Real-Time Water Quality Deployment Report

Voisey's Bay Network

August 14 to September 14, 2019

Newfoundland Labrador

Government of Newfoundland & Labrador

Department of Municipal Affairs and Environment

Water Resources Management Division

Contents

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Real Time Water Quality Monitoring

Staff with the Department of Municipal Affairs and Environment monitor 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 below Camp Pond; Tributary to Reid Brook; and Reid Brook below Tributary.

On August 14, 2019, Vale Environment staff deployed real-time water quality monitoring instruments at the four real-time stations in the Voisey's Bay network. Instruments were removed by Vale Environment and Water Resources Management Division Staff on September 14, 2019. This was the third deployment for the 2019 season.

Quality Assurance and Quality Control

As part of the Quality Assurance and Quality Control protocol (QA/QC), an assessment of the reliability of data recorded by an instrument is made at the beginning and end of the deployment period. This procedure is based on the approach used by the United States Geological Survey.

At deployment and removal, a QA/QC instrument is temporarily deployed adjacent to the field instrument. Values for temperature, pH, conductivity, dissolved oxygen and turbidity are compared between the two instruments**.** Based on the degree of difference between parameters recorded by the field instrument and QA/QC instrument at deployment and at removal, a qualitative statement is made about 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 dependent; temperature compensated; and temperature independent. Because the temperature sensor is not isolated from the rest of the instrument, the entire instrument must be at the same temperature before the sensor will stabilize. The values may take some time to climb to the appropriate reading; if a reading is taken too soon it may not accurately portray the water body.

Deployment and removal comparison rankings for the Voisey's Bay Network stations are summarized in Table 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	August 14	Deployment	Excellent	Fair	Excellent	Good	Excellent
	September 14	Removal	Excellent	Fair	Excellent	Excellent	Excellent
Camp Pond Brook	August 14	Deployment	Excellent	Marginal	Excellent	Fair	Excellent
	September 14	Removal	Excellent	**Poor**	Excellent	Excellent	**Poor**
Reid Brook below Tributary	August 14	Deployment	Excellent	Good	Good	Good	Excellent
	September 14	Removal	Excellent	Good	Good	Excellent	Good
Tributary to Reid Brook	August 14	Deployment	Excellent	Fair	Excellent	Fair	Excellent
	September 14	Removal	Excellent	Excellent	Good	Excellent	**Poor**

Reid Brook at Outlet of Reid Pond

- At deployment, temperature, conductivity, and turbidity all ranked as 'excellent', while pH was 'fair' and dissolved oxygen was 'good'.
- At removal, all parameters ranked as 'excellent' with the exception of pH, which ranked as 'fair'.

Camp Pond Brook below Camp Pond

- At deployment, temperature, conductivity, and turbidity all ranked as 'excellent', while pH was 'marginal' and dissolved oxygen was 'fair'.
- At removal, temperature, conductivity, and dissolved oxygen were 'excellent', while both pH and turbidity were 'poor'. These discrepancies may have been due to the QA/QC sonde not being given sufficient time to acclimate before a reading was taken or not being placed in close enough proximity to the field sonde.

Reid Brook below Tributary

- At deployment, all parameters ranked as either 'excellent' or 'good'.
- At removal, all parameters ranked as either 'excellent' or 'good'.

Tributary to Reid Brook

- At deployment, temperature, conductivity, and turbidity all ranked as 'excellent', while both pH and dissolved oxygen were 'fair'.
- At removal, temperature, pH, and dissolved oxygen were 'excellent', conductivity was 'good', while turbidity was 'poor'. The discrepancy in turbidity readings is being attributed to a buildup of sediment around the instrument observed upon removal.

It is important to note that, in general, there are several conditions under which a less than ideal QA/QC ranking may be obtained. These include, but are not limited to: placement of the QA/QC sonde in relation to the field sonde; the amount of time each sonde is given to stabilize before readings are recorded; and deteriorating performance of one or more of the sensors.

Data Interpretation

The following graphs and discussion illustrate significant water quality-related events from August 14th to September 14th, 2019 in the Voisey's Bay Real-Time Water Quality Monitoring Network.

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

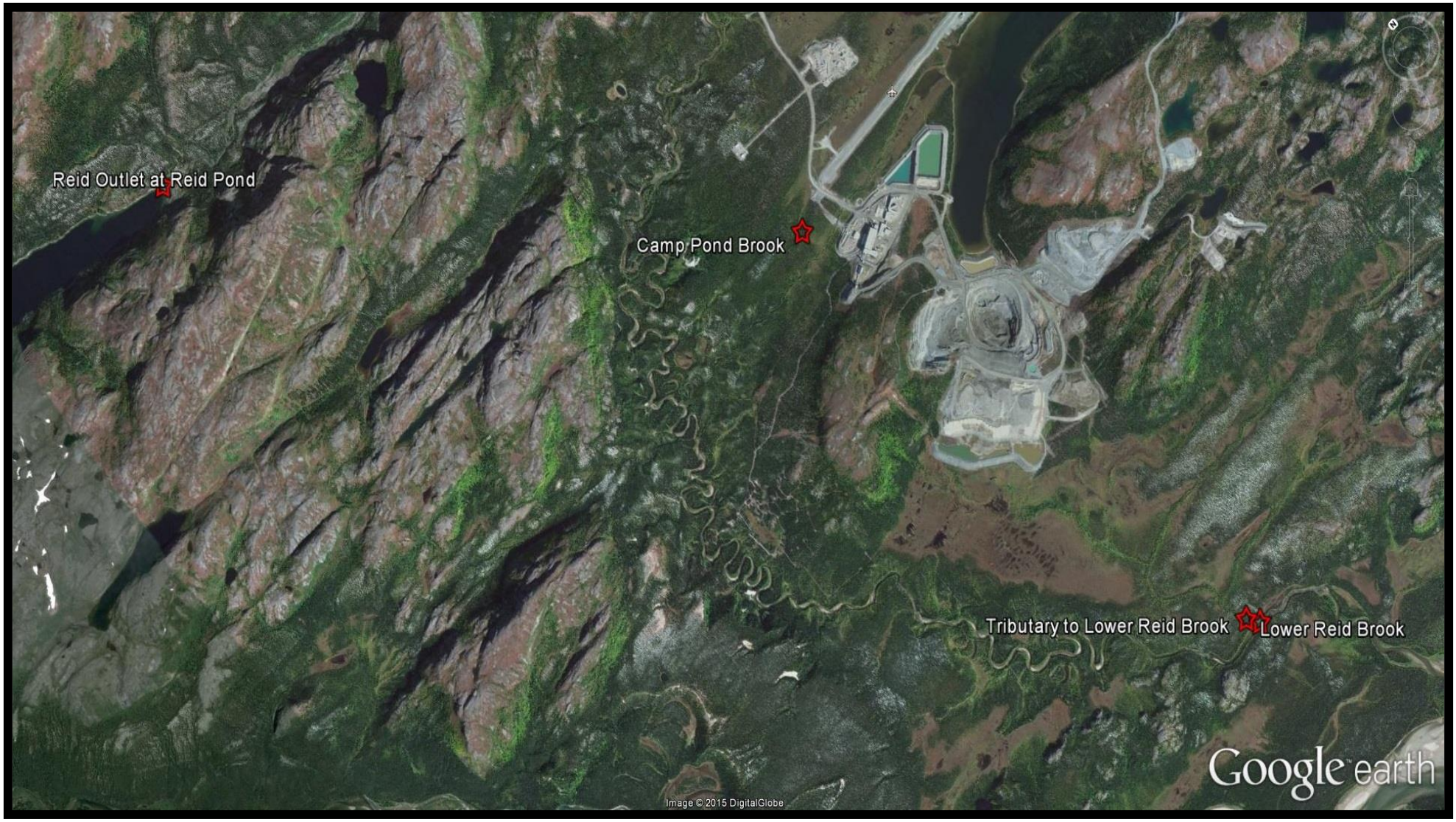

Figure 1: Voisey's Bay Network Station Locations

Reid Brook at Outlet of Reid Pond

Water Temperature

Over the deployment period, water temperature ranged from 8.08°C to 13.99°C, with a median value of 10.85°C (Figure 2). As evidenced in the graph below, air temperature fluctuates to a much greater extent each day compared to water temperature. Air temperature data was obtained from the Voisey's Bay airstrip weather station.

This water body takes longer to acclimatize to changes in temperature as it has a much larger surface area compared to the brooks at the other RTWQ stations in this network. While water temperatures were relatively stable across the deployment period, there was a slightly decreasing trend which is to be expected as summer changed to fall (Figure 2).

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

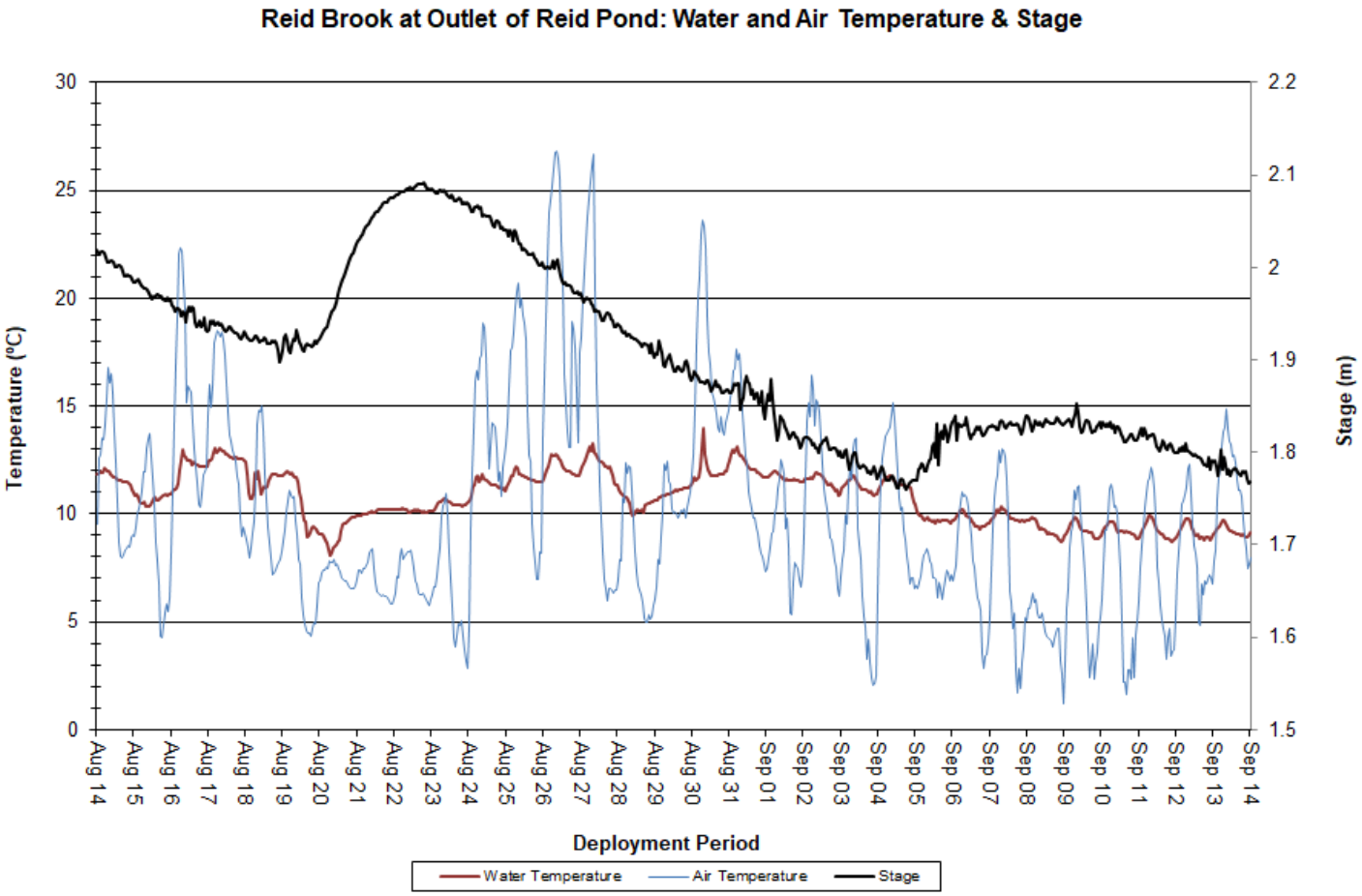

Figure 2: Water and Air Temperature & Stage at Reid Brook at Outlet of Reid Pond

pH

Over the deployment period, pH values ranged from 6.46 pH units to 6.93 pH units, with a median value of 6.78 pH units (Figure 3).

pH levels were within the CCME's Guidelines for the Protection of Aquatic Life for the duration of the deployment period, except for a very brief acclimation period at the beginning of deployment.

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

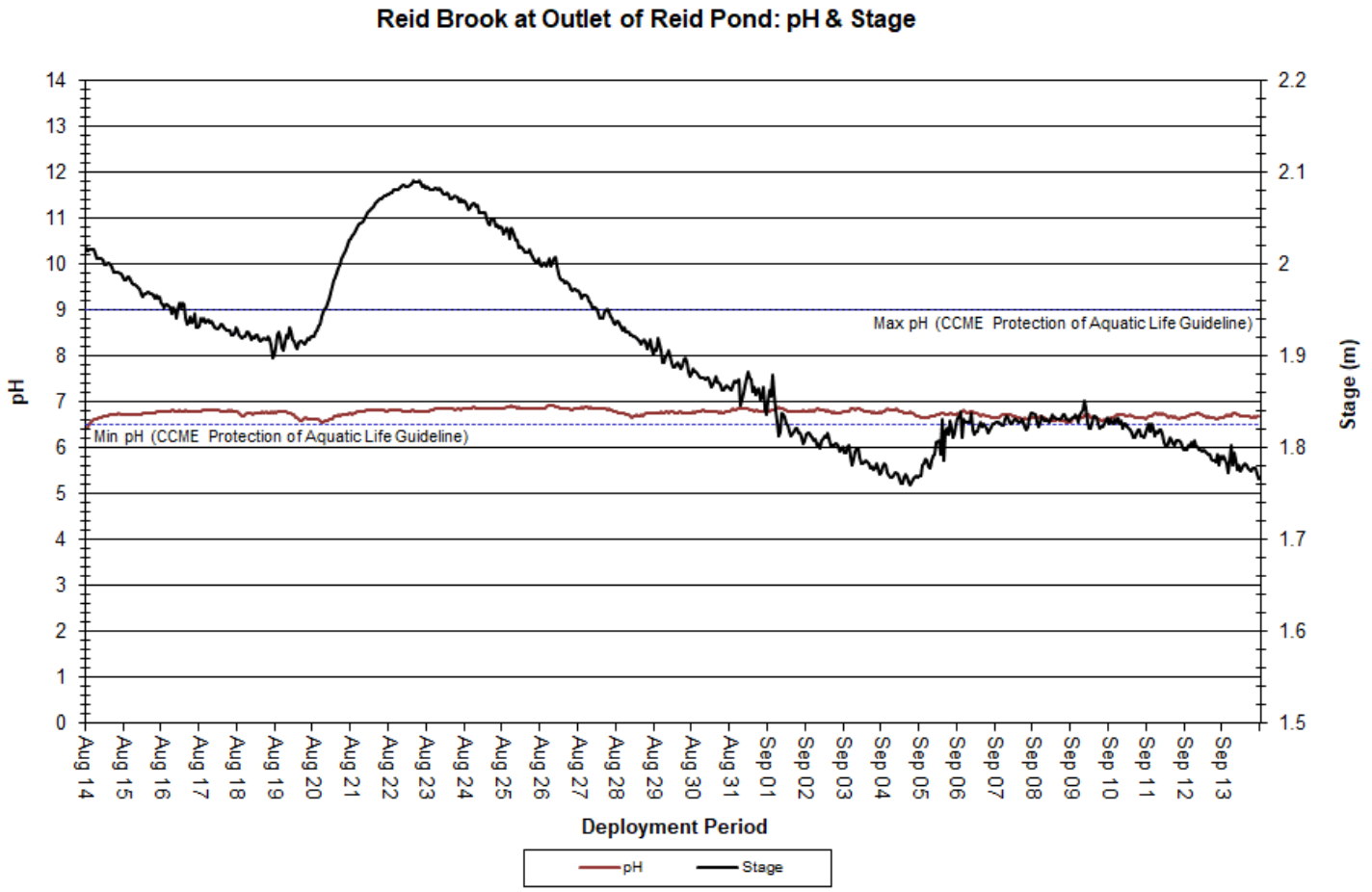

Figure 3: pH & Stage at Reid Brook at Outlet of Reid Pond

Specific Conductivity

Over the deployment period, specific conductivity levels ranged from 11.3µS/cm to 13.8µS/cm, with a median value of 11.6µS/cm (Figure 4). Conductivity at Reid Brook remained very stable; this is to be expected as this water body is pristine in nature and is far removed from any anthropogenic disturbances that could affect water quality.

The relationship between conductivity and stage level is generally inversed. When stage levels decrease, specific conductivity levels increase, as the decreased amount of water in the river system concentrates the solids that are present. Similarly, as stage levels rise, conductivity levels will dip in response. This relationship is not as evident at Reid Brook as it is at other stations in the Voisey's Bay network (Figure 4).

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

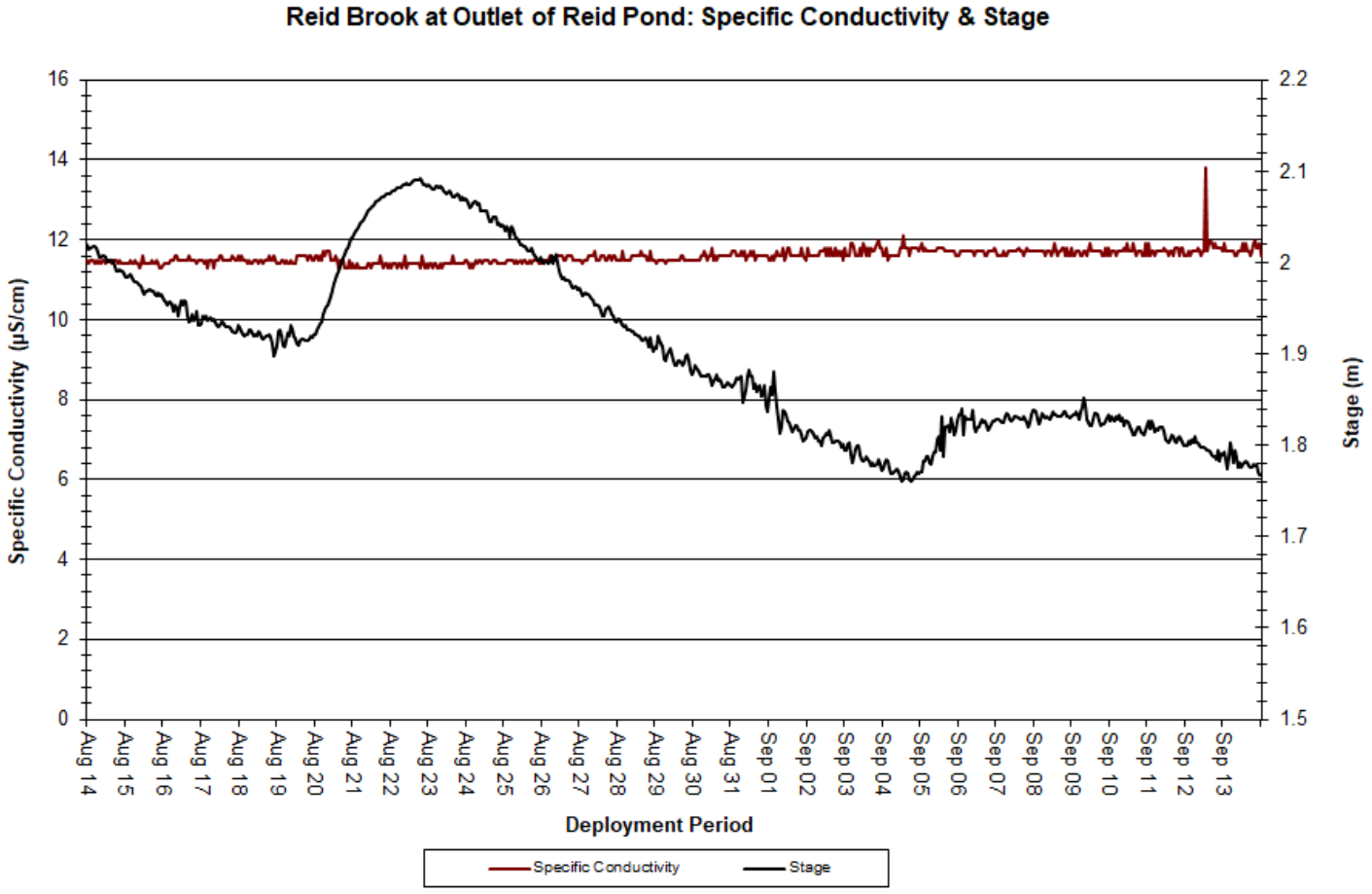

Figure 4: Specific Conductivity & Stage at Reid Brook at Outlet of Reid Pond

Dissolved Oxygen

Over the deployment period, dissolved oxygen concentration levels ranged from 10.37mg/L to 11.40mg/L, with a median value of 10.76mg/L. Percent saturation levels for dissolved oxygen ranged from 94.3% saturation to 105.3% saturation, with a median value of 98.1% saturation (Figure 5).

The water quality instrument measures dissolved oxygen concentration (mg/L) with a dissolved oxygen probe. The instrument then calculates percent saturation (% Sat) taking into account water temperature.

Dissolved oxygen levels were quite stable over the course of the deployment period. This is to be expected, as water temperatures were also quite stable over the same period, with only a slight decrease towards the end of deployment. Dissolved oxygen concentration values remained above the CCME's Guidelines for the Protection of Early Life Stages (9.5 mg/L) and Other Life Stages (6.5 mg/L) for the duration of deployment (Figure 5).

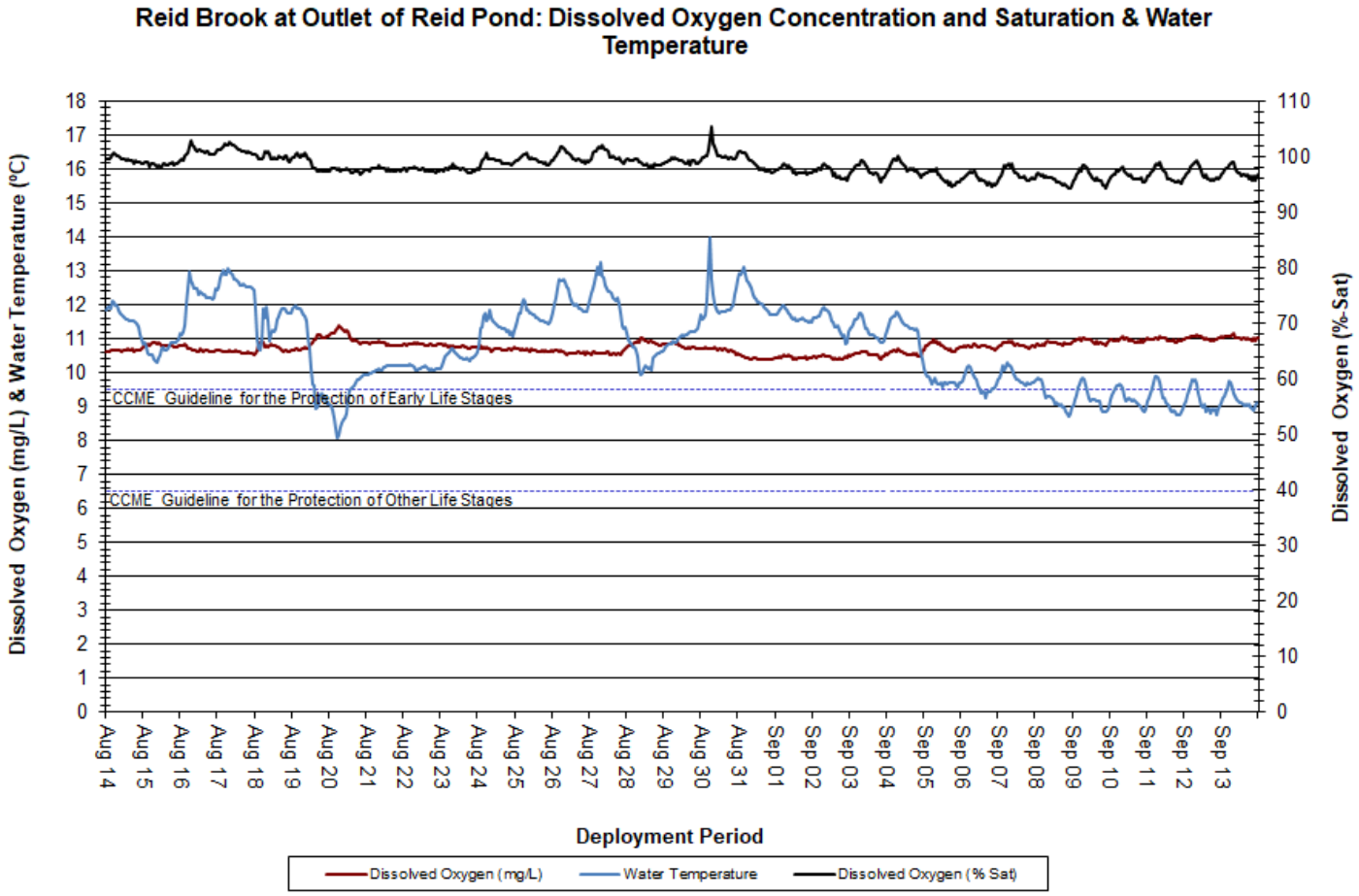

Figure 5: Dissolved Oxygen Concentration and Saturation & Water Temperature at Reid Brook at Outlet of Reid Pond

Turbidity

Over the deployment period, turbidity levels ranged from 0.0NTU to 484.0NTU, with a median value of 0.0NTU (Figure 6). This indicates that there was very little background turbidity at this station during deployment.

All water bodies have a natural level of turbidity. A significant increase in turbidity is of concern when monitoring water quality. Higher turbidity readings would normally be expected during heavy rainfall or runoff events. Generally, turbidity levels increase for a short period of time and then return to within a baseline range. Turbidity values can also increase when there is a decrease in water level, which causes natural material in the water body to become concentrated.

Precipitation events generally do not correlate closely with turbidity levels at this station, as it is pristine in nature and far removed from anthropogenic influences that may affect water quality. Increased turbidity levels observed during the second half of deployment were more likely influenced by changes in the water column (such as sediment or natural debris) than precipitation events (Figure 6).

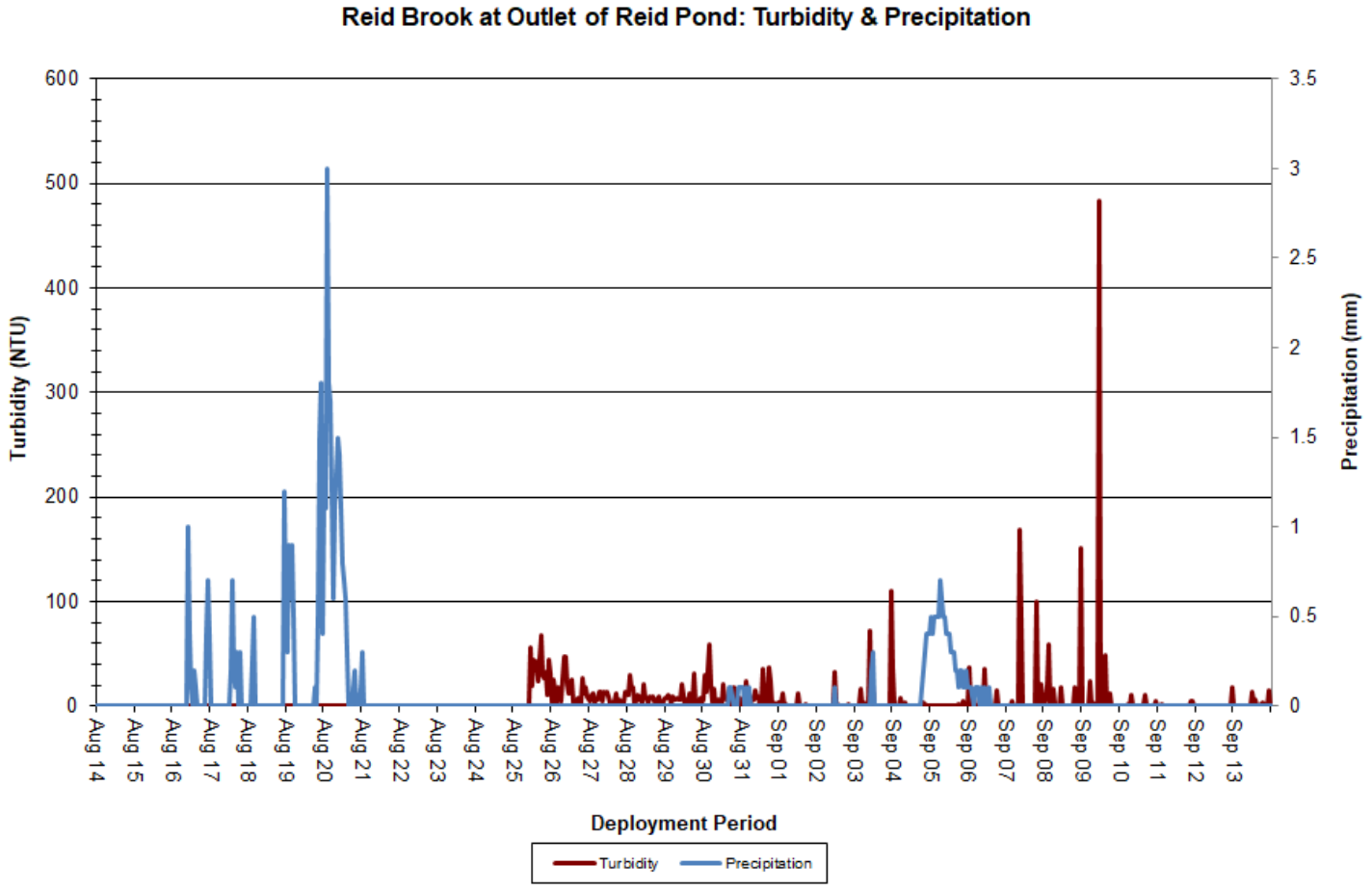

Figure 6: Turbidity & Precipitation at Reid Brook at Outlet of Reid Pond

Stage, Flow & Precipitation

Stage is an important parameter, as it provides an estimate of water level at a station and can explain some of the events that are occurring with other parameters (e.g. specific conductivity, DO, and turbidity). Stage will generally increase during rainfall events (Figure 7) and during any surrounding snow or ice melt; however, direct snowfall will not cause a significant increase in stage.

Over the deployment period, stage values ranged from 1.76m to 2.09m, with a median value of 1.89m. Flow values ranged from 1.12m^3/s to 4.54m^3/s, with a median value of 2.17m^3/s. Precipitation data was obtained from the Voisey's Bay airstrip weather station (Figure 7).

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

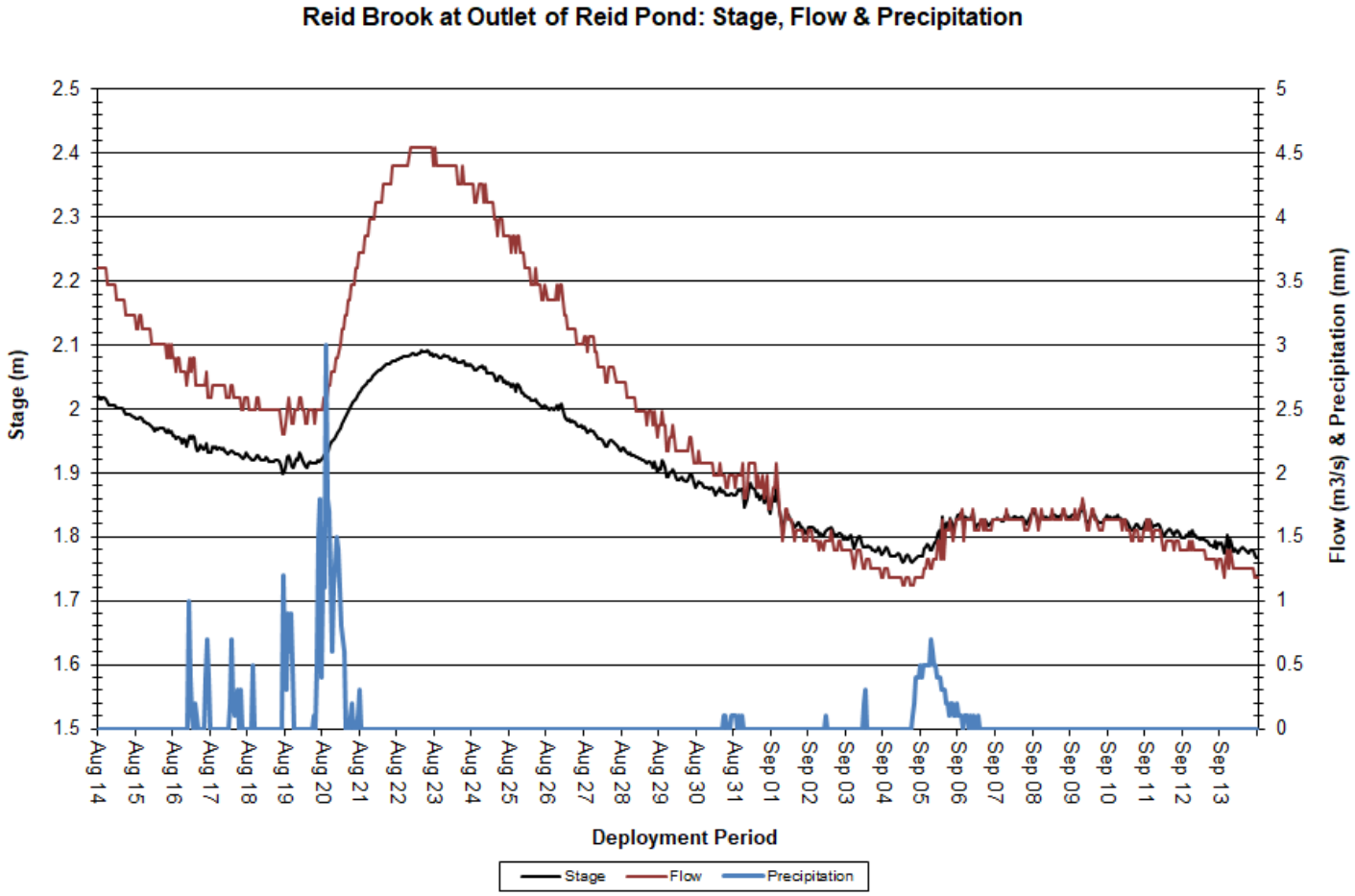

Figure 7: Stage, Flow & Precipitation at Reid Brook at Outlet of Reid Pond

Camp Pond Brook below Camp Pond

Water Temperature

Over the deployment period, water temperature ranged from 8.06°C to 17.25°C, with a median value of 11.92°C (Figure 8).

Water temperature at this station displays diurnal variations. Water temperature was relatively stable for the first half of deployment, after which it started to decrease. This is to be expected as air temperatures followed a very similar trend over the same period (Figure 8). Air temperature data was obtained from the Voisey's Bay airstrip weather station.

Camp Pond Brook is sensitive to changes in 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.

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

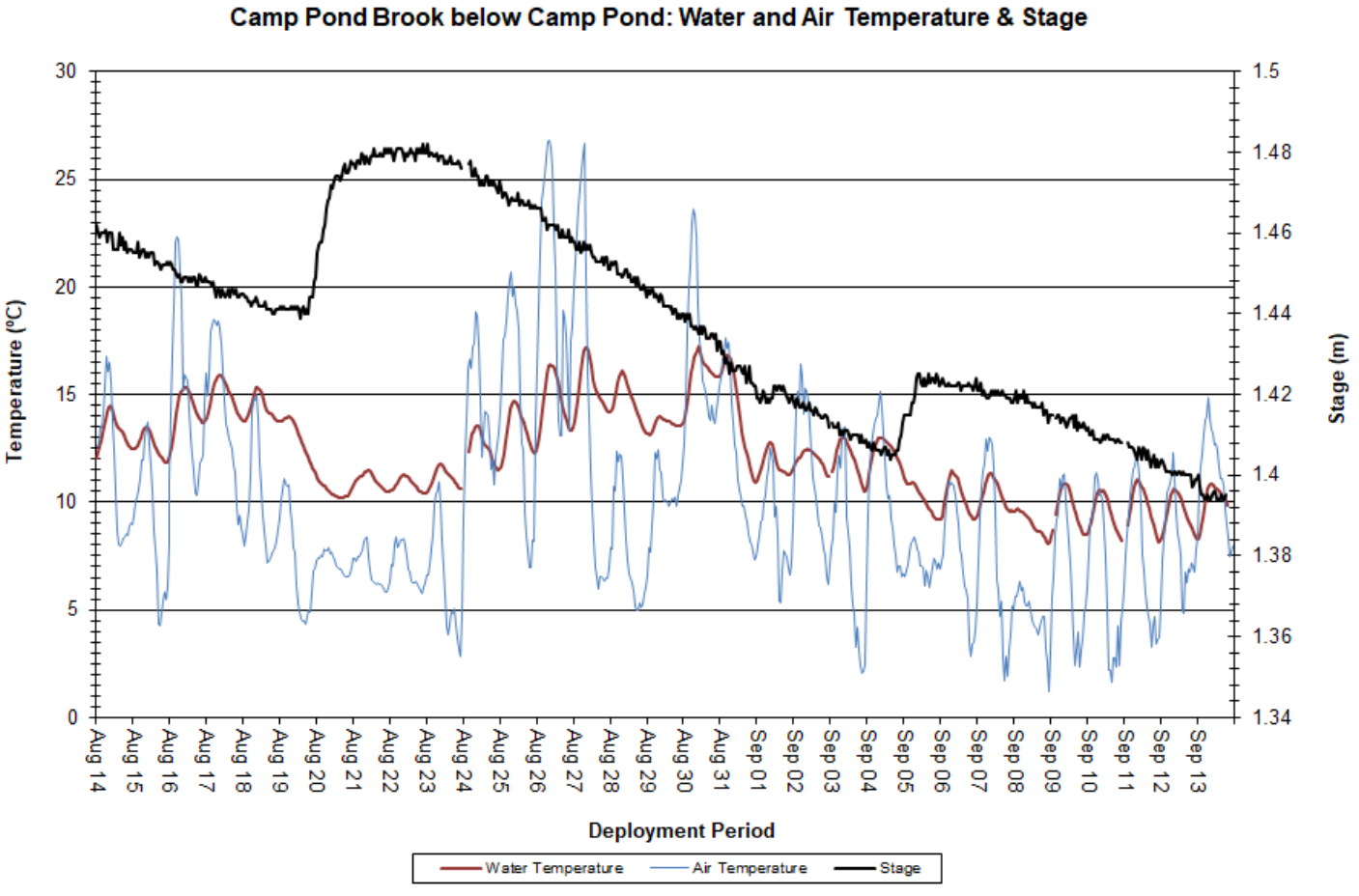

Figure 8: Water and Air Temperature & Stage at Camp Pond Brook below Camp Pond

pH

Over the deployment period, pH values ranged from 6.68 pH units to 7.04 pH units, with a median value of 6.89 pH units (Figure 9).

pH levels were quite stable across the deployment period and remained within the CCME's Guidelines for the Protection of Aquatic Life for the duration of deployment.

Natural events such as rainfall and snow melt will alter the pH of a brook for a period of time - pH levels will decrease slightly during and after high stage levels. This is a natural process and may have contributed to temporary decreases in pH levels observed throughout the deployment period (i.e. August 20 and September 5).

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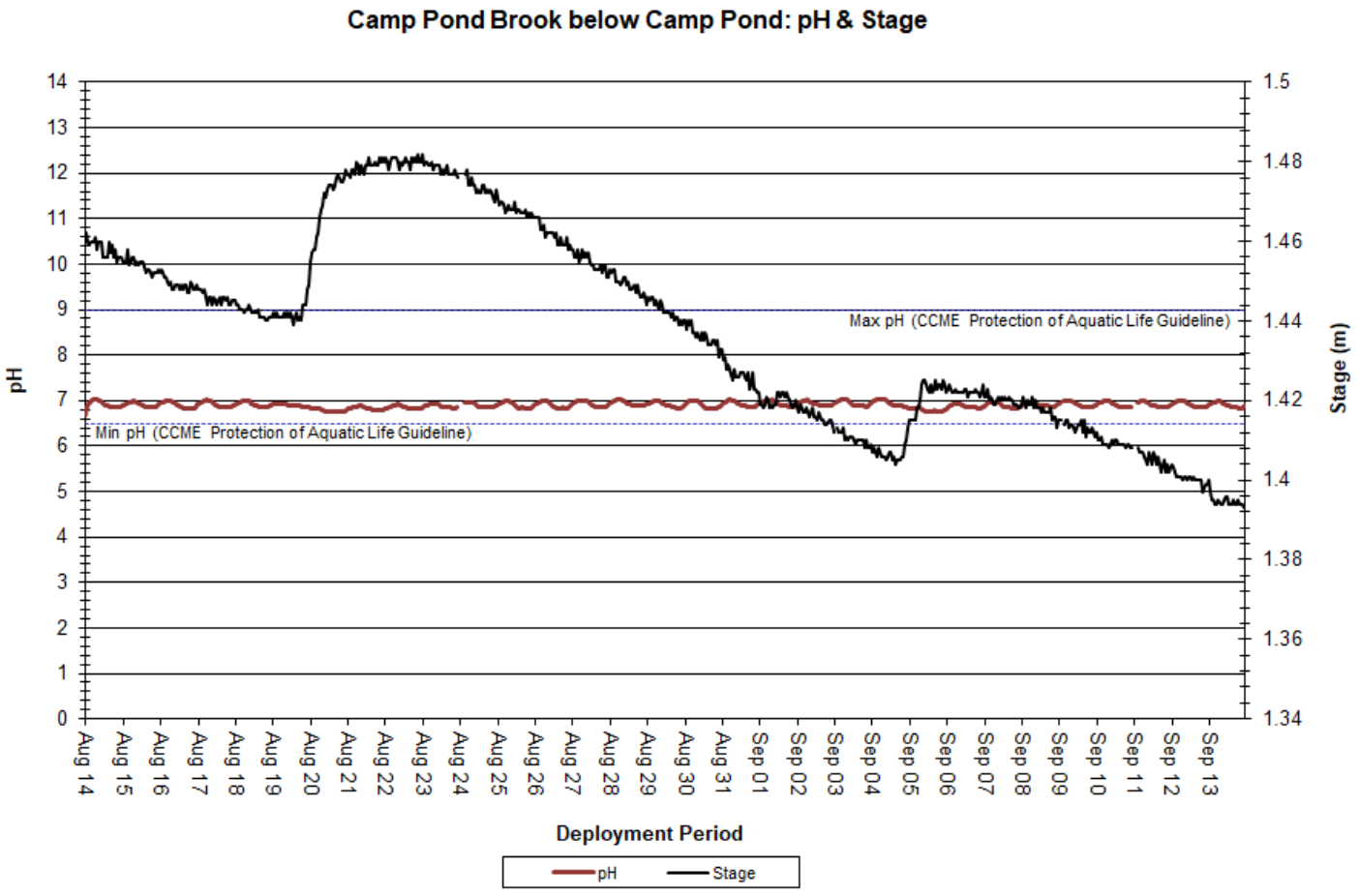

Figure 9: pH & Stage at Camp Pond Brook below Camp Pond

Specific Conductivity

Over the deployment period, specific conductivity ranged from 35.2µS/cm to 49.7µS/cm, with a median value of 36.6µS/cm (Figure 10).

Conductivity levels were variable but slightly increasing across the deployment period, while stage was similarly variable but decreasing over the same period. An increase in water level generally serves to dilute suspended materials in the water column, in turn decreasing specific conductivity. This relationship is visible at times in the graph below; however, sudden increases in stage are often accompanied by similar sudden increases in conductivity, after which conductivity begins to decrease as expected (Figure 10). This is likely due to a third factor, such as a precipitation or runoff event, that serves to temporarily increase both stage and conductivity simultaneously.

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

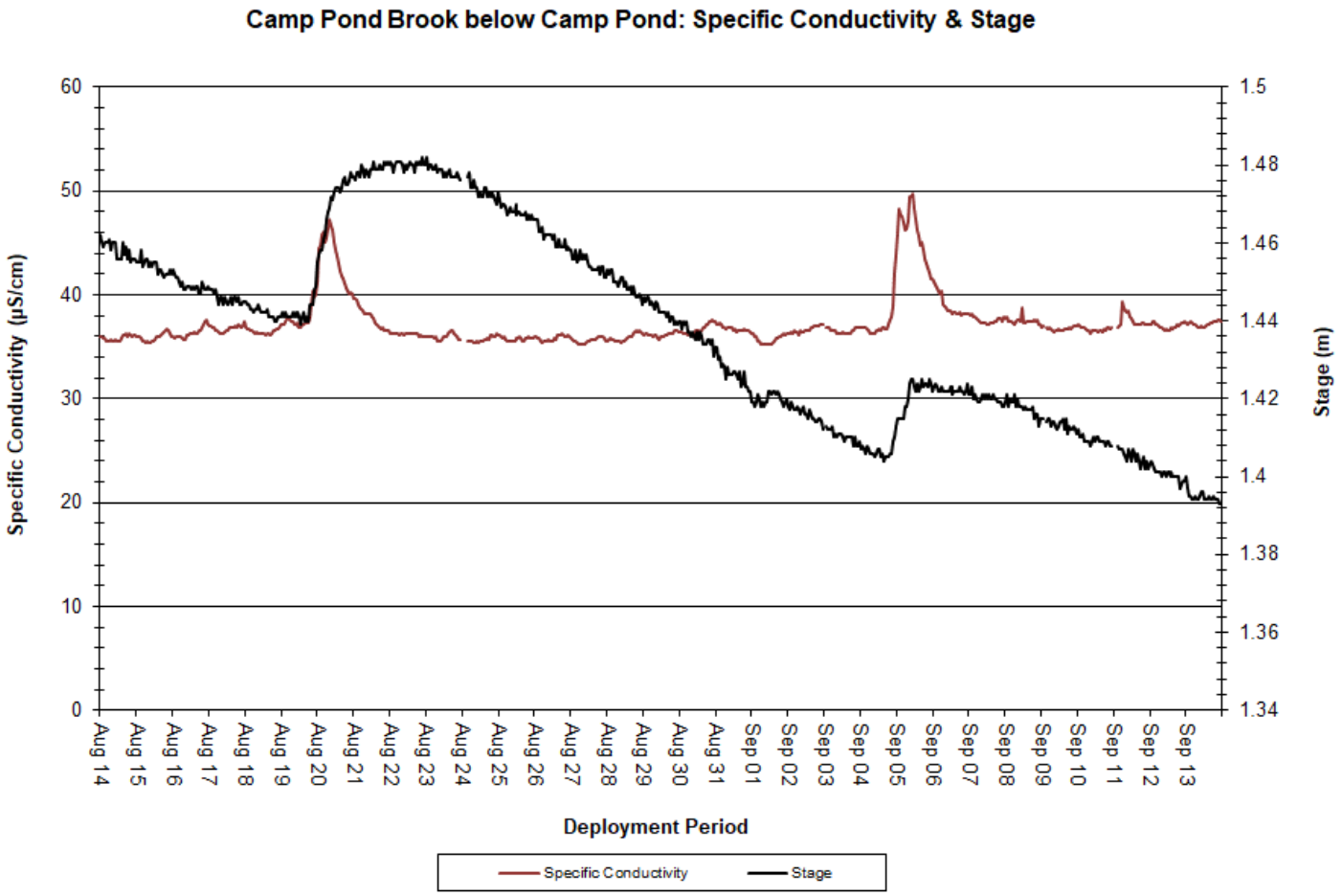

Figure 10: Specific Conductivity & Stage at Camp Pond Brook below Camp Pond

Dissolved Oxygen

Over the deployment period, dissolved oxygen concentration ranged from 9.31mg/L to 11.41mg/L, with a median value of 10.33mg/L. Saturation of dissolved oxygen ranged from 91.7% saturation to 103.0% saturation, with a median value of 97.2% (Figure 11).

Dissolved oxygen concentrations were relatively stable for the first half of deployment, after which they began to increase. In contrast, water temperatures were relatively stable for the first half of deployment and then began to decrease. This observation is to be expected as water temperature directly influences the level of dissolved oxygen present in the water column; as water temperatures increase, dissolved oxygen concentrations decrease, and vice versa.

Dissolved oxygen concentrations were above the CCME's Guidelines for the Protection of Early and Other Life Stages for the majority of the deployment period; exceptions occurred on August 30 and 31 and corresponded closely with higher water temperatures (Figure 11).

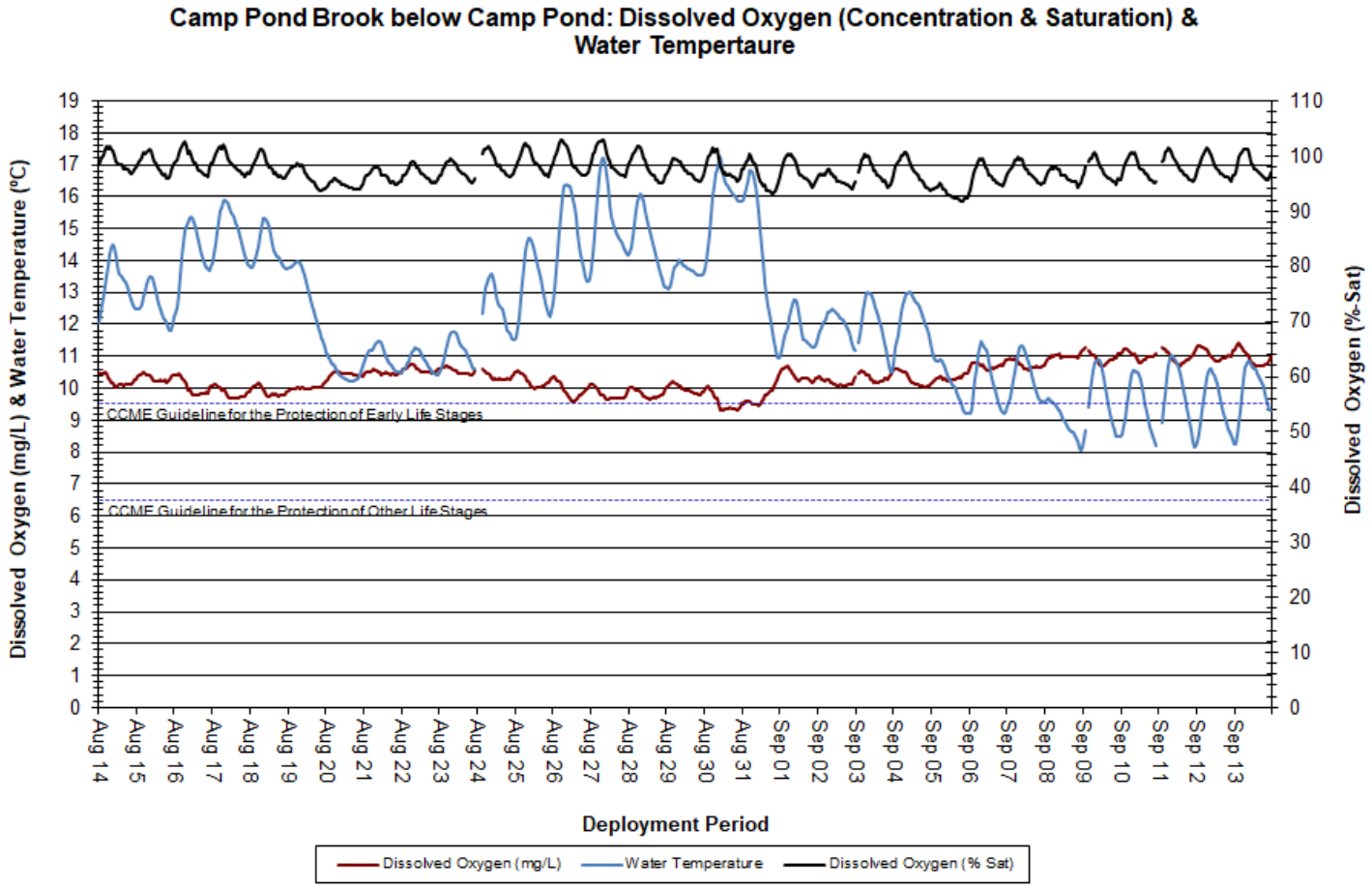

Figure 11: Dissolved Oxygen & Water Temperature at Camp Pond Brook below Camp Pond

Turbidity

Over the deployment period, turbidity ranged from 0.0NTU to 28.6NTU, with a median value of 2.3NTU (Figure 12). A median value of 2.3NTU indicates that there was a small amount of natural background turbidity at this station.

The majority of turbidity peaks observed from throughout the deployment period correlate closely with rainfall events (Figure 12). The observation that turbidity levels did not return to baseline levels following the precipitation event on September 5 could indicate that other changes were occurring in the water column, such as increased sediment or natural debris.

Precipitation data was obtained from the Voisey's Bay airstrip weather station.

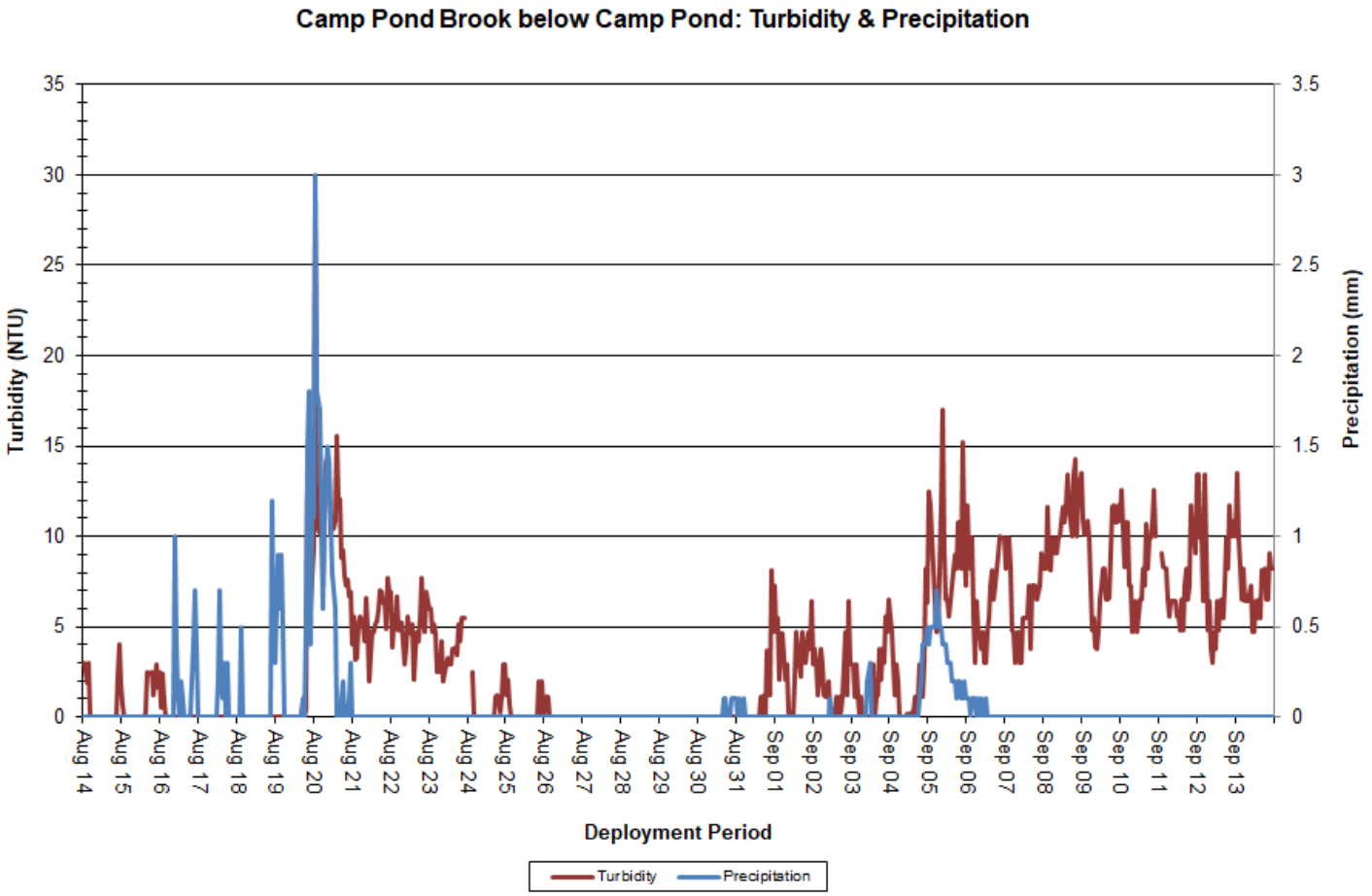

Figure 12: Turbidity & Precipitation at Camp Pond Brook below Camp Pond

Stage, Flow and Precipitation

Over the deployment period, stage values ranged from 1.39m to 1.48m, with a median value of 1.44m. Stream flow values ranged from 0.37m^3/s to 0.84m^3/s, with a median value of 0.56m^3/s (Figure 13). Precipitation data was obtained from the Voisey's Bay airstrip weather station.

Stage and flow were generally decreasing across the deployment period, with temporary increases correlating closely with precipitation events (Figure 13).

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

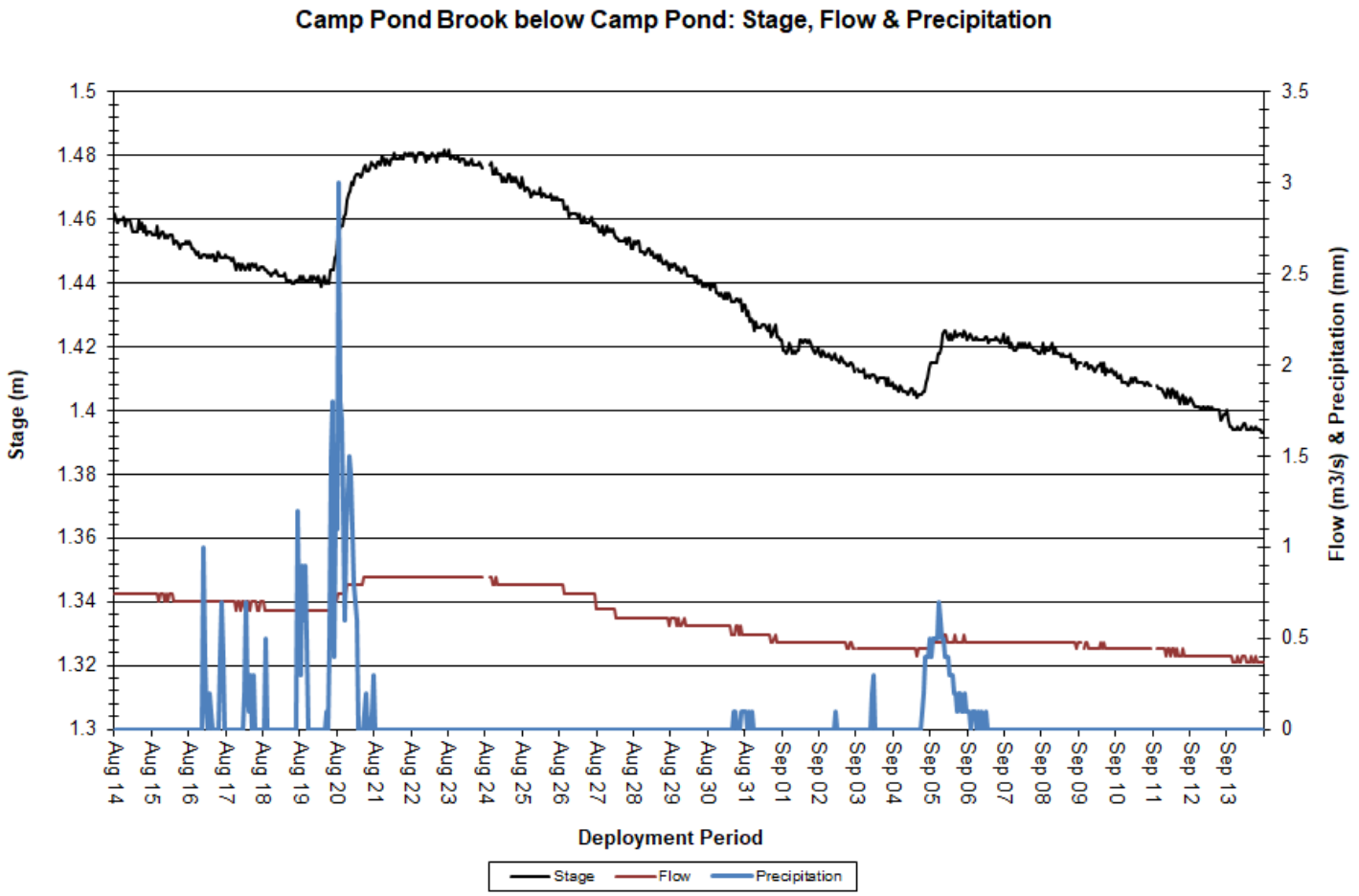

Figure 13: Stage, Flow & Precipitation at Camp Pond Brook below Camp Pond

Reid Brook below Tributary

Water Temperature

Over the deployment period, water temperature ranged from 5.98°C to 14.7°C, with a median value of 10.03°C (Figure 14).

Water temperature at this station displays diurnal variations. Water temperature was relatively stable throughout the first half of deployment, after which it began to steadily decrease as summer changed to fall. This is to be expected as air temperatures followed a very similar trend over the same period (Figure 14). Air temperature data was obtained from the Voisey's Bay airstrip weather station.

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

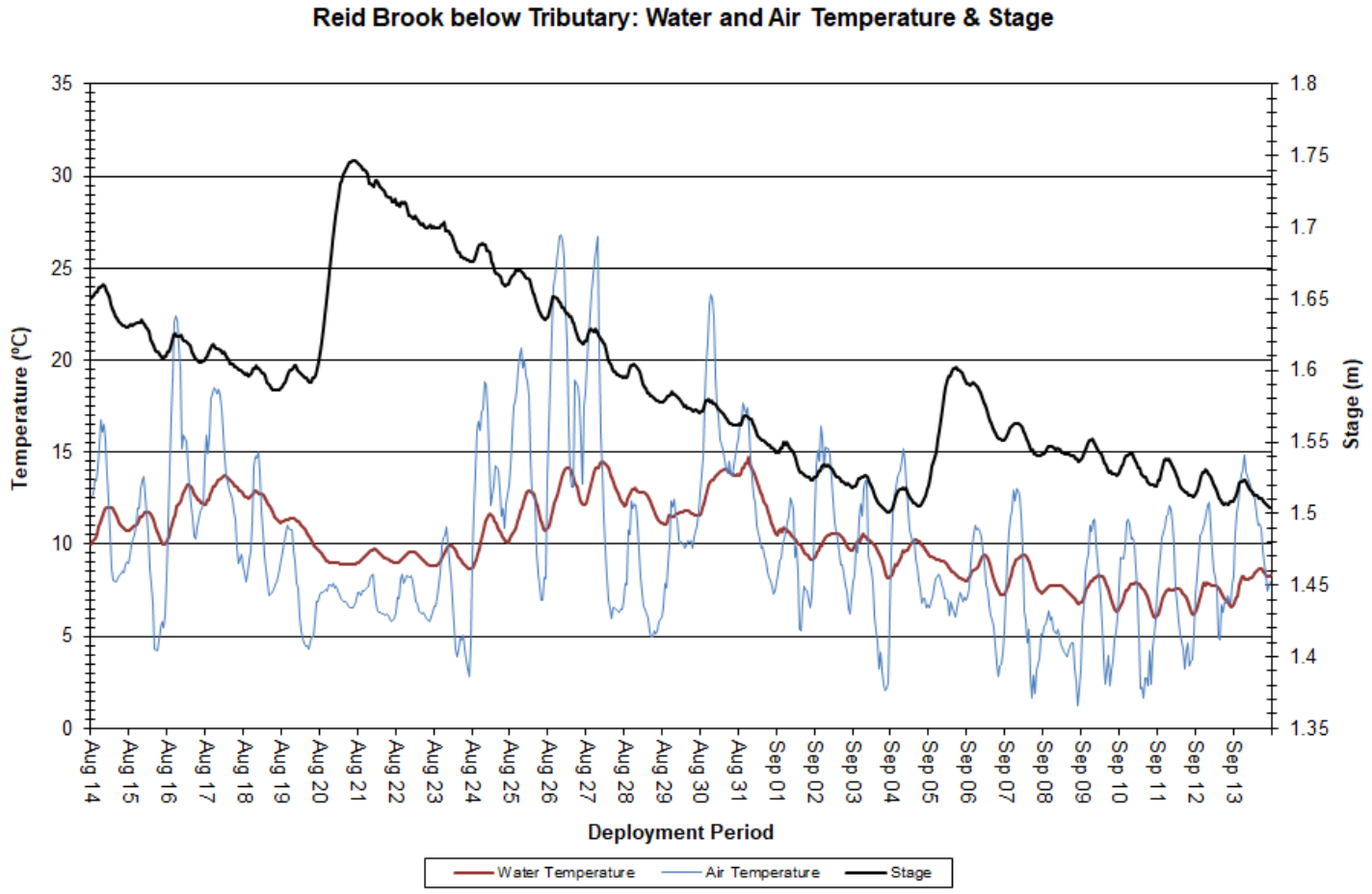

Figure 14: Water and Air Temperature & Stage at Reid Brook below Tributary

pH

Over the deployment period, pH ranged from 6.43 pH units to 7.17 pH units, with a median value of 6.73 (Figure 15).

pH was within the CCME's Guidelines for the Protection of Aquatic Life for the majority of the deployment period. Instances where pH temporarily dipped below the CCME's minimum guideline correlated closely with sharp increases in stage (Figure 15).

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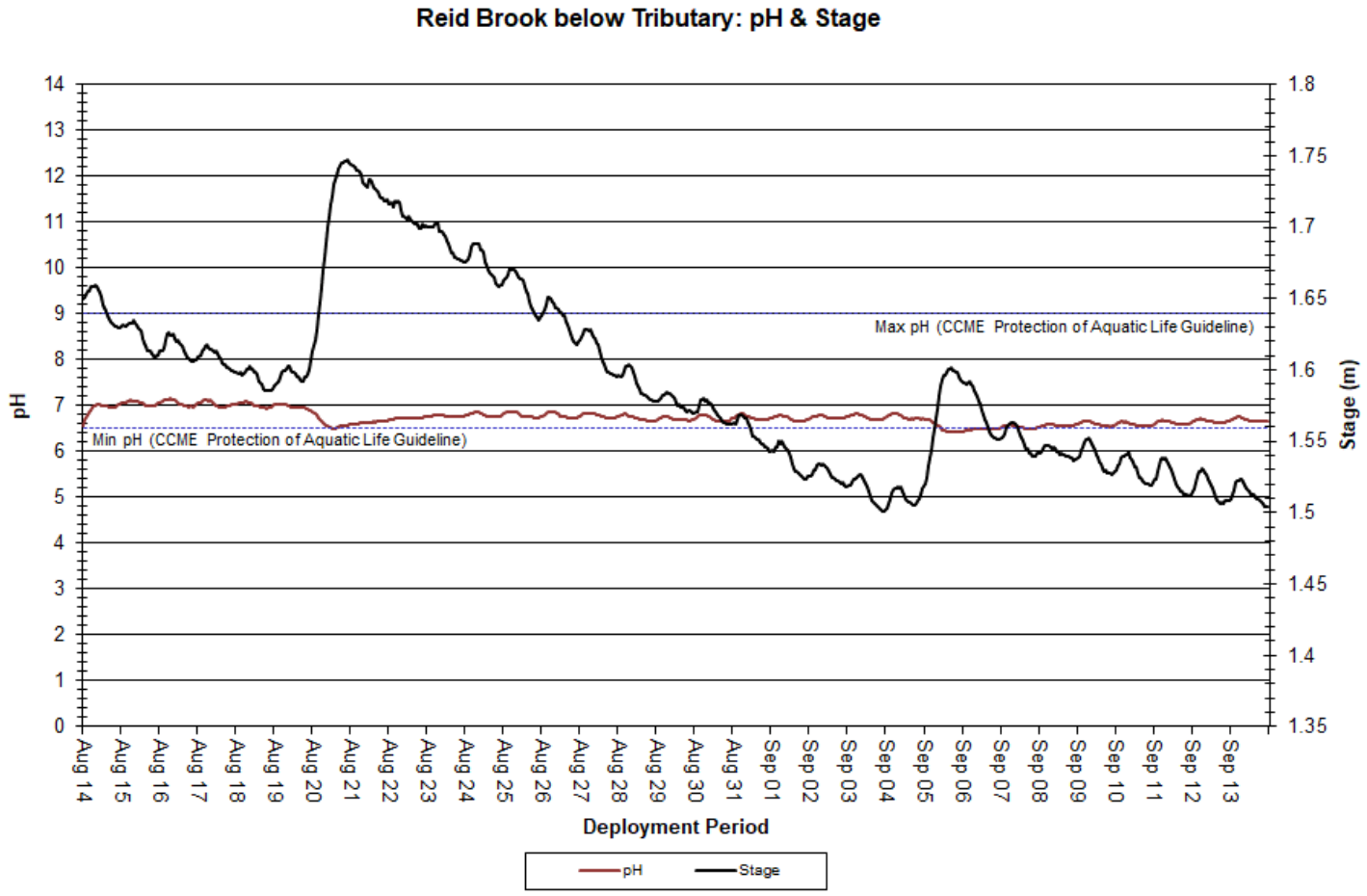

Figure 15: pH & Stage at Reid Brook below Tributary

Specific Conductivity

Over the deployment period, specific conductivity ranged from 29.4µS/cm to 38.4µS/cm, with a median value of 35.8µS/cm (Figure 16).

Specific conductivity steadily increased over the course of deployment (Figure 16).

Specific conductivity and stage generally exhibit an inverse relationship: as one parameter increases, the other decreases. This relationship is evident in the graph below.

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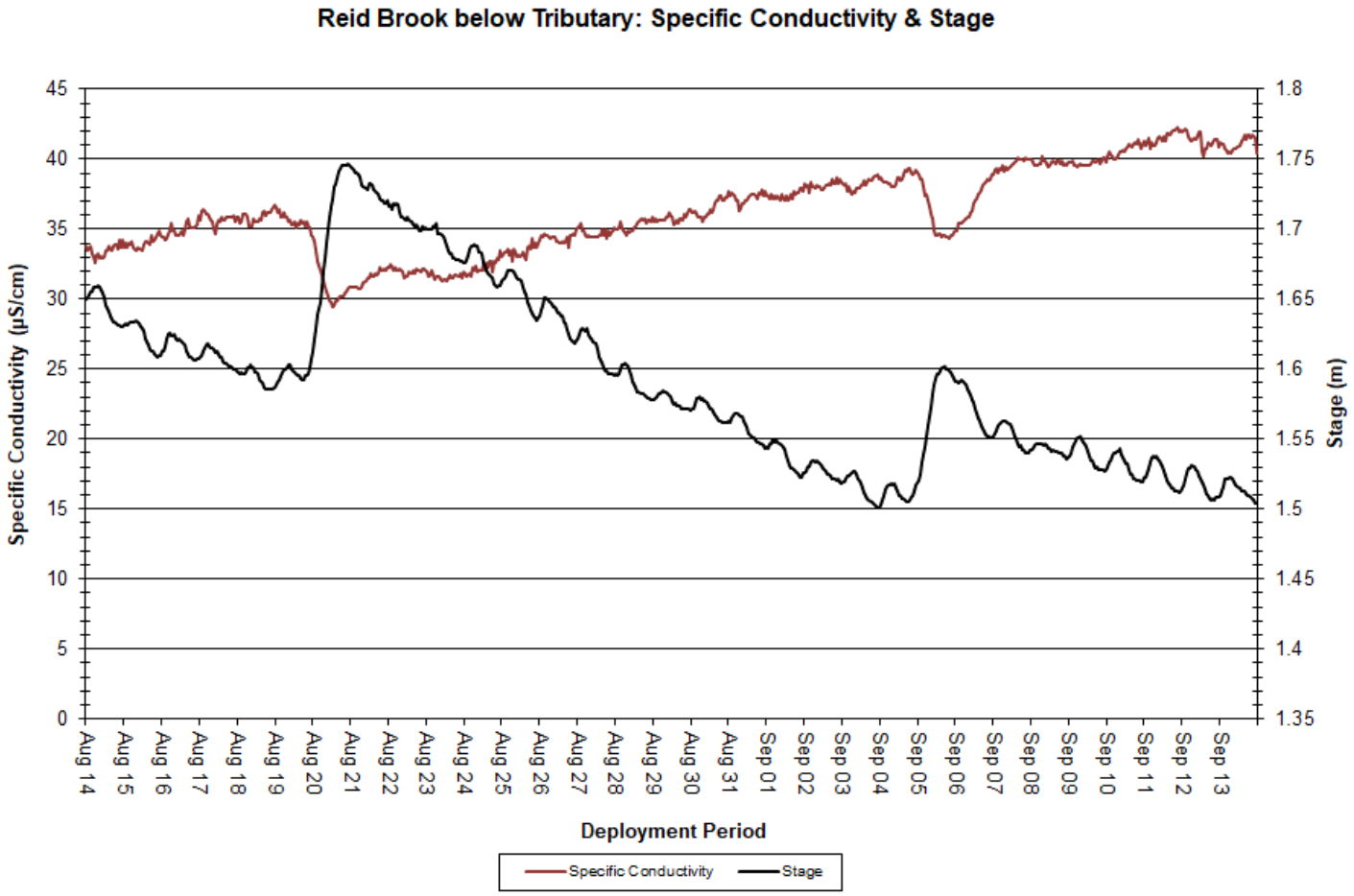

Figure 16: Specific Conductivity & Stage at Reid Brook below Tributary

Dissolved Oxygen

Over the deployment period, dissolved oxygen concentration ranged from 9.66mg/L to 11.36mg/L, with a median value of 10.84mg/L. The saturation of dissolved oxygen ranged from 94.7% saturation to 100.8% saturation, with a median value of 97.4% (Figure 17).

Dissolved oxygen concentrations remained above the CCME's Guidelines for the Protection of Early Life Stages (9.5mg/L) and Other Life Stages (6.5 mg/L) for the duration of deployment. Dissolved oxygen concentration was fairly consistent over the course of deployment, with fluctuations closely connected to changes in water temperature. This is to be expected as water temperature and dissolved oxygen concentration generally exhibit an inverse relationship.

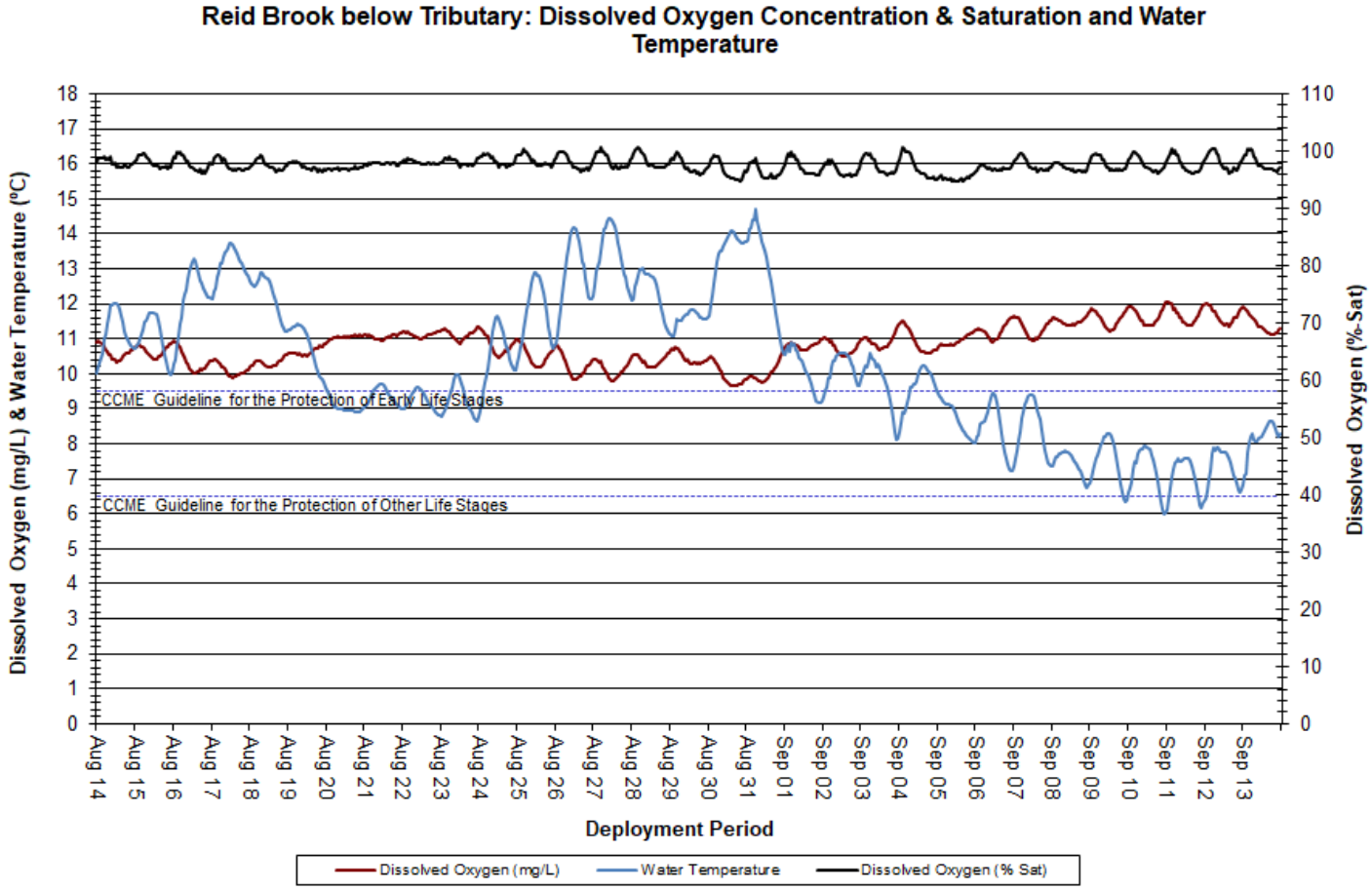

Figure 17: Dissolved Oxygen & Water Temperature at Reid Brook below Tributary

Turbidity

Over the deployment period, turbidity ranged from 0.0 NTU to 28.2 NTU, with a median value of 0.0 NTU (Figure 18). A median turbidity value of 0.0 NTU indicates that there was very little background turbidity at this station.

The majority of the turbidity events observed at this station closely correlated with rainfall events (Figure 18), which can cause mixing of solids in the water column (Figure 18). Precipitation data was obtained from the Voisey's Bay airstrip weather station.

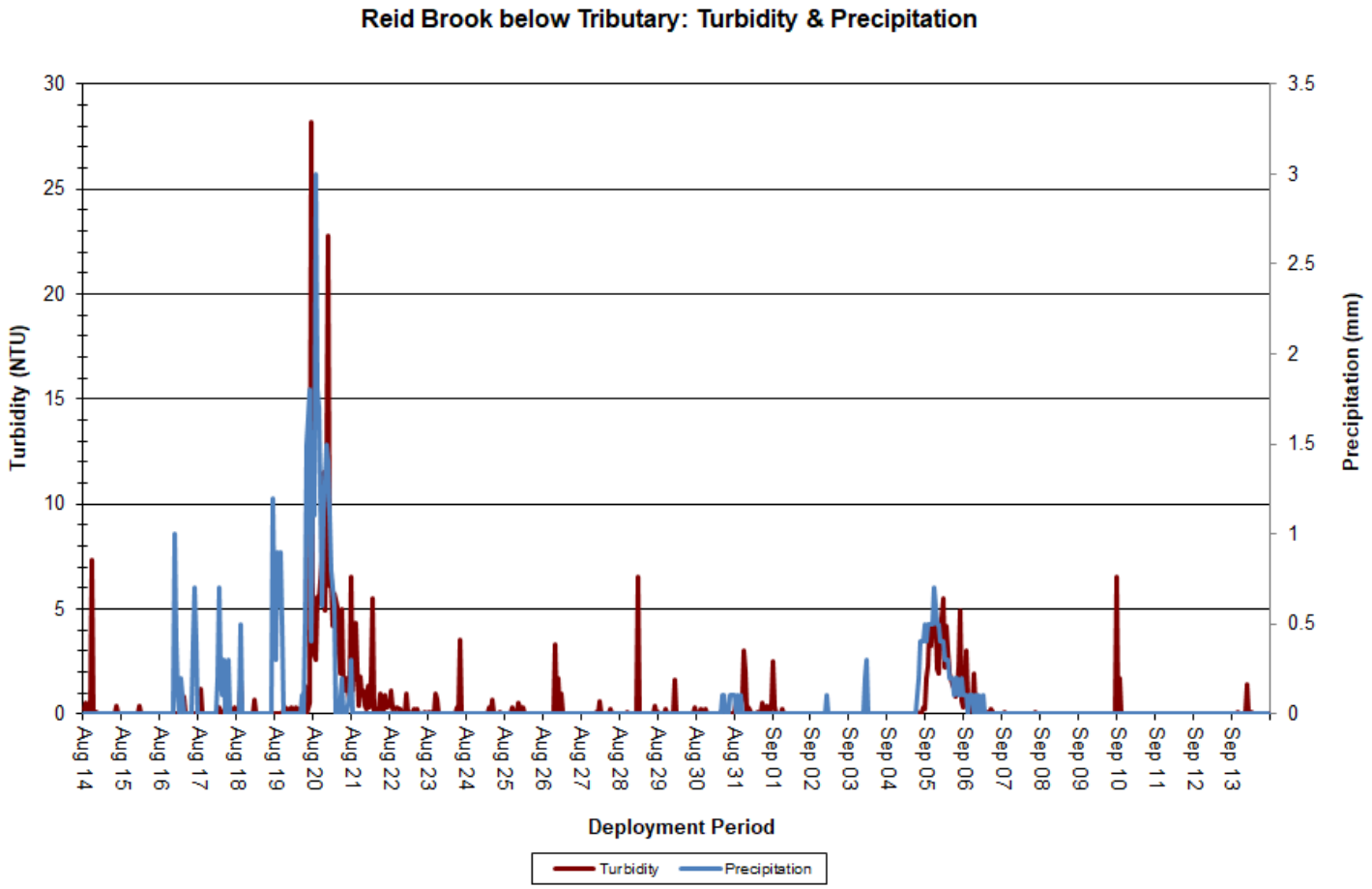

Figure 18: Turbidity & Precipitation at Reid Brook below Tributary

Stage and Flow

Over the deployment period, stage values ranged from 1.50m to 1.75m, with a median value of 1.59m. Stream flow values ranged from 2.29m^3/s to 9.80m^3/s, with a median value of 4.22m^3/s (Figure 19). Precipitation data was obtained from the Voisey's Bay airstrip weather station.

Stage and flow were variable across the deployment period, but generally showed a decreasing trend. Two significant increases in stage and flow (August 20 and September 5) correlated closely with precipitation events (Figure 19).

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

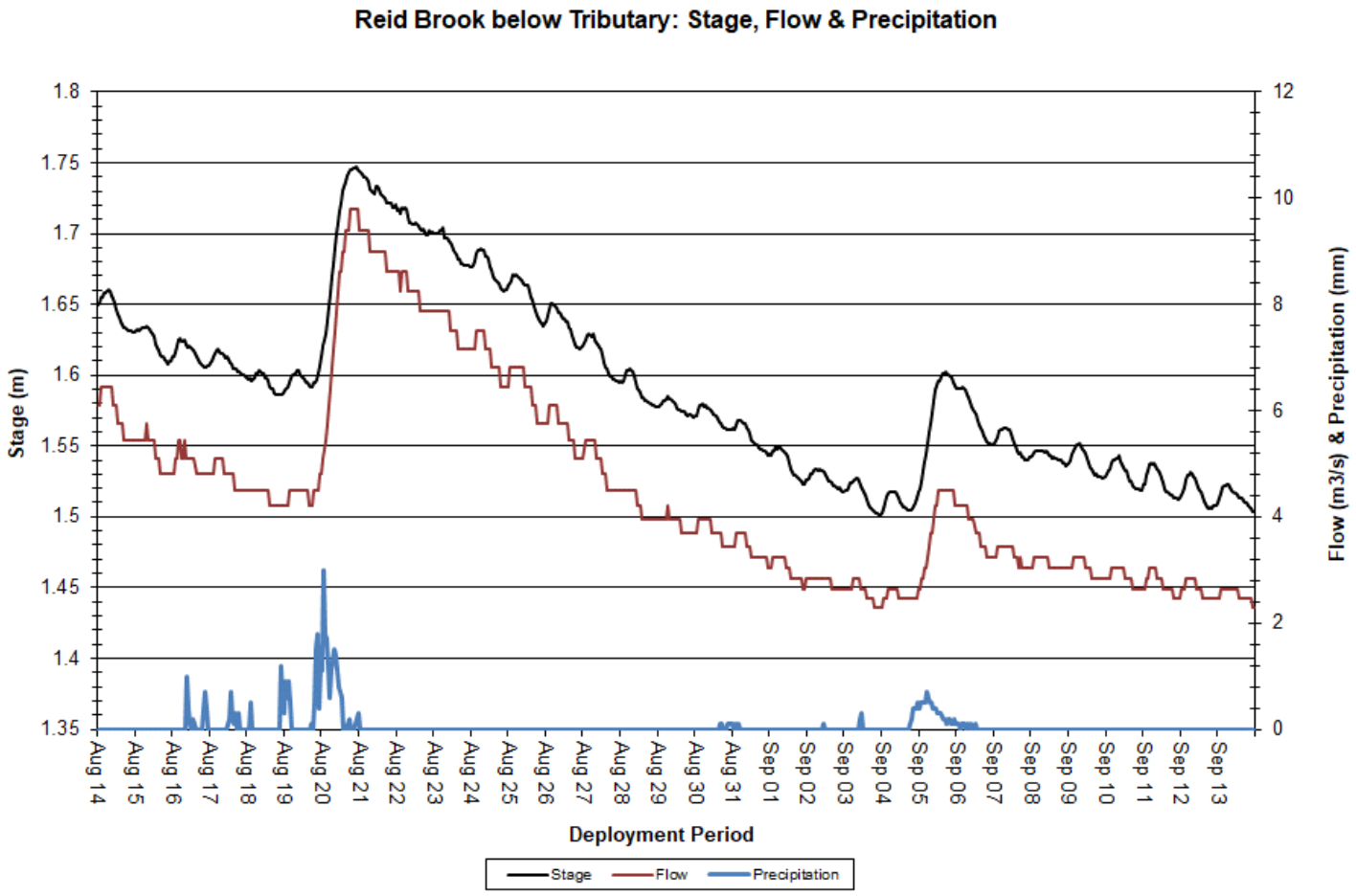

Figure 19: Stage, Flow & Precipitation at Reid Brook below Tributary

Tributary to Reid Brook

Water Temperature

Over the deployment period, water temperature ranged from 5.70°C to 14.40°C, with a median value of 9.85°C (Figure 20). Streams and brooks are sensitive to changes in the ambient air temperature, thus water temperature will fluctuate considerably depending on the weather and the time of day. Air temperature fluctuates to a greater extent compared to water temperature. Air temperature data was obtained from the Voisey's Bay airstrip weather station.

Water temperature data displays a natural diurnal pattern. As expected, water temperatures were stable and higher through August, after which they started to decreased gradually over the remainder of deployment with the change from summer to fall. Water temperatures correlated closely with ambient air temperatures.

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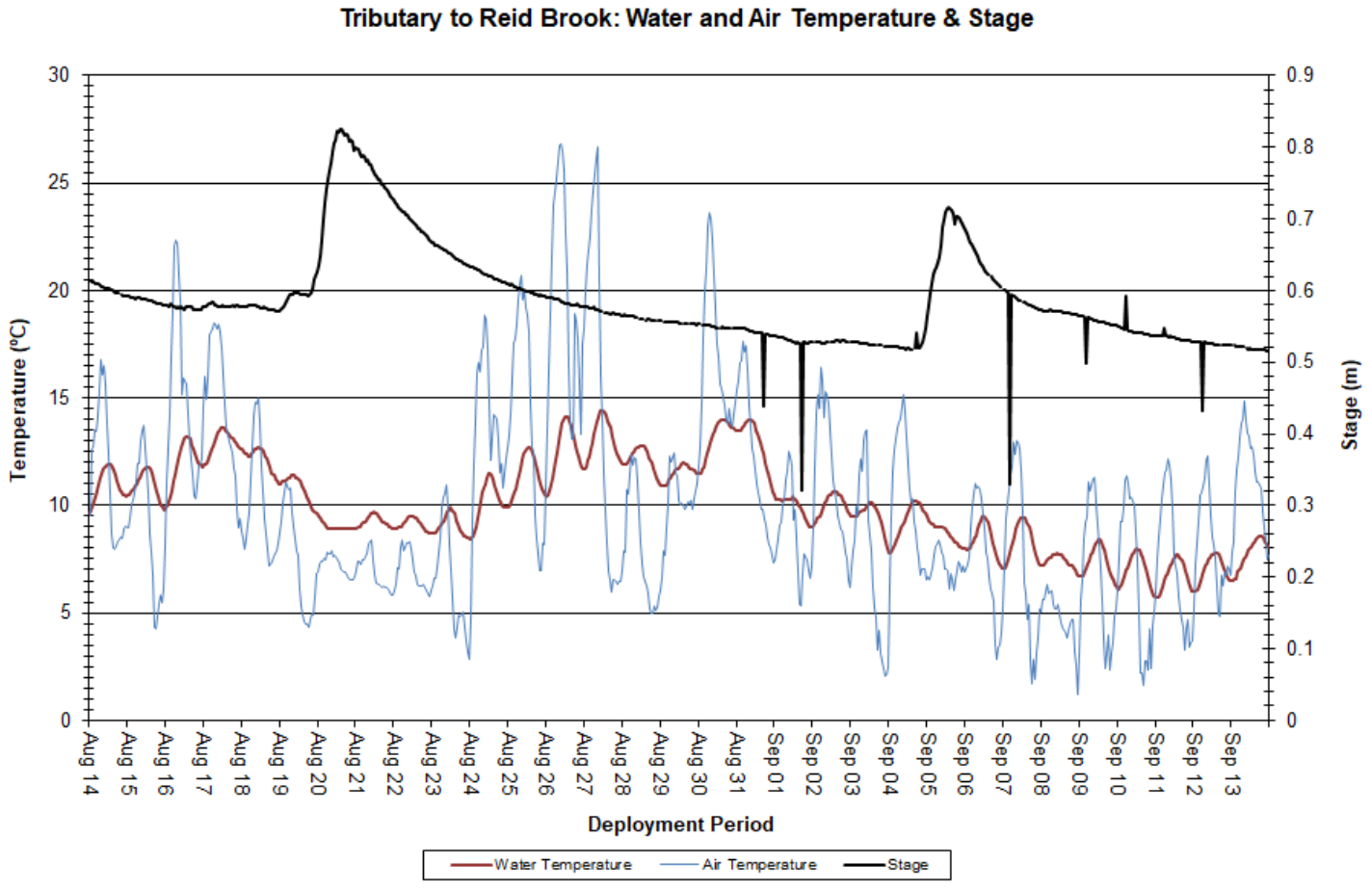

Figure 20: Water and Air Temperature & Stage at Tributary to Reid Brook

pH

Over the deployment period, pH ranged from 6.05 pH units to 6.75 pH units, with a median value of 6.55 (Figure 21).

pH values hovered around the CCME's Minimum Guideline for the Protection of Aquatic Life for the duration of deployment. Significant temporary decreases in pH correlated closely with significant temporary increases in stage.

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

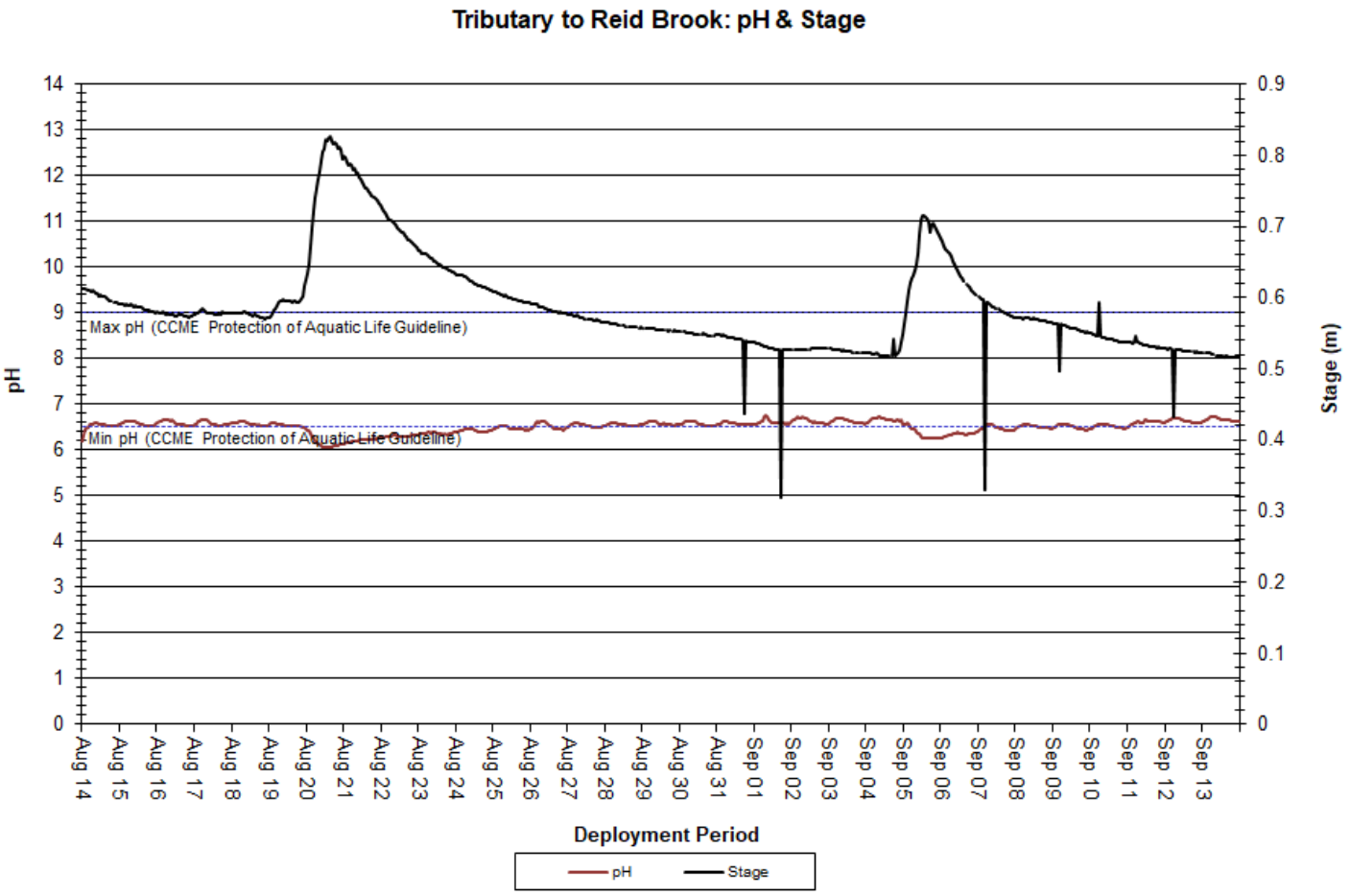

Figure 21: pH & Stage at Tributary to Reid Brook

Specific Conductivity

Over the deployment period, specific conductivity ranged from 8.8µS/cm to 31.9µS/cm, with a median value of 28.9µS/cm (Figure 22).

Specific conductivity and stage generally exhibit an inverse relationship: as one parameter increases, the other decreases. When stage levels decrease, specific conductivity levels increase, as the decreased amount of water in the river system concentrates the solids that are present. This inverse relationship is readily visible in the graph below (Figure 22).

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

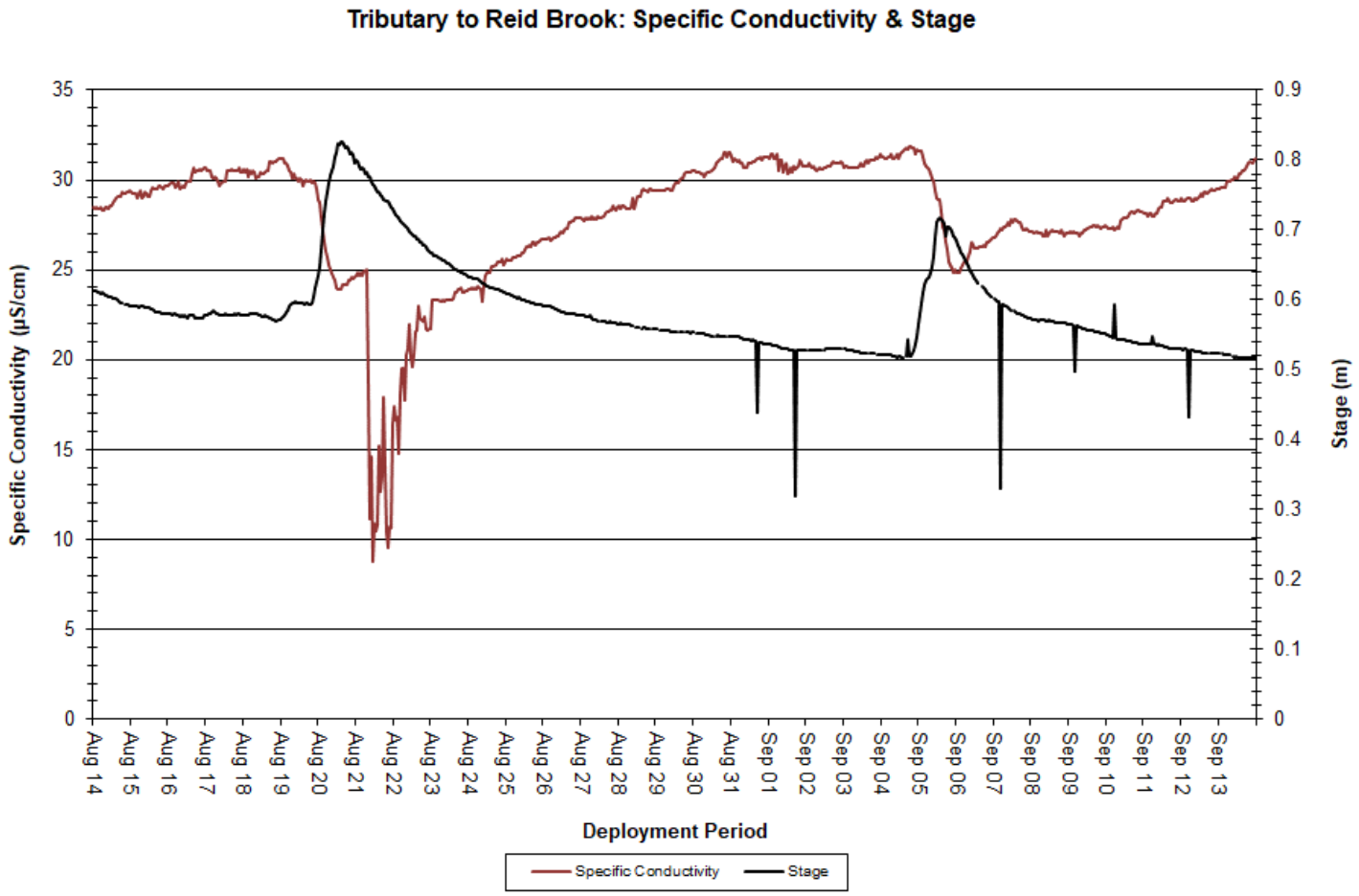

Figure 22: Specific Conductivity & Stage at Tributary to Reid Brook

Dissolved Oxygen

Over the deployment period, dissolved oxygen concentration ranged from 9.73mg/L to 12.31mg/L, with a median value of 10.96mg/L. The saturation of dissolved oxygen ranged from 95.5% saturation to 100.7% saturation, with a median value of 98.3% (Figure 23).

Dissolved oxygen levels remained above the CCME's Guidelines for the Protection of Early and Other Life Stages for the duration of deployment.

Dissolved oxygen concentration displays a diurnal pattern. During nightfall, dissolved oxygen levels are higher as cooler temperatures allow for more DO to be stored in the water column. During the day, dissolved oxygen levels are lower. This is a result of warmer water temperatures and photosynthesis by aquatic plants, which decrease dissolved oxygen levels in the water column.

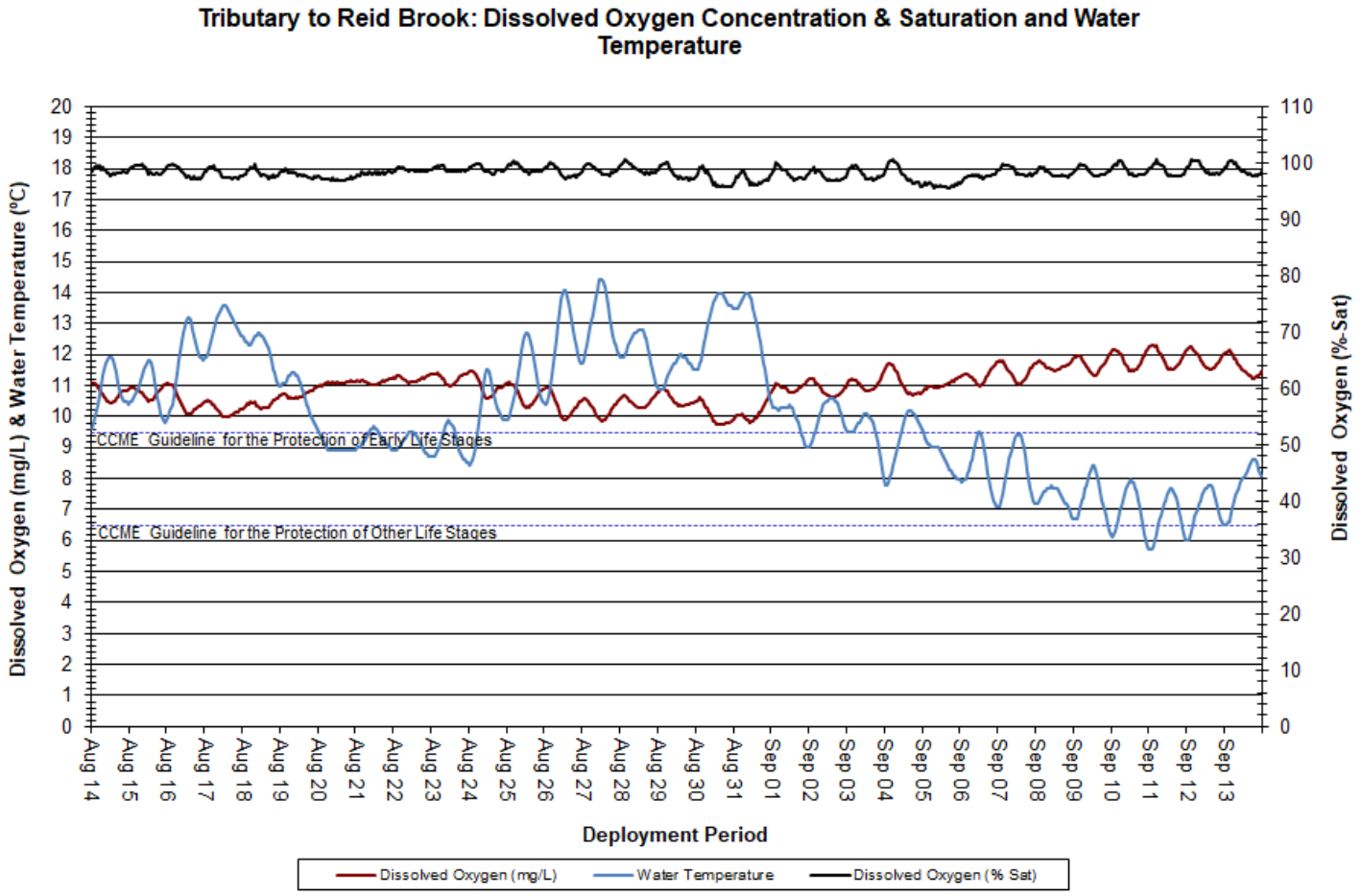

Figure 23: Dissolved Oxygen & Water Temperature at Tributary to Reid Brook

Turbidity

Over the start of the deployment period, turbidity ranged from 0.0 NTU to 11.8 NTU, with a median value of 0.2 NTU (Figure 24). A median value of 0.2 NTU indicates that there was a small amount of natural background turbidity at this station.

There were a number of turbidity events at the start of deployment that correlated closely with rainfall events (Figure 24); however, turbidity data was removed from August 21 onwards due to inaccuracies. Turbidity values rose to 3000NTU on this date and never returned to baseline levels. When Vale Environment and WRMD staff went to remove the instrument on September 13, it was found to have significant sediment build up around the turbidity sensor, which was preventing it from accurately recording turbidity levels.

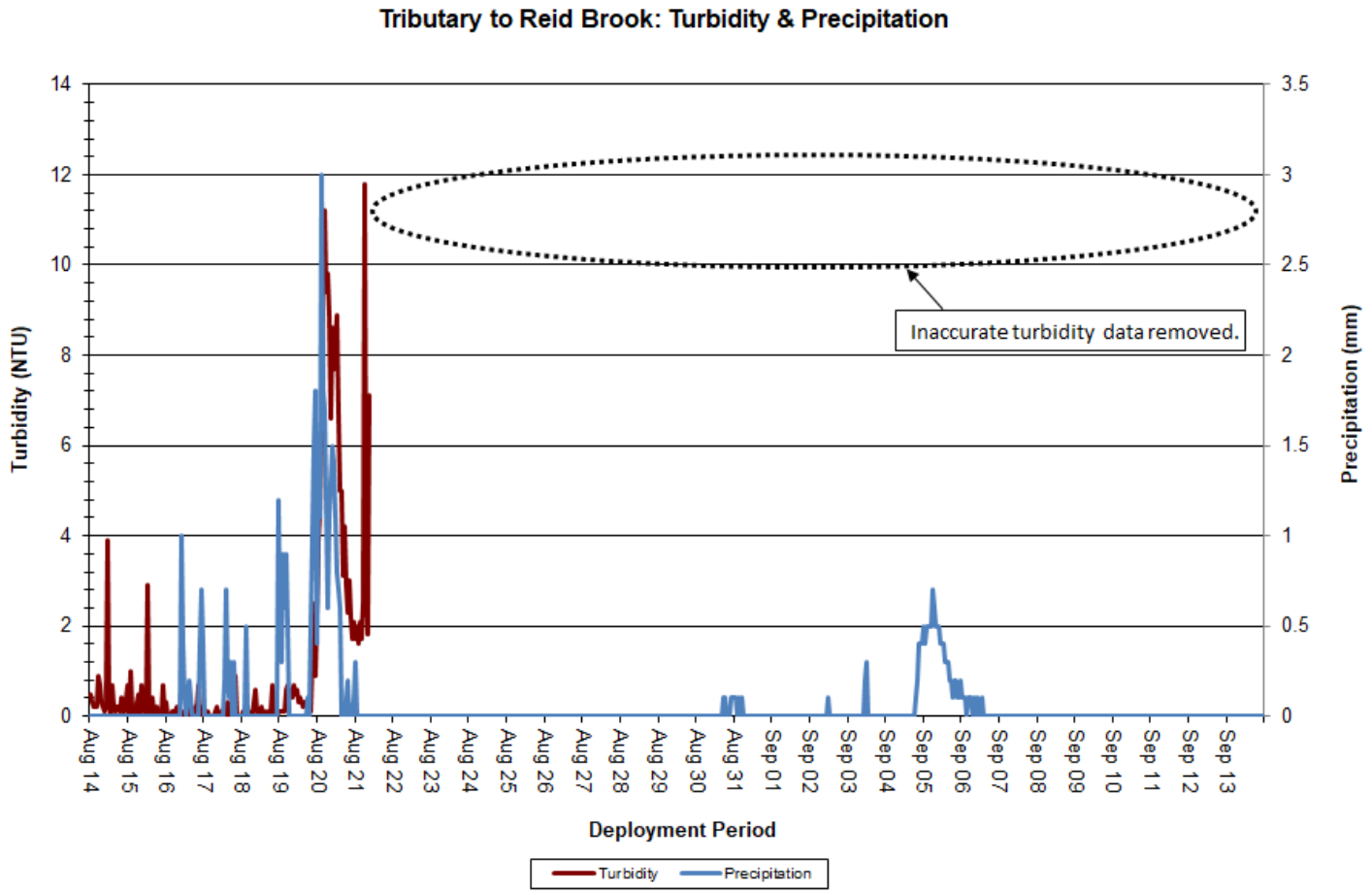

Figure 24: Turbidity & Precipitation at Tributary to Reid Brook

Stage and Flow

Over the deployment period, stage values ranged from 0.32m to 0.83m, with a median value of 0.58m. Stream flow values ranged from 0m^3/s to 1.64m^3/s, with a median value of 0.33m^3/s (Figure 25). Precipitation data was obtained from the Voisey's Bay airstrip weather station.

Stage and flow were quite stable over the deployment period, but generally showed a decreasing trend. Two significant increases in stage and flow (August 20 and September 5) correlated closely with precipitation events (Figure 25).

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

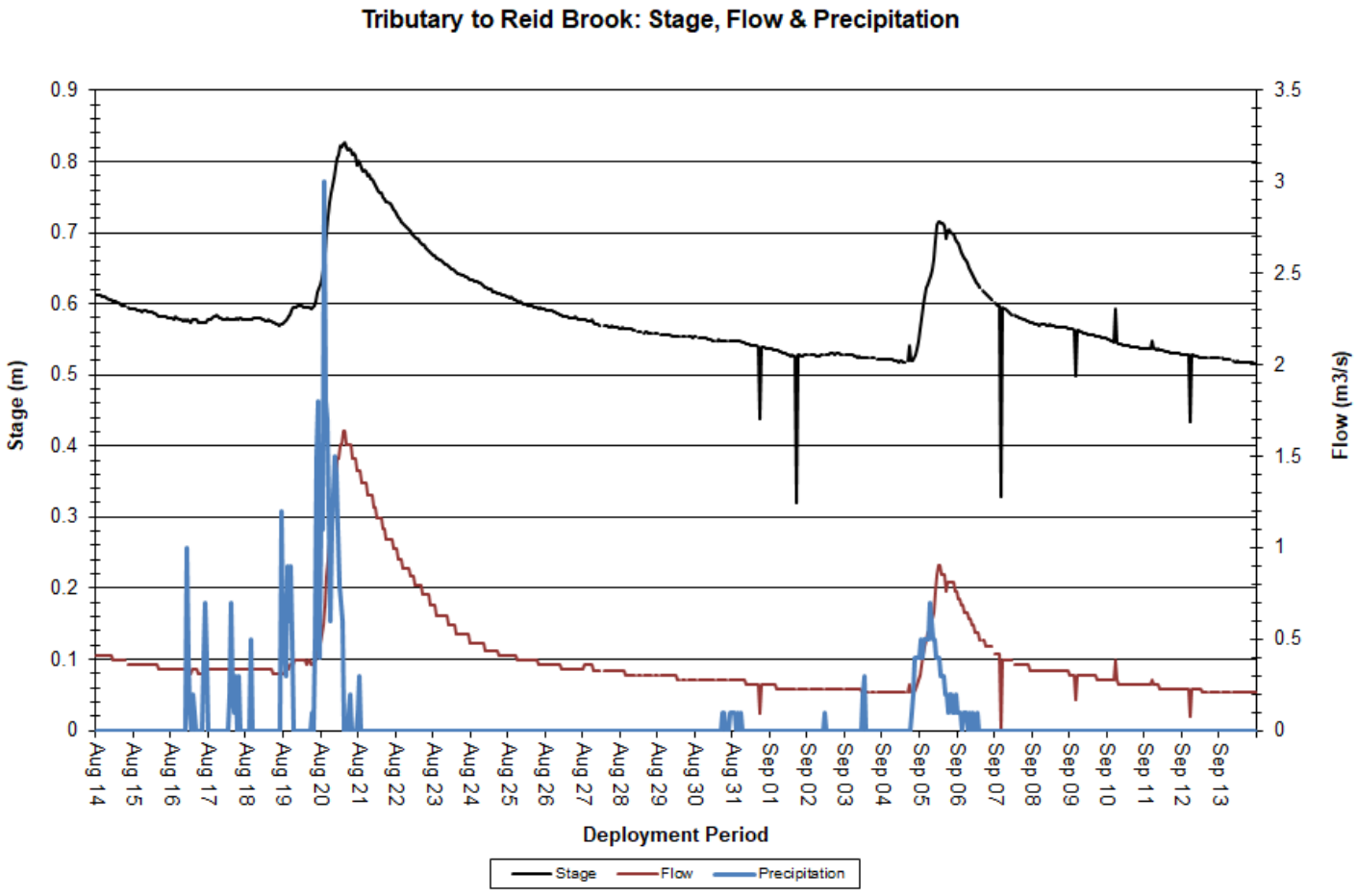

Figure 25: Stage, Flow & Precipitation at Reid Brook below Tributary

Conclusions

Water temperatures across all stations ranged from a minimum of 5.70°C at Tributary to Reid Brook to a maximum of 17.25°C at Camp Pond Brook below Camp Pond. Overall, water temperatures were stable and then decreasing across the network. Stations at Camp Pond Brook, Tributary to Reid Brook, and Reid Brook below Tributary are more sensitive to changes in ambient air temperatures as these sites are brooks with continuously moving water. In contrast, Reid Brook at Outlet of Reid Pond is a large pond with a high surface area and deeper, slower-moving water. This large body of water regulates the rate of warming and cooling.

pH values across all stations ranged from a minimum of 6.05pH units at Tributary to Reid Brook to a maximum of 7.17pH units at Reid Brook below Tributary. pH values at all stations were relatively consistent across the deployment period, and temporary decreases in pH correlated closely with temporary increases in stage.

Specific conductivity across all stations ranged from a minimum of 8.8µS/cm at Tributary to Reid Brook to a maximum of 49.7µS/cm at Camp Pond Brook below Camp Pond. Conductivity values at Reid Brook at Outlet of Reid Pond were the lowest across the network. Camp Pond Brook below Camp Pond had the highest median value at 36.6µS/cm, which is to be expected given the station's proximity to the Voisey's Bay mine site and increased potential for roadway runoff and other anthropogenic influences.

Dissolved oxygen levels across all stations ranged from a minimum of 9.31mg/L at Camp Pond Brook below Camp Pond to a maximum of 12.31mg/L at Tributary to Reid Brook. Dissolved oxygen is generally lower at this time of year and varies diurnally as water temperature is greatly affected by ambient air temperature. Dissolved oxygen levels remained above the CCME's Guideline for the Protection of Early Life Stages at all stations for the duration of deployment, except for at Camp Pond Brook below Camp Pond.

Turbidity levels across all stations ranged from a minimum of 0.0 NTU at all stations to a maximum of 484.0NTU at Reid Brook at Outlet of Reid Pond. Turbidity levels showed natural increases and decreases generally corresponding to precipitation events. Turbidity data was removed from the data set for Tributary to Reid Brook due to sediment build-up, which resulted in inaccurate readings from August 21 onwards.

Air temperature and precipitation data were obtained from the Voisey's Bay weather station, which is located at the airstrip. This data appears to be quite accurate and no modifications were made.

Overall, the changes in water quality parameters over the course of this deployment can be explained by natural events. Camp Pond Brook below Camp Pond does have the potential for anthropogenic influences as the site is the closest to the inhabited area. It is important to note that during a change (a decrease or increase) in water quality, change only occurs for a short period of time and then water quality parameters return to baseline.

References

Canadian Council of Ministers of the Environment. (2014) "Canadian water quality guidelines for the protection of aquatic life" Canadian Council of Ministers of the Environment. Retrieved from: http://www.ccme.ca/en/resources/canadian_environmental_quality_guidelines/index.html

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Mike Sader (2017) "Turbidity Measurement: A Simple, Effective Indicator of Water Quality Change". OTT Hydromet. Retrieved from http://www.ott.com/en-us/products/download/turbidity-white-paper/

Swanson, H.A., and Baldwin, H.L., (1965) "A Primer on Water Quality" U.S. Geological Survey. Retrieved from: http://ga.water.usgs.gov/edu/characteristics.html

APPENDIX A: Comparison Graphs

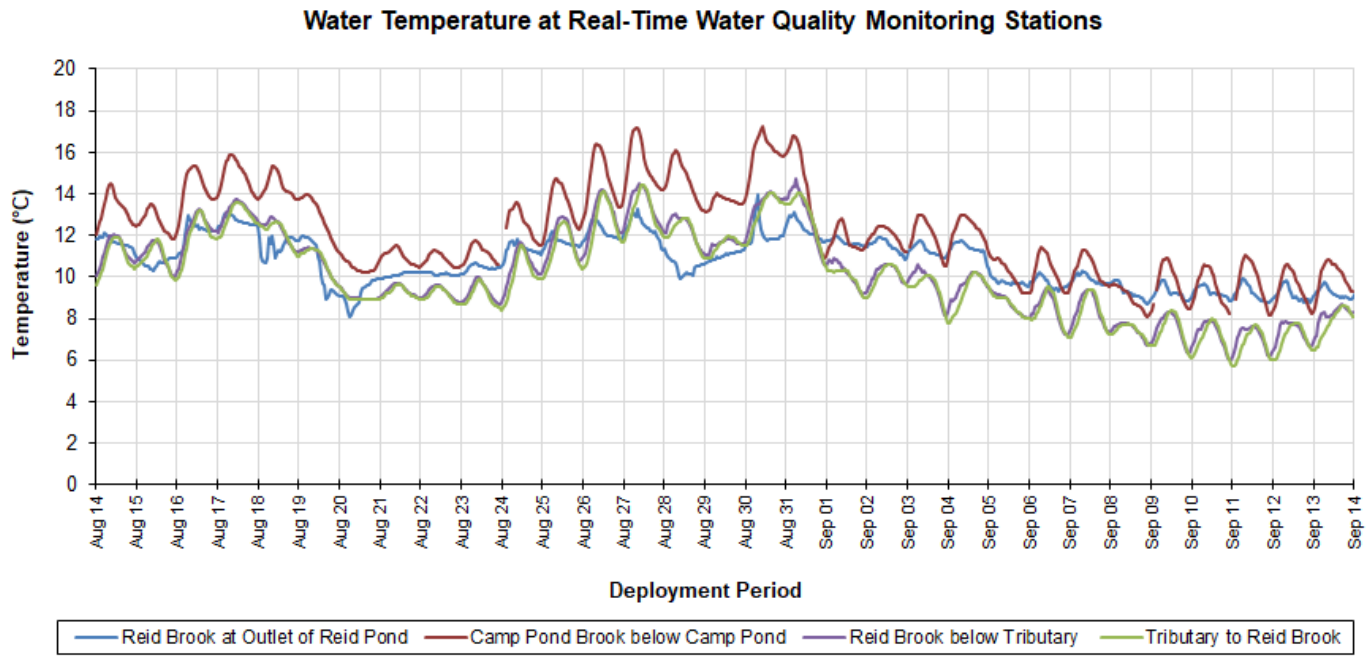


Figure A1: Comparison of Water Temperature (^{0}C) between all Real-Time Stations in Voisey's Bay.

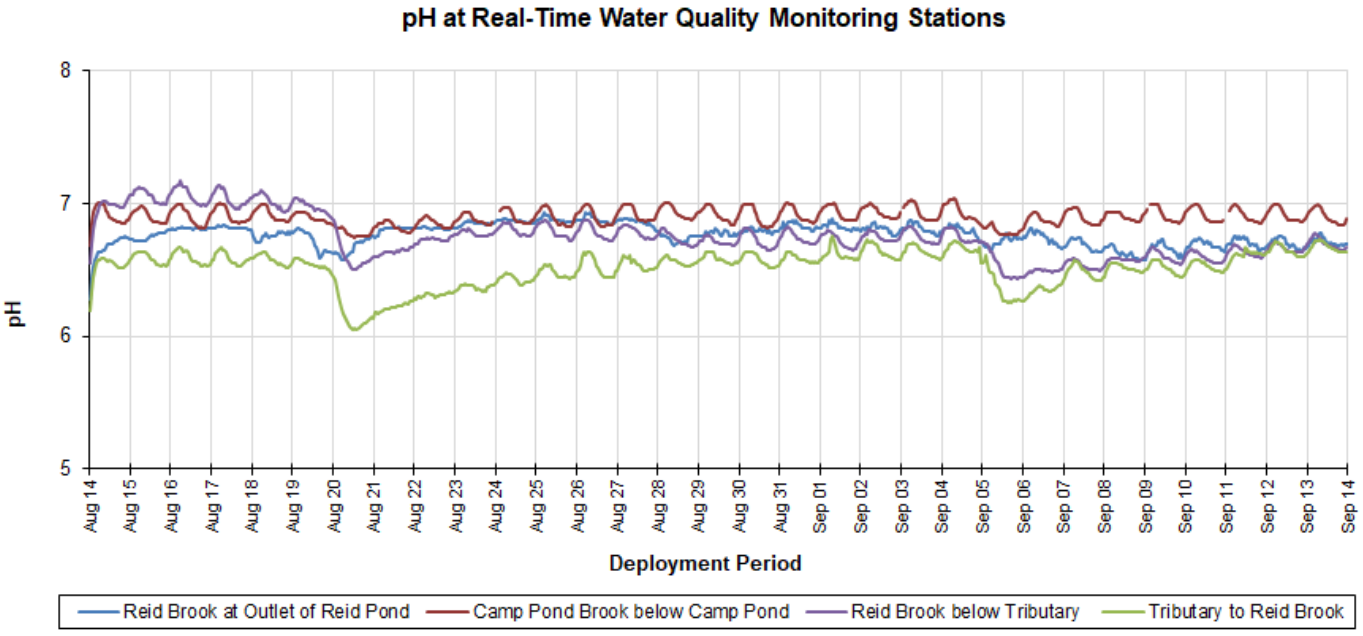


Figure A2: Comparison of pH between all Real-Time Stations in Voisey's Bay.

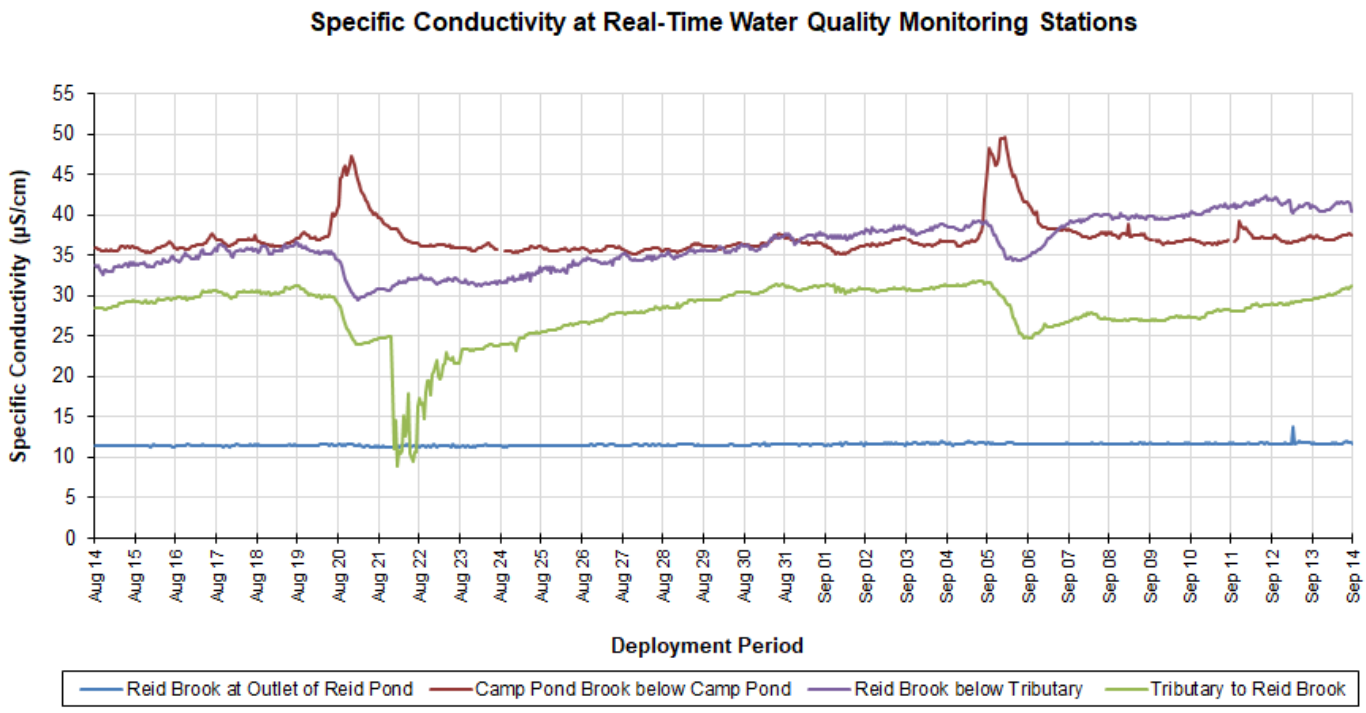


Figure A3: Comparison of Specific Conductivity (µS/cm) between all Real-Time Stations in Voisey's Bay.

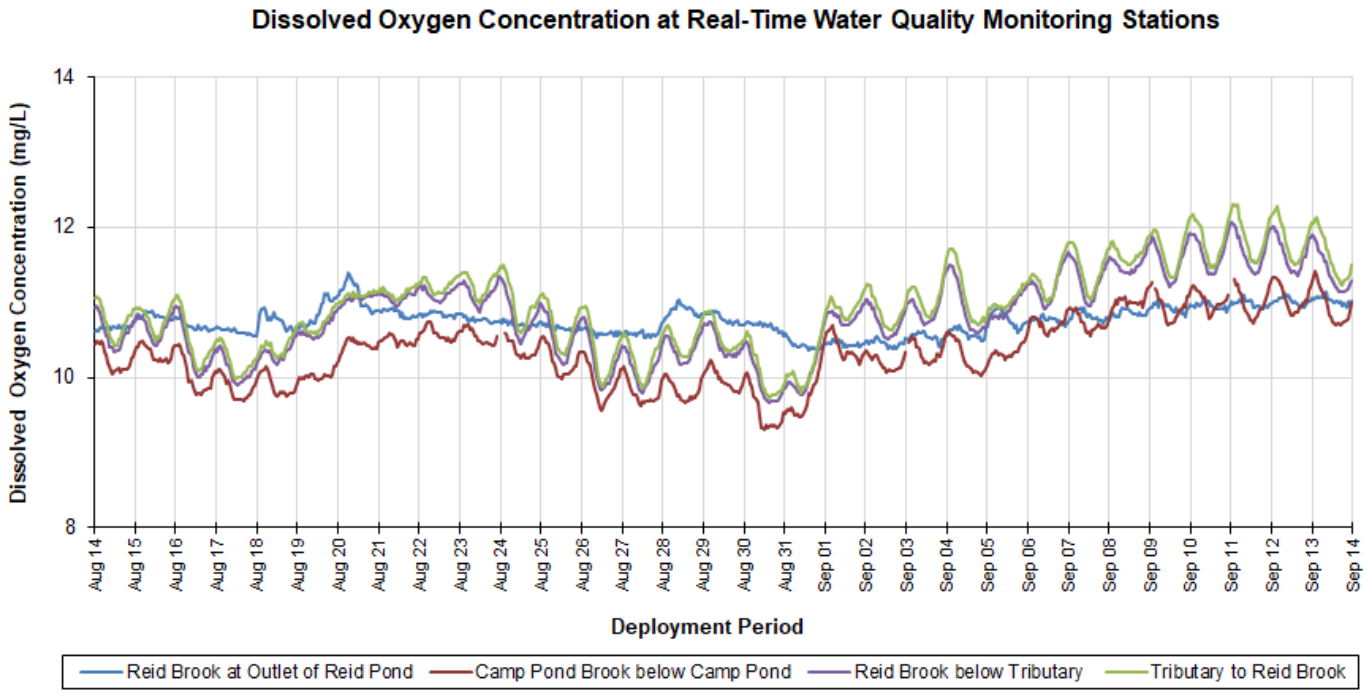


Figure A4: Comparison of Dissolved Oxygen (mg/L) between all Real-Time Stations in Voisey's Bay.

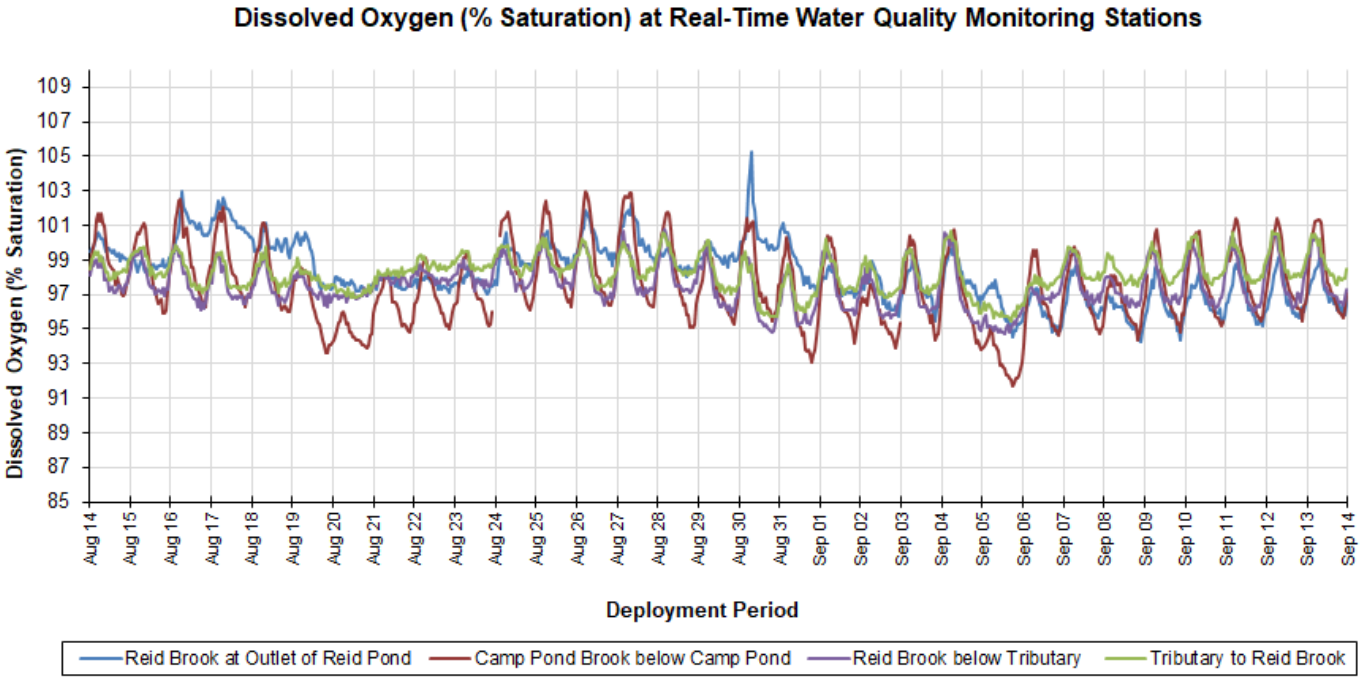


Figure A5: Comparison of Dissolved Oxygen (% Sat) between all Real-Time Stations in Voisey's Bay.

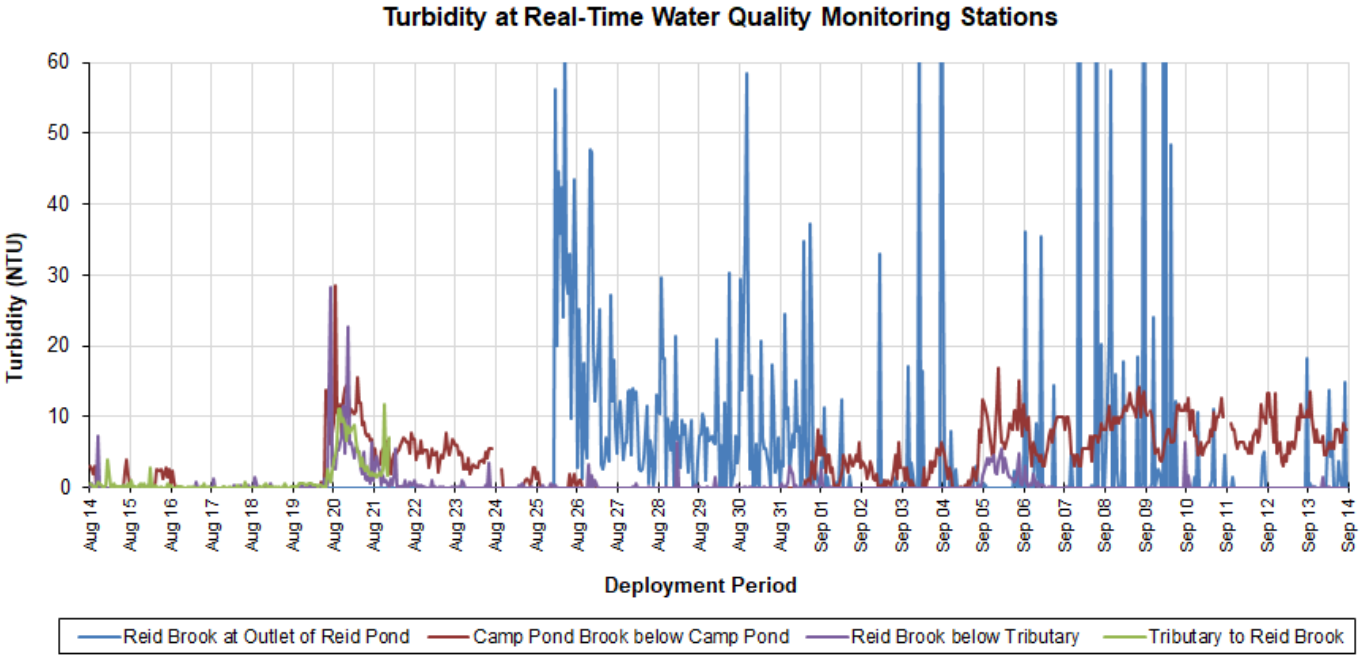


Figure A6: Comparison of Turbidity (NTU) between all Real-Time Stations in Voisey's Bay.

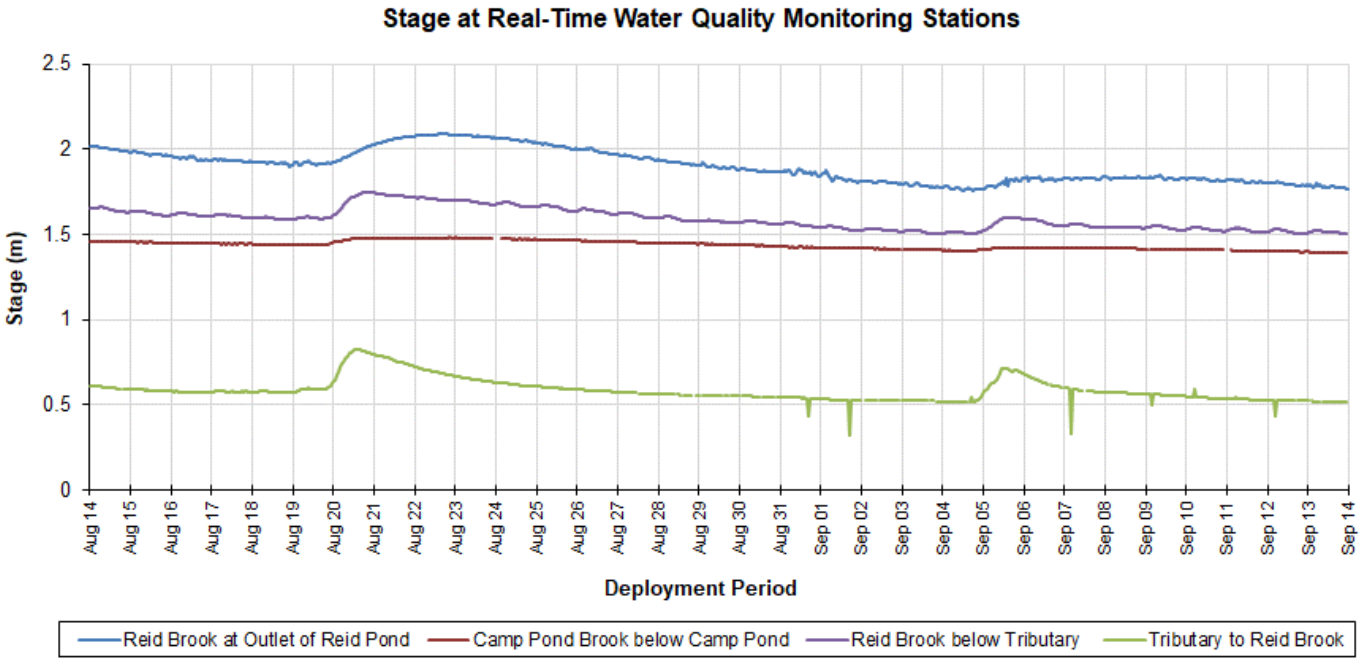


Figure A7: Comparison of Stage (m) between all Real-Time Stations in Voisey's Bay. Please note that stage data is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data.

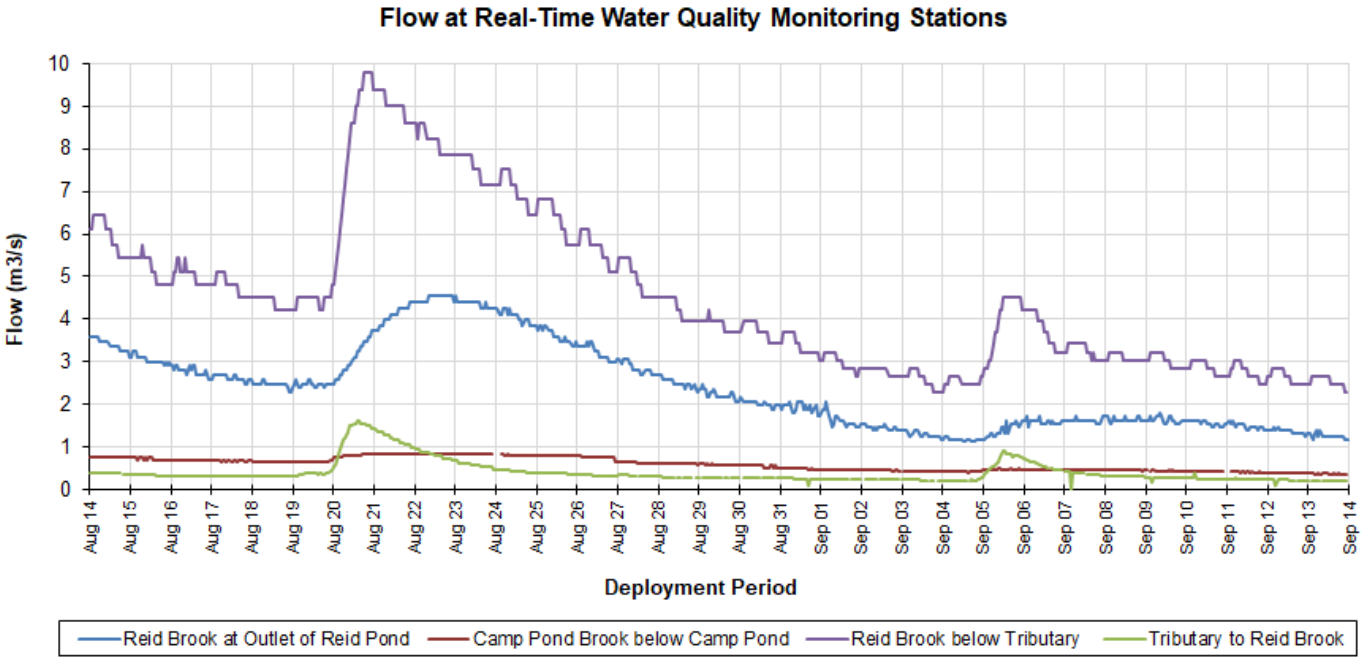


Figure A8: Comparison of Flow (m^3/s) between all Real-Time Stations in Voisey's Bay. Please note that flow data is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data.

APPENDIX B: Water Parameter Description

Dissolved Oxygen: The amount of Dissolved Oxygen (DO) (mg/L or % saturation) in the water is vital to the survival of aquatic organisms. 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 (CCME 2014).

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 (CCME 2014).

Specific conductivity: Specific conductivity (µS/cm) is a measure of water's ability to conduct electricity, with values normalized to a water temperature of 25°C. Specific conductance indicates the concentration of dissolved solids (such as salts) in the water, which can affect the growth and reproduction of aquatic life. Specific conductivity is affected by rainfall events, the composition of inflowing tributaries and their associated geology, saline inflow (e.g., road salt), agricultural run-off and industrial inputs (Swanson and Baldwin 1965).

Stage: Stage (m) is the elevation of the water surface and is often used as a surrogate for the more difficult to measure flow.

Temperature: Essential to the measurement of most water quality parameters, temperature (°C) controls most processes and dynamics of limnology. Water temperature is influenced by such things as ambient air temperature, solar radiation, meteorological events, industrial effluence, wastewater, inflowing tributaries, as well as water body size and depth (OTT Hydromet 2017).

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 (CCME 2014; 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 (Sadar, 2017).

APPENDIX C: Grab Sample Results

REPORT OF ANALYSIS

Lab Report Number: **1915011**

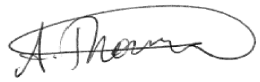
Cient:	Department of Environment	**COC Number:**	847801
Attention:	Ms. Leona Hyde	**Date Reported:**	2019-08-28
Client Project:		**Date Submitted:**	2019-08-20
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1448429	WS-S-0000 Reid Brook @ Outlet	2019-6408-00-SI-SP	2019-08-14	Alkalinity as CaCO3	mg/L	5	<5
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	<1
				Colour	TCU	2	14
				Conductivity	uS/cm	5	13
				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	0.020	<0.020
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.81
				Sulphate	mg/L	1	<1
				Total Dissolved Solids (COND - CALC)	mg/L	1	8
				Total Kjeldahl Nitrogen	mg/L	0.15	<0.15
				Total Organic Carbon	mg/L	0.5	2.2
				Turbidity	NTU	0.1	1.3
				Aluminum	mg/L	0.01	0.04

Sample comment:

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at http://www.cala.ca/scopes/2602.pdf.
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: 

Addrine Thomas

REPORT OF ANALYSIS

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Client Project:		**Date Submitted:**	2019-08-20
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1448429	WS-S-0000 Reid Brook @ Outlet	2019-6408-00-SI-SP	2019-08-14	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	1
				Cadmium	mg/L	0.0001	<0.0001
				Chromium	mg/L	0.001	<0.001
				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	0.005

Sample comment:

Report comment:

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Methods references and/or additional QA/QC information available on request.

APPROVAL: A. Thomas

Addrine Thomas

REPORT OF ANALYSIS

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Attention:	Ms. Leona Hyde	**Date Reported:**	2019-08-28
Client Project:		**Date Submitted:**	2019-08-20
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1448429	WS-S-0000	2019-6408-00-SI-SP	2019-08-14	Uranium	mg/L	0.001	<0.001
	Reid Brook @ Outlet			Zinc	mg/L	0.01	<0.01
				Phosphorus	mg/L	0.002	<0.002
Sample comment:				Total Suspended Solids	mg/L	2	<2

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at http://www.cala.ca/scopes/2602.pdf.
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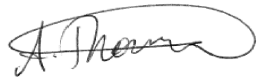
APPROVAL: 

Addrine Thomas

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Attention:	Ms. Leona Hyde	**Date Reported:**	2019-08-28
Client Project:		**Date Submitted:**	2019-08-20
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1448432	WS-S-0000 Camp Pond Brook	2019-6411-00-SI-SP	2019-08-14	Alkalinity as CaCO3	mg/L	5	8
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	2
				Colour	TCU	2	34
				Conductivity	uS/cm	5	38
				Dissolved Organic Carbon	mg/L	0.5	4.3
				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	14
				N-NH3 (Ammonia)	mg/L	0.020	<0.020
				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	5
				Total Dissolved Solids (COND - CALC)	mg/L	1	25
				Total Kjeldahl Nitrogen	mg/L	0.15	0.17
				Total Organic Carbon	mg/L	0.5	4.3
				Turbidity	NTU	0.1	1.0
				Aluminum	mg/L	0.01	0.07

Sample comment:

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at http://www.cala.ca/scopes/2602.pdf.
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Methods references and/or additional QA/QC information available on request.

APPROVAL: Addrine Thomas

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Client Project:		**Date Submitted:**	2019-08-20
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1448432	WS-S-0000	2019-6411-00-SI-SP	2019-08-14	Antimony	mg/L	0.0005	<0.0005
	Camp Pond Brook			Arsenic	mg/L	0.001	<0.001
				Barium	mg/L	0.01	<0.01
Sample comment:				Boron	mg/L	0.01	<0.01
				Calcium	mg/L	1	4
				Cadmium	mg/L	0.0001	<0.0001
Report comment:				Chromium	mg/L	0.001	<0.001
				Copper	mg/L	0.001	0.004
				Iron	mg/L	0.03	0.17
				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	0.032
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	2
				Strontium	mg/L	0.001	0.018

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at http://www.cala.ca/scopes/2602.pdf.
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: A. Thomas

Addrine Thomas

REPORT OF ANALYSIS

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Attention:	Ms. Leona Hyde	**Date Reported:**	2019-08-28
Client Project:		**Date Submitted:**	2019-08-20
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1448432	WS-S-0000	2019-6411-00-SI-SP	2019-08-14	Uranium	mg/L	0.001	<0.001
	Camp Pond Brook			Zinc	mg/L	0.01	<0.01
				Phosphorus	mg/L	0.002	0.004
Sample comment:				Total Suspended Solids	mg/L	2	4

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at http://www.cala.ca/scopes/2602.pdf.
Results relate only to the parameters tested on the samples submitted.
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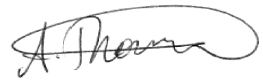
APPROVAL: 

Addrine Thomas

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Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1448431	WS-S-0000 Reid Brook Below Tributary	2019-6410-00-SI-SP	2019-08-14	Alkalinity as CaCO3	mg/L	5	6
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	2
Sample comment:				Colour	TCU	2	56
				Conductivity	uS/cm	5	29
				Dissolved Organic Carbon	mg/L	0.5	5.7
Report comment:				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	7
				N-NH3 (Ammonia)	mg/L	0.020	<0.020
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.90
				Sulphate	mg/L	1	3
				Total Dissolved Solids (COND - CALC)	mg/L	1	19
				Total Kjeldahl Nitrogen	mg/L	0.15	<0.15
				Total Organic Carbon	mg/L	0.5	5.9
				Turbidity	NTU	0.1	0.8
				Aluminum	mg/L	0.01	0.13

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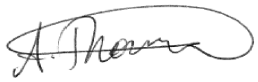
APPROVAL: 

Addrine Thomas

REPORT OF ANALYSIS

Lab Report Number: **1915011**

Cient:	Department of Environment	**COC Number:**	847801
Attention:	Ms. Leona Hyde	**Date Reported:**	2019-08-28
Client Project:		**Date Submitted:**	2019-08-20
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1448431	WS-S-0000	2019-6410-00-SI-SP	2019-08-14	Antimony	mg/L	0.0005	<0.0005
	Reid Brook Below Tributary			Arsenic	mg/L	0.001	<0.001
				Barium	mg/L	0.01	<0.01
Sample comment:				Boron	mg/L	0.01	<0.01
				Calcium	mg/L	1	3
				Cadmium	mg/L	0.0001	<0.0001
Report comment:				Chromium	mg/L	0.001	<0.001
				Copper	mg/L	0.001	0.001
				Iron	mg/L	0.03	0.42
				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	0.008
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	<2
				Strontium	mg/L	0.001	0.015

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APPROVAL: A. Thomas

Addrine Thomas

REPORT OF ANALYSIS

Lab Report Number: **1915011**

Cient:	Department of Environment	**COC Number:**	847801
Attention:	Ms. Leona Hyde	**Date Reported:**	2019-08-28
Client Project:		**Date Submitted:**	2019-08-20
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1448431	WS-S-0000	2019-6410-00-SI-SP	2019-08-14	Uranium	mg/L	0.001	<0.001
	Reid Brook Below Tributary			Zinc	mg/L	0.01	<0.01
				Phosphorus	mg/L	0.002	0.007
Sample comment:				Total Suspended Solids	mg/L	2	5

Report comment:

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APPROVAL: A. Thomas

Addrine Thomas

REPORT OF ANALYSIS

Lab Report Number: **1915011**

Cient:	Department of Environment	**COC Number:**	847801
Attention:	Ms. Leona Hyde	**Date Reported:**	2019-08-28
Client Project:		**Date Submitted:**	2019-08-20
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1448430	WS-S-0000 Tributary to Reid Brook	2019-6409-00-SI-SP	2019-08-14	Alkalinity as CaCO3	mg/L	5	7
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	2
				Colour	TCU	2	57
				Conductivity	uS/cm	5	29
				Dissolved Organic Carbon	mg/L	0.5	6.1
				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	7
				N-NH3 (Ammonia)	mg/L	0.010	<0.010
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.95
				Sulphate	mg/L	1	3
				Total Dissolved Solids (COND - CALC)	mg/L	1	19
				Total Kjeldahl Nitrogen	mg/L	0.15	0.15
				Total Organic Carbon	mg/L	0.5	6.2
				Turbidity	NTU	0.1	1.0
				Aluminum	mg/L	0.01	0.14

Sample comment:

Report comment:

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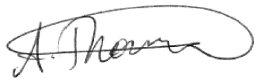
APPROVAL: 

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Attention:	Ms. Leona Hyde	**Date Reported:**	2019-08-28
Client Project:		**Date Submitted:**	2019-08-20
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1448430	WS-S-0000 Tributary to Reid Brook	2019-6409-00-SI-SP	2019-08-14	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
				Copper	mg/L	0.001	0.001
				Iron	mg/L	0.03	0.39
				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	0.009
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	<2
				Strontium	mg/L	0.001	0.016

Sample comment:

Report comment:

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APPROVAL: A. Thomas

Addrine Thomas

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LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1448430	WS-S-0000	2019-6409-00-SI-SP	2019-08-14	Uranium	mg/L	0.001	<0.001
	Tributary to Reid Brook			Zinc	mg/L	0.01	<0.01
				Phosphorus	mg/L	0.002	0.002
Sample comment:				Total Suspended Solids	mg/L	2	<2

Report comment:

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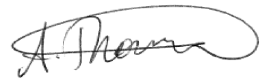
APPROVAL: 

Addrine Thomas