ICR Treatment Study Summary Report

Evaluation of Membrane Technology Using the Single Element Bench-Scale Test for Compliance with the Information Collection Rule

Conducted during the period of May 5, 1998 through March 8, 1999

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Green Meadows WTP
Plant ICR#: 1093

Attachments: 3diskettes containing the *Data Collection Spreadsheets*

ICR Treatment Study Summary Report
Table of Contents

Page No.

ICR Treatment Study Summary Report
List of Tables

ICR Treatment Study Summary Report
List of Figures

I. Conclusions and Recommendations

One form of treatment and disinfection membrane treatment was evaluated during this ICR study at the Green Meadows WTP. The treatment was membrane treatment while the means for disinfection was free chlorine. Membrane treatment has been proven effective in reducing TOC and in turn, reducing the disinfection byproducts THM4 and HAA5/HAA6. The study was performed within the guidelines recommended by EPA such that the results of this study could be compared with the results of other studies nationwide.

The study showed that if membrane treatment is used with free chlorine disinfection, a full capacity membrane plant (9 mgd) will be needed to meet the proposed Stage 2 Disinfectants and Disinfection Byproducts Rule. The existing treatment process was not reviewed in terms of its ability to reduce TOC and minimize THM4 and HAA5/HAA6 disinfection byproduct formation. A blending analysis was performed, but only to the extent to determine the percentage of permeate water to total water produced was needed. No blending analyses was performed using the existing plant product water, as this was not part of the scope of this study.

When using membranes to treat the Green Meadows WTP water supply, two forms of pretreatment is needed. pH adjustment is required to reduce scaling on the membranes. In addition, microfiltration is needed to prevent particles from entering the membrane, which could cause damage to the membranes.

A rough estimate for a new 9-mgd membrane plant is $18 million in capital costs. Since there is no apparent means for concentrate disposal due to the remoteness of the Green Meadows WTP, an injection well may also be needed for concentrate disposal. The capital cost of an injection well may run $3 to $5 million.

Using membranes with free chlorine disinfection to treat the water supply at the Green Meadows plant is technically feasible, but not economically feasible. The following recommendations are offered:

- A study should be performed to evaluate other treatment scenarios and options. This could include alternate disinfection other than free chlorine such as chloramonniation, and alternate treatment techniques such as enhanced softening or anion exchange.

- Use of the existing plant should be maximized. Additional treatment requirements should be based on that level of treatment and quality of water needed to produce a blend water that would satisfy current (Stage 1) and proposed (Stage 2) rules.

II. Background Information

Treatment Plant Description

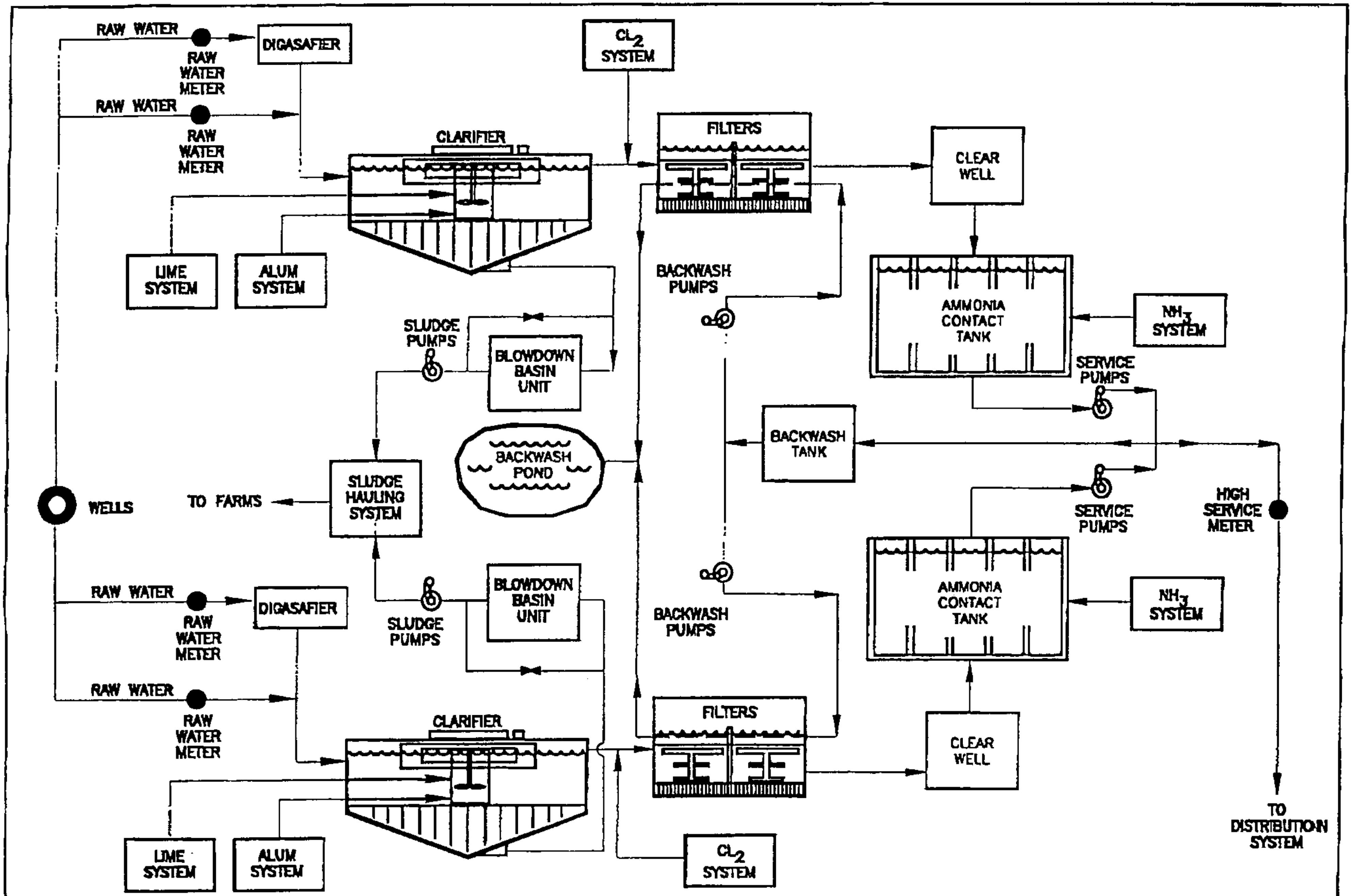
Treatment Plant Schematic: The Green Meadows WTP is a conventional lime softening water plant designed to treat surficial aquifer groundwater. Figure 1, supplied by Florida Cities Water Company, represents the Green Meadows WTP Treatment Process Flow Diagram. As presented in the process flow diagram, raw water is first degasified to reduce the hydrogen sulfide content of the source water. Lime and alum are added and mixed then the water is clarified through a settling tank. Chlorine is added upstream of the filters. Filtered water flows through a clearwell then to an ammonia contact tank. Water is sent to the customers directly from the ammonia tank. Lime and alum sludge is removed through a blowdown basin unit, then transferred to the sludge hauling system. The sludge is land applied to farm land. Filter backwash water is transferred to a backwash pond.

Treatment Plant Design Information: The Green Meadows WTP Design Information is summarized in Table 1.

Treatment Challenges Facing Plant: The greatest challenge facing the Green Meadows WTP is reduction of disinfection byproducts. Membrane treatment is a suitable method for reducing disinfection byproduct formation when using free chlorine, however, concentrate disposal will pose a significant issue since there is no apparent means for concentrate disposal other than deep well injection, which is costly.

Tabular Summary of Source/Finished Water

A summary of the average source and finished water quality is provided in Tables 2 and 3. This summary includes temperature, pH, turbidity, alkalinity, total hardness, calcium hardness, TOC, UV254 and bromide on the raw water and finished water pH, turbidity, and THM4.



TREATMENT PROCESS FLOW DIAGRAM

GREEN MEADOWS WATER TREATMENT PLANT 1996

Figure 1

01-22-96 GM-FL-D

Table 1 – Green Meadows WTP
Existing Plant Design Data

<u>Item</u>	<u>Parameter</u>
Plant Current Design Flow	
A. Capacity	9.0 MGD 4.5 MGD ea. Plant Unit A & B
Wellfield	
A. Capacity	12.47 MGD
B. Number of Units	13 Deep Wells; 14 Shallow Wells
degassifiers (Aerators)	
A. Type	Force Draft Type – New York Blowers
B. Capacity	3125 GPM Each Unit A & B
C. Fan Description	Fume Exhauster
D. Shop No.	PO 7620 100
E. Size	30 GFE
F. Motor	Baldor
1. Speed	1,750 RPM
2. Type	460 VAC
3. Horsepower	10 HP
4. Description	3 Belt Motor
G. Design Info	Units All Fiberglass with PVC Slats
Clarifiers	
A. Type	Solids Contact Type
B. Capacity	9.0 MGD Total, 4.5 MGD Each Unit
C. Tank Volume	370,000 Gallons Each
D. Propeller Drive	
1. Model	Winsmith Model 10CV
2. Drive	Ratio 30:1, 2-1/4” Shaft
E. Scraper Drive	
1. Model	Model # MCVDOW11-WCRM
2. Drive	Ratio: 3000:1 D1750 RPM
Chlorine Scales	
A. Make	(7) Eagle Micro Systems
B. Type	UWI 2000
High Rate Filters	
A. Number of Units	(4) Filters @ 1562 GPM Each
B. Rate	4.8 Gal/Sq. ft/min. Max Flow
C. Filter Media	Multimedia/Anthracite Filters Beads w/ Leopold Under Drains
D. Design Info	Each Filter Has (4) Surface Wash Sweeping Type PVC Nozzles; Leopold Brand

Table 1 – Green Meadows WTP
Existing Plant Design Data (Continued)

Item	Parameter
Clearwell/Ammonia Contact Chamber	
A. Type	Dual Interconnect
B. Volume	300,000 Gal
C. Design Info	(2) Ammonia Injector Nozzles in Clearwell to Ammonia Contact Chamber, Clearwells are Cable of Operating Independent to Each Clarifier
Backwash Pumps	
A. Type	(2) General Electric Motors
B. Motor	
1. Horsepower	60 HP
2. Type	460 VAC, 585, RPM
3. Model No.	5KS445-A1618
4. Serial No.	E5226046, E5226047
C. Pump	
1. Type	(2) Allis Chalmers Pumps
2. Volume	7220 GPM
3. Frame Type	445TS
4. Model No.	150
5. Serial No.	801-33184-3-1, 801-33184-3-2
6. Design Info	25' Head Impeller, Dia. 20"
Main Chlorinators	
A. Type	(4) Wallace & Tiernan Series, V10K 500 PPD
B. Serial No.	1 BE25461 2 BE25462 3 BE25464 4 BE25463
Chlorine Leak Detector	
A. Type	Wallace & Tiernan Series 50-135
B. Serial No.	AK84074, AX86736
C. Design Info	115 VAC, 50/60 Hz, 0.5 Amps
Ammoniators	
A. Type	(2) Ecometric 200 PPD
B. Series	
C. Model	
D. Serial No.	
E. Design Info	North 5656, South 5657; Feed Point Between Filters & Clearwell

Table 1 – Green Meadows WTP
Existing Plant Design Data (Continued)

Item	Parameter
Ammonia Storage Tanks	
A. Capacity	(2) 1,000 gal. Anhydrous Ammonia Tanks
Chlorine Booster Pump	
A. Type	Aurura 85-7095, Type 351-27
B. Horsepower	15 HP
C. Model No.	US 284T-FR
D. ID No.	9504791-248, L1820020
E. Design Info	3520 RPM, 460 VAC, 18 Amps
Chlorine Hoist Equipment	
A. Type	Yale 2 Tone Hoist
B. Model No.	BEW2-215T-1402
C. Serial No.	W305036AB
D. Design Info	Ton Chlorine Cylinder Moving System U-Shape Configuration
HS Pump Room Hoist Equipment	
A. Type	Acco Wright 4 Ton
B. Serial No.	4-79-0435-1
C. Crane Drive	DD-41595
D. Trolley Unit No.	533-05-3038
Lime Slaker & Feed Units	
A. Type	(2) Units Wallace & Tiernan; 1,000 lb/hr/feeders
B. Serial No.	AT-19943 & 21-21MV
1. Volumetric w/ Conveyor Type Grit Remover	AT-34903 & U-27160
C. Model No.	32-210MV
Lime Slurry Fee Pumps	
A. Pump	(3) Waukesha Hose Pumps
1. Type	Mode SP-40
2. Serial No.	3068
B. Motor	Baldor Motors
1. Type	9.0-8.6-4.3 Amps, 208-250-460 VAC
2. RPM	1725 RPM
3. Design Info	3-Phase, Frame 182TC
4. Serial No.	F287
5. Drive Unit	Variable Speed Drive, 3 HP, 10-63 RPM

Table 1 – Green Meadows WTP
Existing Plant Design Data (Continued)

Item	**Parameter**
Alum Feed Pumps & Equipment	
A. Storage Capacity	(2) 5,000 Gal. Above Ground Tanks
1. Type, Model No.	EXERXES Model #50, Fiberglass
B. Pumps	(2) Wallace & Tiernan Chem Tube, Encore 700 Metering Pumps, 16 GPD
1. Model No.	44 Series Diaphragm Metering Pump
C. Motors	Baldor Motors
1. Horsepower	.5 HP
2. Type	1725 RPM @ 460 VAC
3. Serial No.	34A63-872
Sludge Blowdown Units	
A. North Clarifier Pumps	
1. Type	(2) Aurora Pumps, Type 352-27
2. Design Info	GPM 200 @ 23' TDH, 1150 RPM
3. Serial No.	85-7093-1, 85-7093-2
B. North Clarifier Motors	
1. Type	(2) US 3 HP, 1170 RPM, 230/460 VAC
2. Design Info	9.4-4.7 Amps, Type TLE TE
3. Serial No.	F-5830-01-176, F-5830-01-175
C. South Clarifier Pumps	
1. Type	(2) Aurora Pumps, Type 352-27
2. Design Info	GPM 200 @ 49' TDH, 1170 RPM
3. Serial No.	85-7094-1, 85-7094-2
D. South Clarifier Motors	
1. Type	(2) US 7.5 HP, 1170 RPM, 230/460 VAC
2. Design Info	19.6-9.8 Amps, Type TLE TE
3. Serial No.	R-5832-01-229, R-5832-01-220
Sludge Thickening & Holding Tanks	
A. Capacity	25,000 Gallons Each Unit
B. Design Info	Concrete Construction
Sludge Pumping, Tanker Truck Loading	
A. Unit A Pump	
1. Type	Allis Chalmers Pumps
2. Serial No.	52-050-200-014
3. Frame Type	F602-391
4. RPM	1175 RPM
B. Unit A Motor	
1. Type	GE Motor, Type 284T
2. Model No.	5KS284AL300E-LR
3. RPM	1175 RPM

Table 1 – Green Meadows WTP
Existing Plant Design Data (Continued)

Item	Parameter
4. Horsepower, Volts	15 HP, 230/460 VAC
C. Unit B Pump	
1. Type	Allis Chalmers Pumps
2. Serial No.	52-050-200-022
3. Frame Type	F602-341
4. RPM	1175 RPM
D. Unit B Motor	
1. Type	GE Motor, Type 284T
2. Model No.	5KS284AL300E
3. RPM	1175 RPM
4. Horsepower, Volts	15 HP, 230/460 VAC
Auxiliary Generator (Power Unit)	
A. Diesel Storage Capacity	5100 Gal Above Ground Tank
B. Day Tank	
1. Type	50 gallon
2. Model	SFT
C. Day Tank Fuel Pump	Westinghouse B84
1. Horsepower, RPM	1/3 HP @ 1725 RPM
2. Design Info	115V, 1-Phase VAC
D. Generator Engine	Caterpillar
1. Model No.	D-349
2. RPM	1800 RPM
3. Frame No.	687
E. Generator	
1. Rating	750 KW, 60 Hz
2. Serial No.	600TH3382
3. Model No.	SRCR
4. Excitation	135V, 71 Amp
5. Part No.	8L10KVA
6. Low Connection	230V, 2353 Amp
7. High Connection	460V, 1177 Amp
Lift Station	
A. Type	(2) Flygt Pumps
B. Horsepower, RPM	2-1/2 HP, 1800 RPM
C. Rating	260/460 VAC, 3.7 Amps, 3-Phase
Air Compressor Units	
A. Air Compressors	
1. Type	(2) Quincey
2. Horsepower	10 HP ea.
3. Rating	460/3-Phase VAC

Table 1 – Green Meadows WTP
Existing Plant Design Data (Continued)

Item	**Parameter**
4. Model No.	350-21 and 350-18
B. Air Compressor Motors	
1. Type	Baldor Motors
2. Serial No.	303577 and 3714-T
3. Ajax Serial No.	13699L and 52151
C. Air Compressor Air Dryer	
1. Type	Hankson
2. Model No.	8055
3. Serial No.	A14467A
4. Horsepower, Rating	½ HP, 115 VAC 1 pH
Lime Silos	
A. Storage Capacity	200,000 lbs. each Silo
B. Design Info	Lime Silos Approximately 52' High
Lime Dust Collecting Unit	
A. Manufacturer	Consolidated Engineering Company
B. Serial No.	8535
C. Model No.	WS16-6
D. Motor	Baldor
1. Horsepower	3 HP
2. Model No.	3559-P
3. Rating	460/3-Phase VAC
E. Design Info	Located on South Silo
Lime Silo Air Vibrator System	
A. Manufacturer	Consolidated Engineering Company
B. Design Info	Air Injection Valves, Once Unit per Silo Used for Lime Bridging Prevention
Backwash Pond Reclaim Pumps	
A. Manufacturer	(2) Flygt Pumps
B. Horsepower	9.4 HP
C. Rating	12.8 Amps, 460/3-Phase
D. Model No.	WS
Backwash Storage Tank	
A. Manufacturer	Crom
B. Storage Capacity	500,000 Gallons
C. Design Info	Used for Backwashing Filters with Finished Water

Table 1 – Green Meadows WTP
Existing Plant Design Data (Continued)

Item	Parameter
High Service Pump S1	
A. Motor	
1. Make	Marathon Electric
2. Horsepower	300 HP
3. Frame	505US
4. Model No.	505USTDS640AN_W
B. Pump	
1. Type	Allis Chambers
2. Volume	2100 GPM/1750 RPM
3. Serial	851-39273-01-1
4. Type	9000
High Service Pumps N2	
A. Motor	
1. Make	Marathon Electric
2. Horsepower	300 HP
3. Frame	505US
4. Model No.	RU505USTDS640AN_W
B. Pump	
1. Type	Allis Chambers
2. Volume	3200 GPM/1750 RPM
3. Serial	851-39273-4-1
4. Type	9000
High Service Pump S3	
A. Motor	
1. Make	General Electric
2. Horsepower	300 HP
3. Frame	449TS DP
4. Model No.	5KS449AL204
B. Pump	
1. Type	N/A
2. Volume	N/A
3. Serial	N/A
4. Type	N/A
High Service Pump N4	
A. Motor	
1. Make	Toshiba
2. Horsepower	300 HP
3. Frame	447T
4. Model No.	B3004ULF4BD

Table 1 – Green Meadows WTP
Existing Plant Design Data (Continued)

Item	Parameter
B. Pump	
1. Type	Allis Chambers
2. Volume	2100 GPM/1750 RPM
3. Serial	801-33184-2-2
4. Type	N/A

Table 2 – Green Meadows WTP
Source Water Quality
(3/98 – 2/99)

Water Quality Parameter	Average Yearly Concentration	Standard Deviation	Maximum Yearly Value	Minimum Yearly Value
Temperature (°C)	26.8	1.5	29.0	22.0
pH	6.80	0.40	7.57	5.92
Turbidity (ntu)	8.77	8.4	28.0	0.24
Alkalinity (mg/L as $CaCO_3$)	190.6	53.4	260	36
Calcium Hardness (mg/L as $CaCO_3$)	216.3	10.3	240	200
Total Hardness (mg/L as $CaCO_3$)	277.3	9.4	290	260
TOC (mg/L)	6.23	0.87	9.3	5.0
UV_{254}(cm^{-1})	0.24	0.03	0.32	0.2
Bromide (µg/L)	245.4	69.7	420	66

Table 3 – Green Meadows WTP
Finished Water Quality
(3/98 – 2/99)

Water Quality Parameter	Average Yearly Concentration	Standard Deviation	Maximum Yearly Value	Minimum Yearly Value
pH	8.9	0.12	9.3	8.1
Turbidity (ntu)	0.14	0.13	2.28	0.05
Distribution System THM4 (μg/L)	69.8	-----	82.2	57.8

TOC and Temperature data not available.

III. Materials and Methods

The purpose of this section is to describe pretreatment needs, equipment used for the bench-scale study, the experimental design and the analytical methods used.

Pretreatment Process to the Advanced Treatment Process

Schematics of the Pretreatment Process: Pretreatment of the raw water is necessary when using membrane technology for the Green Meadows WTP. The water requires microfiltration to remove potential particles that may enter the system. Since the source water is groundwater supply, the potential exists for sand particles to enter the raw water system. Microfiltration can remove the sand particles and other particles that may be present in the supply.

The water must also be acidified such that scale formation is inhibited. The raw water contains substantial hardness and alkalinity as shown previously in Table 2. The average alkalinity is 190 mg/l while the average Calcium Hardness is over 200 mg/l. The pH must be lowered to inhibit scale formation.

Design Data for Each Pretreatment Process: A single element bench-scale testing unit was assembled for use in this ICR study. The unit consisted of a 4"X40" thin-film composite membrane. Two separate membranes were tested, the TFCS 4921S membrane by Fluid Systems and the NF70-4040 by FilmTec Corporation. The unit was equipped with pressure gages, sample taps, and flow rotometers such that data could be obtained and samples collected for analysis.

Advanced Treatment Process Information

Schematics and descriptions of the process equipment used to Investigate the Advanced Treatment Process: A process flow diagram for the single element bench-scale testing system is provided in Figure 2. Raw water was acidified and pumped through a cartridge filter prior to entering the membrane. Concentrate was recycled to the head of the membrane to simulate 70 to 72 percent recovery. Figure 2 also shows the valving, flow measurement, pressure gage, and sample locations for the test unit.

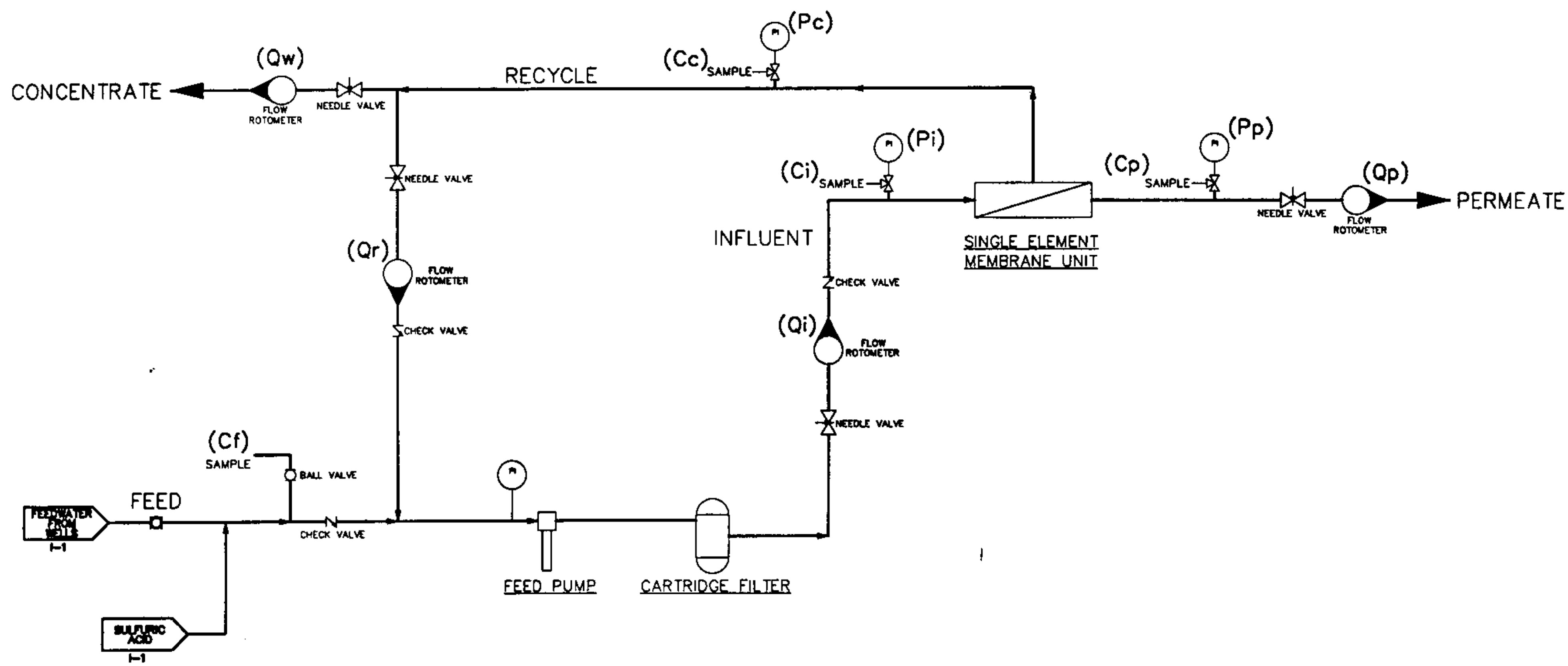


FIGURE 2

FLORIDA CITIES WATER COMPANY
GREEN MEADOWS WTP
SINGLE MEMBRANE ELEMENT PILOT TESTING

Hutcheon Engineers

1 of 1

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Design Data for the Advanced Treatment Process: The single element bench-scale test membrane system included the following equipment:

- Chemical metering pump (12 gpd) for acid feed
- Pressure pump (Grundfos CRN2-70, 2HP, 10 gpm @100 psi)
- Cartridge filter (1μm exclusion size)
- Fluid Systems Membrane (TFCS 4921S)
- FilmTec Membrane (NF70-4040)
- CodeLine Model 40A30 RO Pressure Vessel
- McDaniel stainless steel pressure gages (0-200 psi)
- Flow Rotometers (King Instrument Co., Series 7520)

Procedures Specific to the Treatment Study: Each membrane was tested once per quarter for a duration of four quarters. The membranes were cleaned after four weeks of testing. The cleaning procedure included an acid rinse at a pH of 4 to 5 for approximately 2 hours. Permeate water was run through the membrane for approximately 30 minutes following the acid flushing. The membranes were stored in sealed plastic bags until the next testing period. Green Meadows WTP staff operated the test unit, obtained samples, and recorded instrument readings for the duration of the study.

Experimental Design

The experimental design information is summarized in Table 4. Microfiltration with pH adjustment was used for each membrane every quarter. A cartridge filter with 1μm exclusion was used for particle removal. Hydrochloric acid was used to lower the pH to between 6.3 and 6.5. The water flux rate passing through the membrane ranged from 13 to 14 gallons per day per foot. The recovery ranged from 70 to 72 percent.

Analytical Methods

The analytical methods used for sample analysis are summarized in Table 5 for the parameters monitored during the ICR study. Two separate contract laboratories were used in addition to the Green Meadows WTP staff field and lab measurements. ELAB of Ormond Beach, Florida performed all of the analyses with the exception of TOX. TOX analyses were sub contracted by ELAB to AOX Specialties. A summary of the lab analyses performed by each lab is presented in Table 6.

Table 4 – Green Meadows WTP
Experimental Design Summary (SEBST Study)

Qtr.	Season	Membrane	Pretreatment	Water Flux, gfd	Recovery, %
1	Spring	Fluid Systems	Microfiltration w/ acid	14	72
1	Spring	Film Tec	Microfiltration w/ acid	14	72
2	Summer	Fluid Systems	Microfiltration w/ acid	14	71
2	Summer	Film Tec	Microfiltration w/ acid	14	72
3	Winter	Fluid Systems	Microfiltration w/ acid	13	70
3	Autumn	Film Tec	Microfiltration w/ acid	13	70
4	Winter	Fluid Systems	Microfiltration w/ acid	13	70
4	Winter	Film Tec	Microfiltration w/ acid	13	70

Table 5 – Green Meadows WTP
Analytical Methods Summary

Analyte	Method	Minimum Reporting Level
Alkalinity	SM 2320 B	5mg/L $CaCO_3$
Ammonia	SM 4500-NH_3 D	0.050 mg/L NH_3-N
Bromide	EPA 300.0	0.02 mg/L
Calcium Hardness	SM 2340 B	1.2 mg/L $CaCO_3$
Free Chlorine Residual (SDS)	SM 4500-C1 G	0.050 mg/L
BCAA, DBAA, DCAA, MBAA, MCAA, TCAA	EPA 552.1	1.0 µg/L for each analyte except MCAA which is 2.0 mg/L
pH	150.1	Not applicable
TDS	SM 2540 C	5.0 mg/L
Temperature	SM 2550 B	Not applicable
CHCl3, BDCM, DBCM, CHBr3	EPA 502.2	1.0 µg/L for each analyte except Chloroform which is 5.0 µg/L
Total Hardness	SM 2340 B	1.2 mg/L $CaCO_3$
TOC	SM 5310 B	0.70 mg/L
TOX	SM 5320 B	10 µg/L
Turbidity	180.1	0.10 ntu
UV_{254}	SM 5910	0.0090 cm^{-1}

Table 6 – Green Meadows WTP
Laboratory Summary

Laboratory	Dates of Service	Analyses Performed
ELAB	5/3/98-3/8/99	Alkalinity, Ammonia, Bromide, Calcium hardness, Chlorine residual, $HAA5_S$, pH, THM_S, TDS, Temperature, Total Hardness, TOC, TOX, Turbidity, UV_{254}
Green Meadows Lab	5/3/98-3/8/99	Pressure, Flow pH, Conductivity, Temperature
AOX Specialties	5/3/98-3/8/99	TOX

IV. Results and Discussion

The results of the single element bench-scale test study are presented in the summary spreadsheets provided in Exhibit 1 of this report. This section of the report provides information critical to the interpretation of the results and summarizes key findings of the study. In particular, this section describes problems encountered with the study that are not readily apparent from the data.

Problems Encountered

The most significant problem encountered was the fact that the laboratory did not perform the SDS analyses correctly for the first two quarters of the study. The error was detected by EPA while the third quarter testing was being performed. Laboratory testing was stopped during the second quarter, fourth week while testing the FilmTec membrane per Steve Allgeier's request after determining that the SDS analyses were being performed incorrectly. An explanation from the laboratory documenting the problem is presented in Exhibit 2. Only the third quarter testing had to be repeated per EPA.

The second most significant problem was that the pH feed fluctuated during the earlier portions of the study (first two quarters). When the pH of the feed water was not kept below 6.5 units, scale began to form on the membrane. When this occurred, a lower pH feed was temporarily passed through the membrane to dissolve the scale. The membrane was not taken out of service for cleaning until the end of the four-week test period.

Other problems encountered are associated with sampling or lab error. During the first two quarters, no concentrate samples were taken for analysis. There were also times where the lab received the samples after the maximum holding time due to shipping error. This occurred during the first quarter, second week and the second quarter, second week while testing the FilmTec membrane. Lab error was also noted during the first quarter, first week for the SDS-DBPs.

Water Quality Data

Water Quality of Pretreated Influent: A summary of the average quarterly pretreated feed water quality for the duration of the study is presented in Table 7. There appears to be little difference in temperature, pH, alkalinity, calcium and total hardness, total organic carbon, and bromide levels. Turbidity did show some fluctuation but there is no apparent trend noted. The SDS parameters, THM4, HAA5, HAA6, TOX, and chlorine demand cannot be evaluated in terms of trend since the SDS samples were not analyzed correctly for the first two quarters.

Table 7 – Green Meadows WTP
Average Pretreated Feed Water Quality
(5/98 – 3/99)

Water Quality Parameter	1st Quarter Average (SD)	2nd Quarter Average (SD)	3rd Quarter Average (SD)	4th Quarter Average (SD)
Temperature (°C)	27.4 (0.8)	28.0 (0.6)	26.3 (1.6)	25.8 (1.6)
PH	7.28 (0.17)	6.24 (0.23)	6.74 (0.25)	6.80 (0.16)
Turbidity (ntu)	6.19 (5.2)	1.1 (1.0)	16.58 (8.4)	9.29 (8.1)
Alkalinity (mg/L as $CaCO_3$)	248.8 (8.3)	131.8 (31.5)	188.8 (26.4)	178.3 (57.8)
Calcium Hardness (mg/L as $CaCO_3$)	210.0 (7.6)	216.7 (5.2)	220.0 (10.7)	218.8 (13.6)
Total Hardness (mg/L as $CaCO_3$)	268.8 (6.4)	276.7 (8.2)	285.0 (7.6)	278.8 (8.3)
Bromide (μg/L)	208.0 (88.3)	326.7 (81.9)	240.0 (12.0)	222.5 (10.1)
TOC (mg/L)	5.59 (0.32)	6.07 (0.31)	6.43 (1.22)	6.81 (0.72)
$UV_{254}(cm^{-1})$	0.24 (0.02)	0.24 (0.02)	0.24 (0.03)	0.25 (0.03)
SDS-THM4 (μg/L)	22.9 (16.5)	37.6 (16.4)	239.3 (30.0)	172.6 (71.9)
SDS-HAA5 (μg/L)	6.11 (3.4)	12.9 (8.1)	109.4 (63.4)	81.3 (40.3)
SDS-HAA6 (μg/L)	6.3 (3.7)	14.9 (9.7)	129.6 (70.5)	96.5 (46.0)
SDS-TOX (μg Cl^-/L)	264.9 (62.5)	295.5 (49.6)	805.5 (165.8)	584.5 (172.0)
SDS-Chlorine Demand (mg/L)	2.63 (0.63)	2.35 (0.33)	15.43 (4.93)	10.22 (1.98)

The water mass transfer coefficient was plotted against time for each of the membranes to observe treatment performance. The results are presented in Figures 3 and 4. Typically the water mass transfer coefficient decreases in time. Tracking this parameter can provide an indication of how often the membrane should be taken out of service and cleaned.

As can be seen from Figure 3, some decline was noted with the first quarter readings with the Fluid Systems membrane, but no noticeable decline was observed during the following three quarters. In fact, the water mass transfer coefficient improved. One possible reason the performance improved was the subsequent membrane cleanings may have been more effective. The mass transfer coefficients remained relatively steady with no decline from the first week of the quarter to the last week. One possible reason for this is that the pretreatment operations were improved. The acid feed was stabilized and kept low to minimize scaling.

The FilmTec membrane results were quite different as presented in Figure 4. A decline was noted particularly in the first and fourth quarters. Cleaning of the membranes did not seem to significantly improve membrane performance. One possible reason for the decline in performance could be the pretreatment. If scale build up is permitted due to insufficient pH adjustment, the performance will decline. It is imperative that the pH feed system is maintained.

DBP Data and Data Analysis: Membrane treatment is capable of treating the water to meet the Stage 1 and proposed Stage 2 Disinfectants and Disinfection Byproduct Rules. As such, feed water can be blended at some level to produce the desired water quality. The blending ratio is the percentage of membrane permeate of the total blend. The target blending ratio is based on the percentage of permeate flow needed to achieve THM4 levels 80 μg/l for Stage 1 and 40 μg/l using a 10 percent factor of safety. This results in 72 μg/l for Stage 1 and 36 μg/l for Stage 2.

An evaluation was performed to determine required raw water and permeate blending ratios required to meet the Stage 1 and proposed Stage 2 disinfection requirements. This information is summarized in Tables 8 and 9. Only the third and fourth quarter data was used in the evaluation since the SDS lab results for the first two quarters are incorrect. Based on the data, a permeate to total flow blending ratio of about 90 percent will be needed to meet the Stage 1 requirements and 100 percent for stage 2.

Figure 3
MTCw Decline Curve
(Fluid Systems Membrane)

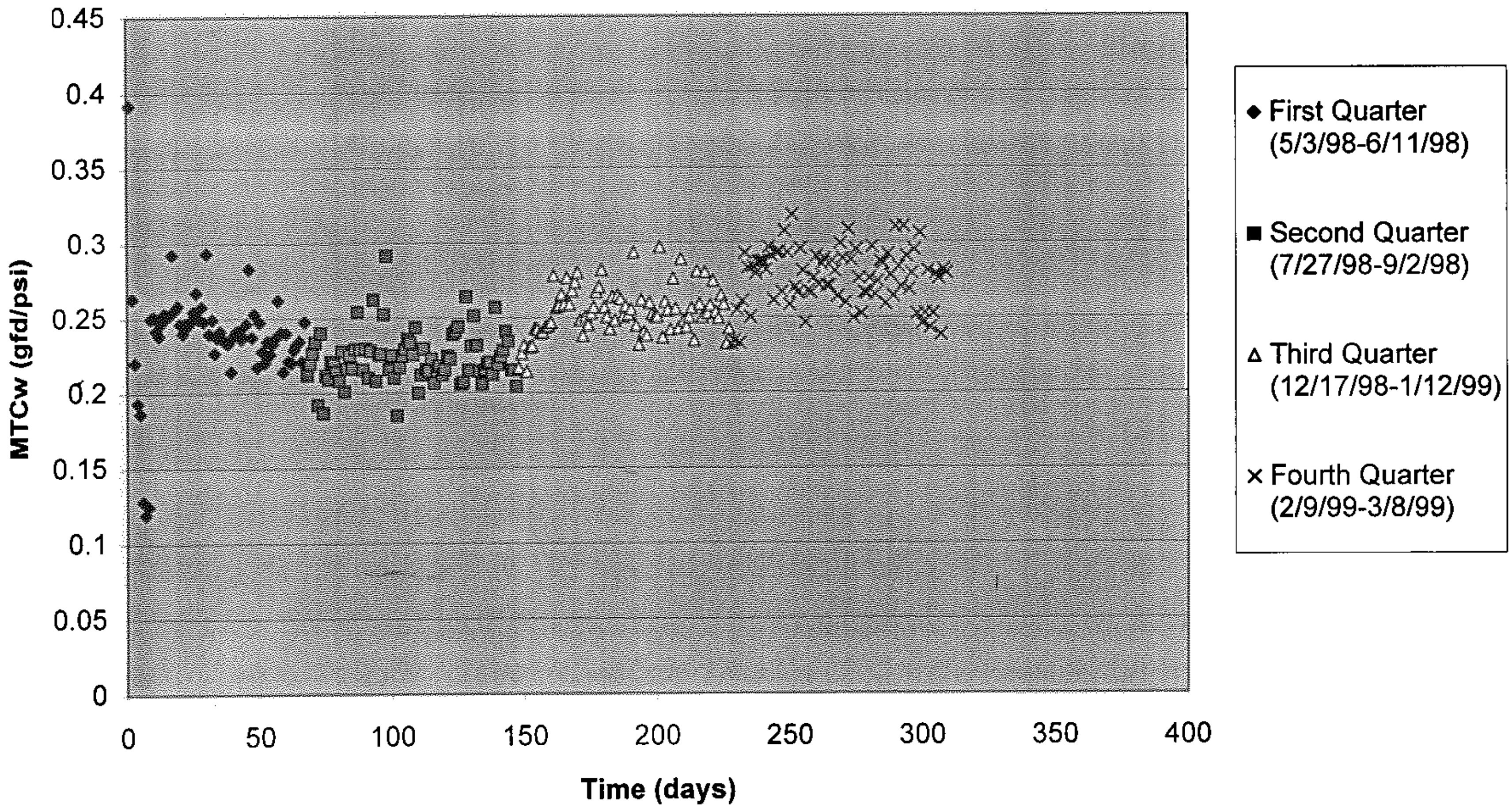

Figure 4
MTCw Decline Curve
(FilmTec Membrane)

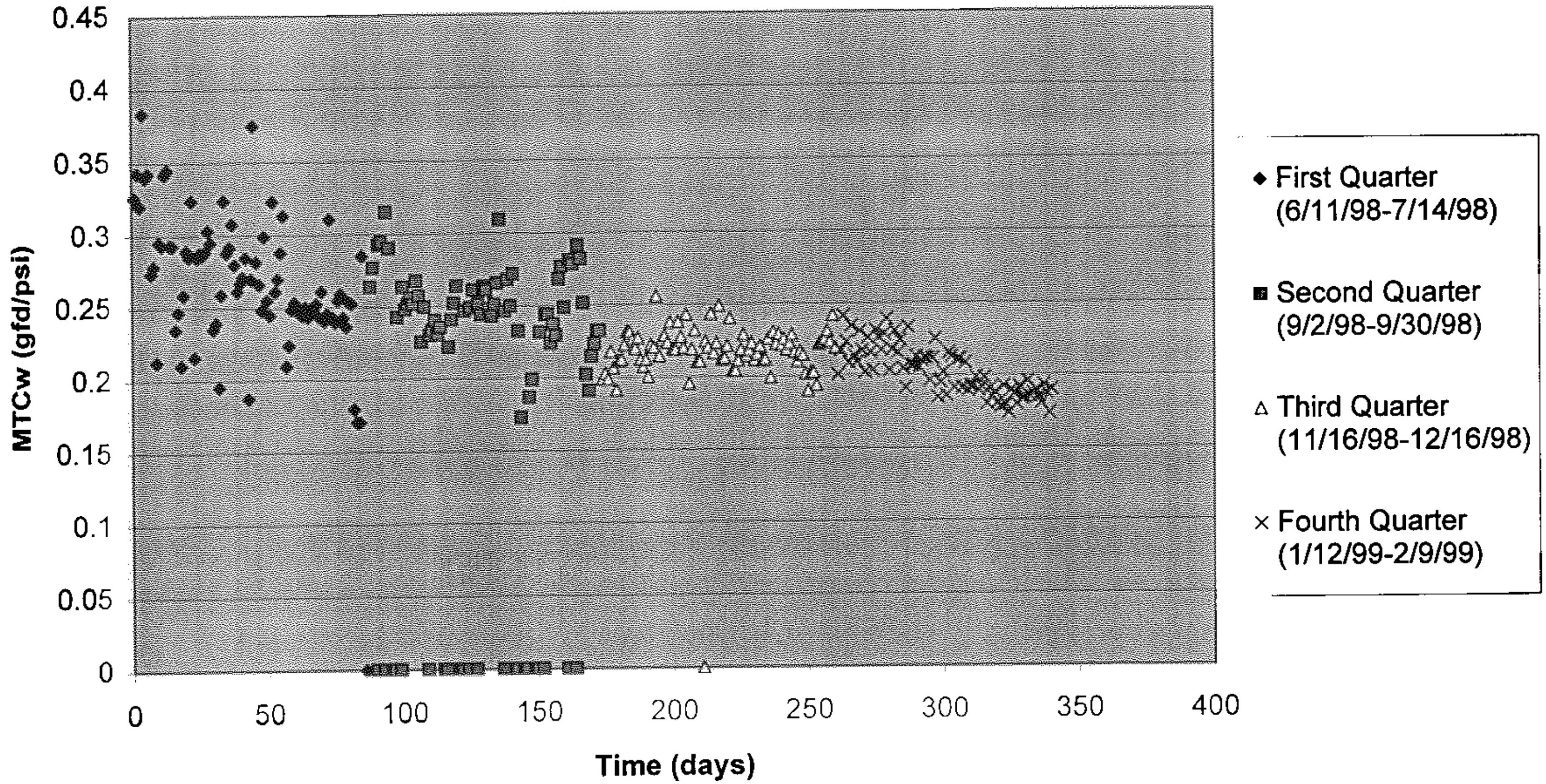

Table 8 – Green Meadows WTP IRC Study
Blending Ratios to Meet Stage 1 DBP Rules

				TOC			SDS THM4			SDS HAA5			SDS HAA6			SDS TOX		
Qtr.	**Wk.**		**Permeate Total Blend Flow Ratio**	**Permeate**	**Feed**	**Blend**	**Permeate**	**Feed**	**Blend**	**Permeate**	**Feed**	**Blend**	**Permeate**	**Feed**	**Blend**	**Permeate**	**Feed**	**Blend**
Fluid Systems																		
3	1	SDS-THM4=72ug/l	0.74	0.0	6.0	1.5	20	222	72	12	46	21	17	64	29	52	625	200
	2	SDS-THM4=72ug/l	0.76	0.0	6.5	1.5	18	249	72	3	13	6	3	16	6	38	648	182
	3	SDS-THM4=72ug/l	0.83	0.0	6.4	1.1	37	242	72	4	112	22	7	131	28	105	1020	262
	4	SDS-THM4=72ug/l	0.88	1.9	6.2	2.4	51	224	72	33	178	50	44	208	63	98	599	158
												0			0			0
4	1	* SDS-THM4=72ug/l	-0.25	0.0	6.0	7.5	24	62	72	10	21	24	14	26	29	67	238	280
	2	SDS-THM4=72ug/l	0.61	0.0	7.7	3.0	31	136	72	5	114	47	8	136	57	64	628	284
	3	SDS-THM4=72ug/l	0.53	0.0	6.4	3.0	25	126	72	3	38	20	5	46	24	47	438	230
	4	SDS-THM4=72ug/l	0.53	0.0	6.0	2.8	0	154	72	0	66	31	0	81	38	12	567	271
FilmTec												0			0			0
3	1	SDS-THM4=72ug/l	0.85	0.0	5.3	0.8	33	300	72	13	183	38	16	210	44	123	972	248
	2	SDS-THM4=72ug/l	0.73	0.9	6.0	2.2	27	195	72	4	108	32	4	130	38	73	934	302
	3	SDS-THM4=72ug/l	0.78	0.7	9.3	2.6	23	243	72	13	70	26	18	90	34	62	816	230
	4	SDS-THM4=72ug/l	0.80	0.0	5.7	1.2	29	239	72	16	165	46	23	188	56	69	830	224
												0			0			0
4	1	SDS-THM4=72ug/l	0.80	0.7	7.9	2.1	18	291	72	8	141	34	11	161	40	32	700	164
	2	SDS-THM4=72ug/l	0.77	0.0	6.7	1.6	19	247	72	7	113	32	10	133	38	53	776	220
	3	SDS-THM4=72ug/l	0.71	0.0	6.6	1.9	20	198	72	6	80	28	8	94	33	52	649	227
	4	SDS-THM4=72ug/l	0.63	1.2		0.8	15	167	72	7	78	33	9	96	41	57	680	289
		Average																
		SDS-THM4=72ug/l	0.74	0.3	6.6	2.0	24	206	72	9	95	32	12	113	39	63	695	229

* Possible labor sampling error on SDS THM 4.

Table 9 – Green Meadows WTP ICR Study
Blending Ratios to Meet Proposed Stage 2 DBPs

				TOC			SDS THM4			SDS HAA5			SDS HAA6			SDS TOX		
Qtr.	Wk.		Permeate: Total Flow Blend Ratio	Permeate	Feed	Blend	Permeate	Feed	Blend	Permeate	Feed	Blend	Permeate	Feed	Blend	Permeate	Feed	Blend
Fluid Systems																		
3	1	SDS-THM4=36ug/l	0.92	0.0	6.0	0.5	20	222	36	12	46	15	17	64	21	52	625	98
	2	SDS-THM4=36ug/l	0.92	0.0	6.5	0.5	18	249	36	3	13	4	3	16	4	38	648	87
	3	SDS-THM4=36ug/l	1.00	0.0	6.4	0.0	37	242	36	4	112	3	7	131	6	105	1020	102
	4	SDS-THM4=36ug/l	1.09	1.9	6.2	1.5	51	224	36	33	178	20	44	208	29	98	599	54
												0			0			0
4	1	SDS-THM4=36ug/l	0.68	0.0	6.0	1.9	24	62	36	10	21	14	14	26	17	67	238	122
	2	SDS-THM4=36ug/l	0.95	0.0	7.7	0.4	31	136	36	5	114	10	8	136	13	64	628	90
	3	SDS-THM4=36ug/l	0.89	0.0	6.4	0.7	25	126	36	3	38	7	5	46	10	47	438	91
	4	SDS-THM4=36ug/l	0.77	0.0	6.0	1.4	0	154	36	0	66	15	0	81	19	12	567	142
FilmTec												0			0			0
3	1	SDS-THM4=36ug/l	0.99	0.0	5.3	0.1	33	300	36	13	183	15	16	210	18	123	972	134
	2	SDS-THM4=36ug/l	0.95	0.9	6.0	1.2	27	195	36	4	108	10	4	130	11	73	934	117
	3	SDS-THM4=36ug/l	0.94	0.7	9.3	1.2	23	243	36	13	70	16	18	90	22	62	816	106
	4	SDS-THM4=36ug/l	0.97	0.0	5.7	0.2	29	239	36	16	165	20	23	188	28	69	830	93
												0			0			0
4	1	SDS-THM4=36ug/l	0.94	0.7	7.9	1.2	18	291	36	8	141	17	11	161	21	32	700	75
	2	SDS-THM4=36ug/l	0.93	0.0	6.7	0.5	19	247	36	7	113	15	10	133	19	53	776	106
	3	SDS-THM4=36ug/l	0.91	0.0	6.6	0.6	20	198	36	6	80	13	8	94	16	52	649	107
	4	SDS-THM4=36ug/l	0.86	1.2		1.0	15	167	36	7	78	16	9	96	20	57	680	142
		Average																
		SDS-THM4=36ug/l	0.94	0.3	6.6	0.7	24	206	36	9	95	15	12	113	19	63	695	103

Note that based on information supplied by Florida Cities Water Company, the distribution system yearly average THM4 level was 69.8 μg/l with a maximum of 82.2 μg/l and a minimum of 57.8 μg/l. The disinfection method used to achieve these levels is chloramoniation rather than free chlorine disinfection, which helps to reduce the THM formation.

It is likely that any improvements made at the Green Meadows WTP will include a blending scenario with the existing process rather than abandon the existing process and use strictly a membrane plant with raw water blend.

Impact of Seasonal Variability

As can be seen from the data presented previously in Table 7, there is little seasonal variation in water quality.

Impact of Specific Variables on Performance

The rate of productivity decline was calculated from the data on a seasonal (quarterly) basis. The results are presented in Table 10. The results are inconclusive in that there were some instances when the final membrane productivity was greater than the initial membrane productivity. Each computation of membrane productivity varied. This may be due to the pressure fluctuations observed by the Green Meadows WTP operators.

Cost Information and Analysis

Relative cost information is provided in the attached spreadsheets under Field 4-12 for the final quarter. These parameters enable EPA to perform a nation wide evaluation of cost impacts to utilities.

Table 10 – Green Meadows WTP IRC Study
Membrane Productivity
Observed Under Varying Operating Conditions

Fluid Systems Membrane					
Quarter	**Average Rate of MTCw Decline (gfd/psi/day)**	**Average Cleaning Interval (days)**	**Initial MTCw (gfd/psi)**	**Final MTCw (gfd/psi)**	**MTCw After Cleaning (gfd/psi)**
1	3.79E-03	N/A	0.392	0.248	0.212
2	2.29E-04	N/A	0.212	0.204	0.216
3	-1.04E-03	31	0.216	0.242	0.232
4	-1.96E-03	18	0.232	0.279	N/A
FilmTec Membrane					
Quarter	**Average Rate of MTCw Decline (gfd/psi/day)**	**Average Cleaning Interval (days)**	**Initial MTCw (gfd/psi)**	**Final MTCw (gfd/psi)**	**MTCw After Cleaning (gfd/psi)**
1	1.24E-03	N/A	0.326	0.285	0.264
2	1.14E-03	N/A	0.264	0.232	0.199
3	-6.67E-04	45	0.199	0.219	0.201
4	4.07E-04	N/A	0.201	0.19	N/A

In general capital costs for membrane treatment in south Florida is about $2 per gallon of treatment capacity. For the Green Meadow WTP, to replace the existing 9-mgd plant with a full-scale membrane plant, the cost could be on the order of $18 million dollars, which is a substantial amount of capital for duplicating the existing capacity with advanced treatment. In addition, the Green Meadows WTP is remote. According to Florida Cities' staff, there is no wastewater collection system nearby for disposal of concentrate. Reuse of concentrate as an irrigation supply in the vicinity of the plant is not viable since the concentrate TDS levels are too high.

Without performing detailed investigation of concentrate disposal options, an injection well may be needed to dispose of the concentrate. An additional capital budget of $3 to $5 million needs to be added to the capital budgeting for the plant.

Summary of Significant Results

This ICR study showed that the membrane treatment process was effective in reducing TOC, THM4 and HAA5/HAA6 levels in the water when using free chlorine disinfection. The study also showed that a 9-mgd membrane plant would be needed to meet the proposed Stage 2 Rules when using free chlorine as the disinfectant.

Pretreatment is essential for this system. pH adjustment is imperative to minimize scale formation. Microfiltration is also necessary to remove particulates that may damage the membranes.

V. QA/QC Summary

The additional summary report spreadsheets as well as the results of all lab analyses are provided in exhibit 3. The first page of the exhibit is a calibration summary table that identifies the test method, frequency of calibrations, and check standards. ELAB, INC provided all lab information in this Exhibit.

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