Real-Time Water Quality

2010 Annual Deployment Report

Voisey's Bay Network

June 5th to October 11th, 2010

Newfoundland Labrador

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

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Acknowledgements

The Real-Time Water Quality Monitoring Network in Voisey's Bay is successful in tracking emerging water quality issues due to the hard work and diligence of certain individuals. The management and staff of Vale work in cooperation with the management and staff of the Department of Environment and Conservation (ENVC) as well as Environment Canada (EC) to ensure the protection of ambient water resources in Voisey's Bay, Labrador.

The Vale Environmental Coordinators on-site, Perry Blanchard and Dennis Martin, and acknowledging the hard work of Paul Hounsell during this deployment period, ensure the Real-Time Water Quality Monitoring Network is operating to the standards set by ENVC. It is only through their dedication to properly maintain and calibrate the equipment and perform acceptable quality control measures that the data can be viewed as reliable and accurate.

Various individuals from ENVC have been integral in ensuring the smooth operation of such a technologically advanced network. Grace Gillis plays the lead role in coordinating and liaising between the major agencies involved, thus, ensuring open communication lines at all times. In addition, Grace is responsible for the data management/reporting, troubleshooting, along with ensuring the quality assurance/quality control measures are satisfactory, During site visits Grace has been assisted by other ENVC staff, Ryan Pugh, Shibly Rahman and Keith Abbott. Paul Neary, Leona Hyde and Amir Ali Khan have worked on the communication aspects of the network ensuring the data is being provided to the general public on a near real-time basis through the departmental web page.

EC staff of the Meteorological Service of Canada: Water Survey Canada (Perry Pretty, Bill Mullins, Brent Ruth, Roger Ellsworth, Dwayne Ackerman and Mike Ludwicki) play an essential role in the data logging/communication aspect of the network. These individuals visit the site often to ensure the data logging equipment is operating properly and transmitting the data efficiently. Finally, they play the lead role in dealing with hydrological quantity and flow issues.

The managers ENVC (Renée Paterson) and EC (Howie Wills) are fully committed to improving this network and ensuring it provides meaningful and accurate water quality/quantity data that can be used in the decision-making process. This network is only successful due to the cooperation of all three agencies involved.

Introduction

- The Real-Time Water Quality Monitoring Network began in Voisey's Bay during the summer of 2003 with the establishment of three surface water stations (Reid Brook at Outlet of Reid Pond– NF03NE0009; Camp Pond Brook below Camp Pond– NF03NE0010; Lower Reid Brook below Tributary – NF03NE0011).
- The three stations have been operational (for summer/fall months) on an annual basis since 2003 and act as an early warning system to capture water quality related events.
- An additional surface water station (Tributary to Lower Reid Brook – NF03NE0012**)** was installed in 2006. This station is located in fairly close proximity to the ovoid and thus it was chosen in particular to capture any water quality events that may result from the actual open-pit mining activities.
- A groundwater monitoring station was also established in 2006 at Headwater Pond (Well below tailings Dam – NF03NE0008) however has not been operational since 2007. The instrument has not been installed from 2008 to 2010 due to complications with the location of the well and damage that occurred over the 2007 winter months. An alternative set-up for this station will be considered in the winter of 2011 for the next deployment year.

Maintenance and Calibration of Instrument

- It is recommended that regular maintenance and calibration take place on a monthly basis to ensure accurate data collection. Due to the limited VALE staff resources during 2010 deployment, ENVC staff took on the monthly maintenance and calibration tasks.
- Maintenance includes a thorough cleaning of the instrument and replacement of any small sensor parts that are damaged or unsuitable for reuse. Once the instrument is cleaned, ENVC staff carefully calibrates each sensor attachment for pH, specific conductivity, dissolved oxygen and turbidity.
- An extended deployment period (>30 days) can result in Datasonde sensor drift which may result in skewed data. The Datasonde sensors will still work to capture any water quality event even though the exact data values collected may be shifted. Installation and removal dates for each station in the 2010 deployment season are summarized in Table 1.

Table 1: Installation and removal dates for 2010 deployment periods

Installation	Removal	Deployment Period
June 5	July 20	46
July 21	Aug 16	27
Aug 17	Oct 11	56

Quality Assurance and Quality Control

Quality Assurance / Quality Control (QAQC) Measures

- As part of the QAQC (Quality Assurance, Quality Control) protocol, 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. See **Table 2**.

Table 2: Ranking limits for Parameters

Parameter	Rank				
	Excellent	**Good**	**Fair**	**Marginal**	**Poor**
Temperature (oC)	<=+/-0.2	>+/-0.2 to 0.5	>+/-0.5 to 0.8	>+/-0.8 to 1	<+/-1
pH (unit)	<=+/-0.2	>+/-0.2 to 0.5	>+/-0.5 to 0.8	>+/-0.8 to 1	>+/-1
Sp. Conductance (µS/cm)	<=+/-3	>+/-3 to 10	>+/-10 to 15	>+/-15 to 20	>+/-20
Sp. Conductance > 35 µS/cm (%)	<=+/-3	>+/-3 to 10	>+/-10 to 15	>+/-15 to 20	>+/-20
Dissolved Oxygen (mg/L) (% Sat)	<=+/-0.3	>+/-0.3 to 0.5	>+/-0.5 to 0.8	>+/-0.8 to 1	>+/-1
Turbidity <40 NTU (NTU)	<=+/-2	>+/-2 to 5	>+/-5 to 8	>+/-8 to 10	>+/-10
Turbidity > 40 NTU (%)	<=+/-5	>+/-5 to 10	>+/-10 to 15	>+/-15 to 20	>+/-20

- Upon deployment, a QAQC **MiniSonde®** is temporarily deployed along side the Field **DataSonde®**. Values for temperature, pH, conductivity, dissolved oxygen and turbidity are compared between the two instruments. Based on the difference between parameters recorded by the Field **DataSonde®**, QAQC **MiniSonde®** a qualitative statement is made on the data quality upon deployment.
- At the end of a deployment period, readings are taken in the water body from the Field **DataSonde®** before and after a thorough cleaning in order to assess the degree of biofouling. During calibration in the laboratory, an assessment of calibration drift is made and the two error values are combined to give Total Error (T_e). If T_e exceeds a predetermined data correction criterion, a correction based on T_e is applied to the dataset using linear interpolation. Based on the value for T_e, a qualitative statement is also made on the data quality upon removal.
- The rankings at the beginning and end of the deployment period are shown in **Table 2** for the Voisey's Bay Stations.

Table 3: Comparison rankings for Voisey's Bay stations, June 5 – October 11, 2010

Station	Date	Action	Instrument Comparison Ranking				
			Temperature	pH	Conductivity	Dissolved Oxygen	Turbidity
Reid Brook at Outlet of Reid Pond	June 5/10	Installation	Good	Poor	Excellent	Excellent	Error Reading*
	July 20/10	Removal	Good	Excellent	Excellent	Fair	Error Reading*
	July 21/10	Installation	Good	Excellent	Excellent	Excellent	Error Reading*
	Aug 16/10	Removal	Excellent	Good	Excellent	Poor	Poor
	Aug 17/10	Installation	Excellent	Excellent	Excellent	Poor	Excellent
	Oct 11/10	Removal	Excellent	Good	Excellent	Error Reading*	Fair
Lower Reid Brook	June 5/10	Installation	Good	Excellent	Excellent	Marginal	Error Reading*
	July 20/10	Removal	Excellent	Fair	Good	Poor	Error Reading*
	July 21/10	Installation	Good	Good	Excellent	Excellent	Error Reading*
	Aug 16/10	Removal	Excellent	Good	Excellent	Marginal	Excellent
	Aug 17/10	Installation	Excellent	Excellent	Excellent	Good	Excellent
	Oct 11/10	Removal	Marginal	Fair	Good	Error Reading*	Error Reading*
Tributary to Lower Reid Brook	June 5/10	Installation	Good	Excellent	Excellent	Excellent	Error Reading*
	July 20/10	Removal	Good	Excellent	Excellent	Good	Error Reading*
	July 21/10	Installation	Excellent	Poor	Excellent	Good	Error Reading*
	Aug 16/10	Removal	Excellent	Excellent	Excellent	Excellent	Excellent
	Aug 17/10	Installation	Excellent	Fair	Excellent	Excellent	Excellent
	Oct 11/10	Removal	Good	Good	Good	Error Reading*	Error Reading*

Camp Pond Brook below Camp Pond	**June 5/10**	**Installation**	Excellent	Good	Good	Good	Error Reading*
	July 20/10	**Removal**	Excellent	Good	Good	Marginal	Error Reading*
	July 21/10	**Installation**	Excellent	Good	Excellent	Excellent	Error Reading*
	Aug 16/10	**Removal**	Excellent	Excellent	Excellent	Poor	Excellent
	Aug 17/10	**Installation**	Excellent	Fair	Excellent	Excellent	Excellent
	Oct 11/10	**Removal**	Fair	Good	Good	Error Reading*	Excellent

***** Error Readings can be a result of battery failure, reduced power to the field instrument or QAQC instrument, probe not functioning correctly or inability to stabilize the reading.

DATA INTERPRETATION

- The following graphs and information illustrates the significant water quality-related events from June 5 to October 11 in the Voisey's Bay Real-Time Network. This review of the entire deployment period for 2010 will identify general trends, variances between months/stations and any significant differences will be noted. Greater analysis and discussion of water quality events can be viewed in the monthly deployment reports for Voisey's Bay Stations.
- The following graphs will include the daily averages for both 2009 deployment data and 2010 deployment data; this provides a general overview of any differences, changes or similarities within the water quality between the two years.
- 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. Where appropriate, corrected data for water quality parameters are indicated.

REID BROOK AT OUTLET OF REID POND

WATER TEMPERATURE

- During the 2010 deployment, the hourly data for water temperature ranged within 1.57 ^{o}C to 19.85^{o}C. Figure 1a and 1b are displaying the **average** data for water temperature in 2010.
- On average, water temperatures are about 2.2°C warmer in 2010 than in 2009. Most evident is the higher averages for temperature in August 2010, when compared to the averages for the same season in 2009 (Figure 1a).
- Water temperature on figure 1b displays the movement of temperature over the deployment period. Initially the temperatures are low, and as the deployment period continues there is an increase in water temperature. The highest daily reading for water temperature reached 19.85^{o}C in August; this also corresponds with a high air temperature reading on the same day.
- Water temperature begins to decrease in the beginning of September as the seasons start to change.

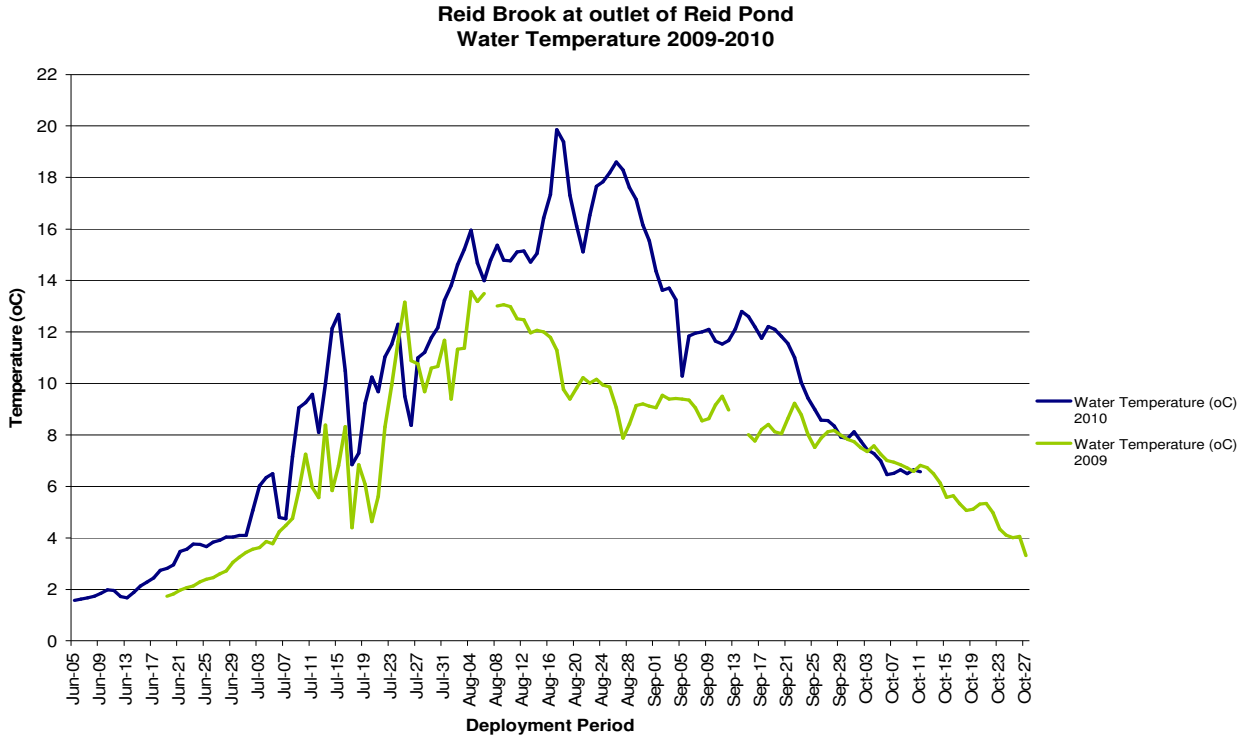

Figure 1a: Water temperature at Reid Brook at outlet of Reid Pond

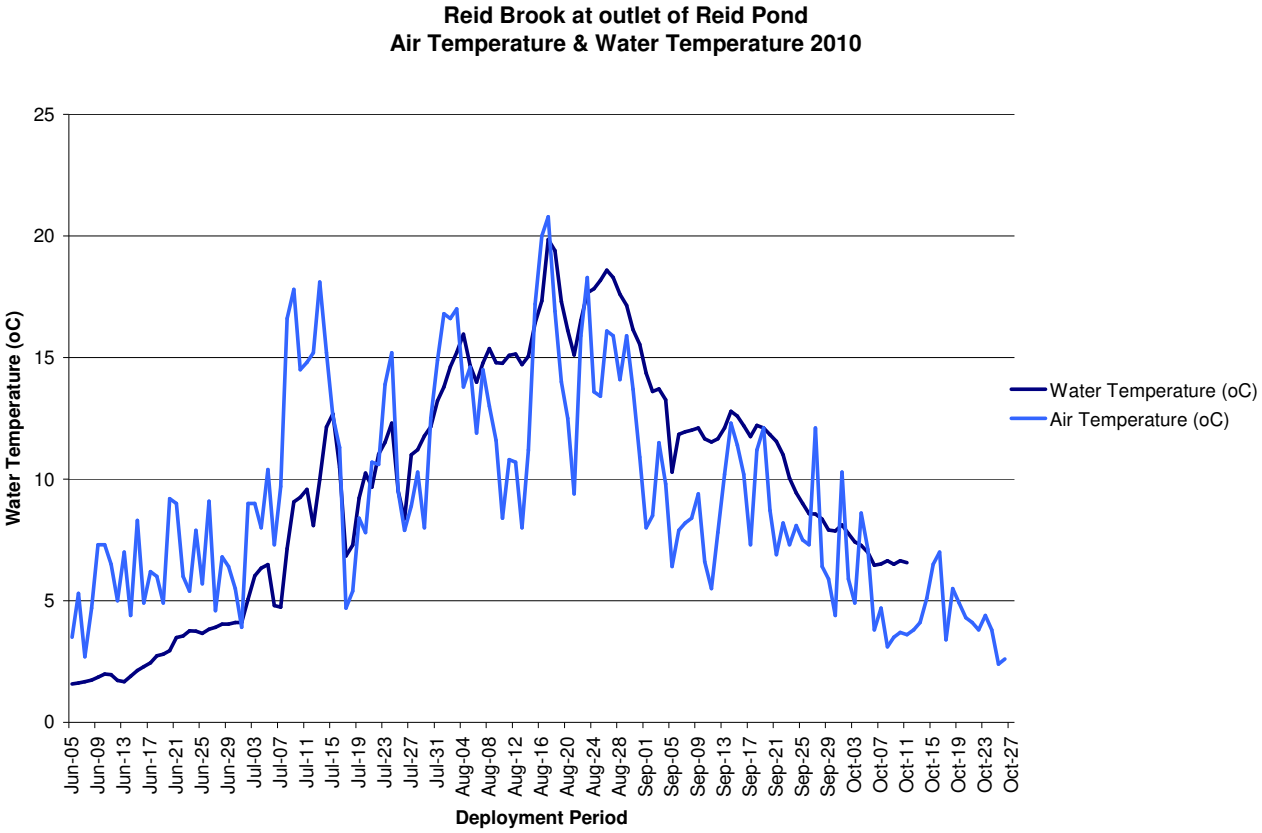

Figure 1b: Average daily air and water temperature at Reid Brook at outlet of Reid Pond

PH

- The hourly data for pH during the 2010 deployment period, ranged within 6.28 and 6.95 pH units. Figure 2 is displaying the daily **averages** of pH for 2010 deployment (Figure 2).
- All values during the deployment season for 2010 are within the CCME Guidelines for the Protection of Aquatic Life. Guidelines are indicated in red on Figure 2.
- pH readings for 2010 on average where lower than 2009. On September 17th, 2009 pH increased to ~7.5 and remained consistent for the remainder of the deployment period. The data for 2010 during that same time frame remained just above the CCME guideline until end of deployment.

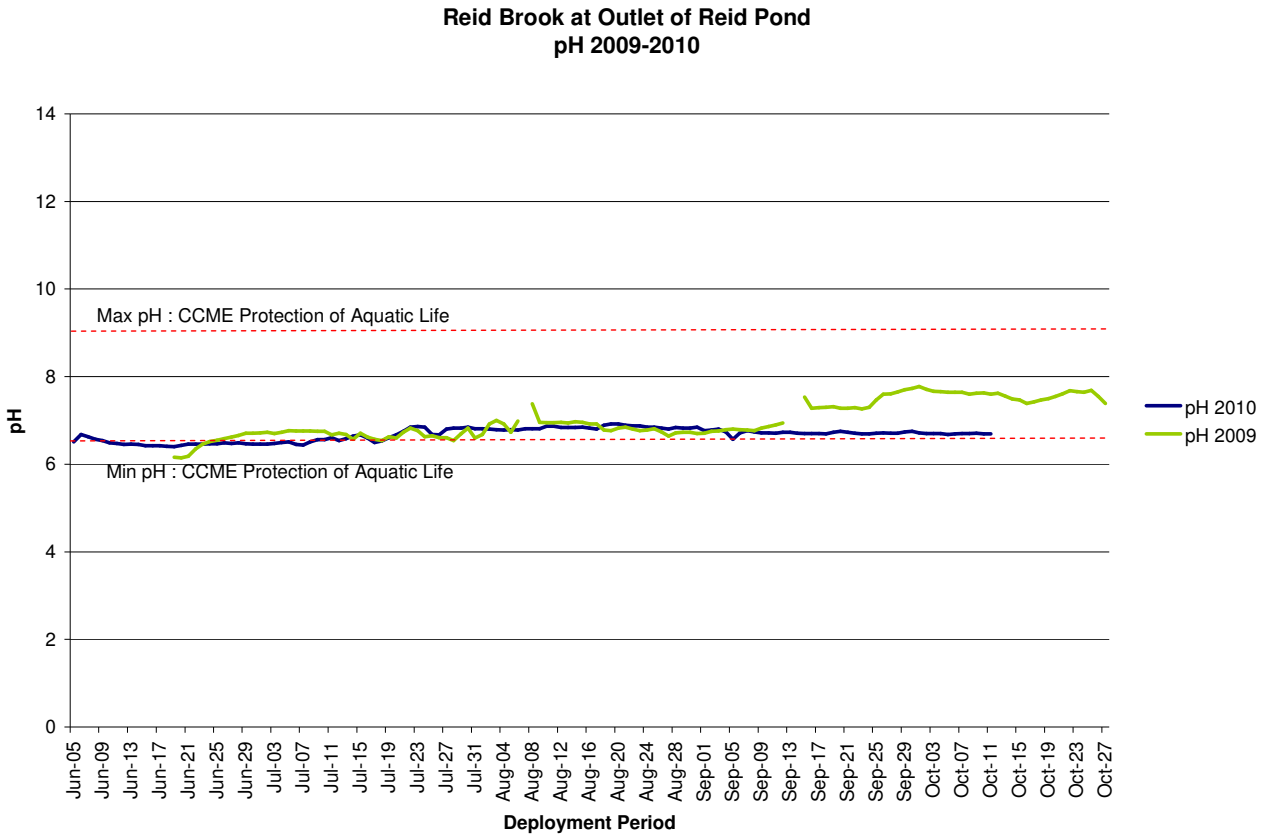

Figure 2: pH at Reid Brook at outlet of Reid Pond

SPECIFIC CONDUTANCE

- The hourly data for specific conductivity ranged within 7.7µS/cm to 10.1µS/cm during the 2010 deployment season. Figure 3 displays the daily **averages** over the deployment period.
- Specific conductivity is influenced by increases/decreases in stage. There are several events during the deployment season that the stage decreases and conductivity increases in response. During 2010 deployment period specific conductance dropped at the beginning of the season then remained steady between ~8µS/cm and ~8.5µS/cm.
- Specific conductivity is slightly higher on average by 0.89µS/cm in 2009 than 2010. This also corresponds with the stage values in 2009, which were on average 0.165µS/cm less than the stage levels for 2010 deployment period (Figure 3: Specific Conductance 2010 data is highlighted in dark blue).
- When compared to data in 2009, specific conductance values peak much later in mid-summer for 2010; however stage levels for 2010 were higher for the season.

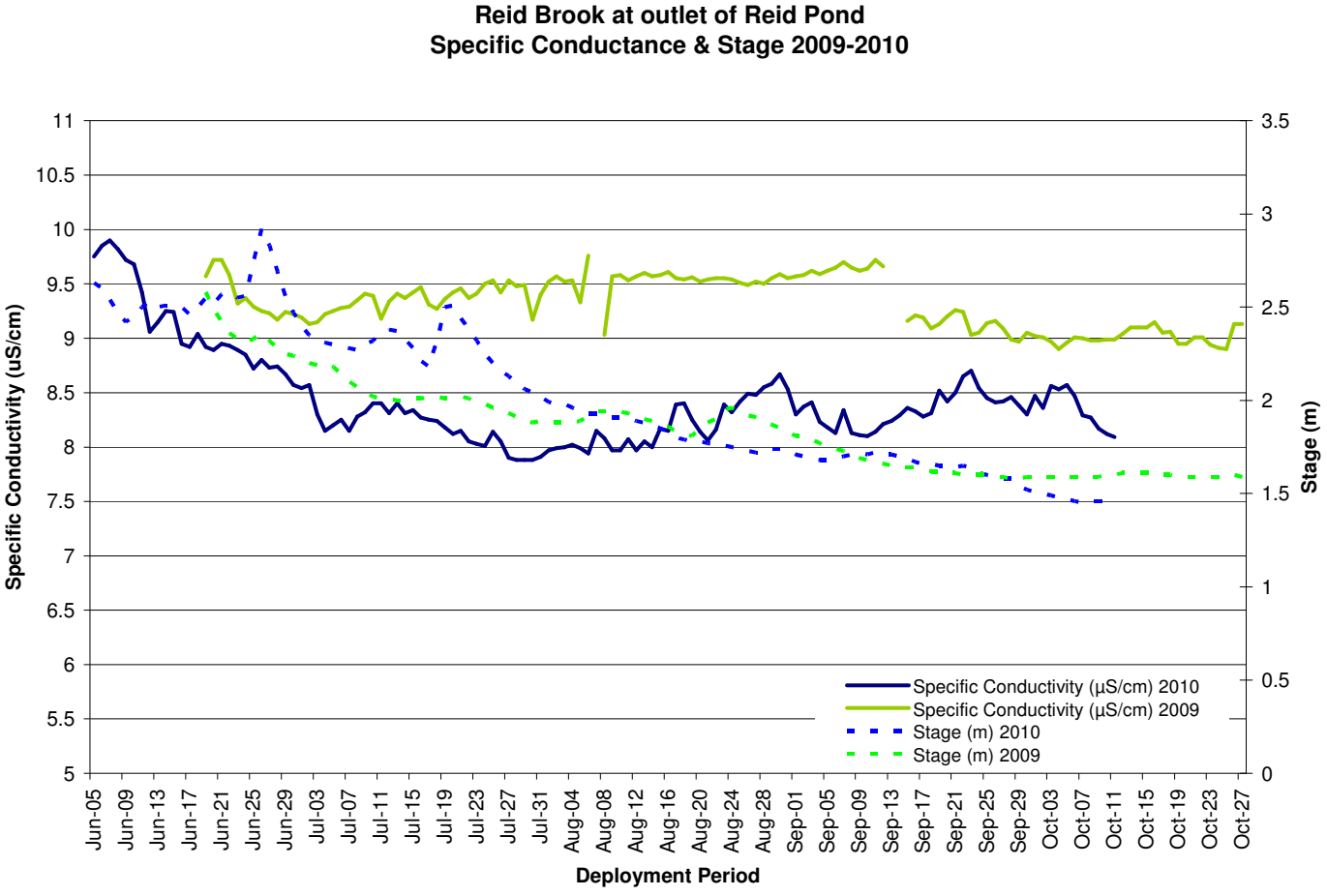

Figure 3: Specific conductivity and stage level at Reid Brook at outlet of Reid Pond

DISSOLVED OXYGEN

- The hourly data for dissolved oxygen content ranged within 5.91mg/L and 13.22mg/L for the 2010 deployment season. Figure 4 is displaying the daily **averages** for the deployment period (Figure 4: Dissolved Oxygen data is highlighted in blue).
- Initially all 2010 readings were above both the minimum CCME Guideline for the Protection of Other Life Stage Cold Water Biota of 6.5 mg/l and the minimum CCME Guideline for the Protection of Early Life Stage Cold Water Biota value of 9.5 mg/l. However mid-summer the DO mg/L levels dropped to below CCME Guideline for the Protection of Early Life Stage Cold Water Biota value of 9.5 mg/l, this behavior of the data is evident of a probe issue with the instrument and data during this period. This data should be used with caution.
- Dissolved oxygen content for 2009 indicates a more typical seasonal fluctuation, decreasing throughout the spring and early summer months during the time when water temperatures are increasing. When water temperatures begin to decrease in the late summer, dissolved oxygen content begins to rise again.

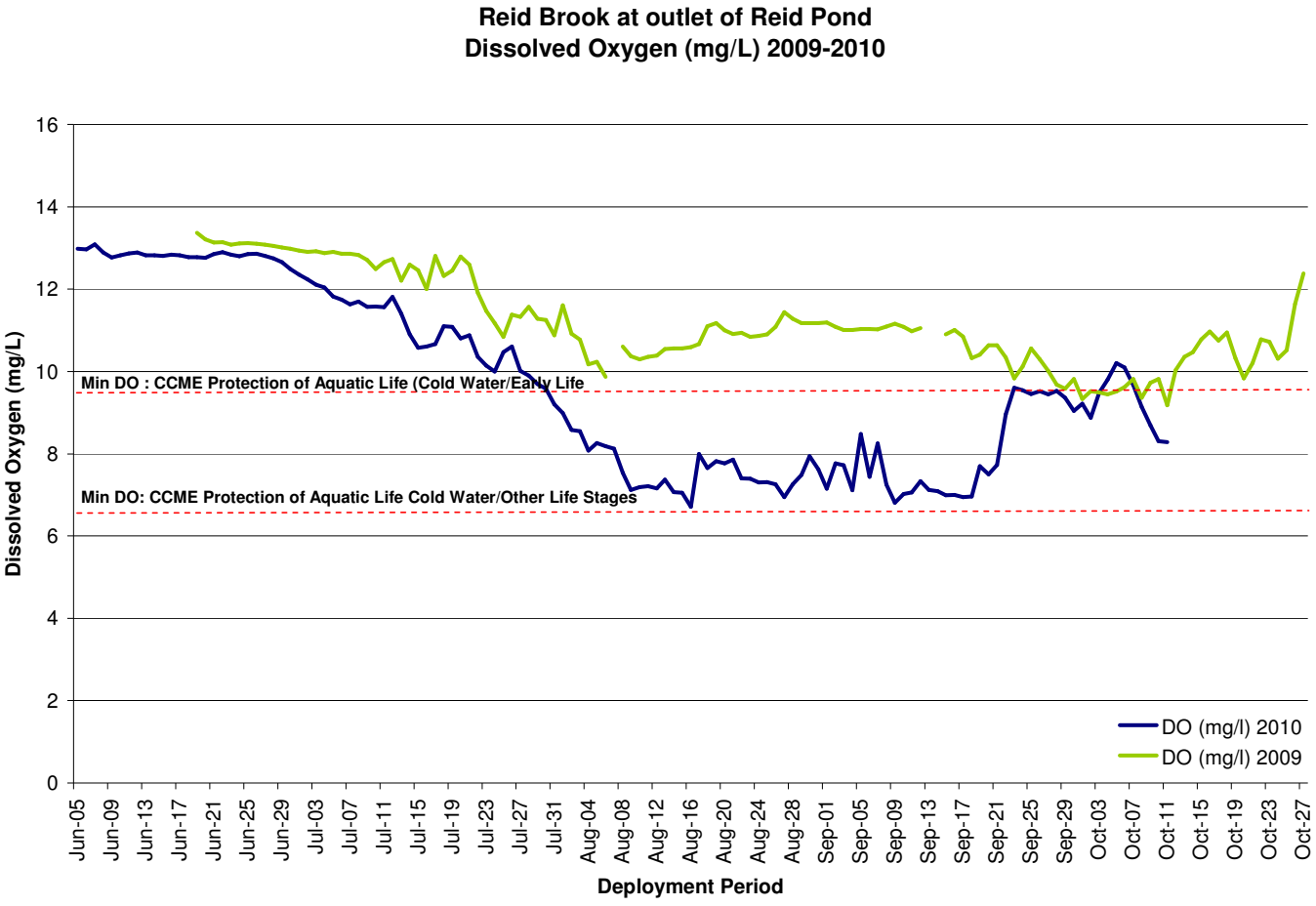

Figure 4: Dissolved oxygen at Reid Brook at outlet of Reid Pond

TURBIDITY

- The hourly readings for turbidity at this station ranged between 0.0NTU and 243.6NTU during the 2010 deployment season. Figure 5 is displaying the daily **averages** for turbidity in 2010. (Figure 5: Average turbidity data for 2010 is highlighted in blue).
- A median of the daily averages totaled 11.29NTU, this value indicates an approximate for the natural background turbidity at this station.
- Figure 5 illustrates significant events during the deployment period. We are aware that the 2010 turbidity readings are not accurate, after the deployment period ended investigation of the probes indicated there was a problem with the turbidity probe. Caution should be taken when using turbidity data from this station.
- A more realist profile of the turbidity readings is provide by 2009 data, the average reading for 2009 data was 0.765NTU compared to that of the 2010 daily data at an average of 22.76NTU.

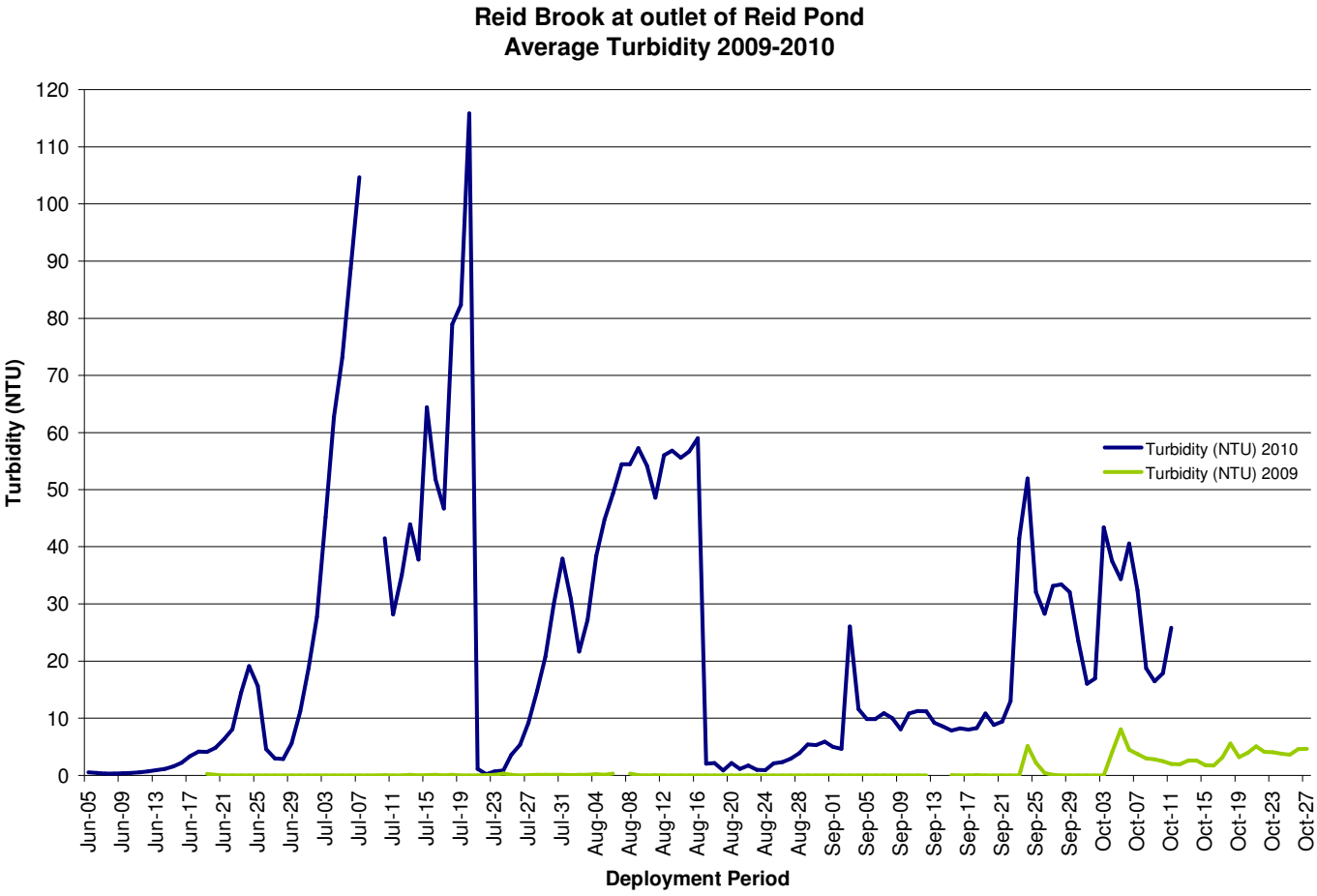

Figure 5: Turbidity at Reid Brook at outlet of Reid Pond

STAGE

- Stage readings decreased during the 2010 deployment season (Figure 6: average stage data for 2010 is highlighted in blue). Precipitation values display several large events; these increases are also evident in the stage readings.
- The precipitation data was obtained from the Environment Canada website http://climate.weatheroffice.gc.ca/climateData/dailydata_e.html?timeframe=2&Prov=CA&StationID=6787&Year=2010&Month=7&Day=20. The closest recorded rainfall to this station is a weather station in Nain.

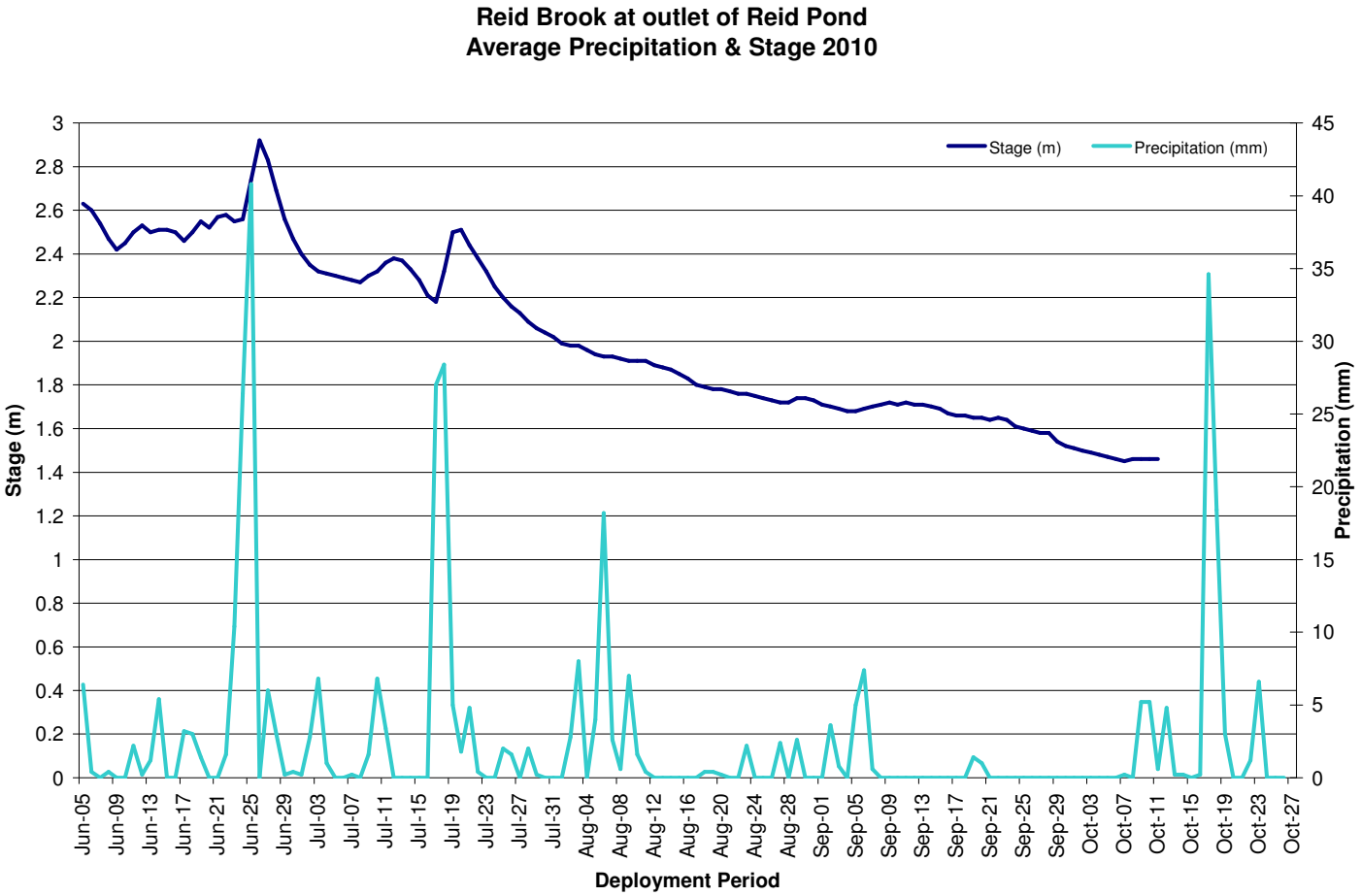

Figure 6: Average daily precipitation and stage level at Reid Brook at outlet of Reid Pond

TRIBUTARY TO LOWER REID BROOK

WATER TEMPERATURE

- The hourly water temperature values ranged between 1.40°C and 18.30°C for the duration of the 2010 deployment season Figure 7a and 7b display the daily **averages** for water temperature in 2010.
- The overall average water temperature for 2010 was ~9.38°C, which was not far off the average for 2009 at ~9.19°C.
- The water temperature graph (Figure 7a) depicts characteristic seasonal temperature over a deployment period. Despite slightly higher temperatures in 2010 over August, both years show similar data.
- The average air temperature for 2010 deployment period was ~ 9.16 °C (Figure 7b). The graph indicates similar peaks in water and air temperature over the deployment period for 2010. Indicates typical seasonal movement of water and air temperatures.

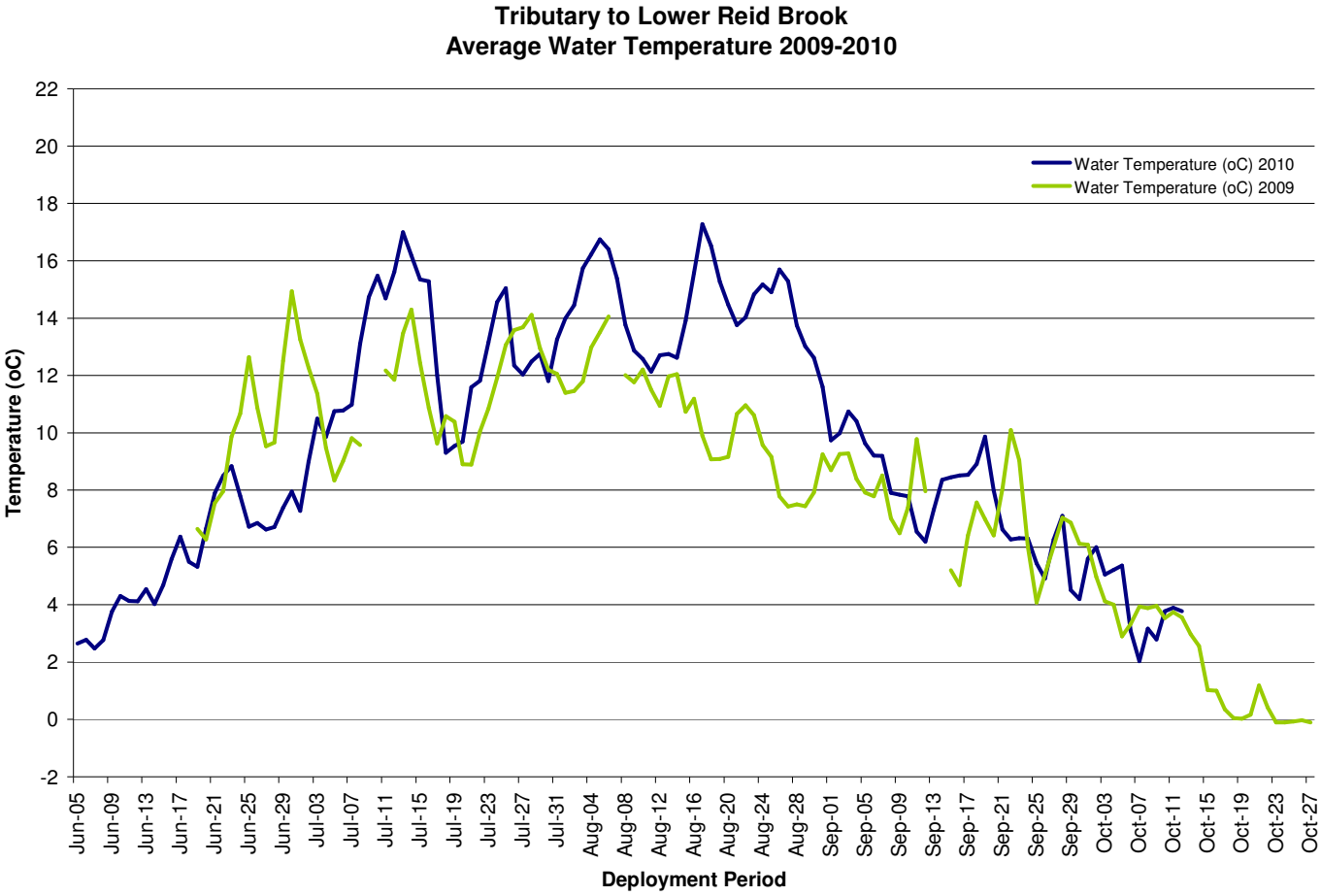

Figure 7a: Water temperature at Tributary to Lower Reid Brook

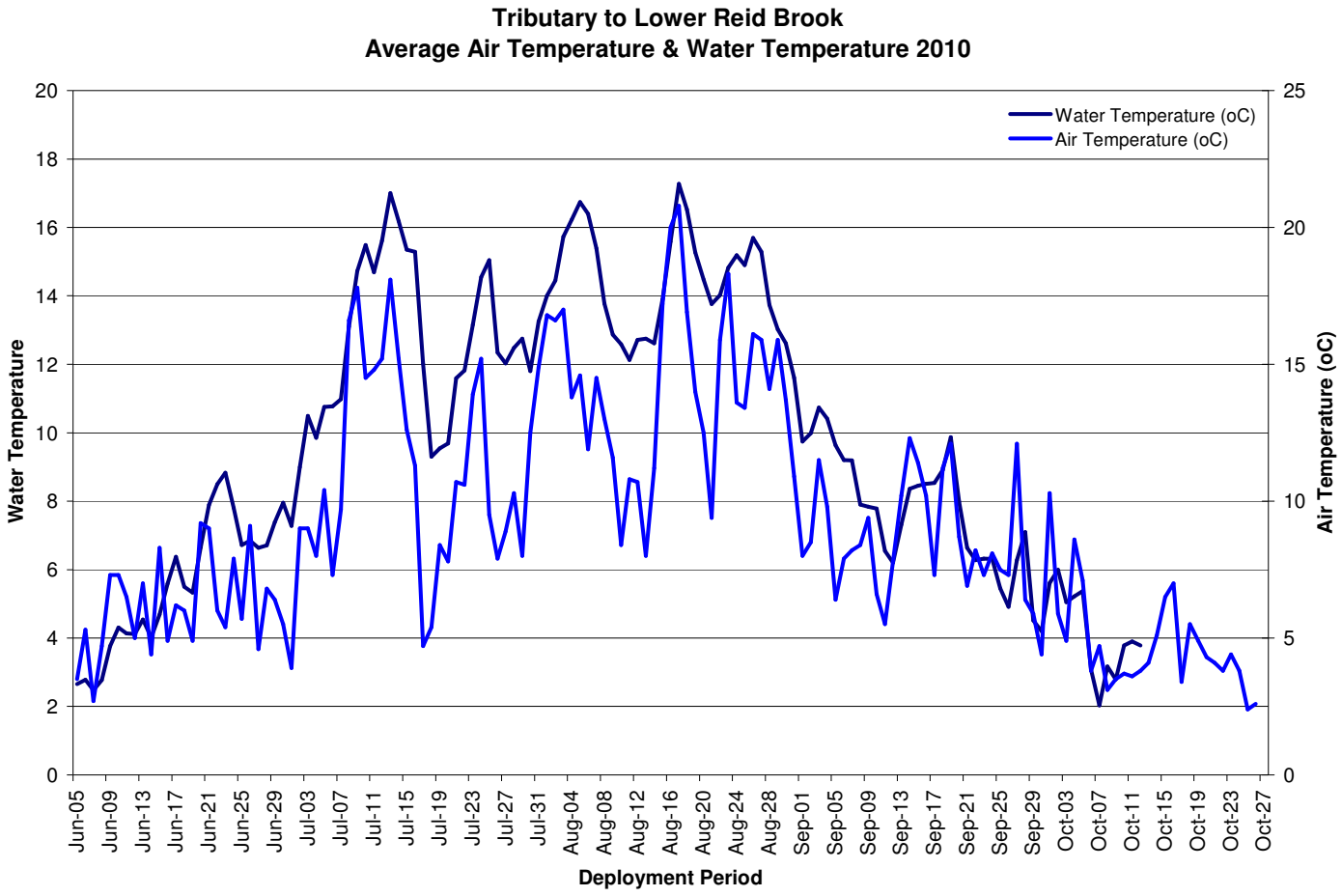

Figure 7b: Average daily air and water temperature at Tributary to Lower Reid Brook

pH

- During the 2010 deployment season the hourly pH range was within 5.55 to 7.23 pH units. Figure 8 displays the daily **averages** for pH in 2010.
- The pH values for the 2010 are slightly lower in the initial deployment, there are large drops in the range of data until around August 20th, 2011 where the levels increase and remain steady at ~7 (Figure 8).
- pH average for 2010 deployment period of 6.77 pH units, is only slightly lower than that of 2009 deployment period, which was 6.95 pH units.

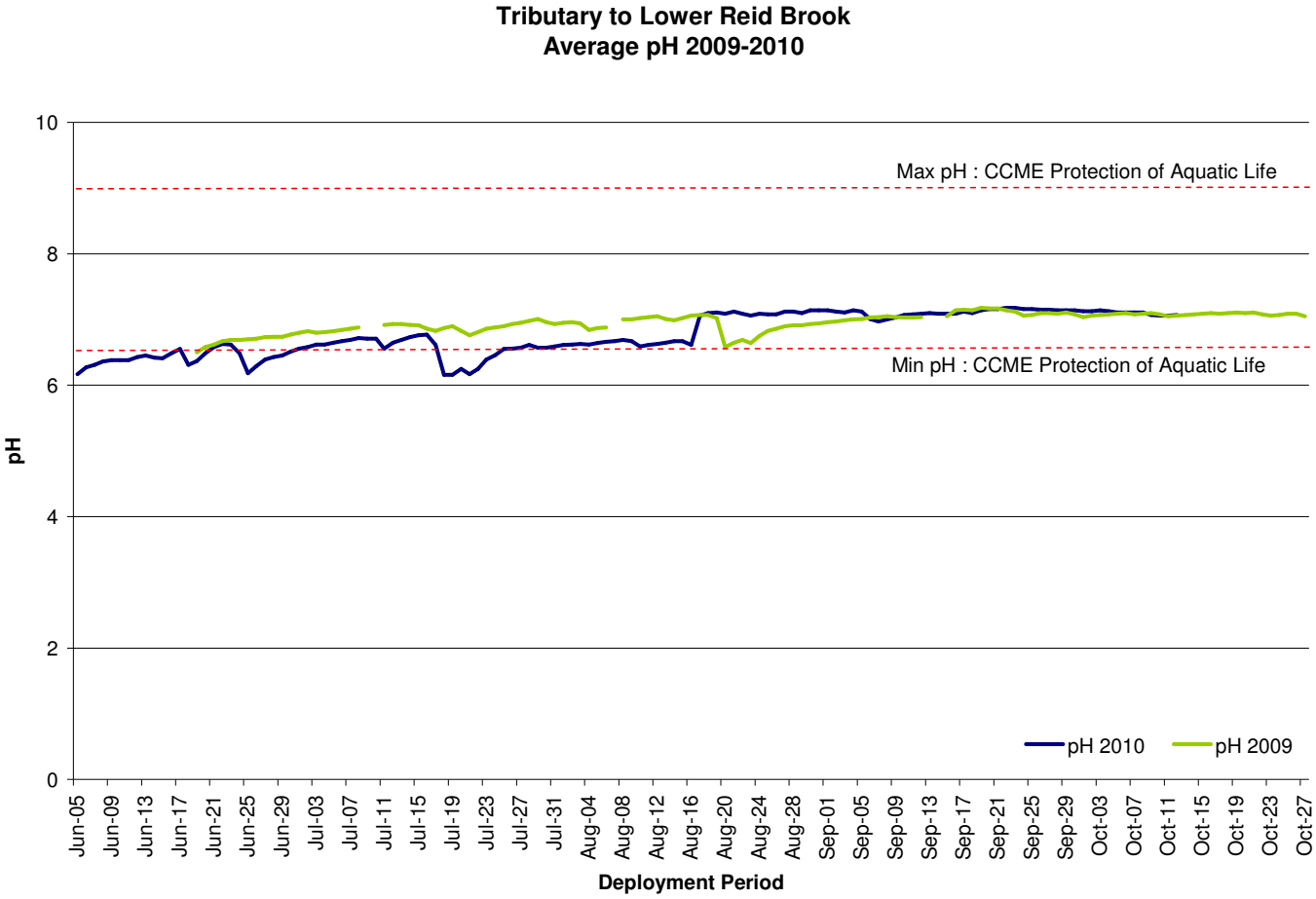

Figure 8: Average pH at Tributary to Lower Reid Brook

SPECIFIC CONDUCTANCE

- During the 2010 deployment period the hourly readings for specific conductivity ranged between a low of 7.1µS/cm to a high of 43.2µS/cm. Figure 9 displays the daily **averages** for specific conductance in 2010.
- When compared to the conductivity average for 2009 at 32.6µS/cm, 2010 data averaged slightly lower at 28.09µS/cm (Figure 9).
- There is a significant relationship between stage and specific conductance; this is evident on figure 9. As stage increases, conductivity levels decreases in the water body. As stage levels decrease over the warmer months of summer, conductivity increases in concentration. This trend is due to the dilution affect on total dissolved solids in the water column.
- When compared to data from 2009, the average specific conductance values for 2010 peak much later in the deployment period. This coincides with the stage levels for 2010; they are slightly lower at that time of year.
- Despite these small differences in conductivity values for 2009 and 2010, the display of data on Figure 9 is comparable.

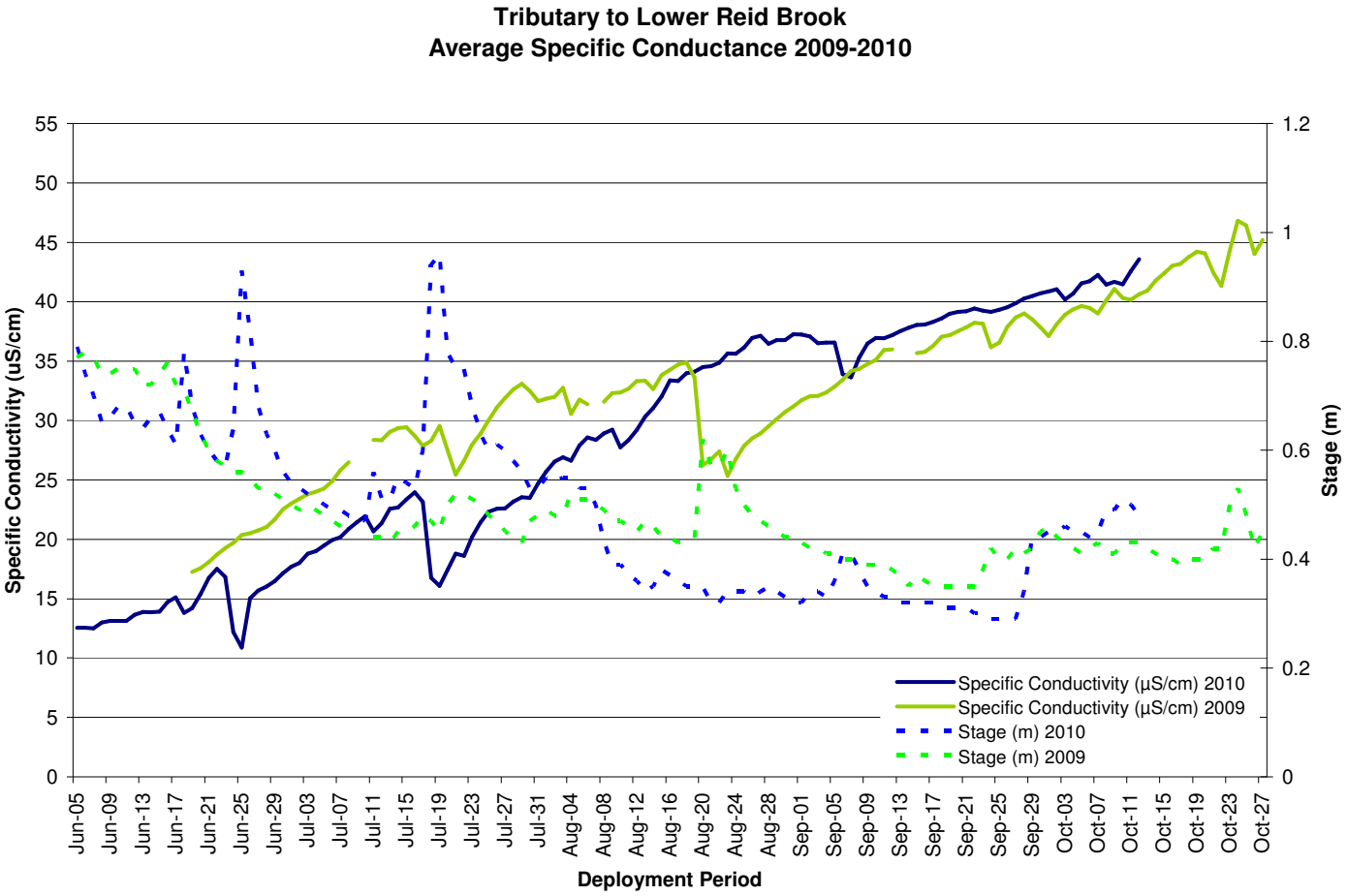

Figure 9: Specific conductivity and stage at Tributary to Lower Reid Brook

DISSOLVED OXYGEN

- During the 2010 deployment the hourly values for dissolved oxygen content ranged between 8.88mg/L to 13.43mg/L. Figure 10 displays the daily **averages** for dissolved oxygen in 2010.
- Despite several dips in DO(mg/L) during August 2010. The majority of dissolved oxygen data was above both CCME guidelines, the Protection of Other Life Stage Cold Water Biota of 6.5 mg/l and for the Protection of Early Life Stage Cold Water Biota value of 9.5 mg/l (Figure 10).
- The lowest DO readings (Figure 10) from late July to early September, correspond with the warmest part of the season (where there were several dips in dissolved oxygen content was just below the guideline). As there is a relationship between DO in mg/L and temperature one would expect to see this activity.
- This relationship is also evident as the temperature cools toward the end of the deployment period. There is a evident hike in DO mg/L. This is a typical pattern for this water body.
- When compared to data from 2009, there is a similar trend between DO (mg/L) and water temperature, as noted in 2010. The average water temperatures in the 2010 were slightly warmer than in 2009, therefore dissolved oxygen content during this time is slightly lower than in 2009.

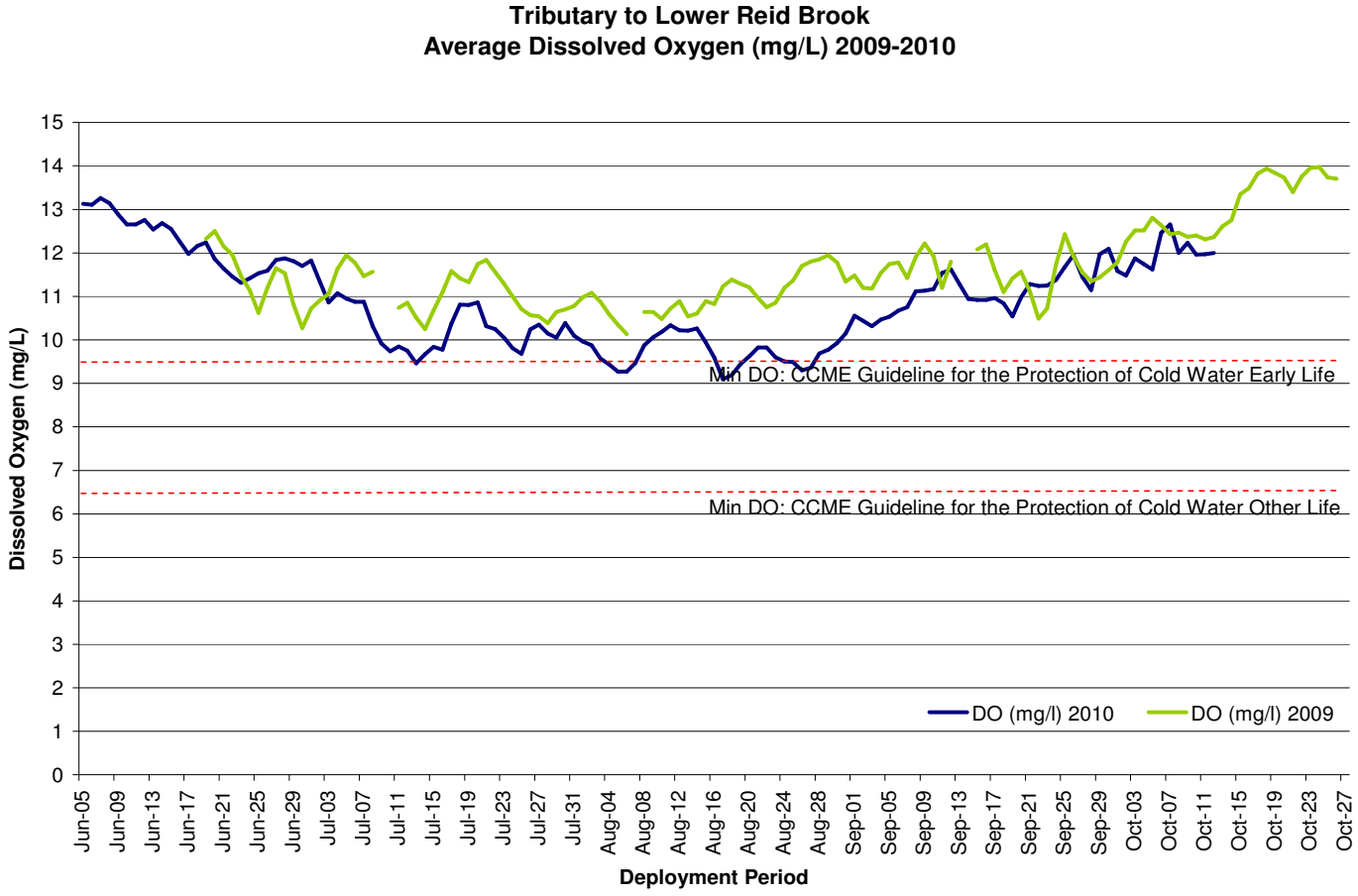

Figure 10: Average dissolved oxygen (mg/L) at Tributary to Lower Reid Brook

TURBIDITY

- During the 2010 deployment the hourly values for turbidity ranged between ~0.0NTU through to 48.6NTU. Figure 11 displays the daily **averages** for turbidity in 2010.
- The median value of 0.12NTU (which was calculated from the 2010 averages) identified that the natural background for turbidity at this location is considerably low.
- There are several variations in the turbidity values during the beginning of the deployment period for 2010, however the turbidity readings settle to below ~3NTU for the remainder of the season. Majority of the turbidity peaks can be linked to weather conditions and precipitation events (Figure 11).
- The average of 0.510NTU for 2009 is slightly lower than the 2010 average of 1.07NTU. This is also the case for the 2009 median of 0.045NTU which is lower than the 2010 median of 0.12NTU.
- It is hard to compare the data from 2009 to 2010, as turbidity events occur at different times of the deployment period. However majoring of the turbidity values for both years are at the lower end of the scale.

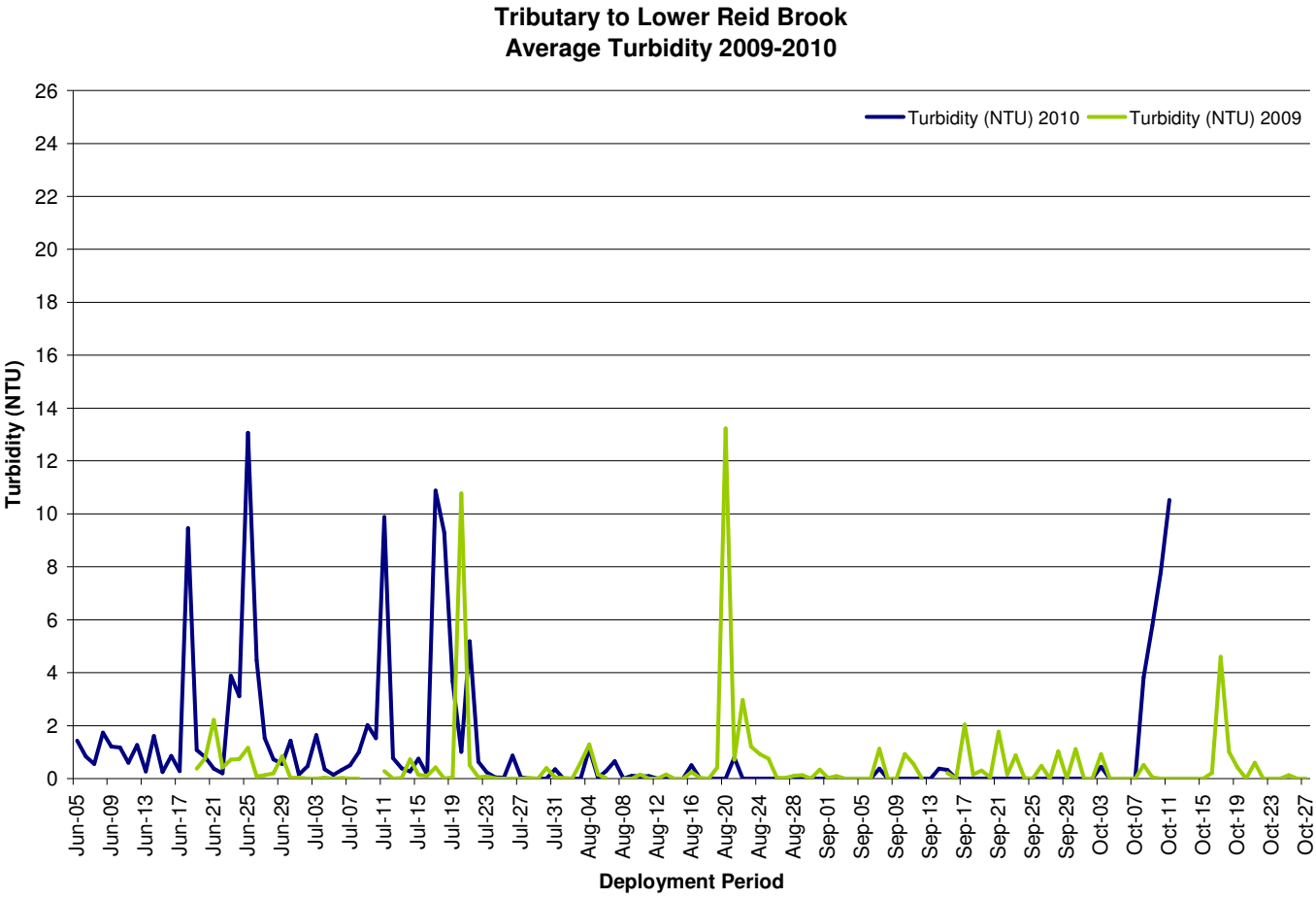

Figure 11: Turbidity at Tributary to Lower Reid Brook

STAGE

- As the 2010 deployment season proceeds the stage level slowly decreases. There are intermittent rainfall events that increase the stage periodically (noted in peaks); however stage continues to decline slightly throughout the deployment period (Figure 12).
- The precipitation data was obtained from the Environment Canada website http://climate.weatheroffice.gc.ca/climateData/dailydata_e.html?timeframe=2&Prov=CA&StationID=6787&Year=2010&Month=7&Day=20. The closest recorded rainfall to this station is a weather station in Nain.

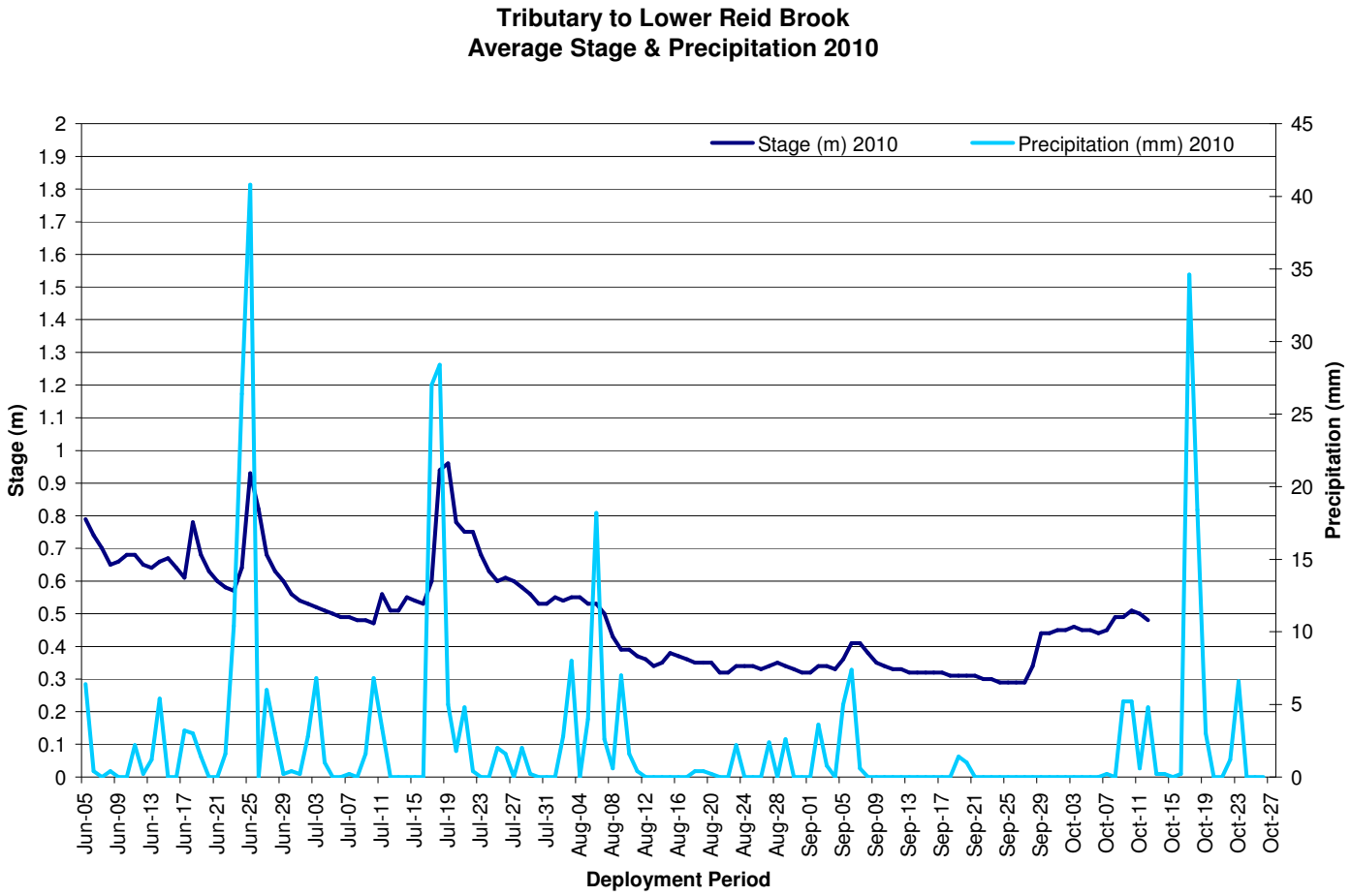

Figure 12: Average daily precipitation and stage level at Tributary to Lower Reid Brook

LOWER REID BELOW TRIBUTARY

TEMPERATURE

- During the 2010 deployment period the hourly values ranged between 1.24°C and 19.96°C. Figure 13a and 13b display the dailys **averages** for water temperature in 2010.
- The natural progression of water temperature can be displayed in Figure 13a in the 2010 average deployment data. The warmer months of the year around mid-summer are also the warmer water temperatures for the deployment period.
- On average, water temperatures are about 0.17°C warmer in 2010 than in 2009. There is a noticeable difference in the water temperatures for late August between 2010 and 2009. 2010 averages for that period are considerably higher than that of 2009 for the same timeframe (Figure 13a).
- Air temperature averages for the deployment period in 2010 depict a typical seasonal progression (Figure 13b) and for the most part the water temperatures resemble the air temperatures. The water temperatures in 2010 peak in late August at an average of ~18°C, then begin to decrease coming into September.

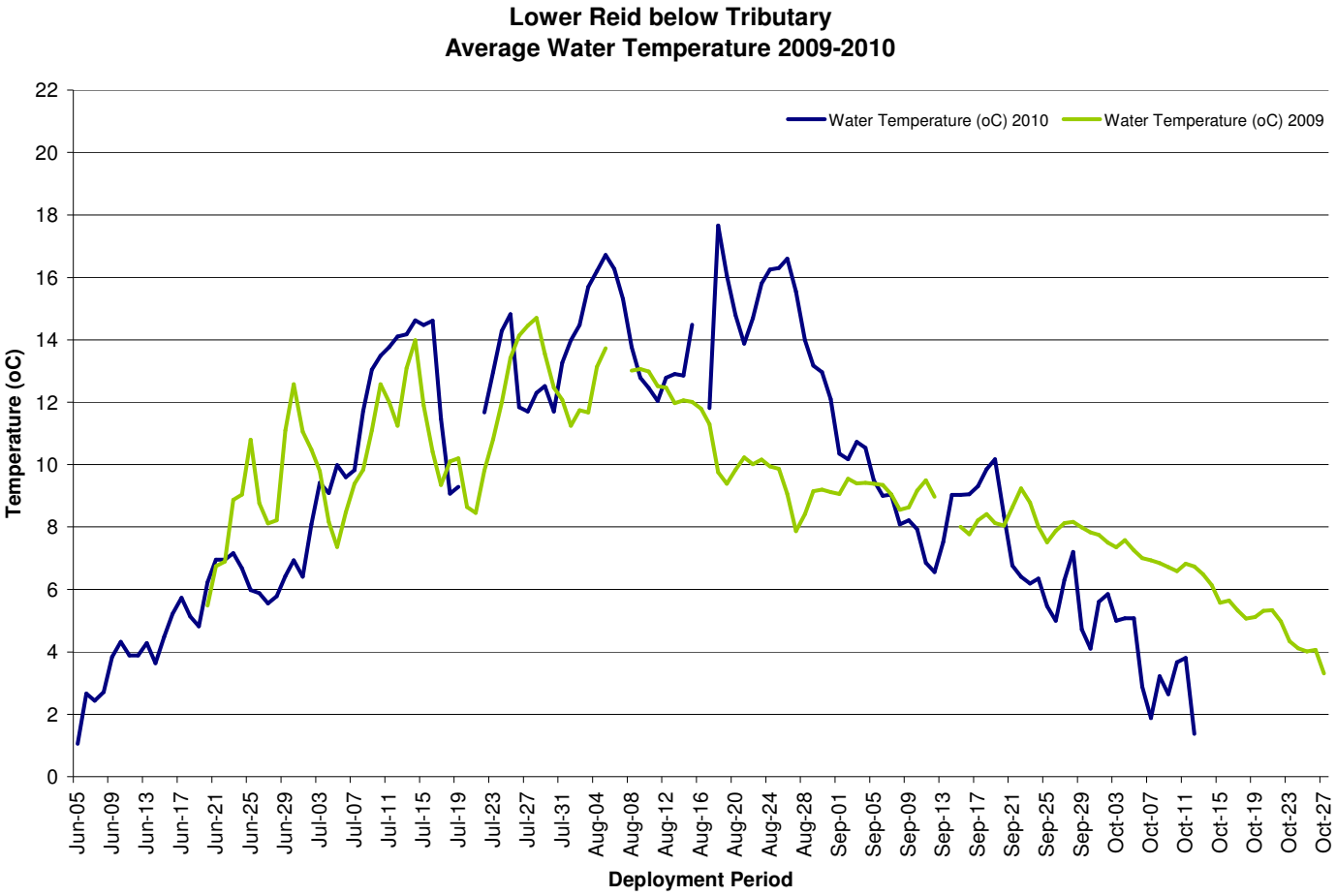

Figure 13a: Water temperature at Lower Reid below Tributary

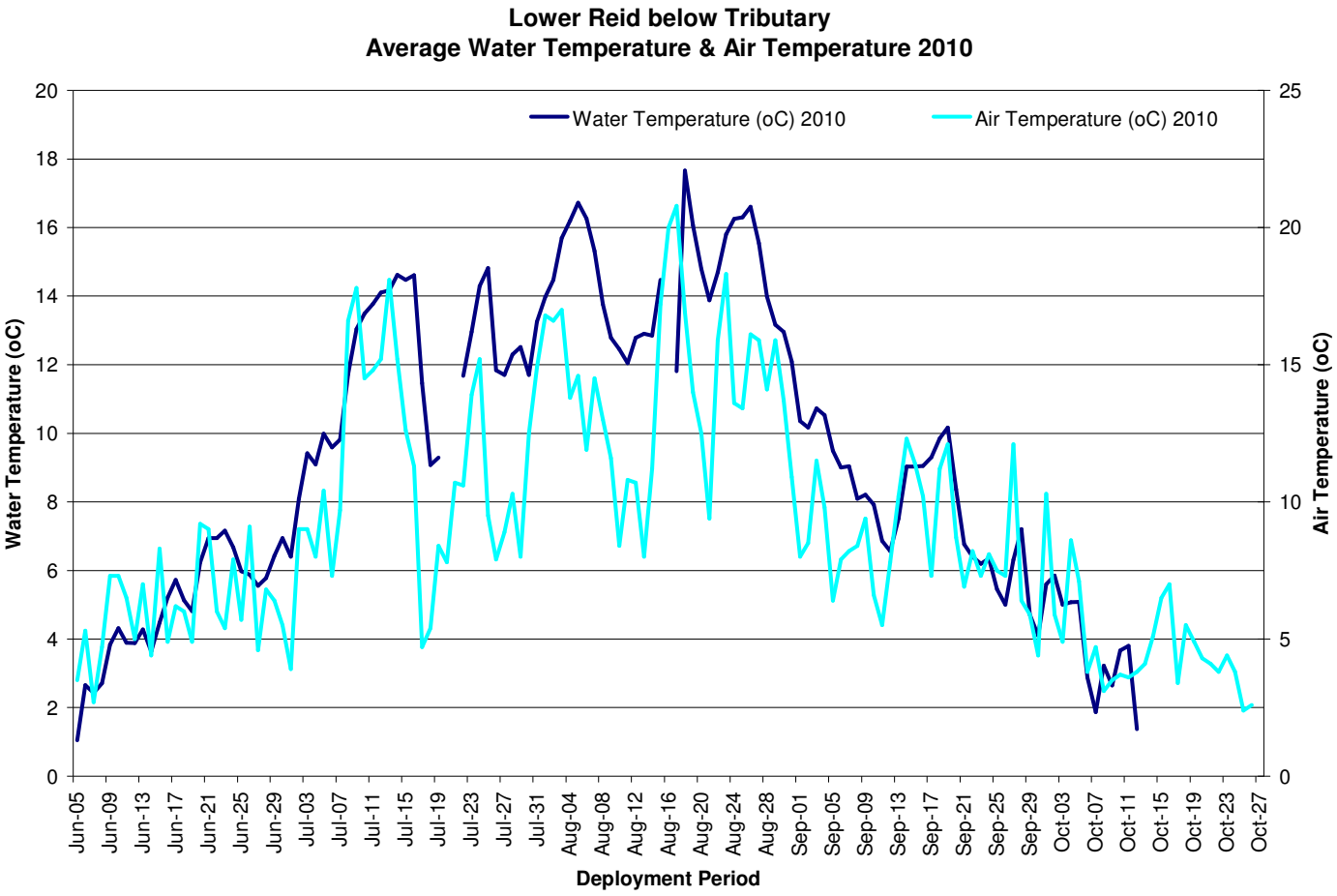

Figure 13b: Average Air and Water temperature at Lower Reid below Tributary

PH

- During the 2010 deployment period the hourly pH readings ranged between 6.06 to 7.23 pH units. Figure 14 displays the daily **averages** for pH in 2010.
- The average pH data for 2010 remains within the CCME Protection of Aquatic Life guidelines, for the deployment period (indicated in red on Figure 14).
- The 2009 pH values are on average ~0.361 pH units greater than the values for 2010.
- The display of the data for both 2009 and 2010 is significantly different from one another. 2009 displays a more gradual increase over the deployment period, with 2010 averages displaying several dips in the pH values early on in the deployment period. The 2010 data eventually settles out towards the end of the summer months.

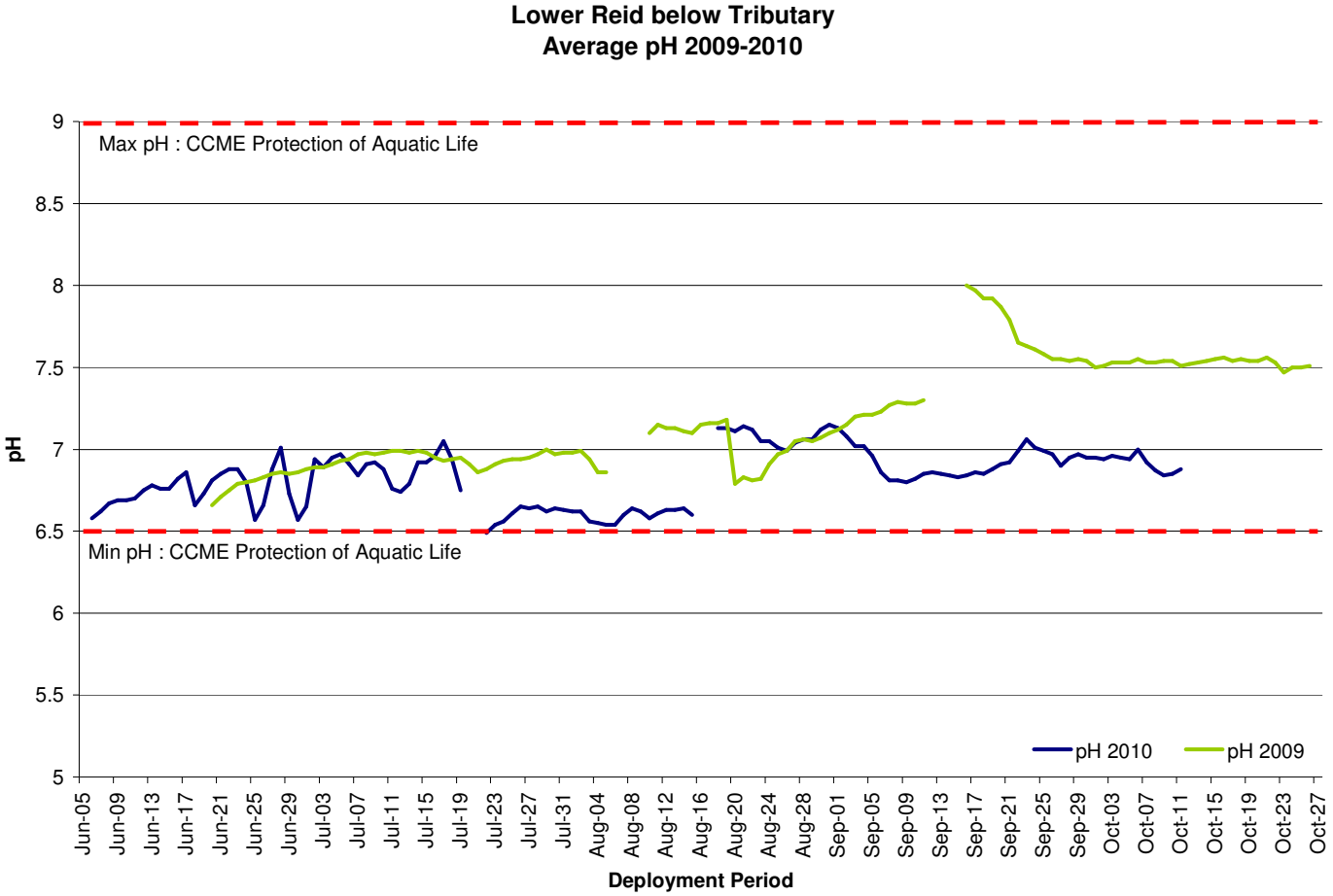

Figure 14: Average pH at Lower Reid below Tributary

SPECIFIC CONDUCTANCE

- During the 2010 deployment period the hourly data for specific conductivity ranged between 9µS/cm and 44µS/cm. Figure 15 displays the daily **averages** for specific conductance in 2010.
- When compared to the specific conductance average for 2009 of 28.3µS/cm, 2010 range is slightly lower at 25.5µS/cm. However the medians for both years are very close with 2009 median at 29µS/cm and 2010 median at 27.31µS/cm. These values identify that the historical background conductance for this station would range between ~29µS/cm and ~27µS/cm.
- There is a significant relationship between stage and specific conductance; this is evident on figure 15. As stage decreases from the start of deployment for both 2010 and 2009, the conductivity levels increase in the water body. This trend and correspondence is due to the dilution affect on total dissolved solids in the water column (Figure 15) .
- When compared to data from 2009, the average specific conductance values for 2010 peak later in the deployment period, however the 2010 conductivity is slightly higher than that of 2009.
- Despite these small differences in conductivity values for 2009 and 2010, the display of data on Figure 15 is comparable.

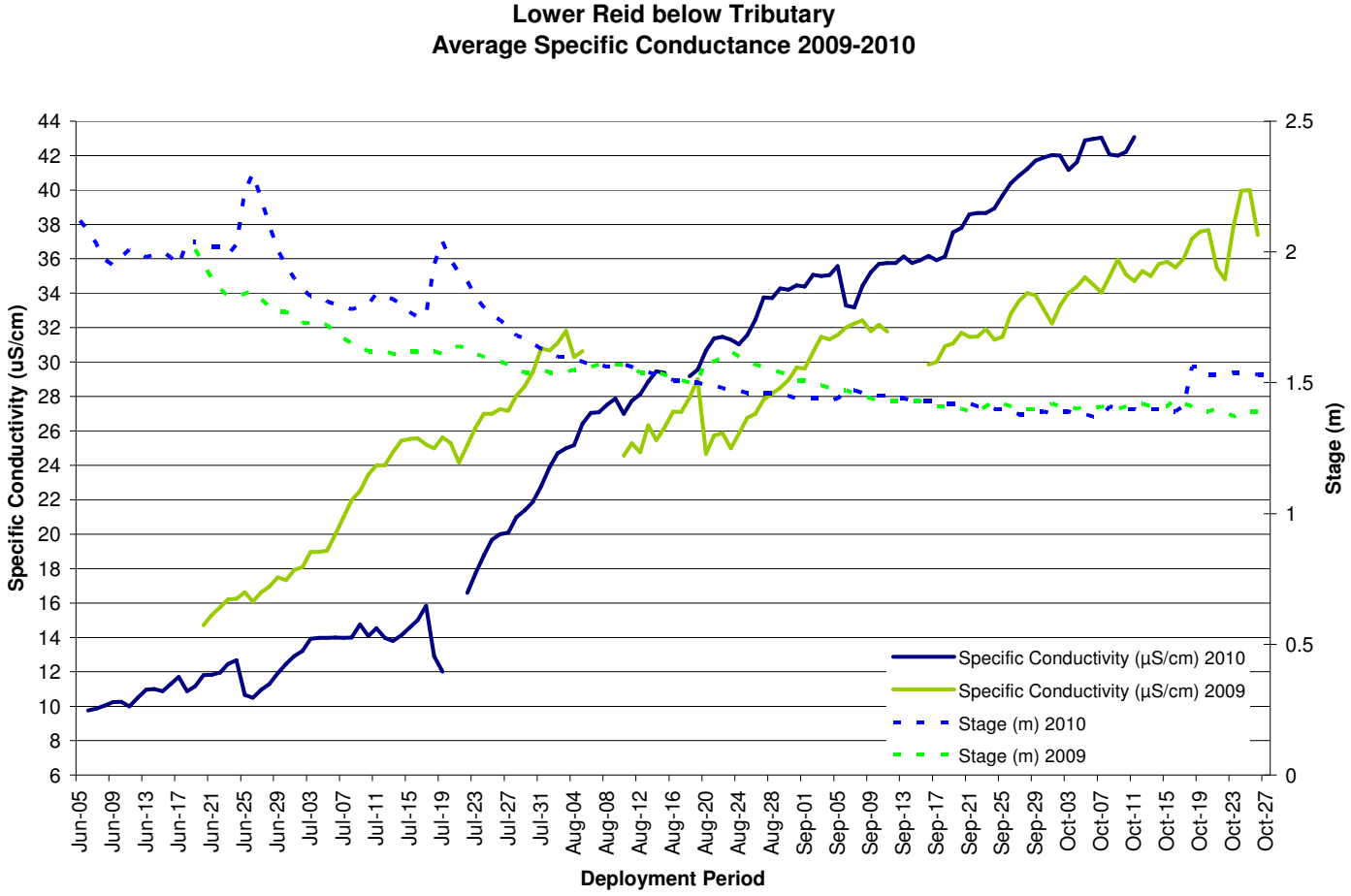

Figure 15: Average Specific conductivity and stage at Lower Reid below Tributary

DISSOLVED OXYGEN

- During the 2010 deployment period the hourly data for dissolved oxygen content ranged between 4.27mg/L to 14.5mg/L. Figure 16 displays the daily **averages** for dissolved oxygen in 2010.
- The low DO reading of 4.27mg/L has been identified as an error reading from the instrument. After the 2010 deployment period, investigation of the probes indicated there was a problem with the dissolved oxygen probe. Caution should be taken when using dissolved oxygen data from this station.
- The 2010 data displays a large drop in dissolved oxygen early in the deployment period; from here the data attempts to stabilize just below the CCME guideline for the Protection of Cold Water/Early Life. However this data is still questionable and should be used with caution (Figure 16).
- When comparing the averages for both deployment years, 2010 data averages at ~9.34mg/L, and 2009 data averages at ~10.6mg/L which is slightly higher.
- The erratic data for 2010 is more evident when compared to data from 2009. The deployment period for 2009 is more consistent and though there are several dips in DO in 2009, the decreases are not extreme. Majority of the data for 2009 stays above the CCME guideline for the Protection of Cold Water/Early Life (Figure 16).

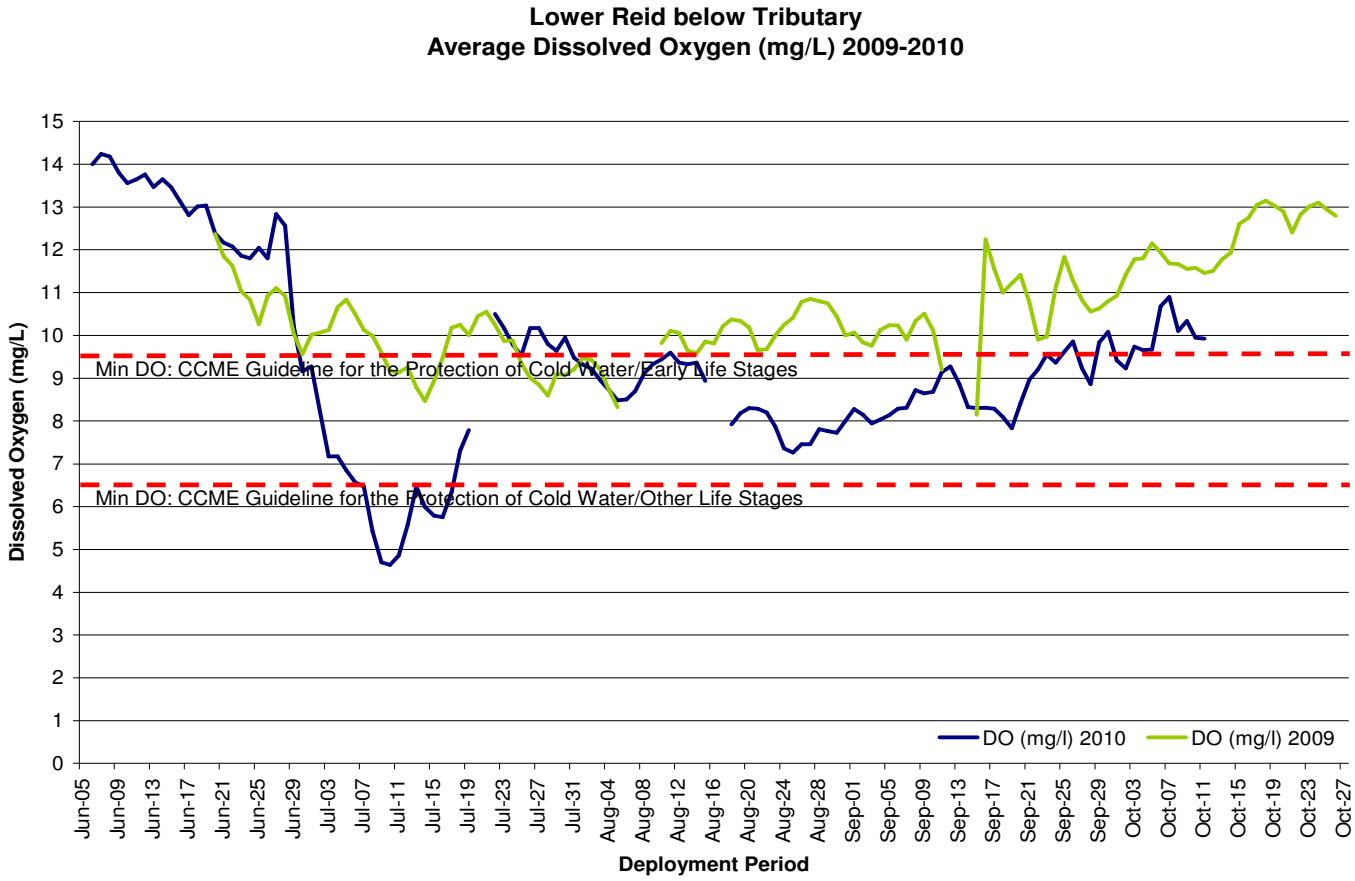

Figure 16: Average Dissolved Oxygen at Lower Reid below Tributary

TURBIDITY

- During the deployment period for 2010, the hourly values for turbidity ranged between 0.0NTU to ~2000NTU. Figure 17 displays the daily **averages** for turbidity in 2010.
- It should be noted that the monthly report for this station identifies readings as high as 3000NTU, however a reading of 3000NTU is identified as an error reading by the sensor and indicates that something has disturbed the sensor. These readings should not be used in data review.
- The large peaks in the turbidity readings for late June and early July 2010 have been linked to a potential issue with the functionality of the turbidity sensor. After the 2010 deployment period, investigation of the probes indicated there was a problem with the turbidity probe. Caution should be taken when using turbidity data from this station. (Figure 17).
- When comparing the turbidity median for 2009 2.42NTU, to the median for 2010 at 3.29NTU, it can be assumed that a typical turbidity reading for this station is generally within 2.42NTU and 3.29NTU.

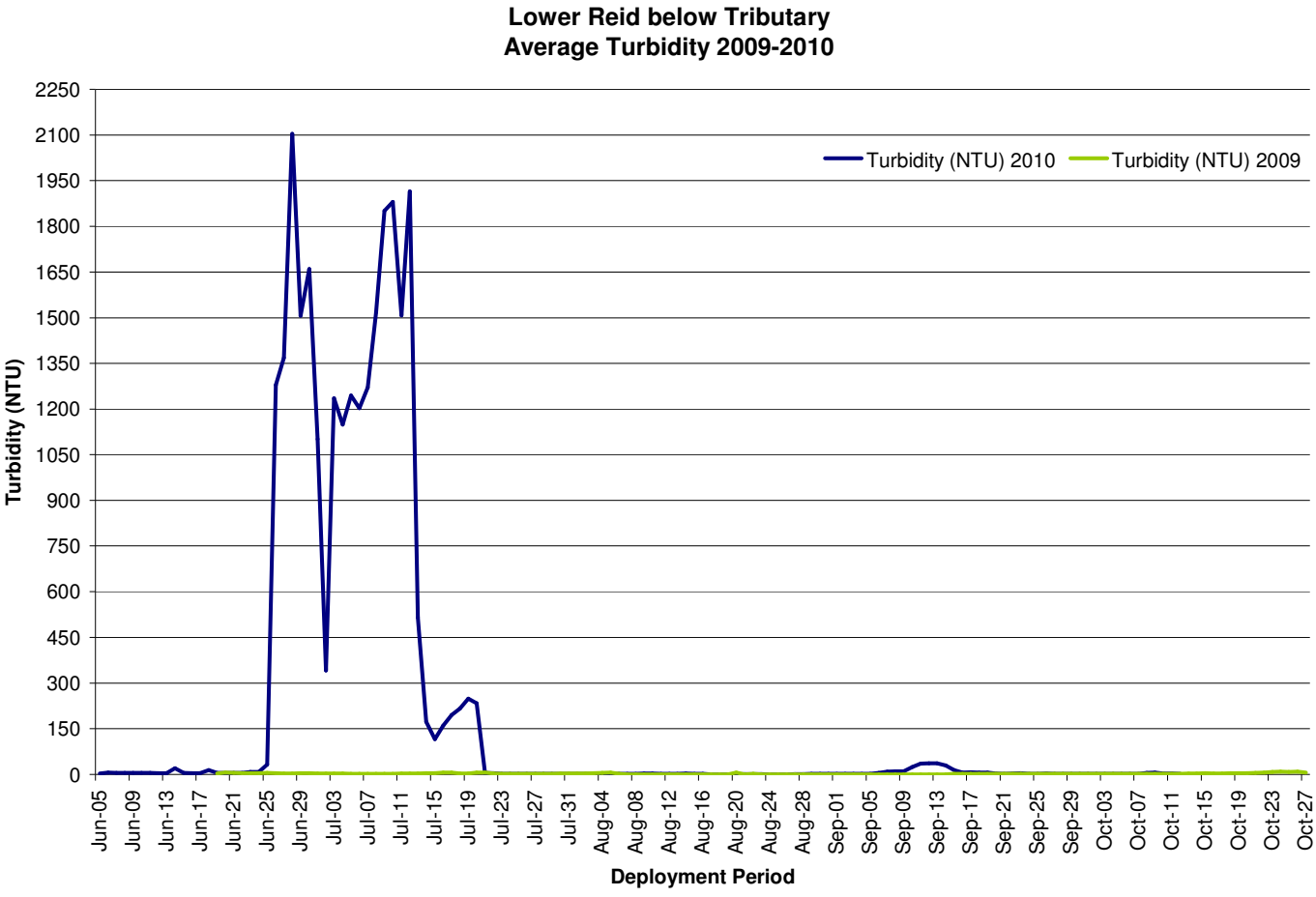

Figure 17: Average Turbidity at Lower Reid below Tributary

STAGE

- The average daily data for stage displays a gradual decrease throughout the deployment season (Figure 8).
- There are several peaks in stage level and they can be jointly associated with the increases in precipitation. However despite the rainfall, stage continues to decline slightly throughout the deployment period (Figure 18). This decline in stage is a typical occurrence during the summer months.
- The precipitation data was obtained from the Environment Canada website http://climate.weatheroffice.gc.ca/climateData/dailydata_e.html?timeframe=2&Prov=CA&StationID=6787&Year=2010&Month=7&Day=20. The closest recorded rainfall to this station is a weather station in Nain.

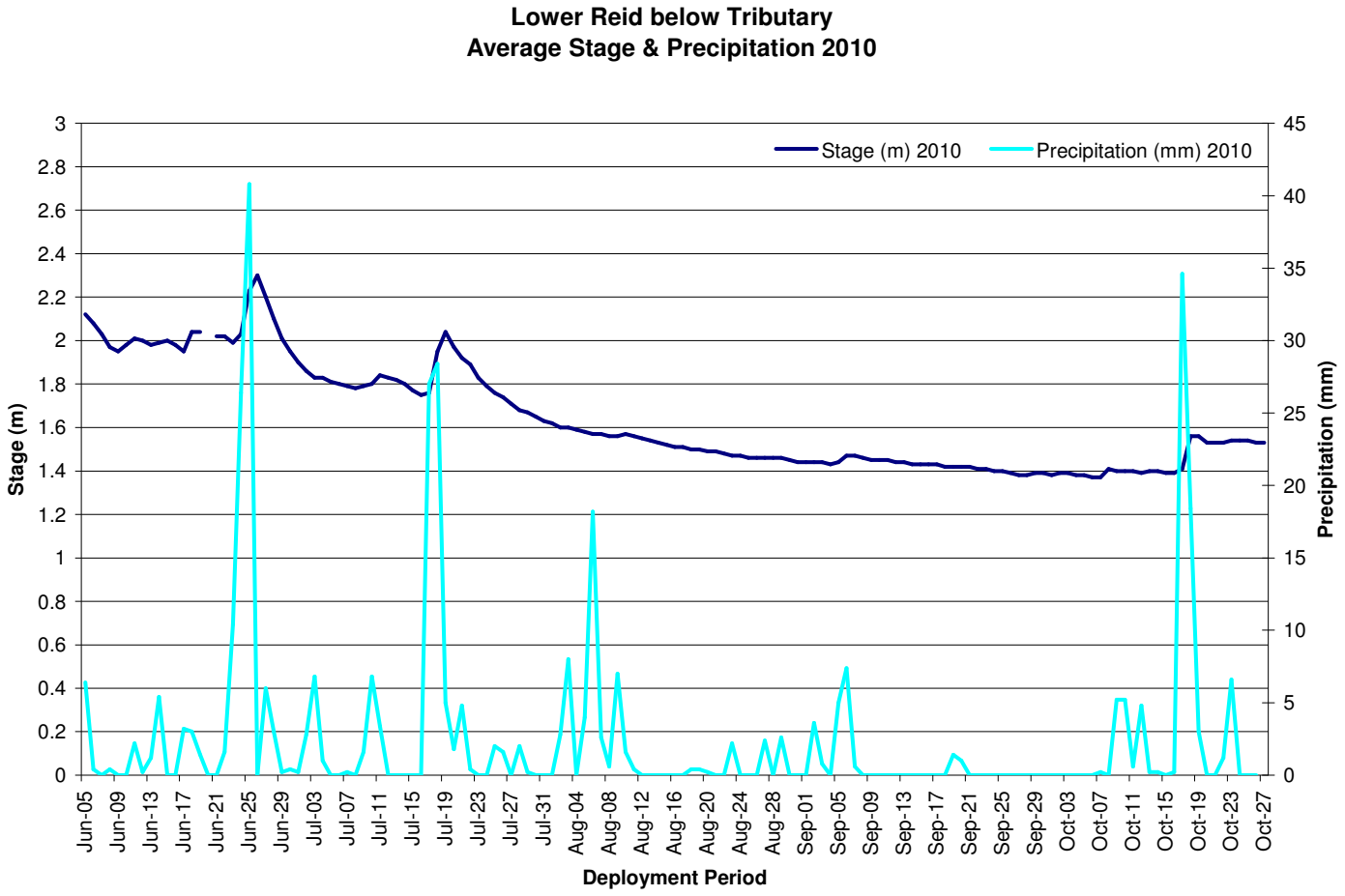

Figure 18: Average daily precipitation and stage level at Lower Reid below Tributary

CAMP POND BROOK BELOW CAMP POND

WATER TEMPERATURE

- During the 2010 deployment period the hourly data for water temperature ranged from 0.7°C to 23.3°C. Figure 19a and 19b displays the daily **averages** for water temperature in 2010.
- On average, the water temperatures are about 1.64°C warmer in 2010 than in 2009.
- When comparing the water temperatures between 2010 and 2009, the graph (Figure 19a) illustrates that there were warmer temperatures in early to mid summer for 2010.
- Water temperature for 2010 is displaying a typical seasonal example, with the height of the water temperatures occurring mid-summer. The water temperatures for both 2010 and 2009 are comparable (Figure 19a).
- Figure 19b displays the water and air temperatures for 2010, there is a visually direct correlation between water and air temperature. As noted on the water temperature data, air temperature displays the seasonal pattern of higher temperatures around mid-summer.

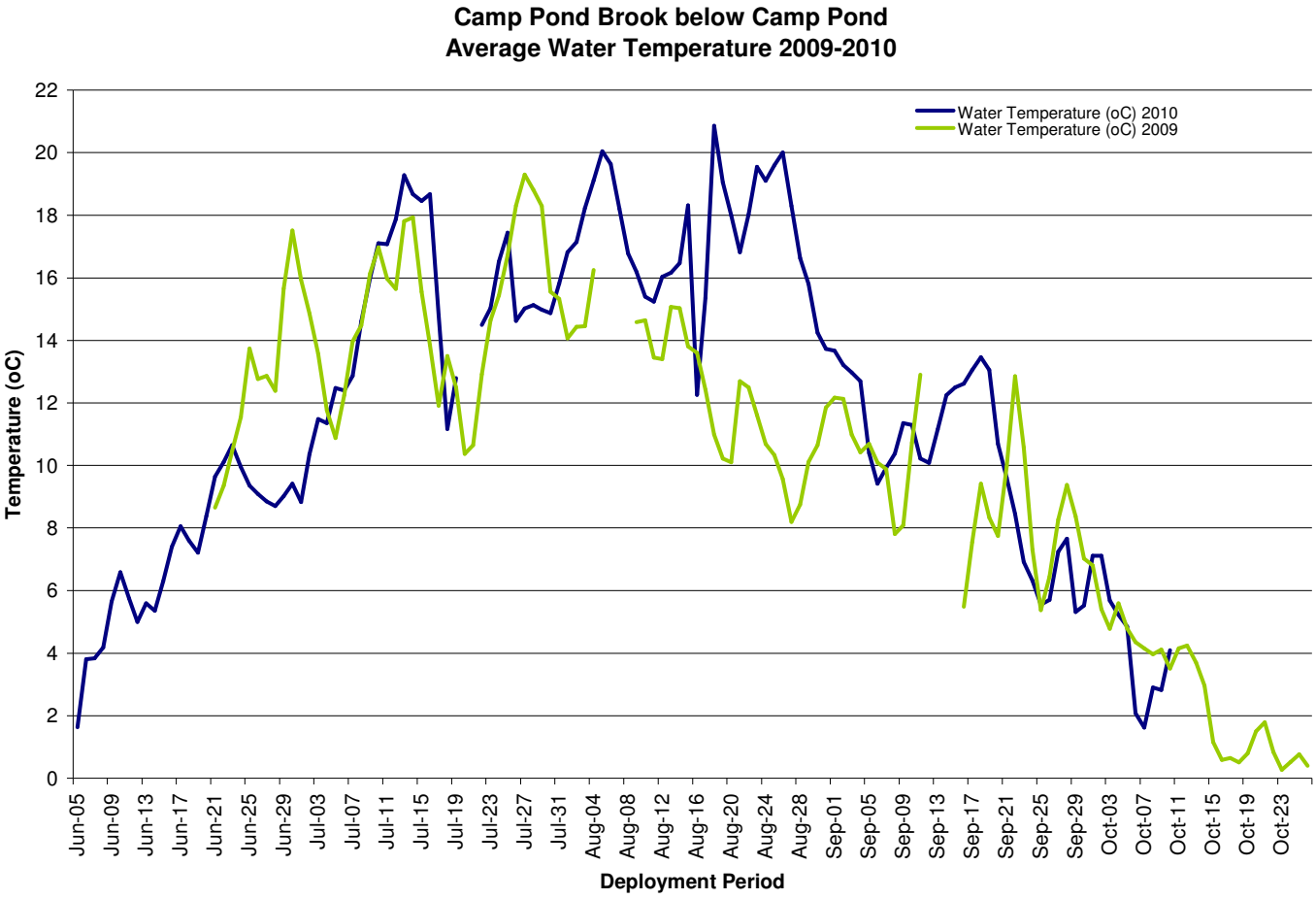

Figure 19a: Average Water Temperatures at Camp Pond Brook below Camp Pond

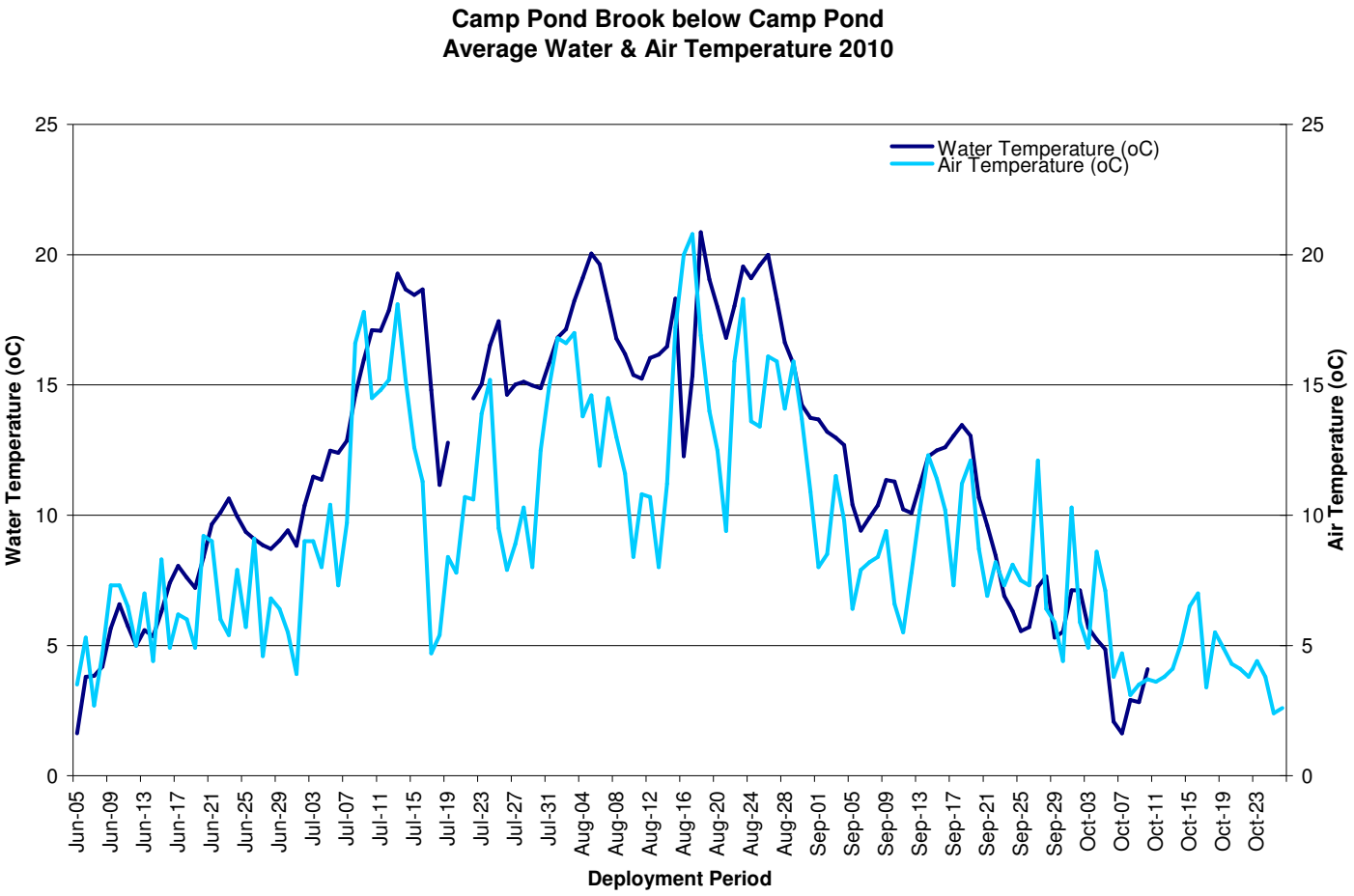

Figure 19b: Average Water temperature at Camp Pond Brook below Camp Pond

PH

- During the 2010 deployment period pH hourly values ranged between 6.18 and 7.45 pH units. Figure 20 displays the daily **averages** for pH in 2010.
- The majority of the pH data for 2010 graphed inside the CCME Guidelines for Protection of Aquatic Life (Figure 20).
- The pH average for 2010 of 6.83 pH units is slightly less than the average for 2009 which was 7.10 pH units.
- The data displayed on the graph (Figure 20) for 2010 increases over the deployment period and pH is at its highest in October 2010. This is also the case when comparing the direction of pH values for 2009.

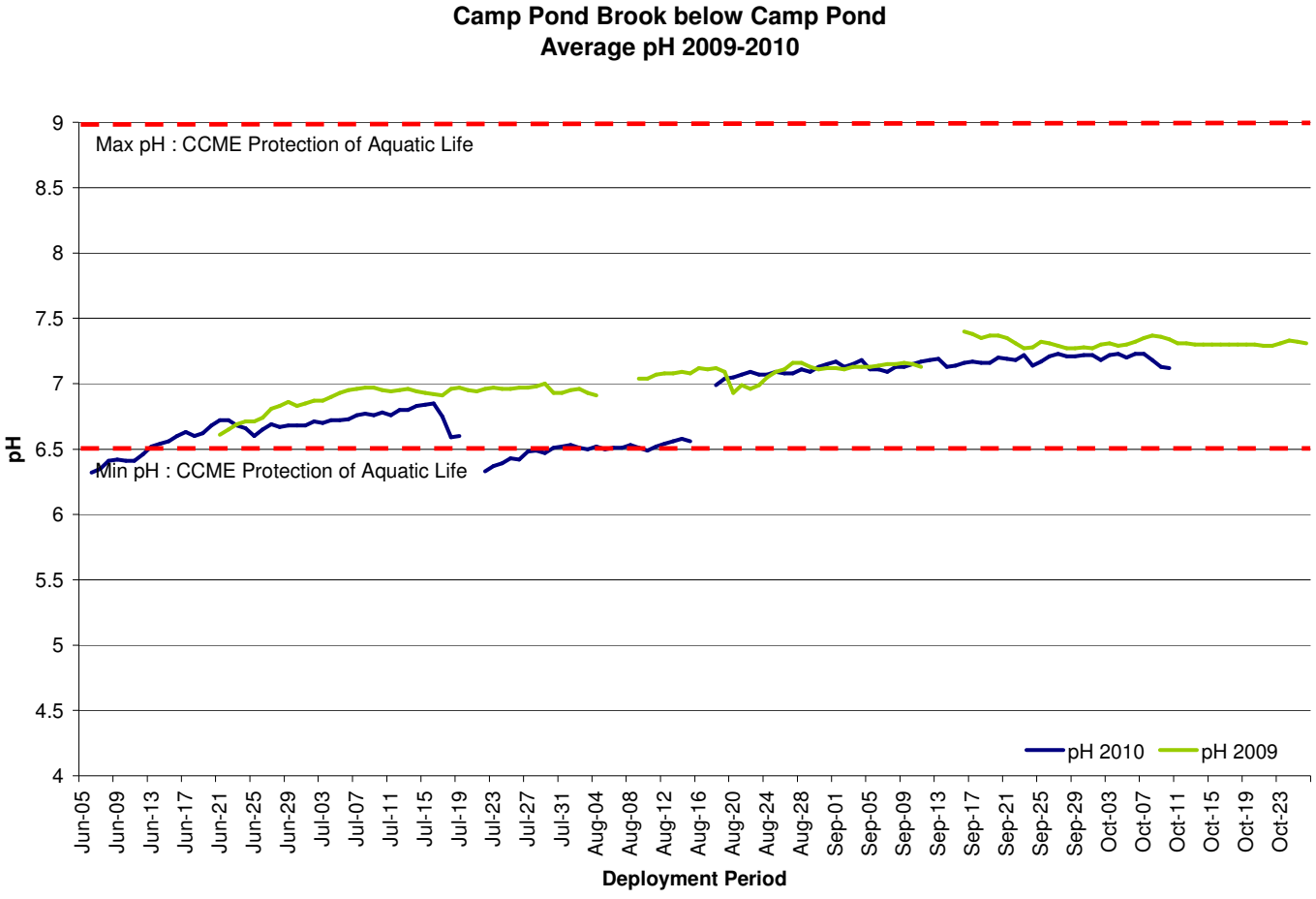

Figure 20: Average pH at Camp Pond Brook below Camp Pond

SPECIFIC CONDUCTANCE

- During the 2010 deployment period the hourly values for specific conductivity ranged from 11.4µS/cm to 60.6µS/cm. Figure 21 displays the daily **averages** for specific conductivity in 2010.
- 2010 conductivity had dropped an average of 3.28µS/cm from the 2009 average. The display of the 2010 data (Figure 21) indicates a steady increase throughout the deployment period, with the highest conductivity readings taking place at the end of September and early October 2010.
- Figure 21 also displays the movement of stage during deployment. As noted on previous graphs stage declines gradually over the deployment period. The relationship between stage and conductivity can be seen on the graph below. As stage decreases, the conductivity levels increase, this trend is due to the dilution affect on total dissolved solids in the water column.
- The 2010 conductivity peaks a little later in the season than 2009 conductivity, there are also greater peaks in 2010.

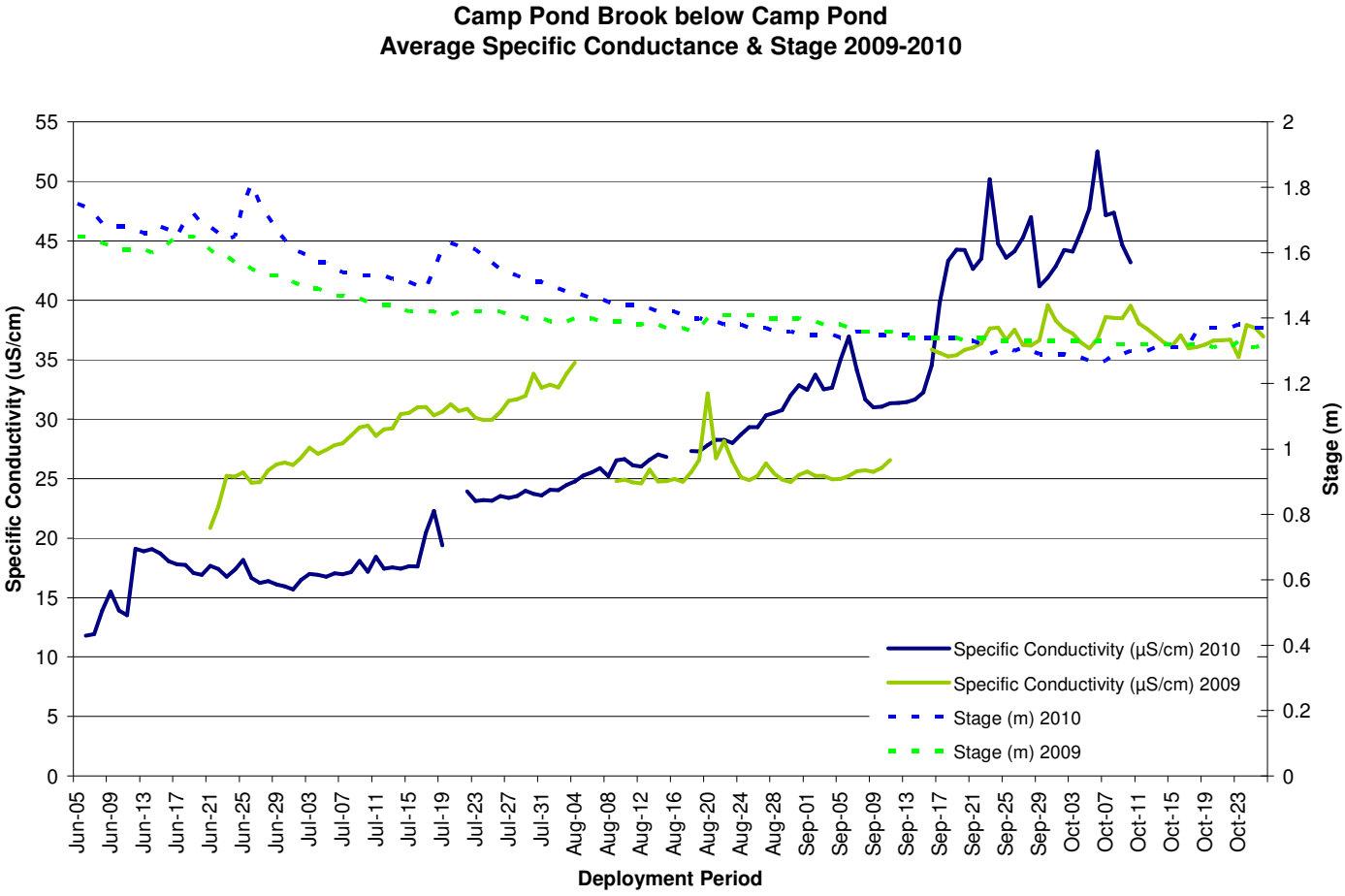

Figure 21: Average Specific conductivity and stage level at Camp Pond Brook below Camp Pond

DISSOLVED OXYGEN

- During the deployment period for 2010 the hourly data for dissolved oxygen content ranged between 6.97mg/L and 12.89mg/L. Figure 22 displays the daily **averages** for dissolved oxygen in 2010.
- Majority of the readings for dissolved oxygen in 2010 remained above the CCME guideline for the Protection of Cold Water/Early Life Stages (9.5mg/L). None of the values fall below the CCME guideline for the Protection of Cold Water/Other Life Stages (6.5mg/L) (Figure 22).
- The dissolved oxygen content for 2010 shows a typical seasonal fluctuation, decreasing throughout the spring and early summer months during the time when water temperatures are increasing.
- Dissolved oxygen content reaches a seasonal low in mid-summer 2010. Water temperatures in the spring 2010 were warmer than in 2009; however the temperatures for 2010 in mid-summer through to fall are slightly lower than the 2009 data. When water temperatures begin to decrease in the late summer, dissolved oxygen content begins to rise again (Figure 22).
- When compared to data from 2009, there is a similar trend due to the inverse relationship between dissolved oxygen and water temperature (Figure 22).

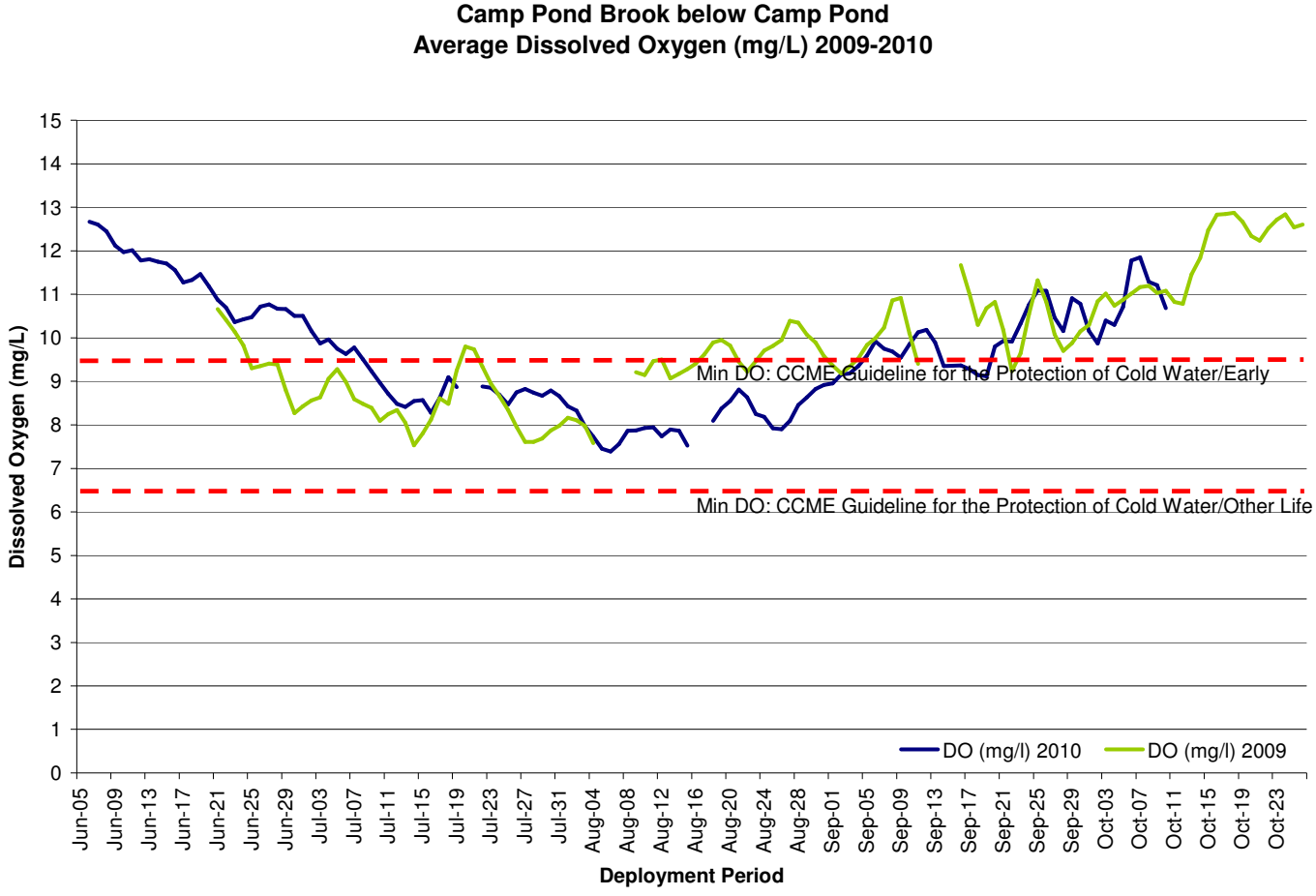

Figure 22: Average Dissolved oxygen at Camp Pond Brook below Camp Pond

TURBIDITY

- During the deployment period for 2010 the hourly turbidity levels ranged between 0.8NTU to 52.5NTU. Figure 23 displays the daily **averages** for turbidity in 2010.
- When looking at the graph (Figure 23) it is evident there are considerably higher turbidity averages for 2010. This is also indicated in the overall average for 2010 which was 3.89NTU greater than 2009 average.
- As identified in the monthly report for this station, several of these high turbidity readings are likely a result of rainfall, and subsequently runoff, at these times.

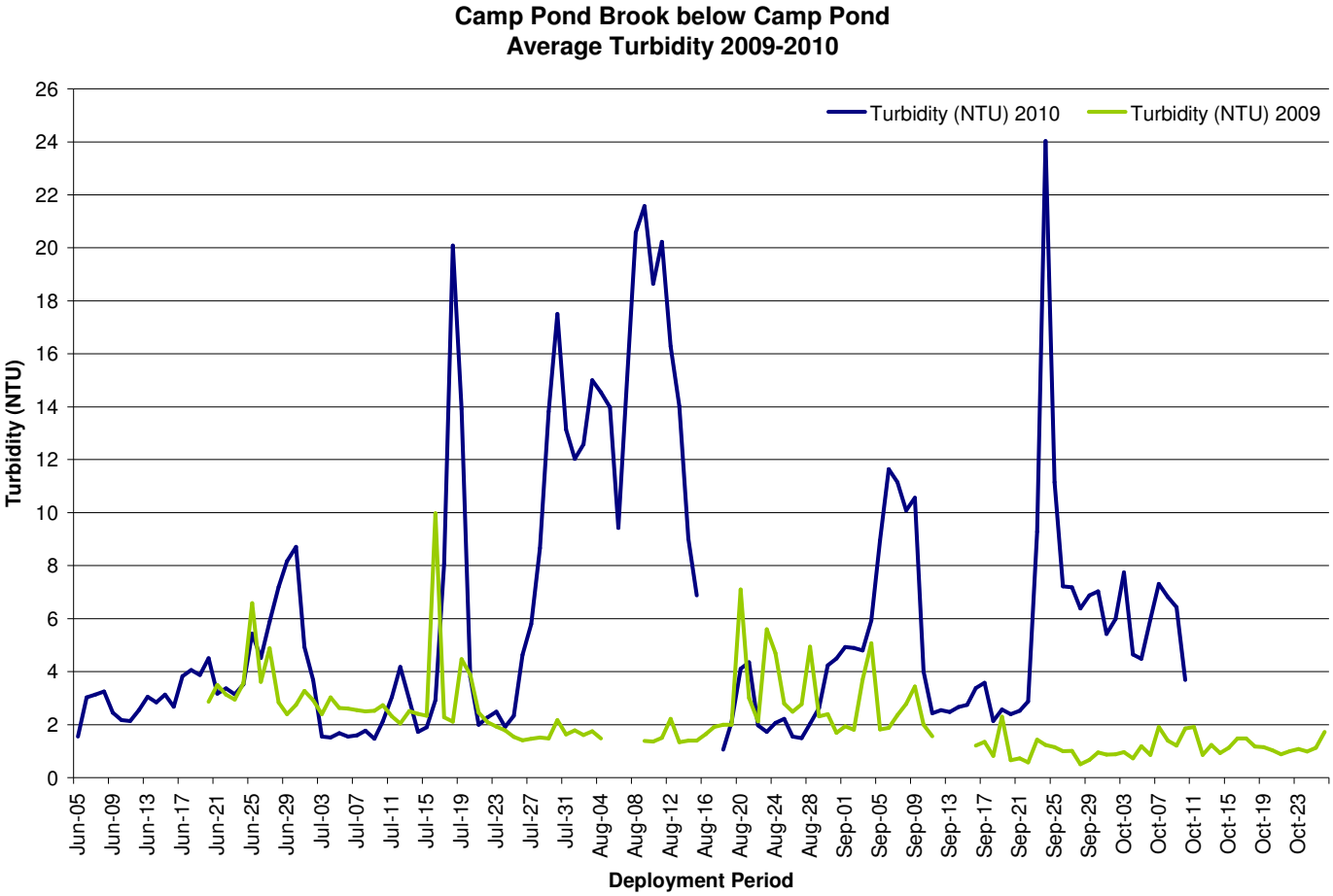

Figure 23: Average Turbidity at Camp Pond Brook below Camp Pond

STAGE

- During the deployment period for 2010, the stage level gradually declined for most of the time frame (Figure 24).
- There are several peaks in stage level during early summer and when compared with the precipitation data it is evident that they are related to one another.
- The precipitation data was obtained from the Environment Canada website http://climate.weatheroffice.gc.ca/climateData/dailydata_e.html?timeframe=2&Prov=CA&StationID=6787&Year=2010&Month=7&Day=20. The closest recorded rainfall to this station is a weather station in Nain.

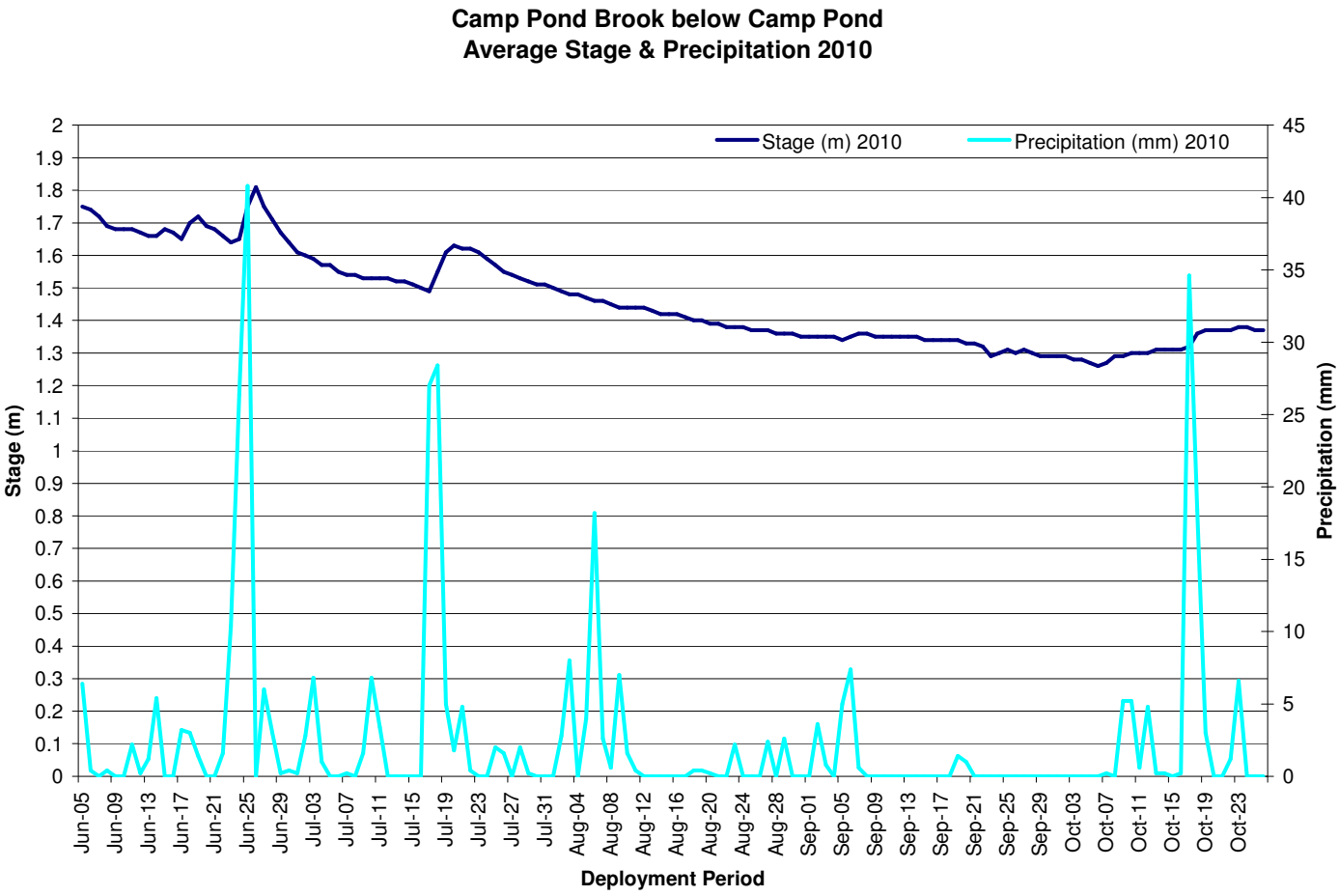

Figure 24: Average daily precipitation and stage level at Camp Pond Brook below Camp Pond

MULTI-STATION COMPARISON

TEMPERATURE

- The daily averages for water temperatures for the Voisey's Bay Stations all display a similar pattern over the deployment period for 2010 (Figure 25).
- Camp Pond Brook below Camp Pond had the highest water temperature average at ~11.04˚C and Lower Reid Brook below Tributary had the lowest at ~9.3˚C.

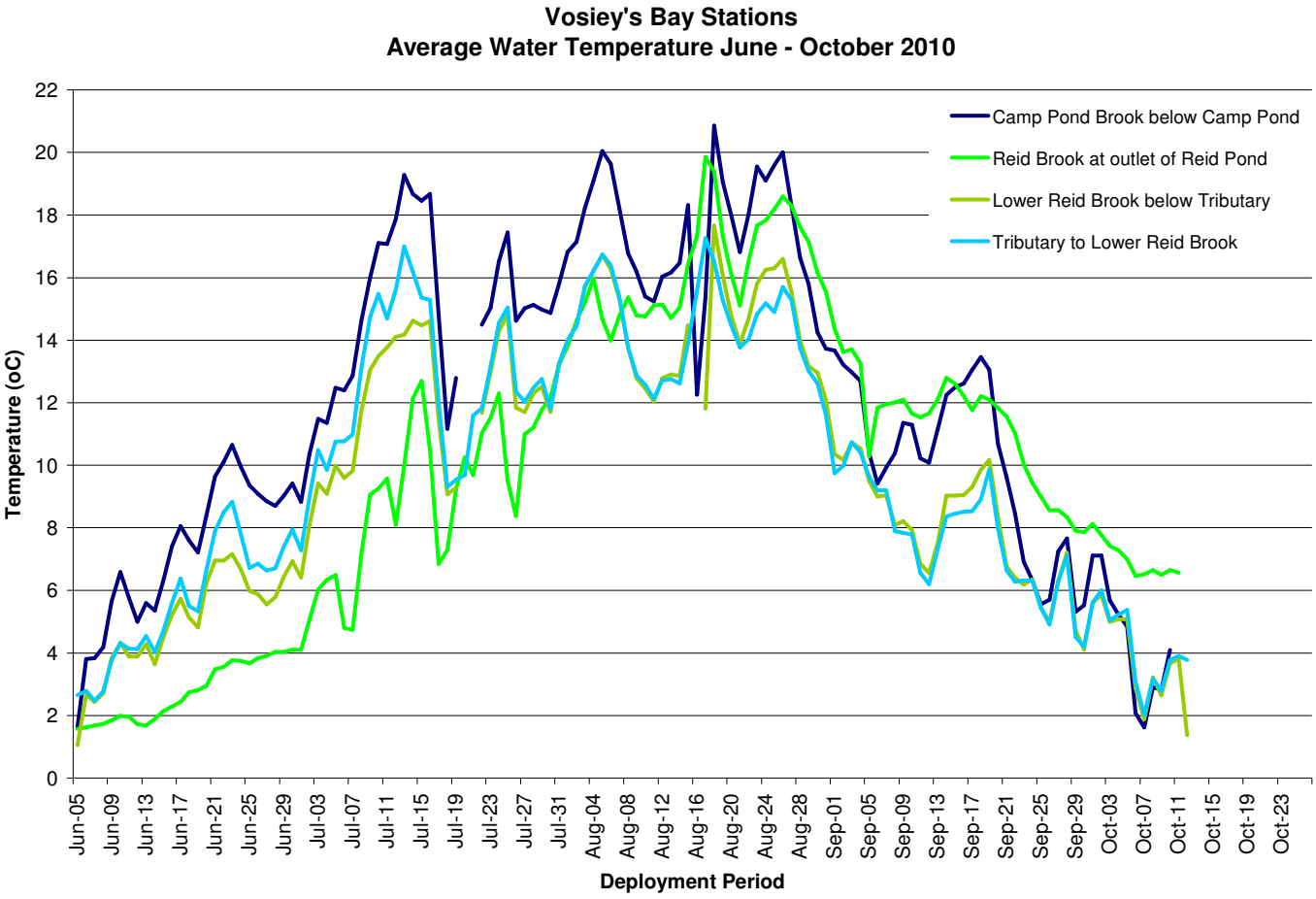

Figure 25: Average Water temperature at the four monitoring stations in Voisey's Bay

PH

- The pH daily averages for the Voisey's Bay Stations display similar data (Figure 26). It appears that during the deployment period the pH climbs gradually. As the season progresses pH values seem to settle out.
- Majority of the data for these stations remain within the CCME guidelines. There are several dips below the Min pH guideline at the beginning of deployment, until mid-summer when the pH values increase.
- When comparing the averages for these stations, they are all close within range. The highest pH was at Camp Pond Brook below Camp Pond which was 6.835, and the lowest was at Reid Brook at Outlet of Reid Pond which was 6.677.

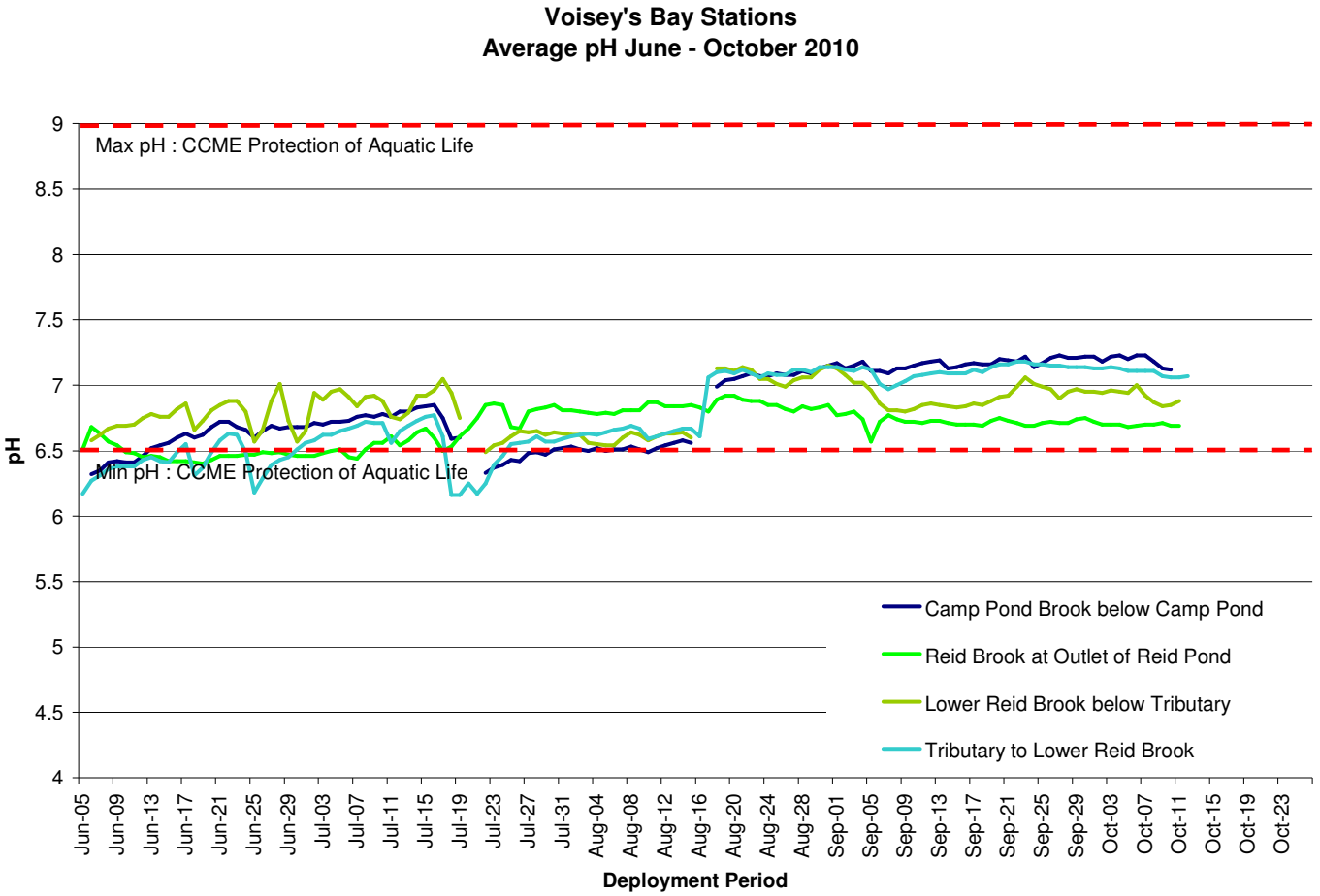

Figure 26: Average pH at the four monitoring stations in Voisey's Bay

SPECIFIC CONDUCTIVITY

- The figure below displays the daily averages for specific conductivity for all Voisey's Bay stations; there are some similarities in the data and noticeable differences (Figure 27).
- Three of the stations display similar trends over the deployment period (Figure 27). The conductivity values start low and then increase steadily over the summer to as high as ~53µS/cm. However Reid Brook at Outlet of Reid Pond displays a gradual decrease in specific conductivity over the summer and the values are considerably lower than the other stations.
- This is a typical trend for Reid Brook at Outlet to Reid Pond as this station is a pristine, natural station that is used as the background for all other stations. The median for the specific conductivity levels for both 2009 and 2010 is low at ~9µS/cm.
- When comparing averages for these stations, three stations are close in range, all within 25µS/cm to 28µS/cm with Reid Brook at outlet of Reid Pond's average as the lowest at 8.43µS/cm.

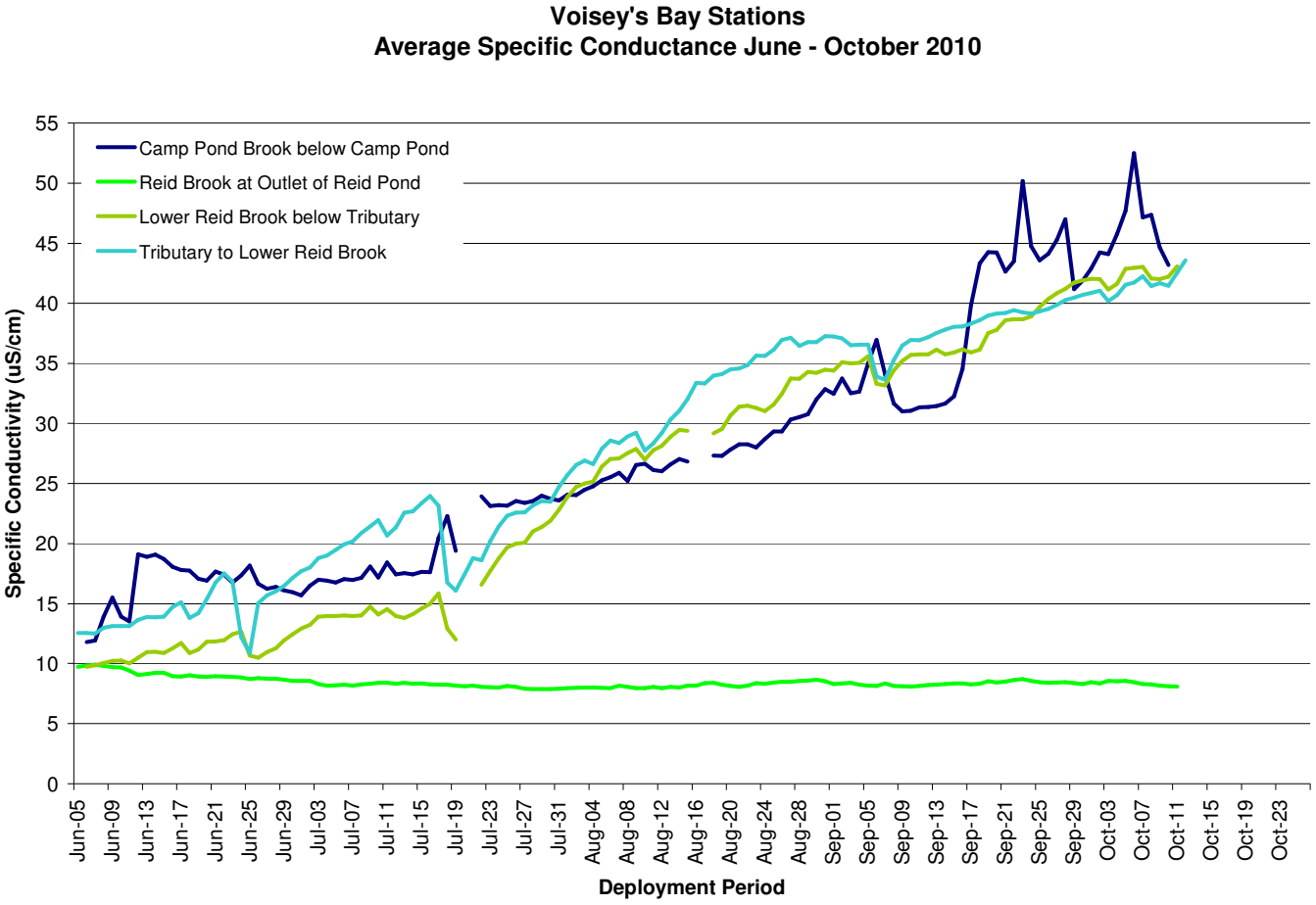

Figure 27: Average Specific conductivity at four monitoring stations in Voisey's Bay

DISSOLVED OXYGEN

- When reviewing the dissolved oxygen daily averages for Voisey's Bay it is evident that some of the stations data is similar. However the Lower Reid Brook below Tributary data indicates an instrument malfunction and error for dissolved oxygen (mg/L and Percent Saturation).
- The dissolved oxygen (mg/L) data displays lower DO mg/L values in mid-summer, generally related to the increased water temperatures at that period. As the water temperatures decrease the DO mg/L content increases as displayed on Figure 28 toward the end of the deployment period.
- Besides the dip in DO mg/L and % Sat from the Lower Reid Brook data, majority of the data remains above the CCME guideline for the Protection of Cold Water/Other Life Stages.

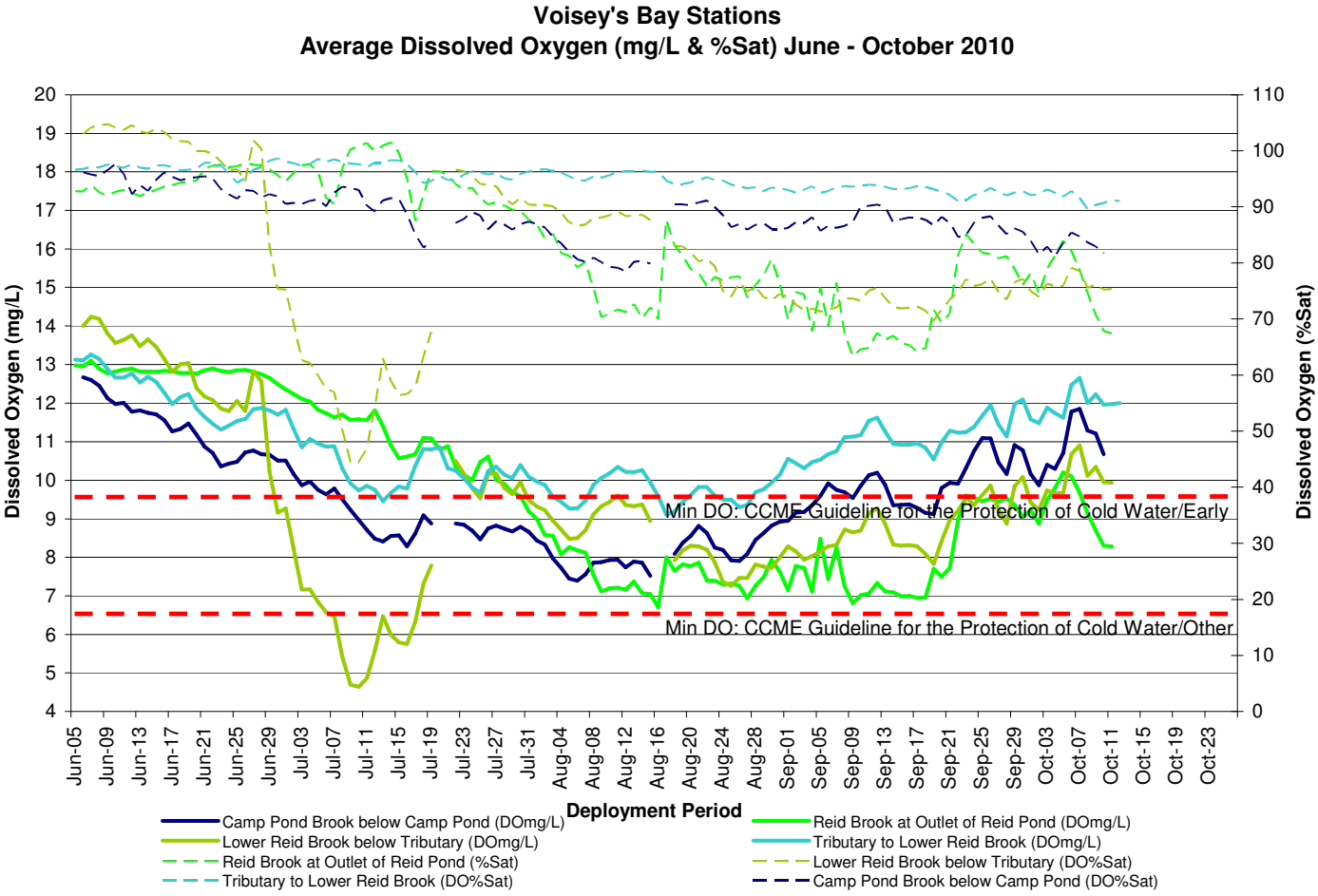

Figure 28: Average Dissolved oxygen and percent saturation at the Voisey's Bay Stations

TURBIDITY

- This deployment period saw a number of turbidity events at Reid Brook at outlet of Reid Pond and Lower Reid Brook below Tributary. There are several smaller turbidity events displayed for Tributary to Lower Reid Brook and Camp Pond Brook below Camp Pond.
- Figure 29a displays the scale of data from 0NTU to 120NTU, this provides a closer detail of the smaller events that occurred in this deployment period. Figure 29b displays the larger turbidity peaks between 0-3000NTU.
- In the daily data for Lower Reid below Tributary and Reid Brook at outlet of Reid Pond (monthly reports) there are turbidity readings for 3000NTU – these readings identify an error with the sensor. When the averages are graphed they still encumber the 3000NTU readings therefore care should be taken when viewing turbidity data from these two stations.
- Several of the smaller turbidity events (at each station) actually coincide with each other. These increases in turbidity were likely a result of a rainfall event that influenced all water bodies at that time.

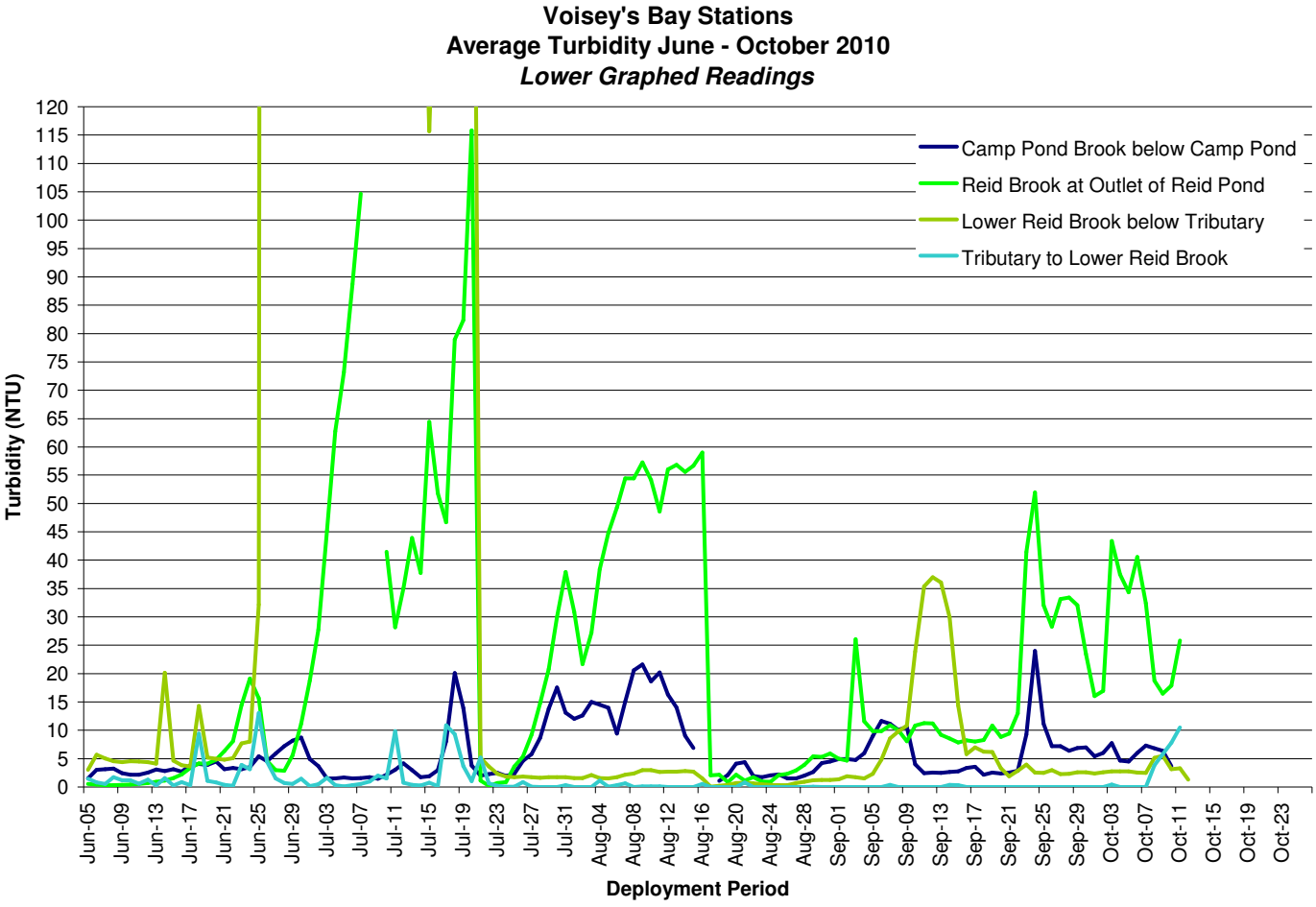

Figure 29a: Average Turbidity (0 to 120 NTU) at Voisey's Bay Stations

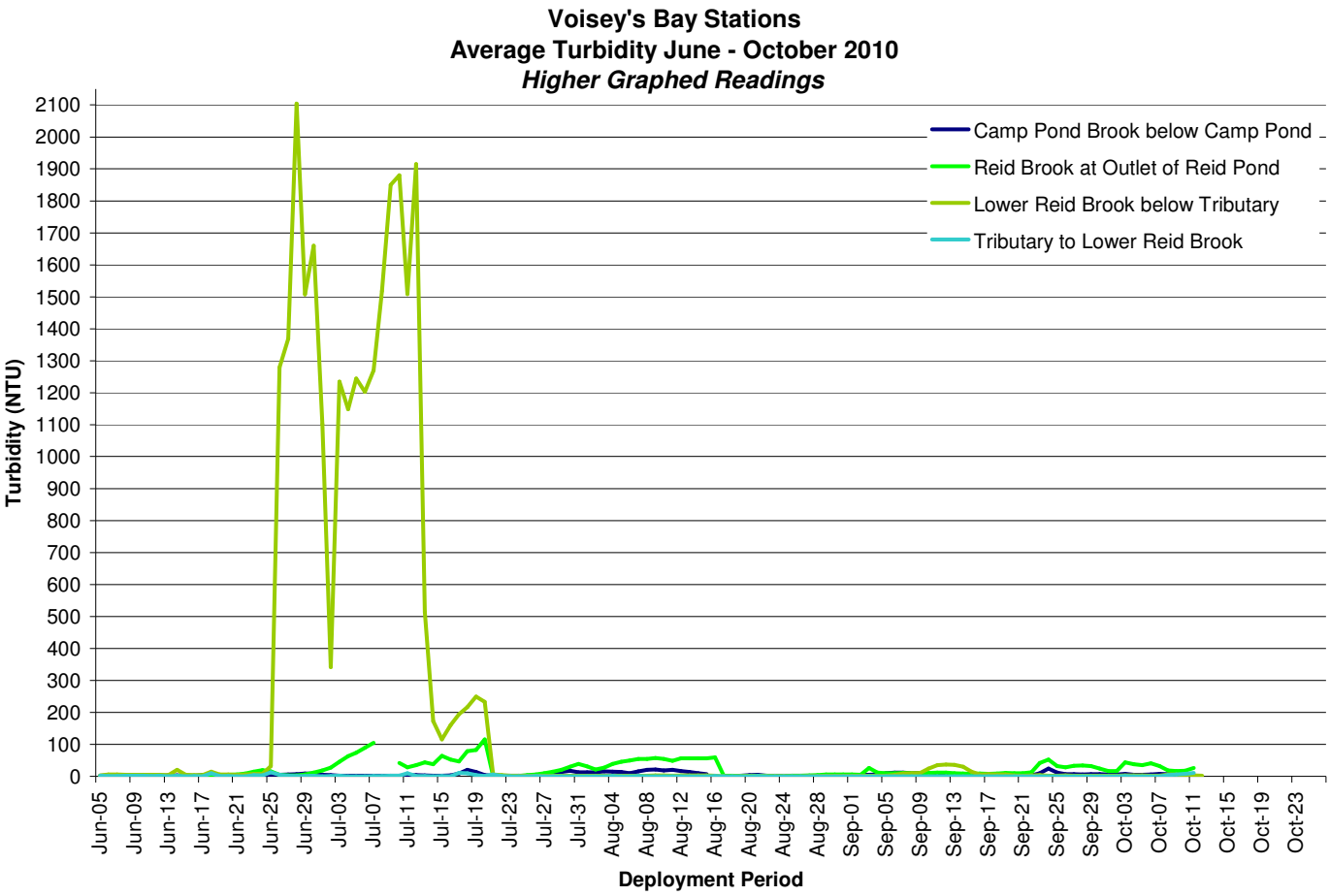

Figure 29b: Average Turbidity (0 to 2100 NTU) at Voisey's Bay Stations

STAGE

- During the 2010 deployment period, stage levels at all stations gradually decreased. There is some similarities between the stage data for the Voisey's Bay Stations.
- All streams seem to increase and decrease simultaneously, likely in response to the precipitation events that occurred during deployment.
- Seasonal highs for the four stations are displayed in mid-June, with seasonal lows for the stations occurring toward the end of deployment in late September – early October.

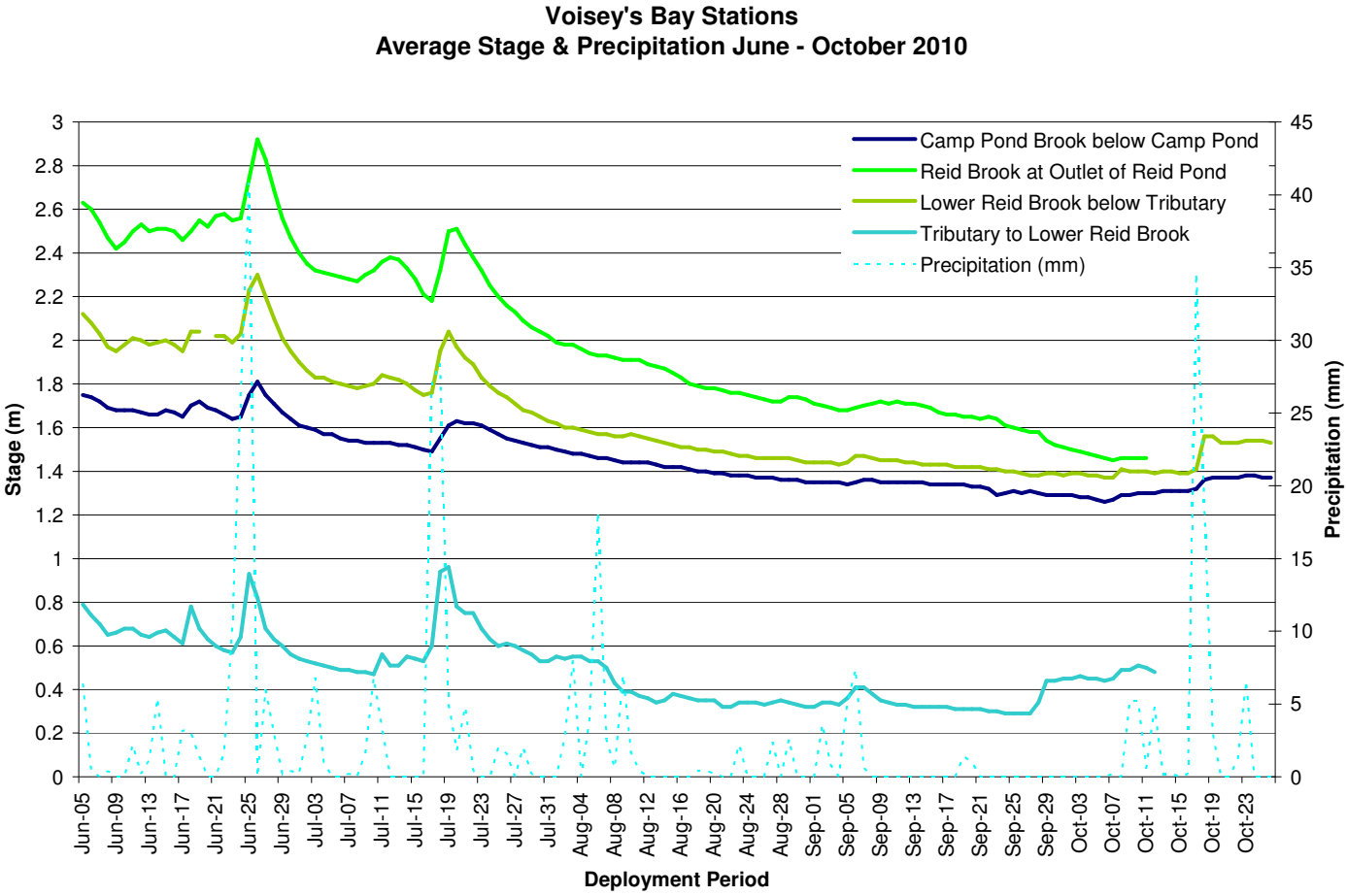

Figure 30: Average Stage and Precipitation at the Voisey's Bay Stations

CONCLUSIONS

- All Voisey's Bay stations had successful deployments during this season. Instruments were deployed on June 5th, 2010 and removal for the season on October 11th, 2010.
- After the deployment period was completed, it was identified that there was instrument error at Reid Brook at outlet of Reid Pond and Lower Reid Brook below Tributary. This must be factored into the integrity and accuracy of the data at these two stations, care should be taken when using this data.
- There were no significant water quality events at Camp Pond Brook below Camp Pond and Tributary to Lower Reid Brook. Majority of the increases and decreases could be explained by precipitation events or increase/decreases in water level (Appendix A).
- Majority of pH values for the Voisey's Bay Stations remained within the suggested guideline from CCME for the Protection of Aquatic Life for pH. pH levels for all four stations gradually increased and stabilized toward the end of the deployment.
- Despite several inaccurate readings in dissolved oxygen (mg/L) from the Lower Reid Brook below Tributary instrument, the DO readings for all stations indicated a typical trend over the deployment period. There was a natural decrease in DO (mg/L) during the warmer temperatures, followed by the increase in DO (mg/L) indicating the drop in temperature toward the end of deployment.
- The entire deployment season consisted of three scheduled maintenance and calibration visits at each station. Ideally a deployment period would be within 30 to 35 days. However, as was the case during the 2010 deployment season maintenance trips were delayed by weather and transportation arrangement. It was difficult to follow a 30-35 day deployment.
- In the case of the Reid Brook at outlet of Reid Pond and Lower Reid Brook below Tributary instruments, both instruments calibrated fine and initially recorded 'normal' data for turbidity, dissolved oxygen and temperature probes. However throughout the duration of deployment the data recorded indicated that there is issues with the dissolved oxygen and turbidity sensor on the Lower Reid Brook instrument and potential problems with the temperature sensor on the Reid Brook at outlet of Reid Pond. Data taken from these parameters should be used with caution and reviewed very carefully.

PATH FORWARD

The success of these four stations is built largely by the individuals working at maintaining and monitoring the Voisey's Bay real-time network. This network has been flourishing since 2003 and continues to improve annually in background knowledge and awareness of the rivers behaviours. This is essential for identifying the difference between natural and unnatural events. As this agreement progresses into the 2011 deployment period for the Voisey's Bay Stations, there are several items listed below that will coincide with deployment and assist in advancement of the stations.

- All stations will be newly deployed an soon as ice conditions allow for the 2011 deployment season.
- In the 2011 deployment season, staff from VALE will once again be responsible for monthly maintenance and calibration (as was the case in the past). ENVC staff will perform regular site visits to audit and assist in the maintenance and calibration procedures from time to time.
- EC staff will perform regular site visits to ensure water quantity instrumentation is correctly calibrated and providing accurate measurements.

- If necessary, changes or improvements to deployment techniques will be made to adapt to each site, ensuring secure and suitable conditions for real time water quality monitoring.
- VALE Voisey's Bay will receive monthly reports outlining the events that occurred in the previous deployment period.
- VALE Voisey's Bay will receive a 2011 annual report summarizing the events of the deployment season.
- Continue to maintain open communication lines between ENVC, EC and VALE Voisey's Bay employees involved with the agreement in order to respond to emerging issues on a proactive basis.
- ENVC staff will conduct a training session for Voisey's Bay staff, educating on the new processes and procedures with handling, maintaining and calibrating the real-time instruments.
- Creation of value added products using the real-time water quality data, remote sensing and water quality indices.
- An email alerting system will be established for the Voisey's Bay stations to catch emeging water quality issues at the startof the 2011 deployment season.
- ENVC will begin development of models using real time water quality monitoring data and grab sample data to estimate a variety of additional water quality parameters (*i.e.* TSS, major ions *etc*.).

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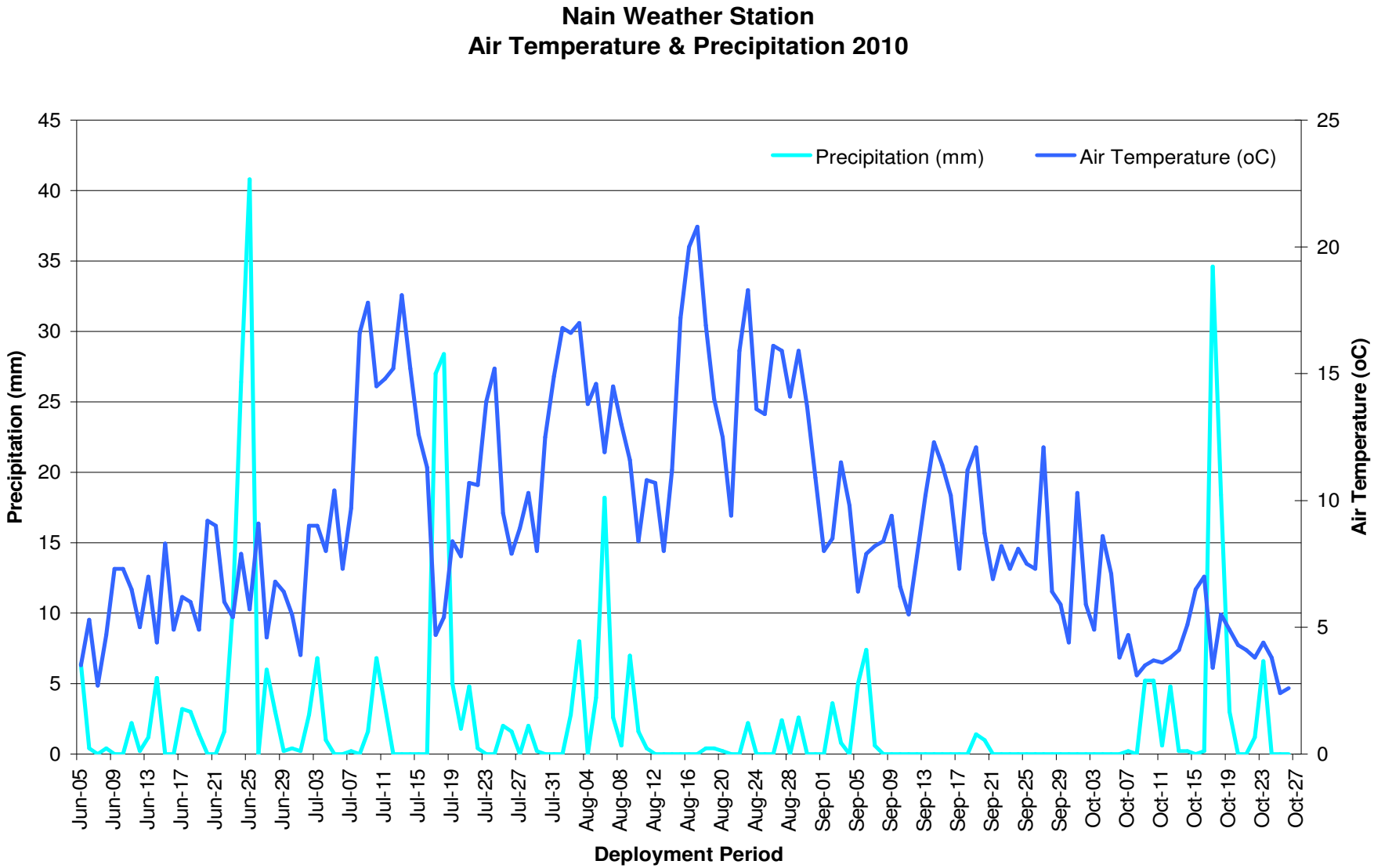
Department of Environment and Conservation
Water Resources Management Division

Appendix A


Nain Weather Station
Air Temperature & Precipitation 2010
Precipitation (mm)
Air Temperature (oC)
Precipitation (mm)
Air Temperature (oC)
Deployment Period
0
5
10
15
20
25
30
35
40
45
0
5
10
15
20
25
Jun-05
Jun-09
Jun-13
Jun-17
Jun-21
Jun-25
Jun-29
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