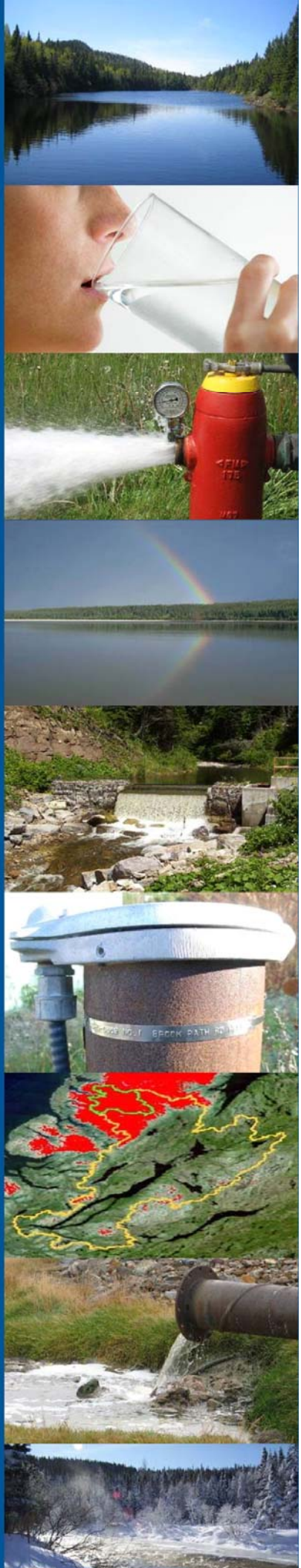

Real Time Water Quality Report

City of St. John's
Outer Cove Brook Network

Annual Deployment Report 2015

January 1, 2015 to November 12, 2015

Newfoundland Labrador

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

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Acknowledgements

The Real-Time Water Quality monitoring network at Outer Cove Brook in St. John's NL, was fully funded by the City of St. John's. The network's success is dependent on a joint partnership between the City of St. John's, Environment Canada (EC), and the Newfoundland and Labrador Department of Environment and Conservation (ENVC). Managers and program leads from each organization, namely Renee Paterson (ENVC), Howie Wills (EC), and David Wadden (City of St. John's), were committed to the operation of this network and ensuring it continually provided meaningful and accurate water quality and quantity data over the past three years.

Staff of Environment Canada (Water Survey Canada) under the management of Howie Wills, played an essential role in the data logging/communication aspect of the network and maintained all water quantity monitoring equipment. EC-WSC staff visited the sites regularly to ensure the data logging and data transmitting equipment were working properly.

ENVC was responsible for maintenance of the real-time water quality monitoring equipment, as well as recording and managing the water quality data. Tara Clinton, under the supervision of Renee Paterson, was ENVC's main contact for the real-time water quality monitoring operations at Outer Cove Brook, and was responsible for maintaining and calibrating water quality instruments, as well as grooming, analyzing and reporting on water quality data recorded at the stations during 2015.

It was determined by the City of St. John's that the stations had completed their role in monitoring water quality and water quantity and the agreement expired. This will be the last report for the Outer Cove Brook Stations. The stations are no longer operational and were decommissioned in November 2015.

Introduction

The Newfoundland and Labrador Department of Environment and Conservation (ENVC), in partnership with the City of St. John's and Environment Canada (EC), established two real-time water quality and quantity monitoring stations in April 2012 at Outer Cove Brook in the east end of St. John's, NL.

The official names of each of the stations are Outer Cove Brook below Airport (NF02ZM0364) and Outer Cove Brook at Clovelly Golf Course (NF02ZM0365). Their locations in relation to each other and surrounding land uses are shown in Figure 1.

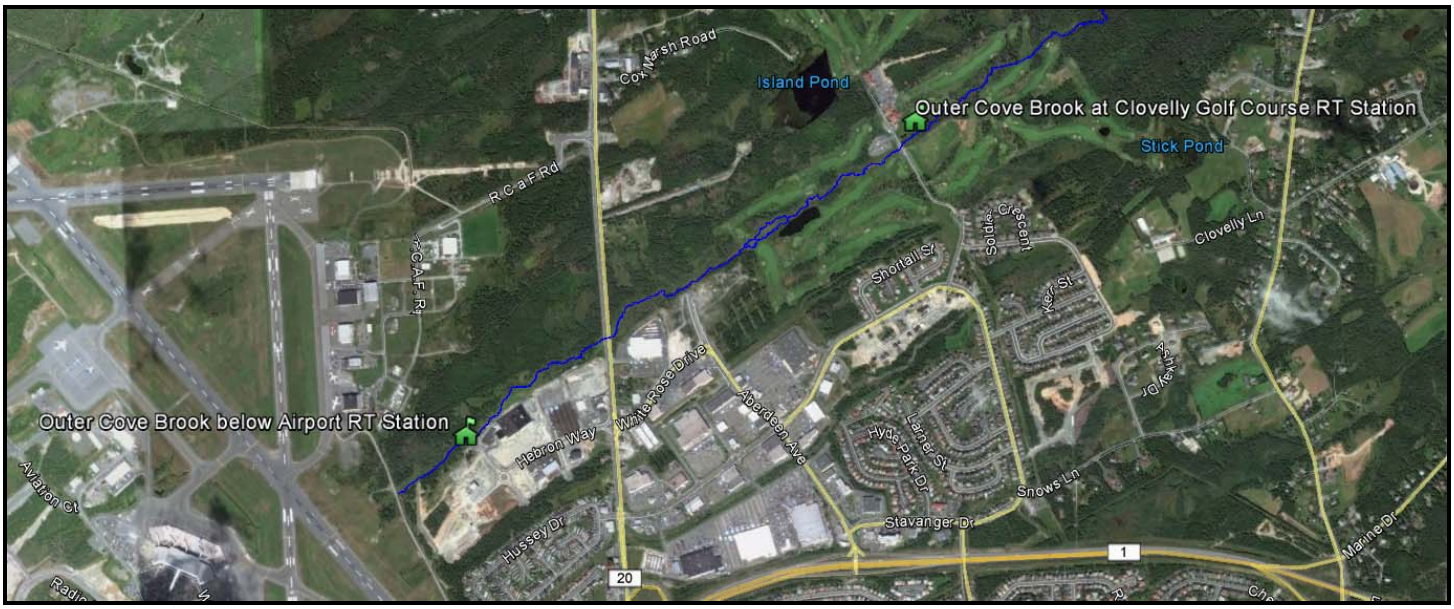


Figure 1: Locations of Outer Cove Brook Real-Time Water Quality and Quantity Monitoring Stations.

The Outer Cove Brook network was established in response to increased commercial development in the Torbay Road North Commercial Development Area. A significant portion of the land surrounding Outer Cove Brook is currently being developed into commercial establishments. One station was located upstream of the developments, while the other station was downstream.

In 2012 an agreement was signed between the City of St. John's and ENVC for the establishment of a real-time monitoring network for Outer Cove Brook. Under the agreement, the City of St. John's was responsible for providing funding for the installation of two real-time water quality and quantity monitoring stations, including associated maintenance and equipment costs. This agreement expired in 2015 and the stations are no longer operational.

The stations were removed at the end of November 2015. This will be the last annual report on the Outer Cove Brook Stations.

Site Descriptions

The headwaters of Outer Cove Brook originate in a boggy area of Airport Heights, just east of Windsor Lake (Figure 2). The brook flows beneath Portugal Cove Road, north toward St. John's International Airport, where it is partially channeled beneath the runways before emerging in a forested area on the eastern perimeter of the airport. The Outer Cove Brook below Airport station is approximately 400m downstream of the airport's perimeter. At this station, the river is surrounded by tall grasses and marshland, with mature conifer forests (see Figure 3a). The sonde is located in a deep section of the well-defined channel.

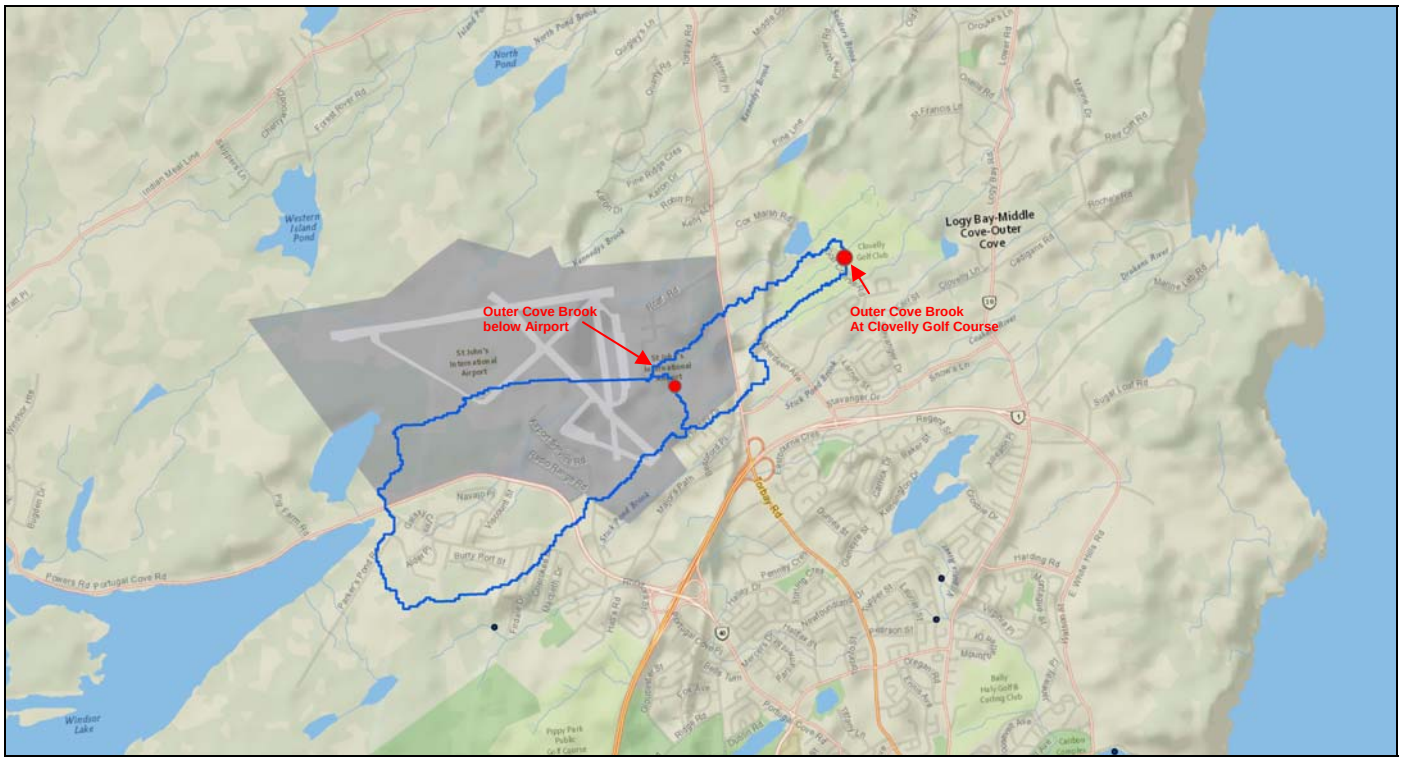


Figure 2: Map of the Outer Cove Brook Real-Time Water Quality/Quantity Monitoring Stations Watersheds

Outer Cove Brook then flows through the new Torbay Road North Commercial Development Area before passing beneath Torbay Road. The brook continues flowing north-east through marshlands surrounded by forest, bordering along the Abderdeen Extension development area, before entering and flowing through a buffer zone within Clovelly Golf Course. The second real-time station, Outer Cove Brook at Clovelly Golf Course, is located in a patch of trees on the eastern side of Golf Course Road adjacent to the clubhouse. The station sits in a marshy area which is heavily saturated during high flows and surrounded by tall grasses and some conifers (Figure 3b). The sonde typically sits in a deep, defined channel upstream of the braided portion of the river.

Downstream of the real-time stations, Outer Cove Brook meanders through the buffer zone in Clovelly Golf Course before entering a heavily forested area, where it continues northeastward to Savage Creek and is joined by Stick Pond Brook before crossing Outer Cove Road and flowing through the valley to its outlet in the Atlantic Ocean at Outer Cove Beach.

Figure 3: (a) Outer Cove Brook below Airport

(b) Outer Cove Brook at Clovelly Golf Course

Station Setup

Water quality parameters are measured at each station using a Hydrolab DataSonde instrument (Figure 4).

Model DS5 © 2005 Hach Company

Figure 4: Hydrolab DataSonde used for monitoring water quality parameters.

Six water parameters are measured at each station, including five water quality parameters (water temperature, dissolved oxygen, pH, turbidity and specific conductivity), and one water quantity parameter (stage). An additional water quality parameter, total dissolved solids (TDS) is calculated from this specific conductivity and water temperature (Appendix II).

Water quality and quantity data are recorded on a quarter-hourly basis (every 15 minutes) at both stations.

All data is viewable and downloadable online through ENVC's Automatic Data Retrieval System (ADRS) located here: http://www.env.gov.nl.ca/wrmd/ADRS/v6/Graphs_List.asp

Quality Assurance and Quality Control

To ensure accurate data collection, water quality instruments are subjected to quality assurance procedures, in order to mitigate any errors caused by biofouling and/or sensor drift. Quality assurance procedures include: (i) a thorough cleaning of the instrument, (ii) replacement of any small sensor parts that are damaged or unsuitable for reuse, and (iii) the calibration of the sensors using standard solutions. Quality assurance procedures are carried out every 30-40 days, before the start of a new deployment period.

Deployment periods for 2015 are summarized in Table 1.

Table 1: Water quality instrument deployment start and end dates for 2015 at Outer Cove Brook Stations

	Deployment	Removal
Outer Cove Brook Network	December 3, 2014	January 21, 2015
	January 21, 2015	March 4, 2015
	March 5, 2015	April 14, 2015
	April 15, 2015	June 2, 2015
	June 2, 2015	July 22 2015
	July 22, 2015	August 28, 2015 & September 2, 2015
	August 28, 2015 & September 2, 2015	October 7, 2015
	October 7, 2015	November 12, 2015

*Please note that due to weather on August 28, 2015 the scheduled maintenance and calibration for Outer Cove Brook below Clovelly Golf Course station was pushed to September 2, 2015.

As part of the quality control procedures, instrument performance is tested at the start and end of its deployment period (Appendix I).

Instruments are assigned a performance ranking (i.e. poor, marginal, fair, good, excellent) for each water quality parameter measured (Appendix I). Appendix I has the details on the instrument performance rankings of each of the instrument sensors deployed at Outer Cove Brook. The main issues which led to poor or marginal performance rankings were the presence of algae or biofouling on the field sonde at removal, and calibration issues with the QA/QC sonde.

For more detailed analyses of a particular time period, date or deployment period, please refer to the individual deployment reports: http://www.env.gov.nl.ca/env/waterres/rti/rtwq/csdr/index.html

Data Interpretation

Performance issues and data records were interpreted for each station during the deployment period for the following parameters:

- Water Temperature (^{o}C)
- pH (pH units)
- Specific Conductivity (uS/cm)
- Total Dissolved Solids (g/L)
- Dissolved Oxygen (mg/L)
- Dissolved Oxygen (%Sat)
- Turbidity (NTU)
- Stage (m)
- Streamflow (m^3/s)

A description of each parameter is provided in Appendix II.

The following parameter analyses cover the entire deployment period from January 1, 2015 to November 12, 2015. These interpretations aim to point out seasonal and overall trends and major issues affecting the parameters.

Any gaps in data are the result of transmission loss, or periods where the instrument was removed from the water.

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

Outer Cove Brook below Airport

Stage & Stream Flow

Stage values are based on a vertical reference that is unique to each station, thus absolute values of stage are not comparable between stations, but relative changes in stage are.

Figure 5 displays stage and stream flow values recorded every 15 minutes at Outer Cove Brook below Airport from January 1, 2015 to November 12, 2015. Please note the stage & stream flow data included in this report is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC. These values are provisional. Quality assured and quality controlled stage values are available through EC (http://www.ec.gc.ca/rhc-wsc/default.asp).

The 2015 stage values ranged from 0.787 m to 1.412 m. The highest stage value was recorded on January 18th 2015 the increase came after several days of precipitation. The 2015 stream flow data ranged between a minimum of 0.031m^3/s and a maximum of 0.787 m^3/s. Fluctuations in stage and stream flow correspond to precipitation events as increased runoff into the river increases the river's volume, raising the stage level (Appendix III).

This stream is naturally flashy under the influence of precipitation. Across the year of data there are frequent although not lengthy high stage periods.

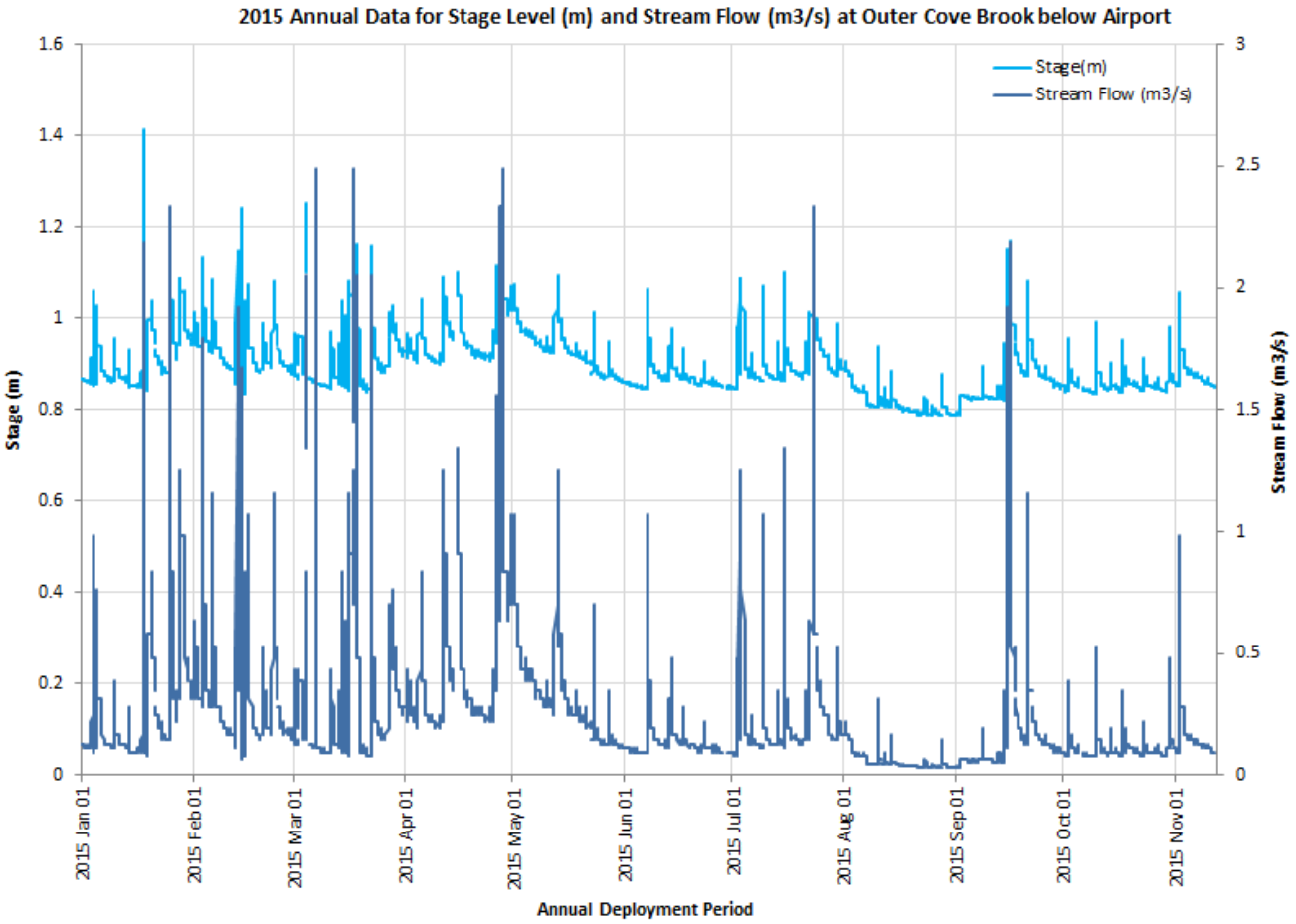


Figure 5: 2015 Stage (m) and Stream Flow (m3/s) values recorded at Outer Cove Brook below Airport.

Averaged daily data for Stage, Stream flow and total Precipitation

Precipitation data was recorded at the St. John's International Airport Weather station. The data collected is an average of the rainfall accumulation over the period of that day (Figure 6).

During this deployment year, the highest averaged daily precipitation recorded was 67mm on September 15th 2015. There is a corresponding increase in stage and stream flow during that rainfall event.

The stage and stream flow data charted below is the average daily value to compare with the total precipitation for the time frame.

Please note the stage & stream flow data included in this report is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC. These values are provisional. Quality assured and quality controlled stage values are available through EC (http://www.ec.gc.ca/rhc-wsc/default.asp).

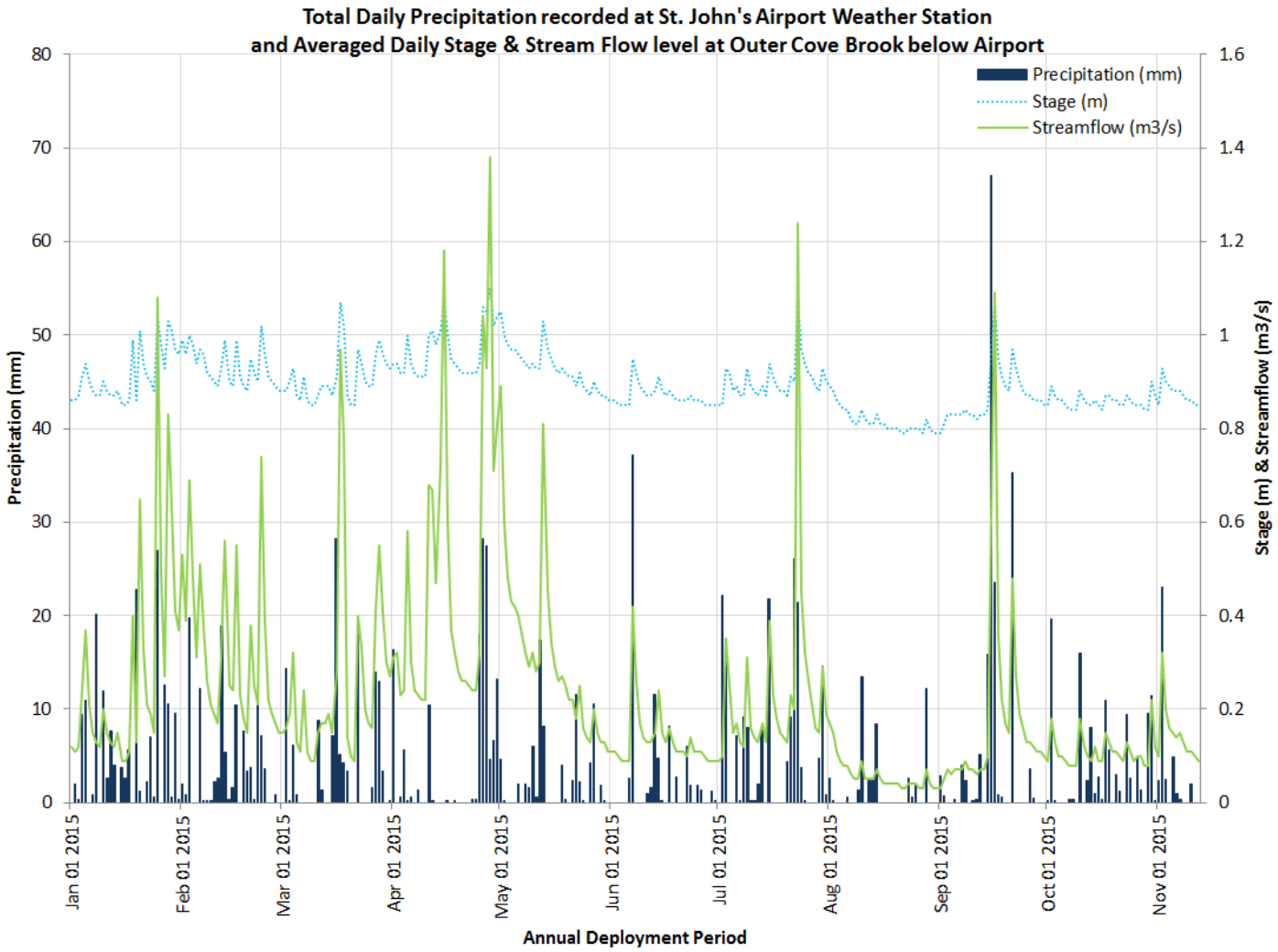


Figure 6: Precipitation recorded at St. John's International Airport Weather Station. Stage (m) and Stream flow (m3/s) values recorded at Outer Cove Brook below Airport

Water Temperature

Water temperature at Outer Cove Brook below Airport displays large diurnal variations, shown in Figure 7, typical of shallow water streams and ponds as they are highly influenced by diurnal variations in ambient air temperatures. Water temperatures start to increase from May through to August. The highest temperatures recorded are in August 2015.

As the air temperatures decrease (Figure 8) the water temperatures also start to decrease. As the deployment year ends the water temperatures start to drop as the Fall season begins.

Water temperatures ranged from a minimum of -0.1°C to a maximum of 19.8°C, with a median of 7°C at Outer Cove Brook below Airport.

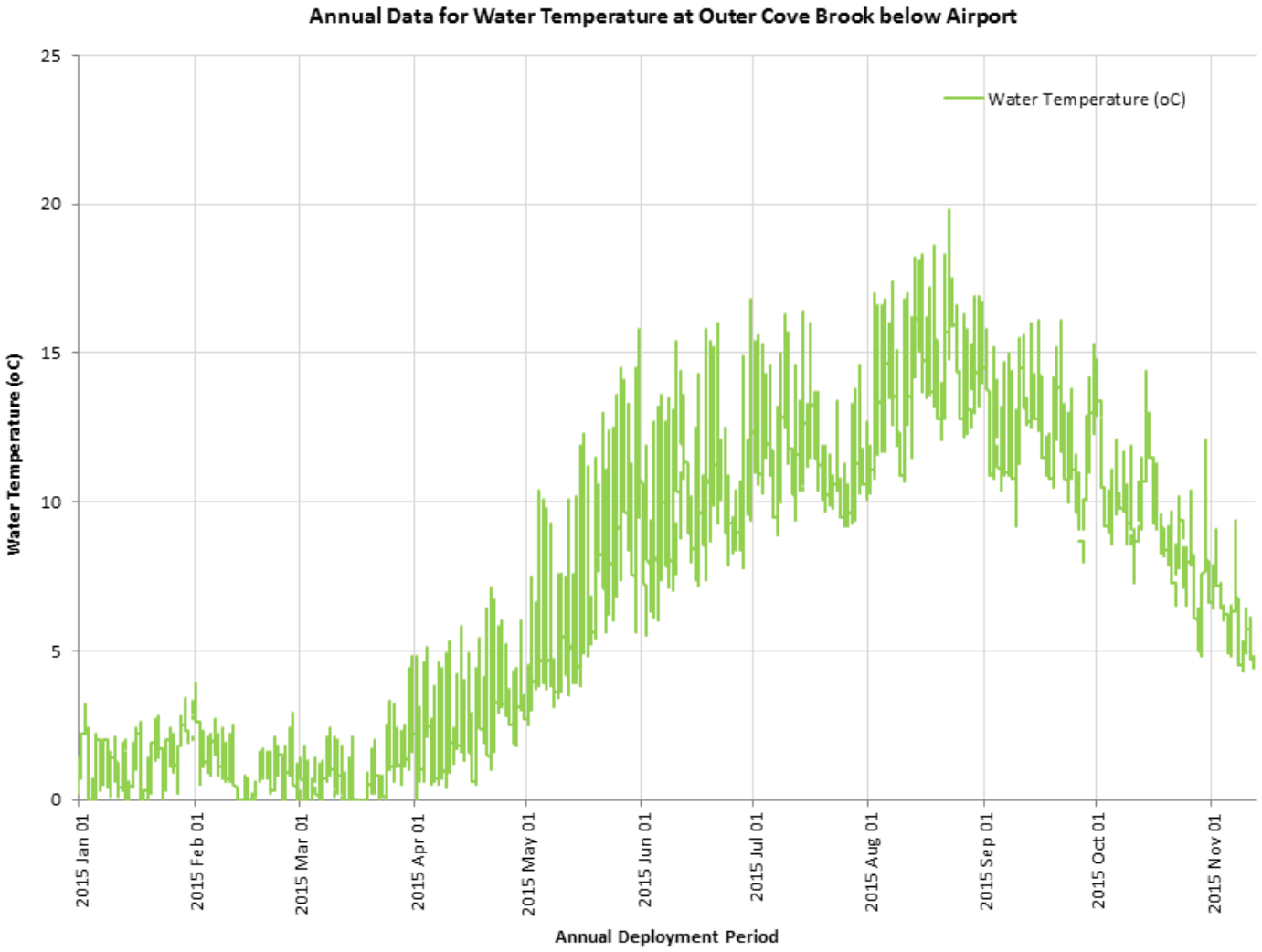


Figure 7: Water temperature (°C) values recorded at Outer Cove Brook below Airport

Water temperature values show a close relationship with air temperatures (Figure 8). Increases and decreases in air temperatures are reflected in water temperature.

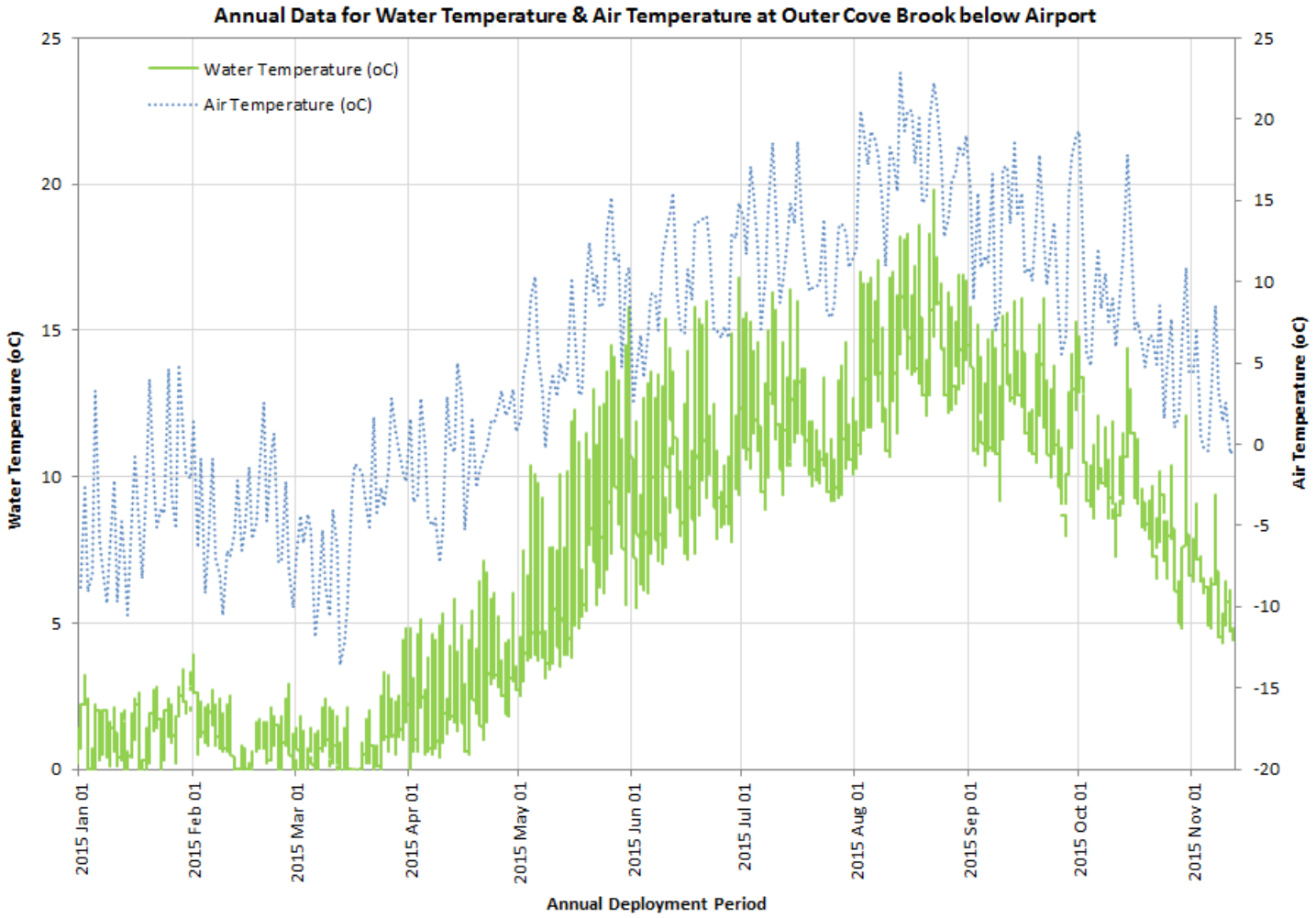


Figure 8: Averaged Air Temperature (°C) from St. John's International Airport & Water temperature (°C) values recorded at Outer Cove Brook below Airport

pH

During the deployment year Outer Cove Brook below Airport had pH values that ranged between a minimum of 5.75 and a maximum of 7.5 pH units, with a median value of 6.65 pH units. The CCME guidelines for the protection of freshwater aquatic life provide a basis by which to judge the overall health of a river system, (the guidelines are indicated in red) (Appendix IV). At this station, pH values do fall closer to the minimum guideline of 6.5, as shown in Figure 9.

The visible increases in pH values can be explained by corresponding precipitation events. As stage level drops down the pH values increase. The reduced stage levels allow for the pH levels to become more alkaline until the next flush of water or runoff through the brook. The data from May 1st to June 2nd, 2015 was removed due to inaccuracies; this was also the case with the data removed from June 26th, to July 26th, 2015 (circled in red on Figure 9).

It should be noted that during the months of December through to April there is a recurrent growth of slime-like aquatic vegetation that coats everything that is in the water (Appendix V). The die off of this substance starts when the water temperatures start to increase in May and into June. The die off can affect the pH levels for a short span of time.

As the deployment year for Outer Cove Brook below Airport ends the pH levels drop below the 6.5 guideline, this is likely a result of the increasing stage level at this time of year.

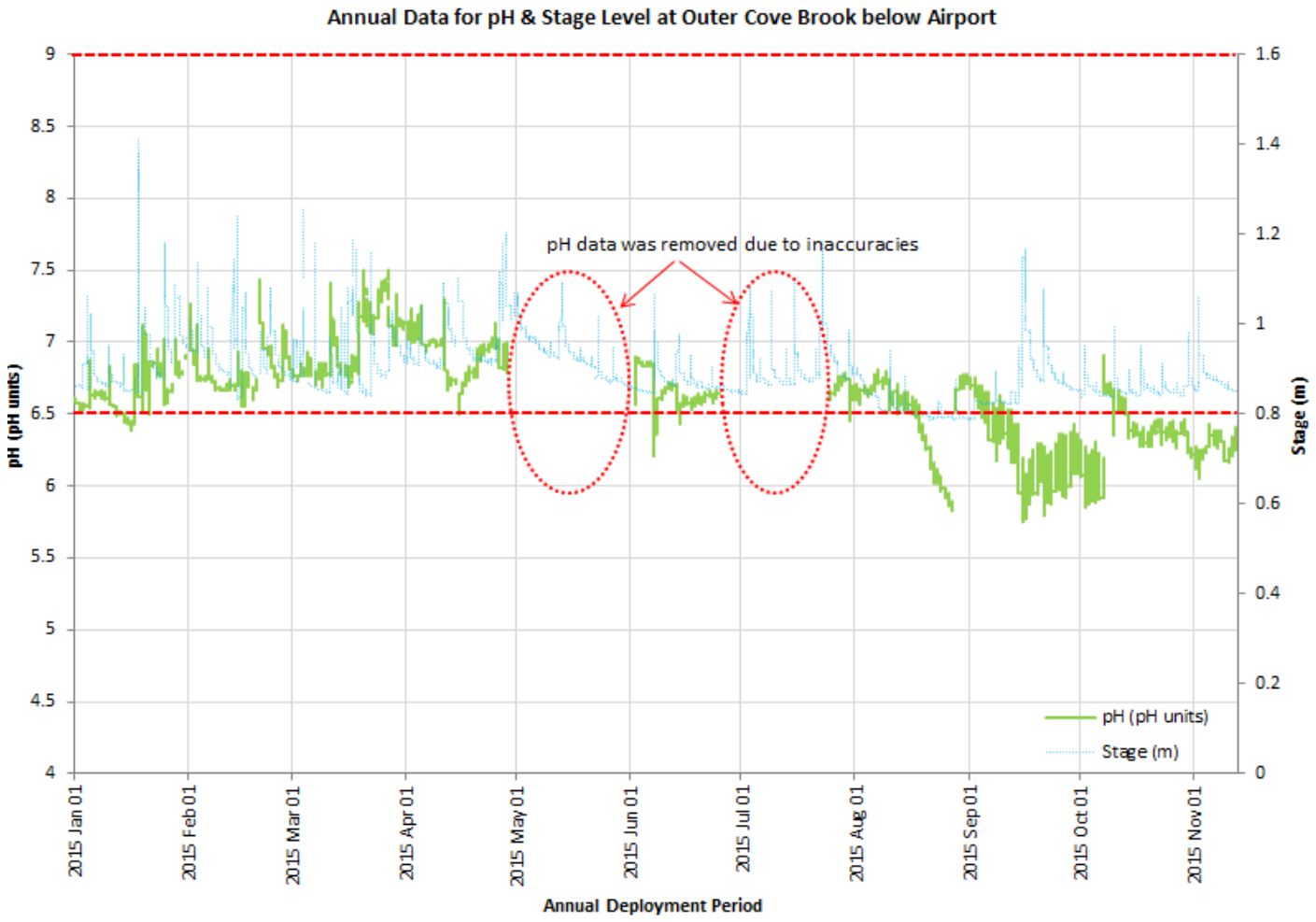


Figure 9: 2015 pH (pH units) values recorded at Outer Cove Brook below Airport

Specific Conductance and Total Dissolved Solids (TDS)

Specific conductivity ranged from 80 µS/cm to 2823 µS/cm, with a median value of 525 µS/cm. Total dissolved solids (TDS) data ranged between 0.0512 and 1.81 g/L, with a median value of 0.336 g/L, TDS is calculated by the instrument.

The maximum values for both parameters were reached early in January and throughout February and March. Cold temperatures and snow throughout these months followed by intermittent rainfalls (Appendix III), washed road salt into the river system, leading to large increases in both Specific Conductivity and Total Dissolved Solids.

As the warmer weather approaches, the conductivity levels decrease. This is evident on Figure 10 as the spikes in conductivity are replaced with lower values and dips during high stage periods. Spring, summer and fall rainfalls increase the stage level at the brook, however without the added pressure of the road salting the TDS and conductivity levels actually dip as the materials and minerals in the brook are diluted by the added freshwater. This is representative of many urban brooks.

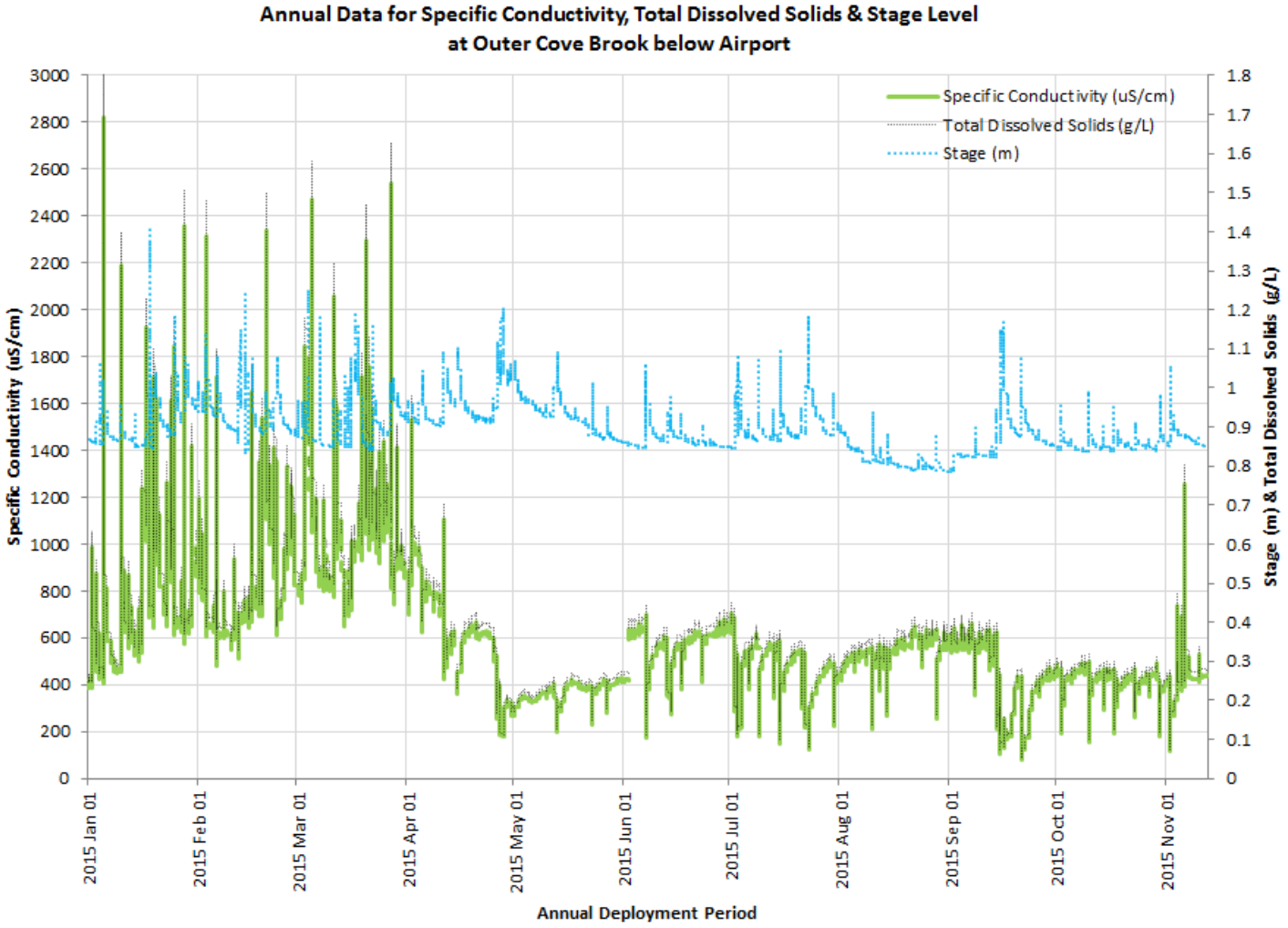


Figure 10: Specific conductivity (µS/cm), total dissolved solids (g/L) and stage level (m) values recorded at Outer Cove Brook below Airport.

Dissolved Oxygen

The Dissolved Oxygen % sat values ranged from 61.7 %Sat to 95.1 %Sat, with a median of 83.7 %Sat. Dissolved Oxygen (mg/L) measured 8.06mg/L to 12.65mg/L, with a median of 10.32mg/L. For most of the deployment year the DO mg/L values sit just above or within the minimum DO guideline for the protection of early life stages (Appendix IV). However during the warmer months in the year the dissolved oxygen content drops below the maximum guideline. The water is warmer during this period and cannot hold the same amount of oxygen as the cooler months (Figure 11).

Due to questionable data during the timeframe of May 19th to June 2nd, 2015 the data was removed from the report. It did not represent the water way and should not be used in any data analysis.

It was identified during a field visit in March that the annual growth of the slime-like aquatic substance had returned to this brook (Appendix V). The substance completely coats anything in the water body, including the instrument and its protective casing. The fouling created issues with the data that was being recorded; the sensors have trouble taking an accurate reading through the substance (Appendix V). During die-off of the algae there is an excessive amount of oxygen being used in the brook and this is possibly captured in the data with the lower dissolved oxygen readings from mid-May.

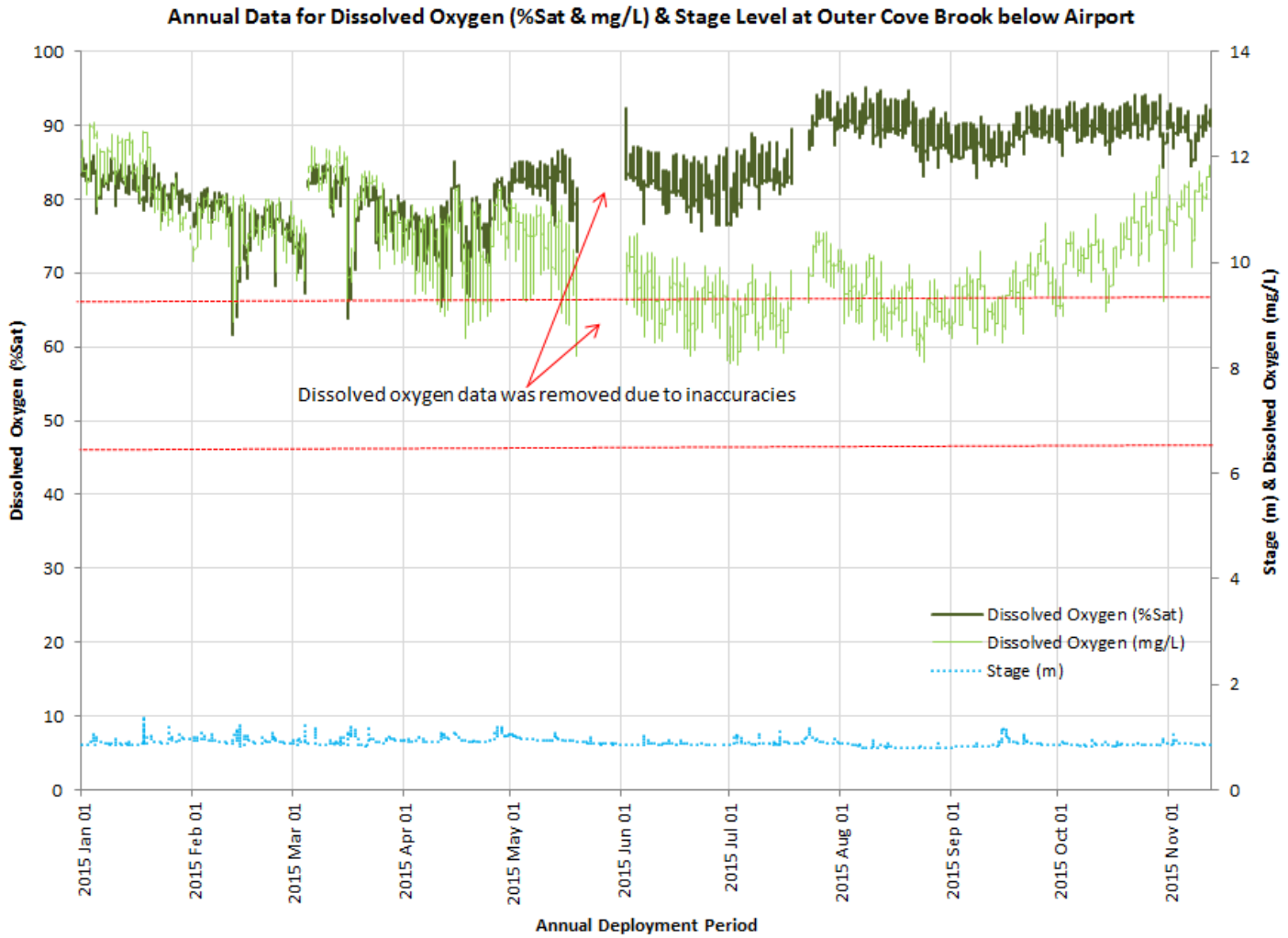


Figure 11: Dissolved oxygen (% Sat & mg/L) and water temperature (°C) values recorded at Outer Cove Brook below Airport.

Turbidity

During this deployment year the turbidity values ranged from 0 NTU to 742 NTU, with a median of 1.8 NTU. The maximum value of 742 NTU was recorded on July 11th 2015 directly after an increase in stage level in July.

Due to questionable data during the timeframe of May 19th to June 3rd, 2015 and August 3rd to August 28th, 2015 the data was removed from the report. It did not represent the water way and should not be used in any data analysis.

Generally, turbidity events coincide with rises in stage, as shown in Figure 12. Rainfall flushes land debris, soil, road salt and gravel into the brooks, these substances can be captured in the turbidity data. Another event that can influence turbidity is the slime-like substance that grows throughout the brook during the winter months (Appendix V). The slim-like algae can interfere by blocking the turbidity sensor or during the die off of the algae which fill the water column.

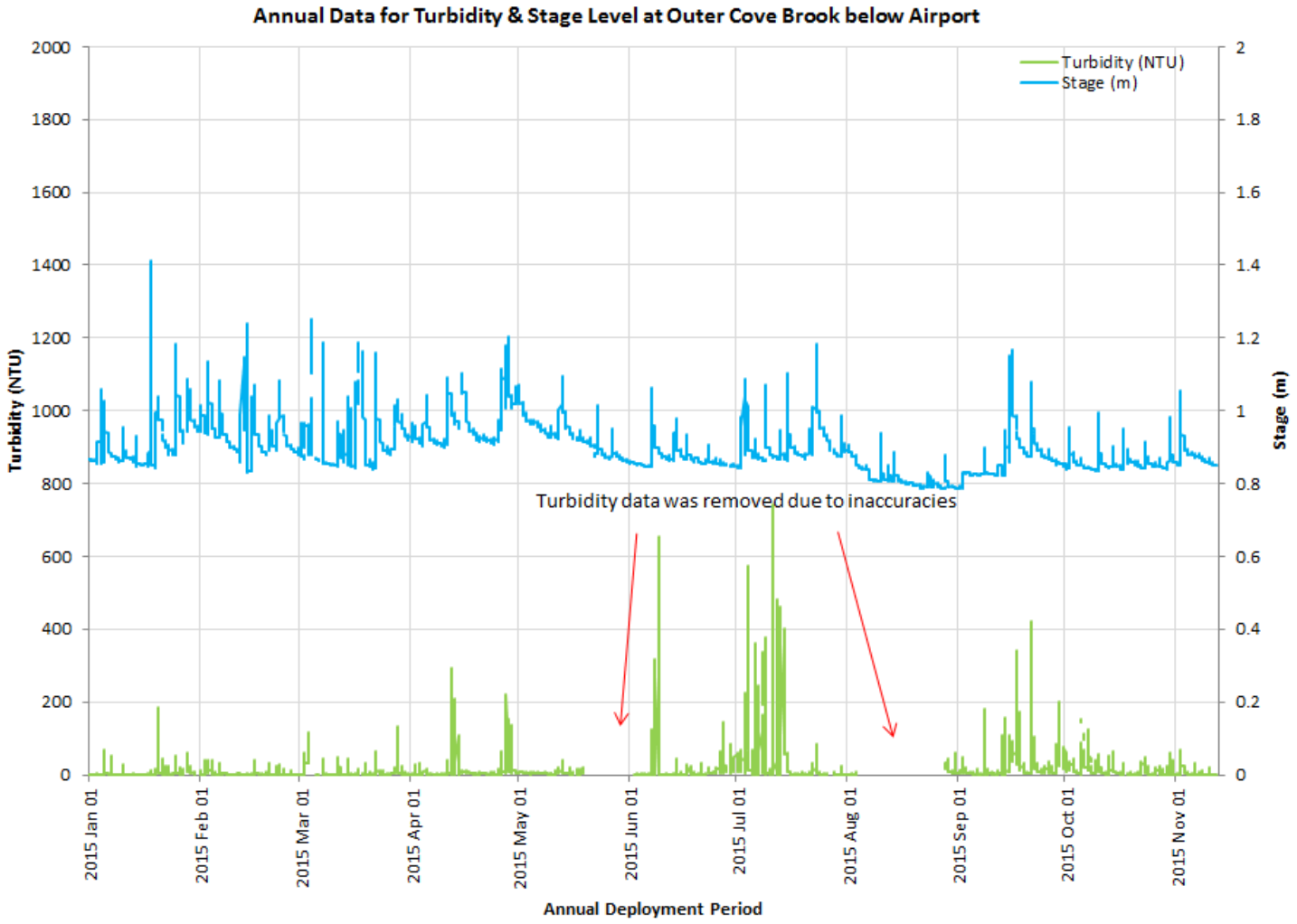


Figure 12: Turbidity (NTU) and stage level (m) values recorded at Outer Cove Brook below Airport.

Conclusions

During the 2015 deployment year, Outer Cove Brook below Airport displayed characteristics typical of other St. John's urban streams. Naturally this stream is very flashy and greatly influenced by snow melt, spring runoff and precipitation throughout the year; therefore there is a lot of variation in the water parameters data. Stage level captured the influences of precipitation and runoff events that occurred over the year.

During the months of January to early June there is a heavy growth of slime-like substance present in the brook. This substance coats the instrument and anything in the water during the time frame. It has caused some issues with the actual data due to the fouling of the sensor and it also impacted the water parameters (i.e. pH, dissolved oxygen content and turbidity) during the growth and die-off periods of the slime-like substance (Appendix V).

The water temperature of the brook is diurnal and also influenced by the surrounding air temperature in relation to the season. The shallow urban streams and brooks respond faster to air temperatures which are clearly seen in the variability of the data.

Outer Cove Brook below Airport had a median pH value of 6.65 which was inside the normal range for stream water. Although the pH median is within the normal range for stream water there is a lot of movement in the data. The movement may be a result of a flashy urban brook influenced by the changing urban areas around it and the lifecycle of the slime-like substance.

Outer Cove Brook below Airport displays two different reactions in specific conductivity. During the winter thaw and high runoff seasons in March and April the conductivity levels increase with the higher stage levels likely a result of salt runoff from the surrounding urban areas and the airport. Into the summer and fall seasons (June through to early November) the conductivity levels drop with high stage levels. The decrease in conductivity during those times was likely a result of periods of rainfall diluting the suspended substances in the brooks.

The Dissolved Oxygen median for this deployment year was 10.32mg/L. As the warmer temperatures started to increase in June the dissolved oxygen levels in the brook were extremely low. It was during this time that the slime-like algae growing in the brook had started to die off, in turn decreasing the dissolved oxygen levels.

Turbidity median for 2015 was 1.8 NTU which was higher than the 2014 median of 0.7 NTU. Majority of the turbidity increases corresponded with the precipitation events that can influence the amount of suspended sediments in the water column.

Outer Cove Brook at Clovelly Golf Course
Stage & Stream Flow

Stage values are based on a vertical reference that is unique to each station, thus absolute values of stage are not comparable between stations, but relative changes in stage are.

Figure 13 displays stage and stream flow values recorded at Outer Cove Brook at Clovelly Golf Course from January 1 to November 12, 2015. Please note the stage & streamflow data included in this report is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC (http://www.ec.gc.ca/rhc-wsc/default.asp).

Stage values ranged from 0.433m to 0.987m over the 2015 deployment year. Stream flow over the deployment year ranged between 0.007 m^3/s to 1.314m^3/s. The fluctuations in stage and stream flow correspond to precipitation events, as runoff into the river increases the river's volume, raising the stage level (Appendix III).

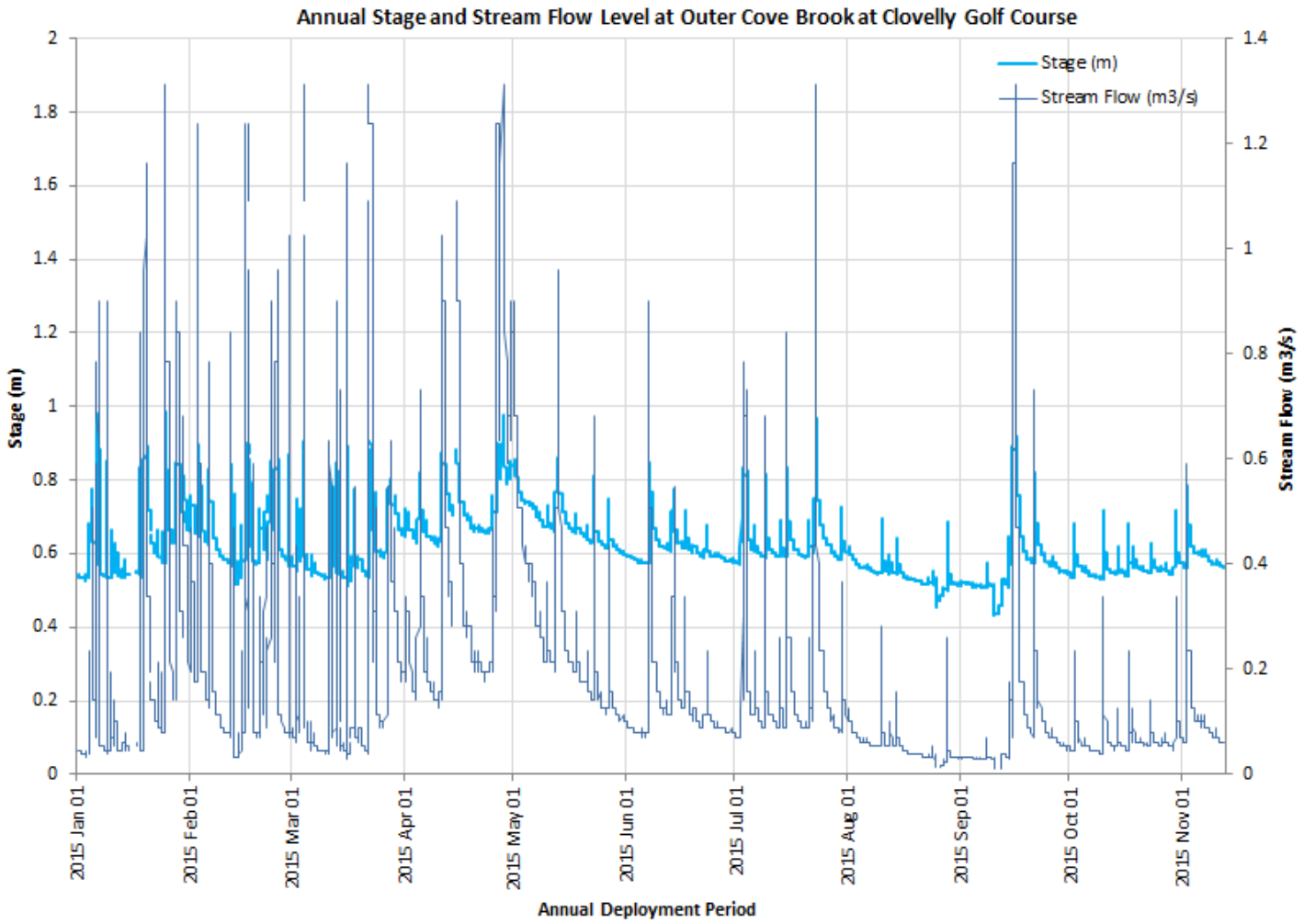


Figure 13: Stage (m) and Stream Flow (m3/s) values recorded at Outer Cove Brook at Clovelly Golf Course.

Temperature

Water temperature at this station displays large diurnal variations, shown in Figure 14, typical of shallow water streams and ponds as they are highly influenced by diurnal variations in ambient air temperatures. The largest daily fluctuations are noticeable from May through to September 2015.

During this deployment period the water temperatures ranged from a minimum of -0.14 to 20.16°C, with a median of 8.05°C which was higher than 2014 median of 6.9°C in water temperature.

Seasonal temperature trends are obvious in Figure 14 as temperatures increase throughout spring and into the summer months, peaking in August, before gradually decreasing again throughout fall as winter approaches.

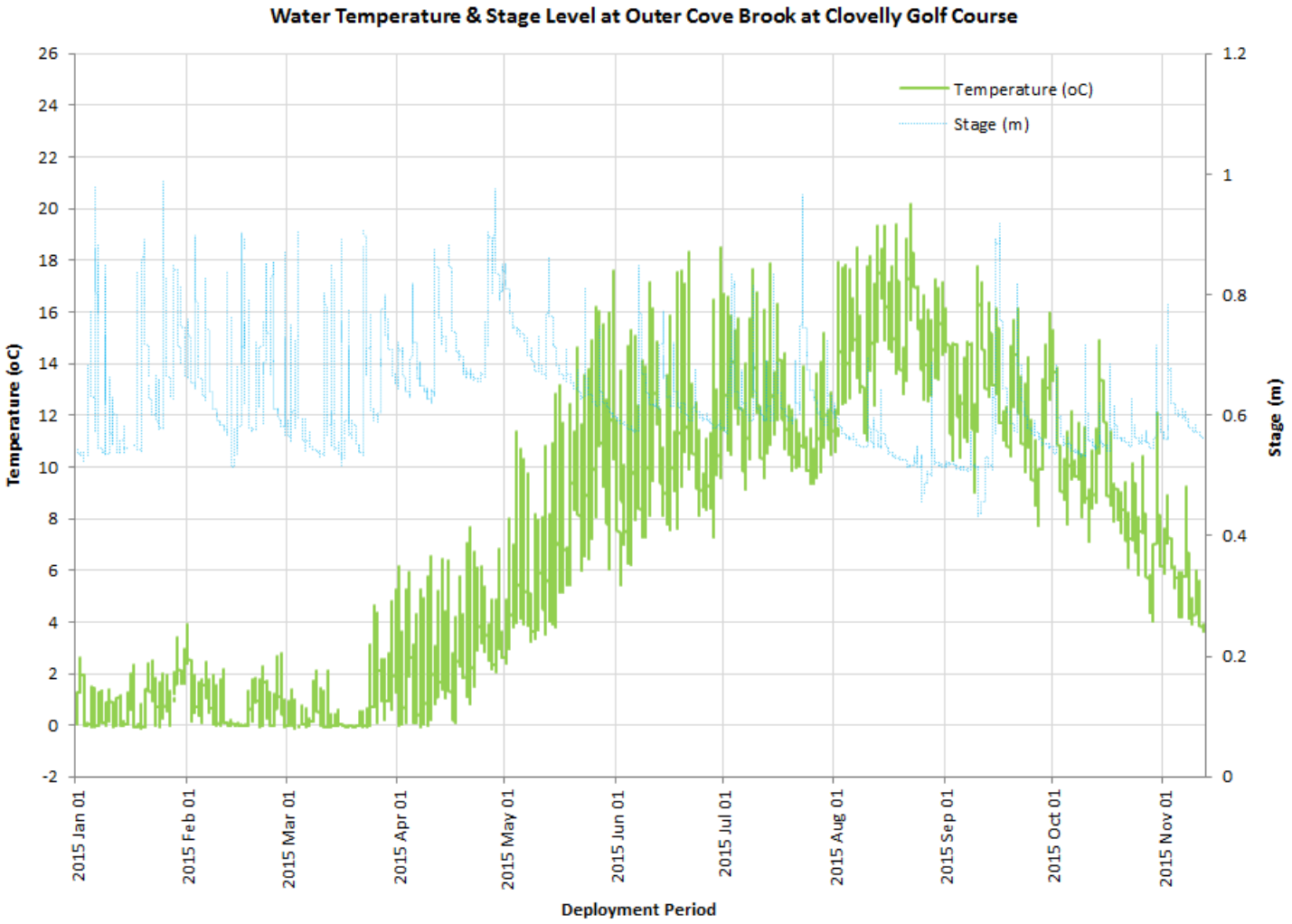


Figure 14: Water temperature (°C) values recorded at Outer Cove Brook at Clovelly Golf Course

Water temperature values show a close relationship with air temperatures (Figure 15). Increases and decreases in air temperatures are reflected in water temperature.

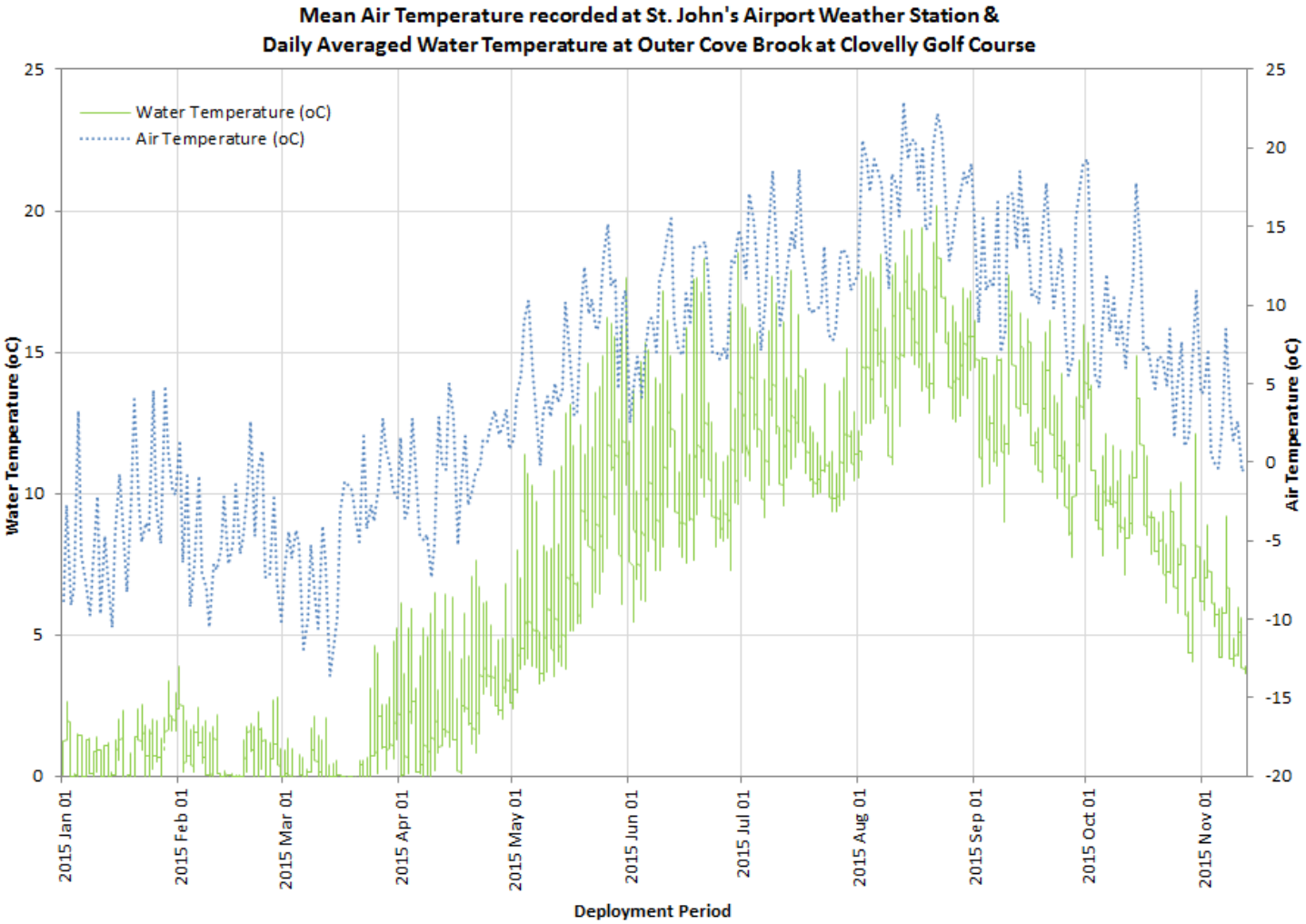


Figure 15: Averaged Air Temperature (°C) from St. John's International Airport & Daily Averaged Water temperature (°C) values recorded at Outer Cove Brook at Clovelly Golf Course

pH

pH values ranged between 5.92 and 7.31 pH units, with a median of 6.45 pH units.

The CCME guidelines for the protection of freshwater aquatic life provide a basis by which to judge the overall health of a river system (Appendix IV). At this station, pH values float above and below the minimum guideline of 6.5, as shown in Figure 16. Naturally, all streams and brooks are different. In the case of Outer Cove Brook at Clovelly Golf Course, pH is generally within the normal range for stream water in St. John's.

There are visible drops in pH values throughout the year; decreases in pH are generally related to precipitation events. This is a natural occurrence between precipitation and pH levels (Figure 16). pH increases may be a result of road salt runoff during spring thaw, as shown early in the deployment year around January, February and March.

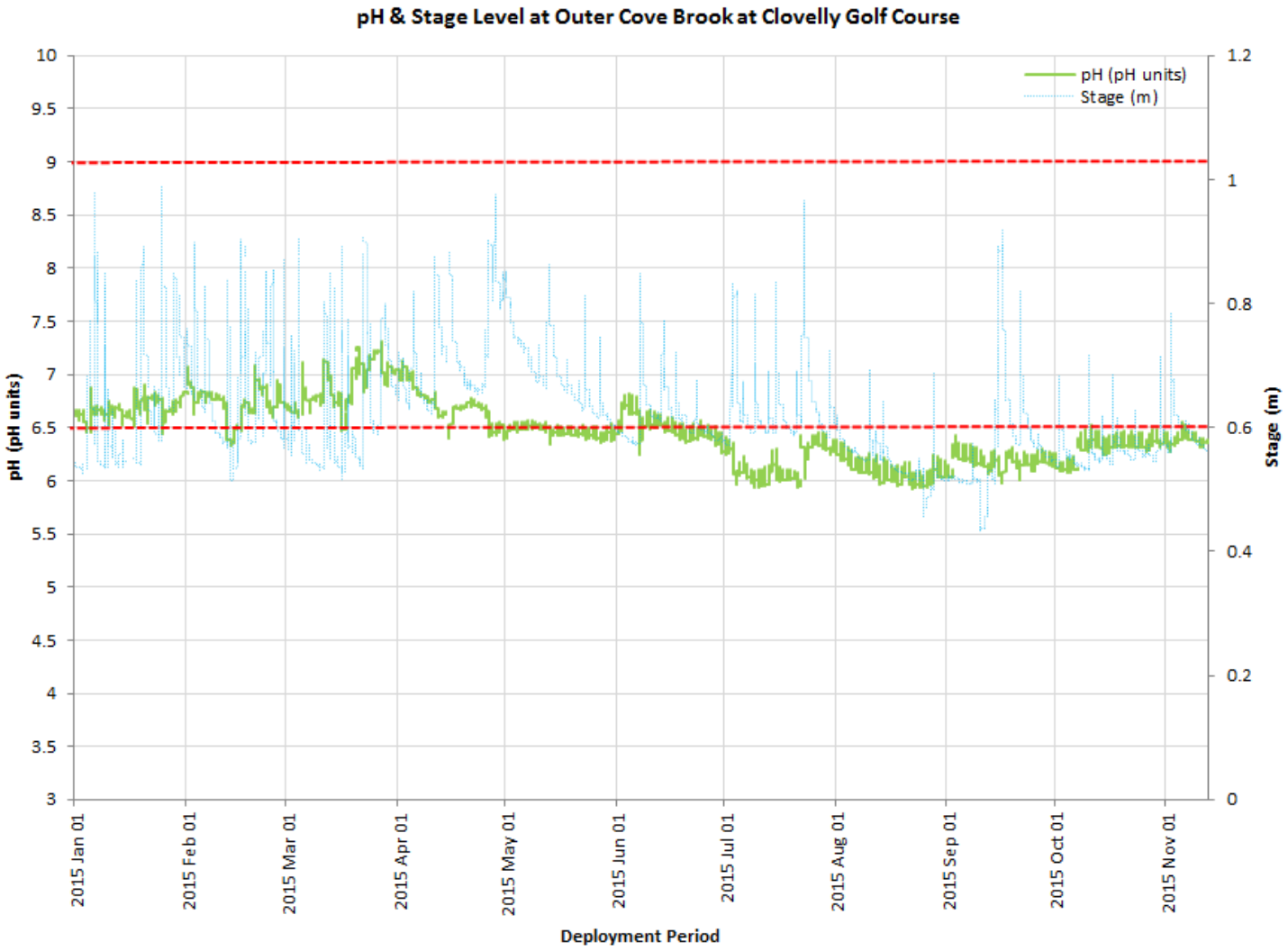


Figure 16: pH (pH units) values recorded at Outer Cove Brook at Clovelly Golf Course.

Specific Conductance and TDS

During the deployment year the specific conductivity ranged from 148.8 to 5249 uS/cm, with a median of 570 uS/cm. Total dissolved solids (TDS) ranged between 0.0952 g/L and 3.36 g/L, with a median of 0.365 g/L.

The maximum values for both parameters were reached on January 19th 2016. Cold temperatures and snow throughout January likely followed by intermittent rainfall for several days, results in the road salt used on roadways during freezing temperatures being flushed into the river system, resulting in the high conductivity values during that time.

A seasonal trend in relation to stage is evident for specific conductivity and TDS in Figure 17. Cold, snowy winter months are marked by spikes in conductivity and TDS with stage increases as salts used on roadways and runways are washed, carried or blown in the brook during winter storms. Spring, summer and fall rainfalls cause increases in stage with drops in TDS and conductivity due to dilution of solids in the brook from the added freshwater.

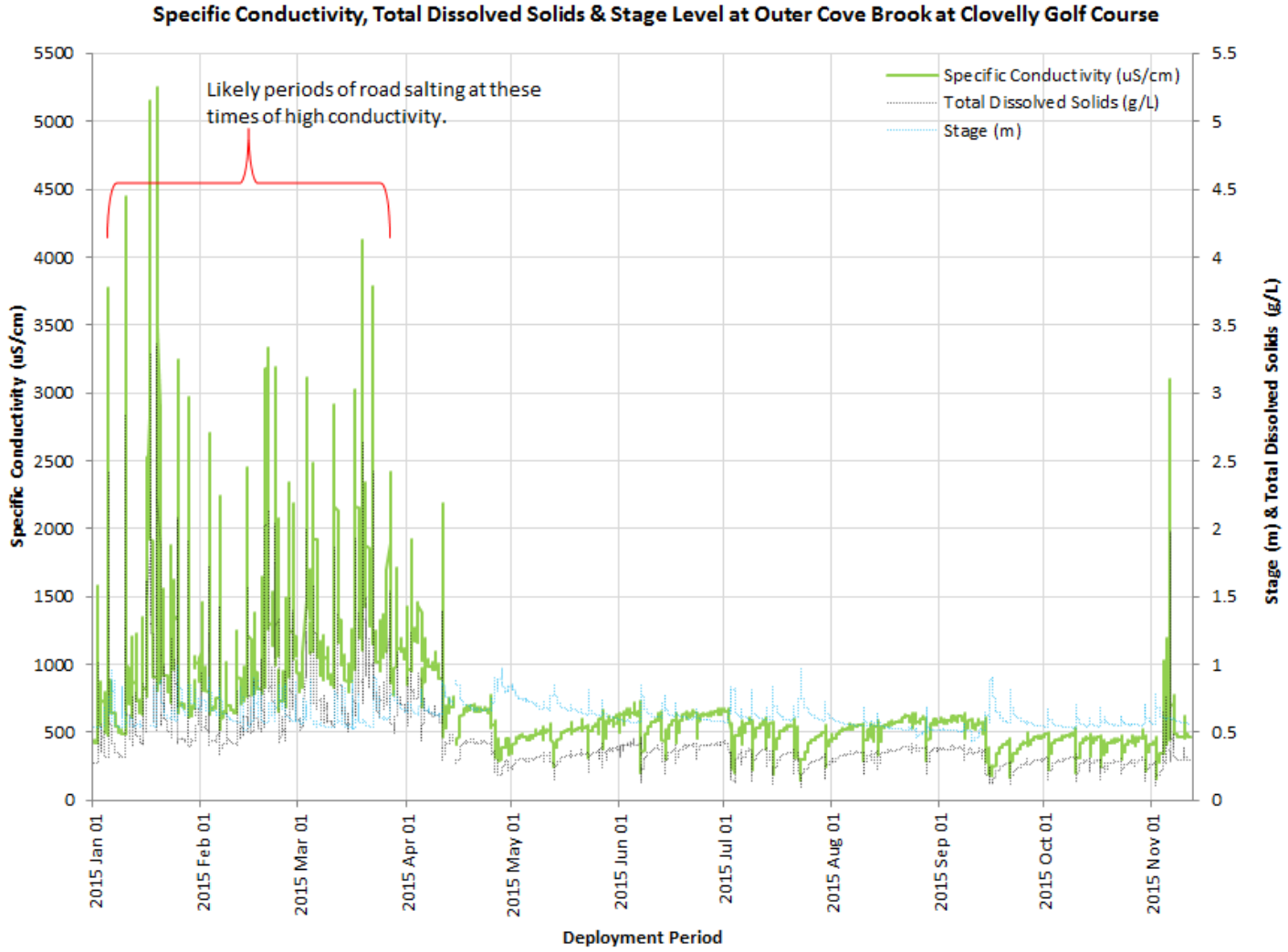


Figure 17: Specific conductivity (µS/cm), total dissolved solids (g/L) and stage level (m) values recorded at Outer Cove Brook at Clovelly Golf Course

Dissolved Oxygen

The instrument measures percent saturation directly, then calculates dissolved oxygen (mg/L) using the percent saturation and water temperature values.

The Dissolved Oxygen % sat values ranged from 46.4 to 98.7 %sat, with a median of 81.1 %sat. Dissolved Oxygen (mg/L) measured 5.97 mg/L to 13.17 mg/L, with a median of 9.82 mg/L. Dissolved oxygen (% sat) remained relatively constant throughout the seasons. Figure 18 demonstrates the natural inverse relationship that exists between dissolved oxygen (mg/L) and water temperature.

The large fluctuations in DO during summer are due to the presence of large amounts of algae and vegetation around this station. During the day, the plants are photosynthesizing, producing oxygen, but cease this process as night due to the absence of sunlight, causing the depletion of oxygen in the water at night.

The two dissolved oxygen events that are circled on February 12th and around March 16th & 17th, 2016 are also evident on the dissolved oxygen graph for Outer Cove Brook below Airport (Figure 11). It is unclear what may have influenced the dissolved oxygen to dip low at both stations. There is a possibility that the low values may be a result of the die-off of the slime-like algae that is present in the brook during these times.

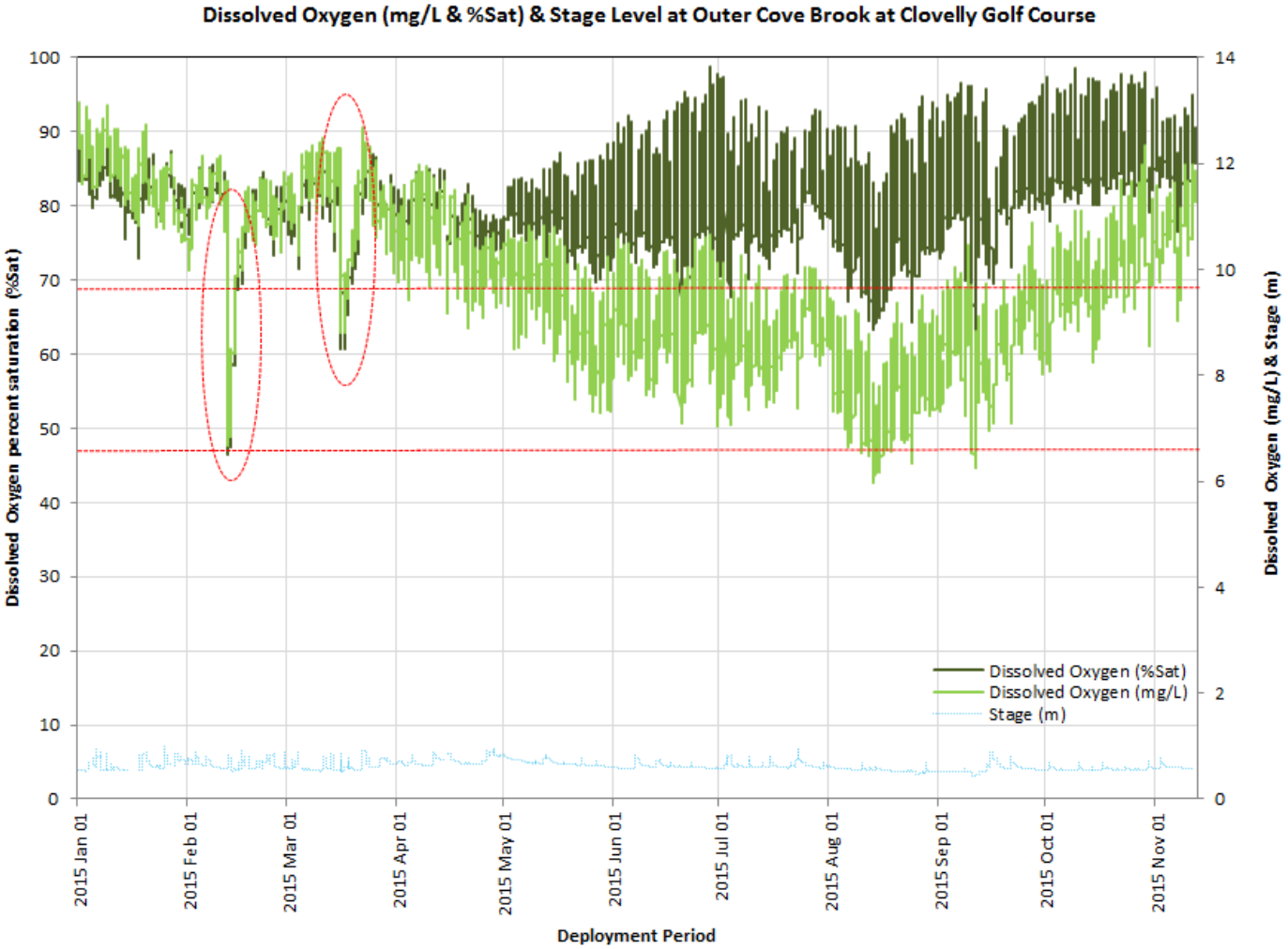


Figure 18: Dissolved oxygen (% Sat & mg/L) and water temperature (°C) values recorded at Outer Cove Brook at Clovelly Golf Course.

Turbidity

For 2015 deployment year the turbidity values ranged from 0 NTU to 196.4 NTU, with a median of 1.9 NTU. Generally, turbidity events coincide with rises in stage, as shown in Figure 19. In turn these events correspond to precipitation during the deployment periods (Appendix III).

In shallow urban streams the slightest disturbance is captured by the turbidity sensor. This is evident across the deployment year with the variability in the turbidity readings displayed on Figure 19.

Short-term turbidity sensor interference events were identified during the monthly review of the turbidity data. Generally interference is due to biofouling, leaf debris, and strands of algae which are abundant in Outer Cove Brook at Clovelly Golf Course blocking the sensor windows (Appendix VI). For these reasons, data was removed for several time periods as this data is inaccurate and should not be used in any statistical analysis.

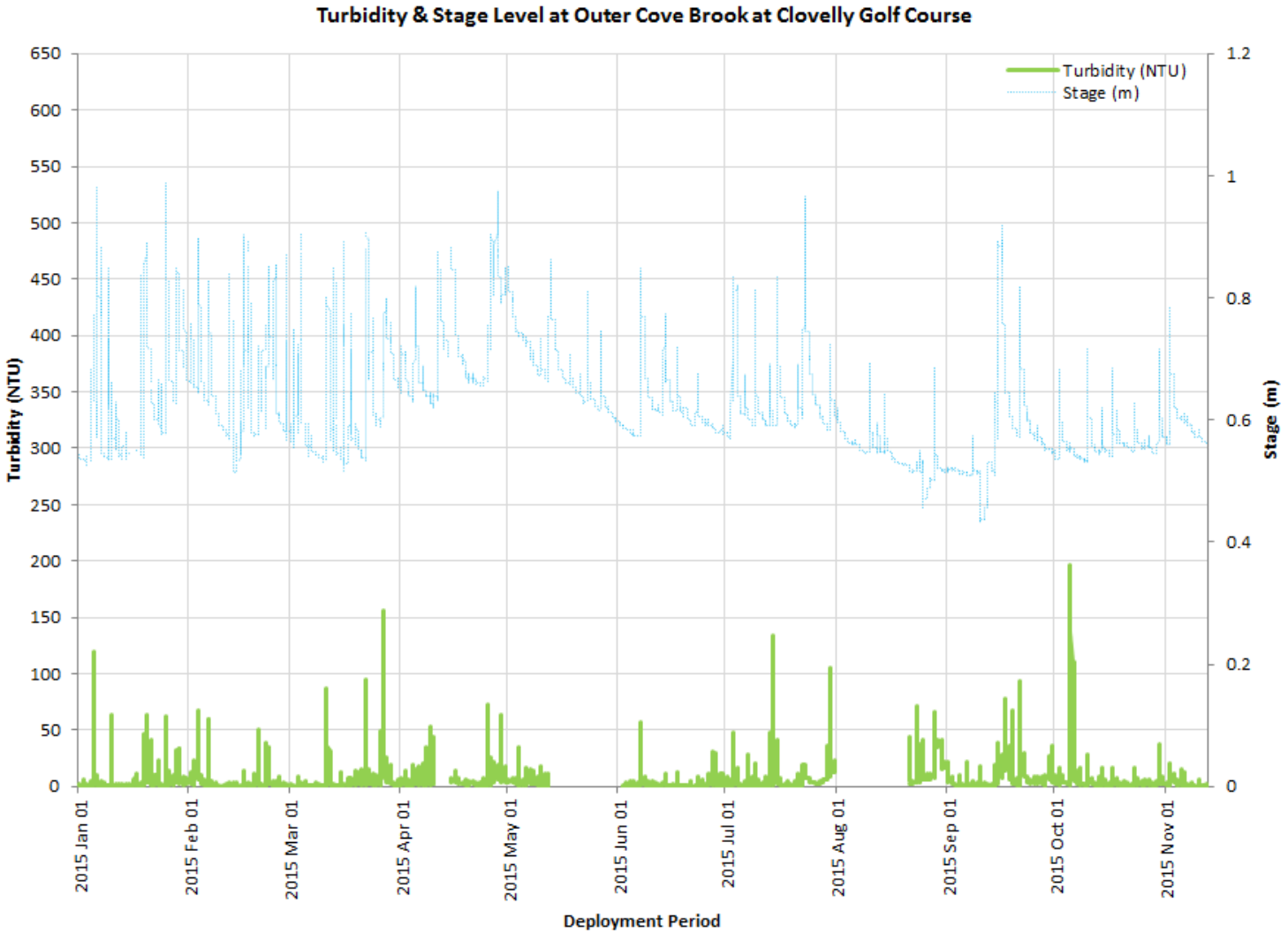


Figure 19: Turbidity (NTU) and stage level (m) values recorded at Outer Cove Brook at Clovelly Golf Course

Conclusions

During the 2015 deployment year Outer Cove Brook at Clovelly Golf Course displayed characteristics similar to that of Outer Cove Brook below Airport. The Clovelly Golf Course stream is also greatly influenced by snow melt, spring runoff and precipitation throughout the year; therefore there is a lot of variation in the water parameters data. Stage level captures the influences of precipitation and runoff events that occurred over the year.

During the months of January to early May there is evidence of the heavy slime-like substance at Clovelly (that is present in the Outer Cove Brook below Airport). While the incident of the substance is not as bad as the Airport Station, there was still a coating of it on the instrument and on the streambed. It has caused some issues with the actual data due to the fouling of the sensor and it also has the potential to change the water parameters during the growth and die-off periods of the algae.

The Clovelly Station water temperatures are diurnal and also influenced by the surrounding air temperatures in relation to the season. The shallow urban streams and brooks respond faster to air temperatures and this can be seen in the variability of the water temperature data with the steady increase in the Summer period and drop off as the season changes to Fall and Winter. This stream is braided and can get very shallow before it deepens where the instrument is located.

Outer Cove Brook at Clovelly Golf Course had a median pH value of 6.45 which was inside the normal range for stream water. The pH data displayed general events in relation to stage increase and rainfall.

Outer Cove Brook at Clovelly Golf Course displays two different reactions in specific conductivity. During the spring thaw and high runoff in February and March the conductivity levels increase with the higher stage levels likely a result of salt runoff from the surrounding urban areas and the airport. Into the summer and fall seasons (June through to early November) the conductivity levels drop with high stage levels. The decrease in conductivity during those times was likely a result of periods of rainfall diluting the suspended substances in the brooks.

There were two obvious dips in dissolved oxygen during this deployment year; these dips were also evident at Outer Cove Brook below Airport. It is not clear what may have influenced the dip, however during this time there is a die-off of the slime-like algae. The Dissolved Oxygen median for this deployment year was 9.82mg/L. As the warmer temperatures started in June the dissolved oxygen levels in the brook started to dip under the CCME guideline for the protection of cold water other life cycles (6.5mg/L). This is a normal response of dissolved oxygen with warmer temperatures.

The turbidity increases corresponded with the precipitation events that can influence the amount of suspended sediments in the water column. Outer Cove Brook at Clovelly Golf Course had large amounts of aquatic vegetation growing in the brook that can cause interference for the turbidity sensor (Appendix VI). Shallow urban brooks can be heavily influenced by their surroundings and there is a lot more movement in the turbidity data.

Outer Cove Brook Network

The instruments were deployed from January 1st until November 12th, 2015 at both station sites. It was decided to decommission the stations at this time and all the instrumentation was removed from the brooks. This will be the last report for Outer Cove Brook.

Variations in stage are attributed to precipitation events. Both stations displayed a trend of decreasing stage values from spring to summer as spring thaw ends, lowest stage levels in the summer, followed by increased stage levels throughout fall due to numerous precipitation events (Appendix III).

Water temperature trends over the year fluctuate diurnally, dependent on the ambient air temperature, warming as summer approaches, peaking in August, and falling as winter approaches. As precipitation increases the stage level it may decrease water temperatures. Outer Cove Brook at Clovelly Golf Course had the highest maximum in water temperature for the deployment year. However the median for water temperature for both Outer Cove Brook stations was close, indicating that overall water temperature remains consistent across the brook (See Table 2).

pH median values at both stations hover around the CCME guideline minimum pH value of 6.5, naturally decreasing with stage increases. Newfoundland waters are naturally slightly acidic and the medians are within the normal range for stream water in St. John's. Outer Cove Brook below Airport had the maximum pH at 7.5 pH units, although both stations had similar medians in pH for the deployment year (See Table 2).

Over the deployment year the fluctuations in specific conductivity are influenced by precipitation events, drops in conductivity after rainfalls due to dilution, and increasing with snowfall and low ambient air temperatures due to the addition of salts from nearby roadways. Clovelly station had a higher minimum and maximum but the medians for both stations were very similar (See Table 2).

Dissolved Oxygen values at both stations dip slightly during the summer months, as the warmer water holds less oxygen. This is likely due to the increase in plant production in the river system during these warm months, depleting the water of its oxygen. Dissolved oxygen levels were lowest at Outer Cove Brook at Clovelly Golf Course; the individual low dissolved oxygen values were recorded around the same time the die-off was occurring of the slime-like substance (Appendix V) (See Table 2).

Both stations were influenced by the presence of biofouling slime (Appendix V). During the beginning of each deployment year there is a high growth of slime for several months that has the potential to affect the sensors performance. At the Clovelly station there is a large amount of aquatic vegetation present all year round and the vegetation does have the potential to interfere with the sensors (Appendix VI). For the most part over the deployment year the increases in turbidity corresponded with stage increases. At Outer Cove Brook below Airport there was a turbidity event captured during July, there is significant rainfall during the month of July with several readings of 20 mm and over of rainfall. It is likely the turbidity in July was a result of this. While the Airport station does have the larger turbidity maximum there is no significant difference between the medians of the two Outer Cove Stations.

Table 2: Minimum, Maximum and median values for each parameter measured at the Outer Cove Brook stations during the 2015 deployment season

	Water Temperature (oC)		pH(pH units)		Specific Conductivity (uS/cm)		Dissolved Oxygen (mg/L)		Turbidity (NTU)	
	Airport	Clovelly	Airport	Clovelly	Airport	Clovelly	Airport	Clovelly	Airport	Clovelly
Min	-0.1	-0.14	5.75	5.92	80	148.8	8.06	5.97	0	0
Max	19.8	20.16	7.5	7.31	2823	5249	12.65	13.17	742	649
Median	7	8.05	6.65	6.45	525	570	10.32	9.82	1.8	1.9

APPENDIX I
Sensor Performance Rankings for Deployment Periods

Station	Date	Action	2015 Comparison Ranking				
			Temperature	pH	Specific Conductivity	Dissolved Oxygen	Turbidity
Airport	Dec 3 2014	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
	Jan 21 2015	Removal	Excellent	Good	Good	Marginal	Fair
Clovelly	Dec 3 2014	Deployment	Excellent	Excellent	Excellent	Good	Excellent
	Jan 21 2015	Removal	Excellent	Excellent	Good	Excellent	Good
Airport	Jan 21 2015	Deployment	Excellent	Excellent	Good	Fair	Good
	March 4 2015	Removal	Good	Good	Marginal	Poor	Poor
Clovelly	Jan 21 2014	Deployment	Excellent	Good	Excellent	Good	Excellent
	March 4 2015	Removal	Excellent	Excellent	Good	Excellent	Poor
Airport	March 5 2015	Deployment	Excellent	Good	Excellent	Excellent	Excellent
	April 14 2015	Removal	Excellent	Excellent	Marginal	Poor	Excellent
Clovelly	March 5 2015	Deployment	Excellent	Excellent	Excellent	Fair	Excellent
	April 14 2015	Removal	Excellent	Excellent	Excellent	Excellent	Poor
Airport	April 15 2015	Deployment	Excellent	Fair	Good	Excellent	Excellent
	June 2 2015	Removal	Fair	Poor	Poor	Poor	Poor
Clovelly	April 15 2015	Deployment	Excellent	Good	Excellent	Excellent	Excellent
	June 2 2015	Removal	Good	Excellent	Excellent	Excellent	Poor
Airport	June 2 2015	Deployment	Excellent	Excellent	Excellent	Good	Excellent
	July 22 2015	Removal	*No*	*Readings*	*Available*	*at*	*Removal*
Clovelly	June 2 2015	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
	July 22 2015	Removal	Excellent	Marginal	Excellent	Good	Good
Airport	July 22 2015	Deployment	Excellent	Excellent	Excellent	Fair	Excellent
	August 28 2015	Removal	Excellent	Fair	Excellent	Poor	Fair
Clovelly	July 22 2015	Deployment	Excellent	Fair	Excellent	Excellent	Excellent
	Sept 2 2015	Removal	Excellent	Good	Excellent	Excellent	Good
Airport	August 28 2015	Deployment	Excellent	Good	Good	Excellent	Good
	October 7 2015	Removal	Poor	Poor	Good	Good	Excellent
Clovelly	Sept 2 2015	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
	October 7 2015	Removal	Poor	Good	Excellent	Good	Excellent
Airport	October 7 2015	Deployment	Excellent	Good	Good	Excellent	Good
	Nov 12 2015	Removal	Poor	Poor	Good	Good	Excellent
Clovelly	October 7 2015	Deployment	Poor	Good	Good	Excellent	Excellent
	Nov 12 2015	Removal	Excellent	Excellent	Good	Excellent	Good

Table3: Rankings of the Outer Cove Brook instruments over the 2015 deployment year

APPENDIX II
Water Parameter Description

Dissolved Oxygen

The amount of Dissolved Oxygen (DO) (mg/l) in the water is vital to aquatic organisms for their survival. The concentration of DO is affected by such things as water temperature, water depth and flow (e.g., aeration by rapids, riffles etc.), consumption by aerobic organisms, consumption by inorganic chemical reactions, consumption by plants during darkness, and production by plants during the daylight (Allan 2010).

pH

pH is the measure of hydrogen ion activity and affects: (i) the availability of nutrients to aquatic life; (ii) the concentration of biochemical substances dissolved in water; (iii) the efficiency of hemoglobin in the blood of vertebrates; and (iv) the toxicity of pollutants. Changes in pH can be attributed to industrial effluence, saline inflows or aquatic organisms involved in the photosynthetic cycling of CO_2 (Allan 2010).

Specific conductivity

Specific conductivity (µS/cm) is a measure of water's ability to conduct electricity, with values normalized to a water temperature of 25ºC. Specific conductance indicates the concentration of dissolved solids (such as salts) in the water, which can affect the growth and reproduction of aquatic life. Specific conductivity is affected by rainfall events, the composition of inflowing tributaries and their associated geology, saline inflow (e.g., road salt), agricultural run-off and industrial inputs (Allan 2010; Swanson and Baldwin 1965).

Stage

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

Temperature

Essential to the measurement of most water quality parameters, temperature (^{o}C) controls most processes and dynamics of limnology. Water temperature is influenced by such things as ambient air temperature, solar radiation, meteorological events, industrial effluence, wastewater, inflowing tributaries, as well as water body size and depth (Allan 2010; Hach 2006).

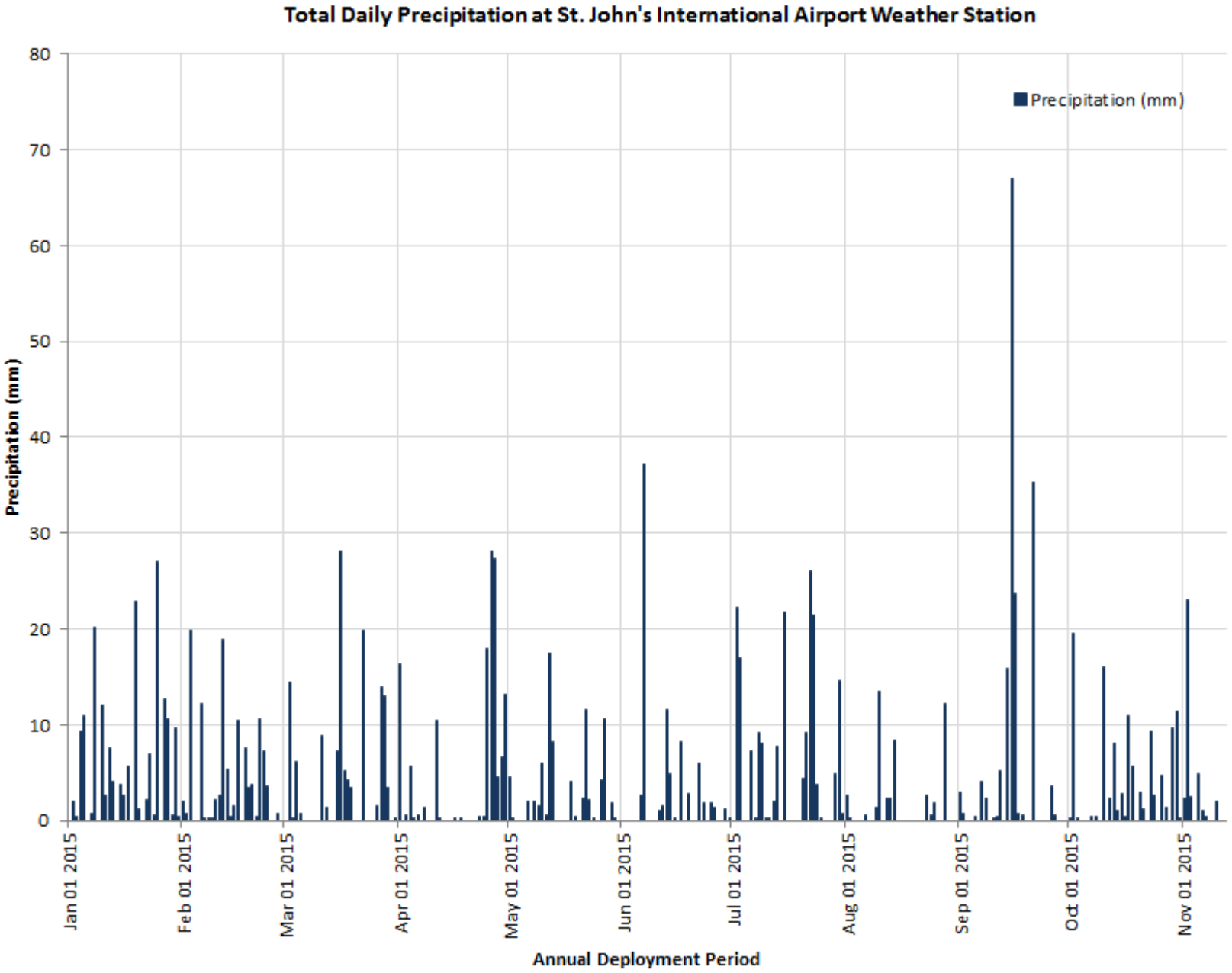
Total Dissolved Solids

Total Dissolved Solids (TDS) (g/l) is a measure of alkaline salts dissolved in water or in fine suspension and can affect the growth and reproduction of aquatic life. It is affected by rainfall events, the composition of inflowing tributaries and their associated geology, saline inflow (e.g., road salt), agricultural run-off and industrial inputs (Allan 2010; Swanson and Baldwin 1965).

Turbidity

Turbidity (NTU) is a measure of the translucence of water and indicates the amount of suspended material in the water. Turbidity is caused by any substance that makes water cloudy (e.g., soil erosion, micro-organisms, vegetation, chemicals, etc.) and can correspond to precipitation events, high stage, and floating debris near the sensor (Allan 2010; Hach 2006; Swanson and Baldwin 1965).

APPENDIX III
Precipitation Data from St. John's International Airport Weather Station


Total Daily Precipitation at St. John's International Airport Weather Station
Precipitation (mm)
80
70
60
50
40
30
20
10
0
Precipitation (mm)
Jan 01 2015
Feb 01 2015
Mar 01 2015
Apr 01 2015
May 01 2015
Jun 01 2015
Jul 01 2015
Aug 01 2015
Sep 01 2015
Oct 01 2015
Nov 01 2015
Annual Deployment Period

APPENDIX IV
References

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Hach (2006) Important water quality factors - H2O University. Hach Company. Online: http://www.h2ou.com/index.htm (accessed August 24, 2010).

Swanson, H.A., and Baldwin, H.L., 1965. A Primer on Water Quality, U.S. Geological Survey. Online: http://ga.water.usgs.gov/edu/characteristics.html (accessed August 24, 2010)

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APPENDIX V
Pictures of Slime-Like Algae in the Outer Cove Brooks

Slime at Outer Cove Brook below Airport
March 4th, 2015

Figure 20: Slime on Airport Instrument in brook

Figure 21: Slime on stream bed at Outer Cove Brook below Airport

Figure 22: Slime on stream bed at Outer Cove Brook below Airport

Figure 23: Slime on Airport Water Quality Instrument

Slime at Outer Cove Brook below Airport
June 2nd, 2015

Figure 24: Covering of slime like algae on the stream bed at Airport

Figure 25: Slime on Airport instrument and sensor cage

Figure 26: Coverage of the slime-algae at Airport station.

Slime at Outer Cove Brook at Clovelly Golf Course
June 2, 2015

Figure 27: Slime-line algae in the brook at Clovelly Station

Figure 28: Slime-line algae in the brook at Clovelly Station

Figure 29: Slime-line algae in the brook at Clovelly Station

APPENDIX VI
Vegetation Present at Outer Cove Brook at Clovelly Golf Course

Vegetation present at Outer Cove Brook at Clovelly Golf Course
September 2, 2015

Figure 30: Vegetation present in the brook at Clovelly Station

Figure 31: Vegetation present in the brook at Clovelly Station