



Real-Time Water Quality Deployment Report

Voisey's Bay Network

August 18 to September 19, 2015



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

Contents

REAL TIME WATER QUALITY MONITORING	1
QUALITY ASSURANCE AND QUALITY CONTROL	1
DATA INTERPRETATION	3
REID BROOK AT OUTLET OF REID POND	5
CAMP POND BROOK	11
TRIBUTARY TO LOWER REID BROOK	19
LOWER REID BROOK BELOW TRIBUTARY	27
CONCLUSIONS	35
APPENDIX A: COMPARISON GRAPHS	36
APPENDIX B: GRAB SAMPLE DATA	41
APPENDIX C: QUALITY ASSURANCE / QUALITY CONTROL PROCEDURES	42
APPENDIX D: WATER PARAMETER DESCRIPTION	43
REFERENCES	44

Prepared by:
Kelly Maher
Environmental Scientist
Water Resources Management Division
Department of Environment & Conservation
Phone (709) 896 - 5542
Fax (709) 896 - 9566
kellymaher@gov.nl.ca

Real Time Water Quality Monitoring

Department of Environment and Conservation staff monitors the real-time web pages regularly.

This deployment report discusses water quality related events occurring at four stations in the Voisey's Bay Network; Reid Brook at Outlet to Reid Pond, Camp Pond Brook, Tributary to Lower Reid Brook, and Lower Reid Brook.

On August 18th and 19th, 2015, Vale Environment Staff deployed real-time water quality monitoring instruments at the four real time stations in the Voisey's Bay network for a period of 30 to 31 days. Instruments were removed by Vale Environment Staff on September 19th, 2015.

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 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 QAQC Instrument at deployment and at removal, a qualitative statement is made on the data quality (Table 1).

Table 1: Ranking classifications for deployment and removal

Parameter	Rank				
	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 dependant, 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 2.

Table 2: Comparison rankings for Voisey's Bay Network stations

Station Voisey's Bay	Date	Action	Comparison Ranking				
			Temperature	pH	Conductivity	Dissolved Oxygen	Turbidity
Reid Brook at Outlet (62885)	August 19, 2015	Deployment	Poor	Good	Excellent	Excellent	Excellent
	September 19, 2015	Removal	Excellent	Fair	Excellent	NA	Excellent
Camp Pond Brook (44175)	August 19, 2015	Deployment	Excellent	Good	Excellent	Excellent	Excellent
	September 19, 2015	Removal	Excellent	Good	Good	Excellent	Excellent
Tributary to Lower Reid Brook (62884)	August 18, 2015	Deployment	Excellent	Good	Excellent	Excellent	Good
	September 19, 2015	Removal	Excellent	Excellent	Excellent	Excellent	Excellent
Lower Reid Brook (62887)	August 19, 2015	Deployment	Good	Good	Excellent	Good	Excellent
	September 19, 2015	Removal	Excellent	Excellent	Excellent	Excellent	Poor

During the deployment for Reid Brook at Outlet of Reid Pond, the pH, conductivity, dissolved oxygen, and turbidity all ranked as 'good' or 'excellent'. Temperature ranked as 'poor'. This discrepancy in temperature could be attributed to a difference in location between the field and QA/QC sonde. Upon removal, temperature, conductivity, and turbidity all ranked as 'good' or 'excellent'. pH ranked as 'fair'. This discrepancy could be attributed to the sonde having not acclimatized to the environment before the reading was recorded. Dissolved Oxygen data could not be compared because some data was removed from the end of the period due to erratic readings.

At the station on Camp Pond Brook, temperature, pH, conductivity, dissolved oxygen and turbidity all ranked as 'good' or 'excellent'. During removal, temperature, pH, conductivity, dissolved oxygen, and turbidity all ranked as 'good' or 'excellent'.

At Tributary to Lower Reid Brook station, the water quality parameters that ranked as 'excellent' or 'good' during deployment. Upon removal, all parameters ranked as 'good' or 'excellent'.

At Lower Reid Brook, the temperature, pH, conductivity, dissolved oxygen, and turbidity all ranked as 'good' or 'excellent'. Upon removal, temperature, pH, conductivity, and dissolved oxygen all ranked as 'excellent'. Turbidity ranked as 'poor'. This discrepancy can be attributed to sensor fouling over the course of the deployment period. The field sonde may have become buried in sediment.

Data Interpretation

- The following graphs and discussion illustrate significant water quality-related events from August 18th to September 19th, 2015 in the Voisey's Bay Real Time Water Quality Monitoring 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 is responsible for QAQC of water quantity data. Corrected data can be obtained upon request.
- Reid Brook at Outlet of Reid Pond had technical issues with the communication capability of the station during this deployment. The station was unable to transmit quality and quantity real-time data for the entire deployment period. The water quality data was taken from the log file of the instrument which records as a backup in case of communication and transmission issues. Specific conductivity and total dissolved solids are calculated parameters which were not recorded to an accurate decimal place on the internal log file therefore some data was taken from the ADRS system when transmissions occurred.
- Tributary to Lower Reid Brook sonde had a dissolved oxygen sensor failure and therefore no accurate DO data was recorded for the deployment period. In addition, some flow data is absent due to transmission errors at this station.

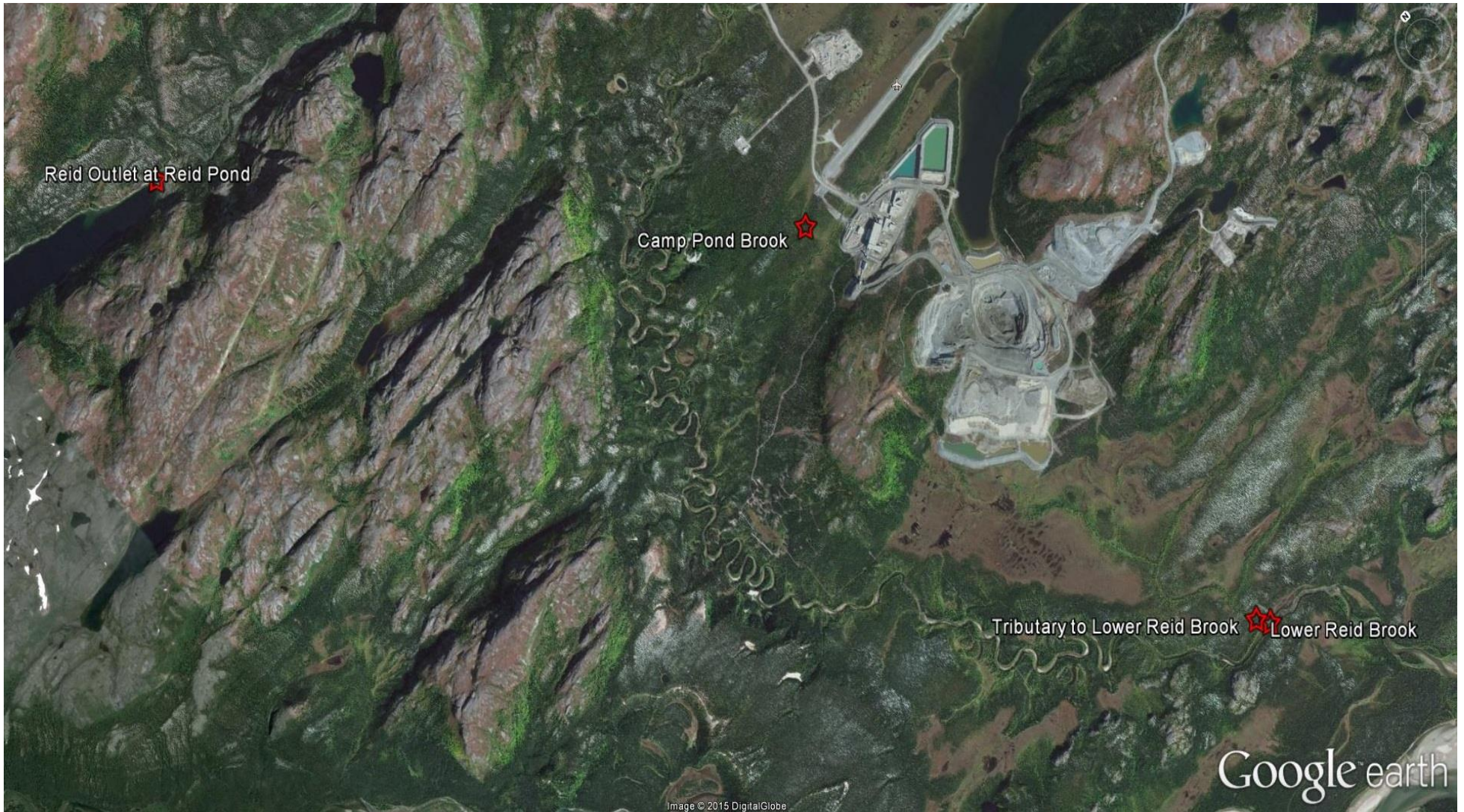


Figure 1: Voisey's Bay Network Station Locations

Reid Brook at Outlet of Reid Pond

Water Temperature

- Water temperature ranges from 8.92 °C to 14.80 °C, with a median value of 11.33 °C (Figure 2).
- Water temperature is gradually decreasing throughout the deployment period. This trend is expected as the air temperatures cool into the autumn months.

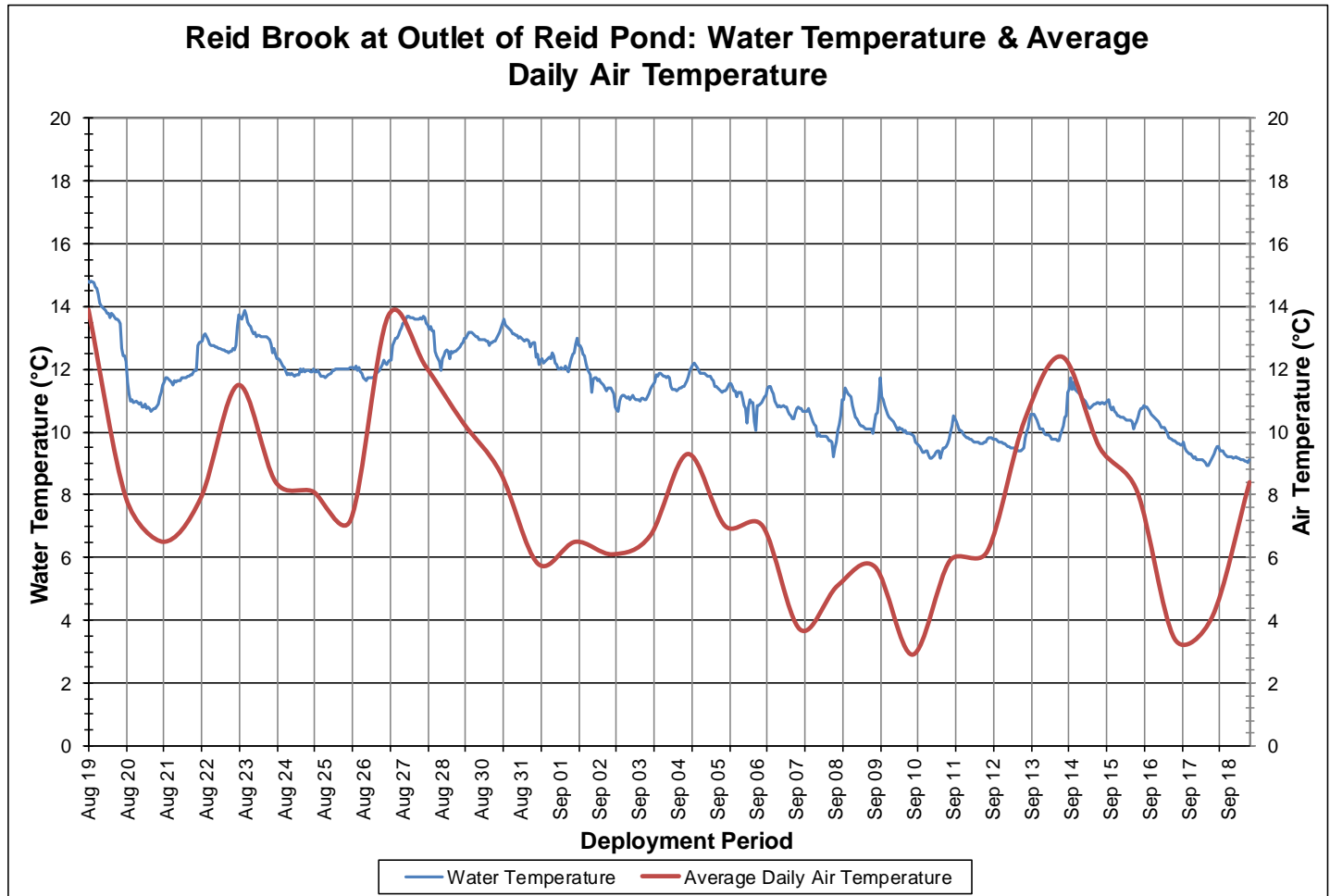


Figure 2: Water Temperature & Average Daily Air Temperature at Reid Brook at Outlet of Reid Pond

pH Levels

- pH ranges from 6.47 to 6.96 pH units, with a median value of 6.75 (Figure 3).
- pH dips below CCME guidelines briefly at the beginning of the deployment period as an increase in stage occurs due to precipitation events. This addition of rain water causes the water to become more acidic and the pH drops.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

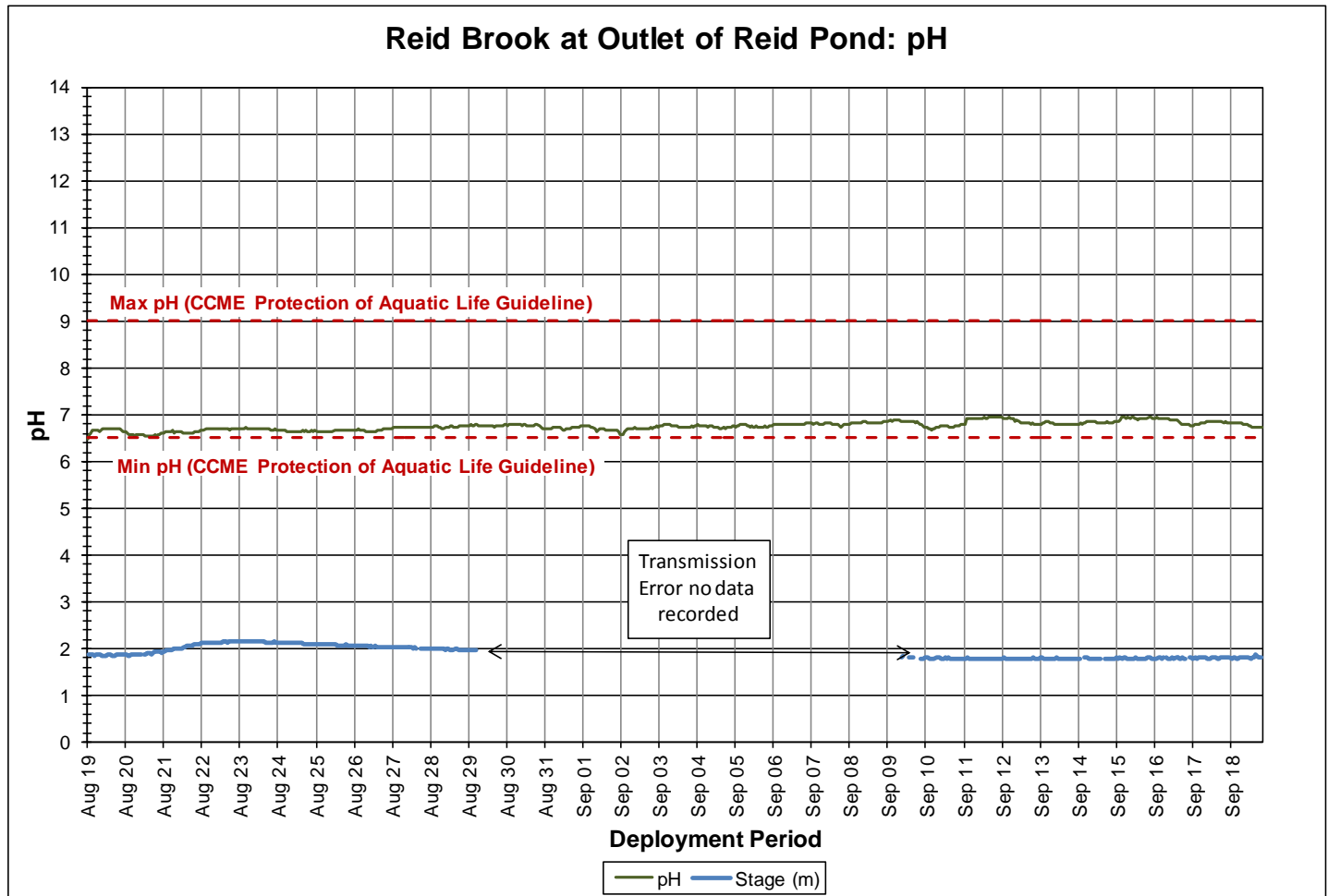


Figure 3: pH at Reid Brook at Outlet of Reid Pond

Specific Conductivity

- Specific conductance ranges between 11.6 $\mu\text{S}/\text{cm}$ to 12.0 $\mu\text{S}/\text{cm}$, with a median value of 11.8 $\mu\text{S}/\text{cm}$ (Figure 4).
- The conductivity at Reid Brook remains very stable. This is expected at this site as it is pristine in nature and a larger distance from any anthropogenic disturbances that could affect water parameters.

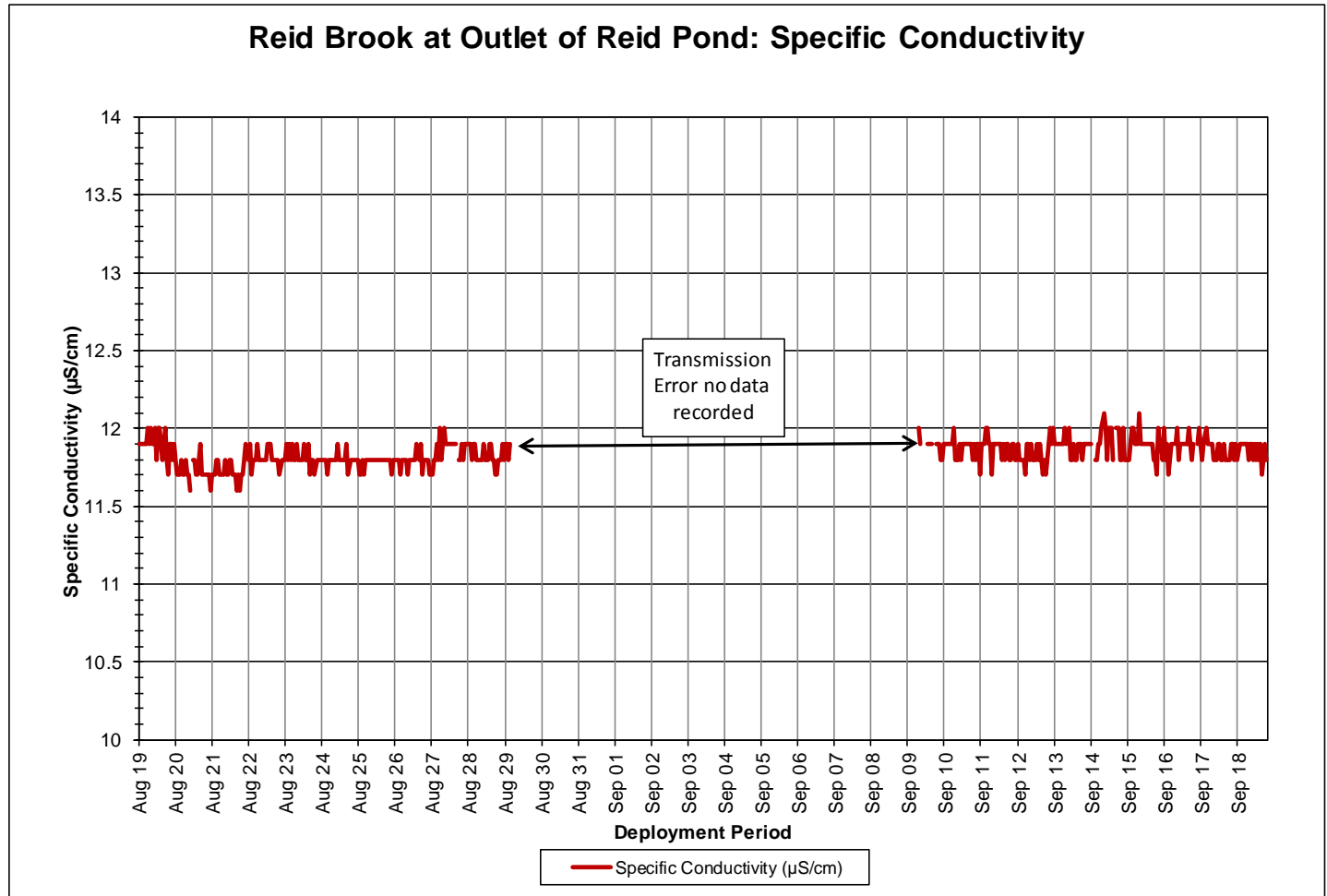


Figure 4: Specific Conductivity at Reid Brook at Outlet of Reid Pond

Dissolved Oxygen (mg/L & % Saturation)

- Dissolved oxygen content ranges between 10.28mg/l and 11.19mg/l during the deployment period. The saturation of dissolved oxygen ranges from 95.2% to 102.4% (Figure 5).
- The water quality instrument measures dissolved oxygen (mg/L) with the dissolved oxygen probe and then the instrument calculates percent saturation (% Sat) with water temperature.
- Dissolved oxygen remained above the CCME guideline of 9.5mg/L during the deployment period (Figure 5).

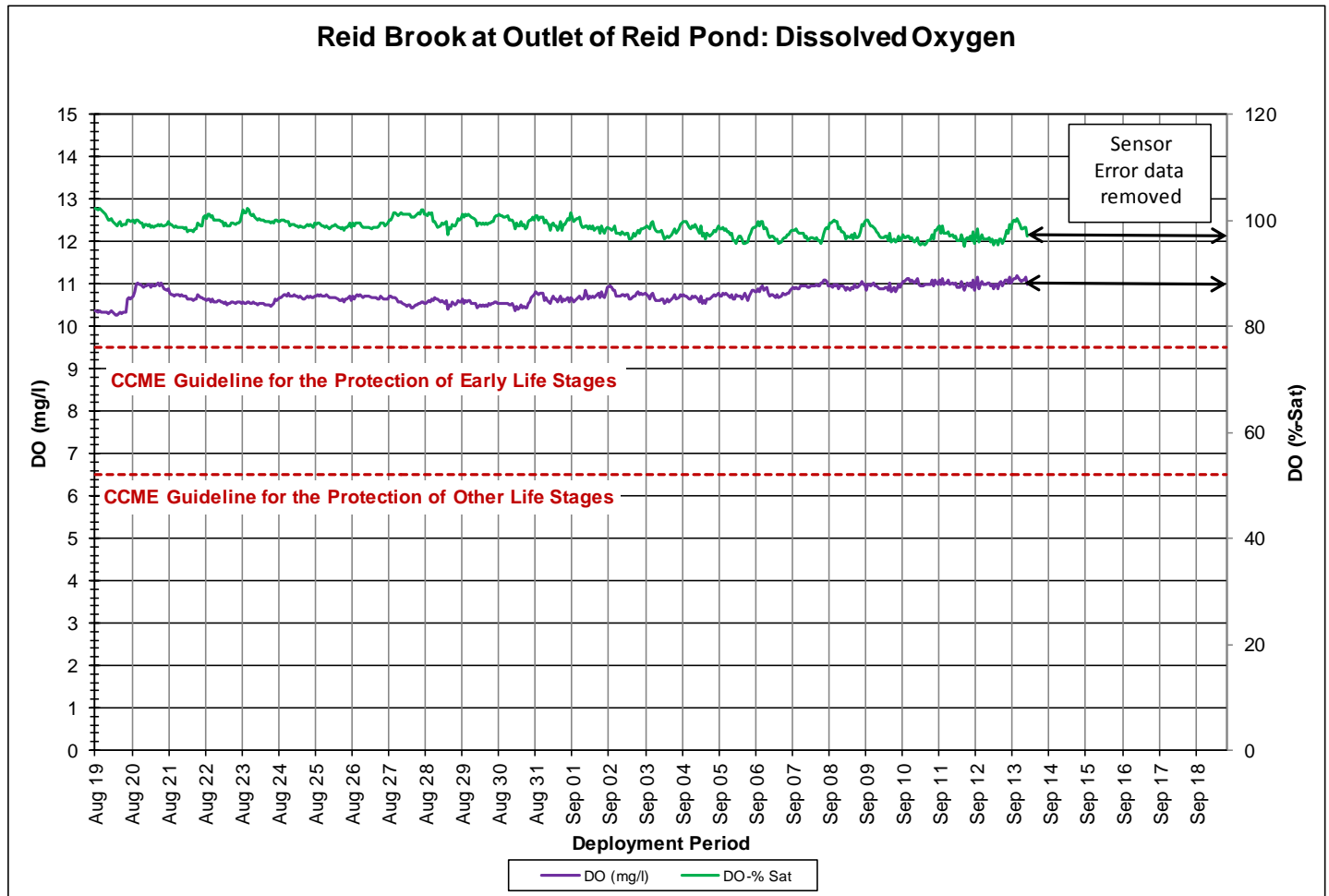


Figure 5: Dissolved Oxygen at Reid Brook at Outlet of Reid Pond

Turbidity

- Turbidity ranges from 0.0NTU to 0.3NTU, with a median value of 0.0NTU (Figure 6).
- Turbidity values remain low at this location. It is not unusual for this station to have low turbidity readings, as the water flowing from the lake is typically very clean, clear, and cold.

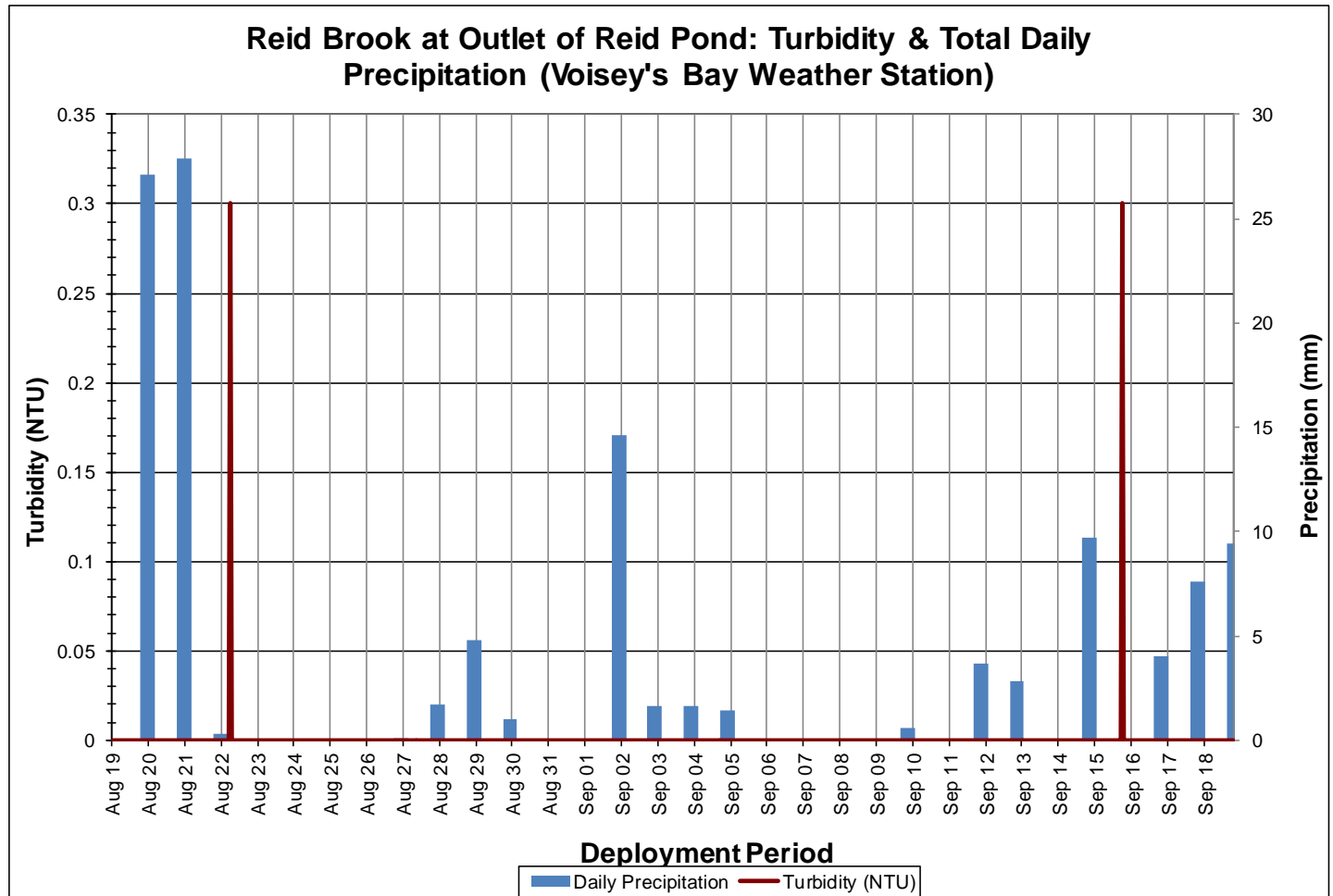


Figure 6: Turbidity and Total Daily Precipitation at Reid Brook at Outlet of Reid Pond

Stage, Flow & Precipitation

- Due to transmission errors during this deployment stage and flow are unavailable from August 29 to September 9, 2015.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.
- Precipitation data was obtained from the Voisey's Bay weather station (Figure 7).
- Precipitation occurs on 18 days during the deployment period and amounts are small in magnitude, with the largest on August 21st with 27.9mm of rain.
- The relationship between precipitation and an increase in stage and flow is very evident at this station during this deployment. Significant rainfall at the beginning of the deployment causes a spike in both stage and flow.
- During the deployment period, the stage values ranged from 1.85m to 2.16m. Streamflow had a minimum amount of 1.86m³/s and a maximum flow of 5.64m³/s.

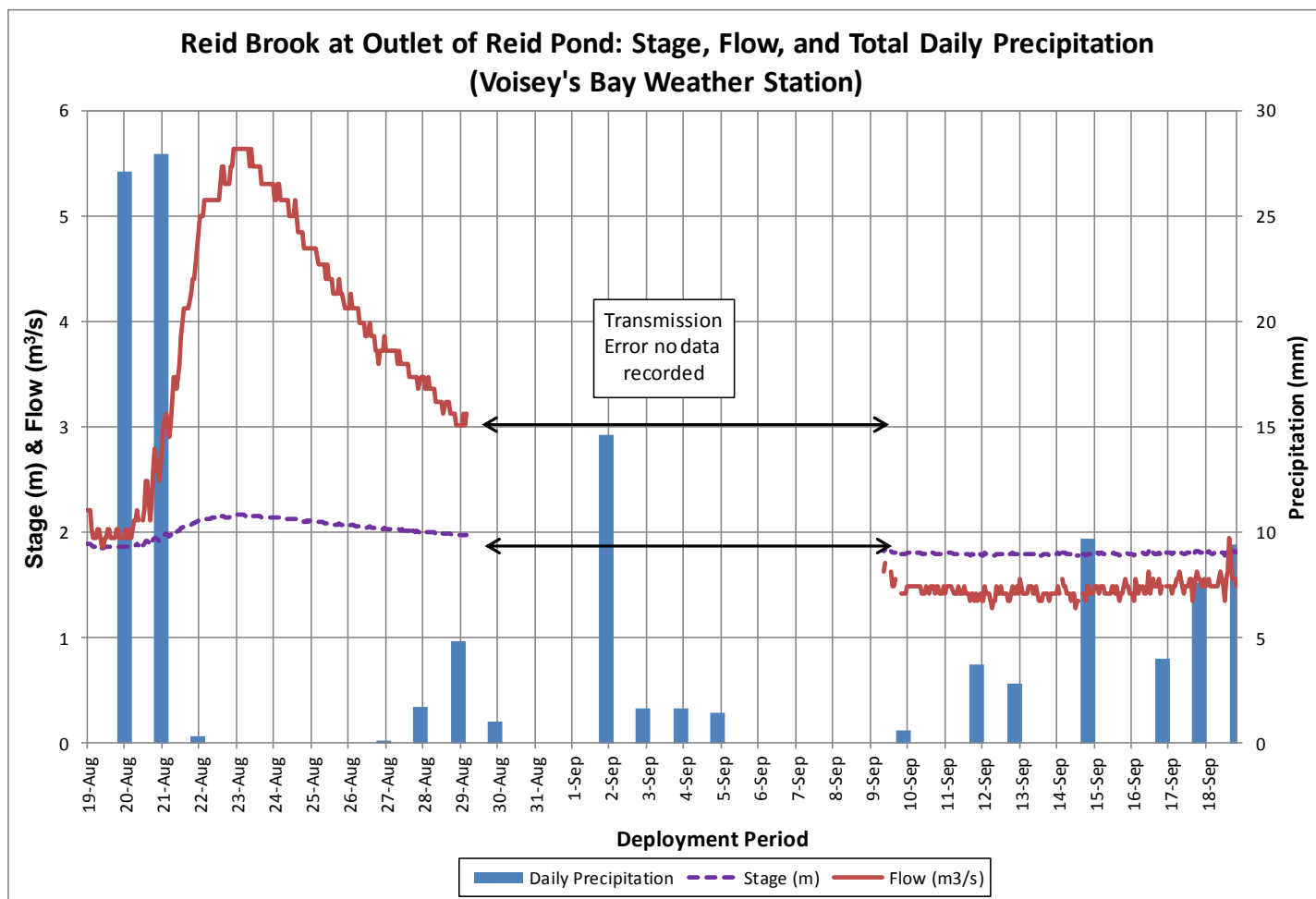


Figure 7: Stage, Flow & Total Daily Precipitation from Vale Voisey's Bay Weather Station

Camp Pond Brook

Water Temperature

- Water temperature ranges from 6.91 °C to 17.37 °C, with a median value of 11.81 °C (Figure 8).
- Water temperature is gradually decreasing throughout the deployment period. This trend is expected as the air temperatures cool in the autumn months.
- This stream is sensitive to changes in the ambient air temperature and fluctuates considerably depending on the weather and time of day. This station typically has the highest water temperatures and greatest fluctuations when compared to the other stations in the network.

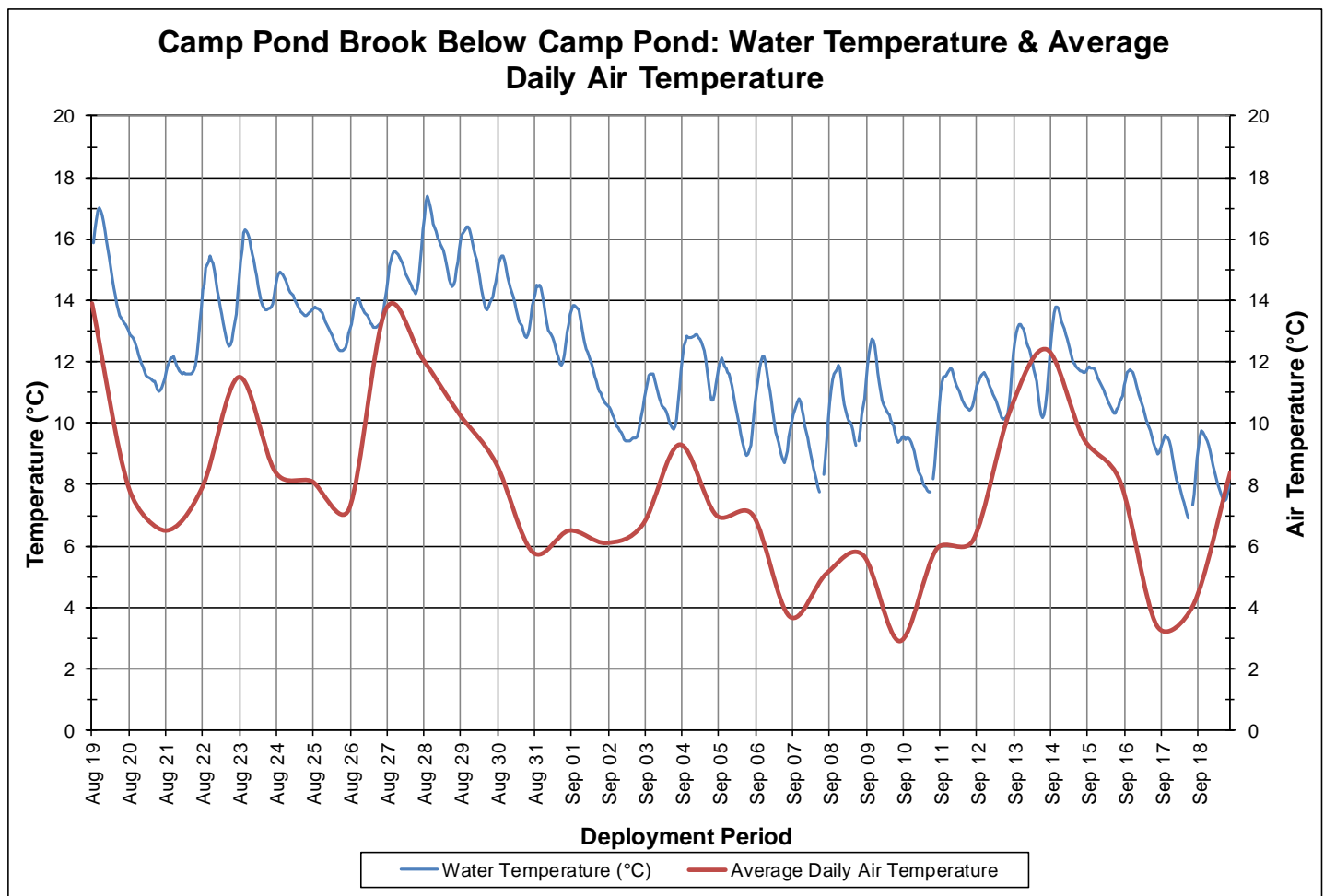


Figure 8: Water Temperature & Daily Average Air Temperature at Camp Pond Brook below Camp Pond

pH

- pH ranges from 6.61 to 7.15 pH units, with a median value of 6.98 (Figure 9).
- The pH values are very stable at this station, fluctuating diurnally during the deployment period.
- The pH values in this deployment period are near the lower CCME guidelines of 6.5 pH units.

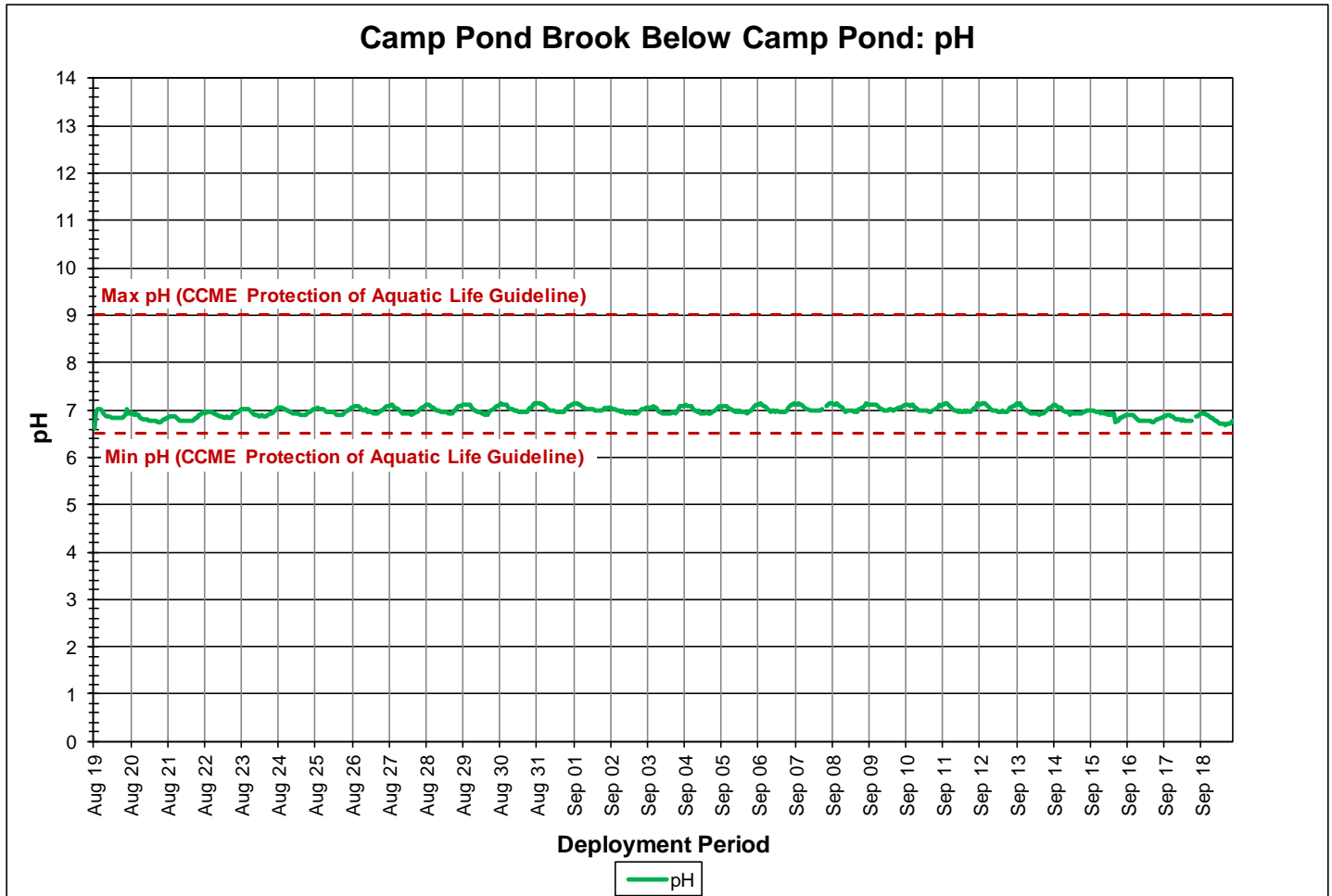


Figure 9: pH at Camp Pond Brook below Camp Pond

Specific Conductivity

- Specific conductivity ranges from 33.0 μ S/cm to 44.5 μ S/cm with a median of 35.0 μ S/cm. (Figure 10).
- Total Dissolved Solids (TDS) ranges between 0.214 g/mL to 0.0285 g/mL during the deployment period, with a median of 0.0224 g/mL (Figure 11).
- Specific conductivity and TDS have a direct relationship but are two separate parameters. Specific conductivity is the ability of the water to conduct electricity. Therefore the value of TDS can be calculated by the conductivity of the water (Figure 11).
- Typically, as stage level decreases, the specific conductivity of the water increases because of the increase in concentration of dissolved solids present in the water column. Inversely, as stage levels increase, specific conductivity generally decreases as the dissolved solids become more diluted in the water column. This trend is not typically experienced at this station (Figure 10). Instead, there is a positive relationship between water level and specific conductance. At this location the increase in specific conductivity is likely from runoff on nearby roadways and heavily used areas during precipitation events causing substances to be flushed into the brook.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

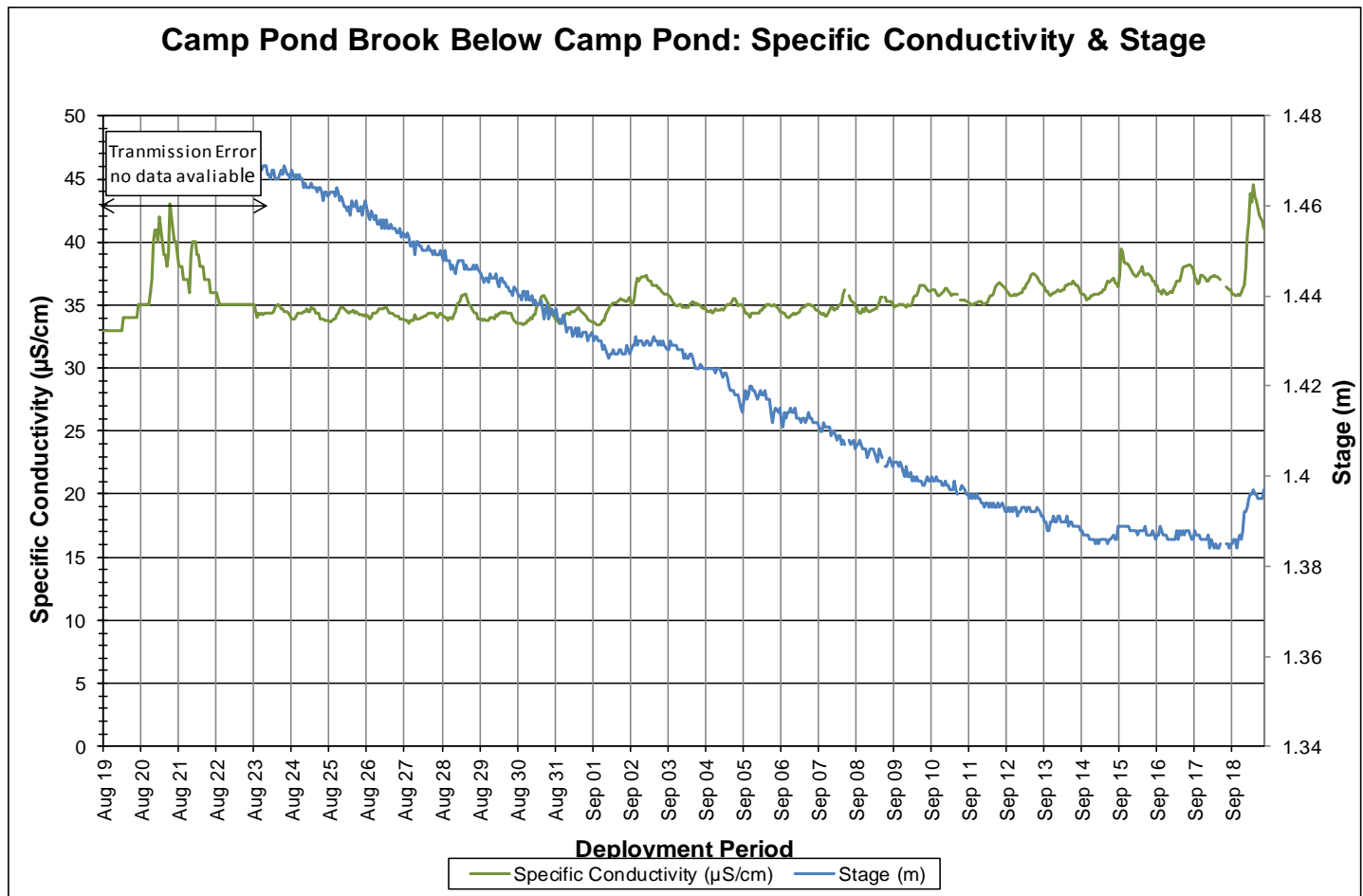


Figure 10: Specific Conductivity & Stage at Camp Pond Brook below Camp Pond

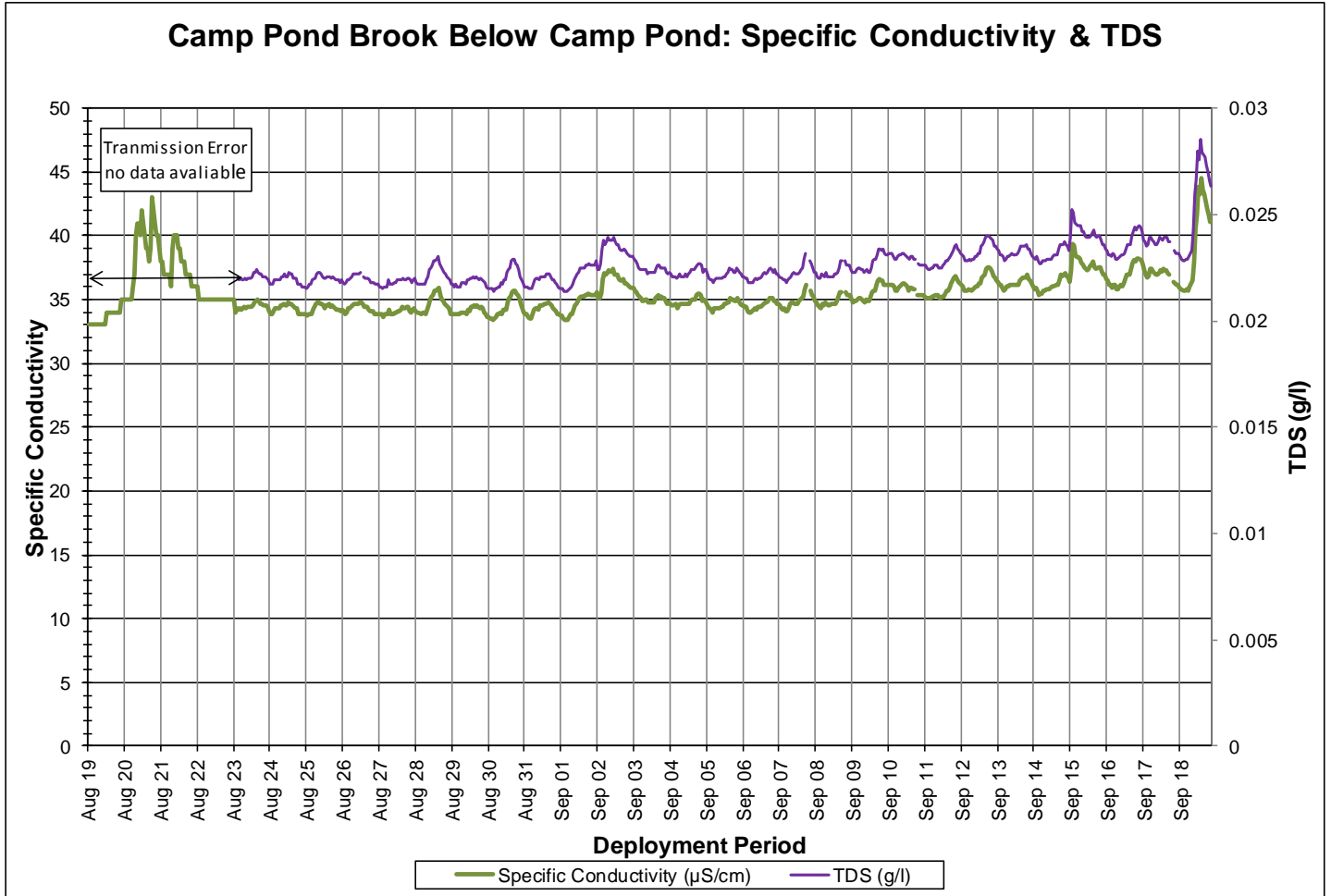


Figure 11: Specific Conductivity & TDS at Camp Pond Brook below Camp Pond

Dissolved Oxygen (mg/L & % Saturation)

- Dissolved oxygen content ranges between 9.42mg/l and 11.55mg/l during the deployment period. The saturation of dissolved oxygen ranges from 91.1% to 101.3% (Figure 12).
- The water quality instrument measures dissolved oxygen (mg/L) with the dissolved oxygen probe and then the instrument calculates percent saturation (% Sat) with water temperature.
- Dissolved oxygen briefly dipped below the CCME guideline of 9.5mg/L during the deployment period. This occurrence corresponds with the warmest water temperature during the deployment period (Figure 12). This is expected as water temperature directly influences the level of dissolved oxygen present in the water column.

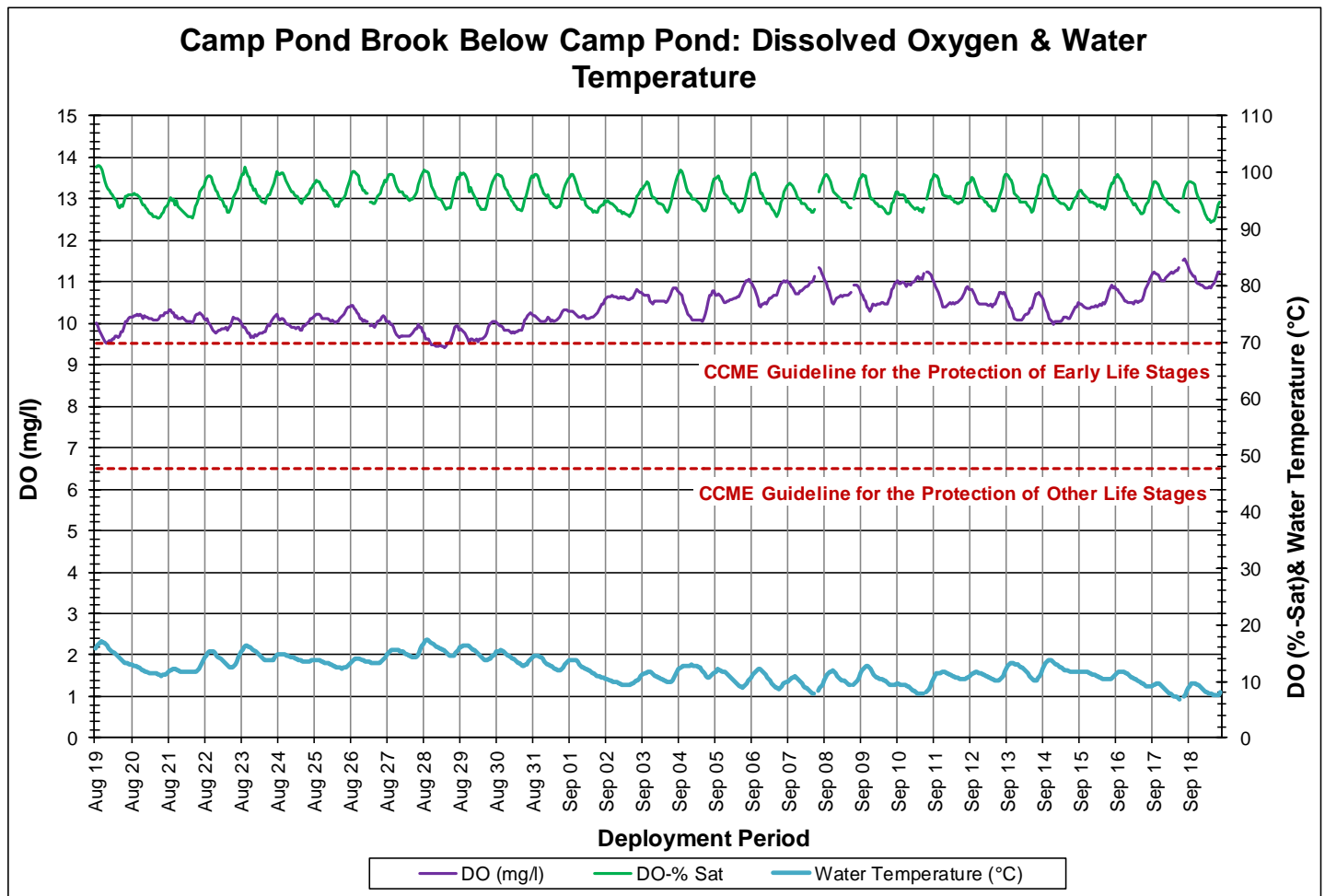


Figure 12: Dissolved Oxygen & Water Temperature at Camp Pond Brook below Camp Pond

Turbidity

- Turbidity ranges from 0.0NTU to 0.5NTU during the deployment period, with a median value of 0.0NTU (Figure 13).
- A median value of 0.0 NTU indicates there is very little natural background turbidity at this station during this deployment period.
- There are a few low turbidity events at this station throughout the duration of this deployment. Some of these turbidity events correlate with precipitation causing increase in stage level and mixing of solids into the water column. (Figure 13, 14).
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

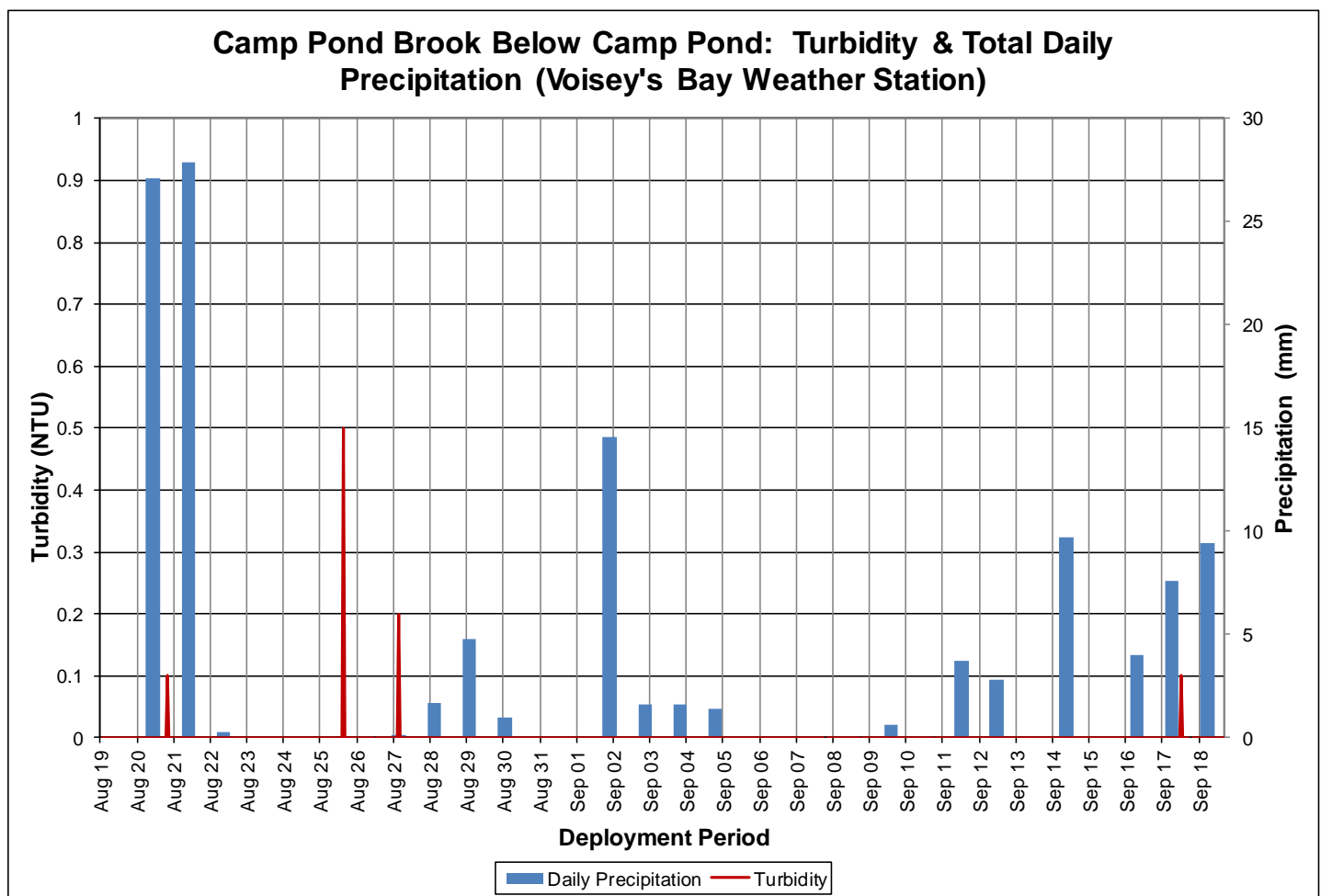


Figure 13: Turbidity & Total Daily Precipitation (Voisey's Bay Weather Station) at Camp Pond Brook below Camp Pond

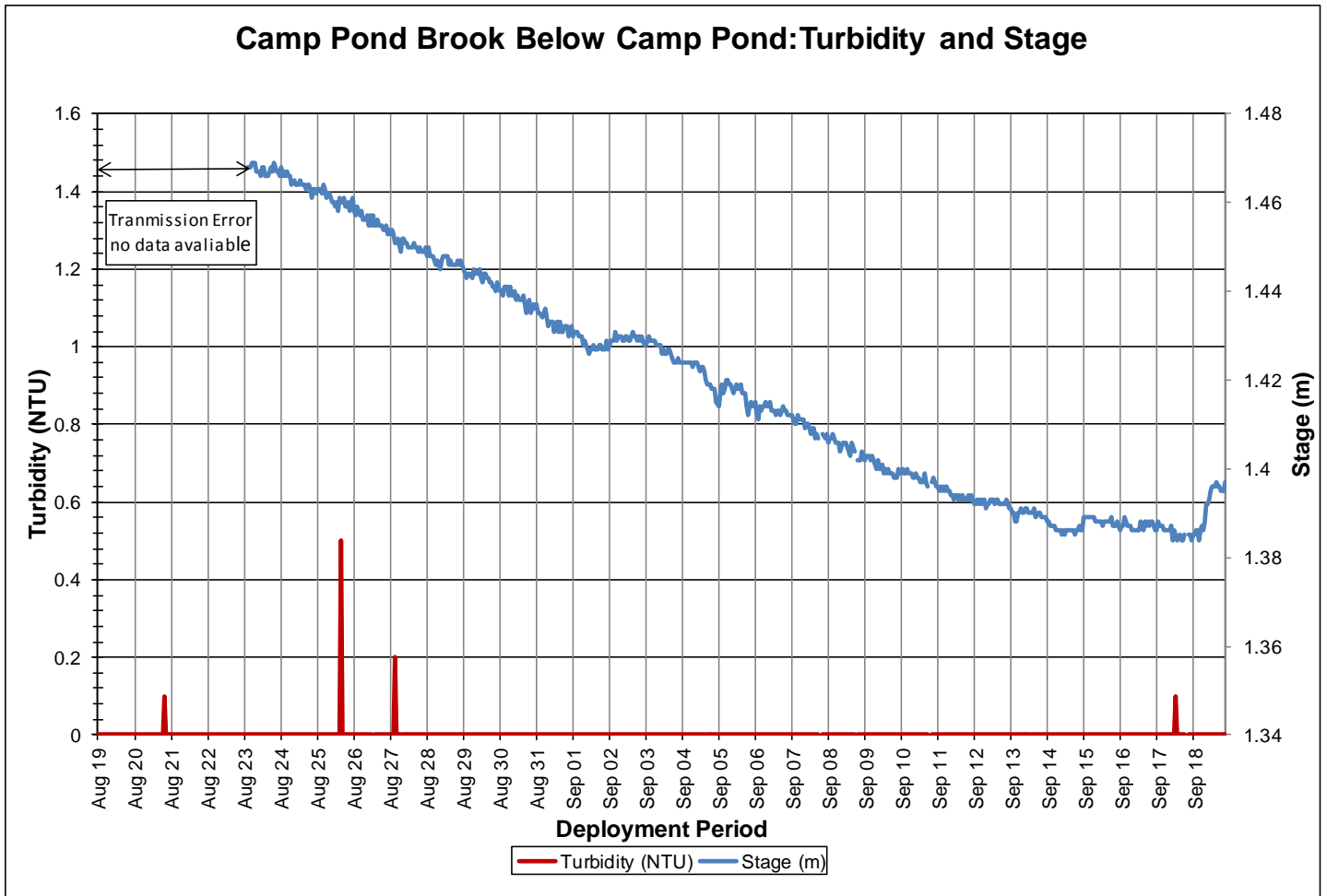


Figure 14: Turbidity & Stage at Camp Pond Brook below Camp Pond

Stage, Flow and Precipitation

- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.
- Precipitation data was obtained from the Voisey's Bay weather station (Figure 15).
- Precipitation occurs on 18 days during the deployment period and amounts are small in magnitude, with the largest on August 21st with 27.9mm of rain.
- During the deployment period, the stage values ranged from 1.38m to 1.47m. Streamflow had a minimum amount of 0.26m³/s and a maximum flow of 0.64m³/s.
- Stage, streamflow and precipitation are graphed below to show the relationship between rainfall and water level (Figure 15).

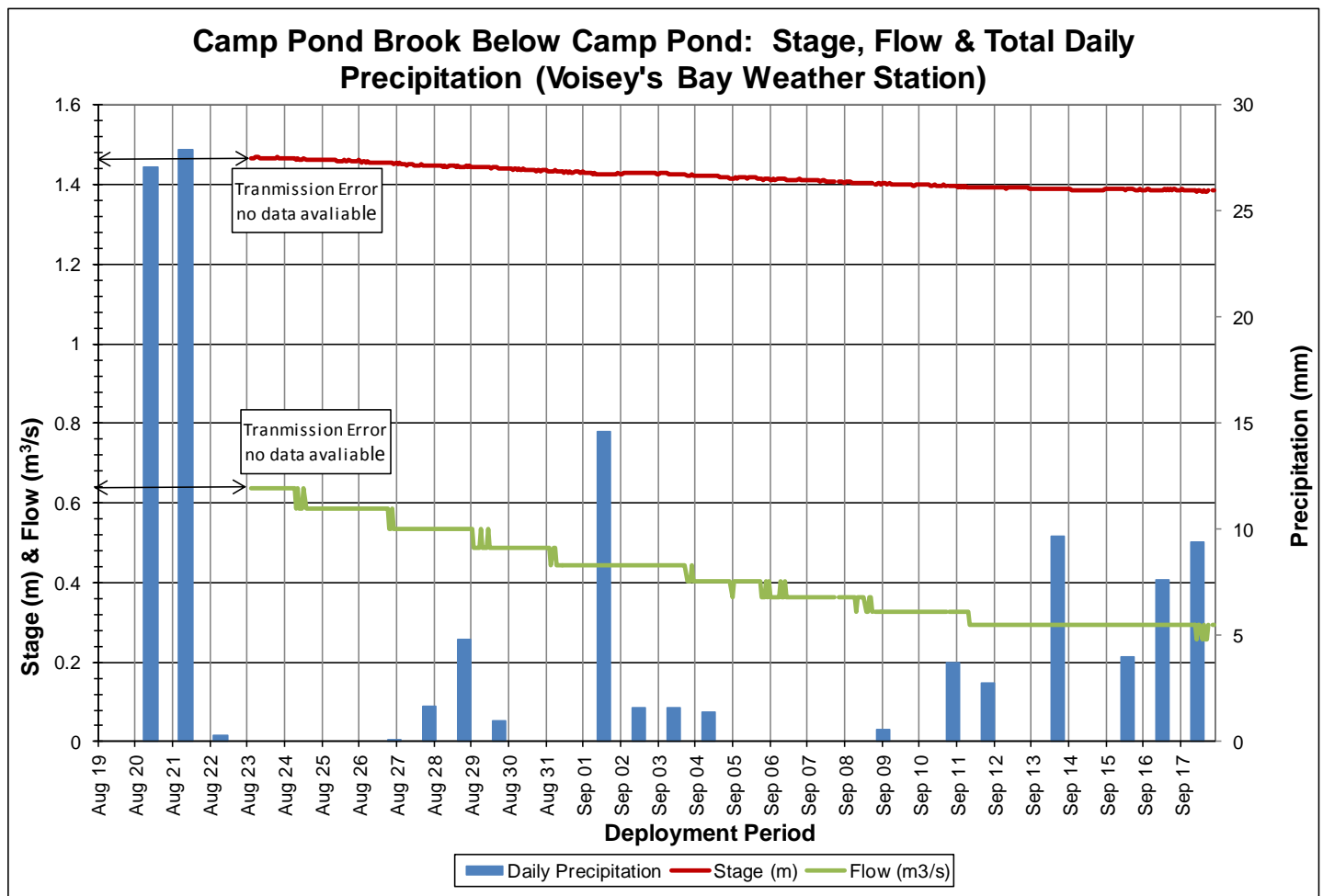


Figure 15: Stage, Flow, and Total Daily Precipitation (Voisey's Bay Weather Station) at Camp Pond Brook below Camp Pond

Tributary to Lower Reid Brook

Water Temperature

- Water temperature ranges from 4.90 °C to 13.70 °C, with a median value of 8.90 °C (Figure 16).
- Water temperature is gradually decreasing throughout the deployment period. This trend is expected as the air temperatures cool in the autumn months.
- Streams and brooks are sensitive to changes in the ambient air temperature and water temperature will fluctuate considerably depending on the weather and the time of day.

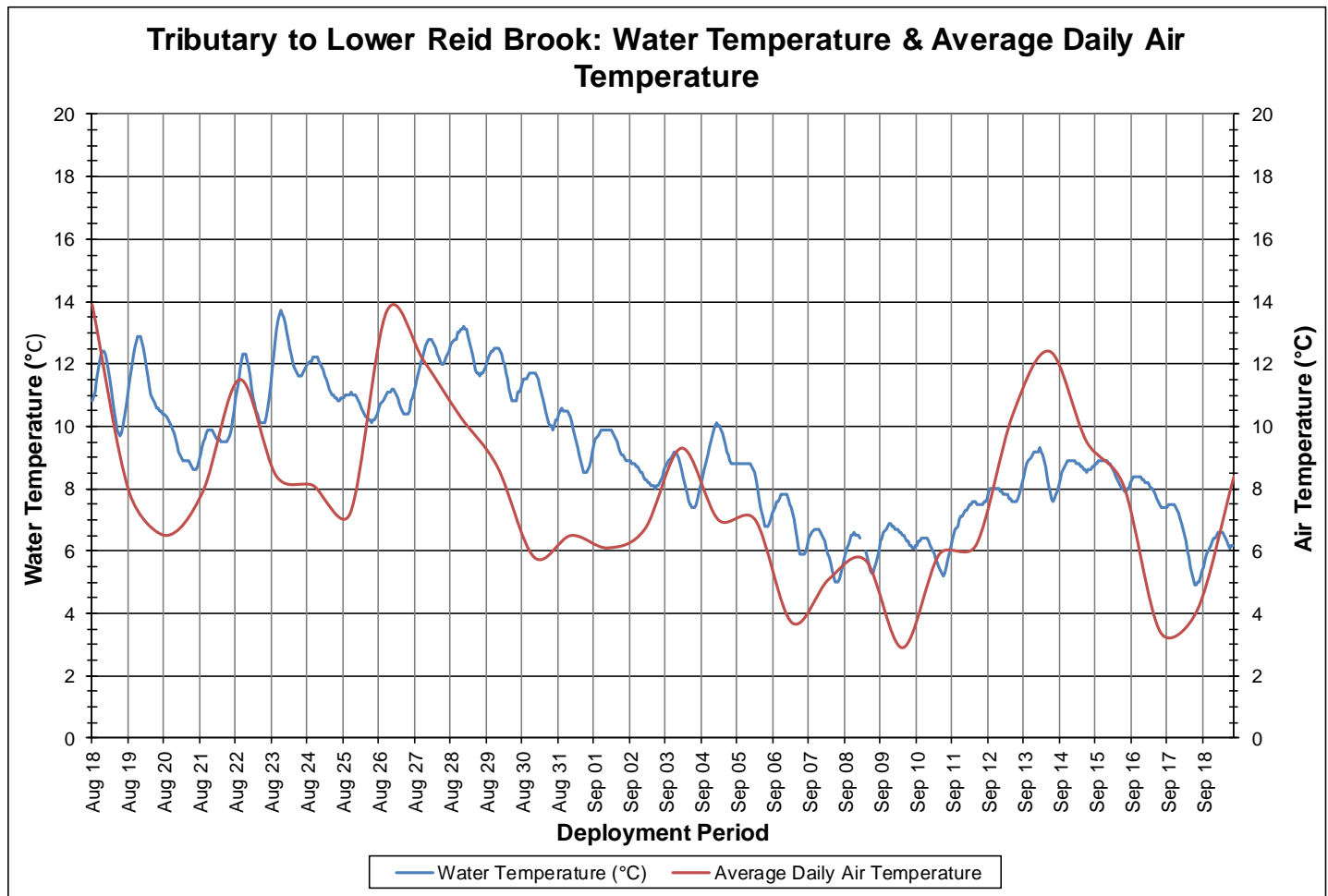


Figure 16: Water Temperature & Average Daily Air Temperature at Tributary to Lower Reid Brook

pH

- pH ranges from 6.47 to 7.06 pH units, with a median value of 6.93 (Figure 17).
- pH dips below CCME guidelines briefly as an increase in stage occurred due to precipitation events. This addition of rain water causes the water to become more acidic and the pH drops.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

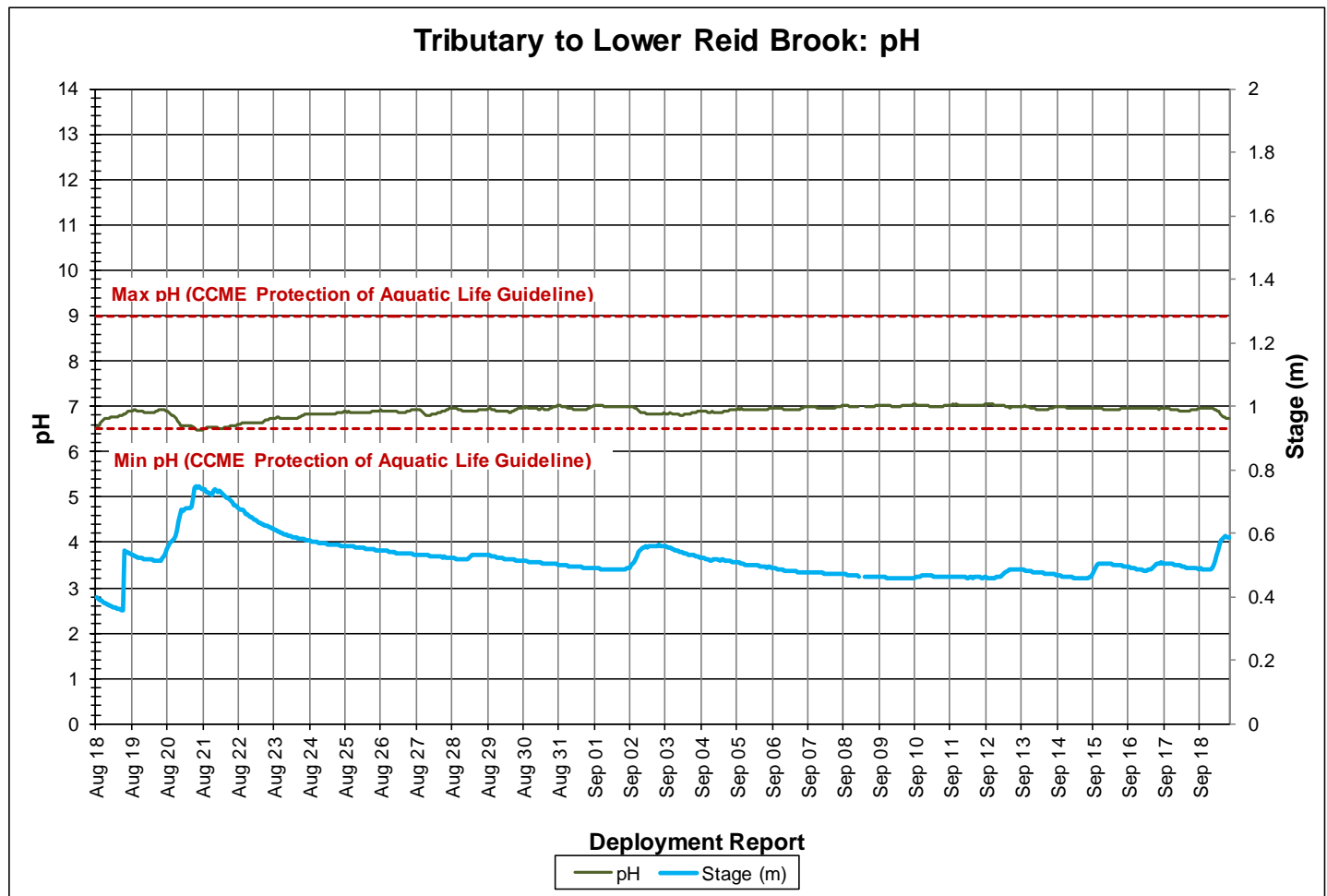


Figure 17: pH & Stage at Tributary to Lower Reid Brook

Specific Conductivity

- Specific conductivity ranges from 24.3 μ S/cm to 40.1 μ S/cm with a median of 34.2 μ S/cm. (Figure 18).
- TDS ranges between 0.0156g/mL to 0.0257g/mL during the deployment period, with a median of 0.0219g/mL (Figure 19).
- Specific conductivity and TDS have a direct relationship but are two separate parameters. Specific conductivity is the ability of the water to conduct electricity. Therefore the value of TDS can be calculated by the conductivity of the water (Figure 19).
- The relationship between conductivity and stage is inversed. When stage level rises, the specific conductance level drops in response as the increased amount of water in the river system dilutes the solids that are present (Figure 18).
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

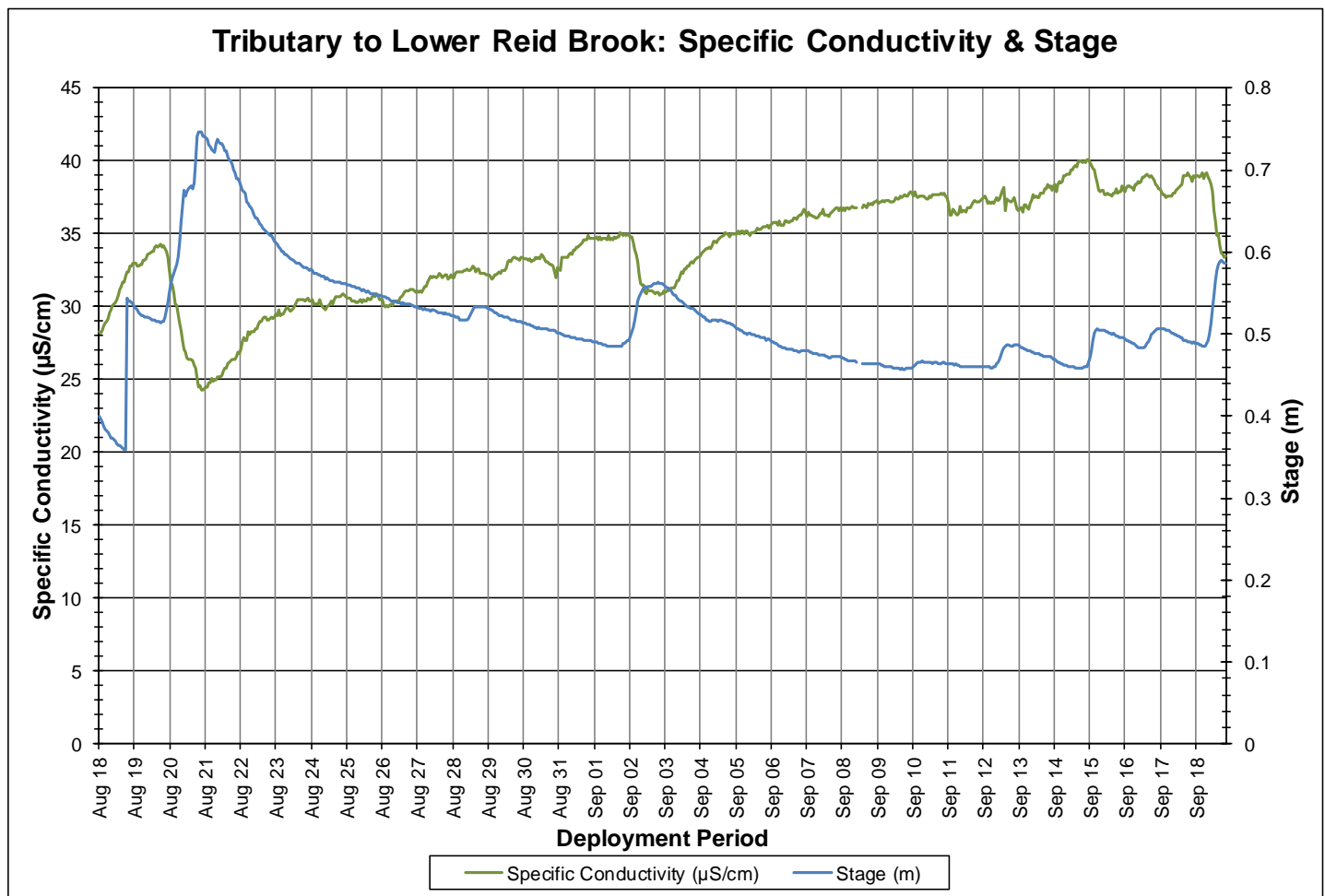


Figure 18: Specific Conductivity & Stage at Tributary to Lower Reid Brook

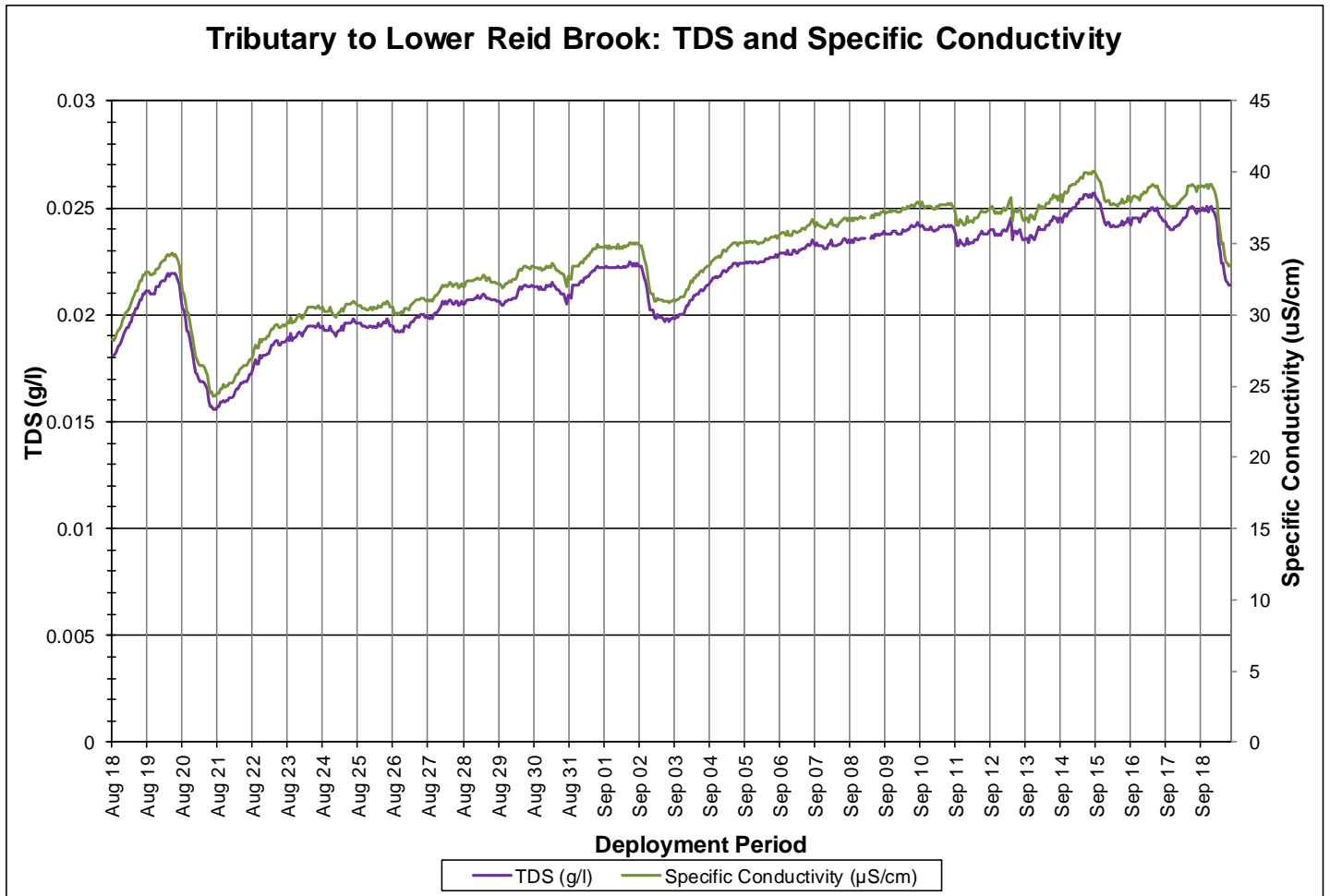


Figure 19: Specific Conductivity & TDS at Tributary to Lower Reid Brook

Dissolved Oxygen

- Dissolved oxygen content ranges between 10.14mg/l and 12.65mg/l during the deployment period. The saturation of dissolved oxygen ranges from 96.0% to 100.8% (Figure20).
- The water quality instrument measures dissolved oxygen (mg/L) with the dissolved oxygen probe and then the instrument calculates percent saturation (% Sat) with water temperature.
- Dissolved oxygen remained above the CCME guideline of 9.5mg/L during the deployment period (Figure 20).

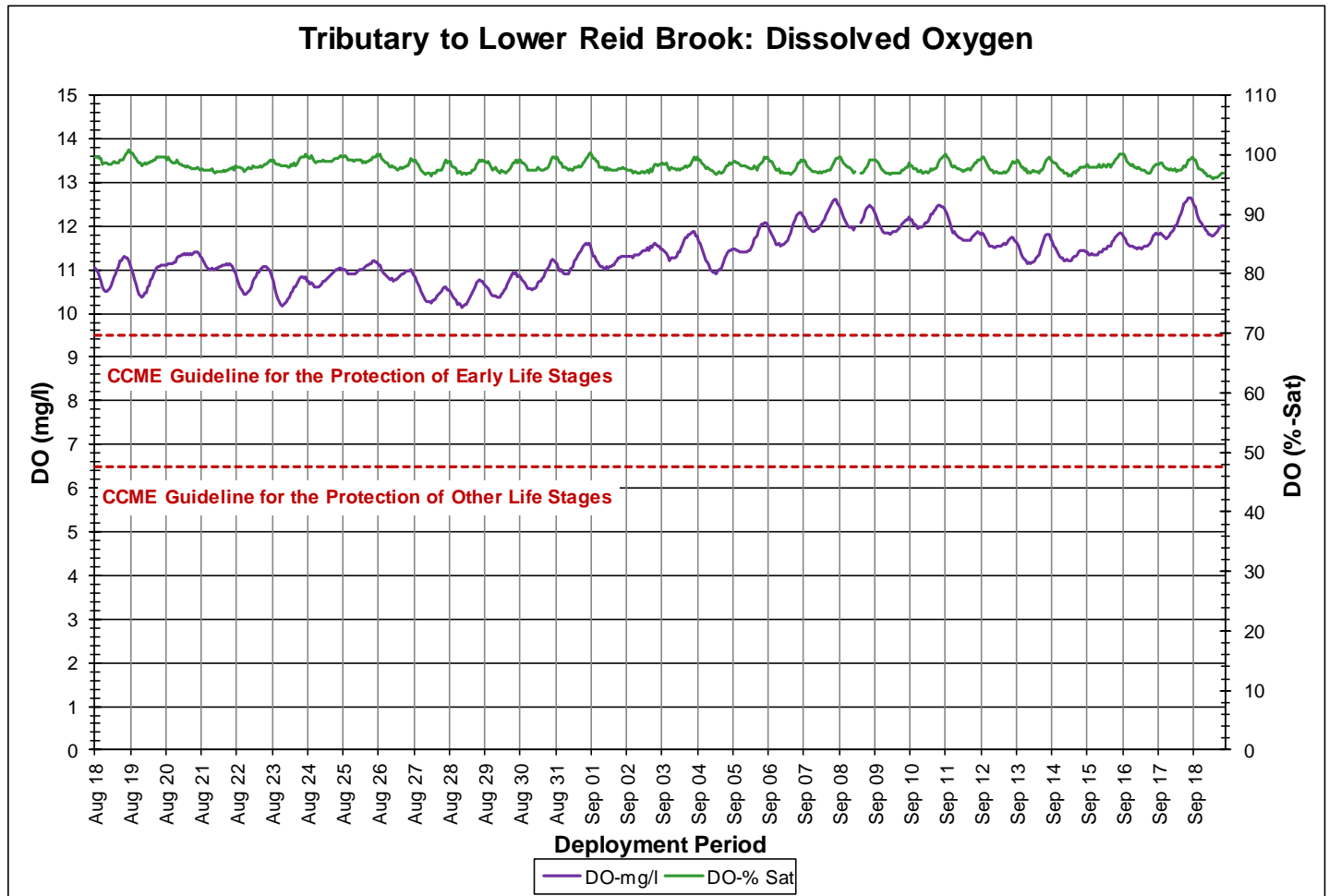


Figure 20: Dissolved Oxygen at Tributary to Lower Reid Brook

Turbidity

- Turbidity ranges from 0.0NTU to 97.0NTU during the deployment period, with a median value of 0.3NTU (Figure 21).
- There are a number of high turbidity events at this station throughout the duration of this deployment (Figure 21, 22). Some of these turbidity events correlate with precipitation causing increase in stage level and mixing of solids into the water column.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

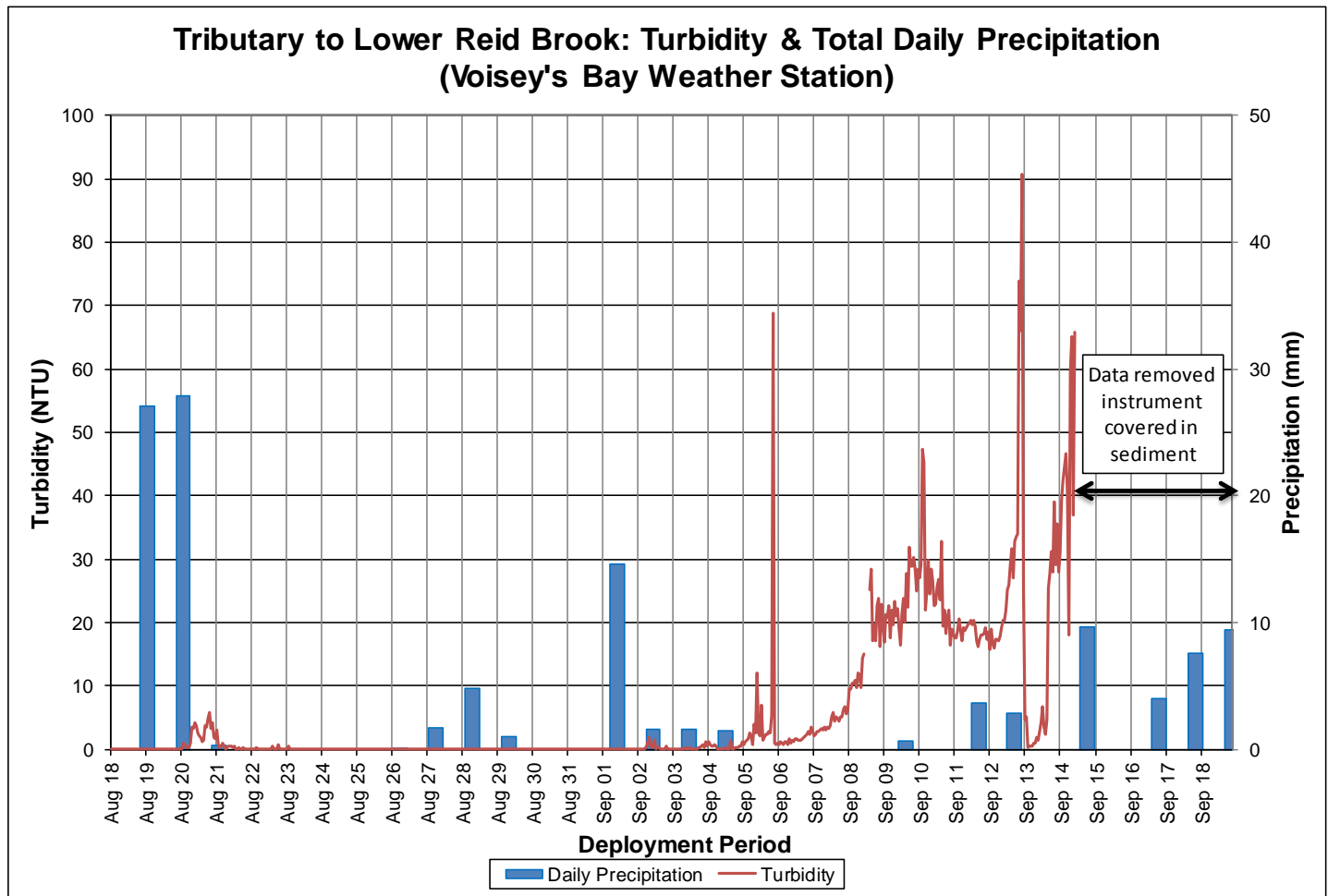


Figure 21: Turbidity & Total Daily Precipitation (Voisey's Bay Weather Station) at Tributary to Lower Reid Brook

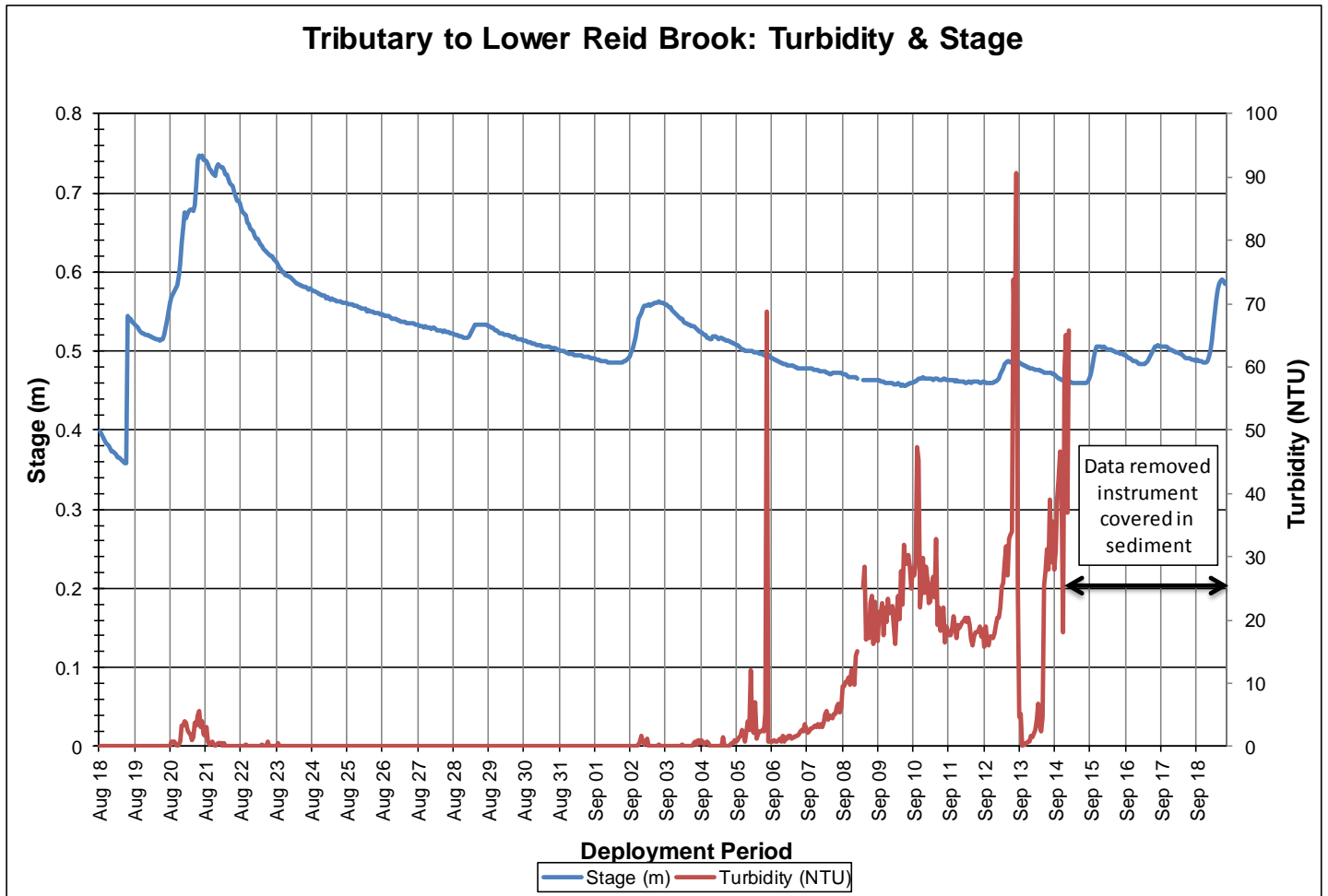


Figure 22: Turbidity & Stage at Tributary to Lower Reid Brook

Stage, Flow and Precipitation

- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.
- Precipitation data was obtained from the Voisey's Bay weather station (Figure 23).
- Precipitation occurs on 18 days during the deployment period and amounts are small in magnitude, with the exception of the largest on August 21st with 27.9mm of rain.
- During the deployment period, the stage values ranged from 0.36m to 0.75m. Streamflow had a minimum amount of $0.05\text{m}^3/\text{s}$ and a maximum flow of $1.14\text{m}^3/\text{s}$.
- Stage, Streamflow and precipitation are graphed below to show the relationship between rainfall and water level (Figure 23). It is evident that the peaks in stage (m) and streamflow data are a result of precipitation.

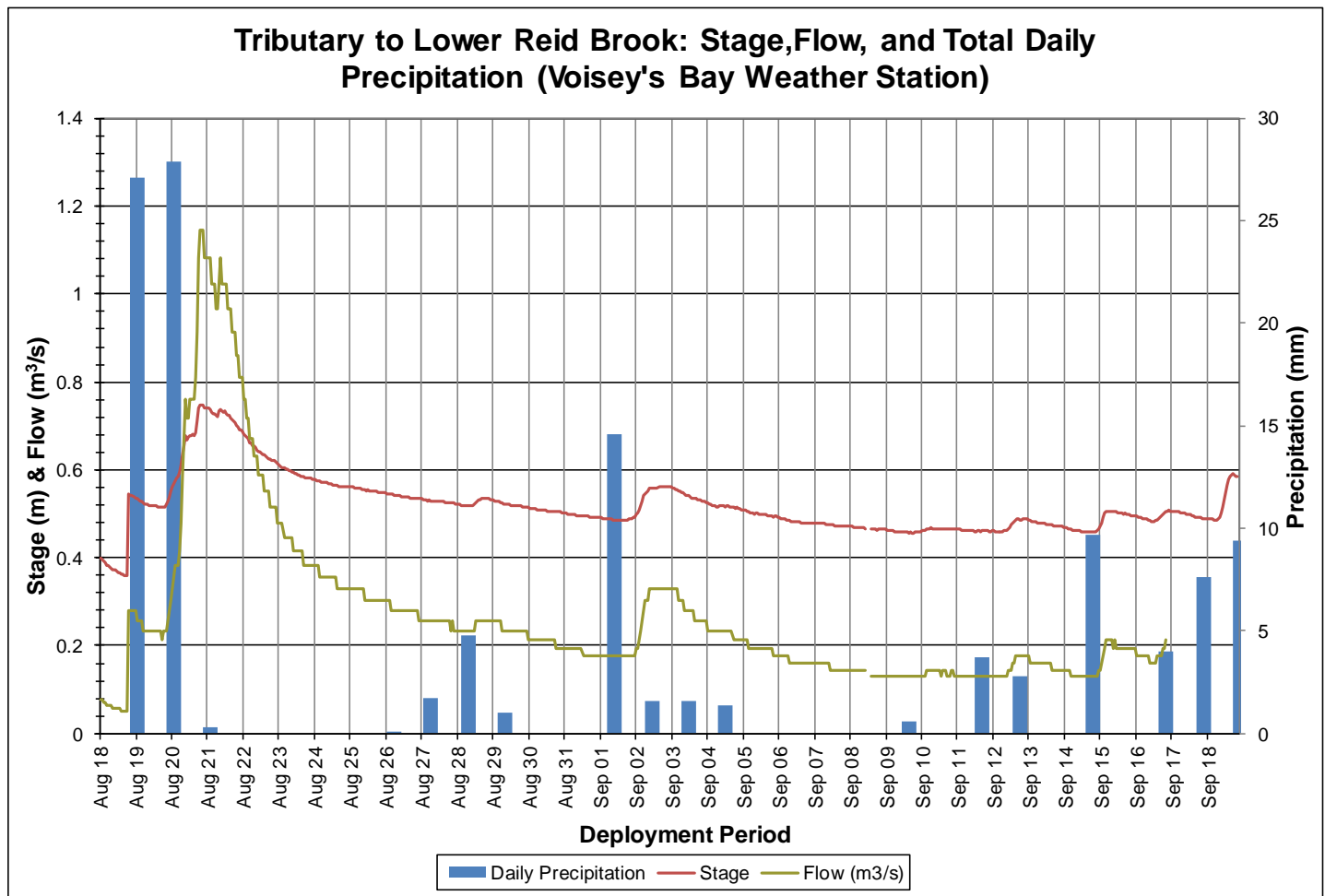


Figure 23: Stage, Flow, and Total Daily Precipitation (Voisey's Bay Weather Station) at Tributary to Lower Reid Brook

Lower Reid Brook below Tributary

Water Temperature

- Water temperature ranges from 5.18 °C to 14.34 °C, with a median value of 9.24 °C (Figure 24).
- Water temperature is gradually decreasing throughout the deployment period. This trend is expected as the air temperatures cool in the autumn months.
- Streams and brooks are sensitive to changes in the ambient air temperature and water temperature will fluctuate considerably depending on the weather and the time of day.

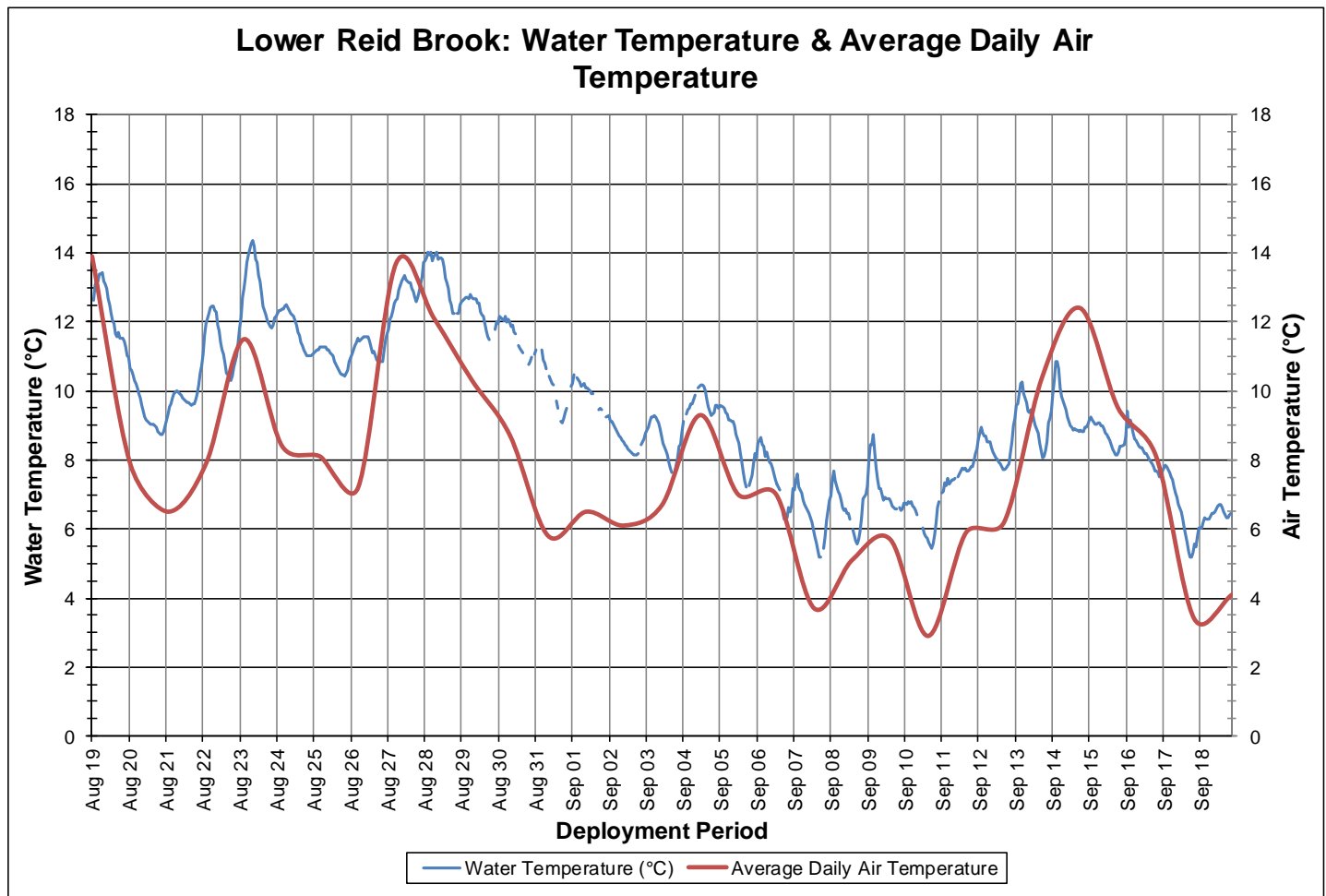


Figure 24: Water Temperature and Daily Average Air Temperature at Lower Reid Brook below Tributary

pH

- pH ranges from 6.45 to 7.05 pH units, with a median value of 6.88 (Figure 25).
- pH dips below CCME guidelines briefly as an increase in stage occurred due to precipitation events. This addition of rain water causes the water to become more acidic and the pH drops.
- The CCME guideline provides a basis by which to judge the overall health of the brook. Naturally, all streams and brooks are different.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

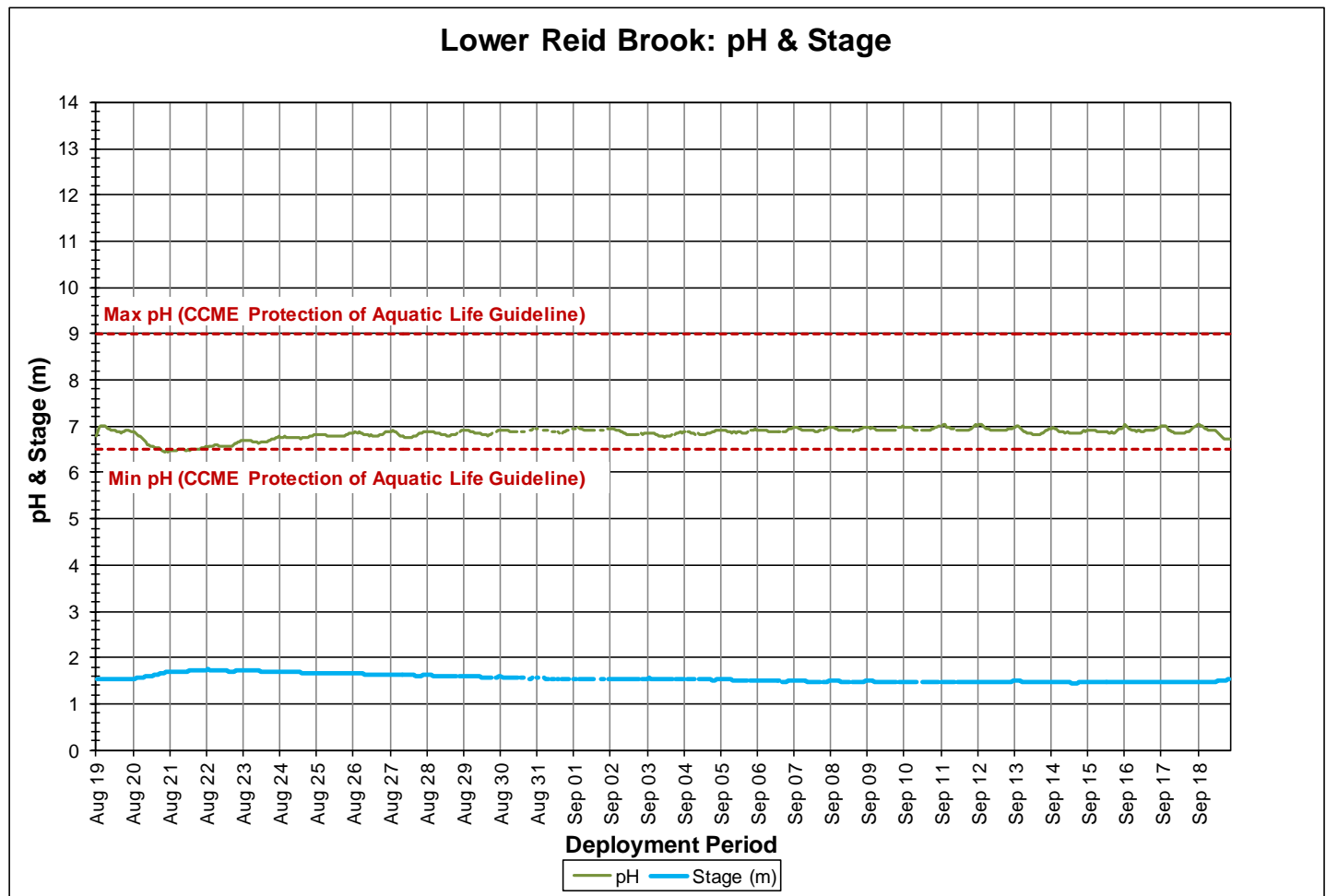


Figure 25: pH & Stage at Lower Reid Brook below Tributary

Specific Conductivity

- Specific conductivity ranges from 23.5 μ S/cm to 36.8 μ S/cm with a median of 31.2 μ S/cm. (Figure 26).
- TDS ranges between 0.0151 g/mL to 0.0235 g/mL during the deployment period, with a median of 0.0200g/mL (Figure 26).
- Specific conductivity and TDS have a direct relationship but are two separate parameters. Specific conductivity is the ability of the water to conduct electricity. Therefore the value of TDS can be calculated by the conductivity of the water (Figure 27)
- The relationship between conductivity and stage is inversed. When stage level rises, the specific conductance level drops in response as the increased amount of water in the river system dilutes the solids that are present (Figure 26).
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request

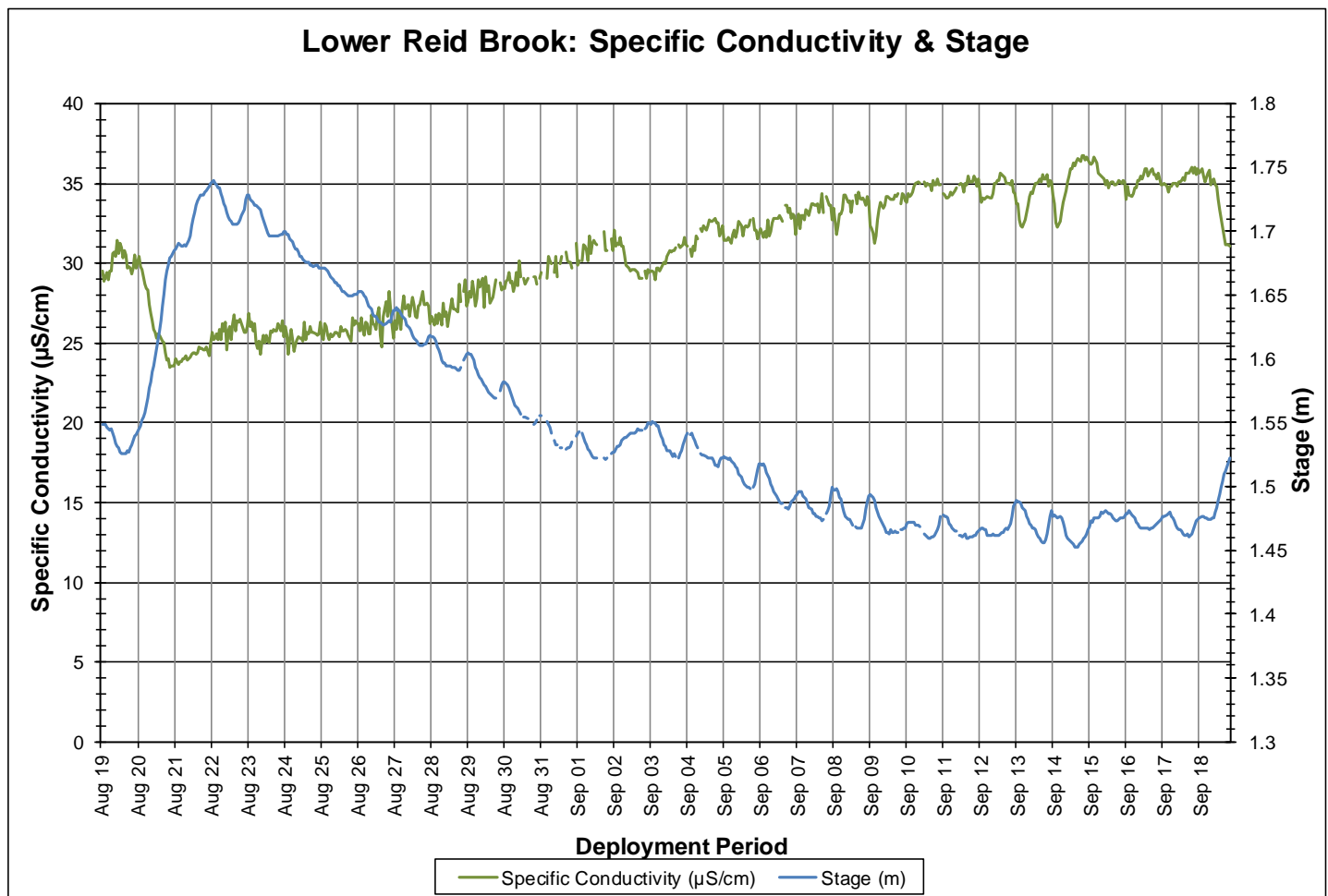


Figure 26: Specific Conductivity & Stage at Lower Reid Brook below Tributary

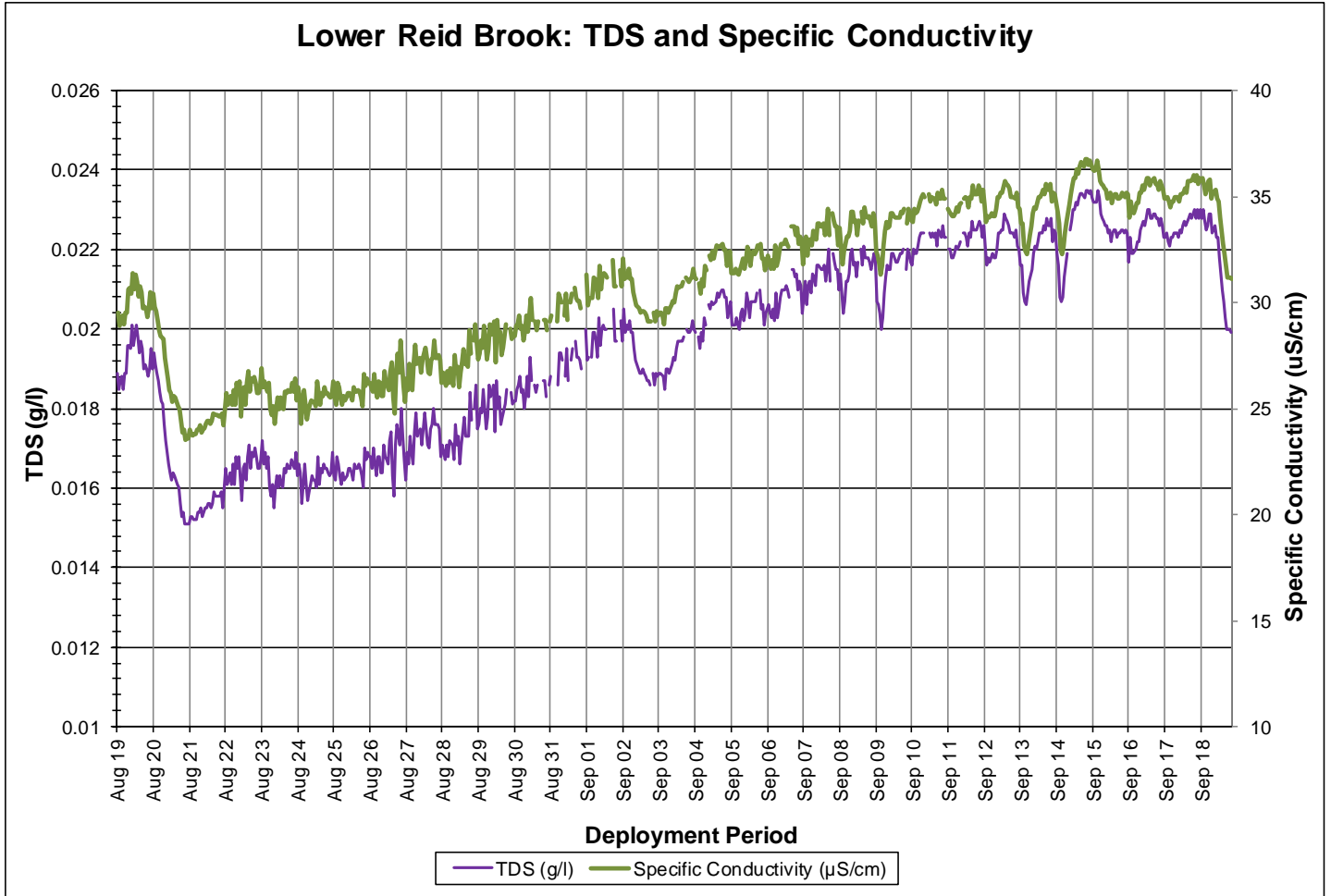


Figure 27: Specific Conductivity & TDS at Lower Reid Brook below Tributary

Dissolved Oxygen

- Dissolved oxygen content ranges between 9.90mg/l and 12.45mg/l during the deployment period. The saturation of dissolved oxygen ranges from 94.5% to 101.7% (Figure 28).
- The water quality instrument measures dissolved oxygen (mg/L) with the dissolved oxygen probe and then the instrument calculates percent saturation (% Sat) with water temperature.
- During this deployment the dissolved oxygen mg/L levels remained above the CCME guidelines for the protection of Early and Other Life Stages.

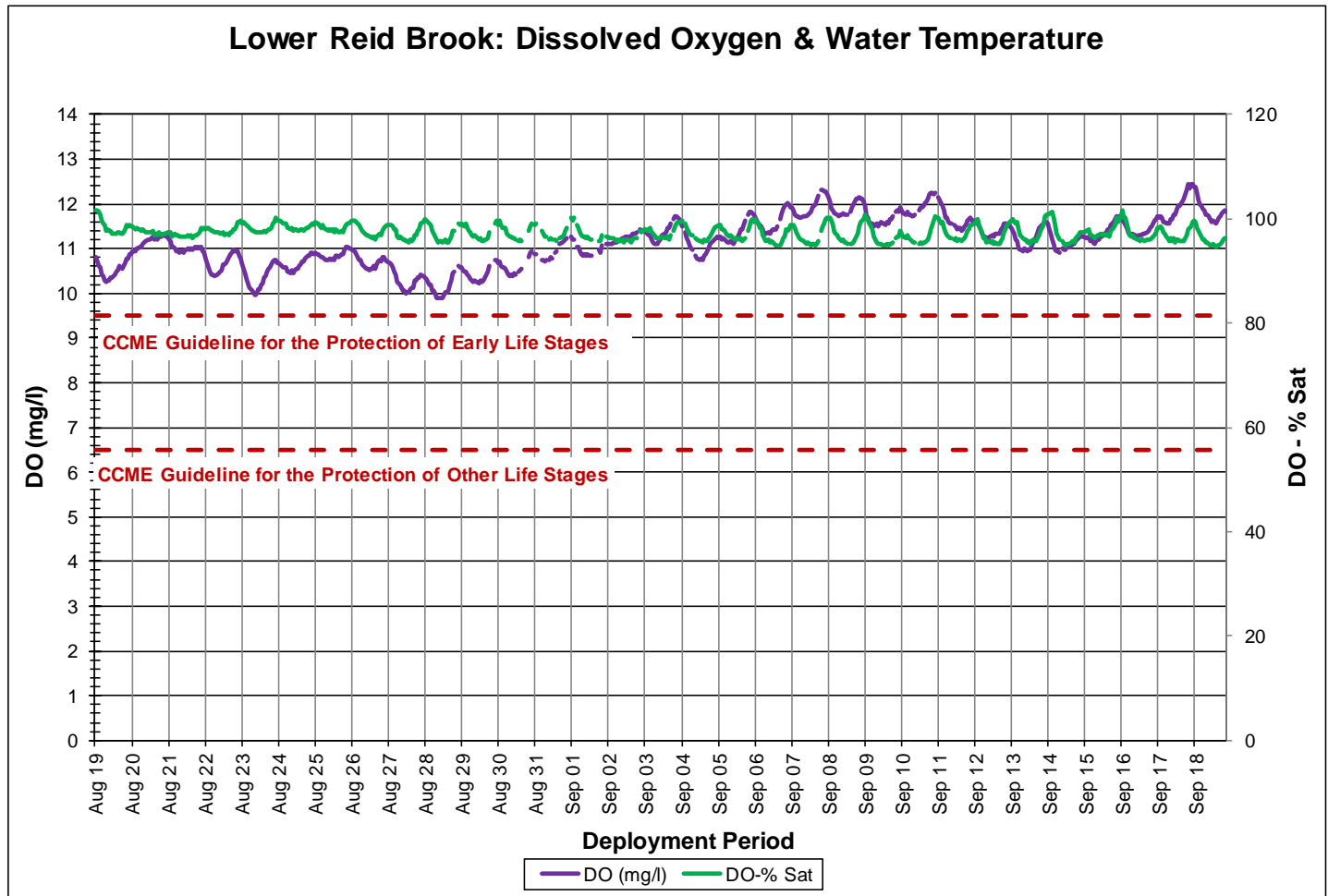


Figure 28: Dissolved Oxygen & Water Temperature at Lower Reid Brook below Tributary

Turbidity

- Turbidity ranges from 0.0NTU to 31.0NTU during the deployment period, with a median value of 0.0NTU (Figure 29).
- There are a number of low and high turbidity events at this station throughout the duration of this deployment. Some of the larger turbidity events correlate with precipitation causing increase in stage level and mixing of solids into the water column. (Figure 29, 30).
- Upon removal the field sonde value was 30.9NTU while the QA/QC sonde was 1.6NTU. This discrepancy and large turbidity events at the end of the deployment period could be attributed to the sensor being fouled. The turbidity sensor could have been repeatedly covered with sediment
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

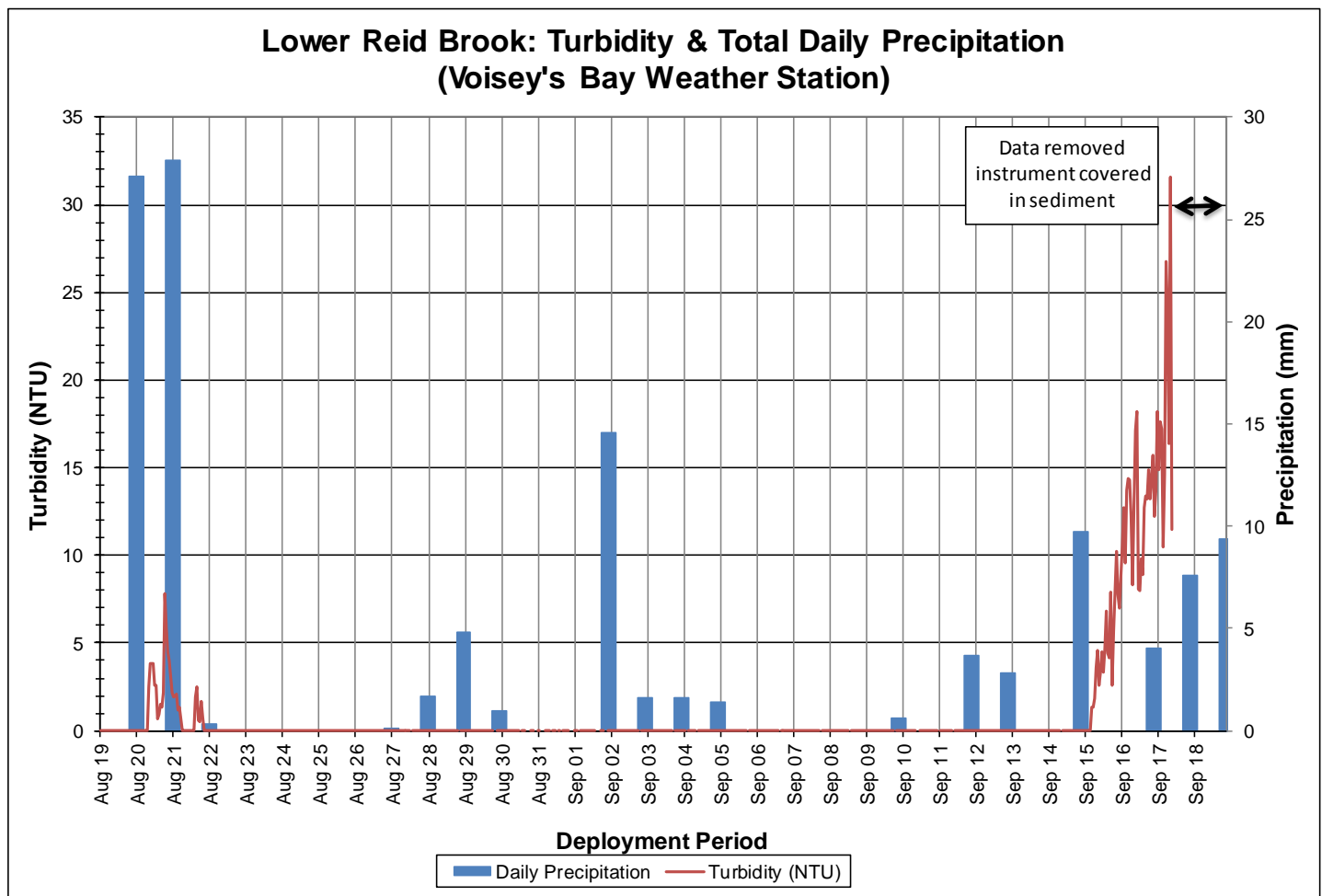


Figure 29: Turbidity & Total Daily Precipitation (Voisey's Bay Weather Station) at Lower Reid Brook below Tributary

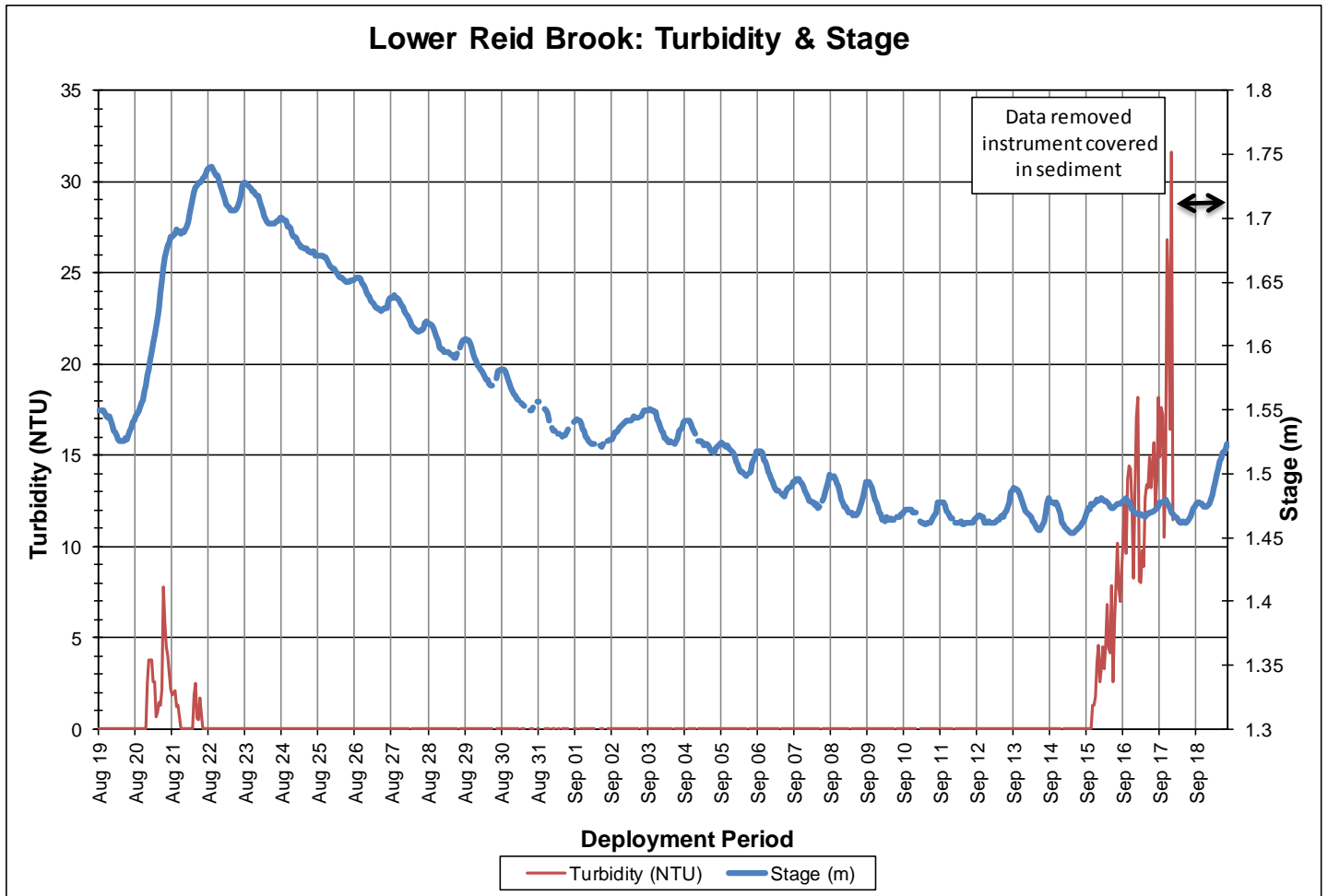


Figure 30: Turbidity & Stage at Lower Reid Brook below Tributary

Stage, Flow, and Precipitation

- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.
- Precipitation data was obtained from the Voisey's Bay weather station (Figure 31).
- Precipitation occurs on 18 days during the deployment period and amounts are small in magnitude, with the exception of the largest on August 21st with 27.9mm of rain.
- During the deployment period, the stage values ranged from 1.45m to 1.74m. Streamflow had a minimum amount of 1.53m³/s and a maximum flow of 9.41m³/s.
- Stage, Streamflow and precipitation are graphed below to show the relationship between rainfall and water level (Figure 31). It is evident that the peaks in stage (m) and streamflow data are a result of precipitation.

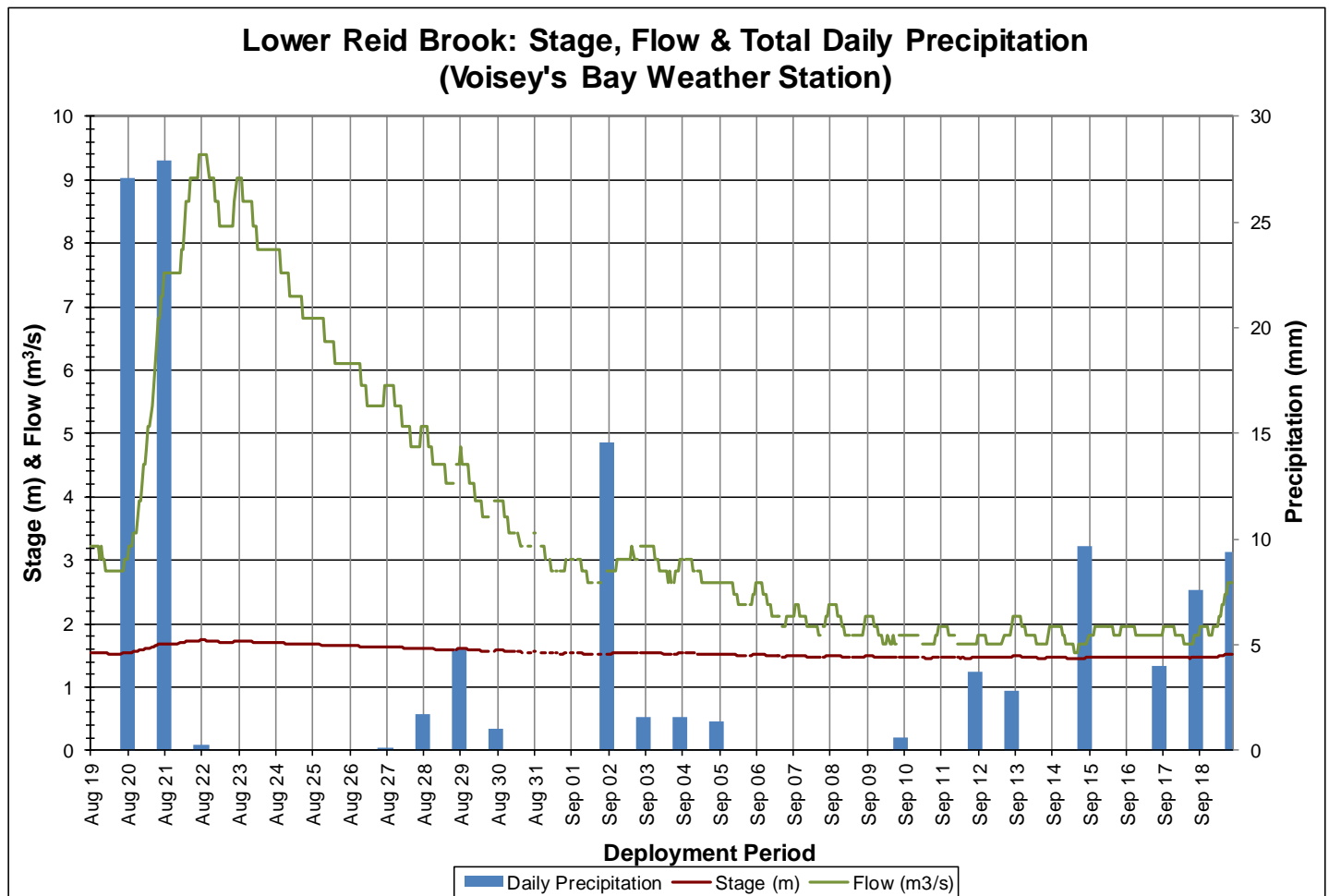


Figure 31: Stage, Flow, and Total Daily Precipitation (Voisey's Bay Weather Station) at Lower Reid Brook below Tributary

Conclusions

- The overall water temperatures across all stations were within a minimum of 4.90°C found at Tributary to Lower Reid Brook and a maximum of 17.37°C recorded at Camp Pond Brook below Camp Pond. Overall the water temperature was increasing across the network of stations. The stations on Camp Pond Brook, Tributary to Lower Reid Brook and Lower Reid Brook are more sensitive to changes in the ambient air temperatures.
- The pH values for this deployment ranged between a minimum of 6.45 pH units at Lower Reid Brook below Tributary and maximum of 7.15 pH units at Camp Pond Brook. All of the stations remained within the CCME guidelines for the majority of the deployment period
- The overall conductivity across all stations were within a minimum of 11.6µS/cm at Reid Brook at Outlet of Reid Pond and a maximum value of 44.5µS/cm at Camp Pond Brook below Camp Pond. Conductivity values at Reid Brook at Outlet of Reid Pond have been the lowest all deployment when compared to the other stations. Camp Pond Brook below Camp Pond maintains the highest median at 32.1µS/cm for July to August deployment period. This is to be expected with Camp Pond Brook being closer to the mine site and the increased potential for roadway runoff and other influences.
- Dissolved oxygen levels for the deployment period ranged between a minimum of 9.42mg/l at Camp Pond Brook below Camp Pond and a maximum of 12.65mg/l found at Tributary to Lower Reid Brook. Dissolved oxygen is gradually getting higher at this time of year due to the cooling temperatures. It also varies diurnally as water temperature is greatly affected by ambient air temperature.
- Turbidity levels for the four real-time stations ranged within a minimum of 0.0NTU from all stations and a maximum of 90.7NTU at Tributary to Lower Reid Brook. Tributary to Lower Reid Brook and Lower Reid Brook has several turbidity events that corresponded with large rain fall events. Some data was removed due to the sensor being covered in sediment.

APPENDIX A: Comparison Graphs

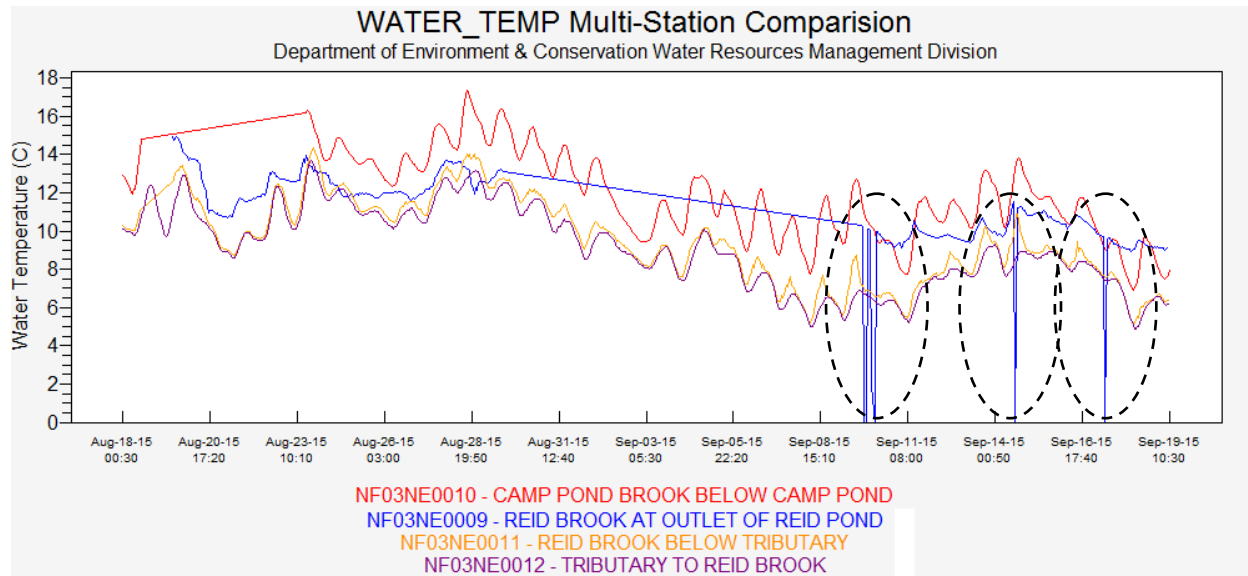


Figure A1: Comparison of Water Temperature at the Real-Time Stations in Voisey's

***Transmission errors are circled on the graph**

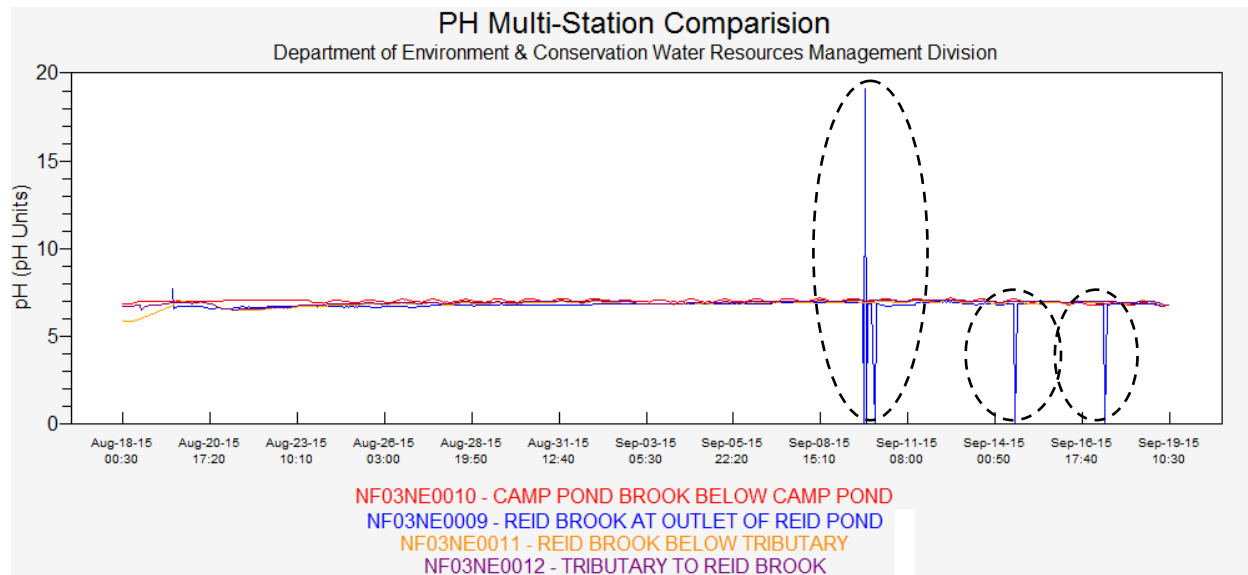


Figure A2: Comparison of pH at the Real-Time Stations in Voisey's Bay

***Transmission errors are circled on the graph**

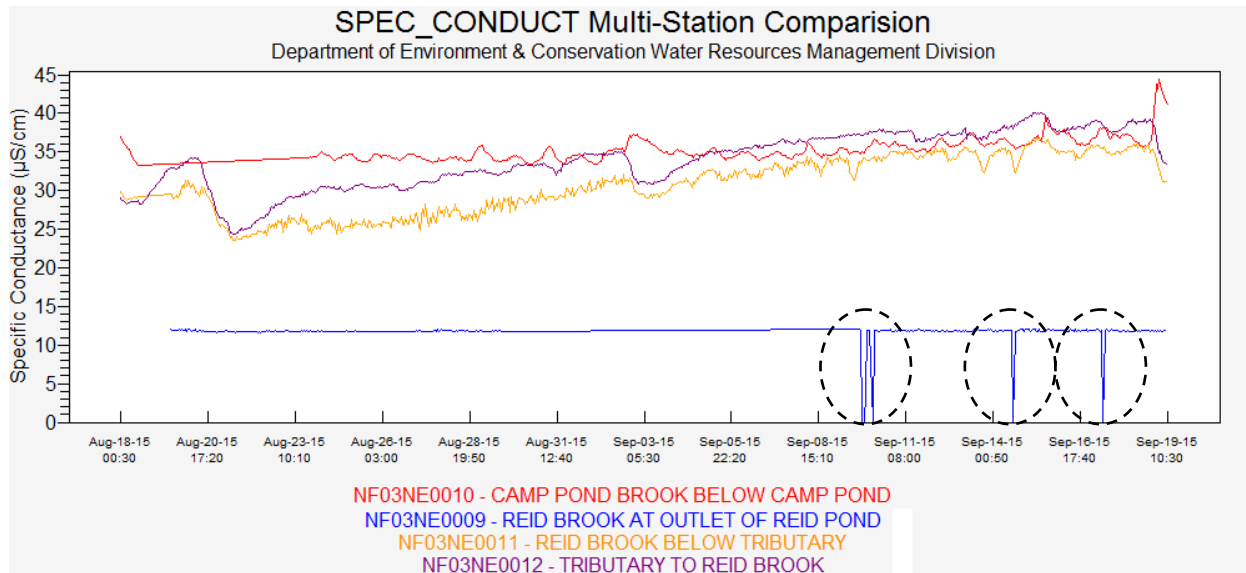


Figure A3: Comparison of Conductivity at the Real-Time Stations in Voisey's Bay

***Transmission errors are circled on the graph**

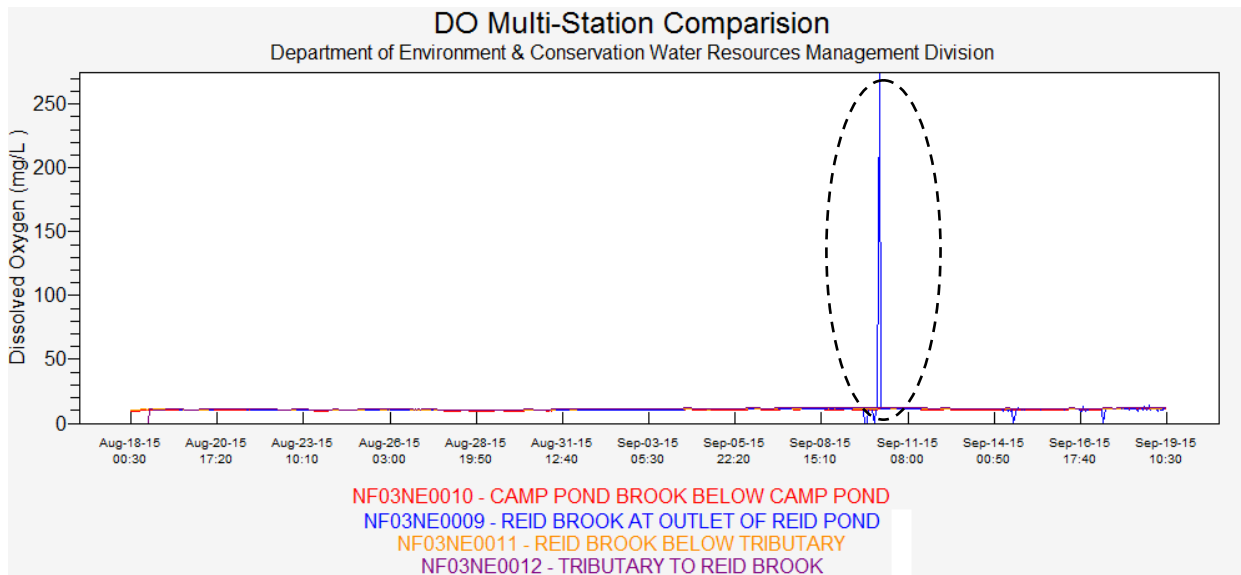


Figure A4: Comparison of Dissolved Oxygen (mg/L) at the Real-Time Stations in Voisey's Bay

***Transmission errors are circled on the graph**

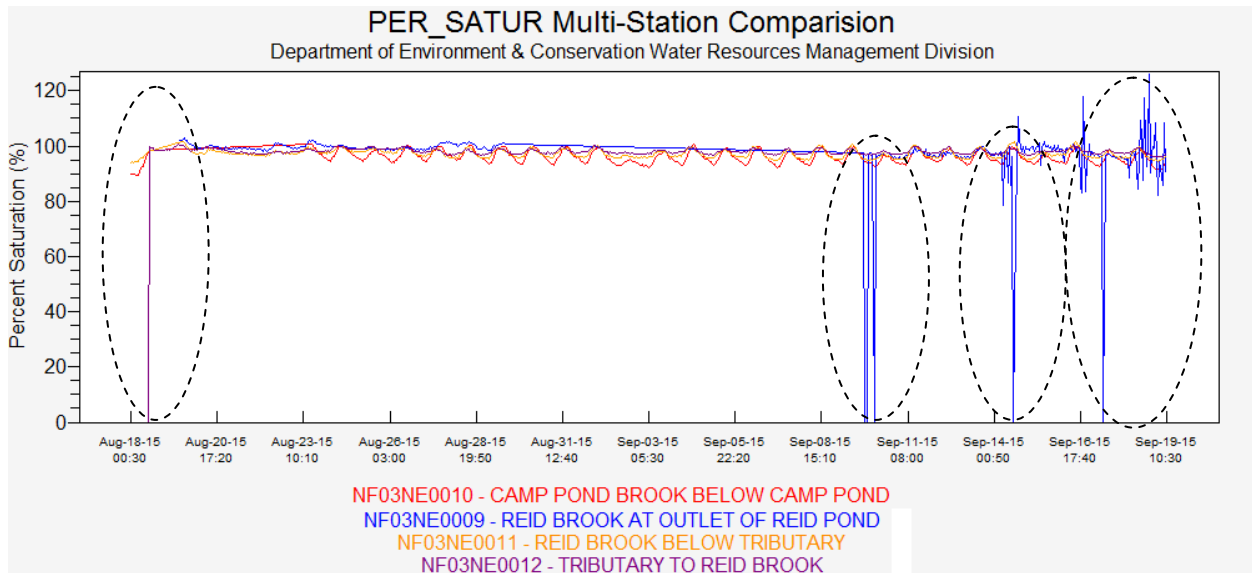


Figure A5: Comparison of Dissolved Oxygen (%Sat) at the Real-Time Stations in Voisey's Bay

***Transmission errors are circled on the graph**

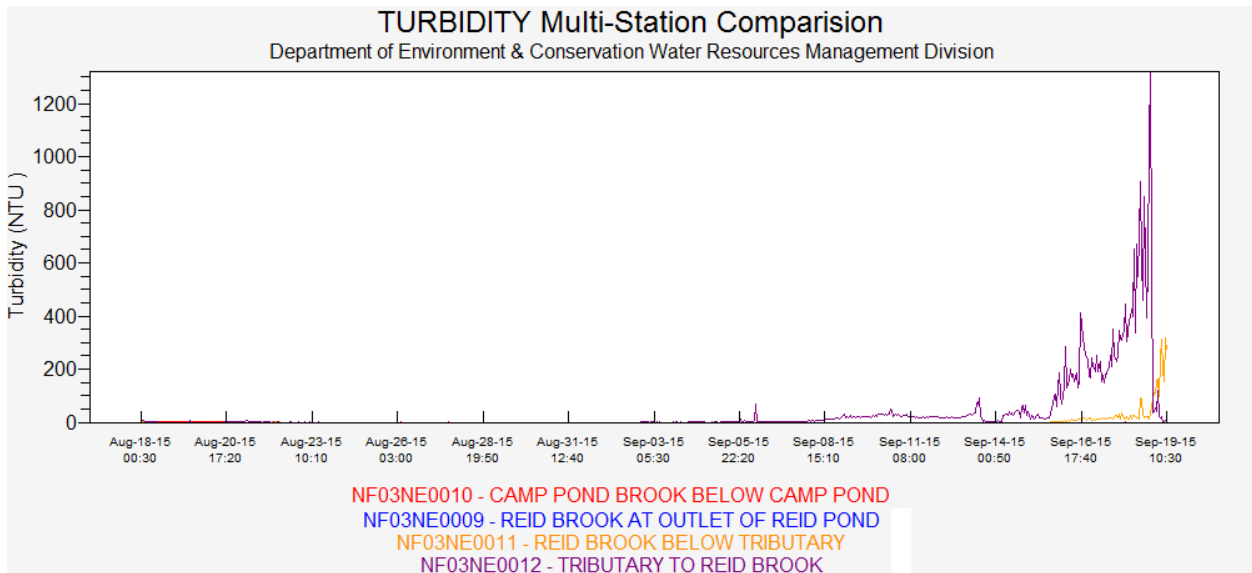


Figure A6: Comparison of Turbidity at the Real-Time Stations in Voisey's Bay

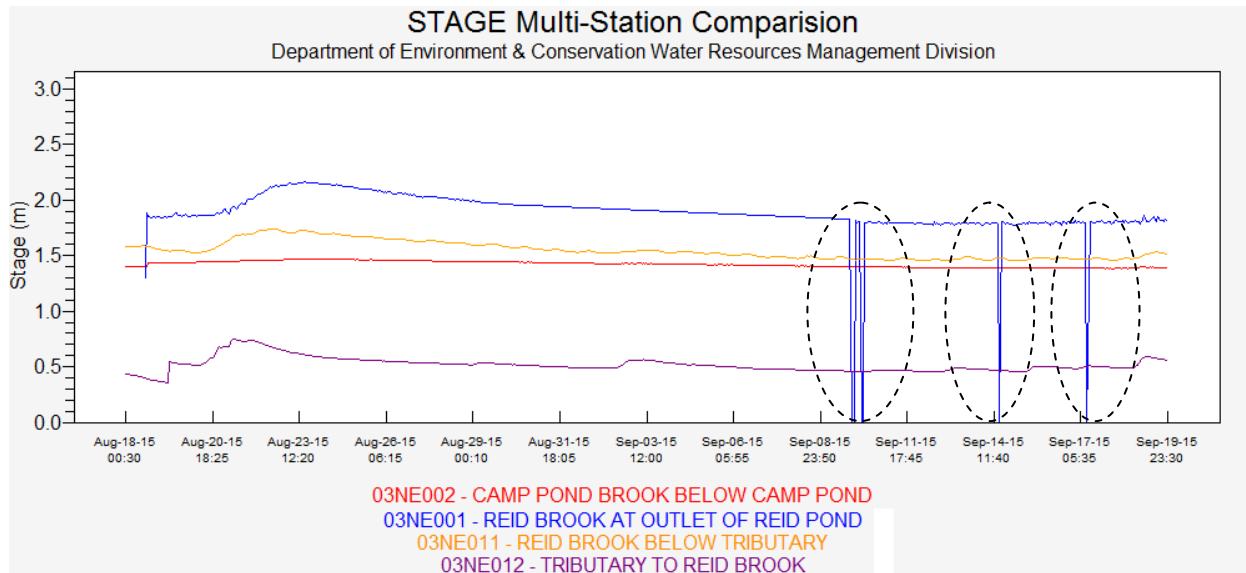


Figure A7: Comparison of Stage (m) at the Real-Time Stations in Voisey's Bay (due to transmission issues Reid Brook real time data does not show up on the graph)

***Transmission errors are circled on the graph**

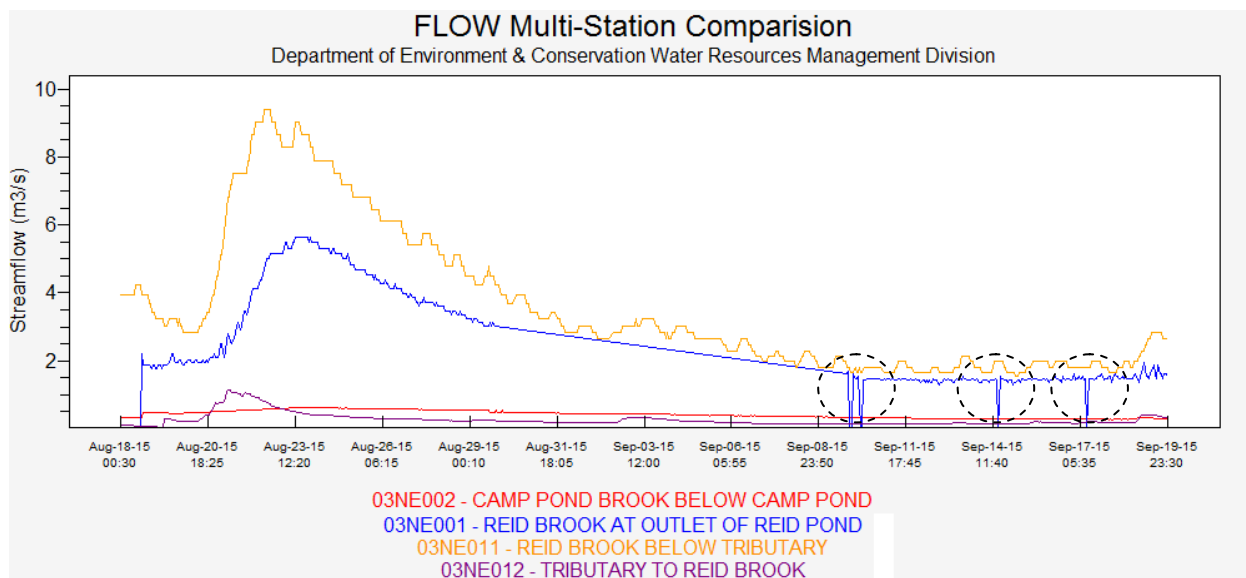


Figure A8: Comparison Flow (m³/s) at the Real-Time Stations in Voisey's Bay

***Transmission errors are circled on the graph**

APPENDIX B: Grab Sample Data

Client: Department of Environment
Attention: Ms. Annette Tobin
Client Project: Happy Valley-Goose Bay
Purchase Order: 214004545

COC Number: 3379
Date Reported: 2015-09-02
Date Submitted: 2015-08-25
Sample Matrix: Water

<u>LAB ID</u>	<u>Supply / Description</u>	<u>Client Sample ID</u>	<u>Sample Date</u>	<u>ANALYTE</u>	<u>UNIT</u>	<u>MRL</u>	<u>RESULT</u>
1197719	WS-S-0000	2015-6408-00-SI-SP	2015-08-19	Alkalinity as CaCO3	mg/L	5	7
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	1
				Colour	TCU	2	6
				Conductivity	uS/cm	5	16
				Dissolved Organic Carbon	mg/L	0.5	1.9
				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	2
				N-NH3 (Ammonia)	mg/L	0.025	0.173
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.93
				Sulphate	mg/L	1	<1
				Total Dissolved Solids (COND - CALC)	mg/L	1	10
				Total Kjeldahl Nitrogen	mg/L	0.07	0.15
				Total Organic Carbon	mg/L	0.5	1.7
				Total Phosphorus	mg/L	0.05	0.05
				Turbidity	NTU	0.1	0.3
				Aluminum	mg/L	0.01	0.06
				Antimony	mg/L	0.0005	<0.0005
				Arsenic	mg/L	0.001	<0.001
				Barium	mg/L	0.01	<0.01
				Boron	mg/L	0.01	<0.01
				Calcium	mg/L	1	1
				Cadmium	mg/L	0.0001	<0.0001
				Chromium	mg/L	0.001	<0.001

Sample comment:

Holding time for NO2 and NO3 analysis was exceeded for entire report. Holding time for turbidity analysis was exceeded.

Report comment:



APPROVAL: _____
 Nadine Pinsonneault

Results relate only to the parameters tested on the samples submitted.
 Methods references and/or additional QA/QC information available on request.

Client: Department of Environment
Attention: Ms. Annette Tobin
Client Project: Happy Valley-Goose Bay
Purchase Order: 214004545

COC Number: 3379
Date Reported: 2015-09-02
Date Submitted: 2015-08-25
Sample Matrix: Water


<u>LAB ID</u>	<u>Supply / Description</u>	<u>Client Sample ID</u>	<u>Sample Date</u>	<u>ANALYTE</u>	<u>UNIT</u>	<u>MRL</u>	<u>RESULT</u>
1197719	WS-S-0000	2015-6408-00-SI-SP	2015-08-19	Copper	mg/L	0.001	<0.001
				Iron	mg/L	0.03	<0.03
				Lead	mg/L	0.001	<0.001
				Magnesium	mg/L	1	<1
				Manganese	mg/L	0.01	<0.01
				Mercury	mg/L	0.0001	<0.0001
				Nickel	mg/L	0.005	<0.005
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	<2
				Strontium	mg/L	0.001	0.006
				Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	<0.01
				Total Suspended Solids	mg/L	1	2

Sample comment:

Holding time for NO2 and NO3 analysis was exceeded for entire report. Holding time for turbidity analysis was exceeded.

Report comment:

Results relate only to the parameters tested on the samples submitted.
 Methods references and/or additional QA/QC information available on request.

APPROVAL: 
 Nadine Pinsonneault



REPORT OF ANALYSIS

Lab Report Number: 1516804

Cient: Department of Environment
Attention: Ms. Annette Tobin
Client Project: Happy Valley-Goose Bay
Purchase Order: 214004545

COC Number: 3379
Date Reported: 2015-09-02
Date Submitted: 2015-08-25
Sample Matrix: Water

<u>LAB ID</u>	<u>Supply / Description</u>	<u>Client Sample ID</u>	<u>Sample Date</u>	<u>ANALYTE</u>	<u>UNIT</u>	<u>MRL</u>	<u>RESULT</u>
1197720	WS-S-0000	2015-6409-00-SI-SP	2015-08-19	Alkalinity as CaCO3	mg/L	5	9
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	2
				Colour	TCU	2	47
				Conductivity	uS/cm	5	31
				Dissolved Organic Carbon	mg/L	0.5	5.9
				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	5
				N-NH3 (Ammonia)	mg/L	0.025	<0.025
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.78
				Sulphate	mg/L	1	2
				Total Dissolved Solids (COND - CALC)	mg/L	1	20
				Total Kjeldahl Nitrogen	mg/L	0.07	0.25
				Total Organic Carbon	mg/L	0.5	5.4
				Total Phosphorus	mg/L	0.05	<0.05
				Turbidity	NTU	0.1	1.2
				Aluminum	mg/L	0.01	0.16
				Antimony	mg/L	0.0005	<0.0005
				Arsenic	mg/L	0.001	<0.001
				Barium	mg/L	0.01	<0.01
				Boron	mg/L	0.01	<0.01
				Calcium	mg/L	1	2
				Cadmium	mg/L	0.0001	<0.0001
				Chromium	mg/L	0.001	<0.001

Sample comment:

Holding time for turbidity analysis was exceeded.

Report comment:

APPROVAL: _____
Nadine Pinsonneault

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

Client: Department of Environment
Attention: Ms. Annette Tobin
Client Project: Happy Valley-Goose Bay
Purchase Order: 214004545


COC Number: 3379
Date Reported: 2015-09-02
Date Submitted: 2015-08-25
Sample Matrix: Water

<u>LAB ID</u>	<u>Supply / Description</u>	<u>Client Sample ID</u>	<u>Sample Date</u>	<u>ANALYTE</u>	<u>UNIT</u>	<u>MRL</u>	<u>RESULT</u>
1197720	WS-S-0000	2015-6409-00-SI-SP	2015-08-19	Copper	mg/L	0.001	0.001
				Iron	mg/L	0.03	0.37
				Lead	mg/L	0.001	<0.001
				Magnesium	mg/L	1	<1
				Manganese	mg/L	0.01	<0.01
				Mercury	mg/L	0.0001	<0.0001
				Nickel	mg/L	0.005	0.006
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	<2
				Strontium	mg/L	0.001	0.016
				Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	<0.01
				Total Suspended Solids	mg/L	1	4

Sample comment:
Holding time for turbidity analysis was exceeded.

Report comment:

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: 
Nadine Pinsonneault

Client: Department of Environment
Attention: Ms. Annette Tobin
Client Project: Happy Valley-Goose Bay
Purchase Order: 214004545

COC Number: 3379
Date Reported: 2015-09-02
Date Submitted: 2015-08-25
Sample Matrix: Water

<u>LAB ID</u>	<u>Supply / Description</u>	<u>Client Sample ID</u>	<u>Sample Date</u>	<u>ANALYTE</u>	<u>UNIT</u>	<u>MRL</u>	<u>RESULT</u>
1197721	WS-S-0000	2015-6410-00-SI-SP	2015-08-19	Alkalinity as CaCO3	mg/L	5	9
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	3
				Colour	TCU	2	37
				Conductivity	uS/cm	5	33
				Dissolved Organic Carbon	mg/L	0.5	4.1
				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	5
				N-NH3 (Ammonia)	mg/L	0.025	0.114
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.83
				Sulphate	mg/L	1	3
				Total Dissolved Solids (COND - CALC)	mg/L	1	21
				Total Kjeldahl Nitrogen	mg/L	0.07	0.26
				Total Organic Carbon	mg/L	0.5	4.5
				Total Phosphorus	mg/L	0.05	<0.05
				Turbidity	NTU	0.1	1.3
				Aluminum	mg/L	0.01	0.12
				Antimony	mg/L	0.0005	<0.0005
				Arsenic	mg/L	0.001	<0.001
				Barium	mg/L	0.01	<0.01
				Boron	mg/L	0.01	<0.01
				Calcium	mg/L	1	2
				Cadmium	mg/L	0.0001	<0.0001
				Chromium	mg/L	0.001	<0.001

Sample comment:

Holding time for turbidity analysis was exceeded.

Report comment:



APPROVAL: _____
 Nadine Pinsonneault

Results relate only to the parameters tested on the samples submitted.
 Methods references and/or additional QA/QC information available on request.

Client: Department of Environment
Attention: Ms. Annette Tobin
Client Project: Happy Valley-Goose Bay
Purchase Order: 214004545


COC Number: 3379
Date Reported: 2015-09-02
Date Submitted: 2015-08-25
Sample Matrix: Water

<u>LAB ID</u>	<u>Supply / Description</u>	<u>Client Sample ID</u>	<u>Sample Date</u>	<u>ANALYTE</u>	<u>UNIT</u>	<u>MRL</u>	<u>RESULT</u>
1197721	WS-S-0000	2015-6410-00-SI-SP	2015-08-19	Copper	mg/L	0.001	0.001
				Iron	mg/L	0.03	0.32
				Lead	mg/L	0.001	<0.001
				Magnesium	mg/L	1	<1
				Manganese	mg/L	0.01	<0.01
				Mercury	mg/L	0.0001	<0.0001
				Nickel	mg/L	0.005	0.006
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	<2
				Strontium	mg/L	0.001	0.017
				Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	<0.01
				Total Suspended Solids	mg/L	1	4

Sample comment:
Holding time for turbidity analysis was exceeded.

Report comment:

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: 
Nadine Pinsonneault



REPORT OF ANALYSIS

Lab Report Number: 1516804

Cient: Department of Environment
Attention: Ms. Annette Tobin
Client Project: Happy Valley-Goose Bay
Purchase Order: 214004545

COC Number: 3379
Date Reported: 2015-09-02
Date Submitted: 2015-08-25
Sample Matrix: Water

<u>LAB ID</u>	<u>Supply / Description</u>	<u>Client Sample ID</u>	<u>Sample Date</u>	<u>ANALYTE</u>	<u>UNIT</u>	<u>MRL</u>	<u>RESULT</u>
1197722	WS-S-0000	2015-6411-00-SI-SP	2015-08-19	Alkalinity as CaCO3	mg/L	5	9
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	3
				Colour	TCU	2	25
				Conductivity	uS/cm	5	35
				Dissolved Organic Carbon	mg/L	0.5	3.2
				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	5
				N-NH3 (Ammonia)	mg/L	0.025	<0.025
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.83
				Sulphate	mg/L	1	4
				Total Dissolved Solids (COND - CALC)	mg/L	1	23
				Total Kjeldahl Nitrogen	mg/L	0.07	0.16
				Total Organic Carbon	mg/L	0.5	3.9
				Total Phosphorus	mg/L	0.05	<0.05
				Turbidity	NTU	0.1	0.6
				Aluminum	mg/L	0.01	0.08
				Antimony	mg/L	0.0005	<0.0005
				Arsenic	mg/L	0.001	<0.001
				Barium	mg/L	0.01	<0.01
				Boron	mg/L	0.01	<0.01
				Calcium	mg/L	1	2
				Cadmium	mg/L	0.0001	<0.0001
				Chromium	mg/L	0.001	<0.001

Sample comment:

Holding time for turbidity analysis was exceeded.

Report comment:

APPROVAL: _____
Nadine Pinsonneault

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

Client: Department of Environment
Attention: Ms. Annette Tobin
Client Project: Happy Valley-Goose Bay
Purchase Order: 214004545


COC Number: 3379
Date Reported: 2015-09-02
Date Submitted: 2015-08-25
Sample Matrix: Water

<u>LAB ID</u>	<u>Supply / Description</u>	<u>Client Sample ID</u>	<u>Sample Date</u>	<u>ANALYTE</u>	<u>UNIT</u>	<u>MRL</u>	<u>RESULT</u>
1197722	WS-S-0000	2015-6411-00-SI-SP	2015-08-19	Copper	mg/L	0.001	0.003
				Iron	mg/L	0.03	0.19
				Lead	mg/L	0.001	<0.001
				Magnesium	mg/L	1	<1
				Manganese	mg/L	0.01	0.01
				Mercury	mg/L	0.0001	<0.0001
				Nickel	mg/L	0.005	0.023
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	<2
				Strontium	mg/L	0.001	0.018
				Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	<0.01
				Total Suspended Solids	mg/L	1	4

Sample comment:
Holding time for turbidity analysis was exceeded.

Report comment:

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: 
Nadine Pinsonneault

APPENDIX C: Quality Assurance / Quality Control Procedures

- As part of the Quality Assurance / Quality Control (QA/QC) protocol, the performance of a station's water quality instrument (i.e., Field Sonde) is rated at the beginning and end of its deployment period. The procedure is based on the approach used by the United States Geological Survey (Wagner *et al.* 2006)¹.
- At the beginning of the deployment period, a newly calibrated QA/QC water quality instrument (i.e., QA/QC Sonde) is temporarily deployed *in-situ* and along side the newly calibrated Field Sonde. A grab sample is also taken from the water body at this time and sent away to a laboratory for analysis. Field Sonde performance ratings for *temperature* (°C) and *Dissolved Oxygen* (% saturation) are based on differences recorded by the Field Sonde and QA/QC Sonde. Field Sonde performance ratings for *specific conductivity* (µS/cm), *pH* (unit) and *turbidity* (NTU) are based on differences between Field Sonde readings and grab sample results.
- At the end of the deployment period, water quality parameters are recorded by the Field Sonde before and after a thorough cleaning of its probes. Error caused by *bio-fouling* (E_f) is assessed by comparing these readings with readings made by a newly calibrated QA/QC Sonde, which is temporarily deployed *in-situ* and along side the Field Sonde. An assessment of *instrument drift error* (E_d) is made during laboratory calibration of the Field Sonde, and the two error values are added to give an estimate of total error ($E_t = E_f + E_d$). If E_t exceeds a predetermined data correction criterion, a correction factor is applied to the dataset based on linear interpolation of E_t . The Field Sonde performance is also rated at the end of the deployment period, based on the E_t value.
- Performance ratings are based on differences listed in the table below.

Parameter	Rating				
	Excellent	Good	Fair	Marginal	Poor
Temperature (°C)	≤ ±0.2	> ±0.2 to 0.5	> ±0.5 to 0.8	> ±0.8 to 1	> ±1
pH (unit)	≤ ±0.2	> ±0.2 to 0.5	> ±0.5 to 0.8	> ±0.8 to 1	> ±1
Sp. Conductance (µS/cm)	≤ ±3	> ±3 to 10	> ±10 to 15	> ±15 to 20	> ±20
Sp. Conductance > 35 µS/cm (%)	≤ ±3	> ±3 to 10	> ±10 to 15	> ±15 to 20	> ±20
Dissolved Oxygen (mg/l) (% Sat)	≤ ±0.3	> ±0.3 to 0.5	> ±0.5 to 0.8	> ±0.8 to 1	> ±1
Turbidity <40 NTU (NTU)	≤ ±2	> ±2 to 5	> ±5 to 8	> ±8 to 10	> ±10
Turbidity > 40 NTU (%)	≤ ±5	> ±5 to 10	> ±10 to 15	> ±15 to 20	> ±20

■ _____

¹ Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments; accessed April 10, 2006, at <http://pubs.water.usgs.gov/tm1d3>

APPENDIX D: Water Parameter Description

- **Dissolved Oxygen** - The amount of Dissolved Oxygen (DO) (mg/l or % saturation) in the water is vital to aquatic organisms for their survival. The concentration of DO is affected by such things as water temperature, water depth and flow (e.g., aeration by rapids, riffles etc.), consumption by aerobic organisms, consumption by inorganic chemical reactions, consumption by plants during darkness, and production by plants during the daylight (Allan 2010).
 - **Flow** – Flow (m³/s) is a measure of how quickly a volume of water is displaced in streams, rivers, and other channels.
 - **pH** - pH is the measure of hydrogen ion activity and affects: (i) the availability of nutrients to aquatic life; (ii) the concentration of biochemical substances dissolved in water; (iii) the efficiency of hemoglobin in the blood of vertebrates; and (iv) the toxicity of pollutants. Changes in pH can be attributed to industrial effluence, saline inflows or aquatic organisms involved in the photosynthetic cycling of CO₂ (Allan 2010).
 - **Specific conductivity** - Specific conductivity (µS/cm) is a measure of water's ability to conduct electricity, with values normalized to a water temperature of 25°C. Specific conductance indicates the concentration of dissolved solids (such as salts) in the water, which can affect the growth and reproduction of aquatic life. Specific conductivity is affected by rainfall events, the composition of inflowing tributaries and their associated geology, saline inflow (e.g., road salt), agricultural run-off and industrial inputs (Allan 2010; Swanson and Baldwin 1965).
 - **Stage** – Stage (m) is the elevation of the water surface and is often used as a surrogate for the more difficult to measure flow.
 - **Temperature** - Essential to the measurement of most water quality parameters, temperature (°C) controls most processes and dynamics of limnology. Water temperature is influenced by such things as ambient air temperature, solar radiation, meteorological events, industrial effluence, wastewater, inflowing tributaries, as well as water body size and depth (Allan 2010; Hach 2006).
 - **Total Dissolved Solids** - Total Dissolved Solids (TDS) (g/l) is a measure of alkaline salts dissolved in water or in fine suspension and can affect the growth and reproduction of aquatic life. It is affected by rainfall events, the composition of inflowing tributaries and their associated geology, saline inflow (e.g., road salt), agricultural run-off and industrial inputs (Allan 2010; Swanson and Baldwin 1965).
- Turbidity** - Turbidity (NTU) is a measure of the translucence of water and indicates the amount of suspended material in the water. Turbidity is caused by any substance that makes water cloudy (e.g., soil erosion, micro-organisms, vegetation, chemicals, etc.) and can correspond to precipitation events, high stage, and floating debris near the sensor (Allan 2010; Hach 2006; Swanson and Baldwin 1965)

References

- Canadian Council of Ministers of the Environment. 2007. Canadian water quality guidelines for the protection of aquatic life: Summary table. Updated December, 2007. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.
 - Online: <http://st-ts.ccme.ca/en/index.html?chems=154,162&chapters=1>
- Swanson, H.A., and Baldwin, H.L., 1965. A Primer on Water Quality, U.S. Geological Survey.
 - Online: <http://ga.water.usgs.gov/edu/characteristics.html>