Real-Time Water Quality 2011 Annual Report

Voisey's Bay Network

June 22 to
October 28, 2011

Newfoundland Labrador

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

Real-Time Water Quality Deployment Report

Voisey's Bay Network

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Contents

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.

Vale Environment staff Perry Blanchard, Dennis Martin, Erin Cullen and Matt Hynes are acknowledged for their hard work during the 2011 deployment period, and ensuring 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. 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.

Environment Canada staff of the Meteorological Service of Canada: Water Survey Canada (Perry Pretty, 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), EC (Howie Wills) and Vale (Perry Blanchard) 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.

Abbreviations

EC	Environment Canada
ENVC	Department of Environment and Conservation
DO	Dissolved Oxygen
NL	Newfoundland and Labrador
QAQC	Quality Assurance and Quality Control
RTWQ(M)	Real Time Water Quality (Monitoring)
WRMD	Water Resources Management Division
%Sat	Percent Saturation

Introduction

- The real-time water quality monitoring network in Voisey's Bay was successfully established by ENVC and EC in cooperation with Vale in 2003 and further expanded in 2006.
- The objective of the network is to identify and track any emerging water quality or quantity management issues and ensure protection of ambient water resources in and around the Voisey's Bay operations.
- The RTWQM network consists of 4 water quality monitoring stations; Upper Reid Brook (Outlet from Reid Pond), Tributary to Lower Reid Brook, Lower Reid Brook below Tributary and Camp Pond Brook below Camp Pond. These stations measure water quality parameters including water temperature, pH, specific conductivity, dissolved oxygen, and turbidity. Two additional parameters, total dissolved solids and percent saturation are calculated from measured parameters.
- These stations also record continuous stage level and flow rate data. These parameters are the responsibility of EC, however, if needed, ENVC staff reporting on water quality will have access to water quantity information to understand and explain water quality fluctuations.
- Continuous monitoring recommenced in spring 2011 when ice conditions permitted. This annual deployment report illustrates, discusses and summarizes water quality related events from June 19 to October 28. During this time, 5 visits were made to each of the 4 real time monitoring sites. Instruments were deployed for four, month long intervals referred to as deployment periods.

Maintenance and Calibration

- It is recommended that regular maintenance and calibration of the instruments take place on a monthly basis to ensure accurate data collection. This procedure is the responsibility of the Vale Environment staff and is performed preferably every 30 days.
- 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, Vale Environment 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 inaccurate. Installation and removal dates for each station in the 2011 deployment season are summarized in Table 1.

Table 1: Installation and removal dates for 2011 deployment periods

Installation	Removal	Deployment Period (days)
June 19/22	July 20	29
July 21	August 30	39
August 31	September 27	28
September 28	October 28	30

Quality Assurance and Quality Control

- As part of the Quality Assurance and Quality Control protocol (QAQC), an assessment of the reliability of data recorded by an instrument is made at the beginning and end of the deployment period. The procedure is based on the approach used by the United States Geological Survey.
  - ► At deployment and removal, a QAQC Instrument is temporarily deployed along side the Field Instrument. Values for temperature, pH, conductivity, dissolved oxygen and turbidity are compared between the two instruments**.** Based on the degree of difference between parameters recorded by the Field Instrument and QAQC Instrument at deployment and at removal, a qualitative statement is made on the data quality (Table 2).

Table 2: Ranking classifications for deployment and removal

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

- It should be noted that the temperature sensor on any instrument is the most important. All other parameters can be broken down into three groups: temperature dependant, temperature compensated and temperature independent. Because the temperature sensor is not isolated from the rest of the instrument the entire instrument must be at the same temperature before the sensor will stabilize. The values may take some time to climb to the appropriate reading; if a reading is taken too soon it may not accurately portray the water body.
- Deployment and removal comparison rankings for the Voisey's Bay Network stations deployed from June 19/22 to October 28, 2011 are summarized in Table 3.
- For additional information and explanations of rankings including "ERROR" rankings, please refer to the monthly deployment reports.

Table 3: Comparison rankings for Voisey's Bay Network stations, June 19/22– October 28, 2011

			Instrument #	Temperature	pH	Specific Conductivity	Dissolved Oxygen	Turbidity
Upper Reid Brook	19-Jun-11	Deployment	40428	Poor	Good	Excellent	Poor	No Turbidity Sensor
	20-Jul-11	Removal	40428	n/a	n/a	n/a	n/a	
	21-Jul-11	Deployment	40428	Good	Good	Excellent	Excellent	
	30-Aug-11	Removal	40428	Excellent	Fair	Excellent	Poor	
	31-Aug-11	Deployment	40428	Good	Good	Excellent	Poor	
	27-Sep-11	Removal	40428	Excellent	Poor	Excellent	Fair	
	28-Sep-11	Deployment	40428	Good	Marginal	Excellent	Fair	
	28-Oct-11	Removal	40428	Excellent	Excellent	Excellent	Fair	
Tributary to Lower Reid Brook	22-Jun-11	Deployment	44175	Good	Good	Excellent	n/a	
	20-Jul-11	Removal	44175	Excellent	Excellent	Fair	Fair	Excellent
	21-Jul-11	Deployment	44175	Excellent	Marginal	Excellent	Good	Excellent
	30-Aug-11	Removal	44175	Excellent	Fair	Good	Excellent	
	31-Aug-11	Deployment	44175	Good	Fair	Excellent	n/a	
	27-Sep-11	Removal	44175	Good	Poor	Excellent	n/a	
	28-Sep-11	Deployment	44175	Good	Good	Good	n/a	
	28-Oct-11	Removal	44175	Good	Good	Good	n/a	
Lower Reid Brook	22-Jun-11	Deployment	40643	Good	Good	Good	Excellent	
	20-Jul-11	Removal	40643	Good	Excellent	Excellent	Poor	Poor
	21-Jul-11	Deployment	40643	Good	Excellent	Good	Poor	Excellent
	30-Aug-11	Removal	40643	Excellent	Fair	Good	Poor	
	31-Aug-11	Deployment	40643	Excellent	Excellent	Good	Good	
	27-Sep-11	Removal	40643	Excellent	Fair	Good	Excellent	
	28-Sep-11	Deployment	40643	Excellent	Excellent	Good	Excellent	
	28-Oct-11	Removal	40643	Excellent	Good	Excellent	Fair	
Camp Pond Brook	22-Jun-11	Deployment	40642	Excellent	Excellent	Excellent	Fair	
	20-Jul-11	Removal	40642	Good	Good	Good	Poor	Fair
	21-Jul-11	Deployment	40642	Good	Good	Good	Good	Excellent
	30-Aug-11	Removal	40642	Excellent	Good	Fair	Excellent	
	31-Aug-11	Deployment	40642	Excellent	Fair	Excellent	Excellent	
	27-Sep-11	Removal	40642	Excellent	Fair	Excellent	Fair	
	28-Sep-11	Deployment	40642	Excellent	Good	Excellent	Excellent	
	28-Oct-11	Removal	40642	Excellent	Fair	Excellent	Fair	

Data Interpretation

- The following graphs and discussion illustrate significant water quality-related events from June 19/22 to October 28 in the Voisey's Bay Real Time Water Quality Monitoring Network.
- With the exception of water quantity data (stage), all data used in the preparation of the graphs and subsequent discussion below adhere to this stringent QAQC protocol. Water Survey of Canada is responsible for QAQC of water quantity data. Corrected data can be obtained upon request.

Upper Reid Brook (Outlet from Reid Pond)

- Water temperature ranged from 2.1 °C to 19.34°C during the 2011 deployment season, averaging 9.11°C (Figure 1).

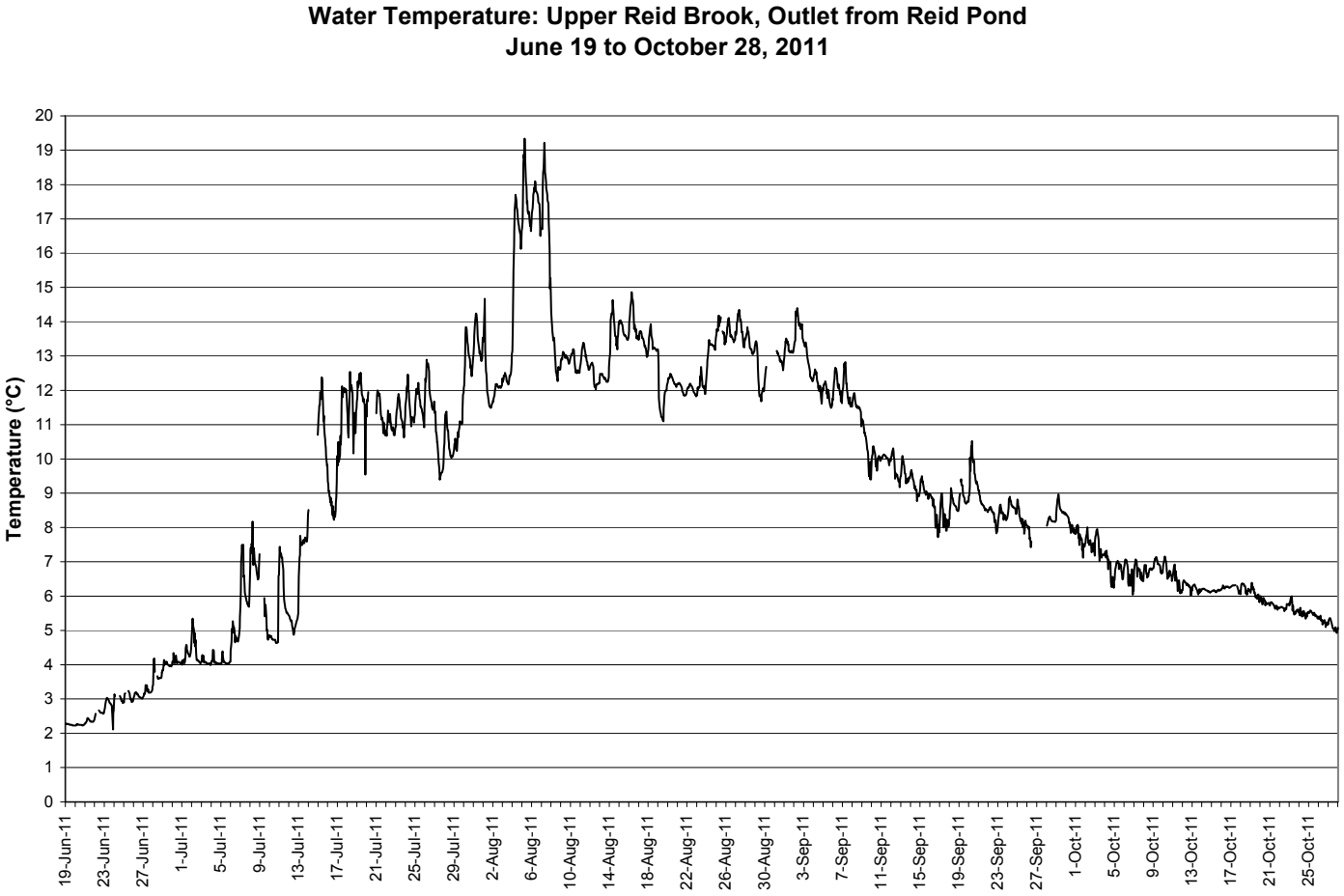


Figure 1: Water temperature at Upper Reid Brook

- Water temperature values show a typical seasonal trend (Figure 2). Water temperature is increasing for the first part of the deployment season during the spring and early summer. Water temperature peaks in early August at 19.34°C. Water temperature begins to decrease in the latter half of August and into the fall season as air temperatures cool.

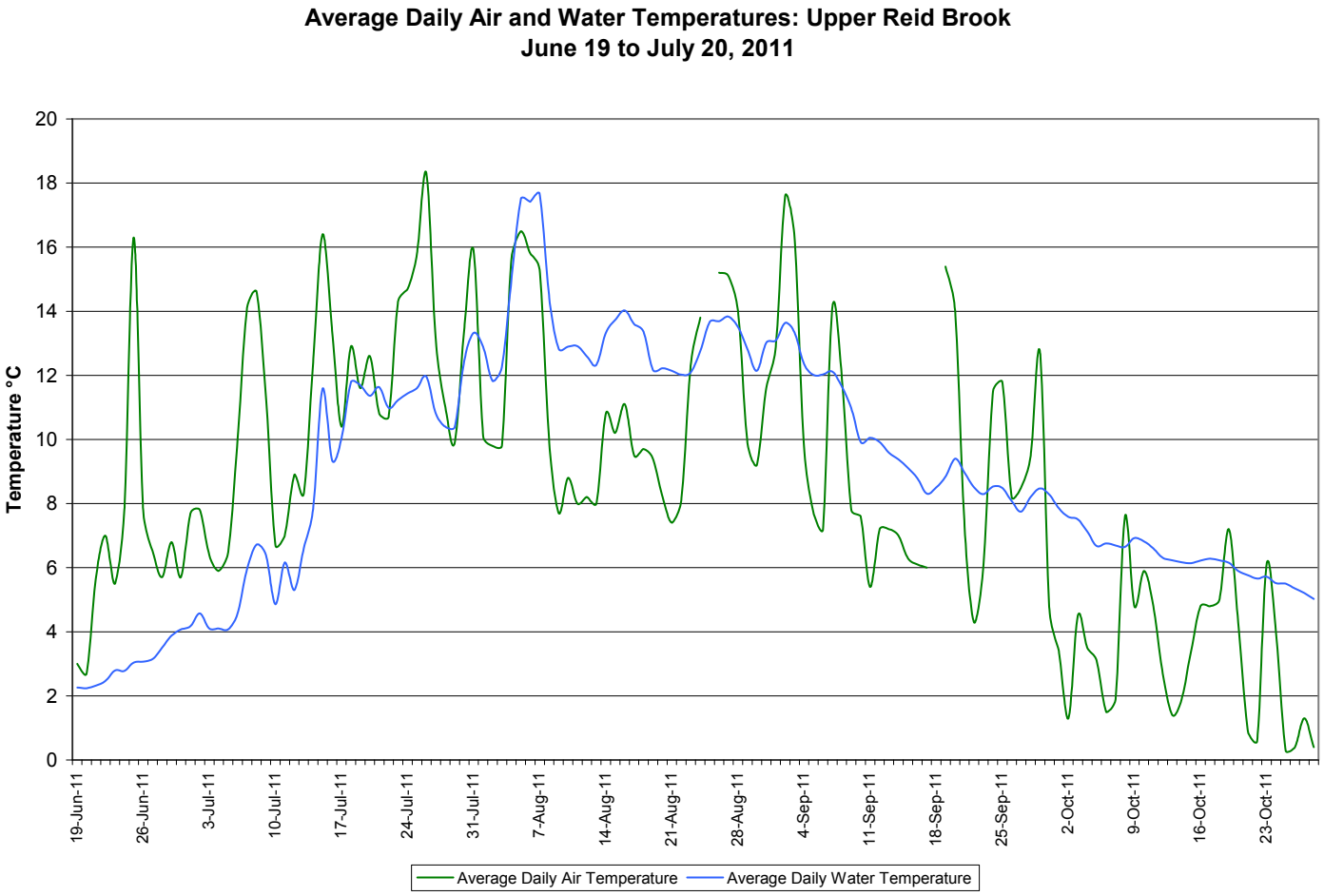


Figure 2: Average daily air and water temperatures at Upper Reid Brook

(weather data recorded at Nain)

- pH ranged between 6.31 and 6.81 pH units throughout the 2011 deployment season, averaging 6.54 pH units (Figure 3).
- Data collected between July 21 and August 30 is subject to error. By the end of the deployment period, the pH values were fluctuating daily over 1 pH unit (increasing and decreasing over 100 times the ion concentration). It is unknown what caused this error. The data will be removed from the data set for future use. This data was not used in the above average and range calculations.
- Excluding the data collected between July 21 and August 30, about 65% of the values are above the minimum CCME Guideline for the Protection of Aquatic Life (>6.5 pH units). The lower 35% of the values remain just below the suggested guideline between 6.31 and 6.49 pH units.

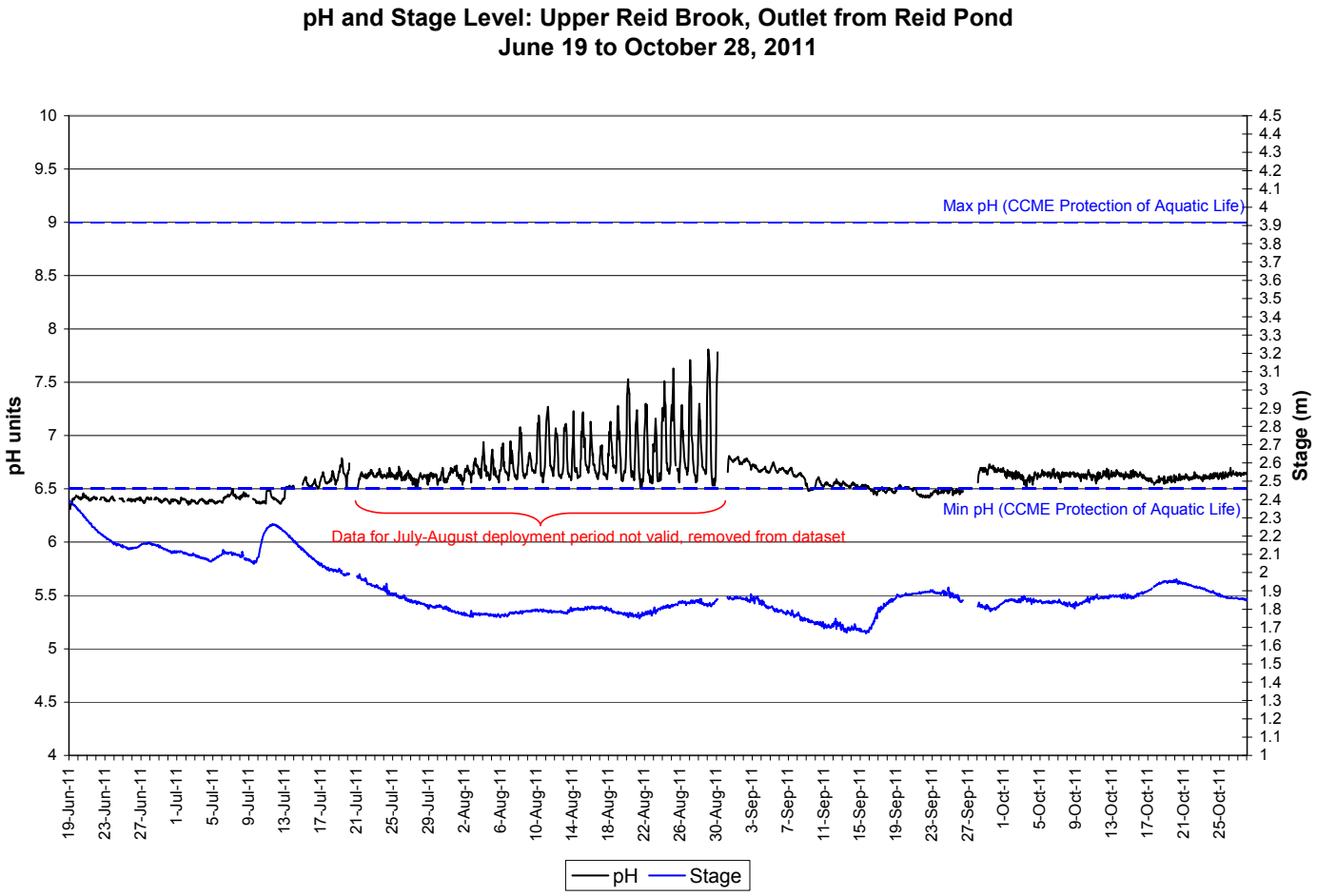


Figure 3: pH and stage level at Upper Reid Brook

- Specific conductivity ranged from 7.8µS/cm to 11.0µS/cm during the deployment season, averaging 9.4µS/cm (Figure 4).
- During the deployment period from July 21 to August 30 and August 31 to September 26, specific conductivity is slightly higher when compared to the first deployment period between June 19 and July 20 and the last deployment period between September 27 and October 28. Although the difference is not much (2-3µS/cm), this difference may be in part due to the solution used during instrument calibration. If the solution was contaminated, this may have resulted in higher than or lower than normal values. The specific conductivity values analyzed from the grab samples range between 13-18µS/cm indicating that the conductivity was probably correct from July 21 to September 27.
- Specific conductivity is generally very low and extremely stable throughout the deployment season with minimal fluctuation regardless of the changing water level. This trend is expected as the flow from this station is directly from a stable lake environment.

Specific Conductivity and Stage Level: Upper Reid Brook, Outlet from Reid Pond
June 19 to October 28, 2011

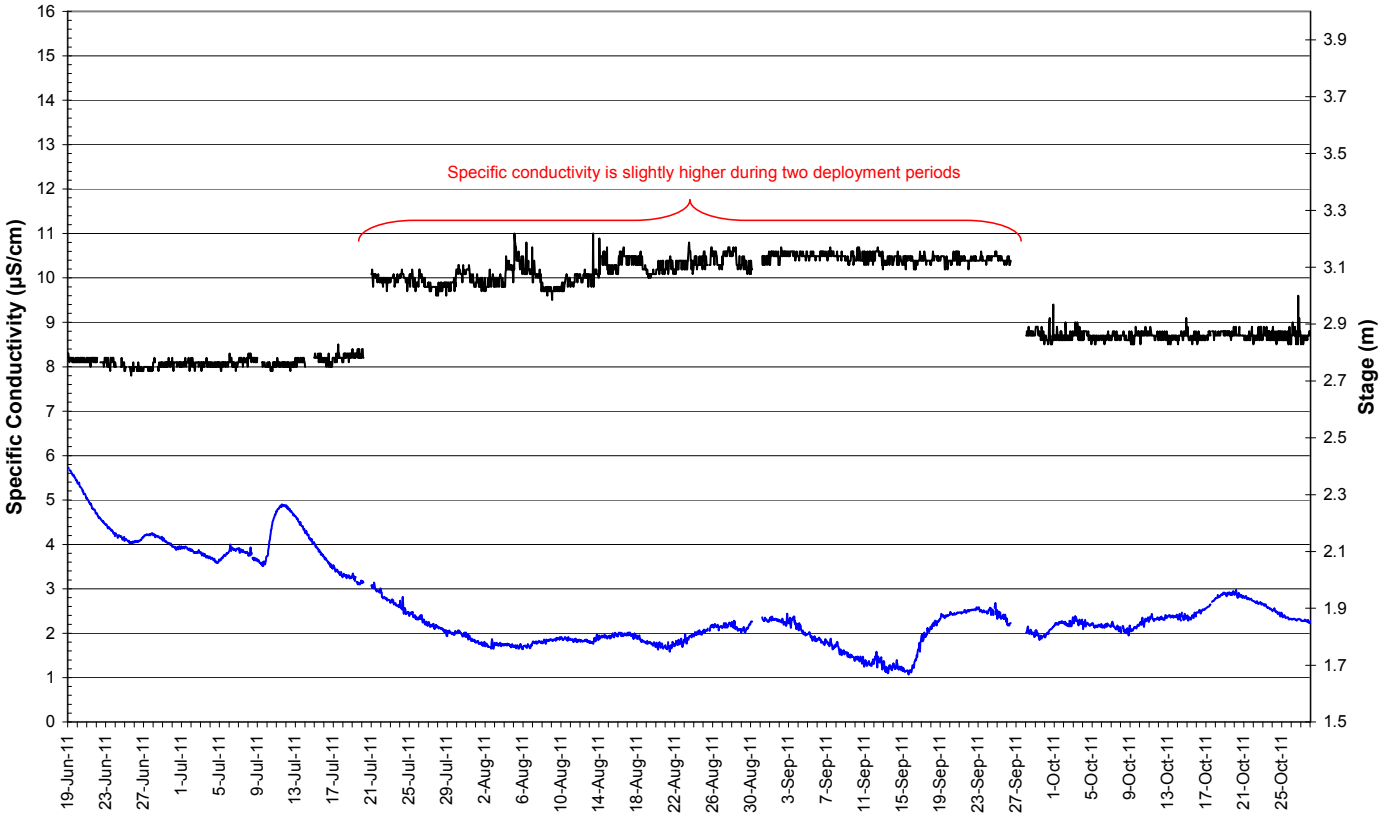


Figure 4: Specific conductivity and stage level at Upper Reid Brook

- Dissolved oxygen content ranged between 7.40mg/L and 12.92mg/L throughout the 2011 deployment season. The saturation of dissolved oxygen ranged from 74.3% to 112.6% (Figure 5).
- There is no dissolved oxygen data for the first part of the deployment period in June due to a programming error experienced at the station. This problem was rectified by Environment Canada Staff on July 16.
- The dissolved oxygen data varies significantly when compared by deployment periods. From July 21 to August 30, the dissolved oxygen is decreasing and fluctuating significantly. The decreasing trend is expected due to the warming water temperatures however the values are generally low and it would be expected that the dissolved oxygen levels would not vary so much throughout the day. This data has been removed from the data set for future use due to its unreliability.
- Data collected between August 31 and September 27 looks good. Values are generally increasing which is expected with the cooling water temperatures. Values do not appear to change significantly on a daily basis.
- The values recorded from September 27 to October 28 also vary significantly on a day to day basis and are generally lower than expected. This data has also been removed from the data set.
- All values were above the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5mg/l). Most values (65%) were above the minimum guideline for Early Life Stages (9.5mg/l) during the deployment season. The guidelines are indicated in blue on Figure 5. The average dissolved oxygen value was 10.11mg/l.

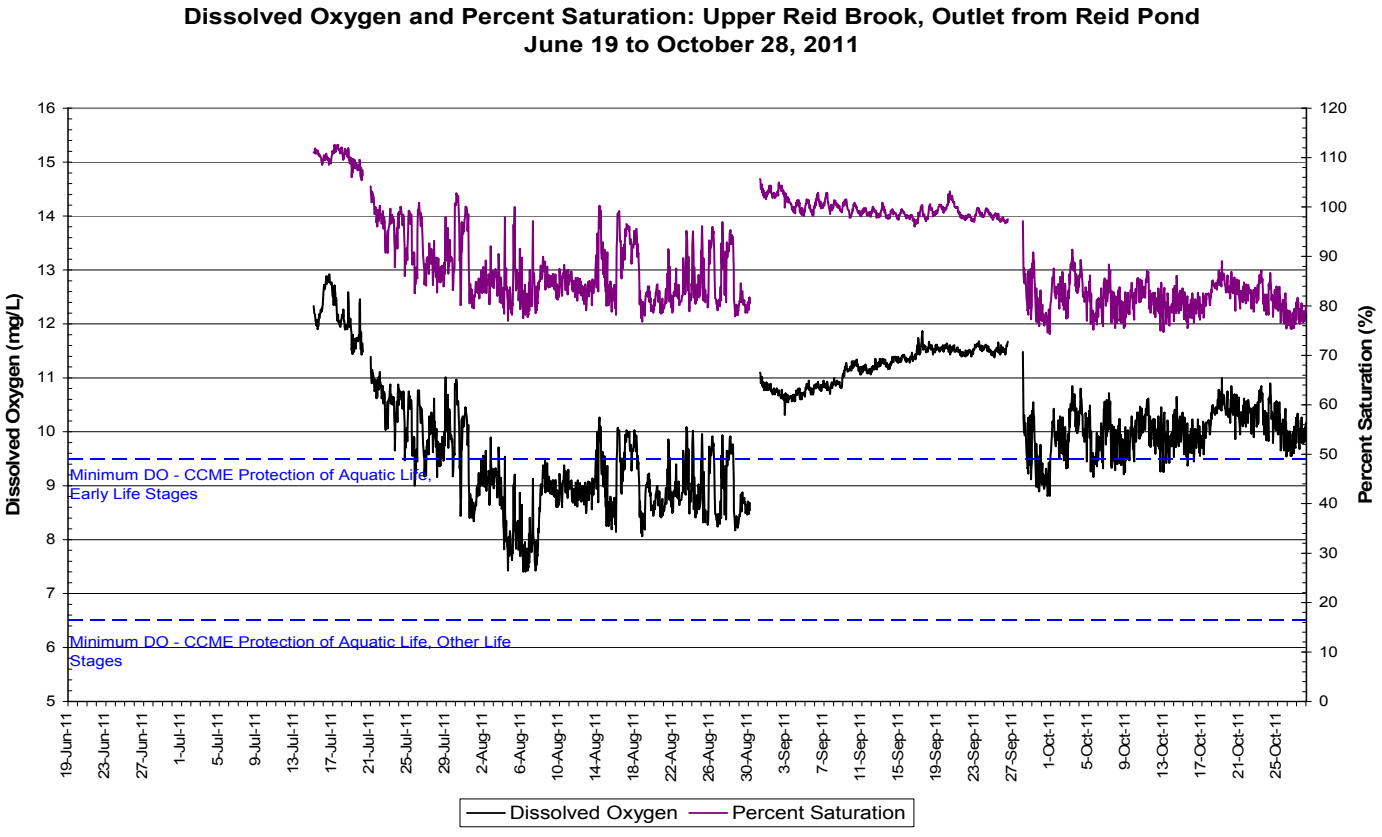


Figure 5: Dissolved oxygen and percent saturation at Upper Reid Brook

- The instrument deployed at Upper Reid Brook during the 2011 deployment season was a replacement instrument provided by the Department of Environment and Conservation. The Minisonde 4a, Special Edition, features a temperature, specific conductivity, Clark cell dissolved oxygen and pH sensors. This instrument is not equipped with a turbidity sensor therefore no turbidity data is available for discussion at this station.

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 6). Stage is generally decreasing for the six weeks of the deployment season. Stage level remains low for the majority of the summer season before beginning to increase in the month of September. Precipitation events are frequent and moderate in magnitude.

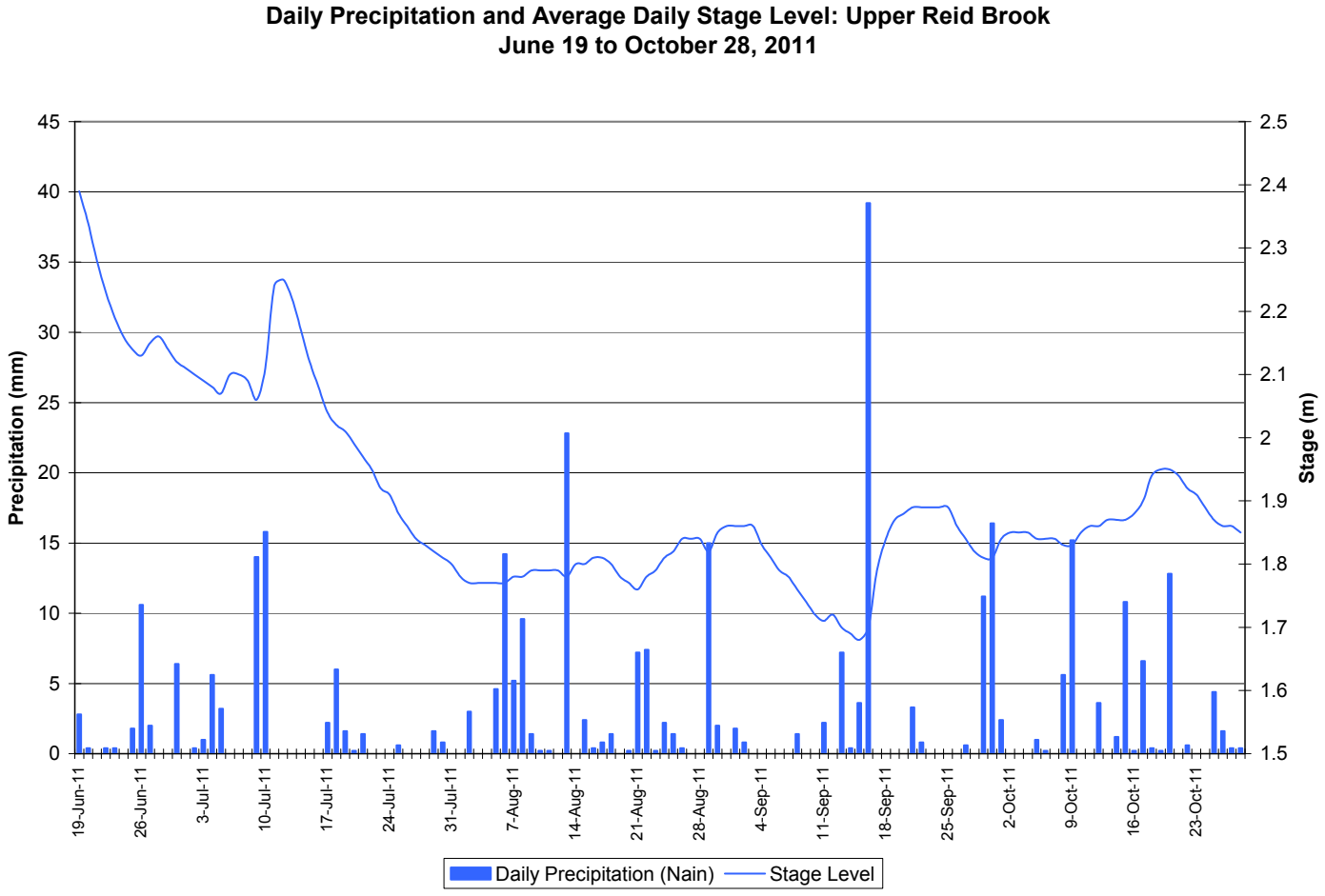


Figure 6: Daily precipitation and average daily stage level at Upper Reid Brook

(weather data recorded at Nain)

Tributary to Lower Reid Brook

- Water temperature ranged from 1.50 °C to 11.8°C during the deployment season, averaging 8.4°C. (Figure 7).

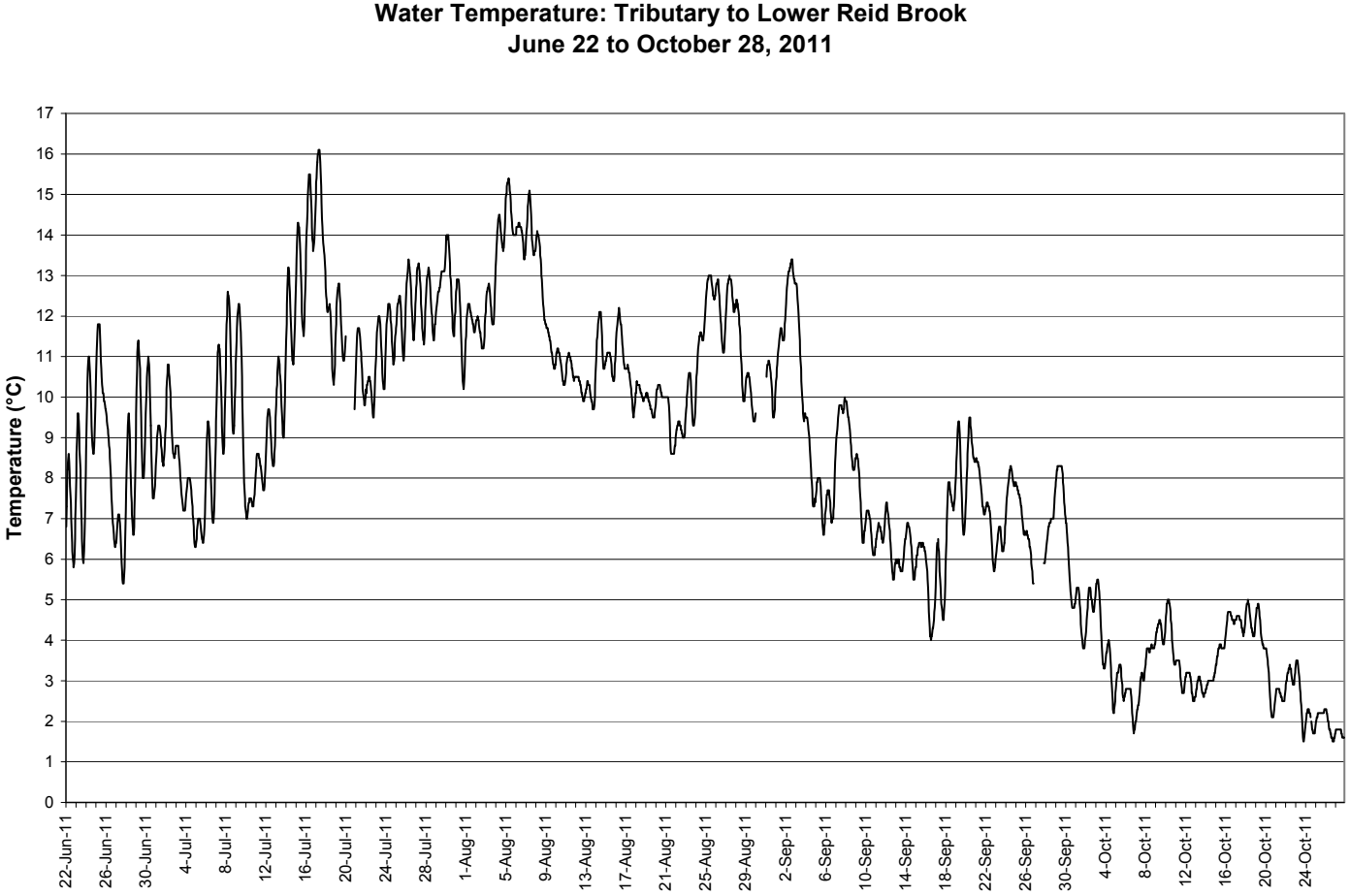


Figure 7: Water temperature at Tributary to Lower Reid Brook

- Water temperature values show a typical seasonal trend (Figure 8). Water temperature is increasing for the first part of the deployment season throughout June and July. Water temperature peaks in mid July at 16.1°C. Water temperature begins to decrease in the latter half of August and into the fall season as air temperatures cool.

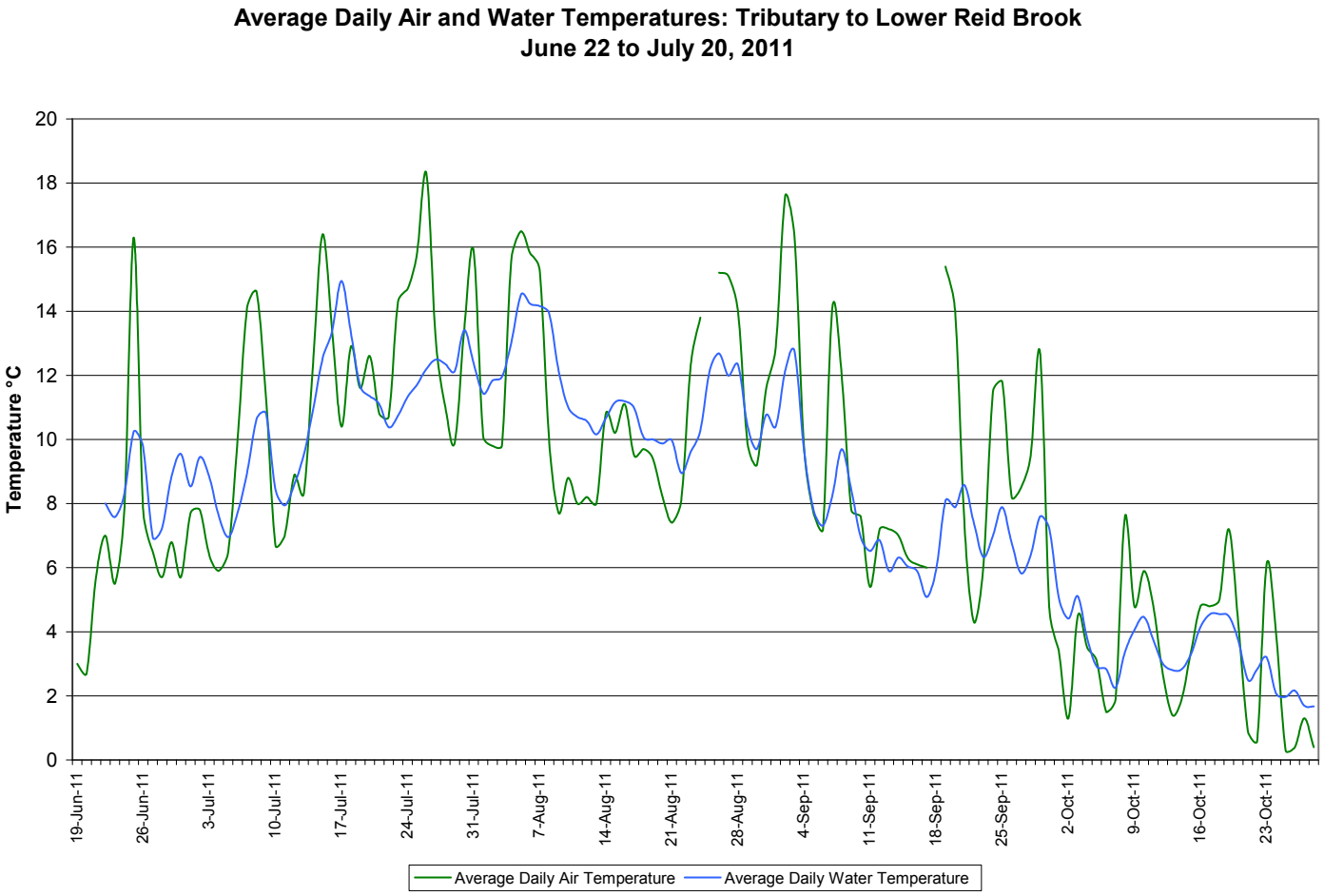


Figure 8: Average daily air and water temperatures at Tributary to Lower Reid Brook

(weather data recorded at Nain)

- pH ranged between 6.24 and 7.13 pH units throughout the deployment season, averaging 6.80 pH units. (Figure 9).
- Stage is included on Figure 9 to show the relationship between water level and pH. Raw uncorrected stage data for this deployment period is depicted below. There is a jump in stage level from 0.402m to 0.234m on August 6. Corrected hydrometric data is available upon request from Environment Canada. pH values fluctuate throughout the deployment period with changing water levels. On a number of occasions, pH decreases as stage increases (indicated by red arrows on Figure 9).
- Most values are within the recommended range for pH as suggested by the CCME Guidelines for the Protection of Aquatic Life (indicated in blue on Figure 9). On some occasions, pH values drop to just below suggested guideline values most often during period of peak flow.

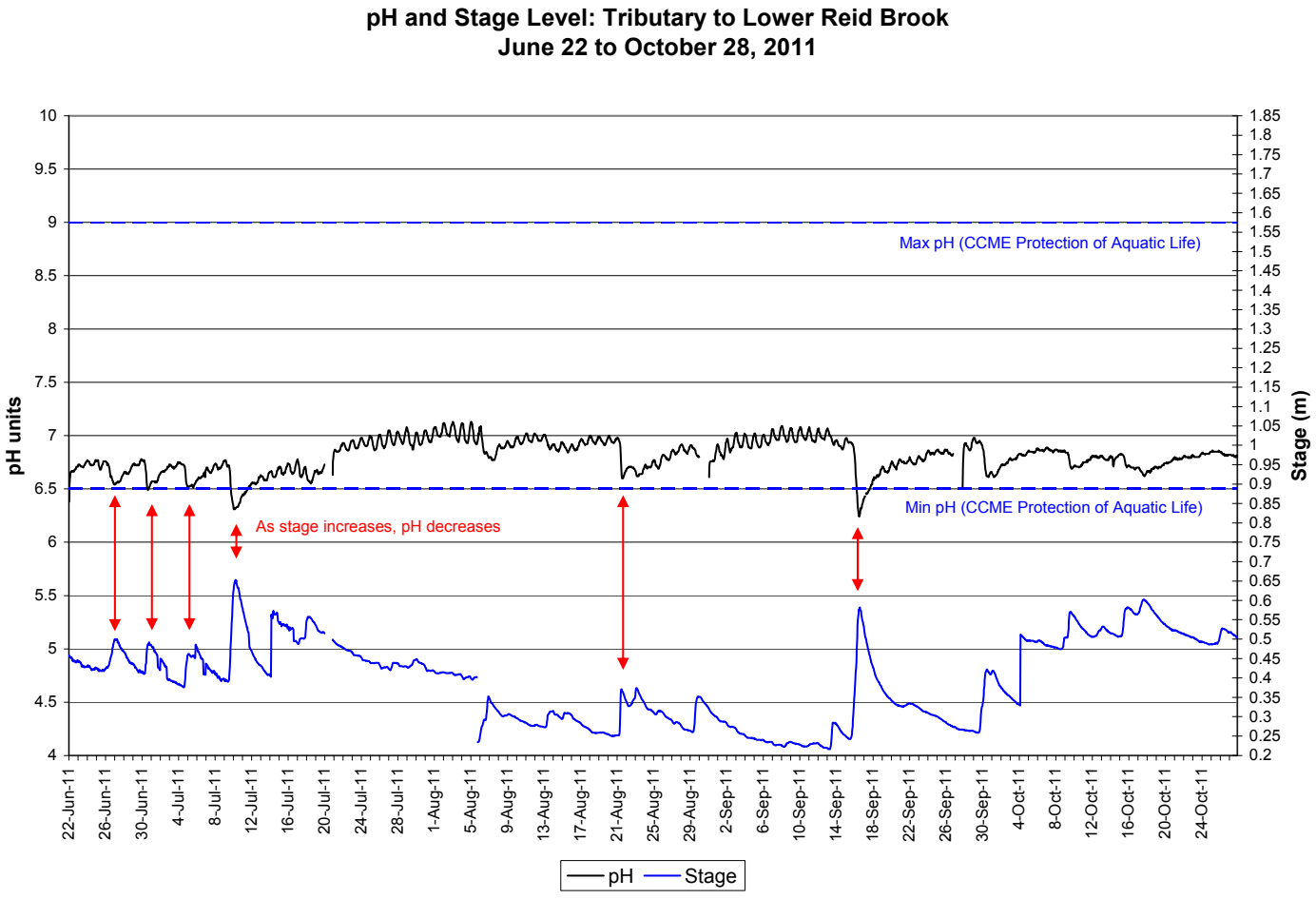


Figure 9: pH and stage level at Tributary to Lower Reid Brook

- Specific conductivity ranged between 12.0µS/cm and 36.8µS/cm throughout the deployment season, generally averaged around 31.8µS/cm (Figure 10).
- Specific conductivity values recorded from June 22 to July 20 are unusually low and are likely incorrect due to an error during calibration (similar to Upper Reid Brook for specific conductivity values during the same time period). The grab sample taken on June 22 reports a value of 38µS/cm for specific conductivity. Similarly, on July 21 when the cleaned and calibrated instrument was replaced at the station, the specific conductivity value from the grab sample analysis was 30us/cm. Both of these values are higher than the average value reported by the instrument between June 22 and July 20. The average specific conductivity calculated for the season does not include the values recorded during this deployment period.
- Stage is included in Figure 10 to illustrate the inverse relationship between conductivity and water level. Generally, stage fluctuates throughout the deployment season. Specific conductivity changes with the varying water level (indicated by red arrows in Figure 10). As stage increases, specific conductivity generally decreases due to the dilution of dissolved solids in the water column. Inversely, as stage decreases, specific conductivity increases as the concentration of dissolved solids increases.

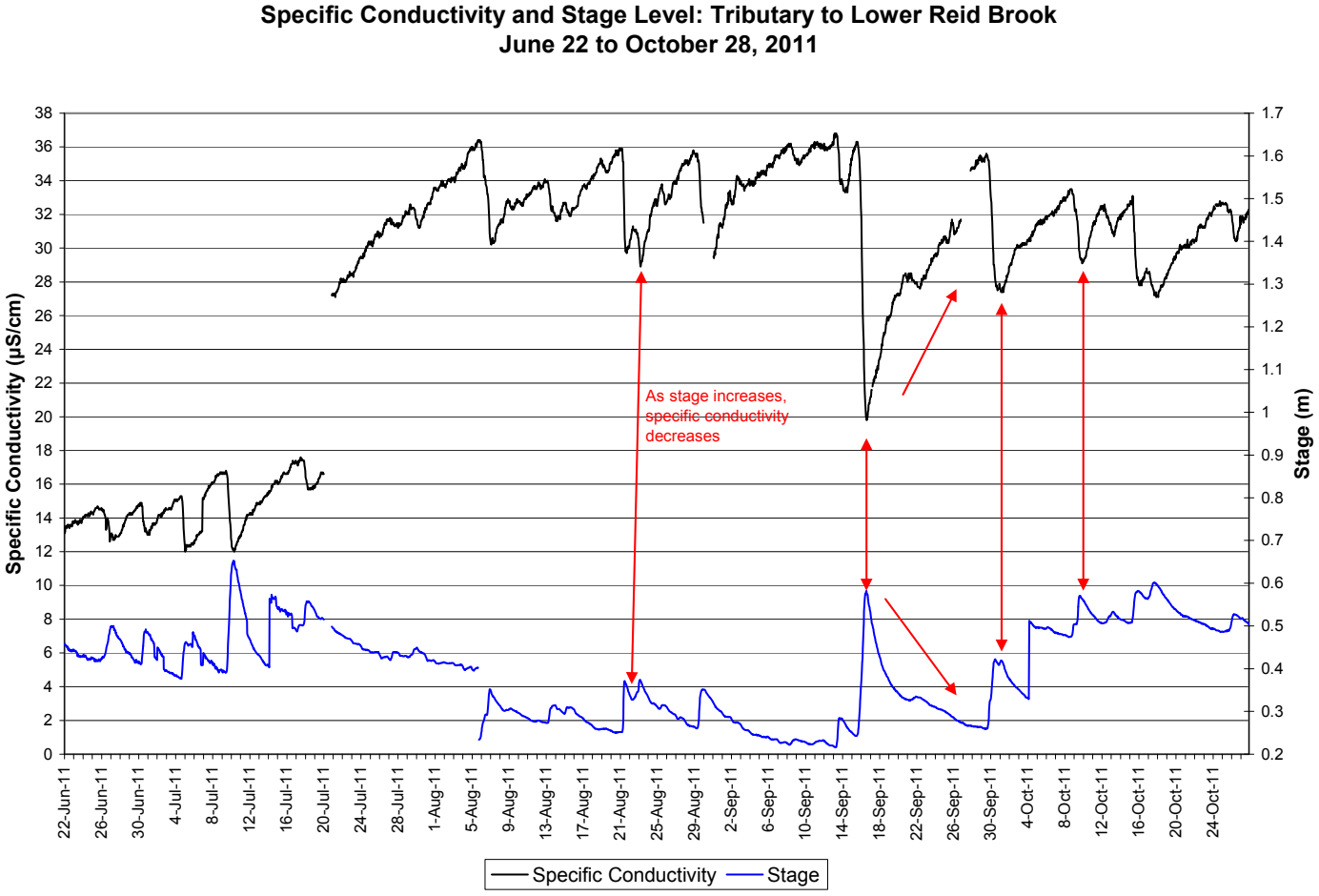


Figure 10: Specific conductivity and stage level at Tributary to Lower Reid Brook

- Dissolved oxygen content ranged between 9.04g/L and 13.58mg/L, averaging 11.14mg/L. The saturation of dissolved oxygen ranged from 90.5% to 101.5%, averaging 94.5% (Figure 11).
- All values were above the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5mg/l). Most values were above the CCME Guideline for the Protection of Aquatic Life at Early Life Stages (9.5mg/l). On a few occasions, during periods of warm air and water conditions, dissolved oxygen contents dropped to just below the suggested guideline. The guidelines are indicated in blue on Figure 11.
- Dissolved oxygen content shows a typical seasonal trend, inverse to water temperature. Values are decreasing throughout the early summer as water temperatures increase. As water temperatures decrease in the late summer and early fall, dissolved oxygen content begins to increase.

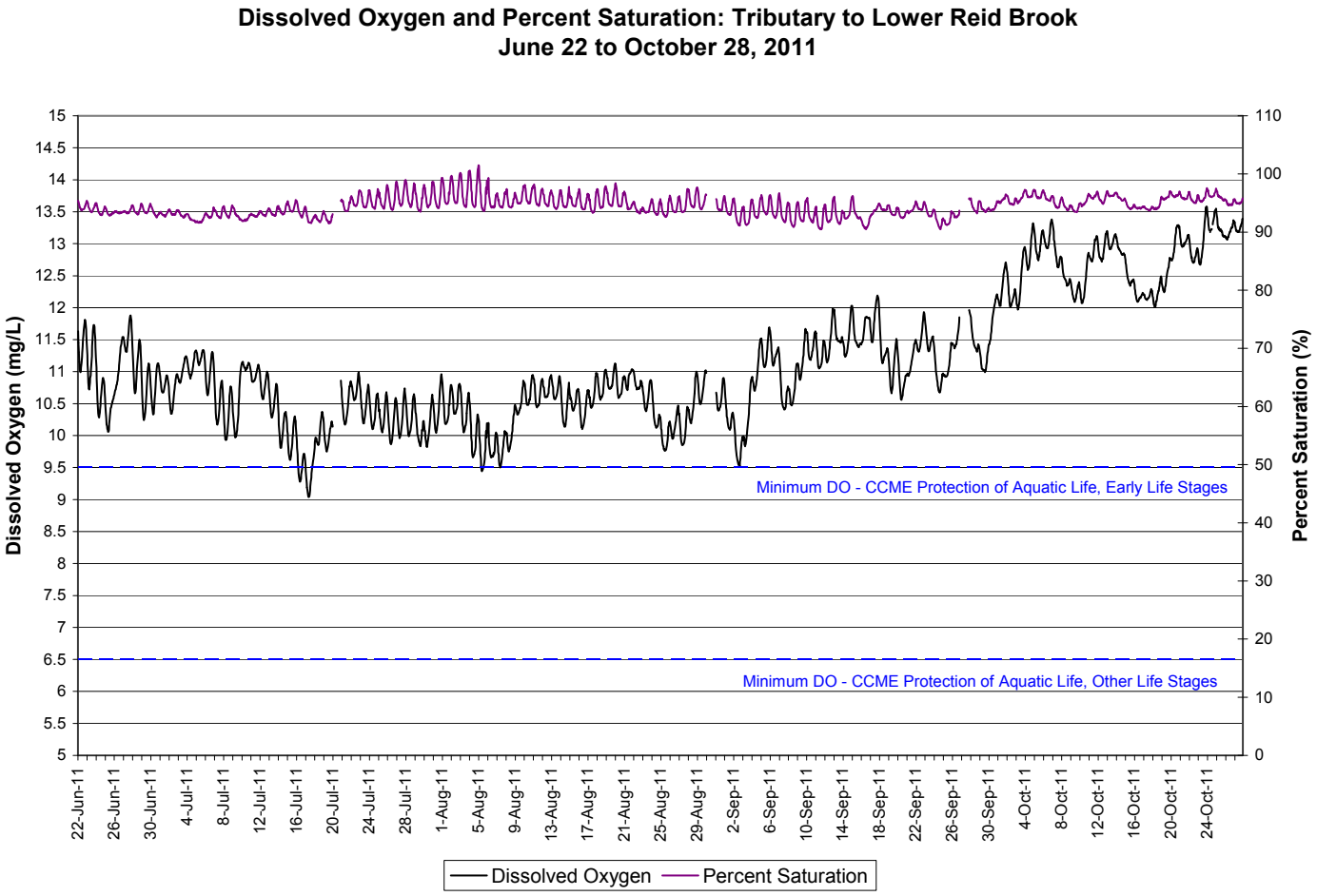


Figure 11: Dissolved oxygen and percent saturation at Tributary to Lower Reid Brook

- The turbidity sensor on the Tributary to Lower Reid Brook instrument (s/n 44175) did not function at full capacity during the 2011 deployment season. The wiper on the instrument no longer completes the revolutions prior to taking the reading. The instrument was deployed at the station regardless and a note was placed on the online graph indicating the turbidity sensor was not functional. Any data values collected during this time will be removed from the data set for future use. The sensor will be replaced prior to the 2012 monitoring season.

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 12). Stage is generally decreasing for the six weeks of the deployment season. Stage level remains low for the majority of the summer season before beginning to increase in the month of September. Precipitation events are frequent and moderate in magnitude.

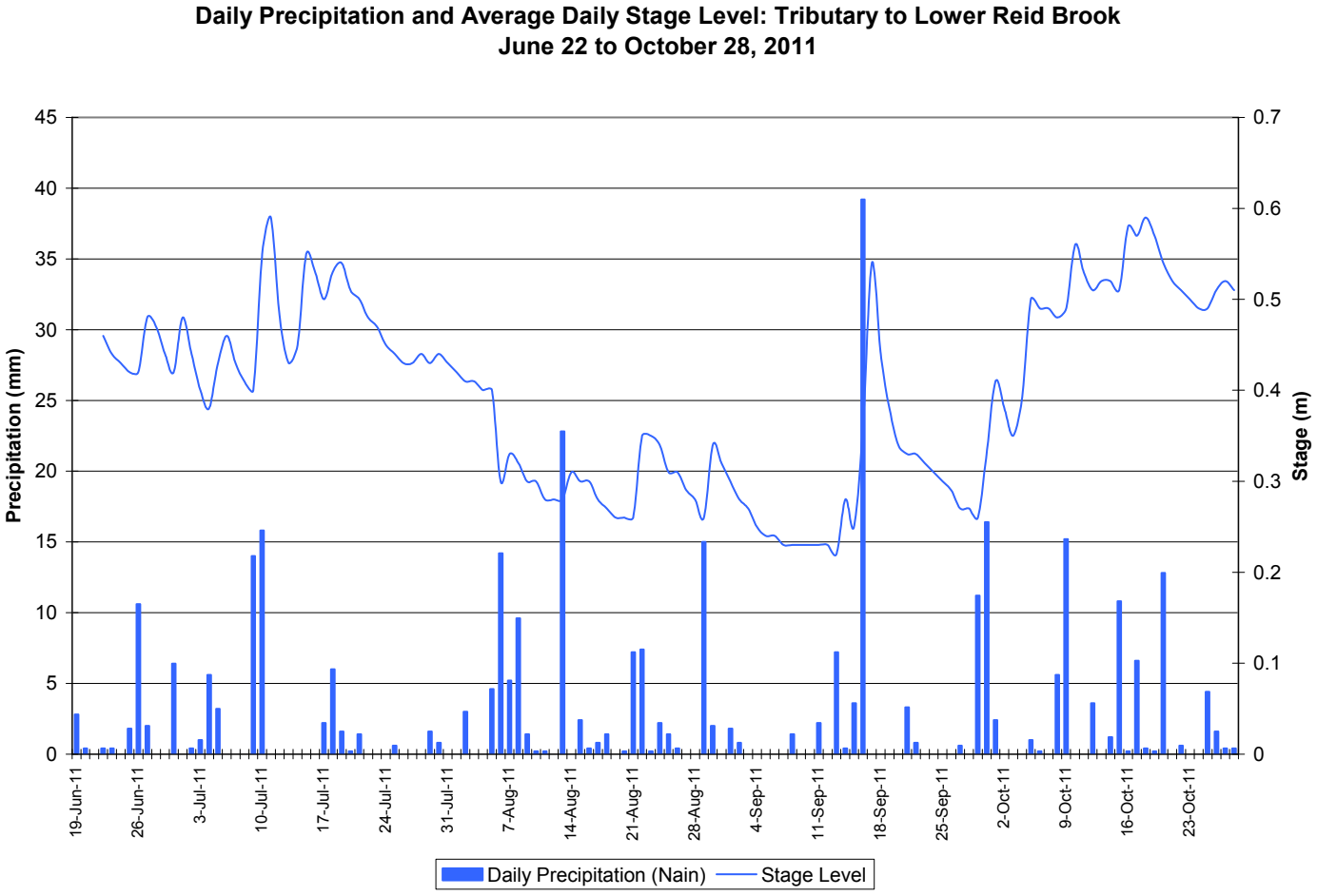


Figure 12: Average Daily Stage and Daily Precipitation at Tributary to Lower Reid Brook

Lower Reid Brook

- Water temperature ranged from 1.30 °C to 19.59°C during the deployment season, averaging 8.60°C (Figure 13).

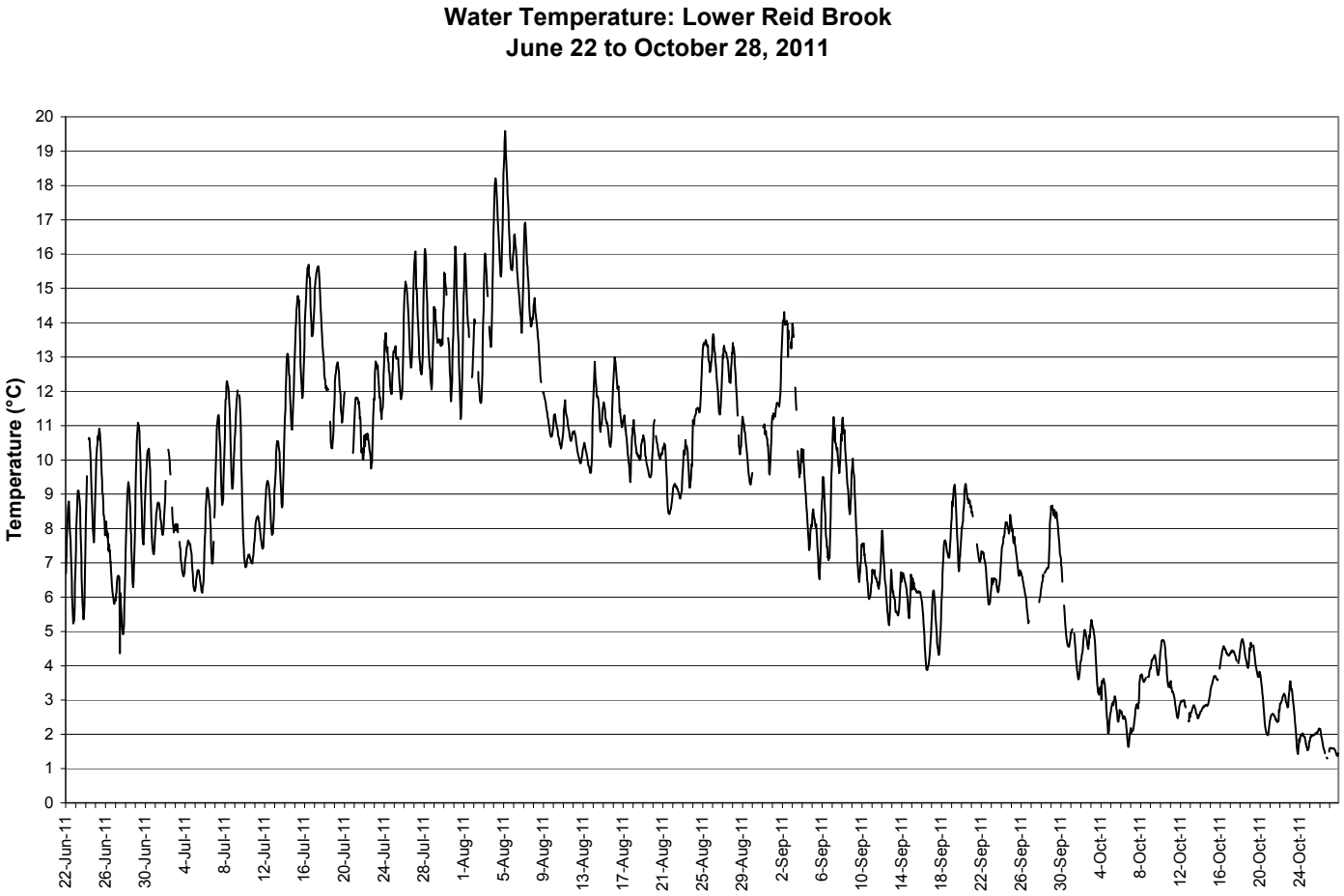


Figure 13: Water temperature at Lower Reid Brook

- Water temperature values show a typical seasonal trend (Figure 14). Water temperature is increasing for the first part of the deployment season throughout June and July. Water temperature peaks in early August at 19.59°C. Water temperature begins to decrease in the latter half of August and into the fall season as air temperatures cool.

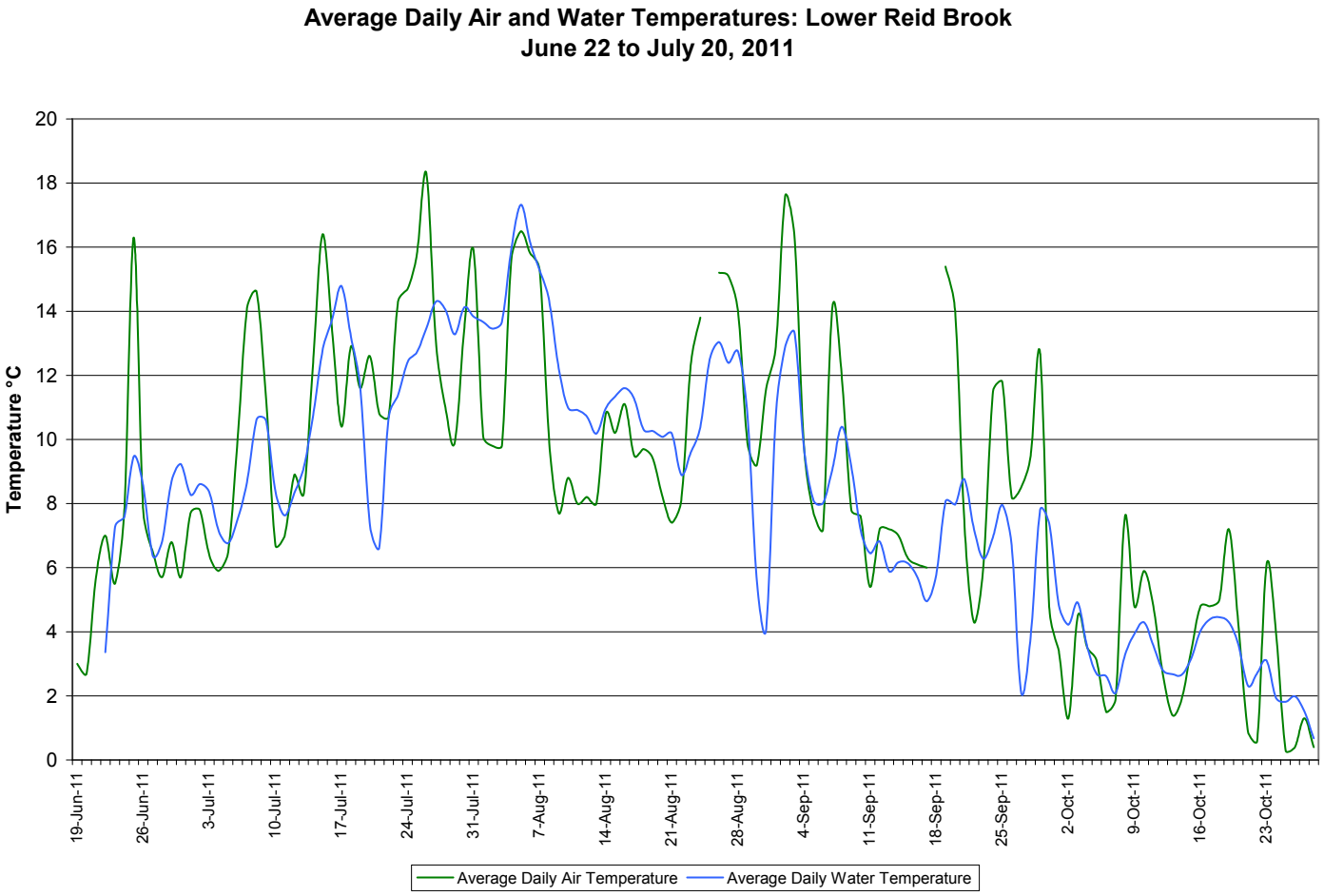


Figure 14: Average daily air and water temperatures at Lower Reid Brook

(weather data recorded at Nain)

- pH ranged between 6.55 and 7.37 pH units during the deployment season, averaging 6.92 pH units (Figure 15).
- Stage is included on Figure 15 to show the relationship between water level and pH. pH values fluctuate throughout the deployment season with changing water levels. On a number of occasions, pH decreases as stage increases (indicated by red arrows on Figure 15).
- All values are within the recommended range for pH as suggested by the CCME Guidelines for the Protection of Aquatic Life (indicated in blue on Figure 15).

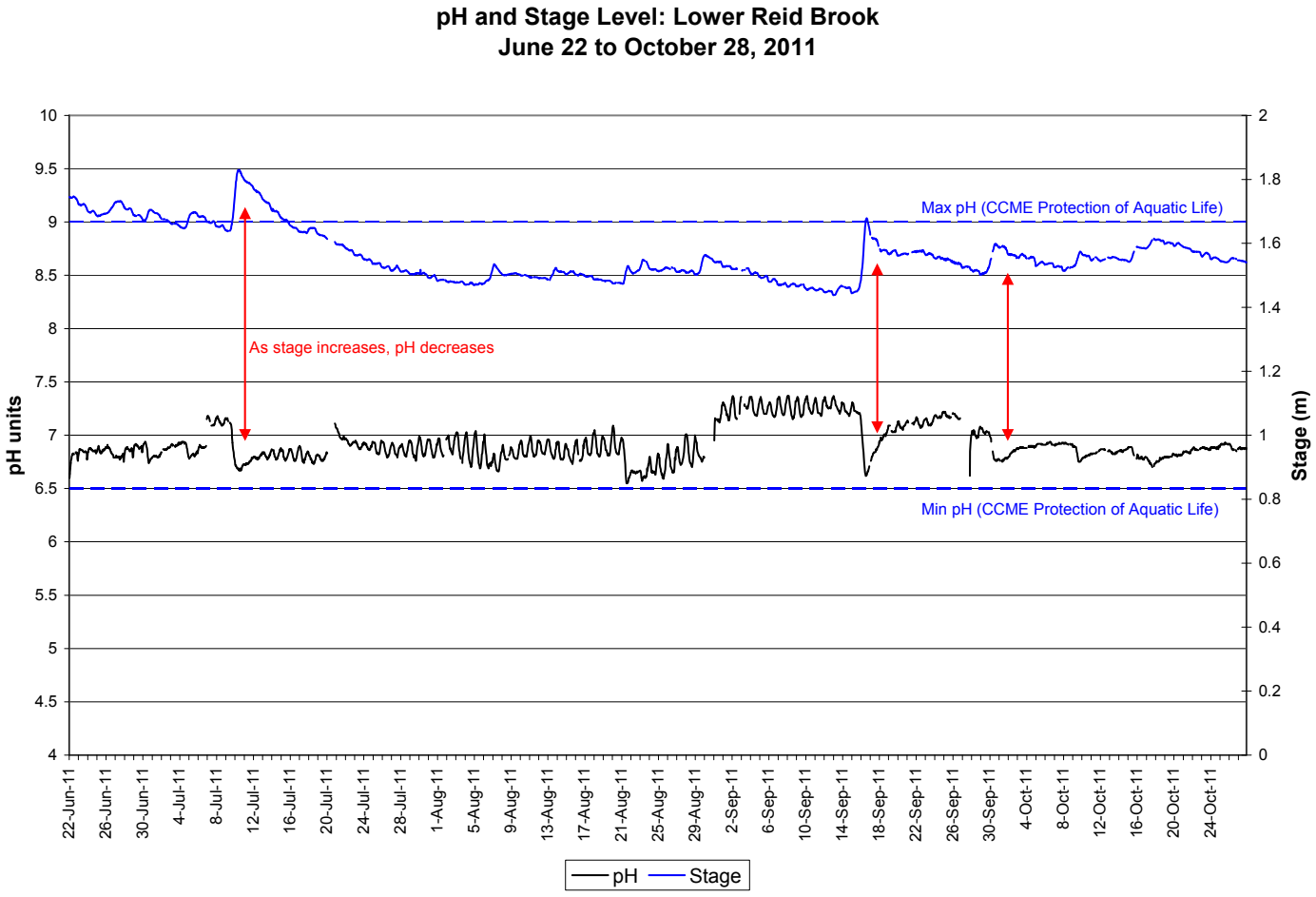


Figure 15: pH and stage level at Lower Reid Brook

- Specific conductivity ranged between 17.0µS/cm and 39.0µS/cm during the deployment season, averaging 29µS/cm (Figure 16). Due to a programming error at this station, specific conductivity is only recorded to zero decimal places.
- Stage is included in Figure 16 to illustrate the inverse relationship between conductivity and water level. Stage fluctuates slightly throughout the deployment period but is mainly decreasing through the month of July. Specific conductivity is increasing during this time and fluctuates significantly day to day. In some instances, when stage increases sharply, a corresponding decrease in specific conductivity is noticeable (indicated by red arrows in Figure 16). As stage increases, specific conductivity generally decreases due to the dilution of dissolved solids in the water column. Inversely, as stage decreases, specific conductivity increases as the concentration of dissolved solids increases.

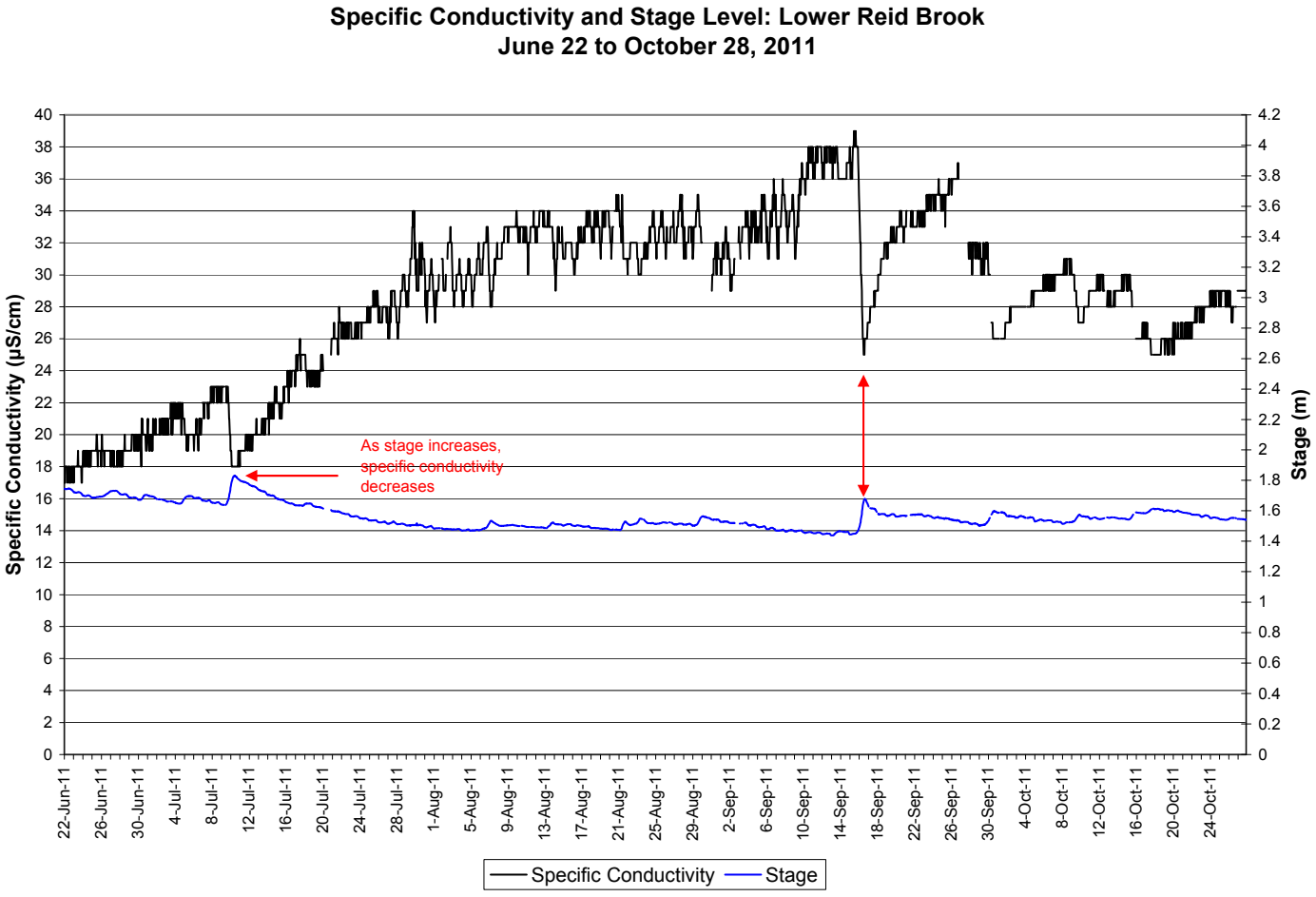


Figure 16: Specific conductivity and stage level at Lower Reid Brook

- The dissolved oxygen sensor on the instrument deployed at Lower Reid Brook (s/n 40643) did not function at full capacity during the 2011 deployment season. Data values collected during 2011 are for the most part invalid and questionable.
- During the deployment period between June 22 and July 20, dissolved oxygen and percent saturation values begin at reasonable values (10 to 12mg/L) but quickly drop off to lower than expected values during the month of July (<9.5mg/L) (Figure 17).
- From July 21 to August 30, dissolved oxygen and percent saturation values are indisputably invalid (6.5 to 7.5mg/L).
- For the remainder of the deployment season for two deployment periods from August 31 to September 27 and September 28 to October 28, values collected are within a reasonable range (9.5 to 12mg/L) but fluctuate considerably day to day.
- Due to the inconsistencies with the sensor throughout the entire season, all values have been removed from the data set for future use.

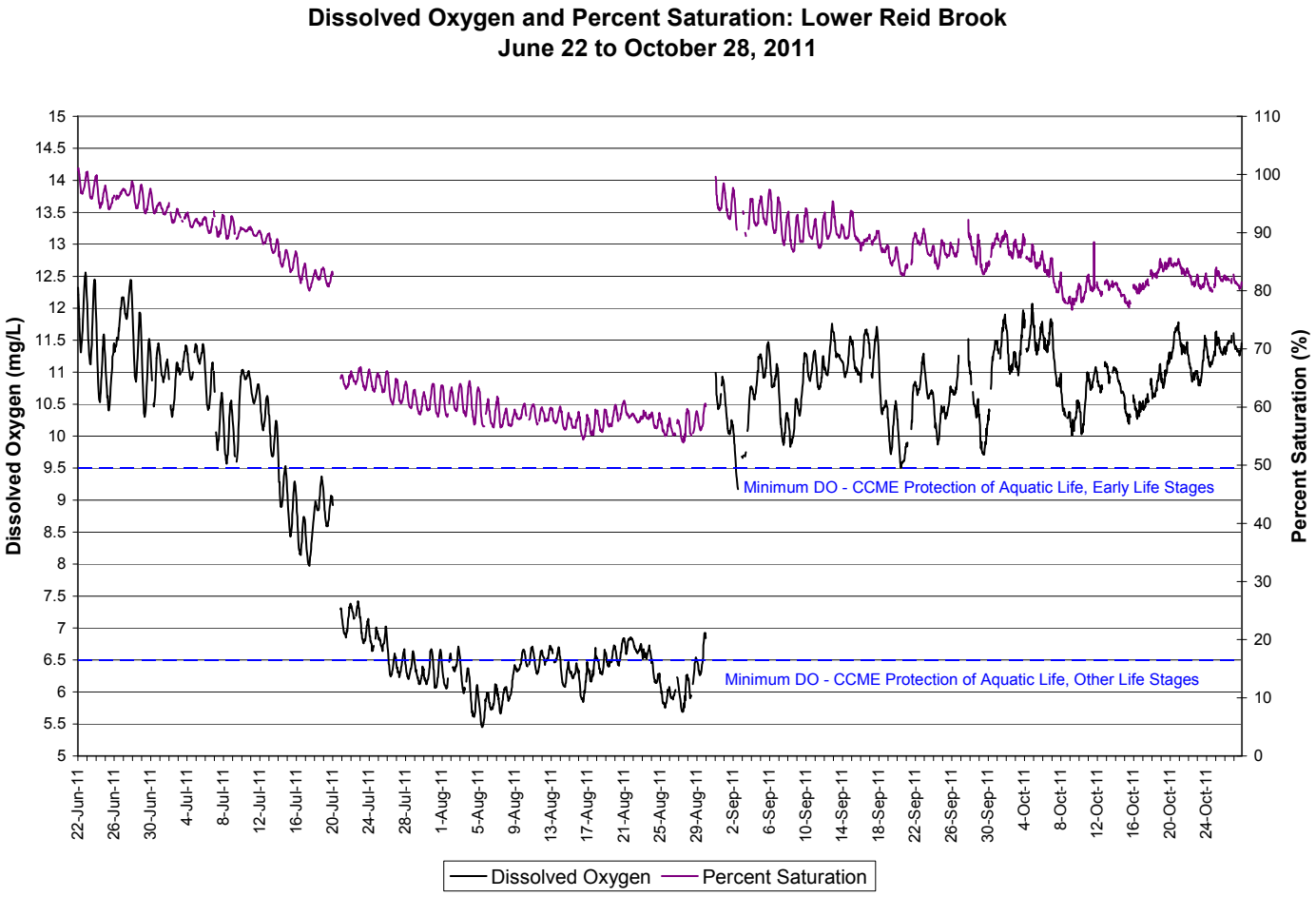


Figure 17: Dissolved oxygen and percent saturation at Lower Reid Brook

- The turbidity sensor on the instrument deployed at Lower Reid Brook (s/n 40643) did not function at full capacity during the 2011 deployment season. Data values collected during 2011 are for the most part invalid and questionable (Figure 18).
- The turbidity sensor on the Lower Reid Brook instrument (s/n 40643) has not functioned at full capacity since the August 2011. In August 2011, the wiper on the instrument no longer cleans the window on the turbidity sensor prior to taking the reading. The instrument was deployed at the station regardless and a note was placed on the online graph indicating the turbidity sensor was not functional.
- The turbidity electronics are closely related to the dissolved oxygen sensor electronics which helps to explain why both sensors were not working properly. Sand is also a major issue at this station. In July 2011, Vale Environment staff engineered and deployed a stand for the instrument to keep the sensors off of the bottom of the river bed. The stand appears to work well and no sand was found in the sensor guard when the instrument was removed for monthly cleaning and calibration. However, damage to the instrument from sand accumulation in previous deployment seasons scratched the surface of the turbidity sensor and readings thereafter were compromised. The instrument has been retired and will not be deployed again to measure turbidity. All values collected for turbidity during this time will be removed from the data set.

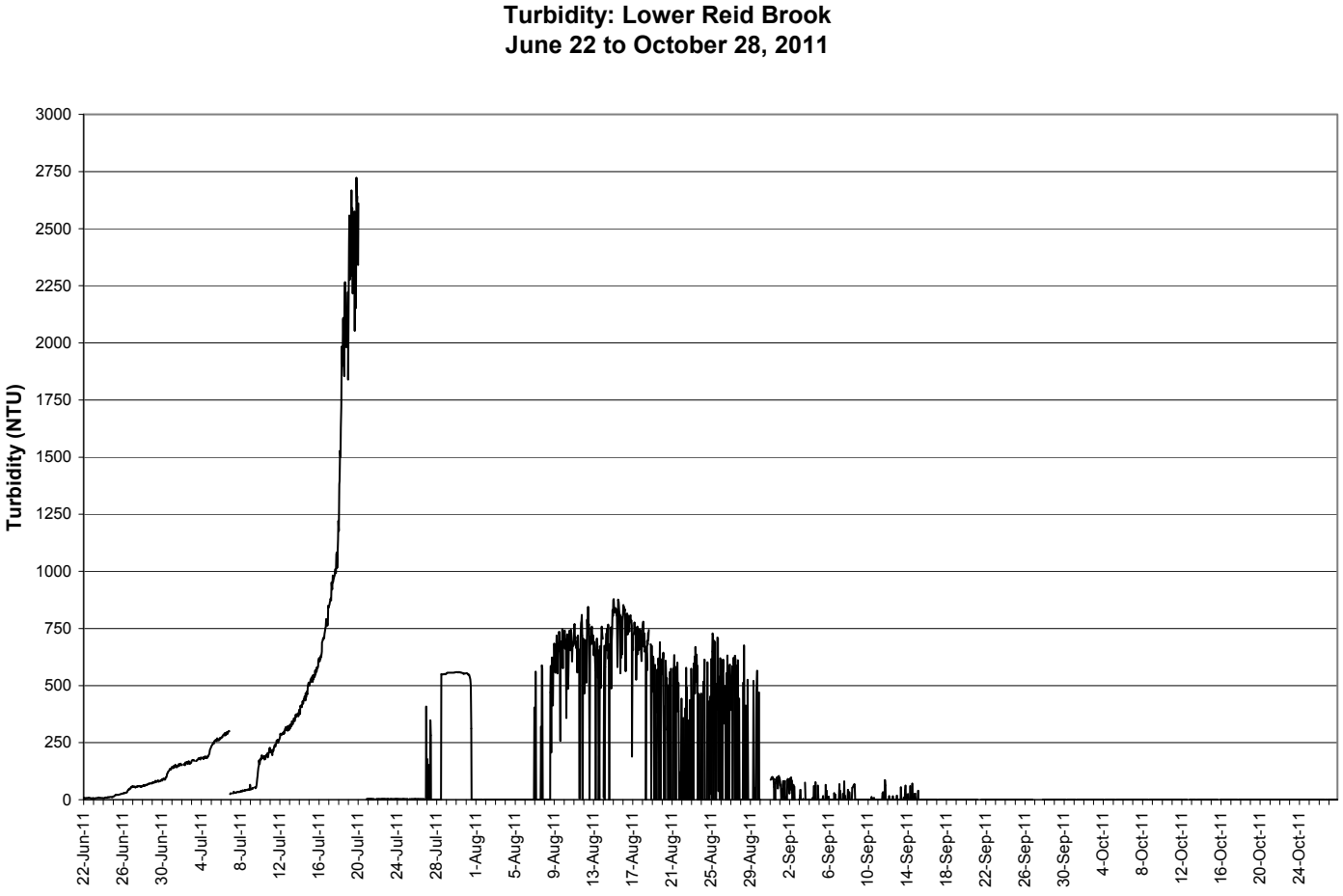


Figure 18: Turbidity at Lower Reid Brook

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 19). Stage is generally decreasing for the first six weeks of the deployment season. Stage level remains low for the majority of the summer season before beginning to increase in the month of September. Precipitation events are frequent and moderate in magnitude.

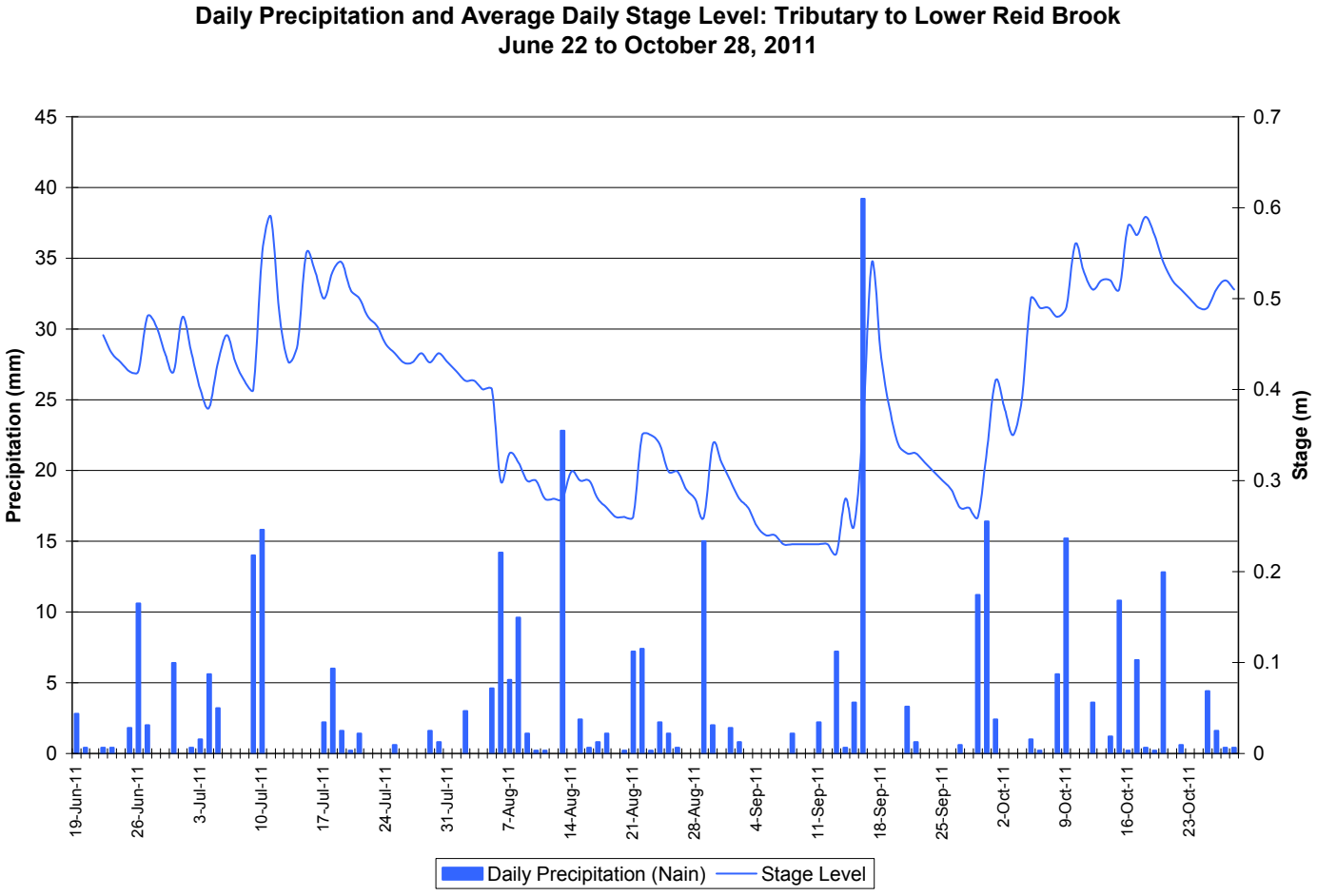


Figure 19: Daily precipitation and average daily stage level at Lower Reid Brook

(weather data recorded at Nain)

Camp Pond Brook

- Water temperature ranged from 0.90 °C to 22.6°C during the deployment season, averaging 11.00°C (Figure 20).

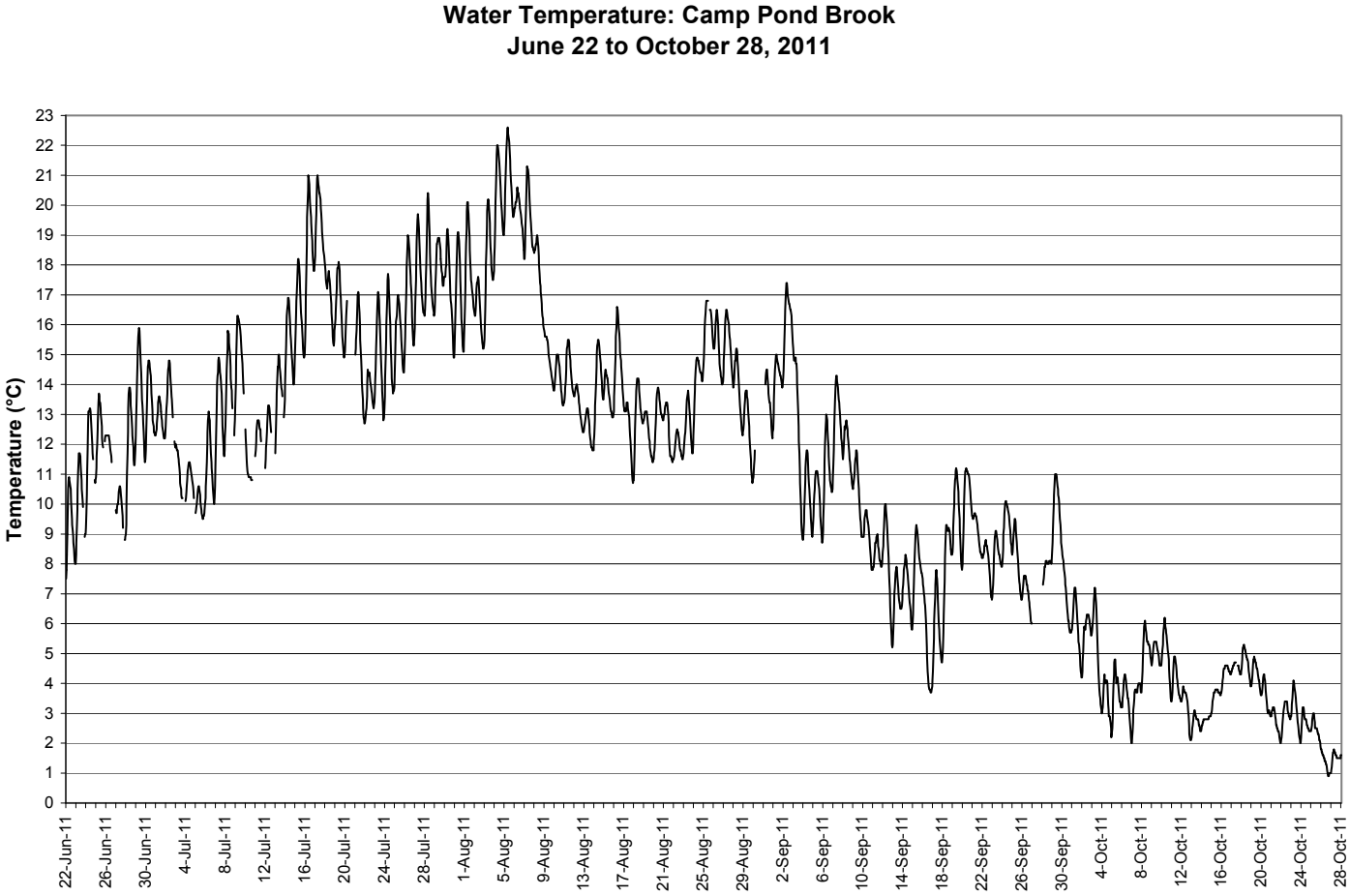


Figure 20: Water temperature at Camp Pond Brook

- Water temperature values show a typical seasonal trend (Figure 21). Water temperature is increasing for the first part of the deployment season throughout June and July. Water temperature peaks in early August at 22.60°C. Water temperature begins to decrease in the latter half of August and into the fall season as air temperatures cool.

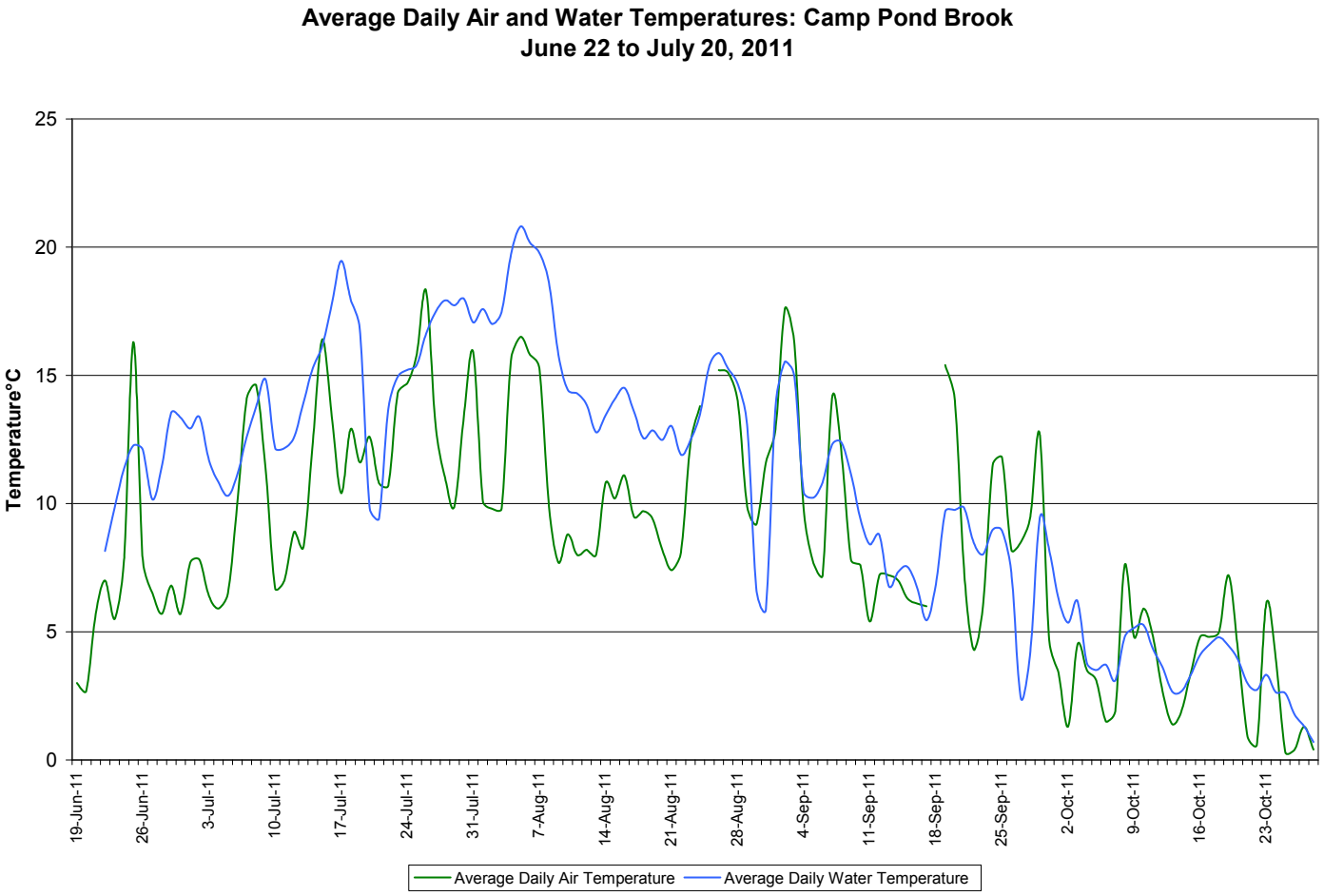


Figure 21: Average daily air and water temperatures at Camp Pond Brook

(weather data recorded at Nain)

- pH ranged between 6.49 and 7.36 pH units during the deployment season, averaging 6.85 pH units (Figure 22).
- Stage is included on Figure 24 to show the relationship between water level and pH. As stage increases there are slight decreases in pH (indicated by red arrows on Figure 22). pH values are generally stable with daily fluctuations throughout the deployment season.
- All values, with the exception of a couple of hours on October 16, are within the recommended range for pH as suggested by the CCME Guidelines for the Protection of Aquatic Life (indicated in blue on Figure 22).

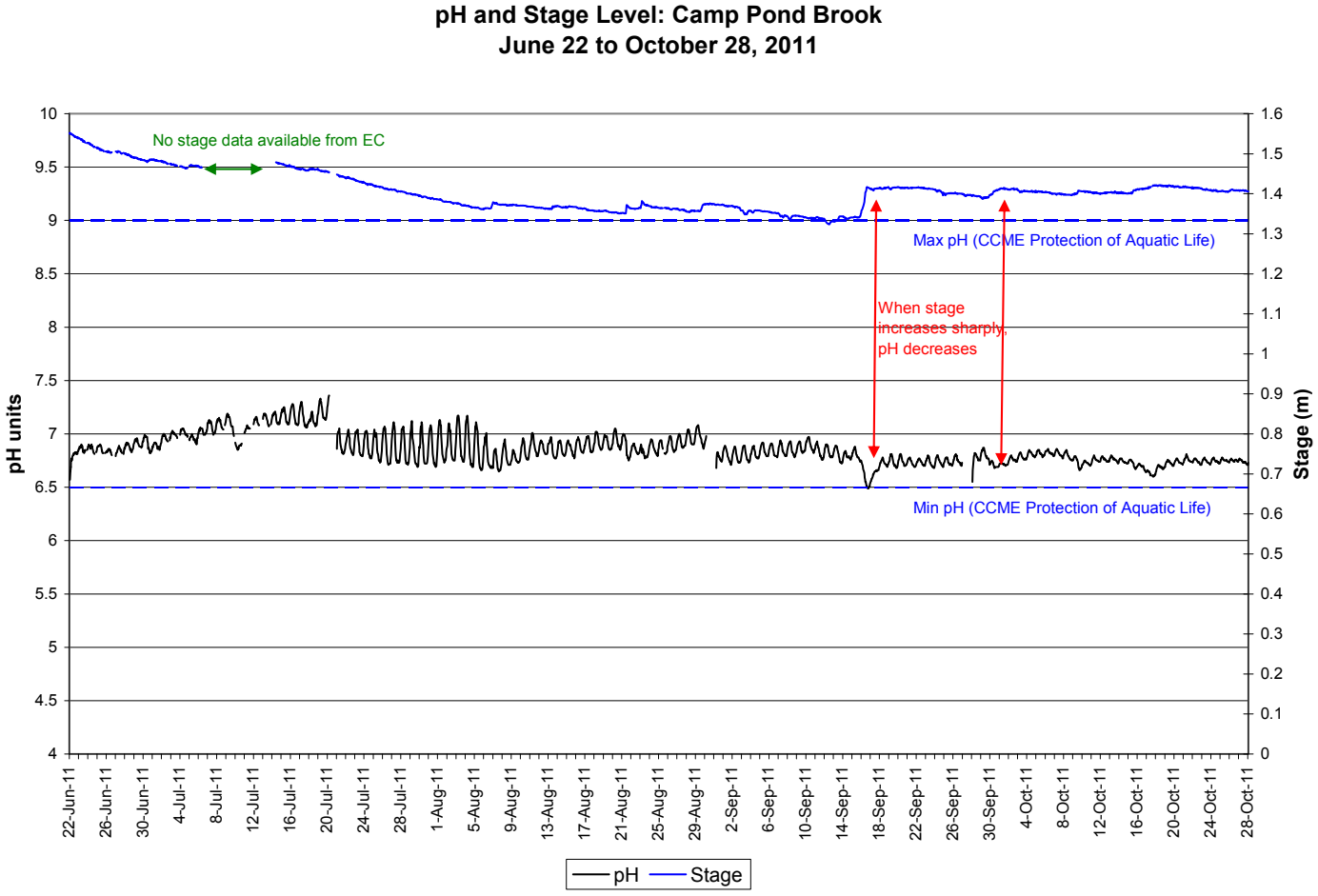


Figure 22: pH and stage level at Camp Pond Brook

- Specific conductivity ranged from 20.5µS/cm to 57.6µS/cm during the deployment season, averaging 33.71µS/cm (Figure 23).
- Stage is included in Figure 23 to illustrate the inverse relationship between conductivity and water level. Stage is generally decreasing throughout the deployment season and specific conductivity is increasing. This shows a typical relationship of water level and specific conductivity whereby decreased flow causes increased concentration of dissolved solids in the water column hence increasing the conductivity (indicated by orange arrows on Figure 23). However, in cases where stage increased sharply during the deployment season, there are often corresponding increases in specific conductivity (indicated with red arrows on Figure 23). This relationship is generally not typical because as precipitation input and stage level increase the conductivity is usually decreased by the dilution of the concentration of dissolved solids present in the water column. However, this pattern has been experienced at this station in the past.

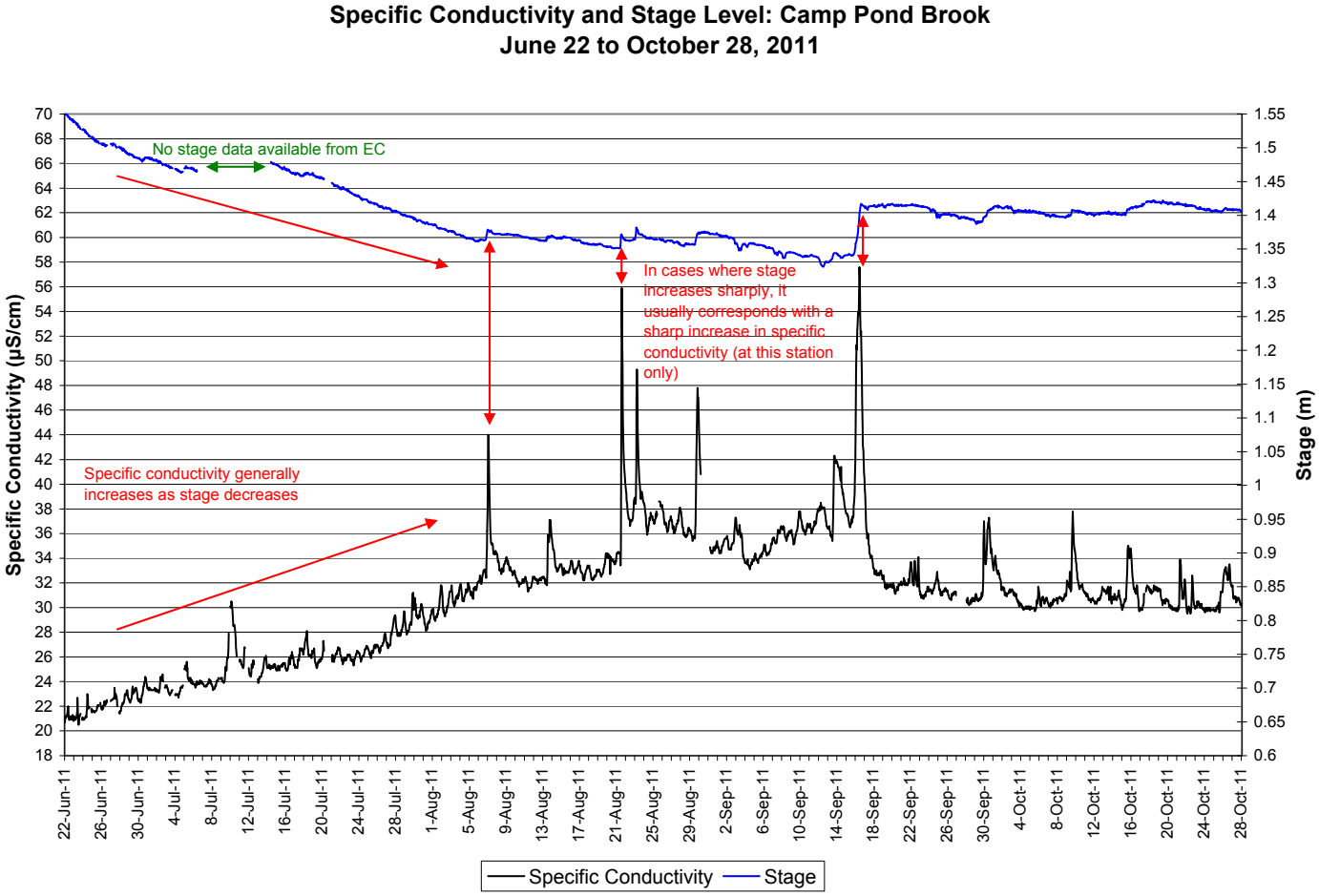


Figure 23: Specific conductivity and stage level at Camp Pond Brook

- Dissolved oxygen and percent saturation values collected during the deployment season vary significantly and fluctuate between 2 to 25 mg/L and 4.6 to 188%. The average dissolved oxygen content is 10.67mg/L. The average percent saturation is 89.17% (Figure 24).
- Average values at this station appear to be acceptable however, the range in which the values fluctuate are highly questionable. The extreme high and low values for both dissolved oxygen and percent saturation are incorrect and do not reflect the true chemistry of the water body. Data should be used with caution. The variability in the data is likely caused by the aging sensor. The dissolved oxygen sensor will be replaced prior to any 2012 deployments.
- Average dissolved oxygen values were above both the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5mg/l) and Early Life Stages (9.5mg/l). In many instances, dissolved oxygen content decreases below the suggested guidelines however these decreases are of short duration (1-2 hours).

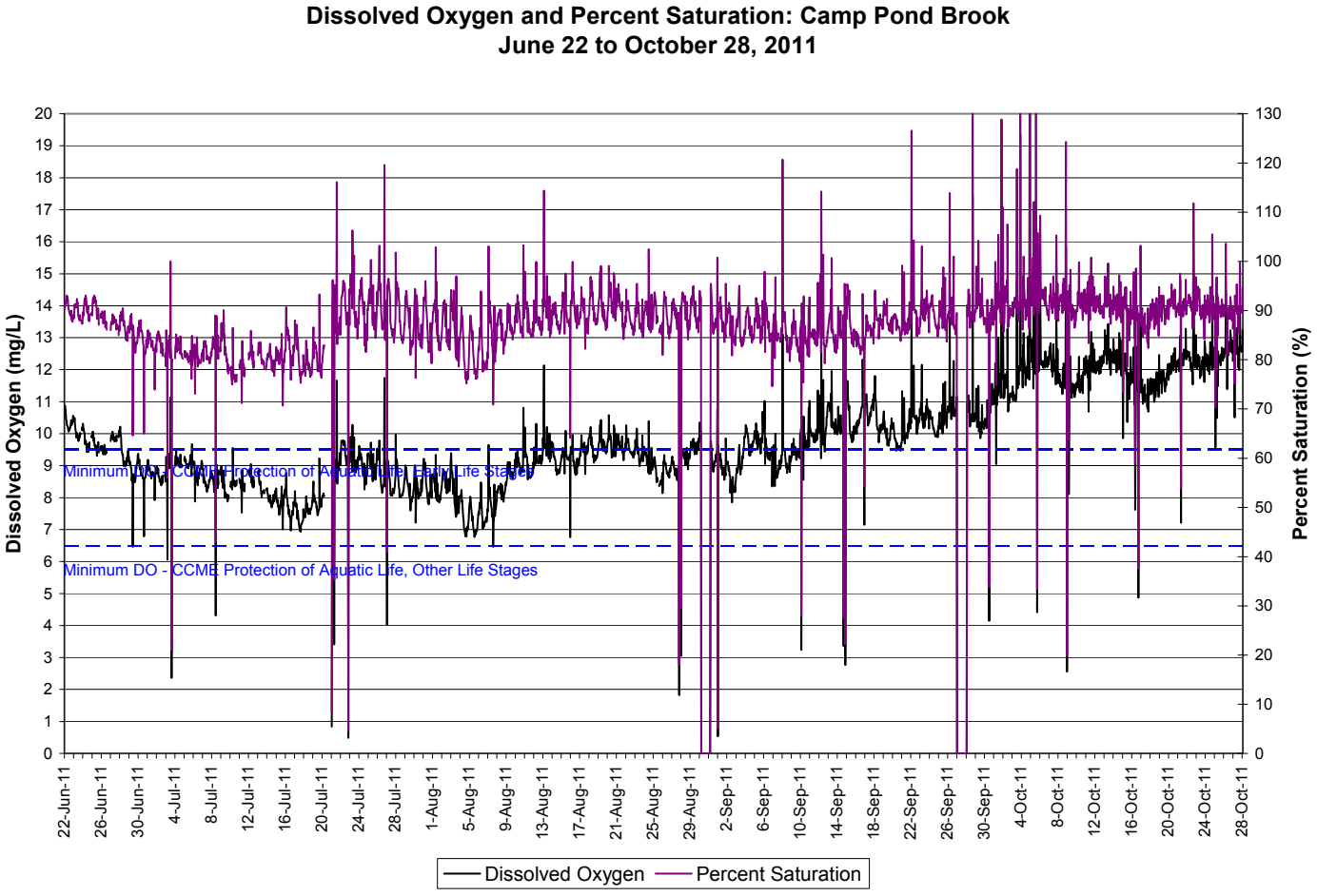


Figure 24: Dissolved oxygen and percent saturation at Camp Pond Brook

- Turbidity generally ranged between 0.6NTU to 65.1NTU (Figure 25). A median value of 7NTU indicates there is a consistent natural background turbidity value at this station.
- It is typical of this station to have consistent background turbidity levels >0NTU. From September 5 to the end of the deployment period on September 27, turbidity increases several times (3 peaks) to as high as 65.1NTU. Small rainfall events during this time occur September 8, 11, 13, 14, 21, and 22 (all >8mm). A significant rainfall event occurs on September 16 with nearly 40mm of rain recorded in Nain, NL on that day.
- Part or all of the increases in turbidity values during this time may be attributed to the rainfall events however, when the instrument is replaced following cleaning and calibration on September 28, turbidity values are much lower and more stable. The instrument may have been subjected to an increase in turbidity in the beginning of September and may not have fully recovered resulting in higher than normal turbidity recordings. In addition, sand, leaves of other organic debris may have caused the sensor to fail. It remains unknown what caused these high values.

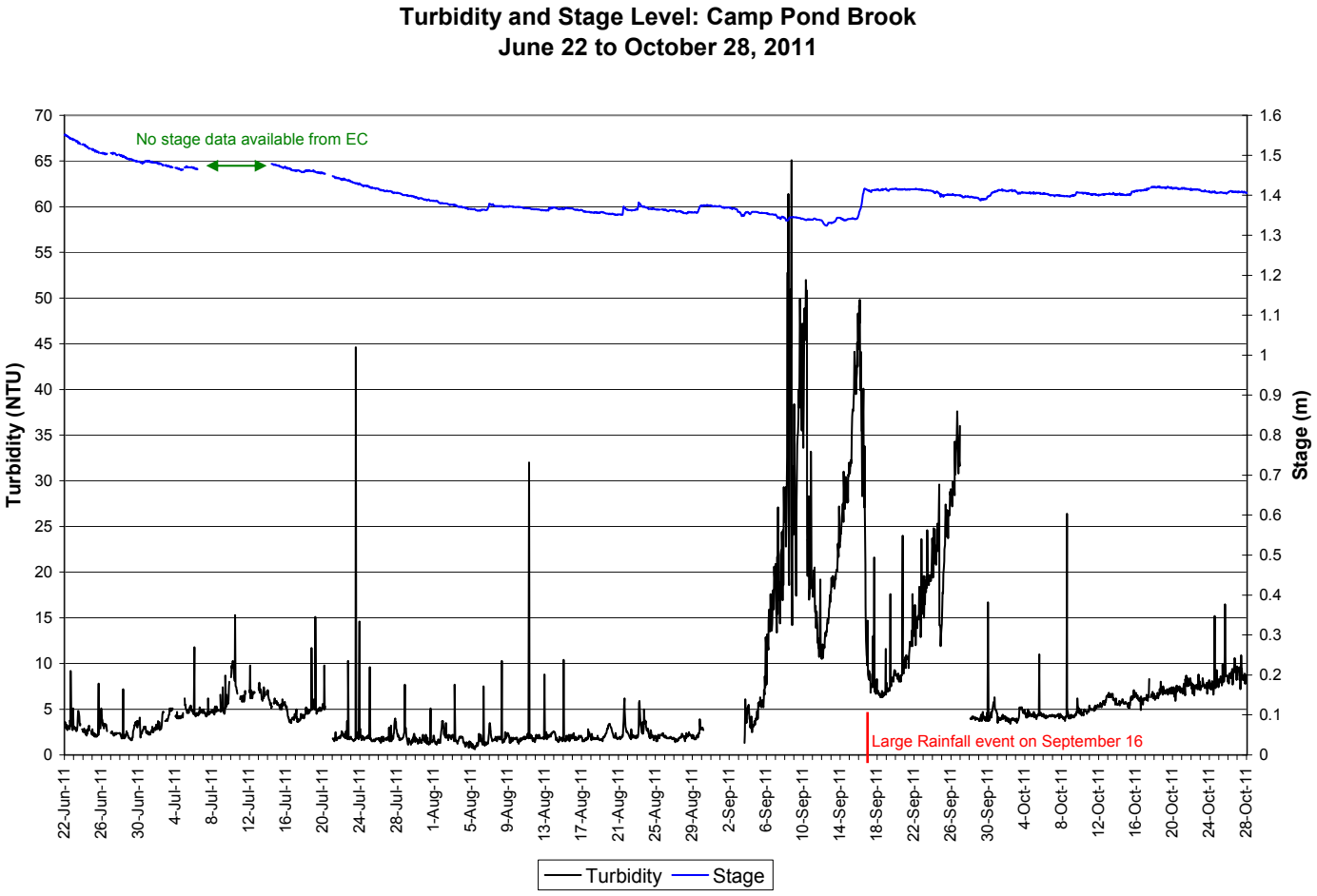


Figure 25: Turbidity and stage level at Camp Pond Brook

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 26). Stage is generally decreasing for the six weeks of the deployment season. Stage level remains low for the majority of the summer season before beginning to increase in the month of September. Precipitation events are frequent and moderate in magnitude.

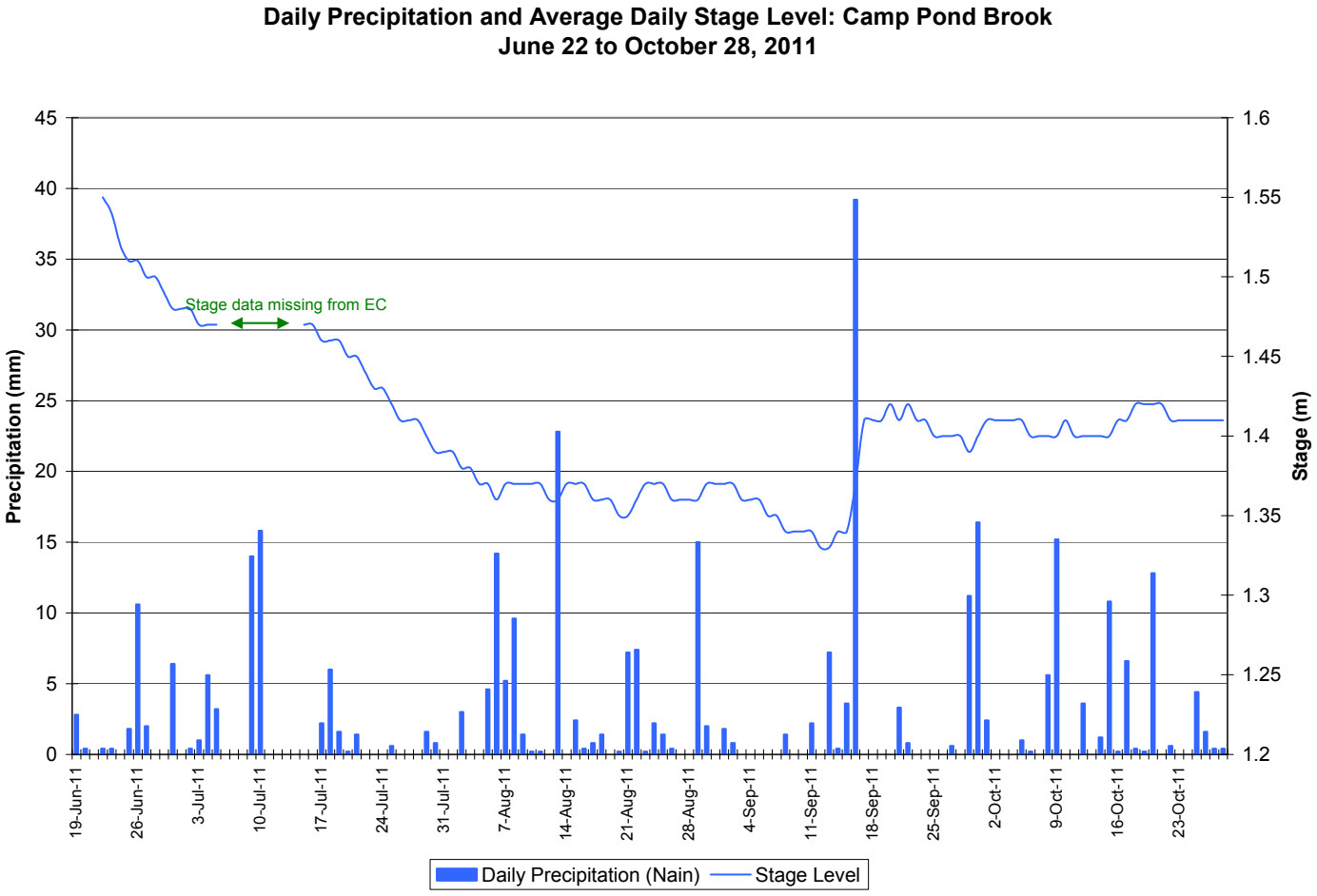


Figure 26: Daily precipitation and average daily stage level at Camp Pond Brook (weather data recorded at Nain)

Multi-Station Comparison

- This section of the annual report focuses on how the stations compared to one another throughout the 2011 deployment season. In order to eliminate some of the variability seen in the hourly data, average daily values were used to compare stations throughout the network.

Temperature

- Water temperature trends at each of the four stations are comparable with one another (Figure 27). There is clear seasonal trend at all stations with water temperature increasing throughout June and July and peaking in early August. Water temperatures then decrease throughout August until the end of the deployment season in late October.

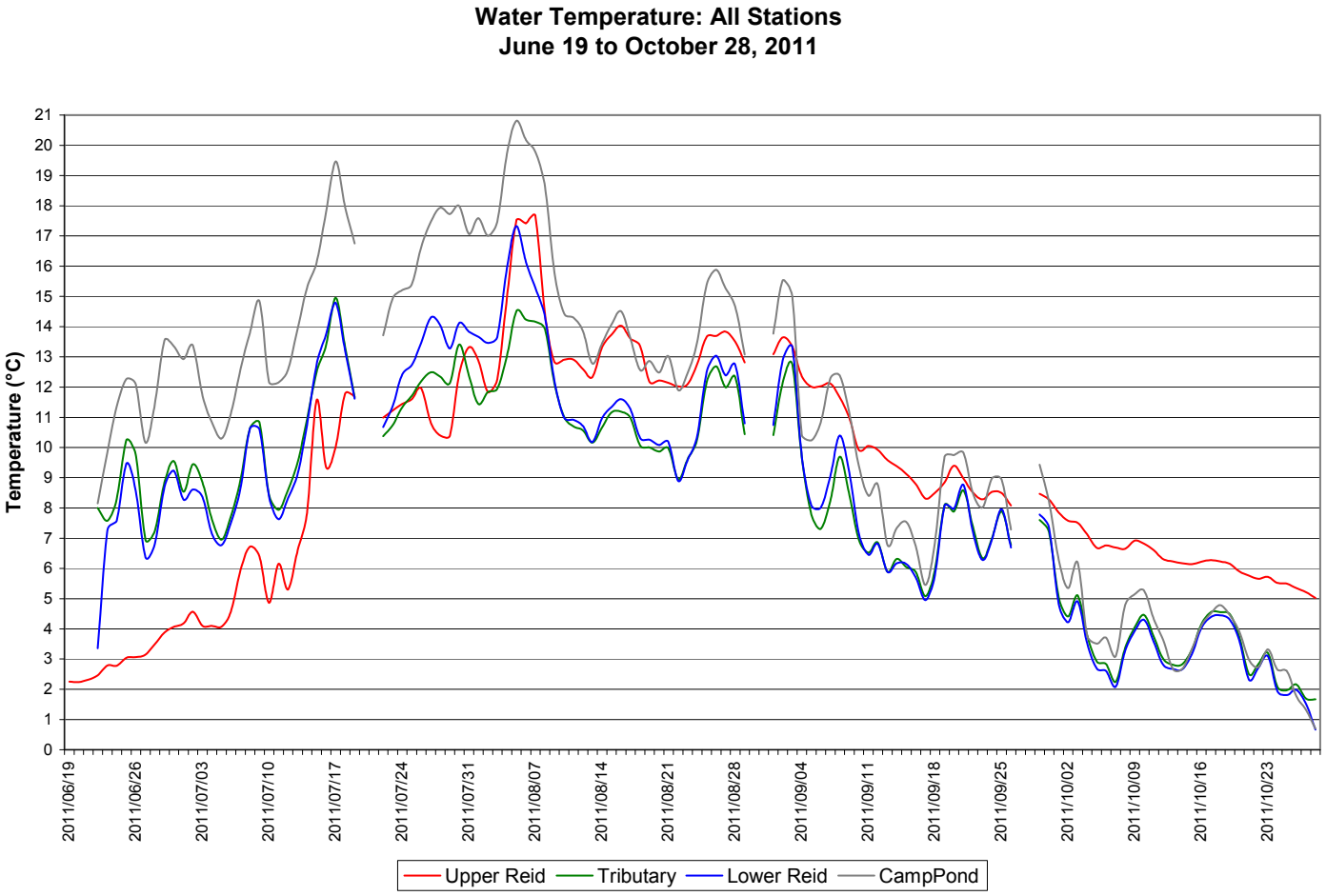


Figure 27: Average daily water temperature at all stations

Temperature (°C)	Upper Reid	Tributary	Lower Reid	Camp Pond
Average	8.96	8.36	8.50	10.93
Max	17.66	14.95	17.33	20.81
Min	2.24	1.67	0.67	0.70

pH

- pH values are also comparable throughout the network of stations averaging between 6.61 and 6.92 pH units (Figure 28).
- There is a noticeable decrease in pH at three of the four stations in mid-September which corresponds with a significant rainfall event on September 16 (indicated by red arrow on Figure 28). The station at Upper Reid Brook remains most stable throughout the deployment season which is expected from this baseline station at the outlet to Reid Pond.

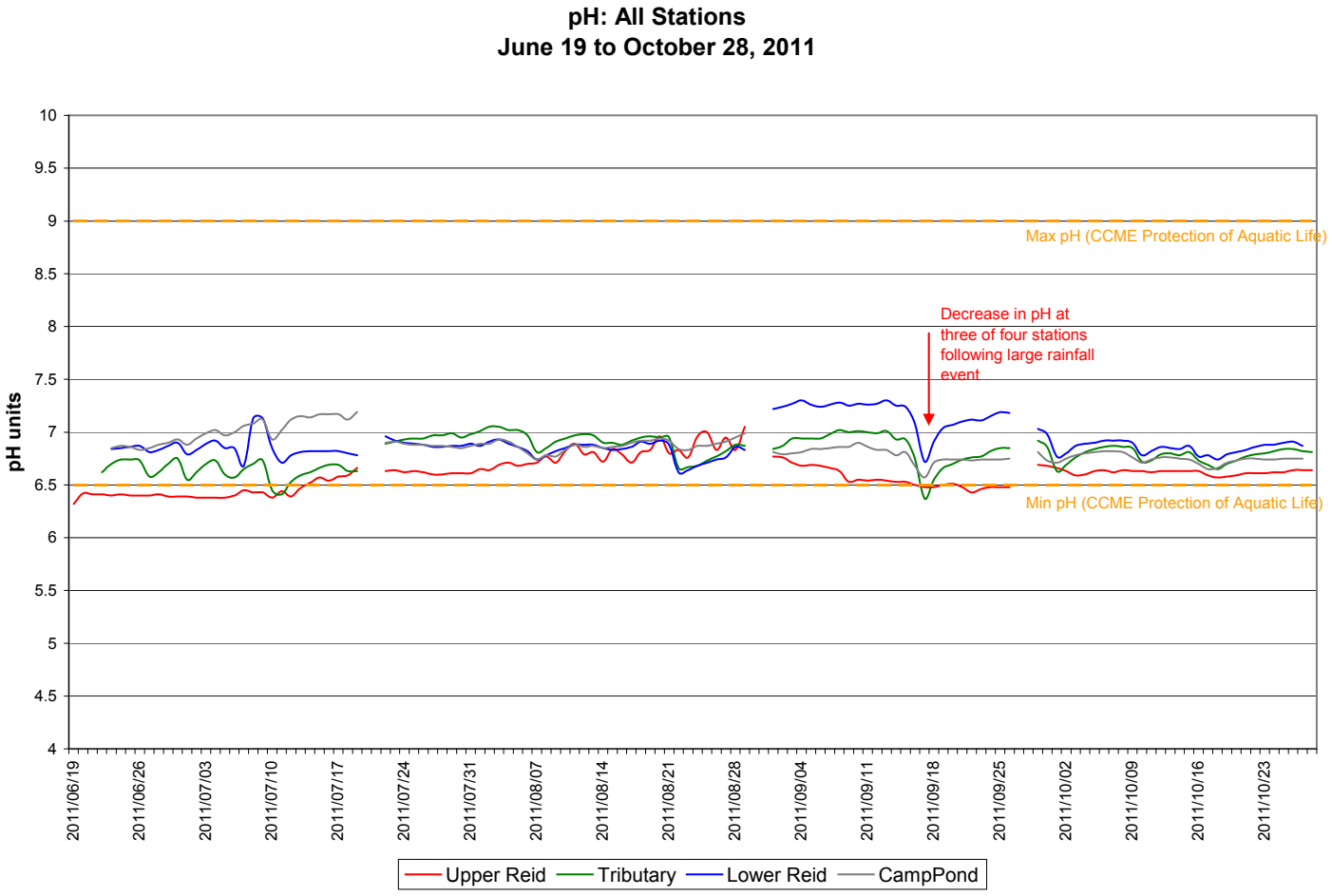


Figure 28: Average daily pH at all stations

pH (units)	Upper Reid	Tributary	Lower Reid	Camp Pond
Average	6.61	6.81	6.92	6.85
Max	7.05	7.05	7.30	7.19
Min	6.32	6.37	6.62	6.57

Specific Conductivity

- Specific conductivity trends are very similar at stations on Lower Reid Brook, Tributary to Lower Reid and Camp Pond Brook (averaging between 27.9 and 30.6µS/cm) and vary with changing water levels (Figure 29). At the station at Upper Reid Brook, conductivity is significantly lower, averaging 9.4 µS/cm, and remaining very stable throughout the entire deployment season regardless of changing water levels.

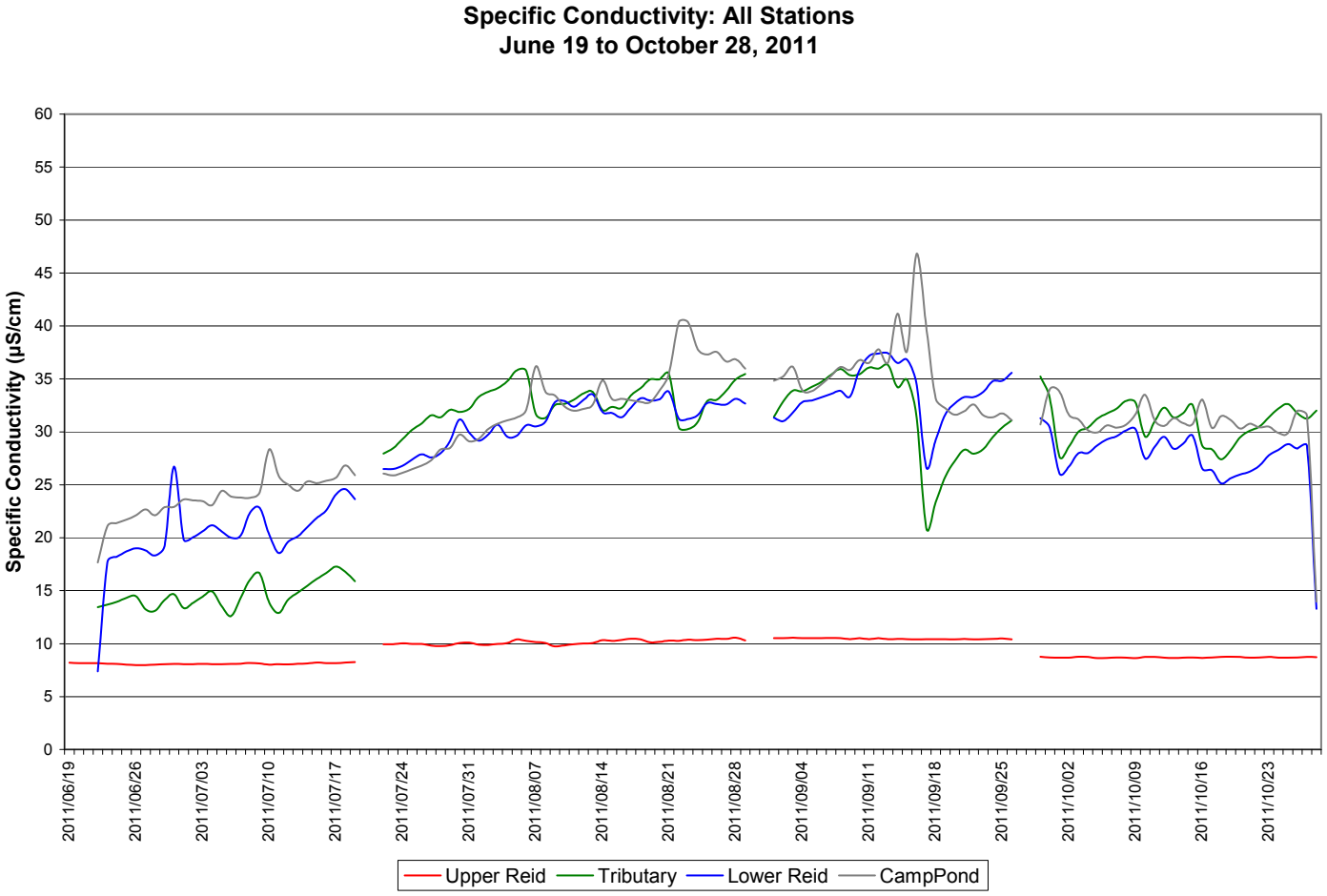


Figure 29: Average daily specific conductivity at all stations

Specific Conductivity (µS/cm)	Upper Reid	Tributary	Lower Reid	Camp Pond
Average	9.4	27.9	28.3	30.6
Max	10.6	36.3	37.4	46.8
Min	8.0	12.6	7.4	14.0

Dissolved Oxygen and Percent Saturation

- The dissolved oxygen sensors at stations at Lower Reid Brook, Camp Pond Brook and Upper Reid Brook all had periods of malfunction throughout the deployment season. Some of the variability, especially with the Camp Pond Brook station, is lost when examining the daily average data.
- Dissolved oxygen content does follow the expected seasonal trend, decreasing in the spring and early summer while water temperatures are increasing and increasing throughout the late summer and fall season when water temperatures are decreasing (Figure 30).

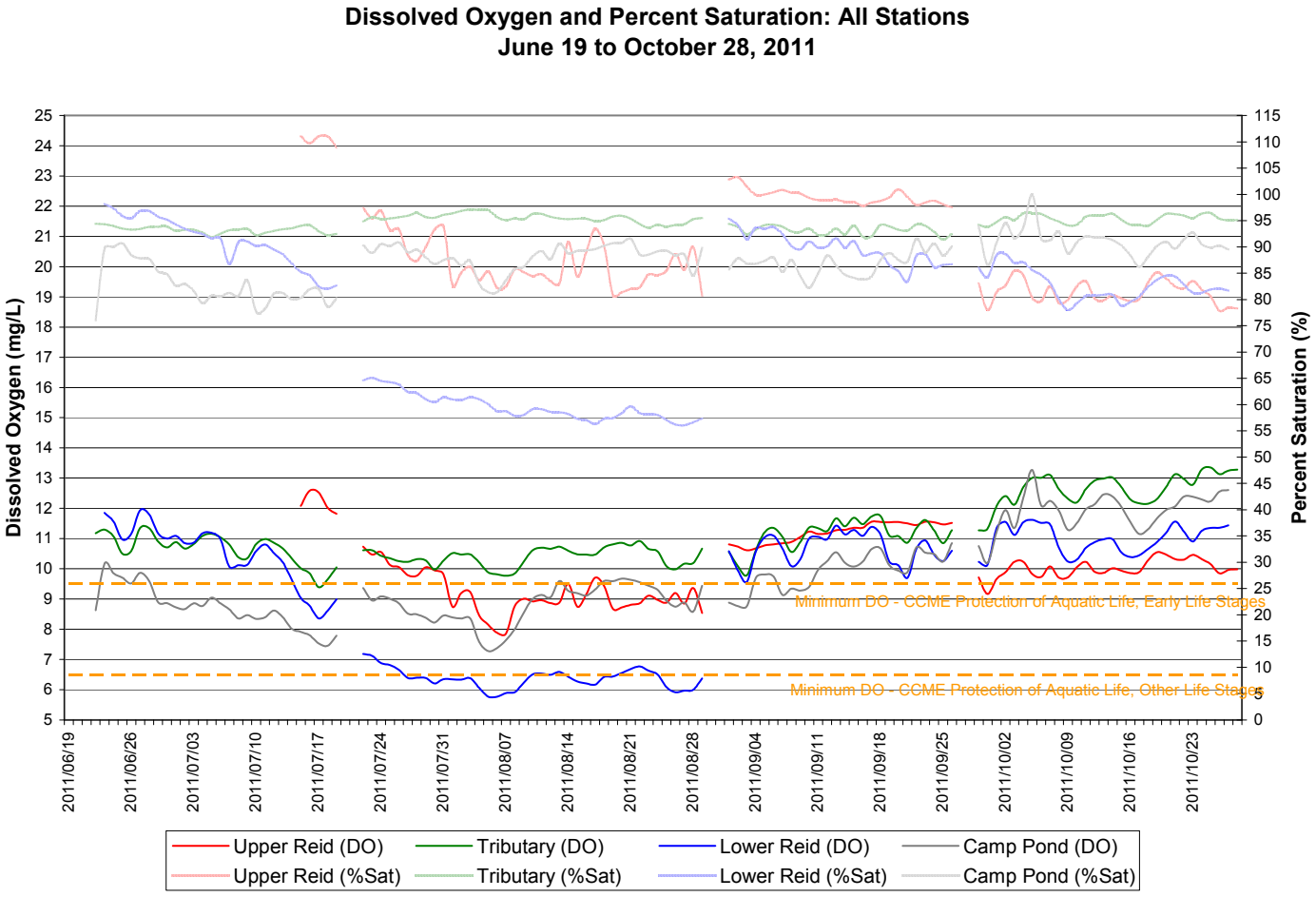


Figure 30: Average daily dissolved oxygen and percent saturation at all stations

	Dissolved Oxygen (mg/L)				Percent Saturation			
	Upper Reid	Tributary	Lower Reid	Camp Pond	Upper Reid	Tributary	Lower Reid	Camp Pond
Average	10.12	11.16	9.32	9.77	89.79	94.47	78.65	87.32
Max	12.58	13.35	11.94	13.27	111.08	97.13	98.20	99.88
Min	7.86	9.39	5.77	7.28	77.84	91.40	56.05	76.01

Turbidity

- Turbidity values are unable to be compared across the station network. Upper Reid Brook did not have a turbidity sensor on instrument deployed there during the 2011 season. Turbidity sensors at stations on the Tributary to Lower Reid Brook and Lower Reid Brook did not function at full capacity and the data collected during the season is invalid in many cases. Camp Pond Brook was the only station with reliable turbidity data during the 2011 deployment season.

Stage

- Stage levels generally decreased at all stations in the network for the first 6 weeks of the deployment season (Figure 31). There is an increase at all stations near mid-July which corresponds with a moderate rainfall event lasting for 2 days. Stage level drops to a seasonal low in early to mid August at all stations and is then followed by another significant increase corresponding with a significant rainfall event on September 16. Stage levels remain at a moderate values for the remainder of the deployment season.

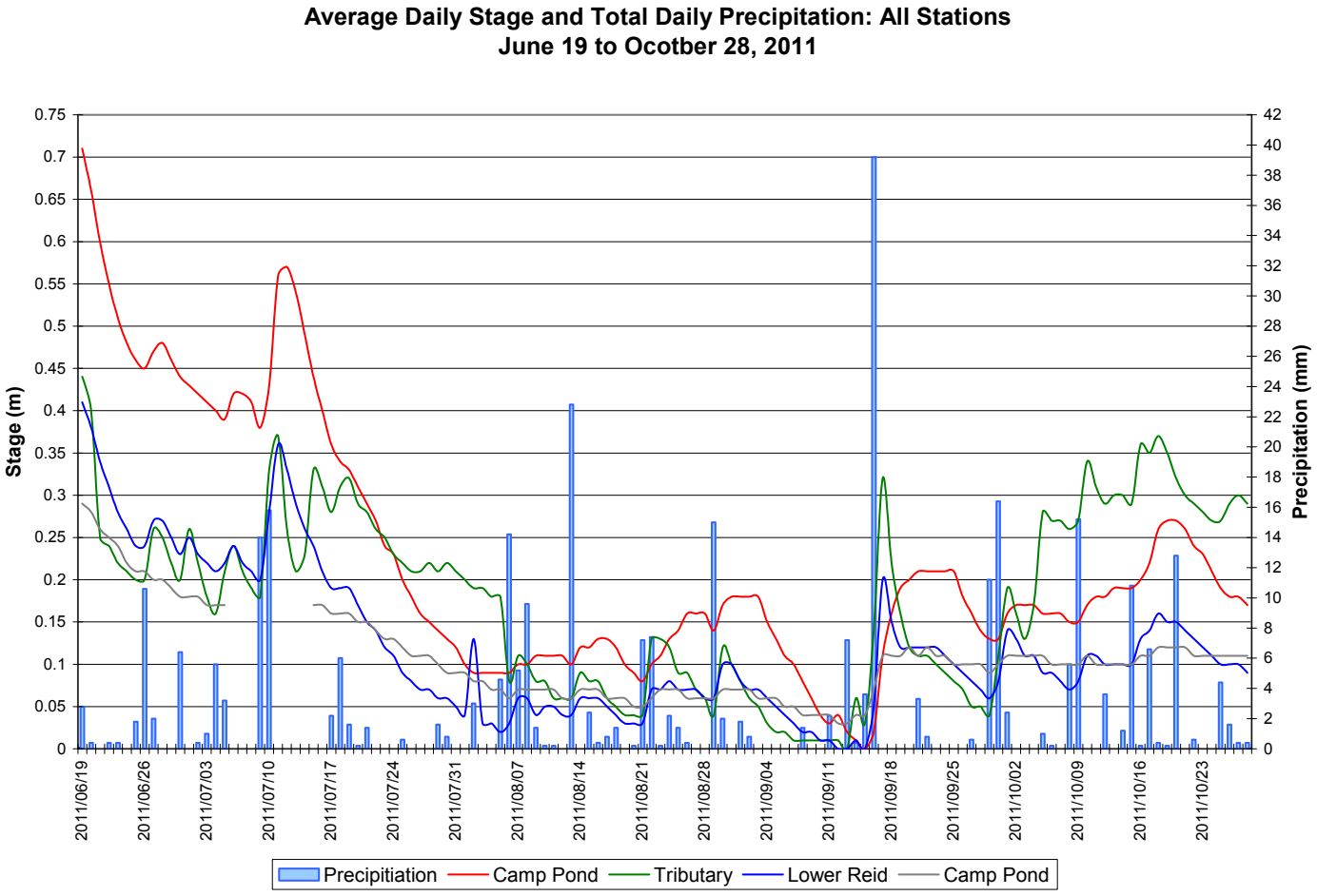


Figure 31: Average daily stage levels at all stations

Conclusions

- Instruments at water quality monitoring stations in the Voisey's Bay Network were deployed during four deployment periods from June 22 to October 28, 2011.
- Many of the data errors and variability occurring throughout the 2011 deployment season can be attributed to the aging sensors on the instruments.

Summary by Station

- At Upper Reid Brook, a replacement instrument loaned to Vale by ENVC was deployed on June 19. This instrument features no turbidity sensor or battery pack therefore there is no turbidity data or option for a back up log file. Temperature displayed a typical seasonal warming and cooling trend throughout the deployment season. pH was stable for three of four deployment periods. From July 21 to August 30, pH data is fluctuating unusually high on a day to day basis. This data has been removed from the data set. Specific conductivity was very stable for the most part and appears to be slightly lower than expected in deployment periods from June 19 to July 20 and from September 28 to October 28. This error is likely due to contamination of the calibration solution as the same pattern is evident at other stations. Due to an error with the programming of the data logger, dissolved oxygen and percent saturation data are not available for this station between June 19 and July 16. The dissolved oxygen sensor did not appear to function at full capacity during the deployment periods between July 20 and August 30 and then again from September 28 to October 28. This data has been removed from the data set. Turbidity was not measured at this station in 2011. Stage levels typically decreased for the first six weeks of the deployment season to a seasonal low in early September. Stage levels increase slightly after that and into the fall season.
- At Tributary to Lower Reid Brook, temperature also displayed a regular seasonal trend, increasing in the spring and summer, peaking in early August and decreasing throughout the fall season. pH was very stable throughout the entire deployment season. Specific conductivity was low during the first deployment period between June 22 and July 20 and is likely in part due to contamination of the calibration solution. Specific conductivity for the remainder of the deployment season is as expected and fluctuates clearly in relation to water level. Dissolved oxygen values are normal and decrease slightly in the spring and early summer as water temperatures are increasing before dropping off in the fall season as water temperatures cool. Turbidity data collected at this station is invalid and has been removed from the data set as the turbidity sensor was not functioning. Stage levels are similar to Upper Reid Brook, decreasing for the first 6 weeks of the deployment and reaching a seasonal low in early September. Stage levels increase again into the fall season.
- At Lower Reid Brook, temperature increased throughout the beginning of the deployment period, peaking in early August. Water temperature decreased throughout the fall deployment periods. pH values were relatively stable throughout the season however there are numerous occasions when pH values decreased sharply during periods of increasing stage and rainfall events. Specific Conductivity generally increased throughout most of the deployment period, fluctuating in response to changing water levels. The dissolved oxygen sensor on the instrument deployed at this station was not functioning at full capacity throughout the 2011 deployment season. Values recorded throughout the deployment season are unreliable and will be removed from the data set. The turbidity sensor on the instrument deployed at Lower Reid Brook was also not functioning properly. All data collected for this parameter in 2011 is invalid and will be removed from the data set. Stage levels decreased in the beginning of the deployment season, reaching a seasonal low in early September. Stage levels generally increase through September and October.
- The turbidity sensor on the instrument deployed at Lower Reid Brook was also not functioning properly. All data collected for this parameter in 2011 is invalid and will be removed from the data set. Stage levels decreased in the beginning of the deployment season, reaching a seasonal low in early September. Stage levels generally increase through September and October.

- At Camp Pond Brook, water temperatures increased in the spring and summer months, peaking in early August. Water temperature decreases throughout the fall season. pH is stable throughout the deployment season. On several occasions, decreases in pH occur caused by changes in the water level during rainfall events. Specific conductivity generally increases throughout the first half of the deployment season as water levels are decreasing and increases in the fall season when stage levels are increasing. When stage levels increase sharply, a rise in specific conductivity also happens. This trend is normal at this station. Average dissolved oxygen and percent saturation values at this station are normal however the hourly fluctuations are very significant and questionable. Average daily data is a much better representation of the typical dissolved oxygen levels for this station. Turbidity values recorded are typical for this station however there are three significant peaks during the deployment period from August 31 to September 28 which are questionable and should be considered with caution. It is possible that sand or debris cause sensor failure during this deployment period. Stage levels typically decreased for the first six weeks of the deployment season to a seasonal low in early September. Stage levels increase slightly after that and into the fall season.

Summary by Parameter

- Temperature averaged between 8.36°C and 8.96°C at the stations on Upper Reid Brook, Tributary to Lower Reid Brook and Lower Reid Brook. At Camp Pond Brook, temperatures were slightly warmer averaging around 10.93°C. At all stations, a typical seasonal trend for temperature, increasing in the spring and summer and cooling in the fall was evident.
- pH values averaged between 6.61 and 6.85 pH units across the network. Most values recorded were within the recommended range as stated by the CCME Guideline for the Protection of Aquatic Life with the exception of the first deployment period at Upper Reid Brook where values were just below the minimum guideline. Decreases in pH corresponding with rainfall events are noticeable at the three lower stations Tributary to Lower Reid Brook, Lower Reid Brook and Camp Pond Brook.
- At Tributary to Lower Reid Brook, Lower Reid Brook and Camp Pond Brook stations, specific conductivity averaged between 27.9µS/cm and 30.6µS/cm. Values at Upper Reid Brook were considerably lower averaging 9.4µS/cm. These lower values are expected from this pristine station at the outflow from Reid Pond. Values at this station tend not to fluctuate a lot even with changing stage levels. At Tributary to Lower Reid and Lower Reid Stations, specific conductivity displayed a clear inverse relationship with stage level, with values decreasing when stage level increased. At Camp Pond Brook, specific conductivity increased sharply when the stage level increased which is typical for this station.
- Dissolved oxygen levels were reasonable at stations on the Tributary to Lower Reid Brook. Average dissolved oxygen values were good at the station on Camp Pond Brook (hourly data had too much erratic fluctuation). At Upper Reid Brook, the dissolved oxygen sensor failed for most of the deployment period resulting in less than expected values and considerable fluctuation from hour to hour. The dissolved oxygen sensor on the instrument deployed at Lower Reid Brook also failed.
- Turbidity values are inaccurate for the station at Tributary to Lower Reid Brook and Lower Reid Brook due to sensor failure. Values recorded at Camp Pond Brook were typical for the station with a median value of 4.3NTU. There is no turbidity sensor on the instrument at Upper Reid Brook.
- Stage increased for the first 6-8 weeks of the deployment period at all stations. Water levels reached a seasonal low in early September at all stations. Stage levels increase slightly for the remainder of the deployment season. Precipitation events were frequent and moderate in magnitude.

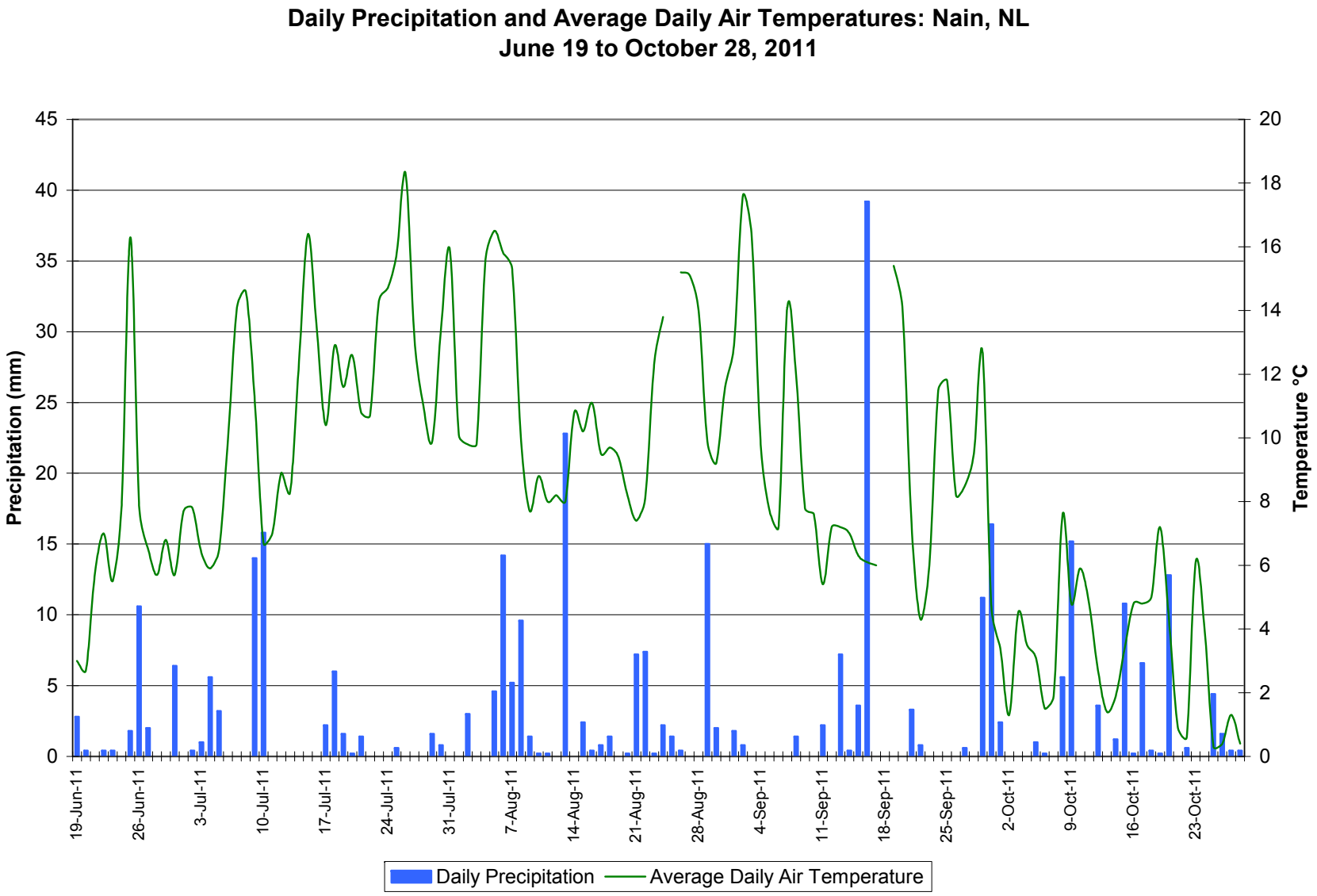
Path Forward

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 improving since 2003 and continues to advance 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 2012 deployment period for the Voisey's Bay Stations, the following is a list of planned activities to be carried out in the upcoming year. The list also includes some multi-year activities planned in the previous year that are still in progress.

- Due to the aging instruments, data integrity was compromised during the 2011 deployment season. Four new Hydrolab Datasonde 5X instruments will be purchased prior to the 2012 season for this network as well as a new Hydrolab Minisonde 5 for QAQC measurements and an Archer handheld display unit.
- Deployments will recommence in the spring 2012 when ice conditions permit.
- In the 2012 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.
- Well station to be installed in 2012 with assistance from WRMD Groundwater Section.
- ENVC staff will outline and produce a comprehensive report on the RT network at Voisey's Bay featuring the network data from the past 9 years. ENVC staff will consult with Vale Environment staff on the direction and content of this report.
- ENVC will work with Vale Environment staff to reassess the network design (station location) and plan for any necessary or desired changes in 2012 or in future seasons.
- 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 and a 2012 annual report summarizing the events of the deployment season.
- Open communication lines will continue to be maintained 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 update Voisey's Bay staff on any changes to processes and procedures with handling, maintaining and calibrating the real-time instruments.
- An email alerting system will be established for the Voisey's Bay stations to catch emeging water quality issues at the start of the 2012 deployment season.
- Continue to work on Automatic Data Retrieval System to incorporate new capabilities.
- Creation of value added products using the real-time water quality data, remote sensing and water quality indices.
- 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*.).

Prepared by: Grace Gillis
Department of Environment and Conservation
Water Resources Management Division

Appendix 1


Daily Precipitation and Average Daily Air Temperatures: Nain, NL
June 19 to October 28, 2011
Precipitation (mm)
Temperature °C
0
5
10
15
20
25
30
35
40
45
0
2
4
6
8
10
12
14
16
18
20
19-Jun-11
26-Jun-11
3-Jul-11
10-Jul-11
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7-Aug-11
14-Aug-11
21-Aug-11
28-Aug-11
4-Sep-11
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18-Sep-11
25-Sep-11
2-Oct-11
9-Oct-11
16-Oct-11
23-Oct-11
Daily Precipitation
Average Daily Air Temperature