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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South Holly WTP, ICR#647

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)

TABLE OF CONTENTS

Page

LIST OF TABLES

No. Description Page

LIST OF FIGURES

No. Description Page

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 Holly 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 Holly WTP uses short free chlorine contact and chloramines for disinfection).

TOC Breakthrough:

- After two 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:

- As with TOC breakthrough, DBP formation potential (with 24 hours of free chlorine contact) started to plateau after two to three months of operation. Total trihalomethane (THM4) formation reached 80 μg/L and 40 μg/L for both the 10 and 20-minute EBCT columns.

THM4 formation reached a plateau at concentrations greater than 80 μg/L. HAA5 formation potential reached a plateau at concentrations at or below 30 μg/L.

GAC Operation / Run-Times:

- For the 10-minute EBCT GAC column, the THM4 concentration reached 80 μg/L after approximately 1 month of operation and 40 μg/L after approximately 2 weeks.

- For the 20-minute EBCT GAC column, the THM4 concentration reached 80 μg/L before 2 months of operation and 40 μg/L after 1 month.

- The influent TOC concentrations and the influent DBP formation potential decreased slightly in the fall season and heading into the winter months. As a result, effluent characteristics followed the same trend, indicating the impacts of seasonal variations in water quality on GAC adsorption.

- Considering the fairly rapid breakthrough rate of THM4 formation potential and rapid use of available adsorption capacity, the rate of carbon replacement or regeneration would likely be significant.

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):

- The fairly rapid breakthrough of THM4 formation potential in the 20-minute EBCT adsorber indicates the FWWD could not feasibly meet DBP MCLs or more stringent division goals with GAC and free chlorine disinfection.

- 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 Holly 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 Holly WTP:

- Implementing GAC adsorption for a 80 MGD facility would require a significant capital investment. In addition to the GAC filter adsorber units, on-site GAC reactivation facilities may be necessary.

- The potentially high carbon usage rate, when operating based on TOC removal, could increase costs significantly. On-site reactivation or GAC replacement every few months would likely make the process infeasible.

- Construction costs could become significant in a retrofit situation. Currently, there are no plans for expanding the Holly WTP. It may be difficult to add GAC adsorption in terms of space, plant configuration, and construction.

- 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 of using GAC adsorption as an additional treatment process (i.e. for additional taste and odor, TOC, and pesticides removal, or 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 Holly 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 constructed a trailer-mounted pilot plant at the Holly WTP. This pilot facility was equipped with two parallel conventional treatment trains, raw and settled water ozone, dual-media filter columns and GAC contactors. From April 14, 1998 through November 1998, one of the Holly pilot plant treatment trains was dedicated to the GAC treatment study. This treatment train simulated the conventional processes of the full-scale treatment train.

The purpose of this section is to provide background information pertaining to the Holly WTP. The discussion includes plant schematics, tables summarizing full-scale design parameters and source and finished water quality, and comments regarding treatment challenges at Holly. After introducing the Holly 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 Holly Water Treatment Plant Description

Figure 2-1 is a schematic of the Holly WTP (80 MGD). Raw water is pumped from the West Fork of the Trinity River to the plant where it is treated and pumped to distribution. The WTP utilizes conventional treatment 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

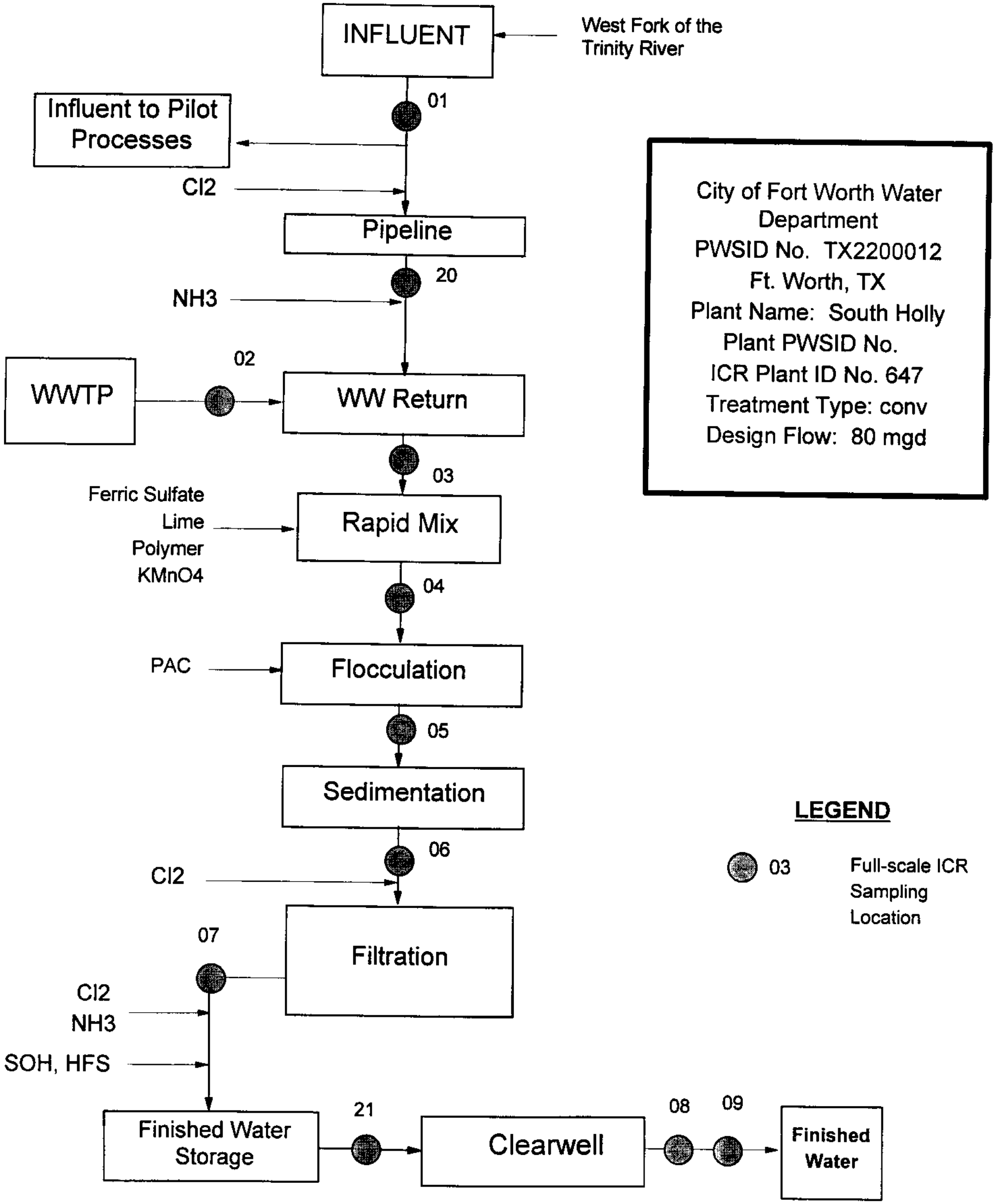


Figure 2-1: Holly WTP Process Schematic

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 Holly 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 chloramine residual for distribution. Other chemicals added at the plant include potassium permanganate (occasionally added for taste and odor), hydrofluosilicic acid, 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 Holly Water Treatment Plant Design Information

Table 2-1 shows design parameters for the Holly WTP.

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

Treatment Plant Name: South Holly WTP	State Approved Plant Capacity (MGD): 100.0
ICR Treatment Plant ID: 647	Historical Min.Water Temperature (deg C): 5.0
Treatment Plant PWS ID:	Installed Sludge Handling Capacity (DPD): 83,800.00
Treatment Plant Category: CONV	Blending Indicator: Y
Water Resource Name: Lake Worth	Hydrologic Unit Code: 12030102
Water Resource Type: Reservoir/lake	River Reach:
Average Residence Time (Days): 175	Latitude (degrees, minutes, seconds): +32 47'22'

Table 2-1: South Holly WTP Process Data (Based on Full-Scale ICR Table A.2)			
Intake Name: Lake Worth		Longitude (degrees, minutes, seconds): -97 25'2'	
Watershed Control: Y		River Reach Miles:	
Seq. Sample No. Location Name	**Sample Location Type**	**Sample Location No.**	**Characteristics**
Chlorine gas	Disinfectant Addition		Chemical Code: Cl2 Measurement Formula: Cl2 Dose Rate (mg/L): 4.30
Pipeline	Other Treatment Process	20	Surface Area (ft2): Liquid Volume (gal): Short Circuiting Factor:
Anhydrous ammonia	Disinfectant Addition		Chemical Code: NH3A Measurement Formula: NH3 Dose Rate (mg/L): 0.86
WW Return	Washwater Return	2	Washwater Treated: N Coagulation/Sedimentation: N Filtration: N Disinfectant Addition: N Plain Sedimentation: Y Other Treatment: 24 hr average Water flow Returned (MGD): 0.76
WW Return	Washwater Return Sample Point	3	
Rapid Mix	Rapid Mix	4	Type of Mixer: ME Baffling Type: UN Liquid Volume (gal): 75,500 Short Circuiting Factor: 0.2 Mean Velocity Gradient (sec-1): 400.0
Flocculation	Flocculation Basin	5	Type of Mixer: ME Liquid Volume (gal): 1,752,000 Short Circuiting Factor: 2.0 Baffling Type: AV Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec-1): 68 Stage Liquid Volume (gal): 292,000 Stage Sequence Number: 2 Stage Mean Velocity Gradient (sec-1): 48 Stage Liquid Volume (gal): 584,000 Stage Sequence Number: 3 Stage Mean Velocity Gradient (sec-1): 28 Stage Liquid Volume (gal): 876,000
Sedimentation	Sedimentation	6	Surface Area (ft2): 99,324 Liquid Volume (gal): 11,172,000 Baffling Type: UN

Table 2-1: South Holly WTP Process Data (Based on Full-Scale ICR Table A.2)			
			Short Circuiting Factor: 0.4 Plate Settler Surface Area (ft2): Plate Settler Brand Name: Tube Settler Surface Area (ft2): Tube Settler Brand Name:
Chlorine gas	Disinfectant Addition		Chemical Code: Cl2 Measurement Formula: Cl2 Dose Rate (mg/L): 0.00
Filtration	Filtration	7	Surface Area (ft2): 17,472 Liquid Volume (gal): 703,718 Total Media Depth (in): 38 Depth of GAC (in): Media Type: DUAL Type of Activated Carbon: Min.Water Depth to Top of Media (ft): 4.0 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
FW Storage	Other Treatment Process	21	Surface Area (ft2): 62,800 Liquid Volume (gal): 1,000,000 Short Circuiting Factor: 0.2
Clearwell	Clearwell		Surface Area (ft2): 62,800 Liquid Volume (gal): 11,800,000 Minimum Liquid Volume (gal): 3,350,000 Baffling Type: UN Short Circuiting Factor: 0.02 Covered Indicator Code: Y
Finished Water	FIN	8	

The Holly WTP was constructed in the first half of this century. The capacity is limited by plant hydraulics. Currently, the FWWD has no plans for expanding the Holly WTP in the future. The most recent improvements at the plant included filter rehabilitation work. Table 2-2 shows chemical application information for the Holly WTP.

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

Table 2-2: South Holly 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	4.30
Pipeline	Other Treatment Process	20			
Anhydrous ammonia	Disinfectant Addition		Anhydrous ammonia	NH3	0.86
WW Return	Washwater Return	2			
WW Return	Washwater Return Sample Point	3			
Rapid Mix	Rapid Mix	4	Calcium hydroxide, Ferric sulfate, Organic polymer-coagulant aid, Potassium permanganate	CaOH FeSO4* 7H2O Cat Floc KmnO4	15.00 24.00 0.70 0.00
Flocculation	Flocculation Basin	5	Powdered activated carbon	PAC	0.00
Sedimentation	Sedimentation	6			
Chlorine gas	Disinfectant Addition		Chlorine gas	Cl2	0.00
Filtration	Filtration	7			
Chlorine gas	Disinfectant Addition		Chlorine gas	Cl2	0.00
Anhydrous ammonia	Disinfectant Addition		Anhydrous ammonia	NH3	0.00
FW Storage	Other Treatment Process	21	Sodium hydroxide Hydrofluosilicic acid	NaOH H2SiF6	0.00 0.00
Clearwell	Clearwell				

2.3 Holly Water Treatment Plant Source and Finished Water Quality

The Holly WTP treats water from the West Fork of the Trinity River via Lake Worth. 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: South Holly WTP Source Water Quality Summary				
Water Quality Parameter	**Average Yearly Value**	**Standard Deviation**	**Maximum Yearly Value**	**Minimum Yearly Value**
Temperature (°C)	20.9	5.7	28.6	11.2
pH	7.99	0.26	8.36	7.62
Turbidity (ntu)	9.34	6.20	22.40	3.26
Alkalinity (mg/L as $CaCO_3$)	128	7	139	118
Calcium Hardness (mg/L as $CaCO_3$)	122	13	146	101
Total Hardness (mg/L as $CaCO_3$)	149	17	173	113
TOC (mg/L)	4.4	0.9	5.5	2.0
UV_{254} (1/cm)	0.098	0.007	0.108	0.090
Bromide (mg/L)	0.21	0.04	0.25	0.09

As shown, Lake Worth water has moderate to high levels of alkalinity, hardness, and TOC. The pH is typically near 8 and, similar to alkalinity, does not vary significantly. Turbidity levels are typically low, less than 10 to 15 NTU. Lake Worth does contain a significant amount of bromide with average concentrations greater than 200 μg/L. It is possible the Holly WTP will treat water directly from Lake Benbrook in the future. Lake Benbrook is in the same series of lakes in the West Fork of the Trinity River as Lake Worth.

Table 2-4 shows Holly finished water quality based on the last twelve months of full-scale ICR sampling data. The FWWD historically meets the current THM4 MCL of 100 μg/L; however, THM4 values have ranged from 80 to 90 μg/L in the summer months, exceeding the proposed Stage 1 MCL of the D/DBP Rule.

Table 2-4: South Holly WTP Finished Water Quality Summary				
Water Quality	**Average Yearly**	**Standard**	**Maximum Yearly**	**Minimum Yearly**

Parameter	Value	Deviation	Value	Value
Temperature (°C)	25.7	4.5	29.3	17.5
pH	8.29	0.10	8.46	8.19
Turbidity (ntu)	0.22	0.08	0.38	0.16
TOC (mg/L)	4.3	0.4	5.0	3.7
Distribution System THM4 (μg/L)	54.7	22.7	80.0	36.0

As shown, the conventional treatment process does not provide significant TOC removal as indicated by the negligible decrease in TOC from the source to finished water, 4.4 mg/L to 4.3 mg/L. The pH is slightly higher than in the source water at 8.3.

2.4 Water Quality Goals and Treatment Challenges at the Holly 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 Holly 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 Holly 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. The current treatment strategy may also allow the FWWD to achieve Stage 1 MCLs of the D/DBP Rule.

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 1 MCLs at the Holly WTP. It is quite possible the Stage 2 "placeholder" MCLs can be met with this strategy, 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 Holly 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

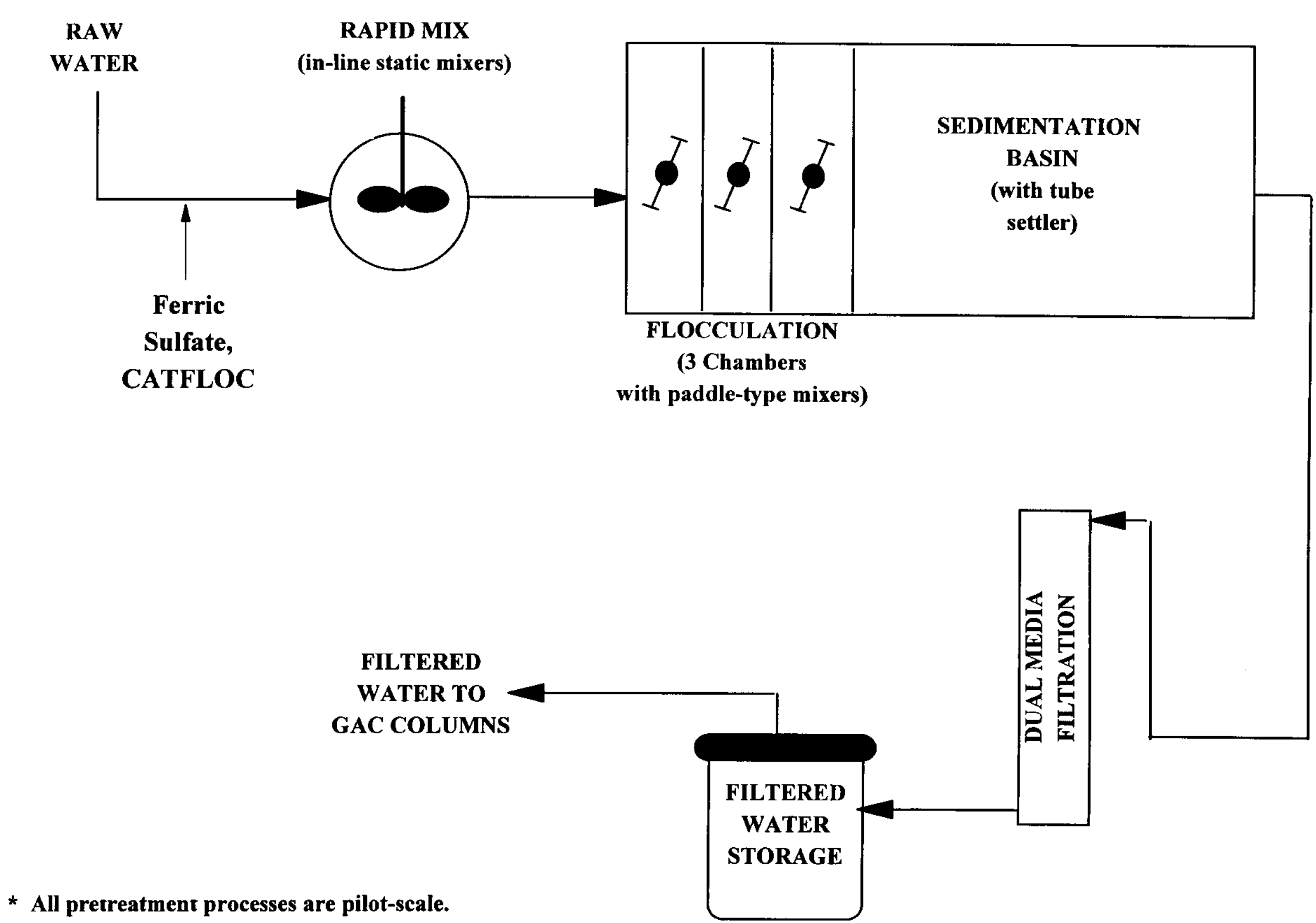
This section provides a discussion of the materials and methods used to conduct the pilot-scale GAC tests. The discussion topics include:

- 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 Holly WTP applies chlorine and ammonia at the beginning of the treatment process, the influent to the pilot process was taken from a 42-inch raw water main at the head of the plant, upstream of all treatment processes and chemical addition. 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 task, Malcolm Pirnie constructed a trailer-mounted pilot plant at the Holly WTP. The trailer was equipped with two parallel conventional treatment trains, dual-media filter columns, GAC contactors, and a laboratory area for conducting on-site analyses.

Figure 3-1 is a schematic of the pilot-scale pretreatment process. A centrifugal pump delivered water from the Holly raw water main through buried 1½-inch PVC piping to a 5-gallon constant head tank at the exterior of the trailer. Plant staff buried the piping to maintain raw water temperatures representative of those at the full-scale plant. Another pump, with the capacity to supply at least 2 gpm to each process train, pumped water from the constant head tank to the treatment basins inside the trailer. Chemical pumps injected ferric sulfate and polymer into the raw water line. Full-scale dosages were used throughout the study. The pilot plant operators checked full-scale dosages with plant staff every two to three days and adjusted pilot chemical



* All pretreatment processes are pilot-scale.

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PILOT-SCALE EVALUATION OF GAC FILTERS - SOUTH HOLLY WTP
PRETREATMENT PROCESS SCHEMATIC*

FIGURE 3-1

feed rates accordingly. One exception to simulating full-scale treatment was that the pilot process did not include lime addition.

Downstream of coagulant addition, a static mixer served as a rapid mix to promote chemical mixing and particle destabilization. Coagulated water was then sent to a 3-stage flocculation process with paddle flocculators providing "G" values used at full-scale. Particles then settled out in the sedimentation basin. The sedimentation basin contained a tube settler to promote settling. Settled water was pumped to the gravity operated dual-media filters. The pilot filter gallery contained four, 3-inch columns with sand and anthracite media underlain by gravel. Filtered water flowed by gravity to the filtered water reservoir, a 55-gallon HDPE tank located outside the trailer. A submersible pump delivered the filtered water to the influent of the GAC contactors inside the trailer.

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

Table 3-1: South Holly WTP Pilot Facility Design Parameters

Process Item	Description/Notes	Parameter	Value
Rapid Mix	In-line static mixer	Flow Rate	2 gpm
		Length	7"
		Nominal Diameter	3/4"
		Number of Mixing Elements	6
Flocculation	3 stages separated by perforated walls; paddle-type impellers	Flow Rate	2 gpm
		Detention Time	24 min. (8 min./stage)
		Mixing Speeds	1st stage: 65-70 rpm; 2nd stage: 45-50 rpm; 3rd stage: 25-30 rpm
Sedimentation	Tube settler	Flow Rate	2 gpm
		Detention Time	65 min.
		Nominal Overflow Rate ('Nominal' does not account for	480 gpd/ft^2

Table 3-1: South Holly WTP Pilot Facility Design Parameters			
Process Item	**Description/Notes**	**Parameter**	**Value**
		effect of tube settler)	
		Effective Overflow Rate ('Effective' does account for effect of tube settler)	330 gpd/ft^2
		Weir Loading Rate	2,660 gpd/ft
Filtration	3"-diameter, dual-media, declining-rate columns	Flow Rate	0.2 to 0.3 gpm (per filter column)
		Gravel Depth	4 inches
		Sand Depth	12 inches
		Anthracite Depth	21 inches
		Loading Rate	4 to 6 gpm/ft^2

The flow rate throughout the duration of the study was maintained at 2 gpm. The interior piping was ½-inch PVC piping, which provided reasonable flow velocities through the pilot process. Ball valves were used to control process flows. Flow meters, placed at the entrance to the flocculation-sedimentation basins and each of the four filter columns, allowed monitoring of process flows. The sedimentation basins and filters contained overflow piping to route overflow to an exterior discharge sump.

The filters operated in a pseudo-constant rate mode. Pilot plant operators adjusted the effluent flow 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 at a rate of approximately 2 gpm. A submersible pump delivered water from the GAC effluent reservoir, a 55-gallon HDPE tank located at the exterior of the trailer, into the backwash line. On occasion, "clumps" of ferric sulfate coagulated particles built up in the filters. A piece of tubing was used during backwashing to break apart these clumps. Filter run times were typically 48 hours.

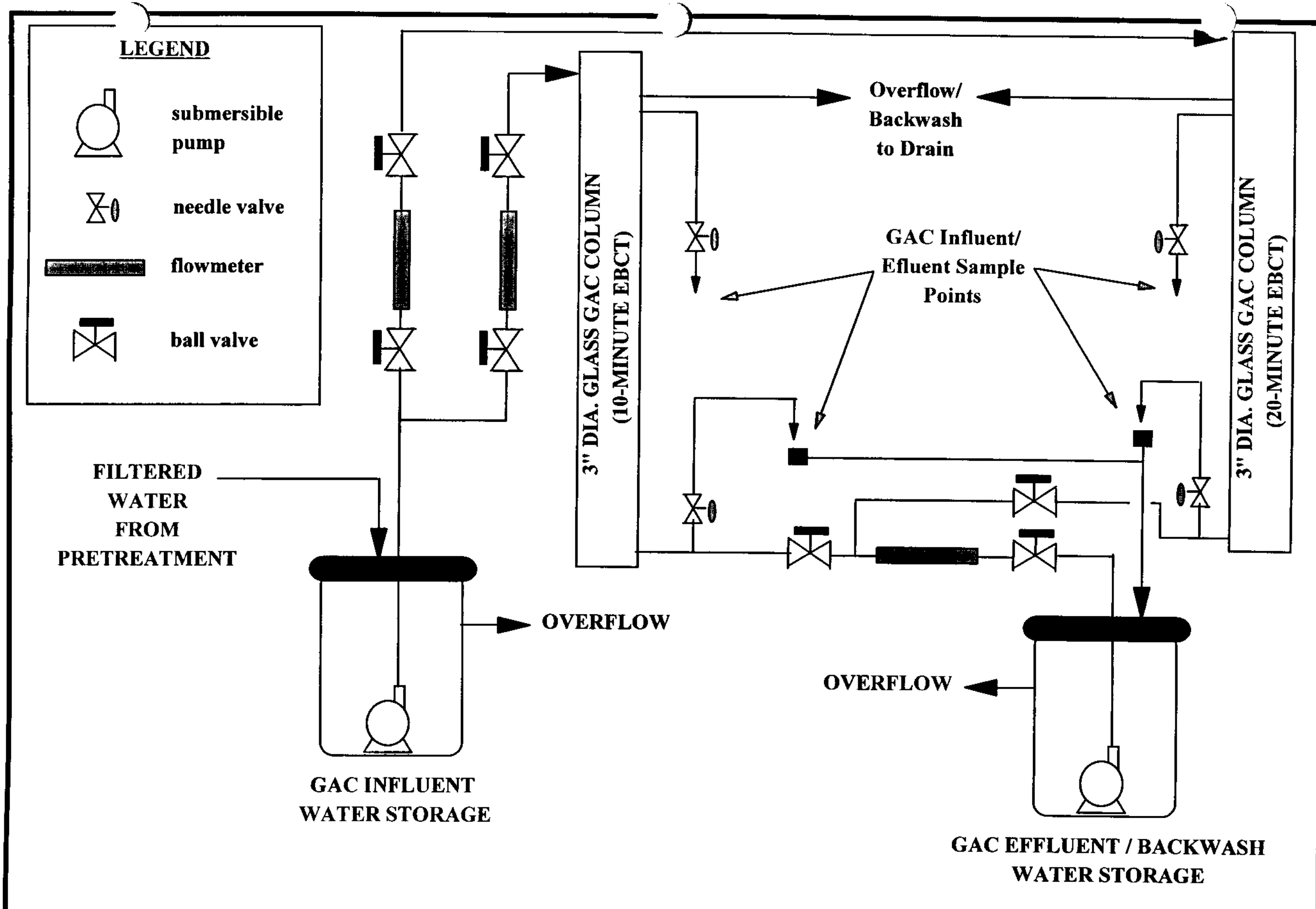
3.2 Description of GAC Filtration Process

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 0.5 L/min to provide the appropriate EBCT. Pilot plant operators monitored and manually adjusted the effluent flow from the GAC columns every two to three days to maintain target flow rates. 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 for the dual-media and GAC filters had to be closely monitored to ensure that adequate flow reached 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."

Table 3-2: South Holly 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



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PILOT-SCALE EVALUATION OF GAC FILTERS - SOUTH HOLLY WTP
GAC ADVANCED TREATMENT PROCESS SCHEMATIC

FIGURE 3-2

Table 3-2: South Holly WTP GAC Column Design Parameters		
	Gravel Depth	4 inches
	GAC Depth	43 inches
	GAC Density	505.7 kg/m^3
	GAC Volume	5000 cm^3
	GAC Mass	2.53 kg
	EBCT	10 min
	Flow Rate	0.5 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
	Gravel Depth	4 inches
	GAC Depth	86 inches
	GAC Density	505.7 kg/m^3
	GAC Volume	10,000 cm^3
	GAC Mass	5.06 kg
	EBCT	20 min
	Flow Rate	0.5 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 a few 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 discharge sump at the trailer's exterior. 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: South Holly 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 and TOC breakthrough curves were fairly steep early in the tests and leveled off at the end. UV-254 breakthrough began to vary up and down as breakthrough reached a plateau, making it difficult to determine sampling times. Therefore, the last few samples were taken based more on spacing over time than incremental increases in UV-254, thus providing a smooth "S-shaped" TOC breakthrough curve. 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: South Holly 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 overflow portion of sedimentation 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 free chlorine residual (0.5 to 1.0 mg/L) 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 basin overflow for 24 hours

- After 24 hours, remove the 1 L bottle, measure pH, temperature and chlorine residual, and pour sample into headspace-free 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), except for the second set of samples. There was no apparent impact on the results. 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: South Holly 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

Table 3-5: South Holly WTP GAC Pilot Study Laboratory Analytical Methods		
Analyte	**Method**	**MDL**
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 levels 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 was 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. When headloss was significant, indicating backwashing was necessary, the high and low end of these ranges were more prominent. For a majority of the study, the EBCTs were maintained very close to 10 and 20 minutes.

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

Design EBCT	Effluent Flow	Actual EBCT
10 minutes	0.45 to 0.55 L/min	9 to 11 minutes
20 minutes	0.45 to 0.55 L/min	18 to 22 minutes

- For the period of June 9, 1998 to June 17, 1998, the effluent flows were mistakenly set at 0.65 L/min, providing EBCTs of 8 and 15 minutes. There was not a noticeable effect on effluent water quality; however, the TOC result for sample A8 (20-min column) appeared slightly elevated (this sample was taken on June 17 prior to discovering the high flow and readjusting).

- To address increasing headloss in the GAC columns, the operators backwashed the GAC. Initially, headloss and decreasing effluent flows were an issue due to algae growth in the filtered water storage reservoir. Since the reservoir was located at the exterior of the plant and exposed to direct sunlight, a noticeable amount of algae growth occurred. The algae gradually formed a "coating" over the surface of the GAC, limiting flow through the columns, eventually to the point where backwashing was necessary. To eliminate the algae problem, the reservoir was covered to block sunlight (May 1998). However, backwashing was necessary on a few other occasions due to drying of the GAC beds from pump malfunctions and full-scale plant shut downs. Table 4-2 shows information regarding backwashing events.

Table 4-2: South Holly WTP GAC Pilot Study GAC Backwashing Events

Date	EBCT	Downtime (hr)*	Reason
5/3/98	10 and 20	3	Headloss
5/18/98	10	1	Headloss/algae problem
5/19/98	20	1	Headloss/algae problem
6/9/98	10 and 20	2	Reservoir imbalance - filtered water (GAC influent) level not maintained due to headloss in dual media filters - GAC dried
7/17/98	10 and 20	24	Filtered water pump problem - no influent - GAC dried
8/5/98	10 and 20	308	Full-scale water main break on 7/23/98 - no supply to trailer - GAC dried - GAC-treated water was put in columns to "wet" GAC until backwashing and startup on 8/5/98
9/19/98	20	1	Headloss
10/4/98	20	24	Severe storm cut off filtered water pump - GAC dried
10/9/98	20	24	Filtered water reservoir sump pump burned out - GAC dried
10/25/98	20	24	Filtered water pump problem - no influent - GAC dried

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

- These events did not appear to affect the study results. However, upon startup of the GAC columns after the full-scale shut down in July, UV-254 values were slightly lower in the effluent than before shut down. After approximately one week, the values increased back into the range of values seen before shutdown.

- Over one 24 hour period, there was no coagulant feed due to pump problems. Thus, the GAC columns received uncoagulated water (likely a higher TOC loading) over this period. Samples were not taken at the time, therefore, there was no noticeable impact on results.

- 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. No samples were taken during significant rain events and there were no noticeable impacts on results.

Data Specific -

- The bromoform result for influent sample A13 appears to be an anomaly.

- The DCAA and TCAA results for the 10-minute EBCT effluent sample A14 appear to be unusually high compared to the other results.

- 20-minute EBCT effluent TOX results for samples A2 (225 μg/L) and A11 (BMRL) appear to be errors and are, therefore, not presented in the figure in Section 4.3.

4.2 Pretreated and GAC Influent Water Quality

Table 4-3 shows pilot-treated water quality at various points in the pretreatment process. The table provides average values for the three seasons in which testing occurred. In addition, the table provides average pretreatment chemical doses for each season. UV-254 and pH measurements were taken throughout the pretreatment process and recorded every seven to ten days. Turbidity readings were taken every other day during the study to monitor pretreatment performance. Only one set of pH and UV-254 measurements was taken in the fall, therefore, there is no standard deviation shown.

Table 4-3: South Holly WTP GAC Pilot Study Process Train Water Quality and Chemical Addition Summary				
Process Location	**Parameter**	**Spring (April to June)**	**Summer (July to September)**	**Fall (October to November)**
Raw Water	pH	7.97 (0.12)	7.52 (0.24)	7.57 (--)
	UV-254 (1/cm)	0.087 (0.005)	0.092 (0.004)	0.086 (--)
	Turbidity (ntu)	10.2 (3.4)	7.4 (2.7)	8.8 (5.1)
Rapid Mix	Coagulant Dose (mg/L dry Ferric Sulfate)	11.9 (2.3)	16.3 (3.4)	19.9 (2.8)
	Polymer Dose (mg/L)	2.0 (0.3)	2.2 (0.1)	2.2 (0.1)
Settled Water	pH	7.56 (0.03)	7.18 (0.18)	7.12 (--)
	UV-254 (1/cm)	0.063 (0.007)	0.067 (0.005)	0.069 (--)
	Turbidity (ntu)	1.53 (0.32)	1.25 (0.24)	1.55 (0.50)
Filter Effluent 1	Turbidity (ntu)	0.17 (0.08)	0.34 (0.06)	--
Filter Effluent 2	Turbidity (ntu)	0.19 (0.06)	0.33 (0.06)	0.40 (0.21)
Filter Effluent 3	Turbidity (ntu)	0.23 (0.09)	0.31 (0.06)	0.38 (0.21)
Filter Effluent 4	Turbidity (ntu)	0.23 (0.09)	0.32 (0.05)	0.37 (0.20)

Average (Standard Deviation)

Table 4-4 provides a summary of the GAC influent (pretreated) water quality. Similar to Table 4-3, this table provides average values for the three seasons in which testing occurred.

Table 4-4: South Holly WTP GAC Pilot Study Pretreated Water Quality Summary

Parameter	Spring (April to June)	Summer (July to September)	Fall (October to November)
pH	7.82 (0.09)	7.85 (0.13)	7.68 (0.16)
Turbidity (ntu)	0.37 (0.14)	0.44 (0.06)	0.70 (0.28)
Alkalinity (mg/L as $CaCO_3$)	126.8 (6.6)	112.8 (8.8)	90.5 (1.8)
Temp (degrees C)	26.7 (3.1)	24.4 (2.6)	17.4 (4.7)
Total Hardness (mg/L as $CaCO_3$)	165 (13)	154 (8)	120 (7)
Calcium Hardness (mg/L as $CaCO_3$)	126 (6)	109 (10)	80 (3)
Bromide (µg/L)	218 (4)	254 (29)	300 (14)
TOC (mg/L)	3.3 (0.2)	3.5 (0.2)	3.3 (0.5)
UV-254 (1/cm)	0.066 (0.004)	0.064 (0.008)	0.051 (0.007)
SUVA (L/mg-m)	2.0 (0.2)	1.8 (0.1)	1.6 (0.1)
SDS TOX (µg/L)	246 (21)	271 (20)	241 (55)
SDS THM4 (µg/L)	130 (11)	174 (30)	128 (30)
SDS HAA5 (µg/L)	35 (4)	40 (2)	31 (7)
SDS HAA6 (µg/L)	49 (5)	55 (3)	44 (10)

Average (Standard Deviation)

4.2.1 Seasonal Trends

Tables 4-3 and 4-4 indicated the following trends:

- Alkalinity, temperature, hardness, and UV-254 all decreased from spring to fall.

- TOC values remained fairly constant with slightly higher values in the summer months. Subsequently, SUVA values decreased from spring to fall.

- DBP levels increased in the summer months and decreased in the fall. This was likely due to the trends in TOC concentration and temperature.

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 that the sampling procedure (based on UV-254 breakthrough) produced a smooth TOC breakthrough curve. The 10 minute EBCT column met the 70% breakthrough criterion. The 20 minute EBCT column met the plateau criterion. The sample points which determined the end of the tests are circled in the figure.

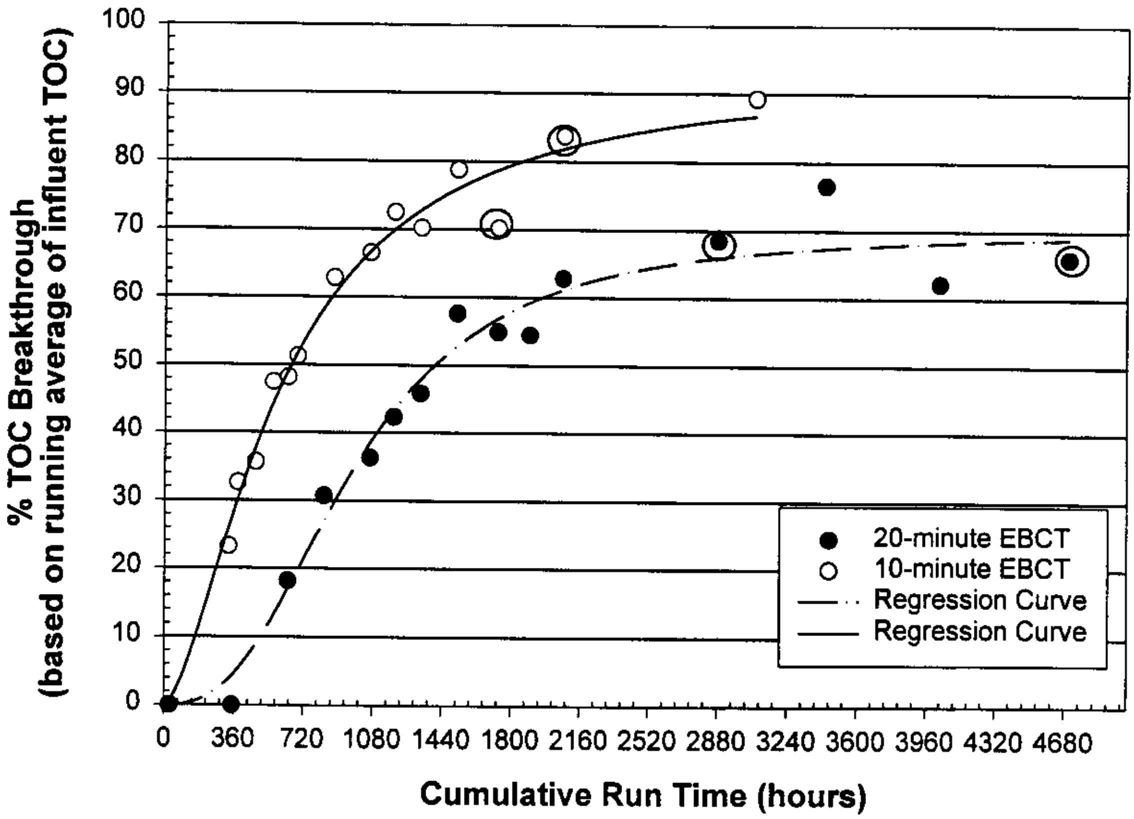
The 20 minute EBCT column reached 70 percent TOC breakthrough at approximately 3500 hours; however, a 70 percent breakthrough result was not achieved again. In addition, this data point was not 10 percent greater than the previous data point (the first circled data point), thus causing the circled data point to eventually determine plateau criteria. Since UV-254 results (shown below in Figure 4-3) reached a plateau (actually varied up and down slightly) and no longer provided an accurate indicator of when to sample for TOC, the last 4 sample events were spaced over time to investigate ICR cutoff criteria (sampling 2 weeks or 2 months apart for 70 percent and plateau criteria).

Figure 4-2 shows the influent TOC concentrations varied between 3 and 3.5 mg/L and increased to over 3.5 mg/L half way through the test. For the last two samples, TOC dropped below 3 mg/L. Subsequently, the 20 minute EBCT effluent TOC decreased in the same fashion. The rate of TOC breakthrough in the 10 minute EBCT column was approximately two times that of the 20 minute EBCT column until these last few samples. The change in breakthrough (reaching a plateau) in the last few samples of the 20 minute EBCT column may be attributable to a change in water quality in the fall season.

UV-254 Breakthrough:

Figure 4-3 shows UV-254 breakthrough results. As with the influent TOC, influent UV-254 decreased in the final samples. As shown, samples were taken at fairly even incremental

Figure 4-1: GAC Pilot Results - South Holly WTP, ICR#647
%TOC Breakthrough Over Time



10-minute EBCT

y=92.95/[1+(x/595.8)^-1.61]
$R^2 = 0.97$

20-minute EBCT

y=69.93/[1+(x/986.3)^-2.63]
$R^2 = 0.97$

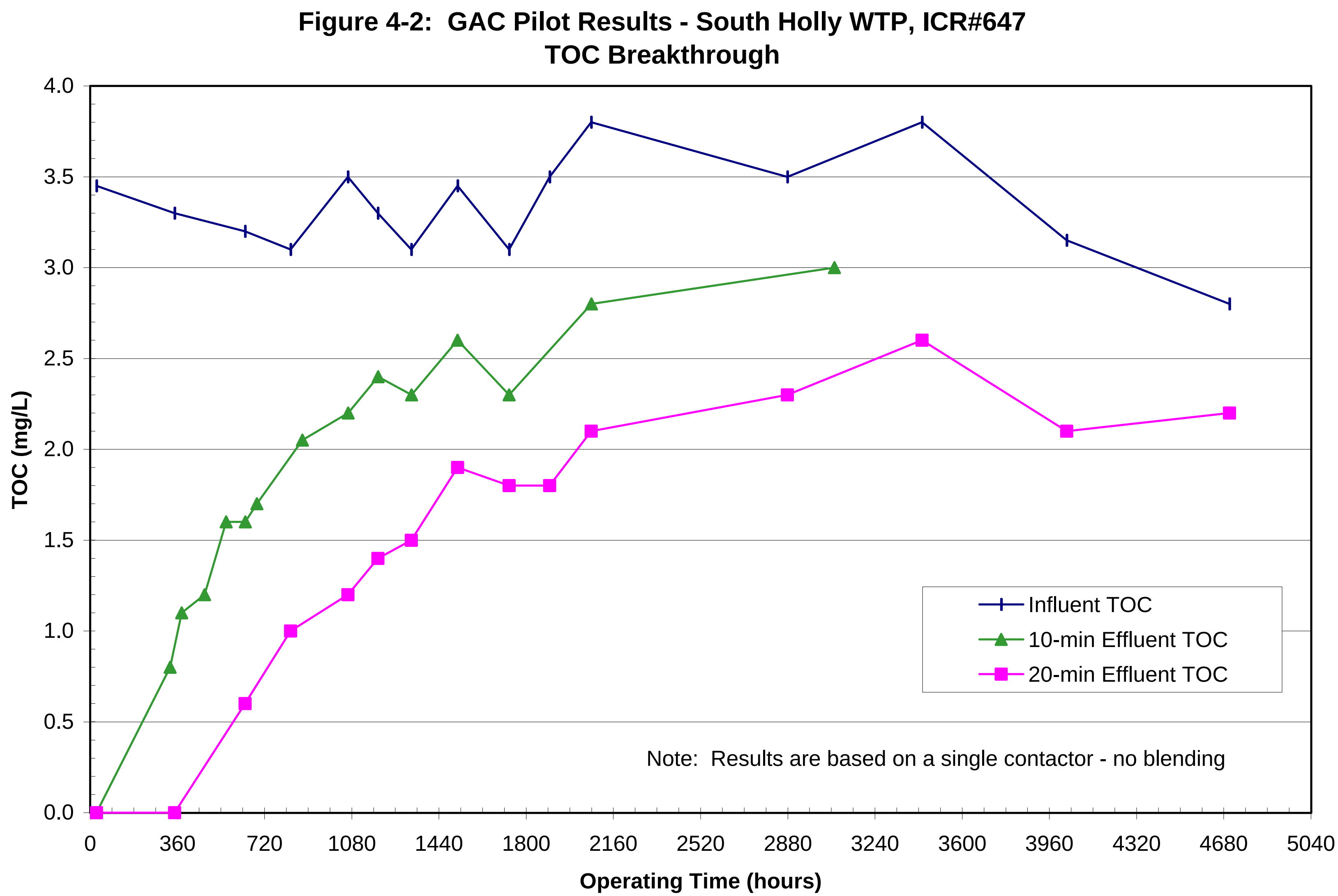


Figure 4-2: GAC Pilot Results - South Holly WTP, ICR#647
TOC Breakthrough
TOC (mg/L)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
360
720
1080
1440
1800
2160
2520
2880
3240
3600
3960
4320
4680
5040
Operating Time (hours)
Influent TOC
10-min Effluent TOC
20-min Effluent TOC
Note: Results are based on a single contactor - no blending

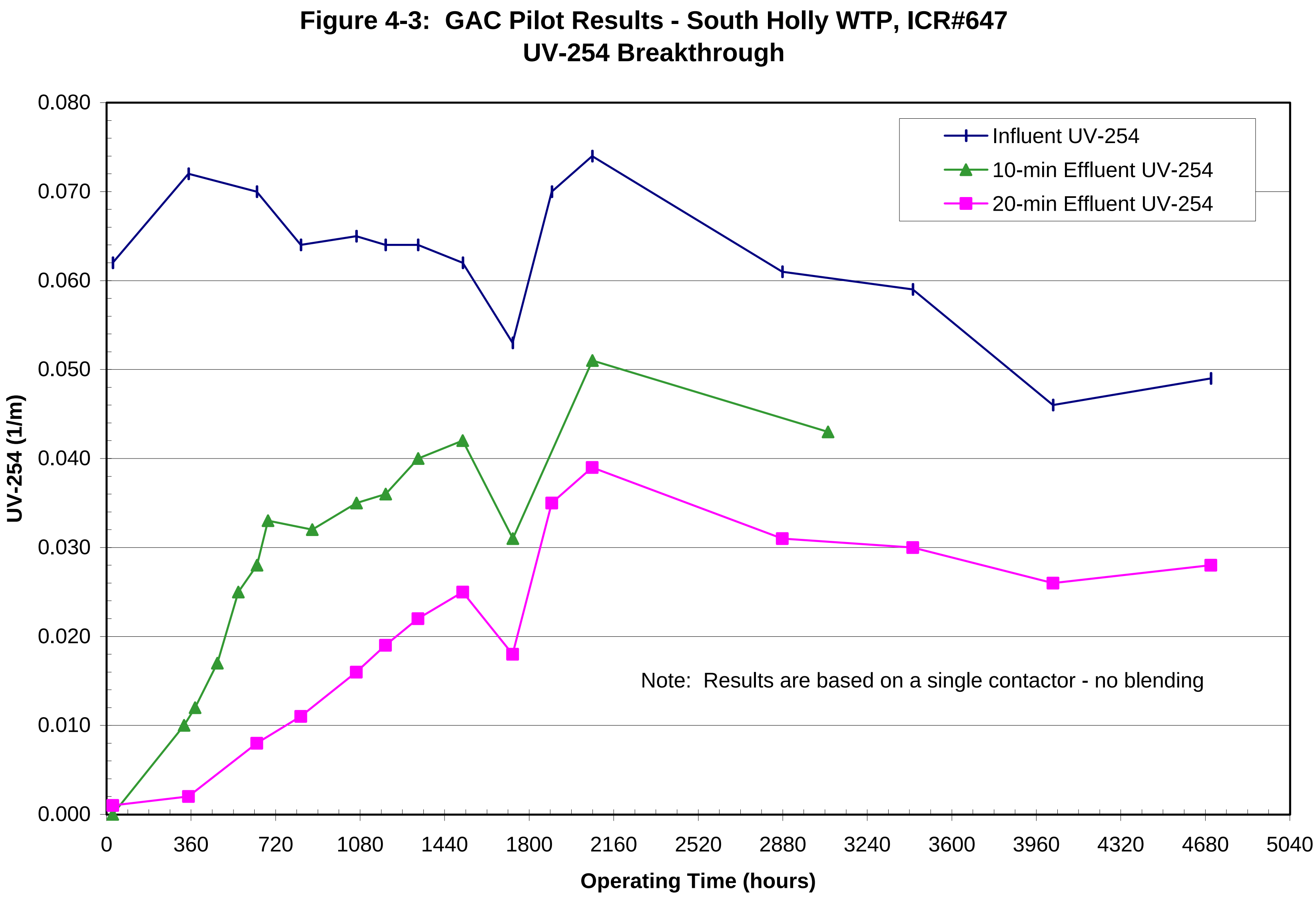


Figure 4-3: GAC Pilot Results - South Holly WTP, ICR#647
UV-254 Breakthrough
UV-254 (1/m)
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
0
360
720
1080
1440
1800
2160
2520
2880
3240
3600
3960
4320
4680
5040
Operating Time (hours)
Influent UV-254
10-min Effluent UV-254
20-min Effluent UV-254
Note: Results are based on a single contactor - no blending

Figure 4-4: GAC Pilot Results - South Holly WTP, ICR#647
SDS-Free Chlorine Demand

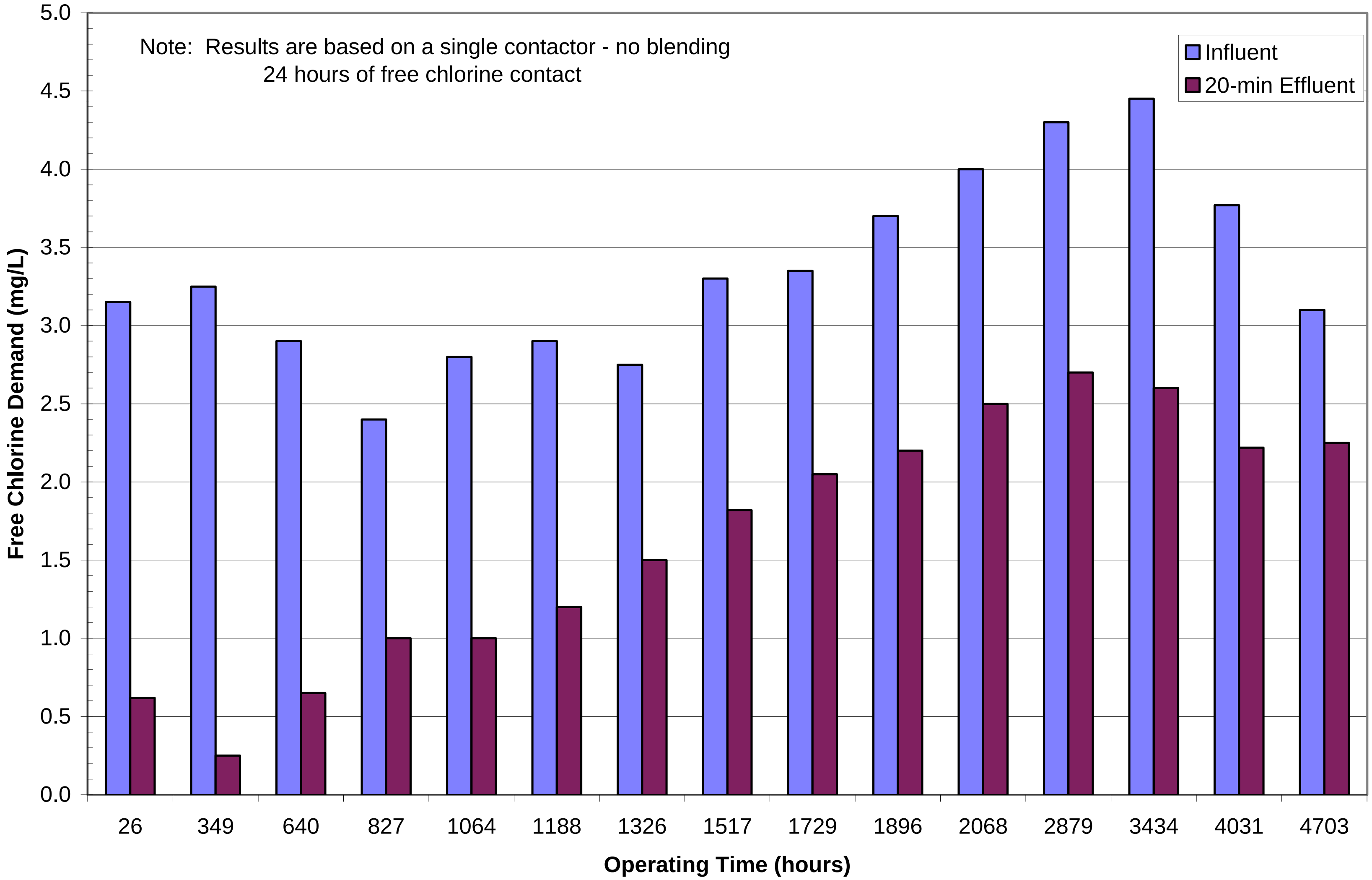
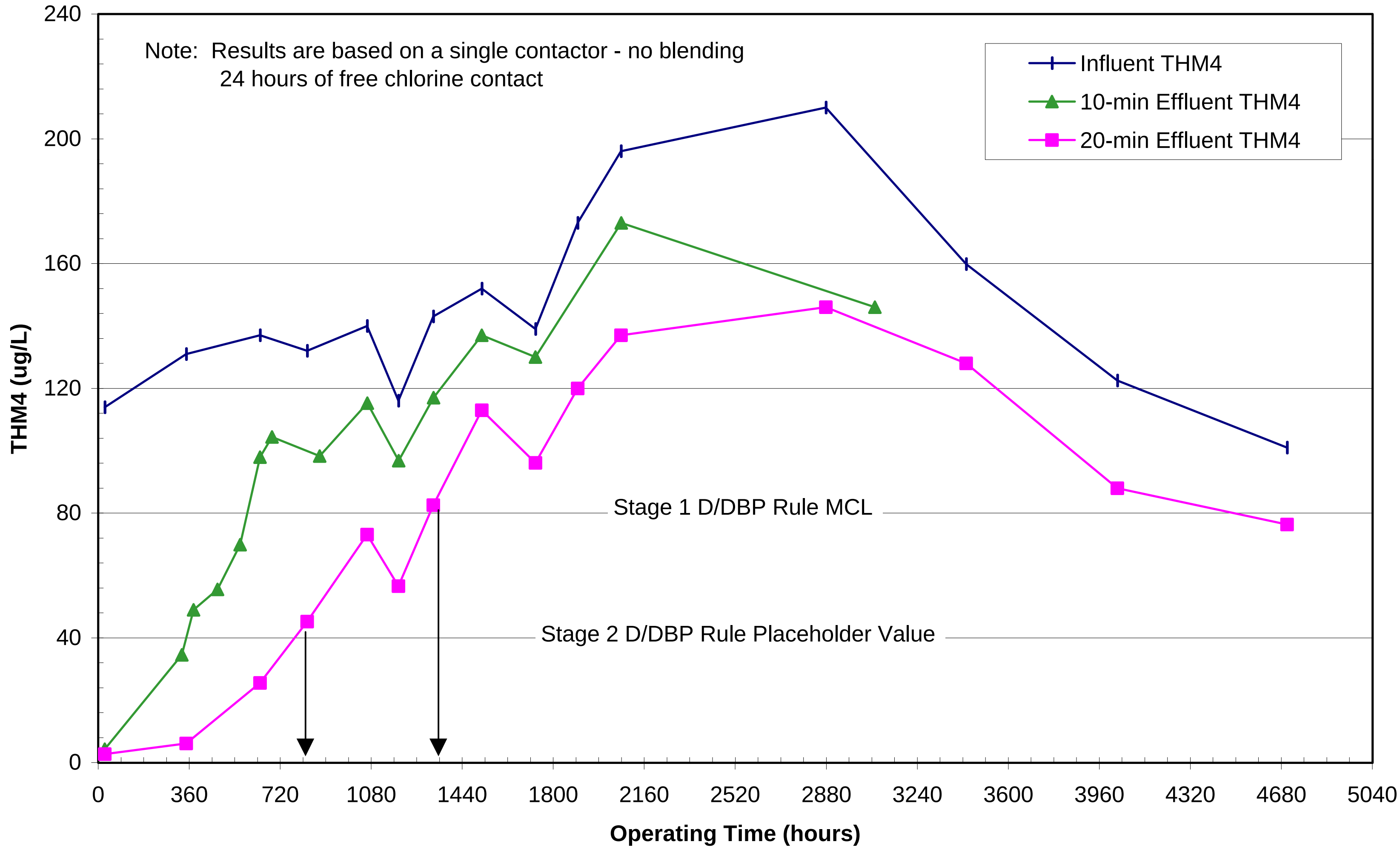


Figure 4-5: GAC Pilot Results - South Holly WTP, ICR#647
THM4 Breakthrough



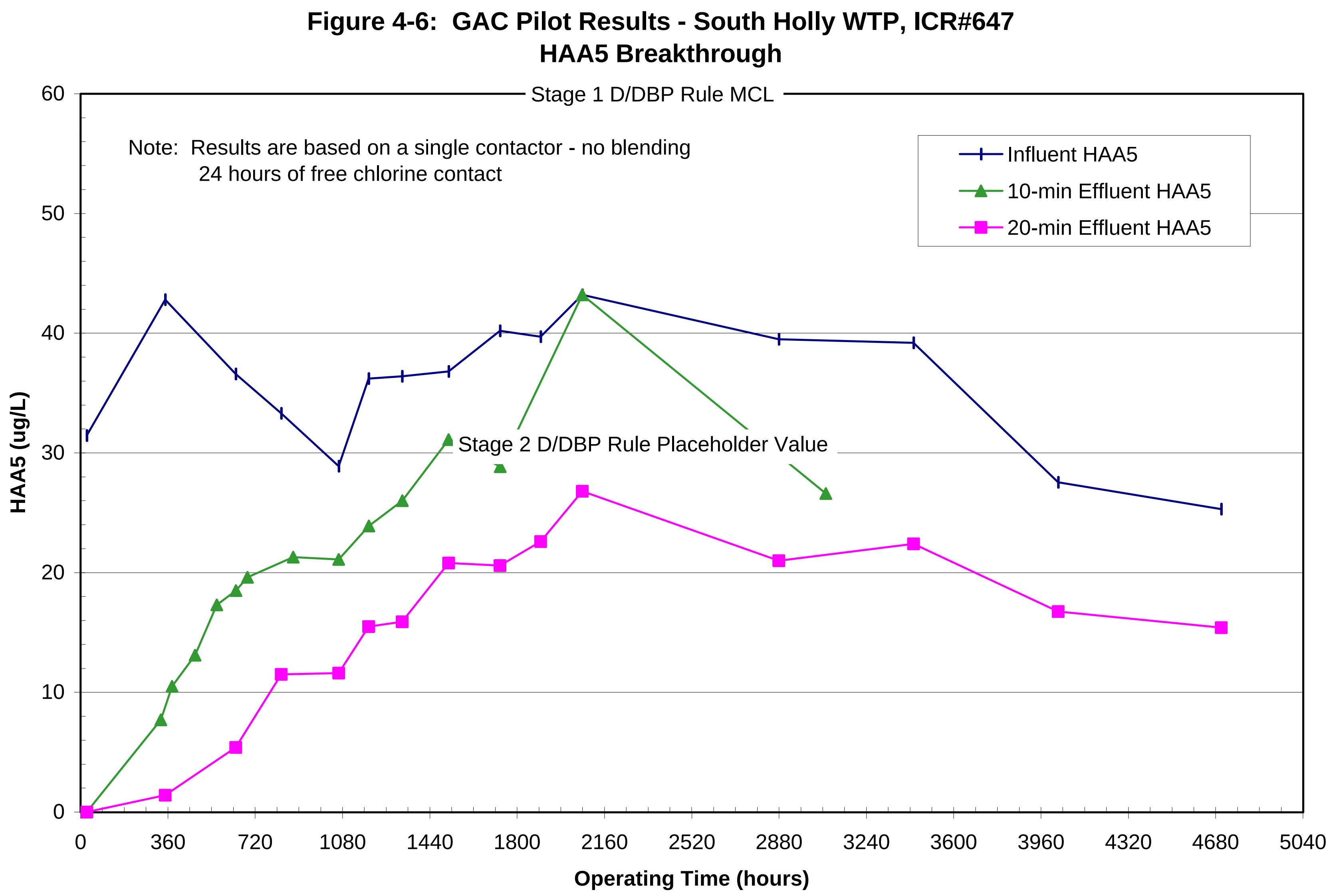


Figure 4-6: GAC Pilot Results - South Holly WTP, ICR#647
HAA5 Breakthrough
Stage 1 D/DBP Rule MCL
Note: Results are based on a single contactor - no blending
24 hours of free chlorine contact
Influent HAA5
10-min Effluent HAA5
20-min Effluent HAA5
Stage 2 D/DBP Rule Placeholder Value
HAA5 (ug/L)
60
50
40
30
20
10
0
0
360
720
1080
1440
1800
2160
2520
2880
3240
3600
3960
4320
4680
5040
Operating Time (hours)

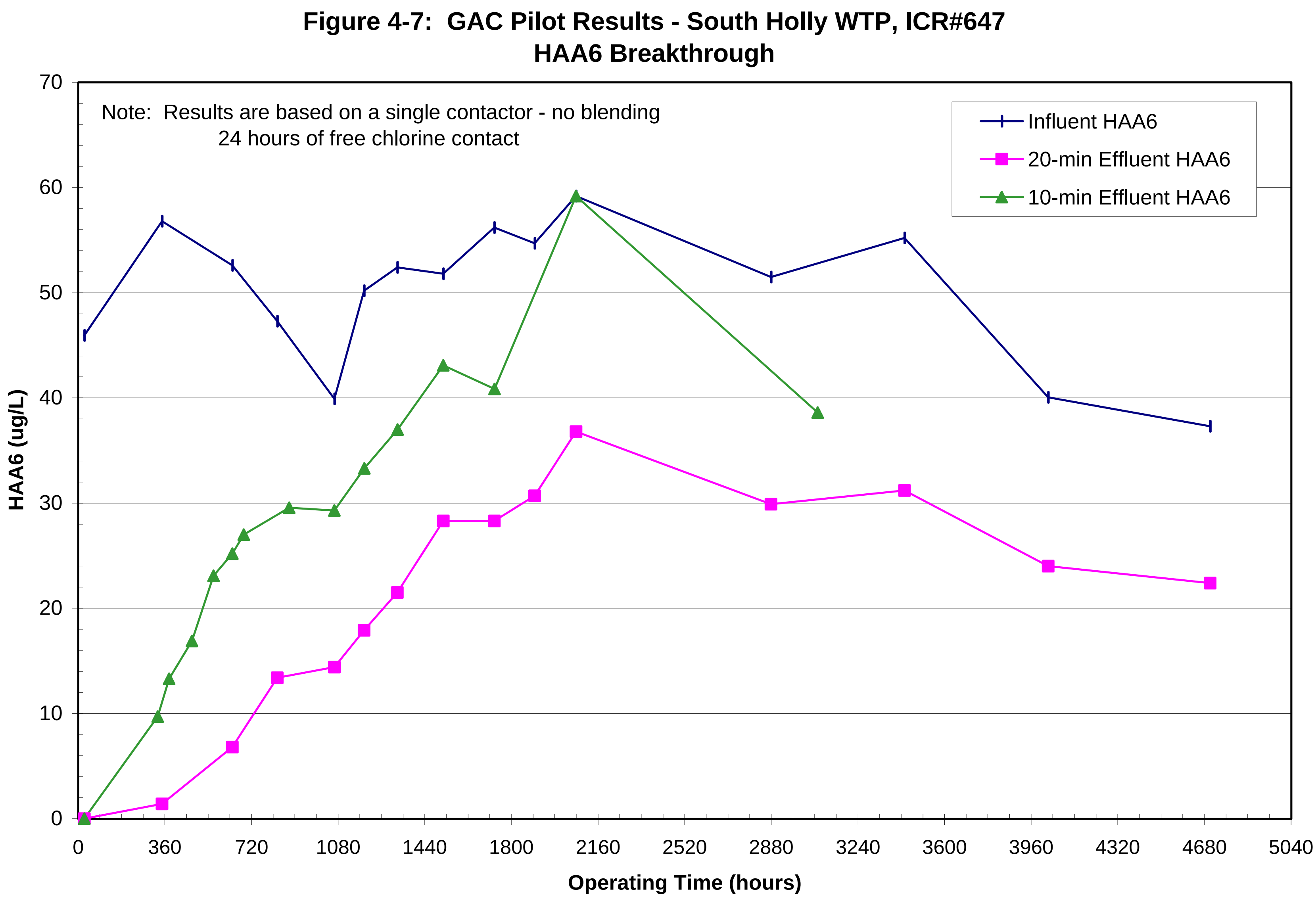


Figure 4-7: GAC Pilot Results - South Holly WTP, ICR#647
HAA6 Breakthrough
Note: Results are based on a single contactor - no blending
24 hours of free chlorine contact
Influent HAA6
20-min Effluent HAA6
10-min Effluent HAA6
HAA6 (ug/L)
Operating Time (hours)
0
10
20
30
40
50
60
70
0
360
720
1080
1440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

increases in UV-254, thus providing the smooth TOC curves in Figure 4-1. One exception is the sample point at approximately 1800 hours. For an unknown reason, the UV-254 values in this time frame decreased in the influent and effluent. A set of samples was taken at this point based on the overall trends of the data instead of the UV-254 readings and to maintain an even distribution of the developing TOC breakthrough curve. As seen in the TOC figures, the TOC result fit fairly well with the TOC trends. As discussed in other sections, the last few UV-254 effluent results decreased and were somewhat variable.

SDS Chlorine Demand:

Figure 4-4 shows SDS free chlorine demand during the study. As expected, with increasing TOC breakthrough, chlorine demand increased. In addition, influent water chlorine demand increased in the summer months and decreased again in the fall. The trends are similar to those in the TOC and UV-254 curves.

DBP Breakthrough:

Figures 4-5 through 4-7 show THM4, HAA5, and HAA6 results. Similar trends are indicated in each of these figures, mimicking the trends of the TOC and UV-254 curves. 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: South Holly 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	820	1350	4920	8100	1.9	1.5	90	90	21	16	29	23	140	95
THM4: 72 µg/L	730	1250	4380	7500	1.8	1.4	72	72	20	15	28	19	125	80
THM4: 36 µg/L	330	740	1980	4440	0.7	0.8	36	36	7	10	10	12	40	45
HAA5: 54 µg/L	--	--	--	--	--	--	--	--	54	54	--	--	--	--
HAA5: 27 µg/L	1350	2080	8100	12480	2.4	2.1	120	135	27	27	37	37	165	140
HAA6: 54 µg/L	1940	--	11640	--	2.6	--	150	--	38	--	54	54	200	--
HAA6: 27 µg/L	650	1440	3900	8640	1.6	1.7	105	100	18	19	27	27	110	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.

- GAC effluent THM4 concentrations for both GAC columns exceeded 90% of both the Stage 1 and Stage 2 placeholder MCLs.

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

- Stage 1 THM4 breakthrough occurred at less than one month for the 10 minute EBCT column and at less than two months for the 20 minute EBCT column. THM4 breakthrough started to plateau soon after these time periods. The combination of these results indicates GAC reactivation or replacement would be necessary on a frequent basis, thus limiting the process feasibility.

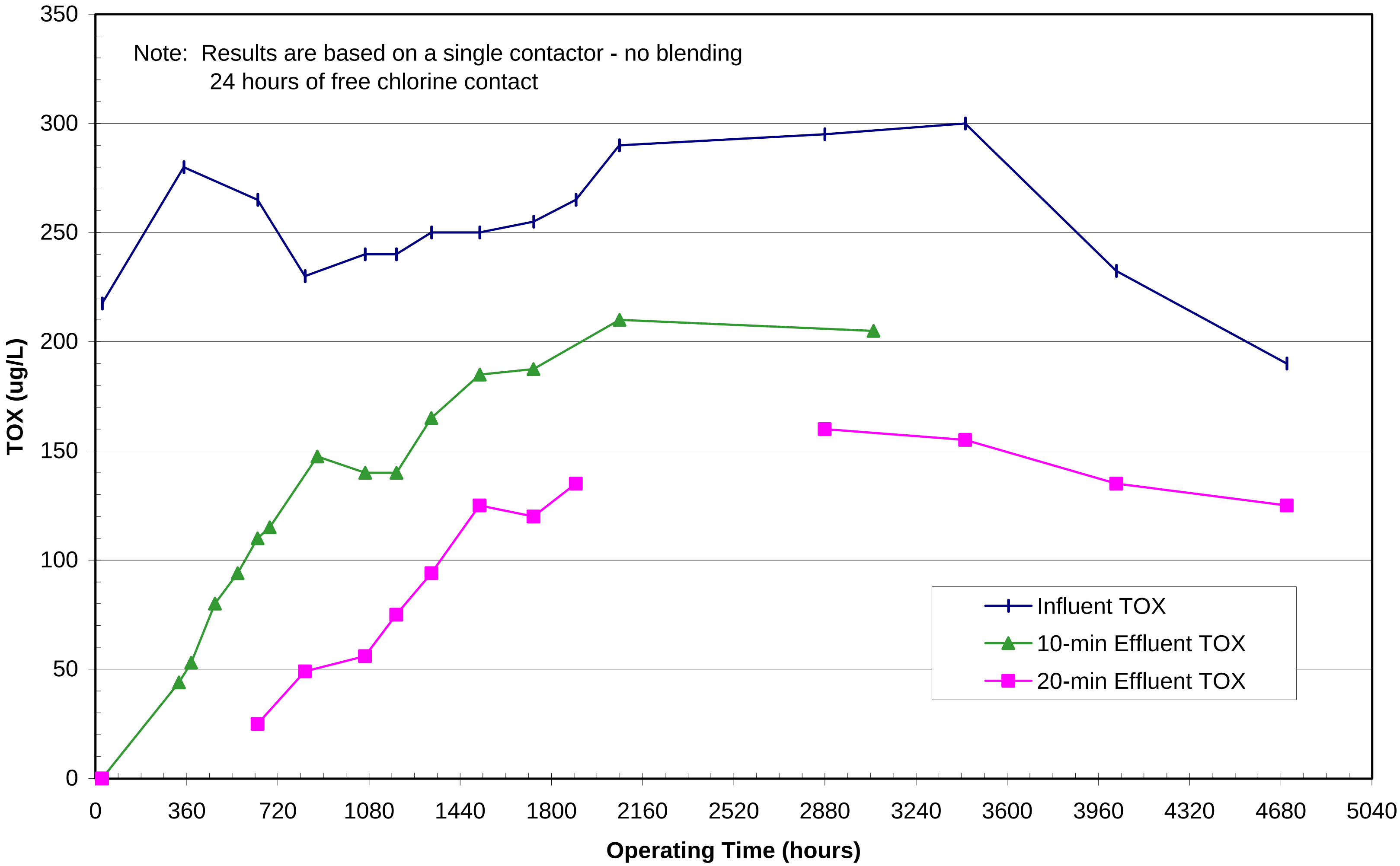
TOX Breakthrough:

Figure 4-8 shows TOX breakthrough results. Again, similar trends in the data were observed. Two questionable data points were omitted from the figure (as discussed in Section 4.1).

4.3.1 Seasonal Trends

Each of the figures presented above indicates similar trends in results. TOC, UV-254, DBP formation potential, and TOX formation potential influent results increased in the mid-summer months and decreased in October and November. Similarly, effluent results decreased slightly in October and November. These trends indicate seasonal changes may have contributed to the decreased breakthrough rates of these parameters at the end of the study. Though the study ended before the winter months, it appeared possible that decreases in influent TOC concentration would provide lower breakthrough of DBP precursors and decreased temperatures in the winter would provide less DBP formation upon chlorination. Therefore, carbon usage rates may decrease in the winter months.

Figure 4-8: GAC Pilot Results - South Holly WTP, ICR#647
TOX Breakthrough



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}

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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 IDA **1.3 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		