Real-Time Water Quality Deployment Report

Voisey's Bay Network

June 16 to July 18, 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 June 16, 2015, Vale Environment and Water Resources 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 and Water Resources on July 18, 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)	June 16, 2015	Deployment	Fair	Fair	Excellent	NA	Excellent
	July 18, 2015	Removal	Poor	Good	Excellent	NA	Excellent
Camp Pond Brook (62885)	June 16, 2015	Deployment	Excellent	Poor	Excellent	Excellent	Excellent
	July 18, 2015	Removal	Excellent	Excellent	Excellent	Excellent	Excellent
Tributary to Lower Reid Brook (62886)	June 16, 2015	Deployment	Excellent	Fair	Excellent	Excellent	Excellent
	July 18, 2015	Removal	Excellent	Excellent	Excellent	Good	Excellent
Lower Reid Brook (62887)	June 16, 2015	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
	July 18, 2015	Removal	Excellent	Poor	Good	Fair	Excellent

During the deployment for Reid Brook at Outlet of Reid Pond, the temperature, pH data all ranked as 'fair'. The conductivity and turbidity data ranked as 'excellent'. During removal temperature ranked as 'poor'. pH, conductivity and turbidity ranked as 'good' or 'excellent'. At this station QA/QC rankings could not be assessed in real time due to the transmission error occurring at the station. The 'poor' reading for temperature could be due to a difference in location between the field sonde and the QA/QC sonde.

At the station on Camp Pond Brook, temperature, conductivity, dissolved oxygen and turbidity all ranked as 'excellent' with pH data ranking as 'poor'. The field value for pH was 5.56 while this QA/QC value was 6.69. This is likely due to the field sonde pH sensor not having stabilized before the value was recorded. During removal, temperature, pH, conductivity, dissolved oxygen, and turbidity all ranked as 'excellent'.

At Tributary to Lower Reid Brook station, the water quality parameters that ranked as 'excellent' were temperature, conductivity, dissolved oxygen, and turbidity. pH data ranked as 'fair' at deployment. The field value for pH was 5.60 while this QA/QC value was 6.37. This is likely due to the field sonde pH sensor not having stabilized before the value was recorded. During removal, temperature, pH, conductivity, dissolved oxygen, and turbidity all ranked as 'good' or 'excellent'.

At Lower Reid Brook all parameters ranked as 'excellent' during deployment. During removal, temperature, conductivity, and turbidity ranked as 'good' or 'excellent'. pH ranked as 'poor' and dissolved oxygen ranked as 'fair'. The discrepancy between the pH and dissolved oxygen values is possibly due to location of the field sonde compared to the QA/QC sonde.

Data Interpretation

- The following graphs and discussion illustrate significant water quality-related events from June 16th to July 18th, 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. Total dissolved solids are a calculated parameter which cannot be recorded to an accurate decimal place on the internal log file. The dissolved oxygen sensor on this instrument was damaged therefore no dissolved oxygen data is available for this time period
- Tributary to Lower Reid Brook had transmission issues with water quantity data for portions of the deployment period.

Figure 1: Voisey's Bay Network Station Locations

Reid Brook at Outlet of Reid Pond

Water Temperature

- Water temperature ranges from 2.51 °C to 11.96 °C, with a median value of 7.21 °C (Figure 2).
- Water temperature is gradually increasing throughout the deployment period. This trend is expected as the air temperatures warm in the spring and summer months.
- A significant increase in air temperature from June 25th to June 30th resulted in a significant increase in water temperature at Reid Brook (Figure 2).

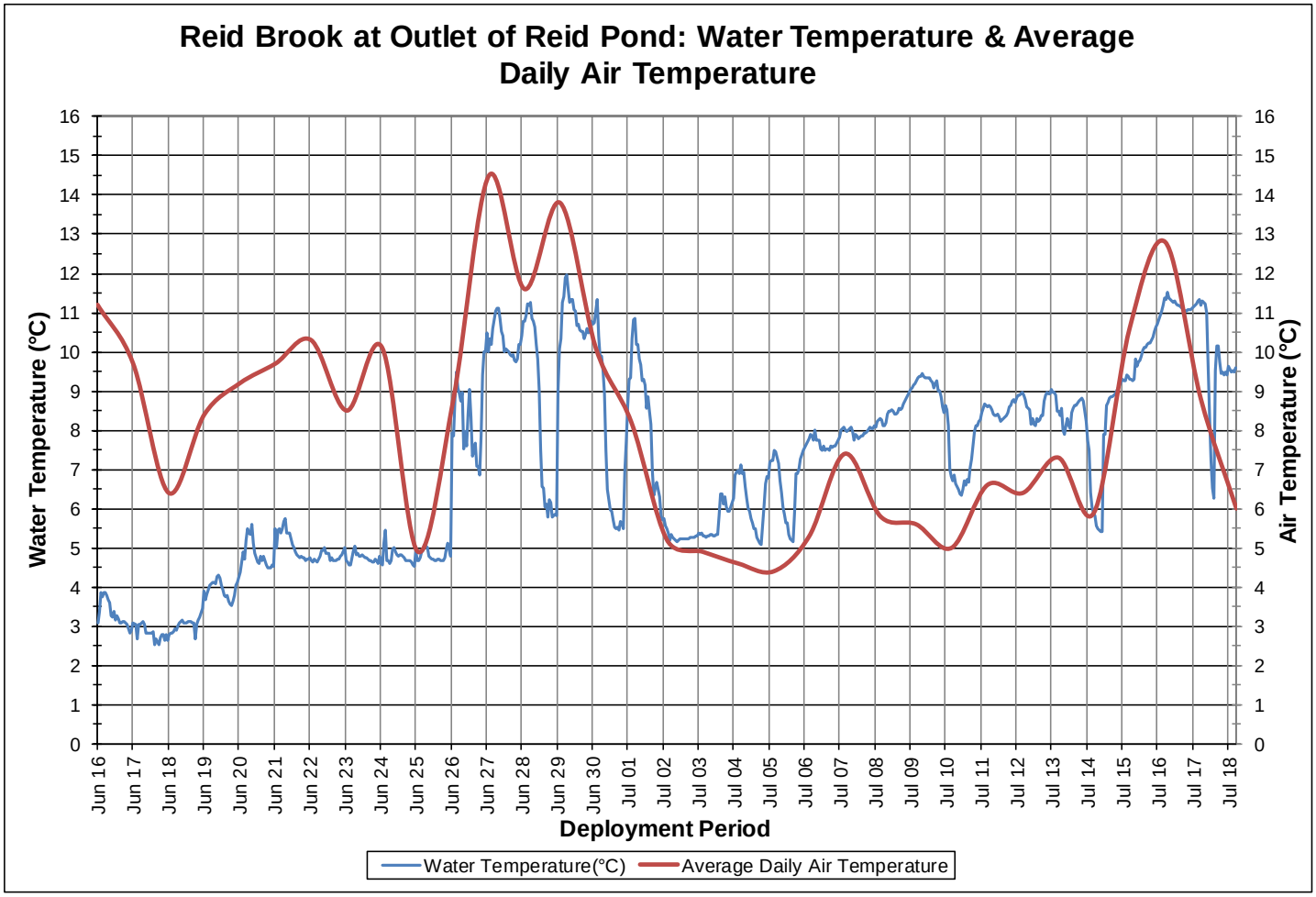

Figure 2: Water Temperature & Average Daily Air Temperature at Reid Brook at Outlet of Reid Pond

pH Levels

- pH ranges from 4.83 to 6.54 pH units, with a median value of 5.73 (Figure 3).
- pH values fell below the CCME protection of Aquatic Life Guidelines for most of the deployment period. During deployment QA/QC ranking for the pH sensor was 'fair' with a field value of 6.38 compared to the QA/QC sonde value of 5.82, and the grab sample value of 6.75 (Appendix B). The pH never acclimatized to the grab sample value.
- Upon removal the QA/QC ranking for the pH sensor was 'marginal' with a field value of 5.67 compared to the QA/QC sonde value of 6.04, and the grab sample value of 6.69 (Appendix B).
- The pH values at this station are naturally low.

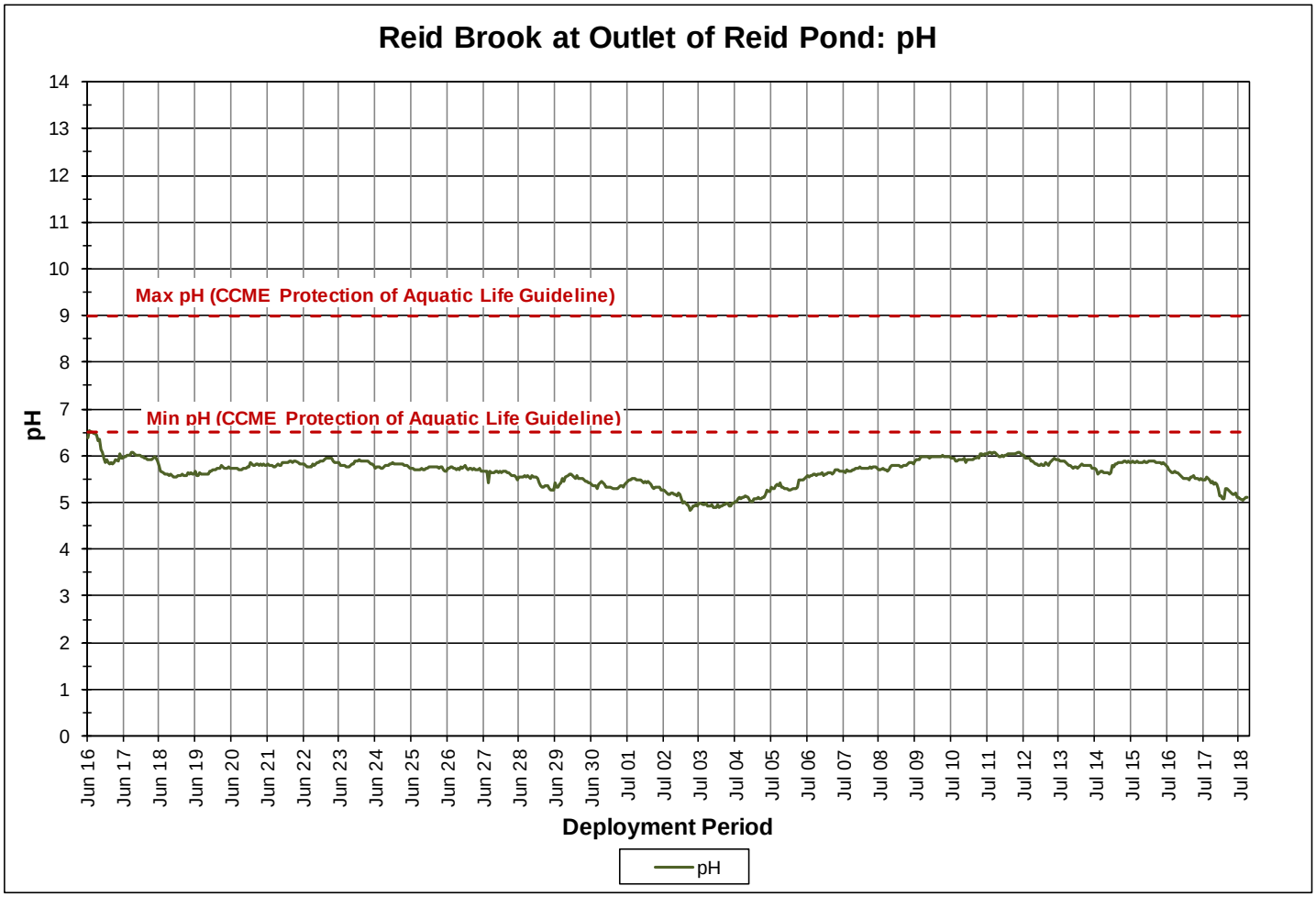

Figure 3: pH at Reid Brook at Outlet of Reid Pond

Specific Conductivity

- Specific conductance ranges between 11.0µS/cm to 12.0µS/cm, with a median value of 12.0µS/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.

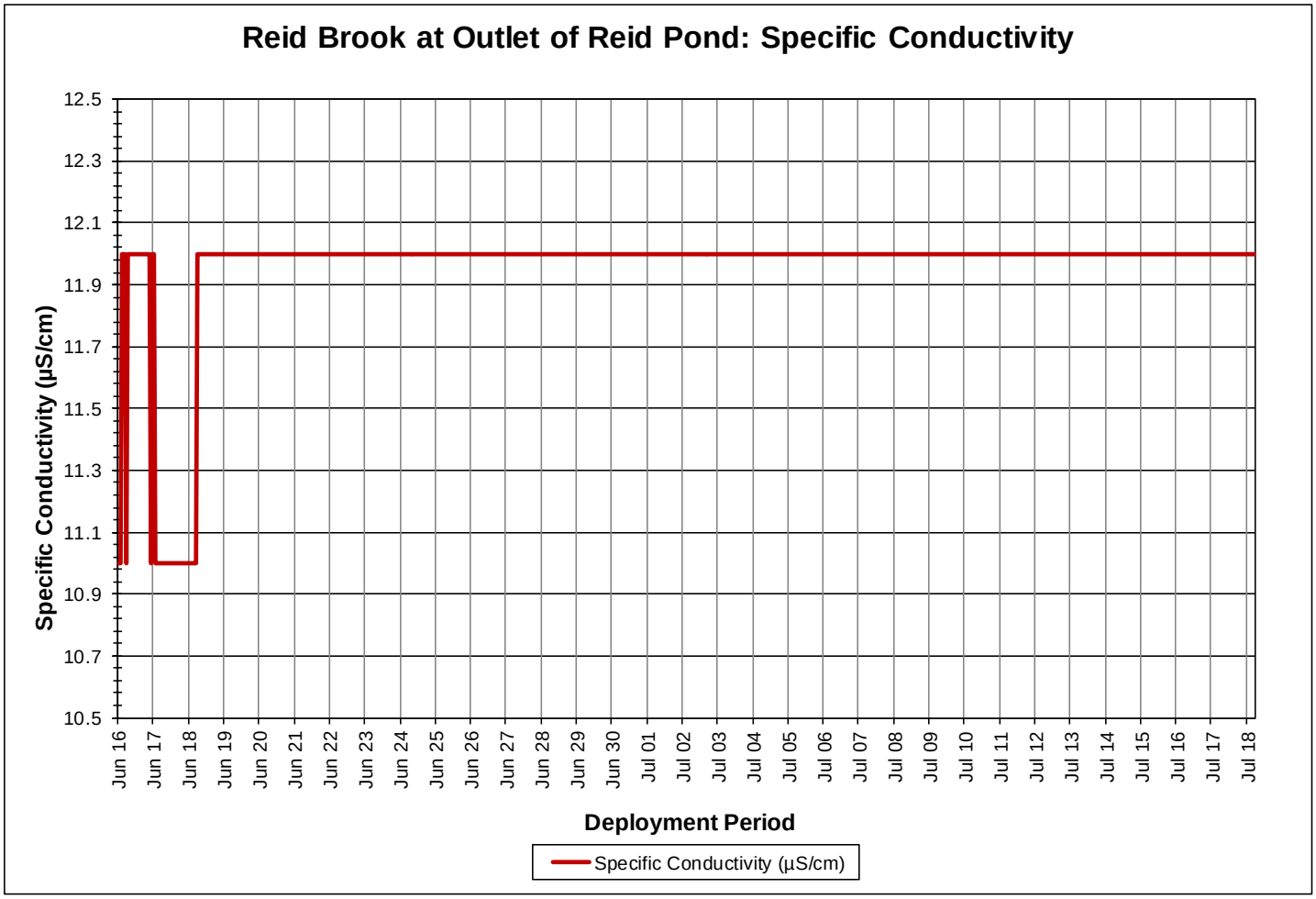

Figure 4: Specific Conductivity at Reid Brook at Outlet of Reid Pond

Dissolved Oxygen

- The dissolved oxygen sensor on this instrument was damaged therefore no dissolved oxygen data is available for this deployment period. When the instrument was retrieved, it was sent to St. John's for the necessary repairs.

Turbidity

- Turbidity ranges from 0.0NTU to 0.2NTU, 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.

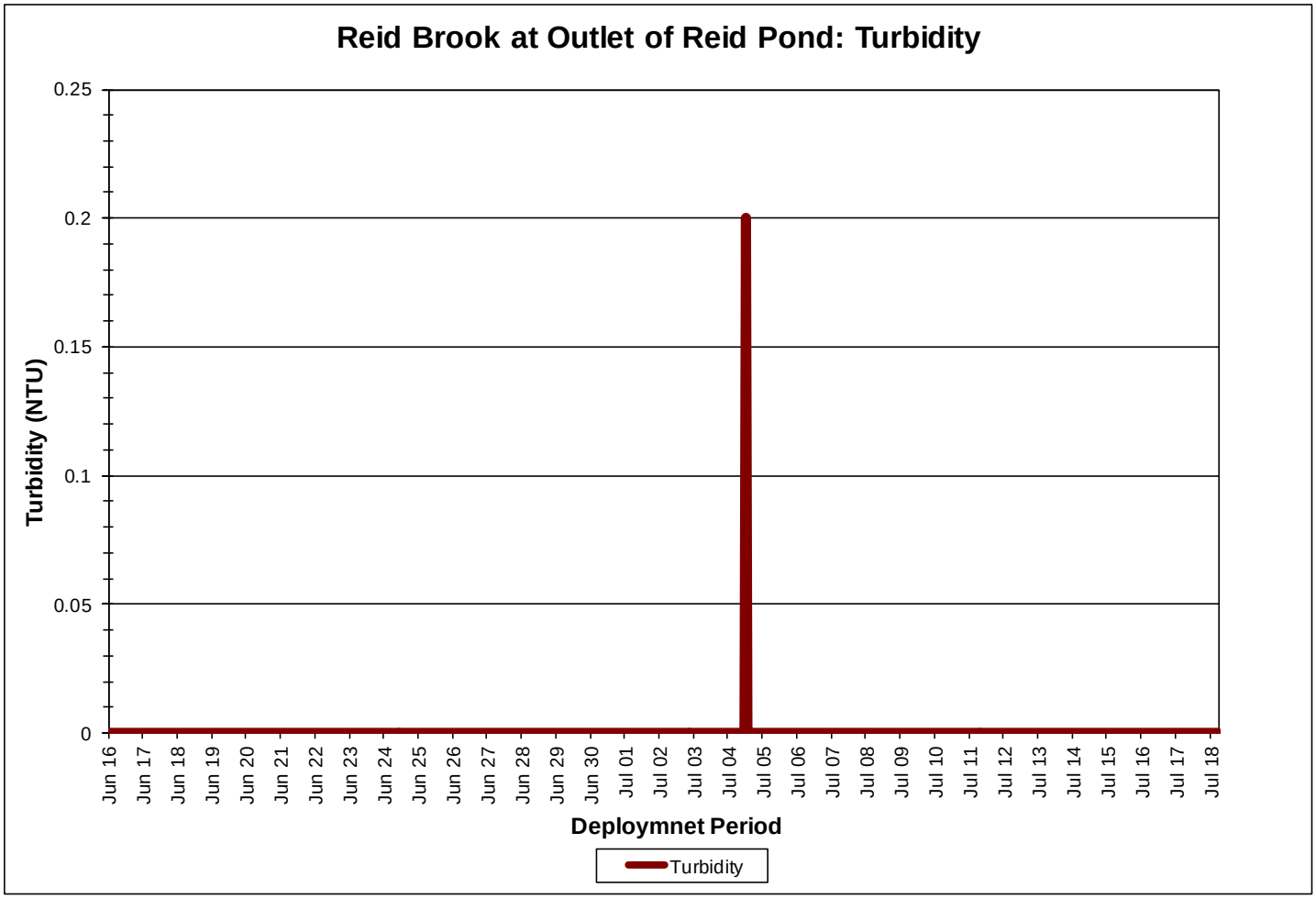

Figure 5: Turbidity at Reid Brook at Outlet of Reid Pond

Stage, Flow & Precipitation

- Due to transmission errors during this deployment no stage or flow data was available.
- 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 Environment Canada weather station at Nain. The weather station is 30 km northeast of Voisey's Bay (Figure 6).
- Precipitation occurs on 21 days during the deployment period and amounts are small in magnitude, with the exception of the largest on July 8th with 40.4mm of rain.

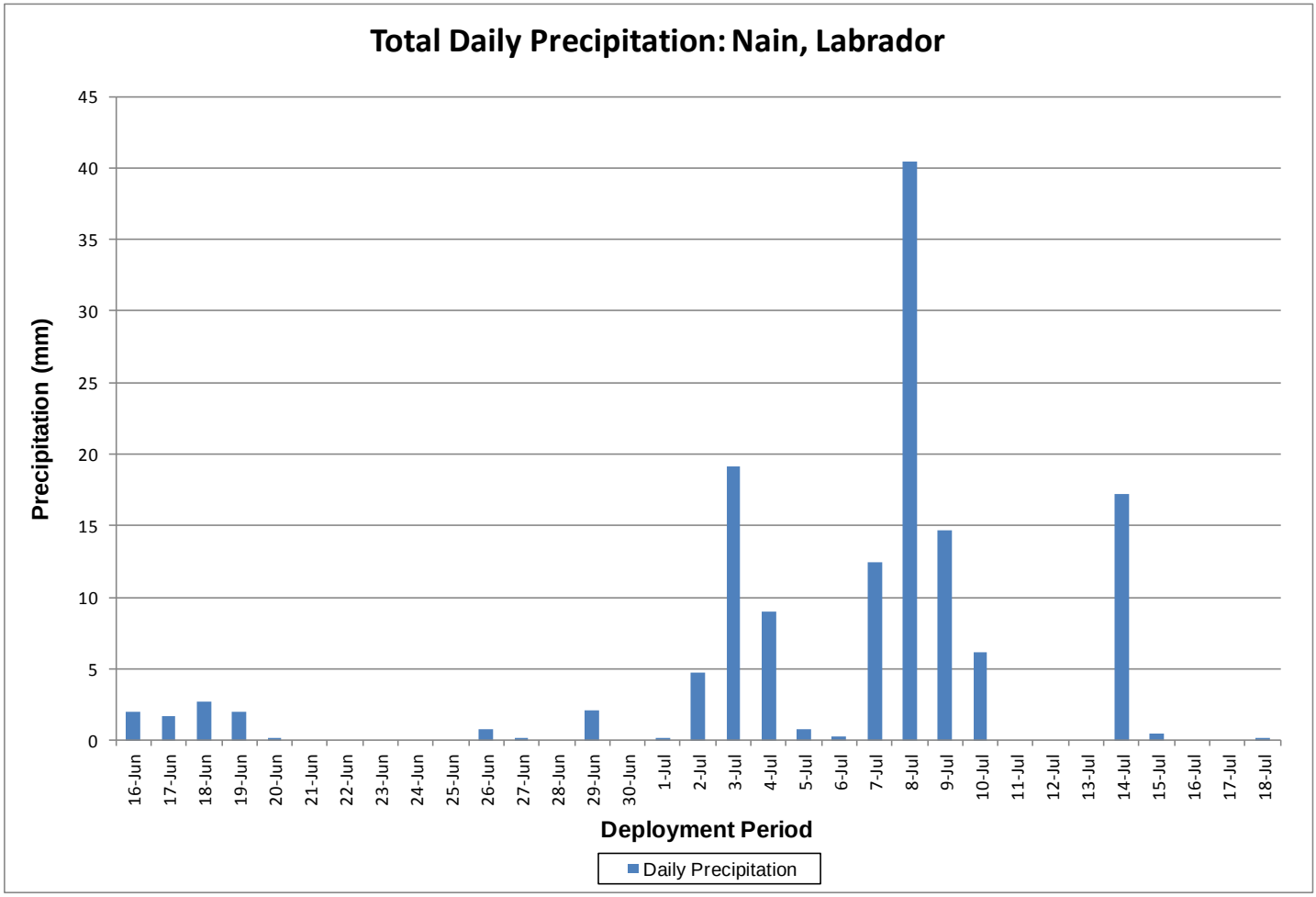

Figure 6: Total Daily Precipitation from Nain, Labrador Weather Station

Camp Pond Brook

Water Temperature

- Water temperature ranges from 8.97 °C to 21.70 °C, with a median value of 12.71°C (Figure 7).
- Water temperature is gradually increasing throughout the deployment period. This trend is expected as the air temperatures warm in the spring and summer months.
- This stream is sensitive to changes in the ambient air temperature and fluctuates considerable 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.

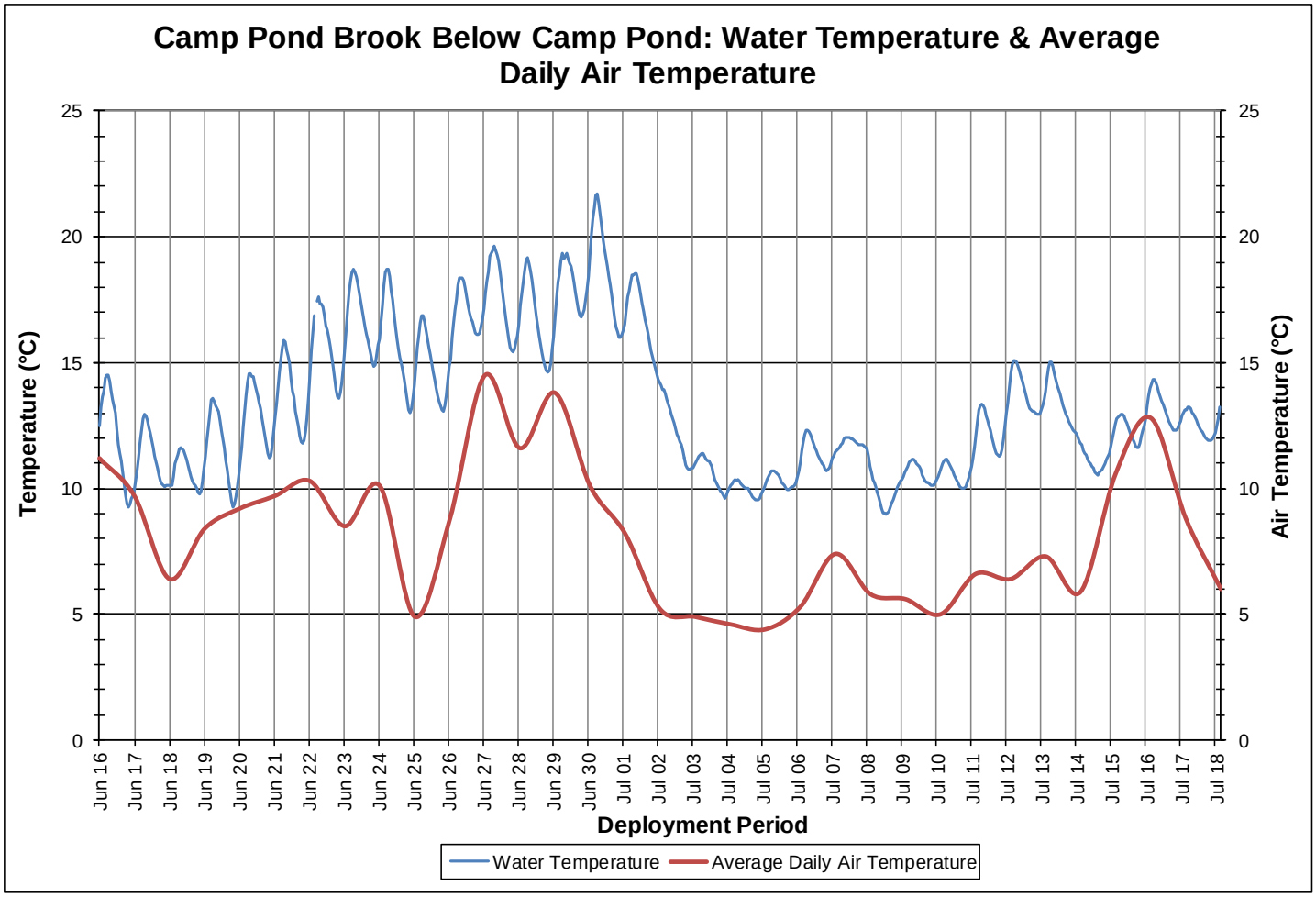

Figure 7: Water Temperature & Daily Average Air Temperature at Camp Pond Brook below Camp Pond

pH

- pH ranges from 6.21 to 6.95 pH units, with a median value of 6.71 (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 or below the lower CCME guidelines of 6.5 pH units.

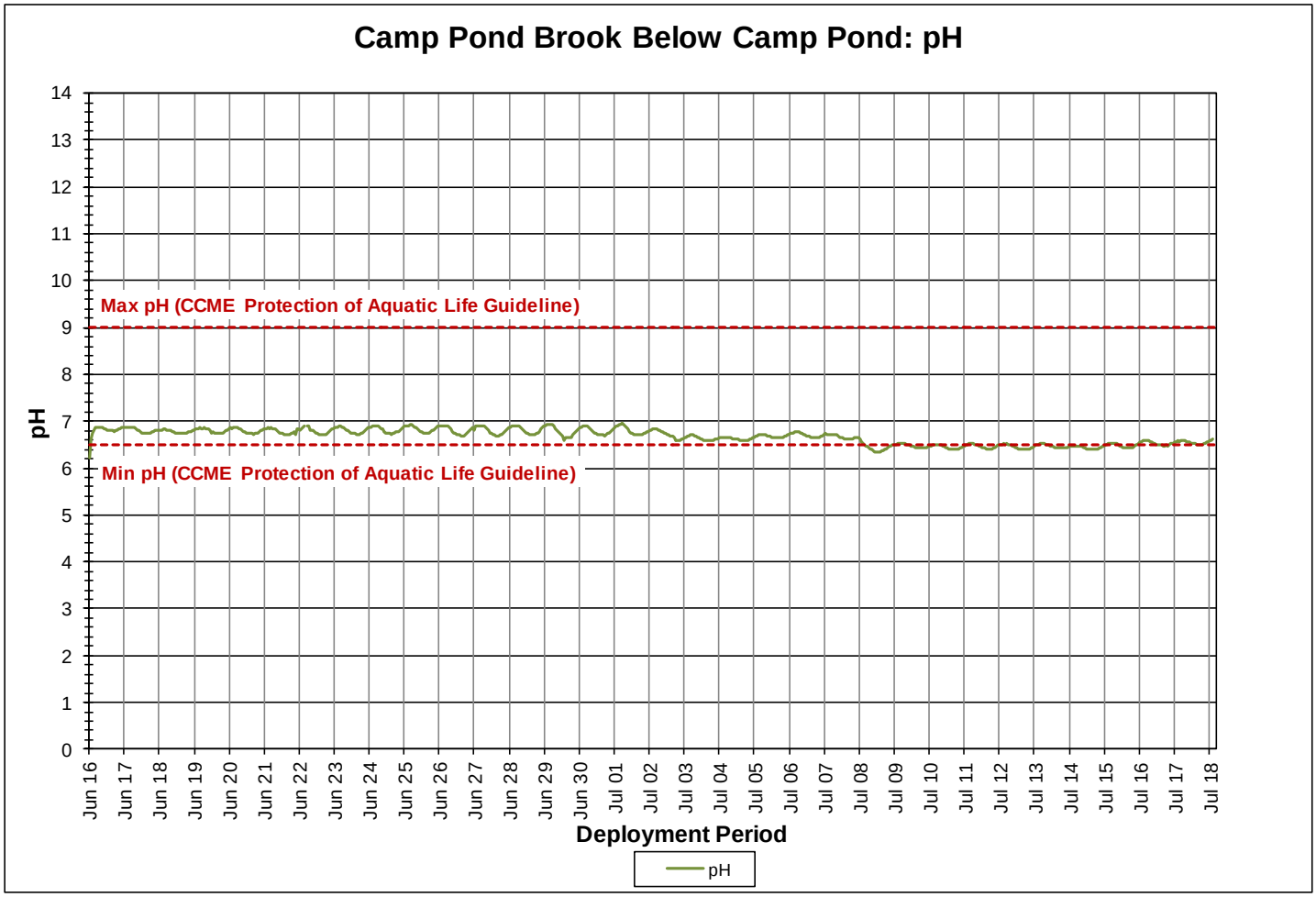

Figure 8: pH at Camp Pond Brook below Camp Pond

Specific Conductivity

- Specific conductivity ranges from 30.3µS/cm to 48.2µS/cm with a median of 35.1µS/cm. (Figure 9).
- Total Dissolved Solids (TDS) ranges between 0.0194 g/mL to 0.0308 g/mL during the deployment period, with a median of 0.0024 g/mL (Figure 10).
- 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)
- The relationship between conductivity and stage at this station is inversed at the beginning of the deployment. 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 9). However it should be noted on July 8th a significant rainfall of 40.4 mm occurred and increased both the stage and conductivity at this station.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

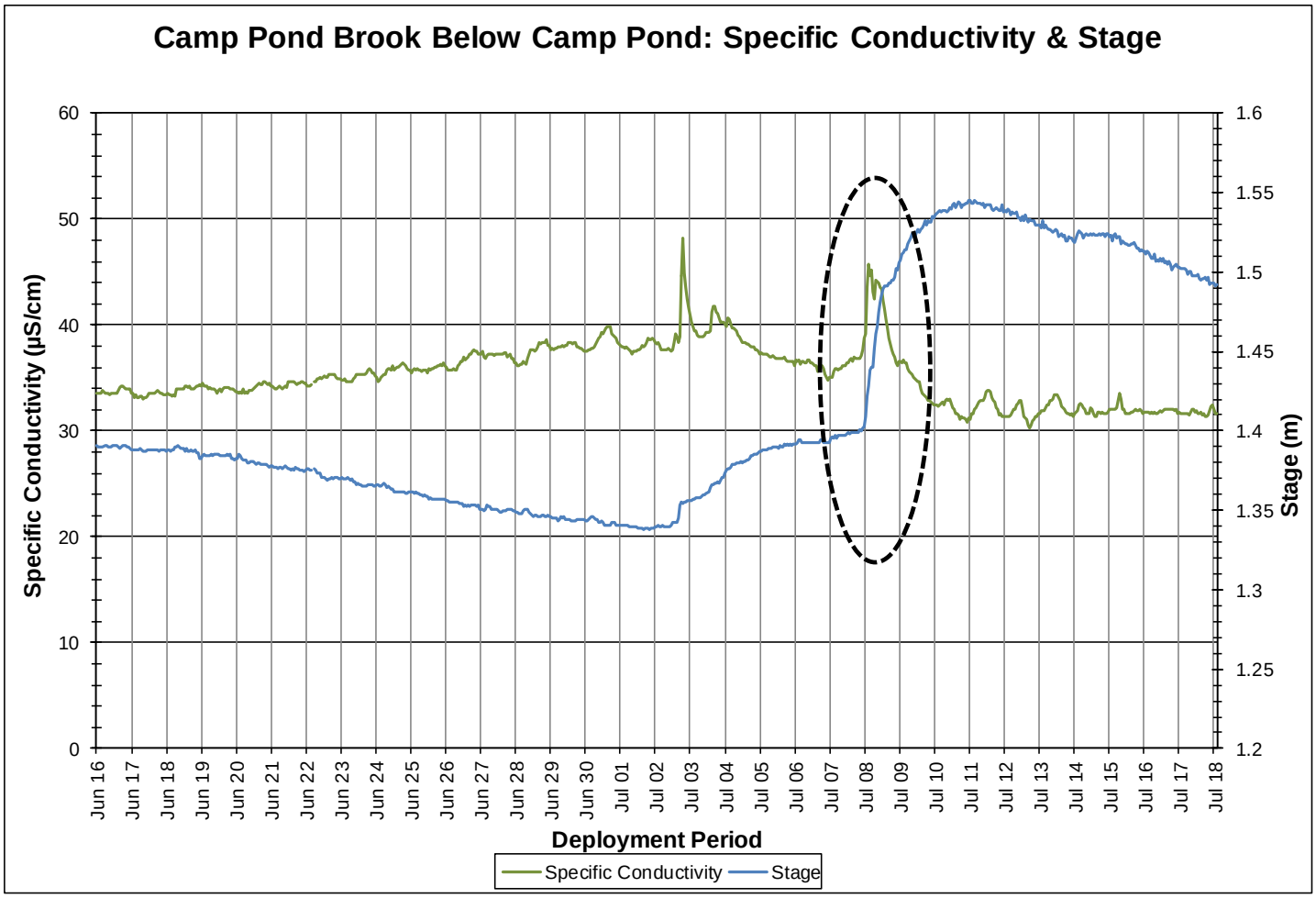

Figure 9: Specific Conductivity & Stage at Camp Pond Brook below Camp Pond

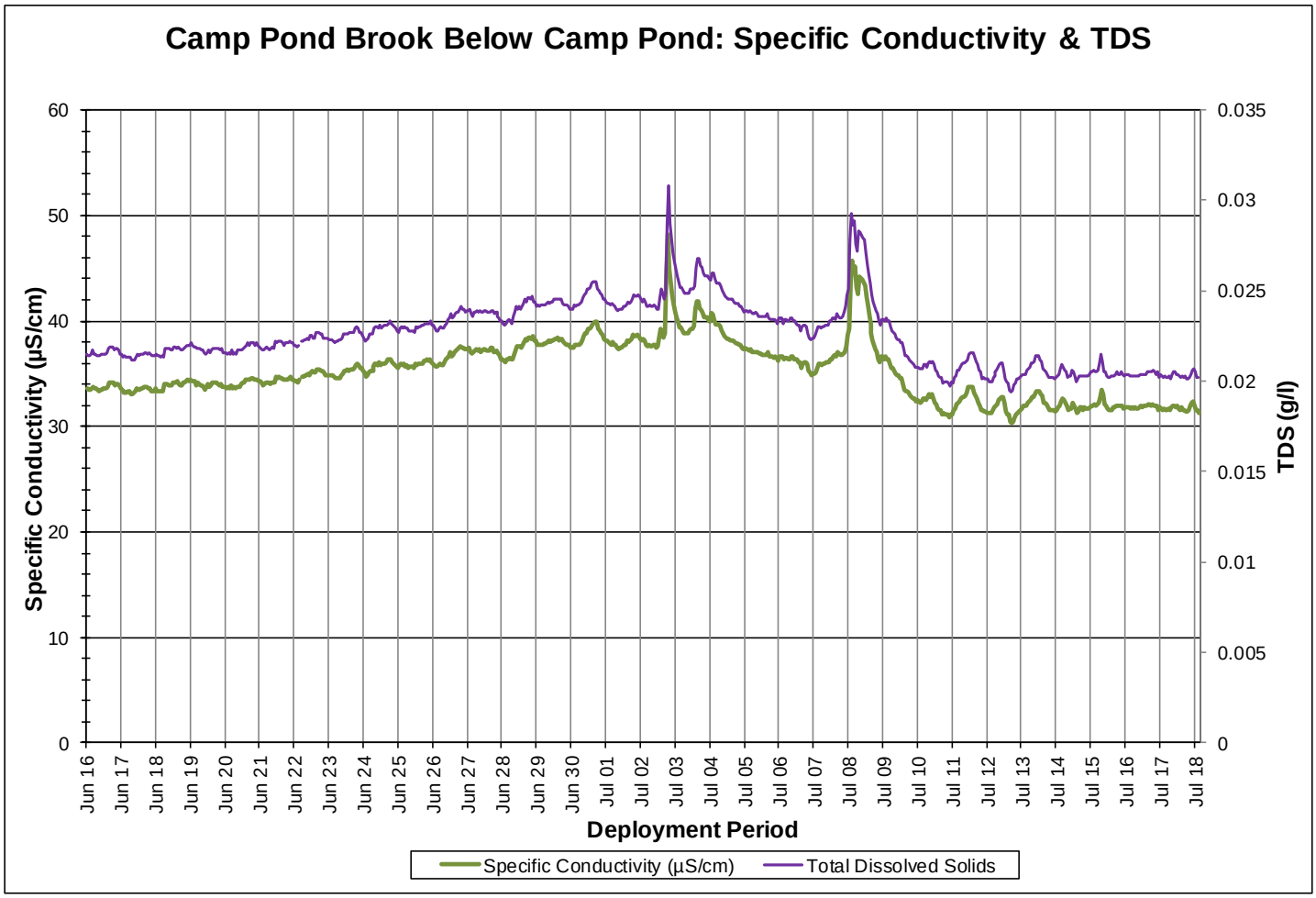

Figure 10: Specific Conductivity & TDS at Camp Pond Brook below Camp Pond

Dissolved Oxygen (mg/L & % Saturation)

- Dissolved oxygen content ranges between 8.51mg/l and 11.10mg/l during the deployment period. The saturation of dissolved oxygen ranges from 90.3% to 102.2% (Figure 11).
- 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 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 11). This is expected as water temperature directly influences the level of dissolved oxygen present in the water column.

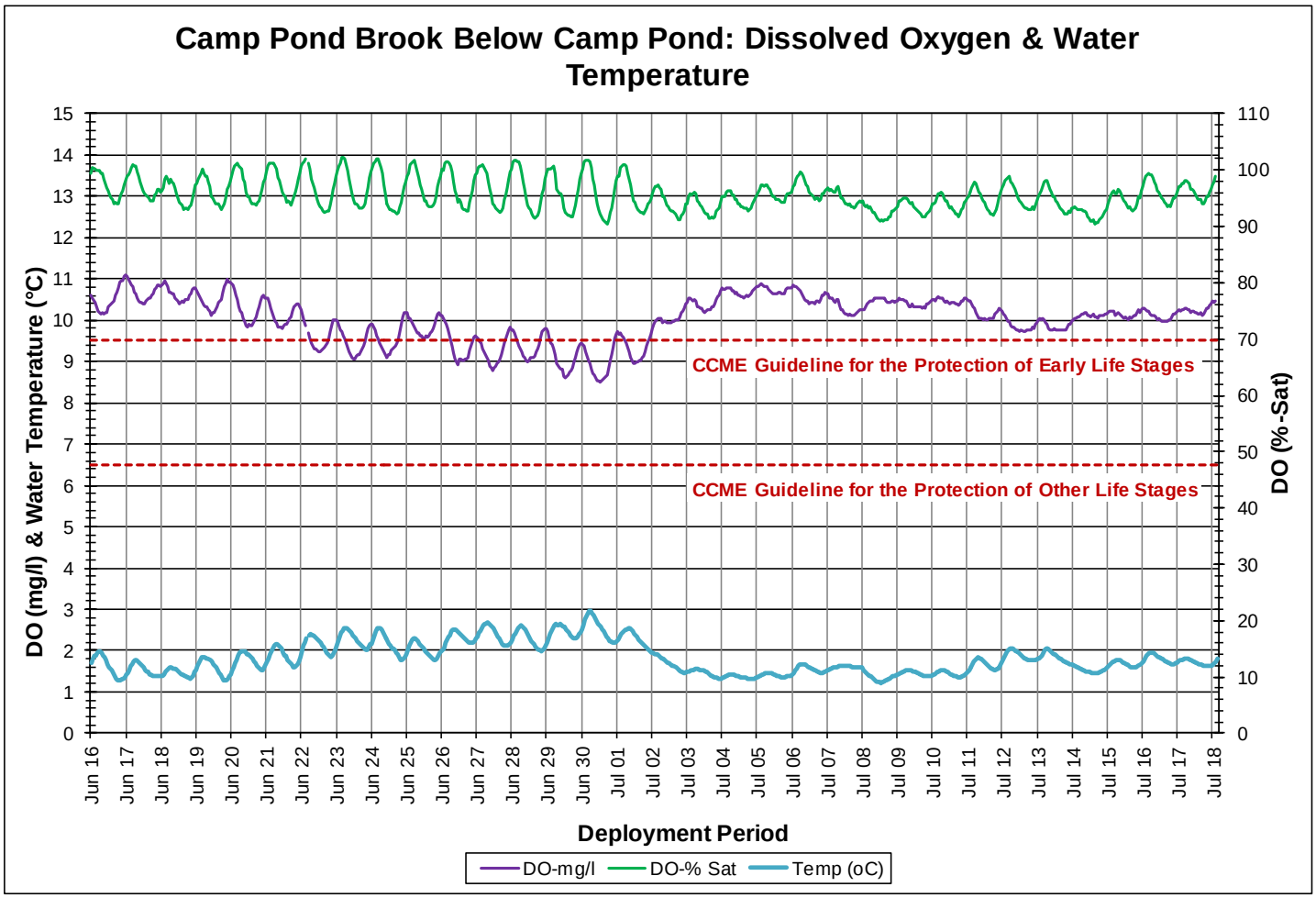

Figure 11: Dissolved Oxygen & Water Temperature at Camp Pond Brook below Camp Pond

Turbidity

- Turbidity ranges from 0.0NTU to 31.5NTU during the deployment period, with a median value of 0.9NTU (Figure 12).
- A median value of 0.9 NTU indicates there is very little natural background turbidity at this station during this deployment period.
- There are a number of low - medium 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 12, 13).
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

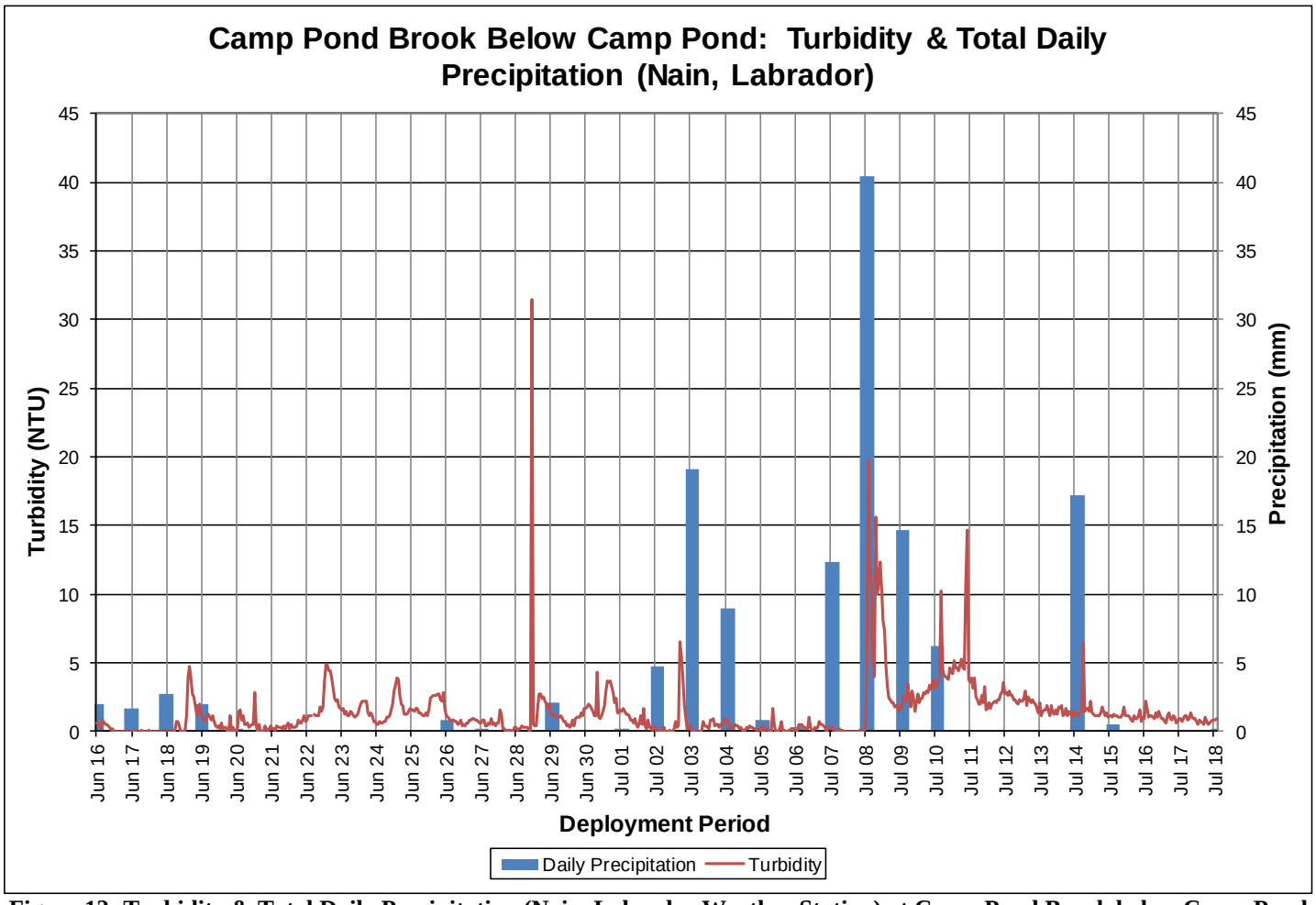

Figure 12: Turbidity & Total Daily Precipitation (Nain, Labrador Weather Station) at Camp Pond Brook below Camp Pond

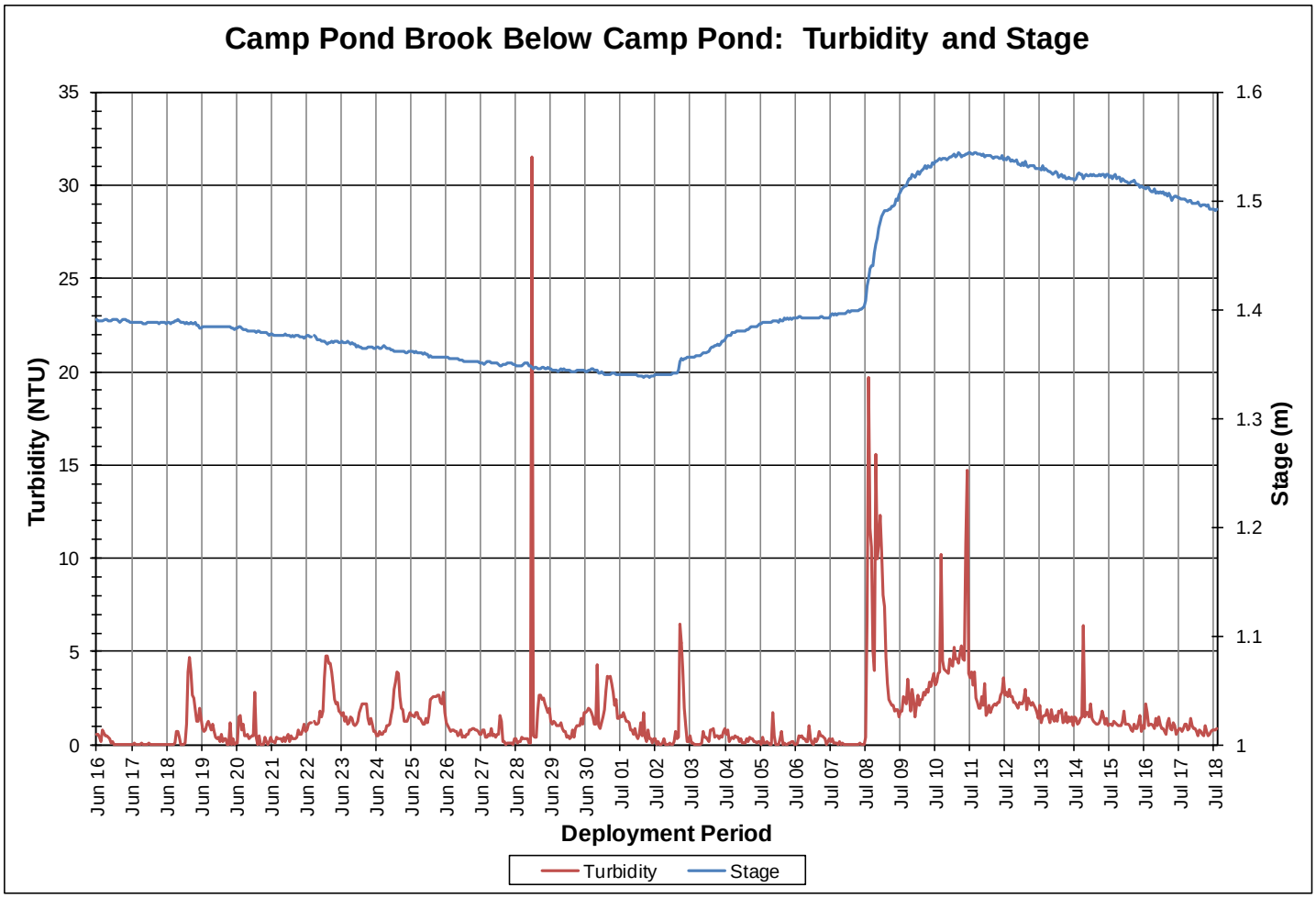

Figure 13: Turbidity & Stage at Camp Pond Brook below Camp Pond

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 Environment Canada weather station at Nain. The weather station is 30 km northeast of Voisey's Bay (Figure 14).
- Precipitation occurs on 21 days during the deployment period and amounts are small in magnitude, with the exception of the largest on July 8th with 40.4mm of rain.
- During the deployment period, the stage values ranged from 1.34m to 1.55m. Streamflow had a minimum amount of 0.15m^3/s and a maximum flow of 1.22m^3/s.
- Stage, Streamflow and precipitation are graphed below to show the relationship between rainfall and water level (Figure 14). It is evident that the peaks in stage (m) and streamflow data are a result of precipitation.

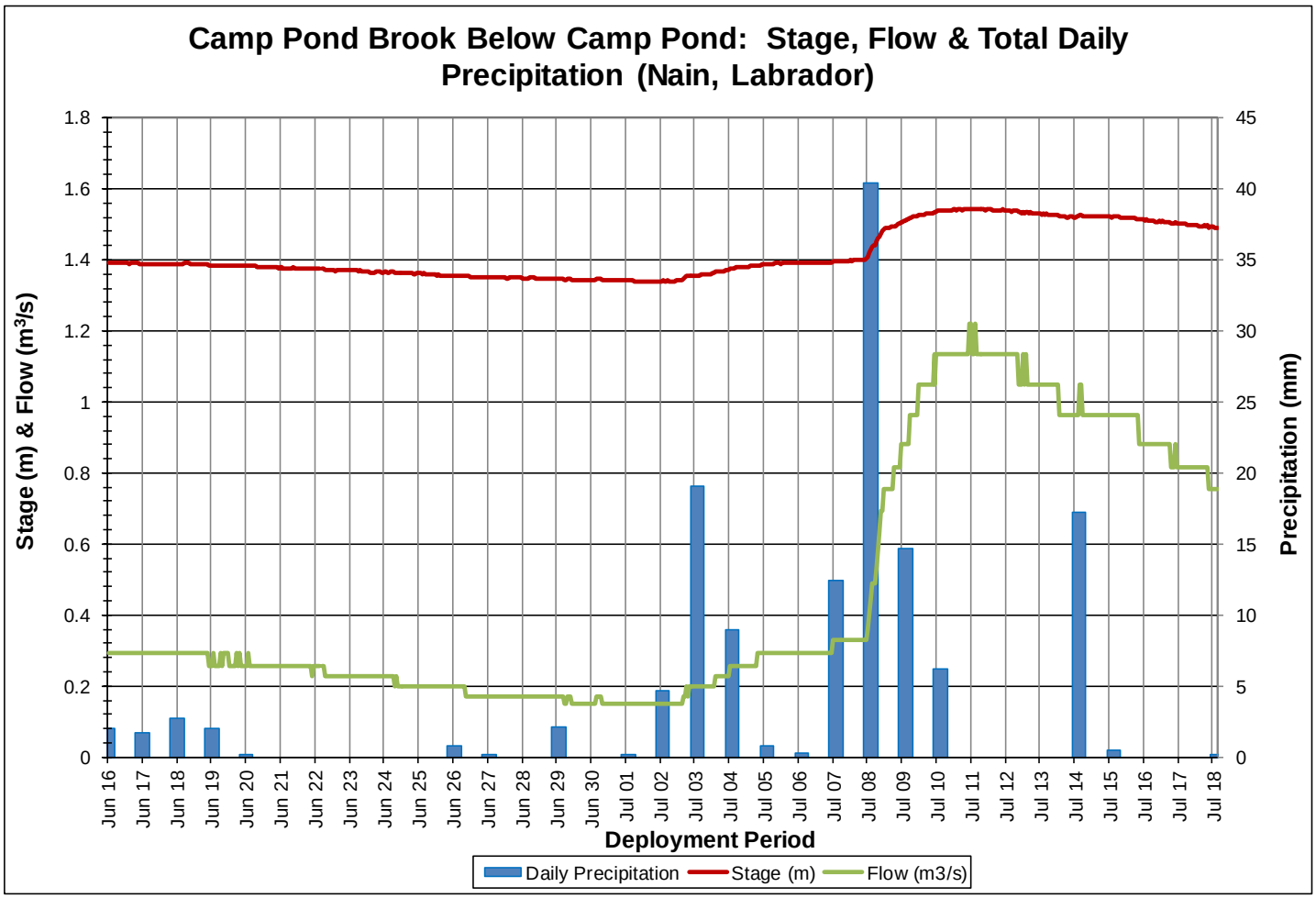

Figure 14: Stage, Flow, and Total Daily Precipitation (Nain, Labrador Weather Station) at Camp Pond Brook below Camp Pond

Tributary to Lower Reid Brook

Water Temperature

- Water temperature ranges from 6.60 °C to 14.50 °C, with a median value of 9.90°C (Figure 15).
- 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.

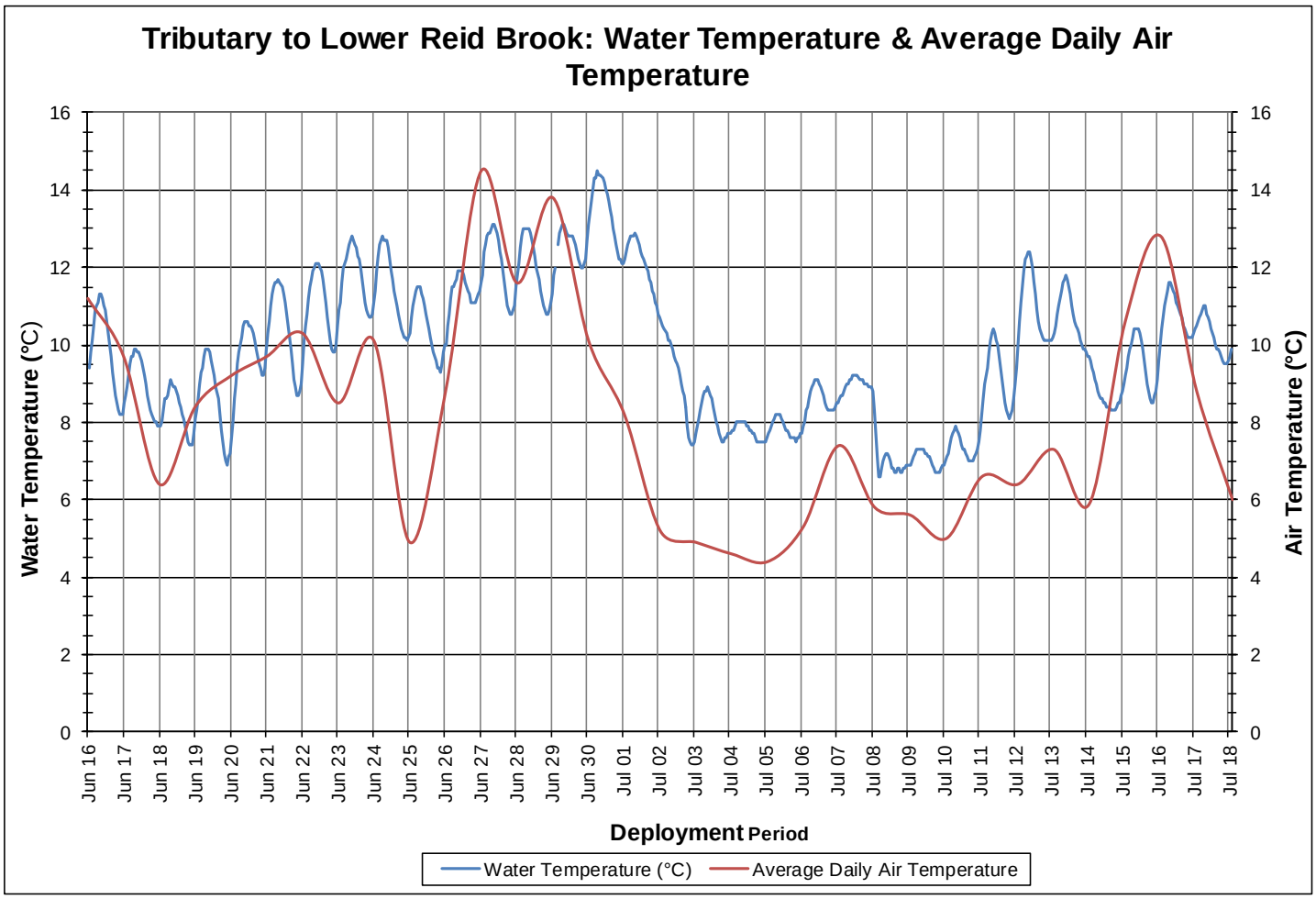

Figure 15: Water Temperature & Average Daily Air Temperature at Tributary to Lower Reid Brook

pH

- pH ranges from 5.66 to 6.98 pH units, with a median value of 6.77 (Figure 16).
- For the majority of this deployment period the pH data remains stable. There is a relationship between pH and stage level, this is evident as stage levels increase the pH values drop slightly as a response. This is a natural reaction between these two parameters. During June the pH levels remain just above the minimum CCME guideline. After July 2nd the pH remains just below the minimum CCME guideline. 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.

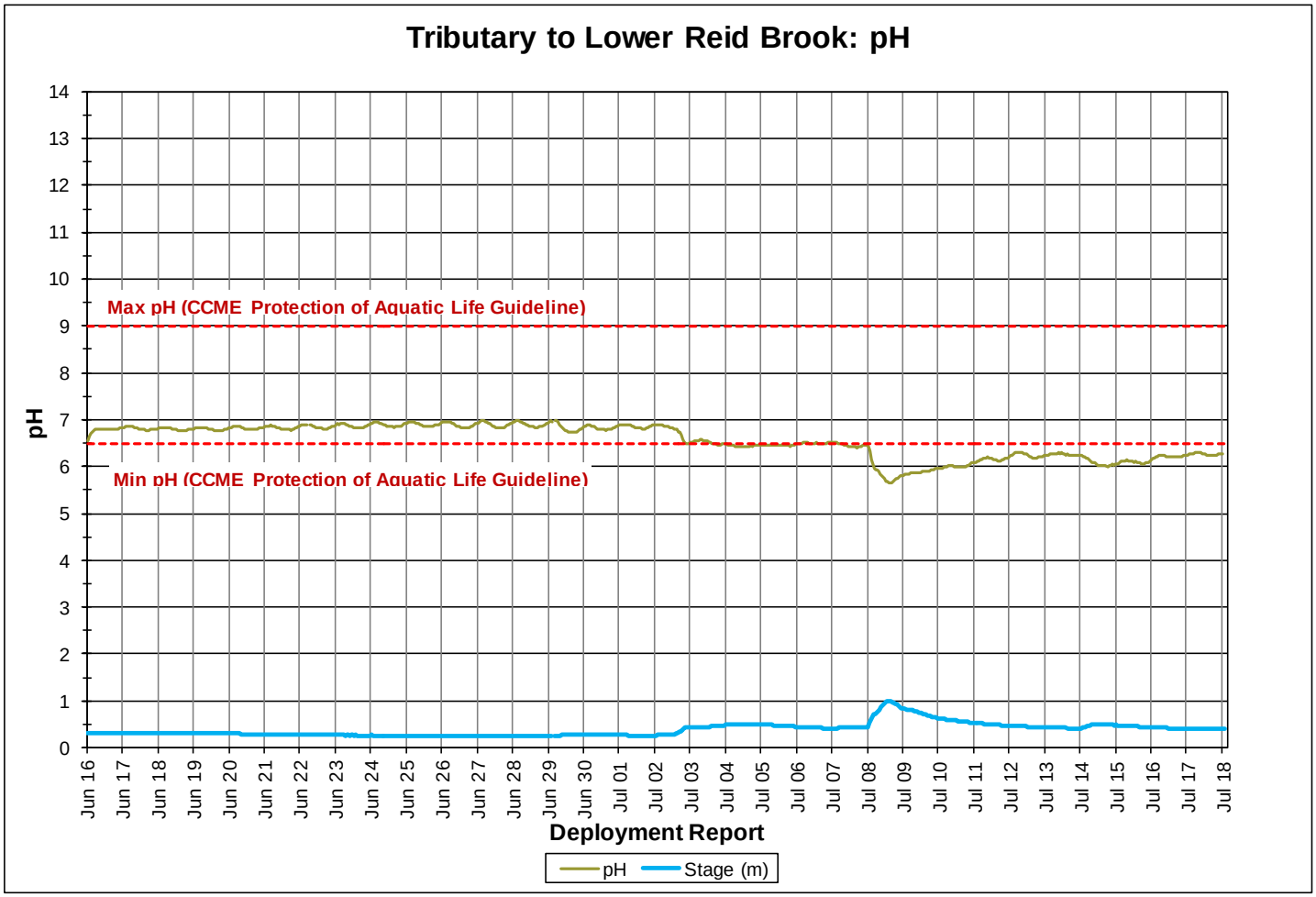

Figure 16: pH & Water Temperature at Tributary to Lower Reid Brook

Specific Conductivity

- Specific conductivity ranges from 16.6µS/cm to 38.1µS/cm with a median of 30.1µS/cm. (Figure 17).
- TDS ranges between 0.0106 g/mL to 0.0244 g/mL during the deployment period, with a median of 0.0193g/mL (Figure 18).
- 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 18)
- 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 17).
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request

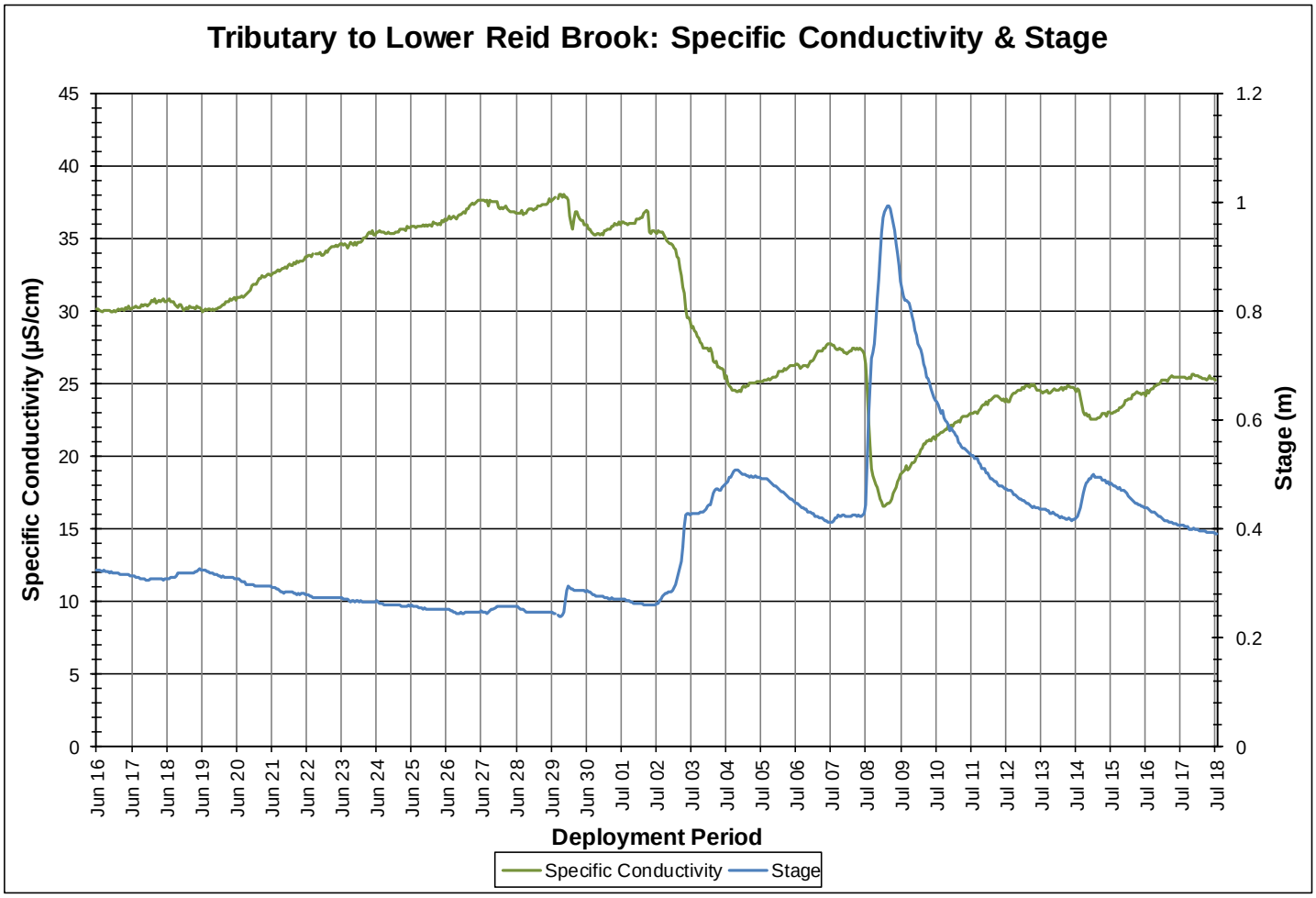

Figure 17: Specific Conductivity & Stage at Tributary to Lower Reid Brook

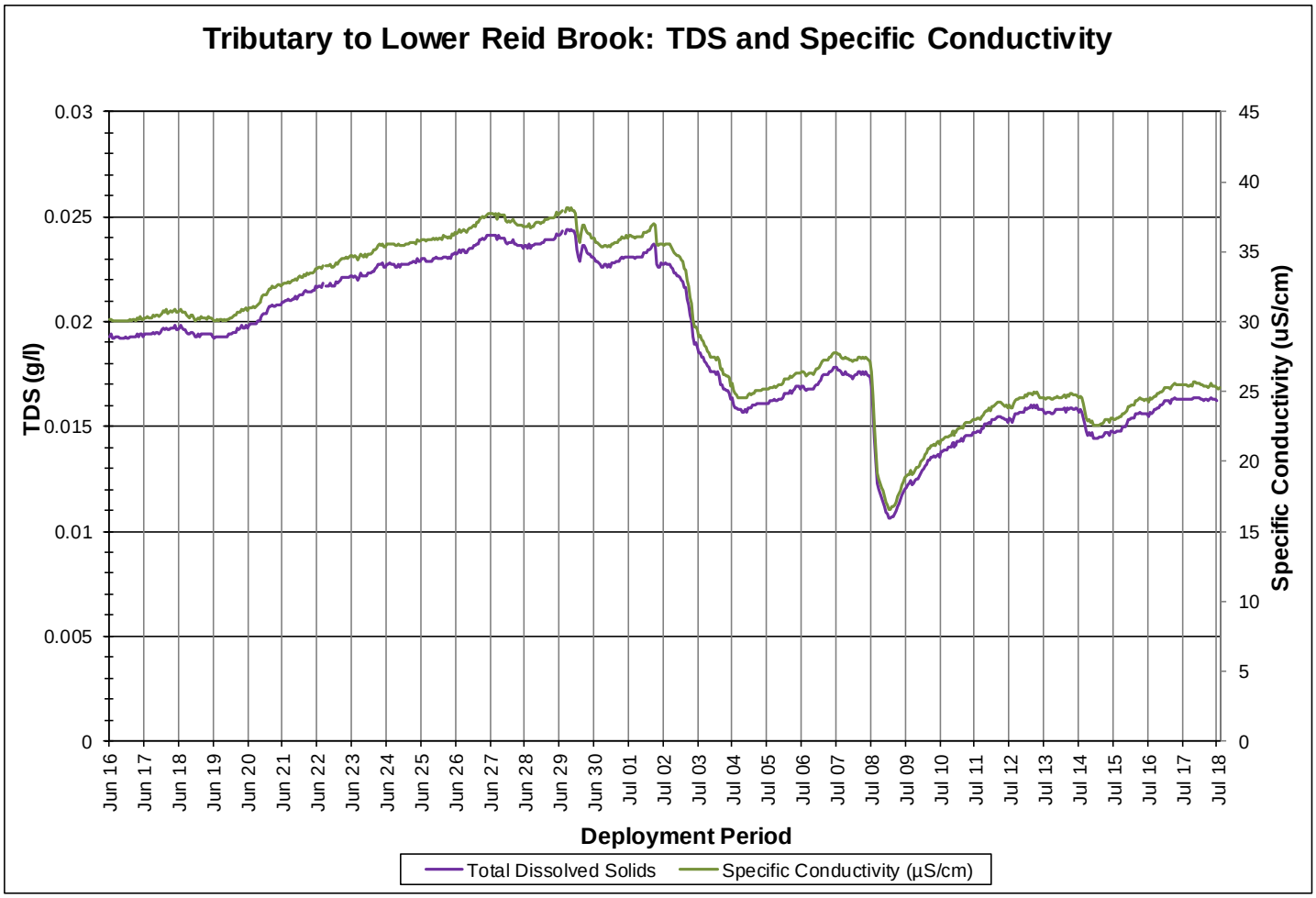

Figure 18: Specific Conductivity & TDS at Tributary to Lower Reid Brook

Dissolved Oxygen

- Dissolved oxygen content ranges between 9.63mg/l and 11.68mg/l during the deployment period. The saturation of dissolved oxygen ranges from 91.6% to 98.8% (Figure 19).
- 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 both CCME guidelines for the protection of early/other life stages.

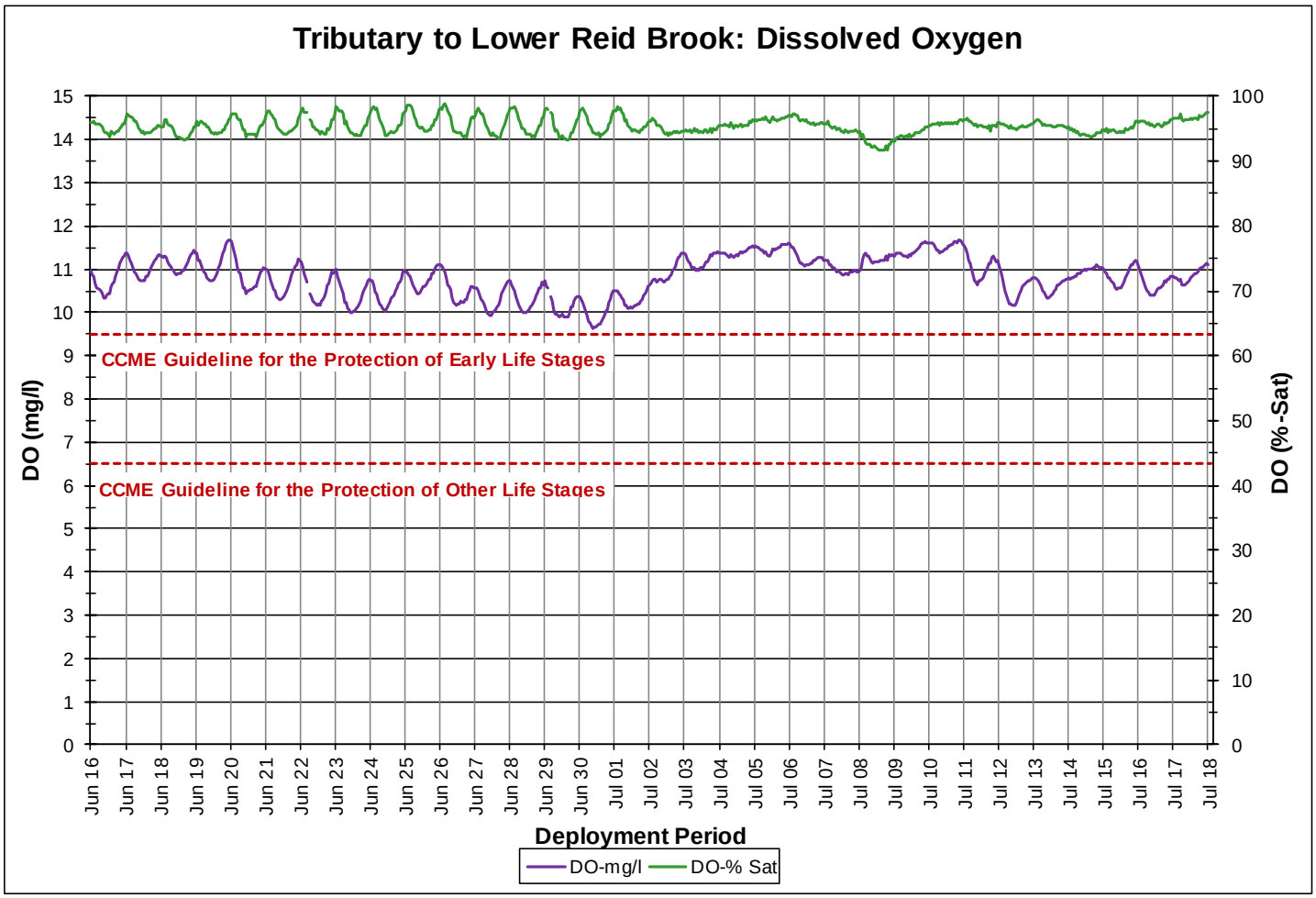

Figure 19: Dissolved Oxygen at Tributary to Lower Reid Brook

Turbidity

- Turbidity ranges from 0.0NTU to 191.5NTU during the deployment period, with a median value of 1.5NTU (Figure 20).
- A median value of 1.5 NTU indicates there is very little natural background turbidity at this station during this deployment period.
- There are a number of low - medium 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 20, 21).
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

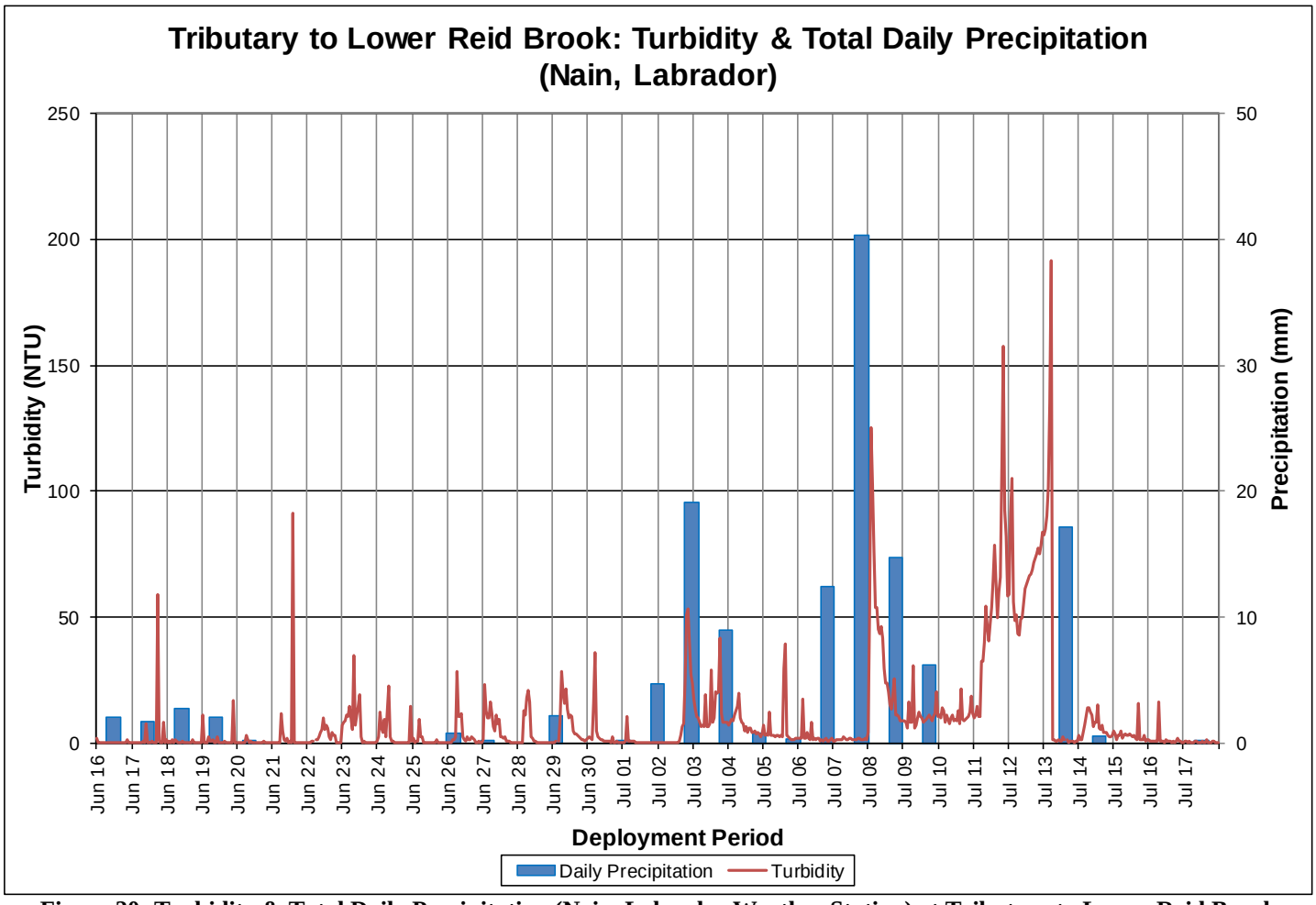

Figure 20: Turbidity & Total Daily Precipitation (Nain, Labrador Weather Station) at Tributary to Lower Reid Brook

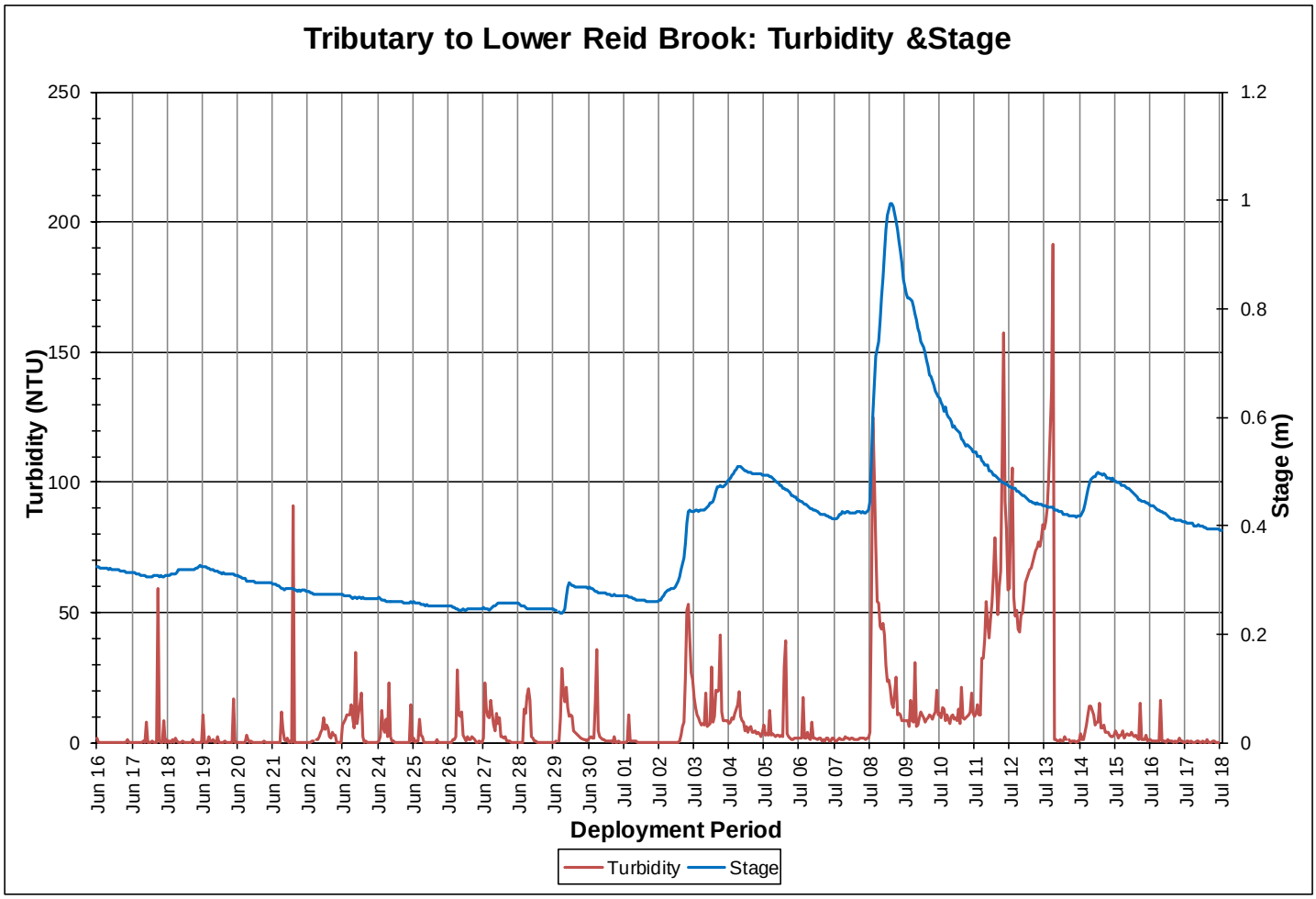

Figure 21: Turbidity & Stage at Tributary to Lower Reid Brook

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 Environment Canada weather station at Nain. The weather station is 30 km northeast of Voisey's Bay (Figure 22).
- Precipitation occurs on 21 days during the deployment period and amounts are small in magnitude, with the exception of the largest on July 8th with 40.4mm of rain.
- During the deployment period, the stage values ranged from 0.24m to 0.99m. Streamflow had a minimum amount of 0.057m^3/s and a maximum flow of 3.5m^3/s.
- Stage, Streamflow and precipitation are graphed below to show the relationship between rainfall and water level (Figure 22). It is evident that the peaks in stage (m) and streamflow data are a result of precipitation.

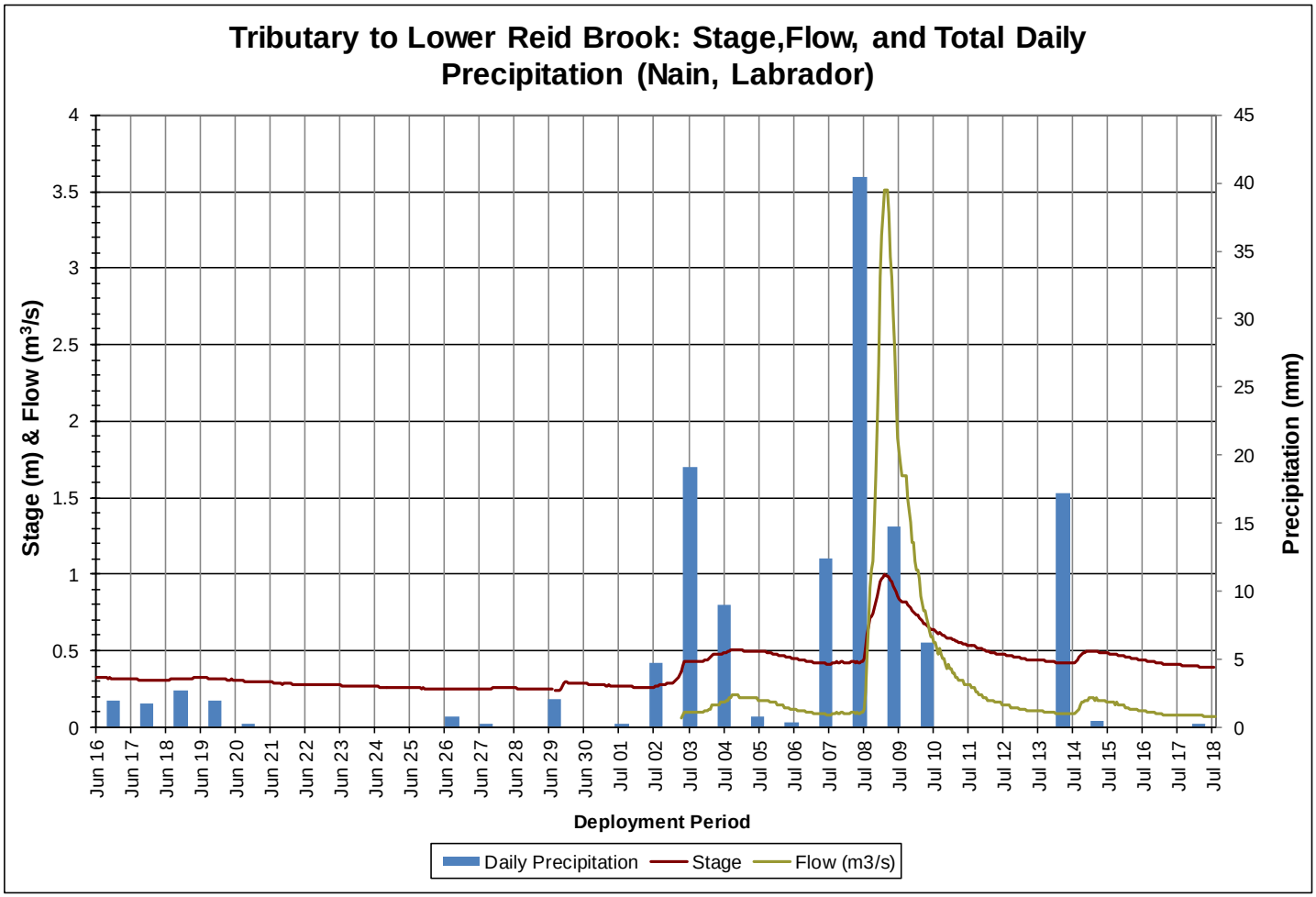

Figure 22: Stage, Flow, and Total Daily Precipitation (Nain, Labrador Weather Station) at Tributary to Lower Reid Brook

Lower Reid Brook below Tributary

Water Temperature

- Water temperature ranges from 6.83 °C to 16.11 °C, with a median value of 10.13°C (Figure 23).
- 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.

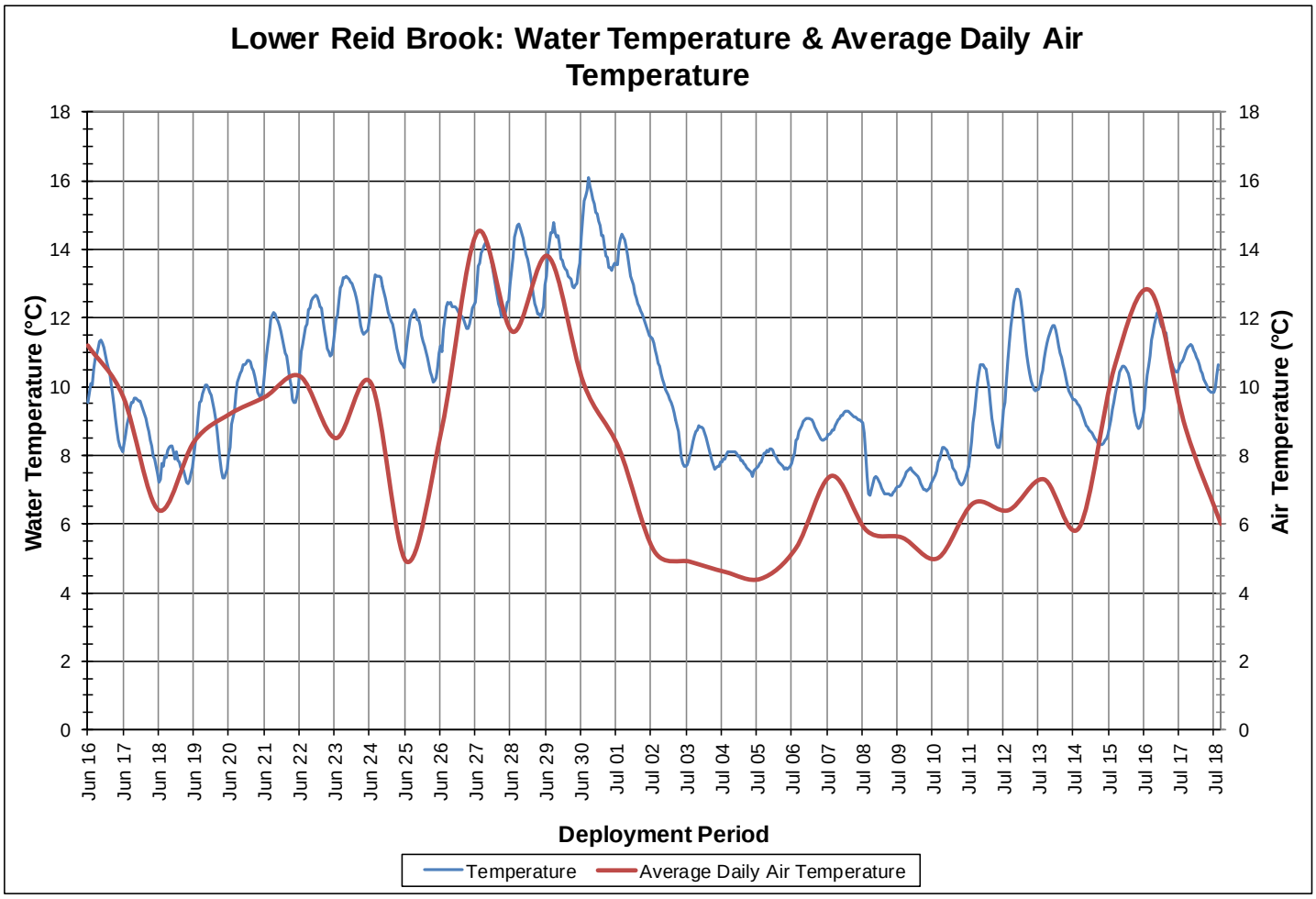

Figure 23: Water Temperature and Daily Average Air Temperature at Lower Reid Brook below Tributary

pH

- pH ranges from 6.90 to 9.80 pH units, with a median value of 7.86 (Figure 24).
- For the majority of this deployment period the pH data remains stable. Despite a couple of days in July, the pH levels remain between the CCME guideline. A significant rainfall and turbidity event around July 8th, 2015 appears to have influenced the pH values at that time. Another precipitation event occurring on July 14th, 2015 caused the pH to drop back into the CCME guideline range.
- 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.

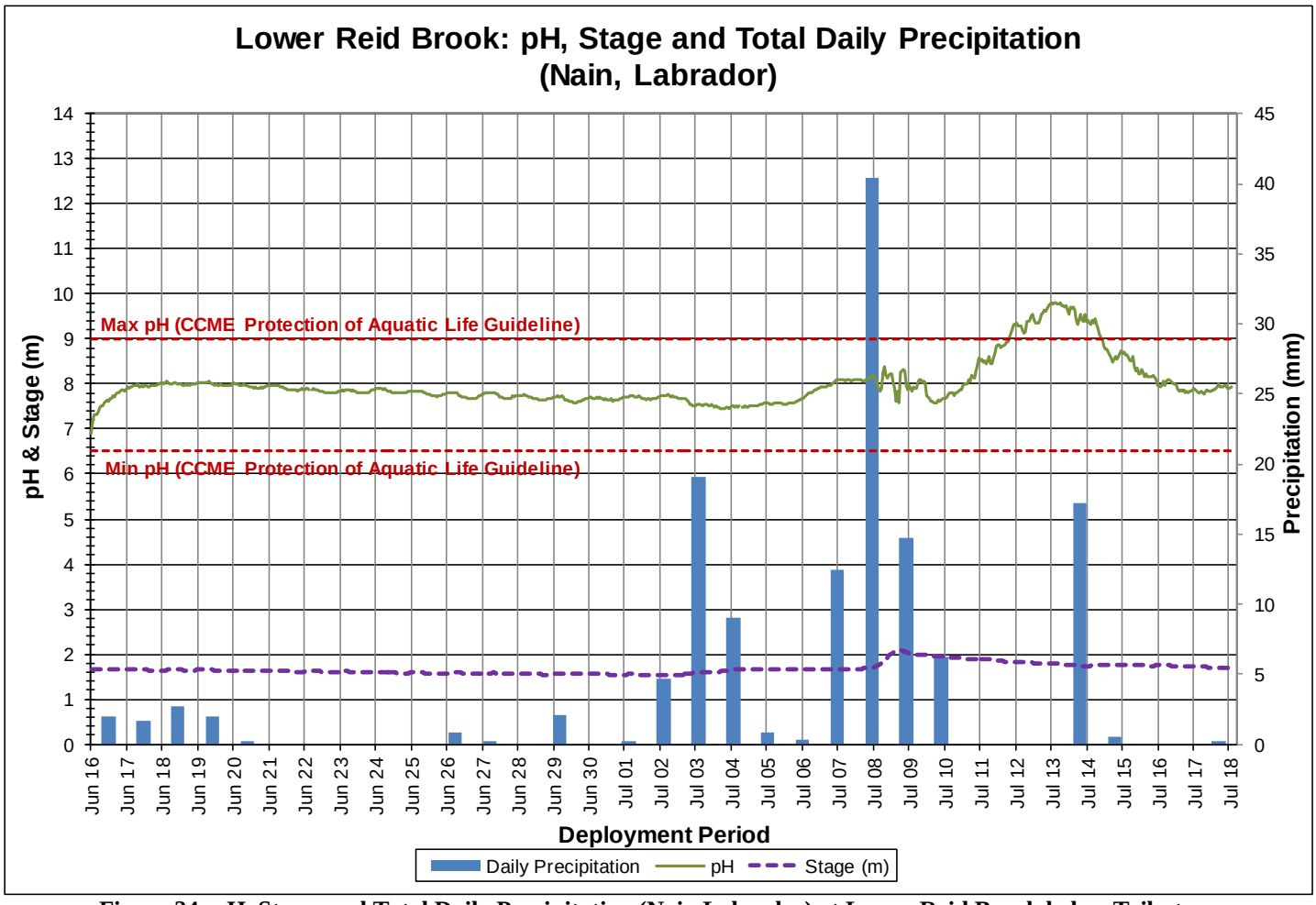

Figure 24: pH, Stage, and Total Daily Precipitation (Nain Labrador) at Lower Reid Brook below Tributary

Specific Conductivity

- Specific conductivity ranges from 15.7µS/cm to 31.3µS/cm with a median of 26.5µS/cm. (Figure 25).
- TDS ranges between 0.0101 g/mL to 0.0200 g/mL during the deployment period, with a median of 0.0170g/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 26)
- 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 25).
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request

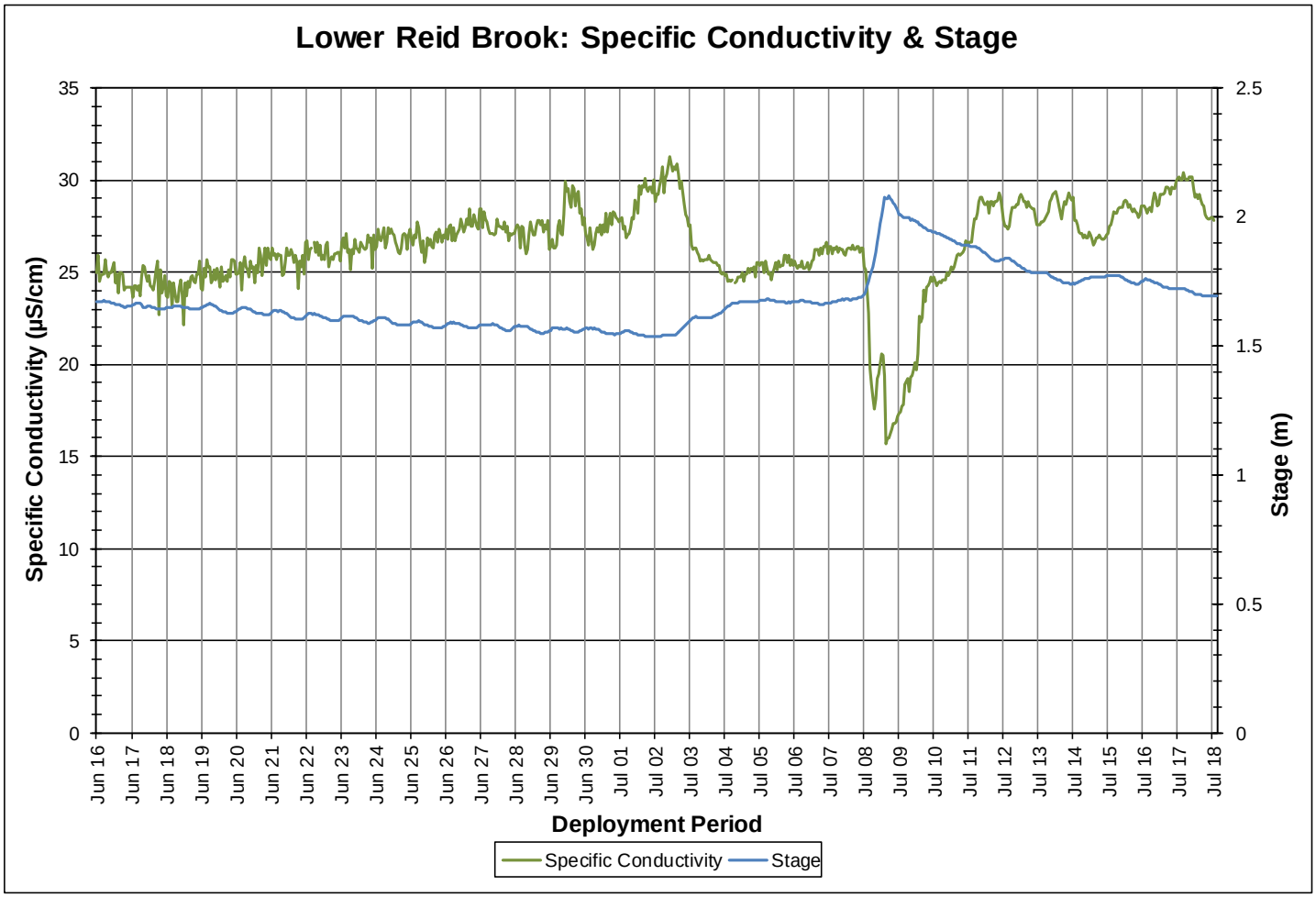

Figure 25: Specific Conductivity & Stage at Lower Reid Brook below Tributary

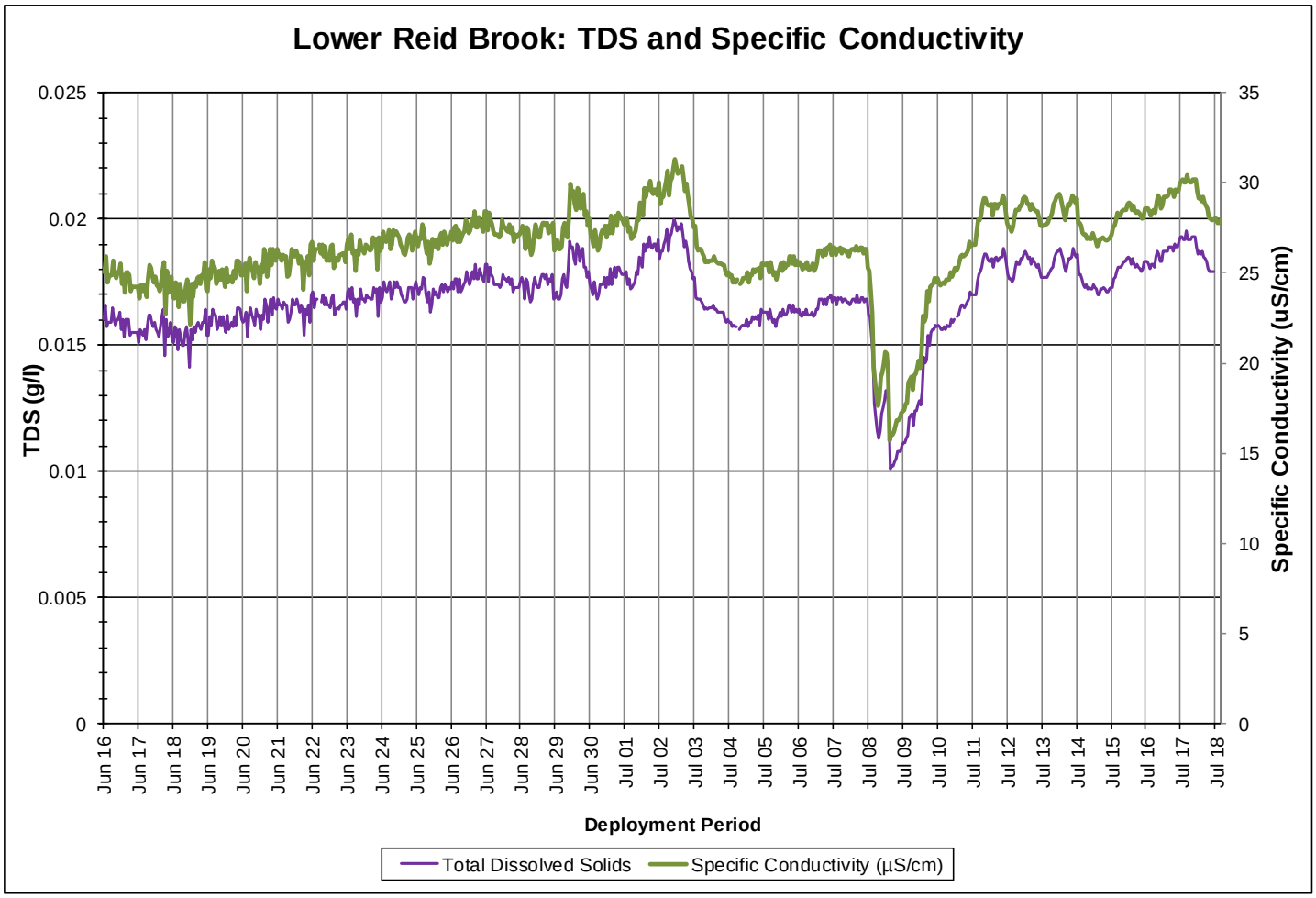

Figure 26: Specific Conductivity & TDS at Lower Reid Brook below Tributary

Dissolved Oxygen

- Dissolved oxygen content ranges between 9.44mg/l and 11.58mg/l during the deployment period. The saturation of dissolved oxygen ranges from 89.6% to 100.8% (Figure 27).
- 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 near or above the CCME guidelines for the protection of early/other life stages.
- The exception is on June 30th when dissolved oxygen fell below 9.5mg/L. This occurrence corresponds with the warmest water temperature during the deployment period (Figure 27). This is expected as water temperature directly influences the level of dissolved oxygen present in the water column.

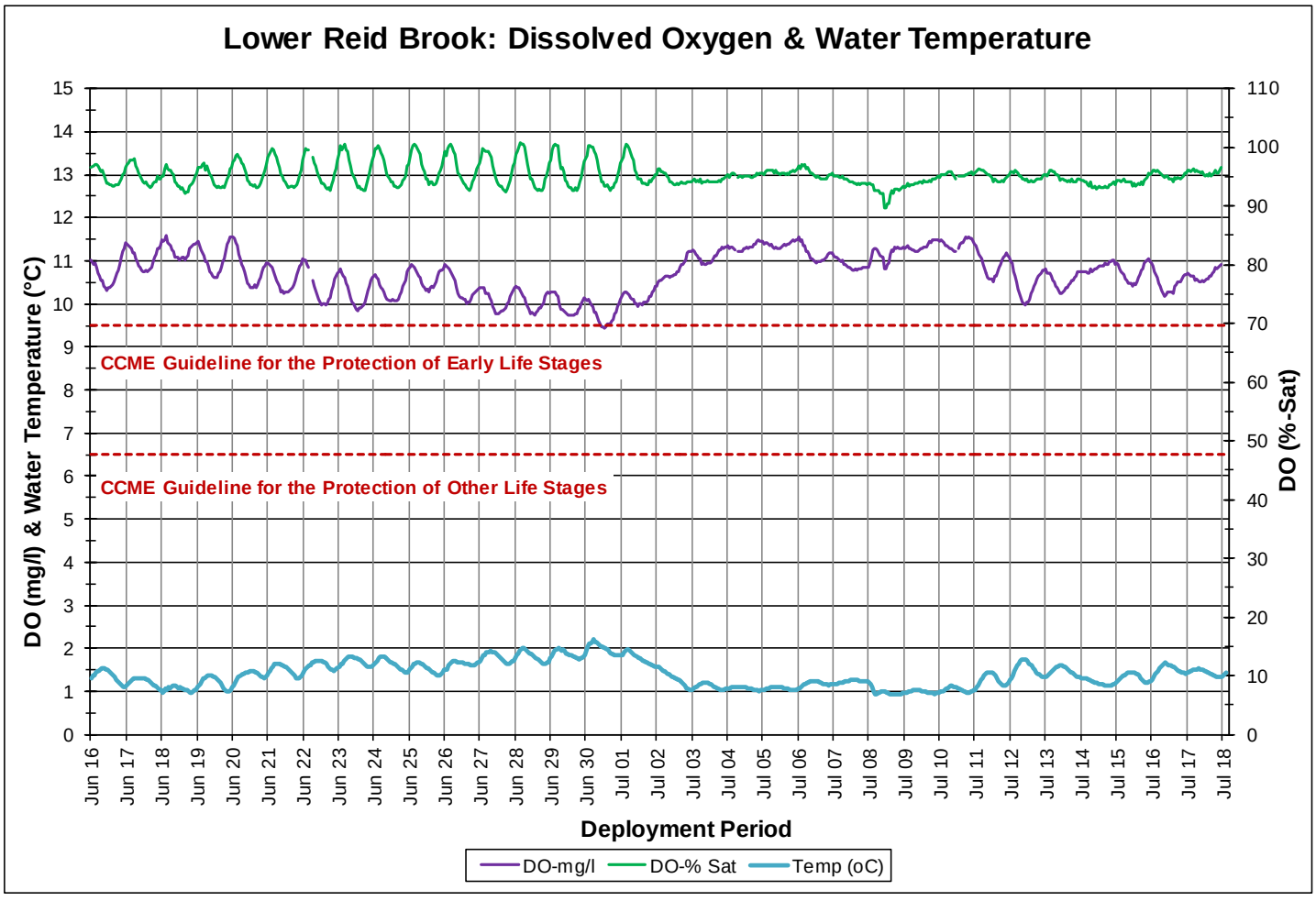

Figure 27: Dissolved Oxygen & Water Temperature at Lower Reid Brook below Tributary

Turbidity

- Turbidity ranges from 0.0NTU to 705.0NTU during the deployment period, with a median value of 0.0NTU (Figure 28).
- 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 number of low-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 28, 29).
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

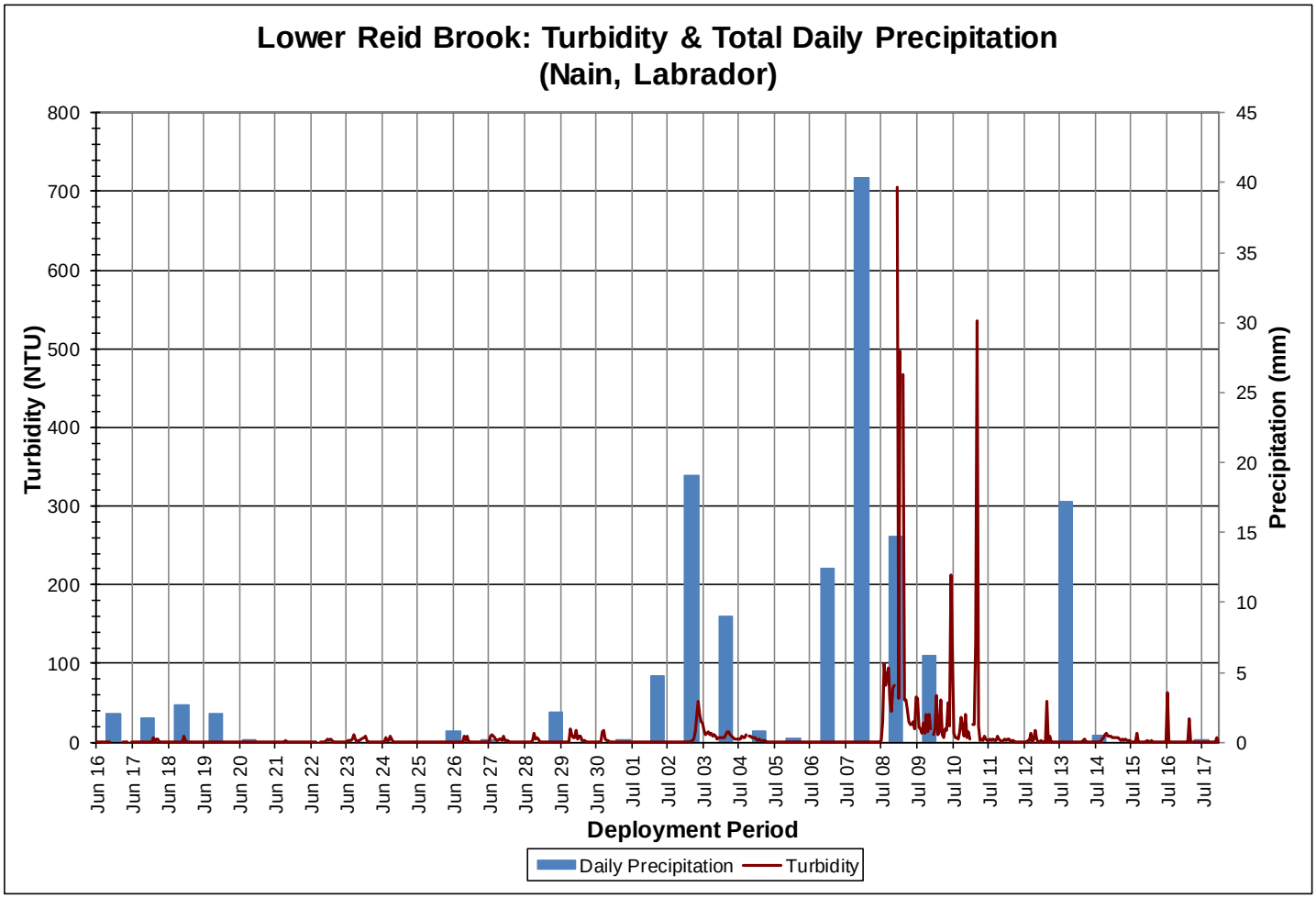

Figure 28: Turbidity & Total Daily Precipitation (Nain, Labrador Weather Station) at Lower Reid Brook below Tributary

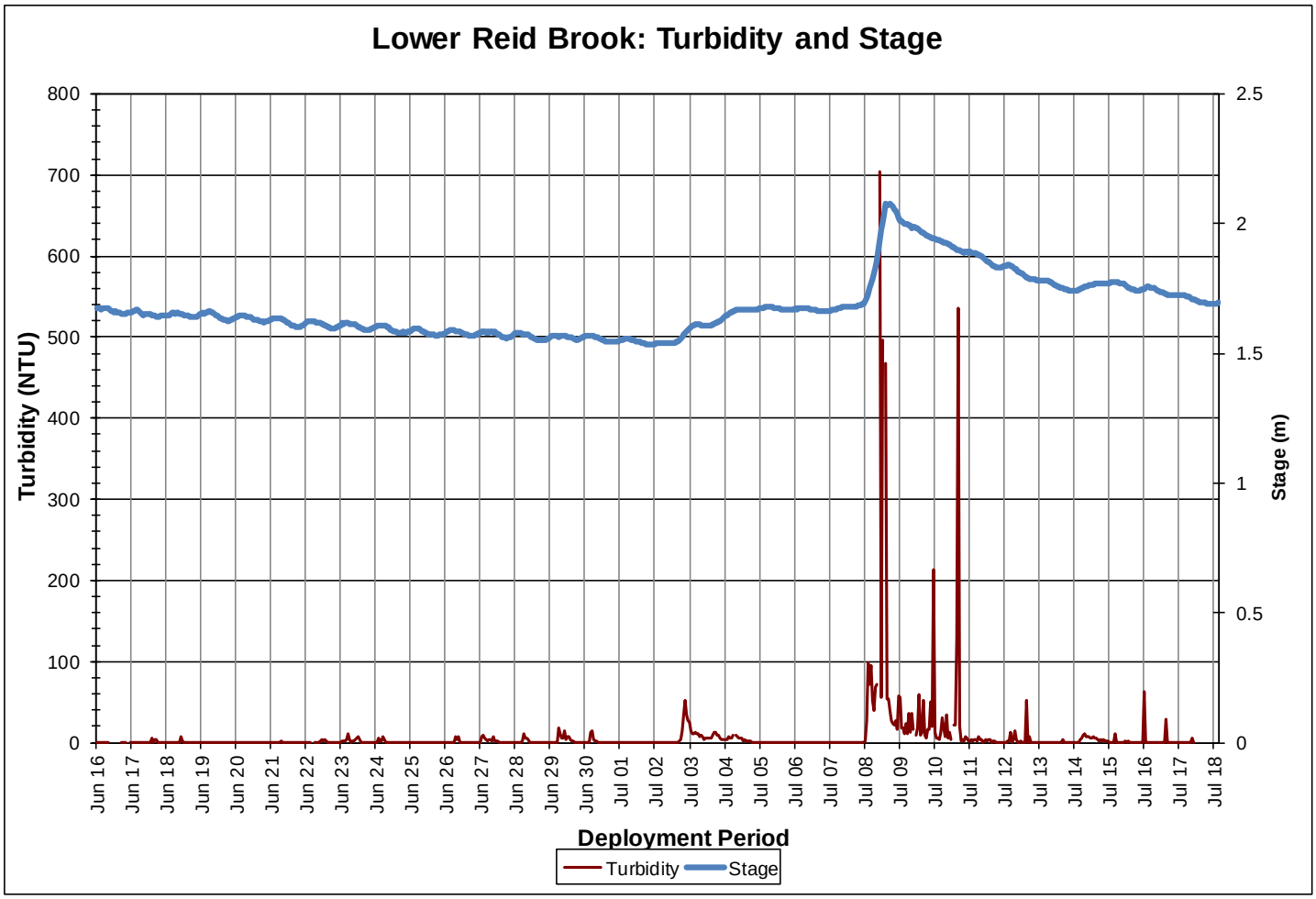

Figure 29: Turbidity & Stage at Lower Reid Brook below Tributary

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 Environment Canada weather station at Nain. The weather station is 30 km northeast of Voisey's Bay (Figure 30).
- Precipitation occurs on 21 days during the deployment period and amounts are small in magnitude, with the exception of the largest on July 8th with 40.4mm of rain.
- During the deployment period, the stage values ranged from 1.54m to 2.08m. Streamflow had a minimum amount of 3.02m^3/s and a maximum flow of 27.49m^3/s.
- Stage, Streamflow and precipitation are graphed below to show the relationship between rainfall and water level (Figure 30). It is evident that the peaks in stage (m) and streamflow data are a result of precipitation.

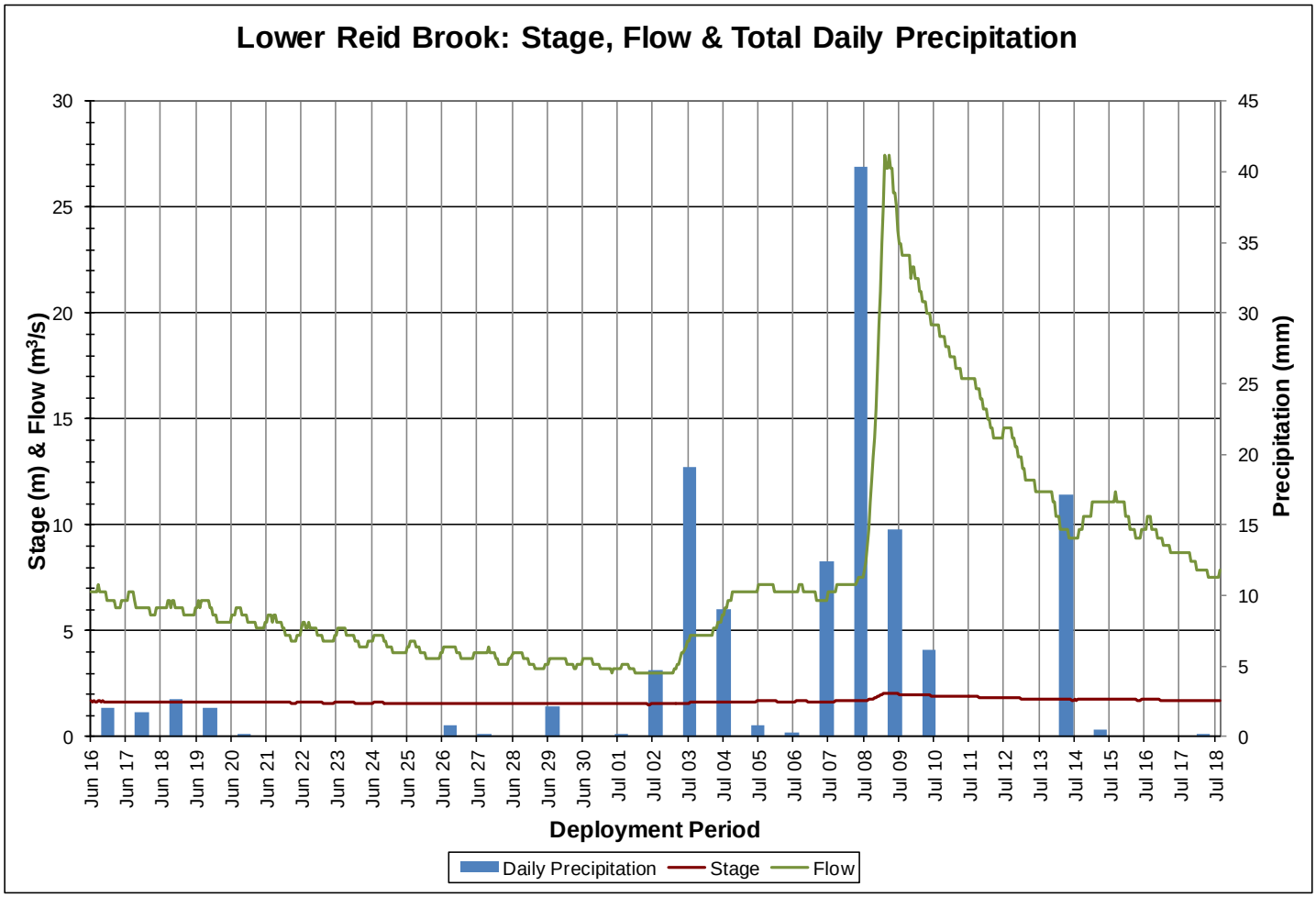

Figure 30: Stage, Flow, and Total Daily Precipitation (Nain, Labrador Weather Station) at Lower Reid Brook below Tributary

Conclusions

- The overall water temperatures across all stations were within a minimum of 2.51°C found at Reid Brook at Outlet of Reid Pond and a maximum of 21.7°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. 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. Hence Reid Brook at Outlet of Reid Pond having the lowest water temperature during the deployment period.
- The pH values for this deployment ranged between a minimum of 4.83 pH units at Reid Brook at Outlet of Reid Pond and maximum of 9.80 pH units at Lower Reid Brook below Tributary. The remaining stations pH graphs were similar in display with the larger decreases in pH occurring during precipitation events. During July 12-14 the Lower Reid Brook pH data behaved differently from the other stations. Lower Reid Brook's pH values increased to above 9 pH units.
- The overall conductivity ranges within the four stations was a minimum of 11.0µS/cm at Reid Brook at Outlet of Reid Pond and a maximum value of 48.2µS/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 35.1µS/cm for June to July 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 8.51mg/l at Camp Pond Brook below Camp Pond and a maximum of 11.68mg/l found at Tributary to Lower Reid Brook. Dissolved oxygen is lower at this time of year and 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 705NTU at Lower Reid Brook. Tributary to Lower Reid Brook and Camp Pond Brook also have several turbidity events which occur during and after larger rainfall events.

APPENDIX A: Comparison Graphs

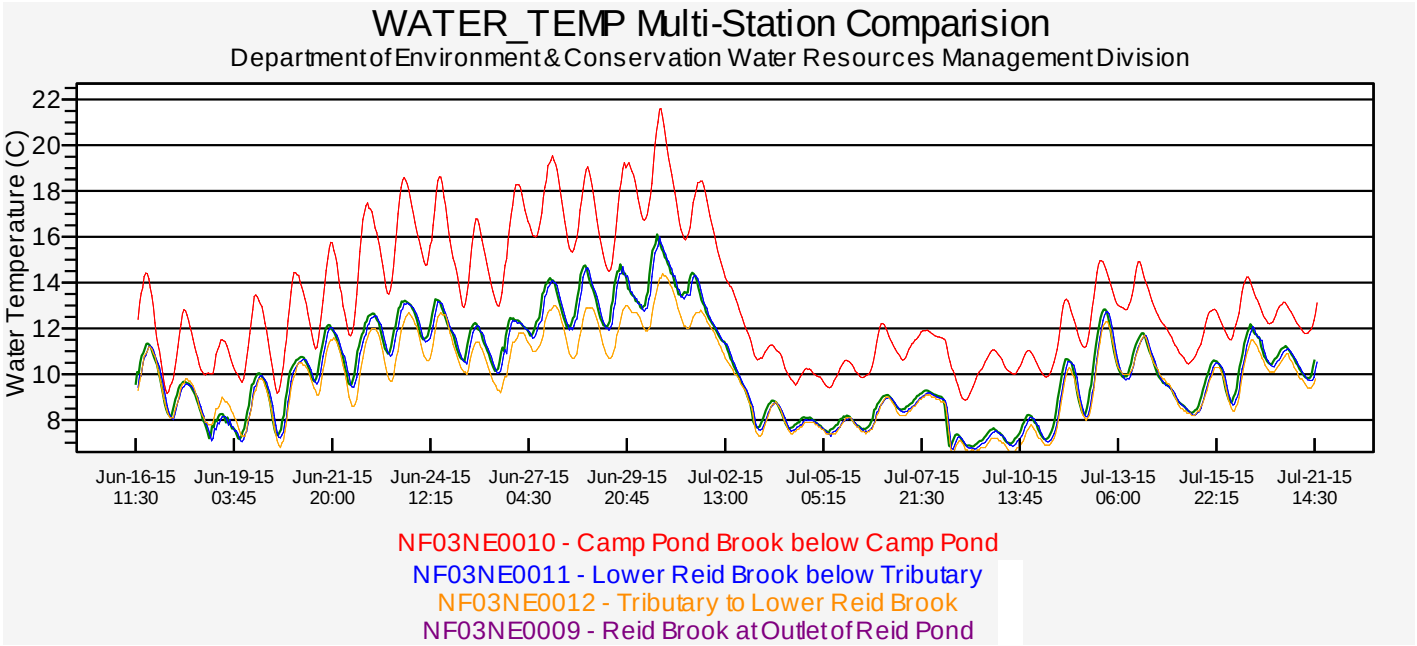

Figure A1: Comparison of Water Temperature at the Real-Time Stations in Voisey's Bay (due to transmission issues Reid Brook real time data does not show up on the graph)

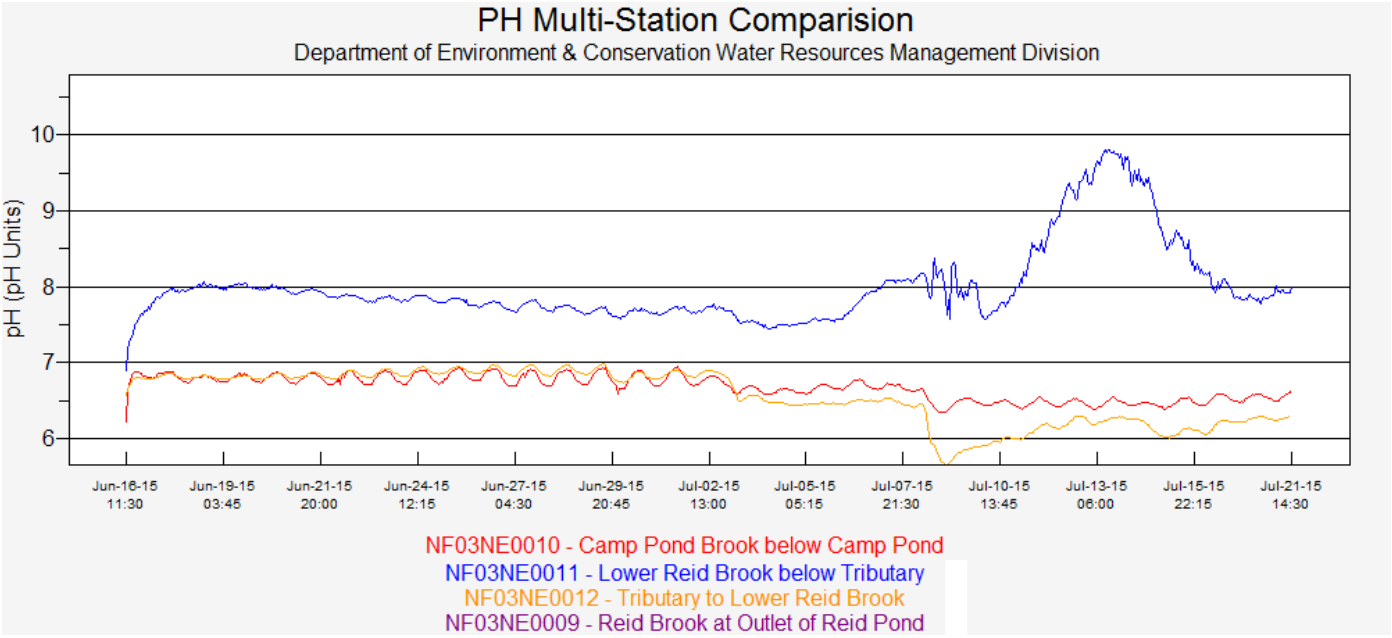

Figure A2: Comparison of pH at the Real-Time Stations in Voisey's Bay (due to transmission issues Reid Brook real time data does not show up on the graph)

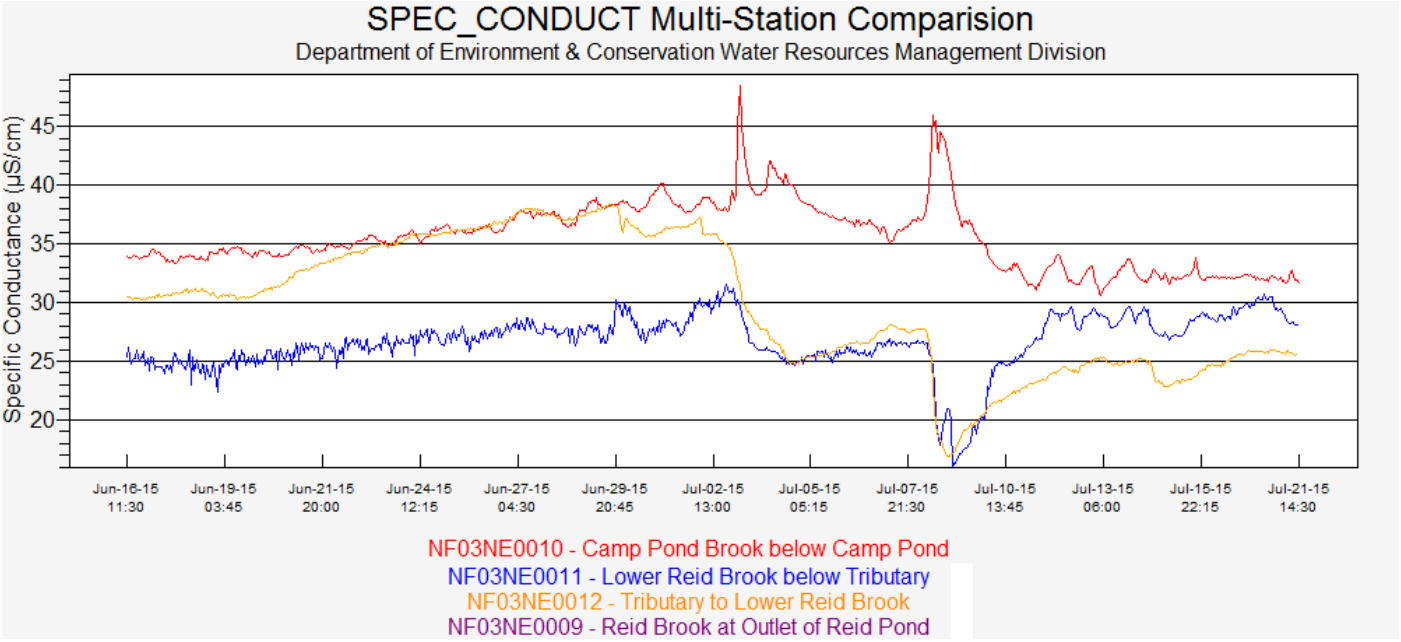

Figure A3: Comparison of Conductivity at the Real-Time Stations in Voisey's Bay (due to transmission issues Reid Brook real time data does not show up on the graph)

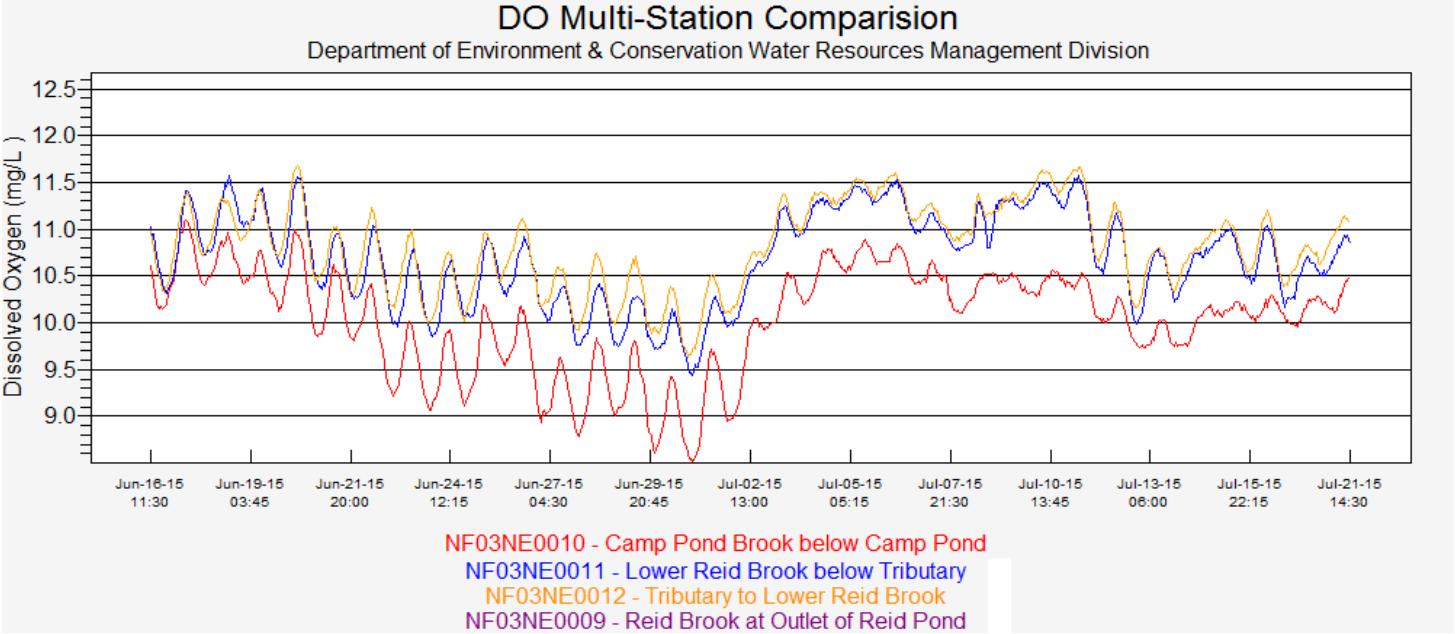

Figure A4: Comparison of Dissolved Oxygen (mg/L) at the Real-Time Stations in Voisey's Bay (due to transmission issues Reid Brook real time data does not show up on the graph)

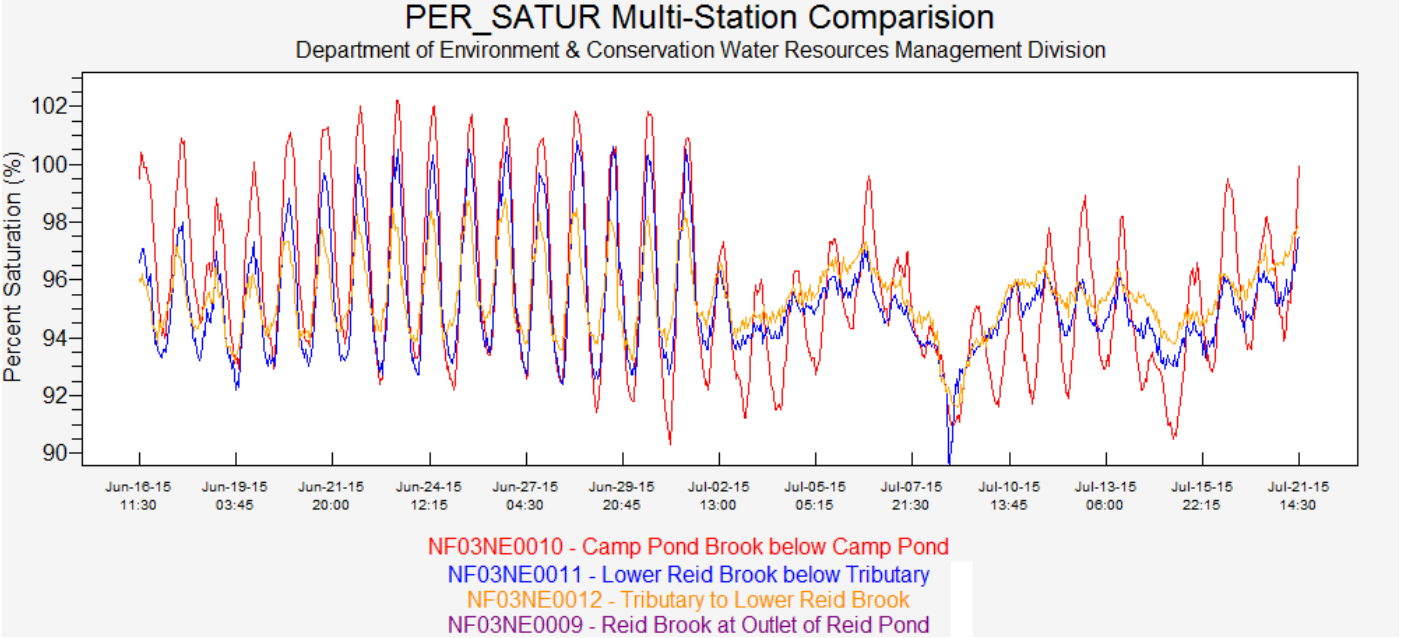

Figure A5: Comparison of Dissolved Oxygen (%Sat) at the Real-Time Stations in Voisey's Bay (due to transmission issues Reid Brook real time data does not show up on the graph)

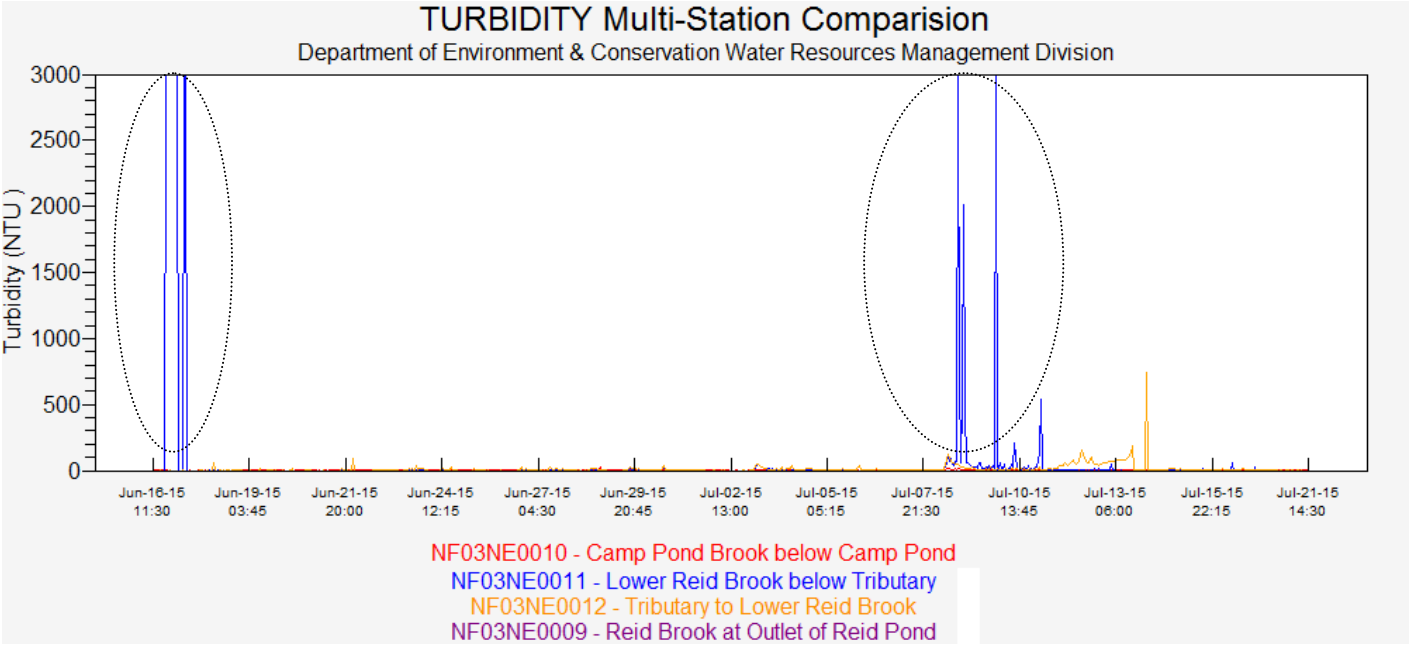

Figure A6: Comparison of Turbidity at the Real-Time Stations in Voisey's Bay (due to transmission issues Reid Brook real time data does not show up on the graph)

*** The circled data for Lower Reid Brook below Tributary is indicating values of 3000NTUs which is considered a sensor error and not an accurate reflection of the aquatic conditions**

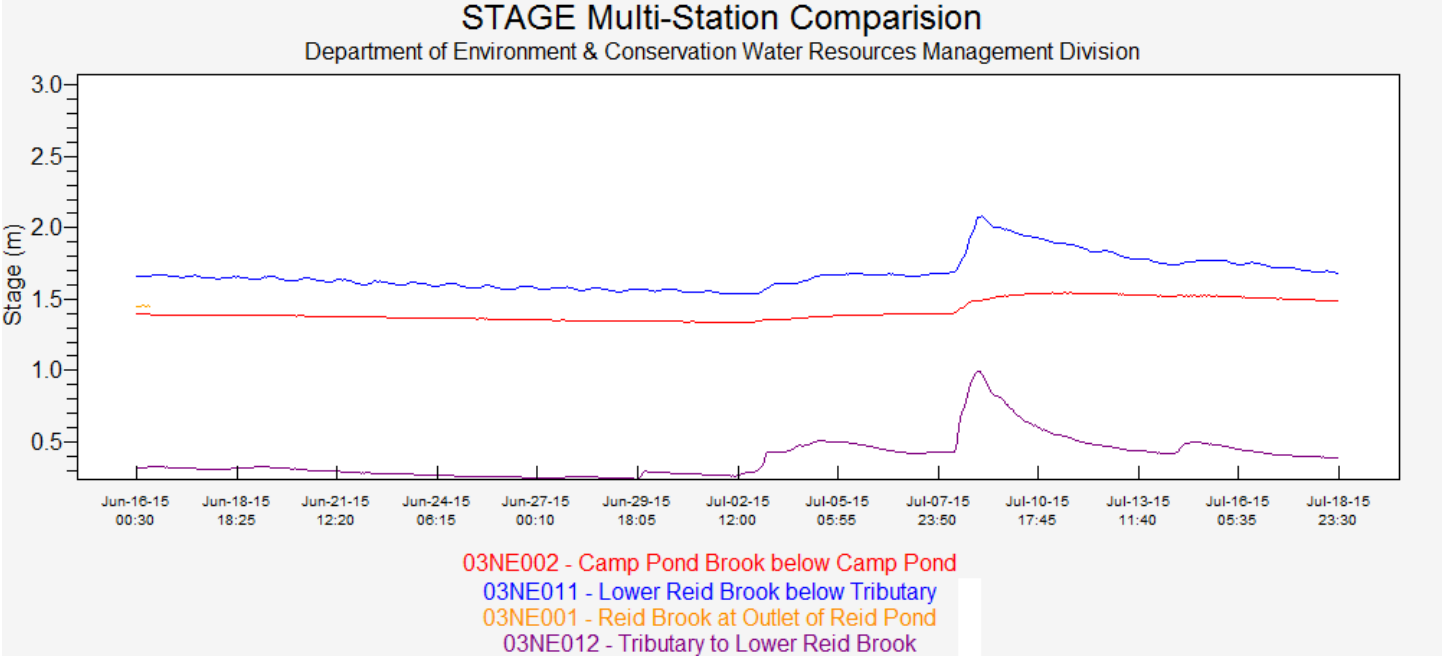

Figure A7: Comparison of Stage (m) at the Real-Time Stations in Voisey's Bay (due to transmission issues Reid Brook real time data does not show up on the graph)

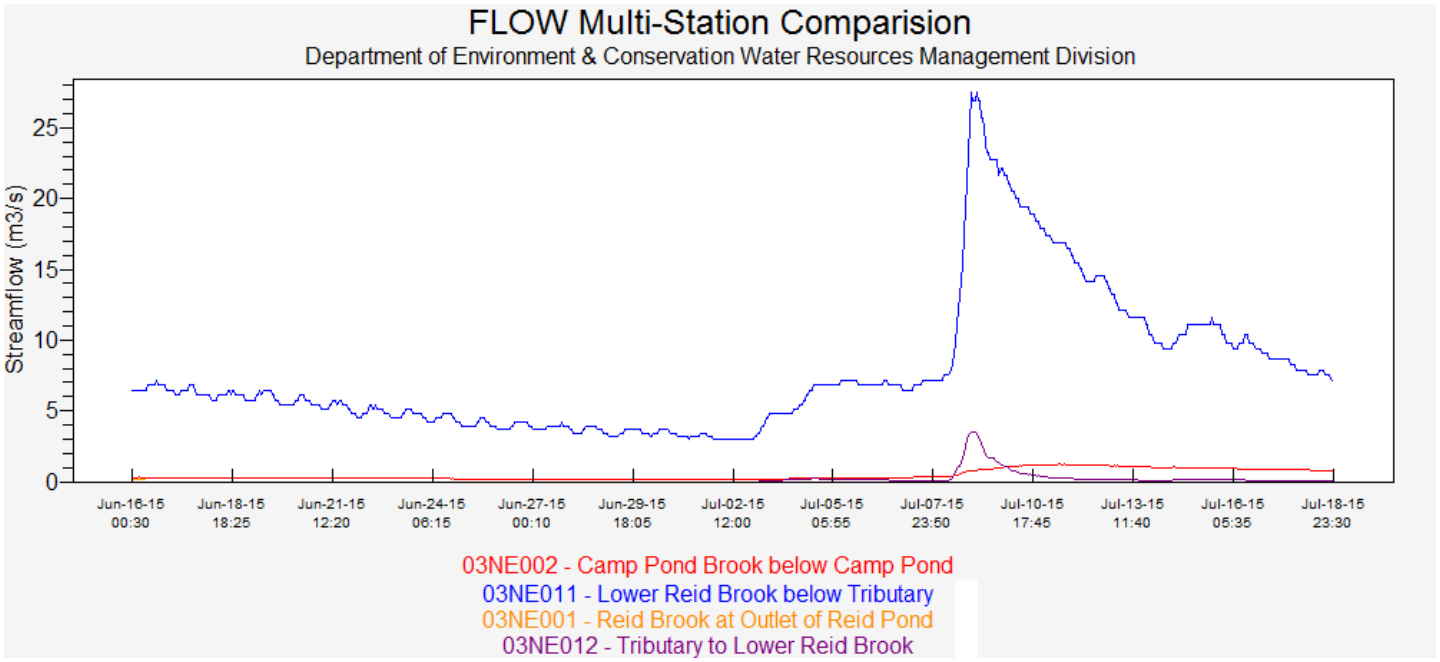

Figure A8: Comparison Flow (m^3/s) at the Real-Time Stations in Voisey's Bay (due to transmission issues Reid Brook real time data does not show up on the graph)

APPENDIX B: Grab Sample Data

REPORT OF ANALYSIS

Lab Report Number: 1511075

Cient:	Department of Environment	**COC Number:**	2832
Attention:	Ms. Annette Tobin	**Date Reported:**	2015-06-29
Client Project:	St Johns	**Date Submitted:**	2015-06-19
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date
1182437	WS-S-0000 Reid Brook At Outlet of Reid Pond	2015-6400-00-SI-SP	2015-06-16

Sample comment:

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	9
Conductivity	uS/cm	5	15
Dissolved Organic Carbon	mg/L	0.5	1.4
Fluoride	mg/L	0.10	<0.10
Hardness as CaCO3	mg/L	1	2
N-NH3 (Ammonia)	mg/L	0.05	<0.05
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	<1
Total Dissolved Solids (COND - CALC)	mg/L	1	10
Total Kjeldahl Nitrogen	mg/L	0.07	0.10
Total Organic Carbon	mg/L	0.5	1.8
Total Phosphorus	mg/L	0.05	<0.05
Turbidity	NTU	0.1	1.6
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

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

Exova - 146 Colonnade Road, Unit 8, Ottawa, ON, K2E 7Y1 Tel: 613-727-5692 Fax: 613-727-5222

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Client Project:	St Johns	**Date Submitted:**	2015-06-19
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1182437	WS-S-0000	2015-6400-00-SI-SP	2015-06-16	Copper	mg/L	0.001	<0.001
	Reid Brook At Outlet of Reid Pond			Iron	mg/L	0.03	0.03
				Lead	mg/L	0.001	<0.001
Sample comment:				Magnesium	mg/L	1	<1
				Manganese	mg/L	0.01	<0.01
				Mercury	mg/L	0.0001	<0.0001
Report comment:				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	0.005
				Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	<0.01
				Total Suspended Solids	mg/L	1	<1

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

Exova

REPORT OF ANALYSIS

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Attention:	Ms. Annette Tobin	**Date Reported:**	2015-06-29
Client Project:	St Johns	**Date Submitted:**	2015-06-19
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1182438	WS-S-0000 Camp Pond Brook below Camp Pond	2015-6401-00-SI-SP	2015-06-16	Alkalinity as CaCO3	mg/L	5	8
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	3
				Colour	TCU	2	20
				Conductivity	uS/cm	5	35
				Dissolved Organic Carbon	mg/L	0.5	3.0
				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	7
				N-NH3 (Ammonia)	mg/L	0.05	<0.05
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	7.09
				Sulphate	mg/L	1	3
				Total Dissolved Solids (COND - CALC)	mg/L	1	23
				Total Kjeldahl Nitrogen	mg/L	0.07	0.14
				Total Organic Carbon	mg/L	0.5	3.3
				Total Phosphorus	mg/L	0.05	<0.05
				Turbidity	NTU	0.1	2.1
				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	3
				Cadmium	mg/L	0.0001	<0.0001
				Chromium	mg/L	0.001	<0.001

Sample comment:

Report comment:

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

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Attention:	Ms. Annette Tobin	**Date Reported:**	2015-06-29
Client Project:	St Johns	**Date Submitted:**	2015-06-19
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1182438	WS-S-0000	2015-6401-00-SI-SP	2015-06-16	Copper	mg/L	0.001	0.003
	Camp Pond Brook below Camp Pond			Iron	mg/L	0.03	0.16
				Lead	mg/L	0.001	<0.001
Sample comment:				Magnesium	mg/L	1	<1
				Manganese	mg/L	0.01	<0.01
				Mercury	mg/L	0.0001	<0.0001
Report comment:				Nickel	mg/L	0.005	0.019
				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	4	<4

Results relate only to the parameters tested on the samples submitted.
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Exova

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Client Project:	St Johns	**Date Submitted:**	2015-06-19
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1182439	WS-S-0000 Tributary to Lower Reid Brook	2015-6402-00-SI-SP	2015-06-16	Alkalinity as CaCO3	mg/L	5	7
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	2
Sample comment:				Colour	TCU	2	35
				Conductivity	uS/cm	5	31
				Dissolved Organic Carbon	mg/L	0.5	4.5
Report comment:				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	7
				N-NH3 (Ammonia)	mg/L	0.05	<0.05
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	7.03
				Sulphate	mg/L	1	3
				Total Dissolved Solids (COND - CALC)	mg/L	1	20
				Total Kjeldahl Nitrogen	mg/L	0.07	0.20
				Total Organic Carbon	mg/L	0.5	4.5
				Total Phosphorus	mg/L	0.05	<0.05
				Turbidity	NTU	0.1	9.2
				Aluminum	mg/L	0.01	0.10
				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

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

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Client Project:	St Johns	**Date Submitted:**	2015-06-19
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1182439	WS-S-0000	2015-6402-00-SI-SP	2015-06-16	Copper	mg/L	0.001	0.001
	Tributary to Lower Reid Brook			Iron	mg/L	0.03	0.28
				Lead	mg/L	0.001	<0.001
Sample comment:				Magnesium	mg/L	1	<1
				Manganese	mg/L	0.01	<0.01
				Mercury	mg/L	0.0001	<0.0001
Report comment:				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	0.014
				Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	<0.01
				Total Suspended Solids	mg/L	5	<5

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

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Attention:	Ms. Annette Tobin	**Date Reported:**	2015-06-29
Client Project:	St Johns	**Date Submitted:**	2015-06-19
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1182440	WS-S-0000 Lower Reid Brook Below Tributary	2015-6403-00-SI-SP	2015-06-16	Alkalinity as CaCO3	mg/L	5	8
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	2
Sample comment:				Colour	TCU	2	30
				Conductivity	uS/cm	5	32
				Dissolved Organic Carbon	mg/L	0.5	3.5
Report comment:				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	7
				N-NH3 (Ammonia)	mg/L	0.05	<0.05
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	7.13
				Sulphate	mg/L	1	4
				Total Dissolved Solids (COND - CALC)	mg/L	1	21
				Total Kjeldahl Nitrogen	mg/L	0.07	0.16
				Total Organic Carbon	mg/L	0.5	3.8
				Total Phosphorus	mg/L	0.05	<0.05
				Turbidity	NTU	0.1	1.3
				Aluminum	mg/L	0.01	0.10
				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

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Attention:	Ms. Annette Tobin	**Date Reported:**	2015-06-29
Client Project:	St Johns	**Date Submitted:**	2015-06-19
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1182440	WS-S-0000	2015-6403-00-SI-SP	2015-06-16	Copper	mg/L	0.001	<0.001
	Lower Reid Brook Below Tributary			Iron	mg/L	0.03	0.24
				Lead	mg/L	0.001	<0.001
Sample comment:				Magnesium	mg/L	1	<1
				Manganese	mg/L	0.01	<0.01
				Mercury	mg/L	0.0001	<0.0001
Report comment:				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	0.013
				Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	<0.01
				Total Suspended Solids	mg/L	4	<4

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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