Deployment	Excellent	Fair	Excellent	Excellent	Poor
	September 4	Removal	Good	Good	Excellent	Excellent	Poor
	September 4	Deployment	Good	Excellent	Excellent	Excellent	Excellent
	October 4	Removal	Good	Excellent	Excellent	Excellent	Excellent
	October 4	Deployment	Good	Fair	Excellent	Excellent	Excellent
	October 30	Removal	Excellent	Excellent	Excellent	Good	Marginal
Churchill River at English Point	May 28	Deployment	Good	Excellent	Excellent	Excellent	Excellent
	July 9	Removal	Excellent	Excellent	Excellent	Excellent	Fair
	July 9	Deployment	Excellent	Good	Excellent	Excellent	Good
	September 4	Removal	Excellent	Good	Excellent	Excellent	Excellent
	September 4	Deployment	Good	Good	Excellent	Excellent	Excellent
	October 4	Removal	Good	Good	Excellent	Good	Fair
	October 4	Deployment	Excellent	Fair	Excellent	Excellent	Excellent
	October 30	Removal	Good	Excellent	Marginal	Fair	Excellent

Data Interpretation and Review

- The following graphs and discussions illustrate significant water quality-related trends from May 28 to October 30 throughout the Churchill River network. In this summary of all 2019 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 and flow), 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 and flow). Corrected data can be obtained upon request.
- For a general comparison, 2017 and 2018 data have been included (where available) to show trends in water quality on the Churchill River over the previous 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

- Over the 2019 deployment season, water temperature ranged from 3.7°C to 17.2°C, with a median value of 10.1°C (Figure 3).
- As expected, this station displayed an increasing trend through June, stabilized through July and August, and then decreased through September and October.

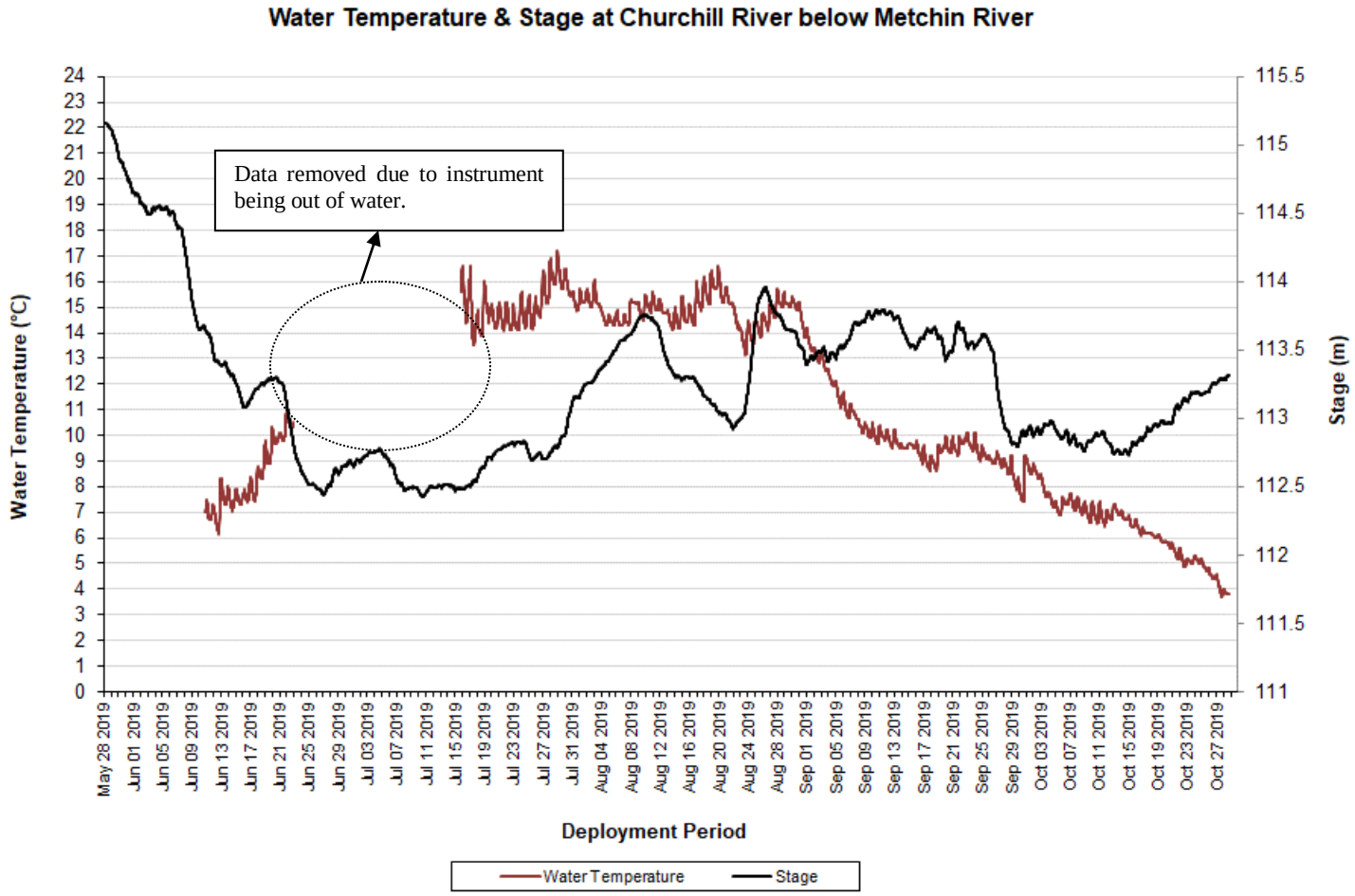

Figure 3: Water Temperature & Stage at Churchill River below Metchin River

Temperature (°C)	2019	2018	2017
Min	3.7	-0.3	2.9
Max	17.2	17.1	8.9
Median	10.1	6.3	5.4

- Water temperature values showed a typical seasonal trend and closely correlated with ambient air temperatures. Water and air temperatures both decreased from mid-August through the fall months (Figure 4). Air temperature data was obtained from the Metchin River near TLH climate station.

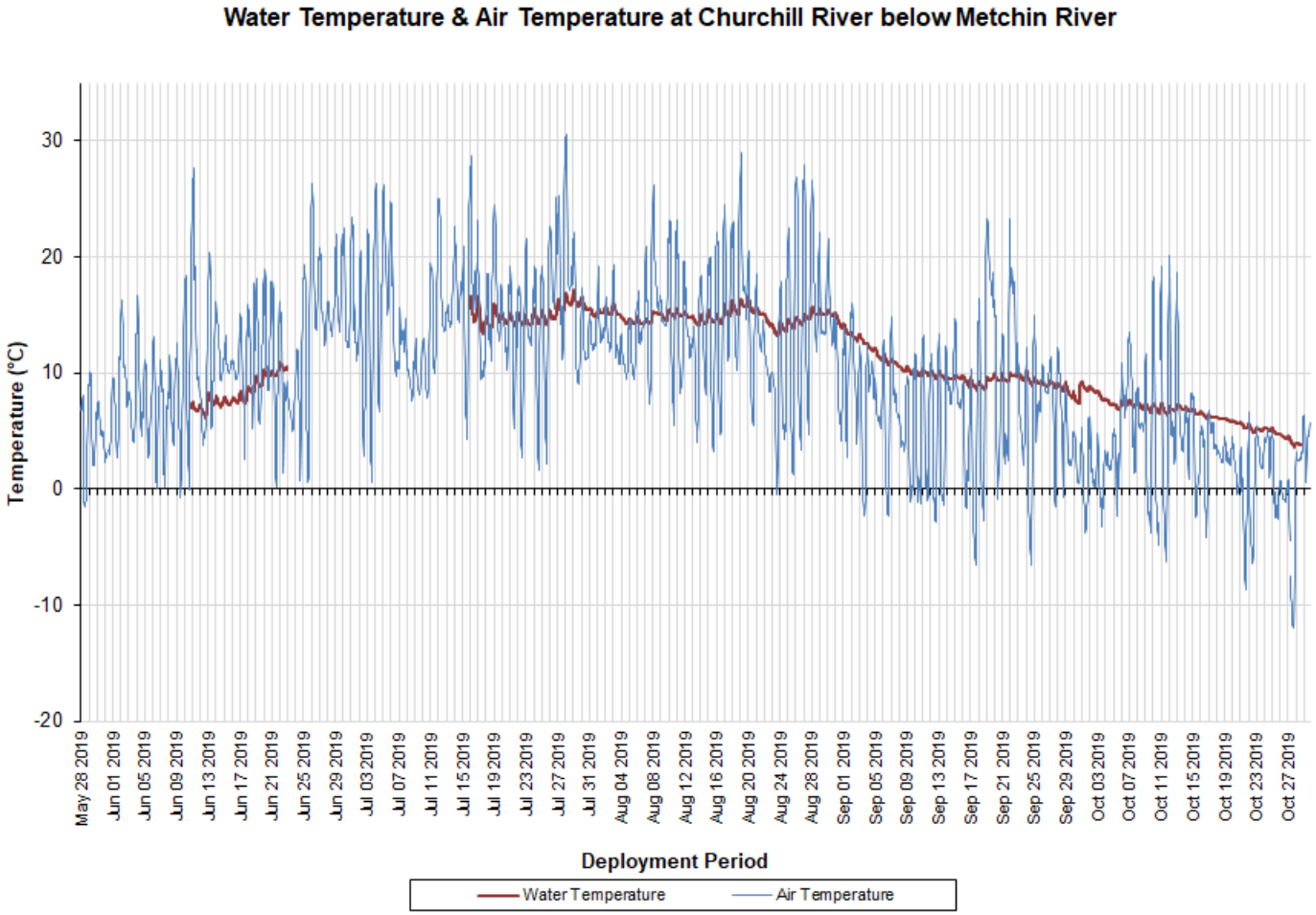

Figure 4: Water Temperature & Air Temperature at Churchill River below Metchin River

pH

- Over the 2019 deployment season, pH ranged from 5.79 to 7.23 pH units, with a median value of 6.98 pH units (Figure 5).
- pH values were relatively consistent over the deployment season, with clear diurnal fluctuation.
- pH values remained within the CCME's Guidelines for the Protection of Aquatic Life (>6.5 and <9.0 pH units) for the majority of the deployment season. The occasions when pH fell below the CCME's Minimum Guideline correlated closely with significant increases in stage.

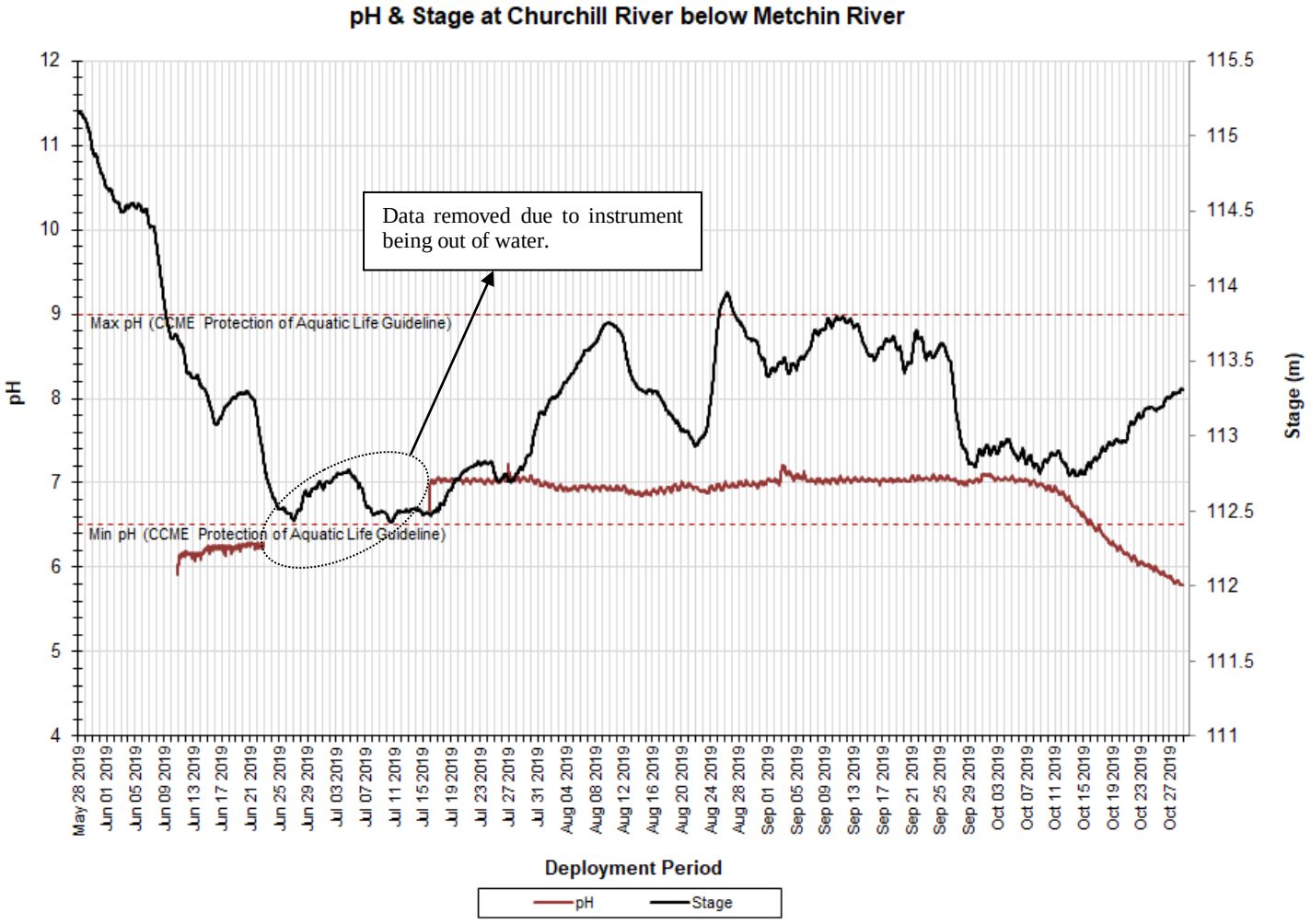

Figure 5: pH & Stage at Churchill River below Metchin River

pH (units)	2019	2018	2017
Min	5.79	6.43	6.58
Max	7.23	6.74	6.95
Median	6.98	6.60	6.75

Specific Conductivity

- Over the 2019 deployment season, specific conductivity ranged from 11.8µS/cm to 34.6µS/cm, with a median value of 18.7µS/cm (Figure 6), which was very similar to previous years.
- Specific conductivity increased at the beginning of the deployment season, after which it was fairly consistent for the remainder of deployment.
- 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.

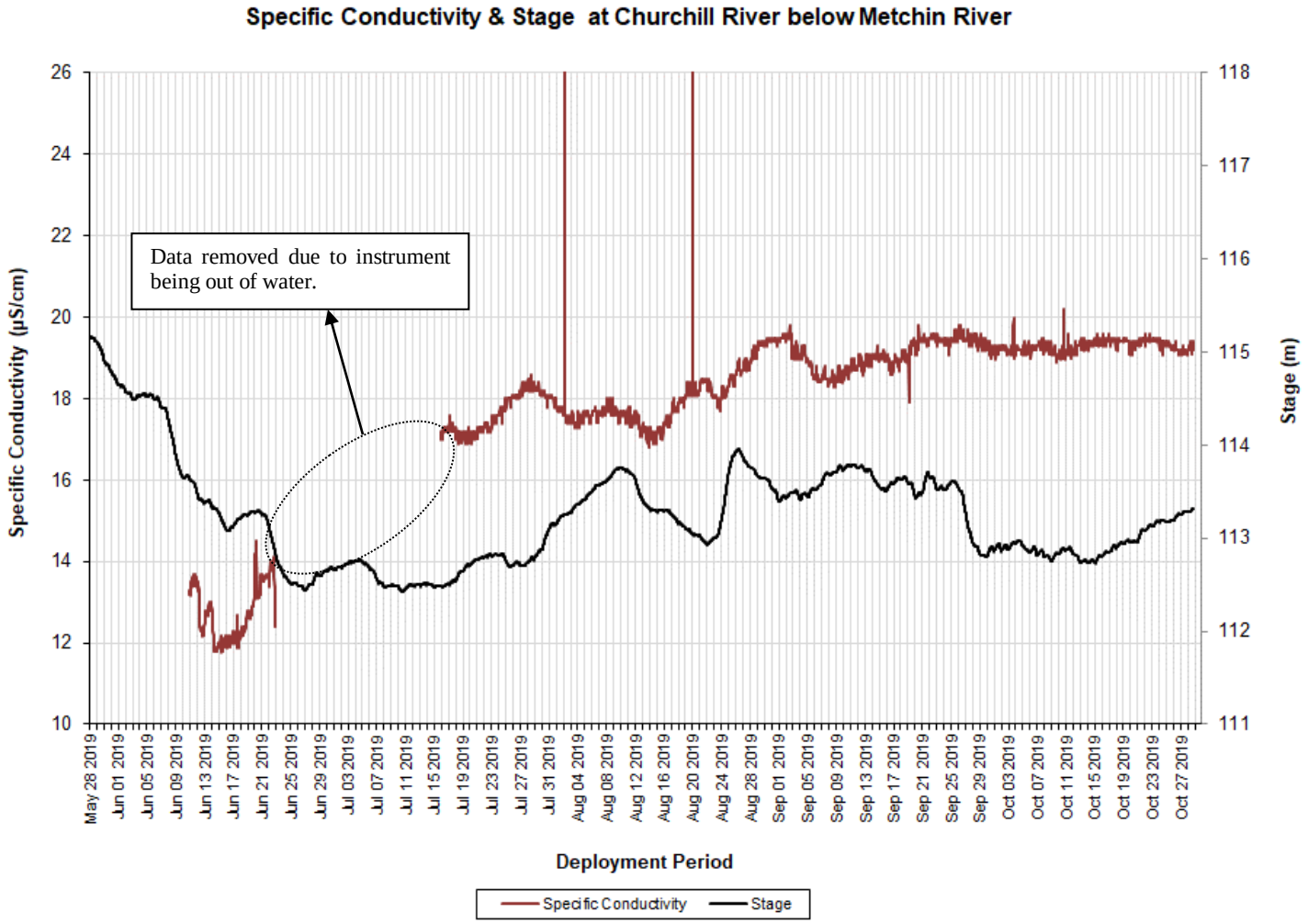

Figure 6: Specific Conductivity & Stage at Churchill River below Metchin River

Specific Conductivity (µS/cm)	2019	2018	2017
Min	11.8	10.6	18.7
Max	34.6	22.8	21.5
Median	18.7	20.3	19.9

Dissolved Oxygen

- Over the 2019 deployment season, dissolved oxygen ranged from 9.15mg/L to 23.11mg/L, with a median value of 10.25mg/L (Figure 7), which was slightly lower than previous years. Percent saturation ranged from 90.4% to 192.5%, with a median value of 94.3% (Figure 7), which was very similar to previous years.
- Dissolved oxygen content fluctuates regularly on a daily basis. Percent saturation is generally consistent throughout the deployment season. As water temperatures decreased into the fall, dissolved oxygen content steadily increased.
- Dissolved oxygen values were above the CCME's Guidelines for the Protection of Early and Other Life Stages (6.5mg/L and 9.5mg/L respectively) for the majority of deployment. The occasion where dissolved oxygen values fell below the CCME's Guideline for the Protection of Early Life Stages closely correlated with a period of higher water temperature. This is to be expected as dissolved oxygen levels are generally lower in warmer water bodies.

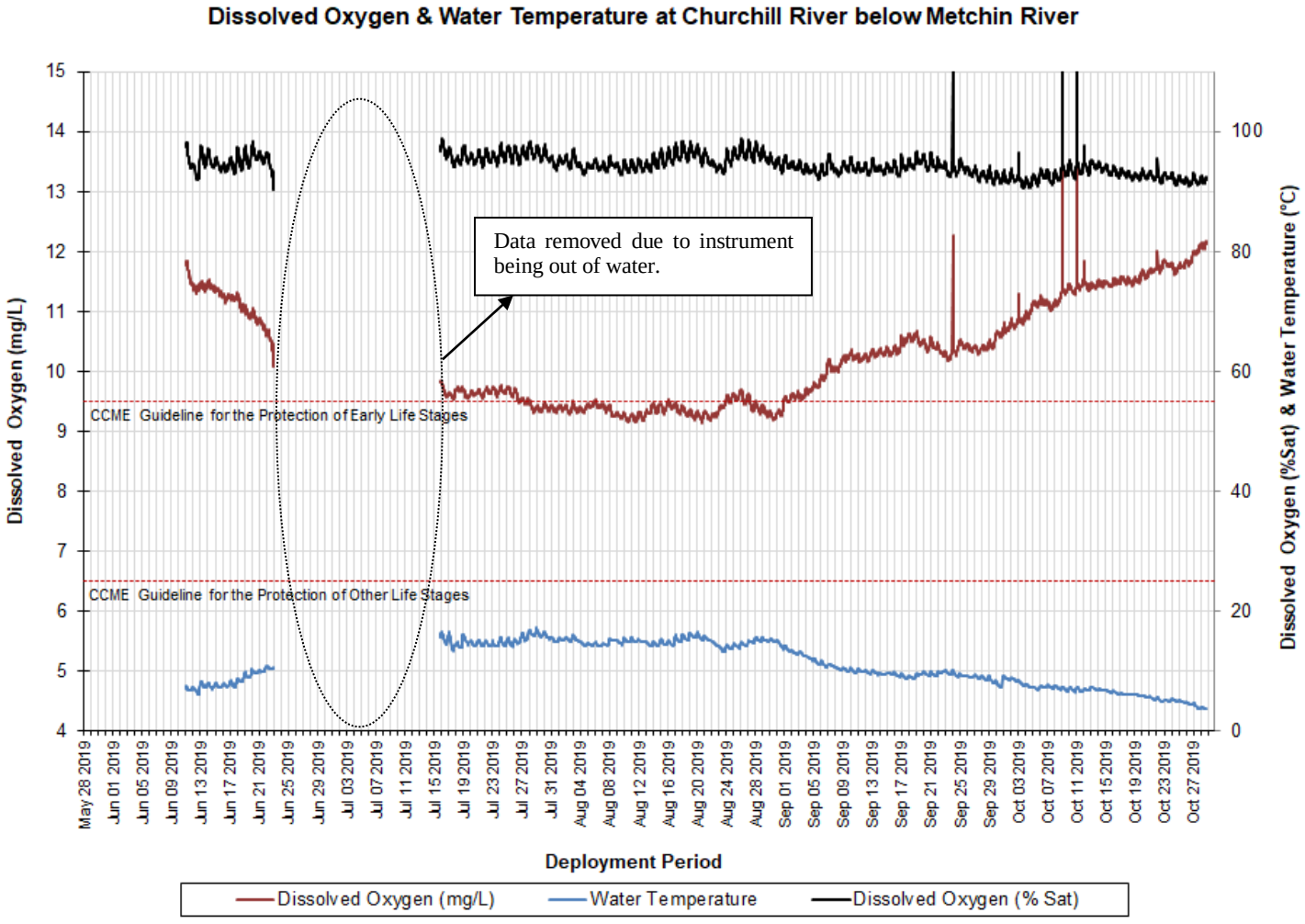

Figure 7: Dissolved Oxygen & Water Temperature at Churchill River below Metchin River

Dissolved Oxygen (mg/L)	2019	2018	2017		Dissolved Oxygen (%Sat)	2019	2018	2017
Min	9.15	9.18	10.67		**Min**	90.4	91.1	90.8
Max	23.11	14.43	12.48		**Max**	192.5	98.0	95.5
Median	10.25	11.56	11.87		**Median**	94.3	94.5	92.4

Turbidity & Precipitation

- Over the 2019 deployment season, turbidity ranged from 0 NTU to 116.2 NTU, with a median value of 0 NTU (Figure 8). A median value of 0 NTU indicates that there is very little natural background turbidity at this station.
- Turbidity is graphed below against stage and precipitation. Precipitation events often correlate closely with temporary increases in both stage and turbidity levels, which can be observed in the graph below. It is important to note, however, that this station is located on a very wide and deep section of the Churchill River and so turbidity is less influenced by precipitation events when compared to other stations. Precipitation data was obtained from the Metchin River at TLH climate station.

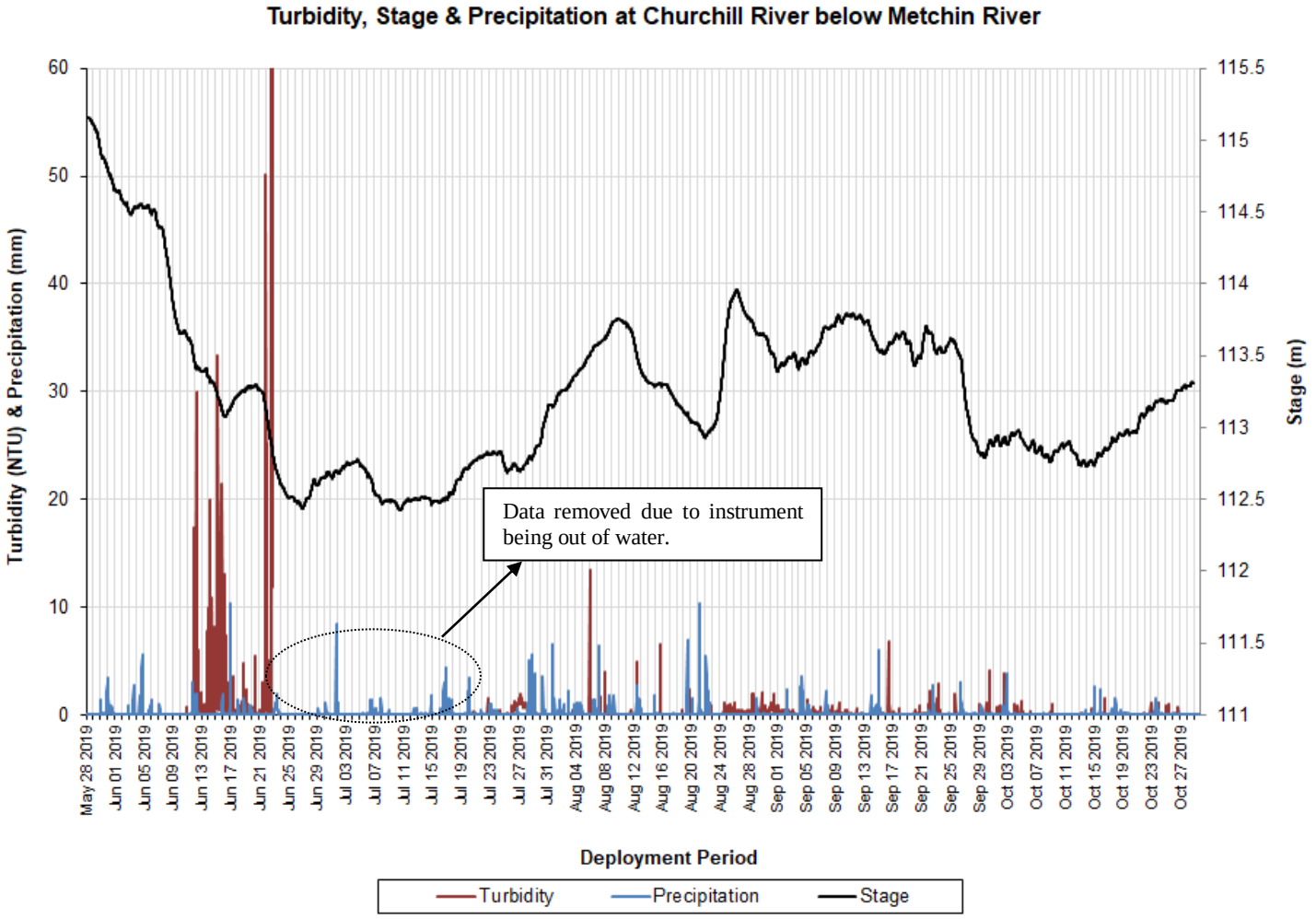

Figure 8: Turbidity, Stage & Precipitation at Churchill River below Metchin River

Turbidity (NTU)	2019	2018	2017
Min	0	0	0
Max	116.2	17.5	59.2
Median	0	0	0

Stage & Flow

- Over the 2019 deployment season, stage ranged from 112.425m to 115.161m, with a median value of 113.190m (Figure 9). Stage remained relatively stable throughout the deployment season and was very similar to previous years. Flow ranged from 1028.733m^3/s to 1791.508m^3/s, with a median value of 1296.666m^3/s, which was very similar to the 2018 median.
- Comparison data is unavailable for flow for the 2017 deployment season.
- Water Survey of Canada (ECCC) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

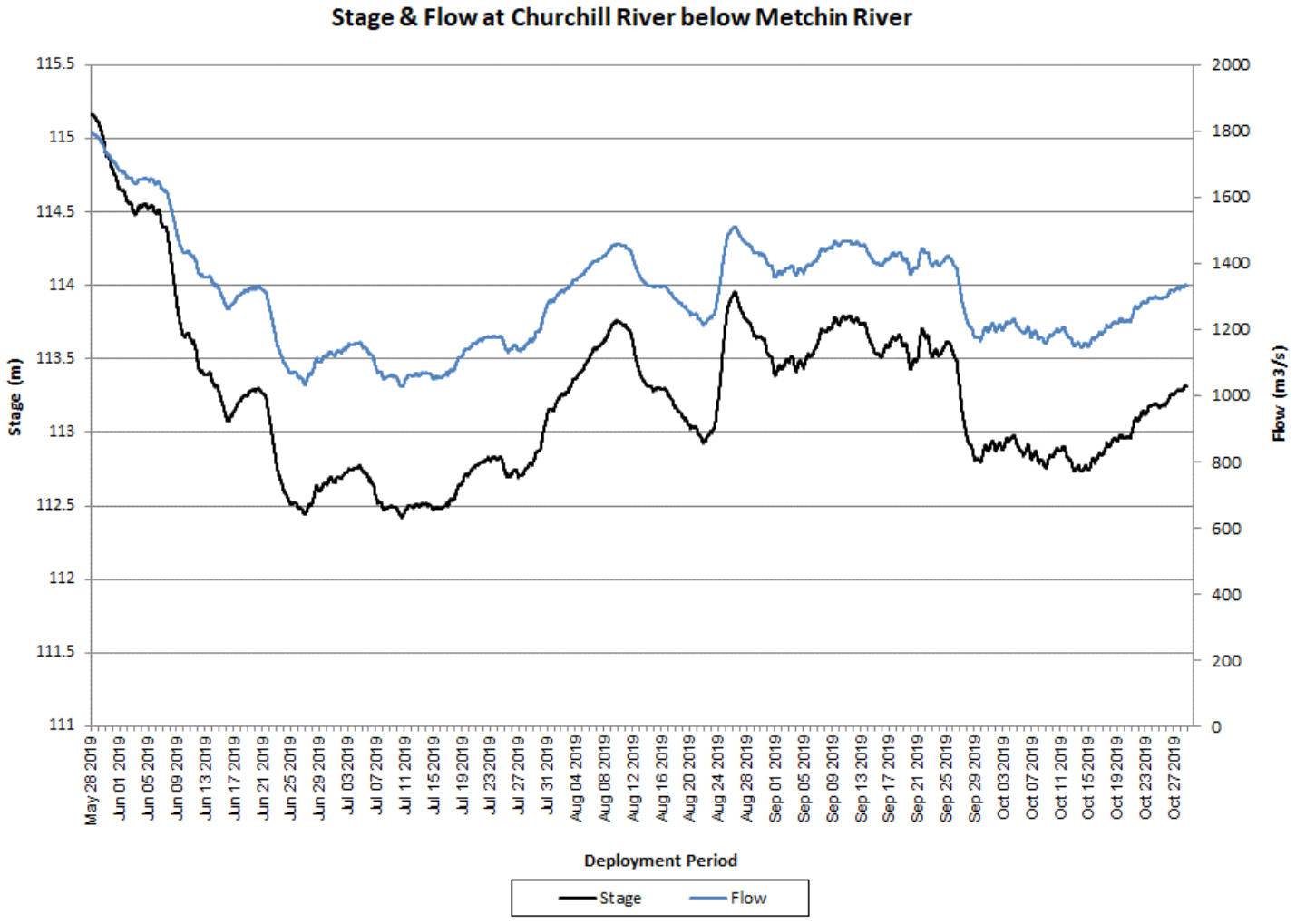

Figure 9: Stage & Flow at Churchill River below Metchin River

Stage (m)	2019	2018	2017		Flow (m^3/s)	2019	2018	2017
Min	112.425	112.242	112.121		**Min**	1028.733	926.532	-
Max	115.161	117.662	113.228		**Max**	1791.508	1695.073	-
Median	113.190	113.099	112.623		**Median**	1296.666	1268.779	-

Churchill River above Grizzle Rapids

Temperature

- Over the 2019 deployment season, water temperature ranged from 5.4°C to 18.2°C, with a median value of 13.45°C (Figure 10).
- Water temperatures peaked in late July and again in late August, after which they steadily declined through September and October.

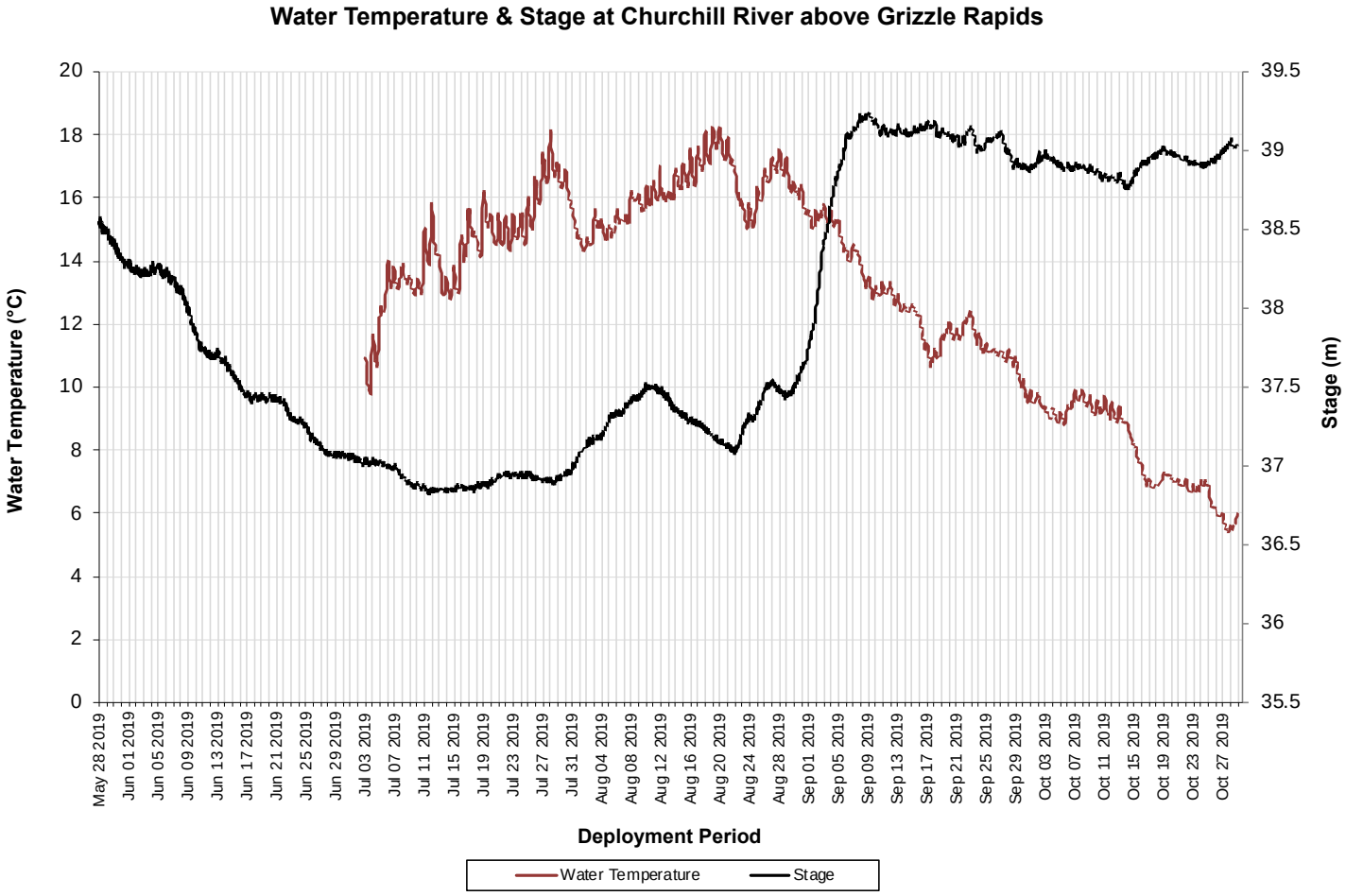

Figure 10: Water Temperature & Stage at Churchill River above Grizzle Rapids

Temperature (°C)	2019	2018	2017
Min	5.4	-0.2	5.58
Max	18.2	19.6	17.57
Median	13.45	12.8	13.98

- Water and air temperatures both showed typical seasonal trends (Figure 11), where temperatures steadily increased until late August, after which they gradually declined again through late summer and fall. Air temperature data was obtained from the Metchin River near TLH climate station.

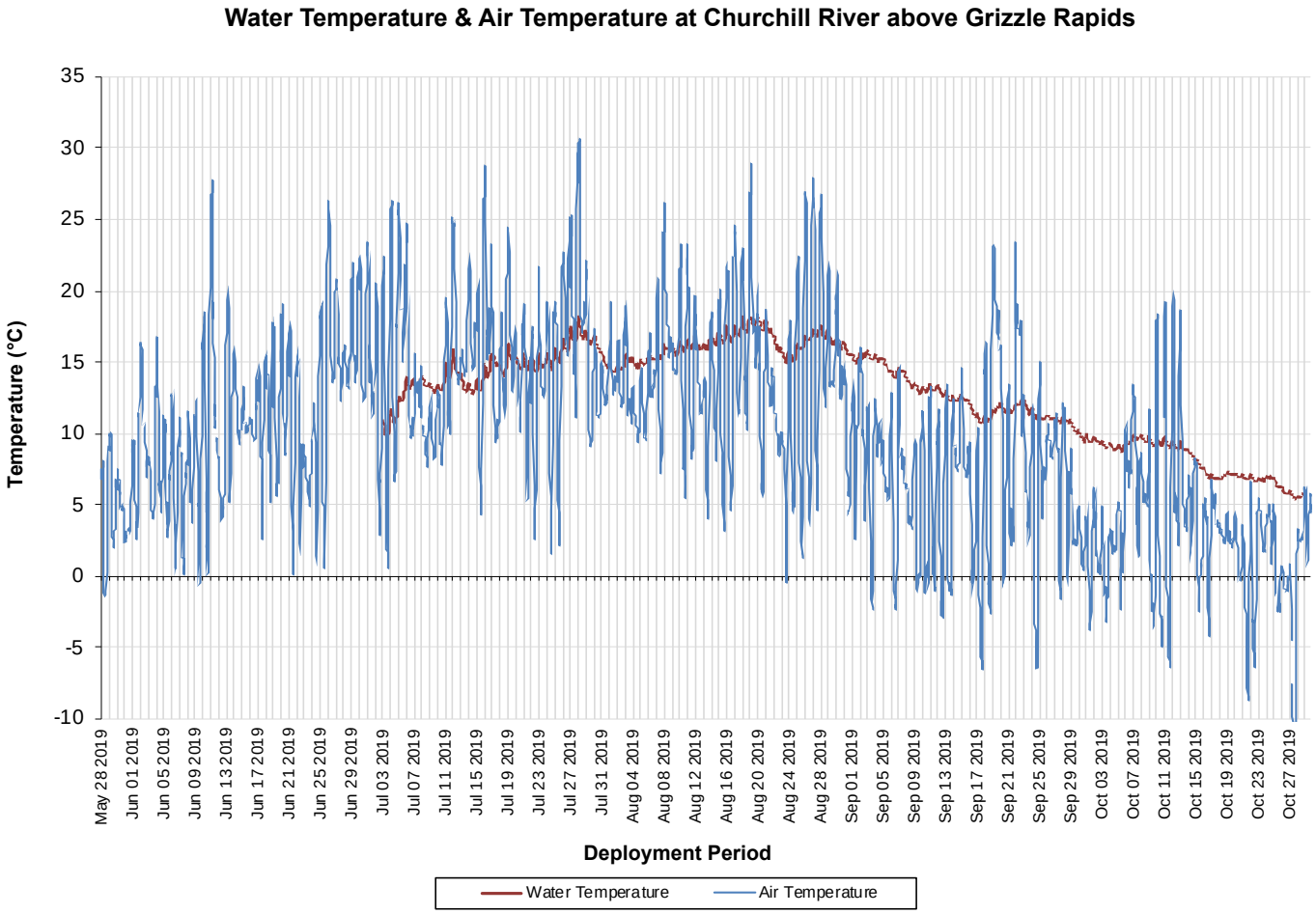

Figure 11: Water Temperature & Air Temperature at Churchill River above Grizzle Rapids

pH

- Over the 2019 deployment season, pH ranged from 6.54 to 7.17 pH units, with a median value of 6.81 pH units (Figure 12).
- pH values were relatively consistent across the deployment season, and remained within the CCME's Guidelines for the Protection of Aquatic Life (>6.5 and <9.0 pH units) for the duration of the deployment season.

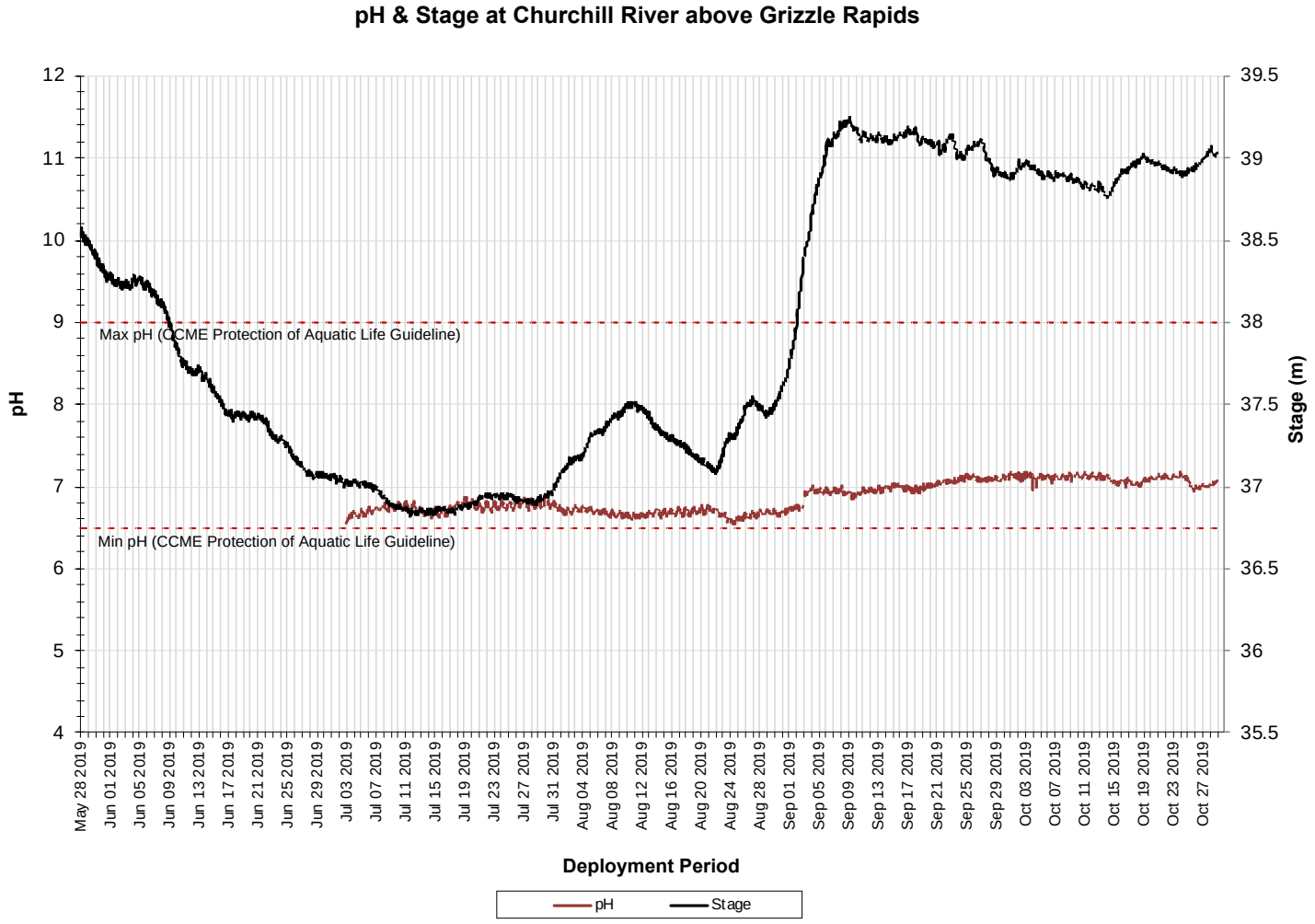

Figure 12: pH & Stage at Churchill River above Grizzle Rapids

pH (units)	2019	2018	2017
Min	6.54	6.47	6.45
Max	7.17	7.00	7.16
Median	6.81	6.78	6.91

Specific Conductivity

- Over the 2019 deployment season, specific conductivity ranged from 12.1µS/cm to 18.2µS/cm, with a median value of 15.5µS/cm (Figure 13), which was similar to, but slightly lower than, the median values from previous years.
- Specific conductivity was relatively consistent across the deployment season, with increases and decreases in specific conductivity generally correlating with 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.

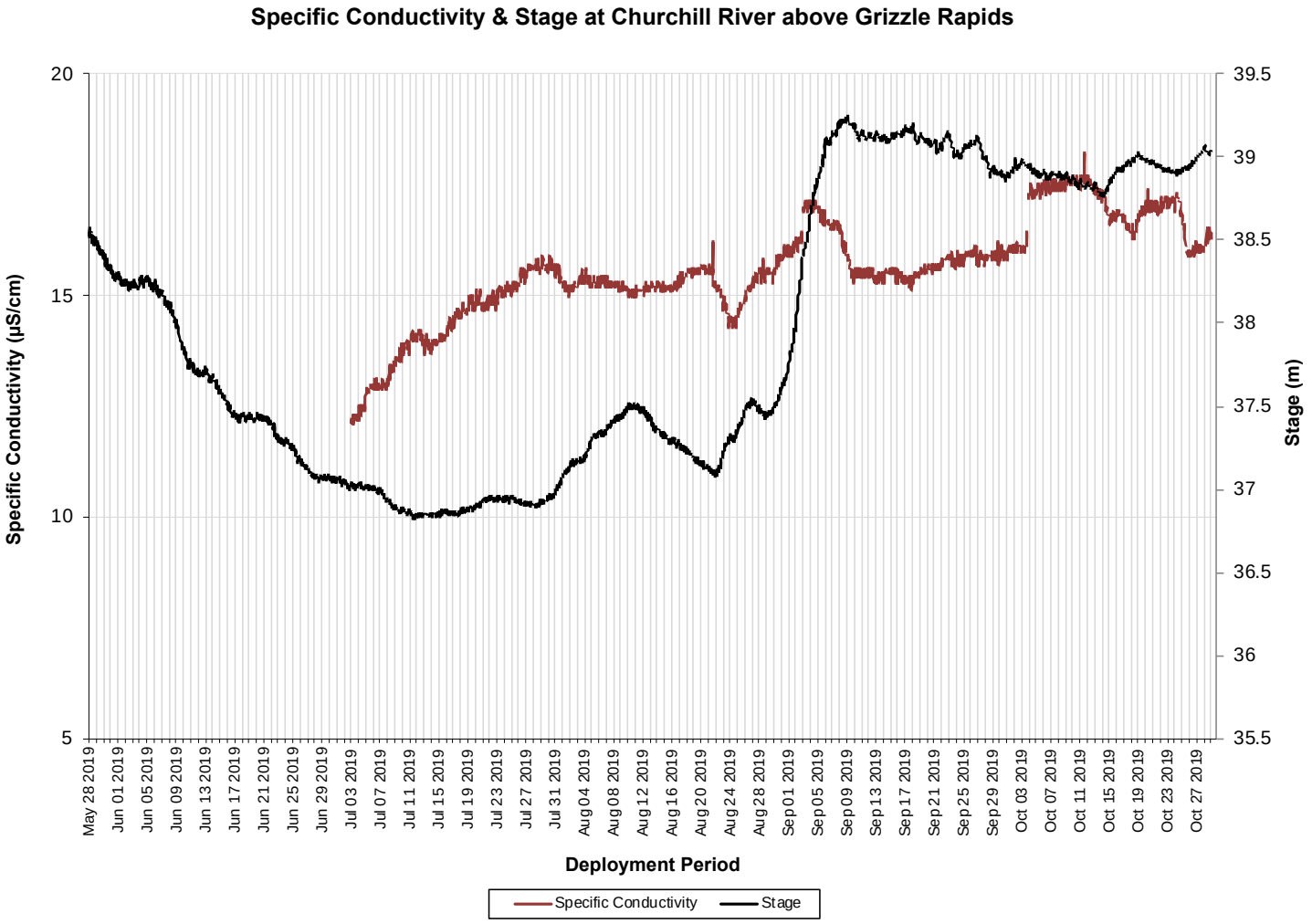

Figure 13: Specific Conductivity & Stage at Churchill River above Grizzle Rapids

Specific Conductivity (µS/cm)	2019	2018	2017
Min	12.1	15.6	15
Max	18.2	20.3	19
Median	15.5	17.9	17

Dissolved Oxygen

- Over the 2019 deployment season, dissolved oxygen ranged from 8.92mg/L to 11.62mg/L, with a median value of 9.88mg/L. Percent saturation ranged from 90.6% to 100.2%, with a median value of 94.0% (Figure 14).
- Dissolved oxygen content displayed a typical seasonal trend, where levels were lowest during the summer months 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 across the deployment season.
- Dissolved oxygen values remained above the CCME's Guideline for the Protection of Early and Other Life Stages (6.5mg/L and 9.5mg/L respectively), with the exception of a period from late July to early September when water temperatures were at their warmest.

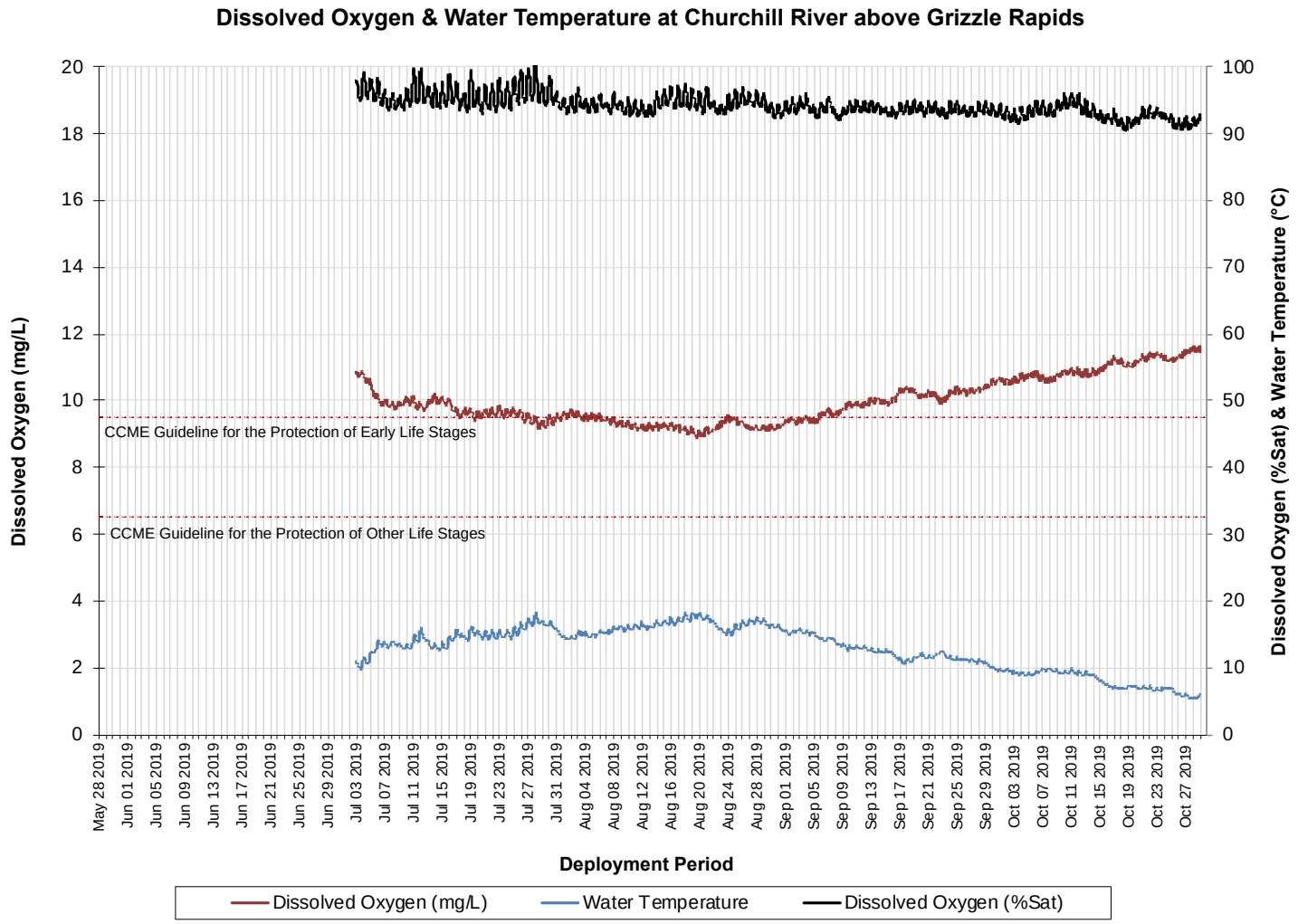

Figure 14: Dissolved Oxygen & Water Temperature at Churchill River above Grizzle Rapids

Dissolved Oxygen (mg/L)	2019	2018	2017		Dissolved Oxygen (% Sat)	2019	2018	2017
Min	8.92	8.82	9.27		**Min**	90.6	92.4	91.9
Max	11.62	14.06	11.81		**Max**	100.2	101.7	101.2
Median	9.88	10.34	9.94		**Median**	94.0	96.0	95.5

Turbidity & Precipitation

- Over the 2019 deployment season, turbidity ranged from 0 NTU to 12.3 NTU, with a median value of 0.1 NTU (Figure 15). A median value of 0.1 NTU indicates that there is very little natural background turbidity at this station.
- Turbidity spikes generally correlate with increases in stage, which often correlate with precipitation events. Turbidity levels returned to background levels following each observed increase.

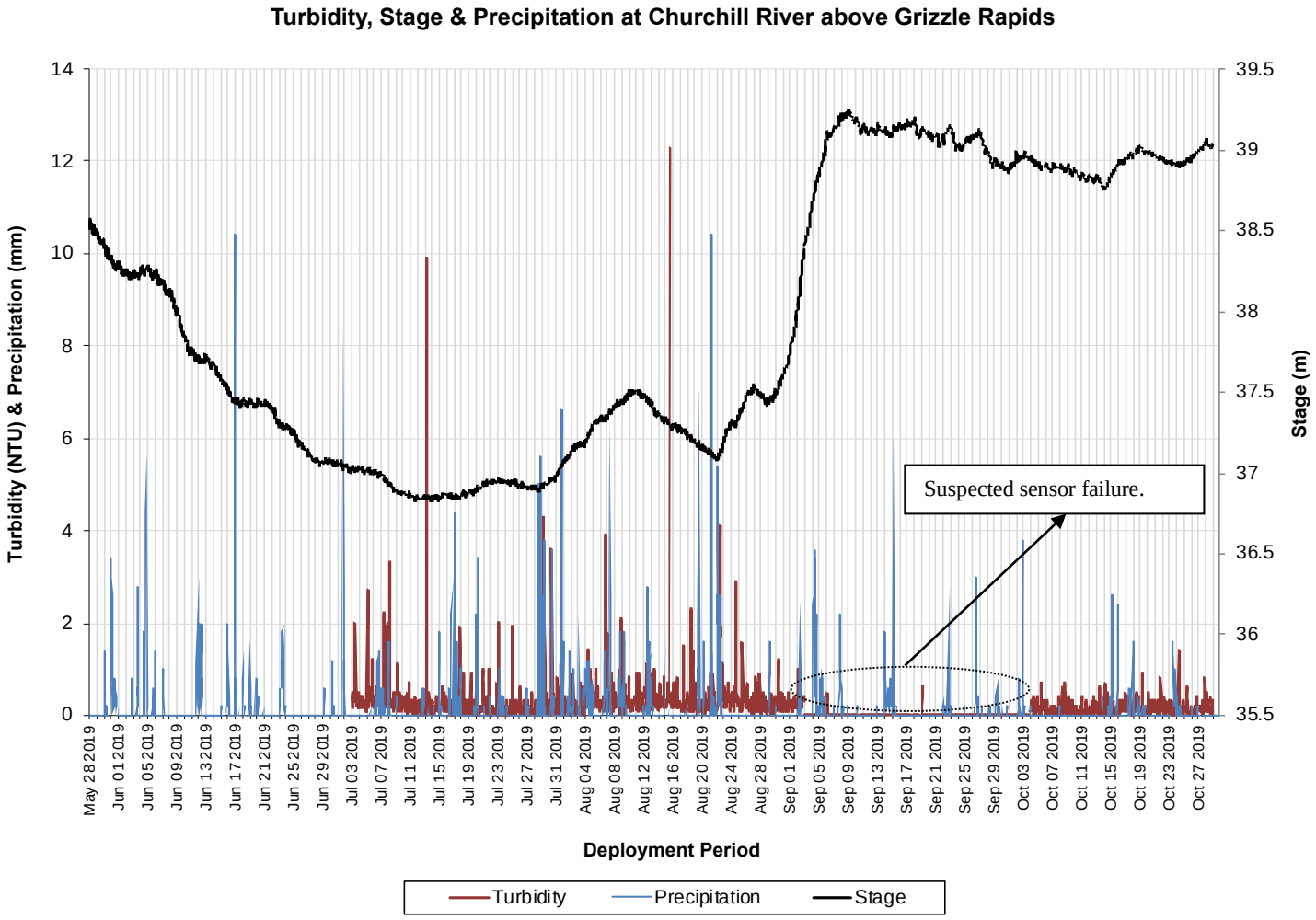

Figure 15: Turbidity, Stage & Precipitation at Churchill River above Grizzle Rapids

Turbidity (NTU)	2019	2018	2017
Min	0	0	0
Max	12.3	36.7	19.3
Median	0.1	0	0

Stage & Flow

- Over the 2019 deployment season, stage ranged from 36.827m to 39.242m, with a median value of 37.585m. Flow ranged from 1247.808m^3/s to 4944.752m^3/s, with a median value of 1852.589m^3/s (Figure 16).
- Comparison data for 2017 is not available for this station for flow. Additionally, as of September 5, this station will no longer record flow.
- Water Survey of Canada (ECCC) is responsible for QA/QC of water quantity data (stage and flow). Corrected data can be obtained upon request.

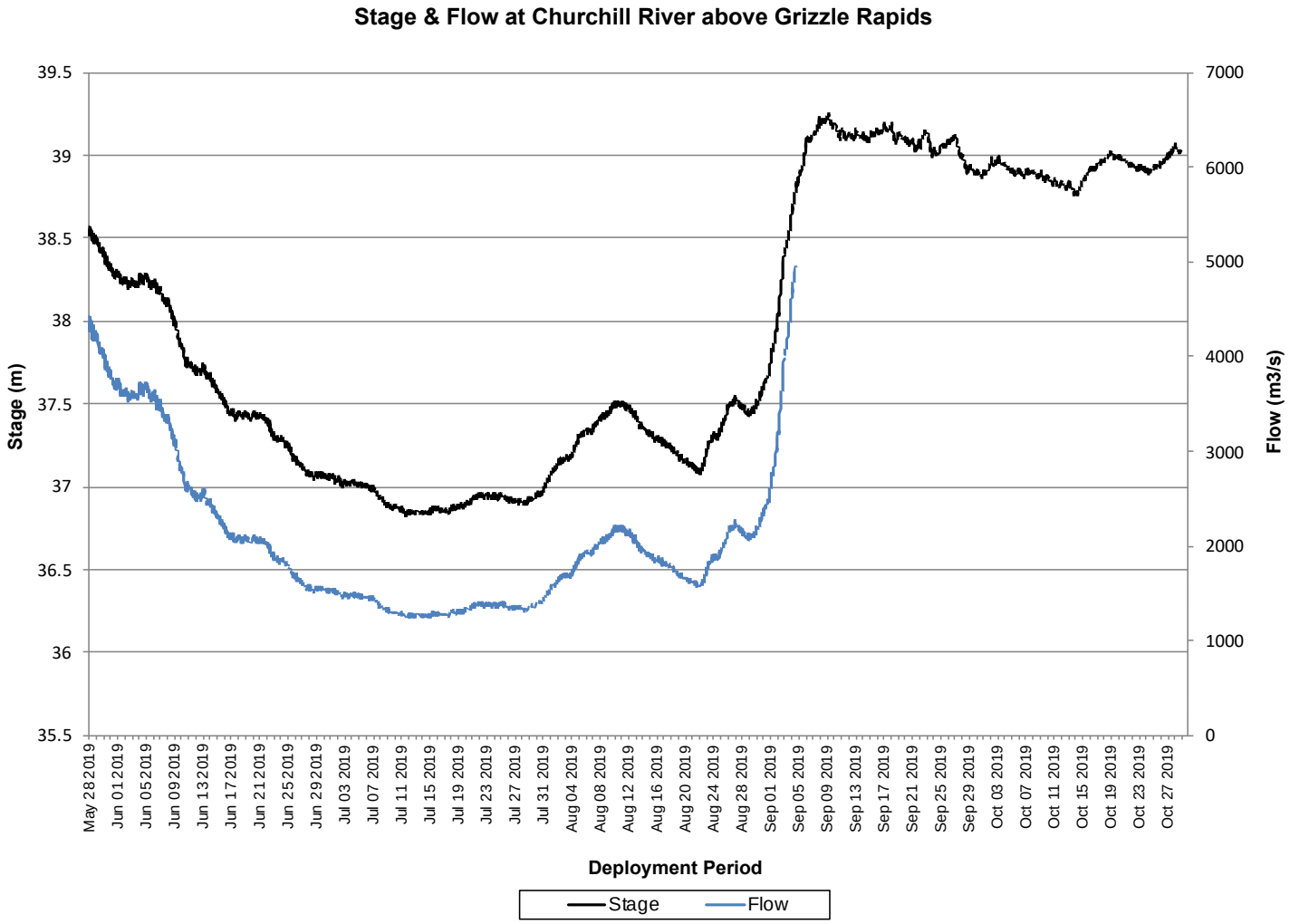

Figure 16: Stage & Flow at Churchill River above Grizzle Rapids

Stage (m)	2019	2018	2017		Flow (m^3/s)	2019	2018	2017
Min	36.827	36.683	36.661		**Min**	1247.808	1082.175	-
Max	39.242	37.58	37.355		**Max**	4944.752	2314.122	-
Median	37.585	37.079	36.866		**Median**	1852.589	1557.811	-

Churchill River below Muskrat Falls

Temperature

- Over the 2019 deployment season, water temperature ranged from 1.6°C to 18.2°C, with a median value of 13.2°C (Figure 17), which was similar to median values from 2018 and 2017.
- Water temperatures followed typical season trends; temperatures increased steadily from May through to late August, after which they steadily declined again through September and October.

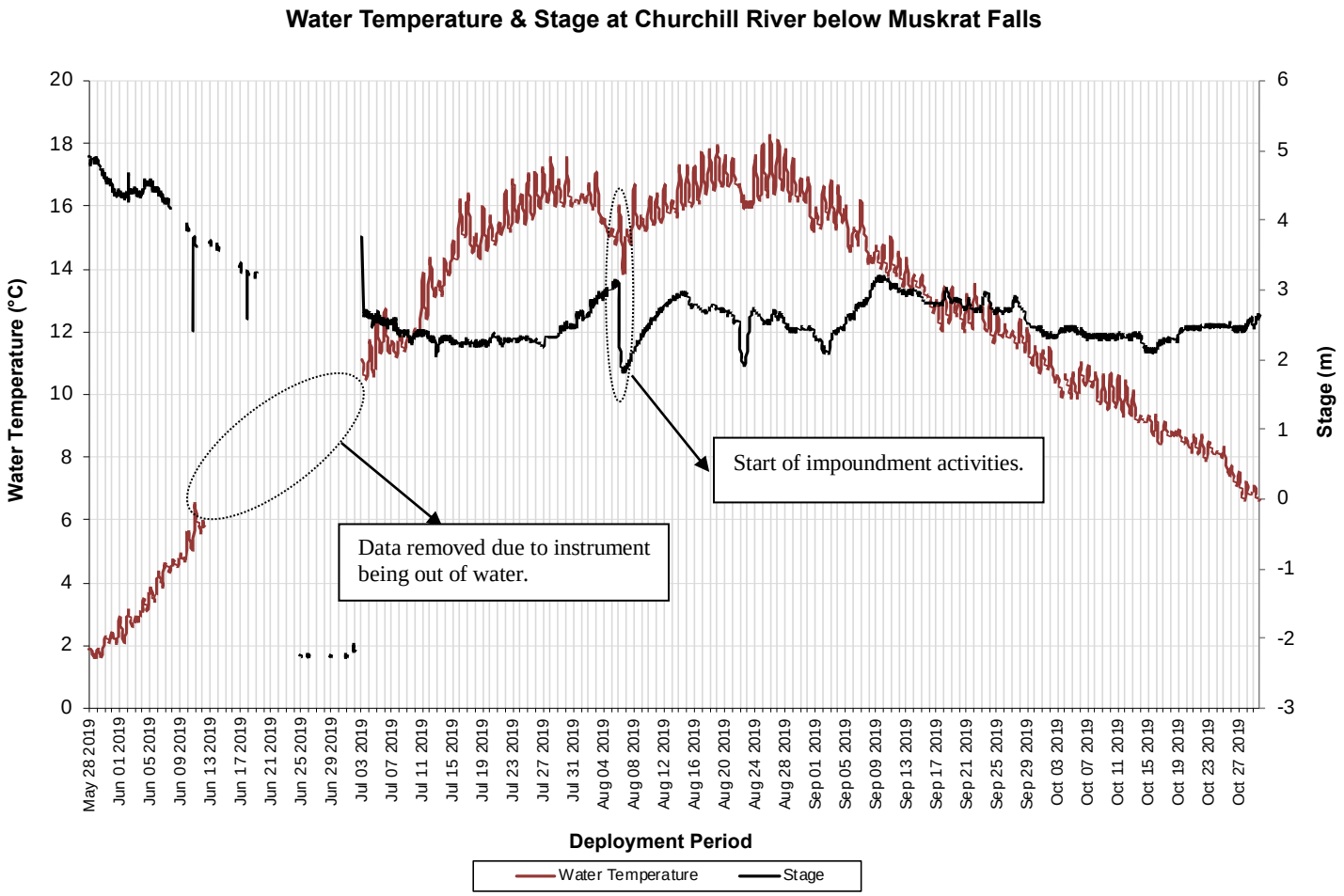

Figure 17: Water Temperature & Stage at Churchill River below Muskrat Falls

Temperature (°C)	2019	2018	2017
Min	1.6	1.2	3.2
Max	18.2	20.2	18.2
Median	13.2	11.3	13.0

- Water temperature values correlated closely with air temperatures; both increased through the summer months and then gradually decreased again into the fall season. Air temperature data was obtained from the Metchin River near TLH climate station.

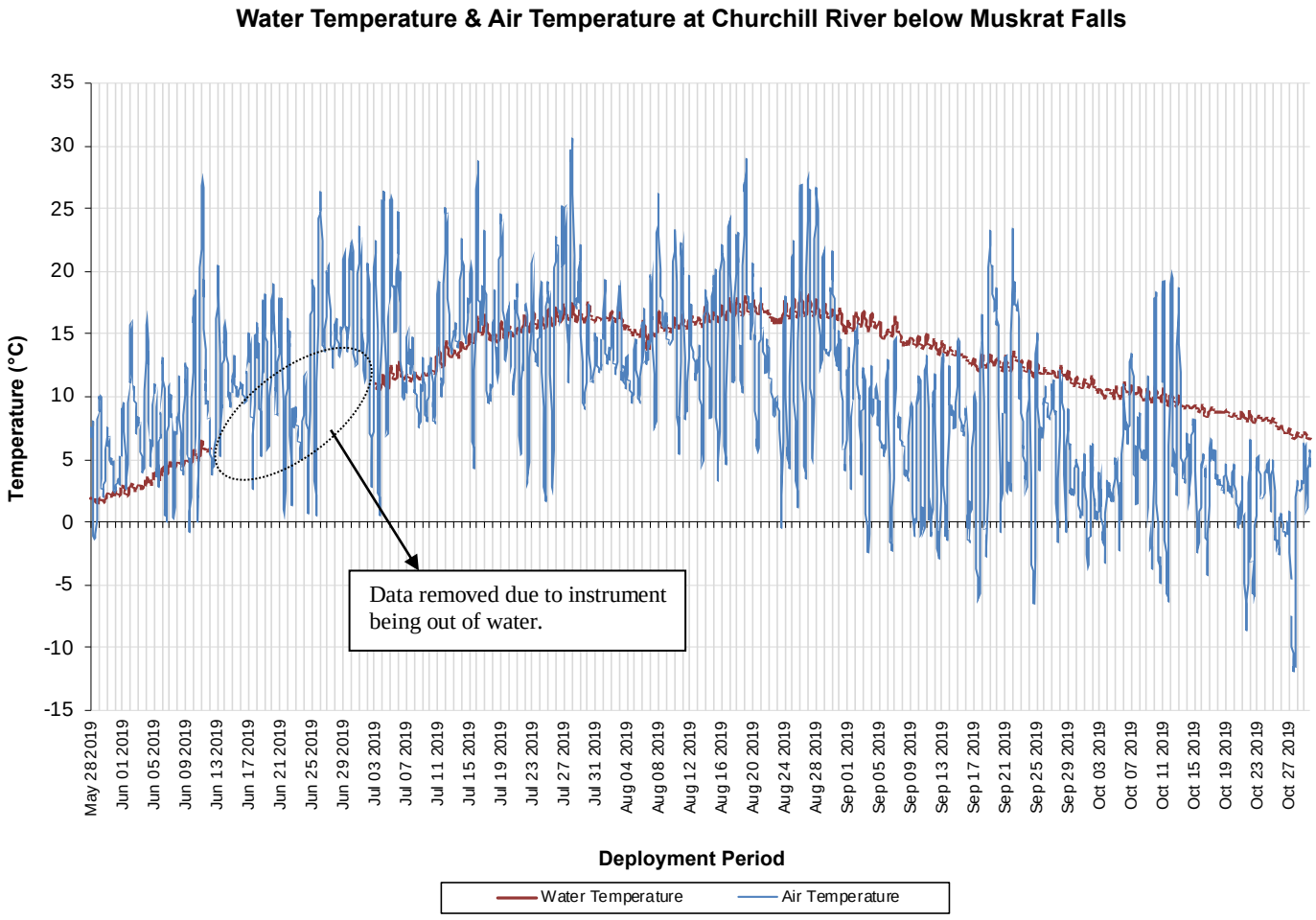

Figure 18: Water Temperature & Air Temperature at Churchill River below Muskrat Falls

pH

- Over the 2019 deployment season, pH ranged from 5.91 to 7.19 pH units, with a median value of 6.32 pH units (Figure 19), which was similar to the 2018 and 2017 median values.
- pH values were below the CCME's Guidelines for the Protection of Aquatic Life for the first three months of the deployment season (>6.5 and <9.0 pH units). pH values were within the CCME's Guidelines from September 5th onwards.

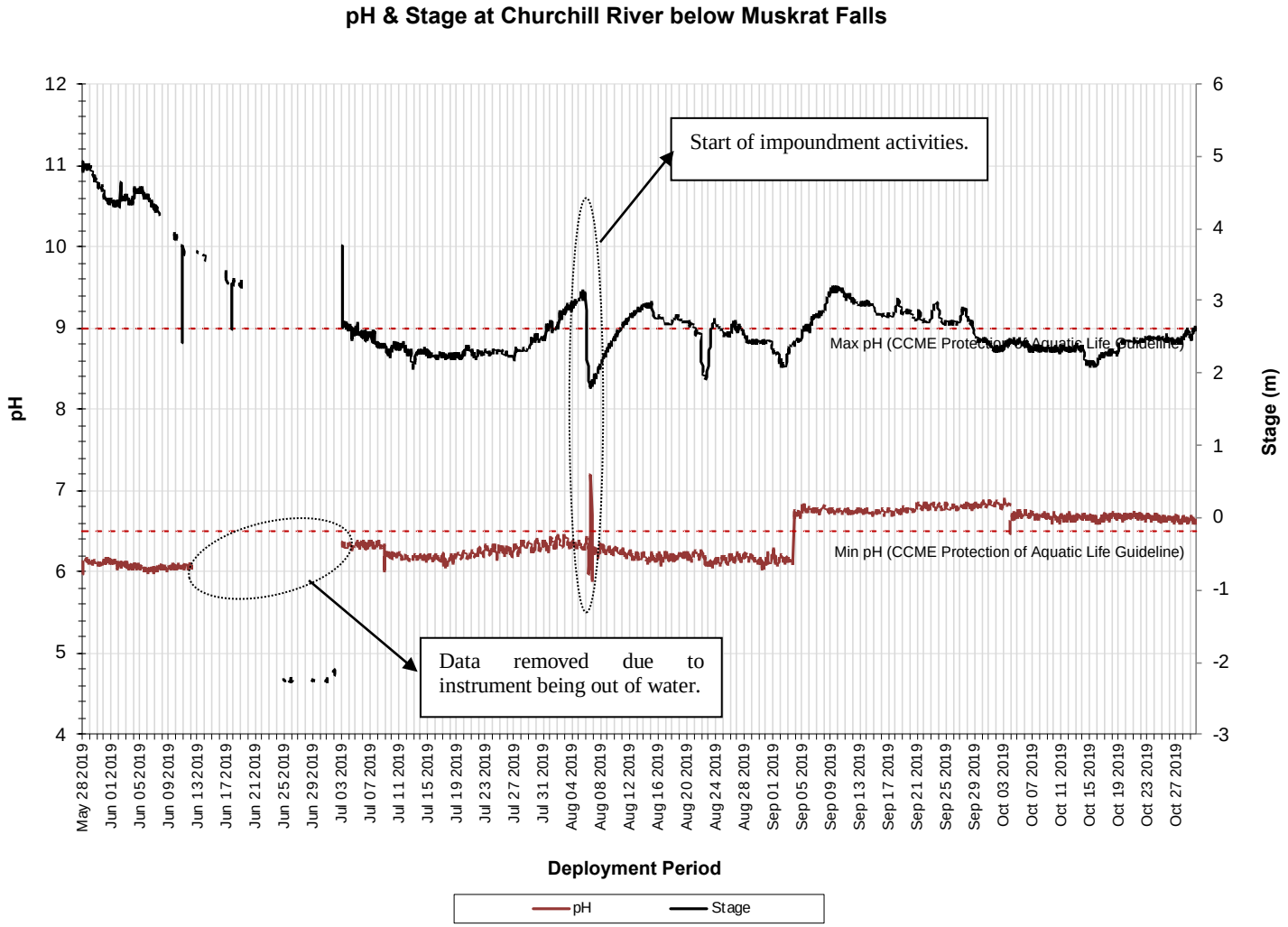

Figure 19: pH & Stage at Churchill River below Muskrat Falls

pH (units)	2019	2018	2017
Min	5.91	5.51	6.01
Max	7.19	7.81	7.19
Median	6.32	6.17	6.67

Specific Conductivity

- Over the 2019 deployment season, specific conductivity ranged from 0µS/cm to 18.9µS/cm, with a median value of 16.4µS/cm (Figure 20), which was comparable to the 2018 and 2017 medians.
- 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 dilution of dissolved solids in the water column. The occurrence of specific conductivity dipping to 0µS/cm on August 7th was likely due to the instrument being briefly out of water.

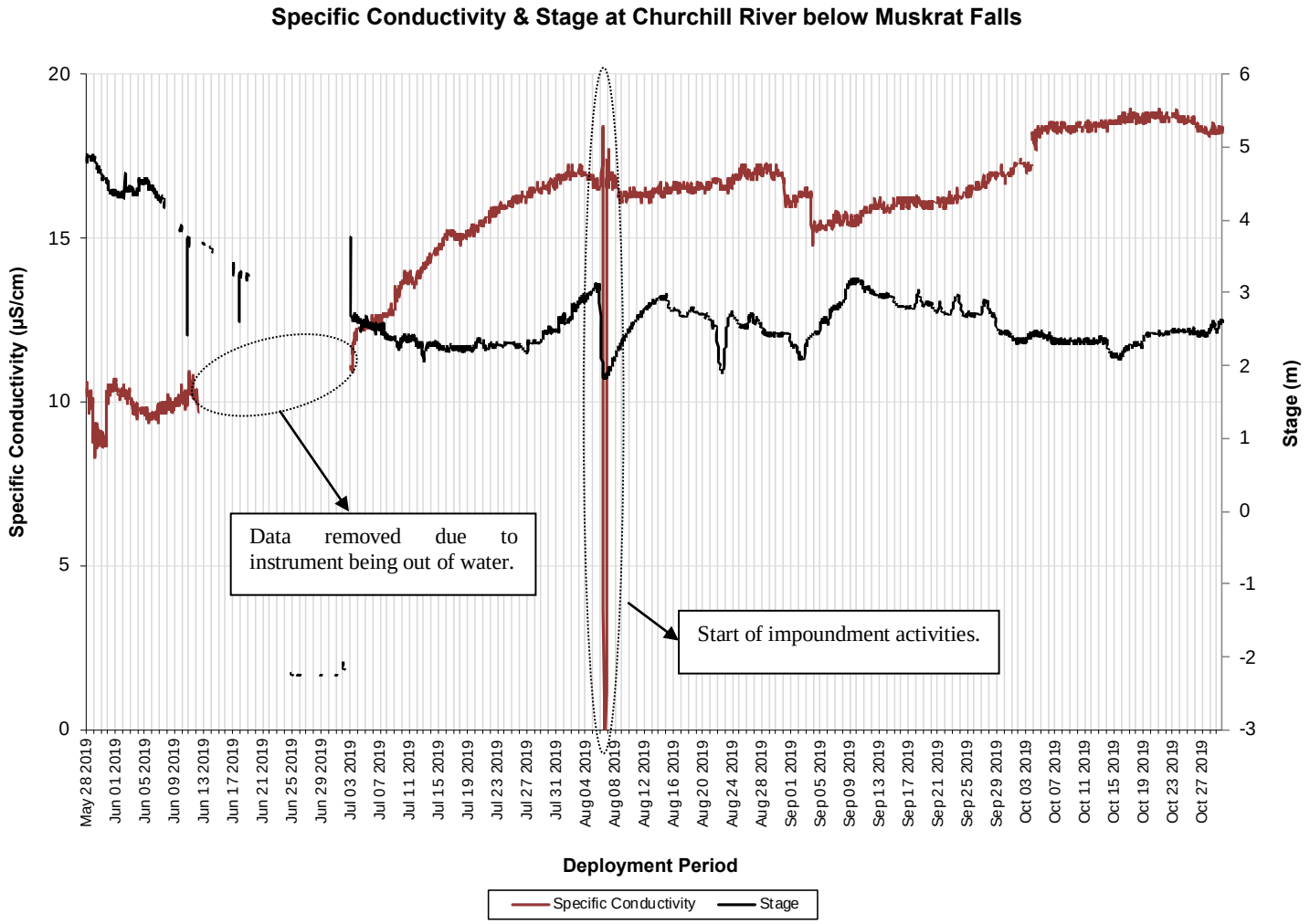

Figure 20: Specific Conductivity & Stage at Churchill River below Muskrat Falls

Specific Conductivity (µS/cm)	2019	2018	2017
Min	0	8.8	11.0
Max	18.9	19.7	20.0
Median	16.4	17.4	18.1

Dissolved Oxygen

- Over the 2019 deployment season, dissolved oxygen ranged from 10.06mg/L to 16.82mg/L, with a median value of 12.13mg/L, which was similar to the 2018 median. Percent saturation ranged from 99.1% to 126.5%, with a median value of 114.6%, which was similar to the 2018 median (Figure 21).
- Dissolved oxygen displayed a typical seasonal trend throughout 2019, with the lowest values observed throughout August. Warmer temperatures decrease the amount of oxygen present in water, and vice versa. Percent saturation remained fairly consistent throughout the deployment season.
- Dissolved oxygen levels remained above the CCME's Guidelines for the Protection of Early and Other Life Stages for the duration of the 2019 deployment season (Figure 21).

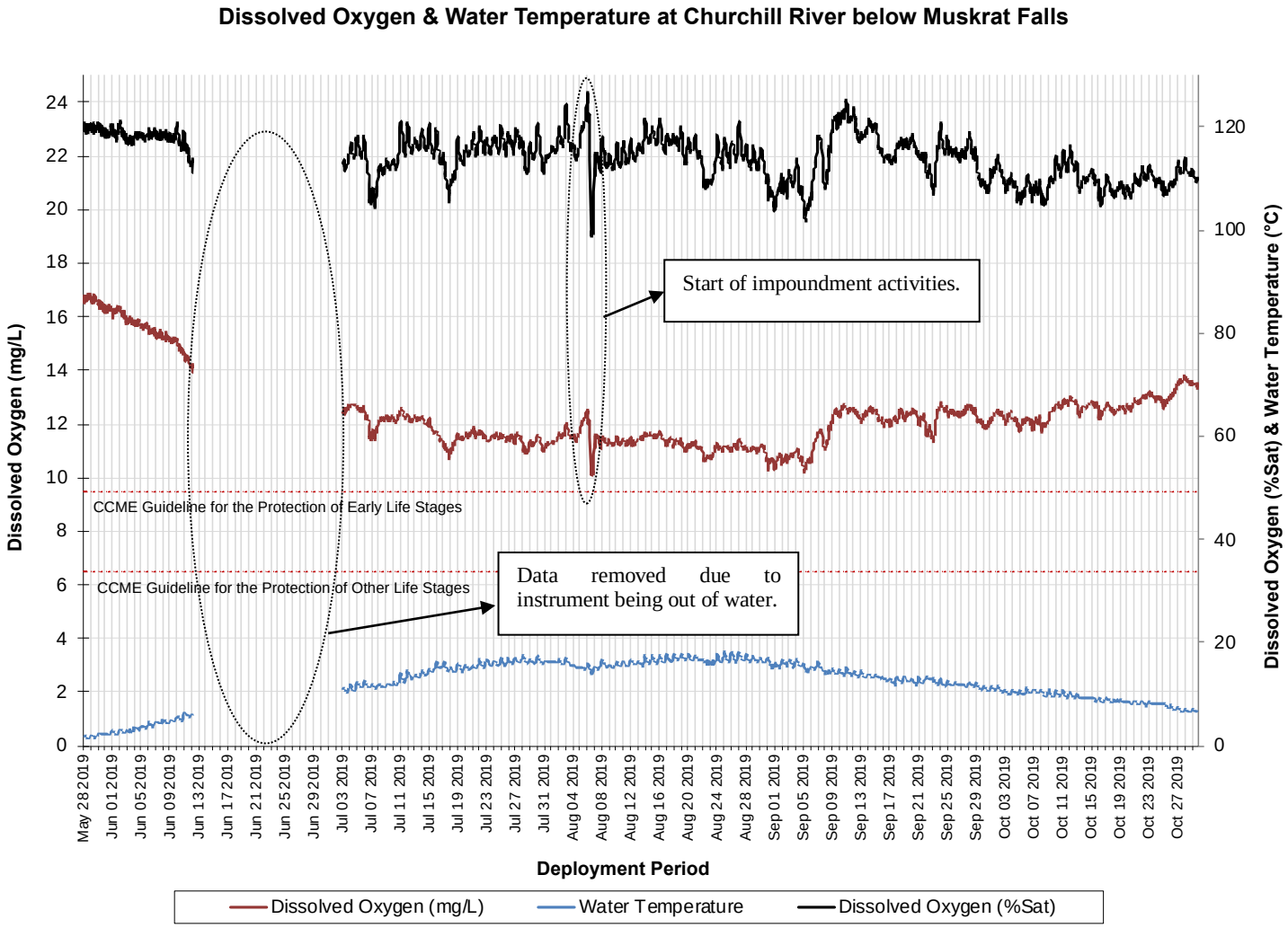

Figure 21: Dissolved Oxygen & Water Temperature at Churchill River below Muskrat Falls

Dissolved Oxygen (mg/L)	2019	2018	2017		Dissolved Oxygen (% Sat)	2019	2018	2017
Min	10.06	9.74	9.54		**Min**	99.1	99.0	96.3
Max	16.82	17.58	14.82		**Max**	126.5	128.1	114.2
Median	12.13	12.23	11.40		**Median**	114.6	113.5	106.4

Turbidity & Precipitation

- Over the 2019 deployment season, turbidity ranged from 0 NTU to 2756 NTU, with a median value of 8.5 NTU. (Figure 22). A median value of 8.5 NTU indicates that there is quite a bit of natural background turbidity at this station, and is higher than the 2018 and 2017 medians.
- Turbidity events throughout the 2019 deployment season correlated somewhat with increases in stage, which were further linked to precipitation events. Sustained high turbidity levels from August 7th through September 4th may have been caused by sediment build-up around the instrument sensors.

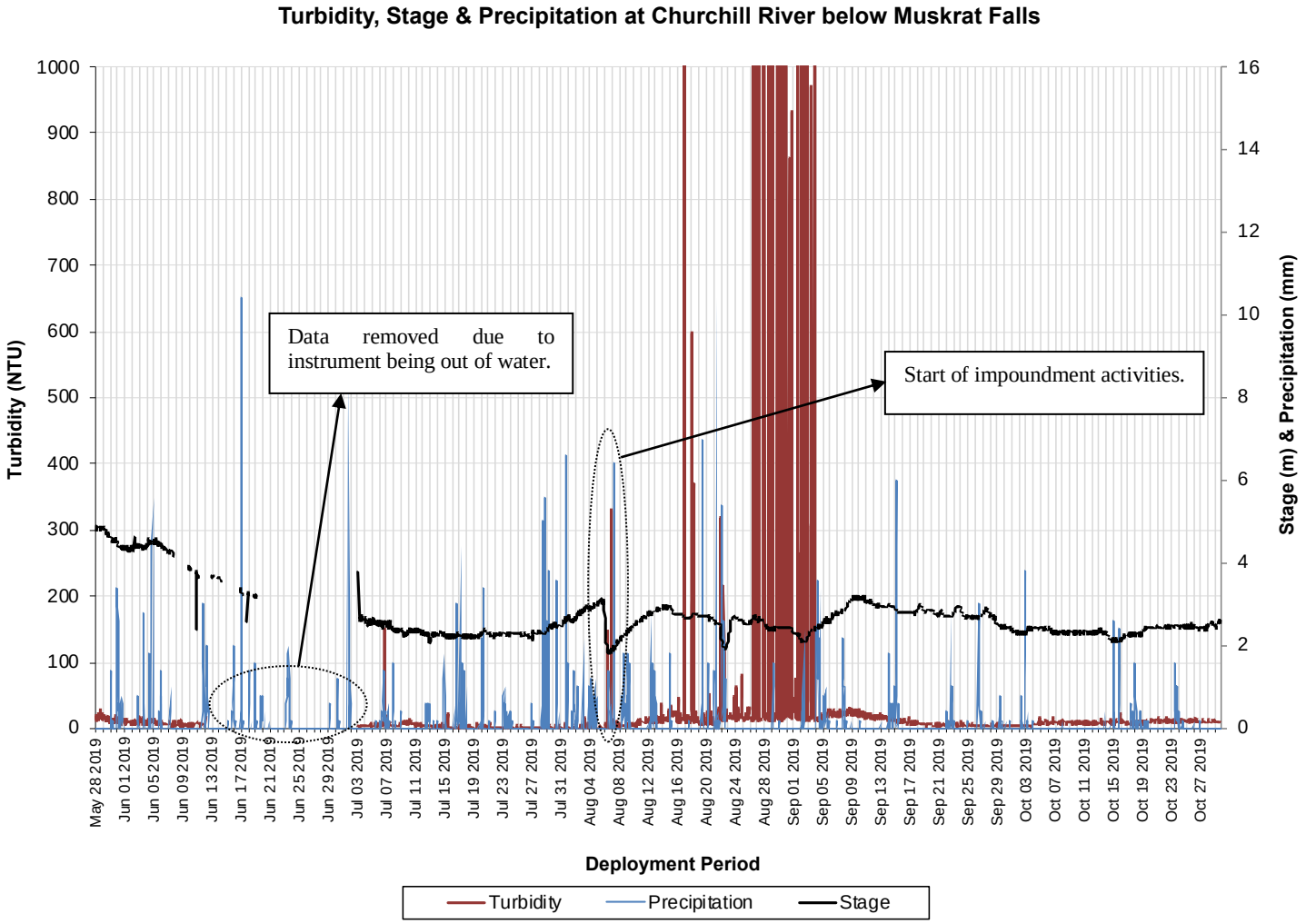

Figure 22: Turbidity, Stage & Precipitation at Churchill River below Muskrat Falls

Turbidity (NTU)	2019	2018	2017
Min	0	0	0
Max	2756	185.2	105.5
Median	8.5	0.3	1.5

Stage

- Over the 2019 deployment season, stage ranged from -2.26m to 4.918m, with a median value of 2.486m (Figure 23), which was comparable to the previous two seasons.
- Stage increases were somewhat associated with precipitation events throughout the 2019 season (Figure 23). Stage was also influenced by impoundment activities occurring at the Muskrat Falls hydroelectric project from early August through early September.
- Water Survey of Canada (ECCC) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

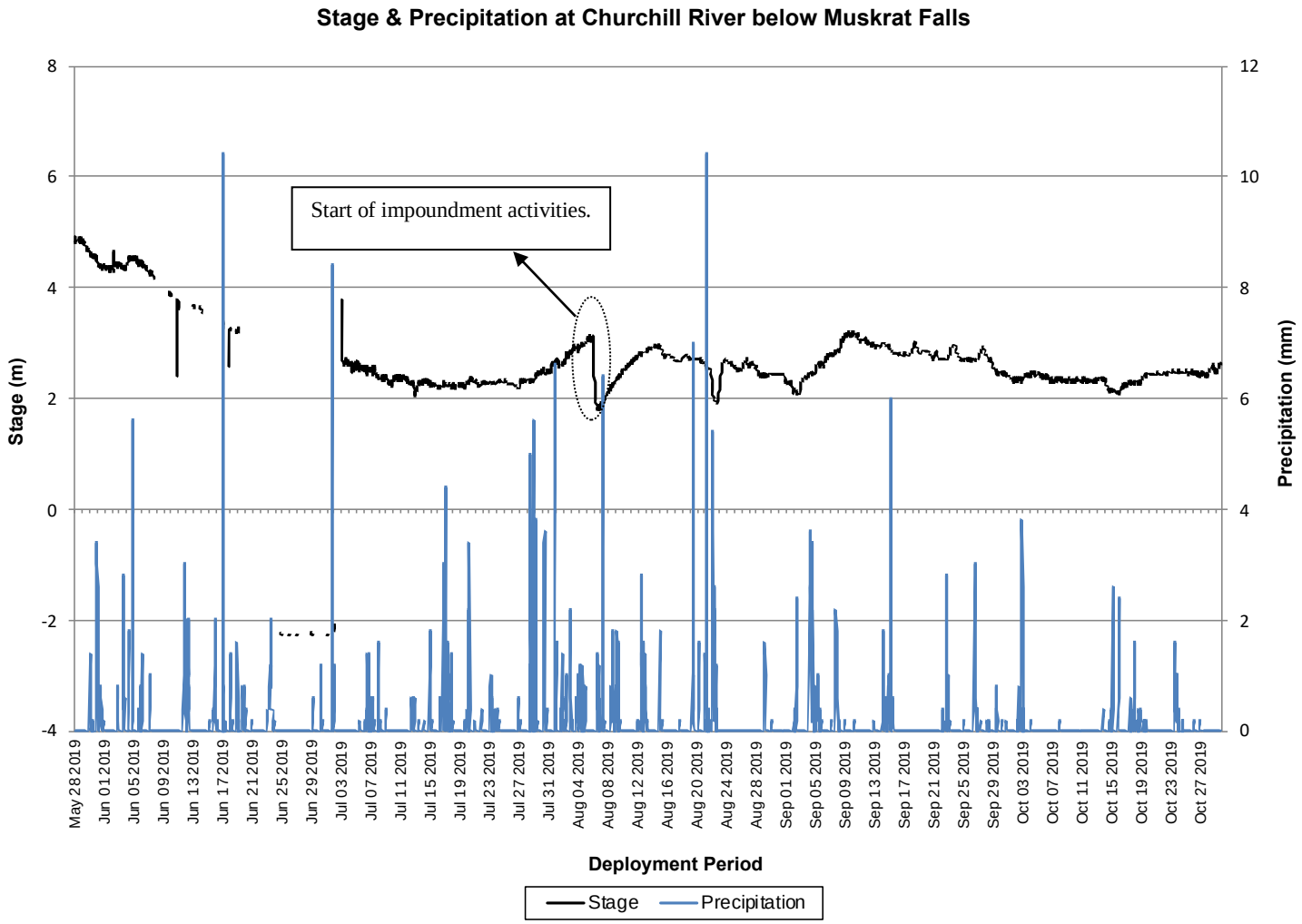

Figure 23: Stage & Precipitation at Churchill River below Muskrat Falls

Stage (m)	2019	2018	2017
Min	-2.26	2.081	2.096
Max	4.918	5.944	3.446
Median	2.486	2.886	2.517

Churchill River at English Point

Temperature

- Over the 2019 deployment season, water temperature ranged from 2.5°C to 19.3°C, with a median value of 11.9°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.

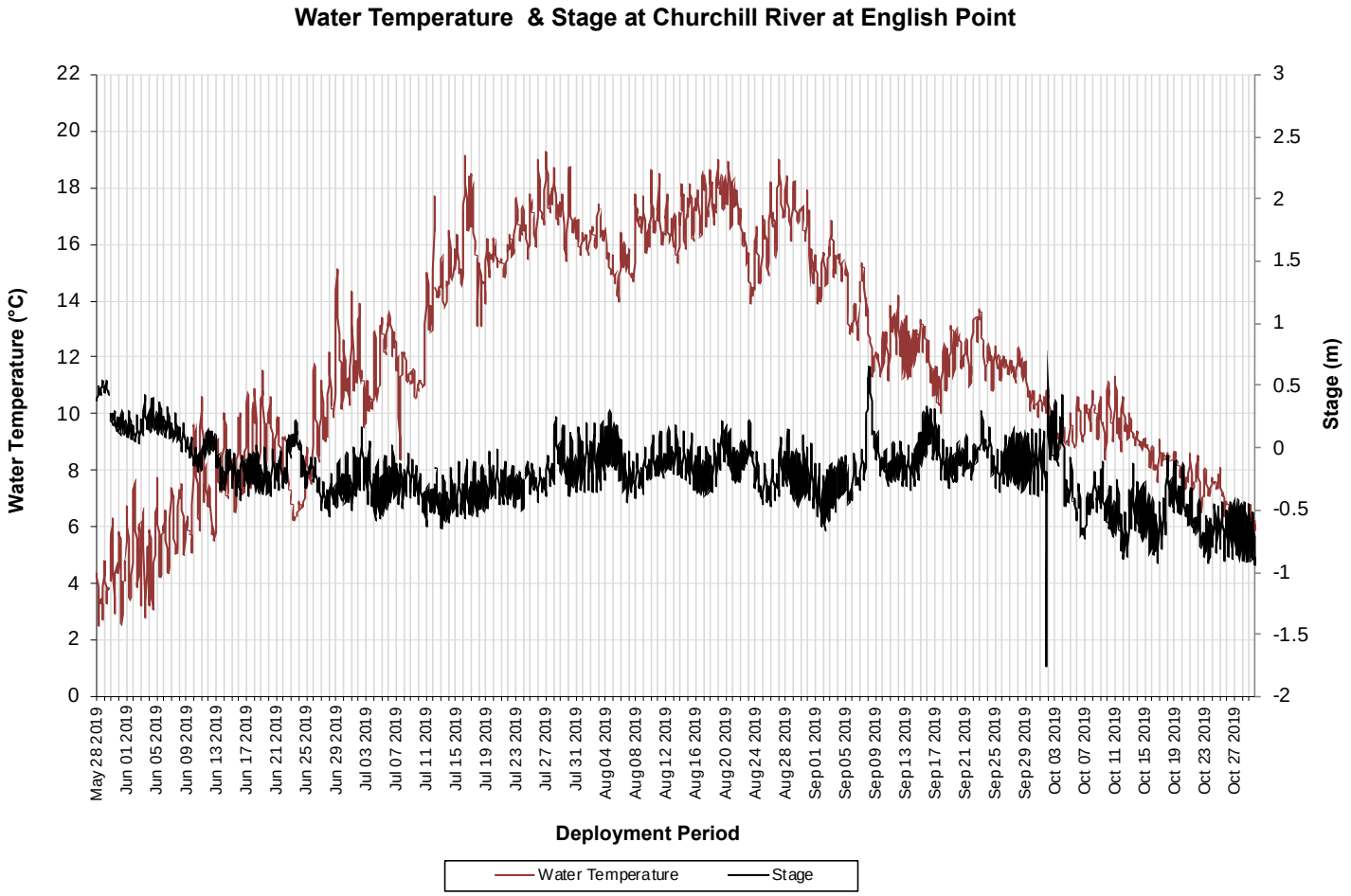

Figure 24: Water Temperature & Stage at Churchill River at English Point

Temperature (°C)	2019	2018	2017
Min	2.5	1.2	4.2
Max	19.3	21.8	20.6
Median	11.9	11.9	13.8

- Temperatures 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 August. Water and air temperatures decreased steadily from September onwards. Air temperature data was obtained from the Metchin River near TLH climate station.

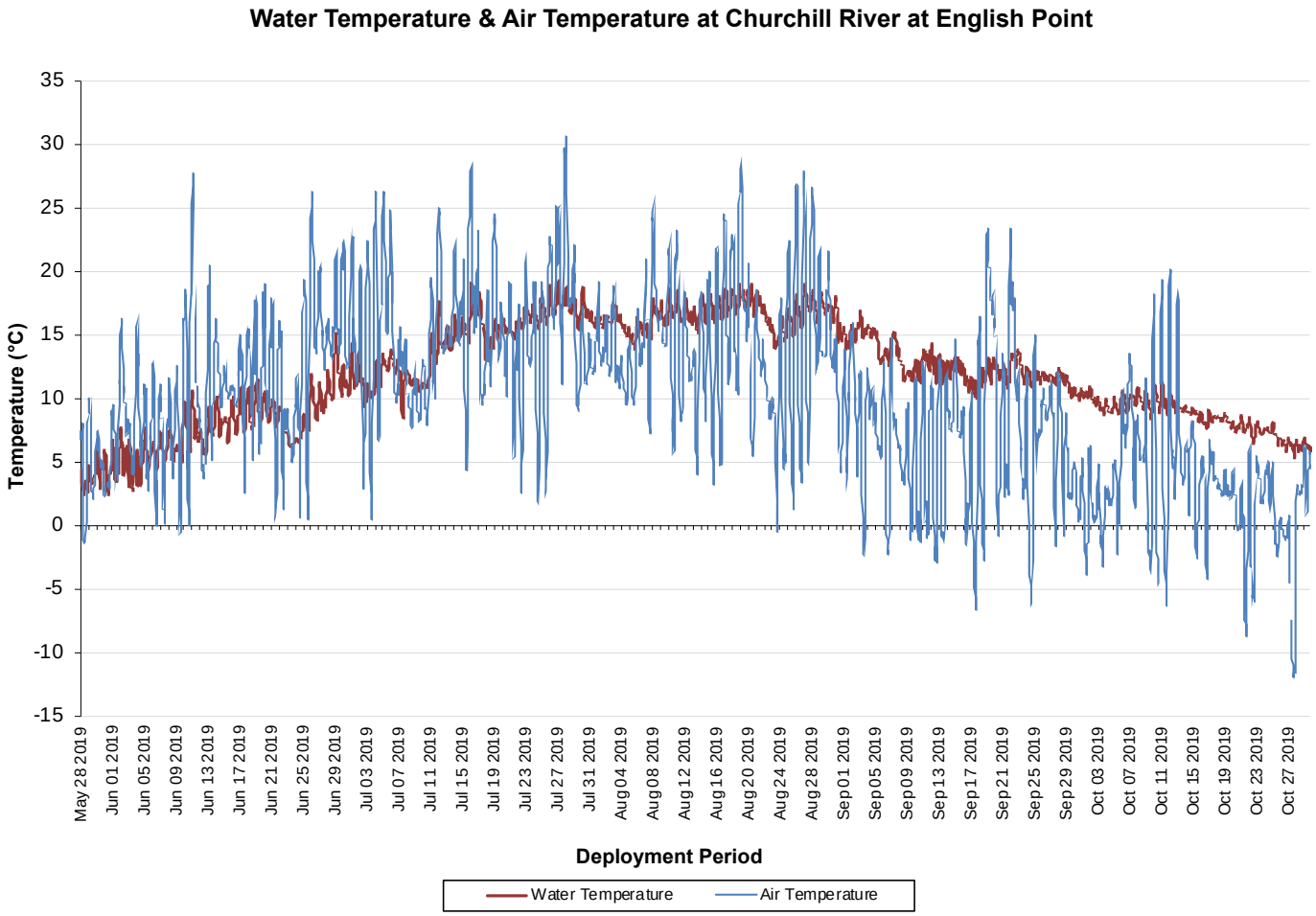

Figure 25: Water Temperature & Air Temperature at Churchill River at English Point

pH

- Over the 2019 deployment season, pH ranged from 5.70 to 7.02 pH units, with a median value of 6.53 pH units (Figure 26), which was comparable to the previous two seasons.
- pH values were within the CCME's Guidelines for the Protection of Aquatic Life (>6.5 and <9.0 pH units) for roughly half of the deployment season (Figure 26).

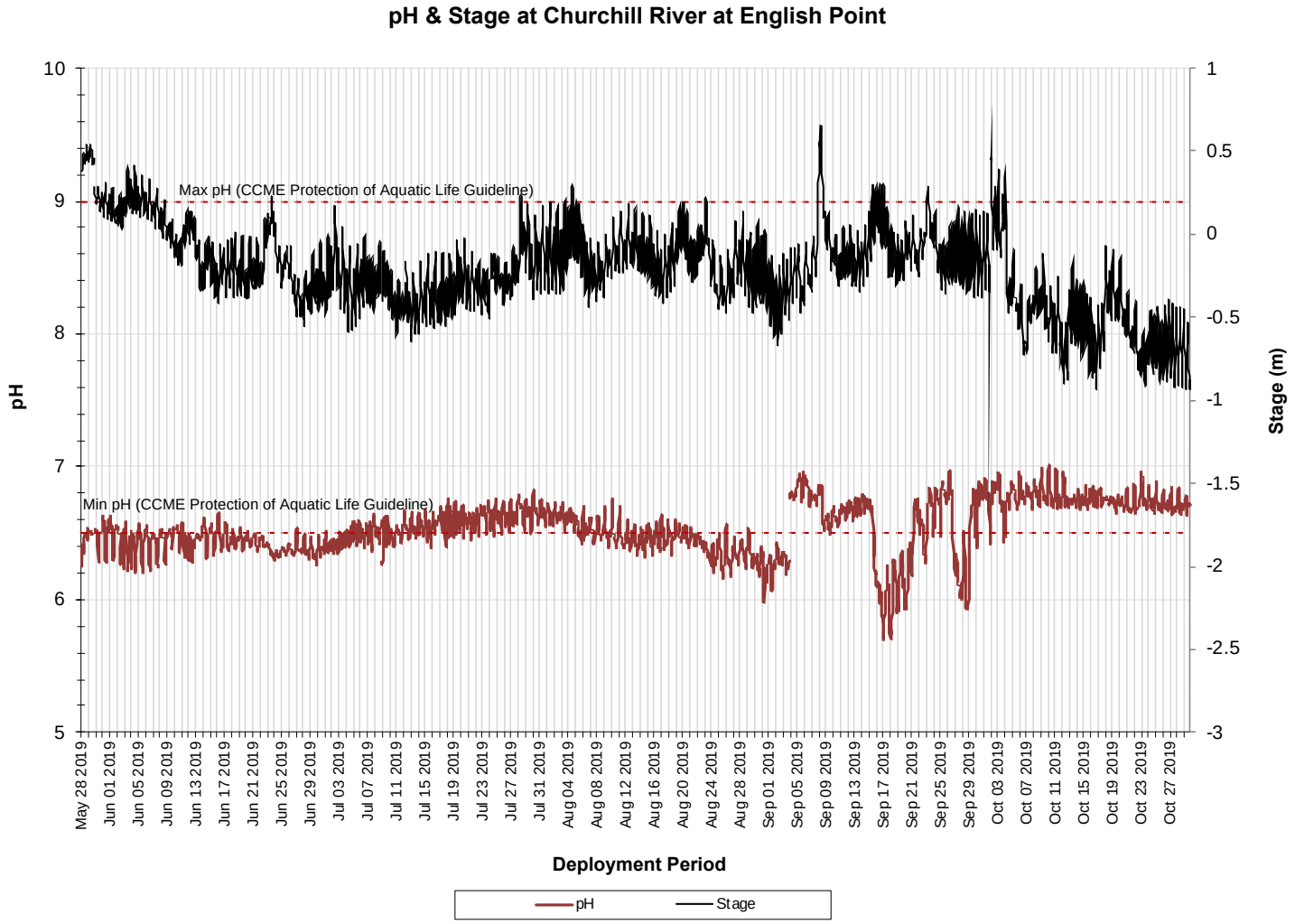

Figure 26: pH & Stage at Churchill River at English Point

pH (units)	2019	2018	2017
Min	5.70	5.67	6.14
Max	7.02	7.33	7.34
Median	6.53	6.48	6.79

Specific Conductivity

- Over the 2019 deployment season, specific conductivity ranged from 9.7µS/cm to 51.6µS/cm, with a median value of 26.7µS/cm, which was 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.

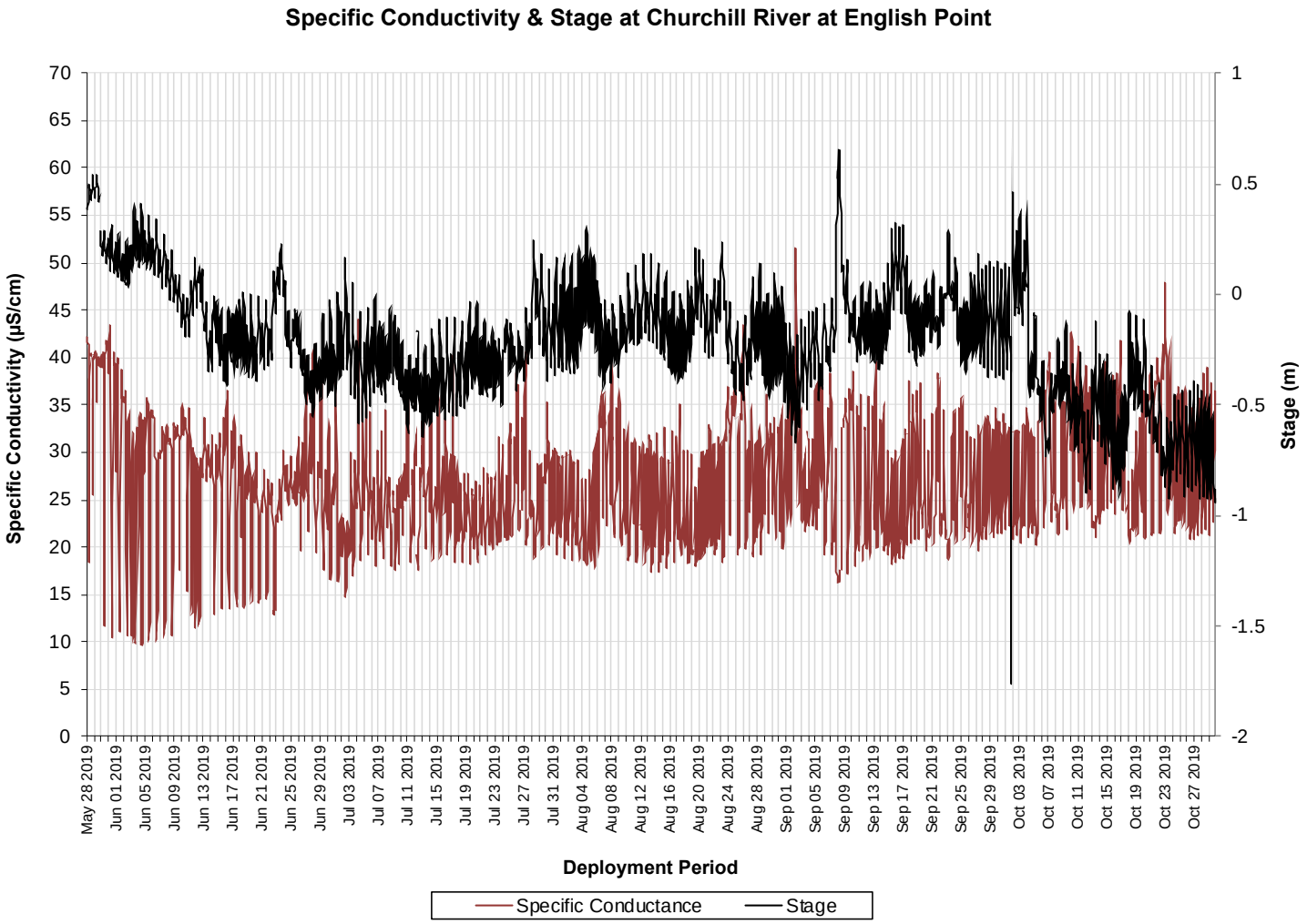

Figure 27: Specific Conductivity & Stage at Churchill River at English Point

Specific Conductivity (µS/cm)	2019	2018	2017
Min	9.7	9.4	16.1
Max	51.6	58.0	60.9
Median	26.7	28.2	29.6

Dissolved Oxygen

- Over the 2019 deployment season, dissolved oxygen ranged from 8.99mg/L to 14.4mg/L, with a median value of 10.79mg/L (Figure 28), which was comparable to previous seasons. Percent saturation ranged from 84.1% to 113.7%, with a median value of 100.2% (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 CCME's Guidelines for the Protection of Other & Early Life Stages (6.5mg/L and 9.5mg/L respectively) for most of the deployment season. Exceptions occurred from mid-July to early September when water temperatures were highest, which is to be expected since dissolved oxygen levels are generally lower in warmer water bodies.

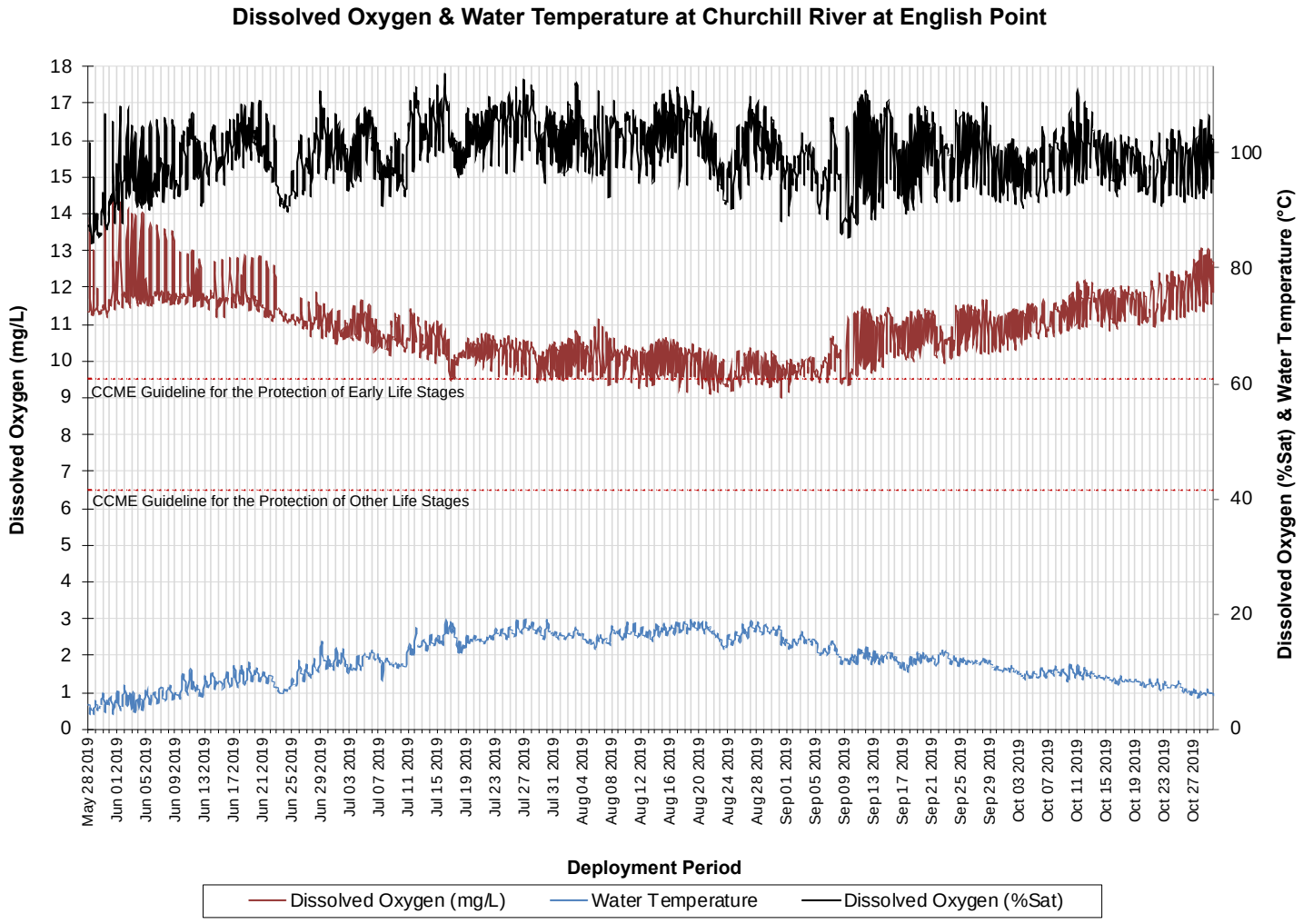

Figure 28: Dissolved Oxygen & Water Temperature at Churchill River at English Point

Dissolved Oxygen (mg/L)	2019	2018	2017		Dissolved Oxygen (% Sat)	2019	2018	2017
Min	8.99	8.39	8.7		**Min**	84.1	80.0	86.9
Max	14.4	15.48	13.31		**Max**	113.7	115.8	112.1
Median	10.79	11.04	10.35		**Median**	100.2	99.8	98.5

Turbidity & Precipitation

- Over the 2019 deployment season, turbidity ranged from 0 NTU to 1314 NTU, with a median value of 8.9 NTU (Figure 29). A median value of 8.9 NTU indicates that there is significant natural background turbidity at this station, and is comparable to previous seasons.
- Turbidity increases were often associated with precipitation events; however, high winds and tidal influences at this station also contribute to increased turbidity levels given the sandy nature of the river bed.

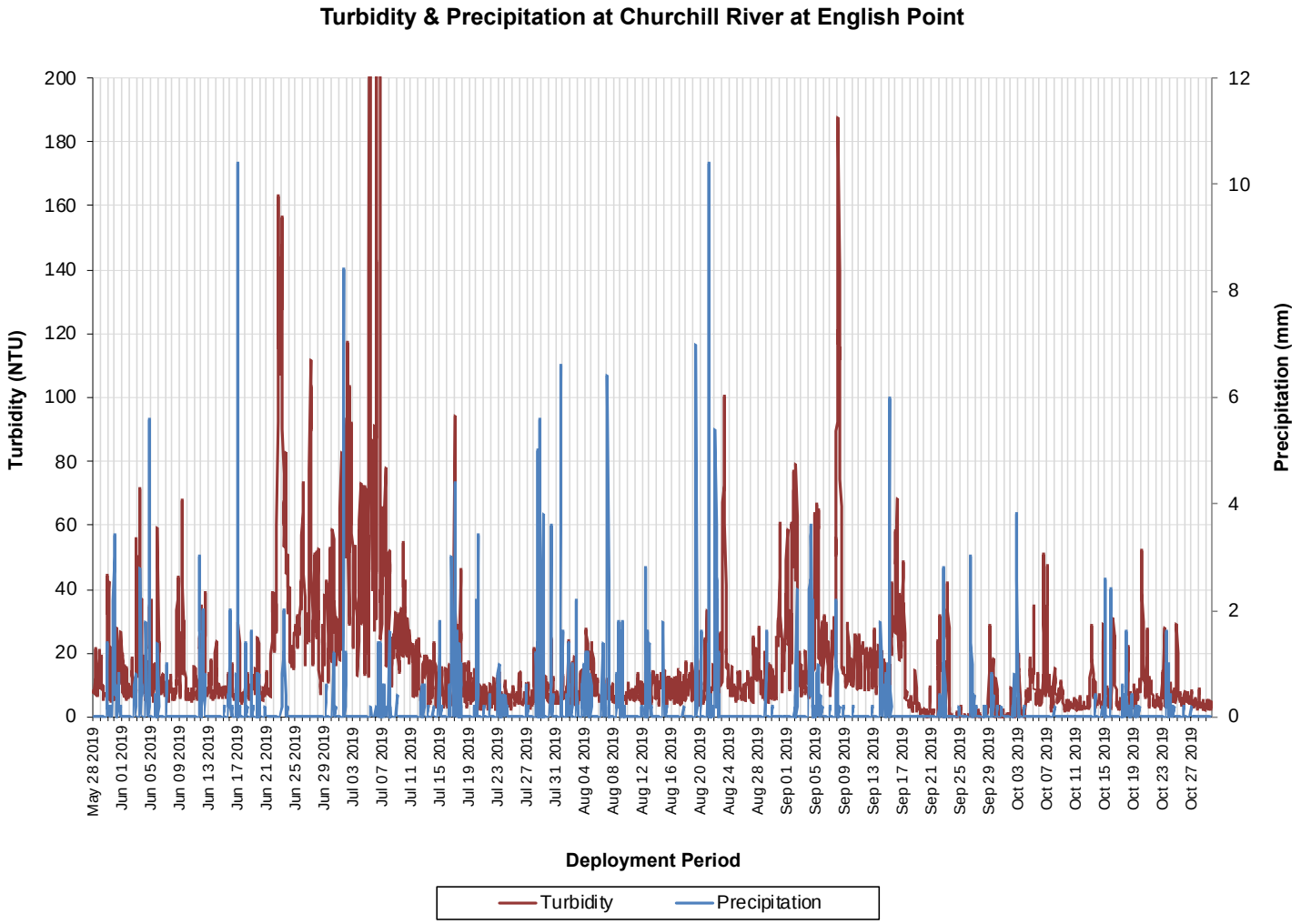

Figure 29: Turbidity, Stage & Precipitation at Churchill River at English Point

Turbidity (NTU)	2019	2018	2017
Min	0.0	0.0	0.0
Max	1314	601.0	117.9
Median	8.9	5.0	5.0

Stage

- Over the 2019 deployment season, stage ranged from -1.761m to 0.784m, with a median value of -0.206m (Figure 30). This median value is quite a bit lower than the previous two seasons, which is due to internal adjustments made after the station was geodetically surveyed.
- 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.

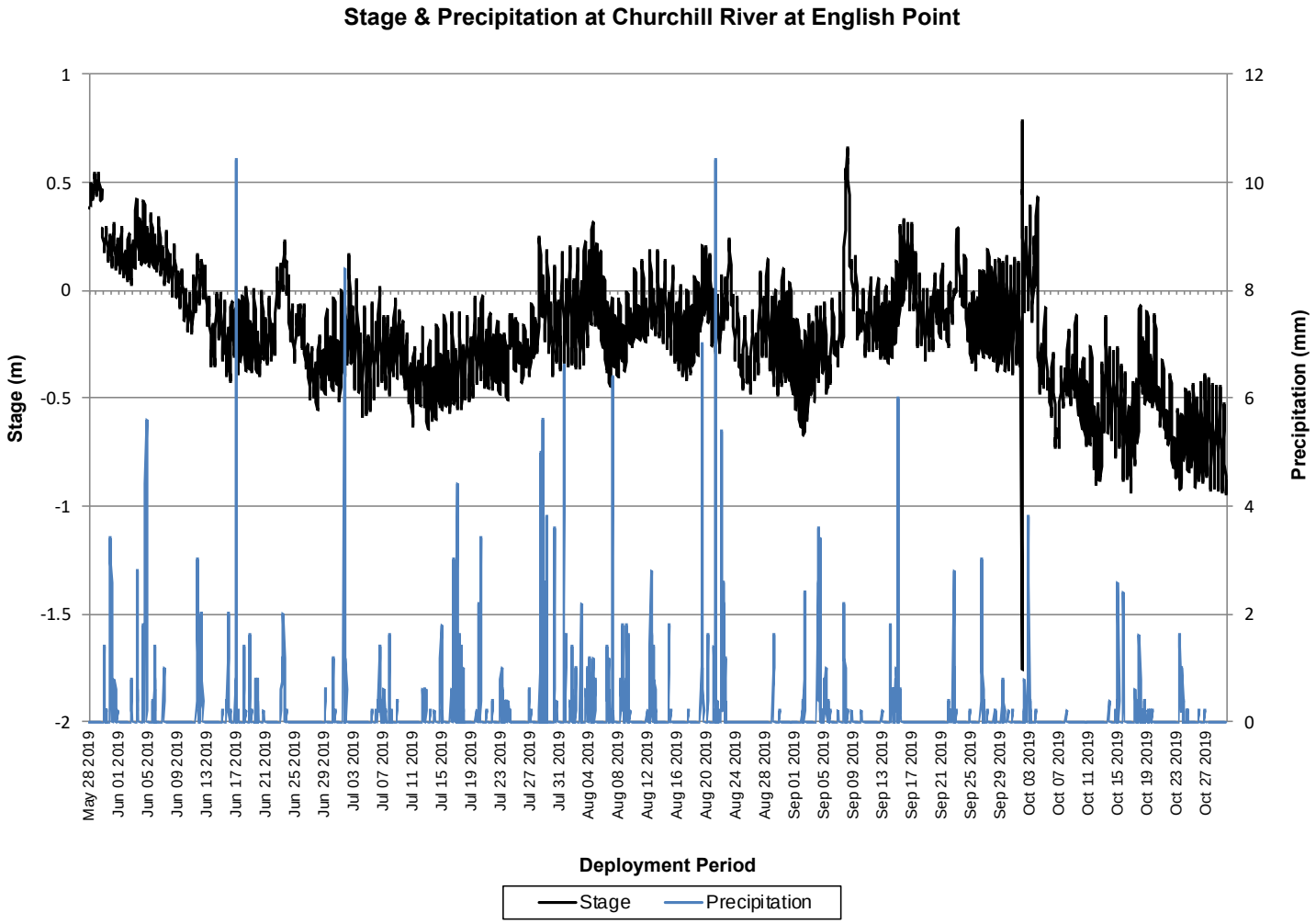

Figure 30: Stage & Precipitation at Churchill River at English Point

Stage (m)	2019	2018	2017
Min	-1.761	-0.575	1.728
Max	0.784	2.982	2.701
Median	-0.206	2.115	2.113

Station Comparison

Temperature

- Water temperatures at each of the four stations on the Churchill River displayed a similar trend throughout the 2019 deployment season (Figure 31). Overall, increases and decreases occurred at all stations around the same time, though to different extents.
- 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 below Metchin River, 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 and some data is missing due to instruments being out of water during the 2019 season, this trend is not observed.

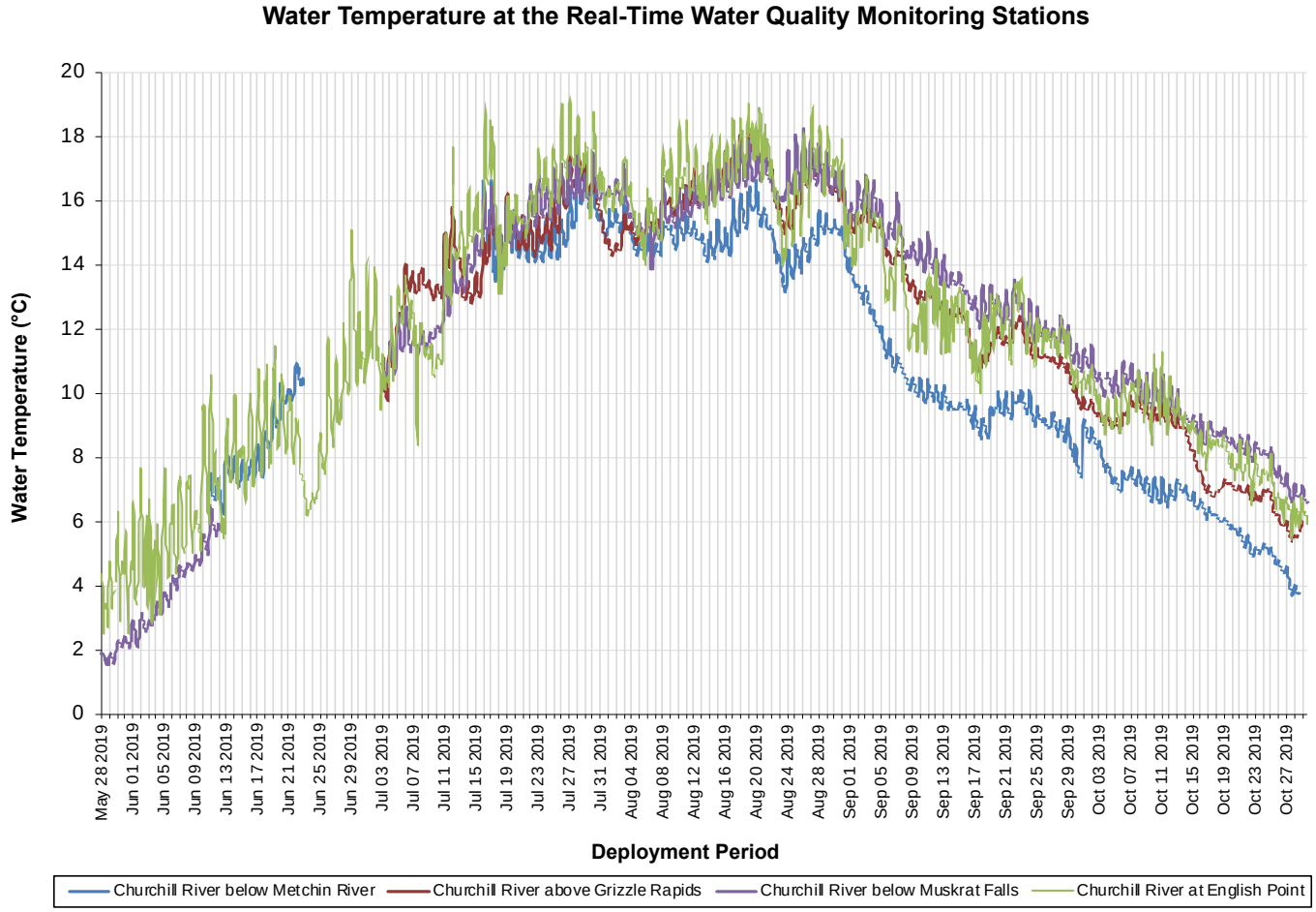

Figure 31: Water Temperature at all Stations on the Churchill River in 2019

Temperature (°C)	CRbelowMR	CRaboveGR	CRbelowMF	CRatEngPt
Min	3.7	5.4	1.6	2.5
Max	17.2	18.2	18.2	19.3
Median	10.1	13.45	13.2	11.9

- 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).

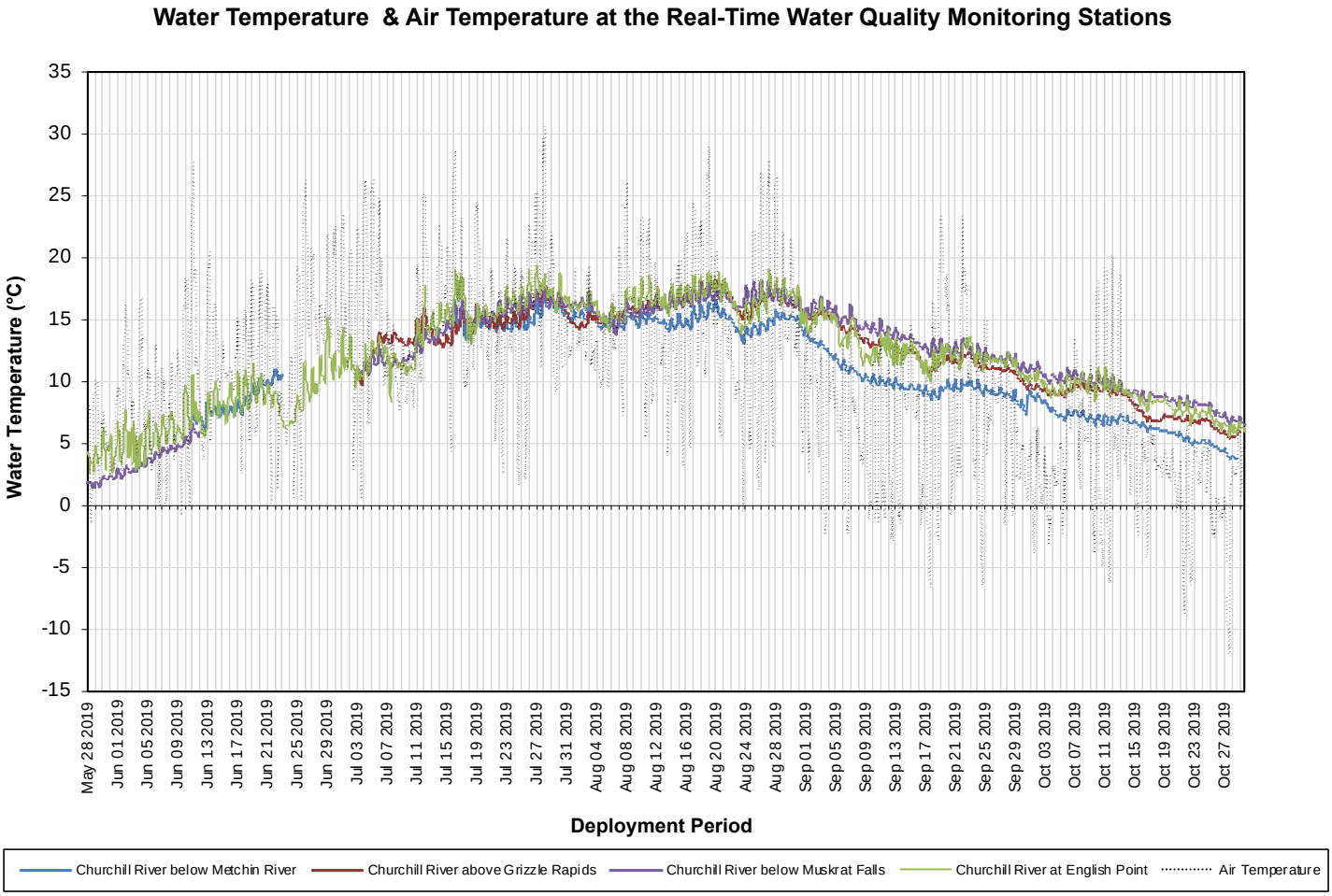

Figure 32: Water Temperature & Air Temperature at all Stations on the Churchill River in 2019

pH

- pH values at each of the four stations on the Churchill River displayed similar trends throughout the 2019 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, above Grizzle Rapids and at English Point were similar, while 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.

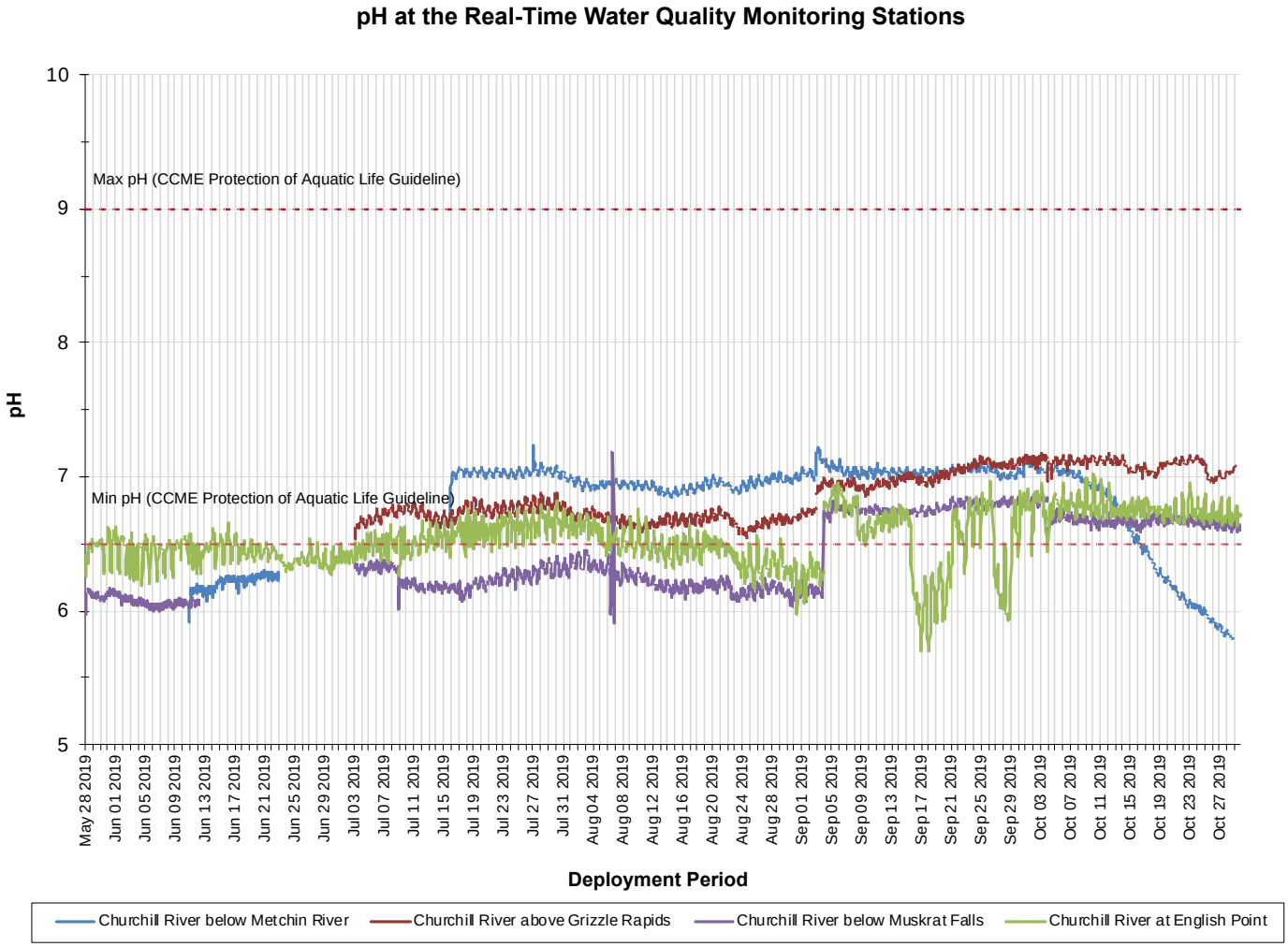

Figure 33: pH at all Stations on the Churchill River in 2019

pH	CRbelowMR	CRaboveGR	CRbelowMF	CRatEngPt
Min	5.79	6.54	5.91	5.70
Max	7.23	7.17	7.19	7.02
Median	6.98	6.81	6.32	6.53

Specific Conductivity

- Specific conductivity values at each of the four stations on the Churchill River displayed similar trends throughout the 2019 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, specific conductivity at English Point is highly variable, fluctuating significantly twice daily due to the tidal influences of the Atlantic Ocean.

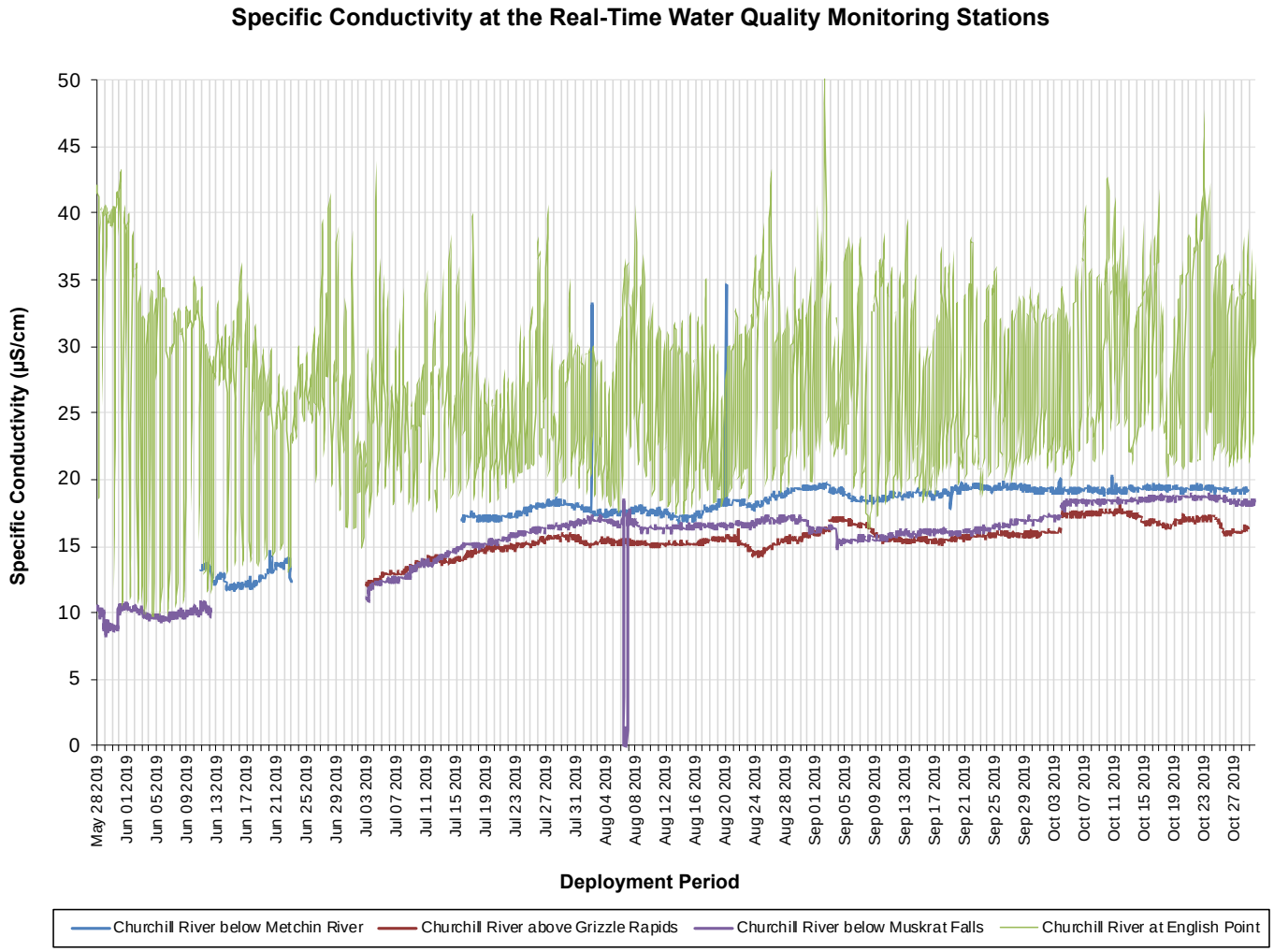

Figure 34: Specific Conductivity at all Stations on the Churchill River in 2019

Specific Conductivity (µS/cm)	CRbelowMR	CRaboveGR	CRbelowMF	CRatEngPt
Min	11.8	12.1	0	9.7
Max	34.6	18.2	18.9	51.6
Median	18.7	15.5	16.4	26.7

Dissolved Oxygen

- Dissolved oxygen content and percent saturation values at each of the four stations on the Churchill River were similar throughout the 2019 deployment season (Figure 35a and 35b).
- 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's Guideline for the Protection of Early Life Stages (9.5mg/L) for the duration of the 2019 deployment season, whereas values at below Metchin River, above Grizzle Rapids and at English Point dipped below the CCME's Guideline for the Protection of Early Life Stages during the warmer summer months. All stations remained above the CCME's Guideline for the Protection of Other Life Stages (6.5mg/L) for the duration of the 2019 deployment season.

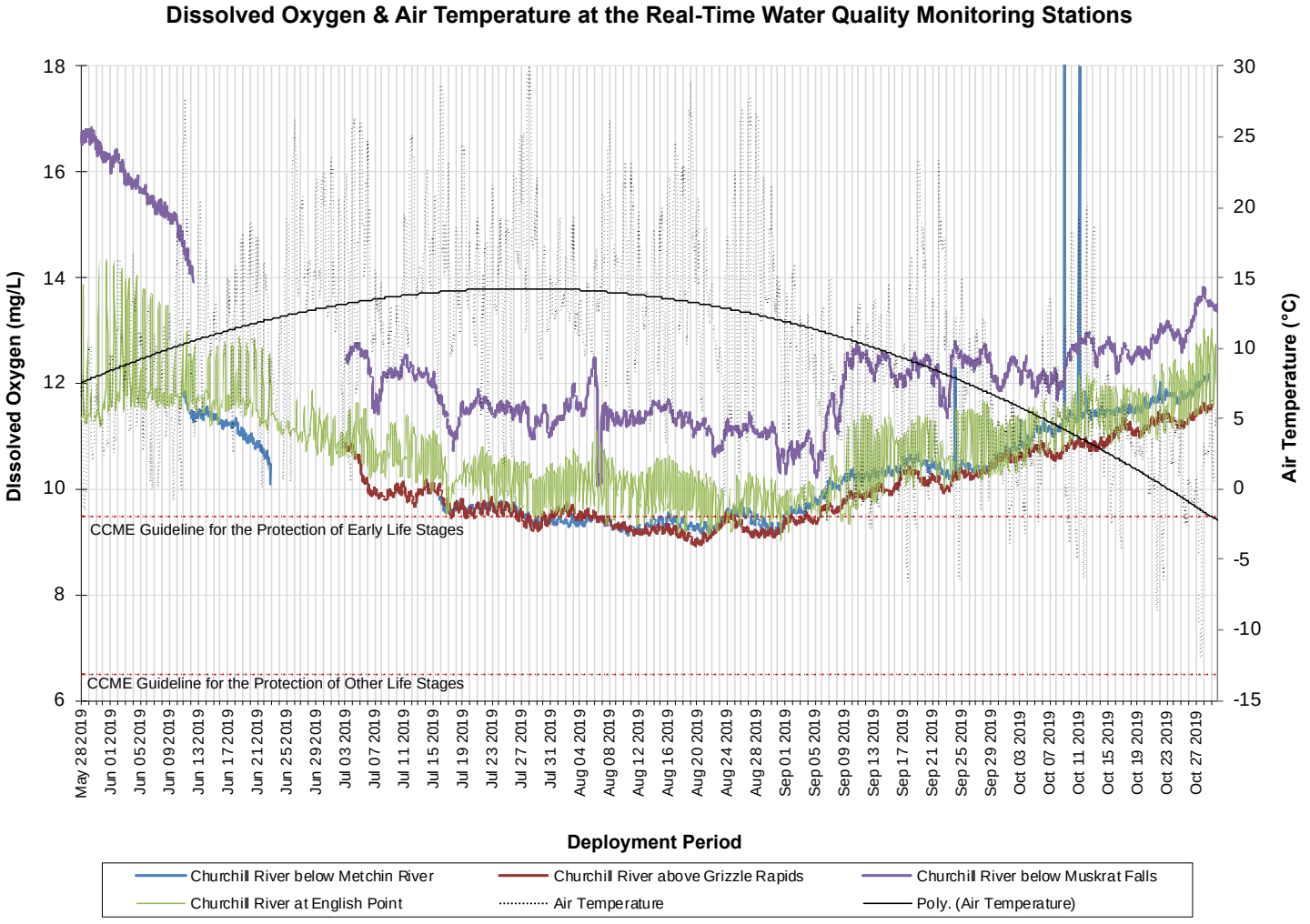

Figure 35a: Dissolved Oxygen (mg/L) at all Stations on the Churchill River in 2019

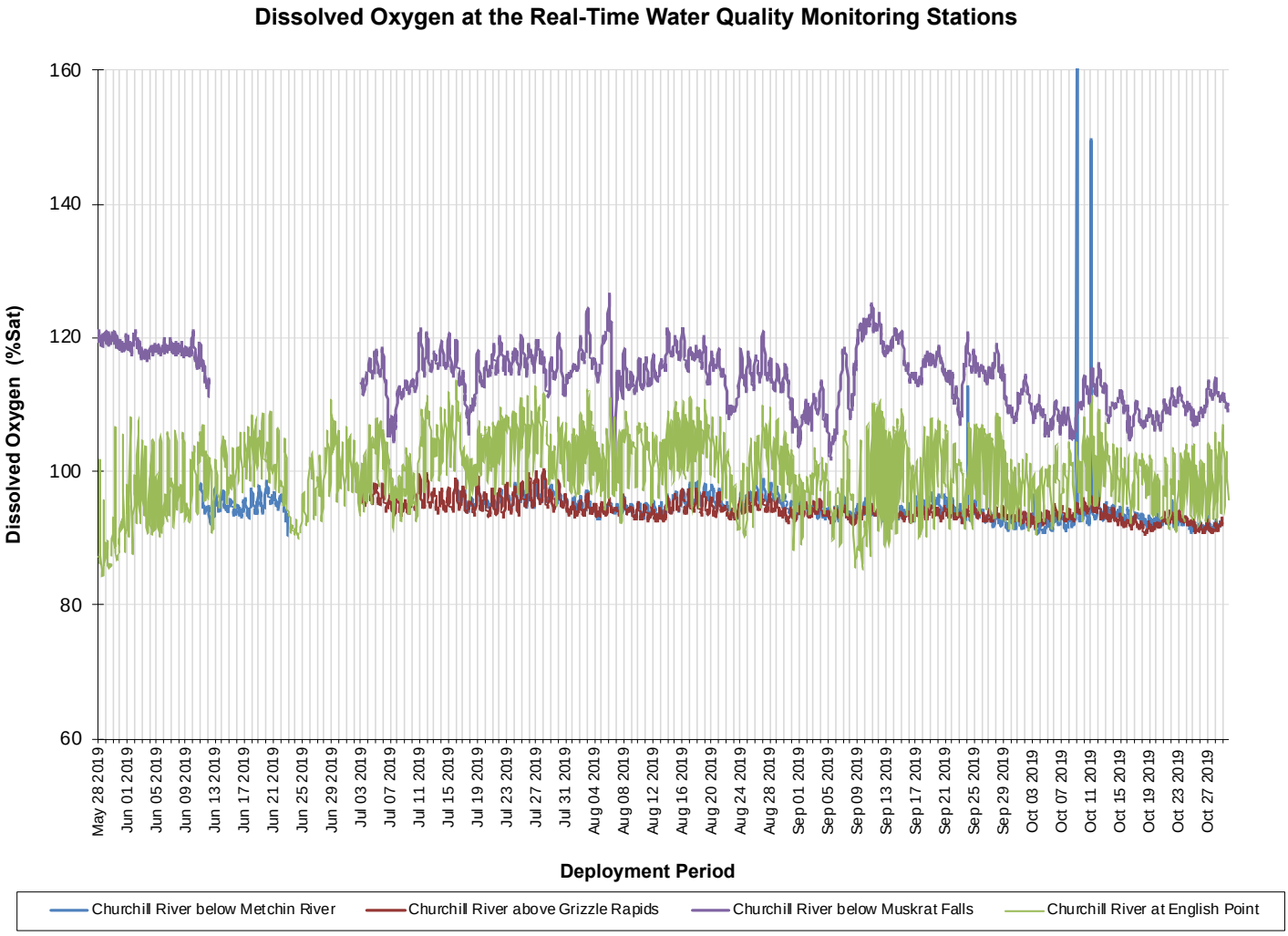

Figure 35b: Dissolved Oxygen (%Sat) at all Stations on the Churchill River in 2019

	Dissolved Oxygen (mg/L)					Dissolved Oxygen (% Sat)			
	CRbelowMR	CRaboveGR	CRbelowMF	CRatEngPt		CRbelowMR	CRaboveGR	CRbelowMF	CRatEngPt
Min	9.15	8.92	10.06	8.99		90.4	90.6	99.1	84.1
Max	23.11	11.62	16.82	14.4		192.5	100.2	126.5	113.7
Median	10.25	9.88	12.13	10.79		94.3	94.0	114.6	100.2

Turbidity

- Turbidity values at each of the four stations on the Churchill River were somewhat similar during the 2019 deployment season (Figure 36), with median values ranging from 0 NTU to 8.9 NTU.
- Turbidity values showed the most variation at below Muskrat Falls and at English Point, where values ranged from 0 NTU to 2756 NTU and from 0 NTU to 1314 NTU, respectively.

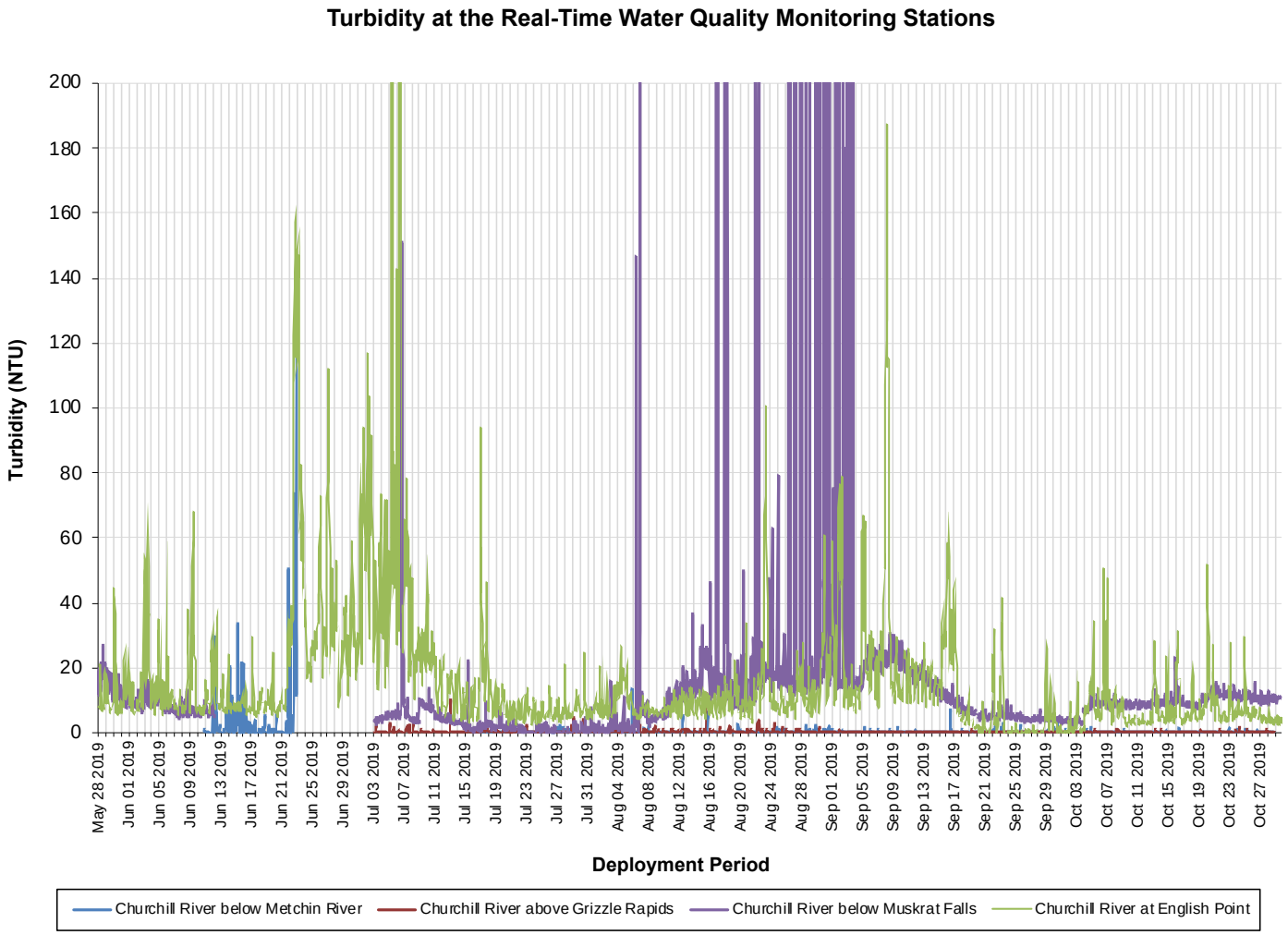

Figure 36: Turbidity at all Stations on the Churchill River in 2019

Turbidity (NTU)	CRbelowMR	CRaboveGR	CRbelowMF	CRatEngPt
Min	0.0	0.0	0.0	0.0
Max	116.2	12.3	2756	1314
Median	0.0	0.1	8.5	8.9

Stage

- Stage values on the Churchill River varied significantly from one station to the next during the 2019 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.

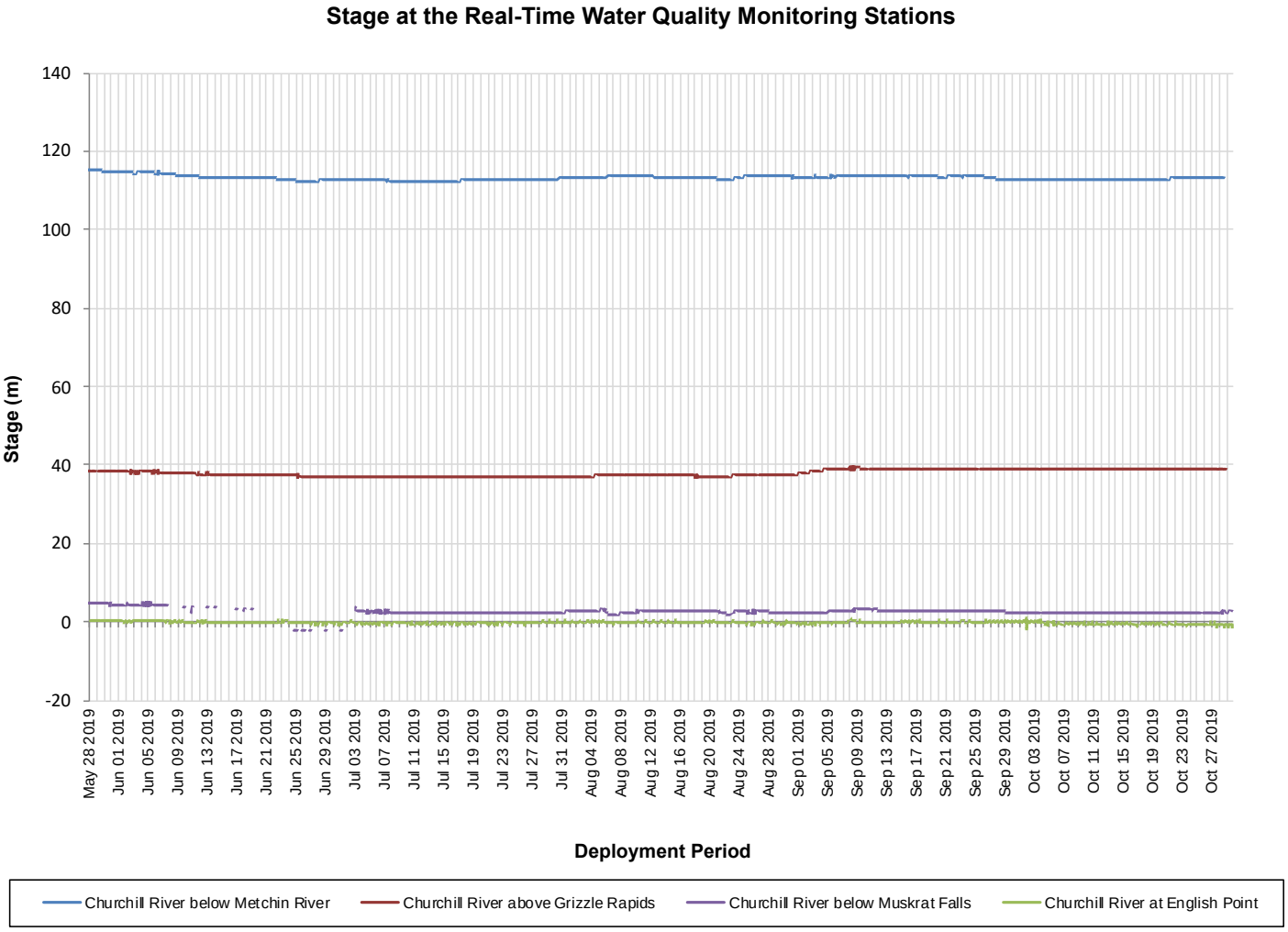

Figure 37: Stage at all Stations on the Churchill River in 2019

Stage (m)	CRbelowMR	CRaboveGR	CRbelowMF	CRatEngPt
Min	112.425	36.827	-2.26	-1.761
Max	115.161	39.242	4.918	0.784
Median	113.19	37.585	2.486	-0.206

Conclusions

- Water quality monitoring instruments were successfully deployed on the Churchill River for different lengths of time during the spring, summer, and fall of 2019. The station above Grizzle Rapids was not deployed until July. The station above Muskrat Falls was not deployed at all in 2019 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 mostly adhered to for the 2019 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. Sediment build-up around the instrument can result in inaccurate turbidity data at times given the sandy nature of the river bed.
- Instruments performed well for much of the deployment season with only limited disruptions to data collection.
- Data collected in 2019 was comparable with datasets from previous years. 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's Guidelines for the Protection of Aquatic Life, with the exception of several extended periods of time at the stations below Metchin River, below Muskrat Falls, and at English Point.
- During the warmer summer months, dissolved oxygen at three stations (below Metchin River, above Grizzle Rapids, and at English Point) fell below the CCME's Guideline for the Protection of Early Life Stages (9.5mg/L). Dissolved oxygen values at all stations remained above the CCME's 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 2019, with median values ranging from 0NTU to 8.9NTU. The stations below Muskrat Falls and at English Point showed frequent turbidity events as expected.

Path Forward

In order for this agreement to be successful, it is essential to continually evaluate and move forward. The 2019 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 2020 when ice conditions allow and perform regular site visits throughout the 2020 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 2020. Satellite imagery will be acquired by MAE to further this area of research.
- RTWQ monitoring was stopped at the Lake Melville station in 2012 following continued damage to the deployed instrument, after which this station was used to monitor water quantity only. All monitoring at this station will be discontinued effective Summer 2020.

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