Real-Time Water Quality Deployment Report

Long Harbour Annual Report

2018

Government of Newfoundland & Labrador
Department of Municipal Affairs and Environment
Water Resources Management Division
St. John's, NL, A1B 4J6 Canada

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Introduction

Real-time monitoring (RTWQ) of surface and groundwater quality on the Vale Long Harbour plant site is carried out by the Department of Municipal Affairs and Environment (MAE), Water Resources Management Division (WRMD). This work is undertaken in circumstances where industrial development has the potential to impact water bodies. The RTWQ program consists of more than 30 stations across the province from Voisey's Bay to St. Lawrence and Corner Brook to St. John's.

RTWQ work in Long Harbour has been ongoing for more than 10 years – beginning with the first station, Rattling Brook below Bridge, in late 2006. In 2009, two additional surface water stations were deployed in the headwaters of Rattling Brook (Big Pond station) and lower in the river system (Rattling Brook below Plant Discharge). These surface water stations were positioned to monitor for long-term changes and water quality events related to the construction and operation of Vale's nickel processing plant.

As the nickel processing plant began to move towards operation, Sandy Pond was chosen as a residue storage area (RSA) to contain solid waste material. A groundwater monitoring network of five stations was deployed around the RSA in late 2012.

Surface and groundwater monitoring stations are depicted in Photo 1 below (green triangles are surface water monitoring stations on Rattling Brook and blue arrows are groundwater monitoring stations around the RSA).

Photo 1: Real-time water quality monitoring stations in Long Harbour, Newfoundland

Methods and Procedures

Work under the RTWQ program is conducted according to the Protocols Manual for Real-Time Water Quality Monitoring in NL[1]. This document outlines the procedures, methods, and QAQC regimen used by all staff involved in the RTWQ program at all stations, province wide. For surface water monitoring, water quality instrumentation – in this case the Hydrolab DS5X multi-parameter sonde – is deployed on six-week intervals with *in situ* data validation at the beginning and end of deployment using an equivalent and freshly calibrated multi-parameter sonde. A grab sample is collected at the start of a deployment as an independent indicator of data quality.

Due to the narrow confines of a 2” monitoring well, insertion of additional instruments into the well for verification purposes results in considerable changes to the well chemistry. As a result, data validation is restricted to capturing a grab sample immediately prior to insertion of newly-calibrated monitoring equipment in the well. Protocol requires a volume equivalent to three well casings to be purged from the well prior to sampling. This process flushes stagnant water from the well and ensures that the water being observed is aquifer water.

In the next section, long-term data from both the surface and groundwater monitoring networks are presented as line and boxplots. Guidelines set by the Canadian Council of Ministers of the Environment (CCME) and site-specific guidelines are indicated by dashed lines. Grab sample data for pH, specific conductivity, and turbidity is presented as black dots in the same figures. Boxplots are presented to illustrate how water quality parameters change from year to year.

Summary statistics are presented for each surface and groundwater parameter in the next section. Each table lists the 2018 median, minimum, and maximum values. *Average median* values for each parameter are calculated from the median values of each previous year and is provided in the same tables and labelled as *average* for simplicity. Median values are preferred throughout this report as a more robust indicator of central tendency than average values, especially given the highly skewed characteristic of environmental data.

Results and Discussion

In November 2017, the water level within Rattling Brook Big Pond was raised for operational purposes. This higher water level allowed equipment to be deployment under ice cover which was previously impossible due to the risk of damage by ice scour. As such, 2018 was the first year with a complete record of water quality at Big Pond station. This complete record closes the winter gap in data and removes the warm-water bias seen in previous years. This is particularly obvious in the record of water temperature and dissolved oxygen at Big Pond.

[1] http://www.mae.gov.nl.ca/waterres/rti/rtwq/NL_RTWQ_Manual.pdf

Surface Water Network

Water Temperature

For the first time, water quality equipment was deployed throughout the winter at Big Pond station in 2018. Because more temperature data was gathered during the cool-water period of the year, the 2018 median water temperature is considerably lower than previous years.

Water temperatures at Bridge station were somewhat higher than average in 2018 temperatures while Plant Discharge station temperatures were somewhat lower in 2018 (Table 1).

Table 1: Water temperatures at Rattling Brook

Station	Segment	Median	Min	Max
Big Pond	Average	10.60	-0.47	23.10
	2018	8.44	-0.43	20.87
Bridge	Average	8.19	-0.54	24.98
	2018	8.65	-0.41	23.98
Discharge	Average	8.46	-0.55	25.48
	2018	7.88	-0.53	24.77

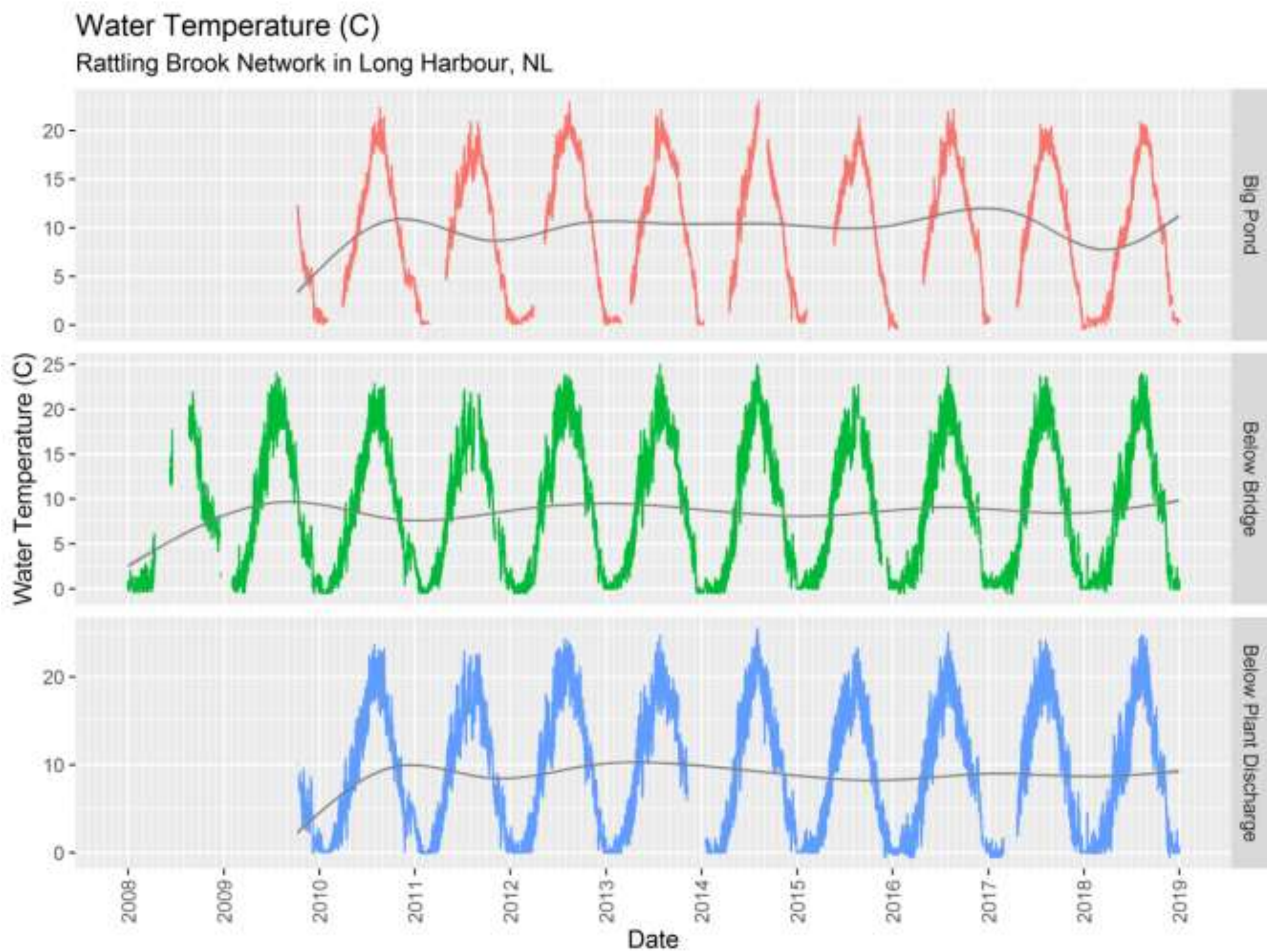

Figure 1: Water Temperature at Rattling Brook from 2008 to 2018

Winter water temperatures were recorded at Big Pond station in 2018, unlike previous years. Figure 2 clearly illustrates the considerable change that resulted from this change in procedure – the red boxplot indicates a notable decline in median value while temperatures at the two river stations are similar to previous years.

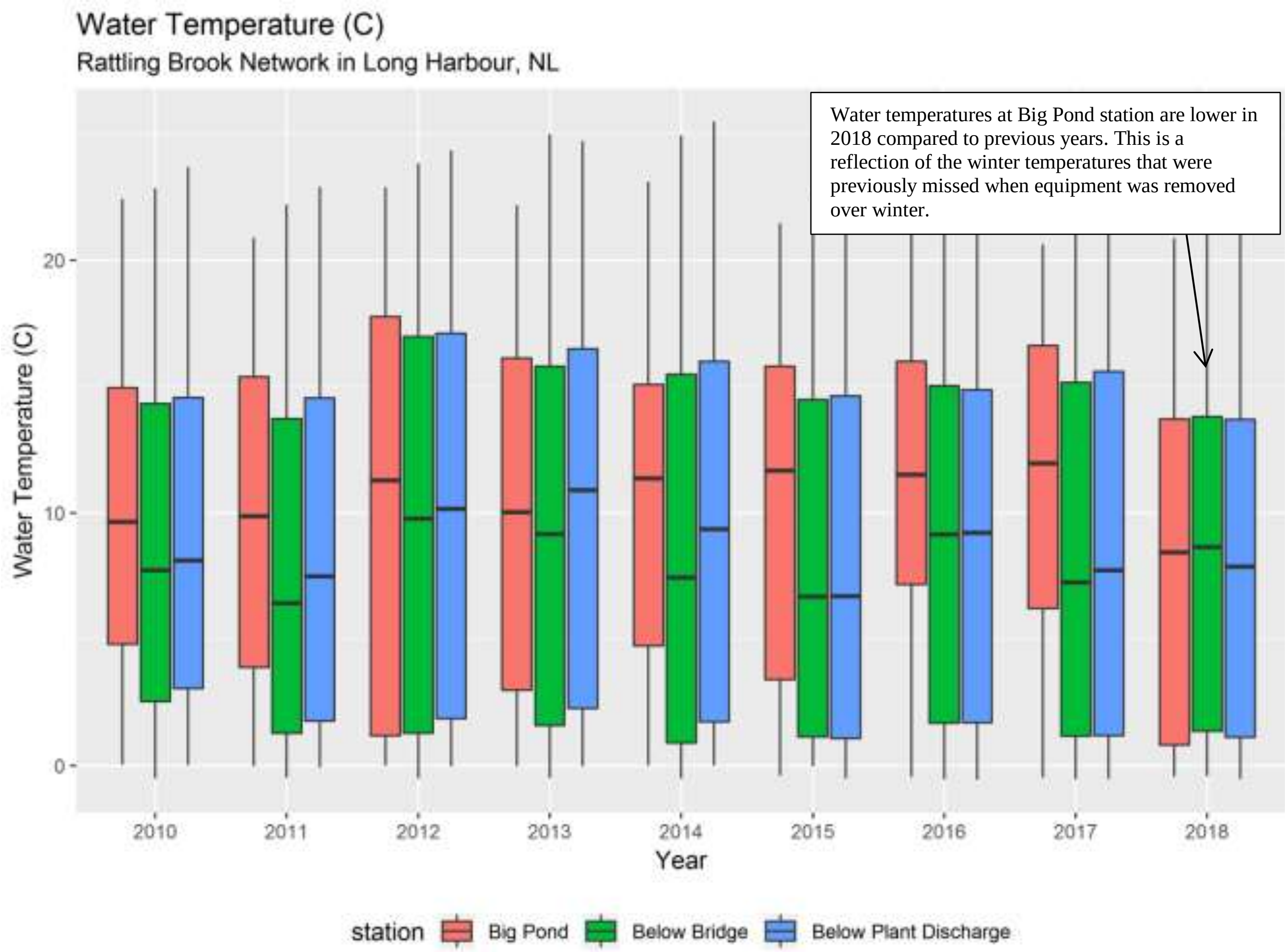

Figure 2: Boxplots of water temperature at Rattling Brook from 2010 to 2018

pH

In 2018, pH levels were below average at Big Pond and Plant Discharge stations and approximately average at Bridge station, according to Table 2.

This variation may have been provoked by water level changes at Big Pond station in 2017. Decomposition of inundated soils and vegetation may result in declining pH levels. A return to normal levels is expected in time, but will be closely monitored.

In 2018, median pH values were within site-specific guidelines[2] (dashed lines) at each station as shown in Figure 3.

Table 2: pH at Rattling Brook

Station	Segment	Median	Min	Max
Big Pond	Normal	6.41	5.02	8.74
	2018	5.95	4.93	6.36
Bridge	Normal	6.22	4.84	7.20
	2018	6.25	4.74	6.92
Discharge	Normal	6.57	4.83	7.67
	2018	6.22	4.59	6.84

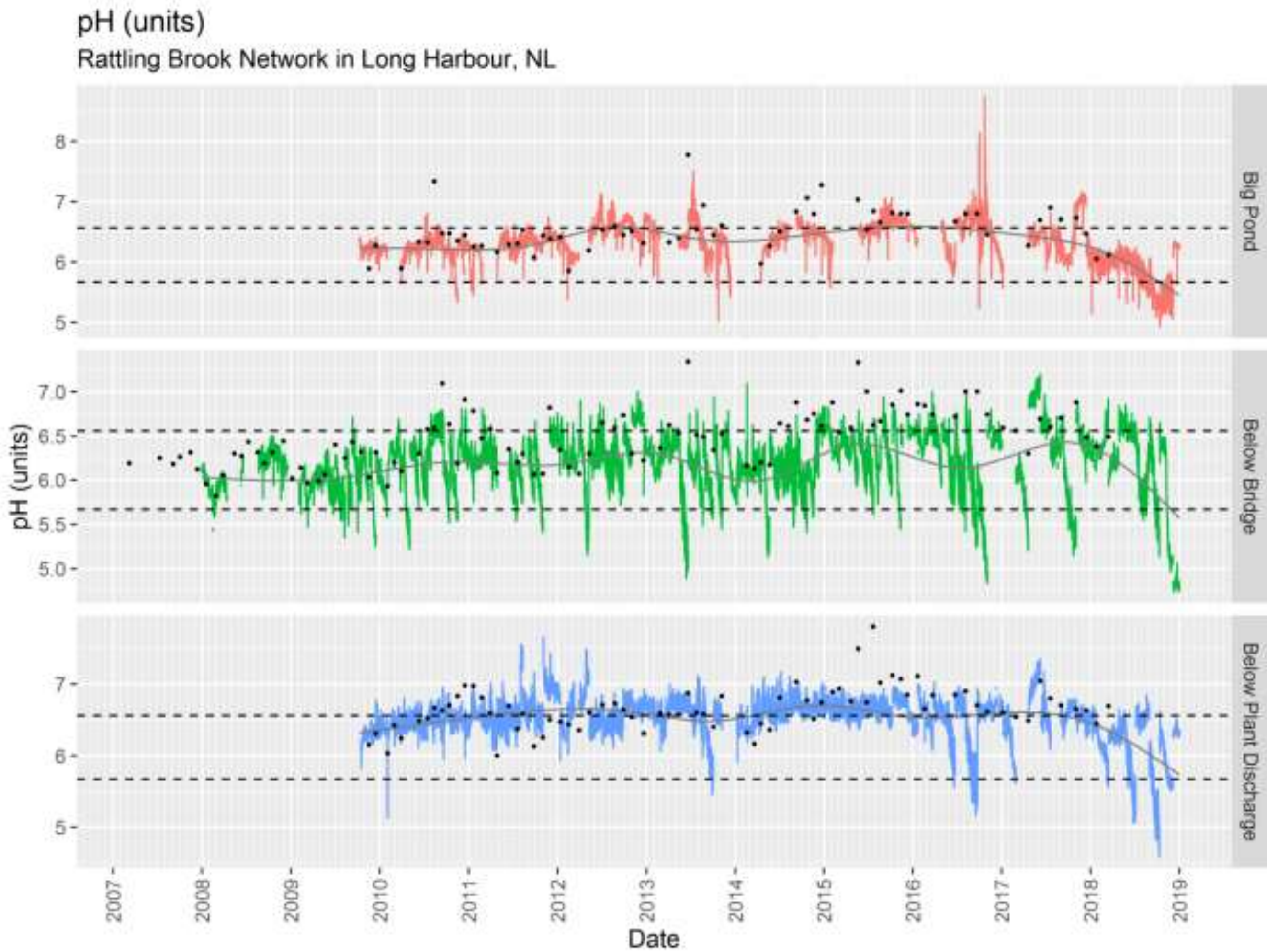

Figure 3: pH at Rattling Brook from 2008 to 2018

[2] Site specific guidelines were determined at 5th and 95th percentiles of pre-development conditions.

Figure 4 illustrates the change in pH values from year to year. A general upward trend appears at each station over time; however, 2018 exhibited a decline at each station from 2017 to 2018.

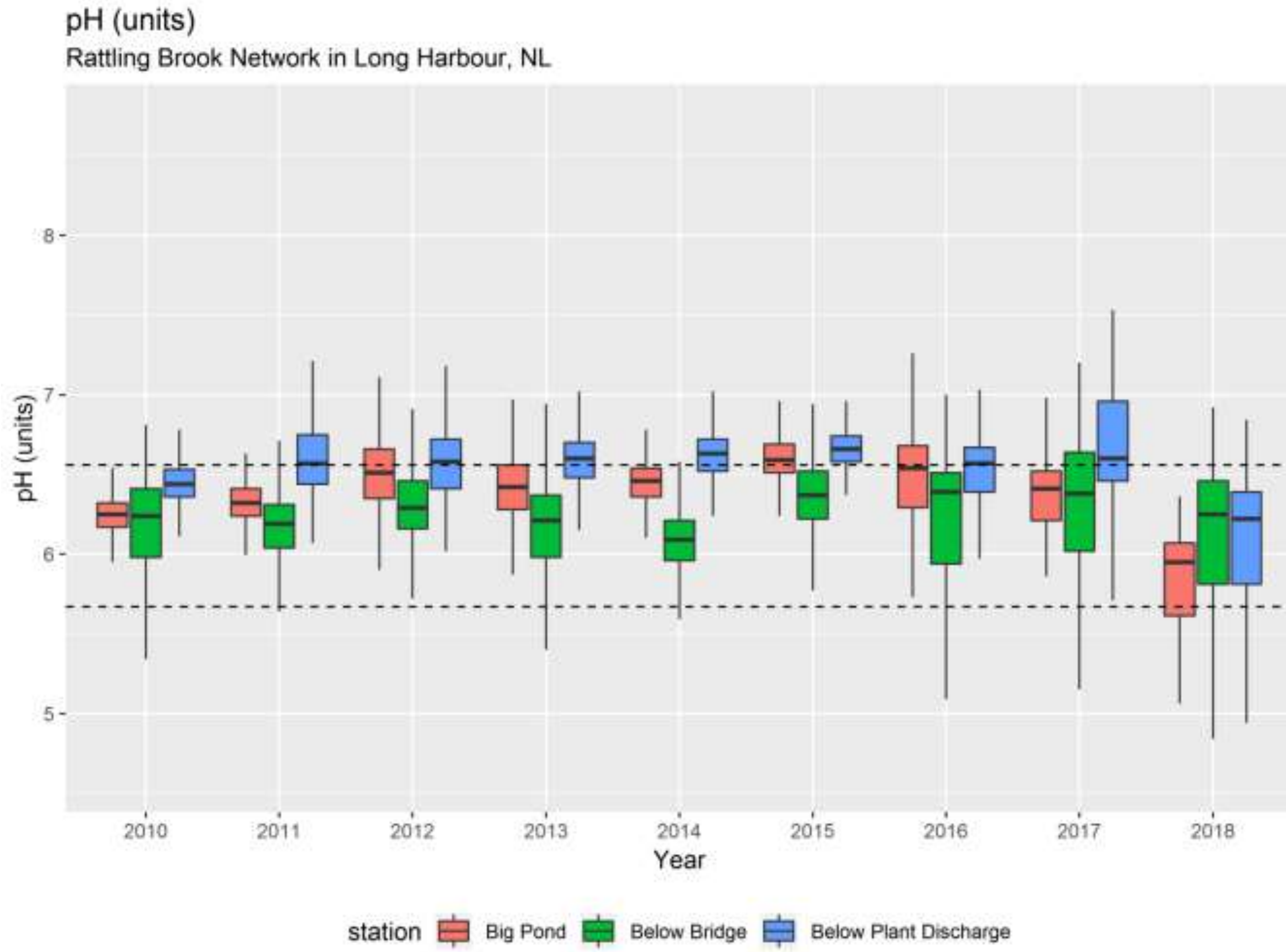

Figure 4: Boxplots of pH at Rattling Brook from 2010 to 2018

Specific Conductivity

Specific conductivity has increased at each station over time, according to Figure 5 and Table 3.

Bridge station exhibited lower conductivity values than Big Pond and Plant Discharge station. This is an unusual characteristic of Rattling Brook compared to other rivers where conductivity generally increases along the river course. This may be the result of recent increases to dissolved solids in Big Pond, but a dilution effect coming from tributaries to Rattling Brook between Big Pond and Bridge station.

Specific conductivity levels increase between Bridge and Plant Discharge stations, likely due to effluent from nearby settling ponds.

Table 3: Specific Conductivity at Rattling Brook

Station	Segment	Median	Min	Max
Big Pond	Normal	56.9	27.4	110.9
	2018	76.6	54.2	135.8
Bridge	Normal	52.7	20.2	120.7
	2018	66.6	37.3	96.2
Discharge	Normal	65.5	30.6	275.0
	2018	70.9	3.7	144.7

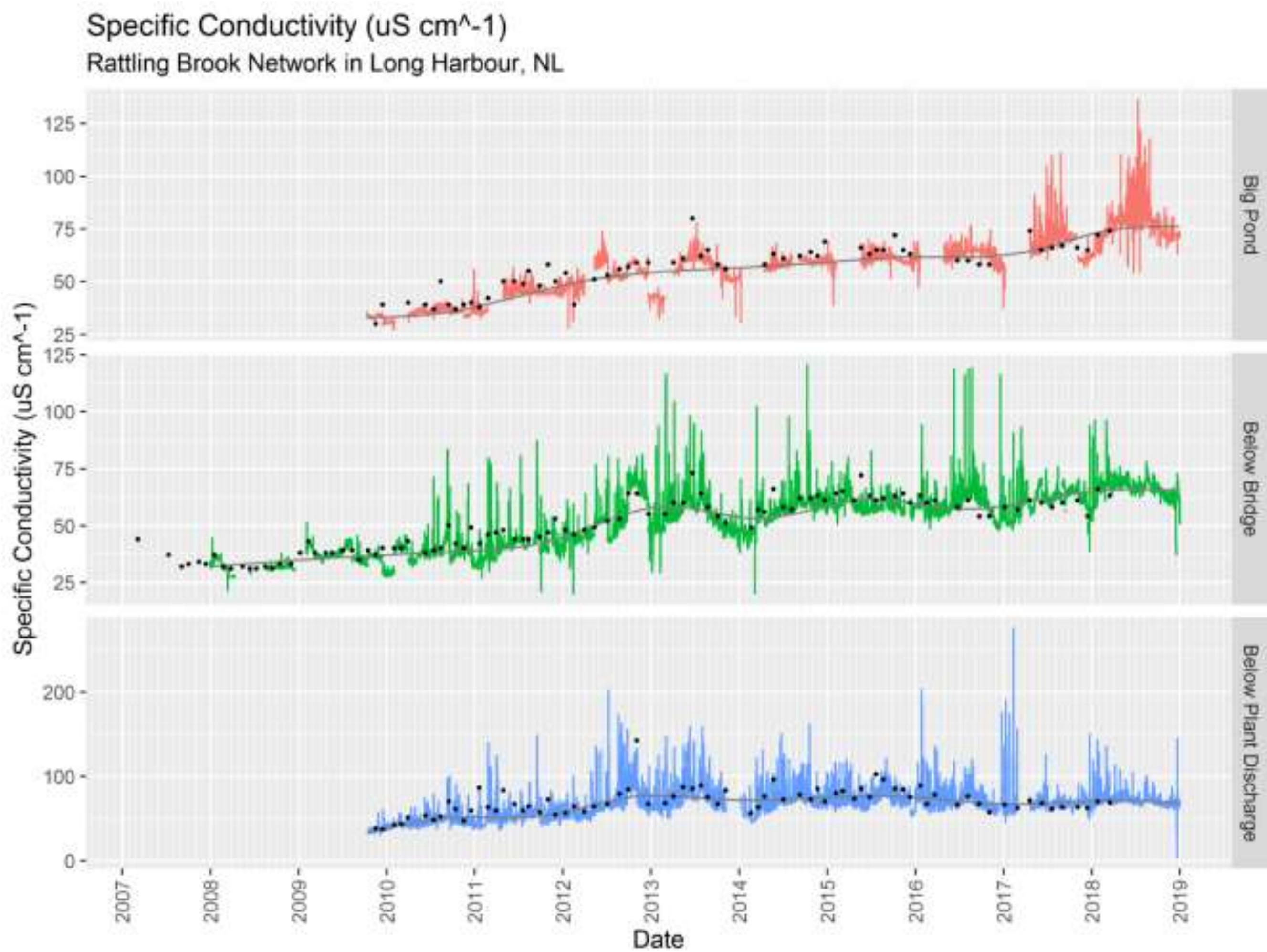

Figure 5: Specific Conductivity at Rattling Brook from 2008 to 2018

Increases in specific conductivity at each station continued into 2018. It is also notable that variability continued to decline from 2016 into 2018 (Figure 6).

The reduction in variability indicates that movement of dissolved solids into the river system is beginning to stabilize. Specific conductivity values could begin to decline in the future.

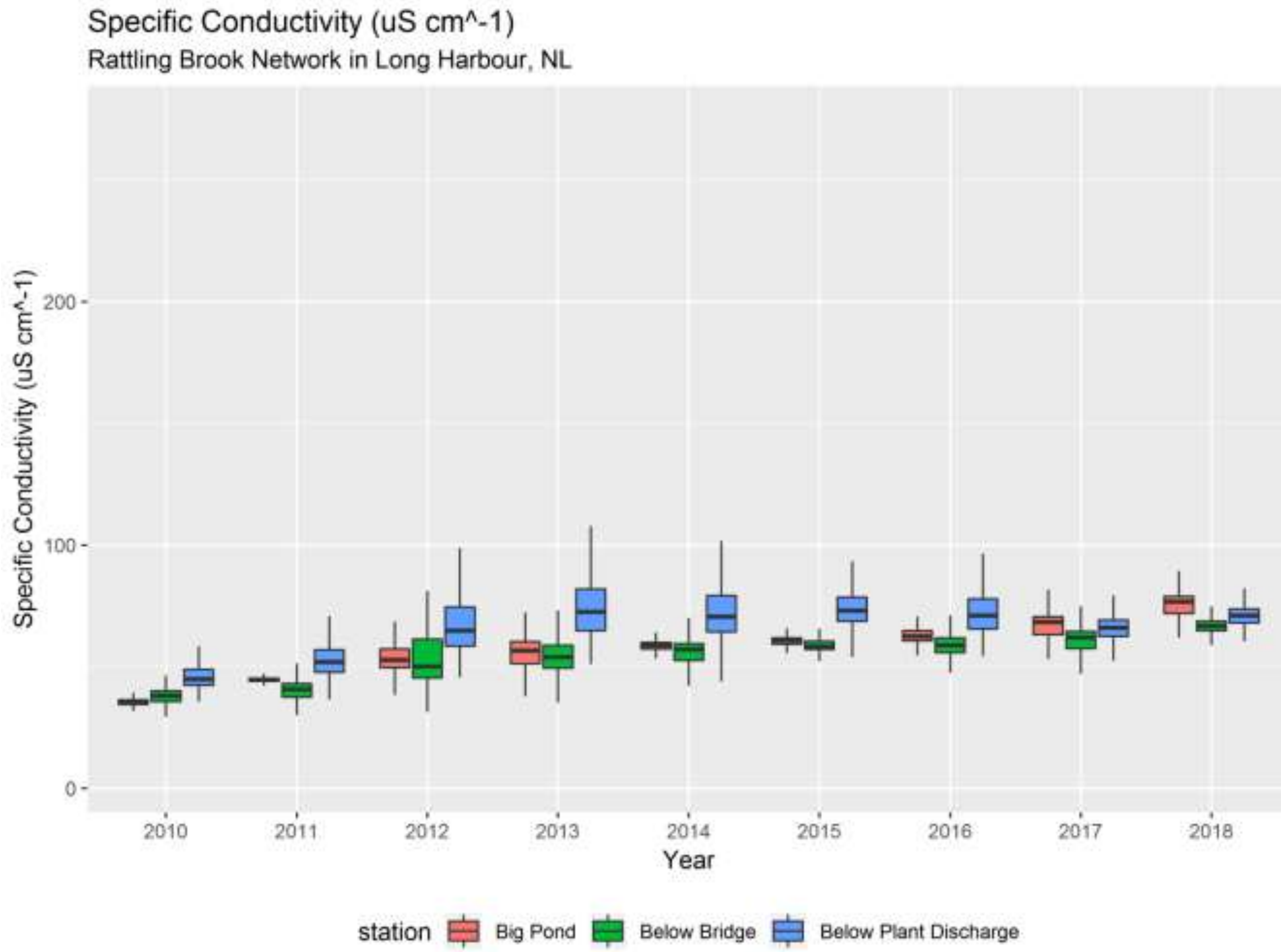

Figure 6: Boxplots of specific conductivity at Rattling Brook from 2010 to 2018

Dissolved Oxygen

A considerable deviation from expected dissolved oxygen concentrations was observed at Big Pond station from November 2017 onwards (Figure 7), indicated by vertical, dashed gray line.

Dissolved oxygen levels were within normal ranges downstream at Bridge and Plant Discharge stations, indicating that the abnormally low oxygen concentrations are likely related to oxygen demand from decaying vegetation and soils recently inundated during the water level rise.

Two CCME guidelines shown as dashed lines give a conservative value of 9.5 mg/l for early life stage organisms and another value of 6.5 mg/l for other life stages. In 2018, all values at Bridge and Plant Discharge stations were found to be above the guideline for other life stages (min values in Table 4). Big Pond tends to show DO values below guidelines during warm water periods.

Table 4: Dissolved Oxygen at Rattling Brook

Station	Segment	Median	Min	Max
Big Pond	Normal	10.56	8.06	15.93
	2018	10.67	4.60	13.50
Bridge	Normal	11.35	7.54	15.51
	2018	11.28	7.64	14.47
Discharge	Normal	11.13	6.46	14.91
	2018	11.35	7.03	14.73

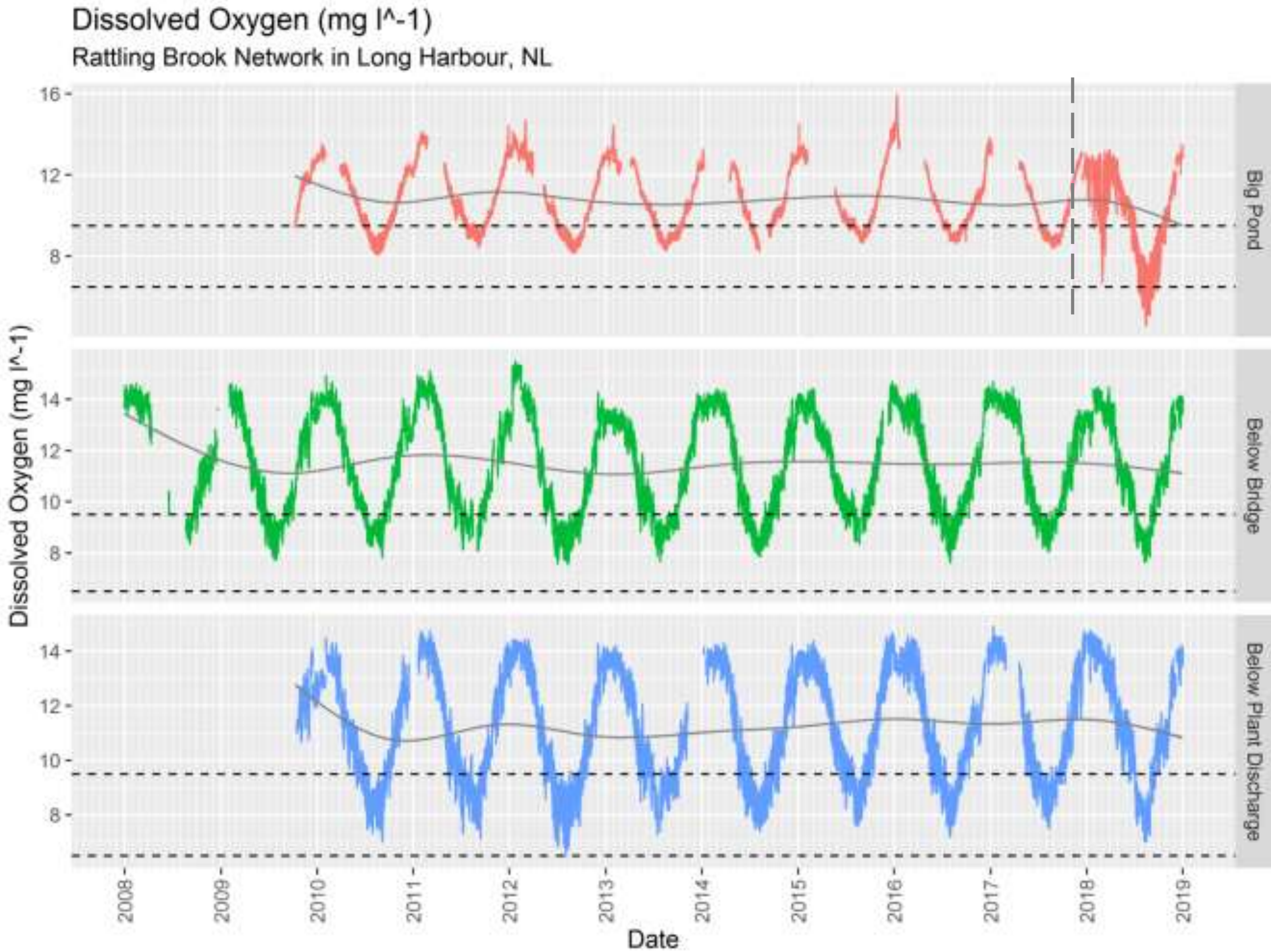

Figure 7: Dissolved oxygen at Rattling Brook from 2008 to 2018

Figure 8 shows the range of dissolved oxygen concentrations at each station from 2010 onwards.

In 2018, the low-end of dissolved oxygen concentrations at Big Pond station were below those observed in previous years. Dissolved oxygen values at Bridge and Plant Discharge stations were found to be within the range of previous years.

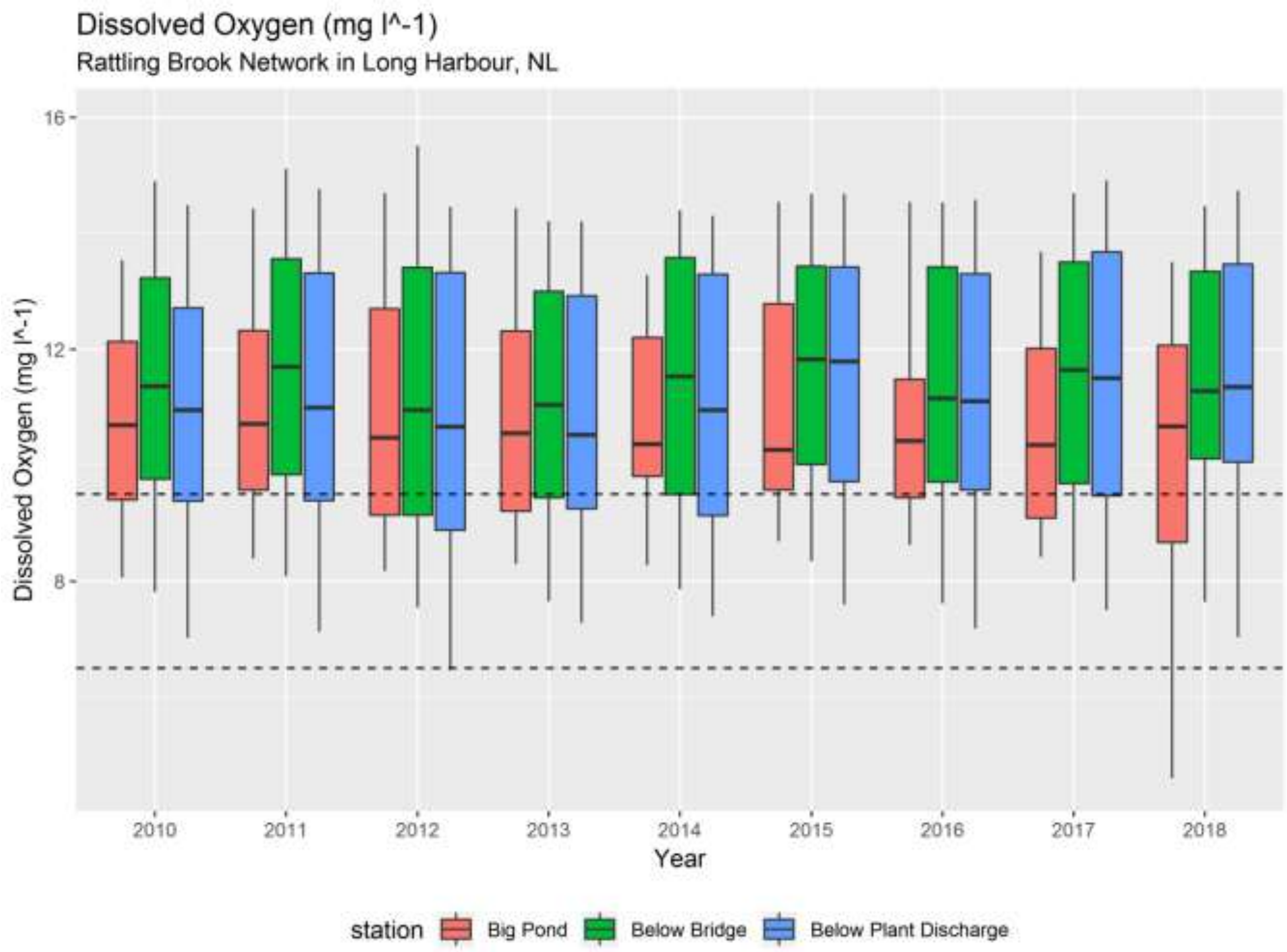

Figure 8: Boxplots of dissolved oxygen at Rattling Brook from 2010 to 2018

Turbidity

In 2018, median turbidity level at Big Pond station was 0.0 NTU – equal to the long-term average. For Bridge and Plant Discharge stations, turbidity levels were also 0.0 NTU, which is below average (Table 5).

In Figure 9, Big Pond has exhibited more frequent and high-level peaks after water level increase in November 2017, indicated by vertical, dashed gray line.

Table 5: Turbidity at Rattling Brook

Station	Segment	Median	Min	Max
Big Pond	Normal	0.0	0.0	116.6
	2018	0.0	0.0	672.0
Bridge	Normal	0.3	0.0	2259.0
	2018	0.0	0.0	353.5
Discharge	Normal	1.2	0.0	1094.0
	2018	0.0	0.0	548.0

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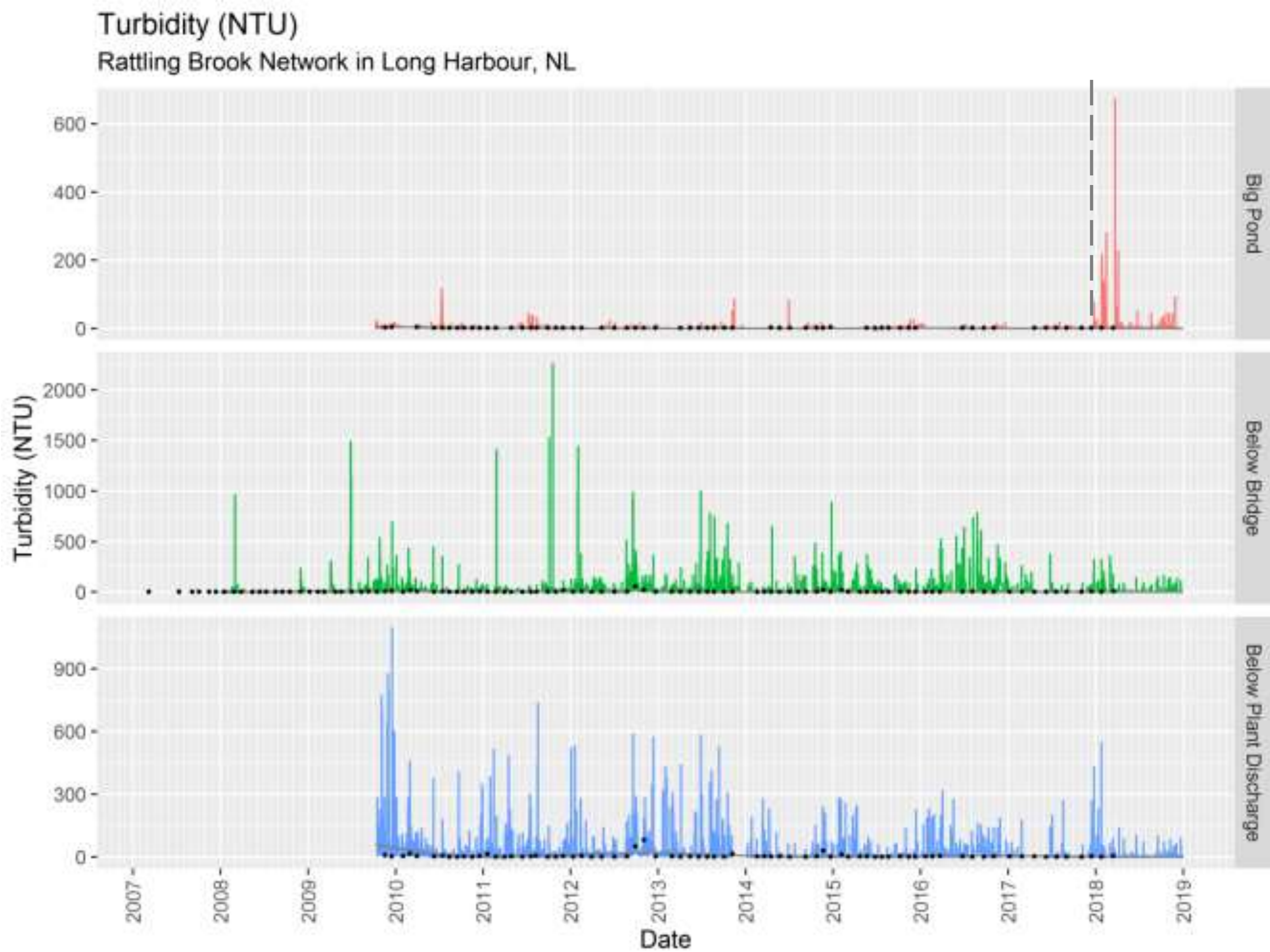

Figure 9: Turbidity at Rattling Brook from 2008 to 2018

As shown in Figure 10, turbidity levels in 2018 are similar to those observed in 2017 although a declining trend is ongoing at Bridge station since 2016.

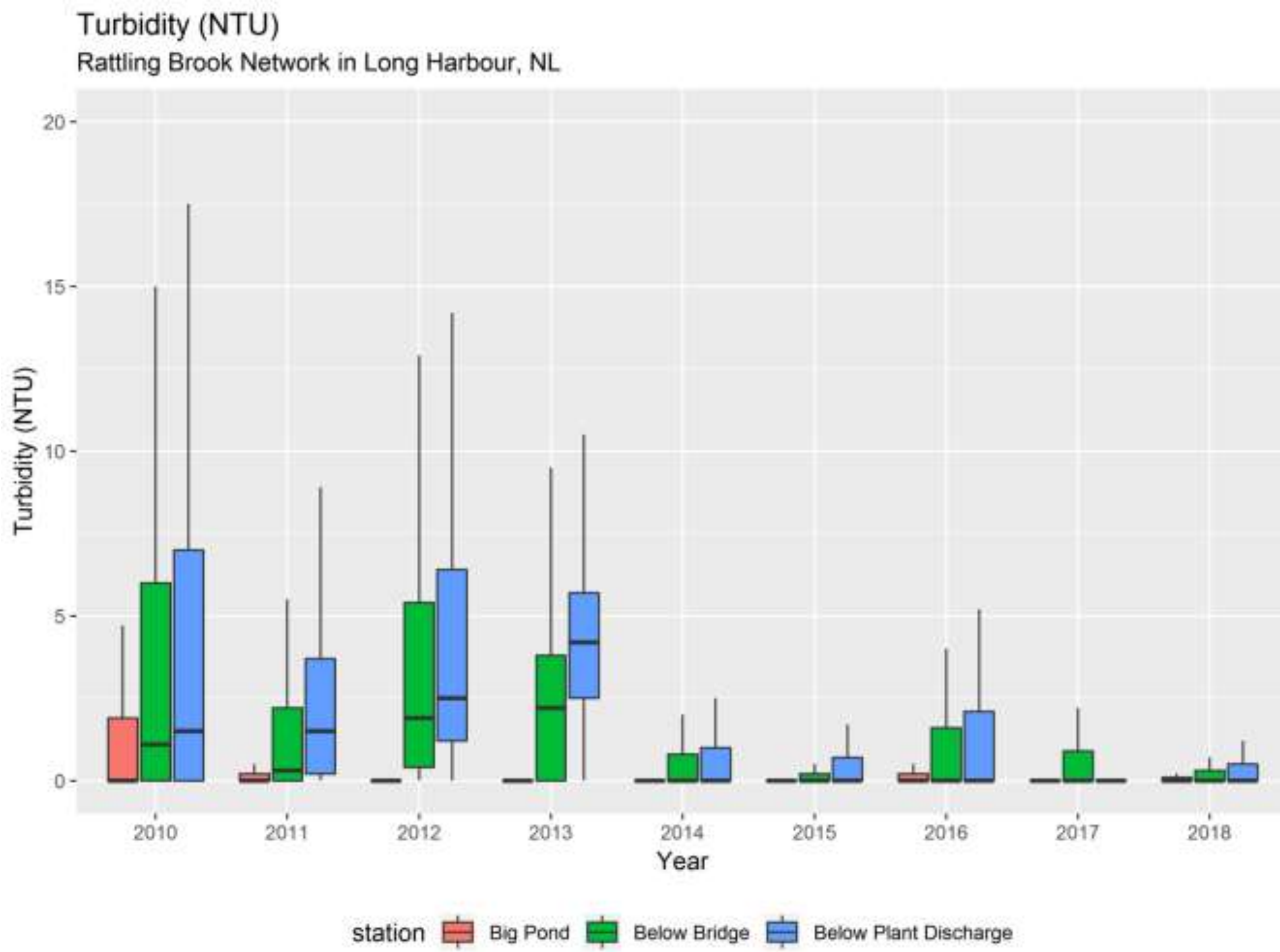

Figure 10: Boxplots of Turbidity at Rattling Brook from 2010 to 2018

Groundwater Network

Water Temperature

As shown in Table 6, in 2018, median water temperature did not substantially deviate from average levels (approximately 0.03°C at wells 1 Deep, 3 Deep, and 4 Deep, according to Table 6). Meanwhile, at wells 2 Shallow and 2 Deep, water temperature varied by 0.2°C and 0.15°C, respectively.

The narrow range of water temperatures is reinforced by the scale of the y-axes in Figure 11.

Table 6: Temperature at Residue Storage Area

Station	Segment	Median	Min	Max
1 Deep	Average	6.64	6.30	7.49
	2018	6.67	6.64	6.73
2 Shallow	Average	6.14	1.03	11.81
	2018	5.94	3.21	11.27
2 Deep	Average	6.31	5.74	6.91
	2018	6.16	5.79	6.46
3 Deep	Average	6.66	6.41	7.01
	2018	6.69	6.61	6.93
4 Deep	Average	6.41	6.18	6.64
	2018	6.42	6.27	6.51

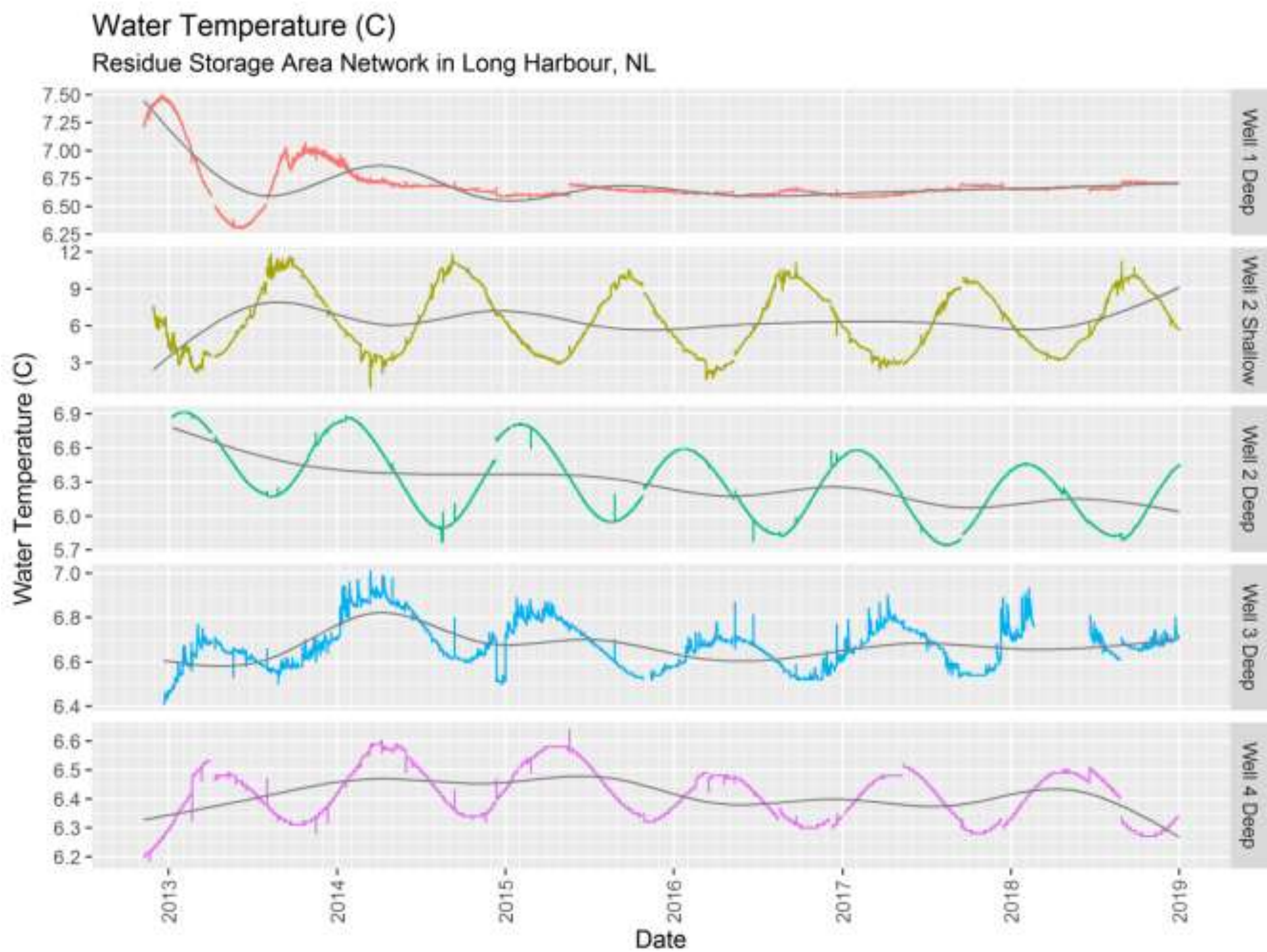

Figure 11: Water temperature at the Residue Storage Area from 2012 to 2018

Within each well, water temperature ranges were similar in 2018 compared to previous years (Figure 12).

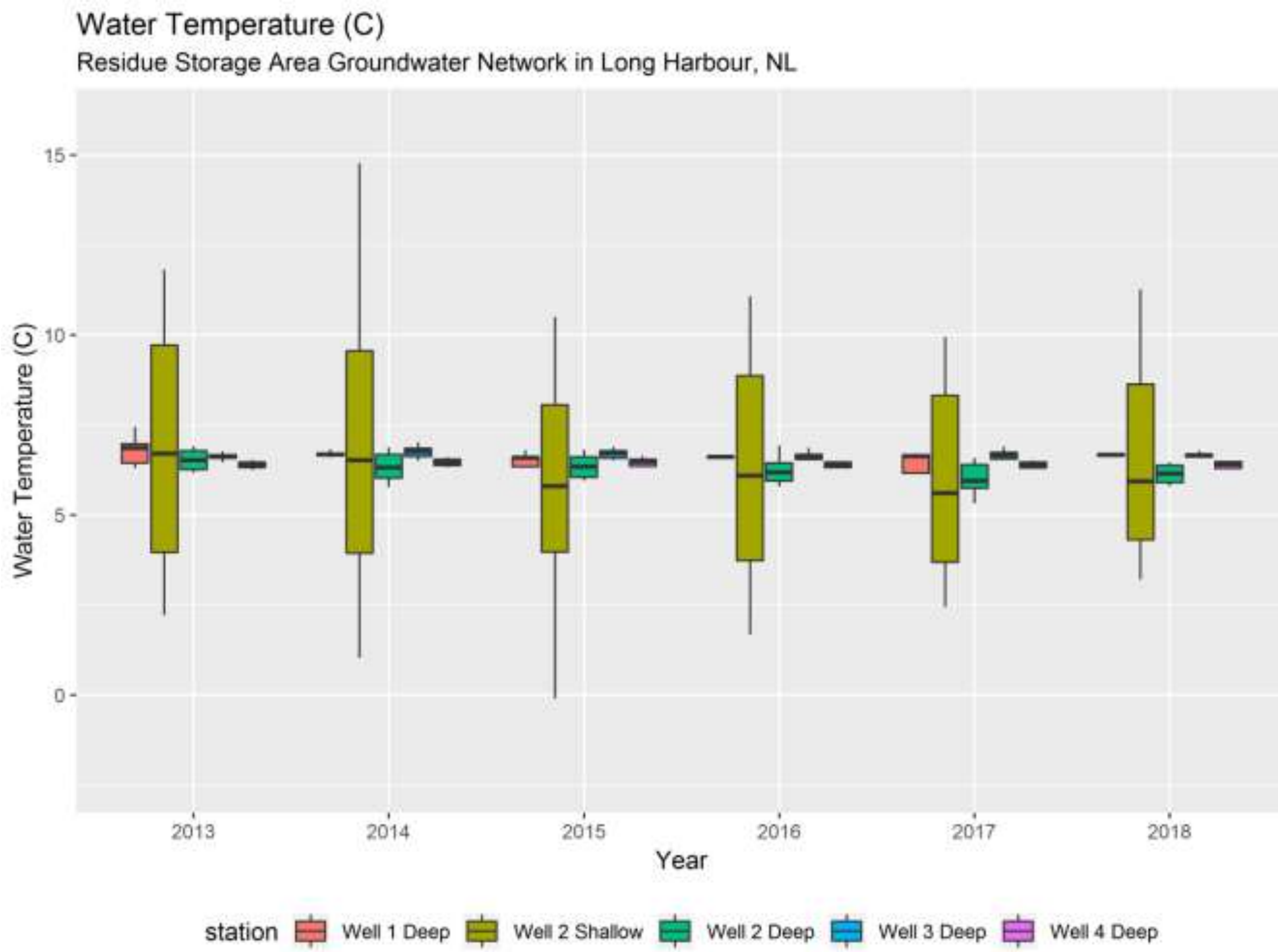

Figure 12: Boxplots of water temperature at the Residue Storage Area from 2012 to 2018

pH

Median pH values were found to be above average levels in 2018 at each station except Well 2 Deep (Table 7).

Long term trends are difficult to extrapolate from Figure 13, but the gray trend lines show potentially rising pH at wells 1 Deep, 2 Deep, 2 Shallow, and 4 Deep. Grab samples support this and show a rising tendency at wells 1 Deep, 2 Shallow, and 2 Deep. This will be closely monitored.

Table 7: pH at Residue Storage Area

Station	Segment	Median	Min	Max
1 Deep	Average	6.52	5.15	7.90
	2018	7.85	7.66	7.94
2 Shallow	Average	5.79	4.52	7.13
	2018	6.13	5.73	6.87
2 Deep	Average	8.23	6.40	8.75
	2018	8.18	6.61	8.74
3 Deep	Average	5.81	5.06	6.25
	2018	5.90	5.55	6.16
4 Deep	Average	7.80	6.43	8.68
	2018	8.37	7.97	8.88

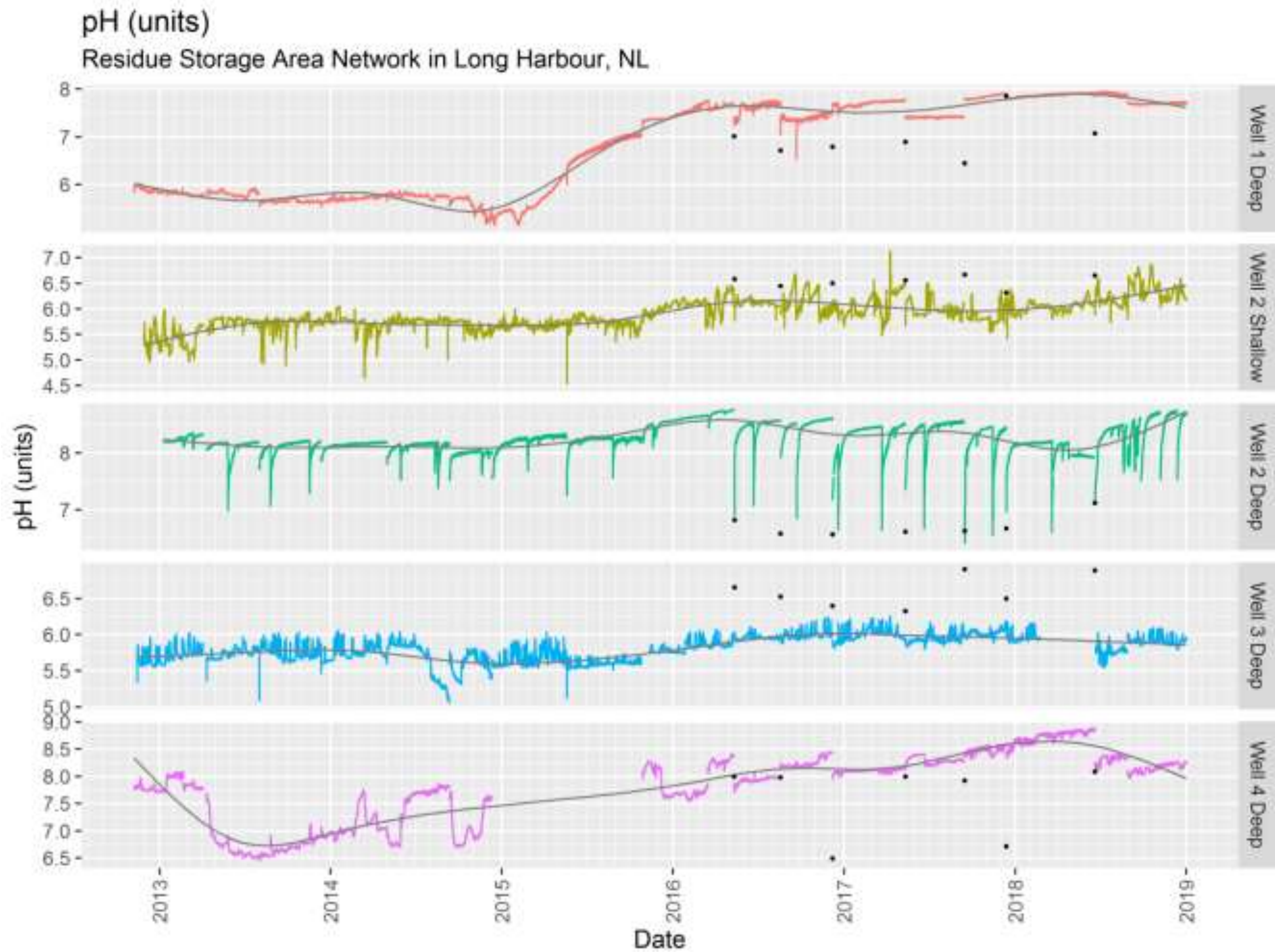

Figure 13: pH at the Residue Storage Area from 2012 to 2018

Increasing pH values are most obvious at wells 1 Deep and 4 Deep and, to a lesser degree, 2 Shallow and 2 Deep, according to Figure 14.

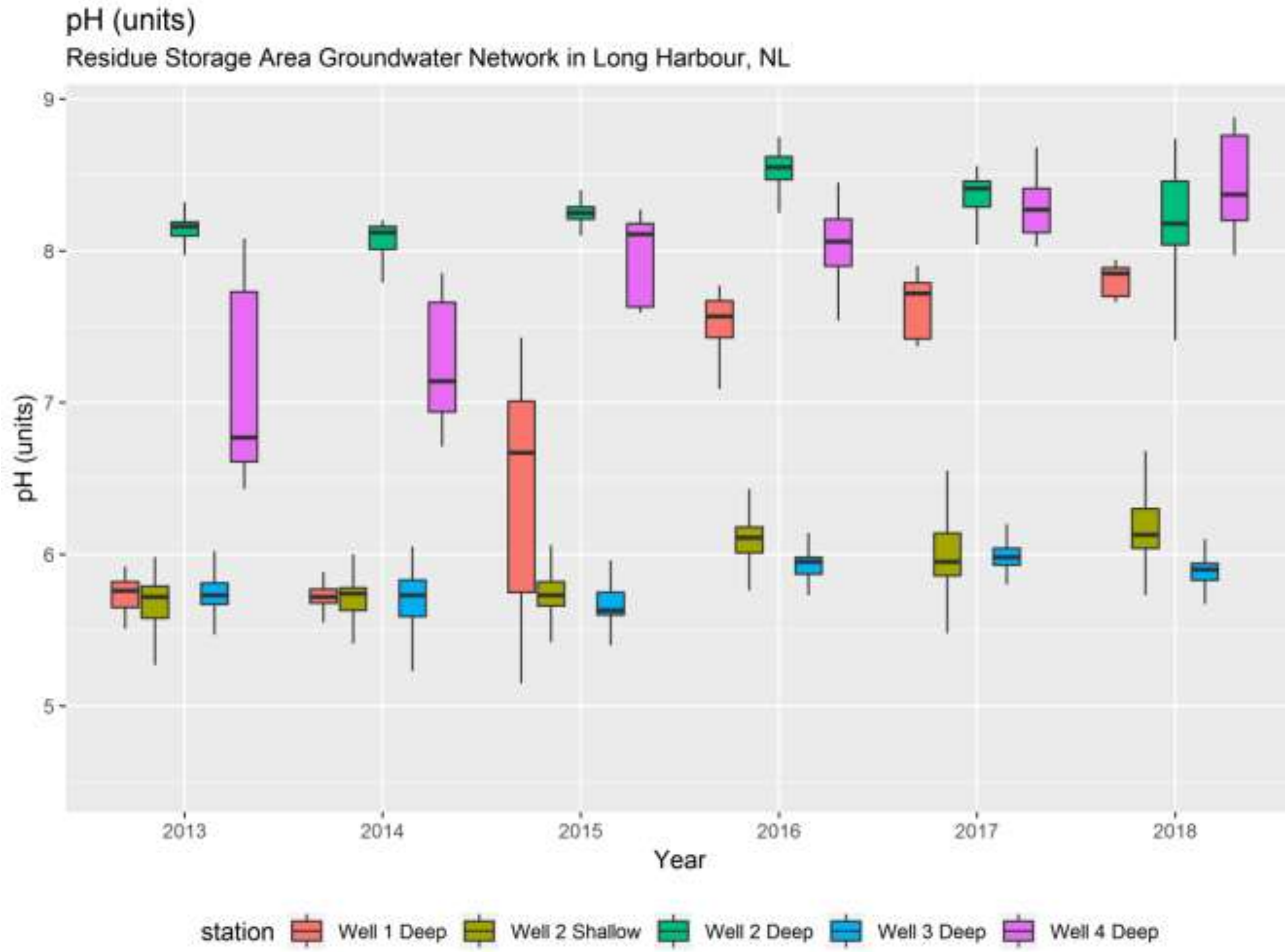

Figure 14: Boxplots of pH at the Residue Storage Area from2013 to 2018

Specific Conductivity

In 2018, median specific conductivity values were above average at each station surrounding the Residue Storage Area – except well 2 Deep where 2018 values were generally less than average, according to Table 8.

Figure 15 shows a continued and steady increase in conductivity at wells 1 Deep and 2 Shallow.

Figure 15 also shows grab samples taken during routine maintenance (black circles). The degree of deviation between instrument and grab sample values varies at each well and is due to the disruption of static water conditions during maintenance activities. Relative transmissivity between each borehole and the surrounding aquifer may be implied by the magnitude of deviation; where strong connections show less deviation.

Table 8: Specific conductivity at Residue Storage Area

Station	Segment	Median	Min	Max
1 Deep	Average	242.0	116.0	503.0
	2018	566.0	470.0	642.0
2 Shallow	Average	100.0	62.0	208.0
	2018	137.0	104.0	194.0
2 Deep	Average	224.0	141.0	236.0
	2018	218.0	198.0	229.0
3 Deep	Average	120.0	81.0	182.0
	2018	128.0	99.0	173.0
4 Deep	Average	262.0	135.0	316.0
	2018	269.0	245.0	284.0

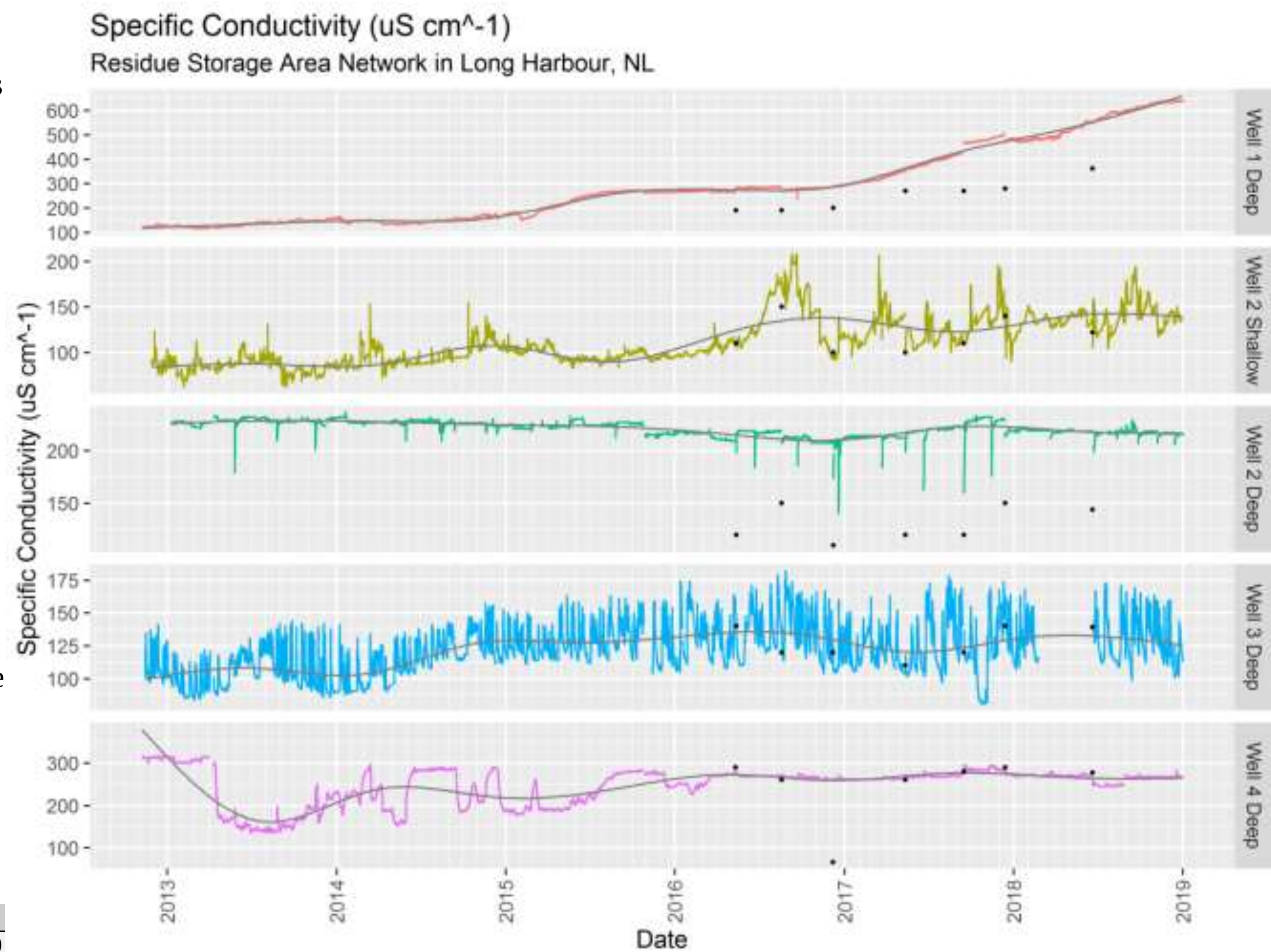

Figure 15: Specific conductivity at the Residue Storage Area from 2012 to 2018

Specific conductivity values continued to increase at well 1 Deep in 2018 as shown by Figure 16. Meanwhile, wells 3 Deep and 4 Deep, show a decline in variability and only a slight increase over the normal range.

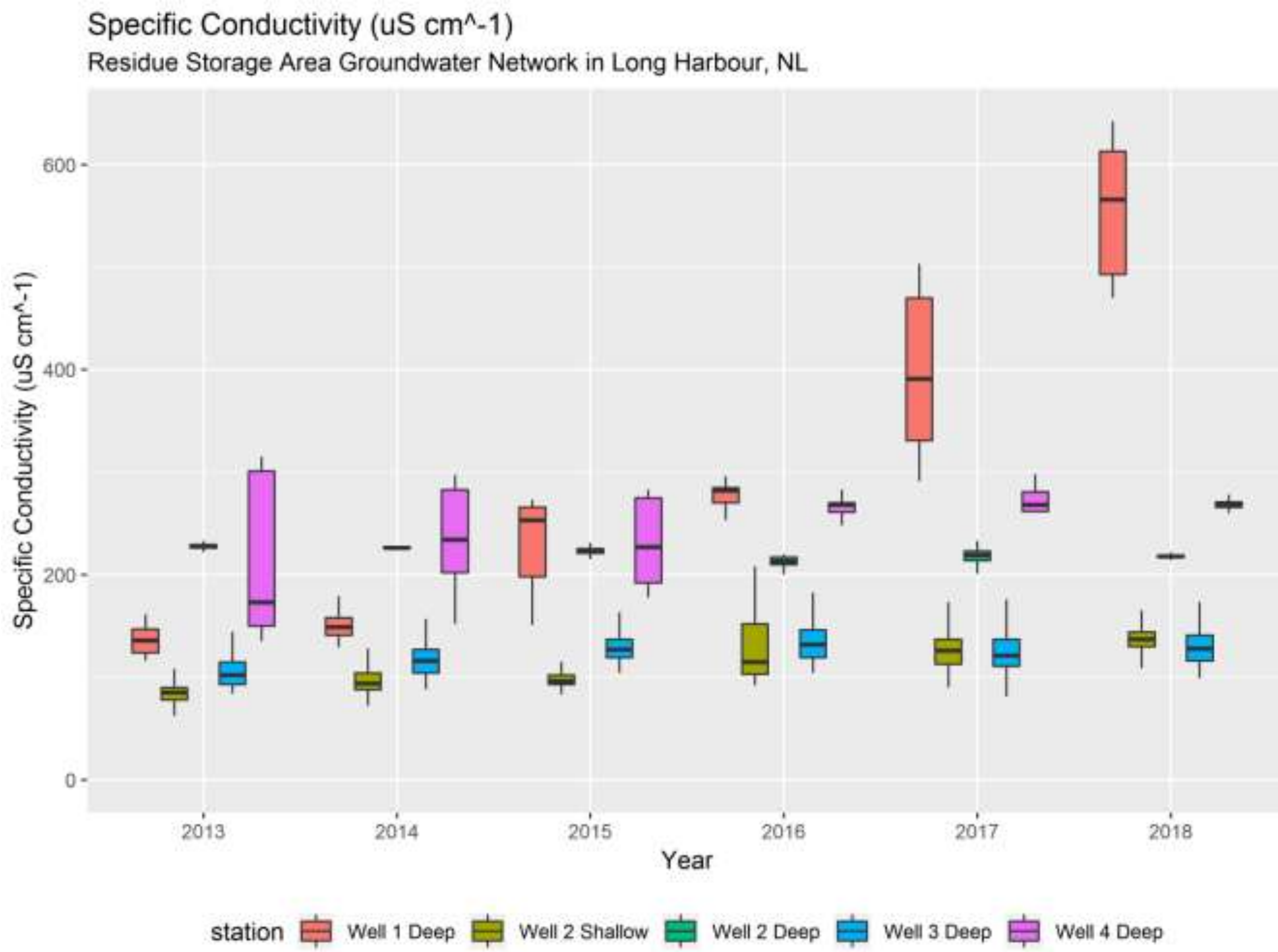

Figure 16: Boxplots of specific conductivity at the Residue Storage Area from 2013 to 2018

Oxidation-Reduction Potential (ORP)

Due to the high variability in ORP values following equipment maintenance, raw ORP values can be challenging to observe. As such, the gray trend lines in Figure 17 give a more intuitive indication of ORP tendency over time.

Table 9 shows that median ORP values from 2018 are greater than average at wells 1 Deep and 3 Deep. In 2018, median ORP values were less than average at wells 2 Shallow, 2 Deep, and 4 Deep.

Table 9: ORP at Residue Storage Area

Station	Segment	Median	Min	Max
1 Deep	Average	-266.8	-481.6	347.3
	2018	-47.4	-201.6	189.2
2 Shallow	Average	257.9	-340.8	466.5
	2018	74.7	-357.6	415.8
2 Deep	Average	-413.7	-502.9	131.9
	2018	-461.3	-497.2	1.7
3 Deep	Average	417.8	-82.3	462.9
	2018	420.1	210.6	461.5
4 Deep	Average	-111.4	-597.8	404.7
	2018	-448.5	-553.4	137.1

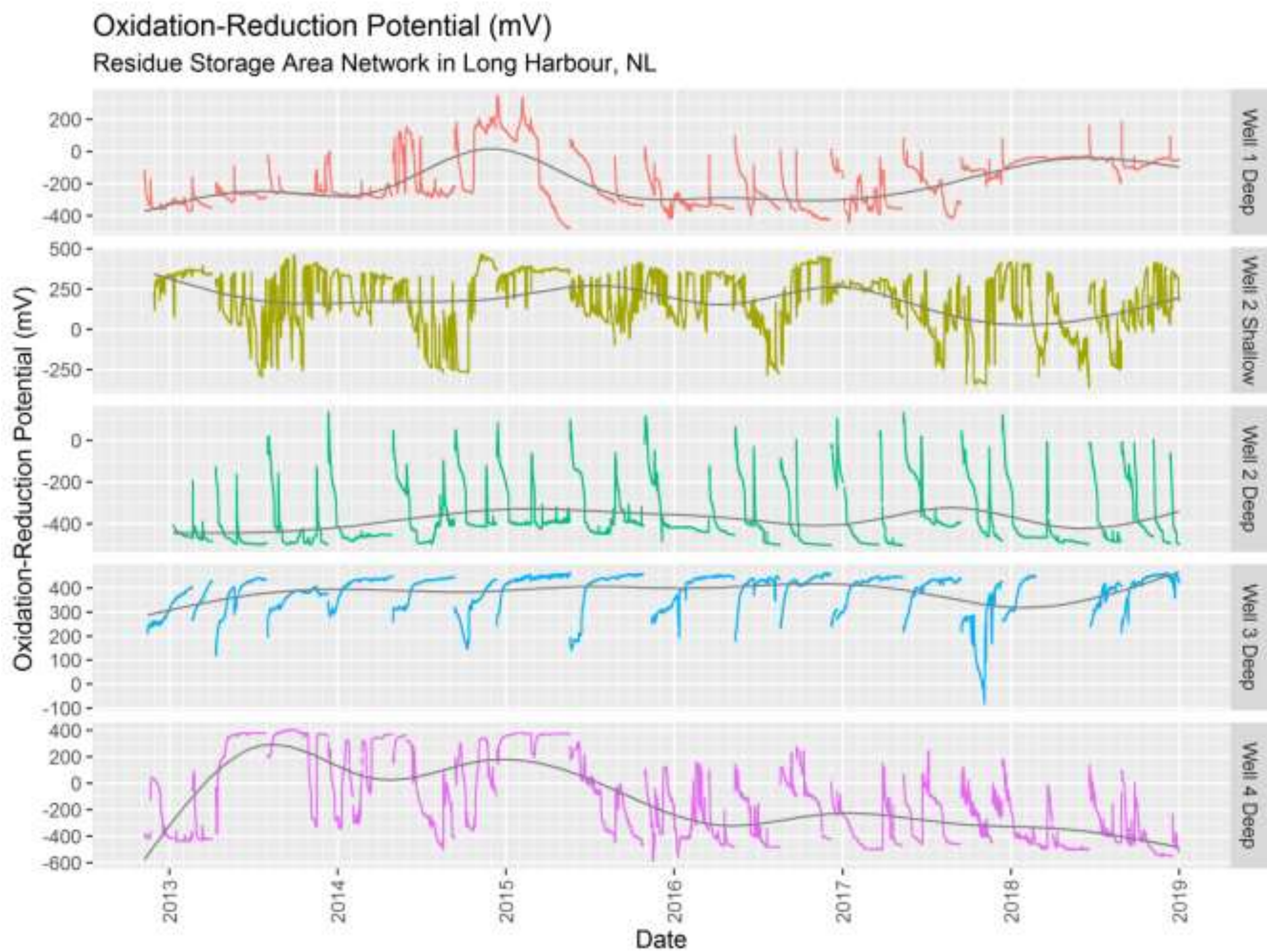

Figure 17: Oxidation-Reduction Potential at the Residue Storage Area from 2012 to 2018

Year-over-year tendency in ORP values are most clearly shown in Figure 18. Wells 1 Deep, 2 Shallow, and 4 Deep can be seen to change to a much larger degree than wells 3 Deep and 2 Deep.

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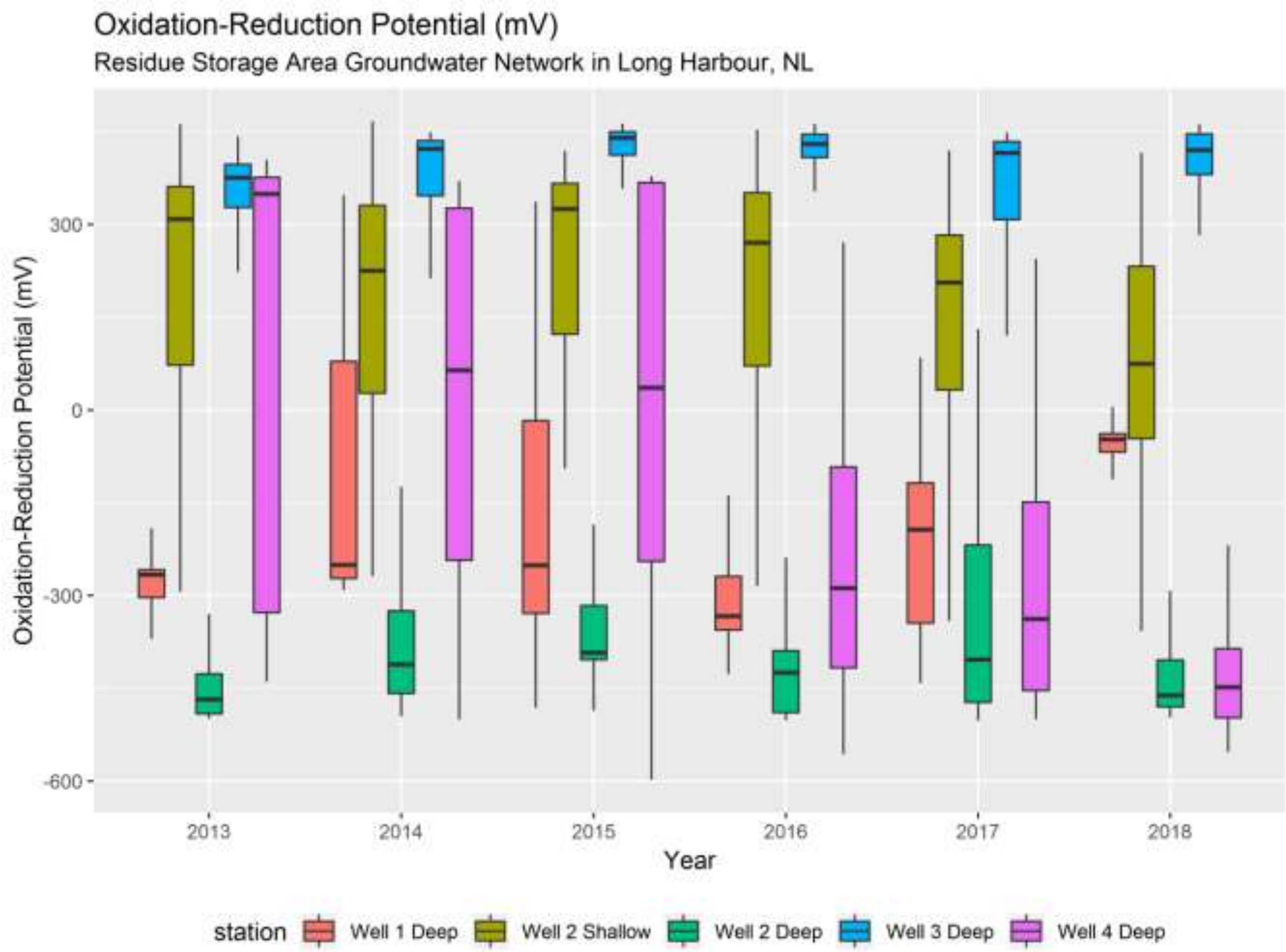


Figure 18: Boxplots of Oxidation-Reduction Potential at the Residue Storage Area from 2013 to 2018

Water Elevation

The local height of the aquifer surrounding each well is closely indicated by the water level in each well. These values are not expected to change a great deal over the long term, barring unforeseen circumstances or major changes to water level in nearby water bodies.

Periodic variation is commonplace as illustrated by Figure 19 but levels in 2018 were close to previous years as shown in Table 10

Table 10: Water level at Residue Storage Area

Station	Segment	Median	Min	Max
1 Deep	Average	131.949	131.276	132.355
	2018	132.080	131.604	132.422
2 Shallow	Average	113.779	113.257	114.165
	2018	113.894	113.600	114.037
2 Deep	Average	113.630	113.206	114.015
	2018	113.558	113.372	113.819
3 Deep	Average	132.995	131.747	135.003
	2018	132.721	132.171	134.062
4 Deep	Average	138.295	137.585	139.102
	2018	138.731	138.332	139.092

Figure 19: Water elevation at the Residue Storage Area from 2012 to 2018

Figure 20 shows the elevation of water levels in each well from 2013 to 2018. Values are largely stable at each well over long periods of time.

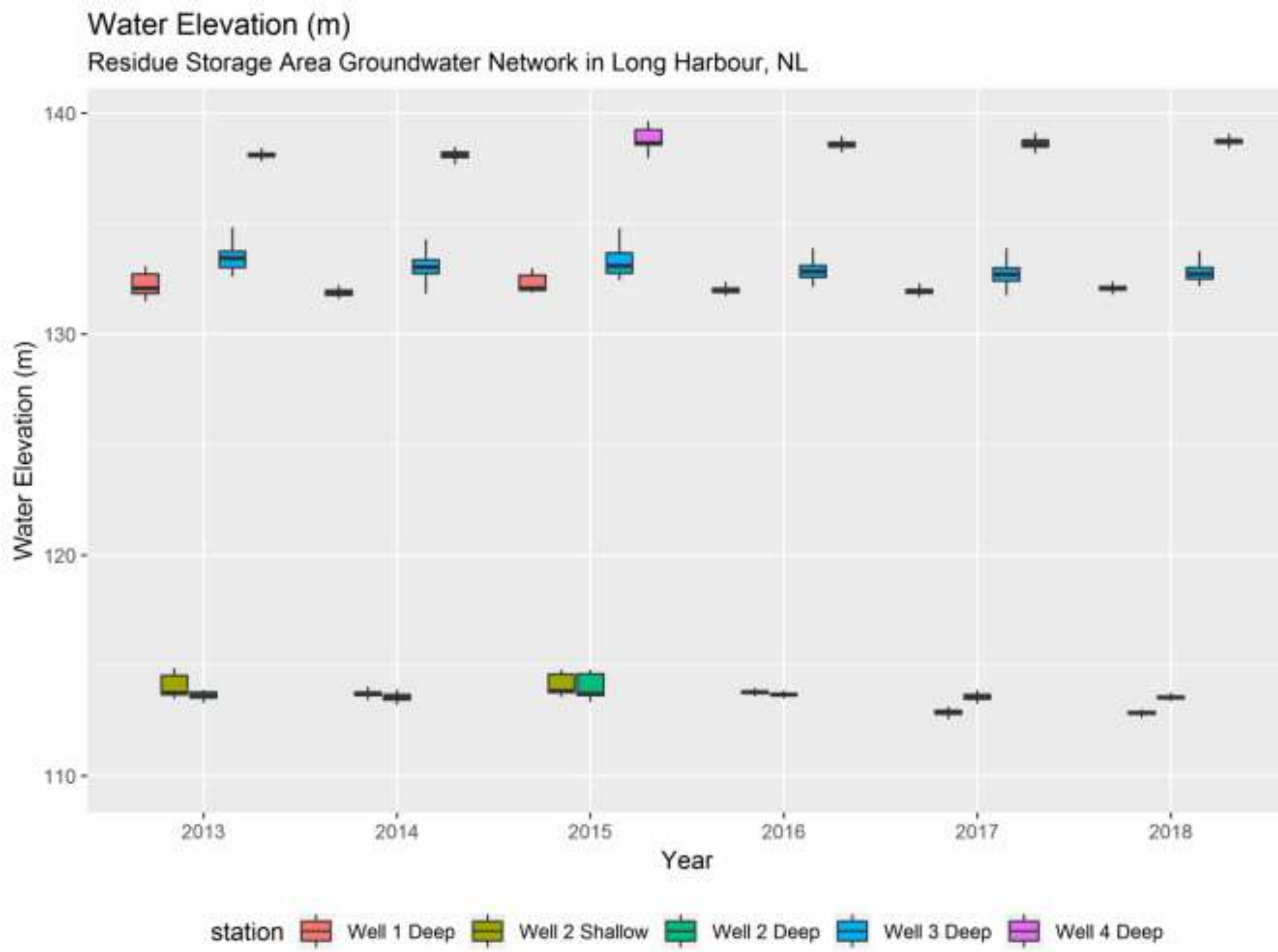


Figure 20: Boxplots of water elevation at the Residue Storage Area from 2013 to 2018

Conclusion and Path Forward

A 1.5 m water level increase at Rattling Brook Big Pond in November 2017 saw the inundation of shoreline vegetation and soils. As the organic matter decays, changes in water quality are expected over the short- to mid-term. In particular, dissolved oxygen concentrations may fall below guidelines set by the CCME during warm water conditions.

Other parameters within the Rattling Brook system show some trends that suggest a return towards baseline and pre-construction values. pH levels have shown some return towards more typical acidic conditions and variation in specific conductivity is declining at some stations.

Meanwhile at the Residue Storage Area, some parameters indicate deviations away from values observed at the initiation of monitoring efforts.

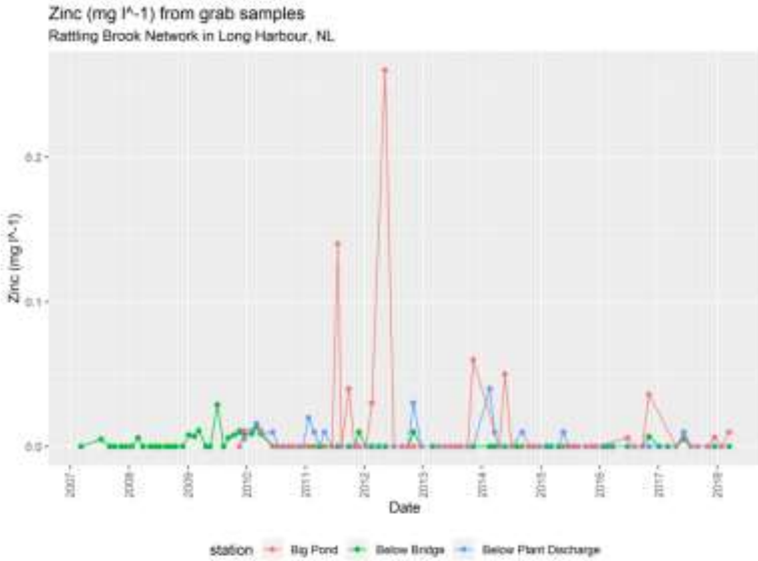
Well 1 Deep and 2 Shallow show increasing pH and specific conductivity values. However, ORP is decreasing at 2 Shallow and increasing at 1 Deep. It is possible that the same mechanism is driving pH, conductivity, and ORP changes. Opposing ORP tendencies may show a convergence. Over time, monitoring may help to clarify this.

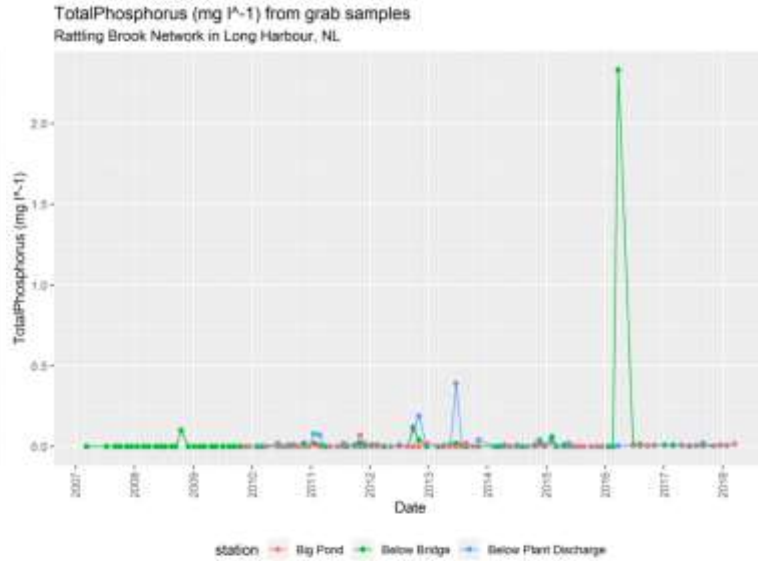
Since 2012, wells 2 Deep and 3 Deep have been relatively stable in comparison to the other three wells. The change in values at other wells could indicate a spatial component in water quality parameters on one side of the RSA compared to the other side.

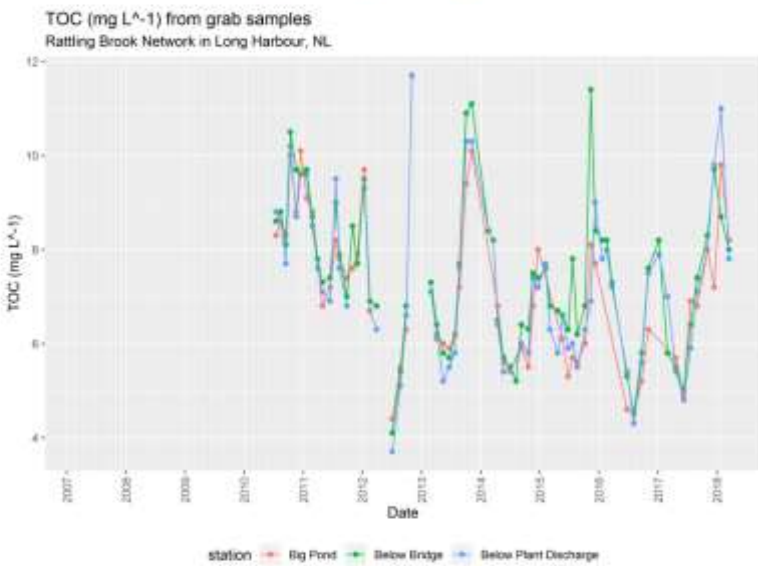
Ongoing and cooperative efforts between the department of Municipal Affairs and Environment and Vale to monitor water quality on a real-time basis have been successful in identifying areas worthy of attention.

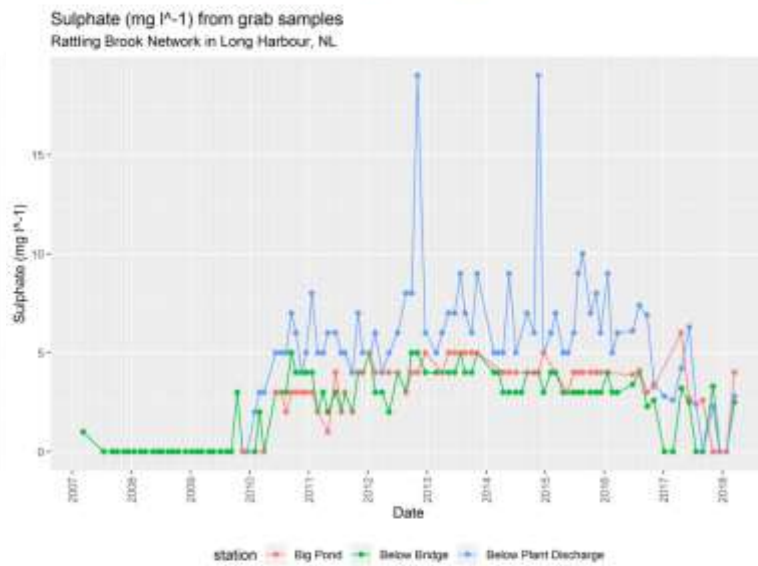
Appendix

The following are results from grab samples for parameters not typically discussed in water quality reports. They are provided without discussion.

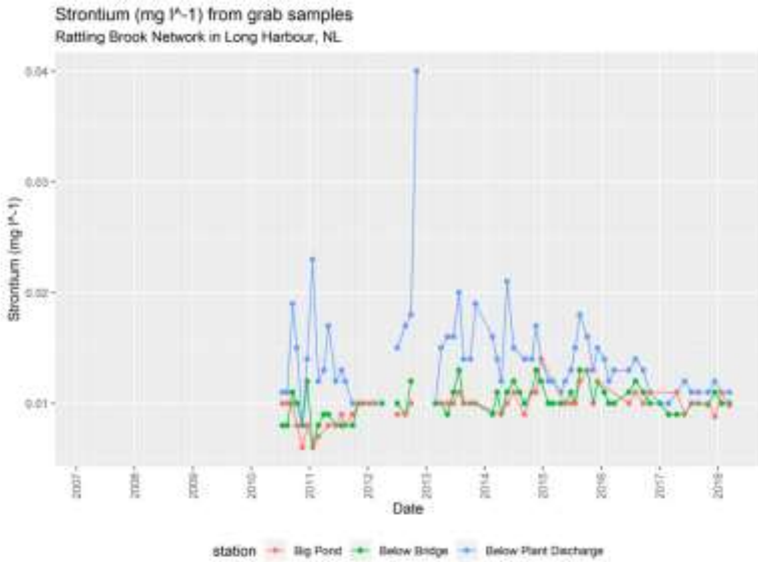


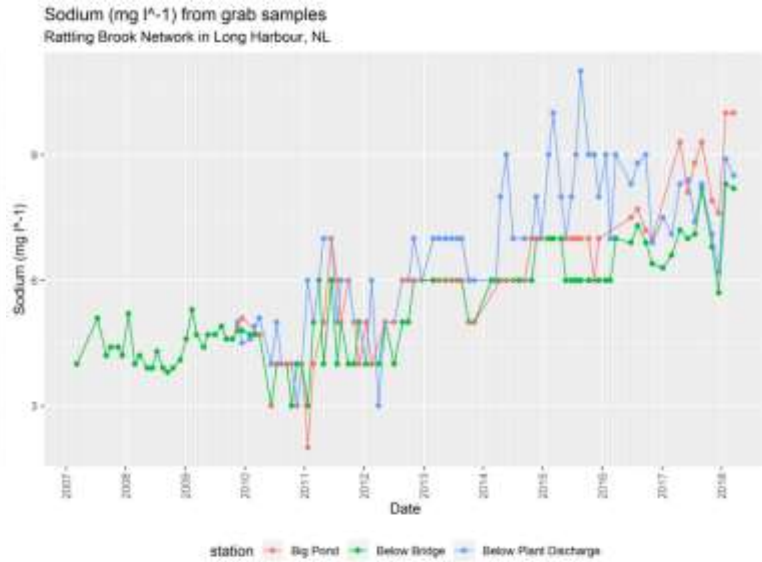


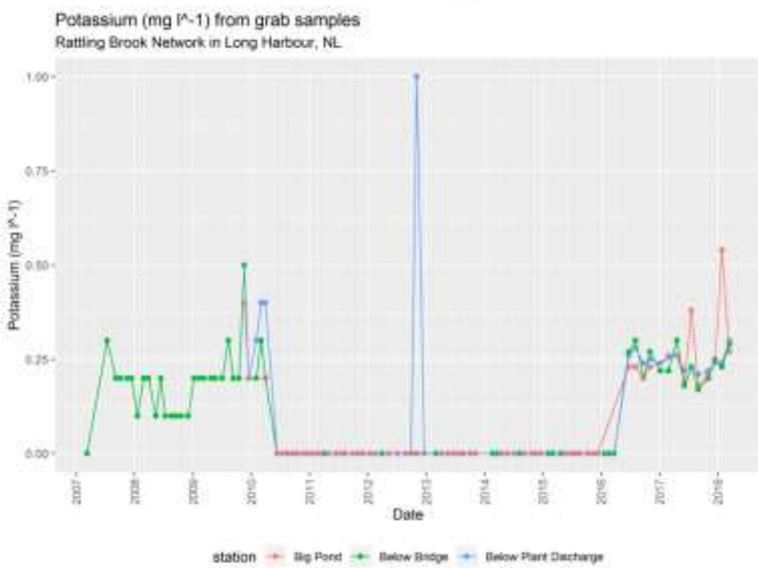


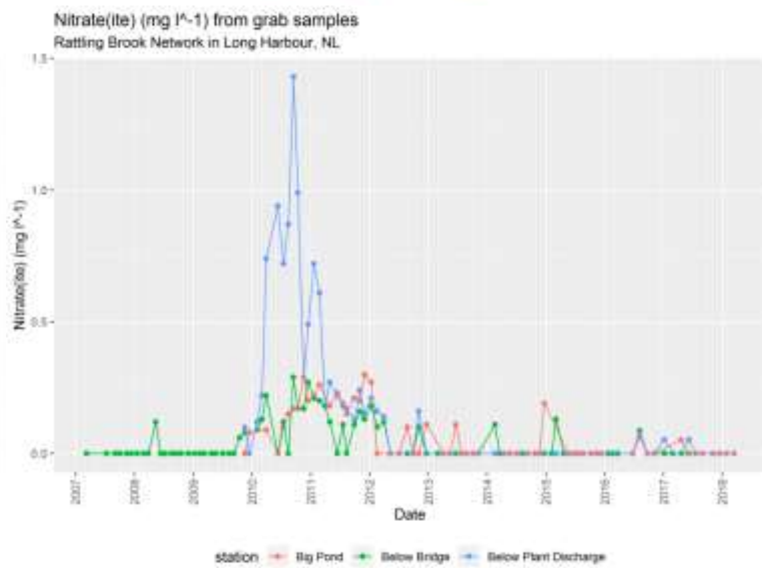


Appendix – Surface Water

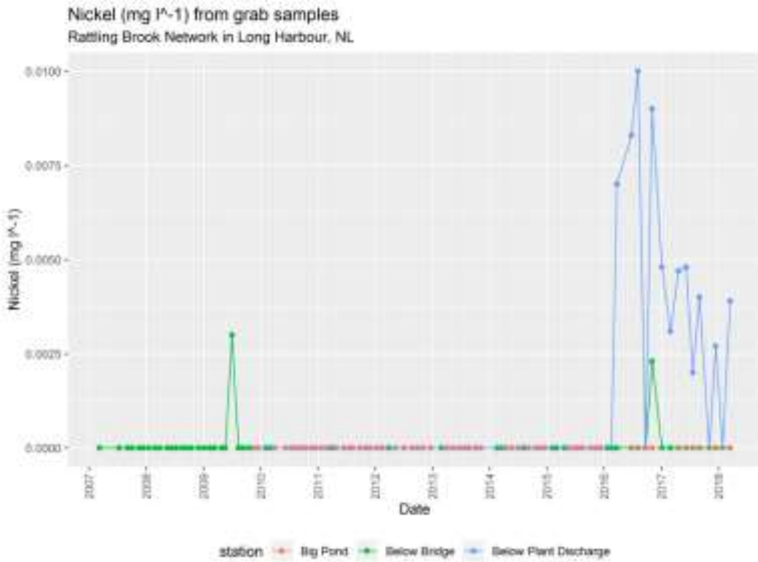


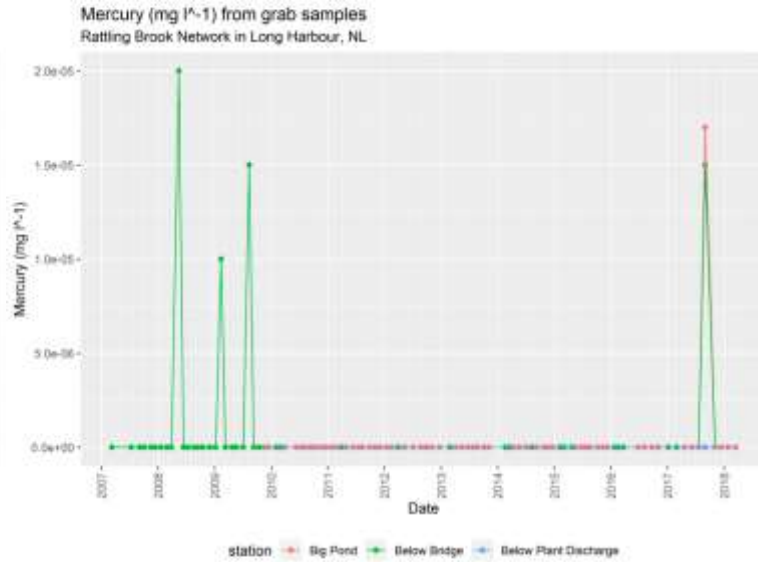


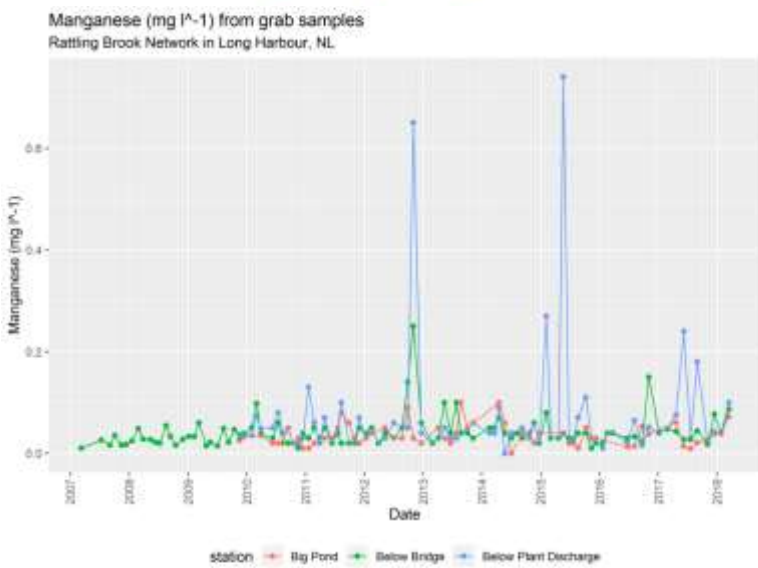


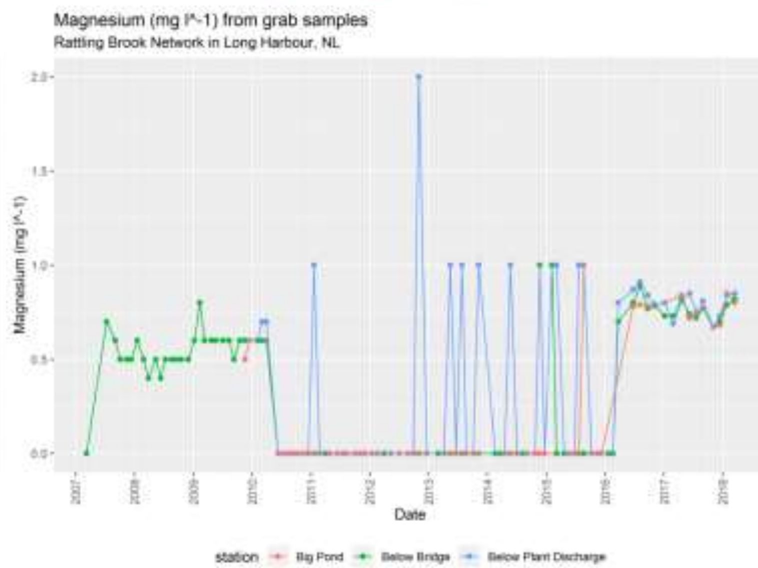


Appendix – Surface Water

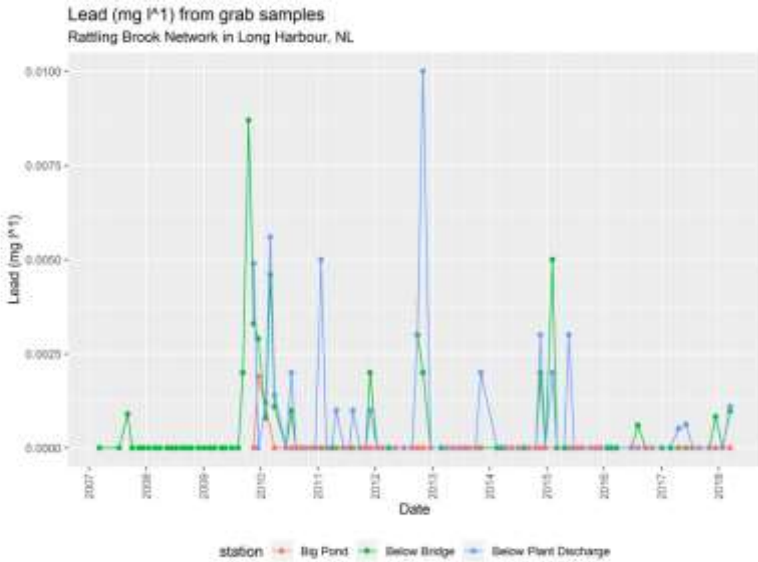


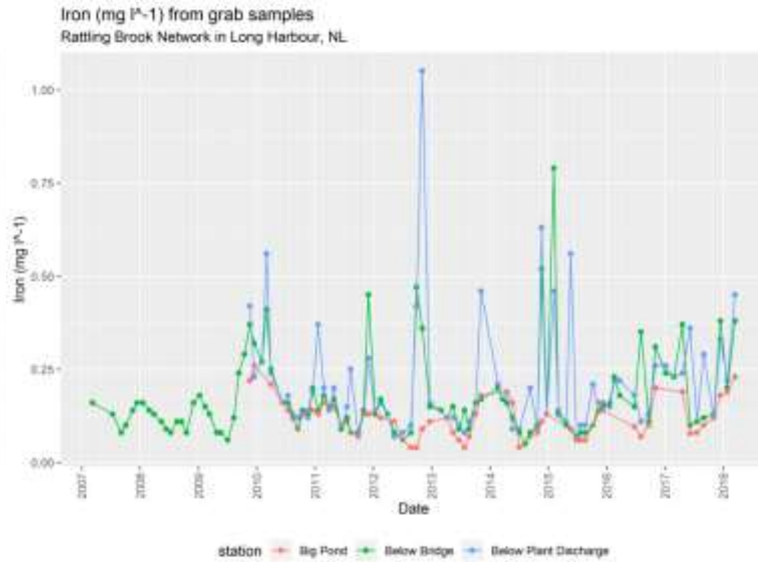


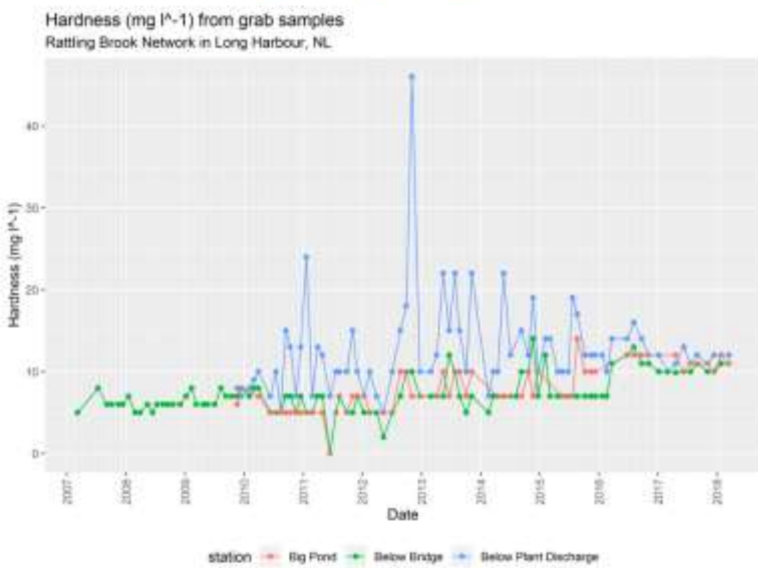


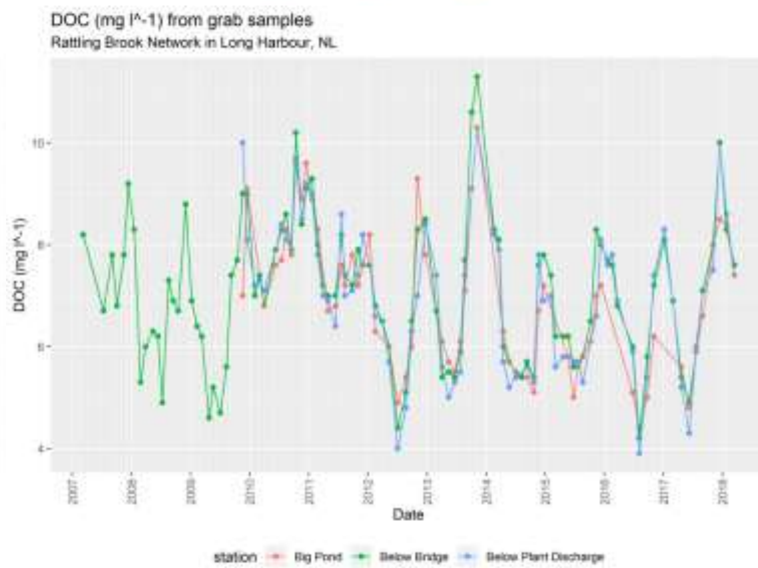


Appendix – Surface Water

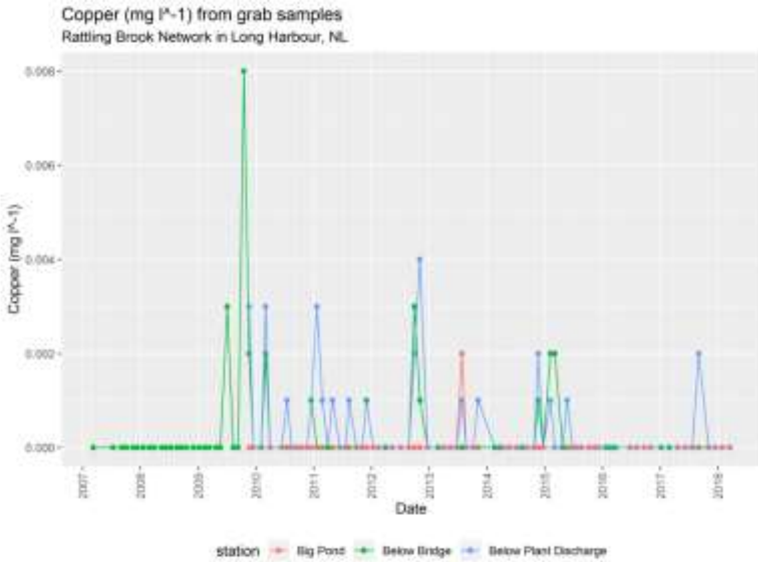


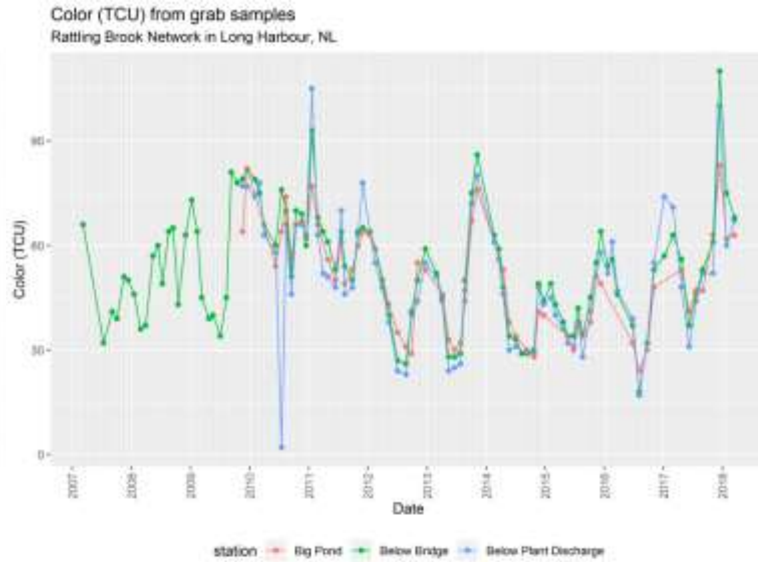


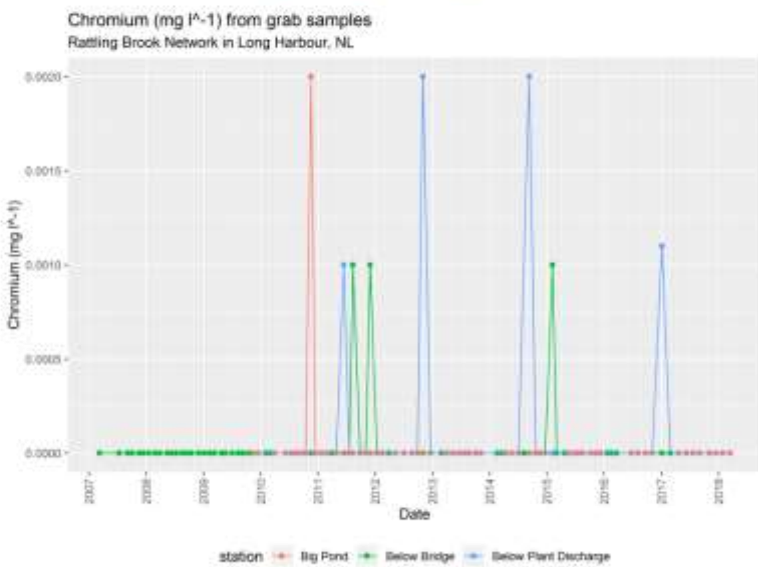


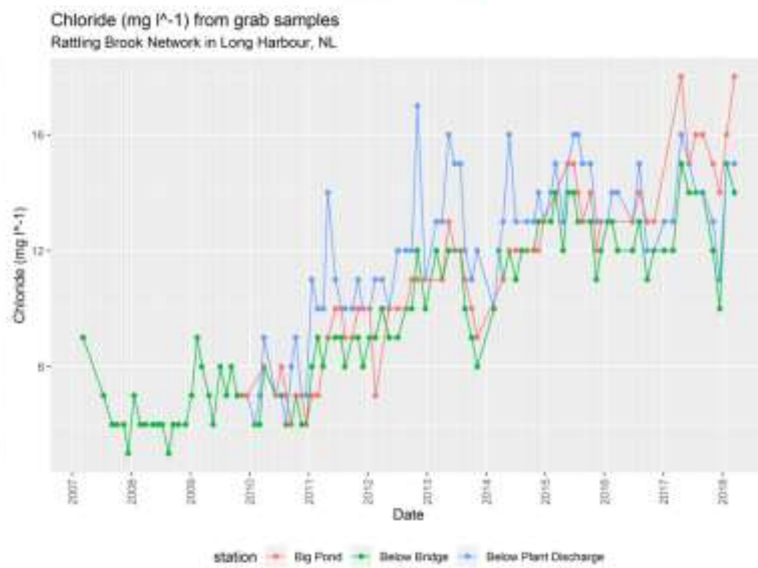


Appendix – Surface Water

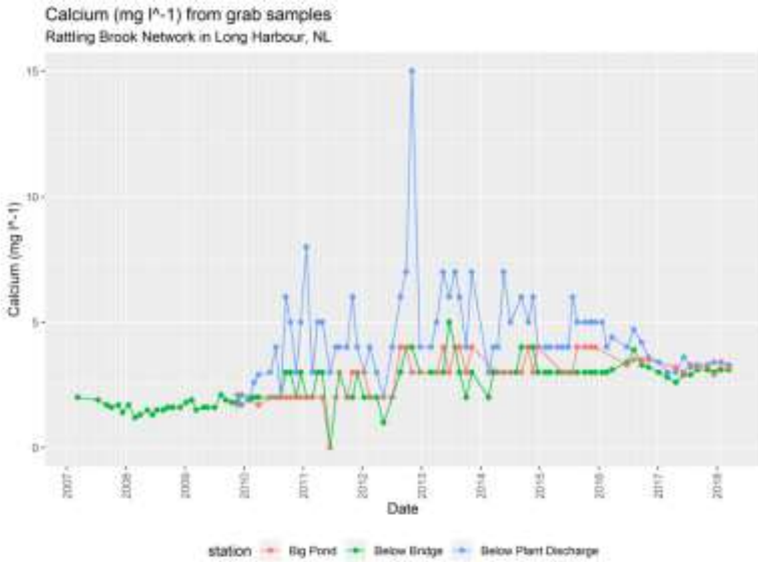


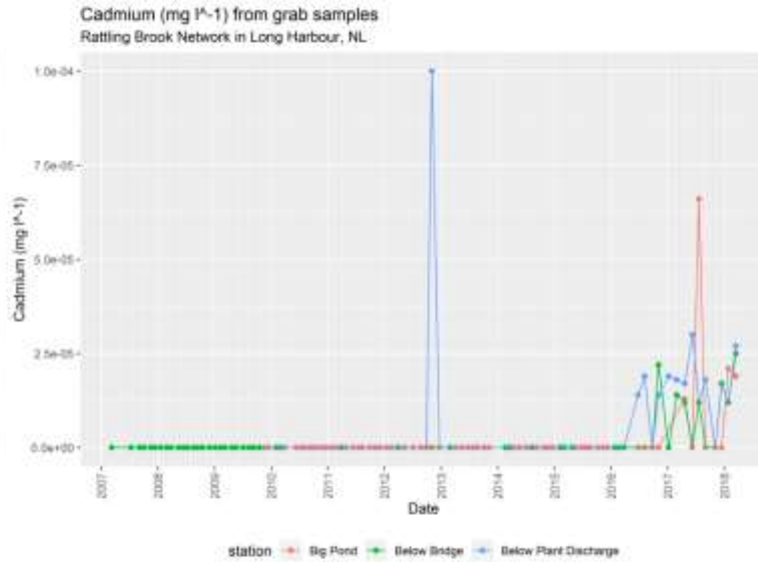


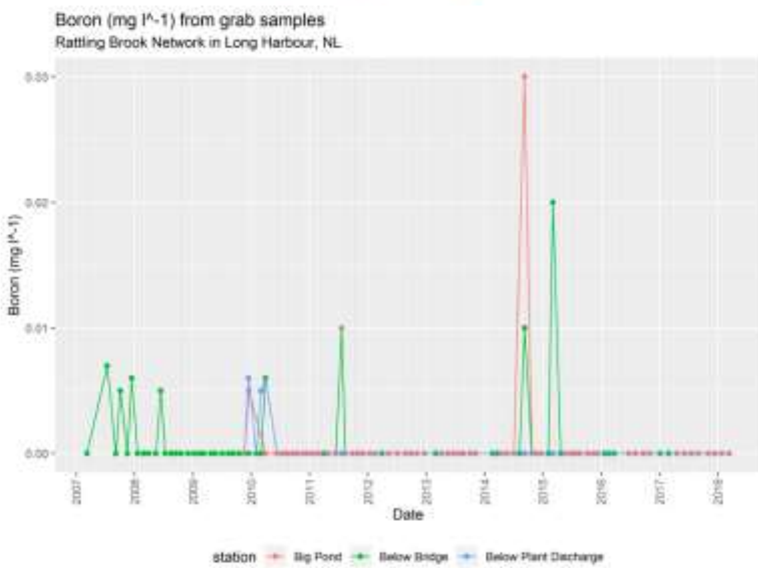


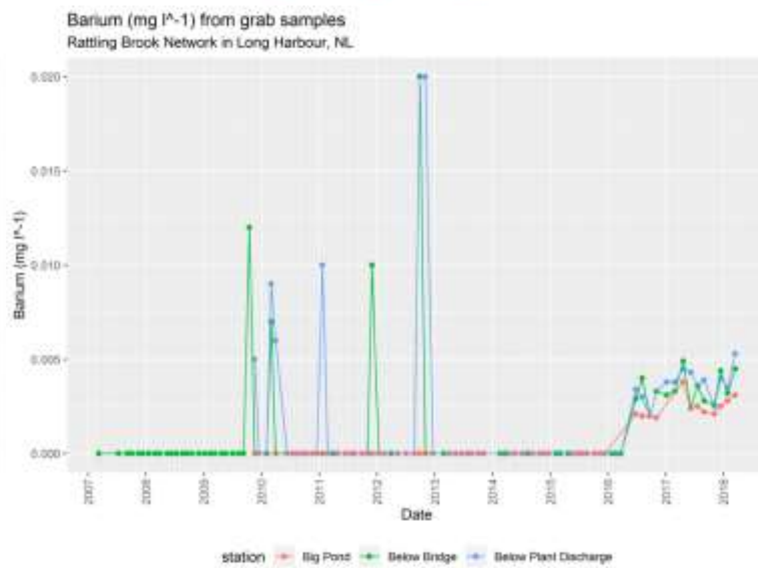


Appendix – Surface Water

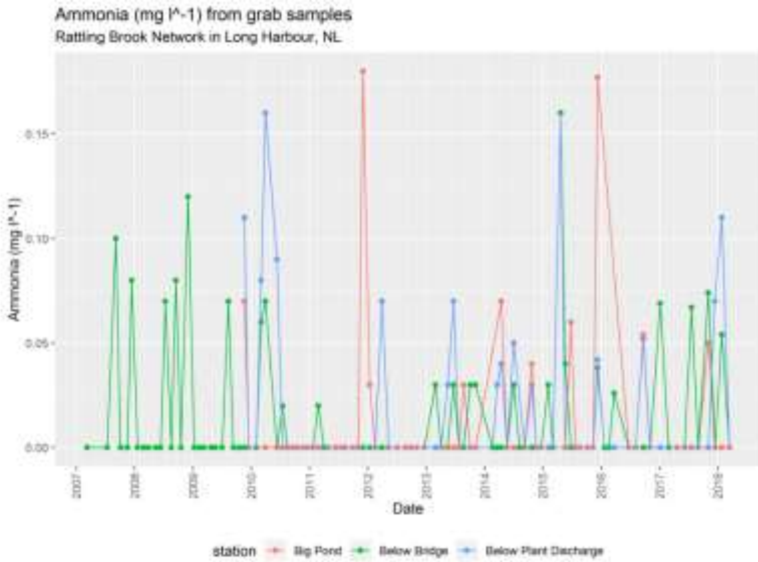


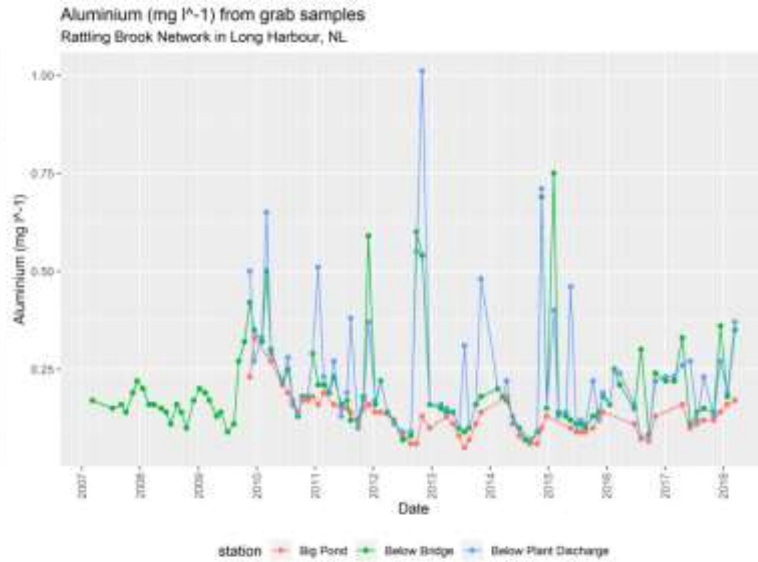


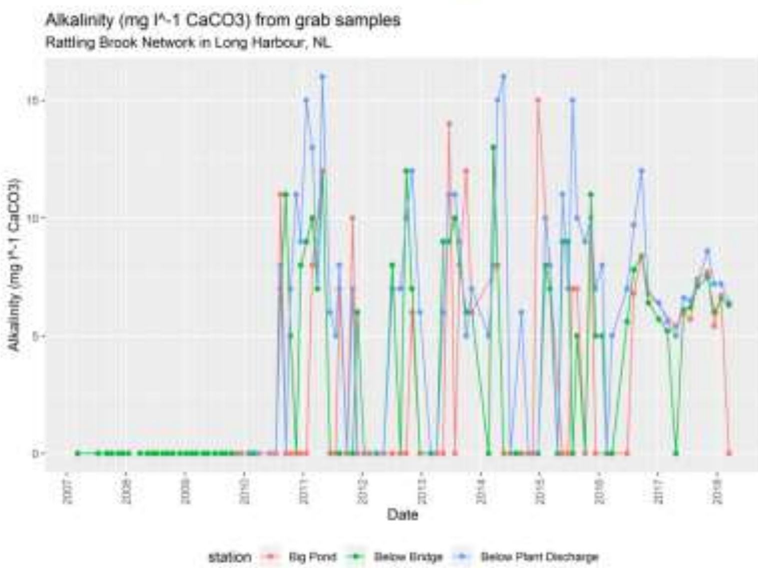




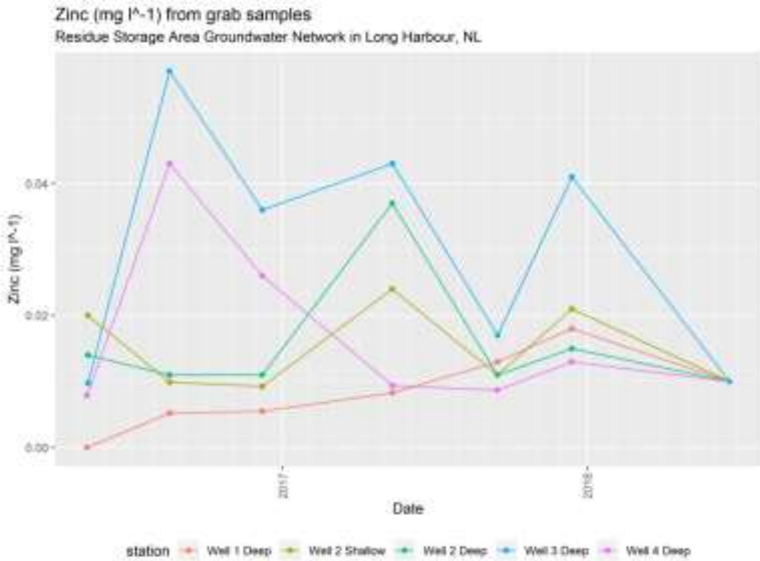
Appendix – Surface Water

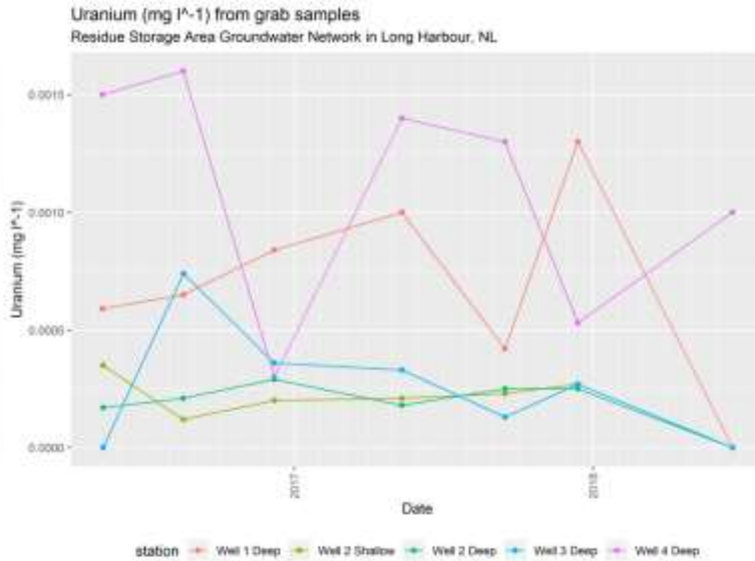


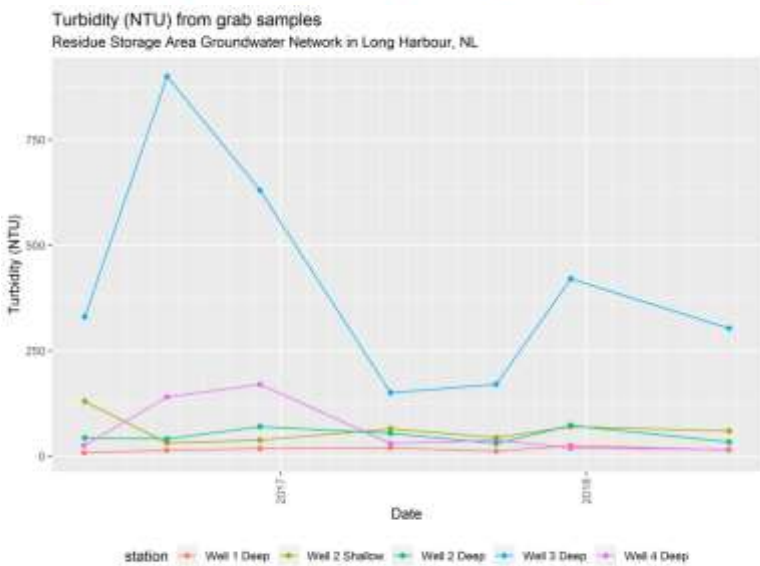


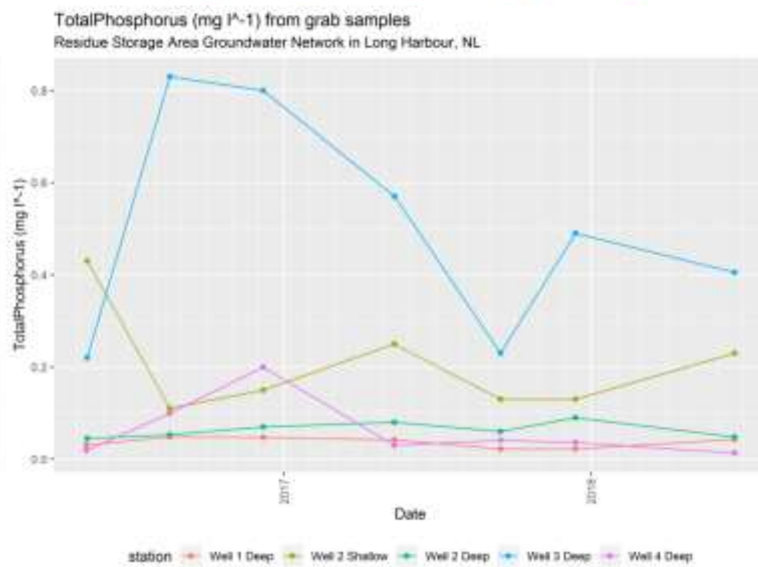


Appendix – Groundwater

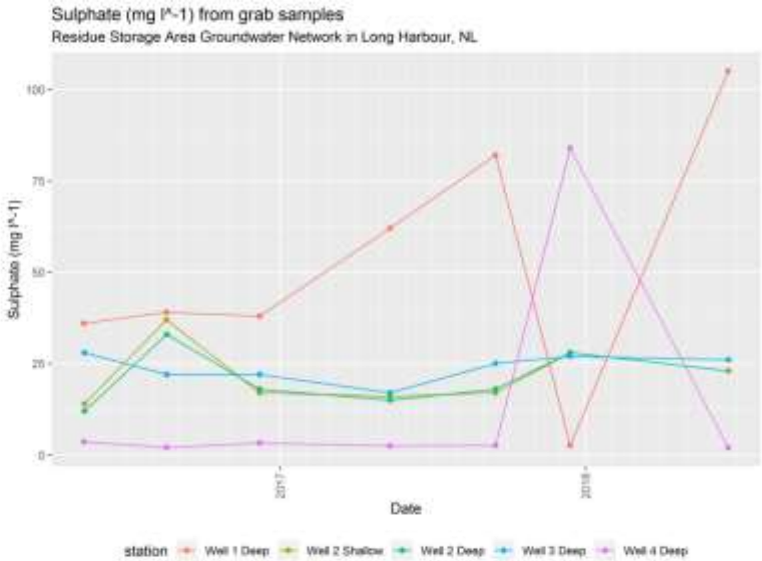


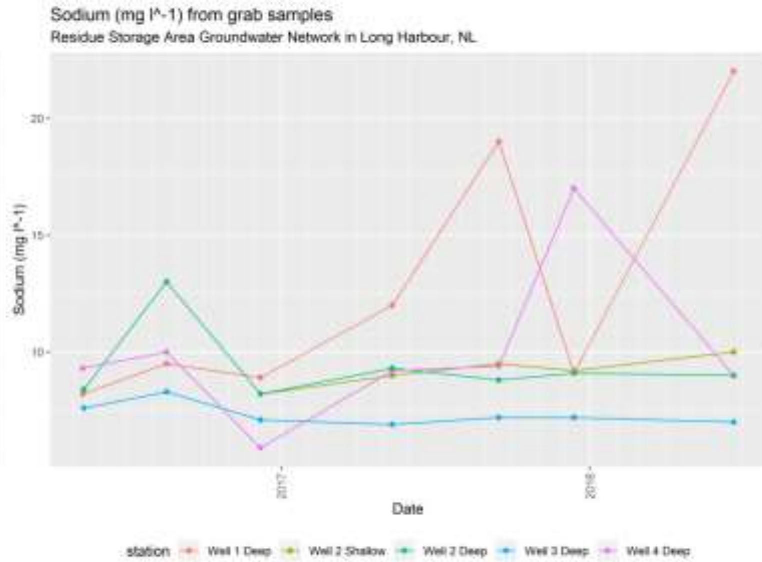


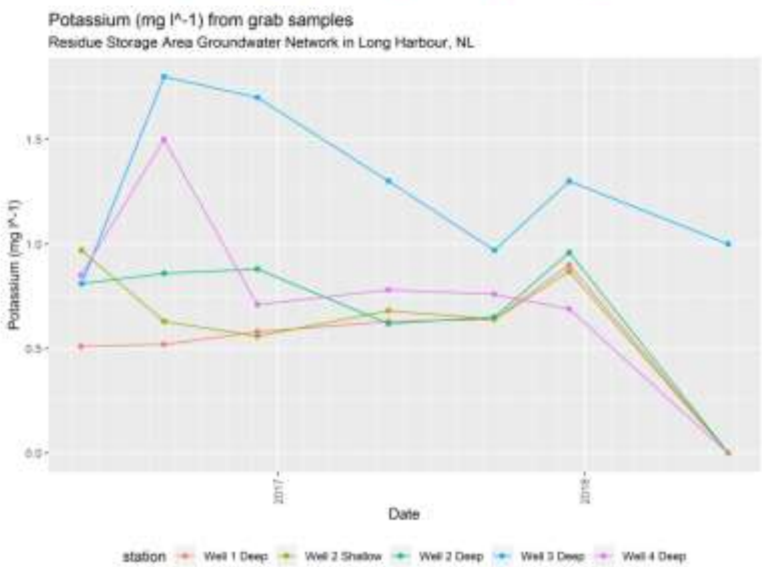


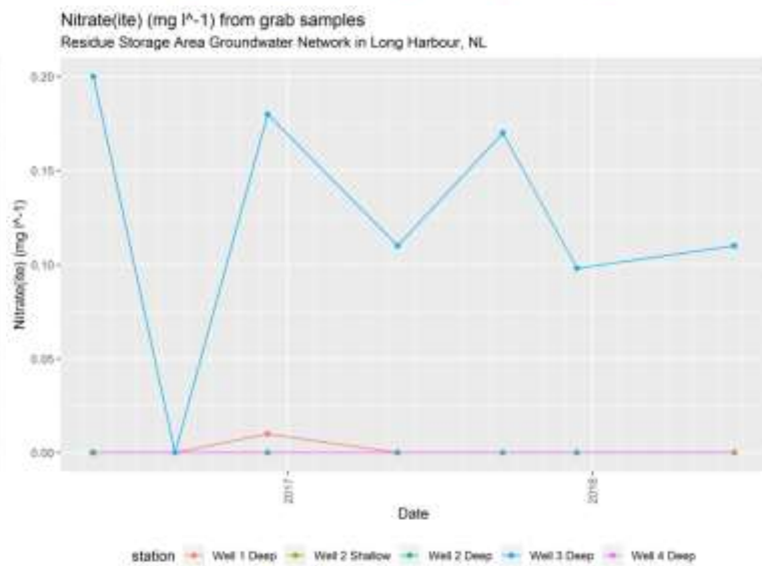


Appendix – Groundwater

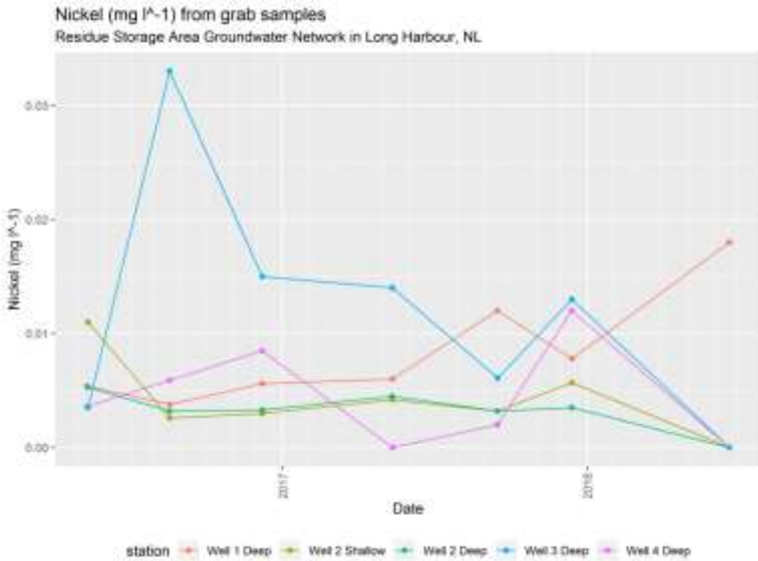


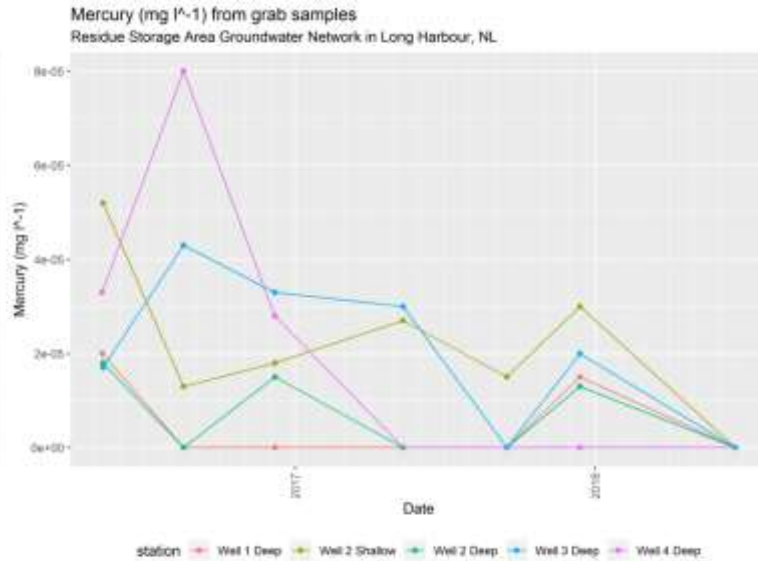


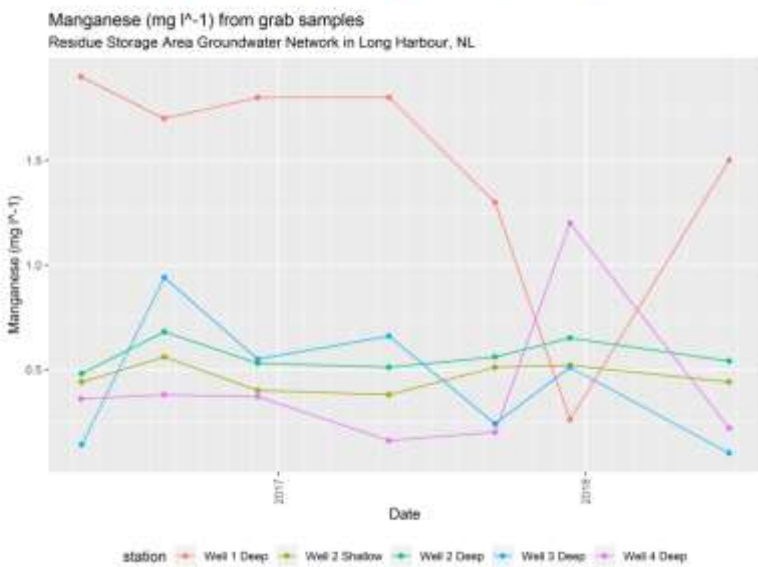


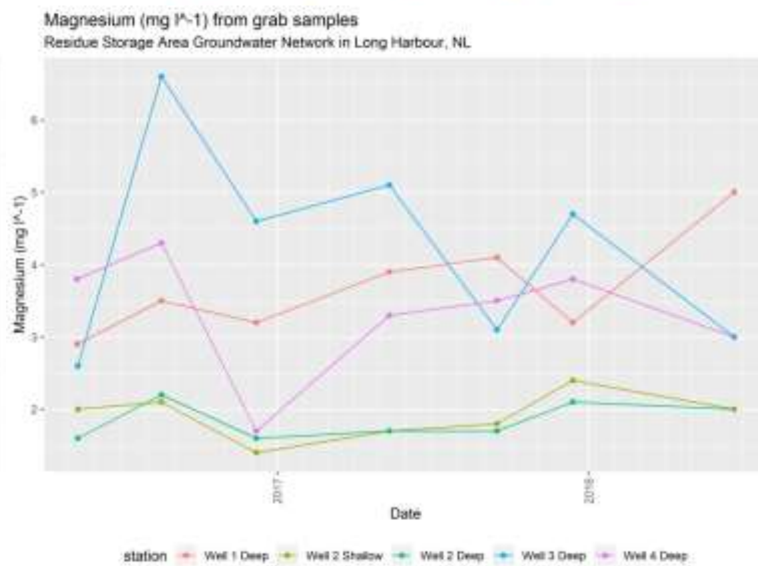


<u>Appendix – Groundwater</u>

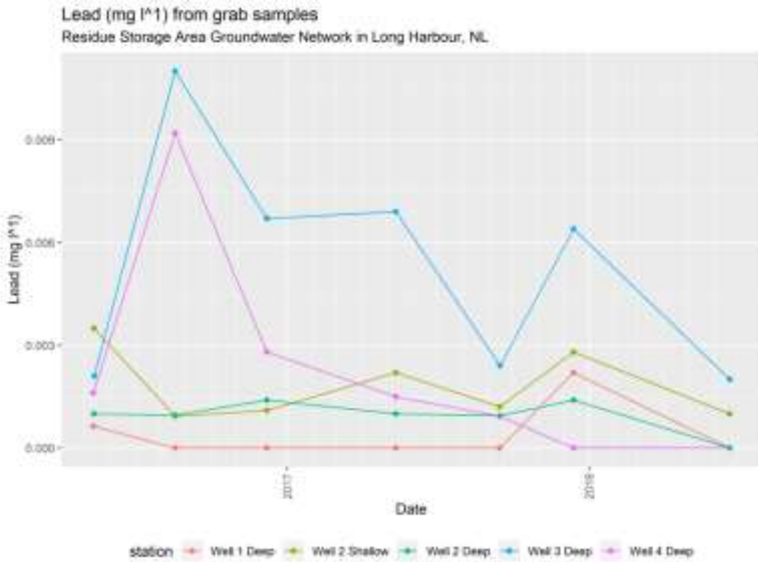


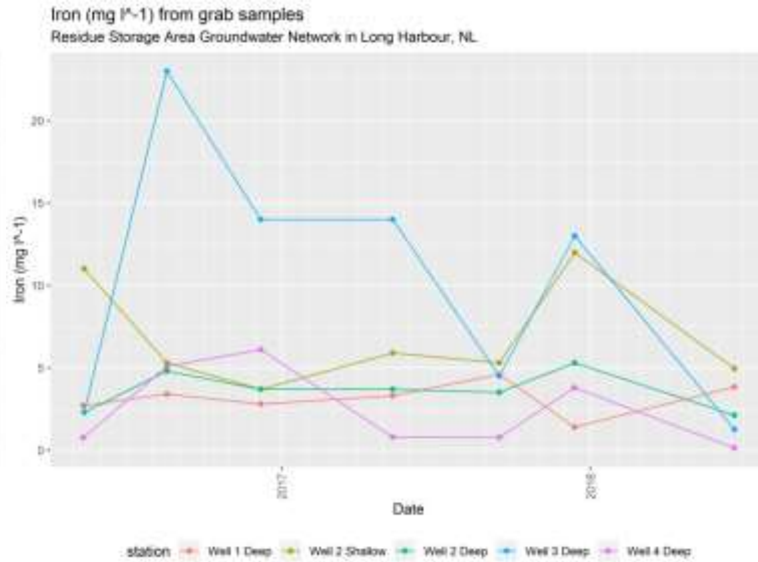


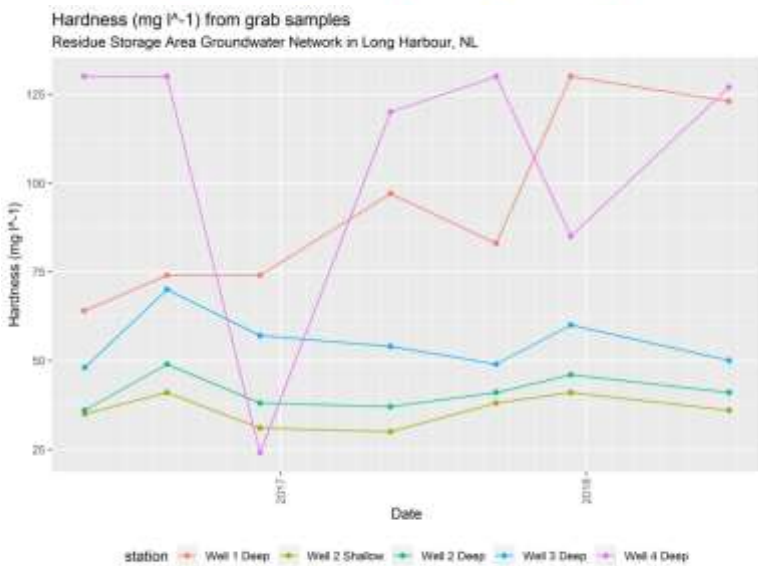


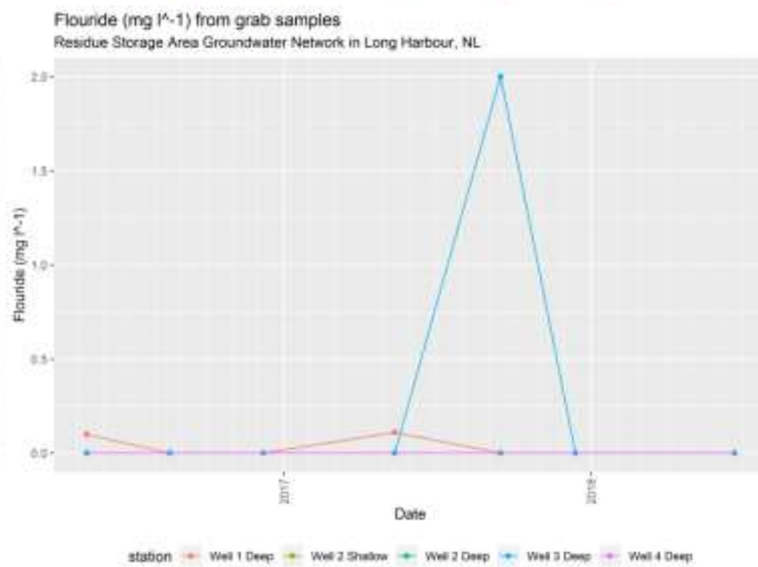


Appendix – Groundwater

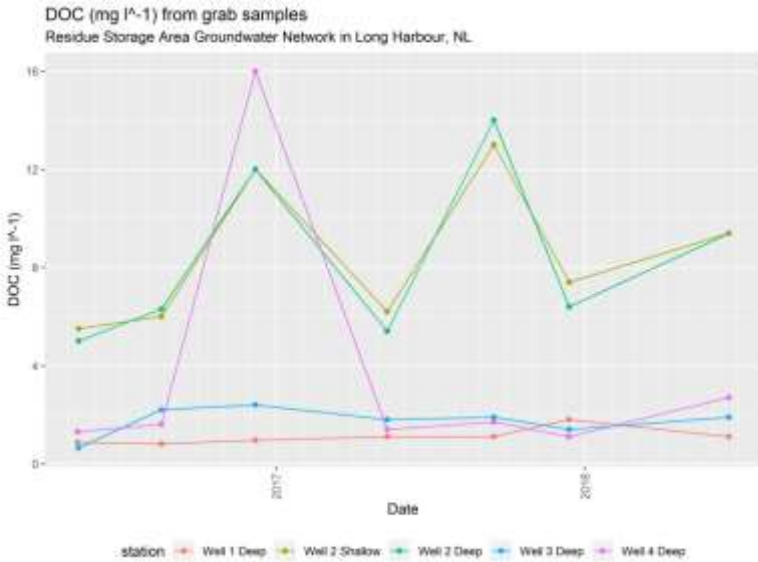


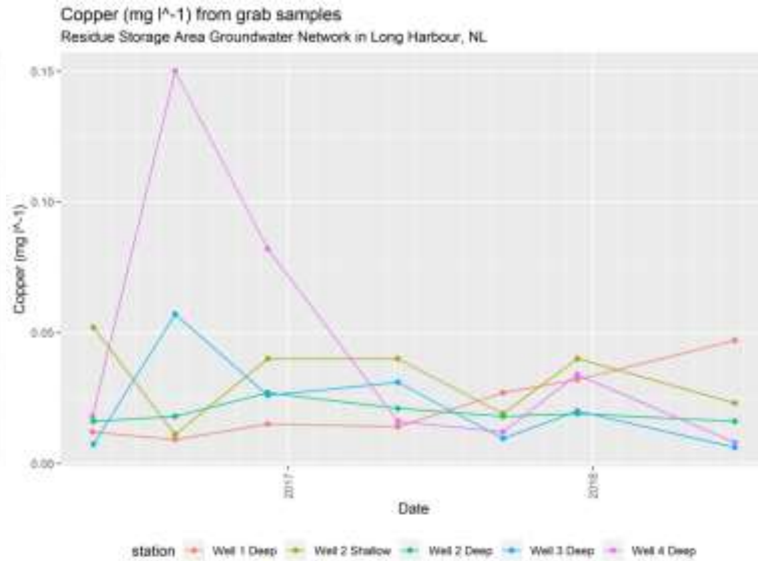


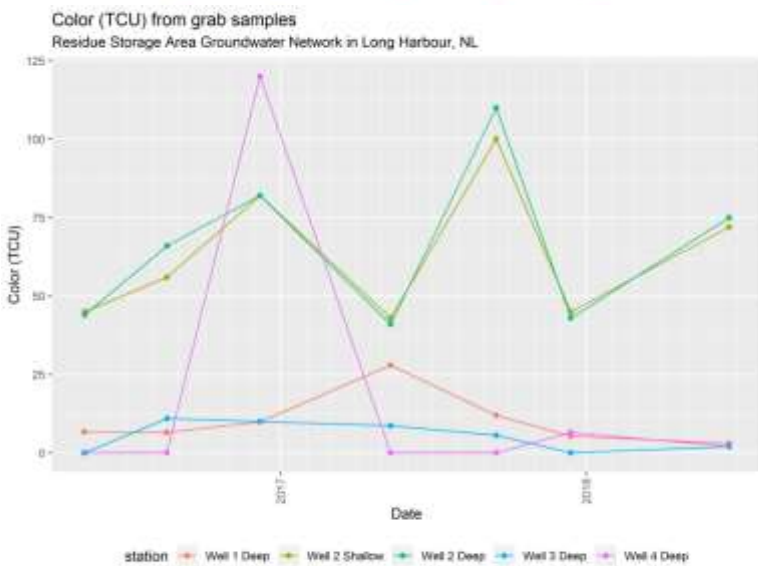


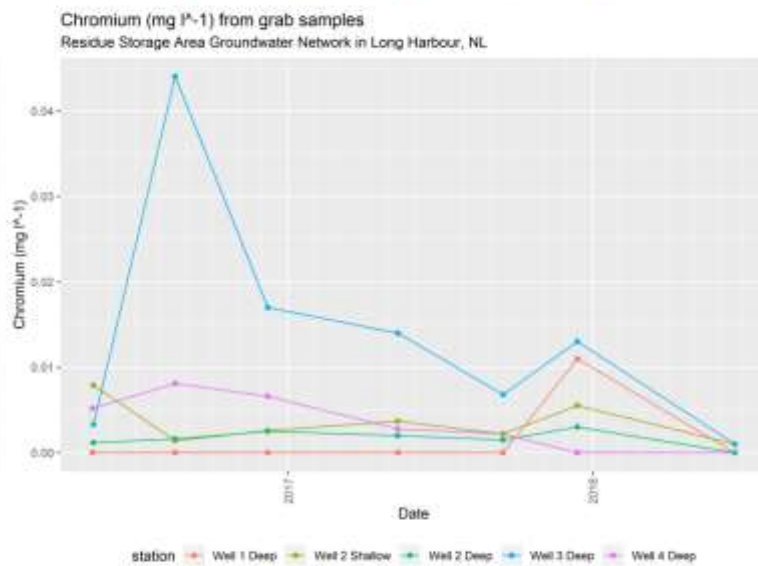


Appendix – Groundwater









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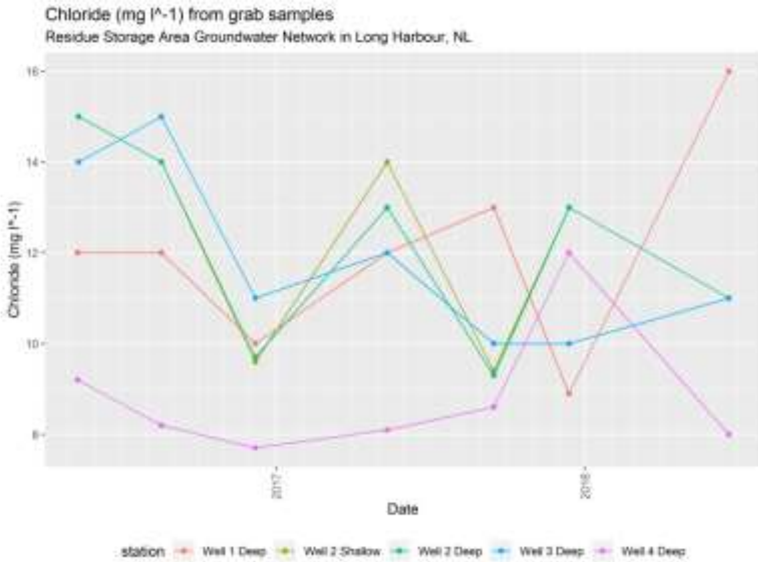

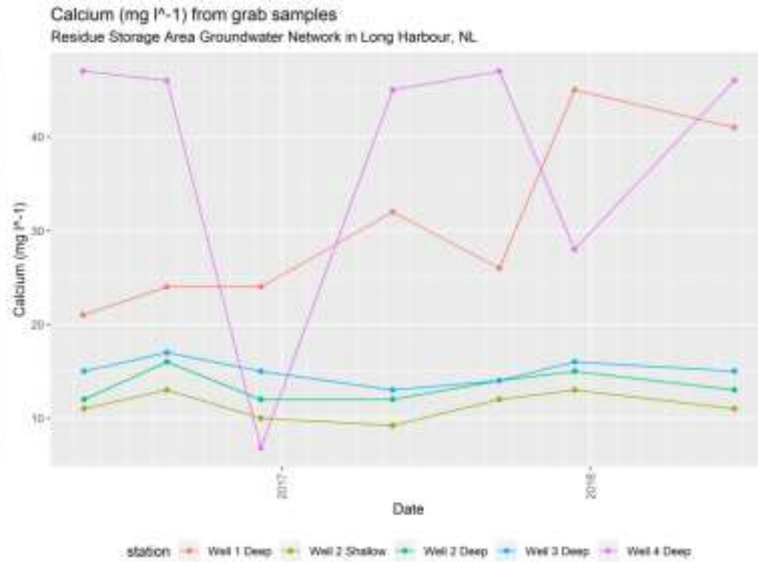

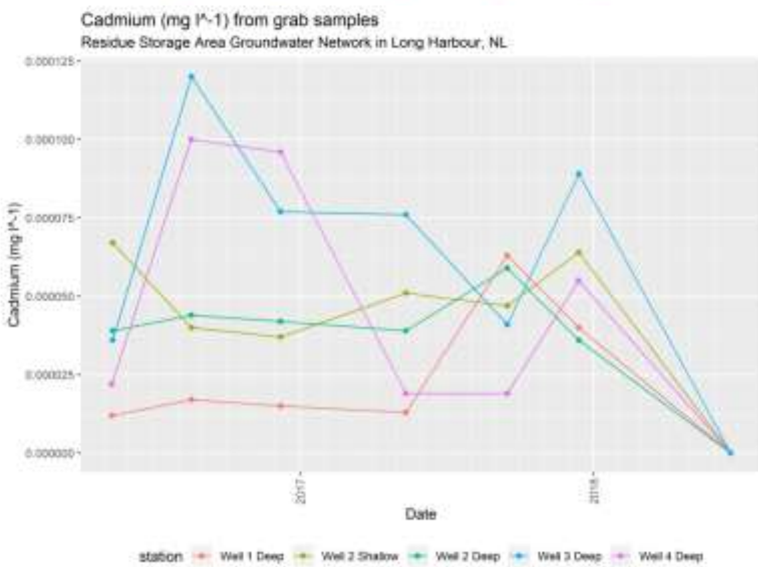

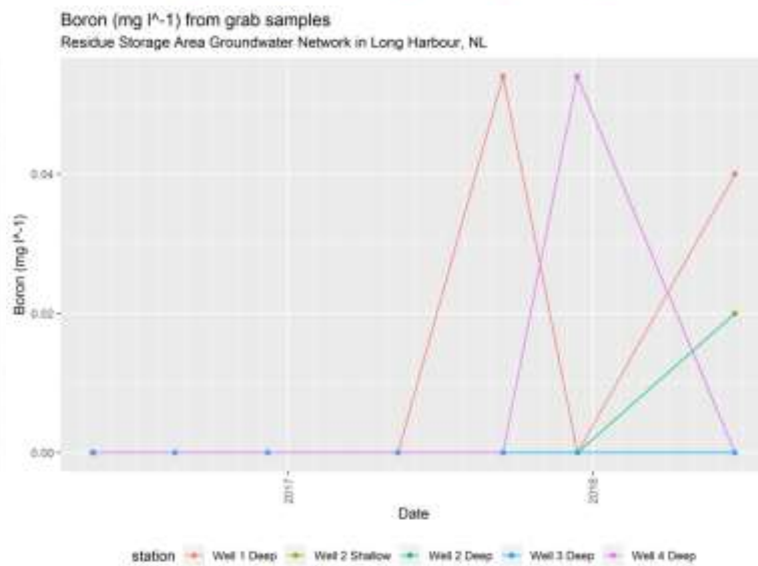

Appendix – Groundwater