Real-Time Water Quality 2017 Annual Report

Voisey's Bay Network

June 7 to October 23, 2017

Newfoundland Labrador

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

Contents

Acknowledgements

The Real-Time Water Quality Monitoring Network in Voisey's Bay is successful in tracking emerging water quality issues due to the hard work and diligence of certain individuals. The management and staff of Vale work in cooperation with the management and staff of the Department of Municipal Affairs and Environment (MAE) Water Resources Management Division (WRMD), as well as Environment and Climate Change Canada (ECCC), to ensure the protection of ambient water resources in Voisey's Bay, Labrador.

Vale Environmental Coordinators are acknowledged for their hard work during the 2017 deployment period, and ensuring the Real-Time Water Quality Monitoring Network is operating to the standards set by MAE. It is only through their dedication to properly maintain and calibrate the equipment and perform acceptable quality control measures that the data can be viewed as reliable and accurate.

Various individuals from WRMD have been integral in ensuring the smooth operation of such a technologically advanced network. WRMD staff played a lead role in coordinating and liaising between the major agencies involved, thus, ensuring open communication lines at all times. In addition, WRMD is responsible for the data management/reporting, troubleshooting, along with ensuring the quality assurance/quality control measures are satisfactory. WRMD provides data to the general public on a near real-time basis through the departmental web page.

Environment and Climate Change Canada staff of the Meteorological Service of Canada: Water Survey Canada play an essential role in the data logging/communication aspect of the network. These individuals visit the site often to ensure the data logging equipment is operating properly and transmitting the data efficiently. Finally, they play the lead role in dealing with hydrological quantity and flow issues.

The managers with MAE, ECCC, and Vale are fully committed to improving this network and ensuring it provides meaningful and accurate water quality/quantity data that can be used in the decision-making process. This network is only successful due to the cooperation of all three agencies involved.

Abbreviations

ECCC	Environment and Climate Change Canada
WSC	Water Survey of Canada
MAE	Department of Municipal Affairs and Environment
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
PTE	Performance Testing and Evaluation

Introduction

The RTWQ network in Voisey's Bay was successfully established by MAE and ECCC in cooperation with Vale in 2003 and further expanded in 2006. The objective of the network is to identify and track emerging water quality or quantity management issues and ensure protection of ambient water resources in and around the Voisey's Bay operations.

The RTWQ network consists of four water quality monitoring stations: Reid Brook at Outlet of Reid Pond, Camp Pond Brook below Camp Pond, Tributary to Reid Brook, and Reid Brook below Tributary. These stations measure water quality parameters including water temperature, pH, specific conductivity, dissolved oxygen, and turbidity. Two additional parameters, total dissolved solids and percent saturation are calculated from measured parameters.

These stations also record continuous stage level and streamflow rate data. These parameters are the responsibility of ECCC; however, if needed, WRMD staff reporting on water quality will have access to water quantity information to understand and explain water quality fluctuations.

Four new Hydrolab Datasonde 5X instruments were purchased in the spring 2012 season for this network, as well as a new Hydrolab Minisonde 5 for QA/QC measurements and an Archer handheld display unit.

This annual deployment report illustrates, discusses and summarizes water quality related events from June 7 to October 23, 2017. During this time, five visits were made to each of the four RTWQ sites. Instruments were deployed for month-long intervals referred to as deployment periods.

Maintenance and Calibration

It is recommended that regular maintenance and calibration of the instruments take place on a monthly basis to ensure accurate data collection. This procedure is the responsibility of the Vale Environment staff and is performed preferably every 30 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, Vale Environment staff members carefully calibrate each sensor attachment for pH, specific conductivity, dissolved oxygen and turbidity.

An extended deployment period (>30 days) can result in instrument sensor drift, which may result in skewed data. Instrument sensors will still work to capture any water quality event, although exact data values collected may be inaccurate. Installation and removal dates for each station in the 2017 deployment season are summarized in Table 1.

Table 1: Installation and removal dates for 2016 deployment periods

Installation	Removal	Deployment
June 7	July 12	35 days
July 13	August 12	31 days
August 13	September 18	37 days
September 19	October 23	35 days

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.

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 (oC)	<=+/-0.2	>+/-0.2 to 0.5	>+/-0.5 to 0.8	>+/-0.8 to 1	<+/-1
pH (unit)	<=+/-0.2	>+/-0.2 to 0.5	>+/-0.5 to 0.8	>+/-0.8 to 1	>+/-1
Sp. Conductance (µS/cm)	<=+/-3	>+/-3 to 10	>+/-10 to 15	>+/-15 to 20	>+/-20
Sp. Conductance > 35 µS/cm (%)	<=+/-3	>+/-3 to 10	>+/-10 to 15	>+/-15 to 20	>+/-20
Dissolved Oxygen (mg/l) (% Sat)	<=+/-0.3	>+/-0.3 to 0.5	>+/-0.5 to 0.8	>+/-0.8 to 1	>+/-1
Turbidity <40 NTU (NTU)	<=+/-2	>+/-2 to 5	>+/-5 to 8	>+/-8 to 10	>+/-10
Turbidity > 40 NTU (%)	<=+/-5	>+/-5 to 10	>+/-10 to 15	>+/-15 to 20	>+/-20

It should be noted that the temperature sensor on any instrument is the most important. All other parameters can be broken down into three groups: temperature dependent, temperature compensated and temperature independent. Because the temperature sensor is not isolated from the rest of the instrument the entire instrument must be at the same temperature before the sensor will stabilize. The values may take some time to climb to the appropriate reading; if a reading is taken too soon it may not accurately portray the water body.

Deployment and removal comparison rankings for the Voisey's Bay Network stations 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 Voisey's Bay Network stations

Station	Date	Action	Temperature	pH	Specific Conductivity	Dissolved Oxygen	Turbidity
Reid Brook at Outlet of Reid Pond	7-Jun	Deployment	Good	Poor	Good	Excellent	Excellent
	12-Jul	Removal	N/A	N/A	N/A	N/A	N/A
	13-Jul	Deployment	Excellent	N/A*	Excellent	Excellent	Excellent
	12-Aug	Removal	Excellent	Excellent	Excellent	Excellent	N/A*
	13-Aug	Deployment	Excellent	Fair	Excellent	Excellent	Excellent
	18-Sep	Removal	Excellent	Excellent	Excellent	N/A*	Excellent
	19-Sep	Deployment	Excellent	Poor	Excellent	Excellent	Excellent
	23-Oct	Removal	Excellent	N/A *	Excellent	Excellent	Good
Camp Pond Brook below Camp Pond	7-Jun	Deployment	Excellent	Marginal	Good	Excellent	Excellent
	12-Jul	Removal	Excellent	Good	Good	Excellent	Marginal
	13-Jul	Deployment	Excellent	N/A*	Excellent	Excellent	Excellent
	12-Aug	Removal	Excellent	Excellent	Poor	Excellent	N/A*
	13-Aug	Deployment	Excellent	Fair	Excellent	Excellent	Excellent
	18-Sep	Removal	Excellent	Fair	Fair	N/A*	N/A*
	19-Sep	Deployment	Excellent	Good	Excellent	Excellent	Excellent
	23-Oct	Removal	Excellent	Excellent	Good	Excellent	Poor
Reid Brook below Tributary	7-Jun	Deployment	Excellent	Excellent	Good	Excellent	Excellent
	12-Jul	Removal	Excellent	Fair	Excellent	Excellent	Excellent
	13-Jul	Deployment	Excellent	Fair	Excellent	Excellent	Excellent
	12-Aug	Removal	Excellent	Excellent	Excellent	Excellent	N/A*
	13-Aug	Deployment	Excellent	Good	Good	Excellent	Excellent
	18-Sep	Removal	Good	Poor	Good	N/A*	N/A*
	19-Sep	Deployment	Excellent	Marginal	Excellent	Good	Poor
	23-Oct	Removal	Good	Good	Excellent	Excellent	Good
Tributary to Reid Brook	7-Jun	Deployment	Excellent	Good	Excellent	Excellent	Excellent
	12-Jul	Removal	Excellent	Fair	Excellent	Poor	Poor
	13-Jul	Deployment	Excellent	Good	Excellent	Excellent	Excellent
	12-Aug	Removal	Excellent	Excellent	Excellent	Excellent	N/A*
	13-Aug	Deployment	Excellent	Fair	Good	Excellent	Excellent
	18-Sep	Removal	Excellent	Marginal	Good	N/A*	N/A*
	19-Sep	Deployment	Excellent	Fair	Poor	Excellent	Excellent
	23-Oct	Removal	Excellent	Good	Poor	Excellent	Excellent

Data Interpretation

The following graphs and discussions illustrate significant water quality-related events from June 7 through October 23, 2017 in the Voisey's Bay RTWQ Network.

With the exception of water quantity data (stage), all data used in the preparation of the graphs and subsequent discussion below adhere to this stringent QA/QC protocol. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

During the first deployment period, the instrument at Reid Brook at Outlet of Reid Pond was out of the water for an extended period. As such, all data for this station from July 5 through July 12 was removed from the dataset. Furthermore, there was a failure with the pH sensor at Reid Brook at Outlet of Reid Pond from October 2 through October 23, and so this data was also removed from the dataset.

During the third deployment period, the transmission cable at Reid Brook below Tributary was severed by wildlife. As a result, all RTWQ data for this station is missing from September 2 through September 18. Water quality data was restored on September 19; however, stage data for this station was not restored until October 17.

All instruments were sent to the St. John's WRMD laboratory at the end of the season for yearly PTE. Any necessary repairs and replacement sensors will be addressed before the 2018 season.

Reid Brook at Outlet of Reid Pond

During the 2017 deployment season, water temperature ranged from 0.6°C to a maximum of 14.9°C (Figure 1). Water temperature minimum and maximum values for 2017 were slightly lower than that of both the 2016 and 2015 deployment seasons (Table 4).

Water temperatures were very stable at the beginning of deployment due to Reid Pond still being covered in ice. Temperatures started to steadily increase from the end of June onwards. By the end of July and throughout August, water temperatures were at their highest. Water temperatures started to decrease again in early September (Figure 1).

Please note that the stage data on the graph below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

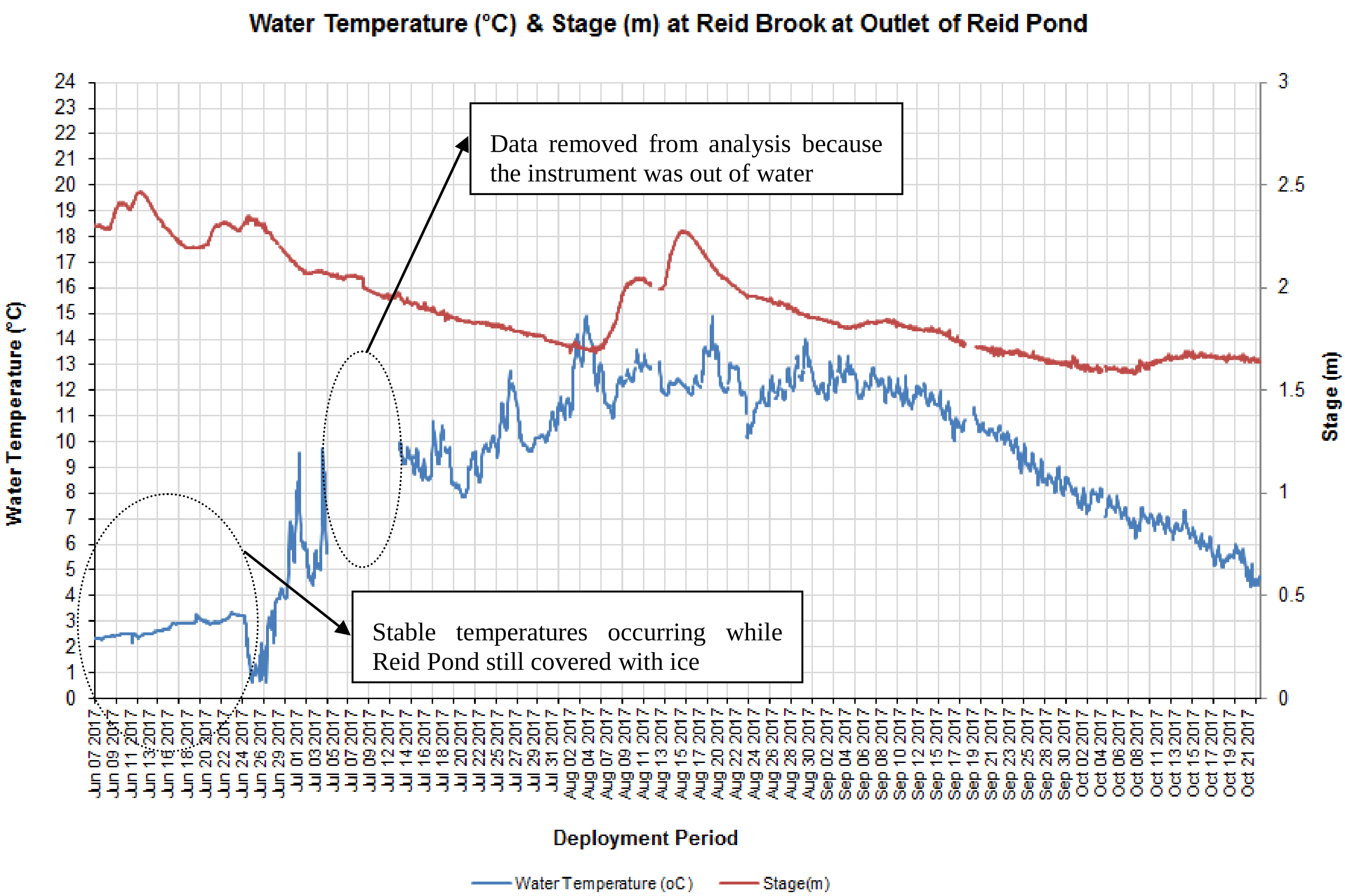

Figure 1: Water Temperature & Stage at Reid Brook at Outlet of Reid Pond

Table 4: Comparisons of Minimum, Maximum and Median from the past three deployment years

Water Temperature	2017	2016	2015
Min	0.6	1.47	2.51
Max	14.9	15.77	18.01
Median	9.53	9.79	9.5

Water temperatures show a close relationship with air temperature (Figure 2). Increases and decreases in air temperatures throughout 2017 were associated with similar changes in water temperature. Air temperatures clearly fluctuate at a greater scale each day when compared with water temperatures. This location is also less susceptible to extreme temperature fluctuations as Reid Pond is a larger body of water.

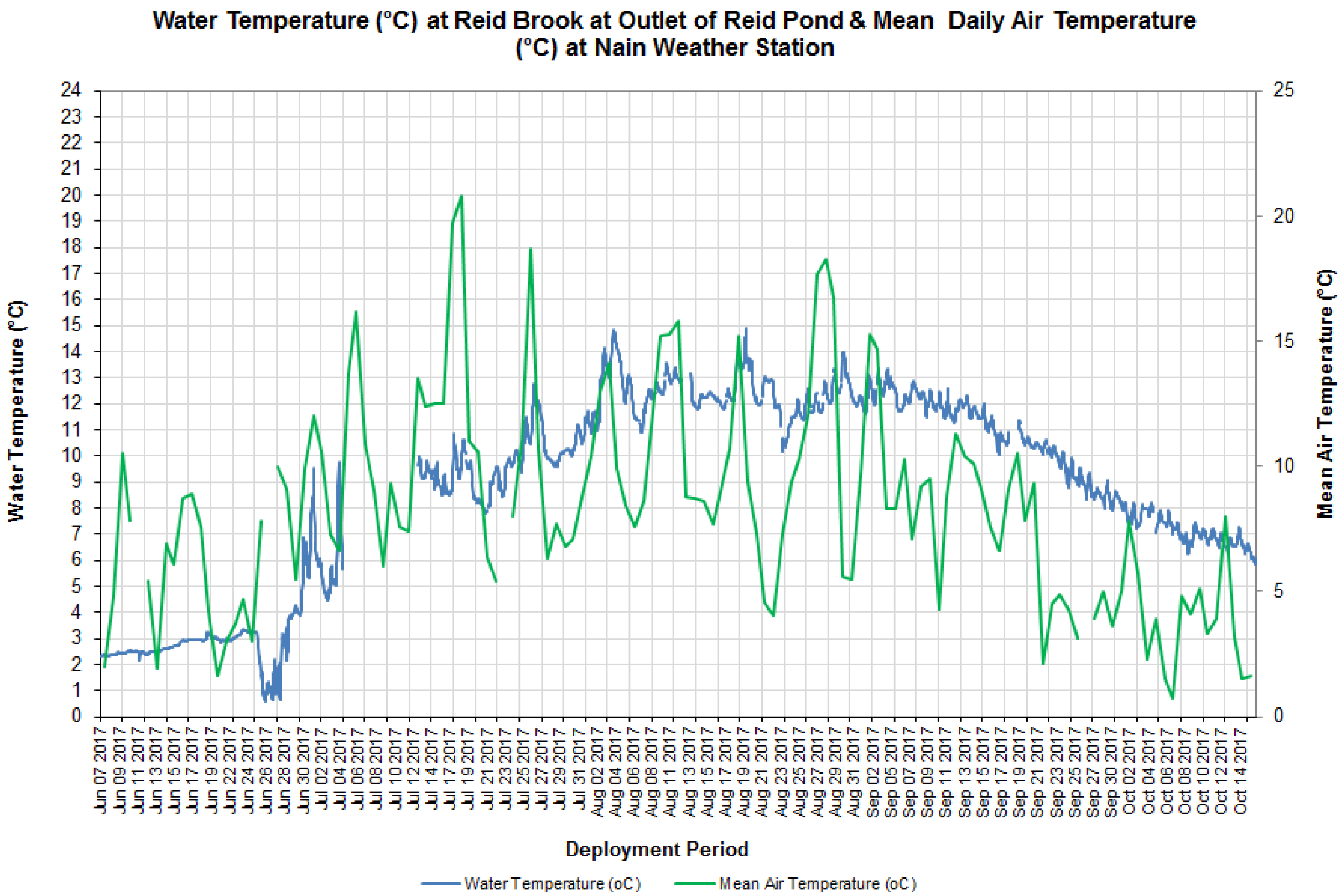

Figure 2: Water Temperature at Reid Brook at Outlet of Reid Pond & Mean Daily Air Temperature at Nain Weather Station

During the 2017 deployment season, pH ranged from 5.34 pH units to a maximum of 7.58 pH units (Table 5). This station is at the outlet of a pond and so pH data has a wider range compared to that of a stream or brook. In a pond environment, water parameters take longer to change after an influence; ponds have a larger volume of water and in turn have a slower turnover rate compared to streams or brooks.

Figure 3 displays the relationship between pH and stage; however, the true relationship between these parameters is difficult to see due to several occurrences of missing data. During the 2017 deployment season, pH did temporarily dip below the minimum CCME guideline.

Please note that the stage data on the graph below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

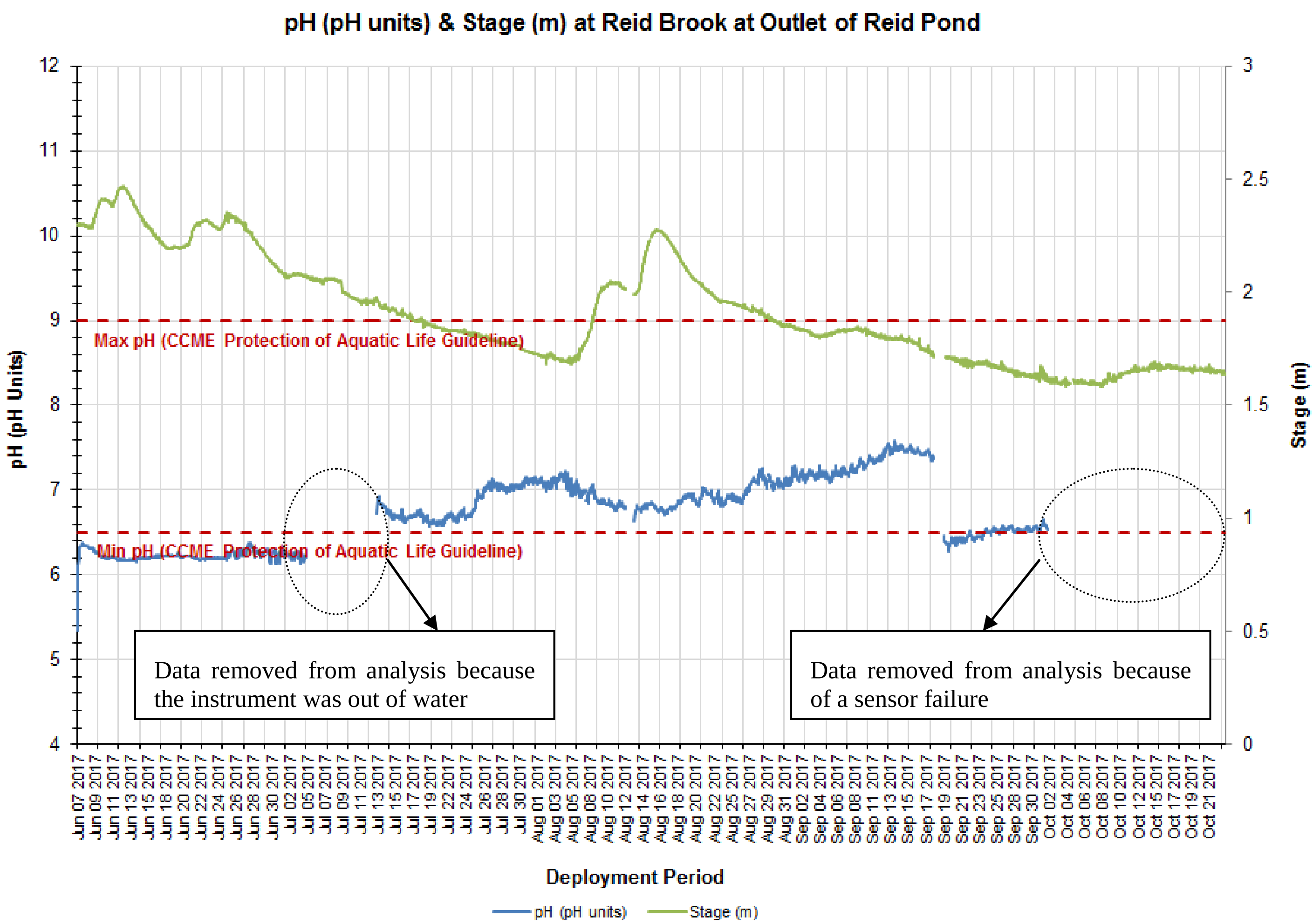

Figure 3: pH & Stage at Reid Brook at Outlet of Reid Pond

Table 5: Comparisons of Minimum, Maximum and Median from the past three deployment years

pH	2017	2016	2015
Min	5.34	6.08	4.83
Max	7.58	7.54	6.96
Median	6.78	6.72	6.05

During the 2017 deployment season, specific conductivity values ranged from 9.4µS/cm to a maximum of 22.3µS/cm. An overall conductivity median of 12.1µS/cm indicates that this station naturally has very low conductivity (Table 6).

Specific conductivity was low and stable throughout the deployment season with only minimal fluctuation, regardless of changing water levels (Figure 4). This trend is to be expected at this station, since it is located at the outflow of the stable lake environment of Reid Pond. There was some movement in specific conductivity near the end of June; this is generally the time of year when snow and ice melt, likely creating more runoff from the surrounding natural environment. There was more significant movement in specific conductivity towards the end of deployment, which may have been associated with increased rainfall and subsequent runoff.

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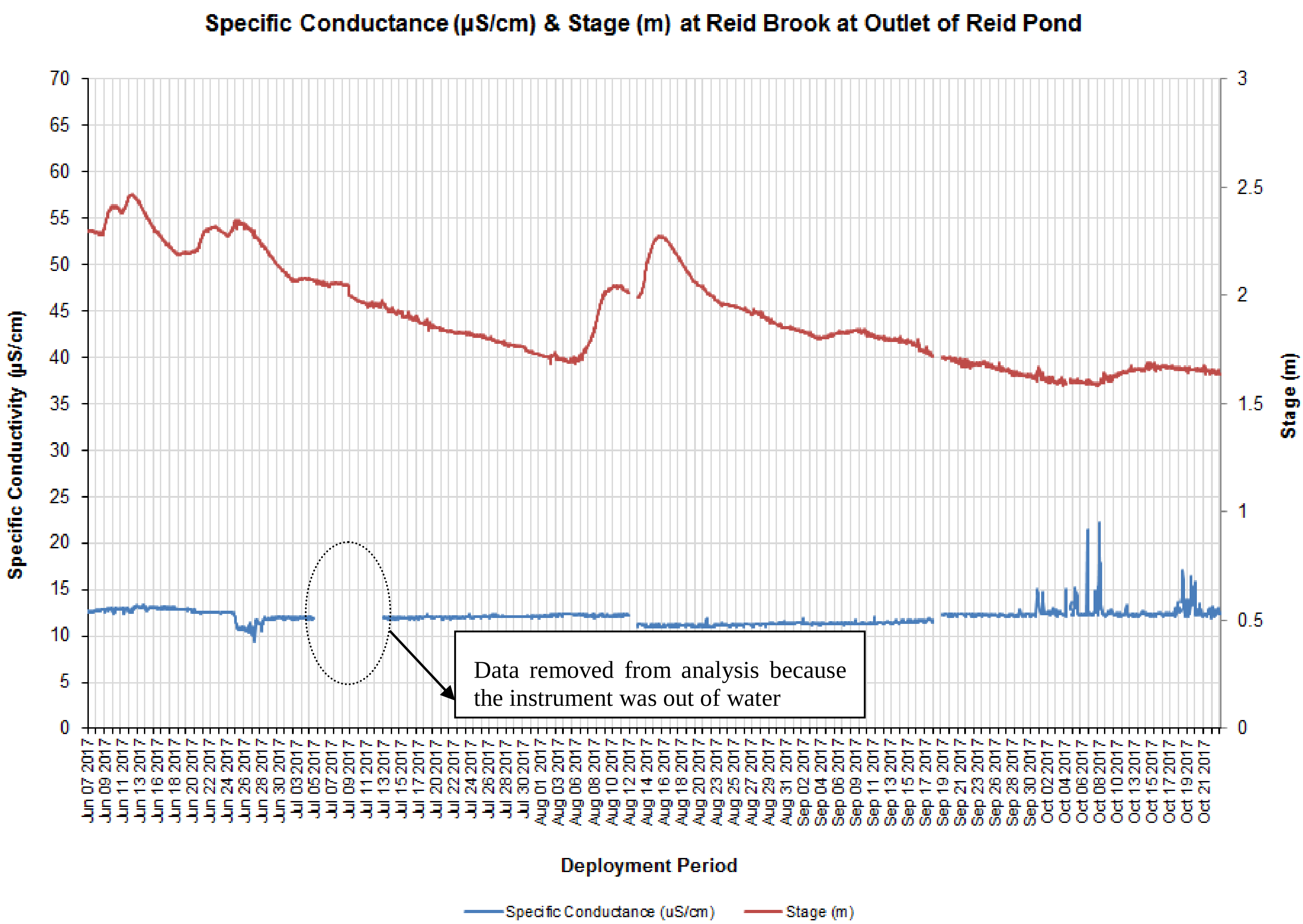

Figure 4: Specific Conductivity & Stage at Reid Brook at Outlet of Reid Pond

Table 6: Comparisons of Minimum, Maximum and Median from the past three deployment years

Specific Conductivity	2017	2016	2015
Min	9.4	9.1	11
Max	22.3	15.9	14
Median	12.1	11.6	12

During the 2017 deployment season, dissolved oxygen concentrations ranged from 10.22mg/L to a maximum of 12.39mg/L. The overall dataset had a median value of 11.265mg/L, which is lower than that of the 2016 deployment season. The saturation of dissolved oxygen ranged from 82.2% to 107.6%, with a median value of 97.1% (Table 7).

Dissolved oxygen content displayed typical seasonal fluctuation throughout the deployment season, and had an inverse relationship with changes in water temperature (Figure 5). Dissolved oxygen values were consistently high at the beginning of the deployment season when Reid Pond was covered by ice and water temperatures were low. Dissolved oxygen values decreased through July, and remained consistently low through the warmest part of the season in August and early September. Dissolved oxygen levels began to increase again in late September as water temperatures began to cool.

Dissolved oxygen values remained above the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5mg/l) and Early Life Stages (9.5mg/l) for the duration of the deployment season.

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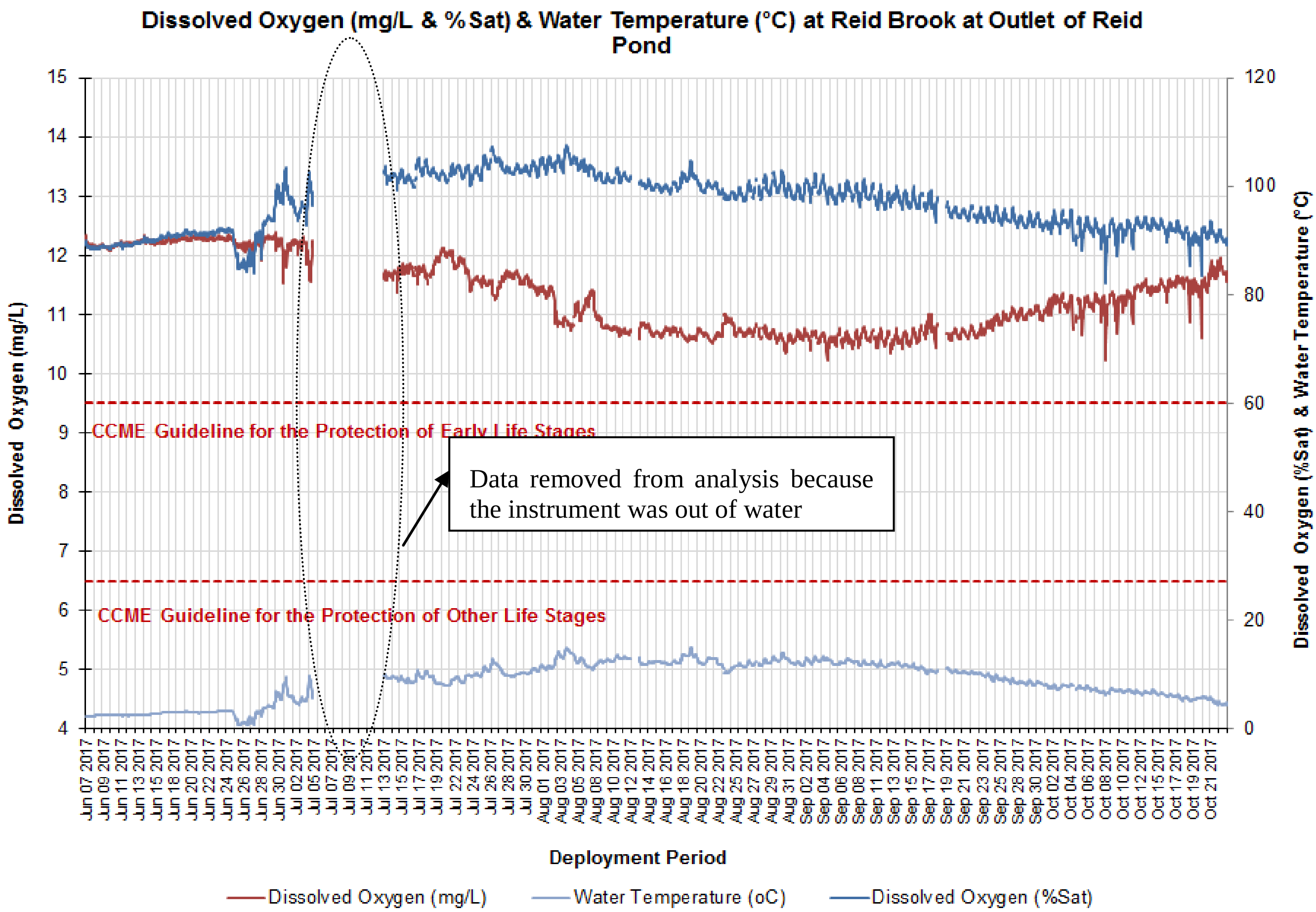

Figure 5: Dissolved Oxygen & Water Temperature at Reid Brook at Outlet of Reid Pond

Table 7: Comparisons of Minimum, Maximum and Median from the past three deployment years

Dissolved Oxygen (mg/L)	2017	2016	2015
Min	10.22	10.76	9.76
Max	12.39	12.46	12.36
Median	11.265	12.09	10.98

Percent Saturation (%)	2017	2016	2015
Min	82.2	95.9	92.6
Max	107.6	106.5	105.9
Median	97.1	97.9	98.1

During the 2017 deployment season, turbidity values ranged from 0NTU to a maximum of 78NTU. A median turbidity value of 0NTU indicates that there is very little natural background turbidity at this station (Table 8).

There was very little movement in turbidity values at this station over the course of deployment (Figure 6). This is to be expected, as this site is pristine in nature and far removed from the Voisey's Bay mine site.

Turbidity levels can be influenced by precipitation and corresponding runoff. It is common to see levels increase during these events and it is important that the turbidity levels return to natural levels after such events.

Please note that the stage data on the graph below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

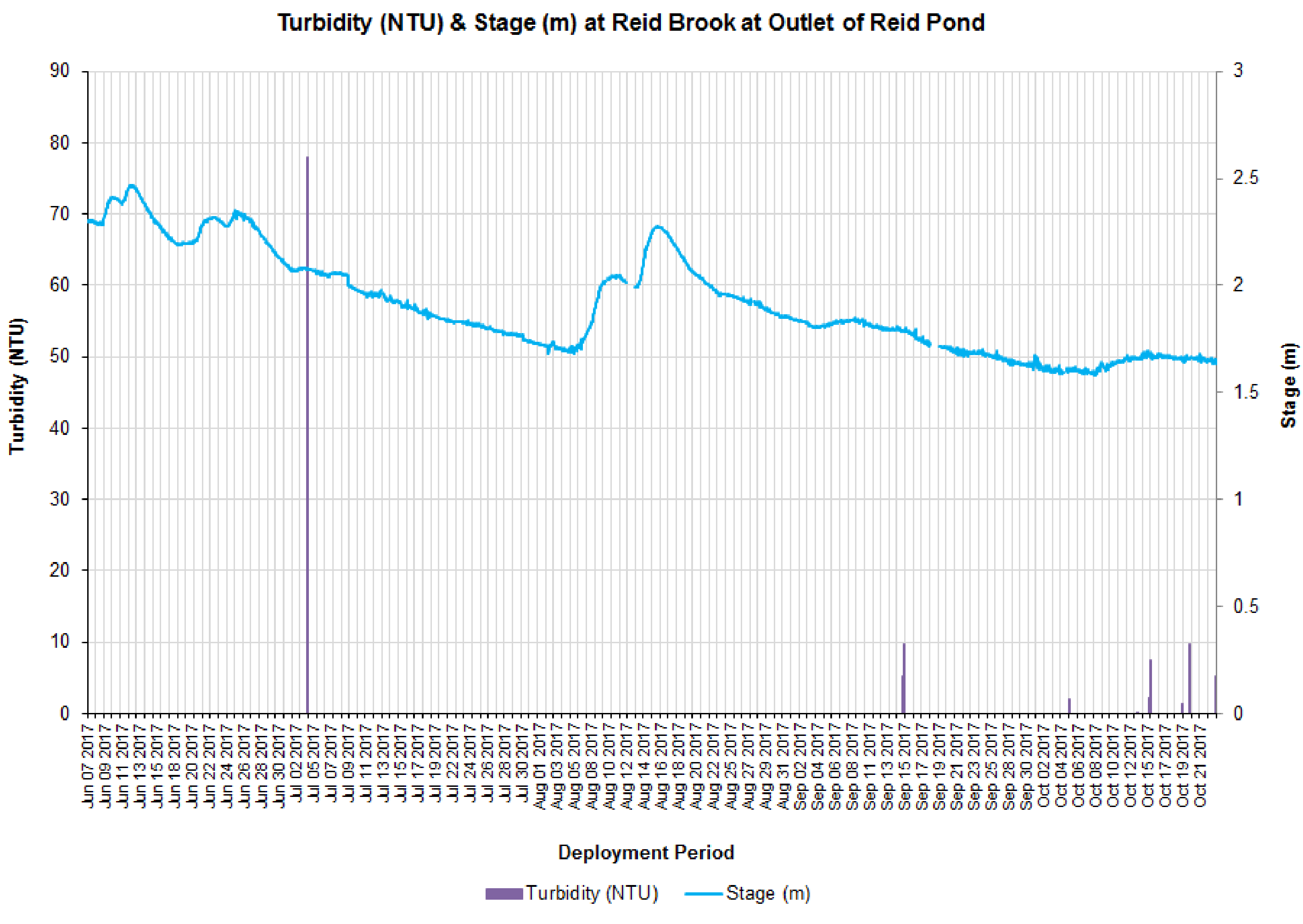

Figure 6: Turbidity & Stage at Reid Brook at Outlet of Reid Pond

Table 8: Comparisons of Minimum, Maximum and Median from the past three deployment years

Turbidity	2017	2016	2015
Min	0.0	0.0	0.0
Max	78	41.3	1.2
Median	0.0	0.2	0.0

Camp Pond Brook below Camp Pond

During the 2017 deployment season, water temperature ranged from 0.22°C to a maximum of 20.52°C. The median temperature of 11.86°C was similar to that of the 2016 deployment season (Table 9).

Water temperature peaked in early August, but remained high for most of the summer season (Figure 7). From September onwards, water temperatures decreased steadily as ambient air temperature also decreased (Figure 8).

Please note that the stage data on the graph below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

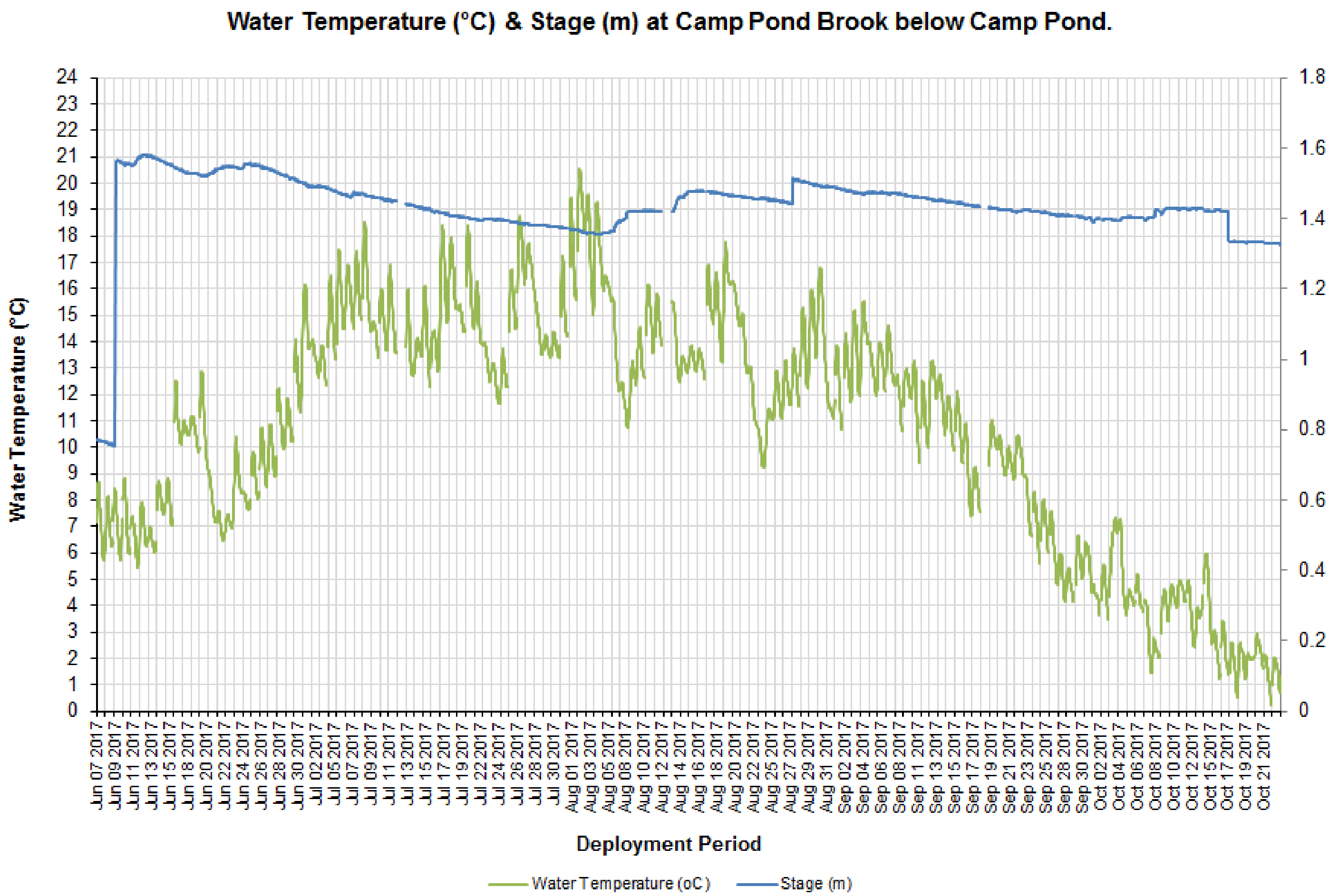

Figure 7: Water Temperature & Stage at Camp Pond Brook below Camp Pond

Water temperature values showed a close relationship with ambient air temperatures (Figure 8), and increases and decreases in air temperatures were reflected in similar changes in water temperatures. Air temperatures clearly fluctuate to a greater extent when compared with water temperatures.

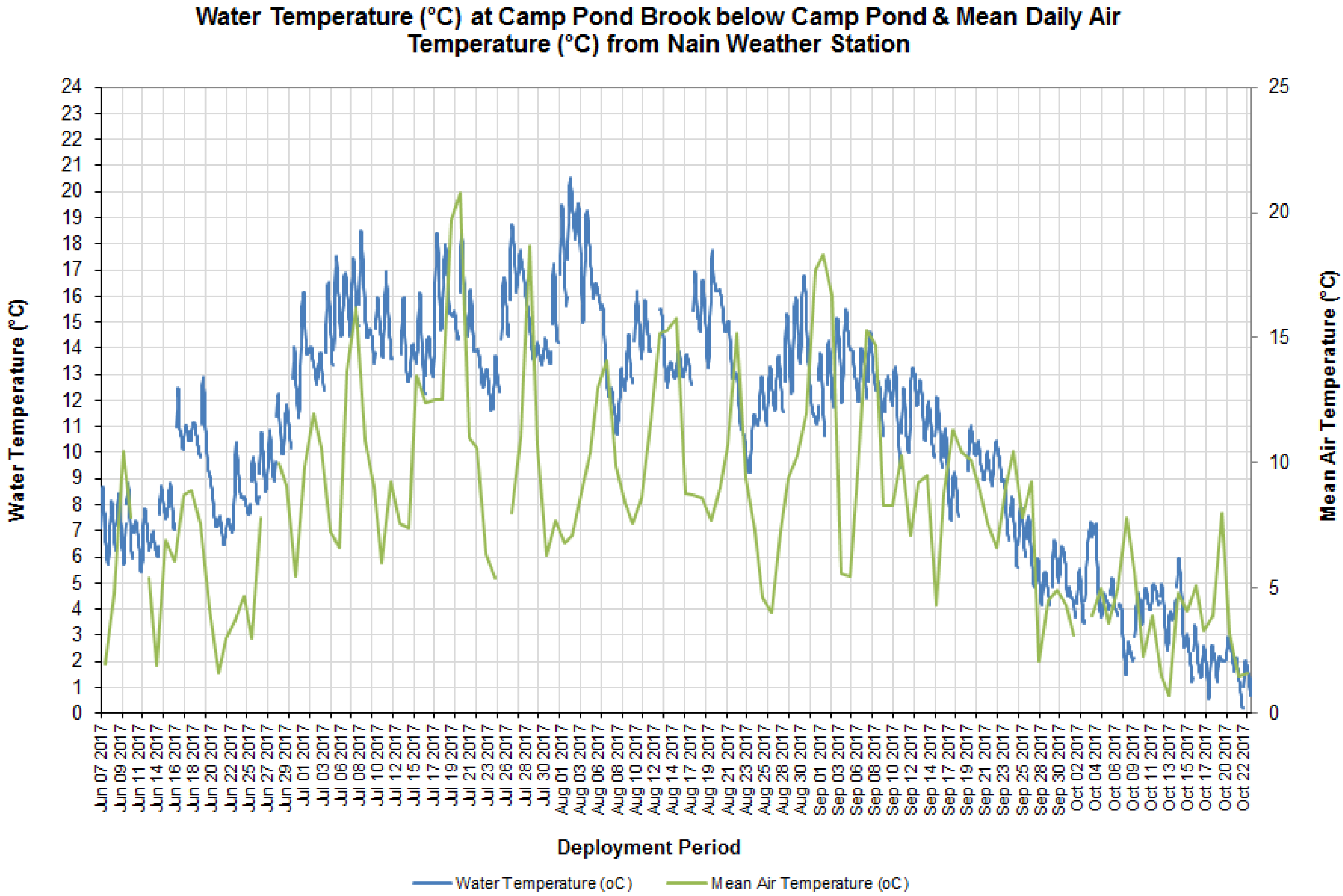

Figure 8: Water Temperature at Camp Pond Brook below Camp Pond & Mean Daily Air Temperature from Nain Weather Station

Table 9: Comparisons of Minimum, Maximum and Median from the past three deployment years

Water Temperature	2017	2016	2015
Min	0.22	0.07	0.38
Max	20.52	22.02	21.7
Median	11.86	12	11.95

During the 2017 deployment season, pH ranged from 6.02 to a maximum of 7.12 pH units. This year's median pH value of 6.87 was very similar to those from both 2016 (6.90 pH units) and 2015 (6.92 pH units) (Table 10).

Stage is included in the graph below to show the relationship between water level and pH values. Across the deployment season, pH data was reasonably stable. pH values were below the minimum CCME guidelines for a short period at the beginning of deployment, but increased through June and were within the Guidelines for the remainder of the deployment season (Figure 9).

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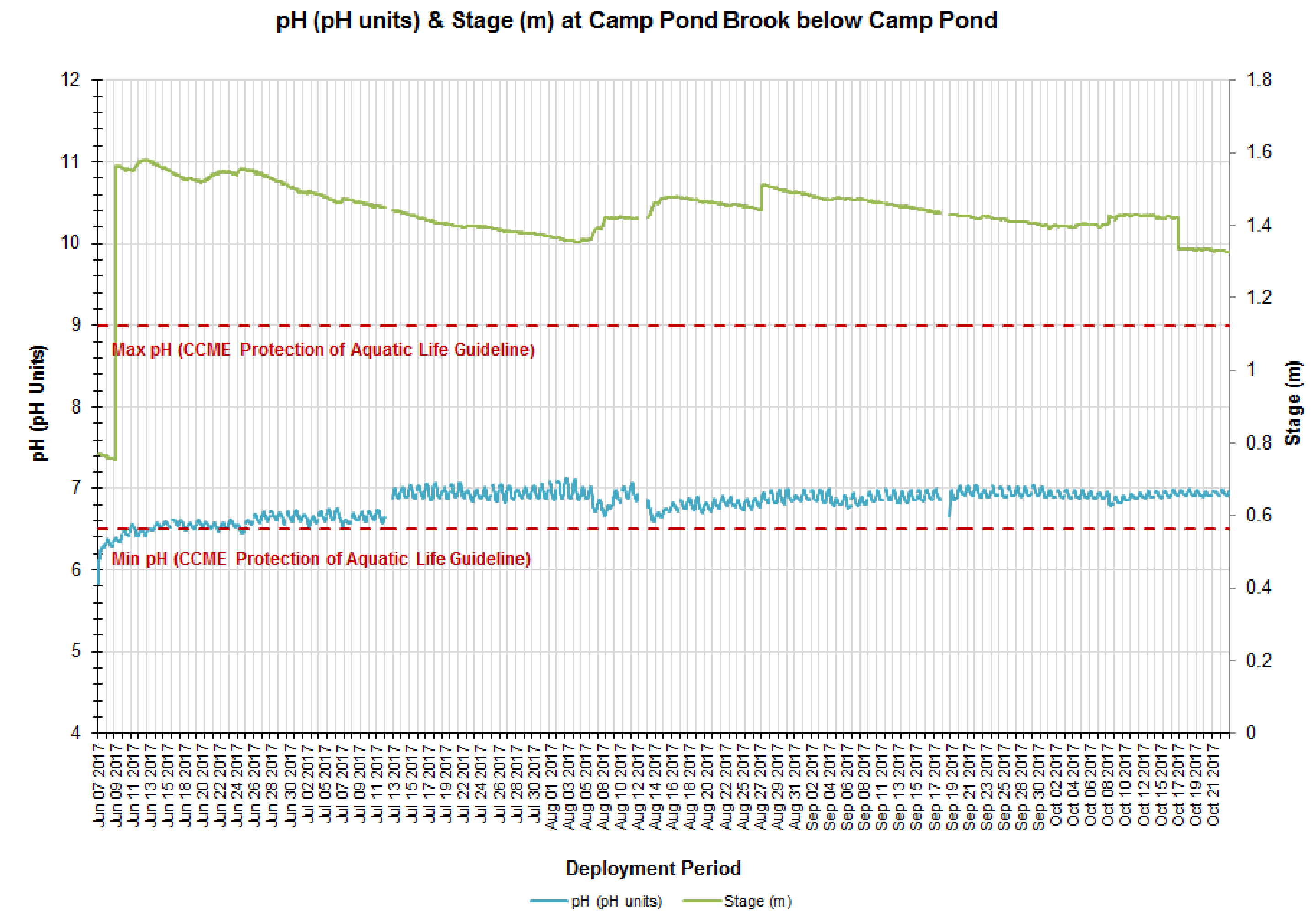

Figure 9: pH & Stage at Camp Pond Brook below Camp Pond

Table 10: Comparisons of Minimum, Maximum and Median from the past three deployment years

pH	2017	2016	2015
Min	6.02	6.54	6.21
Max	7.12	7.2	7.33
Median	6.87	6.90	6.92

During the 2017 deployment season, specific conductivity ranged from 21.2µS/cm to a maximum of 61.1µS/cm (Figure 10). This year's median value of 39.5µS/cm was slightly higher than the 2016 median of 38.2µS/cm (Table 11).

Stage is included in the graph below to illustrate the relationship between conductivity and water level (Figure 10). In general, stage and conductivity exhibit an inverse relationship: when one parameter increases, the other decreases. In some instances, however, sharp increases in stage correlate with similar increases in conductivity, which is likely due to increased rainfall and runoff. This site is in close proximity to the mine site and so is heavily influenced by runoff factors that the other Voisey's Bay real-time stations do not exhibit.

Over the entire deployment season, conductivity levels in Camp Pond Brook increased slightly, while stage decreased slightly. This relationship is to be expected as rainfall and bank runoff generally decrease as the winter season approaches.

Please note that the stage data on the graph below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

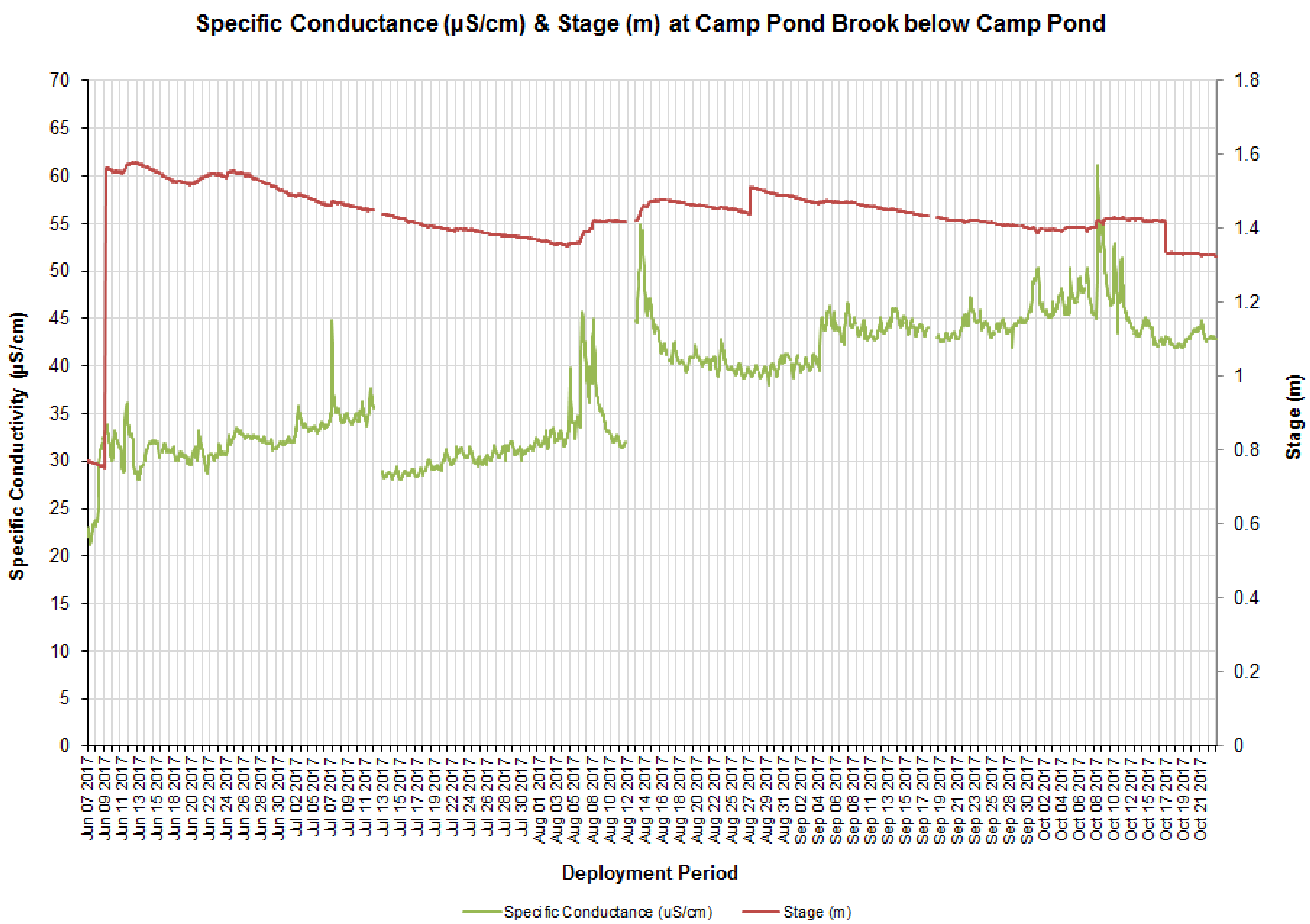

Figure 10: Specific Conductivity & Stage at Camp Pond Brook below Camp Pond

Table 11: Comparisons of Minimum, Maximum and Median from the past three deployment years

Specific Conductivity	2017	2016	2015
Min	21.2	28.7	30.3
Max	61.1	64.0	55.5
Median	39.5	38.2	34.8

During the 2017 deployment season, dissolved oxygen concentrations ranged from 8.61mg/L to a maximum of 13.6mg/L, with a median value of 10.37mg/L that was comparable to the 2016 median of 10.00mg/L. The saturation of dissolved oxygen ranged from 87.7% to 103.9%, with a median value of 94.9% (Table 12).

Dissolved oxygen concentrations exhibited typical seasonal trends, and were inversely related to water temperature. Dissolved oxygen concentrations were lowest throughout July and most of August when water temperatures were warmest. As water temperatures decreased into late summer and early fall, dissolved oxygen concentrations began to increase. Frequent fluctuations in dissolved oxygen levels are consistent with smaller daily changes in water temperature (Figure 11).

Dissolved oxygen concentrations occasionally dipped below the CCME Guideline for the Protection of Aquatic Life at Early Life Stages (9.5mg/L) from early July through late August; however, these dips corresponded with increased water temperatures during the same time frames.

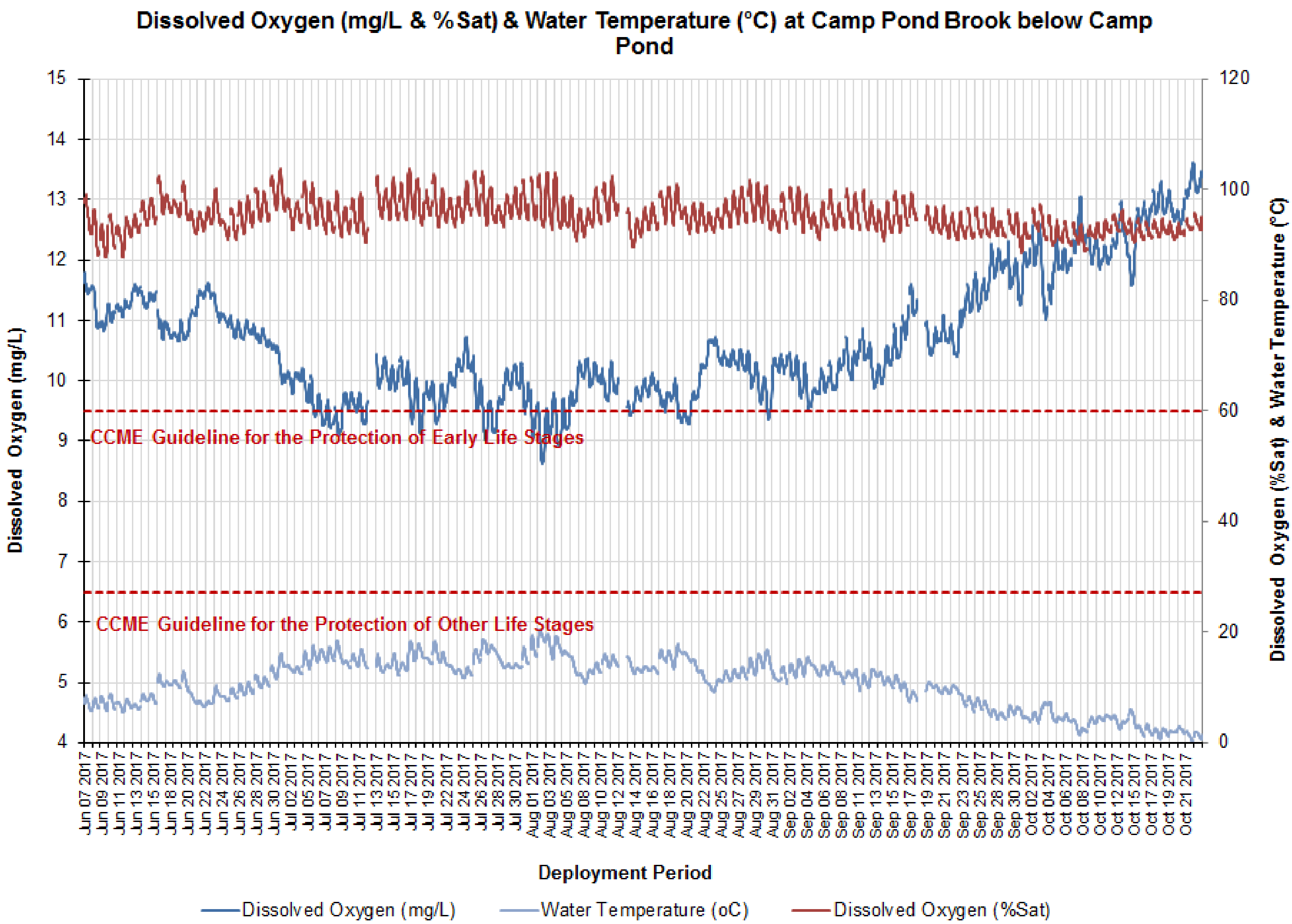

Figure 11: Dissolved Oxygen & Water Temperature at Camp Pond Brook below Camp Pond

Table 12: Comparisons of Minimum, Maximum and Median from the past three deployment years

Dissolved Oxygen (mg/L)	2017	2016	2015
Min	8.61	8.22	8.51
Max	13.6	14.03	11.55
Median	10.37	10	10.03

Percent Saturation (%)	2017	2016	2015
Min	87.7	87.9	89.3
Max	103.9	103.3	102.2
Median	94.9	93.7	95.2

During the 2017 deployment season, turbidity values ranged from 0.0NTU to a maximum of 1509NTU, with a median value of 1.7NTU (Figure 12). A median value of 1.7NTU indicates that there is a small amount of natural background turbidity at this station. Turbidity values at this station have been fairly consistent over recent deployment seasons (Table 13).

While there were a number of turbidity spikes throughout the deployment season, the majority of observed increases corresponded with precipitation events. With the exception of an event on August 6, 2017, all turbidity events were low in magnitude and short in duration.

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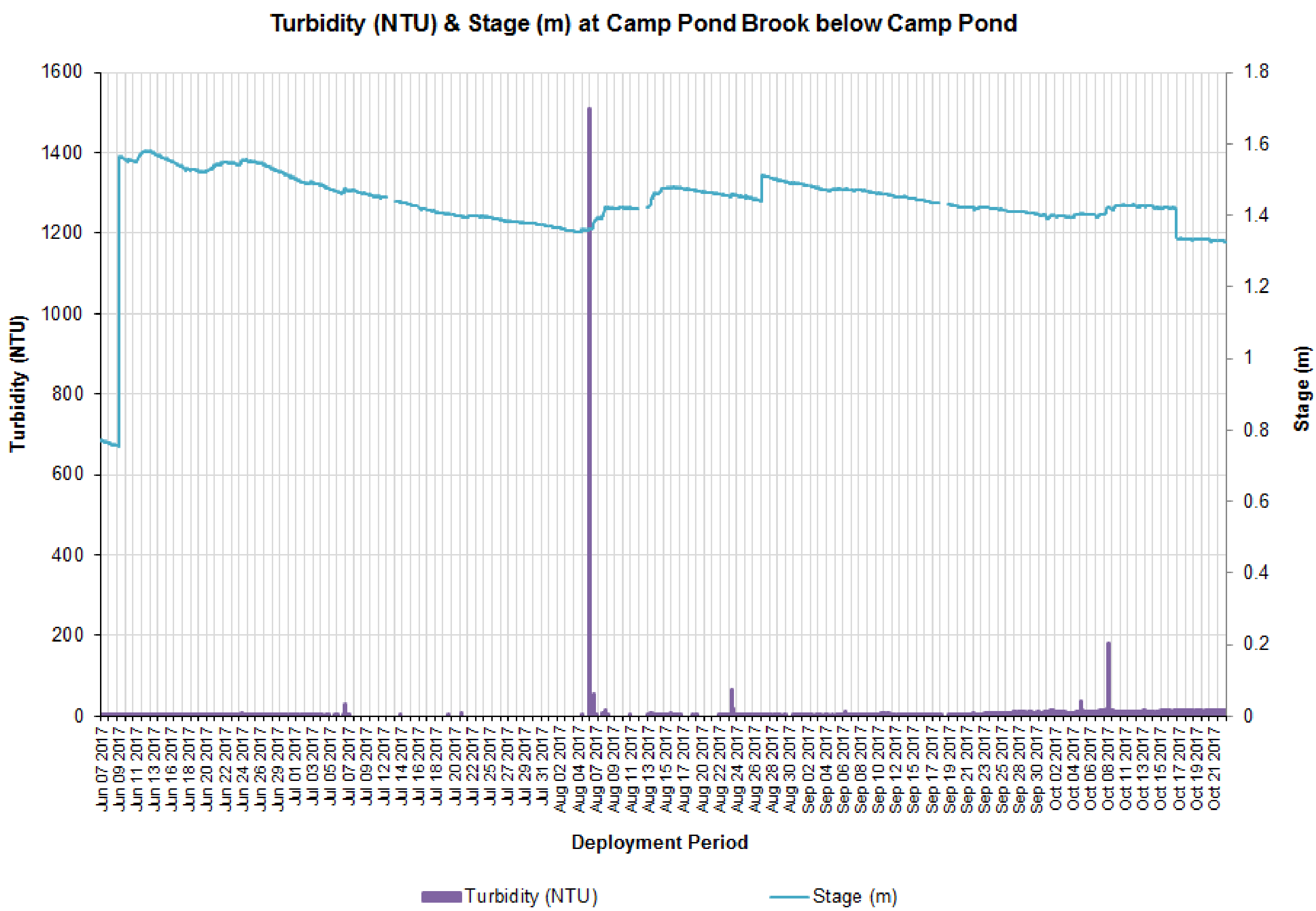

Figure 12: Turbidity & Stage at Camp Pond Brook below Camp Pond

Table 13: Comparisons of Minimum, Maximum and Median from the past three deployment years

Turbidity	2017	2016	2015
Min	0.0	0.0	0.0
Max	1509	3.5	31.5
Median	1.7	0.0	0.0

Tributary to Reid Brook

During the 2017 deployment season, water temperature ranged from 0.0°C to a maximum of 14.5°C, with a median value of 9.3°C (Table 14). Water temperatures were highest in July and early August as air temperatures increased with the summer season. From the end of August onwards, water temperatures steady declined as ambient air temperatures also declined (Figure 13 & 14).

Water temperatures have been very consistent at this station over recent years. The median water temperature value was 9.3°C for both 2017 and 2016 (Table 14).

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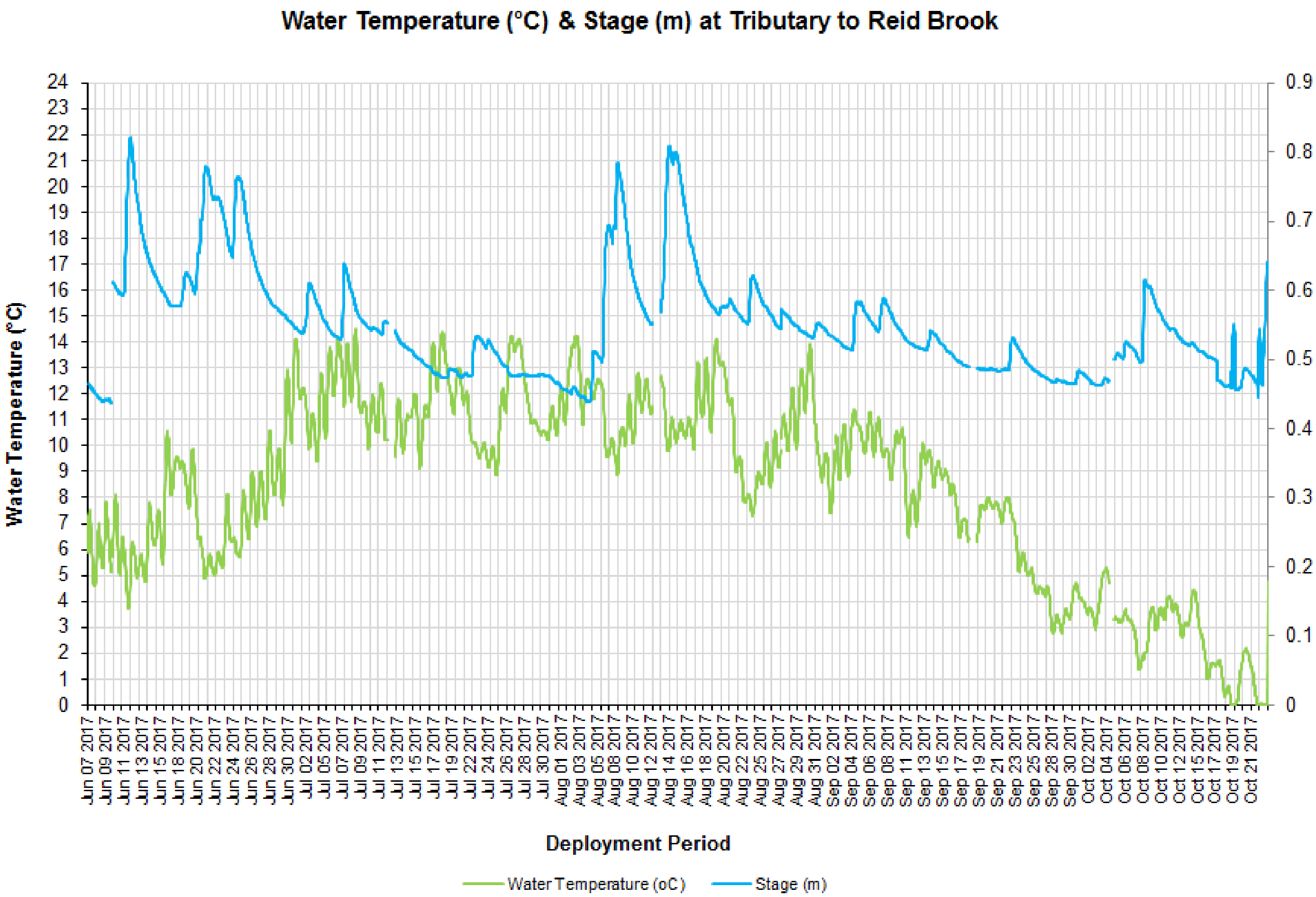

Figure 13: Water Temperature & Stage at Tributary to Reid Brook

Table 14: Comparisons of Minimum, Maximum and Median from the past three deployment years

Water Temperature	2017	2016	2015
Min	0	0.0	0.0
Max	14.5	15.7	15.7
Median	9.3	9.3	9.1

Water temperature values closely correlated with ambient air temperatures; increases and decreases in ambient air temperatures were reflected in water temperatures (Figure 14). Air temperatures fluctuate to a greater extent each day as compared to water temperatures.

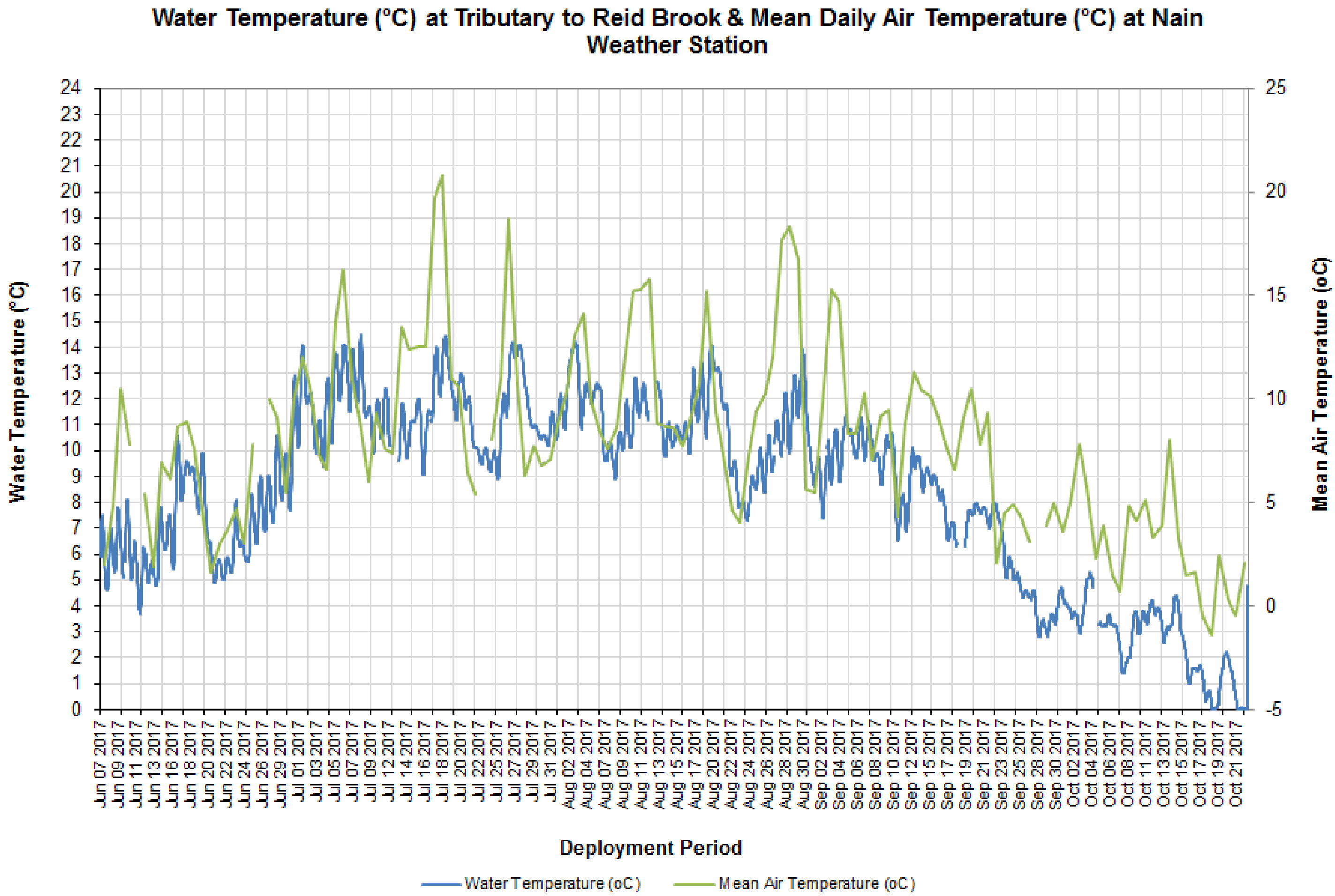

Figure 14: Water Temperature at Tributary to Reid Brook & Mean Daily Air Temperature at Nain Weather Station

During the 2017 deployment season, pH ranged from 6.11 pH units to a maximum of 7.09 pH units, with a median value of 6.74 (Figure 15). pH data at this station has been consistent over recent years with median values of 6.78 in 2015 and 6.89 in 2016 (Table 15).

Stage data is included in Figure 15 to show how stage influences pH over time. In general, as stage increases pH decreases, and vice versa. This is a normal relationship and is expected in brooks.

pH values at this site were within the CCME Guidelines for the Protection of Aquatic Life for the majority of the deployment season. On several occasions, pH values fell below the suggested minimum guideline; however, most of these events correlated with high stage levels.

Please note that the stage data on the graph below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

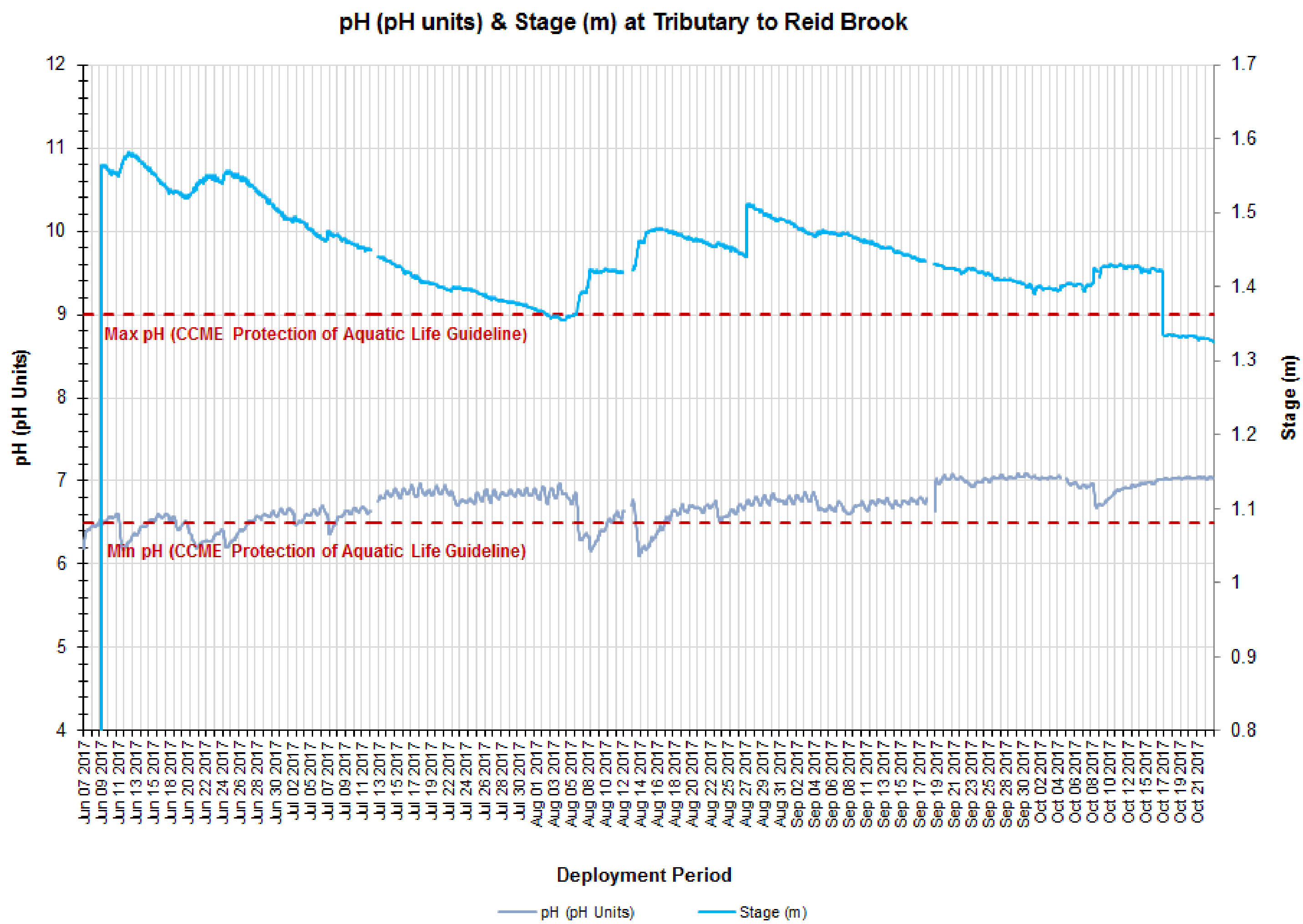

Figure 15: pH & Stage at Tributary to Reid Brook

Table 15: Comparisons of Minimum, Maximum and Median from the past three deployment years

pH	2017	2016	2015
Min	6.11	6.08	5.66
Max	7.09	7.22	7.09
Median	6.74	6.89	6.78

During the 2017 deployment season, specific conductivity levels ranged from 2.5µS/cm to a maximum of 40.9µS/cm, with a median value of 28.6µS/cm (Figure 16). Specific conductivity levels have been consistent at this site over recent years, with median values of 34.9µS/cm in 2016 and 32.2µS/cm in 2016 (Table 16).

Specific conductivity changes with varying water levels: as stage increases, specific conductivity decreases. This is due to dilution of dissolved solids in the water column; as stage decreases, the concentration of dissolved solids increases, in turn increasing specific conductivity.

Please note that the stage data on the graph below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

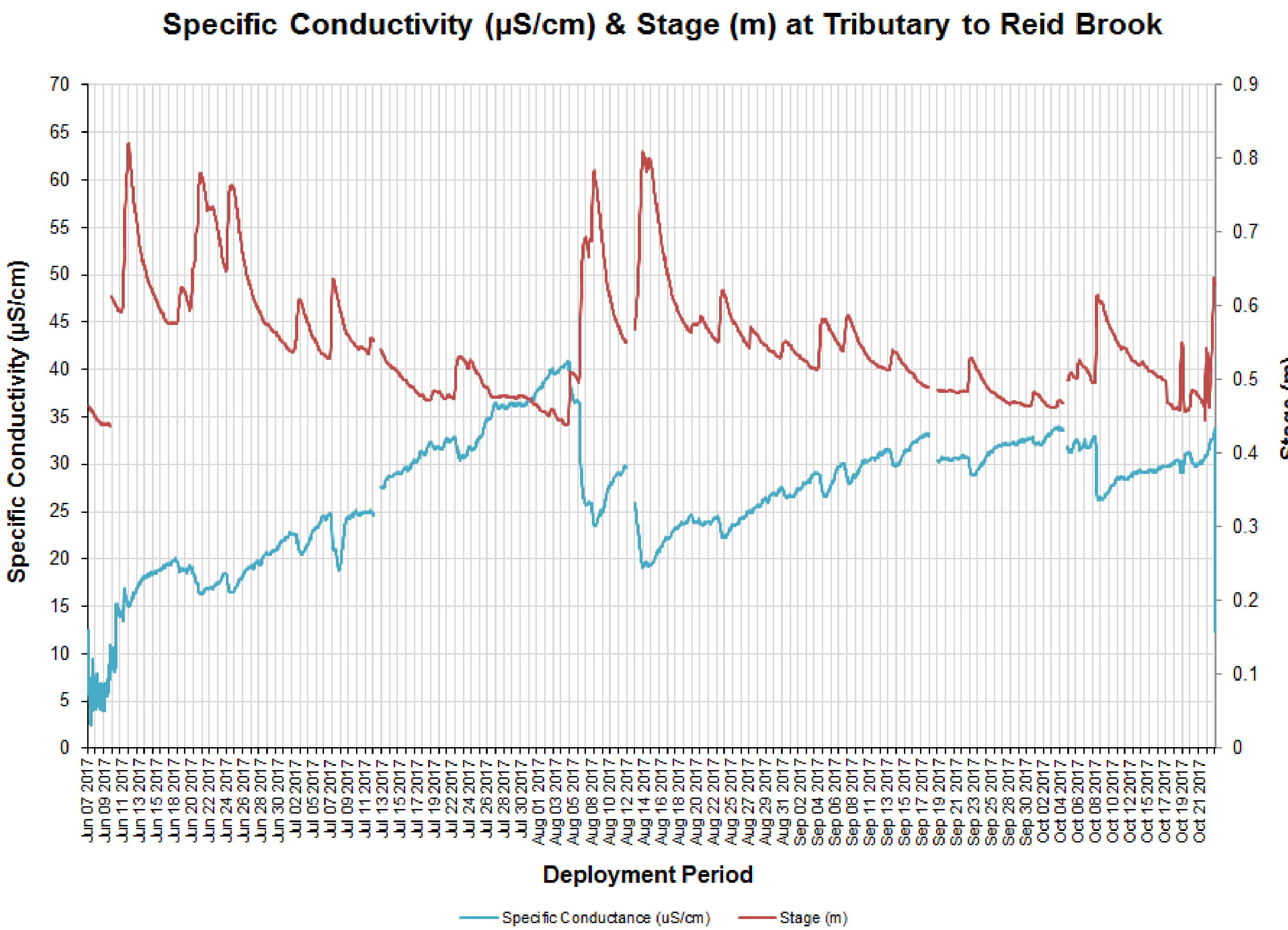

Figure 16: Specific Conductivity & Stage at Tributary to Reid Brook

Table 16: Comparisons of Minimum, Maximum and Median from the past three deployment years

Specific Conductivity	2017	2016	2015
Min	2.5	22.1	16.6
Max	40.9	44	41.4
Median	28.6	34.9	32.2

During the 2017 deployment season, dissolved oxygen concentrations ranged from 9.66mg/L to a maximum of 14.19mg/L, with a median value of 11.04mg/L. The saturation of dissolved oxygen ranged from 90.5% to 100.6%, with a median value of 95.8% (Figure 17). Dissolved oxygen values have been very consistent at this site over recent years (Table 17).

Dissolved oxygen concentrations were lowest through July and August when water temperatures were highest. Increases in water temperature result in less dissolved oxygen being present in a water body. As water temperatures started to decrease from the end of August onwards, dissolved oxygen concentrations started to increase.

Dissolved oxygen concentrations remained above the CCME Guideline for the Protection of Early Life Stages (9.5mg/L) for the duration of the deployment season.

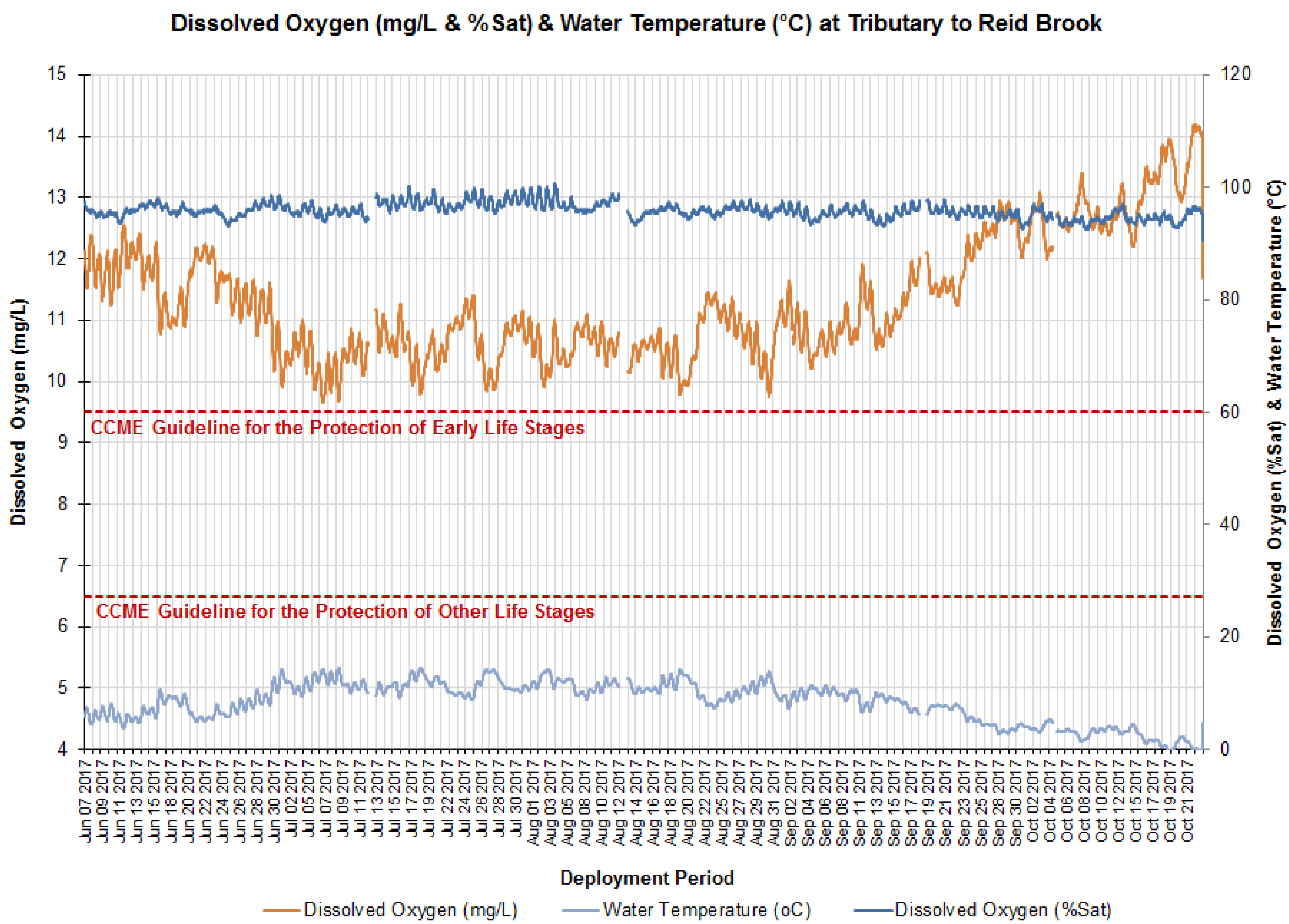

Figure17: Dissolved Oxygen (mg/L & %Sat) & Water Temperature at Tributary to Reid Brook

Table 17: Comparisons of DO (mg/L) Minimum, Maximum and Median from the past three deployment years

Dissolved Oxygen (mg/L)	2017	2016	2015
Min	9.66	9.29	9.63
Max	14.19	14.21	12.65
Median	11.04	11.01	11.05

Percent Saturation (%)	2017	2016	2015
Min	90.5	92.8	91.6
Max	100.6	100.4	100.8
Median	95.8	96.9	97.0

During the 2017 deployment season, turbidity ranged from 0.0NTU to a maximum of 287.2NTU, with a median value of 0.0NTU (Figure 18). Turbidity data has been very consistent at this site over recent years, with the median value for both 2016 and 2015 being 0.0NTU (Table 18).

Many of the turbidity increases at this site corresponded with rainfall events and subsequent runoff. Observed turbidity events were generally low in magnitude and short in duration. It is not uncommon to see turbidity fluctuate in a brook relating to environmental factors, such as changes in stage level, flow rates and precipitation.

Please note that the stage data on the graph below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

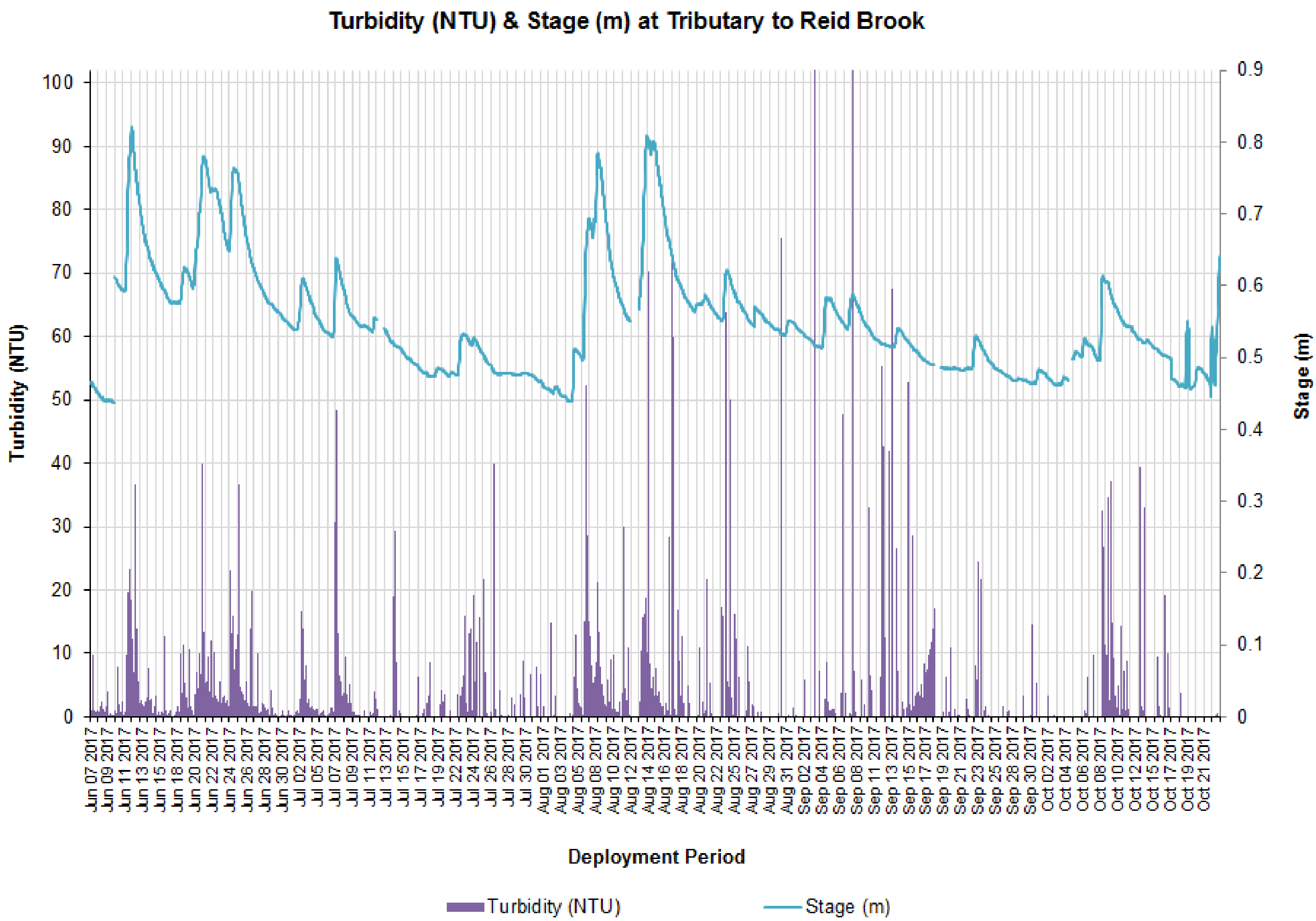

Figure 18: Turbidity & Stage at Tributary to Reid Brook

Table 18: Comparisons of Minimum, Maximum and Median from the past three deployment years

Turbidity	2017	2016	2015
Min	0.0	0.0	0.0
Max	287.2	100.2	738
Median	0.0	0.0	0.0

Reid Brook below Tributary

During the 2017 deployment season, water temperature ranged from 0.17°C to a maximum of 16.81°C, with a median value of 9.21°C (Figure 19). Water temperature at this site has been quite consistent over recent years, with median values of 9.52°C in 2016 and 9.39°C in 2015 (Table 19).

Please note that the stage data on the graph below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

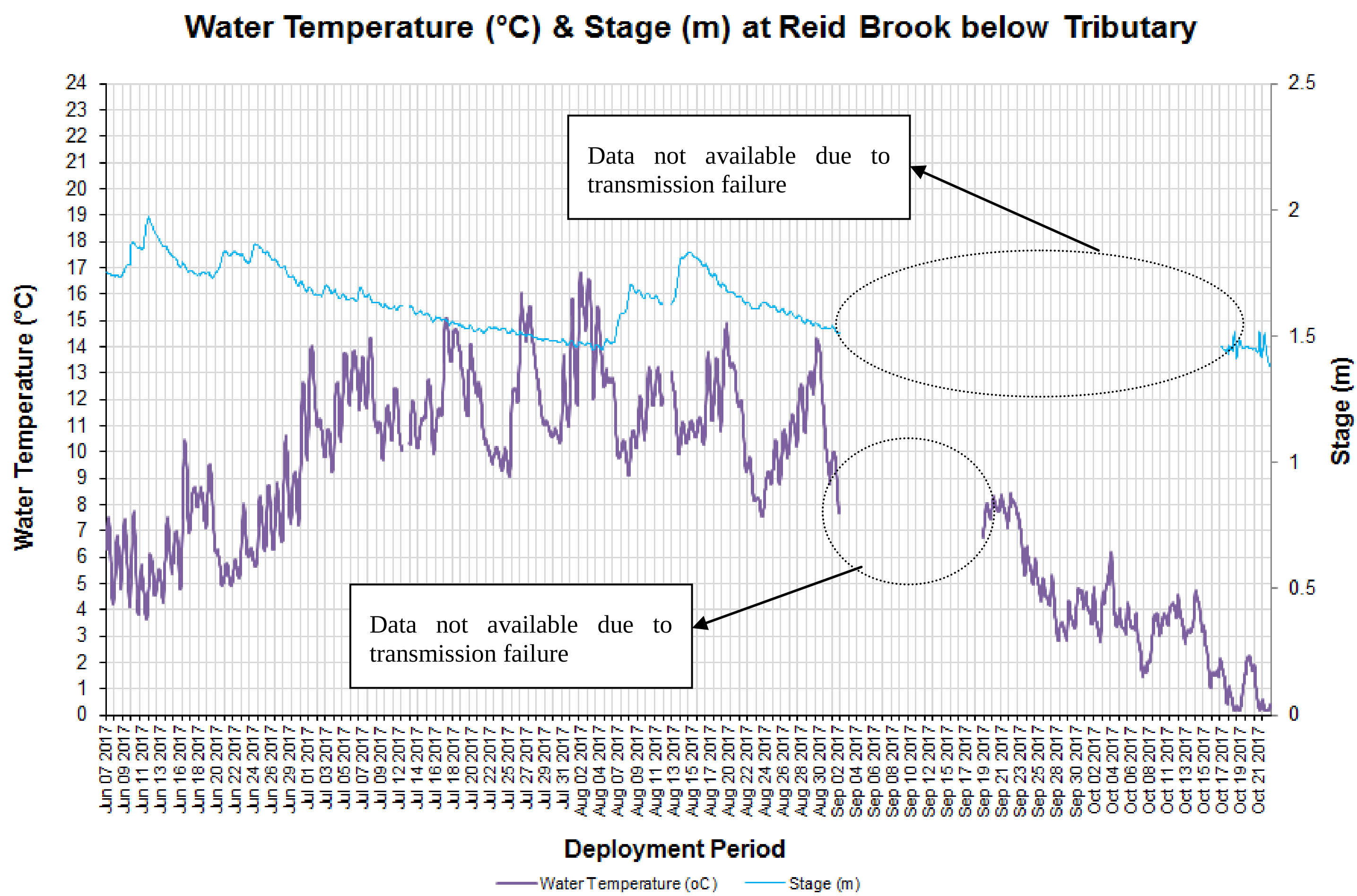

Figure 19: Water Temperature & Stage at Reid Brook below Tributary

Table 19: Comparisons of Minimum, Maximum and Median from the past three deployment years

Water Temperature	2017	2016	2015
Min	0.17	0.19	0.16
Max	16.81	17.34	16.11
Median	9.21	9.52	9.39

Water temperature values showed a close relationship with air temperatures (Figure 20). Increases and decreases in air temperatures were reflected in water temperatures. Air temperatures clearly fluctuate to a greater extent each day when compared with water temperatures.

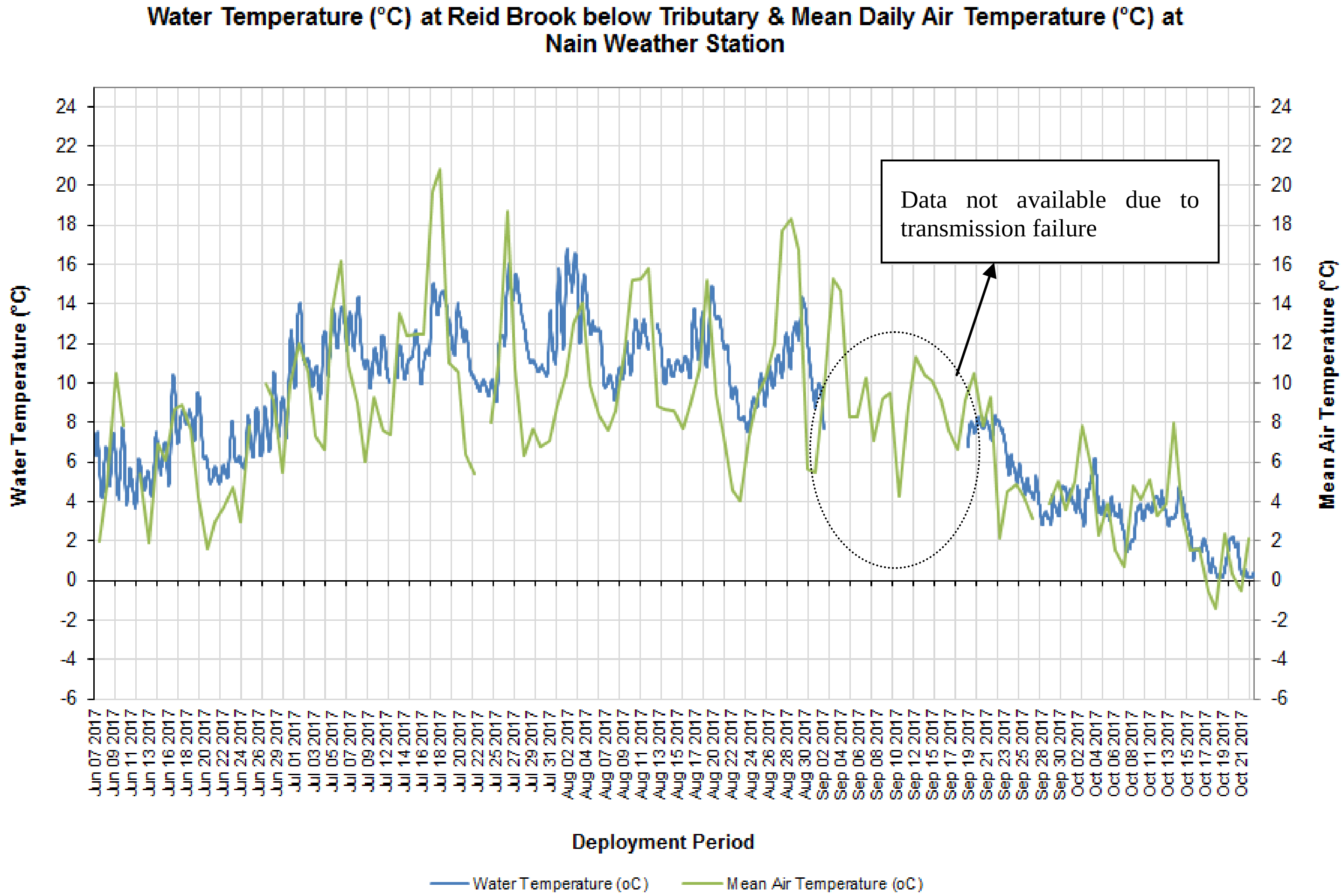

Figure 20: Water Temperature at Reid Brook below Tributary & Mean Daily Air Temperature at Nain Weather Station

During the 2017 deployment season, pH data ranged from 6.06 to a maximum of 7.48 pH units, with a median value of 6.85 pH units (Table 20).

pH values were within the CCME Guidelines for the Protection of Aquatic Life (>6.5 and <9.0 pH units) for most of the deployment season. pH values from the first deployment period were lower than during other deployments, and fluctuated above and below the suggested minimum pH value of 6.5 (Figure 21).

Please note that the stage data on the graph below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

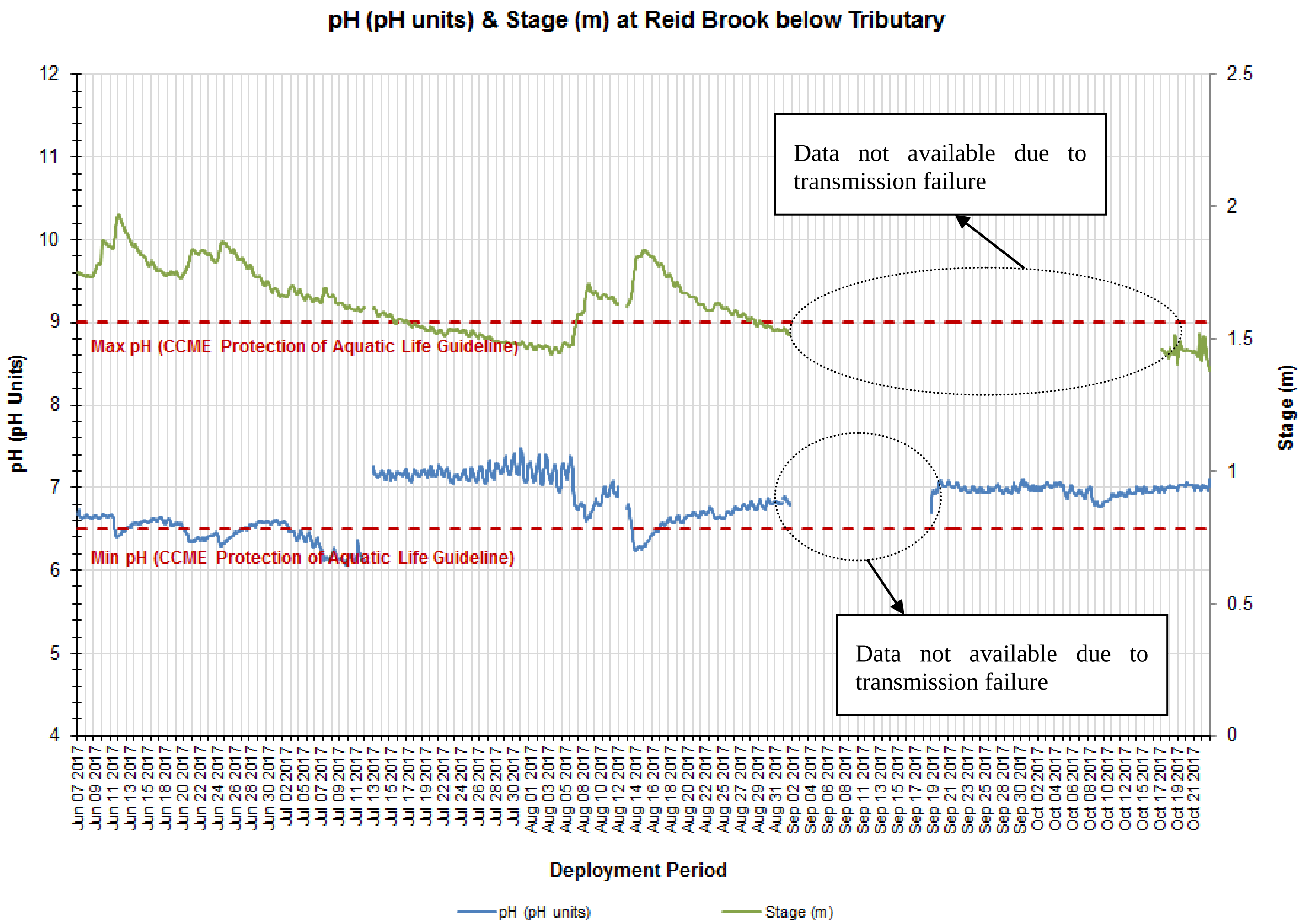

Figure 21: pH & Stage at Reid Brook below Tributary

Table 20: Comparisons of Minimum, Maximum and Median from the past three deployment years

pH	2017	2016	2015
Min	6.06	6.31	5.79
Max	7.48	7.58	9.8
Median	6.85	6.72	6.89

During the 2017 deployment season, specific conductivity ranged from 16.1µS/cm to a maximum of 43µS/cm, with a median value of 28.7µS/cm (Table 21).

Specific conductivity generally increased over the course of deployment, exhibiting an inverse relationship with stage. As stage level increased at this station, specific conductivity decreased. Increases in stage level dilute dissolved solids in the water column, in turn reducing specific conductivity. Inversely, as stage decreases, specific conductivity increases due to dissolved solids becoming more concentration in the water column (Figure 22).

Please note that the stage data on the graph below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

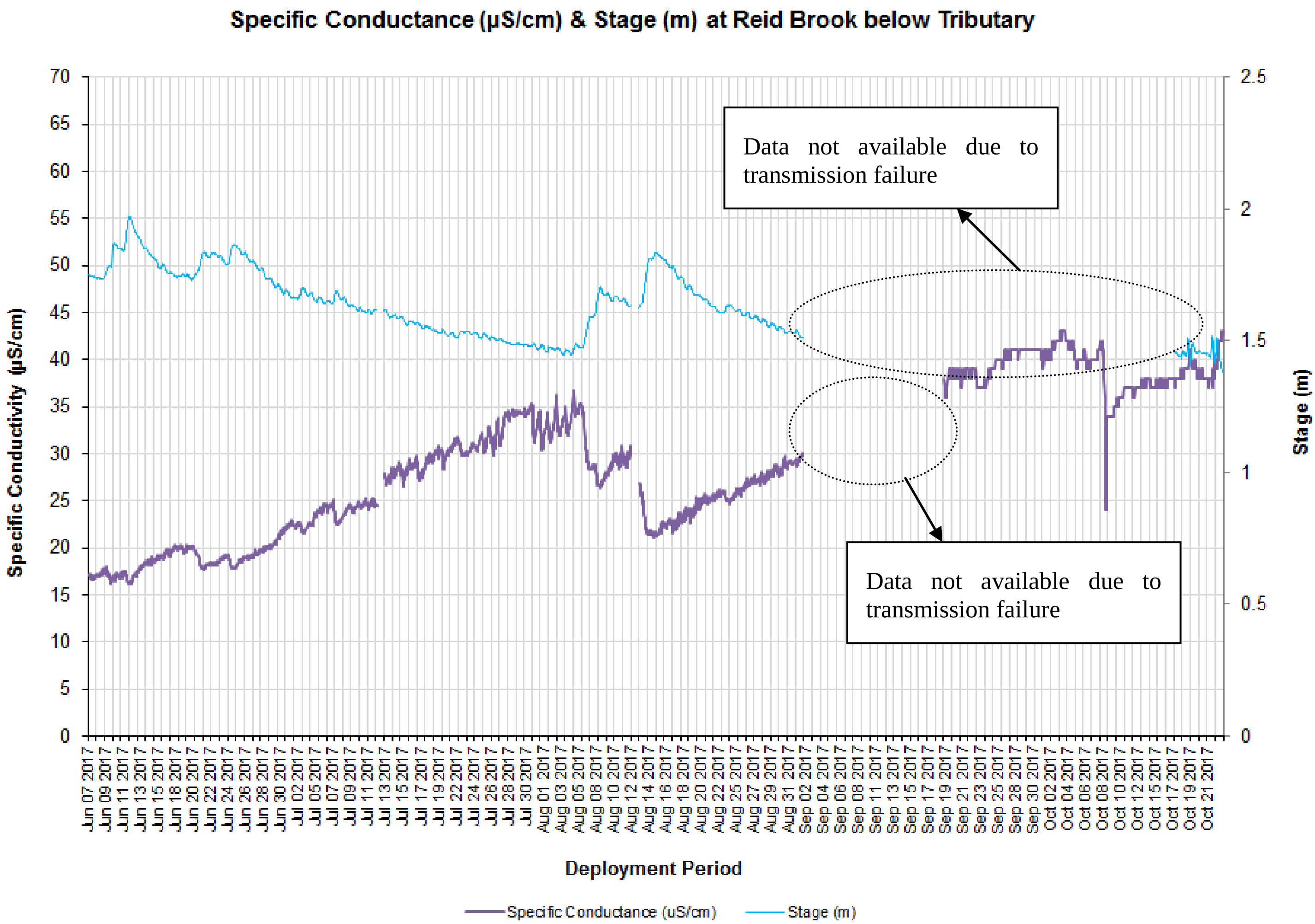

Figure 22: Specific Conductivity & Stage at Reid Brook below Tributary

Table 21: Comparisons of Minimum, Maximum and Median from the past three deployment years

Specific Conductivity	2017	2016	2015
Min	16.1	18.5	15.7
Max	43	44.9	38.5
Median	28.7	32.2	28.9

During the 2017 deployment season, dissolved oxygen concentration ranged from 9.78mg/L to a maximum of 13.56mg/L, with a median value of 11.22mg/L. The saturation of dissolved oxygen ranged from 89.4% to 108.9%, with a median value of 96.8% (Figure 23). Median values for both dissolved oxygen concentration and percent saturation were consistent with values from previous deployment seasons (Table 22).

Observed dissolved oxygen concentrations exhibited typical seasonal trends and were inversely related to water temperature. Dissolved oxygen content decreased through June as water temperatures warmed, was lowest throughout July and August, and began to increase again through September and October as water temperature decreased (Figure 23).

Dissolved oxygen concentrations remained above the CCME Guidelines for the Protection of Other Life Stages (6.5mg/L) and Early Life Stages (9.5mg/L) for the duration of the 2017 deployment season.

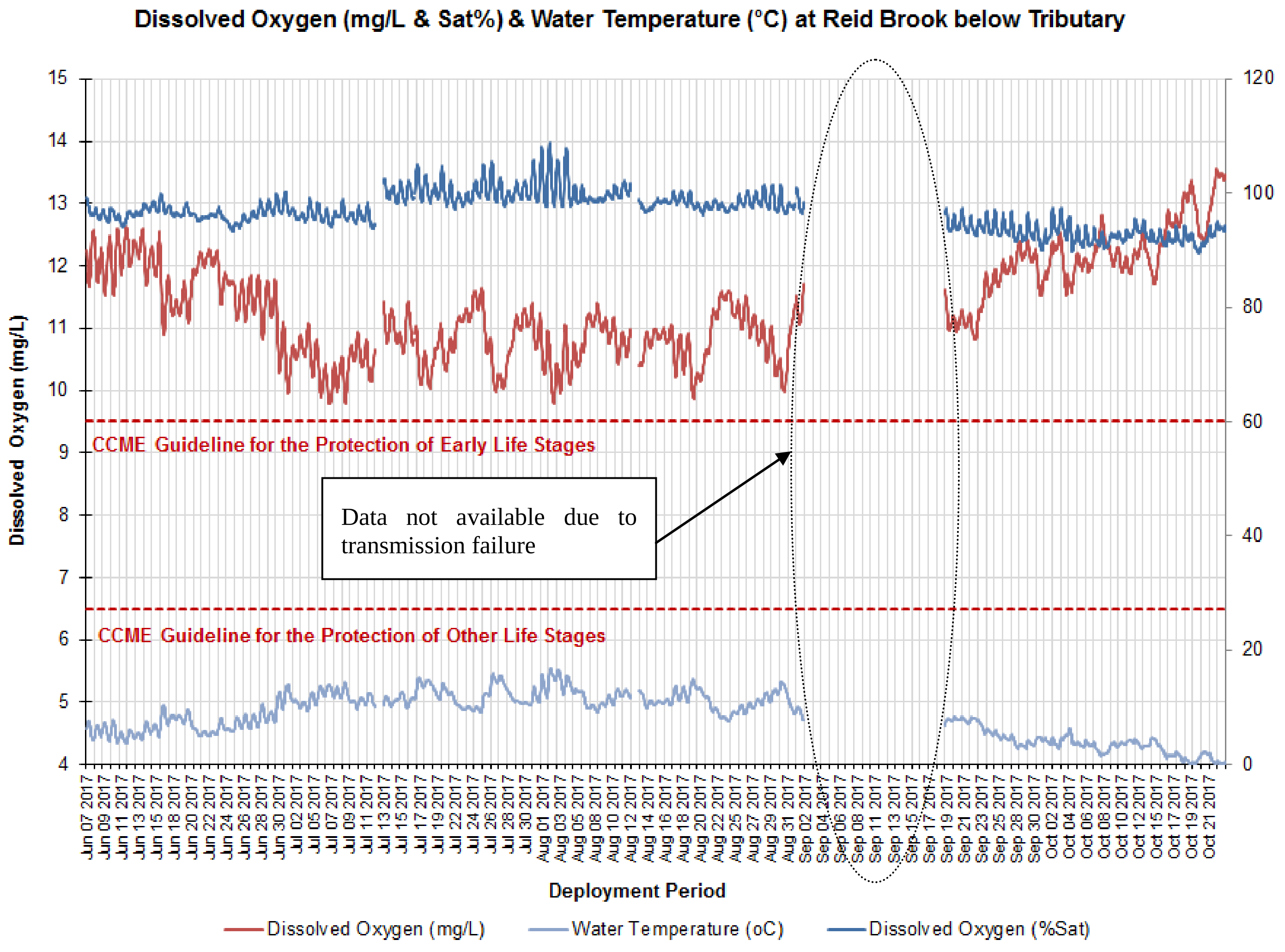

Figure 23: Dissolved Oxygen (mg/L & % Sat) & Water Temperature at Reid Brook below Tributary

Table 22: Comparisons of Minimum, Maximum and Median from the past three deployment years

Dissolved Oxygen (mg/L)	2017	2016	2015
Min	9.78	9.1	9.36
Max	13.56	13.88	14.25
Median	11.22	10.90	11.00

Percent Saturation (%)	2017	2016	2015
Min	89.4	91.6	89.6
Max	108.9	103.9	102.3
Median	96.8	96.1	96.2

During the 2017 deployment season, turbidity ranged from 0.0NTU to a maximum of 54.6NTU, with a median value of 0.8NTU. A median of 0.8NTU indicates that there was some natural background turbidity present at this station (Table 23).

Over the course of the deployment season, increases in turbidity generally corresponded with increases in stage and precipitation events. This is to be expected as increased precipitation and run-off may introduce natural organic matter into the water column. Turbidity levels quickly returned to background levels following stage increases and precipitation events (Figure 24).

Please note that the stage data on the graph below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

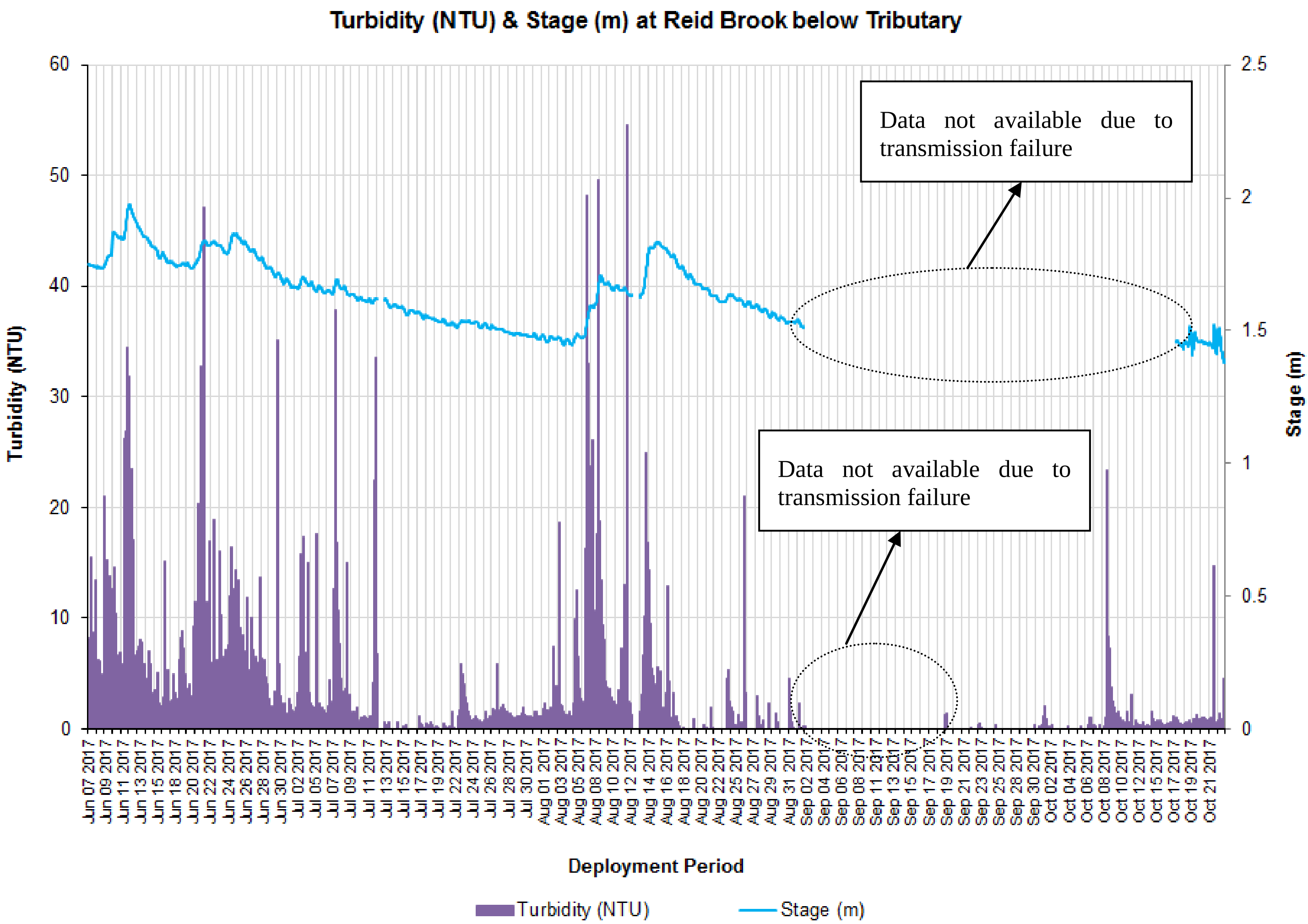

Figure 24: Turbidity & Stage at Reid Brook below Tributary

Table 23: Comparisons of Minimum, Maximum and Median from the past three deployment years

Turbidity	2017	2016	2015
Min	0	0.0	0.0
Max	54.6	64.5	705
Median	0.8	0.0	0.0

Multi-Station Comparison

The following section of this report focuses on comparisons between the four stations in the Voisey's Bay real-time network.

Temperature

During the 2017 deployment season, water temperatures at the four real-time stations ranged from 0°C at Tributary to Reid Brook to a maximum of 20.52°C at Camp Pond Brook below Camp Pond.

Water temperature trends were similar at each of the four RTWQ stations (Figure 25), and closely resembled ambient air temperatures. Water temperatures at Camp Pond Brook, Reid Brook below Tributary and Tributary to Reid Brook all followed a similar trend, peaking in late July/early August. Reid Brook at Outlet of Reid Pond is generally slower to respond to air temperatures since it is a larger volume of water and takes longer to acclimatize. Water temperature at Reid Brook at Outlet of Reid Pond was also very stable throughout June while Reid Pond was still covered in ice.

Tributary to Reid Brook and Reid Brook below Tributary had very similar water temperature data. This is to be expected as Tributary to Reid Brook flows directly into Reid Brook below Tributary. Both are fast flowing sites with similar environmental influences. Camp Pond Brook exhibits more pronounced changes in water temperature compared to the other stations, recording the highest single temperature in the network of 20.52°C, as well as the highest median temperature of 11.86°C (Table 24).

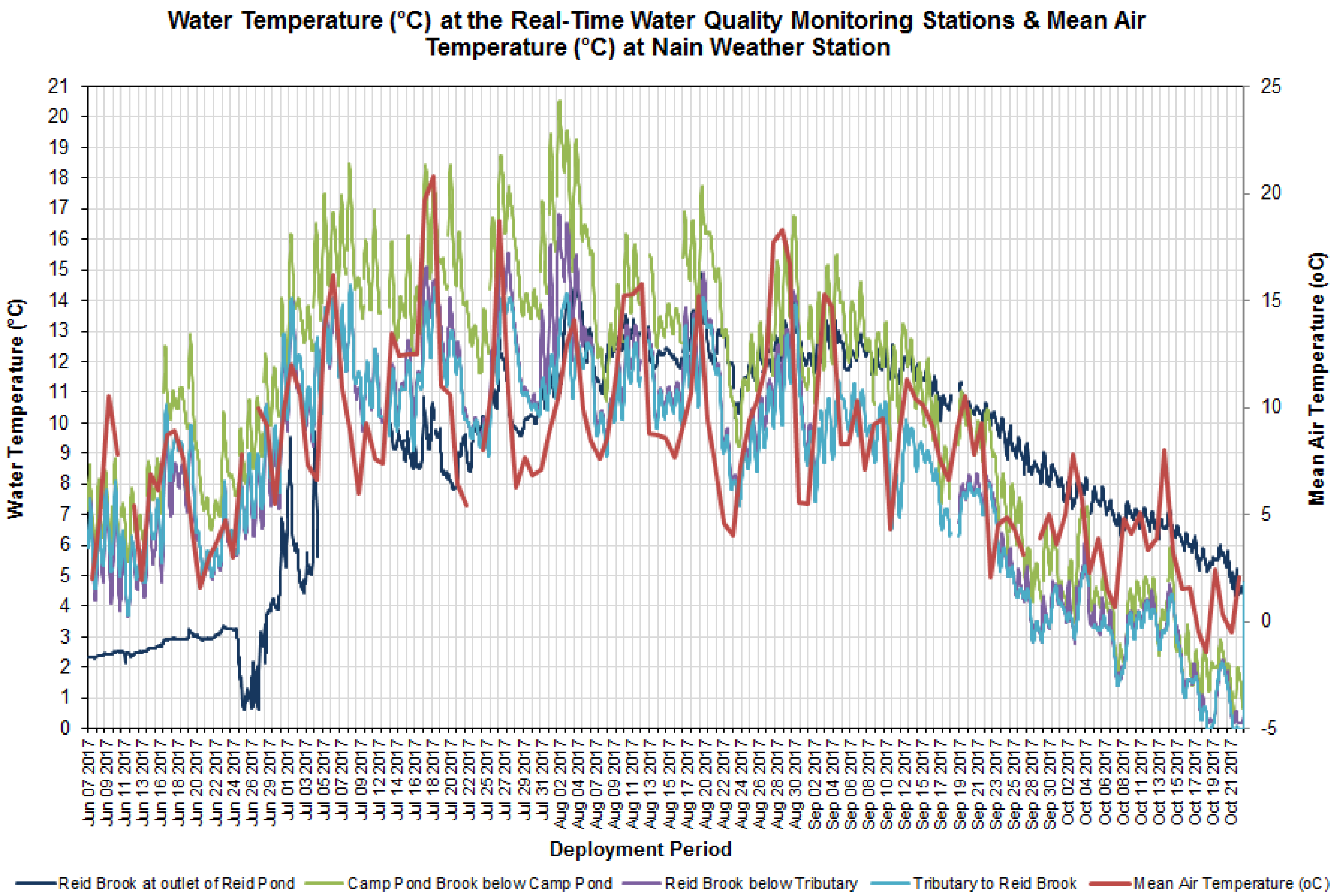

Figure 25: Water Temperature at all RTWQ Stations

Table 24: Comparisons of Minimum, Maximum and Median from the four real-time stations

Temperature (°C)	Reid Brook at Outlet of Reid Pond	Camp Pond Brook below Camp Pond	Reid Brook below Tributary	Tributary to Reid Brook
Min	0.6	0.22	0.17	0
Max	14.9	20.52	16.81	14.5
Median	9.53	11.86	9.21	9.3

pH

During the 2017 deployment season, pH medians at the four real-time stations ranged from 6.74 pH units at Tributary to Reid Brook to 6.87 pH units at Camp Pond Brook below Camp Pond (Table 25).

pH data for all stations followed a similar trend, with Reid Brook at Outlet of Reid Pond displaying the greatest range of pH values. This station is at the outlet of a pond and has different factors influencing pH as compared to the other sites. Camp Pond Brook below Camp Pond, Reid Brook below Tributary, and Tributary to Reid Brook all showed similar pH movements across the deployment season (Figure 26).

There were several events where pH fell below the minimum CCME Guideline for the Protection of Aquatic Life. When compared to precipitation data (Figure 26), there is an evident change in pH levels during higher and longer precipitation events. Many of the fluctuations in the pH data across the real-time stations corresponded with precipitation events.

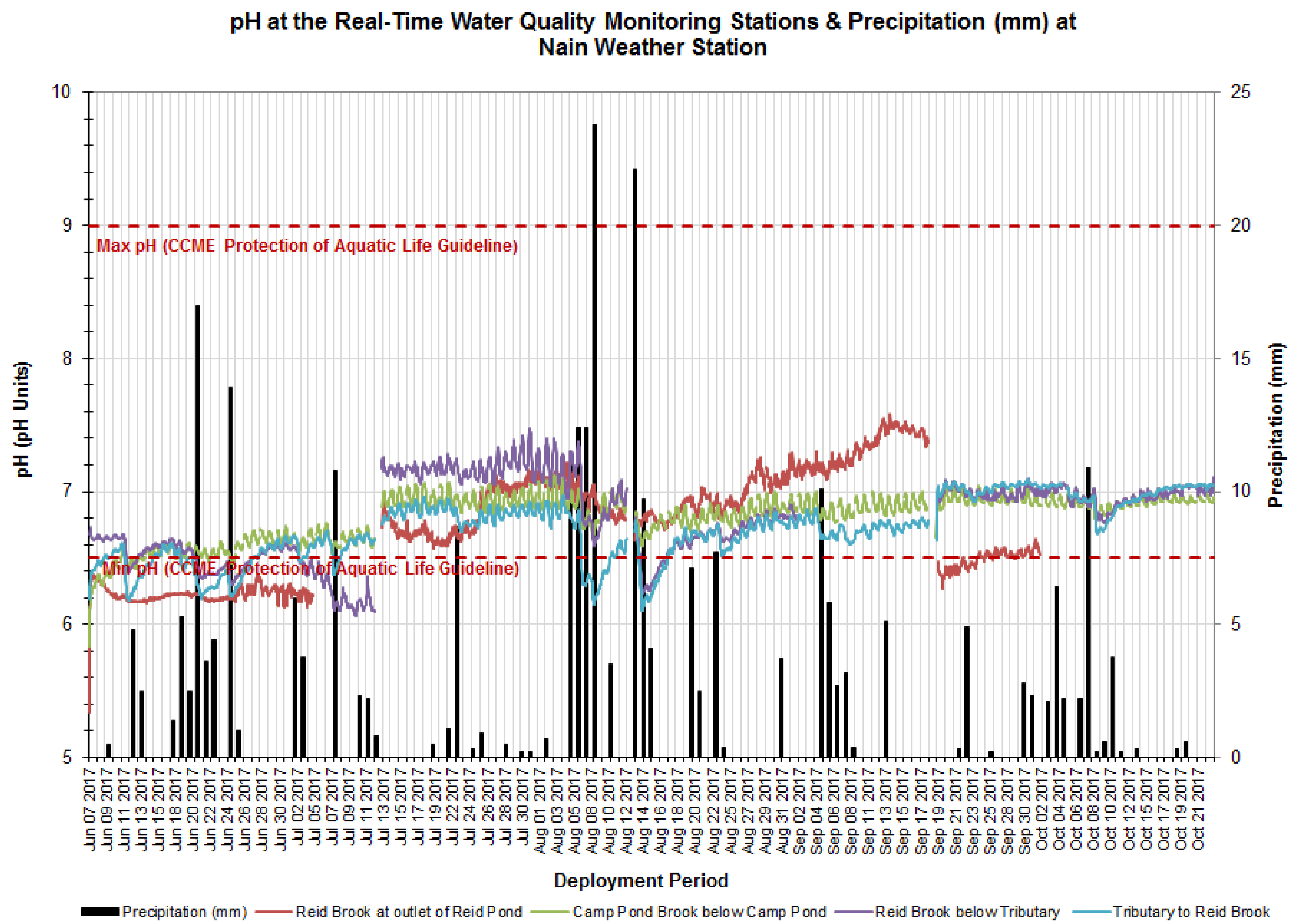

Figure 26: pH at all RTWQ Stations

Table 25: Comparisons of Minimum, Maximum and Median from the four real-time stations

pH (units)	Reid Brook	Camp Pond	Below Tributary	Tributary to Reid
Min	5.34	6.02	6.06	6.11
Max	7.58	7.12	7.48	7.09
Median	6.78	6.87	6.85	6.74

Specific Conductivity

During the 2017 deployment season, specific conductivity medians at all stations ranged from 11.04µS/cm at Tributary to Reid Brook to a maximum of 39.5µS/cm at Camp Pond Brook below Camp Pond (Table 26).

Reid Brook at Outlet of Reid Pond maintained a very stable specific conductivity level across the deployment season. This is to be expected since this station is located in an established pond environment. Reid Brook below Tributary and Tributary to Reid Brook had similar conductivity levels and followed a similar trend. Camp Pond Brook below Camp Pond displayed greater and more fluctuating specific conductivity levels. This trend is typical of this station, as it is located closest to the Voisey's Bay mine site as compared to the other stations (Figure 27).

Reid Brook below Tributary, Tributary to Reid Brook and Camp Pond Brook all displayed increasing conductivity levels across the deployment season. This is to be expected as stage levels decrease and suspended solids become more concentrated in the water column. As Reid Brook below Reid Pond is a more stable water quality environment, conductivity data remained reasonably consistent across the deployment season.

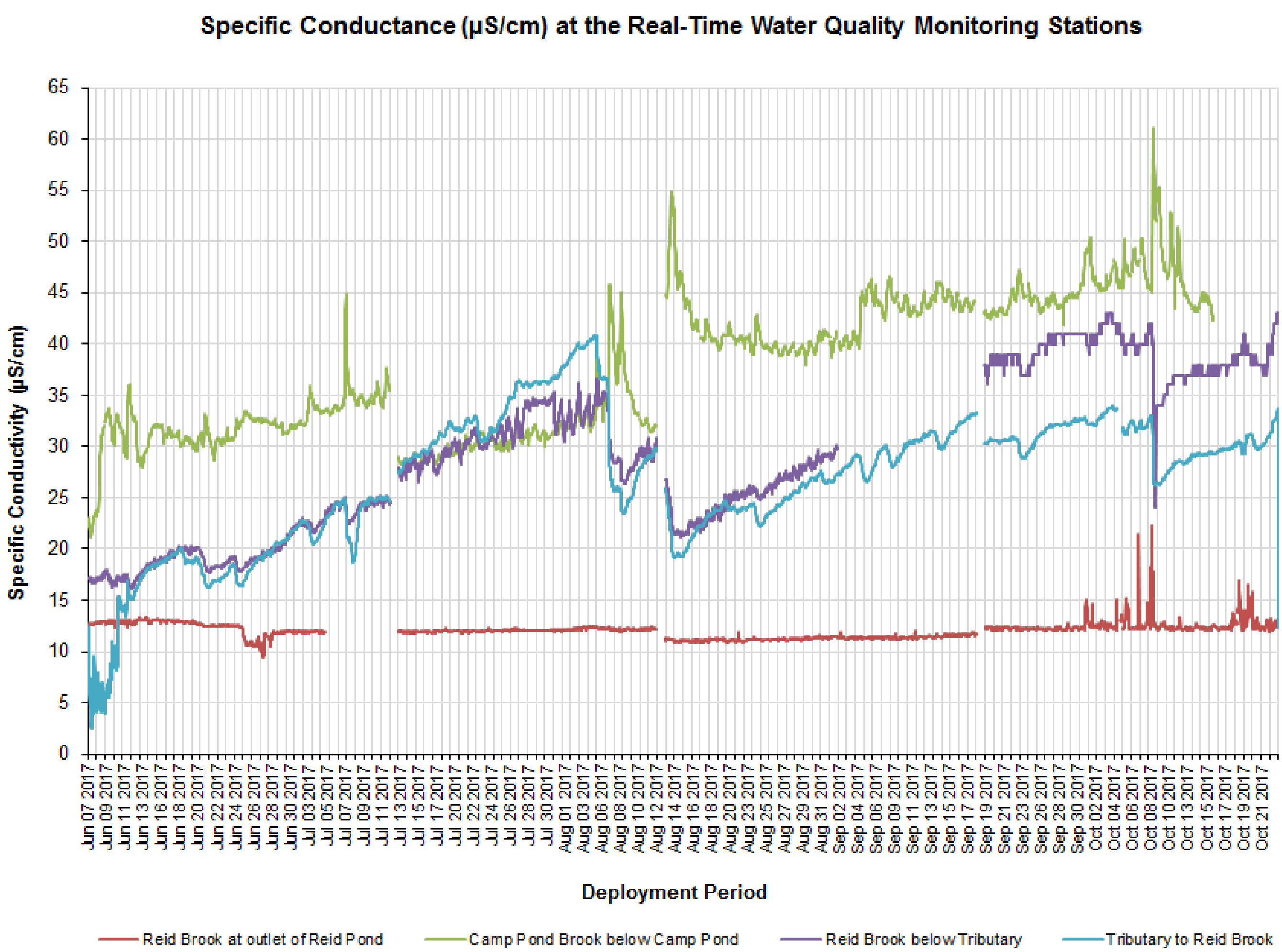

Figure 27: Specific Conductivity at all RTWQ Stations

Table 26: Comparisons of Minimum, Maximum and Median from the four real-time stations

Specific Conductivity	Reid Brook	Camp Pond	Below Tributary	Tributary to Reid
Min	9.4	21.2	16.1	9.66
Max	22.3	61.1	43	14.19
Median	12.1	39.5	28.7	11.04

Dissolved Oxygen (mg/L) and Dissolved Oxygen (% Saturation)

During the 2017 deployment season, dissolved oxygen concentration medians ranged from 10.37mg/L at Camp Pond Brook below Camp Pond to a maximum of 11.265mg/L at Reid Brook at Outlet of Reid Pond (Table 27). Dissolved oxygen concentrations displayed a typical inverse relationship with water temperature at all stations. Dissolved oxygen levels were most stable at Reid Brook below Reid Pond, whereas there was greater fluctuation at the other three stations (Figure 28a).

During the warmer summer season from early July to late August, dissolved oxygen levels at Camp Pond Brook below Camp Pond occasionally fell below the CCME guideline of 9.5mg/L for the Protection of Early Life Stages (Figure 28a). All other stations remained above the CCME Guideline for the Protection of Aquatic Life at Early Life Stages and Other Life Stages (6.5mg/L) for the entire deployment season.

The observed changes in dissolved oxygen levels are not unusual and are to be expected during warmer temperatures. As air temperatures decreased into the cooler fall season, dissolved oxygen levels began to steadily increase.

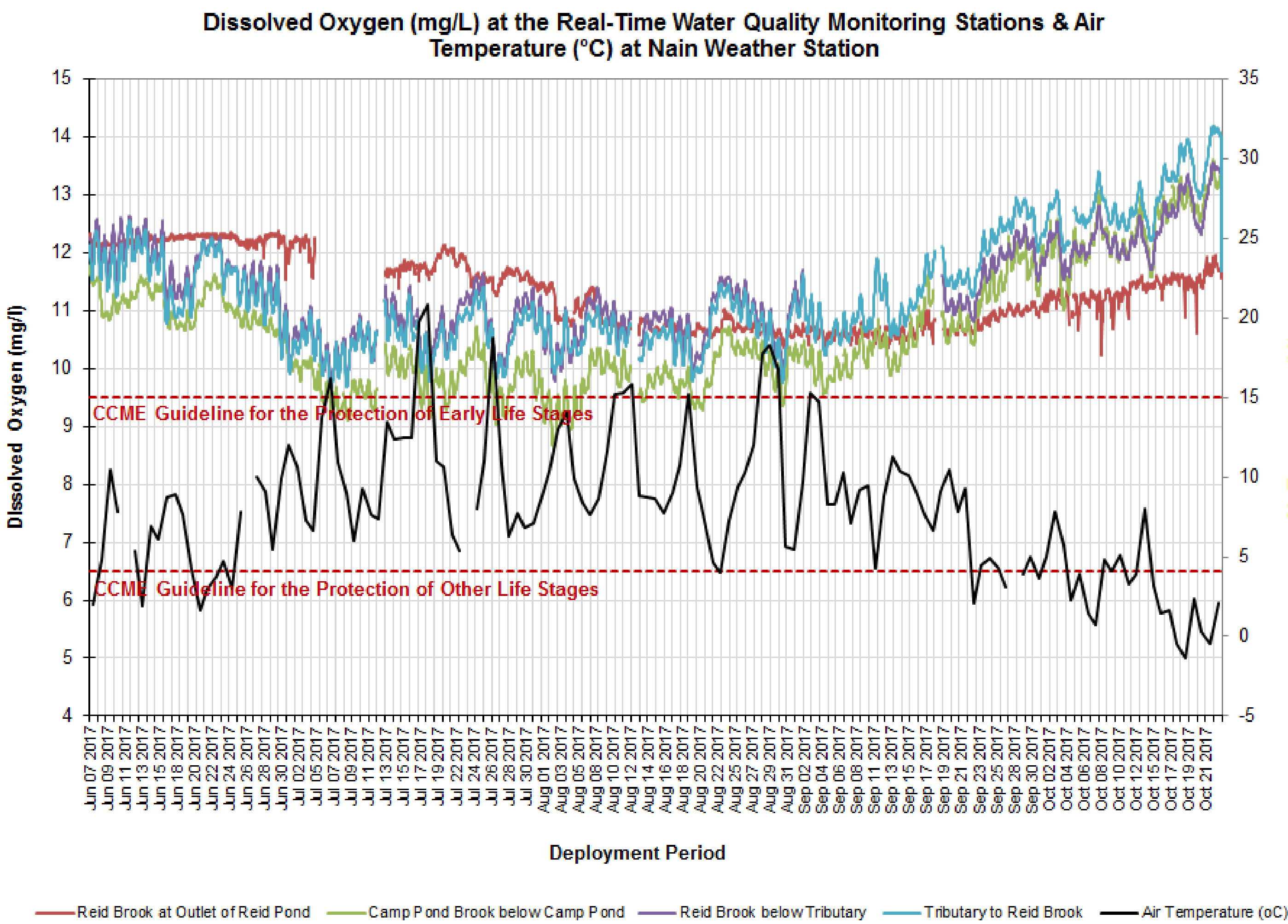

Figure 28a: Dissolved Oxygen (mg/L) at all RTWQ Stations

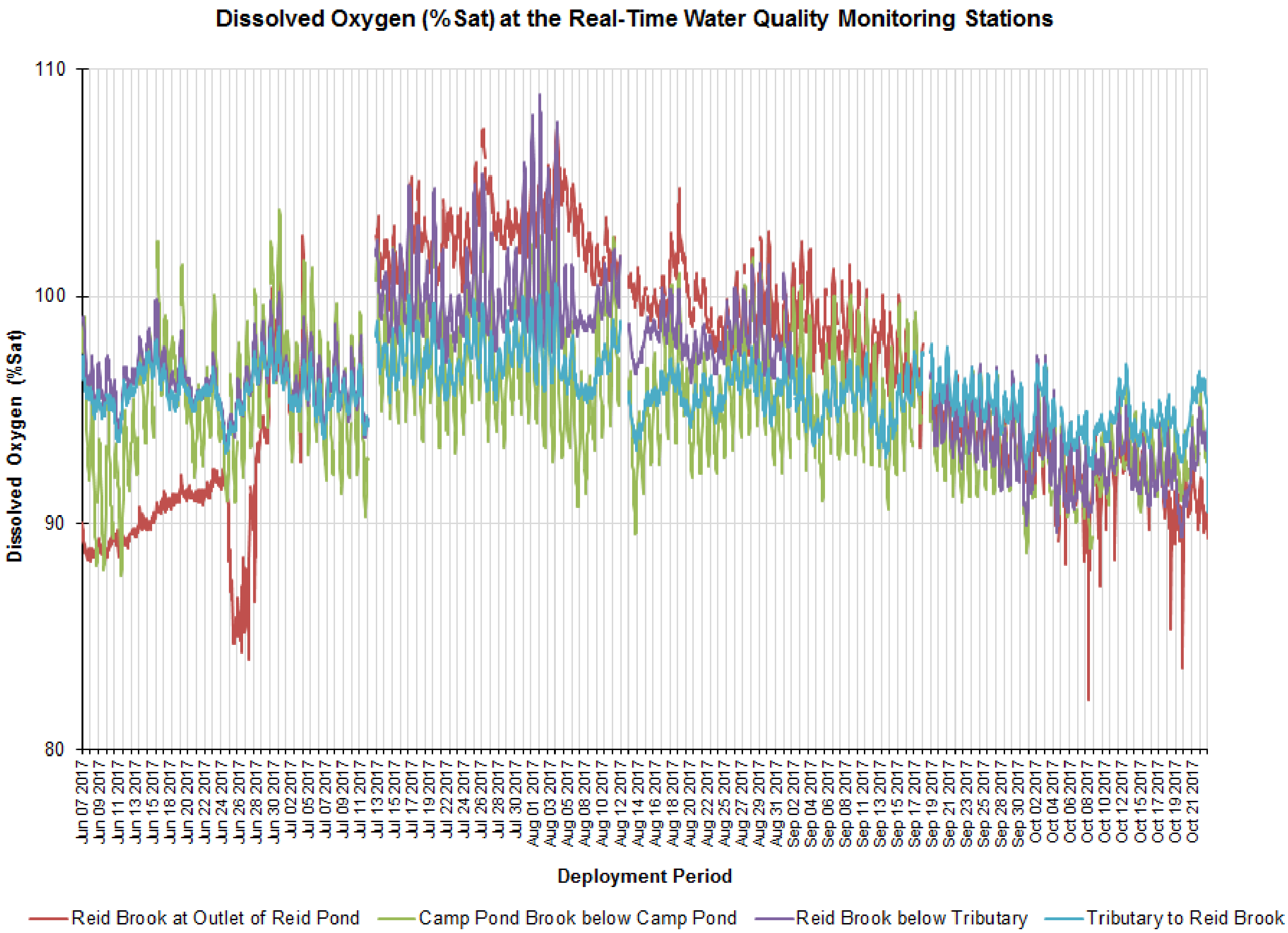

Figure 28b: Dissolved Oxygen (% Saturation) at all RTWQ Stations

Table 27: Comparisons of Minimum, Maximum and Median from the four real-time stations

	Dissolved Oxygen (mg/L)				Dissolved Oxygen (% Saturation)			
	Reid Brook	Camp Pond	Reid Brook below Tributary	Tributary to Reid Brook	Reid Brook	Camp Pond	Reid Brook below Tributary	Tributary to Reid Brook
Min	10.22	8.61	9.78	9.66	82.2	87.7	89.4	90.5
Max	12.39	13.6	13.56	14.19	107.6	103.9	108.9	100.6
Median	11.265	10.37	11.22	11.04	97.1	94.9	96.8	95.8

Turbidity

During the 2017 deployment season, turbidity ranged from 0.0NTU to a maximum of 1509NTU (Table 28). It is not unusual to see significant variability in turbidity data, as this parameter is influenced by many factors (e.g. precipitation, runoff from surrounding environments, high water flow (bubbles) and debris, such as leaf litter). Median turbidity values calculated for the four RTWQ stations ranged from 0.0NTU to 1.7NTU, which indicate that there was little to no background turbidity at these stations and large turbidity events were infrequent.

Figure 29a displays all turbidity data for the four real-time stations, whereas Figure 29b displays turbidity data on a scale of 200NTU. The use of a smaller scale allows for more accurate comparison of turbidity events between the different stations. Figure 29c provides turbidity data alongside total precipitation data from Nain weather station to allow for further comparison. It is evident that there is an association between high precipitation events and turbidity events.

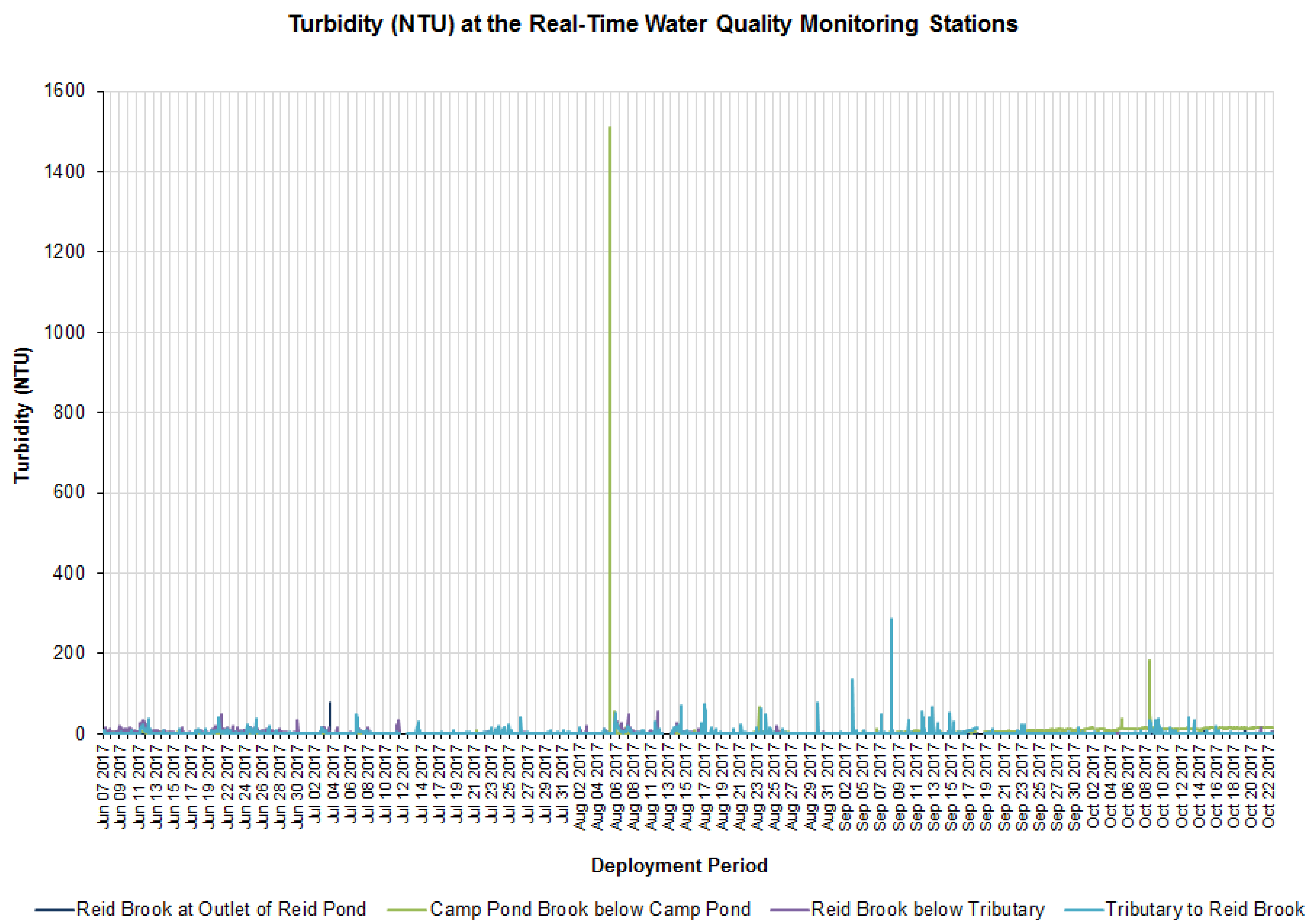

Figure 29a: Turbidity (NTU) at all RTWQ Stations

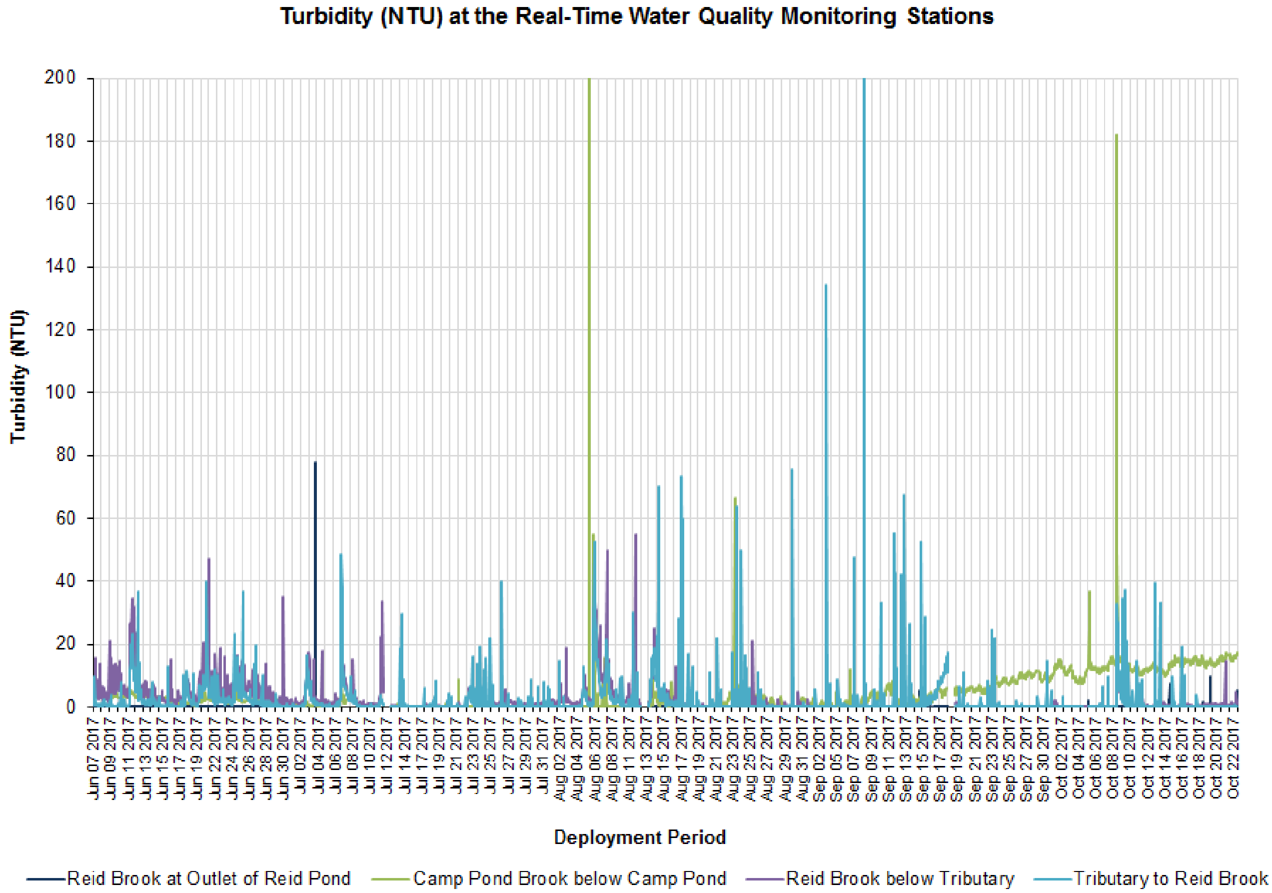

Figure 29b: Turbidity (NTU) at all RTWQ Stations (graphed to 200 NTU maximum)

Table 28: Comparisons of Minimum, Maximum and Median from the four real-time stations

Turbidity (NTU)	Reid Brook	Camp Pond	Reid Brook below Tributary	Tributary to Reid Brook
Min	0.0	0.0	0.0	0.0
Max	78	1509	54.6	287.2
Median	0.0	1.7	0.8	0.0

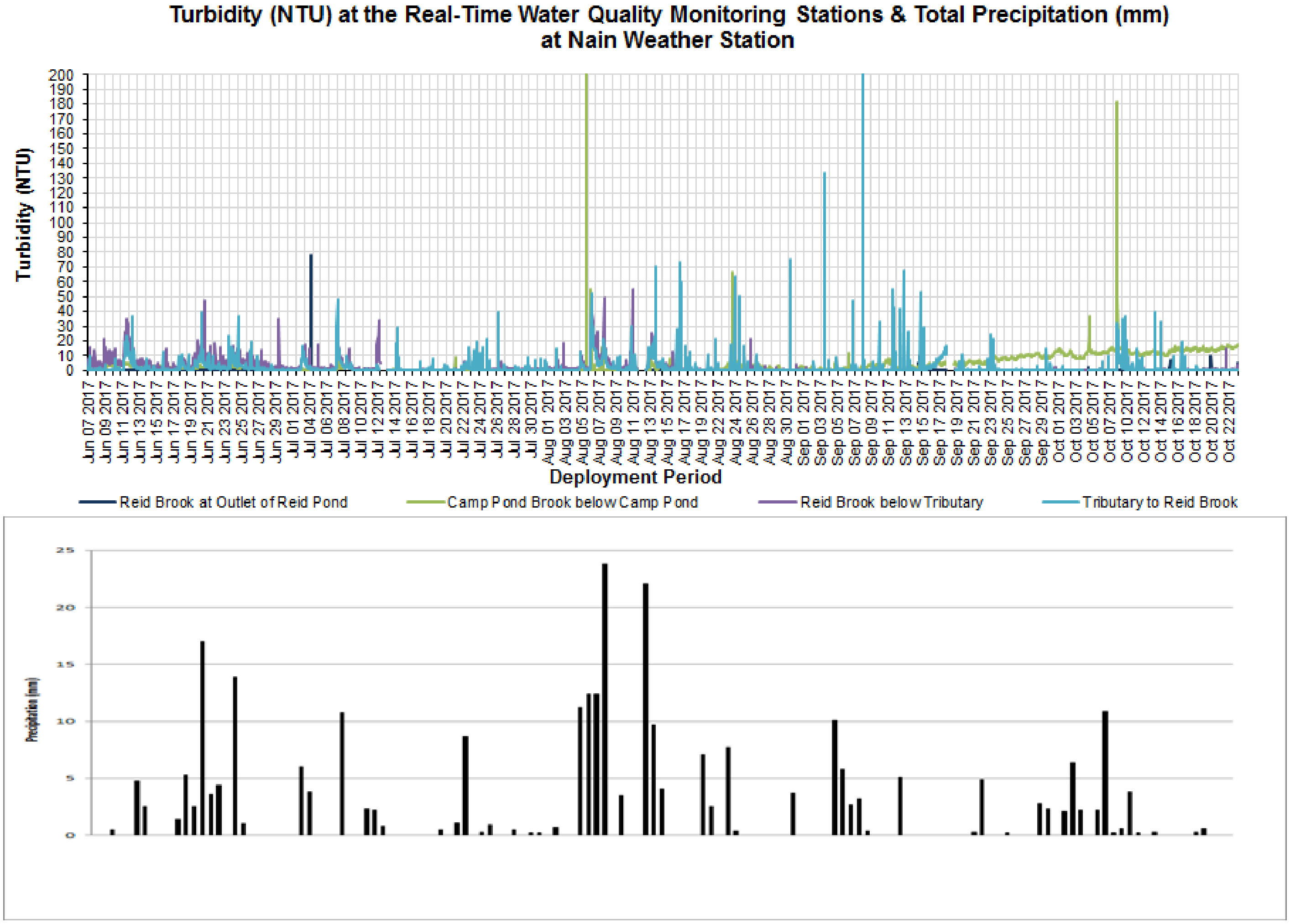

Figure 29c: Turbidity (NTU) at all RTWQ Stations and Total Precipitation (mm) at Nain Weather Station

Stage

Stage levels started high and generally decreased over the course of the 2017 deployment season at all real-time stations. This was likely the result of ground thaw and snow/ice melt from the surrounding river banks. Camp Pond Brook below Camp Pond exhibited the least variation in stage level, but did react to high precipitation events (Figure 30).

Precipitation data from Nain weather station was included in Figure 30 to display the relationship between precipitation and stage. Tributary to Reid Brook, Reid Brook below Tributary, and Reid Brook at Outlet of Reid Pond had obvious responses to precipitation events. Precipitation events had less influence at Camp Pond Brook below Camp Pond as this station is in close proximity to the lake.

Please be advised that WSC is responsible for the QA/QC of water quantity data. Corrected data can be obtained upon request. Stage data is included in this report to highlight the relationship with water quality parameters.

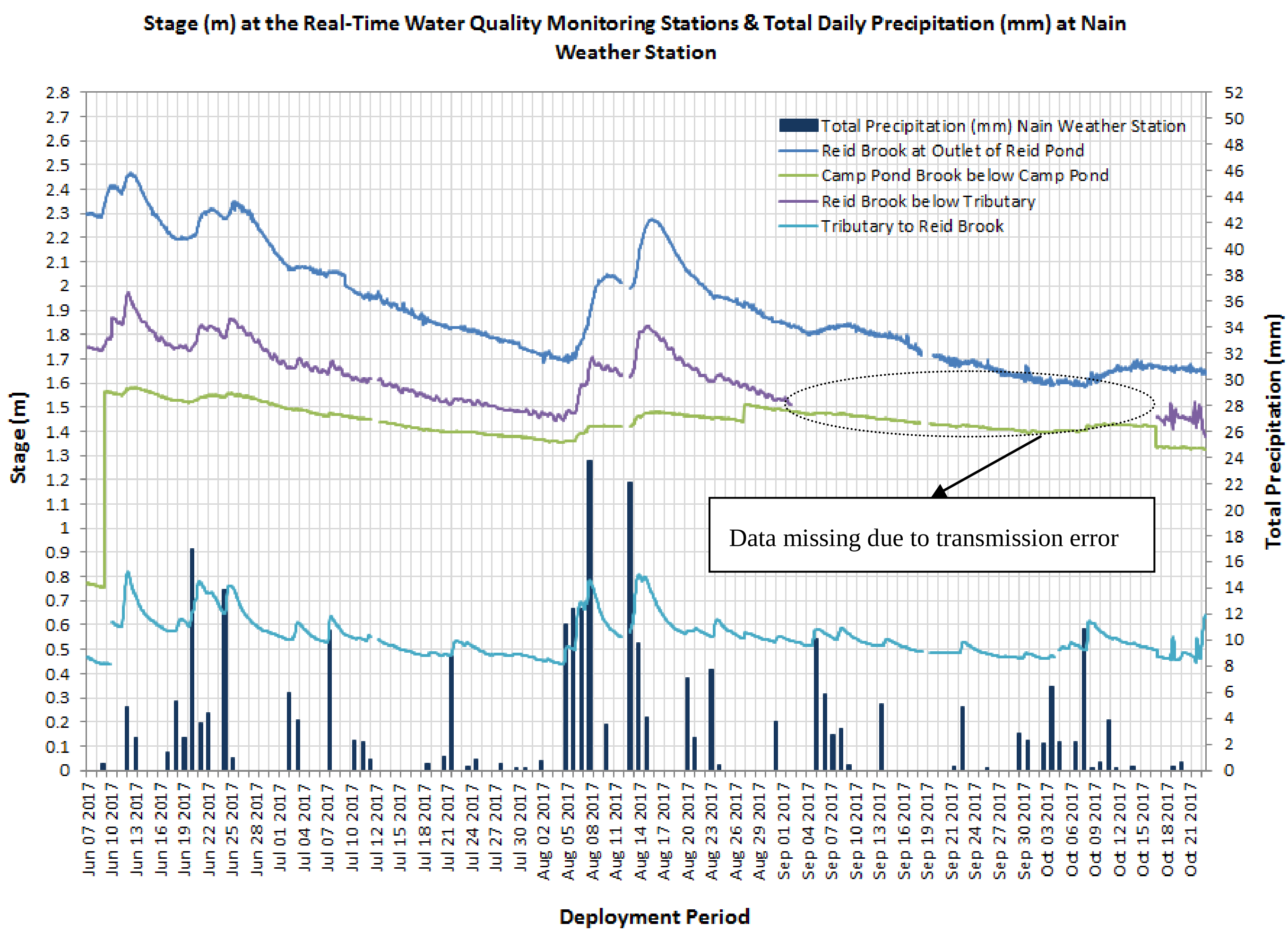

Figure 30: Stage (m) at all RTWQ Stations

Table 29: Comparisons of Minimum, Maximum and Median from the four real-time stations

Stage (m)	Reid Brook	Camp Pond	Reid Brook below Tributary	Tributary to Reid Brook
Min	1.582	0.754	1.381	0.437
Max	2.468	1.582	1.973	0.822
Median	1.839	1.439	1.631	0.535
Difference (Max/Min)	0.886	0.828	0.592	0.385

Conclusions

The 2017 deployment season ran from June 7 until October 23, and consisted of four deployment periods.

The majority of water quality events at the four RTWQ stations can be explained by precipitation events, spring thaw influences, and/or changes in air temperature as the seasons moved from spring to summer to fall.

Water temperature and dissolved oxygen were directly influenced by typical seasonal trends, increasing or decreasing with warming or cooling air temperatures. pH levels were maintained throughout deployment, except during high stage events or precipitation events when pH values decreased for a short period of time.

Three RTWQ stations had specific conductivity levels that increased across the deployment season; Reid Brook at Outlet of Reid Pond was the exception with relatively stable conductivity levels, which are attributed to the stable pond environment nearby.

Turbidity data showed significant variation across the network; however, the majority of turbidity increases were associated with precipitation events occurring at the same time. Observed turbidity events were short in duration and turbidity readings quickly returned to background levels.

Path Forward

The success of the real-time water monitoring network is largely due to environmental staff maintaining and monitoring the Voisey's Bay RTWQ network. This network has been improving since 2003 and continues to advance annually in background knowledge and awareness of the area's characteristics. Data collected within this network is essential for identifying the difference between natural and anthropogenic events. As this agreement progresses into the 2018 deployment period for the Voisey's Bay stations, the following is a list of planned activities to be carried out. This list also includes some multi-year activities planned in the previous year that are still in progress.

- Staff from Vale will be responsible for monthly maintenance and calibration (as was the case in the past). MAE staff will perform regular site visits to audit and assist in the maintenance and calibration procedures from time to time. WSC staff will perform regular site visits to ensure water quantity instrumentation is functioning correctly, calibrated and providing accurate measurements.
- WRMD staff will update Voisey's Bay staff on any changes to processes and procedures with handling, maintaining and calibrating the RTWQ instruments.
- If necessary, changes or improvements to deployment techniques will be adapted to each specific site, ensuring secure and suitable conditions for RTWQ.
- WRMD will work with Vale Environment staff to reassess the network design (station location) and plan for any necessary or desired changes in 2018 or in future seasons.
- Open communication lines will continue to be maintained between WRMD, ECCC and Vale employees involved with the agreement in order to respond to emerging issues on a proactive basis.
- Vale will receive 30 day deployment reports outlining the events that occurred in the previous deployment period and a 2018 annual report summarizing the events of the entire deployment season.
- WRMD will continue to work on Automatic Data Retrieval System to incorporate new capabilities when applicable.
- WRMD will continue to work on the creation of value added products using the RTWQ data, remote sensing and water quality indices.
- WRMD will begin development of models using RTWQ data and grab sample data to estimate a variety of additional water quality parameters (*i.e.* TSS, major ions *etc*.).
- 2018 deployments will recommence in the Spring

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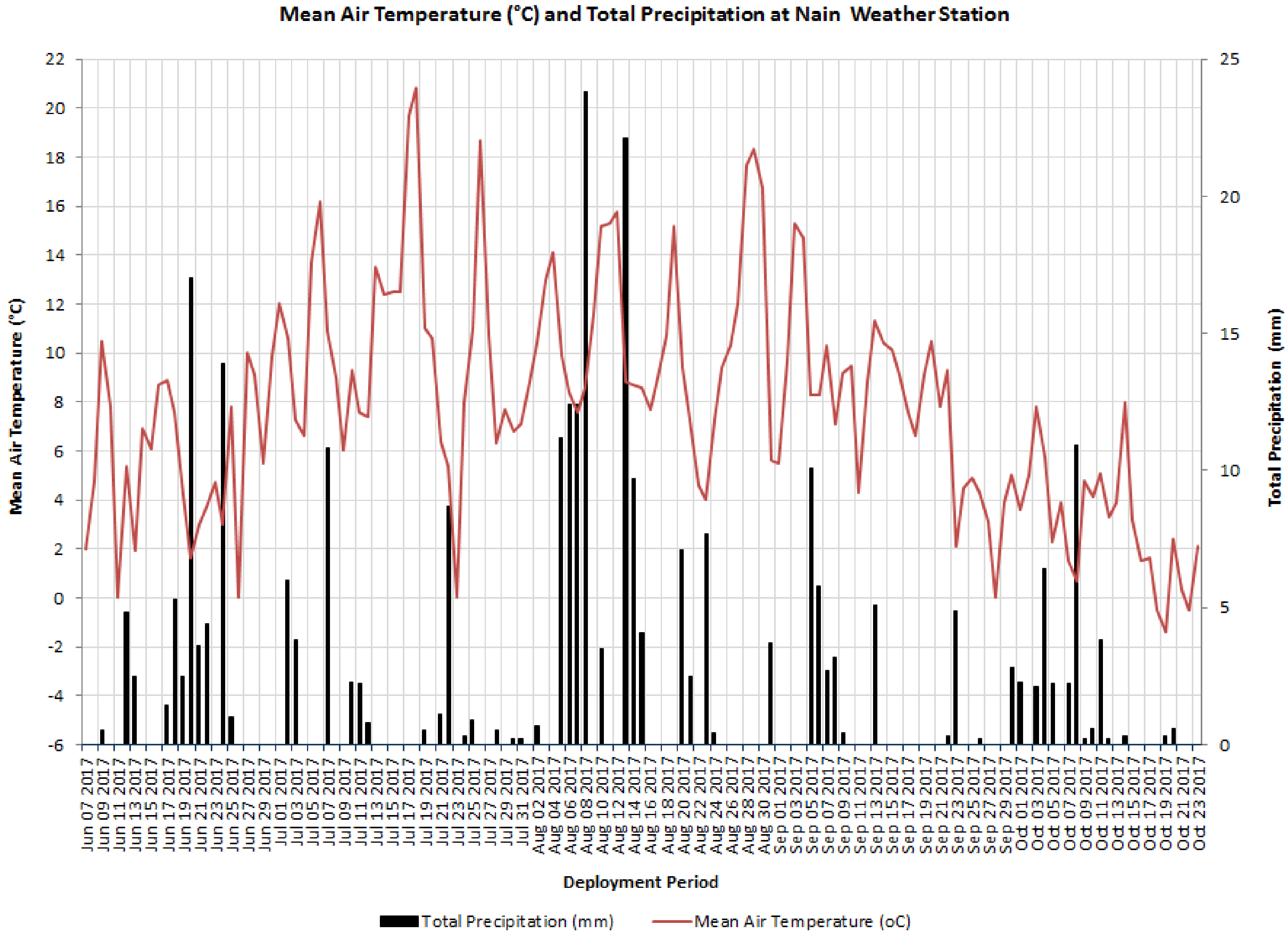
Appendix 1


Mean Air Temperature (°C) and Total Precipitation at Nain Weather Station
Mean Air Temperature (°C)
Total Precipitation (mm)
Deployment Period
Total Precipitation (mm)
Mean Air Temperature (oC)