OB CURTIS AND JH FEWELL WATER TREATMENT PLANTS

OPTIMAL CORROSION CONTROL TREATMENT REPORT

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Prepared For

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TABLE OF CONTENTS

Appendix A – Premise Lead Sampling Data

Appendix B – Treatment Process Information

Appendix C – Demonstration Unit Schematic

Appendix D – Demonstration Unit Data

Part 1 – Purpose

The purpose of the Optimal Corrosion Control Treatment Study is to determine and set parameters for the finished water pH, alkalinity, and dissolved inorganic carbon (DIC). The Desk-top Study recommended demonstration units be operated for six months for the following two treatment approaches: pH and DIC adjustment and phosphate corrosion inhibitor addition.

Part 2 – Introduction

2.1   Historic Data

The city of Jackson water distribution system consists of a surface water system with two treatment plants (OB Curtis and JH Fewell and distribution system and a well field and distribution system. The two systems are hydraulically separated. OB Curtis is a 50 million gallon per day (MGD) plant consisting of a 25 MGD conventional treatment train and a 25 MGD ultrafiltration membrane train. JH Fewell is a 25 MGD conventional water treatment plant. The finished water pH goal for the surface water treatment plants has been 9.0 or higher for more than 30 years. In April 2015, the wells were taken offline and the new booster station (from surface distribution system to well distribution system) was placed into service. The well distribution system began receiving treated surface water primarily from OB Curtis WTP.

The well system uses free chlorine, but the surface water system uses chloramines. Lead and copper samples were collected in June 2015 in accordance with the requirements of the Lead and Copper Rule. Of the top 25 highest lead levels from the June 2015 premise sampling, 13 sites exceeded 15 ppb (parts per billion) and 13 sites were located on the well system. Of the 13 samples that exceeded the action level, 9 sites were located on the well system. Due to high service pump issues at OB Curtis WTP, the wells were placed backed into service in July 2015 switching the well system distribution system back to free chlorine. Of the top 25 highest lead levels from the February 2016 premise sampling, 11 sites exceeded 15 ppb and 7 of the sites were located on the well system. Of the 11 samples that exceeded the action level, only one site was located on the well system. Of the top 25 highest lead levels from the August 2016 premise sampling, 13 sites exceeded 15 ppb and 4 of the sites were located on the well system. Of the 13 samples that exceeded the action level, only 1 site was located on the well system. Lead sampling data for September 2007, July 2012, June 2015, and February 2016 are included in Appendix A.

Fluctuating pH from the OB Curtis WTP is the most likely reason for the increase in lead levels at the consumer taps in the surface water distribution system. The decline in pH in the distribution system from low alkalinity and DIC of both plant's treated water is also a contributing factor. The conversion from free chlorine to chloramines is the most likely reason for the exceedance of the action level for the homes on the well system.

Exhibit D.5: Treatment Process Information from the March 2016 EPA publication entitled *Optimal Corrosion Control Treatment Evaluation Technical Recommendations for Primacy*

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Agencies and Public Water Systems for the OB Curtis WTP and the JH Fewell WTP are included in Appendix B.

2.2   Treatment Approach: pH and Dissolved Inorganic Carbon Adjustment

Using soda ash to modify DIC (increases alkalinity as well) and pH can be used as a passivation technique for controlling soluble lead and copper. The solubility of lead and copper in water is dependent upon the chemical species in which those metals are found. In the absence of corrosion inhibitors, lead will form less soluble scales that are frequently dominated by compounds that result from the reaction of carbonate and divalent lead (Pb^{++}) compounds. In the absence of corrosion inhibitors, copper will form less soluble scales that result from the reaction of the hydroxyl ion and carbonate ion. In general, leaching of lead and copper from consumer plumbing can be minimized by elevating water pH. In addition, sufficient alkalinity must be present to serve as a buffer for preventing changes in pH within the distribution system.

The Desk-Top Study recommended soda ash (Na_2CO_3) be used for final pH adjustment because of the direct addition of the carbonate ion to the water increases both DIC and alkalinity.

2.3   Treatment Approach: Orthophosphate Addition

This method of corrosion control is based on the theory that the addition of rthophosphate to finished water will result in the formation of low-solubility lead-phosphate complexes on interior pipe surfaces. The protective layer acts as a barrier to corrosion, reducing dissolution of lead into the water. Copper solubility is not significantly affected by phosphate inhibitors at reasonable dosages.

Orthophosphate is the most common form used for lead control. The simplest source of orthophosphate is phosphoric acid which is the chemical used in this demonstration unit. The pH range at which orthophosphate is most effective for minimizing lead solubility is 7.2 to 7.8. Above pH 7.8, metal phosphate precipitation can become problematic. Orthophosphate can interact with other cations such as calcium or magnesium which may be present in the water. These interactions represent an orthophosphate demand, which reduces the amount of orthophosphate available to complex with lead.

The city of Jackson has two wastewater treatment plants (WWTPs), the Savanna Street WWTP and Trahon/Big Creek WWTP. Both WWTPs have a total phosphorus limit in the NPDES permit. As part of the city's current Consent Decree, a CCP (Composite Correction Program) was completed for the Savanna Street WWTP. The CCP showed possible upgrades to the treatment process for biological phosphorus removal might not be able to biologically remove the existing phosphorus entering the plant. This analysis did not include the potential load swapping of phosphorus from the Trahon/Big Creek WWTP to the Savanna Street WWTP or the removal of West Rankin Utility Authority. This load swapping will make the biological removal of phosphorus at the Savanna Street WWTP even less achievable. An increase in the concentration of phosphorus will occur if West Rankin Utility Authority ceases to discharge to

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Savanna Street. The addition of a phosphate based corrosion inhibitor was evaluated during the demonstration testing, but will only be implemented if adjustment of pH and DIC proves to be inadequate for lead and copper control.

Lowering of the pH from the long time practice of finished water pH at 9.0 or higher will create problems with stripping of deposits in the distribution system and interfere with the chloramination process.

2.4 OB Curtis Water Treatment Plant Demonstration Units

The Desk-top Study recommended a finished water treatment scheme for the OB Curtis WTP consisting of lime and carbon dioxide ahead of the pre-oxidation basins for alkalinity and calcium supplement and soda ash for finished water pH, alkalinity, and DIC adjustment. After the Desk-top Study was completed, the discovery was made that lime could not be feed in the pre-oxidation basin due to the lime coating the ultrafiltration membranes. The demonstration units were operated during a time period when no pH adjustment occurred prior to coagulation which is the current plant treatment scheme. The decision was made to stop the current practice of using lime for final pH adjustment and start using soda ash as the final pH adjustment chemical so no current treatment demonstration unit was utilized.

Three identical demonstration units were constructed and a schematic is provided as Figure 1 in Appendix C. The lead and copper coupon size was 3" long by 1/2" wide by 1/16" thick with 1/8" radius corners and a 3/16" diameter hole. The lead coupon material code is UNS# L50050 and the copper coupon material code is UNS# C12200.

The following alternate treatment schemes were used during the optimal corrosion control treatment demonstration period at the OB Curtis WTP:

Demonstration Unit No. 1 used the current treatment through filtration from Filter No. 6 with a 5 milligram/liter (mg/l) dose of chlorine using a gaseous chlorine solution from the JH Fewell WTP, used ammonium hydroxide for ammonia addition at a 4 to 1 ratio, used hydrofluosilicic acid for fluoride addition at a 0.60 mg/l dose, and added soda ash for pH adjustment to 9.2 +/- 0.2.

Demonstration Unit No. 2 used the current treatment through filtration from Filter No. 6 with a 5 mg/l dose of chlorine using a gaseous chlorine solution from the JH Fewell WTP, used ammonium hydroxide for ammonia addition at a 4 to 1 ratio, used hydrofluosilicic acid for fluoride addition at a 0.60 mg/l dose, and soda ash for pH adjustment to 8.8 +/- 0.2.

Demonstration Unit No. 3 used the current treatment through filtration from Filter No. 6 with 5 mg/l dose of chlorine using a gaseous chlorine solution from the JH Fewell WTP, using ammonium hydroxide for ammonia addition at a 4 to 1 ratio, used hydrofluosilicic acid for fluoride addition at a 0.60 mg/l dose, used phosphoric acid for PO_4 addition, and added soda ash for pH adjustment to 7.5 +/- 0.2.

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Current chemical treatment through filtration at OB Curtis includes coagulation with aluminum chlorohydrate (ACH).

Chlorine was added to the demonstration units and mixed using a tank mounted mixer and allowed 5 minutes of contact time before the free chlorine residual was tested to determine the amount of ammonia to add. When ammonia, phosphoric acid, hydrofluosilicic acid, or soda ash was added to the demonstration units, the tank was mixed and a five minute minimum wait period was given for the water to stabilize before laboratory testing was performed.

pH, temperature, alkalinity, fluoride, orthophosphate, chloramines, free ammonia, free chlorine, total chlorine, sulfate, and chloride testing of make-up day water and sample day water was performed by Trilogy Engineering Services and the lead and copper analysis was performed by the Mississippi Department of Health Public Health Laboratory.

2.5   JH Fewell Water Treatment Plant Demonstration Units

The Desk-top Study recommended finished water treatment scheme for the JH Fewell WTP is lime addition (for coagulation pH adjustment and alkalinity addition) and soda ash for finished water pH, alkalinity, and DIC adjustment.

Three identical demonstration units were constructed and a schematic is provided as Figure 1 in Appendix C. The lead and copper coupon size was 3" long by 1/2" wide by 1/16" thick with 1/8" radius corners and a 3/16" diameter hole. The lead coupon material code is UNS# L50050 and the copper coupon material code is UNS# C12200.

The following alternate treatment schemes were used during the optimal corrosion control treatment demonstration period at the JH Fewell WTP:

Demonstration Unit No. 1 used the current treatment, using lime as final pH adjustment chemical, by using finished water from the plant with no chemical additions. By using the plant's finished water, fluctuations in pH from normal plant production was tested (control testing apparatus) as well as a low DIC water.

Demonstration Unit No. 2 used the current treatment through filtration (chlorine and ammonia have already been added) from Filter No. 29, used hydrofluosilicic acid for fluoride addition at a 0.60 mg/l dose, used phosphoric acid used for PO_4 addition, and added soda ash for final pH adjustment to 7.5+/- 0.2.

Demonstration Unit No. 3 used the current treatment through filtration (chlorine and ammonia have already been added) from Filter No. 29, used hydrofluosilicic acid for fluoride addition at a 0.60 mg/l dose, added soda ash for final pH adjustment to 8.8+/- 0.2 for 10 batches and 9.2+/- for 12 batches.

Current chemical treatment through filtration at JH Fewell includes coagulation with alum and lime, chlorine addition for disinfection, and ammonia addition for chloramine production.

When phosphoric acid, hydrofluosilicic acid, or soda ash was added to the demonstration units, the tank was mixed and a five minute minimum wait period was given for the water to stabilize before laboratory testing was performed.

pH, temperature, alkalinity, fluoride, orthophosphate, chloramines, free ammonia, free chlorine, total chlorine, sulfate, and chloride testing of make-up day water and sample day water was performed by Trilogy Engineering Services and the lead and copper analysis was performed by the Mississippi Department of Health Public Health Laboratory.

Part 3 – Corrosion Control Testing Results

3.1   OB Curtis Water Treatment Plant

   a.   OBC Demonstration Unit No. 1

Demonstration Unit No. 1 was operated for a period of 28 weeks with 24 lead and copper samples taken. The unit was predominately flushed once per day for 30 to 45 seconds. This length of time would completely exchange the water in the unit. The lead and copper sample port would be flushed as well. On sample collection day, the unit was flushed the same and the lead and copper sample port was given a four second flush and the isolation valves on the influent and effluent lines would be closed. The stagnation time before lead and copper sampling was standardized at eight hours. Testing for sample day pH, temperature, alkalinity, chloramines, free ammonia, free chlorine, total chlorine, fluoride, and chloride were performed immediately after the unit was flushed.

The target pH for Demonstration Unit No. 1 was 9.2 +/-0.2, the target DIC was 6 to 10 mg carbon/liter (mg C/l), and the alkalinity was allowed to fluctuate to satisfy the final pH goal. The hardness of the water was not changed because soda ash was used for pH adjustment. Table 3.1.1 in Appendix D shows the data collected from Demonstration Unit No. 1. The following summarizes the data from Table 3.1.1:

   Lead concentration ranged from 4.1 to 9.4 parts per billion (ppb) with stagnation times ranging from 8.0 to 9.5 hours,
   Copper concentration ranged from 0.0120 to 0.0396 parts per million (ppm) with stagnation times ranging from 8.0 to 9.5 hours,
   Make-up day pH ranging from 9.10 to 9.47,
   Make-up day alkalinity ranging from 32.1 to 58.1 mg/l,
   Make-up day Langelier Index ranging from -0.30 to 0.15,
   Make-up day DIC ranging from 7.0 to 13.5 mg C/l,
   Make-up day soda ash dose ranging from 20.5 to 48.0 mg/l,
   Make-up day chloramines ranging from 2.06 to 4.09 mg/l,
   Make-up day free ammonia ranging from 0.07 to 0.45 mg/l,
   Make-up day sulfate ranging from 0 to 3 mg/l,

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Water age (number of days between make-up day and sample day) ranging from 3 to 10 days,
Sample day pH ranging from 8.27 to 8.98,
Sample day alkalinity ranging from 31.2 to 56.5 mg/l,
Sample day Langelier Index ranging from -1.11 to -0.15,
Sample day DIC ranging from 7.0 to 12.5 mg C/l,
Sample day chloramines ranging from 1.55 to 3.33 mg/l,
Sample day free ammonia ranging from 0.08 to 0.54 mg/l,
Sample day fluoride ranging 0.53 to 1.26 mg/l, (target was 0.60 mg/l but for three batches double amount of fluoride was added due to laboratory analysis error), and
Sample day chloride ranging from 8.4 to 21.0 mg/l.

Taking out batches 3, 4, and 5 with double fluoride added, the make-up day alkalinity ranged from 32.1 to 55.9 mg/l, the make-up day DIC ranged from 7.0 to 12.0 mg C/l, the make-up day soda ash dose ranged from 20.5 to 45.0 mg/l, and the sample day alkalinity ranged from 31.2 to 56.5.

As can be seen from Table 3.1.1, sample day lead concentration appeared to stabilize at week 9 with three significantly higher samples occurring in batches 18, 19, and 20.

Non-parametric statistics was selected to compare the three demonstration unit's treatment. In applying the non-parametric methods to lead and copper testing results, the type of question which they may answer is: Is the population of lead/copper levels from experimental condition in Unit 1 higher, lower, or the same as those from experimental condition in Unit 2 or Unit 3. The Wilcoxon Test is the non-parametric test used to compare and select the treatment method. See Table 3.1.4 in Appendix D.

The comparison was made using batch number 11 through 24 because orthophosphate addition began with batch number 11. The test results were Demonstration Unit No 1 was lower for lead than Demonstration Unit No. 2 and was the same as Demonstration Unit No. 2 for copper. The test results were Demonstration Unit No 1 was lower for lead than Demonstration Unit No. 3 and was the same as Demonstration Unit No. 3 for copper.

b. OBC Demonstration Unit No. 2

Demonstration unit No. 2 was operated for a period of 28 weeks with 24 lead and copper samples taken. The unit was predominately flushed once per day for 30 to 45 seconds. This length of time would completely exchange the water in the unit out. The lead and copper sample port would be flushed as well. On sample collection day, the unit was flushed the same and the lead and copper sample port was given a four second flush and the isolation valves on the influent and effluent lines would be closed. The stagnation time before lead and copper sampling was standardized at eight hours. Testing for sample day pH, temperature, alkalinity, chloramines, free ammonia, free chlorine, total chlorine, fluoride, and chloride were performed immediately after the unit was flushed.

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The target pH for Demonstration Unit No. 2 was 8.8 +/-0.2, the target DIC was 6 to 10 mg C/l, and the alkalinity was allowed to fluctuate to satisfy the final pH goal. The hardness of the water was not changed because soda ash was used for pH adjustment. Table 3.1.2 in Appendix D shows the data collected from Demonstration Unit No. 2. The following summarizes the data from Table 3.1.2:

Lead concentration ranged from 4.2 to 12.3 ppb with stagnation times ranging from 8.0 to 9.5 hours,
Copper concentration ranged from 0.0128 to 0.0287 ppm with stagnation times ranging from 8.0 to 9.5 hours,
Make-up day pH ranging from 8.71 to 9.35,
Make-up day alkalinity ranging from 26.2 to 51.0 mg/l,
Make-up day Langelier Index ranging from -0.82 to 0.13,
Make-up day DIC ranging from 6.0 to 12.0 mg C/l,
Make-up day soda ash dose ranging from 19.0 to 42.0 mg/l,
Make-up day chloramines ranging from 2.24 to 4.22 mg/l,
Make-up day free ammonia ranging from 0.03 to 0.40 mg/l,
Make-up day sulfate ranging from 0 to 3 mg/l,
Water age (number of days between make-up day and sample day) ranging from 3 to 10 days,
Sample day pH ranging from 7.81 to 8.94,
Sample day alkalinity ranging from 26.9 to 48.9 mg/l,
Sample day Langelier Index ranging from -1.71 to -0.36,
Sample day DIC ranging from 6.5 to 12.0 mg C/l,
Sample day chloramines ranging from 1.32 to 3.15 mg/l,
Sample day free ammonia ranging from 0.17 to >0.55 mg/l,
Sample day fluoride ranging 0.53 to 1.26 mg/l, (target was 0.60 mg/l but for three batches double amount of fluoride was added due to laboratory analysis error), and
Sample day chloride ranging from 9.8 to 20.0 mg/l.

Taking out batches 3, 4, and 5 with double fluoride added, the make-up day alkalinity ranged from 26.2 to 49.6 mg/l, the make-up day DIC ranged from 6.0 to 12.0 mg C/l, the make-up day soda ash dose ranged from 19.0 to 37.0 mg/l, and the sample day alkalinity ranged from 26.9 to 48.3.

As can be seen from Table 3.1.2, sample day lead concentration appeared to stabilize at week 9 with two significantly higher samples occurring in batches 19 and 20.

Non-parametric statistics was selected to compare the three demonstration unit's treatment. In applying the non-parametric methods to lead and copper testing results, the type of question which they may answer is: Is the population of lead/copper levels from experimental condition in Unit 1 higher, lower, or the same as those from experimental condition in Unit 1 or Unit 3. The Wilcoxon Test is the non-parametric test used to compare and select the treatment method. See Table 3.1.4 in Appendix D.

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The comparison was made using batch number 11 through 24 because orthophosphate addition began with batch number 11. The test results were Demonstration Unit No 2 was higher for lead than Demonstration Unit No. 1 and was the same as Demonstration Unit No. 1 for copper. The test results were Demonstration Unit No 2 was lower for lead than Demonstration Unit No. 3 and was the same as Demonstration Unit No. 3 for copper.

c. OBC Demonstration Unit No. 3

Demonstration unit No. 3 was operated for a period of 28 weeks with 24 lead and copper samples taken. The unit was predominately flushed once per day for 30 to 45 seconds. This length of time would completely exchange the water in the unit out. The lead and copper sample port would be flushed as well. On sample collection day, the unit was flushed the same and the lead and copper sample port was given a four second flush and the isolation valves on the influent and effluent lines would be closed. The stagnation time before lead and copper sampling was standardized at eight hours. Testing for sample day pH, temperature, alkalinity, chloramines, free ammonia, free chlorine, total chlorine, fluoride, and chloride were performed immediately after the unit was flushed.

The target pH for Demonstration Unit No. 3 was 7.5 +/-0.2, the target DIC was 6 to 10 mg C/l, the target orthophosphate varied from 0.5 to 1.5 mg/l from the addition of phosphoric acid, and the alkalinity was allowed to fluctuate to satisfy the final pH goal. The hardness of the water was not changed because soda ash was used for pH adjustment. Table 3.1.3 in Appendix D shows the data collected from Demonstration Unit No. 3. The following summarizes the data from Table 3.1.3:

Lead concentration ranged from 6.2 to 23.2 ppb with stagnation times ranging from 8.0 to 9.5 hours (the first ten batches were made without addition of phosphoric acid to obtain baseline data),
Copper concentration ranged from 0.0095 to 0.0702 ppm with stagnation times ranging from 8.0 to 9.5 hours,
Make-up day pH ranging from 7.39 to 8.25,
Make-up day alkalinity ranging from 22.6 to 42.6 mg/l,
Make-up day Langelier Index ranging from -2.16 to -1.13,
Make-up day DIC ranging from 5.5 to 10.5 mg C/l,
Make-up day soda ash dose ranging from 13.0 to 32.0 mg/l,
Make-up day orthophosphate ranging from 0.54 to 2.09 mg/l
Make-up day chloramines ranging from 2.27 to 4.04 mg/l,
Make-up day free ammonia ranging from 0.04 to 0.48 mg/l,
Make-up day sulfate ranging from 0 to 3 mg/l,
Water age (number of days between make-up day and sample day) ranging from 3 to 10 days,
Sample day pH ranging from 7.24 to 7.89,
Sample day alkalinity ranging from 21.1 to 39.2 mg/l,
Sample day Langelier Index ranging from -2.38 to -1.33,

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Sample day DIC ranging from 5.0 to 10.0 mg C/l,
Sample day orthophosphate ranging from 0.48 to 1.72 mg/l
Sample day chloramines ranging from 0.98 to 2.97 mg/l,
Sample day free ammonia ranging from 0.23 to >0.55 mg/l,
Sample day fluoride ranging 0.56 to 1.26 mg/l, (target was 0.60 mg/l but for three batches double amount of fluoride was added due to laboratory analysis error), and
Sample day chloride ranging from 9.7 to 23.4 mg/l.

Taking out batches 3, 4, and 5 with double fluoride added, the make-up day alkalinity ranged from 22.6 to 39.5 mg/l, the make-up day DIC ranged from 5.5 to 10 mg C/l, the make-up day soda ash dose ranged from 13.0 to 27 mg/l, and the sample day alkalinity ranged from 21.1 to 37.7.

As can be seen from Table 3.1.3, sample day lead concentration appeared to still be stabilizing at batch 24. Too low of phosphoric acid dose was used at the start to have much of an impact on lead levels but was dropping significantly at the higher orthophosphate dose.

Non-parametric statistics was selected to compare the three demonstration unit's treatment. In applying the non-parametric methods to lead and copper testing results, the type of question which they may answer is: Is the population of lead/copper levels from experimental condition in Unit 3 higher, lower, or the same as those from experimental condition in Unit 1 or Unit 2. The Wilcoxon Test is the non-parametric test used to compare and select the treatment method. See Table 3.1.4 in Appendix D.

The comparison was made using batch number 11 through 24 because orthophosphate addition began with batch number 11. The test results were Demonstration Unit No 3 was higher for lead than Demonstration Unit No. 1 and was the same as Demonstration Unit No. 1 for copper. The test results were Demonstration Unit No 3 was higher for lead than Demonstration Unit No. 2 and was the same as Demonstration Unit No. 2 for copper.

d. Discussion and Recommendation of Alternates

Demonstration Unit No. 1 had the lowest lead concentration of the three units and the non-parametric statistical analysis showed Demonstration Unit No. 1 to have the lowest lead for the duration of the testing and all the units were the same for copper. The testing protocol called for the finished pH to be 9.2. This pH value produced make-up day water with a slightly negative Langelier Index. Using Tetra Tech's (RTW) Water Chemistry, Process, and Corrosion Control software to increase the make-up day water pH to 9.3 resulted in a slightly positive Langelier Index in 33% of the batches and to pH of 9.4 resulted in a slightly positive Langelier Index in 75% of the batches. See Table 3.1.5.

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Table 3.1.5: Demonstration Unit No. 1 Make-up Day Langelier Index, Alkalinity, and DIC Values at pH of 9.3 and 9.4

Batch #	Make Up Day Langelier Index at pH of 9.3	Make Up Day DIC at pH of 9.3	Make Up Day Alkalinity at pH of 9.3	Soda Ash Required at pH of 9.3	Make Up Day Langelier Index at pH of 9.4	Make Up Day DIC at pH of 9.4	Make Up Day Alkalinity at pH of 9.4	Soda Ash Required at pH of 9.4
1	0.26	11.3	52.6	42.8	0.39	11.6	55.5	46.0
2	0.29	12.7	58.4	47.8	0.42	13.1	61.3	51.0
3	0.13	11.1	51.0	43.0	0.25	11.4	53.4	45.7
4	0.23	13.6	62.1	52.4	0.35	13.9	65.0	55.7
5	0.05	10.6	48.4	38.4	0.17	10.8	50.6	40.9
6	0.08	9.5	43.8	30.3	0.20	9.7	45.9	32.7
7	0.04	9.1	41.0	30.0	0.16	9.3	42.8	32.0
8	-0.02	8.5	38.8	27.6	0.10	8.7	40.5	29.5
9	-0.07	8.5	39.4	26.0	0.03	8.5	39.4	26.0
10	-0.13	8.3	36.8	22.8	-0.01	8.5	38.3	24.4
11	-0.07	8.5	38.3	27.7	0.05	8.7	39.9	29.4
12	-0.13	7.5	33.5	22.1	-0.02	7.6	34.9	23.6
13	-0.14	7.7	36.3	30.5	-0.04	7.7	36.3	30.5
14	-0.06	8.6	39.5	28.6	0.06	8.8	41.2	30.5
15	-0.01	8.2	37.5	31.3	0.11	8.4	39.1	33.1
16	-0.18	7.3	33.2	32.2	-0.06	7.5	34.6	33.8
17	-0.15	7.7	34.7	33.4	-0.03	7.9	36.2	35.1
18	-0.12	7.4	33.9	30.1	0.00	7.6	35.4	31.8
19	-0.11	7.8	35.3	34.5	0.01	8.0	36.9	36.3
20	-0.10	7.9	36.6	34.3	0.02	8.1	38.2	36.1
21	-0.12	7.3	33.8	32.5	-0.01	7.4	34.6	33.4
22	-0.02	8.5	38.5	37.2	0.10	8.7	40.2	39.1
23	0.00	8.5	39.0	41.5	0.13	8.8	41.0	43.7
24	-0.06	7.9	36.7	37.5	0.06	8.1	38.1	39.0

Recommended finished water pH range entering the distribution system is 9.3 to 9.4 with a minimum pH of 9.1 and a maximum pH of 9.5 for the OB Curtis Water Treatment Plant. ~~and a minimum distribution pH range of 8.6 to 8.8.~~ The operations staff will monitor the pH on the plant's SCADA system and will collect and analyze grab samples every four hours to insure the pH entering the distribution system is between 9.3 and 9.4.

With a pH of 9.3 or 9.4, the DIC of the water should vary between 7 and 10 mg C/L based on the raw water DIC level. This range is within the EPA recommended range of 5 to 10 mg C/L.

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With a pH of 9.3 or 9.4, the alkalinity of the water should vary between 30 and 45 mg/l as $CaCO_3$ based on the pH and alkalinity of the raw water.

Soda ash is the only chemical added for corrosion control and the dose should vary between 20 and 40 mg/l based on the pH and alkalinity of the raw water.

A pH of 9.2 to 9.3 will be the target pH entering the distribution system for the first three months and will be raised to 9.3 to 9.4 at the beginning of the fourth month.

The minimum distribution system pH was determined by the lowest pH that yielded lead concentrations of one-half of the 15 ppb action level in the demonstration unit. Demonstration Unit No. 1 batches 1 through 24 are the treatment simulations for the recommended pH entering the distribution system. Analyzing the lead data from these 24 batches yielded the following results:

for sample day pH of 8.2 or higher four of 24 samples or 16.7% had lead concentration greater than 7.5 ppb.
for sample day pH of 8.4 or higher three of 20 samples or 15.0% had lead concentration greater than 7.5 ppb.
for sample day pH of 8.5 or higher three of 15 samples or 20.0% had lead concentration greater than 7.5 ppb.
for sample day pH of 8.6 or higher one of 10 samples or 10.0% had lead concentration greater than 7.5 ppb.
for sample day pH of 8.7 or higher one of six samples or 16.7% had lead concentration greater than 7.5 ppb.
for sample day pH of 8.8 or higher zero of four samples or 0% had lead concentration greater than 7.5 ppb.

Recommended minimum distribution pH is 8.6.

3.2   JH Fewell Water Treatment Plant

a. JHF Demonstration Unit No. 1

Demonstration Unit No. 1 was operated for a period of 28 weeks with 24 lead and copper samples taken. The unit was predominately flushed once per day for 30 to 45 seconds. This length of time would completely exchange the water in the unit out. The lead and copper sample port would be flushed as well. On sample collection day, the unit was flushed the same and the lead and copper sample port was given a four second flush and the isolation valves on the influent and effluent lines would be closed. The stagnation time before sampling was standardized at eight hours.

No target pH was established for Demonstration Unit No. 1 because the unit was using plant treated water from Filter No. 28 wash down hose. This hose continuously runs so the water stays fresh. No chemical addition occurred to Demonstration Unit No. 1 for batches 1 through 21. For batches 22 through 24, the unit was converted to using plant

water through filtration and using soda ash for final pH adjustment at a target pH of 9.2. This was done to see how quickly the lead and copper would react to switching to soda ash from lime for final pH adjustment. Table 3.2.1 in Appendix D shows the data collected from Demonstration Unit No. 1. The following summarizes the data from Table 3.2.1:

Lead concentration ranged from 5.8 to 35.9 ppb with stagnation times ranging from 7.5 to 8.0 hours,
Copper concentration ranged from 0.0021 to 0.0450 ppm with stagnation times ranging from 7.5 to 8.0 hours,
Make-up day pH ranging from 8.46 to 9.83,
Make-up day alkalinity ranging from 16.3 to 35.2 mg/l,
Make-up day Langelier Index ranging from -0.97 to 0.86,
Make-up day DIC ranging from 3.8 to 7.0 mg C/l,
Make-up day soda ash dose ranging from 23.0 to 31.0 mg/l for batches 22 through 24,
Make-up day chloramines ranging from 2.17 to >4.60 (exceeded testing equipment limit) mg/l,
Make-up day free ammonia ranging from 0.12 to >0.55 (exceeded testing equipment limit) mg/l,
Make-up day sulfate ranging from 31 to 55 mg/l,
Water age (number of days between make-up day and sample day) ranging from 3 to 11 days,
Sample day pH ranging from 7.51 to 9.18,
Sample day alkalinity ranging from 15.1 to 34.4 mg/l,
Sample day Langelier Index ranging from -1.83 to 0.70,
Sample day DIC ranging from 4.0 to 8.0 mg C/l,
Sample day chloramines ranging from 0.26 to 2.66 mg/l,
Sample day free ammonia ranging from 0.11 to >0.55 (exceeded testing equipment limit) mg/l,
Sample day fluoride ranging 0.54 to 1.60 mg/l, and
Sample day chloride ranging from 9.1 to 13.3 mg/l.

As can be seen from Table 3.2.1, sample day lead concentration fluctuated throughout the 28 weeks of testing and appeared to stabilize in batches 22, 23, and 24 after the unit was converted to using plant water through filtration and soda ash for final pH adjustment at a target pH of 9.2.

Non-parametric statistics was selected to compare the three demonstration unit's treatment. In applying the non-parametric methods to lead and copper testing results, the type of question which they may answer is: Is the population of lead/copper levels from experimental condition in Unit 1 higher, lower, or the same as those from experimental condition in Unit 2 or Unit 3. The Wilcoxon Test is the non-parametric test used to compare and select the treatment method. See Table 3.2.4 in Appendix D.

TRILOGY
ENGINEERING SERVICES

The comparison was made using batch number 12 through 24 because orthophosphate addition began with batch number 12. The test results were Demonstration Unit No 1 was the same for lead as Demonstration Unit No. 2 and was the same as Demonstration Unit No. 2 for copper. The test results were Demonstration Unit No 1 was greater for lead than Demonstration Unit No. 3 and was greater than Demonstration Unit No. 3 for copper.

b. JHF Demonstration Unit No. 2

Demonstration unit No. 2 was operated for a period of 28 weeks with 23 lead and copper samples taken. The unit was predominately flushed once per day for 30 to 45 seconds. This length of time would completely exchange the water in the unit out. The lead and copper sample port would be flushed as well. On sample collection day, the unit was flushed the same and the lead and copper sample port was given a four second flush and the isolation valves on the influent and effluent lines would be closed. The stagnation time before sampling was standardized at eight hours.

The target pH for Demonstration Unit No. 2 was 7.5 +/-0.2, the target DIC was 6 to 10 mg C/l, the target orthophosphate varied from 0.5 to 1.5 mg/l from the addition of phosphoric acid, and the alkalinity was allowed to fluctuate to satisfy the final pH goal. The hardness of the water was not changed because soda ash was used for pH adjustment. Table 3.2.2 in Appendix D shows the data collected from Demonstration Unit No. 2. The following summarizes the data from Table 3.2.2:

> Lead concentration ranged from 6.4 to 59.6 ppb with stagnation time of 8.0 hours (the first nine batches were made without addition of phosphoric acid to obtain baseline data),
> Copper concentration ranged from 0.0141 to 0.0679 ppm with stagnation time of 8.0 hours,
> Make-up day pH ranging from 7.40 to 8.05,
> Make-up day alkalinity ranging from 16.6 to 31.5 mg/l,
> Make-up day Langelier Index ranging from -1.99 to -0.92,
> Make-up day DIC ranging from 4.5 to 8.0 mg C/l,
> Make-up day soda ash dose ranging from 12.0 to 22.0 mg/l,
> Make-up day orthophosphate ranging from 0.53 to 1.55 mg/l,
> Make-up day chloramines ranging from 1.01 to >4.60 (exceeded testing equipment limit) mg/l,
> Make-up day free ammonia ranging from 0.07 to >0.55 (exceeded testing equipment limit) mg/l,
> Make-up day sulfate ranging from 28 to 55 mg/l,
> Water age (number of days between make-up day and sample day) ranging from 3 to 8 days,
> Sample day pH ranging from 7.20 to 8.01,
> Sample day alkalinity ranging from 15.6 to 33.0 mg/l,
> Sample day Langelier Index ranging from -2.39 to -1.01,
> Sample day DIC ranging from 4.0 to 8.0 mg C/l,

TRILOGY
ENGINEERING SERVICES

Sample day orthophosphate ranging from 0.45 to 1.52 mg/l
Sample day chloramines ranging from 0.10 to 2.44 mg/l,
Sample day free ammonia ranging from 0.22 to >0.55 (exceeded testing equipment limit) mg/l,
Sample day fluoride ranging 0.41 to 0.85 mg/l, (target was 0.60 mg/l), and
Sample day chloride ranging from 5.9 to 12.9 mg/l.

As can be seen from Table 3.2.2, sample day lead concentration appeared to still be stabilizing at batch 24 but was dropping significantly at the higher orthophosphate dose. Too low of phosphoric acid dose was used at the start to have much of an impact on lead levels.

Non-parametric statistics was selected to compare the three demonstration unit's treatment. In applying the non-parametric methods to lead and copper testing results, the type of question which they may answer is: Is the population of lead/copper levels from experimental condition in Unit 2 higher, lower, or the same as those from experimental condition in Unit 1 or Unit 3. The Wilcoxon Test is the non-parametric test used to compare and select the treatment method. See Table 3.2.4 in Appendix D.

The comparison was made using batch number 12 through 24 because orthophosphate addition began with batch number 12. The test results were Demonstration Unit No 2 was the same for lead as Demonstration Unit No. 1 and was the same as Demonstration Unit No. 1 for copper. The test results were Demonstration Unit No 2 was higher for lead than Demonstration Unit No. 3 and was the same as Demonstration Unit No. 3 for copper.

c. JHF Demonstration Unit No. 3

Demonstration unit No. 3 was operated for a period of 28 weeks with 23 lead and copper samples taken. The unit was predominately flushed once per day for 30 to 45 seconds. This length of time would completely exchange the water in the unit out. The lead and copper sample port would be flushed as well. On sample collection day, the unit was flushed the same and the lead and copper sample port was given a four second flush and the isolation valves on the influent and effluent lines would be closed. The stagnation time before sampling was standardized at eight hours.

The target pH for Demonstration Unit No. 3 was 8.8 +/- 0.2 for 10 batches 9.2 +/-0.2 for 13 batches, the target DIC was 6 to 10 mg C/l, and the alkalinity was allowed to fluctuate to satisfy the final pH goal. The hardness of the water was not changed because soda ash was used for pH adjustment. Table 3.2.3 in Appendix D shows the data collected from Demonstration Unit No. 3. The following summarizes the data from Table 3.2.3:

Lead concentration ranged from 5.0 to 20.9 ppb with stagnation times of 8.0 hours, Copper concentration ranged from 0.0135 to 0.0442 ppm with stagnation of 8.0 hours,

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Make-up day pH ranging from 8.70 to 9.45,

Make-up day alkalinity ranging from 25.3 to 37.5 mg/l,

Make-up day Langelier Index ranging from -0.36 to 0.39,

Make-up day DIC ranging from 5.0 to 8.5 mg C/l,

Make-up day soda ash dose ranging from 23.0 to 31.0 mg/l,

Make-up day chloramines ranging from 1.01 to >4.60 (exceeded testing equipment limit) mg/l,

Make-up day free ammonia ranging from 0.07 to >0.55 (exceeded testing equipment limit) mg/l,

Make-up day sulfate ranging from 28 to 55 mg/l,

Water age (number of days between make-up day and sample day) ranging from 3 to 8 days,

Sample day pH ranging from 7.97 to 8.80,

Sample day alkalinity ranging from 23.8 to 41.3 mg/l,

Sample day Langelier Index ranging from -1.15 to -0.12

Sample day DIC ranging from 5.5 to 10.0 mg C/l,

Sample day chloramines ranging from 0.64 to 2.62 mg/l,

Sample day free ammonia ranging from 0.16 to >0.55 (exceeded testing equipment limit) mg/l,

Sample day fluoride ranging 0.41 to 0.87 mg/l, (target was 0.60 mg/l), and

Sample day chloride ranging from 6.4 to 13.1 mg/l.

As can be seen from Table 3.2.3, sample day lead concentration appeared to stabilize at week 9 with a significant drop in lead concentration when the pH was raised to 9.20 in batch 12 and a significantly higher lead sample occurred in batch 23.

Non-parametric statistics was selected to compare the three demonstration unit's treatment. In applying the non-parametric methods to lead and copper testing results, the type of question which they may answer is: Is the population of lead/copper levels from experimental condition in Unit 3 higher, lower, or the same as those from experimental condition in Unit 1 or Unit 2. The Wilcoxon Test is the non-parametric test used to compare and select the treatment method. See Table 3.2.4 in Appendix D.

The comparison was made using batch number 12 through 24 because orthophosphate addition began with batch number 12. The test results were Demonstration Unit No 3 was lower for lead than Demonstration Unit No. 1 and was lower than Demonstration Unit No. 1 for copper. The test results were Demonstration Unit No 3 was lower for lead than Demonstration Unit No. 2 and was the same as Demonstration Unit No. 2 for copper.

d. Discussion and Recommendation of Alternates

Demonstration Unit No. 3 had the lowest lead concentration of the three units and the non-parametric statistical analysis showed Demonstration Unit No. 3 to have the lowest lead and copper for the duration of the testing. The testing protocol called for the finished pH to be 9.2. This pH value produced make-up day water with a slightly

TRILOGY
ENGINEERING SERVICES

negative Langelier Index. Using Tetra Tech's (RTW) Water Chemistry, Process, and Corrosion Control software to increase the make-up day water pH to 9.3 resulted in a slightly positive Langelier Index in 96% of the batches and to pH of 9.4 resulted in a slightly positive Langelier Index in 100% of the batches. See Table 3.2.5.

Table 3.2.5: Demonstration Unit No. 3 Make-up Day Langelier Index, Alkalinity, and DIC Values at pH of 9.3 and 9.4

Batch #	Make Up Day Langelier Index at pH of 9.3	Make Up Day DIC at pH of 9.3	Make Up Day Alkalinity at pH of 9.3	Soda Ash Required at pH of 9.3	Make Up Day Langelier Index at pH of 9.4	Make Up Day DIC at pH of 9.4	Make Up Day Alkalinity at pH of 9.4	Soda Ash Required at pH of 9.4
1	ND	ND	ND	ND	ND	ND	ND	ND
2	0.44	8.8	39.9	34.8	0.56	9.0	41.7	36.8
3	0.39	9.3	41.3	33.0	0.51	9.5	42.9	34.8
4	0.38	8.0	36.0	28.0	0.50	8.2	37.4	29.6
5	0.32	8.4	37.9	29.8	0.44	8.6	39.5	31.5
6	0.28	8.1	36.1	27.5	0.40	8.3	37.4	29.0
7	0.34	9.1	40.8	28.3	0.45	9.3	42.3	29.9
8	0.24	8.9	39.7	29.8	0.36	9.1	41.0	31.2
9	0.23	8.4	37.2	29.3	0.35	8.5	38.3	30.6
10	0.23	8.7	38.2	29.7	0.34	8.8	39.3	30.9
11	0.25	7.5	33.4	30.8	0.36	7.7	34.6	32.1
12	0.15	7.0	31.6	25.0	0.25	7.0	31.6	25.0
13	0.27	8.0	35.4	29.3	0.39	8.1	36.6	30.6
14	0.16	6.6	29.3	25.8	0.27	6.7	30.3	26.9
15	0.12	6.5	28.7	27.1	0.24	6.6	29.6	28.1
16	0.22	8.0	35.3	28.6	0.34	8.1	36.5	29.9
17	0.05	5.6	25.5	26.5	0.15	5.6	25.5	26.5
18	0.05	6.2	27.8	28.7	0.17	6.4	28.8	29.8
19	0.04	5.8	26.2	26.0	0.14	5.8	26.6	26.4
20	0.00	5.9	26.1	26.0	0.11	6.0	26.8	26.8
21	-0.03	5.6	25.5	25.0	0.07	5.6	25.5	25.1
22	0.06	5.9	25.8	23.6	0.18	6.0	26.7	24.5
23	0.42	6.4	30.1	31.2	0.54	6.6	31.8	33.1
24	0.40	6.8	31.3	32.9	0.52	7.0	32.9	34.7

Recommended finished water pH range entering the distribution system is 9.3 to 9.4 with a minimum pH of 9.1 and a maximum pH of 9.5 for the JH Fewell Water Treatment Plant. and a minimum distribution pH range of 8.6 to 8.8. The operations staff will monitor the pH on the plant's SCADA system and will collect and analyze grab samples every four hours to insure the pH entering the distribution system is between 9.3 and 9.4.

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With a pH of 9.3 or 9.4, the DIC of the water should vary between 5.5 and 9.5 mg C/L based on the raw/settled water DIC level. This range is within the EPA recommended range of 5 to 10 mg C/L.

With a pH of 9.3 or 9.4, the alkalinity of the water should vary between 25 and 45 mg/l as $CaCO_3$ based on the pH and alkalinity of the settled water. Lime is added for pH adjustment in the rapid mix from the pH drop caused by the addition of alum.

Soda ash is only chemical added for corrosion control and the dose should vary between 20 and 40 mg/l based on the pH and alkalinity of the settled water.

A pH of 9.2 to 9.3 will be the target pH entering the distribution system for the first three month and will be raised to 9.3 to 9.4 at the beginning of the fourth month.

The minimum distribution system pH was determined by the lowest pH that yielded lead concentrations of one-half of the 15 ppb action level in the demonstration unit. Demonstration Unit No. 3 batches 12 through 24 are the treatment simulations for the recommended pH entering the distribution system. Analyzing the lead data from these 13 batches yielded the following results:

> for sample day pH of 8.0 or higher four of 13 samples or 30.8% had lead concentration greater than 7.5 ppb,
> for sample day pH of 8.4 or higher three of 11 samples or 27.3% had lead concentration greater than 7.5 ppb,
> for sample day pH of 8.5 or higher two of nine samples or 22.2% had lead concentration greater than 7.5 ppb,
> for sample day pH of 8.6 or higher one of seven samples or 14.3% had lead concentration greater than 7.5 ppb,
> for sample day pH of 8.7 or higher one of four samples or 25.0% had lead concentration greater than 7.5 ppb,
> for sample day pH of 8.8 or higher zero of one sample or 0% had lead concentration greater than 7.5 ppb.

Recommended minimum distribution pH is 8.6.

Part 4 – Basis of Design

4.1   Introduction

Part 4 details the necessary improvements for Optimal Corrosion Control Treatment at the OB Curtis and JH Fewell Water Treatment plants based on the discussions provided in Part 3 of this report.

4.2   OB Curtis Water Treatment Plant

a. The following items of work are currently scheduled to be completed at the OB Curtis WTP by December 31, 2018 with a completion deadline of May 31, 2019:

- Conversion of both existing lime silos to feed soda ash,
- Installation of eight new soda ash metering pumps for point of application in the influent box of both clearwells and at the existing 4th ammonia application point of both clearwells,
- Installation of new soda ash solution piping,
- Installation of four submersible mixers in the influent box of both clearwells and at the existing 4th ammonia application point of both clearwells,
- Installation of access points in the top slab of both clearwells for mixer retrieval at the existing 4th ammonia application point,
- Update/upgrade existing chlorine feed system,
- Installation of four new vacuum ammonia feeders,
- Update/upgrade to existing ammonia tanks and discharge lines to vacuum regulator and replacement of vacuum regulator,
- Replacement of ammonia feed lines between feeders and points of application with a redundant line for each clearwell,
- Removal of lime deposits in both clearwells, and
- Relocation of conventional side raw water meter for more accurate coagulation chemical dosing.

b. A contract has been awarded and underway for the conversion of both lime silos to feed soda ash with the work to be completed by July 31, 2017.
c. A contract has been awarded to purchase four soda ash solution metering pumps for application point in each clearwell influent box. City personnel will install the
- pumps with the work to be completed by July 31, 2017.
d. Soda ash bids were received on May 30, 2017 for use in the renovated silos.
e. Prices have been obtained and a purchase order is in progress to have two of the ammonia feeders replaced.

4.3   JH Fewell Water Treatment Plant

The following items of work are currently scheduled to be completed at the JH Fewell WTP by December 31, 2018 with a completion deadline of May 31, 2019:

- Necessary updates/upgrades to both raw water lime feed systems,
- Update/upgrade existing chlorine feed system, and
- Installation of new soda ash silo with three solution metering pumps for point of application in the high service pump suction flume. All necessary replacement parts will be purchased to repair normal breakdowns within five days.

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4.4   Distribution System

Water age has a direct impact on the pH of the water in the distribution system which has a direct impact on lead and copper levels at the consumer tap.

The following items of work should be completed across the distribution system to minimize water age:

- A calibrated hydraulic model of the distribution system should be created to predict water age within the distribution system. An analysis between water age for water quality purposes and quantity of elevated storage for fire protection should be performed.
- A valve location and operation program should be performed in conjunction with the hydraulic model.
- A Water Quality Parameter site map should be developed and updated every six months. The site map should have between 25 and 40 sampling locations.
- Establish a flushing program for low pH problem areas of the distribution system.

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