Real-Time Water Quality Deployment Report

Voisey's Bay Network

September 21 to October 23, 2015

Newfoundland Labrador

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

Contents

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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 September 21st, 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 32 days. Instruments were removed by Vale Environment Staff on October 23rd, 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

	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 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 (62884)	September 21, 2015	Deployment	Excellent	Fair	Excellent	Excellent	Excellent
	October 23, 2015	Removal	Excellent	Poor	Excellent	N/A	N/A
Camp Pond Brook (62885)	September 21, 2015	Deployment	Excellent	Excellent	Good	Poor	Excellent
	October 23, 2015	Removal	Excellent	Fair	Good	N/A	N/A
Tributary to Lower Reid Brook (62886)	September 21, 2015	Deployment	Excellent	Poor	Excellent	Poor	Excellent
	October 23, 2015	Removal	Excellent	Fair	Good	N/A	N/A
Lower Reid Brook (62887)	September 21, 2015	Deployment	Excellent	Good	Good	N/A	Excellent
	October 23, 2015	Removal	Good	Good	Excellent	N/A	N/A

During the deployment for Reid Brook at Outlet of Reid Pond, temperature, conductivity, dissolved oxygen, and turbidity all rank as 'excellent'. The pH data recorded during this deployment was removed due to inaccurate data collection and QA/QC rankings of 'fair' and 'poor' upon removal. Upon removal, temperature and conductivity ranked as 'excellent'. Due to insufficient battery supply to the QA/QC sonde the dissolved oxygen sensor and turbidity senor could not be powered at the same time and no readings for these parameters could be recorded.

At the station on Camp Pond Brook, temperature, pH, conductivity, and turbidity all ranked as 'good' or 'excellent'. Dissolved oxygen ranked as 'poor'. The dissolved oxygen sensor failed during the deployment period and no data was recorded. Upon removal, temperature, and conductivity ranked as 'good' or 'excellent'. pH ranked as 'fair'. This discrepancy in readings could be attributed to a difference in sonde location or the QA/QC sonde not having time to acclimatize to the environment. Upon removal and during maintenance testing it was discovered that both the DO and turbidity sensors needed replacing.

At Tributary to Lower Reid Brook station, temperature, conductivity and turbidity all ranked as 'excellent'. pH ranked as 'poor'. Upon removal and during maintenance testing it was discovered that the pH sensor needed replacing. Dissolved oxygen ranked as 'poor'. No dissolved oxygen data was recorded during this deployment period due to sensor failure. Upon removal, temperature, and conductivity ranked as 'good' or 'excellent'. Due to insufficient battery supply to the QA/QC sonde the dissolved oxygen sensor and turbidity senor could not be powered at the same time and no readings for these parameters could be recorded.

At Lower Reid Brook, the temperature, pH, conductivity, and turbidity all ranked as 'good' or 'excellent'. A dissolved oxygen ranking could not be determined due to insufficient battery supply to the QA/QC sonde. Upon removal, temperature, pH, and conductivity all ranked as 'good' or 'excellent'. Upon removal, a

dissolved oxygen and turbidity ranking could not be determined due to insufficient battery supply to the QA/WC sonde.

Data Interpretation

- The following graphs and discussion illustrate significant water quality-related events from September 21st to October 23rd, 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. For portions of the deployment period water quality data was taken from the log file of the instrument which records as a backup in case of communication and transmission issues. Total dissolved solids is a calculated parameter which was not recorded to an accurate decimal place on the internal log file therefore some data was taken from the ADRS system when transmissions occurred. pH recorded during this deployment was not accurate due to sensor failure.
- Camp Pond Brook station had a failure of its dissolved oxygen and no data was recorded during the deployment period.
- Tributary to Lower Reid Book sonde had a dissolved oxygen sensor failure and therefore no accurate DO data was recorded for the deployment period. Transmission errors for water quantity parameters (stage and flow) occurred at this station during this deployment period.

Figure 1: Voisey's Bay Network Station Locations

Reid Brook at Outlet of Reid Pond

Water Temperature

- Water temperature ranges from 4.31 °C to 10.18 °C, with a median value of 7.31 °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.

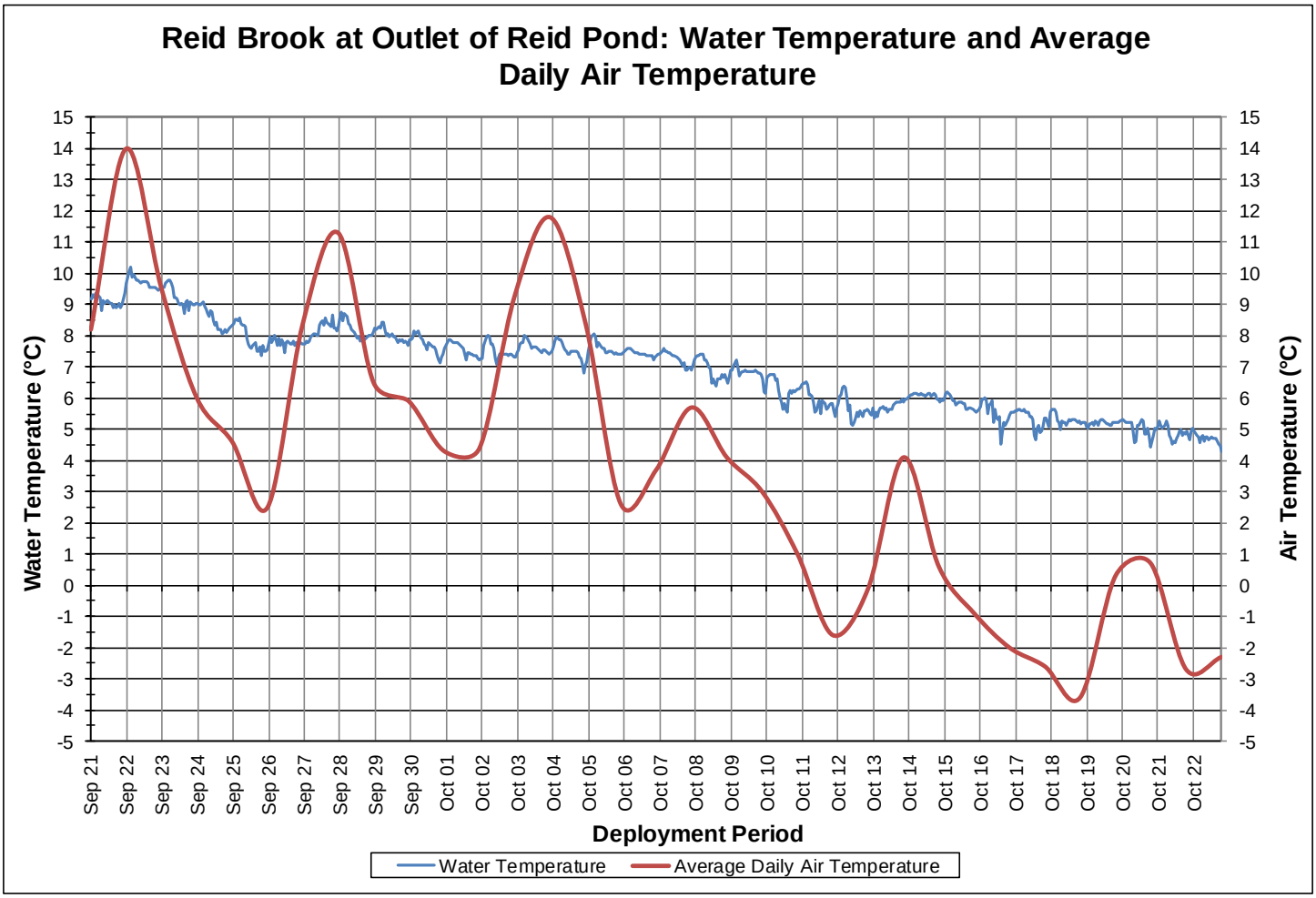

Figure 2: Water Temperature & Average Daily Air Temperature at Reid Brook at Outlet of Reid Pond

pH Levels

- pH recorded during this deployment was not accurate due to sensor failure (Table 2).

Specific Conductivity

- Specific conductance ranges between 11.7µS/cm to 14.0µS/cm, with a median value of 12.0µS/cm (Figure 3).
- 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.

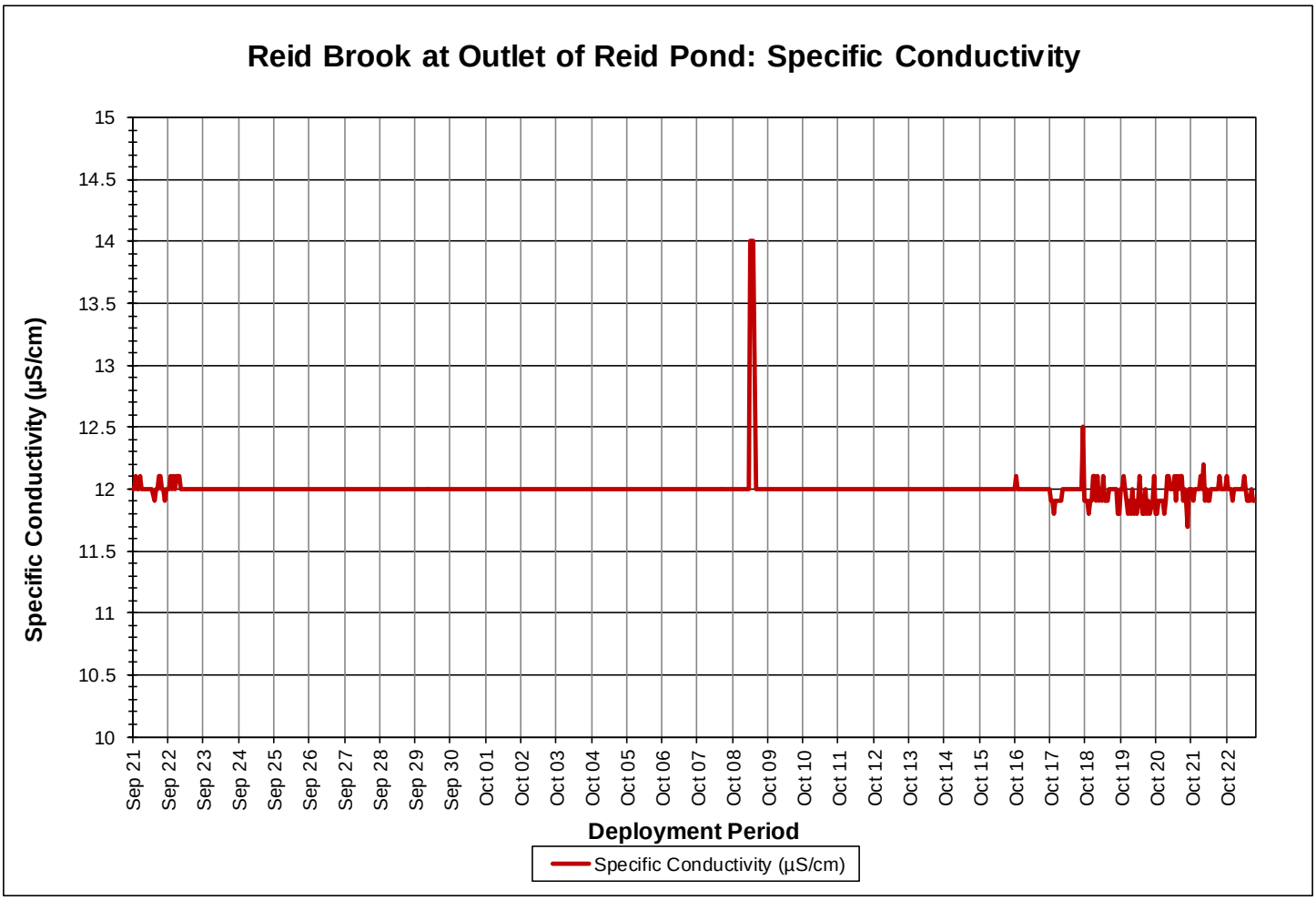

Figure 3: Specific Conductivity at Reid Brook at Outlet of Reid Pond

Dissolved Oxygen (mg/L & % Saturation)

- Dissolved oxygen content ranges between 11.14mg/l and 12.36mg/l during the deployment period. The saturation of dissolved oxygen ranges from 92.6% to 99.7% (Figure 4).
- 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 4).

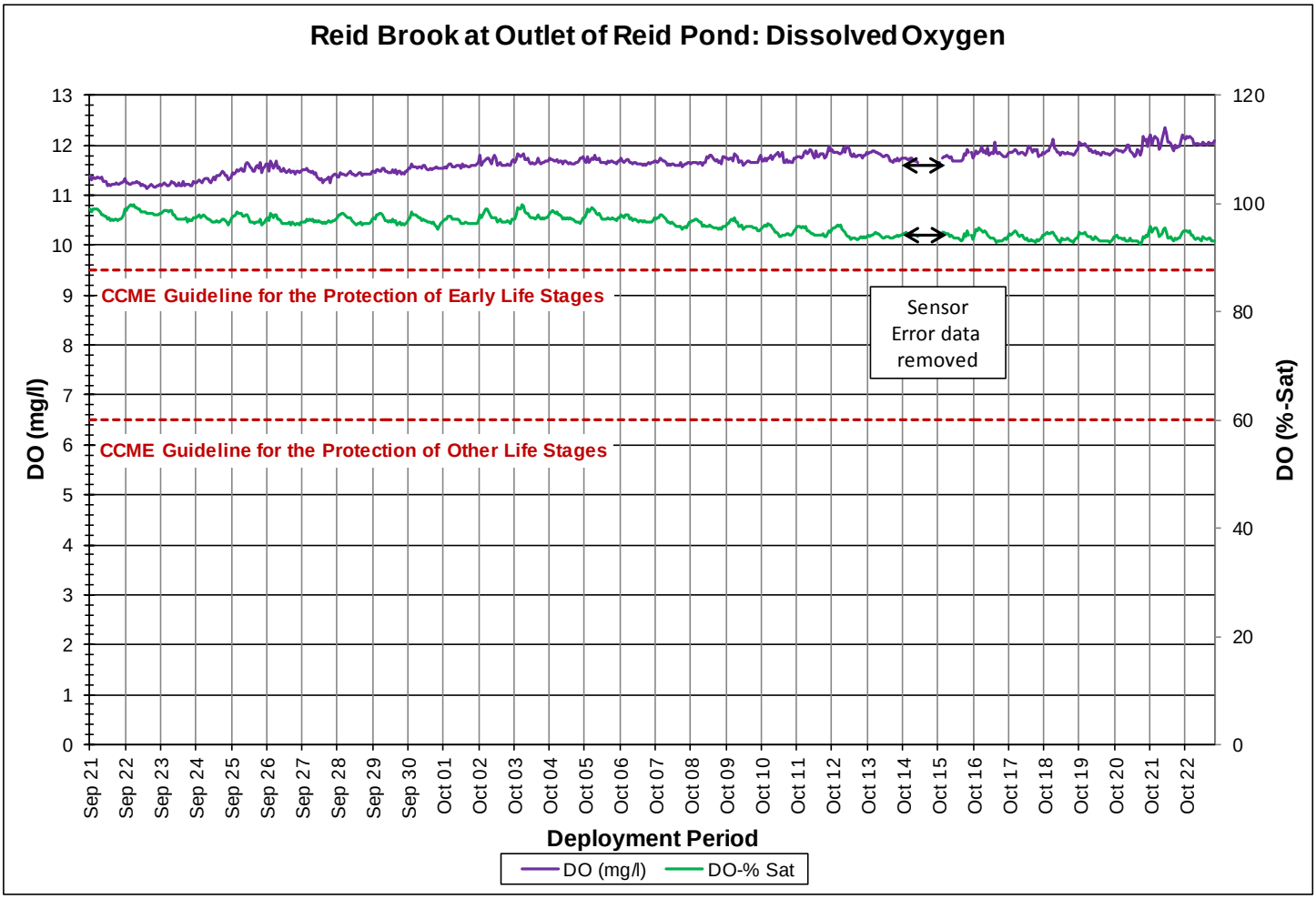

Figure 4: Dissolved Oxygen at Reid Brook at Outlet of Reid Pond

Turbidity

- Turbidity ranges from 0.0NTU to 1.2NTU, with a median value of 0.0NTU (Figure 5).
- 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.

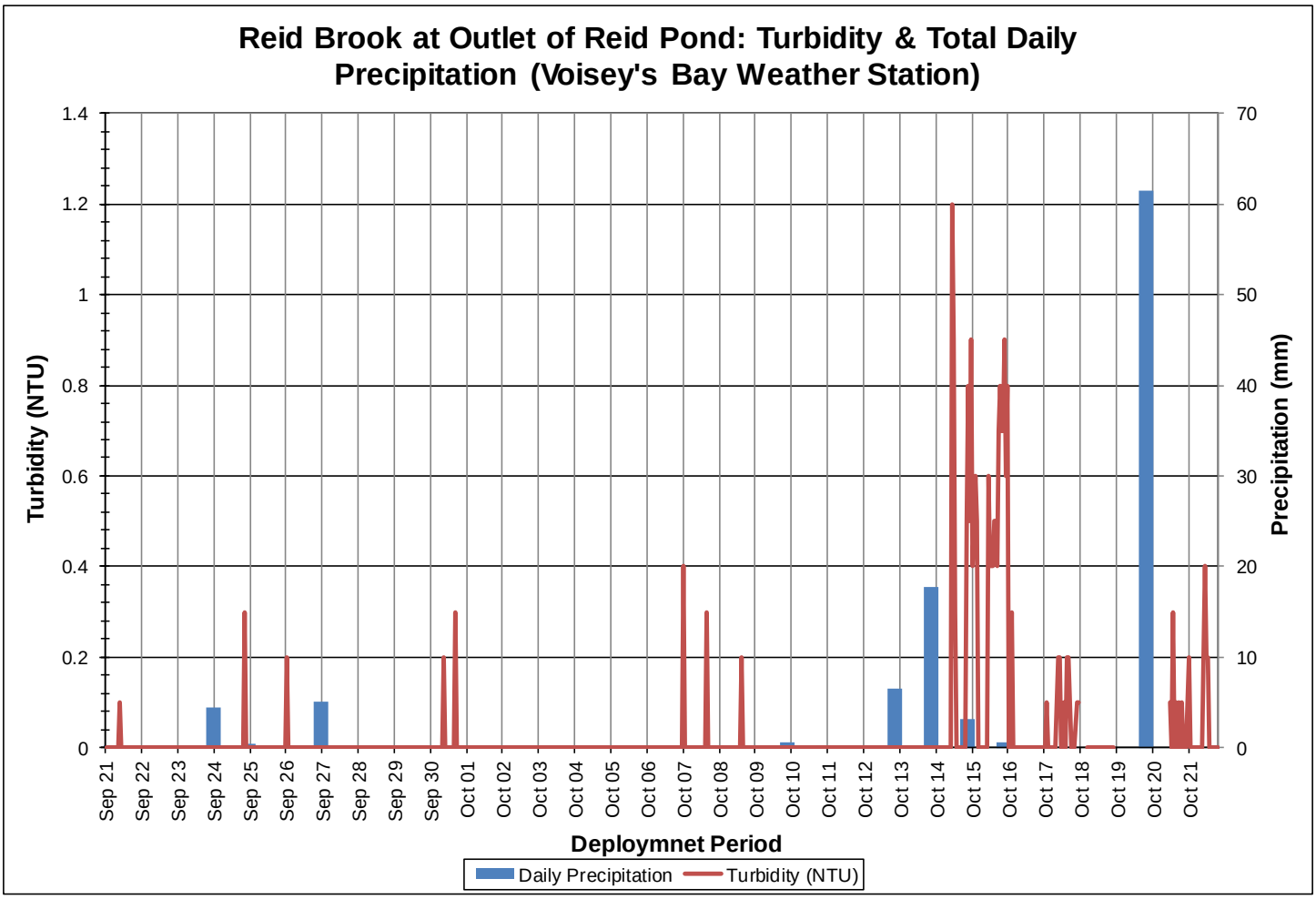

Figure 5: Turbidity and Total Daily Precipitation (Voisey's Bay Weather Station) at Reid Brook at Outlet of Reid Pond

Stage, Flow & Precipitation

- Due to transmission errors stage and flow data was not recorded for the majority of the deployment period.
- 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 13 days during the deployment period and amounts are small in magnitude, with exception of the largest on October 20th with 61.5mm of rain.

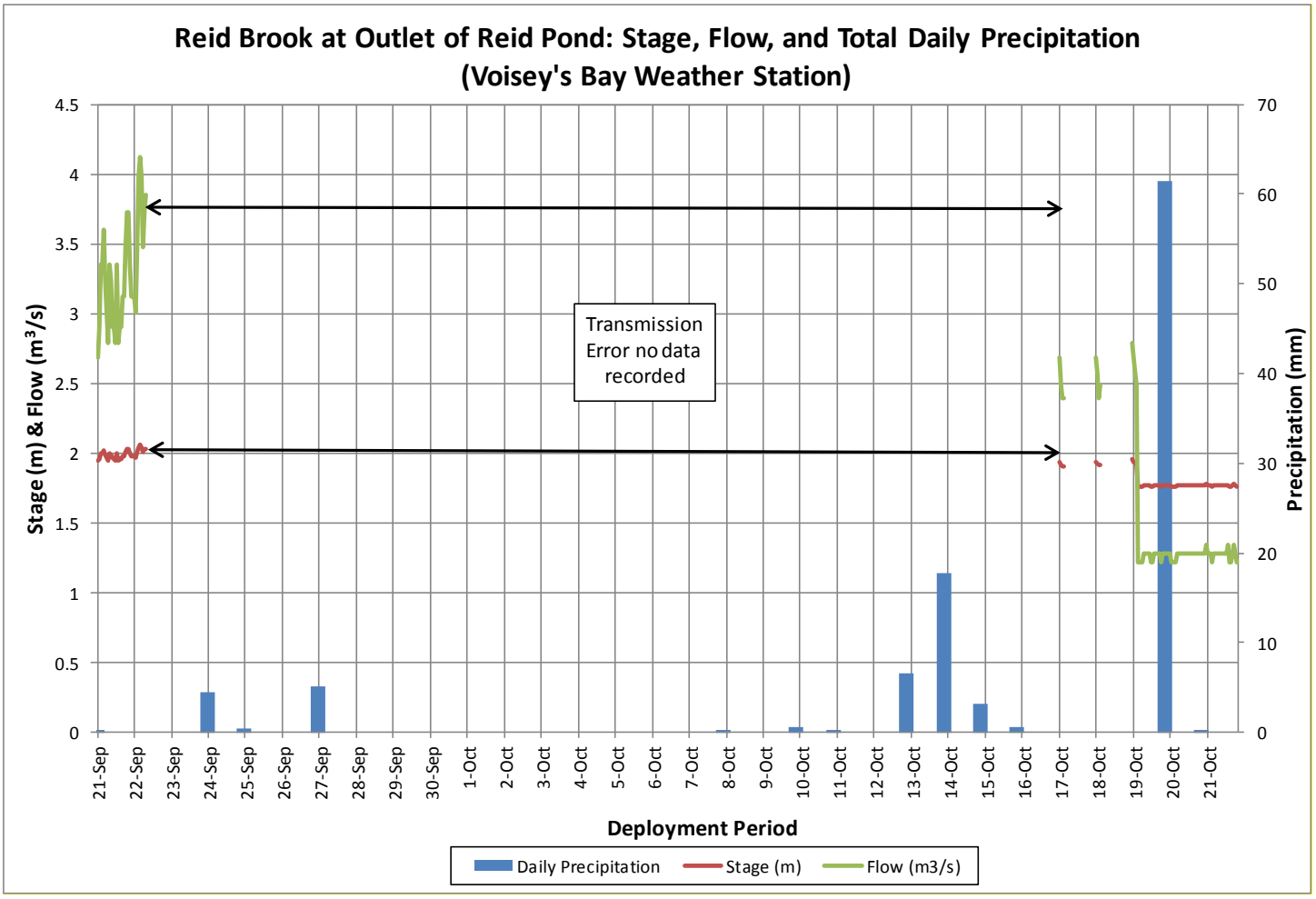

Figure 6: Stage, Flow & Total Daily Precipitation (Voisey's Bay Weather Station) at Reid Brook at Outlet of Reid Pond

Camp Pond Brook

Water Temperature

- Water temperature ranges from 0.38 °C to 12.65 °C, with a median value of 5.56°C (Figure 7).
- 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.

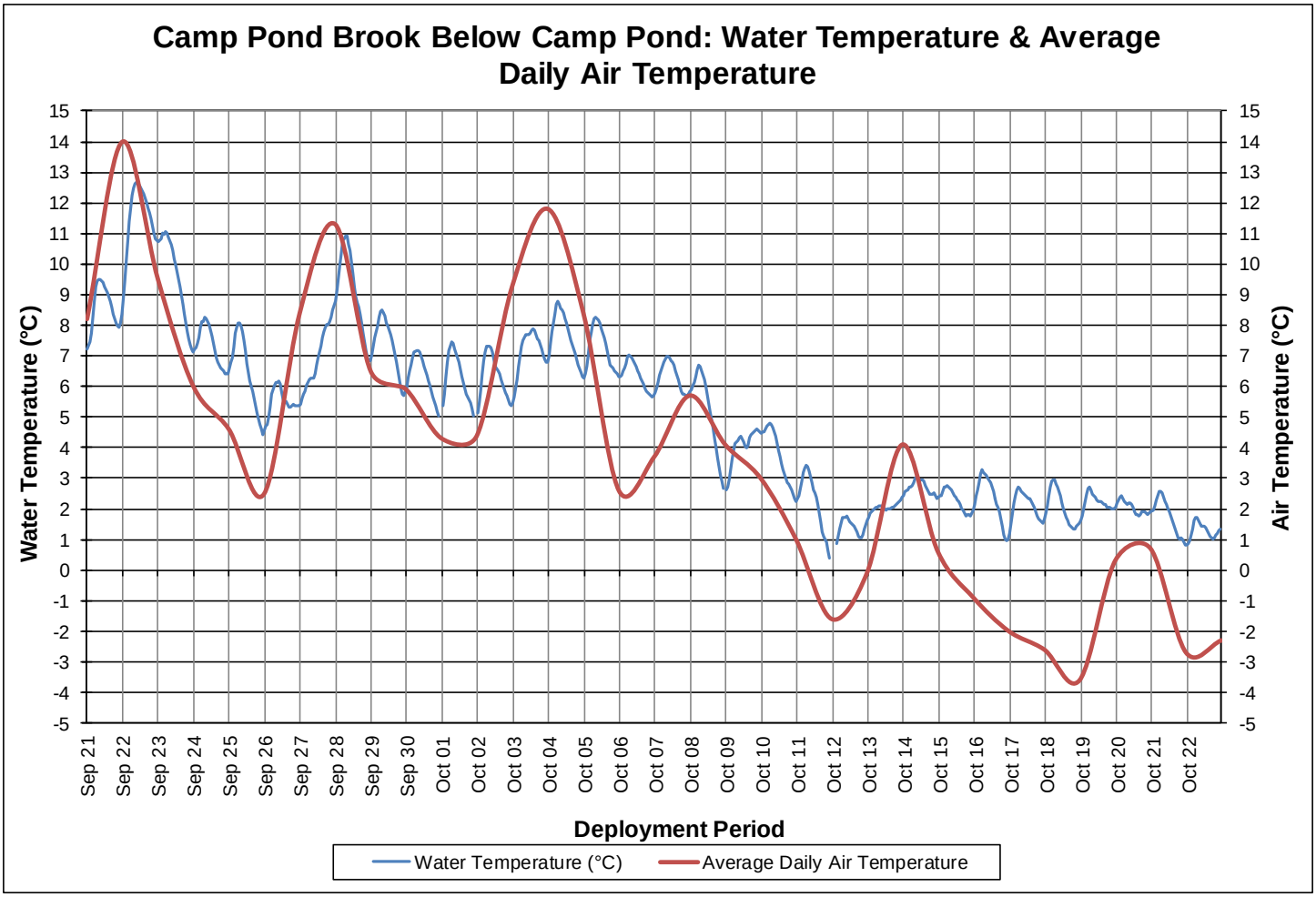

Figure 7: Water Temperature & Daily Average Air Temperature at Camp Pond Brook below Camp Pond

pH

- pH ranges from 6.83 to 7.33 pH units, with a median value of 7.21 (Figure 8).
- 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.

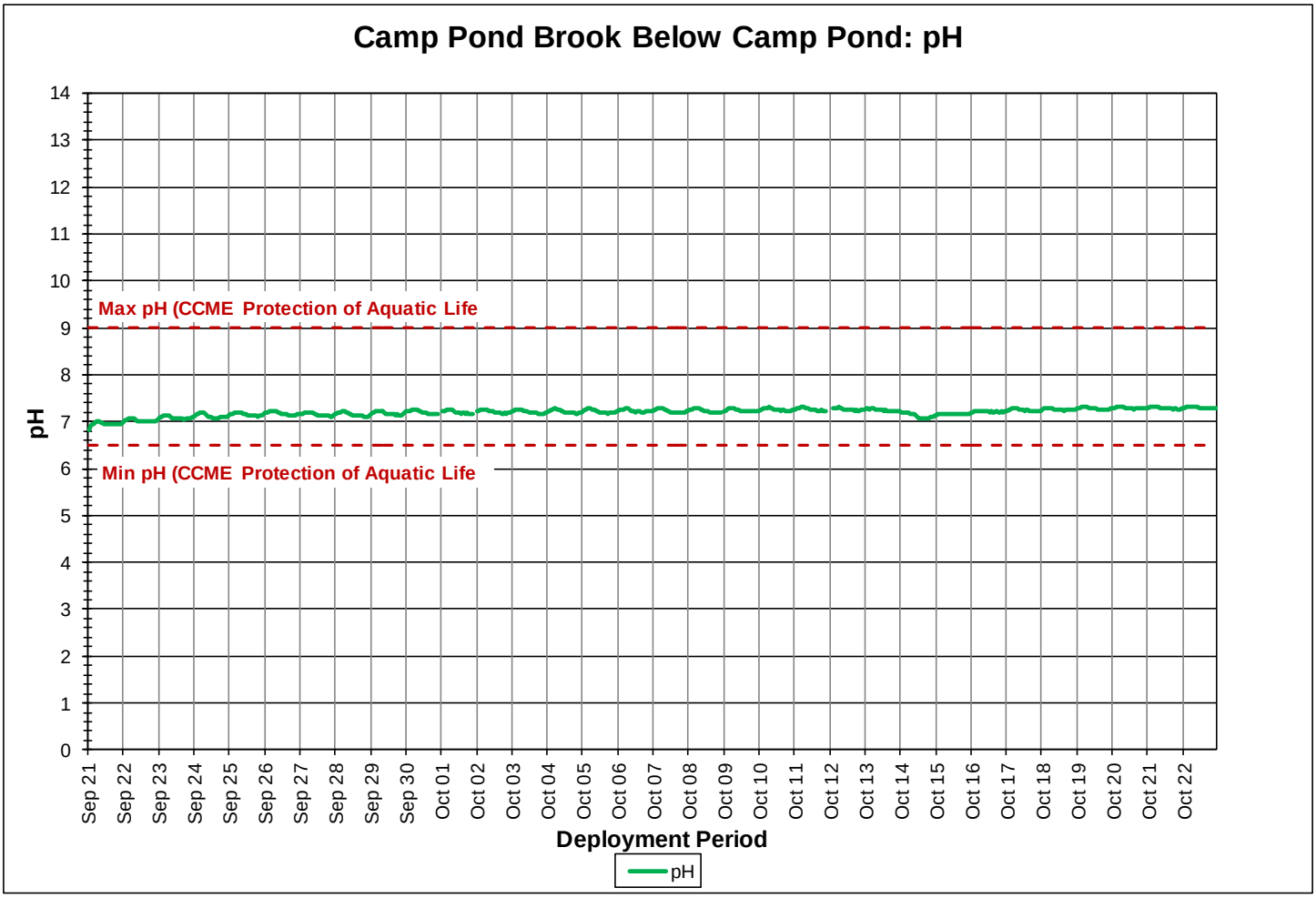

Figure 8: pH at Camp Pond Brook below Camp Pond

Specific Conductivity

- Specific conductivity ranges from 33.8µS/cm to 53.6µS/cm with a median of 36.0µS/cm. (Figure 9).
- Total Dissolved Solids (TDS) ranges between 0.216 g/mL to 0.0343 g/mL during the deployment period, with a median of 0.0231 g/mL (Figure 9).
- 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 10).
- 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 9). 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.

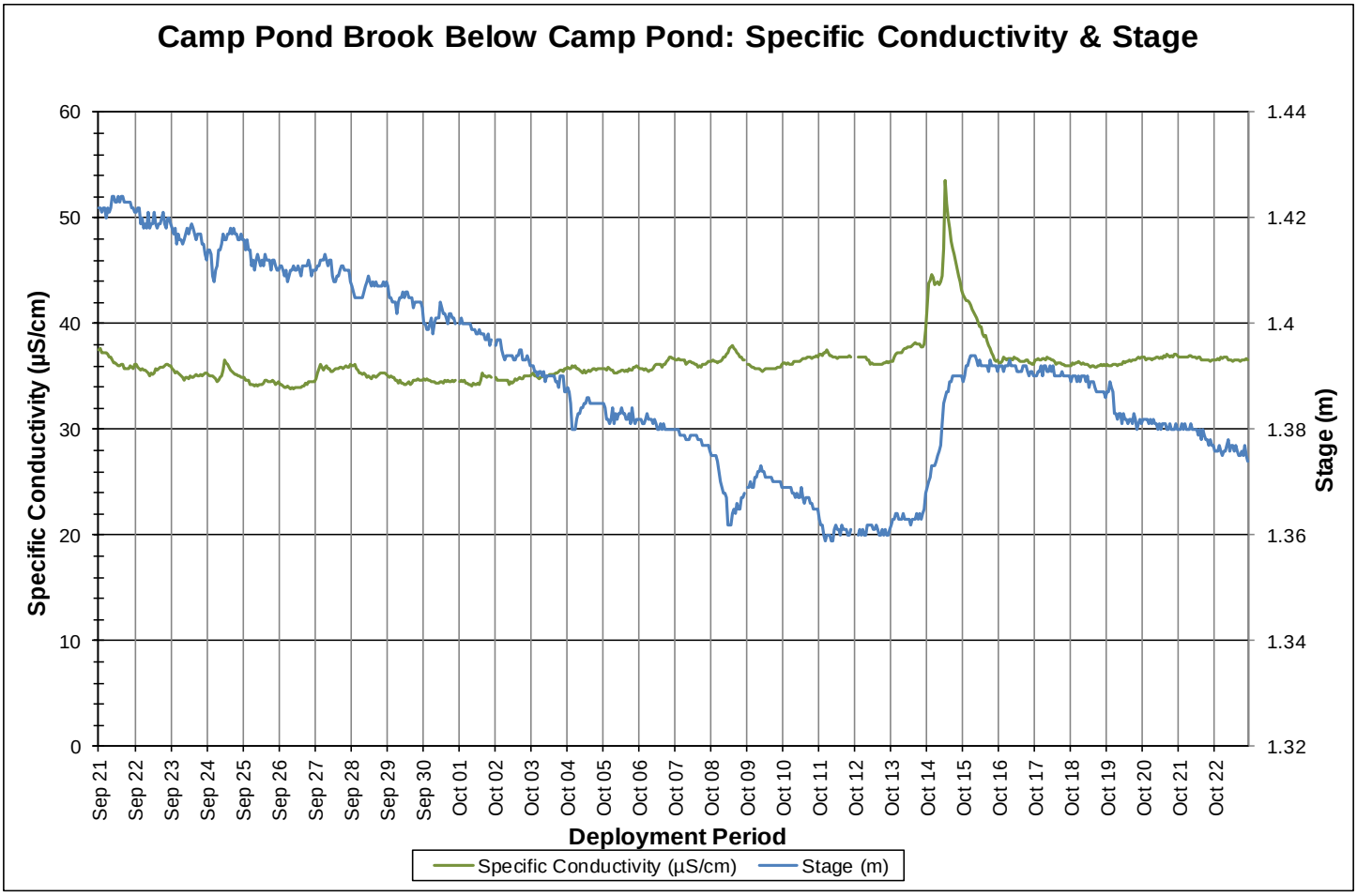

Figure 9: Specific Conductivity & Stage at Camp Pond Brook below Camp Pond

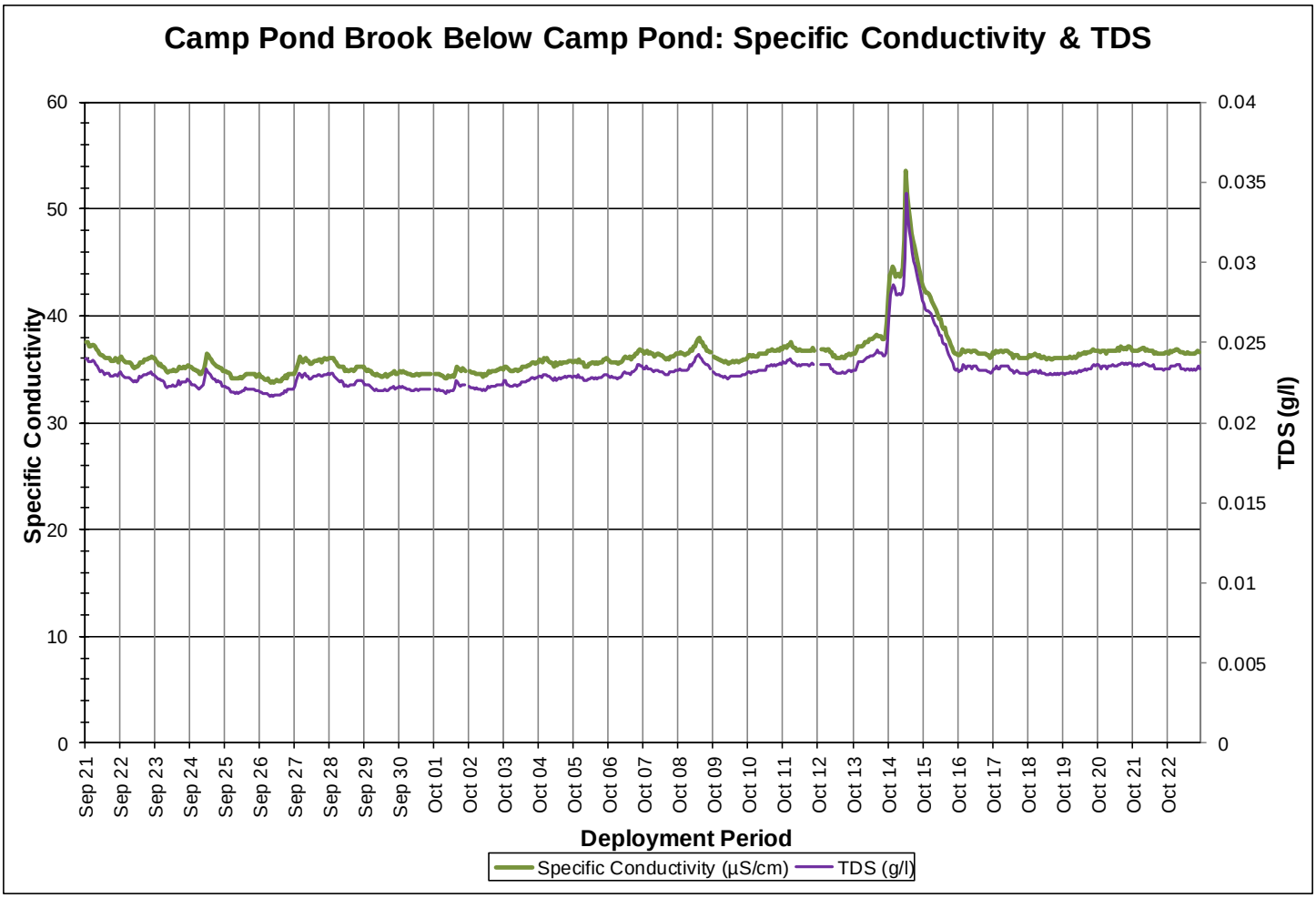

Figure 10: Specific Conductivity & TDS at Camp Pond Brook below Camp Pond

Dissolved Oxygen (mg/L & % Saturation)

- The dissolved oxygen sensor failed and no data was recorded during the deployment period.

Turbidity

- Turbidity ranges from 0.0NTU to 13.4NTU during the deployment period, with a median value of 0.0NTU (Figure 11).
- 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 11, 12).
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

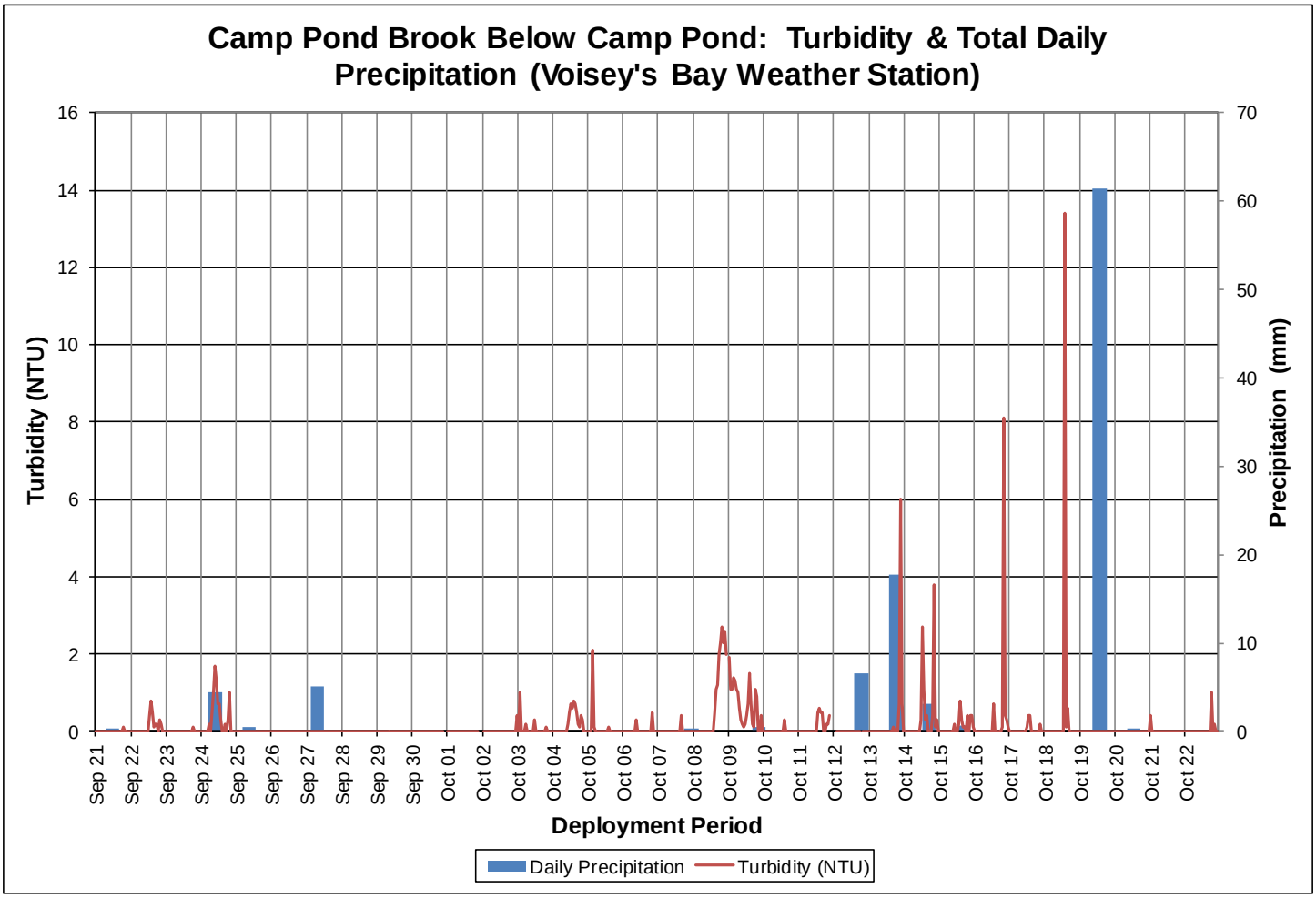

Figure 11: Turbidity & Total Daily Precipitation (Voisey's Bay Weather Station) at Camp Pond Brook below Camp Pond

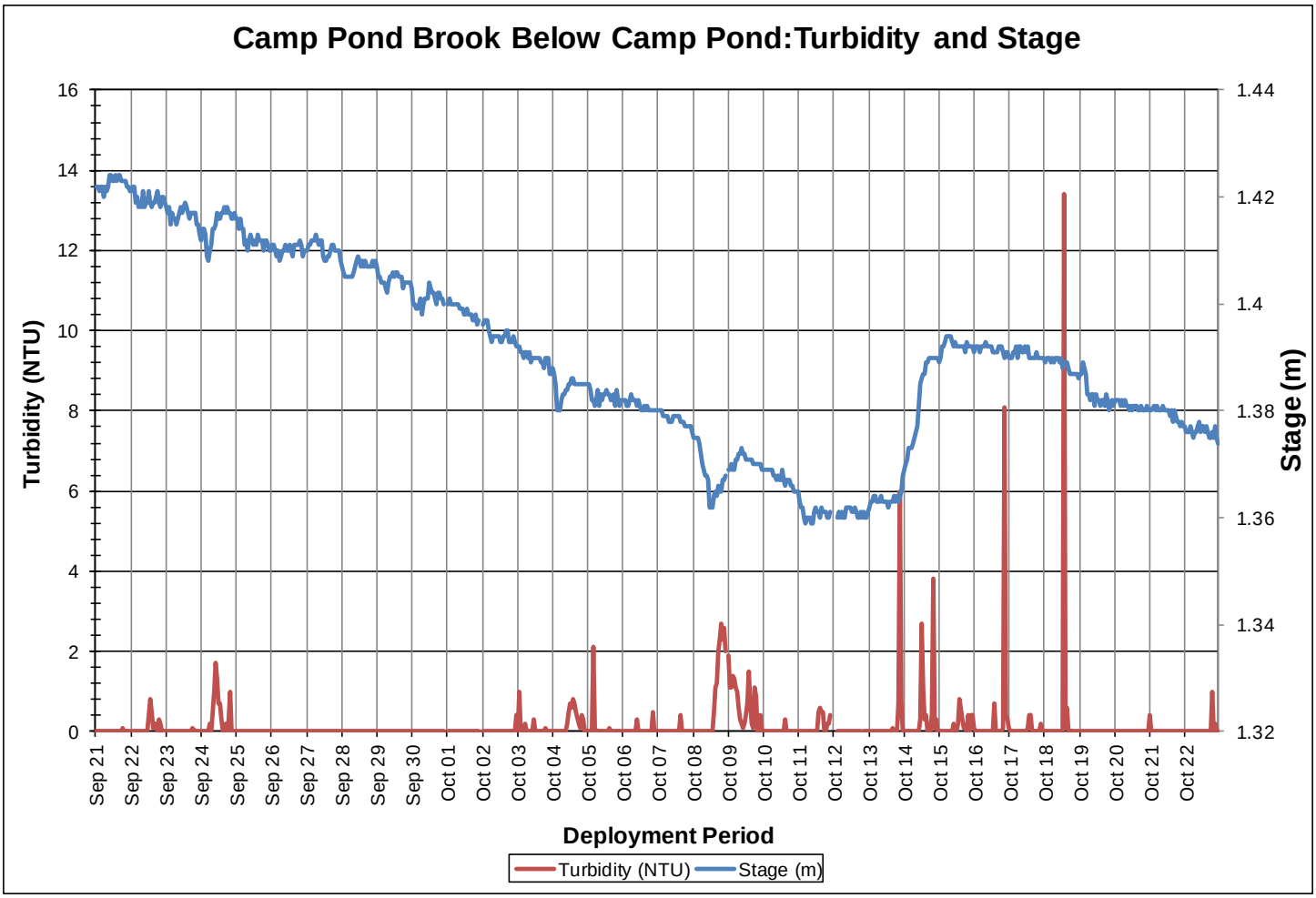

Figure 12: Turbidity & Stage at Camp Pond Brook below Camp Pond

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 13). Precipitation occurs on 13 days during the deployment period and amounts are small in magnitude, with exception of the largest on October 20th with 61.5mm of rain.
- During the deployment period, the stage values ranged from 1.36m to 1.42m. Streamflow had a minimum amount of 0.20m^3/s and a maximum flow of 0.40m^3/s.
- Stage, streamflow and precipitation are graphed below to show the relationship between rainfall and water level (Figure 13).

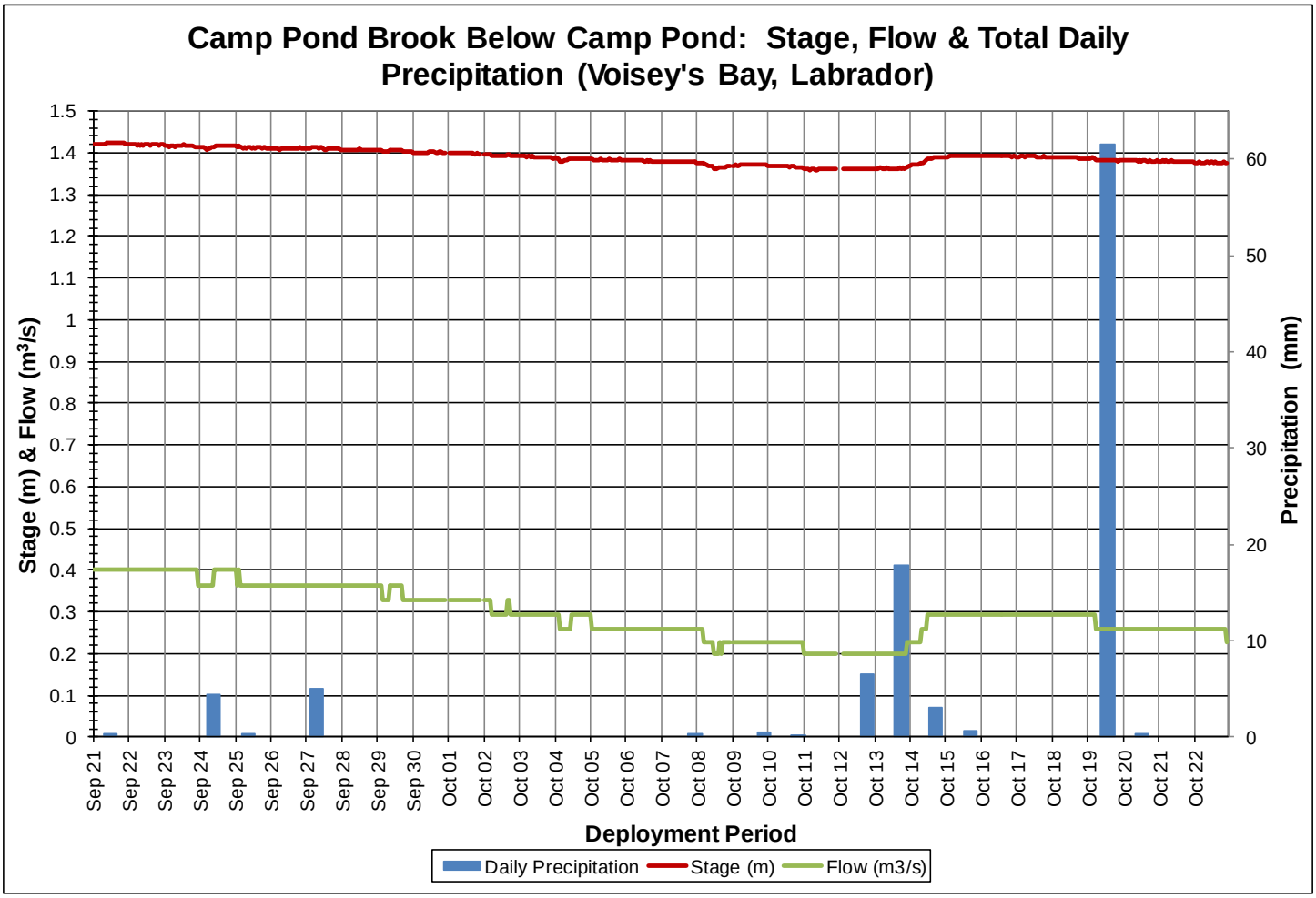

Figure 13: Stage, Flow, & Total Daily Precipitation (Voisey's Bay Weather Station) at Camp Pond Brook below Camp Pond

Tributary to Lower Reid Brook

Water Temperature

- Water temperature ranges from 0.00 °C to 10.00 °C, with a median value of 4.10°C (Figure 14).
- 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.

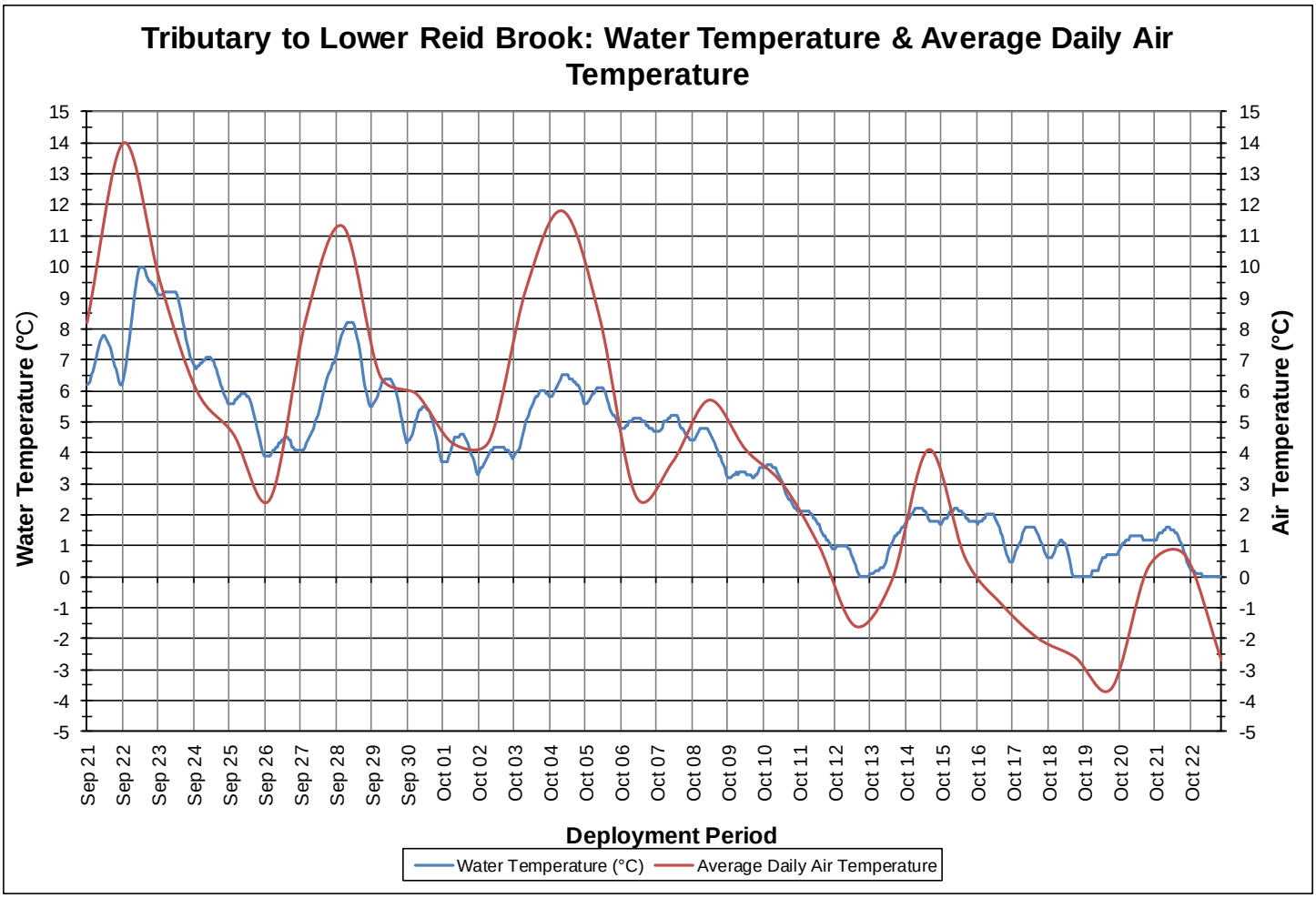

Figure 14: Water Temperature & Average Daily Air Temperature at Tributary to Lower Reid Brook

pH

- pH ranges from 5.74 to 6.79 pH units, with a median value of 6.67 (Figure 15).
- pH dips below CCME guidelines as increases in stage occur 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.

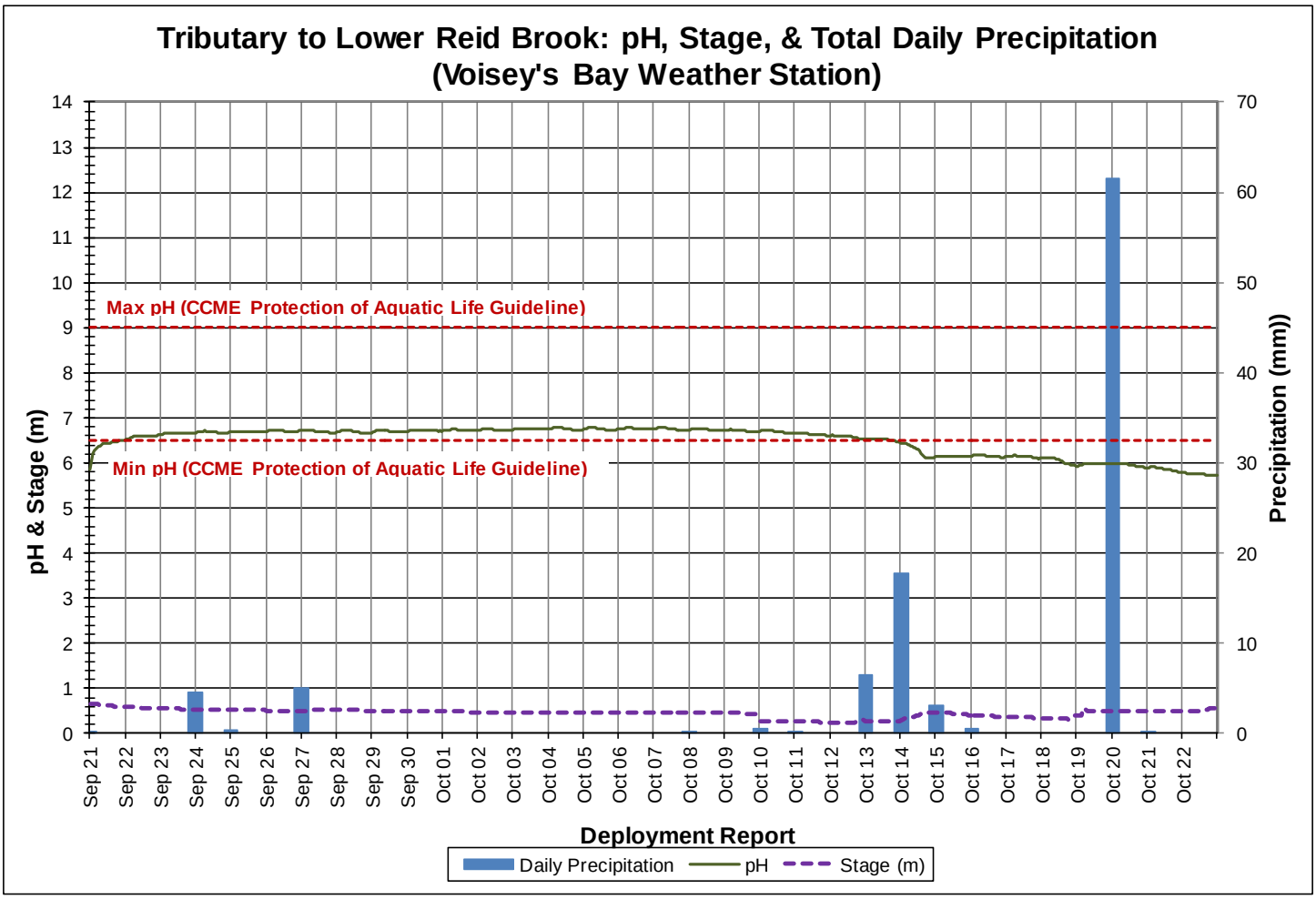

Figure 15: pH, Stage, and Total Daily Precipitation (Voisey's Bay Weather Station) at Tributary to Lower Reid Brook

Specific Conductivity

- Specific conductivity ranges from 27.8µS/cm to 41.4µS/cm with a median of 35.0µS/cm. (Figure 16).
- TDS ranges between 0.0178g/mL to 0.0265g/mL during the deployment period, with a median of 0.0224g/mL (Figure 16).
- 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 17).
- 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 16).
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

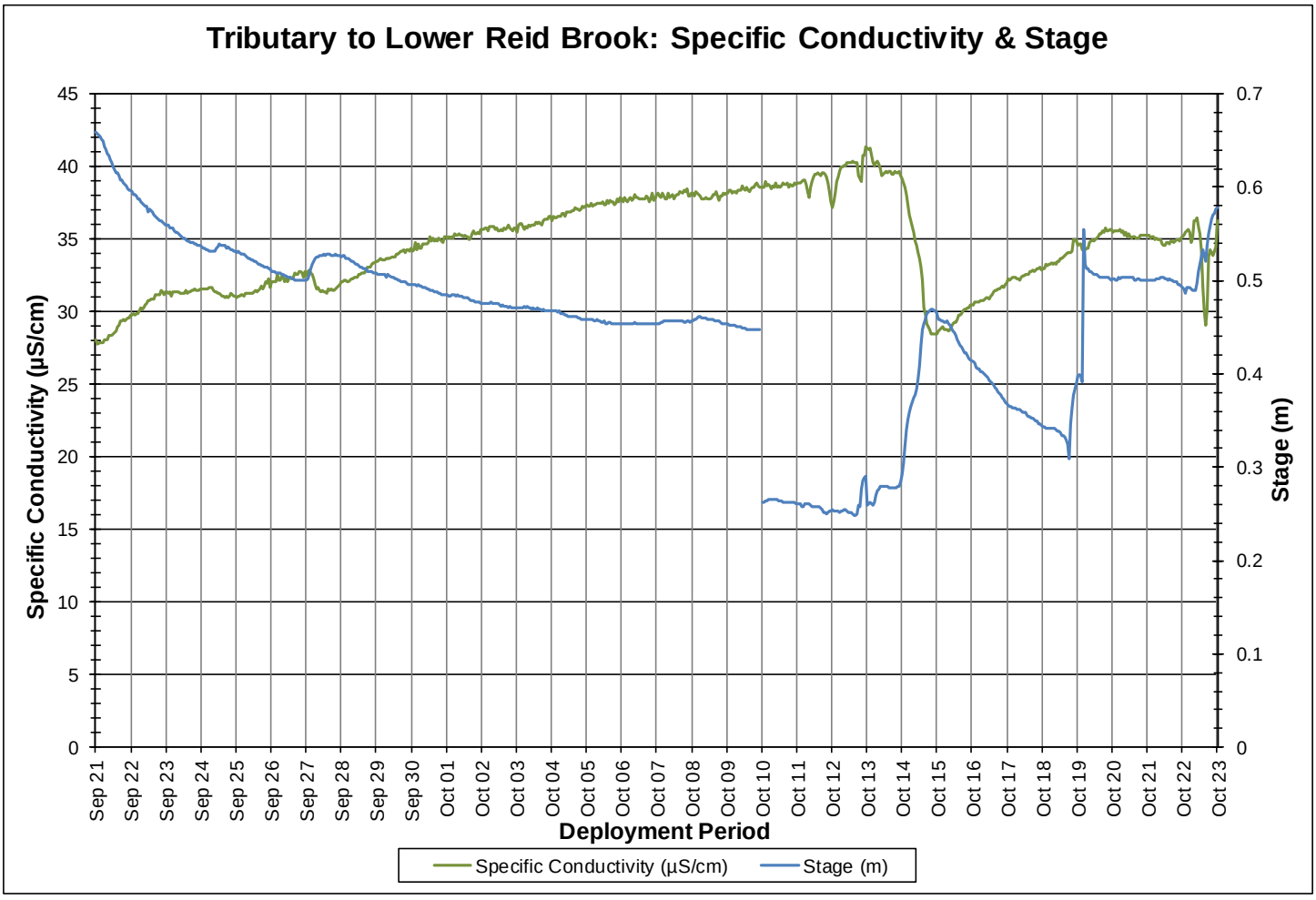

Figure 16: Specific Conductivity & Stage at Tributary to Lower Reid Brook

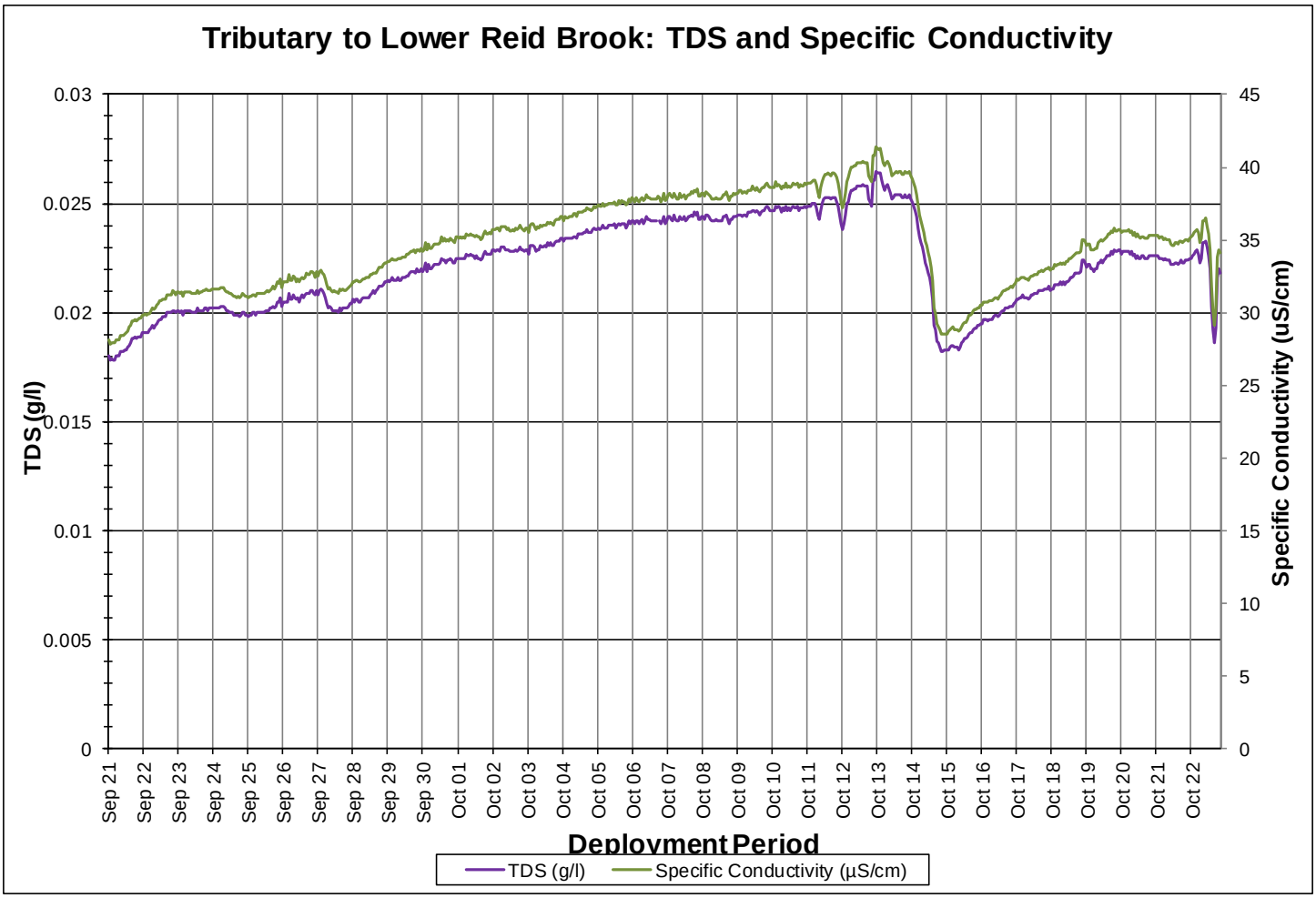

Figure 17: Specific Conductivity & TDS at Tributary to Lower Reid Brook

Dissolved Oxygen

- Tributary to Lower Reid Book sonde had a dissolved oxygen sensor failure and therefore no accurate DO data was recorded for the deployment period (Table 2).

Turbidity

- Turbidity ranges from 0.0NTU to 94.0NTU during the deployment period, with a median value of 0.0NTU (Figure 18).
- There are a number of medium to high turbidity events at this station throughout the duration of this deployment (Figure 18, 19). 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.

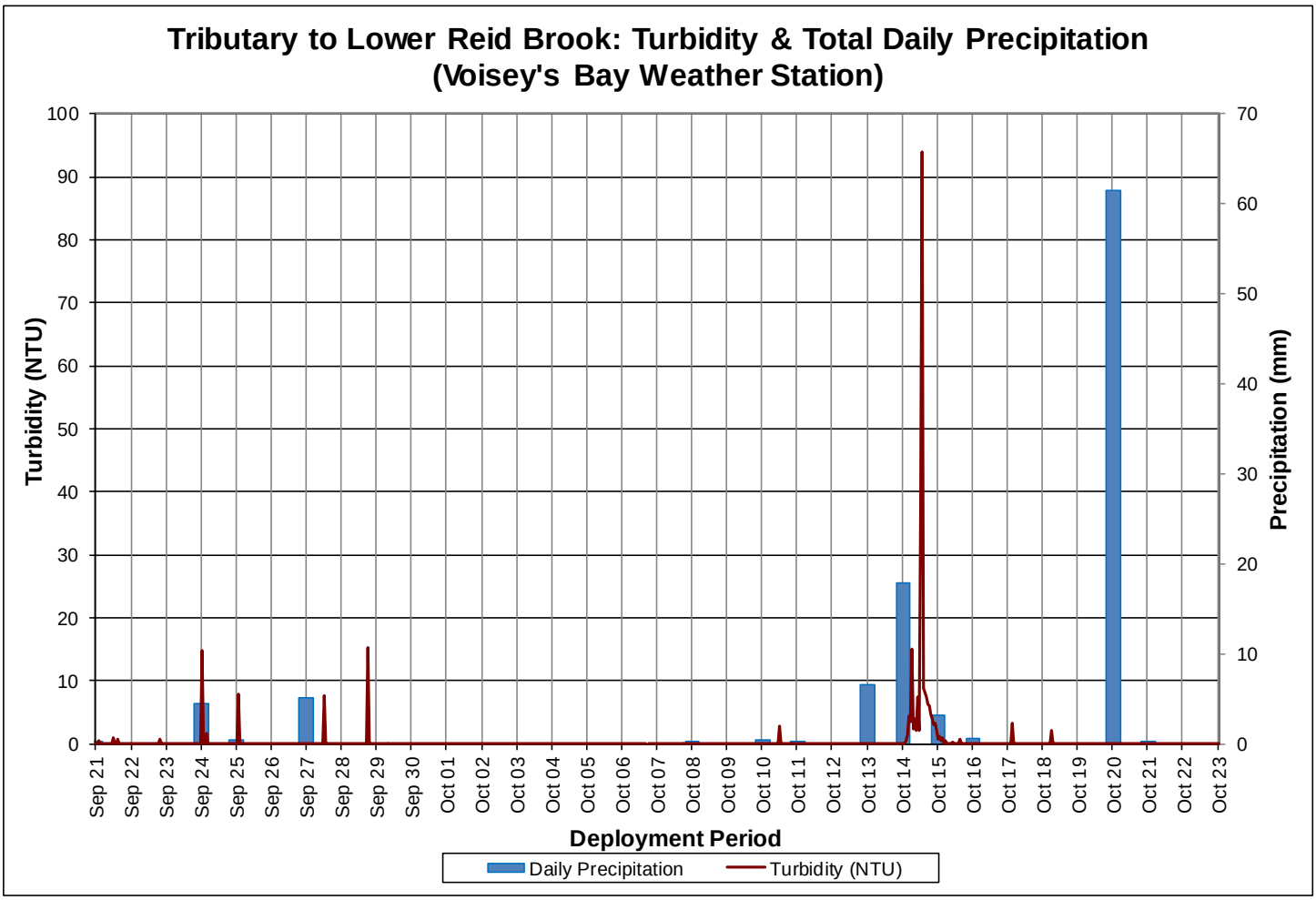

Figure 18: Turbidity & Total Daily Precipitation (Voisey's Bay Weather Station) at Tributary to Lower Reid Brook

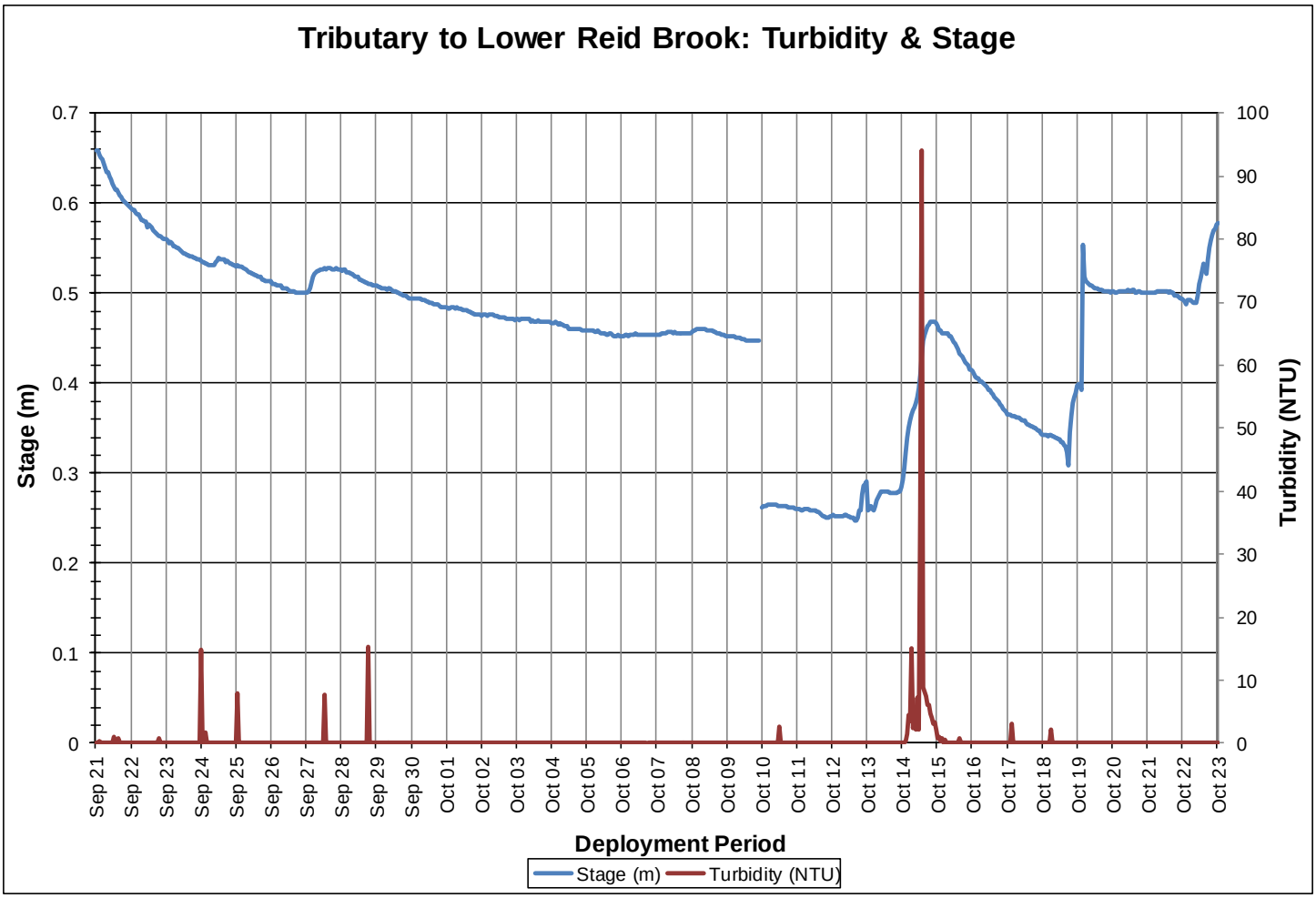

Figure 19: Turbidity & Stage at Tributary to Lower Reid Brook

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 20). Precipitation occurs on 13 days during the deployment period and amounts are small in magnitude, with exception of the largest on October 20th with 61.5mm of rain.
- During the deployment period, the stage values ranged from 0.25m to 0.66m. Streamflow had a minimum amount of 0.05m^3/s and a maximum flow of 0.67m^3/s.
- Stage, Streamflow and precipitation are graphed below to show the relationship between rainfall and water level (Figure 20). It is evident that the peaks in stage (m) and streamflow data are a result of precipitation.

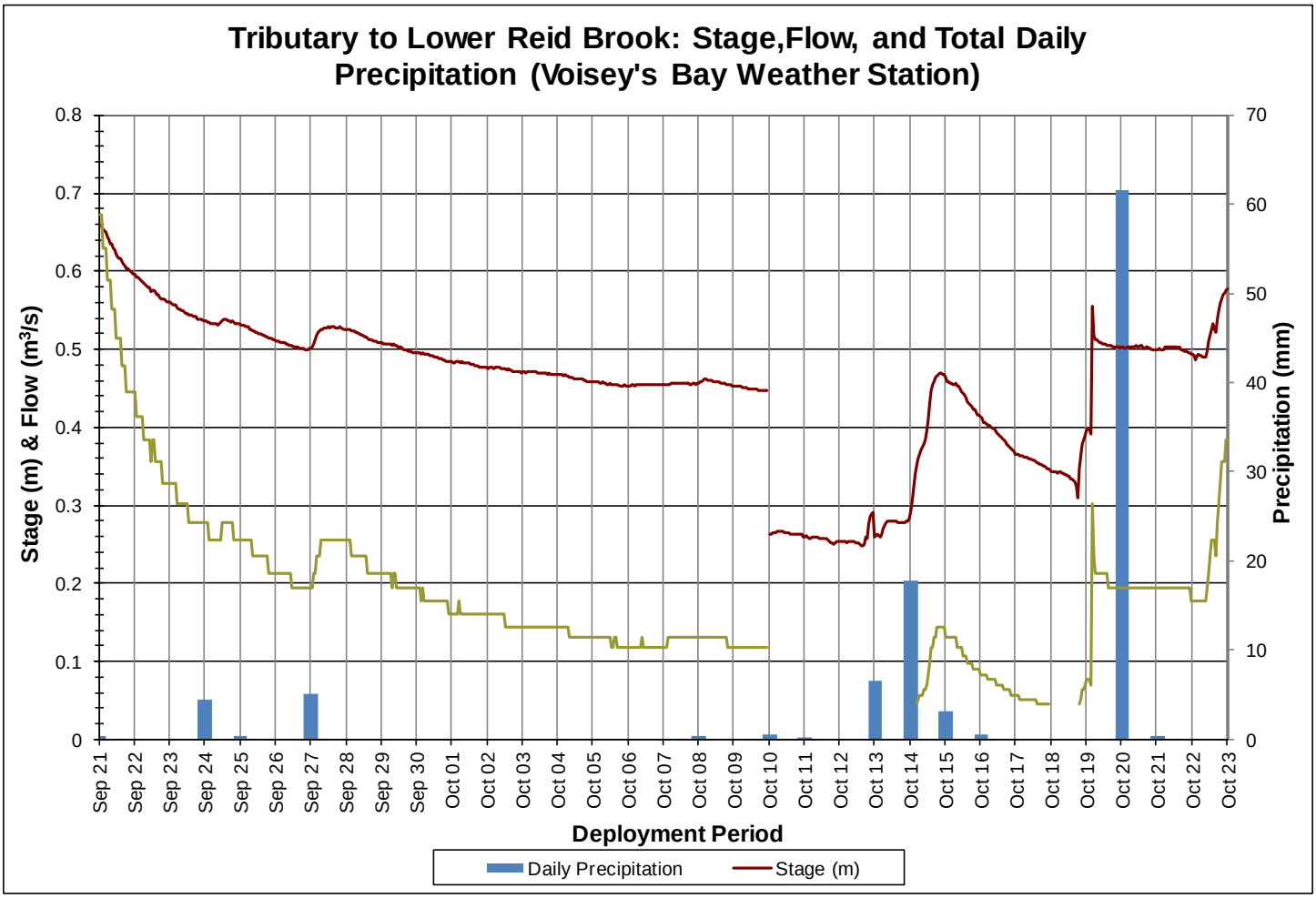

Figure 20: Stage, Flow, and Total Daily Precipitation (Voisey's Bay Weather Station) at Tributary to Lower Reid Brook

Lower Reid Brook below Tributary

Water Temperature

- Water temperature ranges from 0.16 °C to 10.38 °C, with a median value of 4.36°C (Figure 21).
- 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.

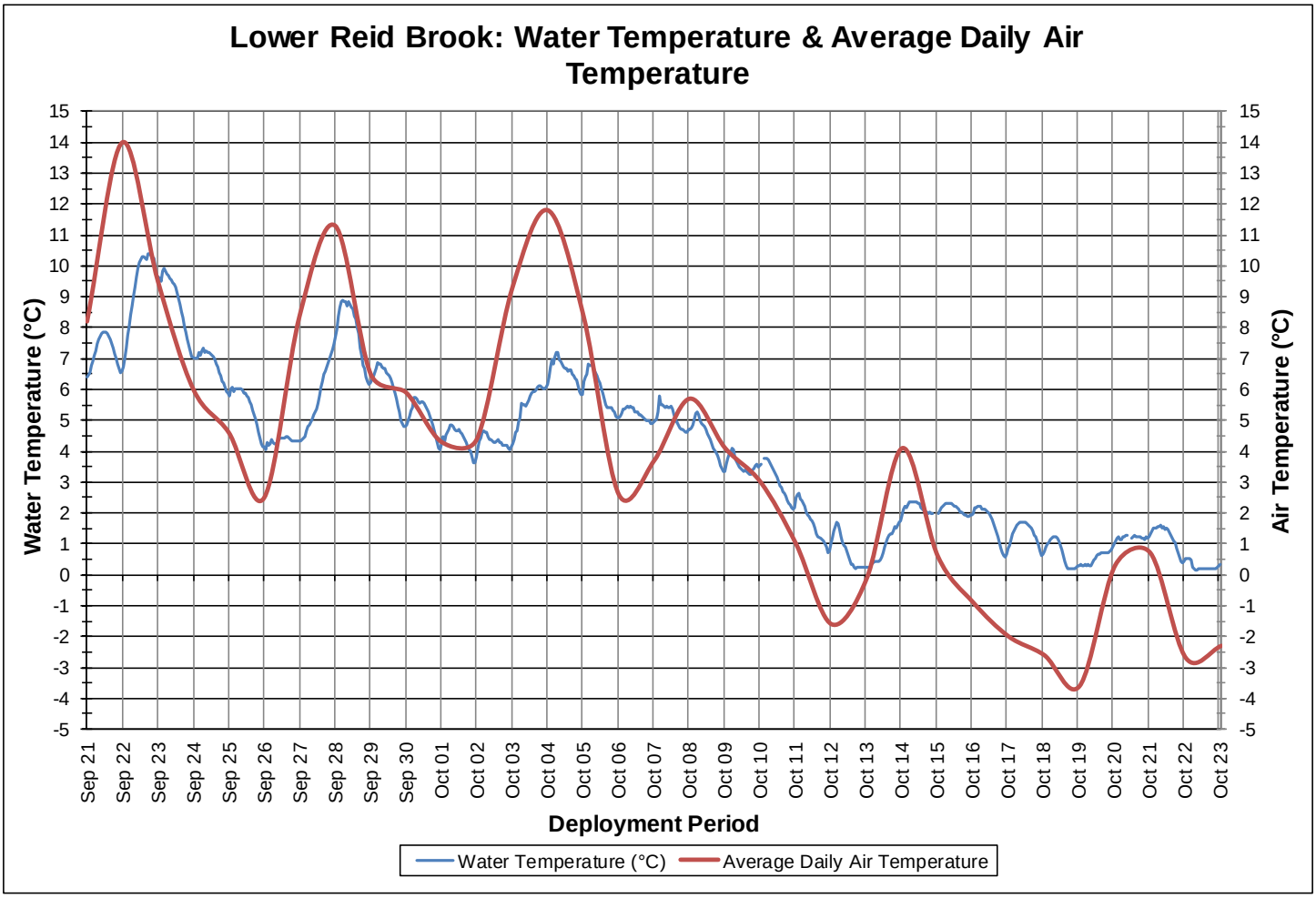

Figure 21: Water Temperature and Daily Average Air Temperature at Lower Reid Brook below Tributary

pH

- pH ranges from 6.40 to 7.06 pH units, with a median value of 6.90 (Figure 22).
- The pH values are very stable at this station, fluctuating diurnally during the deployment period.
- The pH values in this deployment period are near or below the lower CCME guidelines of 6.5 pH units.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

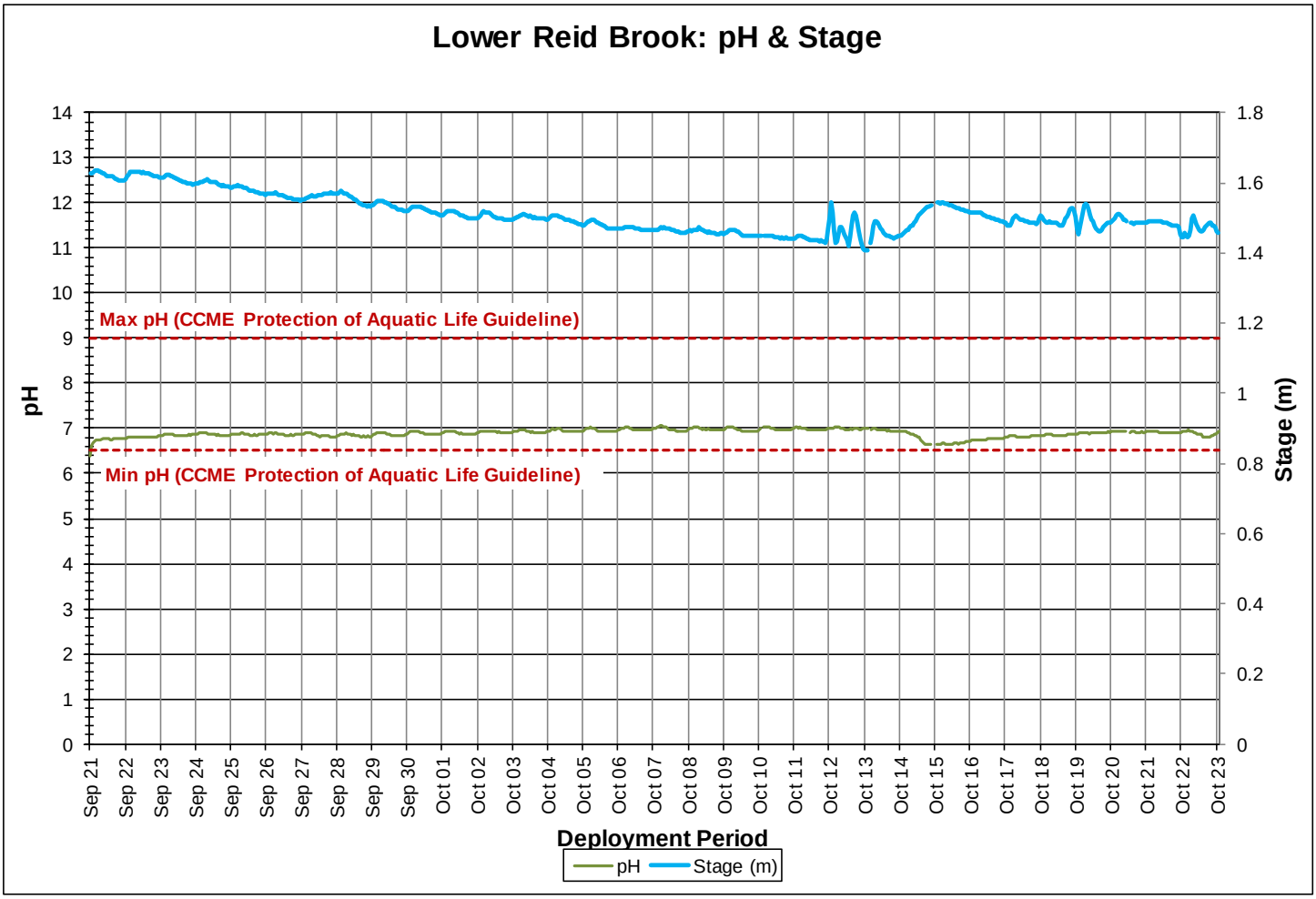

Figure 22: pH & Stage at Lower Reid Brook below Tributary

Specific Conductivity

- Specific conductivity ranges from 26.0µS/cm to 38.5µS/cm with a median of 32.9µS/cm. (Figure 23).
- TDS ranges between 0.0166 g/mL to 0.0246 g/mL during the deployment period, with a median of 0.0211g/mL (Figure 23).
- 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 24)
- 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 23).
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request

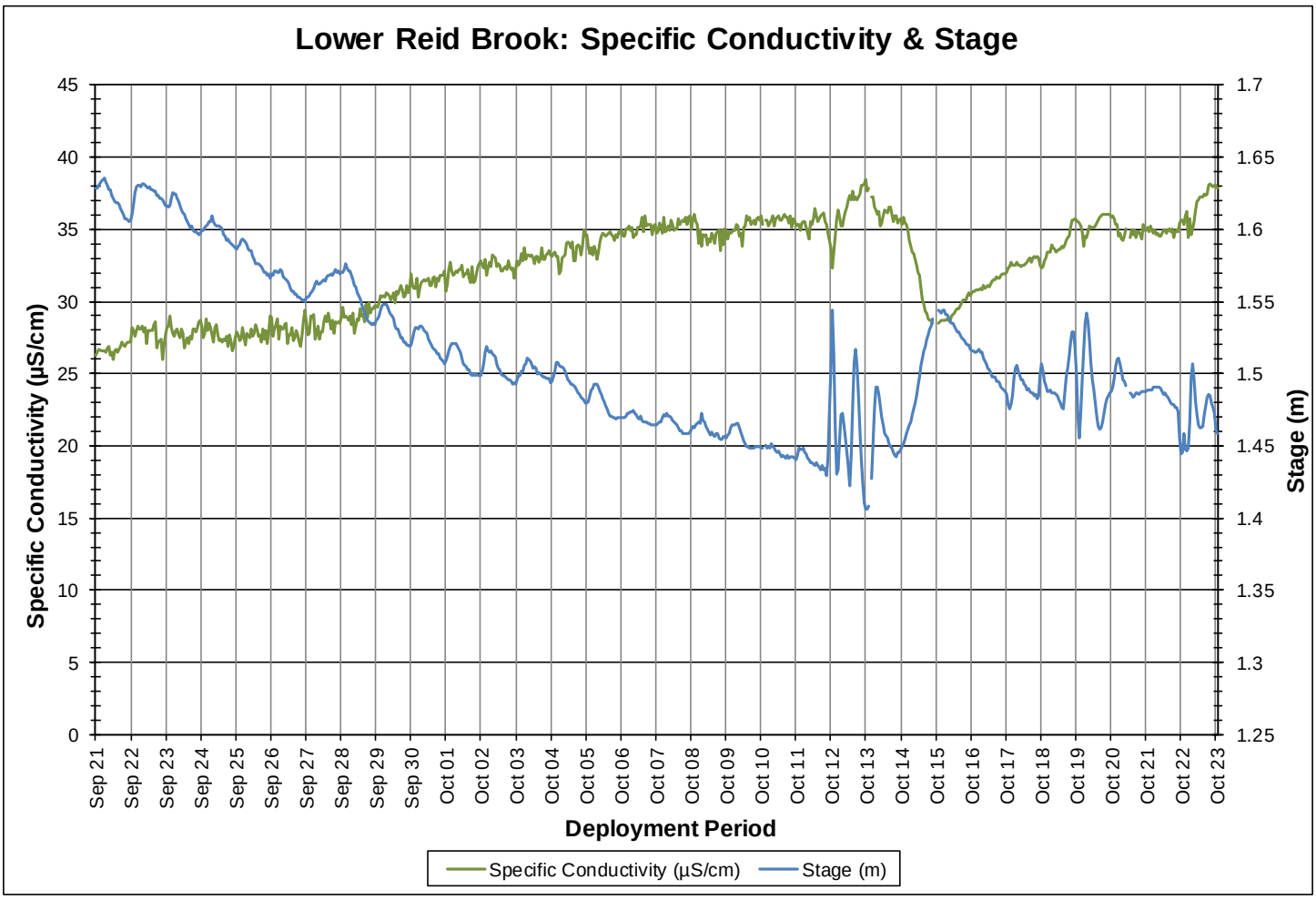

Figure 23: Specific Conductivity & Stage at Lower Reid Brook below Tributary

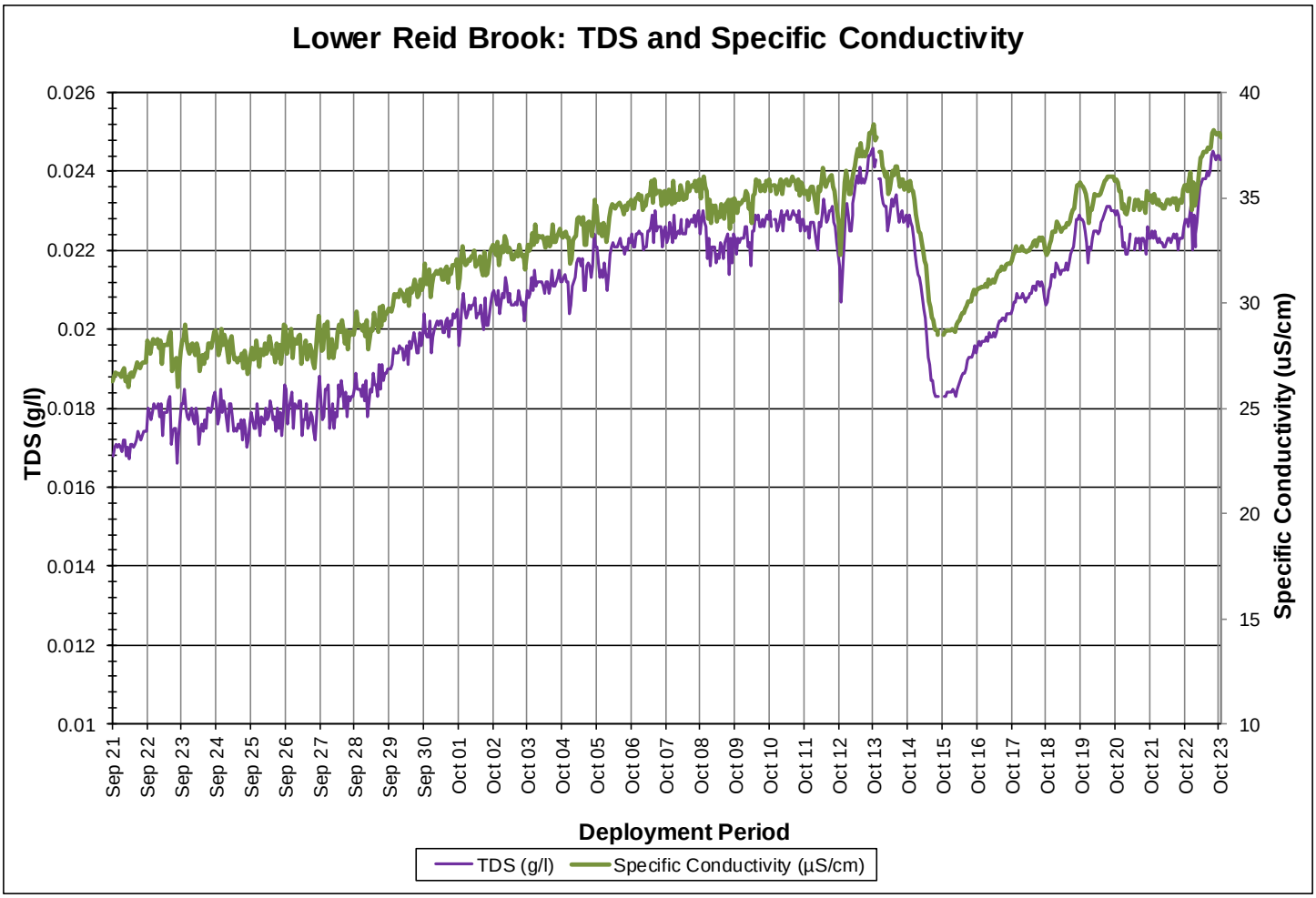

Figure 24: Specific Conductivity & TDS at Lower Reid Brook below Tributary

Dissolved Oxygen

- Dissolved oxygen content ranges between 10.85mg/l and 14.25mg/l during the deployment period. The saturation of dissolved oxygen ranges from 93.4% to 102.3% (Figure 25).
- 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.

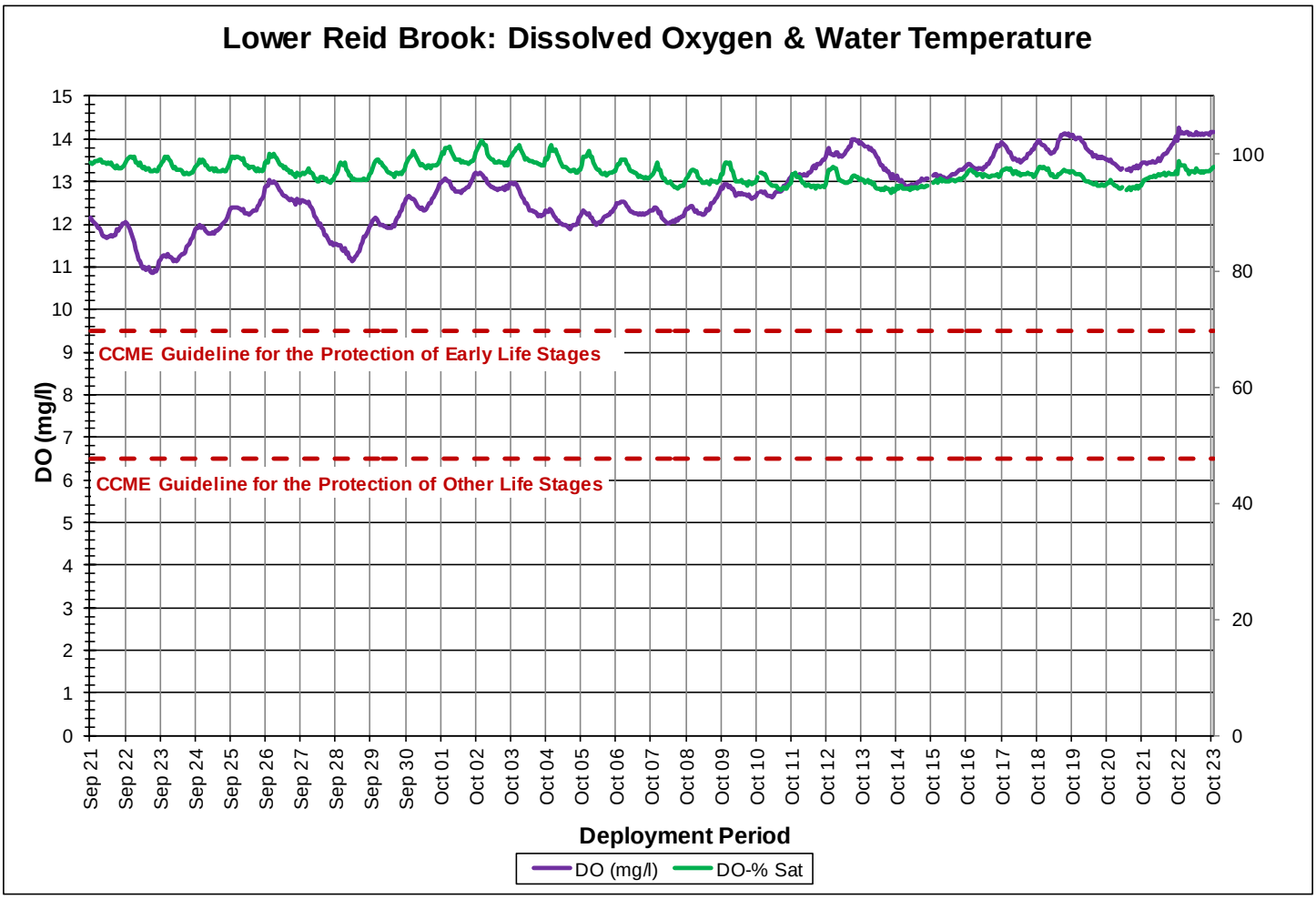

Figure 25: Dissolved Oxygen at Lower Reid Brook below Tributary

Turbidity

- Turbidity ranges from 0.0NTU to 13.8NTU during the deployment period, with a median value of 0.0NTU (Figure 26).
- There are a number of 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 26, 27).
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

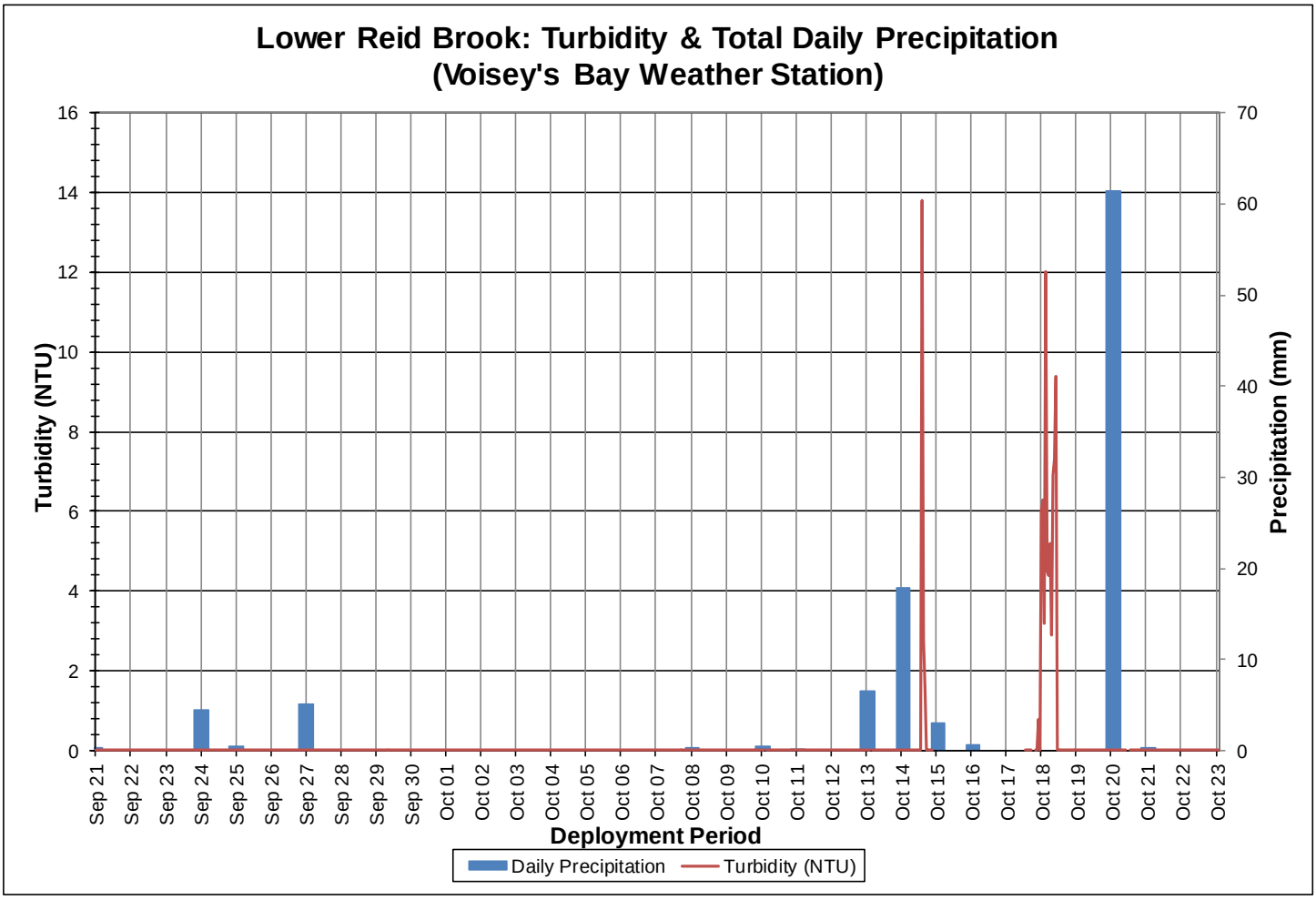

Figure 26: Turbidity & Total Daily Precipitation (Voisey's Bay Weather Station) at Lower Reid Brook below Tributary

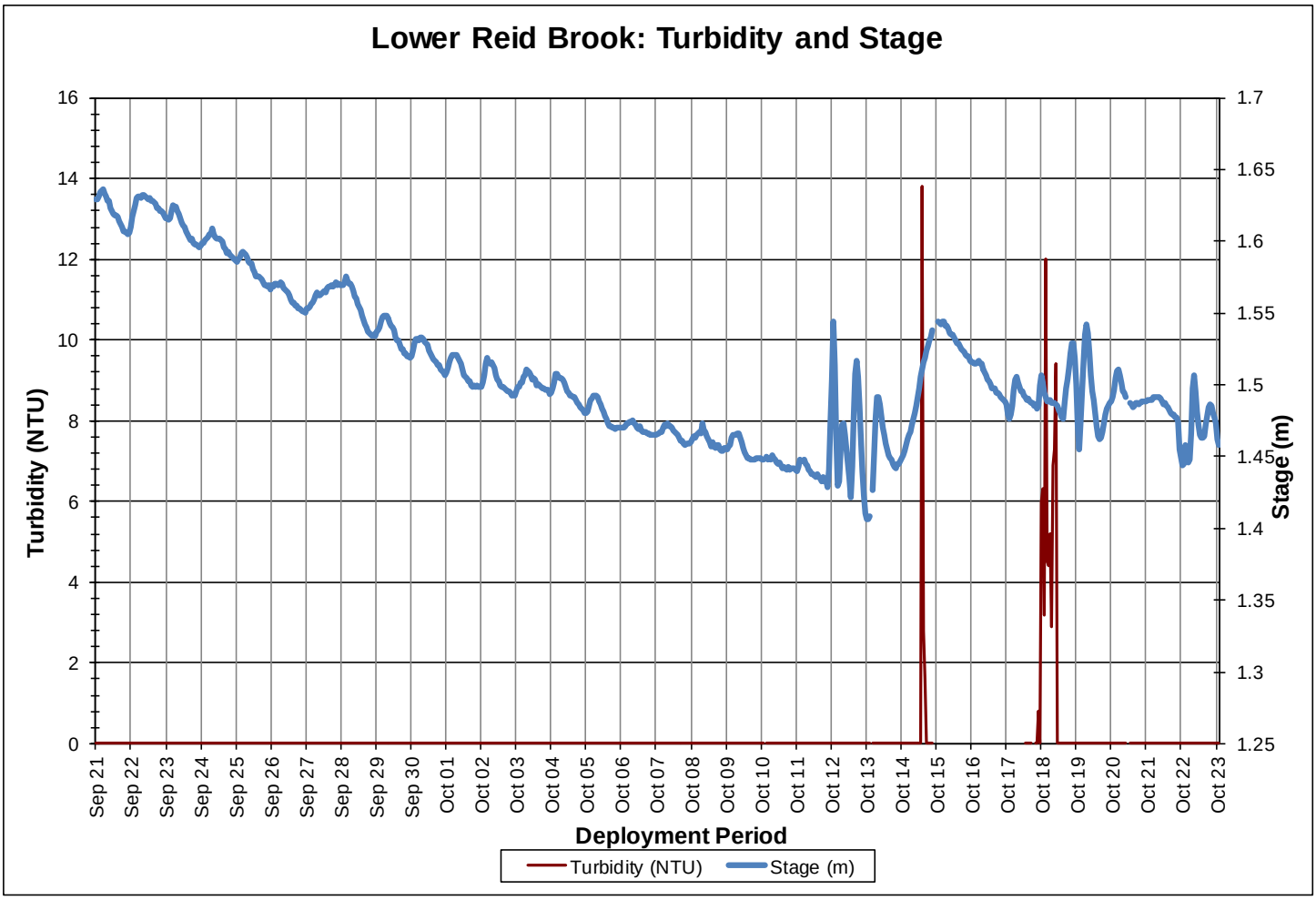

Figure 27: Turbidity & Stage at Lower Reid Brook below Tributary

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 28). Precipitation occurs on 13 days during the deployment period and amounts are small in magnitude, with exception of the largest on October 20th with 61.5mm of rain.
- During the deployment period, the stage values ranged from 1.41m to 1.64m. Streamflow had a minimum amount of 1.04m^3/s and a maximum flow of 5.76m^3/s.
- Stage, Streamflow and precipitation are graphed below to show the relationship between rainfall and water level (Figure 28). It is evident that the peaks in stage (m) and streamflow data are a result of precipitation.

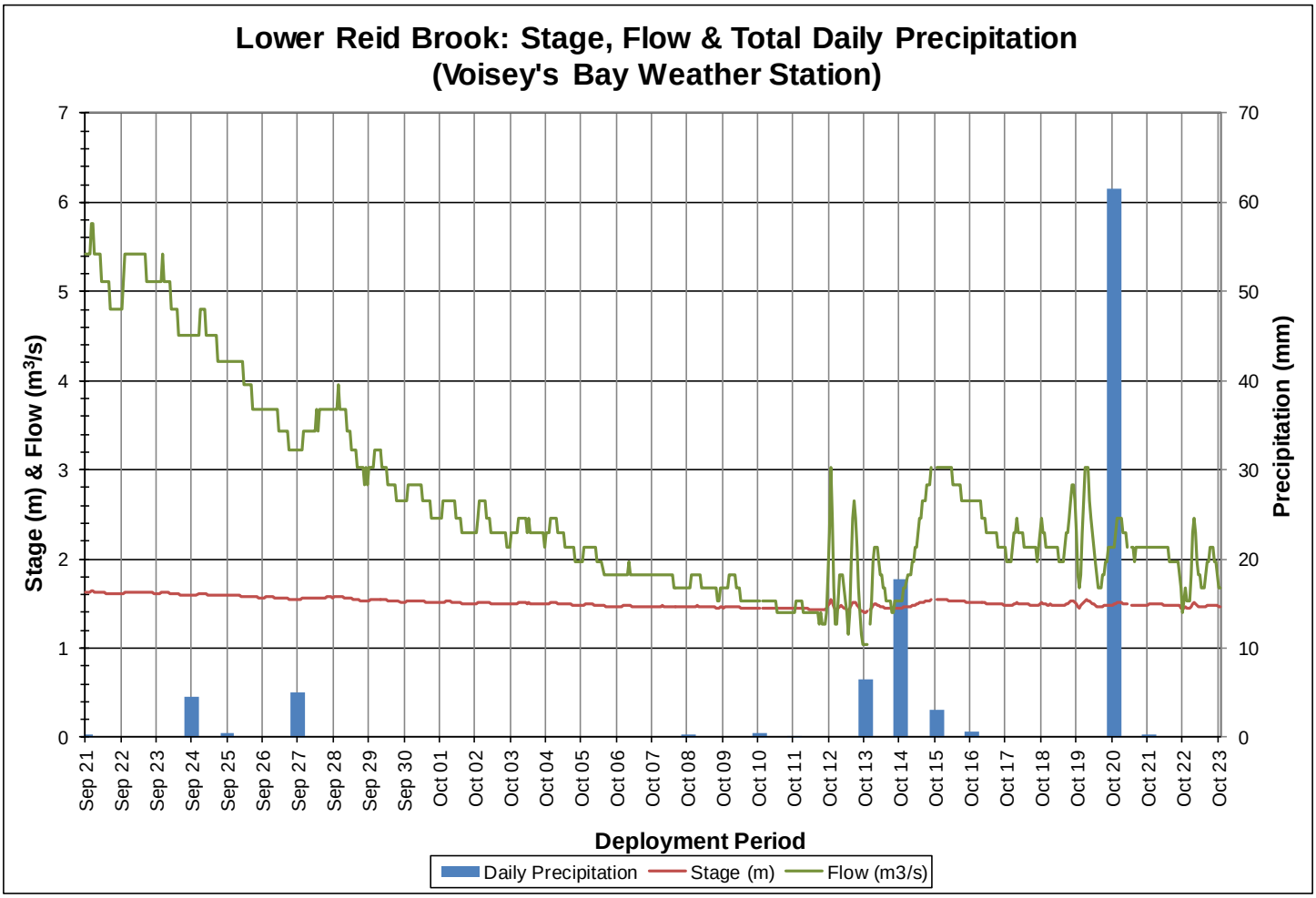

Figure 28: Stage, Flow, and Total Daily Precipitation (Voisey's Bay Weather Station) at Lower Reid Brook below Tributary

Conclusions

- The overall water temperatures across all stations were within a minimum of 0.00°C found at Tributary to Lower Reid Brook and a maximum of 12.65°C recorded at Camp Pond Brook below Camp Pond. Overall the water temperature was decreasing 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. Reid Brook at Outlet of Reid Pond is a large body of water and takes a longer time to adjust to the ambient air temperatures
- The pH values for this deployment ranged between a minimum of 5.74 pH units at Tributary to Lower Reid Brook and maximum of 7.33 pH units at Camp Pond Brook. All of the stations remained within the CCME guidelines for the majority of the deployment period. No pH data was recorded at Reid Brook at Outlet of Reid Pond.
- The overall conductivity across all stations were within a minimum of 11.7µS/cm at Reid Brook at Outlet of Reid Pond and a maximum value of 53.6µS/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 32.9µS/cm for September to October deployment. 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 10.85mg/l at Lower Reid Brook and a maximum of 14.25mg/l found at 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. No dissolved oxygen data was recorded for Camp Pond Brook or Tributary to Lower Reid Brook stations.
- Turbidity levels for the four real-time stations ranged within a minimum of 0.0NTU from all stations and a maximum of 94.0NTU at Tributary to Lower Reid Brook. Tributary to Lower Reid Brook and Camp Pond Brook also have several turbidity events which occurred during and after larger rainfall events.

APPENDIX A: Comparison Graphs

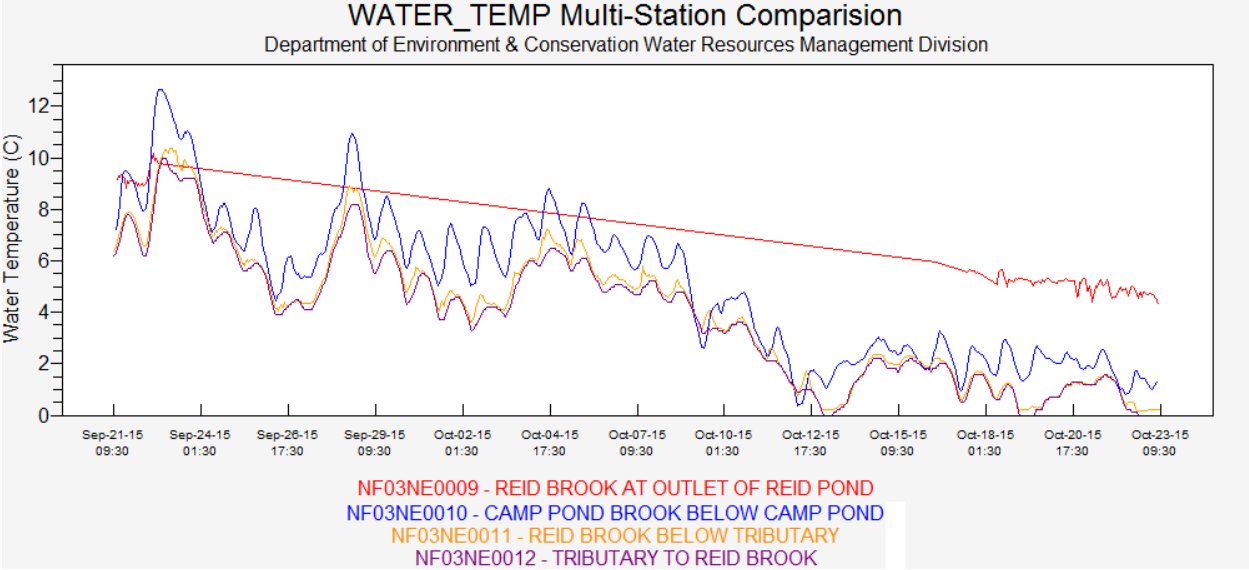

Figure A1: Comparison of Water Temperature at the Real-Time Stations in Voisey's

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

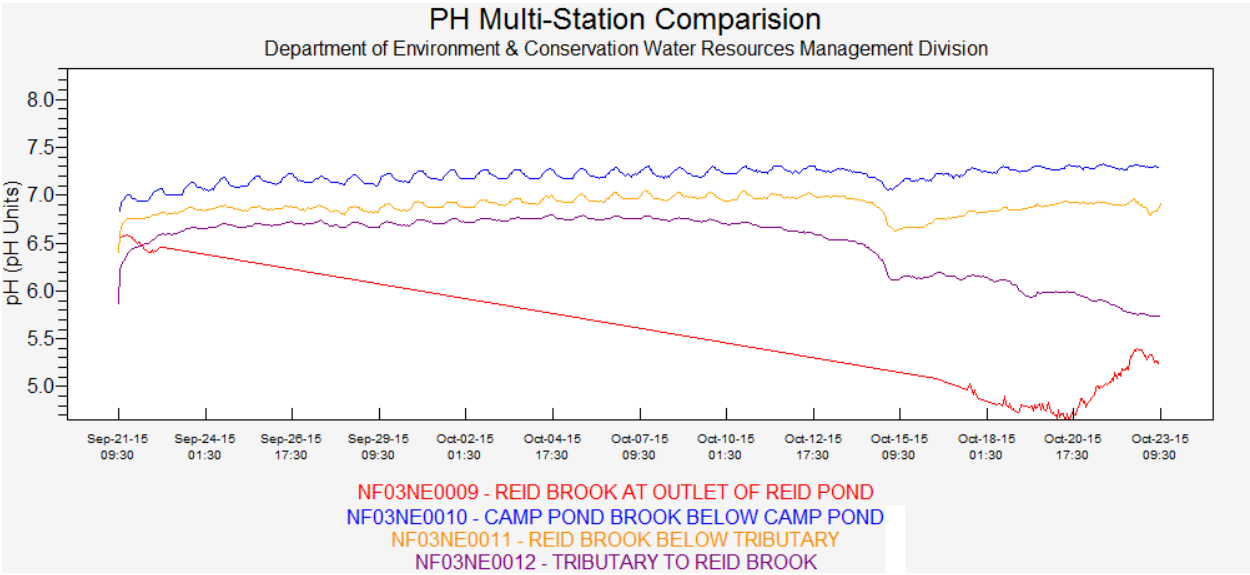

Figure A2: Comparison of pH at the Real-Time Stations in Voisey's Bay

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

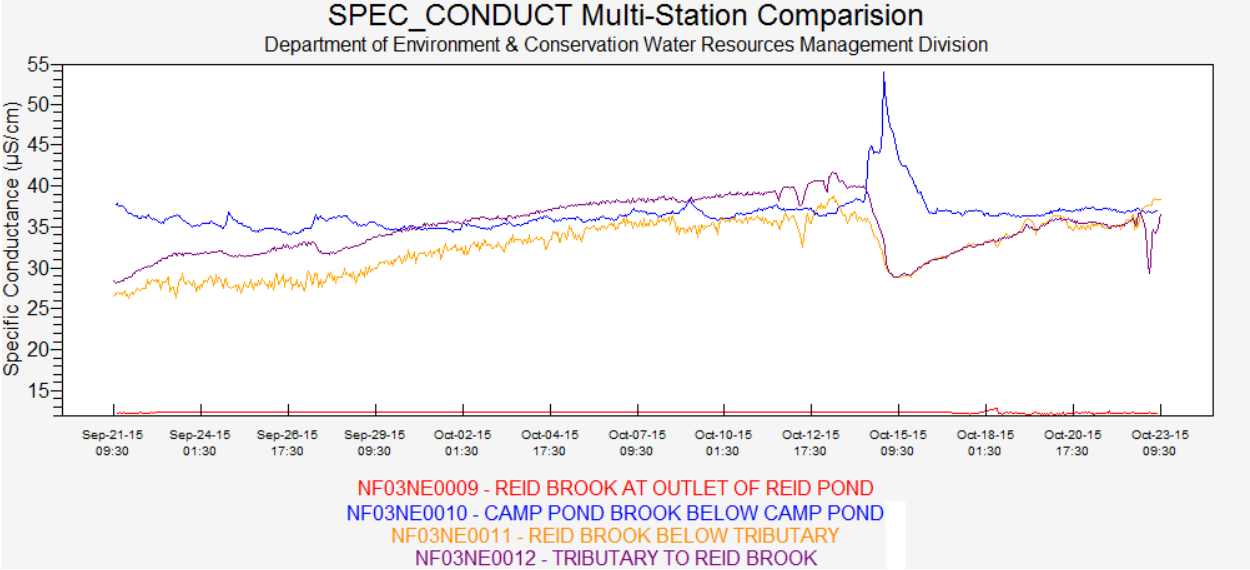

Figure A3: Comparison of Conductivity at the Real-Time Stations in Voisey's Bay

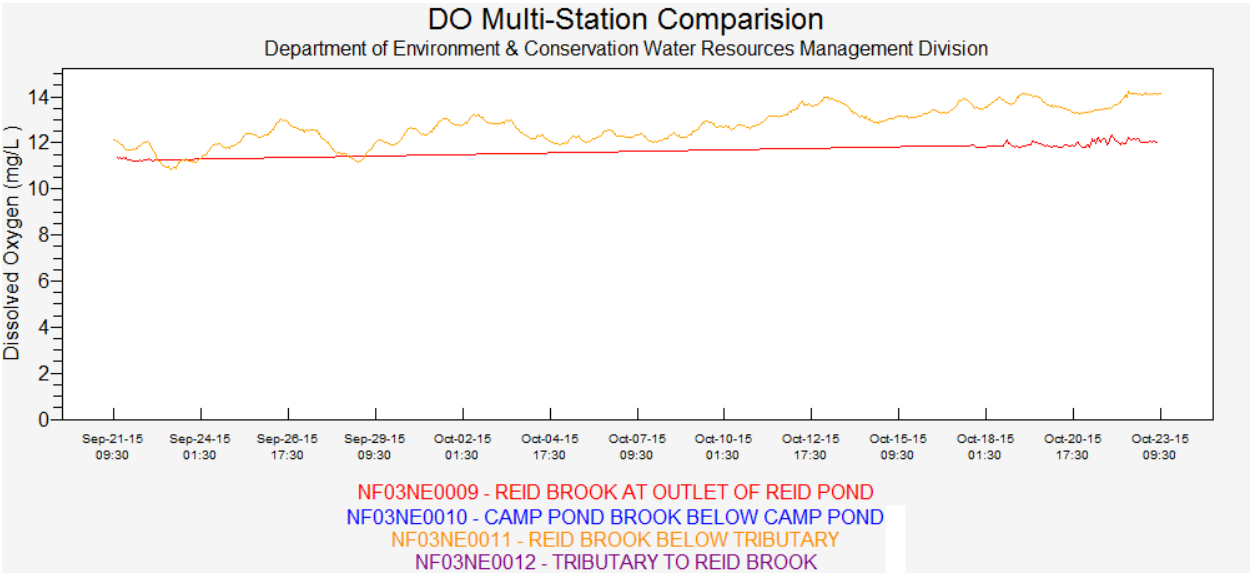

Figure A4: Comparison of Dissolved Oxygen (mg/L) at the Real-Time Stations in Voisey's Bay

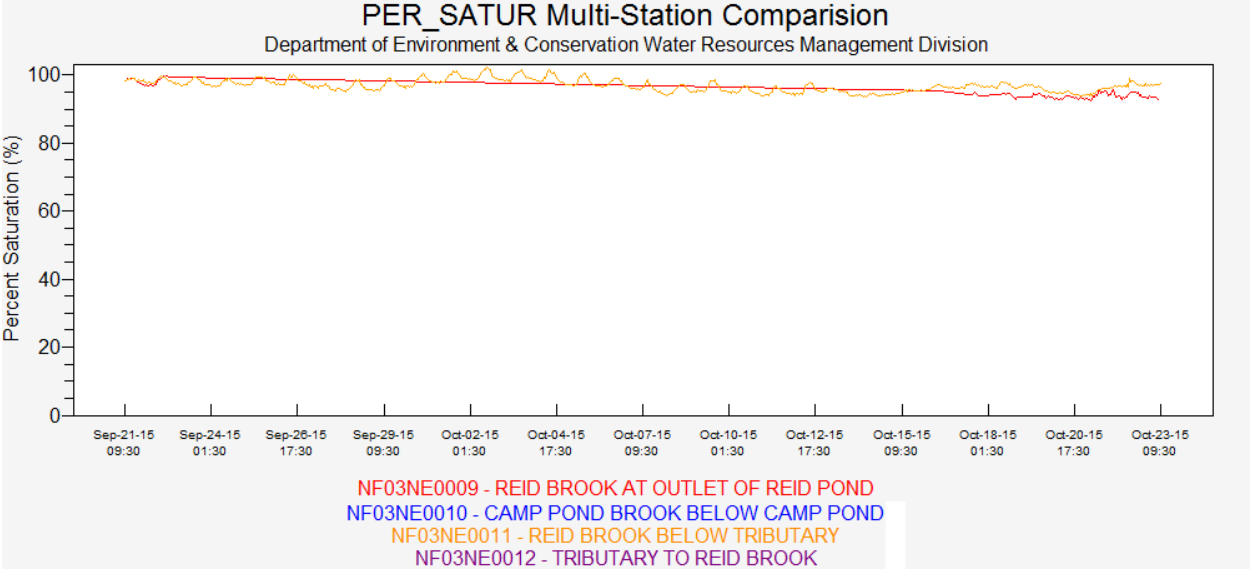

Figure A5: Comparison of Dissolved Oxygen (%Sat) at the Real-Time Stations in Voisey's Bay

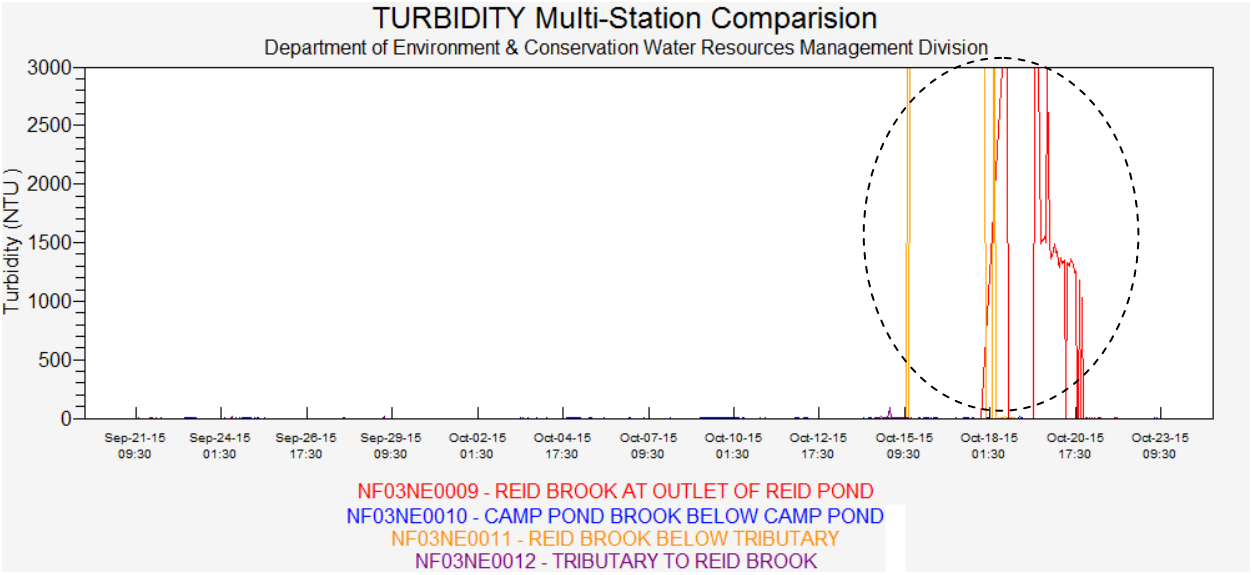

Figure A6: Comparison of Turbidity at the Real-Time Stations in Voisey's Bay

*** circled data removed**

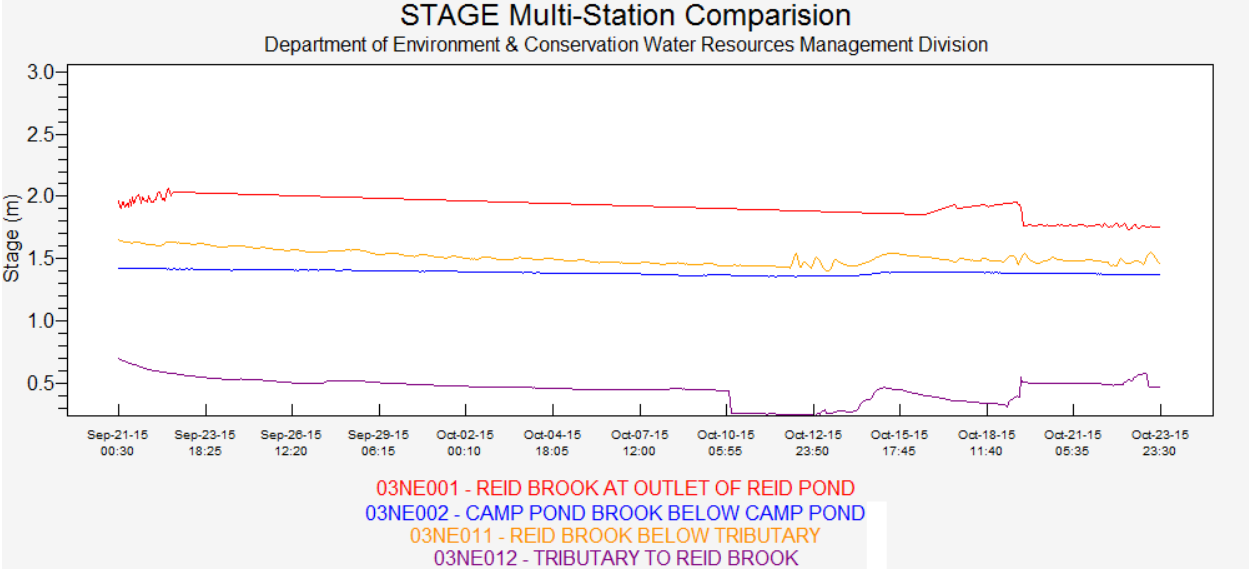

Figure A7: Comparison of Stage (m) at the Real-Time Stations in Voisey's Bay (due to transmission issues Reid Brook real time data does not show up on the graph)

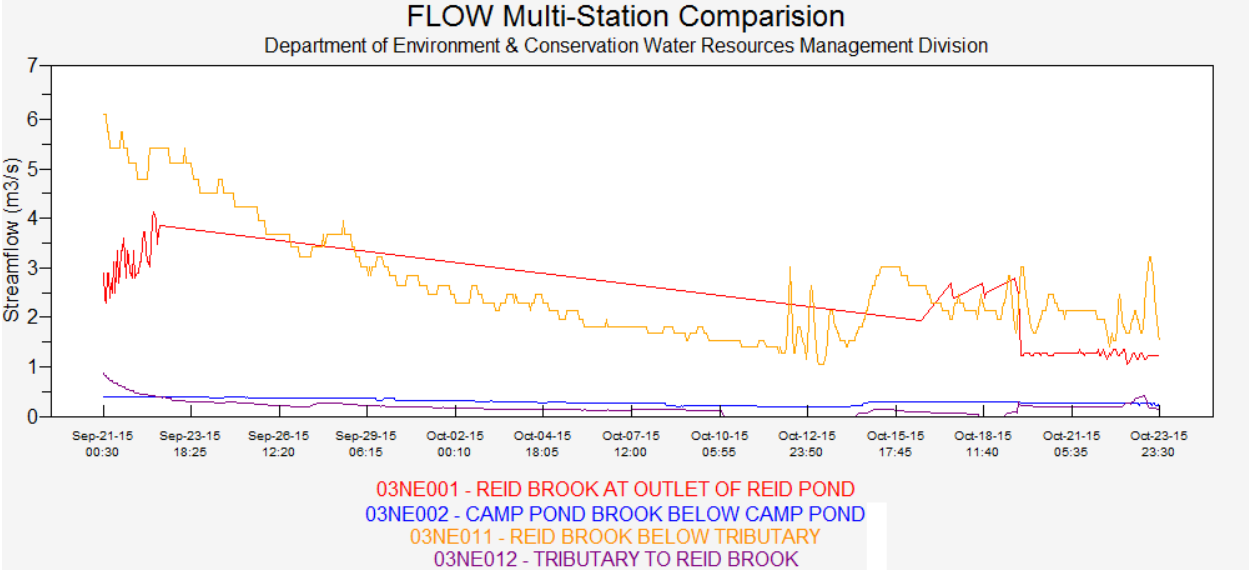

Figure A8: Comparison Flow (m^3/s) at the Real-Time Stations in Voisey's Bay

APPENDIX B: Grab Sample Data

REPORT OF ANALYSIS

Lab Report Number: 1519301

Cient:	Department of Environment	**COC Number:**	3378
Attention:	Ms. Annette Tobin	**Date Reported:**	2015-10-07
Client Project:	Happy Valley - Goose Bay	**Date Submitted:**	2015-09-29
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date
1204377	WS-S-0000 Camp Pond Brook Below Camp Pond	2015-6412-00-SI-SP	2015-09-21

Sample comment:

Holding time for NO2 and NO3 analysis was exceeded.

Report comment:

ANALYTE	UNIT	MRL	RESULT
Alkalinity as CaCO3	mg/L	5	6
Bromide	mg/L	0.25	<0.25
Chloride	mg/L	1	3
Colour	TCU	2	32
Conductivity	uS/cm	5	42
Dissolved Organic Carbon	mg/L	0.5	4.5
Fluoride	mg/L	0.10	<0.10
Hardness as CaCO3	mg/L	1	14
N-NH3 (Ammonia)	mg/L	0.025	0.127
N-NO2 (Nitrite)	mg/L	0.10	<0.10
N-NO3 (Nitrate)	mg/L	0.10	<0.10
pH		1.00	6.91
Sulphate	mg/L	1	5
Total Dissolved Solids (COND - CALC)	mg/L	1	27
Total Kjeldahl Nitrogen	mg/L	0.07	0.35
Total Organic Carbon	mg/L	0.5	5.0
Total Phosphorus	mg/L	0.05	<0.05
Turbidity	NTU	0.1	1.4
Aluminum	mg/L	0.01	0.09
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	4
Cadmium	mg/L	0.0001	<0.0001
Chromium	mg/L	0.001	<0.001

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: 1519301

Cient:	Department of Environment	**COC Number:**	3378
Attention:	Ms. Annette Tobin	**Date Reported:**	2015-10-07
Client Project:	Happy Valley - Goose Bay	**Date Submitted:**	2015-09-29
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1204377	WS-S-0000	2015-6412-00-SI-SP	2015-09-21	Copper	mg/L	0.001	0.004
	Camp Pond Brook Below Camp Pond			Iron	mg/L	0.03	0.23
				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	0.026
				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	2

Sample comment:

Holding time for NO2 and NO3 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: 1519301

Cient:	Department of Environment	**COC Number:**	3378
Attention:	Ms. Annette Tobin	**Date Reported:**	2015-10-07
Client Project:	Happy Valley - Goose Bay	**Date Submitted:**	2015-09-29
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date
1204378	WS-S-0000 Reid Brook at Outlet to Reid Pond	2015-6413-00-SI-SP	2015-09-21

Sample comment:

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

Report comment:

ANALYTE	UNIT	MRL	RESULT
Alkalinity as CaCO3	mg/L	5	<5
Bromide	mg/L	0.25	<0.25
Chloride	mg/L	1	1
Colour	TCU	2	12
Conductivity	uS/cm	5	15
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	<0.025
N-NO2 (Nitrite)	mg/L	0.10	<0.10
N-NO3 (Nitrate)	mg/L	0.10	<0.10
pH		1.00	6.69
Sulphate	mg/L	1	<1
Total Dissolved Solids (COND - CALC)	mg/L	1	10
Total Kjeldahl Nitrogen	mg/L	0.07	0.18
Total Organic Carbon	mg/L	0.5	4.7
Total Phosphorus	mg/L	0.05	<0.05
Turbidity	NTU	0.1	0.3
Aluminum	mg/L	0.01	0.05
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

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: 1519301

Cient:	Department of Environment	**COC Number:**	3378
Attention:	Ms. Annette Tobin	**Date Reported:**	2015-10-07
Client Project:	Happy Valley - Goose Bay	**Date Submitted:**	2015-09-29
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1204378	WS-S-0000 Reid Brook at Outlet to Reid Pond	2015-6413-00-SI-SP	2015-09-21	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	0.004
				Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	<0.01
				Total Suspended Solids	mg/L	1	<1

Sample comment:

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

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: 1519301

Cient:	Department of Environment	**COC Number:**	3378
Attention:	Ms. Annette Tobin	**Date Reported:**	2015-10-07
Client Project:	Happy Valley - Goose Bay	**Date Submitted:**	2015-09-29
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date
1204379	WS-S-0000 Tributary to Lower Reid Brook	2015-6414-00-SI-SP	2015-09-21

Sample comment:

Holding time for NO2 and NO3 analysis was exceeded.

Report comment:

ANALYTE	UNIT	MRL	RESULT
Alkalinity as CaCO3	mg/L	5	13
Bromide	mg/L	0.25	<0.25
Chloride	mg/L	1	2
Colour	TCU	2	69
Conductivity	uS/cm	5	31
Dissolved Organic Carbon	mg/L	0.5	6.7
Fluoride	mg/L	0.10	<0.10
Hardness as CaCO3	mg/L	1	7
N-NH3 (Ammonia)	mg/L	0.025	0.043
N-NO2 (Nitrite)	mg/L	0.10	<0.10
N-NO3 (Nitrate)	mg/L	0.10	<0.10
pH		1.00	6.75
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	6.7
Total Phosphorus	mg/L	0.05	<0.05
Turbidity	NTU	0.1	1.0
Aluminum	mg/L	0.01	0.14
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	3
Cadmium	mg/L	0.0001	<0.0001
Chromium	mg/L	0.001	<0.001

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.

REPORT OF ANALYSIS

Lab Report Number: 1519301

Cient:	Department of Environment	**COC Number:**	3378
Attention:	Ms. Annette Tobin	**Date Reported:**	2015-10-07
Client Project:	Happy Valley - Goose Bay	**Date Submitted:**	2015-09-29
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1204379	WS-S-0000 Tributary to Lower Reid Brook	2015-6414-00-SI-SP	2015-09-21	Copper	mg/L	0.001	0.001
				Iron	mg/L	0.03	0.47
				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	0.007
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	<2
				Strontium	mg/L	0.001	0.014
				Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	<0.01
				Total Suspended Solids	mg/L	1	6

Sample comment:

Holding time for NO2 and NO3 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: 1519301

Cient:	Department of Environment	**COC Number:**	3378
Attention:	Ms. Annette Tobin	**Date Reported:**	2015-10-07
Client Project:	Happy Valley - Goose Bay	**Date Submitted:**	2015-09-29
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date
1204380	WS-S-0000 Lower Reid Below Trib	2015-6415-00-SI-SP	2015-09-21

Sample comment:

Holding time for NO2 and NO3 analysis was exceeded.

Report comment:

ANALYTE	UNIT	MRL	RESULT
Alkalinity as CaCO3	mg/L	5	12
Bromide	mg/L	0.25	<0.25
Chloride	mg/L	1	2
Colour	TCU	2	13
Conductivity	uS/cm	5	31
Dissolved Organic Carbon	mg/L	0.5	6.6
Fluoride	mg/L	0.10	<0.10
Hardness as CaCO3	mg/L	1	7
N-NH3 (Ammonia)	mg/L	0.025	0.070
N-NO2 (Nitrite)	mg/L	0.10	<0.10
N-NO3 (Nitrate)	mg/L	0.10	<0.10
pH		1.00	6.80
Sulphate	mg/L	1	2
Total Dissolved Solids (COND - CALC)	mg/L	1	20
Total Kjeldahl Nitrogen	mg/L	0.07	0.40
Total Organic Carbon	mg/L	0.5	7.0
Total Phosphorus	mg/L	0.05	<0.05
Turbidity	NTU	0.1	1.4
Aluminum	mg/L	0.01	0.14
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	3
Cadmium	mg/L	0.0001	<0.0001
Chromium	mg/L	0.001	<0.001

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.

REPORT OF ANALYSIS

Lab Report Number: 1519301

Cient:	Department of Environment	**COC Number:**	3378
Attention:	Ms. Annette Tobin	**Date Reported:**	2015-10-07
Client Project:	Happy Valley - Goose Bay	**Date Submitted:**	2015-09-29
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1204380	WS-S-0000	2015-6415-00-SI-SP	2015-09-21	Copper	mg/L	0.001	0.001
	Lower Reid Below Trib			Iron	mg/L	0.03	0.44
				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	0.007
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	<2
				Strontium	mg/L	0.001	0.012
				Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	<0.01
				Total Suspended Solids	mg/L	5	<5

Sample comment:

Holding time for NO2 and NO3 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 (^oC)* 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.

	Rating				
Parameter	**Excellent**	**Good**	**Fair**	**Marginal**	**Poor**
Temperature (^{o}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 CO_2 (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 25ºC. 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 (oC) 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

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