ICR Treatment Study Summary Report

Pilot-Scale Evaluation of Granular Activated Carbon Filters

for Compliance with the
Information Collection Rule

Conducted: April 15, 1998 to November 20, 1998

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Rolling Hills WTP, ICR#646

Attachments: 2 diskettes (total) containing
ICR Treatment Study Data Collection Spreadsheets
ICR Treatment Study Summary Report Spreadsheets
ICR Treatment Study Summary Report
(and User's Guides)

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1.0 CONCLUSIONS AND RECOMMENDATIONS

In response to requirements of the USEPA Information Collection Rule (ICR), the City of Fort Worth Water Department (FWWD) retained the services of Malcolm Pirnie, Inc. to conduct pilot-scale granular activated carbon (GAC) tests at the Rolling Hills WTP. Pilot-scale tests began on April 14, 1998 and concluded in November 1998.

This "Treatment Study Summary Report" provides a supplemental discussion of the data presented in the "Treatment Study Data Collection Spreadsheets." This chapter provides the major conclusions and recommendations derived from the study.

1.1 Key Findings and Conclusions

The conclusions presented here are based on results from single GAC contactors. The effects of blending effluent from multiple contactors were not investigated. In addition, DBP formation results are based on 24 hours of free chlorine contact, thus providing a conservative measure of DBP formation potential (considering the Rolling Hills WTP uses short free chlorine contact and chloramines for disinfection).

TOC Breakthrough:

- After two to three months of operation, the 20-minute EBCT GAC filter reached greater than 50 percent total organic carbon (TOC) breakthrough.

- TOC breakthrough did not reach the 70 percent breakthrough criterion. Instead, TOC breakthrough reached a plateau between 60 and 70 percent, indicating steady-state removal (for the remainder of the testing duration) was achieved. This steady-state removal may be indicative of exhaustion of GAC adsorption capacity and continued removal through biological activity on the GAC media.

DBP Formation Potential:

- DBP formation potential (with 24 hours of free chlorine contact) breakthrough was much more gradual than TOC breakthrough and never distinctly reached a plateau; however, it appeared that the breakthrough curve flattened more after three months of operation. Total trihalomethane (THM4) formation potential for the 10 minute EBCT column approached 80 μg/L at the end of the test (just over 4 months). THM4 formation potential reached 40 μg/L in less than three months for both the 10 and 20-minute EBCT columns.

HAA5 formation potential did not reach 30 μg/L for either EBCT.

GAC Operation / Run-Times:

- For the 10-minute EBCT GAC column, the THM4 concentration reached 40 μg/L after approximately 4 weeks. Though the 10-minute column test ended just after four months, it appeared that 80 μg/L would have been reached at approximately 5 months.

- For the 20-minute EBCT GAC column, the THM4 concentration reached 40 μg/L after 2 ½ months.

- The influent TOC concentrations and the influent DBP formation potential were fairly variable throughout the study. This was likely due, in part, to the blending of different types and proportions of source water at the Rolling Hills WTP. There were no recognizable seasonal impacts.

- When considering the breakthrough rate of TOC and formation potential of DBPs, the rate of carbon replacement or regeneration may be reasonable. The carbon usage rate may depend more on other treatment parameters and the overall intended used of the GAC.

Other Water Quality Goals and Issues:

Water quality goals and treatment objectives for the Fort Worth Water Department (FWWD) are primarily driven by the need for safe and aesthetically-pleasing drinking water. To satisfy these goals, the objective of the FWWD is to produce water that complies with all applicable regulations while minimizing or eliminating objections related to aesthetic water quality. It is also important to consider the complete spectrum of pending and anticipated regulations. The following are conclusions based on these goals and issues (see Chapter 2.0 for further discussion):

- GAC with free chlorine for disinfection would likely allow the FWWD to meet Stage 1 DBP MCLs and potentially meet Stage 2 placeholder MCLs.

- The FWWD looks to position itself to meet potential future *Cryptosporidium* inactivation requirements and to remove taste and odor, atrazine, and DBP precursors. GAC adsorption will provide some of these benefits; however, GAC will not provide pathogen inactivation. Thus, ozonation for example, which can accomplish all of these goals, has an advantage over GAC for the Rolling Hills WTP.

Economic Considerations:

Although a cost analysis was not performed as a part of this study, the following conclusions are made with regard to the potential economic feasibility of implementing GAC adsorption with free chlorine disinfection at the Rolling Hills WTP:

- Implementing GAC adsorption for a 160 MGD facility would require a significant capital investment, potentially as great as $25 to $40 million. In addition to the GAC filter adsorber units, on-site GAC reactivation facilities may be necessary.

- Construction costs could become significant. Currently, there are plans to expand the Rolling Hills WTP in 2004 to 200 MGD and in 2014 to 250 MGD. It may be difficult to add GAC adsorption in terms of space, plant configuration, and construction. The increased capacities would require further capital investment to expand the GAC process.

- Advanced disinfection/oxidation processes, such as ozone/biofiltration, can likely achieve the FWWD's water quality goals at a lower cost.

Other Process Studies:

- In addition to the ICR GAC study, the FWWD investigated ozonation and enhanced coagulation. Ozonation is capable of meeting all of the FWWD's water quality goals. Since GAC adsorption does not meet all of these goals and is likely a more costly process, it is not expected that the City of Fort Worth would consider implementing GAC adsorption at this time.

1.2 Recommendations

The following recommendations are based on results of this study and the water quality goals of the FWWD:

- Consider other advanced processes and treatment alternatives that will achieve all of the FWWD's water quality and operational goals.
- However, do not rule out the possibility for using GAC adsorption in some fashion as an additional treatment process (i.e. for additional taste and odor, TOC, and pesticides removal, and as a safeguard against source water contamination) if determined economically feasible in the future.

2.0 BACKGROUND INFORMATION

The USEPA ICR required implementation of an extensive sampling program for the FWWD water treatment plants and distribution system. Monthly (quarterly for some parameters) sampling was started in July 1997 and continued through December 1998. The ICR also required the FWWD to conduct a long-term evaluation of GAC adsorption as a post-filtration treatment technology. To fulfill these requirements and address the FWWD's water quality objectives, the FWWD retained Malcolm Pirnie, Inc. to conduct ICR and process studies for improvements to the Rolling Hills WTP. The process studies, which evaluated ozone and enhanced coagulation, were performed in conjunction with the treatment studies outlined by the ICR.

In preparation for these studies, Malcolm Pirnie, with the assistance of Chiang, Patel, & Yerby, Inc., renovated the existing Rolling Hills pilot facility and retrofitted the facility with GAC filter columns, water storage reservoirs, and new chemical feed pumps. The existing pilot facility was equipped with a conventional treatment train and dual-media filter columns. From April 14, 1998 through November 1998, Chiang, Patel, & Yerby operated the Rolling Hills pilot plant to simulate the conventional processes of the full-scale treatment train.

The purpose of this section is to provide background information pertaining to the Rolling Hills WTP. The discussion includes plant schematics, tables summarizing full-scale design parameters and source and finished water quality, and comments regarding treatment challenges at Rolling Hills. After introducing the Rolling Hills WTP in this section, Section 3.0 proceeds to a discussion of materials and methods used in the pilot-scale tests. Section 4.0 provides additional results and discussion to supplement the data provided in the "Treatment Study Data Collection Spreadsheets."

2.1 Rolling Hills Water Treatment Plant Description

Figure 2-1 is a schematic of the Rolling Hills WTP (160 MGD). Raw water is pumped approximately 90 miles from the Richland Chambers and Cedar Creek Reservoirs to the plant where it is treated and pumped to distribution. The WTP utilizes conventional treatment

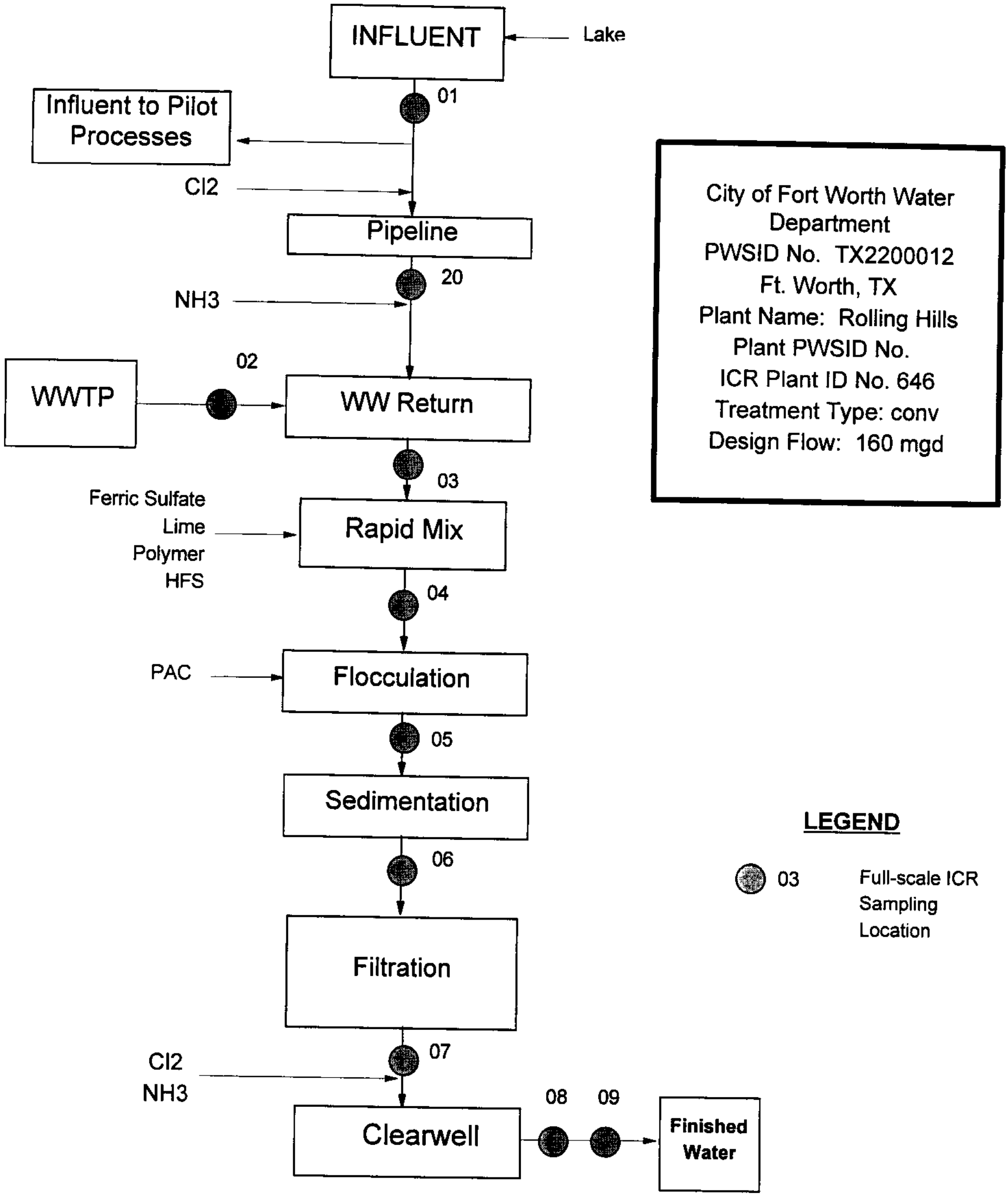


Figure 2-1: Rolling Hills WTP Process Schematic

processes (rapid mix, coagulation, flocculation, and sedimentation) and dual-media filtration to treat the water. Raw water flows into the rapid mix basin where ferric sulfate, lime, and polymer are added for coagulation. Coagulated water proceeds into a three-stage flocculation basin and then to the settling basins. The FWWD occasionally adds PAC at the flocculation/sedimentation basins for taste and odor control. Settled water is then treated by dual media (sand and anthracite) filters. Filtered water enters a series of clearwells and is sent to distribution while spent filter backwash water is recycled to the rapid mix basins.

Combined chlorine is typically the primary disinfectant at the Rolling Hills plant during summer months. Free chlorine and ammonia are added to form chloramines prior to rapid mixing. During winter months, free chlorine contact time is increased by moving ammonia addition further downstream, closer to the rapid mix. The increased free chlorine contact time allows the plant to achieve disinfection CT. Chlorine and ammonia are added after filtration to increase the chloramines residual for distribution. Other chemicals added at the plant include hydrofluosilicic acid at the rapid mix and, much less frequently, caustic for additional pH control.

As shown in Figure 2-1, the influent for the GAC pilot study was taken from the raw water pipeline, upstream of the treatment processes and all chemical addition points.

2.2 Rolling Hills Water Treatment Plant Design Information

Table 2-1 shows design parameters for the Rolling Hills WTP.

Table 2-1: Rolling Hills WTP Process Data (Based on Full-Scale ICR Table A.2)

PWS Name: City of Fort Worth Water	Sampling Period: Design
PWS ID: TX2200012	Design Sampling Start Date: 7/8/97, End Date: 12/31/98
WIDB: 1503	ICR Contact Person: Mr. Richard Talley
Treatment Plant Name: Rolling Hills WTP	State Approved Plant Capacity (MGD): 160.0
ICR Treatment Plant ID: 646	Historical Min. Water Temperature (deg C): 5.0
Treatment Plant PWS ID:	Installed Sludge Handling Capacity (DPD): 63,700.00
Treatment Plant Category: CONV	Blending Indicator: N
Water Resource Name: Cedar Creek Reservoir	Hydrologic Unit Code: 12030107

Table 2-1: Rolling Hills WTP Process Data (Based on Full-Scale ICR Table A.2)

Water Resource Type: Reservoir/lake	River Reach:
Average Residence Time (Days): 544	Latitude (degrees, minutes, seconds): +32, 14', 35"
Intake Name: Cedar Creek	Longitude (degrees, minutes, seconds): -96, 8', 27"
Watershed Control: Y	River Reach Miles:
Water Resource Name:Richland-Chambers	Hydrologic Unit Code: 12030108
Water Resource Type: Reservoir/lake	River Reach:
Average Residence Time (Days): 726	Latitude (degrees, minutes, seconds): +32, 2', 26"
Intake Name:Richland-Chambers	Longitude (degrees, minutes, seconds): -96, 12', 27'
Watershed Control: Y	River Reach Miles:
Process Train Name: RH WTP Process	Process Train Category: CONV

Seq. Sample No. Location Name	Sample Location Type	Sample Loc. No.	Characteristics
Chlorine gas	Disinfectant Addition		Chemical Code: Cl2 Measurement Formula: Cl2 Dose Rate (mg/L): 4.80
Pipeline	Other Treatment Process	20	Surface Area (ft2): Liquid Volume (gal): 287,874 Short Circuiting Factor: 1.0
Anhydrous ammonia	Disinfectant Addition		Chemical Code: NH3A Measurement Formula: NH3 Dose Rate (mg/L): 0.87
WW Return	Washwater Return	2	Washwater Treated: N Coagulation/Sedimentation: N Filtration: N Disinfectant Addition: N Plain Sedimentation: Y Other Treatment: 24 hr ave. Water flow Returned (MGD): 2.36
WW Return	Washwater Return Sample Point	3	
Rapid Mix	Rapid Mix	4	Type of Mixer: ME Baffling Type: AV Liquid Volume (gal): 88,414 Short Circuiting Factor: 0.6 Mean Velocity Gradient (sec-1): 600.0
Flocculation	Flocculation Basin	5	Type of Mixer: ME

Table 2-1: Rolling Hills WTP Process Data (Based on Full-Scale ICR Table A.2)			
			Liquid Volume (gal): 4,051,139 Short Circuiting Factor: 0.6 Baffling Type: AV Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec-1): 60 Stage Liquid Volume (gal): 1,056,386 Stage Sequence Number: 2 Stage Mean Velocity Gradient (sec-1): 50 Stage Liquid Volume (gal): 1,996,502 Stage Sequence Number: 3 Stage Mean Velocity Gradient (sec-1): 35 Stage Liquid Volume(gal): 998,251
Sedimentation	Sedimentation	6	Surface Area (ft2): 447,296 Liquid Volume (gal): 22,560,000 Baffling Type: UN Short Circuiting Factor: 0.5 Plate Settler Surface Area (ft2): Plate Settler Brand Name: Tube Settler Surface Area (ft2): Tube Settler Brand Name:
Filtration	Filtration	7	Surface Area (ft2): 22,440 Liquid Volume (gal): 1,742,690 Total Media Depth (in): 43 Depth of GAC (in): Media Type: DUAL Type of Activated Carbon: Min.Water Depth to Top of Media (ft): 7.0 Depth From Top of Media to Top of Backwash Trough (ft): 3.0
Chlorine gas	Disinfectant Addition		Chemical Code: Cl2 Measurement Formula: Cl2 Dose Rate (mg/L): 0.00
Anhydrous ammonia	Disinfectant Addition		Chemical Code: NH3A Measurement Formula: NH3 Dose Rate (mg/L): 0.00
Clearwell	Clearwell		Surface Area (ft2): 131,939 Liquid Volume (gal): 17,200,000 Minimum Liquid Volume (gal): 3,350,000 Baffling Type: UN Short Circuiting Factor: 0.02 Covered Indicator Code: Y
Finished Water	FIN	8	

Currently, the FWWD plans to expand the Rolling Hills WTP to 200 MGD in 2004 and to 250 MGD in 2014. Table 2-2 shows full-scale chemical application parameters.

Table 2-2: Rolling Hills WTP Chemical Application Parameters (Based on Full-Scale ICR Table A.3)

Sample Location Name	Sample Location Type	Sample Loc. No.	Chemical Name	Measurement Formula	Dose (mg/L)
Chlorine gas	Disinfectant Addition		Chlorine gas	Cl2	4.80
Pipeline	Other Treatment Process	20			
Anhydrous ammonia	Disinfectant Addition		Anhydrous ammonia	NH3	0.87
WW Return	Washwater Return	2			
WW Return	Washwater Return Sample Point	3			
Rapid Mix	Rapid Mix	4	Powdered activated carbon Hydrofluosilicic acid Calcium hydroxide Ferric sulfate Organic polymer - coagulant acid	PAC H2SiF6 CaOH FeSO4* 7H2O Cat Floc	0.00 0.72 11.00 42.00 1.20
Flocculation	Flocculation Basin	5			
Sedimentation	Sedimentation	6			
Filtration	Filtration	7			
Chlorine gas	Disinfectant Addition		Chlorine gas	Cl2	0.00
Anhydrous Ammonia Clearwell	Disinfectant Addition Clearwell	7	Anhydrous Ammonia	NH3	0.00

2.3 Rolling Hills Water Treatment Plant Source and Finished Water Quality

The Rolling Hills WTP treats water from the Richland Chambers and Cedar Creek Reservoirs. Table 2-3 provides a summary of the source water quality. The values in this table were generated from the last twelve months of full-scale ICR sampling data.

Table 2-3: Rolling Hills WTP Source Water Quality Summary				
Water Quality Parameter	**Average Yearly Value**	**Standard Deviation**	**Maximum Yearly Value**	**Minimum Yearly Value**
Temperature (°C)	20.5	7.1	29.6	10.4
pH	7.82	0.49	8.55	6.90
Turbidity (ntu)	15.0	9.68	40.2	6.60
Alkalinity (mg/L as $CaCO_3$)	83	17	101	40
Calcium Hardness (mg/L as $CaCO_3$)	88	18	108	42
Total Hardness (mg/L as $CaCO_3$)	100	18	125	54
TOC (mg/L)	5.2	0.9	7.5	4.3
UV_{254} (1/cm)	0.125	0.027	0.179	0.084
Bromide (mg/L)	0.061	0.015	0.081	0.041

The typical source water at the Rolling Hills WTP consists of approximately 65% Richland Chambers and 35% Cedar Creek water. As shown, the blended source water has moderate levels of alkalinity and hardness. TOC levels are somewhat high. pH typically approaches 8 and, similar to alkalinity, can vary significantly. The variance is likely the result of changes in water blends at different times throughout the year. Cedar Creek water has lower pH, alkalinity, and hardness, and higher TOC and turbidity than Richland Chambers water. Blended water turbidity levels are typically moderate, often near 15 NTU. These reservoirs contain bromide with typical concentrations at approximately 60 μg/L.

Table 2-4 shows Rolling Hills finished water quality based on the last twelve months of full-scale ICR sampling data. Average THM4 values are below the Stage 1 D/DBP Rule MCL.

The FWWD historically meets the current THM4 MCL of 100 μg/L.

Table 2-4: Rolling Hills WTP Finished Water Quality Summary				
Water Quality Parameter	**Average Yearly Value**	**Standard Deviation**	**Maximum Yearly Value**	**Minimum Yearly Value**
Temperature (°C)	20.7	6.0	29.2	12.0
pH	8.26	0.14	8.42	7.96
Turbidity (ntu)	0.21	0.08	0.42	0.11
TOC (mg/L)	3.9	0.3	4.3	3.3
Distribution System THM4 (µg/L)	40.0	9.0	50.0	33.0

As shown, the conventional treatment process provides some TOC removal, likely due to the higher coagulant doses used for turbidity removal. The pH is increased to approximately 8.3 for distribution.

2.4 Water Quality Goals and Treatment Challenges at the Rolling Hills WTP

Water quality goals and treatment objectives for the FWWD are primarily driven by the need for safe and aesthetically-pleasing drinking water. To satisfy these goals, the objective of the FWWD is to produce water that complies with all applicable regulations while minimizing or eliminating objections related to aesthetic water quality. It is also important to plan for flexible processes for meeting pending and anticipated regulations. To meet the regulations and specific finished water quality goals, the FWWD may need to implement an alternate treatment strategy at the Rolling Hills WTP. Table 2-5 summarizes the FWWD's finished water quality goals.

Table 2-5: Water Quality and Treatment Objectives		
Item	**Division Goal**	**Acceptable Upper Bound**
DBPs	Achieve the following target values: • 50 μg/L TTHMs • 30 μg/L HAA_5 • 8 μg/L bromate	Achieve compliance with the Stage 1 D/DBP Rule MCLs: • 80 μg/L TTHMs • 60 μg/L HAA_5 • 10 μg/L bromate
	Achieve compliance with the Stage 2 D/DBP Rule MCLs when finalized: • 40 μg/L TTHMs • 30 μg/L HAA_5 (current "placeholder" MCLs) • 5 μg/L bromate	
Other DBPs (enhanced treatment)	Comply with enhanced coagulation requirements of the Stage 1 D/DBP Rule for TOC reduction	Comply with enhanced coagulation requirements of the Stage 1 D/DBP Rule for TOC reduction
Combined filter turbidity	Less than 0.1 NTU	Less than 0.2 NTU
Disinfection	Meet all disinfection standards and eliminate transmission of waterborne disease	Meet all disinfection standards Minimize/eliminate transmission of waterborne disease
Taste and odor	No complaints	Less than 50 complaints per month
Atrazine	Less than 1.0μg/L; action level of 0.8μg/L	Always less than 3.0μg/L (current MCL)
Treatment	Treatment using similar or equivalent technologies at all plants	Treatment using similar or equivalent technologies at all plants

When considering these goals and the potential impacts of future regulations, a considerable treatment challenge at the Rolling Hills WTP is centered around disinfection practices. Currently, free and combined chlorine are used through the plant for primary disinfection. By using this strategy, the FWWD achieves disinfection requirements for *Giardia* and viruses while limiting THM4 to less than 100 μg/L. With the current treatment strategy, the FWWD can likely meet Stage 1 D/DBP Rule MCLs as well.

Upon implementation of the Stage 1 D/DBP Rule, the FWWD will also be required to practice enhanced coagulation. It is likely enhanced coagulation, with the current disinfection strategy, can be used to meet Stage 2 placeholder MCLs at the Rolling Hills WTP, albeit at higher coagulant doses than necessary to fulfill enhanced coagulation requirements. Therefore, it is probable that an enhanced coagulation-GAC strategy would allow the FWWD to meet D/DBP Rule requirements and achieve a number of its water quality objectives.

However, an enhanced coagulation - GAC strategy alone would not help to achieve potential disinfection requirements for *Cryptosporidium*, the primary challenge at the Rolling Hills WTP. Free chlorine and chloramines are not effective for inactivating *Cryptosporidium*. An alternate disinfection strategy may be necessary depending on requirements of the Long Term Enhanced Surface Water Treatment Rule. This was the impetus for the additional process pilot studies performed along with the ICR study.

3.0 MATERIALS AND METHODS

This section provides a discussion of the materials and methods used to conduct the pilot-scale GAC tests. The discussion topics include:

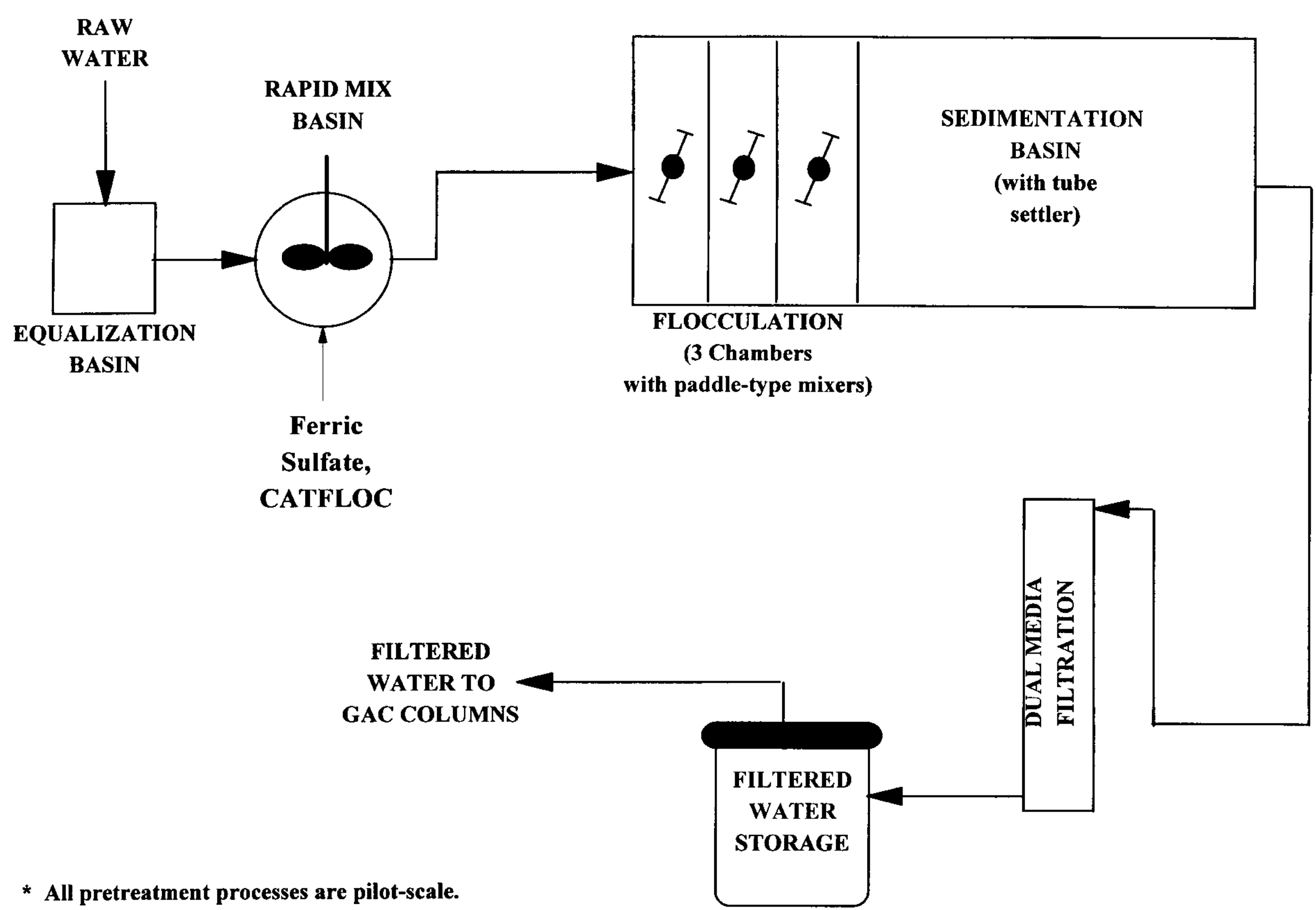
- Description of the pretreatment processes
- Description of the advanced treatment process
- Experimental Design
- Procedures specific to the GAC study
- Analytical methods and testing laboratory information

3.1 Description of Pretreatment Processes

The GAC pilot study required treatment of unchlorinated water. Since the Rolling Hills WTP applies chlorine and ammonia at the beginning of the treatment process, the influent to the pilot plant was taken from the raw water main at the head of the plant, upstream of all WTP treatment processes and chemical addition points. Although free chlorine is occasionally added at the raw water intakes at the reservoirs, it was determined the use of raw water from the above location would fulfill ICR requirements since the chlorine residual was non-detect and TOX concentrations were less than 50 μg/L at that point in the raw water main.

The use of untreated source water made it necessary to use pilot-scale treatment processes to simulate the treatment processes of the full-scale plant prior to treating the water with GAC. To accomplish this, Malcolm Pirnie, with the assistance of Chiang, Patel, & Yerby, Inc., renovated and retrofitted the existing Rolling Hills pilot facility with GAC columns, water storage reservoirs, and new chemical feed pumps. Prior to the retrofit, this pilot facility was equipped with a conventional treatment train and dual-media filter columns.

Figure 3-1 is a schematic of the pilot-scale pretreatment process. The plant influent flow was set at 3.0 gpm using a gate valve located downstream from a constant head basin. There was some variation in the flow rate during the experiment. The influent flow meter became clogged several times during the experiment and flow rates were reduced for short periods until the meter



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PILOT-SCALE EVALUATION OF GAC FILTERS - ROLLING HILLS WTP
PRETREATMENT PROCESS SCHEMATIC*

FIGURE 3-1

could be cleaned. Flow variations in the raw water line to the pilot plant also required periodic adjustments to the gate valve located downstream of the constant head box.

A single stage rapid mix unit was used to flash mix ferric sulfate and polymer. Chemical pumps injected ferric sulfate and polymer into the rapid mix basin. Coagulant dosages comparable to full-scale dosages were used throughout the study. A three stage flocculation unit was used to promote floc formation prior to settling. The first and second floc stages operated at 20 rpm to produce a G value of approximately 40 1/sec. The third stage operated at 16 rpm to produce a G value of approximately 30 1/sec. The flocculator speeds were held constant throughout the experiment. The three-stage flocculation process, with paddle flocculators, provided "G" values similar to those achieved at full-scale. Particles settled out in the sedimentation basin. Settled water was then pumped to the dual-media filters.

Two, 3 ½-inch diameter dual media pressure filters containing gravel, sand, and anthracite, provided additional turbidity removal before the treated water made its way into the filtered water reservoir (a 55-gallon HDPE tank). The flow rate was approximately 0.35 gpm for each filter. The filters required backwashing every 48 hours. Each backwash cycle required approximately 25 gallons of water per filter. Filter effluent turbidity was checked periodically to assure proper filter operation. The filter media was changed once during the experiment. A submersible pump pumped the filtered water from the storage reservoir to the influent of the GAC contactors.

Table 3-1 shows additional details regarding pilot process design parameters.

Table 3-1: Rolling Hills WTP Pilot Facility Design Parameters

Unit Process	**Process Description**
Rapid Mix	Type of Mixer: Mechanical (Impeller) Baffling Type:Unbaffled Stage: Single Stage Liquid Volume (gal)= 8.41 Mean Velocity Gradient (1/sec)= 483.3 Avg. Polymer dosage (mg/L) = 1.0 Avg. Ferric Sulfate dosage (mg/L)= 24.0

Table 3-1: Rolling Hills WTP Pilot Facility Design Parameters

Unit Process	Process Description
Flocculation	Type of Mixer: Mechanical (Paddles) Baffling Type:Unbaffled Stage: 3-Stage Detention time (min.)= 66 Stage Sequence Number: 1 Mean Velocity Gradient (1/sec)= 40.0 Liquid Volume (gal)= 64.83 Stage Sequence Number: 2 Mean Velocity Gradient (1/sec)= 40.0 Liquid Volume (gal)= 64.83 Stage Sequence Number: 3 Mean Velocity Gradient (1/sec)= 30.0 Liquid Volume (gal)= 64.83
Sedimentation	Basin Type: gravity Liquid Volume (gal)= 672 Detention time (hrs) = 3.72 Overflow rate (gpd/ft^2)= 247 Weir loading rate (gpd/ft^2)= 1728
Dual Media Pressure Filters (two filters in use)	Media:12" sand Effective size (mm) = 0.7 Uniformity coefficient = 1.68 18" anthracite Effective size (mm) = 0.85 to 1.10 Uniformity coefficient = 1.50 to 1.60 Flow rate (gpm/filter)= 0.35 Hydraulic loading rate (gpm/ft^2)= 5.25

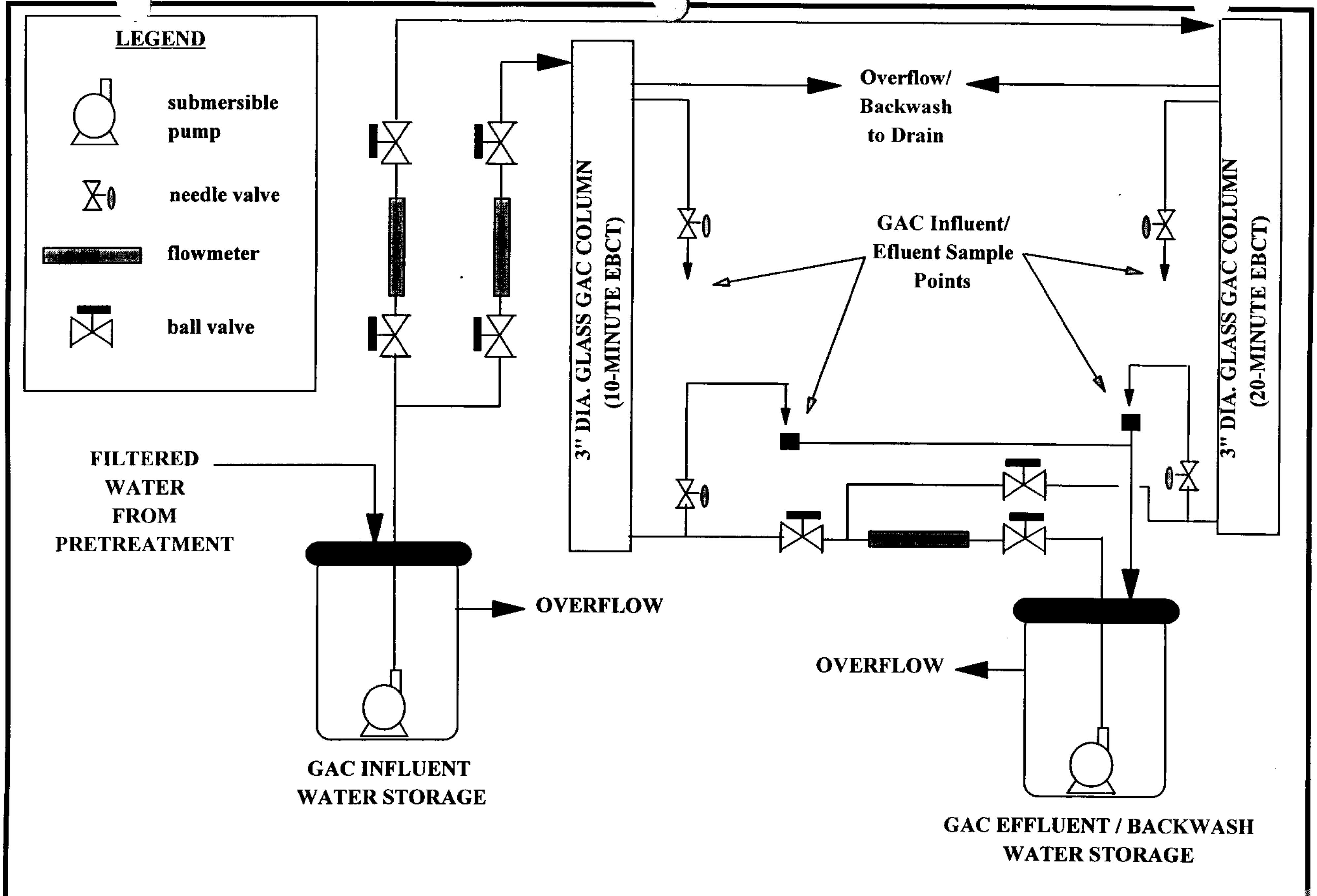
The pilot plant piping consisted of PVC piping and provided reasonable flow velocities through the pilot process. Ball valves were used to dictate flow direction and quantity. Flow meters, placed at the entrance to the treatment basin and each of the filter columns, allowed monitoring of process flows. The sedimentation basins and filters contained overflow piping to route overflow to a floor drain.

The filters operated in a pseudo-constant rate mode. Pilot plant operators adjusted the effluent flow (as flow decreased) using a ball valve to maintain fairly constant flow to the filtered water storage reservoir. The filters were backwashed based on headloss with unchlorinated, GAC treated water. A submersible pump pumped water from the GAC effluent reservoir, a 55-gallon HDPE tank, into the backwash line. On occasion, "clumps" of ferric sulfate coagulated particles built up in the filters. Attempts were made to break up the clumps by tapping the outside of the filter columns. This was moderately successful.

3.2 Description of GAC Filtration Process

Figure 3-2 is a schematic of the GAC treatment process. The process contained two, glass GAC contactors. Filtered water, from the pretreatment process, was pumped to the top of the glass columns. A flowmeter and ball valve were used to monitor and regulate the influent flow to the contactors as necessary. Influent flows throughout the study were maintained at approximately 0.2 to 0.24 gpm. Constant head was maintained on the GAC columns using overflow outlets near the top of each column. Effluent flows were maintained at approximately 0.4 L/min to provide the appropriate EBCT. Pilot plant operators monitored the effluent flow from the GAC columns every two to three days to maintain the flow rate. Effluent flow rates were measured using a graduated cylinder and stop watch and were adjusted with a Teflon needle valve at the base of each column. The influent and effluent flow rates had to be closely monitored for the dual-media and GAC filters to ensure adequate flow reaches the GAC columns to prevent drying of the GAC filter beds.

Table 3-2 shows design parameters for the GAC filtration process. The GAC media used in the study was Calgon Filtrasorb F820. This GAC was selected based on discussions with Calgon Corporation regarding source water quality, carbon adsorptive capacity, diameter, mesh size, full-scale design/operational considerations, and requirements of the "ICR Guidance Manual."



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PILOT-SCALE EVALUATION OF GAC FILTERS - ROLLING HILLS WTP
GAC ADVANCED TREATMENT PROCESS SCHEMATIC

FIGURE 3-2

Table 3-2: Rolling Hills WTP GAC Column Design Parameters		
Column/Description	**Parameter**	**Value**
1 Glass column with ½-inch influent, 1/4-inch influent sample tap, ½-inch overflow, and 1/4-inch effluent/effluent sample tap	Column Height	9 feet
	Column Diameter	3 inches
	Gravel Depth	4 inches
	GAC Depth	38 inches
	GAC Density	505.7 kg/m^3
	GAC Volume	4350 cm^3
	GAC Mass	2.2 kg
	EBCT	10 min
	Flow Rate	0.42 L/min
2 Glass column with ½-inch influent, 1/4-inch influent sample tap, ½-inch overflow, and 1/4-inch effluent/effluent sample tap	Column Height	9 feet
	Column Diameter	3 inches

Table 3-2: Rolling Hills WTP GAC Column Design Parameters		
	Gravel Depth	4 inches
	GAC Depth	76 inches
	GAC Density	505.7 kg/m^3
	GAC Volume	8700 cm^3
	GAC Mass	4.4 kg
	EBCT	20 min
	Flow Rate	0.42 L/min

As required by ICR testing protocol, all construction materials between the influent and effluent taps (including sample taps) of the GAC columns were either glass, Teflon, or stainless steel.

On two occasions it was necessary to backwash the GAC filters. The same backwashing procedure was used as for the dual-media filters. A submersible pump delivered GAC-treated water back through the GAC beds. Spent backwash exited the column through the column overflow, leading to the floor drain. Each filter column was piped with appropriate valving to control backwash rates and to allow backwashing of one filter or all filters simultaneously. Typical backwash rates for the dual-media filters were 2 gpm while lower rates were used for the GAC columns to avoid media loss.

3.3 Experimental Design

The two GAC columns were tested in parallel, one with a 10-minute EBCT and one with a 20-minute EBCT. The filtered water (GAC influent) and the GAC effluent of both columns were each sampled 15 times during the study, as required by the ICR. The GAC columns were run until ICR operating time and/or TOC breakthrough requirements were met. Table 3-3 shows the GAC Study variables.

Table 3-3: Rolling Hills WTP GAC Pilot Study Variables		
Season	**Pretreatment**	**GAC EBCT**
Spring (April to June)	Conventional (pilot-scale simulation of current full-scale)	10 and 20-minute
Summer (July to September)	Conventional (pilot-scale simulation of current full-scale)	10 and 20-minute
Fall (October to November)	Conventional (pilot-scale simulation of current full-scale)	20-minute[1]

[1]The 10-minute EBCT GAC column was shut down, having met ICR requirements prior to the fall season.

As shown, the primary variables evaluated during the study were EBCT and seasonal effects.

The rationale behind the study design focused on fulfilling ICR requirements, investigating the effects of GAC on removing DBP precursors.

3.4 Procedures Specific to the GAC Study

The GAC Study was performed in accordance with the guidelines of the "ICR Manual for Bench- and Pilot-Scale Treatment Studies." The purpose of this section is to describe procedures that require additional explanation such as the method for determining sampling time and the simulated distribution system (SDS) conditions used for DBP formation analysis.

3.4.1 Using UV-254 to Predict TOC Breakthrough and Determine Sampling Times

As defined in the ICR Guidance Manual, each GAC column must be sampled at least 15 times. The duration of the tests depended on TOC breakthrough criteria; however, the ICR established minimum and maximum operation times of 4000 and 8000 hours. The tests ended when either 70 percent TOC breakthrough occurred for two consecutive samples two weeks apart or when TOC breakthrough reached 50 percent and did not increase by more than 10 percent after two months. TOC breakthrough was based on the influent TOC running average.

The goal for monitoring TOC breakthrough in each column was to sample at TOC breakthrough increments of 3 to 7 percent, generating smooth TOC breakthrough curves (TOC breakthrough versus time). Since an off-site, ICR certified laboratory performed TOC analysis, a means to predict TOC breakthrough and sampling times was necessary at the pilot facility. To accomplish this task, the pilot plant operators used an ultraviolet spectrophotometer to measure ultraviolet absorbance at 254 nanometers (UV-254). Although a constant correlation of UV-254 and TOC in the GAC effluent was not expected over time (since GAC typically preferentially removes UV-254 adsorbing organics) it was expected that basing sampling intervals on UV-254 breakthrough would provide a smoother TOC breakthrough curve than the guidelines in the "ICR Guidance Manual." Thus, GAC effluent samples were taken for every 3 to 7 percent increase in UV-254 breakthrough. Section 4.0 provides a discussion of the results. The procedure for measuring UV-254 was as follows:

- Collect influent and effluent samples from each GAC column in glass bottles
- Filter 20 mL of milli-Q water (stored in a glass bottle) through a 0.45 micron syringe filter
- Obtain 6 mL of milli-Q water in the syringe
- Rinse the cuvette with 3 mL of milli-Q using the syringe filter and filter the remaining 3 mL for the blank
- Insert the blank into the spectrophotometer (set for absorbance readings at 254 nanometers) and zero the instrument
- Filter 20 mL of milli-Q water through a new 0.45 micron syringe filter
- Obtain 6 mL of sample water
- Rinse the cuvette with 3 mL of sample using the syringe filter and filter the remaining 3 mL to place in the cuvette for the UV-254 measurement
- Rinse the syringe and use a new syringe filter for each sample (rinsed with 20 mL of milli-Q water)

Rinsing with milli-Q water minimized the possibility of leaching UV-254 adsorbing organics from the syringe filter into the sample. Using a milli-Q blank and following the same preparatory procedures for each sample provided a baseline, and eliminated the contribution of organics from sources other than the GAC-treated water sample.

As expected, UV-254 breakthrough was slightly slower than TOC breakthrough. UV-254 breakthrough reached a plateau after approximately two months and varied up and down through the remainder of the tests. Influent UV-254 decreased through the duration of the study, leading to a decrease in effluent values (percent breakthrough reached a plateau). Due to the variance in UV-254 in the latter portion of the test, the last few samples were taken based more on spacing over time and significant variations in breakthrough rather than incremental increases in UV-254. This was done to evaluate breakthrough criteria for the end of the test rather than taking a number of samples providing potentially similar results (increasing cost) or taking too few to generate the upper portion of the breakthrough curve. These results are provided and discussed further in Section 4.0.

3.4.2 Simulated Distribution System (SDS) Test Conditions:

Table 3-4 shows the target conditions for the SDS tests. The SDS test procedure is outlined in bulleted format below.

Table 3-4: Rolling Hills WTP SDS Target Conditions

Parameter	Value
Chlorination pH	8.2
Chlorination Temperature	Ambient (Water) Temperature
Detention Time	24 hours
Free Chlorine Residual	0.5 to 1.0 mg/L

SDS Test Procedure:

For each GAC column sampling event, the following procedure was used to determine DBP formation in the GAC influent or GAC-treated water:

- Fill one- 1 L glass bottle and three- 250 mL glass bottles (no headspace)
- Refrigerate 1 L bottle to preserve sample

- Spike three- 250 mL bottles with different free chlorine doses

- Place three- 250 mL bottles in sedimentation effluent basin (served as a ambient temperature water bath) for 24 hours

- After 24 hours, measure chlorine residual in each 250 mL sample bottle

- Plot chlorine residual versus dose and determine the appropriate free chlorine dose to provide the target residual in the 1 L sample bottle

- Remove the 1 L sample bottle from the refrigerator and allow the sample to reach room temperature

- Pour the sample into a flask, gently mix, and add caustic to raise the pH to 8.2 (it was previously determined that chlorine addition did not provide a measurable reduction in pH)

- Pour the sample back into the 1 L glass bottle, add chlorine dose, seal, and place in the sedimentation effluent basin for 24 hours

- After 24 hours, remove the 1 L bottle, measure pH, temperature and chlorine residual, and pour sample into THM, HAA, and TOX sample bottles for shipment to the laboratory

The samples were shipped to the laboratory in coolers with ice packs to preserve the samples. The SDS test procedure described above was completed within 5 days of the initial sampling (as recommended in a letter from the ICR Treatment Studies Coordinator). Section 4.0 presents SDS results while the following section discusses analytical methods used during the study.

3.5 Analytical Methods and Testing Laboratory Information

Table 3-5 shows the analytical methods used during the pilot study. Montgomery Watson Laboratories, Pasadena, CA performed the analysis for a majority of the parameters as shown.

Table 3-5: Rolling Hills WTP GAC Pilot Study Laboratory Analytical Methods		
Analyte	**Method**	**MDL**
Montgomery Watson Laboratories		
Alkalinity	SM2320B	2.0 mg/L as $CaCO_3$
Ammonia	EPA 350.1	0.05 mg/L
Bromide	EPA 300	0.02 mg/L
Calcium Hardness	EPA 200.7	5.0 mg/L as $CaCO_3$
HAAs	SM6251B	1.0 µg/L except: TBAA - 4.0µg/L DBCAA & MCAA - 2.0µg/L
THMs	EPA 502.2	1.0 µg/L
Total Hardness	SM2340B	7.0 mg/L as $CaCO_3$
TOC	SM5310C	0.5 mg/L
TOX	SM5320	25 µg/L

Analytical methods and detection limits were the same through the duration of the study. The supplemental laboratory QA/QC data spreadsheets ("Treatment Study Summary Spreadsheet"), included with this "Treatment Study Summary Report," provide QA/QC data and more details regarding analytical methods and detection levels. In addition, Montgomery Watson included information regarding calibration procedures. Section 5.0 references these procedures which are included as an attachment to this summary report. Table 3-6 provides additional laboratory information.

Table 3-6: ICR Laboratory Information					
Laboratory	**Lab #**	**Address**	**Contact**	**Phone Number**	**Fax Number**
Montgomery Watson Laboratories	CA013	555 E. Walnut St., Pasadena, CA 91101	Debbie Frank	626/568-6400	626/568-6324

Temperature, pH, turbidity, chlorine residual and UV-254 analysis were performed on-site by the pilot plant operators using a Hach turbidimeter and pH/temperature meter, a spectrophotometer, and chlorine analyzer. The equipment were calibrated using standard solutions provided by the manufacturer. UV-254 analysis was performed to predict TOC sample times. Section 3.4 provides a discussion regarding procedures for measuring UV-254 with the spectrophotometer.

4.0 RESULTS AND DISCUSSION

This section provides the results of the ICR GAC pilot study.

4.1 Significant Observations

There are some important pieces of information, not shown in the data spreadsheets, that may assist in interpreting the results presented in this section. The following bulleted list provides observations and information not conveyed in the data spreadsheets:

General -

- The GAC columns operated in a pseudo-constant rate mode. Gradual headloss through the columns necessitated consistent monitoring and adjustment of the effluent flow to maintain the EBCTs. Operators adjusted effluent flows (by opening the effluent valve further) to maintain an average flow that produced 10 and 20 minute EBCTs. Table 4-1 shows the approximate range of effluent flows and corresponding EBCTs for each column through the duration of the tests. For a majority of the study, the EBCTs were maintained very close to 10 and 20 minutes.

Table 4-1: Rolling Hills WTP GAC Pilot Study Actual GAC Column Effluent Flow and EBCT Ranges

Design EBCT	Effluent Flow	Actual EBCT
10 minutes	0.40 to 0.44 L/min	10 to 11 minutes
20 minutes	0.40 to 0.44 L/min	20 to 22 minutes

- The actual average EBCTs, based on actual bed volume and average flow were approximately 10.3 and 20.7 minutes.

- The pilot plant operators backwashed the GAC on two occasions. Backwashing was either necessary due to gradual headloss or due to drying of the GAC beds from pilot equipment problems or full-scale plant shut downs. Table 4-2 shows information regarding backwashing events.

Table 4-2: Rolling Hills WTP GAC Pilot Study GAC Backwashing Events			
Date	**EBCT**	**Downtime (hr)***	**Reason**
4/24/98	10 and 20	72	Floc basin ruptured - plant taken off-line
8/1/98	10 and 20	0	High turbidity in the filtered water effluent lead to high loading on the GAC filters. A layer of floc was visible on the media surface, generatingheadloss problems in the columns

*downtime was subtracted from cumulative operating times shown in results and data spreadsheets

- The high turbidity event had a small effect on the study. UV-254 values were slightly higher in the effluent; however, after a few days, the values decreased back into the range of values seen before backwashing.

- On April 24, 1998 the flocculation basin ruptured, causing no flow to the remainder of the pilot process. The GAC columns went dry prior to discovering the break.

- April 15th marked the start of the experiment. On that date the WTP was receiving 100% of its raw water from the Richland Chambers reservoir (RCR). The corresponding ferric dosage was 20.4 mg/L. Based on the previous months' records, the decision was made to set the pilot plant ferric feed rate at 24.0 mg/L.

- On April 20th, the WTP started to receive water from the Cedar Creek reservoir (CCR). The raw water blend was 80% RCR water and 20% CCR water. The blend fluctuated between 80/20 RCR to CCR water and 60/40 RCR to CCR water over the first 2470 hrs of the experiment. The ferric feed rate for the WTP plant fluctuated between 17 and 26 mg/L. The pilot plant ferric feed rate was held constant at 24 mg/L, as the settled water effluent and filtered water effluent turbidity levels were acceptable. From August 27 to September 7, the WTP received 48% RCR, 25% CCR, and 27% Lake Benbrook water.

- Two incidents occurred which resulted in high turbidity influent. The first occurred on July 11; however, the pilot plant was down for repairs due to a break in the raw water line to the pilot plant. No adjustments to chemical feed rates were required. Once the pilot plant was back on line on July 13, the raw water turbidity level had decreased.

- On August 1, the transmission line from the RCR experienced a major break. The plant began receiving 100% CCR water, and the corresponding turbidity levels of the influent water to the plant were much higher. The WTP responded to the change in raw water by increasing the ferric dosage to 50 mg/L. The pilot plant operator was not aware of the switch to 100% CCR water for 48 hours. Spikes in turbidity and UV-254 occurred at the 2500 hour mark in the test. On August 3, ferric dosage rates at the pilot plant were increased to 50 mg/L in response to the use of CCR water. The WTP reduced the ferric feed rate on August 7, to 38 mg/L and then to 28 mg/L on August 8. The feed rate in the pilot plant was reduced to 24 mg/L on August 8, and remained at that rate for the remainder of the experiment.

- The dual media filters were effective in reducing turbidity of the settled water; however, at approximately 3000 hours, the turbidity levels were continuously greater than 1.0 NTU. Each filter was repacked with fresh sand and anthracite in order to increase the removal efficiency.

- There was little rainfall through the duration of the study. The summer months were extremely hot. From May through early September, northeast Texas experienced extremely hot and dry weather. For 35 consecutive days the temperature was greater than 100 F with high temperatures approaching 110 F. There were a few rain events in spring and fall, but none of significance in the summer.

Data Specific -

- For a few influent and effluent samples, the chlorine residual was less than 0.2 mg/L. DBP results corresponding to these samples were not reported in the data collection spreadsheets and are not shown in the figures provided in section 4.3 (the omission of these data contribute to the “fragmented” appearance of the figures).

- Sample A15 for the 10 minute EBCT column possessed a higher chlorine demand and subsequently higher DBP levels than expected from the trends of the previous results. This could be due to changes in source water blend.

4.2 Raw Water and GAC Influent Water Quality

Table 4-3 shows raw water quality during testing. The table provides a range of values for the three seasons in which testing occurred.

Table 4-3: Rolling Hills WTP GAC Pilot Study Raw Water Quality Summary

Time Period	pH	Turbidity (NTU)	Alkalinity (mg/L)
April - May	7.61-8.59	5.2-28.7	76-109
June - August	7.23-7.55	2.3-7.1	49-93
Sept. - Nov.	7.14-7.95	2.4-49.2	58-100

Table 4-4 provides a summary of the GAC influent (pretreated) water quality. This table provides average values for the three seasons in which testing occurred.

Table 4-4: Rolling Hills WTP GAC Pilot Study Pretreated Water Quality Summary

Parameter	Spring (April to June)	Summer (July to September)	Fall (October to November)
pH	7.52 (0.09)	7.51 (0.33)	7.59 (0.18)
Turbidity (ntu)	0.72 (0.62)	0.93 (0.36)	0.72 (0.21)
Alkalinity (mg/L as $CaCO_3$)	76.5 (10.2)	63.8 (14.4)	66.5 (3.3)
Temp (degrees C)	24.1 (1.4)	26.0 (1.6)	22.8 (1.8)
Total Hardness (mg/L as $CaCO_3$)	102 (6)	82 (14)	88 (9)
Calcium Hardness (mg/L as $CaCO_3$)	89 (7)	67 (14)	74 (7)
Bromide (µg/L)	66 (30)	75 (14)	69 (7)
TOC (mg/L)	3.4 (0.2)	4.0 (0.9)	3.4 (0.7)
UV-254 (1/cm)	0.088 (0.025)	0.087 (0.021)	0.062 (0.012)
SUVA (L/mg-m)	2.6 (0.8)	2.2 (0.2)	1.8 (0.1)
SDS TOX (µg/L)	270 (53)	235 (21)	258 (24)
SDS THM4 (µg/L)	101 (24)	94 (6)	88 (9)
SDS HAA5 (µg/L)	41 (12)	31 (1)	37 (5)

Table 4-4: Rolling Hills WTP GAC Pilot Study Pretreated Water Quality Summary			
Parameter	**Spring (April to June)**	**Summer (July to September)**	**Fall (October to November)**
SDS HAA6 (µg/L)	49 (13)	39 (3)	45 (5)

Average (Standard Deviation)

4.2.1 Seasonal Trends

Tables 4-3 and 4-4 indicate the following:

- There were no significant seasonal trends. The changing water source made it difficult to investigate seasonal effects.

- UV-254 and SUVA decreased significantly in the fall months, indicating a change in the type of organics present in the source water.

4.3 Significant Results

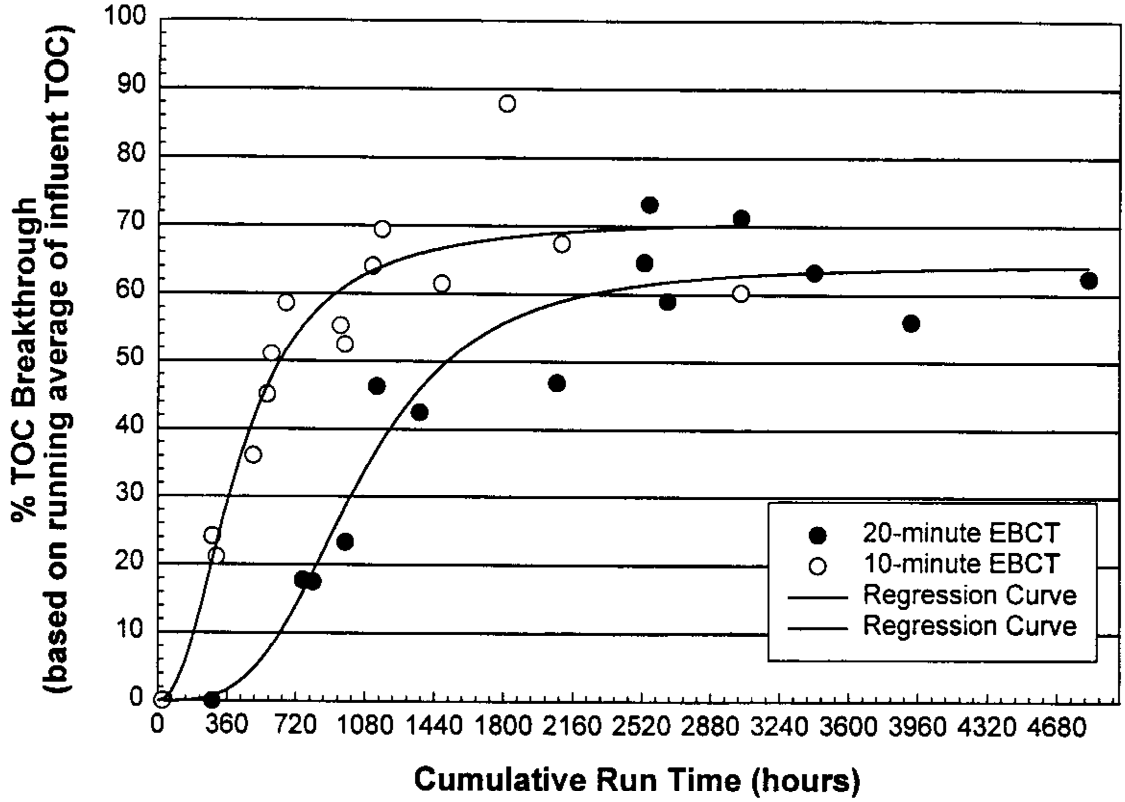
This section provides significant results of the GAC study in graphical and tabular form.

TOC Breakthrough:

Figure 4-1 is a plot of percent TOC breakthrough (based on influent TOC running average) over time and Figure 4-2 shows breakthrough in terms of TOC concentration for the 10 and 20 minute EBCT GAC columns. Figure 4-1 illustrates the distribution of results and the variance in some of the TOC results (likely due to changes in source water). The 10 minute EBCT column reached the 70% breakthrough point and was operated for an additional period of time to obtain the complete set of 15 samples. The 20 minute EBCT column met the plateau criteria.

As shown in Figure 4-1, two samples exceeded 70 percent breakthrough; however, these samples were not collected during consecutive sampling events and hence did not constitute a stopping criterion. The samples collected after these did not provide a breakthrough increase of 10 percent and subsequently led to the plateau criterion . Since UV-254 results (shown below in Figure 4-3) reached a plateau (actually varied up and down) and no longer provided an accurate indicator of when to sample for TOC, the last few sample events were spaced over time.

Figure 4-1: GAC Pilot Results - Rolling Hills WTP, ICR#646 % TOC Breakthrough Over Time



10-minute EBCT

y=71.21/[1+(x/425.6)^-2.17]
R^2 = 0.89

20-minute EBCT

y=64.42/[1+(x/1044.3)^-3.42]
R^2 = 0.94

Figure 4-2: GAC Pilot Results - Rolling Hills WTP, ICR#646
TOC Breakthrough

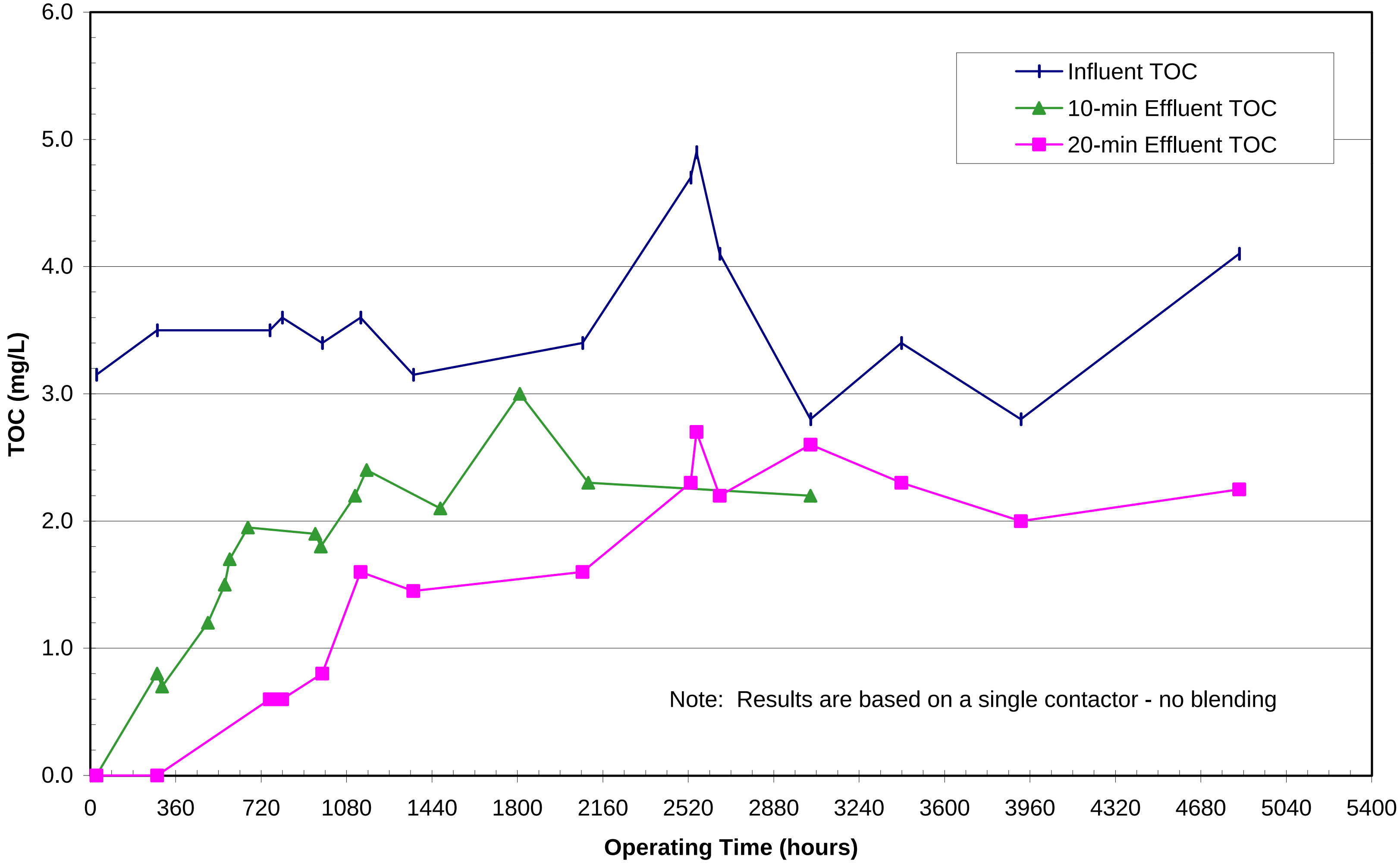


Figure 4-2 shows the influent TOC concentrations varied between 2.8 and 4.9 mg/L. The values at approximately 2500 hours were the result of the switch to 100% Cedar Creek water. As discussed in Section 4.1, the coagulant feed was not adjusted to account for the change in source water (simulating the increase in coagulant feed at the full-scale plant), leading to spikes of organics and turbidity at the filters. The rate of TOC breakthrough in the 10 minute column was approximately two times that of the 20 minute column until these last few samples.

UV-254 Breakthrough:

Figure 4-3 shows UV-254 breakthrough results. Influent UV-254 decreased through the duration of the experiment. The major peaks, or changes in UV-254 occur at times when the source water changed. It appeared UV-254 values were generally between 0.060 and 0.080 (1/m) when the most common blend and type of source water was treated at the WTP. The decreased UV-254 values late in the test could be due to seasonal influences or from a change in source water blend. As shown, samples were taken at fairly even incremental increases in UV-254, except where attempting to define breakthrough at points when the source water quality changed. The tenth set of samples was taken at approximately 2500 hours because of the increase observed in UV-254. It was not known at the time of sampling that the source water had been changed. After adjusting pilot operations, another sample was taken to redefine breakthrough.

SDS Chlorine Demand:

Figure 4-4 shows SDS free chlorine demand during the study. As expected, with increasing TOC breakthrough, chlorine demand increased. Influent water chlorine demand was variable, potentially due to changes in the source water. However, a few influent data points are not shown because the free chlorine residual achieved in the SDS testing was not greater than 0.2 mg/L.

DBP Breakthrough:

Figures 4-5 through 4-7 show THM4, HAA5, and HAA6 results. DBPs tended to increase gradually over time. Like the influent chlorine demand curve, the influent DBP curves

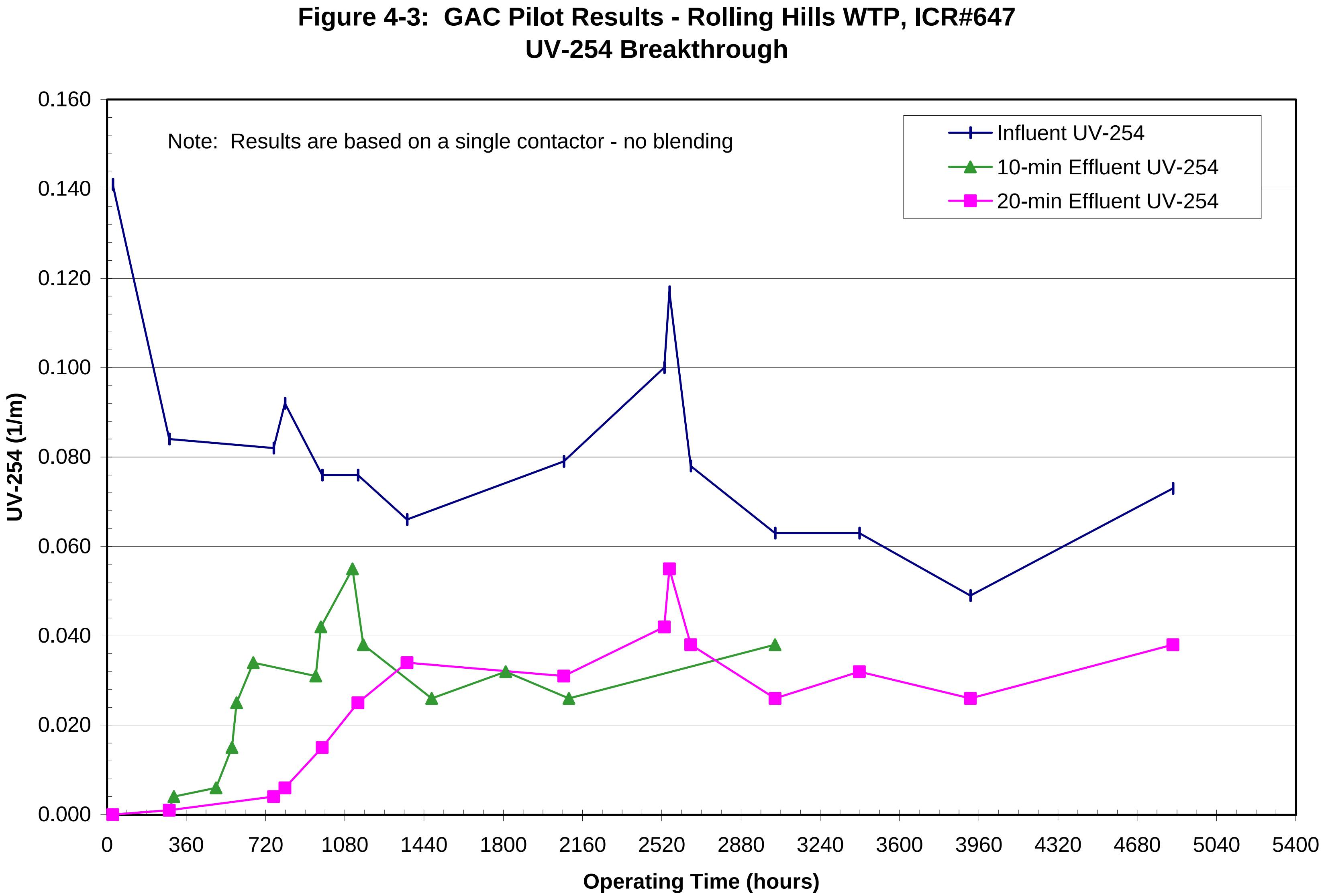


Figure 4-3: GAC Pilot Results - Rolling Hills WTP, ICR#647
UV-254 Breakthrough
Note: Results are based on a single contactor - no blending
Influent UV-254
10-min Effluent UV-254
20-min Effluent UV-254
UV-254 (1/m)
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
0
360
720
1080
1440
1800
2160
2520
2880
3240
3600
3960
4320
4680
5040
5400
Operating Time (hours)

Figure 4-4: GAC Pilot Results - Rolling Hills WTP, ICR#646
SDS-Free Chlorine Demand

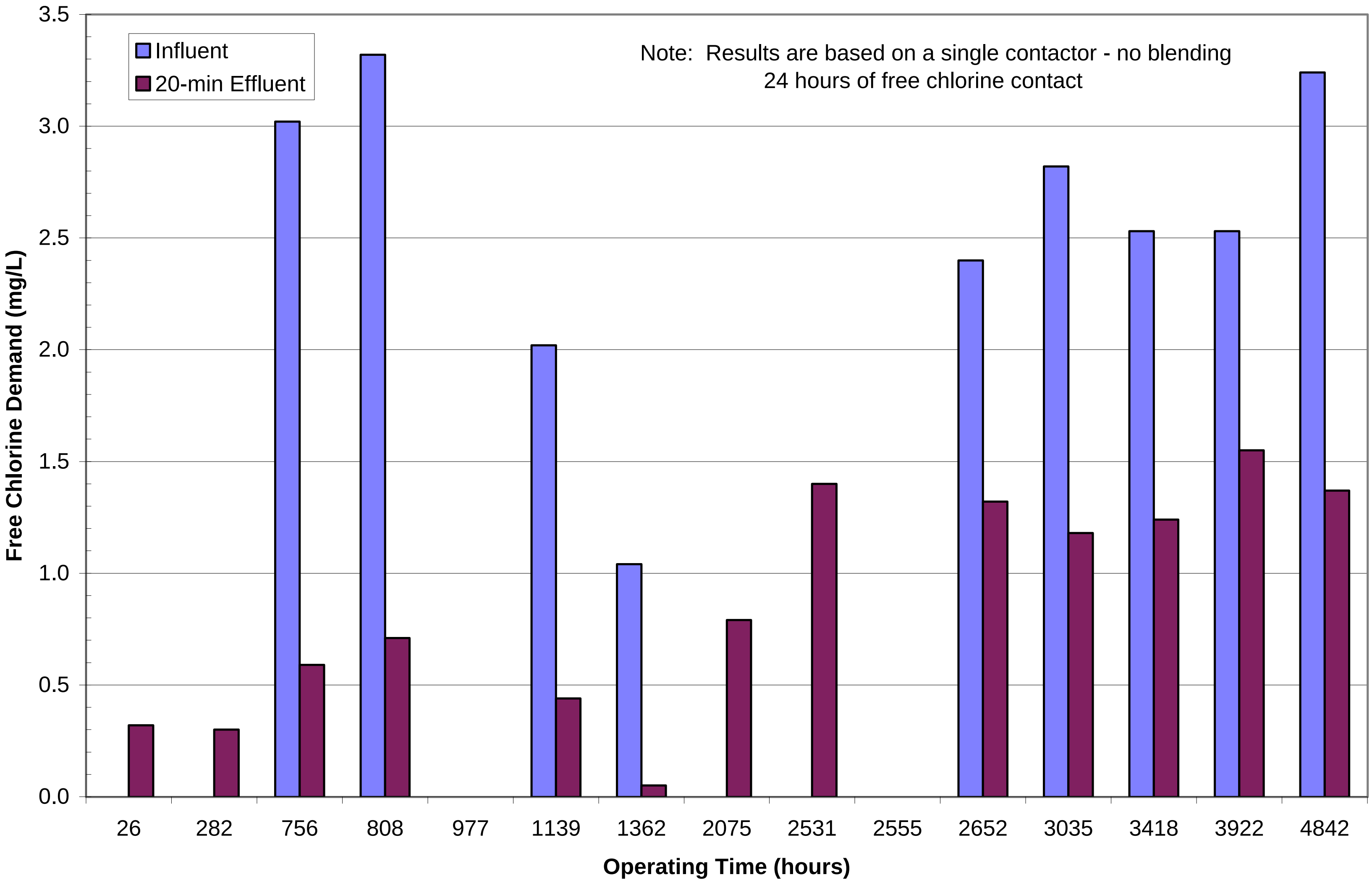


Figure 4-5: GAC Pilot Results - Rolling Hills WTP, ICR#647
THM4 Breakthrough

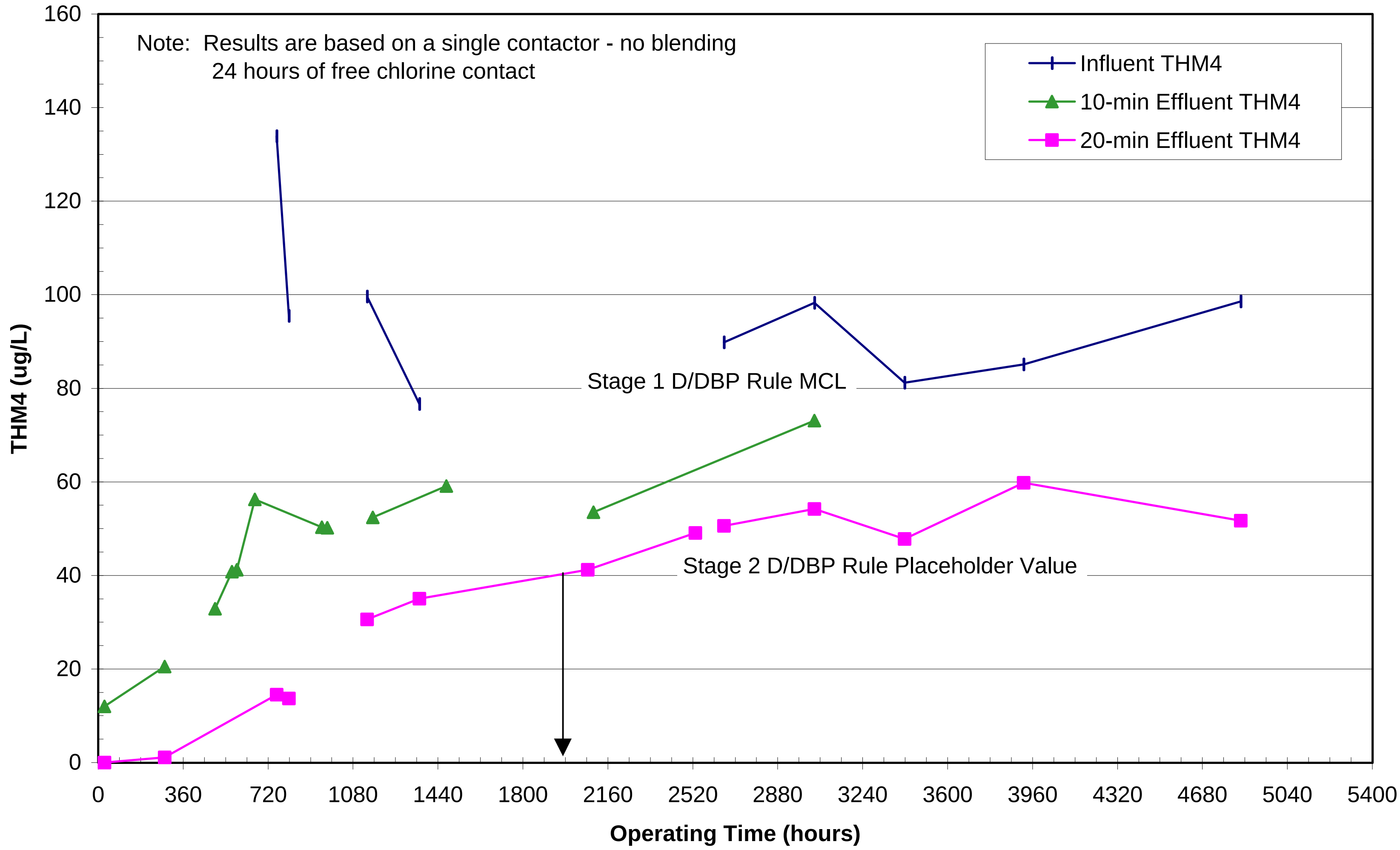
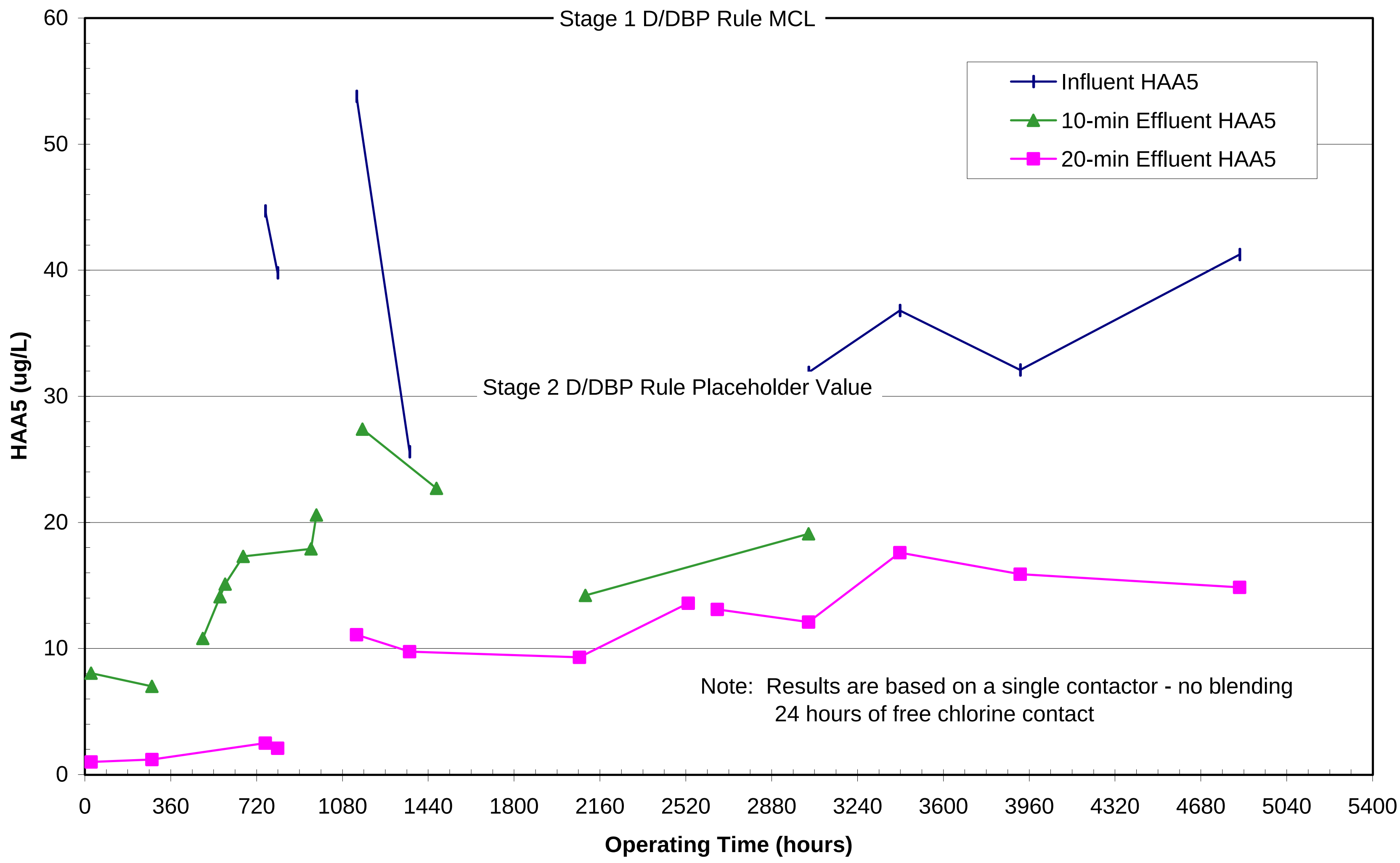


Figure 4-6: GAC Pilot Results - Rolling Hills WTP, ICR#646
HAA5 Breakthrough



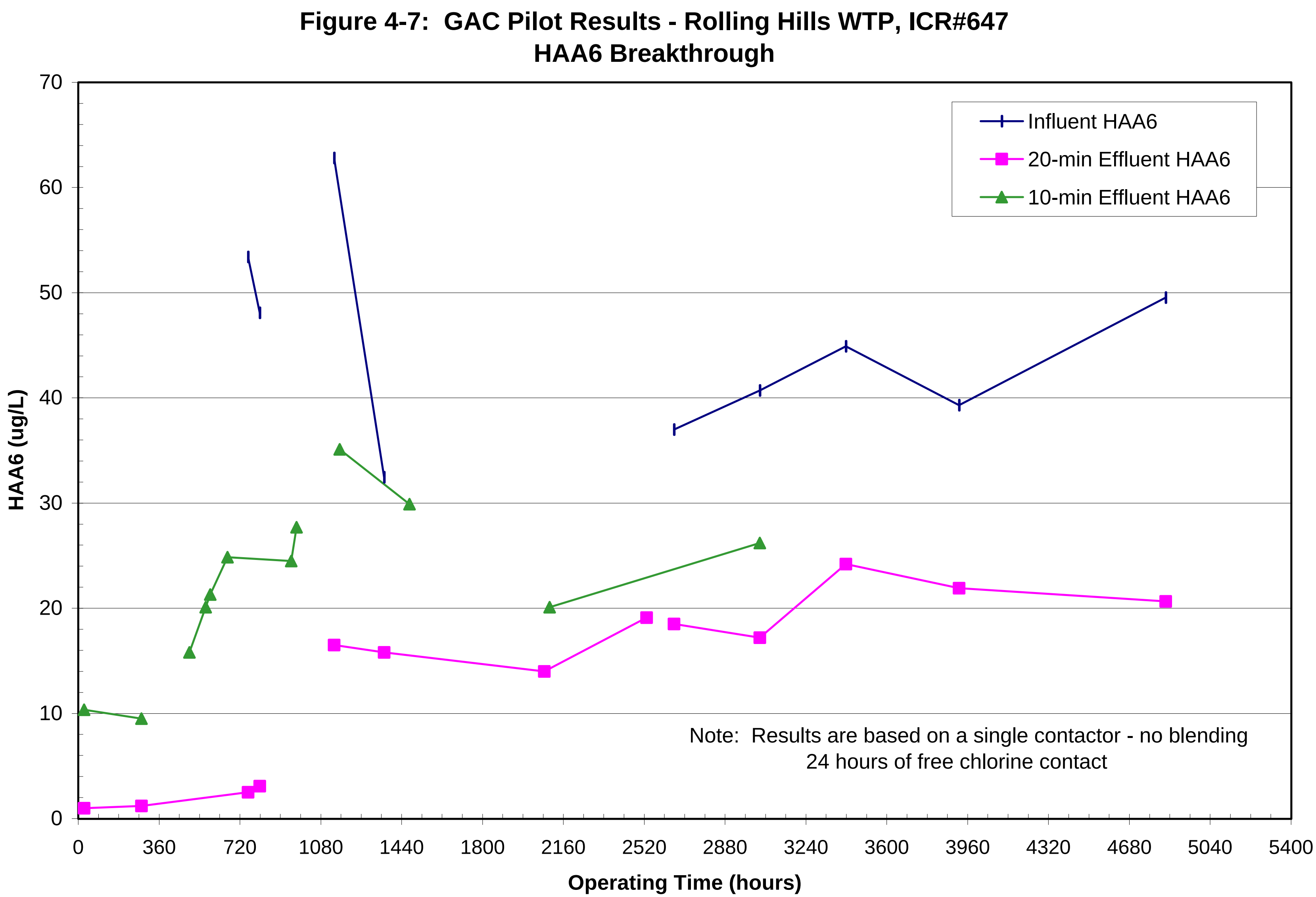


Figure 4-7: GAC Pilot Results - Rolling Hills WTP, ICR#647
HAA6 Breakthrough
HAA6 (ug/L)
0
10
20
30
40
50
60
70
0
360
720
1080
1440
1800
2160
2520
2880
3240
3600
3960
4320
4680
5040
5400
Operating Time (hours)
Influent HAA6
20-min Effluent HAA6
10-min Effluent HAA6
Note: Results are based on a single contactor - no blending
24 hours of free chlorine contact

are variable, especially in the first two months of the tests. Table 4-5 shows run times and bed volumes at which certain DBP breakthrough criteria were met. The breakthrough criteria in the table are based on 90 percent of the Stage 1 D/DBP Rule MCL and the proposed Stage 2 “placeholder” MCLs.

Table 4-5: Rolling Hills WTP GAC Pilot Study Value of Listed Parameters when Various Breakthrough Criteria are Met

Break-through Criterion (under SDS conditions)	Run Time (hours)		Bed Volumes		TOC (mg/L)		THM4 (µg/L)		HAA5 (µg/L)		HAA6 (µg/L)		TOX (µg/L)	
	EBCT (minutes)													
	10	20	10	20	10	20	10	20	10	20	10	20	10	20
THM4: 90 µg/L	--	--	--	--	--	--	90	90	--	--	--	--	--	--
THM4: 72 µg/L	2970	--	17820	--	2.2	--	72	72	19	--	26	--	145	--
THM4: 36 µg/L	500	1350	3000	8100	1.4	1.5	36	36	11	10	16	16	85	70
HAA5: 54 µg/L	--	--	--	--	--	--	--	--	54	54	--	--	--	--
HAA5: 27 µg/L	1170	--	7020	--	2.4	--	53	--	27	27	35	--	165	--
HAA6: 54 µg/L	--	--	--	--	--	--	--	--	--	--	54	54	--	--
HAA6: 27 µg/L	950	--	5700	--	1.9	--	50	--	18	--	27	27	110	--

-- did not reach breakthrough at the stated level

This table provides the following major results (based on a single contactor - no blending):

- GAC effluent HAA5 concentrations for both GAC columns did not exceed 90% of the Stage 1 MCL.

- GAC effluent HAA5 concentrations for the 10 minute EBCT column exceeded 90% of the Stage 2 placeholder MCL.

- THM4 results for the 10 minute EBCT GAC column exceeded 90% of both the Stage 1 and Stage 2 placeholder MCLs. For the 20 minute EBCT column, THM4 exceeded 90% of the Stage 2 placeholder MCL only.

- THM4 breakthrough appears to dictate GAC performance (breakthrough at the THM4 MCL occurs before breakthrough at the HAA5 MCL).

- Stage 1 THM4 breakthrough occurred at approximately 4 months for the 10 minute EBCT column and did not occur for the 20 minute EBCT column.

TOX Breakthrough:

Figure 4-8 shows TOX breakthrough results. Again, similar characteristics in the data were observed. TOX tended to increase gradually over time, reaching a plateau at approximately 150 μg/L. Like the influent chlorine demand curve, the influent TOX curves are variable, especially in the first two months of the tests.

4.3.1 Seasonal Trends

Each of the figures presented indicates similar trends in results. However, these trends are likely more related to changes in the type and combination of source water being treated. The changes in source water and variable nature of some of the results made it difficult to evaluate seasonal effects.

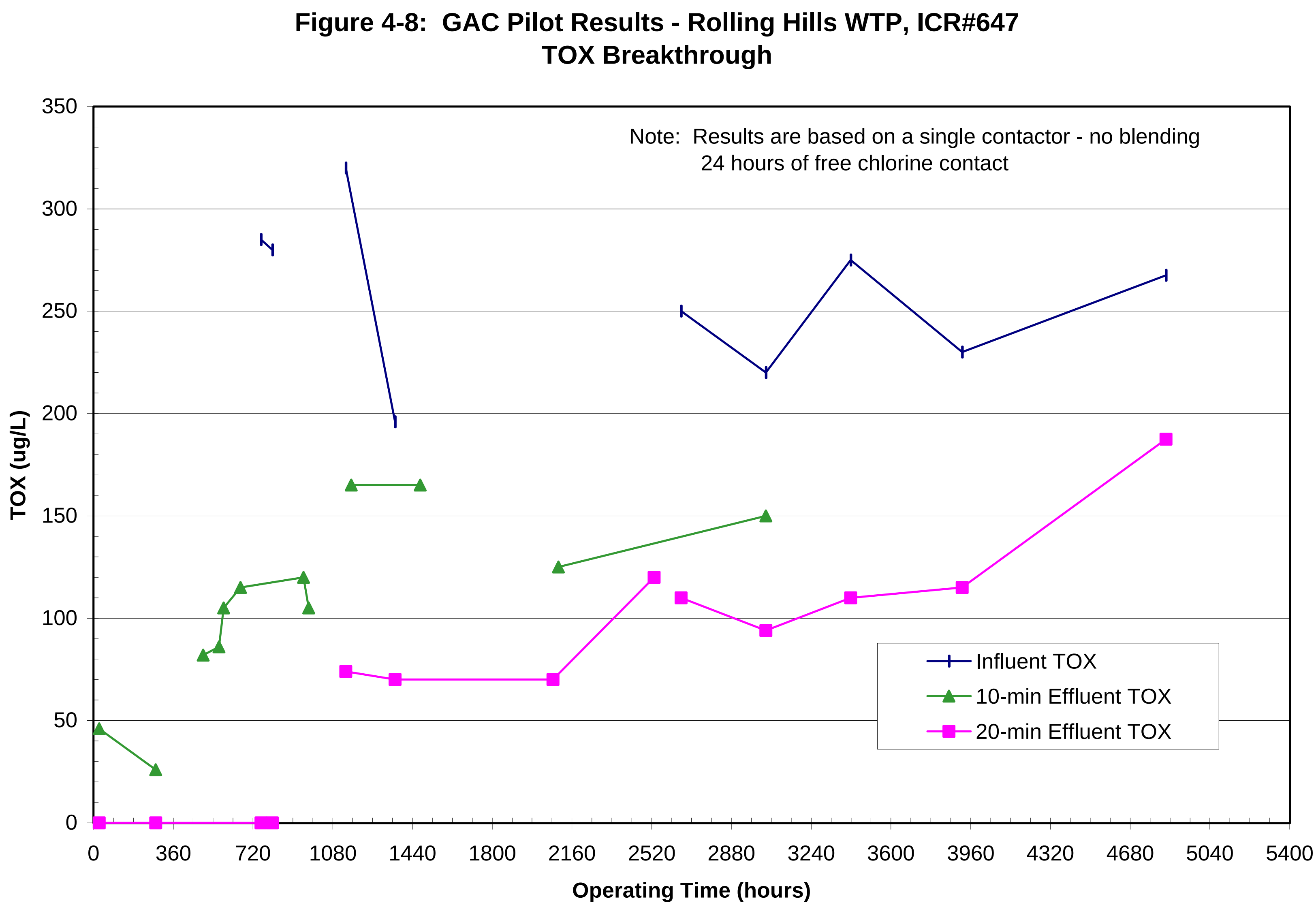


Figure 4-8: GAC Pilot Results - Rolling Hills WTP, ICR#647
TOX Breakthrough
Note: Results are based on a single contactor - no blending
24 hours of free chlorine contact
TOX (ug/L)
Operating Time (hours)
Influent TOX
10-min Effluent TOX
20-min Effluent TOX
0
50
100
150
200
250
300
350
0
360
720
1080
1440
1800
2160
2520
2880
3240
3600
3960
4320
4680
5040
5400

5.0 QA/QC SUMMARY

The “Treatment Study Summary Report Spreadsheet” provides QA/QC information for the GAC pilot study. Montgomery Watson completed the QA/QC portions of the spreadsheet pertaining to their analyses. Attachment A, included with this summary report, provides Montgomery Watson’s calibration procedures for the analytical methods presented in Section 3.0.

ATTACHMENT A

Montgomery Watson Laboratories

Calibration Verification and Quality Control Procedures

CALIBRATION VERIFICATION AND QUALITY CONTROL PROCEDURES - METHOD SPECIFIC

Performance Criteria	Method → Analytes	EPA300.0 A, B *Br*	SM 6251B Haloacetic Acids *(HAA)*	*UV 254* SM 5910 B *UV 254*
↓	Target Analytes	Bromide (Br^-)	Monochloroacetic (MCAA) Dichloroacetic acid (DCAA) Dibromoacetic acid(TCAA) Trichloroacetic acid (TCAA) Monobromoacetic acid (MBAA) Bromochloroacetic acid (BCAA)	UV Absorbance at 254 nm
1.0 IDC				
1.1 IDLSB	Method Blank	< 1/2 MRL	< 1/2 MRL	< 1/2 MRL
1.2 IDA	QC check sample (external source)	+/- 20% of true value	+/- 20% of true value	+/- 20% of true value
1.3 IDP	No. of replicates	5	5	5
	Spike conc.	Br^- 0 .10 mg/L	20	6.5 mg/L ± 0.5 mg/L DOC (Dissolved Organic Carbon)
	% RSD	< 20	< 20	< 20
	% Recovery	80-120	80-120	80-120
	No. of replicates	7	7	7
	Spike conc.	1/2 MRL	1/2 MRL	0.5 mg/L DOC (Dissolved Organic Carbon) = 0.009 cm^{-1}
	% Recovery	50-150	50-150	50-150
2.0 MRL		Br: 0.020 mg/L	MCAA: 2.0 ug/L	0.009 cm^{-1}

CALIBRATION VERIFICATION AND QUALITY CONTROL PROCEDURES - METHOD SPECIFIC

Performance Criteria	Method → Analytes	EPA300.0 A, B *Br*	SM 6251B Haloacetic Acids *(HAA)*	*UV 254* SM 5910 B *UV 254*
			Others:1.0 ug/L	
3.0 Calibration Verification/ Frequency		Lowest level std. analyzed at the beginning of each 24 hour- before first sample run Mid level and high level analyzed alternately after 10th sample and after the last sample.	Lowest level std. analyzed at the beginning of each 24 hour- before first sample run Mid level and high level analyzed alternately after 10th sample and after the last sample.	Lowest level std. analyzed at the beginning of each 24 hour- before first sample run Mid level and high level analyzed alternately after every 10th sample and after the last sample.
Calibration Verification Concentrations and Acceptance Criteria		***Br-*** ***(mg/L) (% rec.)***	***MCAA*** ***(ug/L) (% rec.)***	***UV254*** ***(cm^{-1}) (% rec.) (%RPD)***
	Low	0.02 50-150	2.0 50-150	0.009 75-125 </= 20
	MIdlevel	0.10 90-110	20 80-120	0.088 85-115 </= 10
	High	0.30 90-110	32 80-120	0.866 85-115 </= 10
			All others ***(ug/L) (% rec.)***	
	Low		1 50-150	
	MIdlevel		20 80-120	
	High		32 80-120	
4.0 Reagent (Method) Blank				
Frequency		one per analysis batch	one per analysis batch (one per extraction batch)	Initial zero; Check after each 10 samples
QC Criteria		< 1/2 of MRL	< 1/2 of MRL	< 1/2 of MRL (<0.0045 cm^{-1})

CALIBRATION VERIFICATION AND QUALITY CONTROL PROCEDURES - METHOD SPECIFIC

Performance Criteria	Method → Analytes	EPA300.0 A, B *Br*	SM 6251B Haloacetic Acids *(HAA)*	*UV 254* SM 5910 B *UV 254*
5.0 Shipping Blank	Travel Blank/ Field Reagent Blank	NA	NA	NA
QC Criteria		NA	NA	NA
6.0 LFM	Fortified Sample			
Frequency		5 % per analysis batch	one sample per extraction batch	NA
Matrix spike Level		same concentration as cal verification. If no historical data for sample level, rotate low, mid, high as spike conc.	same concentration as cal verification. If no historical data for sample level, rotate low, mid, high as spike conc.	NA
QC criteria		NA	NA	NA
7.0 Field/Lab Duplicate				Lab duplicate
Frequency		5% of the samples per analysis batch	one lab duplicate per extraction batch	all samples analyzed in duplicate
% RPD				</= 20 % (UV_{254} </=0.045)
QC criteria		NA	NA	</= 10 % (UV_{254} >0.045)
8.0 Internal Std.		NA	1,2-dibromopropane or 1,2,3-trichloropropane in each extract	NA
QC criteria		NA	+/- 30% of calibration curve AVG IS response 70-130 %	NA
9.0 Surrogate Standards		NA	2,3-dibromopropionic acid	NA
9.0 Surrogate Standards			or 2,3,5,6-tetrafluorobenzoic acid in each sample	

CALIBRATION VERIFICATION AND QUALITY CONTROL PROCEDURES - METHOD SPECIFIC

Performance Criteria	Method → Analytes	EPA300.0 A, B *Br*	SM 6251B Haloacetic Acids *(HAA)*	*UV 254* SM 5910 B *UV 254*
QC Criteria		NA	70-130 %	NA
10.0 Method Calibration Procedures	Initial Calibration Curve	Bromide Concentration (mg/L)	MCAA Concentration (ug/L)	NA
	Standard 1	0	2	
	Standard 2	0.02	5	
	Standard 3	0.05	10	
	Standard 4	0.1	20	
	Standard 5	0.3	40	
	Standard 6	0.5	-	
			All others Concentration (ug/L)	
	Standard 1		1	
	Standard 2		2	
	Standard 3		5	
	Standard 4		10	
	Standard 5		20	
	Standard 6		40	

CALIBRATION VERIFICATION AND QUALITY CONTROL PROCEDURES - METHOD SPECIFIC

Performance Criteria	Method → Analytes	EPA300.0 A, B *Br*	SM 6251B Haloacetic Acids *(HAA)*	*UV 254* SM 5910 B *UV 254*

CALIBRATION VERIFICATION AND QUALITY CONTROL PROCEDURES - METHOD SPECIFIC

	Performance Criteria	Method	THMs EPA 551.1	TOC SM 5310 C	TOX SM 5320B
		Analytes Target Analytes	*THM* **Trihalomethanes (THMs)** Chloroform (CHCl3) Bromodichloromethane (BDCM) Dibromochloromethane(DBCM) Bromoform (CHBR3)	*TOC* **Total Organic Carbon**	*TOX* **Total Organic Halide** **(Dissolved Organic Halogen)** **(DOX)**
1.0	IDC				
1.1	IDLSB	Method Blank	< 1/2 MRL	< 1/2 MRL	< 1/2 MRL
1.2 1.3	IDA IDP	QC check sample No. of replicates Spike conc. % RSD % Recovery	+/- 20% of true value 5 THM 20 ug/L < 20 80-120	+/- 20% of true value 5 TOC 4 mg/L < 20 80-120	+/- 20% of true value 5 TOX 250 ug/L < 20 80-120
1.4	MDL	No. of replicates Spike conc. % Recovery	7 1/2 MRL 50-150	7 0.5 50-150	7 1/2 MRL 50-150
2.0	MRL		THM 1.0 ug/L Others: 0.5 ug/L	0.70 mg/L 0.50 mg/L (during treatment studies)	50 ug Cl^-/L 25 ug Cl^-/L (during treatment studies)

CALIBRATION VERIFICATION AND QUALITY CONTROL PROCEDURES - METHOD SPECIFIC

	Performance Criteria	Method	**THMs** **EPA 551.1**	**TOC** **SM 5310 C**	**TOX** **SM 5320B**
3.0	**Calibration Verification**	**Verification Frequency**	Lowest level std. analyzed at the beginning of each 24 hr before the first sample Mid level and high level analyzed alternately after every 10th sample and last sample	Lowest level std. analyzed at the beginning of each 24 hr before the first sample Mid level and high level analyzed alternately after every 10th sample and last sample	3 microcoulometer titration cell checks with NaCl std at start of 8-10 hr. work shift. Lowest level std. analyzed before the first sample. Mid level and high level analyzed alternately after every 7th sample and last sample
	Conc. and QC criteria (%rec)		*THM* ***(ug/L) (% rec)***	*TOC* ***(mg/L) (% rec)***	***TOX*** (ug Cl-/L) (% rec)
		Low	1.0 50-150	0.7 (0.5) 50-150	50 (25) 75-125
		Mid-level	20 80-120	4 90-110	200 85-115
		High	40 80-120	9 90-110	500 85-115
4.0	**Reagent (Method) Blank**	***Frequency***	One per analysis batch (one per extraction batch)	One per analysis batch	2 nitrate-washed activated carbon at the start of ea analysis batch, then 1 after every 7 samples (run in duplicate)- minimum of 3 per day; Analyze 1 system blank per analysis batch.
	QC criteria		< 1/2 MRL	< 1/2 MRL,< 0.35, or< 0.25	<0.80 ug/Cl-/40 mg of activated carbon; < 1/2 of MRL, <25 or < 12.5
5.0	**Shipping Blank Criteria**	**Travel Blank**	NA	NA	NA
6.0	**LFM**	***Fortified Sample***			

CALIBRATION VERIFICATION AND QUALITY CONTROL PROCEDURES - METHOD SPECIFIC

	Performance Criteria	Method	THMs EPA 551.1	TOC SM 5310 C	TOX SM 5320B
	Frequency		one sample in each extraction batch	at least 5% of ICR samples in an analysis batch (fortified sample analyzed in duplicate)	at least 5% of all ICR samples analyzed each quarter (fortified sample analyzed in duplicate
	Matrix spike level		same concentration as cal verification. If no historical data for sample level, rotate low, mid, high as spike conc.	same concentration as cal verification. If no historical data for sample level, rotate low, mid, high as spike conc.	same concentration as cal verification. If no historical data for sample level, rotate low, mid, high as spike conc.
	QC criteria	% Recovery	NA	NA	NA
7.0	Lab (Field) Duplicate		field duplicate	lab duplicate	lab duplicate
	QC Criteria	% RPD	NA	</= 10 % (TOC conc > 2.0 mg/L) </= 20 % (TOC conc </= 2.0 mg/L)	NA
8.0	Internal Std.		BFB if pentane solvent is used; Optional if MTBE is the extracting solvent	NA	NA
	QC Criteria	IS Recoveries	+/- 30% of calibration curve AVG IS response 70-130 % Rec.	NA	NA
9.0	Surrogate QC Standards		decafluorobiphenyl in ea sample	NA	NA
		Surrogate Recoveries	70-130 % Rec.	NA	NA

CALIBRATION VERIFICATION AND QUALITY CONTROL PROCEDURES - METHOD SPECIFIC

Performance Criteria	Method	THMs EPA 551.1	TOC SM 5310 C	TOX SM 5320B
10.0				
Method Calibration Procedures	Initial Calibration Curve	THMs: CHCL3, BDCM Concentration (ug/L)	Conc. (mg/L)	
Trihalomethane	Standard 1	0.5	0.5	
	Standard 2	1	1.0	
	Standard 3	2	5	
	Standard 4	5	10	
	Standard 5	10	20	
	Standard 6	20		
	Standard 7	30		
	Standard 8	40		
	Standard 9	50		
		THMs: DBCM, CHBR3 Concentration (ug/L)		
	Standard 1	0.25		
	Standard 2	0.5		
	Standard 3	1		
	Standard 4	2.5		
	Standard 5	5		
	Standard 6	10		
	Standard 7	15		
	Standard 8	20		
	Standard 9	25		