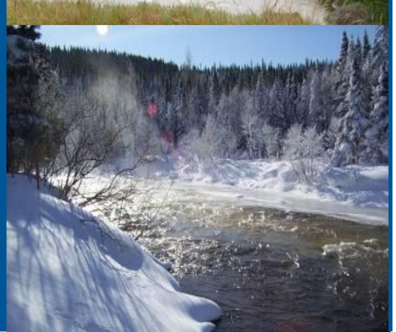










Real-Time Water Quality Deployment Report

Rattling Brook and Residue Storage Area Real-Time Water Quality Networks

Annual Report 2015

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

Introduction

Background

The Real-Time Water Quality Monitoring Network consists of more than 30 stations located on strategic water bodies in and around urban centers and major development projects. The network is supported through a combination of Provincial, Federal, and Industry partners.

Surface water monitoring in Long Harbour began in earnest near the end of 2007 at Rattling Brook below Bridge station. In November 2009 Rattling Brook Big Pond and Rattling Brook below Plant Discharge stations came online just before major groundwork on Vale NL's nickel refinery began. As construction moved along, monitoring around Sandy Pond (now known as the Residue Storage Area) began in 2012 with the installation of five stations.

The plant began limited production in late 2014 and has been slowly increasing production levels through 2015.

Photo 1: Aerial view of Rattling Brook surface water monitoring stations in Long Harbour

- All monitoring stations in Long Harbour report on an hourly basis. Surface water stations record water temperature, pH, specific conductivity, dissolved oxygen, and turbidity. Groundwater stations report water temperature, pH, specific conductivity, oxidation-reduction potential, and static water table elevation. Together, these parameters provide indicators of potential emerging water quality issues.

Photo 2: Aerial view of Sandy Pond (RSA) groundwater monitoring stations in Long Harbour

Maintenance and Calibration

Rattling Brook Surface Water Monitoring Stations

Surface water stations within the Real-Time Water Quality Monitoring Network are generally kept to a thirty day deployment period. Following the deployment period, instrumentation is removed from the water and subjected to a thorough cleaning and calibration process. This deployment period strikes a balance between excessive field outings and avoiding calibration drift and biofouling which impacts the integrity of the data collected.

In 2015, a total of 11 deployments took place with an average deployment duration of 31.2 days (See Table 1).

Table 1: Deployment Schedule for Rattling Brook monitoring stations

Station	Deployment	Removal	Duration (Days)
Big Pond	2015-01-01 00:00	2015-02-05 10:30	35.4
	2015-05-22 10:30	2015-06-25 08:30	33.9
	2015-06-26 10:30	2015-07-23 09:30	27.0
	2015-07-24 10:30	2015-08-20 08:30	26.9
	2015-08-21 10:30	2015-10-08 09:30	48.0
	2015-10-09 10:30	2015-11-12 10:30	34.0
	2015-11-13 10:30	2015-12-10 09:30	27.0
	2015-12-11 10:30	2015-12-31 23:30	20.5
	Percent of Year		69%
Below Bridge	2015-01-01 00:00	2015-02-05 10:30	35.4
	2015-02-06 10:30	2015-03-05 10:30	27.0
	2015-03-06 10:30	2015-04-22 09:30	47.0
	2015-04-23 10:30	2015-05-21 09:30	28.0
	2015-05-22 11:30	2015-06-25 09:30	33.9
	2015-06-26 10:30	2015-07-23 09:30	27.0
	2015-07-23 12:30	2015-08-13 02:30	20.6
	2015-08-21 11:30	2015-10-08 09:30	47.9
	2015-10-09 11:30	2015-11-12 10:30	34.0
	2015-11-13 11:30	2015-11-19 00:00	5.5
	2015-12-11 11:15	2015-12-31 23:30	20.5
	Percent of Year		90%
Below Plant Discharge	2015-01-01 00:00	2015-02-05 11:30	35.5
	2015-02-06 11:30	2015-03-05 10:30	27.0
	2015-03-06 11:30	2015-04-22 09:30	46.9
	2015-04-23 11:30	2015-05-21 09:30	27.9
	2015-05-22 11:30	2015-06-25 09:30	33.9
	2015-06-26 12:00	2015-07-23 11:30	27.0
	2015-07-23 11:30	2015-08-20 11:30	28.0
	2015-08-21 12:00	2015-10-08 11:30	48.0
	2015-10-09 00:00	2015-11-12 11:00	34.5
	2015-11-13 11:30	2015-12-10 11:00	27.0
	2015-12-10 11:00	2015-12-31 23:30	21.5
	Percent of Year		98%

Residue Storage Area Groundwater monitoring stations

Unlike the surface water stations which are subjected to the effects of biofouling and weather, groundwater monitoring instrumentation undergoes three month deployment intervals. Due to challenging purchasing and shipping logistics, a delay in receiving needed replacement pH sensors resulted in changes to the deployment schedule. In total, three deployments were made in 2015.

Table 2: Deployment Schedule for Sandy Pond (RSA) monitoring stations

Station	Deployment	Removal	Duration (days)
Well 1 Deep	2015-01-01 00:36	2015-05-19 09:36	138.4
	2015-05-20 10:36	2015-10-26 09:36	159.0
	2015-10-29 11:36	2015-12-31 23:36	63.5
	Percent of Year		99%
Well 2 Shallow	2015-01-01 00:24	2015-05-19 09:24	138.4
	2015-05-20 10:24	2015-10-26 09:24	159.0
	2015-10-29 12:24	2015-12-31 23:36	63.5
	Percent of Year		99%
Well 2 Deep	2015-01-01 00:36	2015-05-19 09:36	138.4
	2015-05-20 10:36	2015-10-26 09:36	159.0
	2015-10-29 12:36	2015-12-31 23:36	63.5
	Percent of Year		99%
Well 3 Deep	2015-01-01 00:36	2015-05-19 10:36	138.4
	2015-05-20 11:36	2015-10-26 10:36	159.0
	2015-11-13 13:36	2015-12-31 23:36	48.4
	Percent of Year		95%
Well 4 Deep	2015-01-01 00:36	2015-05-19 08:36	138.3
	2015-05-20 09:36	2015-10-26 08:36	159.0
	2015-10-29 13:36	2015-12-31 23:36	63.4
	Percent of Year		99%

Results and Discussion

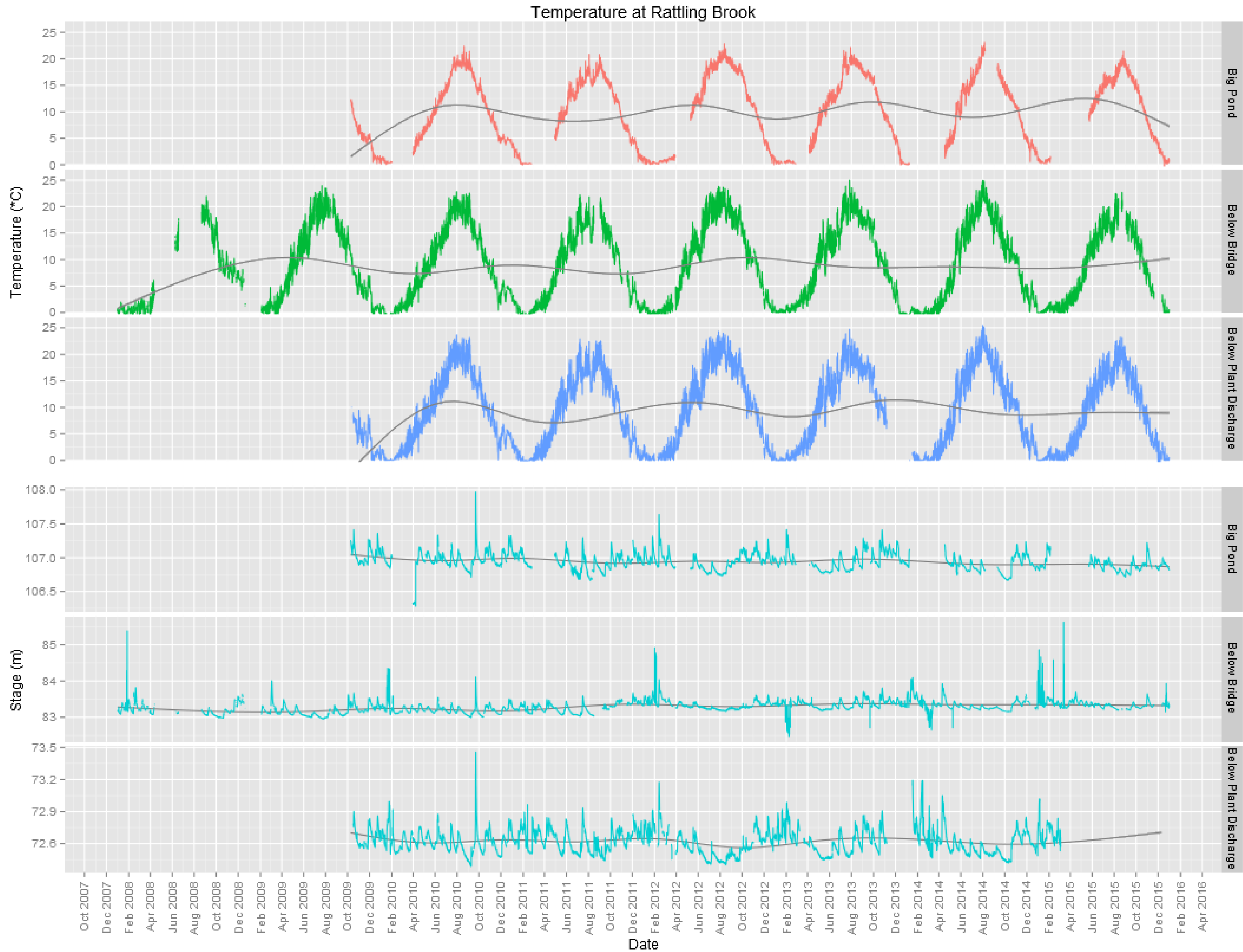
The following sections present and discuss water quality trends and events over the course of 2015 and comparisons to previous years.

Rattling Brook Stations

Water Temperature

- Owing to a cool June and July in the summer of 2015, mean and median water temperatures were lower at Bridge and Plant Discharge stations – as much as a 1.3°C variation observed at Plant Discharge station.
- Interestingly, Big Pond did not show a great deal of difference from past years. This may be due to the relatively large amount of groundwater inflow into Big Pond compared to downstream areas. Groundwater inflow tends to be much more consistent in temperature since it isn't exposed to variations in weather.

Figure 1: Water temperature at the Rattling Brook Real-Time Water Quality Monitoring Network Stations from 2008 to 2015



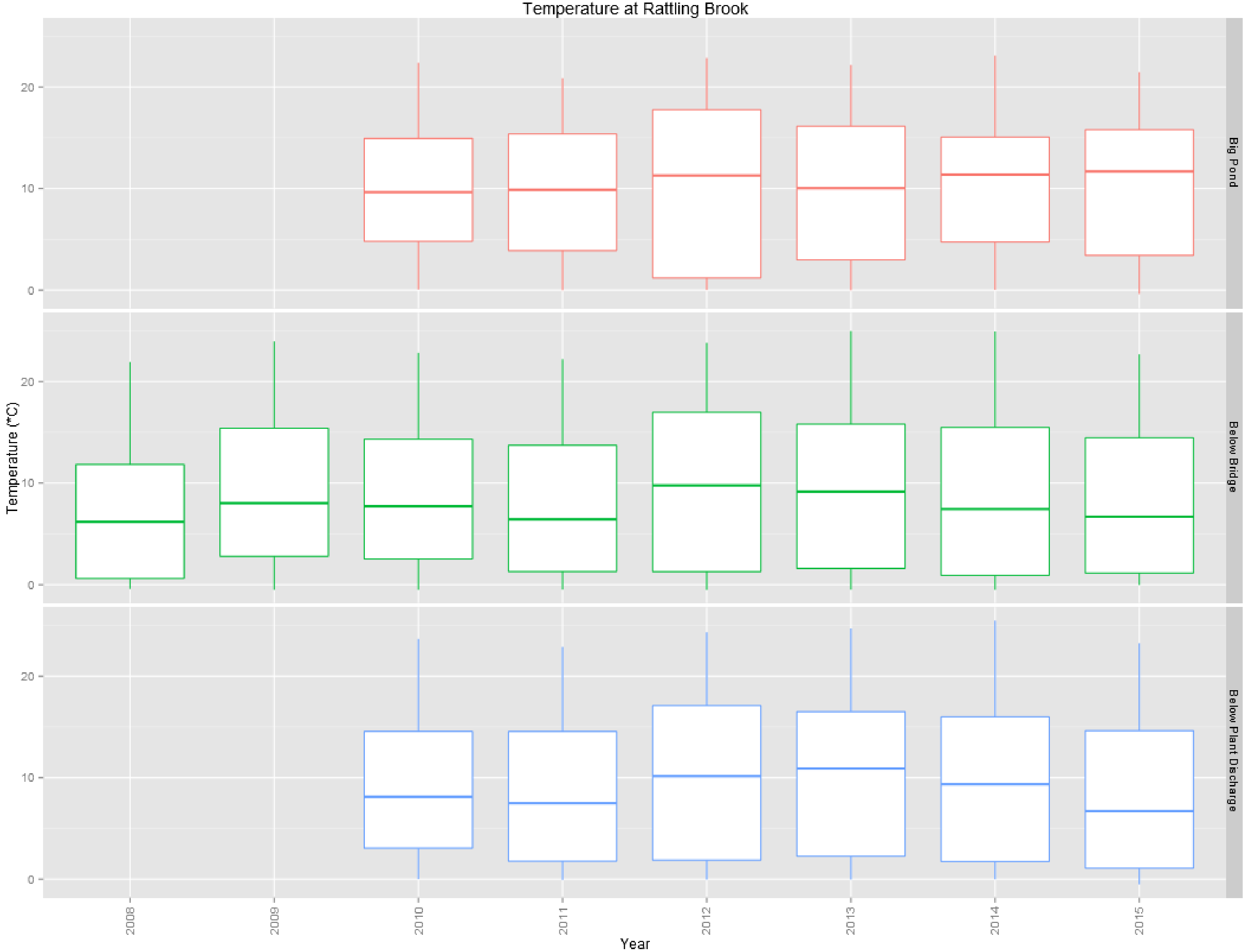
- Boxplots of complete years are shown in Figure 2 allowing for a direct comparison between years and stations. On an annual basis, Big Pond tends to be biased towards warmer temperatures compared to Bridge and Plant Discharge stations, owing to the flowing nature of the water downstream. Big Pond tends to retain more heat over the winter than the lower stations.

Table 3: Surface water temperature – Descriptive Statistics*

Station	Year	Mean	Median	Min	Max
Big Pond	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
	Mean (2010 - 2015): 10.00				
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
	Mean (2008 - 2015): 8.42				
Below Plant Discharge	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
	Mean (2010 - 2015): 9.41				

* Values in °C.

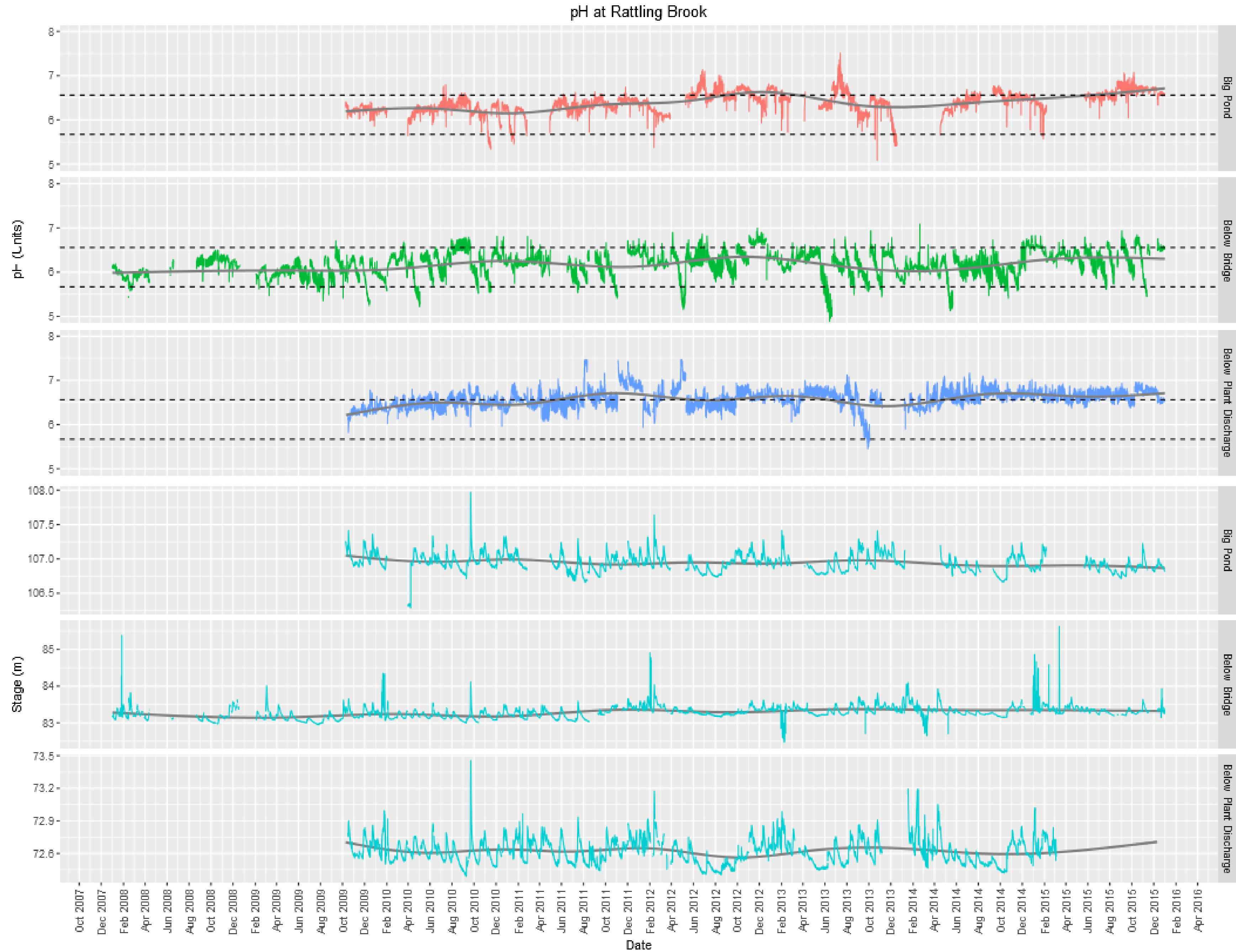
Figure 2: Boxplots of water temperature at the Rattling Brook Real-Time Water Quality Monitoring Network Stations from 2008 to 2015



pH

- pH levels show an increasing trend over time at each of the three Rattling Brook stations. Each stations shows between a 0.2 to 0.3 unit increasing in pH since inception. It is difficult to pinpoint the exact reason for this, however, there is also a concurrent increase in alkalinity throughout Rattling Brook. Alkalinity, the buffering capacity of water, is associated with pH in the sense that soluble ions are less capable of maintaining the typical low pH found in Newfoundland. The increase in alkalinity is likely due to mobility of previously soil-bound ions such as Ca and Mg.
- Most pH values continue to fall near or just above the Site Specific Guidelines set before major construction at the Vale plant site.

Figure 3: pH at the Rattling Brook Real-Time Water Quality Monitoring Network Stations from 2008 to 2015



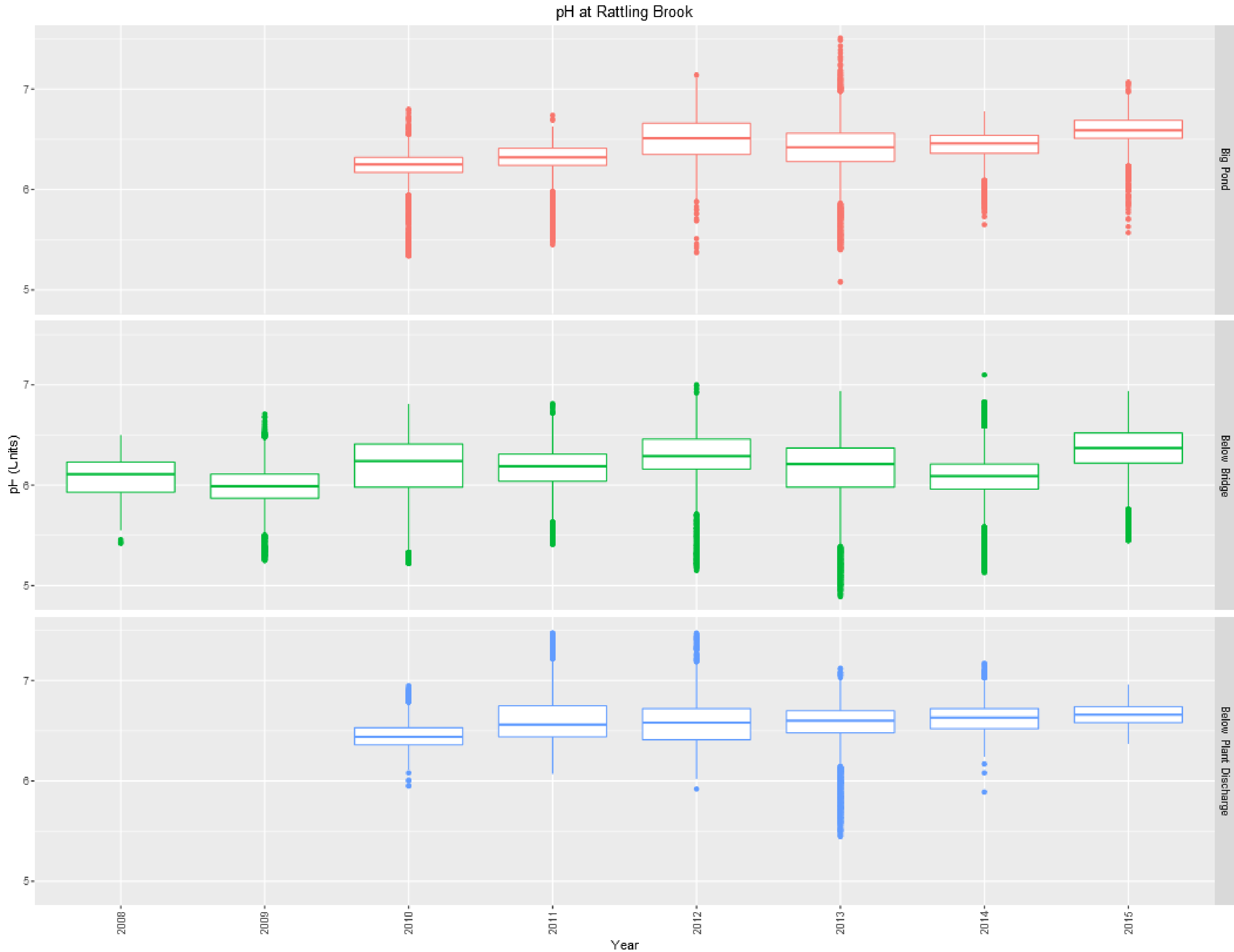
- Variation in pH appears to have been most substantial during the years 2011 to 2013 when major earthworks were occurring in the Rattling Brook area. Following this time, construction was the predominant activity onsite, allowing for soils to settle.
- pH is regularly highest at Plant Discharge Station, followed by Big Pond station and lowest at Bridge station.

Table 4: Surface water pH – Descriptive Statistics*

Station	Year	Mean	Median	Min	Max
Big Pond	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	6.40	6.42	5.08	7.51
	2014	6.43	6.46	5.65	6.78
	2015	6.58	6.59	5.57	7.07
	Mean (2010 - 2015): 6.40				
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
	Mean (2008 - 2015): 6.16				
Below Plant Discharge	2010	6.45	6.44	5.95	6.95
	2011	6.61	6.56	6.07	7.47
	2012	6.58	6.58	5.92	7.47
	2013	6.54	6.60	5.45	7.12
	2014	6.62	6.63	5.89	7.17
	2015	6.66	6.66	6.37	6.96
	Mean (2010 - 2015): 6.58				

*Values in pH Units

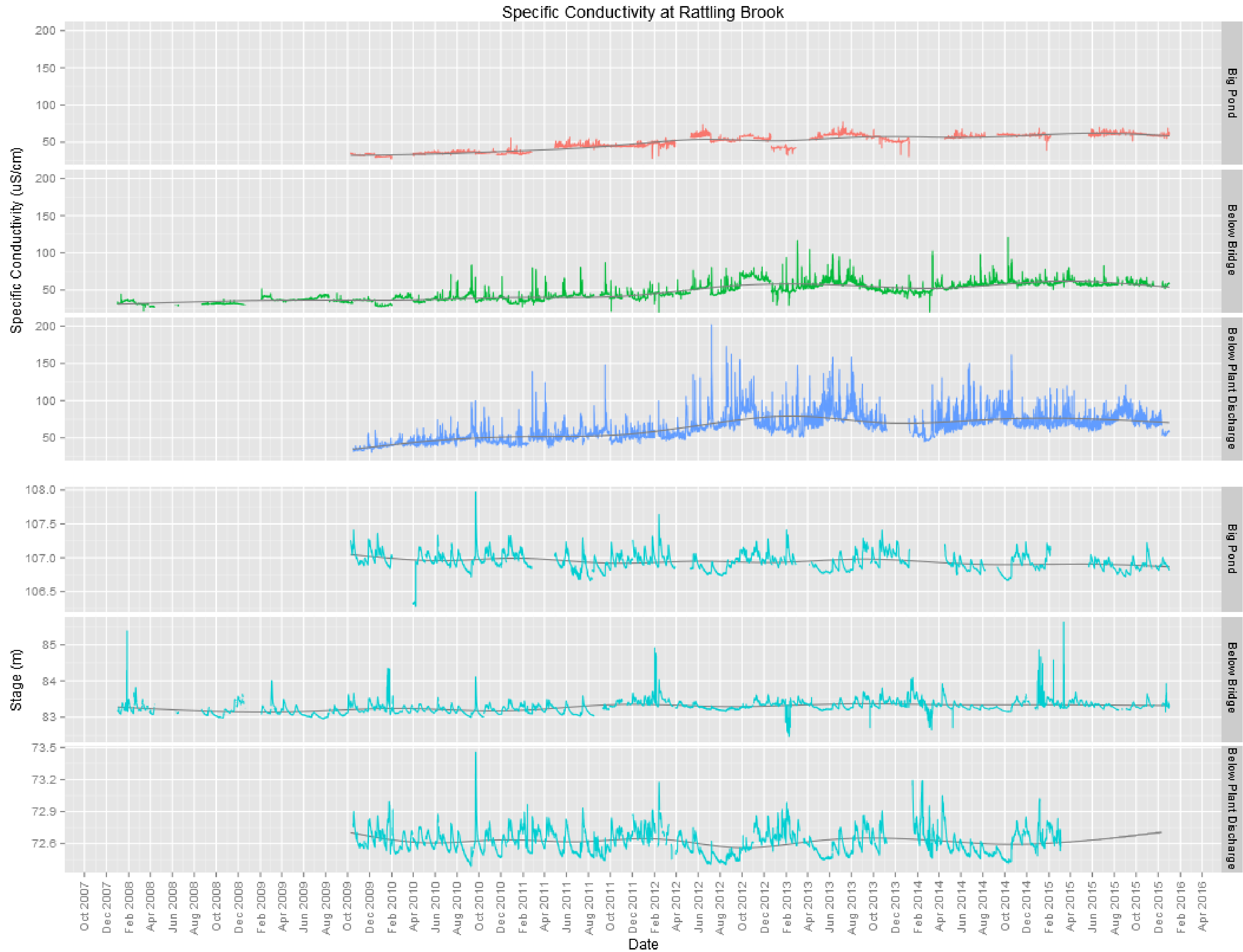
Figure 4: Boxplots of pH at the Rattling Brook Real-Time Water Quality Monitoring Network Stations from 2008 to 2015



Specific Conductivity

- As expected from the consistent increase in pH and alkalinity, specific conductivity has shown a strong increase year over year at Rattling Brook due to soil mobilisation, flow from construction surfaces, and discharge from settling ponds in the case of Plant Discharge station.
- Like pH, Specific Conductivity at Plant Discharge station tends to be highest, followed by Big Pond and then Bridge station. It is unexpected that Bridge station should show lower conductivity than Big Pond station since dissolved solids tend to concentrate towards the lower reaches of a river system. It is possible that a groundwater inflow of lower dissolved solids contributing to the flow of Rattling Brook between Big Pond and Bridge station.

Figure 5: Specific Conductivity at the Rattling Brook Real-Time Water Quality Monitoring Network Stations from 2008 to 2015



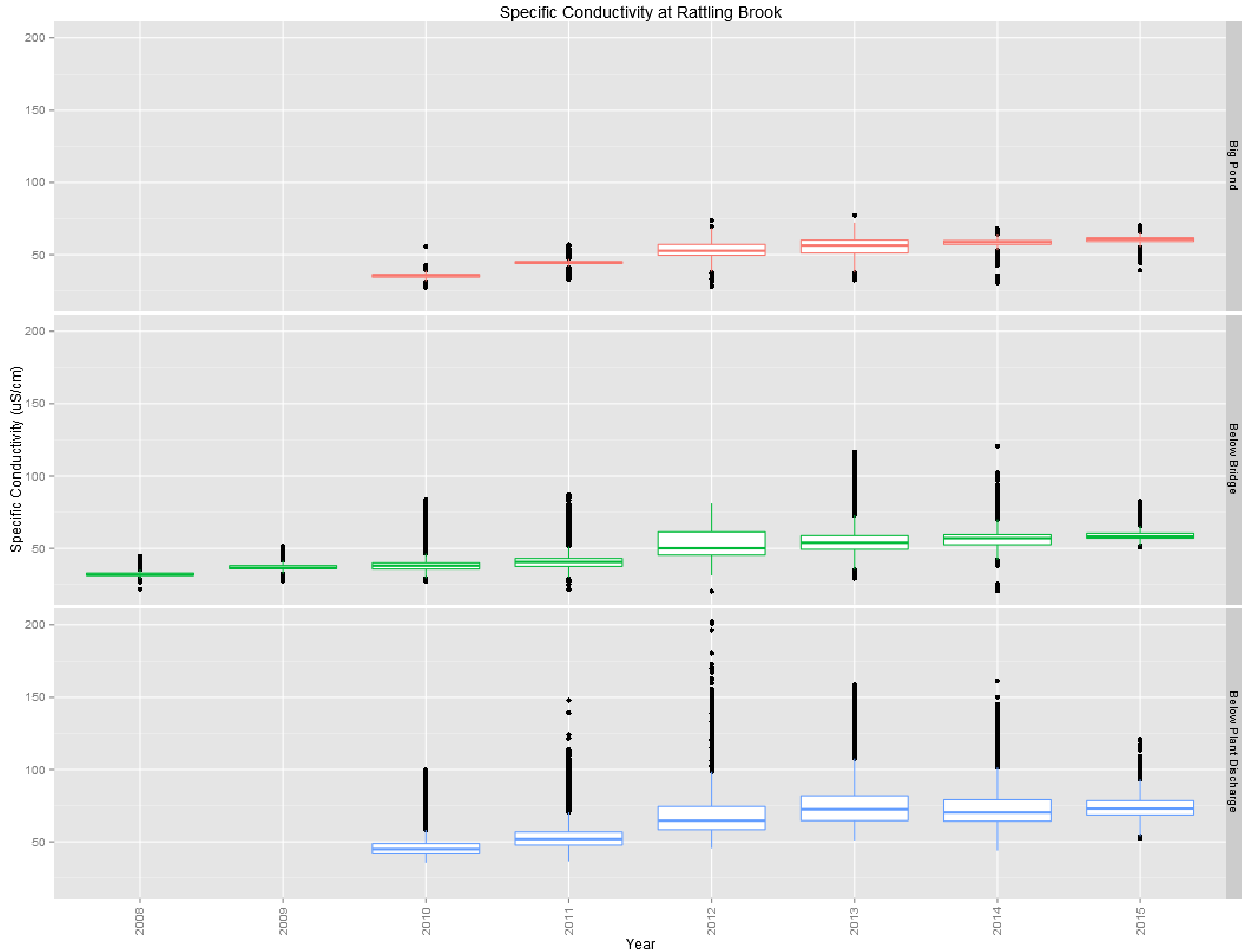
- Variation in conductivity was especially pronounced in 2012 and 2013 at all stations during major earthworks. Since 2013, variation has decreased, although mean and median values have continued to increase.

Table 5: Surface water Specific Conductivity – Descriptive Statistics*

Station	Year	Mean	Median	Min	Max
Big Pond	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
	Mean (2010 - 2015): 50.9				
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
	Mean (2008 - 2015): 46.4				
Below Plant Discharge	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
	Mean (2010 - 2015): 65.2				

*Values in uS/cm

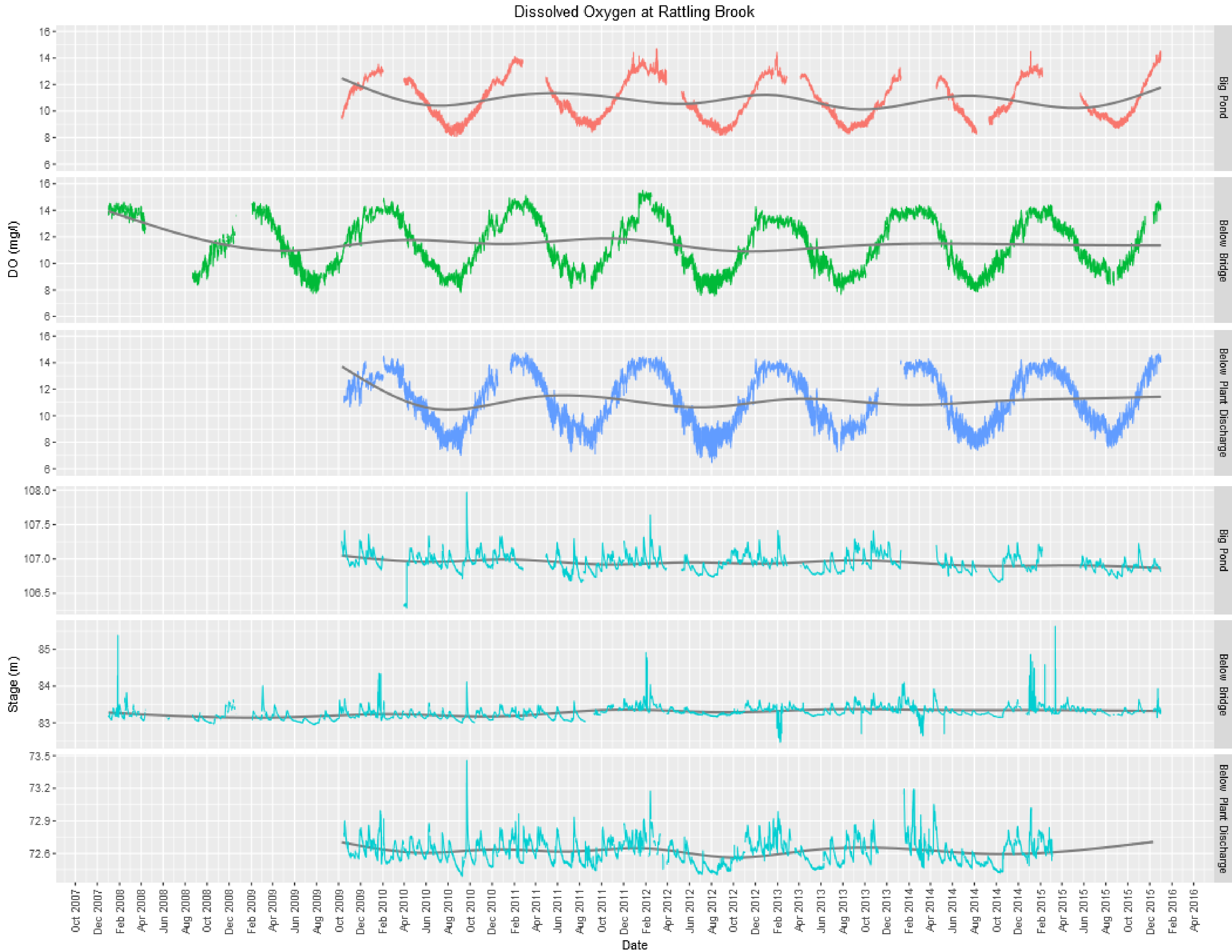
Figure 6: Boxplots of Specific Conductivity at the Rattling Brook Real-Time Water Quality Monitoring Network Stations from 2008 to 2015



Dissolved Oxygen

- The characteristics of dissolved oxygen concentrations in Rattling Brook are similar to those of water temperature, except in reverse. Variation in concentration tends to be low at Big Pond because of the stable water temperature.

Figure 7: Dissolved Oxygen at the Rattling Brook Real-Time Water Quality Monitoring Network Stations from 2008 to 2015



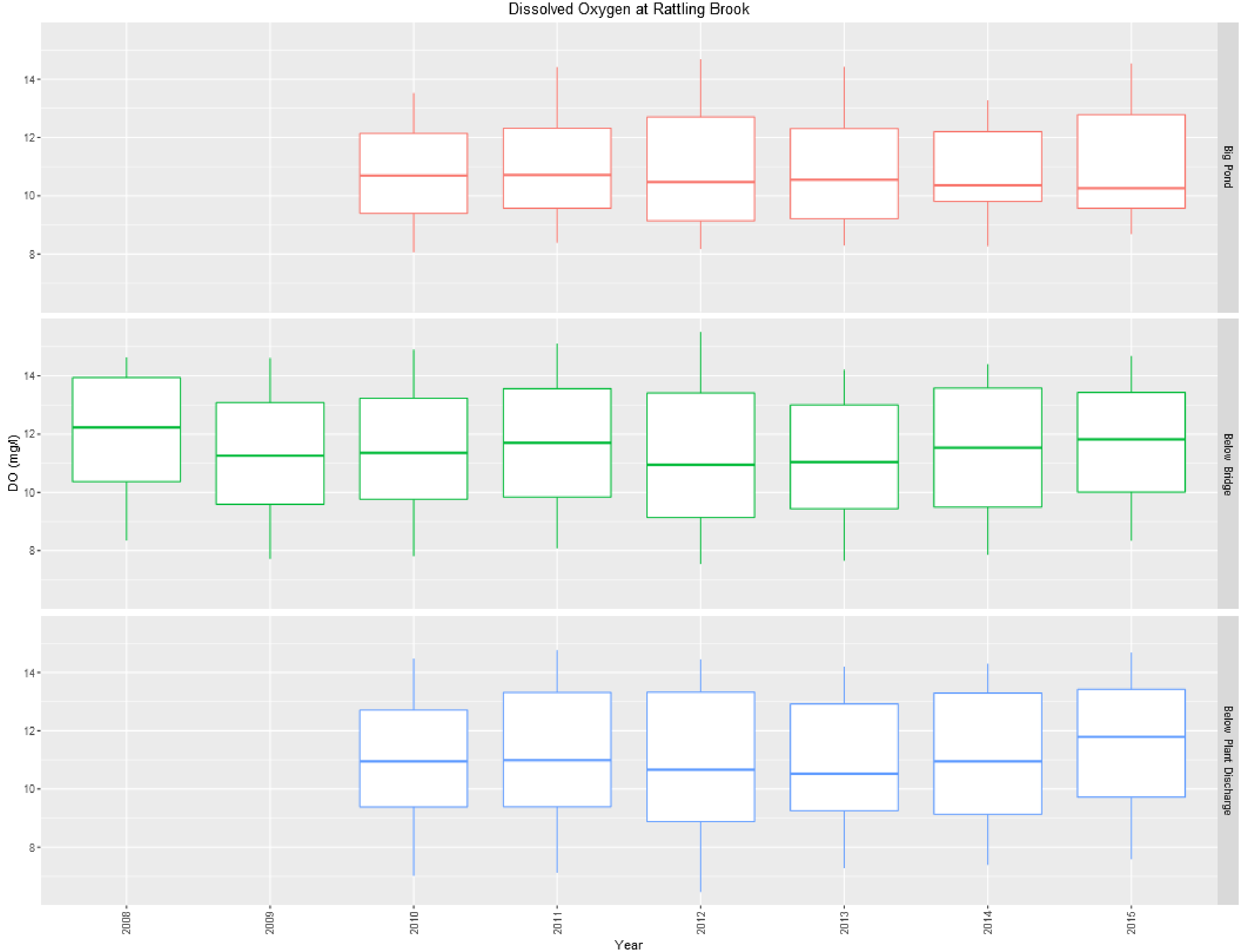
- Big Pond station is usually lower in dissolved oxygen concentration than Bridge and Plant Discharge stations due to warmer temperatures and relatively still water. The flowing conditions downstream encourages greater dissolution of oxygen.

Table 6: Surface water Dissolved Oxygen – Descriptive Statistics*

Station	Year	Mean	Median	Min	Max
Big Pond	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
	Mean (2010 - 2015): 10.83				
Below Bridge	2008	12.08	12.23	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
	Mean (2008 - 2015): 11.52				
Below Plant Discharge	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
	Mean (2010 - 2015): 11.12				

*Values in mg/l

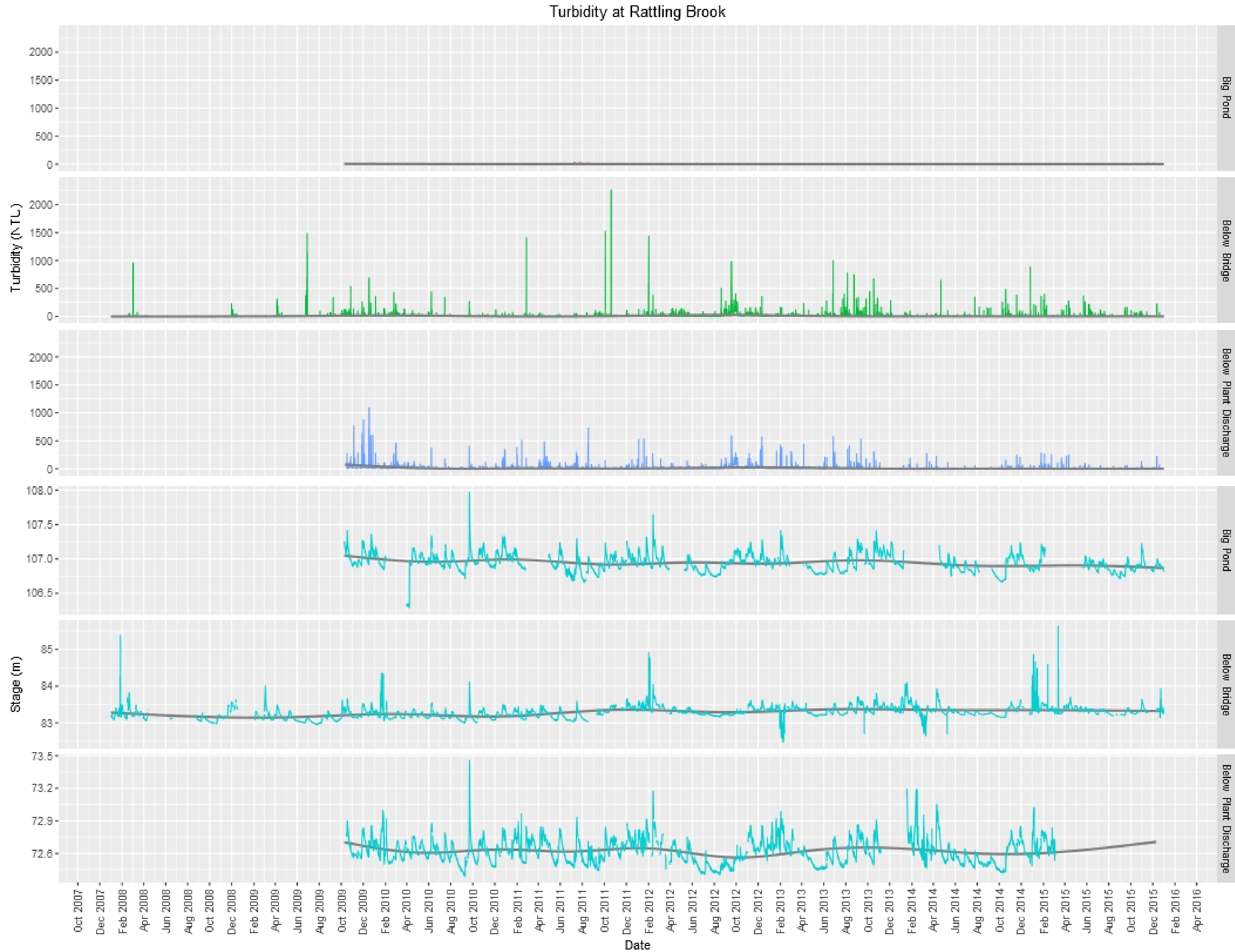
Figure 8: Boxplots of Dissolved Oxygen at the Rattling Brook Real-Time Water Quality Monitoring Network Stations from 2008 to 2015



Turbidity

- For the second year in a row, median turbidity levels at Bridge and Plant Discharge stations have fallen to 0.0 NTU. Construction and earth moving activities were responsible for elevated turbidity levels, especially in 2012 and 2013.
- It is expected that, in time, variability and peak levels following precipitation will continue to decline to pre-2012 levels.

Figure 9: Turbidity at the Rattling Brook Real-Time Water Quality Monitoring Network Stations from 2008 to 2015



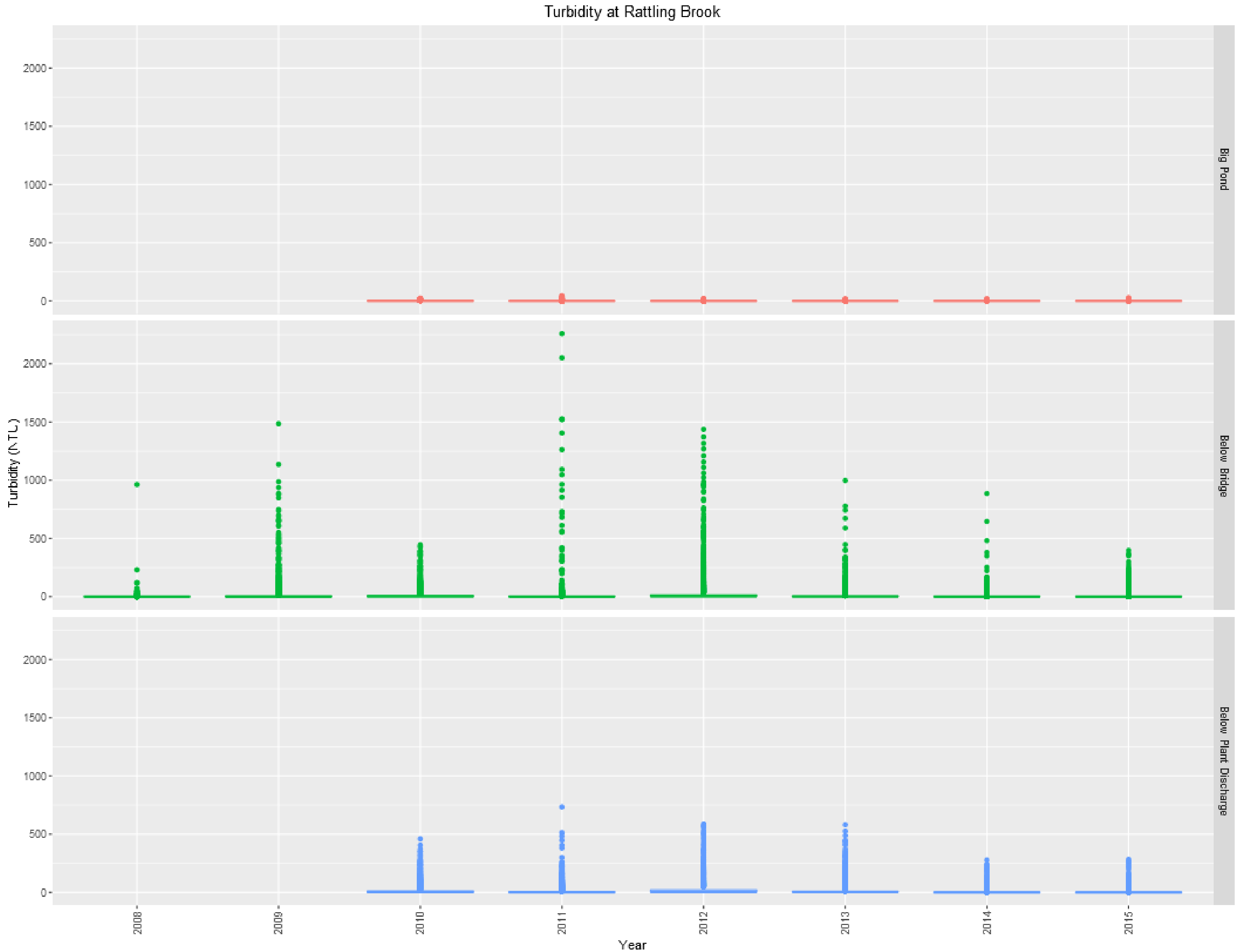
- The boxplots at right illustrate low turbidity levels (coloured rectangles) with a large number of outliers (black dots). These outliers tend to occur during precipitation events and high flows. The gradual decrease in magnitude of outliers from 2012 to 2015 indicates a decreasing trend in high-turbidity events.

Table 7: Surface water Turbidity – Descriptive Statistics*

Station	Year	Mean	Median	Min	Max
Big Pond	2010	1.3	0.0	0.0	23.0
	2011	0.6	0.0	0.0	44.9
	2012	0.2	0.0	0.0	22.0
	2013	0.0	0.0	0.0	19.1
	2014	0.0	0.0	0.0	18.7
	2015	0.3	0.0	0.0	25.3
	Mean (2010 - 2015): 0.4				
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
	Mean (2008 - 2015): 7.7				
Below Plant Discharge	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
	Mean (2010 - 2015): 9.0				

*Values in NTU

Figure 10: Boxplots of turbidity at the Rattling Brook Real-Time Water Quality Monitoring Network Stations from 2008 to 2015

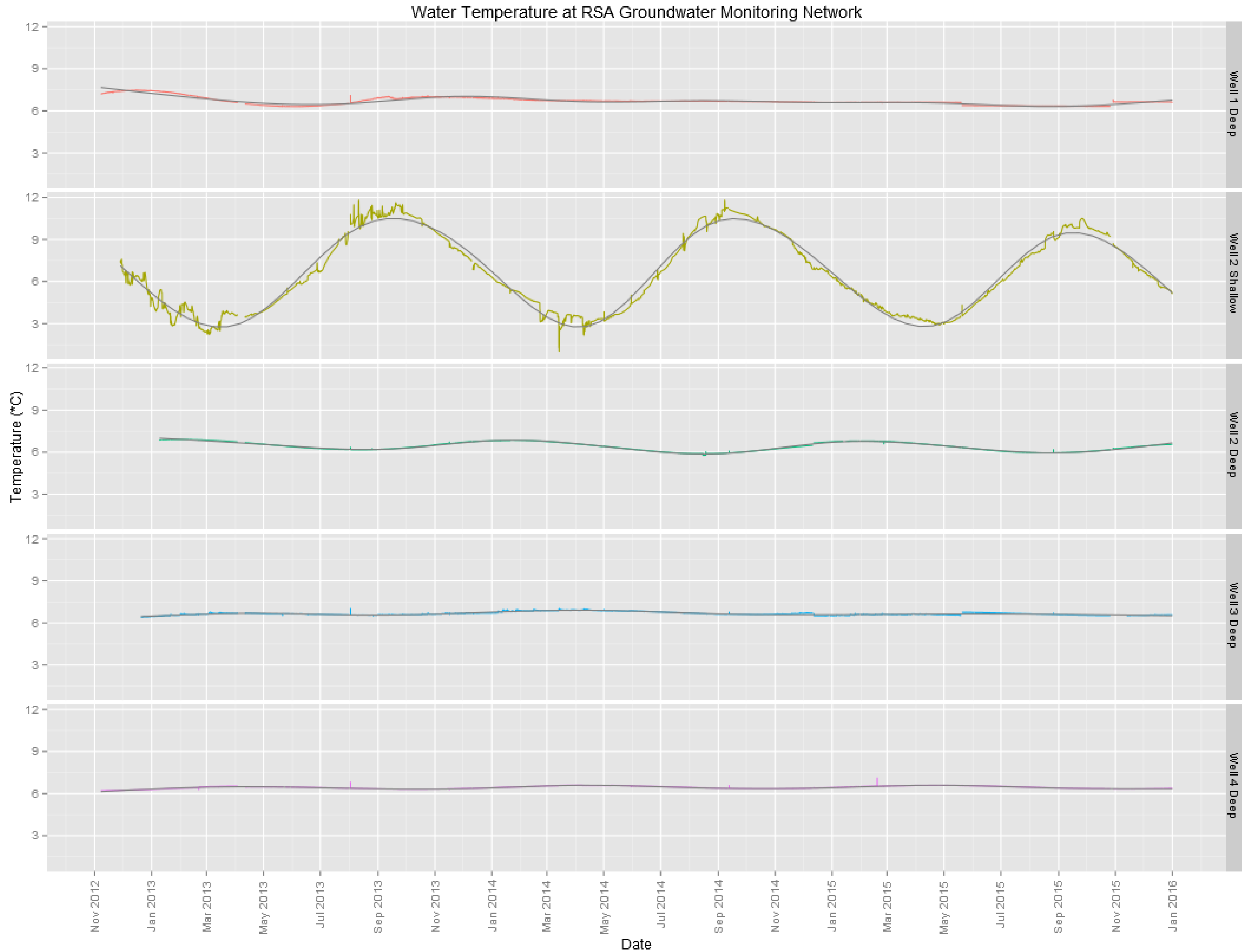


Residue Storage Area Stations

Water Temperature

- Groundwater temperature is a very stable characteristic of an aquifer and variation is indicative of interaction with surface waters. In the figure to the right, at first glance it is readily apparent that Well 2 Shallow is highly influenced by surface interaction. Closer inspection reveals that Well 2 Deep, Well 3 Deep, and Well 4 Deep also exhibit some annual cycling, though to a much smaller extent (Well 1 Deep may exhibit some cycling, but it is less obvious from the graphs).
- Annual temperature cycling is out of phase with surface conditions, with Well 2 Shallow exhibiting closer interaction with surface conditions than the other wells. For instance, water temperature at Well 2 Shallow is highest in September and October (just after the maximum annual surface temperatures). Well 2 Deep tends to peak in January and February indicating that warmer water takes at least five months to percolate into the well. Well 3 Deep and Well 4 Deep are even more out of phase with surface temperatures, peaking in March and April (seven months lag).

Figure 11: Water temperature at the Residue Storage Area Groundwater Quality Monitoring Network from 2012 to 2015



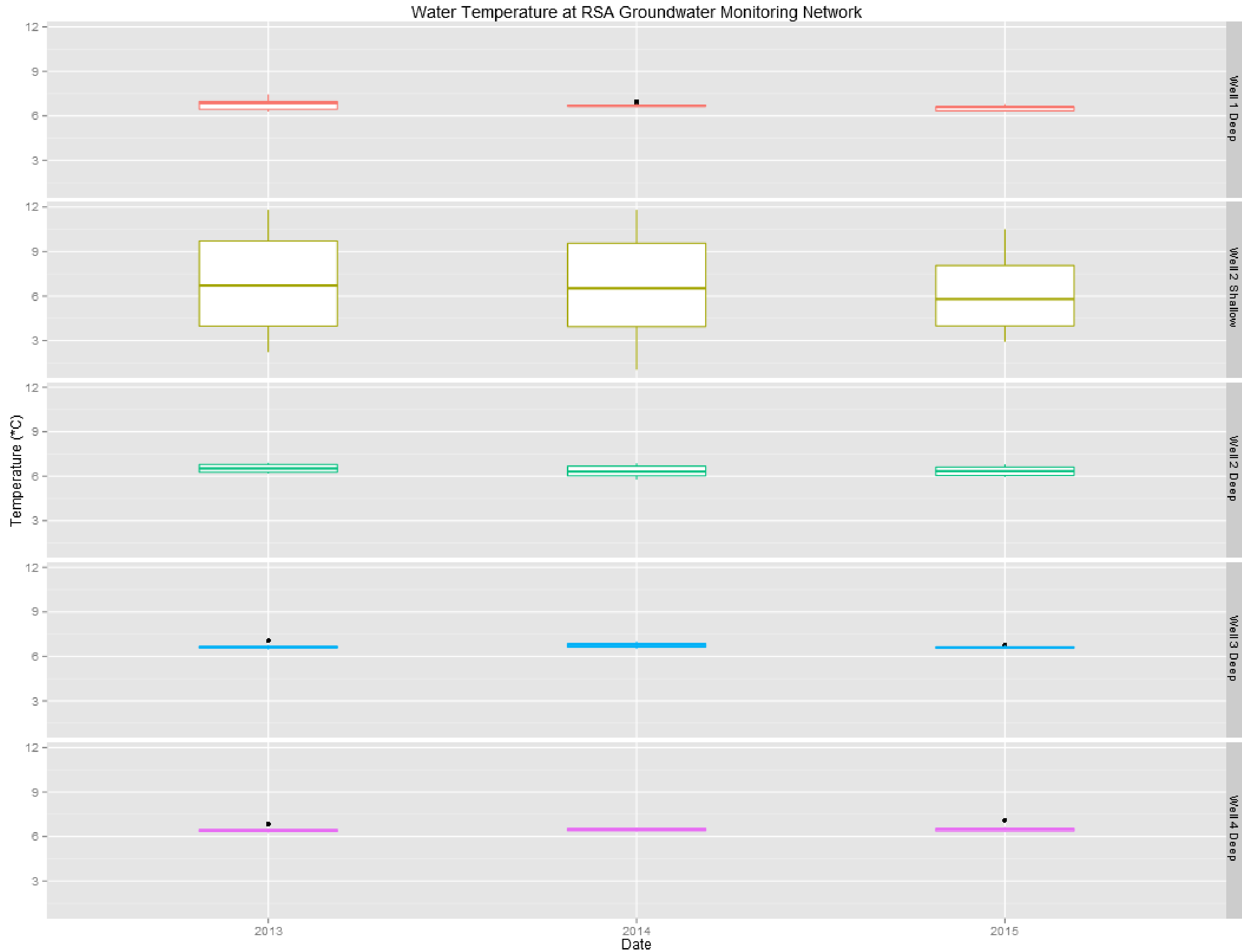
- All wells except Well 2 Shallow show a narrow range of water temperatures with mean and median values between 6.3°C and 6.8°C. Significant temperature variation in Well 2 Shallow is indicative of surface-water interaction.

Table 8: Groundwater temperature – Descriptive Statistics*

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	6.50	6.60	6.32	6.80
	Mean (2013 - 2015): 6.73				
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
	Mean (2013 - 2015): 6.77				
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
	Mean (2013 - 2015): 6.35				
Well 3 Deep	2013	6.62	6.63	6.46	7.05
	2014	6.75	6.76	6.50	7.01
	2015	6.61	6.59	6.50	6.77
	Mean (2013 - 2015): 6.62				
Well 4 Deep	2013	6.40	6.39	6.25	6.85
	2014	6.46	6.46	6.32	6.61
	2015	6.46	6.48	6.32	7.12
	Mean (2013 - 2015): 6.40				

* Values in °C

Figure 12: Boxplots of water temperature at the Residue Storage Area Groundwater Quality Monitoring Network from 2013 to 2015

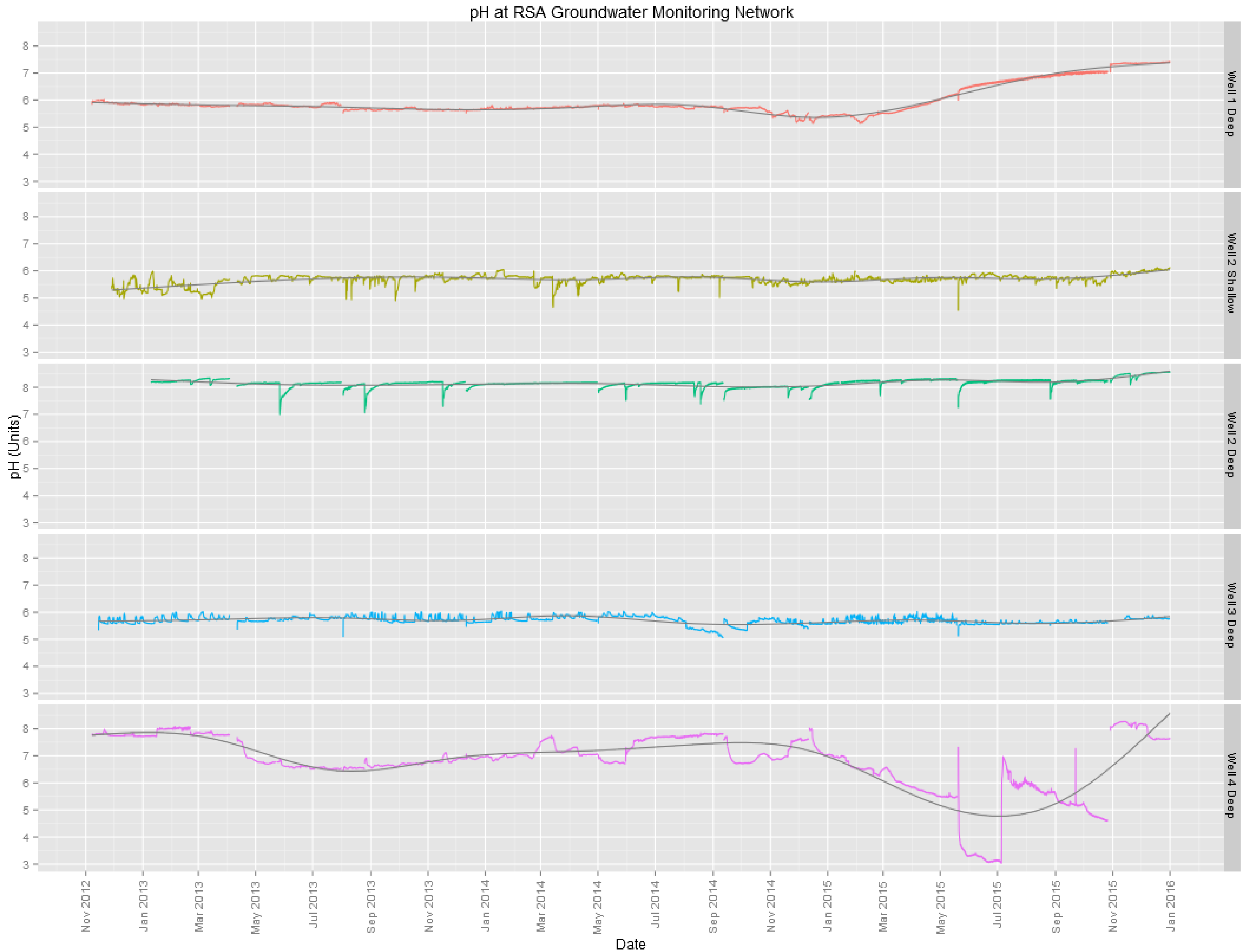


pH

Groundwater pH since monitoring was initiated is presented to the right. From November/December 2012 to January 2015, pH levels were stable, however there is some indication that pH levels are on an upward trend. This trend will be monitored closely.

The changes in pH may also indicate changes to aqueous geochemistry over time due to water's interaction with bedrock. This change may be enhanced by a static water column (i.e. the water in the well is not purged and stays in the borehole, which is open to the atmosphere). pH measured in Well 4 Deep seems to indicate a variable recharge source, which may indicate interaction with either a surface or other groundwater source.

Figure 13: pH at the Residue Storage Area Groundwater Quality Monitoring Network from 2012 to 2015



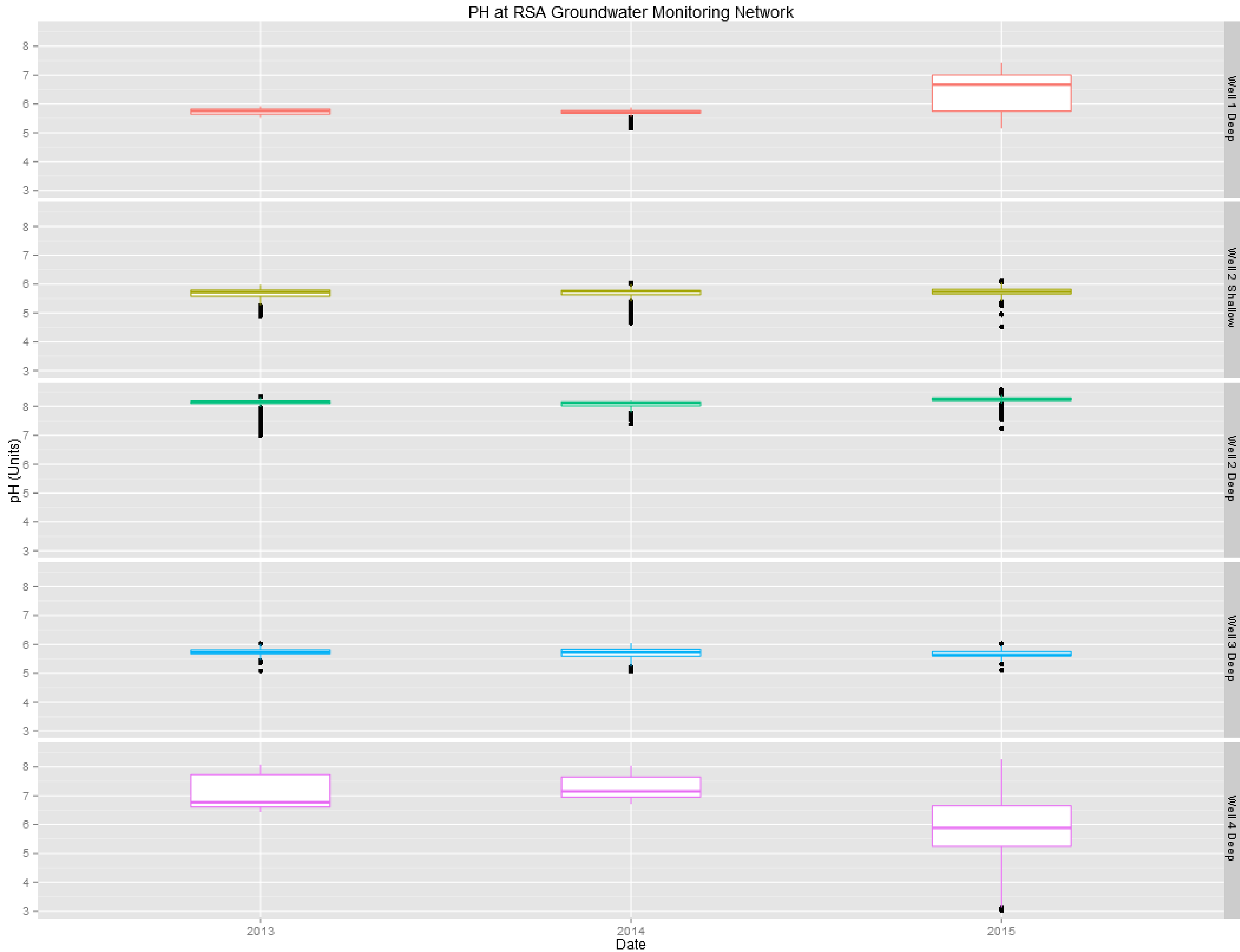
- Boxplots indicate that, aside from outlier low-values (often seen just after deployment), pH is generally very consistent across all wells – Well 4 Deep being the exception. It is unknown why there is a great degree of variation in pH, however, specific conductivity is also highly variable, indicating interaction with another recharge source, either surface water or groundwater.

Table 9: Groundwater pH – Descriptive Statistics*

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
	Mean (2013 - 2015): 5.71				
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
	Mean (2013 - 2015): 5.67				
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
	Mean (2013 - 2015): 8.10				
Well 3 Deep	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
	Mean (2013 - 2015): 5.72				
Well 4 Deep	2013	7.03	6.77	6.43	8.08
	2014	7.25	7.15	6.71	8.04
	2015	5.91	5.88	3.03	8.27
	Mean (2013 - 2015): 7.14				

* Values in pH units.

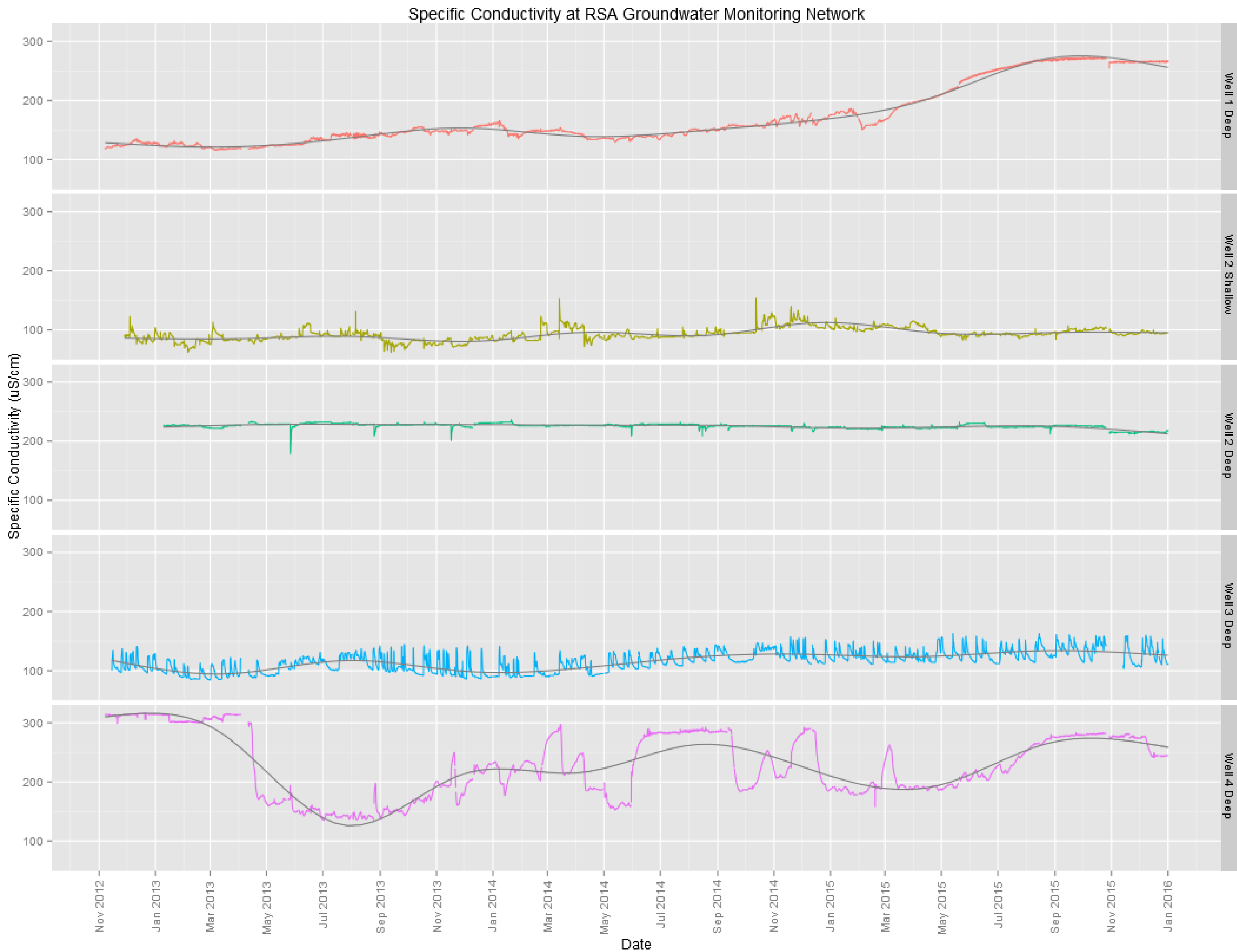
Figure 14: Boxplots of pH at the Residue Storage Area Groundwater Quality Monitoring Network from 2013 to 2015



Specific Conductivity

- Well 2 Deep is the only well not showing an increase in specific conductivity. Conductivity has been slowly increasing at each well since inception, indicating that previously soil-bound minerals may have been liberated due to clearing and earthworks in the area. Since infiltration takes a substantial period of time, this would result in a slow increase over time.
- Infiltration of lower conductivity shallow groundwater into the deeper aquifer of Well 2 Deep may also be a reason for a downward trend in that well.

Figure 15: Specific conductivity at the Residue Storage Area Groundwater Quality Monitoring Network from 2012 to 2015



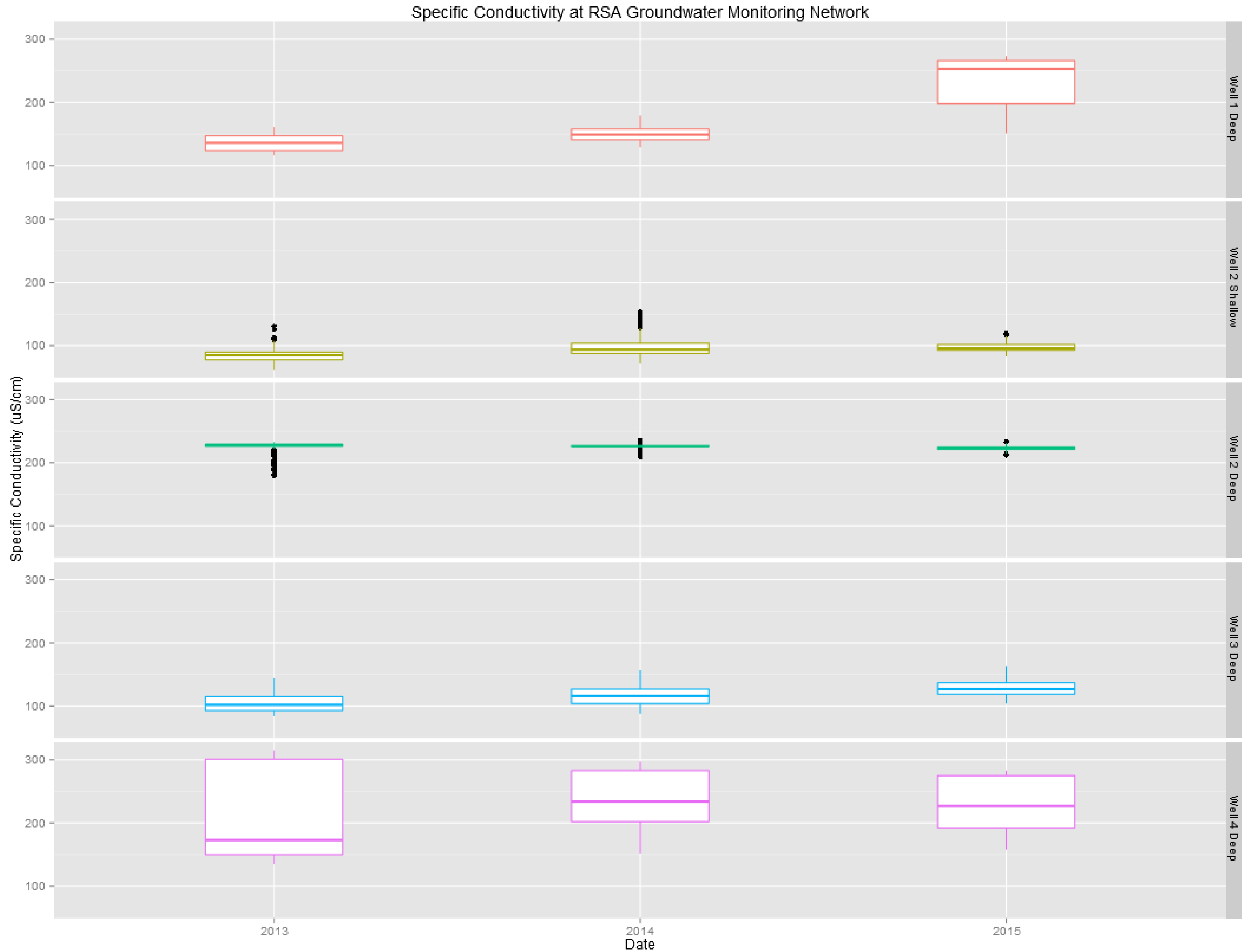
- Whereas specific conductivity has always been variable at Well 4 Deep, specific conductivity at Well 1 Deep has increased substantially in 2015, indicated by the rise near the end of Figure 15 and the large boxplot for 2015 compared to 2013 and 2014. This could be due to water-rock interactions

Table 10: Groundwater specific conductivity – Descriptive Statistics*

Station	Year	Mean	Median	Min	Max
Well 1 Deep	2013	135	136	116	161
	2014	150	149	129	179
	2015	233	253	151	273
	Mean (2013 - 2015): 143				
Well 2 Shallow	2013	85	85	62	131
	2014	96	94	72	154
	2015	97	96	83	120
	Mean (2013 - 2015): 91				
Well 2 Deep	2013	228	228	179	233
	2014	226	226	209	236
	2015	223	224	212	233
	Mean (2013 - 2015): 227				
Well 3 Deep	2013	105	102	84	144
	2014	115	116	88	157
	2015	129	127	104	163
	Mean (2013 - 2015): 110				
Well 4 Deep	2013	206	173	135	315
	2014	237	234	152	297
	2015	232	227	158	283
	Mean (2013 - 2015): 222				

* Values in uS/cm

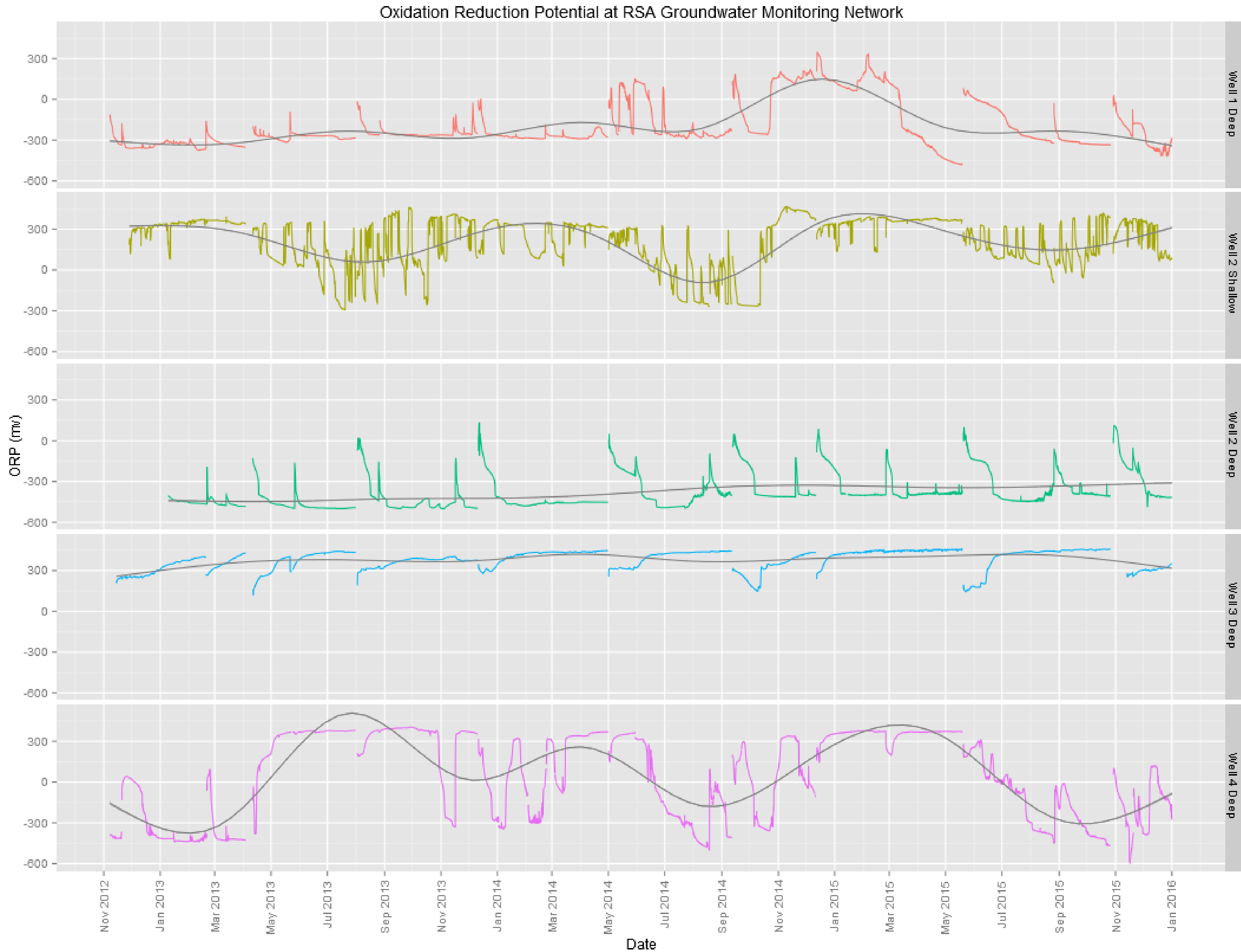
Figure 16: Boxplots of specific conductivity at the Residue Storage Area Groundwater Quality Monitoring Network from 2013 to 2015



Oxidation-Reduction Potential

- Long-term changes in ORP give An increasing ORP trend in wells 2 and 3 Deep indicated that conditions are becoming more oxidative in nature. Other wells show variation over time but no clear trend.
- A high level of variation in ORP may be indicative of low concentrations of ionic species that contribute to redox processes. In such a case, the removal and deployment of instrumentation from the well during maintenance may result in changes to the concentration of ions present. The time needed for ionic concentrations to find equilibrium may be the reason ORP levels take a great deal of time to settle following maintenance.

Figure 17: Oxidation-Reduction Potential at the Residue Storage Area Groundwater Quality Monitoring Network from 2012 to 2015



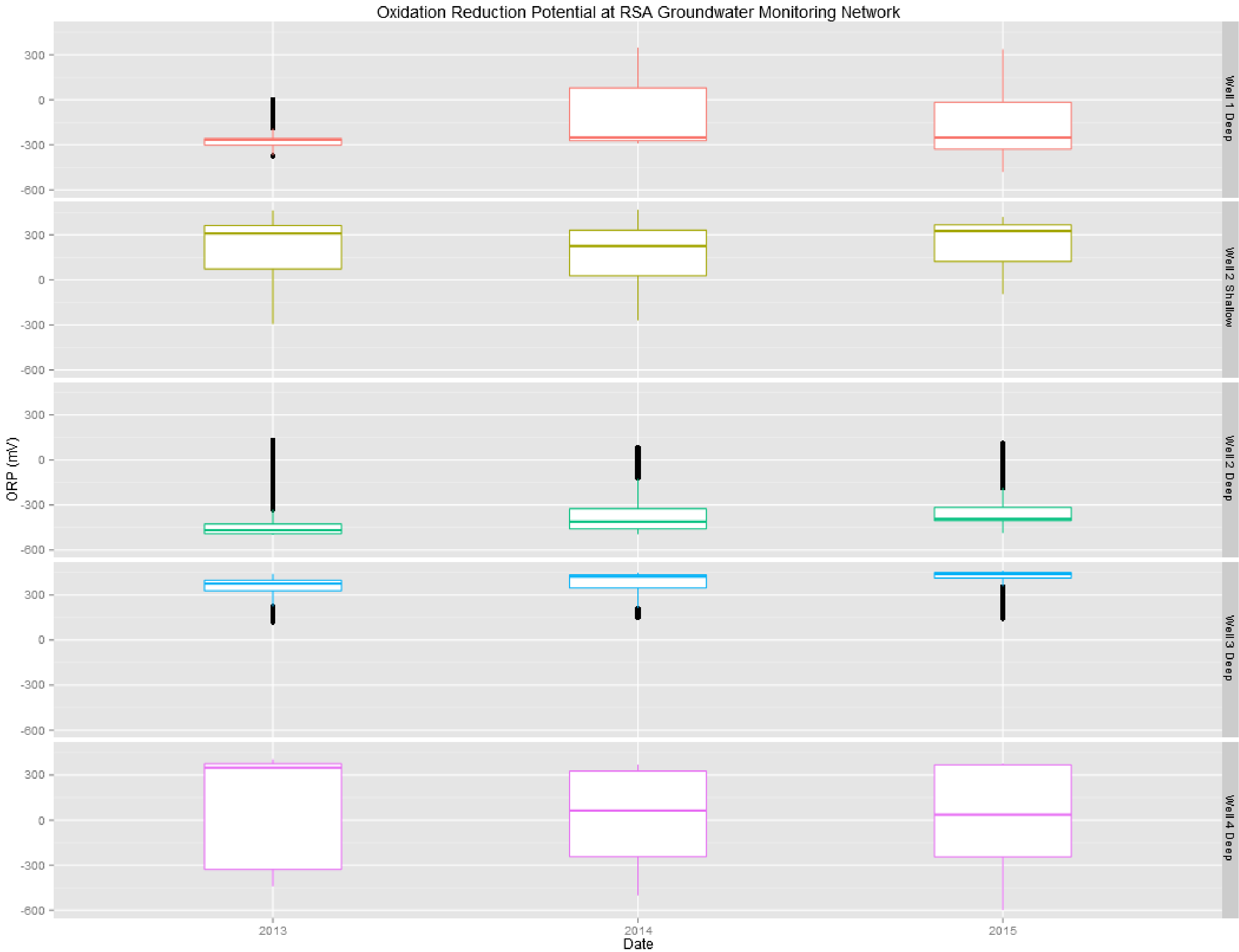
- Because ORP is highly variable at all stations, it is difficult to observe substantial trends over time. It is possible to determine the predominant redox state of each well. Well 1 Deep and Well 2 Deep are predominantly reductive in state. This may also correlate with the changed in pH and specific conductivity. A reductive state in acidic conditions will tend to prefer more soluble metal ions. Conversely, an oxidative state will tend to precipitate metal ions and reduce their mobility through the aquifer.

Table 11: Groundwater oxidation-reduction potential – Descriptive Statistics*

Station	Year	Mean	Median	Min	Max
Well 1 Deep	2013	-271.94	-266.40	-375.20	1.70
	2014	-134.61	-250.60	-291.00	347.30
	2015	-180.84	-250.95	-481.60	336.20
	Mean (2013 - 2015): -203.27				
Well 2 Shallow	2013	208.00	309.00	-293.70	461.70
	2014	155.62	225.50	-269.00	466.50
	2015	252.57	325.35	-94.90	419.20
	Mean (2013 - 2015): 181.81				
Well 2 Deep	2013	-428.69	-467.70	-499.50	131.90
	2014	-370.11	-411.10	-495.40	84.40
	2015	-339.74	-392.10	-486.30	114.00
	Mean (2013 - 2015): -399.4				
Well 3 Deep	2013	364.17	375.90	119.70	442.00
	2014	388.15	422.10	147.20	448.40
	2015	401.80	440.20	143.20	462.90
	Mean (2013 - 2015): 376.16				
Well 4 Deep	2013	98.46	349.50	-439.70	404.70
	2014	44.72	63.95	-501.00	370.10
	2015	42.99	35.70	-597.80	378.10
	Mean (2013 - 2015): 71.59				

*Values in mV.

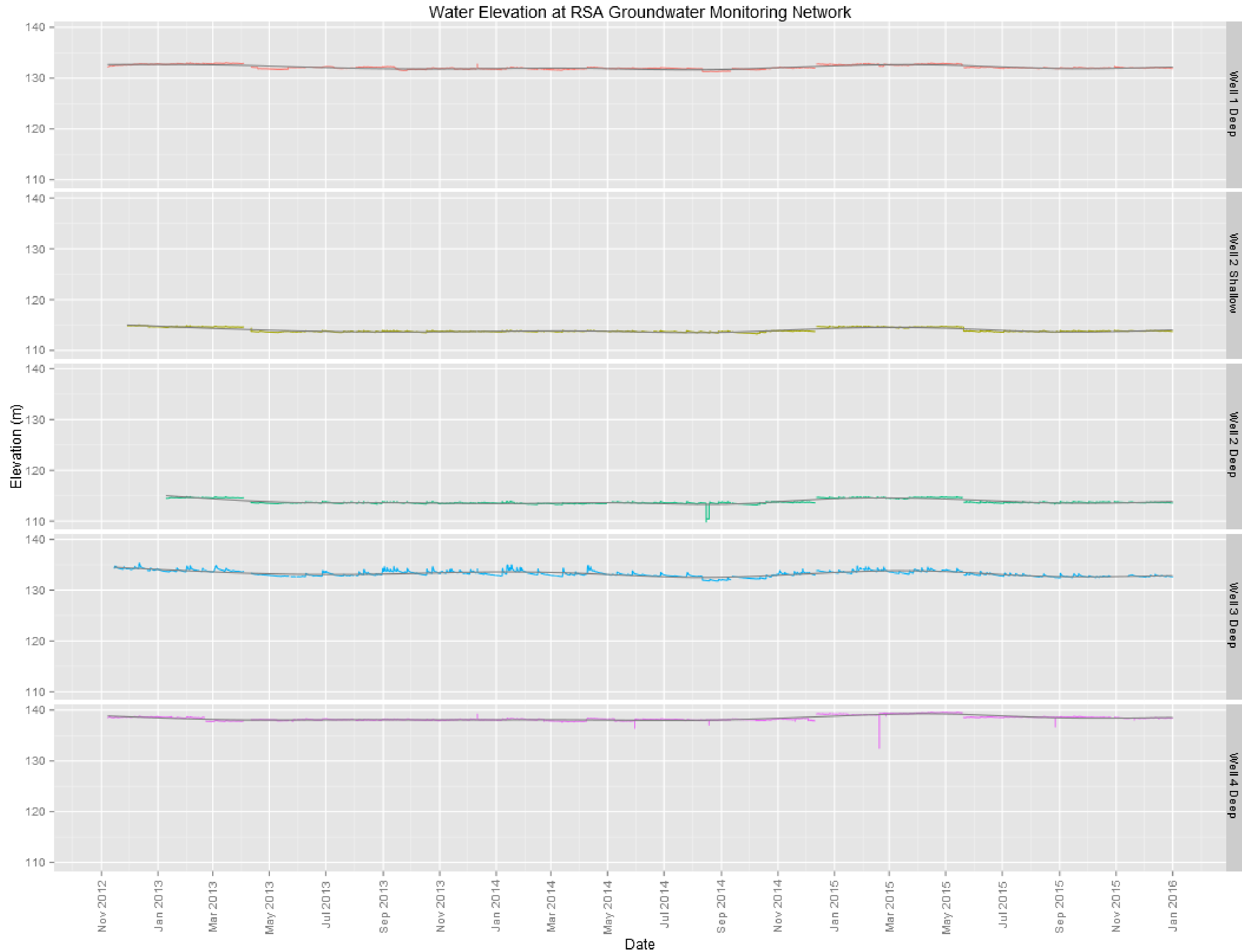
Figure 18: Boxplots of oxidation reduction potential at the Residue Storage Area Groundwater Quality Monitoring Network from 2013 to 2015



Water Elevation

- Well monitors record the height of the water column above them. Because the monitoring equipment is suspended at a constant level in the well and are compensated for atmospheric pressure changes, the height of the water column is subtracted from the local surface elevation to yield water table elevation.
- Water levels at the groundwater monitoring stations indicated stable water levels with no obvious trend from 2012 to 2015.

Figure 19: Water elevation at the Residue Storage Area Groundwater Quality Monitoring Network from 2012 to 2015



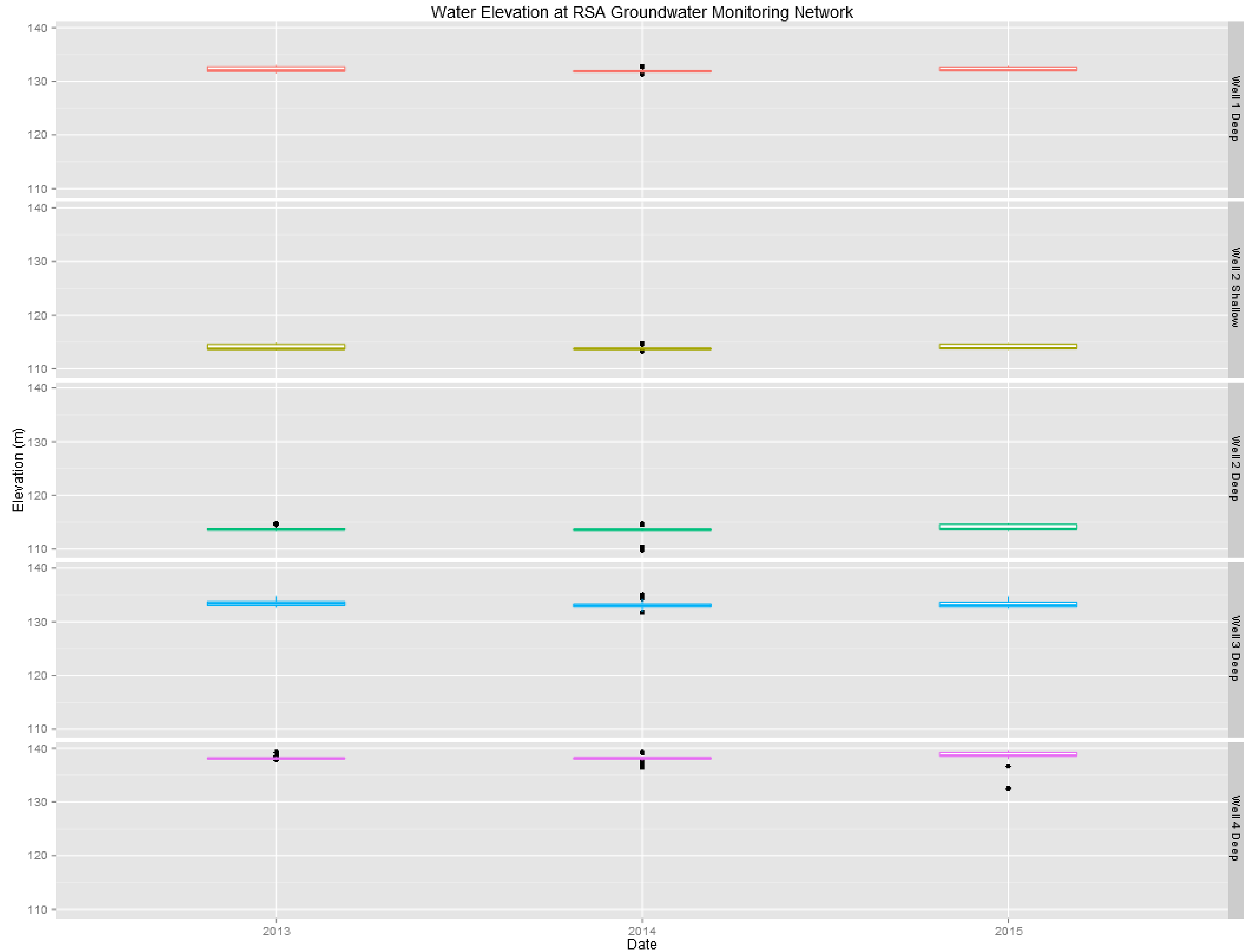
- Very short boxplots indicate that water levels are stable. Indeed, a close agreement between min/max and mean/median values at each well indicates stability.

Table 12: Groundwater elevation – Descriptive Statistics*

Station	Year	Mean	Median	Min	Max
Well 1 Deep	2013	132.1857	132.0651	131.4862	133.0616
	2014	131.8817	131.8829	131.2755	132.8163
	2015	132.2752	132.0724	131.8703	132.9748
	Mean (2013 - 2015): 132.0337				
Well 2 Shallow	2013	113.9496	113.7498	113.4821	114.8793
	2014	113.7590	113.7455	113.2566	114.7687
	2015	114.0923	113.8457	113.5588	114.8140
	Mean (2013 - 2015): 113.8543				
Well 2 Deep	2013	113.8358	113.6258	113.2945	114.8597
	2014	113.5796	113.5634	109.8292	114.7403
	2015	114.0206	113.7168	113.3333	114.8104
	Mean (2013 - 2015): 113.7077				
Well 3 Deep	2013	133.4164	133.4348	132.5933	134.8164
	2014	133.0308	133.0324	131.7996	135.0034
	2015	133.2105	133.0841	132.4325	134.7668
	Mean (2013 - 2015): 133.2236				
Well 4 Deep	2013	138.1344	138.1077	137.7581	139.3048
	2014	138.1593	138.1462	136.4161	139.3029
	2015	138.8406	138.6429	132.4994	139.6152
	Mean (2013 - 2015): 138.1468				

*Values in m.

Figure 20: Boxplots of water elevation at the Residue Storage Area Groundwater Quality Monitoring Network from 2013 to 2015



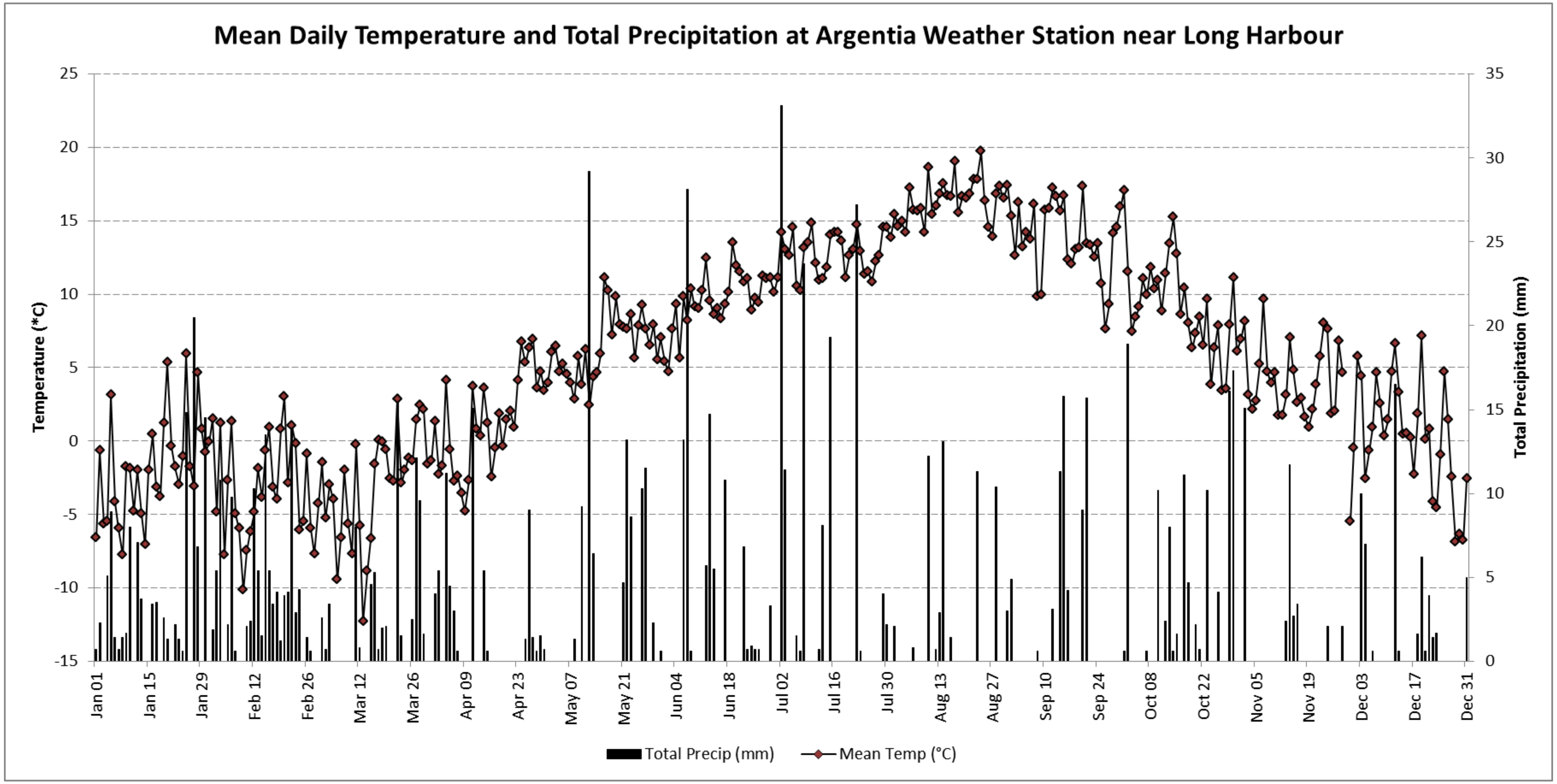
Conclusion

- While turbidity has declined to an annual median value of 0.0 NTU at each Rattling Brook station, specific conductivity and pH have steadily increased. As the majority of construction has moved indoor and vehicular traffic has declined a great deal, less suspended solids are finding their way into the river channel. Dissolved solids continue to enter the river system resulting in higher alkalinity and pH levels. In some grab samples, alkalinity has reached a value as high as 16 mg/l as $CaCO_3$. As a positive offshoot, additional alkalinity in the Rattling Brook system offers a buffering capacity against rapid fluctuations in pH.
- As aquifer monitoring continues around the Residue Storage Area, an increased understanding of trends in groundwater quality is gained. There are some indications of rising pH, specific conductivity, and ORP at some stations. This may be due to heavy groundworks in the area over the past several years, offset by a substantial lag due to the time needed for water to percolate from the surface into the aquifer or even water-rock interactions caused by long-term stagnant water in boreholes.

Path Forward

- Continue monthly calibration and reporting on surface water quality for the Rattling Brook Network and quarterly calibration and annual reporting on groundwater quality for the Residue Storage Area Network.
- Field equipment will undergo routine Proficiency Testing and Evaluation (PTE) in 2016 to ensure proper function.
- Environment and Conservation will continue to enhance the function of its Automatic Data Retrieval System to incorporate new functionality.
- The turbidity alert system will be maintained and turbidity-TSS modelling will be refined on an annual basis in conjunction with the Pollution Prevention Division.
- Open communication and collaboration will continue to be emphasized, as it has in the past.

Appendix



Mean Daily Temperature and Total Precipitation at Argentia Weather Station near Long Harbour
Temperature (*C)
Total Precipitation (mm)
25
20
15
10
5
0
-5
-10
-15
35
30
25
20
15
10
5
0
Jan 01
Jan 15
Jan 29
Feb 12
Feb 26
Mar 12
Mar 26
Apr 09
Apr 23
May 07
May 21
Jun 04
Jun 18
Jul 02
Jul 16
Jul 30
Aug 13
Aug 27
Sep 10
Sep 24
Oct 08
Oct 22
Nov 05
Nov 19
Dec 03
Dec 17
Dec 31
Total Precip (mm)
Mean Temp (°C)

Table 13: Descriptive Statistics of Grab Sample Values at Bridge Station (2008 - 2015)

Variable	Min	Max	Mean	Median
Alkalinity	0	13	2.518518519	0
Color	26	93	54.09756098	51.5
Conductivity	31	73	46.67073171	44
Hardness	0	14	6.695121951	7
pH	5.82	7.34	6.377560976	6.31
TDS	13	47	27.41463415	29
TSS	0.5	37	3.214285714	1
Turbidity	0.2	53.4	2.962195122	0.85
Boron	0	0.02	0.000902439	0
Bromide	0	0	0	0
Calcium	0	5	2.335365854	2
Chloride	5	14	8.658536585	8
Flouride	0	0.5	0.006097561	0
Potassium	0	0.5	0.080487805	0
Sodium	3	7	4.930487805	4.75
Sulphate	0	5	2.207317073	3
Ammonia	0	0.16	0.01304878	0
DOC	4.4	11.3	7.130487805	7
Nitrate	0	0.29	0.047	0
KjeldahlNitrogen	0	0.3	0.1415	0.155
TotalPhosphorus	0	0.12	0.006463415	0
Aluminium	0.06	0.75	0.206463415	0.16
Antimony	0	1.00E-04	1.22E-06	0
Arsenic	0	0	0	0
Barium	0	0.02	0.000597561	0
Cadmium	0	0	0	0
Chromium	0	0.001	3.66E-05	0
Copper	0	0.008	0.000341463	0
Iron	0.05	0.79	0.169146341	0.14
Lead	0	0.0087	0.000640244	0
Magnesium	0	1	0.243902439	0
Manganese	0.01	0.25	0.040609756	0.033
Mercury	0	2.00E-05	5.49E-07	0
Nickel	0	0.003	3.66E-05	0
Selenium	0	0	0	0
Uranium	0	0	0	0
Zinc	0	0.029	0.002207317	0
Temperature.Source	-0.48	21.8	9.257066667	8.36
TOC	4.1	11.1	7.511111111	7.4
Sr	0.006	0.013	0.009888889	0.01

Table 14: Descriptive Statistics of Grab Sample Values at Plant Discharge Station (2010 - 2015)

Variable	Min	Max	Mean	Median
Alkalinity	0	16	5.557377049	6
Color	2	105	51.83606557	51
Conductivity	38	142	70.68852459	67
Hardness	5	46	13.50819672	10
pH	6	7.49	6.553770492	6.54
TDS	18	92	45.44262295	44
TSS	0.5	111	7.805555556	1
Turbidity	0.4	82	7.954098361	2
Boron	0	0.006	0.000180328	0
Bromide	0	0	0	0
Calcium	2	15	4.945901639	4
Chloride	6	17	11.39344262	11
Flouride	0	0	0	0
Potassium	0	1	0.078688525	0
Sodium	3	10	5.990163934	6
Sulphate	0	19	6.442622951	6
Ammonia	0	0.16	0.015081967	0
DOC	4	10.3	7.181967213	7.2
Nitrate	0	1.43	0.191147541	0.11
KjeldahlNitrogen	0	0.43	0.144098361	0.14
TotalPhosphorus	0	0.39	0.02557377	0
Aluminium	0.07	1.01	0.273934426	0.18
Antimony	0	8.00E-04	1.48E-05	0
Arsenic	0	0	0	0
Barium	0	0.02	0.001803279	0
Cadmium	0	1.00E-04	4.92E-06	0
Chromium	0	0.002	0.000147541	0
Copper	0	0.004	0.000606557	0
Iron	0.06	1.05	0.240819672	0.16
Lead	0	0.01	0.001163934	0
Magnesium	0	2	0.281967213	0
Manganese	0	0.74	0.088442623	0.04
Mercury	0	0	0	0
Nickel	0	0	0	0
Selenium	0	0	0	0
Uranium	0	0	0	0
Zinc	0	0.04	0.004360656	0
Temperature.Source	-0.36	22.1	8.445166667	7.07
TOC	3.7	11.7	7.508	7.3
Sr	0.008	0.04	0.01502	0.014

Table 15 Descriptive Statistics of Grab Sample Values at Big Pond Station (2010 - 2015)

Variable	Min	Max	Mean	Median
Alkalinity	0	15	2.720930233	0
Color	28	77	51.39534884	53
Conductivity	30	80	52.6744186	55
Hardness	0	10	6.674418605	7
pH	5.85	7.77	6.47744186	6.43
TDS	16	52	33.72093023	36
TSS	0.5	12	1.605263158	1
Turbidity	0.3	3.4	0.96744186	0.8
Boron	0	0.03	0.001069767	0
Bromide	0	0	0	0
Calcium	0	4	2.676744186	3
Chloride	6	15	9.837209302	10
Flouride	0	0	0	0
Potassium	0	0.4	0.018604651	0
Sodium	2	7	5.258139535	5
Sulphate	0	5	3.441860465	4
Ammonia	0	0.18	0.011162791	0
DOC	4.9	10.3	7.11627907	7.1
Nitrate	0	0.3	0.090465116	0
KjeldahlNitrogen	0	0.36	0.143953488	0.15
TotalPhosphorus	0	0.07	0.003488372	0
Aluminium	0.05	0.27	0.135348837	0.14
Antimony	0	0	0	0
Arsenic	0	0	0	0
Barium	0	0	0	0
Cadmium	0	0	0	0
Chromium	0	0.002	4.65E-05	0
Copper	0	0.002	4.65E-05	0
Iron	0.04	0.23	0.115348837	0.12
Lead	0	0	0	0
Magnesium	0	0.6	0.039534884	0
Manganese	0	0.1	0.037813953	0.03
Mercury	0	0	0	0
Nickel	0	0	0	0
Selenium	0	0	0	0
Uranium	0	0	0	0
Zinc	0	0.26	0.013860465	0
Temperature.Source	-0.3	20.03	9.858292683	11.1
TOC	4.4	10.1	7.327777778	7.2
Sr	0.006	0.014	0.009472222	0.01

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