Real-Time Water Quality Deployment Report

Vale
Long Harbour Annual Report

2019

Newfoundland Labrador

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

Table of Contents

Introduction

Real-time monitoring (RTWQ) of surface and groundwater quality on the Vale Long Harbour Processing 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 Stephenville 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 Figure 1 below (green triangles are surface water monitoring stations on Rattling Brook and blue arrows are groundwater monitoring stations around the RSA).

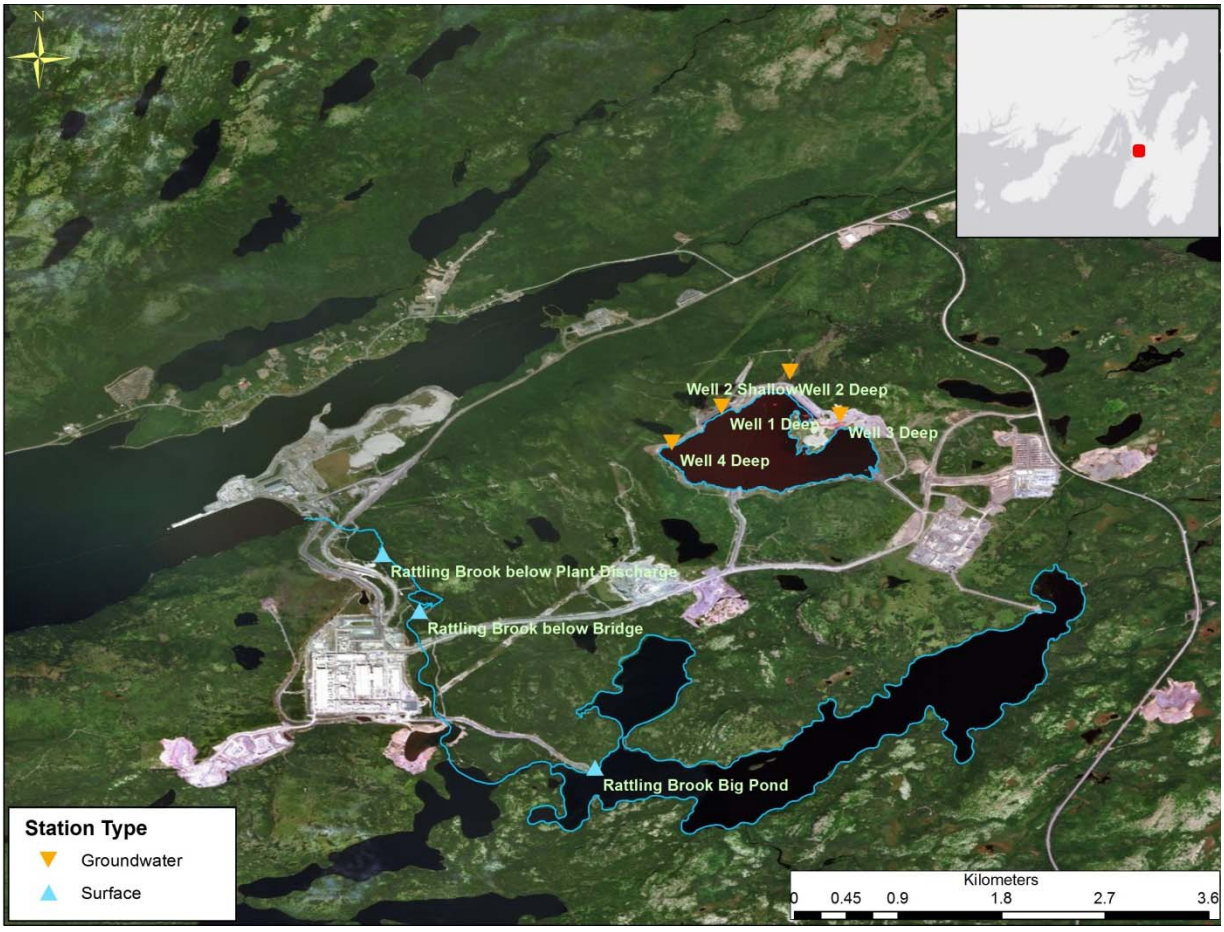

Figure 1: Real-time water quality monitoring stations in Long Harbour, Newfoundland

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 and weather data are presented for each surface and groundwater parameter in the next section. Each table lists the 2019 median, minimum, and maximum values. *Average median* values for each parameter are calculated from the median values of each previous year and are 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 the next sections, data from both surface and groundwater networks are presented as a series of line and box plots for water quality visualization over time and between stations. Summary statistics are presented in the appendix by year and station.

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

Surface Water Network

Water Temperature

Water temperatures for all stations were lower than last year (Table 1).

Table 1: Water temperatures at Rattling Brook

Station	Segment	Median	Min	Max
Big Pond	2018	8.44	-0.43	20.87
	2019	6.76	0.23	22.26
Bridge	2018	8.65	-0.41	23.98
	2019	7.39	-0.05	24.42
Discharge	2018	7.88	-0.53	24.77
	2019	7.705	-0.07	24.67

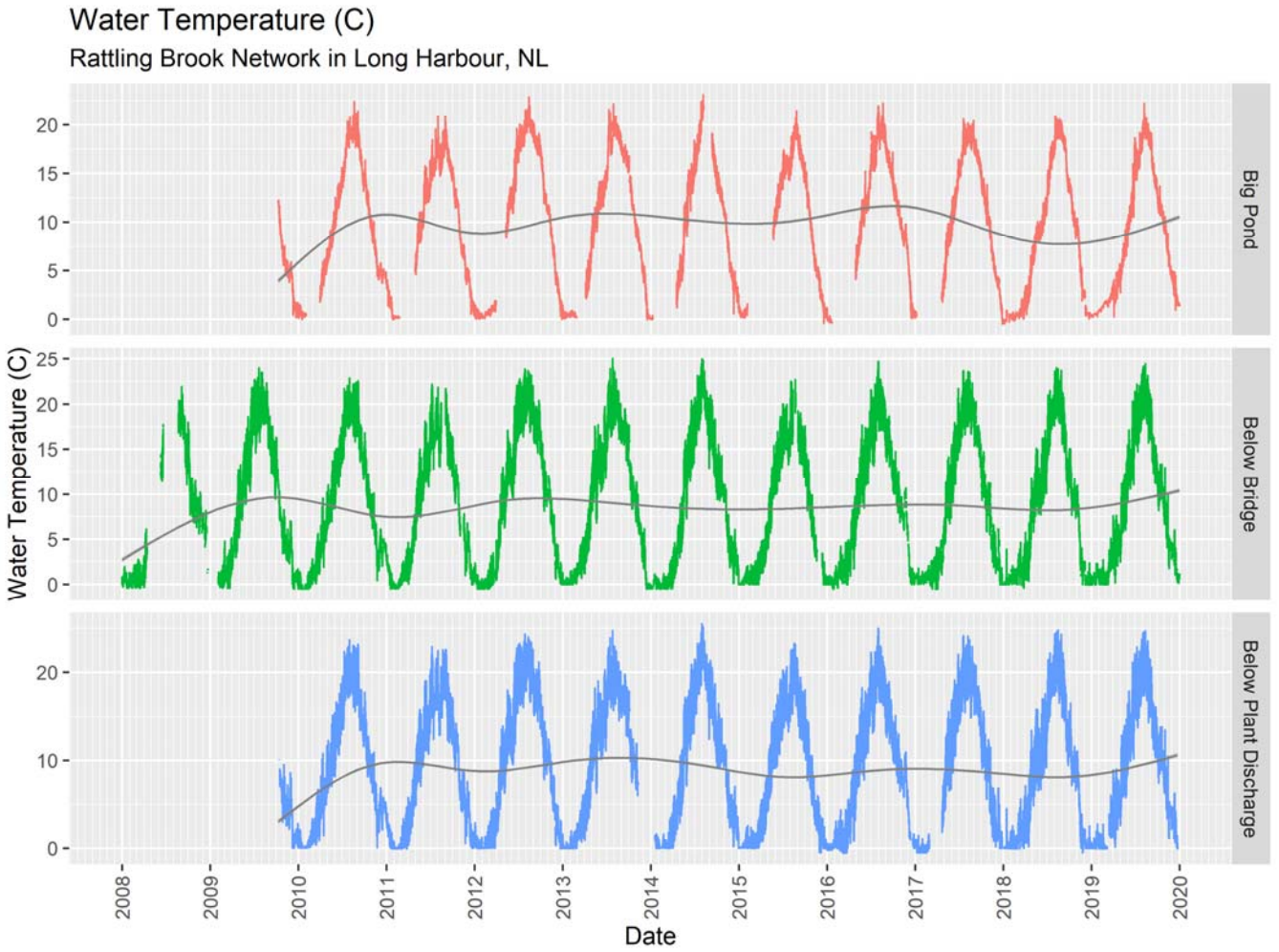

Figure 2: Water Temperature at Rattling Brook from 2008 to 2019

Boxplots in Figure 3 illustrate the spread of data at each of the Rattling Brook stations. In the past, water quality equipment has been removed from Big Pond over the winter to avoid damage from ice. During 2018 and 2019, however, equipment overwintered under the ice to eliminate the sampling bias. This results in the lower range for Big Pond in 2018 and 2019.

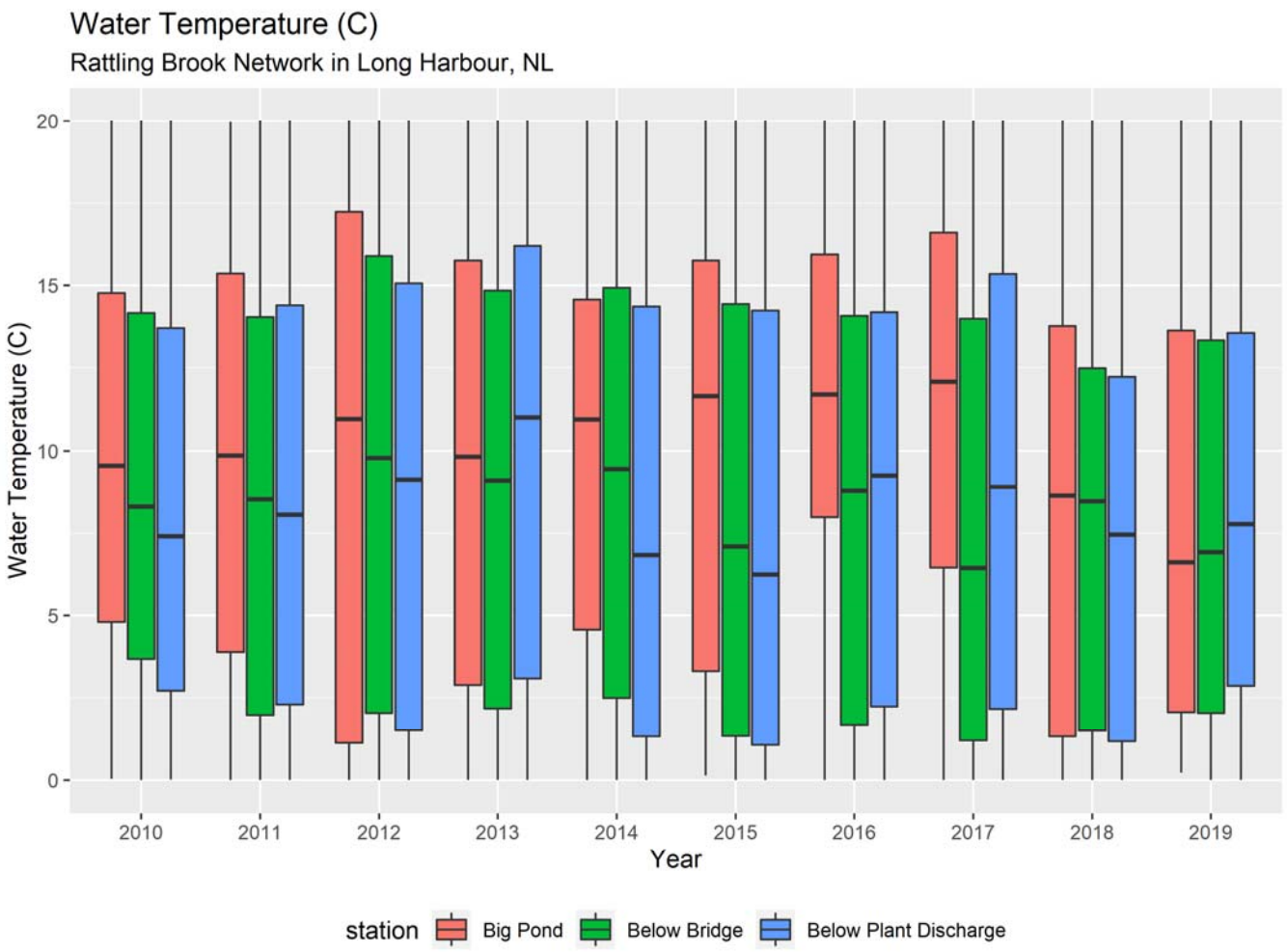

Figure 3: Boxplots of water temperature at Rattling Brook from 2010 to 2019

pH

In 2019, pH levels were above 2018 values at Plant Discharge station are relatively similar at Bridge and Big Pond stations, according to Table 2.

In 2019, median pH values were within site-specific guidelines[2] (dashed lines) at each station as shown in Figure 4.

Table 2: pH at Rattling Brook

Station	Segment	Median	Min	Max
Big Pond	2018	5.95	4.93	6.36
	2019	5.98	4.49	6.89
Bridge	2018	6.25	4.74	6.92
	2019	6.26	4.72	7.05
Discharge	2018	6.22	4.59	6.84
	2019	6.39	5.19	6.97

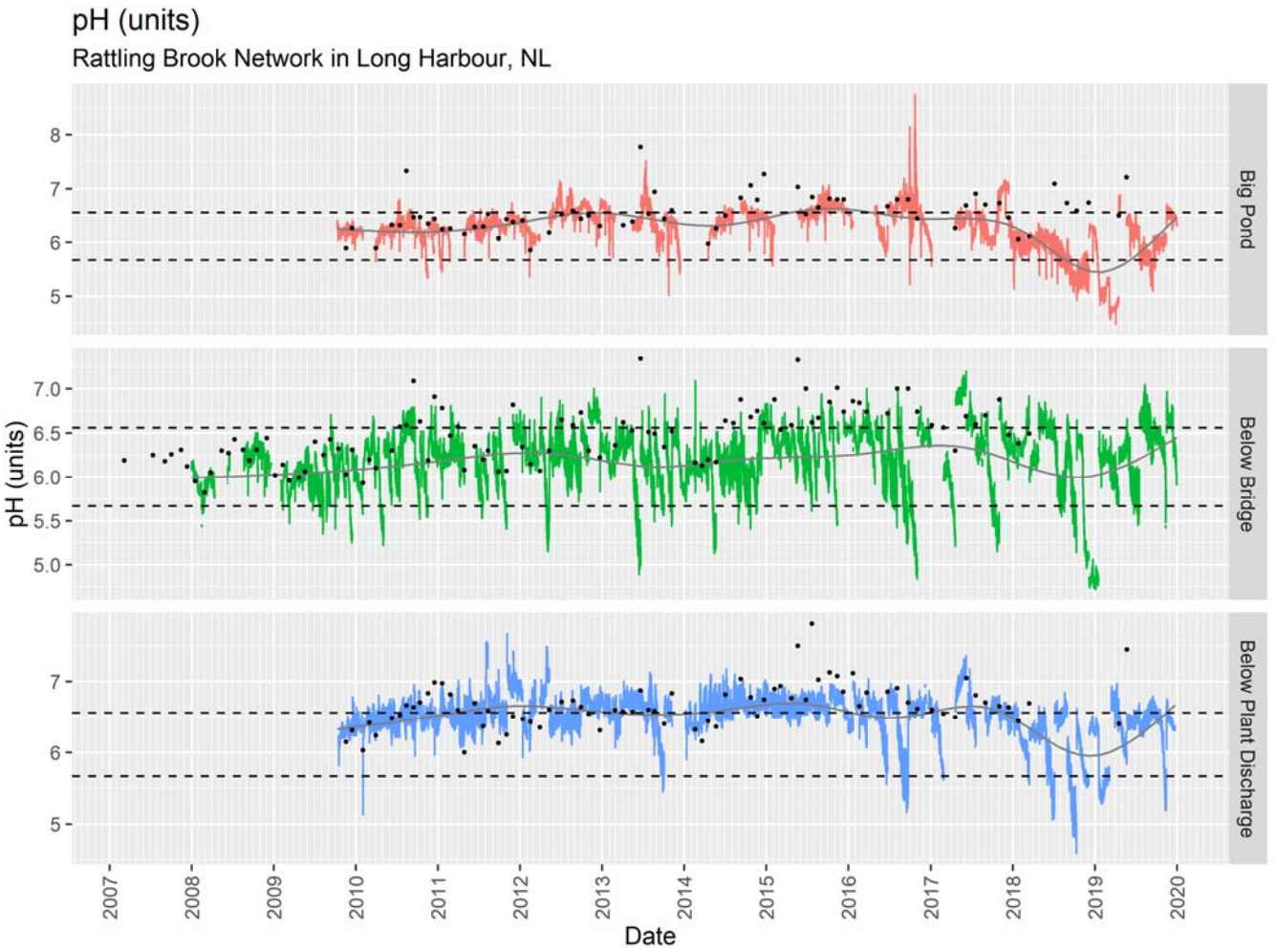

Figure 4: pH at Rattling Brook from 2008 to 2019

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

Specific Conductivity

Specific conductivity has decreased at each station comparably between 2018 and 2019, according to Figure 5 and Table 3.

Big Pond show more variations in conductivity since the water level rose in 2017. Conductivity may remain elevated until soil stability evens out.

Table 3: Specific Conductivity at Rattling Brook

Station	Segment	Median	Min	Max
Big Pond	2018	76.6	54.2	135.8
	2019	73.8	56.8	118.3
Bridge	2018	66.6	37.3	96.2
	2019	62.7	37.6	162.2
Discharge	2018	70.9	3.7	144.7
	2019	68	57.5	222

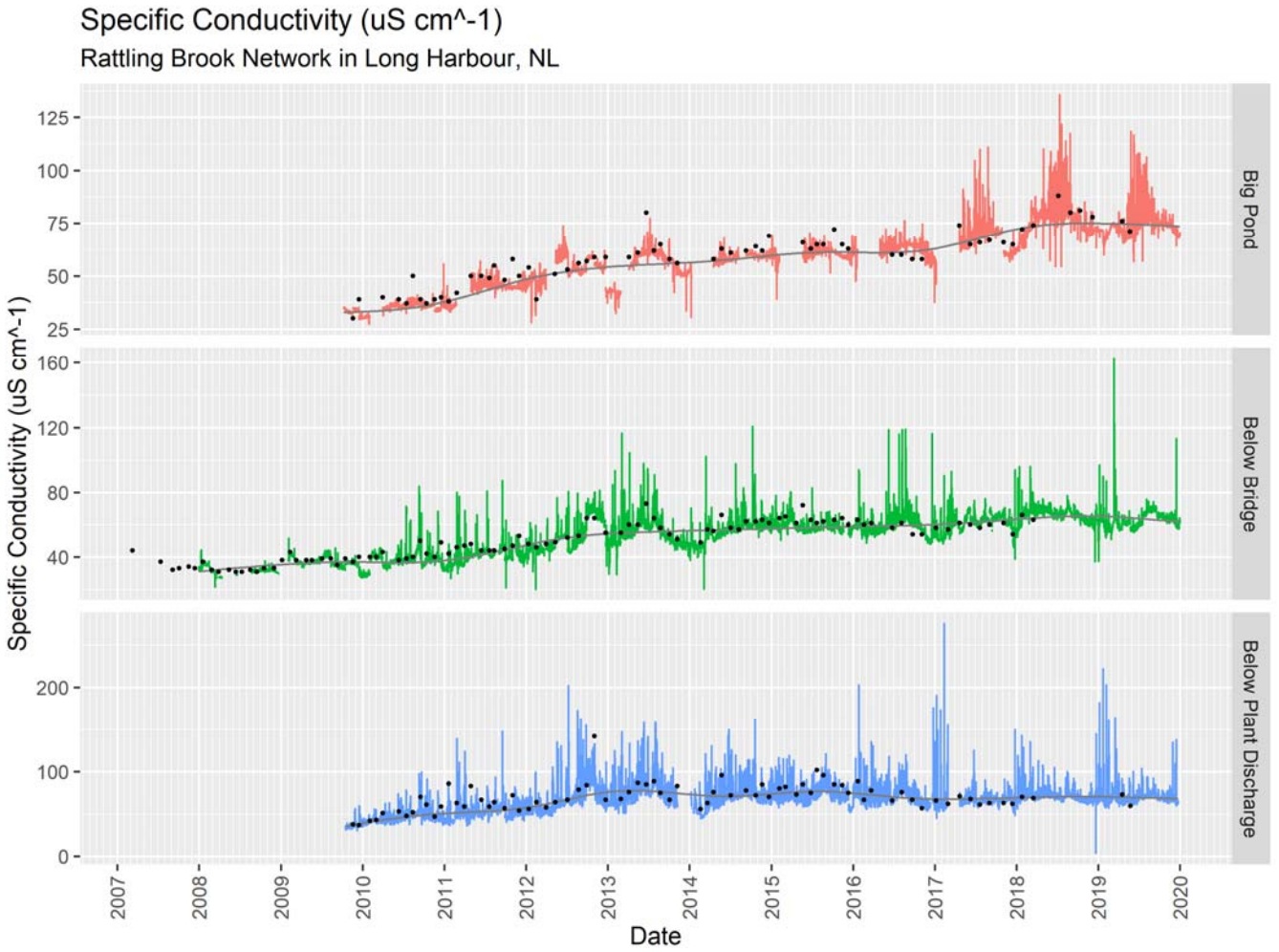

Figure 5: Specific Conductivity at Rattling Brook from 2008 to 2019

Dissolved Oxygen

Deviation from expected dissolved oxygen concentrations was observed at Big Pond station from November 2017 onwards (Figure 6), indicated by the vertical, dashed gray line.

Dissolved oxygen levels were within normal ranges for all stations. In 2019, 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 is more affected by warm temperatures, resulting in lower dissolved oxygen values during summer months.

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.

Table 4: Dissolved Oxygen at Rattling Brook

Station	Segment	Median	Min	Max
Big Pond	2018	10.67	4.60	13.50
	2019	10.85	1.1	13.23
Bridge	2018	11.28	7.64	14.47
	2019	11.44	8.0	14.73
Discharge	2018	11.35	7.03	14.73
	2019	11.19	6.88	14.44

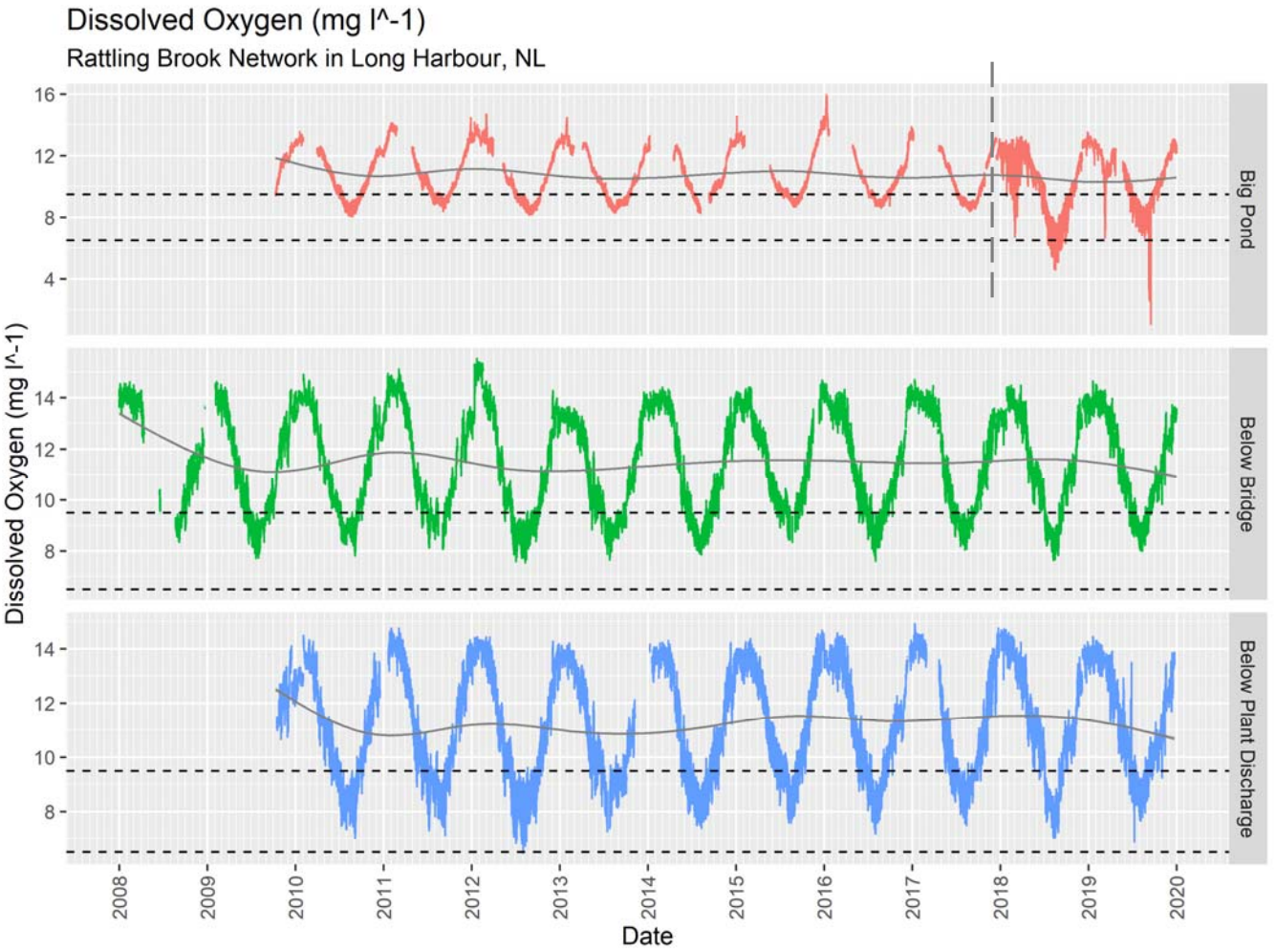

Figure 6: Dissolved oxygen at Rattling Brook from 2008 to 2019

Figure 7 shows the range of dissolved oxygen concentrations at each station from 2010 onwards.

In 2018-19, 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.

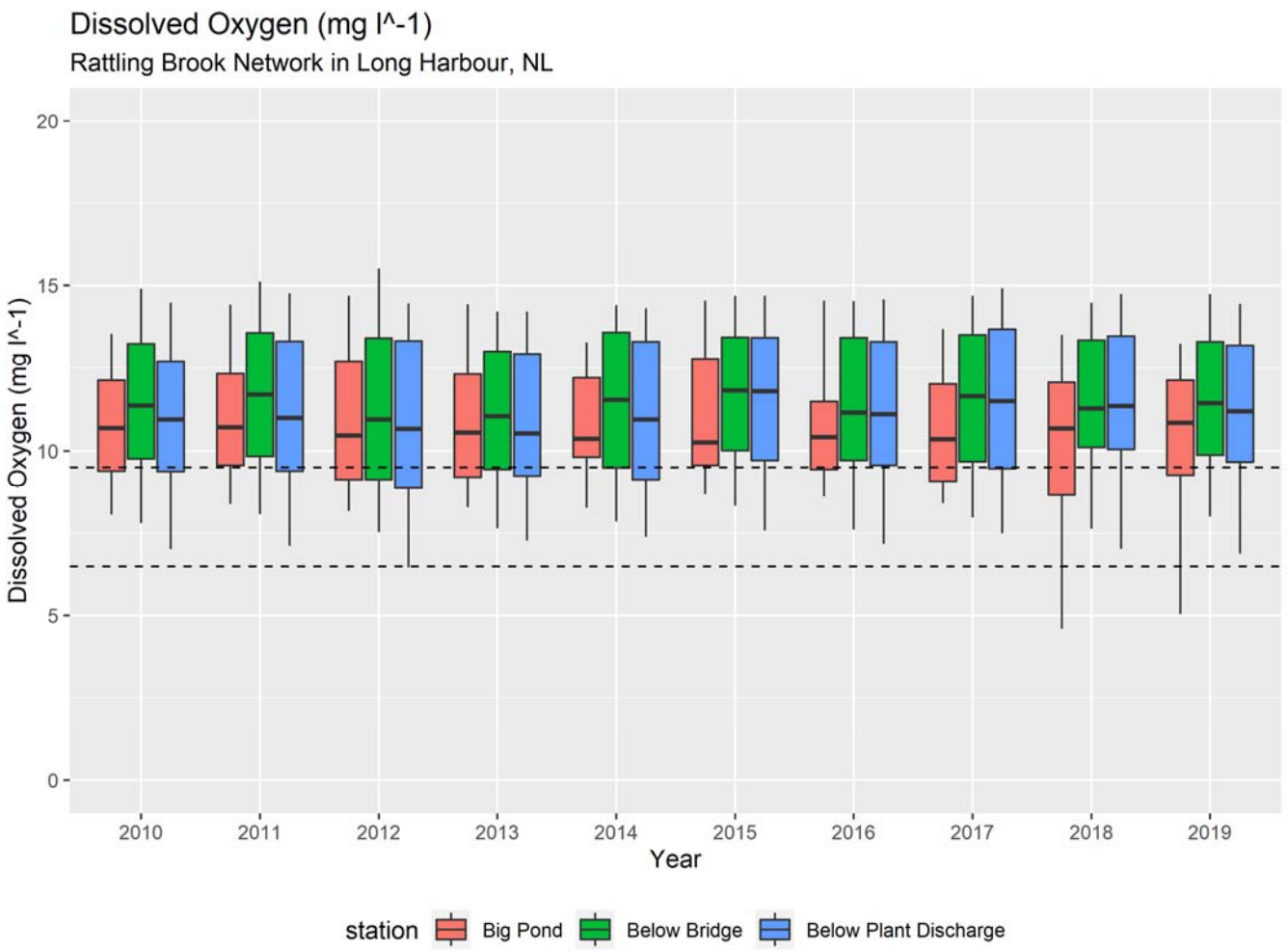

Figure 7: Boxplots of dissolved oxygen at Rattling Brook from 2010 to 2019

Turbidity

In 2019, 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 0.3 and 0.5 NTU respectively (Table 5).

In Figure 8, Big Pond has exhibited frequent high-level peaks after the water level increase in November 2017, indicated by the vertical, dashed gray line.

Table 5: Turbidity at Rattling Brook

Station	Segment	Median	Min	Max
Big Pond	2018	0.0	0.0	672.0
	2019	0.0	0.0	555.0
Bridge	2018	0.0	0.0	353.5
	2019	0.3	0.0	460
Discharge	2018	0.0	0.0	548.0
	2019	0.5	0.0	485

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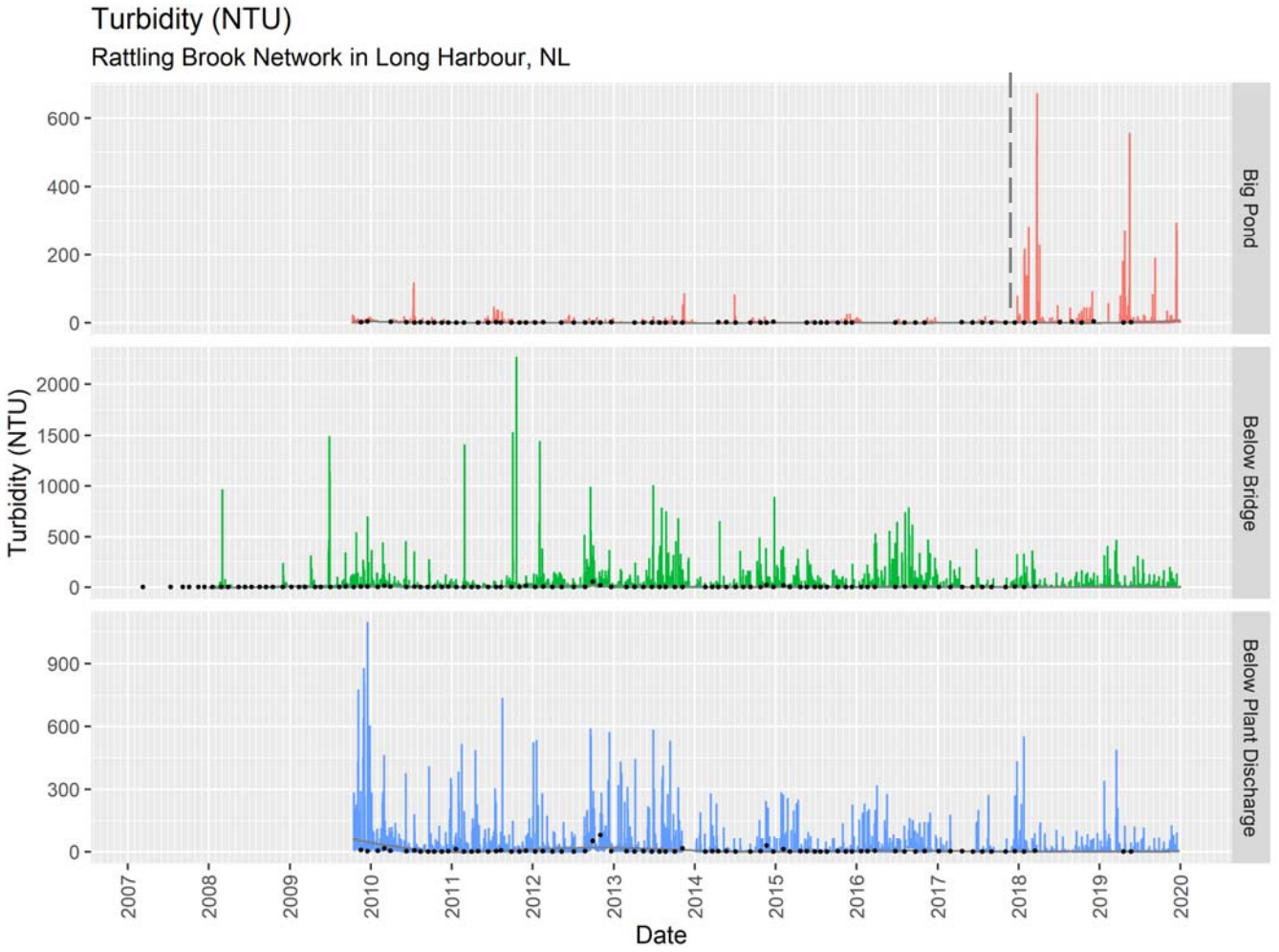

Figure 8: Turbidity at Rattling Brook from 2008 to 2019

Groundwater Network

Water Temperature

As shown in Table 6, in 2019, median water temperature did not substantially deviate from 2018 levels (within 0.06ºC 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 0.29 ºC and 0.15ºC, respectively.

The narrow range of water temperatures is reinforced by the scale of the y-axes in Figure 9.

Table 6: Temperature at Residue Storage Area

Station	Segment	Median	Min	Max
1 Deep	2018	6.67	6.64	7.73
	2019	6.72	6.51	7.02
2 Shallow	2018	5.94	3.21	11.27
	2019	5.65	2.5	10.56
2 Deep	2018	6.16	5.79	6.46
	2019	6.02	5.45	6.51
3 Deep	2018	6.69	6.61	6,93
	2019	6.75	6.4	7.0
4 Deep	2018	6.42	6.27	6.51
	2019	6.47	6.29	6.56

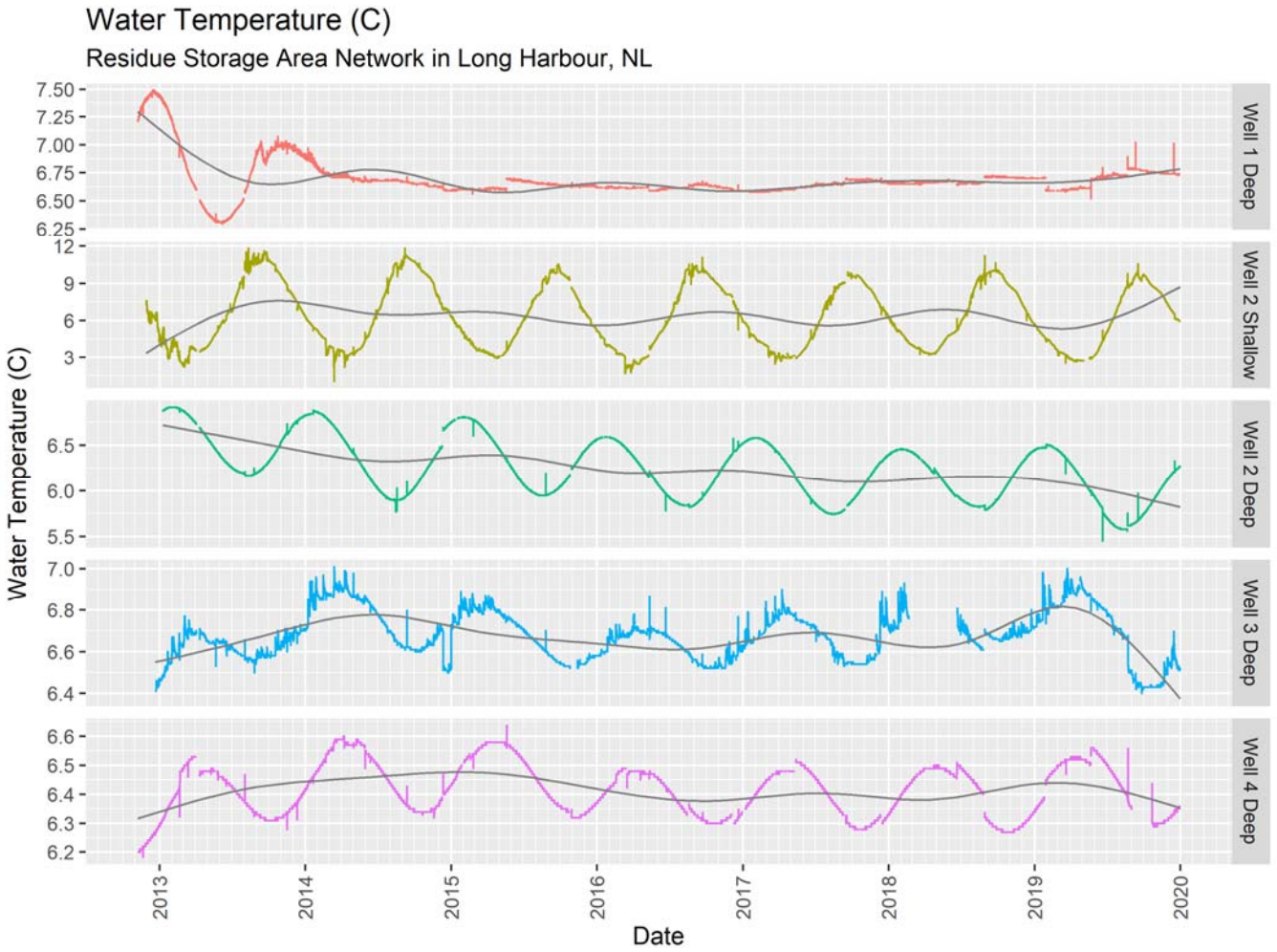

Figure 9: Water temperature at the Residue Storage Area from 2012 to 2019

Within each well, water temperature ranges were similar in 2019 compared to previous years (Figure 10).

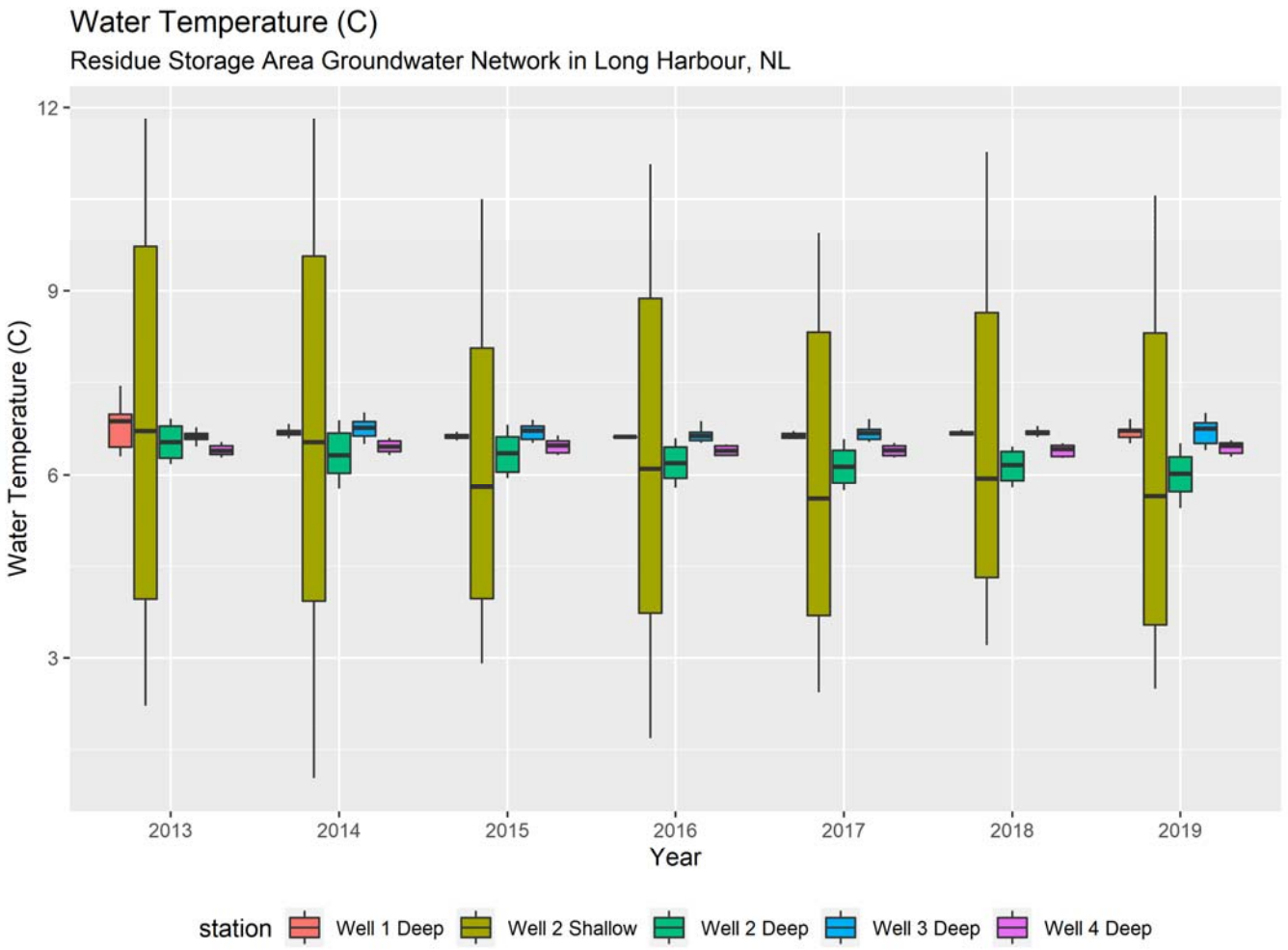

Figure 10: Boxplots of water temperature at the Residue Storage Area from 2012 to 2019

pH

Median pH values were found to be above 2018 levels in 2019 at each station except Well 1 Deep (Table 7).

Long term trends are difficult to extrapolate from Figure 11, but the gray trend lines show lowering pH at well 1 Deep, rising at 2 Shallow, plateau at 2, 3 and 4 Deep. pH and ORP sensors were replaced late in 2019.

Table 7: pH at Residue Storage Area

Station	Segment	Median	Min	Max
1 Deep	2018	7.85	7.66	7.94
	2019	7.64	5.95	8,23
2 Shallow	2018	6.13	5.73	6.87
	2019	6.17	5.36	6.9
2 Deep	2018	8.18	6.61	8.75
	2019	8.53	6.66	9.21
3 Deep	2018	5.90	5.55	6.16
	2019	6.02	3.36	6.48
4 Deep	2018	8.37	7.97	8.88
	2019	8.4	6.1	9.05

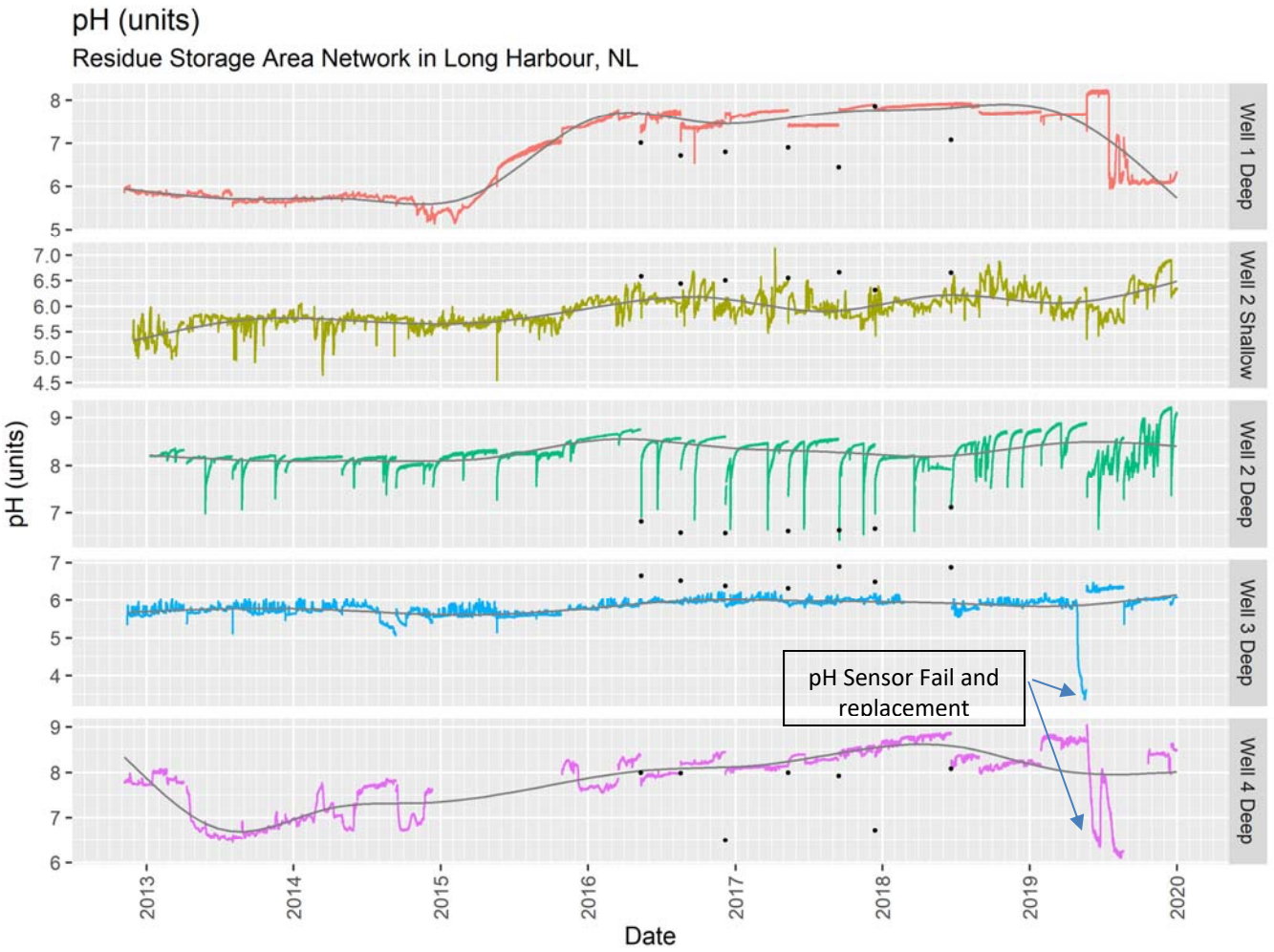

Figure 11: pH at the Residue Storage Area from 2012 to 2019

Decreasing pH values are most obvious at well 1 Deep. Figure 12.

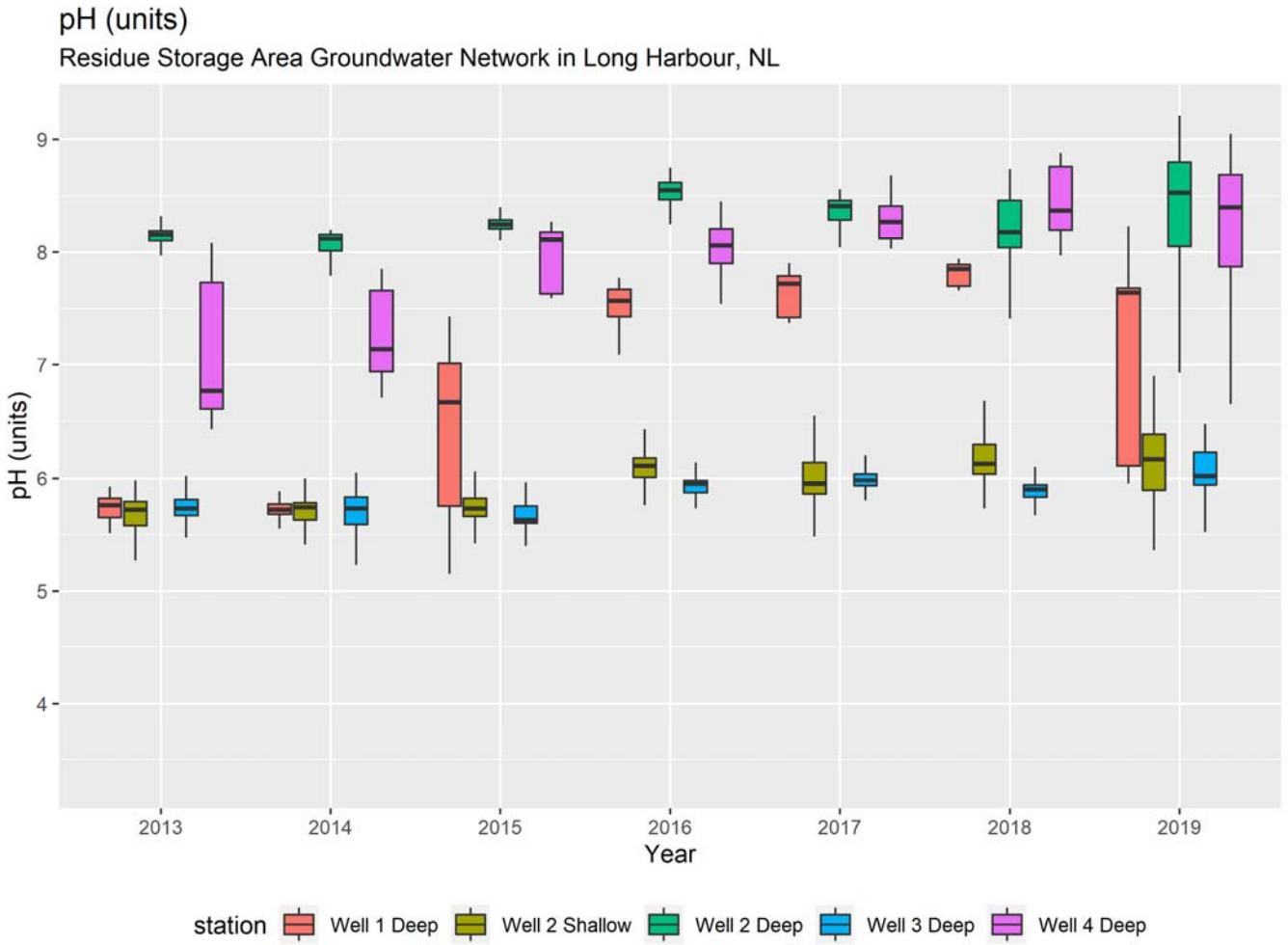

Figure 12: Boxplots of pH at the Residue Storage Area from 2013 to 2019

Specific Conductivity

In 2019, median specific conductivity values were above 2018 values at each station surrounding the Residue Storage Area – except well 3 Deep where values showed little variation, according to Table 8Table.

Figure 13 shows a decline in conductivity at well 1 Deep and continued and steady increases at 2 Shallow and 3 Deep. Well 2 Deep and Well 4 Deep show values have plateaued.

Figure 13 also shows grab samples taken during routine maintenance (black circles).

Table 8: Specific conductivity at Residue Storage Area

Station	Segment	Median	Min	Max
1 Deep	2018	566.0	470.00	642.0
	2019	636	196.0	693.0
2 Shallow	2018	137.0	104.0	194.0
	2019	165.0	124.0	225.0
2 Deep	2018	218.0	198.0	229.0
	2019	220.0	207.0	283.0
3 Deep	2018	128.0	99.0	173.0
	2019	126.0	84.0	159.0
4 Deep	2018	269.0	245.0	284.0
	2019	274.0	267.0	287.0

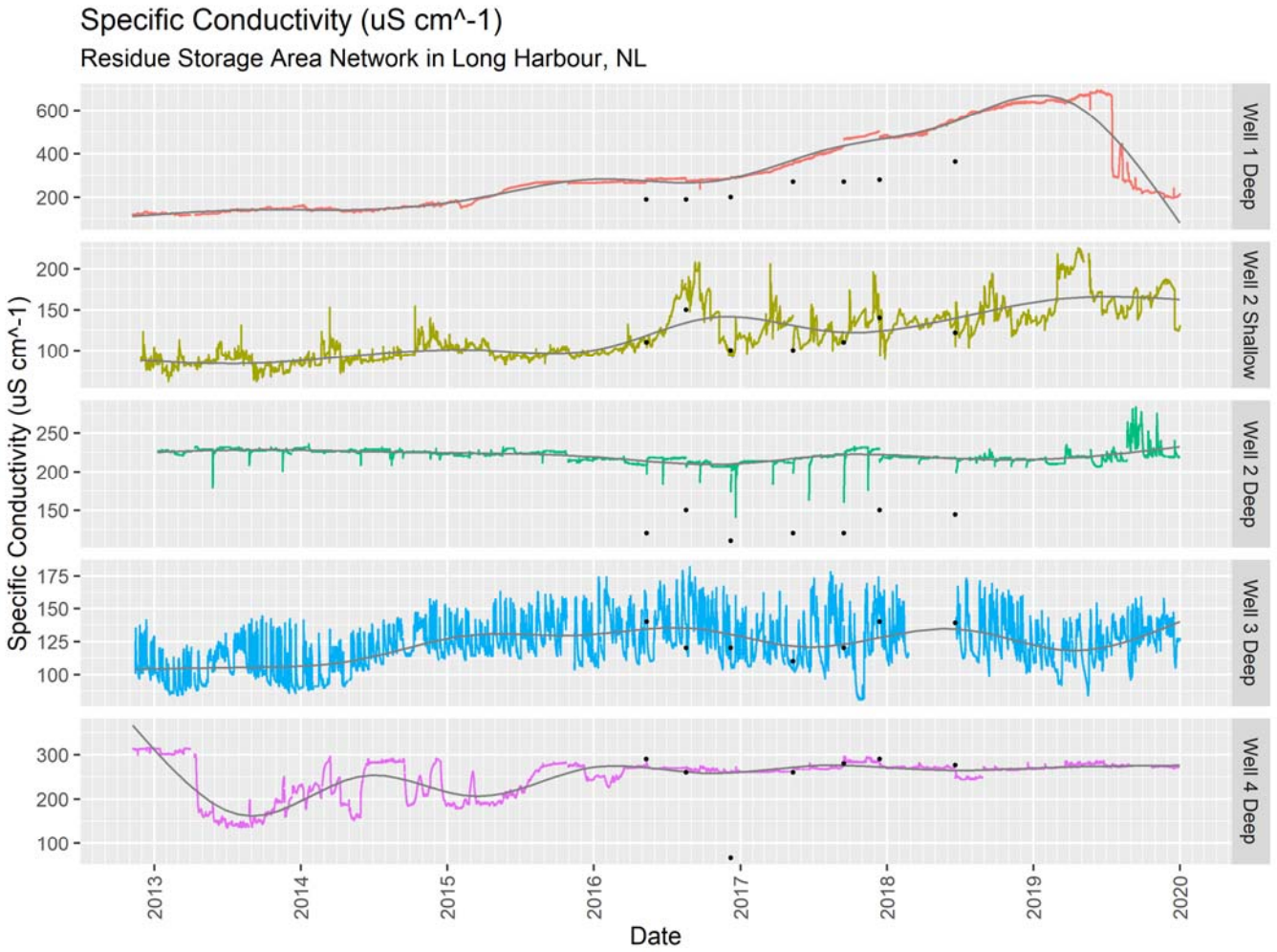

Figure 13: Specific conductivity at the Residue Storage Area from 2012 to 2019

Specific conductivity values showed a decrease at well 1 Deep in 2019 as shown by Figure 14. Meanwhile, wells 3 Deep and 4 Deep, show a decline in variability.

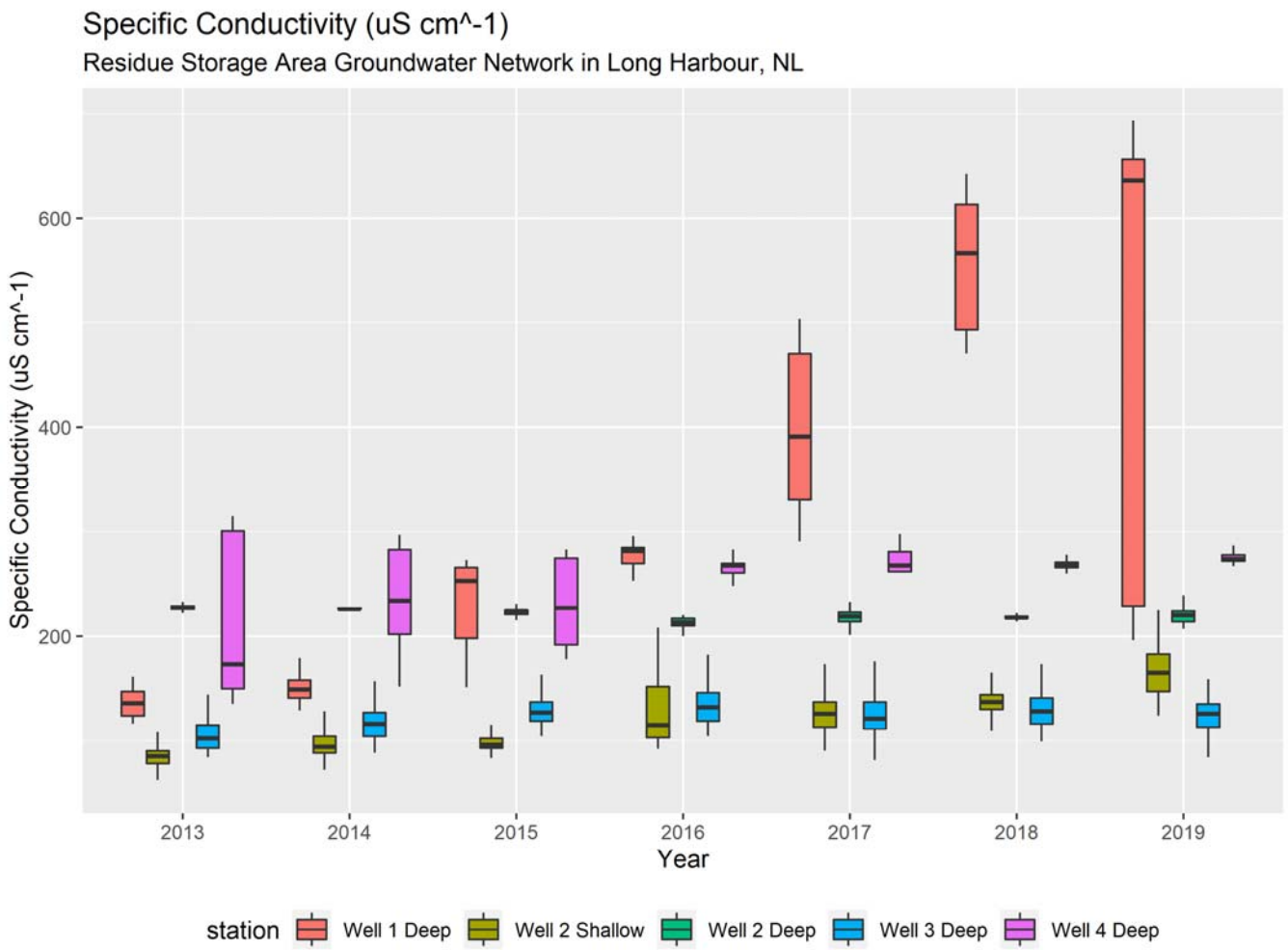

Figure 14: Boxplots of specific conductivity at the Residue Storage Area from 2013 to 2019

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 15 give a more intuitive indication of ORP tendency over time.

Table 9 shows that median ORP values from 2019 are less than 2018 at well 1 Deep. Median ORP values were greater than 2018 levels at wells 2 Shallow, 2 Deep, 3 Deep, and 4 Deep.

Table 9: ORP at Residue Storage Area

Station	Segment	Median	Min	Max
1 Deep	2018	-47.4	201.6	189.2
	2019	-244.9	-481.6	-461.1
2 Shallow	2018	74.7	-357.6	415.8
	2019	239.3	-357.6	466.5
2 Deep	2018	-461.3	-497.2	1.7
	2019	-415.7	-502.9	131.9
3 Deep	2018	420.1	210.6	461.5
	2019	421.6	-112.1	587.1
4 Deep	2018	-448.5	-553.4	137.1
	2019	-218.6	-597.8	404.7

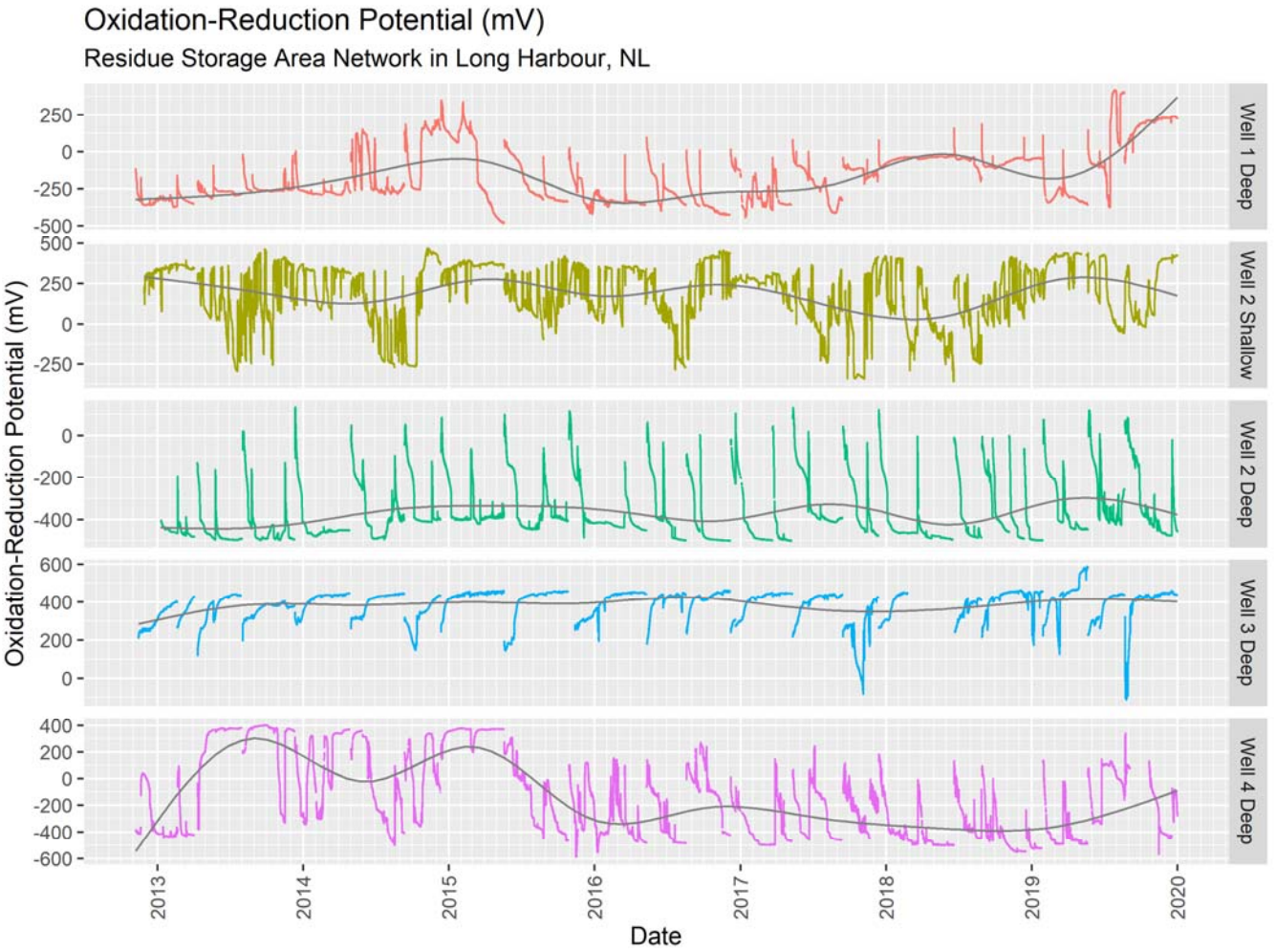

Figure 15: Oxidation-Reduction Potential at the Residue Storage Area from 2012 to 2019

Year-over-year tendency in ORP values are most clearly shown in Figure 16. 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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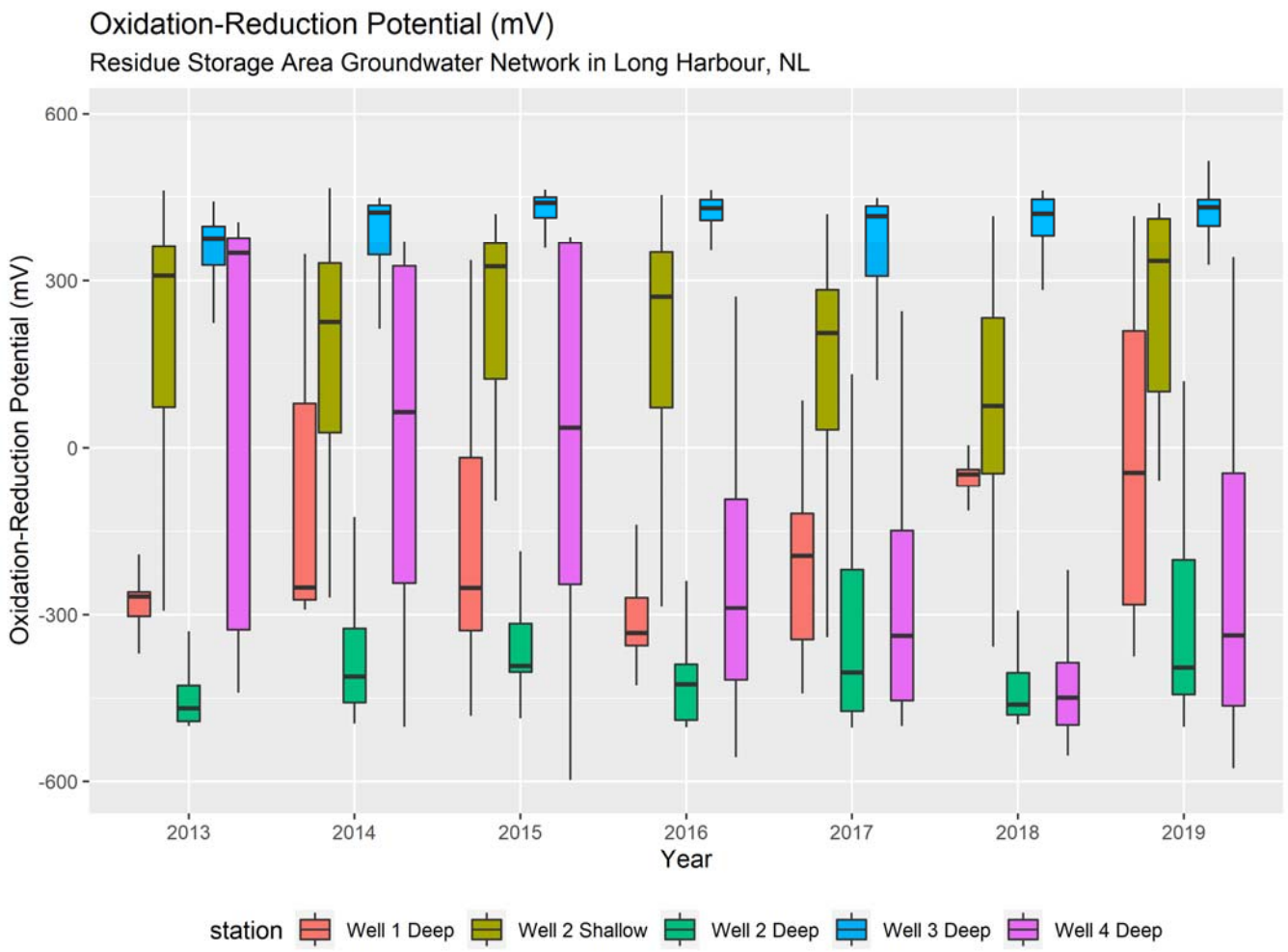


Figure 16: Boxplots of Oxidation-Reduction Potential at the Residue Storage Area from 2013 to 2019

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 17 but levels in 2019 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	2018	132.080	131.604	132.422
	2019	131.950	131.276	132.422
2 Shallow	2018	113.894	113.600	114.037
	2019	113.774	112.598	114.177
2 Deep	2018	113.558	113.372	113.819
	2019	113.613	112.260	114.015
3 Deep	2018	132.721	132.171	134.062
	2019	132.878	131.747	135.003
4 Deep	2018	138.731	138.332	139.092
	2019	138.438	136.144	139.102

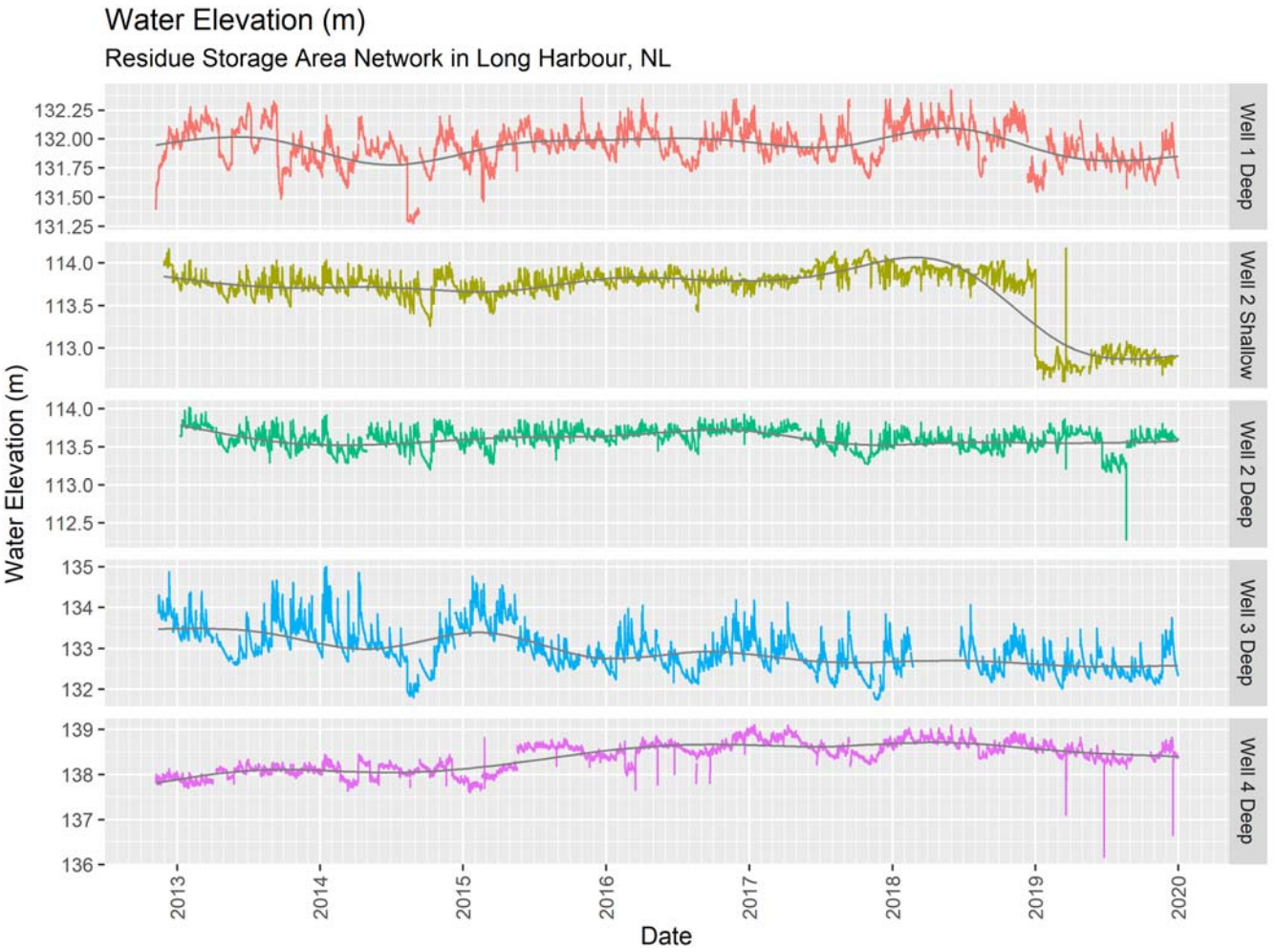


Figure 17: Water elevation at the Residue Storage Area from 2012 to 2019

Figure 18 shows the elevation of water levels in each well from 2013 to 2019. Values are largely stable at each well over long periods of time.

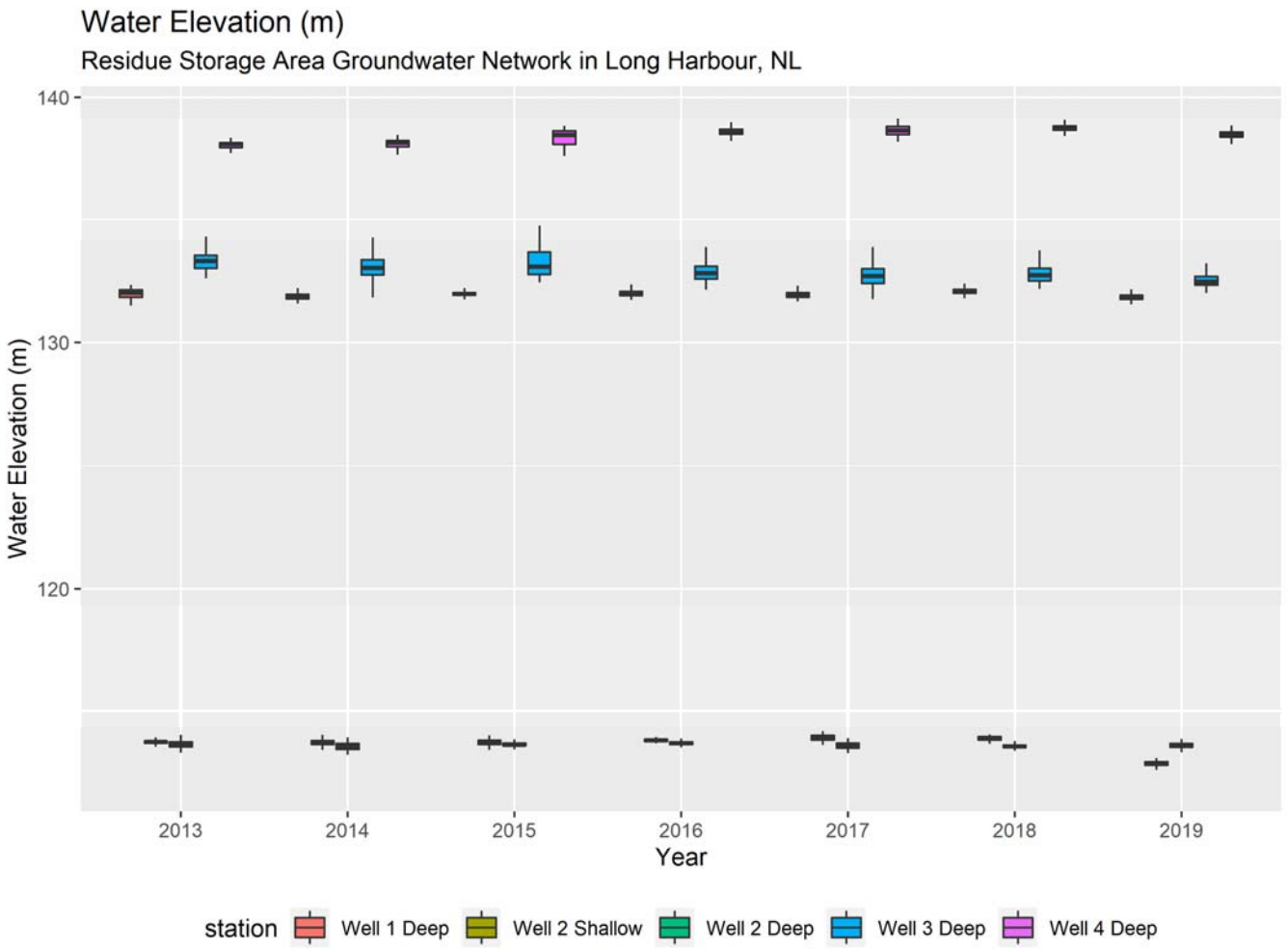


Figure 18: Boxplots of water elevation at the Residue Storage Area from 2013 to 2019

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.

Station maintenance and calibration activities at will continue to take place every six weeks at surface water stations while maintenance and calibration activities will occur 4 time per year at groundwater stations.

Reports on surface water stations will be generated at the end of each deployment period while reports on groundwater data will be included in annual reports, due to the relatively static nature of data from monitoring wells.

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

Table 1: Summary statistics of Water Temperature from 2008 to 2019

Station	Year	Mean	Median	Min	Max
Big Pond	2009	5.13	5.15	0.2	12.26
	2010	10.08	9.65	0.04	22.4
	2011	9.58	9.875	-0.02	20.88
	2012	10.00	11.28	0	22.87
	2013	9.67	10.04	-0.02	22.17
	2014	10.58	11.37	0.01	23.1
	2015	10.11	11.68	-0.39	21.46
	2016	10.87	11.52	-0.44	22.24
	2017	11.24	11.96	-0.47	20.61
	2018	8.07	8.44	-0.43	20.87
	2019	8.24	6.76	0.23	22.26
Below Bridge	2008	6.73	6.195	-0.42	21.93
	2009	9.14	8.025	-0.5	23.97
	2010	8.65	7.73	-0.5	22.84
	2011	7.70	6.43	-0.48	22.2
	2012	9.52	9.77	-0.51	23.82
	2013	9.03	9.16	-0.49	24.98
	2014	8.65	7.455	-0.5	24.93
	2015	7.91	6.69	-0.03	22.69
	2016	9.10	9.15	-0.54	24.69
	2017	8.30	7.25	-0.54	23.67
	2018	8.49	8.65	-0.41	23.98
	2019	8.65	7.39	-0.05	24.42
Plant Discharge	2009	4.02	4.2	0.02	11.37
	2010	9.04	8.12	0.02	23.67
	2011	8.43	7.49	-0.07	22.89
	2012	9.98	10.16	-0.03	24.33
	2013	10.05	10.9	-0.03	24.7
	2014	9.27	9.36	0	25.48
	2015	8.05	6.705	-0.51	23.25
	2016	9.10	9.22	-0.55	25
	2017	8.49	7.74	-0.52	24.13
	2018	8.21	7.88	-0.53	24.77
	2019	8.66	7.705	-0.07	24.67

Table 2: Summary statistics of pH from 2008 to 2019

Station	Year	Mean	Median	Min	Max
Big Pond	2009	6.24	6.24	5.86	6.41
	2010	6.22	6.25	5.34	6.8
	2011	6.29	6.32	5.45	6.74
	2012	6.48	6.51	5.37	7.14
	2013	6.41	6.42	5.02	7.51
	2014	6.43	6.46	5.65	6.78
	2015	6.58	6.59	5.57	7.07
	2016	6.49	6.54	5.23	8.74
	2017	6.43	6.41	5.54	7.16
	2018	5.84	5.95	4.93	6.36
	2019	5.81	5.98	4.49	6.89
Below Bridge	2008	6.08	6.11	5.42	6.5
	2009	5.98	5.99	5.25	6.71
	2010	6.19	6.24	5.22	6.81
	2011	6.16	6.19	5.41	6.81
	2012	6.29	6.29	5.15	7
	2013	6.14	6.21	4.89	6.94
	2014	6.09	6.09	5.13	7.1
	2015	6.34	6.37	5.45	6.94
	2016	6.21	6.39	4.84	7
	2017	6.31	6.38	5.15	7.2
	2018	6.08	6.25	4.74	6.92
	2019	6.21	6.26	4.72	7.05
Plant Discharge	2009	6.30	6.29	5.82	6.78
	2010	6.45	6.44	5.12	6.95
	2011	6.61	6.57	6.07	7.67
	2012	6.58	6.58	5.92	7.48
	2013	6.54	6.6	5.45	7.12
	2014	6.62	6.63	4.83	7.17
	2015	6.66	6.66	6.37	6.96
	2016	6.46	6.57	5.17	7.03
	2017	6.68	6.6	5.62	7.53
	2018	6.08	6.22	4.59	6.84
	2019	6.27	6.39	5.19	6.97

Table 3: Summary statistics of Conductivity from 2008 to 2019

Station	Year	Mean	Median	Min	Max
Big Pond	2009	33.05	33.2	29.6	35.4
	2010	35.18	35.6	27.4	55.7
	2011	43.38	44.6	33.1	57
	2012	52.99	52.8	28.2	73.8
	2013	54.82	56.5	32.5	77.4
	2014	58.35	58.8	30.6	68.1
	2015	60.56	60.8	39.1	70.3
	2016	62.13	62.4	37.6	76.3
	2017	67.23	68.3	45.8	110.9
	2018	76.12	76.6	54.2	135.8
	2019	73.73	73.8	56.8	118.3
Below Bridge	2008	32.17	31.8	21.6	44.4
	2009	36.91	36.5	27.5	51.6
	2010	38.06	38	27.4	83.6
	2011	40.80	40.6	21.2	87.1
	2012	52.87	50.1	20.2	81.1
	2013	55.11	53.9	29.3	116.6
	2014	56.08	57	20.3	120.7
	2015	59.01	58.3	50.6	82.6
	2016	59.15	58.7	47.3	119.1
	2017	60.79	61.9	38.8	94.1
	2018	66.42	66.6	37.3	96.2
	2019	62.88	62.7	37.6	162.2
Plant Discharge	2009	36.24	35.5	30.6	60
	2010	46.48	44.9	35.5	99.8
	2011	53.36	51.9	36.5	147.9
	2012	69.13	64.7	45.5	202
	2013	75.81	72.5	51	158.7
	2014	72.45	70.4	43.9	161.4
	2015	74.03	73	52.3	121
	2016	72.40	71	54.3	203
	2017	66.89	65.9	45.4	275
	2018	71.50	70.9	3.7	144.7
	2019	69.55	68	57.5	222

Table 4: Summary statistics of Total Dissolved Solids from 2008 to 2019

Station	Year	Mean	Median	Min	Max
Big Pond	2009	0.02	0.0213	0.0189	0.0226
	2010	0.02	0.0228	0.0175	0.0357
	2011	0.03	0.0285	0.0212	0.0365
	2012	0.03	0.0338	0.018	0.0473
	2013	0.03	0.0355	0.0208	0.0495
	2014	0.04	0.0376	0.0196	0.0436
	2015	0.04	0.0389	0.025	0.045
	2016	0.04	0.0399	0.022	0.0489
	2017	0.04	0.0437	0.022	0.071
	2018	0.05	0.049	0.0347	0.0869
	2019	0.05	0.0472	0.0364	0.0757
Below Bridge	2008	0.02	0.0204	0.0138	0.0284
	2009	0.02	0.0234	0.0176	0.033
	2010	0.02	0.0243	0.0176	0.0535
	2011	0.03	0.026	0.0136	0.0557
	2012	0.03	0.0321	0.0129	0.0519
	2013	0.04	0.0345	0.0187	0.0746
	2014	0.04	0.0365	0.013	0.0773
	2015	0.04	0.0373	0.0324	0.0528
	2016	0.04	0.0375	0.0303	0.0762
	2017	0.04	0.0396	0.0249	0.0602
	2018	0.04	0.0426	0.0239	0.0616
	2019	0.04	0.0401	0.024	0.1038
Plant Discharge	2009	0.02	0.0227	0.0196	0.0384
	2010	0.03	0.0287	0.0227	0.0639
	2011	0.03	0.0332	0.0234	0.0946
	2012	0.04	0.0414	0.0291	0.129
	2013	0.05	0.0467	0.0329	0.1016
	2014	0.05	0.0451	0.0281	0.1033
	2015	0.05	0.0467	0.0335	0.0774
	2016	0.05	0.0455	0.0347	0.13
	2017	0.04	0.0422	0.0291	0.176
	2018	0.05	0.0454	0.0023	0.0926
	2019	0.04	0.0435	0.0368	0.142

Table 5: Summary statistics of Dissolved Oxygen from 2008 to 2019

Station	Year	Mean	Median	Min	Max
Big Pond	2009	11.56	11.72	9.42	12.88
	2010	10.68	10.69	8.06	13.53
	2011	10.99	10.71	8.39	14.42
	2012	10.86	10.47	8.17	14.69
	2013	10.74	10.55	8.29	14.43
	2014	10.80	10.36	8.27	13.27
	2015	10.90	10.26	8.68	14.54
	2016	10.74	10.42	8.62	15.93
	2017	10.59	10.35	8.41	13.68
	2018	10.36	10.67	4.6	13.5
	2019	10.63	10.85	1.1	13.23
Below Bridge	2008	12.06	12.15	8.35	14.63
	2009	11.30	11.26	7.72	14.61
	2010	11.43	11.36	7.81	14.9
	2011	11.74	11.7	8.08	15.11
	2012	11.32	10.95	7.54	15.51
	2013	11.17	11.04	7.65	14.21
	2014	11.41	11.53	7.86	14.4
	2015	11.70	11.82	8.34	14.68
	2016	11.38	11.15	7.61	14.53
	2017	11.61	11.64	7.98	14.69
	2018	11.48	11.28	7.64	14.47
	2019	11.48	11.44	8	14.73
Plant Discharge	2009	12.25	12.28	10.29	14.1
	2010	10.94	10.95	7.02	14.48
	2011	11.24	10.99	7.12	14.76
	2012	10.91	10.66	6.46	14.45
	2013	10.96	10.52	7.28	14.2
	2014	11.09	10.95	7.39	14.3
	2015	11.55	11.79	7.59	14.68
	2016	11.23	11.1	7.18	14.57
	2017	11.53	11.5	7.5	14.91
	2018	11.45	11.35	7.03	14.73
	2019	11.30	11.19	6.88	14.44

Table 6: Summary statistics of Percent Saturation from 2008 to 2019

Station	Year	Mean	Median	Min	Max
Big Pond	2009	92.14	91.8	86.8	98.9
	2010	94.06	94	85.9	104.4
	2011	94.67	94.2	87.3	109.3
	2012	93.94	93.1	84.8	109.6
	2013	92.31	91.9	81.4	109.1
	2014	95.00	95	82.7	106.4
	2015	95.10	95.1	86.8	106.2
	2016	95.00	94.5	84.8	106.8
	2017	95.07	95.7	82.5	104.8
	2018	85.82	87.2	46.9	99.9
	2019	89.92	91.2	11.1	108.6
Below Bridge	2008	96.07	96.3	89.8	100.6
	2009	96.09	96.3	88.3	102.6
	2010	96.65	96.7	88.9	103.3
	2011	95.93	96.05	88.2	104.4
	2012	96.04	96.5	85.6	105.3
	2013	94.36	94.3	88.7	101.6
	2014	94.80	94.9	87.7	101.5
	2015	96.91	97	89.5	103
	2016	96.72	96.8	88.9	103.5
	2017	96.38	96.7	89	102.5
	2018	95.99	96.2	88.9	102.9
	2019	97.17	96.9	91.2	104
Plant Discharge	2009	94.94	95.5	88.1	101.6
	2010	93.63	94.1	80.1	105.7
	2011	94.33	95.1	72.5	103
	2012	93.33	94.8	70.8	103.4
	2013	94.37	94.3	83.1	103.6
	2014	93.47	94.1	84	101
	2015	95.47	95.9	84.7	103.1
	2016	95.32	95.9	83.5	103.6
	2017	95.48	95.6	85.9	102.8
	2018	94.75	95.6	80.9	103.7
	2019	95.38	95.1	70.7	138.7

Table 7: Summary statistics of Turbidity from 2008 to 2019

Station	Year	Mean	Median	Min	Max
Big Pond	2009	3.37	1.7	0	22
	2010	2.36	0	0	116.6
	2011	0.63	0	0	44.9
	2012	0.20	0	0	22
	2013	0.05	0	0	84.8
	2014	0.03	0	0	81.1
	2015	0.29	0	0	25.3
	2016	0.48	0	0	15
	2017	0.10	0	0	77
	2018	1.19	0	0	672
	2019	2.53	0	0	555
Below Bridge	2008	0.61	0	0	963
	2009	10.37	0	0	1486
	2010	10.24	2.5	0	445
	2011	6.00	0.4	0	2259
	2012	22.64	3.35	0	1437
	2013	6.42	2.4	0	998
	2014	2.31	0	0	886
	2015	2.91	0	0	396.9
	2016	5.42	0	0	781
	2017	1.80	0	0	371.7
	2018	1.91	0	0	353.5
	2019	3.77	0.3	0	460
Plant Discharge	2009	67.35	23.6	4.3	1094
	2010	11.48	3.3	0	460
	2011	6.69	1.7	0	734
	2012	19.41	4.8	0	586
	2013	11.10	4.5	0	580
	2014	2.57	0	0	277.2
	2015	2.51	0	0	282.5
	2016	7.66	0.6	0	314.6
	2017	1.79	0	0	430
	2018	1.93	0	0	548
	2019	2.42	0.5	0	485

Table 8: Summary statistics of Water Temperature at the Residue Storage Area from 2013 to 2019

Station	Year	Mean	Median	Min	Max
Well 1 Deep	2012	7.40	7.43	7.2	7.49
	2013	6.78	6.87	6.3	7.45
	2014	6.69	6.68	6.59	6.97
	2015	6.63	6.63	6.56	6.7
	2016	6.62	6.62	6.59	6.68
	2017	6.64	6.64	6.58	6.71
	2018	6.68	6.67	6.64	6.73
	2019	6.70	6.72	6.51	7.02
Well 2 Shallow	2012	6.17	6.27	4.23	7.6
	2013	6.83	6.71	2.22	11.81
	2014	6.77	6.53	1.03	11.81
	2015	6.15	5.8	2.91	10.5
	2016	6.21	6.1	1.68	11.07
	2017	5.96	5.61	2.44	9.95
	2018	6.38	5.94	3.21	11.27
	2019	5.90	5.65	2.5	10.56
Well 2 Deep	2013	6.53	6.53	6.17	6.91
	2014	6.35	6.32	5.77	6.88
	2015	6.35	6.35	5.95	6.81
	2016	6.20	6.19	5.78	6.59
	2017	6.15	6.13	5.74	6.58
	2018	6.14	6.16	5.79	6.46
	2019	6.03	6.02	5.45	6.51
Well 3 Deep	2012	6.44	6.44	6.41	6.47
	2013	6.62	6.63	6.46	6.77
	2014	6.75	6.76	6.5	7.01
	2015	6.69	6.715	6.52	6.89
	2016	6.62	6.63	6.52	6.87
	2017	6.67	6.68	6.53	6.9
	2018	6.70	6.69	6.61	6.93
	2019	6.69	6.75	6.4	7
Well 4 Deep	2012	6.24	6.24	6.18	6.29
	2013	6.40	6.39	6.28	6.53
	2014	6.46	6.46	6.32	6.6
	2015	6.46	6.48	6.32	6.64
	2016	6.39	6.39	6.3	6.49
	2017	6.39	6.4	6.28	6.52
	2018	6.40	6.42	6.27	6.51
	2019	6.44	6.47	6.29	6.56

Table 9: Summary statistics of pH at the Residue Storage Area from 2013 to 2019

Station	Year	Mean	Median	Min	Max
Well 1 Deep	2012	5.90	5.89	5.81	6.02
	2013	5.75	5.76	5.51	5.92
	2014	5.68	5.72	5.15	5.88
	2015	6.46	6.67	5.15	7.43
	2016	7.55	7.57	6.51	7.77
	2017	7.64	7.72	7.37	7.9
	2018	7.82	7.85	7.66	7.94
	2019	7.06	7.64	5.95	8.23
Well 2 Shallow	2012	5.39	5.32	4.97	5.85
	2013	5.64	5.72	4.89	5.98
	2014	5.70	5.74	4.65	6.05
	2015	5.75	5.73	4.52	6.12
	2016	6.11	6.11	5.61	6.68
	2017	6.00	5.95	5.42	7.13
	2018	6.18	6.13	5.73	6.87
	2019	6.16	6.17	5.36	6.9
Well 2 Deep	2013	8.13	8.16	6.98	8.35
	2014	8.08	8.12	7.38	8.2
	2015	8.27	8.25	7.24	8.57
	2016	8.48	8.55	6.65	8.75

	2017	8.32	8.41	6.4	8.56
	2018	8.24	8.18	6.61	8.74
	2019	8.45	8.53	6.66	9.21
Well 3 Deep	2012	5.66	5.62	5.33	5.96
	2013	5.75	5.73	5.08	6.03
	2014	5.69	5.73	5.06	6.05
	2015	5.67	5.63	5.11	6.03
	2016	5.93	5.95	5.73	6.23
	2017	5.99	5.98	5.8	6.25
	2018	5.89	5.9	5.55	6.16
	2019	5.94	6.02	3.36	6.48
Well 4 Deep	2012	7.77	7.76	7.71	7.98
	2013	7.03	6.77	6.43	8.08
	2014	7.25	7.14	6.71	7.85
	2015	7.97	8.11	6.31	8.27
	2016	8.04	8.06	7.54	8.45
	2017	8.29	8.27	8.03	8.68
	2018	8.46	8.37	7.97	8.88
	2019	8.08	8.4	6.1	9.05

Table 10: Summary statistics of conductivity at the Residue Storage Area from 2013 to 2019

Station	Year	Mean	Median	Min	Max
Well 1 Deep	2012	125.97	126	118	136
	2013	135.18	136	116	161
	2014	149.98	149	129	179
	2015	233.45	253	151	273
	2016	278.12	282	234	296
	2017	393.89	391	291	503
	2018	559.55	566	470	642
	2019	464.76	636	196	693
Well 2 Shallow	2012	87.69	87	76	123
	2013	84.76	85	62	131
	2014	96.49	94	72	154
	2015	97.46	96	83	120
	2016	127.69	115	92	208
	2017	127.23	126	90	206
	2018	138.43	137	104	194
	2019	166.57	165	124	225
Well 2 Deep	2013	227.55	228	179	233
	2014	226.41	226	209	236
	2015	222.67	224	212	233
	2016	213.16	213	141	220
	2017	219.07	219	159	233
	2018	217.58	218	198	229
	2019	222.41	220	207	283
Well 3 Deep	2012	111.26	106	96	141
	2013	104.79	102	84	144
	2014	115.43	116	88	157
	2015	128.63	127	104	163
	2016	133.51	132	104	182
	2017	123.96	121	81	178
	2018	129.30	128	99	173
	2019	124.12	126	84	159
Well 4 Deep	2012	313.74	314	299	316
	2013	206.24	173	135	315
	2014	237.23	234	152	297
	2015	231.61	227	178	283
	2016	263.85	268	226	283
	2017	271.08	268	261	298
	2018	265.54	269	245	284
	2019	274.87	274	267	287

Table 11: Summary statistics of Total Dissolved Solids at the Residue Storage Area from 2013 to 2019

Station	Year	Mean	Median	Min	Max

Well 1 Deep	2012	0.08	0.082	0.077	0.088
	2013	0.09	0.088	0.075	0.105
	2014	0.10	0.097	0.084	0.116
	2015	0.15	0.165	0.098	0.178
	2016	0.18	0.183	0.152	0.192
	2017	0.26	0.254	0.189	0.327
	2018	0.36	0.368	0.305	0.417
	2019	0.30	0.413	0.127	0.451
Well 2 Shallow	2012	0.06	0.056	0.05	0.08
	2013	0.06	0.055	0.04	0.085
	2014	0.06	0.061	0.047	0.1
	2015	0.06	0.062	0.054	0.078
	2016	0.08	0.075	0.06	0.135
	2017	0.08	0.082	0.059	0.134
	2018	0.09	0.089	0.068	0.126
	2019	0.11	0.107	0.081	0.146
Well 2 Deep	2013	0.15	0.148	0.116	0.151
	2014	0.15	0.147	0.136	0.153
	2015	0.14	0.145	0.138	0.151
	2016	0.14	0.139	0.092	0.143
	2017	0.14	0.142	0.104	0.151
	2018	0.14	0.142	0.13	0.149
	2019	0.14	0.143	0.134	0.184
Well 3 Deep	2012	0.07	0.069	0.063	0.092
	2013	0.07	0.066	0.055	0.094
	2014	0.08	0.075	0.057	0.102
	2015	0.08	0.082	0.068	0.106
	2016	0.09	0.0855	0.068	0.118
	2017	0.08	0.079	0.053	0.116
	2018	0.08	0.083	0.064	0.112
	2019	0.08	0.082	0.055	0.103
Well 4 Deep	2012	0.20	0.204	0.194	0.206
	2013	0.13	0.112	0.087	0.205
	2014	0.15	0.152	0.099	0.193
	2015	0.15	0.148	0.115	0.184
	2016	0.17	0.174	0.147	0.184
	2017	0.18	0.174	0.17	0.197
	2018	0.17	0.175	0.159	0.184
	2019	0.18	0.178	0.173	0.187

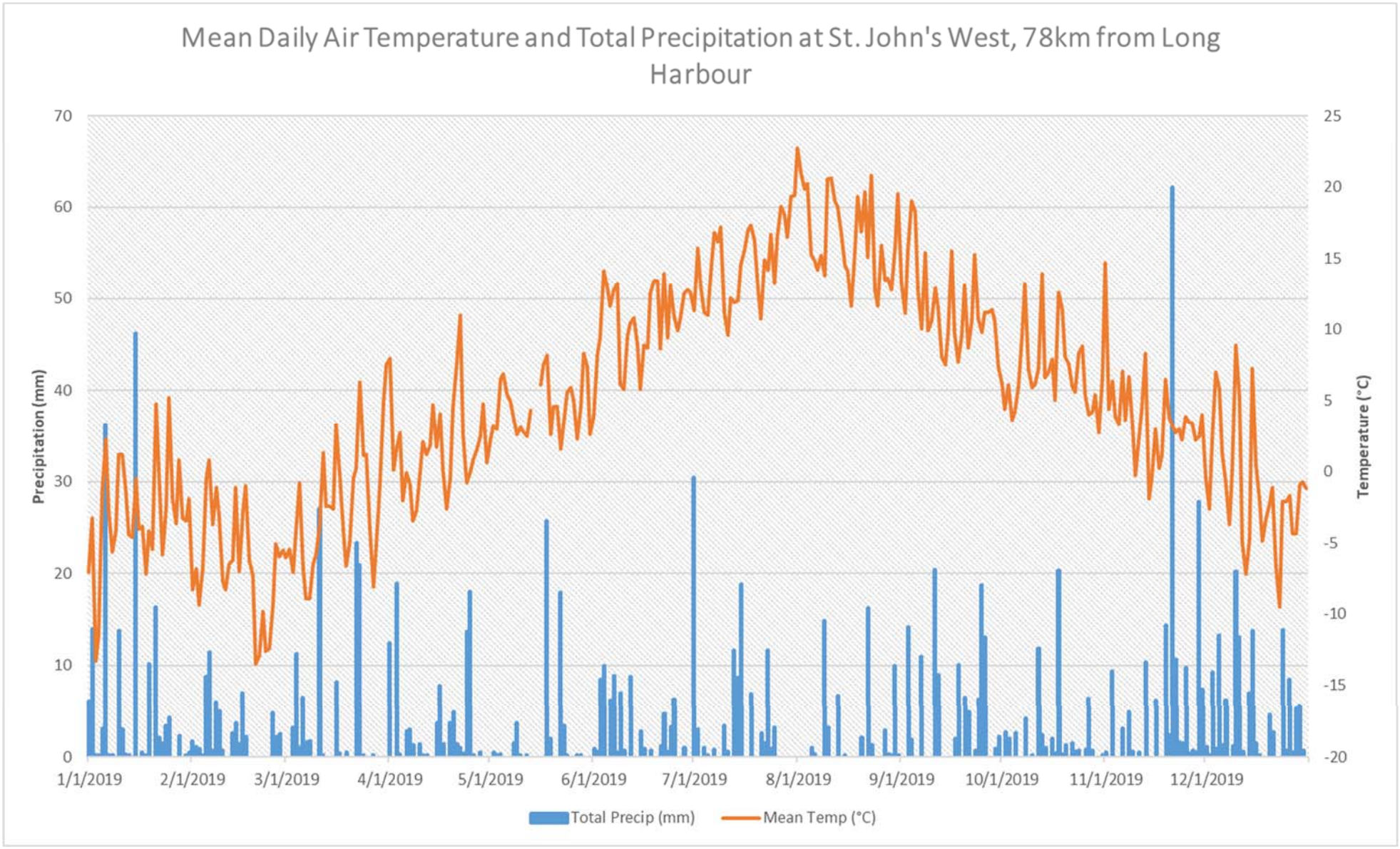
Table 10: Summary statistics of Oxidation Reduction Potential at the Residue Storage Area from 2013 to 2019

Station	Year	Mean	Median	Min	Max
Well 1 Deep	2012	-329.15	-351.9	-361.5	-116.6
	2013	-271.97	-266.4	-375.2	1.7
	2014	-134.61	-250.6	-291	347.3
	2015	-180.86	-251	-481.6	336.2
	2016	-299.52	-333	-426.9	99.8
	2017	-224.67	-193.55	-441.4	84.4
	2018	-57.77	-47.4	-201.6	189.2
	2019	-14.25	-43.9	-375.3	416.1
Well 2 Shallow	2012	298.19	310	120.1	341.5
	2013	208.00	309	-293.7	461.7
	2014	155.62	225.5	-269	466.5
	2015	252.57	325.35	-94.9	419.2
	2016	207.31	270.9	-284.9	453.5
	2017	133.60	206.1	-340.8	419.7
	2018	87.34	74.7	-357.6	415.8
	2019	261.99	334.8	-58.6	439.3
Well 2 Deep	2013	-428.69	-467.7	-499.5	131.9
	2014	-370.11	-411.1	-495.4	84.4
	2015	-339.74	-392.1	-486.3	114
	2016	-384.51	-424.8	-502.1	104.1
	2017	-350.22	-403.5	-502.9	130.9
	2018	-404.73	-461.3	-497.2	1.7
	2019	-324.12	-394.5	-501	118.4

Well 3 Deep	2012	260.80	253.7	210.3	306.5
	2013	364.17	375.9	119.7	442
	2014	388.15	422.1	147.2	448.4
	2015	401.78	440.2	143.2	462.9
	2016	411.14	430.4	179.2	462.7
	2017	364.46	415.6	-82.3	448.7
	2018	402.53	420.1	210.6	461.5
	2019	404.15	432.1	-112.1	587.1
Well 4 Deep	2012	-220.88	-337.6	-416.4	41.9
	2013	98.46	349.5	-439.7	404.7
	2014	44.72	63.95	-501	370.1
	2015	42.97	35.7	-597.8	378.1
	2016	-243.04	-287.95	-556.5	270.8
	2017	-289.34	-337.65	-500	244.4
	2018	-407.39	-448.5	-553.4	137.1
	2019	-263.33	-337.45	-576.5	341.4

Table 11: Summary statistics of Water Elevation at the Residue Storage Area from 2013 to 2019

Station	Year	Mean	Median	Min	Max
Well 1 Deep	2012	131.87	131.9028	131.3874	132.1029
	2013	131.98	132.0205	131.4862	132.3255
	2014	131.84	131.874	131.2755	132.2039
	2015	131.95	131.969	131.4605	132.3551
	2016	131.99	131.9961	131.7217	132.3484
	2017	131.94	131.9131	131.6611	132.3429
	2018	132.06	132.0801	131.6035	132.4215
	2019	131.83	131.8278	131.5443	132.1565
Well 2 Shallow	2012	113.93	113.9759	113.7681	114.1645
	2013	113.73	113.7411	113.4821	114.0309
	2014	113.71	113.7275	113.2566	114.0288
	2015	113.72	113.7245	113.4027	113.9952
	2016	113.79	113.7951	113.4259	113.9767
	2017	113.91	113.901	113.6009	114.1578
	2018	113.88	113.8941	113.5997	114.0373
	2019	112.86	112.8703	112.5978	114.1716
Well 2 Deep	2013	113.63	113.6258	113.2945	114.0146
	2014	113.55	113.555	113.2056	113.9122
	2015	113.62	113.6285	113.2716	113.8631
	2016	113.68	113.6915	113.4072	113.9247
	2017	113.58	113.6053	113.2709	113.8921
	2018	113.56	113.5582	113.3718	113.8193
	2019	113.56	113.6087	112.2598	113.8587
Well 3 Deep	2012	133.86	133.8236	133.3948	134.8782
	2013	133.31	133.3025	132.5933	134.6628
	2014	133.03	133.0324	131.7996	135.0034
	2015	133.21	133.0838	132.4325	134.7668
	2016	132.84	132.8195	132.1306	134.1729
	2017	132.69	132.6946	131.7471	134.1696
	2018	132.76	132.7211	132.1707	134.0623
	2019	132.54	132.4675	131.9998	133.7396
Well 4 Deep	2012	137.94	137.942	137.7747	138.1268
	2013	138.03	138.0717	137.7004	138.3314
	2014	138.09	138.1236	137.6385	138.4492
	2015	138.34	138.442	137.585	138.8119
	2016	138.56	138.5831	137.6365	139.0317
	2017	138.63	138.6243	138.1569	139.1022
	2018	138.72	138.7313	138.3324	139.0918
	2019	138.46	138.4407	136.1444	138.8241


Mean Daily Air Temperature and Total Precipitation at St. John's West, 78km from Long Harbour
Precipitation (mm)
Temperature (°C)
70
60
50
40
30
20
10
0
25
20
15
10
5
0
-5
-10
-15
-20
1/1/2019
2/1/2019
3/1/2019
4/1/2019
5/1/2019
6/1/2019
7/1/2019
8/1/2019
9/1/2019
10/1/2019
11/1/2019
12/1/2019
Total Precip (mm)
Mean Temp (°C)