Great Lakes Water Authority

Comprehensive Corrosion Control Optimization

Pipe Rig Study Results

June 2024

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Acronyms and Abbreviations

°C	degrees Celsius
AL	action level
AP	City of Allen Park Retention Basin
ATP	adenosine triphosphate
AWWA	American Water Works Association
CCT	corrosion control treatment
CS	Central Services Facility
Cu	copper
DS	distribution system
DWSD	Detroit Water and Sewerage Department
EGLE	Michigan Department of Environment, Great Lakes, and Energy
EPTDS	entry point to the distribution system
$FeCl_3$	ferric chloride
GLWA	Great Lakes Water Authority
GPCL	galvanized previously connected to lead
GPM	gallons per minute
GRR	galvanized requiring replacement
HDPE	high-density polyethylene
lb.	pound
LCR	Lead and Copper Rule
LCRI	Lead and Copper Rule Improvements
LCRR	Lead and Copper Rule Revisions
LH	Lake Huron Water Treatment Plant
LSL	lead service line
LSLR	lead service line replacement
mg/L	milligrams per liter
MGD	million gallons per day
MIC	microbiologically influenced corrosion
MSP	monosodium orthophosphate

ND	non-detect
NE	Northeast Water Treatment Plant
NIEA	North Interceptor, East Arm
NPDES	National Pollutant Discharge Elimination Systems
O&M	operations and maintenance
o-PO_4	orthophosphate
OWQP	optimal water quality parameter
P	phosphorus
Pb	lead
pg/cm^2	picograms per square centimeter
pg/mL	picograms per milliliter
POE	point of entry
PVC	polyvinyl chloride
RH	City of Rochester Hills Department of Public Services
SP	Springwells Water Treatment Plant
s.u.	standard units
SW	Southwest Water Treatment Plant
µg/L	micrograms per liter
USEPA	United States Environmental Protection Agency
WA	City of Warren Department of Public Works
WQP	water quality parameter
WRRF	Water Resource Recovery Facility
WTP	water treatment plant
WW	Water Works Park Water Treatment Plant
WWTP	wastewater treatment plant
WY	West Yard

Executive Summary

The Great Lakes Water Authority (GLWA) serves 112 member partners in Southeast Michigan, providing drinking water that meets and exceeds all federal and state standards. Serving over 3.8 million people in southeast Michigan, GLWA ensures a reliable supply of safe drinking water to its communities. In response to the federal Lead and Copper Rule (LCR) promulgated in 1991, GLWA, then operating under Detroit Water and Sewerage Department (DWSD), implemented corrosion control treatment (CCT) using phosphoric acid for a target of 1.0 milligram per liter (mg/L) as orthophosphate (o-PO_4). Over the years, the LCR has undergone revisions and improvements by the United States Environmental Protection Agency (USEPA), and the State of Michigan LCR has been updated by the Michigan Department of Environment, Great Lakes, and Energy (EGLE), both aiming to further reduce lead and copper exposure from drinking water. In anticipation of ongoing regulatory changes, GLWA conducted a proactive comprehensive corrosion control optimization study to evaluate the effects of different CCT conditions on the release of lead and copper from various service line and household plumbing materials and to determine what optimized corrosion control looked like for their system.

While the technical understanding of CCT has evolved since its implementation, it is well understood that optimized CCT is an effective means to reduce lead and copper release from distribution system and premise plumbing materials. Results of a comprehensive system analysis documented in the *Existing Corrosion Control Technical Memorandum* (July 2021) supported GLWA's plan to investigate corrosion control re-optimization and informed the study's design parameters to provide the greatest benefit to GLWA's member partners. A pipe rig study was chosen to evaluate the current CCT against three alternative CCT conditions to determine the optimal treatment strategy to reduce lead and copper concentrations at the tap. This study evaluated lead and copper concentrations in water samples collected from harvested lead service lines (LSLs), harvested galvanized service lines previously connected to lead (GPCL), new manufactured leaded brass with 6-8% lead by weight as was permitted before the 2014 Reduction of Lead in Drinking Water Act, new manufactured copper with leaded solder and new copper pipe. Consistent with USEPA and EGLE regulatory priorities, lead concentrations from LSLs were the primary driver of this study. When present, LSLs have been found to contribute 50 – 75% of lead at the tap (Sandvig, 2008). While data from all test conditions and materials were considered, more in-depth analysis was performed on lead concentrations from LSLs than lead concentrations from other materials or copper concentrations when determining CCT recommendations.

The pipe rig study evaluated the performance of increased o-PO_4 doses at various pH levels. Testing was conducted at five GLWA water treatment plants and at five distribution system locations volunteered by member partners for use during the study. The study was divided into two phases: the conditioning phase and the testing phase, which were planned for six (6) and 10 months, respectively. During the conditioning phase, all test pipes were exposed to finished water at each location to equilibrate with the water quality conditions. During the testing phase, alternative CCT conditions were introduced to three of four rigs at each site, while one rig served as the control. Statistical analysis showed that o-PO_4 and pH targets were successfully met during the testing phase within 0.2 mg/L and standard units (s.u.), respectively.

Lead concentration analytical results showed that increasing the o-PO_4 dose had a statistically significant impact on reducing total lead levels. Furthermore, total lead release from lead pipes, the driver of this study, displayed the most significant improvement when the o-PO_4 dose increased from 2.0 mg/L to 3.0 mg/L. The impacts of low pH on lead release from LSLs were more evident at the 2.0 mg/L o-PO_4 dose and less evident at 3.0 mg/L or 4.0 mg/L as o-PO_4. Newly manufactured materials showed better performance in terms of both lead and copper release as the o-PO_4 dose increased. Overall, a dose of 3.0 mg/L as o-PO_4 was the test condition found to be optimal for reducing total lead release from harvested LSLs based on the conditions evaluated during this study. However, it should be noted that quantitative results from harvested pipe rig studies may not always be representative of lead or copper concentrations measured from tap compliance samples due to various factors. Therefore, the study provides a relative understanding of how different CCT conditions perform comparatively and cannot predict lead levels within individual distribution systems.

Without capital improvements, the current chemical system capacity at the water treatment plants limits the increase to a maximum uniform dose of 2.4 mg/L as o-PO_4. Increasing the dose to 2.4 mg/L as o-PO_4 would allow GLWA to monitor the impacts of an increased dose on lead levels and any secondary impacts at the WTPs or in individual distribution systems. Secondary impacts resulting from increasing the corrosion control inhibitor dose to 3.0 mg/L as o-PO_4 were considered and can include the following:

- Increased phosphorus loading at the wastewater treatment plant and receiving waters
- Post-precipitation and phosphate complexation affecting plant operations, industrial customers and finished water aesthetics
- Reduced filter performance
- Stress on staff resourcing and plant operations
- Increased operations costs
- Increased microbial activity.

As stated in the recently published Lead and Copper Rule Improvements (LCRI), USEPA indicated that while corrosion control can be effective at reducing lead exposure, removing lead pipes provides even greater public health protection by eliminating the key source of lead. This rule, if finalized as written, would require water systems to replace all LSLs and galvanized requiring replacement (GRR) within 10 years of the compliance date (estimated to be completed in 2037). Some systems with existing CCT may not be able to achieve 90th percentile lead levels below the proposed action level (AL) of 10 µg/L, which USEPA has addressed by allowing CCT re-optimization deferment to 100 percent removal of LSLs and GRRs within 5 years. Given these updates, the agency has prioritized LSL replacement as the most effective means of public health protection.

Based on the results of the study, ongoing removal of LSLs in member partner distribution systems, current system capacity limits and secondary impacts discussed above, it is recommended that GLWA begin increasing the o-PO_4 dose to 2.4 mg/L as o-PO_4 at all plants to provide additional protection from lead release in the service area. Upon this increase, the system should be evaluated for secondary impacts, total phosphorus levels at the Water Resource Recovery Facility (WRRF) and LCR compliance in member partner systems. Following the review of at least one year of LCR compliance sampling monitoring rounds from each member partner, additional capital improvements could be considered to expand chemical capacity and increase the target o-PO_4 dose to 3.0 mg/L if further lead reduction is necessary for compliance with finalized regulations. However, these upgrades should be weighed against schedule and operational costs necessary for increased chemical delivery and handling considering the required LSL removal timeframe.

1 Introduction

Great Lakes Water Authority (GLWA) currently serves 112 member partners in eight counties across Southeast Michigan and provides drinking water that meets and exceeds all federal and state finished water quality standards. The system includes three raw water intakes, five drinking water treatment plants (WTPs), 19 pump stations and thousands of miles of buried transmission and distribution system piping. Three of the WTPs — Northeast, Springwells and Water Works Park — share a single intake on the Detroit River, while the Southwest WTP and Lake Huron WTP have separate intakes in the Detroit River and Lake Huron, respectively. Treatment is generally consistent across all five plants and includes pre-oxidation, coagulation (via aluminum sulfate), flocculation, sedimentation, filtration and disinfection. Water Works Park also includes intermediate ozone.

The Lead and Copper Rule (LCR) was originally promulgated in 1991 and established ALs for lead and copper concentrations intended to reduce public exposure to lead and copper resulting from corrosion in distribution systems and premise plumbing. The LCR required utilities to perform routine at-the-tap monitoring of lead and copper and required large systems with established corrosion control treatment (CCT) to conduct water quality parameter (WQP) monitoring at each entry point to the distribution system (EPTDS) and throughout the distribution system. In response to the LCR, GLWA, then operating under DWSD, began dosing phosphoric acid. Following an initial conditioning period of 3.0 mg/L as o-PO_4, a target residual of 1.0 mg/L as o-PO_4 was implemented. In 2000, a daily minimum total phosphate dose requirement of 0.9 mg/L as o-PO_4 was established by the state for each of the five WTPs.

Prior to state and national rules and regulations proposed and promulgated over the past five years, GLWA proactively planned to conduct a comprehensive corrosion control optimization study to evaluate current practices and existing conditions to further optimize corrosion control provided to member partners' distribution systems and to incorporate recent regulatory changes. A pipe rig study was chosen to evaluate the current CCT conditions against alternative CCT conditions. The *Pipe Rig Study Plan Technical Memorandum* was prepared in January 2022 detailing the components of the study. The Pipe Rig Study began on April 4, 2022, and was completed on September 1, 2023.

This document presents results from the Pipe Rig Study completed in September 2023 and provides recommendations to further optimize CCT throughout GLWA member partners' distribution systems. A preliminary plan for full-scale implementation of the proposed changes is presented herein and is subject to change pending approval from EGLE. Conceptual design of chemical storage and feed equipment necessitated by the recommended o-PO_4 dose will follow in a future technical memorandum.

2 Overview of Pipe Rig Study

The GLWA Corrosion Control Optimization Study used flow-through pipe rigs to evaluate the effects of different CCT conditions on metal concentrations released from various samples of service line and household plumbing materials. This study evaluated lead and copper metals release from harvested lead service lines (LSLs), harvested galvanized service lines previously connected to lead (GPCL), new manufactured leaded brass (formulated with 6-8% lead by weight as permitted before the 2014 ban), new manufactured copper with leaded solder and new copper pipe as outlined in the *Pipe Rig Study Plan Technical Memorandum* (January 2022). Consistent with USEPA and EGLE regulatory priorities, lead concentrations from LSLs were the primary driver of this study. While data from all test conditions and materials were considered, more in-depth analysis was performed on lead concentrations from LSLs than lead concentrations from other materials or copper concentrations when determining CCT recommendations. (Sandvig, 2008).

Lead and downstream galvanized service lines were harvested from the GLWA service area by working with member partners on concurrent LSL replacement projects. It should be noted that existing pipe scales were disturbed during harvesting, transport, and installation on the pipe rigs. For this reason and due to differences in flow conditions and sampling approaches, quantitative results from harvested pipe rig studies are not always representative of lead or copper concentrations measured from tap compliance samples. Masters *et al.* (2022) showed that mean lead results from pipe racks were 2.5 times greater than mean lead results in the distribution system for Denver Water. McTigue *et al*. (2023) compared lead levels when sampling directly from a harvested LSL mounted in a pipe rig versus a profile sample represented by a fifth liter type of sampling approach. Direct sampling from a harvested pipe resulted in lead levels four to six times higher than the profile sample, due to the lack of plug flow behavior and subsequent dilution that occurs within homes. Thus, results from this study provide a relative understanding of how different CCT test conditions perform comparatively and cannot be used to predict resultant lead levels within the individual member partners' distribution systems.

This pipe rig study evaluated CCT performance at increased o-PO_4 doses at various pH levels. Chlorine conditions were unaltered during the test. Testing was performed at five GLWA WTPs and at five locations within the distribution system volunteered by member partners. This resulted in four rigs each (labeled A, B, C and D, respectively) at 10 pipe rig locations, for a total of 40 pipe rigs. A representative site layout of the rig system at a location before chemical feed system installation is provided in Figure 2-1. CCT conditions tested at each location are presented in Table 2-1.

CCT conditions at each site included a control rig ("Rig A"). Seven of 10 sites shared an identical test condition setup of control, 2.0 mg/L, 3.0 mg/L, and 4.0 mg/L as o-PO_4, respectively, with no pH adjustment. The remaining three sites that did have pH adjustment were Northeast, Water Works Park, and Springwells WTPs, which share a common intake in the Detroit River. All three sites, in addition to the control rig, tested two pH conditions at the various o-PO_4 doses, and all three sites shared a pH/o-PO_4 test condition with another of the three sites. Based on findings from the *Existing Corrosion Control Technical Memorandum* (2021) and the common intake, finished water quality for key corrosion parameters, specifically pH, alkalinity, orthophosphate residual, and chlorine residual, were largely similar among the three plants. Thus, the shared water source, similar finished water characteristics and duplicated test conditions confirmed the validity of testing variable o-PO_4 doses and pH conditions simultaneously across the three WTPs as shown in Table 2-1.

Figure 2-1: Example Pipe Rig Study Setup at One Study Location (from left: Rig D, Rig C, Rig B, Rig A)

Table 2-1: Pipe Rig Study CCT Target Test Conditions

Source Water	Location	Rig	o-PO_4 Target (mg/L)	pH Target	Location	WTP Source	Rig	o-PO_4 Target (mg/L)	pH Target
Detroit River – Belle Isle Intake	Northeast WTP (NE)	A (Control)	*	*	Warren (WA)	NE	A (Control)	*	*
		B	*	7.0			B	2.0	*
		C	2.0	*			C	3.0	*
		D	2.0	7.0			D	4.0	*
Detroit River – Belle Isle Intake	Water Works Park WTP (WW)	A (Control)	*	*	Central Services Facility (CS)	WW	A (Control)	*	*
		B	2.0	7.0			B	2.0	*
		C	3.0	*			C	3.0	*
		D	3.0	7.0			D	4.0	*
Detroit River – Belle Isle Intake	Springwells WTP (SP)	A (Control)	*	*	West Yard (WY)	SP	A (Control)	*	*
		B	3.0	7.0			B	2.0	*
		C	4.0	*			C	3.0	*
		D	4.0	7.0			D	4.0	*
Detroit River – Fighting Island Intake	Southwest WTP (SW)	A (Control)	*	*	Allen Park (AP)	SW	A (Control)	*	*
		B	2.0	*			B	2.0	*
		C	3.0	*			C	3.0	*
		D	4.0	*			D	4.0	*
Lake Huron Intake	Lake Huron WTP (LH)	A (Control)	*	*	Rochester Hills (RH)	LH	A (Control)	*	*
		B	2.0	*			B	2.0	*
		C	3.0	*			C	3.0	*
		D	4.0	*			D	4.0	*

* Finished water as received

The pipe rig study was performed in two phases as detailed in Figure 2-2.

- **Conditioning Phase.** From April 4, 2022, to October 30, 2022, all test pieces were conditioned with finished water from each location. Samples were collected from April 4, 2022, to October 7, 2022. While data analysis concerning stabilization was ongoing, the rigs continued to receive finished water from each location from October 7, 2022, to October 30, 2022.
- **Testing Phase.** From October 31, 2022, to September 1, 2023, the testing phase occurred after confirmation of stabilization at the end of the conditioning phase. In this phase, one rig (Control Rig A) continued to be exposed to existing finished water from the site while the other three rigs were exposed to finished water that was modified to meet the alternative CCT conditions listed in Table 2-1. At all sites, the rigs continued to receive conditioned water while data were being reviewed and statistical analysis was being conducted.

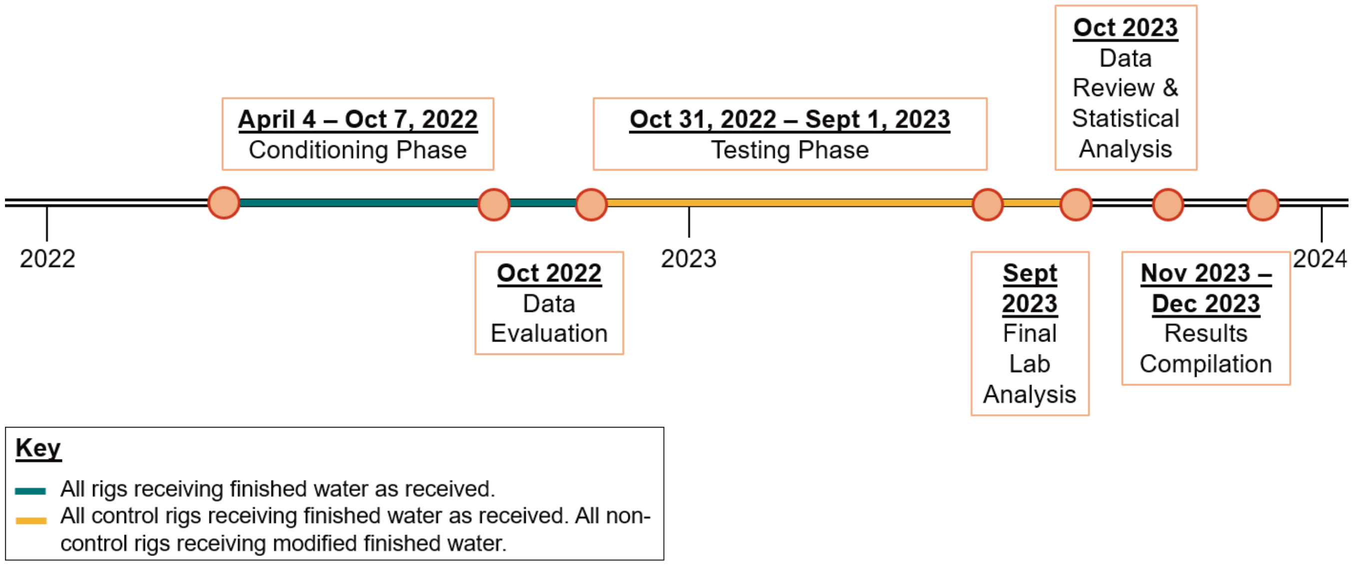


Figure 2-2: Pipe Rig Study Timeline

Detailed pipe rig operations were documented in the *Pipe Rig Operations Plan Technical Memorandum* (January 2023). The pipe rigs were operated in a manner representative of typical household conditions, with several periods of flowing water with intermittent periods of stagnation (i.e., water sitting stagnant in the service line). Stagnant and flowing samples, as described in Table 2-2, were collected over the course of the study to ensure target conditions were met and assess lead and copper release. Each site was monitored weekly, at a minimum, with the exception of holidays.

Table 2-2: Sampling Frequency During Conditioning and Testing Phases

Type of Sample		Conditioning Phase	Testing Phase
Stagnant samples	On-site WQP analysis	Weekly-Biweekly for all lines	Weekly-Biweekly for all lines
	Lab-analyzed metals samples	Weekly for all lines	Weekly for all lines
Flowing samples	On-site WQP analysis	Weekly for one rig	Weekly for all rigs

Lead and copper samples were regularly shipped to a laboratory for analysis, which was completed within two to four weeks of receiving the samples. Data received from the lab was checked for quality control by the study team. Any anomalies, such as results that were considerably higher or lower than previous samples from the same test piece, were discussed with the laboratory and re-analyzed from the same sample volume if necessary.

3 Conditioning Phase

The conditioning phase occurred between April 4, 2022, and October 7, 2022 (approximately six months). During this phase, all 40 pipe rigs were exposed to finished water from each facility without adjustment to allow the test pipes time to stabilize prior to introducing alternate CCT conditions in the testing phase. As shown in Figure 2-2, between October 7, 2022, and October 30, 2022, as data analysis was ongoing, all 40 pipe rigs continued to receive finished water from each facility and were monitored weekly for only flowing WQPs.

3.1 Water Quality Conditions

The key water quality parameter conditions evaluated included the following:

- Free chlorine
- o-PO_4
- pH
- Temperature

These parameters were measured weekly at each site during the conditioning phase. Although weekly WQP analysis began on the conditioning phase start date of April 4, 2022, the date range for the purpose of the analysis presented below began on May 2, 2022. The exclusion of data from the first several weeks of startup avoids data spikes due to the initial acclimation period of the new or disturbed pipes. Table 3-1 and Table 3-2 provide a summary of median water quality influent flowing conditions (as received) from May 2, 2022, to October 7, 2022, for the five WTP and five distribution system rig locations, respectively. Minimum and maximum temperatures observed during the conditioning period are presented alongside median temperatures. Detailed tables summarizing median, minimum, maximum and count of data for each parameter and location are provided in Appendix B, along with box and whisker plots for both flowing and stagnated samples for chlorine residual, o-PO_4, and pH as analyzed from LSLs and copper pipes.

Table 3-1: Median Conditioning Phase Influent Water Quality Conditions at WTPs (May 2, 2022 – October 7, 2022)

Source Water	WTP	Rig	Free Chlorine (mg/L)	o-PO_4 (mg/L)	pH	Temperature (degrees Celsius (°C))		
						Median	Minimum	Maximum
Detroit River – Belle Isle Intake	Northeast WTP	A (Control)	0.97	1.3	7.3	22.5	11.2	24.4
		B	0.91	1.2	7.3	23.0	18.5	24.4
		C	0.96	1.3	7.3	23.1	23.1	23.1
		D	0.98	1.2	7.3	17.4	12.9	24.0
Detroit River – Belle Isle Intake	Water Works Park WTP	A (Control)	0.79	1.4	7.4	22.3	9.3	25.0
		B	0.84	1.4	7.4	19.2	9.5	24.1
		C	0.86	1.3	7.5	23.4	9.5	24.3
		D	0.85	1.4	7.4	17.4	9.9	21.9

Source Water	WTP	Rig	Free Chlorine (mg/L)	o-PO_4 (mg/L)	pH	Temperature (degrees Celsius (°C))		
						Median	Minimum	Maximum
Detroit River – Belle Isle Intake	Springwells WTP	A (Control)	1.08	1.7	7.3	23.2	17.5	24.3
		B	1.10	1.5	7.2	22.5	17.7	24.5
		C	0.95	1.5	7.2	21.2	17.8	25.0
		D	1.11	1.4	7.3	18.6	11.7	24.0
Detroit River – Fighting Island Intake	Southwest WTP	A (Control)	1.03	1.6	7.3	23.4	18.4	24.5
		B	0.99	1.5	7.3	22.6	15.7	24.1
		C	1.05	1.2	7.3	22.4	17.9	23.2
		D	1.02	1.5	7.4	19.3	14.1	25.0
Lake Huron Intake	Lake Huron WTP	A (Control)	1.30	1.3	7.4	20.5	7.4	25.4
		B	1.21	1.3	7.4	15.4	7.6	20.4
		C	1.18	1.3	7.5	17.2	7.1	23.2
		D	1.24	1.4	7.4	10.8	6.5	19.9

Table 3-2: Median Conditioning Phase Influent Water Quality Conditions at Distribution System Sites (May 2, 2022 – October 7, 2022)

Location (DS Location and Associated WTP)		Rig	Free Chlorine (mg/L)	o-PO_4 (mg/L)	pH	Temperature (°C)		
						Median	Minimum	Maximum
Warren DPW	Northeast WTP	A (Control)	0.38	1.2	7.3	21.0	10.7	22.8
		B	0.53	1.2	7.4	22.4	10.0	22.8
		C	0.76	1.2	7.1	9.9	9.9	9.9
		D	0.69	1.2	7.3	16.8	9.9	22.8
Central Services Facility	Water Works Park WTP	A (Control)	0.06	1.1	7.6	21.8	14.6	23.4
		B	0.09	1.2	7.5	20.7	14.1	22.7
		C	0.10	1.3	7.6	22.6	14.9	23.0
		D	0.22	1.3	7.4	18.2	15.0	22.2

Location (DS Location and Associated WTP)		Rig	Free Chlorine (mg/L)	o-PO_4 (mg/L)	pH	Temperature (°C)		
						Median	Minimum	Maximum
West Yard	Springwells WTP	A (Control)	0.68	1.5	7.4	22.7	21.6	23.7
		B	0.93	1.4	7.3	20.6	19.6	22.7
		C	0.82	1.4	7.3	23.0	21.5	23.6
		D	0.83	1.4	7.3	17.5	14.5	22.4
Allen Park Retention Basin	Southwest WTP	A (Control)	0.03	1.3	7.4	19.6	18.9	20.1
		B	0.08	1.2	7.5	18.8	15.6	19.9
		C	0.12	1.3	7.5	16.7	13.4	18.9
		D	0.46	1.3	7.5	14.1	11.7	16.9
Rochester Hills DPW	Lake Huron WTP	A (Control)	0.71	1.4	7.5	20.6	18.3	21.8
		B	0.64	1.3	7.7	19.7	17.2	21.3
		C	0.72	1.4	7.6	19.8	16.1	21.4
		D	1.01	1.4	7.6	14.3	12.2	17.3

Lake Huron WTP site generally had the highest chlorine and pH and the lowest temperature of the WTPs. It was interesting to note that Rig D typically had lower median temperature at each WTP site. This likely occurred due to the large volume of water required for operation of rigs which acted as a system flush, and temperature decreased as the flow cycle progressed through rigs A, B, C, and D. Water Works Park had slightly lower median chlorine levels compared to the other WTP locations. All WTP locations had similar median o-PO_4 levels, typically ranging from 1.2 – 1.4 mg/L, with Springwells medians were slightly higher, ranging from 1.4 – 1.7 mg/L.

For the distribution system (DS) sites, influent chlorine levels were lower, and temperatures were higher than their corresponding WTP locations, as would be expected given the increased travel time to, and water age at, the distribution system locations. Median chlorine residual levels were significantly lower at Central Services and Allen Park, due to the large diameter mains and low water usage at those locations. Rig D often had higher median chlorine and lower temperature at each of the distribution system sites, likely due to being the final rig in the flow schedule and receiving flushed water. Orthophosphate levels were consistent across the distribution system sites and were similar to WTP levels.

During the 8-hour stagnation period within the LSLs, chlorine residuals decreased by approximately 0.2 – 0.4 mg/L at the WTP locations. Due to water age and travel time, the distribution system sites experienced a wider range of influent residuals. Chlorine demand during stagnation was more variable at the distribution system sites and is representative of water quality across all systems. pH and o-PO_4 levels were fairly consistent before and after stagnation within the LSLs, with approximately 0.1 mg/L decrease in o-PO_4 levels after stagnation.

Eight-hour stagnation within the new copper pipes exerted a strong chlorine demand across the 10 locations (approximately 0.7 – 1.0 mg/L), which was expected with passivation of new copper materials. Orthophosphate concentration decreases during stagnation were slightly larger in the copper pipes compared to the LSLs, with approximately 0.2 mg/L o-PO_4 demand.

Conclusions of the WQP evaluation during the conditioning phase included the following:

- At the WTP locations, the ranges of chlorine were higher, and the ranges of temperatures were lower than conditions within DS rig locations as well as throughout the GLWA service area. However, the range of chlorine residuals and temperatures across the DS rig locations were representative of chlorine and temperature conditions across the GLWA service area.
- pH conditions were relatively consistent across and within WTP and DS rig locations. DS median pH conditions were overall higher than median conditions previously summarized in the *Existing Corrosion Control Technical Memorandum* (July 2021). This observation further supported the need to verify CCT performance at current pH conditions as well as at the lower pH condition of 7.0.

3.2 Conditioning Phase Stabilization

Harvested and new pipes require time to achieve an equilibrium state with the contacting water. It is important that the pipes have this equilibrating (conditioning) period so that the scales within the pipes have time to either adjust to or develop with new water conditions. Lead and copper levels generally show the most variance and highest concentrations immediately after introducing or changing the water conditions flowing through the pipes. These levels then decrease until they reach a point at which they maintain a consistent average with lower variance. At that point, the pipes are considered to have stabilized to the imposed water conditions.

On two separate occasions in mid-2022, each pipe was flushed at a flow rate of 3.0 gallons per minute (GPM) for 30 minutes in an effort to reduce sporadic total lead levels in harvested lead and galvanized service lines likely caused by particulate lead release from the pipe scale. Following the first flushing event in June, a sudden upward trend in total lead levels was observed, likely due to a buildup of flushed material in the effluent sample valves. The second flushing event, in July, included a step to flush each sample valve following the test piece flushing. Total lead levels were observed to generally be less sporadic after the second event. Dissolved lead levels in samples from harvested lead and galvanized service lines were more consistent than total lead levels within sites from the beginning of the study.

3.2.1 Methodology

Pipes introduced to new water quality conditions can take months to stabilize before water quality parameter and metals concentration level off. Furthermore, new pipe materials exposed to water for the first time require an initial passivation period during which metals release may be higher compared to long term concentrations. Methods to determine stabilization included a combination of statistical analysis, visual assessments, and engineering judgement.

It is important with any study involving statistics to gather as many samples as possible to increase the accuracy of statistical comparisons within the practical limitations of the study (Lenth, 2001) (Maxwell, 2008). For a typical pipe rig study, 10 samples have been used to conclude stability of pipes (Water Research Foundation, 2023). However, this guidance document to use pipe rigs to inform CCT decisions was actively being developed in parallel timeline to this study and is not a firm industry standard. The design of the GLWA study provides redundancy in having multiple pipes (i.e. duplicates, triplicates or quadruplicates) installed per condition across a total of 10 site locations. The sample size was intended to balance the practicality of achieving statistical criteria guidelines with visual assessments and engineering judgment. Given the robustness of the data set, the goal of the analytical tests for stability testing was to gather six stable samples per pipe.

The goal of stabilization in the condition phase is to determine that pipes have reached an equilibrium state under the new water conditions. If the pipes have maintained a constant total lead level (determined statistically and visually) during this time, then the individual pipes are considered stable based on best engineering judgement. The CCT test conditions would then be introduced once a reasonable proportion of pipes maintained constant lead levels. This approach was used for the lead pipes of the study, while all other pipes (and total copper levels) would only need to show visual confirmation of stability. Lead release from harvested lead service lines was the primary driver of this study and was therefore evaluated more in-depth to determine stabilization. Galvanized pipe material was not evaluated in depth for stabilization due to the consistent non-detect lead concentrations coming from the test pieces. Selection of statistical methods for a pipe rig study depends on data normality, sample size and the goals of the study (Water Research Foundation, 2023). Samples from stabilized pipes commonly display non-normal distributions, particularly at low sample sizes. As such, total lead and total copper results were analyzed statistically using non-parametric tests, which are not dependent on normality. To analyze for stability, a Spearman's correlation of zero was tested against a select number of samples to analyze for a constant lead level (i.e., a zero-slope trend). However, inconsistent lead or copper concentrations, frequently due to periodic particulate release, can also indicate no apparent correlation, which can be misleading for determining stabilization. Therefore, a target range of 0 ± 0.50 was determined as a stability goal from the Spearman's correlation to target no strong positive or negative correlation among the total lead and/or total copper concentrations from a specific test piece.

For the visual assessment, lead concentrations over time were evaluated based on a list of goals:

- The slope factor was 0 under a 95th confidence interval.
- Data had no more than one outlier per site.
- No upward or downward trend was observed.

Data were collected on a regular basis to continuously assess stabilization with visual assessments of graphed data. For instance, these visuals could show the relationship among metals concentrations from pipes, such as pipes with similar trends at a particular site. A comparison of individual pipe median lead concentrations along with minimum, 25th percentile, 75th percentile and maximum values was utilized to evaluate data tightness and to identify outliers.

Engineering judgement considers factors outside of the study's parameters and is used to evaluate the statistical analysis and visual assessment of results to determine if the data have met stability goals. Factors considered in this study include specific disruptions and characteristics at a given site. During stability testing, engineering judgment was considered in parallel with the statistical analysis and visual assessment of the data.

3.2.2 Results

Table 3-3 shows the results of pipe stabilization for statistical analysis only by pipe material for samples collected between August 10, 2022, and September 23, 2022. Table 3-4 shows the stability results for all materials at all sites, with symbols indicating if stability was achieved at a particular location using statistical analysis, visual assessment of the data, and engineering judgement. Each material was evaluated based on total lead results, except for copper pipes, which relied on total copper results. These data were presented at the second conditioning phase workshop in October 2022, during which the decision to move forward to the testing phase was made.

Overall, the harvested lead and galvanized test pieces showed good stability based on statistical analysis, visual assessment, and engineering judgement. Flushing of test pieces did improve stability, resulting in lower, more consistent lead concentrations from harvested lead and galvanized pipes. New manufactured test pieces (leaded brass, copper, and copper with leaded solder) did show some variation. For instance, differences in lead release for manufactured brass and copper with leaded solder were observed both across locations and within select sites; however, pipes generally trended together at a site. Copper pipes were still likely passivating; however, median values were consistent across rigs within a site, and copper was not the primary driver of the study. As such, it was recommended that the study proceed into the testing phase. Additional details regarding lead and copper release from each pipe material are provided below in Sections 3.2.2.1 and 3.2.2.2.

Table 3-3: Pipe Stability of Lead and Copper Levels based on Statistical Analysis Only by Material Type During Conditioning Phase

Material	Total Pipes	Stabilized	Not Fully Stabilized	Stabilized per Material
Lead	113	98	15	87%
Galvanized	32	29	3	91%
Brass	80	59	21	74%
Copper-Lead Solder	80	69	11	86%
Copper[1]	80	63	17	79%
Total	**385**	**318**	**67**	**83%**

[1]Based on copper concentrations

Table 3-4: Stabilization per Site for All Materials based on Statistical Analysis, Visual Assessment, and Engineering Judgment During Conditioning Phase

Material	AP	CS	LH	NE	RH	SP	SW	WA	WW	WY
Lead	✓	✓	✓	⚠	✓	✓	✓	✓	⚠	✓
Galvanized	N/A	N/A	✓	✓	⚠	N/A	N/A	✓	N/A	N/A
Brass	✓	✓	✓	⚠	⚠	✓	✓	⚠	✓	✓
Copper-Lead Solder	✓	✓	⚠	✓	✓	✓	✓	⚠	✓	⚠
Copper[1]	✓	⚠	✓	✓	⚠	✓	✓	✓	✓	⚠

[1]Based on copper concentrations

Material	AP	CS	LH	NE	RH	SP	SW	WA	WW	WY

Results based on using data collected from August 10, 2022 – September 23, 2022, n = 6

Stabilized ⚠ Not fully stabilized

3.2.2.1 Lead Level Stability

Note that lead concentrations shown in this section were used only as reference points for the testing phase and are not necessarily representative of absolute levels that would be observed within the water system.

Harvested lead pipes averaged a median of 15 µg/L for all rigs. As noted in Table 3-3 a total of 98 pipes (87%) of the lead pipes achieved stability based on the statistical analyses discussed in Section 3.2.2. The remaining 15 pipes did not show full stability during the statistical analysis; however, after applying the visual assessment of the data and engineering judgement, sites containing pipes with lower stabilization percentages showed that the statistics were influenced by outliers, occurred on redundant replicates, were easily skewed based on very low analytical results, or exhibited consistent lead levels that were similar to other pipes at their site. Based on statistical analysis only, Southwest WTP had the lowest LSL stability percentage at 62%, due largely to total lead levels continuing to decrease; however, the total lead levels from LSLs at this site trended closely together, prompting the designation of LSLs at the site overall as stabilized. in Table 3-4. Although all LSLs at Northeast WTP and Water Works Park WTP achieved a 100% stability percentage during statistical analysis, caution signs were designated in Table 3-4 due to site-wide total lead spikes in samples collected on September 21, 2022, and September 13, 2022, respectively. Pipes tested at the remaining seven sites evaluated met the stability goals and were designated as stabilized to transition to the testing phase.

Harvested galvanized pipes displayed consistently low lead levels below the detection limit of 1 µg/L. Only three galvanized pipes did not appear to have fully stabilized, two of which were located in Rochester Hills. Total lead levels were consistently below the detection limit by the beginning of the testing phase.

Newly manufactured brass pipes averaged a median lead concentration of 23 µg/L for all rigs. It was expected that the average median lead levels for brass pipes would continue to decrease, as many of the pipes that did not meet the stability goals displayed the lowest lead levels during the end of the conditioning phase. Differences could be attributed to the manufacturing process or operational disruption of pipes. Therefore, while only 74% of the brass pipes met the stability goals, lead pipes were weighed more heavily in the decision to proceed to CCT testing.

Newly manufactured copper pipes with leaded solder averaged a median of 11 µg/L for all rigs. 84% of the copper pipes with leaded solder pipes met the stability goals. Like the brass pipes, it was expected that the average median lead levels for copper with leaded solder pipes would further decrease, as some of the pipes that did not meet the stability goals displayed the lowest lead levels during the end of the selected stabilized period. As the copper with leaded solder pipes were newly manufactured materials, it is likely that galvanic corrosion was still occurring. The length of dominance of galvanic corrosion in copper-lead solder pipes varies widely between systems for many reasons including water quality, flow rate and temperature. Lead levels during the conditioning phase indicated that galvanic corrosion was still occurring and continued into the testing phase.

3.2.2.2 Copper Level Stability

The following copper results were observed for each applicable pipe material. Note that copper concentrations shown in this section were used only as reference points for the testing phase, and not necessarily representative of absolute levels that would be observed within the water system.

- Copper pipes averaged a median of 197 µg/L for all rigs. Some pipes were likely still declining in copper levels at the end of the conditioning phase, but these levels were consistent between rigs at a given site.
- Brass pipes averaged a median of 51 µg/L for all rigs. Most pipes seemed to have stabilized based on visual assessment, and copper levels were consistent between rigs at a given site and across sites.
- Copper with leaded solder pipes averaged a median of 157 µg/L for all rigs. Copper concentrations for some pipes were likely still declining at the end of the conditioning phase, but these levels were consistent between rigs at a given site.

Because copper was not the primary driver for this study and pipes maintained similar trends within a site, it was recommended that the study advance into the testing phase as planned.

4 Testing Phase

The planned 10-month testing phase introduced different test conditions to specific rigs. A complete list of all test conditions at all sites is shown in Table 2-1. The design of the test allowed for the observation of uniform corrosion control treatment performance across the full range of water quality conditions present in the GLWA system. This includes the simulation of low pH as observed in the data analysis completed during the development of *Existing Corrosion Control Technical Memorandum* (July 2021), as well as high water age and low chlorine residual which represent “worst case” water quality scenarios in the distribution system. Furthermore, the time period of the study captured a variety of seasonal conditions including high and low temperatures and seasonal turnovers of raw water. Data from all locations were analyzed in an aggregated group as well as individually to achieve a comprehensive view of the GLWA water system and determine the optimal tested dose from a holistic perspective.

For each site, Rig A remained on the existing (current) water conditions, serving as a control rig. For Rigs B, C, and D, different o-PO_4 concentrations and/or pH targets were applied per rig to test the effectiveness of each condition at reducing total lead, total copper, and/or dissolved lead release from test pieces. The pipes on Rigs B, C, and D that received CCT test conditions required time to achieve an equilibrium state under the new water quality conditions. As discussed in Section 3.2.1, this equilibrating period allowed the scales within the pipes to either develop or adjust to altered water quality conditions. Lead and copper levels generally show the most variance and highest concentrations immediately after introducing or changing the water conditions flowing through the pipes. These levels then tend to decrease until they reach a point at which they maintain a consistent average with lower variance. At that point, the pipes are considered to have stabilized to the imposed water conditions. As discussed in Section 2, the common raw water intake allowed the study to test the impacts of a low pH only at the Northeast, Water Works Park, and Springwells WTP rigs by dosing sulfuric acid to select rigs. Chemical feed systems were installed and began operation at each site by November 4, 2022, with weekly total metals sampling and water quality parameter monitoring beginning November 7, 2022. Sampling and monitoring of the rigs finished on September 1, 2023. Dissolved lead sampling occurred intermittently throughout the testing phase with a particular focus on lead test pieces towards the end of the study.

4.1 Water Quality Conditions

Water quality parameters including pH, o-PO_4, free chlorine residual, and temperature were routinely measured during the testing phase in each pipe material from the influent samples and after stagnation at all locations. WQP testing conditions by location and rig were previously shown in Table 2-1. Where pH and o-PO_4 levels were modified, a treatment target standard deviation of ± 0.2 s.u. or mg/L, respectively, was set. WQPs were measured weekly throughout the testing phase from the influent flowing rigs, and biweekly from individual test pieces after stagnation, although the frequency was increased at the beginning of the study period to observe initial o-PO_4 uptake, and as needed during the study period.

WQP conditions were analyzed across the entire testing phase beginning on October 31, 2022. Similarly to the WQP analysis for the conditioning phase presented in Section 3.1, the date range for the testing phase analysis began on December 5, 2022, once the test pieces on rigs exposed to alternate CCT conditions acclimated to the new conditions. Detailed WQP results in Appendix B summarize data collected from December 5, 2022 – September 1, 2023.

The WQP analysis below focuses on a subset of the study period representing 10 consecutive sampling events, which were used for total lead and total copper Wilcoxon rank-sum statistical comparison. The method for selecting this sample set is discussed in Section 4.2. Tabular and graphical results for the entire testing phase are provided in Appendix B, Section B.2 (Figures B.2.1 through B.2.15).

The following discussion focuses on WQPs collected during 10 consecutive sampling events that represent the stabilization period used for comparing CCT conditions.

Table 4-1 and Table 4-2 present median influent WQP conditions during this period. Review of the o-PO_4 and/or pH medians for o-PO_4 and/or pH-adjusted rigs confirmed that all treatment target medians for all treated rigs at all sites were within ± 0.2 s.u. or mg/L, respectively, of their corresponding treatment target conditions.

Table 4-1: Median Testing Phase Influent Water Quality Conditions at WTPs (10-Sample Stability Period)

Source Water	WTP	Rig	Free Chlorine (mg/L)	o-PO_4 (mg/L)	o-PO_4 Target (mg/L)	pH	pH Target	Temperature (°C)		
								Median	Minimum	Maximum
Detroit River - Belle Isle Intake	Northeast WTP	A (Control)	0.93	1.2	*	7.3	*	20.7	15.0	23.9
		B	0.96	1.2	*	7.1	7.0	20.7	15.0	23.8
		C	0.93	1.9	2.0	7.3	*	21.5	14.9	23.8
		D	1.01	1.9	2.0	7.0	7.0	21.8	14.8	25.2
Detroit River - Belle Isle Intake	Water Works Park WTP	A (Control)	0.94	1.5	*	7.5	*	20.8	15.1	24.1
		B	0.93	2.1	2.0	7.0	7.0	20.5	15.0	24.1
		C	0.90	3.0	3.0	7.5	*	20.7	15.0	24.1
		D	0.90	3.1	3.0	7.0	7.0	20.7	15.1	24.1
Detroit River - Belle Isle Intake	Springwells WTP	A (Control)	1.39	1.6	*	7.2	*	20.0	15.2	24.0
		B	1.30	3.0	3.0	7.0	7.0	20.9	15.9	24.1
		C	1.34	3.9	4.0	7.2	*	21.1	16.4	24.0
		D	1.37	4.0	4.0	7.0	7.0	21.1	17.5	24.1
Detroit River - Fighting Island Intake	Southwest WTP	A (Control)	1.03	1.4	*	7.3	*	20.4	14.6	23.8
		B	1.04	1.8	2.0	7.3	*	20.8	15.5	24.1
		C	1.00	2.8	3.0	7.2	*	20.7	15.9	24.3
		D	1.04	4.0	4.0	7.2	*	21.0	15.7	24.3

Source Water	WTP	Rig	Free Chlorine (mg/L)	$o\text{-}PO_4$ (mg/L)	$o\text{-}PO_4$ Target (mg/L)	pH	pH Target	Temperature (°C)		
								Median	Minimum	Maximum
Lake Huron Intake	Lake Huron WTP	A (Control)	1.09	1.3	*	7.5	*	15.1	10.4	19.4
		B	1.20	2.0	2.0	7.5	*	15.1	10.5	19.3
		C	1.24	3.0	3.0	7.5	*	15.3	10.1	19.3
		D	1.27	4.1	4.0	7.5	*	15.0	10.1	19.9

* Finished water as received

Table 4-2: Median Testing Phase Influent Water Quality Conditions at Distribution System Locations (10-Sample Stability Period)

Location (DS Location and Associated WTP)		Rig	Free Chlorine (mg/L)	$o\text{-}PO_4$ (mg/L)	$o\text{-}PO_4$ Target (mg/L)	pH	Temperature (°C)		
							Median	Minimum	Maximum
Warren DPW	Northeast WTP	A (Control)	0.46	1.2	*	7.4	18.1	13.3	21.0
		B	0.65	1.9	2.0	7.4	18.5	13.6	21.5
		C	0.64	3.1	3.0	7.3	18.6	13.6	21.4
		D	0.65	3.9	4.0	7.4	18.5	13.5	21.4
Central Services Facility	Water Works Park WTP	A (Control)	0.16	1.2	*	7.6	19.4	17.1	22.9
		B	0.21	2.0	2.0	7.6	19.7	17.1	22.5
		C	0.22	3.2	3.0	7.6	19.6	17.3	22.2
		D	0.21	3.9	4.0	7.6	19.1	17.1	22.0
West Yard	Springwells WTP	A (Control)	1.12	1.4	*	7.3	19.8	15.4	22.6
		B	1.14	2.0	2.0	7.3	20.6	16.5	23.0
		C	1.17	3.1	3.0	7.2	20.4	17.0	23.1
		D	1.18	4.0	4.0	7.2	20.4	16.8	23.2
Allen Park Retention Basin	Southwest WTP	A (Control)	0.28	1.2	*	7.4	15.7	12.4	18.6
		B	0.27	2.0	2.0	7.4	16.8	14.6	19.5
		C	0.27	2.9	3.0	7.4	16.6	14.3	19.3
		D	0.30	4.0	4.0	7.3	16.9	14.0	22.9

Location (DS Location and Associated WTP)		Rig	Free Chlorine (mg/L)	o-PO_4 (mg/L)	o-PO_4 Target (mg/L)	pH	Temperature (°C)		
							Median	Minimum	Maximum
Rochester Hills DPW	Lake Huron WTP	A (Control)	0.90	1.3	*	7.5	16.5	13.2	19.5
		B	0.88	1.9	2.0	7.5	17.9	15.0	19.8
		C	0.87	3.0	3.0	7.5	18.0	15.3	20.2
		D	0.92	3.8	4.0	7.5	18.1	15.3	20.3

* Finished water as received

Figure 4-1, Figure 4-2, Figure 4-3 and Figure 4-4 show box and whisker plots for rig influent chlorine residual, o-PO_4, pH, and temperature respectively, by location. Key observations include the following:

Figure 4-1: Chlorine was typically highest at Springwells, which translated into higher chlorine at West Yard. Chlorine was lowest at Central Services Facility, followed by Allen Park, despite similar chlorine levels at their respective WTPs. As discussed previously, high water age and low demands at these distribution system locations resulted in significant chlorine demand entering the facilities. These lower chlorine levels represented higher water age and low-use locations within the service area.

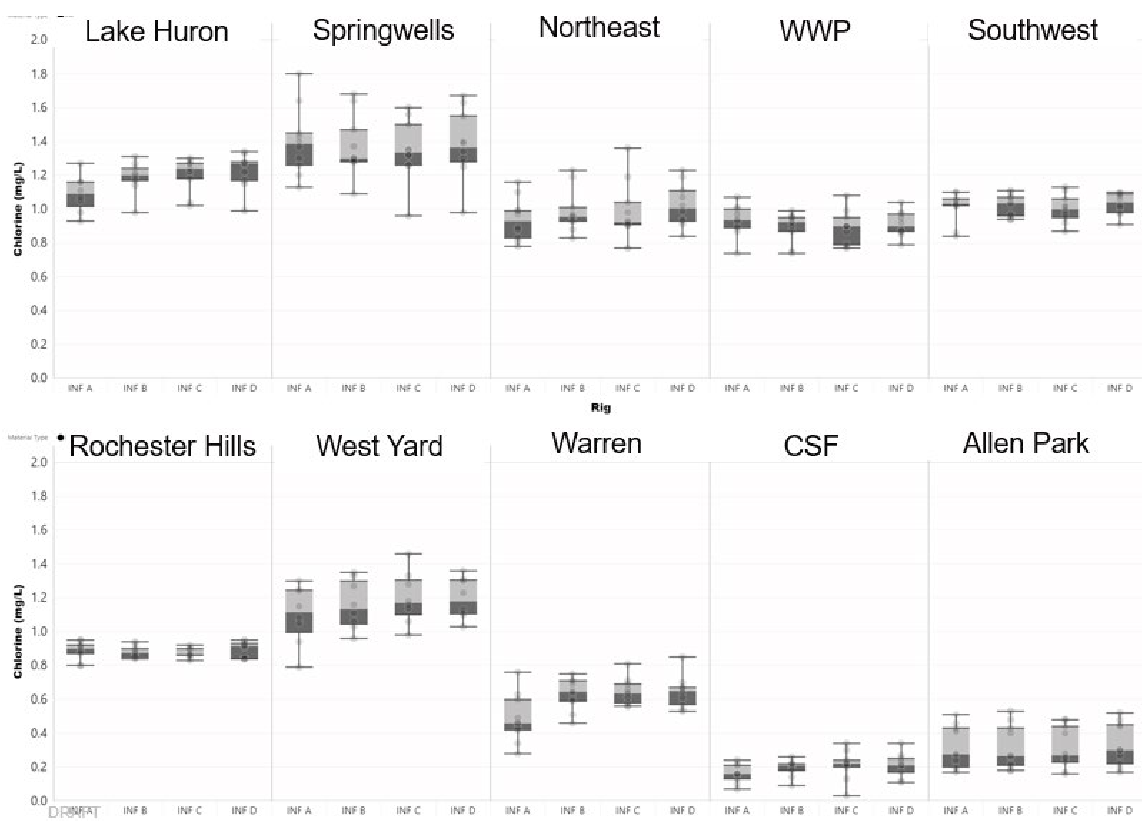
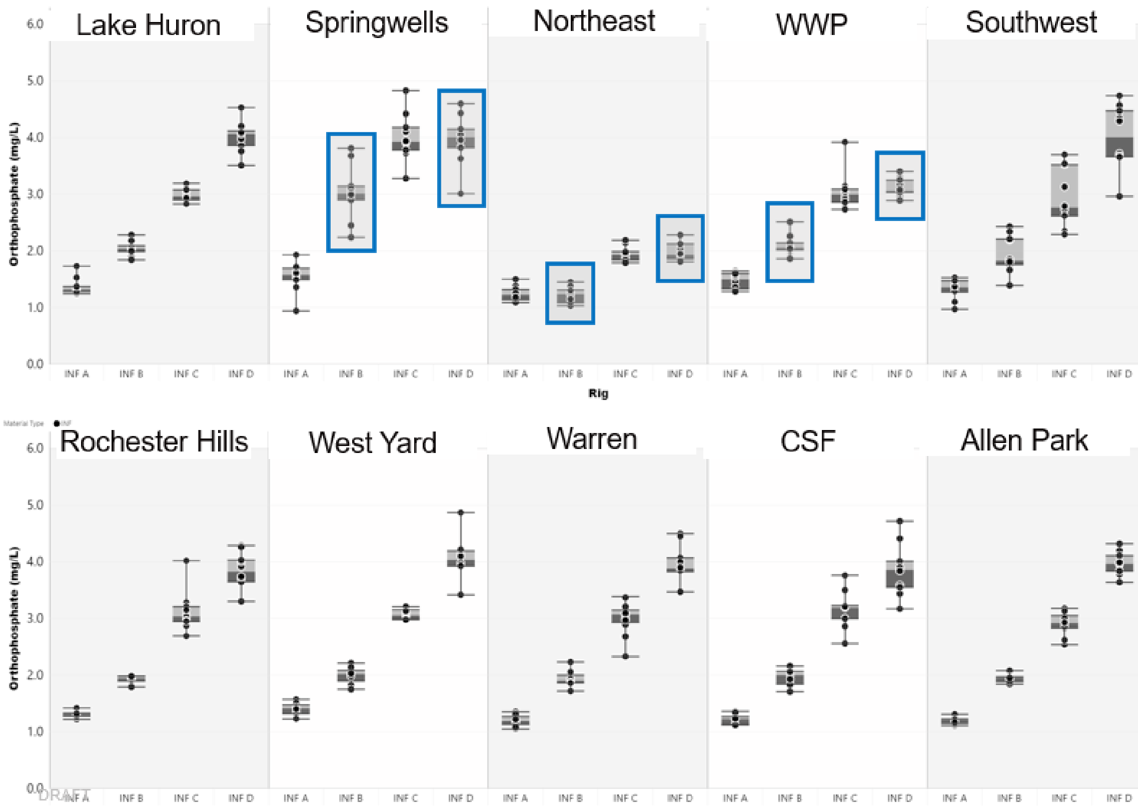


Figure 4-1: Rig Influent Chlorine Residuals during Testing Phase (10-Sample Stability Period)

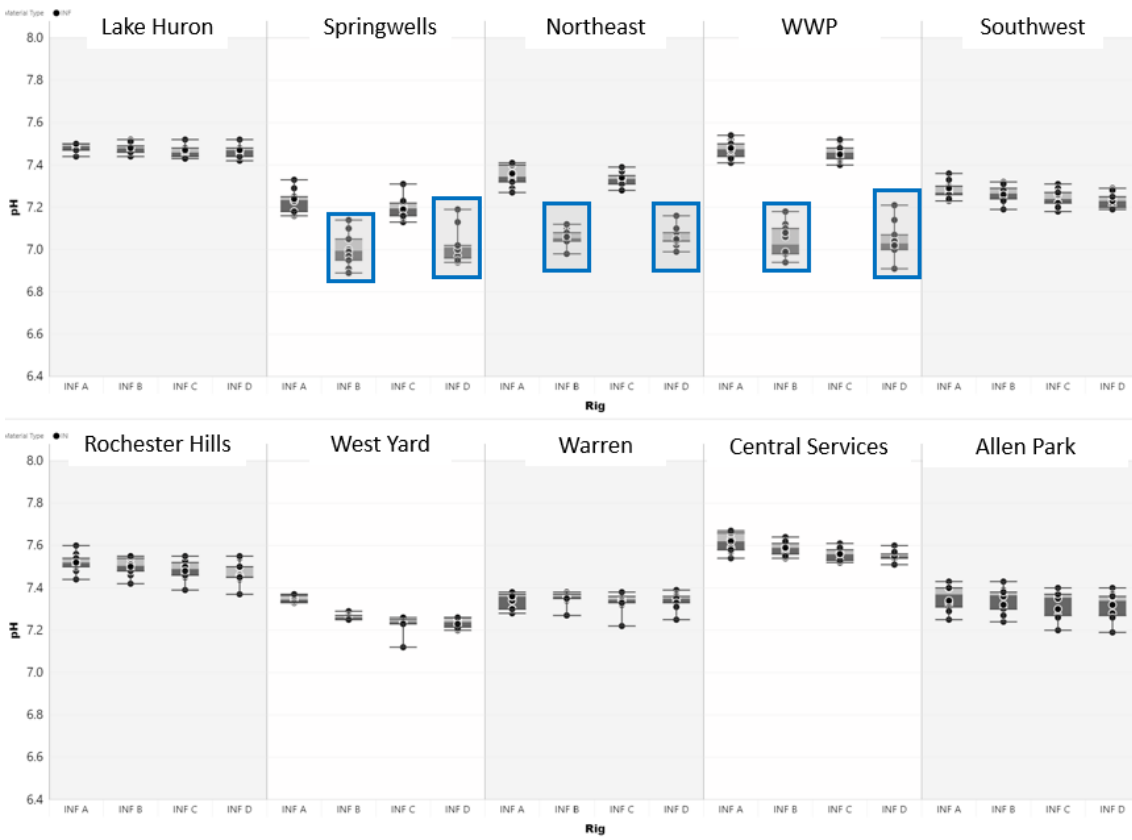
Figure 4-2: Influent o-PO_4 was typically highest at the Water Works Park and Springwells WTPs (medians of 1.5 and 1.6 mg/L, respectively). This translated into a slightly higher median o-PO_4 level at West Yard, which receives Springwells water. The remaining WTP and distribution system median influent o-PO_4 levels ranged from 1.2 – 1.4 mg/L. All rigs with o-PO_4 dosage increases met the operating target range of ± 0.2 mg/L, with and without pH adjustment. Figure 4-2 shows which rigs also received pH adjustment to 7.0, as indicated by blue boxes.



Note: blue boxes indicate rigs with pH adjustment to 7.0.

Figure 4-2: Rig Influent o-PO_4 during Testing Phase (10-Sample Stability Period)

Figure 4-3: Median influent pH was highest at Lake Huron and Water Works Park (median of 7.5) and ranged between 7.2 – 7.3 for the other WTP locations. pH was decreased to 7.0 for Rigs B and D at three WTPs (Northeast, Water Works Park, and Springwells). pH standard deviation for the adjusted rigs met the ± 0.2 target range, and statistical analysis of the median pH conditions verified a statistically significant difference between the median pH for the adjusted rigs vs. the unadjusted (as-received) rigs. Median pH values at distribution system locations were typically within 0.1 s.u. of their respective WTP medians, with Rochester Hills and Central Services having the highest pH levels.



Note: blue boxes indicate rigs with pH adjustment to 7.0.

Figure 4-3: Rig Influent pH Levels during Testing Phase (10-Sample Stability Period)

Figure 4-4: Median influent temperature was lowest at Lake Huron (approximately 15.2° C) compared to the other WTP locations with median temperatures of approximately 21.0° C. The date range represented by the 10 sampling events used in the statistical analyses captured the period of most significant temperature increases across all locations.

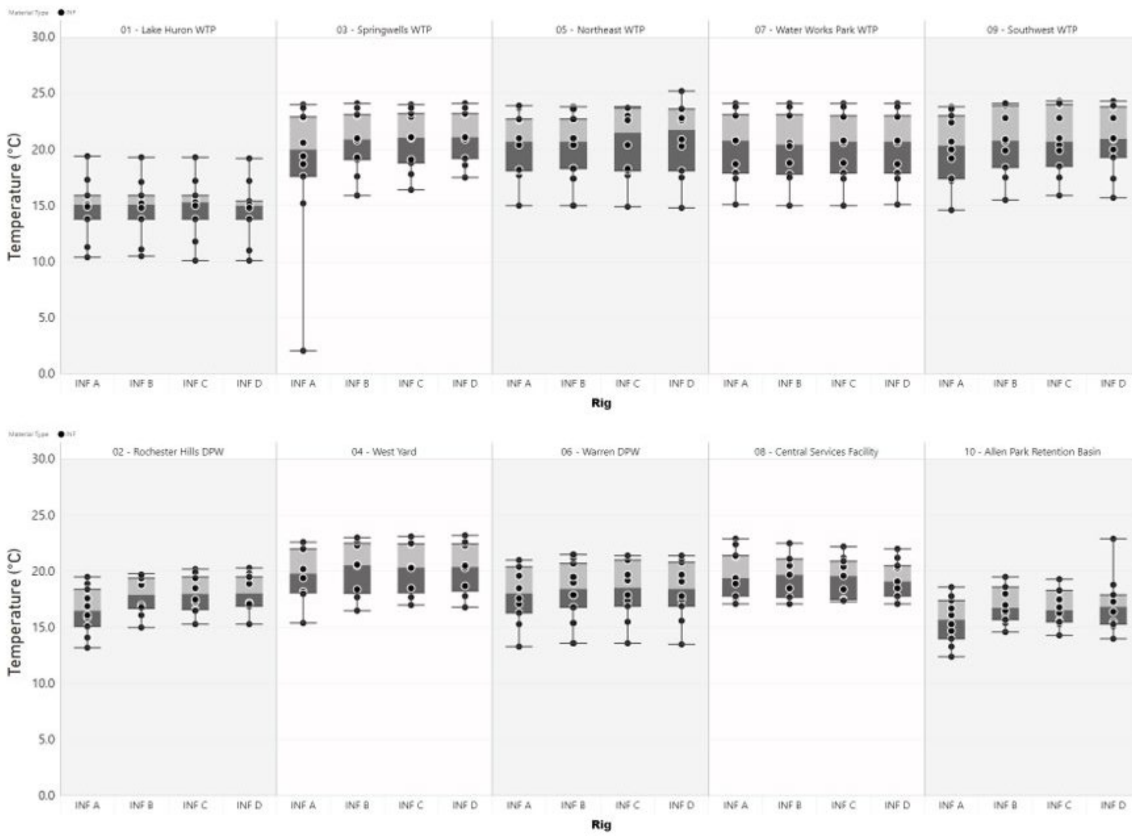


Figure 4-4: Rig Influent Temperature during Testing Phase (10-Sample Stability Period)

4.1.1 Stagnation Water Quality Parameter Conditions

A summary of stagnation impacts on WQPs is provided. Appendix B includes tables and graphics showing stagnation conditions for LSL and copper pipe materials.

Chlorine residual. LSL post-stagnation median chlorine residuals ranged between 0.05 – 1.10 mg/L, with most rig medians in the range of 0.4 – 0.8 mg/L, resulting in a typical chlorine decrease of approximately 0.2 – 0.4 mg/L through the LSLs. Central Services and Allen Park had the lowest post-stagnation chlorine levels for LSLs with median levels ≤ 0.1 mg/L, as could be expected based on low influent chlorine residuals to the two sites. Chlorine demand was higher during stagnation in copper pipes, with most pipes exerting a demand ≥ 0.4 mg/L. Central Services and Allen Park had the lowest post-stagnation chlorine levels for copper pipes with median levels ≤ 0.01 mg/L.

o-PO_4. o-PO_4 demand ranged between approximately 0.1 – 0.3 mg/L for both LSL and copper pipe materials.

pH. pH levels were quite stable during stagnation with median differences of approximately ±0.1 s.u. through both LSL and copper pipe materials.

Temperature. Temperature generally increased between 1 – 5 °C during stagnation across the locations, compared to influent temperature conditions.

4.1.2 Conclusions

WQP medians met treatment targets within and across the WTPs. Thus, it was valid to compare impacts of lowering pH to 7.0 vs. as-received pH on CCT performance, and to compare rigs with the same o-PO_4 and pH treatment targets within and across locations. Minor chlorine variability was observed across the WTP rig locations but not within the WTPs, suggesting that chlorine levels within a location were not a variable impacting CCT performance. WQP medians also met treatment targets within the individual DS locations. Significant chlorine variability was observed across the DS rig locations, but again, not within the DS locations. The range of chlorine levels and temperatures captured across the DS rig locations represented a wide range of conditions and were likely representative of chlorine levels and temperatures across the GLWA service area.

4.2 Testing Phase Stabilization

The combination of statistical, visual assessment, and engineering judgement used to determine stabilization during the conditioning phase (refer to Section 3.2.1) was also used to determine stabilization during the testing phase. These goals were applied only to lead release from lead pipes as this was the primary driver of this study and was therefore evaluated more in depth to determine stabilization. All other pipes (and copper levels) were evaluated using visual confirmation of stability. Rolling statistical stability analyses were completed on total lead and/or total copper data received from the laboratory throughout the test to determine the most representative data set for comparison. In parallel, visual assessments on the data trends were reviewed weekly.

The goal for the analytical tests used for stabilization in the testing phase was to gather 10 consecutive samples per pipe that showed consistent total lead levels, indicating that fluctuation had leveled off. This same time frame was used for additional analytical tests as outlined in Section 4.3 for comparing the CCT conditions to determine dose effectiveness for pipes that have reached steady state.

The 10 samples collected from May 22, 2023, to July 28, 2023 were selected for stability analysis based on the following considerations:

- Test pieces needed to restabilize following the addition of new corrosion control treatment test conditions; therefore, including data from the first several months of the testing period contain greater statistical slopes in the data. The period selected was associated with a “leveling off” of the data indicating that the pipes were approaching or had reached stability.
- The period selected minimized outliers and elucidated data trends.
- Disturbances were observed across several sites in the month of August 2023. This data was not included in the stability analysis to avoid bias from these unexplained disruption events.

The results of the stability analysis are presented in Table 4-3. While three of the ten sites did not meet the stability criteria for lead pipes, the data sets were reviewed, and engineering judgement and visual analysis of trends was used to determine that the results were representative of real-world conditions. Separate statistical analysis of only the stable lead pipes was considered. However, as ongoing particulate releases and outliers are known to occur in distribution systems, this behavior is representative of real-world conditions and eliminating individual pipes that failed the statistical stability metrics from the analysis could bias the results.

Table 4-3: Stabilization per Site for All Materials During Testing Phase

Material	AP	CS	LH	NE	RH	SP	SW	WA	WW	WY
Lead	✓	✓	✓	✓	✓	✓	✓	⚠	⚠	⚠
Galvanized	N/A	N/A	✓	✓	✓	N/A	N/A	✓	N/A	N/A
Brass	✓	✓	✓	⚠	⚠	✓	✓	⚠	⚠	✓
Copper-Lead Solder	✓	✓	⚠	⚠	✓	✓	✓	✓	⚠	✓
Copper[1]	⚠	⚠	⚠	⚠	⚠	⚠	⚠	⚠	⚠	⚠

[1]Based on copper concentrations
n = 10
✓ Stabilized ⚠ Not fully stabilized

4.3 Comparison of CCT Conditions

The Wilcoxon rank-sum test was used for the comparison of CCT conditions during the testing phase. This test is statistically identical to the Mann-Whitney U test and is a recognized statistical method for comparing two different treatment conditions for their performance in reducing lead levels (Water Research Foundation, 2023). The Wilcoxon rank-sum test is a nonparametric statistical analysis method that checks two datasets (a baseline and a comparison) for a relationship defined by a null and alternative hypothesis. The objective is to determine the probability of the null hypothesis being true. The Wilcoxon rank-sum test null and alternative hypotheses utilized in this study are given below in Equation 1 as H_0 and H_a respectively.

Equation 1: Null and Alternative Hypotheses Utilized for This Study's Dataset Comparison

$$H_0 = The\ control\ or\ baseline\ values\ are\ generally\ less\ than\ or\ equal\ to\ the\ compared\ data\ values$$

$$H_a = The\ control\ or\ baseline\ values\ are\ generally\ greater\ than\ the\ compared\ data\ values$$

If the null hypothesis is rejected, then there is insufficient evidence to say that, at the selected alpha level (or significance level), the baseline values are generally less than or equal to the compared distribution of values. The alternative hypothesis is then accepted; the baseline values are likely higher than the compared values. The alpha level was 5% (alternately stated, the statistical significance was evaluated at 95%) for all tests conducted during this study. The alpha level defines the Type I error rate, which is the probability of rejecting the null hypothesis when it is true. The statistic produced by the test to evaluate if the two datasets are different enough from each other to cross the alpha level threshold is the p-value. If the p-value generated by the test is less than or equal to the alpha value chosen before the test (for this study, 0.05), the null hypothesis is rejected and the alternate hypothesis is accepted.

The Wilcoxon rank-sum test compares two datasets by comparing the sum of ranks, numbers that represent the order of sample values from least to greatest (ex. For two datasets with 10 samples each, the samples are ranked in descending order from 1 to 20). The Wilcoxon rank-sum test's use of ranks in the calculation of a p-value makes it robust to non-normal distributions of the data and/or the presence of outliers that are typically present with lead and copper concentration data from pipe rig studies.

As a result, the Wilcoxon rank-sum test generally produces fewer Type I errors when used with data not normally distributed. It has been found that the power of non-parametric tests to accurately reject the null hypothesis when it is truly false is up to 300% more likely over parametric methods when the data is skewed (not normally distributed) and/or the data contains outliers (Helsel, 2020). Fewer Type I errors, in context of this study, means that there is greater power to correctly indicate when the control or baseline in each test conducted is a better case scenario and when it is not.

Lead and copper results from the same CCT condition were aggregated across all 10 site locations for a given test piece material to represent a dataset. Results from a larger 8-month subset of the testing phase (January 2, 2023 – August 18, 2023) and the 10 sample events used for stability testing were compared using the Wilcoxon rank-sum test. For these tests, two datasets that have different CCT conditions were compared to determine if the lead or copper levels were statistically lower in one CCT condition as compared to a second CCT condition for a given test material (i.e., LSLs). The information presented in the following sections displays the results of the Wilcoxon rank-sum test by aggregated o-PO_4 dose. In addition to these tests, median values along with 25th and 75th percentiles were evaluated using box and whisker plots, which were also aggregated by o-PO_4 dose.

4.3.1 Lead Pipe

Figure 4-5 shows the total lead (Pb) levels from lead pipes, aggregated across sites by o-PO_4 dose, for the 10-sample set. The points appeared to become more precise with a lower lead concentration as the dose increased from the control to 2.0 mg/L as o-PO_4 and from 2.0 mg/L to 3.0 mg/L as o-PO_4, but not from 3.0 mg/L to 4.0 mg/L as o-PO_4. The results of the Wilcoxon rank-sum comparisons between aggregated o-PO_4 doses are displayed in Table 4-4. This table shows a similar trend to Figure 4-5, with the 3.0 mg/L and 4.0 mg/L as o-PO_4 doses improving upon the lower doses, but no statistical improvement when increasing from a 3.0 mg/L dose to a 4.0 mg/L as o-PO_4 dose. Lead results from lead pipes are further detailed in Appendix A. The same Wilcoxon rank-sum test was done on the larger dataset to capture seasonal changes from January 2, 2023 – August 18, 2023. Results from the larger dataset provided in Figure 4-6 and Table 4-5 yielded the same conclusions as outlined in the 10-sample event dataset used for stabilization testing.

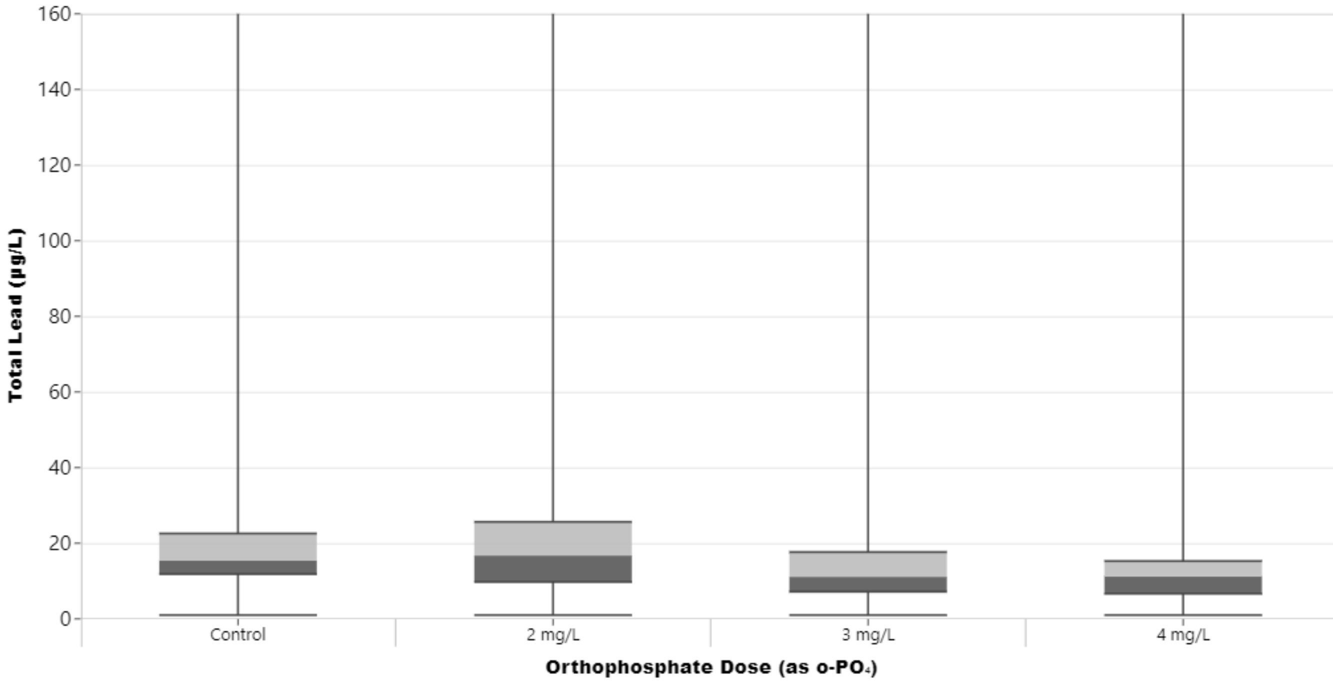


Figure 4-5: Total Lead Results for Lead Pipes Aggregated Across Sites by o-PO_4 Dose (10-Sample Stability Period)

Table 4-4: Wilcoxon Rank-sum Comparison Summary by o-PO_4 Dose for Total Lead Levels from Lead Test Pieces (10-Sample Stability Period)

Dose Comparison[1] (mg/L as o-PO_4)	Did the higher o-PO_4 dose result in statistically lower total lead levels?
Control vs 2.0	No
Control vs 3.0	Yes
Control vs. 4.0	Yes
2.0 vs 3.0	Yes
2.0 vs 4.0	Yes
3.0 vs 4.0	No

[1] "Control" indicates finished water as received, with a median level of 1.31 mg/L as o-PO_4 across all control rigs during the statistical analysis period.

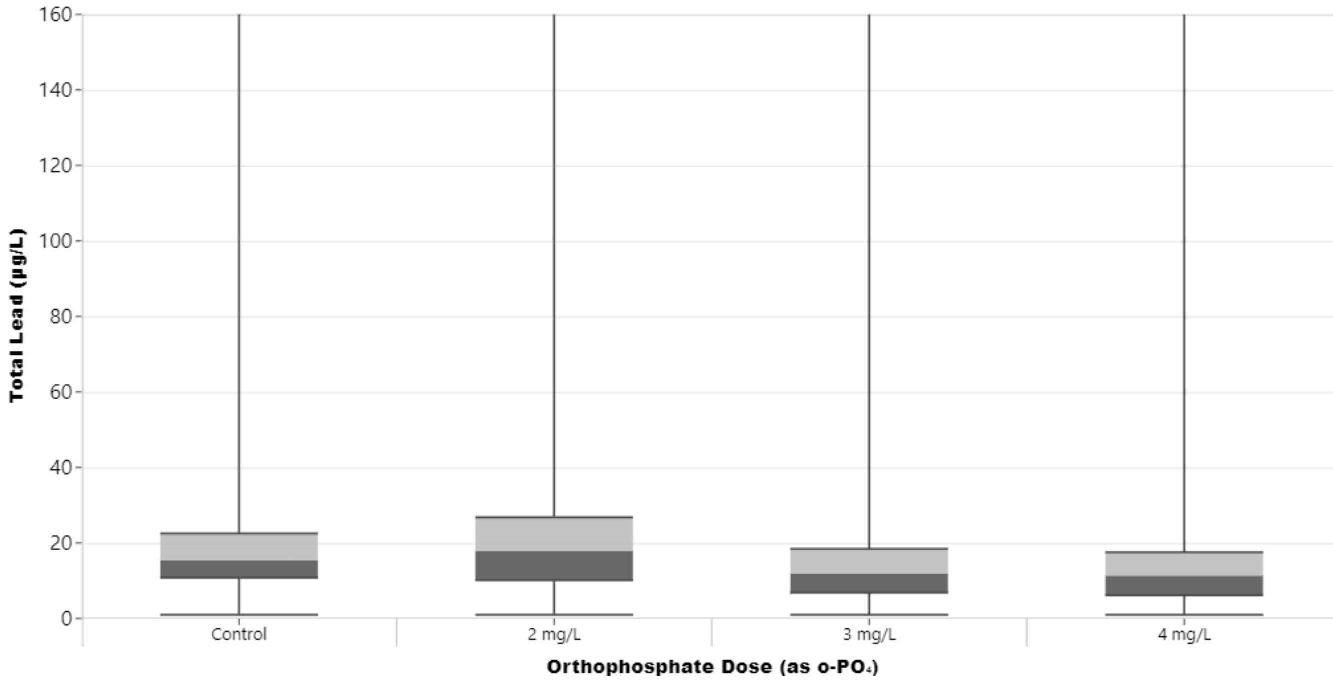


Figure 4-6: Total Lead Results for Lead Pipes Aggregated Across Sites by o-PO_4 Dose (January 2, 2023 - August 18, 2023)

Table 4-5: Wilcoxon Rank-sum Comparison Summary by o-PO_4 Dose for Total Lead Levels from Lead Test Pieces (January 2, 2023 - August 18, 2023)

Dose Comparison[1] (mg/L as o-PO_4)	Did the higher o-PO_4 dose result in statistically lower total lead levels?
Control vs 2.0	No
Control vs 3.0	Yes
Control vs. 4.0	Yes
2.0 vs 3.0	Yes
2.0 vs 4.0	Yes
3.0 vs 4.0	No

[1] "Control" indicates finished water as received, with a median level of 1.35 mg/L as o-PO_4 across all control rigs during the statistical analysis period.

Dissolved lead results from lead pipes, aggregated across sites by o-PO_4 dose from March 27, 2023, to July 28, 2023, are shown in Figure 4-7. The date range for the 10-sample statistical analysis was longer than that for total lead analysis due to lower frequency of dissolved lead sampling. Dissolved lead results from lead pipes are detailed in Appendix A.

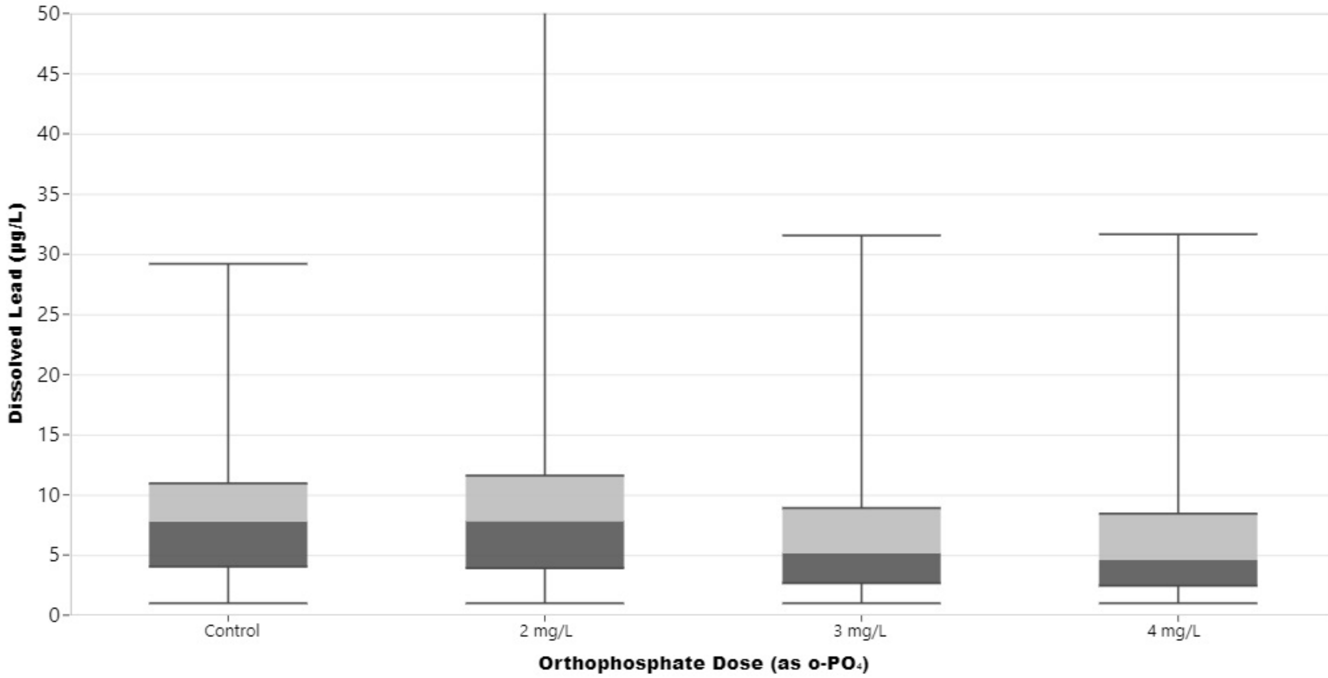


Figure 4-7: Dissolved Lead Results for Lead Pipes Aggregated Across Sites by o-PO_4 Dose (10-Sample Stability Period)

4.3.2 Galvanized Iron Pipe

Figure 4-9 shows the total lead levels from galvanized pipes, aggregated across sites by o-PO_4 dose, for the 10-sample set. Total lead levels from the galvanized pipes were typically at or below the detection limit of 1 µg/L. The results of the Wilcoxon rank-sum comparisons between aggregated o-PO_4 doses are displayed in Table 4-6. Lead results from galvanized pipes are detailed in Appendix A.

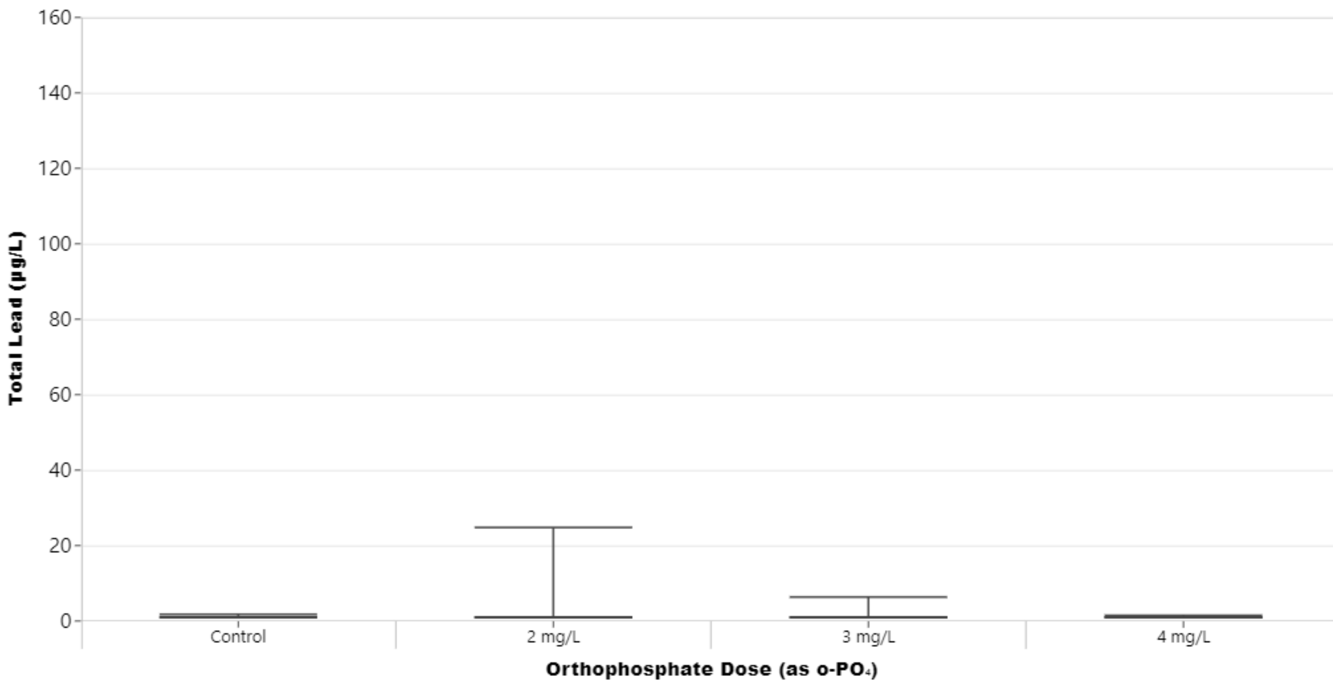


Figure 4-8: Total Lead Results for Galvanized Pipes Aggregated Across Sites by o-PO_4 Dose (10-Sample Stability Period)

Table 4-6: Wilcoxon Rank-sum Comparison Summary by o-PO_4 Dose for Total Lead Levels from Galvanized Test Pieces (10-Sample Stability Period)

Dose Comparison[1] (mg/L as o-PO_4)	Did the higher o-PO_4 dose result in statistically lower total lead levels?
Control vs 2.0	No
Control vs 3.0	No
Control vs. 4.0	No
2.0 vs 3.0	No
2.0 vs 4.0	No
3.0 vs 4.0	No

[1] "Control" indicates finished water as received, with a median level of 1.31 mg/L as o-PO_4 across all control rigs during the statistical analysis period.

4.3.3 Brass Pipe

Figure 4-10 shows the total lead levels from new brass pipes (6 – 8% lead by weight, corresponding to brass manufactured pre-2014 Reduction of Lead in Drinking Water Act), aggregated across sites by o-PO_4 dose for the 10-sample set. The results of the Wilcoxon rank-sum comparisons between aggregated o-PO_4 doses are displayed in Table 4-7. Lead and copper results from brass pipes are detailed in Appendix A.

Throughout the study, brass pipes generally had lower chlorine residuals in stagnant samples as compared to lead or galvanized pipes.

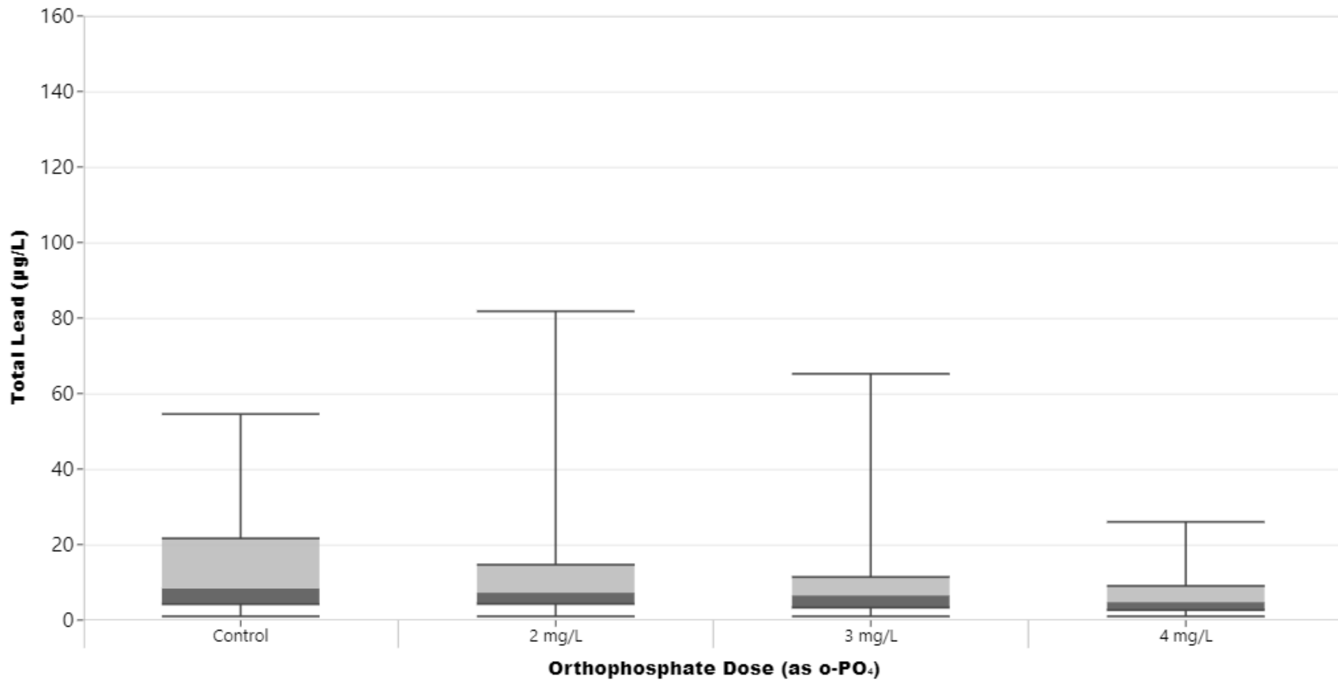


Figure 4-9: Total Lead Results for Brass Pipes Aggregated Across Sites by o-PO_4 Dose (10-Sample Stability Period)

Table 4-7: Wilcoxon Rank-sum Comparison Summary by o-PO_4 Dose for Total Lead Levels from Brass Test Pieces (10-Sample Stability Period)

Dose Comparison[1] (mg/L as o-PO_4)	Did the higher o-PO_4 dose result in statistically lower total lead levels?
Control vs 2.0	Yes
Control vs 3.0	Yes
Control vs. 4.0	Yes
2.0 vs 3.0	Yes
2.0 vs 4.0	Yes
3.0 vs 4.0	Yes

[1] "Control" indicates finished water as received, with a median level of 1.31 mg/L as o-PO_4 across all control rigs during the statistical analysis period.

4.3.4 Copper Pipe with Leaded Solder

Figure 4-10 shows the total lead levels from copper pipes with leaded solder, aggregated across sites by o-PO_4 dose, for the 10-sample set. The results of the Wilcoxon rank-sum comparisons between aggregated o-PO_4 doses are displayed in Table 4-8. Lead and copper results from copper pipes with leaded solder are detailed in Appendix A.

As mentioned in Section 3.2.2.1, galvanic corrosion occurs on an unpredictable time frame. At some point after installation, copper-lead solder pipes form protective coating, and galvanic corrosion gives way to solubility control as the major source of lead release in the pipe. Given GLWA water quality and the long history of dosing o-PO_4, lead release from copper pipes with leaded solder in the distribution system is likely solubility-controlled, not galvanically controlled. In this study, median total lead levels in the range of 3 – 5 µg/L indicated that copper-lead solder pipes on the rigs were already solubility-controlled by the end of the testing phase on September 1, 2023.

Throughout the study, copper-lead solder test pieces consistently had low chlorine residuals when stagnant samples were analyzed.

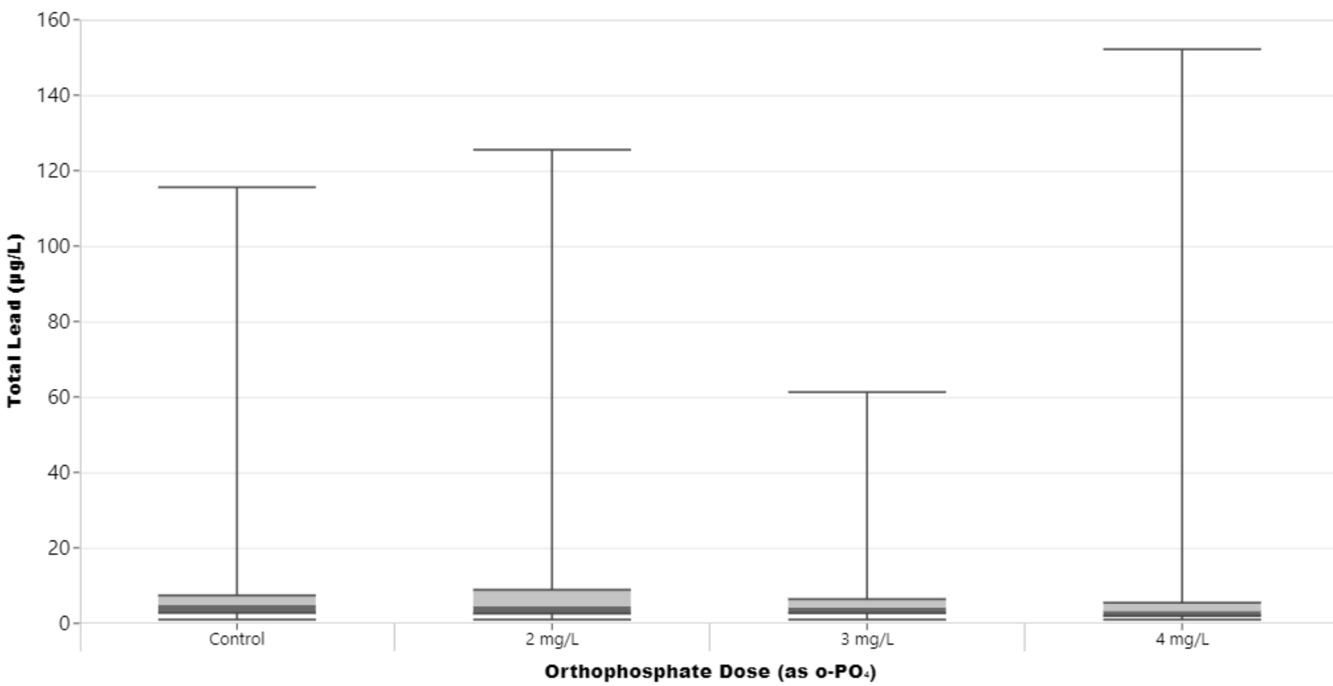


Figure 4-10: Total Lead Results for Copper Pipes with Leaded Solder Aggregated Across Sites by o-PO_4 Dose (10-Sample Stability Period)

Table 4-8: Wilcoxon Rank-sum Comparison Summary by o-PO_4 Dose for Total Lead Levels from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Dose Comparison[1] (mg/L as o-PO_4)	Did the higher o-PO_4 dose result in statistically lower total lead levels?
Control vs 2.0	No
Control vs 3.0	Yes

Dose Comparison[1] (mg/L as o-PO_4)	Did the higher o-PO_4 dose result in statistically lower total lead levels?
Control vs. 4.0	Yes
2.0 vs 3.0	No
2.0 vs 4.0	Yes
3.0 vs 4.0	Yes
[1] "Control" indicates finished water as received, with a median level of 1.31 mg/L as o-PO_4 across all control rigs during the statistical analysis period.	

4.3.5 Copper Pipe

Figure 4-11 shows the total copper levels from copper pipes, aggregated across sites by o-PO_4 dose for the 10-sample set. The results of the Wilcoxon rank-sum comparisons between aggregated o-PO_4 doses are displayed in Table 4-9. Copper results from copper pipes are detailed in Appendix A.

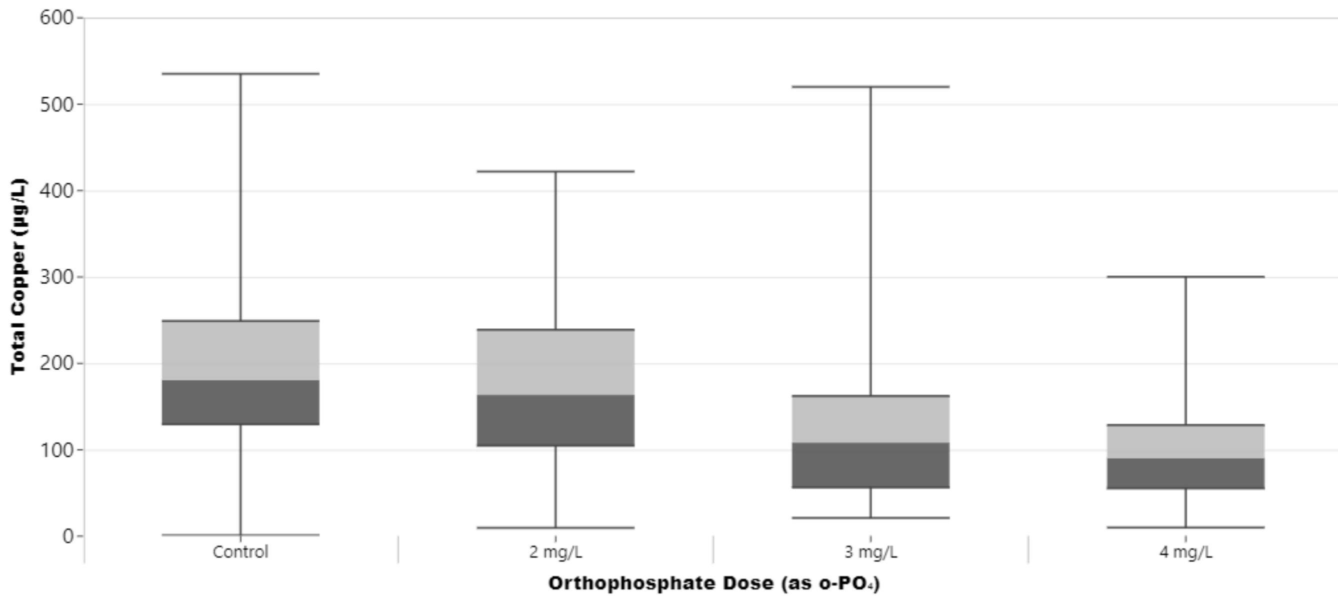


Figure 4-11: Total Copper Results for Copper Pipes Aggregated Across Sites by o-PO_4 Dose (10-Sample Stability Period)

Table 4-9: Wilcoxon Rank-sum Comparison Summary by o-PO_4 Dose for Total Copper Levels from Copper Test Pieces (10-Sample Stability Period)

Dose Comparison[1] (mg/L as o-PO_4)	Did the higher o-PO_4 dose result in statistically lower copper levels?
Control vs 2.0	No
Control vs 3.0	Yes
Control vs. 4.0	Yes
2.0 vs 3.0	Yes

Dose Comparison[1] (mg/L as o-PO_4)	Did the higher o-PO_4 dose result in statistically lower copper levels?
2.0 vs 4.0	Yes
3.0 vs 4.0	No

[1] "Control" indicates finished water as received, measured as 1.31 mg/L as o-PO_4 across all control rigs during the statistical analysis period.

The copper pipes were likely still passivating and will continue to do so for some time. Throughout the study, they consistently displayed low chlorine residuals when stagnant samples were analyzed, indicating ongoing chlorine demand.

4.4 Conclusions

The following conclusions were made based on analysis of total and dissolved lead results from lead test pieces from both the 10-sample set and the 8-month period.

- Based on a review of all data, lead release from lead test pieces generally showed trendlines that were neither increasing nor decreasing.
- Data do not show a significant improvement between the control and 2.0 mg/L as o-PO_4 conditions.
- Data do show a significant improvement between the 2.0 mg/L and 3.0 mg/L as o-PO_4 conditions.
- Data do not show a significant improvement between the 3.0 mg/L and 4.0 mg/L as o-PO_4 conditions.
- Impacts of low pH were more evident when the dose was 2.0 mg/L as o-PO_4 and less evident when the dose was greater than or equal to 3.0 mg/L as o-PO_4.
- Dissolved lead release from lead test pieces showed the best performance at a dose of 4.0 mg/L as o-PO_4. This agrees with theoretical solubility curves, but at diminishing returns.

The following conclusions were made based on analysis of total lead and total copper results from all other materials of test pieces for the 10-sample set.

- Galvanized test pieces showed no statistical difference between o-PO_4 doses due to low total lead levels.
- Newly manufactured materials showed better performance in terms of both lead and copper release at higher o-PO_4 doses. Total lead and copper release was generally higher from new materials.
- Newly manufactured materials showed no negative impacts of low pH on either total lead or copper release.
- Copper concentrations were not the driving recommendation of this study as low copper levels have been observed throughout the system and during this study.

5 Biostability Testing

To assess impacts on biostability from changes in CCT, adenosine triphosphate (ATP) was measured in both bulk water and biofilm samples collected from polyvinyl chloride (PVC) pipe installed on the test rigs at two sites: Water Works Park WTP (WW) and its corresponding distribution location, Central Services Facility (CS). These sites were selected for the following reasons:

- WW uses ozone treatment, which can increase the amount of carbon available for biological activity, and GLWA biological research initiatives were already occurring onsite.
- WW maintains a high chlorine residual, whereas CS historically maintains a low chlorine residual as a result of high water age due oversized internal facility plumbing and low water usage throughout the facility.

Biostability analyses were performed on rigs representing two test conditions: the control rigs at WW and CS which received finished treated plant water, and the 4.0 mg/L as o-PO_4 test condition at CS. Only the control rig was tested for water sampling at WW as a dose of 4.0 mg/L as o-PO_4 was not evaluated at WW. The methods used for biostability testing were the LuminUltra Quench Gone Aqueous (QGA) for water sampling and the LuminUltra Deposit and Surface Analysis (DSA) for biofilm sampling.

DSA sampling was performed on a 2-inch PVC nipple installed onto the existing PVC pipe of the rig. Biofilm sampling was only conducted at CS due to the site representing the worst-case scenario for chlorine residual and water use. Two nipples each were installed on both the control rig and the 4.0 mg/L as o-PO_4 test condition at CS for sampling. After installation of new test pieces, they were allowed to establish biological growth for four weeks before being tested.

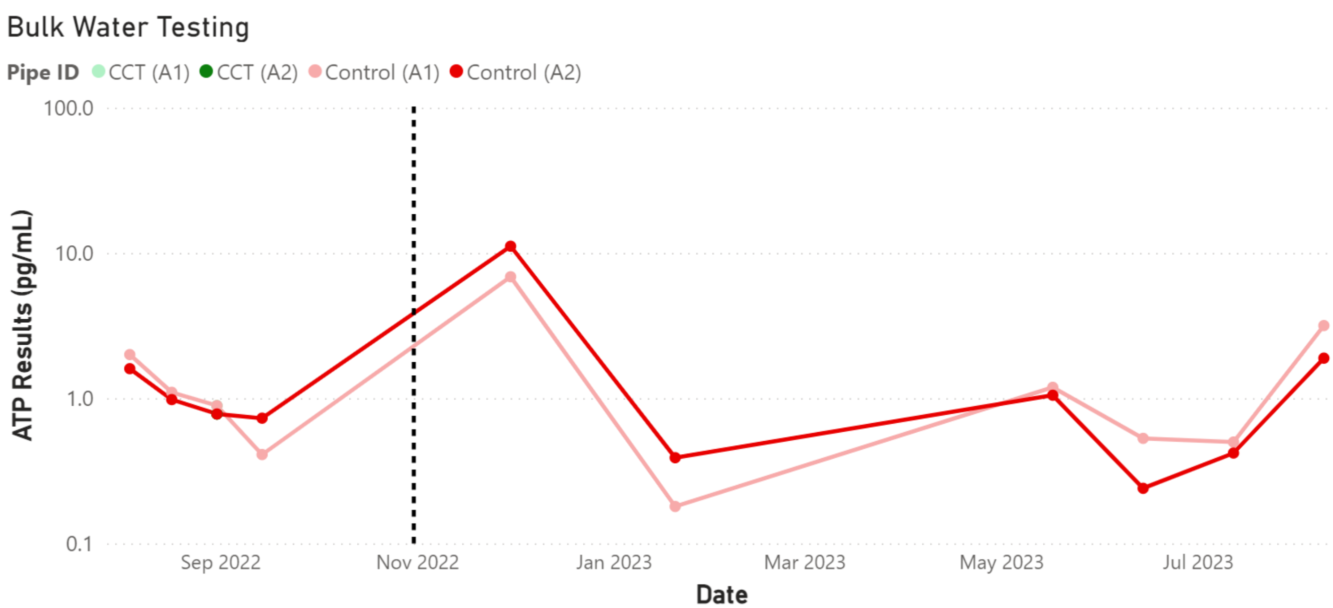
During the conditioning phase, four water sampling events were conducted to determine the baseline data. Results for water sampling were consistent across all events and are shown in Figure 5-1 and Figure 5-2.

Two biofilm sampling events were conducted during the conditioning phase to gather baseline data. The test pieces were installed 2 weeks before the first sample event and 4 weeks before the second sample event to allow the biofilm time to establish and evaluate growth rate. Results for biofilm sampling were consistent across all events with one outlier and are shown in Figure 5-3.

During the testing phase, six biofilm sampling events were conducted at each location. Two events were conducted in the winter months, two in the spring months, and two in the summer months, to capture any seasonal effects of water quality parameters including chlorine, pH, and temperature. WQPs, including o-PO_4, free chlorine, pH, and temperature, were measured in flowing water samples collected from the PVC pipe being tested.

5.1 Water Sampling

Results at WW ranged from 0.41 picograms per milliliter (pg/mL) ATP to 2.0 pg/mL ATP during the conditioning phase and 0.18 pg/mL ATP to 11.15 pg/mL ATP during the testing phase. The results had a mean value of 2.3 pg/mL ATP and a median value of 0.79 pg/mL ATP for the six events. ATP water results for WW are shown in Figure 51 and Table 5-1. The pipe IDs “Control (A1)” and “Control (A2)” refer to duplicate aliquot bulk water samples collected from a PVC pipe on the control rig at Water Works Park WTP. The first event in November and the sixth event in August had similar results when compared to the other four events. There was no clear impact of temperature on ATP levels despite the higher water temperature in July (23.7°C) compared to November (9.5°C).



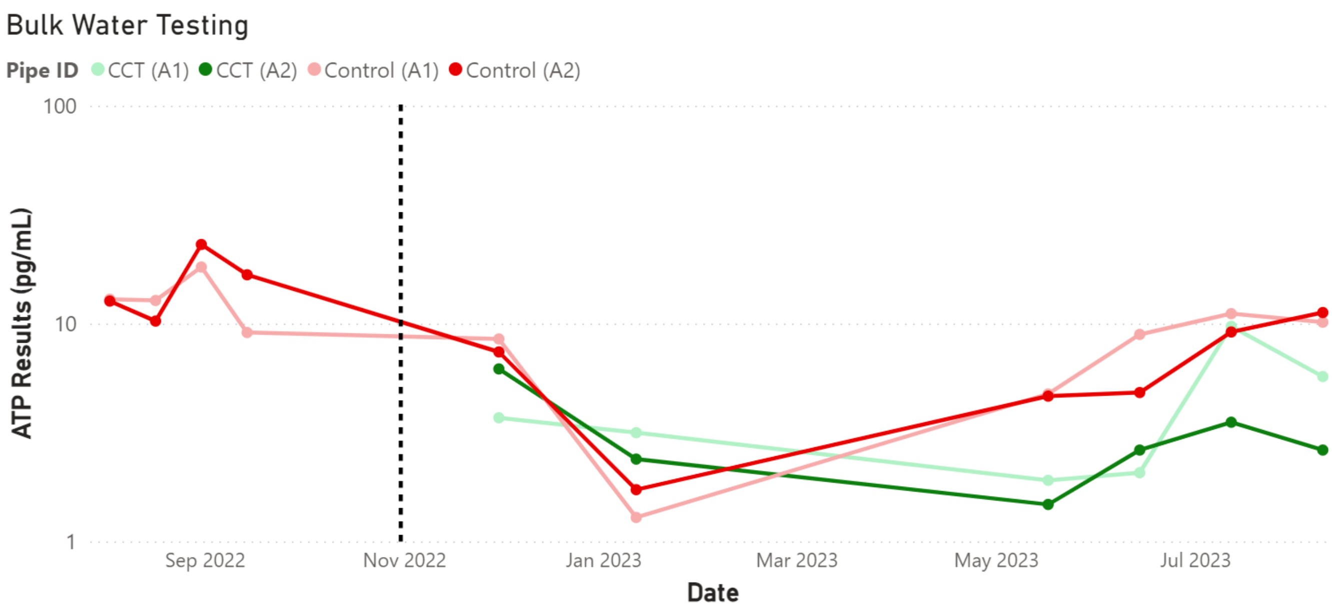
The transition between the conditioning phase and the testing phase is denoted by a vertical dashed black line.

Figure 5-1: WW Conditioning and Testing Phase Water Sampling Results for ATP – Control Condition

Table 5-1: WW Conditioning and Testing Phase Water Sampling Results for ATP – Control Condition

Study Phase	Testing Location	o-PO_4 Dose (mg/L)	Number of Sampling Events	ATP Results (pg/mL) from Bulk Water Testing			
				Minimum	Maximum	Mean	Median
Conditioning	Water Works Park WTP	As received	4	0.41	2.00	1.06	0.94
Testing	Water Works Park WTP	As received	6	0.18	11.15	2.30	0.79

Central Services Facility had consistent ATP water sampling results throughout the testing phase. The control condition results ranged from 9.11 pg/mL ATP to 23.1 pg/mL ATP during the conditioning phase and 1.29 pg/mL ATP to 11.3 pg/mL ATP during the testing phase. The control condition results had a mean value of 6.96 pg/mL ATP and a median value of 7.97 pg/mL ATP. The 4.0 mg/L as o-PO_4 test condition results ranged from 1.48 pg/mL ATP to 9.72 pg/mL ATP during the test phase. These results had a mean value of 3.76 pg/mL and a median value of 2.90 pg/mL ATP. During the summer months, CS experienced a low free chlorine residual of 0.13 mg/L for the control condition and 0.18 mg/L for the 4.0 mg/L as o-PO_4 test condition. The corresponding ATP results were higher during the summer months as compared to the winter month results for the control condition and partially for the 4.0 mg/L as $o\text{-}PO_4$ condition. Water ATP results for CS are shown in Figure 5-2 and Table 5-2. The pipe IDs “Control (A1)” and “Control (A2)” refer to duplicate bulk water samples collected from a PVC pipe on the control rig at Central Services Facility, while “CCT (A1)” and “CCT (A2)” refer to the duplicate samples from a PVC pipe that received a CCT test condition of 4.0 mg/L as $o\text{-}PO_4$.



The transition between the conditioning phase and the testing phase is denoted by a vertical dashed black line.

Figure 5-2: CS Conditioning and Testing Phase Water Sampling Results for ATP

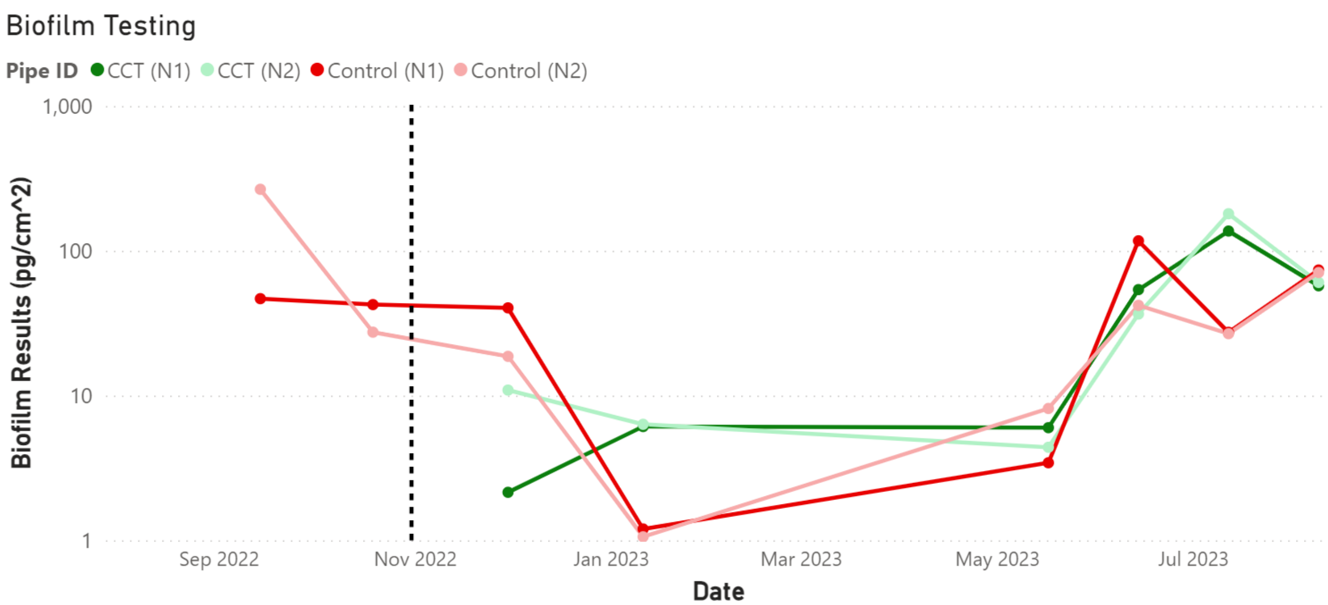
Table 5-2: CS Conditioning and Testing Phase Water Sampling Results for ATP

Study Phase	Testing Location	$o\text{-}PO_4$ Dose (mg/L)	Number of Sampling Events	ATP Results (pg/mL) from Bulk Water Testing			
				Minimum	Maximum	Mean	Median
Conditioning	Central Services Facility	As received	4	9.11	23.10	14.49	12.87
Testing	Central Services Facility	As received	6	1.29	11.30	6.96	7.97
Testing	Central Services Facility	4.0	6	1.48	9.72	3.76	2.90

5.2 Biofilm Sampling

The PVC test pieces were not sterile when installed; however, a preliminary test before installation was performed on two of the test pieces to establish baseline conditions. The ATP results of these analyses were 0.59 picograms per square centimeter (pg/cm^2) and 0.52 pg/cm^2, confirming that pre-sterilization of test pieces was not needed.

Results of the biofilm sampling are shown in Figure 5-3. The control condition had a mean biofilm value of 35.9 pg/cm^2 ATP and a median value of 27.1 pg/cm^2 ATP. The 4.0 mg/L as o-PO_4 condition had a mean value of 46.9 pg/cm^2 ATP and a median value of 23.8 pg/cm^2 ATP. Biofilm results during the winter and early spring months were low and consistent. Higher values were measured during the late spring and summer months for both conditions, with an ATP spike in July for the 4.0 mg/L as o-PO_4 condition. Visually, there was no difference in ATP when comparing control results to 4.0 mg/L as o-PO_4 condition results. In addition to lower temperatures, free chlorine levels during the winter and early spring sampling events were higher for both conditions when compared to free chlorine in the late spring and summer events. The pipe IDs “Control (N1)” and “Control (N2)” refer to duplicate samples collected from a PVC pipe on the control rig at Central Services Facility, while “CCT (N1)” and “CCT (N2)” refer to the duplicate samples from a PVC pipe that received a CCT test condition of 4.0 mg/L as o-PO_4.



The transition between the conditioning phase and the testing phase is denoted by a vertical dashed black line.

Figure 5-3: CS Conditioning and Testing Phase Biofilm Results

5.3 Conclusions

In conclusion, increasing the o-PO_4 concentration to 4.0 mg/L as o-PO_4 did not appear to affect the biostability of the pipe rig system. Microbial growth was impacted to a higher degree by chlorine residual for water samples and by chlorine residual and temperature for biofilm samples.

6 Conclusions and Recommendations

This section summarizes key findings from the pipe rig study and presents other factors considered when determining CCT recommendations and how to implement those recommendations throughout GLWA member partners' distribution systems.

6.1 Summary of Pipe Rig Study Findings

A flow-through pipe rig study was performed to evaluate the effects from different CCT conditions on metals release from various service line and household plumbing materials. The study specifically evaluated the impacts of higher o-PO_4 doses and lower pH on total lead and/or total copper release from harvested LSLs, harvested galvanized service lines previously connected to lead, new manufactured leaded brass with a pre-2014 formulation, new manufactured copper with leaded solder, and new copper pipe. Key findings are presented below.

6.1.1 Lead Release

Consistent with USEPA and EGLE regulatory priorities, lead concentrations from harvested LSLs were the primary driver of this study. For the 10-sample statistical analysis period, the following conclusions were made regarding the impact of o-PO_4 dosages on total lead release from LSLs:

- Data did not show a statistically significant reduction in total lead concentrations between the current (control) condition and the 2.0 mg/L as o-PO_4 condition.
- Data did show a statistically significant reduction in total lead concentrations between the 2.0 mg/L as o-PO_4 and 3.0 mg/L as o-PO_4 conditions.
- Data did not show a statistically significant reduction in total lead concentrations between the 3.0 mg/L as o-PO_4 and 4.0 mg/L as o-PO_4 conditions.
- The median total lead level of the control rig (1.31 mg/L as o-PO_4) across all sites was 15.4 µg/L. A dose of 2.0 mg/L as o-PO_4 had a median of 16.7 µg/L, and a dose of 3.0 mg/L as o-PO_4 had a median of 11.1 µg/L. However, a dose of 4.0 mg/L as o-PO_4 had a median of 11.3 µg/L, showing marginal returns beyond a dose of 3.0 mg/L as o-PO_4. Based on the results of the Wilcoxon rank-sum analysis of lead pipes for both the 10-sample event statistical analysis period and a larger 8-month sample event analysis period, the greatest improvement in performance was observed when comparing the current o-PO_4 dose to a dose of 3.0 mg/L as o-PO_4. As such, a 3.0 mg/L as o-PO_4 was determined to be the optimal tested dose to limit the release of lead from LSLs.

The impacts of o-PO_4 dosages on total lead release from other materials are summarized below:

- Harvested galvanized pipes frequently displayed total lead levels below the detection limit (1 µg/L) throughout the course of the study. As a result, there was no statistically significant reduction in lead release at the higher o-PO_4 doses. These samples indicate that the galvanized pipes downstream of lead within the distribution system are not a major source of lead release for the GLWA system.
- New brass pipes manufactured with the typical lead content before the 2014 Reduction of Lead in Drinking Water Act displayed an overall decrease in total lead levels with increasing o-PO_4 doses. Increasing the dose from the current dose to either 2.0 mg/L, 3.0 mg/L, or 4.0 mg/L as o-PO_4 showed a statistically significant

reduction of total lead levels. When compared to the 3.0 mg/L as o-PO_4 dose, the 4.0 mg/L as o-PO_4 dose showed statistically significant reduction of total lead levels.

- New copper pipes with leaded solder displayed an overall decrease in total lead levels with increasing o-PO_4 doses. The largest improvements were seen when increasing the current o-PO_4 dose to either 3.0 mg/L as o-PO_4 or 4.0 mg/L as o-PO_4. When compared to the 3.0 mg/L as o-PO_4 dose, the 4.0 mg/L as o-PO_4 dose showed a statistically significant reduction of total lead levels.

6.1.2 Copper Release

Copper levels from brass, copper-lead solder, and copper pipes were well below the action level (AL) of 1.3 mg/L (1300 µg/L) throughout the course of the study and below 0.8 mg/L (800 µg/L) during the testing phase. The median copper levels during the 10-sample statistical analysis period were 136 µg/L from copper pipes, 31 µg/L for brass pipes, and 53 µg/L for copper pipes with leaded solder, respectively, across rigs. Copper concentrations from these pipes were likely still stabilizing at the conclusion of the study, but their low copper levels and continuing downward trend suggested that copper would not cause a public health or regulatory compliance concern. These pipes were all new materials installed at the onset of the test, and therefore the copper results from these materials were expected to be more conservative than what would actually be seen in the system at compliance monitoring locations where the pipes have already formed a passivating scale layer. It should also be noted that no copper AL exceedances have occurred in the GLWA system since the LCR was established. For these reasons, copper was less critical than lead when determining CCT recommendations.

6.1.3 pH Impacts

When testing pipes at the lowest acceptable pH of 7.0 for the system, the study showed that o-PO_4 generally performed similarly to as-received pH (median of 7.35 across all site locations) at the 3.0 mg/L or 4.0 mg/L as o-PO_4 doses tested. The lower pH of 7.0 resulted in statistically significant increases of lead and copper for the median control dose of 1.38 mg/L as o-PO_4 and the 2.0 mg/L as o-PO_4 dose.

6.2 Implementation Considerations

Beyond statistical analysis of lead and copper results, other factors were considered when determining the CCT recommendations. Factors included regulatory considerations, chemical product and system (storage and feed) capacity, increased phosphorus loading to wastewater treatment plants (WWTPs), secondary impacts of raising the o-PO_4 dose, and cost and schedule considerations with respect to operations & maintenance (O&M) as well as capital improvements.

6.2.1 Regulatory Considerations

EGLE established the Michigan LCR requirements in 2019 to further reduce lead in drinking water, identify and eliminate lead sources, and educate the public. The Michigan LCR expands the definition of a LSL to include any service line that contains a lead pigtail, lead gooseneck, or any lead fitting. Under the Michigan LCR, the lead AL lowers from 15 to 12 µg/L beginning in 2025 and requires LSL replacement at a rate of 5% per year for LSLs and GRR. All identified LSLs and GRR must be replaced within 20 years, unless as part of an alternative schedule under an EGLE approved asset management program.

In 2021, the USEPA finalized the Lead and Copper Rule Revisions (LCRR) with broad implications related to compliance sampling, service line inventorying, replacement, public outreach and CCT, among other issues related to lead and copper. A review of the draft regulation was presented in the *Comprehensive Corrosion Control Optimization Regulatory Review Technical Memorandum* (September 2020).

In November 2023, the USEPA proposed the Lead and Copper Rule Improvements (LCRI) to further strengthen the LCRR. USEPA has indicated that while corrosion control can be effective at reducing lead exposure, removing lead pipes provides even greater public health protection by eliminating the key source of lead. This rule, if finalized as written, would require water systems to replace all LSLs and GRR within 10 years of the compliance date (estimated to occur in 2037). The LCRI also proposed lowering the lead AL from 15 µg/L to 10 µg/L while eliminating the 10 µg/L lead trigger level introduced by the LCRR. Water systems that exceed the AL would need to inform the public and take action to install or re-optimize CCT or defer to removing 100 percent of lead and GRR service lines at a minimum rate of 20 percent per year within five years of being triggered into CCT steps. The proposed LCRI does not directly address installation or re-optimization of CCT by wholesale systems such as GLWA and consecutive systems such as GLWA's member communities. State primacy agencies have taken different approaches under the existing LCR, and it is likely that this would continue under the proposed LCRI. In many cases, if an AL exceedance (or future AL exceedance) is not a system-wide problem, individual member communities would likely be required to take action to accelerate lead service line replacement (LSLR) or optimize/re-optimize CCT as long as GLWA is meeting point-of-entry optimal water quality parameters (OWQPs). Wholesale system responsibilities may be delineated in contracts or agreements between wholesale and consecutive systems, and individual cases may be evaluated at EGLE's discretion. Some systems with existing CCT may not be able to attain 90^{th} percentile total lead levels below 10 µg/L, which USEPA has addressed by allowing deferment to 100 percent removal of LSLs and GRRs within 5 years. The proposed LCRI is also adapting tap sampling best practices that came from states like Michigan that would require water systems to collect first- and fifth-liter samples at sites with LSLs and use the higher of the two values to determine compliance. The USEPA has stated an intent to finalize the LCRI prior to the LCRR compliance date of October 16, 2024.

With the recent publication of the draft LCRI, LSLs may be removed from GLWA's service area by 2037. Given the state and direction of the regulatory environment around lead, focus should be directed toward removing the sources of lead while improving CCT in the finished water.

6.2.2 Chemical Product

Results from the pipe rig study showed that a pH of 7.0 resulted in higher total lead levels from LSLs than a pH of 7.38 (the median as received pH from all locations over the statistical analysis period) at o-PO_4 doses of 2.0 mg/L as o-PO_4 or lower. At o-PO_4 doses of 3.0 or 4.0 mg/L, the effects of lower pH appeared to be mitigated. No negative impacts on either total lead or copper release from newly manufactured materials were observed at the lower pH of 7.0.

Following the testing phase, additional pilot testing was completed at Springwells and Lake Huron WTPs to assess pH impacts of an increased dose of phosphoric acid, GLWA's current corrosion control inhibitor. Rigs at both locations that previously received monosodium orthophosphate (MSP) at a 3.0 mg/L as o-PO_4 dose were fed a phosphoric acid dilution to achieve a target dose of 3.0 mg/L as o-PO_4. Results showed a dose of 3.0 mg/L as o-PO_4 using phosphoric acid corresponded to a decrease in pH of approximately 0.05 s.u. Based on these results and the assessment of pH discussed in Section 6.1.3, continued use of phosphoric acid is recommended at all plants in conjunction with ongoing WQP review.

EGLE has established a requirement for all member partners to maintain a distribution system pH of 7.0 or higher with no more than nine days below 7.0 in a given monitoring period. Since the establishment of this requirement in 2022, one excursion has occurred throughout the GLWA distribution system due to reporting delays. Although pilot testing described above did not predict that a dose of 3.0 mg/L as o-PO_4 would cause a significant pH decrease, conditions in the distribution system can vary. If pH is regularly below 7.0 with targeted flushing efforts across the distribution system, it is recommended that GLWA evaluate a transition to MSP to avoid further depressing the pH (note this may be needed at select plants only). According to the chemical manufacturer, material compatibility for MSP and phosphoric acid are nearly the same, although phosphoric acid is more corrosive than MSP. Both phosphoric acid and MSP have compatible piping materials that include Schedule 80 PVC, polyethylene tubing, and clear vinyl tubing, and have compatible storage tank materials that include high-density polyethylene (HDPE) and glass-lined/epoxy-lined steel tanks. Phosphoric acid has a typical pH less than 2.5 s.u., and MSP has a pH between 4.3 – 4.8 s.u. according to information provided from the manufacturers. Due to the difference in solution strength, the volume required to store MSP would be approximately double that required for phosphoric acid. There are no compatibility concerns with using MSP but impacts on cost and conceptual design to accommodate storage capacities would be anticipated.

If pH becomes a concern in the future, GLWA could consider adding pH adjustment such as caustic to the finished water to boost the pH leaving all or select WTPs.

6.2.3 Chemical System Capacity

An evaluation of the existing chemical storage and feed system capacities at all five GLWA WTPs was performed to assess the feasibility of higher o-PO_4 doses from both a storage and feed perspective. Plant finished water flows from December 1, 2022 – November 29, 2023 were analyzed to determine the maximum dose that can reliably be consistently achieved using existing chemical systems at each plant. This evaluation is presented in Table 6-1. Based on chemical supplier availability, this analysis assumed a 30-day chemical storage supply using the existing tanks and average flows as calculated from the data set, all five WTPs could reliably sustain a phosphoric feed sufficient for a consistent target dose of 2.4 mg/L as o-PO_4. Note that these calculated values do not include a safety factor and may not be achievable during sustained high flow conditions.

Table 6-1: Maximum Achievable o-PO_4 Dose per WTP for Average and Maximum Plant Flows

GLWA WTP	Average Flow (MGD)[1,2]	Maximum Flow (MGD)[1,2]	Max Achievable Dose as o-PO_4 (mg/L)[3]	
			During Average Flow[1]	During Maximum Plant Flow[1]
Lake Huron WTP	120	150	2.4	1.9
Springwells WTP	120	265	2.6	1.2
Water Works Park WTP	60	90	5.2	3.5
Southwest WTP	50	70	5.7	4.0

GLWA WTP	Average Flow (MGD)[1,2]	Maximum Flow (MGD)[1,2]	Max Achievable Dose as o-PO_4 (mg/L)[3]	
			During Average Flow[1]	During Maximum Plant Flow[1]
Northeast WTP	85	195	3.3	1.5

A desktop analysis was performed to understand the impacts chemical availability, storage, and delivery frequencies for the average flow maximum achievable dose of 2.4 mg/L as o-PO_4 and for 3.0 mg/L as o-PO_4 under average flow conditions as outlined in Table 6-2. It was determined that all plants have sufficient metering capability to feed a dose of 3.0 mg/L as o-PO_4; however, chemical storage was limited at some plants. To further evaluate operational feasibility, the flow data was analyzed to identify the maximum rolling 30-day flow for each water treatment plant. This "max month" represents a worst-case scenario at each plant, and the potential increase in chemical deliveries needed to achieve a dose of 2.4 mg/L as o-PO_4 and 3.0 mg/L as o-PO_4 is provided in Table 6-3. Note that calculations do not include a safety factor. Furthermore, the chemical metering pumps at all plants are capable of feeding a dose of 3.0 mg/L as o-PO_4 at maximum day flows.

Table 6-2: Chemical Storage Supply for 2.4 mg/L as o-PO_4 and 3.0 mg/L as o-PO_4 at Average Flow per WTP

GLWA WTP	Average Flow (MGD) [1]	Dose as o-PO_4	Supply (Days)	Dose as o-PO_4	Supply (Days)
Lake Huron WTP	120		30		24
Springwells WTP	120		32		26
Water Works Park WTP	60	2.4 mg/L	65	3.0 mg/L	52
Southwest WTP	50		71		57
Northeast WTP	85		42		33

[1]*Based on flow data from December 1, 2022 – November 29, 2023*

Highlighted sites do not meet the 30-day storage requirement for a given flow and dose scenario.

Table 6-3: Chemical Deliveries for 2.4 mg/L as o-PO_4 and 3.0 mg/L as o-PO_4 at an Annual Max 30-day Flow Period per WTP

GLWA WTP	Average Flow over Max 30-day Period (MGD) [1]	Dose as o-PO_4	Number of Chemical Deliveries	Days until Second Delivery Required[2]	Dose as o-PO_4	Number of Chemical Deliveries	Days until Second Delivery Required[2]
LH	130	2.4 mg/L	2	28	3.0 mg/L	2	22
SP	205		2	18		2	14
WW	70		1	61		1	48
SW	55		1	68		1	54
NE	150		2	25		2	19

[1]Based on the max 30-day flow period for each plant from December 1, 2022 – November 29, 2023
[2]Assuming Day 1 begins with a new chemical delivery
Highlighted sites do not meet the 30-day storage requirement for a given flow and dose scenario.

Nominal chemical system capacity at Water Works Park WTP, Southwest WTP, and Northeast WTP has been reviewed and was determined to have adequate existing capacity to feed 3.0 mg/L as o-PO_4 at average and max month flows. Upgrades to chemical facilities at Lake Huron WTP and Springwells WTP could take several years before a dose greater than 2.4 mg/L as o-PO_4 could reliably be achieved across all five water treatment plants. While the draft LCRI requirements outlined in Section 6.2.1 highlight that LSLs and GRR service lines may need to be removed from GLWA's service area by 2037, it should be noted that capital improvements may take five (5) to 10 years to implement at all plants or could defer other planned capital improvements throughout the system. Increasing the current o-PO_4 dose using the existing chemical equipment while lead and GRR service lines are simultaneously being replaced would reduce capital costs and the ultimate burden on rate payers, while providing greater public health protection by eliminating the key source of lead as outlined by USEPA in the draft LCRI (USEPA, 2023).

6.2.4 Increased Phosphorus Loading at WWTPs

GLWA has recently experienced reduced infiltration and inflow in their collection system due to recent collection system improvements. As a result, an increase in phosphorus concentration has been observed at GLWA's Water Resource Recovery Facility (WRRF). Increasing the o-PO_4 dose for finished drinking water will impact the WRRF, requiring additional phosphorus removal at the WRRF to meet discharge limits, resulting in increased chemical loading and sludge production. Phosphorus loading to surrounding water bodies could result in increased algal blooms.

An exact mass balance detailing the current and future contributions of CCT to total and soluble phosphorus loads entering the WRRF is difficult to define due to unknown parameters including volumetric losses due to water main leakage, outdoor water use, and/or flow diverting to other non-GLWA WWTPs, as well as the introduction of volume and/or phosphorus into the collection system from inflow and infiltration and/or seasonal runoff. A basic mass balance was performed based on a GLWA-provided data set collected from the North Interceptor, East Arm

(NIEA) including total daily flow, total phosphorus concentrations, and soluble phosphorus concentrations from October 1, 2022, to December 14, 2022. This interceptor was selected as representative for the collection system with minimal inflow and infiltration, especially during this dry-weather period. Per GLWA, NIEA may be considered 29% of the total WRRF influent volume during dry spells and may be assumed to mainly consist of water from the WTPs.

The average observed dose at each WTP during the corrosion control study was weighted by flow across all plants to yield a current system-wide average dose of 1.42 mg/L as o-PO_4. This memorandum recommends an immediate increase to 2.4 mg/L as o-PO_4 at all WTPs based on maximum uniform dosing across all five WTPs. The optimal tested dose determined by this study was 3.0 mg/L as o-PO_4, which would require chemical system upgrades at three of the five WTPs. All three of these dosing scenarios were evaluated for their estimated impact on soluble phosphorus loading and associated costs of chemical phosphorus removal.

The NIEA data set was extrapolated to represent the entire WRRF influent from October 1, 2022 – December 14, 2022. As a worst-case soluble phosphorus concentration scenario, it was assumed that all WRRF influent was from WTPs. October 31 and November 27 – 30 were excluded from the data set due to much higher WRRF flows caused by precipitation. Median values for total and soluble phosphorus concentrations and total WRRF flow were identified from the NIEA data set as 4.6 mg/L as phosphorus (P), 2.5 mg/L as P, and 351 MGD, respectively. Daily soluble and total phosphorus loads and the maximum contribution of CCT to the daily soluble phosphorus load were calculated for each date.

Table 6-4 shows the results of the mass balance calculations. For each CCT dose, internal GLWA calculations based on the overall WRRF influent were combined with results from this analysis to yield a probable range for each output. Internal GLWA calculations were based on total WRRF influent, average daily phosphorus loads, and a daily WTP flow of 300 MGD. The projected daily soluble phosphorus load to the WRRF increased from 18% - 21% to 27% - 31% during the 2.4 mg/L as o-PO_4 dosing period and increased to 32% - 34% during the 3.0 mg/L as o-PO_4 dosing period.

Increased usage of ferric chloride ($FeCl_3$) to remove added soluble phosphorus was calculated using a 31% removal efficiency in addition to stoichiometry (i.e., 18.1 pounds (lbs.)) of dry $FeCl_3$ required to remove 1 lb. of soluble phosphorus). Removal efficiency was assumed to be linear with added ferric chloride for the range of phosphorus concentrations in this analysis. Efficiency would become non-linear at phosphorus concentrations approach zero. Ferric chloride costs were calculated using a price of $997 per dry ton from October 2023 and were rounded up to the nearest $500. GLWA's average daily usage of 14.2 tons from 2021 – 2022 was adjusted up from an average dose of 1.2 mg/L as o-PO_4 to an average dose of 1.42 mg/L as o-PO_4 to more accurately represent the CCT dose during the NIEA reference period. Note that it was assumed that the WRRF operated at or below its National Pollutant Discharge Elimination Systems (NPDES) discharge limits for total phosphorus from the secondary clarifier effluent (049B) during the NIEA reference period. At the time of this publication, the NPDES discharge limit for total phosphorus from the secondary clarifier effluent (049B) changes seasonally and is 0.6 mg/L as P (April – September) or 0.7 mg/L as P (October – March). If discharge limits were not met, or if GLWA would like to target a lower discharge concentration, additional ferric chloride usage may be needed.

Table 6-4: Estimated Effects of Increased o-PO_4 Dose on WRRF Soluble Phosphorus (P) Loads and Ferric Chloride Usage

CCT Dose as o-PO_4 (mg/L)	CCT Dose as P (mg/L)	Total WRRF Influent Soluble P	Total WRRF Influent Soluble P	Contribution of CCT to Total WRRF Soluble P Load	Ferric Chloride Needed for Removal	Total Cost of Ferric Chloride
		lb. as P/day	mg/L as P	%	dry tons/day	USD/day
1.42	0.49	5144 - 7164	1.8 – 2.5	18% - 21%	16.0 – 17.5	$16,000 - $17,500
2.4	0.78	5859 - 8096	2.0 – 2.8	27% - 31%	22.0 – 25.0	$22,000 - $25,000
3.0	0.98	6216 – 8664	2.1 – 3.0	32% - 34%	25.0 – 29.5	$25,000 - $29,500

In reality, volumetric losses exist in the distribution and collection systems due to water main leaks, outdoor water use, and flow diversion to other WWTPs. This mass balance represents a worst-case concentration scenario wherein there are no volumetric losses from the WTPs to the WRRF, and no inflow and infiltration to dilute phosphorus in the WRRF influent. The maximum daily soluble phosphorus load from CCT, in pounds of phosphorus, will also vary seasonally with varying WTP flows. Additionally, it was assumed that all o-PO_4 from CCT leaves the WTPs as soluble phosphorus and remains as such throughout the system until entering the WRRF.

6.2.5 Secondary Impacts

Increasing the o-PO_4 dose may lead to secondary impacts and unintended consequences at the WTPs and in the distribution system. These may include the following.

Post-Precipitation of Solids. In the distribution system, post-precipitation of solids may increase turbidity and contribute to color. Water with saturated o-PO_4 levels (above 3.0 mg/L as o-PO_4) has been observed to cause clouded, discolored water as precipitates form with iron and calcium compounds (Tesfai, 2006). Precipitation of aluminum or iron phosphates, formed from dissolved aluminum or iron in the water, can occur in water with non-saturated phosphate levels but may increase with an increased o-PO_4 dose. The severity of post-precipitation depends on the concentrations of aluminum, iron, calcium, and manganese in the system. Industrial users who manipulate temperature for internal processes may be more likely to experience post-precipitation.

Reduced Filter Performance. Water treatment plants using finished water to backwash filters may experience new or increased clogging of filters or underdrains as a result of an increased o-PO_4 dose, especially when metals such as aluminum are present in the finished water supply (AWWA, 2017).This could result in additional operational or capital costs to maintain a similar level of filtration performance, including moving the chemical application point further downstream or pulling backwash water earlier in the plant process.

Reduced pH. Increased phosphoric acid feed will result in a slight depression in pH, which could result in pH levels below 7.0 if the source water pH were already low. However, as discussed in Section 6.1.3, recent data indicate that distribution system and point of entry (POE) pH levels have remained above 7.0 s.u. In the event of low pH in the distribution system due to water age, flushing can be implemented to mitigate.

Chemical Supply Availability and Costs. Phosphorus resources have historically been limited, and demand is expected to increase as more water systems begin to use or increase current use of phosphate-based corrosion inhibitors. Prices may increase further for systems which use proprietary solutions that are often more expensive than their non-proprietary counterparts. The average cost of phosphoric acid in particular has historically increased up to 200% per year and will likely continue to increase. Chemical system resiliency may be increased through improvements such as increased storage capacity or backup contracts with different chemical suppliers.

Increased Microbial Activity. Though not observed through the ATP testing conducted as part of this study, there is still a potential for increased microbial growth following an o-PO_4 dose increase. The severity of risk depends on the configurations of both the distribution system and premise plumbing. Increased microbial growth, if observed, could result in further taste, odor, and color issues, increased chlorine demand, or microbiologically influenced corrosion (MIC). Increased microbial activity, if it occurs in the distribution system, may be mitigated by flushing, optimizing storage facilities, and managing water age.

6.2.6 Cost Considerations

Capital and additional chemical costs for increased phosphoric acid were evaluated for all five plants. Capital costs developed from Lake Huron WTP's ongoing phosphoric acid system upgrade include design options that repurpose existing space within the plant as well as the construction of a new building to house new chemical storage tanks, metering pumps, and electrical upgrades. Current estimates were based on average flows at the plant from December 2015 – June 2020 and ranged from $1.7 million to $7 million. These include engineering, construction, a 30% contingency, and are consistent with an AACE Class 4 level cost estimate in 2021 dollars. Costs were escalated to 2023 dollars considering a 12% inflation rate (U.S. Bureau of Labor Statistics, 2023) and range from $2 million to $8 million depending on the amount of construction required (Table 6-5). Water treatment plants that have been identified to have chemical storage capacity restrictions, Springwells WTP and Northeast WTP, may see capital improvement costs within this range. Additional annual chemical costs provided in Table 6-5 include a 20% contingency for chemical costs at the current rate of $10.98/gallon. Note these costs are high-level estimates only and will be refined following the completion of the conceptual design task included in this Study.

Table 6-5: Additional Annual Chemical Costs for Doses of 2.4 mg/L and 3.0 mg/L as o-PO_4

Dose[1]	LH	SP	WW	SW	NE	TOTAL
2.4 mg/L as o-PO_4	$1,240,000	$1,240,000	$620,000	$520,000	$880,000	$4,500,000
3.0 mg/L as o-PO_4	$1,490,000	$1,490,000	$740,000	$620,000	$1,050,000	$5,390,000
[1]*Based on average flow data from December 1, 2022 – November 29, 2023 and includes a 20% contingency*						

6.3 Implementation Strategy

As discussed above, the results of this study concluded that 3.0 mg/L as o-PO_4 was the optimal tested dose for controlling lead release from harvested LSLs and that this dose will provide additional benefits for controlling lead and copper release from the other materials tested. As shown in Section 6.2.3, the existing chemical system capacity is limited to a maximum uniform dose of 2.4 mg/L as o-PO_4 while maintaining a 30-day supply of chemical in accordance with the Great Lakes Upper Mississippi River Board Ten States Standards for Water Works at three of the five WTPs, which would require capital improvements to reach a dose of 3.0 mg/L as o-PO_4. Conceptual design of chemical systems (to be completed under this project) is expected to be completed by May 2024. However, detailed design, bidding, construction, and commissioning may take five (5) to 10 years to complete for all three plants, by which time most or all LSLs may have been removed from member partner's distribution systems per the new LSL and GRR replacement timeline as stated in the draft LCRI.

Over the course of the study, the median o-PO_4 value observed across all five water treatment plants was 1.38 mg/L as o-PO_4. Based on the implementation considerations discussed in Section 6.2, an immediate recommendation is to increase the phosphoric acid dose to 2.4 mg/L as o-PO_4 to the extent possible at each plant. Following this increase, potential secondary impacts as listed in Section 6.2.5 should be evaluated across the system, from the plants to the distribution system and the downstream wastewater treatment plants. In addition, LCR compliance sampling and water quality parameter monitoring results should be evaluated during each monitoring period to determine the effectiveness of the interim achievable dose. If there are no concerns identified, those water treatment plants that have capacity to increase the dose to 3.0 mg/L as o-PO_4 while maintaining a 30-day chemical supply should do so. It should be noted that this immediate recommended dose of 2.4 mg/L as o-PO_4 does not include safety factors accounting for chemical delivery delays.

Finally, LSLs will continue to be removed from member partner systems during this period which is expected to further reduce lead levels throughout the GLWA service area. This aligns with USEPA's focus on LSLR, specifically "while corrosion control is generally effective at reducing lead to low levels, elimination of LSLs can result in even greater public health protection by eliminating a lead exposure source and minimizes the opportunities for error that have often occurred over the years" (USEPA, 2023). The combination of enhanced CCT with LSLR may allow for deferment of capital improvements and additional costs to the customers while providing improved public health protection.

6.4 CCT Following 100% LSL Removal

Given the regulatory requirements and ongoing efforts by member partners to replace LSLs throughout the GLWA service area, it may be appropriate to reduce the target o-PO_4 dose following the removal of all known LSLs in the system. However, as premise plumbing including copper with leaded solder and leaded brass will remain in the system following LSL removal, CCT should remain in place in perpetuity. When considering a reduced o-PO_4 dose, at a minimum a desktop review of data should include, but is not limited to, updated member community distribution system materials inventories and member community 90th percentile compliance sampling results.

Any reduced dosing approach would need to be done in coordination with EGLE and supported by full-scale compliance monitoring to verify ongoing optimal CCT performance over time.

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Appendix A

Lead and Copper Results by Site for the Statistical Analysis Period

Appendix B

Detailed WQP Results

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A.1 Lead Pipe

A.1.1 Total lead results from lead pipes

Table A.1.1: Wilcoxon Rank-sum Comparison Summary by Orthophosphate Dose for Total Lead Levels from Lead Test Pieces (10-Sample Stability Period)

Dose Comparison[1] (o-PO_4 Dose)	Did the higher dose results in statistically lower total lead concentrations?										
	AP	CS	LH	RH	SW	WA	WY	NE	WW	SP	Percent Performance
Control vs 2.0	No	Yes	No	No	Yes	No	Yes	Yes			50%
Control vs 3.0	Yes	Yes	No	Yes	Yes	No	Yes		Yes		75%
Control vs 4.0	Yes	Yes	No	Yes	Yes	Yes	No			No	63%
2.0 vs 3.0	Yes	Yes	Yes	Yes	No	No	No				57%
2.0 vs 4.0	Yes	Yes	No	Yes	No	Yes	No				63%
3.0 vs 4.0	No	No	No	Yes	No	Yes	No				29%

[1] "Control" indicates finished water as received, measured as 1.31 mg/L as o-PO_4 across all control rigs during the statistical analysis period.
Blank cells indicate that a specific comparison did not exist at that site, for acid-adjusted sites only.
The "Percent Performance" column indicates the percentage of sites for which the latter dose in the compared pair was statistically preferred.

Table A.1.2: Wilcoxon Rank-sum Comparison Summary by Orthophosphate Dose and pH Condition for Total Lead Levels from Lead Test Pieces (10-Sample Stability Period)

Dose Comparison ($oNoPO_4$/pH)	Did the second dose results in statistically lower total lead concentrations?		
	NE	WW	SP
Control/7 vs Control	No		
Control/7 vs 2.0/7	No		
2.0/7 vs 2.0	Yes		
3.0/7 vs 3.0		No	
4.0/7 vs 4.0			No
2.0/7 vs 3.0 /7		Yes	
3.0/7 vs 4.0/7			No

[1] "Control" indicates finished water as received, measured as 1.31 mg/L as o-PO_4 across all control rigs during the statistical analysis period. /7 indicates pH adjusted to pH 7.0.

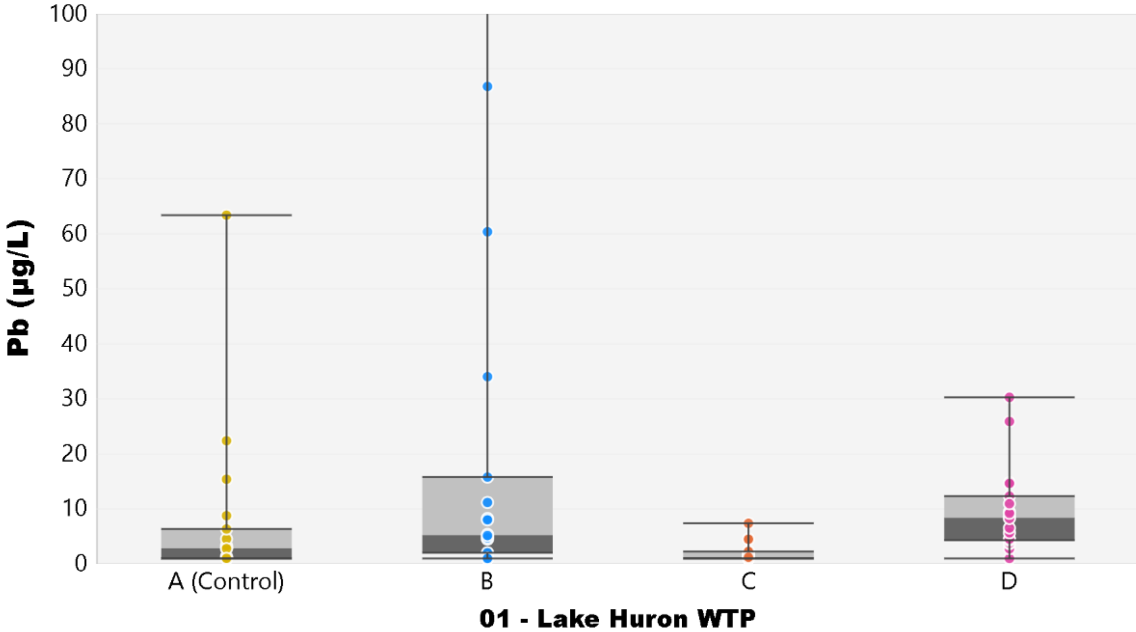


Figure A.1.1: Total Lead Results from Lake Huron WTP from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

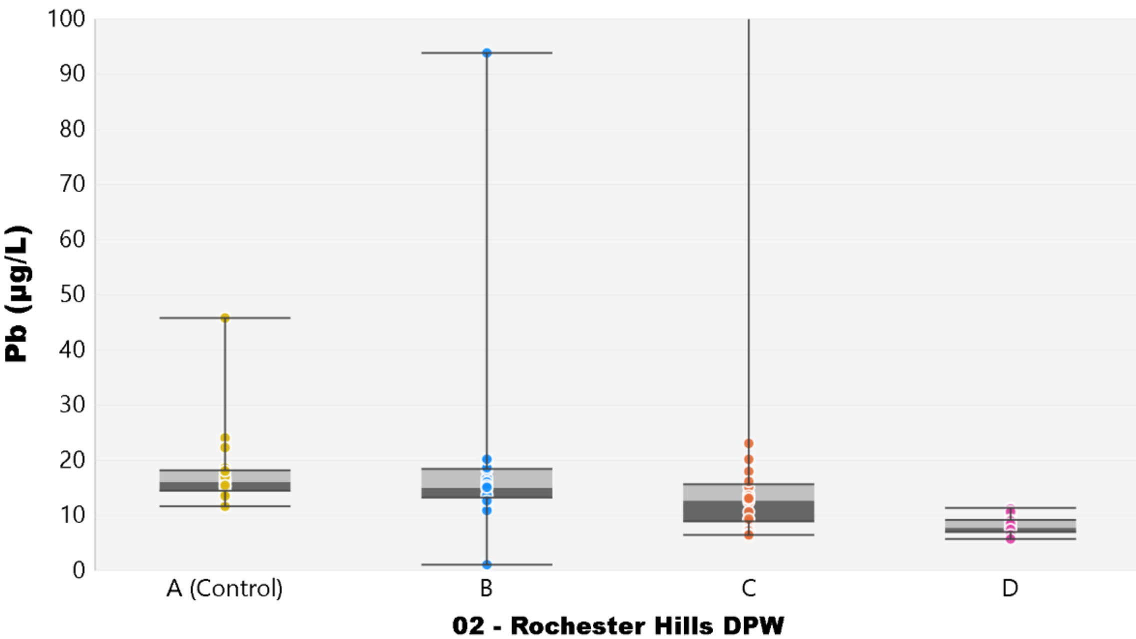


Figure A.1.2: Total Lead Results from Rochester Hills DPW from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

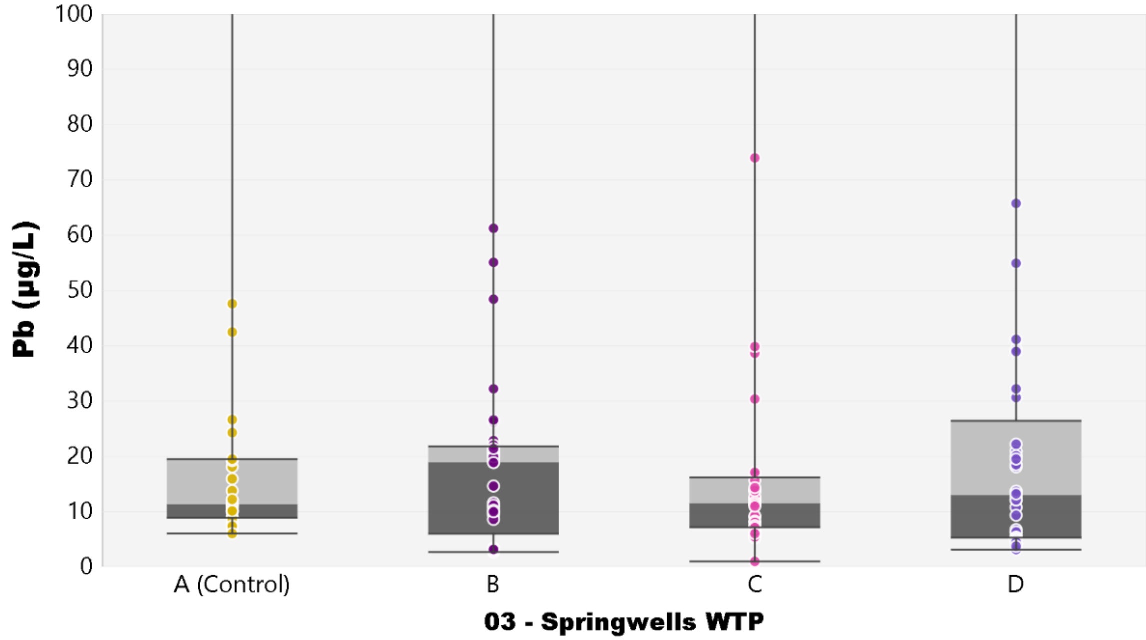


Figure A.1.3: Total Lead Results from Springwells WTP from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (2.0 mg/L, 7.0), Rig C (3.0 mg/L), Rig D (4.0 mg/L, 7.0)

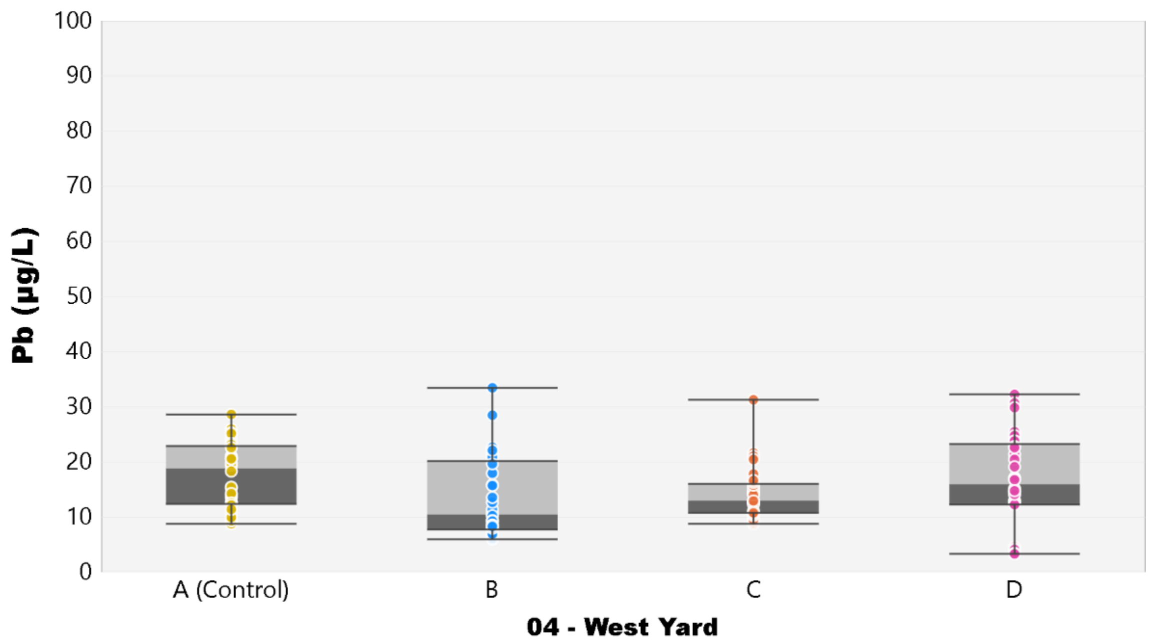


Figure A.1.4: Total Lead Results from West Yard from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

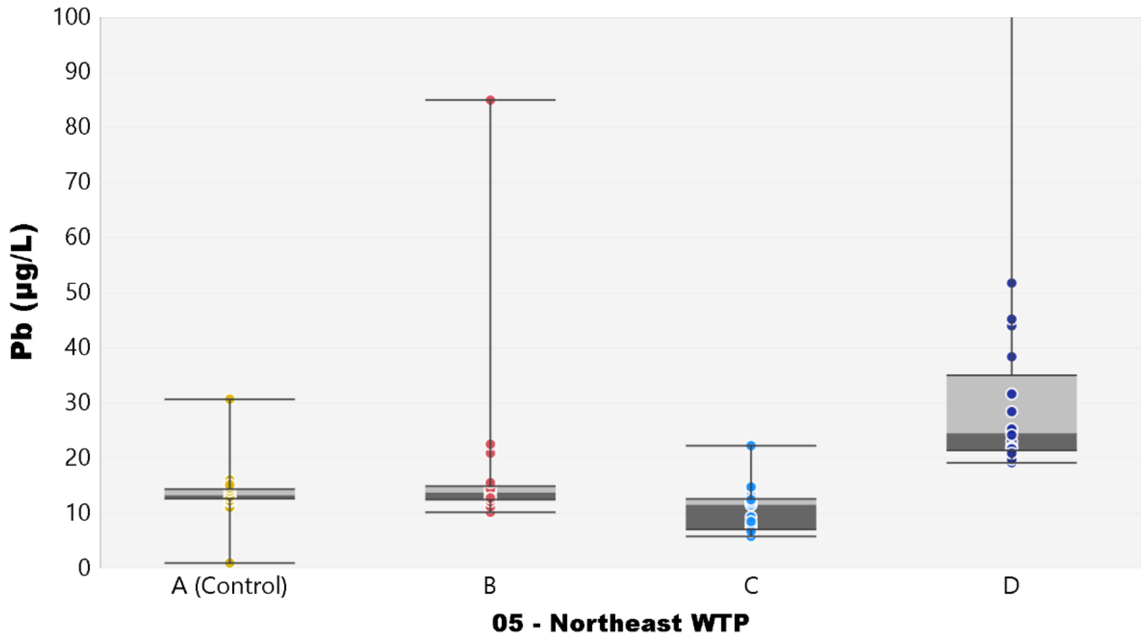


Figure A.1.5: Total Lead Results from Northeast WTP from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (control, 7.0), Rig C (2.0 mg/L), Rig D (2.0 mg/L, 7.0)

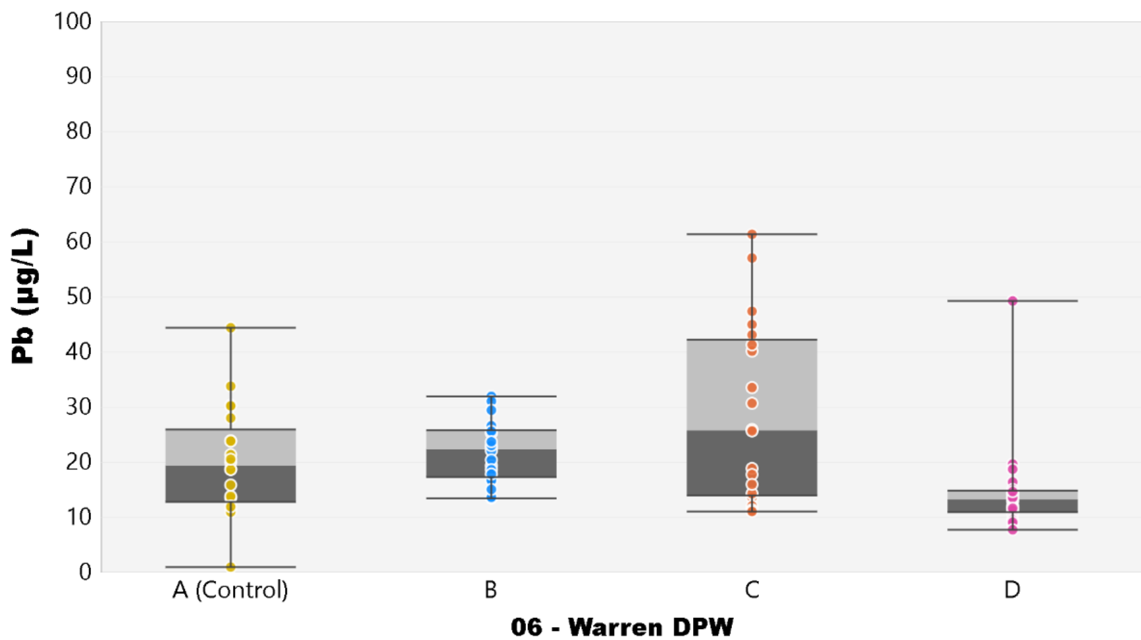


Figure A.1.6: Total Lead Results from Warren DPW from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

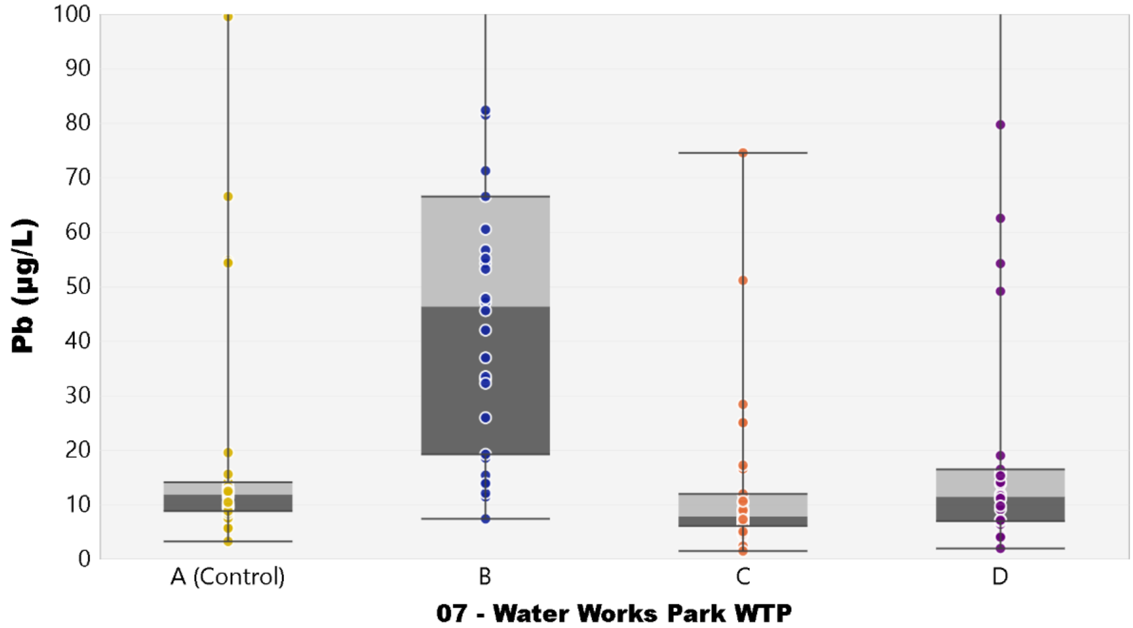


Figure A.1.7: Total Lead Results from Water Works Park WTP from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (2.0, 7.0), Rig C (3.0 mg/L), Rig D (3.0 mg/L, 7.0)

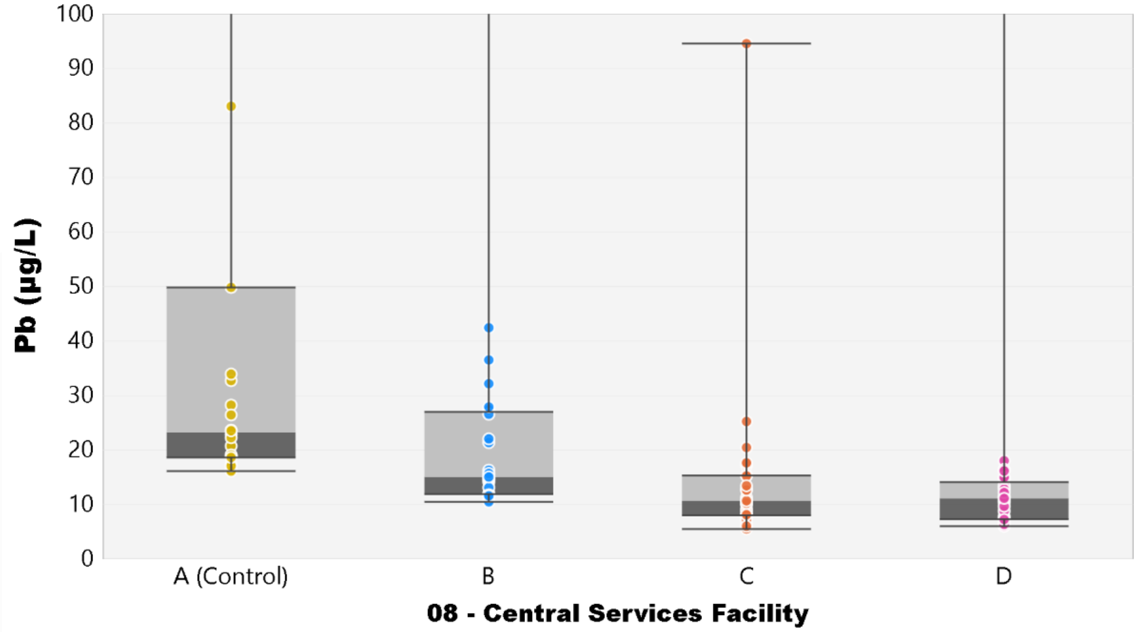


Figure A.1.8: Total Lead Results from Central Services Facility from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

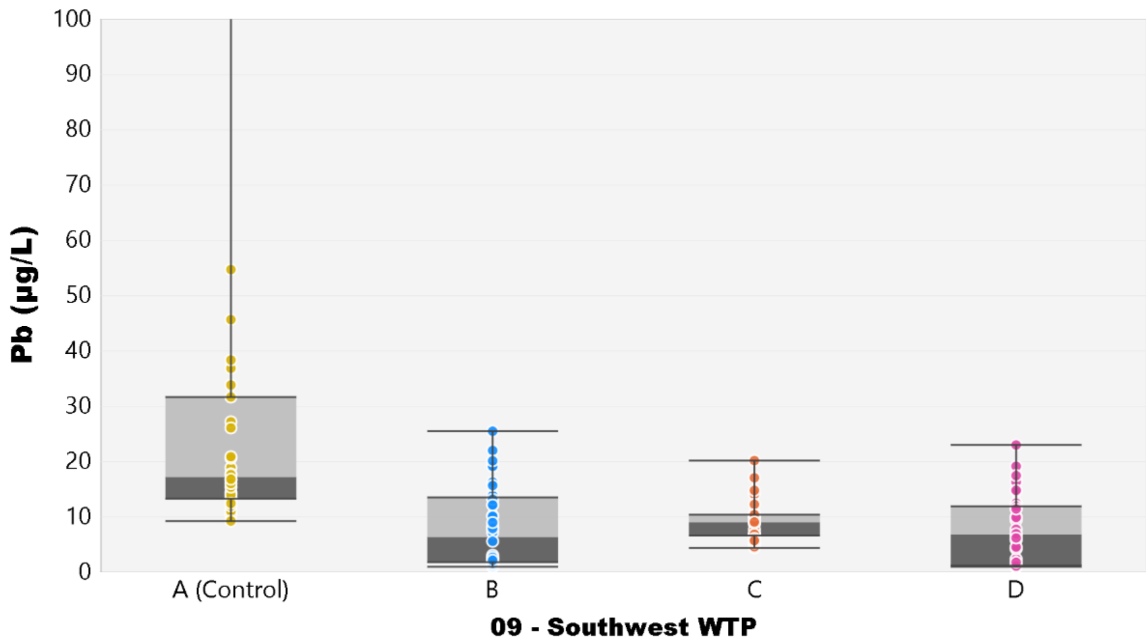


Figure A.1.9: Total Lead Results from Southwest WTP from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

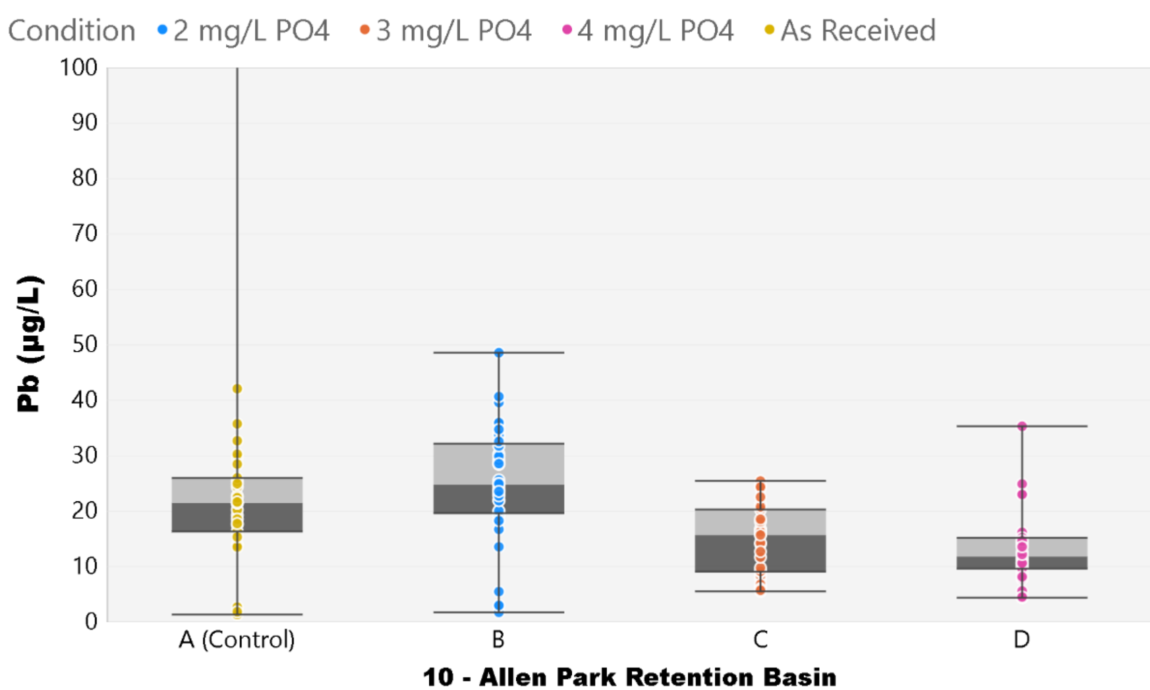


Figure A.1.10: Total Lead Results from Allen Park Retention Basin from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

A.1.2 Dissolved lead results from lead pipes

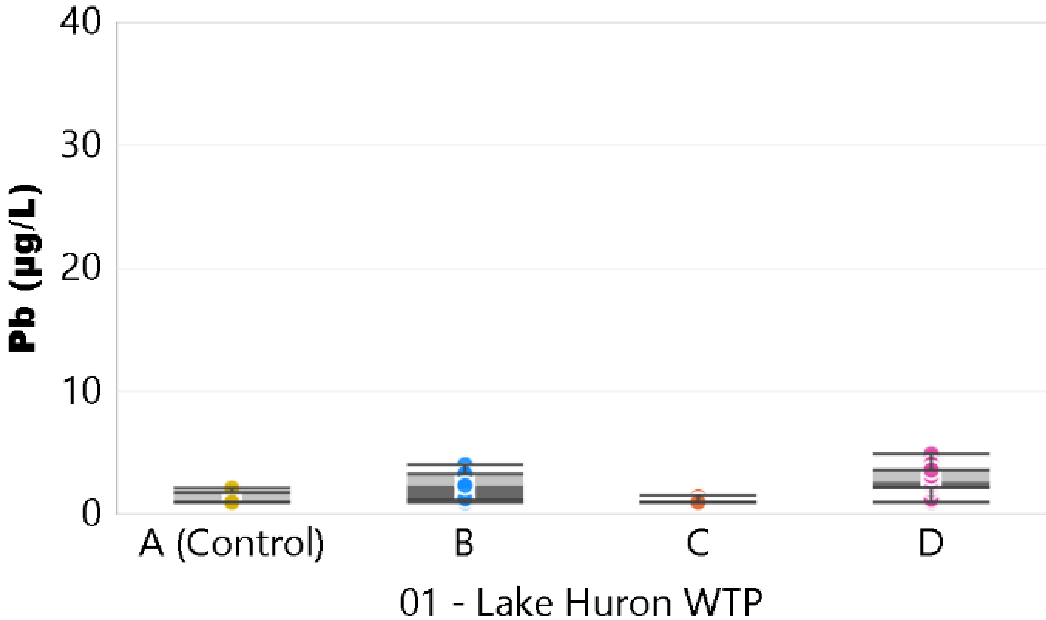


Figure A.1.11: Dissolved Lead Results from Lake Huron WTP from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

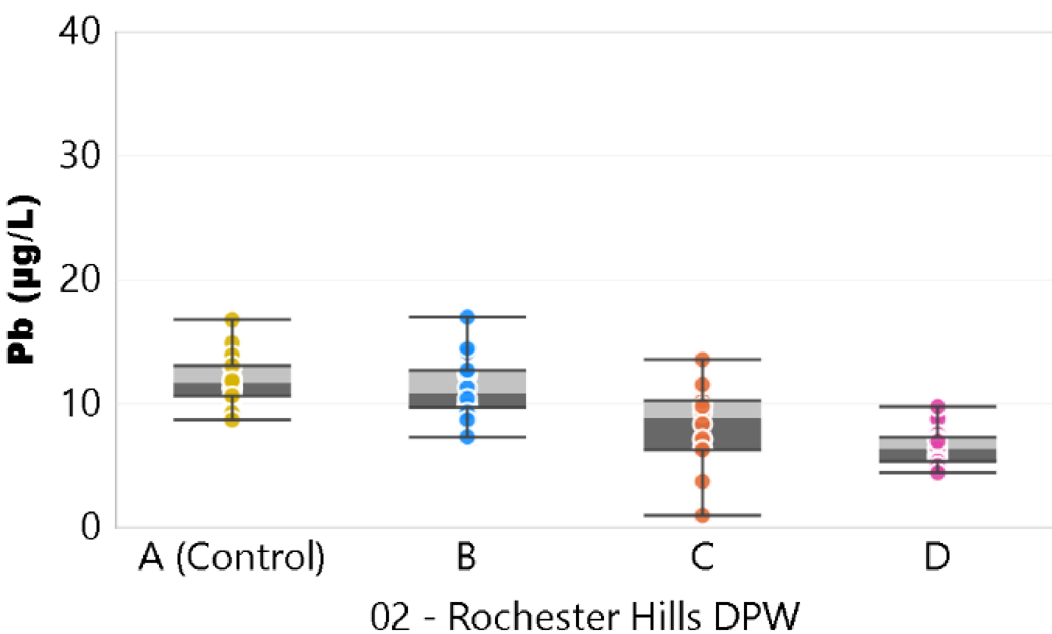


Figure A.1.12: Dissolved Lead Results from Rochester Hills DPW from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

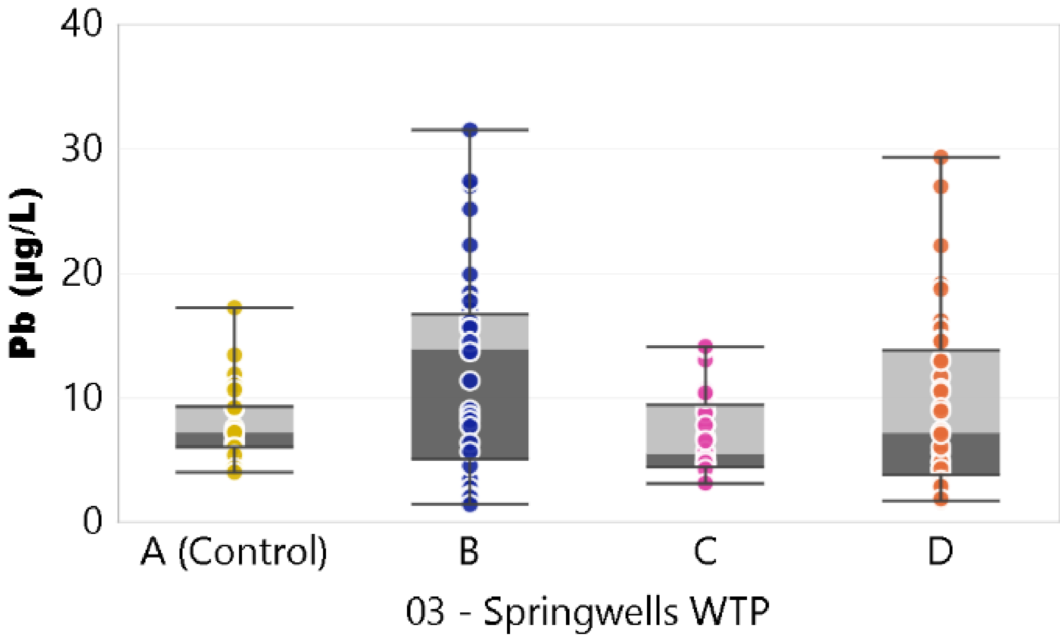


Figure A.1.13: Dissolved Lead Results from Springwells WTP from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (2.0 mg/L, 7.0), Rig C (3.0 mg/L), Rig D (4.0 mg/L, 7.0)

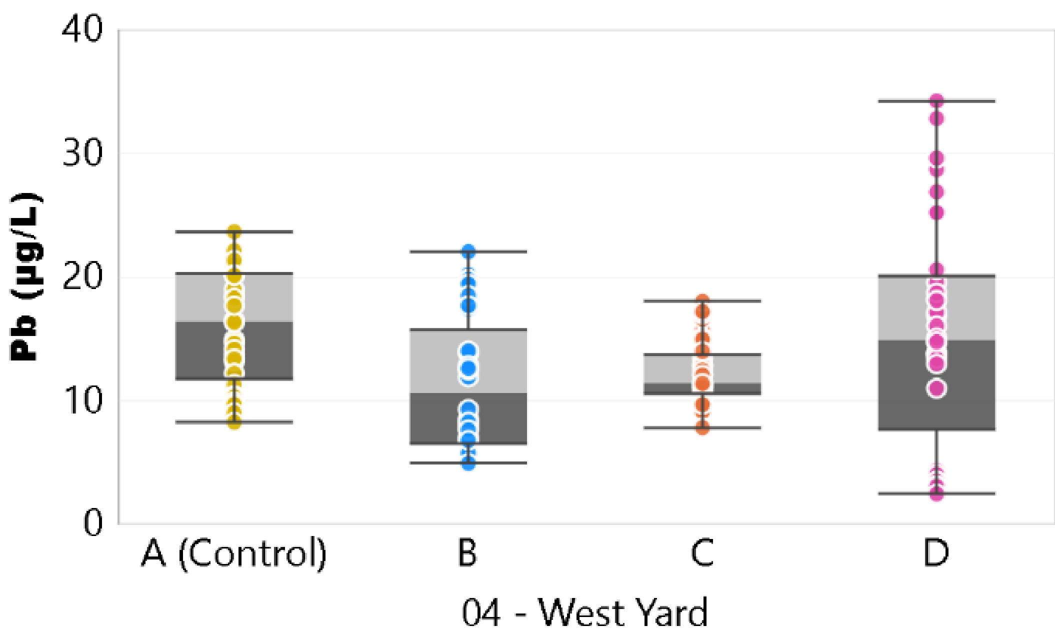


Figure A.1.14: Dissolved Lead Results from West Yard from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

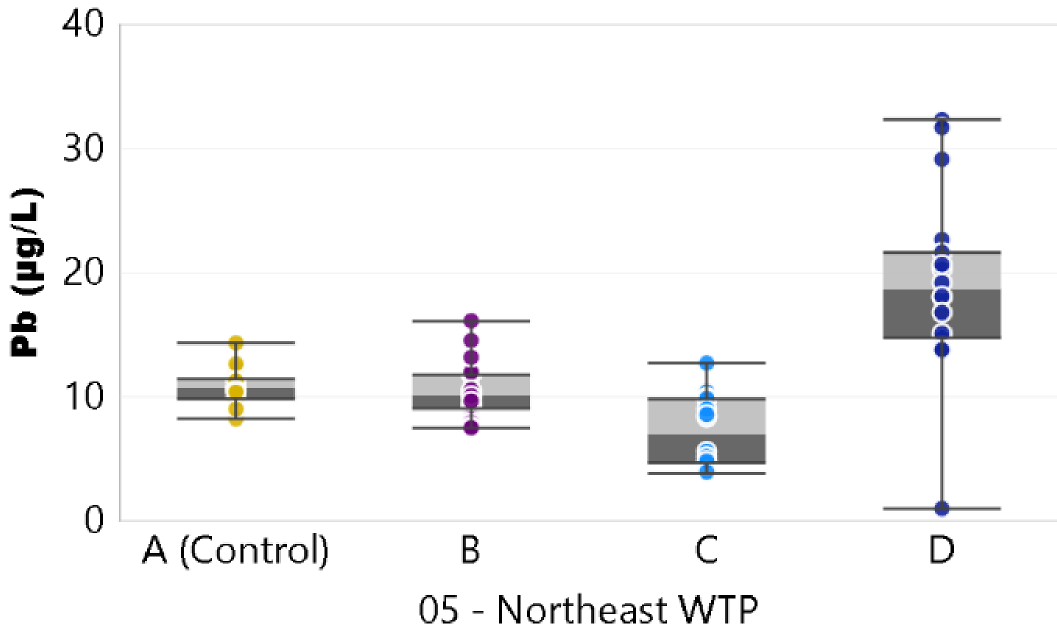


Figure A.1.15: Dissolved Lead Results from Northeast WTP from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (control, 7.0), Rig C (2.0 mg/L), Rig D (2.0 mg/L, 7.0)

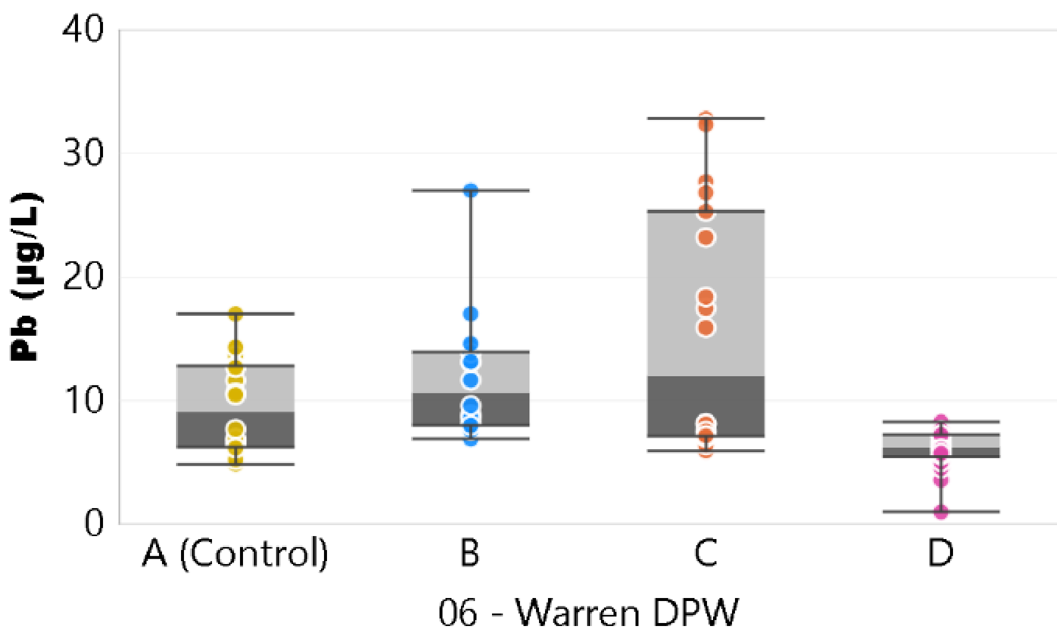


Figure A.1.16: Dissolved Lead Results from Warren DPW from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

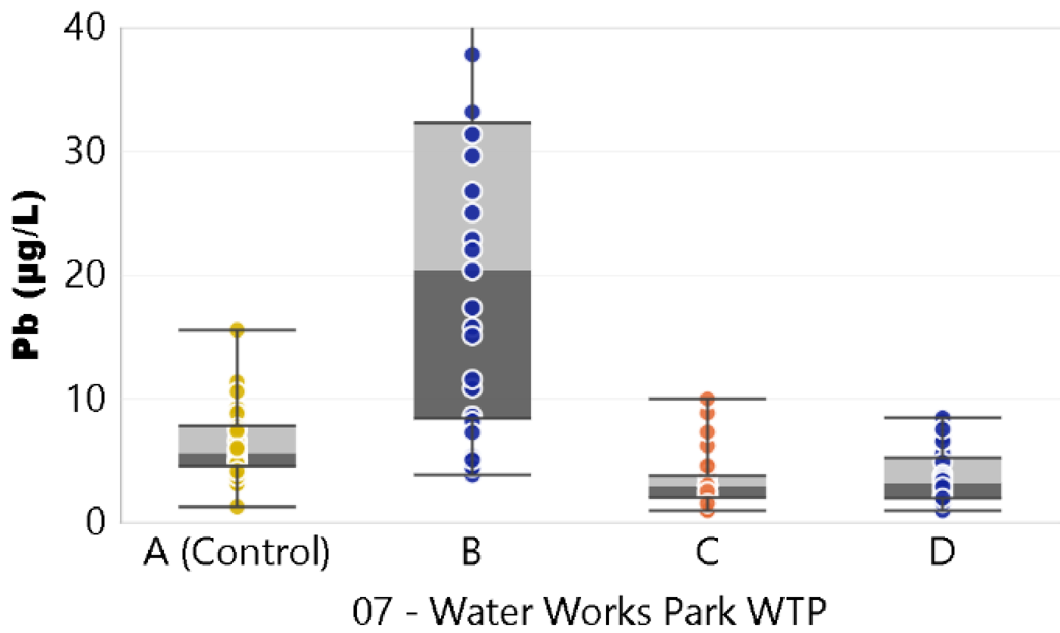


Figure A.1.17: Dissolved Lead Results from Water Works Park WTP from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (2.0, 7.0), Rig C (3.0 mg/L), Rig D (3.0 mg/L, 7.0)

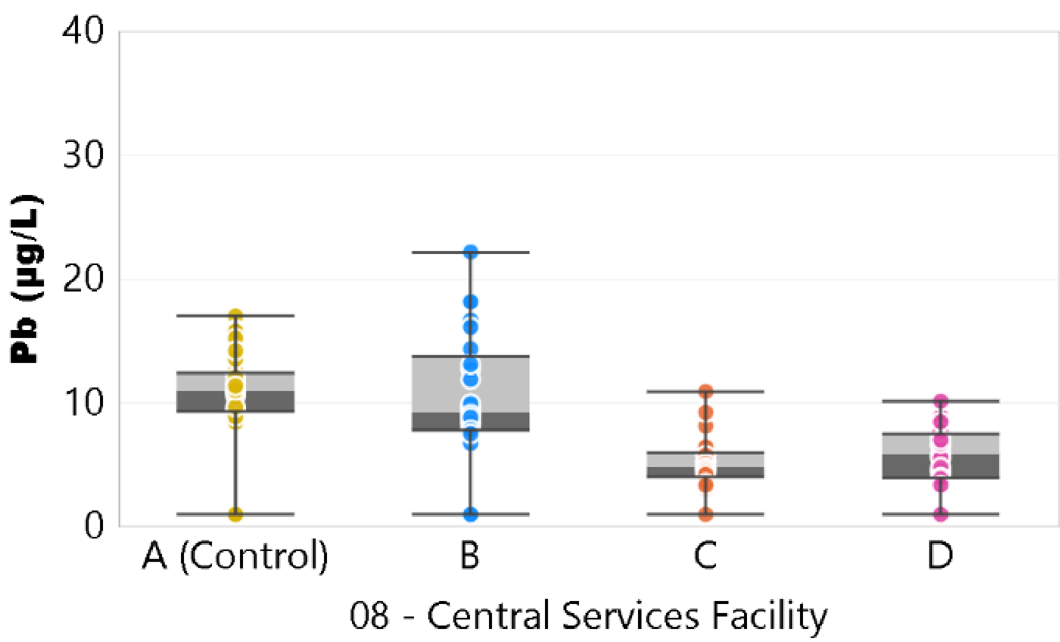


Figure A.1.18: Dissolved Lead Results from Central Services Facility from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

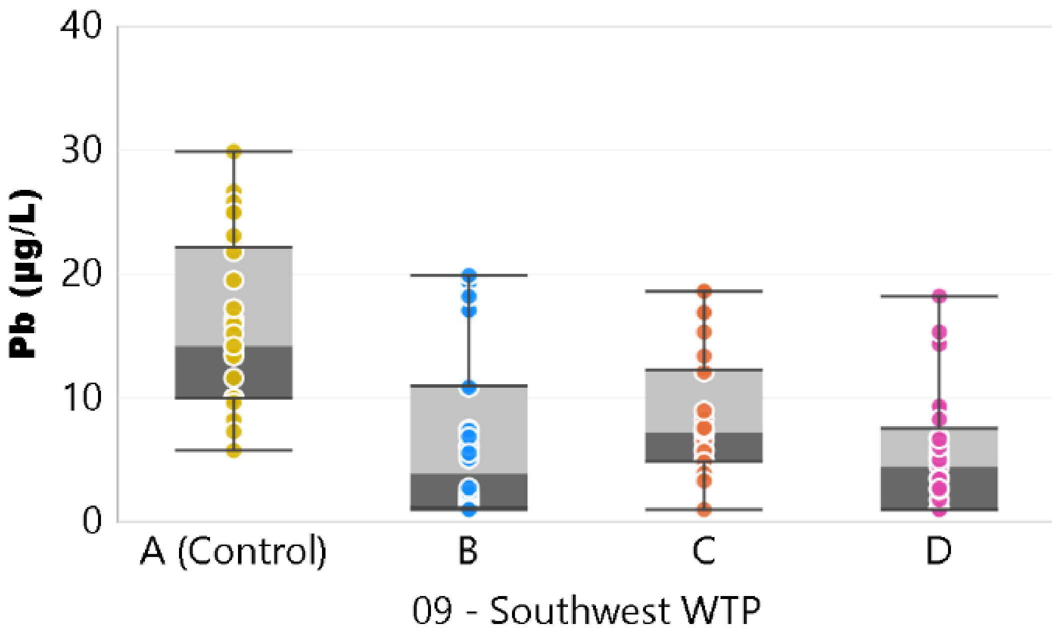


Figure A.1.19: Dissolved Lead Results from Southwest WTP from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

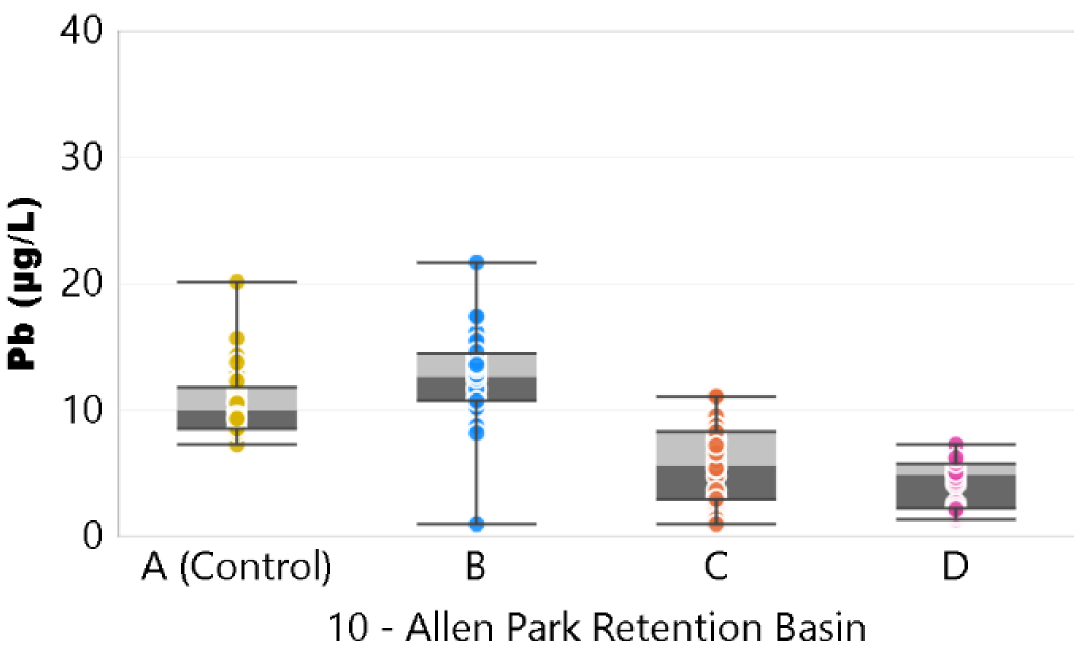


Figure A.1.20: Dissolved Lead Results from Allen Park Retention Basin from Lead Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

A.2 Galvanized Pipe

A.2.1 Total lead results from galvanized pipes

Table A.2.1: Wilcoxon Rank-sum Comparison Summary by Orthophosphate Dose for Total Lead Levels from Galvanized Test Pieces (10-Sample Stability Period)

Dose Comparison[1] (o-PO_4 Dose)	Did the higher dose results in statistically lower total lead concentrations?		
	LH	RH	WA
Control vs 2.0	No	No	No
Control vs 3.0	No	No	No
Control vs 4.0	No	No	No
2.0 vs 3.0	Yes	No	No
2.0 vs 4.0	No	No	No
3.0 vs 4.0	No	No	No

[1] "Control" indicates finished water as received, measured as 1.31 mg/L as o-PO_4 across all control rigs during the statistical analysis period.
Blank cells indicate that a specific comparison did not exist at that site, for acid-adjusted sites only.
The "Percent Performance" column indicates the percentage of sites for which the latter dose in the compared pair was statistically preferred.

Table A.2.2: Wilcoxon Rank-sum Comparison Summary by Orthophosphate Dose and pH Condition for Total Lead Levels from Galvanized Test Pieces (10-Sample Stability Period)

Dose Comparison[1] (o-PO_4 and pH)	Did the second dose results in statistically lower total lead concentrations?
	NE
Control vs 2.0	No
Control/7 vs Control	No
Control/7 vs 2.0/7	No
2.0/7 vs 2.0	No

[1] "Control" indicates finished water as received, measured as 1.31 mg/L as o-PO4 across all control rigs during the statistical analysis period.

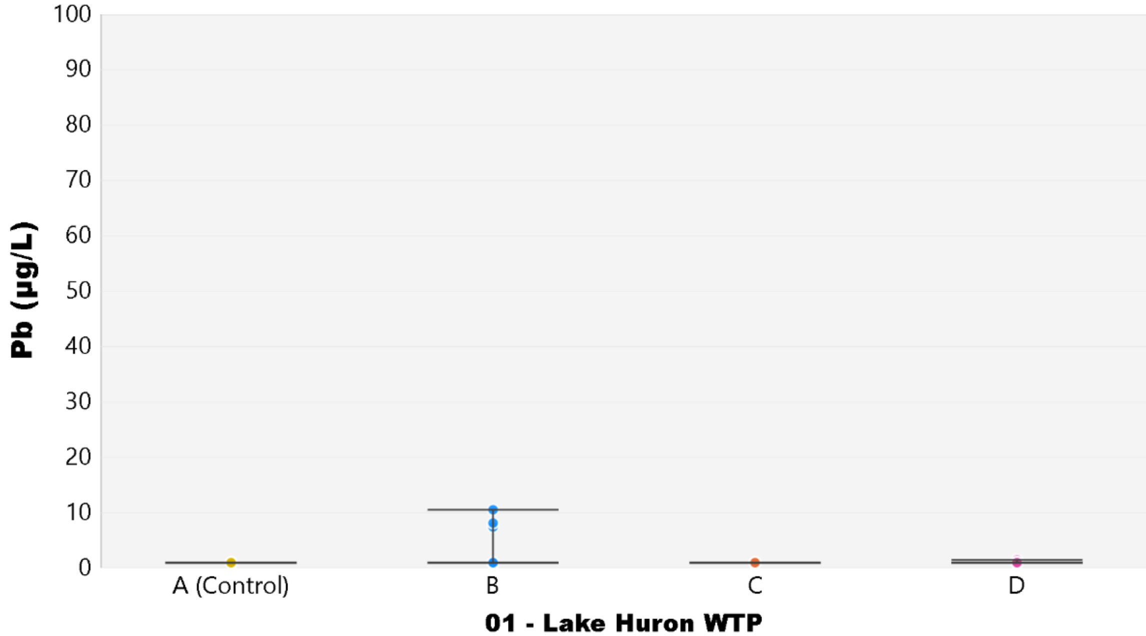


Figure A.2.1: Total Lead Results from Lake Huron WTP from Galvanized Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

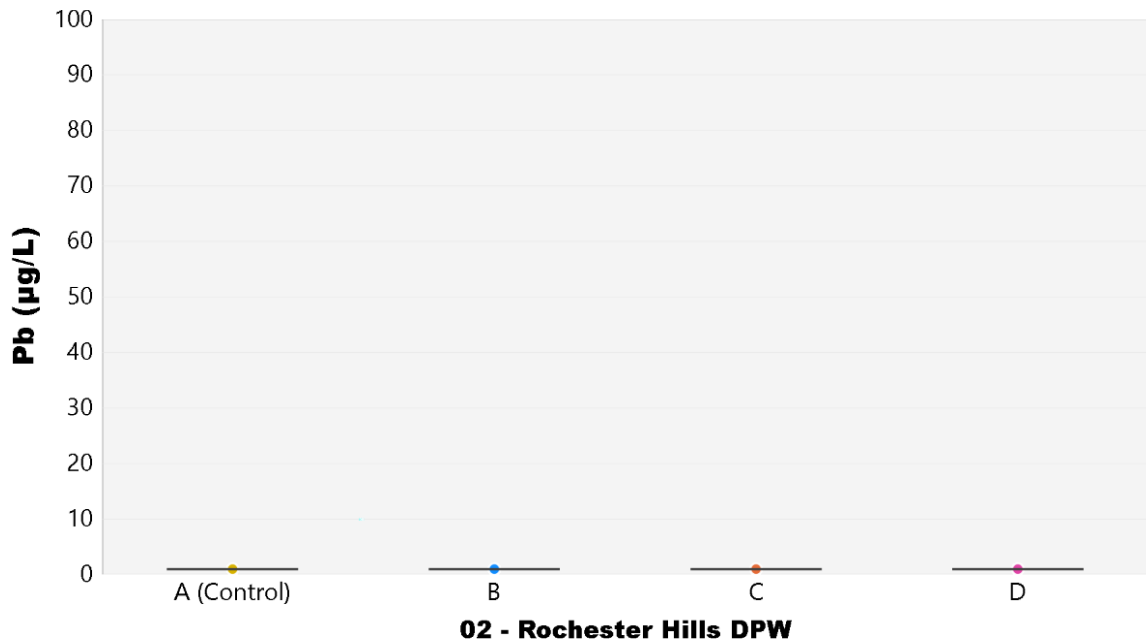


Figure A.2.2: Total Lead Results from Rochester Hills DPW from Galvanized Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

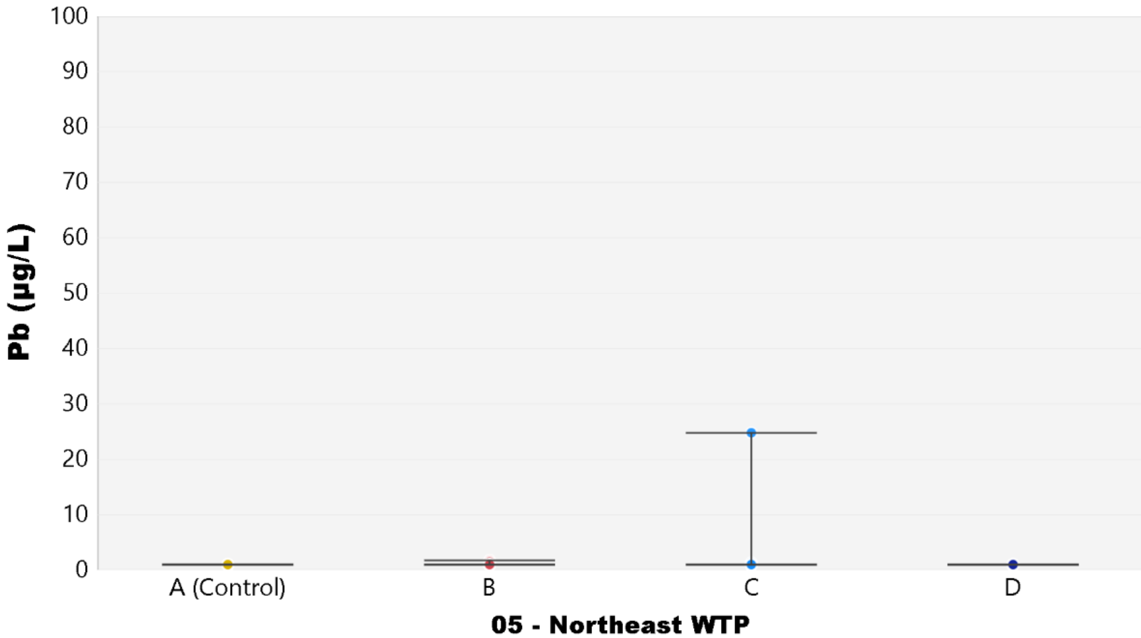


Figure A.2.3: Total Lead Results from Northeast WTP from Galvanized Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (control, 7.0), Rig C (2.0 mg/L), Rig D (2.0 mg/L, 7.0)

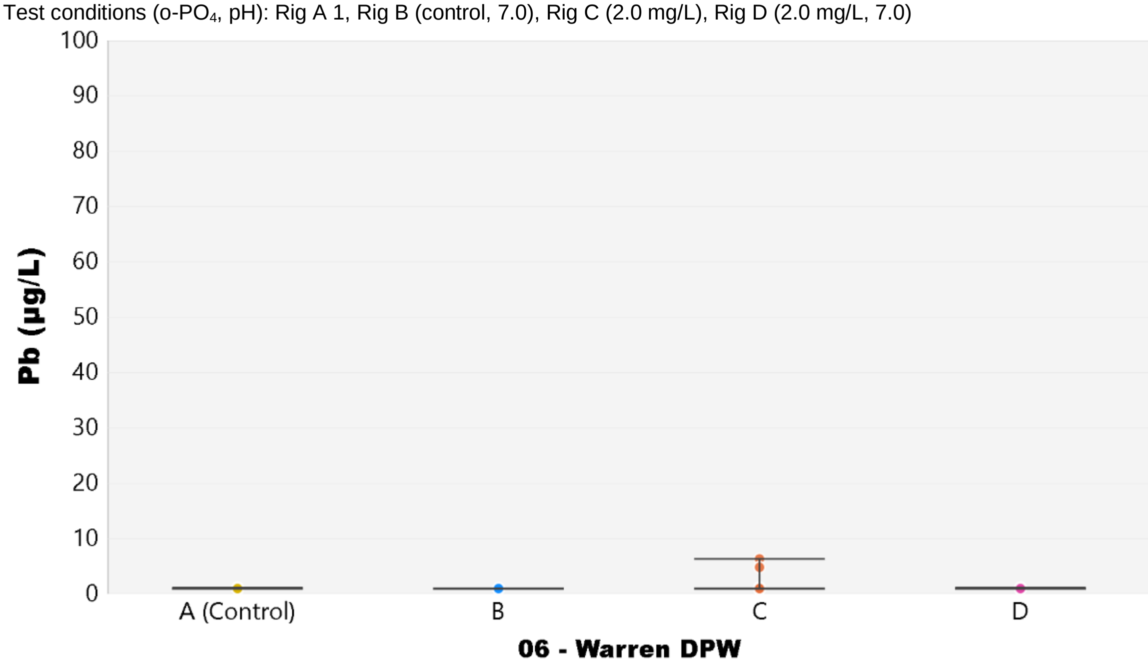


Figure A.2.4: Total Lead Results from Warren DPW from Galvanized Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

A.3 Brass Pipe

A.3.1 Total lead results from brass pipes

Table A.3.1: Wilcoxon Rank-sum Comparison Summary by Orthophosphate Dose for Total Lead Levels from Brass Test Pieces (10-Sample Stability Period)

Dose Comparison[1] (o-PO_4 Dose)	Did the higher dose results in statistically lower total lead concentrations?										
	AP	CS	LH	RH	SW	WA	WY	NE	WW	SP	Percent Performance
Control vs 2.0	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No			87%
Control vs 3.0	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes		100%
Control vs 4.0	Yes	Yes	Yes	Yes	Yes	Yes	Yes			Yes	100%
2.0 vs 3.0	No	Yes	No	Yes	No	Yes	Yes				57%
2.0 vs 4.0	No	Yes	No	Yes	No	Yes	Yes				57%
3.0 vs 4.0	Yes	Yes	No	Yes	No	Yes	No				57%

[1] "Control" indicates finished water as received, measured as 1.31 mg/L as o-PO_4 across all control rigs during the statistical analysis period.
Blank cells indicate that a specific comparison did not exist at that site, for acid-adjusted sites only.
The "Percent Performance" column indicates the percentage of sites for which the latter dose in the compared pair was statistically preferred.

Table A.3.2: Wilcoxon Rank-sum Comparison Summary by Orthophosphate Dose and pH Condition for Total Lead Levels from Brass Test Pieces (10-Sample Stability Period)

Comparison ($o\text{-}PO_4$/pH)	Did the second dose results in statistically lower total lead concentrations?		
	NE	WW	SP
Control/7 vs Control	Yes		
Control/7 vs 2.0/7	Yes		
2.0/7 vs 2.0	No		
3.0/7 vs 3.0		Yes	
4.0/7 vs 4.0			No
2.0/7 vs 3.0 /7		No	
3.0/7 vs 4.0/7			Yes

[1] "Control" indicates finished water as received, measured as 1.31 mg/L as $o\text{-}PO_4$ across all control rigs during the statistical analysis period. Blank cells indicate that a specific comparison did not exist at that site, for acid-adjusted sites only.

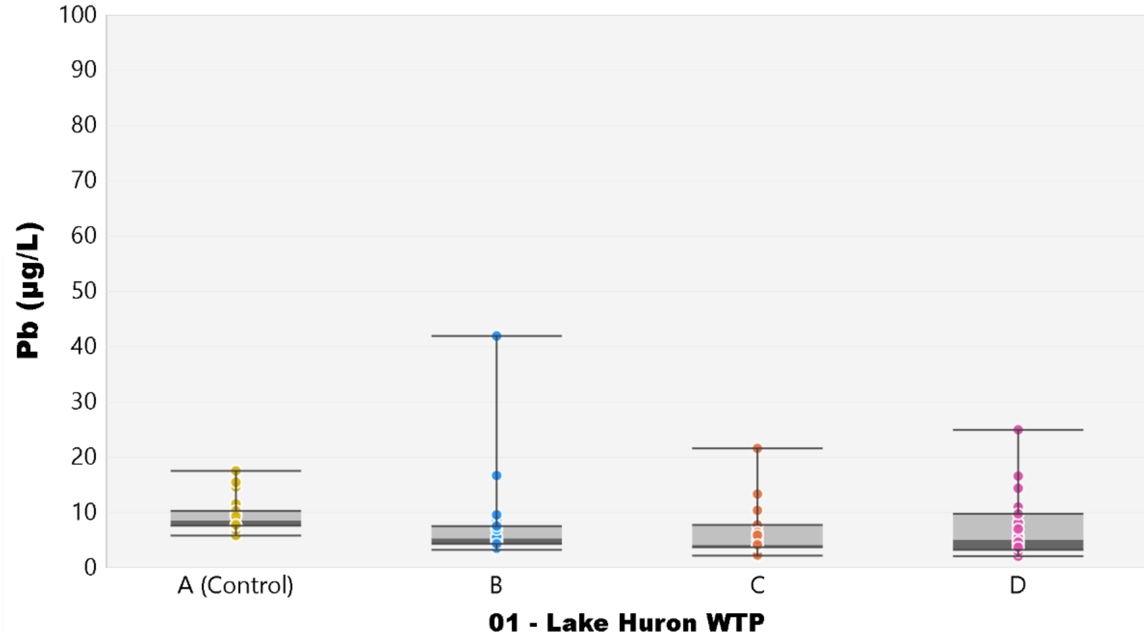


Figure A.3.1: Total Lead Results from Lake Huron WTP from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

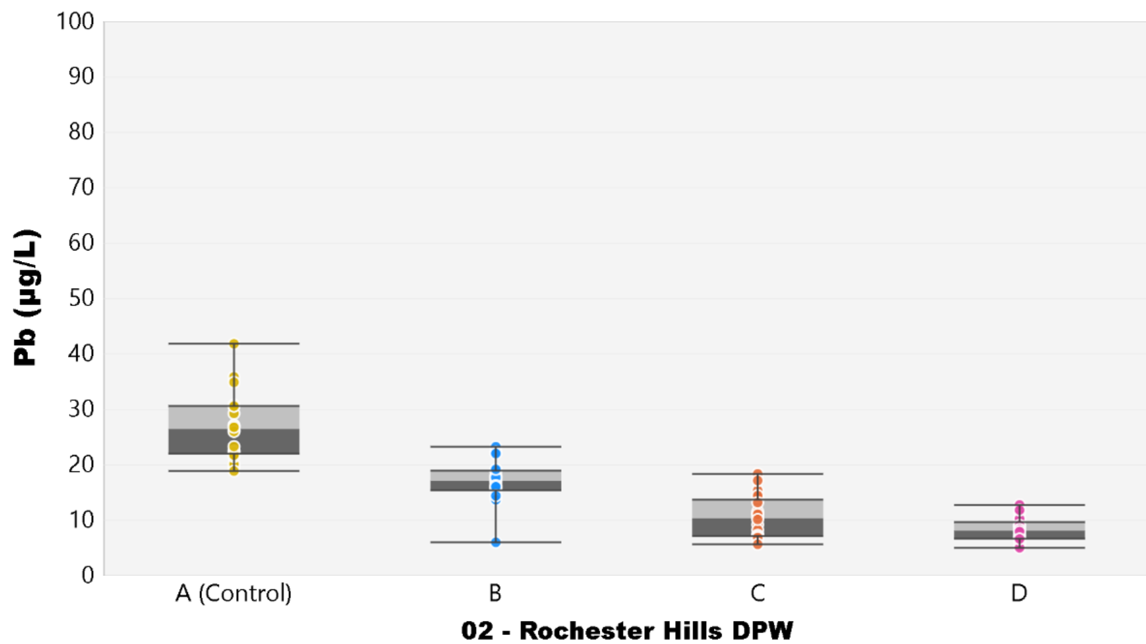


Figure A.3.2: Total Lead Results from Rochester Hills DPW from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

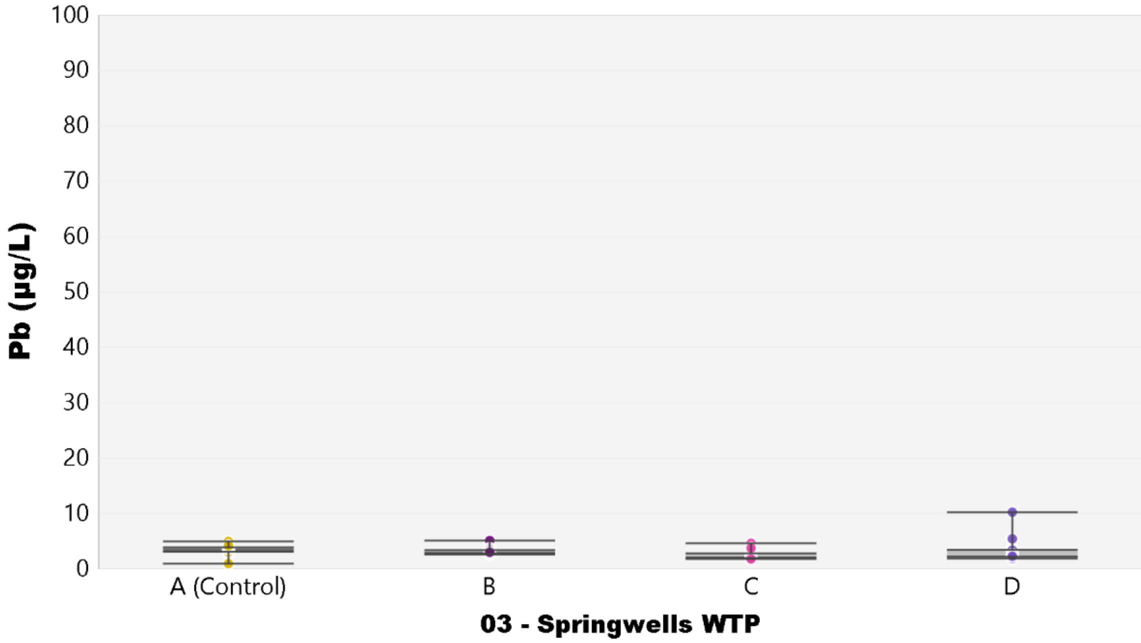


Figure A.3.3: Total Lead Results from Springwells WTP from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (2.0 mg/L, 7.0), Rig C (3.0 mg/L), Rig D (4.0 mg/L, 7.0)

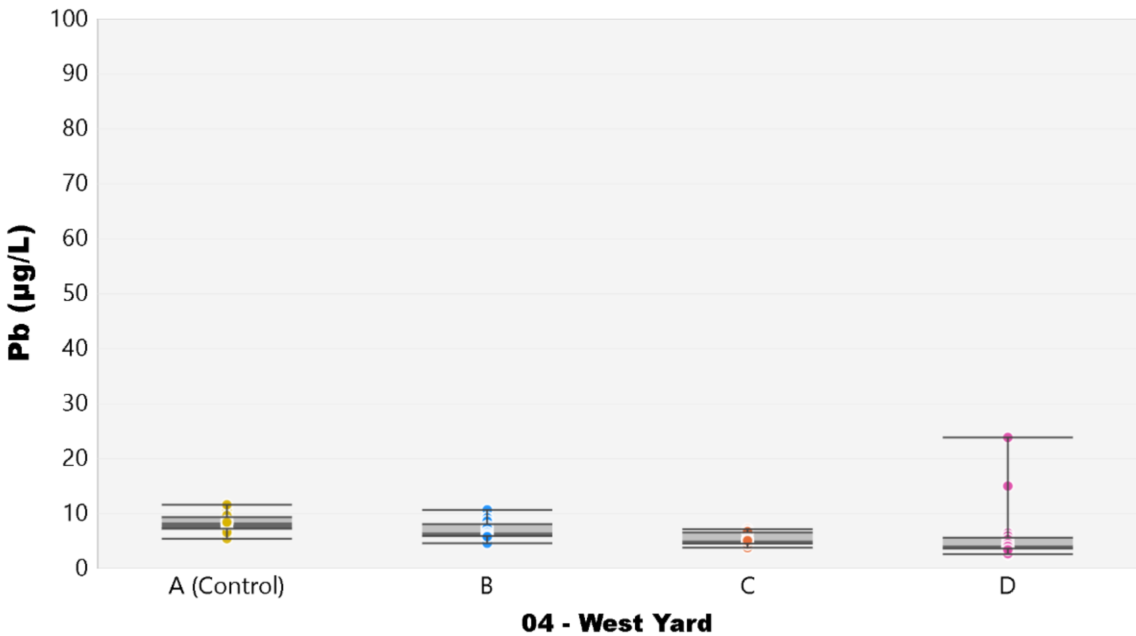


Figure A.3.4: Total Lead Results from West Yard from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

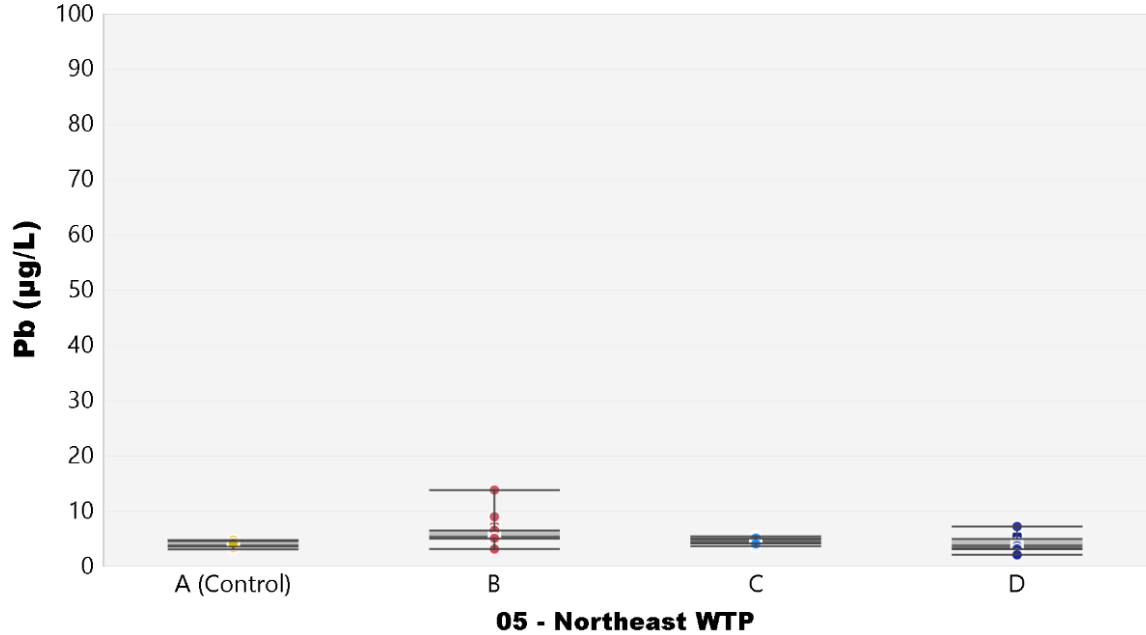


Figure A.3.5: Total Lead Results from Northeast WTP from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (control, 7.0), Rig C (2.0 mg/L), Rig D (2.0 mg/L, 7.0)

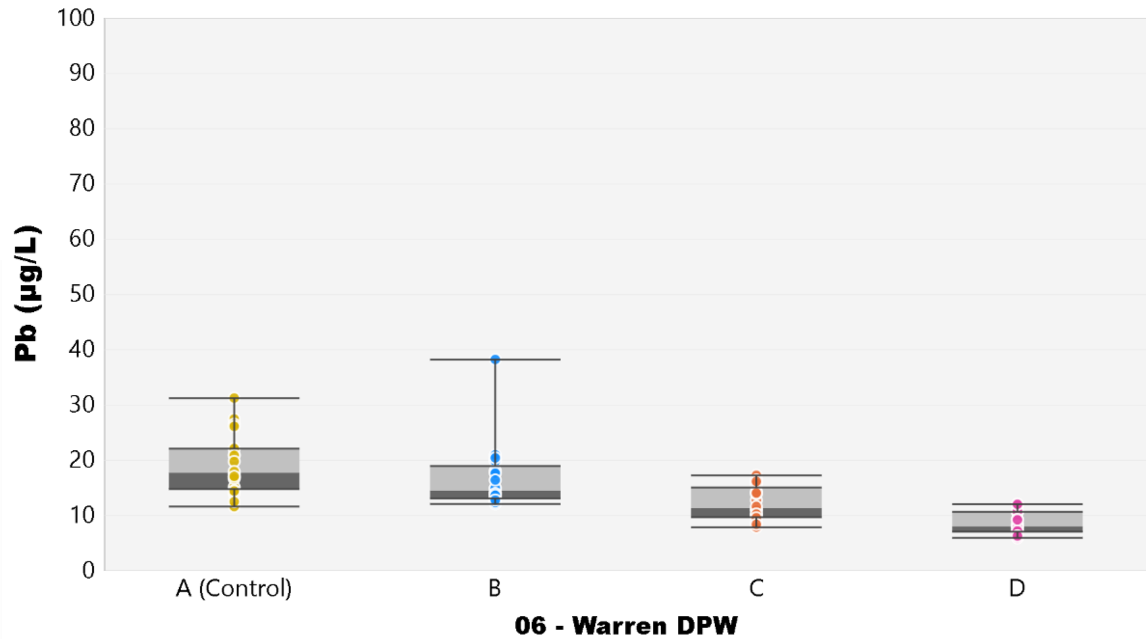


Figure A.3.6: Total Lead Results from Warren DPW from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

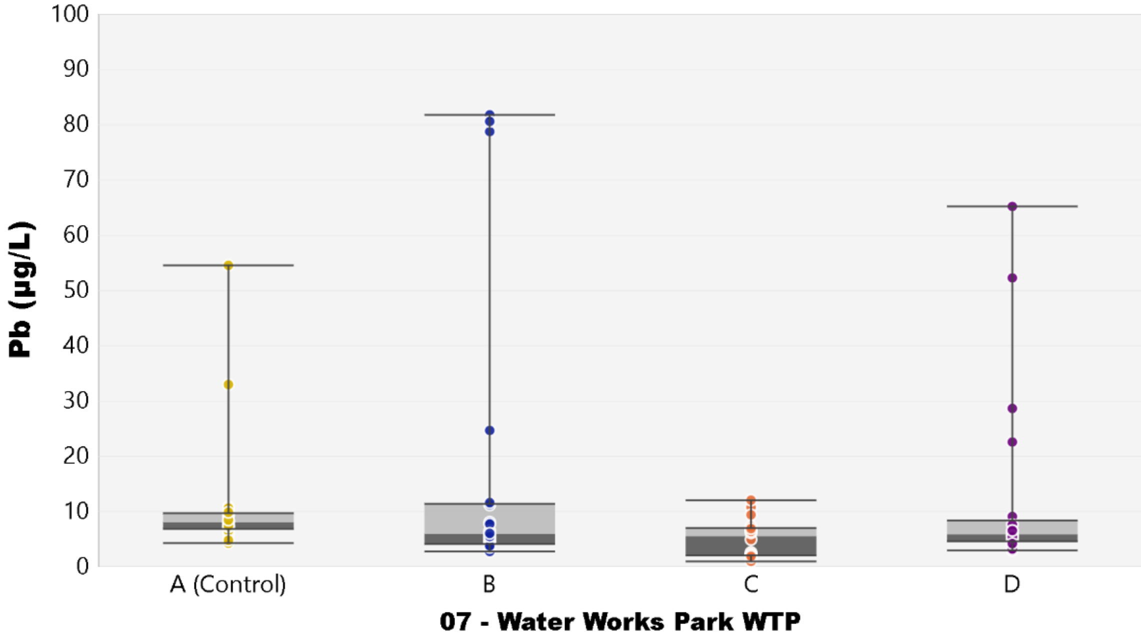


Figure A.3.7: Total Lead Results from Water Works Park WTP from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (2.0, 7.0), Rig C (3.0 mg/L), Rig D (3.0 mg/L, 7.0)

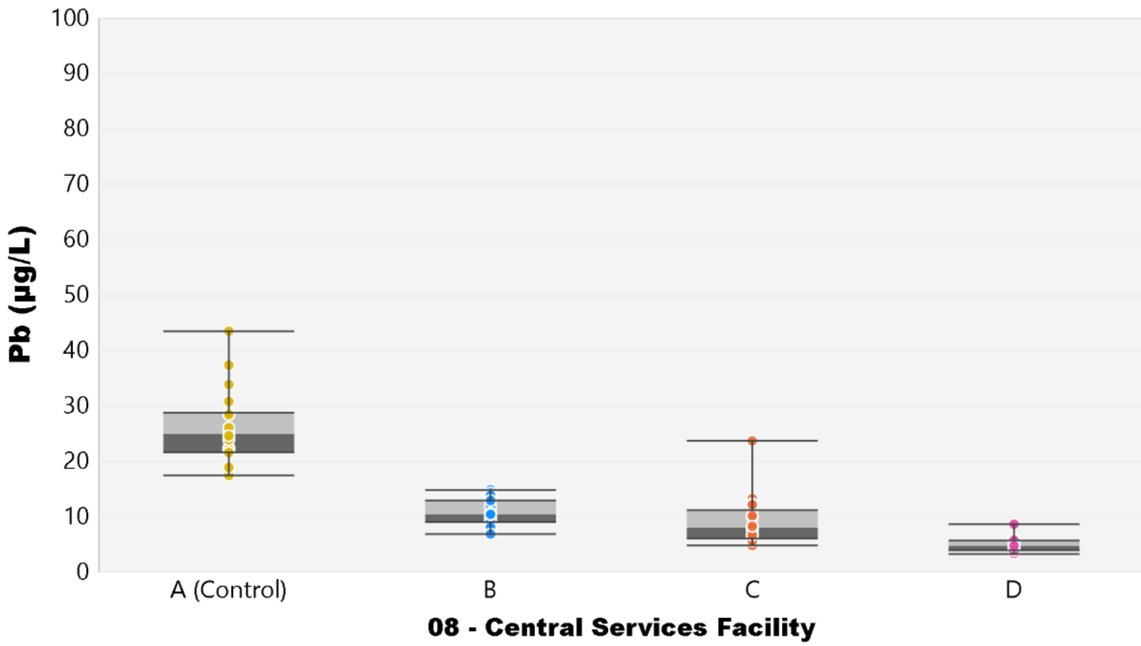


Figure A.3.8: Total Lead Results from Central Services Facility from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

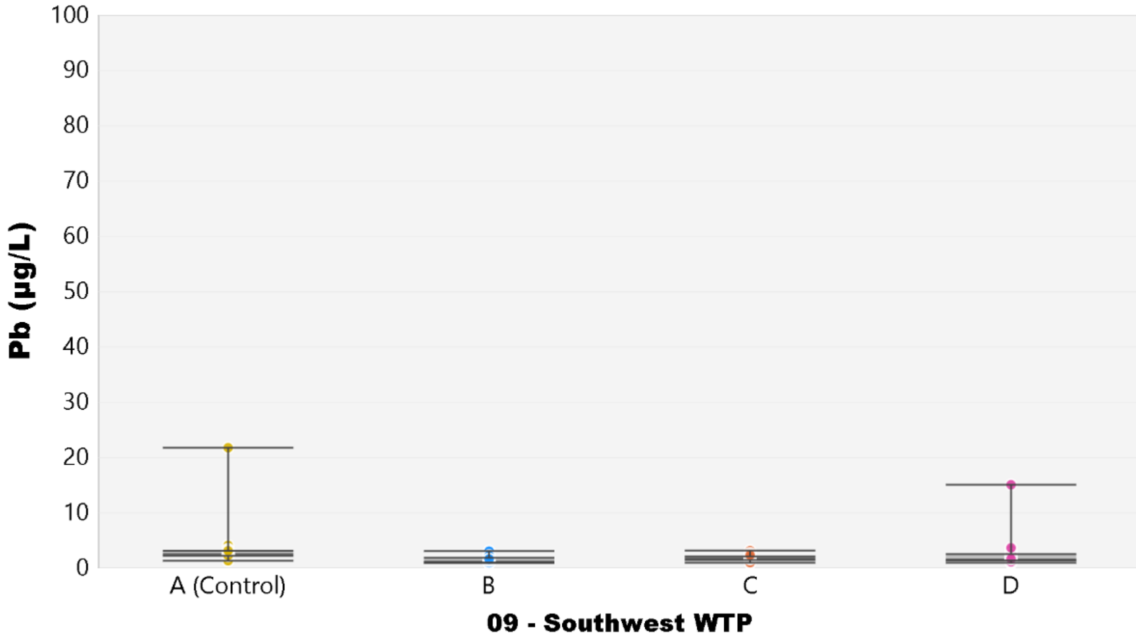


Figure A.3.9: Total Lead Results from Southwest WTP from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

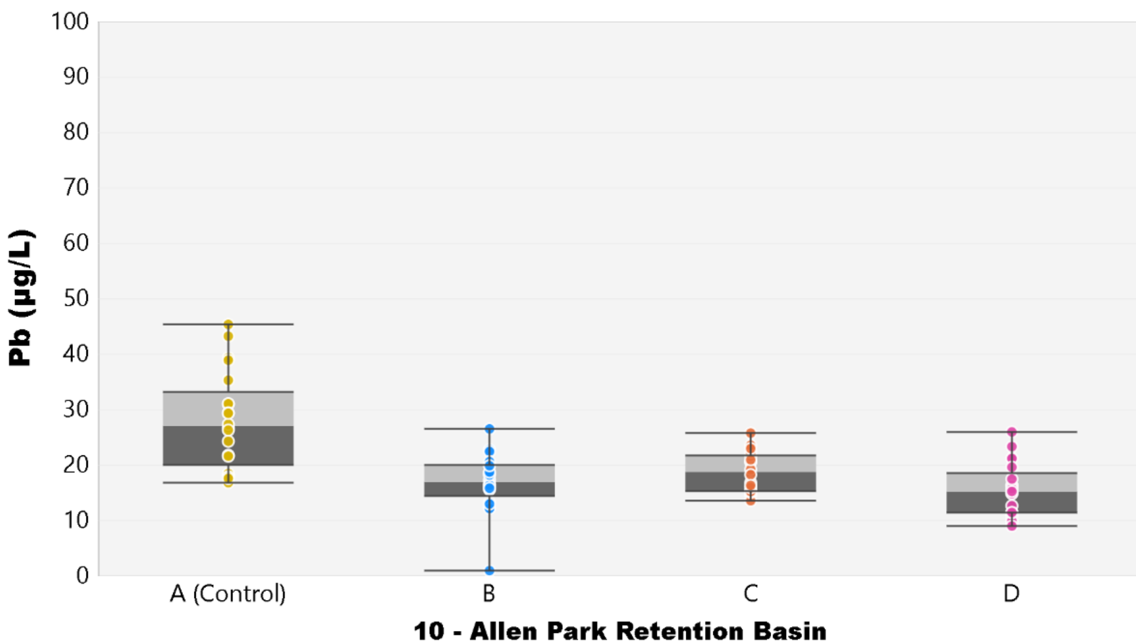


Figure A.3.10: Total Lead Results from Allen Park Retention Basin from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

A.3.2 Total copper results from brass pipes

Figure A.3.11 below shows the total copper (Cu) levels from brass pipes, aggregated across sites by o-PO_4 dose, for the representative 10-sample set. The results of the Wilcoxon rank-sum comparisons between aggregated o-PO_4 doses are further displayed in Table A.3.3 below.

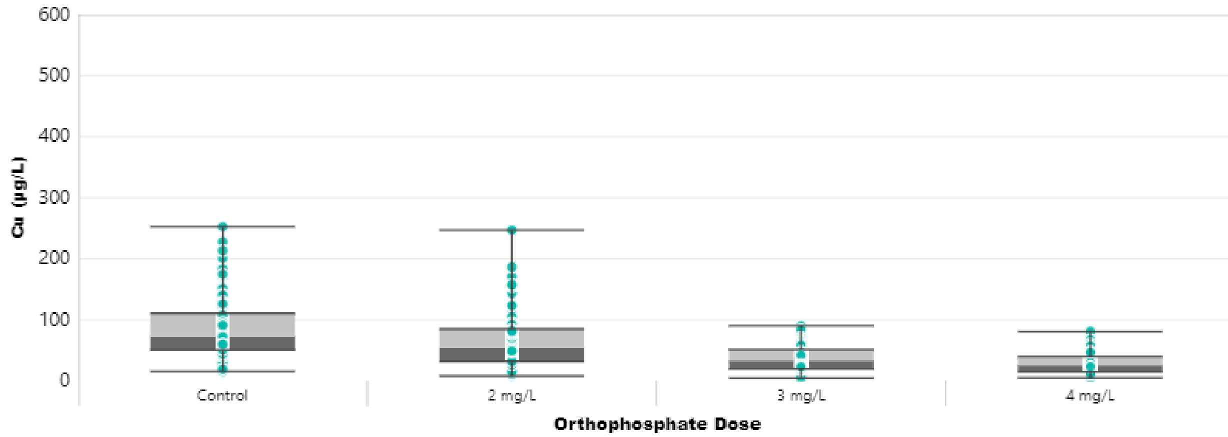


Figure A.3.11: Total Copper Results for Brass Pipes Aggregated Across Sites by o-PO_4 Dose

Table A.3.3: Wilcoxon Rank-sum Comparison Summary by Orthophosphate Dose for Total Copper Levels from Brass Test Pieces

Dose Comparison[1] (mg/L)	Did the higher dose results in statistically lower total lead concentrations?
Control vs 2.0	Yes
Control vs 3.0	Yes
Control vs. 4.0	Yes
2.0 vs 3.0	Yes
2.0 vs 4.0	Yes
3.0 vs 4.0	No

[1] "Control" indicates finished water as received, measured as 1.31 mg/L as o-PO_4 across all control rigs during the statistical analysis period.

(-) Indicates that the second dose did not have statistically lower copper levels than the first dose.

Table A.3.4: Wilcoxon Rank-sum Comparison Summary by Orthophosphate Dose for Total Copper Levels from Brass Test Pieces (10-Sample Stability Period)

Dose Comparison[1] (o-PO_4 Dose)	Did the higher dose results in statistically lower total lead concentrations?										
	AP	CS	LH	RH	SW	WA	WY	NE	WW	SP	Percent Performance
Control vs 2.0	No	Yes	No	Yes	Yes	Yes	Yes	Yes			75%
Control vs 3.0	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes		100%
Control vs 4.0	Yes	Yes	Yes	Yes	Yes	Yes	Yes			Yes	100%
2.0 vs 3.0	Yes	Yes	Yes	Yes	No	Yes	Yes				86%
2.0 vs 4.0	Yes	Yes	Yes	Yes	No	Yes	Yes				86%
3.0 vs 4.0	No	No	Yes	Yes	No	Yes	Yes				57%

[1] "Control" indicates finished water as received, measured as 1.31 mg/L as o-PO_4 across all control rigs during the statistical analysis period.
Blank cells indicate that a specific comparison did not exist at that site, for acid-adjusted sites only.
The "Percent Performance" column indicates the percentage of sites for which the latter dose in the compared pair was statistically preferred.

Table A.3.5: Wilcoxon Rank-sum Comparison Summary by Orthophosphate Dose and pH Condition for Total Copper Levels from Brass Test Pieces (10-Sample Stability Period)

Dose Comparison[1] (o-PO_4 / pH)	Did the second dose results in statistically lower total copper concentrations?		
	NE	WW	SP
Control/7 vs Control	Yes		
Control/7 vs 2.0/7	No		
2.0/7 vs 2.0	Yes		
3.0/7 vs 3.0		Yes	
4.0/7 vs 4.0			No
2.0/7 vs 3.0 /7		Yes	
3.0/7 vs 4.0/7			Yes

[1] "Control" indicates finished water as received, measured as 1.31 mg/L as o-PO_4 across all control rigs during the statistical analysis period. Blank cells indicate that a specific comparison did not exist at that site, for acid-adjusted sites only.

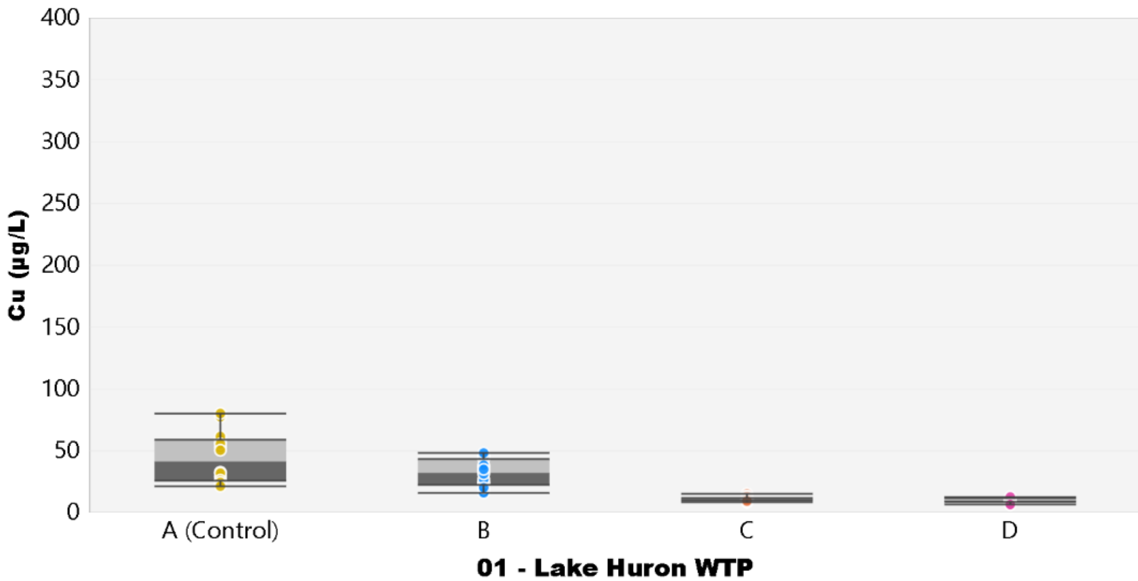


Figure A.3.12: Total Copper Results from Lake Huron WTP from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

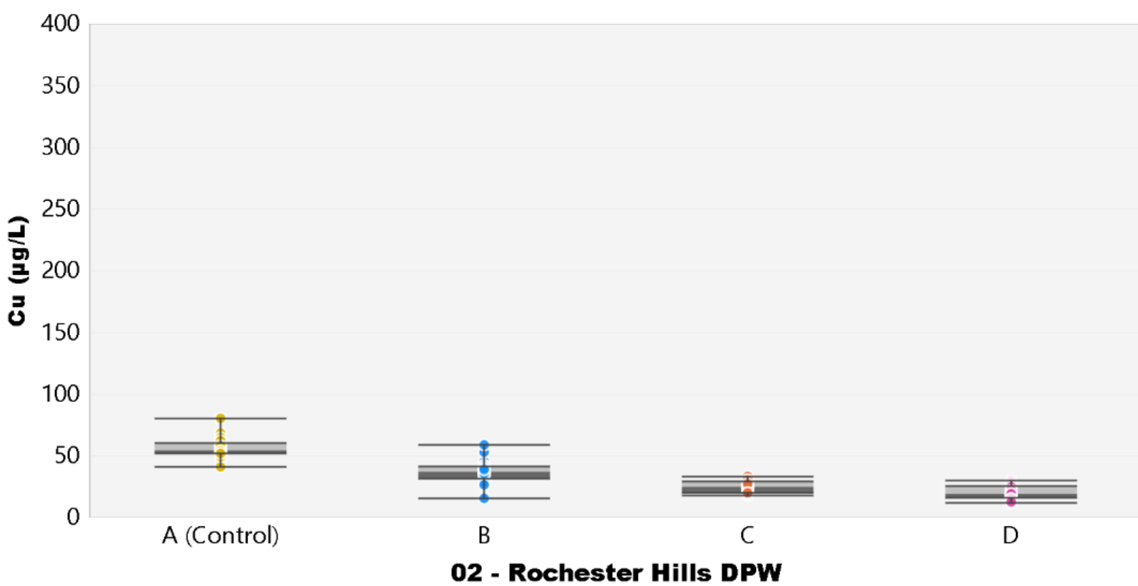


Figure A.3.13: Total Copper Results from Rochester Hills DPW from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

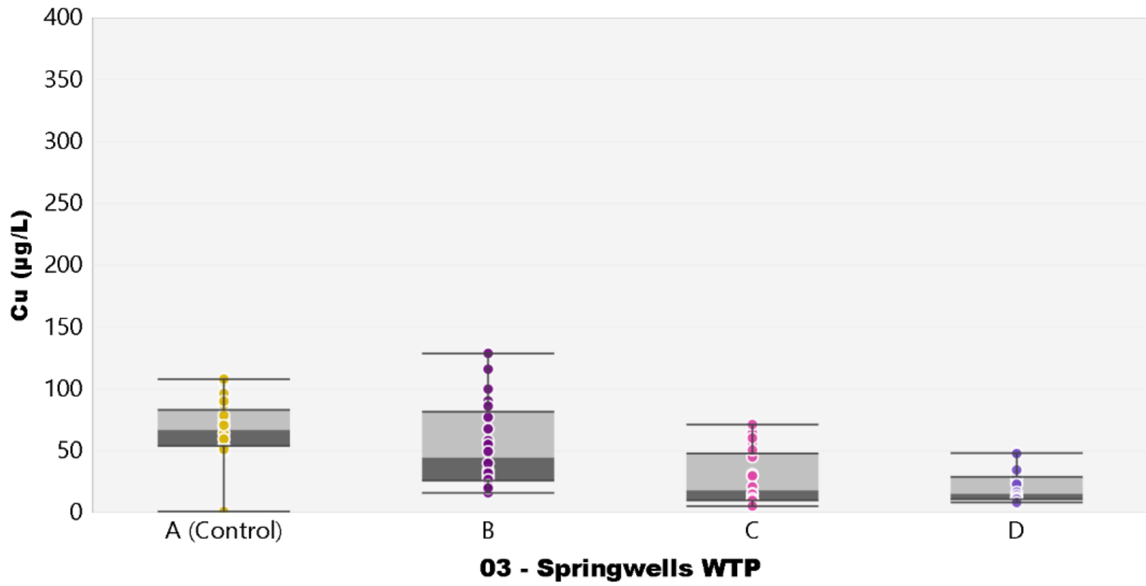


Figure A.3.14: Total Copper Results from Springwells WTP from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (2.0 mg/L, 7.0), Rig C (3.0 mg/L), Rig D (4.0 mg/L, 7.0)

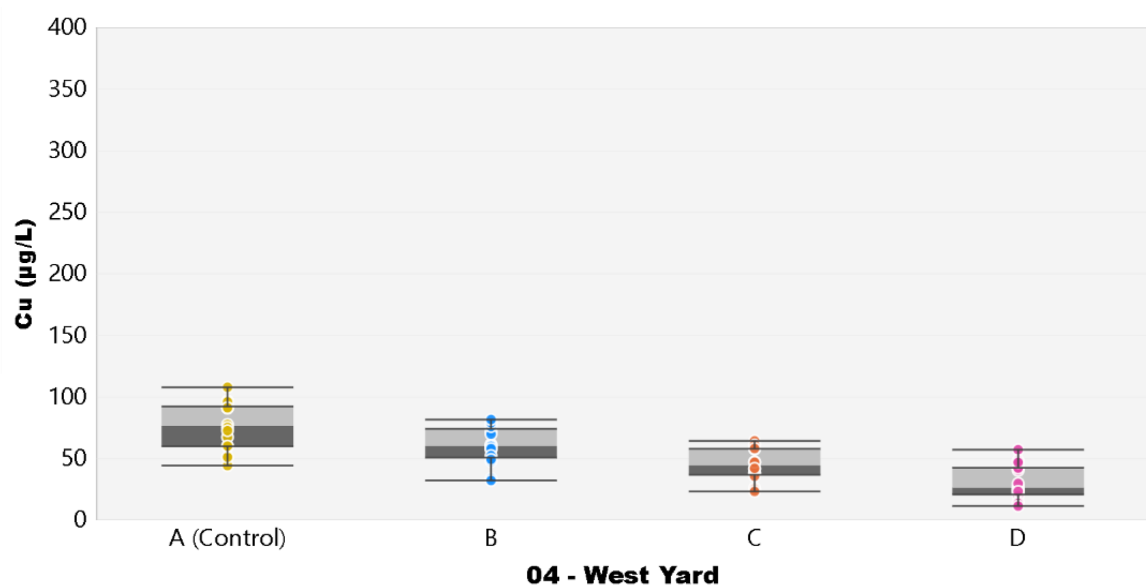


Figure A.3.15: Total Copper Results from West Yard from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

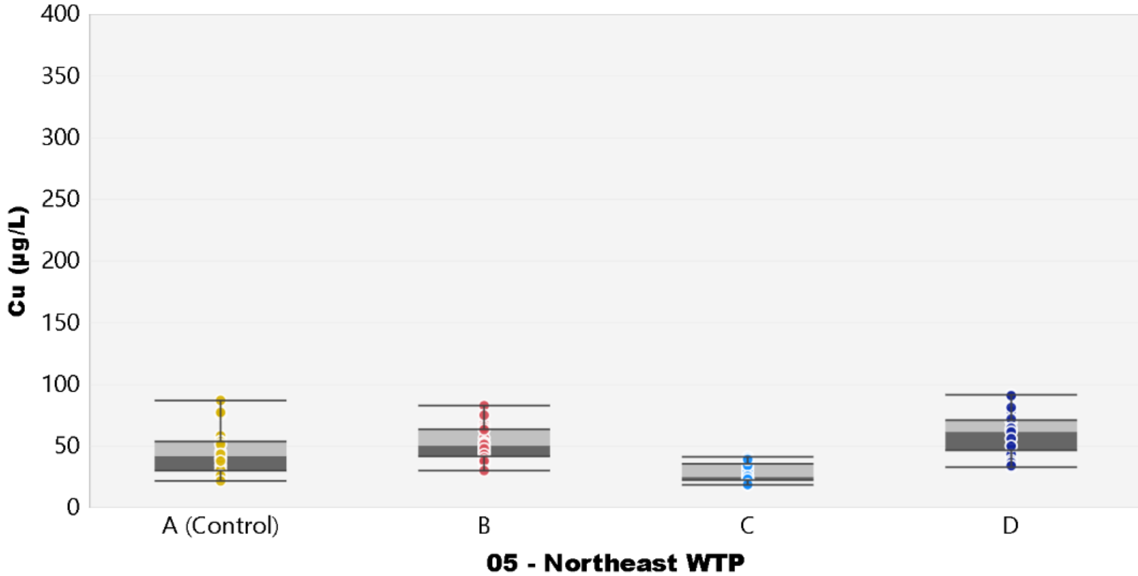


Figure A.3.16: Total Copper Results from Northeast WTP from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (control, 7.0), Rig C (2.0 mg/L), Rig D (2.0 mg/L, 7.0)

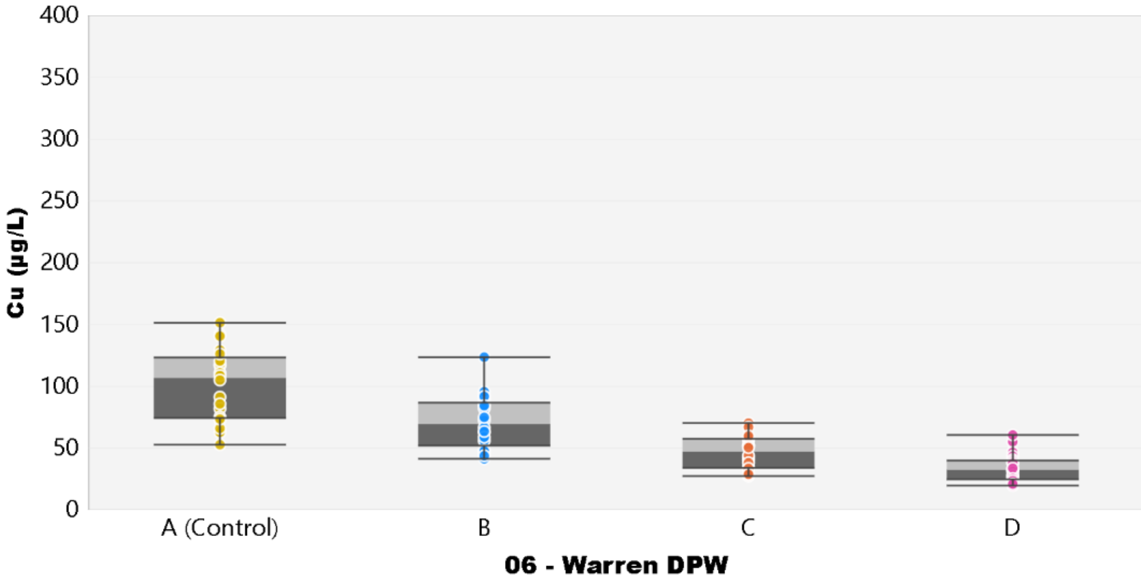


Figure A.3.17: Total Copper Results from Warren DPW from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

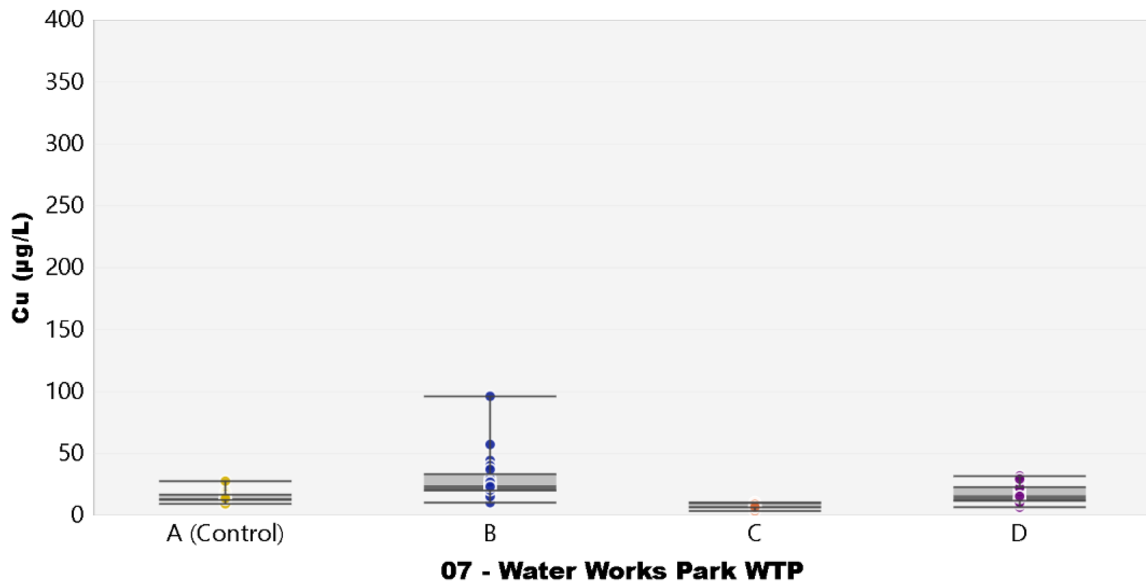


Figure A.3.18: Total Copper Results from Water Works Park WTP from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (2.0, 7.0), Rig C (3.0 mg/L), Rig D (3.0 mg/L, 7.0)

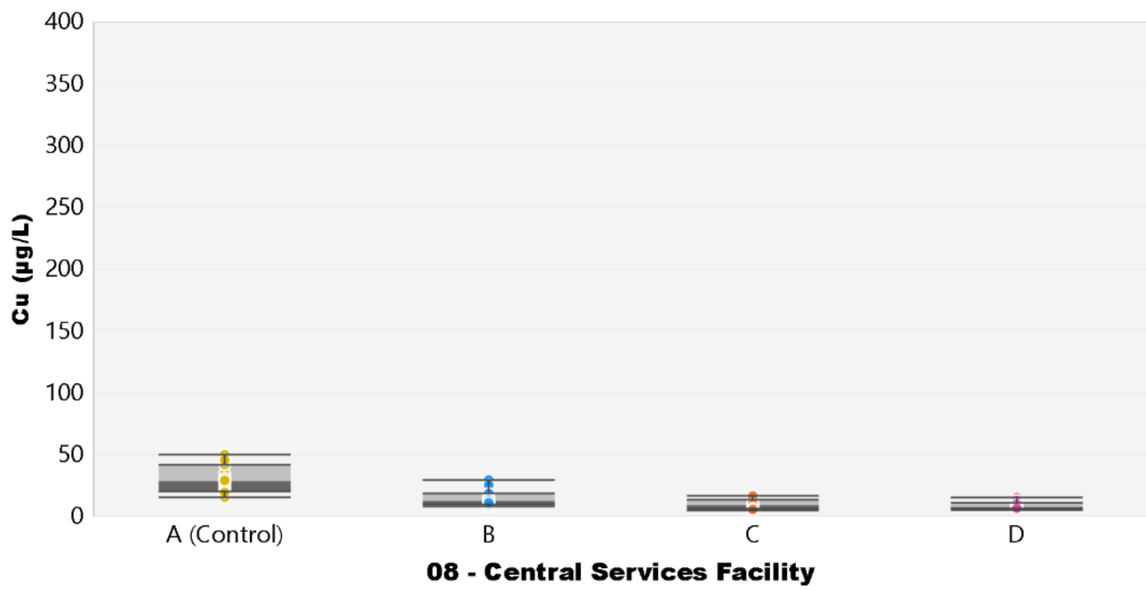


Figure A.3.19: Total Copper Results from Central Services Facility from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

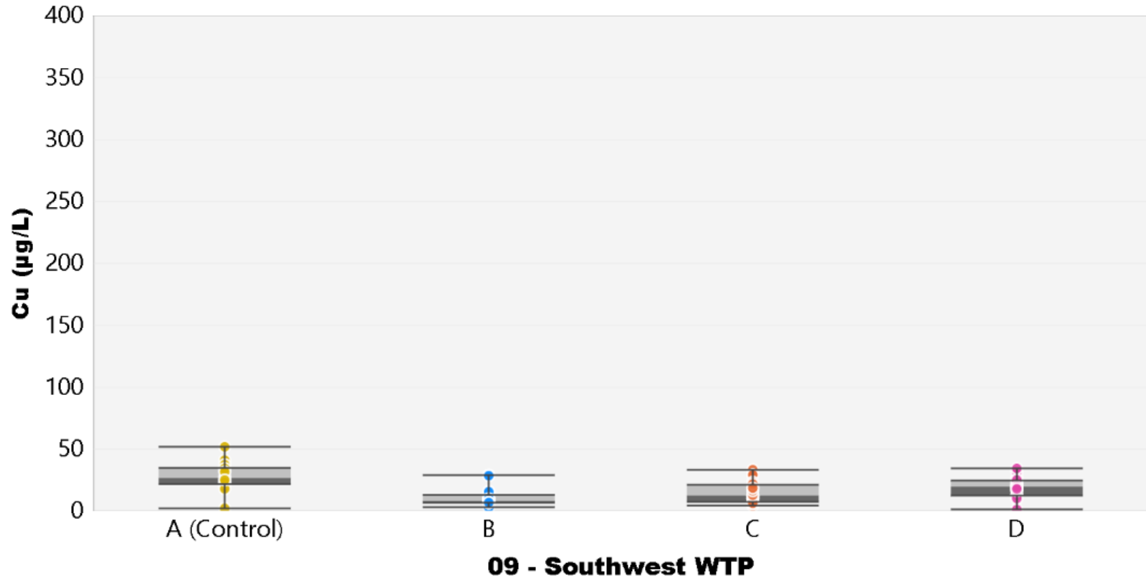


Figure A.3.20: Total Copper Results from Southwest WTP from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

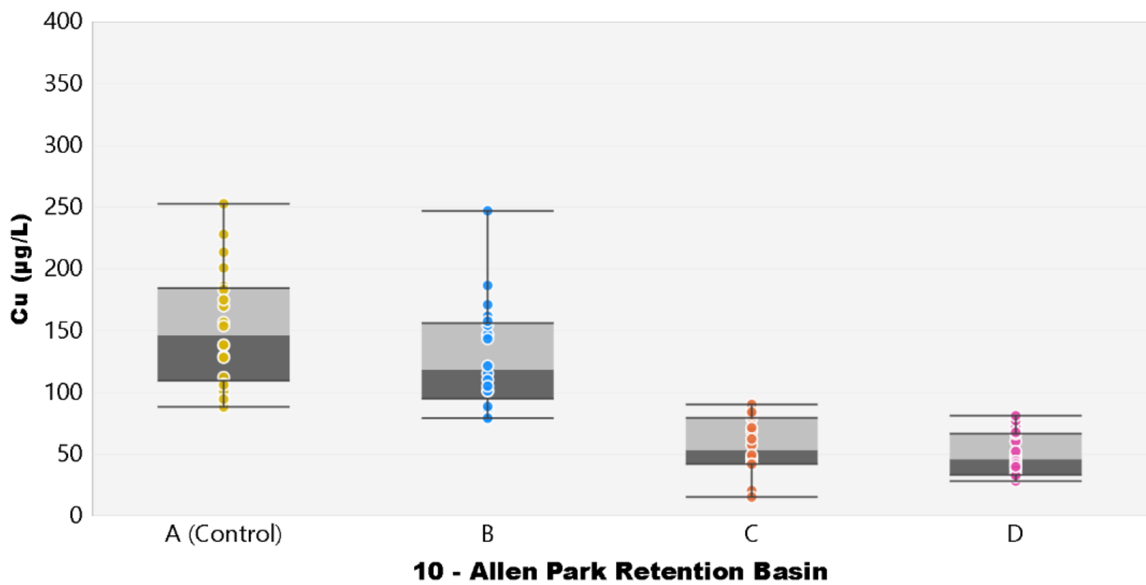


Figure A.3.21: Total Copper Results from Allen Park Retention Basin from Brass Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

A.4 Copper Pipe with Leaded Solder

A.4.1 Total lead results from copper pipes with leaded solder

Table A.4.1: Wilcoxon Rank-sum Comparison Summary by Orthophosphate Dose for Total Lead Levels from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Dose Comparison[1] ($o-PO_4$ Dose)	Did the higher dose results in statistically lower total lead concentrations?										
	AP	CS	LH	RH	SW	WA	WY	NE	WW	SP	Percent Performance
Control vs 2.0	No	No	No	Yes	No	Yes	Yes	No			29%
Control vs 3.0	Yes	No	No	Yes	Yes	No	Yes		No		57%
Control vs 4.0	No	No	Yes	Yes	No	Yes	No			Yes	57%
2.0 vs 3.0	Yes	No	No	No	Yes	No	No				33%
2.0 vs 4.0	Yes	No	No	No	No	Yes	No				33%
3.0 vs 4.0	No	No	No	Yes	No	Yes	No				33%

[1] "Control" indicates finished water as received, measured as 1.31 mg/L as $o-PO_4$ across all control rigs during the statistical analysis period.
Blank cells indicate that a specific comparison did not exist at that site, for acid-adjusted sites only.
The "Percent Performance" column indicates the percentage of sites for which the latter dose in the compared pair was statistically preferred.

Table A.4.2: Wilcoxon Rank-sum Comparison Summary by Orthophosphate Dose and pH Condition for Total Lead Levels from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Comparison ($o\text{-}PO_4$/pH)	Did the second dose results in statistically lower total lead concentrations?		
	NE	WW	SP
Control/7 vs Control	Yes		
Control/7 vs 2.0/7	No		
2.0/7 vs 2.0	Yes		
3.0/7 vs 3.0		No	
4.0/7 vs 4.0			No
2.0/7 vs 3.0 /7		Yes	
3.0/7 vs 4.0/7			Yes

[1] "Control" indicates finished water as received, measured as 1.31 mg/L as $o\text{-}PO_4$ across all control rigs during the statistical analysis period. Blank cells indicate that a specific comparison did not exist at that site, for acid-adjusted sites only.

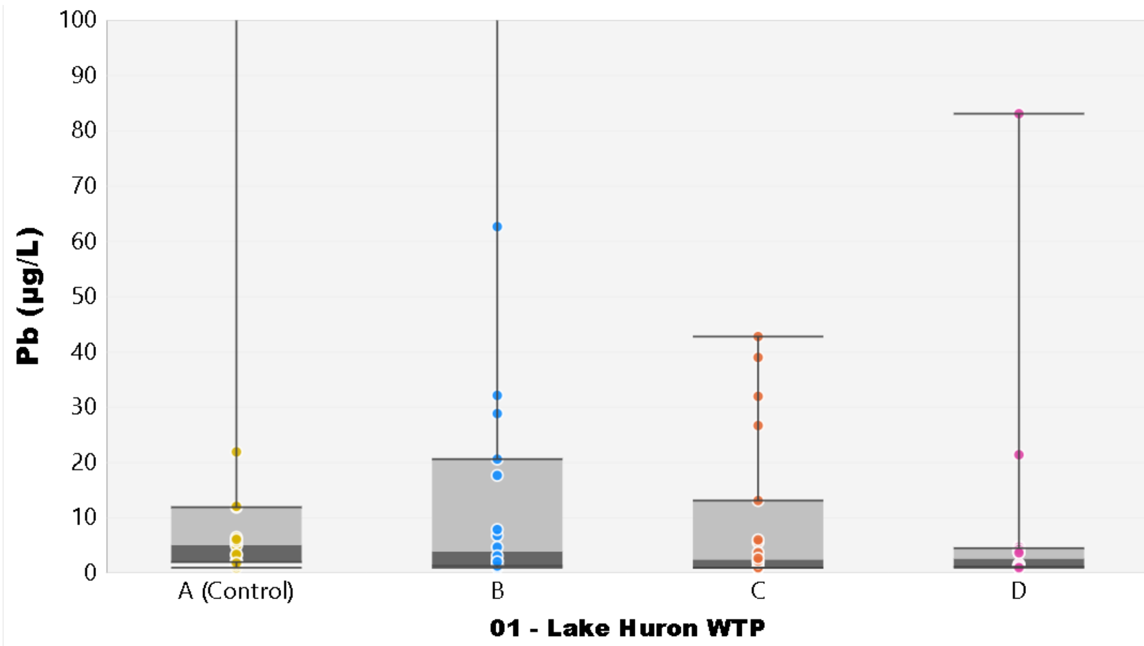


Figure A.4.1: Total Lead Results from Lake Huron WTP from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

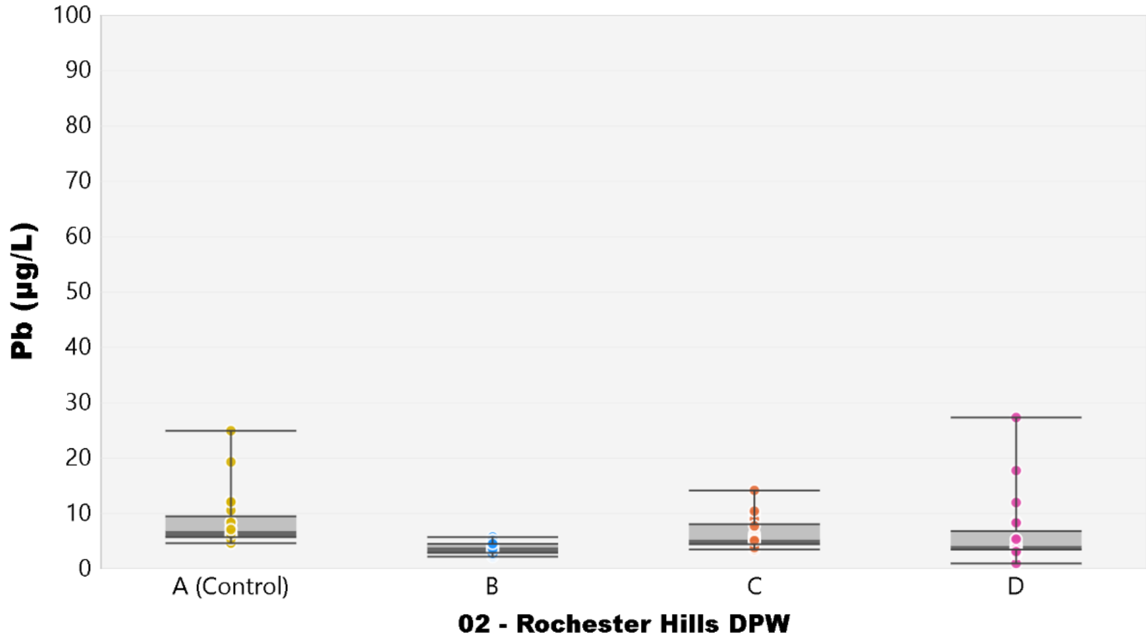


Figure A.4.2: Total Lead Results from Rochester Hills DPW from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

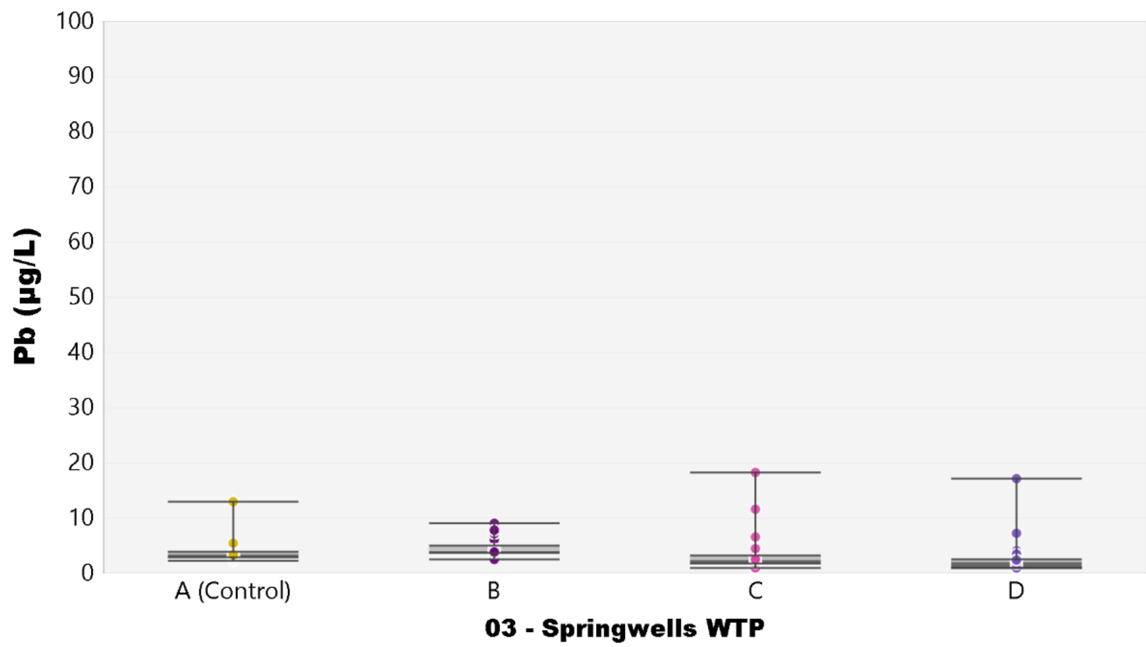


Figure A.4.3: Total Lead Results from Springwells WTP from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (2.0 mg/L, 7.0), Rig C (3.0 mg/L), Rig D (4.0 mg/L, 7.0)

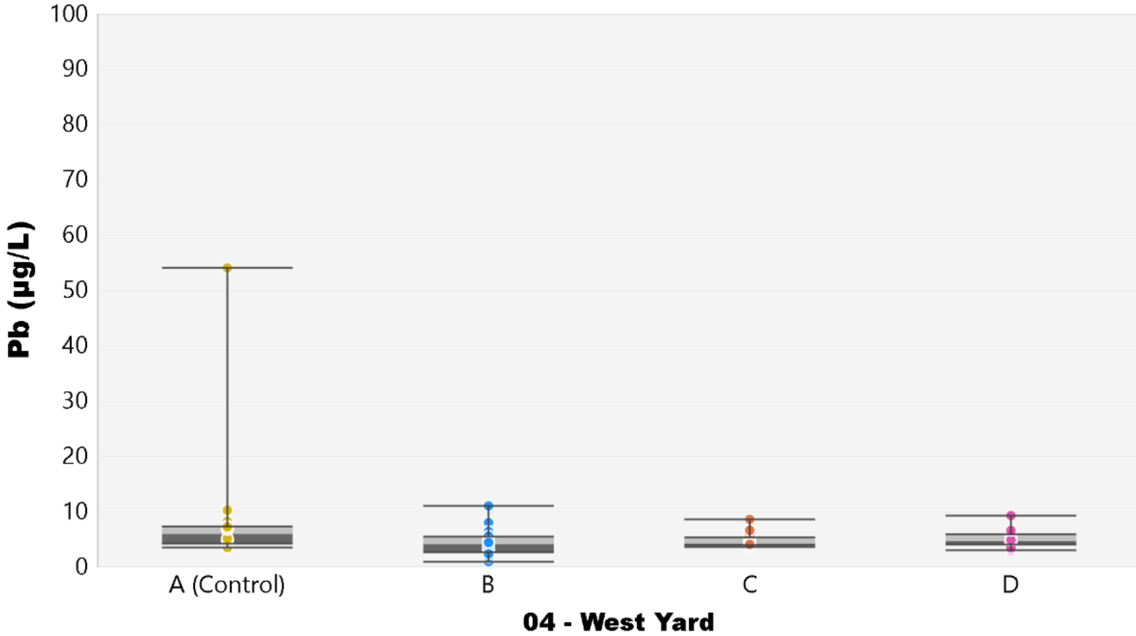


Figure A.4.4: Total Lead Results from West Yard from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

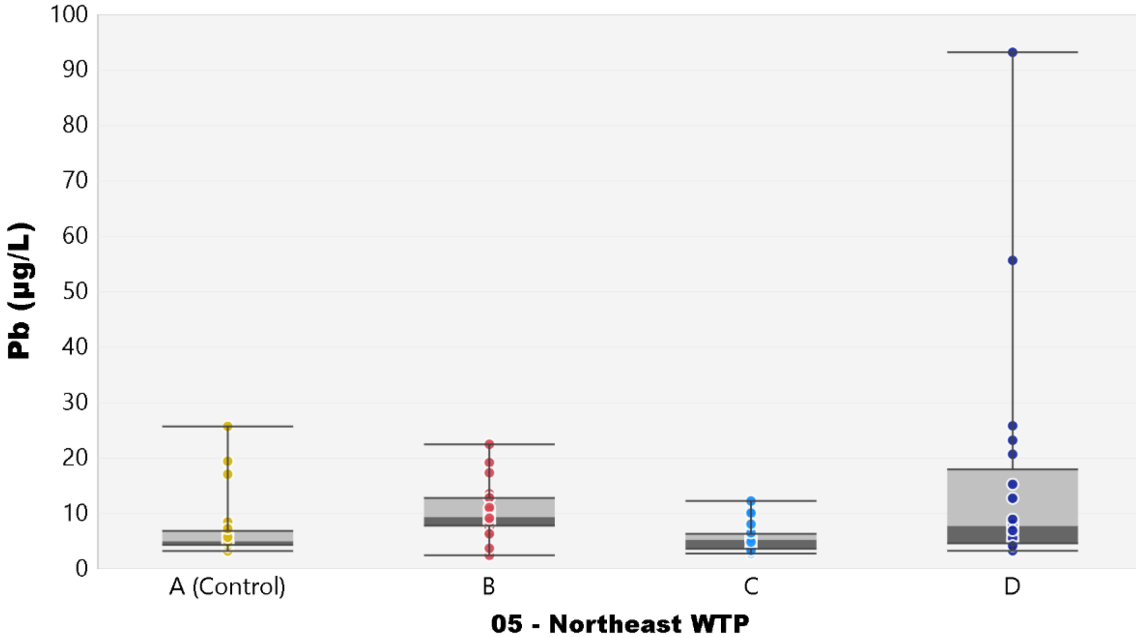


Figure A.4.5: Total Lead Results from Northeast WTP from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (control, 7.0), Rig C (2.0 mg/L), Rig D (2.0 mg/L, 7.0)

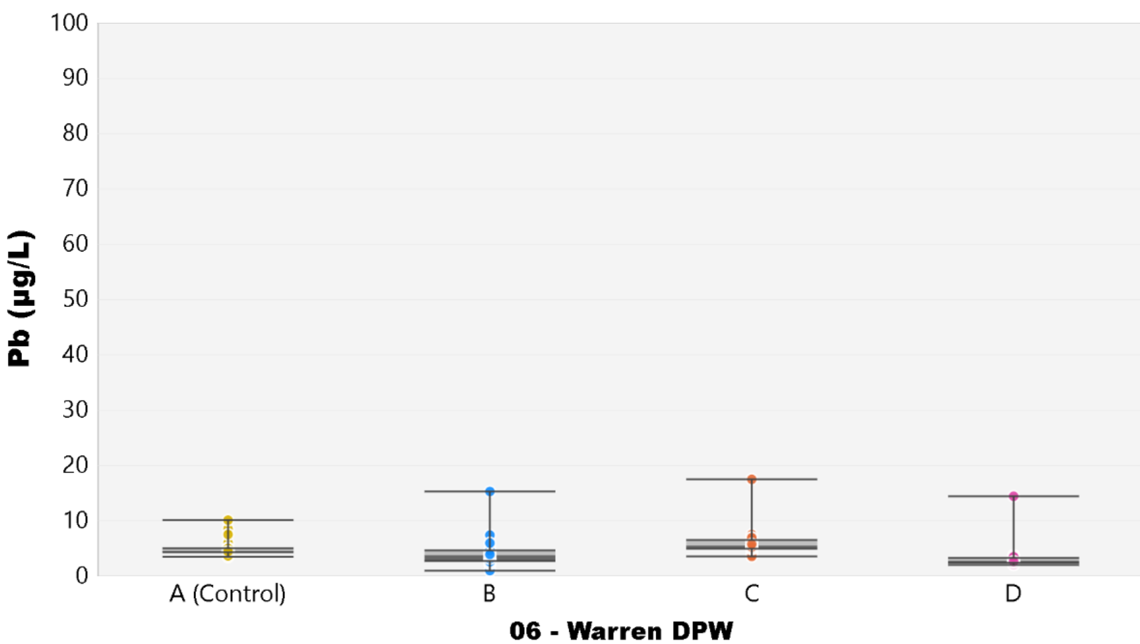


Figure A.4.6: Total Lead Results from Warren DPW from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

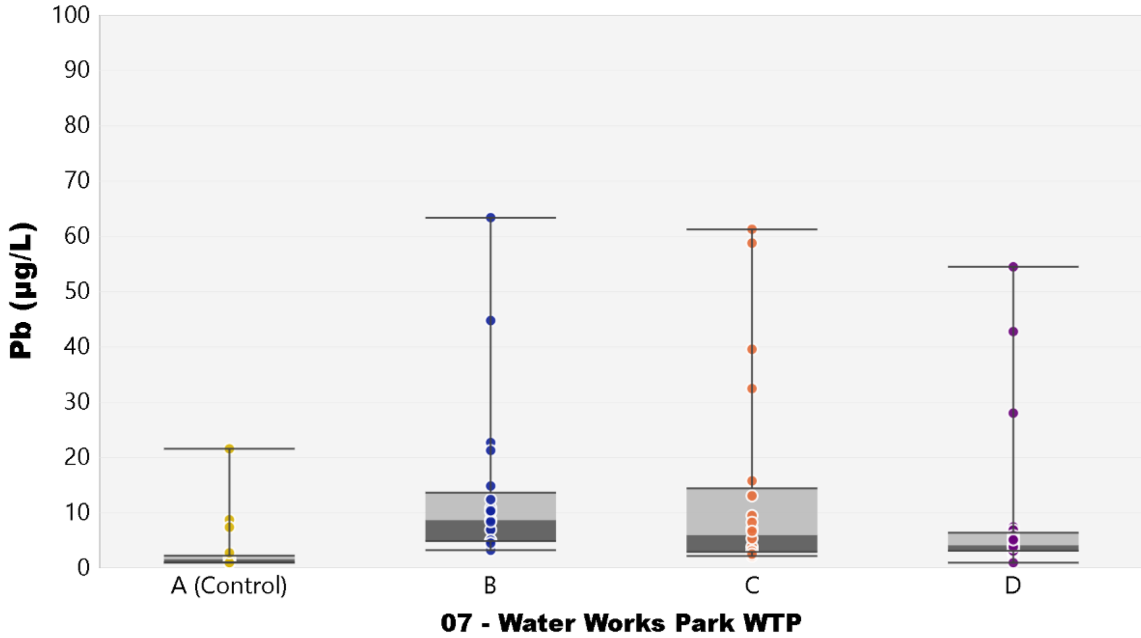


Figure A.4.7: Total Lead Results from Water Works Park WTP from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (2.0, 7.0), Rig C (3.0 mg/L), Rig D (3.0 mg/L, 7.0)

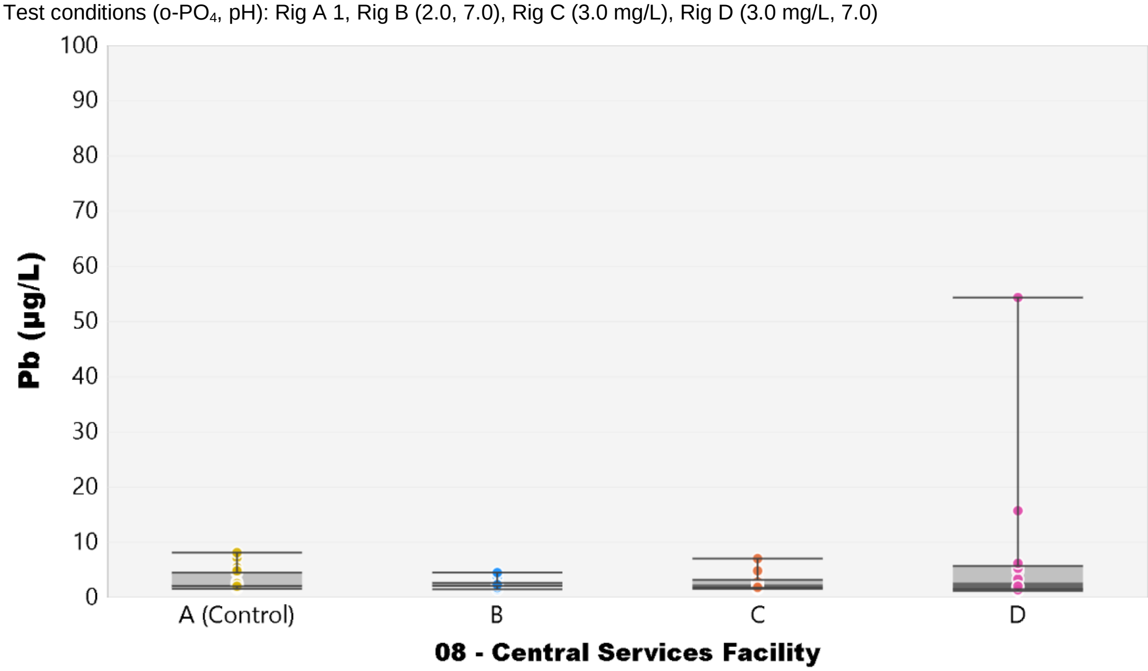


Figure A.4.8: Total Lead Results from Central Services Facility from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

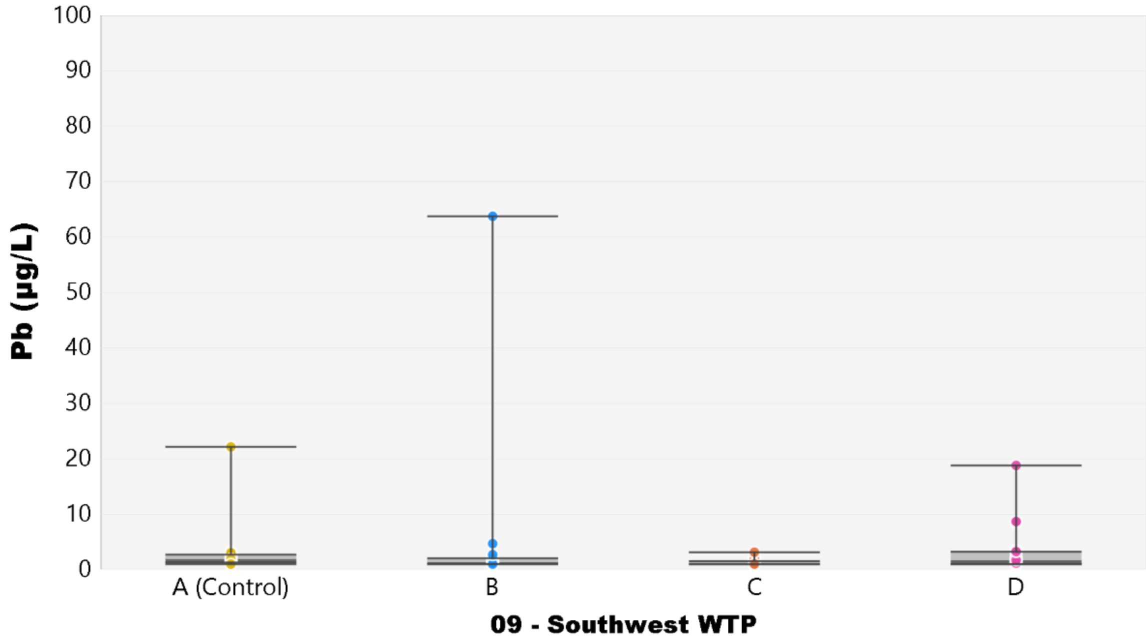


Figure A.4.9: Total Lead Results from Southwest WTP from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

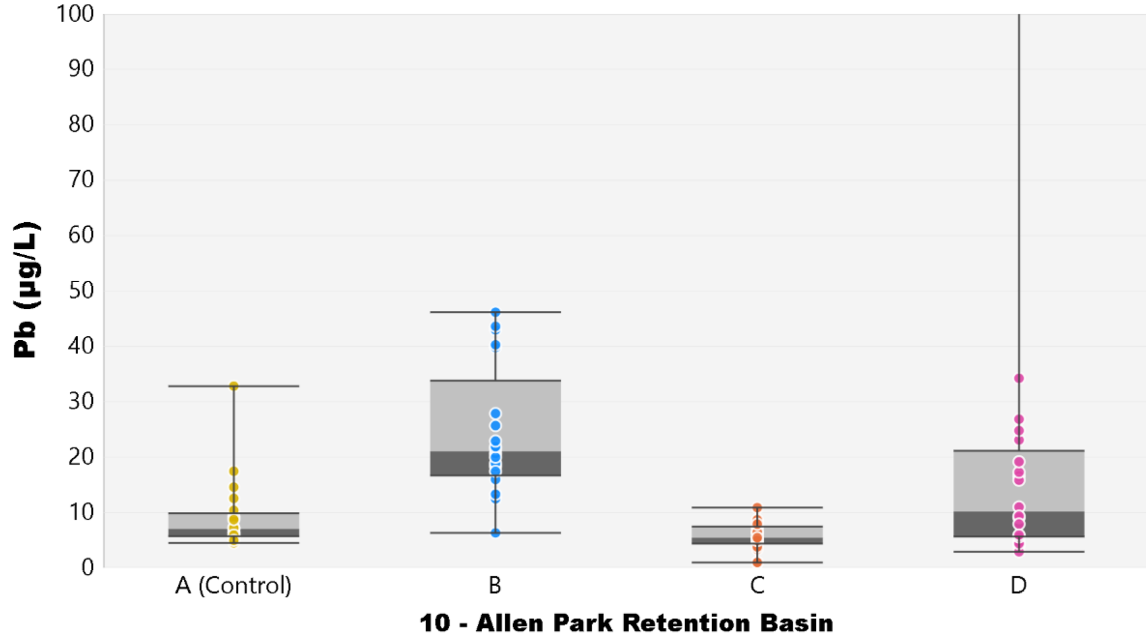


Figure A.4.10: Total Lead Results from Allen Park Retention Basin from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

A.4.2 Total copper results from copper pipes with leaded solder

Figure A.4.11 below shows the total copper levels from copper pipes with leaded solder, aggregated across sites by o-PO_4 dose, for the representative 10-sample set. The results of the Wilcoxon rank-sum comparisons between aggregated o-PO_4 doses are further displayed in Table A.4.3 below.

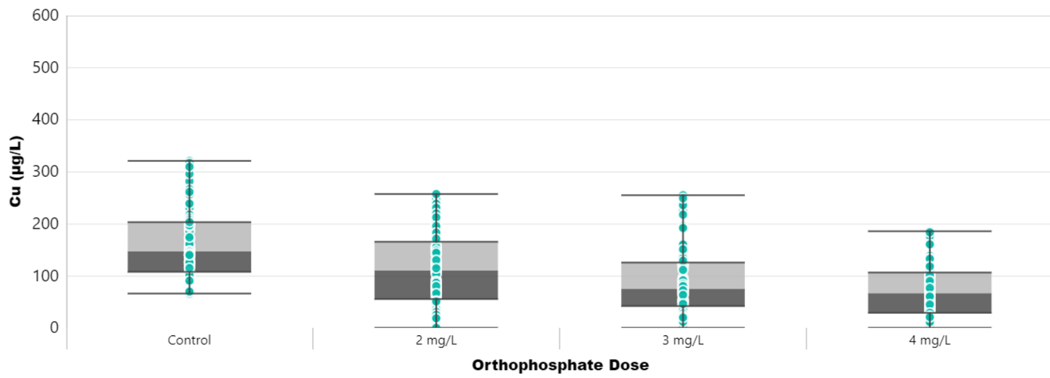


Figure A.4.11: Total Copper Results for Copper Pipes with Leaded Solder Aggregated Across Sites by o-PO_4 Dose (10-Sample Stability Period)

Table A.4.3: Wilcoxon Rank-sum Comparison Summary by Orthophosphate Dose for Total Copper Levels from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Dose Comparison[1] (o-PO_4 Dose)	Did the higher dose results in statistically lower total lead concentrations?
Control vs 2.0	Yes
Control vs 3.0	Yes
Control vs. 4.0	Yes
2.0 vs 3.0	Yes
2.0 vs 4.0	Yes
3.0 vs 4.0	Yes

[1] "Control" indicates finished water as received, measured as 1.31 mg/L as o-PO_4 across all control rigs during the statistical analysis period.

Table A.4.4: Wilcoxon Rank-sum Comparison Summary by Orthophosphate Dose for Total Lead Levels from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Dose Comparison[1] ($o\text{-}PO_4$ Dose)	Did the higher dose results in statistically lower total lead concentrations?										Percent Performance
	AP	CS	LH	RH	SW	WA	WY	NE	WW	SP	
Control vs 2.0	Yes	Yes	No	Yes	Yes	No	Yes	Yes			75%
Control vs 3.0	Yes	Yes	No	Yes	Yes	Yes	Yes		Yes		88%
Control vs 4.0	Yes	Yes	Yes	Yes	Yes	Yes	Yes			No	88%
2.0 vs 3.0	No	Yes	No	Yes	No	Yes	Yes				57%
2.0 vs 4.0	Yes	Yes	Yes	Yes	No	Yes	Yes				86%
3.0 vs 4.0	Yes	Yes	Yes	Yes	No	No	No				57%

[1] "Control" indicates finished water as received, measured as 1.31 mg/L as $o\text{-}PO_4$ across all control rigs during the statistical analysis period.
Blank cells indicate that a specific comparison did not exist at that site, for acid-adjusted sites only.
The "Percent Performance" column indicates the percentage of sites for which the latter dose in the compared pair was statistically preferred.

Table A.4.5: Wilcoxon Rank-sum Comparison Summary by Orthophosphate Dose and pH Condition for Total Copper Levels from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Comparison ($o\text{-}PO_4$/pH)	Did the second dose results in statistically lower total copper concentrations?		
	NE	WW	SP
Control/7 vs Control	Yes		
Control/7 vs 2.0/7	No		
2.0/7 vs 2.0	Yes		
3.0/7 vs 3.0		No	
4.0/7 vs 4.0			No
2.0/7 vs 3.0 /7		Yes	
3.0/7 vs 4.0/7			No

[1] "Control" indicates finished water as received, measured as 1.31 mg/L as $o\text{-}PO_4$ across all control rigs during the statistical analysis period. Blank cells indicate that a specific comparison did not exist at that site, for acid-adjusted sites only.

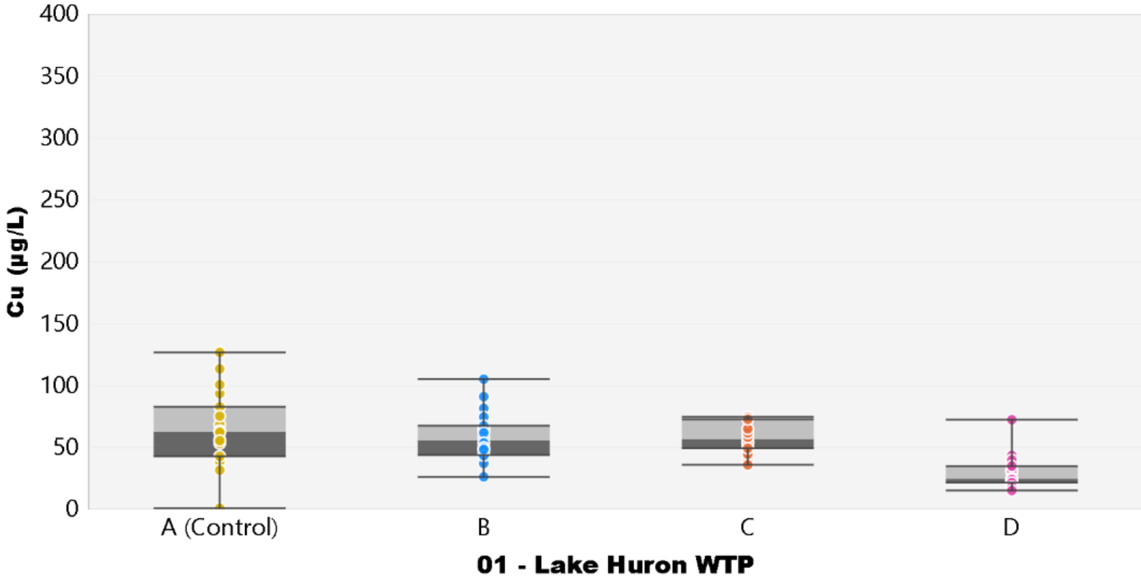


Figure A.4.12: Total Copper Results from Lake Huron WTP from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

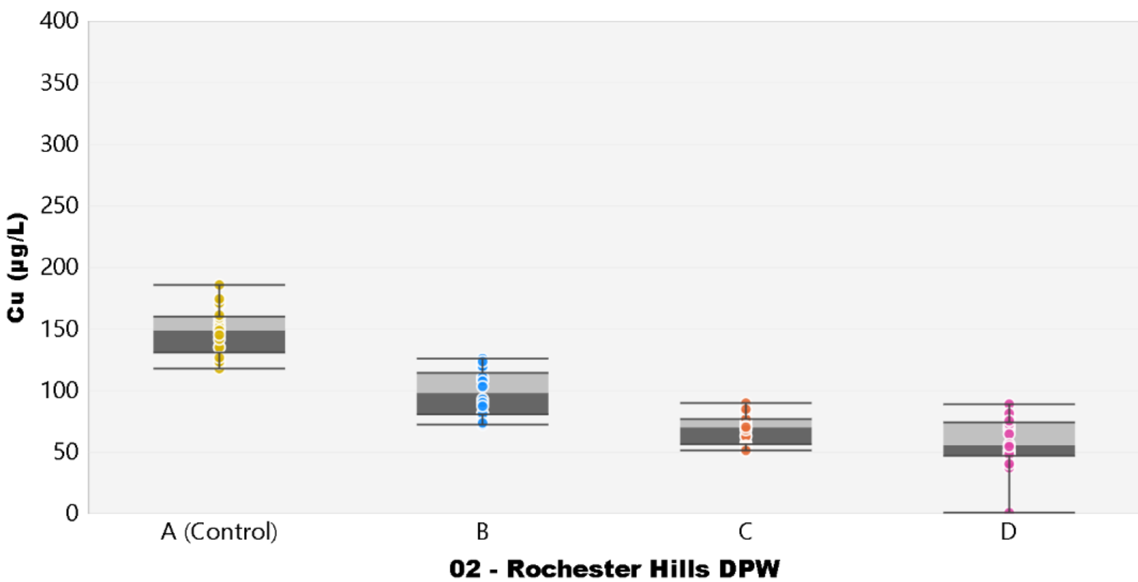


Figure A.4.13: Total Copper Results from Rochester Hills DPW from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

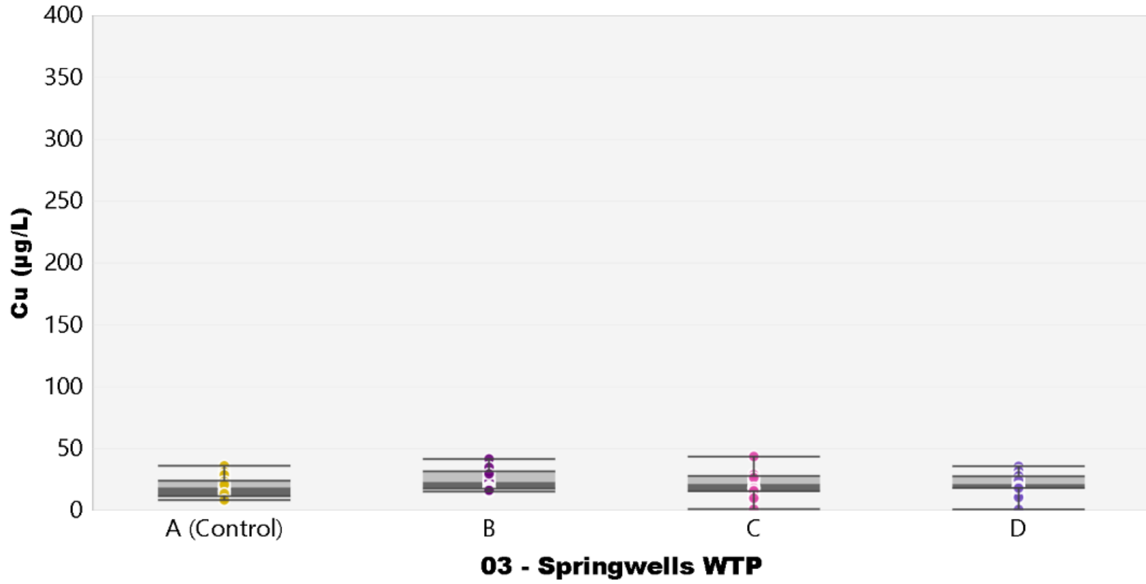


Figure A.4.14: Total Copper Results from Springwells WTP from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (2.0 mg/L, 7.0), Rig C (3.0 mg/L), Rig D (4.0 mg/L, 7.0)

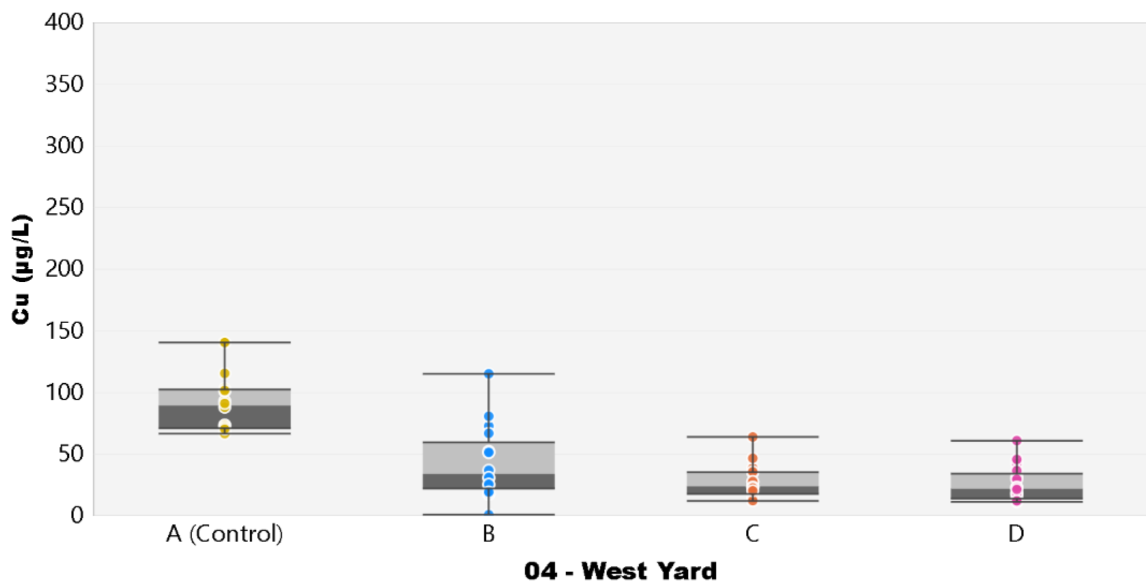


Figure A.4.15: Total Copper Results from West Yard from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

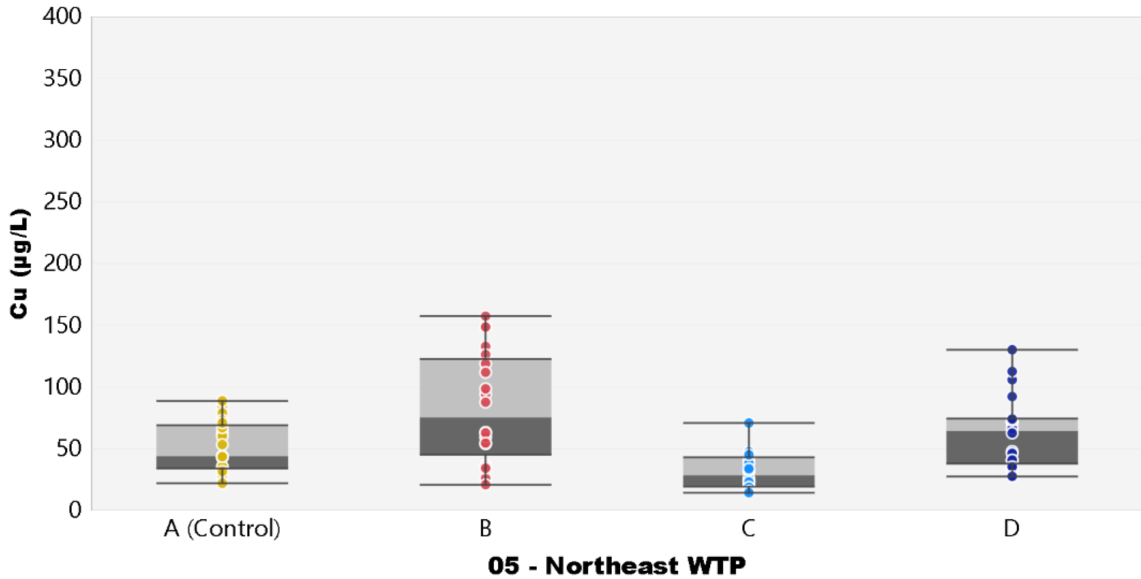


Figure A.4.16: Total Copper Results from Northeast WTP from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (control, 7.0), Rig C (2.0 mg/L), Rig D (2.0 mg/L, 7.0)

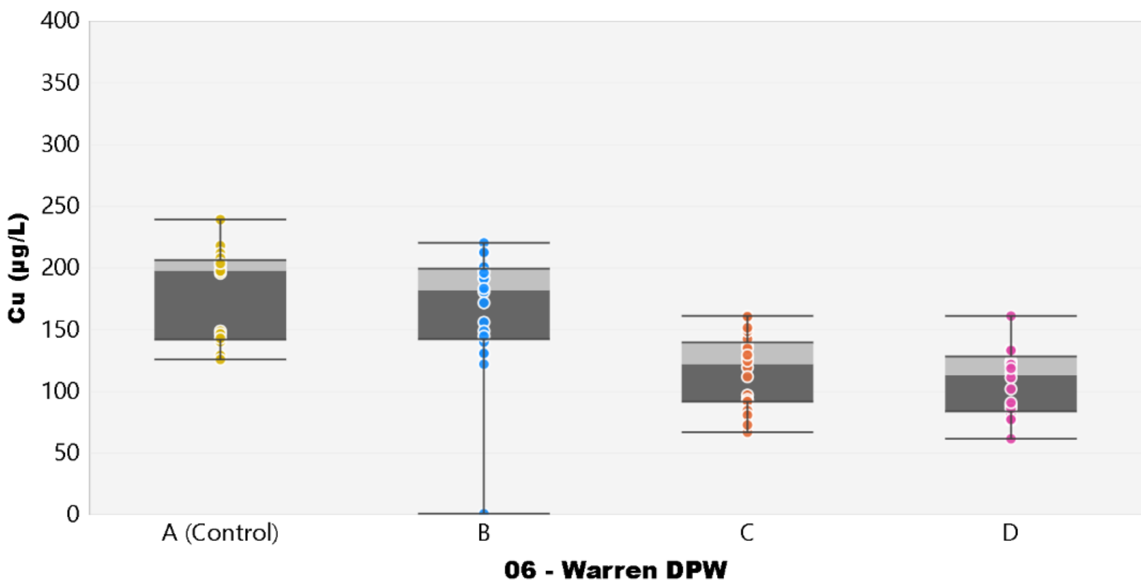


Figure A.4.17: Total Copper Results from Warren DPW from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

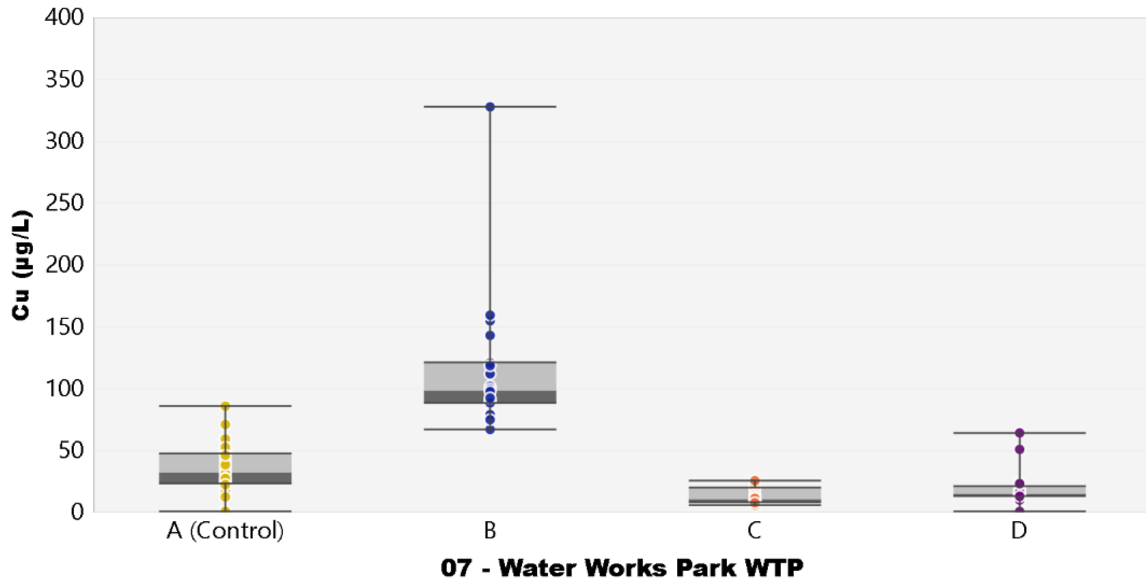


Figure A.4.18: Total Copper Results from Water Works Park WTP from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (2.0, 7.0), Rig C (3.0 mg/L), Rig D (3.0 mg/L, 7.0)

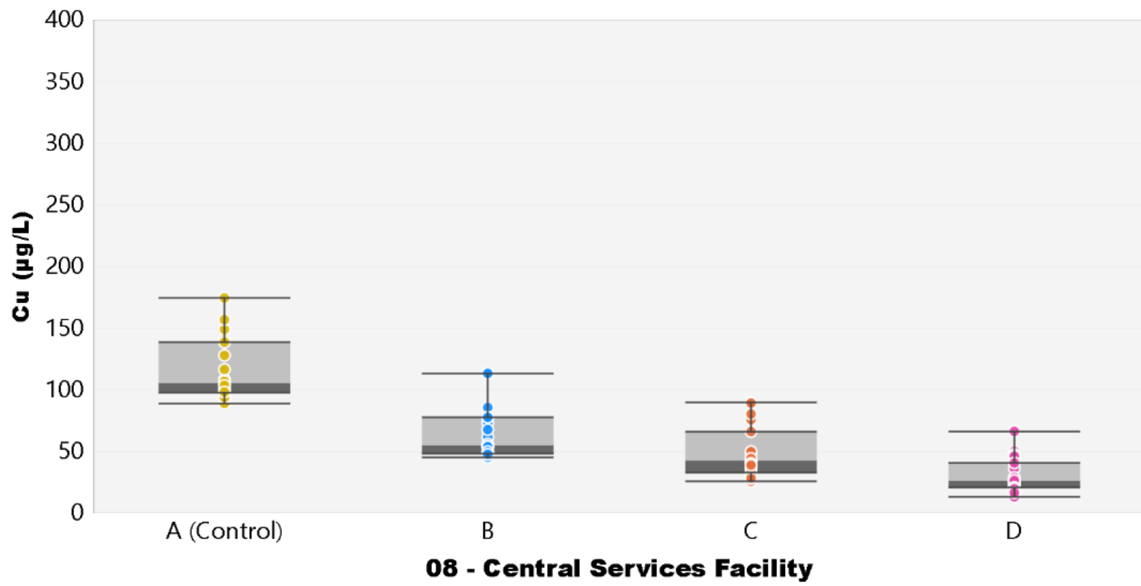


Figure A.4.19: Total Copper Results from Central Services Facility from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

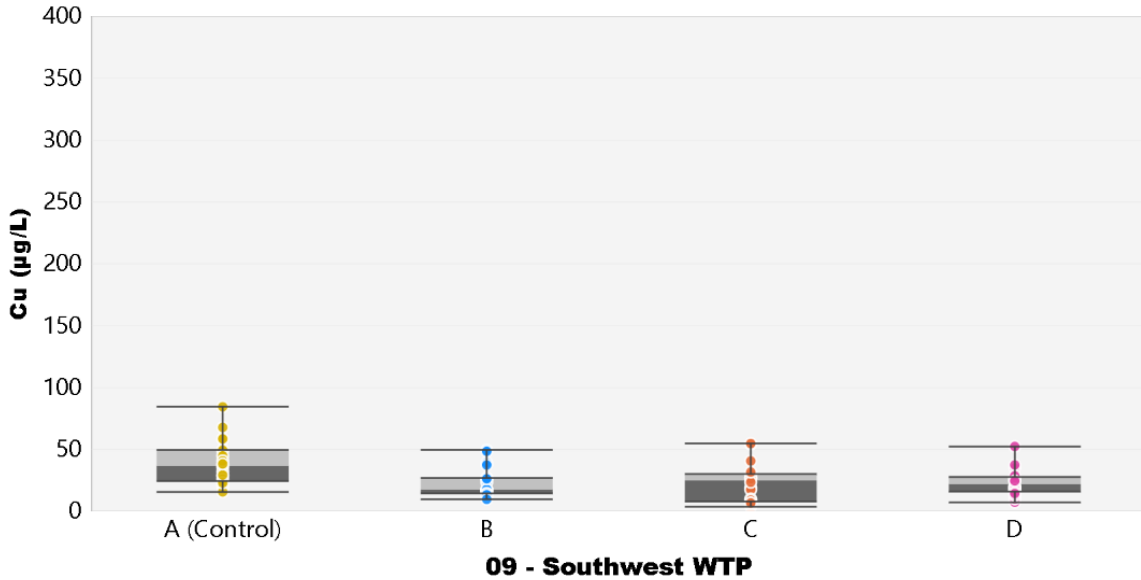


Figure A.4.20: Total Copper Results from Southwest WTP from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

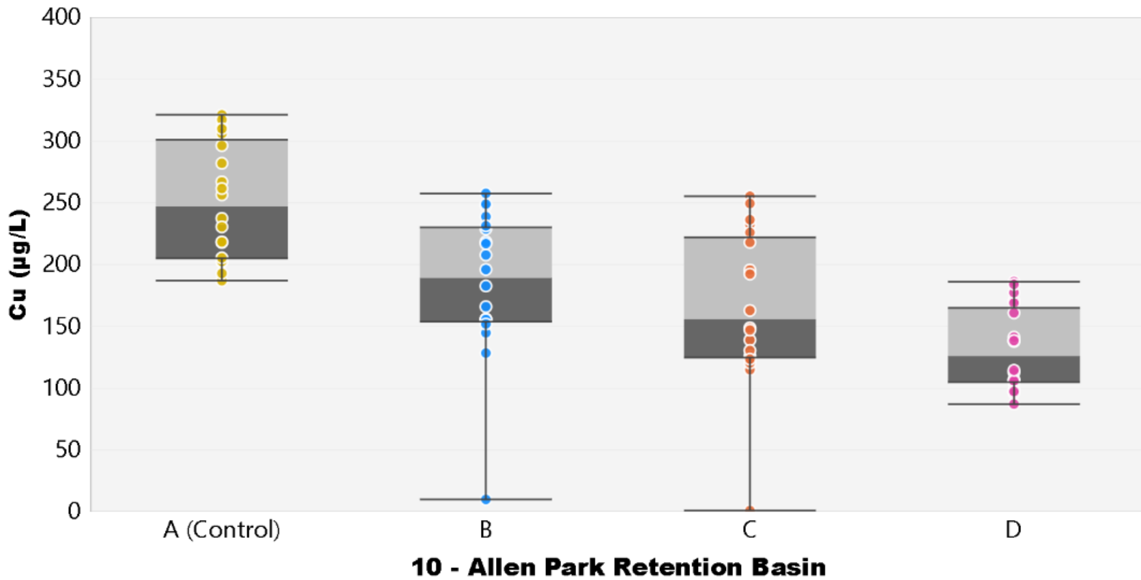


Figure A.4.21: Total Copper Results from Allen Park Retention Basin from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

A.5 Copper Pipe

A.5.1 Total copper results from copper pipes

Table A.5.1: Wilcoxon Rank-sum Comparison Summary by Orthophosphate Dose for Total Lead Levels from Copper-Lead Solder Test Pieces (10-Sample Stability Period)

Dose Comparison[1] (o-PO_4 Dose)	Did the higher dose results in statistically lower total lead concentrations?										
	AP	CS	LH	RH	SW	WA	WY	NE	WW	SP	Percent Performance
Control vs 2.0	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes			88%
Control vs 3.0	Yes	Yes	Yes	Yes	No	Yes	Yes		No		75%
Control vs 4.0	Yes	Yes	Yes	Yes	No	Yes	Yes			Yes	88%
2.0 vs 3.0	Yes	Yes	Yes	No	No	Yes	No				57%
2.0 vs 4.0	Yes	Yes	Yes	Yes	No	Yes	Yes				86%
3.0 vs 4.0	Yes	Yes	No	Yes	Yes	Yes	Yes				86%

[1] "Control" indicates finished water as received, measured as 1.31 mg/L as o-PO_4 across all control rigs during the statistical analysis period.
Blank cells indicate that a specific comparison did not exist at that site, for acid-adjusted sites only.
The "Percent Performance" column indicates the percentage of sites for which the latter dose in the compared pair was statistically preferred.

Table A.5.2: Wilcoxon Rank-sum Comparison Summary by Orthophosphate Dose and pH Condition for Total Copper Levels from Copper Test Pieces (10-Sample Stability Period)

Comparison ($o\text{-}PO_4$/pH)	Did the second dose results in statistically lower total copper concentrations?		
	NE	WW	SP
Control/7 vs Control	Yes		
Control/7 vs 2.0/7	No		
2.0/7 vs 2.0	Yes		
3.0/7 vs 3.0		Yes	
4.0/7 vs 4.0			No
2.0/7 vs 3.0 /7		Yes	
3.0/7 vs 4.0/7			Yes

[1] "Control" indicates finished water as received, measured as 1.31 mg/L as $o\text{-}PO_4$ across all control rigs during the statistical analysis period. Blank cells indicate that a specific comparison did not exist at that site, for acid-adjusted sites only.

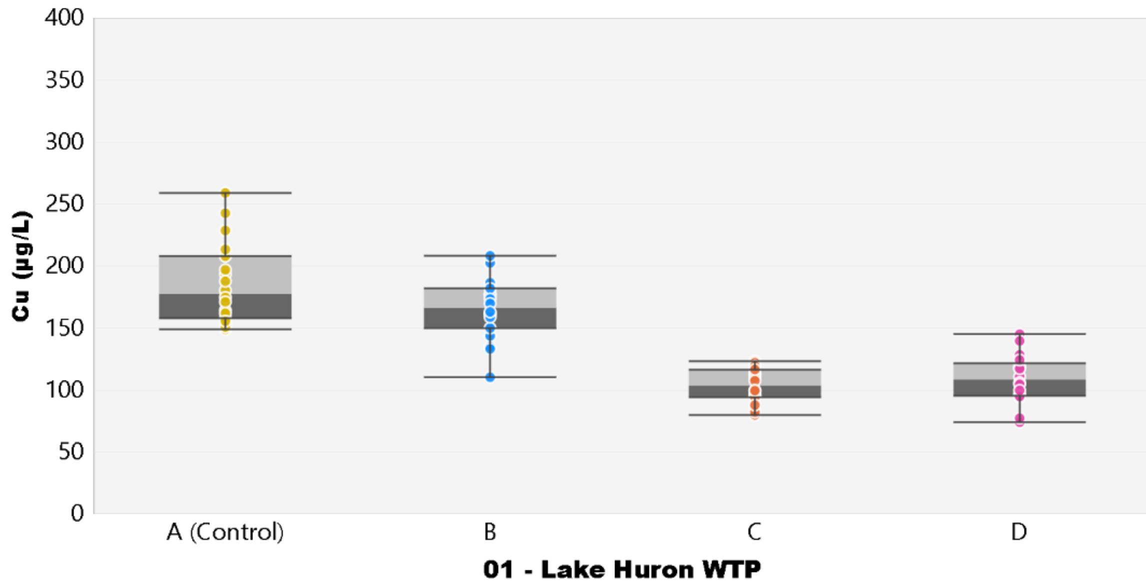
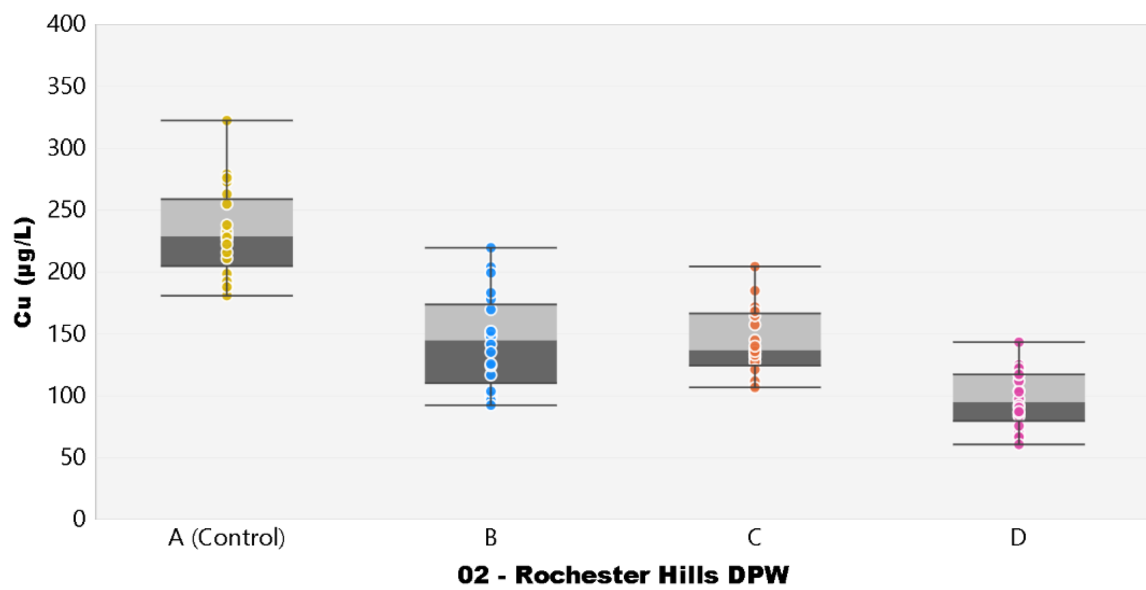


Figure A.5.1: Total Copper Results from Lake Huron WTP from Copper Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)



Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

Figure A.5.2: Total Copper Results from Rochester Hills DPW from Copper Test Pieces (10-Sample Stability Period)

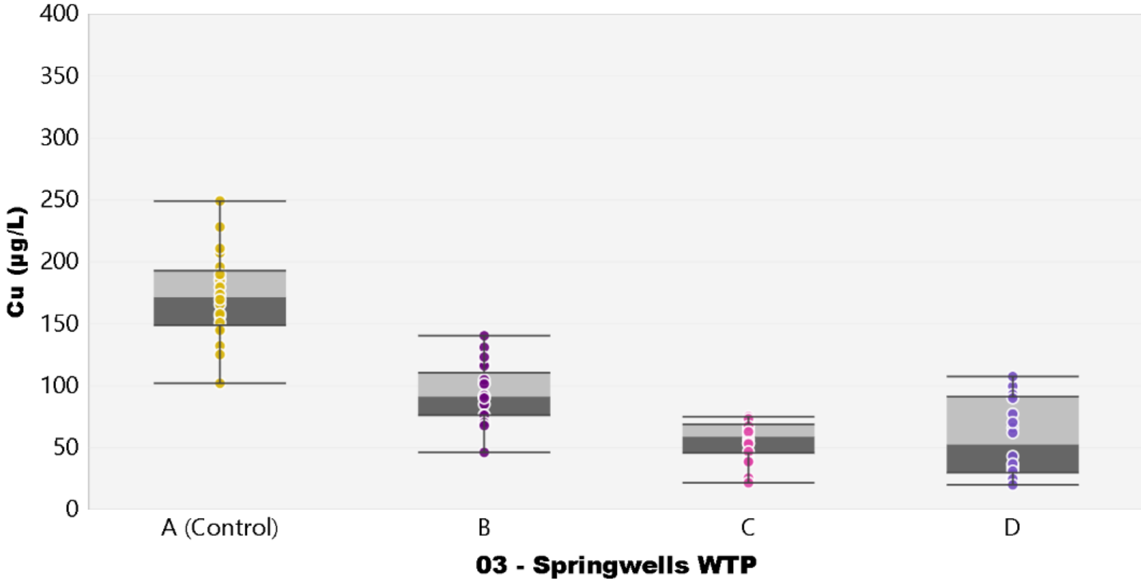


Figure A.5.3: Total Copper Results from Springwells WTP from Copper Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (2.0 mg/L, 7.0), Rig C (3.0 mg/L), Rig D (4.0 mg/L, 7.0)

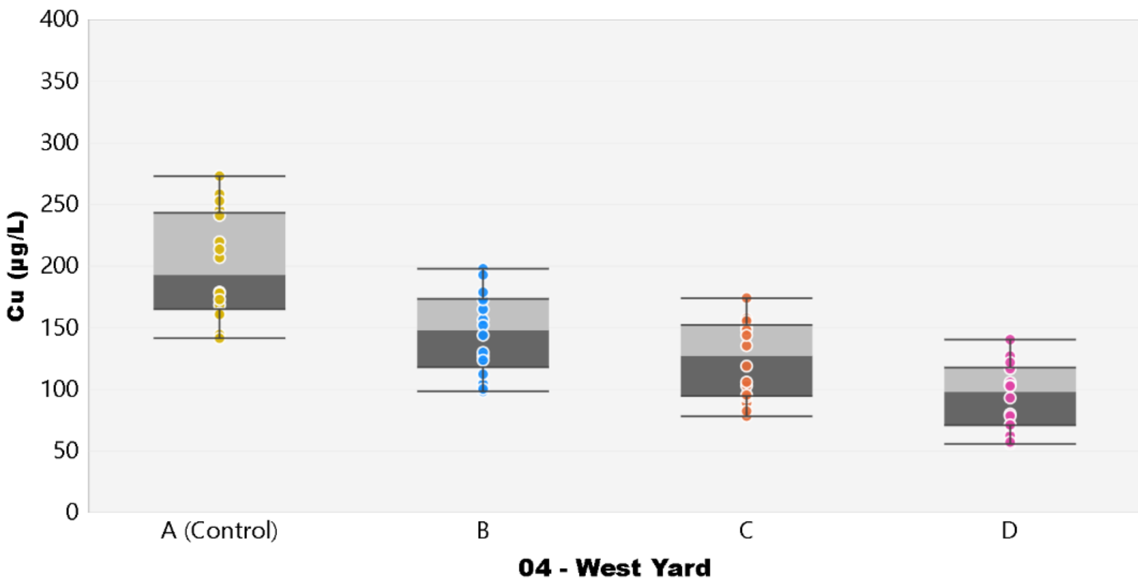


Figure A.5.4: Total Copper Results from West Yard from Copper Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

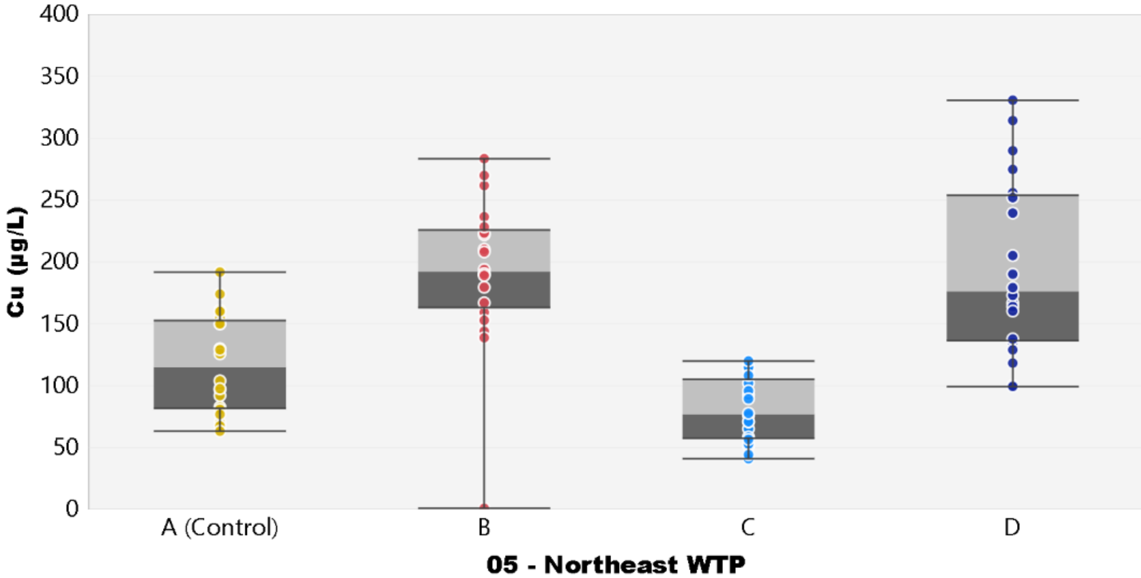


Figure A.5.5: Total Copper Results from Northeast WTP from Copper Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (control, 7.0), Rig C (2.0 mg/L), Rig D (2.0 mg/L, 7.0)

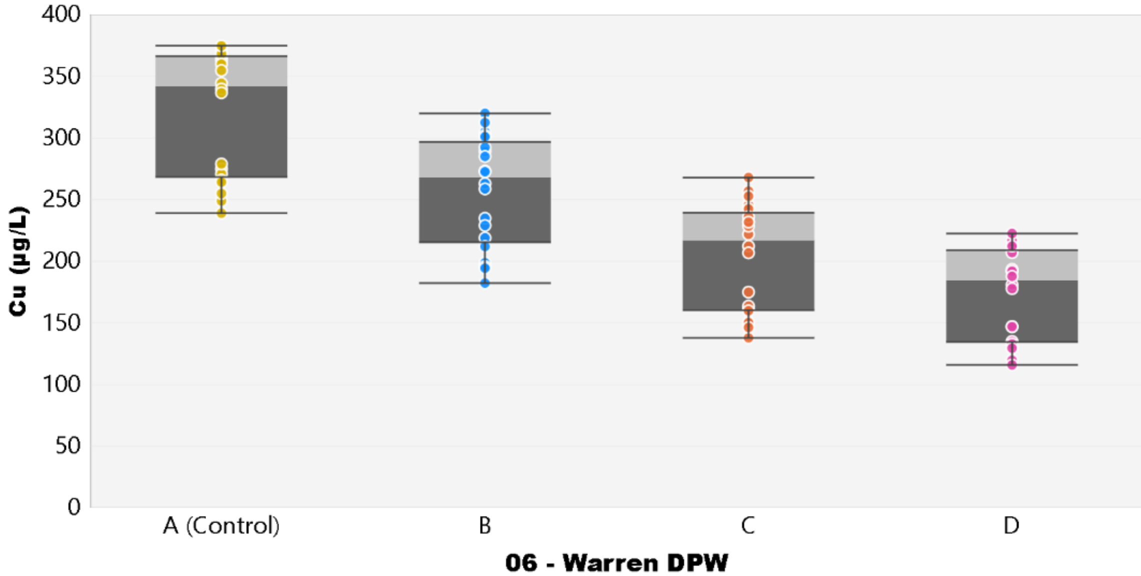


Figure A.5.6: Total Copper Results from Warren DPW from Copper Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

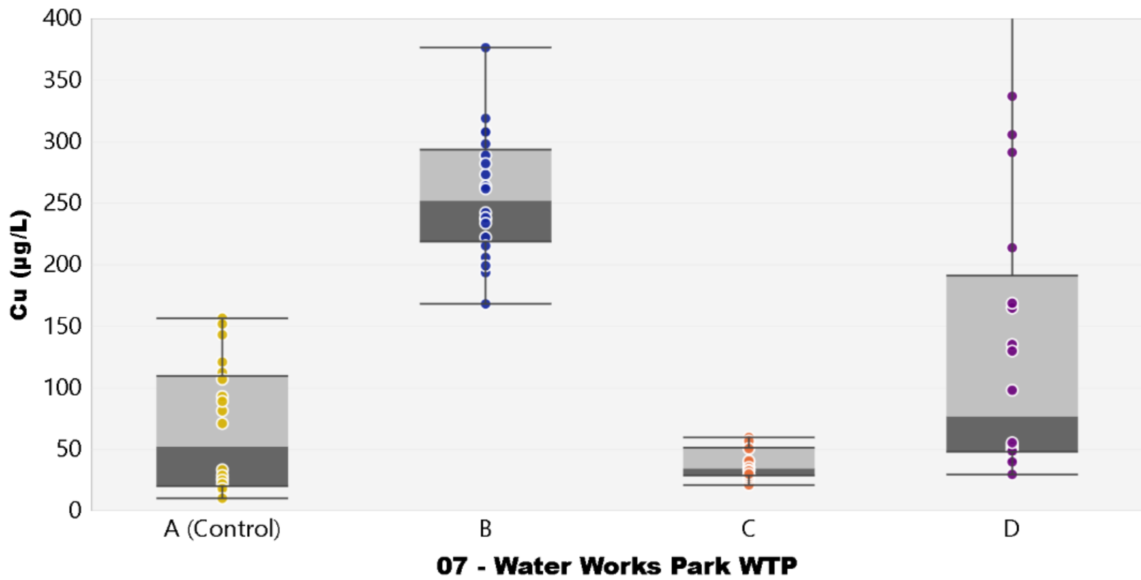


Figure A.5.7: Total Copper Results from Water Works Park WTP from Copper Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4, pH): Rig A 1, Rig B (2.0, 7.0), Rig C (3.0 mg/L), Rig D (3.0 mg/L, 7.0)

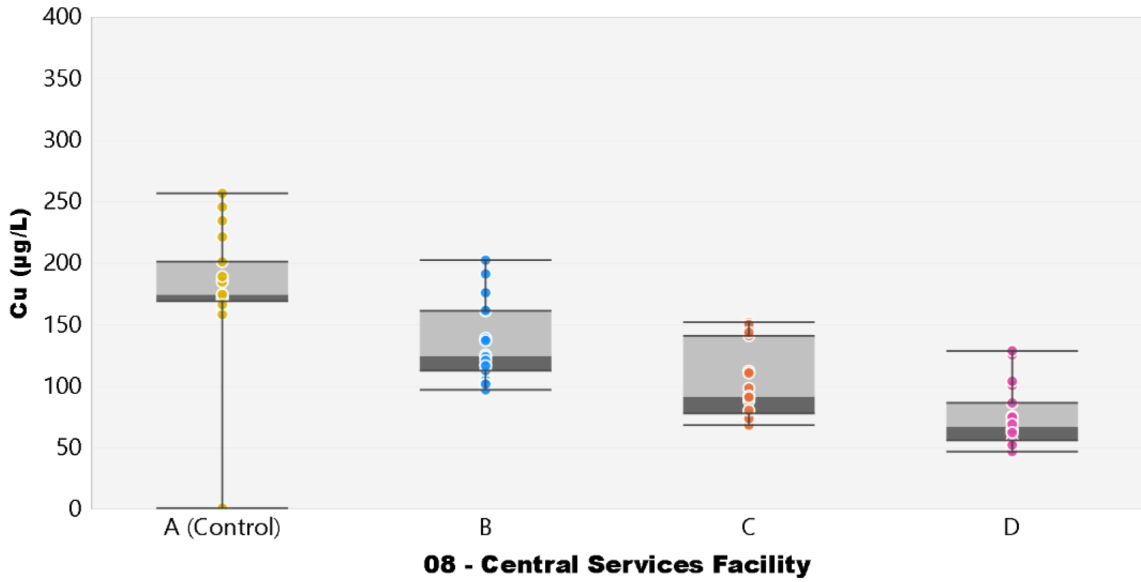


Figure A.5.8: Total Copper Results from Central Services Facility from Copper Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

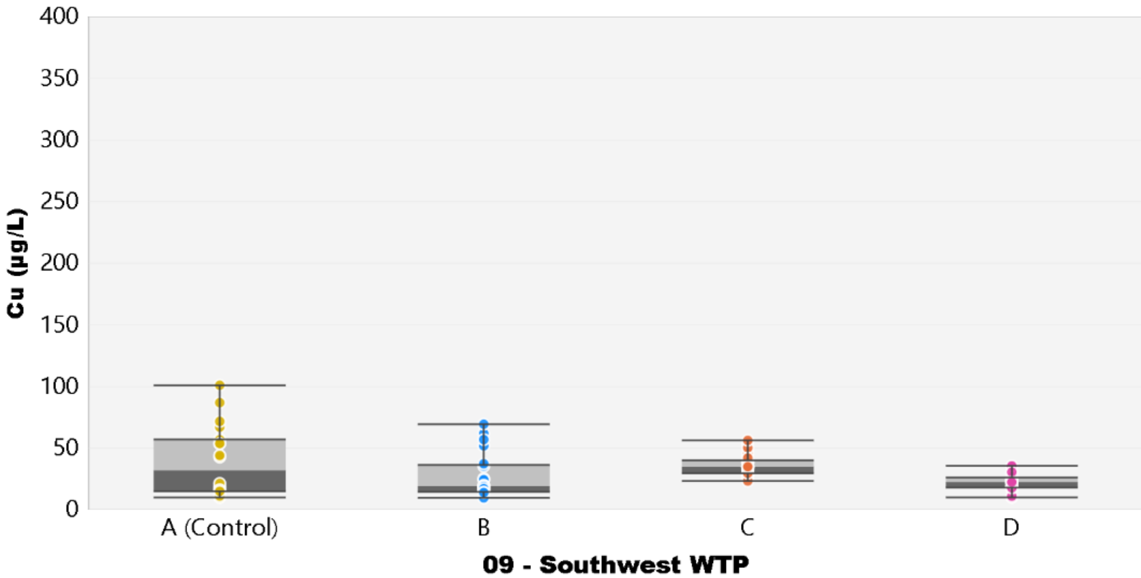


Figure A.5.9: Total Copper Results from Southwest WTP from Copper Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

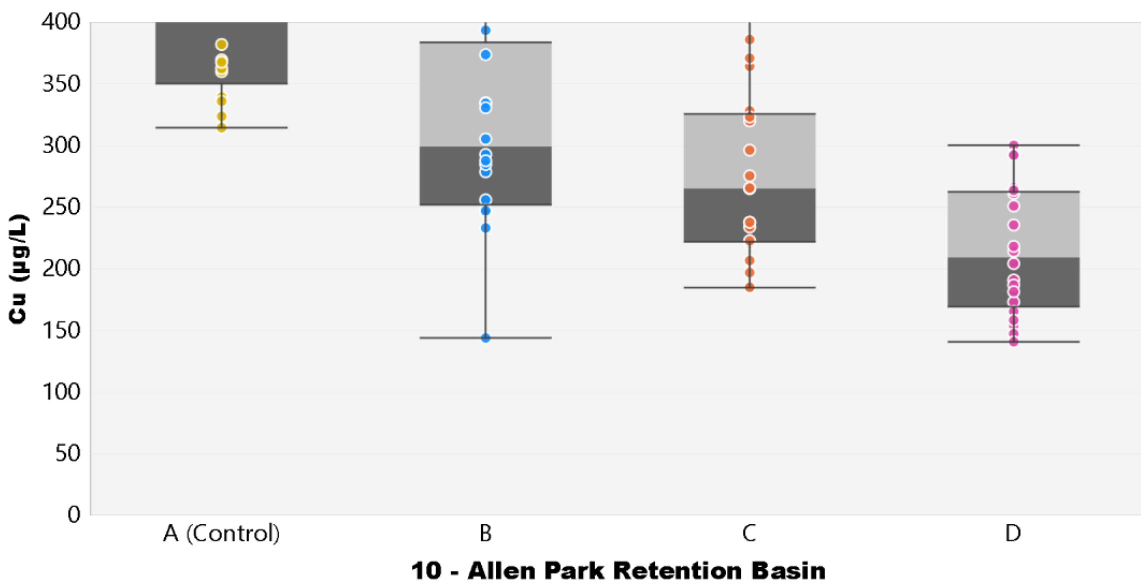


Figure A.5.10: Total Copper Results from Allen Park Retention Basin from Copper Test Pieces (10-Sample Stability Period)

Test conditions (o-PO_4): Rig A 1, Rig B (2.0 mg/L), Rig C (3.0 mg/L), Rig D (4.0 mg/L)

B.1 Conditioning Phase

B.1.1 Chlorine

Median of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	1.30	0.71	1.08	0.68	0.97	0.38	0.79	0.06	1.03	0.03
INF B	1.21	0.64	1.11	0.93	0.91	0.53	0.85	0.09	0.99	0.08
INF C	1.18	0.72	0.95	0.82	0.96	0.76	0.86	0.10	1.05	0.12
INF D	1.24	1.01	1.11	0.83	0.98	0.69	0.85	0.22	1.02	0.46

Minimum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	1.07	0.61	0.92	0.59	0.68	0.16	0.62	0.03	1.01	0.02
INF B	0.98	0.54	0.98	0.74	0.73	0.41	0.74	0.02	0.93	0.02
INF C	0.53	0.47	0.84	0.18	0.96	0.76	0.77	0.02	1.05	0.07
INF D	0.81	0.78	0.85	0.74	0.77	0.44	0.70	0.08	0.97	0.11

Maximum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	1.88	0.88	1.12	0.84	1.16	0.55	1.06	0.33	1.09	0.10
INF B	1.80	0.86	1.19	1.02	1.00	0.73	1.06	0.28	1.17	0.24
INF C	1.26	0.82	1.19	0.89	0.96	0.76	1.06	0.29	1.05	0.35
INF D	1.41	1.09	1.13	1.06	1.13	0.81	1.03	0.34	1.10	0.95

Count of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	8	7	5	4	7	8	10	9	5	3
INF B	5	5	4	3	6	5	4	5	6	6
INF C	4	5	8	5	1	1	3	3	3	5
INF D	9	6	5	7	9	9	9	9	9	4

Figure B.1.1: Chlorine Statistics for Influent Samples (May 2, 2022 - October 7, 2022)

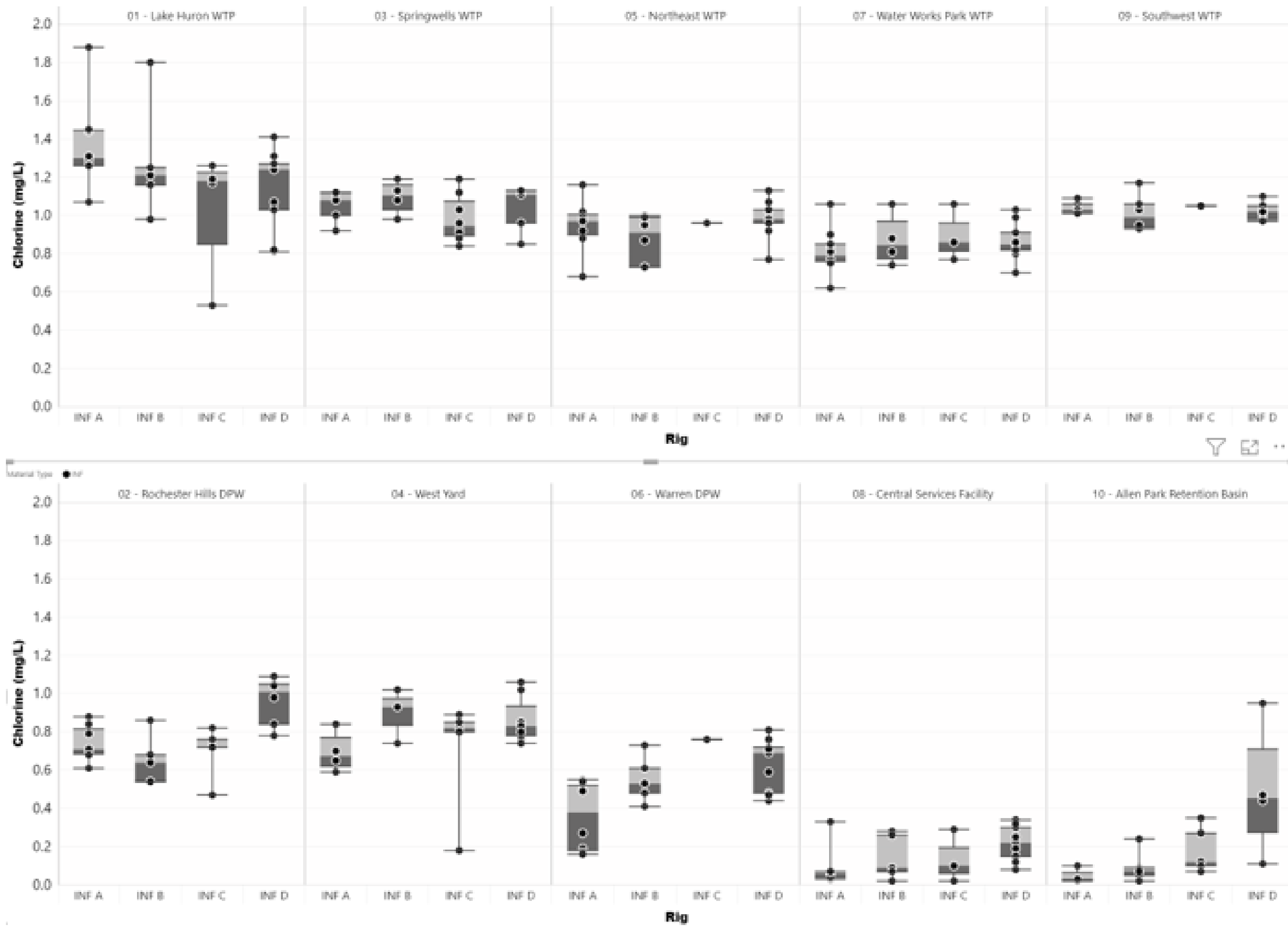


Figure B.1.2: Chlorine Plots for Influent Samples (May 2, 2022 - October 7, 2022)

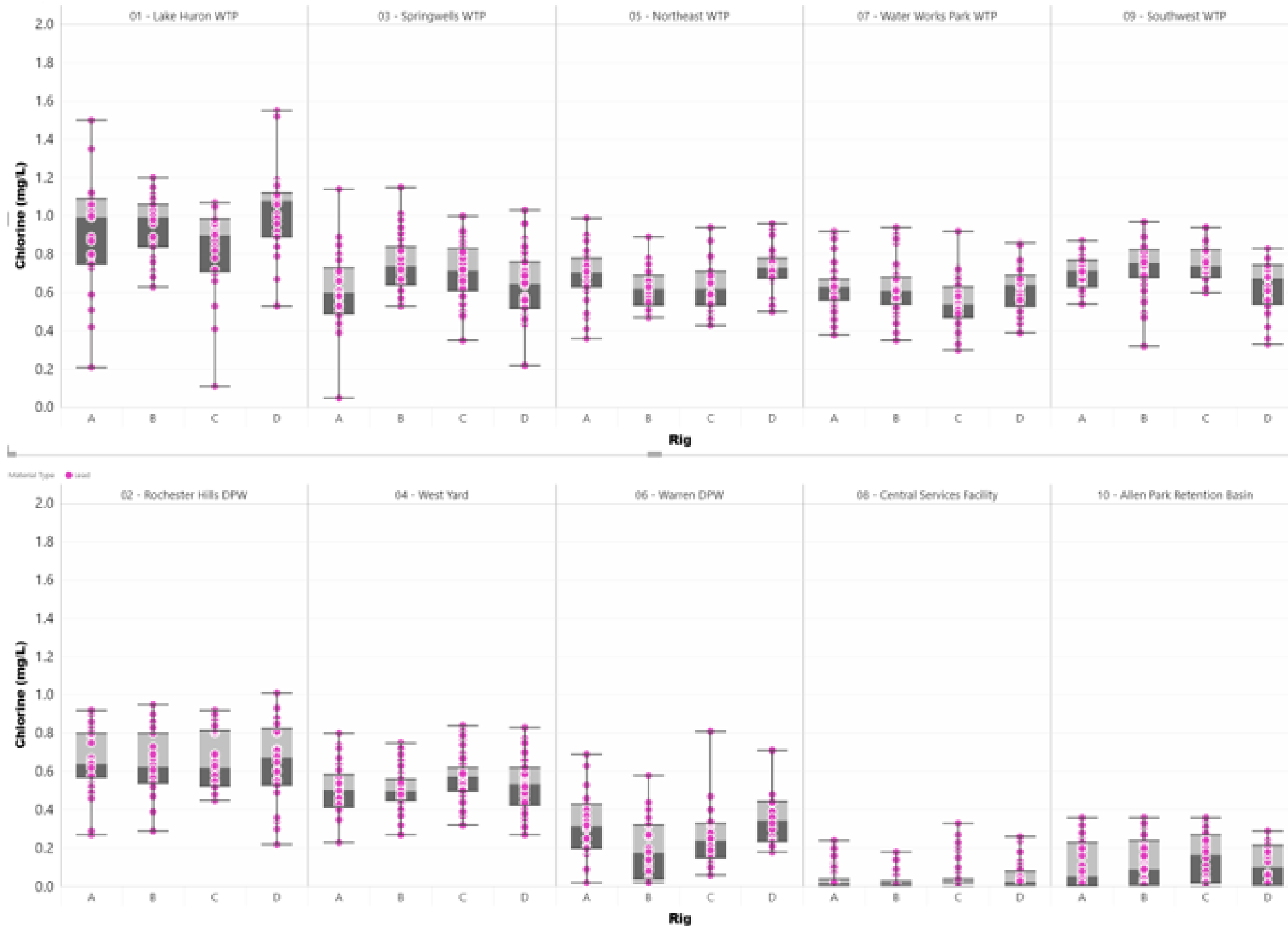


Figure B.1.3: Chlorine Plots for Stagnant Samples from LSLs (May 2, 2022 - October 7, 2022)

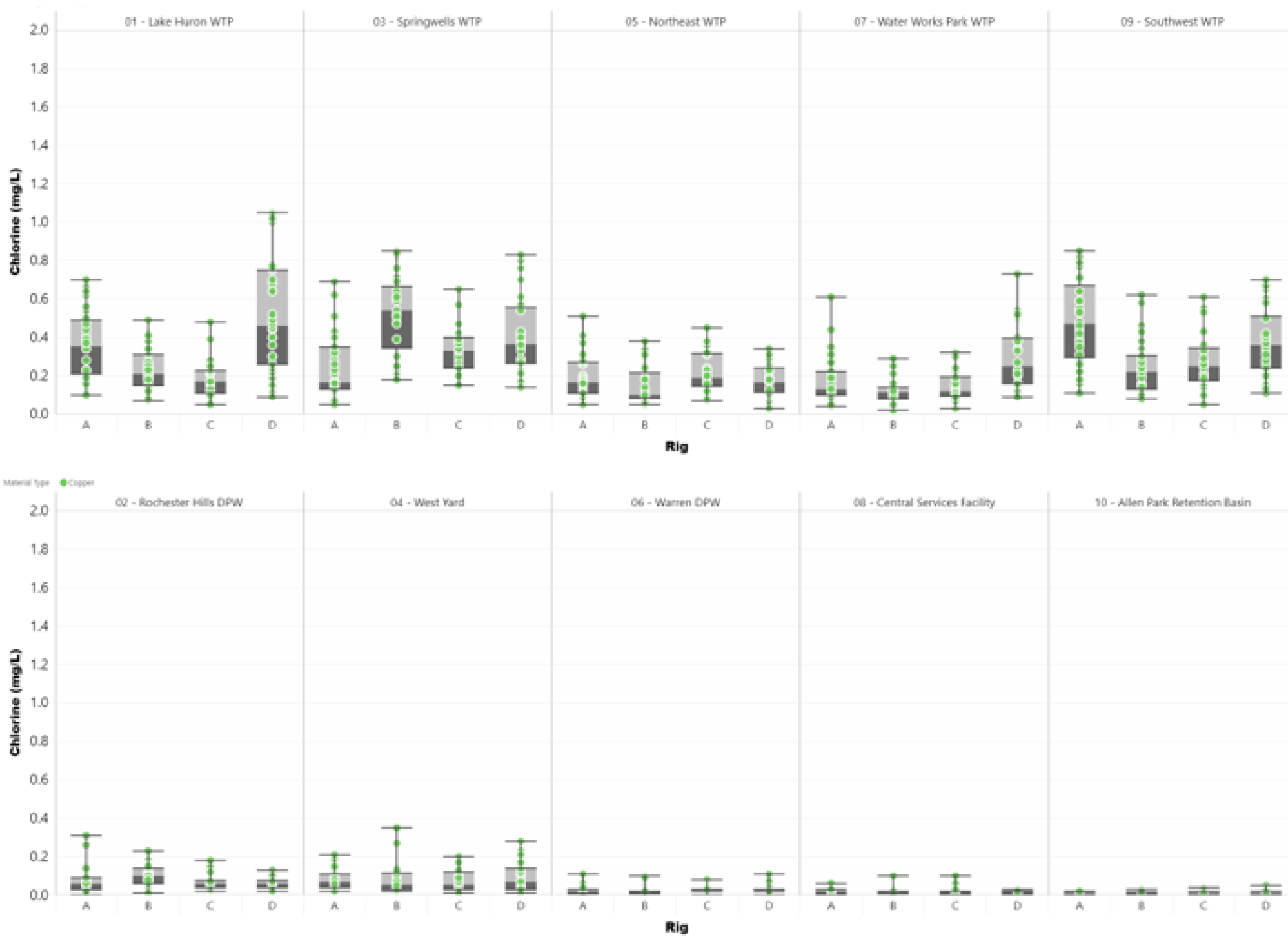


Figure B.1.4: Chlorine Plots for Stagnant Samples from Copper Pipes (May 2, 2022 - October 7, 2022)

B.1.2 o-PO_4

Median of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	1.3	1.4	1.7	1.5	1.3	1.2	1.4	1.1	1.6	1.3
INF B	1.3	1.3	1.5	1.4	1.2	1.2	1.4	1.2	1.5	1.2
INF C	1.3	1.4	1.5	1.4	1.3	1.2	1.3	1.3	1.2	1.3
INF D	1.4	1.4	1.4	1.4	1.2	1.2	1.3	1.3	1.5	1.3

Minimum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	1.1	1.3	1.3	1.3	1.1	1.0	1.3	1.0	1.4	1.3
INF B	1.3	1.3	1.4	1.2	1.0	0.9	1.3	1.1	1.2	1.1
INF C	1.2	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.3
INF D	1.2	1.2	1.4	1.3	1.0	1.0	1.2	1.2	1.2	1.2

Maximum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	2.0	1.6	1.9	1.6	1.5	1.4	2.0	1.3	1.7	1.4
INF B	3.2	1.5	1.7	1.6	1.6	1.3	1.5	1.5	1.7	1.3
INF C	1.5	2.1	1.7	1.5	1.3	1.2	1.4	1.4	1.7	1.6
INF D	1.5	1.7	1.7	1.5	1.5	1.2	2.4	1.3	1.7	1.3

Count of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	8.0	7.0	5.0	4.0	7.0	8.0	10.0	9.0	5.0	3.0
INF B	7.0	5.0	4.0	3.0	6.0	5.0	4.0	5.0	6.0	6.0
INF C	4.0	5.0	8.0	5.0	1.0	1.0	4.0	3.0	3.0	5.0
INF D	9.0	6.0	5.0	7.0	9.0	9.0	10.0	9.0	9.0	4.0

Figure B.1.5: o-PO_4 Statistics for Influent Samples (May 2, 2022 - October 7, 2022)

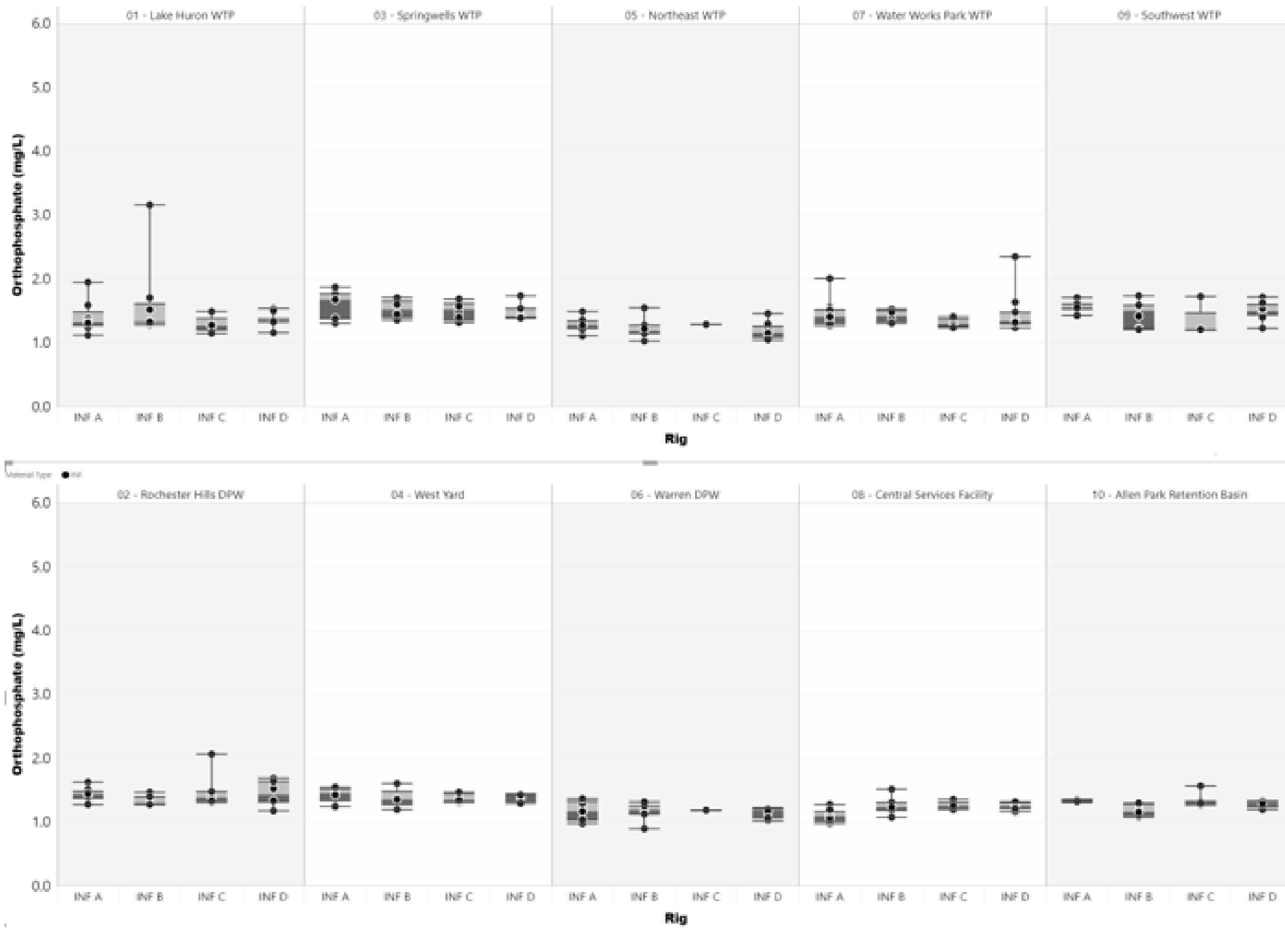


Figure B.1.6: o-PO₄ Plots for Influent Samples (May 2, 2022 - October 7, 2022)

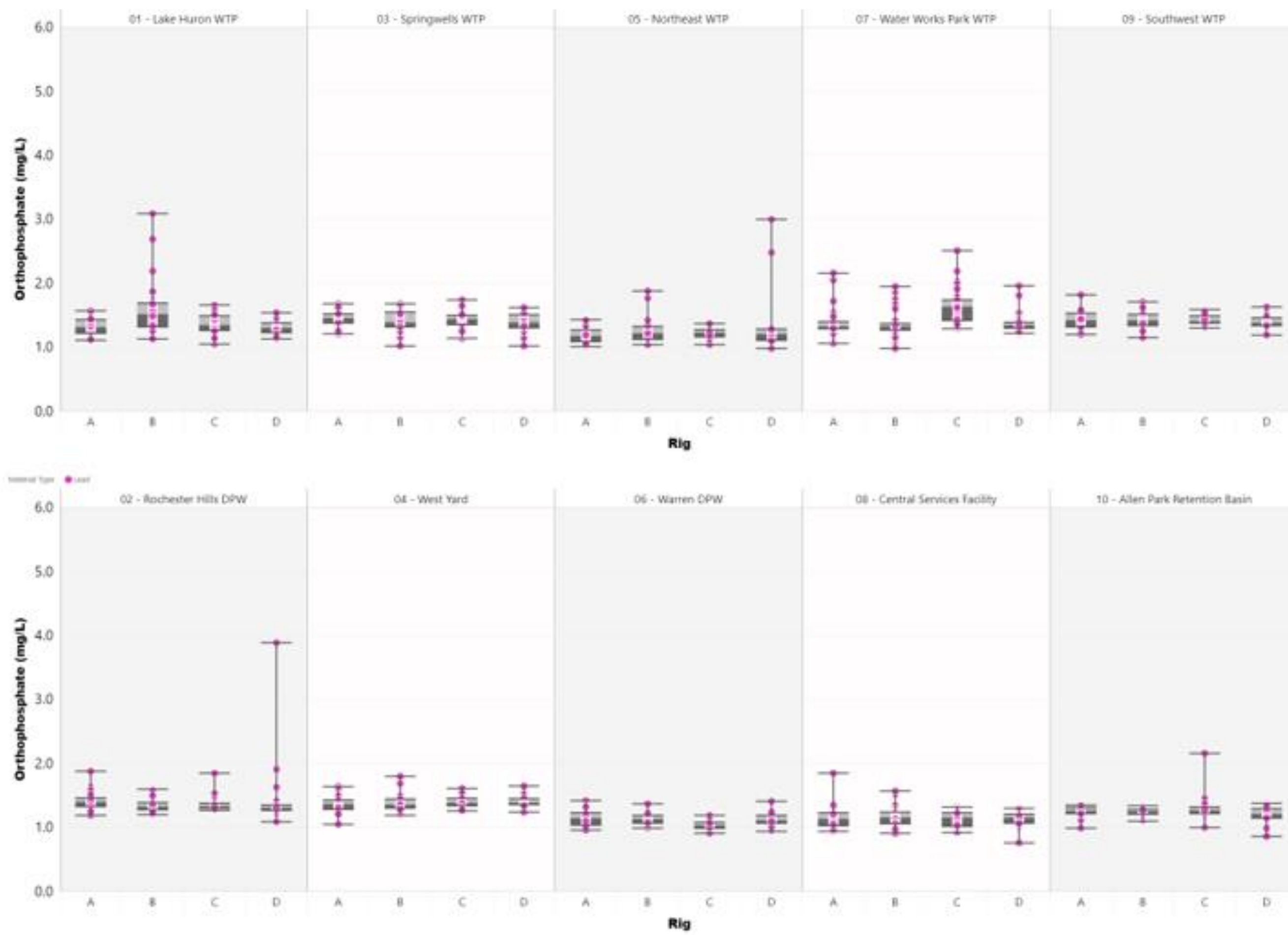


Figure B.1.7: o-PO_4 Plots for Stagnant Samples from LSLs (May 2, 2022 - October 7, 2022)

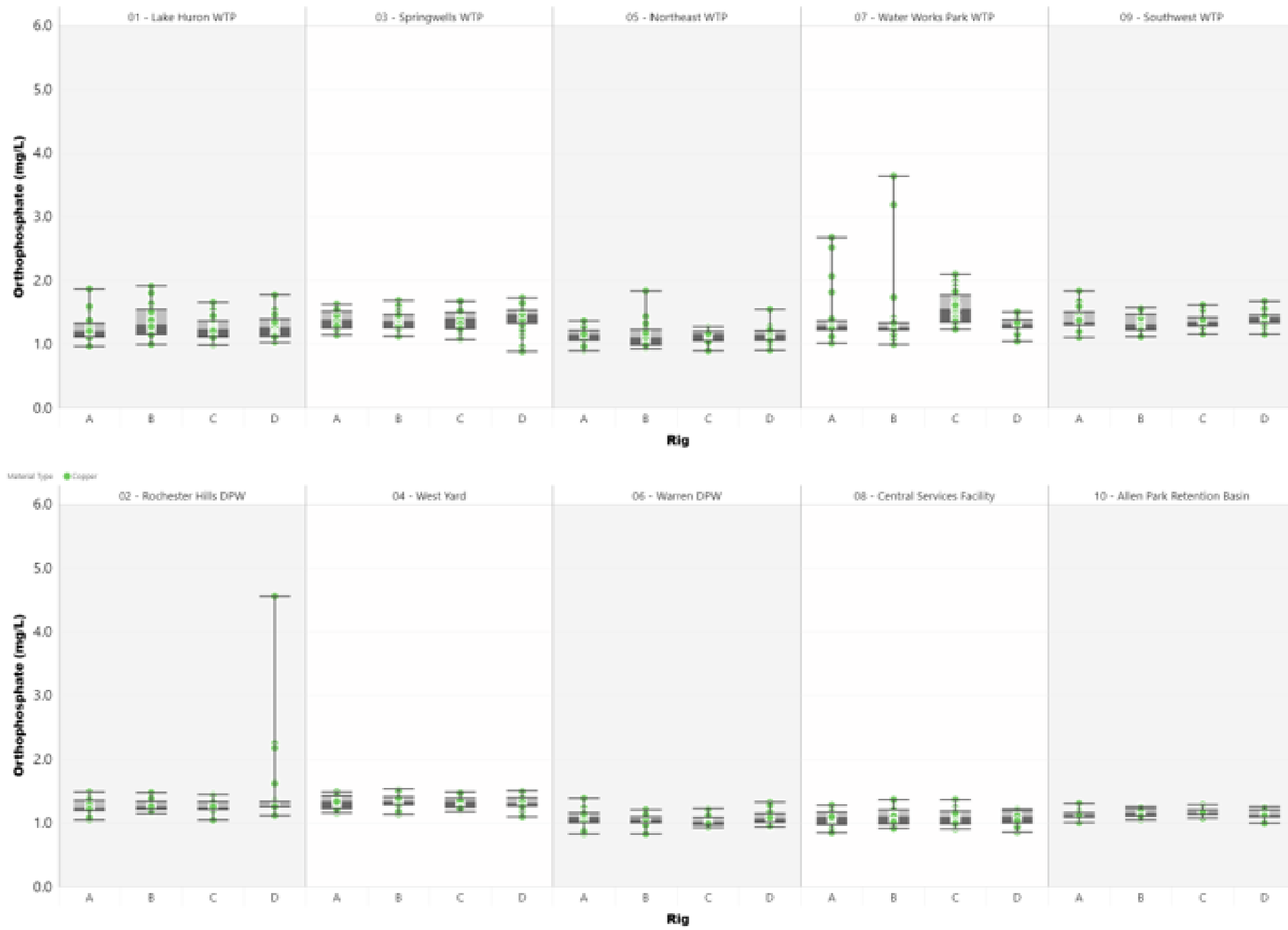


Figure B.1.8: o-PO_4 Plots for Stagnant Samples from Copper Pipes (May 2, 2022 - October 7, 2022)

B.1.3 pH

Median of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	7.4	7.5	7.3	7.4	7.3	7.3	7.4	7.6	7.3	7.4
INF B	7.4	7.7	7.2	7.3	7.3	7.4	7.4	7.5	7.3	7.5
INF C	7.5	7.6	7.2	7.3	7.3	7.1	7.5	7.6	7.3	7.5
INF D	7.4	7.6	7.3	7.3	7.3	7.3	7.4	7.4	7.4	7.5

Minimum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	7.1	7.4	7.1	7.4	7.0	7.1	7.1	7.2	7.2	7.3
INF B	7.1	7.4	7.2	7.3	7.2	7.1	7.1	7.2	7.1	7.3
INF C	7.1	7.3	7.1	7.2	7.3	7.1	7.1	7.2	7.2	7.4
INF D	7.1	7.4	7.1	7.2	7.2	7.1	7.1	7.2	7.2	7.3

Maximum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	7.6	7.7	7.3	7.4	7.4	7.4	7.5	7.7	7.4	7.4
INF B	7.6	7.8	7.4	7.4	7.4	7.4	7.5	7.7	7.4	7.6
INF C	7.6	7.7	7.3	7.4	7.3	7.1	7.6	7.6	7.4	7.6
INF D	7.6	7.8	7.4	7.5	7.4	7.5	7.5	7.6	7.7	7.7

Count of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	8.0	7.0	5.0	4.0	7.0	8.0	9.0	9.0	5.0	3.0
INF B	5.0	5.0	4.0	3.0	6.0	5.0	4.0	5.0	6.0	6.0
INF C	4.0	5.0	8.0	5.0	1.0	1.0	3.0	3.0	3.0	5.0
INF D	9.0	7.0	6.0	8.0	9.0	9.0	9.0	9.0	8.0	5.0

Figure B.1.9: pH Statistics for Influent Samples (May 2, 2022 - October 7, 2022)

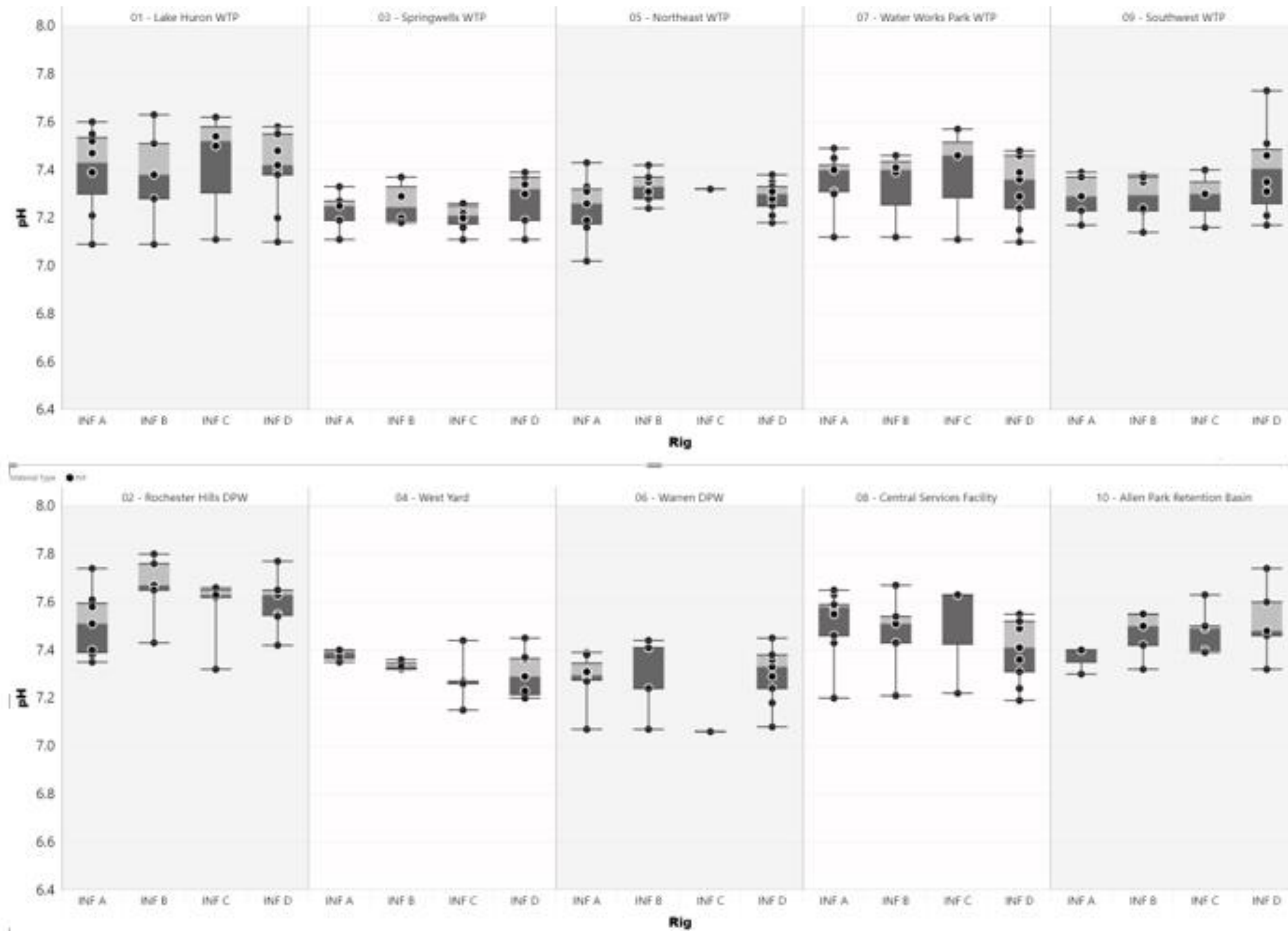


Figure B.1.10: pH Plots for Influent Samples (May 2, 2022 - October 7, 2022)

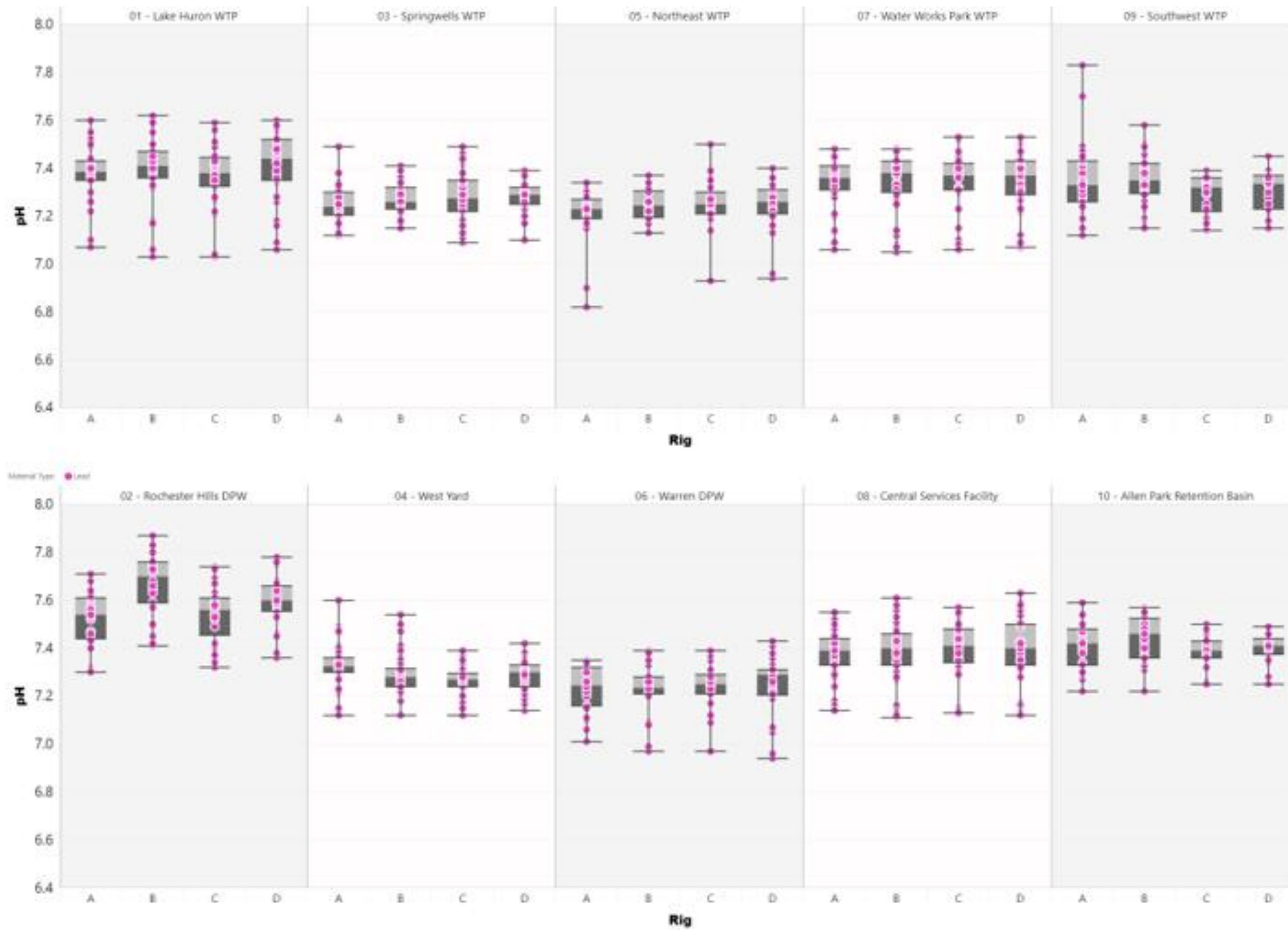


Figure B.1.11: pH Plots for Stagnant Samples from LSLs (May 2, 2022 - October 7, 2022)

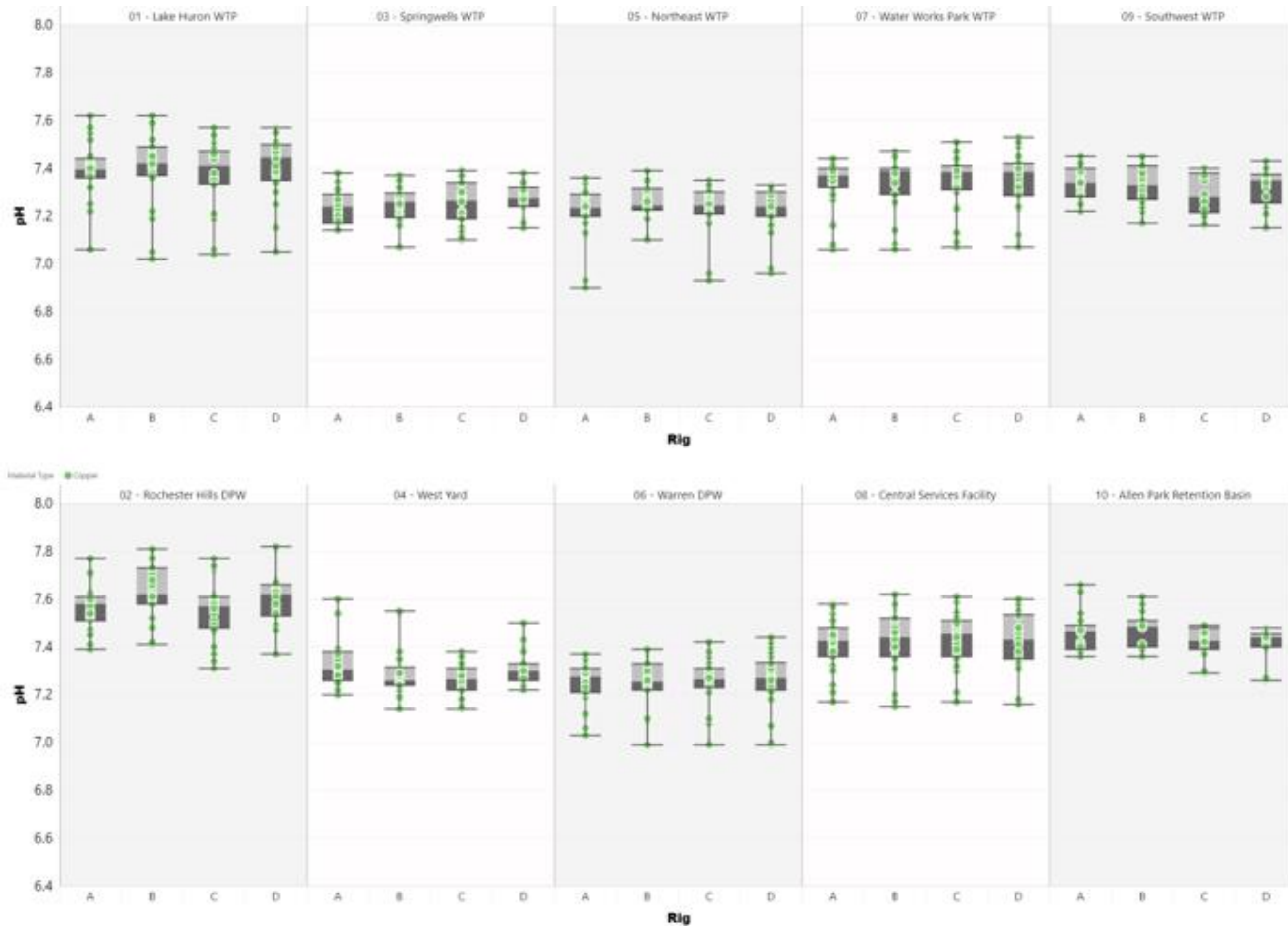


Figure B.1.12: pH Plots for Stagnant Samples from Copper Pipes (May 2, 2022 - October 7, 2022)

B.1.4 Temperature

Median of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	20.5	20.6	23.2	22.7	22.5	21.0	22.3	21.8	23.4	19.6
INF B	15.4	19.7	22.5	20.6	23.0	22.4	19.2	20.7	22.6	18.8
INF C	17.2	19.8	21.2	23.0	23.1	9.9	23.4	22.6	22.4	16.7
INF D	10.8	14.3	18.6	17.5	17.4	16.8	17.4	18.2	19.3	14.1

Minimum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	7.4	18.3	17.5	21.6	11.2	10.7	9.3	14.6	18.4	18.9
INF B	7.6	17.2	17.7	19.6	18.5	10.0	9.5	14.1	15.7	15.6
INF C	7.1	16.1	17.8	21.5	23.1	9.9	9.5	14.9	17.9	13.4
INF D	6.5	12.2	11.7	14.5	12.9	9.9	9.9	15.0	14.1	11.7

Maximum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	25.4	21.8	24.3	23.7	24.4	22.8	25.0	23.4	24.5	20.1
INF B	20.4	21.3	24.5	22.7	24.4	22.8	24.1	22.7	24.1	19.9
INF C	23.2	21.4	25.0	23.6	23.1	9.9	24.3	23.0	23.2	18.9
INF D	19.9	17.3	24.0	22.4	24.0	22.8	21.9	22.2	25.0	16.9

Count of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	8.0	7.0	5.0	4.0	7.0	8.0	9.0	9.0	5.0	3.0
INF B	5.0	5.0	4.0	3.0	6.0	5.0	4.0	5.0	6.0	6.0
INF C	4.0	5.0	8.0	5.0	1.0	1.0	3.0	3.0	3.0	5.0
INF D	9.0	5.0	6.0	7.0	9.0	9.0	9.0	9.0	8.0	5.0

All temperatures were recorded as °C.

Figure B.1.13: Temperature Statistics for Influent Samples (May 2, 2022 - October 7, 2022)

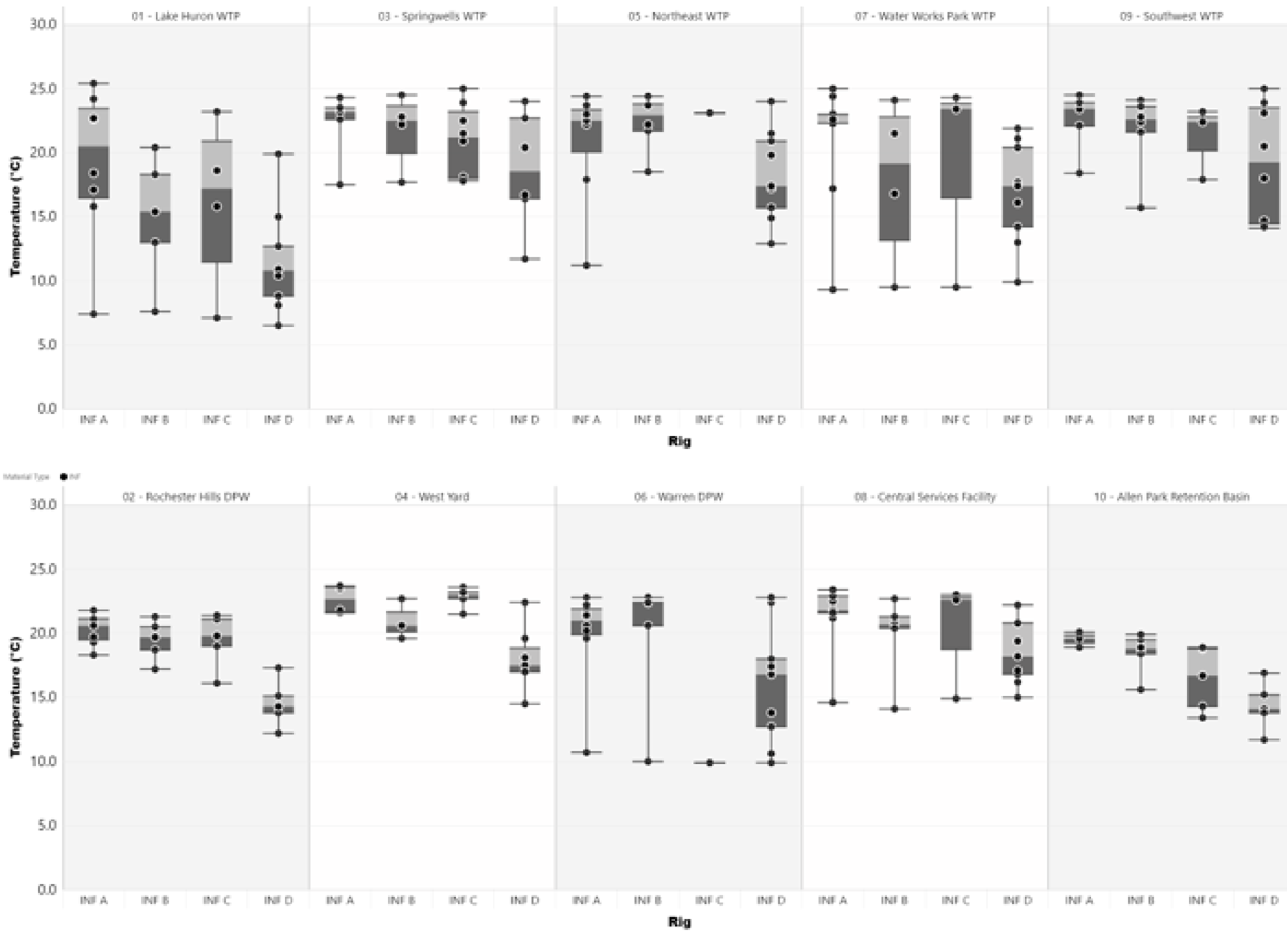


Figure B.1.14: Temperature Plots for Influent Samples (May 2, 2022 - October 7, 2022)

B.1.5 Summary

Median of Data - Chlorine (mg/L)

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	1.30	0.71	1.08	0.68	0.97	0.38	0.79	0.06	1.03	0.03
INF B	1.21	0.64	1.11	0.93	0.91	0.53	0.85	0.09	0.99	0.08
INF C	1.18	0.72	0.95	0.82	0.96	0.76	0.86	0.10	1.05	0.12
INF D	1.24	1.01	1.11	0.83	0.98	0.69	0.85	0.22	1.02	0.46

Median of Data - o-PO_4 (mg/L)

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	1.3	1.4	1.7	1.5	1.3	1.2	1.4	1.1	1.6	1.3
INF B	1.3	1.3	1.5	1.4	1.2	1.2	1.4	1.2	1.5	1.2
INF C	1.3	1.4	1.5	1.4	1.3	1.2	1.3	1.3	1.2	1.3
INF D	1.4	1.4	1.4	1.4	1.2	1.2	1.3	1.3	1.5	1.3

Median of Data - pH

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	7.4	7.5	7.3	7.4	7.3	7.3	7.4	7.6	7.3	7.4
INF B	7.4	7.7	7.2	7.3	7.3	7.4	7.4	7.5	7.3	7.5
INF C	7.5	7.6	7.2	7.3	7.3	7.1	7.5	7.6	7.3	7.5
INF D	7.4	7.6	7.3	7.3	7.3	7.3	7.4	7.4	7.4	7.5

Median of Data - Temperature (deg. C)

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	20.5	20.6	23.2	22.7	22.5	21.0	22.3	21.8	23.4	19.6
INF B	15.4	19.7	22.5	20.6	23.0	22.4	19.2	20.7	22.6	18.8
INF C	17.2	19.8	21.2	23.0	23.1	9.9	23.4	22.6	22.4	16.7
INF D	10.8	14.3	18.6	17.5	17.4	16.8	17.4	18.2	19.3	14.1

Figure B.1.15: Medians of Influent Samples for all WQPs (May 2, 2022 - October 7, 2022)

Median Cl2

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	1.00	0.64	0.60	0.51	0.71	0.32	0.63	0.02	0.72	0.06
B	1.00	0.63	0.74	0.50	0.62	0.18	0.61	0.02	0.76	0.09
C	0.90	0.62	0.72	0.58	0.62	0.24	0.54	0.02	0.74	0.17
D	1.08	0.68	0.65	0.54	0.73	0.35	0.64	0.03	0.68	0.10

Median PO4

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	1.3	1.4	1.5	1.4	1.2	1.2	1.3	1.1	1.4	1.3
B	1.5	1.3	1.4	1.4	1.2	1.1	1.3	1.2	1.4	1.3
C	1.4	1.3	1.4	1.4	1.2	1.0	1.6	1.2	1.4	1.3
D	1.3	1.3	1.4	1.4	1.2	1.1	1.3	1.2	1.4	1.2

Median pH

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	7.4	7.5	7.2	7.3	7.2	7.2	7.4	7.4	7.3	7.4
B	7.4	7.7	7.3	7.3	7.2	7.2	7.4	7.4	7.4	7.5
C	7.4	7.6	7.3	7.3	7.3	7.3	7.4	7.4	7.3	7.4
D	7.4	7.6	7.3	7.3	7.3	7.3	7.4	7.4	7.3	7.4

Figure B.1.16: Medians of Stagnant Samples (Cl_2, o-PO_4, pH) from LSLs (May 2, 2022 - October 7, 2022)

Median Cl2

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	0.36	0.06	0.17	0.07	0.17	0.02	0.13	0.02	0.47	0.01
B	0.21	0.10	0.54	0.06	0.10	0.02	0.12	0.02	0.22	0.01
C	0.17	0.06	0.33	0.06	0.19	0.02	0.12	0.02	0.25	0.01
D	0.46	0.06	0.37	0.07	0.17	0.02	0.25	0.02	0.36	0.01

Median PO4

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	1.2	1.2	1.4	1.4	1.2	1.1	1.3	1.1	1.4	1.1
B	1.3	1.3	1.4	1.3	1.1	1.1	1.3	1.1	1.3	1.2
C	1.2	1.3	1.4	1.3	1.2	1.0	1.6	1.1	1.4	1.2
D	1.3	1.3	1.5	1.3	1.2	1.1	1.3	1.1	1.4	1.1

Median pH

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	7.4	7.6	7.2	7.3	7.2	7.3	7.4	7.4	7.3	7.5
B	7.4	7.6	7.3	7.3	7.2	7.3	7.4	7.4	7.3	7.5
C	7.4	7.6	7.3	7.3	7.2	7.3	7.4	7.5	7.3	7.4
D	7.4	7.6	7.3	7.3	7.2	7.3	7.4	7.4	7.4	7.4

Figure B.1.17: Medians of Stagnant Samples (Cl_2, o-PO_4, pH) from Copper Pipes (May 2, 2022 - October 7, 2022)

B.2 Entire Testing Phase

B.2.1 Chlorine

Median of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	1.09	0.88	1.19	0.98	0.96	0.52	0.88	0.29	1.06	0.46
INF B	1.17	0.86	1.14	0.98	1.00	0.72	0.88	0.28	1.07	0.44
INF C	1.18	0.86	1.19	1.01	0.98	0.73	0.84	0.33	1.07	0.44
INF D	1.20	0.86	1.21	1.03	0.99	0.73	0.86	0.31	1.10	0.47

Minimum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	0.86	0.48	0.91	0.69	0.38	0.23	0.58	0.02	0.69	0.13
INF B	0.93	0.44	0.91	0.74	0.34	0.45	0.45	0.07	0.68	0.12
INF C	0.94	0.41	0.96	0.74	0.41	0.45	0.69	0.03	0.65	0.07
INF D	0.96	0.44	0.98	0.88	0.26	0.50	0.59	0.04	0.74	0.17

Maximum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	1.27	1.06	1.80	1.30	1.19	0.90	1.07	0.69	1.23	0.59
INF B	1.31	1.02	1.68	1.35	1.23	0.92	1.03	0.77	1.28	0.57
INF C	1.35	1.04	1.60	1.46	1.36	0.95	1.08	0.74	1.23	0.58
INF D	1.34	1.02	1.67	1.36	1.23	0.96	1.04	0.78	1.26	0.56

Count of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	37	37	39	36	40	38	39	36	38	37
INF B	38	38	39	36	40	37	39	38	38	37
INF C	38	38	39	36	40	37	39	38	38	36
INF D	38	38	39	36	39	38	39	38	38	37

Blue boxes indicate medians that were particularly low within a site or across sites.

Figure B.2.1: Chlorine Statistics for Flowing Samples (December 5, 2022 - September 1, 2023)

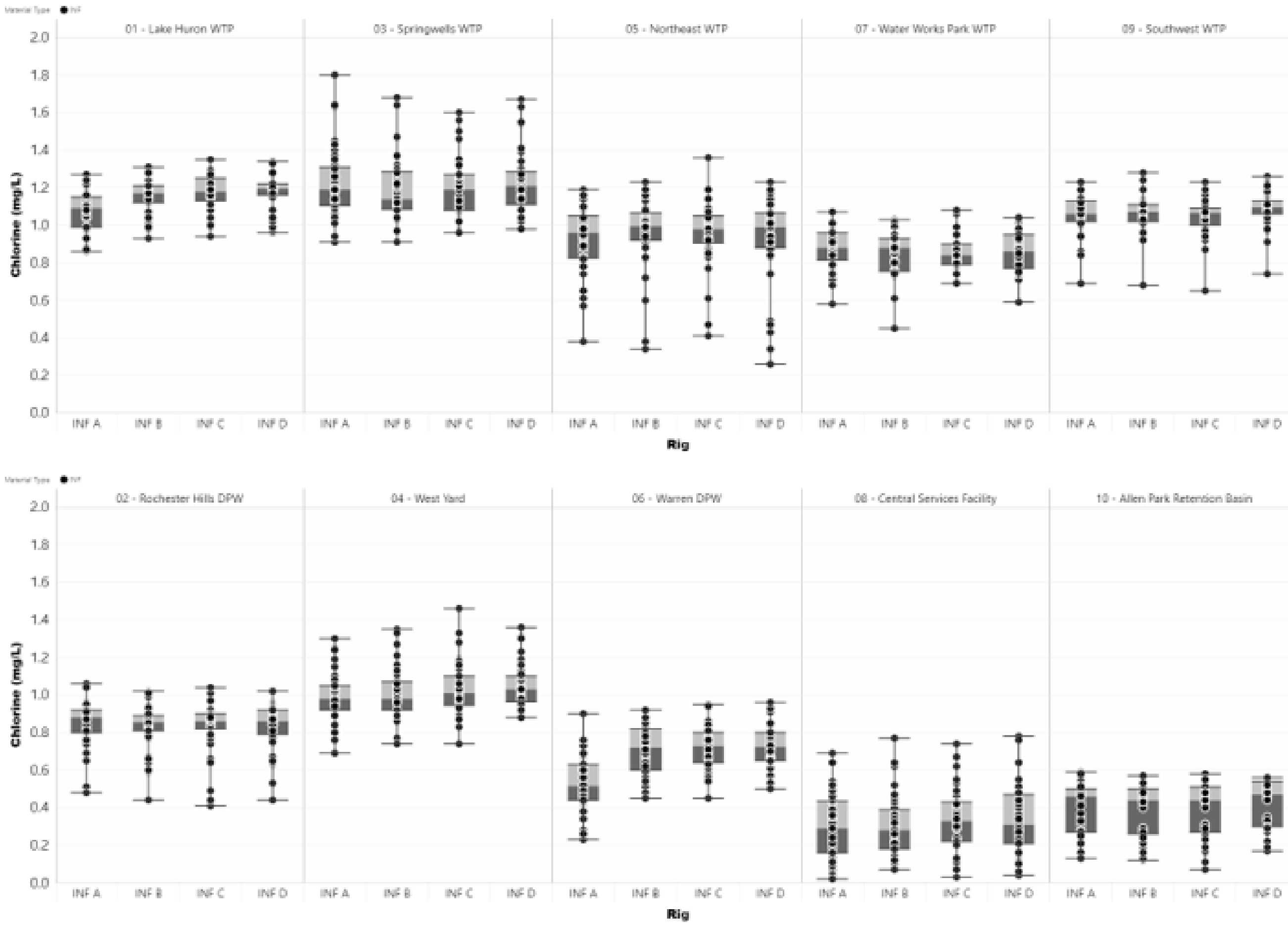


Figure B.2.2: Chlorine Plots for Flowing Samples (December 5, 2022 - September 1, 2023)

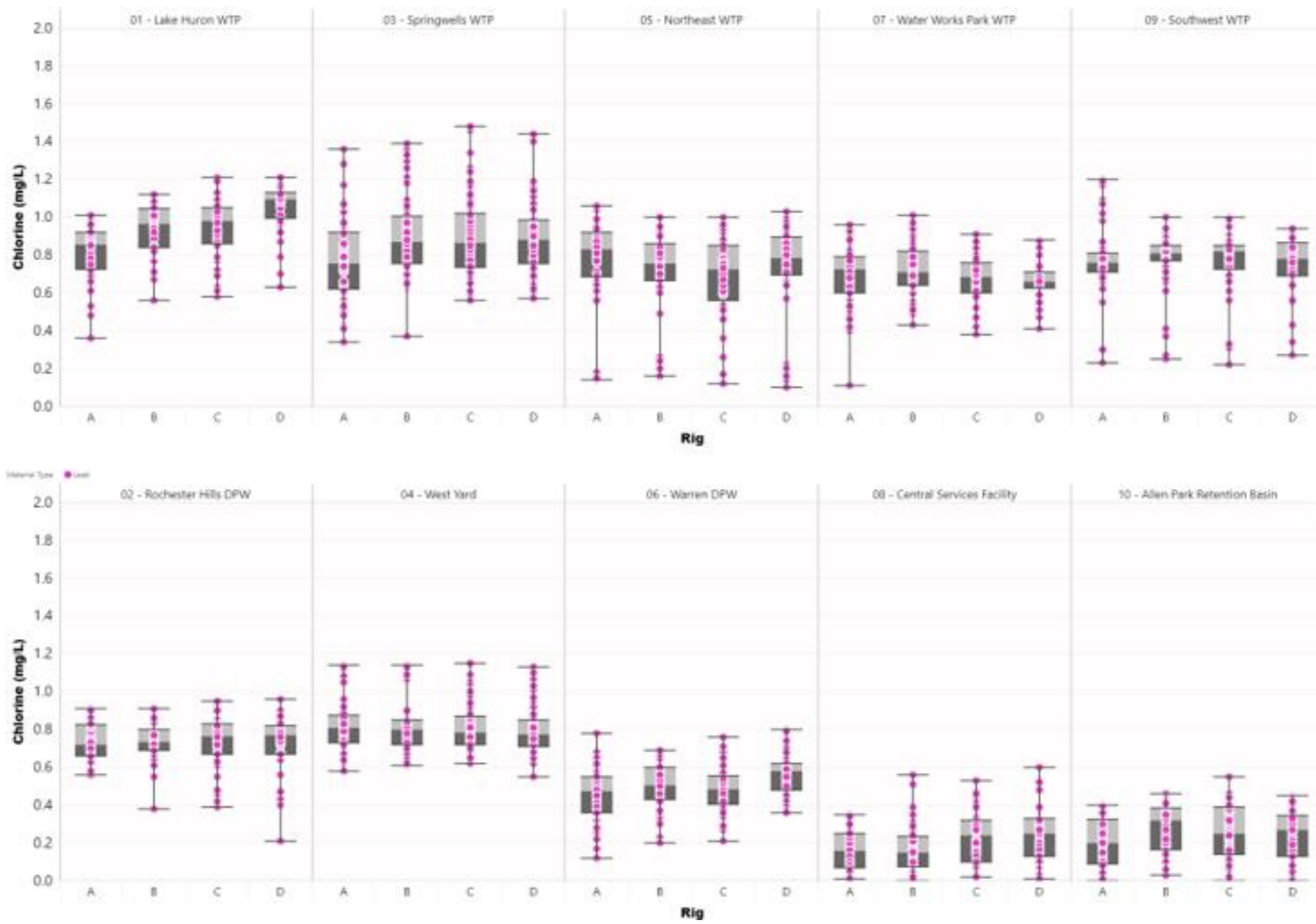


Figure B.2.3: Chlorine Plots for Stagnant Samples from LSLs (December 5, 2022 - September 1, 2023)

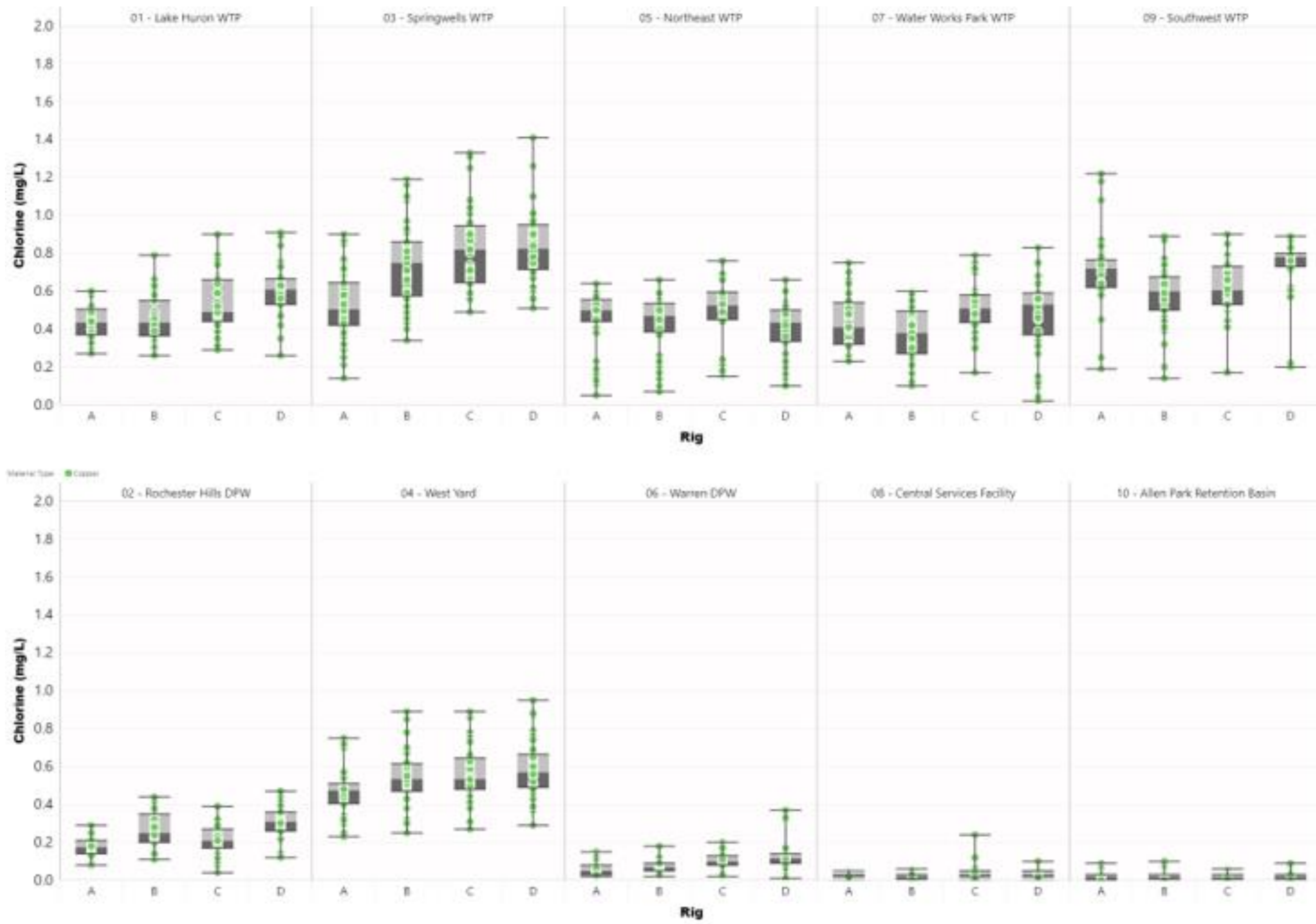


Figure B.2.4: Chlorine Plots for Stagnant Samples from Copper Pipes (December 5, 2022 - September 1, 2023)

B.2.2 o-PO_4

Median of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	1.4	1.3	1.5	1.4	1.3	1.3	1.4	1.2	1.4	1.2
INF B	2.0	1.9	3.0	2.0	1.3	1.9	2.0	2.0	2.0	1.9
INF C	3.0	3.0	3.9	3.0	2.0	3.0	3.0	3.0	2.9	3.0
INF D	3.9	3.8	4.0	4.0	2.0	3.9	3.1	4.0	4.1	4.0

Minimum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	1.0	1.2	0.9	1.2	1.1	1.0	1.1	1.1	1.0	1.1
INF B	1.7	1.3	2.2	1.4	1.0	1.0	1.4	1.7	1.4	1.7
INF C	2.6	2.5	3.3	2.6	1.5	1.5	2.3	2.4	2.3	2.5
INF D	3.4	3.3	3.0	3.2	1.6	1.4	2.5	2.1	3.0	3.6

Maximum of Data

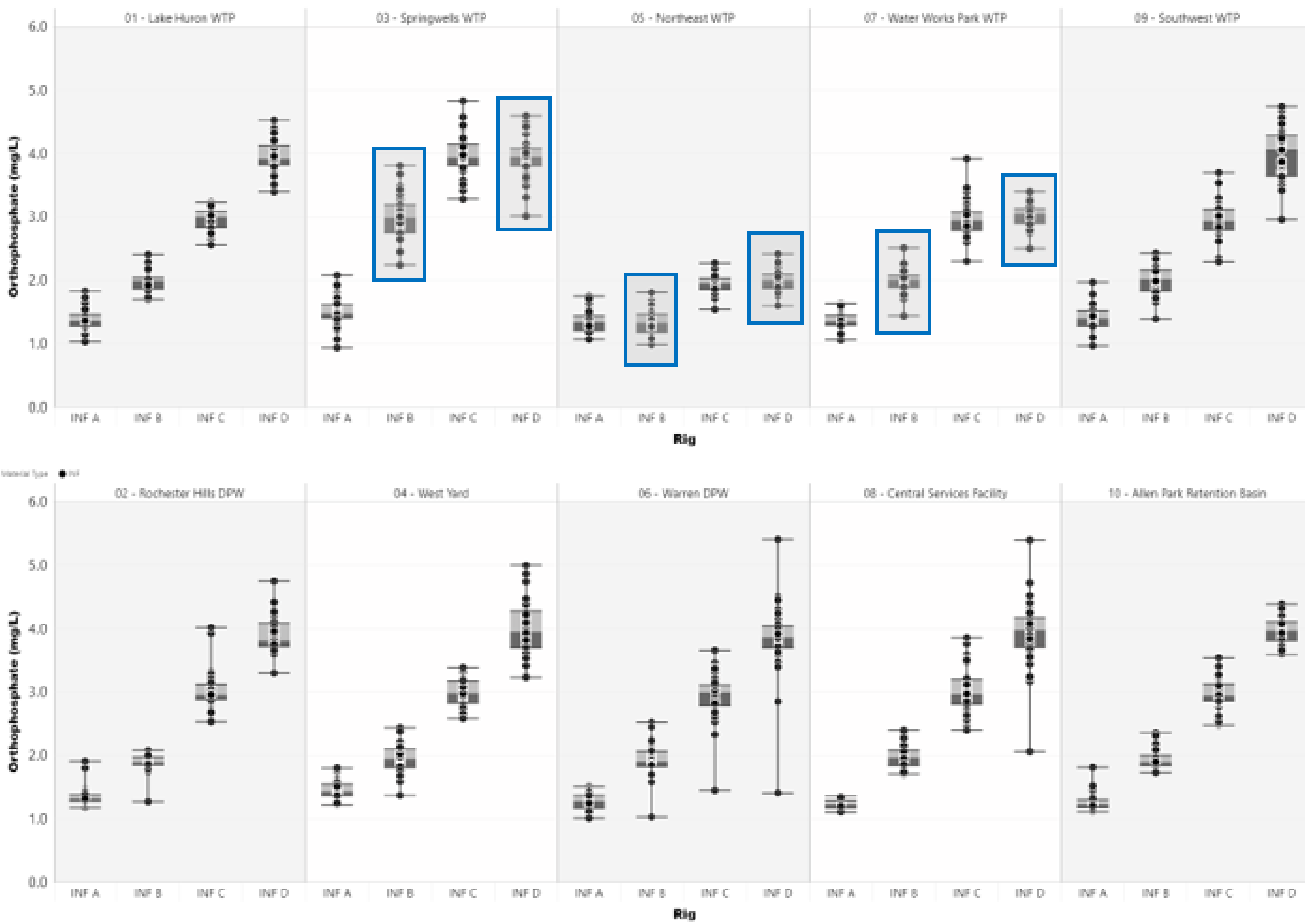
Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	1.8	1.9	2.1	1.8	1.8	1.5	1.6	1.4	2.0	1.8
INF B	2.4	2.1	3.8	2.4	1.8	2.5	2.5	2.4	2.4	2.4
INF C	3.2	4.0	4.8	3.4	2.3	3.7	3.9	3.9	3.7	3.5
INF D	4.5	4.8	4.6	5.0	2.4	5.4	3.4	5.4	4.7	4.4

Count of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	38	37	39	36	41	39	39	38	38	37
INF B	37	39	39	36	40	39	39	38	39	37
INF C	37	39	39	36	41	40	39	39	39	37
INF D	37	39	39	36	40	40	39	40	39	37

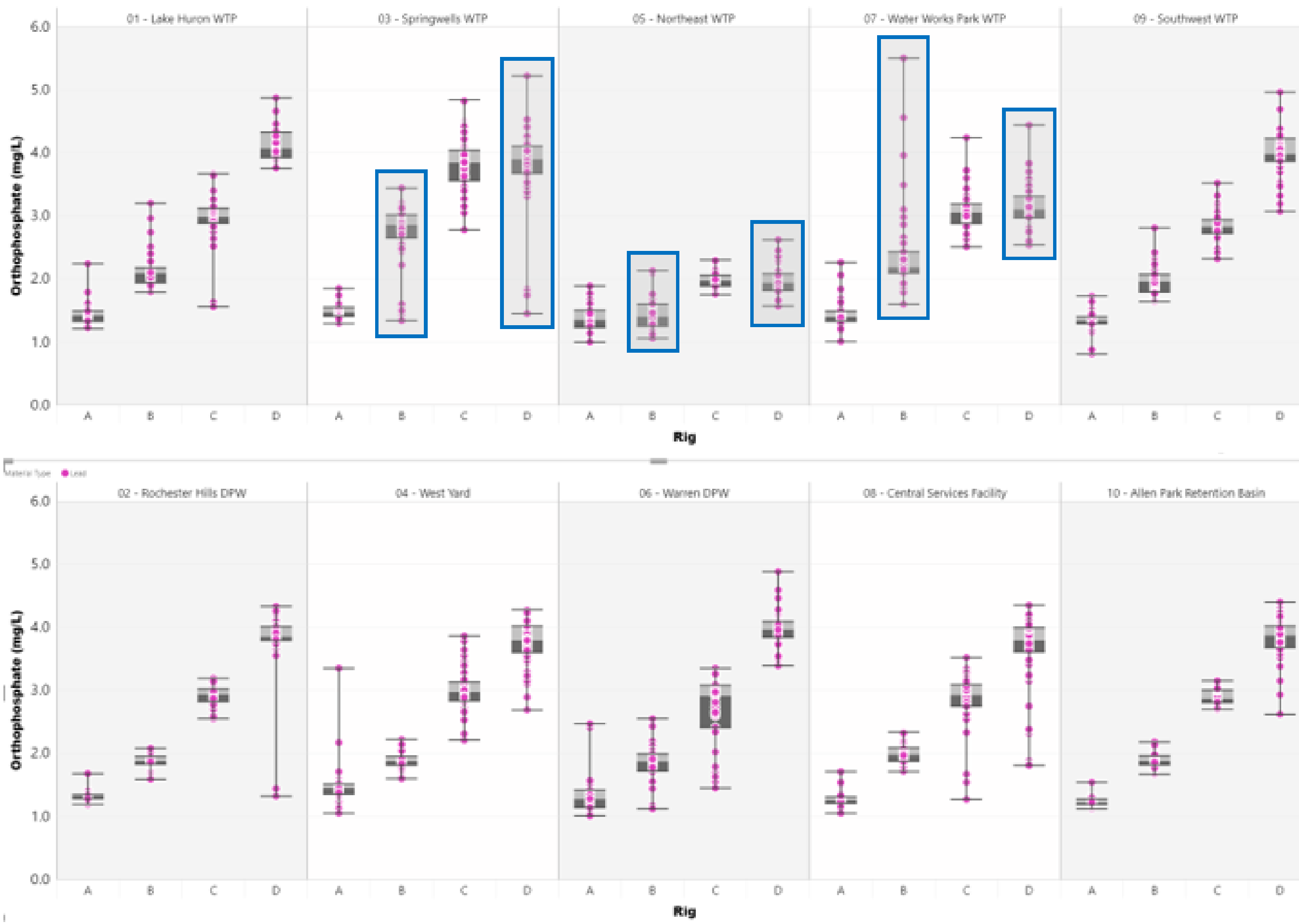
Colored boxes indicate deviations from the target value: green (± 0.0 mg/L), orange (± 0.1 mg/L), and red (± 0.2 mg/L).

Figure B.2.5: o-PO_4 Statistics for Flowing Samples (December 5, 2022 - September 1, 2023)



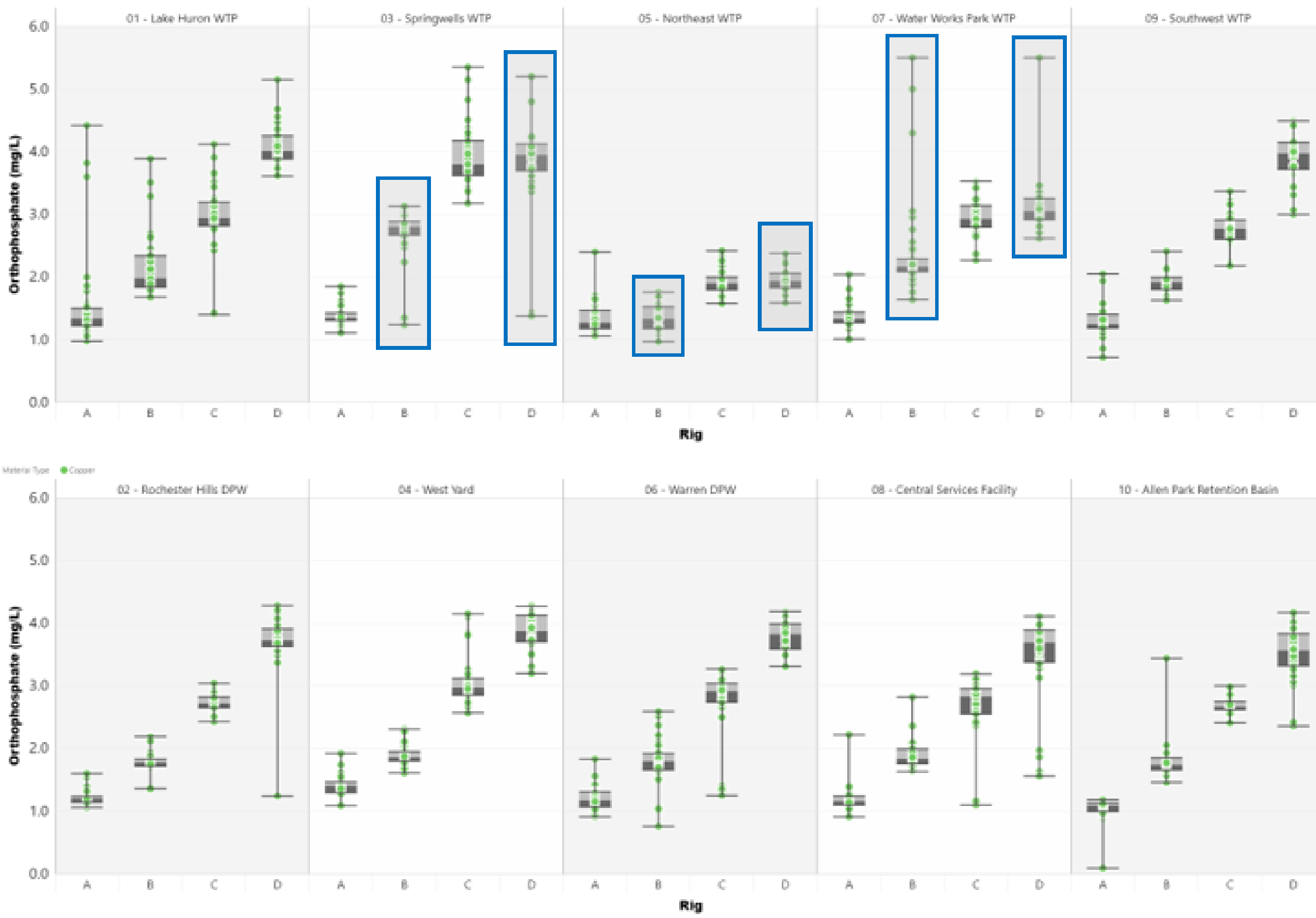
Blue boxes indicate rigs which received pH adjustment to a target of pH 7.0.

Figure B.2.6: o-PO_4 Plots for Flowing Samples (December 5, 2022 - September 1, 2023)



Blue boxes indicate rigs which received pH adjustment to a target of pH 7.0.

Figure B.2.7: o-PO_4 Plots for Stagnant Samples from LSLs (December 5, 2022 - September 1, 2023)



Blue boxes indicate rigs which received pH adjustment to a target of pH 7.0.

Figure B.2.8: o-PO_4 Plots for Stagnant Samples from Copper Pipes (December 5, 2022 - September 1, 2023)

B.2.3 pH

Median of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	7.5	7.6	7.2	7.3	7.3	7.3	7.4	7.5	7.3	7.3
INF B	7.5	7.5	7.0	7.3	7.1	7.3	7.1	7.4	7.2	7.3
INF C	7.4	7.5	7.2	7.2	7.3	7.3	7.4	7.4	7.2	7.3
INF D	7.4	7.5	7.0	7.2	7.1	7.3	7.0	7.4	7.2	7.2

Minimum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	7.4	7.4	6.9	7.1	6.9	7.0	7.1	7.2	7.0	7.2
INF B	7.4	7.4	6.7	7.0	6.8	7.0	6.8	7.2	7.0	7.1
INF C	7.3	7.3	6.9	7.0	6.9	7.0	7.1	7.2	7.0	7.1
INF D	7.3	7.3	6.7	7.0	6.8	6.9	6.9	7.2	7.0	7.1

Maximum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	7.6	7.8	7.3	7.4	7.4	7.4	7.6	7.7	7.4	7.5
INF B	7.6	7.8	7.2	7.4	7.2	7.4	7.3	7.7	7.4	7.4
INF C	7.6	7.8	7.3	7.4	7.4	7.4	7.5	7.7	7.4	7.4
INF D	7.6	7.7	7.2	7.4	7.2	7.4	7.3	7.7	7.3	7.4

Count of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	38	36	41	36	40	40	40	37	38	35
INF B	38	37	39	36	40	39	40	37	38	35
INF C	37	37	39	35	40	39	39	38	38	34
INF D	37	37	39	36	41	38	40	37	38	35

Colored boxes indicate deviations from the target value: green (± 0.0 mg/L), orange (± 0.1 mg/L), and red (± 0.2 mg/L).

Figure B.2.9: pH Statistics for Flowing Samples (December 5, 2022 - September 1, 2023)

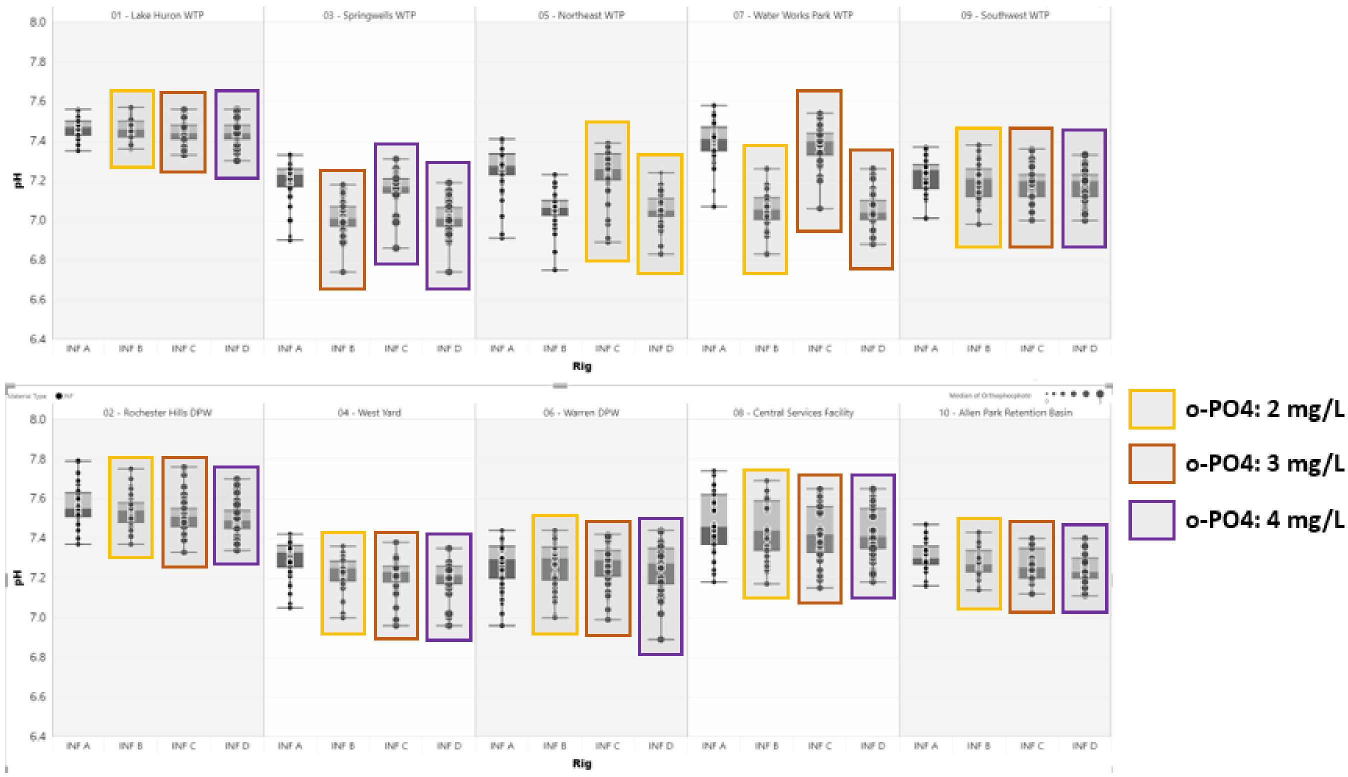


Figure B.2.10: pH Plots for Flowing Samples (December 5, 2022 - September 1, 2023)

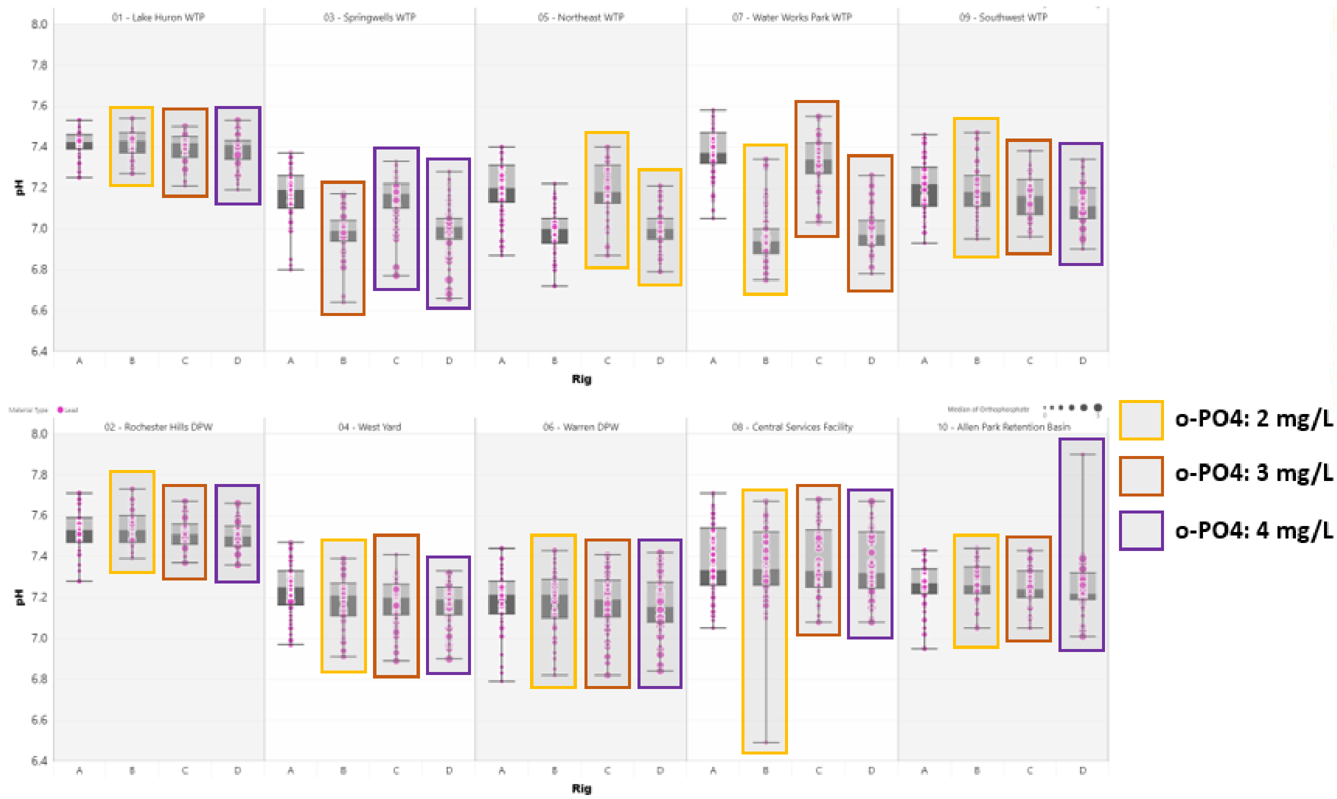


Figure B.2.11: pH Plots for Stagnant Samples from LSLs (December 5, 2022 - September 1, 2023)

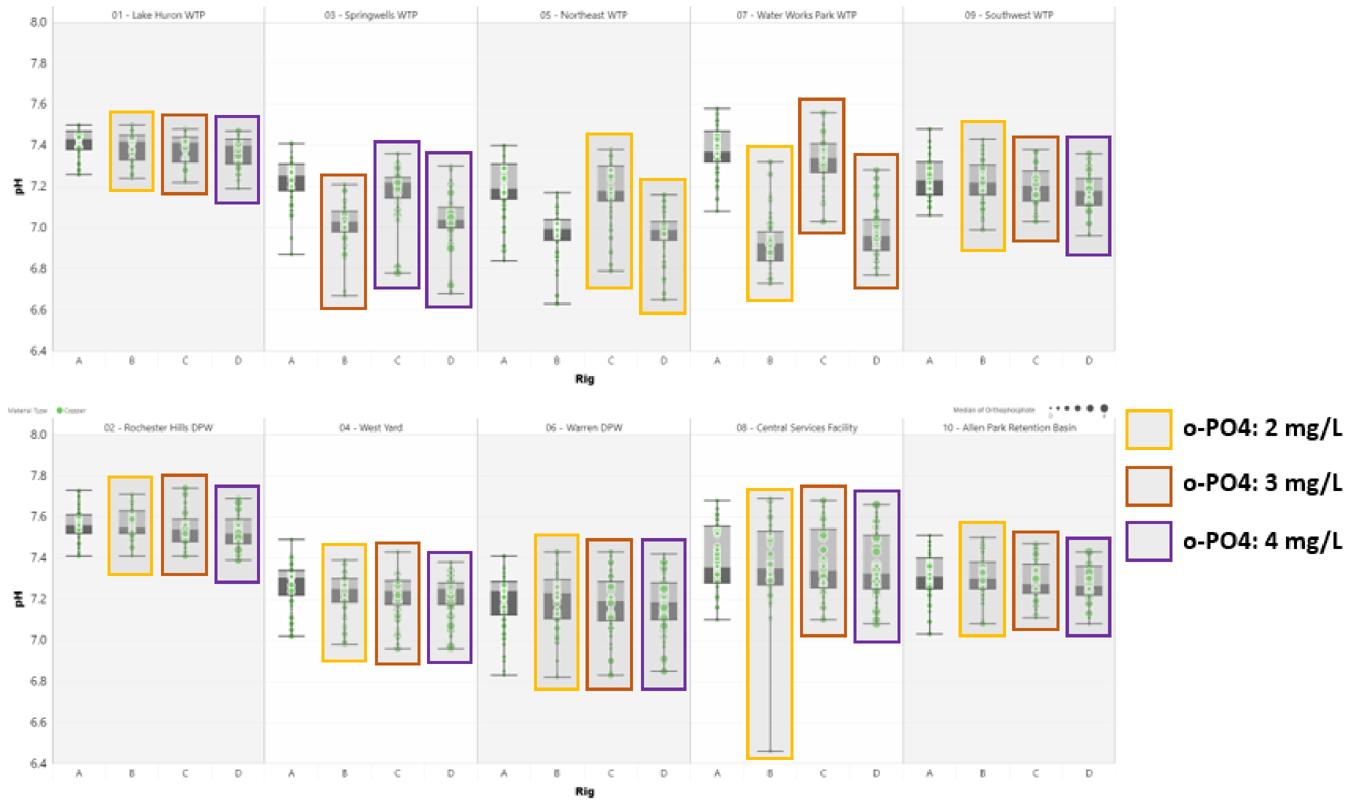


Figure B.2.12: pH Plots for Stagnant Samples from Copper Pipes (December 5, 2022 - September 1, 2023)

B.2.4 Temperature

Median of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	7.6	12.1	9.8	11.6	9.5	11.7	8.1	15.5	11.0	12.4
INF B	7.7	14.5	14.2	13.2	9.3	10.9	8.1	15.4	13.8	14.4
INF C	7.2	14.3	14.0	13.6	9.3	10.8	7.8	15.8	13.3	14.2
INF D	6.9	14.6	12.6	13.0	9.1	10.9	8.0	15.5	13.3	13.7

Minimum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	2.6	8.7	2.1	7.4	4.0	7.4	1.6	9.8	4.2	9.0
INF B	2.4	10.6	7.3	8.3	3.6	7.4	2.0	10.1	4.2	9.4
INF C	1.9	10.9	7.0	7.3	3.7	7.1	1.9	9.7	4.3	9.9
INF D	2.0	10.7	7.9	1.0	3.7	7.3	1.7	9.9	4.3	9.6

Maximum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	22.5	20.8	24.0	23.2	23.9	21.9	24.1	22.9	23.8	19.6
INF B	22.6	22.0	24.1	23.1	23.8	24.1	24.1	22.5	24.1	20.6
INF C	22.5	21.6	24.0	23.1	23.8	22.4	24.1	22.3	24.3	19.8
INF D	22.5	22.4	24.1	23.2	25.2	22.2	133.0	22.0	24.3	22.9

Count of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	38	36	39	36	40	39	39	37	38	35
INF B	38	37	38	36	40	39	39	37	38	35
INF C	37	37	39	35	40	39	39	38	38	34
INF D	37	37	38	36	41	38	39	37	38	35

Lake Huron Intake (01 - Lake Huron WTP, 02 - Rochester Hills DPW)

Detroit River – Belle Isle Intake (03 - Springwells WTP through 08 - Central Services Facility)

Detroit River – Fighting Island Intake (09 - Southwest WTP, 10 - Allen Park Retention Basin)

All temperatures were recorded as °C.

Red boxes indicate medians that were particularly low within a site.

Figure B.2.13: Temperature Statistics for Flowing Samples (December 5, 2022 - September 1, 2023)

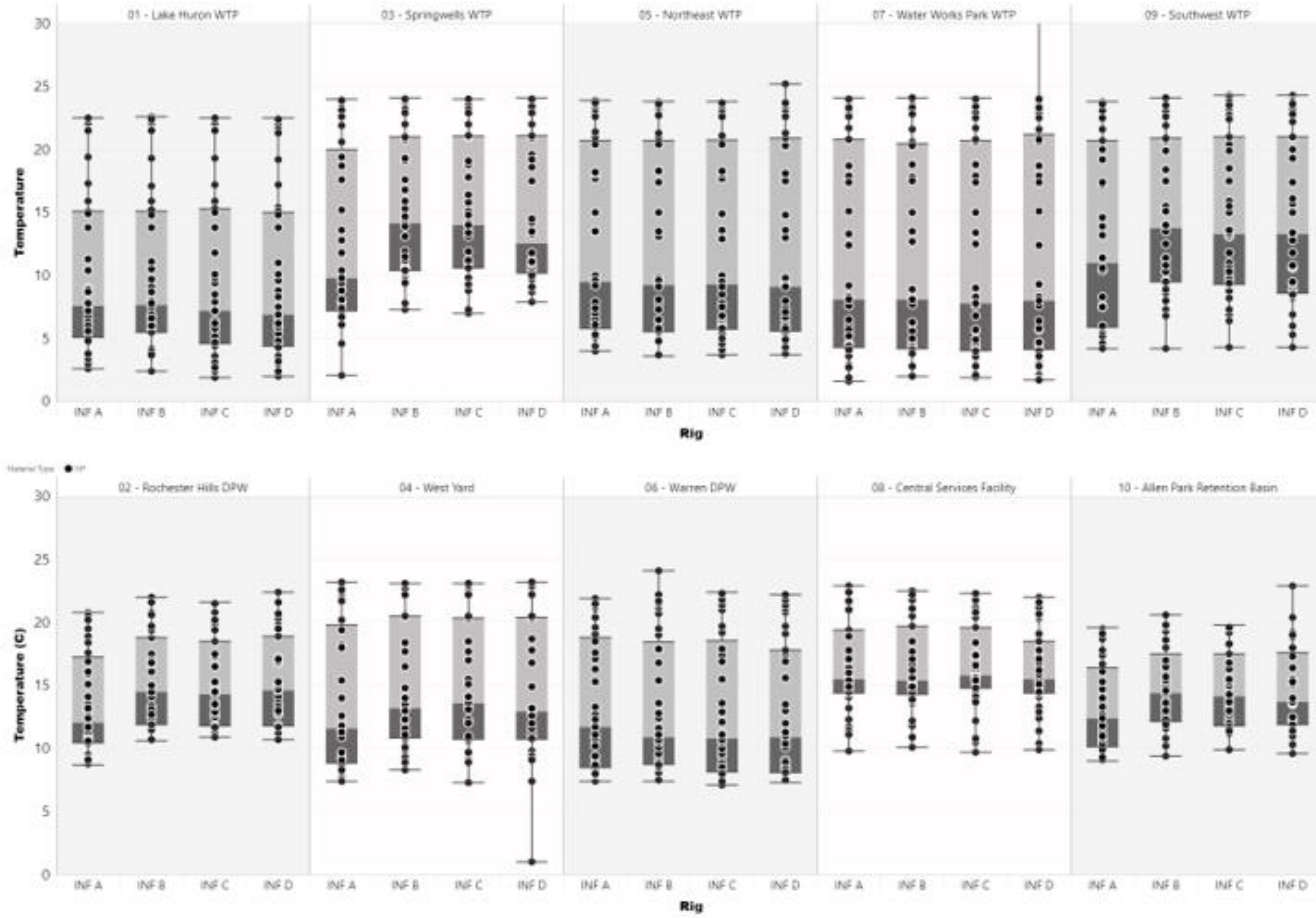


Figure B.2.14: Temperature Plots for Flowing Samples (December 5, 2022 - September 1, 2023)

B.2.5 Summary

Median Cl2

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	0.86	0.72	0.76	0.81	0.83	0.48	0.73	0.16	0.76	0.20
B	0.97	0.74	0.87	0.80	0.76	0.51	0.71	0.15	0.81	0.32
C	0.98	0.77	0.87	0.79	0.73	0.49	0.69	0.24	0.82	0.25
D	1.10	0.77	0.88	0.78	0.79	0.58	0.66	0.25	0.78	0.27

Median PO4

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	1.4	1.3	1.5	1.5	1.4	1.3	1.4	1.3	1.3	1.2
B	2.1	1.9	2.9	1.9	1.4	1.9	2.2	2.0	2.0	1.9
C	3.0	2.9	3.8	3.0	2.0	2.9	3.1	2.9	2.8	2.9
D	4.1	3.9	3.9	3.8	1.9	4.0	3.1	3.8	4.0	3.9

Median pH

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	7.4	7.5	7.2	7.3	7.2	7.2	7.4	7.3	7.2	7.3
B	7.4	7.5	7.0	7.2	7.0	7.2	6.9	7.3	7.2	7.3
C	7.4	7.5	7.2	7.2	7.2	7.2	7.3	7.3	7.2	7.3
D	7.4	7.5	7.0	7.2	7.0	7.2	7.0	7.3	7.1	7.2

Cl2 demand for medians of LSLs

Rig	01-Lake Huron WTP	02-Rochester Hills DPW	03-Springwells WTP	04-West Yard	05-Northeast WTP	06-Warren DPW	07-Water Works Park WTP	08-Central Services Facility	09-Southwest WTP	10-Allen Park Retention Basin
A	0.23	0.16	0.43	0.17	0.13	0.04	0.15	0.13	0.30	0.26
B	0.20	0.12	0.27	0.18	0.24	0.21	0.17	0.13	0.26	0.12
C	0.20	0.09	0.32	0.22	0.25	0.24	0.15	0.09	0.25	0.19
D	0.10	0.09	0.33	0.25	0.20	0.15	0.20	0.06	0.32	0.20

PO4 demand for medians of LSLs

Rig	01-Lake Huron WTP	02-Rochester Hills DPW	03-Springwells WTP	04-West Yard	05-Northeast WTP	06-Warren DPW	07-Water Works Park WTP	08-Central Services Facility	09-Southwest WTP	10-Allen Park Retention Basin
A	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	-0.1	0.1	0.0
B	-0.1	0.0	0.1	0.1	-0.1	0.0	-0.2	0.0	0.0	0.0
C	0.0	0.1	0.1	0.0	0.0	0.1	-0.1	0.1	0.1	0.1
D	-0.2	-0.1	0.1	0.2	0.1	-0.1	0.0	0.2	0.1	0.1

Red boxes indicate medians that were particularly high within a site.

Figure B.2.15: Medians of Stagnant Samples (Cl_2, o-PO_4, pH) from LSLs (December 5, 2022 - September 1, 2023)

Median Cl2

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	0.44	0.18	0.51	0.48	0.50	0.05	0.41	0.02	0.72	0.02
B	0.44	0.25	0.75	0.54	0.47	0.07	0.38	0.02	0.60	0.02
C	0.49	0.21	0.82	0.54	0.53	0.10	0.51	0.03	0.61	0.02
D	0.61	0.31	0.83	0.57	0.44	0.12	0.53	0.03	0.78	0.02

Median PO4

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	1.3	1.2	1.4	1.4	1.3	1.2	1.3	1.2	1.2	1.1
B	2.0	1.8	2.8	1.9	1.3	1.8	2.2	1.8	1.9	1.7
C	2.9	2.7	3.8	3.0	1.9	2.9	2.9	2.8	2.8	2.7
D	4.0	3.7	4.0	3.9	1.9	3.8	3.1	3.7	4.0	3.6

Median pH

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	7.4	7.5	7.2	7.3	7.2	7.2	7.4	7.3	7.2	7.3
B	7.4	7.5	7.0	7.2	7.0	7.2	6.9	7.3	7.2	7.3
C	7.4	7.5	7.2	7.2	7.2	7.2	7.3	7.3	7.2	7.3
D	7.4	7.5	7.0	7.2	7.0	7.2	7.0	7.3	7.1	7.2

Cl2 demand for medians of Copper pipe

Rig	01-Lake Huron WTP	02-Rochester Hills DPW	03-Springwells WTP	04-West Yard	05-Northeast WTP	06-Warren DPW	07-Water Works Park WTP	08-Central Services Facility	09-Southwest WTP	10-Allen Park Retention Basin
A	0.65	0.70	0.68	0.50	0.46	0.47	0.47	0.27	0.34	0.44
B	0.73	0.61	0.39	0.44	0.53	0.65	0.50	0.26	0.47	0.42
C	0.69	0.65	0.37	0.47	0.45	0.63	0.33	0.30	0.46	0.42
D	0.59	0.55	0.38	0.46	0.55	0.61	0.33	0.28	0.32	0.45

PO4 demand for medians of Copper pipe

Rig	01-Lake Huron WTP	02-Rochester Hills DPW	03-Springwells WTP	04-West Yard	05-Northeast WTP	06-Warren DPW	07-Water Works Park WTP	08-Central Services Facility	09-Southwest WTP	10-Allen Park Retention Basin
A	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.2	0.1
B	0.0	0.1	0.2	0.1	0.0	0.1	-0.2	0.2	0.1	0.2
C	0.1	0.3	0.1	0.0	0.1	0.1	0.1	0.2	0.1	0.3
D	-0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.3	0.1	0.4

Red boxes indicate medians that were particularly low or high within or across sites.

Figure B.2.16: Medians of Stagnant Samples (Cl_2, o-PO_4, pH) from Copper Pipes (December 5, 2022 - September 1, 2023)

B.3 10-Sample Stability Period of Testing Phase

B.3.1 Chlorine

Median of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	1.09	0.90	1.39	1.12	0.93	0.46	0.94	0.16	1.03	0.28
INF B	1.20	0.88	1.30	1.14	0.96	0.65	0.93	0.21	1.04	0.27
INF C	1.24	0.87	1.34	1.17	0.93	0.64	0.90	0.22	1.00	0.27
INF D	1.27	0.92	1.37	1.18	1.01	0.65	0.90	0.21	1.04	0.30

Minimum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	0.93	0.80	1.13	0.79	0.78	0.28	0.74	0.07	0.84	0.17
INF B	0.98	0.84	1.09	0.96	0.83	0.46	0.74	0.09	0.94	0.18
INF C	1.02	0.83	0.96	0.98	0.77	0.56	0.77	0.03	0.87	0.16
INF D	0.99	0.84	0.98	1.03	0.84	0.53	0.79	0.11	0.91	0.17

Maximum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	1.27	0.95	1.80	1.30	1.16	0.76	1.07	0.24	1.10	0.51
INF B	1.31	0.94	1.68	1.35	1.23	0.75	0.99	0.26	1.11	0.53
INF C	1.30	0.92	1.60	1.46	1.36	0.81	1.08	0.34	1.13	0.48
INF D	1.34	0.95	1.67	1.36	1.23	0.85	1.04	0.34	1.10	0.52

Count of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	8	10	10	8	10	10	10	9	10	10
INF B	9	10	10	8	10	10	10	9	10	10
INF C	9	10	10	8	10	10	10	9	10	10
INF D	9	10	10	8	10	10	10	9	10	10

Figure B.3.1: Chlorine Statistics for Flowing Samples (10-Sample Stability Period)

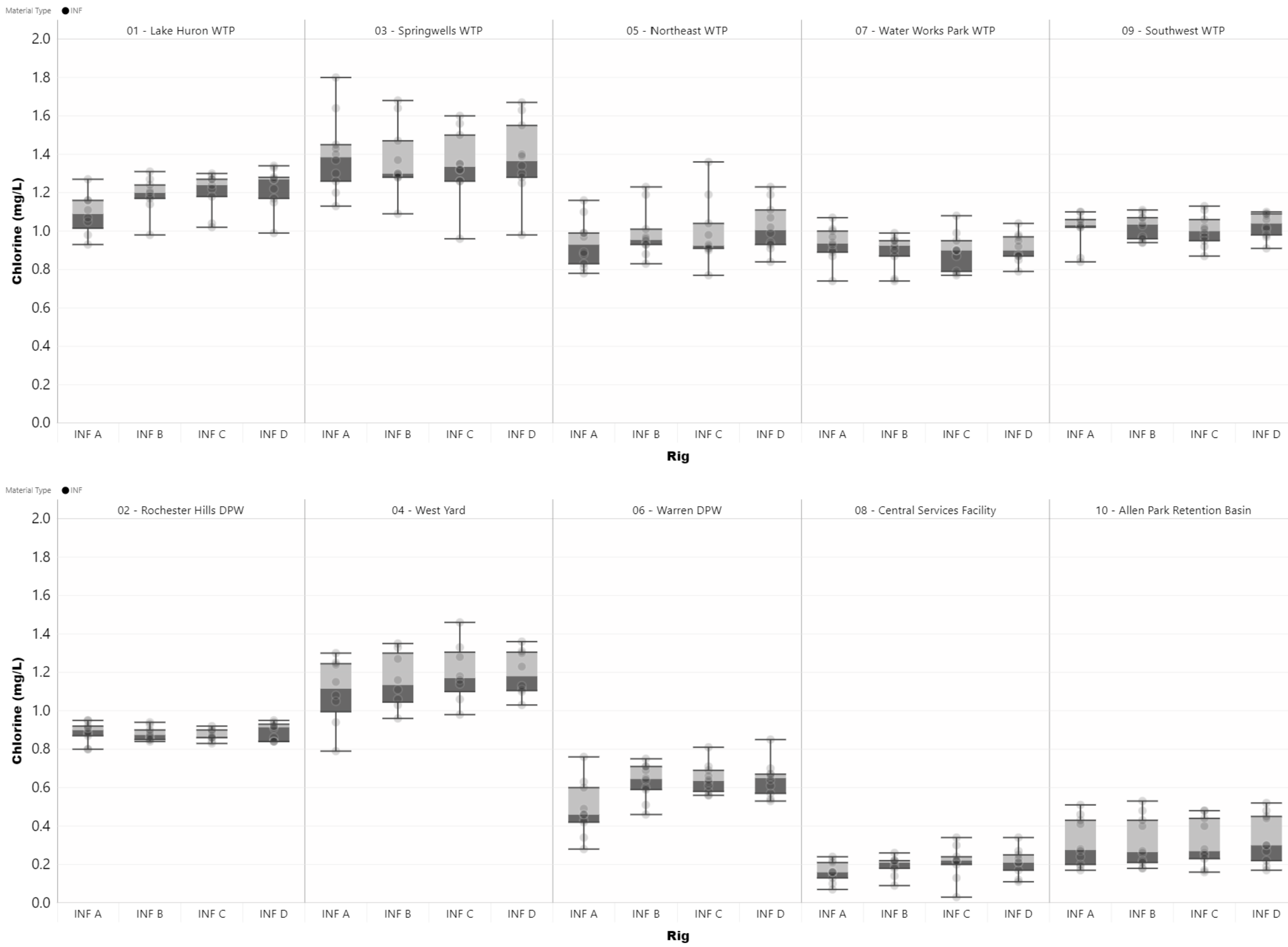


Figure B.3.2: Chlorine Plots for Flowing Samples (10-Sample Stability Period)

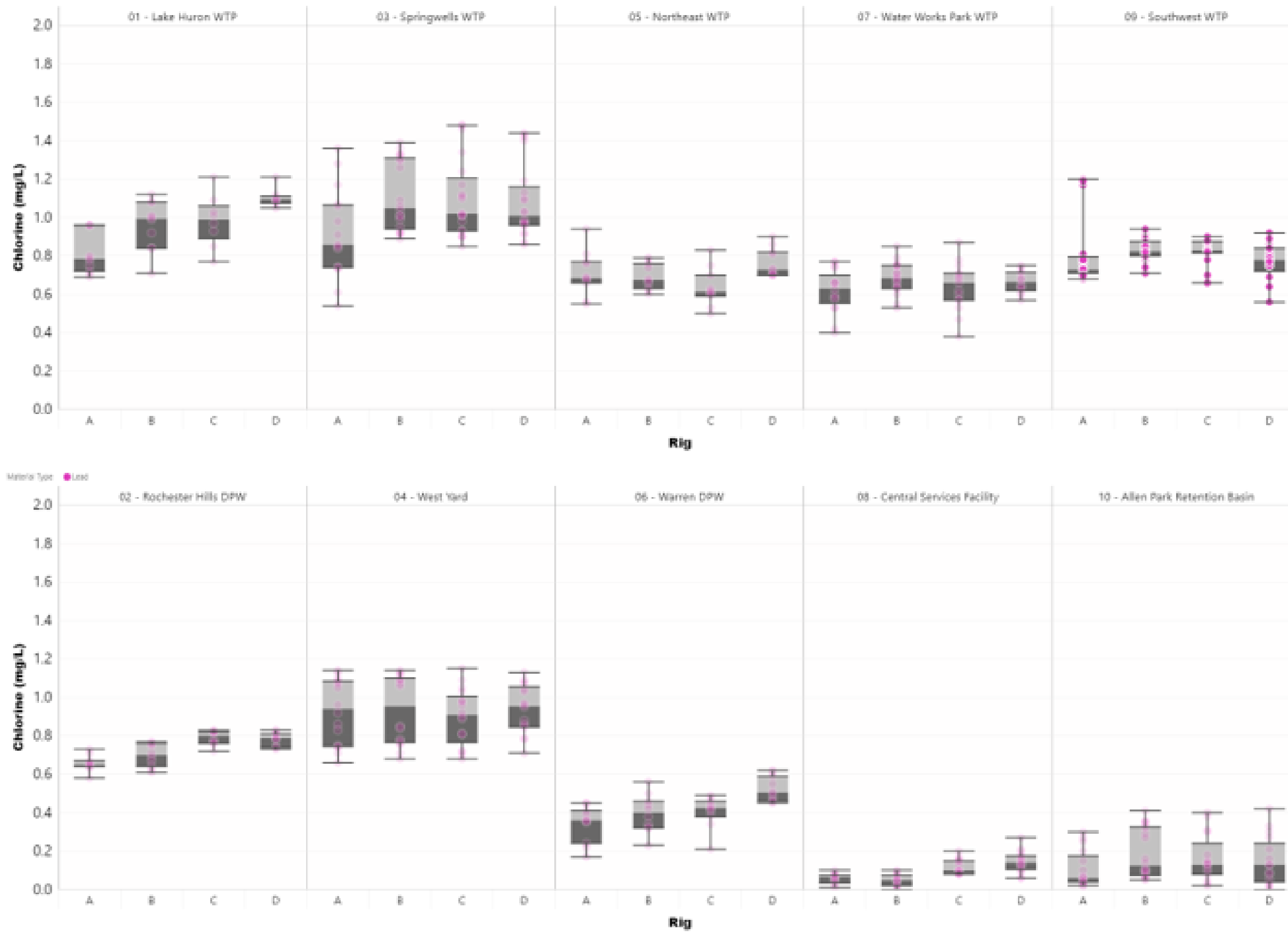


Figure B.3.3: Chlorine Plots for Stagnant Samples from LSLs (10-Sample Stability Period)

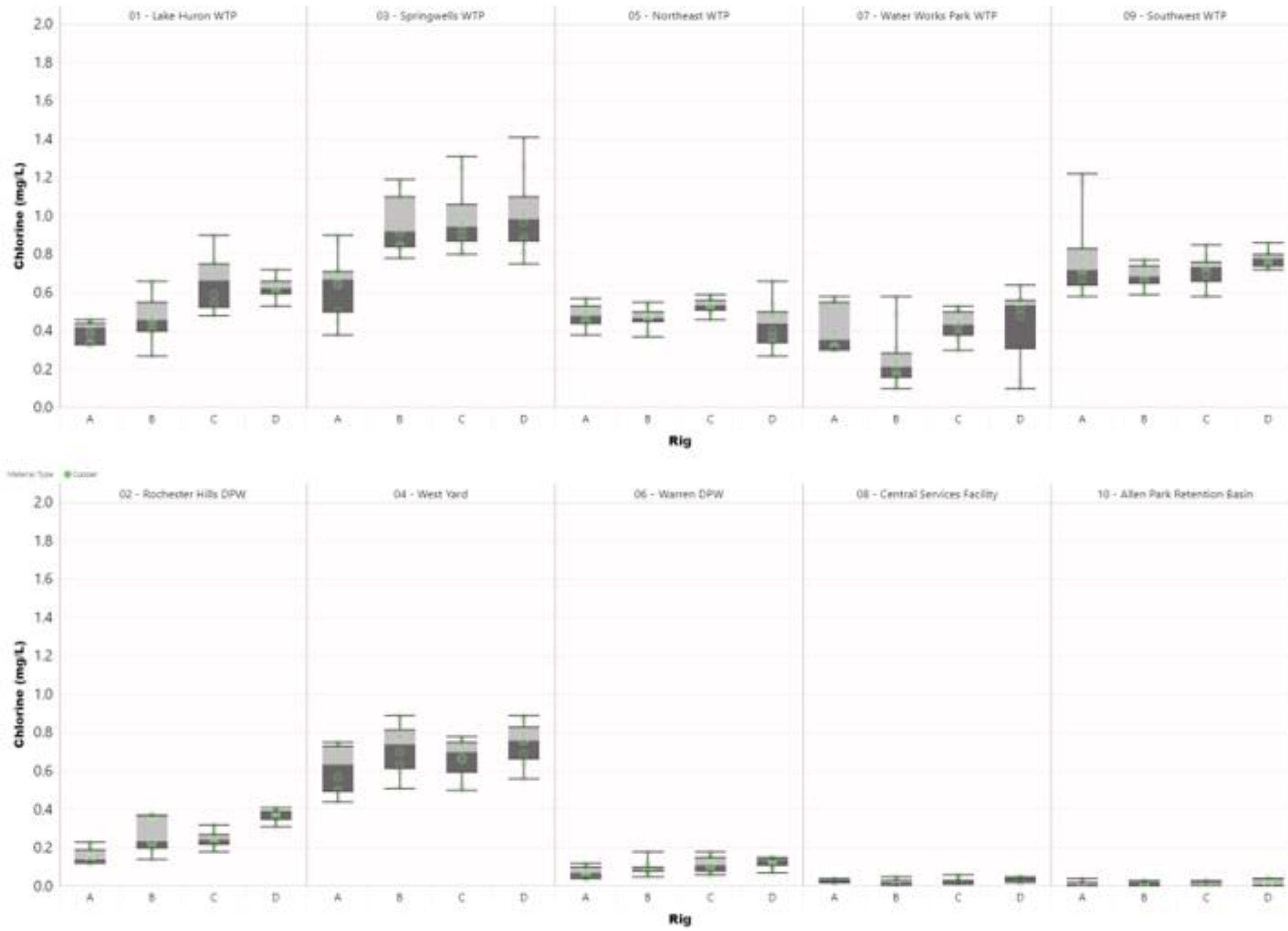


Figure B.3.4: Chlorine Plots for Stagnant Samples from Copper Pipes (10-Sample Stability Period)

B.3.2 o-PO_4

Median of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	1.3	1.3	1.6	1.4	1.2	1.2	1.5	1.2	1.4	1.2
INF B	2.0	1.9	3.0	2.0	1.2	1.9	2.1	2.0	1.8	2.0
INF C	3.0	3.0	3.9	3.1	1.9	3.1	3.0	3.2	2.8	2.9
INF D	4.1	3.8	4.0	4.0	1.9	3.9	3.1	3.9	4.0	4.0

Minimum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	1.2	1.2	0.9	1.2	1.1	1.1	1.3	1.1	1.0	1.1
INF B	1.8	1.8	2.2	1.8	1.0	1.7	1.9	1.7	1.4	1.8
INF C	2.8	2.7	3.3	3.0	1.8	2.3	2.7	2.6	2.3	2.5
INF D	3.5	3.3	3.0	3.4	1.8	3.5	2.9	3.2	3.0	3.6

Maximum of Data

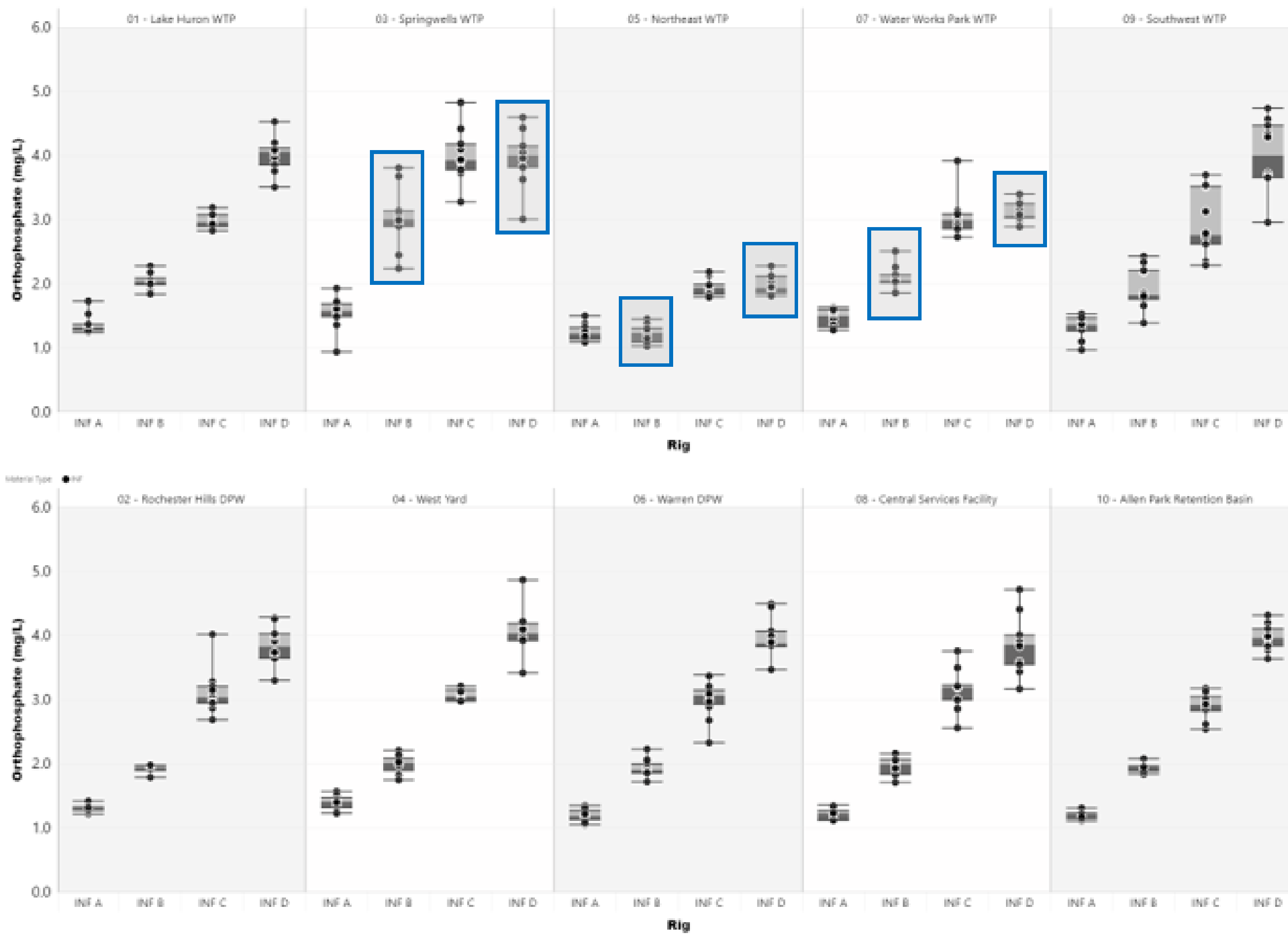
Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	1.7	1.4	1.9	1.6	1.5	1.4	1.6	1.4	1.5	1.3
INF B	2.3	2.0	3.8	2.2	1.5	2.2	2.5	2.2	2.4	2.1
INF C	3.2	4.0	4.8	3.2	2.2	3.4	3.9	3.8	3.7	3.2
INF D	4.5	4.3	4.6	4.9	2.3	4.5	3.4	4.7	4.7	4.3

Count of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	9	10	10	8	10	10	10	9	10	10
INF B	9	10	10	8	10	10	10	9	10	10
INF C	9	10	10	8	10	11	10	9	10	10
INF D	9	10	10	8	10	10	10	10	10	10

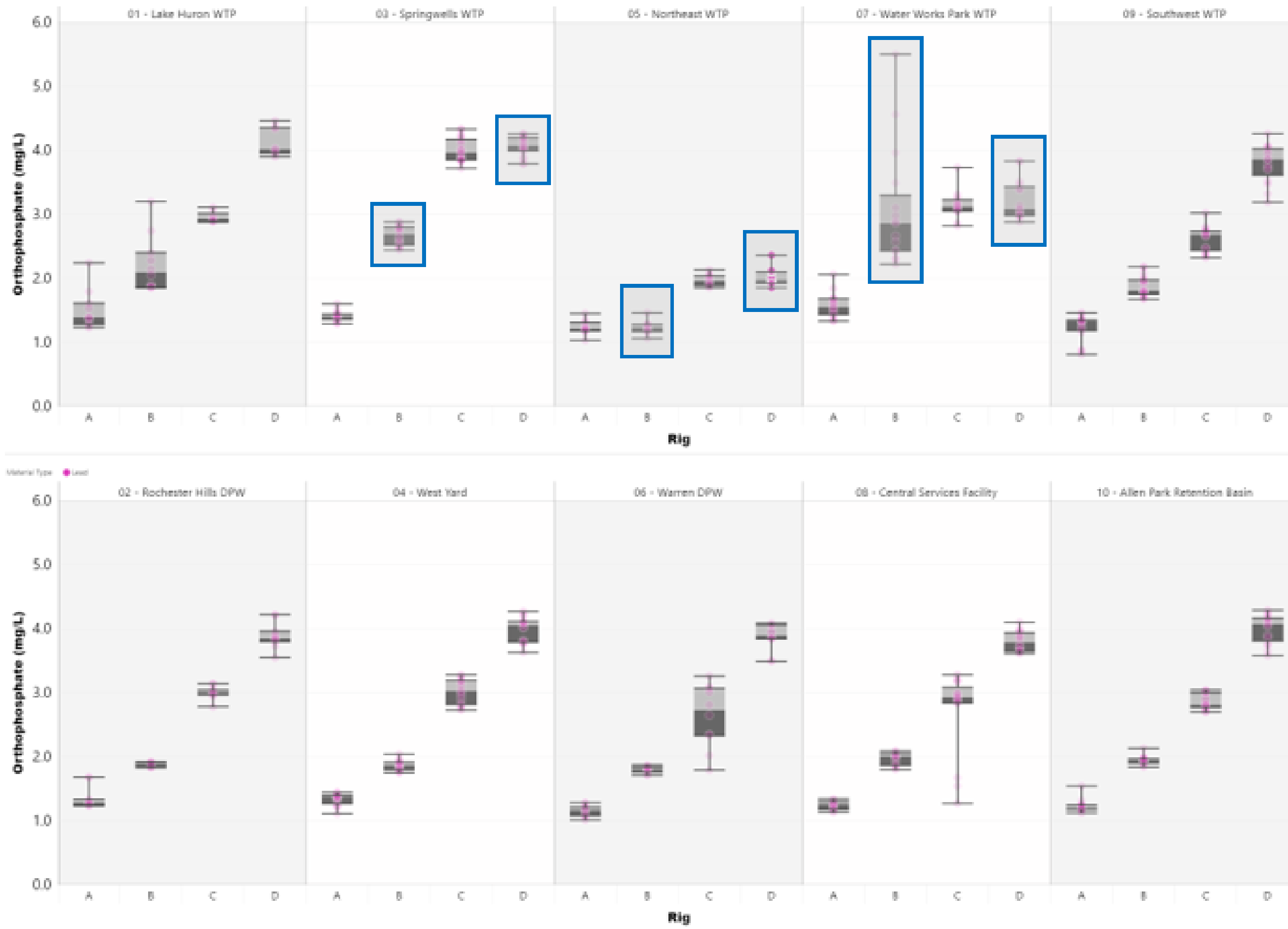
Colored boxes indicate deviations from the target value: green (± 0.0 mg/L), orange (± 0.1 mg/L), and red (± 0.2 mg/L).

Figure B.3.5: o-PO_4 Statistics for Flowing Samples (10-Sample Stability Period)



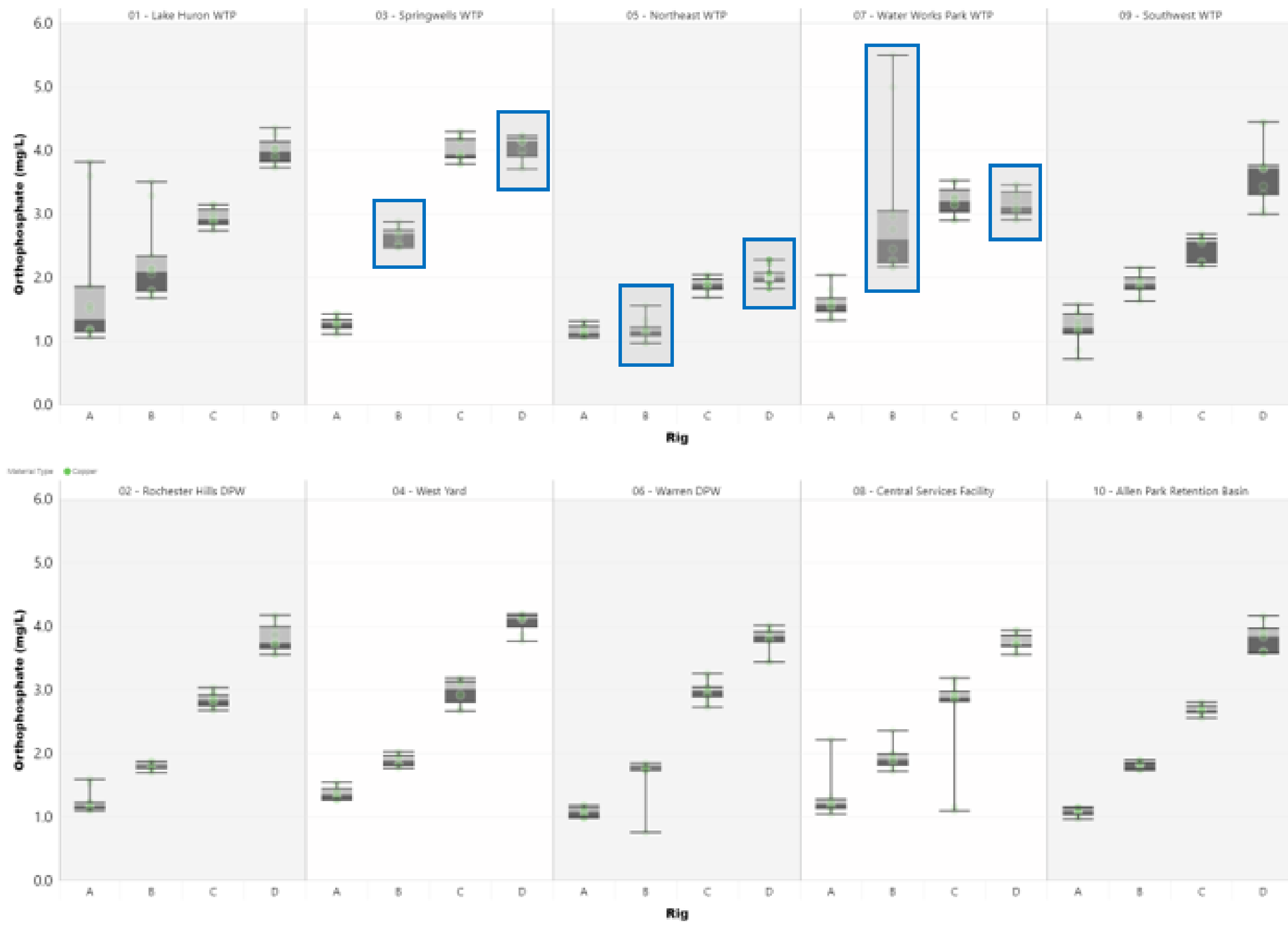
Blue boxes indicate rigs which received pH adjustment to a target of pH 7.0.

Figure B.3.6: o-PO_4 Plots for Flowing Samples (10-Sample Stability Period)



Blue boxes indicate rigs which received pH adjustment to a target of pH 7.0.

Figure B.3.7: o-PO_4 Plots for Stagnant Samples from LSLs (10-Sample Stability Period)



Blue boxes indicate rigs which received pH adjustment to a target of pH 7.0.

Figure B.3.8: o-PO_4 Plots for Stagnant Samples from Copper Pipes (10-Sample Stability Period)

B.3.3 pH

Median of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	7.5	7.5	7.2	7.3	7.3	7.4	7.5	7.6	7.3	7.4
INF B	7.5	7.5	7.0	7.3	7.1	7.4	7.0	7.6	7.3	7.4
INF C	7.5	7.5	7.2	7.2	7.3	7.3	7.5	7.6	7.2	7.4
INF D	7.5	7.5	7.0	7.2	7.0	7.4	7.0	7.6	7.2	7.3

Minimum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	7.4	7.4	7.2	7.3	7.3	7.3	7.4	7.5	7.2	7.3
INF B	7.4	7.4	6.9	7.3	7.0	7.3	6.9	7.5	7.2	7.2
INF C	7.4	7.4	7.1	7.1	7.3	7.2	7.4	7.5	7.2	7.2
INF D	7.4	7.4	6.9	7.2	7.0	7.3	6.9	7.5	7.2	7.2

Maximum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	7.5	7.6	7.3	7.4	7.4	7.4	7.5	7.7	7.4	7.4
INF B	7.5	7.6	7.1	7.3	7.1	7.4	7.2	7.6	7.3	7.4
INF C	7.5	7.6	7.3	7.3	7.4	7.4	7.5	7.6	7.3	7.4
INF D	7.5	7.6	7.2	7.3	7.2	7.4	7.2	7.6	7.3	7.4

Count of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	9.0	10.0	10.0	8.0	10.0	10.0	10.0	9.0	10.0	10.0
INF B	9.0	10.0	10.0	8.0	10.0	10.0	10.0	9.0	10.0	10.0
INF C	9.0	10.0	10.0	8.0	10.0	10.0	10.0	9.0	10.0	10.0
INF D	9.0	10.0	10.0	8.0	10.0	10.0	10.0	9.0	10.0	10.0

Colored boxes indicate deviations from the target value: green (± 0.0 mg/L), orange (± 0.1 mg/L), and red (± 0.2 mg/L).

Figure B.3.9: pH Statistics for Flowing Samples (10-Sample Stability Period)

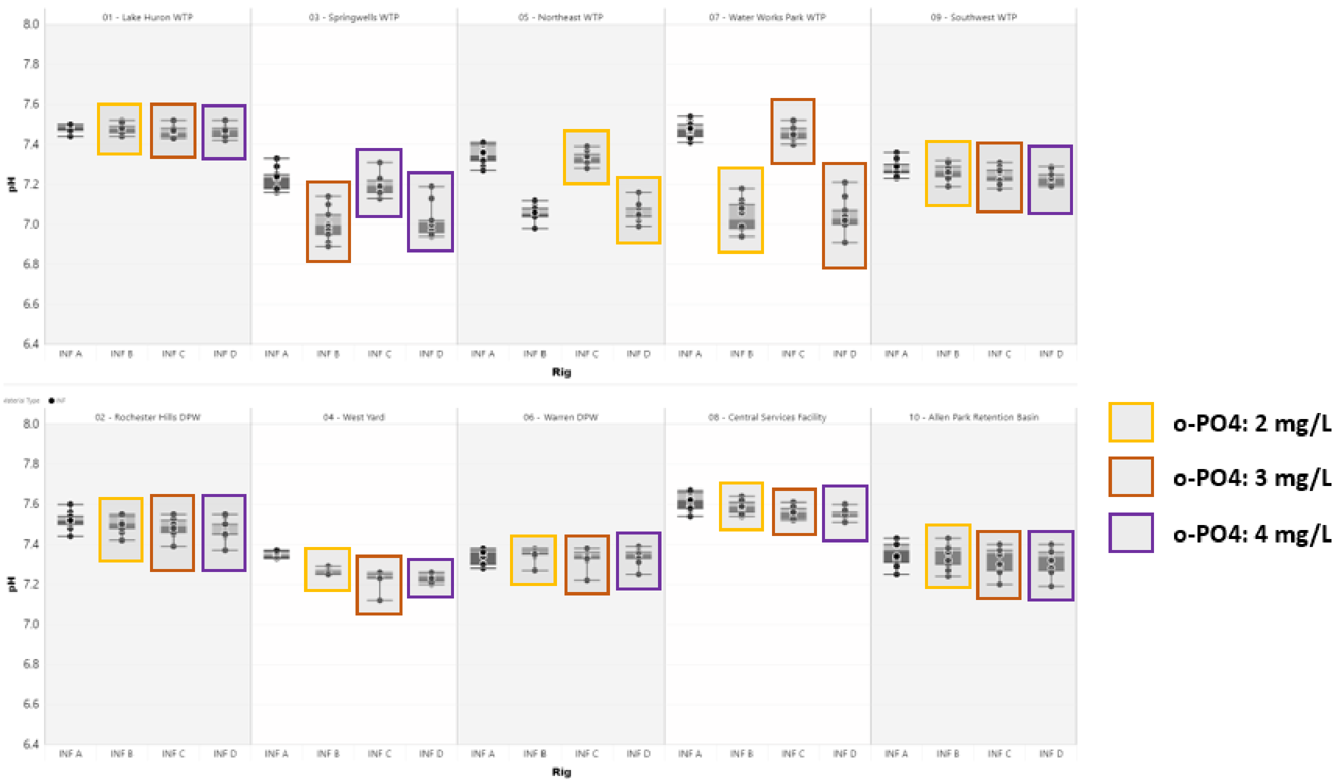


Figure B.3.10: pH Plots for Flowing Samples (10-Sample Stability Period)

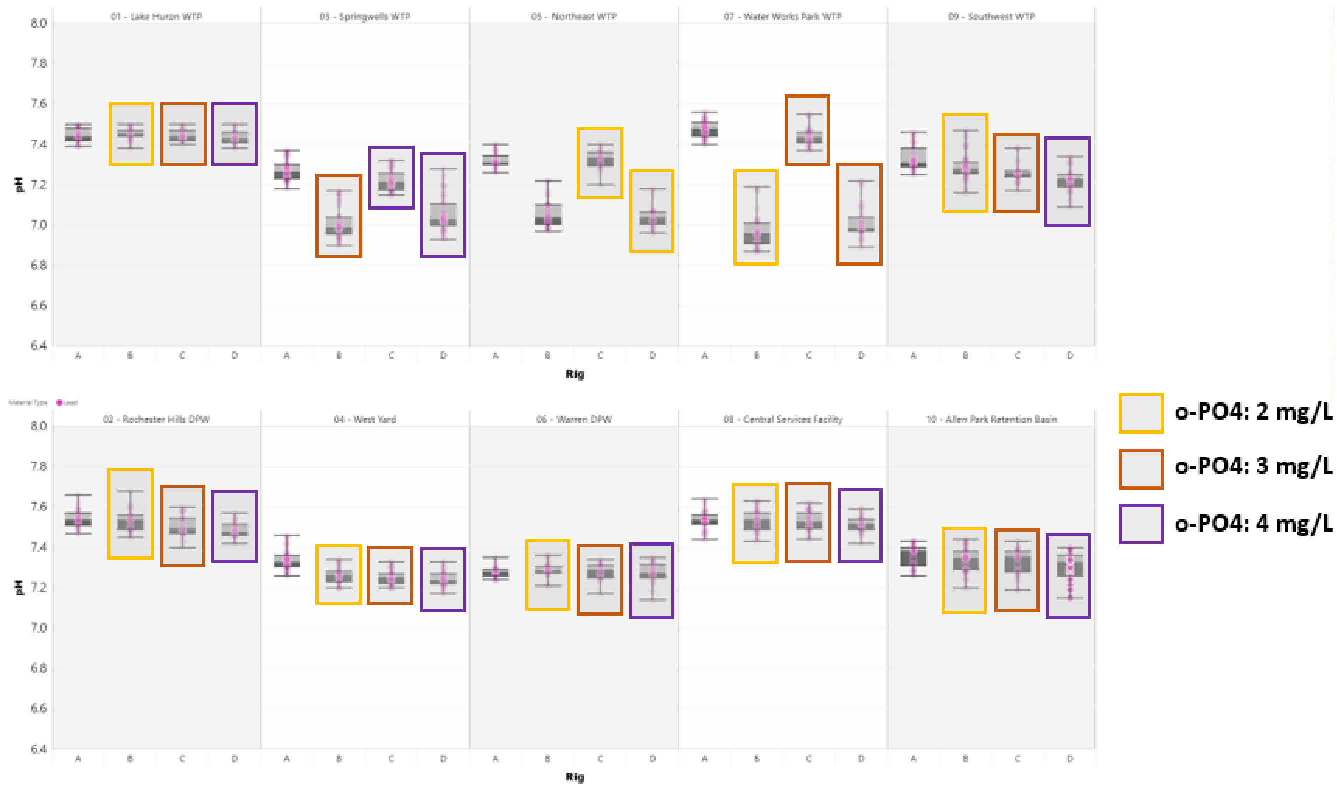


Figure B.3.11: pH Plots for Stagnant Samples from LSLs (10-Sample Stability Period)

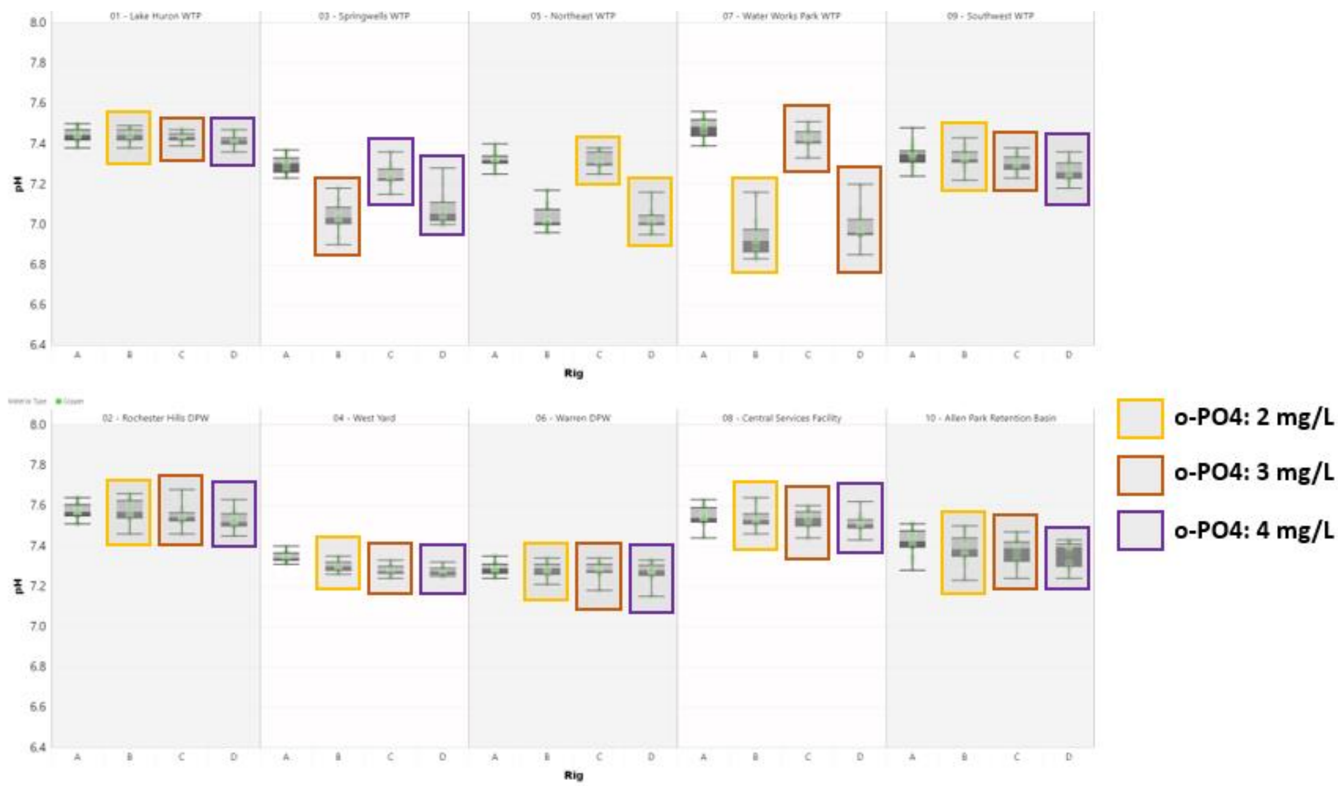


Figure B.3.12: pH Plots for Stagnant Samples from Copper Pipes (10-Sample Stability Period)

B.3.4 Temperature

Median of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	15.1	16.5	20.0	19.8	20.7	18.1	20.8	19.4	20.4	15.7
INF B	15.1	17.9	20.9	20.6	20.7	18.5	20.5	19.7	20.8	16.8
INF C	15.3	18.0	21.1	20.4	21.5	18.6	20.7	19.6	20.7	16.6
INF D	15.0	18.1	21.1	20.4	21.8	18.5	20.7	19.1	21.0	16.9

Minimum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	10.4	13.2	2.1	15.4	15.0	13.3	15.1	17.1	14.6	12.4
INF B	10.5	15.0	15.9	16.5	15.0	13.6	15.0	17.1	15.5	14.6
INF C	10.1	15.3	16.4	17.0	14.9	13.6	15.0	17.3	15.9	14.3
INF D	10.1	15.3	17.5	16.8	14.8	13.5	15.1	17.1	15.7	14.0

Maximum of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	19.4	19.5	24.0	22.6	23.9	21.0	24.1	22.9	23.8	18.6
INF B	19.3	19.8	24.1	23.0	23.8	21.5	24.1	22.5	24.1	19.5
INF C	19.3	20.2	24.0	23.1	23.8	21.4	24.1	22.2	24.3	19.3
INF D	19.2	20.3	24.1	23.2	25.2	21.4	24.1	22.0	24.3	22.9

Count of Data

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
INF A	9.0	10.0	10.0	8.0	10.0	10.0	10.0	9.0	10.0	10.0
INF B	9.0	10.0	10.0	8.0	10.0	10.0	10.0	9.0	10.0	10.0
INF C	9.0	10.0	10.0	8.0	10.0	10.0	10.0	9.0	10.0	10.0
INF D	9.0	10.0	9.0	8.0	10.0	10.0	10.0	9.0	10.0	10.0

Lake Huron Intake (01–02) *Detroit River – Belle Isle Intake* (03–08) *Detroit River – Fighting Island Intake* (09–10)

All temperatures were recorded as °C.

Figure B.3.13: Temperature Statistics for Flowing Samples (10-Sample Stability Period)

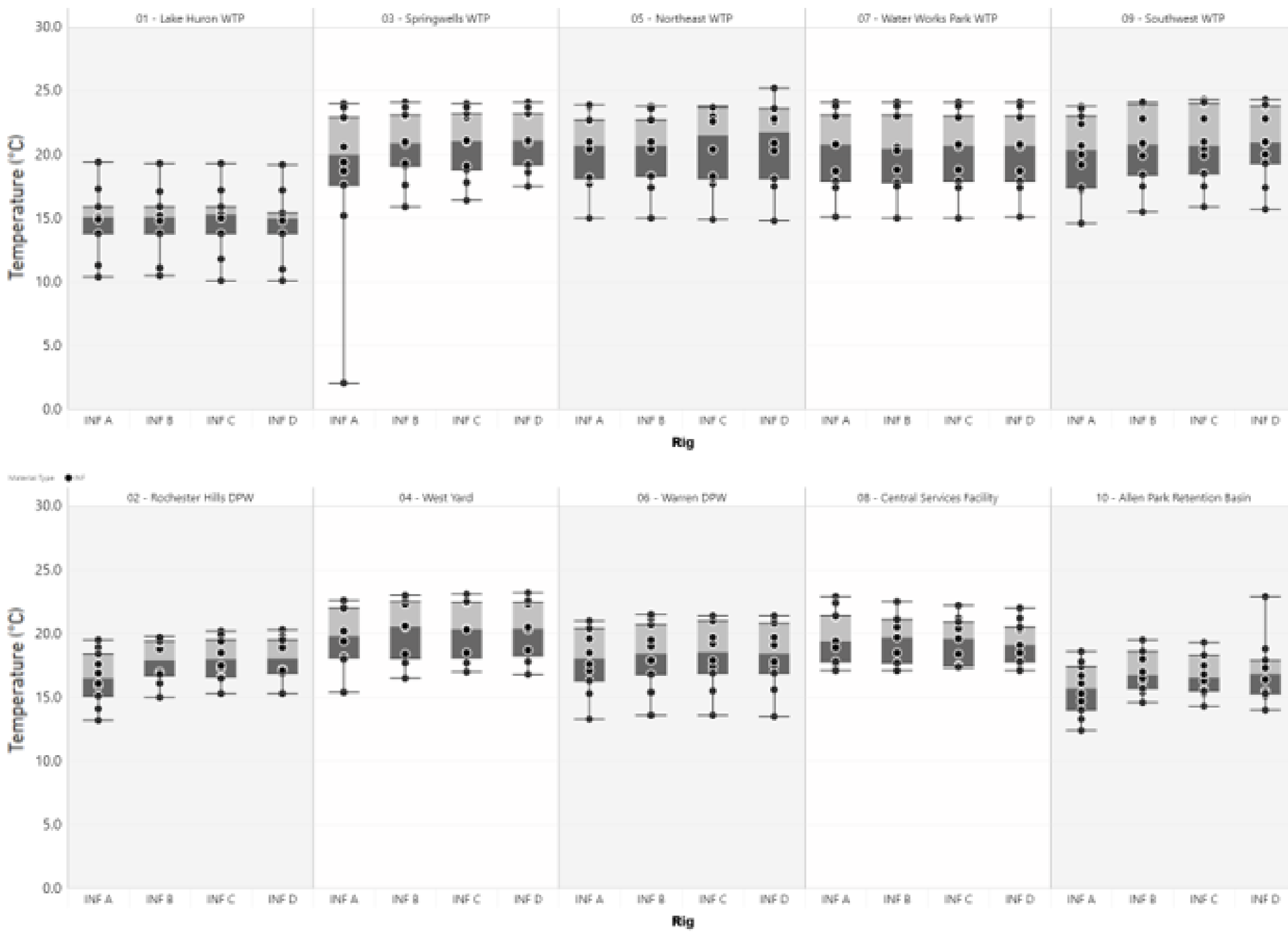


Figure B.3.14: Temperature Plots for Flowing Samples (10-Sample Stability Period)

B.3.5 Summary

Median of Cl2

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	0.79	0.65	0.86	0.94	0.69	0.36	0.63	0.07	0.73	0.06
B	1.00	0.70	1.05	0.96	0.68	0.40	0.69	0.05	0.83	0.13
C	0.99	0.80	1.02	0.91	0.62	0.43	0.66	0.10	0.83	0.13
D	1.10	0.79	1.01	0.96	0.73	0.51	0.67	0.14	0.78	0.13

Count of Cl2

A	10	10	15	16	10	10	15	12	15	15
B	10	10	20	16	10	10	18	12	20	20
C	8	10	20	16	10	10	15	15	15	15
D	8	10	20	16	10	10	12	15	15	15

Median of PO4

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	1.4	1.3	1.4	1.4	1.2	1.2	1.6	1.3	1.3	1.2
B	2.1	1.9	2.7	1.9	1.2	1.8	2.9	2.0	1.8	1.9
C	2.9	3.0	4.0	3.0	2.0	2.7	3.1	2.9	2.7	2.8
D	4.0	3.9	4.1	4.1	2.0	3.9	3.1	3.8	3.9	4.1

Count of PO4

A	10.0	10.0	15.0	16.0	10.0	10.0	15.0	12.0	15.0	15.0
B	10.0	10.0	20.0	16.0	10.0	10.0	15.0	12.0	20.0	20.0
C	8.0	10.0	20.0	16.0	10.0	10.0	12.0	15.0	15.0	15.0
D	8.0	10.0	20.0	16.0	10.0	10.0	15.0	15.0	15.0	15.0

Median pH

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	7.4	7.5	7.3	7.3	7.3	7.3	7.5	7.5	7.3	7.4
B	7.5	7.5	7.0	7.3	7.0	7.3	7.0	7.5	7.3	7.4
C	7.4	7.5	7.2	7.3	7.3	7.3	7.4	7.5	7.3	7.4
D	7.4	7.5	7.0	7.2	7.0	7.3	7.0	7.5	7.2	7.3

Count of pH

A	18.0	20.0	30.0	32.0	20.0	20.0	30.0	27.0	30.0	30.0
B	18.0	20.0	40.0	32.0	20.0	20.0	30.0	27.0	40.0	40.0
C	18.0	20.0	40.0	32.0	20.0	20.0	30.0	27.0	30.0	30.0
D	18.0	20.0	40.0	32.0	20.0	20.0	30.0	27.0	30.0	30.0

Figure B.3.15: Medians of Stagnant Samples (Cl_2, o-PO_4, pH) from LSLs (10-Sample Stability Period)

Median of Cl2

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	0.42	0.14	0.67	0.64	0.48	0.07	0.36	0.03	0.72	0.01
B	0.46	0.24	0.92	0.74	0.47	0.09	0.22	0.02	0.69	0.02
C	0.67	0.25	0.95	0.70	0.54	0.11	0.44	0.03	0.74	0.01
D	0.63	0.39	0.99	0.76	0.44	0.14	0.54	0.04	0.78	0.01

Count of Cl2

A	10	10	10	8	10	10	10	8	10	10
B	10	10	10	8	10	10	12	8	10	10
C	8	10	10	8	10	10	10	10	10	10
D	8	10	10	8	10	10	8	10	10	10

Median of PO4

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	1.3	1.2	1.3	1.4	1.1	1.1	1.6	1.2	1.2	1.1
B	2.1	1.8	2.7	1.9	1.2	1.8	2.6	1.9	1.9	1.9
C	2.9	2.8	3.9	3.0	1.9	3.0	3.2	2.9	2.6	2.7
D	4.0	3.7	4.2	4.1	2.0	3.9	3.1	3.7	3.7	3.8

Count of PO4

A	10.0	10.0	10.0	8.0	10.0	10.0	10.0	8.0	10.0	10.0
B	10.0	10.0	10.0	8.0	10.0	10.0	10.0	8.0	10.0	10.0
C	8.0	10.0	10.0	8.0	10.0	10.0	8.0	10.0	10.0	10.0
D	8.0	10.0	10.0	8.0	10.0	10.0	10.0	10.0	10.0	10.0

Median pH

Rig	01 - Lake Huron WTP	02 - Rochester Hills DPW	03 - Springwells WTP	04 - West Yard	05 - Northeast WTP	06 - Warren DPW	07 - Water Works Park WTP	08 - Central Services Facility	09 - Southwest WTP	10 - Allen Park Retention Basin
A	7.4	7.6	7.3	7.3	7.3	7.3	7.5	7.5	7.4	7.4
B	7.4	7.6	7.0	7.3	7.0	7.3	6.9	7.5	7.3	7.4
C	7.4	7.5	7.2	7.3	7.3	7.3	7.4	7.5	7.3	7.4
D	7.4	7.5	7.1	7.3	7.0	7.3	7.0	7.5	7.3	7.4

Count of pH

A	18.0	20.0	20.0	16.0	20.0	20.0	20.0	18.0	20.0	20.0
B	18.0	20.0	20.0	16.0	20.0	20.0	20.0	18.0	20.0	20.0
C	18.0	20.0	20.0	16.0	20.0	20.0	20.0	18.0	20.0	20.0
D	18.0	20.0	20.0	16.0	20.0	20.0	20.0	18.0	20.0	20.0

Figure B.3.16: Medians of Stagnant Samples (Cl_2, o-PO_4, pH) from Copper Pipes (10-Sample Stability Period)