Real-Time Water Quality 2011 Annual Report

Lower Churchill River Network

May 26 to November 2, 2011

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

CONTENTS

Acknowledgements

The Real-Time Water Quality Monitoring (RTWQM) Network on the Lower Churchill River is successful in tracking emerging water quality issues as well as creating a database of baseline water quality data due to the hard work and diligence of certain individuals. The management and staff of Nalcor 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 the Lower Churchill River.

Various individuals from ENVC have been integral in ensuring the smooth operation of such a technologically advanced network. In 2011, ENVC Environmental Scientist, Grace Gillis, was responsible for deployment and removal of instruments including cleaning/calibration and preparation of monthly deployment reports. Tara Clinton, Ryan Pugh, Shibly Rahman and Maria Murphy are acknowledged for their efforts during deployment and removal procedures in 2011.

EC staff, under the Meteorological Service of Canada Water Survey Canada (Brent Ruth, Perry Pretty, Roger Ellsworth, Dwayne Akerman and Mike Ludwicki) play an essential role in the data logging/communication aspect of the network. These individuals visit the site regularly 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 from each agency (Marion Organ and Steve Pellerin– Nalcor; Robert Picco and Renee Paterson - ENVC; Howie Wills – EC) 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. In March and April 2011, ENVC (Water Resources Management Division) participated in the Public Hearings for the Lower Churchill Hydroelectric Generation Project in Happy Valley-Goose Bay, NL. ENVC will continue to provide information and expertise for all workshops and information sessions throughout all phases of the project. In June 2011, Nalcor staff, Peter Madden and Julia Hiscock attended the 3rd Real Time Water Quality Monitoring Workshop hosted by ENVC in St. John’s, NL. Finally, throughout the summer and fall months there was continued communication (meetings, email correspondence etc.) between ENVC and Nalcor Energy towards the renegotiation of an updated Agreement. This network is continually successful due the participation and collaboration of all three agencies.

Abbreviations

EC	Environment Canada
ENVC	Department of Environment and Conservation
CRaboveMF	Station at Churchill River above Muskrat Falls
CRbelowGR	Station at Churchill River below Grizzle Rapids
CRbelowMF	Station at Churchill River below Muskrat Falls
CRbelowMR	Station at Churchill River below Metchin River
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 on the Lower Churchill was successfully established by ENVC and EC in cooperation with Nalcor Energy in September 2008.
- 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 along the Lower Churchill River. The information currently being collected will serve as a baseline from which changes throughout the several phases of the Lower Churchill Hydroelectric Generation Project can be monitored.
- The RTWQM network consists of 4 water quality monitoring stations along the Churchill River from just below the confluence with Metchin River to just below Muskrat Falls. 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 as well as 2 additional stations along the Lower Churchill (Churchill River below the Tailrace and Churchill River above Grizzle Rapids) 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 better 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 May 26 to November 2, 2011. During this time, 6 visits were made to each of the 4 real time monitoring sites. Instruments were deployed for five, 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 ENVC 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, 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 inaccurate. Installation and removal dates for each station in the 2009 deployment season are summarized in Table 1.

Table 1: Installation and removal dates for 2011 deployment periods

Installation	Removal	Deployment Period (days)
26/27-May	29-Jun	34
29-Jun	2-Aug	34
02/03-Aug	01/02-Sep	30
01/02-Sep	04/05- Oct	33
04/05- Oct	1/2-Nov	28

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.
- Comparison rankings for the Lower Churchill River stations, deployed for 5 deployment periods from May 26 to November 1-2, 2011, are summarized in Table 3. Deployment and removal dates marked an asterisk (*) are short (1 day) deployment periods where an error with the instrument occurred. The instrument was removed the following day and replaced with a clean, calibrated instrument.
- For additional information and explanations of rankings including “ERROR” rankings, please refer to the monthly deployment reports.

Table 3: Comparison rankings for Lower Churchill River stations, May 26 – November 2, 2011

			Instrument #	Temperature	pH	Specific Conductivity	Dissolved Oxygen	Turbidity
Below Metchin River	27-May-11	Deployment	45701	Excellent	Excellent	Excellent	Excellent	Excellent
	29-Jun-11	Removal	45701	Good	Excellent	Excellent	Excellent	Fair
	29-Jun-11	Deployment	45707	Good	Good	Excellent	Excellent	Good
	2-Aug-11	Removal	45707	Good	Excellent	Excellent	Excellent	Excellent
	2-Aug-11	Deployment	45701	Excellent	Good	Excellent	Excellent	Excellent
	1-Sep-11	Removal	45701	Excellent	Good	Excellent	Excellent	Fair
	1-Sep-11	Deployment	45707	Good	Excellent	Excellent	Good	Fair
	4-Oct-11	Removal	45707	Good	Fair	Excellent	ERROR	ERROR
	4-Oct-11	Deployment	45701	Good	Fair	Excellent	Excellent	Excellent
	1-Nov-11	Removal	45701	Good	Good	Good	Excellent	Excellent
Below Grizzle Rapids	27-May-11	No deployment due to remaining ice wall at station						
	29-Jun-11							
	29-Jun-11	Deployment	45699	Excellent	Excellent	Excellent	Excellent	Excellent
	2-Aug-11	Removal	45699	Excellent	Excellent	Excellent	Excellent	Excellent
	2-Aug-11	Deployment	45709	Good	Fair	Excellent	Excellent	Excellent
	1-Sep-11	Removal	45709	Good	Good	Excellent	Excellent	Good
	1-Sep-11	Deployment	45699	Excellent	Excellent	Excellent	Good	Fair
	4-Oct-11	Removal	45699	Excellent	Excellent	Good	Excellent	Excellent
	4-Oct-11	Deployment	45709	Good	Fair	Excellent	Excellent	Excellent
	1-Nov-11	Removal	45709	Fair	Excellent	Excellent	ERROR	ERROR
Above Muskrat Falls	26-May-11	Deployment	45709	Good	Excellent	Excellent	Excellent	Excellent
	29-Jun-11	Removal	45709	Instrument exposed to air upon removal				
	29-Jun-11	Deployment	45042	Fair	Excellent	Excellent	Excellent	Good
	2-Aug-11	Removal	45042	Good	Excellent	Excellent	Fair	Good
	2-Aug-11	Deployment	47590	Excellent	Good	Excellent	Good	Excellent
	1-Sep-11	Removal	47590	Excellent	Excellent	Excellent	Good	Fair
	1-Sep-11	Deployment	47589	Excellent	Excellent	Good	Excellent	Poor
	4-Oct-11	Removal	47589	Excellent	Excellent	Good	Excellent	Excellent
	4-Oct-11	Deployment*	47590	Excellent	Good	Excellent	Excellent	ERROR
	5-Oct-11	Removal*	47590	Excellent	Good	Excellent	Excellent	ERROR
	5-Oct-11	Deployment	47589	Excellent	Fair	Excellent	Good	Excellent
	1-Nov-11	Removal	47589	Excellent	Excellent	Good	Marginal	Excellent
Below Muskrat Falls	27-May-11	Deployment	45700	Fair	Excellent	Excellent	Good	Excellent
	29-Jun-11	Removal	45700	Instrument exposed to air upon removal				
	29-Jun-11	Deployment	45708	Good	Excellent	Excellent	Excellent	Excellent
	2-Aug-11	Removal	45708	Good	Excellent	Excellent	Excellent	Good
	2-Aug-11	Deployment*	45700	Good	Excellent	Excellent	ERROR	ERROR
	3-Aug-11	Removal*	45700	Good	Excellent	Excellent	ERROR	ERROR
	3-Aug-11	Deployment	45708	Excellent	Good	Excellent	Excellent	Excellent
	1-Sep-11	Removal	45708	Good	Excellent	Good	Good	Poor
	1-Sep-11	Deployment*	45700	Good	Good	Excellent	ERROR	ERROR
	2-Sep-11	Removal*	45700	Good	Good	Excellent	ERROR	ERROR
	2-Sep-11	Deployment	45708	Good	Excellent	Excellent	Excellent	Poor
	5-Oct-11	Removal	45708	Good	Good	Excellent	Poor	Marginal
	5-Oct-11	Deployment	45699	Good	Good	Excellent	Excellent	Excellent
	2-Nov-11	Removal	45699	Fair	Good	Good	Excellent	Excellent

* 1 day deployment period where an error with the instrument occurred. The instrument was removed the following day and replaced with a clean, calibrated instrument.

Data Interpretation and Review

- The following graphs and discussion illustrate significant water quality-related trends from May 26 to November 2 in the Lower Churchill River Network. In this summary of the deployment periods for 2011, general patterns will be discussed. More detailed analysis and discussion of specific events can be found in the monthly deployment reports.
- 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.
- For a general comparison, 2009 and 2010 data has been included in the following graphs to show differences in trends in water quality on the Lower Churchill River over the past 3 years.

Churchill River below Metchin River

- Water temperature ranged from 2.10°C to 19.00°C during the 2011 deployment season, averaging 11.07°C (Figure 1).
- On average, water temperatures are slightly cooler in 2011 when compared to 2010 values and slightly warmer than in 2009.

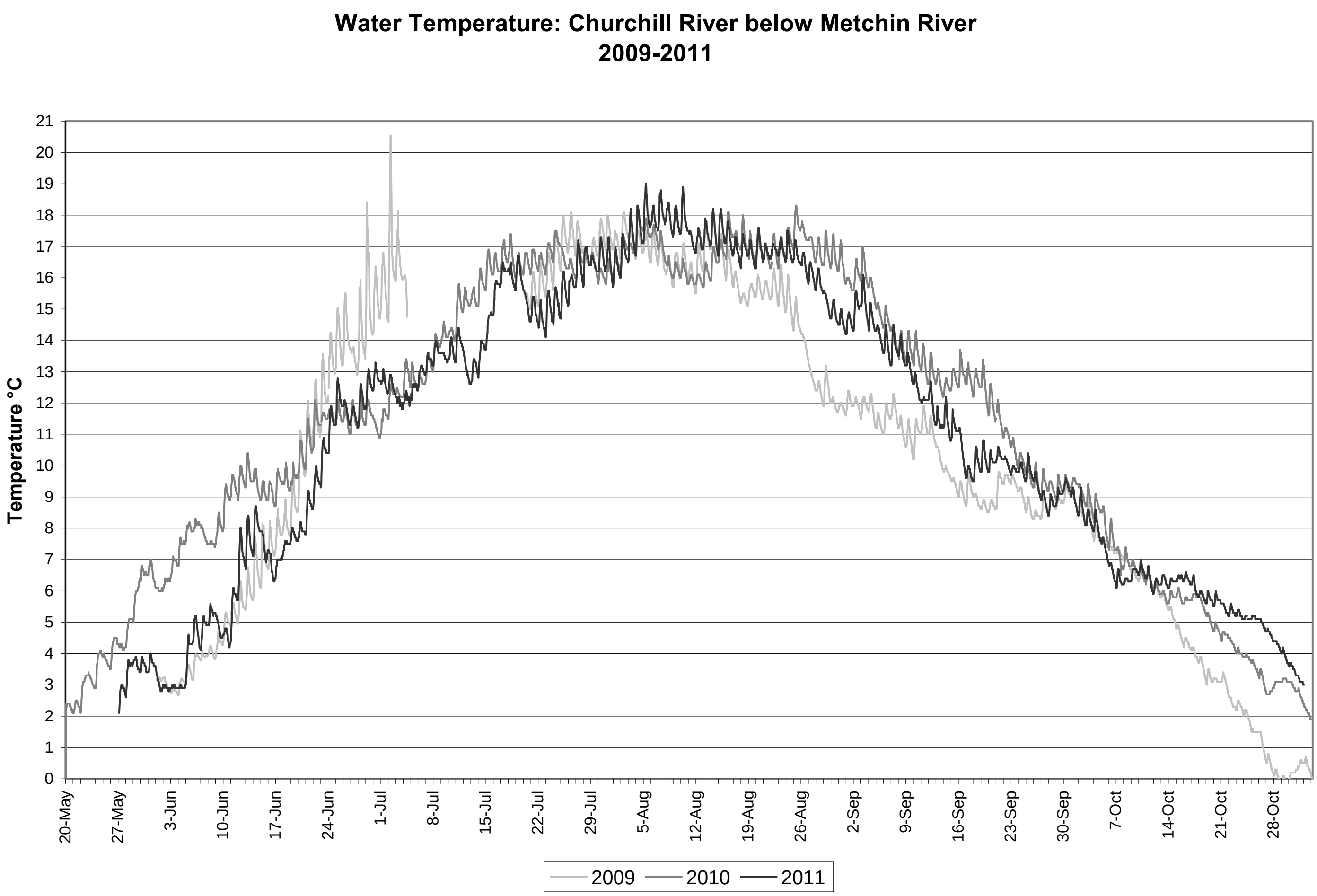


Figure 1: Water temperature at Churchill River below Metchin River

Lower Churchill River, Newfoundland and Labrador

- 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 19.00°C. Water temperature begins to decrease in the latter half of August and into the fall season as air temperatures cool.

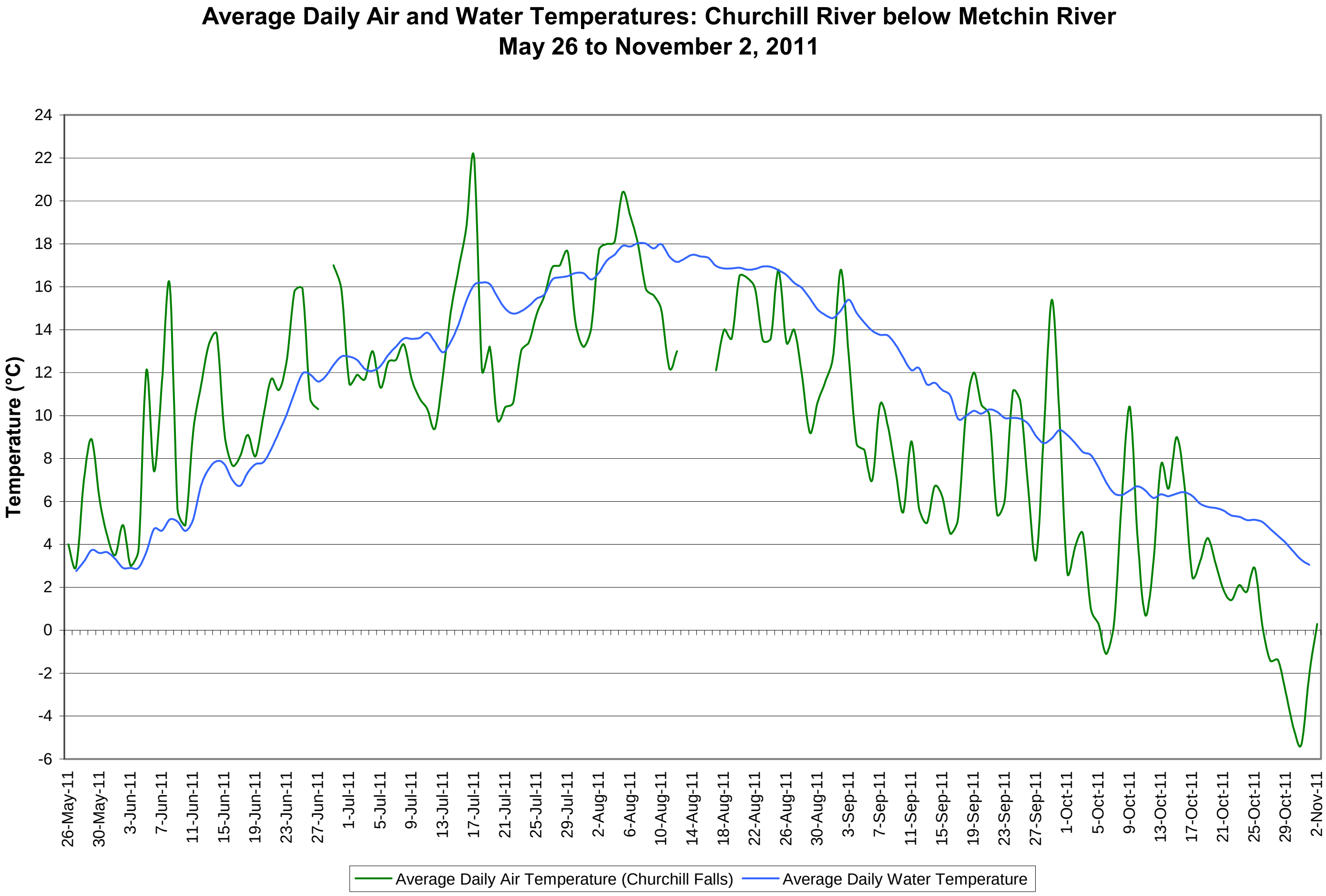


Figure 2: Average daily air and water temperatures at Churchill River below Metchin River

(weather data recorded at Churchill Falls)

Temperature	2011	2010	2009
Average	11.07	11.33	10.27
Max	19.00	18.30	20.54
Min	2.10	1.90	-0.10

- pH ranged between 6.39 and 7.36 pH units throughout the 2011 deployment season, averaging 6.91 pH units (Figure 3).
- Most values during the deployment are within the CCME Guidelines for the Protection of Aquatic Life (indicated in blue on Figure 3). At the beginning of the first deployment period on May 27, pH values are just below the minimum guideline however within a number of days increase to >6.5 pH units.
- pH values on average are slightly lower than in previous years. During the deployment period between September 1 and October 4, pH appears to be on average higher than normal and is likely in part due to an error during instrument calibration.

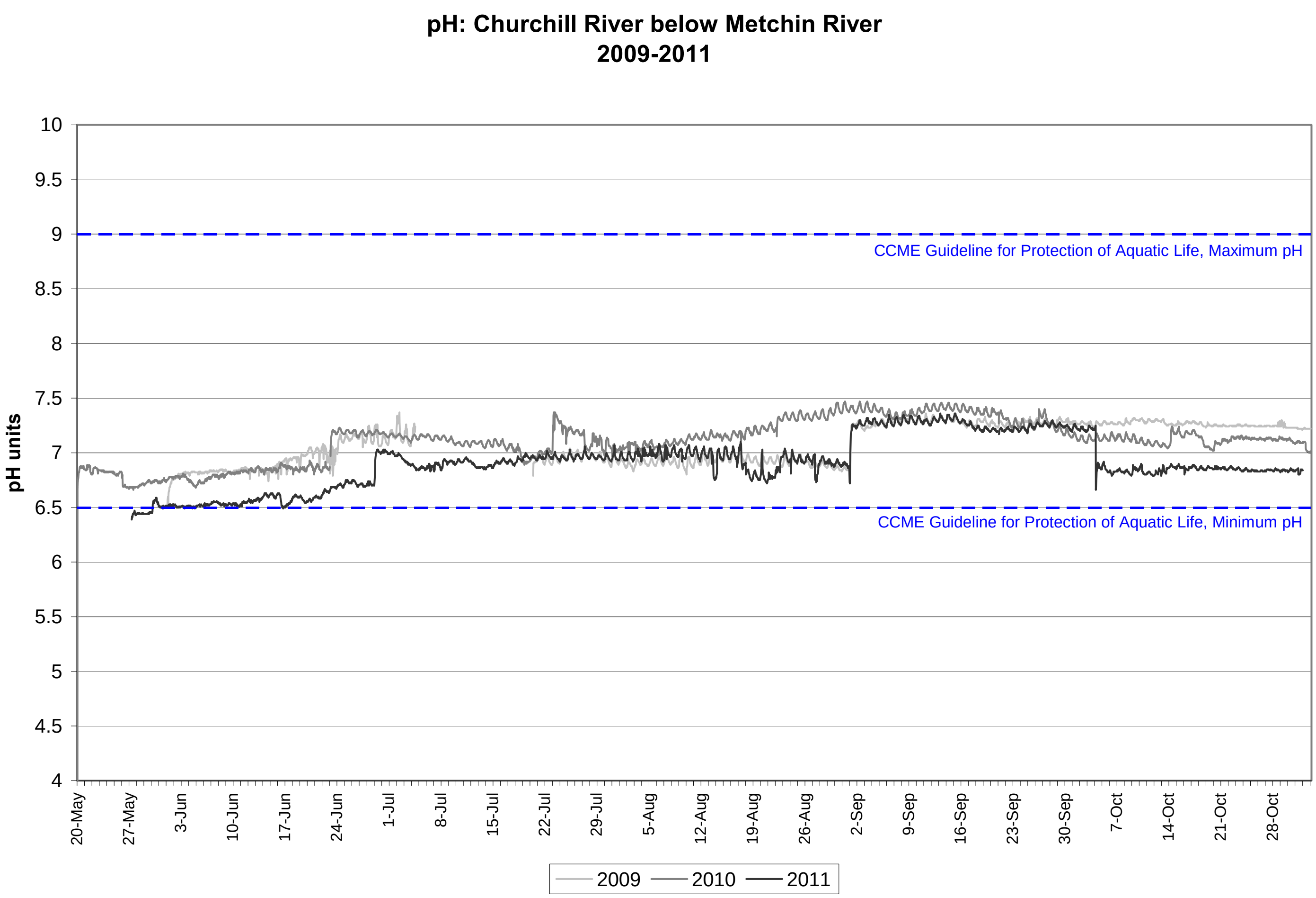


Figure 3: pH at Churchill River below Metchin River

pH (units)	2011	2010	2009
Average	6.91	7.11	7.09
Max	7.36	7.47	7.37
Min	6.39	6.66	6.50

- Specific conductivity ranged from 14.5 to 32.1µS/cm during the 2011 deployment season, averaging 19.4µS/cm (Figure 4).
- Specific conductivity is increasing for the first half of the deployment period before leveling off in early August. Values begin to decrease slightly into the fall season and throughout the month of October.
- When 2011 values are compared to data collected in 2009 and 2010, it is interesting to note the high variability in specific conductivity during the first month of deployment (late May to late June). The increased amount of 'spikes' may in part be due to the spring run off and higher water levels.
- Stage is included in Figure 4 to illustrate the inverse relationship between conductivity and water level. Stage is fluctuating throughout much of the 2011 season. As stage decreases, specific conductivity usually increases as the concentration of dissolved solids increases. Inversely, when stage increases, specific conductivity generally decreases due to the dilution of dissolved solids in the water column.

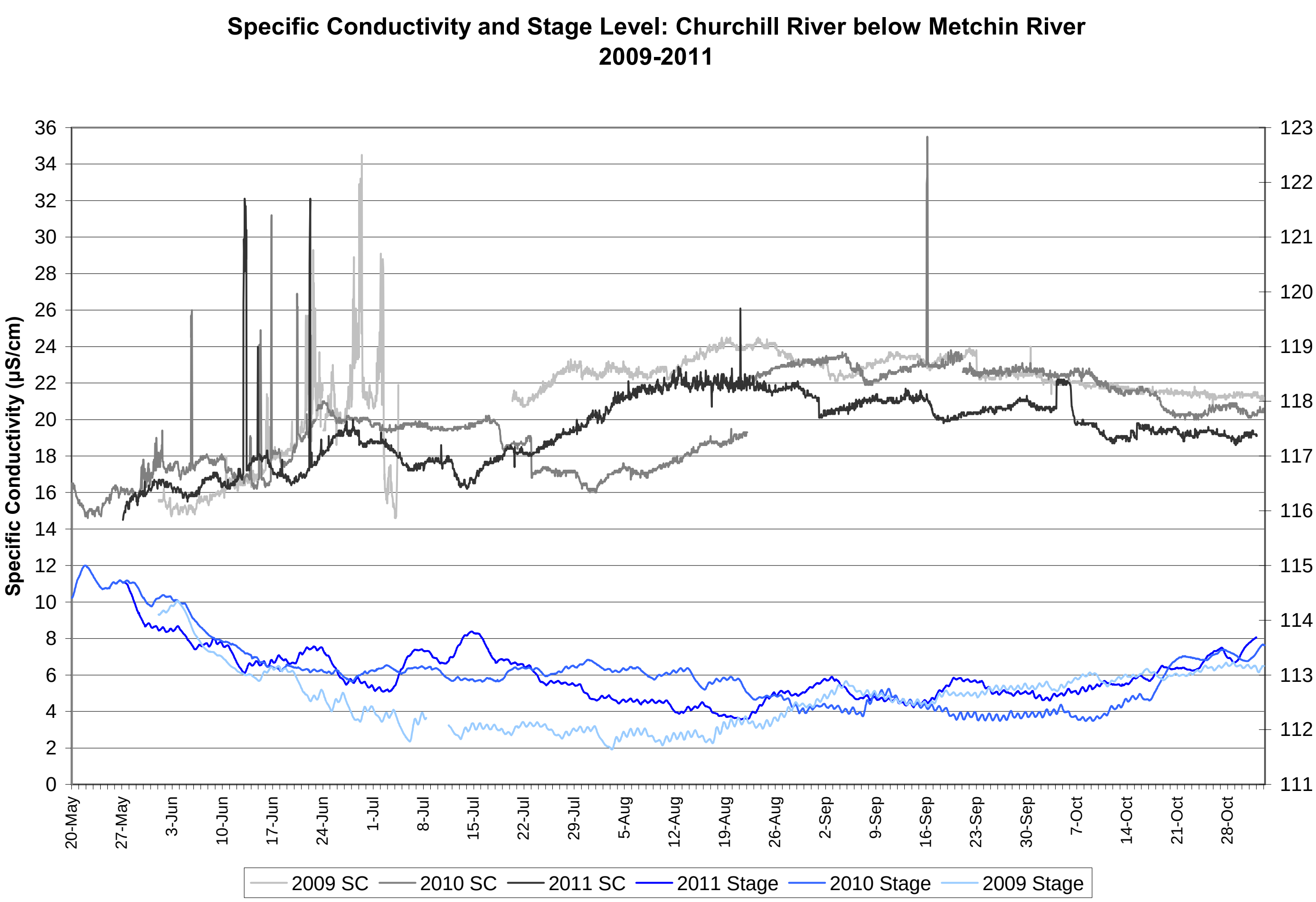


Figure 4: Specific conductivity and stage level at Churchill River below Metchin River

Specific Conductivity (µS/cm)	2011	2010	2009
Average	19.4	19.9	21.5
Max	32.1	35.5	34.5
Min	14.5	14.6	14.6

- Throughout the 2011 deployment season, dissolved oxygen ranged from 8.91 to 12.99mg/l, averaging 10.50mg/l, while percent saturation ranged from 90.7 to 101.5%, averaging 94.8% (Figure 5).
- All values were above the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5 mg/l). Most values were above the minimum CCME Guideline for the Protection of Aquatic Life at Early Life Stages (9.5mg/l). From late July to early September, during the warmest part of the season, dissolved oxygen content was just below the guideline. The guidelines are indicated in blue on Figure 5.
- Dissolved oxygen content shows a typical seasonal fluctuation in 2011, decreasing throughout the spring and early summer months during the time when water temperatures are increasing. Dissolved oxygen content reaches a seasonal low in early August. When water temperatures begin to decrease in the late summer and fall, dissolved oxygen content begins to rise again.
- When compared to data from 2009 and 2010, the same trend is evident due to the inverse relationship between dissolved oxygen and water temperature.

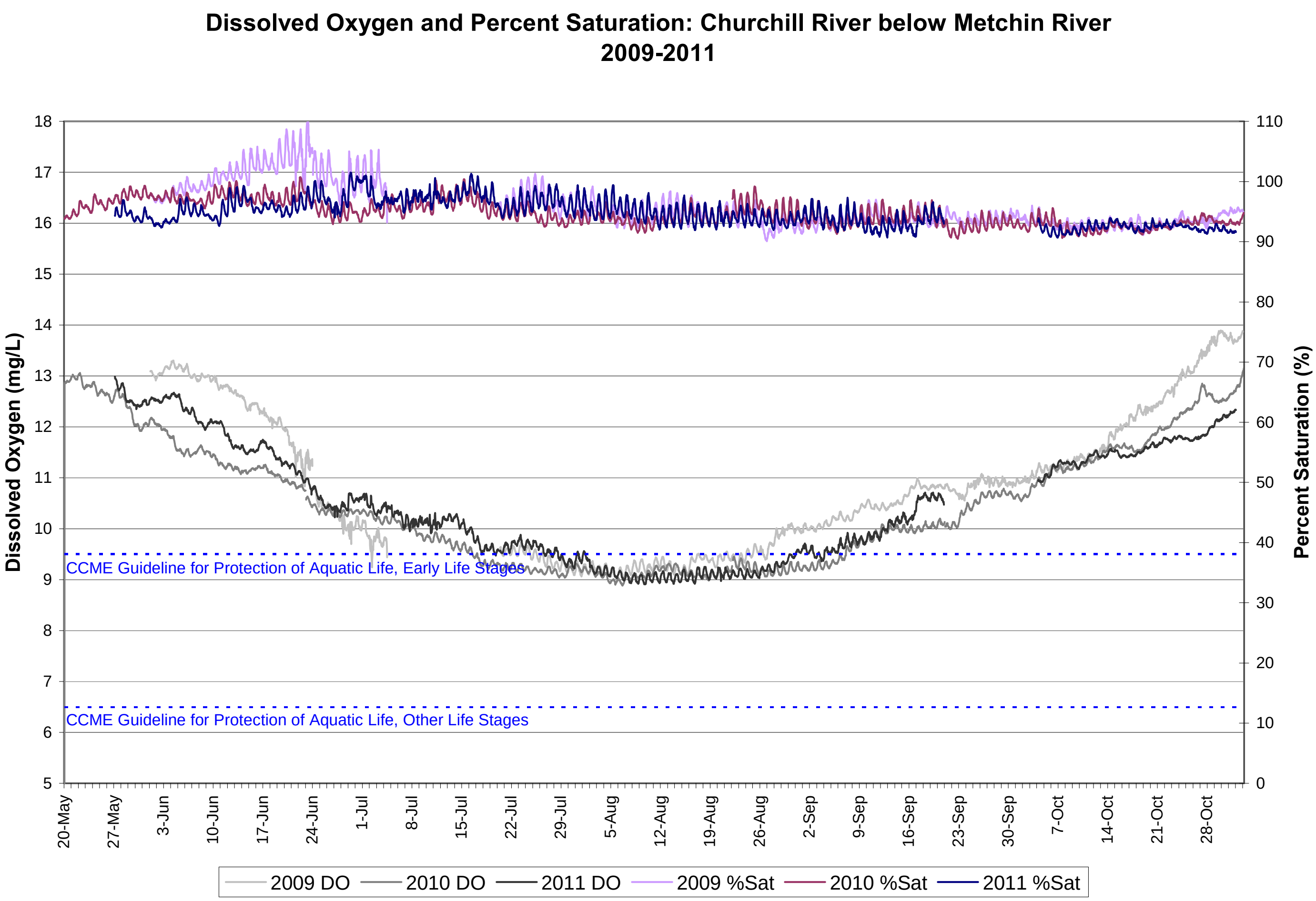


Figure 5: Dissolved oxygen and percent saturation at Churchill River below Metchin River

Dissolved Oxygen (mg/L)	2011	2010	2009		Percent Saturation (%)	2011	2010	2009
Average	10.50	10.48	10.88		**Average**	94.8	94.7	95.8
Max	12.99	13.15	13.89		**Max**	101.5	100.7	110.5
Min	8.91	8.88	9.00		**Min**	90.7	90.5	90.1

- Turbidity generally remains at 0NTU for the majority of the deployment season (Figure 6). A median value of 0 NTU indicates there is no natural background turbidity value at this station.
- There are a couple of instances where turbidity increases (to as high as 76.2NTU) for very short periods of time (1-3 hours). These are not considered water quality events as they are isolated and infrequent occurrences.
- When 2011 values are compared to 2009 and 2010 values it is interesting to note the amount of variability in turbidity during the first month of deployment (late May to late June). A similar pattern is seen with specific conductivity (Figure 4). This increased variability and higher turbidity values may be in part caused by the spring run off and higher water levels.

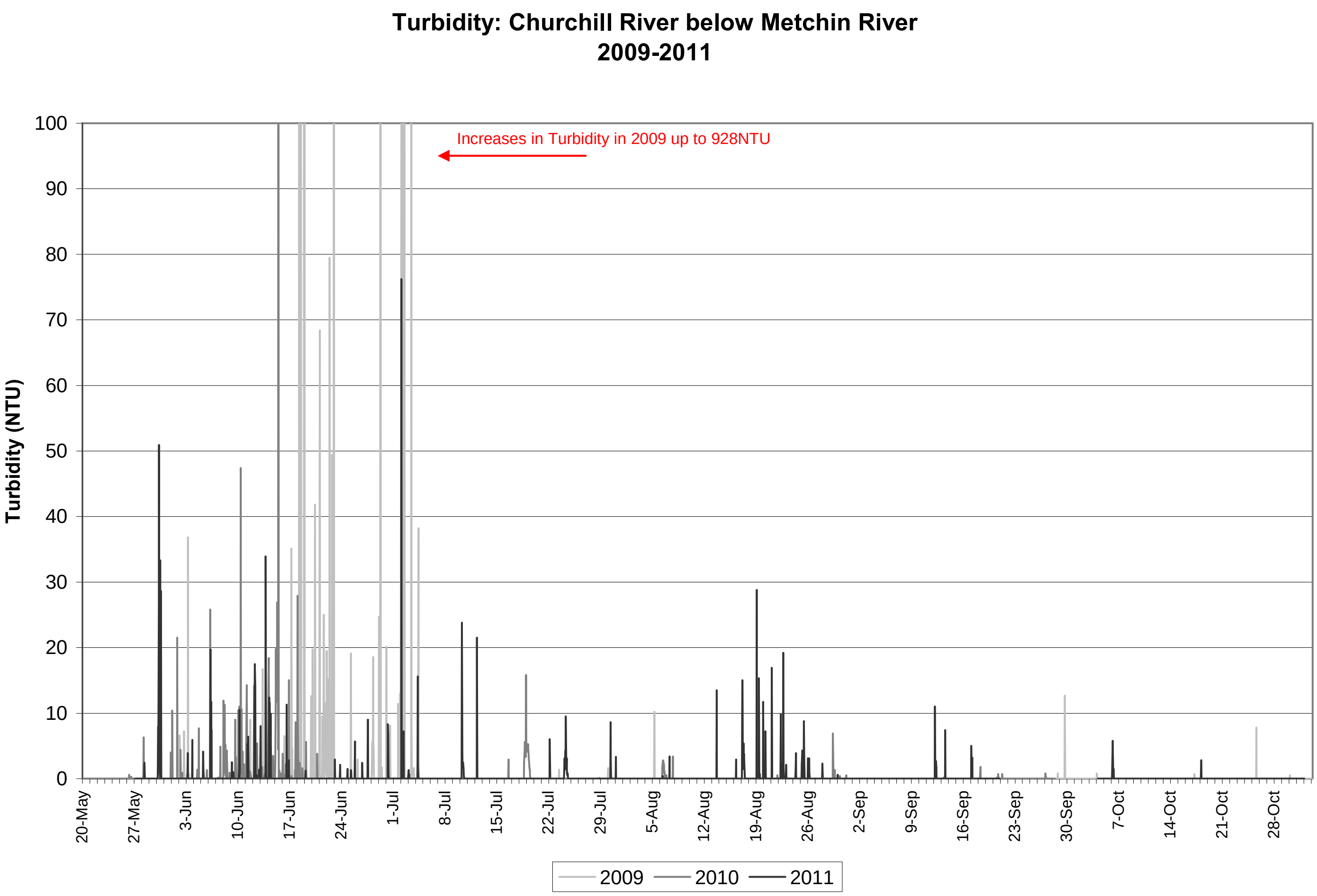


Figure 6: Turbidity at Churchill River below Metchin River

Turbidity (NTU)	2011	2010	2009
Median	0	0	0
Max	76.2	204.2	928
Min	0	0	0

Lower Churchill River, Newfoundland and Labrador

- Stage levels from 2009-2011 are graphed below to show how stage levels vary throughout the season and from year to year (Figure 7). Stage level trends typically following the same pattern, decreasing in the spring and early summer, reaching a seasonal low late in the summer or early fall. Stage levels throughout the season were comparable throughout the three years. Stage levels are on average lower in 2009 through the summer months when compared to the 2010 and 2011 data.

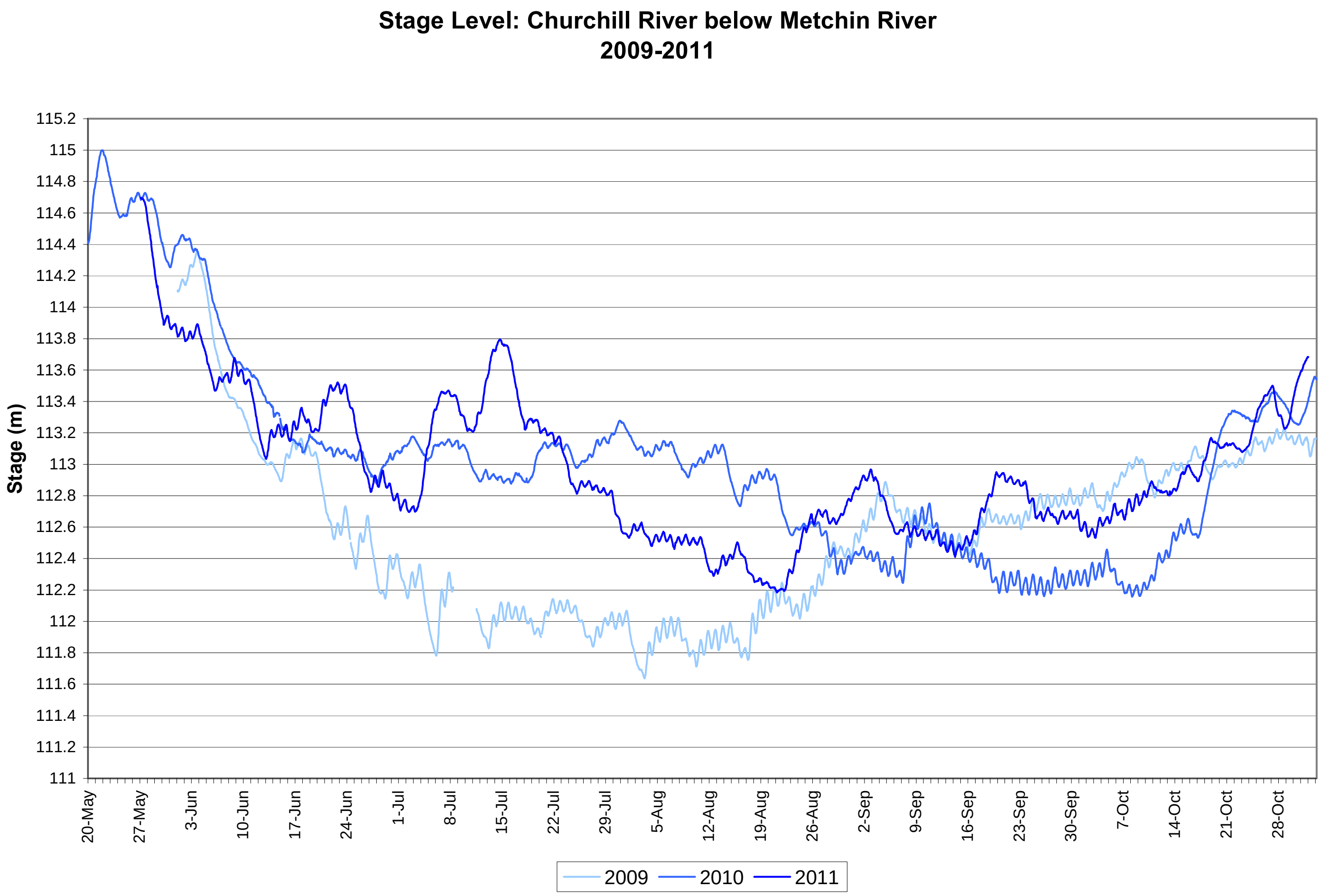


Figure 7: Stage level at Churchill River below Metchin River

Stage (m)	2011	2010	2009
Average	112.970	113.029	112.576
Max	114.696	114.999	114.356
Min	112.184	112.157	111.637

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 8). Stage is decreasing for much of the first half of the deployment period with a significant increase in late July that corresponds with consistent moderate rainfall events. Stage began to increase again near the end of August for the remainder of the deployment season until November.

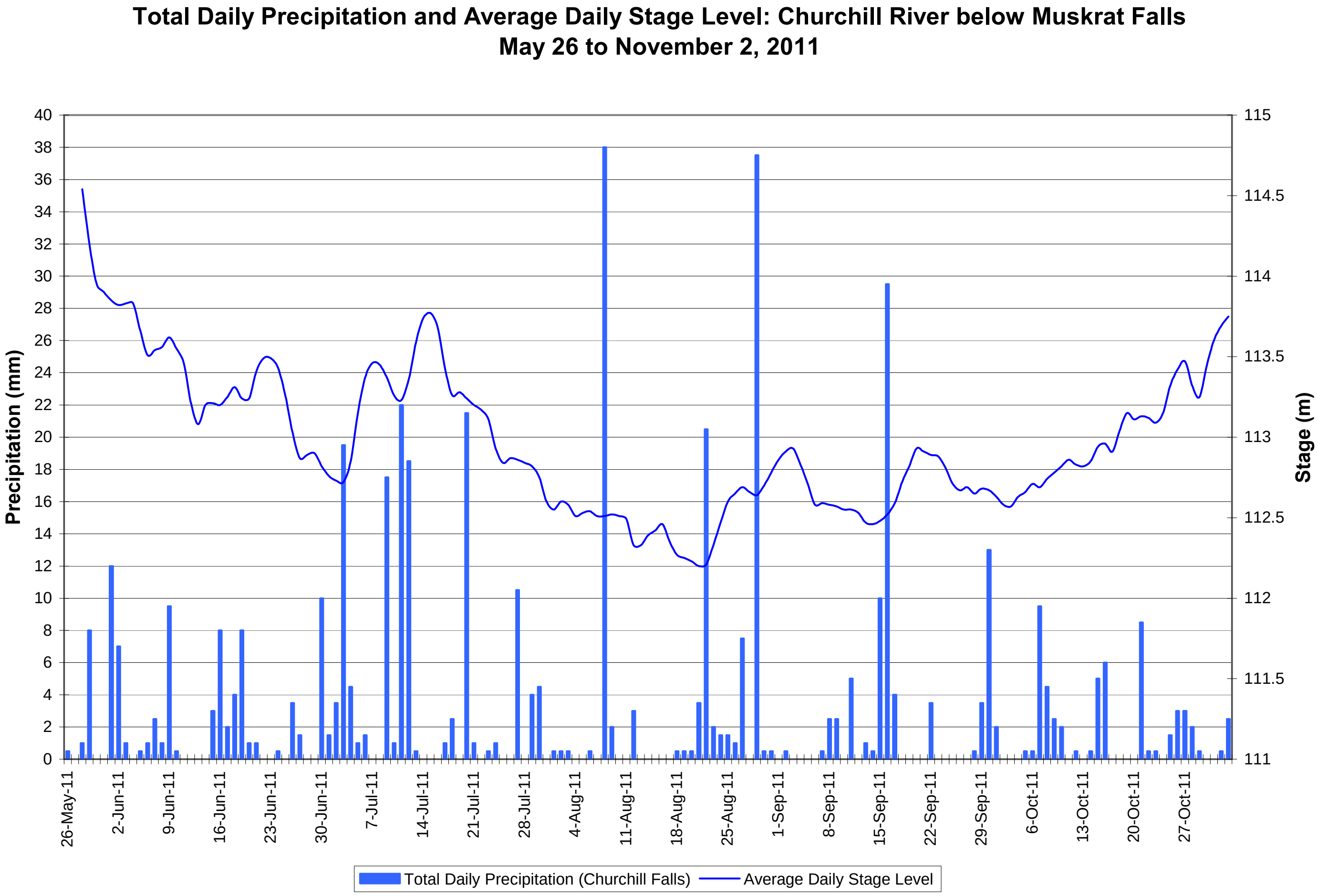


Figure 8: Daily precipitation and average daily stage level at Churchill River below Metchin River

(weather data recorded at Churchill Falls)

Churchill River below Grizzle Rapids

- No instrument was deployed at this station during the deployment period between May 27 and June 29. A large ice wall remained on the river edge preventing safe access to the water body. Similar delays in deployment have occurred in 2009 and 2010 at this station.

- Water temperature ranged from 2.10°C to 19.90°C during the 2011 deployment season, averaging 19.91°C (Figure 9).
- On average, water temperatures are slightly cooler in 2011 when compared to 2010 values and slightly warmer than in 2009.

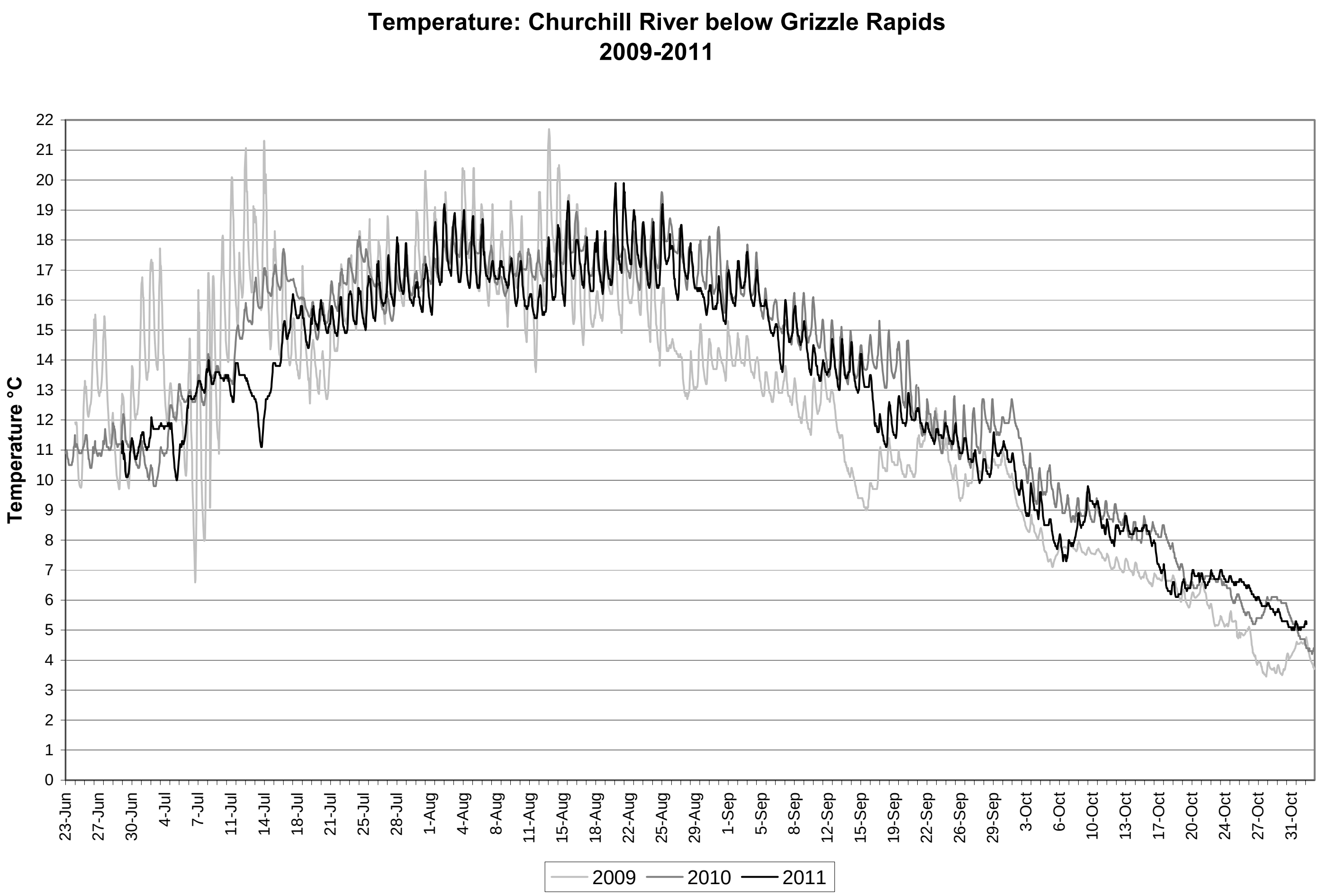


Figure 9: Water temperature at Churchill River below Grizzle Rapids

Temperature	2011	2010	2009
Average	12.91	13.26	12.36
Max	19.90	19.60	21.70
Min	5.00	4.20	3.45

- Water temperature values show a typical seasonal trend (Figure 10). Water temperature is increasing for the first part of the deployment season during the early summer. Water temperature peaks in mid August at 19.90°C. Water temperature begins to decrease in the latter half of August and into the fall season as the air temperatures cool.

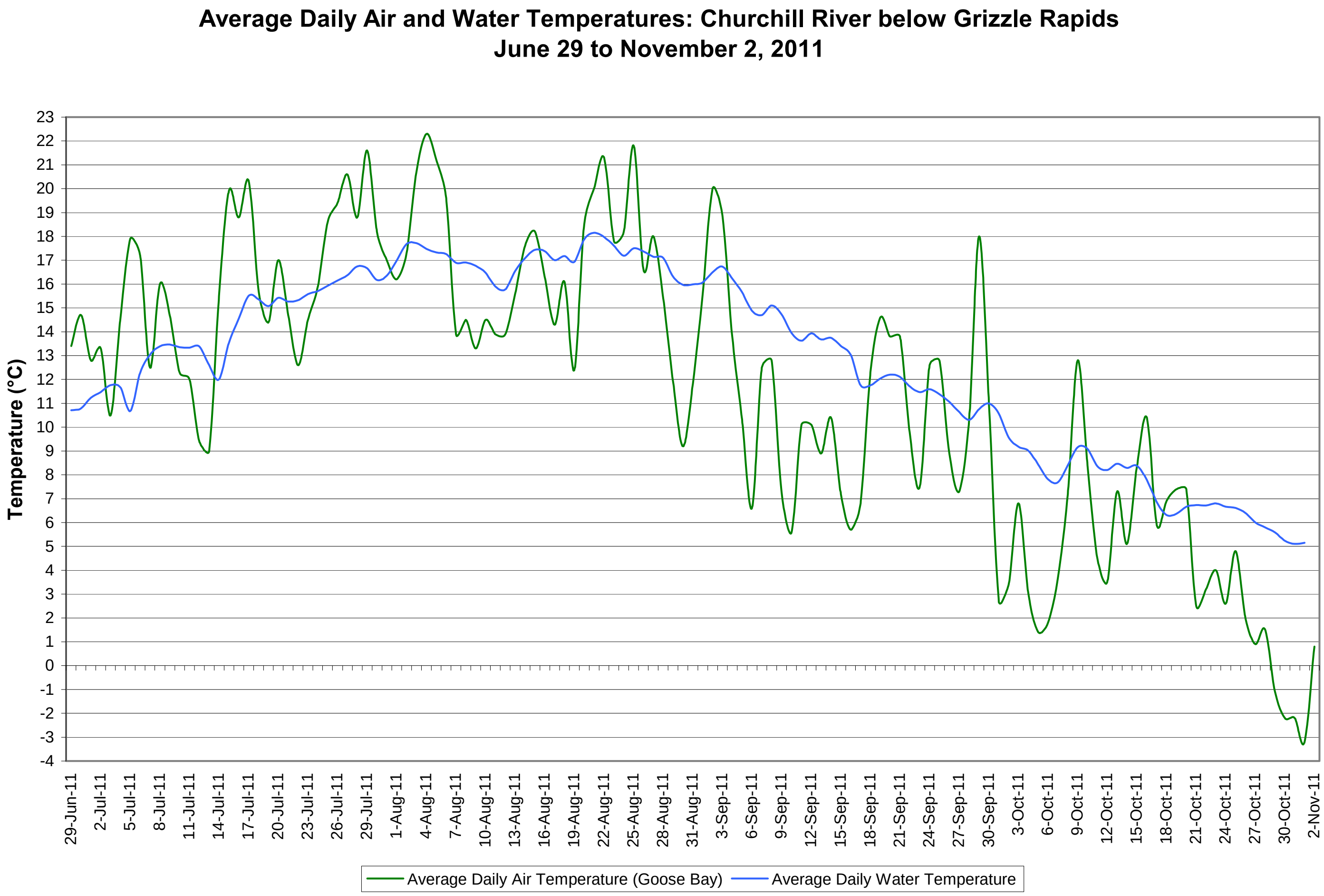


Figure 10: Average daily air and water temperatures at Churchill River below Grizzle Rapids (weather data recorded at Goose Bay)

- pH ranges between 6.73 and 7.44 pH units throughout the 2011 deployment season, averaging 7.09 pH units (Figure 11).
- pH values are consistent throughout the deployment season with a clear diurnal fluctuation. pH values in 2011 are comparable to the data collected in 2009 and 2010 for this station.
- All values during the 2011 deployment season are within the CCME Guidelines for the Protection of Aquatic Life (indicated in blue on Figure 11).

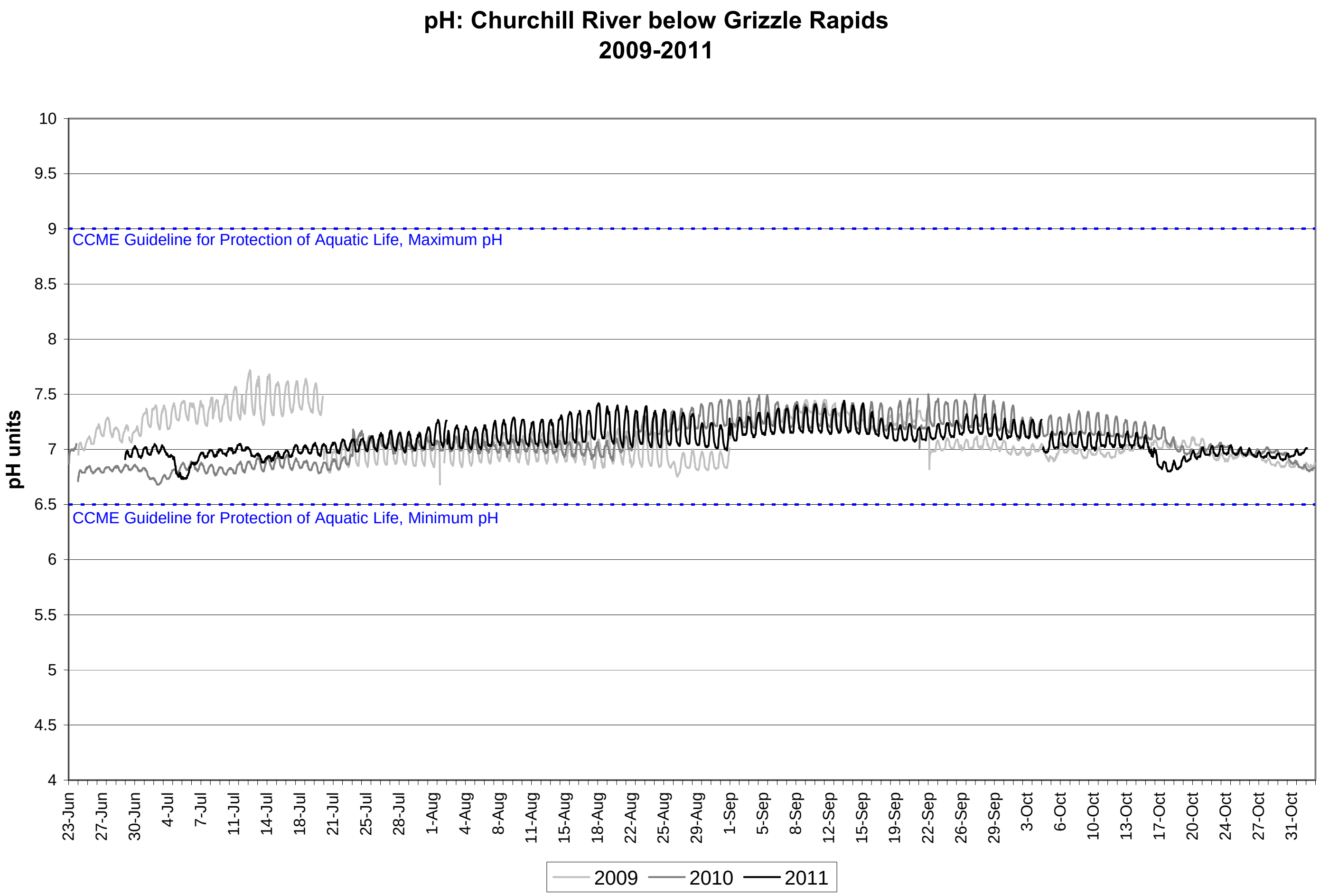


Figure 11: pH at Churchill River below Grizzle Rapids

pH (units)	2011	2010	2009
Average	7.09	7.07	7.10
Max	7.44	7.50	7.72
Min	6.73	6.68	6.68

- Specific conductivity ranges from 12.7 to 21.9µS/cm during the 2011 deployment season, averaging 17.88µS/cm (Figure 12).
- Specific conductance tends to increase for the first half of the deployment season while stage decreases. For the deployment period between September 1 and October 4, specific conductivity values are on average lower than expected. Unusually low specific conductivity values were also found at the stations above Muskrat Falls for the same time period and at below Muskrat Falls from August 2 to September 1. These low values are specific to the deployment period therefore it is likely that this is an error caused by instrument calibration. Specific conductivity values are within the expected range for the remainder of the deployment season until November 2011.
- Stage is included in Figure 12 to illustrate the inverse relationship between conductivity and water level. Stage is generally decreasing throughout the first half of the deployment season while specific conductivity in increasing. As stage decreases, specific conductivity usually increases as the concentration of dissolved solids increases. Inversely, as stage increases, specific conductivity generally decreases due to the dilution of dissolved solids in the water column.

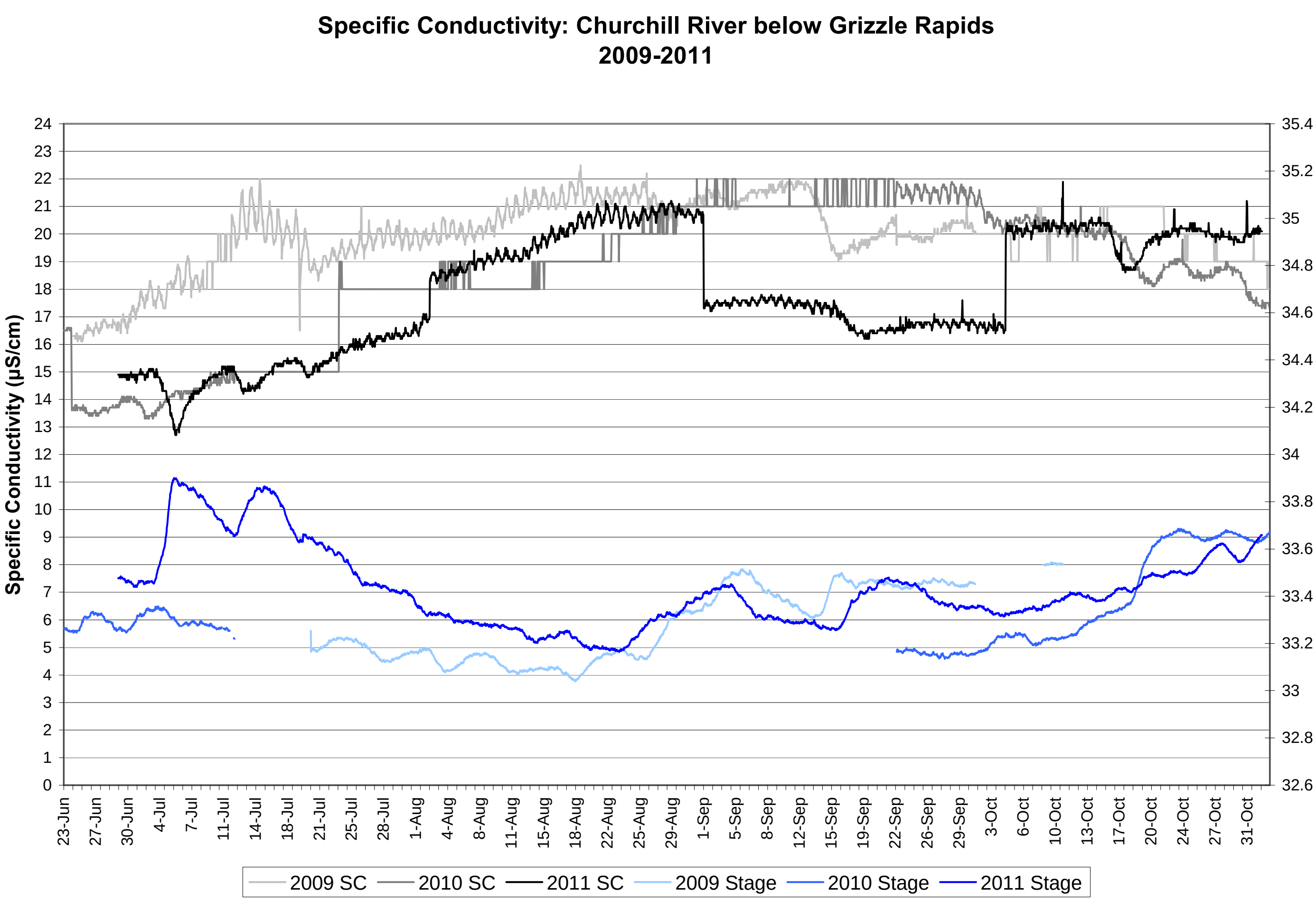


Figure 12: Specific conductivity and stage level at Churchill River below Grizzle Rapids

Specific Conductivity (µS/cm)	2011	2010	2009
Average	17.9	18.6	20.0
Max	21.9	22.0	22.5
Min	12.7	13.3	16.1

- During the 2011 deployment season, dissolved oxygen ranged from 8.9 and 11.4mg/l, averaging 9.93mg/l, while percent saturation ranged from 91.5% to 104.7%, averaging 97.4% (Figure 13). There is no dissolved oxygen or percent saturation data available for the last deployment period between October 4 and November 1 due to sensor failure.
- All values were above the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5 mg/l). Most values were above the minimum CCME Guideline for the Protection of Aquatic Life at Early Life Stages (9.5mg/l). From early August to early September, during the warmest part of the season, dissolved oxygen content was just below this guideline. The guidelines are indicated in blue on Figure 13.
- Dissolved oxygen content shows a typical seasonal fluctuation in 2011, decreasing throughout the spring and early summer months during the time when water temperatures are increasing. Dissolved oxygen content reaches a seasonal low in early August. When water temperatures begin to decrease in the late summer and fall, dissolved oxygen content begins to rise again.
- When compared to data from 2009 and 2010, the same trend is evident due to the inverse relationship between dissolved oxygen and water temperature.

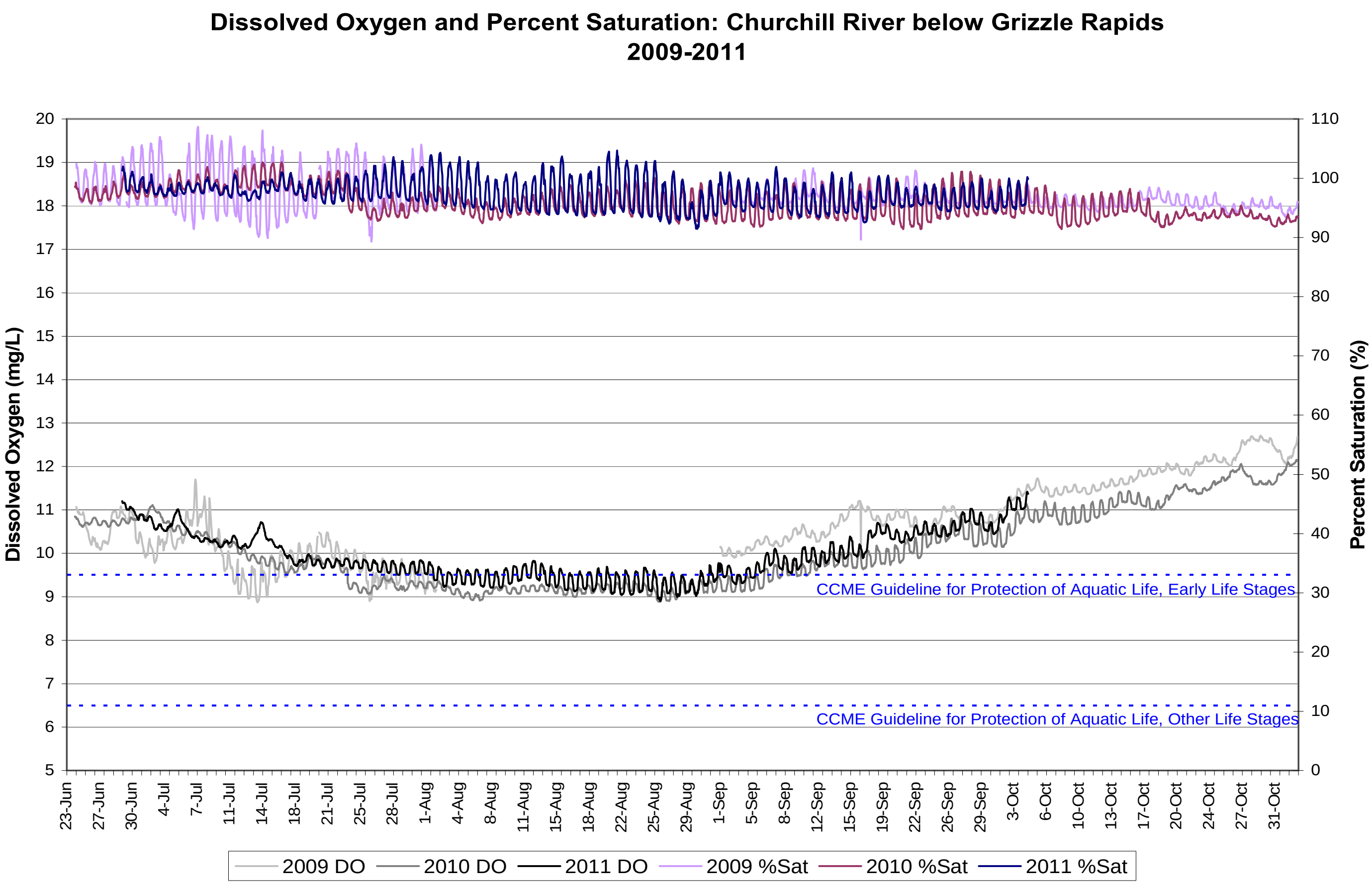


Figure 13: Dissolved oxygen and percent saturation at Churchill River below Grizzle Rapids

Dissolved Oxygen (mg/L)	2011	2010	2009		Percent Saturation	2011	2010	2009
Average	9.93	10.10	10.77		Average	97.4	95.8	97.3
Max	11.42	12.15	12.71		Max	104.7	102.7	108.7
Min	8.90	8.89	8.87		Min	91.5	91.4	89.3

- Turbidity generally remains at 0NTU for the majority of the deployment season (Figure 14). A median value of 0 NTU indicates there is no natural background turbidity value at this station.
- There are a couple of instances where turbidity increases (to as high as 41.7NTU) for very short periods of time (1-3 hours). These are not considered water quality events as they are isolated and infrequent occurrences.
- Similar trends have been identified in the 2009 and 2010 datasets for this station.

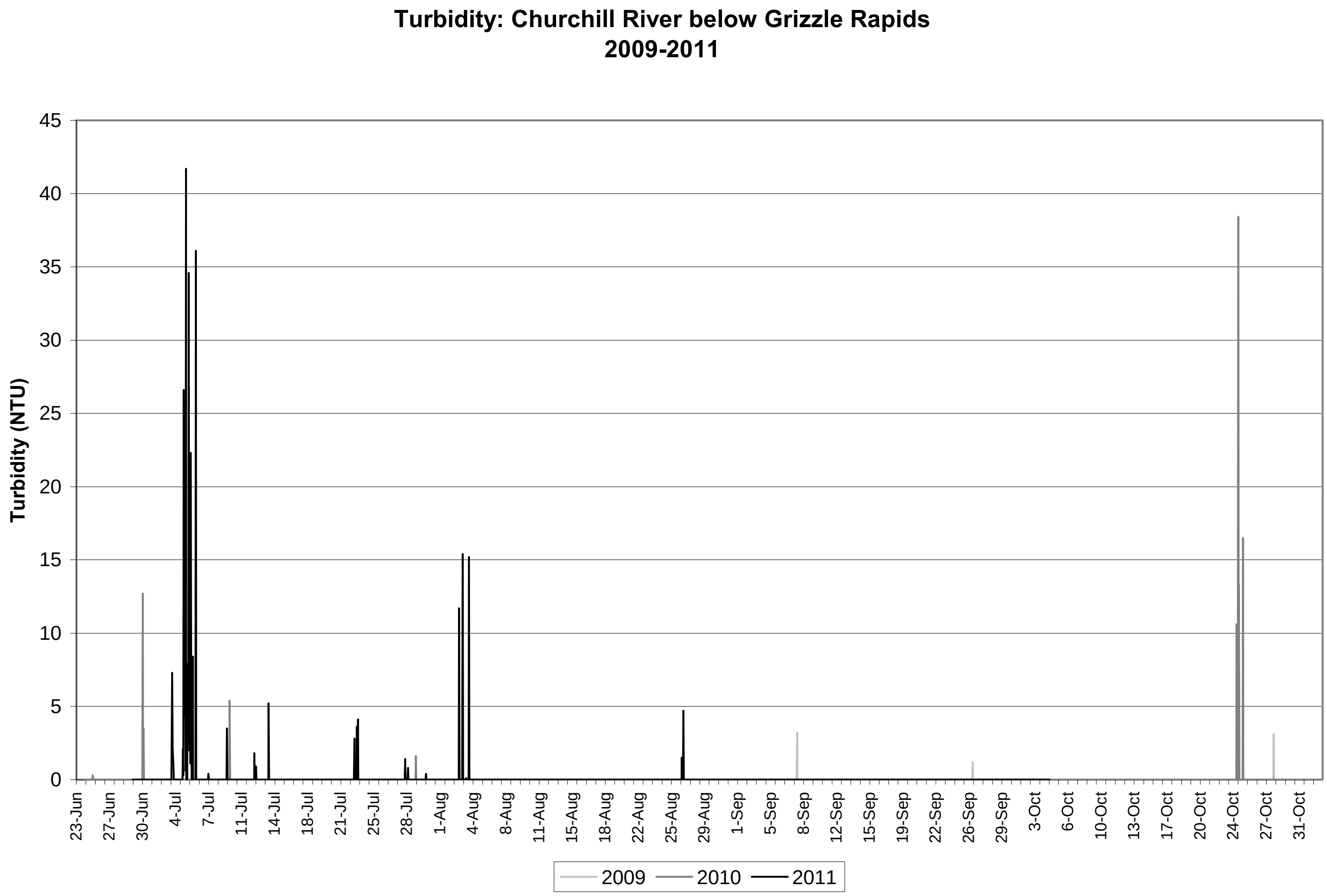


Figure 14: Turbidity at Churchill River below Grizzle Rapids

Turbidity (NTU)	2011	2010	2009
Median	0	0	0
Max	41.7	38.4	3.2
Min	0	0	0

- Stage levels from 2009-2011 are graphed below to show how stage levels vary throughout the season and from year to year (Figure 15). Stage level trends differ slightly from year to year at this station. Large parts of the dataset are missing for the 2009 and 2010 seasons because the station was not transmitting. In 2011, stage increases at the beginning of the deployment season in early July before decreasing consistently and reaching a seasonal low in late August. Stage fluctuates for a number of weeks before increasing slightly towards the end of the deployment season in November.

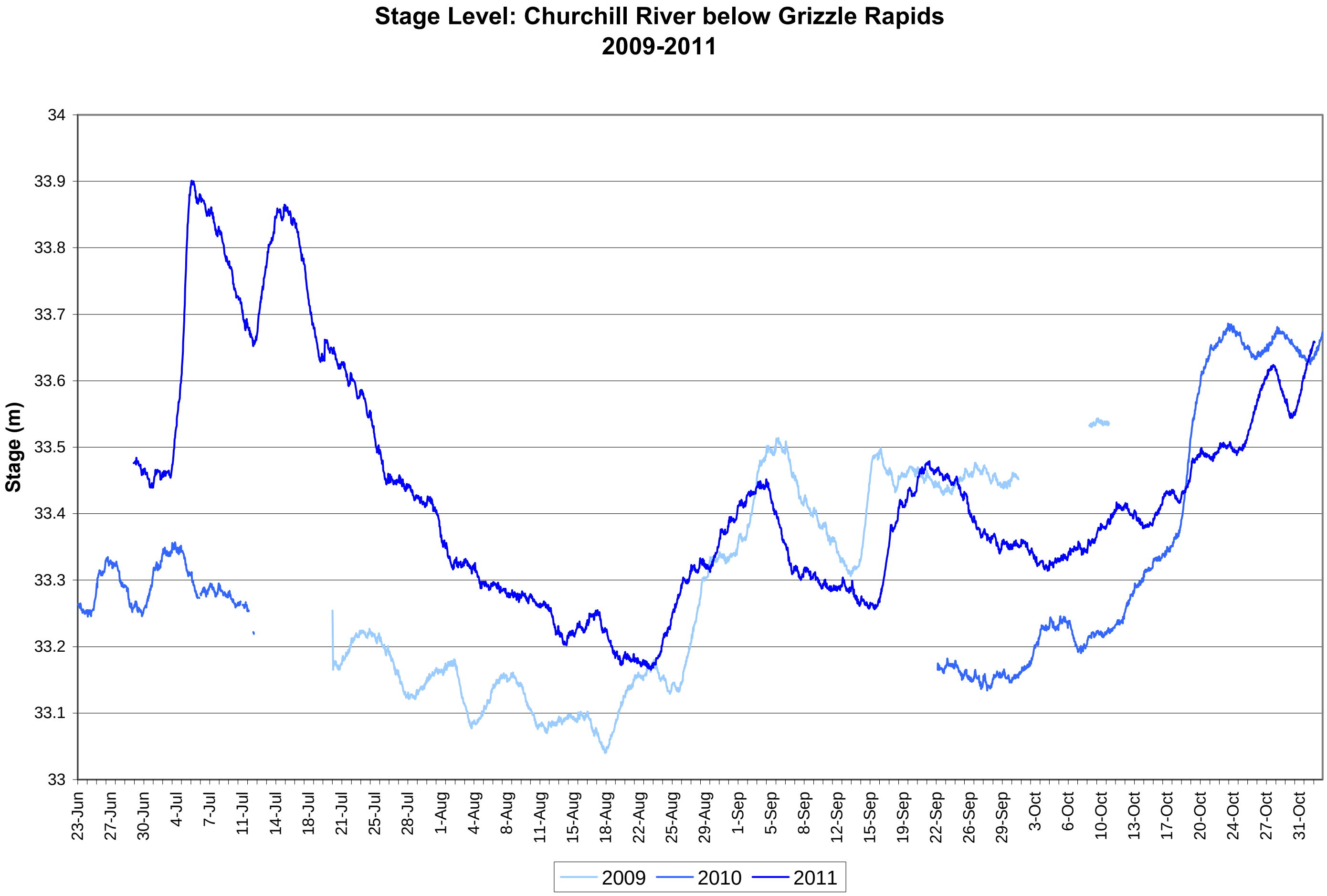


Figure 15: Stage level at Churchill River below Grizzle Rapids

Stage (m)	2011	2010	2009
Average	33.430	33.347	33.278
Max	33.901	33.686	33.543
Min	33.165	33.134	33.040

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 16). Stage increases in early July during consistent moderate rainfall events before decreasing for much of the first half of the deployment period Stage began to increase again near the end of August for the remainder of the deployment season until November.

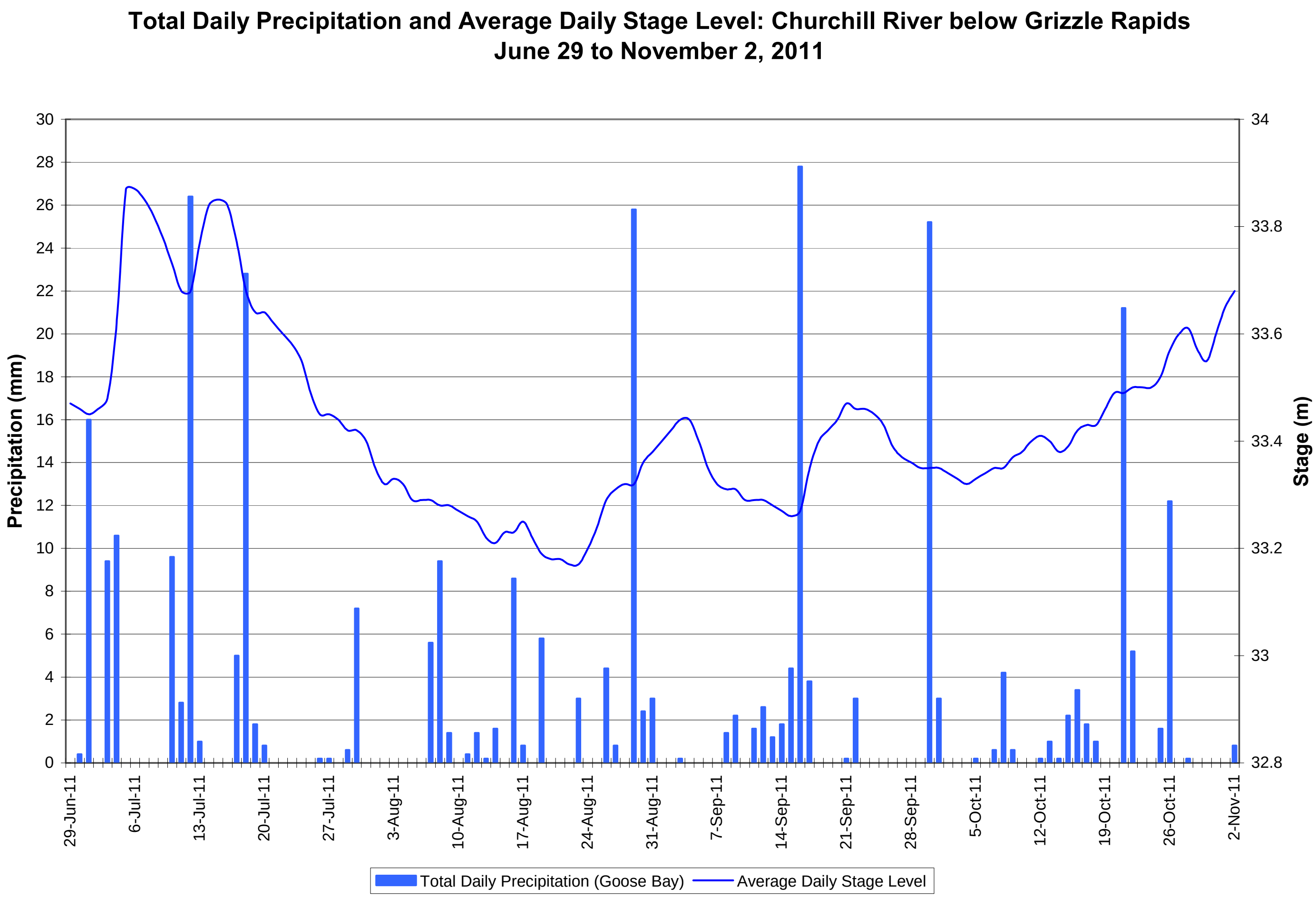


Figure 16: Daily precipitation and average daily stage level at Churchill River below Grizzle Rapids

(weather data recorded at Goose Bay)

Churchill River above Muskrat Falls

- Water temperature ranged from 2.72 to 19.3°C during the 2011 deployment season, averaging 12.28°C (Figure 17).
- On average, water temperatures are slightly warmer in 2011 when compared to 2009 and slightly cooler than in 2010.

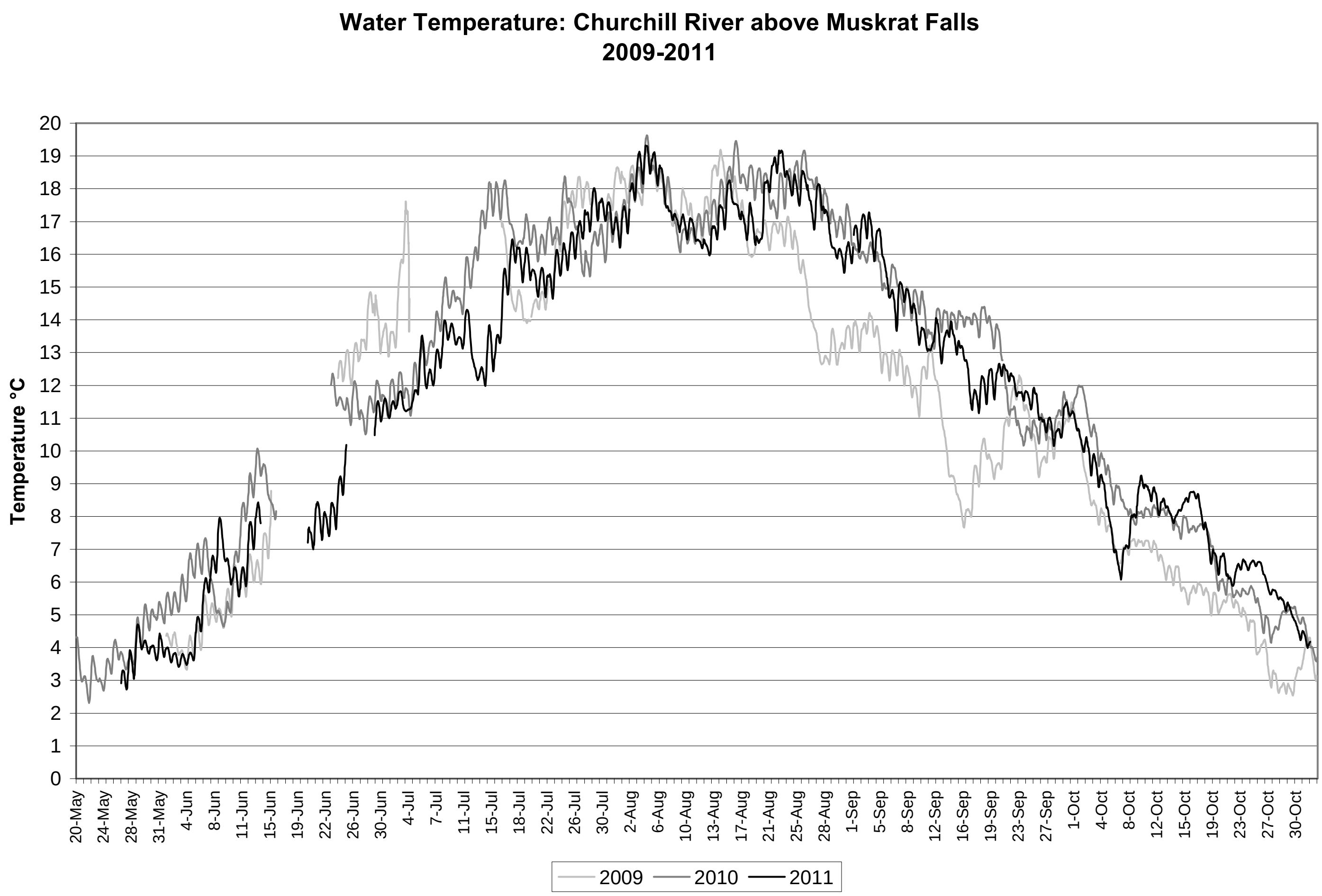


Figure 17: Water temperature at Churchill River above Muskrat Falls

Temperature	2011	2010	2009
Average	11.87	11.98	11.32
Max	19.32	19.63	19.26
Min	2.72	2.31	2.54

- Water temperature values show a typical seasonal trend (Figure 18). 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 19.30°C. Water temperature begins to decrease in the latter half of August and into the fall season as air temperatures cool.

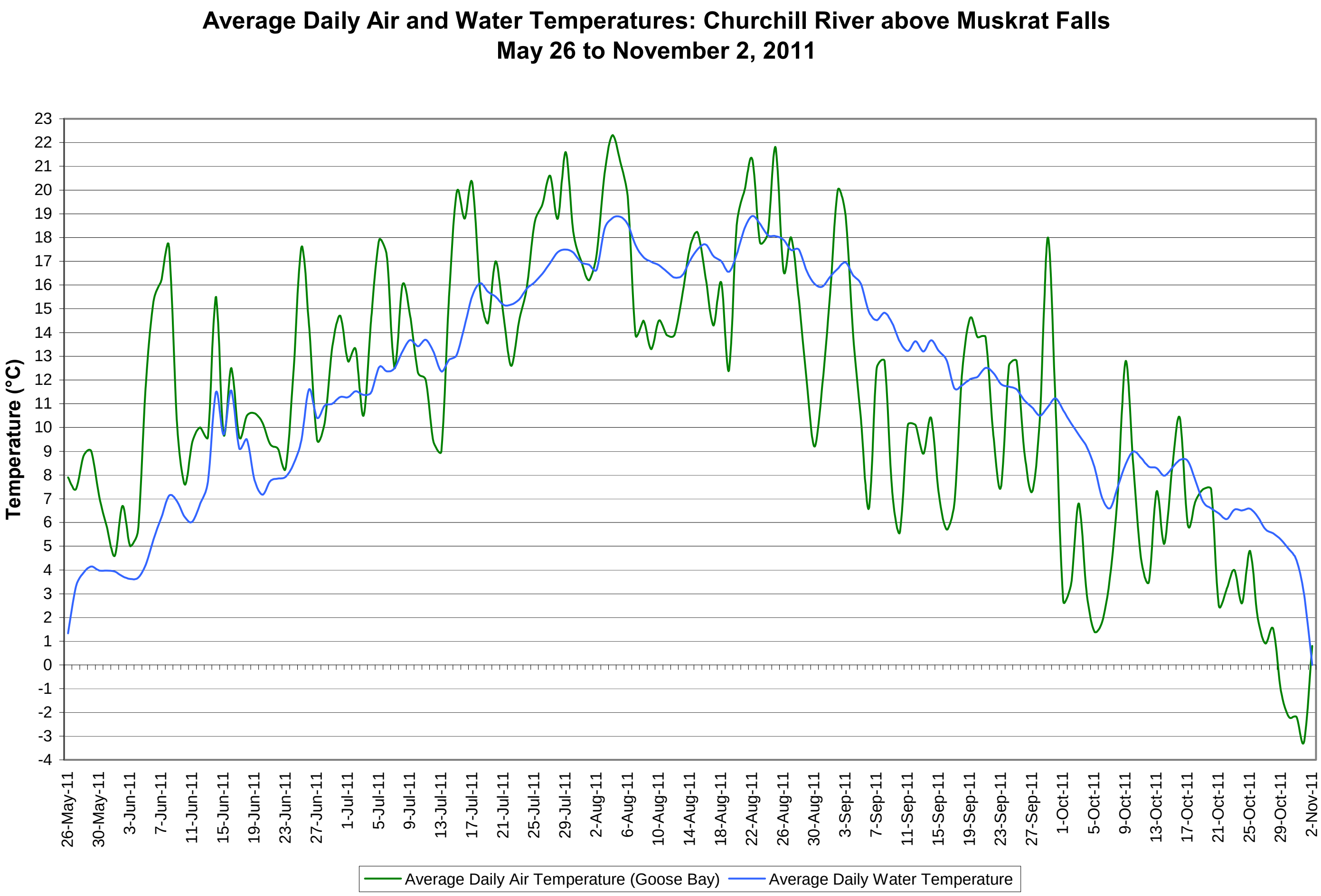


Figure 18: Average daily air and water temperatures at Churchill River above Muskrat Falls

(weather data recorded at Goose Bay)

- pH ranged between 6.40 and 7.36 pH units during the 2011 deployment season, averaging 7.02 pH units (Figure 19).
- pH values are increasing slightly through the first half of the deployment season when the water is warming and stage is decreasing. pH values are very consistent throughout the three years of data collected at this station.
- All values are within the CCME Guidelines for the Protection of Aquatic Life with the exception at the very beginning of the May-June 2011 deployment period when values were just below the guideline for a short period of time. Guidelines are indicated in blue on Figure 19.

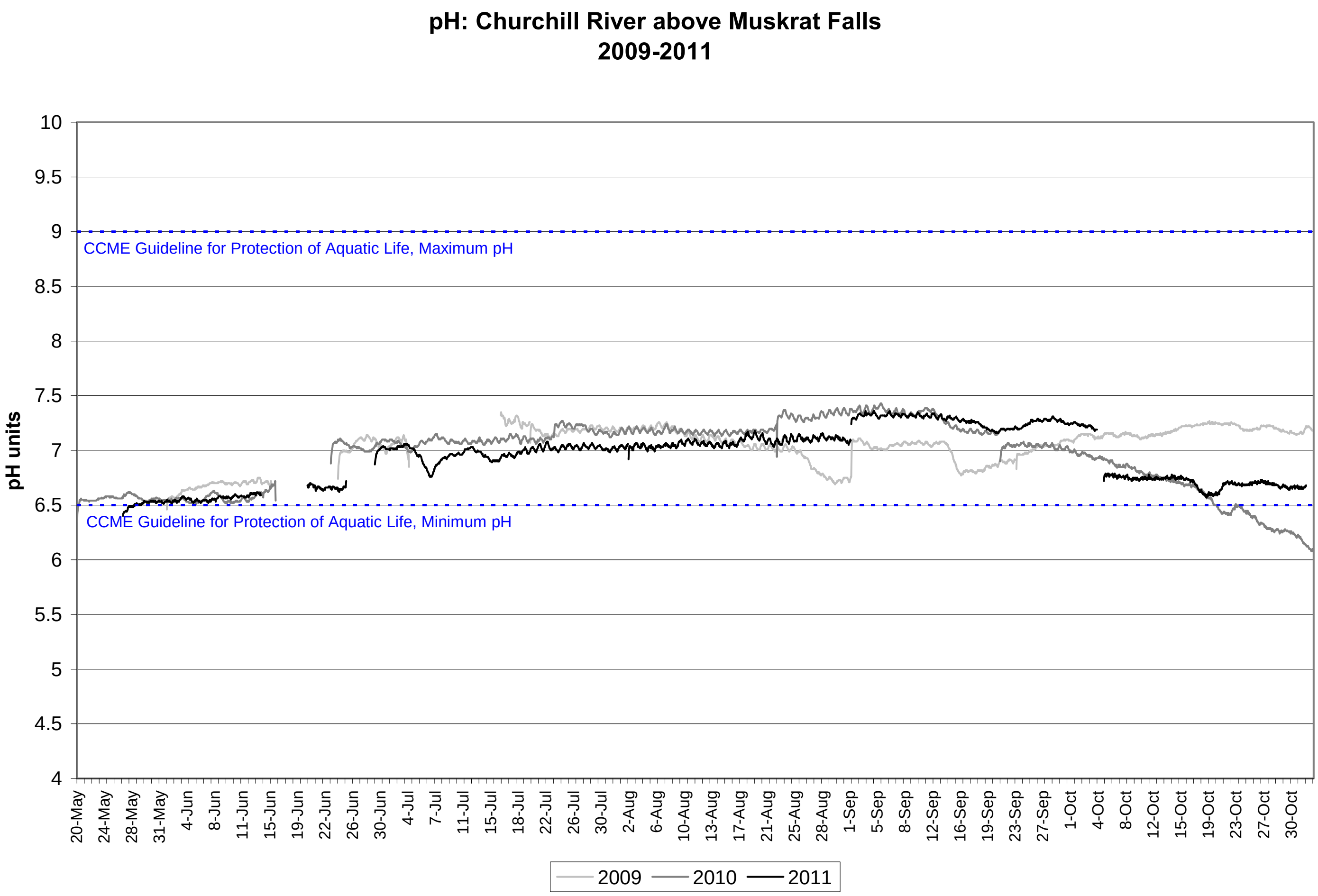


Figure 19: pH at Churchill River above Muskrat Falls

pH (units)	2011	2010	2009
Average	6.95	6.95	7.04
Max	7.36	7.43	7.35
Min	6.40	6.08	6.46

- Specific conductivity ranged from 12.0 to 31.3µS/cm during the 2011 deployment season, averaging 16.9µS/cm (Figure 20).
- Specific conductance is generally increasing throughout the first half of the deployment season while stage is decreasing. For the deployment period between September 1 and October 4, specific conductivity values are on average lower than expected. These low values are specific to the deployment period therefore it is likely that this is an error caused by instrument calibration. This calibration error is evident at the station below Grizzle Rapids for the same time period and below Muskrat Falls from August 2 to September 1. Specific conductivity values decrease slightly during the October deployment period.
- Stage is included in Figure 20 to illustrate the inverse relationship between conductivity and water level. Stage is generally decreasing throughout the first half of the deployment season while specific conductivity in increasing. As stage decreases, specific conductivity usually increases as the concentration of dissolved solids increases. Inversely, as stage increases, specific conductivity generally decreases due to the dilution of dissolved solids in the water column.

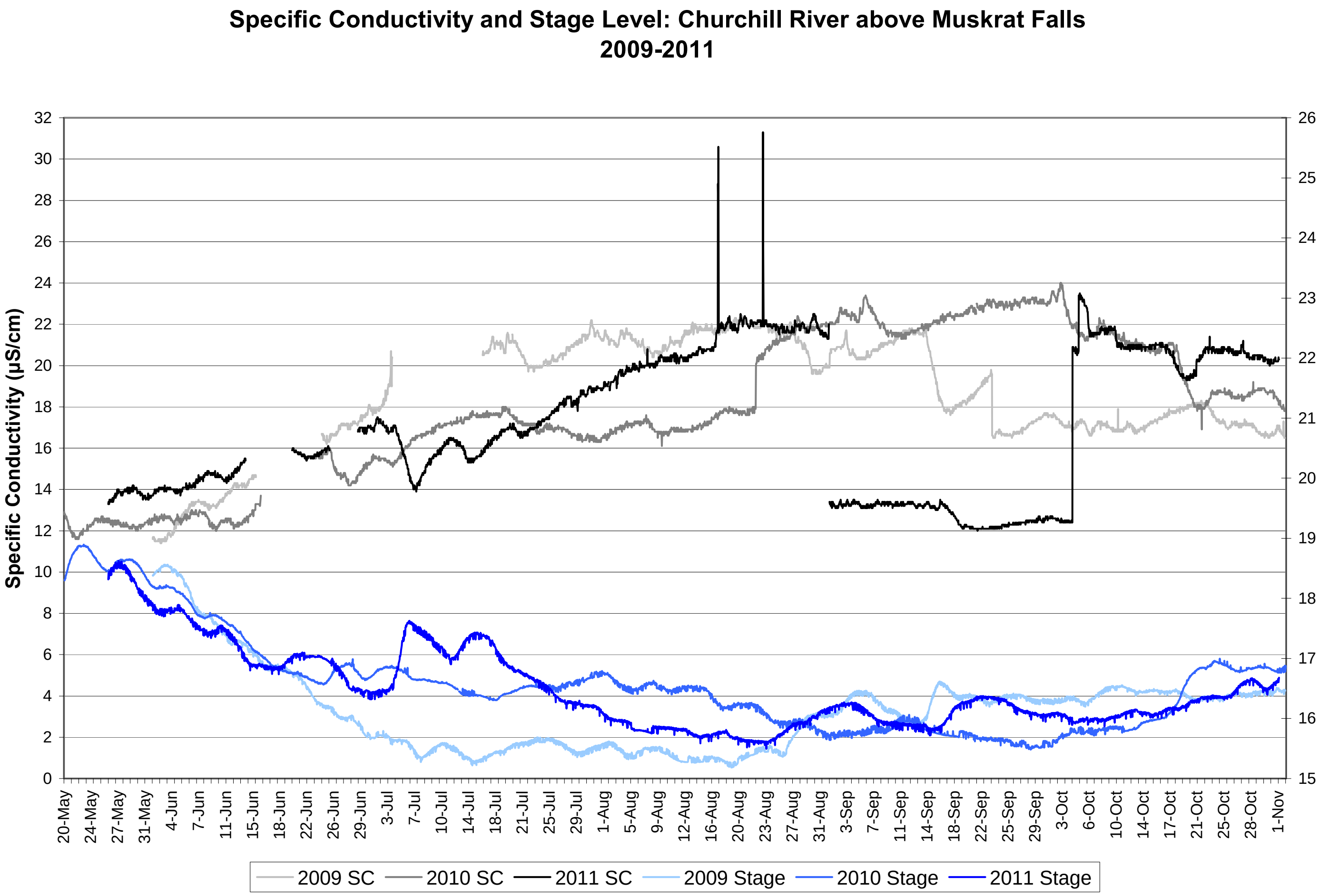


Figure 20: Specific conductivity and stage level at Churchill River above Muskrat Falls

Specific Conductivity (µS/cm)	2011	2010	2009
Average	17.2	18.1	18.7
Max	31.3	24.0	22.4
Min	12.0	11.6	11.4

- Throughout the 2011 deployment season, dissolved oxygen ranged from 9.06 and 13.2mg/l, averaging 10.42mg/L, while percent saturation ranged from 88.9% to 102.3% averaging 95.5% (Figure 21).
- All values were above the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5 mg/l). Most values were above the minimum CCME Guideline for the Protection of Aquatic Life at Early Life Stages (9.5mg/l). From mid July to early September, during the warmest part of the season, dissolved oxygen content was just below this guideline. The guidelines are indicated in blue on Figure 21.
- Dissolved oxygen content shows a typical seasonal fluctuation in 2011, decreasing throughout the spring and early summer months during the time when water temperatures are increasing. Dissolved oxygen content reaches a seasonal low in late August. When water temperatures begin to decrease in the late summer and fall, dissolved oxygen content begins to rise again.
- When compared to data from 2009 and 2010, the same trend is evident due to the inverse relationship between dissolved oxygen and water temperature.

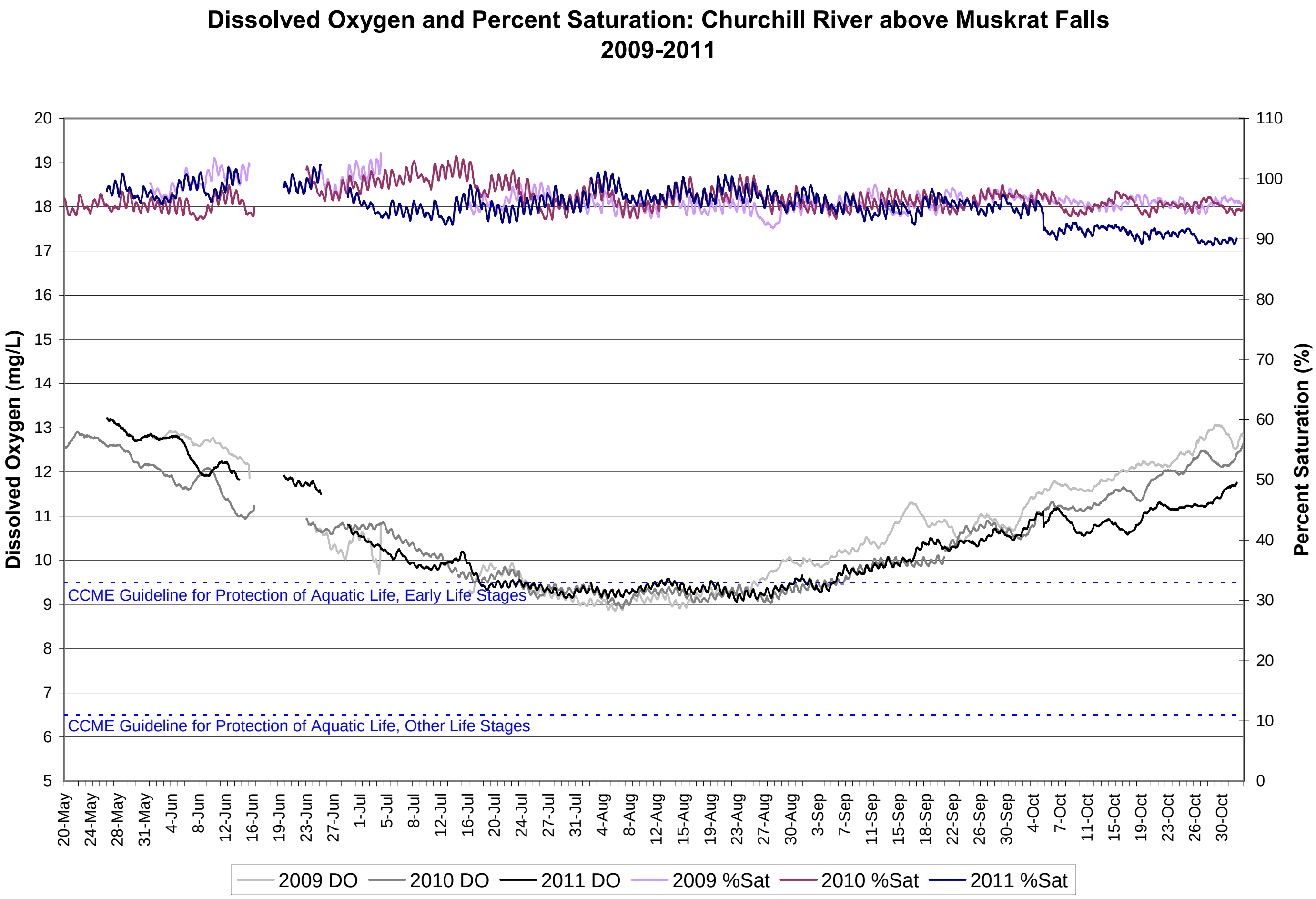
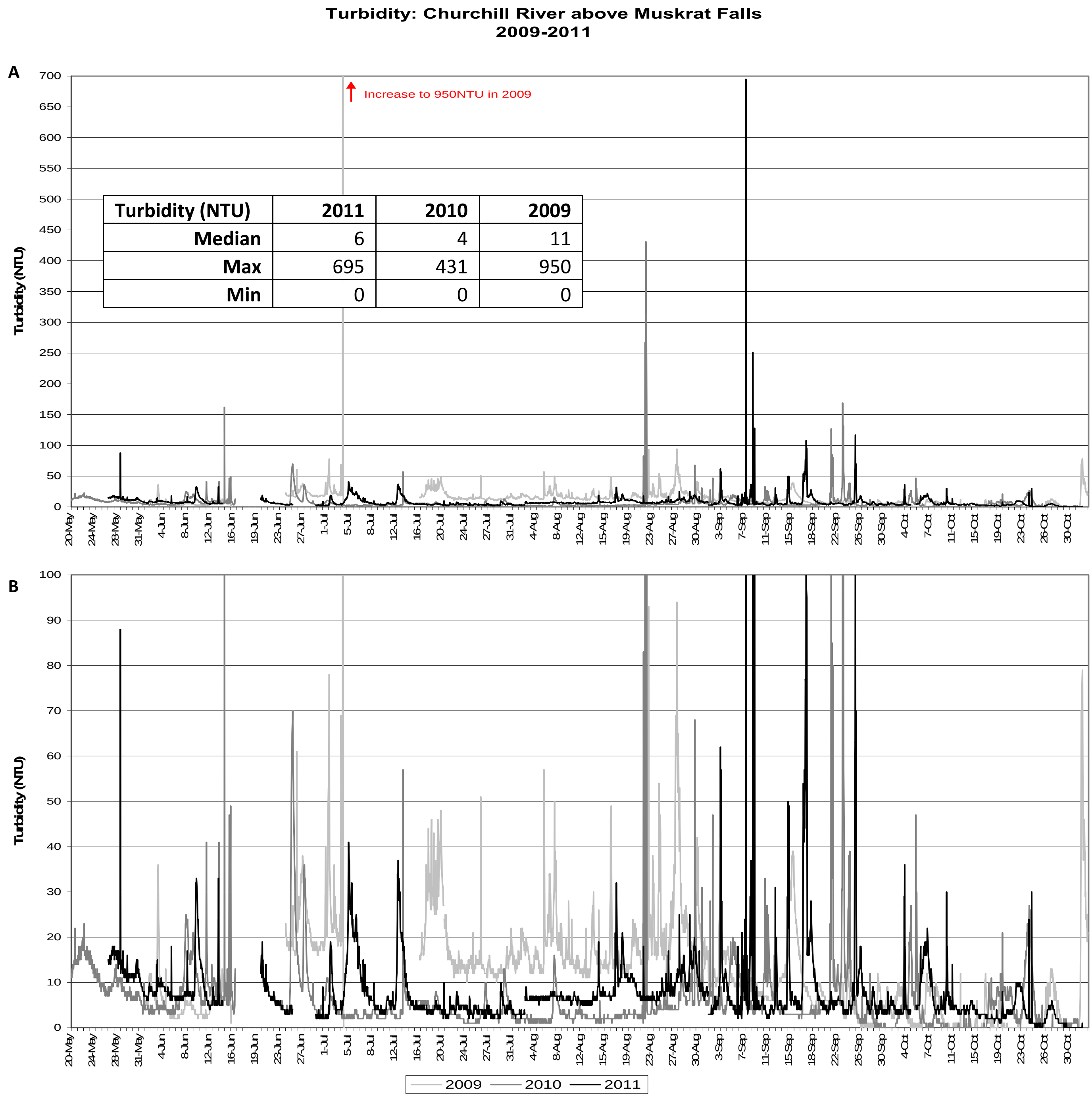


Figure 21: Dissolved oxygen and percent saturation at Churchill River above Muskrat Falls

Dissolved Oxygen (mg/L)	2011	2010	2009		Percent Saturation	2011	2010	2009
Average	10.42	10.55	10.70		Average	95.5	96.8	96.6
Max	13.22	12.91	13.07		Max	102.3	103.8	104.3
Min	9.06	8.92	8.85		Min	88.9	93.1	91.7

- The **majority** of turbidity values (95%) were <18NTU during the 2011 deployment season (Figure 22 a & b). A median value of 6.0NTU indicates there is a consistent natural background turbidity value at this station.
- Turbidity values from 2009 to 2011 are depicted in Figures 22a and 22b below. Figure 22a shows data up to 700NTU. On a number of occasions, turbidity increased above average background levels for short periods of time throughout the deployment season, to as high as 695NTU. Figure 22b shows data at a smaller scale, focusing on the regular consistent background levels, below 100NTU.



Turbidity (NTU)	2011	2010	2009
Median	6	4	11
Max	695	431	950
Min	0	0	0

Figure 22a (top): Turbidity to 700NTU at Churchill River above Muskrat Falls

Figure 22b (bottom): Turbidity to 100NTU at Churchill River above Muskrat Falls

- Stage levels from 2009-2011 are graphed below to show how stage levels vary throughout the season and from year to year (Figure 23). Stage levels differ slightly from year to year at this station. Stage is decreasing at the beginning of each deployment season from 2009 to 2011. In early July 2011, there is a significant increase in stage before levels begin to decrease again until reaching a seasonal low in late August. The seasonal low in 2009 was also in late August but was considerably lower than in 2011. In 2010, the seasonal low did not occur until late September. Stage levels in all years are increasing throughout the last deployment periods in each year.

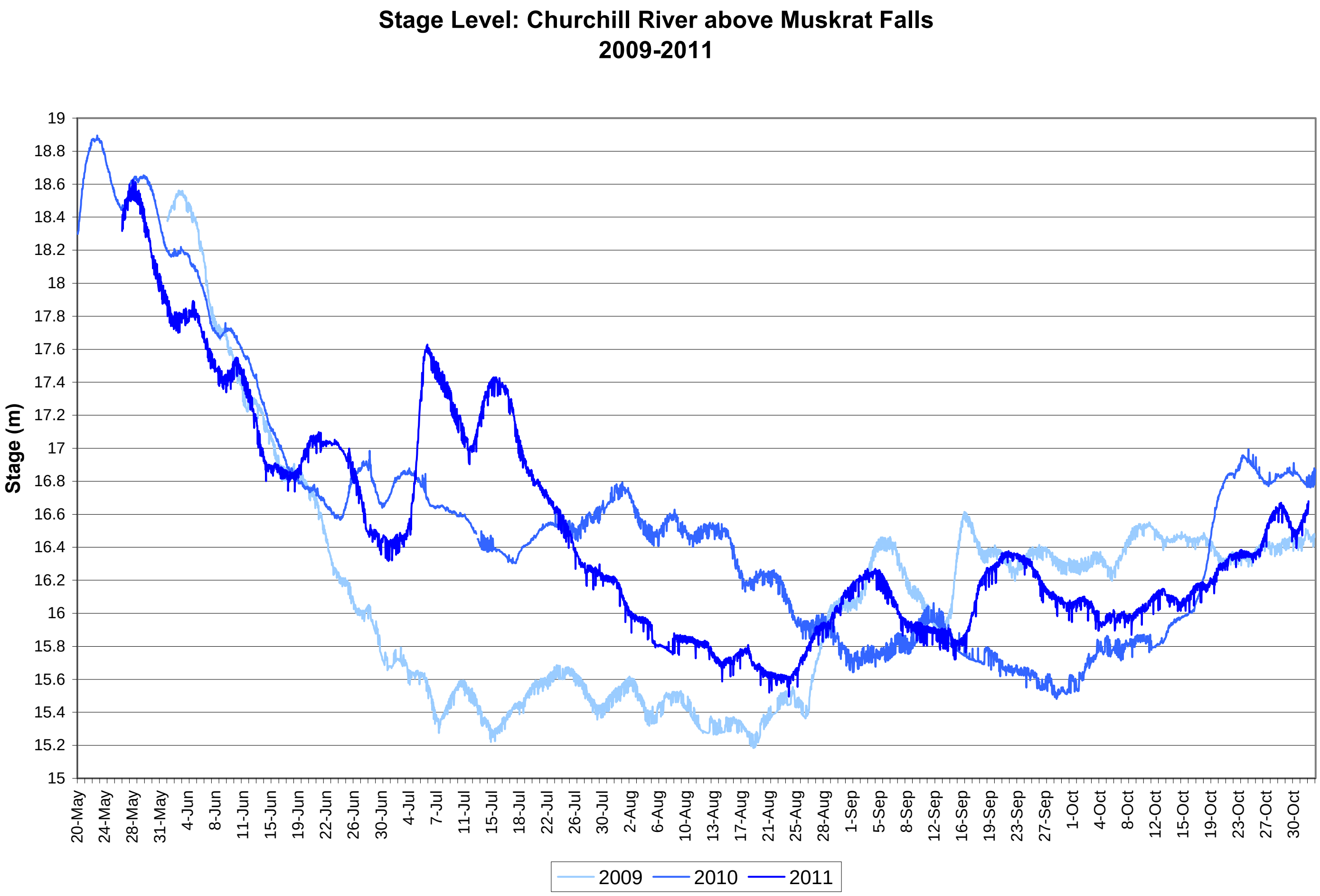


Figure 23: Daily stage level at Churchill River above Muskrat Falls

Stage (m)	2011	2010	2009
Average	16.489	16.576	16.142
Max	18.626	18.896	18.561
Min	15.495	15.481	15.184

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 24). Stage is decreasing at the beginning of the May deployment period and increases in late June during consistent moderate rainfall events. Stage decreases consistently until reaching a seasonal low in late August. Levels increase slowly throughout the fall season.

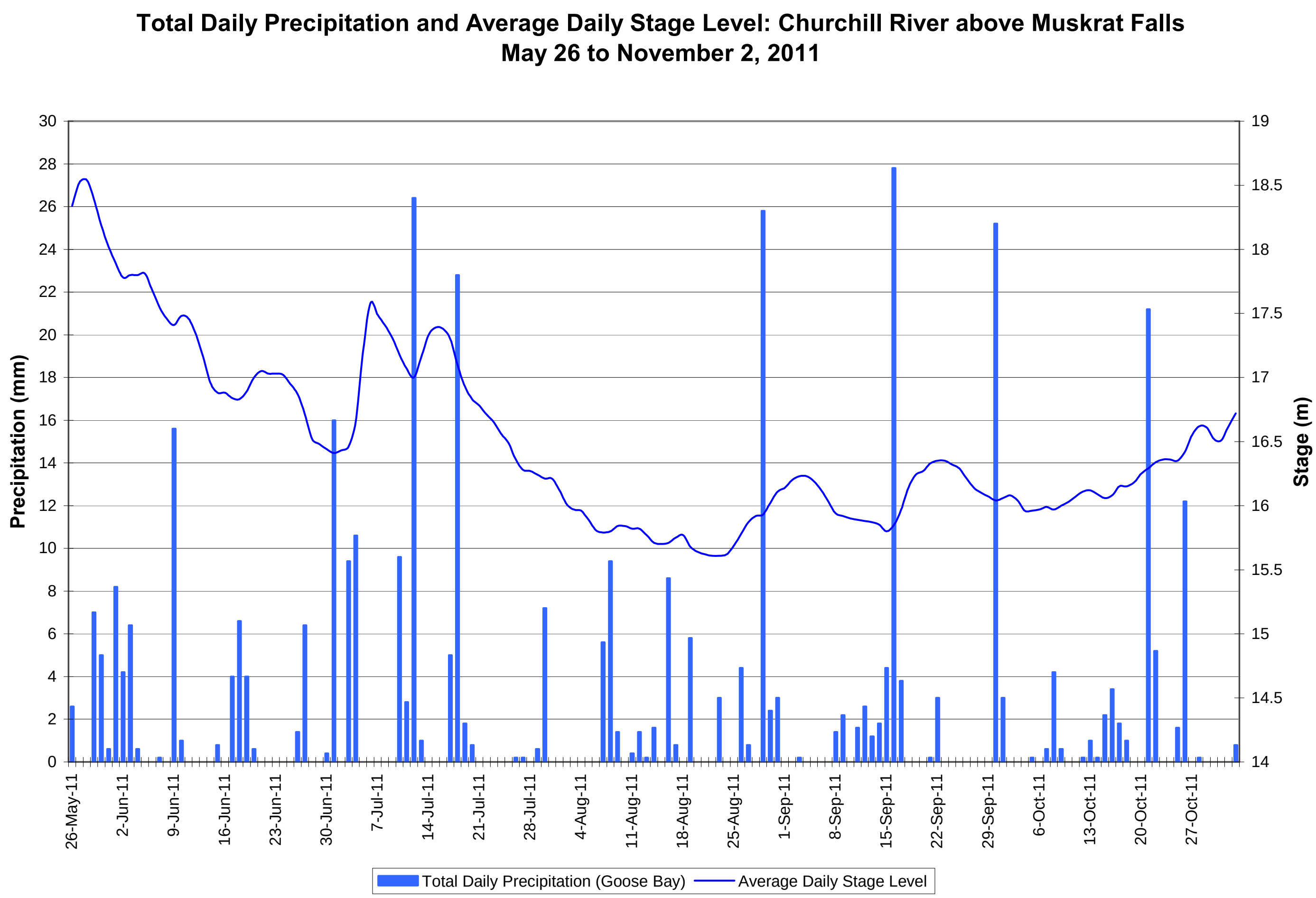


Figure 24: Daily precipitation and average daily stage level at Churchill River above Muskrat Falls

(weather data recorded at Goose Bay)

Churchill River below Muskrat Falls

- Water temperature ranged from 1.9 to 19.2°C during the 2011 deployment season, averaging 12.0°C (Figure 25).
- On average, water temperatures are slightly warmer when compared to data collected in 2009 and slightly cooler than those values recorded in 2010.

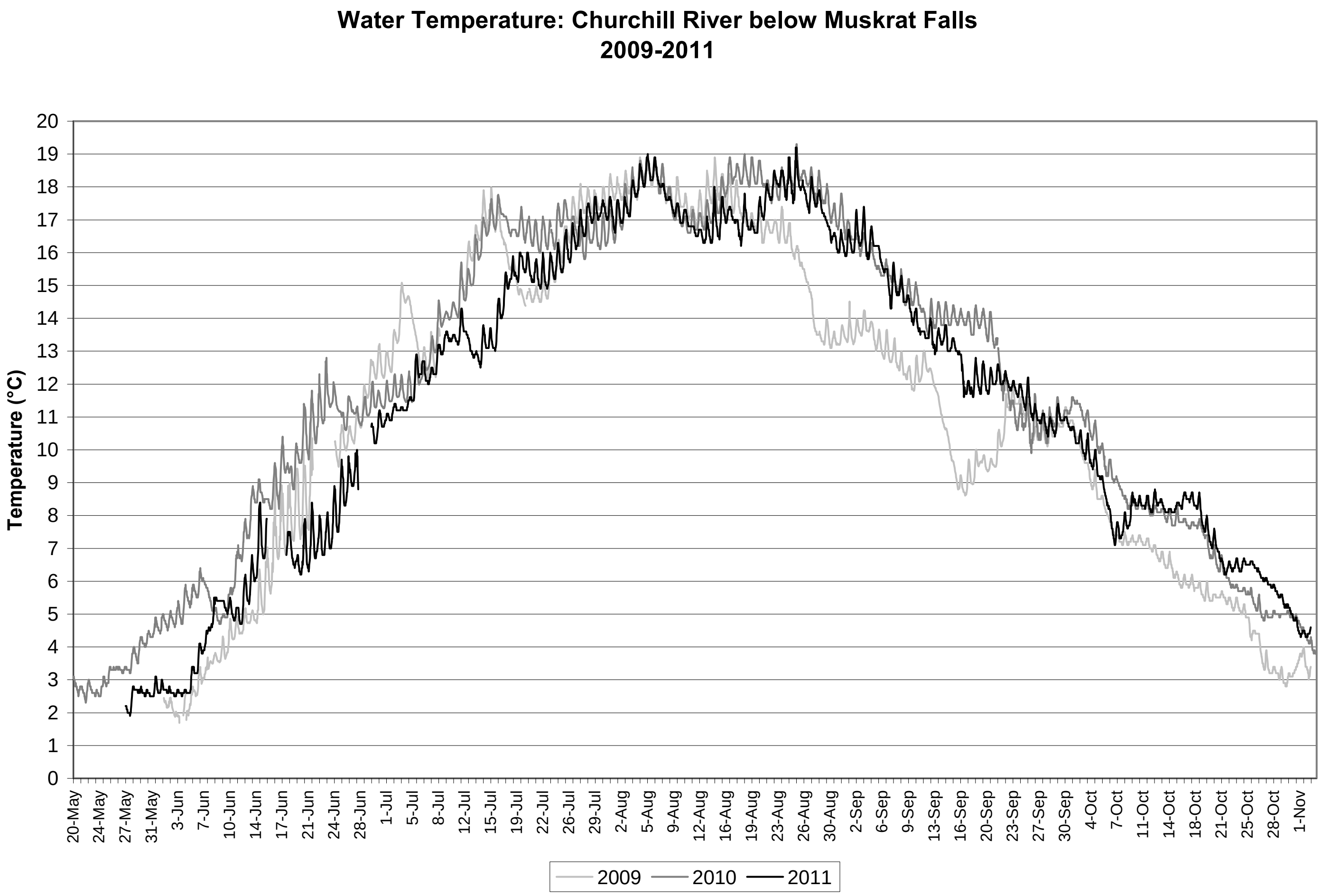


Figure 25: Water temperature at Churchill River below Muskrat Falls

Temperature	2011	2010	2009
Average	11.56	11.80	11.28
Max	19.20	19.30	18.90
Min	1.90	2.30	1.69

- Water temperature values show a typical seasonal trend (Figure 26). 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 19.20°C. Water temperature begins to decrease in the early September and into the fall season as air temperatures cool.

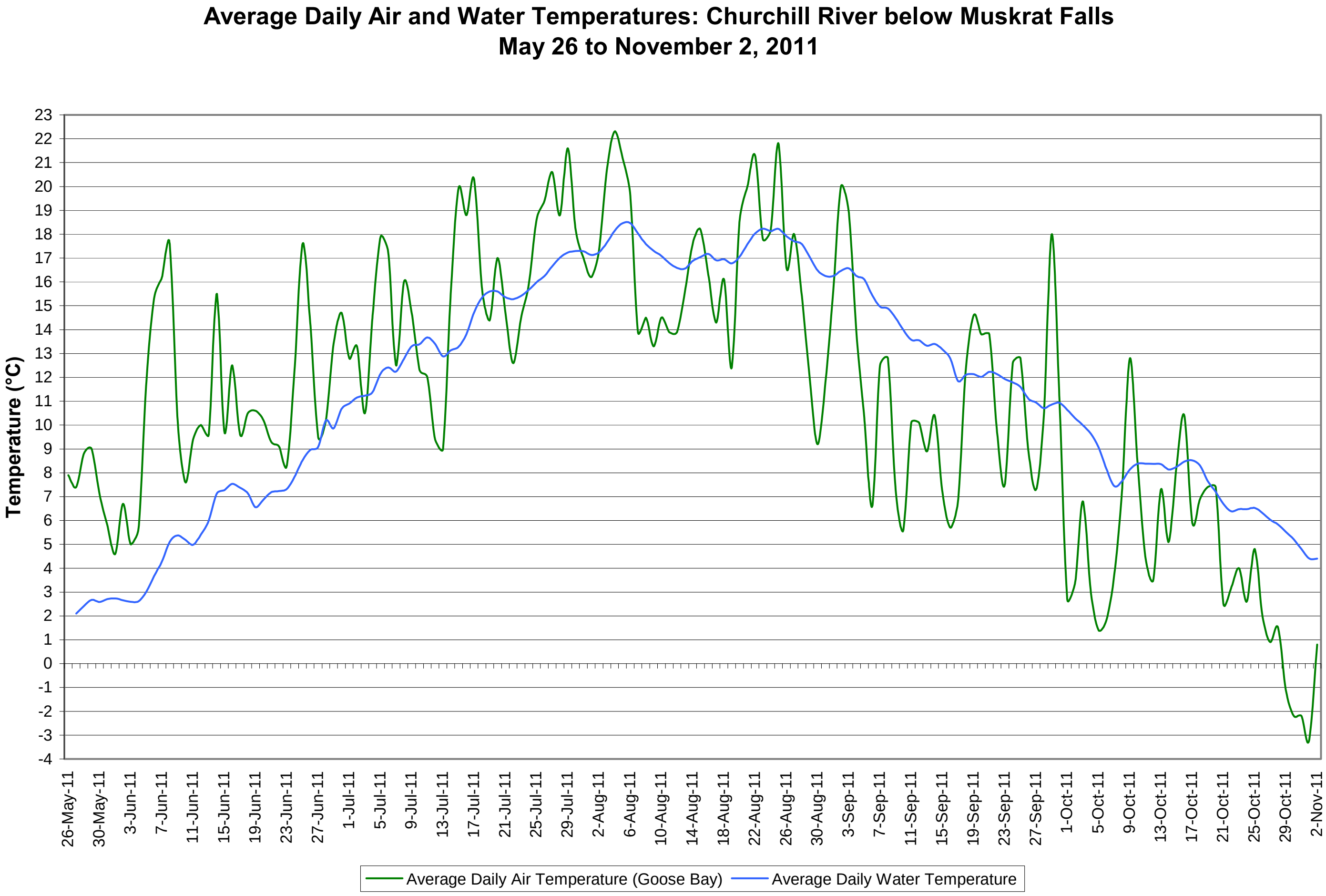


Figure 26: Average daily air and water temperatures at Churchill River below Muskrat Falls

(weather data recorded at Goose Bay)

- pH ranges between 6.55 and 7.58 pH units during the 2011 deployment season, averaging 7.02 pH units (Figure 27).
- pH values are increasing throughout most of the deployment period while the stage is decreasing. pH values begin to decrease in mid September.
- All values during the 2011 deployment season are within the CCME Guidelines for the Protection of Aquatic Life (indicated in blue on Figure 27).
- pH trends and values are very similar throughout the three years of data collected.

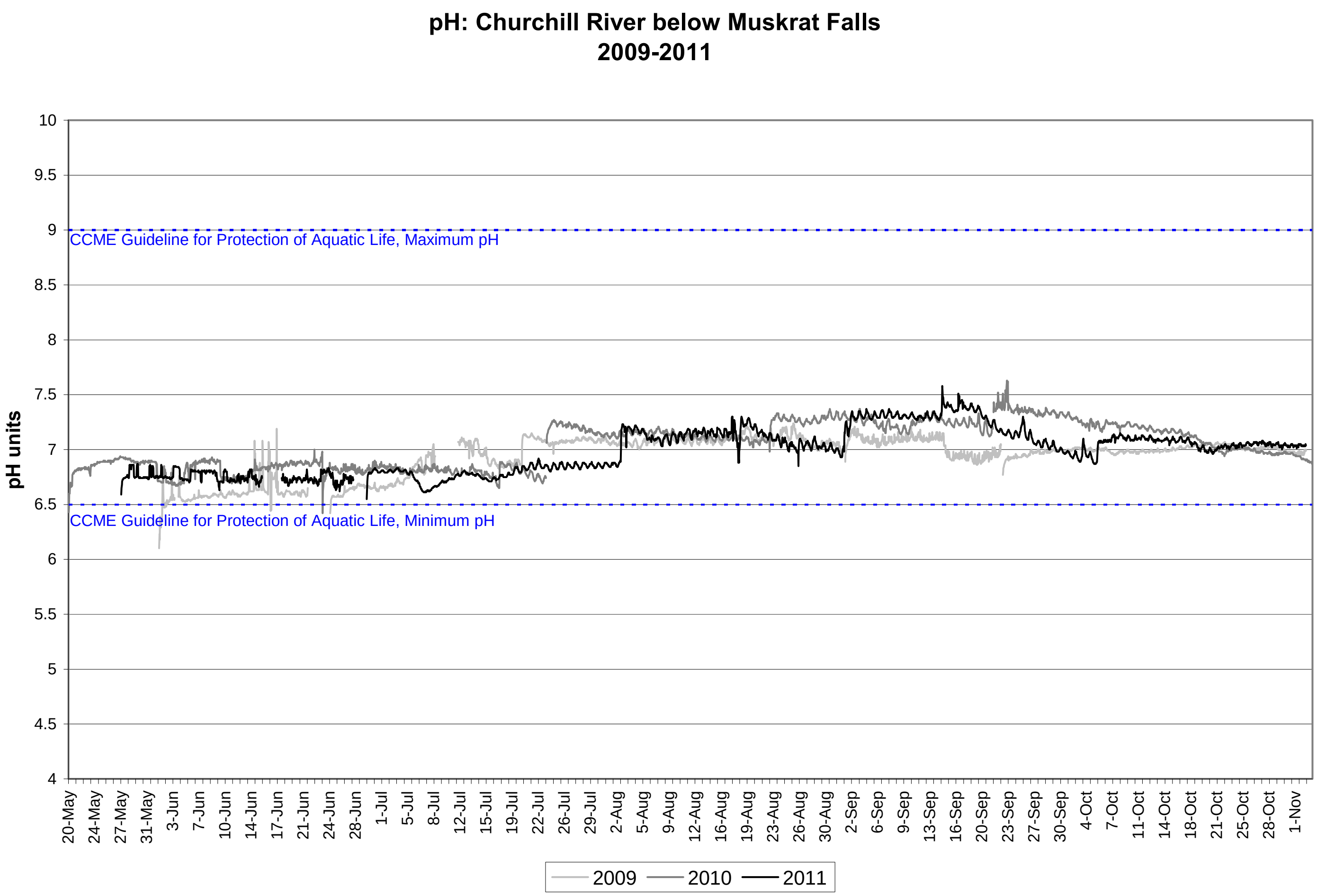


Figure 27: pH at Churchill River below Muskrat Falls

pH (units)	2011	2010	2009
Average	6.99	7.04	6.95
Max	7.58	7.63	7.24
Min	6.55	6.42	6.10

- Specific conductance ranged between 6.7 and 22.0µS/cm, averaging 16.6µS/cm during the 2011 deployment season (Figure 28).
- Specific conductance is generally increasing throughout the first half of the deployment season. For the deployment period between August 2 and September 1, specific conductivity values are on average lower than expected. These low values are specific to the deployment period therefore it is likely that this is an error caused by instrument calibration. A similar calibration error was detected with specific conductivity at station below Grizzle Rapids and above Muskrat Falls for the deployment period between September 1 and October 4.
- Stage is included in Figure 28 to illustrate the inverse relationship between conductivity and water level. Stage is generally decreasing throughout the first half of the deployment season while specific conductivity in increasing. As stage decreases, specific conductivity usually increases as the concentration of dissolved solids increases. Inversely, as stage increases, specific conductivity generally decreases due to the dilution of dissolved solids in the water column.

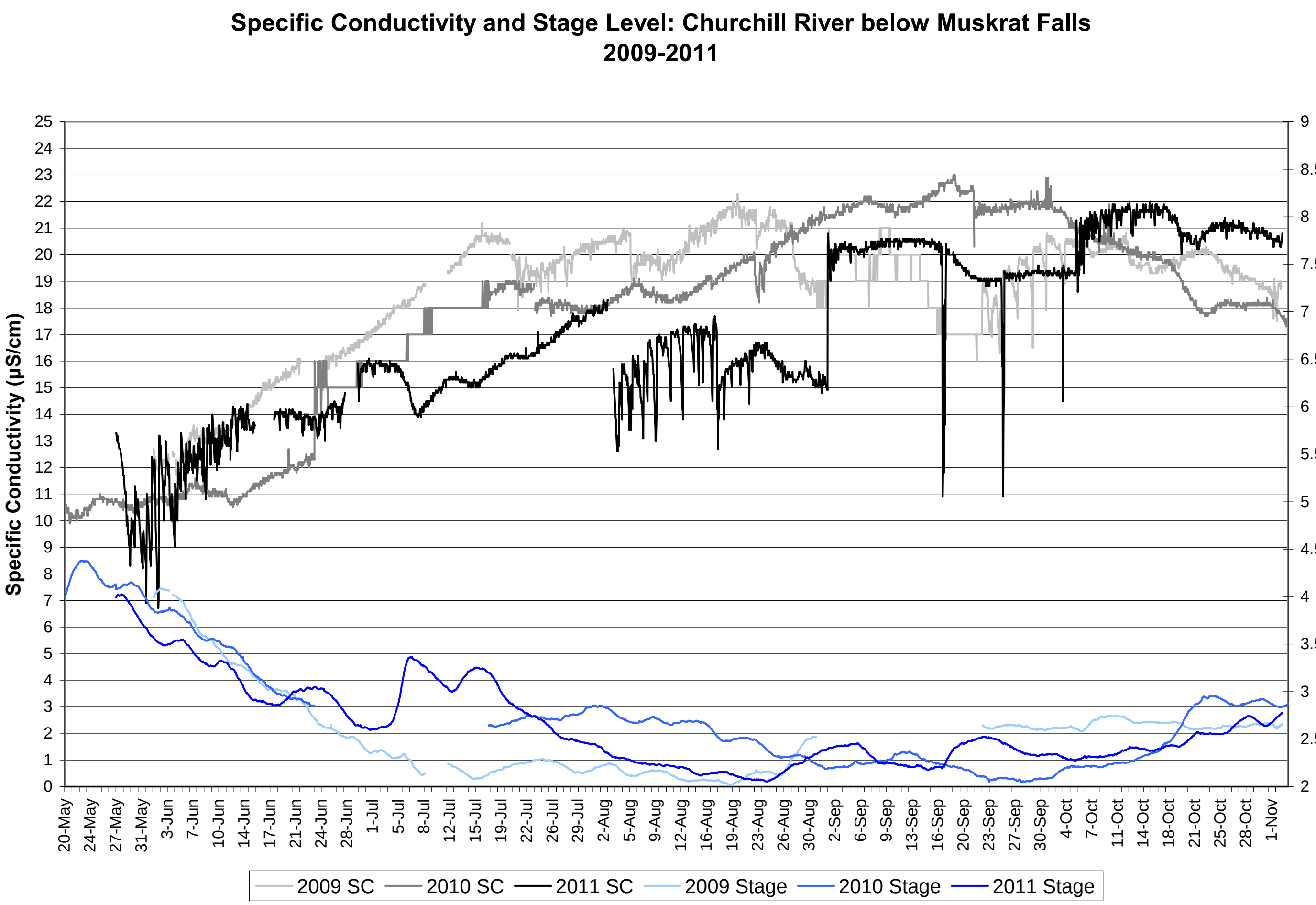


Figure 28: Specific conductivity and stage level at Churchill River below Muskrat Falls

Specific Conductivity (µS/cm)	2011	2010	2009
Average	17.1	17.6	18.7
Max	22.0	23.0	22.3
Min	6.7	9.9	11.7

- Throughout the 2011 deployment season, dissolved oxygen ranged from 9.71 and 15.3mg/l, averaging 12.02mg/l, while percent saturation ranged from 99.7% to 118.2%, averaging 109.0% (Figure 29). No dissolved oxygen data is available between September 13 and October 4 due to sensor failure.
- All values were above both the minimum CCME Guidelines for the Protection of Cold Water Biota at Other Life Stages of 6.5 mg/l and at Early Life Stages of 9.5mg/l. The guidelines are indicated in blue on Figure 29.
- Dissolved oxygen content shows a typical seasonal fluctuation in 2011, decreasing throughout the spring and early summer months during the time when water temperatures are increasing. Dissolved oxygen content reaches a seasonal low in late August. When water temperatures begin to decrease in the late summer and fall, dissolved oxygen content begins to rise again. Dissolved oxygen is typically higher at this station compared to the other stations further upstream due to the addition of oxygen to the water at Muskrat Falls.
- When compared to data from 2009 and 2010, the same trend is evident due to the inverse relationship between dissolved oxygen and water temperature.

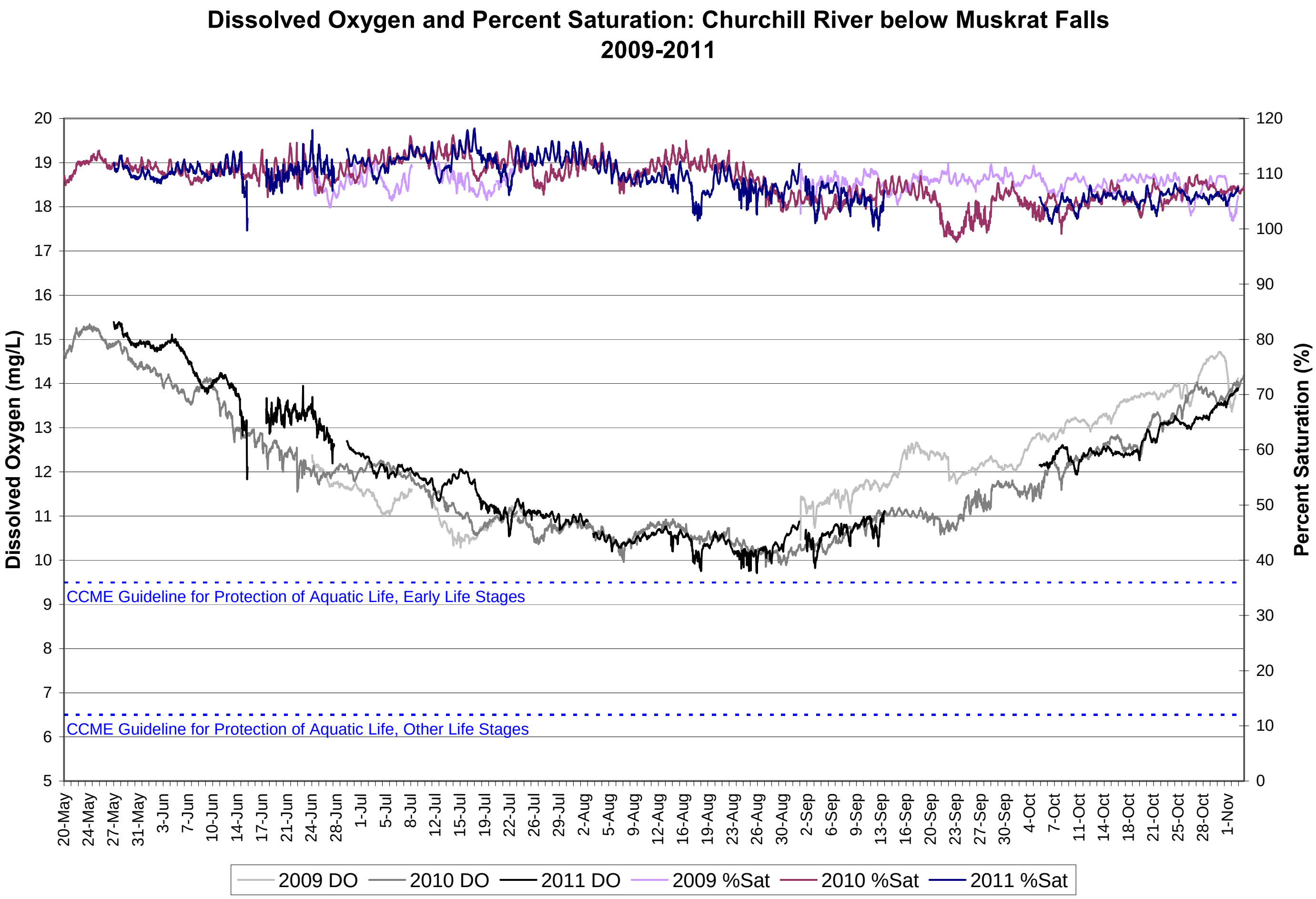


Figure 29: Dissolve oxygen and percent saturation at Churchill River below Muskrat Falls

Dissolved Oxygen (mg/L)	2011	2010	2009		Percent Saturation	2011	2010	2009
Average	12.02	11.91	12.25		**Average**	109.0	108.8	108.4
Max	15.39	15.34	14.72		**Max**	118.2	117.0	114.3
Min	9.71	9.85	10.28		**Min**	99.7	97.6	101.4

- The majority of turbidity values (95%) were <21.3NTU during the 2011 deployment season (Figure 30). A median value of 4.7NTU indicates there is a consistent natural background turbidity value at this station.
- Turbidity values from 2009 to 2011 are depicted in Figures 30a and 30b below. Figure 30a shows data up to 500NTU. On a number of instances, turbidity increased above average background levels for short periods of time throughout the 2011 deployment season, to as high as 489NTU (up to 693NTU in 2009 and 944NTU in 2010). Figure 30b shows data at a smaller scale, focusing on the regular consistent background levels, below 100NTU.

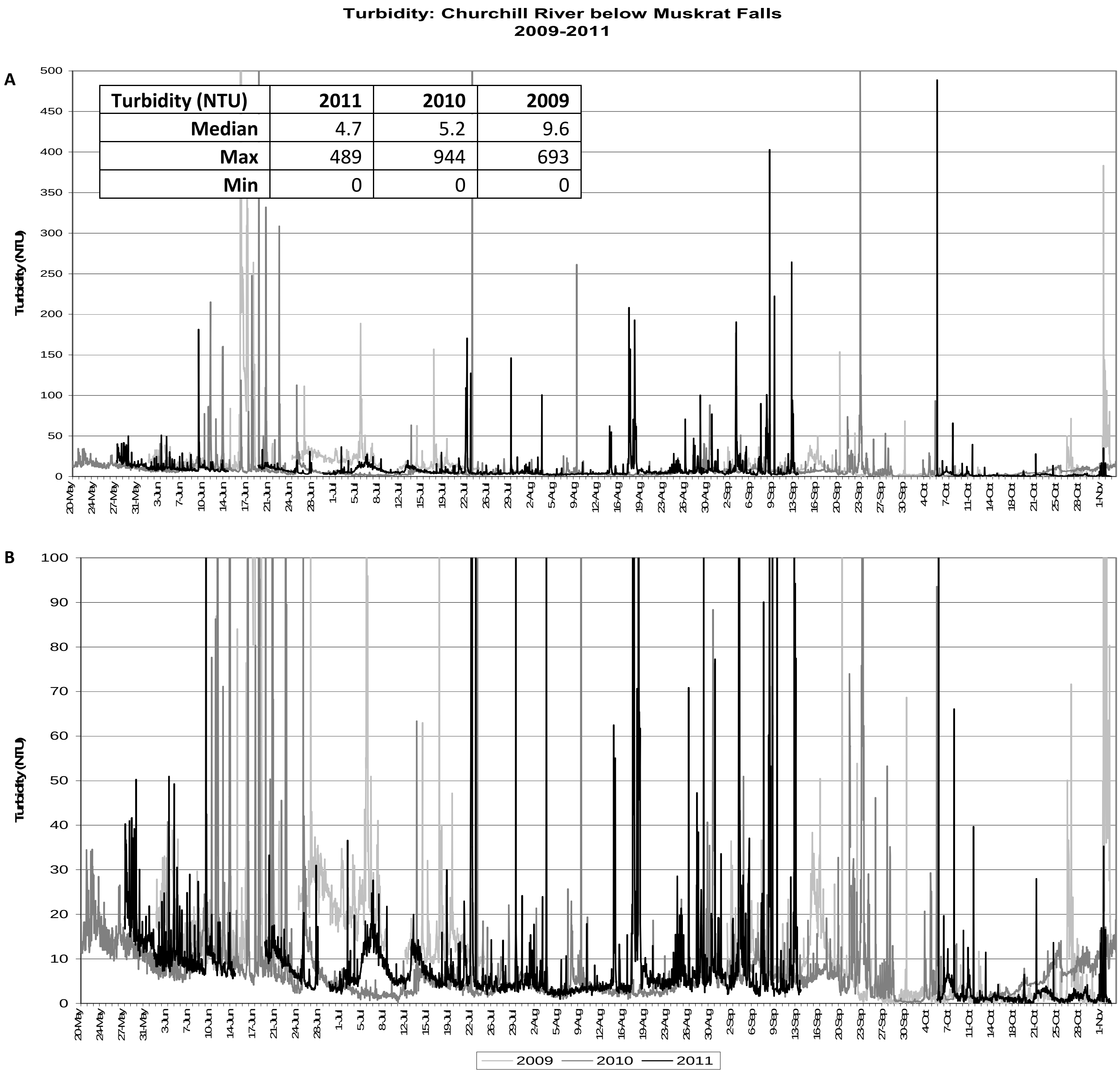


Figure 30a (top): Turbidity to 700NTU at Churchill River above Muskrat Falls

Figure 30b (bottom): Turbidity to 100NTU at Churchill River above Muskrat Falls

- Stage levels from 2009-2011 are graphed below to show how stage levels vary throughout the season and from year to year (Figure 31). Stage is decreasing at the beginning of each deployment season from 2009 to 2011. In early July 2011, there is a significant increase in stage before levels begin to decrease again until reaching a seasonal low in late August. The seasonal low in 2009 was also in late August and was slightly lower than in 2011. In 2010, the seasonal low did not occur until late September. Stage levels in all years are increasing throughout the last deployment periods in each year.

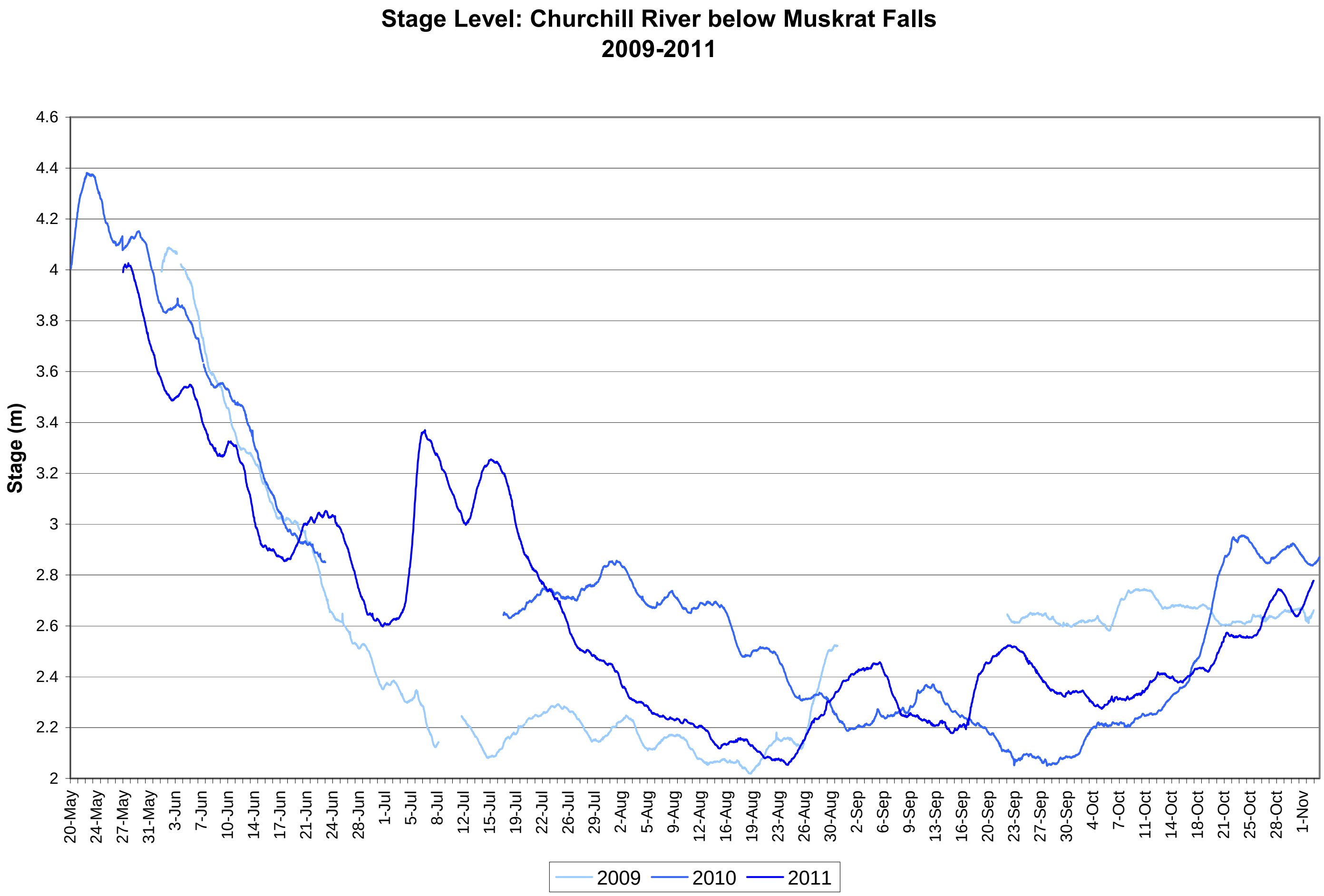


Figure 31: Stage level at Churchill River below Muskrat Falls

Stage (m)	2011	2010	2009
Average	2.637	2.754	2.557
Max	4.026	4.381	4.088
Min	2.053	2.050	2.019

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 32). Stage is decreasing at the beginning of the May deployment period and increases in early July during consistent moderate rainfall events. Stage decreases consistently until reaching a seasonal low in late August. Levels increase slowly throughout the fall season.

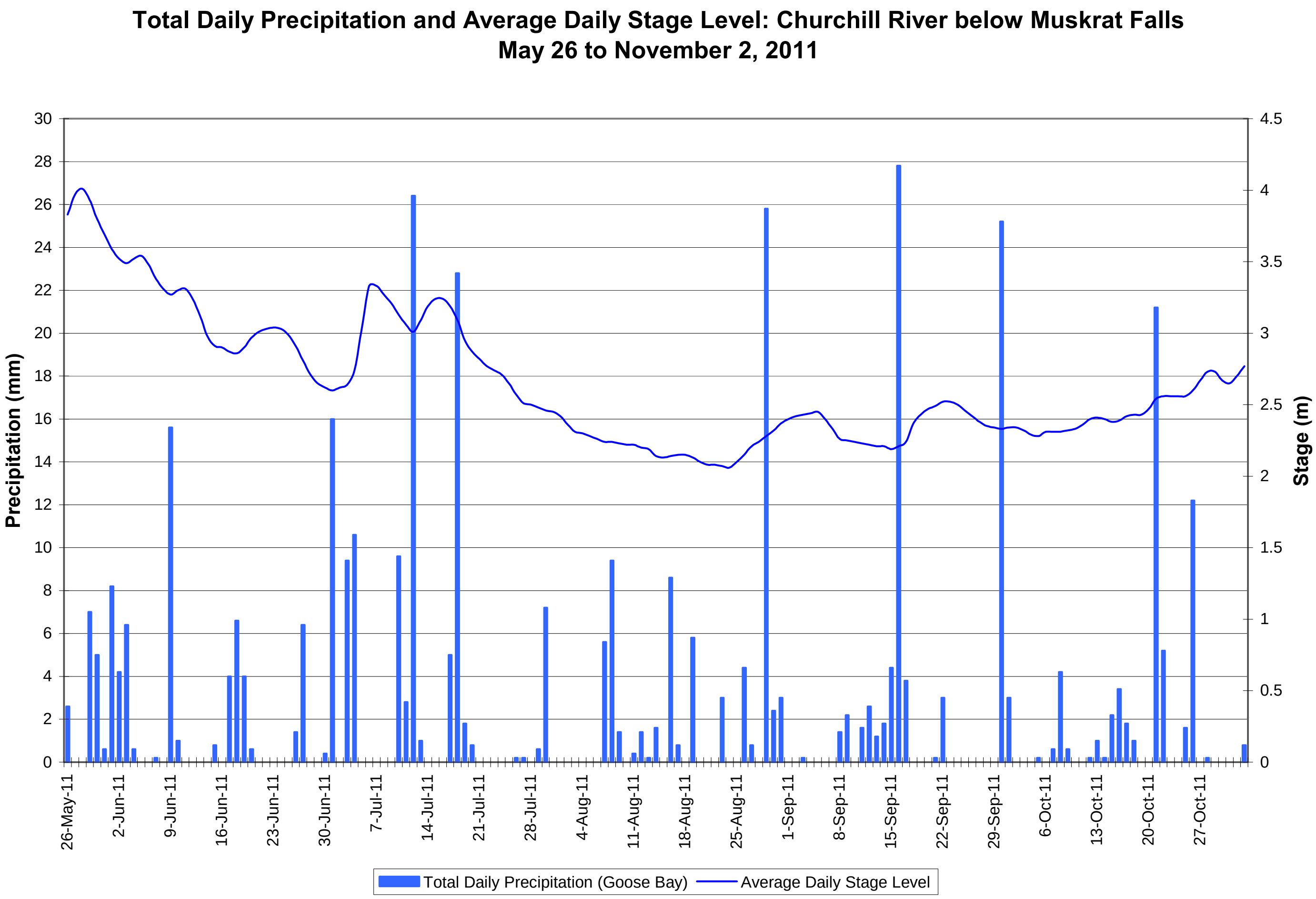


Figure 32: Daily precipitation and average daily stage level at Churchill River below Muskrat Falls

(weather data recorded at Goose Bay)

Station Comparison

- Water temperature at each of the four stations shows a similar trend throughout the 2011 deployment season (Figure 33).
- Water temperature on average was warmest at Churchill River below Grizzle Rapids and had the greatest diurnal fluctuations. The coolest water temperatures on average were found at Churchill River below Metchin River however this station is the first to warm up in the spring and the first to cool down in fall. Stations above and below Muskrat falls were very similar as is expected with their close proximity to one another (~7km).

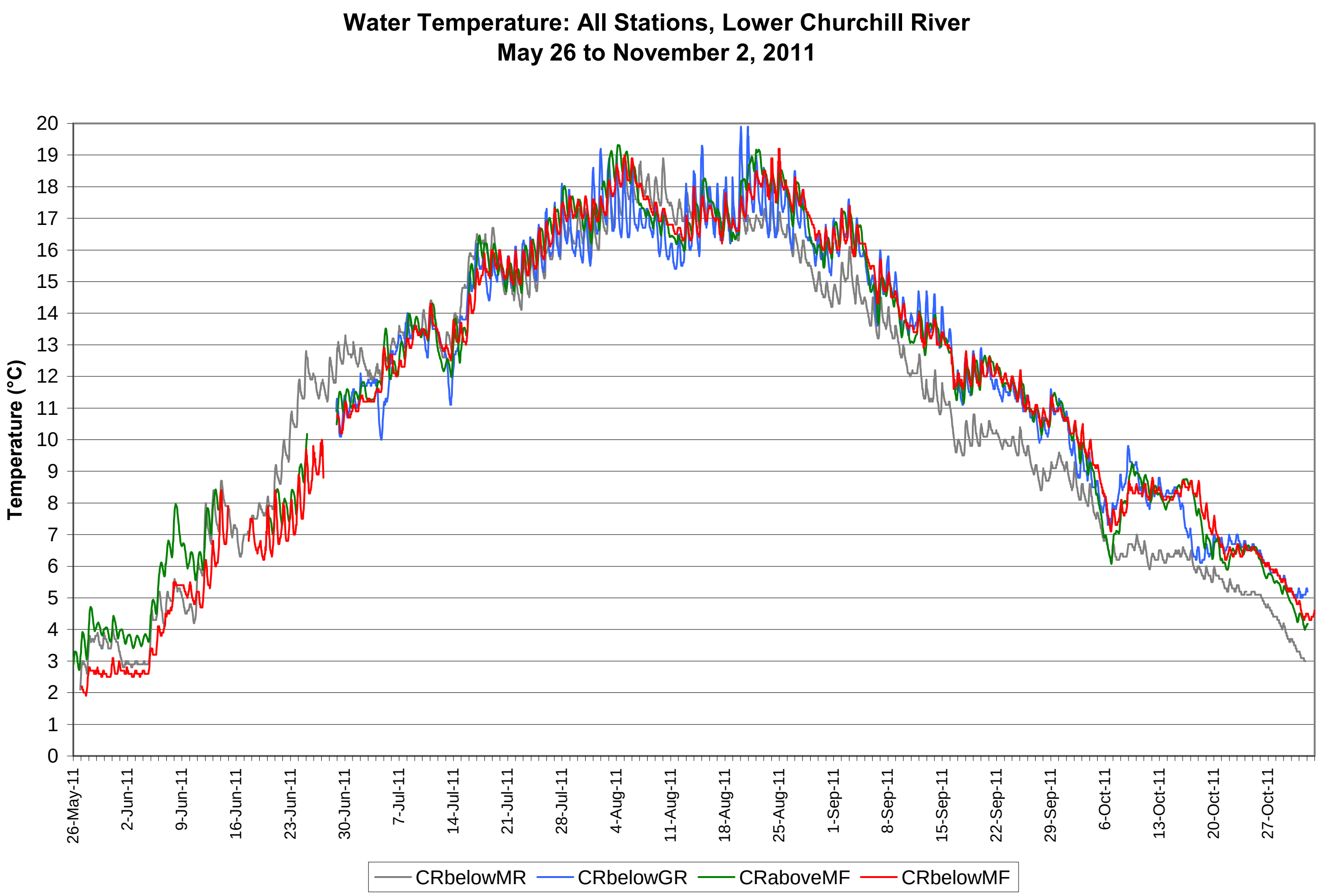


Figure 33: Temperature at all stations in 2011, Lower Churchill River

Temperature	CRbelowMR	CRbelowGR	CRaboveMF	CRbelowMF
Average	11.07	12.91	11.87	11.56
Max	19.00	19.90	19.32	19.20
Min	2.10	5.00	2.72	1.90

- Water temperatures at all four stations display clear seasonal trends in response to changes in air temperatures throughout the deployment season (Figure 34).

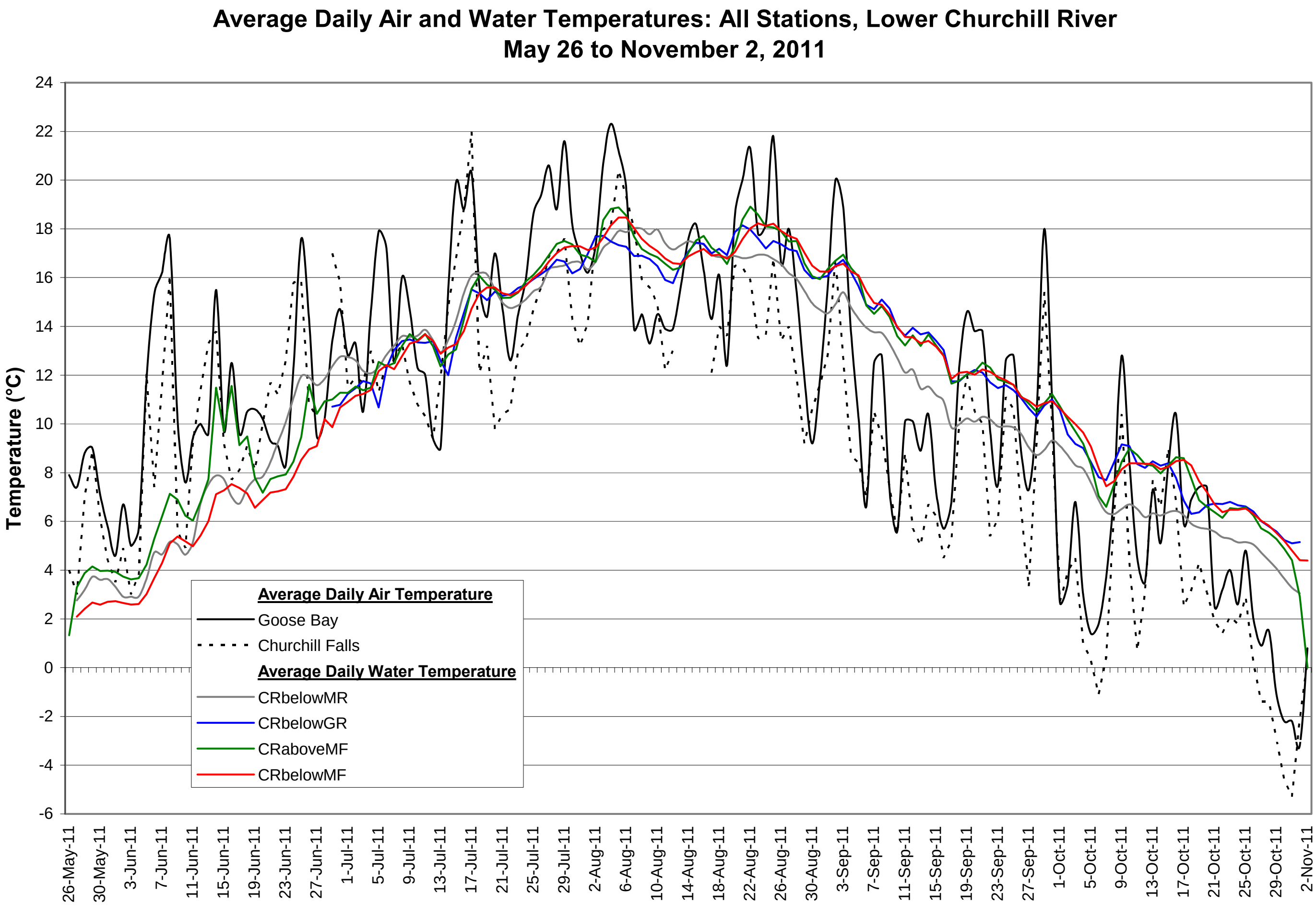


Figure 34: Average daily air and water temperatures at all stations in 2011, Lower Churchill River

- pH values are similar at the four monitoring sites throughout the 2011 deployment season (Figure 35).
- Average values range between 6.91 (Churchill River below Metchin River) and 7.08 (Churchill River below Grizzle Rapids). Values at the station below Grizzle Rapids appear to fluctuate diurnally more significantly than the other stations.

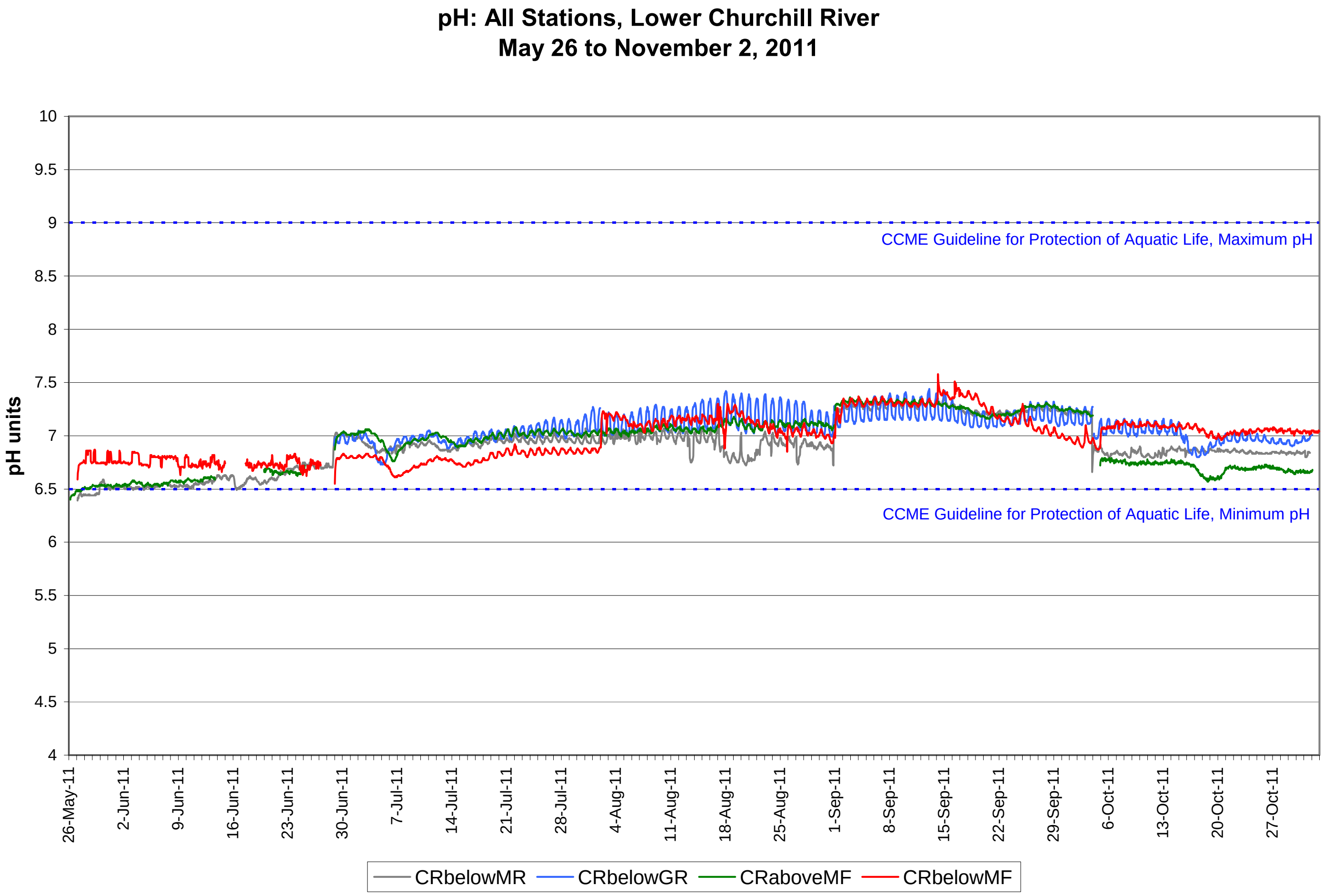


Figure 35: pH at all stations in 2011, Lower Churchill River

pH (units)	CRbelowMR	CRbelowGR	CRaboveMF	CRbelowMF
Average	6.91	7.09	6.95	6.99
Max	7.36	7.44	7.36	7.58
Min	6.39	6.73	6.40	6.55

- Specific conductivity trends are similar along the Lower Churchill River at the four monitoring stations (Figure 36).
- Specific conductivity is increasing in the first half of the deployment season at all stations. Values level off around early August and either remain stable or decrease slightly in to the fall. Specific conductivity at the station below Metchin River is on average higher than at the other stations further downstream at 19.43µS/cm. The three other stations average around 17µS/cm.
- It is clear in this station comparison that the below average values occurring between August 1 and September 1 at the station below Muskrat Falls and from September 1 to October 4 at station below Grizzle Rapids and above Muskrat Falls are not accurate and are likely caused by an error during calibration.

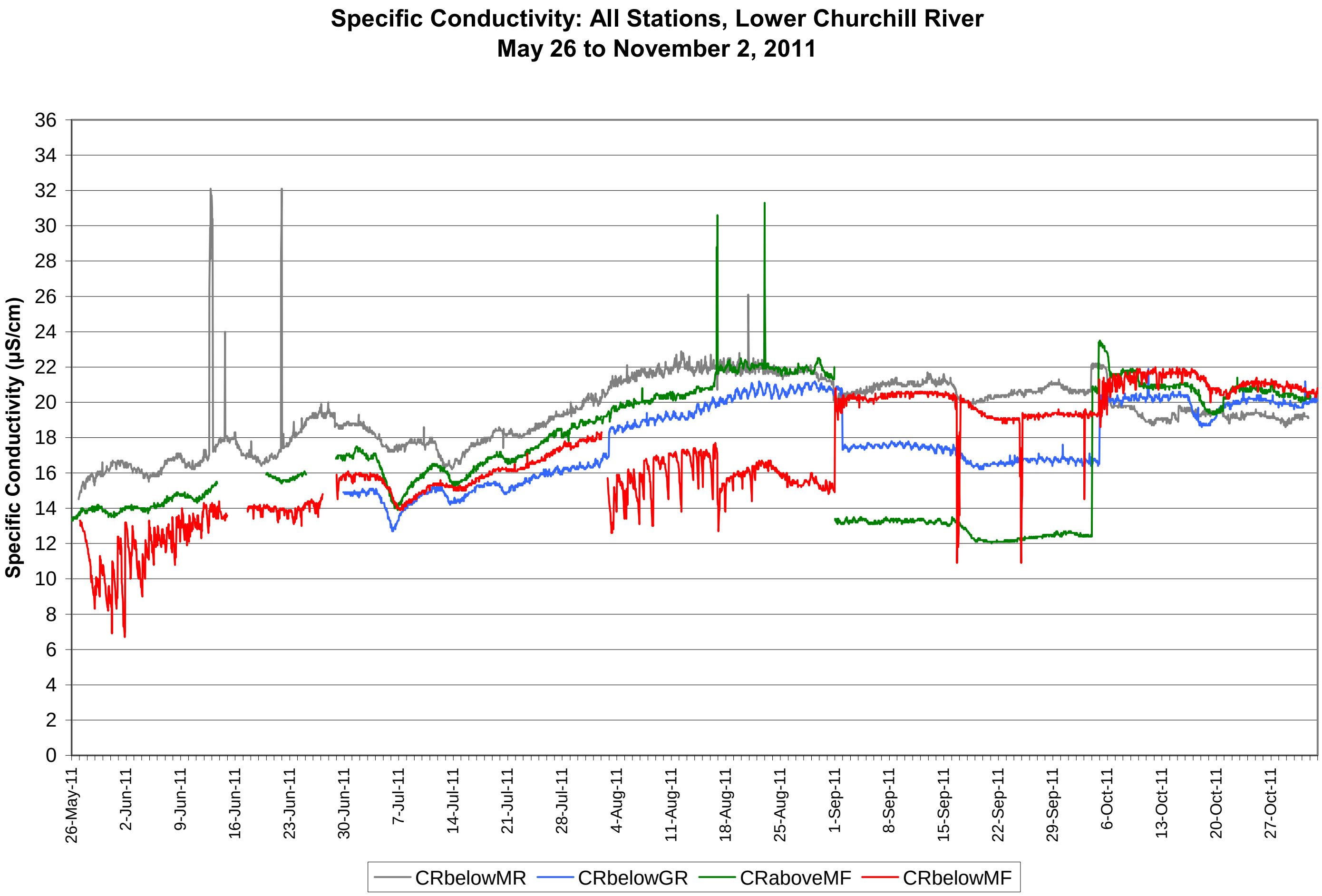


Figure 36: Specific conductivity at all stations in 2011, Lower Churchill River

Specific Conductivity (µS/cm)	CRbelowMR	CRbelowGR	CRaboveMF	CRbelowMF
Average	19.4	17.9	17.2	17.1
Max	32.1	21.9	31.3	22.0
Min	14.5	12.7	12.0	6.7

- Dissolved oxygen content and percent saturation values are very similar at stations above Muskrat Falls, below Grizzle Rapids and below Metchin River, averaging from 9.93 to 10.5mg/l and 94.5% to 97.3 % (Figure 37).
- Values at the station below Muskrat Falls average 12.0mg/l for dissolved oxygen and 109.1% for percent saturation. This is due to the location of Muskrat Falls upstream from the station. Water as it moves over Muskrat Falls is aerated and this increases the amount of oxygen in the water. The station below Muskrat Falls is the only station where dissolved oxygen content does not fall below the minimum CCME Guideline for the Protection of Early Life Stage Cold Water Biota value at 9.5 mg/l during any part of the season. Guidelines are indicated in blue on Figure 37.
- All stations experience a typical seasonal fluctuation and inverse relationship to water temperature, decreasing in the spring and early summer while water temperature are increasing and increasing in the late summer and fall seasons as the water temperatures cool.

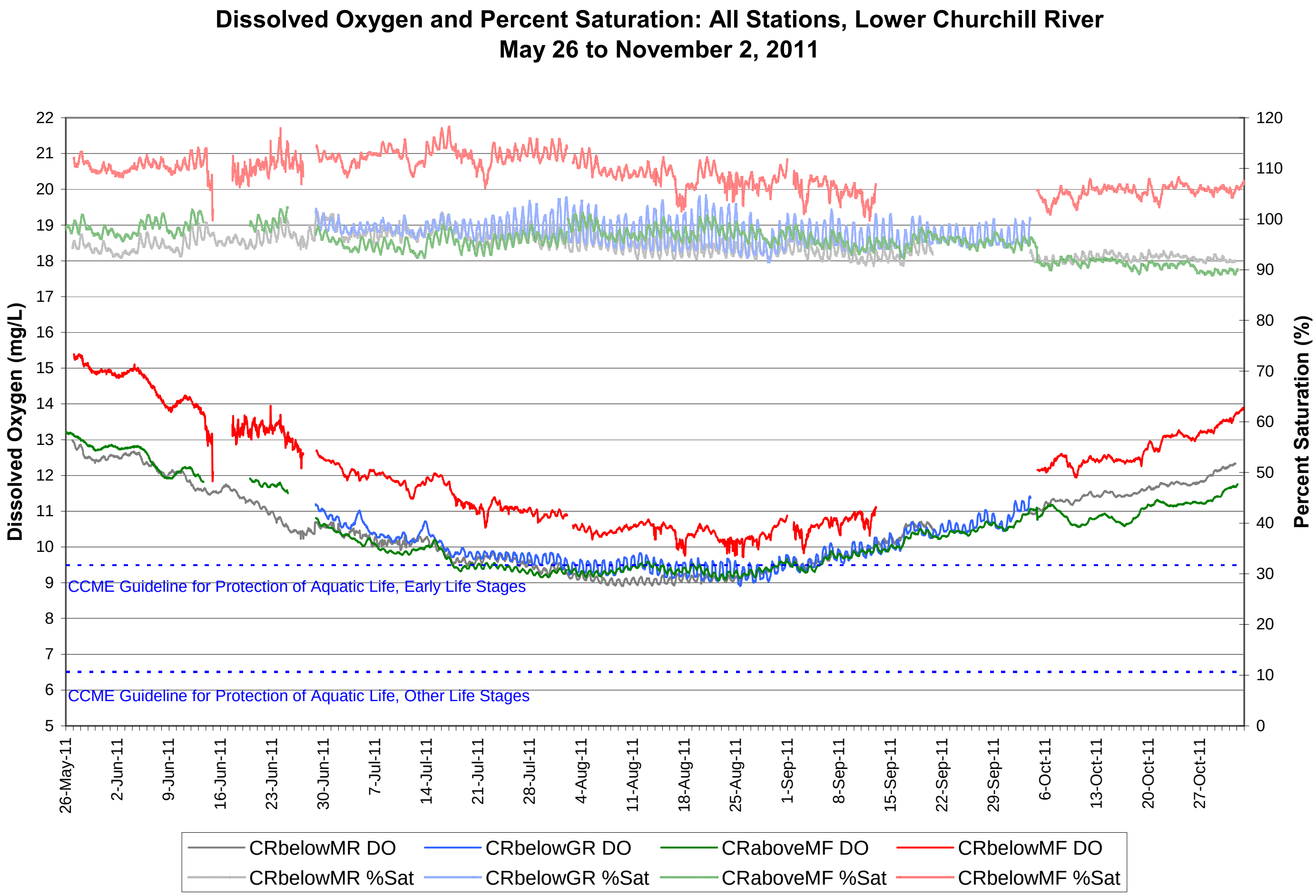
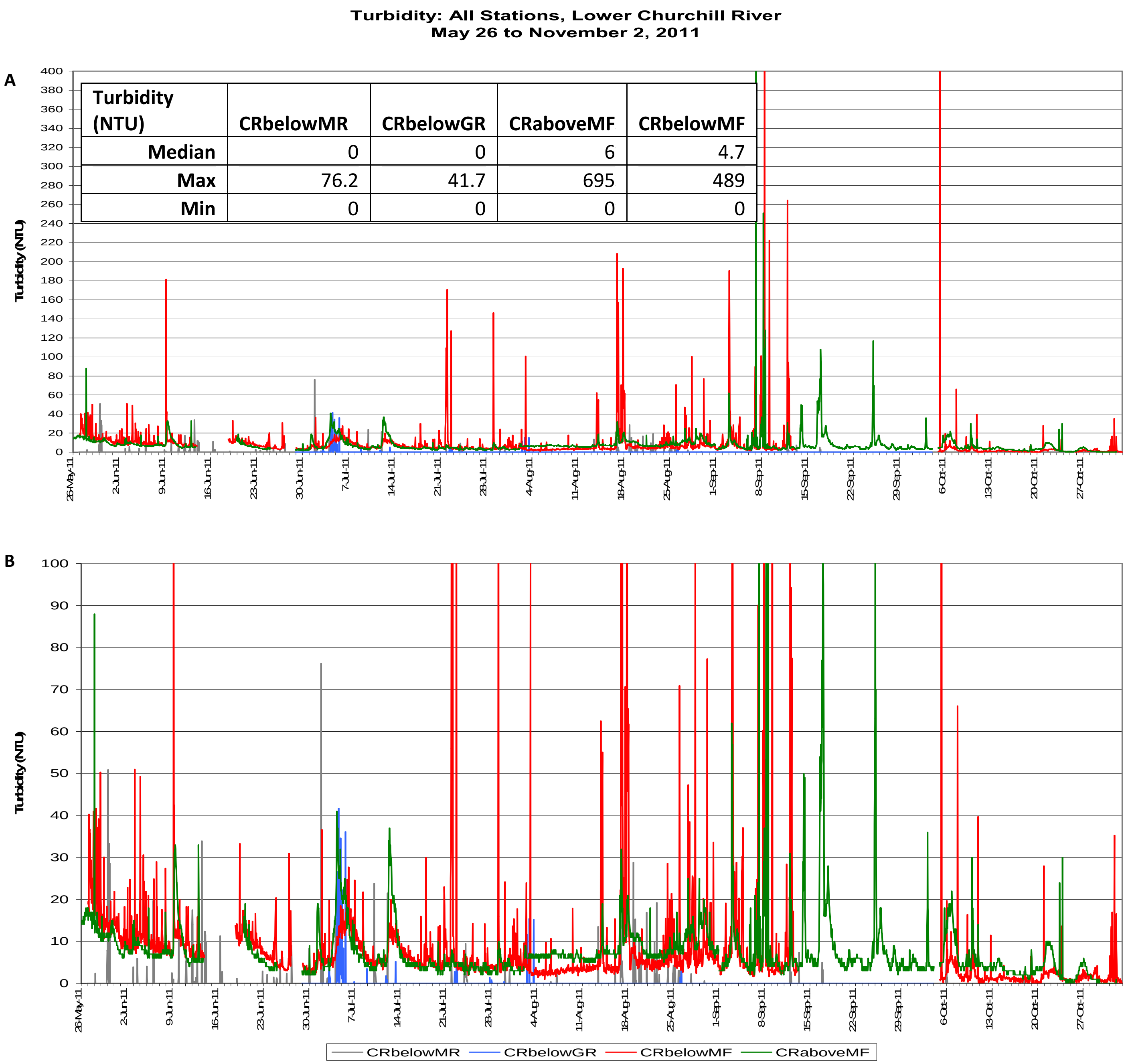


Figure 37: Dissolved oxygen and percent saturation at all stations in 2011, Lower Churchill River

	Dissolved Oxygen (mg/l)					Percent Saturation (%)			
	CRbelowMR	CRbelowGR	CRaboveMF	CRbelowMF		CRbelowMR	CRbelowGR	CRaboveMF	CRbelowMF
Average	10.50	9.93	10.42	12.02		94.8	97.4	95.5	109.0
Max	12.99	11.42	13.22	15.39		101.5	104.7	102.3	118.2
Min	8.91	8.90	9.06	9.71		90.7	91.5	88.9	99.7

- Turbidity values at stations below Grizzle Rapids and below Metchin River are generally 0.0NTU with minimal, short lived turbidity events (Figures 6 & 14). In the lower reaches of the Churchill River, at the stations above and below Muskrat Falls, the water quality is generally more turbid and the water is visibly cloudy. Median turbidity values at these two stations range between 4.7 and 6.0NTU for the 2011 deployment season. Increases in turbidity often correspond with weather related events in the area and can be tracked at both stations (given their close proximity (~7km).
- Figure 38a shows turbidity data on a scale from 0 to 400NTU to illustrate the higher magnitude events. Figure 38b displays the same data on a smaller scale, 0 to 100NTU, to clearly show the background turbidity values throughout the deployment season.



Turbidity (NTU)	CRbelowMR	CRbelowGR	CRaboveMF	CRbelowMF
Median	0	0	6	4.7
Max	76.2	41.7	695	489
Min	0	0	0	0

Figure 38a (top): Turbidity to 400NTU at all stations in 2011, Lower Churchill River

Figure 38b (bottom): Turbidity to 100NTU at all stations in 2011, Lower Churchill River

Lower Churchill River, Newfoundland and Labrador

- Stage levels are very similar across the network throughout the 2011 deployment season (Figure 39). Stage is decreasing at all stations deployed in late May through the month of June. There is a large increase at all stations in the beginning of July that corresponds with consistent moderate rainfall events. Stage values decrease for the remainder of the summer reaching a seasonal low at all stations in late August. Values begin to increase slowly, fluctuating during the month of September and increasing throughout October.

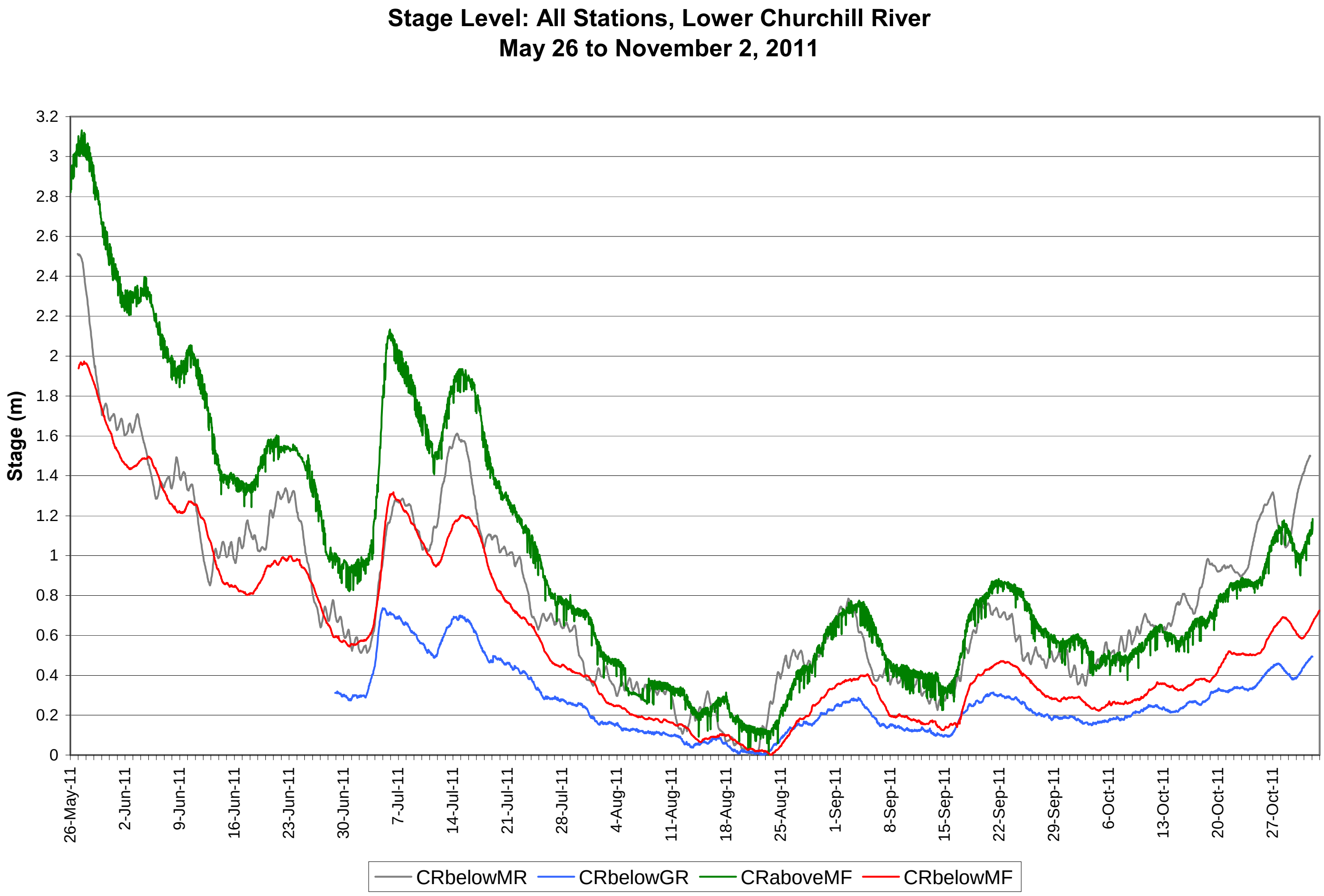


Figure 39: Stage levels at all stations in 2011, Lower Churchill River

Conclusions

- Water quality monitoring instruments were successfully deployed on the Lower Churchill River at stations above and below Muskrat Falls, and below Metchin River from May 20 to November 1/2, 2010 and at the station below Grizzle Rapids from June 29 to November 1, 2010.
- In most cases, weather related events or increase/decreases in water level could be used to explain the fluctuations. The four stations continue to perform well at capturing water quality baseline data along different reaches of the river.
- Most values recorded were within ranges as suggested by the CCME Guidelines for the Protection of Aquatic Life for pH.
- At stations above Muskrat Falls, below Grizzle Rapids and below Metchin River, dissolved oxygen content did fall below the minimum CCME Guideline for the Protection of Aquatic Life during early life stages (9.5mg/L) during the warmest part of the season (late July to early September). All values at all stations remained above the minimum CCME Guideline for the Protection of Aquatic Life during other life stages (6.5mg/L)
- Regular visits on a near 30 day deployment schedule have been adhered to for the most part. This has provided good quality data with limited drift.
- The instruments performed well for much of the deployment season with limited disruptions to data collection.
    - In late June 2011, instruments at station above and below Muskrat Falls became exposed to air as stage levels dropped significantly. This trend is expected at these stations during this time of year and is not known to cause instruments any damage.
    - In early August, the instrument deployed at the station below Muskrat Falls experienced a dissolved oxygen and turbidity sensor failure. Because of the close proximity to Goose Bay, ENVC staff were able to replace the instrument the following day. A similar incident happened at the same station the following month on September 2, where the same instrument, thought to be in good working order, was deployed again and immediately failed. The instrument was again replaced the following day.
    - At the station above Muskrat Falls, an error with the turbidity sensor occurred shortly after deployment on October 4. The instrument was replaced on October 5.
    - At the station below Metchin River, dissolved oxygen and turbidity sensors failed midway through deployment on September 21. There is no data for dissolved oxygen between this date and the end of that deployment period, October 4.
    - At the station below Grizzle Rapids, dissolved oxygen and turbidity sensors failed almost immediately after deployment on October 4. ENVC staff were unable to replace the instrument the following day as this station is not within close proximity to Goose Bay and would require additional resources. There is no data for dissolved oxygen or turbidity between October 4 and November 1.
- Data collected in 2011 is comparable with datasets from previous years in 2009 and 2010. Water quality parameters do not tend to vary significantly. Stage appears to be the greatest variable from year to year.

Path Forward

In order for this agreement to be successful, it is essential to continually evaluate and move forward. The 2011 deployment season was successful in providing baseline water quality data for the Lower Churchill Project. 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.

- ENVC has successfully established 2 new real time water quality monitoring stations in the Lower Churchill River and Lake Melville area. These stations are located at the mouth of the Churchill River at English Point and approximately 70km east of Goose Bay on Lake Melville east of Little River. These stations are owned and operated by ENVC, however Nalcor will continue to be provided with data and monthly reports from these stations.
- ENVC staff will deploy real time water quality instruments in spring 2012 when ice conditions allow and perform regular site visits throughout the 2012 deployment season for calibration and maintenance of the instruments. If necessary, deployment techniques will be evaluated and adapted to each site, ensuring secure and suitable conditions for real time water quality monitoring.
- The additional of chlorophyll sensors will be fixed to existing instruments deployed regularly at the stations above and below Muskrat Falls prior to the beginning of the 2012 monitoring season. Investigation into stand alone TSS sensors for stations above and below Muskrat Falls will continue until sufficient information and trial periods have been completed.
- EC staff will perform regular site visits to ensure water quantity instrumentation is correctly calibrated and providing accurate measurements.
- Nalcor will continue to be informed of data trends and any significant water quality events in the form of a monthly deployment report when the deployment season begins. Nalcor will also receive an annual report summarizing the events of the deployment season.
- Nalcor will continue to receive batch datasets of all real time water quality data on a 3 month basis unless otherwise requested.
- 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*.).
- Open communication lines will continue to be maintained between ENVC, EC and Nalcor employees involved with the agreement in order to respond to emerging issues on a proactive basis.
- 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.
- There were plans to install a new hydrometric station (between Upper and Lower Muskrat Falls); a web camera station equipped with two cameras; and a back-up gauge station at the existing above Grizzle Rapids hydrometric station in the 2011-12 fiscal year. However, it was decided by Nalcor that some of the work needed to be postponed until a later date. The back-up gauge station above Grizzle Rapids was installed in 2011. No decision has been made whether the additional gauge station (between upper and Lower Muskrat Falls) and the web camera station will be installed in the upcoming year.

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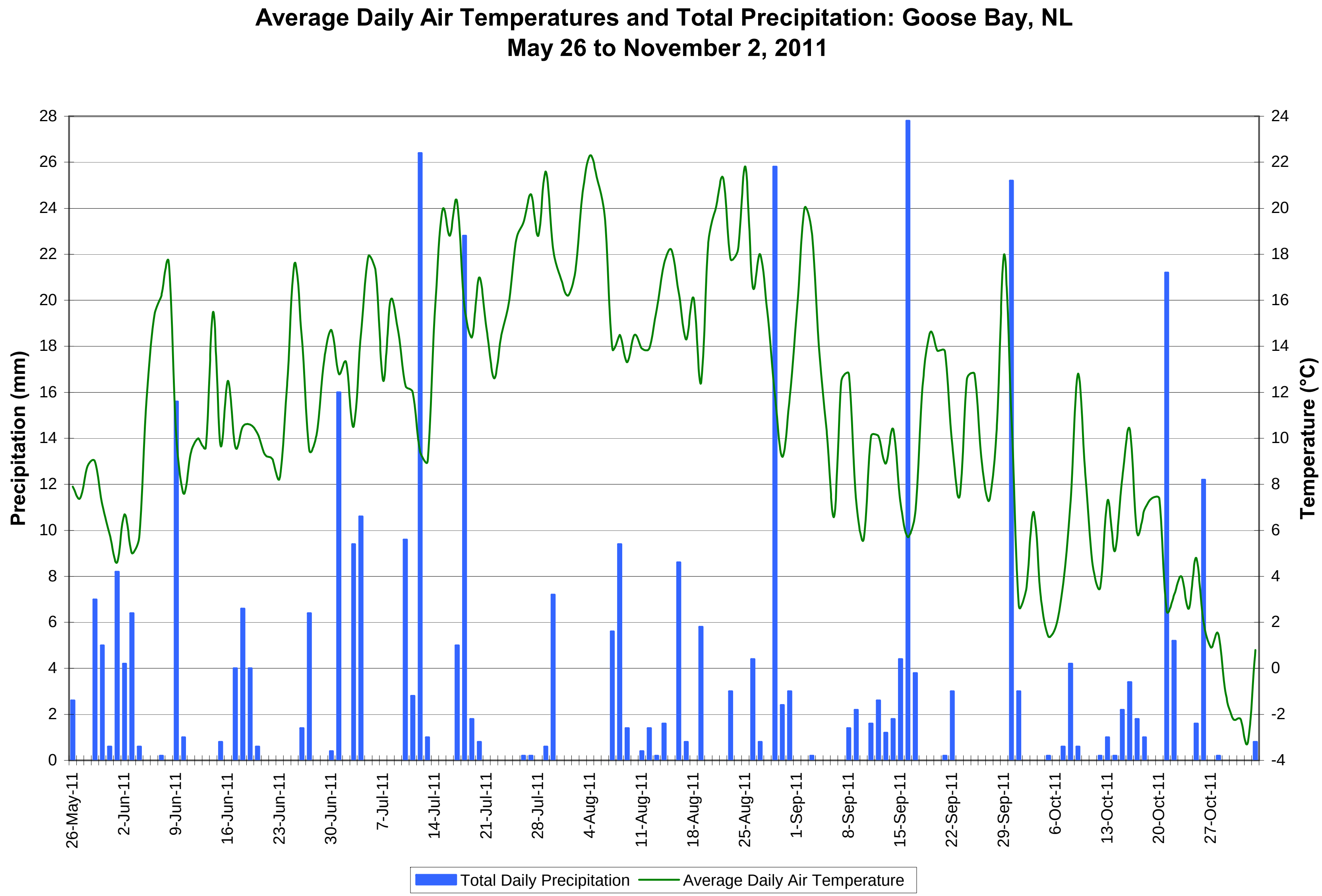
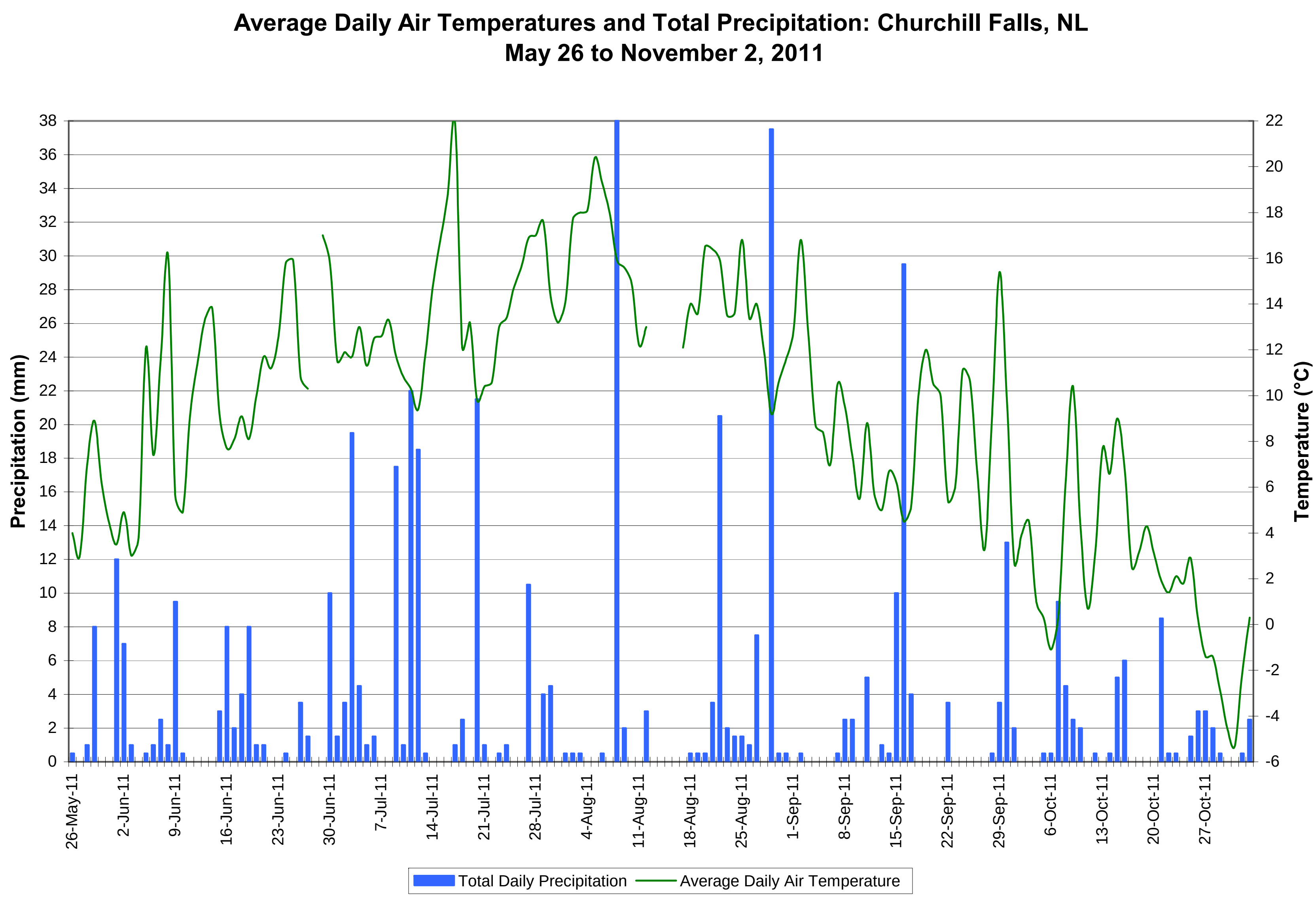
Appendix 1


Average Daily Air Temperatures and Total Precipitation: Goose Bay, NL
May 26 to November 2, 2011
Precipitation (mm)
Temperature (°C)
Total Daily Precipitation
Average Daily Air Temperature
26-May-11
2-Jun-11
9-Jun-11
16-Jun-11
23-Jun-11
30-Jun-11
7-Jul-11
14-Jul-11
21-Jul-11
28-Jul-11
4-Aug-11
11-Aug-11
18-Aug-11
25-Aug-11
1-Sep-11
8-Sep-11
15-Sep-11
22-Sep-11
29-Sep-11
6-Oct-11
13-Oct-11
20-Oct-11
27-Oct-11


Average Daily Air Temperatures and Total Precipitation: Churchill Falls, NL
May 26 to November 2, 2011
Precipitation (mm)
Temperature (°C)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
-6
-4
-2
0
2
4
6
8
10
12
14
16
18
20
22
26-May-11
2-Jun-11
9-Jun-11
16-Jun-11
23-Jun-11
30-Jun-11
7-Jul-11
14-Jul-11
21-Jul-11
28-Jul-11
4-Aug-11
11-Aug-11
18-Aug-11
25-Aug-11
1-Sep-11
8-Sep-11
15-Sep-11
22-Sep-11
29-Sep-11
6-Oct-11
13-Oct-11
20-Oct-11
27-Oct-11
Total Daily Precipitation
Average Daily Air Temperature