WQTS
Water Quality & Treatment Solutions, Inc.
An Environmental Engineering & Science Consulting Company

TECHNICAL MEMORANDUM

www.WQTS.com

Date: August 13, 2018

To: Mr. Jack Hoagland
General Manager
Idyllwild Water District

WQTS Project No.: 0124•0020

From: Issam Najm, Ph.D., P.E.

Project: Evaluation of DBP Mitigation Strategies for the Foster Lake Wells

Re: **DRAFT** Alternatives Analysis & Recommendation

The Idyllwild Water District (District) owns and operates the drinking water system serving the community of Idyllwild in the San Bernardino Mountains. The groundwater system serves approximately 1,600 connections spread across 2,500 acres. In the 2nd Quarter of 2018, the District's Locational Running Annual Average (LRAA) values for trihalomethanes (THMs) and haloacetic acids (HAAs), both of which are regulated disinfection by-products (DBPs), exceeded their respective maximum allowable limits of 80 µg/L and 60 µg/L, respectively. The primary cause was an elevated concentration of naturally-occurring total organic carbon (TOC) in the groundwater produced by the Foster Lake Wells. In accordance with the requirements of the State Water Resources Control Board's Division of Drinking Water (DDW), the District issued a public notice to its customers, with a commitment to identify and implement the treatment system/approach necessary to bring the system into compliance.

The District retained the services of Water Quality & Treatment Solutions, Inc. (WQTS) to analyze available options that can mitigate the DBP formation challenge and make a recommendation to the District for implementation.

THE DBP CHALLENGE

The District collects DBP compliance samples from two locations referred to as Station 5 and Station 7. Prior to 2017, the District was collecting samples annually. After the 2017 sample was determined to contain 92 µg/L of HAA5 and 79 µg/L of THMs, the District began quarterly monitoring. The results since have shown elevated levels of THMs and HAA5, and after four quarterly results were collected (i.e., 2nd quarter 2018), the compliance LRAA level was calculated. The quarterly values and the compliance LRAA levels for THMs and HAA5 at Station 5 are presented in Figures 1 and 2, respectively. As shown, the LRAA for THMs at Station 5 was 87.1 µg/L compared to the regulatory limit of 80 µg/L, while that for HAA5 was 65 µg/L compared to the regulatory limit of 60 µg/L. It is noted that the levels at Station 7 were significantly lower as shown in Figures 3 and 4 for both THMs and HAA5, respectively.

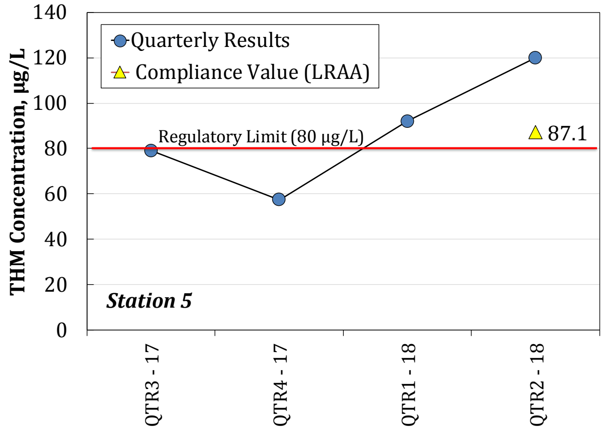

Figure 1 – Quarterly & Compliance Levels of Total THMs at Station 5

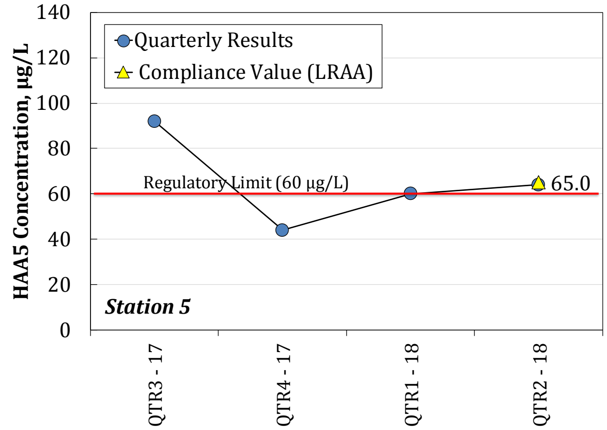

Figure 2 – Quarterly & Compliance Levels of HAA5 at Station 5

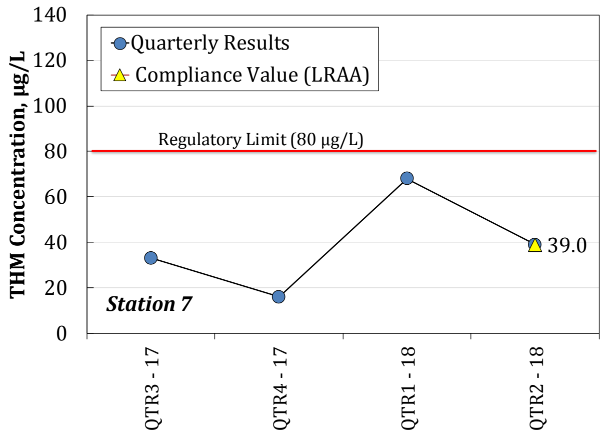

Figure 3 – Quarterly & Compliance Levels of Total THMs at Station 7

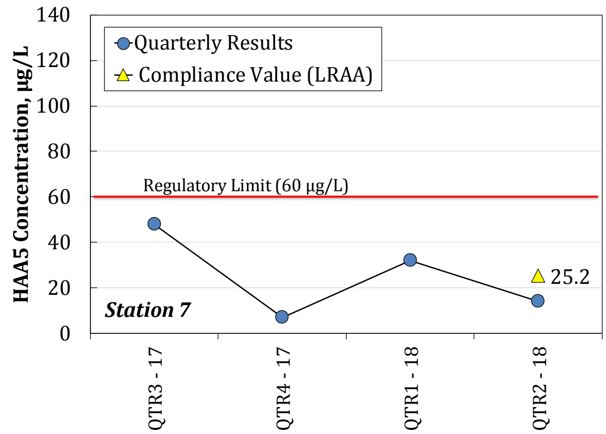

Figure 4 – Quarterly & Compliance Levels of HAA5 at Station 7

WATER SUPPLY & WATER QUALITY

Figure 5 shows a map of the District's main water system components, along with the locations of the two Stage 2 DBP Sampling Stations 5 & 7, and the locations of 11 special DBP sampling locations discussed later in this TM. The District relies exclusively on local groundwater extracted from 14 active wells. The wells range in production capacity from 7 gpm to as high as 97 gpm. While the wells are generally scattered around the service area, five are adjacent to Foster Lake, which are referred to as the Foster Lake wells, while the rest are referred to as the City Wells. The District diverts available water from local streams and stores it in Foster Lake. Depending on the weather, annual diversions from Lilly Creek and Strawberry Creek may range from 0 to 100 Acre-Feet per year (AFY). The District water demand is approximately 300 AFY, which represents an annual average daily flow of 0.27 MGD. It is noted that Station 5 and Station 7 are both located on dead-end streets, and Station 5 is on a shorter street than Station 7. Unfortunately, during stagnation, THMs and HAA5 continue to form in the water. Therefore, the longer the stagnation, the higher are the THM and HAA5 levels.

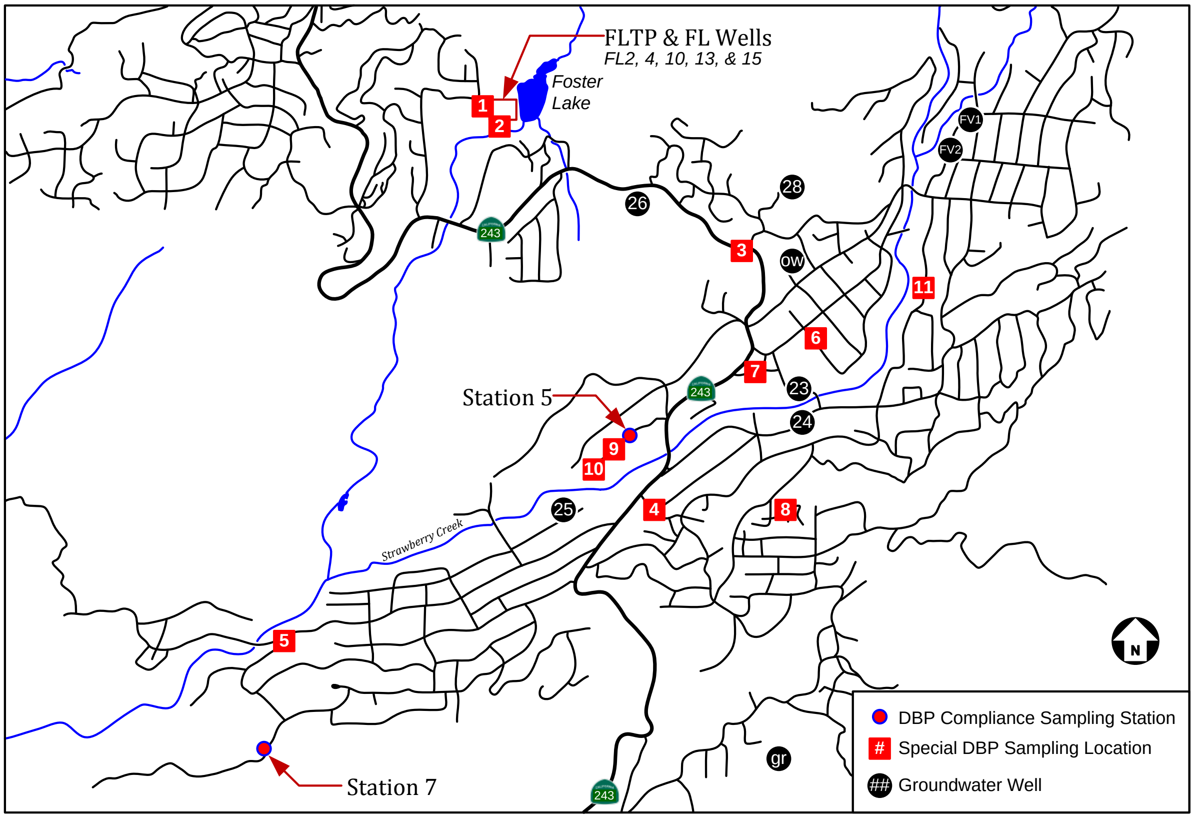

Figure 5 – Locations of the Two DBP Compliance Sampling Stations relative to the FL Wells the FLTP, and the active wells, as well as Locations of 11 Special DBP Sampling Sites
[5 Foster Lake Wells are not individually shown on Map but are located next to Foster Lake]

The Foster Lake wells are of lower quality compared to the City Wells in that they contain elevated levels of iron and manganese which required the District to build and operate an iron-and-manganese removal plant; the Foster Lake Treatment Plant (FLTP). The plant, which has a capacity of 200 gpm, treats water from a blend of five active wells. The general quality of these wells, as well as their production capacity, are presented in Table 1.

In addition to the elevated levels of manganese and iron in the FL wells, Table 1 also shows elevated levels of Total Organic Carbon (TOC) in all the FL wells. This is noteworthy because higher TOC concentrations are directly associated with higher formation of chlorination by-products, specifically THMs and HAAs. The TOC concentrations are not typically measured in groundwater sources because they are generally quite low (<1 mg/L). However, in the FL wells, the TOC concentration ranges from 2.6 mg/L to 4.6 mg/L. These levels were measured in samples collected in 2017 and 2018. It is noted that TOC levels in samples collected from City wells were below 0.5 mg/L. On the other hand, the TOC concentration measured in a Foster Lake sample collected in 2018 was as high as 8.4 mg/L.

Table 1 – General Water Quality of Foster Lake Wells

Parameter	Unit	FL2 (96 gpm)	FL4 (37 gpm)	FL10 (7 gpm)	FL13 (41 gpm)	FL15 (10 gpm)
TOC	mg/L	3.1	3.0	2.6	2.8	4.6
Alkalinity	mg/L $CaCO_3$	63	65	99	49	72
Calcium	mg/L	13	12	20	9.7	13
Hardness, Total	mg/L $CaCO_3$	40	40	72	30	41
Manganese	mg/L	0.10	0.27	0.15	0.20	0.89
Iron	mg/L	0.87	0.62	0.33	0.13	1.1
pH	--	6.5	6.5	6.4	7.8	7.0
Conductivity	µS/cm	150	150	250	130	130
TDS	mg/L	88	170	180	110	90
Chloride	mg/L	4.9	6.1	12	3.4	5.4
Sodium	mg/L	13	13	22	12	11

Based on the high TOC levels in the FL wells, it is suspected that the Natural Organic Matter (NOM) present in the FL wells is the primary cause of the elevated THMs and HAAs in the system. TOC is a measure of the concentration of NOM in water. NOM reacts with the chlorine added to the water to form DBPs:

$$NOM + Chlorine \rightarrow THMs \,\&\, HAAs$$

Therefore, to reduce the THM and HAA levels in the District's water system, the above reaction must be disrupted. Any water treatment technology applied must achieve this goal.

SPECIAL DBP SAMPLING

On July 23, 2018 the District collected samples from 11 locations in the distribution system and analyzed them for THMs and HAA5 levels. The locations of the 11 sampling sites were shown in Figure 5. They begin at the FLTP and extend throughout the District's service area. Location #1 is the effluent of the FLTP while Location #2 is the outlet of the Foster Lake Tanks to which the FLTP discharges. It is noted that sites #9 and #10 are the same sample location but #9 was collected before hydrant flushing, while #10 was collected after hydrant flushing. The purpose of comparing #9 to #10 was to look at the effect of flushing a dead-end pipe on the DBP levels in the water.

Figure 6 presents the THM and HAA5 levels measured at each site with the THM values listed in the red "squares" and the HAA5 values listed in the green "circles" under the squares. The diamond symbols are the locations of the wells. The results clearly illustrate the effect of the higher TOC in FL wells and that of water storage time on DBP formation in the system. For example, while the outlet of the FLTP contained only 14 µg/L THMs, the level increased to 73 µg/L as the water sat in the FL Tanks before it was pumped into the system. Similarly, the HAA5 level increased from 11 µg/L in the

FLTP outlet to 48 µg/L in the water leaving the FL Tanks. These comparisons strongly suggest that the water stagnation time in the FL Tanks is a significant contributor to higher DBP levels in the distribution system. The same effect is expected to take place as water from the FLTP is stored in all the other tanks in the system. Unfortunately, water storage tanks are critical, especially in fire seasons when life and property are threatened.

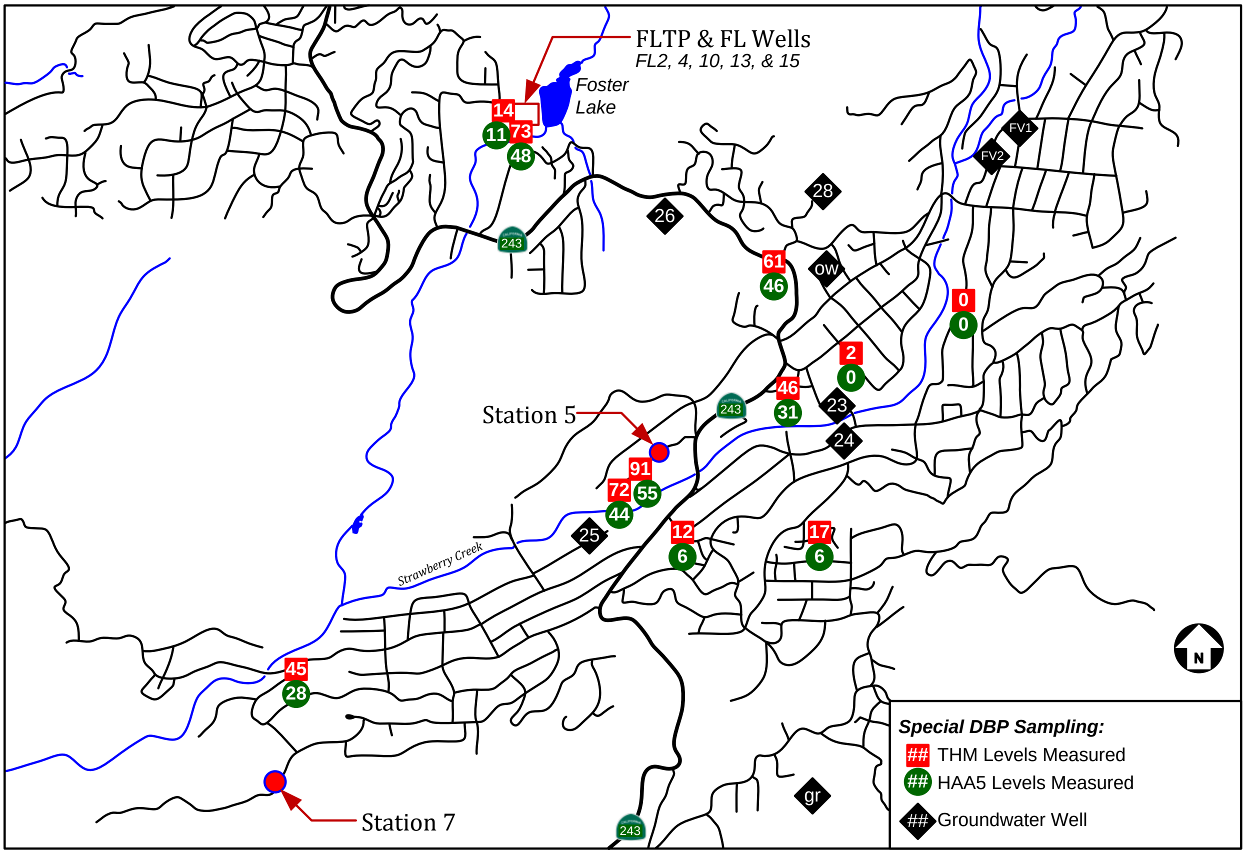

Figure 6 – Results of the Special DBP Sampling Shown Relative to the Well Locations

The values in Figure 6 also show that as the water from FLTP is blended in the system with water from the other wells, which contain significantly lower TOC levels, the DBP levels decrease. This is mainly because the chlorinated water from the other wells contains very low levels of DBPs. In fact, at one location (#11 at Tahquitz Drive), the THMs and HAA5 levels were both non-detected.

Finally, comparing the results at Location #9 and Location #10 illustrate the effect of water stagnation in dead-end pipes on DBP levels. Before flushing (i.e., #9), the THM level was measured at 91 µg/L and the HAA5 level was measured at 55 µg/L. After flushing (i.e., #10), the THM level decreased to 72 µg/L and the HAA5 level decreased to 44 µg/L. While these reductions are not large, they do represent the difference between compliance and non-compliance with the DBP limits. It is noted that this location is on the same street as the DBP Compliance Station #5 where the regulatory limits were exceeded.

DBP CONTROL ALTERNATIVES

Any viable DBP control strategy must fall in one of the following three categories:

I. Remove sufficient NOM from the water (i.e., lower the TOC level) before chlorine addition
II. Remove the DBPs after they are formed, but before they are served to the community
III. Minimize chlorine contact time

The following is a discussion of each of these categories.

Category I – NOM Removal

This category includes common modifications implemented at water treatment plants to improve the removal of NOM and reduce the concentration of TOC in the water. A number of technologies have been implemented in water treatment for NOM removal. For groundwater applications, the viable removal technologies include the following:

I.1. Adsorption on Granular Activated Carbon (GAC)
I.2. Ion-Exchange using Anion Exchange (AIX) Resin
I.3. Removal with high-pressure membrane filtration (HPMF)

Granular Activated Carbon **–** GAC is a material manufactured from coal, wood, coconut-shells, or other organic material. It is processed in a way that "activates" the surface of the material to give it a high capacity to adsorb organic chemicals. It is used in drinking water treatment for removing NOM or other organic natural or synthetic chemicals. The material is granular with a typical size of 1 to 2 mm. It is put inside a vessel similar to vessels used at the FLTP, and the water is passed through it. As the water passes between the GAC grains, the organic material adsorbs onto the GAC surface, and is thus removed from the water. However, as the GAC becomes more and more saturated with NOM, the TOC concentration in the treated water begins to rise, and the DBP levels in the distribution system will rise with it. When the treated-water TOC concentration reaches a pre-determined target value, the saturated GAC must be removed from the vessel and replaced with fresh GAC. The used GAC is hauled off site by the GAC supplier for disposal. The GAC replacement frequency can be as high as every three to four months, or as low as every two to three years. The exact value will depend on many factors including the quality of the GAC, the level of TOC in the influent water, and the volume of water treated through the GAC. It is this replacement frequency that will greatly impact the GAC replacement cost, which is the primary operating cost of a GAC treatment system.

Anion Exchange Resin **–** AIX resin is also effective at NOM removal and it behaves similar to GAC. While the AIX resin is not replaced like GAC, it requires regeneration with a high-concentration salt brine, which then requires proper handling and disposal. This is similar to a home-softener but at a much larger scale. At this time, there are no practical or economical options for the District to dispose of the waste salt brine generated from this process. For this reason, WQTS believes this to be a fatal flaw for the application of AIX at the District's FL wells.

High-Pressure Membrane Filtration **–** HPMF refers to the use of Nanofiltration (NF) or Reverse Osmosis (RO) membranes to treat the water. These membranes remove more than 90% of the NOM present in the water. This would allow the District to treat only 50% to 75% of the FLTP effluent and still achieve high TOC reduction. However, the capital cost of installing a HPMF system at the FLTP is quite high. In addition, the process will generate a waste concentrate stream that could be as much as 10% to 15% of the water treated through the membranes and will require proper handling and disposal. Most importantly, this waste stream will have a high salinity content, which will limit its disposal options, if any. At this time, WQTS believes the waste disposal limitation to be a fatal flaw for the application of HPMF at the FLTP and will therefore remove this process from further consideration.

Category II – DBP Removal

The treatment approaches under this category focus on the removal of DBPs from the water after they are formed. The primary technology that stands out in this category is air-stripping of the DBPs in the FLTP tanks before the water is pumped to the distribution system.

Stripping of DBPs in treated-water reservoirs is one of the tools available to water agencies to lower DBP levels in their drinking water. This approach takes advantage of the fact that some DBPs, mainly THMs, are volatile chemicals that can be stripped from the water into the air by implementing measures that increase the surface area contact between the water and the air. Unfortunately, HAAs are non-volatile and cannot be removed from the water with air stripping. Since the District exceeded the limits for both THMs and HAA5, air-stripping is not a viable option for achieving compliance with the Maximum Contaminant Levels (MCLs) since it does not remove HAAs from the water.

Category III – Minimizing or Eliminating Free Chlorine Contact Time

The approaches under this category focus on either minimizing or eliminating free chlorine contact with the water as a means of minimizing THM and HAA formation. The only viable option under this category is to convert the disinfectant in the distribution system from free chlorine to chloramine. This is achieved by adding ammonia to the water leaving the FLTP. The reaction between the chlorine present in the water and the added ammonia forms chloramine, which forms much less THMs or HAAs. This action would essentially stop the formation of THMs and HAAs as the water travels through the distribution system.

While this is a simple approach to DBP control, it has its complications and drawbacks. The primary drawback is the fact that water containing chloramine cannot be blended in the distribution system with water containing chlorine. Therefore, if the District chooses to convert the water produced by the FLTP to chloramine, it will need to convert all its water sources to chloramine as well, and that includes the water from all the wells. This will require the installation and operation of an ammonia feed system at each well.

Another concern with chloramine is the fact that it forms its own by-products, primarily nitrosamines, which is a class of nitrogen-containing chemicals. The main nitrosamine of concern is *nitroso-di-methyl-amine* (NDMA). NDMA does not currently have a drinking water standard but does have a California Notification Level (NL) of 10 ng/L (i.e., 0.01 µg/L) because it is classified as a probable human carcinogen. Therefore, any implementation of chloramine as a solution to DBP control must take into consideration the possibility of a future MCL for NDMA or other nitrosamines formed and ensure that their formation can be adequately controlled. It should be noted that nitrosamine formation from chloramines is typically experienced in surface water, and therefore is unlikely to be an issue for the District. However, bench-scale testing should be conducted to validate this assumption and ensure that any NDMA levels formed are acceptable.

Finally, systems using chloramine frequently experience higher-than-usual biological growth in the distribution system due to nitrification. The ammonia added at the FLTP and the other wells to convert chlorine to chloramine becomes embedded in the chloramine. As chloramine decays in the distribution system, it releases the ammonia back into the water. Naturally-occurring bacteria consume the released ammonia and if left unchecked could result in excessive bacterial growth, which in turn accelerates the loss of disinfectant residual in the water. For the District, this matter is further complicated by the long water age in the system storage tanks. The longer the water sits in these tanks, the greater is the potential to experience biological nitrification.

VIABLE TREATMENT ALTERNATIVES

Based on the preceding analysis, WQTS believes that only two treatment alternatives are technically and economically applicable to reducing THMs and HAAs in the water produced from the FL wells:

1. Adsorption on GAC
2. Converting the distribution system to chloramine

Either treatment could be applied at the FLTP with the understanding that chloramine conversion would also need to be applied at the other wells. The following subsections present a brief description of the FLTP, followed by a discussion of how each of the above treatment alternatives would be implemented.

Foster Lake Treatment Plant

A schematic of the FLTP process train, which has a capacity of approximately 200 gpm, is shown in Figure 6. Water drawn from FL wells passes through two parallel low-profile aerators aimed at stripping carbon dioxide (CO_2) from the water and raise its pH. Booster pumps then lift the aerated water and push it through a Filtronics® oxidation/filtration treatment system comprised of an oxidation contactor and a media filter. Chlorine is added at the inlet of the oxidation tank to oxidize any remaining un-oxidized iron or manganese in the water. Chlorine is also needed to continuously regenerate the media in the filtration process. The filter media is backwashed on a daily basis, and the waste backwash water is discharged to a local pond.

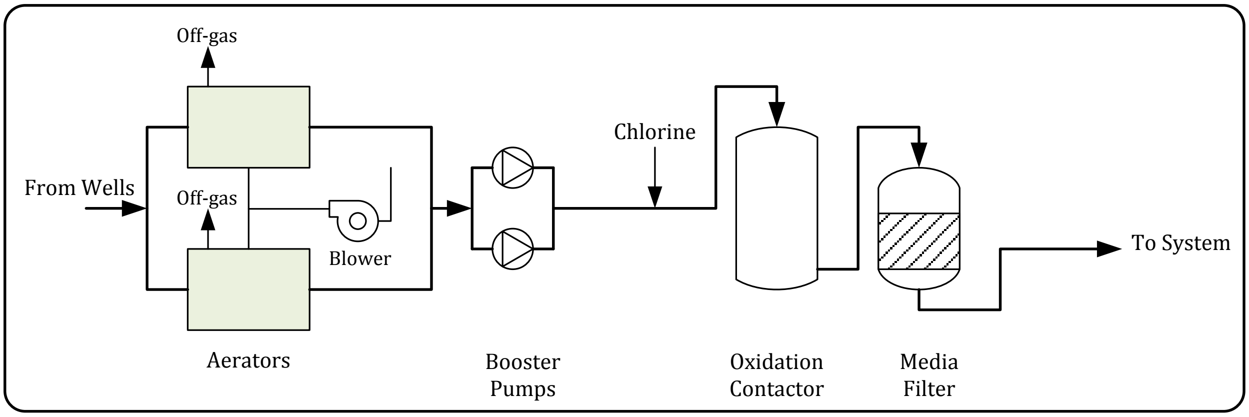

Figure 6 – Schematic of the 200 gpm Foster Lake Water Treatment Plant

Application of GAC Treatment at the FLTP

GAC application at the FLTP will require the addition of one or more vessels upstream of the point of chlorine addition. Considering that chlorine is required for effective manganese removal through the Filtronics® process, it will be necessary to divert the pump discharge flow to the GAC vessels and bring it back to the inlet to the oxidation contactor. A modified schematic of the FLTP incorporating GAC treatment is shown in Figure 7. In this configuration, one 10-ft diameter vessel is inserted between the feed water booster pump and the oxidation contactor. The vessel will not fit inside the existing FLTP building, and therefore, the piping will need to be routed outside to where the vessel will be installed, and then back into the building to continue through the treatment system. Also shown in Figure 7 is a by-pass line around the GAC vessel. This configuration allows the District to treat only a portion of the flow through the GAC when the TOC concentration is low and increase that portion when the TOC concentration is high. This approach increases the life of the GAC by ensuring that it is used only as needed.

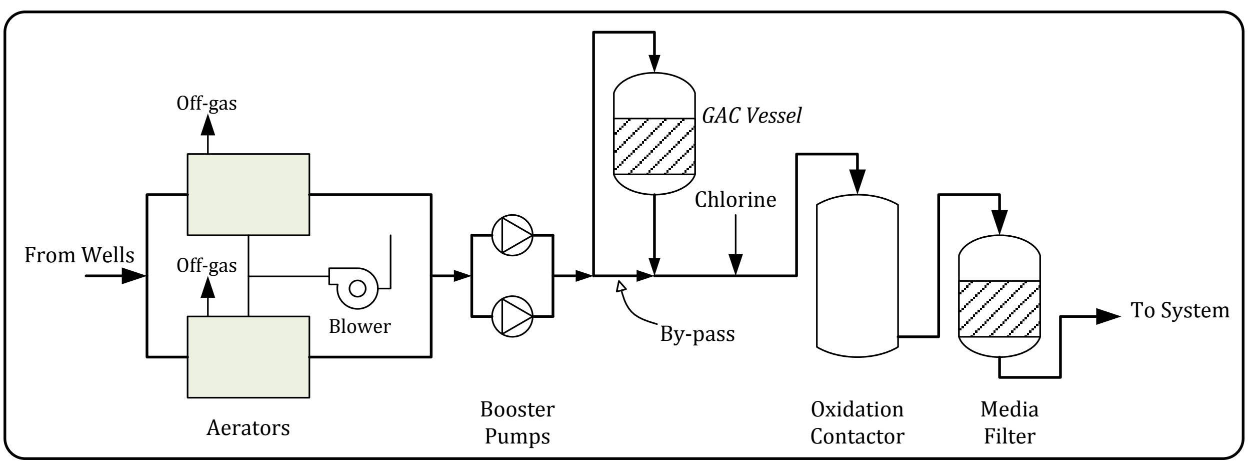

Figure 7 – Schematic of the 200 gpm Foster Lake Water Treatment Plant with added GAC Treatment

Table 2 presents the general sizing of the GAC treatment system and its associated components. Aside from the 10-ft diameter vessel, no backwash pumps or waste backwash water was assumed based on conversation with District staff. The intent is to use the backwash system currently applied at the FLTP.

Table 2 – Sizing of the GAC System & Associated Components

Parameter	Value	Comment/Basis/Reason
Flow Rate	200 gpm	Full capacity of the FLTP
Empty Bed Contact Time (EBCT)	15 minutes	at 200 gpm
Vessel Diameter	10 ft	Standard size
Hydraulic Loading Rate	2.5 gpm/sf	
GAC Depth	61 inches	
GAC Volume	400 cu-ft	
Estimated GAC weight	12,000 lbs	
Estimated Clean Bed Headloss	1.5 ft of H_2O	through GAC only
Max. Anticipated Headloss	6 ft of H_2O	through GAC only

The greatest unknown about the GAC system is the anticipated GAC replacement frequency. If the District choses to implement GAC treatment, pilot-scale testing can be conducted prior to the start of the design process to estimate the GAC replacement frequency and select the best GAC product to be used. At this time, WQTS estimates that the GAC in the vessel will likely need to be replaced once every eight (8) months of operation. This estimate assumes that the plant utilization rate is 90%, which means that the annual average flow through the plant is 180 gpm compared to its capacity of 200 gpm.

Based on the GAC sizing criteria presented in Table 2, and the placeholder 8-month GAC replacement frequency estimated above, the capital cost and the annual Operations & Maintenance (O&M) cost of the GAC system were estimated and are presented in Table 3. <u>Based on the available information, it is WQTS' opinion that the capital cost is likely to be between $700,000 and $1,500,000. This includes construction cost and professional services cost. The probable annual O&M cost is currently projected at a range of $42,000/yr to $86,000/yr</u>. It should be noted that the capital cost could be lower if District staff takes on some of the installation and construction activities.

Table 3 – Opinion of Probable Cost of the GAC Design, Construction, and Operation

Parameter	Range	Includes / Basis
Capital Cost		
Equipment & Building	$200,000 – $400,000	GAC vessel, misc. items (e.g., valves, instruments), 456 SF building, and taxes on equipment purchase
Construction Activities	$300,000 – $700,000	Mobilization, site work & yard piping, electrical, instrumentation & controls, first GAC purchase, contractor overhead and profit, and a construction contingency (25%)
Professional Services	$200,000 – $400,000	Engineering design, construction management, pilot-scale testing of GAC, permitting, admin. & legal, and startup support services
Total Capital Cost	**$700,000 – $1,500,000**	
Annual Operations & Maintenance Cost		
GAC Replacement	$29,000/yr – $61,000/yr	Based on 90% utilization rate, 21,000 Bed Volumes between replacements, and a delivered GAC unit cost of $75/cf
Analytical Cost	$850/yr – $1,800/yr	Assuming 26 TOC samples @ $50 ea.
Power Cost	$200/yr – $400/yr	1,280 kW-hr/yr @ $0.25/kW-hr
Maintenance Cost	$11,000/yr – $23,000/yr	Placeholder estimate for maintenance labor and supplies
Total O&M Cost	**$42,000/yr – $86,000/yr**	

Application of Chloramine Conversion

Under this solution, an ammonia feed system must be installed at the FLTP and at each of the other nine operating wells that feed into the system. Figure 7 shows a schematic of the FLTP that includes the location where ammonia would be added. The ammonia dose will depend on the target chloramine concentration. In most systems using chloramine, the target chloramine concentration in the treated water is approximately 2.5 mg/L. Therefore, the chlorine dose at the FLTP and all the wells must be increased to result in a chlorine residual of 2.5 mg/L at the point of ammonia addition. The ammonia dose is then set at 0.5 to 0.6 mg/L as N in order to form chloramine at a concentration of 2.5 mg/L as Cl_2. At this time, it is assumed that the existing chlorine feed systems at the FLTP and the nine wells can deliver a chlorine residual of 2.5 mg/L as Cl_2, and therefore no upgrades to the chlorine storage and/or feed systems are required.

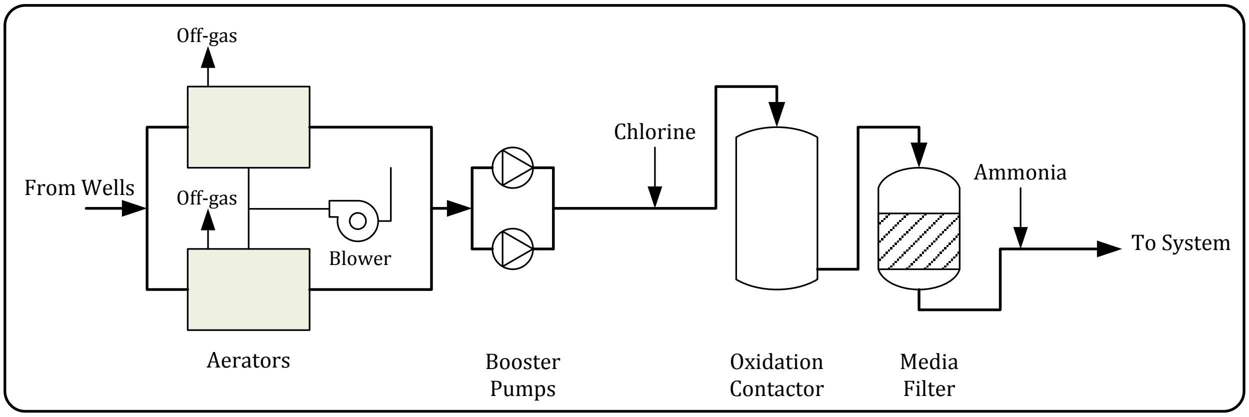

Figure 7 – Schematic of the 200 gpm Foster Lake Water Treatment Plant with added Chloramine Treatment

The ammonia dose must be properly paced with the flowrate as well as the chlorine residual present in the water just upstream of ammonia addition. This requires a water flowmeter and an online chlorine analyzer at each ammonia addition point. Proper control programming should be implemented to modulate the ammonia feed rate in order to maintain a balanced chloramine chemistry in the water entering the system. If the water chemistry is out of balance, the chloramine residual may decay rapidly in the system which could lead to increased biological growth. Figure 8 presents a general schematic of the control system required at each ammonia addition point. A Programmable Logic Controller (PLC) will receive data from the flow meter and the online chlorine analyzer and based on internal setpoints and calculations it will direct the chlorine pump and the ammonia pump to maintain a specific feed rate. A static mixer is recommended at the point of ammonia addition to ensure rapid mixing of the ammonia solution with the chlorine in the water to form chloramines.

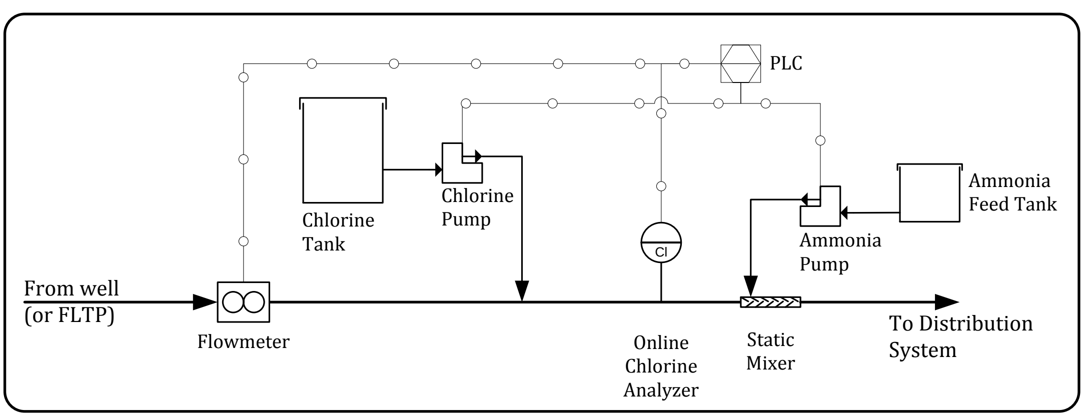

Figure 8 – Conceptual Schematic of the Ammonia Feed Control Strategy

Commercial ammonia solutions are commonly sold as a 19% solution, which contain 1.21 lbs of NH_3-N per gallon of solution. Table 4 presents a summary of the sizing requirements for the ammonia feed systems at the FLTP and each of the City wells. These calculations are based on an ammonia dose of 0.56 mg/L as N. Considering the low well capacities, the solution storage volumes range from 10 gallons at five wells to 55 gallons at the FLTP. These are small volumes that can fit within the well house at each location.

Table 4 – Sizing of the Ammonia Feed Systems
[based on an ammonia dose of 0.56 mg/L as N]

Location	Capacity, gpm	Solution Consumption Rate, gpd	Solution Feed Rate, mL/min	Ammonia Solution Volume, gal.	Days of Operation, days
FLTP	200	1.1	2.89	55	45
FV1A	42	0.23	0.61	20	78
FV2	38	0.21	0.55	20	86
Well #23	42	0.23	0.61	20	78
Well #24	43	0.24	0.62	20	76
Well #25	10	0.05	0.14	10	164
Well #26	21	0.12	0.30	10	78
Well #28	23	0.13	0.33	10	71
Golden Rod	18	0.10	0.26	10	91
Oakwood	35	0.19	0.51	10	47

The primary cost of implementing chloramine conversion is the installation of the ammonia feed solution and other associated PLC control components shown in Figure 8 at each location. Table 5 includes WQTS' opinion of the probable capital and O&M costs for converting the District's distribution system from free chlorine to chloramine. The overall capital cost, which includes equipment purchase, installation, programming, and professional services, is projected to be in the range of $450,000 to $950,000. The annual O&M cost includes the chemical cost, increased labor cost for distribution system monitoring and flushing, and maintenance cost of the 10 additional online instruments and control systems. The total annual O&M cost is projected to range between $30,000/yr and $62,000/yr. The O&M cost is dominated by additional labor required for the management of the chloramine chemistry in the system reservoirs, as well as the maintenance of the additional 14 online chlorine analyzers and PLCs installed.

Table 5 – Opinion of Probable Capital and Annual O&M Costs of Chloramine Conversion

Parameter	Range	Includes / Basis
Capital Cost		
Equipment, Installation, & Programming	$320,000 – $680,000	10 online chlorine analyzers, static mixers, chemical feed pumps, control components, PLCs, installation, and programming.
Professional Services	$130,000 – $270,000	Technical support for engineering, environmental permitting, DDW permitting, public notification, admin. & legal, and startup support
Total Capital Cost	**$450,000 – $950,000**	
Annual Operations & Maintenance Cost		
Chemical Cost	$4,000/yr – $8,000/yr	Higher hypochlorite usage and added ammonia usage
DS Operator Cost	$12,000/yr – $26,000/yr	Additional 0.25 FTE for additional DS monitoring and flushing
Maintenance Cost	$14,000/yr – $28,000/yr	Placeholder estimate for maintenance labor and supplies for the 10 instruments and control systems
Total O&M Cost	**$30,000/yr – $62,000/yr**	

SUMMARY & RECOMMENDATIONS

The Idyllwild Water District experienced an excursion in the levels of THMs and HAA5 in its distribution system resulting in exceedances of the regulatory limits for both disinfection by-products. This Technical Memorandum included an analysis of the potential cause of these excursions, and the options available to the District to lower the formation of DBPs in the distribution system. The analysis suggests that the main source of DBPs are the FL wells, which have a higher concentration of TOC than the District's other wells. Unfortunately, the FL wells are also the District' highest producing wells and cannot be removed from service. Based on WQTS' analysis of the options available to the District, WQTS recommends that one of the following two alternatives be implemented by the District:

- ◊ Install GAC treatment at the FLTP
- ◊ Convert the distribution system disinfectant from chlorine to chloramine

The strengths and weaknesses of each of the two treatment technologies are highlighted in Table 6. GAC treatment requires the installation of a single additional pressure vessel at the FLTP to remove the natural organic matter from the water, and thus reduce the TOC concentration and reduce the levels of THMs and HAAs in the system. The process is highly passive in that it does not require significant operator attention and has no moving parts that require ongoing maintenance. On other hand, the process has a higher capital cost than that of chloramine conversion and requires replacing the exhausted GAC with new GAC on a frequent basis, which constitutes the majority of the annual O&M cost. This replacement frequency is uncertain at this time and can vary over time. It is anticipated that the GAC will need to be replaced approximately every eight (8) months. However, this is highly uncertain and requires verification with either bench-scale or pilot-scale testing prior to implementation.

Chloramine conversion achieves DBP control by eliminating the free chlorine contact time in the system. Ammonia is added at each entry point to the system to convert the free chlorine to chloramine, which does not form THMs or HAAs. Unfortunately, if this strategy is implemented at the FLTP, it will need to be implemented at the other 9 operating wells because chloramine cannot be mixed with chlorine in the distribution system. While chloramine conversion can be significantly less costly than that of GAC treatment, it has its operational challenges in that it increases the potential for biological growth in the distribution system which will require a significant increase in distribution operator time and attention. In addition, the installation of 10 online chlorine analyzers and PLC controllers will also increase the maintenance requirements on the District.

Table 6 – Strengths & Weaknesses of the two Viable Alternatives

Treatment Alternative	Strengths/Benefits	Weaknesses/Drawbacks
GAC Treatment at FLTP	◊ Passive treatment with little to no operator attention required	◊ Significantly higher capital cost than that of chloramine conversion
	◊ Removes NOM and thus reduces the formation of all disinfection by-products	◊ Requires GAC replacement on a relatively high frequency
	◊ Low maintenance due to lack of moving parts or monitoring instruments	◊ GAC replacement frequency, and thus cost, can vary with changing water quality, which increases the uncertainty of the annual cost
	◊ Implemented only at the FLTP	
Chloramine Conversion	◊ Significantly lower capital cost than GAC treatment	◊ A significant increase in the number of online instruments and control systems that require ongoing maintenance
	◊ Cost of consumables (chlorine and ammonia) is well defined	◊ Although unlikely in groundwater, chloramines could form nitrosamines, which are carcinogens with a possible future regulatory limit
	Depending on the stability of chloramine, the ongoing labor cost may not be as high as anticipated	◊ Could result in nitrification and loss of disinfectant residual in the system reservoirs that require operator attention and increased flushing
		◊ Will require ammonia feed and control at any new well in the future

Figure 9 presents WQTS' opinion of the probable capital costs, annual O&M costs, and total annualized costs of the two DBP reduction strategies. The capital cost of the GAC treatment system is expected to range from $700,000 to $1.5M while that of chloramine conversion is expected to range from $450,000 to $950,000. These include all equipment purchase, installation, and professional services. The annual O&M costs of the GAC process are projected to range between $42,000/yr and $86,000/yr, the bulk of which is the GAC replacement cost, which needs to be confirmed through pilot-scale testing. The annual O&M cost of the chloramine conversion approach is projected to range from $30,000/yr to $62,000/yr depending on the amount of operator attention required and maintenance needs of the added instruments.

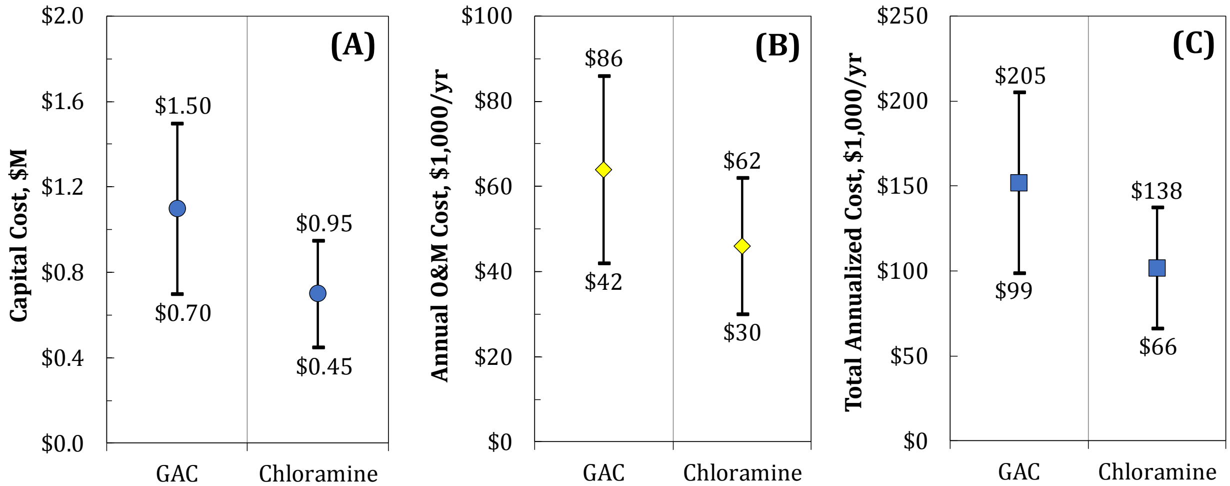

Figure 9 – Summary & Comparison of Probable (A) Capital Cost, (B) Annual O&M Cost, & (C) Total Annualized Cost [i.e., sum of Amortized Capital Cost, 20 yrs @ 5%, and Annual O&M Cost] for GAC Treatment and Chloramine Conversion

Figure 9 also includes the total annualized cost of the two alternatives. This value is calculated as the sum of the amortized capital cost and the annual O&M cost. Capital cost amortization assumes an interest rate of 5% and a 20-year payment period. Using these assumptions, the total annualized cost of the GAC process is expected to range from $99,000/yr to $205,000/yr compared to that of chloramine conversion, which is expected to range from $66,000/yr to $138,000/yr.

Finally, if the District chooses to implement chloramine conversion, a significant amount of coordination with DDW will be required. It will also be important to hold public meetings to explain the change in treatment to the rate payers. DDW will require that the District conduct a public information campaign to provide the residents enough time to prepare for the change in disinfectant in the water. On the other hand, if the District chooses to implement GAC treatment, it is recommended that bench-scale or pilot-scale testing be commissioned to get a better estimate of the GAC replacement frequency and refine the GAC replacement cost.