CRESCENTA VALLEY WATER DISTRICT

2700 FOOTHILL BOULEVARD
LA CRESCENTA, CALIFORNIA

To be held on
November 8, 2023 at 3:30 PM

Agenda for the Meeting of the Engineering & Operations Committee
of the Crescenta Valley Water District

Posted November 7, 2023 at 3:30 PM

TELECONFERENCING NOTICE

This meeting will be conducted in person at the address listed above. Members of the public may also participate virtually by using a touchtone phone. You may select any of the following phone numbers (there are more than one for increased reliability during this time of increased phone traffic).

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Those members of the public who are able to and would like to additionally participate with a computer through videoconference may access the Zoom videoconferencing tool available at the following link:

https://us02web.zoom.us/j/82877172920

If there is a disruption of service, this meeting will continue without remote participation. The remote participation option is provided as a convenience to the public and is not required.

Any person may make a request for a disability-related modification or accommodation needed for that person to be able to participate in the public meeting by contacting the District by phone or in writing at customerservice@cvwd.com. Requests must specify the nature of the disability and the type of accommodation requested. A telephone number or other contact information should be included so that District staff may discuss appropriate arrangements. Persons requesting a disability-related accommodation should make the request with adequate time before the meeting for the District to provide the requested accommodation.

Call to Order

Adoption of Agenda

Public Comment:

At this time, members of the public shall have an opportunity to address the Committee on items of interest that are within the subject matter jurisdiction of this Committee. This opportunity is non-transferable, and speakers are limited to three (3) minutes each. Under the provisions of the Brown Act, the Board is prohibited from taking action on items not listed on the agenda, except under certain circumstances.

Action Item(s)

The public shall have an opportunity to comment on any action item as each item is considered by the Committee. This opportunity is non-transferrable, and speakers are limited to one two-minute (2) comment each.

1. Status of Local Water Supply

2. Report Review for Conversion to Chloramine Disinfection

3. LADWP-CVWD Emergency Interconnection

4. Rosemont Overcrossing Update

5. Montrose Pipeline Replacement Update

6. 23/24 CIP Update

7. PFAS Update and Discussion

Committee Members' Request for Future Agenda Items

Adjournment

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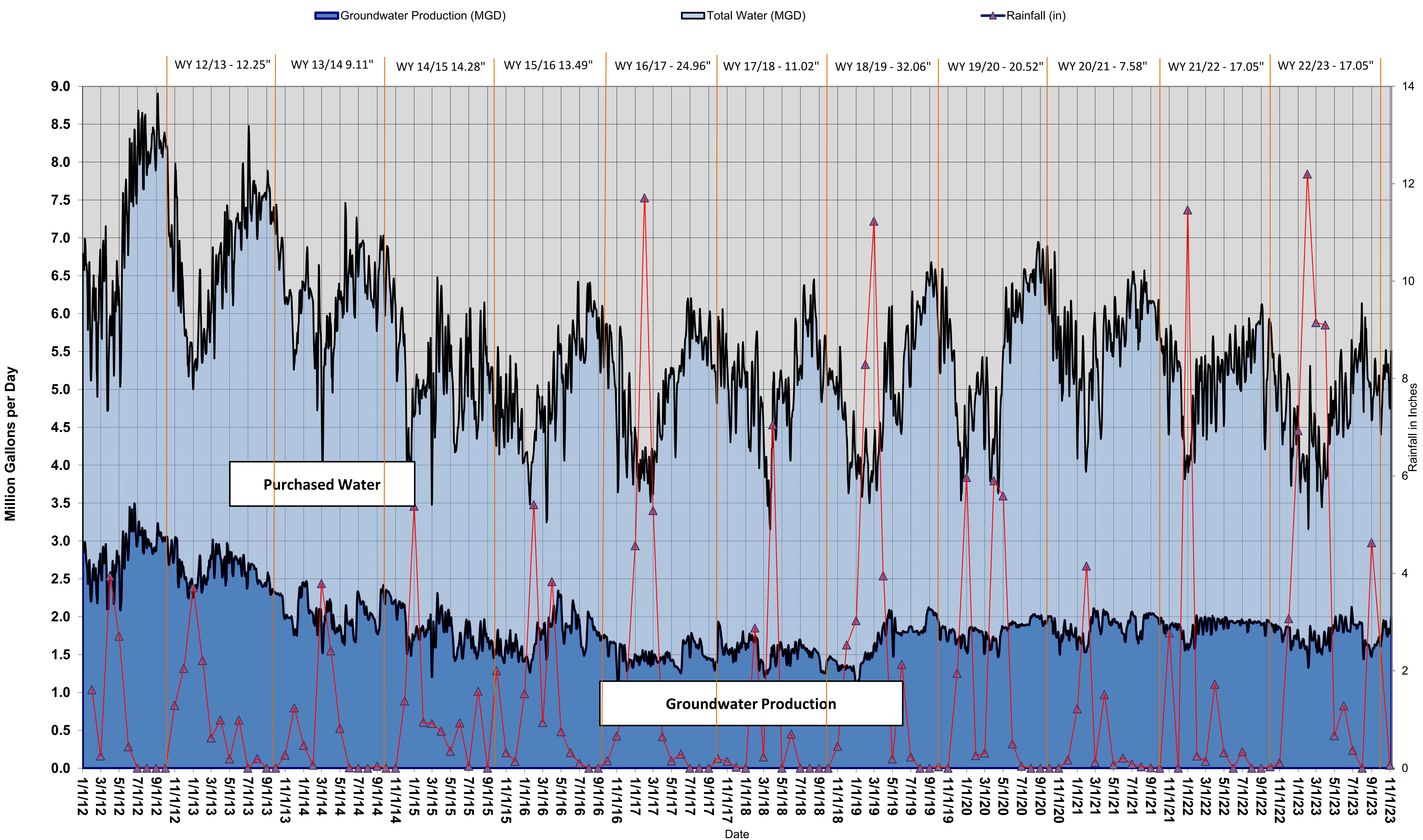
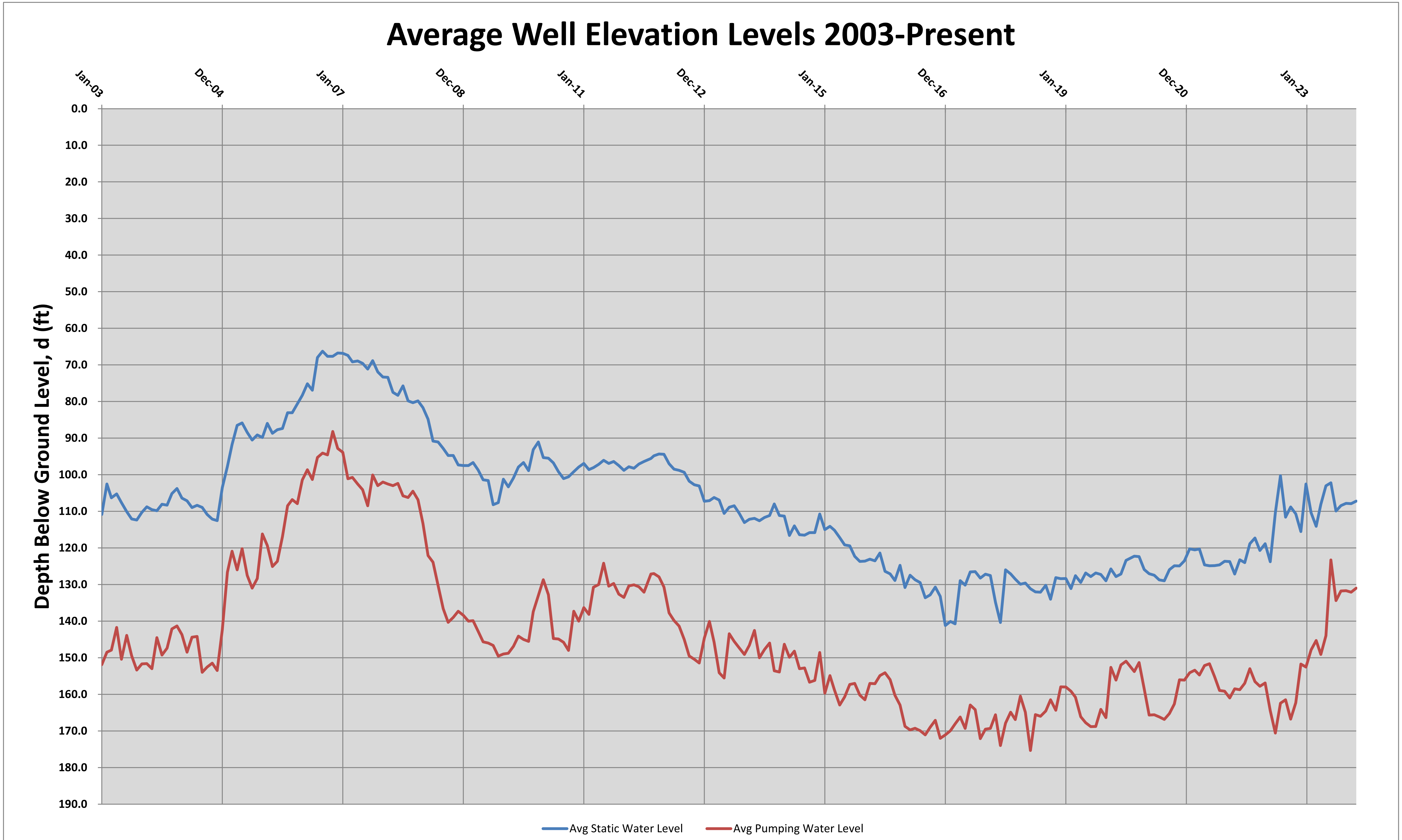
Water Production Chart w/ Rainfall 2012-2023




Average Well Elevation Levels 2003-Present
Jan-03
Dec-04
Jan-07
Dec-08
Jan-11
Dec-12
Jan-15
Dec-16
Jan-19
Dec-20
Jan-23
Depth Below Ground Level, d (ft)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
140.0
150.0
160.0
170.0
180.0
190.0
Avg Static Water Level
Avg Pumping Water Level

Monitoring Well Static Level Measurements	MW 1	MW 2	MW 4	VD-VPB-01	VD-VPB-02	VD-VPB-05	VD-VPB-06	VD-VPB-07
Location	CV Dog Park	Orangedale & Mira Vista Park	Encinal & Pennsylvania SE corner	Mayfield Ave. 120' E. of La Crescenta Ave	Sunnyview Dr. 60' E. of Oceanview Blvd	Broadview Dr. 135' E of Roselawn Ave	Fairchild St. 200' E of Dunsmore Ave	Orange Cove Ave. 281' E of Briggs Ave
Construction Date	Jan-03	Jan-03	Dec-02	Jan-90	Dec-89	Jan-90	Jan-90	Dec-89
Casing Depth	120	300	310	210	136	156	96	216
Screen Depth	40 - 100	200 - 280	200 - 290	190 - 210	116 - 136	136 - 156	76 - 96	196 - 216
Top of Column Elevation	1431.7	1295.9	1446.7	1395.4	1169.0	1216.1	1647.8	1844.8
Date	SWL, ft bgs	SWL, ft bgs	SWL, ft bgs	SWL, ft bgs	SWL, ft bgs	SWL, ft bgs	SWL, ft bgs	SWL, ft bgs
Mar-03	28	202	140					
Jun-03	27	202	143					
Sep-03	29	200	145					
Dec-03	28	200	144					
Mar-04	20	203	140					
Feb-05	22	204	143					
Jan-06	22		119					
Sep-06	24	192	106					
Jan-07	24	184	108					
Jan-09			127					
Feb-10		203	130					
Mar-10	28	198	129					
Apr-10	26	198	128					
May-10	26	203	131					
Nov-10	31	195	134					
Dec-10	31		134					
Jan-11	28		136					
Feb-11	28		136					
Mar-11	27		135					
May-11	23		132					
Jul-11	24		133					
Aug-11	24		133					
Sep-11	27		135					
Dec-11	27		134					
May-12			137					
May-13	32							
Apr-17	35							
Apr-23	26	205	154	210	116	142	75	216
Oct-23	29	202	148	210	116	141	76	168

CRESCENTA VALLEY WATER DISTRICT
STAFF REPORT

Information Item No. 2
November 8, 2023

To: Engineering and Operations Committee

From: Brook Yared, M.S., P.E. – Interim Director of Engineering & Operations

Subject: **Conversion to Chloramines, Project E-1052 – WQTS Technical Memorandum Review**

INFORMATION ITEM:

Disinfection Conversion to Chloramines, Project E-1052 – WQTS Technical Memorandum Review

BACKGROUND:

In August 2018, with groundwater production not fully recovered from the past drought, CVWD's water supply blend shifted to 40% groundwater and 60% imported water. This, coupled with the additional chlorine needed to achieve breakpoint chlorination in the system, caused an increase in total trihalomethanes (TTHM) levels at the four (4) regulatory compliance points within the distribution system. Staff implemented a water quality sampling plan to measure levels of TTHMs weekly to ensure CVWD complies with Department of Drinking Water's (DDW) Disinfection By-product Rule. As shown on the attached charts, since August 2018, CVWD's TTHM quarterly running annual average level has trended below the maximum contaminate level (MCL) of 80 micrograms/liter. Levels have been well below the MCL since these measures were implemented. Since starting this work in 2018, CVWD has installed new equipment to help reduce TTHM production while on free chlorine and reduce "water age." These improvements have the added benefit of contributing to more advanced control and monitoring strategies for chloramine disinfection.

After receiving direction from the Engineering Committee at the March 1, 2023, meeting, staff has contracted with Water Quality and Treatment Solutions (WQTS), one of the lead consultants in the Chloramine permit development undertaken in 2018, to review all permitting requirements, assist in ordering any additional probes and/or analyzers, and developing a strategy to transition CVWD's water system to chloramine disinfection.

DISCUSSION:

WQTS completed their review of water quality and flow data across CVWD's distribution system. WQTS highlighted several common issues related to conversion from free chlorine disinfection to Chloramines. WQTS regards the risk of converting to chloramine disinfection to be very low. They also estimate the cost of doing a demonstration using CVWD source water in actual pipe taken from our distribution system to be between $500,000 - $800,000. At this cost, WQTS is recommending that the risks described in their report do not warrant the cost of a conversion demonstration. Staff wants to highlight and discuss these issues, the likelihood of their occurrence, and review the benefits of conversion.

Chloramine Decay and Water Age: Similar to free chlorine, chloramine decays over time in a distribution system. The extent of chloramine loss depends on several factors including water temperature, water age, and system cleanliness. During hot summer months, chloramine will decay faster than it does in colder winter months just like what is currently experienced with free chlorine. Water age also plays a role, since the longer the water resides in the distribution system storage reservoirs, the further the chloramine residual decays. When analyzing water age across the distribution system, it was discovered that the Cresta Heights reservoir serving Zone 8 was increasing the overall water age in Zone 8 and all above zones. Cresta Heights consists of two 500,000-gallon reservoirs that serve a small population. Water can sit in this reservoir for longer periods than other higher demand zones in similar elevations. Staff has removed one of the tanks at Cresta Heights from operation, which has prevented disinfection byproduct formation in Zone 8 and higher zones. This should translate to a reduction in risk of forming nitrifying bacteria when converting to chloramines.

Nitrification: Nitrification is an issue in all systems that utilize chloramine disinfection. Nitrifying bacteria do not cause any harm and exist everywhere in nature. The concern about the growth of nitrifying bacteria is the fact that they also react with chloramine and thus accelerate the loss of chloramine residual in the distribution system. In 2019, WQTS put together a Nitrification Monitoring and Control Plan, which staff has since implemented, to get ahead of nitrification issues and have an action plan to mitigate nitrification should we experience it in the system. Should nitrification occur, CVWD would need to flush dead ends and reservoirs to purge the nitrifying bacteria, which would represent a large cost if/when it were to occur.

Discolored (Red) Water: While it is impossible to predict, some residences may experience discolored tap water within a period after conversion to chloramine. This is caused by the dissolution of iron from distribution system pipes or from older galvanized iron pipes in people's homes. Therefore, this is limited to areas served by unlined iron pipes in the distribution system and to homes with galvanized plumbing. WQTS reviewed CVWD's customer lateral material spreadsheet and reviewed the amount of unlined water main material as part of their recent analysis. Generally, issues with red water surrounding chloramine conversion are difficult to isolate, since most case studies available also incorporate a significant change to the source water being introduced into the system. South Pasadena being one such case, changed from serving mostly groundwater (free chlorine) to serving mostly imported water (chloramine) after experiencing water quality issues in their groundwater basin. This was not only a disinfection method change but also a complete change in their water composition. They experienced water discoloration issues until their groundwater wells were reactivated and they were able to switch back to free chlorine disinfection. A second case study from the Serrano Water District (Serrano) in Orange County tells a different story. Serrano converted to chloramine disinfection without changing the composition of their water source and experienced no water discoloration. As with nitrification, there is the real cost of flushing water from the system should water discoloration become an issue.

Break Point Chlorination Savings: Currently, CVWD uses break point chlorination to convert imported water from chloramine disinfection to free chlorine disinfection. This requires high doses of free chlorine. This free chlorine then interacts with the chloramines in our imported water until all chloramines are destroyed and free chlorine is established as the main disinfection method. Dosing groundwater with chloramines would take roughly 5 ppm less of chlorine disinfection to establish a sufficient chloramine residual. This represents approximately 40% reduction in sodium hypochlorite purchases with slight cost increases for monitoring of ammonia analyzer probes.

Disinfection Byproduct Formation Reduction: Since 2019, CVWD has increased our TTHM sampling throughout the system, to avoid facing the same compliance issues as in 2018. While compliance sampling has remained low, staff did see an increase in TTHM formation at noncompliance locations while Paschall Booster B was out of service. Converting to chloramines would eliminate the need for this additional sampling, although this cost will likely be replaced with additional sampling as part of the Nitrification Monitoring and Control Plan.

Also, disinfection byproduct rules are expected to change in the coming years with a reduction to the MCL from 80 ppm to an unknown level. With current TTHM levels at compliance points within the District, a reduction to 60 ppm of TTHMs would only be achievable with a conversion to Chloramines.

Regional Emergency Interconnection: CVWD has access to two Interconnections for emergency water supply, one with Glendale Water and Power and the other connection with Los Angeles Department of Water and Power in case there is an interruption of supply coming from the Foothill Municipal Water District (FMWD). Both interconnections utilize chloramine disinfection and do not currently have injection points in place to perform break point chlorination. Also, La Cañada Irrigation District (LCID) and all FMWD Member Agencies currently utilize chloramine disinfection their systems. FMWD may need to rely on our emergency interconnections to supply Member Agencies with water during upcoming shutdowns. Currently, the difference in our disinfection methods makes supplying FMWD Member Agencies difficult.

Groundwater Contamination: Similar to what occurred in the City of South Pasadena, emerging or currently unregulated contaminants could necessitate that CVWD turn off several wells. With MTBE, staff shut down well 5, which is our largest groundwater producing well. The results of PFAS testing and health findings may also require that our wells be shut down in response. Converting to chloramines now would eliminate many risks associated with converting to chloramines while simultaneously changing source water conditions.

Recommendation:

WQTS regards the risk of converting to chloramine disinfection to be very low. They also estimate the cost of doing a demonstration using CVWD source water in actual pipe taken from our distribution system to be between $500,000 - $800,000. At this cost, WQTS is recommending that the risks described in their report do not warrant the cost of a conversion demonstration.

Prepared by:	Submitted by:
Kellen J. Boyce	Brook Yared, M.S., P.E.
System Operations Manager	Interim Director of Engineering & Operations

Attachments:
1. WQTS - Impact of Chloramine Conversion on Water Quality
2. CVWD TTHM Compliance Monitoring Table and Graphs
3. WQTS – Nitrification Monitoring and Control Plan

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Date: October 11, 2023

To: Mr. Brook Yared, P.E.
Engineering Manager
Crescenta Valley Water District

WQTS Project No.: 0137.0030

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

Project: Technical Support for Implementation of Chloramine Conversion

Re: Impact of Chloramine Conversion on Water Quality

The Crescenta Valley Water District (District) serves a blend of local groundwater and treated surface water purchased from the Metropolitan Water District of Southern California (MWD) through the Foothill Municipal Water District (FMWD). The District's groundwater is chlorinated, while the purchased MWD water contains chloramine. Blending of chloramine with chlorine would result in the rapid loss of disinfectant residual (both chlorine and chloramine) in the distribution system. For this reason, the District either has to add chloramine to its groundwater to blend with the chloraminated MWD water or convert the chloraminated MWD water to free chlorine to blend with the chlorinated groundwater. The District has thus far chosen the latter strategy and implemented breakpoint chlorination of the MWD water to destroy the chloramine and convert it to chlorine, which allowed the District to maintain free chlorine in its distribution system.

Unfortunately, free chlorine contact with water containing elevated levels of natural organic matter (NOM) results in the formation of disinfection by-products, DBPs, including two regulated DBPs: trihalomethanes, THMs, and haloacetic acids, HAAs, both of which have strict limits in drinking water. While the District's groundwater is low in organic content, the NOM levels in the imported MWD water are significantly higher. The MWD water also contains elevated levels of bromide, Br^-, which enhances the formation of THMs and HAAs in chlorinated water. Thus, the levels of DBPs formed in the District's distribution system is highly dependent on the blend ratio between MWD water and local groundwater. The DBP levels formed in chlorinated MWD water also depend on the blend ratio between Colorado River water, which contains lower NOM concentrations, and State Water Project water with higher NOM concentrations.

In past years, the District relied more heavily on its groundwater supply than on imported MWD supply. However, due to the prolonged drought period of 2012 through 2017 which resulted in diminished groundwater supply, the District greatly increased its reliance on MWD water to meet its demand resulting in high DBP levels in the District's drinking water. Figure 1 shows the compliance levels of THMs in the District's drinking water system at its four compliance locations as compared to the regulatory limit of 80 µg/L and an operational goal of 64 µg/L (80% of the MCL). The green triangles are individual quarterly averages, while the red circles are the Locational Running Annual Average (LRAA) compliance values. The profiles in Figure 1 show that the District came very close to violating the THM MCL in 2018 as it increased reliance on MWD water, but the compliance levels have since decreased in concentration.

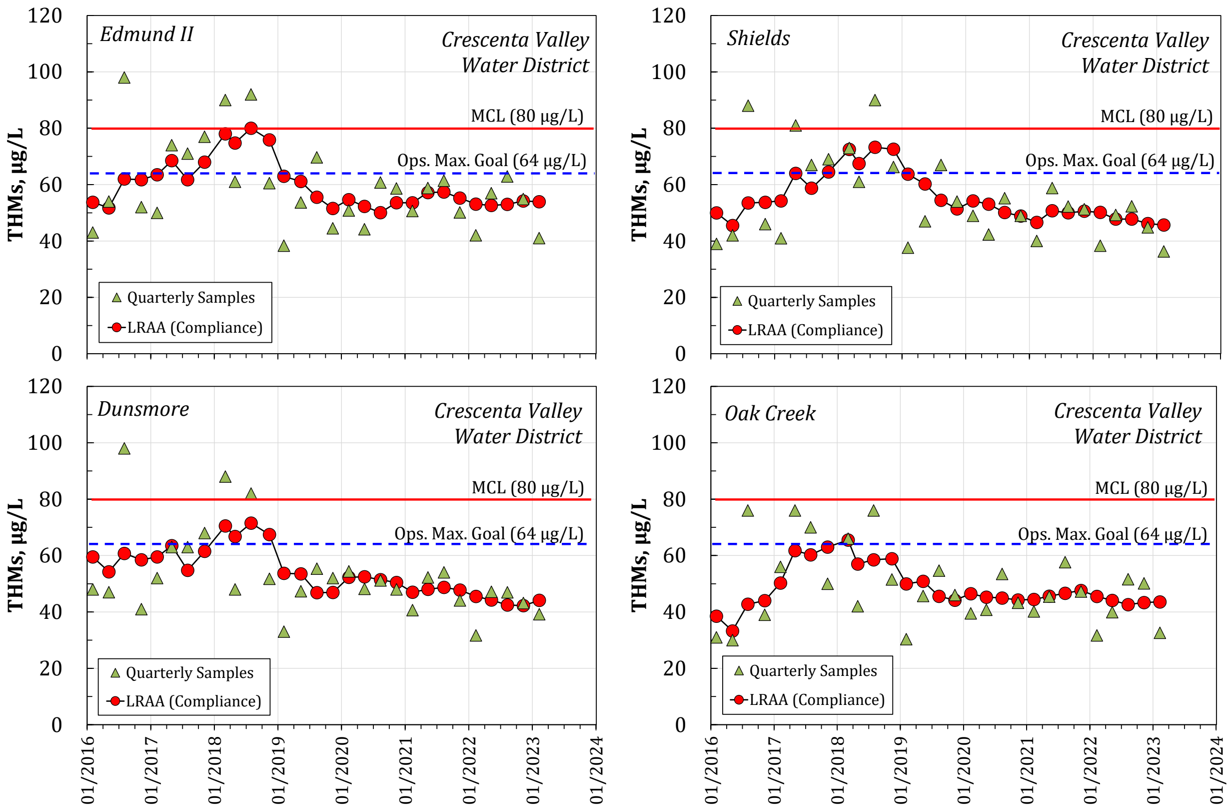


Figure 1 – THM Profiles at the District's Four Compliance Locations

In response to the rise in DBP formation in 2018, the District made the decision to convert the distribution system disinfectant from free chlorine to chloramine. Since then, the District completed the following actions:

1. Installed an ammonia feed system at the Glenwood WTP
2. Installed an ammonia feed system at the Mills WTP
3. Installed an ammonia feed system at the Well 2 Nitrate Treatment Plant
4. Installed new chlorine and ammonia feed systems at the Pickens Tank
5. Installed several online chlorine analyzers throughout the distribution system

Then, in preparation for the conversion, the District also issued public notification and conducted public information campaigns about the planned conversion, developed a Nitrification Monitoring and Control Plan (NMCP), and applied for and received a permit amendment to convert the system from free chlorine to chloramine. However, the District held off on converting to chloramine as water quality conditions changed and as groundwater supplies increased. In addition, the COVID-19 pandemic forced the District – and all other Districts – to realign their priorities regarding the operation of their water systems. With this effort, WQTS is assisting the District in re-starting the chloramine conversion effort beginning with an analysis of the potential impacts of chloramine conversion on the District's water quality.

1.0 SYSTEM CONFIGURATION

Figure 2 presents a detailed schematic of the hydraulic zones in the District's distribution system, with specific emphasis on water flow path from the lower zones to the upper zones, and storage volume in each zone. The schematic also identifies the locations of chlorine and ammonia feeds, as well as the locations of the online chlorine analyzers.

The District operates three Water Treatment Plants (WTPs): The Glenwood WTP that uses ion-exchange (IX) to remove nitrate from water, the Mills WTP which relies on blending to maintain nitrate below the maximum contaminant limit (MCL) of 10 mg/L as N, and the Aronite™ WTP which relies on biological treatment to remove nitrate from Well 2 water. Water from the Glenwood WTP is diverted to the Ramsdell Blending Station where it blends with imported FMWD water received through the Briggs meter. The blended water then flows to the 3-MG Encinal Reservoir that serves the water demand in Zone 1.

Water is pumped from the Encinal Reservoir into Zone 2 which contains two storage reservoirs: Williams and Ordunio. The Well 2 water treated at the Aronite™ WTP is mostly blended with system water in Ordunio Reservoir. Water from the Oceanview FMWD meter may enter the system in Zone 2, primarily blending into Williams Reservoir.

Water pumped out of Williams Reservoir is then blended with water pumped from the Mills WTP and any water purchased from FMWD at the Paschall meter and the blended water is directed to Zone 4 before it flows into Oak Creek Reservoirs. Water flows down from Zone 4 into Zone 3 and its Rosemont Reservoir.

Water is pumped from Rosemont Reservoir and from Oak Creek Reservoirs up to Zone 5, which contains Eagle Canyon and Markridge Reservoirs. Water is then pumped from Markridge Reservoir into Zones 6 (Goss Canyon), Zone 7 (Dunsmore), and Zone 8 (Cresta Heights). Water is also pumped from Eagle Canyon reservoir into Zone 6 (Goss Canyon).

Water continues to be pumped from Goss Canyon Reservoir in Zone 6 to Zone 9, which contains Edmund Tanks 1 and 2. Water from Edmund 1 is then pumped up to Zone 11 (Pickens Canyon) and water from Edmund 2 is pumped to Zone 10 (Shields). Water is also pumped from Zone 8 (Cresta Heights) to Zone 9 (Edmund 2), but as discussed later in this TM, this is seldom practiced.

Finally, a small flow stream of 25 to 30 gpm collected from Pickens Tunnel is dosed with chlorine and ammonia and blended into Pickens Canyon Reservoir serving the water demand in Zone 11.

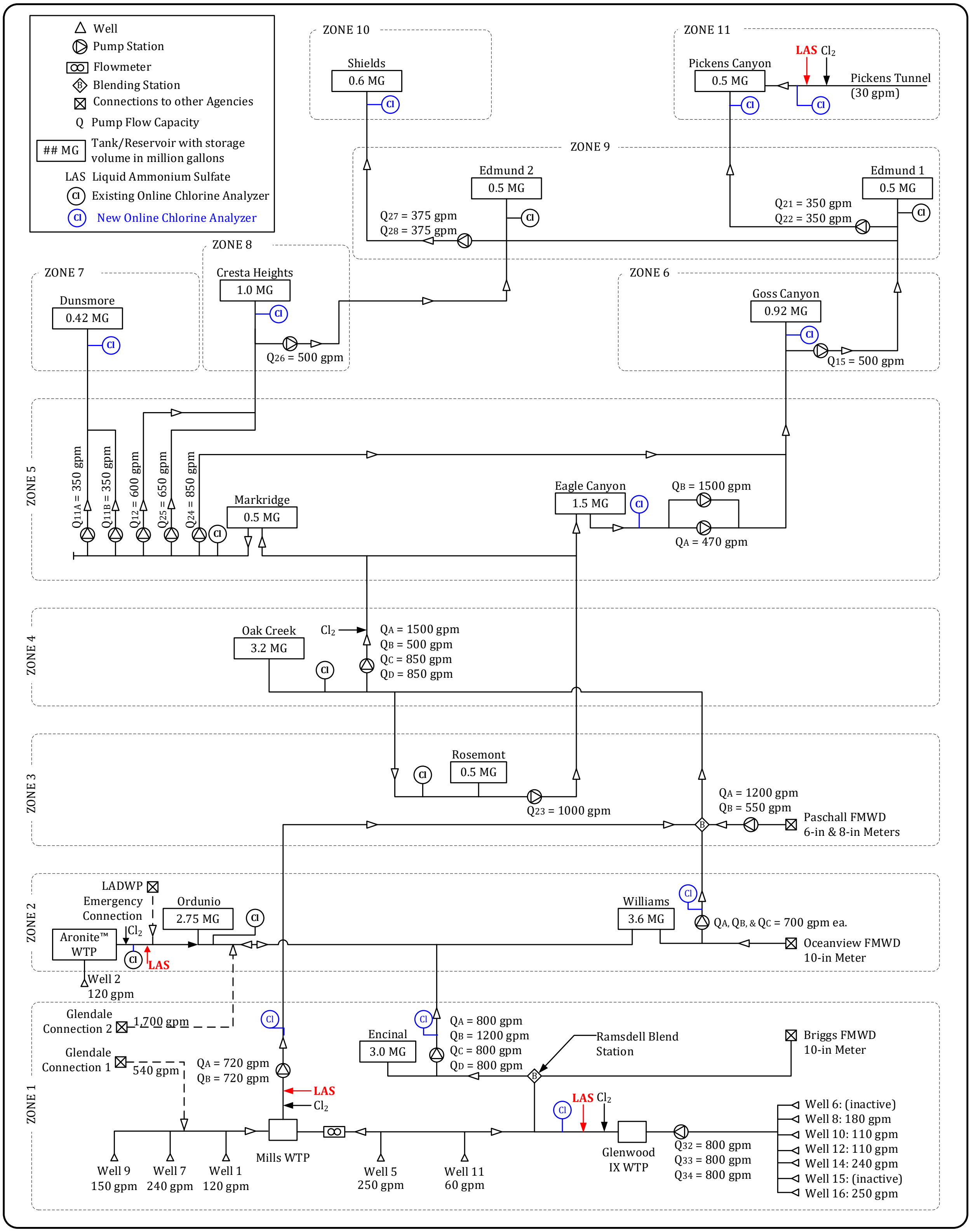


Figure 2 – Crescenta Valley Water District System Components and Hydraulic Zones

2.0 POTENTIAL CHALLENGES WITH CHLORAMINE CONVERSION

Switching the disinfectant in a distribution system from free chlorine to chloramine is likely to have no noticeable impact on most of the residents. The District has already gone through the public notice process about the conversion to chloramine and customers should have already made the changes to their aquariums and any dialysis machines to filter out chloramine. However, the District's customers can benefit from a second reminder of this conversion before it takes place. The remaining issues of concern are related to three main potential challenges that are discussed briefly herein.

2.1 Chloramine Decay and Nitrification

Similar to free chlorine, chloramine decays over time in a distribution system. The extent of chloramine loss depends on several factors including water temperature, water age, and system cleanliness. During hot summer months, chloramine will decay faster than it does in cold(er) winter months just like what is currently experienced with free chlorine. Water age also plays a role since the longer the water resides in the distribution system storage reservoirs, the further the chloramine residual decays. Finally, deposits in reservoirs and pipes harbor biofilms that further consume the disinfectant in the water. Ensuring that reservoirs and pipes remain clean from such deposits helps improve the stability of the disinfectant in the water.

When chloramine decays in water, it releases back into the water the ammonia that was used to generate it. The released ammonia can serve as a nutrient to bacteria and could thus lead to excessive biological growth in the distribution system, especially storage reservoirs. The type of bacteria that consumes ammonia are referred to as Nitrifying bacteria, and their act of consuming ammonia is referred to as "Nitrification". Nitrifying bacteria do not cause any harm and exist everywhere in nature. The only concern about the growth of nitrifying bacteria is the fact that they also react with chloramine and thus accelerate the loss of chloramine in the water. Ultimately, it is the loss of chloramine in the system that raises the concern over the potential growth of coliform bacteria in the system.

In preparation for the conversion to chloramine, the District developed a Nitrification Monitoring and Control Plan (NMCP) which will serve as a guide to District staff to track the development of nitrification activities in the various reservoirs and take measures to minimize the growth of nitrifying bacteria.

2.2 Potential for Discolored Water Events

While it is impossible to predict, some residences may experience discolored tap water within a period of time after conversion to chloramine. The color may range from faint yellow tint to dark brown. This is caused by the dissolution of iron from distribution system pipes or from old(er) galvanized iron pipes in people's homes. Therefore, this is limited to areas served by unlined iron pipes in the distribution system and to homes with galvanized iron pipes. The following is a brief description of why this may happen and how it can be triggered by the conversion to chloramine.

When water flows through an iron pipe, the bare iron/steel surface is exposed to water containing oxygen, chlorine, or chloramine, all of which are referred to as "oxidants". With this exposure to oxidants, the solid iron material is oxidized to ferrous iron (Fe^{2+}), which is highly soluble in water. At elevated concentrations, this dissolved iron will begin to appear as a yellow or brown color in the water. Continued exposure to the water further oxidizes this soluble ferrous iron, Fe^{2+}, to ferric iron, Fe^{3+}, which is highly insoluble. The ferric iron begins to form a hard layer over the ferrous iron which then prevents the underlying ferrous iron from continuing to dissolve into the water. The stronger the oxidant type and concentration in the water, the harder the ferric layer covering the soluble iron. Chloramine is a weaker oxidant than free chlorine under typical concentrations in drinking water, and thus a change from free chlorine to chloramine has the potential to weaken this hard layer. The weaker the layer gets, the more of the underlying soluble iron will dissolve into the water.

However, many factors other than the type of disinfectant also contribute to the hardness of the protective ferric layer, including the calcium carbonate precipitation potential and the mineral content of the water. Therefore, it is not possible to predict if the switch from chlorine to chloramine alone is sufficient to cause enough weakening of the protective layer to result in a significant rise in the iron concentration in the water. In fact, almost all of southern California maintains chloramine in its drinking water distribution system and clearly does not experience discolored water. This is because the protective scale in the unlined iron pipes has adapted to chloramine as the oxidant in the water. Therefore, if water discoloration does take place, it is not because of chloramine, but rather because of the switch from free chlorine to chloramine.

WQTS worked with the District to identify the locations of the unlined iron pipes in the distribution system. While it is not possible to know the number of homes with galvanized iron plumbing, the District does maintain a database on the material of service lines (SLs) between the pipe mains in the streets and individual properties. This information was analyzed as part of this work and is presented and discussed in this TM.

2.3 Potential Increase in Lead and Copper Release

While it is highly unlikely, it is important to recognize that the same mechanism discussed above about the potential release of dissolved iron into the water with the switch from free chlorine to chloramine may also apply to other metal surfaces in contact with the water. Of particular interest are lead and copper due to their potential adverse health effects. While iron release into the water can be detected as discolored water, a rise in the concentrations of lead and/or copper in tap water cannot be detected without laboratory analysis of water samples.

To address this concern, close monitoring of the lead and copper levels in tap water will be conducted after chloramine conversion and compared to their levels measured under current free chlorine conditions. Assuming chloramine conversion will be completed during the fall of 2023, two 6-month

Lead-and-Copper Rule (LCR) monitoring campaigns will be conducted during the 1st half and 2nd half of 2024 as required by DDW.

3.0 POTENTIAL FOR CHLORAMINE LOSS AND NITRIFICATION

In order to assess the potential for chloramine loss in the system, the data provided by the District was analyzed to estimate the water age through the various zones and reservoirs, and to study the fate of free chlorine over winter and summer seasons. The District's reservoir cleaning and inspection records were also obtained and analyzed. The outcome of these analyses is presented in this section.

3.1 Water Age

A longer water age results in further decay of the chlorine residual. In the lower zones of the system, the water has a relatively low age, and the chlorine residual is generally the highest in the system. As the water is pumped up to higher zones, the water age increases due to the additional storage volume as well as the prevalence of lower water demand in the upper zones resulting in a significant decrease in the chlorine residual concentration. Thus, a detailed analysis of 5-minute intervals of all pump flowrate data and water reservoir level data were analyzed to conduct an overall mass balance on each zone in order to estimate the water demand in that zone, and thus the water age. This analysis was conducted for the winter and summer seasons based on data from the Winter and Summer of 2022.

The methodology used for estimating the water demand in each zone was as follows:
For each zone, the water demand in that zone between two consecutive times, t_i and t_{i+1}, was first estimated using Equation 1:

$$Demand\Big|_{t_i \to t_{i+1}} = \left[\frac{Q_{in,t_i} + Q_{in,t_{i+1}}}{2}\right] \times \left(t_{i+1} - t_i\right) - \left[\frac{Q_{out,t_i} + Q_{out,t_{i+1}}}{2}\right] \times \left(t_{i+1} - t_i\right) - \left[V_{t_i} - V_{t_{i+1}}\right] \qquad (1)$$

Where Q_{in,t_i} = Flowrate into the zone at time t_i

$Q_{in,t_{i+1}}$ = Flowrate into the zone at time t_{i+1}

Q_{out,t_i} = Pumped flowrate out of the zone at time t_i

$Q_{out,t_{i+1}}$ = Pumped flowrate out of the zone at time t_{i+1}

V_{t_i} = Storage volume in the zone at time t_i

$V_{t_{i+1}}$ = Storage volume in the zone at time t_{i+1}

In the data received from the District, the span of time between t_i and t_{i+1} was five (5) minutes, and thus Equation 1 was used to estimate the water demand in each zone over each five-minute interval. A 24-hr rolling average of the calculated 5-minute demand values was then calculated to smooth out large swings in the calculated 5-minute demand values resulting mostly from inaccuracies in the water level readings in each reservoir.

The outcomes of the analysis for Winter 2022 and Summer 2022 are presented in Figures 3 and 4, respectively. The comparison shows that the water demand calculated herein using reservoir volume balance agrees with the water production from all the District's sources. Therefore, the methodology used provides a reasonable estimate of the water demand, and thus water age in each zone.

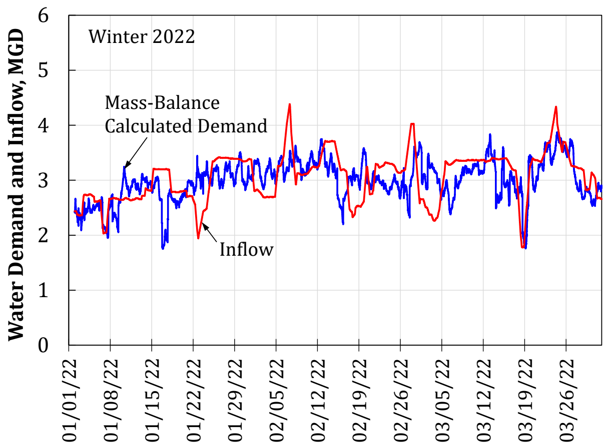


Figure 3 – Comparison between the Winter 2022 Water Demand Calculated herein based on Mass-Balance and Water Inflow from all Sources

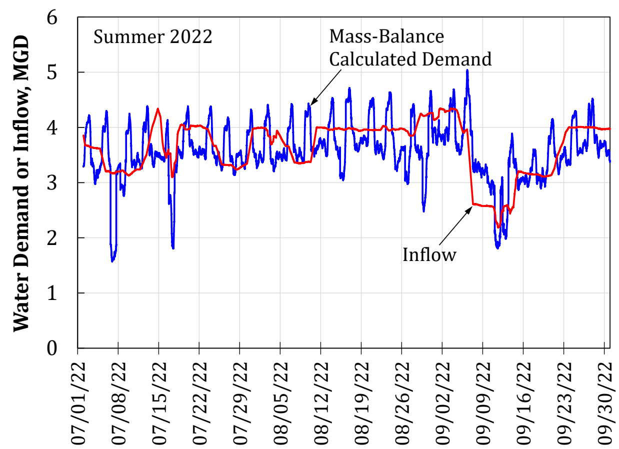


Figure 4 – Comparison between the Summer 2022 Water Demand Calculated herein based on Mass-Balance and Water Inflow from all Sources

Finally, the split between surface water (i.e., FMWD water) and local groundwater depends on various factors. The District relies on FMWD water to meet its demand as well as blend down the nitrate in the groundwater. During winter 2022, the District relied mostly on its groundwater supply as demonstrated by the profile in Figure 5. With the higher demand in the summer months, the District water demand was split almost equally between groundwater and FMWD water (Figure 6).

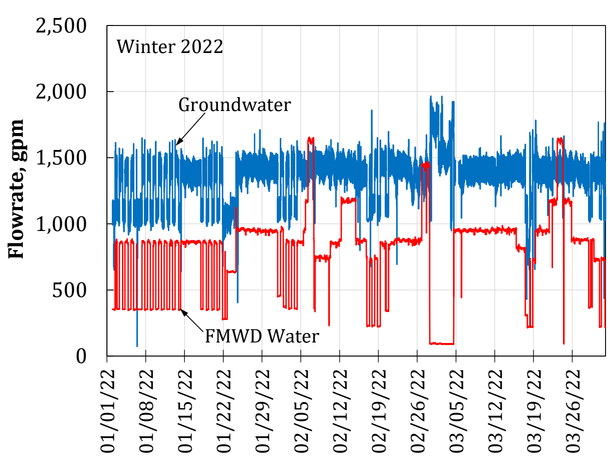


Figure 5 – Groundwater vs. FMWD Water Supply during Winter 2022

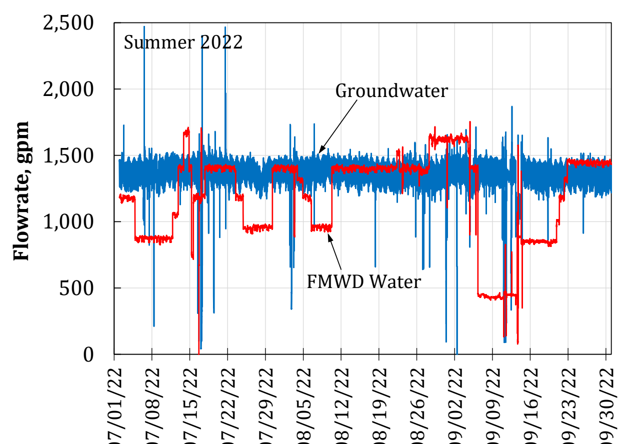


Figure 6 – Groundwater vs. FMWD Water Supply during Summer 2022

The calculated daily water demand values presented above were then used to estimate the 24-hr running average water age in each hydraulic zone in the system. The calculation was based on Equation 2 in which the average storage volume recorded over a 24-hr period was divided by the sum of the average pumped flowrate out of each storage volume and the average water demand for that 24-hr period estimated using the approach described earlier.

$$Water\ Age\Big|_{Ave.} = \frac{\left[Volume\right]_{Ave.}}{\left[Q_{out,Ave} + Demand_{Ave}\right]} \tag{2}$$

The water age analysis was conducted for each zone individually with the exception of Zones 3 and 4 which were treated as one zone because the water can flow from 3 to 4 and back from 4 to 3 before it is pumped up to Zone 5 as shown in Figure 2. The cumulative water age in each zone was then calculated as the sum of the water age estimates for all the preceding zones. It is important to note that one simplifying assumption of this analysis is that the storage volume in each zone is treated as one mixed volume. In zones that have multiple reservoirs, especially those that are apart from each other, this approach can result in high inaccuracies. The most significant one is in Zone 2 where the volumes of Williams and Ordunio Reservoirs were treated as one volume, when in reality most of the water flow out of the zone does not pass through Ordunio Reservoir on the way up to the upper zones. Therefore, the water age through Zone 2 is somewhat over-estimated. However, the water age in the Ordunio reservoir and its service area is under-estimated since the water stagnates in that section of the zone.

An analysis of the operating conditions of Zone 6 and Zone 8 showed that minimal water is pumped from Zone 8 to Zone 9 and that the vast majority of Zone 9 water is pumped from Zone 6. The pumping rates in and out of Zones 6 and 8 between January and March 2022 are presented in Figure 7 to illustrate this point. In the upper chart, water is pumped from Zone 5 into Zone 6 at about 600 gpm and is pumped out of Zone 6 to Zone 9 at about 500 gpm on a daily basis. However, the lower chart shows that while water is pumped approximately 3 times a week into Zone 8, it was pumped out to Zone 9 only a few times over the three-month period presented. This operational mode was also confirmed by District staff.

Based on the preceding analysis, the water age estimation was conducted by setting Zone 8 as a terminal zone, similar to Zone 7, and thus the water age estimation was focused on four routes:

1. Zone 1 → Zone 2 → Zones 3 & 4 → Zone 5 → Zone 7
2. Zone 1 → Zone 2 → Zones 3 & 4 → Zone 5 → Zone 8
3. Zone 1 → Zone 2 → Zones 3 & 4 → Zone 5 → Zone 6 → Zone 9 → Zone 10
4. Zone 1 → Zone 2 → Zones 3 & 4 → Zone 5 → Zone 6 → Zone 9 → Zone 11

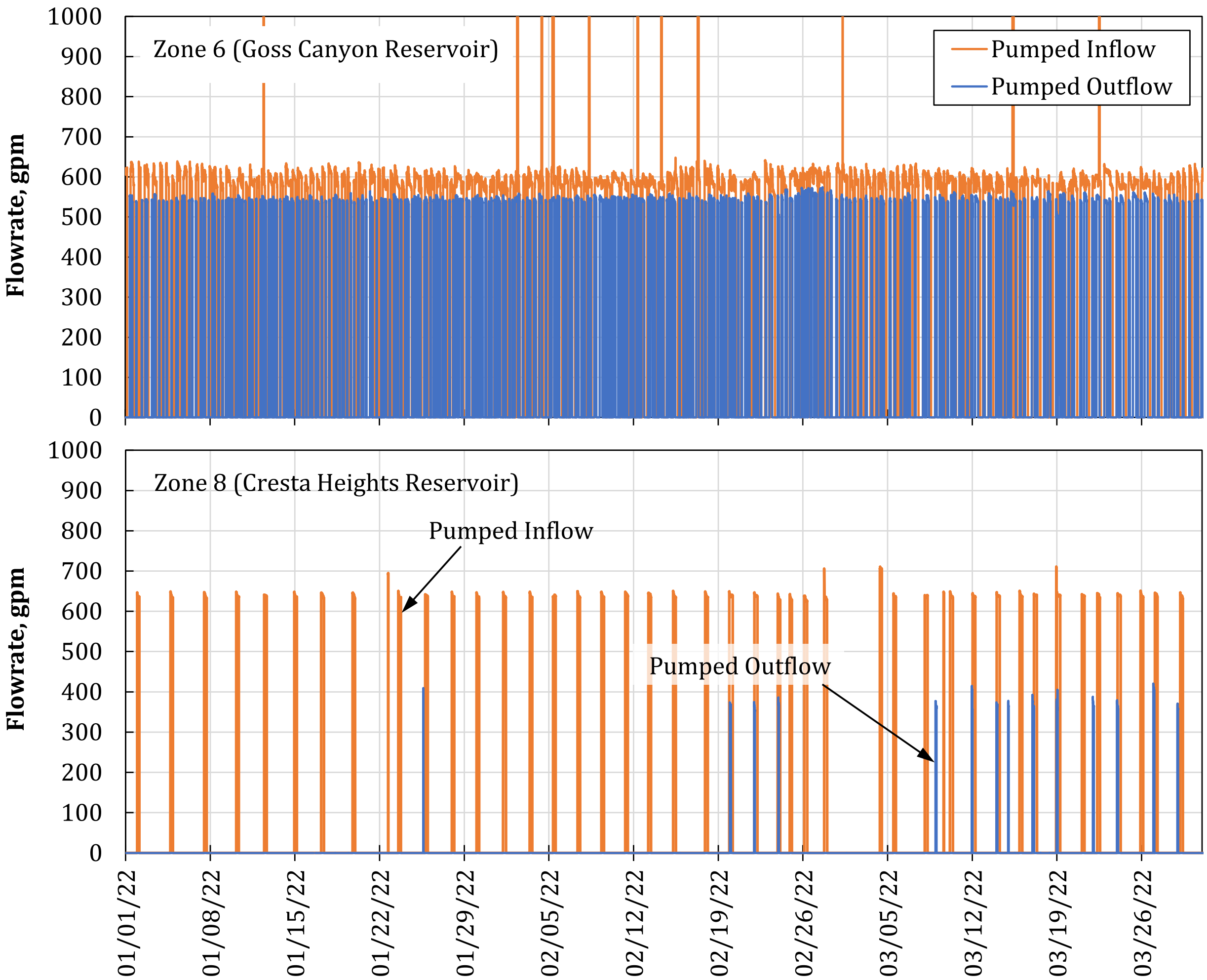


Figure 7 – Difference in Inflow and Outflow Patterns between Goss Canyon Reservoir in Zone 6 (upper chart) and Cresta Heights Reservoir in Zone 8 (lower chart)

Table 1 presents a summary of the water age estimates for all four water routes under the Winter and Summer conditions of 2022. The values presented include the average water age, as well as the 10th percentile and 90th percentile values for each route in each season. The highest average water age was up to Zone 10 (Shields) and was estimated at 19 days in the Winter season, with a 90th percentile of 24 days, and then 15 days in the Summer season with a 90th percentile of 19 days. While the summer water age is lower than that in the winter, the higher summer temperatures tend to cause greater loss of disinfectant residual in the storage tanks as discussed later herein.

While Table 1 presented the overall water age from Zones 1 to the terminal zones, the water age through each zone under each season are also presented in the subsequent figures. Figure 8 presents a breakdown of the water age by zone along the path from Zone 1 to Zone 7(upper chart) and from Zone 1 to Zone 8 (lower chart) during Winter 2022. The upper chart shows that the total age of the water in Zone 7 (Dunsmore Reservoir) in Winter 2022 was generally no more than 10 days with the majority of it in Zone 2 and Zone 7. The lower chart shows that the age of the water in Cresta Heights

Reservoir (Zone 8) was mostly between 10 and 15 days, most of which occurred in the Cresta Heights reservoir.

Table 1 – Summary of 10th Percentile (%ile), Average, and 90th %ile Water Age Estimates (Days) for Winter 2022 and Summer 2022 Conditions

Water Path	Winter 2022			Summer 2022		
	10th %ile	Average	90th %ile	10th %ile	Average	90th %ile
1. Up to Zone 7	9.1	11	14	7.0	9.2	12
2. Up to Zone 8	12	15	19	8.5	12	15
3. Up to Zone 10	15	19	24	11	15	19
4. Up to Zone 11	13	18	25	10	14	17

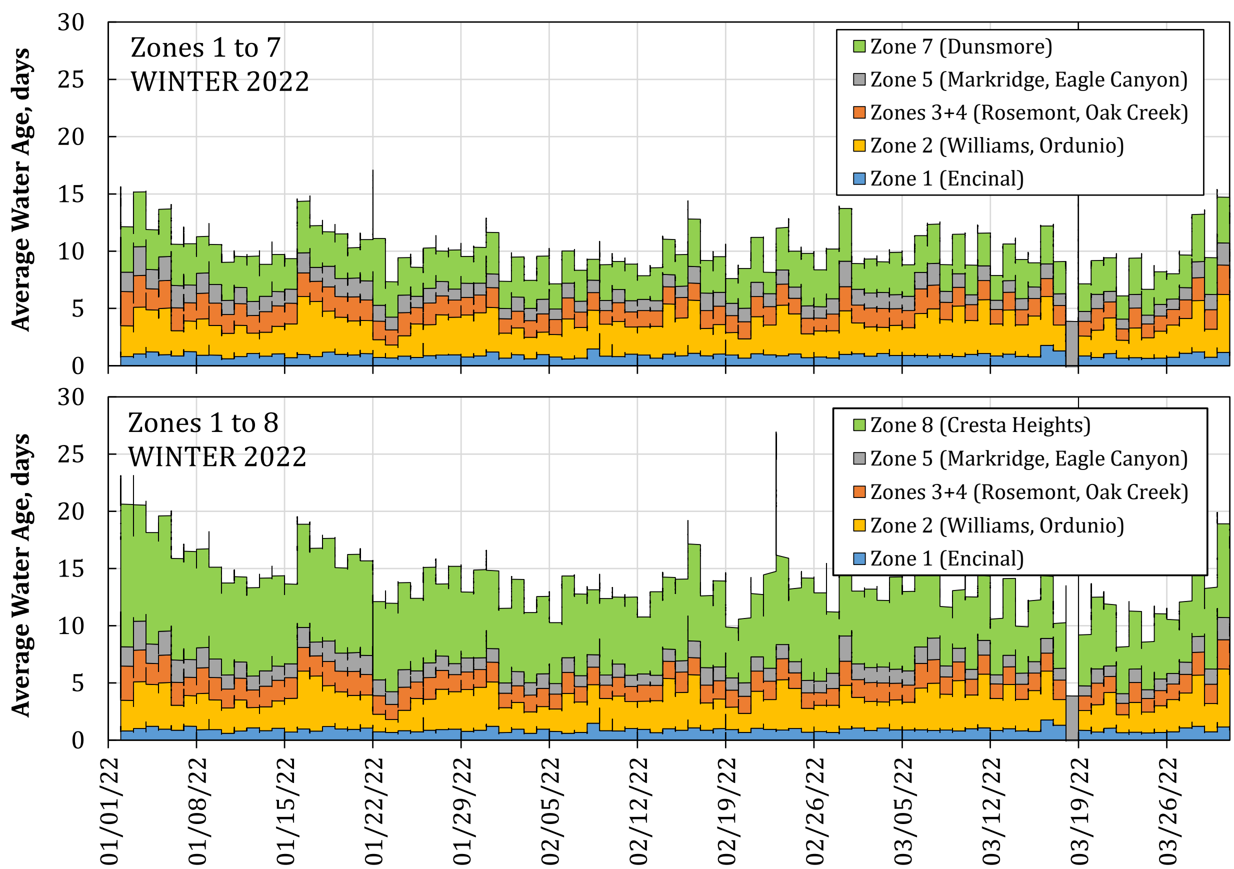


Figure 8 – Estimated Winter 2022 Water Age as the Water Travels from the Sources to Dunsmore Reservoir in Zone 7 (upper chart) or Cresta Heights Reservoir in Zone 8 (lower chart)

Figure 9 shows a similar analysis for Summer 2022. The water age to Zone 7 (upper chart) was less than 10 days for most of the summer, but the age to Zone 8 (lower chart) was between 10 and 15 days most of the time with about 50% of the water residence time spent in Cresta Heights reservoirs.

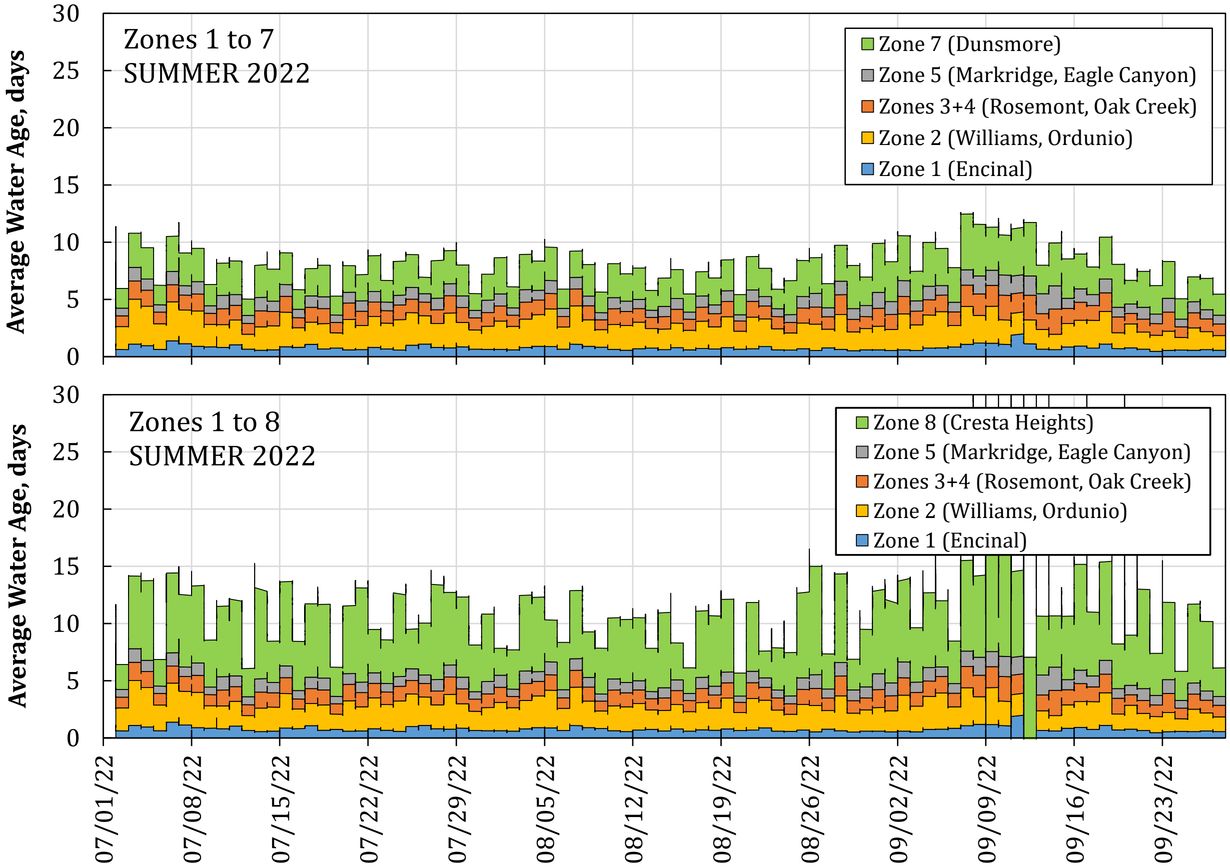


Figure 9 – Estimated Summer 2022 Water Age as the Water Travels from the Sources to Dunsmore Reservoir in Zone 7 (upper chart) or Cresta Heights Reservoir in Zone 8 (lower chart)

Figures 10 and 11 present the breakdown of the water age from sources to Zone 10 in Winter 2022 and Summer 2022, respectively. Similar to the breakdown profiles shown in Figures 8 and 9, almost half the age of the water consumed in Zone 10 was spent in Shields reservoir. This observation suggests that the majority of chloramine residual loss in the system is likely to take place in the terminal reservoirs Dunsmore, Cresta Heights, and Shields. Thus, any future consideration for boosting chloramine residual can be focused on these reservoirs or the flow from the zone feeding them, but not any of the other lower zones.

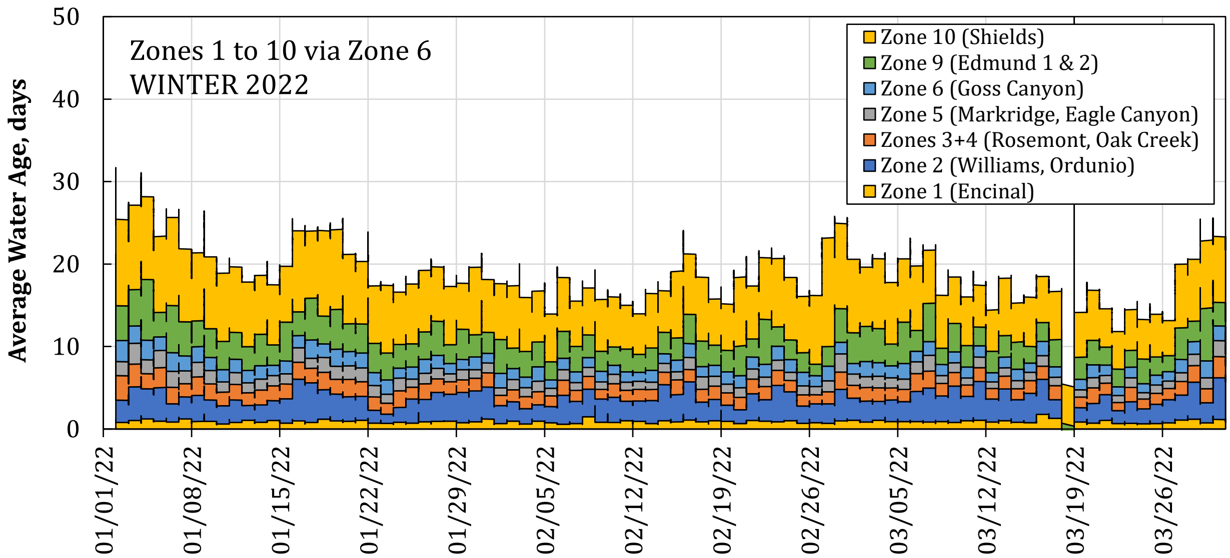


Figure 10 – Estimated Average Water Age in Winter 2022 as the Water Travels from Sources to Zone 10 via Zone 6

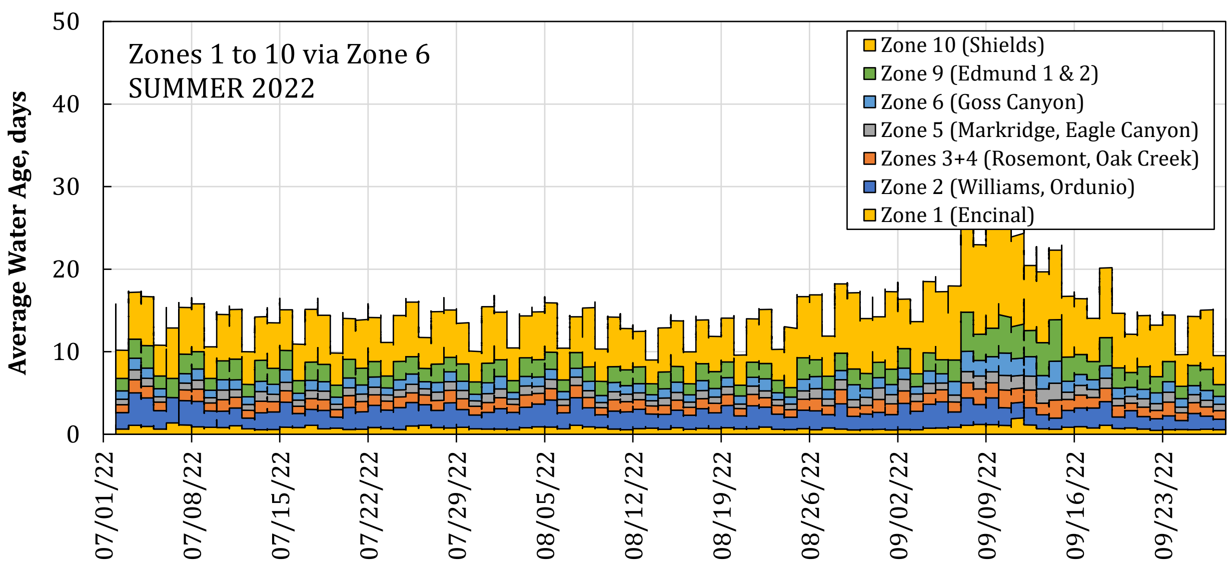


Figure 11 – Estimated Average Water Age in Summer 2022 as the Water Travels from Sources to Zone 10 via Zone 6

3.2 Chlorine Decay

A longer water age results in further decay of the chlorine residual. An analysis was also conducted on the chlorine residual data collected by the District to further characterize the impact of system operation and water age on the loss of chlorine residual as the water moves up through the various hydraulic zones. Figure 12 presents the chlorine residual profiles in Zones 5, 8, and 10 during 2022. The profiles show that the District maintains a sufficient chlorine residual through the system, but as expected, the terminal zones can experience significant chlorine residual loss, especially in the summer months when the water temperature increases. This is clearly demonstrated in Zone 10 when the chlorine residual was less than 0.5 mg/L for most of the summer of 2022.

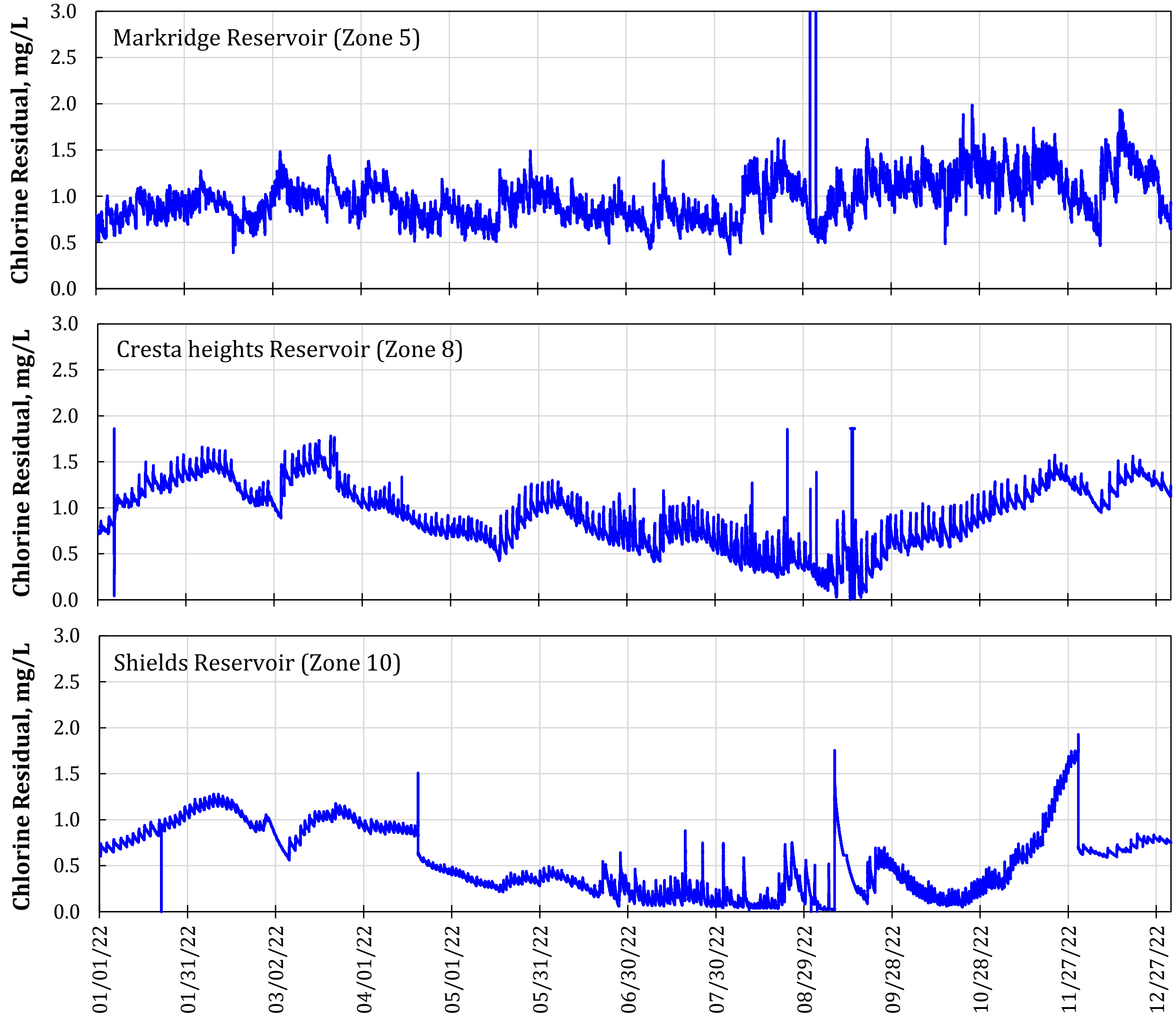


Figure 12 – Chlorine Residual Profiles in Zones 5, 8, and 10 throughout 2022

The analysis of the chlorine residual data reinforce the conclusion of the water age analysis that the terminal zones, especially Zone 10 (Shields), are most susceptible to chlorine residual loss, which may result in increased biological growth, especially during the summer months.

3.3 Reservoir Cleaning

The District's 17 water storage reservoirs are scattered throughout all hydraulic zones. The inspection, rehabilitation, and/or cleaning record of the reservoirs is summarized in Table 2. District's records indicate that all reservoirs were inspected in the last three years with the exception of one of the Goss Canyon Reservoirs which was last inspected in 2015. The last column in Table 2 identifies the number of years since the last cleaning or rehabilitation work done on each reservoir. The data show that eight highlighted reservoirs have not been cleaned or rehabilitated for 15 to 25 years. This does not necessarily mean that the reservoirs require cleaning since all of them have been inspected in the last three years. Nonetheless, it is advisable that these reservoirs be scheduled for cleaning in order to reduce the potential for biofilm growth in the sediment or on the walls of the reservoirs.

Table 2 – Reservoir Inspection and Cleaning Conducted since 1998

Reservoir	Zone	Capacity, MG	Last Inspection	Last Cleaned or Rehabilitated	Years since Last Cleaning or Rehabilitation
Encinal	1	3.0	2020	NA	--
Oceanview (Williams)	2	3.6	2022	2022	1
Ordunio	2	2.75	2022	2022	1
Rosemont	3	0.5	2021	2021	2
Oak Creek #1	4	1.6	2020	2018	5
Oak Creek #2	4	1.6	2020	2019	4
Eagle Canyon	5	1.5	2020	2001	22
Markridge	5	0.5	2020	2020	3
Goss Canyon #1	6	0.46	2015	2023	0
Goss Canyon #2	6	0.44	2015	1999	24
Dunsmore	7	0.42	2022	2022	1
Cresta Heights #1	8	0.5	2021	1999	24
Cresta Heights #2	8	0.5	2021	1999	24
Edmund #1	9	0.5	2021	2008	15
Edmund #2	9	0.5	2020	1998	25
Shields	10	0.6	2023	1998	25
Pickens	11	0.5	2023	2001	2

4.0 POTENTIAL FOR RED WATER OCCURRENCE & METALS RELEASE

As discussed earlier, red water discoloration may occur if a high concentration of iron is mobilized from the corrosion scales on unlined iron pipes into the bulk water. The extent of iron mobilization will depend on how much the protective iron-oxide layer over the corrosion scale will weaken and release the underlying iron into the water. The strength of the oxide layer is primarily determined by two factors: The strength of the water's oxidation potential, which results in a strong(er) protective layer, and the chemical precipitation potential of the water, primarily that of calcium carbonate, $CaCO_3$, which helps cement the oxide layer and strengthen it. Since the source water entering the system is not changing with this action, the precipitation of $CaCO_3$ will not change. However, the change from free chlorine to chloramine will lower the oxidation potential of the water, and thus has the potential to weaken the protective oxide layer. Unfortunately, it is impossible to determine if the reduction in the oxidation strength of the water will sufficiently weaken the oxide later and release enough iron to result in discolored water.

Two types of analyses are conducted in this section. The first is an analysis of the distribution system water quality data to assess its potential to precipitate $CaCO_3$. The second is an analysis of the prevalence of unlined iron pipes in the distribution system and galvanized steel service lines between the mains and customer meters and properties.

4.1 Water Quality

CVWD collects quarterly water quality samples from the 11 hydraulic zones in the system and analyzes them for a range of constituents. The data collected over the five-year period of 2017 to 2021 were consolidated and analyzed. The data were then used to calculate the Langelier Saturation Index (LSI) and the calcium carbonate precipitation potential (CCPP). The water quality data and the calculated LSI and CCPP values are summarized in Table 3. For each parameter, the 5-year average value is listed as well as the 10^{th} and 90^{th} percentiles of the 220 values measured in the 11 zones.

Table 3 – Summary of Distribution System Water Quality Measured Quarterly (2017 – 2021)

Parameter	Unit	Average	10^{th} Percentile	90^{th} Percentile
Field pH	--	7.7	7.4	8.0
Alkalinity	mg/L as $CaCO_3$	121	91	140
Calcium	mg/L	60	43	73
Field Temperature	°C	21	15.6	27
Conductivity	µS/cm	754	491	927
LSI	--	0.07	−0.16	+0.31
CCPP	mg/L $CaCO_3$	1.1	–5.28	+6.35

The data show that the water is well buffered with an average alkalinity of 121 mg/L as $CaCO_3$, and contains a significant concentration of calcium with an average of 60 mg/L. The field pH measured averaged only 7.7 with a 90^{th} percentile not exceeding 8.0. This is a slightly lower pH than desired because it results in LSI and CCPP values that are close to zero which suggest that the water neither precipitates nor dissolves $CaCO_3$. Figure 13 shows a plot of the quarterly average and range of LSI (left) and CCPP (right) across the 11 zones. While the values fluctuated between positive and negative, it was mostly slightly positive which is desirable.

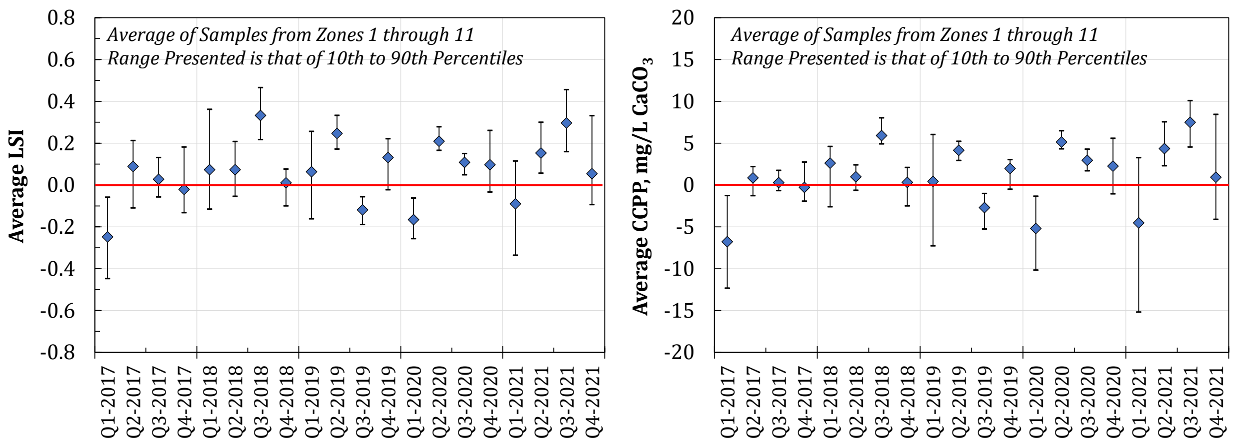


Figure 13 – Average and Range of Quarterly LSI (left) and CCPP (right) Values Measured

In summary, the water quality analysis suggests that the District's water has only a slight tendency to precipitate $CaCO_3$ as it travels through the distribution system, and thus it is likely to have a minor contribution to the strength of the iron corrosion protective layer when present.

4.2 Pipe Material

Like many other distribution systems, CVWD's distribution system contains pipes of different sizes and materials. Pipe material may include plastic, asbestos cement, cement-coated steel, and uncoated steel. From the mains, service laterals (SLs) deliver water to each customer meter, and then another SL delivers water from the meter to the property. These SLs can also be made from various materials including plastic, copper, galvanized steel, and lead. Finally, internal plumbing and fixtures in a customer's home can be made from plastic, copper, galvanized steel, and brass (which contains lead and copper).

As discussed earlier, all metal pipes corrode when exposed to water, and form a corrosion scale above the bare metal surface that protects the metal from further corrosion. With the conversion from free chlorine to chloramine, there is the potential for the protective scale to weaken and allow the release of a significant mass of metal into the water. The three types of metals exposed to the water are iron (distribution system mains and galvanized plumbing), copper (copper plumbing and brass fixtures), and lead (lead SLs, lead-containing solder, and brass).

4.2.1 Iron Pipes

Figure 14 shows a map of the distribution system pipes with the red lines being unlined iron pipes. The map shows that unlined pipes are present throughout all the system zones from the plants to the upper reservoirs. It is WQTS' understanding that the District is implementing a program to replace the unlined iron pipes in the system with cement-lined pipes, but this will take several years to complete.

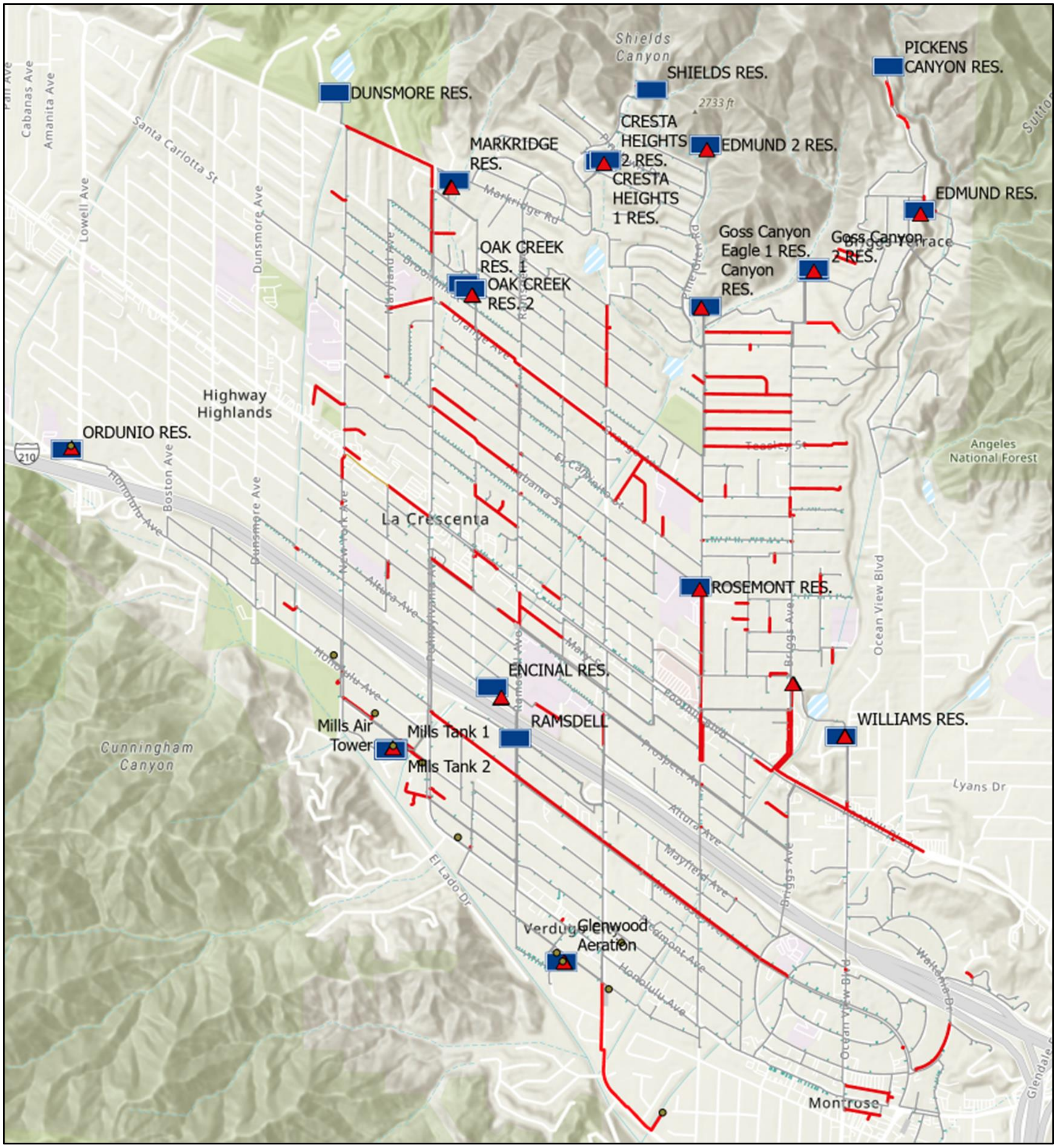


Figure 14 – Unlined Iron Pipes (Red) in the District's Distribution System

Figure 15 includes two photographs of the degree of tuberculation inside a 4-inch unlined iron pipe removed from the distribution system at the corner of Cecilville Avenue and Orange Avenue. In the photograph to the left, the upper protective layer and the underlying soft iron layer (reddish) are marked as 1 and 2, respectively, for illustration purposes. If this degree of tuberculation is in all the distribution system unlined iron pipes, it increases the risk of red-water occurrence.

Figure 15 – Internal Corrosion of an Unlined Iron Pipe Removed from the Corner of Cecilville Avenue and Orange Avenue

WQTS also analyzed the SL inventory provided by the District. Table 4 presents a listing of the number of addresses with galvanized iron SLs on the customer side of the meter, District side of the meter, or both. At this time, the District has 1,820 addresses with at least one galvanized iron SL. The inside condition of these SLs is unknown. However, they are likely to be as tuberculated as the unlined iron mains in the system. This would also make them possible contributors to a red-water challenge in customers' tap water.

Table 4 – Number of Steel Service Lines (SLs) in Each Hydraulic Zone

Zone	No. of Addresses with Only Customer Steel SL	No. of Addresses with Only CVWD Steel SL	No. of Addresses with Both Steel SLs	No of Addresses with at least one Steel SL
1	116	38	20	174
2	114	57	18	189
3	72	26	24	122
4	69	259	66	394
5	50	126	25	201
6	79	224	50	353
7	12	24	2	38
8	34	48	15	97
9	44	84	19	147
10	21	2	1	24
11	16	48	17	81
Total	627	936	257	1,820

4.2.2 Lead and Copper

Lead and copper levels in tap water are monitored per the requirements of the Lead and Copper Rule (LCR). They are used as indicators of lead and copper release from service laterals and in-home plumbing material. Figures 16 and 17 present the LCR monitoring results for lead and copper, respectively, from 2011 through 2023. Since 2014, the District has been on a tri-annual LCR monitoring schedule. When monitoring is conducted, the District solicits the participation of at least 30 homeowners. Each homeowner collects a first-flush water sample from a drinking tap in the home (typically, a kitchen faucet), and provides it to the District for analysis for both lead and copper. The results for each are then ranked, and the 90th percentile is compared to the regulatory action levels of 15 µg/L for lead and 1.3 mg/L for copper.

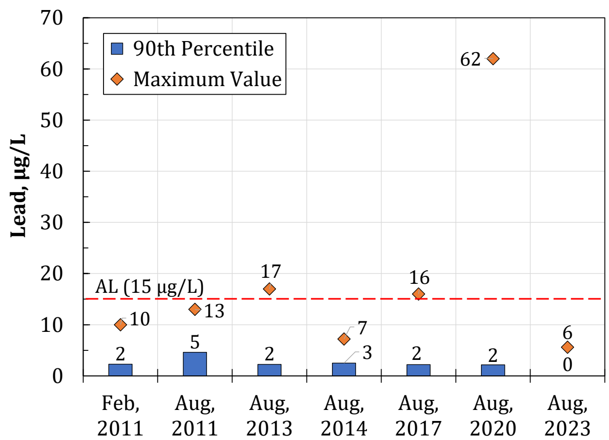


Figure 16 – Lead Levels Measured under the LCR Monitoring Program (2011 through 2023)

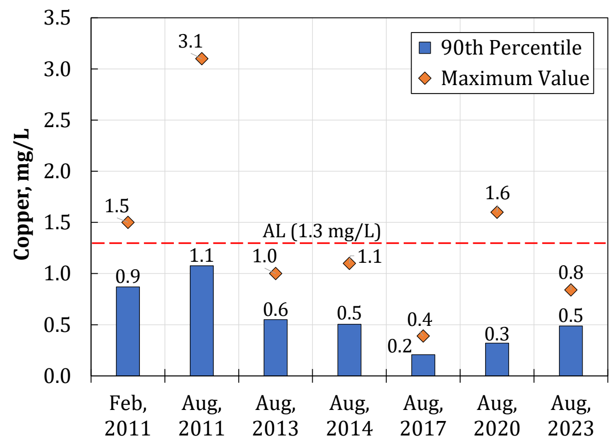


Figure 17 – Copper Levels Measured under the LCR Monitoring Program (2011 through 2023)

The results presented in Figures 16 and 17 show that the 90th percentile lead and copper levels in each of the seven monitoring events since 2011 have been below their respective action levels. Once the system is converted to chloramine, DDW will require the District to conduct LCR monitoring for two consecutive 6-month periods and will require the monitoring to be conducted at a minimum of 60 homes. The monitoring results will then be compared to those presented in Figures 16 and 17 to determine if the conversion from free chlorine to chloramine in the distribution system resulted in a significant rise in the lead and copper levels in the District's tap water.

5.0 Summary & Recommendations

The District's plans to convert the distribution system from free chlorine to chloramine were set in motion a few years ago, but the conversion has not yet taken place. The analysis conducted herein focused on two primary areas of concern: The first was the potential loss of chloramine residual and onset of biological nitrification, while the second was the potential increase in metals release from the distribution system piping and in-home plumbing material as the disinfectant is changed from free chlorine to chloramine.

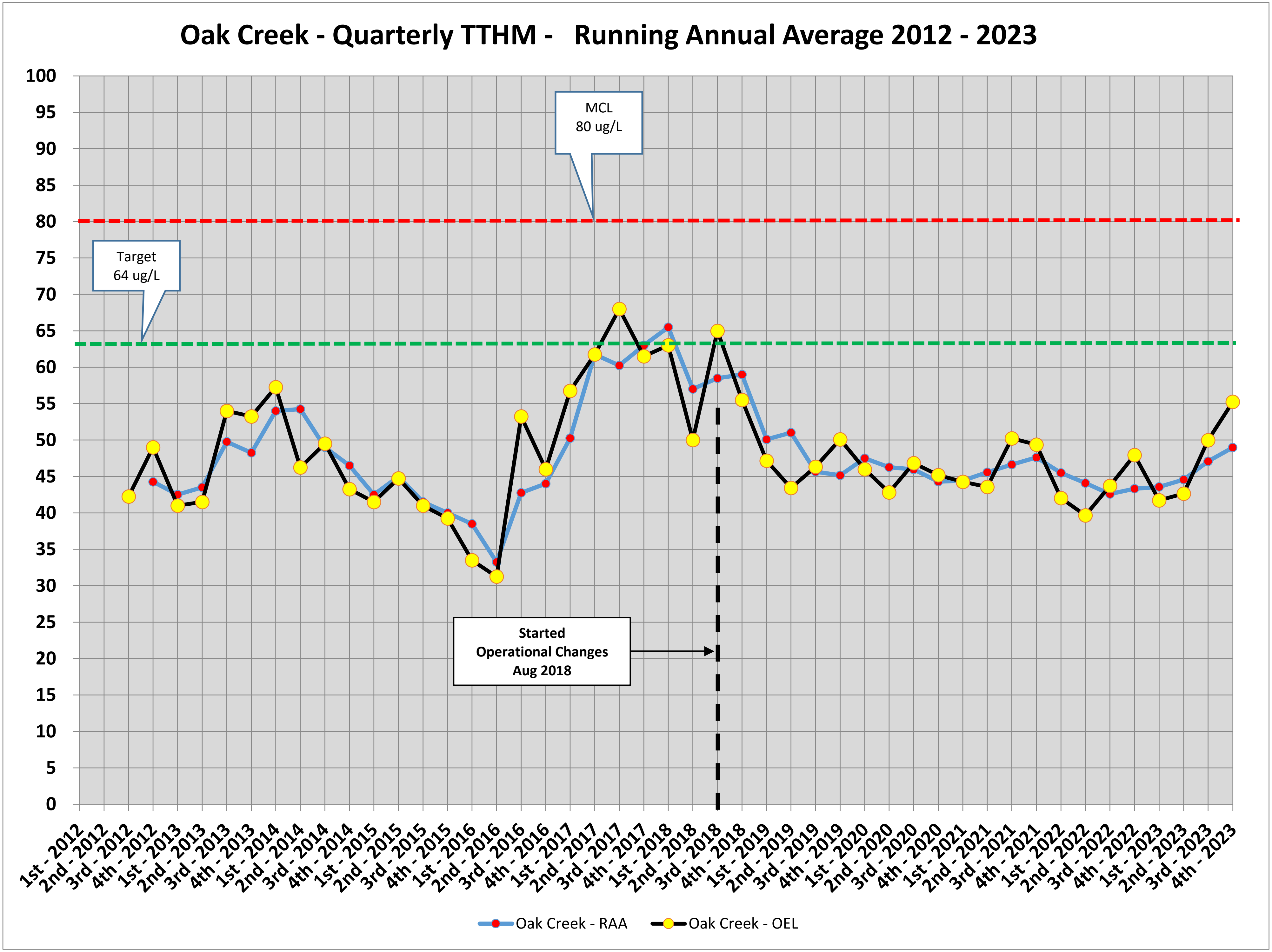
All systems that utilize chloramine in the distribution system experience episodes of nitrification, which are prompted by the loss of chloramine residual to levels that allow the proliferation of nitrifying bacteria in the system, especially in storage reservoirs. These occurrences are commonly mitigated by implementing measures to maintain a reasonably high chloramine residual in the water throughout the system to minimize bacterial growth. This includes reservoir cleaning and managing the storage volume to minimize water age. Depending on the District's experience during the first two or three years, it may be determined that one or two chloramine boosting systems are required to maintain the necessary chloramine residual in the District's distribution system reservoirs.

The analysis conducted showed that there is a significant number of unlined iron pipes in the distribution system, and that about 1,800 customers have galvanized iron service laterals. Aside from the change in disinfectant, there will be no change in the chemistry of the water to which the pipes are exposed. Hence, it is unlikely that the District will experience any metals release challenges in the system. However, the possibility does exist that a change in the disinfectant from a strong oxidant (free chlorine) to a weaker oxidant (chloramine) may allow for the release of sufficient iron from the unlined iron pipes in the system, and from galvanized service lines, that would appear as discolored water at residential taps. Aside from the objectionable look of it, discolored water caused by elevated iron concentrations can cause staining of laundry and home appliances.

Based on the analysis presented herein, the District may consider one of two alternative paths: The first is to proceed with the conversion to chloramine with the recognition that a slight risk of temporary red-water occurrence may take place in the system, but the risk is too low to warrant additional investigations. Alternatively, the District may decide that the risk, while low, is of sufficient concern that additional investigations into the potential for red-water occurrence should be conducted before chloramine conversion takes place.

If the District chooses the first alternative, WQTS will continue to work with operations staff to finalize system preparedness and begin the conversion to chloramine. If the District chooses the second alternative, then the implementation of chloramine conversion will need to be delayed for about a year during which pilot-scale testing of the impact of chloramine conversion on metals release from District pipes. This will require harvesting several galvanized pipes from the system (possibly service laterals or in-home plumbing) and setting up a pipe testing unit with some pipes receiving chlorinated District water and other pipes receiving chloraminated District water. This testing program can also address the question of whether chloramine conversion will have an effect on lead and copper levels in tap water. This is a significant and lengthy testing program that may cost the District between $500,000 and $800,000.

ID No.	Pressure Zone Month & Year	Influent Paschall	1 Encinal	2 Ocean View	2 Ordunio	3 Rosemont	4 4715 Ramsdell	4 Oak Creek #1	4 Oak Creek #2	Oak Creek	5 Markridge	5 Eagle Canyon	6 Goss Canyon #1	6 Goss Canyon #2	3250 Brookhill	7 Dunsmore	8 Cresta Heights #1	8 Cresta Heights #2	5603 Pineglen	9 ED2	9 ED1	2752 Pinelawn	10 Shields	11 Pickens
	Source Out	Rosemont - Zone 3 & Oak Creek - Zone 4	Ocean View, Ordunio	Paschall, Rosemont - Zone 3 & Oak Creek - Zone 4	Paschall, Rosemont - Zone 3 & Oak Creek - Zone 4	Eagle Canyon - Zone 5		Markridge & Eagle Canyon - Zone 5	Markridge & Eagle Canyon - Zone 5		Goss Canyon - Zone 6 Dunsmore - Zone 7 Cresta Hts - Zone 8	Goss Canyon - Zone 6	ED #1 & #2 - Zone 9	ED #1 & #2 - Zone 9		Terminal Reservoir	ED #1 & #2 - Zone 9	ED #1 & #2 - Zone 9		Shields - Zone 10	Pickens - Zone 11		Terminal Reservoir	Terminal Reservoir
324	3/6/2023	**24.7**	15.2	17.9	29.8	32.6	19.8	31.5	30.9	31.5	28.2	38.7	out of service	38.6	38.5	43.0	45.2	47.7	50.1	37.4	43.3	36.0	33.2	18.5
325	3/13/2023	**27.1**							37.0	37.0			out of service	45.9	41.2		52.2		**54.9**		46.6			
326	3/20/2023	**20.7**							28.3	28.3			out of service	48.3	55.4		53.8		**58.2**		50.0			
327	3/27/2023	**16.7**							32.6	32.6			out of service	39.9	44.5		49.6		**52.2**		43.1			
328	4/4/2023	**17.2**	17.9	18.6	29.8	37.3	29.7	35.2	32.7	32.7	34.5	39.1	out of service	42.3	55.7	45.9	48.0	52.4	56.3	41.3	44.0	38.1	38.6	19.3
329	4/10/2023	**18.7**							44.1	44.1			out of service	49.5	49.9		54.6		**60.4**		49.5			
330	4/17/2023	**18.5**							54.1	54.1			out of service	64.1	66.5		70.3		**66.7**		66.8			
331	4/24/2023	**17.3**							52.6	52.6			out of service	59.1	63.9		65.3		**70.1**		59.5			
332	5/5/2023	19.1	20.8	33.4	39.6	42.1	28.3	52.7	46.9	46.9	50.9	58.2	out of service	55.7	53.4	63.5	75.8	66.4	76.3	56.6	70.4	54.8	51.3	32.0
333	5/8/2023	**14.5**							47.8	47.8			out of service	65.5	58.8		65.4		**69.6**		60.0			
334	5/15/2023	**18.6**							48.4	48.4			out of service	38.3	57.0		56.9		**80.6**		62.9			
335	5/23/2023	**18.2**							48.6	48.6			out of service	55.7	48.0		65.2		**65.8**		53.0			
336	5/30/2023	**16.9**							41.5	41.5			out of service	59.4	44.5		63.4		**75.6**		55.5			
337	6/6/2023	**18.6**	20.2	26.5	33.1	38.5	25.0	43.9	42.1	43.9	39.2	52.1	out of service	51.3	43.3	42.7	58.8	59.2	64.8	50.8	56.3	45.5	43.8	278.3
338	6/12/2023	**17.0**							44.5	44.5			out of service	49.9	46.2		61.4		**59.2**		57.3			
339	6/19/2023	**22.0**							48.1	48.1			out of service	59.3	47.4		65.3		**79.1**		59.3			
340	6/26/2023	**24.0**							48.2	48.2			out of service	55.7	52.1		69.0		**75.4**		67.0			
341	7/5/2023	**23.7**	40.5	41.7	54.3	47.4	36.1	59.2	26.6	59.2	50.8	68.0	out of service	58.2	62.0	60.4	74.2	74.7	79.5	64.7	68.8	66.5	61.2	48.9
342	7/10/2023	**26.9**							53.0	53.0			out of service	59.2	57.5		71.6		75.7		71.1			
343	7/19/2023	**24.5**							55.3	55.3			57.4		56.6		62.0		51.6		61.4			
344	7/24/2023	**25.9**							59.3	59.3			59.1		65.4		71.4		85.3		76.4			
345	7/31/2023	**23.7**							59.0	59.0			54.3		57.2		67.5		74.5		69.0			
346	8/8/2023	**18.6**	43.9	42.0	57.4	51.5	25.5	55.9	50.1	55.9	56.4	66.5	62.0	59.0	61.7	59.7	68.6	69.6	62.4	64.7	73.8	54.6	54.1	59.4
347	8/14/2023	**22.6**							71.7	71.7			82.3		61.7		81.7		75.5		84.3			
348	8/21/2023	**31.8**							55.5	55.5			75.9		65.7		70.8		75.9		70.6			
349	8/28/2023	**27.8**							57.4	57.4			68.5		62.9		80.1		71.5		84.1			
350	9/6/2023	**21.5**	40.6	60.0	68.4	61.6	24.5		61.4	61.4	60.3	75.4	72.5	76.2	66.9		84.0	83.8	93.5	72.2	89.3	59.0		64.0
351	9/11/2023	**20.6**						69.9	45.0	69.9			82.4		64.1	51.9	82.5		64.6		83.6		67.0	
352	9/18/20023	**24.9**							67.9	67.9			87.1		65.3		84.9		91.2		83.2			
353	9/25/2023	**23.1**							59.9	59.9			73.7		45.5		65.4		67.8		64.3			
354	10/3/2023	**22.4**	32.5	33.9	59.7	47.7	32.4	57.7	57.7	57.7	56.6	73.6	75.4	79.1	53.2	53.9	73.2	68.7	81.5	57.0	63.1	52.2	48.8	38.7
355	10/9/2023	**17.8**							56.1	56.1			65.8		44.7		58.0		61.7		63.3			
356	10/16/2023	**17.9**							51.5	51.5			66.2		55.1		62.4		70.9		67.0			
357	10/24/2023	**19.9**							64.0	64.0			75.3		59.0		71.1		67.7		79.1			



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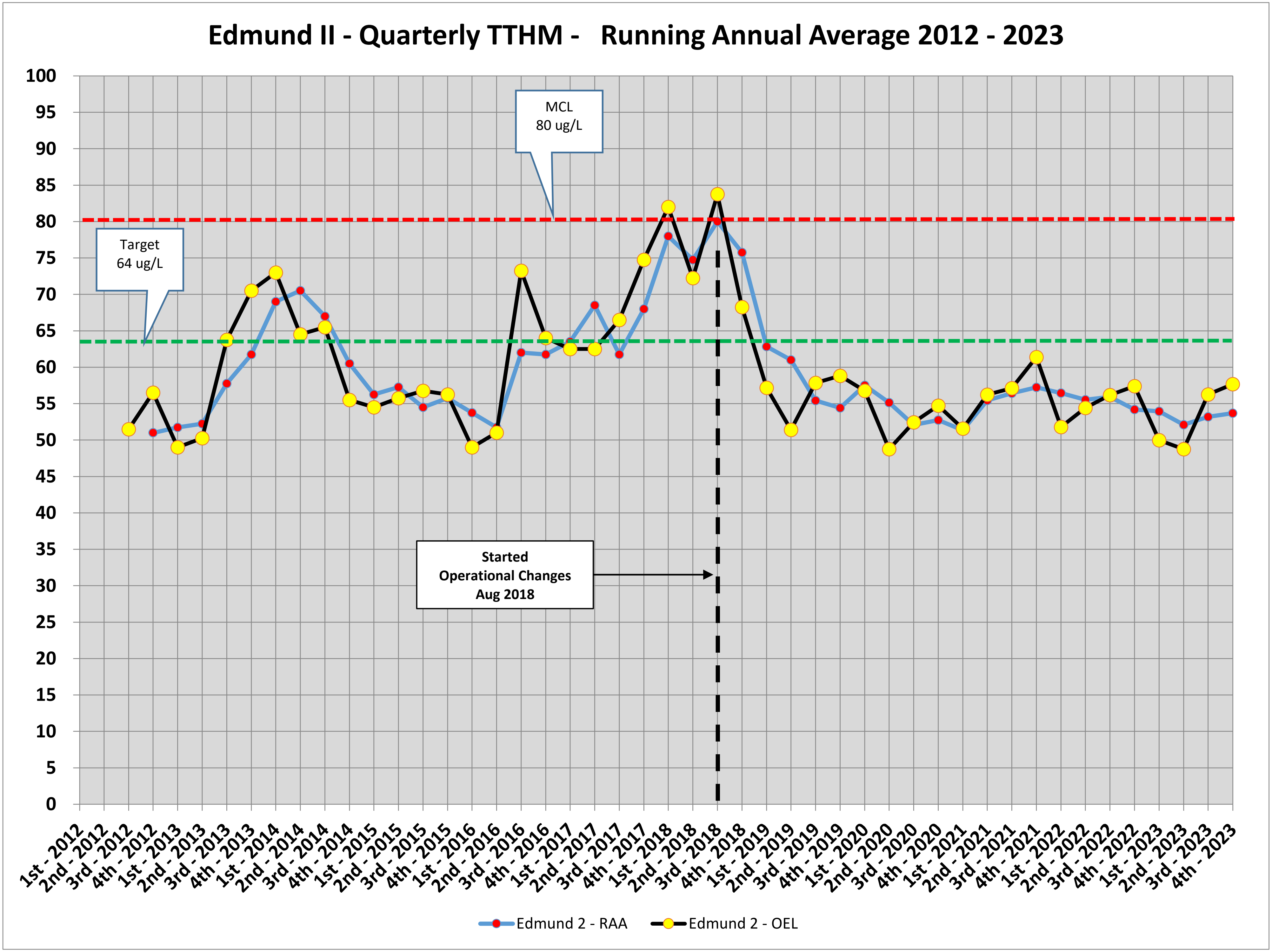

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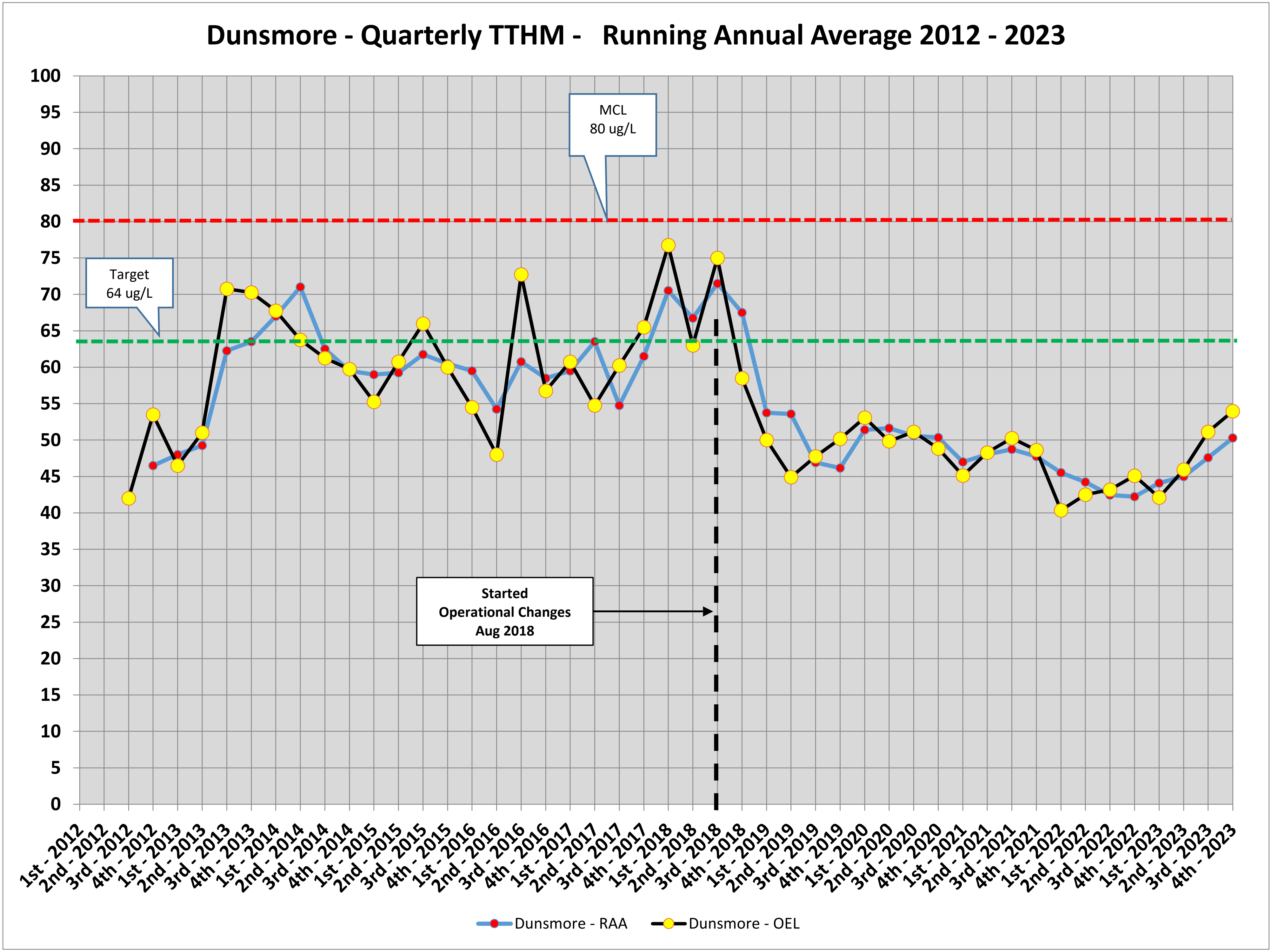

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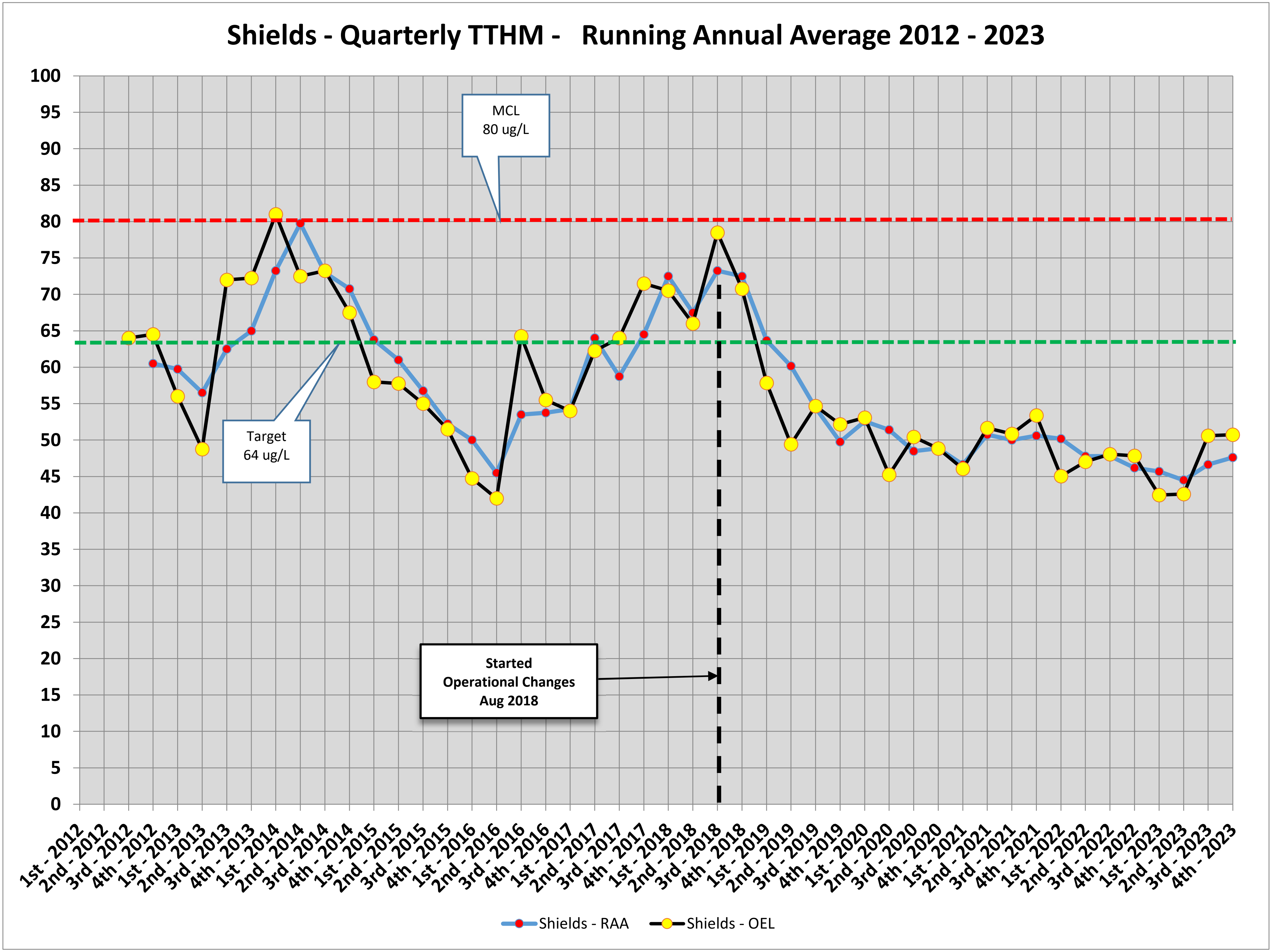

Date: 11/6/2023

NITRIFICATION PREVENTION, MONITORING, & CONTROL PLAN

PREPARED FOR:

CRESCENTA VALLEY WATER DISTRICT
2700 FOOTHILL BLVD.
LA CRESCENTA, CALIFORNIA 91214

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LOS ANGELES, CALIFORNIA

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FEBRUARY 25, 2019

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SECTION 1.0 – INTRODUCTION

The Crescenta Valley Water District (CVWD) provides drinking water services to a population of approximately 32,000 in the unincorporated communities of La Crescenta, Montrose, and Verdugo City, California, as well as a small portion of the City of La Canãda-Flintridge. CVWD's service area lies along the corridor between the Verdugo mountains to the southwest and the Angeles National Forest to the northeast. Neighboring water agencies include the City of Glendale to the southwest and the Foothill Municipal Water District (FMWD), a wholesale agency providing water to several retail water agencies in La Canãda-Flintridge and Altadena.

The District serves a blend of local groundwater and imported treated surface water from the Metropolitan Water District of Southern California (MWDSC) via FMWD. While the imported surface water contains chloramine, the District has always converted the chloramine in the imported water to free chlorine and maintained free chlorine in the distribution system. This is achieved by adding a sufficiently high chlorine dose to the groundwater being blended with the treated MWDSC water such that full breakpoint chlorination of the chloramine present in the MWDSC water is achieved resulting in a blended water containing only free chlorine. However, driven by a steady rise in the levels of disinfection by-products (DBPs) in its drinking water, the District made the decision to convert the distribution system from free chlorine to chloramine. To implement this decision, the District will add chlorine and ammonia to the groundwater to form chloramine before it blends it with the chloraminated MWDSC water.

With the conversion from free chlorine to chloramine, the District is likely to experience biological nitrification in its storage tanks and in the system. The concern over nitrification in storage tanks is that it is accompanied by loss of chloramine residual, which in turn increases the likelihood for additional biological growth in the system. If left unchecked, this can result in the proliferation of total coliform bacterial, and even *E. Coli*. For this reason, it is important that biological nitrification be monitored and controlled.

This document is a comprehensive guide for District staff to understand, monitor, prevent, and control biological nitrification in the District's distribution system in general, and storage tanks in particular.

SECTION 2.0 – SYSTEM DESCRIPTION

Figure 1 shows a map of the CVWD service area. Shown on Figure 1 are also the locations of the water storage reservoirs in the service area and their names.

CVWD receives water from two primary sources:

- Imported treated water from MWDSC received through via FMWD
- Local Groundwater

The imported water is treated at MWDSC's Weymouth filtration plant, which receives a blend of Colorado River Water (CRW) and State Water Project (SWP) water. MWDSC applies chloramine to its treated water before it is transmitted to its member agencies, including FMWD. Therefore, the treated MWDSC water received by CVWD also contains chloramine as the disinfectant.

The local groundwater is extracted through wells located in the Verdugo Basin. Because most of the local groundwater contains elevated nitrate levels, treatment is implemented to most wells. Some wells are treated at the Glenwood Ion-Exchange (IX) treatment plant, while the others are treated through blending with MWDSC's water before the blend is served to the District's customers.

Due to the local topography, the District's water system is divided into 11 hydraulic pressure zones, with each zone containing at least one storage tank. Figure 2 shows a schematic of the District's 11 zones. Figure 2 also shows the various tanks in each zone, how the two water supplies are blended in the system, and how the water is moved from one zone to another. The wells treated at the Glenwood WTP and the Mills Plant are not shown for clarity.

Figure 2 clearly shows how the water moves through the District's system, which also provides insight into the potential hot-spots for nitrification. The District's water sources enter the system in zones 1, 2, and 4. Groundwater enters in Zones 1 and 4, while the imported surface water enter in Zone 2. Water then is pumped progressively to the higher elevation zones 4 through 11. This means that a drop of water consumed in Zone 10 or 11 will have had to travel through all the other zones and their storage tanks before making it to either zone, which will result in the lowest chlorine residual dominating the storage tanks in the upper zones. This also suggests that nitrification is most likely to occur in these upper zones well before it occurs in the storage tanks in zones 1 through 3.

Finally, Table 1 lists the specifics of the District's distribution system tanks including each tank's total capacity, volume per ft of depth, and the pressure zone in which it is located.

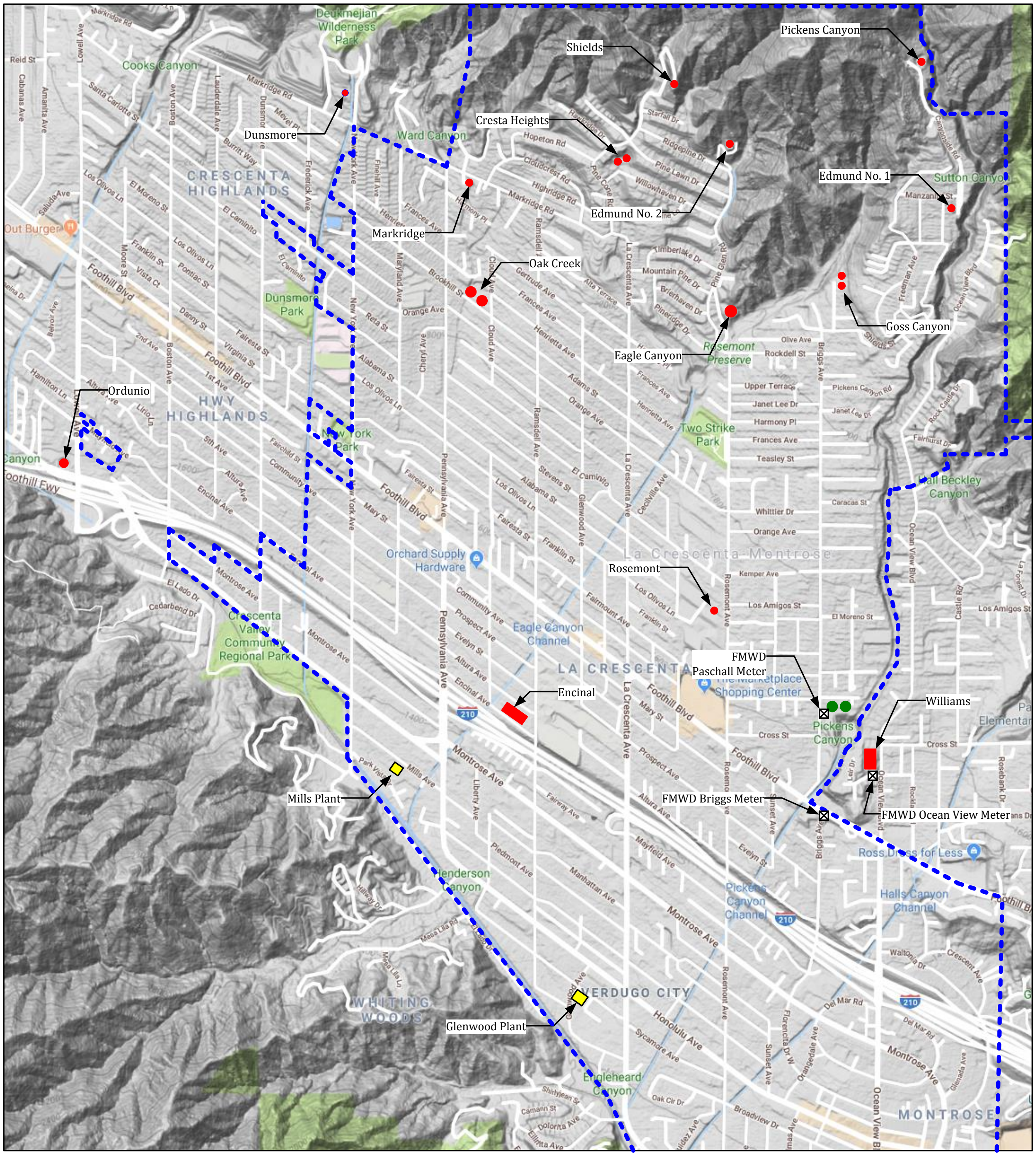

Figure 1 – Boundaries of the Crescenta Valley Water District and the Locations of its Storage Tanks/Reservoirs, FMWD Connections, and Treatment Plants

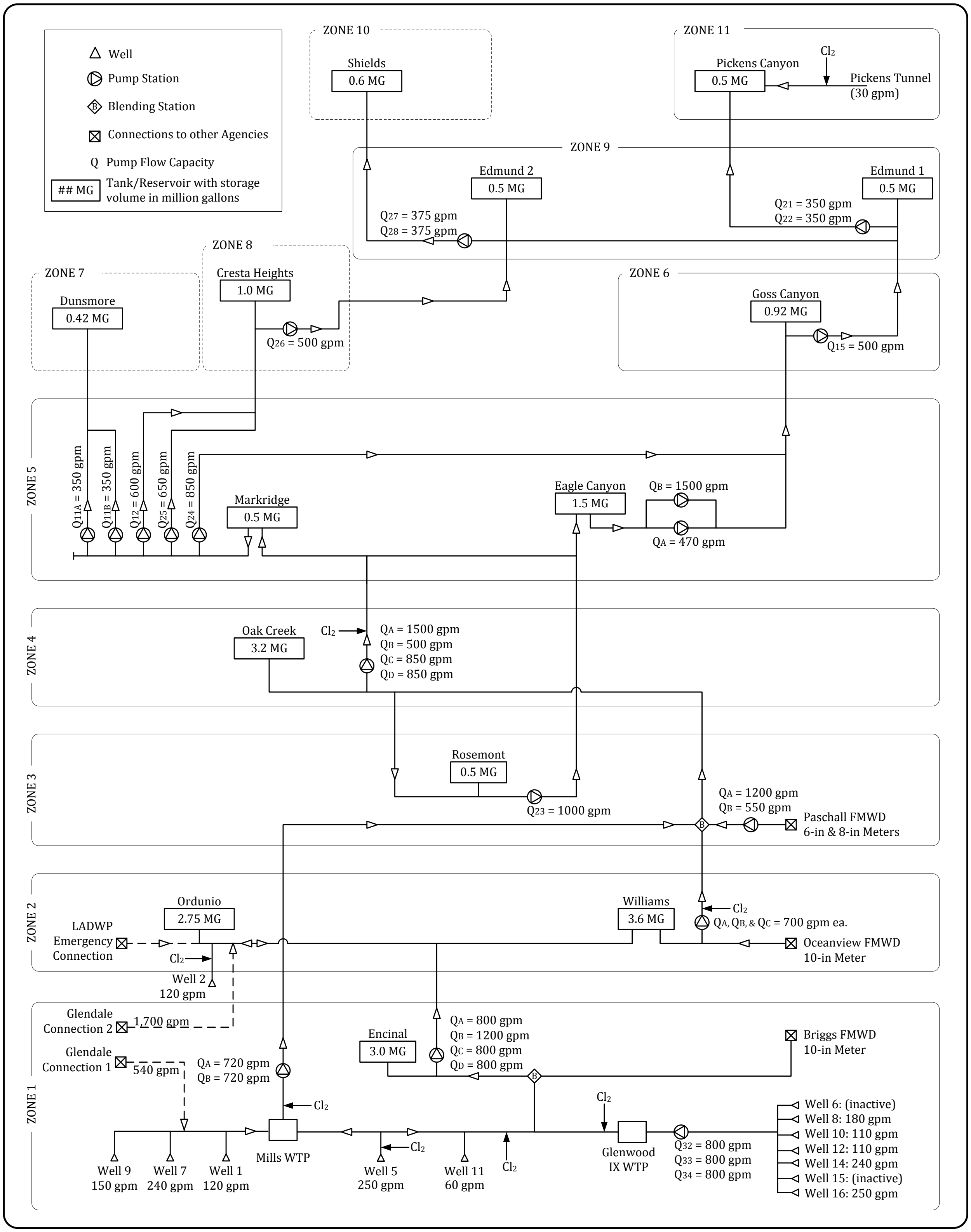

Figure 2 – Schematic of the District's Hydraulic Zones and Water System Components

Table 1 – CVWD Storage Facilities

Tank	Volume (MG)	Unit Volume, gal/ft	Pressure Zone
Encinal	3.0	131,589	1
Williams	3.6	139,128	2
Ordunio	2.75	88,880	2
Rosemont	0.5	24,821	3
Oak Creek 1	1.6	71,085	4
Oak Creek 2	1.6	71,085	4
Markridge	0.5	47,586	5
Eagle Canyon	1.5	24,821	5
Goss Canyon 1	0.42	17,131	6
Goss Canyon 2	0.5	21,149	6
Dunsmore	0.42	17,131	7
Cresta Heights 1	0.5	21,860	8
Cresta Heights 2	0.5	21,860	8
Edmund 1	0.5	28,786	9
Edmund 2	0.5	21,860	9
Shields	0.6	19,763	10
Pickens Canyon	0.5	17,771	11

SECTION 3.0 – CHLORAMINE CHEMISTRY

This section discusses chloramine formation chemistry, and the decay of chloramine in the distribution system.

CHLORAMINE FORMATION

Chloramine is generated by combining free chlorine, $\mathbf{Cl_2}$, and ammonia, $\mathbf{NH_3}$. These two chemicals react rapidly with each other according to the following reaction to form monochloramine, $\mathbf{NH_2Cl}$:

$$Cl_2 + NH_3 \rightarrow NH_2Cl + H^+ + Cl^- \qquad (1)$$

Since the molecular weight of Cl_2 is 70 and the molecular weight of nitrogen, N, is 14, Reaction 1 basically says that every 70 mg of free chlorine reacts with 14 mg of ammonia-nitrogen, NH_3-N. Recognizing that the ratio of 70:14 is 5:1, Reaction 1 states that chlorine and ammonia-nitrogen react with each other at a 5:1 weight ratio (i.e., mg/mg). Under virtually all applications, chlorine is added to the water first, and ammonia is added at a downstream location. Regardless of the chlorine dose applied, the reaction to form chloramine is based on the chlorine residual concentration immediately at the ammonia addition point. In other words, the target ammonia dose should be based on a measured chlorine residual as close as possible to the ammonia injection point.

Since both free chlorine and chloramine are measured in mg/L as Cl_2, when chloramine is formed from free chlorine, the weight concentration of the generated chloramine is the same as that of the free chlorine consumed by the reaction when the concentration of both is expressed in mg/L as Cl_2. Therefore, if a target chloramine residual of 2.5 mg/L as Cl_2 is to be formed, Reaction 1 suggests that the free chlorine concentration in the water immediately upstream of the ammonia addition point should be 2.5 mg/L as Cl_2 and the ammonia feed system should add a dose of 0.5 mg/L NH_3-N as N. This translates into a chlorine:ammonia ratio of 5:1. While this appears to be the proper target, WQTS recommends that the ammonia dose be set at a slightly higher value to result in a chlorine:ammonia ratio of 4.5:1 at the point of ammonia addition. Therefore, if the free chlorine concentration in the water is 2.5 mg/L, then the ammonia dose set point should be 0.55 mg/L as N, which is calculated as such:

$$NH_3\text{-N Dose} = [Cl_2 \text{ Residual}] \div 4.5 = 2.5 \div 4.5 = 0.55 \text{ mg/L as N} \qquad (2)$$

The reason for the recommended ratio of 4.5:1 will be discussed later in this section. For a dose of 0.55 mg/L as N, 0.5 mg/L will react with the 2.5 mg/L chlorine to form 2.5 mg/L chloramine within a period of no more than 30 seconds (assuming excellent mixing of the ammonia solution into the water). This leaves 0.05 mg/L of free ammonia-nitrogen in the water, which will remain in the water as it enters the distribution system. If the ammonia dose were 0.6 mg/L, then the same amount of 0.5 mg/L will react with the free chlorine to form 2.5 mg/L chloramine, while the ammonia balance of 0.1 mg/L as N will remain in the water as free ammonia.

However, if the added ammonia dose in the above example was only 0.4 mg/L as N, then there is inadequate ammonia to react with the 2.5 mg/L chlorine. It is noted that the chlorine:ammonia ratio in this scenario is 6.25:1, which is calculated as 2.5÷0.4 = 6.25. In this scenario, what will happen is a two-step process as follows:

Step 1 (**Rapid**) – The available ammonia will react very rapidly (<30 seconds) with available free chlorine at a ratio of 5:1 to form chloramine. Since only 0.4 mg/L NH_3-N is added in the above example, then all the added ammonia will react with 2.0 mg/L of the free chlorine in the water (because 0.4×5 = 2.0) to form 2.0 mg/L chloramine. This leaves 0.5 mg/L of <u>free chlorine</u> in the water.

Step 2 (**Slow**) – Since free chlorine and chloramine are incompatible chemicals, they will react with each other at a relatively slow rate (about 15 to 20 minutes) until one of the two chemicals is completely destroyed. This is the chemical reaction commonly referred to as the "breakpoint reaction". Under typical conditions, every 1 mg/L excess free chlorine remaining after Step 1 will react with somewhere between 1 and 2 mg/L of the chloramine formed in Step 1 reaction. For ease of calculation, it is reasonable to assume that every 1 mg/L excess chlorine reacts with 1.5 mg/L chloramine. Therefore, in the above example, the excess free chlorine of 0.5 mg/L remaining in the water will react with 0.75 mg/L (because 0.5×1.5 = 0.75) of the chloramine formed in Step 1. The remaining chloramine will be the only residual disinfectant remaining in the water, which is calculated as 2.0 – 0.75 = 1.25 mg/L as Cl_2.

In this example, while the water contained 2.5 mg/L chlorine before ammonia addition, the addition of 0.4 mg/L NH_3-N resulted in the loss of as much as 1.25 mg/L of the chlorine residual within 15 minutes of flow after ammonia addition. For this reason, the possibility of adding an insufficient amount of ammonia to the water should be avoided as much as possible. It is for this reason that attempting to target a chlorine:ammonia ratio of 5:1 should be avoided because a slight error in the ammonia feed system that results in an under-feed of the ammonia solution can result in a significant loss of chlorine residual due to the unplanned breakpoint reaction. Therefore, it is safer to target a slight over-dose of ammonia such that an unforeseen error has a lower chance of triggering the breakpoint reaction.

Figure 3 shows a general schematic of chlorine and ammonia addition to a flowing water pipe, as well as the general control strategy that can be used to maintain a stable chlorine residual in the treated water. As noted above, chlorine is added first into the water to develop a target free chlorine residual. An online free chlorine analyzer is installed downstream to confirm that the target free chlorine residual is in the water just before ammonia addition. Figure 3 shows a static mixer at the point of chlorine addition. However, it is common that a static mixer is not available and hydraulic flow through the pipe is relied upon to achieve chemical mixing. In this case, it is critical that a sufficient distance is provided between the chlorine addition point and the chlorine analyzer takeoff point to ensure adequate chemical mixing has occurred before the analyzer draws a sample for analysis. If the chemical is not fully mixed in the water by the time it reaches the analyzer, then the residual chlorine concentration is bound to fluctuate widely and cause erratic chemical feed controls. The reason is that the chlorine feed pump is controlled by a feed-back loop from the chlorine analyzer via a Programmable Logic Controller (PLC) as shown in Figure 3. The PLC is relied upon to modify the chlorine pump flow to achieve a pre-determined target chlorine residual at the analyzer.

Downstream of the analyzer, ammonia is then added to convert the free chlorine to chloramine. The ammonia feed pump flow is also controlled by the PLC to achieve the proper chlorine:ammonia ratio. Figure 3 also shows a static mixer at the point of ammonia addition, but that may not be in place in some cases. Sample taps 1 and 2 are indicated in Figure 3 to allow for the collection of grab samples to periodically check the free chlorine and total chlorine concentrations.

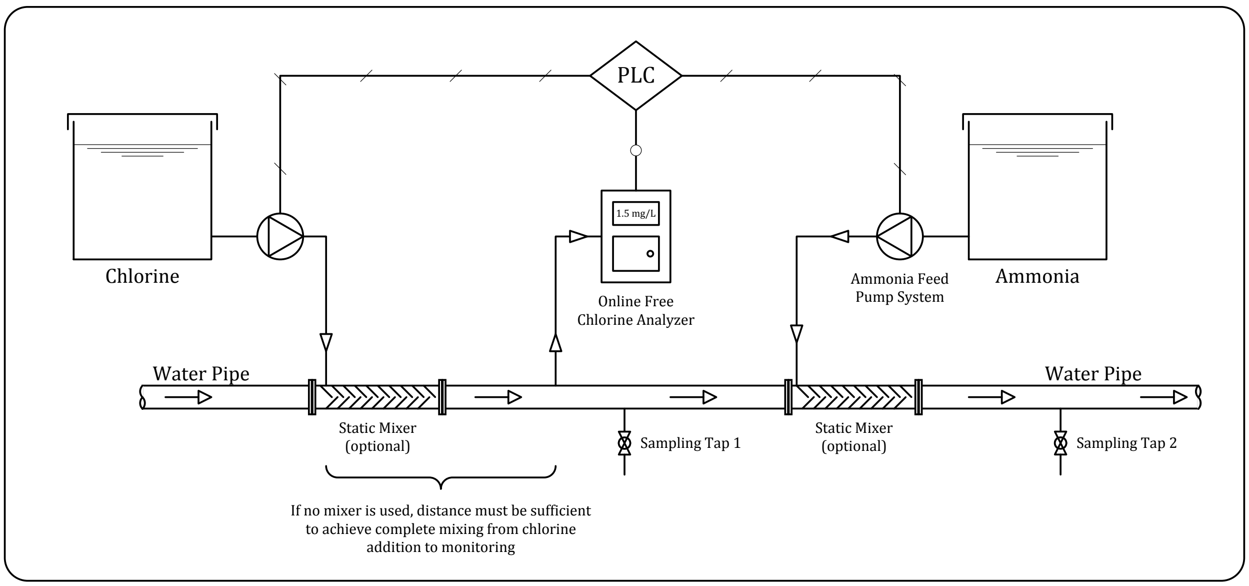

Figure 3 – General Schematic of Chlorine and Ammonia Addition to a Groundwater Source, and the Control Scenario that can be used to Maintain a Stable Total Chlorine Residual

CHLORAMINE DECAY

As water containing chloramine flows through the distribution system, the chloramine begins to decay similar to how free chlorine decays over time in water. This is caused by the reaction of chloramine with various constituents such as natural organic matter (NOM), biofilms present on the walls of pipes and tanks, iron corrosion scales in the system, and others. When chloramine decays, it releases the ammonia bound in the chloramine back into the water as free ammonia such as shown in Reaction 3 below for the reaction between chloramine and NOM as an illustration:

$$NH_2Cl + H^+ + NOM \rightarrow NH_3 + Cl^- \quad (3)$$

Since the chlorine and ammonia were bound at a 5:1 weight ratio, when the ammonia is released back into the water, the amount of ammonia released is thus 1/5th of the amount of chloramine decayed. For example, if the chloramine residual decreases by 1 mg/L as Cl_2, then the amount of ammonia-nitrogen released into the water is expected to be 0.2 mg/L as N (because 1 ÷ 5 = 0.2). It is this increase in free ammonia that may result in biological nitrification as discussed later in this document.

CHLORAMINE MONITORING

There are three chemical constituents that are of interest when monitoring chloramine chemistry in a distribution system. They include:

1. Total Chlorine
2. Total Ammonia
3. Free Chlorine
4. Free Ammonia

The total chlorine and total ammonia concentrations can be measured by EPA-approved colorimetric methods using handheld instruments such as those purchased from HACH or other suppliers. However, while colorimetric methods are also available to measure the concentrations of free chlorine and free ammonia in the distribution system samples, their measurements are not recommended in a chloraminated system because they can only lead to confusion. First, since the sample was collected at least 30 minutes downstream of the ammonia addition point, it is chemically impossible for free chlorine to be present in combination with chloramine. For this reason, the free chlorine concentration should be automatically assumed to be zero regardless of whether a measurement suggests its presence. Second, while there are methods for measuring free ammonia in a water containing chloramine, these methods are not reliable, especially at low levels. WQTS does not recommend that colorimetric methods be used to measure free ammonia in a chloraminated water. Instead, WQTS recommends using the measured concentrations of total chlorine, expressed in mg/L as Cl_2, and total ammonia, expressed in mg/L as N, to calculate the free ammonia concentration in the water (based on the fact that chlorine and ammonia always combine in a 5:1 ratio) using the flowchart shown in Figure 4.

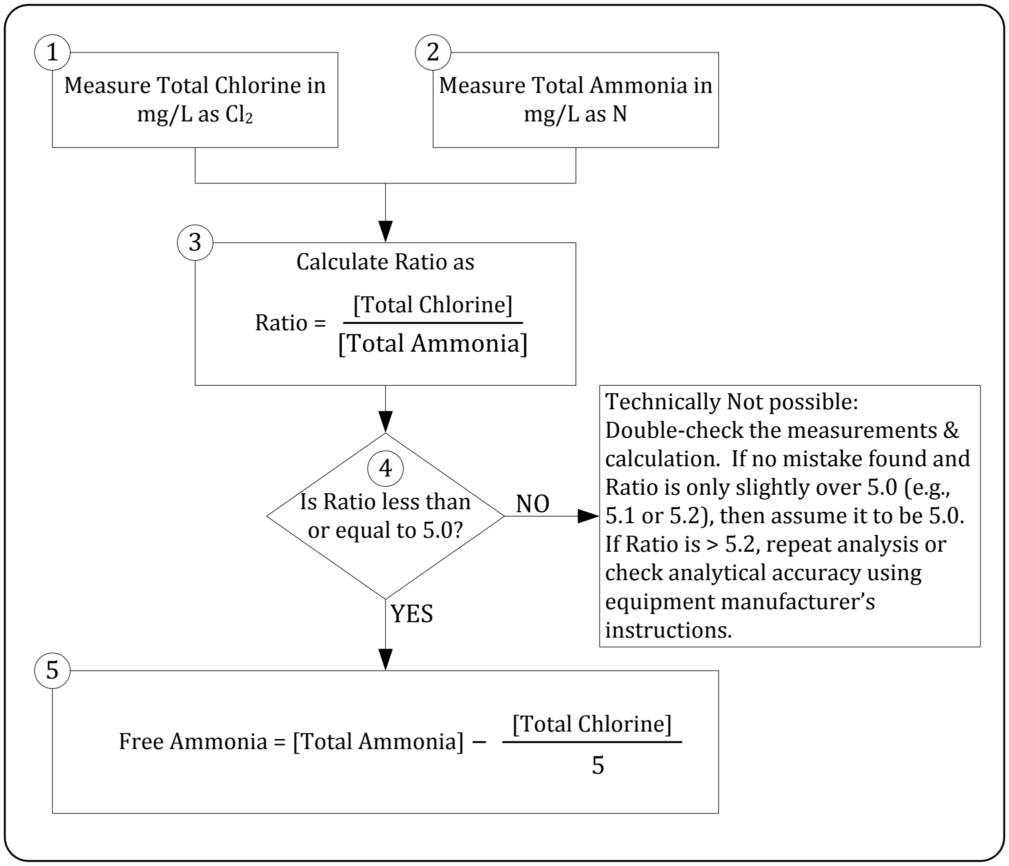

Figure 4 – Procedure to Calculate the Concentration of Free Ammonia in a Water Sample Collected from a Chloraminated Distribution System at a Location that is at least 30 minutes Downstream of any Chemical Addition Point (hydraulic flow time)

The following is an example of how to use the flowchart in Figure 4 to calculate the free ammonia concentration in a water distribution system sample collected from a location at least 30 minutes downstream of the nearest chlorine or ammonia addition point:

Step 1 – Measure the total chlorine residual. Assume it was measured at 2.4 mg/L as Cl_2

Step 2 – Measure the total ammonia concentration. Assume it was measured at 0.57 mg/L as N

Step 3 – Calculate the Ratio of the two values as: 2.4 ÷ 0.57 = 4.21

Step 4 – Ratio is confirmed to be less than or equal to 5.0

Step 5 – Free Ammonia is then calculated as: [0.57] – [2.4/5] = [0.57] – [0.48] = 0.09 mg/L as N

The check on whether the ratio is less than or equal to 5.0 in Step 4 is important because it represents a potential measurement or calculation error. The reason is that a water sample collected more than 30 minutes downstream of where the last location where either chlorine or ammonia was added should not have a ratio higher than 5.0. Having said that, if the ratio is very close to 5.0 (e.g., 5.1 or 5.2), then it could be attributed to normal analytical accuracy and can be assumed to be equal to 5.0. Note that at a ratio equal to 5.0, the free ammonia concentration will be zero.

SECTION 4.0 – NITRIFICATION OCCURRENCE

In a chloraminated system, nitrification refers to the consumption of ammonia-nitrogen by specific bacteria. Figure 5 shows a schematic representation of the two-step biological reactions that take place during a nitrification event. In the first step, Ammonia-Oxidizing Bacteria (AOBs) utilize dissolved oxygen to convert ammonia to nitrite, NO_2^-. A second type of bacteria, referred to as Nitrite-Oxidizing Bacteria (NOBs) then utilize more of the dissolved oxygen to convert the nitrite generated by the AOBs to nitrate, NO_3^-.

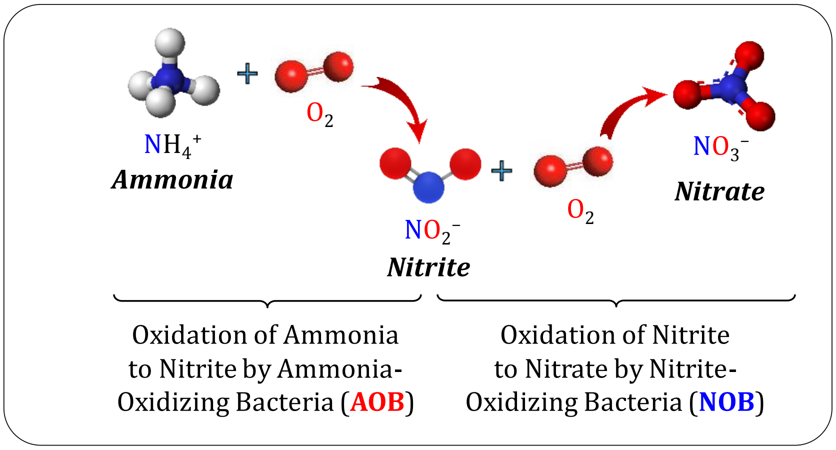

Figure 5 – Schematic Representation of Biological Nitrification Reactions

The prevalence of nitrification is driven by several contributing factors:

1. Excess free ammonia
2. Insufficient chloramine residual
3. Availability of bacterial hiding places
4. Long water stagnation time
5. Warm temperature
6. High organic carbon concentration

The following are brief discussions of the significance of each factor and how it affects nitrification.

Free ammonia serves as the primary "food" for AOBs, which kicks off the nitrification process. Therefore, it is always desirable that the concentration of free ammonia in the water be minimized as much as possible. Since the free ammonia concentration increases in the system as a result of loss of chloramine as discussed earlier, minimizing free ammonia concentration is achieved by minimizing the loss of chloramine residual as much as possible. Alternatively, if free ammonia is released after the loss of chloramine, chlorine can be added to re-combine the free ammonia to form chloramine, and thus boosting the chloramine residual and eliminating the availability of free ammonia as food for the AOBs.

Insufficient chloramine residual is a critical challenge in a chloraminated system because chloramine is relied upon to suppress the growth of nitrifying bacteria (i.e., both AOBs and NOBs). However, there is no avoiding the loss of chloramine residual as water travels through the distribution system and stagnates in storage tanks. Not only does this loss of residual reduce the concentration of the primary disinfectant, but also releases free ammonia into the water as noted above. For this reason, it is important that a sufficient chloramine residual be maintained in the water throughout the system.

Bacterial hiding places in a distribution system make it difficult to adequately disinfect the system even in the presence of a relatively high chloramine residual concentration. Specifically, bacteria can hide in corrosion scales and crevices on the inside surfaces of iron pipes, which protects them from the chloramine residual in the bulk water. Similarly, high concentration of bacterial cells can hide in sediment layers in pipes and storage tanks, which chloramine residual cannot easily penetrate. Therefore, even if the bulk water is confirmed to contain a high chloramine residual, if this residual cannot reach bacteria that are hiding in corrosion scales and sediment layers, then biological activity (i.e., nitrification) may not be adequately suppressed. This makes it important that the system be properly cleaned on a frequent basis in order to minimize the availability of bacterial hiding places.

Long water stagnation times in storage tanks is one of the most challenging aspects of operating a chloraminated distribution system. As water sits stagnant in a storage tank (or a dead end), more chloramine decay will take place resulting in a progressively lower chloramine residual, which releases more free ammonia in the water. Longer stagnation also provides more time for nitrifying bacteria to grow in the tank. Therefore, in the interest of minimizing the loss of chloramine residual, it is important not to allow the water to stagnate in a storage tank. Unfortunately, the time water sits in a storage reservoir is highly determined by the storage volume and the water demand in the zone served by that reservoir. Measures that can reduce stagnation times include allowing for wider fluctuations in the water volume in the tank by delaying the fill cycle until after the water volume decreases to lower levels than typical. For example, while the District may currently limit water level fluctuations in the tank to no more than two feet before the fill cycle is initiated, increasing this fluctuation allowance to four feet or more makes more room for system water to enter the tank and boost the chloramine residual level in the overall water. It is noted that this action will also reduce the frequency of filling the tank with fresh water since the District will have to wait longer to fill the tank. Finding the right operational scenario is highly dependent on the quality of the water and the operational conditions of each zone.

Warm Water Temperature results in accelerated chloramine loss and accelerated bacterial growth. Clearly, there is nothing that the District can do about the temperature of the water it receives into the system. However, it is important for District operations staff to recognize the fact that chloramine loss and incidences of nitrification will increase during summer months when the water temperature is higher than winter months. Fortunately, with higher demands in the summer months, the water will stagnate for shorter times in the reservoirs compared to winter months. Nonetheless, it is the experience of most systems that the detrimental effect of higher water temperature is greater than the beneficial effect of shorter stagnation times.

Higher Organic Carbon Concentrations in the water increases the concern over nitrification because the organic carbon serves as a necessary food for the nitrifying bacteria. In addition, higher organic carbon concentration results in a higher chloramine loss rate. Therefore, greater nitrification incidences will take place in a water containing higher organic carbon levels. For the District, the total organic carbon (TOC) concentration in the groundwater is significantly lower than that in the imported surface water. Even for the surface water, it can contain vastly different levels of TOC concentration depending on whether the Weymouth WTP is treating predominantly CRW water, which is low in organic content, or predominantly SWP water, which is high in organic content. Therefore, it is important that the District remain fully informed on a weekly basis of which water source is being treated by Metropolitan at the Weymouth WTP.

SECTION 5.0 – NITRIFICATION PREVENTION

The previous section presented and discussed the various factors that promote the occurrence of nitrification in a water distribution system. Therefore, nitrification prevention aims at controlling or eliminating these contributing factors to the extent possible. Specifically, there are three focus areas for the District to consider for nitrification prevention:

1. Reduce water age
2. Maintain a clean system
3. Boost chloramine residual

The following is a discussion of each measure.

REDUCE WATER AGE

Long water age in storage reservoirs is probably the largest contributor to the occurrence of nitrification in chloraminated distribution systems. There are two values of the water age to consider: the first is the “average” water age, which is simply the ratio between the storage volume, V, in a service zone, and the total water demand, D, in that zone:

$$\text{Average Water Age} = [\text{Volume}] / [\text{Demand}] = [V / D]$$

For example, the District’s data show that the demand on Zone 11 during the period of June 1 through August 15, 2018, was approximately 98,000 gallons per day. The storage volume in Zone 11 is that of Pickens Canyon Reservoir, which was, on average, 365,000 gallons during that period. Therefore, the average water age in Zone 11 during that period was 3.7 days, or approximately 90 hours.

$$\text{Average Water Age} = [365{,}000] / [98{,}000] = 3.7 \text{ days}$$

It is important to note that this value is in addition to the time the water took to travel from the sources to Zone 11, which is likely to be several additional days.

Therefore, to reduce the average water age in a zone, one can reduce the storage volume or increase water demand. Lowering the storage volume in a reservoir is feasible, but it goes against the desire to maximize storage volume for firefighting. Increasing apparent water demand can be induced by increased hydrant flushing during low demand periods. However, flushing is not only wasteful but also goes against the District’s water conservation efforts and will be frowned upon by customers. Nonetheless, lowering storage volume and frequent flushing can help reduce the average water age in the system.

Aside from the “average” water age, one should be concerned about the “true” water age in a tank. The true water age is not a single value, but a distribution of values. For example, while the average water age in Pickens Canyon Reservoir was calculated in the above example at 3.7 days, some water entering the Reservoir will sit in the reservoir for a shorter time, and some will sit in the reservoir for a longer time. It is the portion with the long water age that is of concern because it provides an opportunity for nitrifying bacteria to increase in numbers to a level that is difficult to control. Therefore, while there is no avoiding the fact that the water age will have a range of values, it is desirable to narrow the range as much as possible for the purpose of minimizing or eliminating long water age in the tank.

Of specific concern are reservoirs that experience thermal stratification due to slight temperature differences between the water volume in the tank and that entering the tank. In general, the water entering the tank is slightly colder than the water that had been sitting in the tank. This is especially true for aboveground steel tanks, which is how most of the District's tanks are in the upper zones. As the colder water enters the bottom of the tank, it remains at the bottom of the tank and the warmer water simply floats up and down on top of the cold water. When water is exiting the tank from the bottom, the cold water which had just entered the tank and remained at the bottom will be the first to exit the tank. This "first-in-first-out" behavior results in continued stratification of the water in the tank, with the warmer water on top having a much longer water age than the water entering-and-exiting the tank. The water with the longer residence time will likely have a lower chloramine residual and greater free ammonia and may develop significant biological nitrification. Unfortunately, since most monitoring is conducted on the water entering or exiting the tank, the operator may not know that nitrification is taking place in the tank until a high demand period draws enough water from the tank such that the nitrified water enters the system and seed nitrifying bacteria to the rest of the system.

With the above in mind, it is important to conduct proper monitoring to determine if stratification is taking place in each tank in the system, and then make modifications that minimize or eliminate it. To assess whether stratification is taking place, the District should conduct depth monitoring of each tank during the summer season when the probability of stratification and nitrification is higher. The Parameters to be monitored include temperature and total chlorine. Depth sampling can be conducted with a portable depth sampler that District staff can lower into the reservoir from a roof hatch and collect samples at different depths, or using permanent sample taps installed along the depth of the reservoir. If sample taps are installed, it is important that they do not terminate at the wall of the reservoir, but rather extend several feet into the water body to ensure that a bulk water sample is being collected.

If stratification is determined to be prevalent and a serious contributor to nitrification in a tank, the District may need to make changes to the piping configuration of the tank to force water to enter the tank from the top and exit from the bottom. Alternatively, the District may install a mixing system in the tank to prevent stratification. The District can use commercially available tank mixers or design and construct an engineered pumped-water mixing system in the tank where water is pumped from the bottom and discharged at the top of the tank.

MAINTAIN A CLEAN SYSTEM

As discussed in the previous section, nitrifying bacteria can hide in crevices and sediments that protect the bacteria from chloramine. Most common crevices are those created by iron corrosion scales in unlined iron pipes. Sediments are also prevalent in distribution system piping, especially dead-end pipes, and storage tanks. In order to minimize the availability of these hiding places, it is important that the District maintain a clean distribution system.

System cleaning includes two components: 1) unidirectional flushing (UDF) and 2) tank cleaning. UDF refers to a planned flushing program that manipulates system valves to allow for the generation of a minimum scouring velocity when a hydrant is opened. The velocity should be high enough to scour the sediment and biofilms, but not too high to dislodge corrosion tubercles from unlined iron pipes, which could eventually compromise the integrity of the pipe. To remove silt and loose sediment, the velocity may need to only be between 3 and 5 feet-per-second, fps. However, in order to dislodge biofilms, the velocity needs to be higher than 6 fps. In the design of a UDF program, system valves are manipulated to direct sufficient water towards the open hydrant in order to result in the required velocity. Monitoring is then conducted on the flushed water to decide when to turn off the hydrant and move to another section in the system.

The District is familiar with tank cleaning practices and should continue with it on a regular basis. The District's 5-year rotation of tank cleaning is a reasonable practice.

BOOST CHLORAMINE RESIDUAL

A sufficient chloramine residual is the best deterrent against biological nitrification. Unfortunately, as the water moves through the system from one zone to another, it will continue to lose chloramine residual. This will result in the lowest chloramine residual in the upper zones of the system, mainly Zones 10 and 11. The two reservoirs in these two zones, Shields and Pickens Canyon, are essentially "terminal" reservoirs in that the water in them is only used locally and is not pumped to other zones. Therefore, if other measures – such as flushing to increase demand or cleaning – are not sufficient to maintain a sufficient chloramine residual in the tanks, localized boosting of the chloramine residual may be necessary.

There are two ways of boosting the chloramine residual in a reservoir. The simple(r) approach is to utilize the available free ammonia in the tank and in the water entering the tank to boost the residual by adding only chlorine to bind the free ammonia and recombine it to form chloramine. This requires that sufficient free ammonia be present in the water to support the target increase in chloramine residual. If that is not the case because the free ammonia had already been consumed, then the more complicated approach needs to be employed in which both chlorine and ammonia need to be added to the water to achieve the target increase in chloramine residual.

Manual Chloramine Boosting

If the need to boost the chloramine residual in a specific reservoir is infrequent, then it can be conducted by District staff using a manual chlorine feed system. Figure 6 presents a conceptual schematic of a manual chlorine boosting system that the District can assemble and use as a mobile chlorine boosting station. The system includes a sodium hypochlorite feed tank, a metering pump, a flowmeter, a check-valve, and isolation valves. The District can assemble such system and use it to boost the chloramine residual at a specific tank. For this system to work, there needs to be above-ground access to the inlet pipe to the tank along with an injection point (as shown). In addition, the District should be able modify the "FILL" and "EMPTY" trigger set points in SCADA to ensure that the tank is in FILL mode during the entire boosting period.

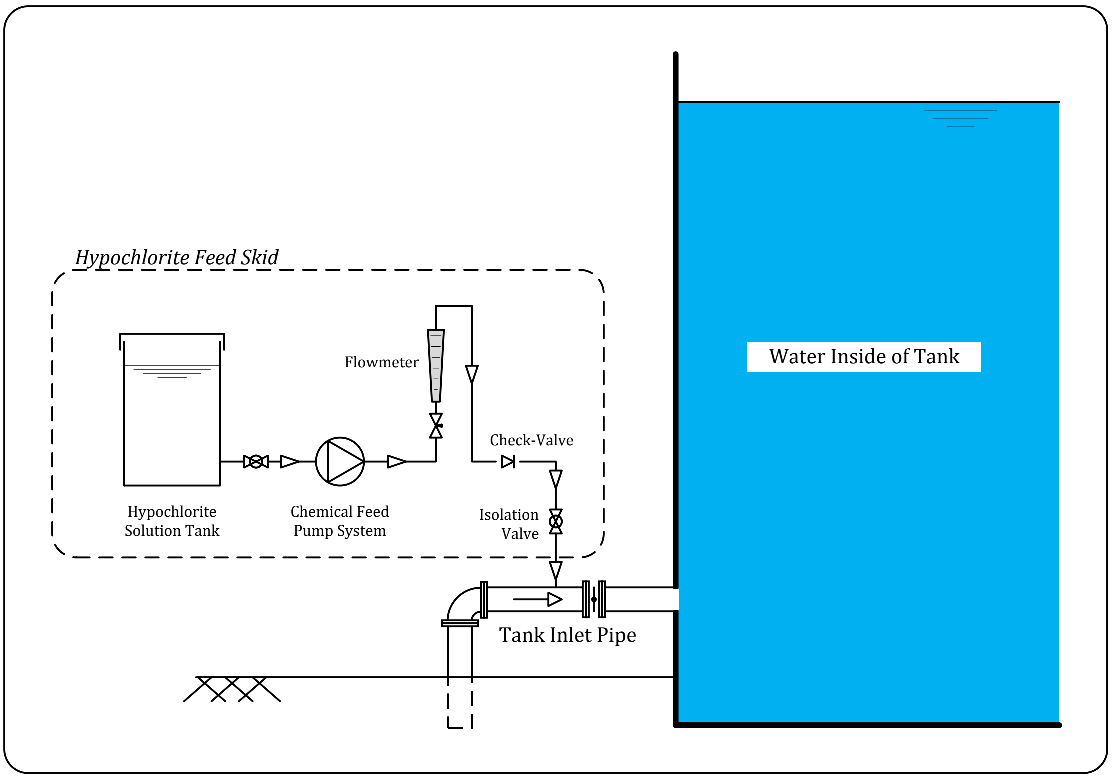

Figure 6 – Schematic Representation of a Manual Chloramine Boosting Skid

If the District assembles the hypochlorite feed system depicted in Figure 6, it can use the Chloramine Boosting Calculator developed by WQTS and delivered to the District. A screenshot of the calculator is shown in Figure 7. This calculator already has the required information regarding each reservoir such as volume/ft of depth (same as those in Table 1), minimum water depth, and maximum water depth. The Calculator includes three sections: The left section titled: "INPUT KNOWN INFORMATION:" is where a user enters all known information and is self-explanatory. The middle section titled: "CALCULATED VALUES:", and a right-side section titled: "READ CHLORINE DOSING CALCULATIONS:". The following is a discussion of the content of each section.

In the INPUT KNOWN INFORMATION section, there are four types of information to enter:

Tank Information: including tank name from a drop-down menu, starting water level, water level at end of fill, and the expected fill rate. In the example shown, Dunsmore Tank is selected, which sets the unit volume per ft of depth as shown at 17,131 gal/ft, while the starting water level is set at 17 ft, the water level at the end of the fill cycle is set at 20 ft, and the expected fill rate is projected at 0.5 ft/hr. It is noted that this value can be changed any time by the user.

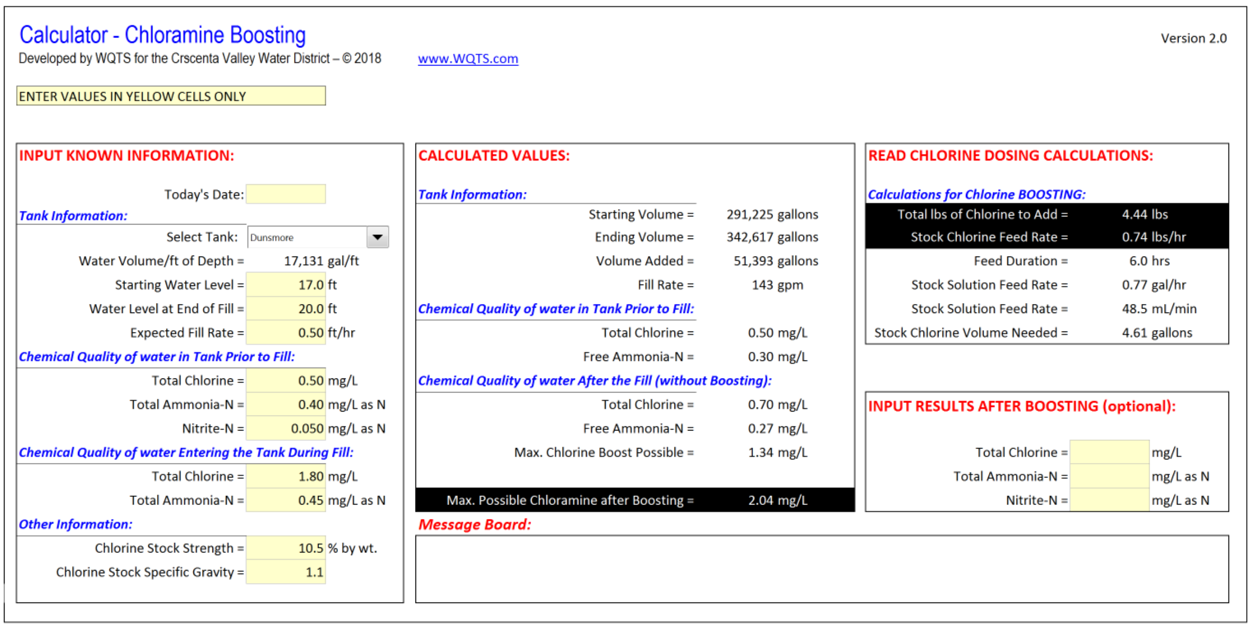

Figure 7 – Screenshot of the Reservoir Chloramine Boosting Calculator Developed by WQTS for the District

Chemical Quality of the water in the Tank to be boosted: Values required include the total chlorine residual, total ammonia concentration, and nitrite concentration. These parameters should be measured from a water sample collected from the water in the tank. If it is not possible to collect a water sample from the inside of the tank, a sample from the water EXITING the tank during operation can be used. In the example shown in Figure 7, the water in the tank was determined to contain 0.5 mg/L total chlorine, 0.4 mg/L as N of total ammonia, and 0.05 mg/L as N of nitrite.

Chemical Quality of the water Used to Fill the Tank: Values required include the total chlorine residual and total ammonia concentration. These parameters should be measured from a water sample collected from the zone from which water will be pumped to the target tank to fill it. In the example shown in Figure 7, the water to be pumped into the tank was determined to contain 1.8 mg/L total chlorine and 0.45 mg/L as N of total ammonia.

Other Information: This section requires information on the hypochlorite solution used to boost the chlorine residual. Specifically, the calculator asks for stock solution strength in percent by wt. and the solution's specific gravity. In the example shown in Figure 7, the hypochlorite solution contains free chlorine at 10.5% by wt., and has a specific gravity of 1.1. It should be noted that while the percent chlorine content in a fresh hypochlorite solution may have been 12.5%, its chlorine content degrades over time, and therefore it is important that the true chlorine content in the solution be determined in order to enter the accurate value in the calculator.

In the CALCULATED VALUES section, there are three types of parameters for which values are presented:

Tank Information: This section documents the calculated starting volume in the tank, final volume after fill, volume of water added, and the anticipated fill water flowrate. In the example shown, the starting water volume is 291,225 gallons, the ending volume is 342,617 gallons, and the fill rate is projected at 143 gpm.

Chemical Quality of the Water in the Tank Prior to Fill: This section documents the calculated total chlorine concentration in the tank water (which was entered by the user) as well as the calculated free ammonia concentration in the water. In the example shown, the total chlorine residual in the tank prior to fill was 0.5 mg/L and the free ammonia concentration was calculated at 0.3 mg/L as N.

Chemical Quality of the Water in the Tank after the Fill WITHOUT Boosting: This section documents what the chemistry of the water in the Tank would be if it is filled with the available water without chlorine boosting. This is added to the calculator to help the user determine if the filled tank water would have satisfactory total chlorine residual without having to boost it. In the example shown, if the tank is filled with the available water without boosting, it would contain a total chlorine residual of 0.7 mg/L and the free ammonia concentration of 0.27 mg/L as N.

Also shown at the bottom of this middle section the "*Max. Possible Chloramine after Boosting*", which for the conditions shown in Figure 7 is calculated at 2.04 mg/L. This value is calculated to alert the user about the maximum possible residual that can be achieved with boosting. If this value is deemed insufficient, then the user may decide to forego the boosting exercise and implement other measures, if any are available. Alternatively, the user may decide to implement boosting, but also implement other measures to aid in avoiding nitrification.

Finally, in the right-hand-side section, the calculator presents the operating conditions for the boosting system. Based on the information provided, the calculator ultimately determines the hypochlorite solution feed rate and the total solution volume needed. In the example shown, the calculator determines that the solution feed rate during the 6-hr fill period is 0.77 gal/hr, or 48.5 mL/min, and the total solution volume required is projected at 4.61 gallons. This information is used to set the pumping rate and the volume of hypochlorite solution to have available to complete the task.

To use the above calculator for a specific tank, the following steps should be implemented:

Step 1 – Temporarily modify the FILL trigger set-point for that Tank in SCADA to allow the water level to be lowered to a low level "A".

Step 2 – Allow the demand in the tank to lower the Tank level to "A". During this step, measure the total chlorine concentration, total ammonia concentration, and the nitrite concentration in the water exiting the tank while it is emptying.

Step 3 – While the tank is emptying, take a water sample from the vicinity of the pump station that will fill the tank and analyze it for total chlorine, total ammonia, and nitrite. If the nitrite concentration in the Tank is high (e.g., >100 μg/L), then it is advisable that this water be discarded and not emptied into the system.

Step 4 – While the tank is still emptying, use the Chloramine Boosting Calculator to estimate the minimum hypochlorite solution volume needed and the anticipated solution feed rate. Use level "A" as the starting level in the calculator and decide on the full water level "B" the operator wants to bring the tank to. Level "B" MUST be lower than the EMPTY trigger set point in SCADA. In other words, as the tank is filling from level "A" to level "B", the fill pumps must be ON at all times which forces the tank to be in fill mode.

Step 5 – By the time the tank reaches level "A", the chlorine boosting station should be ready to feed chlorine. However, if the operator is unsure of the tank fill rate required by the calculator (i.e., ft/hr), then the operator should wait until the water level rises to 1 ft above level "A", calculate the rise rate as 1 divided by the number of hours the water level took to rise by this 1 ft. For example, if it took 1.5 hrs for the water level to increase by 1 ft, then the fill rate entered into the calculator is 0.67, which is calculated as [1/1.5].

Step 6 – As the tank is filling with water and the chlorine is being boosted, the operator should take samples from the influent water upstream of boosting to confirm that the original values used are still correct and should time the rise rate and make adjustment to the fill-rate in the calculator as deemed necessary.

Step 7 – When the water level reaches level "B", which is BELOW the EMPTY trigger set point, the chlorine boosting system should be turned off and disconnected from the influent pipe to the tank.

Step 8 – Before the Tank begins to discharge into the system, it is important to test the water in the tank and confirm that it contains acceptable total chlorine concentration, that the total ammonia is within the vicinity of $1/5^{th}$ the total chlorine, and that the nitrite concentration is low.

IMPORTANT NOTE: The chlorine dose applied to the influent water during boosting could be much higher than 4 mg/L because it is designed to combine with the free ammonia in the tank and boost the residual in the tank water as well. Therefore, it is CRITICAL that the tank is in FILL mode throughout the boosting exercise. Therefore, the operator must be absolutely sure that the FILL and

EMPTY trigger set points in SCADA will NOT allow the Tank to empty while the water is rising from level "A" to level "B". If the tank begins to empty while the booster is ON, the water entering the distribution system will contain unacceptably high levels of chlorine residual. This should be stopped immediately.

Automatic Chloramine Boosting

If a tank has a chronic problem of losing chlorine residual that requires frequent intervention by the operator and becomes a significant draw on resources, the District may decide to invest in a permanent automatic chloramine boosting system. Example suppliers of such systems include *UGSI Solutions, Inc*. (www.ugsicorp.com), which provides the **Monoclor**® RCS system, or *Medora Corporation, Inc.* (www.medoraco.com), which provides the **ResidualHQ**© system. These are not recommended systems but are only referenced as examples. Both systems are designed to draw water out of a tank, monitor its residual concentration, boost the residual in the drawn water as necessary, and circulate it back into the tank. These systems are more costly than the manual system described above, and include various mechanical components and instrumentation that requires routine maintenance like other equipment used by the District.

SECTION 6.0 – NITRIFICATION MONITORING

The most important step in mitigating nitrification in distribution systems is "monitoring". Strict monitoring of water quality across the distribution system will provide the District with critical information about pending nitrification occurrences in various tanks and thus afford the District the opportunity to implement mitigation measures to prevent them. This is a critical aspect of nitrification control because stopping a nitrification event when the bacterial level is still low has a much higher chance of success compared to responding after nitrifying bacterial counts have increased to uncontrollable levels in the tank.

A nitrification monitoring program is designed to look for signs of nitrification. Based on the material presented in earlier sections of this document, nitrification is accompanied by three water quality changes:

1. Loss of chloramine residual
2. Loss of total ammonia concentration
3. Increase in nitrite concentration

While the above changes occur when biological nitrification takes place, they are not all conclusive indicators of nitrification. For example, many other factors contribute to the loss of chloramine residual in the water, such as chloramine demand by natural organic matter or auto-decomposition of chloramine. Similarly, while loss of total ammonia suggests that some non-chemical action is consuming the ammonia, the analytical method for total ammonia can easily be off by 0.1 mg/L as N or greater. In addition, background biological activity unrelated to nitrification also consumes some ammonia. For these reasons, reductions in either chloramine or ammonia level is not a direct indicator of nitrification.

On the other hand, nitrite is formed exclusively by the action of nitrifying bacteria on free ammonia-nitrogen in the water. Therefore, it is a direct indicator of the onset of nitrification. Moreover, nitrite is easy to measure at levels as low as 0.010 mg/L as N with colorimetric methods using handheld field instruments. For this reason, monitoring nitrite levels in a chloraminated distribution system is a critical component of nitrification monitoring. In addition to the above, other water quality parameters to monitor include pH, temperature, coliform bacteria, and HPC bacteria. The bacteriological quality of the water is already collected under the Bacterial Monitoring Plan as required under Title 22. The bacterial samples to be collected under a nitrification monitoring program only need to be conducted on samples collected from storage tanks and only if they contain a total chlorine residual that is below a minimum threshold concentration that raises concern over the bacteriological quality of the water at that location. WQTS recommends the adoption of a minimum total chlorine residual threshold of 0.5 mg/L as Cl_2.

Table 2 lists the parameters to be monitored, their possible analytical method, and the frequency of their monitoring. Table 3 lists the specific locations where the parameters in Table 2 are to be monitored each week of the month, which include three Point of Entry (POE's), 17 tanks, and four (4) dead-ends. It is recommended that monitoring be conducted on Mondays and Tuesdays in each week to allow time during the subsequent week days to identify and remedy problem areas in the system.

Table 2 – List of Parameters to be Monitored, their Possible Methods, and Frequency

Parameter	Method (or Equivalent)	Frequency
Total Chlorine, mg/L as Cl_2	DPD Method (Hach Method 10070)	Weekly
Total Ammonia-Nitrogen	Hach Method 8155 (Salicylate Method)	Weekly
Nitrite, mg/L as N	Hach Method 8507 (Diazotization method)	Weekly
pH	Standard Method 4500H	Weekly
Temperature, °C	Standard Method 2550	Weekly
Total Coliforms, MPN/100mL	MPN (density) Method	Conditional
HPC Bacterial Counts, CFU/mL	Pour Plate PCA Media	Conditional

Coliform and HPC analysis is to be conducted only on Tank Samples that contain < 0.5 mg/L total chlorine

Table 3 – Possible Locations of Weekly Nitrification-Related Water Quality Monitoring

Week 1	Week 2	Week 3	Week 4	Week 5
Point of Entry (POE)				
Glenwood Effluent	Glenwood Effluent	Glenwood Effluent	Glenwood Effluent	Glenwood Effluent
Mills Effluent	Mills Effluent	Mills Effluent	Mills Effluent	Mills Effluent
FMWD Connections	FMWD Connections	FMWD Connections	FMWD Connections	FMWD Connections
Storage Tanks				
All 17 Tanks	All 17 Tanks	All 17 Tanks	All 17 Tanks	All 17 Tanks
Dead Ends (Block Numbers Listed)				
2800 Manhattan(1)	2000 Hilldale(2)	3700 Park Place(1)	3000 Manhattan(2)	3400 Altura(3)
4600 Briggs(3)	3100 Fairmont(4)	4400 Rockland(3)	2300 El Sereno(4)	2300 El Moreno(5)
4700 New York(5)	5000 Humphrey(6)	3400 Gromer(7)	3100 Markridge(8)	3300 Hopeton(9)
2700 Rockpine(9)	5200 Ramsdell(8)	2600 Seapine(9)	2700 Starfall(10)	2800 Pinelawn(10)
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(#) = Zone Number

The sampling locations in Table 3 are divided into three categories: Point-of-Entry (POE's), Storage Tanks, and dead ends. There POE's are to be monitored each week, and they are the effluent of the Glenwood WTP, the effluent of the Mills WTP, and any active FMWD connection(s).

Storage tank samples are to be collected from all 17 tanks each week. It is important that tank samples are collected from the inside of the tanks or from the outlet pipe. If water is collected from the inside of the tank, it is important that the sample line extends few feet away from the water and into the water volume in the tank in order to collect as much of a bulk-water sample as possible. If a tank has a common inlet-outlet line, then the sample should be collected only when the tank is emptying, and not when it is filling. If the sample is taken from the pipe while the tank is filling, then that sample will not be representative of water in the tank, but rather the water in the distribution system entering the tank. The sampler should carry Bacterial sampling bottles with him/her during the rounds. If the total chlorine residual from the tank is less than the recommended threshold concentration of 0.5 mg/L as Cl_2, then a bacterial sample should be collected and analyzed.

For dead ends, the sample locations selected were all blow-off valves, with the exception of two locations which are fire hydrants: 3700 Park Place (week 3) and 2000 Manistee (Week 5). It is understood that the water in the line from the main to the valve will have no measurable chlorine residual. It is important that sufficient water flows through the line until a chlorine residual is detected before any of the other parameters are taken. Regardless of the chlorine residual level, no bacterial samples need to be collected from these dead ends.

SECTION 7.0 – NITRIFICATION RESPONSE ACTION PLAN

The previous sections discussed how to monitor for parameters that are associated with nitrification, and how to implement measures to prevent or suppress nitrification. This section utilizes the results of the monitoring effort described in Section 6 to identify signs of imminent or active nitrification and recommends response actions to stop the progress of nitrification and/or reverse it using the preventive measures discussed in Section 5.

The two water quality changes that are most associated with concern over nitrification are nitrite formation and loss of chlorine residual. For this reason, response action plans are recommended for trigger levels of each parameter. Table 3 lists the recommended trigger levels for nitrite levels in storage tanks. Three levels are noted:

Level 1: Background – Nitrite less than 0.015 mg/L as N (i.e., 15 µg/L as N).
Level 2: Nitrification is Developing – Nitrite between 0.015 mg/L as N and 0.030 mg/L as N.
Level 3: Active Nitrification – Nitrite greater than 0.030 mg/L as N.

For each level, a number of response actions are recommended. For Level 1, a nitrite level below 0.015 mg/L as N is considered to be a background level and thus no action is required. For Level 2, with nitrite between 0.015 mg/L as N and 0.030 mg/L as N, it is believed that nitrification is developing and requires attention. Under this condition, the District should increase monitoring beyond the weekly frequency, and take active steps to move water in and out of the tank to reduce water age, which may require flushing in the target tank's service area. Finally, for Level 3, with nitrite in the tank exceeding 0.030 mg/L as N, nitrification is considered to be in full action and immediate action is required. Specifically, the District should take actions to boost chloramine in the tank, increase tank cycling frequency with daily monitoring, and be prepared to take the tank off line and convert the tank to free chlorine if the mitigation actions are not successful in suppressing nitrification.

Table 3 – Nitrite Concentration Alert Levels in Storage Tanks and Potential Response Action

Nitrite Level Trigger	Level	Meaning	Response
NO_2-N < 0.015 mg/L as N	1	Background	No Action
0.015 < NO_2-N < 0.030 mg/L as N	2	Nitrification is developing	Increase monitoring, move water to reduce water age, flush if needed
NO_2-N > 0.030 mg/L as N	3	Active Nitrification	Boost chloramine, increase cycling frequency, go to daily monitoring, be prepared to convert the water in the tank to free chlorine if necessary

Another parameter that warrants action triggers is total chlorine residual concentration. It is important to note that while an increase in nitrite concentration is a direct indicator of nitrification, the loss of total chlorine is not. It only suggests that nitrification could occur soon – or already is active – since the only disinfectant in the water is becoming too low to suppress bacterial growth. With that in mind, Table 4 presents recommended total chlorine trigger levels and corresponding response actions. The three recommended levels are:

1. Total Chlorine Residual >1.5 mg/L as Cl_2
2. Total Chlorine Residual between 0.5 mg/L and 1.5 mg/L as Cl_2
3. Total Chlorine Residual <0.5 mg/L as Cl_2

A total chlorine residual in a water tank greater than 1.5 mg/L as Cl_2 is likely to be sufficient to adequately suppress biological growth in the tank. However, if the total chlorine residual in the tank decreases to a range between 0.5 mg/L and 1.5 mg/L as Cl_2, while this level of residual may be sufficient, it suggests that there is active loss of residual considering the fact that the water entering the distribution system had as much as 2.5 mg/L total chlorine. Therefore, if the residual chlorine is in this middle range, the District may consider increasing the tank monitoring frequency to multiple times a week and make an effort to move water in and out of the tank to raise the residual concentration. However, if the total chlorine residual in the tank decreases to less than 0.5 mg/L as Cl_2, it may be incapable of suppressing biological activity, and there is a strong likelihood that biological nitrification will soon take place (if not already active). Under this condition, the District should consider taking action to boost the chloramine residual in the tank if there is sufficient free ammonia available, increase tank cycling, flush the system, and go to daily monitoring to ensure that nitrification is not allowed to take over the water in the tank. The District should also be prepared to remove the tank from service if it is not able to raise the total chlorine residual above 0.5 mg/L as Cl_2 for any extended period of time.

Table 4 – Total Chlorine Concentration Alert Levels in Tanks and Potential Response Action

Total Chlorine Trigger	Meaning	Response
>1.5 mg/L as Cl_2	Good	No Action
0. 5 to 1.5 mg/L as Cl_2	Moderate	Increase monitoring, move water to raise residual
<0.5 mg/L as Cl_2	Low	Boost chloramine, increase tank cycling frequency, flush to increase demand and lower water age, go to daily monitoring, be prepared to remove the tank from service

While the above information provides recommendations for tracking and preventing nitrification, it should be noted that, at times, the response actions may not be successful at meeting their goals. If the District is not able to raise the total chlorine residual above 0.5 mg/L for at least a 24-hour period without intervention, the District should consider taking the tank off line and determining if the water should be disposed or should be converted to free chlorine and flushed into the system. However, if the water is determined to have positive total coliform bacteria, it should not be served into the system.

Finally, on a weekly basis, the District should organize the data collected in a single database, generate trends of each parameter over time at each location, and then discuss them at a weekly operations meeting. This will greatly help the District stay on top of the data and ensure that imminent problems are addressed before they materialize.

CRESCENTA VALLEY WATER DISTRICT

STAFF REPORT

Information Item No. 3
November 8, 2023

To: Engineering and Operations Committee

From: Brook Yared, M.S., P.E. – Interim Director of Engineering and Operations

Subject: Project Update - CVWD-LADWP Interconnection, E-766

INFORMATION ITEM:

Project Update - CVWD-LADWP Interconnection, E-766 – Update regarding a new emergency interconnection with Los Angeles Department of Water and Power (LADWP).

BACKGROUND:

In 2012, CVWD constructed an interconnection at the Ordunio Reservoir site with LADWP. This was part of grant funding from Proposition 50 to provide regional water supply reliability to all Foothill Municipal Water District (FMWD) Member Agencies. At the time of construction, this interconnection was meant to convey 2.2 Cubic Feet per Second (CFS) of water from LADWP's system into CVWD's zone 2. The larger plan was to convey this LADWP water from Ordunio to Oceanview and utilize the chloramine conversion infrastructure at Ocean View to convey the water to FMWD in case of a shutdown at Metropolitan Water District's (MWD) Weymouth Treatment Plant in La Verne.

Due to the City of Los Angeles' inability to sell water directly to MWD customers, an agreement was never made to allow the operation of the facility. Staff kept the facility in place in case emergency water was needed whether an agreement was replaced or not. During the Well 2 project, the emergency interconnection was set up for Supervisory Control and Data Acquisition (SCADA) monitoring and control.

During the drought in late 2022, water providers that were reliant on the State Water Project (SWP) faced reliability issues after strict allocation amounts were set. LADWP and MWD along with CVWD staff, began meeting to determine if there was any way to convey water from the Colorado River Aqueduct (CRA) to LADWP's system. Weymouth Treatment Plant receives water from both the SWP and CRA. This would provide LADWP with more resiliency should persistent drought reduce the SWP allocation to 2022 levels in the future.

Figure 1: CVWD-LADWP Intertie, 2023

DISCUSSION:

On Thursday, October 26, 2023, CVWD staff met with LADWP at the Ordunio Reservoir site. We performed a brief flow test at the site to confirm that all infrastructure was still in working order. All meters were found to be operating properly, and aside from a few leaks at gaskets that had dried out since the project was constructed, all the pipelines were also in good operating condition.

We also discussed measures that would need to be taken for CVWD to operate the Emergency Interconnection. It is critical that CVWD perform these actions in preparation of a Weymouth Treatment Plant shutdown happening in February 2024, to have ample water supply to assist FMWD Member Agencies for the duration of the 10-day shutdown.

At this time, project work necessary to convey water back to LADWP was not discussed, since that project work would require the installation of new high horsepower pumps. Once the interconnection is online and tested, we plan to begin negotiations with FMWD and LADWP for the infrastructure improvements to convey water back to LADWP.

Site Changes: LADWP is requiring that an air gap and backflow preventer be installed at Interconnection to prevent any chance of water seeping back into their system. Staff will also need to calibrate the flow control valve at the site and replace all the gaskets in the area.

DDW Permitting: Once plans are drawn up showing the backflow prevention changes, CVWD will need to apply for an operating permit for the Interconnection. This will detail the SCADA controls involved with the operation of the facility. It will also spell out the break point chlorination at the site that will be required to accept chloraminated water from LADWP.

FMWD-LADWP Interconnection Agreement: An agreement between FMWD and LADWP will be required to allow for the transfer of water back to LADWP, since direct sales of potable water between LADWP and MWD agencies is still prohibited.

Prepared by:

Kellen Boyce
System Operations Manager

Submitted by:

Brook Yared, M.S., P.E.
Interim Director of Engineering & Operations

Attachments: None

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CRESCENTA VALLEY WATER DISTRICT
STAFF REPORT

Information Item No. 4
November 8, 2023

To: Engineering and Operations Committee
From: Brook Yared, M.S., P.E. – Interim Director of Engineering and Operations
Subject: Project Update - Water Main Repair on the Rosemont Ave. Overcrossing, Project E-1070

INFORMATION ITEM:

Project Update - Water Main Repair on the Rosemont Ave. Overcrossing, Project E-1070 – Discussion regarding construction and inspection activities on the Rosemont Overcrossing.

BACKGROUND:

On August 30, 2023, there was a water main break on the 12-inch pipeline that crosses over the 210 Freeway at Rosemont Ave. This main break resulted in the closing of the westbound lanes of the 210 Freeway. The main was able to be isolated with only two customers being affected by the shutdown, One residential customer on the northwest corner of intersection of Rosemont and Mayfield and a Cal Trans irrigation meter used to irrigate plants on the freeway embankment. In the weeks since the incident, staff has taken various steps to restore service to existing meters in the area and make a repair to the main so it can be returned to service.

DISCUSSION:

Fire Flow testing: The first step that staff took after isolating the damaged main was performance of a Fire Flow test south of the freeway. This was done to ensure that isolating the main in the crossing did not restrict flows to the point that it sacrificed our ability to provide water for fire protection in the area. The Fire Flow test was performed on September 14, 2023 and was found to be sufficient for fire protection, which provided staff additional time to trouble shoot the damage and find a more permanent solution.

Confined Space Entry and Inspection: The first step in determining the extent of the damage to the pipeline in the overcrossing was to contact Caltrans and attain construction details for the overcrossing. When the overcrossing was constructed, maintenance access holes were installed in the precast concrete structure. Since excavation on precast structures such as freeway overcrossings is not allowed, staff planned to use the maintenance holes on the bridge to perform a confined space inspection of the pipeline on the south of the bridge. CVWD staff had never performed a confined space entry on any of its overcrossings prior to this main break. There were safety concerns regarding performing the confined space entry, so staff decided to hire a contractor, Ancon Inc., to assist with the confined space entry.

Figure 1: Interior of the Rosemont Overcrossing

The inspection was performed on September 22, 2023, with Ancon and Caltrans teams in attendance. It was determined that the leak took place inside of a casing on the south end of the 210 Freeway. The exact location of the damage still could not be determined at that time, but the general location was found.

Exploratory Excavation: On October 16, 2023, after reviewing as-built information, staff purchased a new bore hole inspection camera that would allow us to inspect the annular space between the existing pipe casing and the pipeline. CVWD crews potholed in the area and exposed the casing.

Figure 2: Bore Inspection Snapshot of Leak

After removing a small section of the casing, the borehole camera was deployed, and we were able to see the damaged section of the pipe. The break was much larger than staff anticipated. Fortunately, the break in the pipe was south of the Rosemont Overcrossing and could be excavated and repaired using conventional methods.

Future Repair Plans: Starting on November 6, 2023, CVWD crews will be repairing between 35-40 LF of 12-inch main south of the freeway overcrossing on Rosemont Ave. A new 12-inch valve will be installed so that isolation of the main can be performed in the future without discontinuing service to any CVWD customers. This will allow CVWD to plan for a cast-in-place pipe solution in an upcoming budget without causing any additional public inconvenience.

Prepared by:

Darlene Telles
Distribution Operations Manager

Submitted by:

Brook Yared, M.S., P.E.
Interim Director of Engineering & Operations

Attachments: None

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CRESCENTA VALLEY WATER DISTRICT
STAFF REPORT

Information Item No. 5
November 8, 2023

To: Engineering and Operations Committee

From: Brook Yared, M.S., P.E. – Interim Director of Engineering and Operations

Subject: Project Update - Water Main Replacement on the 3000-3100 Blocks of Montrose Ave., Project E-1067

INFORMATION ITEM:

Project Update - Water Main Replacement on the 3000-3100 Blocks of Montrose Ave., Project E-1067 – Update regarding the main and pavement replacement on the 3000-3100 Blocks of Montrose Ave.

BACKGROUND:

On August 11, 2023, there was a major water main break on the existing 10-inch pipeline in front of 3013 Montrose Ave that resulted in significant road damage, causing erosion of the subgrade under the existing paving in the area. The water main on Montrose Ave was previously identified as a common location for leaks and was in line for future planned replacement. The break itself was a result of aging infrastructure (pipeline installed in 1961). CVWD staff successfully repaired the main break, but the repair was identified as temporary, with the watermain within the 3000 and 3100 block categorized as in need of emergency repair. Prior to repairing the pavement damaged by the leak, staff recommends to first repair the water main to eliminate multiple construction mobilizations and future leaks due to the aged infrastructure. Staff moved forward preparing in-house design plans and specifications and requested from the Board of Directors the authority to request bids and award a contract for the construction of the water main replacement.

DISCUSSION:

After presenting bid results at the Board Meeting on October 24, 2023, CVWD awarded the pipeline replacement contract to Toro Enterprises, Inc. (Toro) for the replacement of the existing 10-inch main on the 3000-3100 block of Montrose Ave. Materials were ordered for the project in August 2023 based on the 50% design drawing that staff had put together for the work. Staff anticipates all materials to be in by the week of November 13, 2023.

Final design plans were submitted to the City of Glendale for review. The City of Glendale has requested that CVWD proceed with construction and that permitting be finalized as an "after the fact" permit. The last remaining elements for permit approval are traffic control plans, which are being created by Toro. A Preconstruction meeting has been scheduled for Thursday, November 9, 2023, to review construction plans and attain any unsubmitted utility plans for the area. Toro plans to begin exploratory excavation and placing no parking signs the week of November 13, 2023, once permits are approved. Construction is planned to start after the materials have been received.

Prepared by:

Elias Sebhatu, P.E.
Senior Engineer

Submitted by:

Brook Yared, M.S., P.E.
Interim Director of Engineering & Operations

Attachments: None

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CRESCENTA VALLEY WATER DISTRICT
STAFF REPORT

Information Item No. 6
November 8, 2023

To: Engineering and Operations Committee
From: Brook Yared, M.S., P.E. – Interim Director of Engineering & Operations
Subject: Status Update - FY 23/24 Capital Improvement Project Budget

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DISCUSSION:
The following is a status and budget update of the FY 23/24 Capital Improvement Program.

1. **2600 & 2700 Blocks of Orange & 5000 Block of El Adobe (E-1046)**
   a. Rock and Paving Negotiations
      i. Paving Quantity reduced to 16,000 sq-ft from 18,000 sq-ft
      ii. Requesting reduction in Unit Price cost from J. Vega Construction

FY 2023/24 CIP Program Cost Update: 11/8/23	E-Job	Recorded FY 22/23	Budget FY 23/24	FY 23/24 Cost to date from 7/1/23 to 11/8/23	Projected FY 23/34
2600 & 2700 Block of Orange & 5000 Block of El Adobe - 2700 LF	E-1046	$392,301	$1,350,050	$948,640	$100,000 - $200,000

2. **3000 & 3100 Blocks of Montrose Ave (E-1067)**
   a. See Memo

FY 2023/24 CIP Program Cost Update: 11/8/23	E-Job	Budget FY 23/24	FY 23/24 Cost to date from 7/1/23 to 11/8/23	Projected FY 23/34
3000 & 3100 Blocks of Montrose Ave - 1650 LF	E-1067	$0	$155,000	1,290,916

3. **Rosemont Overcrossing Repairs – E-1070**
   a. See Memo
   b. Inspection of Additional Overcrossings
      i. La Crescenta Ave.
      ii. Ramsdell Ave.
      iii. Briggs Ave.
      iv. Ocean View Ave.
   c. Future CIPP main relining and Isolation Valve installation
4. **Transfer of Services to Glendale Water and Power (E-1051)**
   a. Transfer of Services on Frederick and Thelma (1929) to Glendale Water and Power to avoid capital replacement.
   b. Work is planned to begin with Glendale in December 2023.
5. **Steel Reservoir Rehabilitation**
   a. Edmund No. 2 (E-1036)
      i. Warranty Repairs – November 13, 2023
   b. Goss Canyon No. 1 (E-1053)
      i. Warranty Inspection – May 2024
   c. Goss Canyon No. 2 (E-1066)
      i. Finalizing Specifications
      ii. Work Scheduled to begin week of December 4, 2023

FY 2023/24 CIP Program Cost Update: 11/8/23	E-Job	Recorded FY 22/23	Budget FY 23/24	*FY 23/24* *Cost to date from 7/1/23 to 11/8/23*	Projected FY 23/34
Goss Canyon #2 - Reservoir Rehabilitation	**E-1066**	**$ -**	**$818,000**	**$6,555**	**$811,445**

6. Replacement of SCADA Equipment, Programming & Integration (E-939)

a. Project Schedule – April 2022 to March 2024

b. APEX – Sites Pending Integration (2023)

i. Edmund I
ii. Edmun II
iii. Goss Canyon
iv. Dunsmore
v. Pickens
vi. Shields

c. Radio Communication Upgrade – Moved to FY 23/24

FY 2023/24 CIP Program Cost Update: 11/8/23	E-Job	Recorded FY 22/23	Budget FY 23/24	*FY 23/24* *Cost to date from 7/1/23 to 11/8/23*
Communication Radio Network	**E-1025**	**$ -**	**$25,000**	**$ -**
SCADA Replacement - Installation	**E-939**	**$266,063**	**$100,000**	**$12,215**

7. AMI – Installation of ¾" & 1" meters (E-1035)

a. Currently 119 customers are waiting to be configured for the Customer Engagement Platform

b. 356 are active on the Customer Engagement Platform

c. Approximately 7074 radios and lids to install/replace

d. 160, ¾ & 1-inch meters including laterals to replace

8. AMI – Installation of 3" & 4" meters (E-1031) – USBR Grant

a. Install and connect 32 – 3" & 4" meters – Deadline extended

i. Testing meter adapters for radios on steel lids

b. 1-1/2-inch meter installation – Grant awarded in late 22/23, Installation beginning week of November 27, 2023

FY 2023/24 CIP Program Cost Update: 11/8/23	E-Job	Recorded FY 22/23	Budget FY 23/24	*FY 23/24* *Cost to date from 7/1/23 to 11/8/23*
AMI - Communication	**E-1020**	**$ 29,902**	**$ -**	**$ -**
GRANT - 3" & 4" Smart Meters	**E-1031**	**$24,731**	**$ -**	**$ -**
AMI - Meter Lids - Zones 9, 10 & 11	**E-1035**	**$192,694**	**$ -**	**$ -**
GRANT - 1-1/2" Smart Meters - USBR Grant	**E-1041**	**$ -**	**$ 335,000**	**$ -**

9. Conversion of Disinfection System to Chloramines (E-1052)

a. See Memo

FY 2023/24 CIP Program Cost Update: 11/8/23	E-Job	Recorded FY 22/23	Budget FY 23/24	FY 23/24 Cost to date from 7/1/23 to 11/8/23
Conversion to Chloramination	E-1052	$20,840	$ 80,000	$30,075

10. Grant Funding Opportunities

a. FEMA Local Hazard Mitigation Plan (M-1004)
   i. Project 1 – New emergency electrical generators at 5 sites - Deferred pending Grant availability
   ii. Project 2 – Seismic Evaluation of CVWD's facilities application – Deferred pending Grant availability

b. Carl Moyer Grant – New Dump Truck, transitioned to SCAQMD SOON program for additional funding

c. Water Recycling Grant – Application Submitted July 10, 2023

11. New Pressure Reducing Station & Rehabilitation of the Ramsdell Mixing Station (E-977)

a. Hydraulic Modeling Review Complete

b. Installation of two fire hydrants to provide additional bypass options to Zone 1 – FY 23/24

FY 2023/24 CIP Program Cost Update: 11/8/23	E-Job	Recorded FY 22/23	Budget FY 23/24	FY 23/24 Cost to date from 7/1/23 to 11/8/23
Upgrade - Ramsdell Mixing Station	E-977	$7,645	$60,000	$ -

12. CVWD-LADWP Interconnection

a. Changes to the Interconnection

b. DDW Permitting

13. Well 2

a. Developing permit amendment for a bypass option to avoid repairs to the Biological Nitrate Removal Facility. PFAS issue discussion.

14. Well 14

a. Investigation Complete and Changes Implemented

b. New Pump Installed on November 2, 2023

FY 2023/24 CIP Program Cost Update: 11/8/23	E-Job	Recorded FY 22/23	Budget FY 23/24	FY 23/24 Cost to date from 7/1/23 to 11/8/23	Projected FY 23/34
Well 14 Rehabilitation	E-1065	$ -	$150,000	$ 121,784	$10,000

15. **Paschall Booster B**
    a. Rental Pump Installed
    b. Vertical Turbine Pump installation to continue after Annual Pump and Well Contract 23/24 award
16. **Wastewater Master Plan**
    a. Draft 1 review December 2023

SUMMARY:

Staff will continue to update the Engineering Committee on FY 23/24 CIP spending throughout the course of the year.

Prepared & submitted by:

Brook Yared, M.S., P.E.
Interim Director of Engineering & Operations

Attachments: None

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CRESCENTA VALLEY WATER DISTRICT
STAFF REPORT

Information Item No. 7
November 8, 2023

To: Engineering and Operations Committee
From: Patrick Atwater, Regulatory and Public Affairs Manager
Subject: **PFOS Sampling Results**

INFORMATION ITEM:

Discussion of PFOS Regulations and Sampling Results

BACKGROUND:

Per- and polyfluoroalkyl substances (PFAS) are a group of more than 12,000 human-made substances that are not naturally occurring and are resistant to heat, water, and oil. These chemicals have been used and produced extensively in the United States for both commercial and industrial purposes, as well as for emergency fire response. Due to their unique chemistry, PFAS have been widely used as surface coatings and protectant formulations in consumer goods such as carpet and home textiles; clothing; food packaging; and non-stick cookware. PFAS substances have also been used as a surfactant in chrome plating, firefighting foam, and other industrial applications. In typical conditions, PFAS are resistant to degradation and do not break down in the environment. These substances can accumulate within the human body and are toxic at relatively low concentrations.

On March 14, 2023, US EPA announced the proposed National Primary Drinking Water Regulation (NPDWR) for six PFAS including perfluorooctanoic acid (PFOA), perfluorooctane sulfonic acid (PFOS), perfluorononanoic acid (PFNA), hexafluoropropylene oxide dimer acid (HFPO-DA, commonly known as GenX Chemicals), perfluorohexane sulfonic acid (PFHxS), and perfluorobutane sulfonic acid (PFBS). US EPA is proposing a maximum contaminant level (MCL) for PFOA and PFOS of 4 ng/L. US EPA is also proposing health-based, non-enforceable Maximum Contaminant Level Goals (MCLGs) for these six PFAS.

DISCUSSION:

The District began its UCMR 5 testing in late February. Upon receiving results for the laboratory, the District informed the Department of Drinking Water (DDW) that there were sample results greater than the DDW notifications levels for PFOA. PFOS, and PFHxs. Samples collected at imported water only locations were all not detected for any PFOS substances. DDW requested the District perform confirmation samples and additional samples on the District's groundwater wells.

On April 19, 2023, the District collected confirmation samples at UCMR 5 sampling locations and samples from CVWD groundwater wells. These are the results that are summarized in the attached table. In summary, nearly half of the District's wells had PFOA or PFOS above the States Notification Levels and one location, Well 8, greater than the State's Response Level. Please note that Well 9 was undergoing rehabilitation and unable to be sampled.

Staff developed a mass balance at Glenwood to estimate the contribution of Well 8 on the combined flow exiting the Glenwood Nitrate Facility. The table below summarizes those results based on the average flows for the month of June 2023 and the sampling results collected in April. Additional samples were collected in June, July and August. The samples collected after April all show a large drop in concentrations of PFOA, PFOS and all other Gen-X constituents, but concentrations of certain wells were still above the proposed federal MCL.

The District has continued monitoring and has sampled on June 28, July 19, August 8 and September 11 of 2023. In the September sampling, Wells 1, 8 and 11 showed levels above the US EPA's proposed MCL of 4 ng/L for PFOA. Well 8 had a result of 5.1 ng/L of PFOA, below the result of 23 ng/L of PFOA from the Well 8 April sample. Well 8 also had a PFOS result of 4.5 ng/L

Prepared by:

Patrick Atwater
Regulatory and Public Affairs Manager

Submitted by:

Brook Yared, MS, PE
Interim Director of Engineering & Operations

Attachments:

1. PFAS Sampling Results – September 2023
2. PFOA and PFOS Concentration Summary – September 2023

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PFAS Results
September 2023

Sample Date 9/11/2023
EPA 533 in ng/L

Sample Description	PFBA	PFBS	PFDA	PFHpA	PFHxA	PFHxS	PFNA	PFOA	PFOS	PFPeA	PFPeS
Well 8	4.8	6.5	ND	2.4	7.4	5.7	ND	5.1	4.5	8	1.6
Glenwood Plant Blend	3.9	5.1	ND	2.3	5.9	4.4	ND	3.4	1.9	6.7	1.2
Wells 1, 5, 7 & 9	4.5	6.2	ND	2.4	7.1	4.9	ND	3.8	0.89	8.2	1.5
Well 11	5.2	9	ND	3.3	7.9	5.1	ND	6.3	2.8	8.5	1.3
Well 5	3.5	5	ND	1.8	5.9	4	ND	3	0.82	6.5	1.3
4703 Briggs	3.6	2.5	ND	1.2	2.9	1.8	ND	1.9	0.87	3.4	ND
Encinal Reservoir	3.4	2.8	ND	1.3	3.1	2.1	ND	2.1	1.2	3.9	ND
Well 1	4.8	8.2	ND	2.9	8	5.9	ND	5.3	1.8	8.8	1.6
Well 7	4.6	6.5	ND	2.4	7.9	5.6	ND	3.5	0.83	9.6	1.6
Well 9	6.2	6.5	ND	2.5	6.8	3.8	ND	4.4	0.98	8.1	1.2
Williams Reservoir	3.6	2.9	ND	1.4	3.4	2.3	ND	2.2	1.2	3.9	ND
Paschall	3.2	ND	ND	ND	0.96	ND	ND	0.98	0.8	1.2	ND
Well 12	4.1	6	ND	3	7.9	5	ND	3.9	0.93	8.3	1.3
Well 16	2.4	2.6	ND	1.1	3.7	2.6	ND	1.3	ND	4.5	1.1
Well 10	2.5	3	ND	1.1	3.3	1.8	ND	1.5	ND	4.2	0.79

Point of Use data - Proposed Federal MCL 4 ng/L MCL

Proposed Hazard Index regulation

Regulated by the State Divison of Driking Water

Over US EPA proposed MCL

* all field blank data ND unless otherwise specified.

RED TEXT — Over the States Response Level

CVWD Glenwood PFOA Concentration Summary – September 2023

Date	Glenwood Well 8 GPM	Hours	PFOA, ng/L	Glenwood Well 10 GPM	Hours	PFOA, ng/L	Glenwood Well 12 GPM	Hours	PFOA, ng/L	Glenwood Well 14 GPM	Hours	PFOA, ng/L	Glenwood Well 16 GPM	Hours	PFOA, ng/L	Glenwood Booster Pump Discharge, GPM	Hours	Calculated PFOA in effluent, ng/L	Sampled PFOA in effluent, ng/L	Glenwood Well 5 GPM	Hours	PFOA, ng/L	Glenwood Well 11 GPM	Hours	PFOA, ng/L	FMWD Briggs Flow, GPM	Hours	PFOA, ng/L	Calculated PFOA at Point of Use ng/L	Sampled PFOA at Point of Use
1-Sep-23	169.45	24.00		49.16	24.00		179.95	24.00		0.00	0.00		101.71	24.00		515.71	24.00	3.44		193.50	24		92.97	24		515.71	24		2.60	
2-Sep-23	169.52	24.00		49.22	24.00		179.92	24.00		0.00	0.00		101.58	24.00		516.52	24.00	3.43		188.45	24		91.85	24		516.52	24		2.59	
3-Sep-23	169.43	24.00		49.18	24.00		180.16	24.00		0.00	0.00		101.75	24.00		514.56	24.00	3.45		190.59	24		92.72	24		514.56	24		2.60	
4-Sep-23	169.30	24.00		49.12	24.00		179.82	24.00		0.00	0.00		101.63	24.00		514.37	24.00	3.44		188.81	24		91.83	24		514.37	24		2.60	
5-Sep-23	166.38	24.00		48.69	24.00		179.88	24.00		0.00	0.00		101.46	24.00		512.48	24.00	3.42		254.21	24		92.15	24		512.48	24		2.62	
6-Sep-23	163.40	24.00		48.53	24.00		180.08	24.00		0.00	0.00		100.88	24.00		507.04	24.00	3.43		233.75	24		91.95	24		507.04	24		2.61	
7-Sep-23	163.07	24.00		48.77	24.00		179.86	24.00		0.00	0.00		101.50	24.00		507.44	24.00	3.43		233.02	24		92.20	24		507.44	24		2.61	
8-Sep-23	162.90	24.00		48.72	24.00		179.83	24.00		0.00	0.00		101.46	24.00		506.75	24.00	3.43		230.96	24		91.47	24		506.75	24		2.61	
9-Sep-23	163.02	24.00		48.60	24.00		180.28	24.00		0.00	0.00		101.17	24.00		503.17	24.00	3.46		215.28	24		91.25	24		503.17	24		2.61	
10-Sep-23	163.35	24.00		48.43	24.00		179.98	24.00		0.00	0.00		100.54	24.00		509.29	24.00	3.41		230.43	24		90.90	24		509.29	24		2.61	
11-Sep-23	163.35	24.00	5.10	48.43	24.00	1.50	179.98	24.00	3.90	0.00	0.00	-	100.54	24.00	1.30	509.29	24.00	3.41	3.40	230.43	24	3	90.90	24	6.3	509.29	24	0.98	2.61	2.1
12-Sep-23	163.60	24.00		48.23	24.00		180.03	24.00		0.00	0.00		100.71	24.00		508.17	24.00	3.42		230.72	24		90.75	24		508.17	24		2.61	
13-Sep-23	163.37	24.00		48.53	24.00		180.28	24.00		0.00	0.00		100.46	24.00		507.79	24.00	3.43		228.85	24		90.40	24		507.79	24		2.61	
14-Sep-23	163.83	24.00		48.60	24.00		180.03	24.00		0.00	0.00		100.38	24.00		507.85	24.00	3.43		222.22	24		91.92	24		507.85	24		2.61	
15-Sep-23	163.72	24.00		48.56	24.00		180.07	24.00		0.00	0.00		100.21	24.00		506.10	24.00	3.44		225.02	24		92.37	24		506.10	24		2.61	
16-Sep-23	163.62	24.00		48.60	24.00		179.95	24.00		0.00	0.00		100.21	24.00		507.67	24.00	3.43		218.93	24		91.25	24		507.67	24		2.61	
17-Sep-23	163.38	24.00		48.48	24.00		180.03	24.00		0.00	0.00		100.04	24.00		509.90	24.00	3.41		225.00	24		91.82	24		509.90	24		2.61	
18-Sep-23	167.51	24.00		48.56	24.00		180.04	24.00		0.00	0.00		100.13	24.00		507.90	24.00	3.46		223.34	24		91.43	24		507.90	24		2.61	
19-Sep-23	174.42	24.00		48.39	24.00		180.21	24.00		0.00	0.00		99.96	24.00		520.42	24.00	3.45		221.70	24		91.90	24		520.42	24		2.60	
20-Sep-23	174.37	24.00		47.90	24.00		180.00	24.00		0.00	0.00		100.04	24.00		519.17	24.00	3.45		204.89	24		91.80	24		519.17	24		2.60	
21-Sep-23	174.33	24.00		47.77	24.00		180.47	24.00		0.00	0.00		100.04	24.00		516.71	24.00	3.47		224.15	24		91.60	24		516.71	24		2.60	
22-Sep-23	174.42	24.00		48.01	24.00		180.32	24.00		0.00	0.00		100.04	24.00		519.98	24.00	3.45		206.11	24		91.20	24		519.98	24		2.60	
23-Sep-23	174.63	24.00		47.78	24.00		180.26	24.00		0.00	0.00		100.25	24.00		519.42	24.00	3.46		187.34	24		91.45	24		519.42	24		2.59	
24-Sep-23	174.98	24.00		47.84	24.00		180.21	24.00		0.00	0.00		100.38	24.00		520.48	24.00	3.45		182.03	24		91.95	24		520.48	24		2.59	
25-Sep-23	174.93	24.00		47.85	24.00		180.19	24.00		0.00	0.00		100.25	24.00		520.56	24.00	3.45		205.75	24		91.50	24		520.56	24		2.60	
26-Sep-23	174.98	24.00		48.11	24.00		179.99	24.00		0.00	0.00		100.08	24.00		518.48	24.00	3.47		258.48	24		91.75	24		518.48	24		2.61	
27-Sep-23	174.95	24.00		47.93	24.00		180.19	24.00		0.00	0.00		100.13	24.00		521.69	24.00	3.44		237.95	24		91.20	24		521.69	24		2.60	
28-Sep-23	175.03	24.00		48.30	24.00		180.08	24.00		0.00	0.00		100.00	24.00		519.35	24.00	3.46		232.53	24		92.05	24		519.35	24		2.61	
29-Sep-23	175.02	24.00		47.89	24.00		180.42	24.00		0.00	0.00		100.00	24.00		519.75	24.00	3.46		237.35	24		91.55	24		519.75	24		2.61	
30-Sep-23	175.07	24.00		48.01	24.00		180.80	24.00		0.00	0.00		100.04	24.00		518.79	24.00	3.47		210.08	24		90.50	24		518.79	24		2.60	

*Sampling date highlighted in blue.

** All cells in calculated columns are calculated based on same monthly sampling data

CVWD Glenwood PFOS Concentration Summary – September 2023

Date	Glenwood Well 8 GPM	Hours	PFOS, ng/L	Glenwood Well 10 GPM	Hours	PFOS, ng/L	Glenwood Well 12 GPM	Hours	PFOS, ng/L	Glenwood Well 14 GPM	Hours	PFOS, ng/L	Glenwood Well 16 GPM	Hours	PFOS, ng/L	Glenwood Booster Pump Discharge, GPM	Hours	Calculated PFOS in effluent, ng/L	Sampled PFOS in effluent, ng/L	Glenwood Well 5 GPM	Hours	PFOS, ng/L	Glenwood Well 11 GPM	Hours	PFOS, ng/L	FMWD Briggs Flow, GPM	Hours	PFOS, ng/L	Calculated PFOS at Point of Use ng/L	Sampled PFOS at Point of Use
1-Sep-23	169.45	24.00		49.16	24.00		179.95	24.00		0.00	0.00		101.71	24.00		515.71	24.00	1.80		193.50	24		92.97	24		515.71	24		1.37	
2-Sep-23	169.52	24.00		49.22	24.00		179.92	24.00		0.00	0.00		101.58	24.00		516.52	24.00	1.80		188.45	24		91.85	24		516.52	24		1.38	
3-Sep-23	169.43	24.00		49.18	24.00		180.16	24.00		0.00	0.00		101.75	24.00		514.56	24.00	1.81		190.59	24		92.72	24		514.56	24		1.38	
4-Sep-23	169.30	24.00		49.12	24.00		179.82	24.00		0.00	0.00		101.63	24.00		514.37	24.00	1.81		188.81	24		91.83	24		514.37	24		1.38	
5-Sep-23	166.38	24.00		48.69	24.00		179.88	24.00		0.00	0.00		101.46	24.00		512.48	24.00	1.79		254.21	24		92.15	24		512.48	24		1.35	
6-Sep-23	163.40	24.00		48.53	24.00		180.08	24.00		0.00	0.00		100.88	24.00		507.04	24.00	1.78		233.75	24		91.95	24		507.04	24		1.36	
7-Sep-23	163.07	24.00		48.77	24.00		179.86	24.00		0.00	0.00		101.50	24.00		507.44	24.00	1.78		233.02	24		92.20	24		507.44	24		1.36	
8-Sep-23	162.90	24.00		48.72	24.00		179.83	24.00		0.00	0.00		101.46	24.00		506.75	24.00	1.78		230.96	24		91.47	24		506.75	24		1.36	
9-Sep-23	163.02	24.00		48.60	24.00		180.28	24.00		0.00	0.00		101.17	24.00		503.17	24.00	1.79		215.28	24		91.25	24		503.17	24		1.36	
10-Sep-23	163.35	24.00		48.43	24.00		179.98	24.00		0.00	0.00		100.54	24.00		509.29	24.00	1.77		230.43	24		90.90	24		509.29	24		1.36	
11-Sep-23	163.35	24.00	4.50	48.43	24.00	0.00	179.98	24.00	0.93	0.00	0.00	-	100.54	24.00	0.00	509.29	24.00	1.77	1.90	230.43	24	0.82	90.90	24	2.8	509.29	24	0.8	1.36	1.2
12-Sep-23	163.60	24.00		48.23	24.00		180.03	24.00		0.00	0.00		100.71	24.00		508.17	24.00	1.78		230.72	24		90.75	24		508.17	24		1.36	
13-Sep-23	163.37	24.00		48.53	24.00		180.28	24.00		0.00	0.00		100.46	24.00		507.79	24.00	1.78		228.85	24		90.40	24		507.79	24		1.36	
14-Sep-23	163.83	24.00		48.60	24.00		180.03	24.00		0.00	0.00		100.38	24.00		507.85	24.00	1.78		222.22	24		91.92	24		507.85	24		1.36	
15-Sep-23	163.72	24.00		48.56	24.00		180.07	24.00		0.00	0.00		100.21	24.00		506.10	24.00	1.79		225.02	24		92.37	24		506.10	24		1.36	
16-Sep-23	163.62	24.00		48.60	24.00		179.95	24.00		0.00	0.00		100.21	24.00		507.67	24.00	1.78		218.93	24		91.25	24		507.67	24		1.36	
17-Sep-23	163.38	24.00		48.48	24.00		180.03	24.00		0.00	0.00		100.04	24.00		509.90	24.00	1.77		225.00	24		91.82	24		509.90	24		1.36	
18-Sep-23	167.51	24.00		48.56	24.00		180.04	24.00		0.00	0.00		100.13	24.00		507.90	24.00	1.81		223.34	24		91.43	24		507.90	24		1.36	
19-Sep-23	174.42	24.00		48.39	24.00		180.21	24.00		0.00	0.00		99.96	24.00		520.42	24.00	1.83		221.70	24		91.90	24		520.42	24		1.36	
20-Sep-23	174.37	24.00		47.90	24.00		180.00	24.00		0.00	0.00		100.04	24.00		519.17	24.00	1.83		204.89	24		91.80	24		519.17	24		1.37	
21-Sep-23	174.33	24.00		47.77	24.00		180.47	24.00		0.00	0.00		100.04	24.00		516.71	24.00	1.84		224.15	24		91.60	24		516.71	24		1.36	
22-Sep-23	174.42	24.00		48.01	24.00		180.32	24.00		0.00	0.00		100.04	24.00		519.98	24.00	1.83		206.11	24		91.20	24		519.98	24		1.37	
23-Sep-23	174.63	24.00		47.78	24.00		180.26	24.00		0.00	0.00		100.25	24.00		519.42	24.00	1.84		187.34	24		91.45	24		519.42	24		1.38	
24-Sep-23	174.98	24.00		47.84	24.00		180.21	24.00		0.00	0.00		100.38	24.00		520.48	24.00	1.83		182.03	24		91.95	24		520.48	24		1.38	
25-Sep-23	174.93	24.00		47.85	24.00		180.19	24.00		0.00	0.00		100.25	24.00		520.56	24.00	1.83		205.75	24		91.50	24		520.56	24		1.37	
26-Sep-23	174.98	24.00		48.11	24.00		179.99	24.00		0.00	0.00		100.08	24.00		518.48	24.00	1.84		258.48	24		91.75	24		518.48	24		1.35	
27-Sep-23	174.95	24.00		47.93	24.00		180.19	24.00		0.00	0.00		100.13	24.00		521.69	24.00	1.83		237.95	24		91.20	24		521.69	24		1.35	
28-Sep-23	175.03	24.00		48.30	24.00		180.08	24.00		0.00	0.00		100.00	24.00		519.35	24.00	1.84		232.53	24		92.05	24		519.35	24		1.36	
29-Sep-23	175.02	24.00		47.89	24.00		180.42	24.00		0.00	0.00		100.00	24.00		519.75	24.00	1.84		237.35	24		91.55	24		519.75	24		1.36	
30-Sep-23	175.07	24.00		48.01	24.00		180.80	24.00		0.00	0.00		100.04	24.00		518.79	24.00	1.84		210.08	24		90.50	24		518.79	24		1.36	

*Sampling date highlighted in blue.

** All cells in calculated columns are calculated based on same monthly sampling data

CVWD Mills PFOA Concentration Summary – September 2023

Date	Well 1 GPM	Hours	PFOA, ng/L	Well 7 GPM	Hours	PFOA, ng/L	Well 9 GPM	Hours	PFOA, ng/L	Mills Well 5 GPM	Hours	PFOA, ng/L	Mills Booster Pump Discharge, GPM	Hours	Calculated PFOA in effluent (forebay), ng/L	Sampled PFOA in effluent (forebay), ng/L	Paschall Discharge, GPM	Hours	Sampled PFOA in effluent (Paschall), ng/L	Williams Discharge, GPM	Hours	Sampled PFOA in effluent (Williams), ng/L	Calculated PFOA in effluent (Fairmount and Briggs), ng/L	Sampled PFOA in effluent (Fairmount and Briggs), ng/L
1-Sep-23	97.48	11.00		245.05	11.00		121.00	11.00		218.46	11.00		620.75	11.00	4.13		1233.45	11.00		1530.88	8.00		2.03	
2-Sep-23	97.09	11.00		244.55	11.00		120.97	11.00		225.67	11.00		623.75	11.00	4.14		1223.02	11.00		1408.30	3.00		1.98	
3-Sep-23	97.50	11.00		244.73	11.00		120.80	11.00		223.78	11.00		633.50	11.00	4.07		1223.52	11.00		1367.67	4.50		2.00	
4-Sep-23	97.50	10.50		244.76	10.50		120.73	10.50		225.25	11.00		623.75	11.00	4.00		1208.22	11.00		1396.11	5.00		2.01	
5-Sep-23	97.40	7.50		245.87	7.50		121.26	7.50		131.86	7.00		541.41	8.00	3.95		1196.26	8.00		1522.94	18.00		2.09	
6-Sep-23	98.02	11.00		244.33	11.00		120.84	11.00		127.81	11.00		546.50	11.00	4.19		1239.67	11.00		1547.61	3.50		1.92	
7-Sep-23	97.70	11.00		244.33	11.00		120.71	11.00		130.77	11.00		553.50	11.00	4.15		1231.93	11.00		1529.94	8.50		1.99	
8-Sep-23	97.43	11.00		244.51	11.00		120.84	11.00		132.42	11.00		553.25	11.00	4.16		1228.57	11.00		1542.80	9.50		2.00	
9-Sep-23	97.48	14.00		242.83	14.00		120.55	14.00		130.60	14.00		548.82	14.00	4.17		1225.36	14.00		1518.77	6.00		1.95	
10-Sep-23	97.77	11.00		243.93	11.00		120.67	11.00		131.77	11.00		549.50	11.00	4.18		1236.47	11.00		1565.66	8.50		1.99	
11-Sep-23	97.77	11.00	5.3	243.93	11.00	3.5	120.67	11.00	4.40	131.77	11.00	3.00	549.50	11.00	4.18	3.80	1236.47	11.00	0.98	1565.66	8.50	2.20	1.99	1.9
12-Sep-23	97.59	11.00		243.93	11.00		120.77	11.00		131.36	11.00		553.00	11.00	4.15		1234.62	11.00		1527.15	7.50		1.98	
13-Sep-23	98.09	11.00		244.69	11.00		120.97	11.00		134.08	11.00		553.25	11.00	4.18		1233.61	11.00		1570.66	8.50		1.99	
14-Sep-23	97.83	13.00		244.15	13.00		120.81	13.00		130.90	13.00		550.85	13.00	4.17		975.66	13.00		1521.93	7.50		2.07	
15-Sep-23	97.63	13.00		243.69	13.00		120.73	13.00		127.20	13.00		549.37	13.00	4.16		845.17	13.00		1497.09	9.50		2.14	
16-Sep-23	98.04	13.00		243.75	13.00		121.00	13.00		135.35	13.00		553.81	13.00	4.17		838.33	13.00		1508.05	8.50		2.14	
17-Sep-23	97.75	13.00		243.66	13.00		121.03	13.00		125.85	13.00		545.13	13.00	4.18		835.06	13.00		1481.12	5.50		2.13	
18-Sep-23	97.88	13.00		243.45	13.00		120.89	13.00		127.85	13.00		547.46	13.00	4.18		845.02	13.00		1552.40	7.50		2.13	
19-Sep-23	97.85	13.00		243.97	13.00		120.75	13.00		132.50	13.00		547.04	13.00	4.21		827.38	13.00		1447.21	12.00		2.15	
20-Sep-23	97.63	16.00		243.13	16.00		120.68	16.00		132.40	16.00		551.03	16.00	4.17		859.44	16.00		899.22	8.50		2.11	
21-Sep-23	98.20	12.50		245.41	12.50		121.09	12.50		131.56	12.50		550.63	13.00	4.03		857.55	13.00		1181.93	8.00		2.12	
22-Sep-23	97.66	15.50		242.66	15.50		120.54	15.50		133.40	15.50		550.35	15.50	4.17		859.95	15.50		810.56	15.50		2.12	
23-Sep-23	97.91	16.00		243.27	16.00		120.68	16.00		129.23	19.50		539.86	16.00	4.40		846.03	16.00		805.31	20.00		2.13	
24-Sep-23	97.34	16.00		242.52	16.00		120.46	16.00		129.84	20.50		549.48	16.00	4.36		845.57	16.00		1440.16	5.50		2.12	
25-Sep-23	97.64	16.00		242.53	16.00		120.41	16.00		129.80	16.00		546.39	16.00	4.18		852.52	19.50		1432.68	5.00		2.01	
26-Sep-23	97.92	6.50		244.64	12.50		120.95	6.50		128.20	6.50		550.46	6.00	6.07		848.71	10.50		1514.42	12.00		2.02	
27-Sep-23	97.80	10.00		245.12	10.00		121.66	10.00		130.65	10.00		556.33	10.00	4.14		1041.83	10.00		1494.89	13.50		2.09	
28-Sep-23	98.05	11.00		243.85	11.00		121.52	11.00		132.60	11.00		556.22	11.50	3.96		1041.83	11.10		1562.85	4.50		2.04	
29-Sep-23	98.43	10.00		246.48	10.00		121.87	10.00		132.21	10.00		552.48	10.00	4.19		1041.83	10.00		1216.34	13.00		2.08	
30-Sep-23	97.56	15.50		243.02	15.50		121.25	15.50		128.41	15.50		550.69	16.00	4.02		1041.83	15.60		1434.59	6.50		2.03	
Average	97.73	12.17	5.30	244.09	12.37	3.50	120.90	12.17	4.40	143.12	12.43	3.00	559.93	12.23	4.21	3.80	1041.83	12.47	0.98	1413.16	8.72	2.20	2.05	1.90

*Sampling date highlighted in blue.

** All cells in calculated columns are calculated based on same monthly sampling data

***Orange Cells contain Estimated data due to Water Meter being out for Service

CVWD Mills PFOS Concentration Summary – September 2023

Date	Well 1 GPM	Hours	PFOS, ng/L	Well 7 GPM	Hours	PFOS, ng/L	Well 9 GPM	Hours	PFOS, ng/L	Mills Well 5 GPM	Hours	PFOS, ng/L	Mills Booster Pump Discharge, GPM	Hours	Calculated PFOS in effluent (forebay), ng/L	Sampled PFOS in effluent (forebay), ng/L	Paschall Discharge, GPM	Hours	Sampled PFOS in effluent (Paschall), ng/L	Williams Discharge, GPM	Hours	Sampled PFOS in effluent (Williams), ng/L	Sampled PFOS in effluent (Fairmount and Briggs), ng/L	Sampled PFOS in effluent (Fairmount and Briggs), ng/L
1-Sep-23	97.48	11.00		245.05	11.00		121.00	11.00		218.46	11.00		620.75	11.00	1.09		1233.45	11.00		1530.88	8.00		0.97	
2-Sep-23	97.09	11.00		244.55	11.00		120.97	11.00		225.67	11.00		623.75	11.00	1.09		1223.02	11.00		1408.30	3.00		0.89	
3-Sep-23	97.50	11.00		244.73	11.00		120.80	11.00		223.78	11.00		633.50	11.00	1.07		1223.52	11.00		1367.67	4.50		0.92	
4-Sep-23	97.50	10.50		244.76	10.50		120.73	10.50		225.25	11.00		623.75	11.00	1.06		1208.22	11.00		1396.11	5.00		0.93	
5-Sep-23	97.40	7.50		245.87	7.50		121.26	7.50		131.86	7.00		541.41	8.00	1.04		1196.26	8.00		1522.94	18.00		1.07	
6-Sep-23	98.02	11.00		244.33	11.00		120.84	11.00		127.81	11.00		546.50	11.00	1.10		1239.67	11.00		1547.61	3.50		0.91	
7-Sep-23	97.70	11.00		244.33	11.00		120.71	11.00		130.77	11.00		553.50	11.00	1.09		1231.93	11.00		1529.94	8.50		0.98	
8-Sep-23	97.43	11.00		244.51	11.00		120.84	11.00		132.42	11.00		553.25	11.00	1.09		1228.57	11.00		1542.80	9.50		0.99	
9-Sep-23	97.48	14.00		242.83	14.00		120.55	14.00		130.60	14.00		548.82	14.00	1.10		1225.36	14.00		1518.77	6.00		0.93	
10-Sep-23	97.77	11.00		243.93	11.00		120.67	11.00		131.77	11.00		549.50	11.00	1.10		1236.47	11.00		1565.66	8.50		0.98	
11-Sep-23	97.77	11.00	1.8	243.93	11.00	0.83	120.67	11.00	0.98	131.77	11.00	0.82	549.50	11.00	1.10	0.89	1236.47	11.00	0.80	1565.66	8.50	1.20	0.98	1.9
12-Sep-23	97.59	11.00		243.93	11.00		120.77	11.00		131.36	11.00		553.00	11.00	1.09		1234.62	11.00		1527.15	7.50		0.96	
13-Sep-23	98.09	11.00		244.69	11.00		120.97	11.00		134.08	11.00		553.25	11.00	1.10		1233.61	11.00		1570.66	8.50		0.98	
14-Sep-23	97.83	13.00		244.15	13.00		120.81	13.00		130.90	13.00		550.85	13.00	1.10		975.66	13.00		1521.93	7.50		0.97	
15-Sep-23	97.63	13.00		243.69	13.00		120.73	13.00		127.20	13.00		549.37	13.00	1.09		845.17	13.00		1497.09	9.50		1.00	
16-Sep-23	98.04	13.00		243.75	13.00		121.00	13.00		135.35	13.00		553.81	13.00	1.10		838.33	13.00		1508.05	8.50		0.99	
17-Sep-23	97.75	13.00		243.66	13.00		121.03	13.00		125.85	13.00		545.13	13.00	1.10		835.06	13.00		1481.12	5.50		0.95	
18-Sep-23	97.88	13.00		243.45	13.00		120.89	13.00		127.85	13.00		547.46	13.00	1.10		845.02	13.00		1552.40	7.50		0.98	
19-Sep-23	97.85	13.00		243.97	13.00		120.75	13.00		132.50	13.00		547.04	13.00	1.11		827.38	13.00		1447.21	12.00		1.02	
20-Sep-23	97.63	16.00		243.13	16.00		120.68	16.00		132.40	16.00		551.03	16.00	1.10		859.44	16.00		899.22	8.50		0.93	
21-Sep-23	98.20	12.50		245.41	12.50		121.09	12.50		131.56	12.50		550.63	13.00	1.06		857.55	13.00		1181.93	8.00		0.96	
22-Sep-23	97.66	15.50		242.66	15.50		120.54	15.50		133.40	15.50		550.35	15.50	1.10		859.95	15.50		810.56	15.50		0.97	
23-Sep-23	97.91	16.00		243.27	16.00		120.68	16.00		129.23	19.50		539.86	16.00	1.16		846.03	16.00		805.31	20.00		0.99	
24-Sep-23	97.34	16.00		242.52	16.00		120.46	16.00		129.84	20.50		549.48	16.00	1.15		845.57	16.00		1440.16	5.50		0.93	
25-Sep-23	97.64	16.00		242.53	16.00		120.41	16.00		129.80	16.00		546.39	16.00	1.10		852.52	19.50		1432.68	5.00		0.91	
26-Sep-23	97.92	6.50		244.64	12.50		120.95	6.50		128.20	6.50		550.46	6.00	1.56		848.71	10.50		1514.42	12.00		1.05	
27-Sep-23	97.80	10.00		245.12	10.00		121.66	10.00		130.65	10.00		556.33	10.00	1.09		1041.83	10.00		1494.89	13.50		1.04	
28-Sep-23	98.05	11.00		243.85	11.00		121.52	11.00		132.60	11.00		556.22	11.50	1.04		1041.83	11.10		1562.85	4.50		0.94	
29-Sep-23	98.43	10.00		246.48	10.00		121.87	10.00		132.21	10.00		552.48	10.00	1.10		1041.83	10.00		1216.34	13.00		1.01	
30-Sep-23	97.56	15.50		243.02	15.50		121.25	15.50		128.41	15.50		550.69	16.00	1.06		1041.83	15.60		1434.59	6.50		0.93	

*Sampling date highlighted in blue.

** All cells in calculated columns are calculated based on same monthly sampling data

***Orange Cells contain Estimated data due to Water Meter being out for Service