Real-Time Water Quality 2015 Annual Report

Voisey's Bay Network

June 16 to October 23, 2015

Newfoundland Labrador

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

Newfoundland Labrador

Real-Time Water Quality Deployment Report

Voisey's Bay Network

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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 Environment and Conservation (ENVC) Water Resources Management Division as well as Environment Canada (EC) to ensure the protection of ambient water resources in Voisey's Bay, Labrador.

Vale Environmental Coordinators are acknowledged for their hard work during the 2015 deployment period, and ensuring the Real-Time Water Quality Monitoring Network is operating to the standards set by ENVC. 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 in Goose Bay, Kelly Maher- Environmental Scientist, plays the 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 the data to the general public on a near real-time basis through the departmental web page.

Environment 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 ENVC (Renée Paterson), EC (Howie Wills) and Vale (Perry Blanchard) 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

EC	Environment Canada
WSC	Water Survey of Canada
ENVC	Department of Environment and Conservation
DO	Dissolved Oxygen
NL	Newfoundland and Labrador
QAQC	Quality Assurance and Quality Control
RTWQ	Real-time Water Quality
WRMD	Water Resources Management Division
%Sat	Percent Saturation
PTE	Performance Testing and Evaluation
RB	Reid Brook (at Outlet of Reid Pond)
CP	Camp Pond Brook (below Camp Pond)
TribLRB	Tributary to Lower Reid Brook
LowerRBk	Lower Reid Brook below Tributary

Introduction

The RTWQ network in Voisey's Bay was successfully established by ENVC and EC 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 Lower Reid Brook, and Lower 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 flow rate data. These parameters are the responsibility of EC, 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 spring 2012 season for this network as well as a new Hydrolab Minisonde 5 for QAQC measurements and an Archer handheld display unit.

This annual deployment report illustrates, discusses and summarizes water quality related events from June 16 to October 23, 2015. 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 carefully calibrates 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. The instrument sensors will still work to capture any water quality event even though the exact data values collected may be inaccurate. Installation and removal dates for each station in the 2015 deployment season are summarized in Table 1.

Table 1: Installation and removal dates for 2015 deployment periods

Installation	Removal	Deployment
June 16	July 18	32 days
July 18/19	August 18	29-30 days
August 19	September 19	30 days
September 21	October 23	32 days

Quality Assurance and Quality Control

As part of the Quality Assurance and Quality Control protocol (QAQC), 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 QAQC Instrument is temporarily deployed along side 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 QAQC 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	Instrument #	Temperature	pH	Specific Conductivity	Dissolved Oxygen	Turbidity
Upper Reid Brook	June 16	Deployment	62884	Fair	Fair	Excellent	n/a	Excellent
	July 18	Removal		Poor	Good	Excellent	n/a	Excellent
	July 18	Deployment	44175	Excellent	Good	Excellent	Excellent	Excellent
	August 18	Removal		Excellent	Poor	Excellent	Fair	Excellent
	August 19	Deployment	62885	Poor	Good	Excellent	Excellent	Excellent
	September 19	Removal		Excellent	Fair	Excellent	Excellent	Excellent
	September 21	Deployment	62884	Excellent	Fair	Excellent	Excellent	Excellent
	October 23	Removal		Excellent	Poor	Excellent	n/a	n/a
Camp Pond Brook	June 16	Deployment	62885	Excellent	Poor	Excellent	Excellent	Excellent
	July 18	Removal		Excellent	Excellent	Excellent	Excellent	Excellent
	July 19	Deployment	62885	Excellent	Excellent	Excellent	Excellent	Excellent
	August 18	Removal		Excellent	Excellent	Excellent	Good	Excellent
	August 19	Deployment	44175	Excellent	Good	Excellent	Excellent	Excellent
	September 19	Removal		Excellent	Good	Good	Excellent	Excellent
	September 21	Deployment	62885	Excellent	Excellent	Good	Poor	Excellent
	October 23	Removal		Excellent	Fair	Good	n/a	n/a
Lower Reid Brook	June 16	Deployment	62887	Excellent	Excellent	Excellent	Excellent	Excellent
	July 18	Removal		Excellent	Poor	Good	Fair	Excellent
	July 19	Deployment	62887	Excellent	Marginal	Excellent	Good	Excellent
	August 18	Removal		Excellent	Fair	Excellent	Poor	Excellent
	August 19	Deployment	62887	Good	Good	Excellent	Good	Excellent
	September 19	Removal		Excellent	Excellent	Excellent	Excellent	Poor
	September 21	Deployment	62887	Excellent	Good	Good	n/a	Excellent
	October 23	Removal		Good	Good	Excellent	n/a	n/a
Tributary to Lower Reid Brook	June 16	Deployment	62886	Excellent	Fair	Excellent	Excellent	Excellent
	July 18	Removal		Excellent	Excellent	Excellent	Good	Excellent
	July 19	Deployment	62886	Excellent	Good	Excellent	Fair	Excellent
	August 18	Removal		Excellent	Excellent	Excellent	n/a	Poor
	August 19	Deployment	62884	Excellent	Good	Excellent	Excellent	Good
	September 19	Removal		Excellent	Excellent	Excellent	Excellent	Excellent
	September 21	Deployment	62886	Excellent	Poor	Excellent	Poor	Excellent
	October 23	Removal		Excellent	Fair	Good	n/a	n/a

Data Interpretation

The following graphs and discussion illustrate significant water quality-related events from June 16 to October 23, 2015 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 QAQC protocol. Water Survey of Canada (WSC) is responsible for QAQC of water quantity data. Corrected data can be obtained upon request to Water Survey of Canada.

During this deployment year there were several transmission issues with the data due to connectivity issues and sensor failures. Reid Brook at Outlet of Reid Pond did not transmit for the first deployment period due to the station being off line and needing a cable replacement. During this deployment the Dissolved Oxygen sensor also failed and no data for that parameter was recorded on the internal log file. During the rest of the deployment season transmission errors occurred with water quantity parameters (stage & flow). This data can be obtained from Environment Canada upon request. pH data collected during two deployment periods was deemed inaccurate due to QAQC recordings. In the final deployment from September to October the Dissolved Oxygen sensor failed and no data was recorded for this parameter.

Camp Pond Brook had a DO sensor failure during the last deployment period from September to October. Tributary to Lower Reid Brook experienced DO sensor failure during two deployment periods between July and August and then between September and October.

All instruments were sent to the St. John's WRMD laboratory at the end of the season for the instruments' yearly Performance Evaluation Testing (PTE). Any necessary repairs and replacement sensors will be addressed before the 2016 season.

Reid Brook at Outlet of Reid Pond

During this deployment season the water temperature ranged within a minimum of 2.51°C to a maximum of 18.01°C. The water temperature median was (9.49) slightly higher than 2014 which was 7.90 and 2013 which was 8.26 for the deployment period (Figure 1).

Water temperatures start to steadily increase at the onset of June. By the end of July and throughout August the water temperatures were at the highest. As the fall season started the water temperatures steadily started to decrease.

A decrease in water temperature on August 20-21st can be attributed to a precipitation event of 55mm over the two days period.

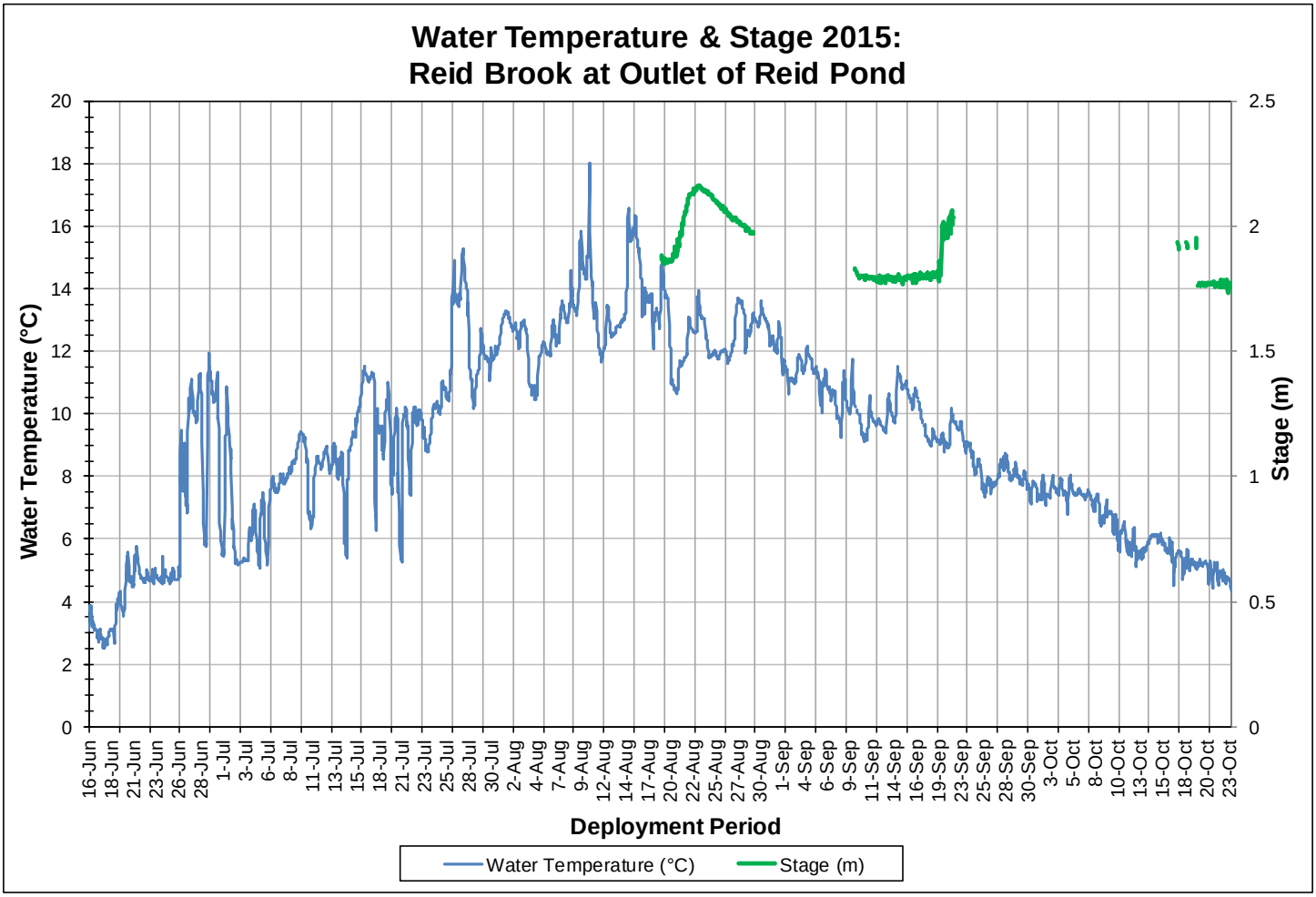

Figure 1: Water Temperature & Stage at Reid Brook at Outlet of Reid Pond

Water Temperature	2015	2014	2013
Min	2.51	2.21	1.10
Max	18.01	19.25	17.83
Median	9.49	7.90	8.26

Water temperature values show a close relationship with air temperature (Figure 2). Increases and decreases in air temperatures are reflected in water temperatures. Air temperatures clearly fluctuate at a greater scale each day when compared with water temperatures.

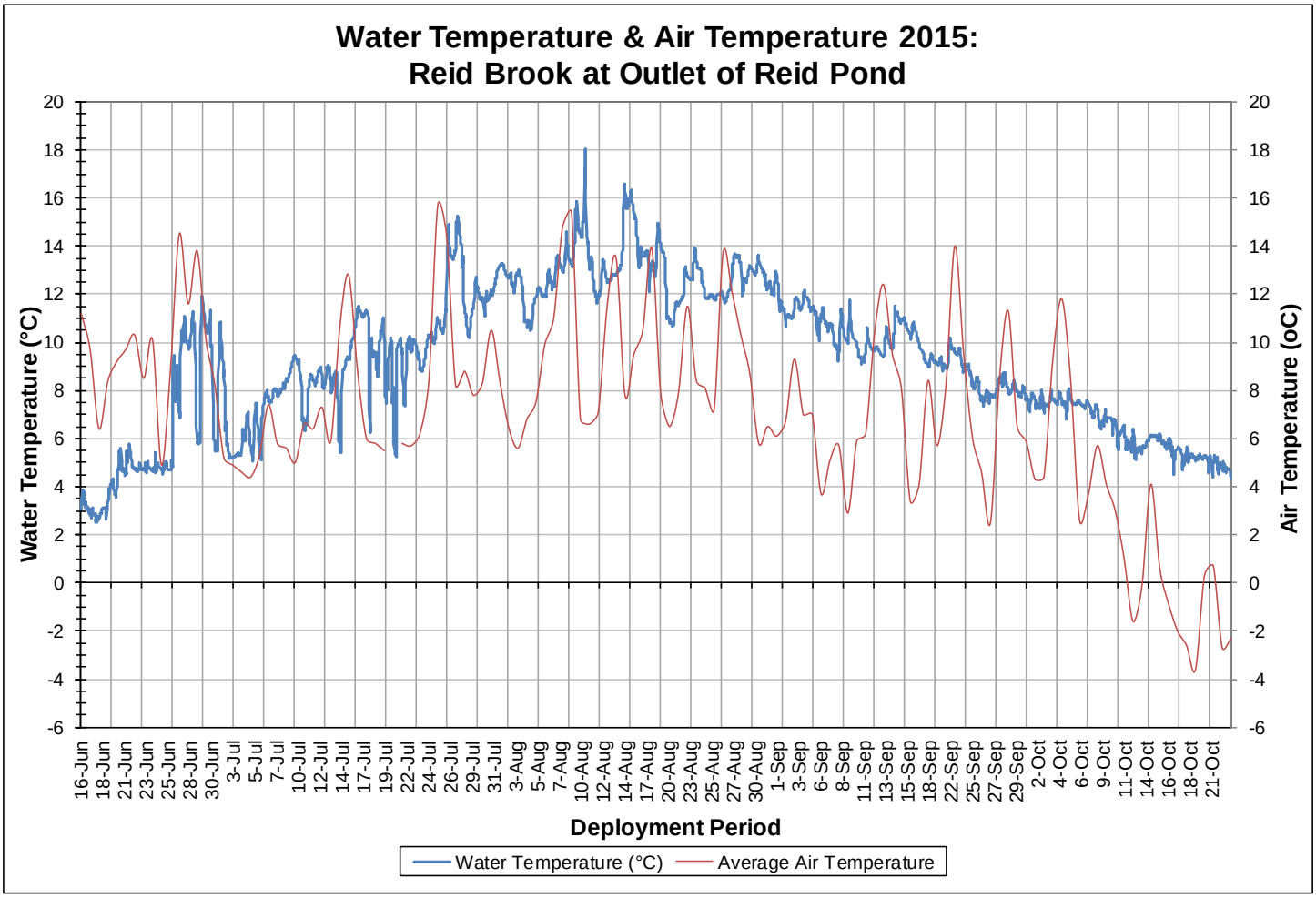

Figure 2: Average Daily Air Temperature from Nain weather station and Water Temperature at Reid Brook at Outlet of Reid Pond

During this deployment season the pH data ranged between a minimum of 4.83 pH units and a maximum of 6.96 pH units.

Some pH values at this station were removed during the QAQC process. At the beginning of the deployment season pH values were fluctuating below the minimum guideline due to several large rain fall events. The pH remained higher during the mid- summer deployment

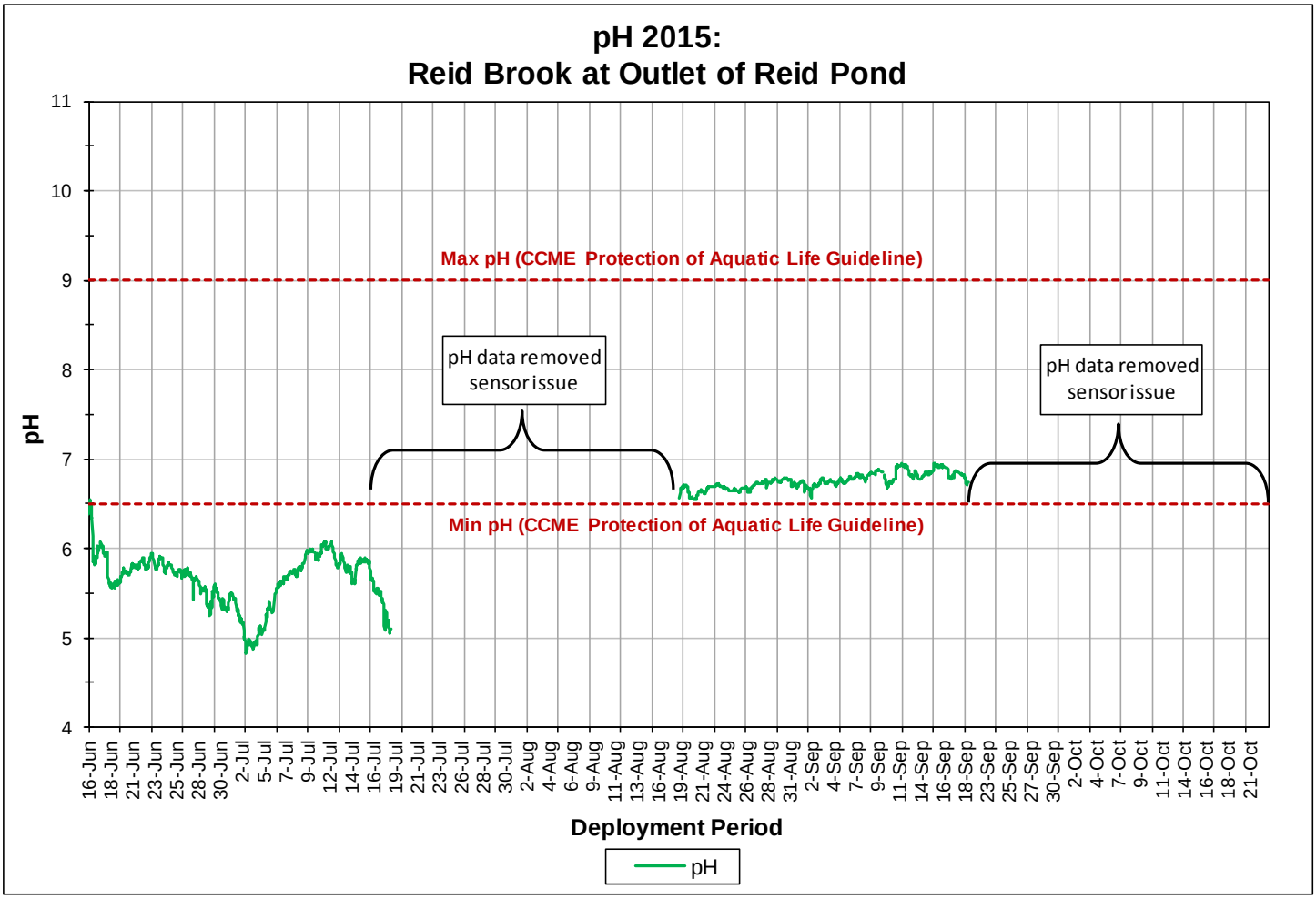

Figure 3: pH and Stage Level at Reid Brook at Outlet of Reid Pond

pH	2015	2014	2013
Min	4.83	5.38	6.35
Max	6.96	8.96	7.16
Median	6.05	6.78	6.86

This deployment season had specific conductivity values ranging from a minimum of 11µS/cm to a maximum of 14.0µS/cm. The overall conductivity median of 12µS/cm (Figure 4) indicated that this station naturally has really low conductivity.

Specific conductivity was very low and stable throughout the deployment season with minimal fluctuation regardless of the changing water level. This trend is to be expected as this station due to its location on a stable lake environment, Reid Pond.

The difference in the data display on the graph is a result of the internal log file being used for portions of the deployment periods. The internal log file does not record to as many decimal places as the datalogger therefore the data is rounded slightly and when graphed doesn't have the same data display as transmitted data.

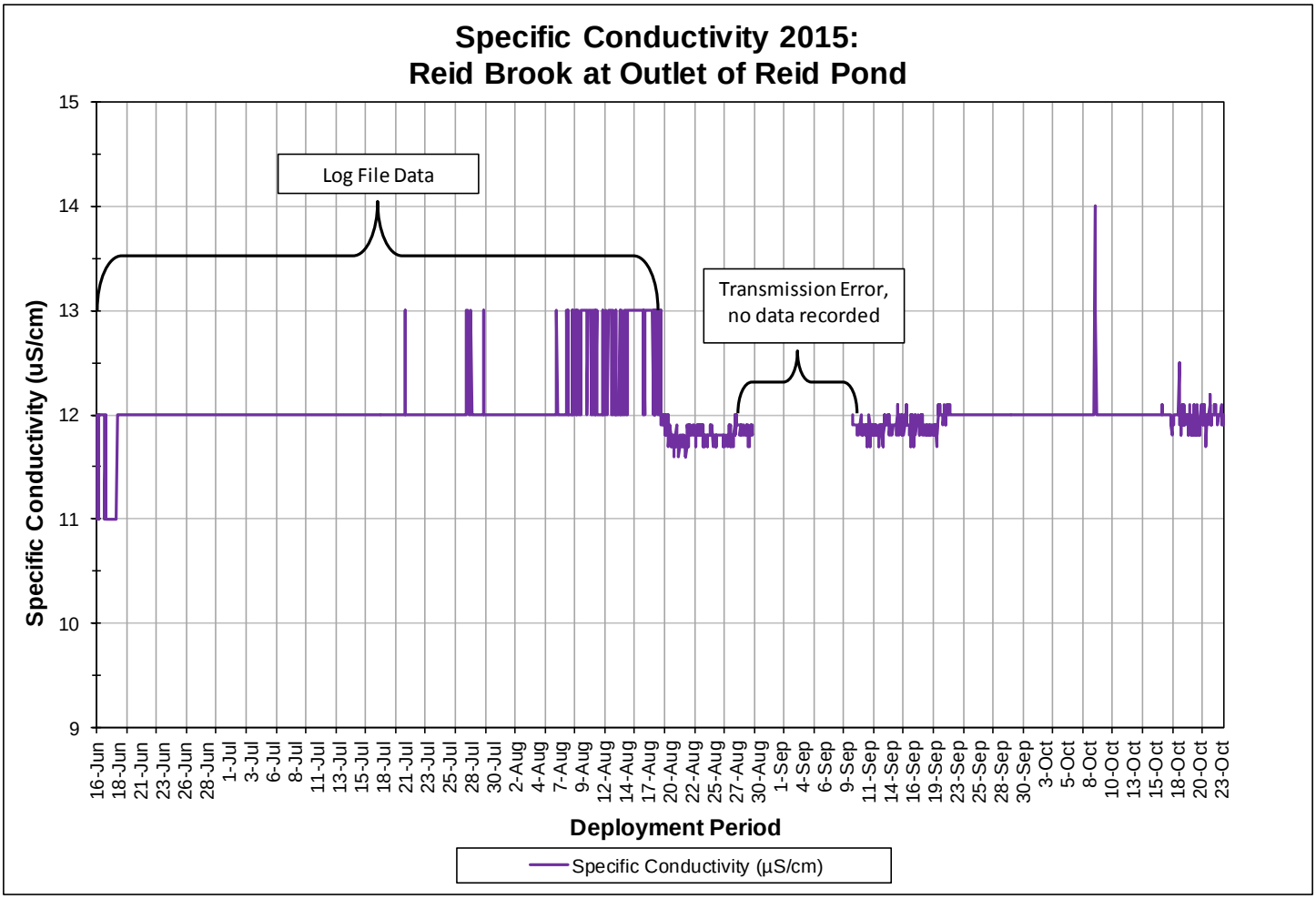

Figure 4: Specific conductivity at Reid Brook at Outlet of Reid Pond

Specific Conductivity	2015	2014	2013
Min	11	9.7	9.4
Max	14	13	12.6
Median	12	12	11.7

During this deployment season the dissolved oxygen content ranged between a minimum of 9.76mg/l and a maximum of 12.36mg/l. The overall dataset had a median value of 10.98mg/l (Figure 5).

Dissolved oxygen content shows a typical seasonal fluctuation in 2015, and is inversely proportional to the changes in water and air temperature (Figure 5). Dissolved oxygen values were low and consistent through the warmest part of the season and began to increase in mid to late September as water and air temperatures began to cool with the change to the fall season.

All values were above both 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) during the deployment season. The guidelines are indicated in red on Figure 5.

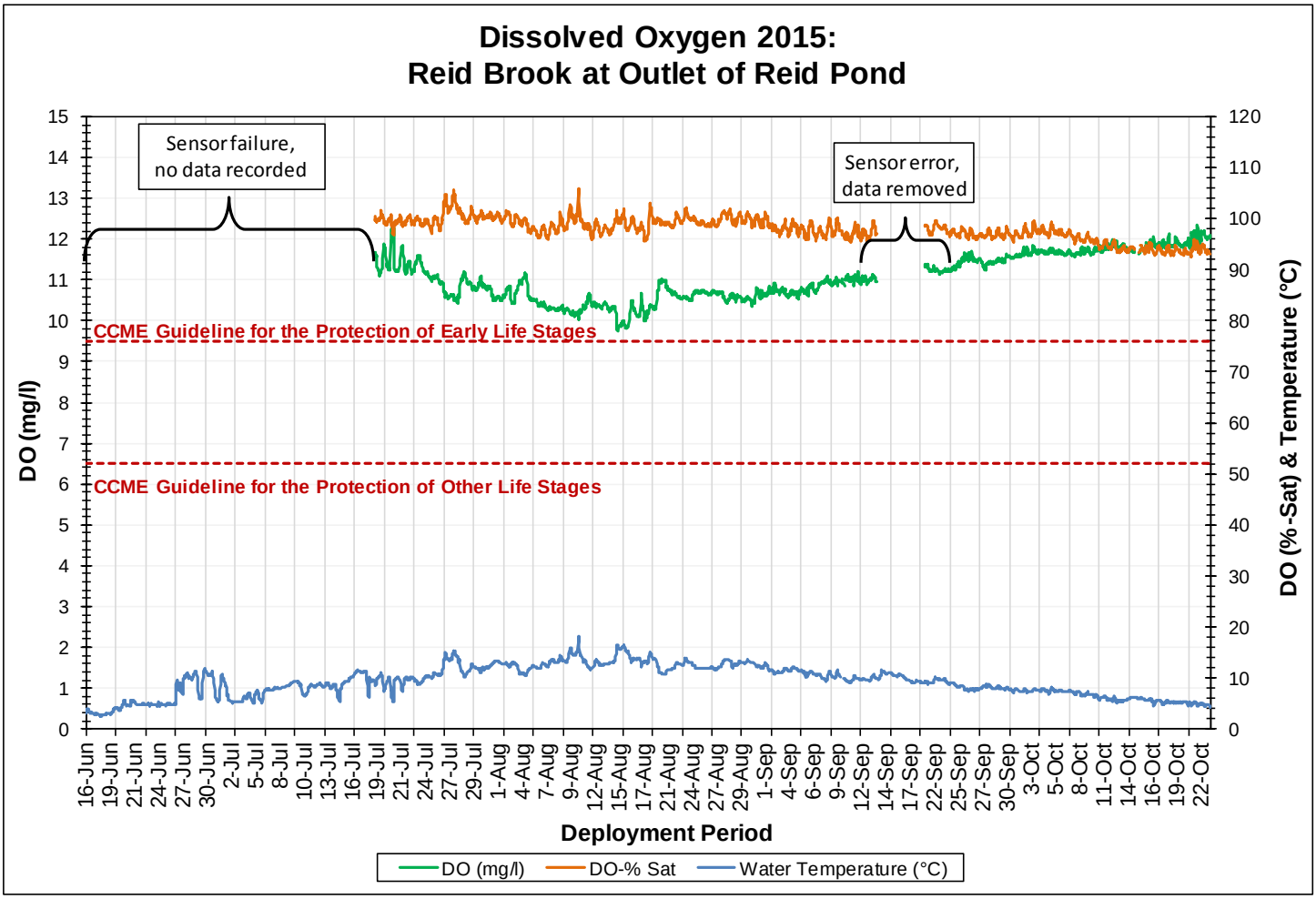

Figure 5: Dissolved oxygen and Water Temperature at Reid Brook at Outlet of Reid Pond

Dissolved Oxygen (mg/l)	2015	2014	2013
Min	9.76	9.54	9.67
Max	12.36	12.82	12.65
Median	10.98	11.66	11.35

Turbidity values during this deployment period ranged between a minimum of 0.0NTU and a maximum of 1.2NTU. The median for the turbidity data remained a 0.0NTU. This indicates that there is no natural background turbidity at this station (Figure 6)

This station remains stable during this deployment season with no large changes in the turbidity dataset.

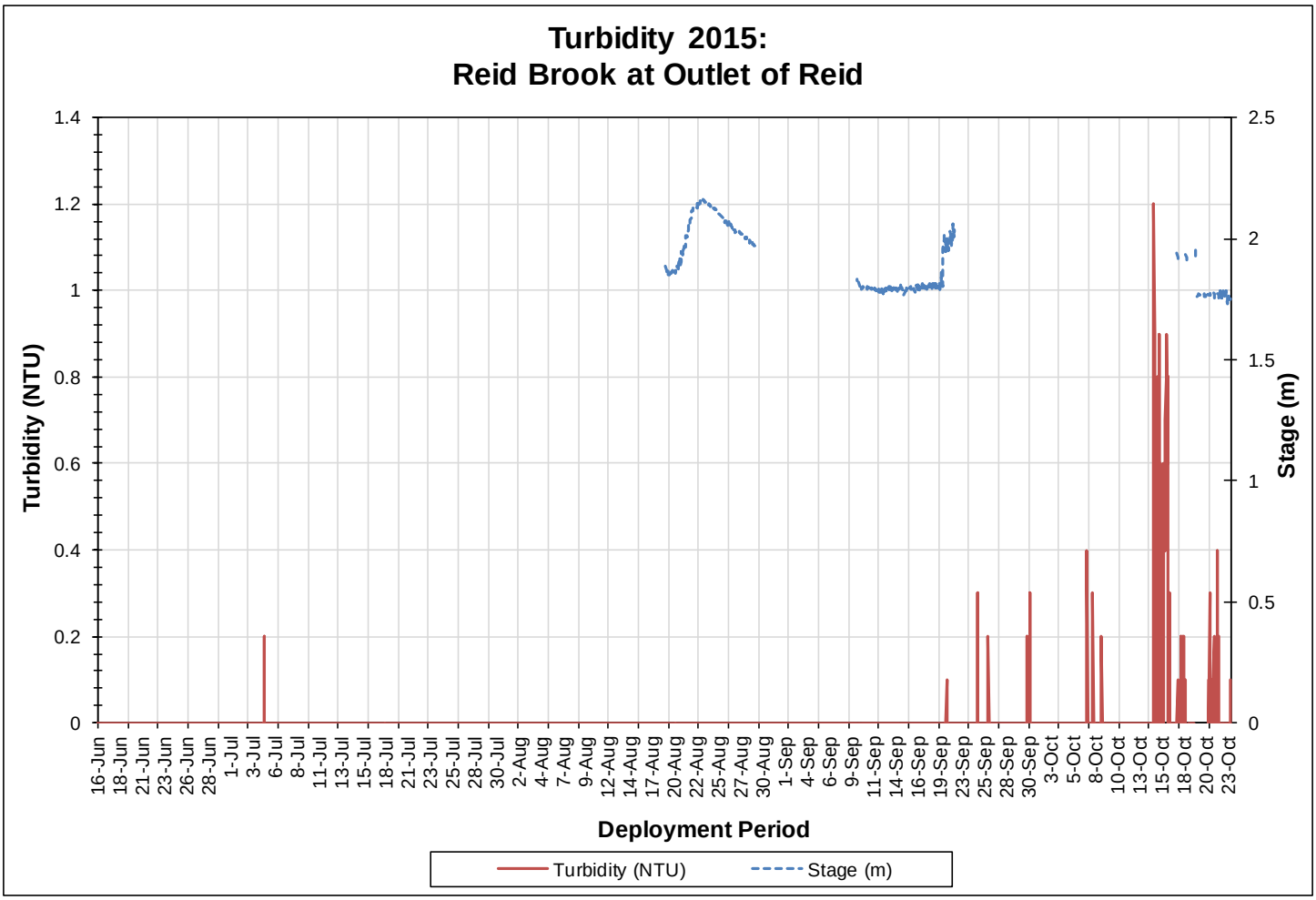

Figure 6: Turbidity and Stage data at Reid Brook at Outlet to Reid Pond

Turbidity	2015	2014	2013
Min	0.0	0.0	0.0
Max	1.2	49.3	51.1
Median	0.0	0.0	0.0

Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

During this deployment season there was an ongoing issue with data transmission for the stage and flow data.

To provide an overview of the external factors that can influence water quality and quantity parameters precipitation was included in the graph below (Figure 7).

Precipitation was graphed with stage and streamflow to indicate how external factors such as rainfall, can influence the change in water bodies (Figure 7). The precipitation data was received from the weather station in Nain. As of August 19th the weather station in Nain was no longer providing precipitation data therefore this data was obtained from the onsite Voisey's Bay weather station for the remainder of the deployment period.

This deployment season had frequent rainfall. The rainfall events occurred about ~52% of the deployment period. Precipitation over the deployment had a minimum of 0.0mm to a maximum of 61.5mm on October 20, 2015.

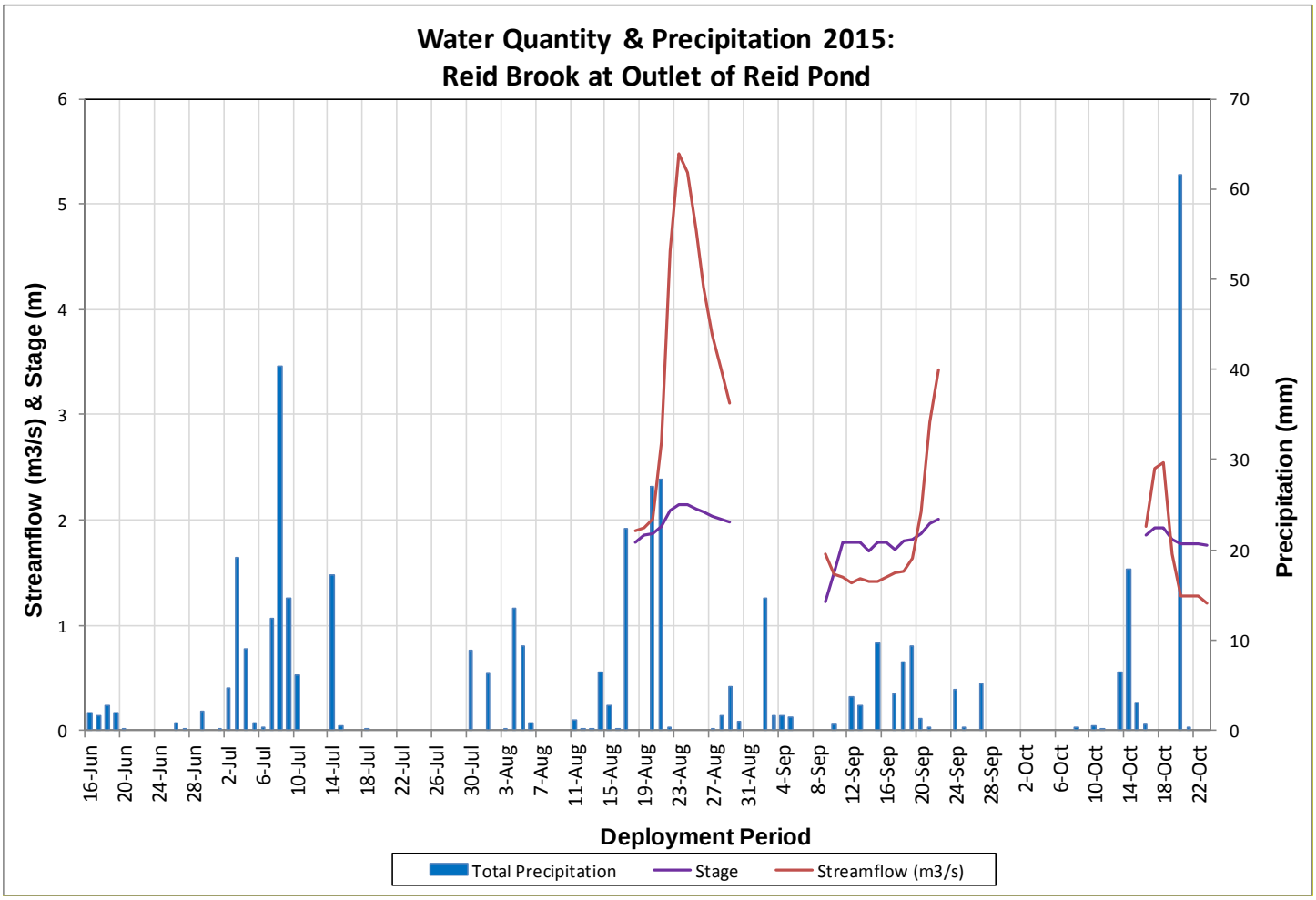

Figure 7: Daily Precipitation and average daily Stage and Streamflow at Reid Brook at Outlet of Reid Pond (Weather data recorded at Nain & Voisey's Bay weather station)

All photos were taken by WRMD Staff during a visit to Voisey's Bay in July 2015.

Figure 8: Animal damage at Reid Brook at Outlet of Reid Pond

Figure 9: Vale Staff deploying instrument at Reid Brook

Figure 10: Reid Brook at Outlet of Reid Pond Station

Figure 11: Vale Staff installing new cable at Reid Brook

Figure 12: Panorama of Reid Brook at Outlet of Reid Pond

Camp Pond Brook below Camp Pond

During this deployment season the water temperature values at Camp Pond Brook ranged from a minimum of 0.38°C to a maximum of 21.7°C (Figure 13). The highest temperatures occurred in late June and then again throughout July and August.

Overall the water temperature increased at the beginning of the first deployment period and peaked during the second and third deployment. At the end of August the water temperatures steadily decline as the air temperatures change with the winter season approaching.

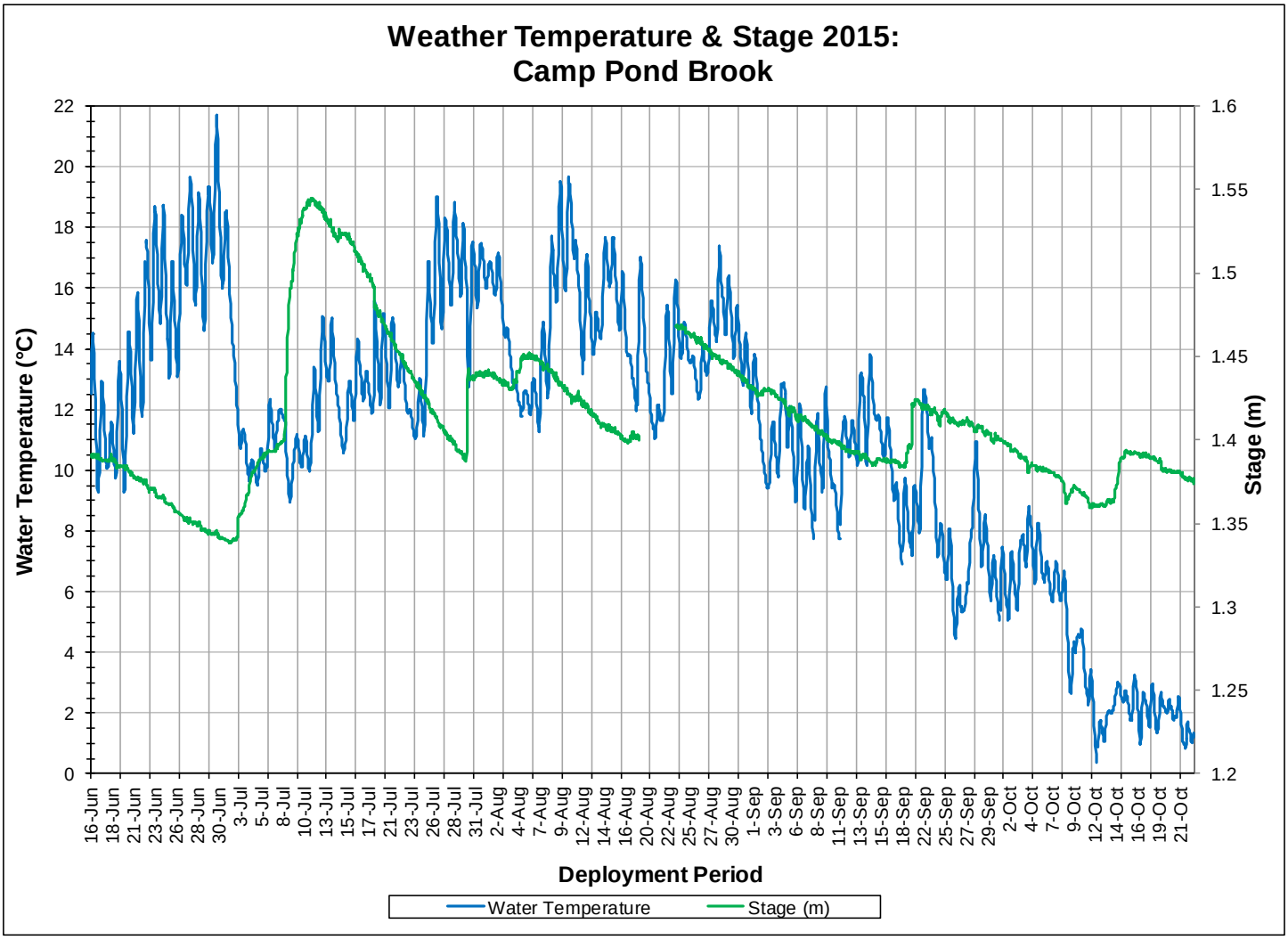

Figure 13: Water temperature and Stage Level at Camp Pond Brook below Camp Pond

Water Temperature	2015	2014	2013
Min	0.38	0.39	0.03
Max	21.7	22.90	21.06
Median	11.95	12.34	10.48

Water temperature values show a close relationship with air temperatures (Figure 14). Increases and decreases in air temperatures are reflected in water temperatures. Air temperatures clearly fluctuate at a greater scale each day when compared with water temperatures.

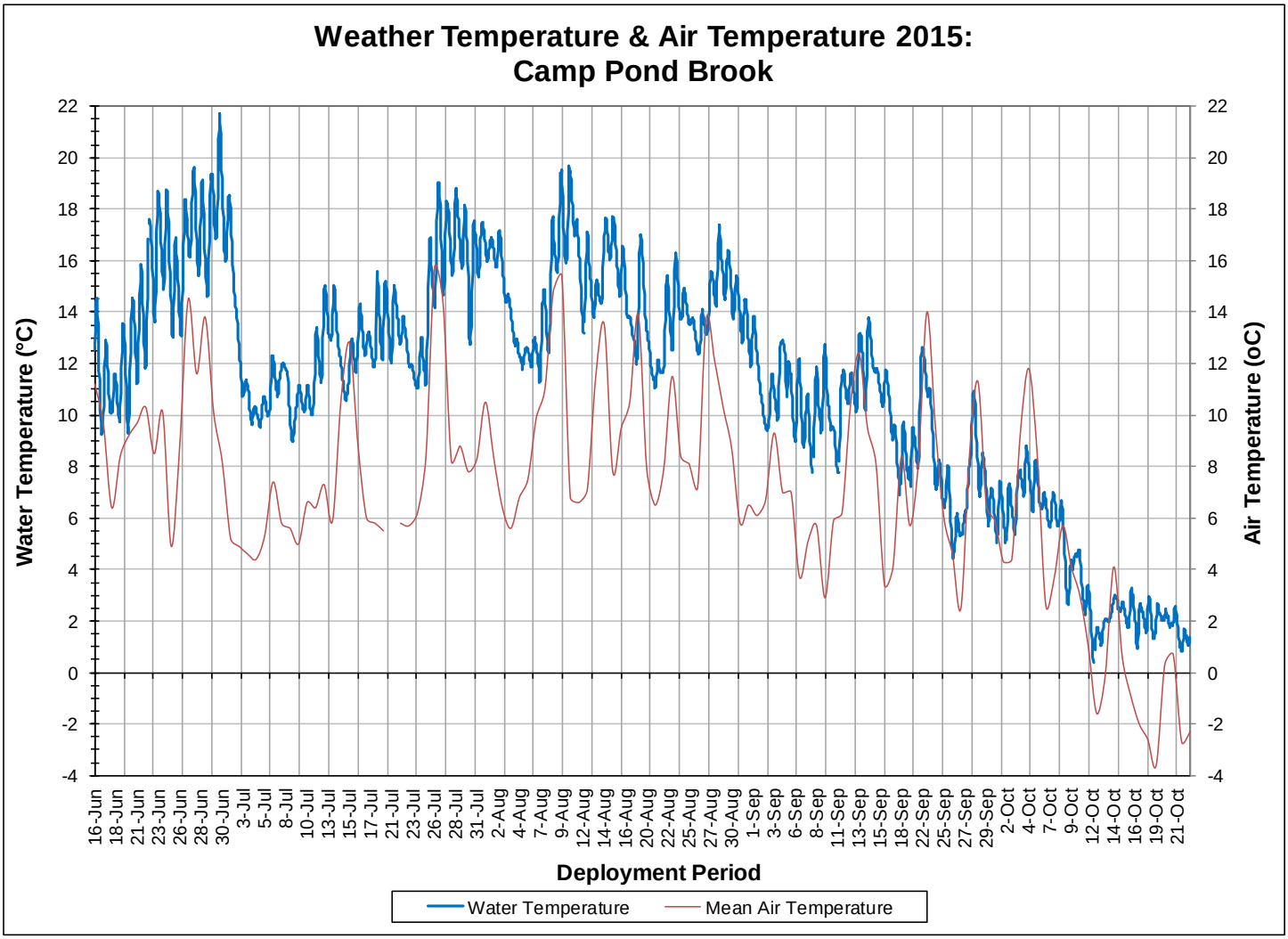

Figure 14: Average Daily Air Temperature from Nain weather station and Water Temperature at Camp Pond Brook below Camp Pond

During this deployment season the pH data ranged between a minimum of 6.21 and a maximum of 7.33 pH units throughout the deployment season (Figure 15). The data for 2015 has a median value of 6.92 pH units when compared with the median value of 6.85 pH units in 2014 and 6.95 in 2013.

Stage is included on Figure 15 to show the relationship between water level and pH. The pH data is reasonably stable, except for a small dip on July 9th to July 18th where the values drop below the minimum guideline for a short span of time. Majority of the events in this deployment season can be linked to precipitation during the same time frames.

Most of the pH data is within the recommended range that is suggested by the CCME Guidelines for the Protection of Aquatic Life (>6.5 and <9.0 pH units). Guidelines are indicated in red on Figure 15.

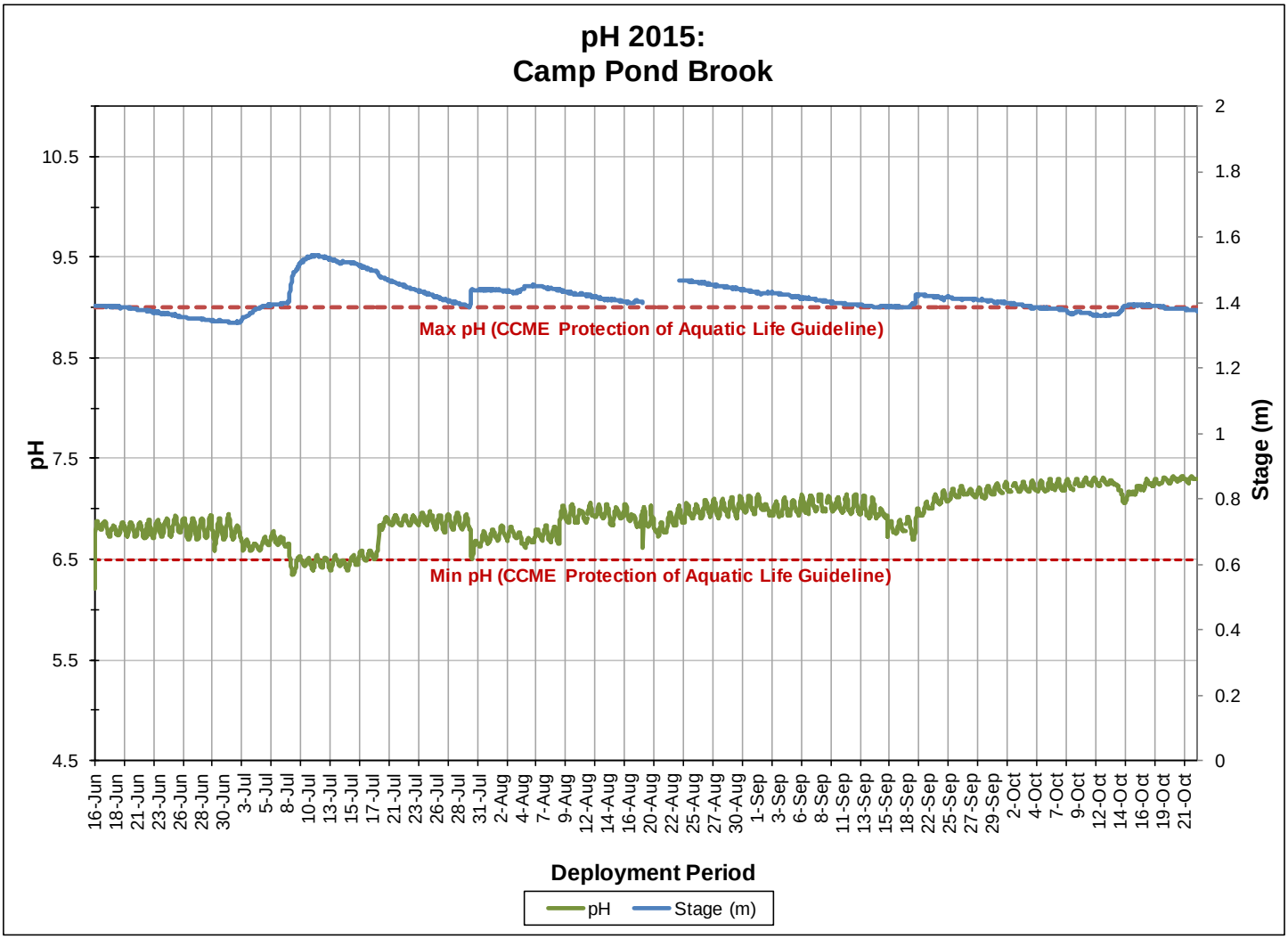

Figure 15: pH and Stage Level at Camp Pond Brook below Camp Pond

pH	2015	2014	2013
Min	6.21	6.40	6.20
Max	7.33	7.08	7.21
Median	6.92	6.85	6.95

This deployment season had specific conductivity data within a minimum of 30.3µS/cm and a maximum of 55.5µS/cm (Figure 16). This deployment season had a slightly lower conductivity median of 34.8µS/cm when compared with the 2014 conductivity median of 35.5µS/cm.

Stage is included in Figure 16 to illustrate the comparable relationship between conductivity and water level. At this station when stage levels are high the conductivity level also increases. This is generally not the case at other stations, however due to the proximity of this brook to roadways and the mine site this brook is heavily influenced by runoff factors that the other Voisey's Bay real-time stations do not exhibit.

Over the entire deployment season the conductivity level in the brook increased slightly, while the stage level decreased. This relationship is to be expected as the incidents of rainfall and bank runoff start to decrease as the winter season approaches.

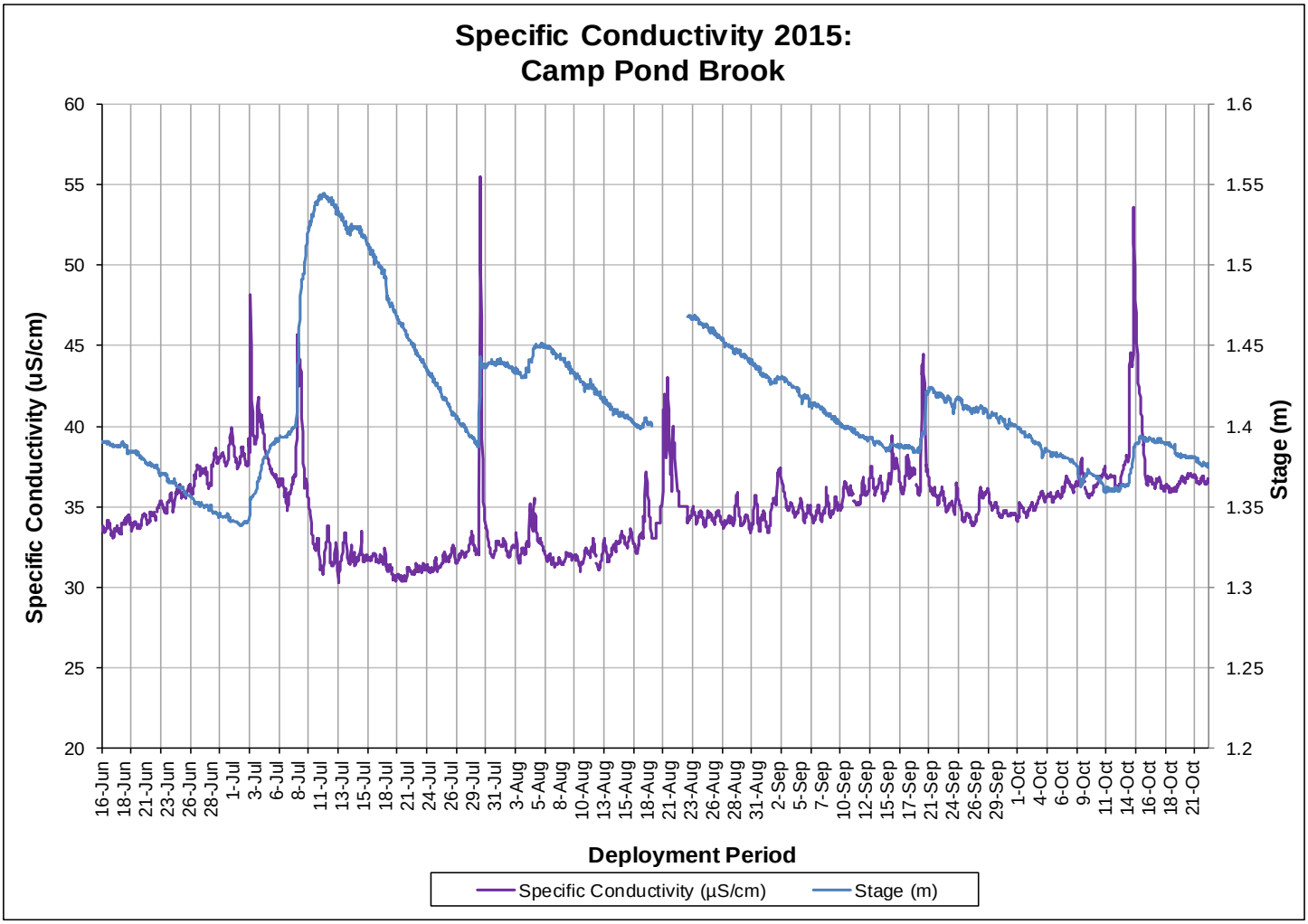

Figure 16: Specific conductivity and Stage Level at Camp Pond Brook below Camp Pond

Specific Conductivity	2015	2014	2013
Min	30.3	27.8	14.9
Max	55.5	56.7	47.5
Median	34.8	35.5	36.3

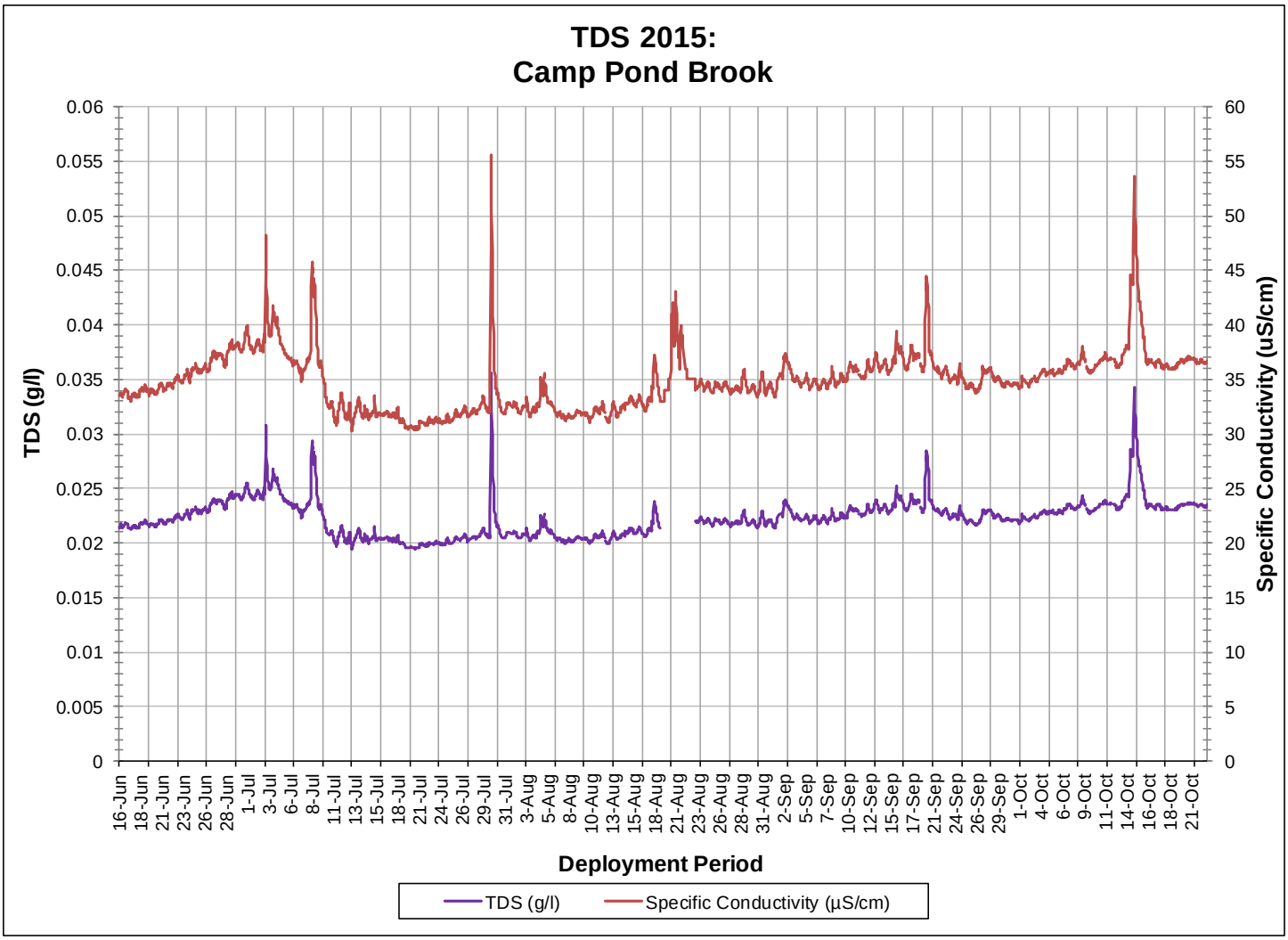

Figure 17: TDS and Specific conductivity at Camp Pond Brook below Camp Pond

This deployment season at Camp Pond Brook had dissolved oxygen values that ranged between a minimum of 8.51mg/l and a maximum of 11.55mg/l, with a slightly higher median value of 10.03mg/L than the 2014 median of 9.86mg/l. The saturation of dissolved oxygen ranged from a minimum of 89.3% to 102.2%, with a median value of 95.2% (Figure 18).

Dissolved oxygen content showed a typical seasonal trend, inverse to water temperature. Dissolved oxygen content is decreasing throughout June and July reaching a seasonal low toward the end of August when water temperatures are the warmest. As water temperatures decrease in the late summer and early fall, dissolved oxygen content begins to increase. There are fluctuations that are concurrent with the changes in water temperature. No data was recorded for this parameter in the final deployment period due to a sensor failure.

All values were above the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5mg/l). There were some dips below the CCME Guideline for the Protection of Aquatic Life at Early Life Stages (9.5mg/l) however the dips correspond with water temperature lows during those same time frames. The guidelines are indicated in red on Figure 18.

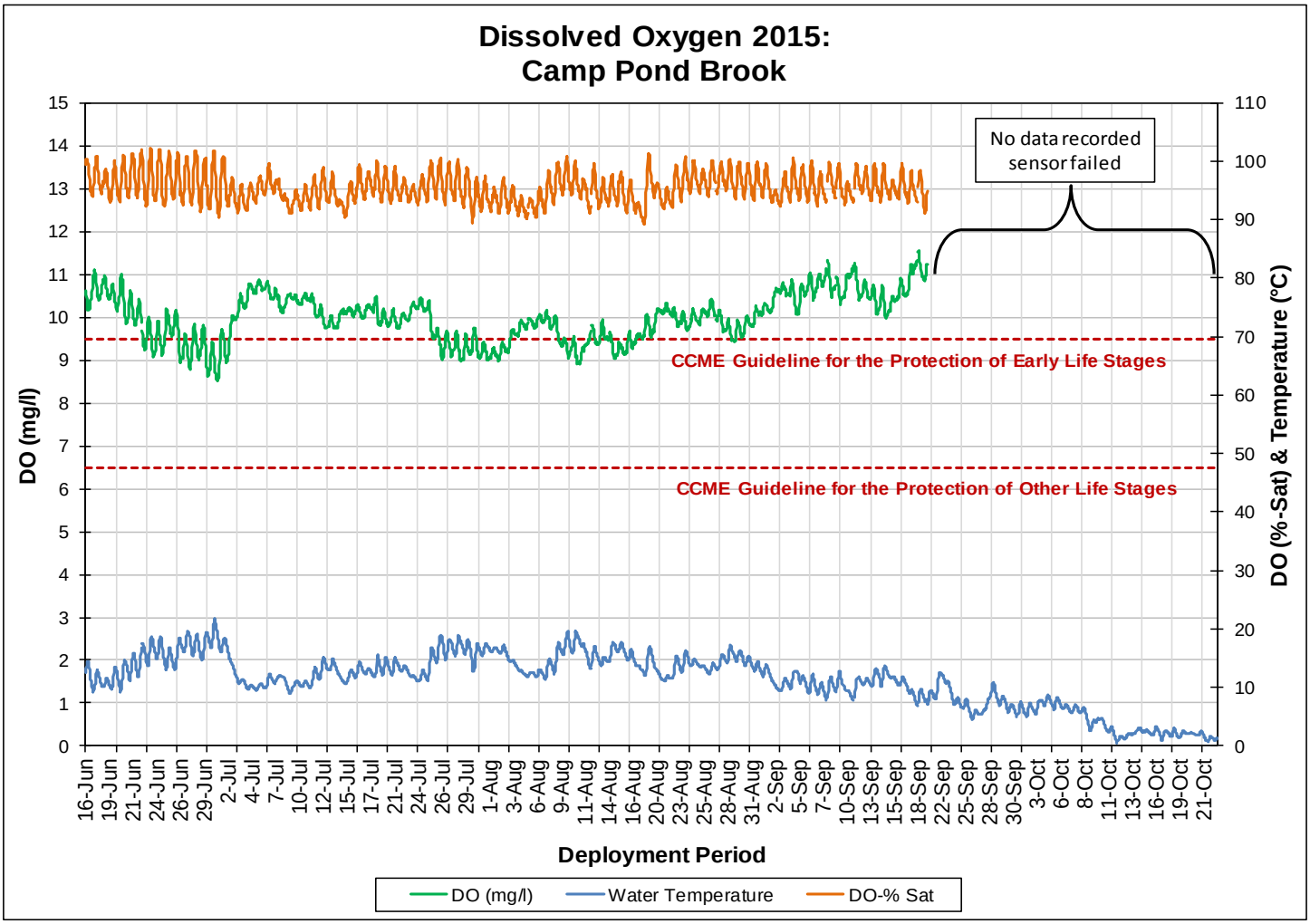

Figure 18: Dissolved Oxygen and Water Temperature at Camp Pond Brook below Camp Pond

Dissolved Oxygen (mg/l)	2015	2014	2013
Min	8.51	8.08	8.47
Max	11.55	13.67	13.72
Median	10.03	9.86	10.40

Camp Pond Brook below Camp Pond had turbidity values that ranged between a minimum of 0.0NTU and a maximum of 31.5NTU during the 2015 deployment season (Figure 19). A median value of 0.0NTU indicates there is very little or no natural background turbidity occurring at this station.

While there are a number of turbidity spikes throughout the four deployment periods from June to October 2015, the majority of these increases correspond with rainfall events. Turbidity events are similar throughout the deployment season. Most events are low in magnitude and short in duration.

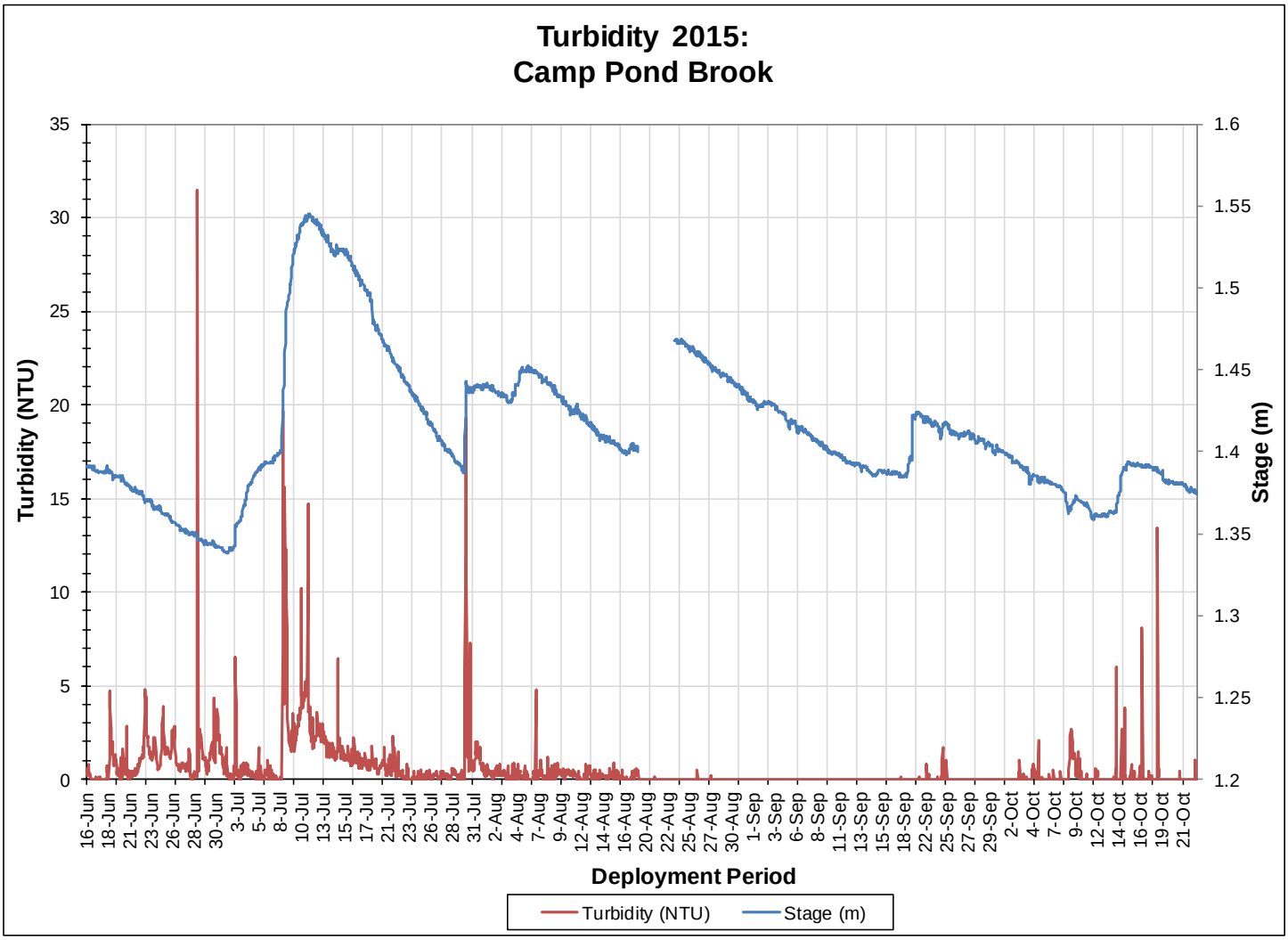

Figure 19: Turbidity and Stage Level at Camp Pond Brook below Camp Pond

Turbidity	2015	2014	2013
Min	0.0	0.0	0.0
Max	31.5	117.7	61.4
Median	0.0	0.3	0.0

Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

Camp Pond Brook below Camp Pond had transmission issues once in the middle of the deployment season from August 19th to 23rd. The deployment season stage levels ranged within a daily average minimum of 1.34m to a daily average maximum of 1.54m. The streamflow data ranged between a daily average minimum of 0.15m^3/s and a daily average maximum of 1.14m^3/s at Camp Pond (Figure 20).

To provide an overview of the external factors that can influence water quality and quantity, parameters precipitation was included in the graph below (Figure 20).

Precipitation was graphed with stage and streamflow to indicate how external factors such as rainfall, can influence the change in water bodies (Figure 20). The precipitation data was received from the weather station in Nain. As of August 19th the weather station in Nain was no longer providing precipitation data therefore this data was obtained from the onsite Voisey's Bay weather station for the remainder of the deployment period.

This deployment season had frequent rainfall. The rainfall events occurred about ~52% of the deployment period. Precipitation over the deployment had a minimum of 0.0mm to a maximum of 61.5mm on October 20, 2015.

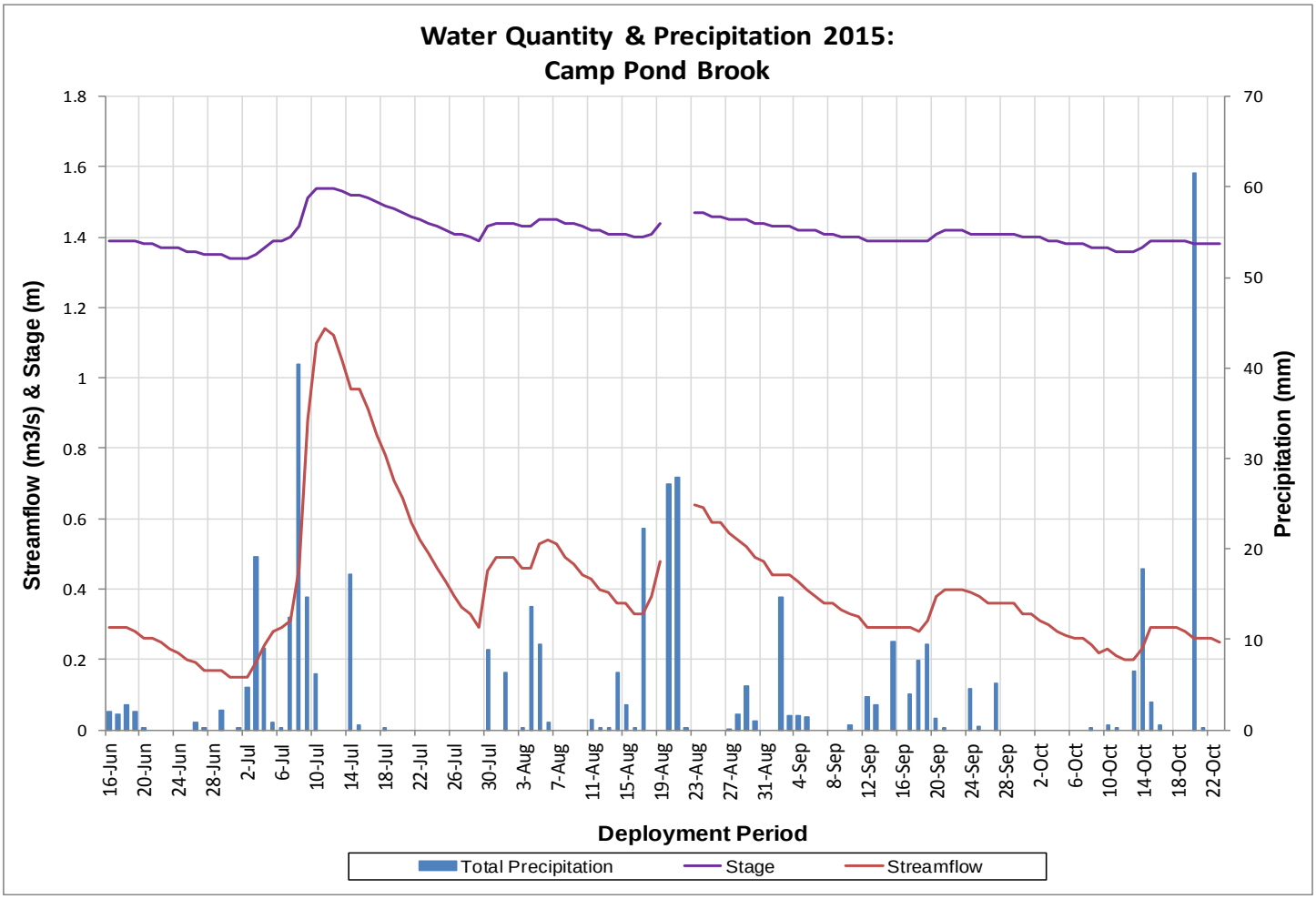

Figure 20: Daily precipitation and daily Stage and Streamflow at Camp Pond Brook below Camp Pond (Weather data recorded at Nain and Vosisey's Bay weather stations)

All photos were taken by WRMD Staff during a visit Voisey's Bay in July 2015.

Figure 21: Vale Staff deploying instrument at Camp Pond Brook

Figure 22: Camp Pond Brook Station

Figure 23: Camp Pond Brook

Figure 24: Vale Staff sampling at Camp Pond Brook

Figure 25: Panorama of Camp Pond Brook Station

Tributary to Lower Reid Brook

During this deployment season the water temperatures ranged between a minimum of 0.0°C to a maximum of 15.7°C at Tributary to Lower Reid Brook (Figure 26). The water temperatures were highest from early July to the end of August as the air temperatures increased with the summer season. From the end of August onwards the water temperatures made a steady decline as the ambient air temperatures adjusted to the fall and winter seasons approaching.

This station had an overall water temperature median value of 9.1°C which was slightly lower than 2014 water temperature median of 9.30°C (Figure 26).

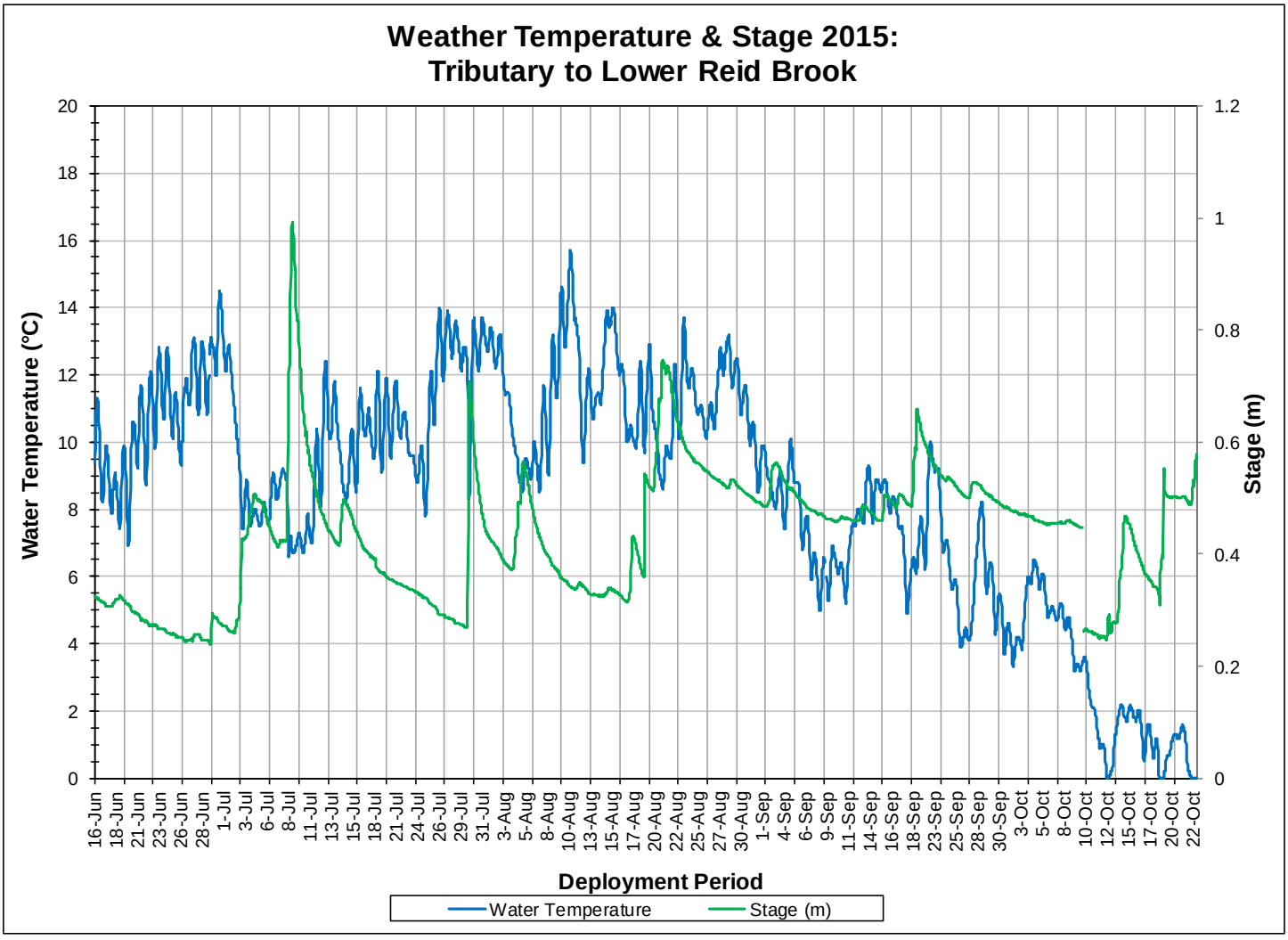

Figure 26: Water temperature and Stage Level at Tributary to Lower Reid Brook

Water Temperature	2015	2014	2013
Min	0.0	0.10	0.0
Max	15.7	18.30	16.40
Median	9.1	9.30	7.90

Water temperature values show a close relationship with air temperatures (Figure 27). Increases and decreases in air temperatures are reflected in water temperatures. Air temperatures clearly fluctuate at a greater scale each day when compared with water temperatures.

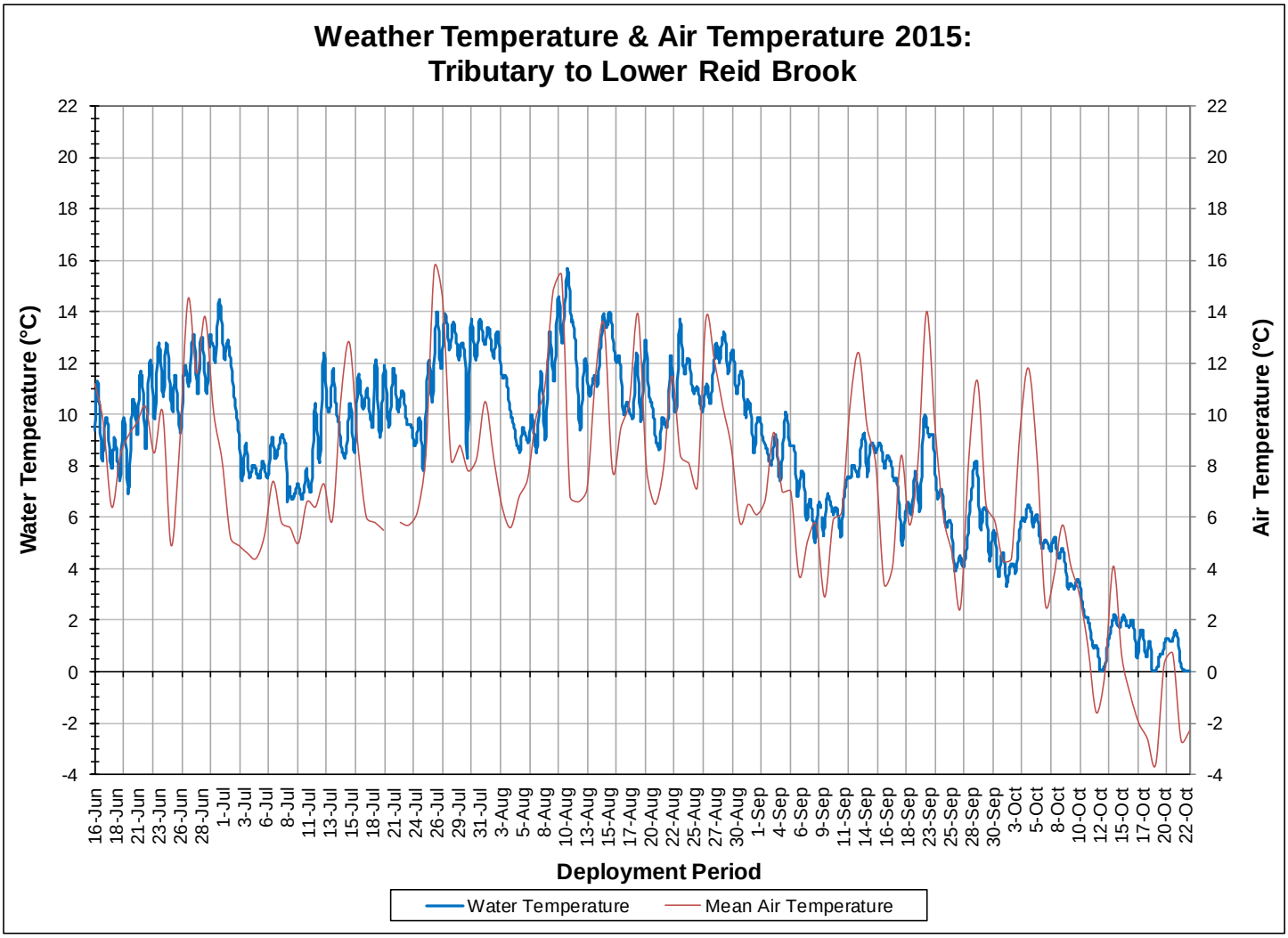

Figure 27: Average Daily Air Temperature from Nain weather station and Water Temperature at Tributary to Lower Reid Brook

The pH data at Tributary to Lower Reid Brook ranged between a minimum of 5.66 pH units and a maximum of 7.09 pH units throughout the deployment season. This data had a median of 6.78 pH units (Figure 28).

Stage is included on Figure 28 to show the relationship between water level and pH. pH values fluctuated throughout the deployment season corresponding with the changing water levels. On a number of occasions, pH decreases as stage increased. This trend is experienced throughout the different deployment periods.

pH values during this deployment season are mostly found along the minimum CCME Guideline for the Protection of Aquatic Life. The guidelines are indicated in red on Figure 28. On several occasions, the pH values drop under the suggested guideline however most of these events are during periods of high stage levels.

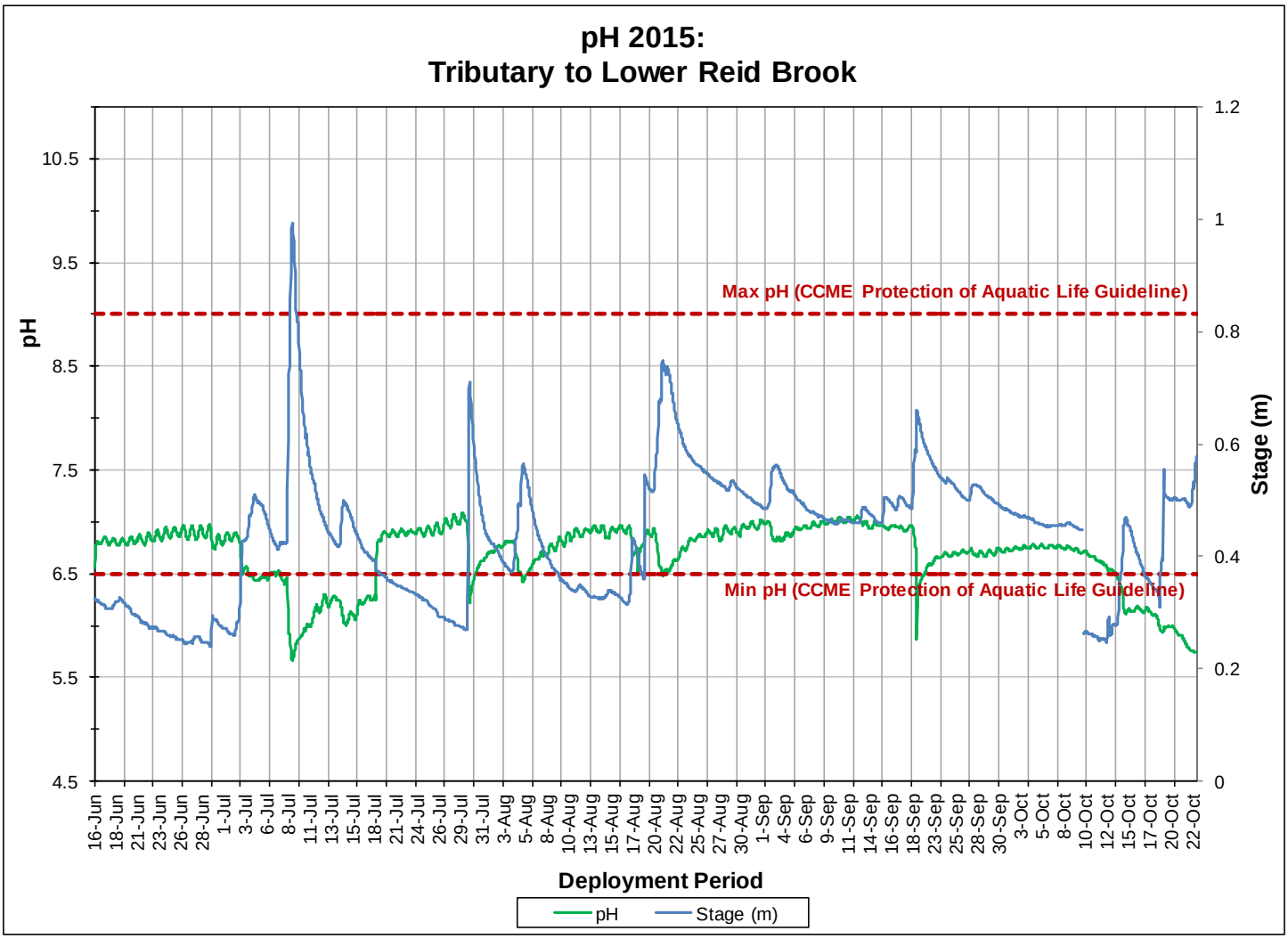

Figure 28: pH and stage level at Tributary to Lower Reid Brook

pH	2015	2014	2013
Min	5.66	6.07	6.46
Max	7.09	7.10	7.21
Median	6.78	6.69	6.88

The specific conductivity levels at Tributary to Lower Reid Brook ranged between a minimum of 16.6µS/cm to a maximum amount of 41.4µS/cm during the deployment season. This deployment period data had a median value of 32.2µS/cm (Figure 29).

Stage is included in Figure 29 to illustrate the inverse relationship between conductivity and water level. Generally, the stage was decreasing during the deployment season with periodic short increases. Specific conductivity changes with the varying water level. As stage increases, specific conductivity generally decreases due to the dilution of dissolved solids in the water column. Inversely, as stage decreases, specific conductivity increases as the concentration of dissolved solids increases.

Specific conductivity is increasing throughout the entire deployment season with periodic short decreases. The general trend corresponds with the decreasing stage level. The relationship between stage levels and specific conductivity levels is typically very evident at this station.

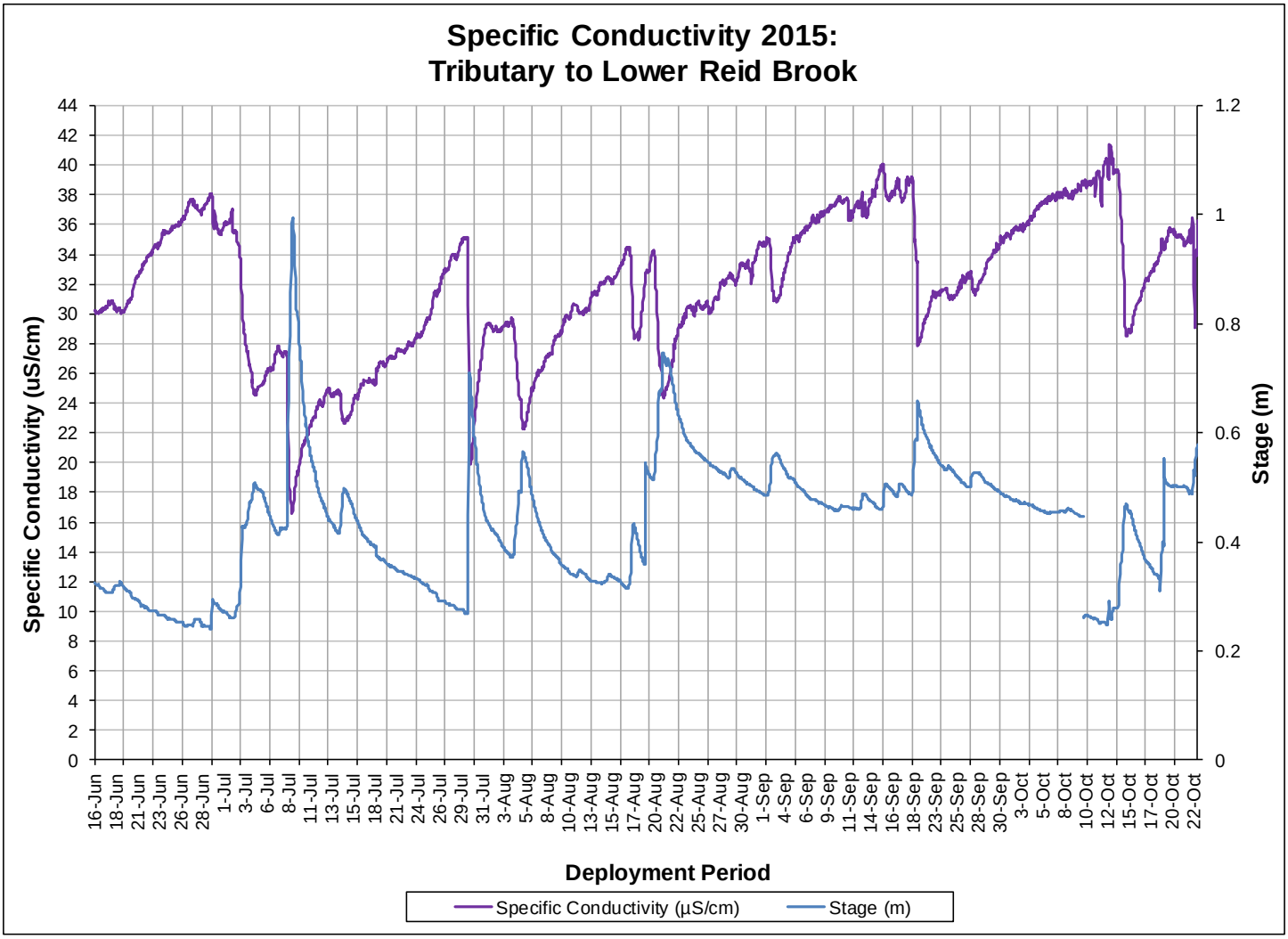

Figure 29: Specific conductivity and stage level at Tributary to Lower Reid Brook

Specific Conductivity	2015	2014	2013
Min	16.6	18.4	16.0
Max	41.4	42.6	56.6
Median	32.2	32.2	38.1

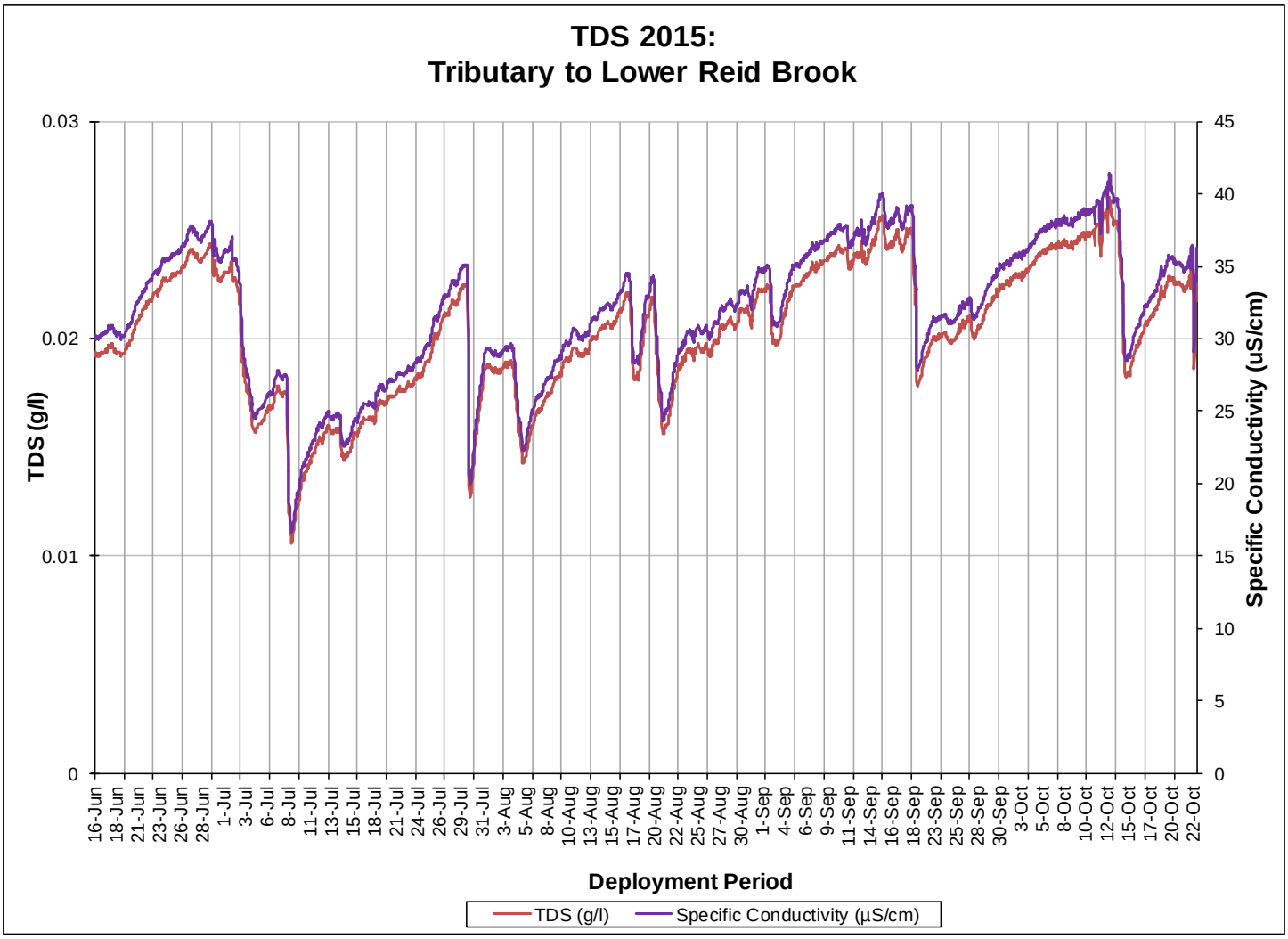

Figure 30: TDS and Specific conductivity at Tributary to Lower Reid Brook

This deployment season had dissolved oxygen content that ranged between a minimum of 9.63mg/l and a maximum of 12.56mg/l, with a median value of 11.05mg/l. The saturation of dissolved oxygen ranged from 91.6% to 100.8%, with a median value of 97% (Figure 31).

Dissolved oxygen content showed a typical seasonal trend, inverse to water temperature. Values are lower in the early summer months of June and July while water temperatures are increasing. As water temperatures decrease in the late summer and early fall, dissolved oxygen content begins to increase. No data was recorded during July and August and then September to October due to sensor failure on the instruments.

All of the recorded dissolved oxygen values were above the CCME Guideline for the Early Life Stages (9.5mg/l).

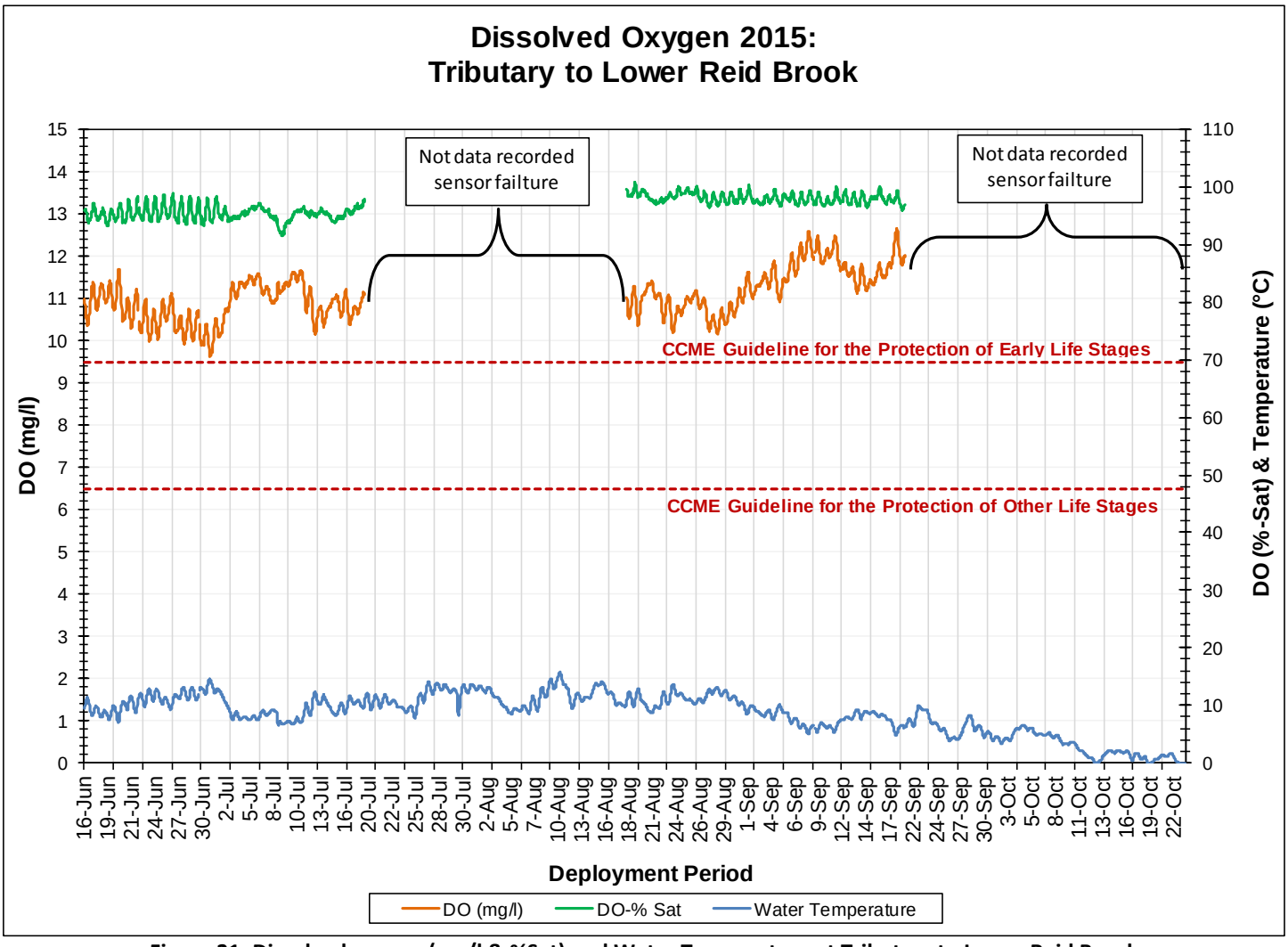

Figure 31: Dissolved oxygen (mg/l & %Sat) and Water Temperature at Tributary to Lower Reid Brook

Dissolved Oxygen (mg/l)	2015	2014	2013
Min	9.63	8.99	9.26
Max	12.65	14.12	13.96
Median	11.05	10.88	11.02

Tributary to Lower Reid Brook station had turbidity data that ranged within a minimum of 0.0NTU to a maximum of 738NTU during the 2015 deployment season (Figure 32). This data had a median value of 0.0NTU. The low turbidity median indicated that there is little to no natural background turbidity at this station.

There were a number of turbidity events throughout the four deployment periods from June to October. Many of the increases corresponded with rainfall events as indicated in the monthly deployment reports. Turbidity events were similar throughout the deployment season. The events that were captured were generally low in magnitude and short in duration.

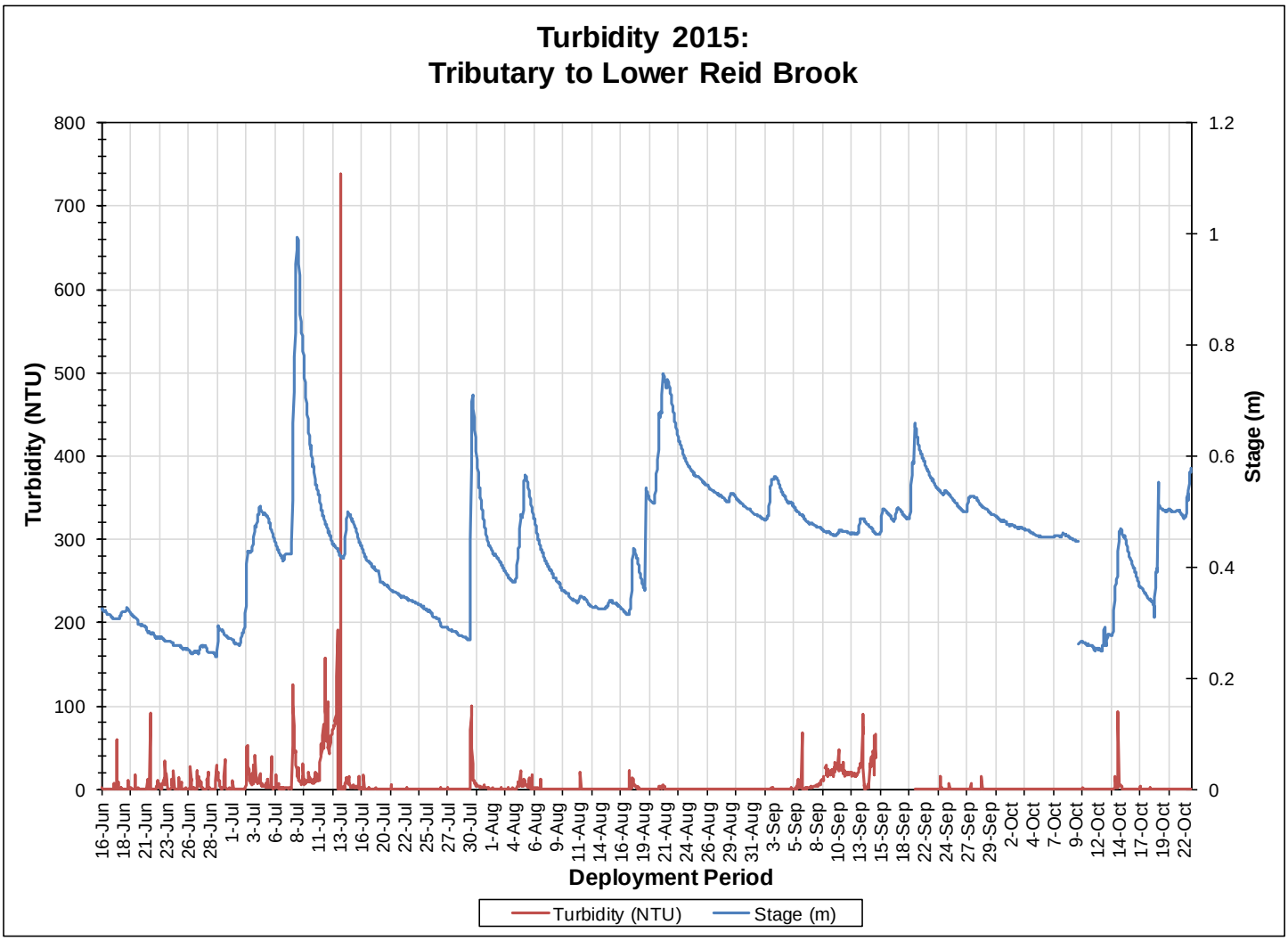

Figure 32: Turbidity and Stage level at Tributary to Lower Reid Brook

Turbidity	2015	2014	2013
Min	0.0	0.0	0.0
Max	738	125.3	68.6
Median	0.0	0.0	0.0

Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request. Tributary to Lower Reid Brook experienced some transmission errors with flow data over the course of the deployment season.

Tributary to Lower Reid Brook stage levels ranged within a daily average minimum of 0.25m to a daily average maximum of 0.86m. The streamflow data ranged between a daily average minimum of 0.01m^3/s and a daily average maximum of 2.14m^3/s at Tributary to Lower Reid (Figure 33).

Precipitation was graphed with stage and streamflow to indicate how external factors such as rainfall, can influence the change in water bodies (Figure 33. The precipitation data was received from the weather station in Nain. As of August 19th the weather station in Nain was no longer providing precipitation data therefore this data was obtained from the onsite Voisey's Bay weather station for the remainder of the deployment period.

This deployment season had frequent rainfall. The rainfall events occurred about ~52% of the deployment period. Precipitation over the deployment had a minimum of 0.0mm to a maximum of 61.5mm on October 20, 2015.

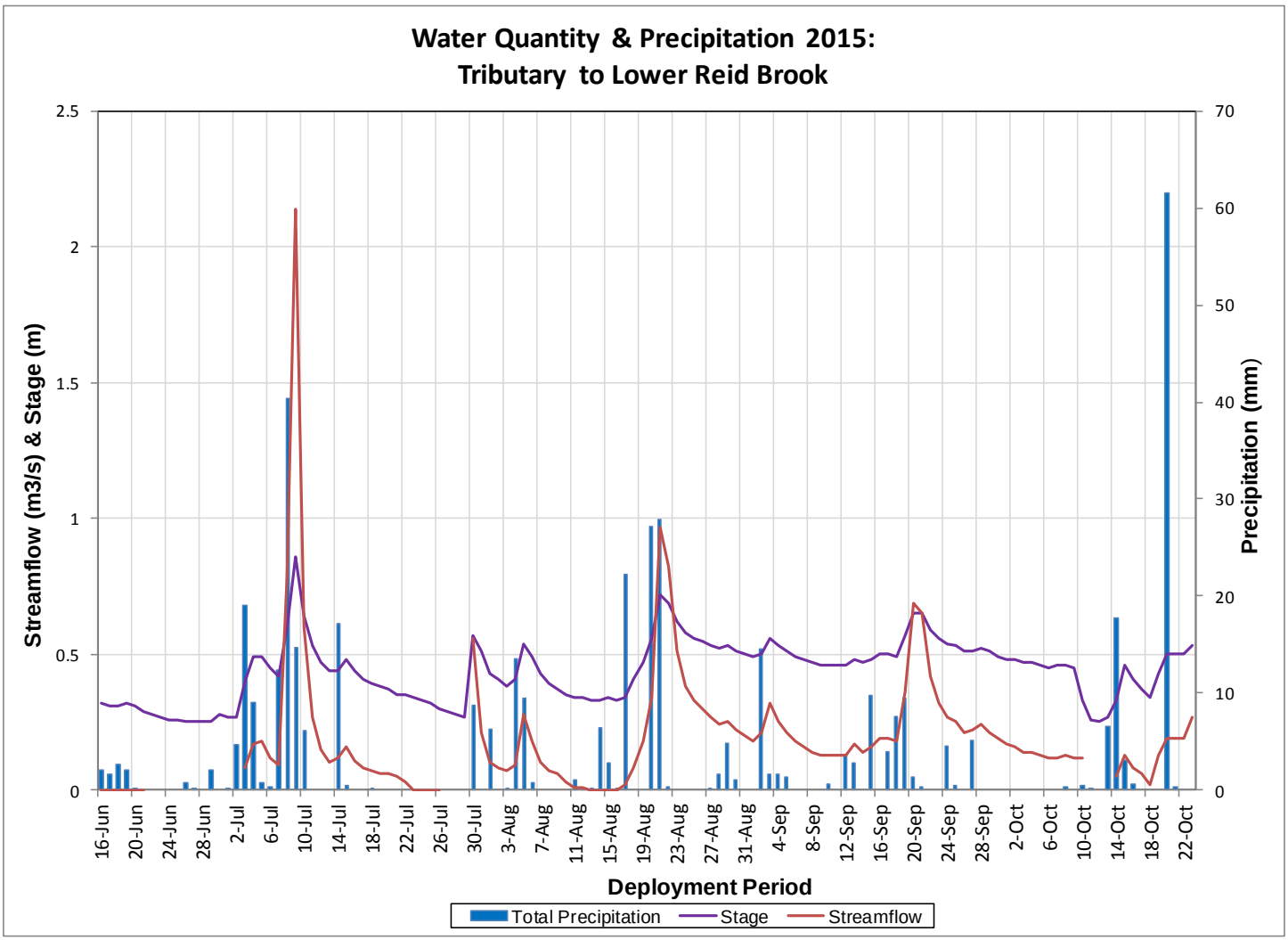

Figure 33: Daily Precipitation and average daily Stage and Streamflow level at Tributary to Lower Reid Brook (Weather data recorded at Nain & Voisey's Bay weather stations)

All photos were taken by WRMD Staff during a visit to the Voisey's Bay in July 2015.

Figure 34: Tributary to Lower Reid Brook

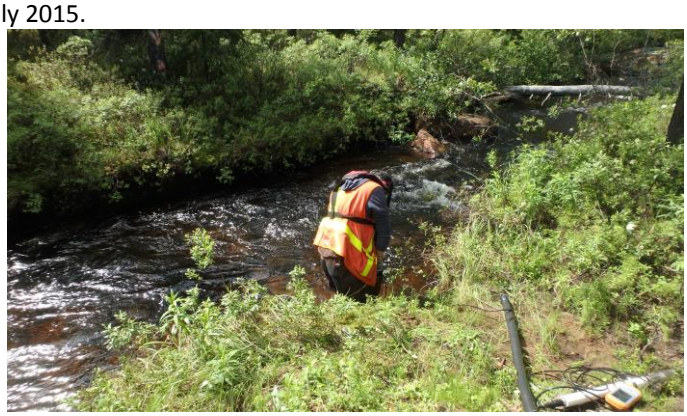

Figure 35: Vale Staff deploying instrument at Tributary to Lower Reid Brook

Figure 36: Tributary to Lower Reid Brook Station

Figure 37: Animal damage at Tributary to Lower Reid Brook

Lower Reid Brook below Tributary

During the deployment season the water temperature ranged between a minimum of 0.16°C to a maximum of 16.11°C. This station had a median of 9.39°C which was exactly the same as the 2014 deployment season (Figure 38).

During the July and August months the water temperature for Lower Reid brook displayed the highest temperatures for the deployment season. When the summer period (July and August) ended the water temperatures started to decline almost immediately as the climate changed as the fall and winter seasons approached.

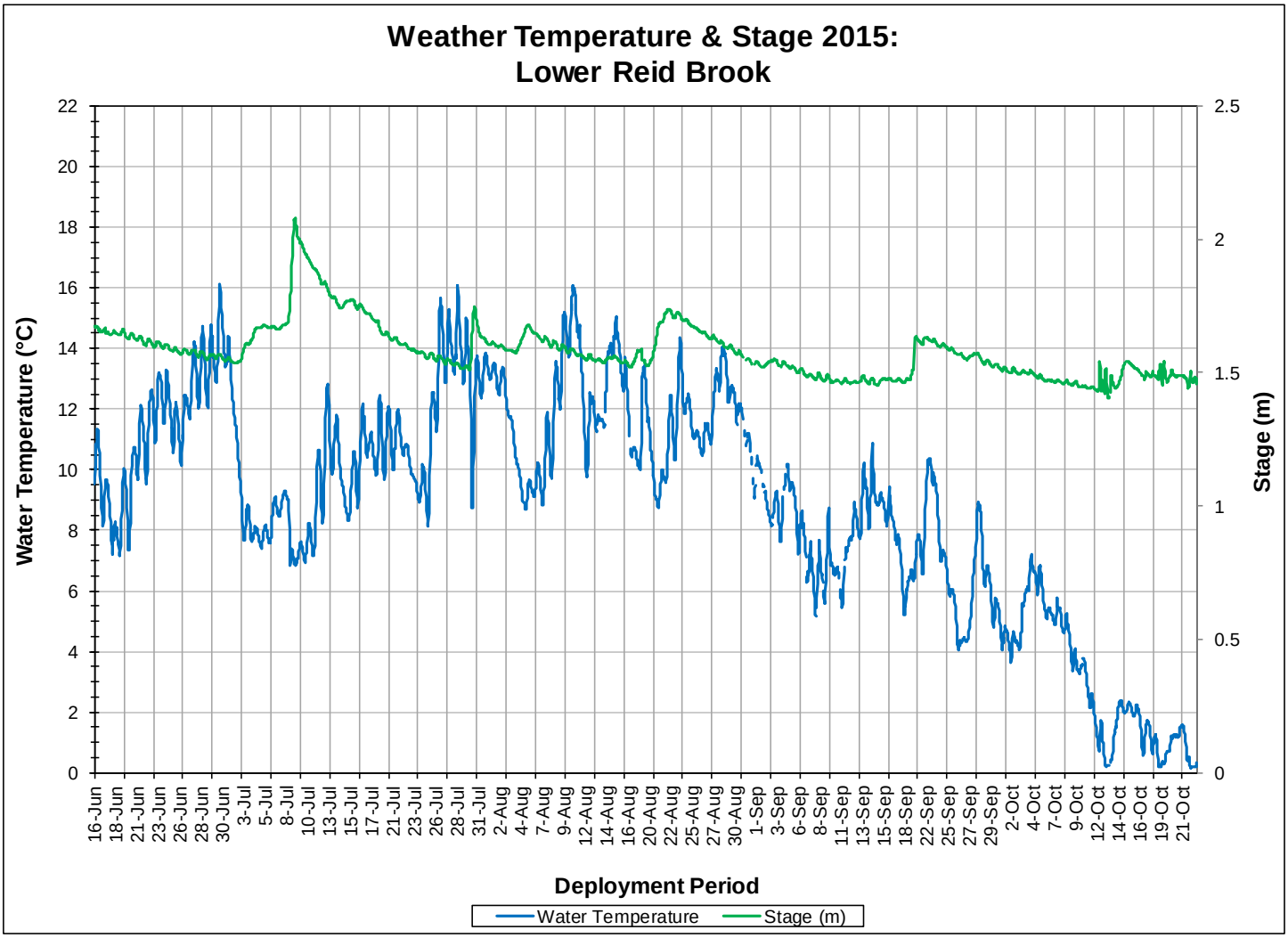

Figure 38: Water temperature at Lower Reid Brook below Tributary

Water Temperature	2015	2014	2013
Min	0.16	0.15	0.19
Max	16.11	19.44	16.68
Median	9.39	9.39	8.12

Water temperature values show a close relationship with air temperatures (Figure 39). Increases and decreases in air temperatures are reflected in water temperatures. Air temperatures clearly fluctuate at a greater scale each day when compared with water temperatures.

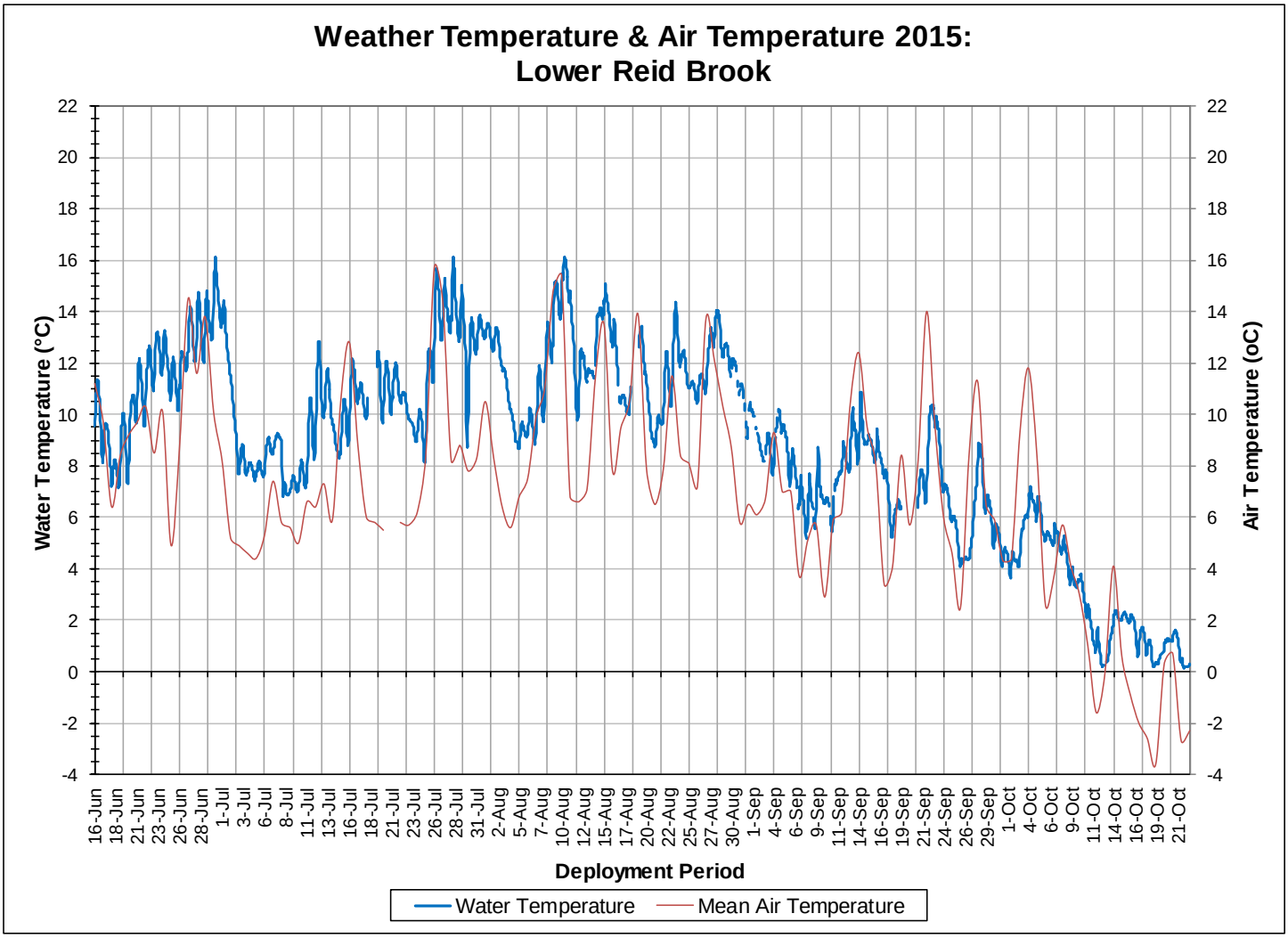

Figure 39: Water temperatures at Lower Reid Brook below Tributary and Average Daily Air Temperatures at Nain Weather Station

At Lower Reid Brook below Tributary the pH data during the deployment season ranged between a minimum of 5.79 to a maximum of 9.8 pH units during the deployment season, with a median value of 6.89 pH units (Figure 40).

Most of the values were within the recommended range for pH as suggested by the CCME Guidelines for the Protection of Aquatic Life (>6.5 and <9.0 pH units). Guidelines are indicated in red on Figure 40. There were several days that pH dipped below the minimum guideline, this seemed to occur during higher stage levels and after several days the pH levels climbed back within the CCME guideline. A large increase in pH occurred early in the season from July 11-16th. This increase was preceded by 4 days of rain, totalling 73.7 mm. The instrument also experienced an increase in turbidity at the time possibly altering the pH sensors readings.

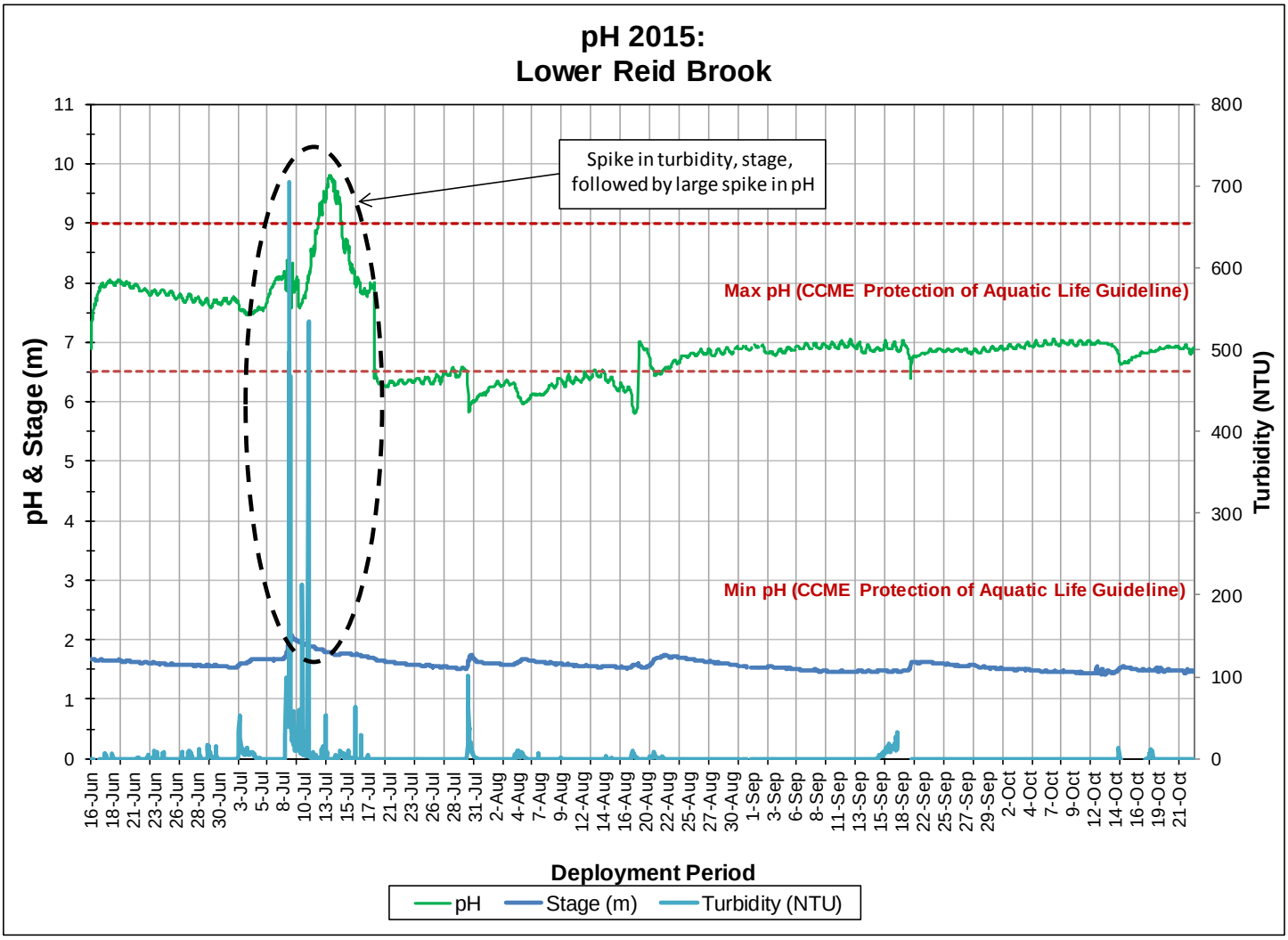

Figure 40: pH and stage level at Lower Reid Brook below Tributary

pH	2015	2014	2013
Min	5.79	6.07	5.96
Max	9.8	7.42	7.25
Median	6.89	6.77	6.86

The specific conductivity data ranged between a minimum of 15.7µS/cm to a maximum of 38.5µS/cm during the deployment season. The specific conductivity data had a median of 28.9µS/cm which was just slightly lower than 2014 deployment season which had a median value of 31.7µS/cm (Figure 41).

Stage was included in Figure 41 to illustrate the inverse relationship between conductivity and water level. Generally, stage fluctuates throughout the deployment season. Specific conductivity levels do change with the varying water level. As the stage level increased, specific conductivity generally decreased due to the dilution of dissolved solids in the water column. Inversely, as stage decreased, specific conductivity increased as the concentration of dissolved solids rises.

Specific conductivity values generally increase throughout the entire deployment season. The relationship between stage level and specific conductivity values was evident throughout the entire deployment season.

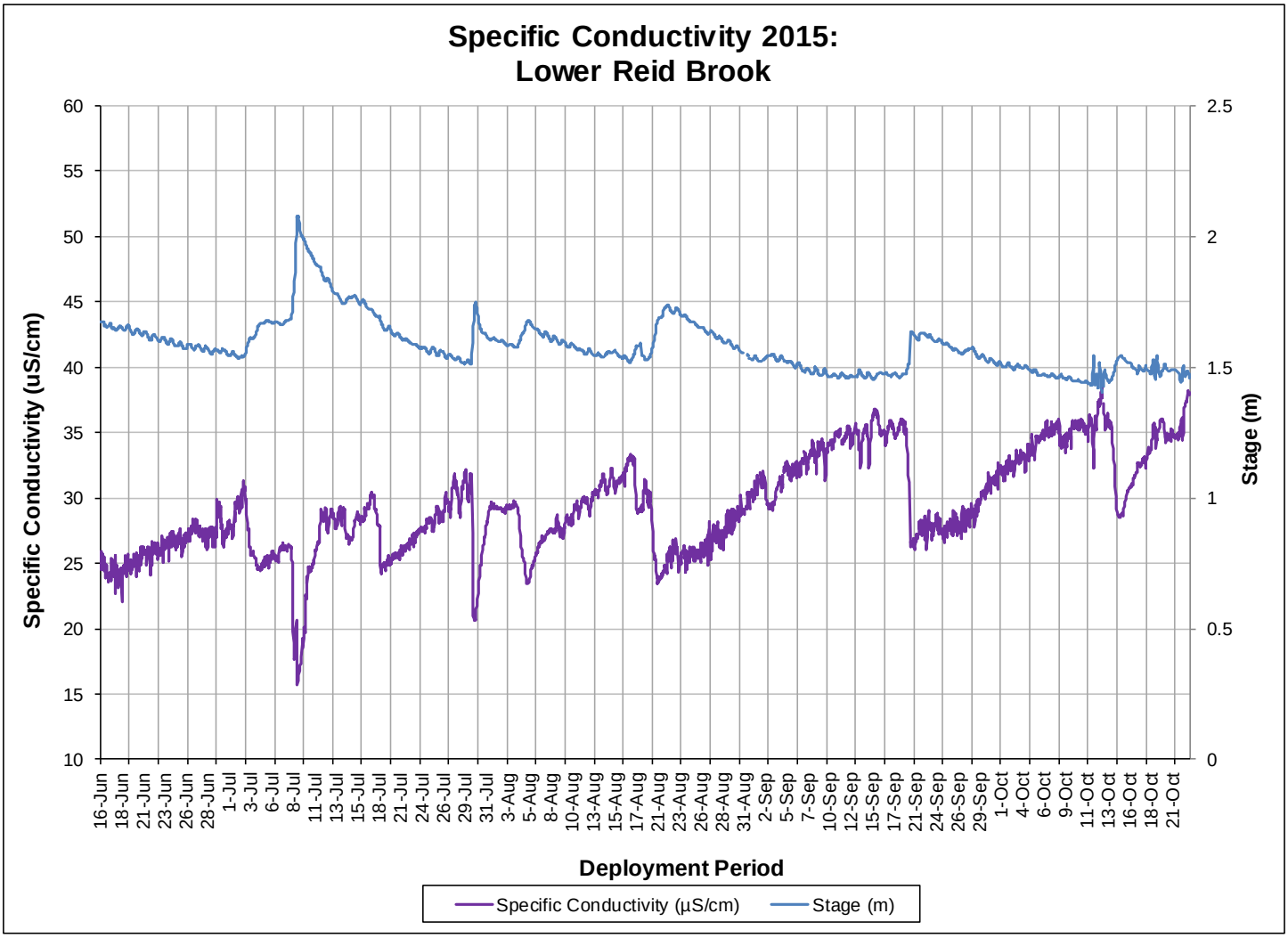

Figure 41: Specific conductivity and stage level at Lower Reid Brook below Tributary

Specific Conductivity	2015	2014	2013
Min	15.7	15.1	13.9
Max	38.5	41.5	52.5
Median	28.9	31.7	34.6

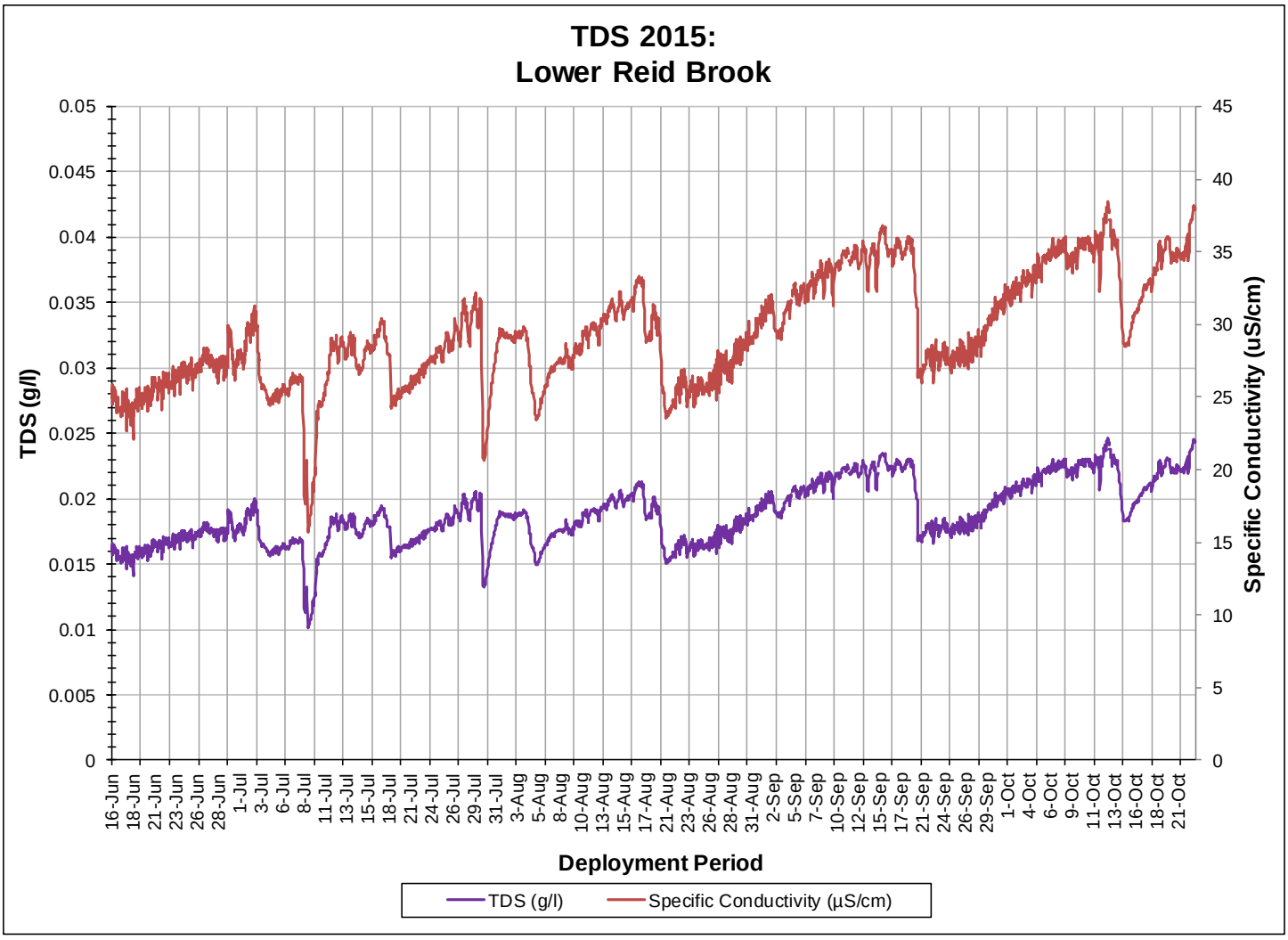

Figure 42: TDS and Specific Conductivity at Lower Reid Brook below Tributary

The dissolved oxygen content at Lower Reid Brook below Tributary ranged between 9.36mg/l to 14.25mg/l, with a median value of 11mg/l during this deployment season. The saturation of dissolved oxygen ranged within 89.6% to 102.3%, with a median value of 96.2% (Figure 43).

Dissolved oxygen content indicated a typical seasonal trend, inverse to water temperature. Dissolved oxygen content was lower throughout the latter half of June and the month of July reaching a seasonal low in late July. As water temperatures decrease in the late summer and early fall, dissolved oxygen content begins to increase.

All the dissolved oxygen concentration values were above the minimum CCME Guideline for the Protection of Other Life Stages (6.5mg/l). During warmer temperature the dissolved oxygen did drop below the Guideline for the Protection of Early Life Stages (9.5mg/L) on June 30th and August 10th for brief periods of time.

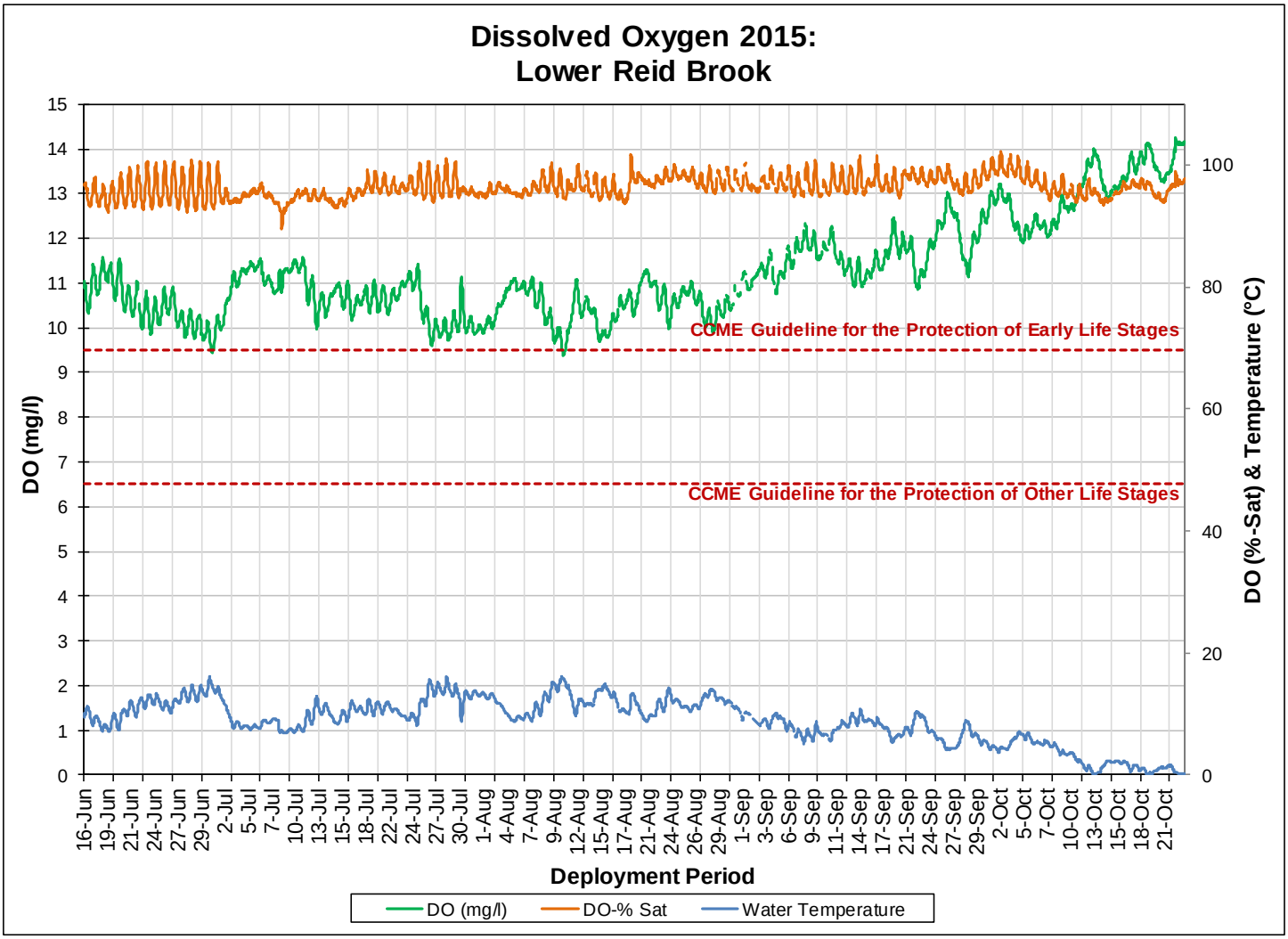

Figure 43: Dissolved Oxygen (mg/L & % Sat) and Water Temperature at Lower Reid Brook below Tributary

Dissolved Oxygen (mg/l)	2015	2014	2013
Min	9.36	8.91	9.43
Max	14.25	13.93	13.89
Median	11	10.70	11.46

The turbidity data at Lower Reid Brook below Tributary ranged between a minimum of 0.0NTU and a maximum of 705NTU during the 2015 deployment season (Figure 44). This data set had a median value of 0.0NTU which indicated that there was little to no natural turbidity present at this station.

There are a number of turbidity events throughout the four deployment periods from June to October. Many of these increases corresponded with rainfall events as indicated in the monthly deployment reports.

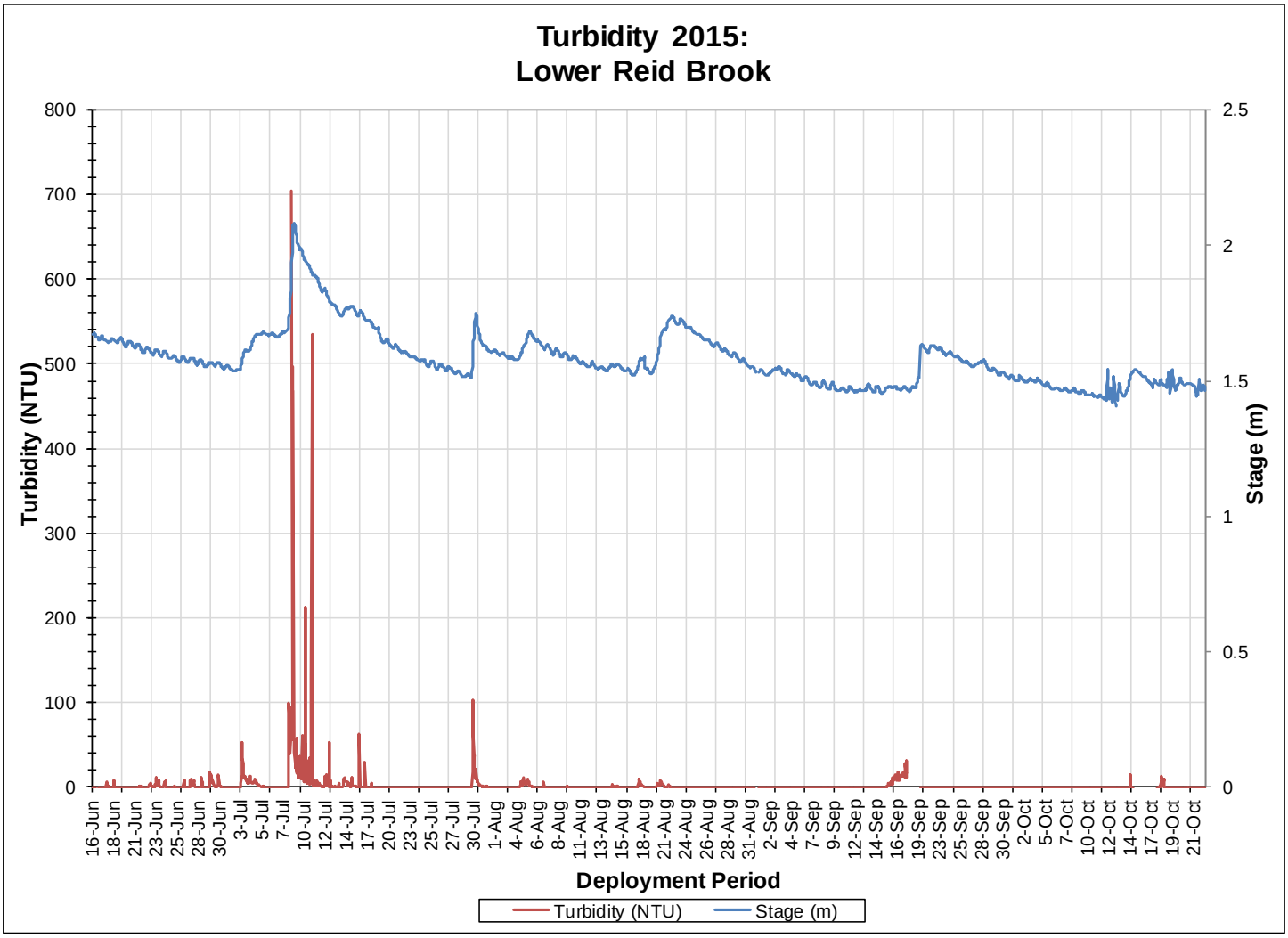

Figure 44: Turbidity and Stage Level at Lower Reid Brook below Tributary

Turbidity	2015	2014	2013
Min	0.0	0.0	0.0
Max	705	48.1	258.7
Median	0.0	0.0	0.0

Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

Lower Reid Brook stage levels ranged within a daily average minimum of 1.44m to a daily average maximum of 2.02m. The streamflow data ranged between a daily average minimum of 1.43m^3/s and a daily average maximum of 24.16m^3/s at Lower Reid (Figure 45).

Precipitation was graphed with stage and streamflow to indicate how external factors such as rainfall, can influence the change in water bodies (Figure 45). The precipitation data was received from the weather station in Nain. As of August 19th the weather station in Nain was no longer providing precipitation data therefore this data was obtained from the onsite Voisey's Bay weather station for the remainder of the deployment period.

This deployment season had frequent rainfall. The rainfall events occurred about ~52% of the deployment period. Precipitation over the deployment had a minimum of 0.0mm to a maximum of 61.5mm on October 20, 2015.

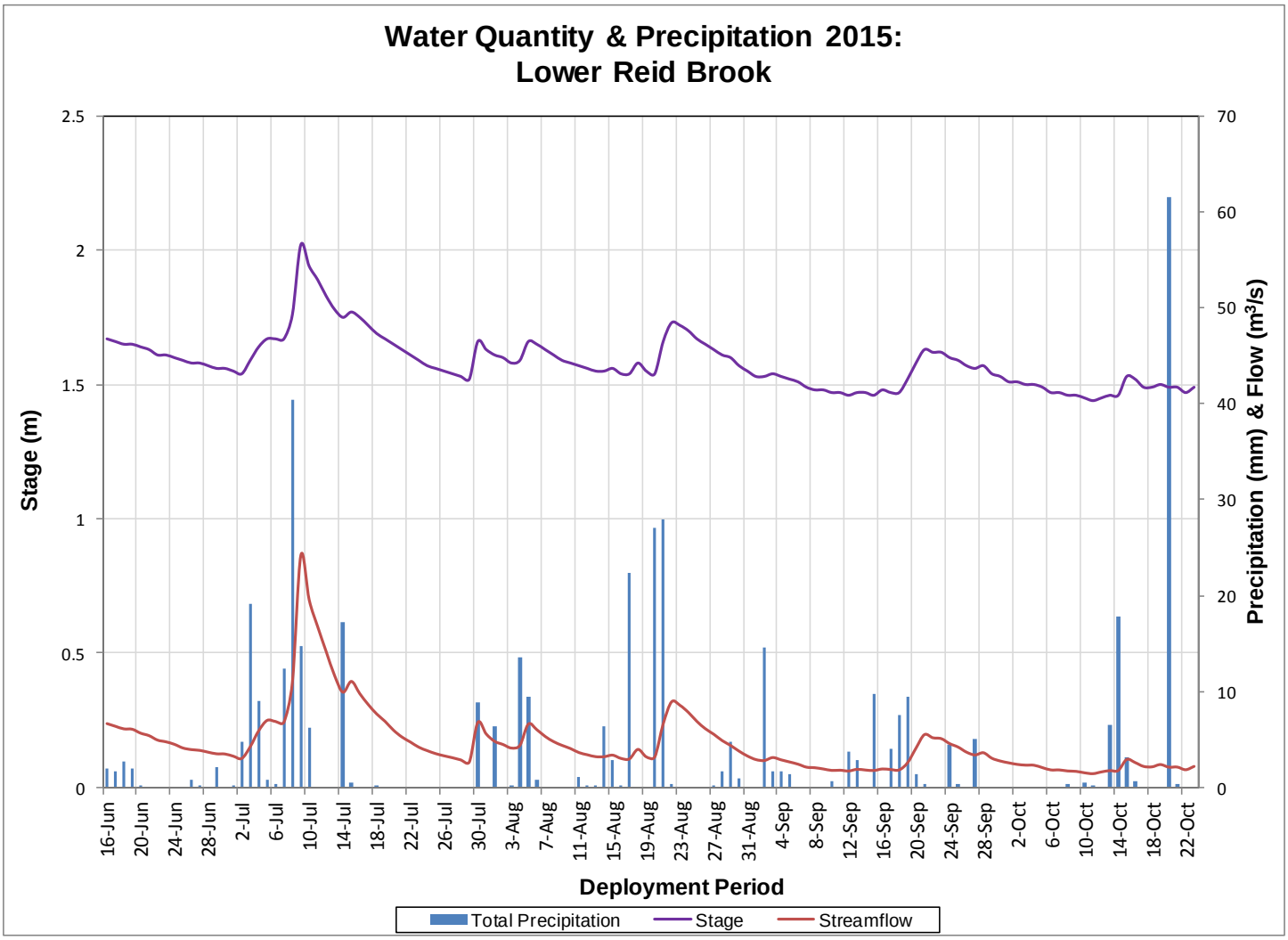

Figure 45: Stage and Streamflow level at Lower Reid Brook below Tributary and Precipitation data from the Nain Weather Station.

All photos were taken by WRMD Staff during a visit to Voisey's Bay in July 2015.

Figure 46: Lower Reid Brook below Tributary Station

Figure 47: Animal damage at Lower Reid Brook

Figure 48: Vale Staff sampling at Lower Reid Brook

Figure 49: Lower Reid Brook

Multi-Station Comparison

This section of the 2015 annual report focuses on the real-time stations compared against each other during the entire deployment season.

Temperature

Water temperature trends at each of the four stations are comparable with one another (Figure 50). There is clear seasonal trend at all stations with water temperatures. Water temperatures at Camp Pond Brook and Lower Reid Brook peak in late June while Reid Brook and Tributary to Lower Reid Brook peak in early to mid-August. A large increase in air temperature in late June has a significant effect on the water temperatures at Camp Pond Brook and Lower Reid Brook. Temperatures in early July remained colder and the water slowly started to increase again into the summer months.

Water temperatures then start to decrease at the end of August. The deployment season had a steady decline in water temperatures until the end of the deployment season in early October.

For the 2015 deployment season Camp Pond Brook recorded the highest temperature in the network at 21.7°C. Camp Pond also had the highest median value for temperature at 11.95°C. Lower Reid Brook and Tributary to Lower Reid Brook have very similar water temperatures throughout the season.

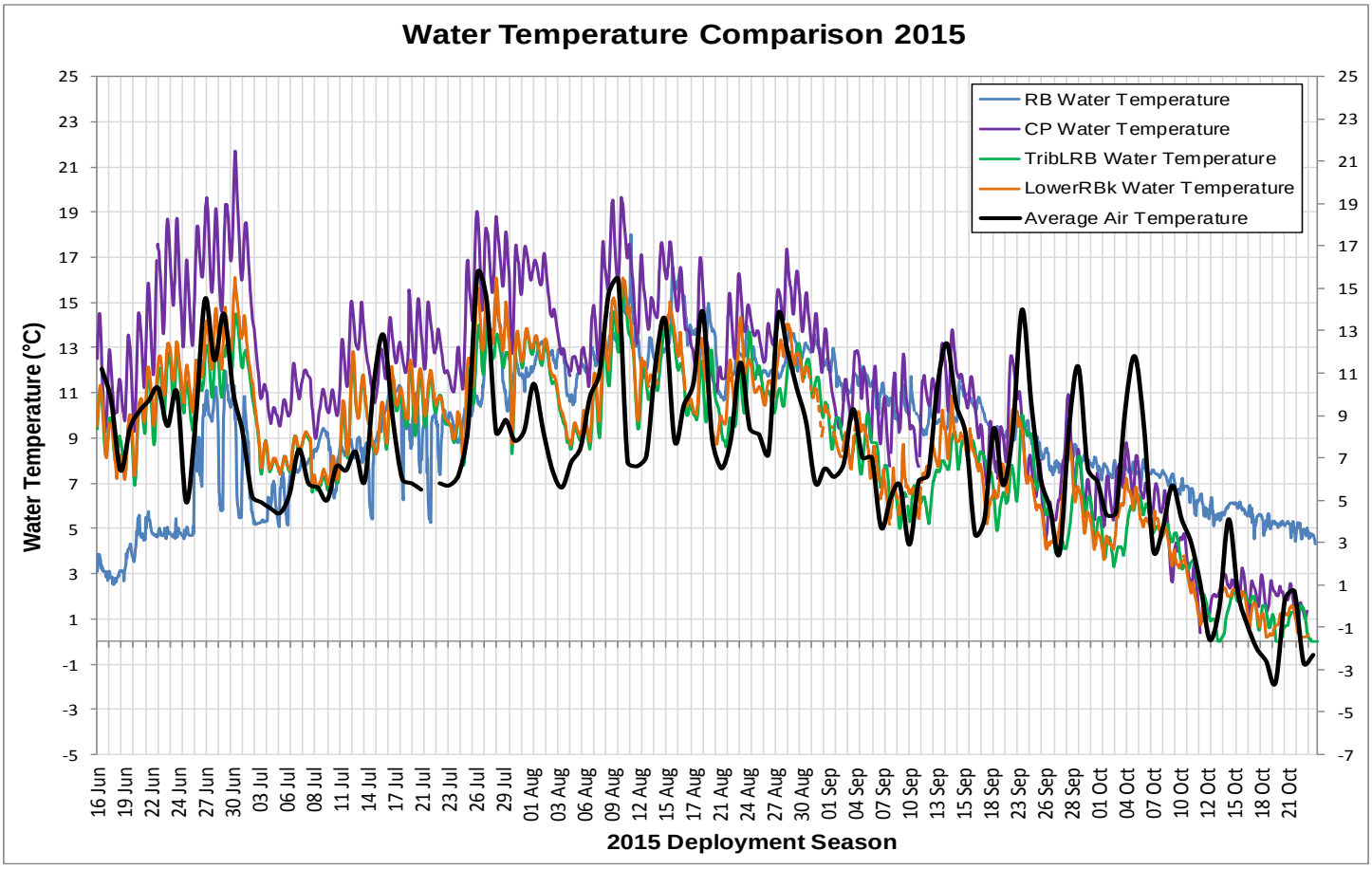

Figure 50: Water temperature at all stations

Temperature (°C)	Reid Brook	Camp Pond	Tributary	Lower Reid
Min	2.51	0.38	0	0.16
Max	18.01	21.7	15.7	16.11
Median	9.49	11.95	9.1	9.39

pH

During the 2015 deployment period the pH medians of the Real-Time stations were within 6.51 to 6.92 pH units (Figure 51). The majority of the pH data collected was within this range.

Reid Brook at Outlet of Reid Pond remained lower initially then all the other stations.

Lower Reid Brook also experienced a distinct event July 11 16th when the pH recorded as significantly higher than any of the other stations. This increase was preceded by 4 days of rain, totalling 73.7 mm. The instrument also experienced an increase in turbidity at the time possibly altering the pH sensors readings

The other stations maintain reasonably steady pH values throughout the deployment season. The fluctuations in the data are represented in all the pH values.

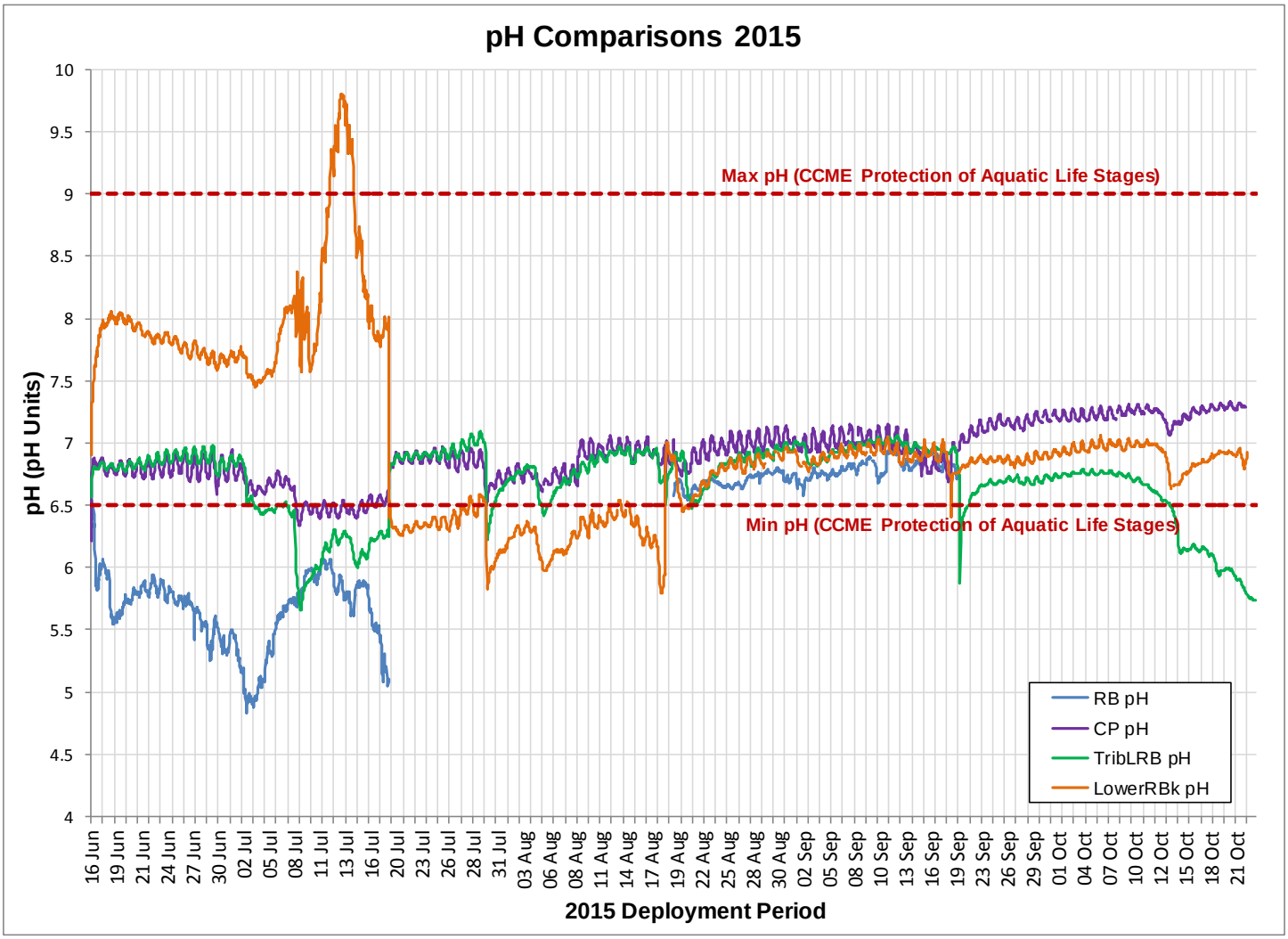

Figure 51: pH at all stations

pH (units)	Reid Brook	Camp Pond	Tributary	Lower Reid
Min	4.66	6.21	5.66	5.79
Max	8.17	7.33	7.09	9.8
Median	6.51	6.92	6.78	6.89

Specific Conductivity

Specific conductivity trends vary throughout the network. At the station at Upper Reid Brook, specific conductivity levels are low and stable with a median value of 12.0µS/cm. Specific conductivity at Upper Reid Brook is stable throughout the entire deployment season as this station is located at the outlet from Reid pond, a stable lake environment. Downstream in the network, specific conductivity is increasing steadily throughout the deployment season at the remaining three stations (Figure 52).

At the stations on Camp Pond Brook, Tributary to lower Reid and Lower Reid Brook, median values for specific conductivity are 34.8 µS/cm, 32.2 µS/cm and 28.9 µS/cm, respectively. At these stations specific conductivity values fluctuate in response to changing stage levels and rainfall events. Generally at Tributary to Lower Reid and Lower Reid Brook, as stage increases, specific conductivity decreases. This is caused by the dilution of major ions in the water column from the rainfall. Vice versa, as stage levels decrease, specific conductivity increases due to the increase in concentration of major ions.

At Camp Pond Brook below Camp Pond station the specific conductivity does not follow a typical inverse relationship with stage level increase during precipitation events. Instead, when water levels increase, there is an increase in specific conductivity. Although this association is not typically expected, this is the relationship most often seen at this station. Specific conductivity is also on average higher at this station than at the other stations in the network.

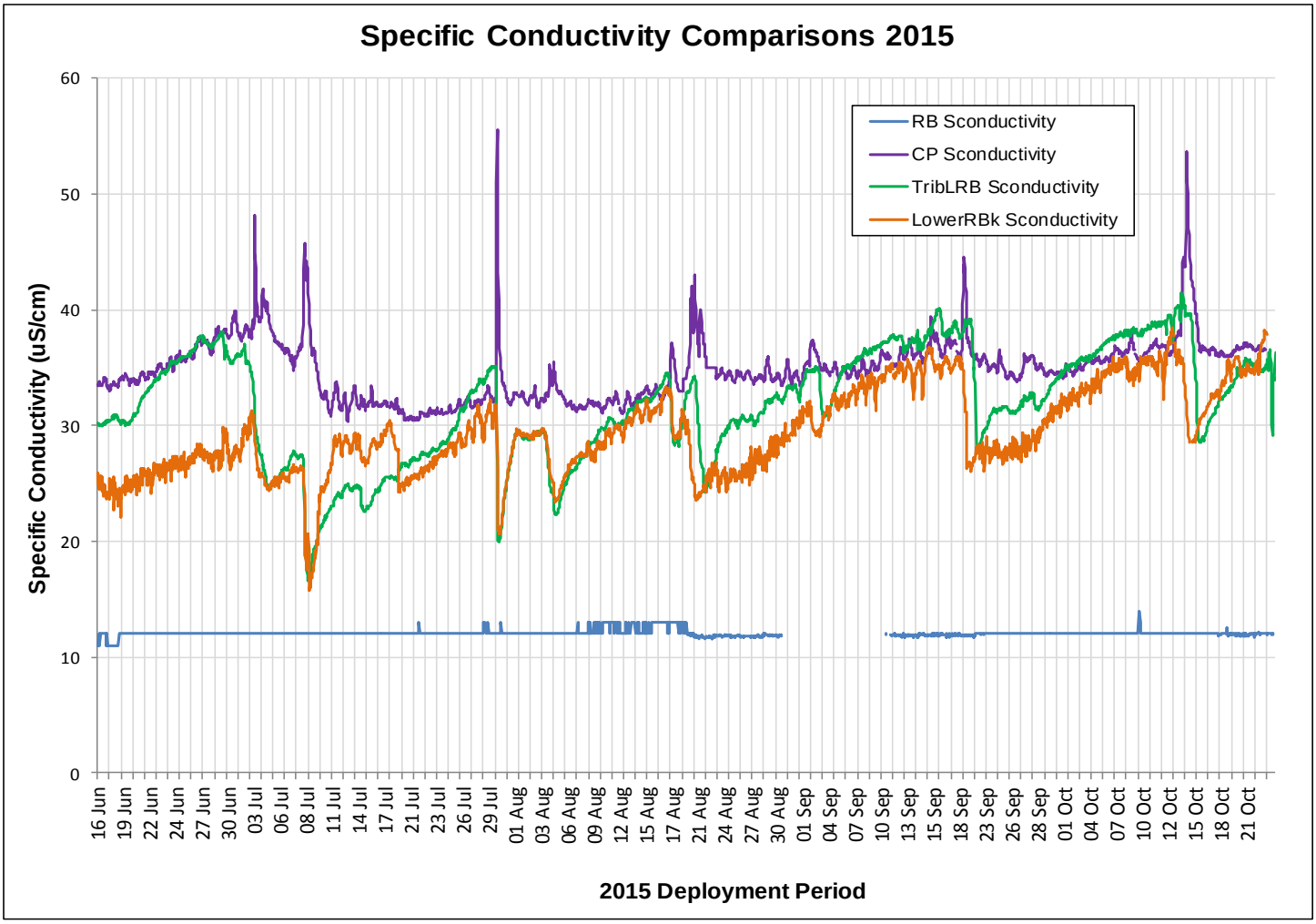

Figure 52: Specific conductivity at all stations

Specific Conductivity	Reid Brook	Camp Pond	Tributary	Lower Reid
Min	11	30.3	16.6	15.7
Max	14	55.5	41.4	38.5
Median	12	34.8	32.2	28.9

Dissolved Oxygen and Percent Saturation

The dissolved oxygen content this deployment season had median values between 10.03mg/l and 11.05mg/l throughout the network. Dissolved oxygen content showed a typical inverse relationship with water temperature at all stations. DO values are most stable at the station at Reid Brook below Reid Pond and showed greater fluctuation at stations further downstream where water temperatures also fluctuate more.

All values at all stations were above the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5mg/l). All values at the station at Upper Reid Brook and Tributary to Lower Reid Brook were above the CCME Guideline for the Protection of Aquatic Life at Early Life Stages (9.5mg/l). During the warmer temperatures DO content does dip below the CCME Guideline for Early Life Stages for Lower Reid Brook below Tributary and at Camp Pond Brook below Camp Pond stations. The warmer water temperatures are during the months of June and August which is also when the larger decreases in DO content occur. The guidelines are indicated in on Figure 53.

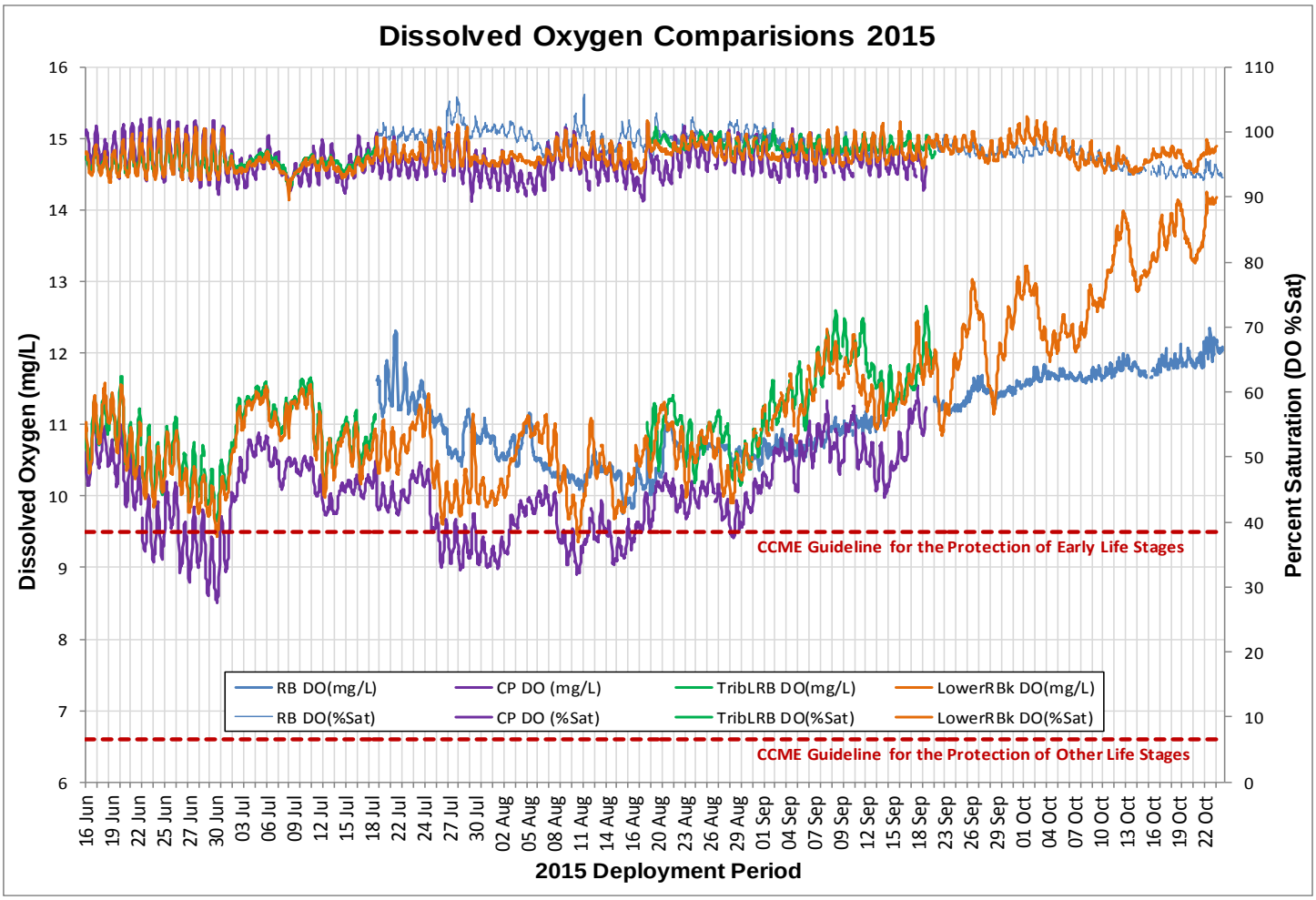

Figure 53: Dissolved oxygen and percent saturation at all stations

	Dissolved Oxygen (mg/l)				Percent Saturation			
	Reid Brook	Camp Pond	Tributary	Lower Reid	Reid Brook	Camp Pond	Tributary	Lower Reid
Min	9.76	8.51	9.63	9.36	92.6	89.3	91.6	89.6
Max	12.36	11.5	12.65	14.25	105.9	102.2	100.8	102.3
Median	10.98	10.03	11.05	11	98.1	95.2	97	96.2

Turbidity

Turbidity values vary somewhat across the network throughout the 2015 season (Figure 54 a & b). Median values at all real-time stations were 0.0NTU indicating there is no background turbidity at any of the stations.

During this deployment season there is little to no turbidity at the Reid Brook below Reid Pond. Reid Brook below Reid Pond remains very much in its natural state and is not impacted in any way.

Camp Pond Brook below Camp Pond, Tributary to Lower Reid Brook and Lower Reid Brook below Tributary can be influenced from anthropogenic sources. Although the majority of the turbidity values are 0.0NTU, during rainfall or runoff events there are a number of short lived, relatively low magnitude events occurring. The turbidity levels did increase during rainfall events however the levels settle back to baseline values (0NTU) in a matter of hours, sometimes days after the event.

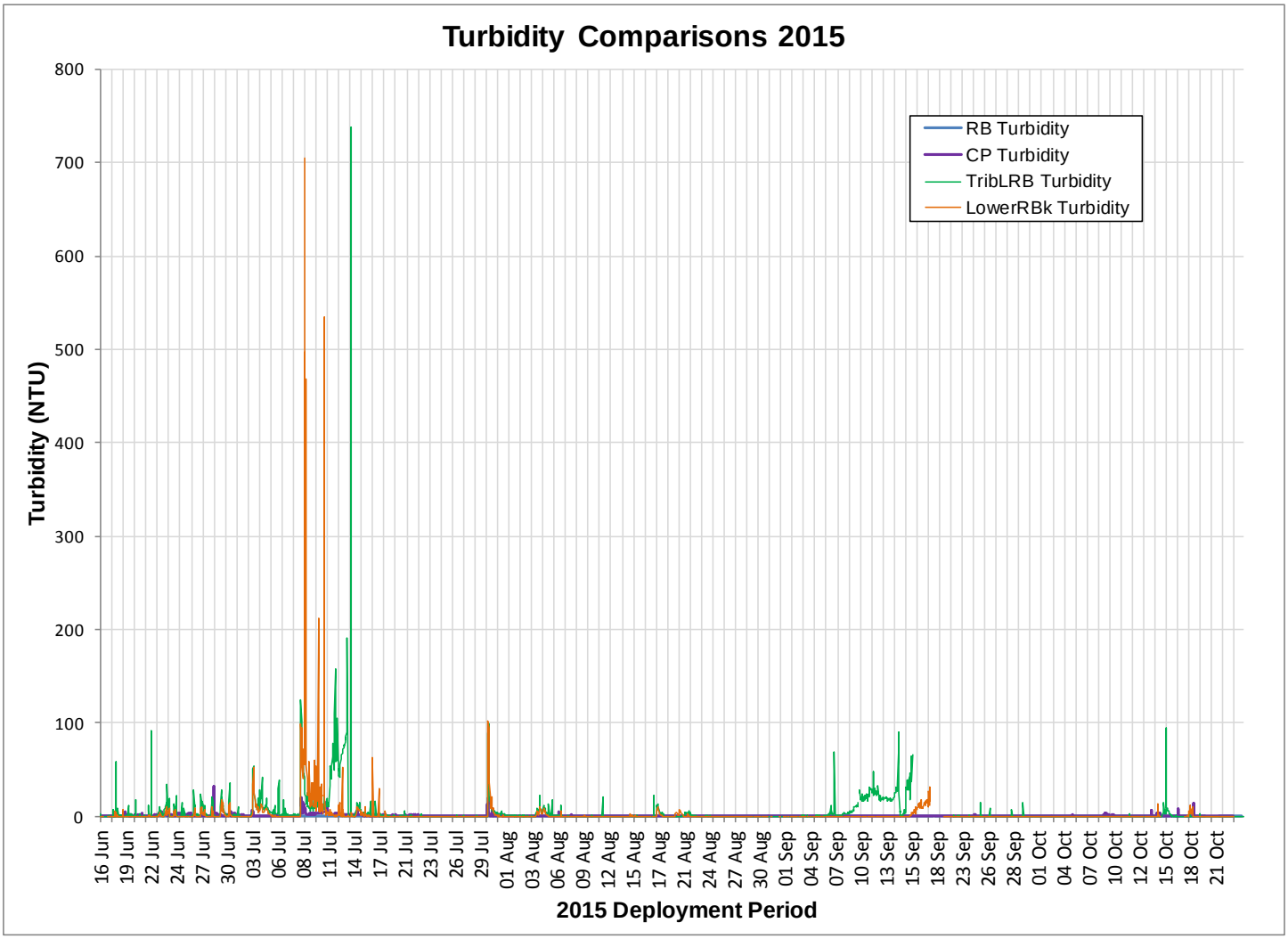

Figure 54a: Turbidity at all stations scale to 800NTUs

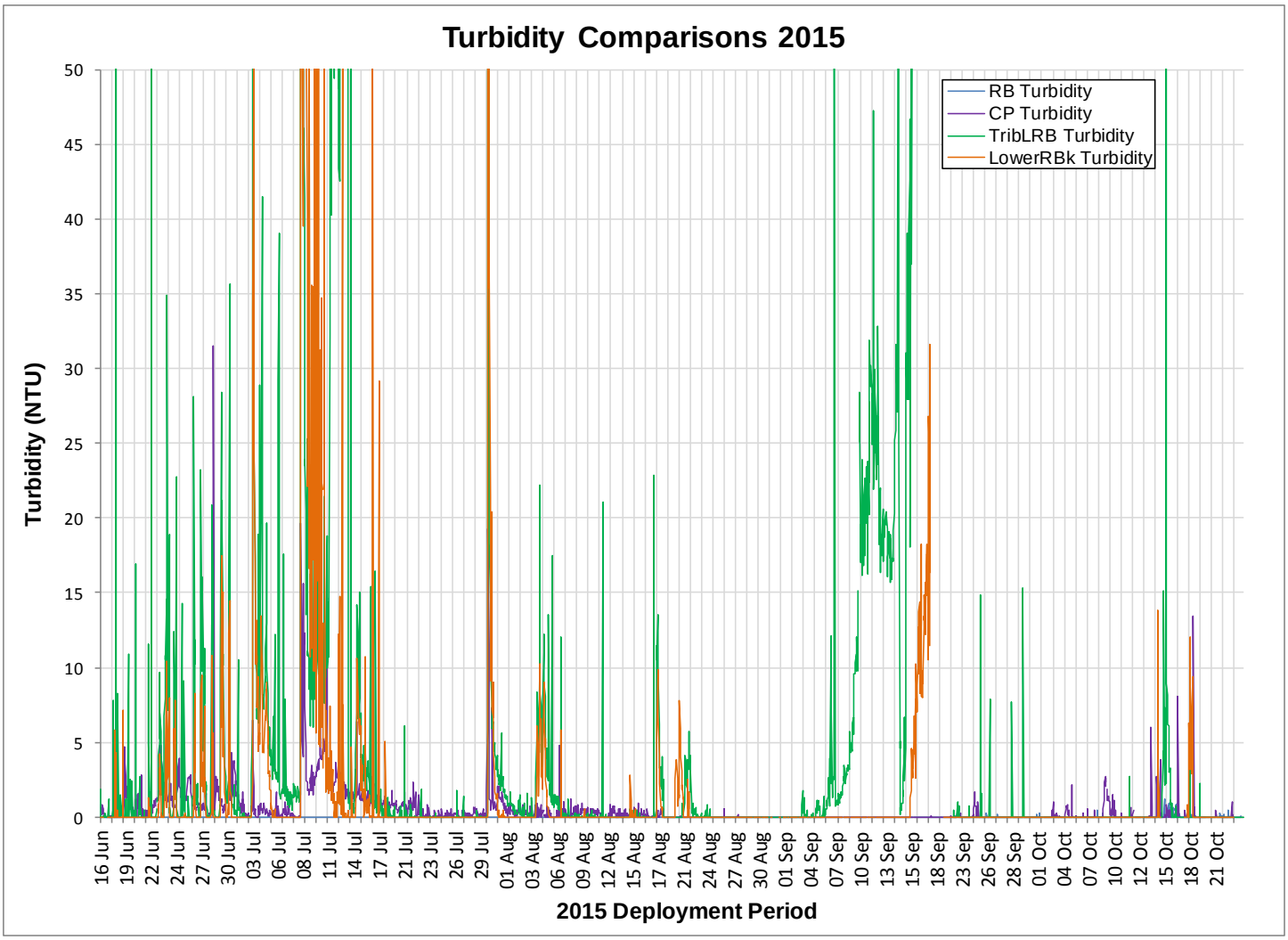

Figure 54b: Turbidity at all stations scale to 50NTUs

Turbidity (NTU)	Reid Brook	Camp Pond	Tributary	Lower Reid
Median	0.0	0.0	0.0	0.0
Max	1.2	31.5	1322	705
Min	0.0	0.0	0.0	0.0

Stage

Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

The beginning of deployment season has higher stage levels as it is capturing the end of the spring thaw. Throughout the deployment the stage levels remain reasonably constant for each station (Figure 55). Peaks in the stage level can be linked to rainfall events or runoff from surrounding environment (Appendix 1).

Rainfall events have a large effect on the streams in the real-time network. Significant increases in stage level are noticed almost immediately following a rainfall event in the area. The influences of precipitation events are not as evident at Camp Pond Brook below Camp Pond and the stage increases are somewhat less significant at this station.

The greatest difference in stage level of the deployment season was Tributary to Lower Reid Brook with a difference of 0.704 between its highest stage and lowest stage.

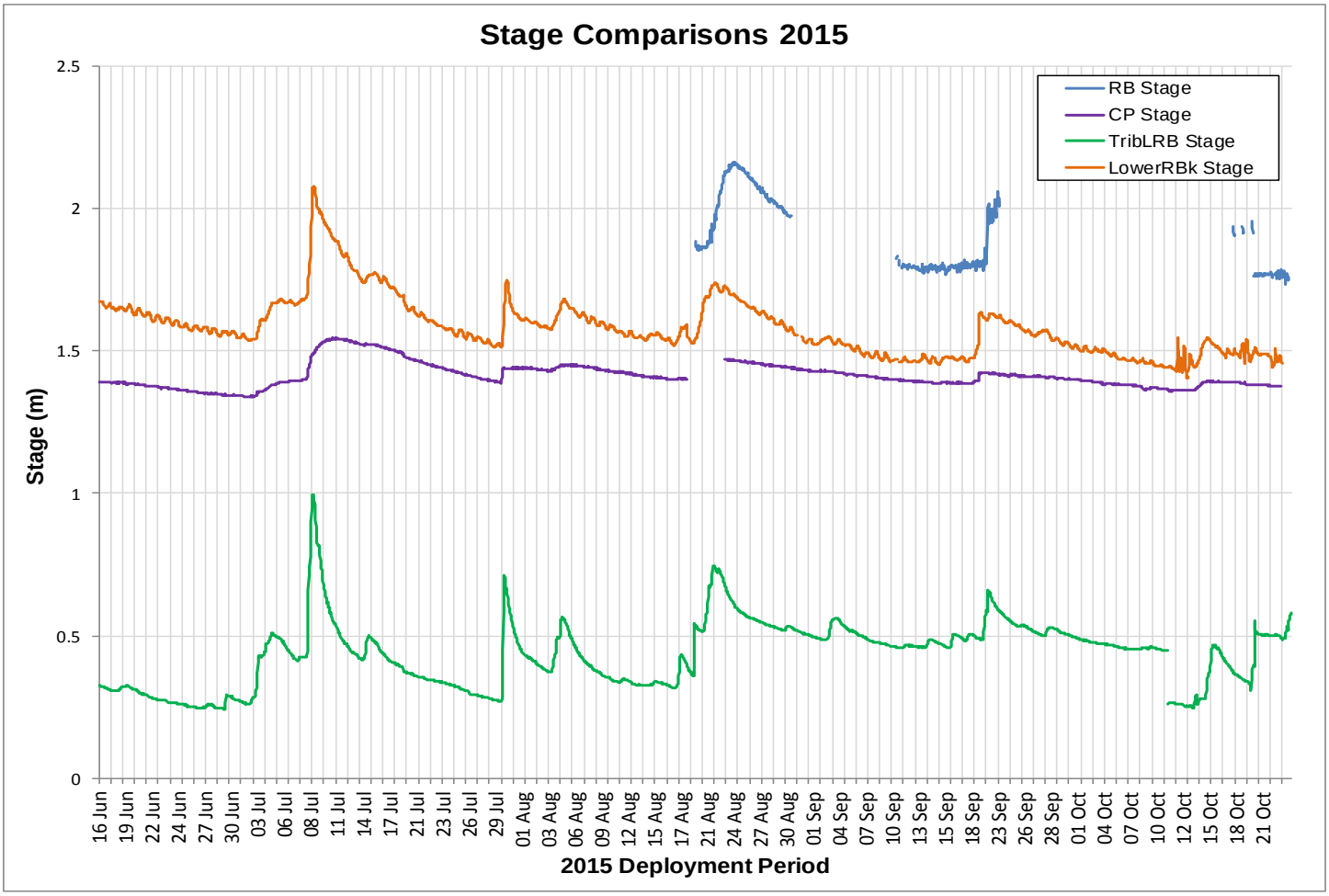

Figure 55: Stage levels at all stations

Stage (m)	Reid Brook	Camp Pond	Tributary	Lower Reid
Max	1.733	1.338	0.24	1.406
Min	2.163	1.545	0.994	2.08
Median	1.817	1.404	0.456	1.569
Difference	0.43	0.207	0.704	0.674

Conclusions

Instruments at water quality monitoring stations in the Voisey's Bay Network were deployed during four deployment periods from June 16 to October 23, 2015.

In most cases, weather related events or increases/decreases in water level could be used to explain the fluctuations. Water temperature and dissolved oxygen showed typical seasonal trends, increasing or decreasing with warming and cooling air temperatures. Stage levels decreased throughout the season which caused general increasing trends in specific conductivity and pH except for at the Reid Brook below Reid Pond station. The Reid Brook below Reid Pond station is extremely constant. This station has steady pH values and unwavering specific conductivity values. Across all stations turbidity values showed a median of 0.0NTU indicating there is naturally no background turbidity in this network of brooks. When turbidity events did occur most were short lived, relatively low in magnitude and similar throughout the season.

Regular visits on a near 30 day deployment schedule have been adhered to in cooperation with Vale Environmental Staff and WRMD staff. This has provided good quality data with limited drift. The effects of bio fouling rarely impact the instruments due to the regular maintenance, cooler water temperatures and pristine nature of the rivers.

There were several sensor failures and transmission issues during this deployment season which are now being addressed in the off season with repairs and maintenance to the instruments. Repairs and maintenance are always needed to continue ensuring this program captures the data accurately and efficiently.

Path Forward

The success of the real-time water monitoring network is largely due to the 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 rivers' characteristics. The data collected is essential for identifying the difference between natural and irregular events. As this agreement progresses into the 2016 deployment period for the Voisey's Bay stations, the following is a list of planned activities to be carried out in the upcoming year. The list also includes some multi-year activities planned in the previous year that are still in progress.

- In the 2016 deployment season, staff from Vale will be responsible for monthly maintenance and calibration (as was the case in the past). ENVC staff will perform regular site visits to audit and assist in the maintenance and calibration procedures from time to time. EC Water Survey of Canada 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. WRMD is organizing a maintenance and calibration training session available for all industry partners to attend. The details and content of the training session will be communicated with Vale closer to the scheduled timeframe.
- 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 2016 or in future seasons.
- Open communication lines will continue to be maintained between WRMD, EC 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 2016 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*.).
- 2016 deployments will recommence in the Spring as soon as the ice conditions in the brooks permit.

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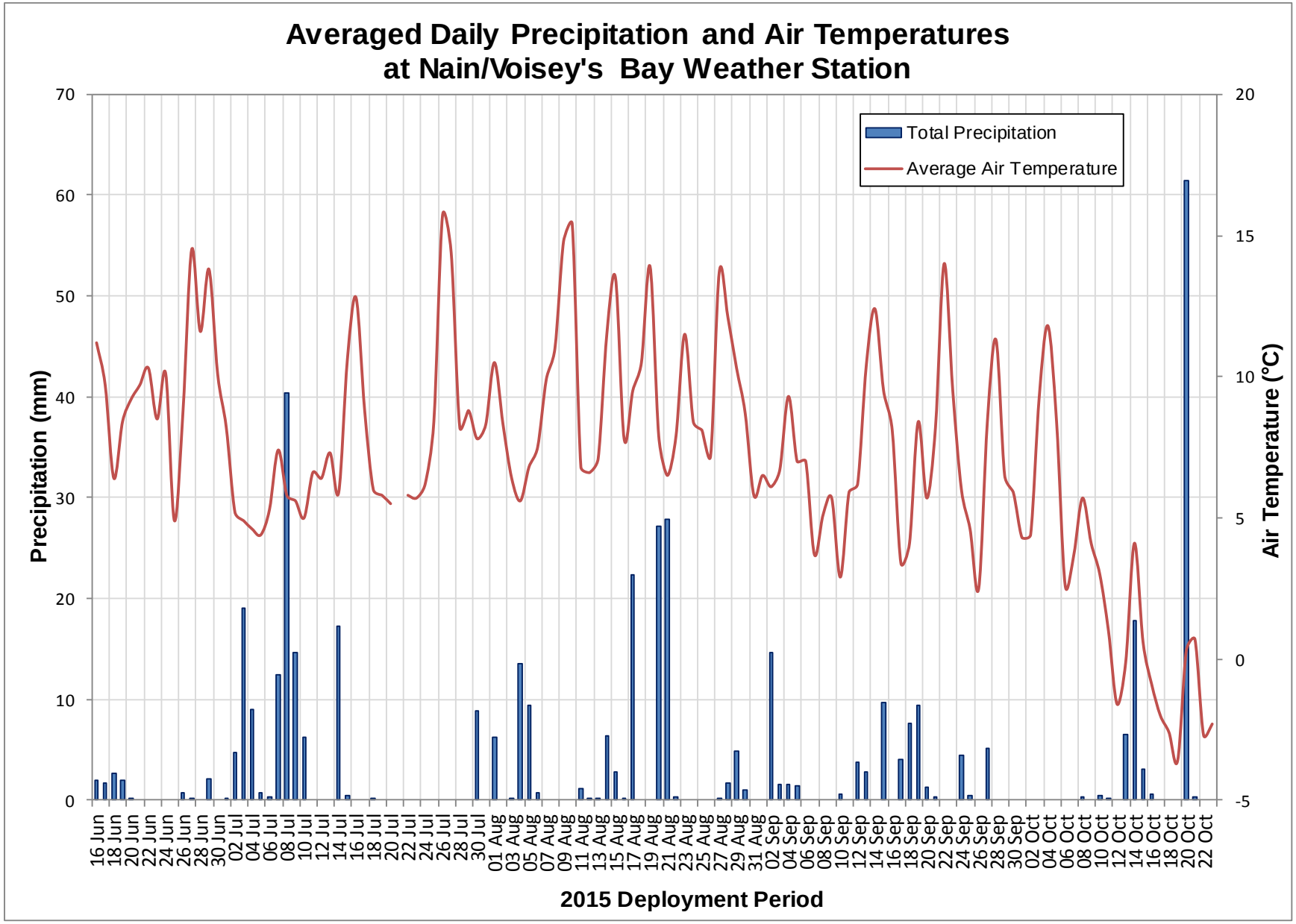
Appendix 1


Averaged Daily Precipitation and Air Temperatures
at Nain/Voisey's Bay Weather Station
Total Precipitation
Average Air Temperature
Precipitation (mm)
Air Temperature (°C)
2015 Deployment Period