confluence ENGINEERING GROUP LLC
517 NE 92nd Street, Seattle, WA 98115 ph (206) 527-6832 fx (206) 527-3148 confluence-engineering.com

To: Dan Smith, Steve Craig; City of Tumwater

From: Stephen Booth, Ph.D., Michael Hallett; Confluence

CC: Melinda Friedman, P.E.; Confluence

Date: April 19, 2017

Subject: FINAL Technical Memorandum

Project: Water Quality Evaluation at the Lathrop Water System

INTRODUCTION AND BACKGROUND

The City of Tumwater recently took over ownership and operation of the Lathrop Water System. Lathrop is a small system serving a single residential dwelling and several industrial customers. A well serves as the only source of supply for the system. Water is pumped from the well, chlorinated, and stored in a nearby 120,000-gallon reservoir. The 178-foot deep well has recently suffered from reduced hydraulic productivity. Also, a large amount of brown sediment has been accumulating in the reservoir. The reservoir is now undergoing a cleaning every six months. The City has been receiving an increased volume of dirty water complaints. It is not known whether the decreased well productivity is related to the apparently increasing amount of sediment in the well water.

Two parallel 6- and 8-inch diameter mains bring water into the system immediately downstream of the reservoir. Interties connecting these to mains were installed several years ago. The interties do not include valves to isolate either of the two parallel mains. This arrangement makes it difficult to perform flushing since water flows in an uncontrolled manner between the two mains. The City is considering replacing these two mains with a single ductile iron main, although that project will not occur for several years. The nearest Tumwater service main is on the opposite side of Interstate 5 and a construction project is required to install a connection to the Lathrop system. Since an alternate source of supply would require several years to implement, the City would like to address the water quality issues with the existing well. The purpose of this study was to determine the origin and nature of the solids accumulating in the reservoir, and elsewhere in the system, to help determine appropriate steps to remediate the problem.

APPROACH

Available system and water quality data were reviewed and data gaps were identified. One day of sample collection and analysis was performed in the field to fill data gaps, to gather data to better understand existing conditions, and to characterize solids accumulating in the system.

Sampling and Analysis Plan

Water quality monitoring performed by Confluence included bulk raw and treated well water, water from the reservoir, and other sample locations within the distribution system. A chlorine demand/decay curve (CDD) for the treated well water was also prepared. Water quality data were also collected during spot flushing since the City has found that flushing tends to disturb solids in the system resulting in colored water. The water quality parameters included in the field investigation are presented in Table 1.

Table 1. Bulk Water Sampling and Analysis Plan

Parameter	Measured On Site	Measured at Laboratory
General Chemistry	pH, temperature, alkalinity (raw water only), turbidity, apparent color, oxidation-reduction potential (ORP) dissolved oxygen (DO), conductivity	Elemental scan (Ca, Mg, Fe, As, Mn, Si, Tl, Pb)
Disinfection Related	Free and total chlorine residual	Ammonia (raw water only)
Microbial		Adenosine triphosphate (ATP)[1], heterotrophic plate count (HPC)[2], total organic carbon (TOC)[2], microscopic exam[3], iron/sulfur bacteria enumeration[3]

Notes:

1. Confluence lab using QGA method by LuminUltra Technologies (Fredericton, New Brunswick, Canada, luminultra.com)
2. Edge Analytical, Burlington, WA.
3. Water Management Laboratory, Tacoma. WA.

RESULTS AND DISCUSSION

Basic water quality for the well water, treated water (downstream of chlorine addition), the reservoir outlet water, and several samples in the distribution system are presented in Table 2. Following a gentle flush to clear the hydrant barrel, distribution system samples were collected at a low flow rate to avoid disturbing solids in the system.

Table 2. Basic Water Quality Data

Parameter	Raw	Treated	Res. Outlet	9702 Lathrop	9809 Blomberg	9630 Blomberg	BMW[1]
pH	7.5	7.4	7.6	7.4	7.4	7.3	7.3
Temp. (°C)	9.9	10.3	9.6	8.9	6.9	5.7	7.6
Turbidity (NTU)	0.05	0.08	0.29	0.31	0.33	0.88	3.15
Apparent Color	3	8	13	16	15	64	62
ORP (mV)	-98	563	523	549	604	657	560
DO (mg/L)	0.4	0.3	3.0	3.2	2.8	3.6	2.9
Conductivity (µS/cm)	105	110	111	110	108.1	109.9	111.1
Free Cl2 (mg/L)	-	0.71	0.31	0.37	0.35	0.56	0.17
Total Cl2 (mg/L)	-	0.91	0.34	0.43	0.43	0.63	0.26
Ammonia (mg/L)	0.10	-	-	-	-	-	-
TOC (mg/L)	0.35	0.31	0.33	0.35	0.28	0.34	0.37

Notes:

1. Near building "B" at industrial park on Blue Mountain Way.

The pH of the water was between 7.3 and 7.6. The raw water contained a small amount of ammonia and had an alkalinity of 50 mg/L. Temperatures varied somewhat with the raw water at 10°C and distribution system water a few degrees lower. Turbidity and apparent color of the raw, treated, and reservoir outlet water were reasonably low. Elevated turbidity and apparent color were observed at 9630 Blomberg and at the sample location on Blue Mountain Way. The raw water ORP was negative, as expected for a groundwater. Chlorination increased the ORP to above 550 mV and it remained above that level throughout the distribution system. There is essentially no DO in the raw water and slightly higher levels of DO were found in the distribution system (approximately 3 mg/L). Conductivity was consistent throughout the system, as expected. The treated water had a reasonable free chlorine residual of 0.7 mg/L, however, the free chlorine residual decreased to approximately 0.3 mg/L at the reservoir outlet. CDD in the distribution system was low with only a slight drop in chlorine residuals. The TOC of the raw water was found to be approximately 0.3 mg/L and TOC levels remained close to that value for all other sample locations.

A CDD curve for the treated well water is presented in Figure 1. Most of the CDD is associated with oxidation of native iron and ammonia in the raw water causing chlorine residuals to decrease significantly within the first 2 to 3 hours of holding time. Subsequent CDD appears to be relatively minor with a decrease of only approximately 0.2 mg/L between the 24-hour and 96-hour holding times. These results are consistent with chlorine residuals measured in the system which indicated that most of the CDD occurred within the reservoir and little CDD was associated with the distribution system.

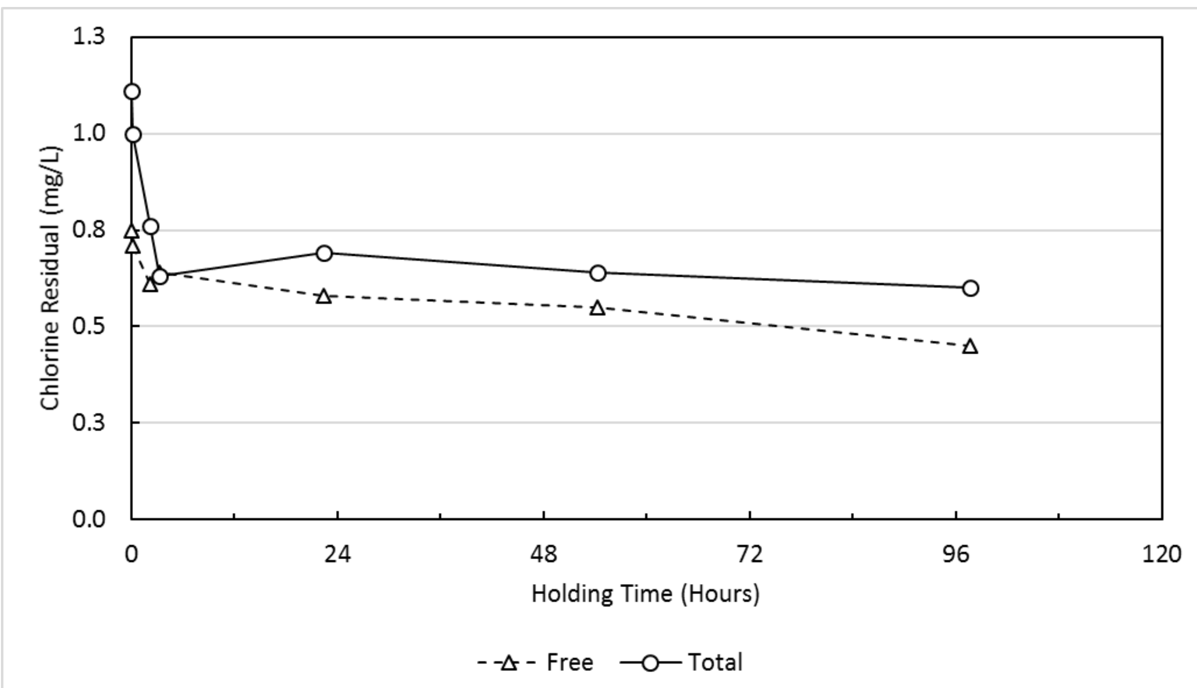

Figure 1. CDD curve for treated water.

Iron, manganese, and arsenic data are presented in Figure 2. The raw water and reservoir outlet water had roughly the same levels of these metals, with concentrations of approximately 0.4 mg/L, 0.1 mg/L, and 0.002 mg/L of iron, manganese, arsenic, respectively. Iron, and to a lesser extent manganese, were found to be significantly higher for the booster pump station sample, the 9630 Blomberg flush sample and the sample collected at 93rd and Lathrop. The pump station sample was collected by connecting a hose to a hose bib on a booster pump which was not in operation at the time. When the valve on the hose bib was opened water was allowed to flow back from the bottom of the reservoir out through the hose. This water was visibly colored and included particles and sediment from the bottom of the reservoir. The 9630 Blomberg flush sample was collected after increasing the flow rate at the hydrant to perform spot flushing at that location. The increased flow rate was sufficient to stir up solids in that part of the system. The water was found to have a similar reddish-brown color as observed at the booster pump station. Iron and manganese concentrations were found to be an order of magnitude higher than the raw water at the following locations:

- Booster pump station
- 9630 Blomberg flush
- 93rd and Lathrop flush

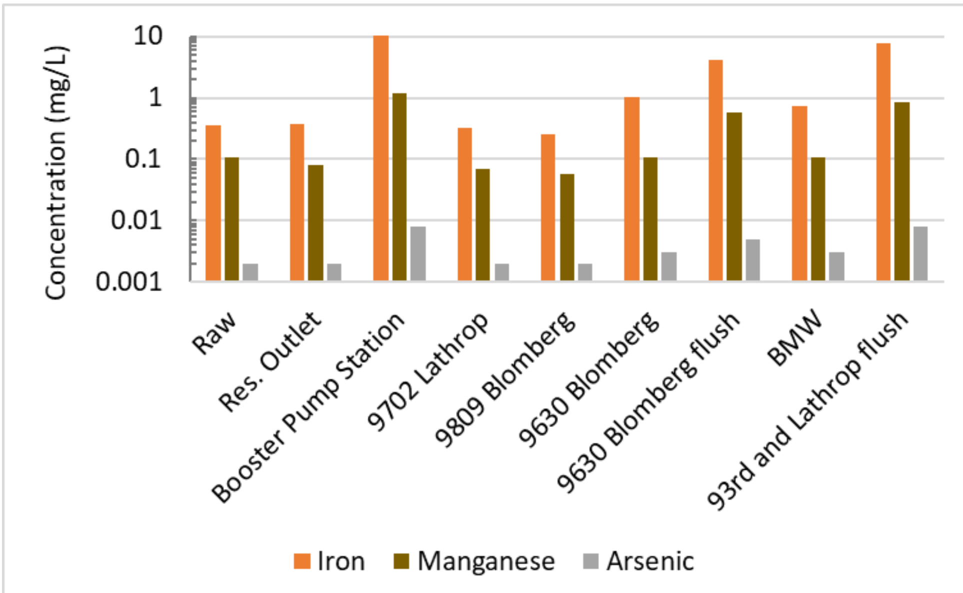

Figure 2. Metals data summary.

Although manganese is currently considered an aesthetic concern, recent health effects research has linked elevated manganese to neurological effects in young children. The Canadian Federal-Provincial-Territorial Committee on Drinking Water is considering revised manganese regulations to address these emerging health concerns connecting manganese in drinking water to neurological effects in children. Canada has proposed a health-based maximum acceptable concentration (MAC) of 0.1 mg/L for manganese and an aesthetic objective (AO) of 0.02 mg/L for manganese in drinking water. In the US, the EPA has established a Secondary Maximum Contaminant Level (MCL) of 0.05 mg/L and in 2016, manganese was included on the Final Contaminant Candidate List 4 (CCL4). The concentration of manganese in the Lathrop system raw and reservoir outlet waters were found to be close to the proposed Canadian MAC and above the EPA Secondary MCL.

One potential concern with iron and manganese sediments accumulating and remaining in a distribution system is the potential for the co-occurrence of other trace metals of concern. Scales and sediments rich in iron tend to attract arsenic. Table 3 presents additional metals data for the same locations as presented above in Figure 2. Slightly elevated arsenic levels of 0.005 mg/L and 0.008 mg/L were observed for the 9630 Blomberg flush and 93rd and Lathrop flush samples. Those levels are below the MCL of 0.01 mg/L and indicate arsenic accumulation is likely occurring to only a limited extent in the Lathrop system. Analyses also included the metals lead and thallium which tend to co-occur with manganese. Thallium was not detected in any of the samples and lead was detected in only two samples at levels of 0.003 mg/L and 0.002 mg/L in the booster pump station and Blue Mountain Way samples, respectively. These data indicate a negligible accumulation of these trace metals within the sediment in the system.

Table 3. Metals Data for Sample Locations in the Lathrop System.

Metal	Raw	Reservoir Outlet	Booster Pump Station	9702 Lathrop	9809 Blomberg	9630 Blomberg	9630 Blomberg flush	BMW	93rd and Lathrop flush
Iron	0.35	0.37	11.10	0.32	0.25	1.05	4.13	0.73	7.59
Manganese	0.11	0.08	1.20	0.07	0.06	0.11	0.59	0.11	0.85
Arsenic	0.002	0.002	0.008	0.002	0.002	0.003	0.005	0.003	0.008
Lead	< 0.001	< 0.001	0.003	< 0.001	< 0.001	< 0.001	< 0.001	0.002	< 0.001
Thallium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Data for other common elements found in drinking waters are presented in Figure 3. Levels of calcium, magnesium, and silica were found to be very consistent throughout the system with essentially no change in the levels of those constituents among the raw, treated, and distribution system samples. Calcium, magnesium, and silica do not comprise a significant fraction of the sediment in the system.

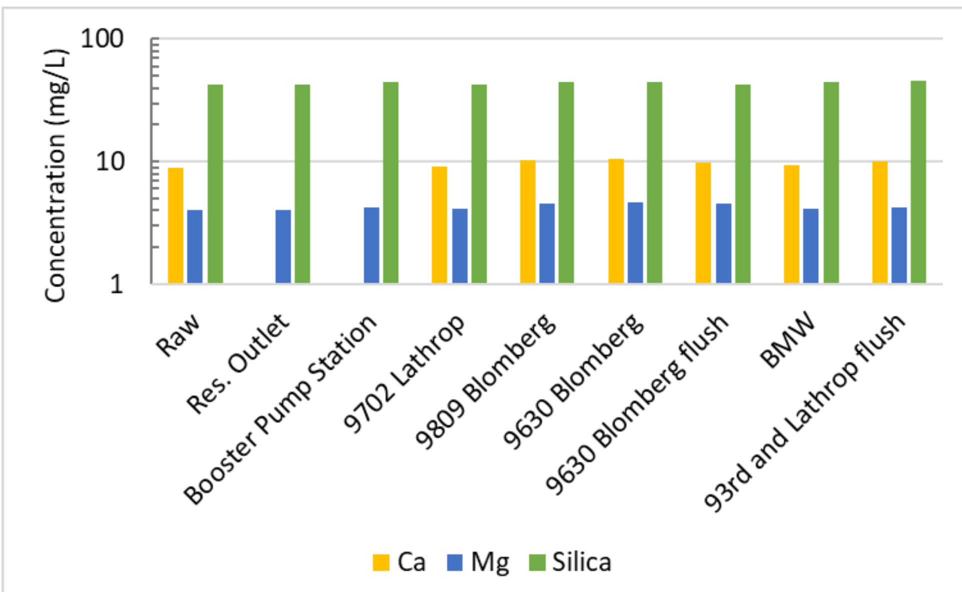

Figure 3. Data for common water quality constituents.

Data for several microbial parameters are presented in Figure 4. ATP levels were found to be reasonably low at all sample locations. Note that ATP levels below 0.5 pg/mL indicate good control, levels between 0.5 and 10 pg/mL indicate the need for a review of preventative strategies, and levels above 10 pg/mL indicate corrective action is required. The raw water had somewhat elevated HPCs and also contained some iron bacteria, although sulfur bacteria were not detected in the raw water. ATP tended to correlate reasonably with HPC and sulfur bacteria although ATP did not correlate with iron bacteria. Further investigation would be required to determine reasons for the lack of correlation between those two parameters.

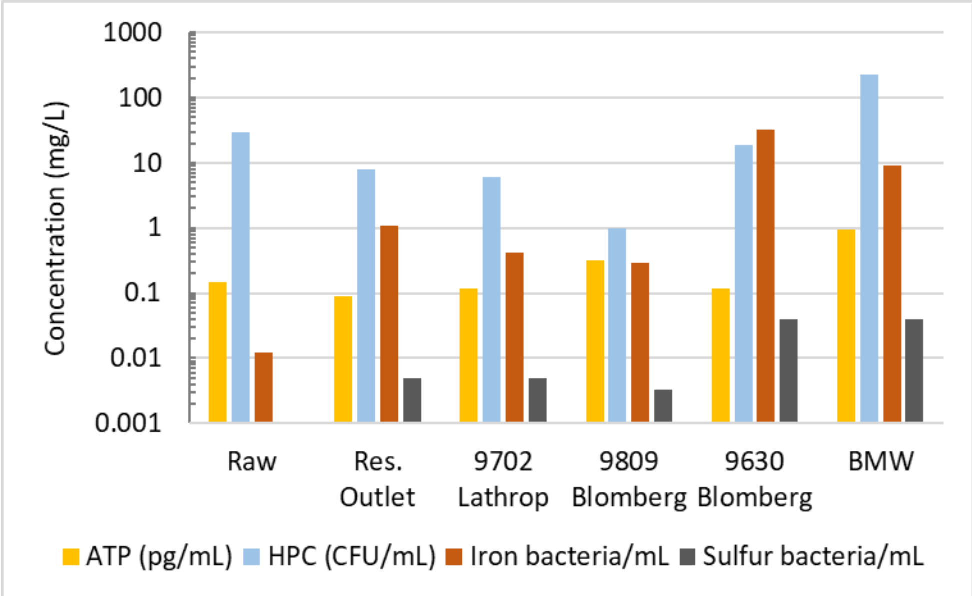

Figure 4. Microbial data summary.

ATP and HPC of the reservoir outlet water were similar to the raw water, however, iron bacteria were two orders of magnitude higher in the reservoir outlet water compared to the raw water. The reservoir outlet water also contained sulfur bacteria, whereas, sulfur bacteria were not detected in the raw water.

HPCs within the distribution system were found to be significantly higher than the raw water at only the Blue Mountain Way sample location. Iron bacteria were 2 to 3 orders of magnitude higher in the distribution system compared to the raw water. The highest levels of sulfur bacteria were detected at the 9630 Blomberg and at the Blue Mountain Way sample locations.

CONCLUSIONS

Conclusions from this investigation are as follows:

- The sediment observed in the Lathrop System consists largely of iron oxide particles with a lesser amount of manganese oxides.
- The iron originates from the well water. The well water contains dissolved iron which is oxidized to form an iron oxide particle following the addition of chlorine immediately upstream of the reservoir. Because of the historically low demands within the system the water age within the reservoir is relatively high resulting in iron particles settling to the bottom of the reservoir. This sediment at the bottom of the tank is disturbed periodically as booster pumps turn on to serve the system. The amount of sediment entrained in the water pumped into the system is likely a function of the number of booster pumps in operation and the frequency in which a given booster pump cycles on and off.
- Based on a system demand of 0.05 MGD and 0.4 mg/L of iron in the well water, approximately 0.17 lb of iron is being loaded into the reservoir each day. This level of iron would result in the accumulation of close to 60 lbs of iron oxide particles in a 6-month period. Iron loading into the system will continue to increase as system demands increase and more water is consumed in the system.

- Iron bacteria are occurring in the Lathrop system. The system is seeded due to the presence of iron bacteria in the raw water. The relatively low chlorine residuals throughout the distribution system likely contribute to proliferation of iron (and other types of) bacteria. Furthermore, sediment accumulating within the distribution system likely provides a localized habitat for bacterial growth in some locations. Sulfur bacteria appear to be less problematic, although levels of sulfur bacteria were associated with higher levels of iron and elevated HPC in the system.
- Trace metals which can potentially co-occur with iron and manganese do not appear to be problematic. Lead and thallium were found to be below or only slightly above the detection limits at all sample locations. Some arsenic accumulation may be occurring although arsenic levels did not exceed the MCL.
- The presence of iron bacteria in the well water could explain the reduced hydraulic productivity of the well. Iron bacteria can contribute to plugging of well screens as slimes develop within the well. Further investigation is required to evaluate the effect if iron bacteria on the condition of the well.

RECOMMENDATIONS

Recommendations are as follows:

- If the City intends to continue using the existing well in the Lathrop System, treatment to remove iron and manganese is recommended. Iron and manganese treatment systems are commonly used throughout Western Washington. The systems generally include chlorination upstream of filter vessels which contain either greensand or pyrolusite media. Iron and manganese adsorb to the media resulting in low to non-detectable levels of iron and manganese in the treated water. The media is periodically backwashed resulting in a backwash wastewater rich in iron and manganese. Treatment or disposal of backwash wastewater would need to be assessed. One option would be to construct a backwash holding tank as part of the treatment system from which the backwash wastewater could be pumped to the sewer at a desired flow rate.
- Increasing the chlorine dose to provide a residual of at least 0.6 mg/L in the reservoir outlet water is recommended. A higher residual in the distribution system is anticipated to help control bacterial growth in the system and reduce iron bacteria and HPC levels.
- The particles accumulating in the system appear to be hydraulically mobile and flushing would be anticipated to be an effective main cleaning technique. However, the system cannot be properly valved to perform unidirectional flushing due to the presence of interties between the two mains downstream of the pump house. These interties are likely to be problematic for other main cleaning techniques, such as swabbing. The City should consider expediting the replacement of these existing mains with a single pipe including appropriate valves to allow proper implementation of unidirectional flushing.
- As an interim measure, the City could determine the feasibility of raising the outlet piping within the reservoir to avoid entraining accumulated solids in the water pumped out to the distribution system.