Real-Time Water Quality Deployment Report

Long Harbour Annual Report

2017

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

Introduction

Ambient surface water quality monitoring is carried out by the Water Resources Management Division (WRMD) of the Department of Municipal Affairs and Environment (MAE). Much of this work is carried out under the Real-Time Water Quality (RTWQ) monitoring program, especially in instances where industrial development could potentially impact ambient 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.

Water quality monitoring has been ongoing in Long Harbour for more than 10 years – beginning with the first station in 2007 at Rattling Brook below Bridge. In 2009, two additional surface water stations were deployed in the headwaters of Rattling Brook (Rattling Brook Big Pond) and lower in the river system (Rattling Brook below Plant Discharge). These surface water stations are 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). A groundwater monitoring network of five stations was deployed around the RSA in late 2012.

Photo 1: Real-time water quality monitoring stations in Long Harbour, Newfoundland (surface water network green triangles, groundwater network blue triangles)

*All surface water hydrometric data is provisional and is subject to correction. Please consult Water survey of Canada for finalized data and interpretation.

Methods and Procedures

Work under the RTWQ program is conducted according to the Protocols Manual for Real-Time Water Quality Monitoring in NL*. 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. Additionally, a grab sample is collected at the start of a deployment as an independent indicator of data quality.

Due to the complicated nature of groundwater monitoring, data validation is restricted to the use of grab samples at the time of deployment. During groundwater sampling a volume equivalent to three well casings is 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.

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.

* http://www.mae.gov.nl.ca/waterres/rti/rtwq/NL_RTWQ_Manual.pdf

Surface Water Network

Water Temperature

Since monitoring began at Rattling Brook, summertime high temperatures have varied and shown no strong trend one way or another.

Summertime water temperatures at Big Pond tend to be warmer than those observed at Bridge and Plant Discharge stations. Additionally, temperatures tend to be warmer at Plant Discharge station than Bridge station, according to both summer time highs and winter lows.

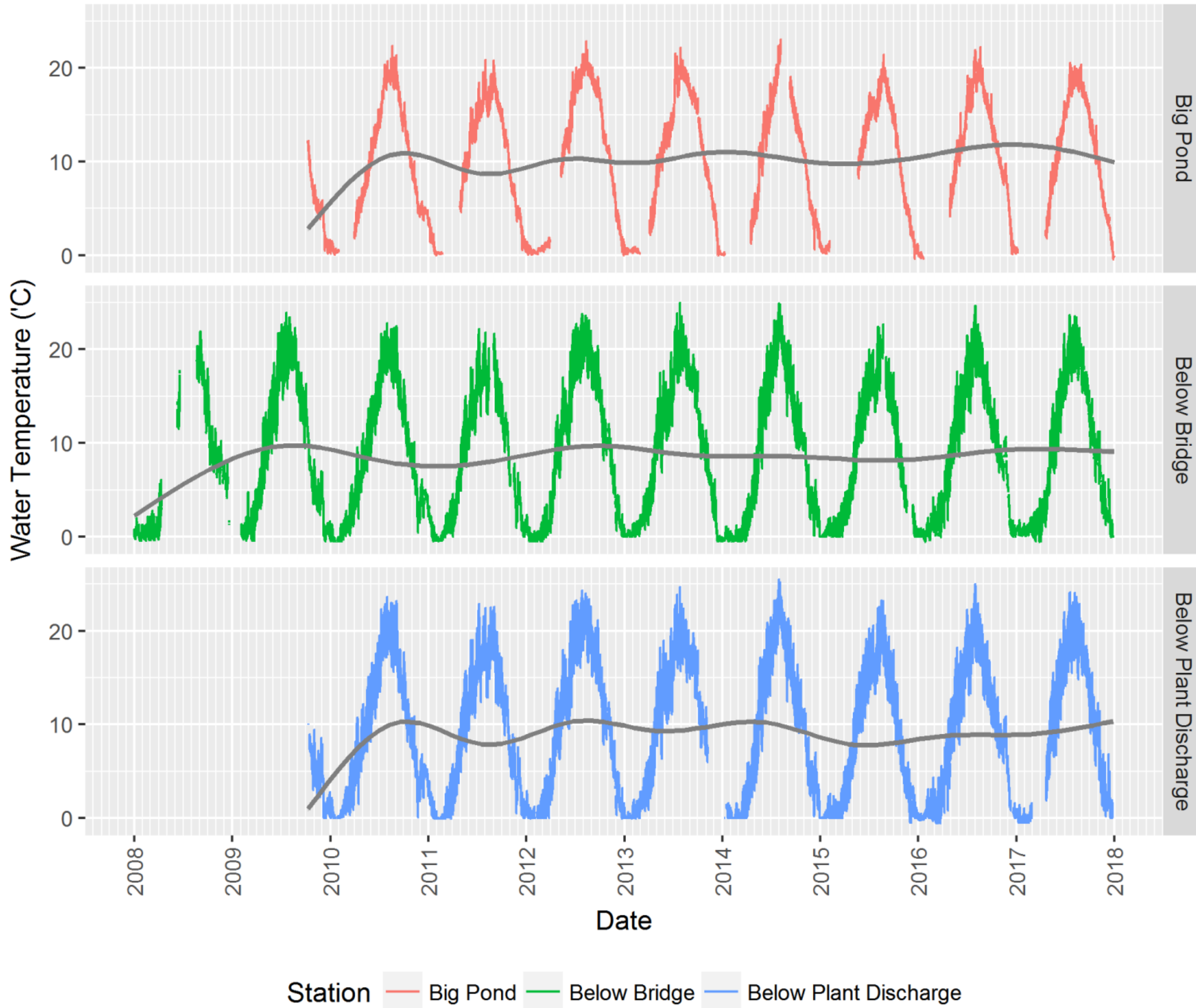

Figure 1: Water Temperature at Rattling Brook from 2008 to 2017

Boxplots in Figure 2 illustrate the spread of data at each of the Rattling Brook stations. While Big Pond may appear to be warmer than both Bridge and Plant Discharge stations, this is due to a sampling bias. In the past, water quality equipment has been removed from Big Pond over the winter to avoid damage from ice. Beginning in 2018, however, equipment will overwinter under the ice to eliminate this sampling bias.

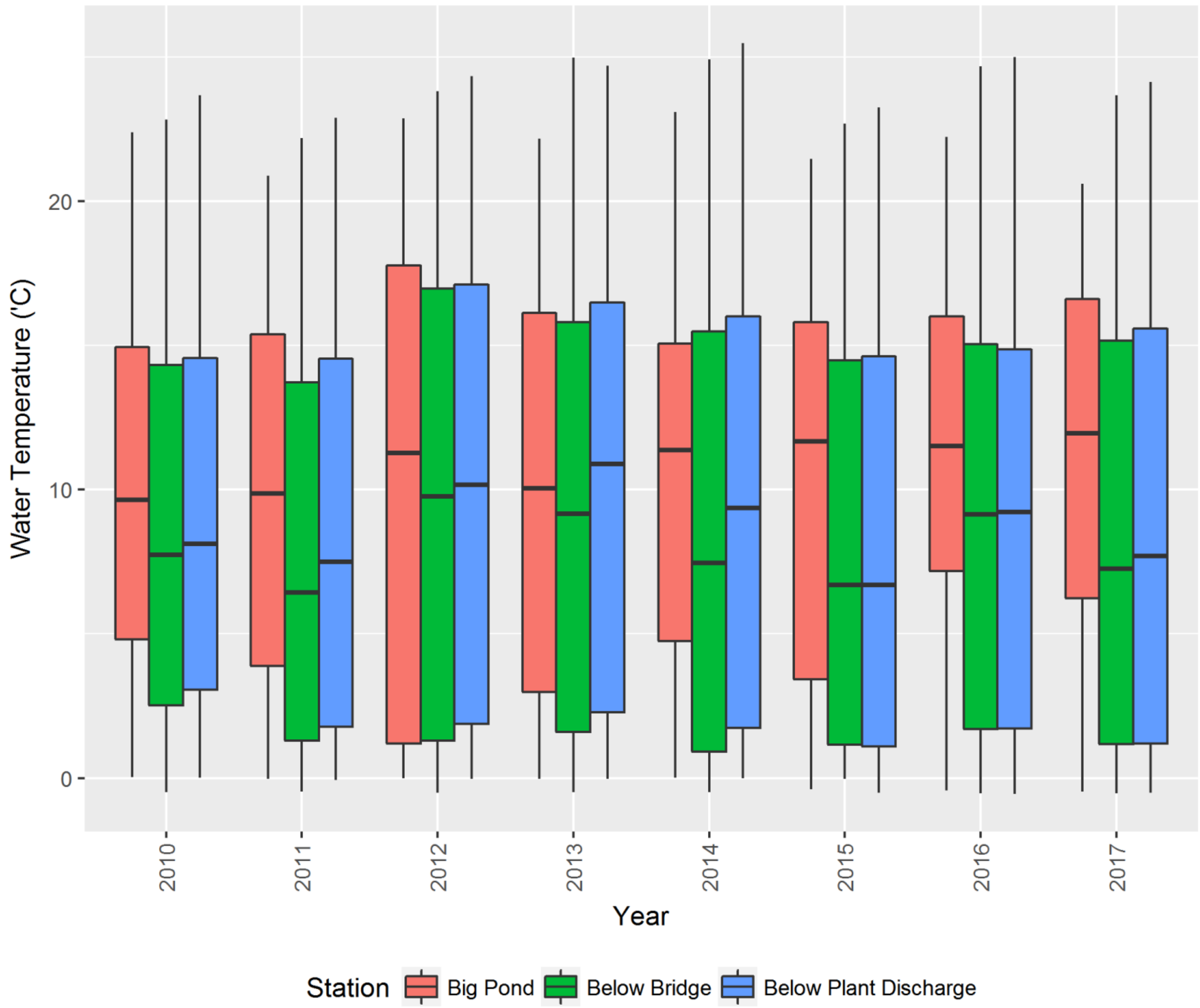

Figure 2: Boxplots of water temperature at Rattling Brook from 2010 to 2017

pH

Dashed lines in Figure 3 to the right indicate Site Specific Guidelines (SSGs) for pH. These guidelines were established prior to major construction events at the Vale site.

Following the initiation of construction, pH values were found to slowly, but steadily, increase at all three stations. When the SSGs were initially developed, most values fell equidistant from the upper and lower guidelines. As time progressed, values have tended to fall on, or just above, the upper SSG.

An upward trend in pH could be the result of increasing alkalinity over time. Soil disturbance and sediment movement within the watershed could be responsible for the migration of ionic species that contribute to alkalinity migrating into the river system. Ionic species such as carbonates tend to resist changes in pH and would allow the water to approach a more neutral condition compared to the acidic conditions normally found on the island.

Figure 3: pH at Rattling Brook from 2008 to 2017

Although year-to-year pH levels fluctuate from station to station, over time, pH is trending upwards at each station.

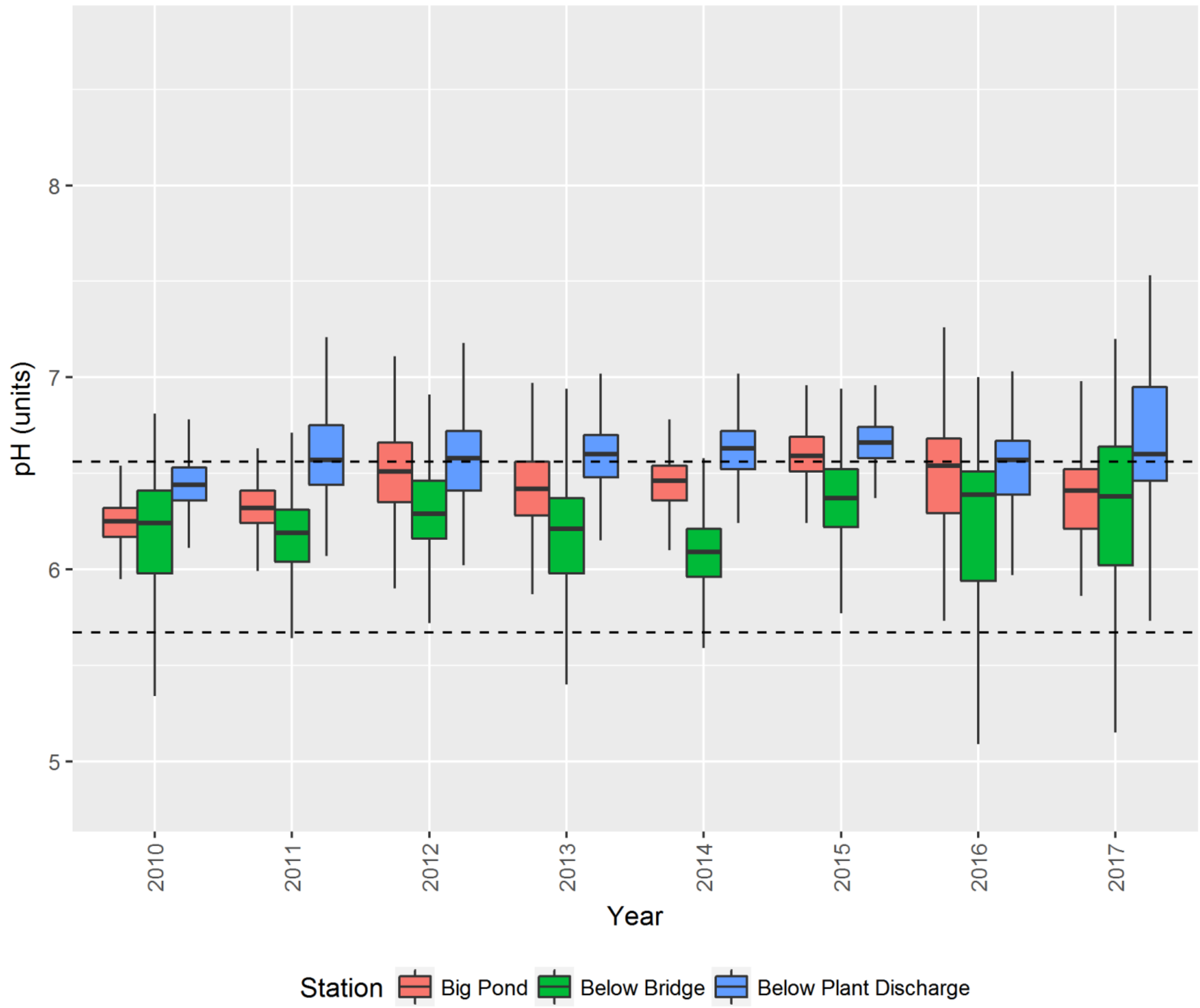

Figure 4: Boxplots of pH at Rattling Brook from 2010 to 2017

Specific Conductivity

Specific conductivity, an indicator of dissolved solids, has increased at all monitoring stations since construction efforts began in Long Harbour.

Especially noteworthy is the conductivity levels at Big Pond station in 2017. The development of a flow control structure at the head of Big Pond, and subsequent water level rise following commission, resulted in a period of higher-than-normal conductivity. It is likely that conductivity levels will remain elevated for some time to come as soil stability evens out.

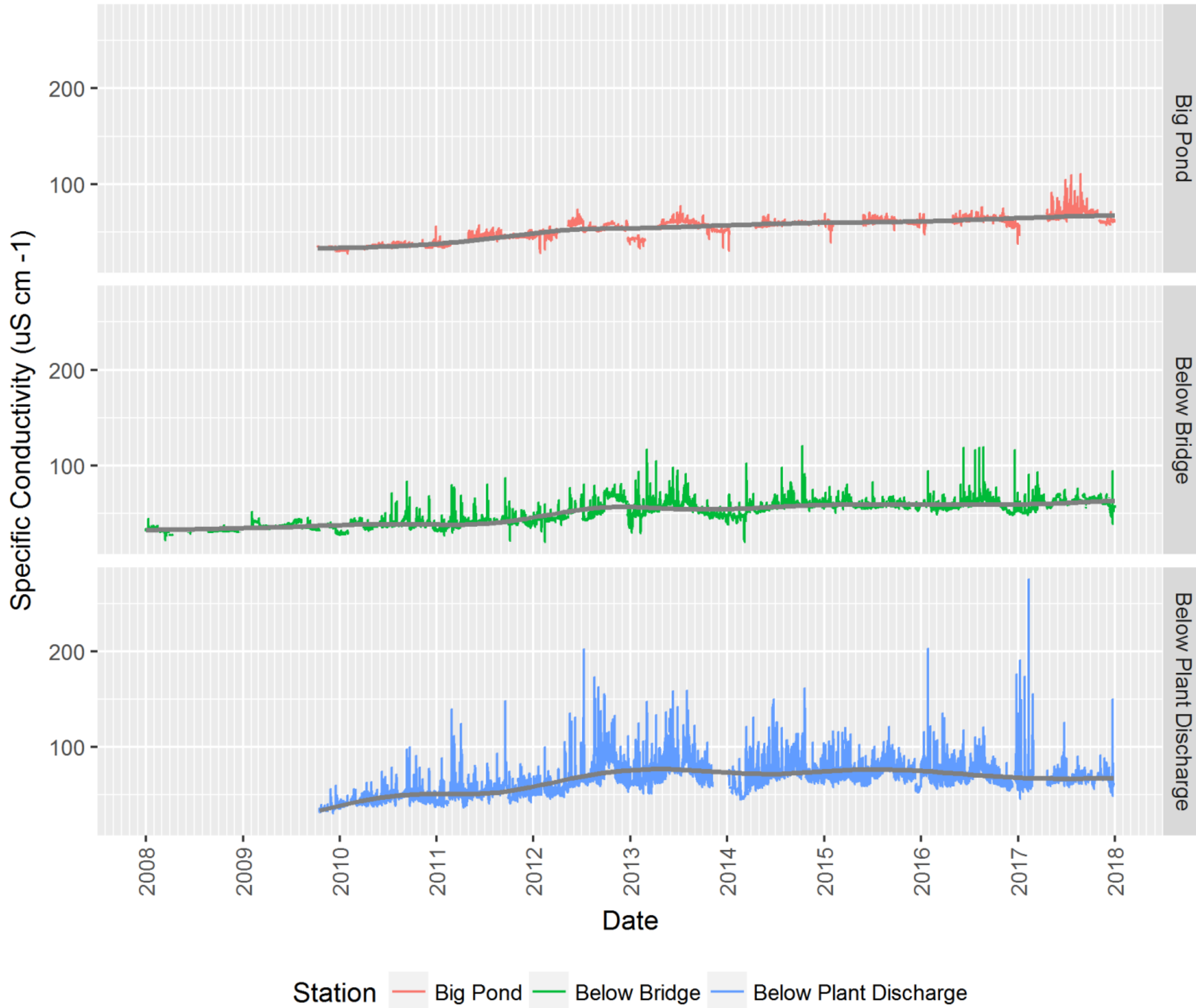

Figure 5: Specific Conductivity at Rattling Brook from 2008 to 2017

Since 2010 to 2016, specific conductivity has generally been higher at Plant Discharge station compared to stations up stream (Figure 6). This was expected since Rattling Brook will naturally pick up more dissolved material as water flows downstream. Median conductivity levels at Plant Discharge station have been declining since 2015, however, and appear to be moving into a similar range as both Big Pond and Bridge stations (where values are still continuing to rise). In fact, median conductivity was higher at Big Pond than Plant Discharge station in 2017.

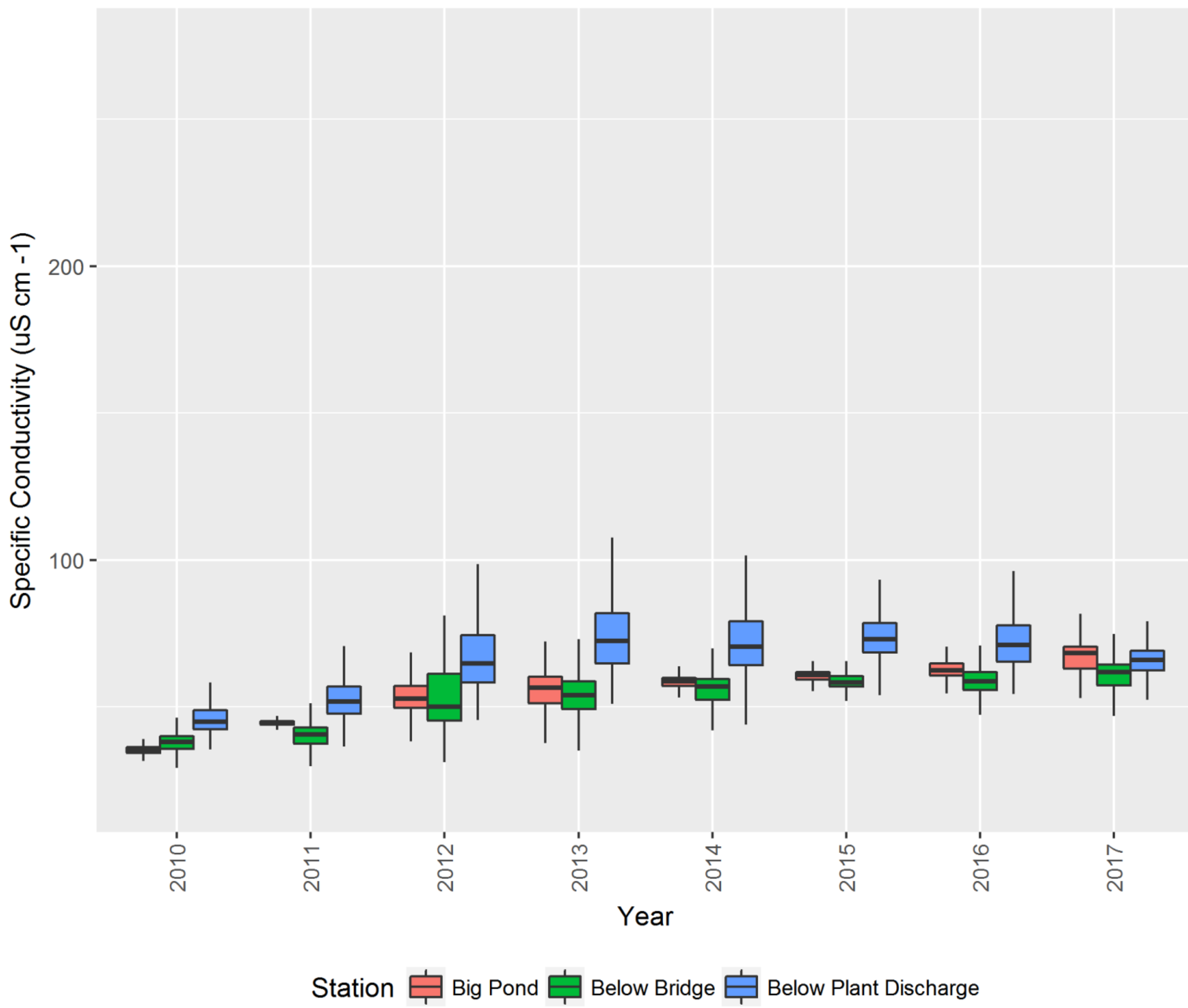

Figure 6: Boxplots of specific conductivity at Rattling Brook from 2010 to 2017

Dissolved Oxygen

Like water temperature, the concentration of dissolved oxygen has shown no particular long-term trends at Rattling Brook. More importantly, no acute or unexplained drops in dissolved oxygen were detected in 2017. Such events can lead to fish kills and cause harm to other aquatic organisms.

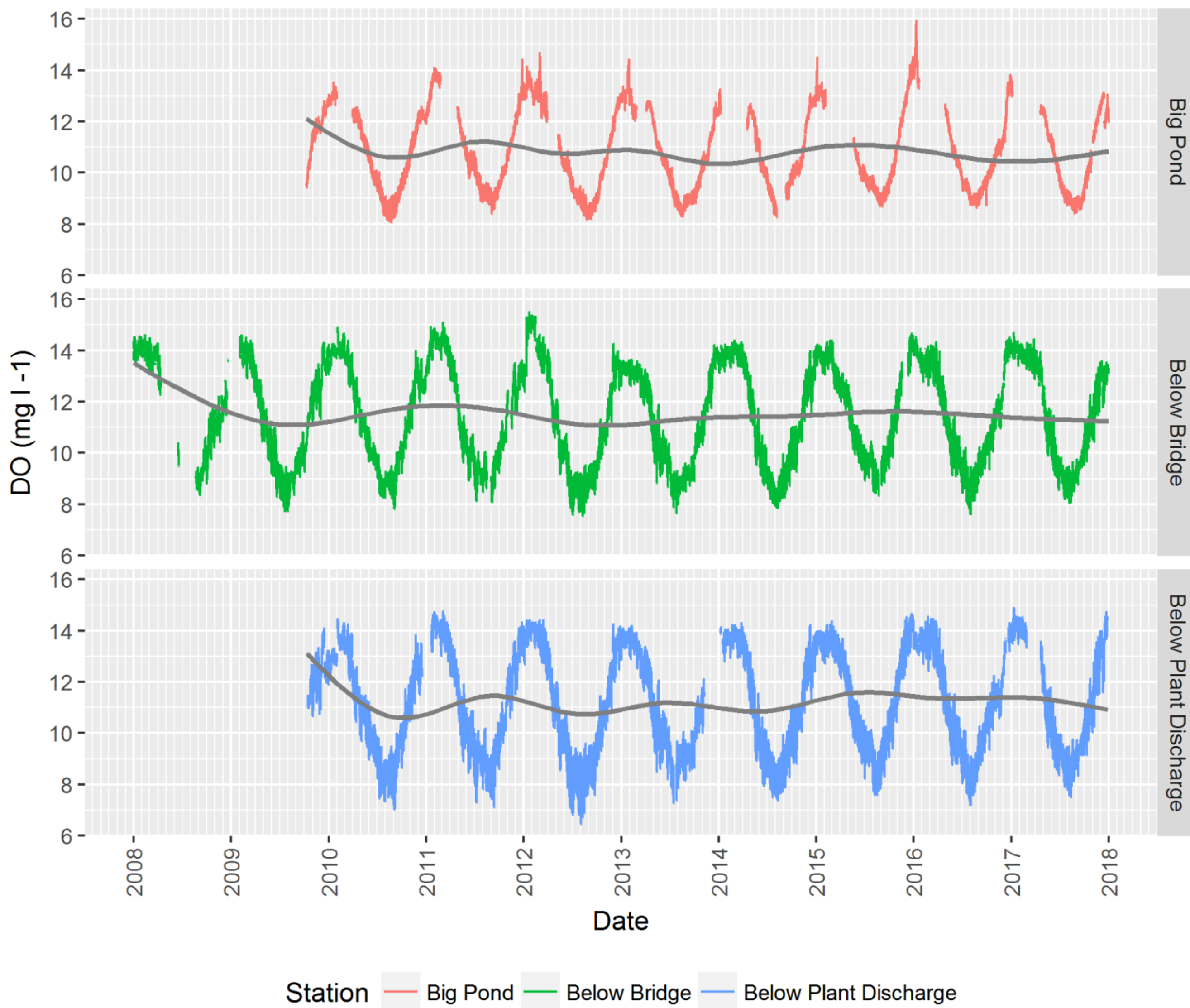

Figure 7: Dissolved oxygen at Rattling Brook from 2008 to 2017

Since equipment has normally been removed from Big Pond during ice-cover, a bias is introduced into the Big Pond station boxplots in Figure 8. Low water temperatures occurring over the winter allows for higher oxygen concentrations which haven't been captured in past years. Going forward, equipment will remain at Big Pond station to record oxygen levels over winter.

Due to flow conditions, dissolved oxygen concentrations are usually higher at Bridge and Plant Discharge stations (Figure 8). Additionally, oxygen concentrations at Bridge station are often higher than Plant Discharge station.

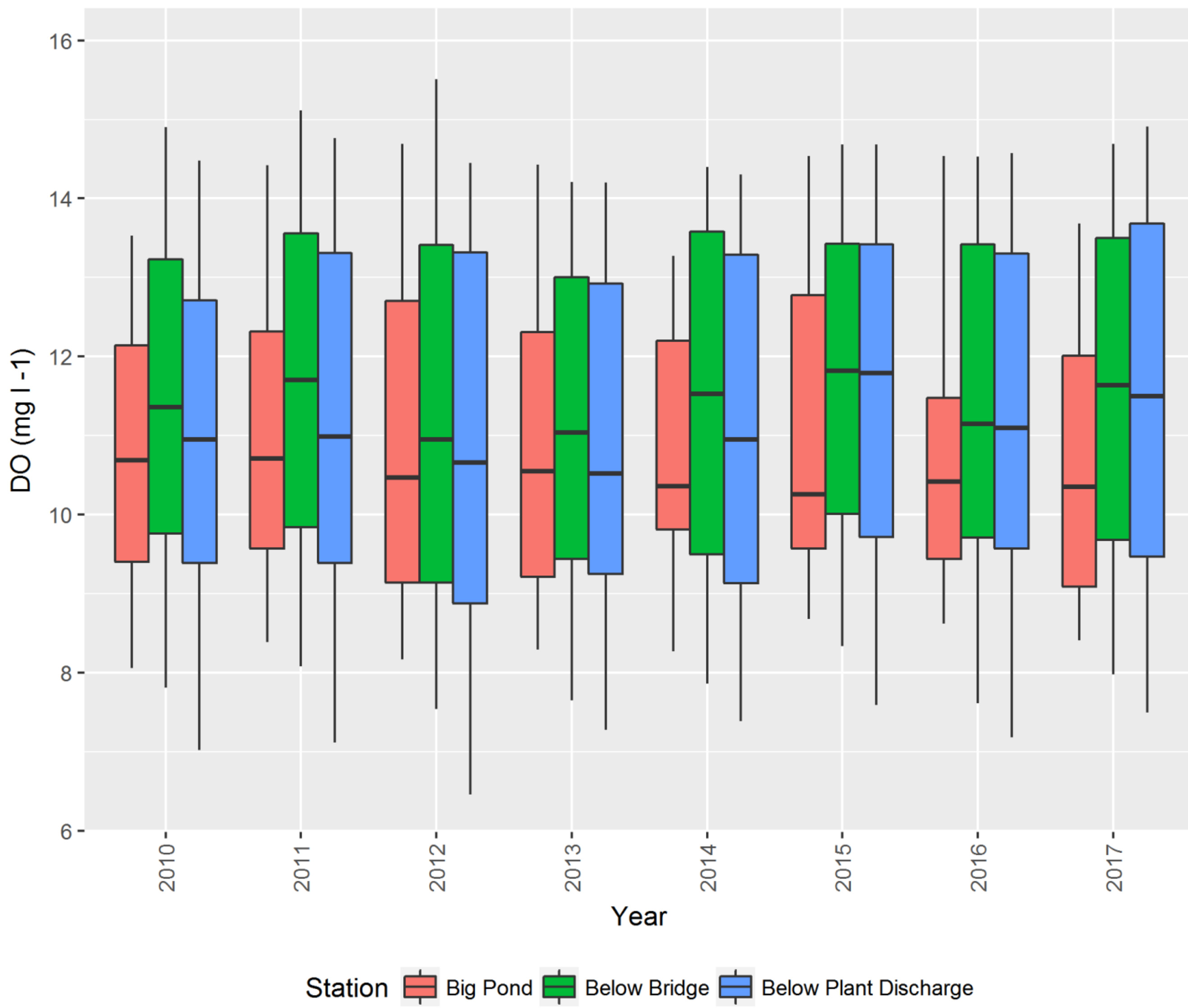

Figure 8: Boxplots of dissolved oxygen at Rattling Brook from 2010 to 2017

Turbidity

Due to the short duration and high variability of turbidity events, it is challenging to derive information from line graphs such as the one to the right.

Immediately visible is the relative level of turbidity at each station: Big Pond generally has low turbidity and few events. Bridge and Plant Discharge stations show a much more variable turbidity characteristic. Although, Bridge station appears to show more substantial turbidity events than Plant Discharge station, these events tend to exhibit an initial high peak before quickly returning to lower levels. Meanwhile, at Plant Discharge station, it appears that turbidity events do not peak as high as those at Bridge station, but tend to run longer at moderate levels. These characteristics are illustrated best in Figure 10.

With a substantial increase in water level at Rattling Brook Big Pond station near the end of 2017, it is likely that wave action on newly submerged soils will result in erratic turbidity levels in the future.

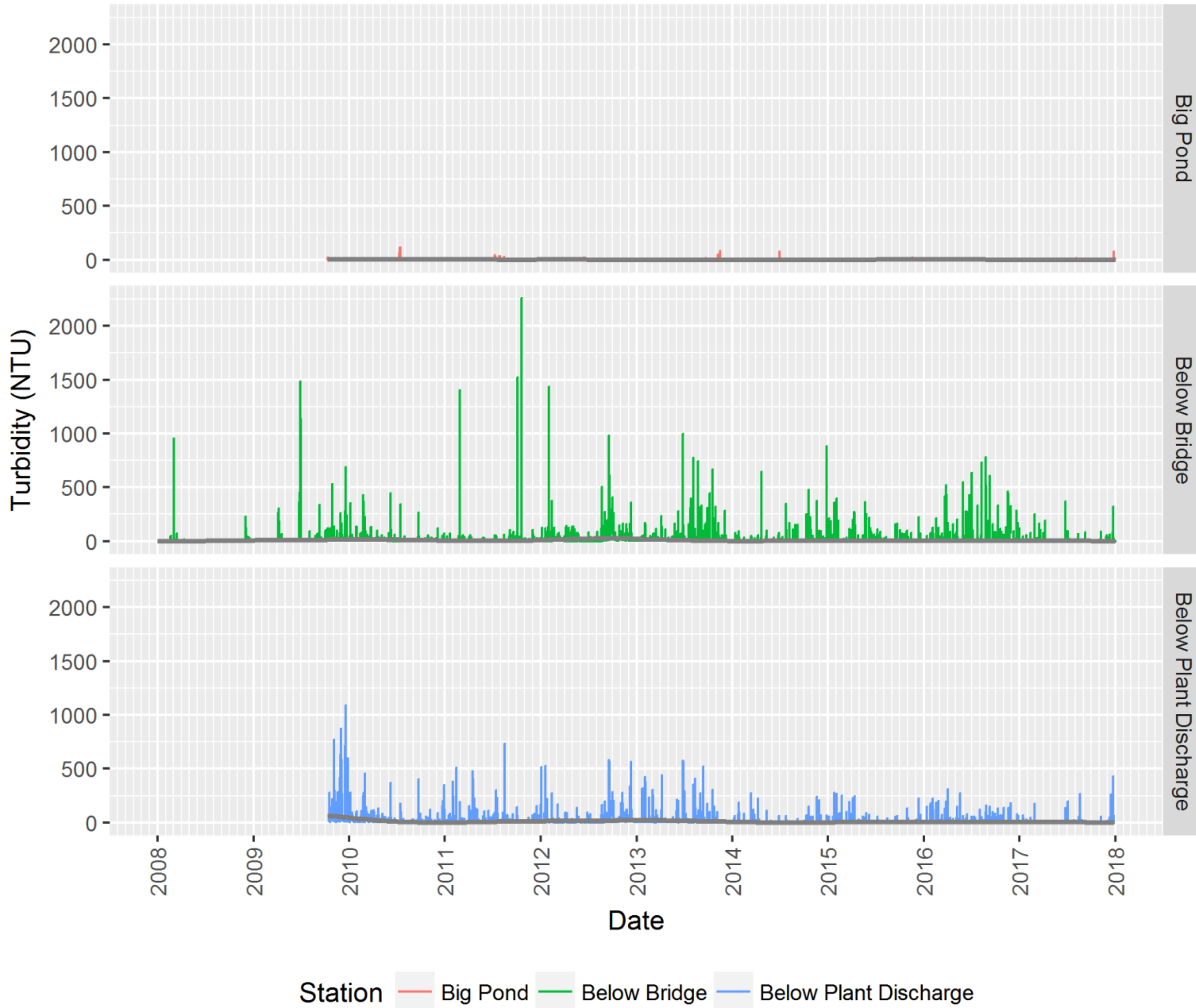

Figure 9: Turbidity at Rattling Brook from 2008 to 2017

Highly variable and elevated turbidity levels were commonplace from 2010 and into 2013 during the initial earthworks and construction phases of the Vale processing plant. Following these years of variable turbidity, levels have generally tended towards background as work effort was concentrated on buildings and interiors.

In 2015, median turbidity levels fell to 0.0 NTU at all three monitoring stations. 2016 saw some extra turbidity before declining once again in 2017.

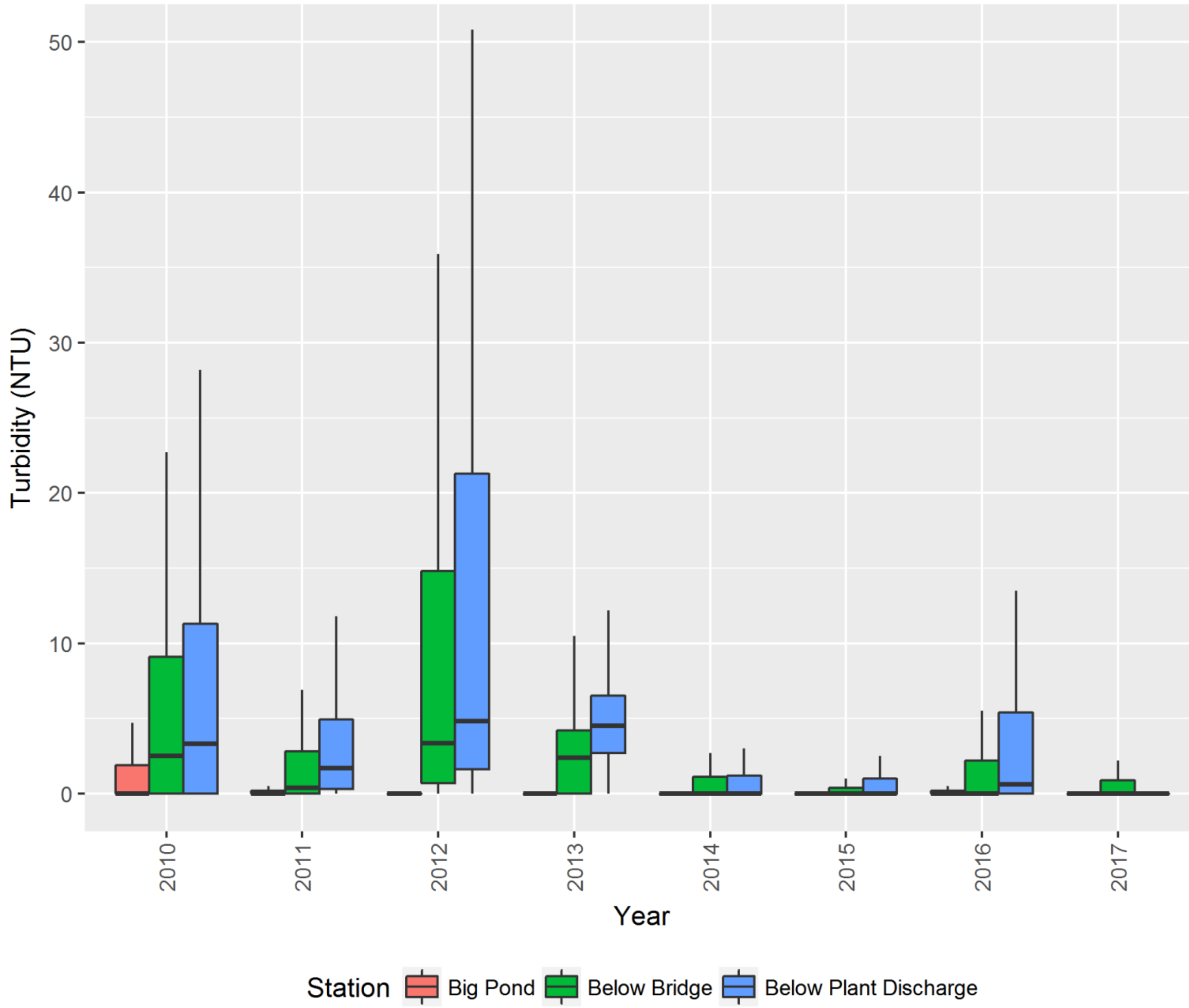

Figure 10: Boxplots of Turbidity at Rattling Brook from 2010 to 2017

Stage Level

Since monitoring began at the Vale site, stage level has generally been an indicator parameter of precipitation-based water quality events, as water level change is generally temporary.

In 2017, however, construction began on a flow control structure at the head of Rattling Brook Big Pond. With construction finishing in November 2017 and the gates closed, water level increased quickly. In fact, water level increased more than a meter within a single deployment period between November and December at Big Pond.

No substantial change has been observed at Bridge or Plant Discharge stations.

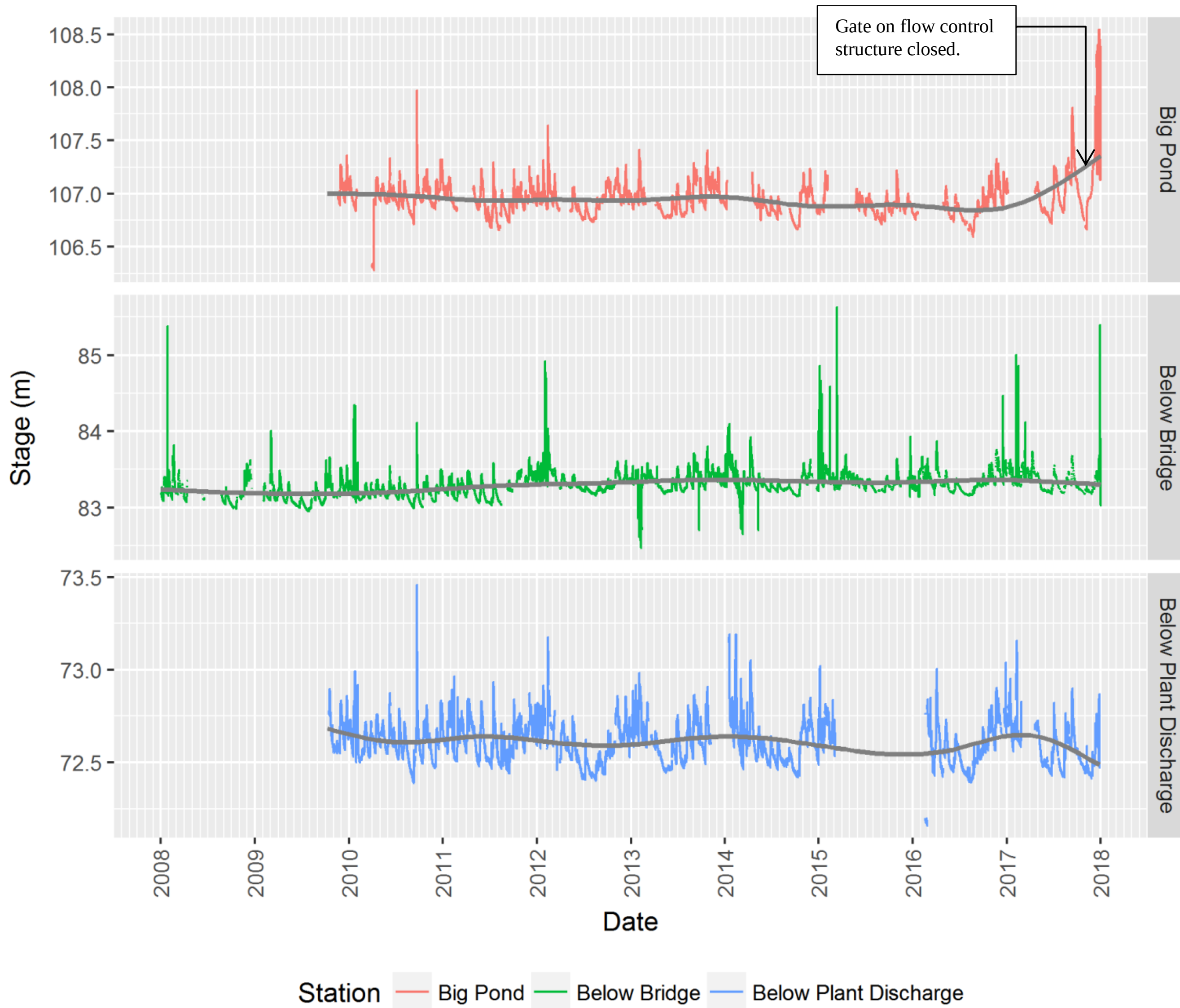

Figure 11: Stage level at Rattling Brook from 2008 to 2017

Groundwater Network

The water quality parameters previously discussed for the three Rattling Brook stations tend to fall within similar ranges of variation and a visual comparison between graphs is relatively simple. However, due to substantial variation between different aquifers, water quality within one well can be very different than the next. As a result, the following graphs may be presented with different y-axes for each well.

Box plots allow for a better station-to-station comparison.

Water Temperature

The degree of connection between groundwater and surface conditions can be implied by the variability of water temperature within each well. For example, the mean range in water temperature at Well 2 Shallow is 8.87°C, implying a substantial surface connection compared to Well 4 Deep where the mean range in temperature is 0.26°C.

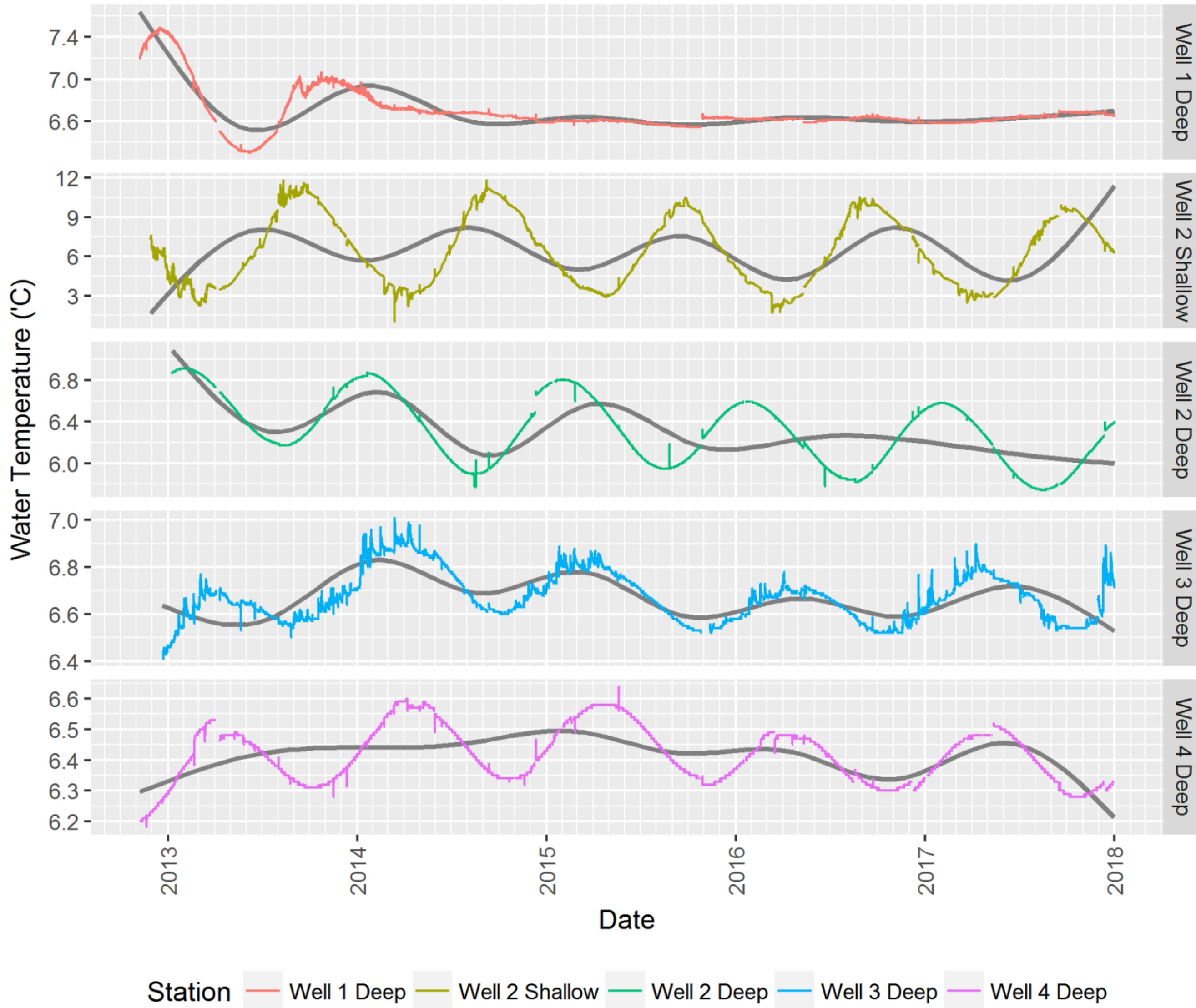

Figure 12: Water temperature at the Residue Storage Area from 2012 to 2017

The spread of water temperature observed at Well 2 Shallow is easily seen in Figure 13 and dwarfs all other wells.

Aside from the range of values, there appears to be a multiple-year decline in median water temperatures at Well 1 Deep, Well 2 Shallow, and Well 2 Deep. This trend can be observed in both Figure 13 and Table 6. At this time, it is uncertain whether these trends are related to environmental conditions or management of the Residue Storage Area.

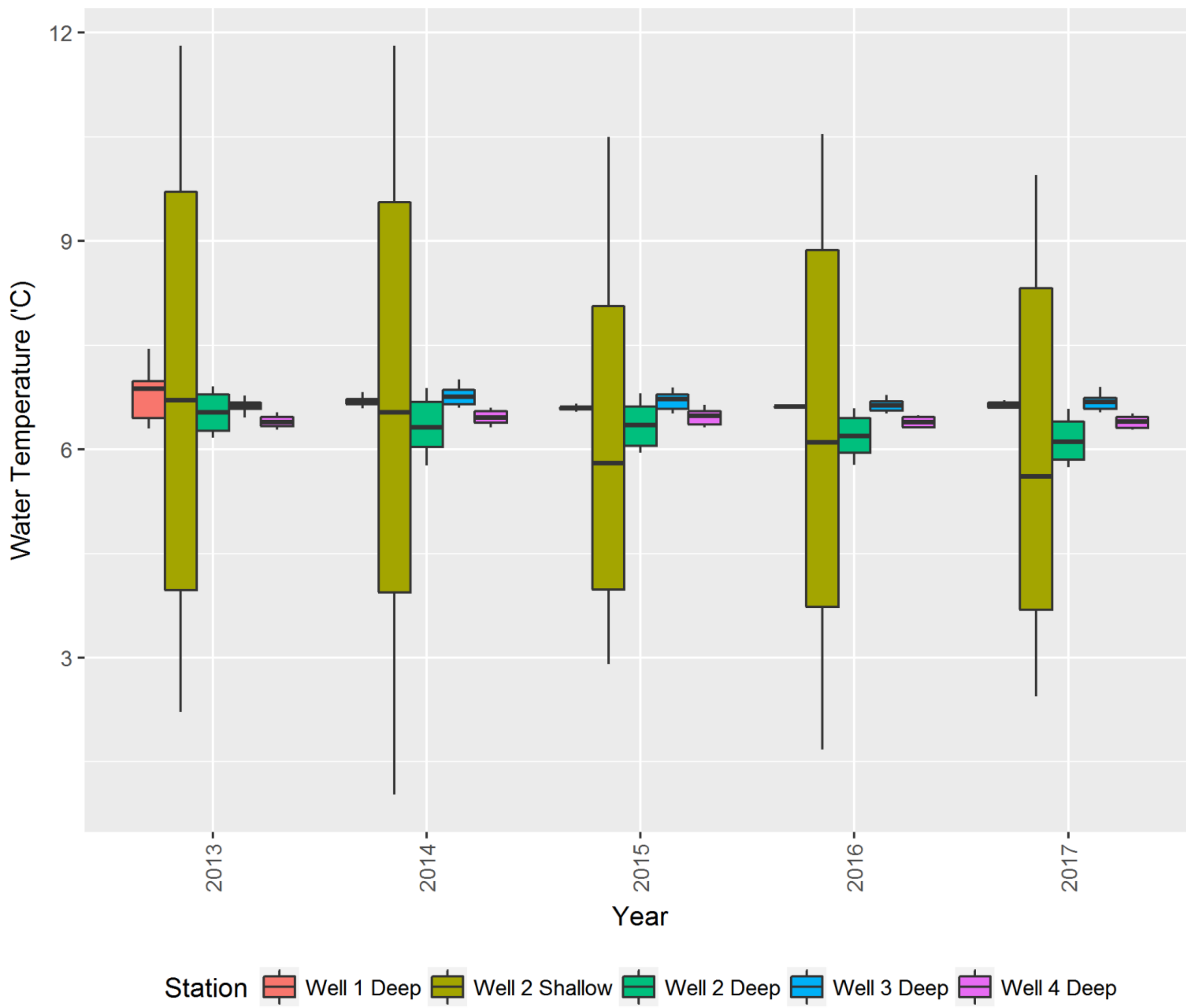

Figure 13: Boxplots of water temperature at the Residue Storage Area from 2012 to 2017

pH

From 2015 into 2016, pH increased at all stations surrounding the Residue Storage Area. Into 2017, however, pH declined at Well 2 Shallow and Well 2 Deep.

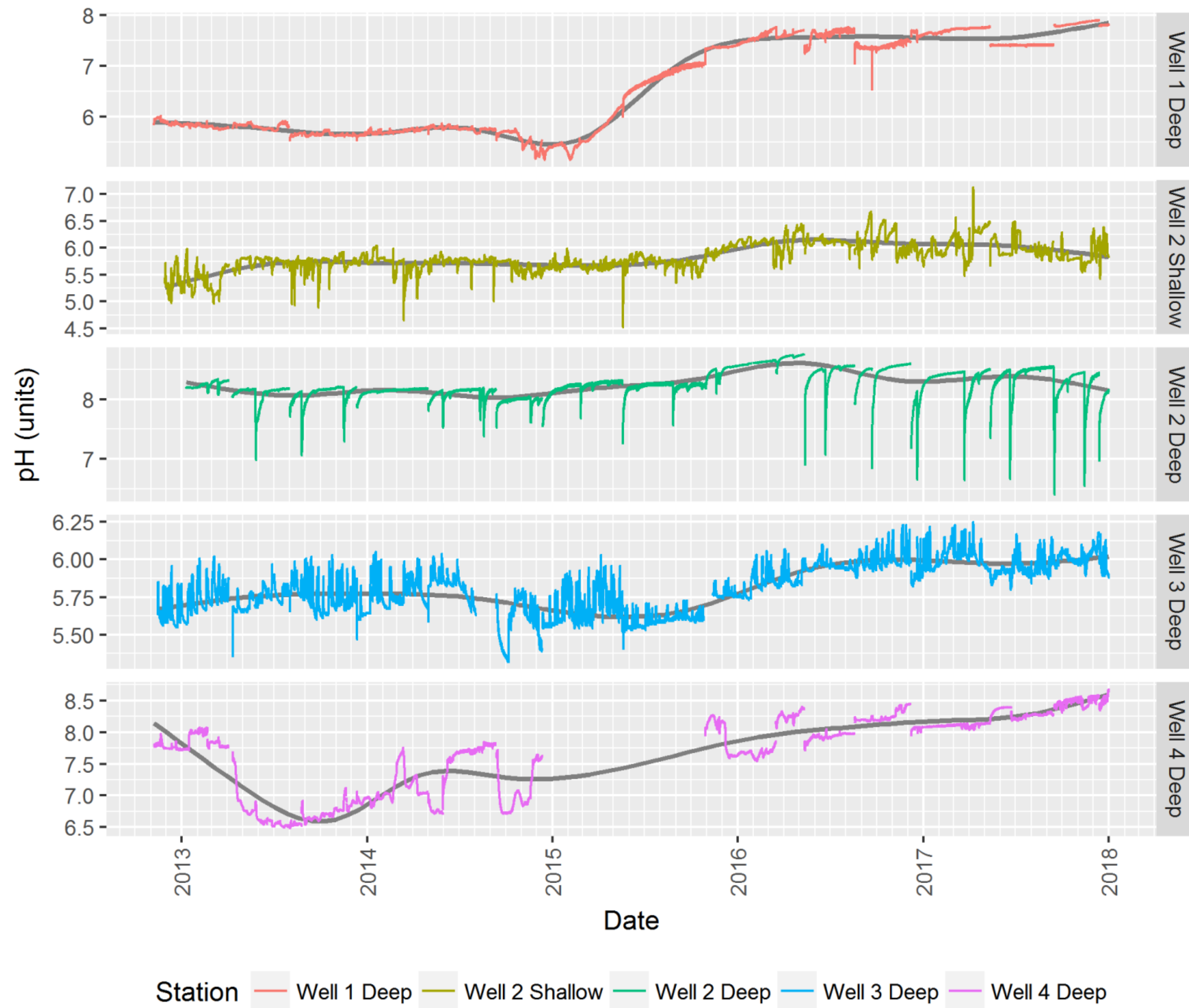

Figure 14: pH at the Residue Storage Area from 2012 to 2017

Figure 15 is more effective than Figure 14 at illustrating the year-to-year trends at each well and comparing ranges from one well to another.

These trends will be observed closely in the future.

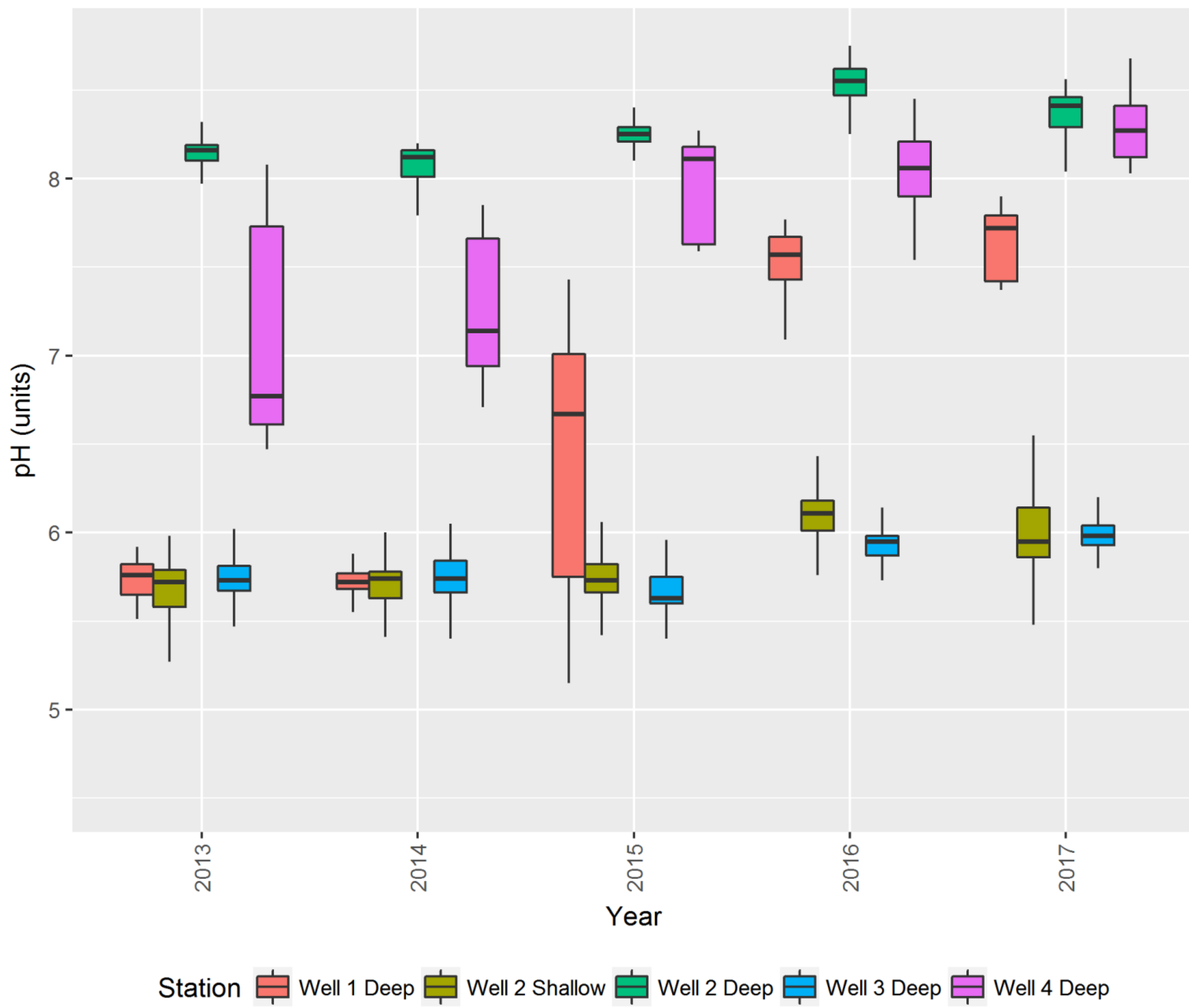

Figure 15: Boxplots of pH at the Residue Storage Area from2013 to 2017

Specific Conductivity

Specific conductivity is a measure of the total dissolved solids in water. This parameter has increased at four of five monitoring wells since 2013. Only Well 2 Deep indicated static conditions or a slight downward trend over time, although, a rising trend was seen at this well throughout 2017 and will be monitored closely.

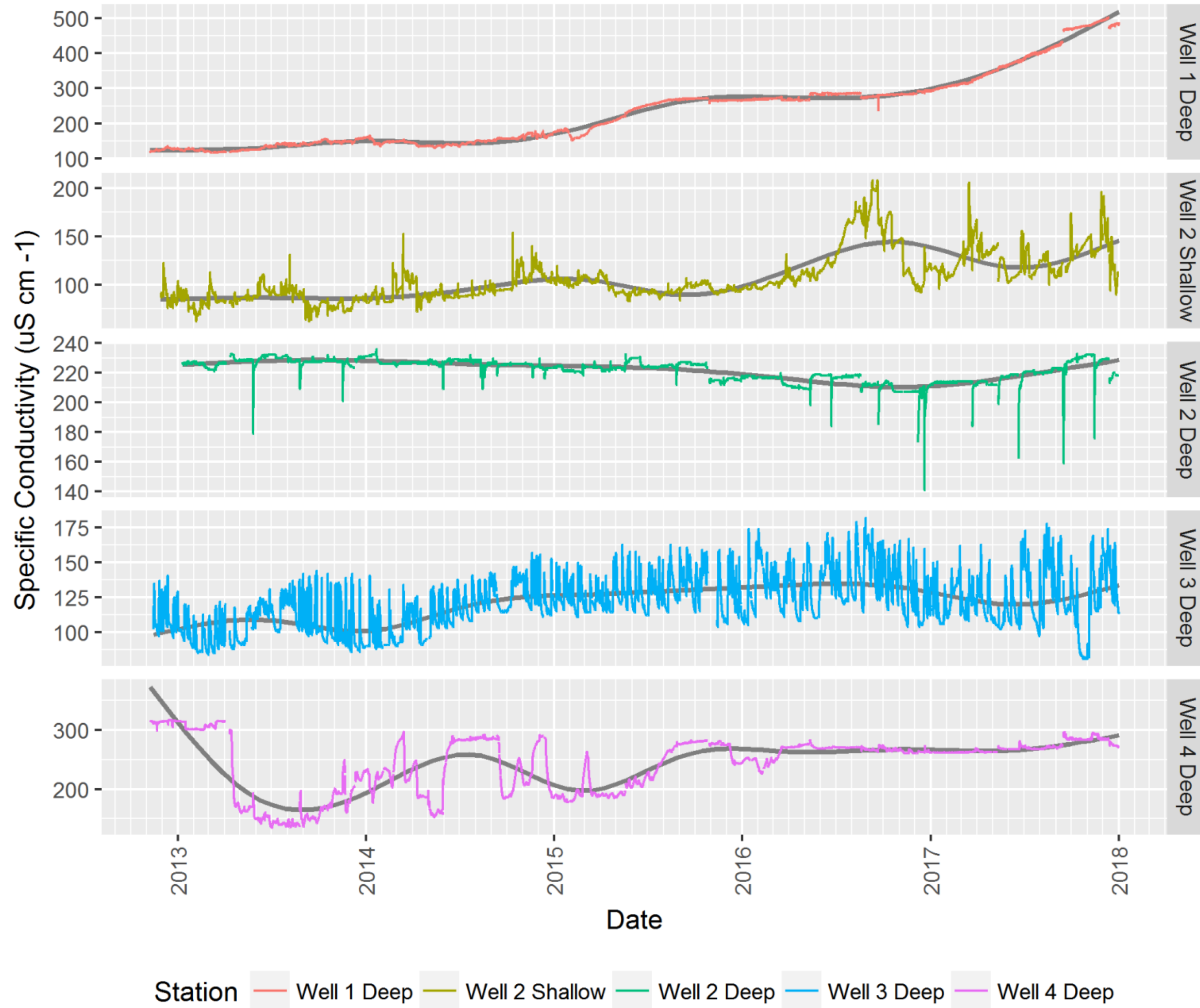

Figure 16: Specific conductivity at the Residue Storage Area from 2012 to 2017

Rising trends are particularly evident in the boxplots in Figure 17.

Variation in conductivity values is increasing over time at Well 1 Deep, Well 2 Shallow, and Well 2 Deep. Conductivity at Well 3 Deep appears to be consistent year to year while Well 4 Deep shows a consolidation of values around the median with no obvious change upwards or downwards.

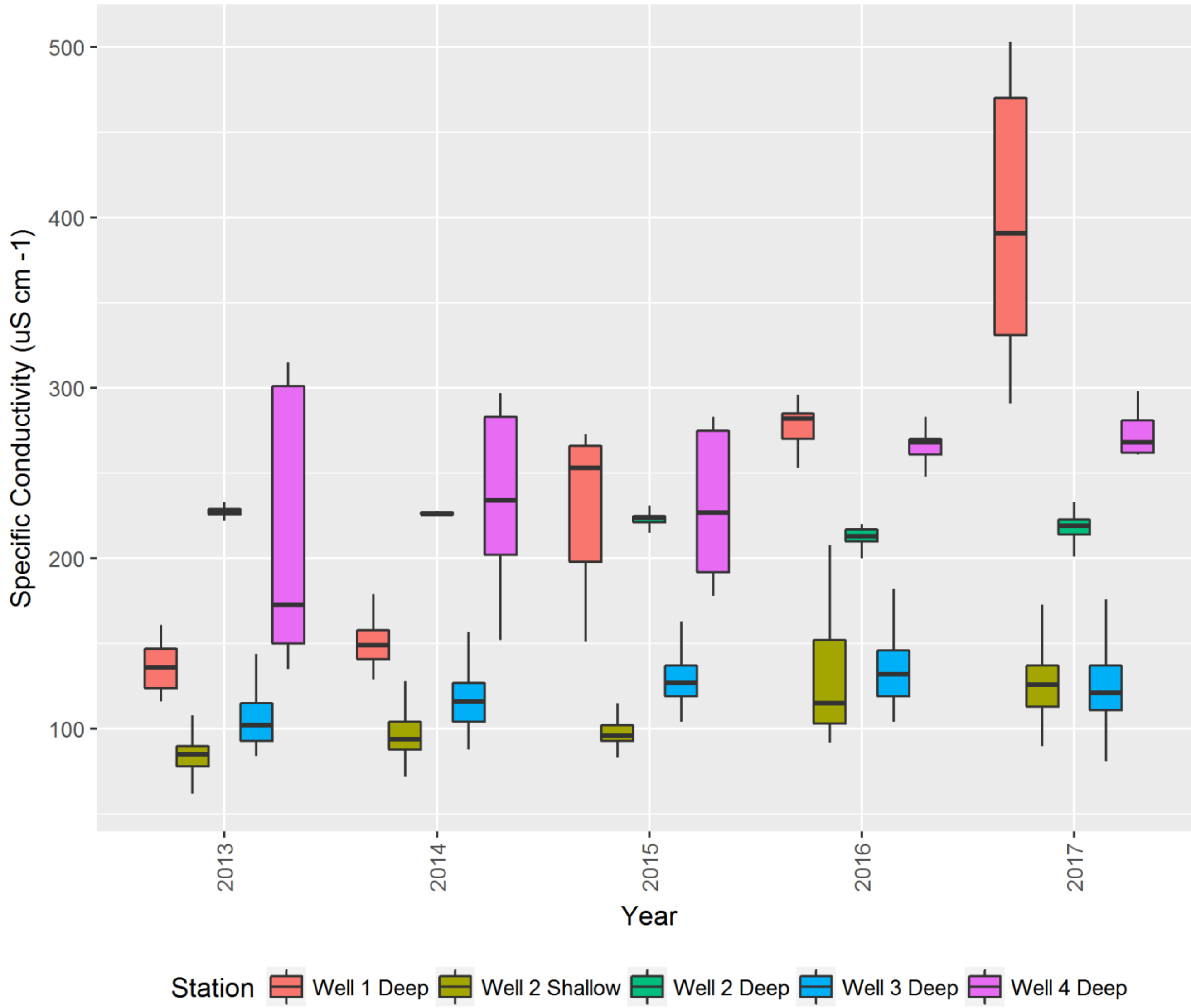

Figure 17: Boxplots of specific conductivity at the Residue Storage Area from 2013 to 2017

Oxidation-Reduction Potential (ORP)

ORP is an indicator of the water's ability to oxidize or reduce ionic species present in the monitoring well and help predict the mobility of metal ions through the aquifer. For instance, at certain ORP levels, a metal ion may be in a dissolved ionic state or in an insoluble state as a precipitate.

ORP levels tend to fluctuate greatly within each monitoring well, especially following maintenance activities when water chemistry in the monitoring well is disturbed through well purging and the movement of equipment.

Figure 18 displays ORP at each monitoring well from initial deployment to the end of 2017. Due to the substantial variability, often in short periods of time, it is easier to derive meaning from Figure 19.

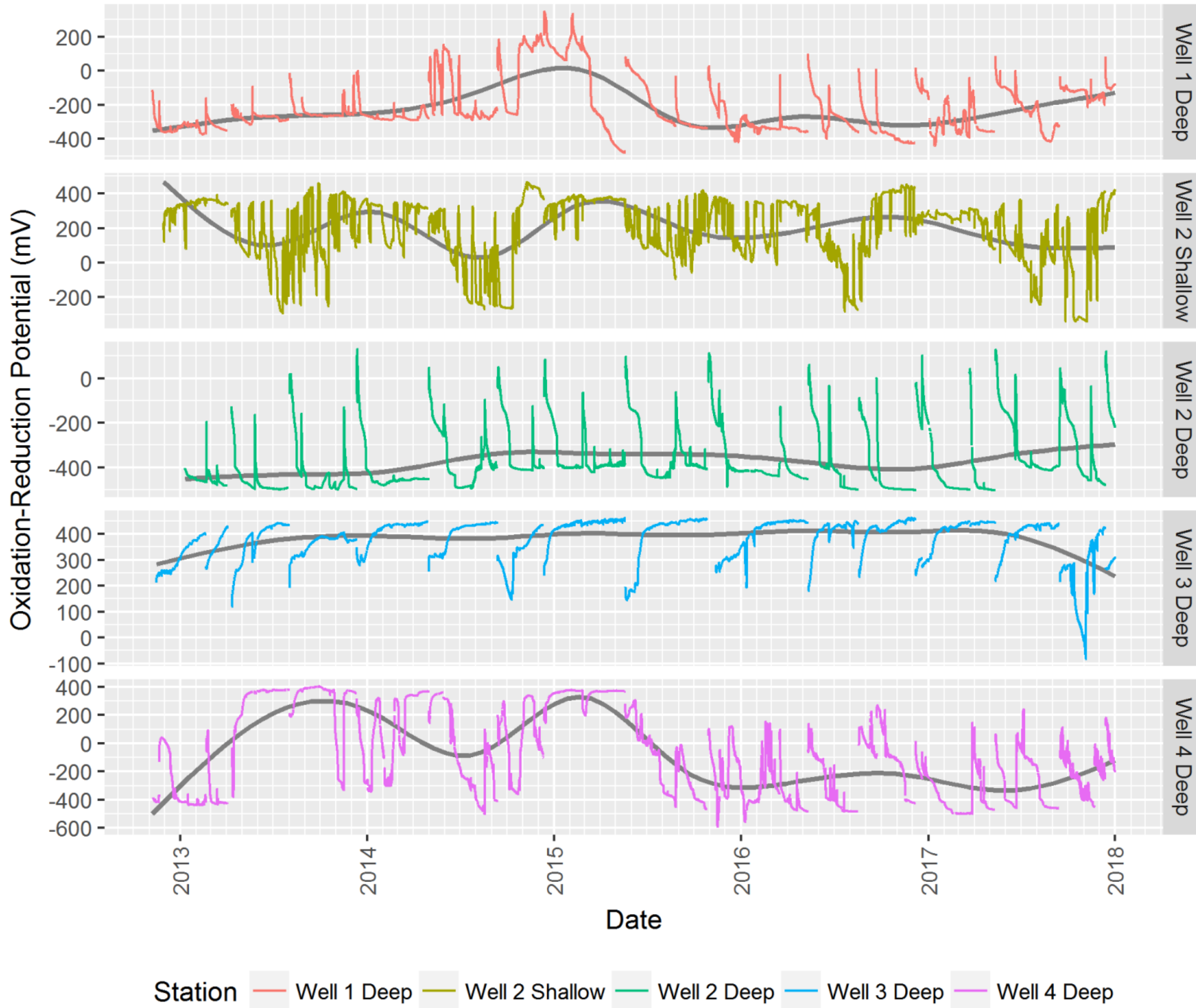

Figure 18: Oxidation-Reduction Potential at the Residue Storage Area from 2012 to 2017

Variability in ORP values is illustrated by the height of boxplots in Figure 19.

Interestingly, well depth and horizontal distance between wells does not appear to have an impact on ORP. For instance, horizontal distance between Well 2 Shallow and Well 2 Deep is less than one meter, and less than 10 meters vertical depth, yet ORP values at Well 2 Shallow are predominantly oxidative and reductive at Well 2 Deep. Yet, Well 3 Deep, which is even deeper and separated by almost 500 meters, is entirely oxidative – even at a depth of 17 meters below ground.

Instead, the local geochemistry and the particular aquifer penetrated by each well appears to govern ORP.

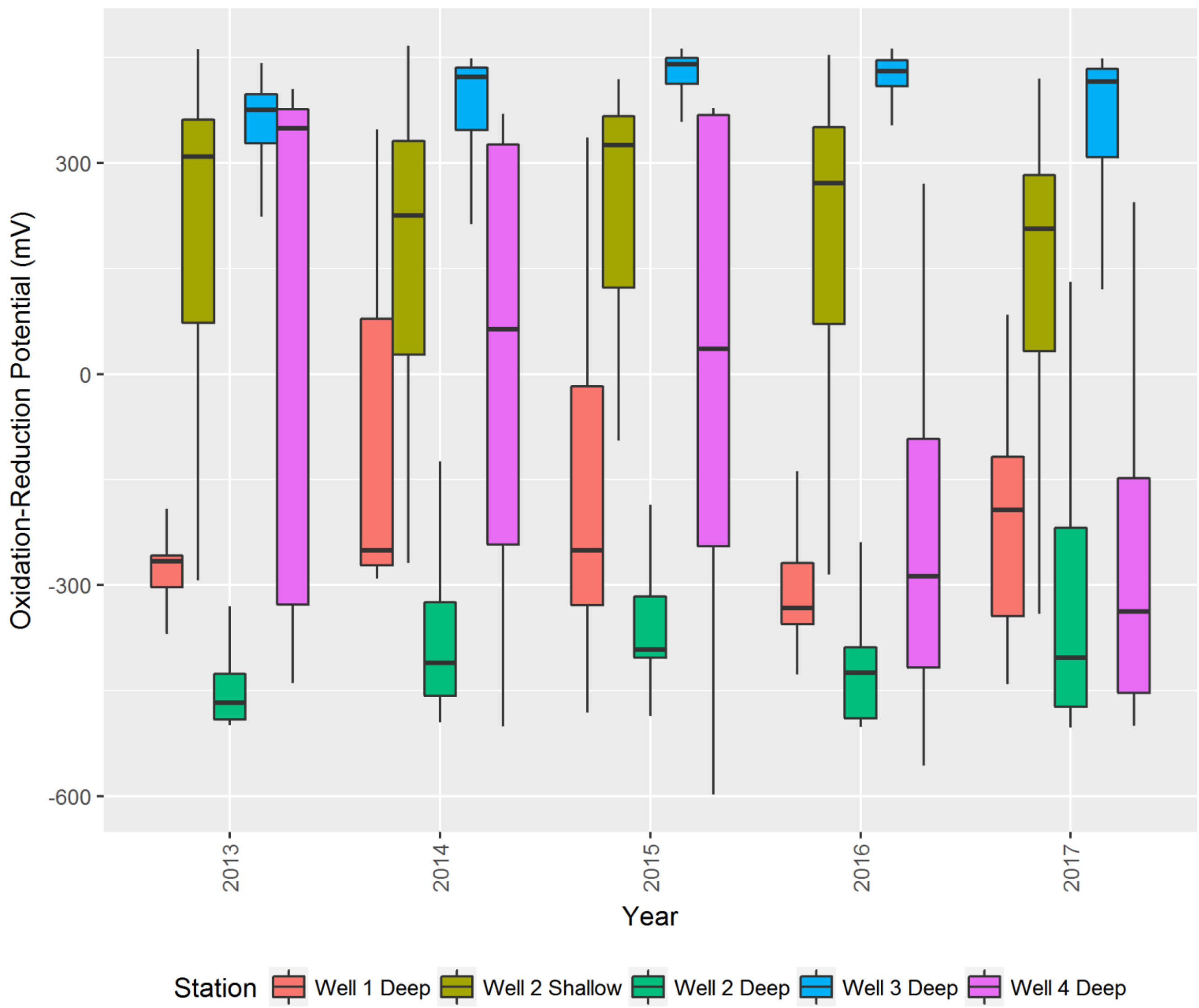

Figure 19: Boxplots of Oxidation-Reduction Potential at the Residue Storage Area from 2013 to 2017

Water Elevation

Water elevation – the geodetic level of the water within each well – is an indicator of where the water table or aquifer resides in the area surrounding each monitoring well. Because this value is closely associated with local topography, the value does not change to a great degree.

Periodic rises and falls are commonplace as illustrated by Figure 20.

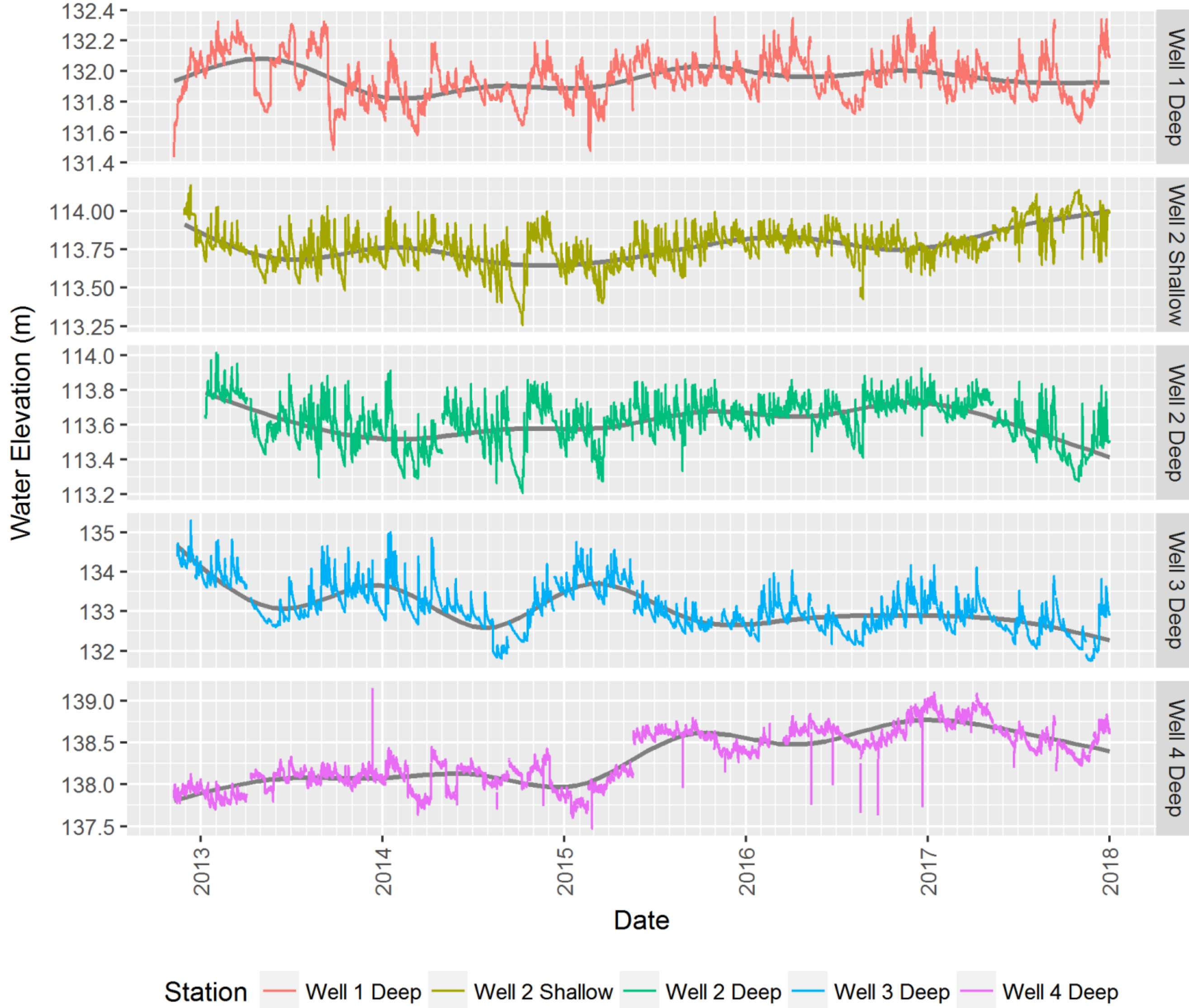

Figure 20: Water elevation at the Residue Storage Area from 2012 to 2017

A slight downward trend appears to be under way at Well 3 Deep as seen in Figure 21. Due to the time frames involved in groundwater recharge, trends in water level are likely long-term and based on variation in rainfall over a multi-year timeframe.

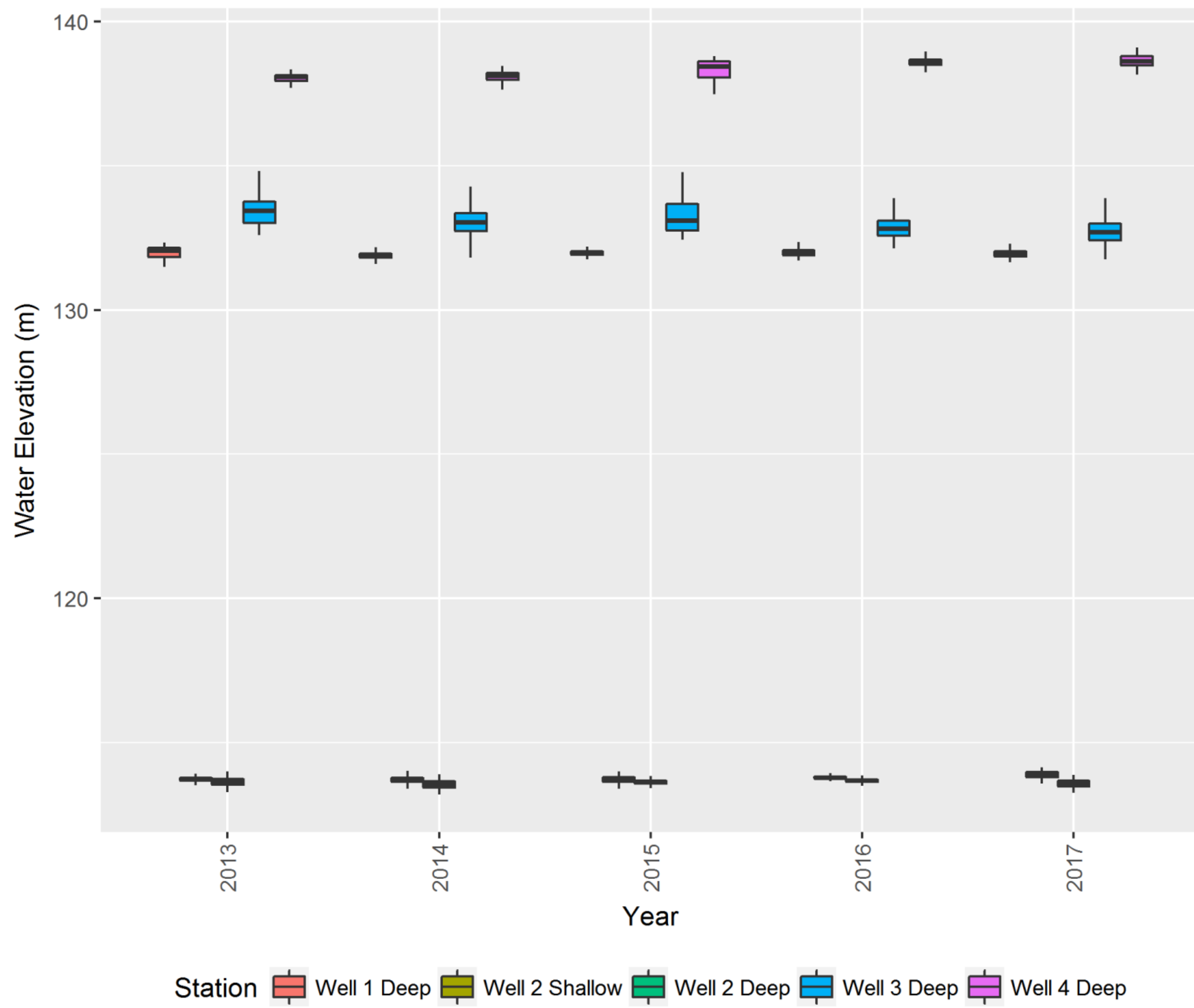

Figure 21: Boxplots of water elevation at the Residue Storage Area from 2013 to 2017

Path Forward

- As work efforts at the Vale Long Harbour plant site evolve, environmental challenges also evolve. In 2017, work on a Rattling Brook Big Pond flow control structure was initiated and finally completed in November. An anticipated water level rise of 1.5m may cause disruption to bank stability and water quality parameters due to inundation of soils and newly submerged vegetation.
- Water quality equipment at Rattling Brook Big Pond station will be left to freeze in over the winter season to allow for a continuous stream of data during the critical post-inundation period. With deeper waters in the deployment area, damage from rafting ice is reduced.
- 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 every 12 weeks 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.

Appendix 1: Surface Water

Table 1: Water temperature at Rattling Brook from 2008 to 2017

Station	Year	Mean	Median	Min	Max
Big Pond	2009	5.13	5.15	0.20	12.26
	2010	10.08	9.65	0.04	22.40
	2011	9.58	9.88	-0.02	20.88
	2012	10.00	11.28	0.00	22.87
	2013	9.67	10.04	-0.02	22.17
	2014	10.58	11.37	0.01	23.10
	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
Below Bridge	2008	6.73	6.20	-0.42	21.93
	2009	9.14	8.03	-0.50	23.97
	2010	8.65	7.73	-0.50	22.84
	2011	7.70	6.43	-0.48	22.20
	2012	9.52	9.77	-0.51	23.82
	2013	9.03	9.16	-0.49	24.98
	2014	8.65	7.46	-0.50	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
Below Plant Discharge	2009	4.02	4.20	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	10.90	-0.03	24.70
	2014	9.27	9.36	0.00	25.48
	2015	8.05	6.71	-0.51	23.25
	2016	9.10	9.22	-0.55	25.00
	2017	8.49	7.70	-0.52	24.13

Table 2: pH at Rattling Brook from 2008 to 2017

Station	Year	Mean	Median	Min	Max
Big Pond	2009	6.24	6.24	5.86	6.41
	2010	6.22	6.25	5.34	6.80
	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
Below Bridge	2008	6.08	6.11	5.42	6.50
	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	7.00
	2013	6.14	6.21	4.89	6.94
	2014	6.09	6.09	5.13	7.10
	2015	6.34	6.37	5.45	6.94
	2016	6.21	6.39	4.84	7.00
	2017	6.31	6.38	5.15	7.20
Below 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	6.60	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	6.60	5.62	7.53

Table 3: Summary statistics of specific conductivity at Rattling Brook from 2008 to 2017

Station	Year	Mean	Median	Min	Max
Big Pond	2009	33.0	33.2	29.6	35.4
	2010	35.2	35.6	27.4	55.7
	2011	43.4	44.6	33.1	57.0
	2012	53.0	52.8	28.2	73.8
	2013	54.8	56.5	32.5	77.4
	2014	58.4	58.8	30.6	68.1
	2015	60.6	60.8	39.1	70.3
	2016	62.1	62.4	37.6	76.3
	2017	67.2	68.3	45.8	110.9
Below Bridge	2008	32.2	31.8	21.6	44.4
	2009	36.9	36.5	27.5	51.6
	2010	38.1	38.0	27.4	83.6
	2011	40.8	40.6	21.2	87.1
	2012	52.9	50.1	20.2	81.1
	2013	55.1	53.9	29.3	116.6
	2014	56.1	57.0	20.3	120.7
	2015	59.0	58.3	50.6	82.6
	2016	59.1	58.7	47.3	119.1
	2017	60.8	61.9	38.8	94.1
Below Plant Discharge	2009	36.2	35.5	30.6	60.0
	2010	46.5	44.9	35.5	99.8
	2011	53.4	51.9	36.5	147.9
	2012	69.1	64.7	45.5	202.0
	2013	75.8	72.5	51.0	158.7
	2014	72.4	70.4	43.9	161.4
	2015	74.0	73.0	52.3	121.0
	2016	72.4	71.0	54.3	203.0
	2017	66.9	65.9	45.4	275.0

Table 4: Summary statistics for dissolved oxygen at Rattling Brook from 2008 to 2017

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
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	14.90
	2011	11.74	11.70	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	14.40
	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
Below Plant Discharge	2009	12.25	12.28	10.29	14.10
	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	14.20
	2014	11.09	10.95	7.39	14.30
	2015	11.55	11.79	7.59	14.68
	2016	11.23	11.10	7.18	14.57
	2017	11.53	11.50	7.50	14.91

Table 5: Summary statistics of turbidity at Rattling Brook from 2008 to 2017

Station	Year	Mean	Median	Min	Max
Big Pond	2009	3.4	1.7	0.0	22.0
	2010	2.4	0.0	0.0	116.6
	2011	0.6	0.0	0.0	44.9
	2012	0.2	0.0	0.0	22.0
	2013	0.1	0.0	0.0	84.8
	2014	0.0	0.0	0.0	81.1
	2015	0.3	0.0	0.0	25.3
	2016	0.5	0.0	0.0	15.0
	2017	0.1	0.0	0.0	77.0
Below Bridge	2008	0.6	0.0	0.0	963.0
	2009	10.4	0.0	0.0	1486.0
	2010	10.2	2.5	0.0	445.0
	2011	6.0	0.4	0.0	2259.0
	2012	22.6	3.4	0.0	1437.0
	2013	6.4	2.4	0.0	998.0
	2014	2.3	0.0	0.0	886.0
	2015	2.9	0.0	0.0	396.9
	2016	5.4	0.0	0.0	781.0
	2017	1.8	0.0	0.0	371.7
Below Plant Discharge	2009	67.3	23.6	4.3	1094.0
	2010	11.5	3.3	0.0	460.0
	2011	6.7	1.7	0.0	734.0
	2012	19.4	4.8	0.0	586.0
	2013	11.1	4.5	0.0	580.0
	2014	2.6	0.0	0.0	277.2
	2015	2.5	0.0	0.0	282.5
	2016	7.7	0.6	0.0	314.6
	2017	1.8	0.0	0.0	430.0

Appendix 2: Ground Water

Table 6: Summary statistics of water temperature at the Residue Storage Area from 2013 to 2017

Station	Year	Mean	Median	Min	Max
Well 1 Deep	2013	6.78	6.87	6.30	7.45
	2014	6.69	6.68	6.59	6.97
	2015	6.59	6.60	6.54	6.68
	2016	6.62	6.62	6.59	6.68
	2017	6.64	6.64	6.58	6.71
Well 2 Shallow	2013	6.83	6.71	2.22	11.81
	2014	6.77	6.53	1.03	11.81
	2015	6.15	5.80	2.91	10.50
	2016	6.21	6.10	1.68	10.54
	2017	5.96	5.61	2.44	9.95
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	6.14	6.11	5.74	6.58
Well 3 Deep	2013	6.62	6.63	6.46	6.77
	2014	6.76	6.76	6.60	7.01
	2015	6.69	6.72	6.52	6.89
	2016	6.62	6.63	6.52	6.78
	2017	6.67	6.68	6.53	6.90
Well 4 Deep	2013	6.40	6.39	6.28	6.53
	2014	6.46	6.46	6.32	6.60
	2015	6.46	6.48	6.32	6.64
	2016	6.39	6.39	6.30	6.49
	2017	6.39	6.40	6.28	6.52

Table 7: Summary statistic of pH at the Residue Storage Area from 2013 to 2017

Station	Year	Mean	Median	Min	Max
Well 1 Deep	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	7.90
Well 2 Shallow	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
Well 2 Deep	2013	8.13	8.16	6.98	8.35
	2014	8.08	8.12	7.38	8.20
	2015	8.27	8.25	7.24	8.57
	2016	8.48	8.55	6.65	8.75
	2017	8.32	8.41	6.40	8.56
Well 3 Deep	2013	5.75	5.73	5.35	6.03
	2014	5.73	5.74	5.32	6.05
	2015	5.67	5.63	5.40	6.03
	2016	5.93	5.95	5.73	6.23
	2017	5.99	5.98	5.80	6.25
Well 4 Deep	2013	7.03	6.77	6.47	8.08
	2014	7.25	7.14	6.71	7.85
	2015	7.97	8.11	7.59	8.27
	2016	8.04	8.06	7.54	8.45
	2017	8.29	8.27	8.03	8.68

Table 8: Summary statistics of specific conductivity the Residue Storage Area from 2013 to 2017

Station	Year	Mean	Median	Min	Max
Well 1 Deep	2013	135	136	116	161
	2014	150	149	129	179
	2015	233	253	151	273
	2016	278	282	234	296
	2017	394	391	291	503
Well 2 Shallow	2013	85	85	62	131
	2014	96	94	72	154
	2015	97	96	83	120
	2016	128	115	92	208
	2017	127	126	90	206
Well 2 Deep	2013	228	228	179	233
	2014	226	226	209	236
	2015	223	224	212	233
	2016	213	213	141	220
	2017	219	219	159	233
Well 3 Deep	2013	105	102	84	144
	2014	115	116	88	157
	2015	129	127	104	163
	2016	134	132	104	182
	2017	124	121	81	178
Well 4 Deep	2013	206	173	135	315
	2014	237	234	152	297
	2015	232	227	178	283
	2016	264	268	226	283
	2017	271	268	261	298

Table 9: Summary statistics of oxidation-reduction potential at the Residue Storage Area from 2013 to 2017

Station	Year	Mean	Median	Min	Max
Well 1 Deep	2013	-271.9	-266.4	-375.2	1.7
Well 1 Deep	2014	-134.6	-250.6	-291.0	347.3
Well 1 Deep	2015	-180.8	-251.0	-481.6	336.2
Well 1 Deep	2016	-299.5	-333.0	-426.9	99.8
Well 1 Deep	2017	-224.7	-193.6	-441.4	84.4
Well 2 Shallow	2013	208.0	309.0	-293.7	461.7
Well 2 Shallow	2014	155.6	225.5	-269.0	466.5
Well 2 Shallow	2015	252.6	325.4	-94.9	419.2
Well 2 Shallow	2016	207.3	270.9	-284.9	453.5
Well 2 Shallow	2017	133.6	206.1	-340.8	419.7
Well 2 Deep	2013	-428.7	-467.7	-499.5	131.9
Well 2 Deep	2014	-370.1	-411.1	-495.4	84.4
Well 2 Deep	2015	-339.7	-392.1	-486.3	114.0
Well 2 Deep	2016	-384.5	-424.8	-502.1	104.1
Well 2 Deep	2017	-350.2	-403.5	-502.9	130.9
Well 3 Deep	2013	364.2	375.9	119.7	442.0
Well 3 Deep	2014	388.2	422.1	147.2	448.4
Well 3 Deep	2015	401.8	440.2	143.2	462.9
Well 3 Deep	2016	411.1	430.4	179.2	462.7
Well 3 Deep	2017	364.5	415.6	-82.3	448.7
Well 4 Deep	2013	98.5	349.5	-439.7	404.7
Well 4 Deep	2014	44.7	64.0	-501.0	370.1
Well 4 Deep	2015	43.0	35.7	-597.8	378.1
Well 4 Deep	2016	-243.0	-288.0	-556.5	270.8
Well 4 Deep	2017	-289.3	-337.7	-500.0	244.4

Table 10: Summary statistics of water elevation at the Residue Storage Area from 2013 to 2017

Station	Year	Mean	Median	Min	Max
Well 1 Deep	2013	131.9970	132.0444	131.4862	132.3334
	2014	131.8823	131.8847	131.5790	132.2039
	2015	131.9608	131.9732	131.4791	132.3551
	2016	131.9903	131.9961	131.7217	132.3484
	2017	131.9389	131.9131	131.6611	132.3429
Well 2 Shallow	2013	113.7266	113.7411	113.4821	114.0309
	2014	113.7073	113.7273	113.2566	114.0288
	2015	113.7206	113.7244	113.4017	113.9952
	2016	113.7911	113.7914	113.4259	113.9767
	2017	113.8881	113.8799	113.5798	114.1367
Well 2 Deep	2013	113.6312	113.6258	113.2945	114.0146
	2014	113.5478	113.5530	113.2056	113.9122
	2015	113.6218	113.6285	113.2716	113.8631
	2016	113.6787	113.6915	113.4072	113.9247
	2017	113.5848	113.6053	113.2709	113.8921
Well 3 Deep	2013	133.4164	133.4348	132.5933	134.8164
	2014	133.0308	133.0324	131.7996	135.0034
	2015	133.2103	133.0839	132.4325	134.7668
	2016	132.8376	132.8195	132.1306	134.1729
	2017	132.6919	132.6946	131.7471	134.1696
Well 4 Deep	2013	138.0338	138.0717	137.7004	139.1523
	2014	138.0880	138.1236	137.6385	138.4492
	2015	138.3378	138.4420	137.4713	138.7961
	2016	138.6010	138.5980	137.6273	139.0317
	2017	138.6301	138.6243	138.1569	139.1022