Parsons, Susan

From: Dee White <deewhite1@mindspring.com>
Sent: Monday, March 06, 2017 1:33 PM
To: Moore-Love, Karla
Subject: 4 Agenda item 215/235 for March 8 PWB contract with Confluence
Attachments: 3rd Quarter - PWB WQ Corrosion Study.pdf

Karla,

Please include these documents in the record for this agenda item. Please also send me a receipt that you have received. THANKS so much.

Dee White

QUARTERLY REPORT

WATER QUALITY CORROSION STUDY 3RD MONITORING PERIOD REPORT – DRAFT REV1

PWB CONTRACT# 30003222

B&V PROJECT NO. 182435

PREPARED FOR

City of Portland, Portland Water Bureau

NOVEMBER 14, 2016

BLACK & VEATCH
Building a world of difference.

City of Portland, Water Bureau

WATER QUALITY CORROSION STUDY

Quarterly Data Report – Q3 2016

Acknowledgements

Data Analysis by: Abigail Cantor, PE, Process Research Solutions, LLC

Reviewed by: Melinda Friedman, P.E., Confluence Engineering Group, LLC

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Abbreviations and Acronyms

A list of abbreviations and acronyms used in this Technical Memorandum (TM) are summarized in the following list:

ATP	Adenosine Triphosphate
DOC	Dissolved Organic Carbon
Fe	Iron
GIS	Geographic Information System
HPC-R2A	Heterotrophic Plate Counts
IQR	Interquartile range
JMP	Joint Monitoring Plan
LCR	Lead and Copper Rule
mg/L	milligrams per Liter
Mn	Manganese
ND	Non-detect
NTU	Nephelometric Turbidity Units
ORP	Oxidation Reduction Potential
pg/L	Picograms per liter
PRS	Process Research Solutions, LLC
PWB	City of Portland, Portland Water Bureau
Q1	First quarter
Q2	Second Quarter
Q3	Third Quarter
Q4	Fourth quarter
Study	Water Quality Corrosion Study
TCR	Total Coliform Rule
TM	Technical Memorandum
TM2	Technical Memorandum 2 – Distribution System Sampling Plan
ug/L	Micrograms per liter
UCL	Upper Control Limit
WQP	Water Quality Parameter
WQSS	Water Quality Sampling Stations
Zn	Zinc

1 Introduction

The Portland Water Bureau (PWB) is conducting a Water Quality Corrosion Study (Study) to document baseline water quality conditions and identify the causes of lead release in the PWB distribution system. At the end of the study the results will assist PWB in understanding the potential impact future operational or treatment changes could have on lead release in the distribution system. TM2 – Distribution System Sampling Plan (TM2) was developed earlier in this study to aid in the collection of the information necessary to answer specific questions and hypotheses regarding water quality in the PWB distribution system.

The monitoring quarters are defined in order to best align with seasonal temperatures. In this way, each quarter will be representative of a season with data influenced by a narrower temperature range than if the period was divided otherwise. For the purposes of the quarterly reports generated for this project the monitoring quarters are aligned as shown in Table 1-1.

Table 1-1: Monitoring Quarter Date Ranges

QUARTER	DATE RANGE	NOTES
Q4 2015*	Sep 2015 - Nov 2015	Typical nitrification season
Q1 2016*	Dec 2015 - Feb 2016	Typical winter conditions
Q2 2016*	Mar 2016 - May 2016	Typical spring conditions
Q3 2016*	Jun 2016 - Aug 2016	Typical summer conditions
Q4 2016	Sep 2016 - Nov 2016	Typical nitrification season

Notes:
* Indicates the quarters analyzed in this monitoring report

Monitoring periods Q4 2015 – Q3 2016 are described in this report, with a focus on data collected during the third quarter (Q3) 2016.

It should be noted that the main intent of the quarterly reports is to analyze the data sufficiently to determine if any changes are warranted to the sampling plan moving forward. While the quarterly reports will identify preliminary trends in the data observed during the reporting period, it should be acknowledged that conclusions regarding any trends in the data should not be made until the remaining quarters' data have been collected. At the end of the study a final report will be assembled which interprets all of the data collected during the 5 quarters of monitoring. Any conclusions or extrapolation to what may be occurring in the actual distribution system will be reserved for the final report to allow for interpretation of all available data and should not be made from the data collected during this quarter alone.

2 Data Analysis

2.1 SUMMARY OF AVAILABLE DATA

This section summarizes the data that was collected during this sampling period. The data are organized according to the sampling pool for which the data are collected as described in TM2.

Data were collected during the current monitoring period from the following sample pools:

Operations Data. The PWB maintains a log of operational changes that may have an impact on distribution system water quality.

Total Coliform Rule Monitoring Sites. The PWB collects water quality parameters at 89 sites, with approximately 250 samples collected per month.

Nitrification Route Sites. The PWB developed a Nitrification Monitoring and Action Plan in 2013 that identifies approximately 45 sites per week for nitrification parameter monitoring. While some of these sites are also Total Coliform Rule (TCR) sample sites, a few were established specifically for the nitrification monitoring. These data are typically collected during the summer and fall, when nitrification is expected to be at its highest. Nitrification data were collected in Q4 2015, and again during Q3 2016 at the end of July and continued through the end of August. Additional nitrification data will be collected during Q4 2016.

Lead and Copper Rule Compliance Data. A compliance lead sampling event did not take place during this quarter. Other water quality parameter data were taken from various flowing water sites in the distribution system according to the LCR requirements.

Voluntary Customer Lead Data. Approximately 2,900 voluntary customer samples were received and analyzed for lead during this monitoring period. Results are presented for samples collected from the beginning of May through the middle of August.

Supplemental in home sampling. Follow up residential customer sampling was performed during last monitoring period (Q2 2016) at 5 homes and during this period (Q3 2016) at 21 homes.

Monitoring Stations and Extended Water Quality Monitoring Sites. The PWB purchased and installed three Process Research Solutions (PRS) monitoring stations to better monitor for various flowing water and stagnation sample parameters. The monitoring stations and a description of the water quality parameters monitored are described in more detail in TM2. The data collected from the monitoring stations are described in this quarterly report.

The following sections summarize the data collected this monitoring period for each sampling pool.

2.2 DATA ANALYSIS TECHNIQUES

The data analysis techniques used in this study were defined previously in TM2. One additional tool used in this report is the cumulative frequency plot. A cumulative frequency plot is a way to display values and the percentage of data points that are less than or equal to particular values.

This makes it easy to identify the spread of the data as well as other key data points such as the 90th percentile value.

2.3 OPERATIONS DATA

The PWB maintains a log of operations data so that any observations from the data can be associated back with any operational changes made during the monitoring period. The following operational activities may have impacted water quality observed in the distribution system since this monitoring program began:

- Groundwater was used to augment supply from approximately June 11 through November 4, 2015. Groundwater comprised between 20% and 40% of the total supply during June through August, and between 40% and 75% for much of September and October. This represented a higher than average usage of groundwater during a typical operating year for the PWB. Groundwater was used as a maintenance run from July 25 through August 10, 2016 at approximately 12-16% of the total supply
- On December 16th 2015 the chloramine dosing target was reduced from 2.5 mg/L to 2.2 mg/L. On July 25th 2016 the chloramine dosing target was increased from 2.2 mg/L to 2.5 mg/L.
- June 30, 2016 marked the beginning of the Bull Run drawdown.

The full operations log is included as Appendix A.

2.4 TCR DATA

Samples are collected from 89 TCR sites and analyzed for water temperature, pH, total chlorine residual, and turbidity. The TCR data present a good opportunity to observe general water quality parameters in the distribution system as the TCR sites are spread throughout the system. This section summarizes the water quality data collected from the TCR sites during this monitoring period. Additional discussion and extrapolation of what these data may indicate related to overall water quality in the PWB water system will be reserved for the final report.

2.4.1 Turbidity

Turbidity values from 89 TCR sites from Q4 2015 through Q3 2016 are shown in Figure 2-1 below. Observing the data from all the sampling sites on one graph is a valuable way to visualize system wide and seasonal trends. As observed, the turbidity was consistently below 0.5 Nephelometric Turbidity Units (NTU) throughout the distribution system during Q2 2016, with the exception of a few sites which had turbidities around 1 NTU during the beginning to middle of March. This is a similar turbidity pattern as has been observed throughout the study period with the exception of the elevated turbidity (approximately 2 NTU) observed between November 2015 and January 2016 due to rains and runoff event in the Bull Run watershed. For the most part, the turbidity remained low throughout Q3 2016, with the exception of some elevated turbidities during the second half of July at some sites, during the same time that groundwater was brought into the system.

The five sites with the highest average and most variable turbidity during Q3 sorted from highest to lowest are listed below. Variability for this purpose is defined from Shewhart control statistics as the upper control limit minus the lower control limit. These are plotted on Figure 2-2, and are shown spatially on a GIS plot in section 2.4.5.

Table 2-1: Five Sites with the Highest Average Turbidity

SITE ID	SITE LOCATION	TURBIDITY AVG, NTU
WQSS0069	NE Cornfoot & Alderwood	0.53
WQSS0185	NE 29TH & BRYANT	0.49
WQSS0022	SCHOOL DIST 1, 2045 N Vancouver & Tillamook	0.49
WQSS0180	Legacy Emmanuel 2 -North	0.47
WQSS0034	St. Johns Precinct, North	0.46

Table 2-2: Five Sites with the Most Variable Turbidity

SITE ID	SITE LOCATION	TURBIDITY VARIABILITY, NTU
WQSS0185	NE 29TH & BRYANT	1.20
WQSS0053	Margaret Scott Elementary -NE	1.19
WQSS0070	STANTON YARD, 2700 N Borthwick by Knott	1.16
WQSS0069	NE Cornfoot & Alderwood	1.15
WQSS0022	SCHOOL DIST 1, 2045 N Vancouver & Tillamook	1.13

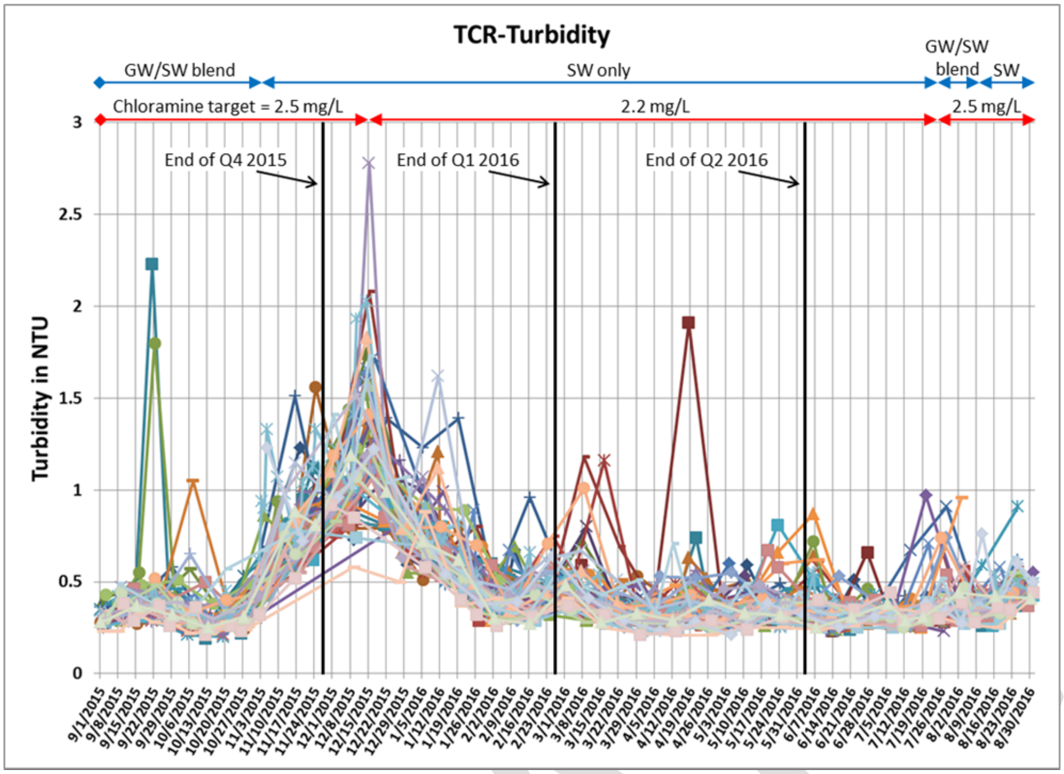


Figure 2-1: Turbidity Values from Q4 2015 through Q3 2016 for 89 Individual TCR Sites

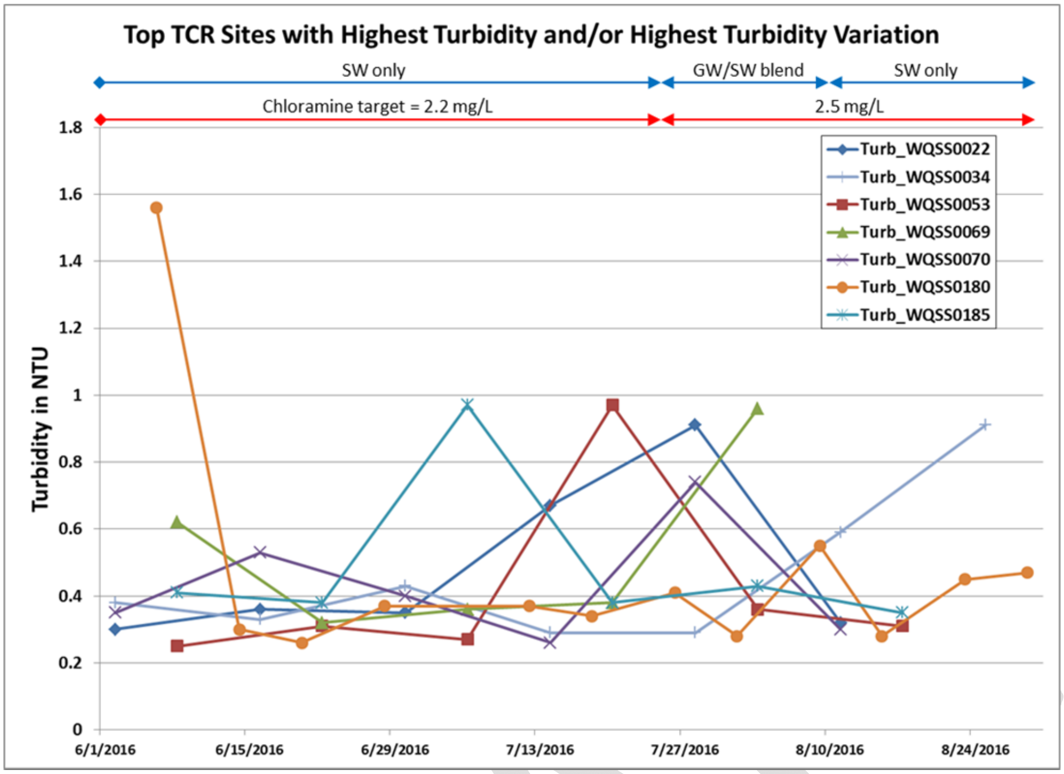


Figure 2-2: Turbidity Values for the Individual TCR Sites with the Highest Average or Most Variable Turbidity from Q3 2016

2.4.2 Chlorine Residual

Total chlorine residuals from 89 TCR sites for Q4 2015 through Q3 2016 are shown in Figure 2-3. The chlorine residuals were lowest and most variable during Q4 2015, during the typical nitrification season. Chlorine residuals were then similar from Q1 through Q3 2016, with the residuals generally spread between 1.5 mg/L and 2.2 mg/L. Shortly after the increase in chloramine target residual to 2.5 mg/L on July 25, 2016, the chlorine residual in the system increased. However, the increase was short lived and the residual began tapering off again at the end of August.

There are a few sites with persistently lower chlorine residuals than the system wide average, and which trended downward during Q3. The five sites with the lowest average or most variable chlorine residual during Q3 sorted from highest to lowest are listed below. Variability for this purpose is defined from Shewhart control statistics as the upper control limit minus the lower control limit. These are plotted on Figure 2-4, and are shown spatially on a GIS plot in section 2.4.5.

Table 2-3: Five Sites with the Lowest Chlorine Residual

SITE ID	SITE LOCATION	Cl2 AVG, mg/L
WQSS0095	SE 9th & Ochoco	0.86
WQSS0031	Engine 7 -SE	0.99
WQSS0178	NE 46th & SIMPSON	1.24
WQSS0169	NE 24th & Emerson	1.27
WQSS0065	SE 144th & Harney	1.31

Table 2-4: Five Sites with the Most Variable Chlorine Residual

SITE ID	SITE LOCATION	Cl2 VARIABILITY, mg/L
WQSS0031	Engine 7 -SE	2.19
WQSS0178	NE 46th & SIMPSON	2.13
WQSS0069	NE Cornfoot & Alderwood	2.02
WQSS0026	Engine 48 -NE	2.00
WQSS0197	SE 74th & Evergreen	1.50

It should be noted that with the exception of WQSS0069 (highly variable turbidity and Cl2) none of the sites with high or variable turbidity are the same as those with low or variable chlorine, suggesting that overall the source of turbidity is not exerting a disinfectant demand.

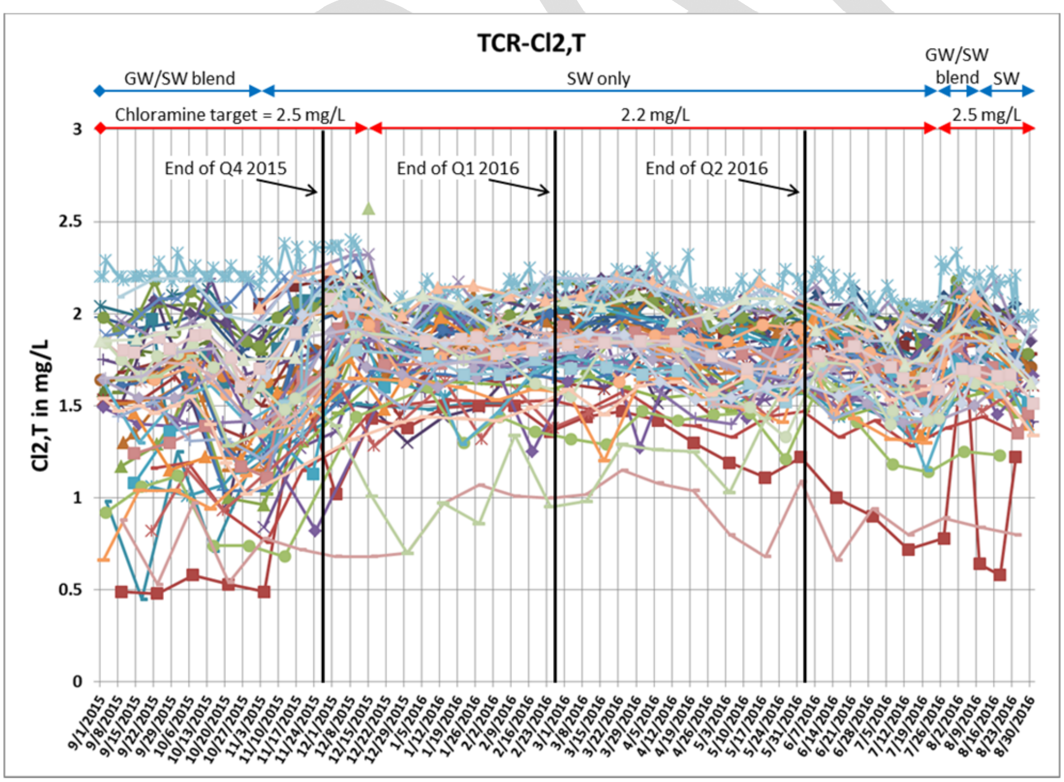


Figure 2-3: Total Chlorine Residual from Q4 2015 through Q2 2016 for 89 Individual TCR Sites

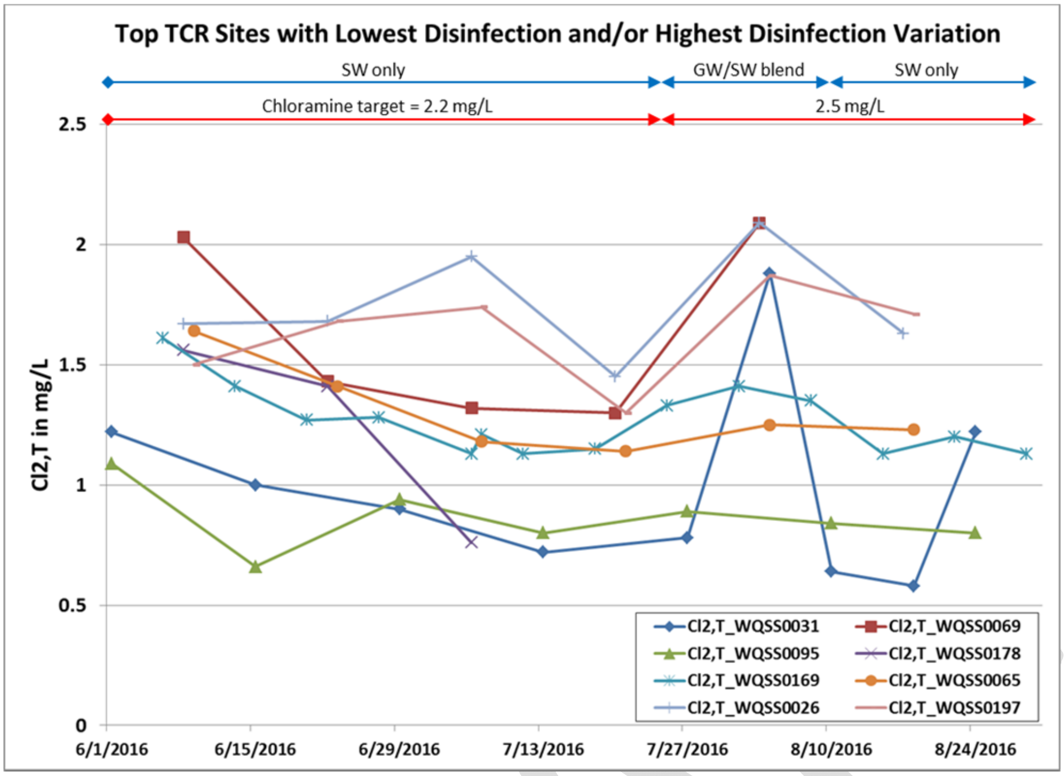


Figure 2-4: Total Chlorine Residual Values for the Individual TCR Sites with the Highest Average or Most Variable Chlorine Residual from Q3 2016

2.4.3 pH

TCR sites are monitored routinely for pH and give a good indication for how the pH changes throughout the distribution system. The pH values at 89 TCR sites are shown in Figure 2-5 below. As observed in the graph, the least variation of pH in the distribution system was seen in 2015 Q4, during the time a higher percentage of groundwater was used. The wider variation range of pH has persisted since Q1 2016, and was observed throughout Q3 2016. Higher pH values were observed in the distribution system during the early part of August, during and shortly following the period of groundwater use.

A few sites had lower pH values during Q3, with three of the five sites with the lowest pH also on the list of sites with the most evidence of nitrification (see Nitrification section). The five sites with the lowest average or most variable pH during Q3 are listed below. Variability for this purpose is defined from Shewhart control statistics as the upper control limit minus the lower control limit. These are plotted on Figure 2-6, and are shown spatially on a GIS plot in section 2.4.5.

Table 2-5: Five Sites with the Lowest pH

SITE ID	SITE LOCATION	pH AVG, SU
WQSS0095	SE 9th & Ochoco	7.50
WQSS0178	NE 46th & SIMPSON	7.61
WQSS0031	Engine 7 -SE	7.62
WQSS0065	SE 144th & Harney	7.67
WQSS0169	NE 24th & Emerson	7.73

Table 2-6: Five sites with the Most Variable pH

SITE ID	SITE LOCATION	pH VARIABILITY, SU
WQSS0194	RES 3 OUTLET DS	1.53
WQSS0017	NW 19th & Everett	1.50
WQSS0143	3928 SE 136TH AVE. (PV-29)	1.22
WQSS0124	98TH & CLINTON (PV-10)	1.22
WQSS0038	Hayden Island Mobile Park -North	1.13

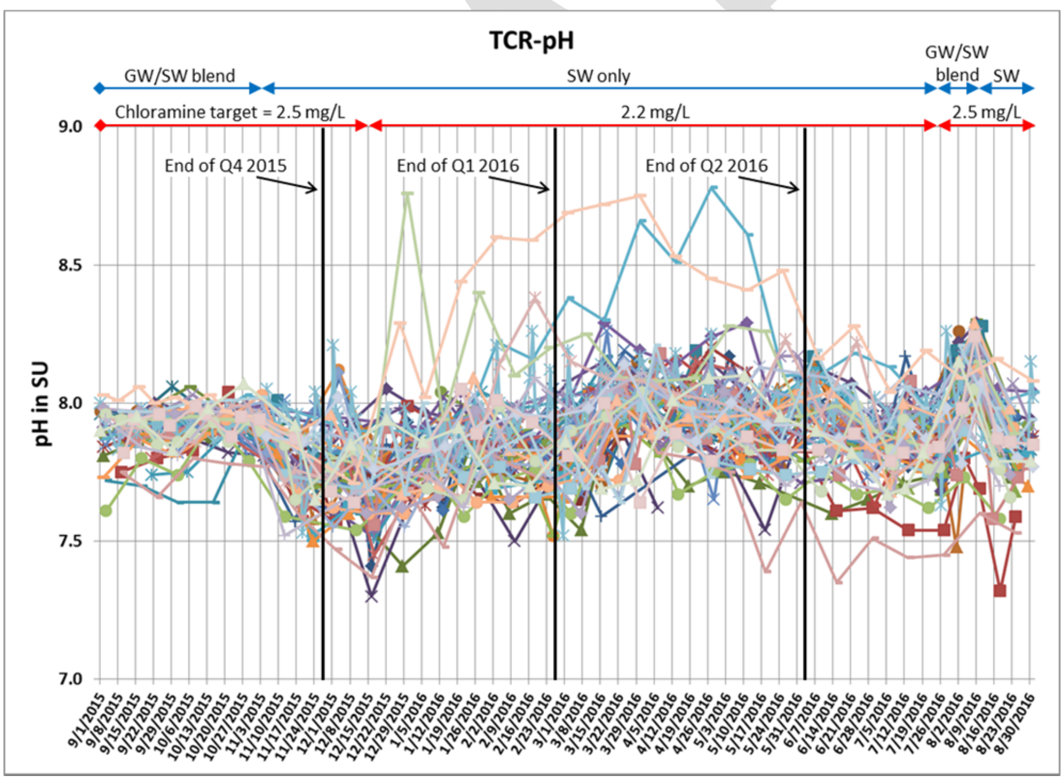


Figure 2-5: pH Values from Q4 2015 through Q3 2016 for 89 Individual TCR Sites

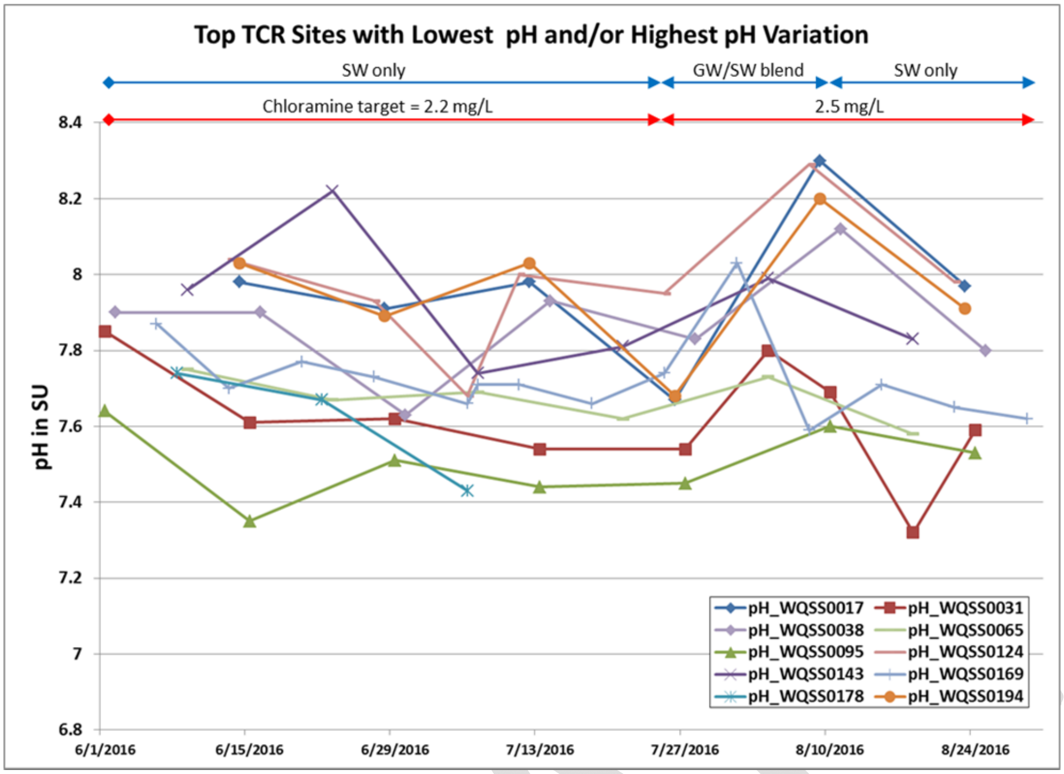


Figure 2-6: pH Values for the Individual TCR Sites with the Lowest Average or Most Variable pH from Q3 2016

2.4.4 Temperature

Temperature is monitored routinely at 89 TCR sites and gives a good indication for system wide and seasonal trends. Temperature values are shown in Figure 2-7 below. As observed in the graph, the temperature has climbed steadily throughout Q2 and Q3, to an average of approximately 18 degrees C by the end of August 2016, due to the warming of ambient temperatures. An interesting trend can be observed in that the temperature data are more widely spread during August 2016 than during the similar period during 2015.

The five sites with the highest average or most variable temperature during Q3 sorted from highest to lowest are listed below. Variability for this purpose is defined from Shewhart control statistics as the upper control limit minus the lower control limit. These are plotted on Figure 2-8, and are shown spatially on a GIS plot in section 2.4.5.

Table 2-7: Five Sites with Highest Temperature

SITE ID	SITE LOCATION	TEMPERATURE AVG, °C
WQSS0169	NE 24th & Emerson	21.7
WQSS0210	SE 50th & Rhone	20.5
WQSS0159	NE 162nd Ave & Stanton	20.3
WQSS0031	Engine 7 -SE	20.0
WQSS0095	SE 9th & Ochoco	19.8

Table 2-8: Five Sites with the Most Variable Temperature

SITE ID	SITE LOCATION	TEMPERATURE VARIABILITY, °C
WQSS0176	SE 59th & Lincon - Lincoln Line	14.9
WQSS0069	NE Cornfoot & Alderwood	9.3
WQSS0031	Engine 7 -SE	8.0
WQSS0020	Engine 24 -North	6.7
WQSS0197	SE 74th & Evergreen	6.2

It should be noted that three of the five sites with higher temperature were also identified as sites with lower chlorine.

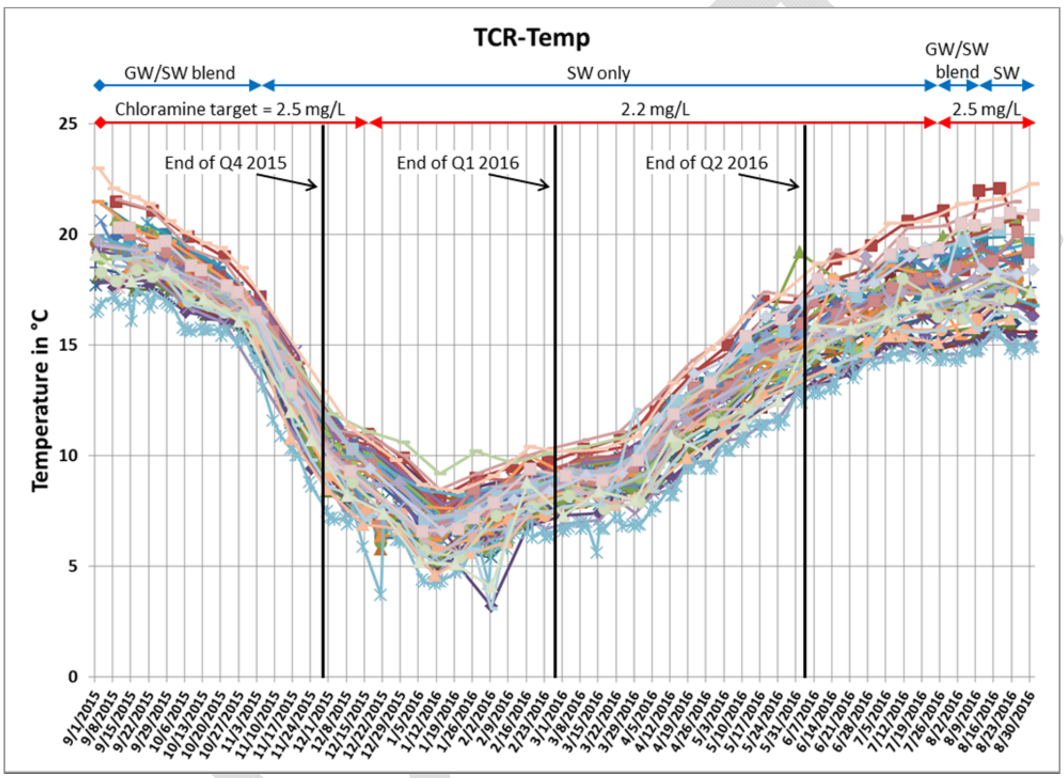


Figure 2-7: Temperature Values from Q4 2015 through Q2 2016 for 89 Individual TCR Sites

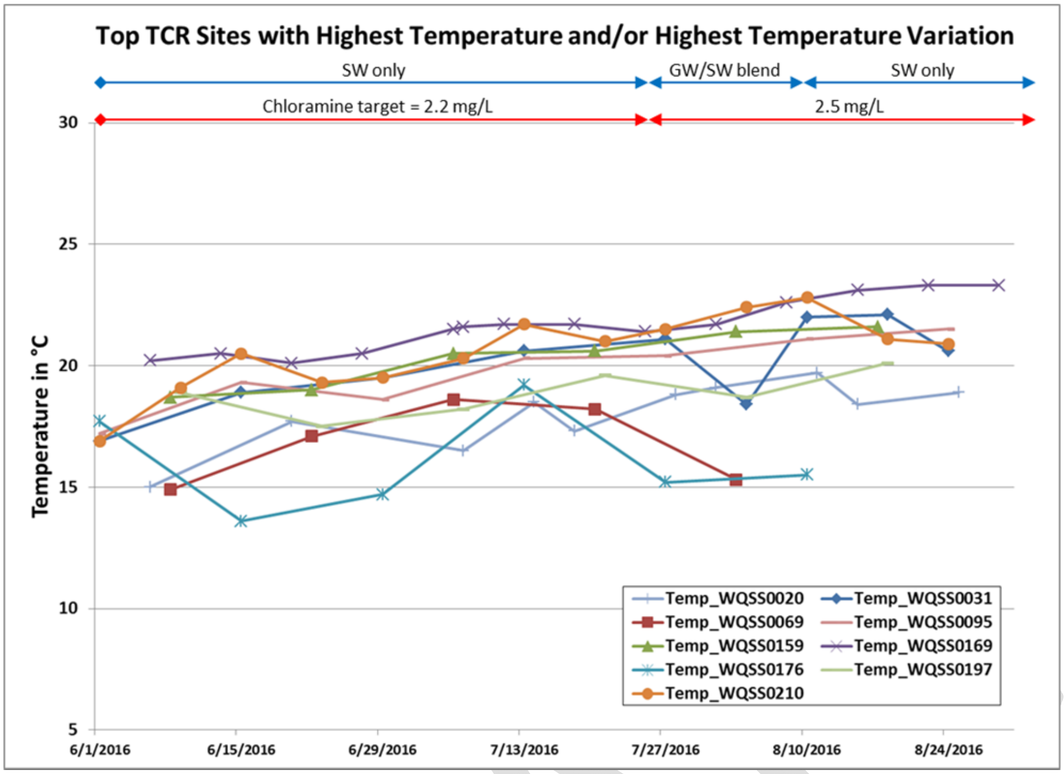


Figure 2-8: Temperature Values for the Individual TCR Sites with the Highest Average or Most Variable Temperature from Q3 2016

2.4.5 GIS Analysis

The water quality results from the TCR sampling were plotted in GIS to help visualize spatial patterns of water quality. This is shown for turbidity, total chlorine, pH, and temperature in the figures below.

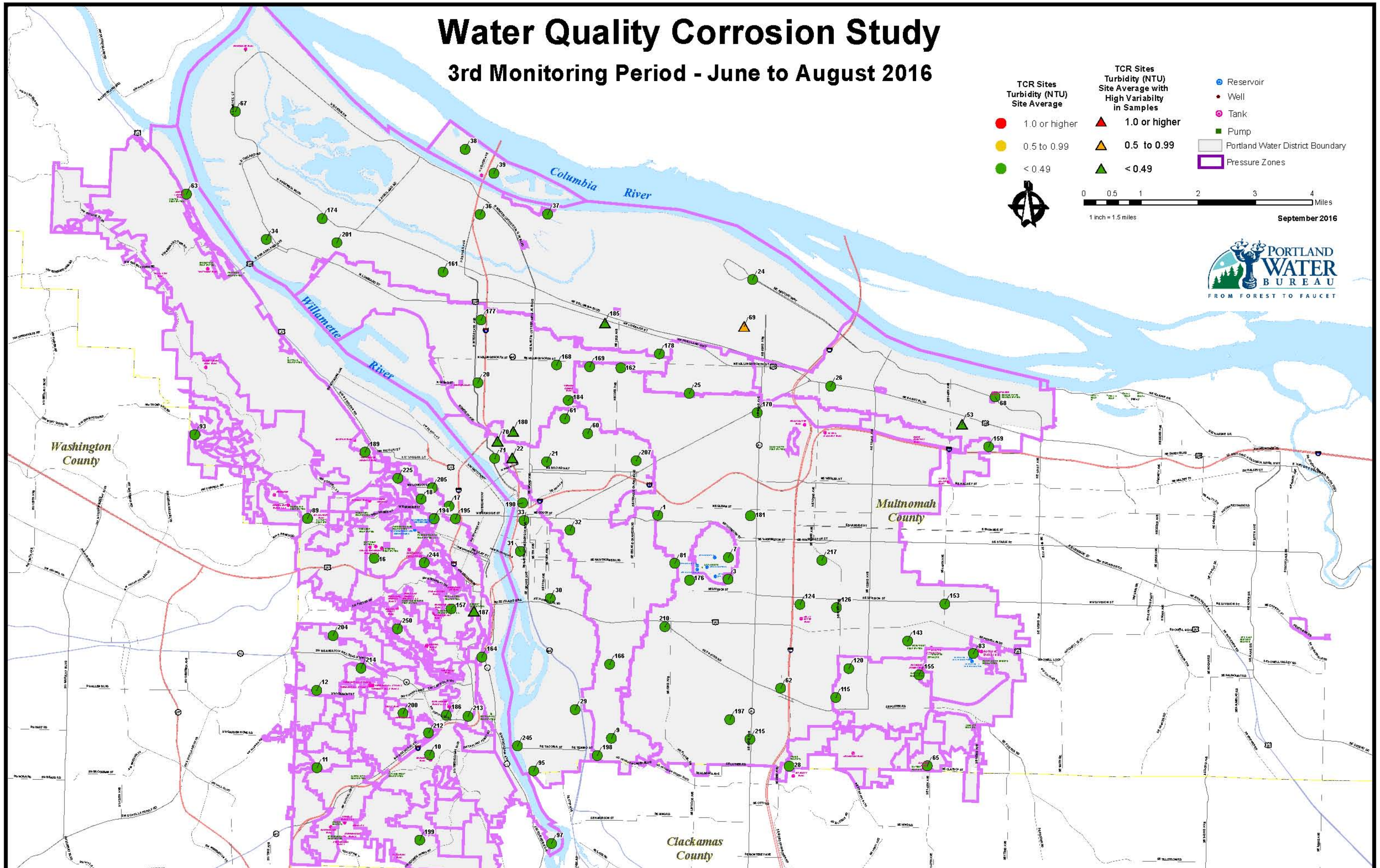


Figure 2-9: GIS Plot Showing Spatially the Turbidity Values throughout Distribution System during Q3 2016

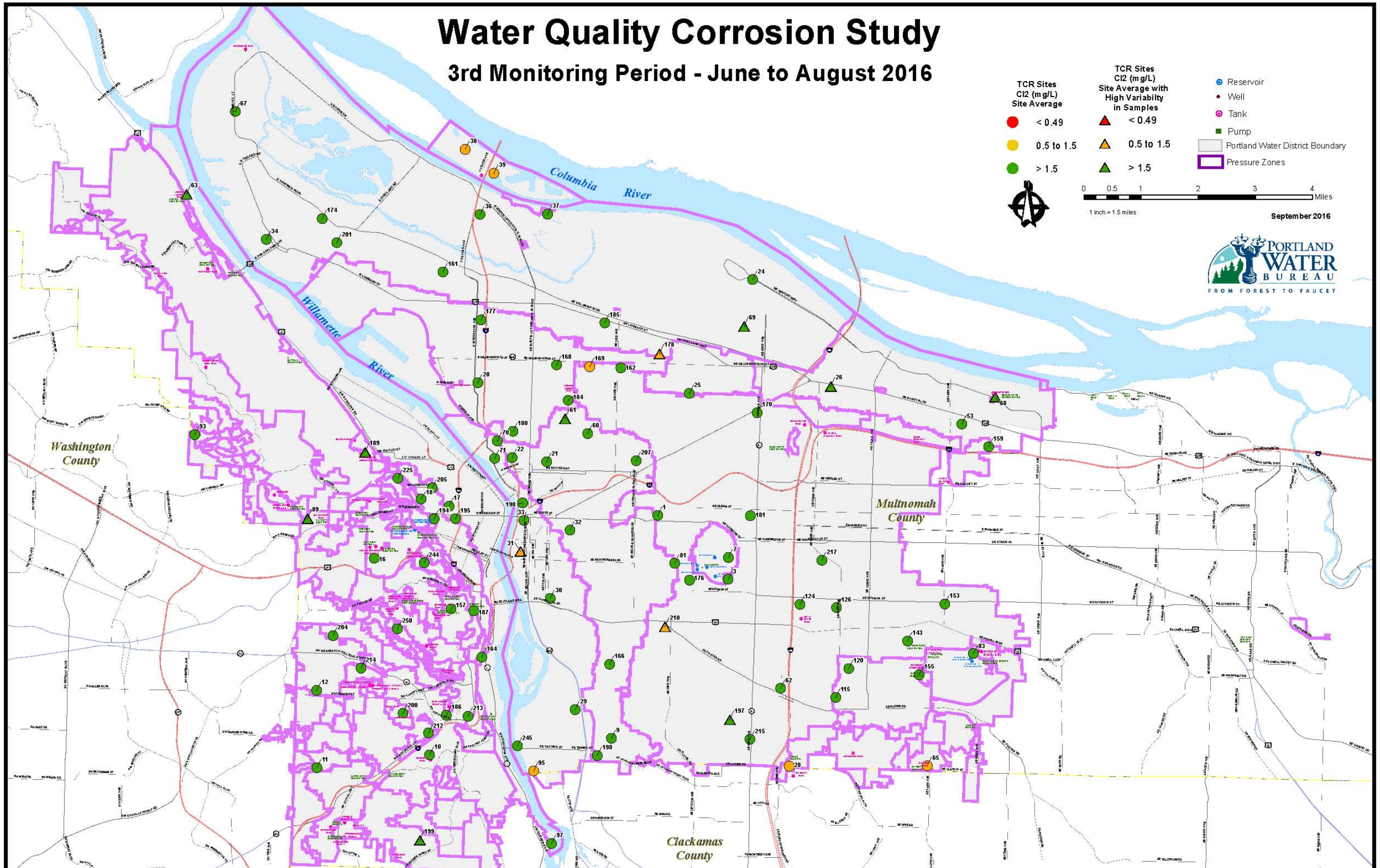


Figure 2-10: GIS Plot Showing Spatially the Total Chlorine Values throughout Distribution System during Q3 2016

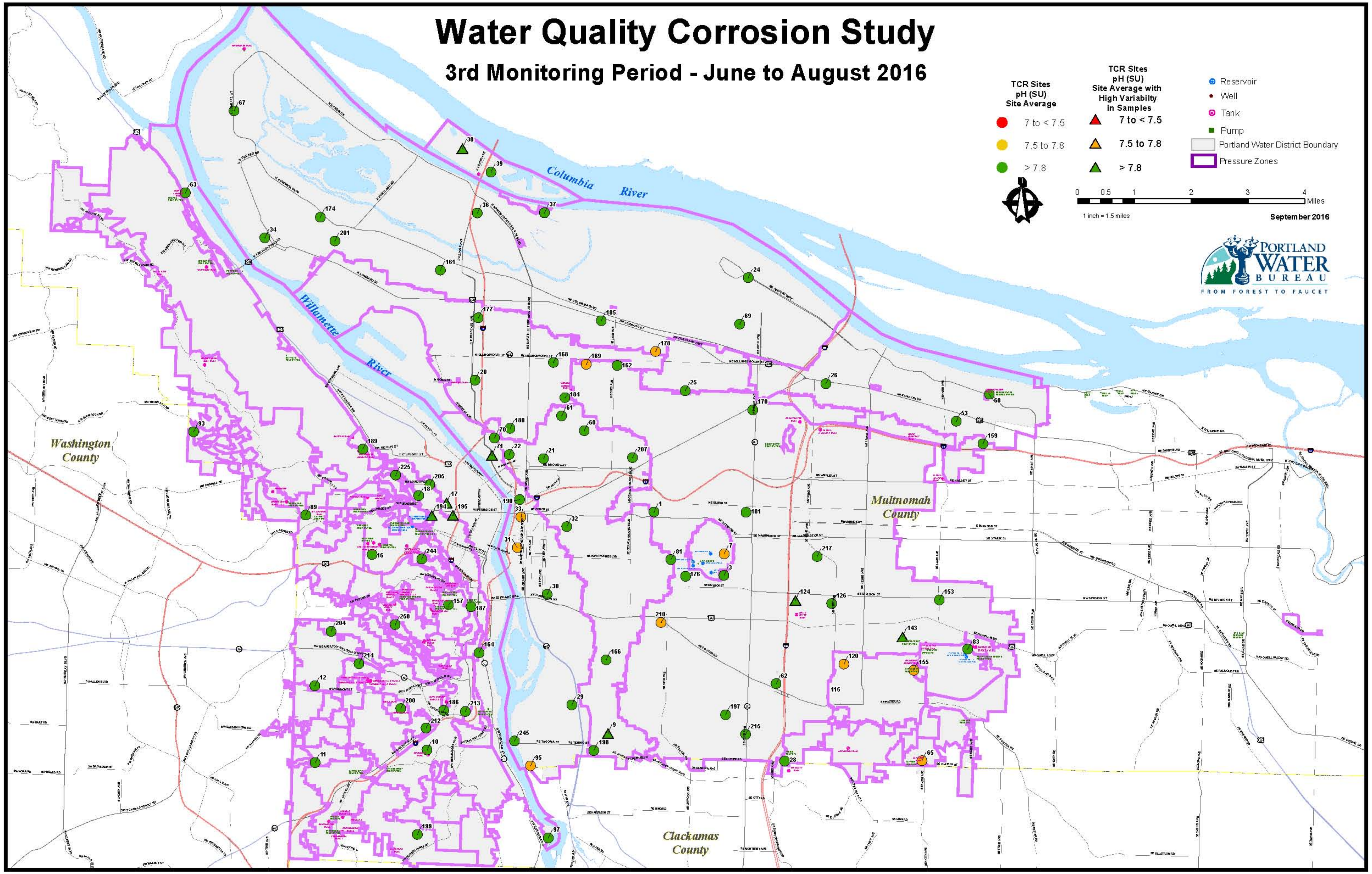


Figure 2-11: GIS Plot Showing Spatially the pH Values throughout Distribution System during Q3 2016

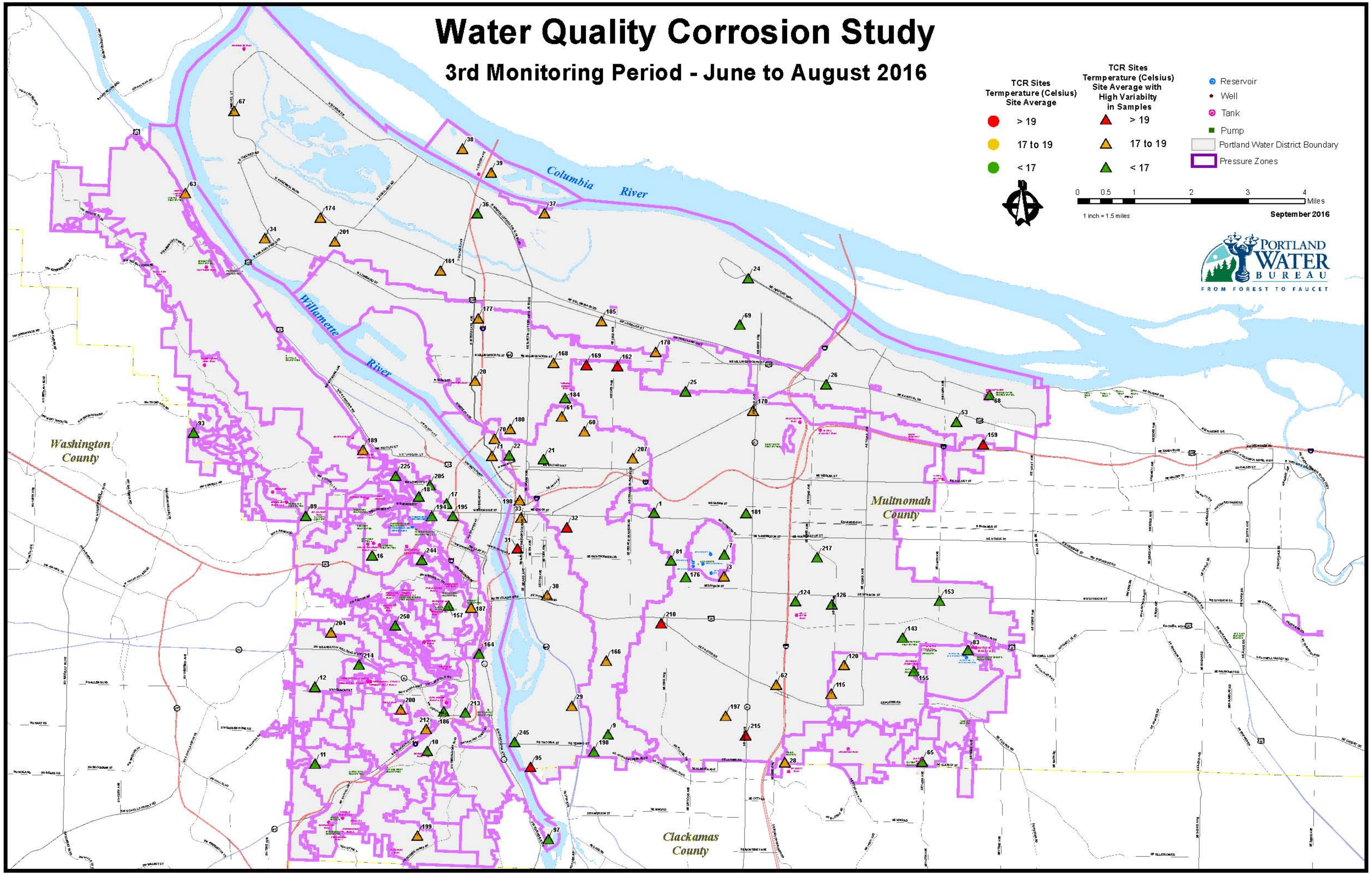


Figure 2-12: GIS Plot Showing spatially the Temperature Values throughout Distribution System during Q3 2016

2.4.6 Summary of TCR Data

In summary, the following observations were made from a review of the TCR data:

- Overall, the TCR data indicate good water quality control during the quarter. There were minor system-wide drops in pH and chlorine during the quarter, likely associated with the onset of the typical nitrification season.
- The turbidity was consistently below 0.5 NTU throughout the majority of the distribution system during Q2 and Q3 2016.
- The chloramine target residual was increased during Q3 2016 from 2.2 mg/L to 2.5 mg/L as a nitrification prevention strategy. In general chlorine residuals were similar from Q1 through Q3 2016, with the residuals generally spread between 1.5 mg/L and 2.2 mg/L. Shortly after the increase in chloramine target the chlorine residual in the system increased. However, the residual began tapering off at the end of August.
- The pH in most of the distribution system during Q3 2016 was similar to the previous 2 quarters, with values generally between 7.8 and 8.1. Higher pH values were observed in the distribution system during the early part of August, during and shortly following the period of groundwater use. A few sites had lower pH values during Q3 than previous quarters, with a few pH values near 7.0 observed.
- The temperature increased steadily during Q3 2016, reaching a system-wide average of approximately 18 degrees C by the end of the quarter. Three of the five sites with elevated temperature also had lower chlorine residual observed during this quarter.
- No spatial patterns of poor water quality were observed.
- It should be noted that a more complete set of water quality parameters was monitored at two of the TCR sites (extended WQSS). These data are presented in section 2.9 below.

2.5 NITRIFICATION DATA

The PWB monitors select sites to determine the extent to which nitrification is occurring within the Portland distribution system. These data are typically collected during the summer and fall, when nitrification is expected to be at its highest. Samples are collected and analyzed for total chlorine, oxidation reduction potential (ORP), Heterotrophic Plate Counts (HPC) using R2A agar (R2A), free ammonia, nitrite, nitrate, pH, temperature, and turbidity. This section summarizes the most relevant water quality data collected from the sites monitored for nitrification from Q4 2015 and Q3 2016. It should be noted that data are limited for Q3 2016 (some sites only had 2 data points for individual parameters), and the bulk of the 2016 nitrification data are expected to be collected during the next quarter, Q4 2016.

2.5.1 Nitrification Action Plan Summary

The PWB has developed target, alert, and action levels for selected water quality parameters describing nitrification. The triggers and response levels are summarized in 2-1.

Table 2-9: Summary of Nitrification Trigger and Response Levels (from PWB's Nitrification Monitoring and Action Plan, 2014)

PARAMETER	TARGET	ACTION LEVEL 1	ACTION LEVEL 2	ACTION LEVEL 3
Total Chlorine (mg/L)	>1.0 (tanks) >0.5 (DS)_	<1.0 <0.5	<0.5 <0.5	
Nitrite-N (mg/L)	<0.020	>0.020	>0.050	>0.1
Nitrate-N (mg/L)	Background (during Nitrification Study, background nitrate ranged from 0 - 0.043 mg/L in the Bull Run)	Increase relative to background		
R2A HPC (cfu/ml)	<200	>500 or a significant increase from the previous sampling date	>1000	>1000
Free Ammonia-N (mg/L)	<0.05 (pipes) 0.05-0.15 (tanks)	>0.35	>0.40	
pH	As close to 8 as possible			
Action Level 1	• Evaluate increased sampling. • Ensure optimization at chlorine and ammonia injection points (both at Lusted Hill Treatment Facility and booster chlorination sites). • Evaluate pumping operations to see if operations could be altered / synchronized up the cascade to bring fresher water to the area. • Evaluate whether tanks can be cycled more effectively. • If at a wholesaler connection, evaluate recent wholesaler consumption data.			
Action Level 2	• Continue performing Action Level 1 responses. • Drain and refill tanks with fresh water (disinfect if necessary). • Clean Tank. • Evaluate whether additional storage can be taken offline (may not be possible based on hydraulics). • Perform flushing in the area. • Notify affected wholesalers.			
Action Level 3	• Perform UDF of the area (and in the process look for erroneously closed valves). • Evaluate breakpoint chlorination.			

2.5.2 Nitrification Data

HPCs were monitored at all nitrification sites and are shown in Figure 2-13 below. As indicated the HPCs were similar in Q3 2016 to the similar period during the previous year. A few sites had consistently higher HPCs than the other sites. The five stations with the highest HPC values during Q3 2016 and the five stations with the highest variability between HPC values are listed below:

Table 2-10: Five Sites with the Highest HPCs

SITE ID	SITE LOCATION	R2A AVG, cfu/mL
WQSS5005	Whitwood Tank Outlet	2147
WQSS5023	Marigold Tank	1683
WQSS5006	North Linnton Tank Outlet	943

SITE ID	SITE LOCATION	R2A AVG, cfu/mL
WQSS5017	Lexington Tank Outlet	860
WQSS5014	King Heights Tank Outlet	710

Table 2-11: Five Sites with Most Variable HPCs

SITE ID	SITE LOCATION	R2A VARIABILITY, cfu/mL
WQSS5005	Whitwood Tank Outlet	11217
WQSS5023	Marigold Tank	6764
WQSS5006	North Linnton Tank Outlet	4548
WQSS5017	Lexington Tank Outlet	2536
WQSS5019	Rose Parkway Tank Outlet	2292

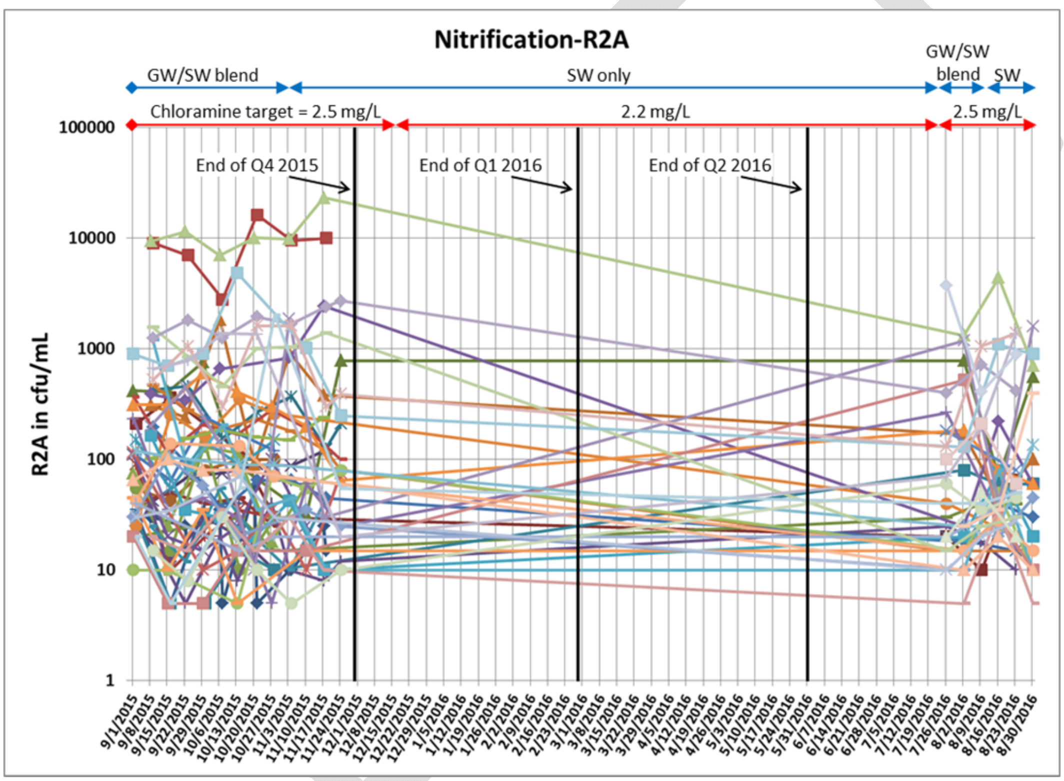


Figure 2-13: Heterotrophic Plate Counts using R2A Agar from Nitrification Sites during Q4 2015 and Q3 2016

Release of free ammonia-N was monitored at all nitrification sites and is shown in Figure 2-14 below. As observed there was an increase in free ammonia at most sites towards the end of November during Q4 2015. With the exception of a high spike at WQSS0019, the ammonia levels are similar during Q3 2016 as the same period last year. The five stations with the highest free ammonia values during Q3 2016 and the five stations with the highest variability between free ammonia values are listed below:

Table 2-12: Five Sites with the Highest Free Ammonia

SITE ID	SITE LOCATION	FREE AMMONIA AVG, mg/L
WQSS0019	PITTOCK TNK, 3229 NW Pittock D	0.19
WQSS5017	Lexington Tank Outlet	0.15
WQSS5019	Rose Parkway Tank Outlet	0.15
WQSS5018	NE 148th and Halsey Tank Outlet	0.13
WQSS5008	Vernon Low	0.13

Table 2-13: Five Sites with the Most Variable Free Ammonia

SITE ID	SITE LOCATION	FREE AMMONIA VARIABILITY, mg/L
WQSS0019	PITTOCK TNK, 3229 NW Pittock D	0.68
WQSS5006	North Linnton Tank Outlet	0.27
WQSS0188	Penridge Tank	0.22
WQSS0063	7 - 11 Linnton -NW	0.20
WQSS0053	Margaret Scott Elementary -NE	0.16

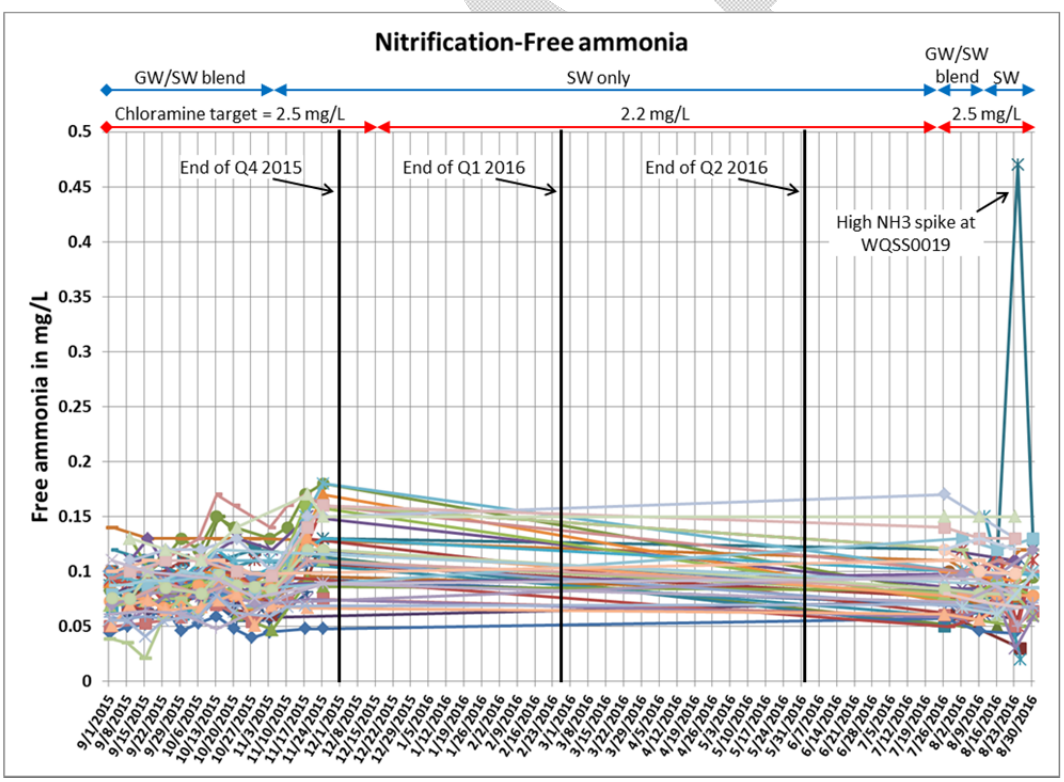


Figure 2-14: Free Ammonia Observed at Nitrification Sites during Q4 2015 and Q3 2016

The presence of nitrite is a good indication that nitrification is actively occurring, as once generated nitrite concentrations tend to be quickly converted to nitrate. The nitrite concentrations observed at nitrification monitoring sites is shown in Figure 2-15 below. With the exception of WQSS0095, the nitrite concentrations are lower in Q3 2016 than the same period a year ago. All sites had an average nitrite concentration less than 0.01 mg/L.

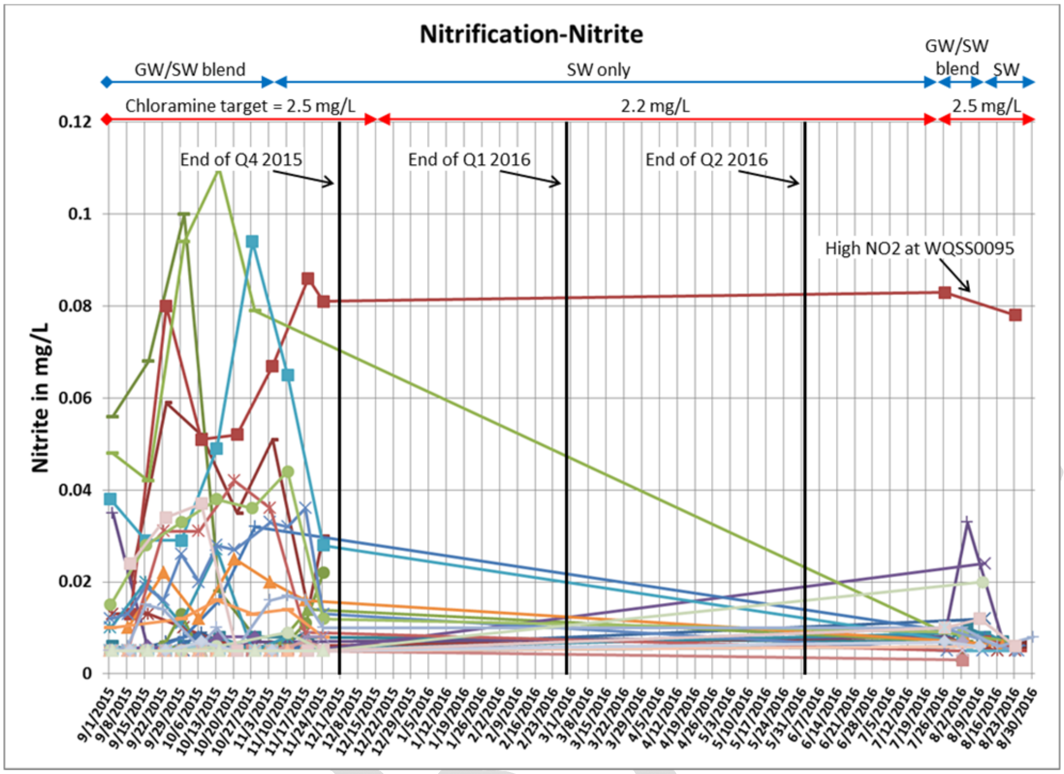


Figure 2-15: Nitrite Concentrations Observed at Nitrification Monitoring Sites during Q4 2015 and Q3 2016

Nitrate forms when nitrite is converted to nitrate. The nitrate concentrations observed at nitrification monitoring sites is shown in Figure 2-16 below. The nitrate concentrations during Q3 2016 are low as would be expected for the time of year. It should be noted that WQSS0108, which had a high nitrate concentration throughout Q4 2015, was not monitored during Q3 2016.

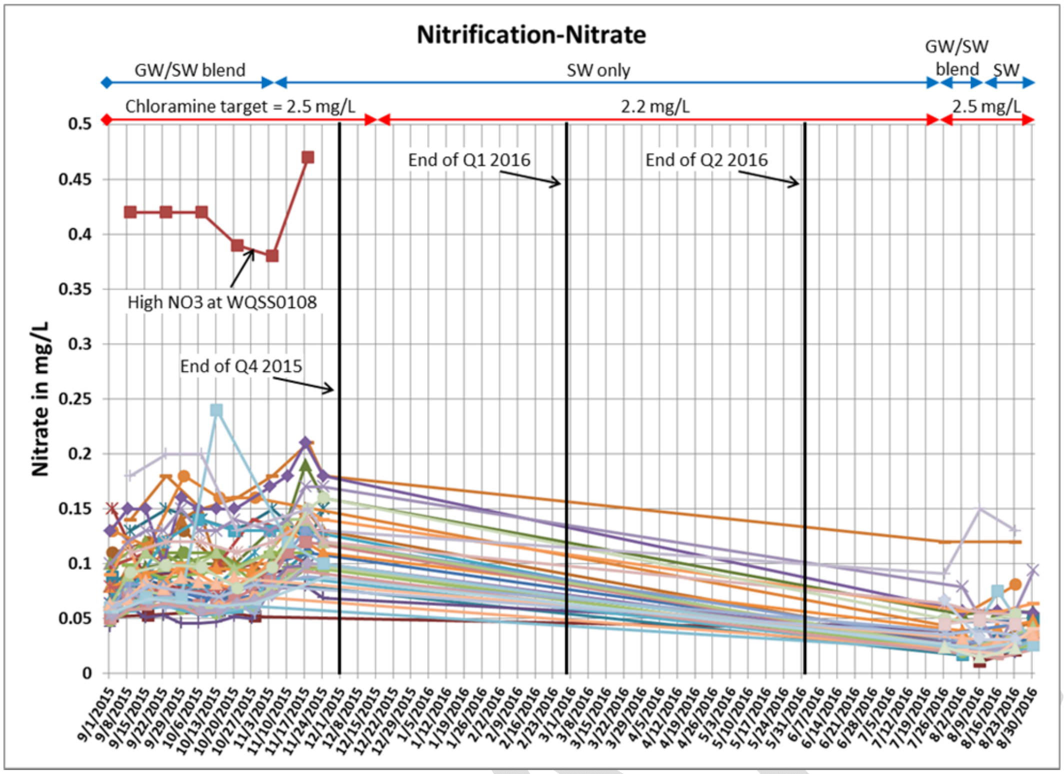


Figure 2-16: Nitrate Concentrations Observed at Nitrification Monitoring Sites during Q4 2015 and Q3 2016

Hydrogen ion formation during the production of both nitrite and nitrate can result in a drop of pH with the onset of nitrification. The pH observed at nitrification monitoring sites is shown in Figure 2-17 below. The pH during Q3 2016 was generally more variable than the similar period last year, due presumably to the high percentage of high alkalinity groundwater present during the nitrification season in 2015. The five stations with the lowest pH during Q3 2016 and the five stations with the highest variability between pH values are listed below:

Table 2-14: Five Sites with the Lowest pH

SITE ID	SITE LOCATION	pH AVG, SU
WQSS0108	SE Roswell	7.41
WQSS5018	NE 148th and Halsey Tank Outlet	7.51
WQSS0097	SW Riverwood Rd	7.53
WQSS5011	Arlington Heights 2 &3 CH Outlet	7.54
WQSS5012	Portland Heights 2 &3 CH Outlet	7.64

Table 2-15: Five Sites with the Most Variable pH

SITE ID	SITE LOCATION	pH VARIABILITY, SU
WQSS5018	NE 148th and Halsey Tank Outlet	3.88
WQSS0097	SW Riverwood Rd	3.40
WQSS0108	SE Roswell	2.50
WQSS5010	Marquam Hill 2 Tank Outlet	2.23
WQSS0028	SE Tenino Ct & Clatsop	2.21

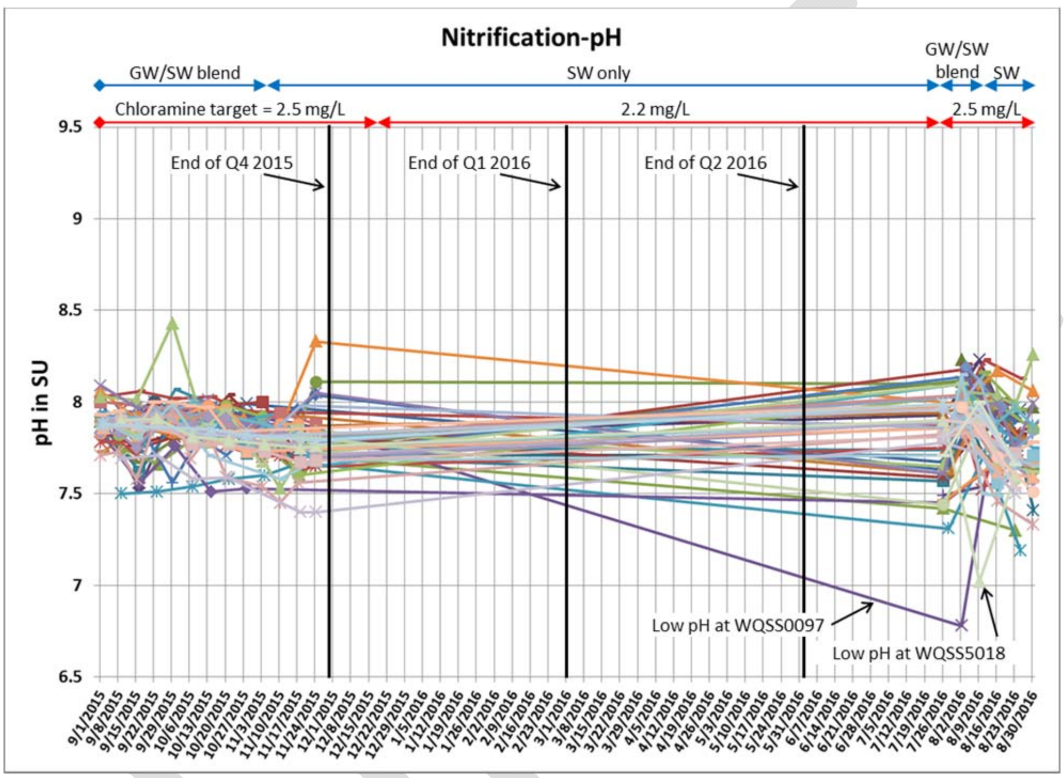


Figure 2-17: pH Observed at Nitrification Monitoring Sites during Q4 2015 and Q3 2016

2.5.3 Summary of Nitrification Data

In summary, the following observations were made from a review of the nitrification data:

- The bulk of the nitrification season typically occurs during Q4, and will be described further in the next quarterly report. GIS plots will be made at that time, since there was not enough data during this quarter to merit the creation of GIS plots.

Table 2-2 below indicates the water quality stations with the highest values of HPC, free ammonia, nitrite, nitrate, and lowest pH for Q4 2015 and Q3 2016. It should be noted that the data are limited for 2016 and will be updated once the Q4 2016 data are collected.

Table 2-16: Stations with the Most Evidence of Nitrification

STATION	SITE LOCATION	2015					2016				
		HPC	FREE AMMONIA	NITRITE	NITRATE	PH	HPC	FREE AMMONIA	NITRITE	NITRATE	PH
WQSS0019	PITTOCK TNK, 3229 NW Pittock D							X			
WQSS0031	Engine 7 -SE			X							
WQSS0034	St. Johns Precinct, North			X							
WQSS0064	WILLALATIN TANK, NW Skyline (1		X								
WQSS0069	NE Cornfoot & Alderwood		X								
WQSS0095	SE 9th & Ochoco			X	X	X			X		
WQSS0097	SW Riverwood Rd										X
WQSS0108	SE Roswell	X			X	X					X
WQSS0169	NE 24th & Emerson			X	X	X					
WQSS0182	SW Alta Dena & Santa Monica			X							
WQSS0188	Penridge Tank									X	
WQSS5002	Forest Park Tank Outlet									X	
WQSS5005	Whitwood Tank Outlet	X	X				X				
WQSS5006	North Linnton Tank Outlet	X					X			X	
WQSS5008	Vernon Low							X			
WQSS5011	Arlington Heights 2 &3 CH Outlet					X					X
WQSS5012	Portland Heights 2 &3 CH Outlet										X

STATION	SITE LOCATION	2015					2016				
		HPC	FREE AMMONIA	NITRITE	NITRATE	PH	HPC	FREE AMMONIA	NITRITE	NITRATE	PH
WQSS5013	Council Crest Tank Outlet	X									
WQSS5014	King Heights Tank Outlet	X			X		X				
WQSS5017	Lexington Tank Outlet		X				X	X		X	
WQSS5018	NE 148th and Halsey Tank Outlet							X			X
WQSS5019	Rose Parkway Tank Outlet		X		X	X		X		X	
WQSS5023	Marigold Tank						X				

2.6 LEAD AND COPPER COMPLIANCE DATA

2.6.1 Lead and Copper Compliance Data (Tier 1 Homes)

The PWB did not collect a compliance round of LCR Tier 1 home sampling during Q3 2016. The PWB previously collected compliance samples during Q4 2015 and Q2 2016. Compliance samples are collected by the residential customers. The previously collected samples were analyzed for total lead (Pb), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn).

A cumulative frequency plot of the joint monitoring plan (JMP) compliance lead sample results from Q4 2015 and Q2 2016 is shown in Figure 2-18 below.

The 90th percentile lead concentration of the JMP compliance dataset in Q2 2016 was 13.1 micrograms per liter (ug/L) and in Q4 2015 it was 14.1 ug/L. During Q2 2016, ten of the 114 homes had a lead concentration equal to or greater than the action level of 15 ug/L, with the highest lead sample having a concentration of 648 ug/L. While during Q4 2015, eleven of the 114 homes had a lead concentration equal to or greater than the action level of 15 ug/L, with the highest lead sample having a concentration of 38 ug/L. While lead speciation was not performed, it is presumed that the majority of the lead in the highest samples was in particulate form. This is commonly observed for lead spikes and such elevated concentrations of soluble lead would be highly unlikely based on lead dissolution theory..

Of the 114 samples for Q2 2016 from the JMP, 31 of the samples were from the PWB system, while the remaining homes are from wholesale customers. A review of the compliance samples from the PWB system only shows that 3 of the 31 homes were over the action level of 15 ug/L with a 90th percentile concentration of 13.1 ug/L (same 90th percentile as for the JMP set of data). The two highest lead concentrations (greater than 100 ug/L) from the JMP were not from the PWB system, but rather from wholesaler systems.

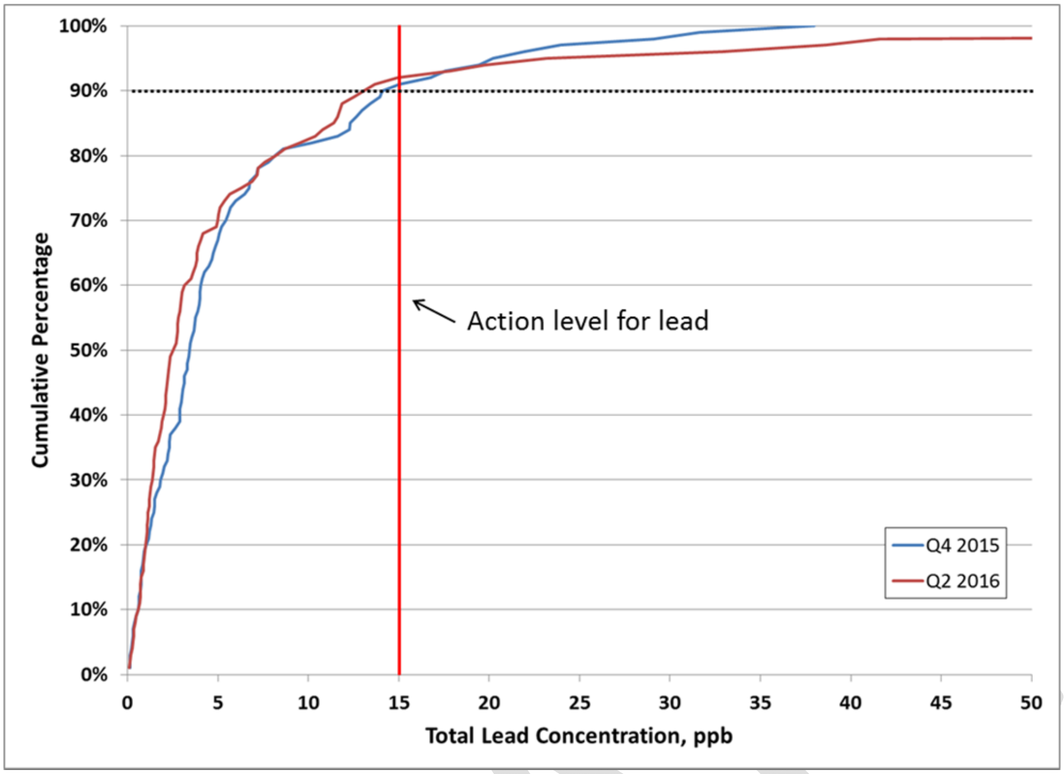


Figure 2-18: Results for LCR Compliance Lead Sampling from Q2 2016 and Q4 2015 from Joint Monitoring Plan (114 Samples)

Note that the graph above is cutoff at 50 ppb for clarity, but two samples from Q2 2016 were over 100 ug/L and the maximum lead value was 648 ug/L.

The 90th percentile copper concentration of the JMP compliance dataset in Q2 2016 was 287.7 micrograms per liter (ug/L) and in Q4 2015 it was 336.4 ug/L, which were both well below the action level of 1,300 ug/L. A cumulative frequency plot of the JMP compliance copper sample results from 2015 and 2016 is shown in Figure 2-19 below.

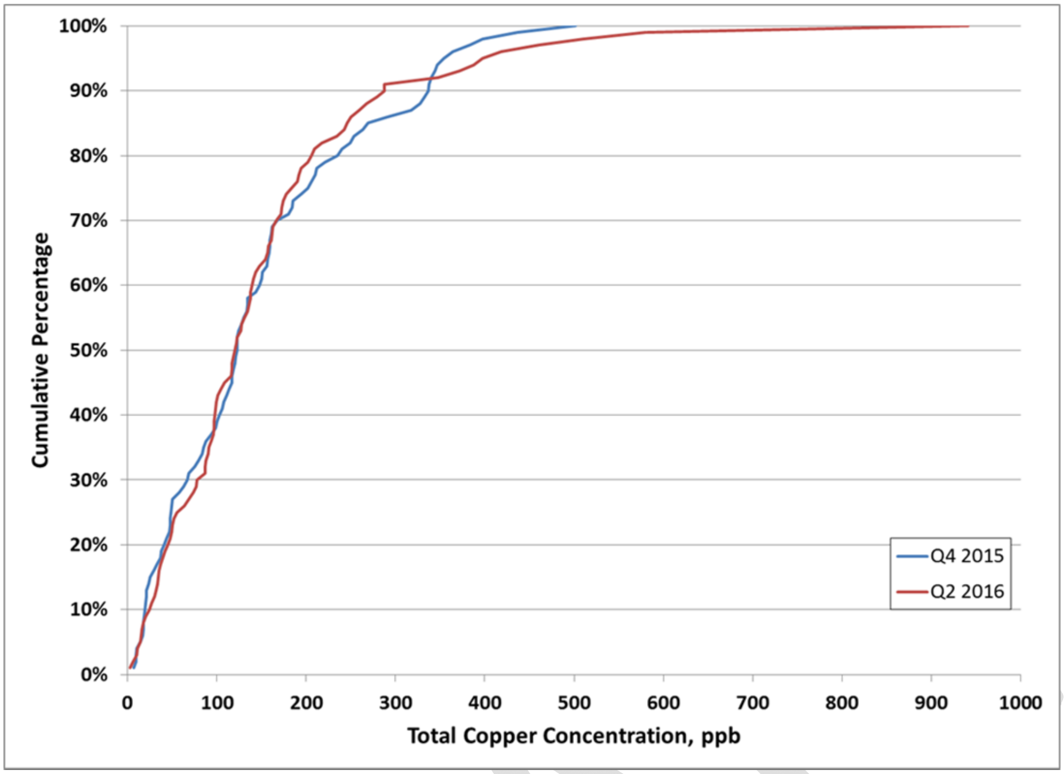


Figure 2-19: Cumulative Frequency Plot of Total Copper Concentration (ug/L) Collected as Part of LCR Compliance Sampling from Q2 2016 and Q4 2015 from Joint Monitoring Plan (114 Samples)

An analysis of additional metals (Zn, Fe, Mn) concentrations was performed together with lead and copper analysis. The concentration data for iron, manganese, and zinc are shown in Figures 2-20, 2-21, and 2-22, respectively. The higher concentrations are likely due to pipe wall scale release as that is a typical pattern with spikes in these metals, though speciation between dissolved and particulate form was not conducted on compliance samples to verify. The total levels of metals lower in Q2 2016 were generally lower than during Q4 2015. The total levels were well below associated secondary MCLs for iron and manganese in the vast majority of samples, and all samples were well below the secondary MCL for zinc.

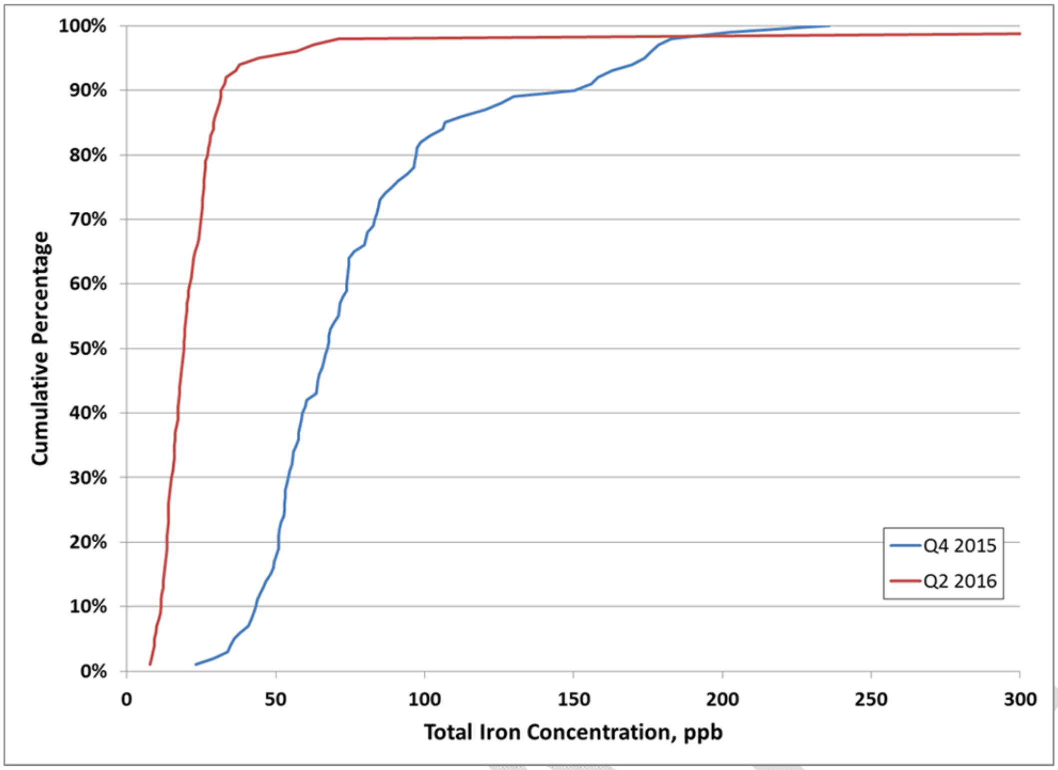


Figure 2-20: Cumulative Frequency Plot of Total Iron Concentration (ug/L) Collected as Part of LCR Compliance Sampling from 114 Sites

Note that the graph above is cutoff at 300 ppb for clarity, but two samples from Q2 2016 were between 400 and 600 ug/L and are not shown. The secondary MCL for iron is 300 ppb.

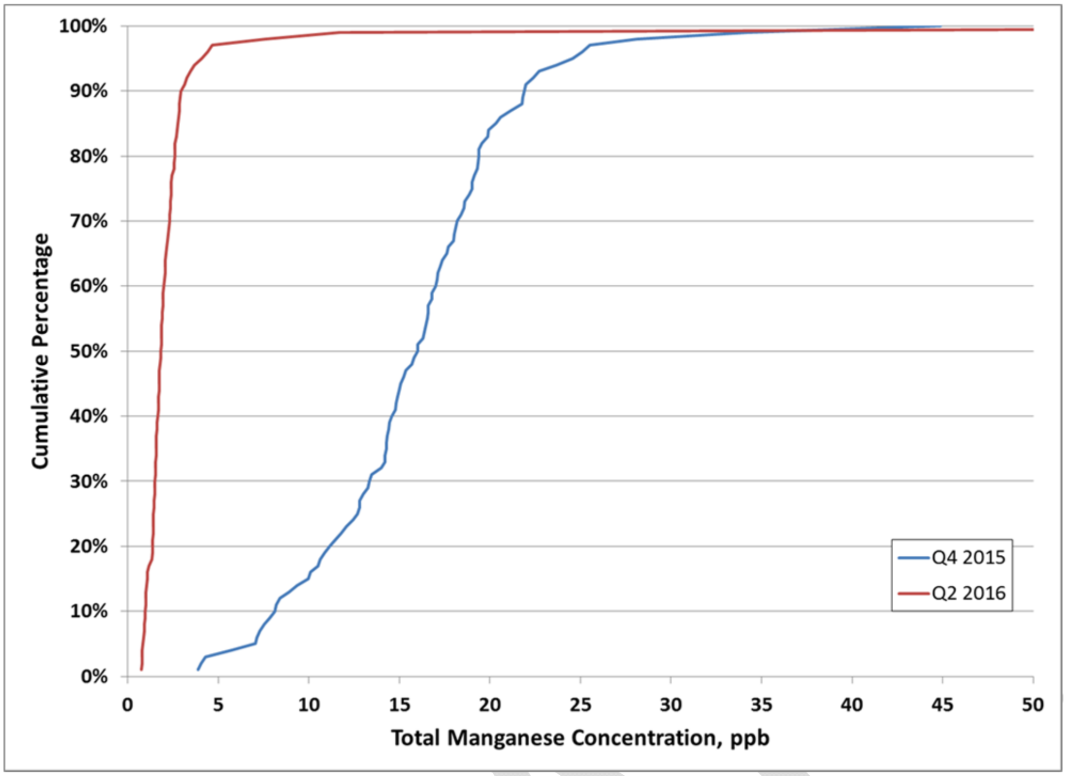


Figure 2-21: Cumulative Frequency Plot of Total Manganese Concentration (ug/L) Collected as Part of LCR Compliance Sampling from 114 Sites

Note that the graph above is cutoff at 50 ppb for clarity, but one sample from Q2 2016 was near 100 ug/L and is not shown. The secondary MCL for manganese is 50 ppb.

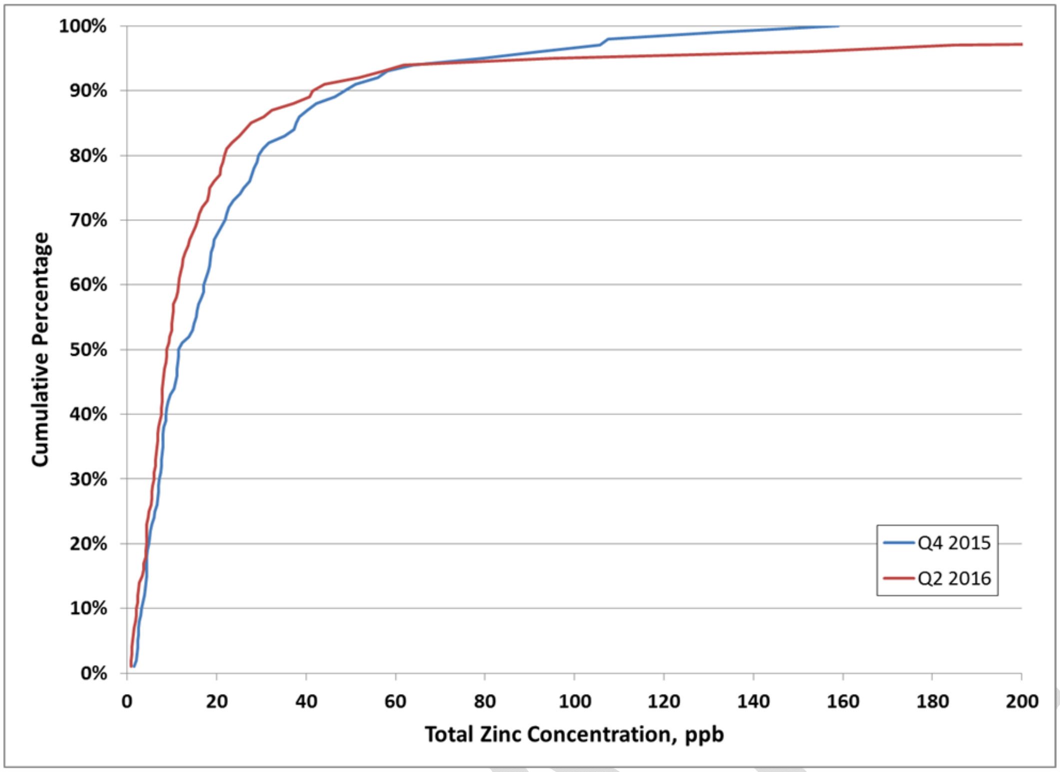


Figure 2-22: Cumulative Frequency Plot of Total Zinc Concentration (ug/L) Collected as Part of LCR Compliance Sampling from 114 Sites

Note that the graph above is cutoff at 200 ppb for clarity, but the maximum value from Q2 2016 was over 800 ug/L and is not shown. The secondary MCL for zinc is 5000 ppb.

Pearson's coefficients were generated in MS Excel® between the various metals concentrations. This provides a rapid means for determining if two parameters are trending together – coefficients greater than 0.5 indicate a higher probability that the two variable trend together. The Pearson's coefficient between lead and zinc for the whole JMP set of data was between 0.5 and 0.6, indicating that the lead data may be trending with the zinc data. When considering only the PWB set of data, the coefficients between all metals were less than 0.5, indicating the data do not trend together as often. These data should continue to be monitored throughout the study to strengthen the statistical analysis. It should be noted that only the total concentrations of each metal are known – the relationship between just the particulate fraction of metals would be expected to be stronger if scale release is contributing towards the higher metals concentrations.

2.6.2 Lead and Copper Compliance Water Quality Parameter Data

Water quality parameter samples were collected as part of the LCR sampling program and analyzed for pH and alkalinity. Note that these are not paired samples with the lead samples, as the samples discussed below were collected in the distribution system and not from customer taps. Therefore these data can only be interpreted as what the general conditions were during the time of compliance sampling, and should not be used to draw correlations between individual lead samples and water quality parameters such as pH.

Samples in Q3 2016 were collected between August 1 and 10, during the time that groundwater was fed to the system and towards the end of April 2016 (Q2), approximately during the same time as the majority of the compliance lead samples were collected. Twenty-seven WQP samples were collected and analyzed for pH and alkalinity. A handful of samples were also analyzed for total chlorine, temperature, and conductivity, though these were from the wholesaler systems and are not presented here.

The alkalinity and pH data collected during Q4 2015, Q2 2016, and Q3 2016 are summarized in the cumulative frequency plots below in Figures 2-23 and 2-24, respectively. The pattern in alkalinity matches exactly with the percentage of groundwater being fed to the system, with the highest alkalinity and most groundwater fed during Q4 2015. The pH did not follow the same pattern, with the highest pH values observed during Q3 2016, when a lower percentage of groundwater was being fed compared to Q4 2015. Elevated pH values were observed throughout the distribution system at that same time in Q3 2016 as when the WQP pH values were collected as observed in the TCR data.

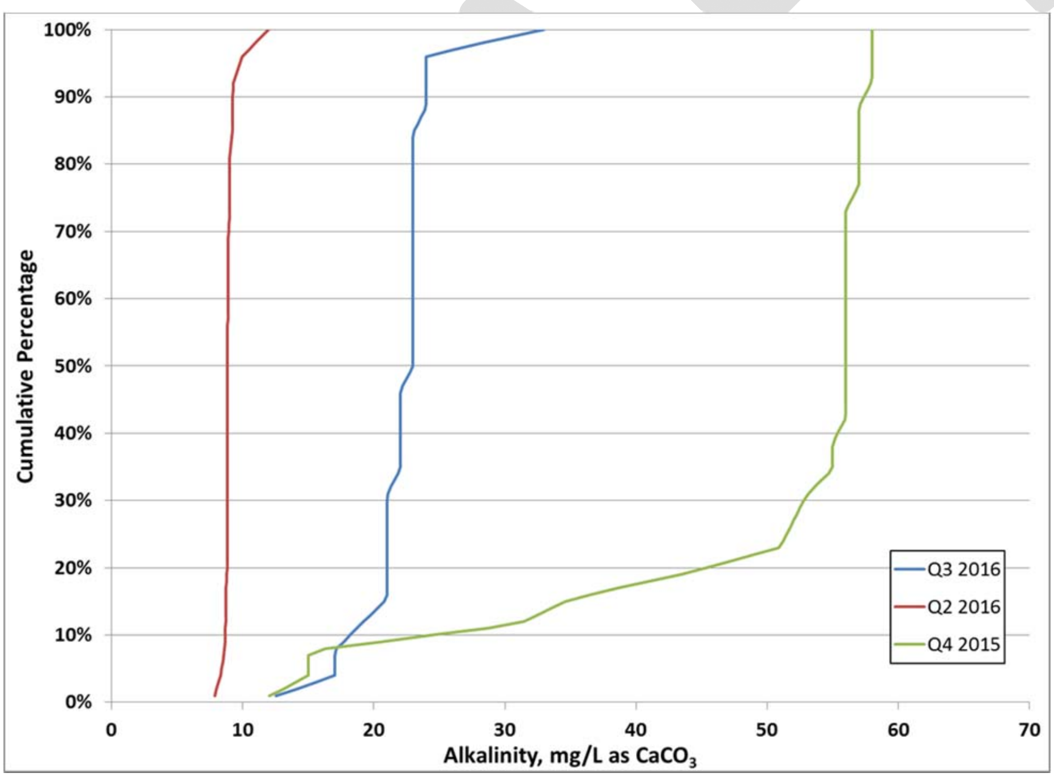


Figure 2-23: Alkalinity (mg/L as CaCO3) for 27 Water Quality Parameter Compliance Samples Collected from Q4 2015 through Q3 2016

Note that in Q4 2015 a blend of surface water and groundwater (40% – 75% of total supply) was used until November 4, 2015. In Q2 2016, only surface water was used, and in Q3 2016 a

blend of surface water and groundwater (12% – 16% of total supply) was used from July 25 through August 10, 2016.

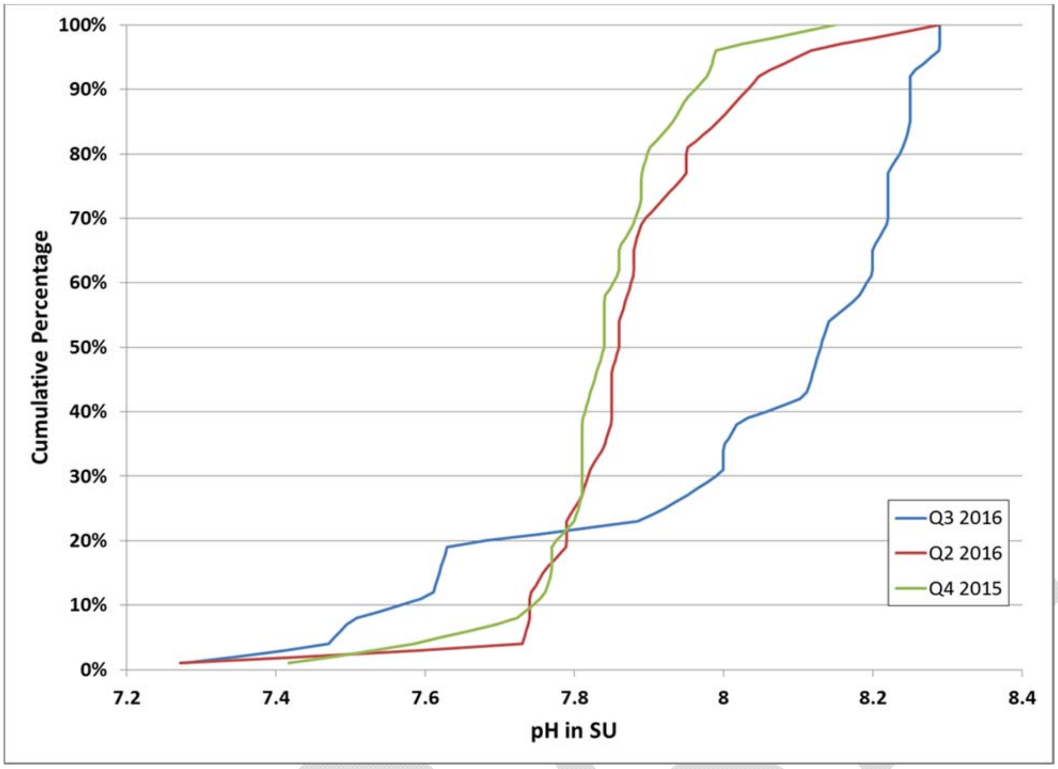


Figure 2-24: pH values (standard units) for 27 Water Quality Parameter Compliance Samples Collected from Q4 2015 through Q3 2016

Note that in Q4 2015 a blend of surface water and groundwater (40% – 75% of total supply) was used until November 4, 2015. In Q2 2016, only surface water was used, and in Q3 2016 a blend of surface water and groundwater (12% – 16% of total supply) was used from July 25 through August 10, 2016.

2.6.3 GIS Analysis

The results from the LCR compliance lead samples were plotted in GIS to look for spatial patterns of lead release within the Portland system. These are shown together with the voluntary customer lead data in section 2.7 below.

2.6.4 Summary of LCR Compliance Data

In summary, the following observations were made from a review of the LCR compliance data:

- A Tier 1 home compliance round of lead and copper sampling took place during Q2 2016. The 90th percentile lead concentration was 13.1 ug/L overall from the set of homes in the JMP. Two samples had lead concentrations greater than 100 ug/L, from Portland Wholesale customers. The 90th percentile lead concentration from just the set of PWB Tier 1 homes (31 samples) was also 13.1 ug/L.

- Both the JMP and the Portland-only data were very similar in Q2 2016 and the previous compliance sampling round conducted during Q4 2015.
- An examination of Pearson's coefficients indicates that lead is likely trending together with zinc in the compliance samples when considering the entire JMP data set. This relationship will continue to be monitored. Relationships with iron and manganese are not as strong.
- The next round of LCR compliance sampling is scheduled to take place during Q4 2016.

2.7 VOLUNTARY CUSTOMER LEAD DATA

The PWB has a program in place that allows customers to request that a stagnation sample be collected from the home and analyzed for lead by the PWB.

2.7.1 Metals Analysis

The PWB analyzed approximately 2,900 samples during the monitoring period (May 1 – Aug 15) for customers requesting lead testing. Voluntary customer samples in the majority of cases were analyzed for total lead (Pb) only. Copper (Cu) was analyzed for in 38 of the samples. Additional metals analysis such as for iron (Fe), manganese (Mn), and zinc (Zn) was not conducted this quarter due to the high volume of samples requested.

The 90th percentile lead concentration of the voluntary customer dataset was 3.8 ug/L in Q3 2016, down from 5.0 ug/L in Q2 2016 and 4.3 ug/L in Q1 2016. Seventy-two of the 2,940 samples (2.4%) were over the action level, compared to 2.7% over the action level in Q21 2016 and 1.4% over the action level in Q1 2016. The copper concentrations were generally very low, with an average of 110 ug/L, well below the action level of 1.3 mg/L.

It should be noted that individual voluntary customer samples do not necessarily have a source of lead or copper in the homes, explaining why the values are lower overall than the set of compliance Tier 1 homes reported above. It should also be noted that while the pool of homes included in each quarter are not the same and direct comparisons between the rounds are not necessarily valid, an analysis of the data in this way can provide indications on trends in lead release throughout the system.

The Pearson's coefficients were previously generated in MS Excel® for the Q2 2016 dataset to determine if the lead release data are trending together with any of the other metals. The coefficients were between 0.5 and 0.8, indicating a likelihood that both lead and copper are trending with iron, manganese and zinc. It should be noted that only the total concentrations of each metal are known – the relationship between just the particulate fraction of metals is expected to be stronger due if scale release is contributing to the higher metals concentrations. These metals were not collected in Q3 2016, and it is not known at this time if they will be collected in the future due to the large volume of samples received by PWB.

2.7.2 GIS Analysis

The results from the lead analyses for the voluntary customer results were plotted in GIS to better visualize the lead release data spatially (LCR compliance samples were not collected this quarter and therefore are not included in the plot). This is shown in Figure 2-25 below. The areas with relative water quality challenges are shown together with the high lead concentrations in Figure 2-26. As indicated in the graphs, there is no obvious spatial pattern to the lead release observed in the system nor a pattern connecting water quality conditions to elevated lead release.

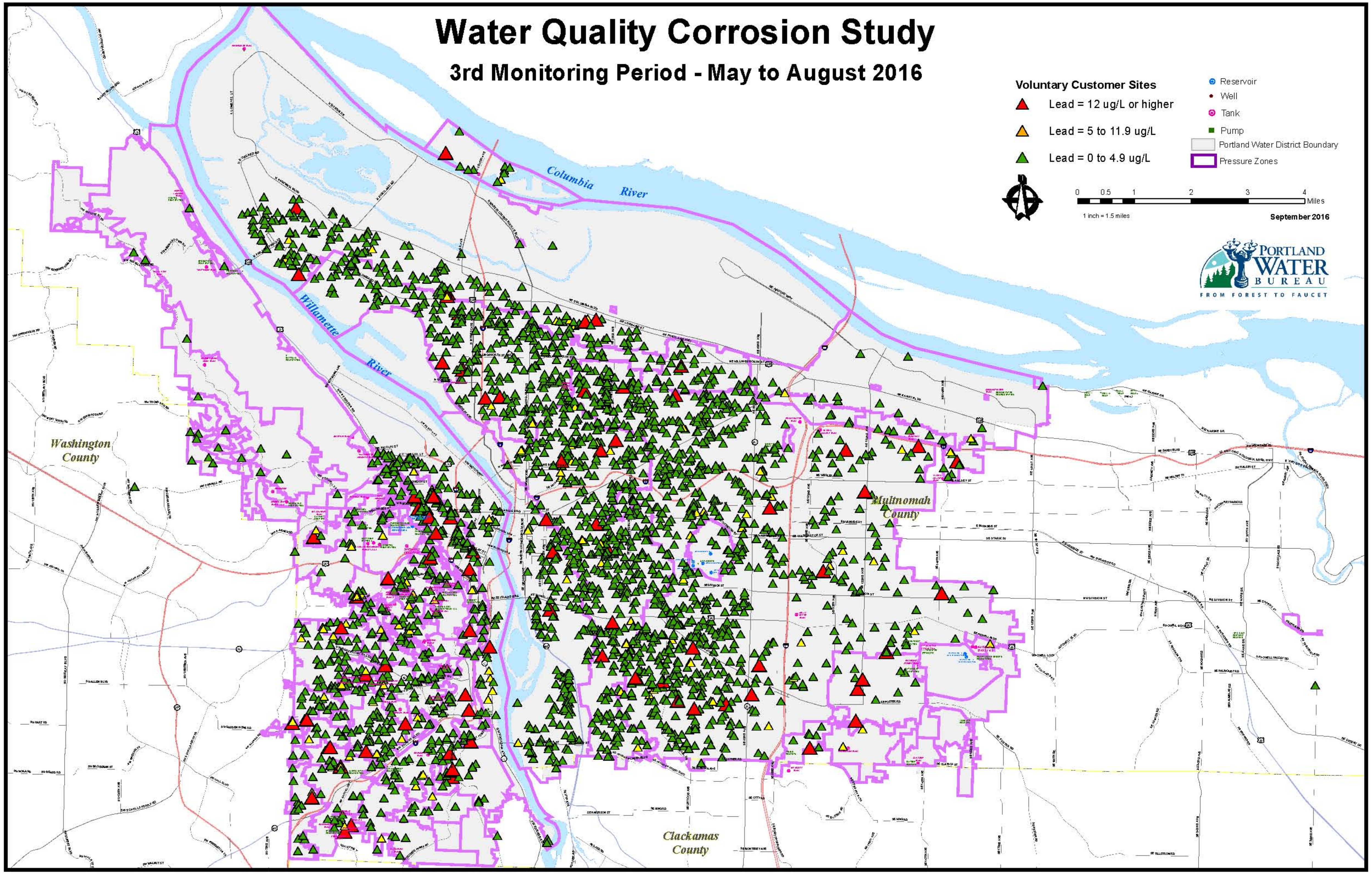
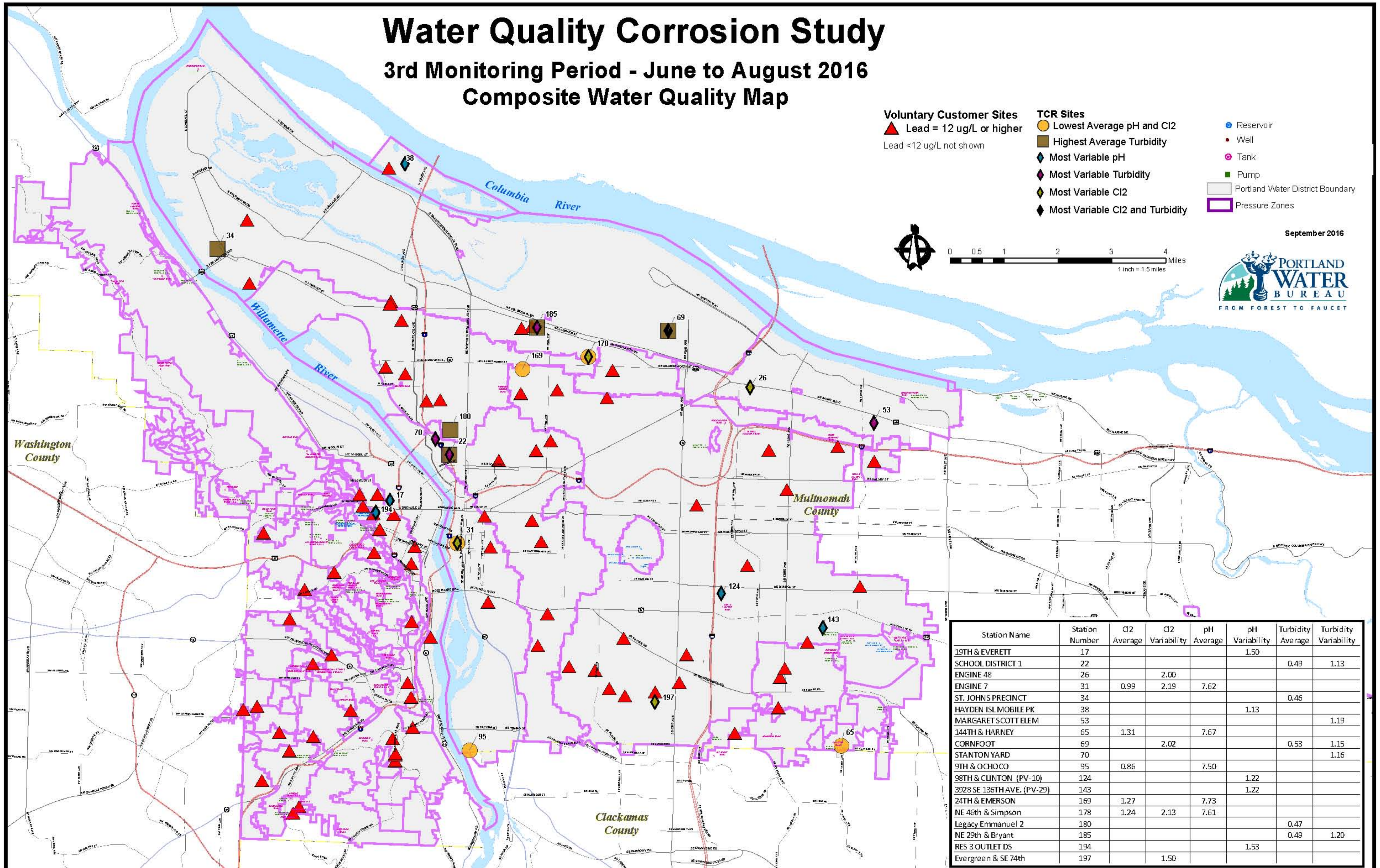


Figure 2-25: GIS Plot of Lead Concentrations Observed from Voluntary Customer Samples during Q3 2016



Station Name	Station Number	Cl2 Average	Cl2 Variability	pH Average	pH Variability	Turbidity Average	Turbidity Variability
19TH & EVERETT	17				1.50		
SCHOOL DISTRICT 1	22					0.49	1.13
ENGINE 48	26		2.00				
ENGINE 7	31	0.99	2.19	7.62			
ST. JOHNS PRECINCT	34					0.46	
HAYDEN ISL MOBILE PK	38				1.13		
MARGARET SCOTT ELEM	53						1.19
144TH & HARNEY	65	1.31		7.67			
CORNFOOT	69		2.02			0.53	1.15
STANTON YARD	70						1.16
9TH & OCHOCO	95	0.86		7.50			
98TH & CLINTON (PV-10)	124				1.22		
3928 SE 136TH AVE. (PV-29)	143				1.22		
24TH & EMERSON	169	1.27		7.73			
NE 46th & Simpson	178	1.24	2.13	7.61			
Legacy Emmanuel 2	180					0.47	
NE 29th & Bryant	185					0.49	1.20
RES 3 OUTLET DS	194				1.53		
Evergreen & SE 74th	197		1.50				

Figure 2-26: GIS Plot of High Lead Concentrations Observed from Voluntary Customer Samples Together with Areas with Water Quality Challenges Observed in TCR Sampling during Q3 2016

2.7.3 Summary of Voluntary Customer Lead Data

In summary, the following observations were made from a review of the voluntary customer lead data:

- 2.4% of the homes were over the action level during Q3 2016, compared to 2.7% of the homes during Q2 2016 and 1.4% of the homes during Q1 2016. Overall the range of data is similar between the three sampling quarters.
- Based on available data, elevated lead levels do not seem to correspond to geographical areas with corrosion-related water quality challenges.

2.8 SUPPLEMENTAL RESIDENTIAL CUSTOMER TESTING

A more detailed testing protocol is described in TM2 for collecting additional water chemistry data at residential customer homes from a select group of voluntary customer homes. The intent is to capture water quality data together with lead release across homes with a spread of lead concentrations. This data set is expected to generate water quality data paired with the lead analysis to aid in identifying the specific mechanisms of and factors influencing lead release in the Portland water system. A more complete statistical analysis of the data will be performed in the final report, once all of the data have been collected. Initial trends are presented in this quarterly report.

Follow up sampling in residential customer homes was performed during this monitoring period at 21 homes, as well as the five homes where sampling occurred during the previous quarter. All 26 homes were from the voluntary customer lead pool and not the compliance pool. Both a flowing water and stagnation sample are collected from each home and analyzed for all of the parameters describing uniform corrosion, biostability, and scale release. It should be noted that the flowing water sample is actually collected following stagnation to eliminate the need to visit the home on two separate sampling occasions.

The distribution of lead release from stagnating samples is shown in Figure 2-27 below. As indicated there is a good spread of lead concentrations, with four homes with a lead concentration less than five ug/L, nine homes between five and 12 ug/L, and seven homes greater than 12 ug/L. The highest lead concentration was 101 ug/L total lead.

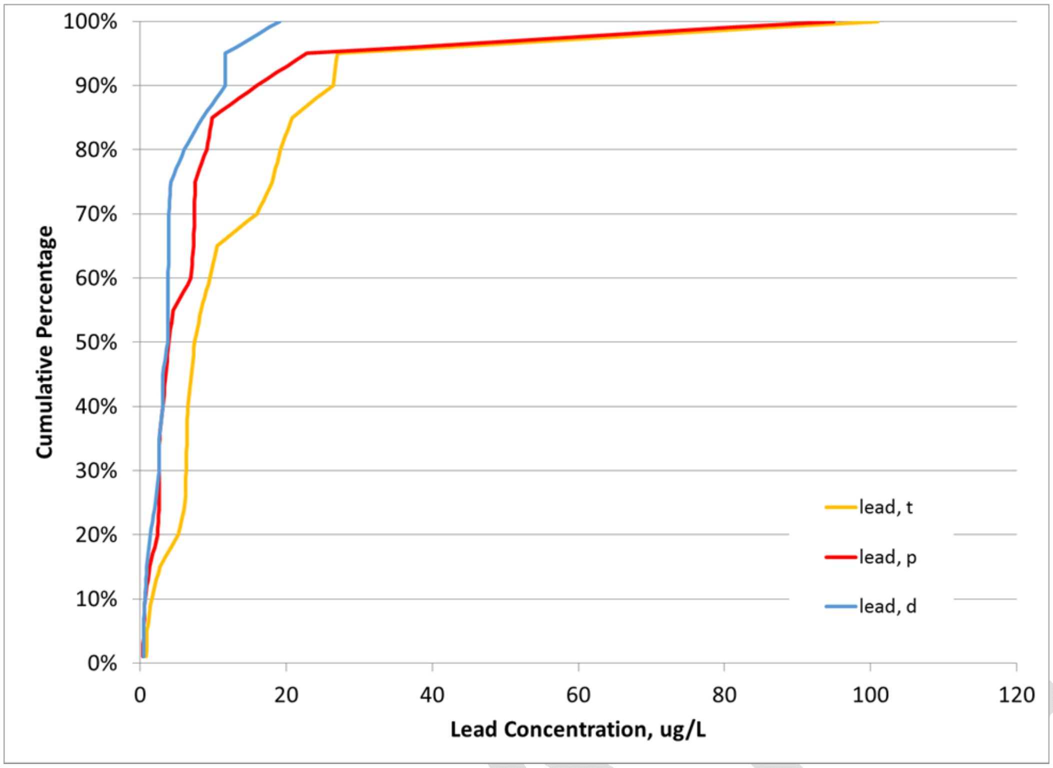


Figure 2-27: Lead Concentration Data for Supplemental Residential Samples Collected during Q3 2016

The lead release from stagnation samples was approximately 50% particulate and 50% dissolved in most of the samples. However, in the two homes with the highest total lead, the average percent particulate was 90%. That is to say that particulate lead was predominantly responsible for the lead spikes observed. Additionally, the four homes with the highest particulate lead in stagnation samples were the same four homes with the highest concentration of particulate iron, particulate zinc, total manganese, and the highest turbidity. The home with the highest particulate lead concentration (94 ug/L particulate lead, 101 ug/L total lead) had a turbidity of 21 NTU and a particulate iron concentration of 1.2 mg/L.

Table 2-3 showing the water quality from each customer sample is shown below.

Table 2-17: Supplementary Water Quality Data Collected at Residential Taps

Location	Collection	Al,d	Al,T	Alk,T	ATP	Ca,T	Chloride	Cl2,T	Cond	Cu,d	Cu,T	DOC	ORP	Fe,d	Fe,T	Hardness	Mg,d	Mg,T	Mn,d	Mn,T	NH3-N	Ni,T	NO2-N	NO3-N	P,T	Pb,d	Pb,T	Pb,P	Pb, %P	pH	TDS	T	Turb	Zn,d	Zc,T
	Date	ug/L	ug/L	mg/L as CaCO3	pg/mL	mg/L	mg/L	mg/L	uS/cm	ug/L	ug/L	mg/L	mv	ug/L	ug/L	mg/L as CaCO3	mg/L	mg/L	ug/L	ug/L	mg/L	ug/L	mg/L	mg/L	mg/L	ug/L	ug/L			units	mg/L	° C	NTU	ug/L	ug/L
1- Flowing	8/16/2016 3	10.0	15.0	12	0.39	2.3	3.2	1.48	37.0	8.50	9.27	1.1	370.1	24.9	61.7	9.2	0.83	0.82	0.87	8.93	0.03	<0.50	<0.005	0.027	<0.01	0.24	0.38	0.14		7.83	29	17.6	0.33	2.05	2.22
1- Stagnant	8/16/2016 3	12.1	16.0		0.55	3.1		0.45	45.8	78.4	92.9		237.5	20.7	56.6		1.1	1.1	1.17	8.18	0.19	<0.50	0.010	0.045		3.77	8.33	4.56	55%	7.65		24.1	0.36	74.2	76.2
2- Flowing	7/12/2016 2	11.6	16.7	12	0.45	2.4	3.2	1.28	40.0	18.4	21.7	0.91	458.6	14.1	35.9	9.2	0.78	0.79	0.99	3.76	0.05	<0.50	<0.005	0.038	<0.01	0.32	0.55	0.23		7.70	31	20.5	0.34	0.59	0.63
2- Stagnant	7/12/2016 2	10.6	15.0		2.58	2.3		0.59	42.9	129	150		443.9	12.1	40.1		0.81	0.81	1.06	3.83	0.17	<0.50	0.008	0.032		3.08	6.17	3.09	50%	7.70		19.1	0.47	6.03	6.73
3- Flowing	8/16/2016 8	10.1	14.2	11	0.51	2.3	3.2	1.62	37.1	6.31	7.34	1.2	472.5	26.2	55.3	9.0	0.79	0.80	1.38	6.03	0.07	<0.50	<0.005	0.032	<0.01	0.27	0.39	0.12		7.81	25	20.9	0.25	0.71	0.65
3- Stagnant	8/16/2016 7	13.3	17.7		0.80	2.4		0.64	40.2	85.1	97.2		282.7	24.9	53.2		0.85	0.86	1.26	4.64	0.16	<0.50	0.008	0.031		3.80	6.40	2.6	41%	7.72		19.8	0.30	8.42	8.53
4- Flowing	6/14/2016 3	13.3	14.7	11	FE	2.3	3.2	1.19	36.5	38.2	9.03	0.88	320.1	11.5	26.6	8.7	0.77	0.72	0.95	4.01	0.08	<0.50	<0.005	0.029	<0.01	0.20	0.26	0.06		7.83	23	17.0	0.32	1.48	1.01
4- Stagnant	6/14/2016 3	13.1	16.4		FE	2.3		1.05	88.2	62.4	69.4		315.6	11.0	23.9		0.74	0.73	1.20	2.92	0.11	<0.50	0.007	0.024		0.89	1.56	0.67	43%	7.70		18.7	0.47	5.87	6.08
5- Flowing	7/19/2016 7	12.4	15.9	14	0.60	2.5	2.9	1.45	40.9	2.81	3.63	0.95	479.3	16.0	37.7	9.5	0.78	0.79	0.92	3.95	0.07	<0.50	0.005	0.027	<0.01	0.42	0.77	0.35		8.04	27	16.9	0.24	0.59	0.59
5- Stagnant	7/19/2016 7	13.1	17.6		0.69	2.7		0.55	42.1	49.3	57.8		387.1	12.8	33.3		0.83	0.83	0.91	3.40	0.07	<0.50	0.011	0.040		11.7	20.8	9.1	44%	7.72		19.3	0.27	14.7	14.3
6- Flowing	6/21/2016 7	11.6	23.6	11	0.71	2.1	3.0	1.73	33.0	10.5	15.2	1.2	303.1	11.4	57.4	8.3	0.75	0.74	0.96	10.9	0.04	<0.50	<0.005	0.023	<0.01	0.27	0.70	0.43		7.60	27	15.9	0.54	0.87	1.33
6- Stagnant	6/21/2016 7	13.7	23.4		2.44	2.2		0.29	35	187	214		259.1	8.1	21.3		0.77	0.76	0.79	2.28	0.19	0.58	0.016	0.021		3.84	6.50	2.66	41%	7.66		16.0	0.24	37.6	38.5
7- Flowing	5/24/2016 8	11.8	15.4	10	0.96	1.8	2.8	1.67	44.1	9.99	11.8	0.88	488.2	18.5	30.5	7.1	0.66	0.65	1.29	2.46	0.05	<0.50	<0.005	0.020	<0.01	0.82	1.17	0.35		7.63	25	15.6	0.24	1.49	1.69
7- Stagnant	5/24/2016 8	9.33	12.4		2.55	1.8		0.12	42.3	135	149		289.7	11.8	24.4		0.74	0.73	0.62	1.70	0.24	<0.50	0.021	0.046		19.1	26.4	7.3	28%	7.65		19.7	0.30	33.1	33.7
8- Flowing	7/26/2016 6	9.73	12.7	15	0.68	2.9	3.2	1.45	42.6	21.3	23.2	1.1	488.6	22.4	43.5	11	1.1	1.0	1.68	4.13	0.08	<0.50	0.005	0.028	<0.01	0.16	0.23	0.07		7.67	34	17.5	0.24	0.55	<0.50
8- Stagnant	7/26/2016 6	8.05	11.7		1.21	2.1		0.22	38.9	203	231		399.9	14.2	37.6		0.81	0.75	1.07	2.80	0.22	1.27	0.021	0.037		1.38	2.68	1.3	49%	7.62		20.7	0.34	13.0	12.9
9- Flowing	6/28/2016 8	11.6	15.6	12	0.58	2.2	3.0	1.61	43.8	14.9	21.3	0.95	344.5	20.2	49.8	8.7	0.77	0.77	1.91	4.69	0.06	2.32	<0.005	0.019	<0.01	0.86	1.88	1.02		7.83	33	19.8	0.43	2.76	3.31
9- Stagnant	6/28/2016 7	7.72	15.3		7.09	2.4		<0.1	41.7	109	724		256.7	65.8	1310		0.82	0.84	13.5	17.4	0.21	0.60	0.033	0.033		6.06	101	94.9	94%	7.61		20.3	21.1	32.4	65.1
10- Flowing	8/9/2016 9:	10.6	12.9	22	0.52	4.3	4.1	1.11	61.0	12.7	14.8	1.1	394.6	34.8	75.1	18	1.8	1.7	2.75	9.47	0.07	<0.50	0.016	0.069	0.02	0.093	0.16	0.07		7.76	48	22.5	0.35	31.1	30.2
10- Stagnant	8/9/2016 9:	5.27	9.70		1.14	4.2		0.26	67.1	22.6	62.0		237.2	121	1110		1.8	1.7	13.0	17.3	0.07	0.76	0.028	0.19		2.10	18.1	16	88%	7.47		19.4	3.57	913	1070
11- Flowing	5/24/2016 3	6.99	16.4	11	FE	1.7	2.8	1.42	34.6	36.7	18.5	1.2	297.7	13.6	23.4	7.2	0.72	0.71	0.73	2.56	0.06	<0.50	<0.005	0.015	<0.01	0.76	1.53	0.77		7.65	24	19.7	0.29	20.0	0.65
11- Stagnant	5/24/2016 3	13.0	15.3		FE	1.8		0.78	34.9	83.4	99.8		294.5	8.4	20.0		0.77	0.75	0.53	1.84	0.13	<0.50	0.007	0.013		8.54	16.0	7.46	47%	7.53		18.9	0.37	4.59	4.08
12- Flowing	8/16/2016 4	10.8	15.0	13	0.51	2.6	3.3	1.52	38.6	16.7	19.6	1.2	421.9	24.6	58.8	10	0.90	0.90	1.17	7.65	FE	<0.50	<0.005	0.036	<0.01	0.27	0.46	0.19		7.91	30	19.1	0.32	1.64	1.68
12- Stagnant	8/16/2016 3	15.1	24.3		5.61	2.8		0.25	48.7	140	202		275.6	91.7	297		0.95	0.96	2.18	12.4	FE	<0.50	0.012	0.055		2.60	9.57	6.97	73%	7.84		28.6	1.48	43.7	61.1
13- Flowing	6/7/2016 8:	13.0	16.4	11	1.23	1.9	2.8	1.78	33.1	7.63	8.27	0.91	358.8	13.0	30.5	7.8	0.69	0.72	0.99	4.21	0.04	<0.50	<0.005	0.021	<0.01	0.27	0.36	0.09		7.62	24	16.8	0.40	1.26	1.11
13- Stagnant	6/7/2016 8:	18.3	25.5		0.32	2.1		0.30	38.0	163	182		238.1	10.3	24.4		0.74	0.76	1.54	2.94	0.20	<0.50	0.017	0.038		3.89	6.28	2.39	38%	7.64		20.5	0.33	13.3	13.5
14- Flowing	7/26/2016 1	10.1	16.5	14	0.82	2.6	3.2	1.23	40.5	14.9	18.6	1.2	461.1	22.3	59.9	10	0.95	0.96	2.61	7.31	0.07	<0.50	<0.005	0.034	<0.01	0.53	1.01	0.48		7.66	34	19.0	0.39	<0.50	<0.50
14- Stagnant	7/26/2016 1	13.7	17.4		4.33	2.3		<0.1	41.1	135	156		239.6	14.5	38.3		0.86	0.85	2.03	3.83	0.23	<0.50	0.021	0.032		11.7	19.2	7.5	39%	7.70		23.0	0.37	3.03	3.09
15- Flowing	7/19/2016 7	10.3	15.0	13	0.87	2.3	3.2	0.97	41.3	21.3	24.8	1.2	424.6	17.4	44.9	9.0	0.76	0.78	1.67	5.25	0.10	<0.50	0.008	0.050	<0.01	0.15	0.26	0.11		7.66	27	17.0	0.31	0.74	0.82
15- Stagnant	7/19/2016 7	7.96	11.5		1.27	2.4		<0.1	40.9	311	359		396.1	11.3	33.3		0.78	0.79	1.56	3.54	0.16	<0.50	0.029	0.054		0.46	0.92	0.46	50%	7.61		20.1	0.39	11.0	10.7
16- Flowing	7/12/2016 8	10.9	16.4	12	0.45	2.4	3.1	1.19	39.2	6.46	8.43	0.87	411.4	13.2	39.8	9.2	0.79	0.78	1.02	4.02	0.04	2.14	<0.005	0.038	<0.01	0.25	3.09	2.84		7.73	33	FE	0.33	11.6	29.9
16- Stagnant	7/12/2016 8	10.4	117		0.98	2.5		1.09	52.6	5.60	22.6		417.6	14.6	233		0.78	0.80	0.62	40.8	0.08	21.8	0.008	0.037		0.64	10.5	9.86	94%	7.49		FE	3.95	640	910
17- Flowing	6/7/2016 3:	11.1	14.5	11	2.54	2.7	3.5	0.34	37.4	10.4	11.5	0.86	419.6	19.6	39.9	9.6	0.70	0.72	1.52	3.03	0.07	<0.50	0.038	0.24	<0.01	0.31	0.50	0.19		7.59	27	19.0	0.52	0.65	0.66
17- Stagnant	6/7/2016 2:	7.72	12.6		3.99	2.8		<0.1	40.1	83.8	113		253.5	15.8	28.6		0.72	0.72	1.27	2.15	0.11	<0.50	0.011	0.30		3.12	7.01	3.89	55%	7.49		24.95	0.41	35.5	23.9
18- Flowing	6/28/2016 8	10.2	15.9	12	0.71	2.2	3.0	1.60	42.7	8.25	9.58	0.98	507.0	15.8	40.5	8.5	0.75	0.76	0.99	4.25	0.04	<0.50	<0.005	0.022	<0.01	0.16	0.26	0.1		7.58	35	17.5	0.29	1.31	1.30
18- Stagnant	6/28/2016 8	11.2	15.7		1.66	2.3		<0.1	40.6	215	247		259.5	11.2	38.9		0.80	0.79	1.35	3.96	0.22	1.02	0.022	0.038		2.60	5.21	2.61	50%	7.57		21.0	0.42	12.4	13.1
19- Flowing	8/16/2016 9	9.76	14.3	11	0.40	2.2	3.2	1.67	35.3	2.34	2.53	1.2	410.2	36.6	69.0	8.8	0.79	0.81	1.95	6.58	0.08	<0.50	<0.005	0.028	<0.01	0.069	0.071	0		7.74	21	19.1	0.39	2.93	2.65
19- Stagnant	8/16/2016 9	9.72	12.8		0.49	2.5		0.20	44.9	30.2	38.7		310.0	81.1	172		1.0	1.0	1.74	4.16	0.09	2.01	0.066	0.22		0.44	0.81	0.37	46%	7.60		18.6	0.57	27.9	29.7
20- Flowing	6/14/2016 1	9.48	14.5	11	FE	2.1	3.6	0.80	35.1	24.0	26.3	0.89	442.1	55.3	124	8.2	0.73	0.74	4.84	6.59	0.10	<0.50	<0.005	0.11	<0.01	0.38	0.99	0.61		7.63	26	19.0	0.58	15.7	18.3
20- Stagnant	6/14/2016 1	5.82	49.0		FE	2.3		<0.1	38.1	59.6	146		411.4	112	829		0.78	0.81	11.2	23.8	0.03	0.55	0.013	0.36		4.20	27.0	22.8	84%	7.41		20.5	4.53	216	285
21- Flowing	6/21/2016 7	11.1	15.5	10	1.21	2.2	3.2	1.35	34.5	10.2	12.4	0.91	360.2	11.6	33.3	8.5	0.68	0.69	0.65	3.96	0.06	<0.50	0.006	0.043	<0.01	0.22	0.46	0.24		7.73	30	15.4	0.30	2.11	2.12
21- Stagnant	6/21/2016 7	10.6	14.5		1.61	2.4		0.14	37.2	129	150		536.3	22.1	53.5		0.72	0.74	2.24	4.34	0.18	1.36	0.026	0.098		3.94	7.46	3.52	47%	7.39		16.8	0.33	41.0	42.9

As seen in the chart, the pH in most of the homes dropped between 0.1 and 0.3 units during stagnation.

Pearson's coefficients were generated in MS Excel® between lead and the various other water quality parameters. This provides a rapid means for determining if two parameters are trending together – coefficients greater than 0.5 indicate a higher probability that the two variable trend together. A more detailed statistical analysis will be performed in the final report. This initial analysis revealed that dissolved lead did not appear to trend with parameters that typically describe uniform corrosion. However, particulate lead is trending with particulate copper, ATP, particulate iron, and turbidity. These relationships for particulate lead can be seen visually in the following graphs.

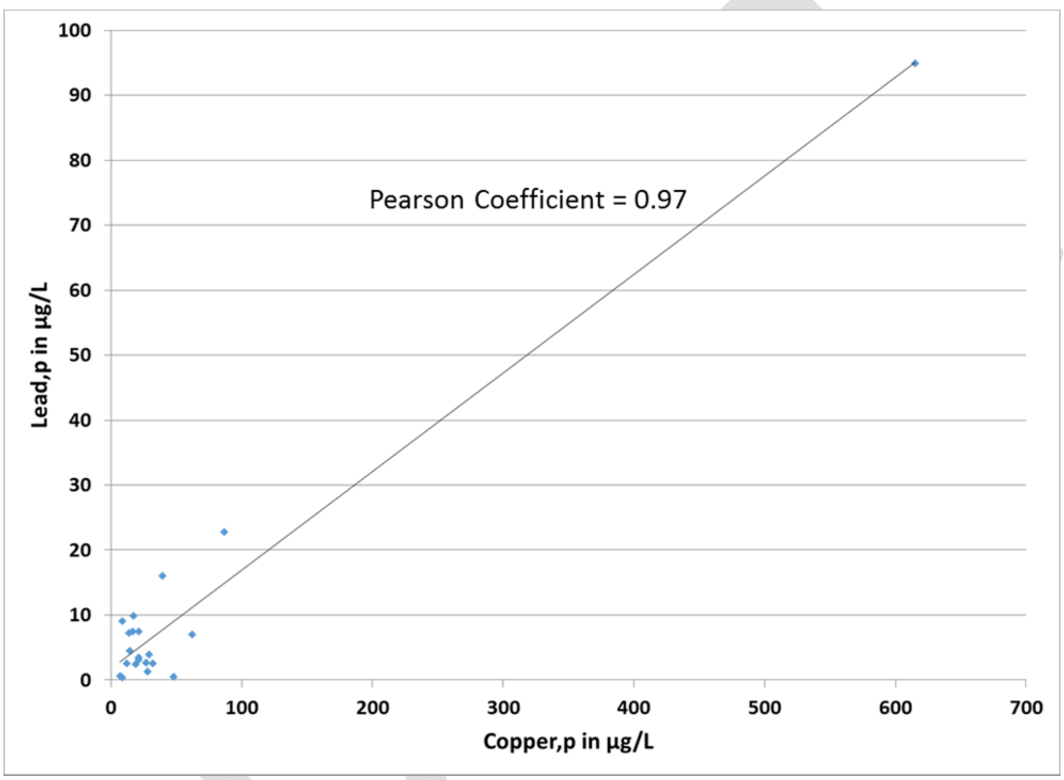


Figure 2-28: Correlation Plot Showing Relationship between Particulate Lead and Particulate Copper for Supplemental Residential Samples Collected during Q3 2016

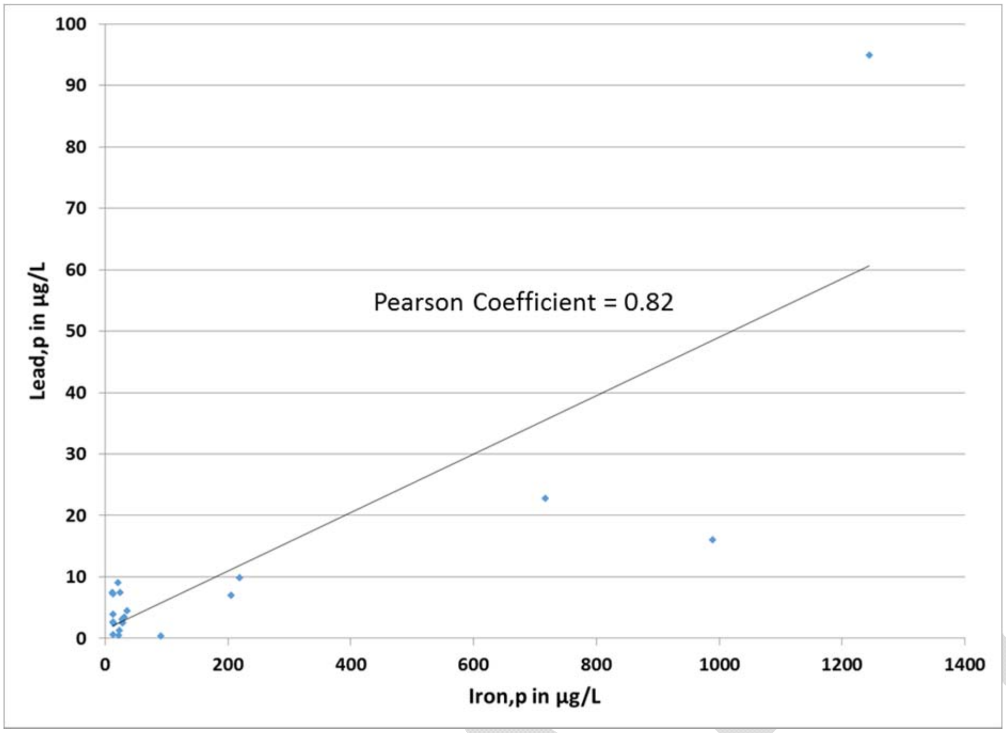


Figure 2-29: Correlation Plot Showing Relationship between Particulate Lead and Particulate Iron for Supplemental Residential Samples Collected during Q3 2016

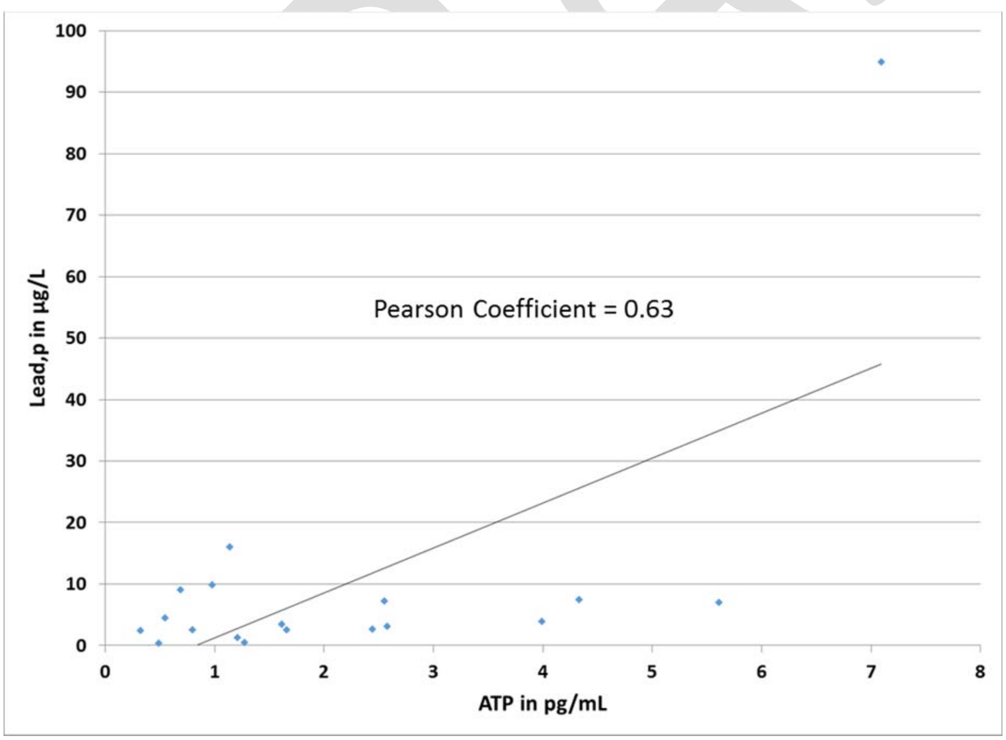


Figure 2-30: Correlation Plot Showing Relationship between Particulate Lead and ATP for Supplemental Residential Samples Collected during Q3 2016

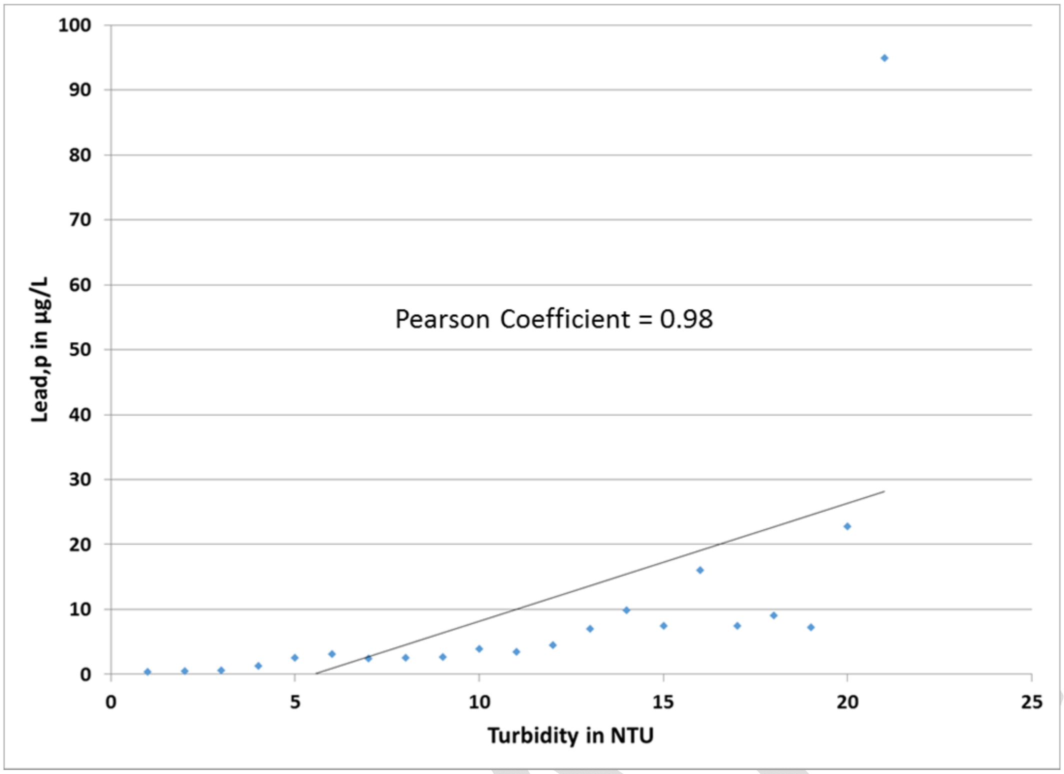


Figure 2-31: Correlation Plot Showing Relationship between Particulate Lead and Turbidity for Supplemental Residential Samples Collected during Q3 2016

The PWB should continue to prioritize collection of additional supplemental residential samples during Q4 2016.

2.9 PRS MONITORING STATION AND EXTENDED WQ SAMPLE STATION DATA

Data from the three monitoring stations and the two extended water quality stations are presented in this section. The PRS Monitoring Stations were started up with flowing water in October 2015, during the middle of Q4 2015. Samples from the test chambers were not taken until a month after startup to allow for the development of metal plate surface scales and biofilm. Therefore, the data collected from the stagnation chambers began in Q1 2016 and are ongoing.

The monitoring stations are installed at the following sites:

- Powell Butte (defined as "Entry point" for the purposes of this study, EP)
- Willalatin Tank. (DS 1)
- Vernon Low Tank. (DS2)

Analysis was conducted on the flowing water entering the monitoring stations, as well as on the stagnant water that has been in contact with metal test chambers (23 hour per day stagnation period). The test chamber materials were selected to represent the sources of lead known to have been used historically by PWB water customers. It should be noted that there are no lead service lines in PWB's service area; lead was selected to show the exaggerated response of lead to other water quality conditions. The following test chambers are in use:

- Lead.
- Copper with Lead Solder Connection.
- Galvanized Iron.
- Brass.

The Monitoring Stations are designed to exaggerate the release of lead and copper into the water. This exaggeration serves to magnify the factors that are at work in the distribution system that shape water quality and allow for better understanding of the relationships between parameters. It should be noted that for this reason the concentrations of metals detected in the monitoring stations are not necessarily reflective of the concentrations that are present in customer tap samples.

The same data collected at the influent of the monitoring stations are also collected from two additional extended water quality sampling stations (WQSS) selected from the TCR sites and are also reported in this section. These extended WQSS provide more detailed water quality information from the distribution system than is collected at all TCR sites. The extended sites for sampling are WQSS 0031(DS 3) and WQSS 0093 (DS 4).

All of the parameters describing uniform corrosion, biostability, and scale release were monitored in the monitoring stations and extended WQSS.

The monitoring stations are identified by codes which consist of two parts: PRS-XX-YY

XX and YY for each monitoring station vary depending on the station location and the test chamber material, as shown below in Table 2-4. This code is applicable to the figures throughout this chapter.

Table 2-18: Station Location Comparison

XX (STATION LOCATION)	YY (TEST CHAMBER MATERIAL)
Powell Butte (PB)	Brass (BR)
Willalatin Tank (WI)	Copper with Lead Solder Connection (CU)
Vernon Low Tank (VE)	Lead (PB)
	Influent Flowing (FL)
	Galvanized Iron (GA)

2.9.1 Lead Release in the PRS Monitoring Station Data

Time series plots of dissolved, particulate, and total lead concentration in the flowing water and stagnation chambers since the beginning of the study are found below in Figures 2-32, 2-33, and 2-

34, respectively. These time series plots provide a useful way to monitor trends in the lead release data. As observed, lead release was higher initially, and has since trended downward. Elevated initial lead concentrations are often observed during startup, however there was also a system-wide change in water quality (increase in turbidity and some metals) observed at the same time due to heavy rains, and so the effects from startup and elevated turbidity are confounding events which make it difficult to draw cause and effect relationships with respect to the increased lead observed during November and December. The lead release from the lead test chambers began increasing again at the end of the Q3 monitoring period associated with the warming temperatures. The highest dissolved, particulate, and total lead were consistently observed from the Vernon Low Tank monitoring station.

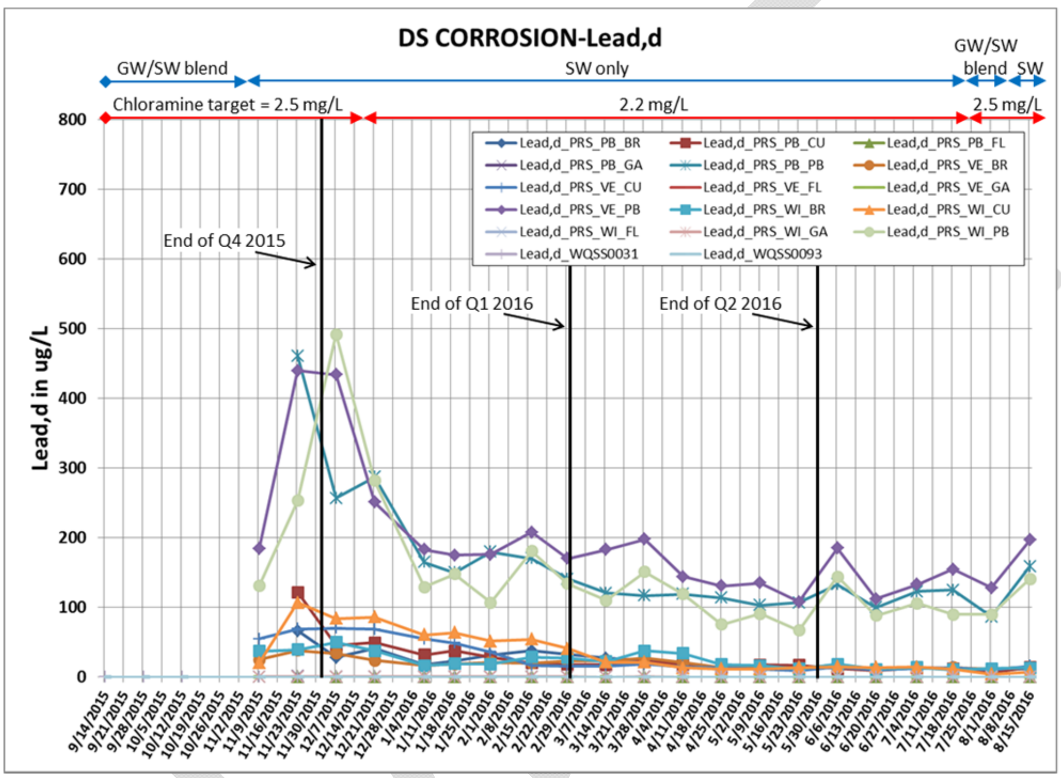


Figure 2-32: Dissolved Lead Concentrations from PRS Monitoring Station Data for Q1 2016 through Q3 2016

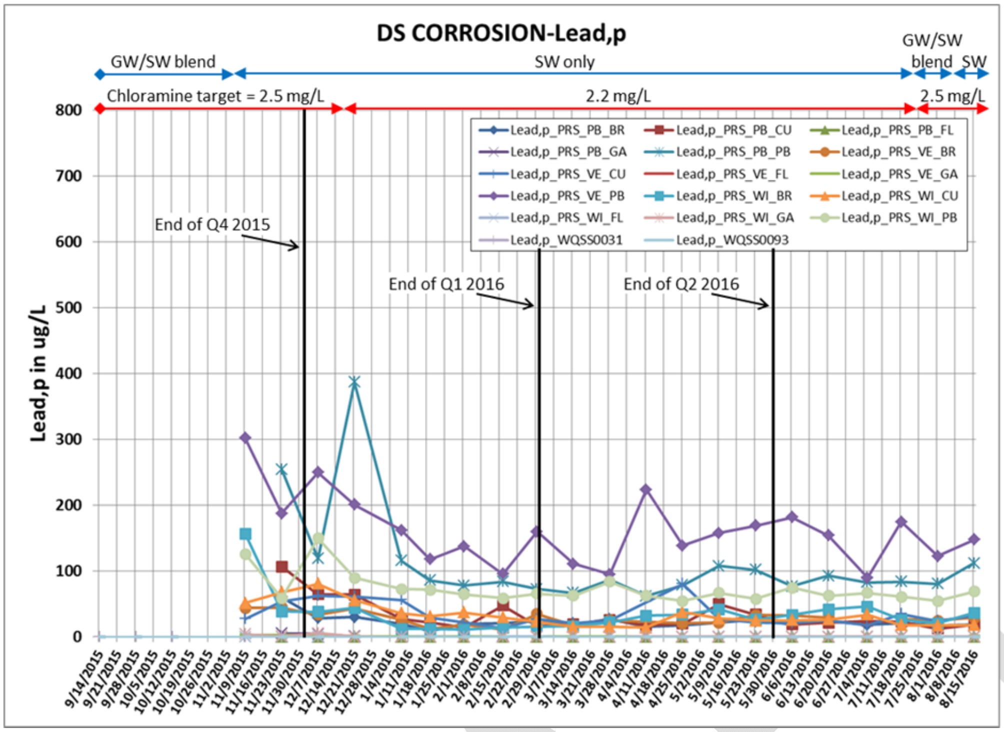


Figure 2-33: Particulate Lead Concentrations from PRS Monitoring Station Data for Q1 2016 through Q3 2016

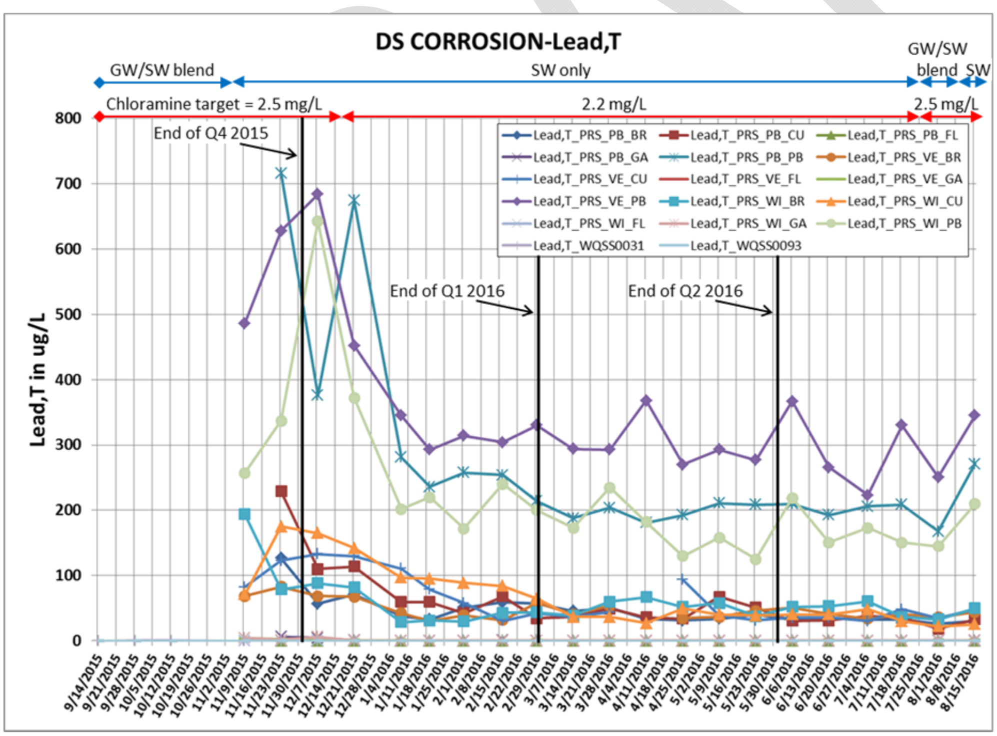


Figure 2-34: Total Lead Concentrations from PRS Monitoring Station Data for Q1 2016 through Q3 2016

A comparison of lead release between monitoring station locations and test chambers can be observed using Shewhart control chart statistics plot, shown below in Figure 2-35. The highest lead comes from the lead stagnation chambers, followed by the copper/lead solder chamber and brass chambers. This highest average lead concentration is from the lead chamber in the Vernon Low Tank monitoring station. It should be noted that this site has the highest concentration of lead and copper entering the station, as discussed in the flowing water section below. The galvanized steel test chambers did not show significant lead at any test station. Lead is monitored in the galvanized chambers because the zinc coating on the galvanized steel contains lead.

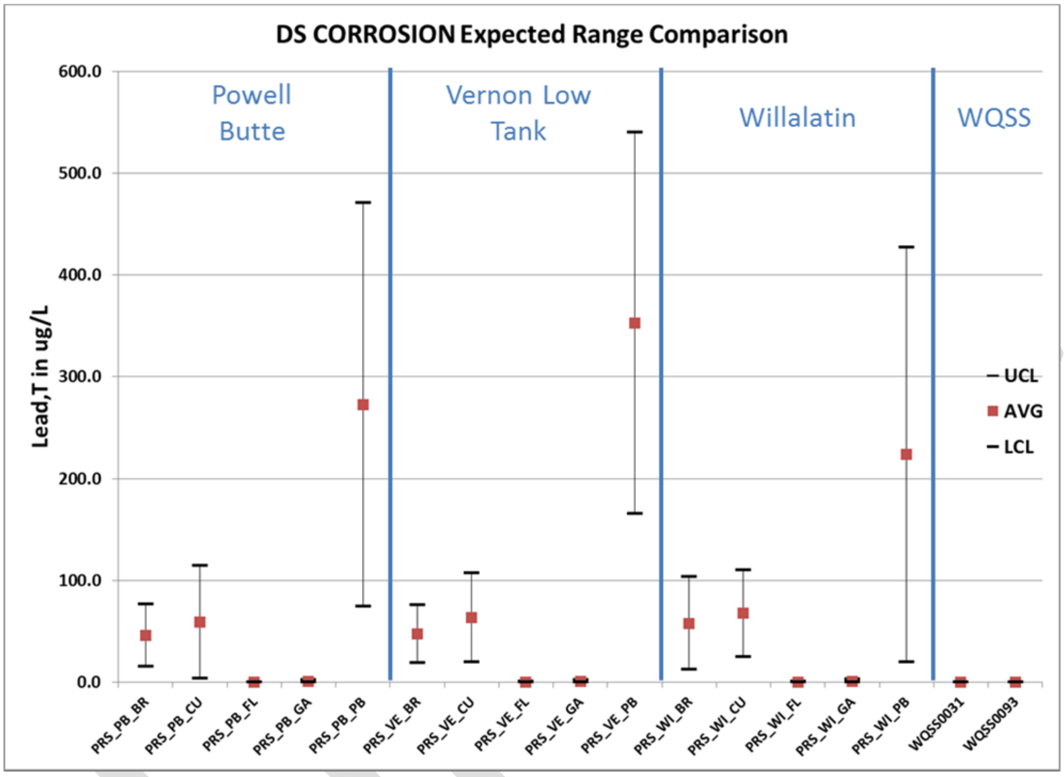


Figure 2-35: Total Lead Concentrations from PRS Monitoring Station Data for Q1 2016 through Q3 2016

Red squares indicate the average lead concentration for each location and test chamber. The "whiskers" emanating from the average indicate the expected range of the data at that site where 99% of the data will fall as calculated by the Shewhart Control Chart statistical concept of variation.

2.9.2 Categories of Lead Release

Water quality parameters are monitored at the PRS monitoring stations to allow for paired sample analysis between lead release and the various water quality parameters describing the potential mechanisms of lead release. These data are presented in the sections below according to the mechanism of lead release which the water quality parameters describe.

2.9.2.1 Uniform Corrosion

Roughly 50% of the lead measured in the PRS monitoring stations continues to be in the dissolved form, indicating solubility processes such as in uniform corrosion were occurring in the test chambers. The parameters describing carbonate chemistry (pH, alkalinity, hardness, and temperature), chloride and sulfate chemistry, and ORP were monitored along with lead release in the test chamber effluents to determine if relationships existed between the water quality parameters and lead release.

The pH in the test chambers can be observed in Figure 2-36 below. As observed, the pH is generally close to 8.0 in the flowing water samples, with a drop of between 0.2 and 0.3 pH units in the test chambers following the stagnation period compared to the flowing water pH.

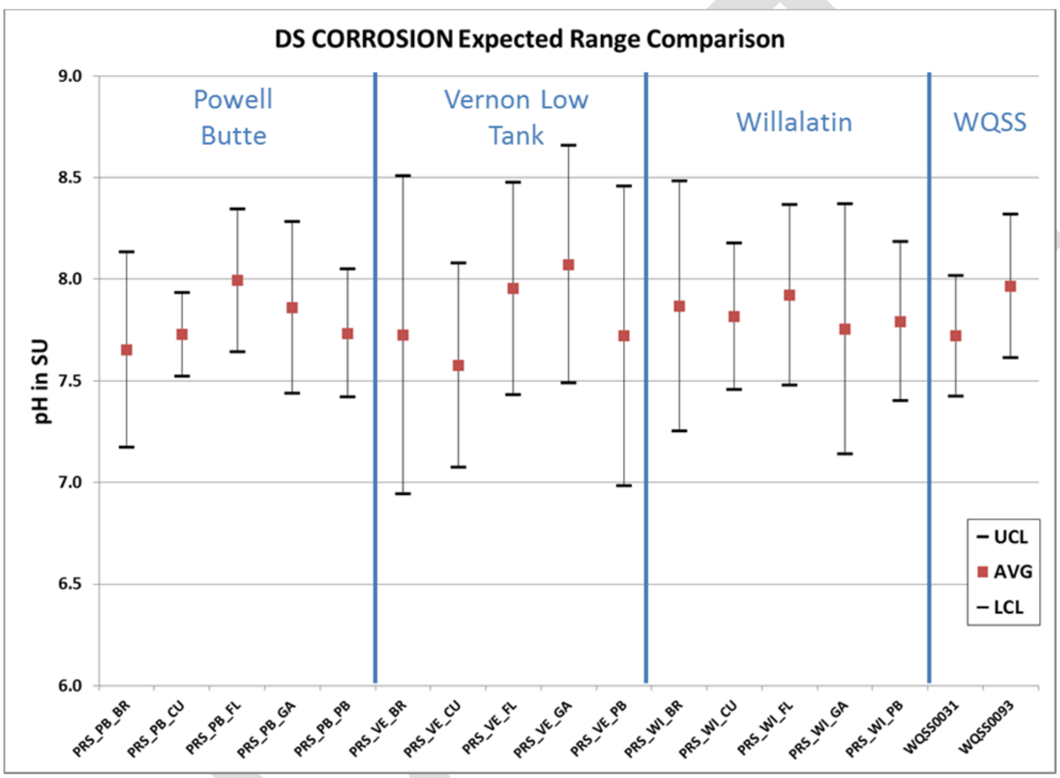


Figure 2-36: pH Expected Values in the Flowing Water Entering the Test Chambers (FL) and the Various Test chambers after Stagnation from Q1 through Q3 2016

Red squares indicate the average lead concentration for each location and test chamber. The "whiskers" emanating from the average indicate the expected range of the data at that site where 99% of the data will fall as calculated by the Shewhart Control Chart statistical concept of variation.

The alkalinity and hardness of all stations was very similar, and can be seen in Figure 2-37 below. The expected ranges of alkalinity are seen when the PWB is served by surface water only and with the groundwater blend. The remaining parameters describing uniform corrosion are similar between the various station locations and are typical of the pattern seen in the alkalinity graph.

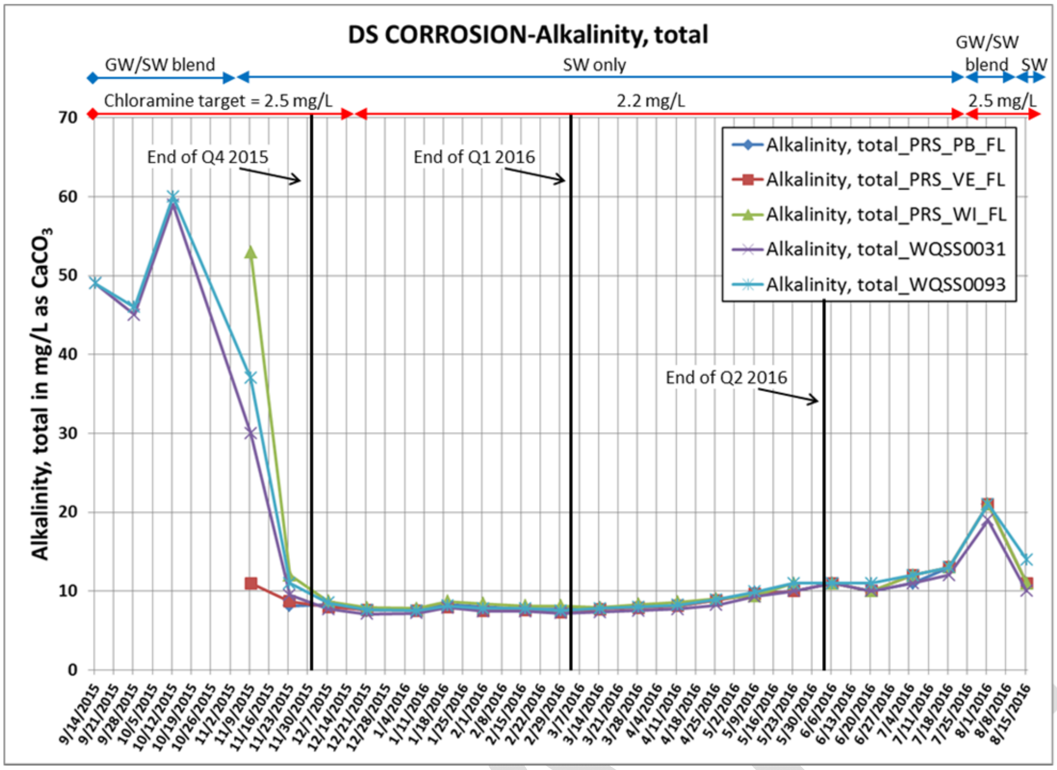


Figure 2-37: Alkalinity (mg/L as CaCO3) Observed at Extended WQSS from Q4 2015 through Q3 2016

More detailed statistical analysis will be performed in the final report after all the data are accumulated to determine if there exists a correlation between lead release and any of the water quality parameters describing uniform corrosion processes.

2.9.2.2 Biostability

The ATP at all monitoring station locations is shown below in Figure 2-38. ATP is a measure of overall microbial activity and an increase in ATP indicates an increase in overall microbial activity. ATP is in general low, and the ATP is similar in the influent flowing water and the stagnating test chambers, indicating good microbial control with the water characteristics. ATP was slightly elevated system-wide following the switch to surface water in November, was lower during December and January, and increased again between February and April. The ATP was then lower during May and June. There was an increase in ATP in July, followed by another drop. This activity will continue to be monitored during Q4 2016, which is the season which typically sees the most microbiological activity of the year.

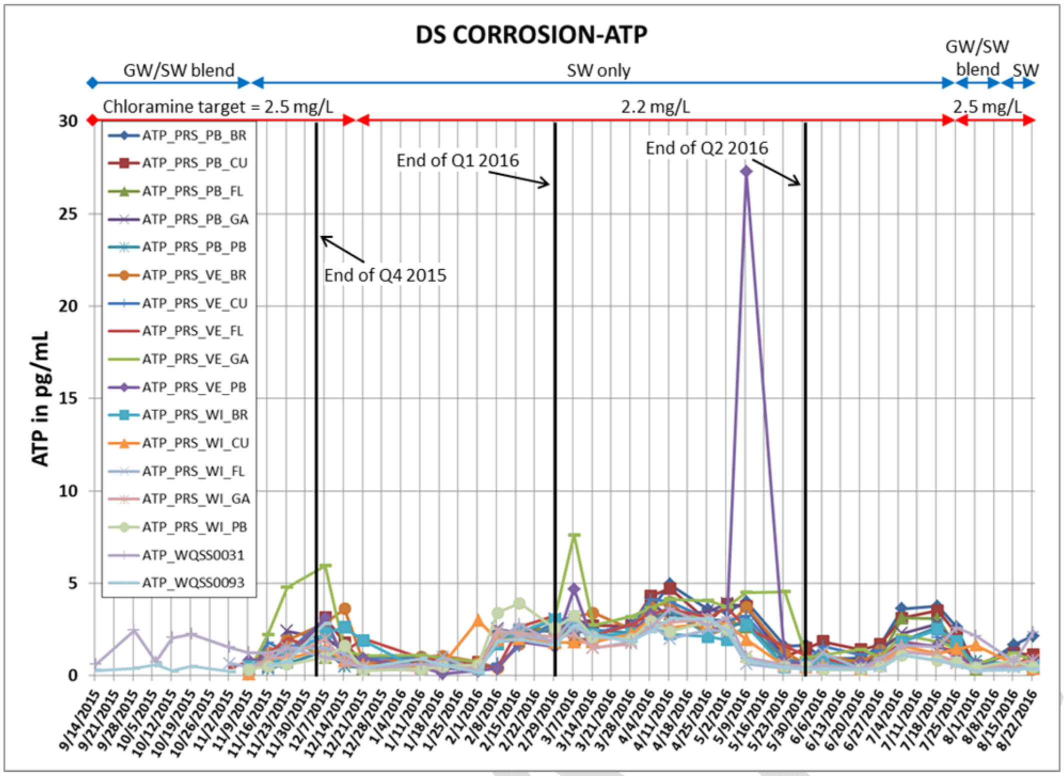


Figure 2-38: ATP at PRS Monitoring Station Locations from Q1 through Q3 2016

Another measure of biostability is the decay of chloramine residual, followed by release of free ammonia and generation of nitrate and nitrite. The monochloramine residuals from the monitoring stations are shown below in Figure 2-39. As observed, Willalatin has a consistently lower chloramine residual than the other sites, with the brass and copper test chambers having the lowest residual. It also had the highest concentrations of nitrite and nitrate, indicating that nitrification is likely actively occurring in that site. It should be noted that these same trends were observed in the water flowing into the Willalatin station and at WQSS0031 as discussed further in the section on flowing water sites below. This trend will continue to be monitored.

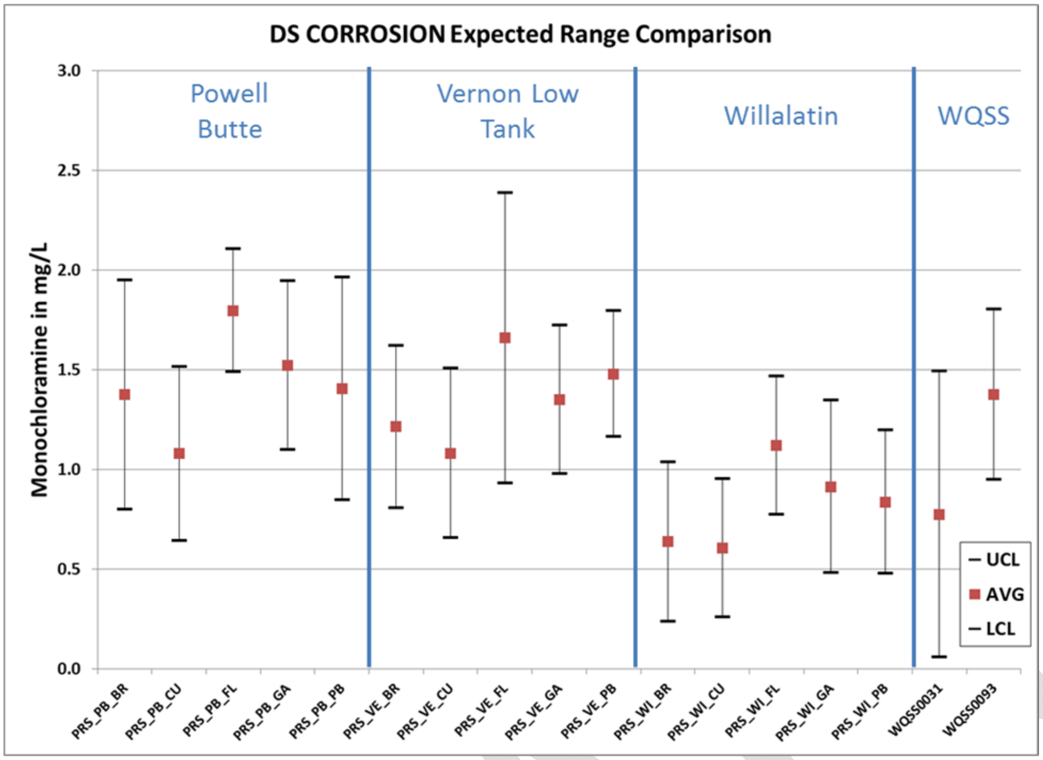


Figure 2-39: Monochloramine Residuals Observed in the Monitoring Stations from Q1 through Q3

More detailed statistical analysis will be performed in the final report after all the data are accumulated to determine if there exists a correlation between lead release and any of the water quality parameters describing biostability.

2.9.2.3 Scale Release

Roughly 50% of the total lead detected at the PRS monitoring stations was in particulate form in most samples indicating that scale release is contributing towards total lead release in the monitoring stations. Many of the spikes in total lead observed in the monitoring stations (in particular for the lead chamber from Vernon Low Tank) were attributed to particulate lead.

The dissolved, particulate, and total iron concentrations for all monitoring stations from Q1 2016 to Q3 2016 are shown in the figures below. Note that aluminum and manganese follow similar patterns as the iron; the concentrations of these metals trend together very strongly. The December spike in particulate metals in the test chamber effluent is of interest because it was associated with the spike in particulate lead, indicating that release of metal scale containing iron, manganese, aluminum, and lead is likely responsible for that lead spike in the PRS test chamber effluent. The metals concentrations were noticeably lower from January through May, but appear to have increased again in August. This trend will continue to be monitored during Q4 2016.

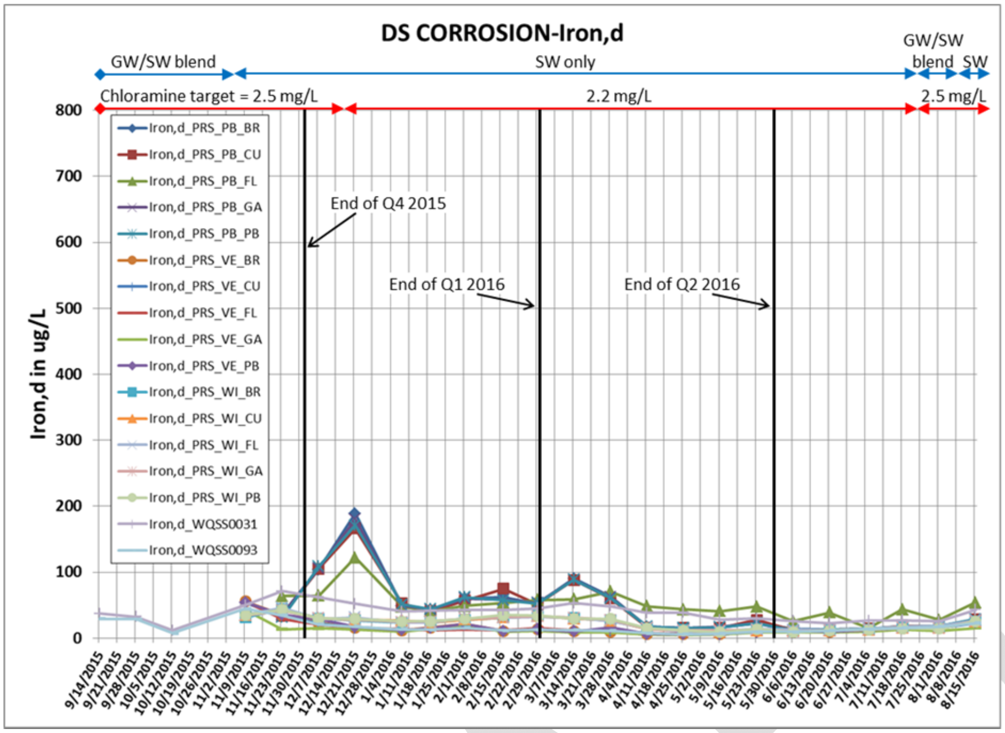


Figure 2-40: Dissolved Iron Concentration from Q1 2016 through Q3 2016 for All Monitoring Stations

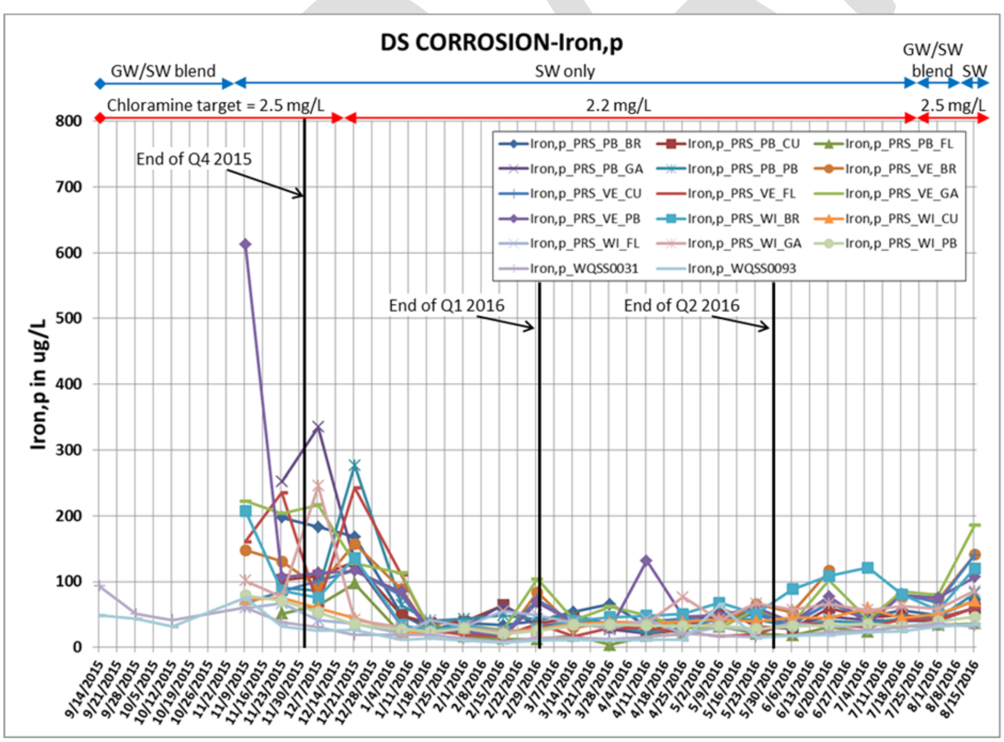


Figure 2-41: Particulate Iron Concentration from Q1 2016 through Q3 2016 for All Monitoring Stations

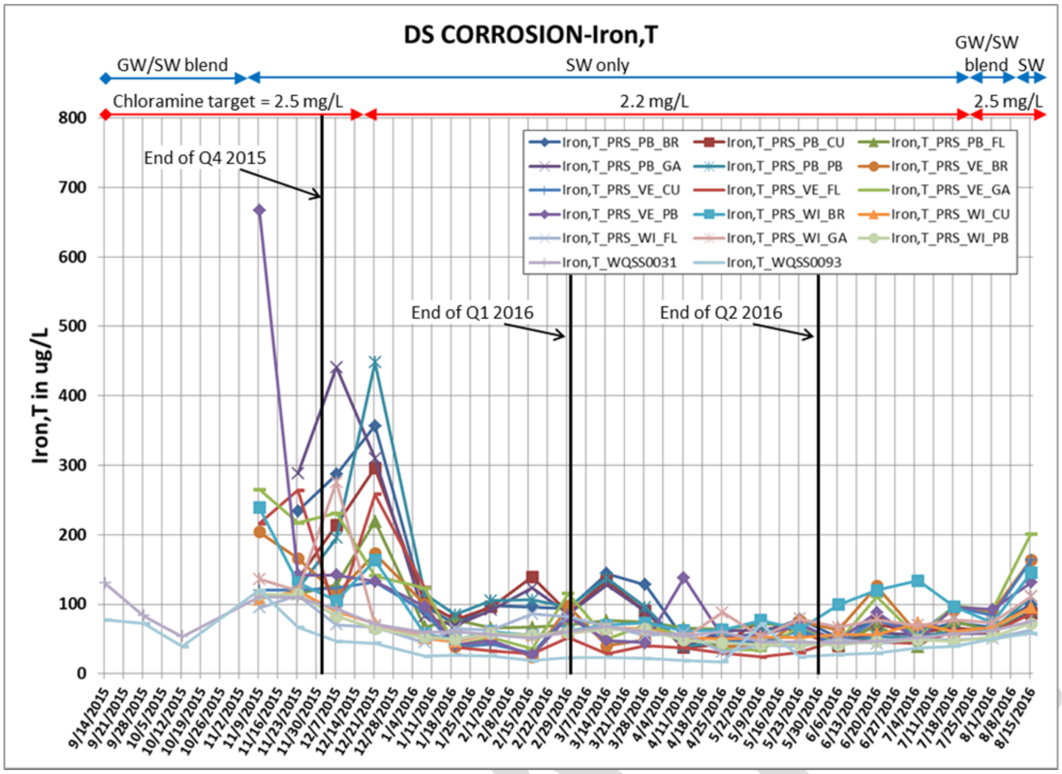


Figure 2-42: Total Iron Concentration from Q1 2016 through Q3 2016 for All Monitoring Stations

More detailed statistical analysis will be performed in the final report after all the data are accumulated to determine if there exists a correlation between lead release and any of the water quality parameters describing scale release.

2.9.3 Extended WQSS data

Two TCR sites (WQSS 0031and WQSS 0093) were selected to monitor additional water quality parameters than are monitored at the remainder of the TCR sites. In this way the extended WQSS provide an excellent opportunity to gather additional details on water quality in the distribution system. These stations, along with the flowing water samples from the three monitoring stations, also provide information on the amount of lead being released from the PWB distribution system itself, since the water has not been in contact with customer premise plumbing or service lines.

2.9.3.1 Lead and Metals

The lead concentration was monitored in the flowing water samples collected at the extended WQSS and monitoring station locations. As shown below in Figure 2-43, the Vernon Low Tank and Willalatin had higher total lead concentrations than the other sites, with particulate lead observed up to 0.6 ug/L. Both the particulate lead and dissolved lead appear to be increasing in WQSS0031 as the water warms up. This trend will continue to be monitored. The dissolved lead was very similar amongst all sites, at approximately 0.2 ug/L.

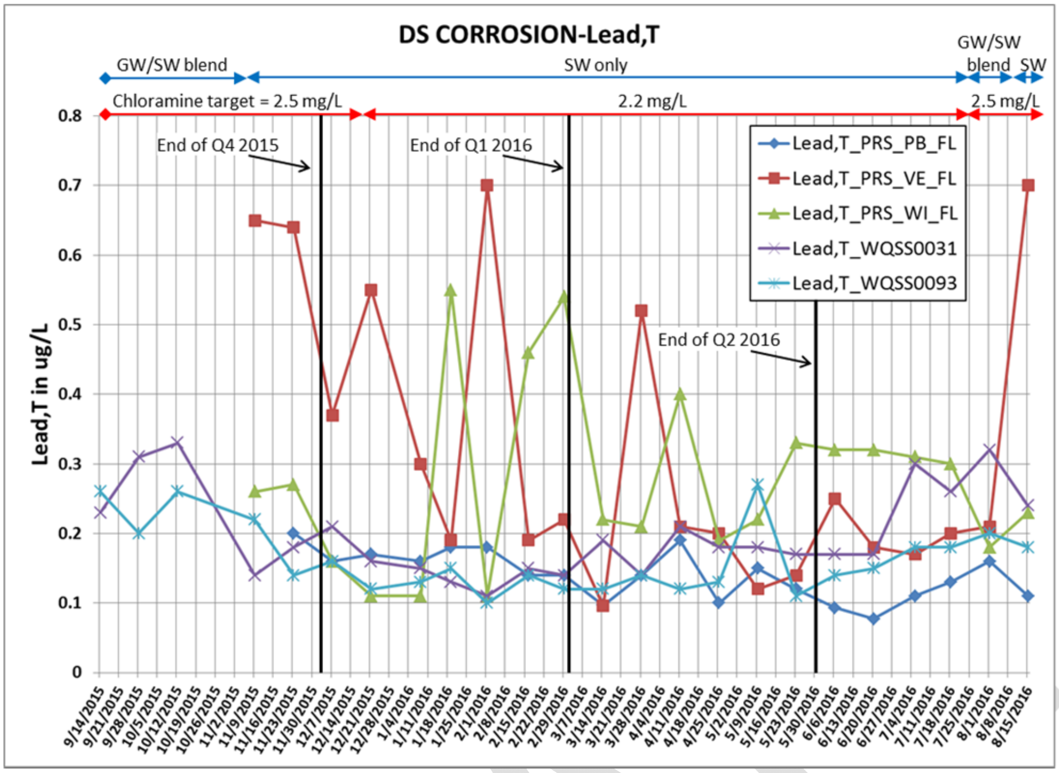


Figure 2-43: Total Lead Concentration Measured at Five Sites in the Distribution System from Q1 through Q3 2016

The copper concentrations at the flowing water sites are shown below in Figure 2-44. As shown, Vernon Low Tank has had a consistently higher copper concentration than the remaining sites. Upon investigation it was determined that this site is fed from a copper sample line, while the other stations are fed by plastic lines. Both the dissolved and particulate copper concentrations are elevated at Vernon Low Tank, and appear to be increasing as the water warms up. This trend will continue to be monitored for its impact on lead release.

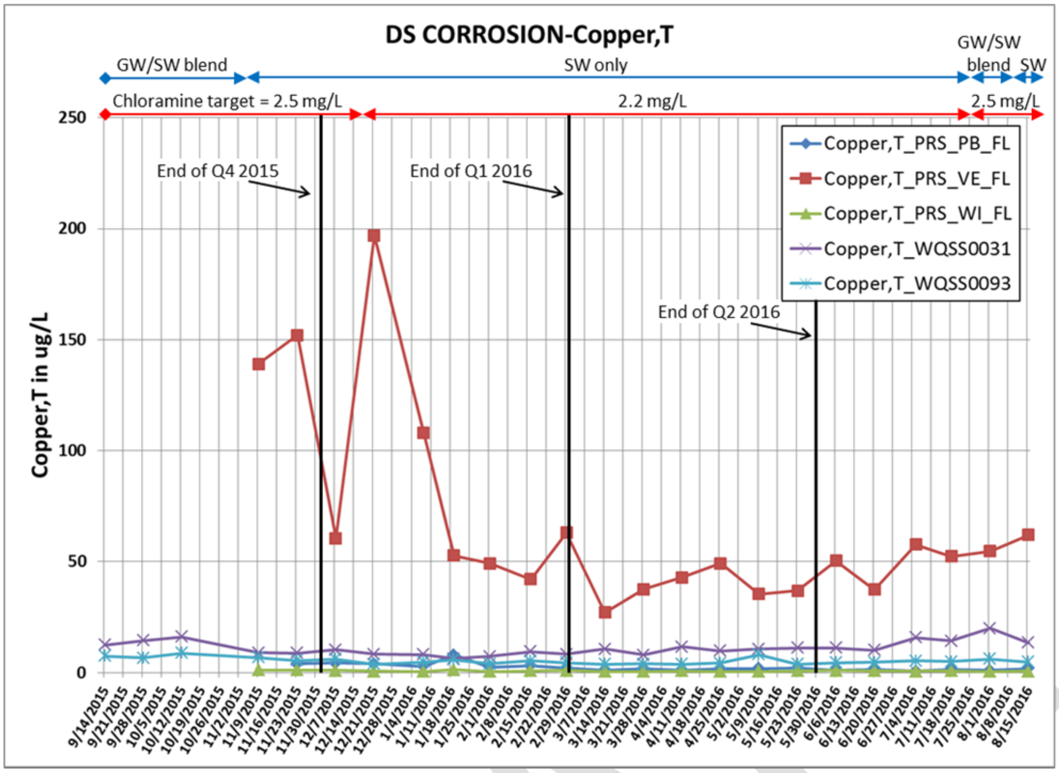


Figure 2-44: Total Copper Concentrations at Five Flowing Water Sites in the Distribution System from Q1 through Q3 2016

The total iron concentration measured at the distribution system flowing water sites is shown below in Figure 2-45. As indicated, after some early spikes in iron during Q4 2015, the concentration was consistently lower throughout the distribution system until it begins to increase again in July and August. Aluminum and manganese exhibit similar temporal patterns. It should be noted that the metals concentrations observed were all well below any secondary MCL for these metals – the "elevated" levels are only of significance in that these metals are known to combine with lead and then transport together when the metal scales release from the pipe wall surface.

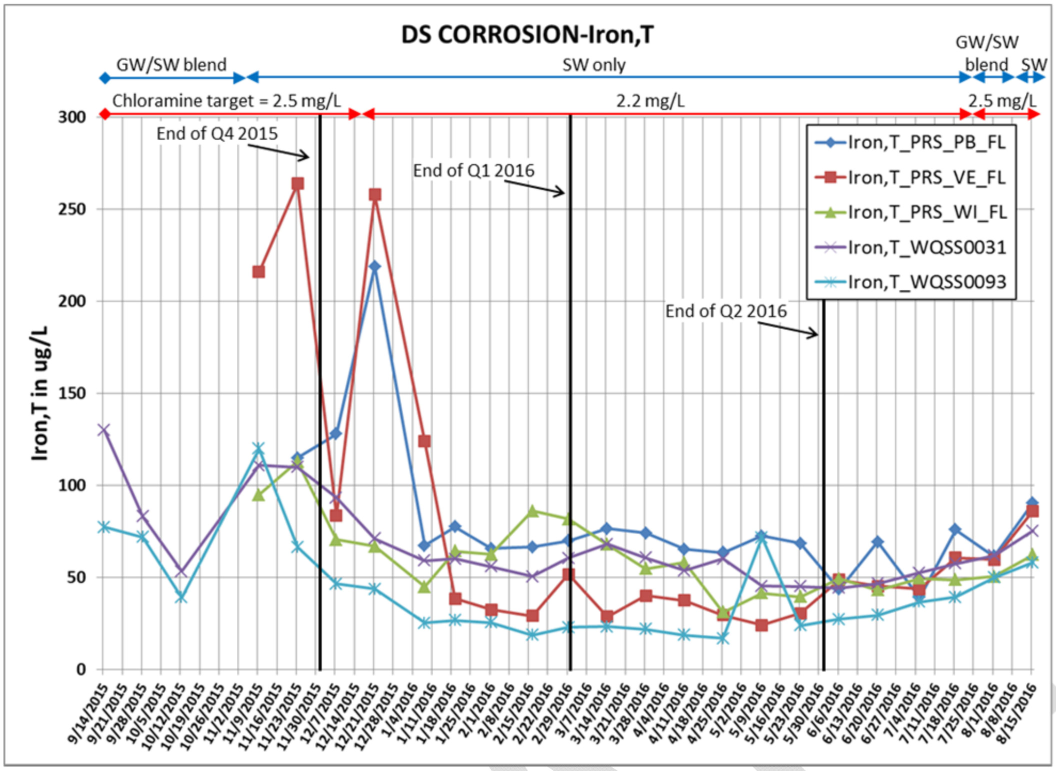


Figure 2-45: Total Iron Concentration Measured at Five Sites in the Distribution System from Q1 through Q3 2016

2.9.3.2 pH

The pH was monitored at the five distribution system sites and is shown below in Figure 2-46. As observed, after some initial higher variability at the Vernon Low Tank site, the pH was similar amongst the three sites with monitoring stations, generally around 8.0. WQSS0031 consistently had the lowest pH, and was trending downward in pH to a minimum of about 7.4 by the end of Q3 2016.

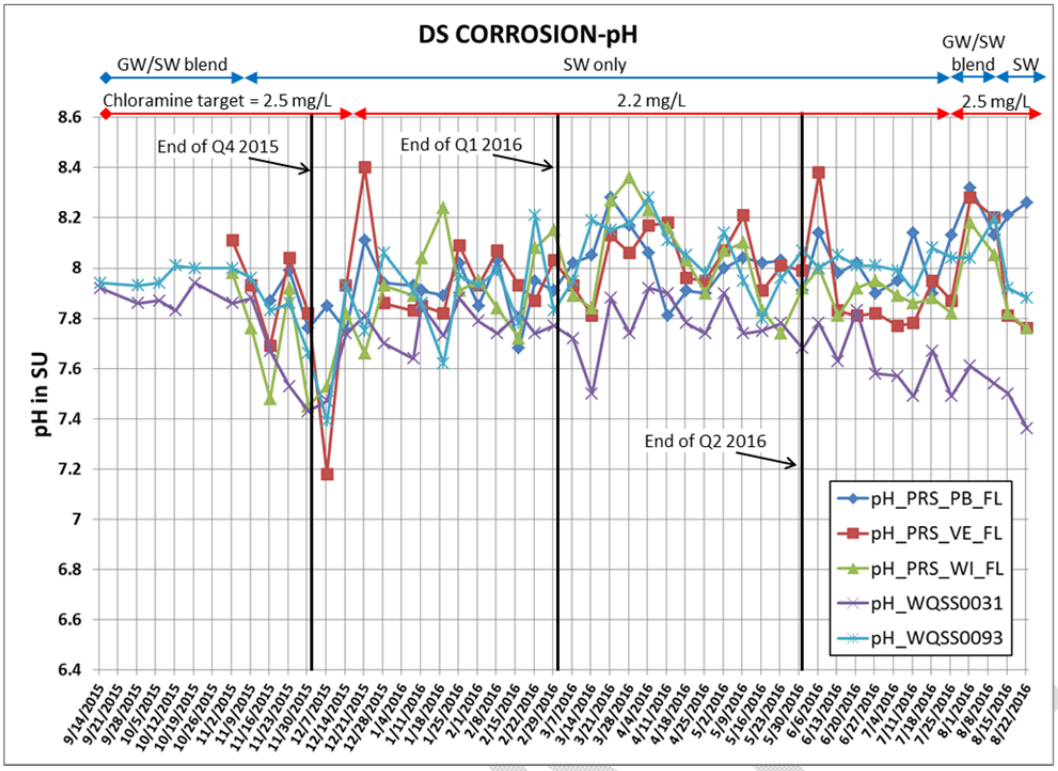


Figure 2-46: pH Observed at Five Distribution System Sites from Q1 2015 through Q3 2016

2.9.3.3 Biostability

The ATP and monochloramine were monitored at the five distribution system sites and are shown below in Figures 2-47 and 2-48, respectively. The pattern of biological activity as measured by ATP is very similar amongst the five sites, with an increase observed between February and April. The most biological activity is observed at WQSS0031. The ATP levels were increasing towards the end of Q3 2016. The monochloramine was lower at Willalatin and WQSS0031 than the other stations.

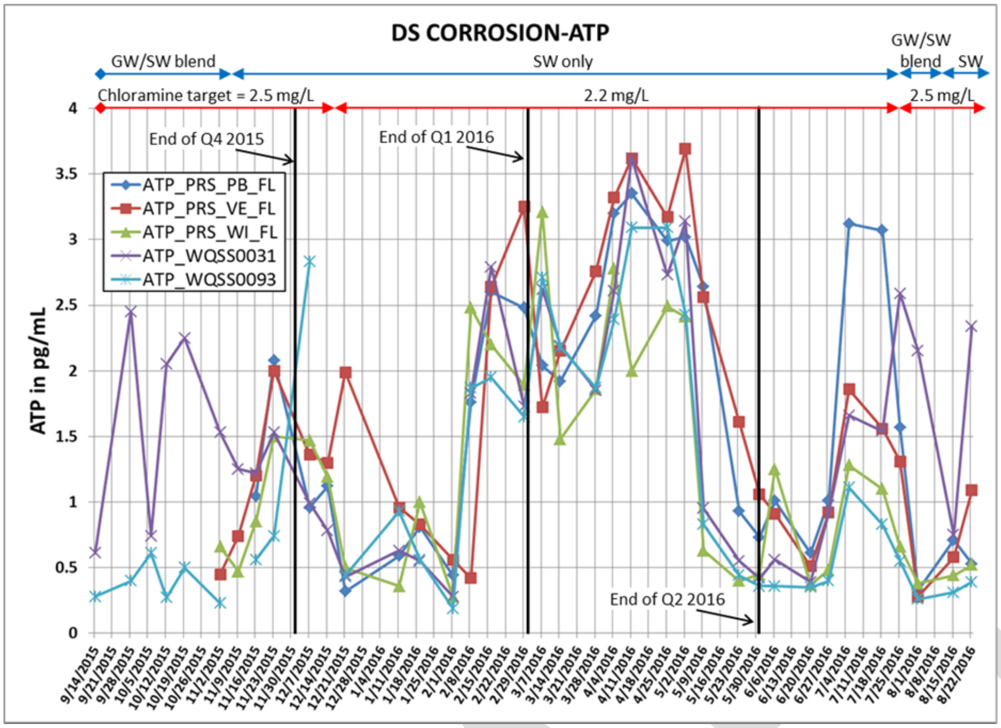


Figure 2-47: ATP Measured at Flowing Water Sites in the Distribution System from Q1 through Q3 2016

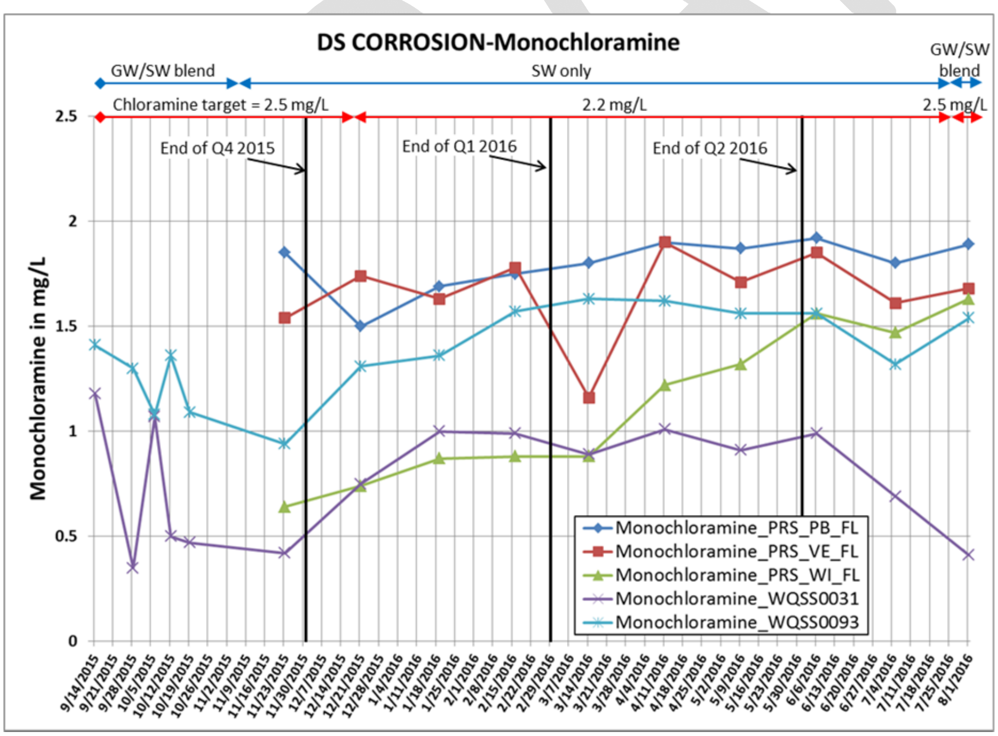


Figure 2-48: Monochloramine Residual Measured at Flowing Water Sites in the Distribution System from Q1 through Q3 2016

2.9.4 Summary of PRS Monitoring Station and Extended WQSS Data

In summary, the following observations were made from a review of the PRS monitoring station and extended WQSS data:

- In most samples lead release was approximately 50% attributable to soluble lead, and 50% attributed to particulate lead. This is similar to the data observed from the supplemental residential samples.
- The elevated lead observed at the beginning of the study may have been due to startup effects, or to the elevated turbidity and metals (iron and manganese) that was present from heavy rains during the switch to surface water.
- Lead has been trending downwards in the monitoring stations since November 2015 (suggesting that the water may have been forming protective scales on the metal chamber surfaces), but began increasing again in August 2016. Scales are anticipated to be harvested and analyzed at the end of the study period.
- The highest lead released was observed in the lead test chamber from Vernon Low Tank monitoring station location.
- The extended WQSS data suggest that iron, manganese, and aluminum were elevated (compared to background levels, still below secondary MCLs) in the distribution system during November and December, were consistently low between January and June, and began increasing again in July 2016.
- The bulk of the nitrification season is anticipated to be seen during Q4 2016.

2.10 QA/QC DATA

The QA/QC data are collected regularly to ensure accuracy of the field measurements. The QA/QC data indicate that the analyses have a high degree of both accuracy and precision. The average recovery (accuracy) and precision are shown in Table 2-19 below.

Table 2-19: Average Recovery and Precision from Q1 through Q3 2016

ITEM MEASURED	UNITS	AVERAGE ACCURACY (AVERAGE PERCENT RECOVERY)	AVERAGE PRECISION (+/-)
ATP- UltraCheck duplicate	RLU	-	1618
ATP-PRS_PB_Fl duplicate	pg/mL	-	0.56
Cl2, T	mg/L	-	0.22
Conductivity	uS/cm	91.7%	1.6
ORP	mV	96.4%	52.4
pH	SU	100.4%	0.3
Temperature	deg C	-	1.6
Turbidity	NTU	99.8%	0.22

ITEM MEASURED	UNITS	AVERAGE ACCURACY (AVERAGE PERCENT RECOVERY)	AVERAGE PRECISION (+/-)
Note: The percent recovery is increasing for conductivity, but the accuracy is slightly decreasing for ORP. The ATP spiked once, but the current trend is good. The pH measurement has declined and is currently above 0.1.			

3 Preliminary Observations

This section identifies the major observations made during this quarter.

3.1 DEVIATIONS FROM SAMPLING PLAN

- Fewer supplemental residential samples have been collected up to this point in the study than was recommended.
- Additional metals were not collected with voluntary lead samples this quarter

3.2 FIELD SAMPLING NOTES AND OBSERVATIONS

Field sampling was conducted according to the monitoring plan.

On April 11, 2016 there was an insufficient sample volume from the lead test chamber at the Vernon site. Further research revealed that low test chamber volumes were typical at the Vernon station but enough volume was collected for the required samples. Following this event all three of the PRS stations were inspected and it was determined that excess pipe thread sealant had become lodged in the check valves and was preventing the valves from sealing properly. This resulted in partial drainage of the test chambers during sampling. Due to the configuration and hydraulics of the stations cross contamination between test chambers was determined to be unlikely. The check valves on all three PRS stations were replaced and a ball valve was added to the outlet side of each test chamber as an additional precaution.

Sampling protocols were revised to ensure that the test chambers are not hydraulically connected during sampling. The revised protocol requires the sampler to close both the inlet and outlet valves on each test chamber prior to taking the sample from the chamber. Thread sealant also becomes lodged in the needle valves reducing flow to the test chambers. Exercising of the needle valves releases the thread sealant and returns flows to normal. Thread sealant has also been observed in some of the test chamber samples.

The Material Safety Data Sheets for the thread sealant, typically used in drinking water pipes, describes a highly insoluble material of synthetic organic compounds encompassing mineral material. Dried thread sealant was sent to a commercial laboratory for analysis. The material was sent as a solid. It was weighed and placed in reagent water where the complete sample was digested with acid and high temperature, thereby dissolving the thread sealant. These data were reviewed and it was determined that it is unlikely that the material is impacting the PRS Monitoring Station data.

3.3 LAB ANALYSIS NOTES AND OBSERVATIONS

Laboratory analysis was conducted according to the monitoring plan. There were no anomalies in laboratory data to be reported.

3.4 SUMMARY OF DATA TRENDS

Data trends which are indicative of specific mechanisms of lead release are identified below. The intention of this section of the report is to identify trends in the data from this monitoring period which should continue to be observed throughout the remaining monitoring quarters. Sufficient data may not yet be available to draw final conclusions about what mechanisms are or are not contributing to lead release throughout the Portland water system. Any conclusions or extrapolation of the current data will be reserved for the final report after one full year of data are evaluated.

3.4.1 Uniform Corrosion

Approximately 50% of the total lead observed in the PRS monitoring station test chamber effluent and the supplemental customer sampling was in the dissolved form, indicating solubility processes related to lead release are occurring. In general the water quality parameters describing uniform corrosion, such as pH, are relatively stable throughout the distribution system. The collection of additional data as prescribed in the monitoring plan is expected to help determine the extent to which specific water quality parameters are influencing lead release from uniform corrosion in the Portland water system. A discussion on uniform corrosion indices in the PWB system is included below.

DIC is a direct measure of the available carbonate species in the water that can react with lead and copper to form the passivating scales. The DIC throughout the PWB system is generally between 2 and 3 mg/L as C. While not a direct measure of uniform corrosion, a useful parameter to measure the tendency for calcium carbonate precipitation is the calcium carbonate precipitation potential, CCPP. The CCPP is the PWB system is generally between -6 and -7, indicating a very low potential for formation of calcium carbonate layer.

Chloride and sulfate can form complexes with metals that are orders of magnitude more soluble than carbonate compounds. Therefore, there is the potential that the presence of chloride and sulfate can enhance the corrosion of metals. One measure of the contribution of chloride and sulfate to corrosion is the Larson's ratio (LR), defined as:

$$LR = alkalinity / (Cl^{-} + SO4^{2-})$$

It is generally recommended to maintain a LR greater than 5 to ensure carbonate reactions are predominantly controlling lead solubility. The LR in the PWB system is generally between 2 and 3, indicating that chloride and sulfate may be inhibiting lead carbonate formation and contributing towards increased lead solubility.

Another ratio which has been shown to influence lead release is the chloride to sulfate mass ratio (CSMR). Higher CSMR values have been shown to increase galvanic corrosion in the case where lead is directly coupled to a dissimilar metal, such as when lead solder is used on copper piping. While guidance varies, the literature suggests that values greater than 0.6 can increase the risk of galvanic corrosion due to the ratio of chloride to sulfate. The CSMR in the Portland system when served by surface water (as was the case during Q2 2016) is between 7 and 8.

3.4.2 Biostability

Overall ATP levels are low and suggest good microbial control in the PWB system. Microbial activity as measured by ATP was slightly elevated system-wide following the switch to surface water in November, was lower during December and January, and increased and decreased again sporadically February and August. The ATP appears to be rising again in August. During the next quarter the water temperature is expected to increase as late summer conditions exist, which may cause an increase in microbial activity. These data will continue to be monitored.

3.4.3 Scale Release

Particulate lead release accounted for approximately 50% of the total lead release observed in most of the test chambers and supplemental customer sampling. Occasional spikes in total lead observed in the test chamber effluents during Q1 2016 were predominantly in the particulate form. These spikes in lead were strongly associated with similar spikes in particulate iron, manganese, and aluminum, indicating that release of these metal scales is contributing to the lead spikes observed in the PRS monitoring station test chambers.

3.4.4 Lead Release in the Distribution System

Lead concentrations were monitored at WQSS and PRS monitoring station inlets to determine if there are any significant sources of lead from the actual distribution system (as opposed to service line and customer premise plumbing). Dissolved lead was typically below 0.2 ug/L in these samples, with particulate lead accounting for some results up to 0.6 ug/L. Lead will continue to be monitored at the extended WQSS and monitoring station inlets during Q4 2016 and will provide additional information related to lead release in the distribution system.

4 Next Quarter Look-Ahead

4.1 RECOMMENDED CHANGES FOR NEXT QUARTER

The following are recommended changes to the monitoring plan based upon the data analyzed this monitoring period.

- Prioritization should continue to be given to the supplemental residential customer water chemistry and lead sampling during the next quarter. It was anticipated that the supplemental sampling be conducted in 50 homes throughout the year. To date supplemental sampling has been conducted in 26 homes.
- Discontinue the measurement of cadmium, chromium, cobalt, as they are found at concentrations below the detection levels.
- Continue monitoring for remaining parameters at the frequencies described in TM2.

4.2 ANTICIPATED PROJECT SCHEDULE

The following outlines the next steps in the PWB Water Quality and Corrosion Study.

- The Q4 2016 quarterly report will be prepared covering data collecting from September through November, 2016.
- Final report and workshop to be scheduled after Q4 2016 data are analyzed.

APPENDIX A
OPERATIONS LOG

APPENDIX A
Corrosion Study Operations Log

Start Date	End Date	Event	Questions/Comments
11/2/2009	present	Reservoir 6 South Cell off line PERMANENTLY	date is approximate
10/1/2010	present	Reservoir 6 North Cell off line PERMANENTLY	
7/20/2011	7/21/2011	Reservoir 3 out of service	
7/21/2011	11/8/2011	Reservoir 3 in service	
9/9/2011	present	Reservoir 4 off line PERMANENTLY	
11/8/2011	3/23/2012	Reservoir 3 out of service	
1/21/2012	1/31/2012	Turbidity event in watershed; Groundwater activated	Range of Daily GW Production: 18 - 83.6 MGD; Total Volume Pumped: 0.82 BG
2/23/2012	2/27/2012	Turbidity event in watershed; Groundwater activated	Range of Daily GW Production: 23.6 - 52.4 MGD; Total Volume Pumped: 0.22 BG
3/23/2012	7/20/2012	Reservoir 3 in service	
7/20/2012	8/3/2012	Reservoir 3 out of service	
8/3/2012	10/18/2012	Reservoir 3 in service	
8/6/2012	8/23/2012	Groundwater Maintenance Operation	Range of Daily GW Production: 0-5 MGD; Total Volume Pumped: 0.03 BG
10/18/2012	4/22/2013	Reservoir 3 out of service	
4/22/2013	6/12/2013	Reservoir 3 in service	
6/12/2013	7/3/2013	Reservoir 3 out of service	
7/3/2013	9/18/2013	Reservoir 3 in service	
7/30/2013	8/8/2013	Groundwater Maintenance Run for summer 2013	Range of Daily GW Production: 0-5 MGD; Total Volume Pumped: 0.03 BG
9/1/2013	present	Switched from a systematic flushing program to a targeted flushing program due to Berth TC event	
9/18/2013	present	Reservoir 3 out of service	
10/2/2013	12/3/2013	Increased target chlorine residual at Lusted Hill from 1.8 mg/L to 3.0 mg/L.	

12/4/2013	1/16/2014	Reduced target chlorine residual at Lusted Hill from 3.0 mg/L to 2.5 mg/L.	
1/16/2014	6/10/2014	Reduced target chlorine residual at Lusted Hill from 2.5 mg/L to 2.2 mg/L.	
5/19/2014	6/29/2015	Powell Butte floating on the inlet or outlet main to permit thrust harness replacement at 162nd Ave. conduit interties.	
3/10/2014	3/12/2014	Testing of Dam 2 North Tower gates	
4/1/2014	present	Began using Dam 2 North Tower gates	see "North Tower Gate Positions" for gates in use and percent open **(through 12/31/2014)**
6/6/2014	6/6/2014	Inadvertent opening of N. Tower lower gate	A few hours only and resulted in lower water temps and increased chlorine demand
6/10/2014	12/9/2014	Increased target chlorine residual at Lusted Hill from 2.2 mg/L to 2.5 mg/L.	
7/9/2014		Powell Butte II West Cell was placed into service.	
7/1/2014	7/9/2014	Groundwater Maintenance Operation + supplemental supply due to Conduit 3 break/repair.	Range of Daily GW Production: 0-27.8 MGD; Total Volume Pumped: 0.12 BG
7/28/2014	11/19/15	Powell Butte I South Cell out of service	
8/15/2014		Powell Butte II East Cell placed into service	
10/28/2014	11/19/15	Powell Butte I North Cell out of service	
10/29/2014	11/14/2014	Switched from N. Tower to S. Tower during this period	Sheen on Diversion Pool; related to Powerhouse 2 Operations
12/9/2014	6/8/2015	Reduced target chlorine residual at Lusted Hill from 2.5 mg/L to 2.2 mg/L.	
12/23/2014	12/29/2014	Increase in turbidity at Diversion Pool	Elevated turbidity also observed at upper elevations in Reservoir 2. Switched from N. Tower to S. Tower during this period to pull water from
1/1/2015	2/28/2015	All gates open on N. Tower (upper, middle, and lower gates open)	
2/26/2015	present	Westside connected directly to Conduit 2 and/or 3	
3/1/2015	6/18/2015	Closed lower gates on N. Tower (upper and middle gates open)	
3/23/2015	present	Kelly Butte East Cell on line	
3/25/2015	present	Kelly Butte West Cell on line	
5/8/2015	11/17/2015	Bull Run Reservoir drawdown period; **refill on 11/17/15**	Dates per 2015 Summer Water Supply Season Retrospective Report
5/11/2015	present	New regulator was activated. It supplies WP229 and Palatine area from 30" Tabor 411 bridge crossing to 16" main in SW Macadam	Keep for now; may not be relevant to corrosion study

6/1/2015	11/1/2015	Seasonal mitigation of nitrification by managing storage	Approximate dates
6/8/2015	12/16/2015	Increased target chlorine residual at Lusted Hill from 2.2 mg/L to 2.5 mg/L.	
6/11/2015	6/29/2015	Groundwater activated to meet system demands due to scheduled work on conduit #4; also used as annual GW	See demand sheet for % supply from GW.
6/19/2015	7/4/2015	Gradual closing of upper gates on N. Tower (middle gates open, lower gates closed)	
6/30/2015	7/15/2015	Groundwater off	
6/29/2015	present	Powell Butte returned to normal operation with separate inlet & outlet mains. (End of Powell Butte float for thrust harness project	
7/5/2015	11/17/2015	Closed upper gates on N. Tower (middle gates open, lower gates closed)	normal operations for temp/WQ mgmt
7/15/2015	present	Stopped booster chlorination at Washington Park	
7/16/2015	11/4/2015	Groundwater re-started for summer supply	See Demand spreadsheet for % supply from GW.
8/6/2015	present	Reservoir 1 taken out of service	
11/3/2015	11/18/2015	Partial use of S. Tower during this period	Sheen on Diversion Pool; related to operation of North Howell Bunger Valves
11/4/2015		Groundwater off, no longer needed for summer supply	
11/17/2015		Bull Run Reservoirs refilled - end of draw down	
11/18/2015	11/18/2015	Closed all gates on N. Tower	related to S. Tower use and sheen on diversion Pool? **Needs further verification by PWB.**
11/19/2015	12/2/2015	Opened middle gates on N. Tower (upper gates closed, lower gates closed)	normal operations for temp/WQ mgmt
11/19/2015	2/4/2016	Powell Butte 1 (North & South cells) in service	
12/2/2015	present	Reservoir 5 off line PERMANENTLY	
12/3/2015		Bull Run reservoir turn over date; reservoir fully mixed	
12/3/2015	1/19/2016	Opened all gates on N. Tower	normal operations for temp/WQ mgmt
12/16/2015	present	Reduced chlorine dosing target to achieve 2.2 mg/L at Lusted Hill	
1/20/2016	7/22/2016	Closed lower gates on N. Tower (upper gates open, middle gates open)	normal operations for temp/WQ mgmt
2/4/2016	present	Powell Butte 1 (North & South cells) taken out of service	
6/30/2016	present	Beginning of Bull Run Reservoir draw down	

7/22/2016	present	Closed south upper gate on N. Tower (north upper gate open, middle gates open, lower gates closed)	
7/25/2016	8/10/2016	Groundwater Maintenance Run for summer 2016	17-18 MGD or 12-16 % of supply
7/25/2016	present	Increased chlorine dosing target to achieve 2.5 mg/L at Lusted Hill	
7/26/2016	present	Closed north upper gate on N. Tower (upper gates closed, middle gates open, lower gates closed)	
8/16/2016	9/13/2016	Needle valve transfer from Bull Run Lake 1 to Lake 2	Powerhouse 1 (PHP1) off-line for annual maintenance and cold water transfer to cool down Diversion Pool temps.
9/21/2016	present	Powell Butte II East Cell off-line for cleaning	