ICR Treatment Study Summary Report

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

Conducted during the period of April 1998 through Jan 1999

Prepared by:
Environmental Health Laboratories
110 S. Hill St.
South Bend, IN 46617

Black & Veatch
5728 LBJ Freeway, Suite 300
Dallas, TX 75240

In June 1999

For:
City of Beaumont, TX1230001
P.O. Box 3827
Beaumont, TX 77704-3827
Telephone (409) 866-0023
Facsimile (409) 860-4672

Beaumont Water Plant, #636

Attachments: 2 diskettes containing the *Data Collection Spreadsheets*
1 diskette containing the *Treatment Summary Report Spreadsheets*
2 diskettes containing the *ICR Treatment Summary Report*

Outline For The Treatment Study Summary Report

I. Conclusions and Recommendations

II. Background Information

A. Treatment plant description
   1. Treatment plant schematic
   2. Treatment plant design information
   3. Treatment plant challenges facing plant
B. Tabular summary of source/finished water quality

III. Materials and Methods

A. Pretreatment processes to the advanced treatment process
   1. Schematics of pretreatment processes
   2. Design data for each pretreatment process
B. Advanced treatment process information
   1. Schematics and descriptions of the process equipment used to investigate the advanced treatment process
   2. Design data for the advanced treatment process
   3. Procedures specific to the treatment study
C. Experimental Design
D. Analytical Methods

IV. Results and Discussion

A. Problems encountered
B. Water quality data
   1. Water quality of pretreated influent
   2. DBP data and data analysis
C. Impact of seasonal variability
D. Impact of specific variables on performance
E. Cost information and analysis
F. Summary of significant results

V. QA/QC Summary

I. Conclusions and Recommendations

Both membranes performed similarly well, as determined by evaluating the Simulated Distribution System samples, in controlling the concentration of total organic carbon (TOC) and disinfection byproducts (DBPs) in the distribution system. During the course of the bench-scale study, significant membrane fouling occurred in both membranes. Additional antiscalant was added in the fourth quarter and the membranes were operated at a slightly lower flux. These actions significantly improved flux loss.

Prior to decision-making regarding the use of this technology to meet future regulations, the City should evaluate membrane technology in a more detailed study. The goal of this study would be to obtain data on long-term fouling, performance, treatment design criteria, and residuals disposal.

II. Background Information

A. Treatment Plant Description

The Beaumont Water Treatment Plant (WTP) is a conventional clarification plant consisting of rapid mix, clarification, filtration, and storage. The clarification basins are equipped with pulsator equipment. Raw water is pumped from the Neches River through a canal to the treatment plant. The treatment process includes rapid mixing, pulsator flocculating/settling, dual-media filtration, and ground storage. Figure 1 presents a schematic of the full-scale treatment plant.

The sample for use in the bench-scale membrane study was collected after the filter in the full-scale plant. The chlorinator prior to the sampling point was turned off and residual chlorine was measured to ensure that the sample was free of chlorine.

Table 1a contains the full-scale plant unit process design information; Table 1 b contains the Bench-scale unit process information.

The existing water treatment plant would require some facility rehabilitation to provide a consistent feed water quality to a membrane treatment system. Additional pumps will be needed to deliver the feed water at a pressure required to operate a membrane system. In addition to these facilities, current corrosion control practices and post-treatment disinfection will still be required. Membrane cleaning facilities will be required as well as additional residuals disposal facilities to handle not only the sludge from the clarification basins and the backwash from the filters, but also the concentrate from the membrane system. Space at the existing treatment plant may be available but would require removal or renovation of existing facilities already occupying this space. Additional study of the quality of the water from a membrane treatment plant and its interaction with the ground water from the City’s wells should also be included in any

B. Tabular summary of source and finished water quality: Tables 2a and 2b contain the summary of source and finished water quality provided by the water treatment plant.

III. Materials and Methods

A. Pretreatment Processes to the Advanced Treatment Process

Schematics of pretreatment processes: Figure 1 outlines the full-scale process used in the plant prior to the sampling point. At the bench-scale level, the following pretreatment was performed at the laboratory:

Bench-scale mixing with antiscalant; cartridge filtration; nanofiltration. See Figure 2. Table 1b has all of the information concerning the pretreatment of the water prior to nanofiltration. See Table 1a for design information on the full scale plant.

B. Advanced Treatment Process Information

A schematic for the process equipment used for the RBSMT is shown in Figure 3. This schematic shows only one unit, but two identical units were used during the study. This allowed for the simultaneous evaluation of two membranes using the same influent water. The ICR Manual for Bench and Pilot-scale Studies was used as a guide in the set-up of the apparatus.

In general, the guidelines for evaluating the membranes in the RBSMT came directly from the ICR Manual for Bench and Pilot-scale Studies. The membranes were cleaned as described in the manual using manufacturer recommended cleaning solutions. For both membranes, the following procedure was used:

1. Rinse with reagent water for 1-2 min at high cross- flow velocity (using recycle pump setting near “8”).
2. Clean with 0.5% phosphoric acid for 20 min at high cross-flow velocity.
3. Rinse with reagent water, 1-2 min.
4. Clean with 0.1% sodium hydroxide for 20 min at high cross-flow velocity.
5. Rinse with reagent water, 1-2 min.

After the final rinse, the membrane cell was re-attached to the system. The MTCw was then evaluated at 30% recovery using the test water. Note: At no time was the membrane cell opened during cleaning. After cleaning, the system was run until a stable MTCw was obtained, and permeate and concentrate samples were taken to compare feed rejection prior to cleaning. The system was then shut down for total cleaning.

C. Experimental Design

Table 3 describes the experimental design used in the study. Seasonal variability was examined as the primary variable using two nanofiltration membranes. Flux during each season was essentially held constant, and the four recoveries of 30, 50, 70, and 90 % were investigated. During the 4th quarter, more antiscalant was added in order to observe the effect on fouling. The two membranes chosen for the study were the NF200 and the BW30-XLE. The XLE is considered the "tighter" membrane since it rejects a higher percentage of inorganic ions than the NF-200. Each membrane meets the ICR MWCO criteria set forth in the ICR Treatment Studies Manual.

D. Analytical Methods

Table 4 lists the analytical methods and MRLs used for the study. There were no deviations from the QA/QC procedures outlined in the DBP/ICR Analytical Methods Manual.

All analytical services were performed at Environmental Health Laboratories.

ICR Lab ID # IN004
Environmental Health Laboratories
110 South Hill Street
South Bend, Indiana 46617

Contact person: Ed George
Phone: 219-233-4777
Fax: 219-233-8207

IV. Results and Discussion

A. Problems Encountered

During the study, significant membrane fouling occurred in both membranes. The pretreated influent appeared very clear and had a relatively low TDS, pH and Turbidity. Some of the parameters outlined in the data collection spreadsheets in Field 1-4 were tested on the influent water (See Data Collection Spreadsheets). Additional antiscalant was added (more than recommended dosage) in quarter 4, along with operation at a slightly lower flux. This significantly improved flux loss.

During the first quarter, temperature measurements on the influent were made with in-line temperature gauges. These gauges were found to be inaccurate. As a result, an NIST calibrated thermometer was used to measure the influent temperature during the last 3 quarters of the study.

At 90% recovery, high mass balance errors were generally observed in the spreadsheets. This may be due to inaccurate flow-rate measurements. To improve accuracy at the low flow-rates observed for the concentrate at 90%, volumetric measurements over a longer period of time were used, along with a longer stabilization period when the recovery was switched from 70 to 90%. No specific guidance on flow-rate measurements is given in the manual, except that a volumetric measurement must be taken.

B. Water Quality Data

1. The water quality of the pretreated influent is summarized in Table 5. Table 6 contains the specific simulated distribution system (SDS) conditions for each quarter in the study. Table 5 includes a summary of the DBP data obtained at these SDS conditions in the influent water.

C. Impact of Seasonal Variability

During the course of the study, seasonal variability did not have a significant impact on the performance of either membrane.

D. Impact of Specific Variables on Performance

Included in this final report are several Tables and Graphs that illustrate the performance of the membranes throughout the course of the study. They are as follows:

1. Flux and water mass transfer coefficient relationships- XLE Membrane
   - Figures 4–7: Flux as a function of operation time
   - Figures 8-12: MTCw as a function of operation time
   - Figures 13-16: Rate of MTCw Decline Linear Regression Plots
   - Table 7: Summary of Membrane Productivity for each season

2. Pressure, temperature, pH, and TDS grab samples-XLE Membrane
   - Figures 17-20: Influent, osmotic, and NDP as a function of operation time
   - Figures 21-24: Influent and ave feed temperature as a function of operation time
   - Figures 25-28: pH of permeate, concentrate, and feed as a function of operation time
   - Figures 29-32: TDS of feed and permeate as a function of operation time

3. Analyte concentration and DBP formation as a function of recovery- XLE Membrane
   - Figure 33: Recovery plot for all 4 quarters as a function of operation time
   - Figures 34-39: Permeate water quality parameters as a function of recovery
   - Figures 40-44: Permeate SDS THMs as a function of recovery
   - Figures 45-49: Permeate SDS HAA6 as a function of recovery

4. Feed and bulk rejection plots- XLE Membrane
   - Tables 8a-d: Effect of recovery on feed rejection on the composite samples for the RBSMT
   - Figures 50-57: TDS and UV254 rejection as a function of operation time

5. Flux and water mass transfer coefficient relationships- NF200 Membrane
    Figures 58-61: Flux as a function of operation time
    Figures 62-66: MTCw as a function of operation time
    Figures 67-70: Rate of MTCw Decline Linear Regression Plots
    Table 13: Summary of Membrane Productivity for each season

6. Pressure, temperature, pH, and TDS grab samples-NF200 Membrane
    Figures 71-74: Influent, osmotic, and NDP as a function of operation time
    Figures 75-78: Influent and ave feed temperature as a function of operation time
    Figures 79-82: pH of permeate, concentrate, and feed as a function of operation time
    Figures 83-86: TDS of feed and permeate as a function of operation time

7. Analyte concentration and DBP formation as a function of recovery- NF200 Membrane
    Figure 87: Recovery plot for all 4 quarters as a function of operation time
    Figures 88-93: Permeate water quality parameters as a function of recovery
    Figures 94-98: Permeate SDS THMs as a function of recovery
    Figures 99-103: Permeate SDS HAA6 as a function of recovery

8. Feed and bulk rejection plots- NF200 Membrane
    Table 14a-d: Effect of recovery on feed rejection on the composite samples for the RBSMT
    Figures 104-111: TDS and UV254 rejection as a function of operation time

E. Cost Information and Analysis

No cost analyses were performed.

F. Summary of Significant Results

In addition to the tables and graphs listed above in Sections C and D, the following tables illustrate the blend ratios to achieve various finished water qualities for each membrane:

Tables 9-12: Blend Ratio Tables –XLE Membrane
Tables 15-18: Blend Ratio Tables- NF200 Membrane

In general, both membranes reject significant amounts of precursor material at all recoveries (UV 254 and TOC at > 90%). The XLE membrane can be considered a “softening membrane”, as it generally rejects a higher percentage of inorganic constituents.

V. QA/QC Summary

All QA/QC procedures and requirements were followed as described in the DBP/ICR Analytical Methods Manual. Note that Table 4 lists the MRLs, some of which are lower than those listed in the manual.

All results for lab duplicates and lab fortified matrices are summarized in the ICR Treatment Study Summary Report Spreadsheets, along with some miscellaneous data about the public water supply.

PE results: Environmental Health Laboratories is a certified ICR lab that participated in all ICR PE studies. The results for these studies are listed in Tables 19-22.

Calibration Procedures: The calibration procedures for HAA, THM, TOX, Br, and TOC used during the study are consistent with the DBP/ICR Analytical Methods Manual. Tables 9.1 to 9.4 in this manual were used as guidelines for the frequency and percent recovery requirements.

Noted QC failures: The following samples failed QC criteria and were reported as “NR” in the spreadsheets:

Permeate sample for XLE membrane at 30 % for HAA analysis: The surrogate standard was not added to the sample due to lab error. This data, however, was graphed but not reported in the Data Collection Spreadsheets.

Table 1a: Treatment Plant Design Information

Unit Process	Process Description
Rapid Mix	Type of Mixer: Mechanical Baffling Type: Unbaffled - Mixed Tank Liquid Volume (gal): 56,885 Mean Velocity Gradient (sec^{-1}): 128.0 Coagulant Addition: Aluminum Sulfate (Alum) Coagulant Dose (mg/L): 40.00 Coagulant Aid: Organic Polymer - JFLOC 800 Coagulant Aid Dose (mg/L): 0.50 pH Adjustment: Sodium Hydroxide pH Adjustment Dose (mg/L): 25.00
Pulsator (Solids Contact Clarifier)	Clarifier Type: Rectangular basin, upflow, sludge blanket Brand Name: Infilco Surface Area (ft^2): 22,125 Liquid Volume (gal): 2,730,668 Baffling Type: Unbaffled
Filtration	Surface Area (ft^2): 4,380 Liquid Volume (gal): 180,193 Total Media Depth (in.): 38 Media Type: Dual - Anthracite/sand Minimum Water Depth to Top of Media (ft): 2.3 Depth From Top of Media to Top of Backwash Trough (ft): 2.3
Disinfection	Chemical Type: Chlorine Gas Measured as: Cl_2 Dose Rate (mg/L): 3.57
Reservoir (Clearwell)	Surface Area (ft^2): 44,700 Liquid Volume (gal): 5,000,000 Baffling Type: Unbaffled Covered Contactor: Yes Corrosion Control: Polyphosphate Corrosion Control Dose (mg/L): 0.60 pH Adjustment: Sodium Hydroxide pH Adjustment Dose (mg/L): 11.00 + 5.30 Other Chemical: Hydrofluorosilic Acid Other Chemical Dose (mg/L): 0.70

Table 1b: Bench-Scale Pretreatment Data

Unit Process	Process Description
Scale Control (Bench-Scale)	Chemical Type: Hypersperse AF 200 ul
	Adjusted pH: NA
	Dose Rate (mg/L): Q1-Q3 = 3.0, Q4 = 4.0
Cartridge Filtration (Bench-Scale)	Surface Area (ft2): 4.5
	Nominal Pore Size (µm): 1.0
	Filter Material: Polypropylene
	Filter Life (gallons of processed water): NA

Table 2a: Tabular Summary of Source Water Quality

Water Quality Parameter	Average Yearly Concentration	Standard Deviation	Maximum Yearly Value	Minimum Yearly Value
Temperature (oC)	23.4	6.3	31.7	14.4
pH	6.58	0.23	6.93	6.21
Turbidity (ntu)	32.6	10.6	59.2	17.3
Alkalinity (mg/L as CaCO3)	20	5	25	9
Calcium Hardness (mg/L as CaCO3)	18	4	23	9
TOC (mg/L)	8.1	2.7	13.0	5.4
UV254 (cm-1)	0.466	0.178	0.753	0.240
Bromide (µg/L)	0.049	0.016	0.081	<0.020

Table 2b: Tabular Summary of Finished Water Quality

Water Quality Parameter	Average Yearly Concentration	Standard Deviation	Maximum Yearly Value	Minimum Yearly Value
Temperature (^{o}C)	22.7	5.8	31.4	14.4
pH	8.09	0.31	8.44	7.36
Turbidity (ntu)	0.17	0.05	0.28	0.08
TOC (mg/L)	3.4	0.5	4.7	2.8
Distribution System THM4 (µg/L)	71.0	16.2	90.0	44.9

Table 3: Experimental Design Summary for a RBSMT Study

Season	Membrane	Pretreatment	Water Flux, gfd	Recovery, %
Spring	Membrane A	Conventional filtration & antiscalant addition	18.3	30, 50, 69, & 89
Spring	Membrane B	Conventional filtration & antiscalant addition	15.0	30, 49, 69, & 88
Summer	Membrane A	Conventional filtration & antiscalant addition	18.3	29, 50, 69, & 89
Summer	Membrane B	Conventional filtration & antiscalant addition	15.0	29, 51, 70, & 89
Fall	Membrane A	Conventional filtration & antiscalant addition	18.3	30, 50, 70, & 90
Fall	Membrane B	Conventional filtration & antiscalant addition	15.0	30, 51, 70, & 89
Winter	Membrane A	Conventional filtration & antiscalant addition	18.3	30, 51, 70, & 90
Winter	Membrane B	Conventional filtration & antiscalant addition	15.0	30, 50, 70, & 90

Notes:
Membrane A: NF200
Membrane B: XLE

Table 4: Summary of Analytical Methods and MRLs Used During a Study

Analyte	Method	Minimum Reporting Level
Alkalinity	SM 2320 B	1.0 mg/L $CaCO_3$
Ammonia	SM 4500-NH_3 D	0.30 mg/L NH_3-N
Bromide	EPA 300.0	20 µg/L
Calcium Hardness	SM 2340 B	0.25 mg/L $CaCO_3$
Chlorine Residual	SM 4500-Cl G	0.1 mg/L
BCAA, DBAA, DCAA, MBAA, MCAA, TCAA,	EPA 552.2	2.0 µg/L for MCAA 1.0 µg/L for all others
pH	SM 4500-H^+	Not Applicable
TDS	SM 2510 B (TDS meter)	5.0 mg/L
Temperature	SM 2550 B	Not Applicable
CHCl3, BDCM, DBCM, CHBr3	EPA 524.2	1.0 µg/L for each analyte
Total Hardness	SM 2340 B	0.33 mg/L $CaCO_3$
TOC	SM 5310 C	0.50 mg/L
TOX	SM 5320 B	25.0 µg/L
Turbidity	EPA 180.1	0.05 ntu
UV_{254}	SM 5910	0.001 cm^{-1}

Table 5: Average Pretreated Feed Water Quality During 4 Seasons of the RBSMT Study

Water Quality Parameter	Units	Spring Average	Spring S.D.	Summer Average	Summer S.D.	Fall Average	Fall S.D.	Winter Average	Winter S.D.
pH	---	6.13	0.23	6.09	0.31	5.67	0.45	5.71	0.14
Temperature	°C	20.5	0.71	21.5	2.12	22.5	0.00	22.0	0.35
Alkalinity	mg/L as $CaCO_3$	2.3	0.35	5.9	0.85	2.5	0.14	2.3	0.35
Total dissolved solids	mg/L	111.8	0.92	112.1	2.90	104.9	0.35	106.3	0.35
Total hardness	mg/L as $CaCO_3$	25.4	2.55	30.1	1.77	28.6	1.98	23.7	0.71
Calcium hardness	mg/L as $CaCO_3$	12.8	2.47	19.8	0.35	16.1	1.27	15.2	0.14
Turbidity	ntu	0.34	0.16	0.17	0.01	0.16	0.00	0.12	0.03
Ammonia	mg NH_3-N / L	BMRL	BMRL	BMRL	BMRL	BMRL	BMRL	BMRL	BMRL
Total organic carbon	mg/L	3.75	0.07	3.65	0.07	3.53	0.11	3.20	0.00
UV_{254}	cm^{-1}	0.060	0.02	0.074	0.00	0.074	0.00	0.055	0.00
SUVA	L/(mg*m)	1.60	0.52	2.03	0.04	2.09	0.04	1.72	0.00
Bromide	µg/L	60.0	2.83	60.5	3.54	56.2	3.96	53.0	1.41
SDS-Cl_2 dose	mg/L	3.25	1.06	3.67	0.04	5.00	0.00	4.15	0.49
SDS-Free Cl_2 residual	mg/L	1.66	1.19	1.26	0.57	2.20	0.05	2.22	0.40
SDS-Cl_2 demand	mg/L	1.59	0.13	2.41	0.61	2.81	0.05	1.94	0.09
SDS-Chlorination temp.	°C	20.9	0.00	23.9	0.00	30.0	0.00	11.0	0.00
SDS-Chlorination pH	---	7.70	0.00	8.06	0.08	7.80	0.01	8.09	0.04
SDS-Incubation time	hours	6.8	0.04	6.4	0.00	6.0	0.00	6.0	0.00
SDS-TOX	µg Cl^-/L	417.50	272.24	272.50	3.54	267.50	3.54	172.50	17.68
SDS-*CHCl3*	µg/L	46.00	6.51	62.84	13.27	56.81	9.02	31.69	3.38
SDS-*BDCM*	µg/L	20.08	1.87	21.11	2.85	18.86	2.91	12.67	0.95
SDS-*DBCM*	µg/L	5.00	0.42	5.34	0.59	3.85	0.50	3.37	0.52
SDS-*CHBr3*	µg/L	BMRL	BMRL	BMRL	BMRL	0.10	NA	BMRL	BMRL
SDS-THM4	µg/L	71.08	8.80	89.29	16.71	79.57	12.37	47.73	1.91
SDS-*MCAA**	µg/L	2.04	NA	2.15	0.57	BMRL	BMRL	BMRL	BMRL
SDS-*DCAA**	µg/L	20.13	0.36	20.36	1.94	27.74	3.73	16.64	1.29
SDS-*TCAA**	µg/L	19.51	4.59	17.32	1.67	28.60	4.43	13.50	1.73
SDS-*MBAA**	µg/L	BMRL	BMRL	BMRL	BMRL	BMRL	BMRL	BMRL	BMRL
SDS-*DBAA**	µg/L	1.04	NA	1.21	0.14	1.03	NA	1.28	0.21
SDS-*BCAA**	µg/L	5.88	0.62	5.78	0.59	7.15	1.95	5.56	0.99
SDS-*TBAA*	µg/L	NA	NA	NA	NA	NA	NA	NA	NA
SDS-*CDBAA*	µg/L	NA	NA	NA	NA	NA	NA	NA	NA
SDS-*DCBAA*	µg/L	NA	NA	NA	NA	NA	NA	NA	NA
SDS-HAA5	µg/L	41.17	4.24	41.04	0.16	56.86	8.89	31.41	3.22
SDS-HAA6	µg/L	47.05	3.62	46.82	0.44	64.01	10.84	36.97	4.21

Table 6: SDS (Simulated Distribution System) Conditions

Parameters	Units	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
pH	-	7.7	8.1	7.8	8.1
Temperature	°C	20.9	30.0	30.0	11.0
Target residual	mg/L	0.5 - 1.0	0.5 - 1.0	2.2	1.9
Retention Time	hours	6.43	6.43	6.00	6.00

Table 7: Average XLE Membrane Productivity Observed Under Different Operating Conditions During the RBSMT Study

Operating Conditions	Average Rate of MTCw Decline (gfd/psi/day)	*Initial MTCw (gfd/psi)	Final MTCw (gfd/psi)	MTCw After Cleaning (gfd/psi)
Spring	-0.0291	0.250	0.109	0.248
Summer	-0.0216	0.363	0.226	0.283
Fall	-0.0323	0.407	0.174	0.309
Winter	-0.0055	0.310	0.267	0.262

*MTCw at setting

Effect of Recovery on Feed Rejection for a RBSMT Study (XLE) - Composite Samples

Table 8a: 1st Quarter

Water Quality Parameter	Feed Rejection at Listed Recovery (%)			
	Recovery=30%	Recovery=49%	Recovery=69%	Recovery=88%
TDS	93.65	94.45	93.80	89.30
Ca Hardness	100.00	100.00	100.00	100.00
Total Hardness	100.00	100.00	100.00	98.80
Bromide	100.00	100.00	100.00	100.00
TOC	100.00	100.00	100.00	100.00
UV254	96.67	100.00	88.30	76.70
SDS-THM4	100.00	100.00	100.00	100.00
SDS-HAA5	100.00	100.00	100.00	100.00
SDS-HAA6	100.00	100.00	100.00	100.00
SDS-TOX	100.00	100.00	100.00	100.00

Table 8b: 2nd Quarter

Water Quality Parameter	Feed Rejection at Listed Recovery (%)			
	Recovery=29%	Recovery=51%	Recovery=70%	Recovery=89%
TDS	94.56	95.45	90.90	85.00
Ca Hardness	84.81	98.99	98.00	87.30
Total Hardness	90.02	99.33	98.30	89.00
Bromide	100.00	0.83	100.00	58.70
TOC	100.00	100.00	100.00	100.00
UV254	97.30	94.59	95.90	95.90
SDS-THM4	100.00	100.00	100.00	98.80
SDS-HAA5	100.00	100.00	100.00	100.00
SDS-HAA6	100.00	100.00	100.00	100.00
SDS-TOX	100.00	100.00	100.00	100.00

Table 8c: 3rd Quarter

Water Quality Parameter	Feed Rejection at Listed Recovery (%)			
	Recovery=30%	Recovery=51%	Recovery=70%	Recovery=89%
TDS	91.03	91.89	90.40	82.50
Ca Hardness	97.52	55.28	95.30	95.00
Total Hardness	97.55	74.13	96.70	96.50
Bromide	100.00	100.00	100.00	52.00
TOC	100.00	100.00	100.00	100.00
UV254	98.64	97.28	100.00	100.00
SDS-THM4	99.42	99.11	99.00	98.20
SDS-HAA5	100.00	100.00	100.00	100.00
SDS-HAA6	100.00	100.00	100.00	100.00
SDS-TOX	100.00	100.00	76.40	100.00

Table 8d: 4th Quarter

Water Quality Parameter	Feed Rejection at Listed Recovery (%)			
	Recovery=30%	Recovery=50%	Recovery=70%	Recovery=90%
TDS	93.32	94.16	89.90	80.50
Ca Hardness	100.00	100.00	100.00	97.40
Total Hardness	100.00	100.00	99.60	97.00
Bromide	100.00	100.00	100.00	41.50
TOC	100.00	100.00	100.00	100.00
UV254	100.00	98.18	98.20	94.50
SDS-THM4	100.00	100.00	100.00	97.60
SDS-HAA5	100.00	100.00	100.00	100.00
SDS-HAA6	100.00	100.00	100.00	100.00
SDS-TOX	100.00	100.00	100.00	100.00

Table 9: Quarter 1 - Blend Ratios to Achieve Various Finished Water Qualities for the XLE Nanofiltration Membrane

Stage	Controlling Treatment Objective	Value of Listed Parameter at Blend Ratio to Achieve Controlling Treatment Objective				
		Permeate:Total Flow Blend Ratio	*TOC (mg/L)*	*SDS-THM4 (µg/L)*	*SDS-HAA5 (µg/L)*	*SDS-HAA6 (µg/L)*
1	SDS-THM4 = 80 (µg/L) (Recovery = 30%)	NA	NA	NA	NA	NA
2	SDS-THM4 = 40 (µg/L) (Recovery = 30%)	0.494	BMRL	36.00	20.85	23.81
1	SDS-THM4 = 80 (µg/L) (Recovery = 49%)	NA	NA	NA	NA	NA
2	SDS-THM4 = 40 (µg/L) (Recovery = 49%)	0.494	BMRL	36.00	20.85	23.81
1	SDS-THM4 = 80 (µg/L) (Recovery = 69%)	NA	NA	NA	NA	NA
2	SDS-THM4 = 40 (µg/L) (Recovery = 69%)	0.494	BMRL	36.00	20.85	23.81
1	SDS-THM4 = 80 (µg/L) (Recovery = 88%)	NA	NA	NA	NA	NA
2	SDS-THM4 = 40 (µg/L) (Recovery = 88%)	0.494	BMRL	36.00	20.85	23.81

Stage	Controlling Treatment Objective	Value of Listed Parameter at Blend Ratio to Achieve Controlling Treatment Objective				
		Permeate:Total Flow Blend Ratio	*TOC (mg/L)*	*SDS-THM4 (µg/L)*	*SDS-HAA5 (µg/L)*	*SDS-HAA6 (µg/L)*
1	SDS-HAA5 = 60 (µg/L) (Recovery = 30%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (µg/L) (Recovery = 30%)	0.344	BMRL	46.62	27.00	30.86
1	SDS-HAA5 = 60 (µg/L) (Recovery = 49%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (µg/L) (Recovery = 49%)	0.344	BMRL	46.62	27.00	30.86
1	SDS-HAA5 = 60 (µg/L) (Recovery = 69%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (µg/L) (Recovery = 69%)	0.344	BMRL	46.62	27.00	30.86
1	SDS-HAA5 = 60 (µg/L) (Recovery = 88%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (µg/L) (Recovery = 88%)	0.344	BMRL	46.62	27.00	30.86

Note:
Stage 1: SDS-HAA5 = 60 µg/L
Stage 2: SDS-HAA5 = 30 µg/L
The value of SDS-HAA6 at the appropriate blend ratio (Q_P/Q_T) was calculated using the following formula:

$$(Q_P/Q_T)/100 * (SDS\text{-}HAA6_P - SDS\text{-}HAA6_F) + SDS\text{-}HAA6_F$$

Table 10: Quarter 2 - Blend Ratios to Achieve Various Finished Water Qualities for the XLE Nanofiltration Membrane

Stage	Controlling Treatment Objective	Value of Listed Parameter at Blend Ratio to Achieve Controlling Treatment Objective				
		Permeate:Total Flow Blend Ratio	***TOC (mg/L)***	***SDS-THM4 (µg/L)***	***SDS-HAA5 (µg/L)***	***SDS-HAA6 (µg/L)***
1	SDS-THM4 = 80 (µg/L) (Recovery = 29%)	0.194	NA	72.00	33.09	37.74
2	SDS-THM4 = 40 (µg/L) (Recovery = 29%)	0.597	NA	36.00	16.55	18.87
1	SDS-THM4 = 80 (µg/L) (Recovery = 51%)	0.194	NA	72.00	33.09	37.74
2	SDS-THM4 = 40 (µg/L) (Recovery = 51%)	0.597	NA	36.00	16.55	18.87
1	SDS-THM4 = 80 (µg/L) (Recovery = 70%)	0.194	NA	72.00	33.09	37.74
2	SDS-THM4 = 40 (µg/L) (Recovery = 70%)	0.597	NA	36.00	16.55	18.87
1	SDS-THM4 = 80 (µg/L) (Recovery = 89%)	0.196	NA	72.00	33.00	37.64
2	SDS-THM4 = 40 (µg/L) (Recovery = 89%)	0.604	NA	36.00	16.24	18.54

Stage	Controlling Treatment Objective	Value of Listed Parameter at Blend Ratio to Achieve Controlling Treatment Objective				
		Permeate:Total Flow Blend Ratio	***TOC (mg/L)***	***SDS-THM4 (µg/L)***	***SDS-HAA5 (µg/L)***	***SDS-HAA6 (µg/L)***
1	SDS-HAA5 = 60 (µg/L) (Recovery = 29%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (µg/L) (Recovery = 29%)	0.342	NA	58.74	27.00	30.81
1	SDS-HAA5 = 60 (µg/L) (Recovery = 51%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (µg/L) (Recovery = 51%)	0.342	NA	58.74	27.00	30.81
1	SDS-HAA5 = 60 (µg/L) (Recovery = 70%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (µg/L) (Recovery = 70%)	0.342	NA	58.74	27.00	30.81
1	SDS-HAA5 = 60 (µg/L) (Recovery = 89%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (µg/L) (Recovery = 89%)	0.342	NA	59.11	27.00	30.81

Note:
Stage 1: SDS-HAA5 = 60 µg/L
Stage 2: SDS-HAA5 = 30 µg/L
The value of SDS-HAA6 at the appropriate blend ratio (Q_P/Q_T) was calculated using the following formula:

$$(Q_P/Q_T)/100 * (\text{SDS-HAA6}_P - \text{SDS-HAA6}_F) + \text{SDS-HAA6}_F$$

Table 11: Quarter 3 - Blend Ratios to Achieve Various Finished Water Qualities for the XLE Nanofiltration Membrane

Stage	Controlling Treatment Objective	Value of Listed Parameter at Blend Ratio to Achieve Controlling Treatment Objective				
		Permeate:Total Flow Blend Ratio	*TOC (mg/L)*	*SDS-THM4 (µg/L)*	*SDS-HAA5 (µg/L)*	*SDS-HAA6 (µg/L)*
1	SDS-THM4 = 80 (µg/L) (Recovery = 30%)	0.096	NA	72.00	51.42	57.87
2	SDS-THM4 = 40 (µg/L) (Recovery = 30%)	0.551	NA	36.00	25.54	28.74
1	SDS-THM4 = 80 (µg/L) (Recovery = 51%)	0.096	NA	72.00	51.40	57.87
2	SDS-THM4 = 40 (µg/L) (Recovery = 51%)	0.552	NA	36.00	25.44	28.68
1	SDS-THM4 = 80 (µg/L) (Recovery = 70%)	0.096	NA	72.00	51.40	57.87
2	SDS-THM4 = 40 (µg/L) (Recovery = 70%)	0.553	NA	36.00	25.42	28.61
1	SDS-THM4 = 80 (µg/L) (Recovery = 89%)	0.097	NA	72.00	51.35	57.80
2	SDS-THM4 = 40 (µg/L) (Recovery = 89%)	0.558	NA	36.00	25.15	28.29

Stage	Controlling Treatment Objective	Value of Listed Parameter at Blend Ratio to Achieve Controlling Treatment Objective				
		Permeate:Total Flow Blend Ratio	*TOC (mg/L)*	*SDS-THM4 (µg/L)*	*SDS-HAA5 (µg/L)*	*SDS-HAA6 (µg/L)*
1	SDS-HAA5 = 60 (µg/L) (Recovery = 30%)	0.050	NA	75.59	54.00	60.81
2	SDS-HAA5 = 30 (µg/L) (Recovery = 30%)	0.525	NA	38.03	27.00	30.40
1	SDS-HAA5 = 60 (µg/L) (Recovery = 51%)	0.050	NA	75.61	54.00	60.81
2	SDS-HAA5 = 30 (µg/L) (Recovery = 51%)	0.525	NA	38.16	27.00	30.40
1	SDS-HAA5 = 60 (µg/L) (Recovery = 70%)	0.050	NA	75.61	54.00	60.81
2	SDS-HAA5 = 30 (µg/L) (Recovery = 70%)	0.525	NA	38.19	27.00	30.40
1	SDS-HAA5 = 60 (µg/L) (Recovery = 89%)	0.050	NA	75.64	54.00	60.81
2	SDS-HAA5 = 30 (µg/L) (Recovery = 89%)	0.525	NA	38.55	27.00	30.40

Note:
Stage 1: SDS-HAA5 = 60 µg/L
Stage 2: SDS-HAA5 = 30 µg/L
The value of SDS-HAA6 at the appropriate blend ratio (Q_P/Q_T) was calculated using the following formula:

$$(Q_P/Q_T)/100 * (SDS\text{-}HAA6_P - SDS\text{-}HAA6_F) + SDS\text{-}HAA6_F$$

Table 12: Quarter 4 - Blend Ratios to Achieve Various Finished Water Qualities for the XLE Nanofiltration Membrane

Stage	Controlling Treatment Objective	Value of Listed Parameter at Blend Ratio to Achieve Controlling Treatment Objective				
		Permeate:Total Flow Blend Ratio	*TOC (mg/L)*	*SDS-THM4 (µg/L)*	*SDS-HAA5 (µg/L)*	*SDS-HAA6 (µg/L)*
1	SDS-THM4 = 80 (µg/L) (Recovery = 30%)	NA	NA	NA	NA	NA
2	SDS-THM4 = 40 (µg/L) (Recovery = 30%)	0.246	NA	36.00	23.69	27.88
1	SDS-THM4 = 80 (µg/L) (Recovery = 50%)	NA	NA	NA	NA	NA
2	SDS-THM4 = 40 (µg/L) (Recovery = 50%)	0.246	NA	36.00	23.69	27.88
1	SDS-THM4 = 80 (µg/L) (Recovery = 70%)	NA	NA	NA	NA	NA
2	SDS-THM4 = 40 (µg/L) (Recovery = 70%)	0.246	NA	36.00	23.69	27.88
1	SDS-THM4 = 80 (µg/L) (Recovery = 90%)	NA	NA	NA	NA	NA
2	SDS-THM4 = 40 (µg/L) (Recovery = 90%)	0.252	NA	36.00	23.50	27.65

Stage	Controlling Treatment Objective	Value of Listed Parameter at Blend Ratio to Achieve Controlling Treatment Objective				
		Permeate:Total Flow Blend Ratio	*TOC (mg/L)*	*SDS-THM4 (µg/L)*	*SDS-HAA5 (µg/L)*	*SDS-HAA6 (µg/L)*
1	SDS-HAA5 = 60 (µg/L) (Recovery = 30%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (µg/L) (Recovery = 30%)	0.140	NA	41.03	27.00	31.79
1	SDS-HAA5 = 60 (µg/L) (Recovery = 50%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (µg/L) (Recovery = 50%)	0.140	NA	41.03	27.00	31.79
1	SDS-HAA5 = 60 (µg/L) (Recovery = 70%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (µg/L) (Recovery = 70%)	0.140	NA	41.03	27.00	31.79
1	SDS-HAA5 = 60 (µg/L) (Recovery = 90%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (µg/L) (Recovery = 90%)	0.140	NA	41.19	27.00	31.79

Note:
Stage 1: SDS-HAA5 = 60 µg/L
Stage 2: SDS-HAA5 = 30 µg/L
The value of SDS-HAA6 at the appropriate blend ratio (Q_P/Q_T) was calculated using the following formula:

$$(Q_P/Q_T)/100 * (\text{SDS-HAA6}_P - \text{SDS-HAA6}_F) + \text{SDS-HAA6}_F$$

Table 13: Average NF200 Membrane Productivity Observed Under Different Operating Conditions During the RBSMT Study

Operating Conditions	Average Rate of MTCw Decline (gfd/psi/day)	*Initial MTCw (gfd/psi)	Final MTCw (gfd/psi)	MTCw After Cleaning (gfd/psi)
Spring	-0.0290	0.390	0.227	0.456
Summer	-0.0150	0.333	0.213	0.341
Fall	-0.0120	0.34	0.209	0.357
Winter	0.0002	0.309	0.265	0.383

*MTCw at setting

Effect of Recovery on Feed Rejection for a RBSMT Study (NF200)

Composite Samples

Table 14a: 1st Quarter

Water Quality Parameter	Feed Rejection at Listed Recovery (%)			
	Recovery=30%	Recovery=50%	Recovery=69%	Recovery=89%
TDS	67.96	66.35	61.00	54.50
Ca Hardness	83.53	82.75	79.20	81.20
Total Hardness	83.46	83.07	80.10	88.60
Bromide	1.67	5.00	0.00	0.00
TOC	100.00	100.00	100.00	100.00
UV254	93.33	83.33	83.30	71.70
SDS-THM4	96.61	95.58	91.50	84.40
SDS-HAA5	100.00	100.00	100.00	96.90
SDS-HAA6	100.00	100.00	100.00	97.30
SDS-TOX	100.00	100.00	100.00	100.00

Table 14b: 2nd Quarter

Water Quality Parameter	Feed Rejection at Listed Recovery (%)			
	Recovery=29%	Recovery=50%	Recovery=69%	Recovery=89%
TDS	71.80	67.60	60.30	53.10
Ca Hardness	81.27	81.27	80.50	77.20
Total Hardness	82.70	82.70	81.40	79.00
Bromide	22.31	0.83	0.00	0.00
TOC	100.00	100.00	100.00	100.00
UV254	94.59	94.59	94.60	90.50
SDS-THM4	98.68	96.86	93.40	88.00
SDS-HAA5	100.00	100.00	96.20	96.20
SDS-HAA6	100.00	100.00	95.60	94.20
SDS-TOX	100.00	100.00	100.00	100.00

Table 14c: 3rd Quarter

Water Quality Parameter	Feed Rejection at Listed Recovery (%)			
	Recovery=30%	Recovery=50%	Recovery=70%	Recovery=90%
TDS	71.58	71.39	65.50	56.30
Ca Hardness	88.20	86.96	82.60	82.60
Total Hardness	87.76	85.31	81.30	81.50
Bromide	14.59	14.59	0.00	0.00
TOC	100.00	100.00	100.00	100.00
UV254	95.92	93.20	97.30	94.60
SDS-THM4	96.36	96.47	93.20	87.40
SDS-HAA5	100.00	100.00	100.00	98.20
SDS-HAA6	100.00	100.00	100.00	98.40
SDS-TOX	100.00	100.00	100.00	100.00

Table 14d: 4th Quarter

Water Quality Parameter	Feed Rejection at Listed Recovery (%)			
	Recovery=30%	Recovery=51%	Recovery=70%	Recovery=90%
TDS	77.13	75.34	69.80	61.80
Ca Hardness	93.42	91.45	93.80	90.80
Total Hardness	92.83	91.98	92.20	90.70
Bromide	13.21	11.32	0.00	0.00
TOC	100.00	100.00	100.00	100.00
UV254	98.18	94.55	96.40	92.70
SDS-THM4	100.00	100.00	97.50	89.70
SDS-HAA5	100.00	100.00	100.00	95.20
SDS-HAA6	100.00	100.00	100.00	92.90
SDS-TOX	67.54	100.00	100.00	100.00

Table 15: Quarter 1 - Blend Ratios to Achieve Various Finished Water Qualities for the NF200 Nanofiltration Membrane

Stage	Controlling Treatment Objective	Value of Listed Parameter at Blend Ratio to Achieve Controlling Treatment Objective				
		Permeate:Total Flow Blend Ratio	*TOC (mg/L)*	*SDS-THM4 (µg/L)*	*SDS-HAA5 (µg/L)*	*SDS-HAA6 (µg/L)*
1	SDS-THM4 = 80 (µg/L) (Recovery = 30%)	NA	NA	NA	NA	NA
2	SDS-THM4 = 40 (µg/L) (Recovery = 30%)	0.511	NA	36.00	20.14	23.01
1	SDS-THM4 = 80 (µg/L) (Recovery = 50%)	NA	NA	NA	NA	NA
2	SDS-THM4 = 40 (µg/L) (Recovery = 50%)	0.516	NA	36.00	19.91	22.77
1	SDS-THM4 = 80 (µg/L) (Recovery = 69%)	NA	NA	NA	NA	NA
2	SDS-THM4 = 40 (µg/L) (Recovery = 69%)	0.539	NA	36.00	18.97	21.69
1	SDS-THM4 = 80 (µg/L) (Recovery = 89%)	NA	NA	NA	NA	NA
2	SDS-THM4 = 40 (µg/L) (Recovery = 89%)	0.585	NA	36.00	17.84	20.27

Stage	Controlling Treatment Objective	Value of Listed Parameter at Blend Ratio to Achieve Controlling Treatment Objective				
		Permeate:Total Flow Blend Ratio	*TOC (mg/L)*	*SDS-THM4 (µg/L)*	*SDS-HAA5 (µg/L)*	*SDS-HAA6 (µg/L)*
1	SDS-HAA5 = 60 (µg/L) (Recovery = 30%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (µg/L) (Recovery = 30%)	0.344	NA	47.44	27.00	30.86
1	SDS-HAA5 = 60 (µg/L) (Recovery = 50%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (µg/L) (Recovery = 50%)	0.344	NA	47.70	27.00	30.86
1	SDS-HAA5 = 60 (µg/L) (Recovery = 69%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (µg/L) (Recovery = 69%)	0.344	NA	48.69	27.00	30.86
1	SDS-HAA5 = 60 (µg/L) (Recovery = 89%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (µg/L) (Recovery = 89%)	0.355	NA	49.77	27.00	30.80

Note:
Stage 1: SDS-HAA5 = 60 µg/L
Stage 2: SDS-HAA5 = 30 µg/L
The value of SDS-HAA6 at the appropriate blend ratio (Q_P/Q_T) was calculated using the following formula:

$$(Q_P/Q_T)/100 * (SDS\text{-}HAA6_P - SDS\text{-}HAA6_F) + SDS\text{-}HAA6_F$$

Table 16: Quarter 2 - Blend Ratios to Achieve Various Finished Water Qualities for the NF200 Nanofiltration Membrane

Stage	Controlling Treatment Objective	Value of Listed Parameter at Blend Ratio to Achieve Controlling Treatment Objective				
		Permeate:Total Flow Blend Ratio	***TOC (mg/L)***	***SDS-THM4 (μg/L)***	***SDS-HAA5 (μg/L)***	***SDS-HAA6 (μg/L)***
1	SDS-THM4 = 80 (μg/L) (Recovery = 29%)	0.196	NA	72.00	32.98	37.64
2	SDS-THM4 = 40 (μg/L) (Recovery = 29%)	0.605	NA	36.00	16.22	18.49
1	SDS-THM4 = 80 (μg/L) (Recovery = 50%)	0.200	NA	72.00	32.83	37.45
2	SDS-THM4 = 40 (μg/L) (Recovery = 50%)	0.616	NA	36.00	15.75	17.98
1	SDS-THM4 = 80 (μg/L) (Recovery = 69%)	0.207	NA	72.00	32.85	36.97
2	SDS-THM4 = 40 (μg/L) (Recovery = 69%)	0.639	NA	36.00	15.80	18.22
1	SDS-THM4 = 80 (μg/L) (Recovery = 89%)	0.220	NA	72.00	32.35	37.68
2	SDS-THM4 = 40 (μg/L) (Recovery = 89%)	0.678	NA	36.00	14.26	16.91

Stage	Controlling Treatment Objective	Value of Listed Parameter at Blend Ratio to Achieve Controlling Treatment Objective				
		Permeate:Total Flow Blend Ratio	***TOC (mg/L)***	***SDS-THM4 (μg/L)***	***SDS-HAA5 (μg/L)***	***SDS-HAA6 (μg/L)***
1	SDS-HAA5 = 60 (μg/L) (Recovery = 29%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (μg/L) (Recovery = 29%)	0.342	NA	59.15	27.00	30.80
1	SDS-HAA5 = 60 (μg/L) (Recovery = 50%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (μg/L) (Recovery = 50%)	0.342	NA	59.71	27.00	30.80
1	SDS-HAA5 = 60 (μg/L) (Recovery = 69%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (μg/L) (Recovery = 69%)	0.355	NA	59.65	27.00	30.93
1	SDS-HAA5 = 60 (μg/L) (Recovery = 89%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (μg/L) (Recovery = 89%)	0.356	NA	61.36	27.00	31.11

Note:
Stage 1: SDS-HAA5 = 60 μg/L
Stage 2: SDS-HAA5 = 30 μg/L
The value of SDS-HAA6 at the appropriate blend ratio (Q_P/Q_T) was calculated using the following formula:

$$(Q_P/Q_T)/100 * (\text{SDS-HAA6}_P - \text{SDS-HAA6}_F) + \text{SDS-HAA6}_F$$

Table 17: Quarter 3 - Blend Ratios to Achieve Various Finished Water Qualities for the NF200 Nanofiltration Membrane

Stage	Controlling Treatment Objective	Value of Listed Parameter at Blend Ratio to Achieve Controlling Treatment Objective				
		Permeate:Total Flow Blend Ratio	*TOC (mg/L)*	*SDS-THM4 (µg/L)*	*SDS-HAA5 (µg/L)*	*SDS-HAA6 (µg/L)*
1	SDS-THM4 = 80 (µg/L) (Recovery = 30%)	0.099	NA	72.00	51.24	57.67
2	SDS-THM4 = 40 (µg/L) (Recovery = 30%)	0.568	NA	36.00	24.55	27.65
1	SDS-THM4 = 80 (µg/L) (Recovery = 50%)	0.099	NA	72.00	51.25	57.67
2	SDS-THM4 = 40 (µg/L) (Recovery = 50%)	0.568	NA	36.00	24.59	27.65
1	SDS-THM4 = 80 (µg/L) (Recovery = 70%)	0.102	NA	72.00	51.05	57.48
2	SDS-THM4 = 40 (µg/L) (Recovery = 70%)	0.587	NA	36.00	23.45	26.44
1	SDS-THM4 = 80 (µg/L) (Recovery = 90%)	0.109	NA	72.00	50.78	57.15
2	SDS-THM4 = 40 (µg/L) (Recovery = 90%)	0.626	NA	36.00	21.90	24.58

Stage	Controlling Treatment Objective	Value of Listed Parameter at Blend Ratio to Achieve Controlling Treatment Objective				
		Permeate:Total Flow Blend Ratio	*TOC (mg/L)*	*SDS-THM4 (µg/L)*	*SDS-HAA5 (µg/L)*	*SDS-HAA6 (µg/L)*
1	SDS-HAA5 = 60 (µg/L) (Recovery = 30%)	0.050	NA	75.72	54.00	60.81
2	SDS-HAA5 = 30 (µg/L) (Recovery = 30%)	0.525	NA	39.31	27.00	30.40
1	SDS-HAA5 = 60 (µg/L) (Recovery = 50%)	0.050	NA	75.71	54.00	60.81
2	SDS-HAA5 = 30 (µg/L) (Recovery = 50%)	0.525	NA	39.26	27.00	30.40
1	SDS-HAA5 = 60 (µg/L) (Recovery = 70%)	0.050	NA	75.84	54.00	60.81
2	SDS-HAA5 = 30 (µg/L) (Recovery = 70%)	0.525	NA	40.63	27.00	30.40
1	SDS-HAA5 = 60 (µg/L) (Recovery = 90%)	0.051	NA	76.01	54.00	60.80
2	SDS-HAA5 = 30 (µg/L) (Recovery = 90%)	0.535	NA	42.36	27.00	30.32

Note:
Stage 1: SDS-HAA5 = 60 µg/L
Stage 2: SDS-HAA5 = 30 µg/L
The value of SDS-HAA6 at the appropriate blend ratio (Q_P/Q_T) was calculated using the following formula:

$$(Q_P/Q_T)/100 * (SDS\text{-}HAA6_P - SDS\text{-}HAA6_F) + SDS\text{-}HAA6_F$$

Table 18: Quarter 4 - Blend Ratios to Achieve Various Finished Water Qualities for the NF200 Nanofiltration Membrane

Stage	Controlling Treatment Objective	Value of Listed Parameter at Blend Ratio to Achieve Controlling Treatment Objective				
		Permeate:Total Flow Blend Ratio	*TOC (mg/L)*	*SDS-THM4 (μg/L)*	*SDS-HAA5 (μg/L)*	*SDS-HAA6 (μg/L)*
1	SDS-THM4 = 80 (μg/L) (Recovery = 30%)	NA	NA	NA	NA	NA
2	SDS-THM4 = 40 (μg/L) (Recovery = 30%)	0.246	NA	36.00	23.69	27.88
1	SDS-THM4 = 80 (μg/L) (Recovery = 51%)	NA	NA	NA	NA	NA
2	SDS-THM4 = 40 (μg/L) (Recovery = 51%)	0.246	NA	36.00	23.69	27.88
1	SDS-THM4 = 80 (μg/L) (Recovery = 70%)	NA	NA	NA	NA	NA
2	SDS-THM4 = 40 (μg/L) (Recovery = 70%)	0.252	NA	36.00	23.49	27.65
1	SDS-THM4 = 80 (μg/L) (Recovery = 90%)	NA	NA	NA	NA	NA
2	SDS-THM4 = 40 (μg/L) (Recovery = 90%)	0.274	NA	36.00	23.22	27.56

Stage	Controlling Treatment Objective	Value of Listed Parameter at Blend Ratio to Achieve Controlling Treatment Objective				
		Permeate:Total Flow Blend Ratio	*TOC (mg/L)*	*SDS-THM4 (μg/L)*	*SDS-HAA5 (μg/L)*	*SDS-HAA6 (μg/L)*
1	SDS-HAA5 = 60 (μg/L) (Recovery = 30%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (μg/L) (Recovery = 30%)	0.140	NA	41.03	27.00	31.79
1	SDS-HAA5 = 60 (μg/L) (Recovery = 50%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (μg/L) (Recovery = 50%)	0.140	NA	41.03	27.00	31.79
1	SDS-HAA5 = 60 (μg/L) (Recovery = 70%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (μg/L) (Recovery = 70%)	0.140	NA	41.20	27.00	31.79
1	SDS-HAA5 = 60 (μg/L) (Recovery = 90%)	NA	NA	NA	NA	NA
2	SDS-HAA5 = 30 (μg/L) (Recovery = 90%)	0.147	NA	41.41	27.00	31.92

Note:
Stage 1: SDS-HAA5 = 60 μg/L
Stage 2: SDS-HAA5 = 30 μg/L
The value of SDS-HAA6 at the appropriate blend ratio (Q_P/Q_T) was calculated using the following formula:

$$(Q_P/Q_T)/100 * (\text{SDS-HAA6}_P - \text{SDS-HAA6}_F) + \text{SDS-HAA6}_F$$

Table 19: PE Study for 1st Quarter (PE Study #6)

Parameter	Units	True Value	Measured Value	RPD
UV_{254}	cm^{-1}	0.101	0.090	10.89
TOC	mg/L	2.69	3.01	11.90
TOX	µg Cl^-/L	135	102.0	24.44
Bromide	mg/L	0.059	0.056	5.08
Inorganic DBPs:				
ClO_2^-	µg/L	73.6	63.0	14.40
BrO_3^-	µg/L	16.2	17.10	5.56
ClO_3^-	µg/L	141	140.0	0.71
HAAs:				
MCAA	µg/L	9.04	7.86	13.05
MBAA	µg/L	8.10	6.84	15.56
DCAA	µg/L	18.1	16.60	8.29
TCAA	µg/L	26.2	26.80	2.29
BCAA	µg/L	11.1	8.50	23.42
DBAA	µg/L	4.97	4.36	12.27
THMs:				
$CHCl_3$	µg/L	16.2	15.10	6.79
BDCM	µg/L	22.8	23.20	1.75
DBCM	µg/L	28.6	29.70	3.85
$CHBr_3$	µg/L	20.2	20.20	0.00
HANs:				
TCAN	µg/L	-	5.97	-
DCAN	µg/L	10.9	9.02	17.25
DCP	µg/L	9.00	8.30	7.78
BCAN	µg/L	13.0	12.00	7.69
TCP	µg/L	8.01	6.90	13.86
DBAN	µg/L	15.9	15.20	4.40
CH	µg/L	12.2	13.80	13.11

Table 20a: PE Study for 2nd Quarter (PE Study #7)

Parameter	Units	True Value	Measured Value	RPD
UV_{254}	cm^{-1}	0.361	0.339	6.09
TOC	mg/L	1.22	1.29	5.74
TOX	$\mu g\ Cl^-/L$	188	149.0	20.74
Inorganic DBPs:				
ClO_2^-	µg/L	483	449.0	7.04
BrO_3^-	µg/L	26.1	24.50	6.13
ClO_3^-	µg/L	375	352.0	6.13
HAAs:				
MCAA	µg/L	5.94	5.07	14.65
MBAA	µg/L	11.1	7.50	32.43
DCAA	µg/L	24.0	17.10	28.75
TCAA	µg/L	15.0	12.90	14.00
BCAA	µg/L	12.1	7.37	39.09
DBAA	µg/L	14.0	9.03	35.50
THMs:				
$CHCl_3$	µg/L	17.0	16.00	5.88
BDCM	µg/L	11.0	11.30	2.73
DBCM	µg/L	28.1	28.00	0.36
$CHBr_3$	µg/L	18.2	18.20	0.00
HANs:				
TCAN	µg/L	12.1	12.00	0.83
DCAN	µg/L	19.0	18.60	2.11
DCP	µg/L	5.06	5.22	3.16
BCAN	µg/L	9.10	8.69	4.51
TCP	µg/L	11.1	11.80	6.31
DBAN	µg/L	14.0	14.30	2.14
CH	µg/L	22.1	20.10	9.05

Table 20b: Makeup PE Study for 2nd Quarter

Parameter	Units	True Value	Measured Value	RPD
Bromide	mg/L	0.091	0.090	1.10

Table 21a: PE Study for 3rd Quarter (PE Study #8)

Parameter	Units	True Value	Measured Value	RPD
UV_{254}	cm^{-1}	0.072	0.066	8.33
TOC	mg/L	2.62	3.14	19.85
TOX	µg Cl^-/L	80.3	62.8	21.79
Bromide	mg/L	0.325	0.296	8.92
Inorganic DBPs:				
ClO_2^-	µg/L	687	635.0	7.57
BrO_3^-	µg/L	13.1	12.30	6.11
ClO_3^-	µg/L	768	700.0	8.85
HAAs:				
MCAA	µg/L	13.0	12.60	3.08
MBAA	µg/L	16.0	14.30	10.63
DCAA	µg/L	14.2	12.60	11.27
TCAA	µg/L	8.03	6.76	15.82
BCAA	µg/L	5.07	4.77	5.92
DBAA	µg/L	18.0	17.90	0.56
HANs:				
TCAN	µg/L	6.92	5.52	20.23
DCAN	µg/L	6.16	4.51	26.79
DCP	µg/L	4.09	4.38	7.09
BCAN	µg/L	10.0	7.44	25.60
TCP	µg/L	2.99	3.61	20.74
DBAN	µg/L	5.07	4.52	10.85
CH	µg/L	9.08	10.60	16.74

Table 21b: Makeup PE Study for 3rd Quarter

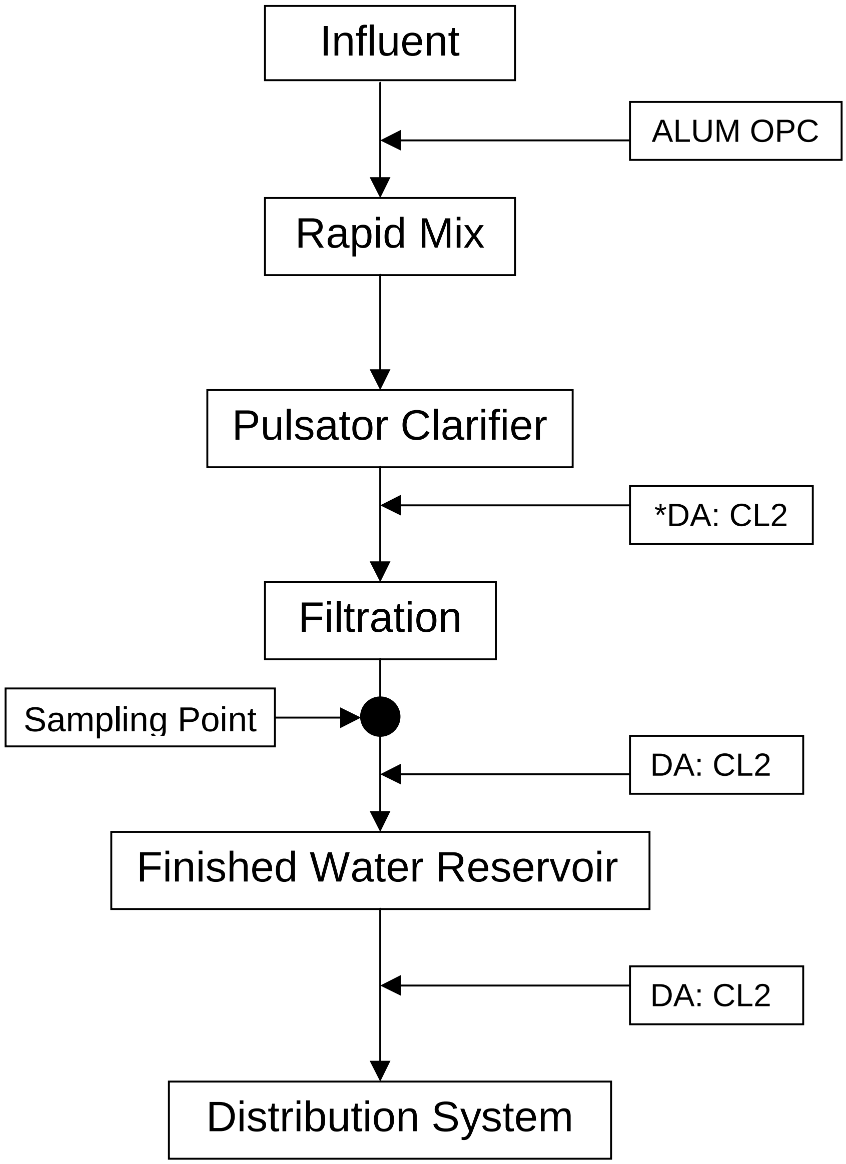
Parameter	Units	True Value	Measured Value	RPD
THMs:				
$CHCl_3$	µg/L	17.1	17.10	0.00
BDCM	µg/L	11.0	11.00	0.00
DBCM	µg/L	28.1	26.70	4.98
$CHBr_3$	µg/L	18.2	18.10	0.55

Table 22: PE Study for 4th Quarter (PE Study #9)

Parameter	Units	True Value	Measured Value	RPD
UV_{254}	cm^{-1}	0.223	0.206	7.62
TOC	mg/L	4.19	4.25	1.43
TOX	µg Cl^- /L	92.9	62.5	32.72
Bromide	mg/L	0.091	0.092	1.10
Inorganic DBPs:				
ClO_2^-	µg/L	167	170.0	1.80
BrO_3^-	µg/L	9.17	9.68	5.56
ClO_3^-	µg/L	211	209.0	0.95
HAAs:				
MCAA	µg/L	11.1	12.10	9.01
MBAA	µg/L	9.11	8.54	6.26
DCAA	µg/L	8.01	7.39	7.74
TCAA	µg/L	12.0	9.47	21.08
BCAA	µg/L	7.05	5.60	20.57
DBAA	µg/L	5.00	3.85	23.00
THMs:				
$CHCl_3$	µg/L	32.2	32.10	0.31
BDCM	µg/L	15.0	14.90	0.67
DBCM	µg/L	9.10	8.73	4.07
$CHBr_3$	µg/L	2.98	2.91	2.35
HANs:				
TCAN	µg/L	17.0	18.30	7.65
DCAN	µg/L	16.2	16.20	0.00
DCP	µg/L	8.13	9.73	19.68
BCAN	µg/L	14.1	11.50	18.44
TCP	µg/L	14.1	14.50	2.84
DBAN	µg/L	12.1	9.64	20.33
CH	µg/L	19.1	15.30	19.90

Figure 1

BEAUMONT WATER PLANT
Full-Scale Treatment Plant Schematic



*Note: Sample was taken after chlorinator had been turned off, therefore no chlorine residual was present at the time of the collection.

Figure 2

Pretreatment System Prior To Bench-Scale Nanofiltration

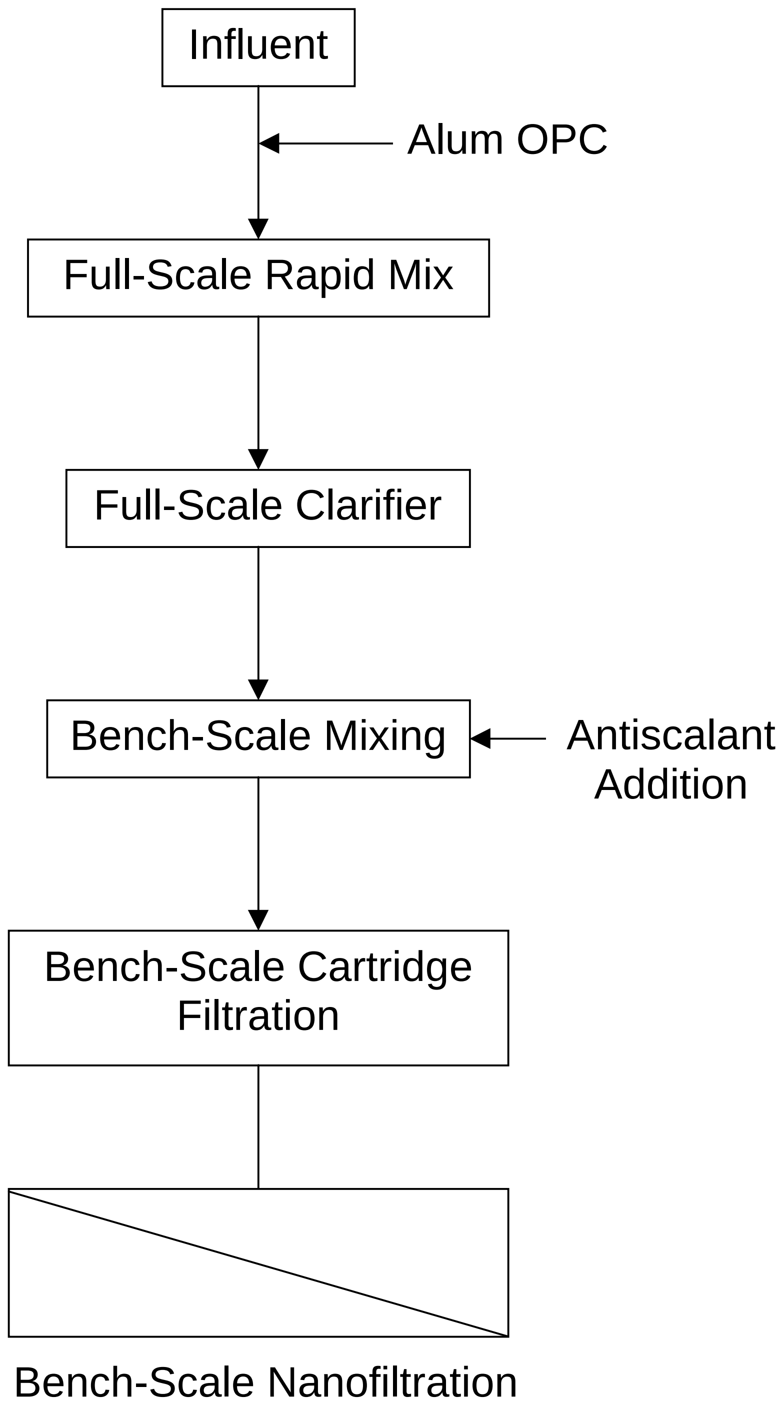
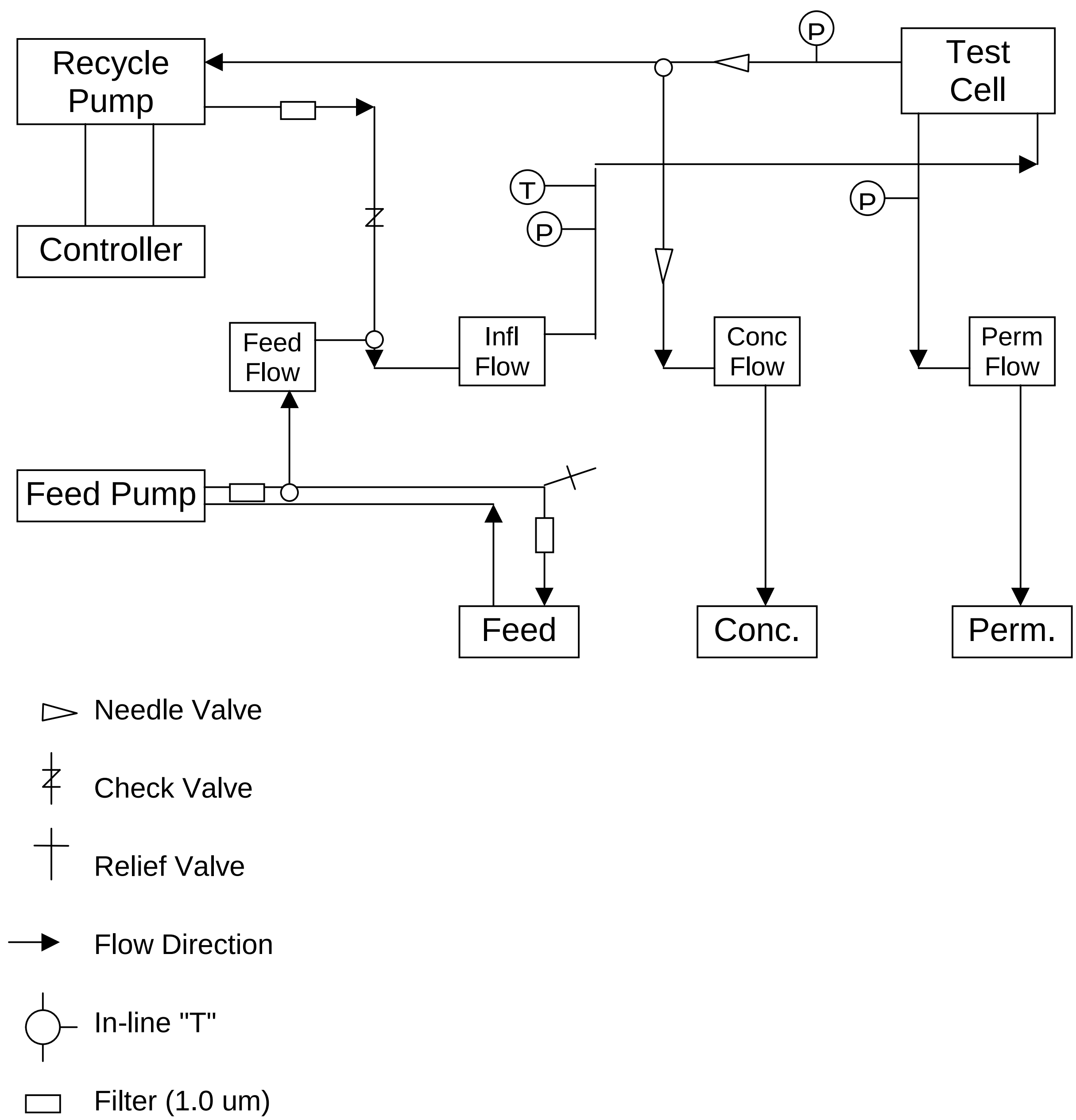


Figure 3

RBSMT Test Apparatus Diagram



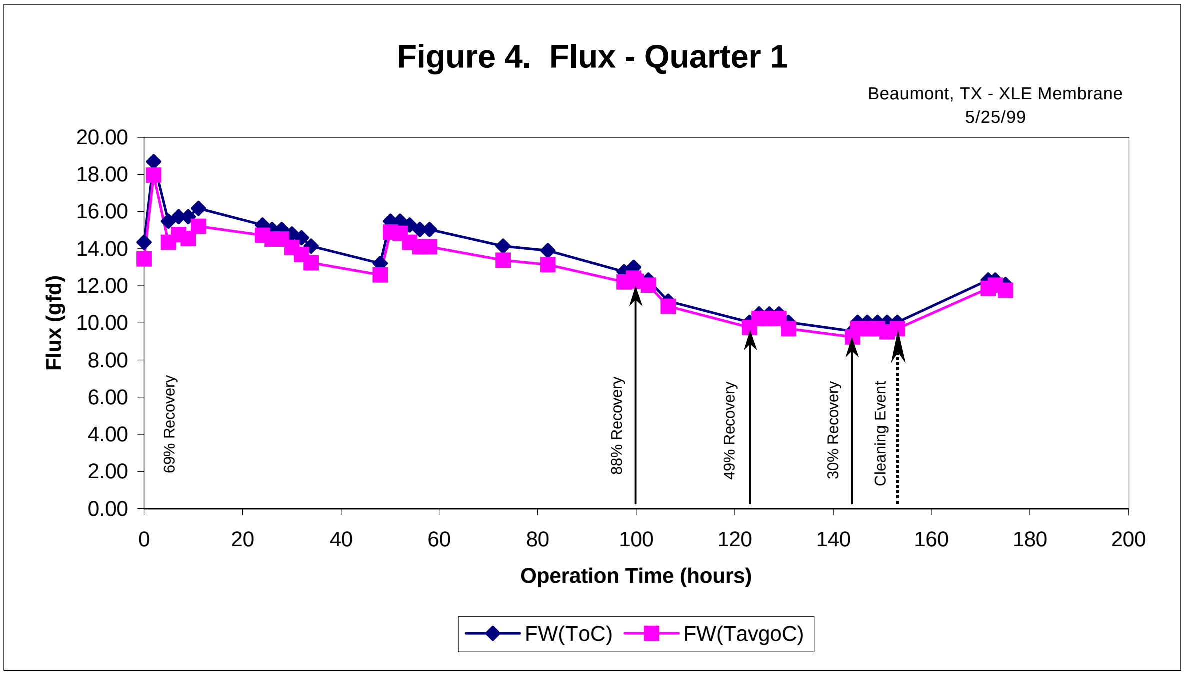


Figure 4. Flux - Quarter 1
Beaumont, TX - XLE Membrane
5/25/99
Flux (gfd)
Operation Time (hours)
69% Recovery
88% Recovery
49% Recovery
30% Recovery
Cleaning Event
FW(ToC)
FW(TavgoC)

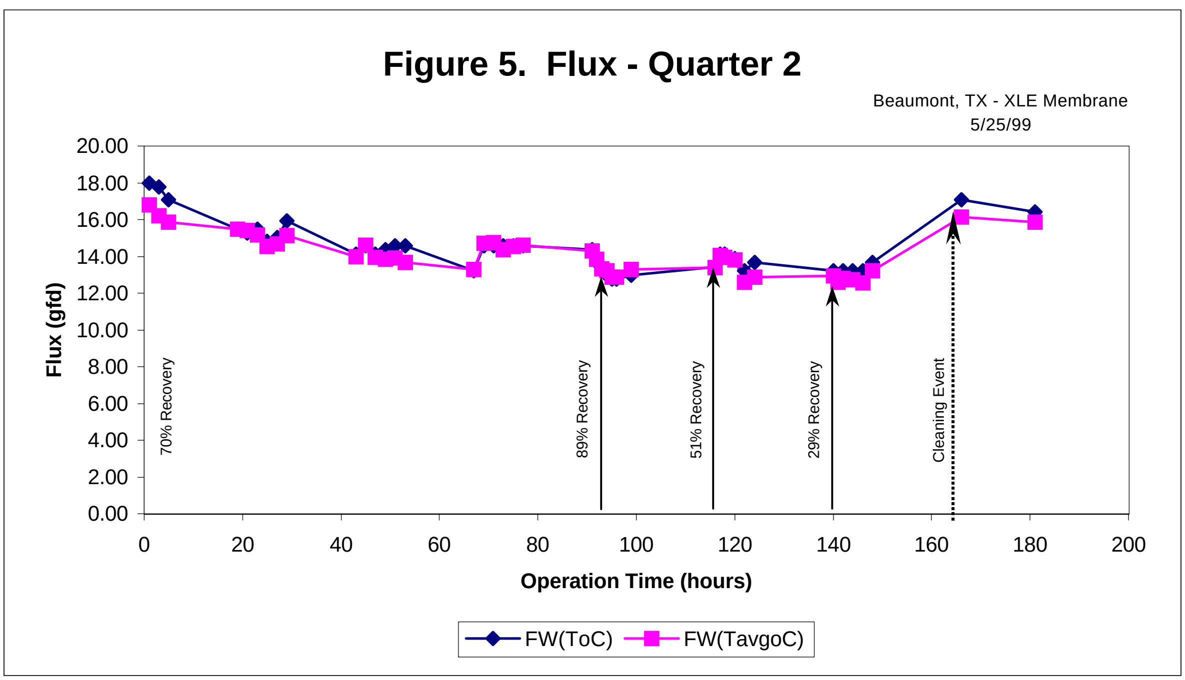


Figure 5. Flux - Quarter 2
Beaumont, TX - XLE Membrane
5/25/99
Flux (gfd)
Operation Time (hours)
70% Recovery
89% Recovery
51% Recovery
29% Recovery
Cleaning Event
FW(ToC)
FW(TavgoC)

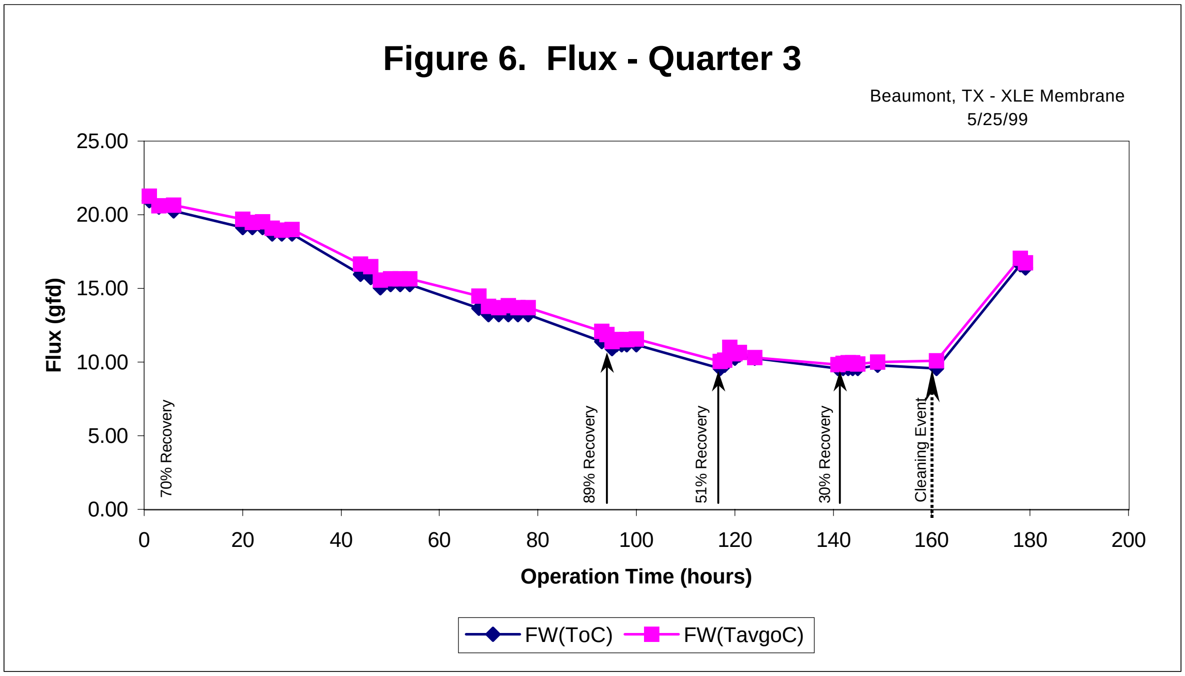


Figure 6. Flux - Quarter 3
Beaumont, TX - XLE Membrane
5/25/99
Flux (gfd)
25.00
20.00
15.00
10.00
5.00
0.00
0
20
40
60
80
100
120
140
160
180
200
Operation Time (hours)
70% Recovery
89% Recovery
51% Recovery
30% Recovery
Cleaning Event
FW(ToC)
FW(TavgoC)

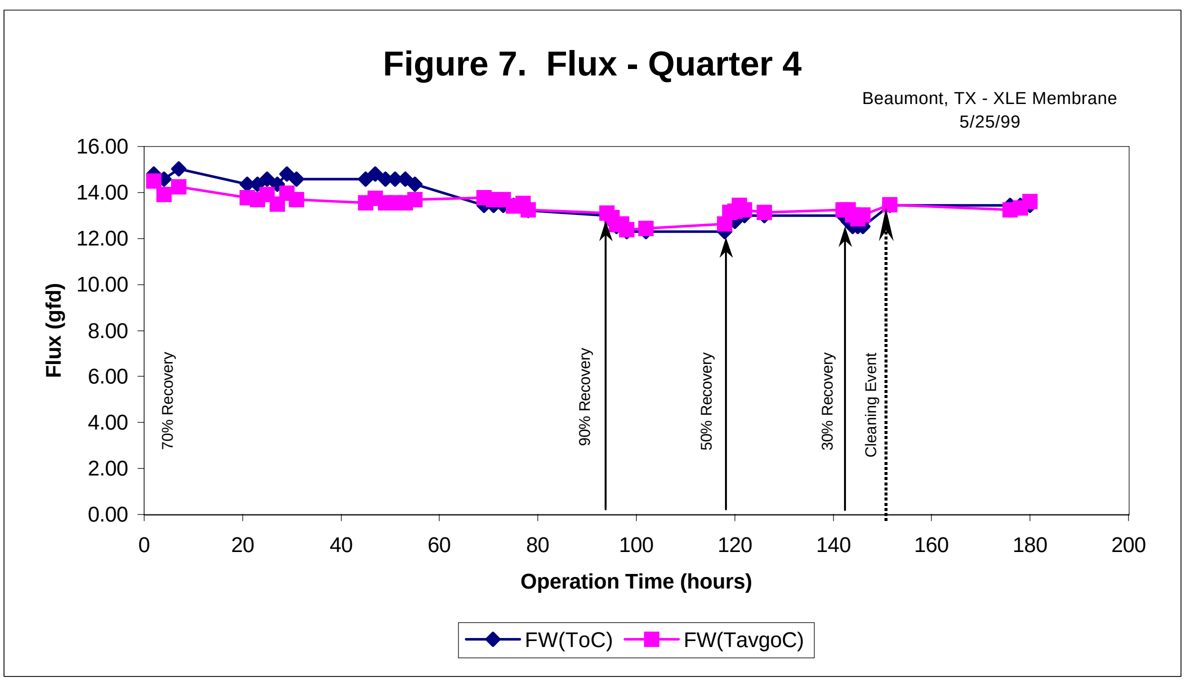


Figure 7. Flux - Quarter 4
Beaumont, TX - XLE Membrane
5/25/99
Flux (gfd)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
20
40
60
80
100
120
140
160
180
200
Operation Time (hours)
70% Recovery
90% Recovery
50% Recovery
30% Recovery
Cleaning Event
FW(ToC)
FW(TavgoC)

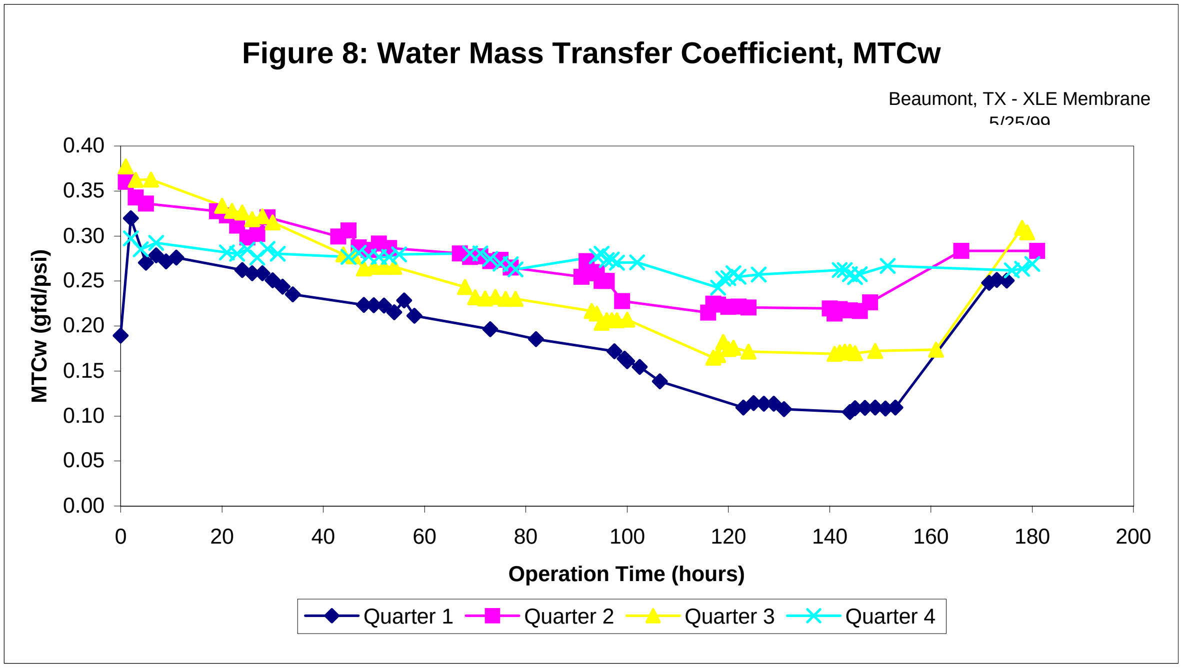


Figure 8: Water Mass Transfer Coefficient, MTCw
Beaumont, TX - XLE Membrane
MTCw (gfd/psi)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
20
40
60
80
100
120
140
160
180
200
Operation Time (hours)
Quarter 1
Quarter 2
Quarter 3
Quarter 4

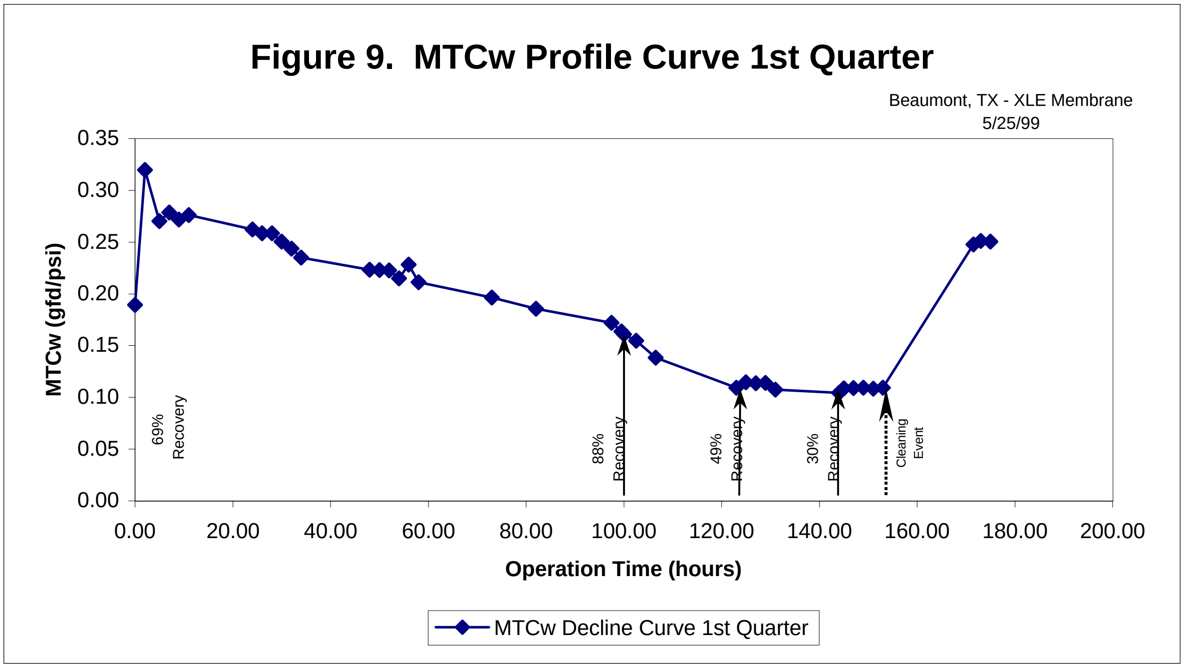


Figure 9. MTCw Profile Curve 1st Quarter
Beaumont, TX - XLE Membrane
5/25/99
MTCw (gfd/psi)
Operation Time (hours)
69% Recovery
88% Recovery
49% Recovery
30% Recovery
Cleaning Event
MTCw Decline Curve 1st Quarter

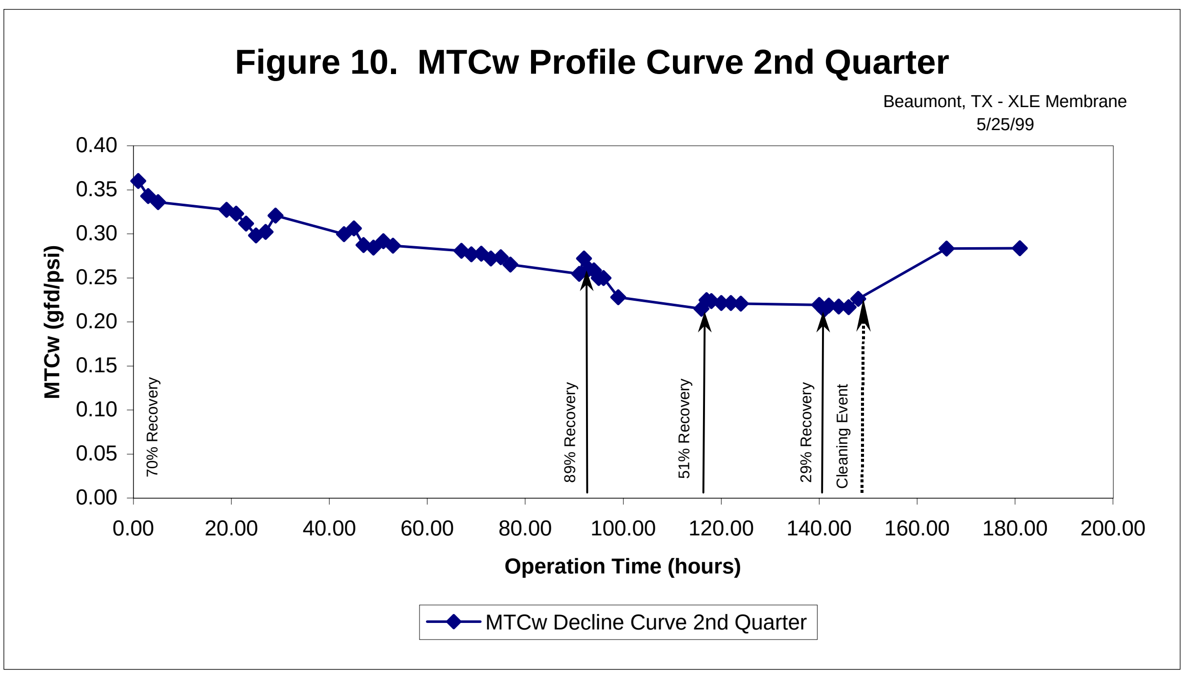


Figure 10. MTCw Profile Curve 2nd Quarter
Beaumont, TX - XLE Membrane
5/25/99
MTCw (gfd/psi)
Operation Time (hours)
70% Recovery
89% Recovery
51% Recovery
29% Recovery
Cleaning Event
MTCw Decline Curve 2nd Quarter

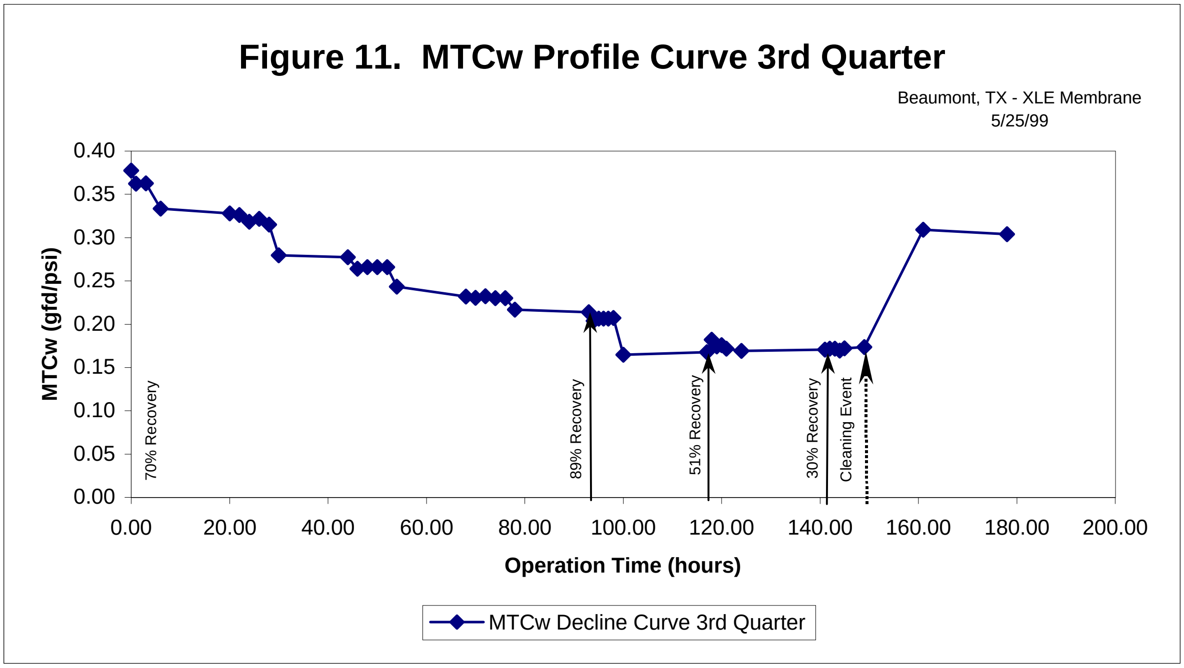


Figure 11. MTCw Profile Curve 3rd Quarter
Beaumont, TX - XLE Membrane
5/25/99
MTCw (gfd/psi)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
70% Recovery
89% Recovery
51% Recovery
30% Recovery
Cleaning Event
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
MTCw Decline Curve 3rd Quarter

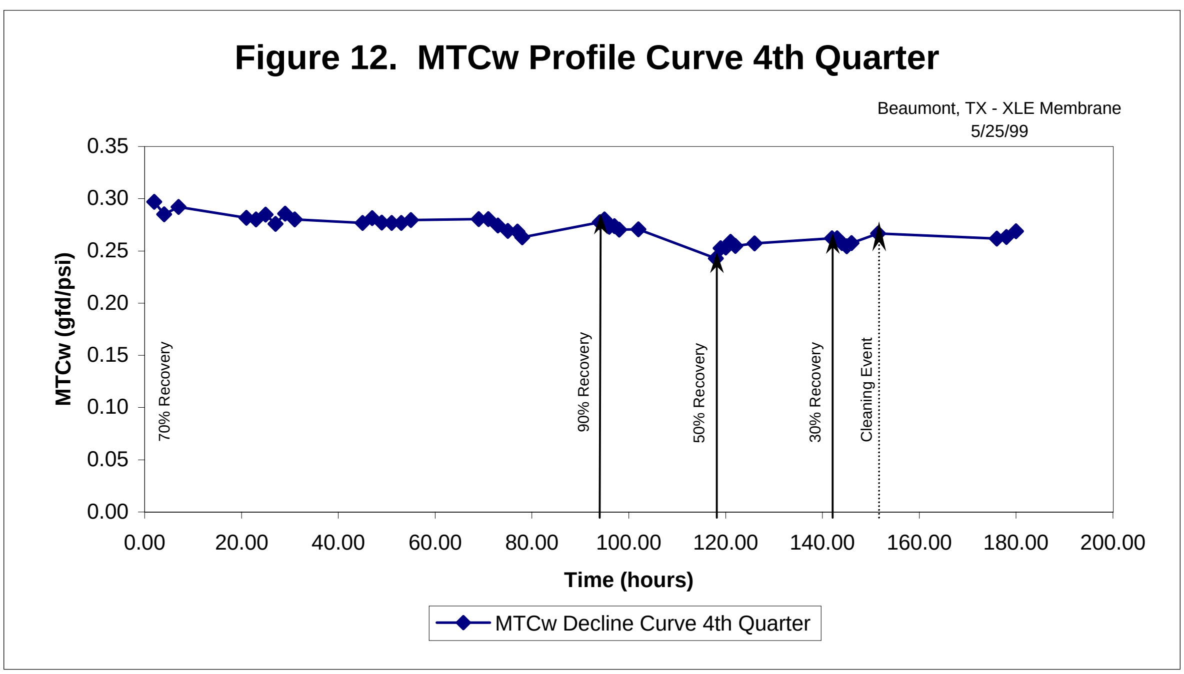


Figure 12. MTCw Profile Curve 4th Quarter
Beaumont, TX - XLE Membrane
5/25/99
MTCw (gfd/psi)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
70% Recovery
90% Recovery
50% Recovery
30% Recovery
Cleaning Event
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Time (hours)
MTCw Decline Curve 4th Quarter

Figure 13. Rate of MTCw Decline for Quarter 1

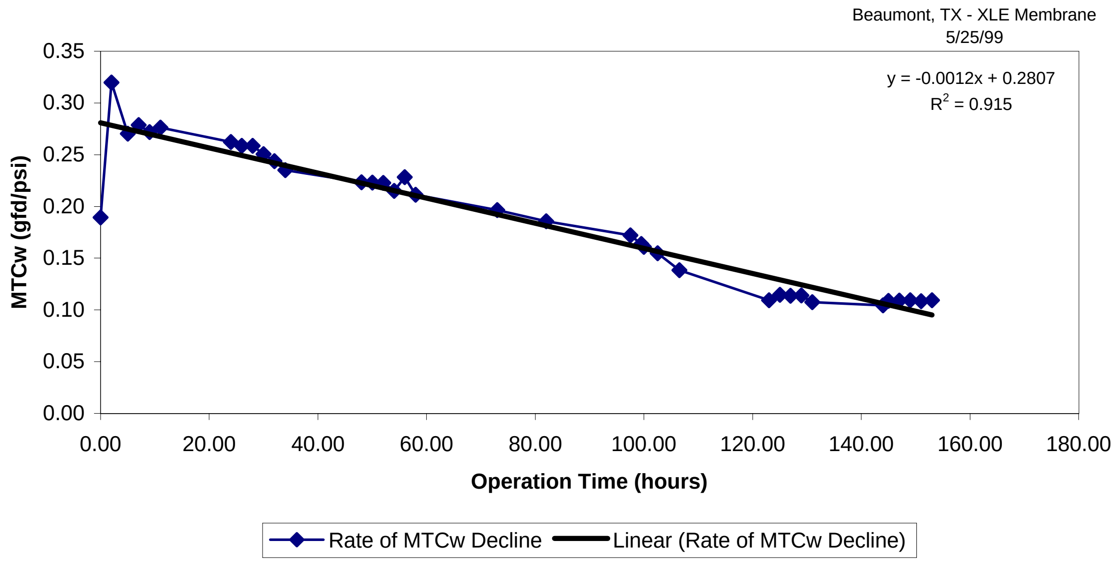
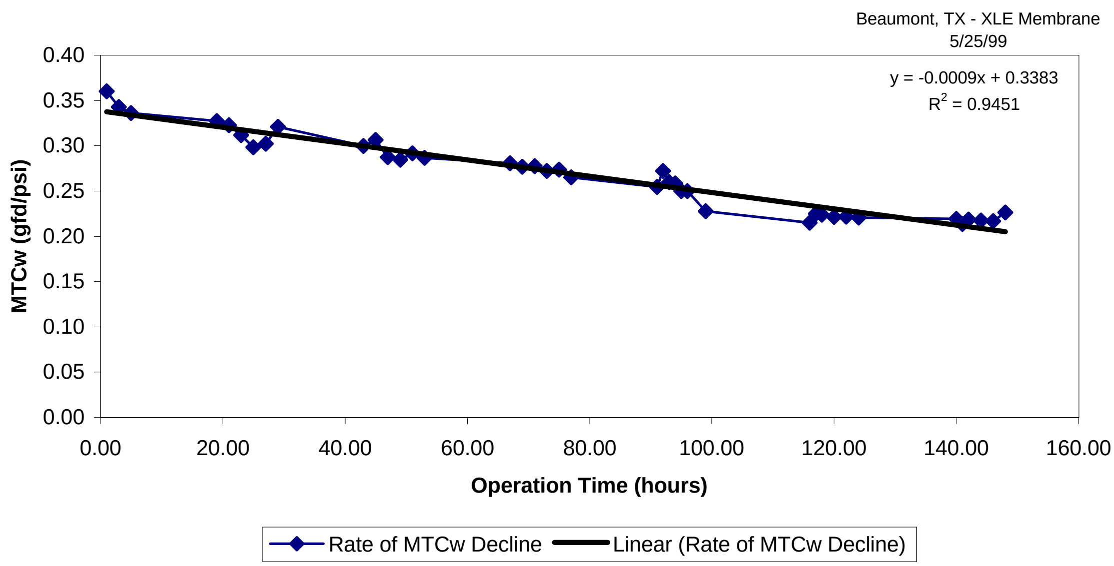


Figure 14. Rate of MTCw Decline for Quarter 2



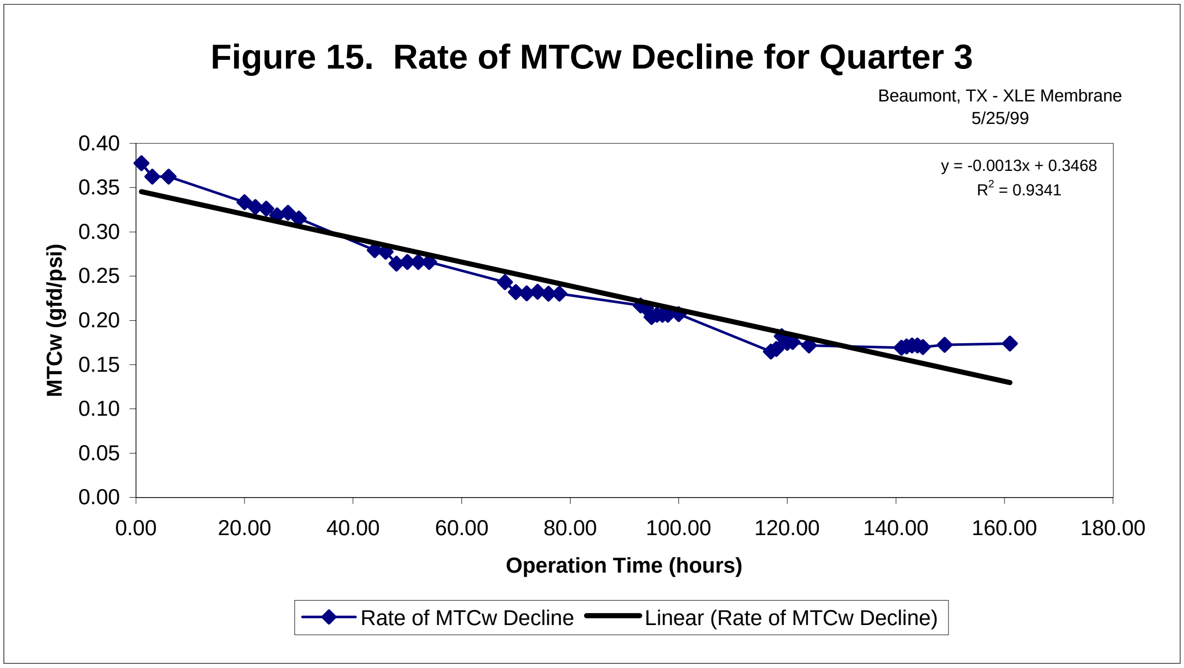


Figure 15. Rate of MTCw Decline for Quarter 3
Beaumont, TX - XLE Membrane
5/25/99
y = -0.0013x + 0.3468
R2 = 0.9341
MTCw (gfd/psi)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
Operation Time (hours)
Rate of MTCw Decline
Linear (Rate of MTCw Decline)

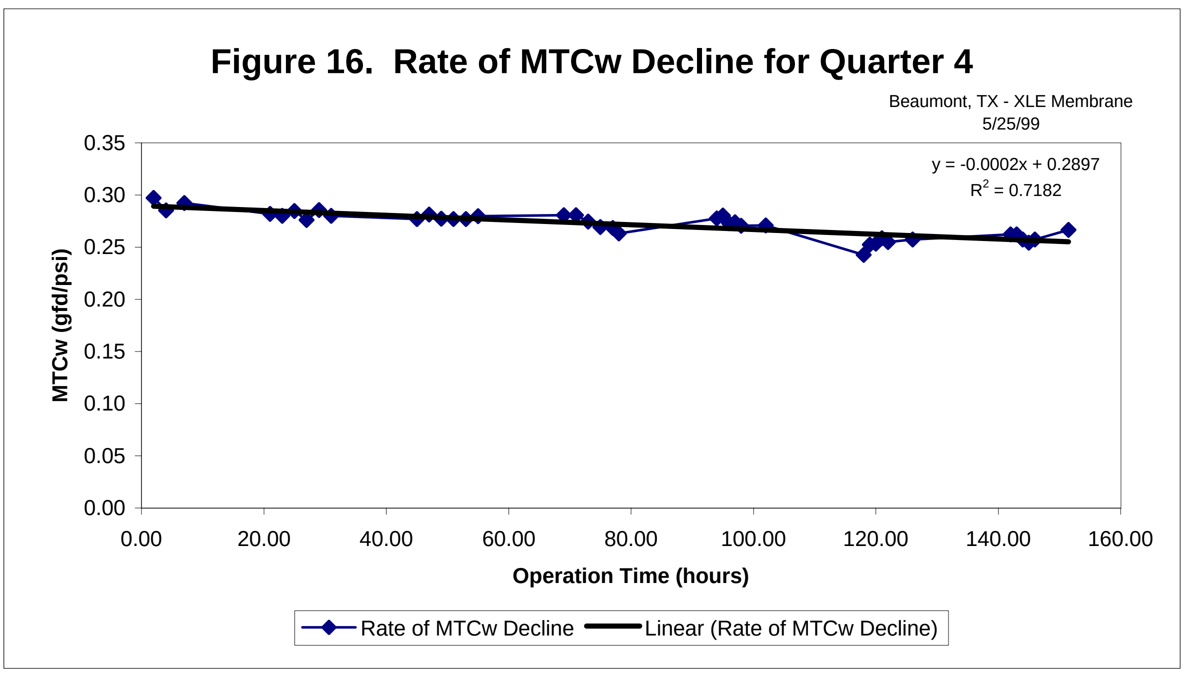


Figure 16. Rate of MTCw Decline for Quarter 4
Beaumont, TX - XLE Membrane
5/25/99
y = -0.0002x + 0.2897
R2 = 0.7182
MTCw (gfd/psi)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Operation Time (hours)
Rate of MTCw Decline
Linear (Rate of MTCw Decline)

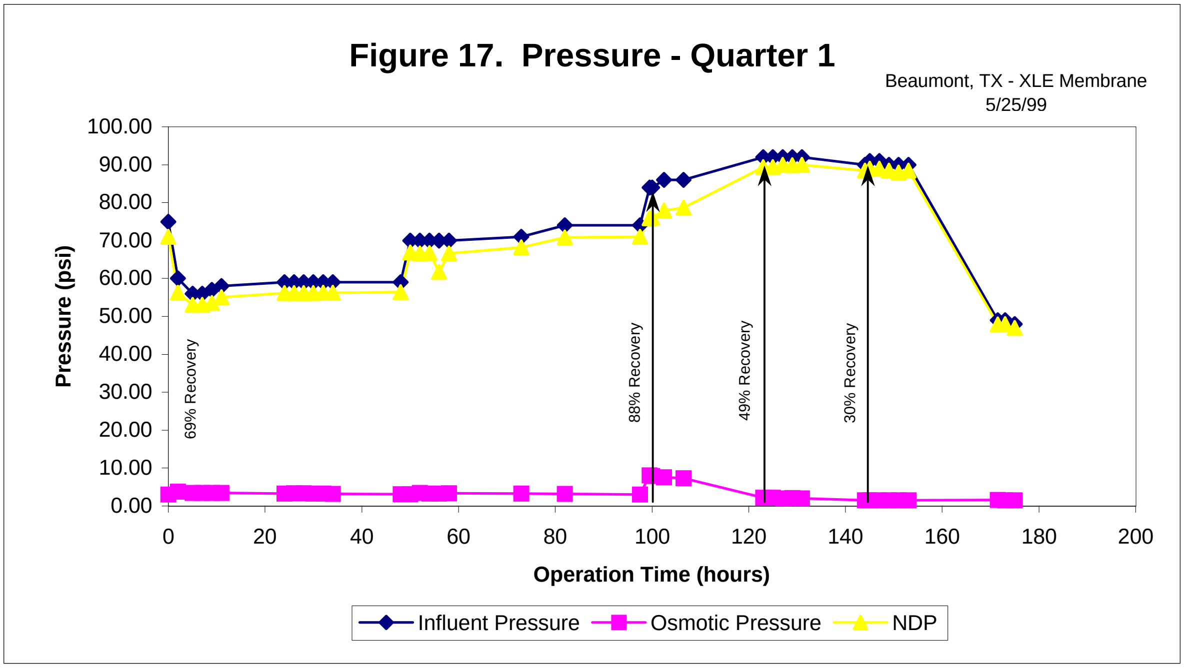


Figure 17. Pressure - Quarter 1
Beaumont, TX - XLE Membrane
5/25/99
Pressure (psi)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
69% Recovery
88% Recovery
49% Recovery
30% Recovery
0
20
40
60
80
100
120
140
160
180
200
Operation Time (hours)
Influent Pressure
Osmotic Pressure
NDP

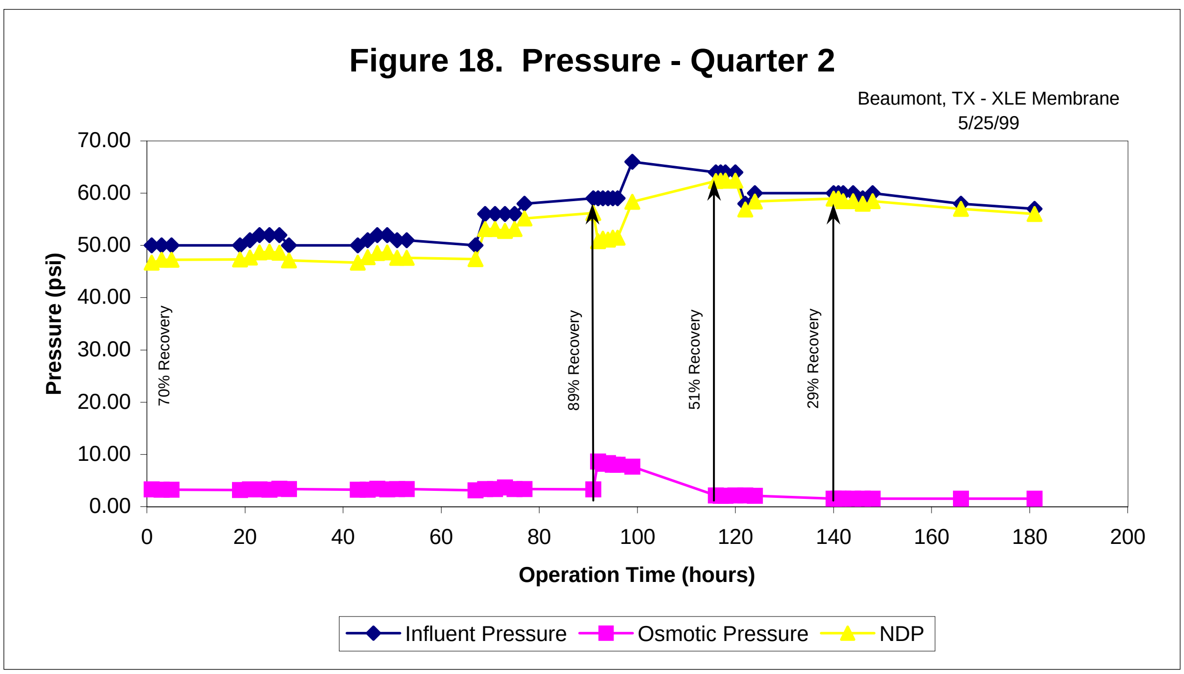


Figure 18. Pressure - Quarter 2
Beaumont, TX - XLE Membrane
5/25/99
Pressure (psi)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
70% Recovery
89% Recovery
51% Recovery
29% Recovery
0
20
40
60
80
100
120
140
160
180
200
Operation Time (hours)
Influent Pressure
Osmotic Pressure
NDP

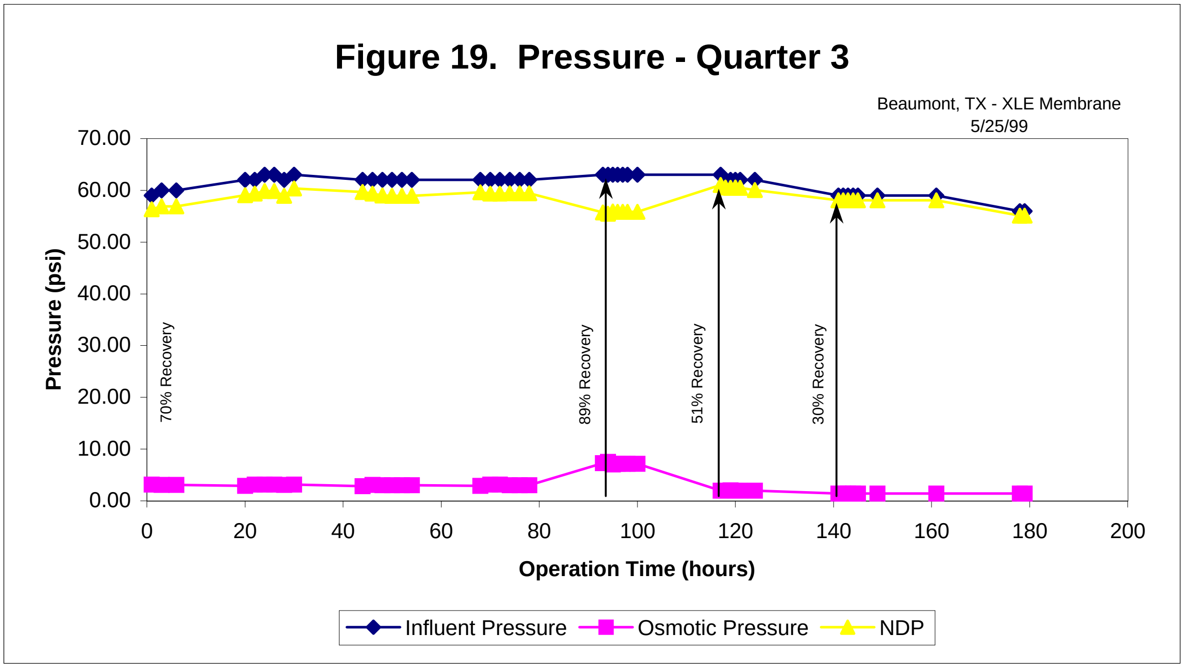


Figure 19. Pressure - Quarter 3
Beaumont, TX - XLE Membrane
5/25/99
Pressure (psi)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
20
40
60
80
100
120
140
160
180
200
Operation Time (hours)
70% Recovery
89% Recovery
51% Recovery
30% Recovery
Influent Pressure
Osmotic Pressure
NDP

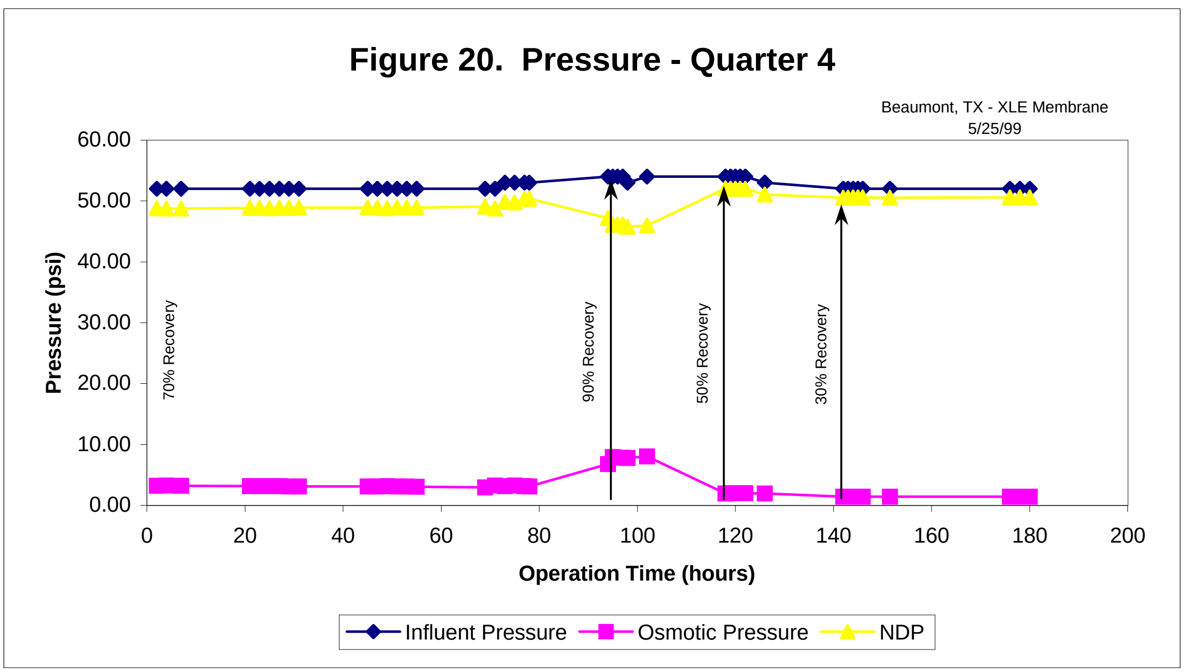


Figure 20. Pressure - Quarter 4
Beaumont, TX - XLE Membrane
5/25/99
Pressure (psi)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
20
40
60
80
100
120
140
160
180
200
Operation Time (hours)
70% Recovery
90% Recovery
50% Recovery
30% Recovery
Influent Pressure
Osmotic Pressure
NDP

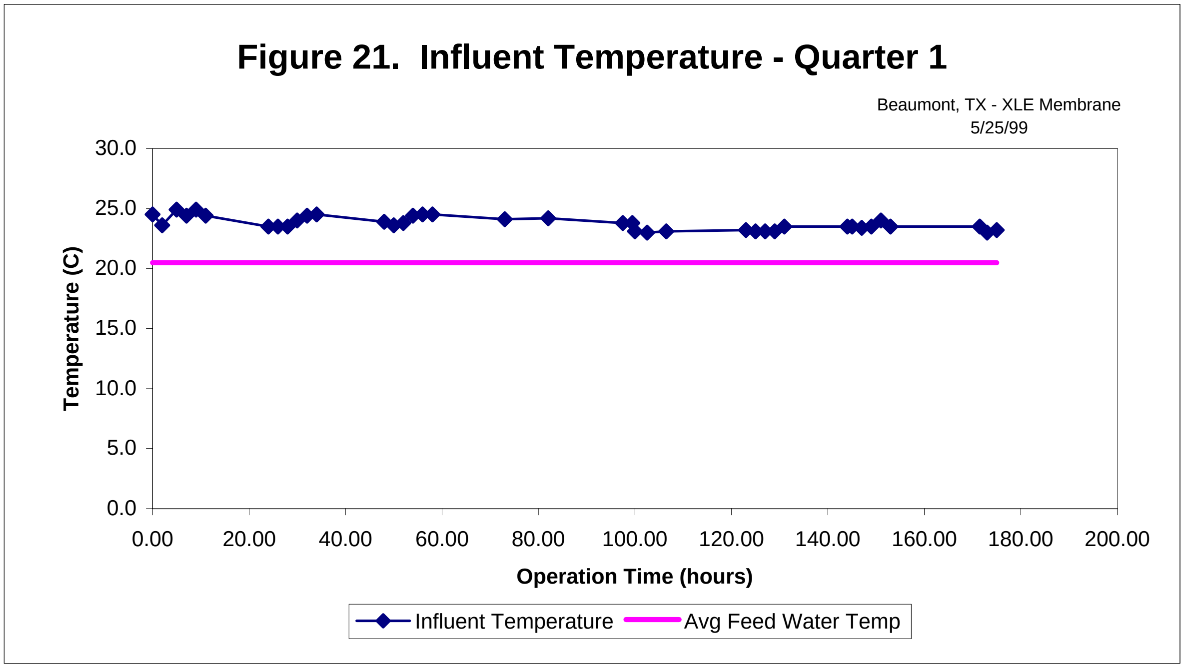


Figure 21. Influent Temperature - Quarter 1
Beaumont, TX - XLE Membrane
5/25/99
Temperature (C)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Influent Temperature
Avg Feed Water Temp

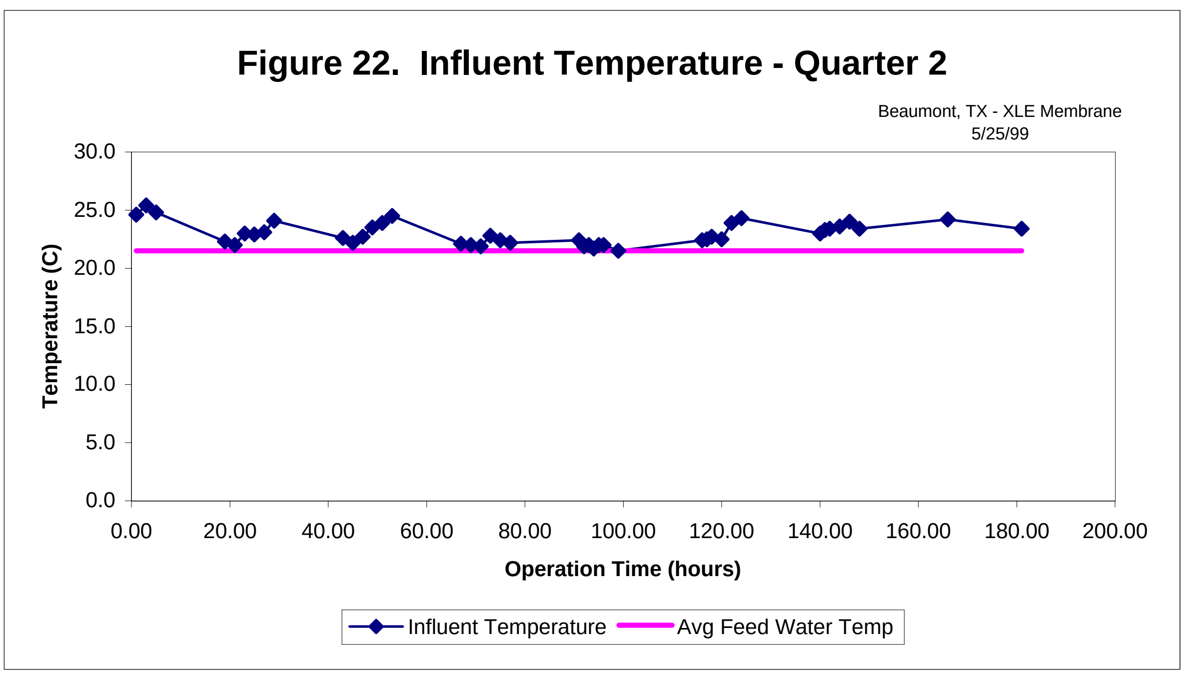


Figure 22. Influent Temperature - Quarter 2
Beaumont, TX - XLE Membrane
5/25/99
Temperature (C)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Influent Temperature
Avg Feed Water Temp

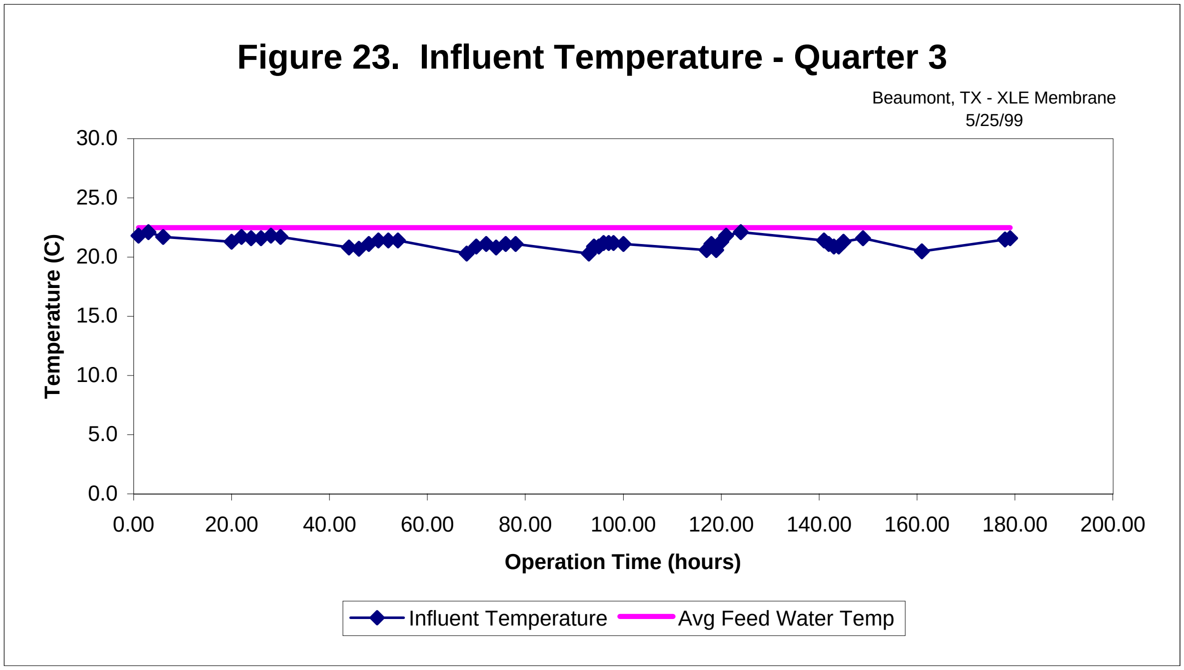


Figure 23. Influent Temperature - Quarter 3
Beaumont, TX - XLE Membrane
5/25/99
Temperature (C)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Influent Temperature
Avg Feed Water Temp

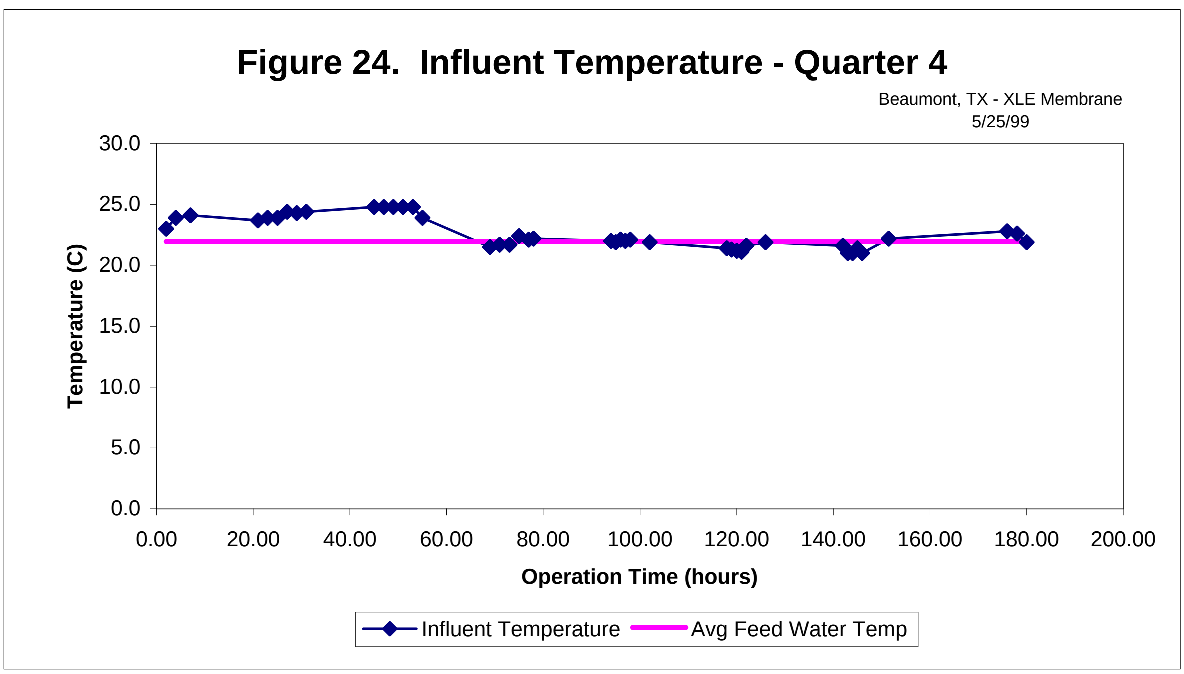


Figure 24. Influent Temperature - Quarter 4
Beaumont, TX - XLE Membrane
5/25/99
Temperature (C)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Influent Temperature
Avg Feed Water Temp

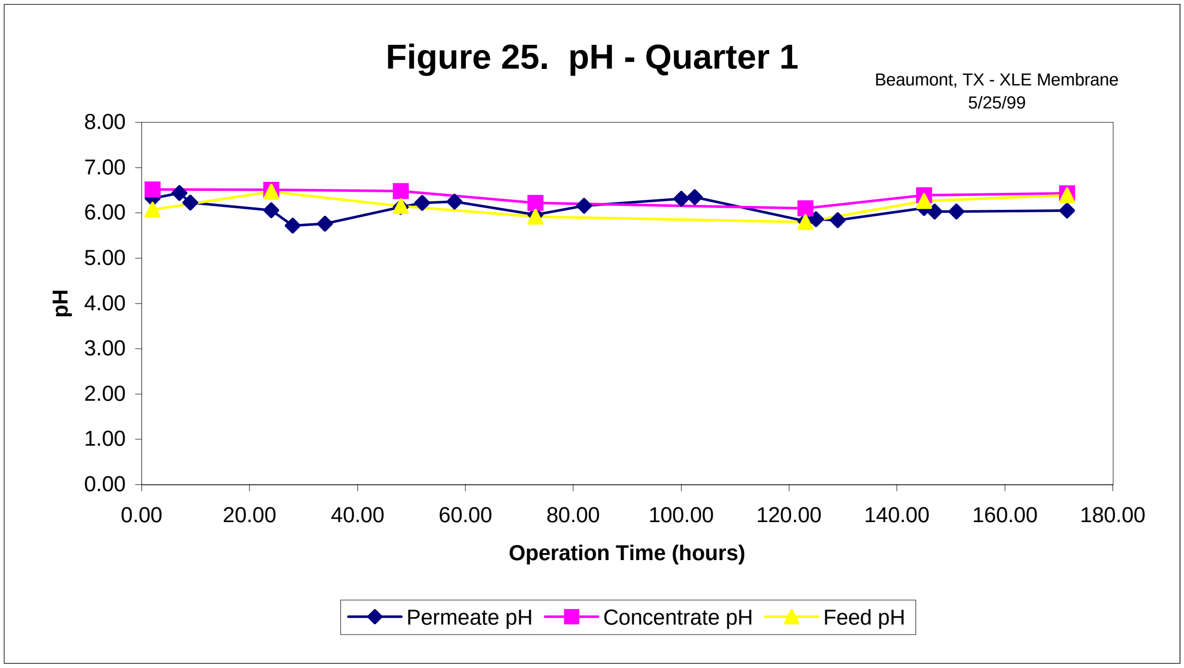


Figure 25. pH - Quarter 1
Beaumont, TX - XLE Membrane
5/25/99
pH
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
Operation Time (hours)
Permeate pH
Concentrate pH
Feed pH

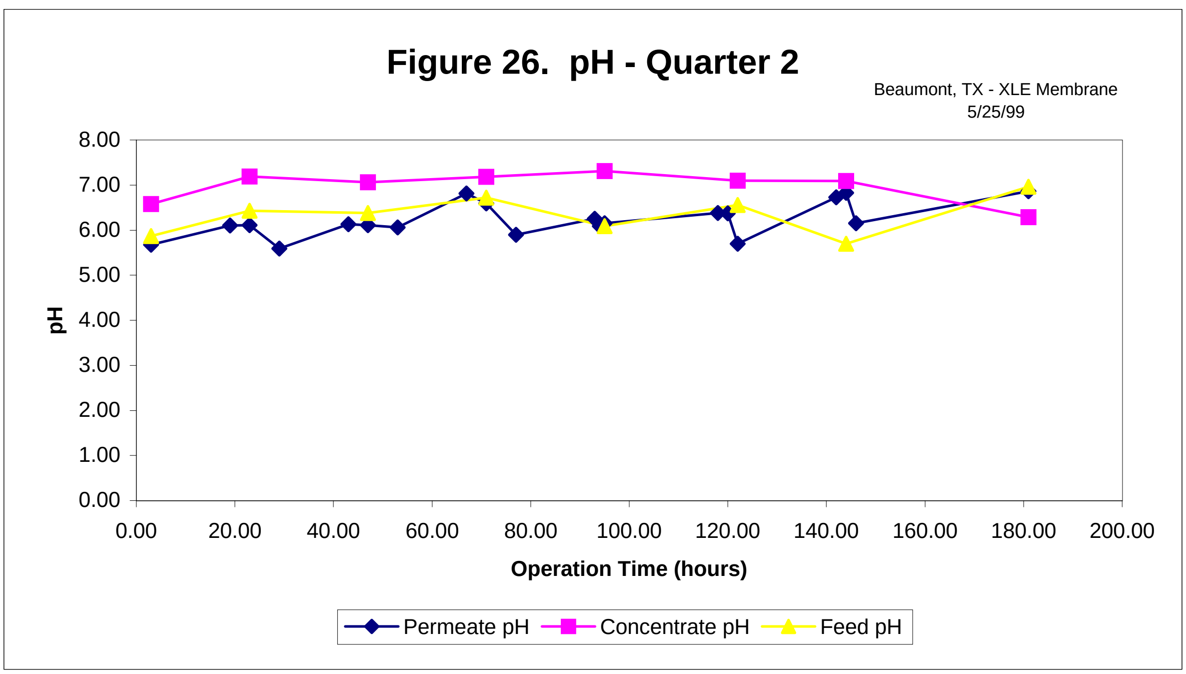


Figure 26. pH - Quarter 2
Beaumont, TX - XLE Membrane
5/25/99
pH
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Permeate pH
Concentrate pH
Feed pH

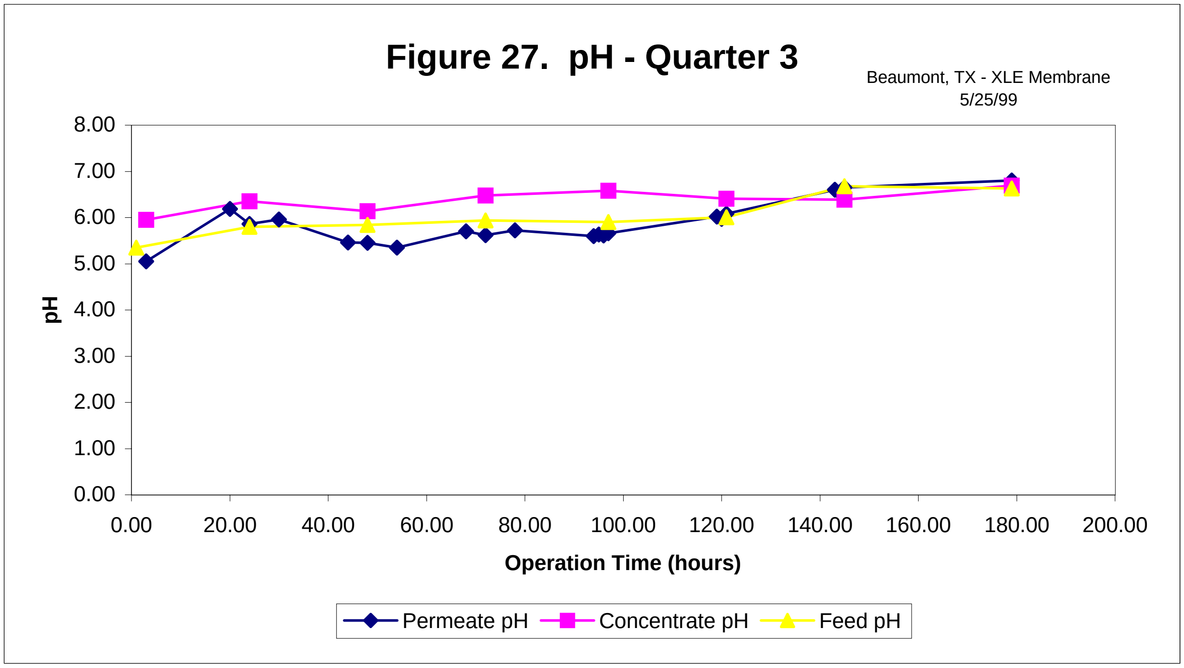


Figure 27. pH - Quarter 3
Beaumont, TX - XLE Membrane
5/25/99
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
pH
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Permeate pH
Concentrate pH
Feed pH

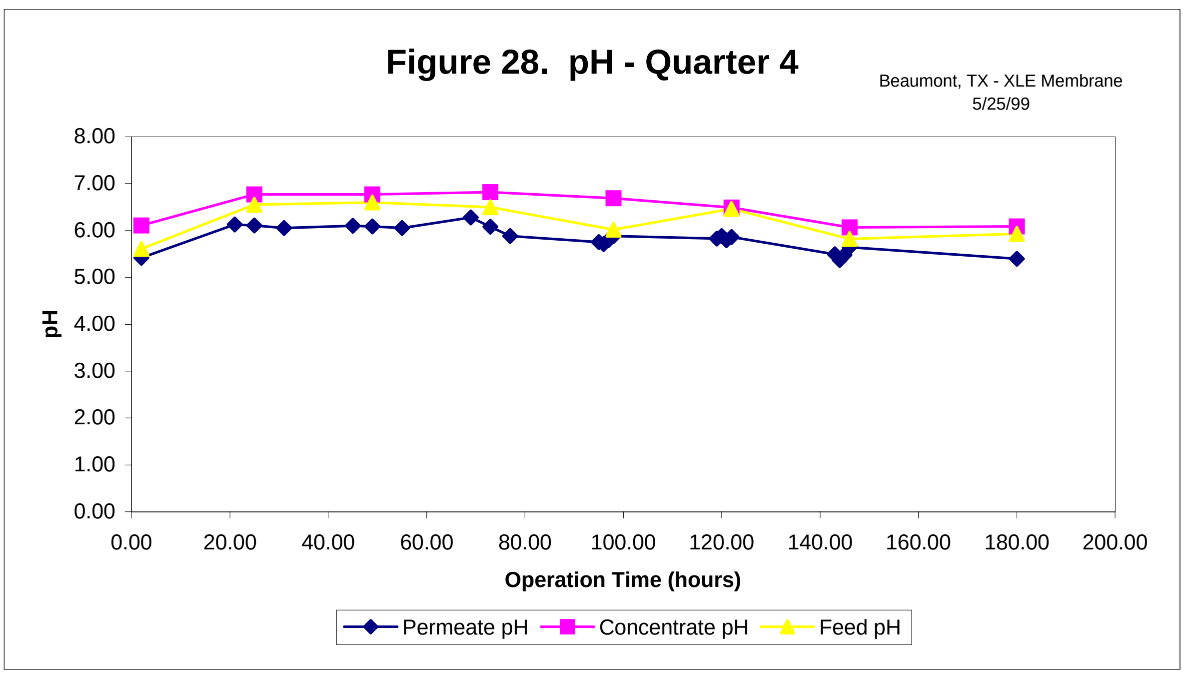


Figure 28. pH - Quarter 4
Beaumont, TX - XLE Membrane
5/25/99
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
pH
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Permeate pH
Concentrate pH
Feed pH

Figure 29. Total Dissolved Solids - Quarter 1

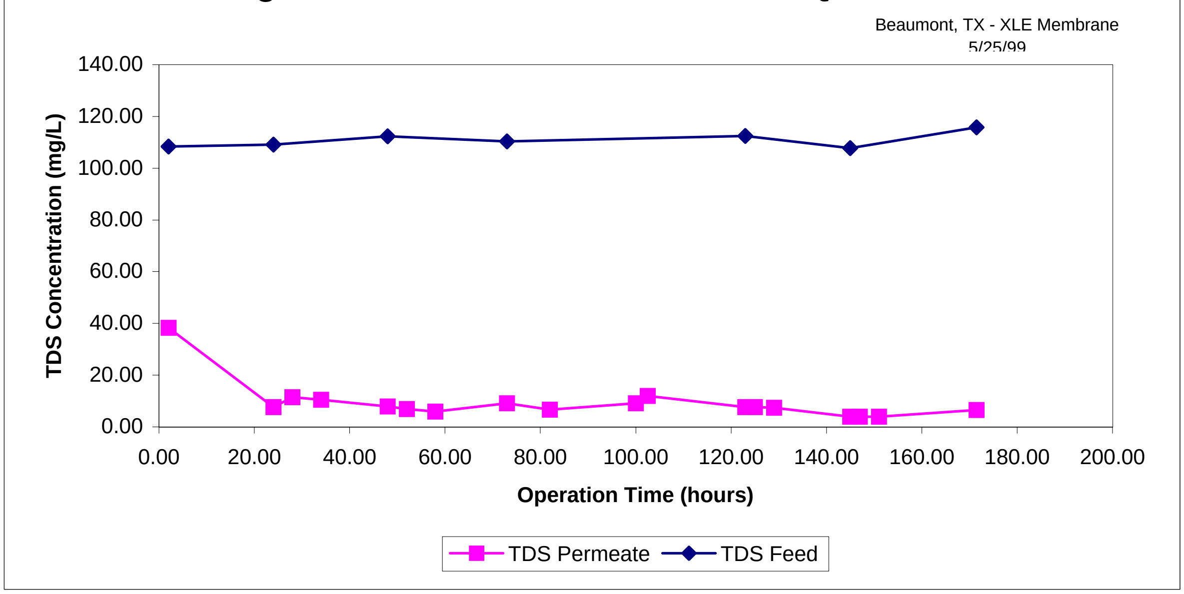
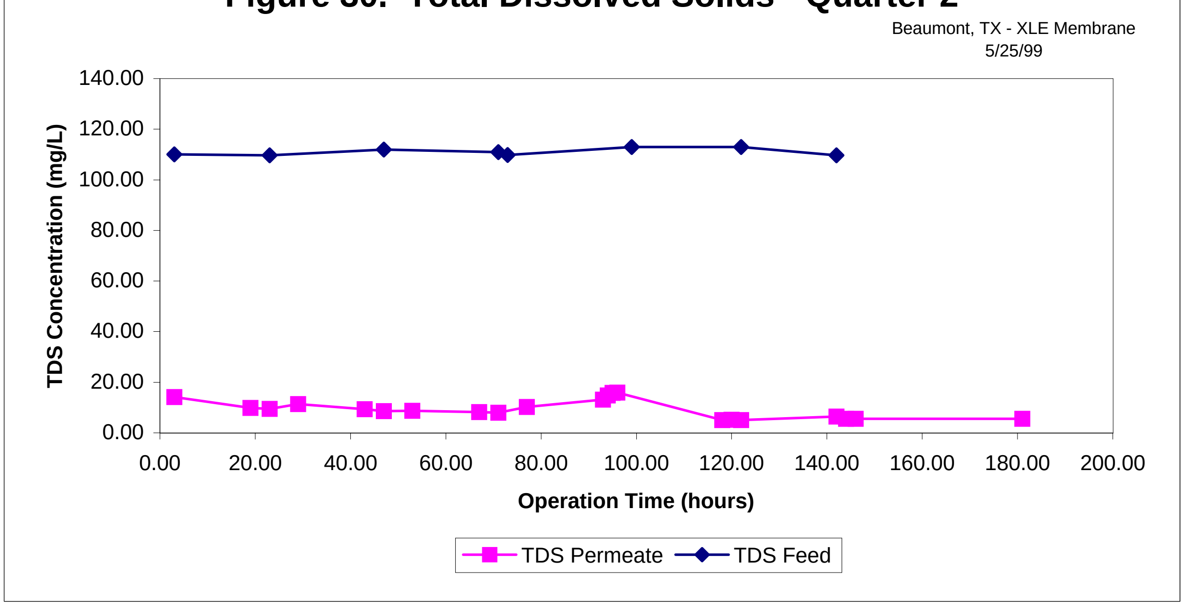


Figure 30. Total Dissolved Solids - Quarter 2



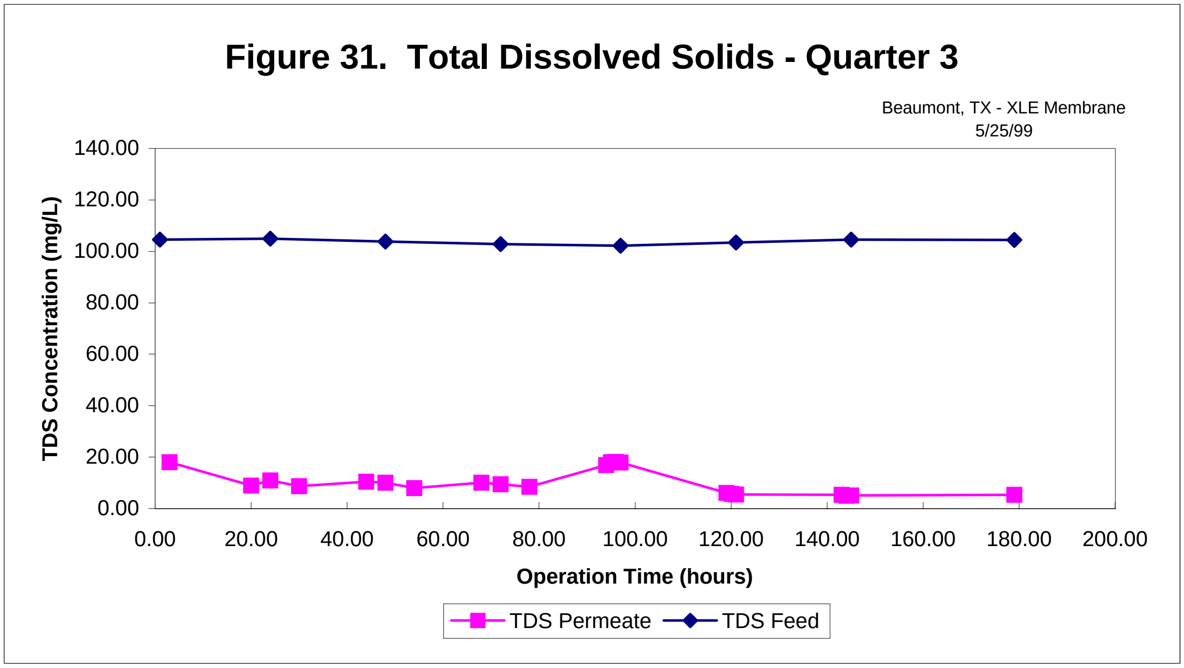


Figure 31. Total Dissolved Solids - Quarter 3
Beaumont, TX - XLE Membrane
5/25/99
TDS Concentration (mg/L)
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
TDS Permeate
TDS Feed

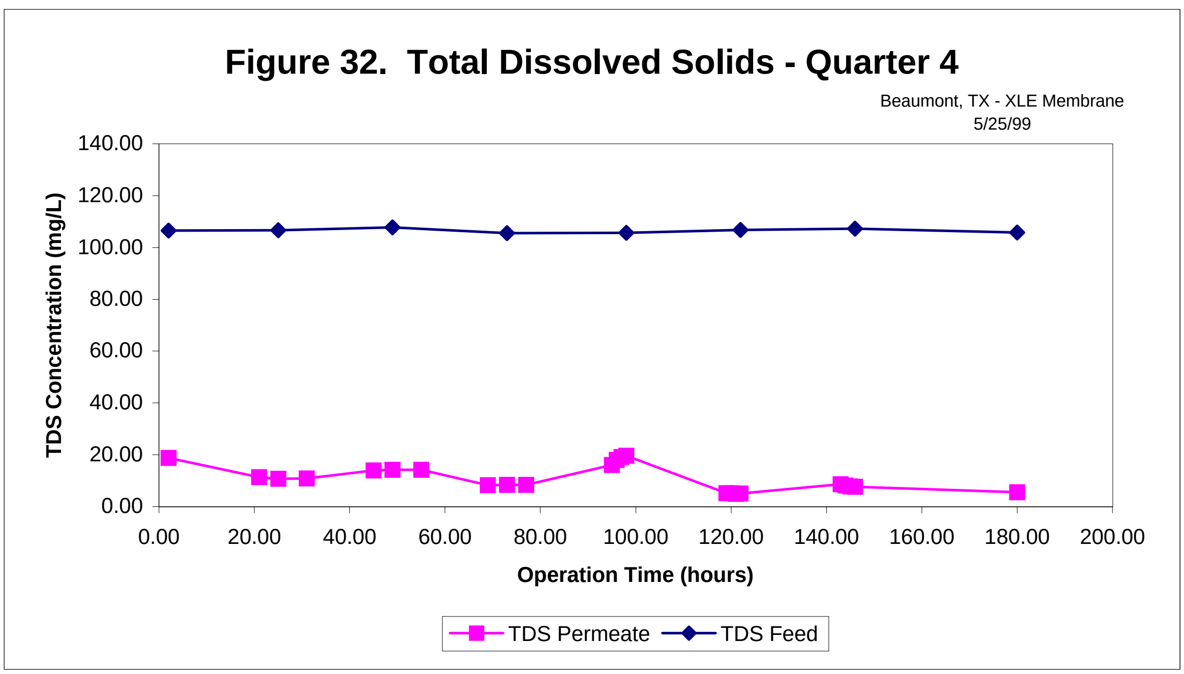
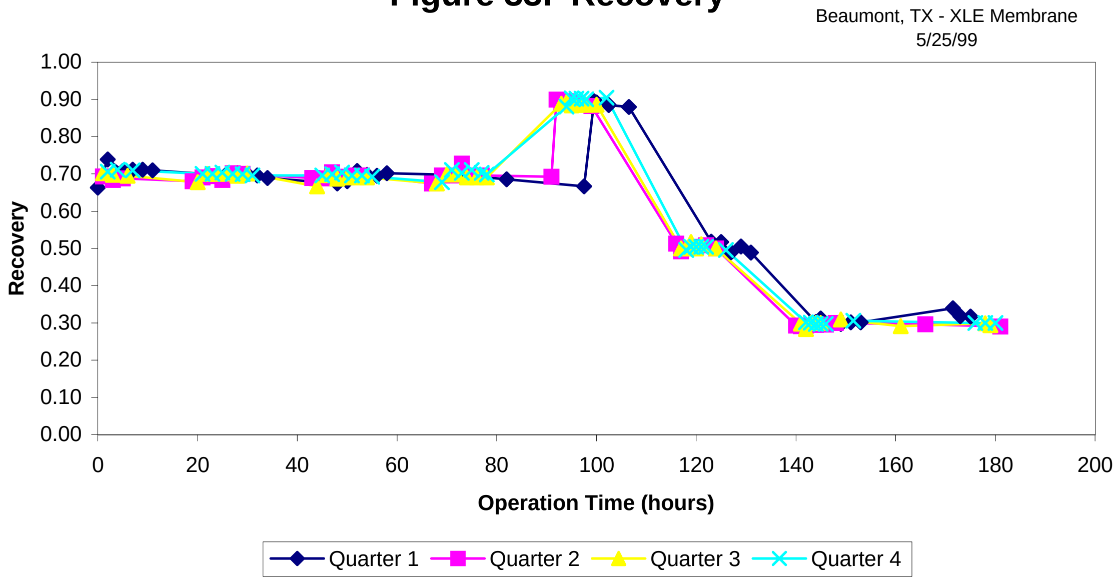


Figure 32. Total Dissolved Solids - Quarter 4
Beaumont, TX - XLE Membrane
5/25/99
TDS Concentration (mg/L)
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
TDS Permeate
TDS Feed

Figure 33. Recovery



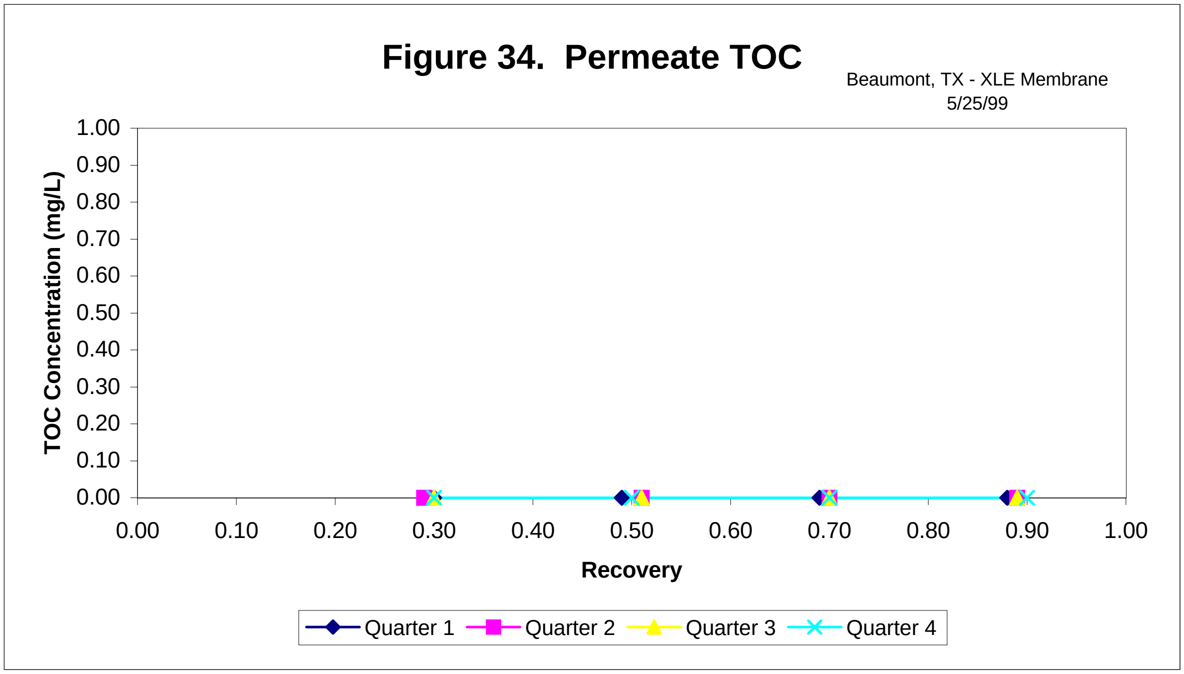


Figure 34. Permeate TOC
Beaumont, TX - XLE Membrane
5/25/99
TOC Concentration (mg/L)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Recovery
Quarter 1
Quarter 2
Quarter 3
Quarter 4

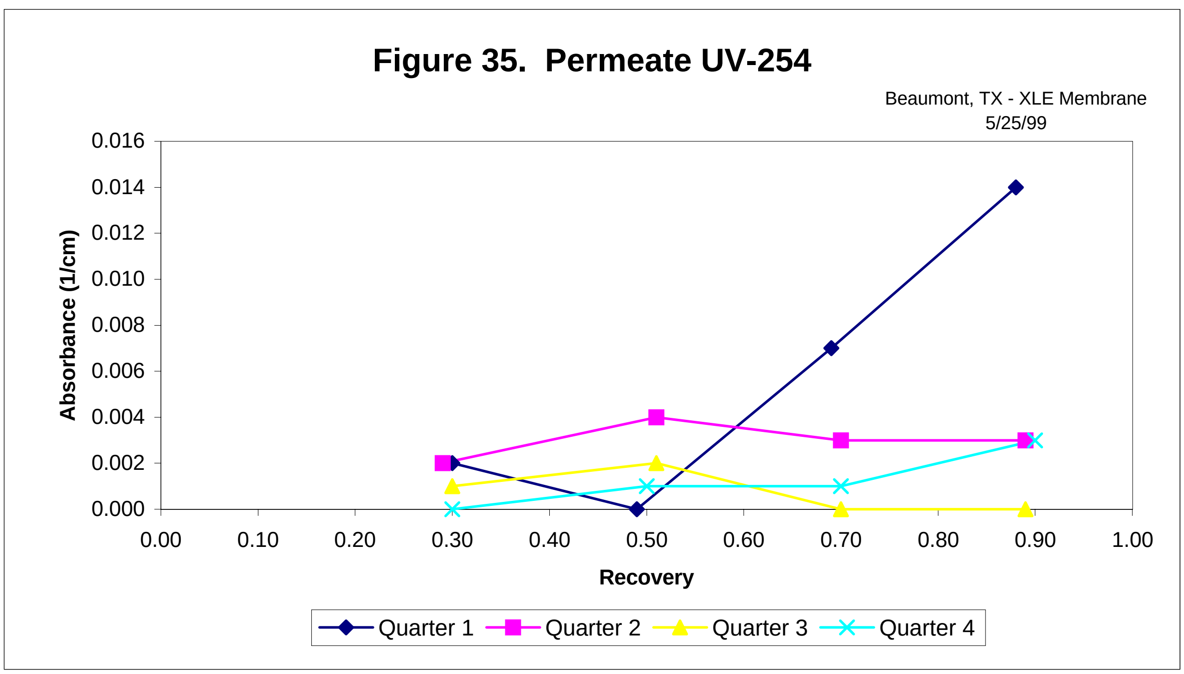


Figure 35. Permeate UV-254
Beaumont, TX - XLE Membrane
5/25/99
Absorbance (1/cm)
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Recovery
Quarter 1
Quarter 2
Quarter 3
Quarter 4

Figure 36. Permeate Total Dissolved Solids

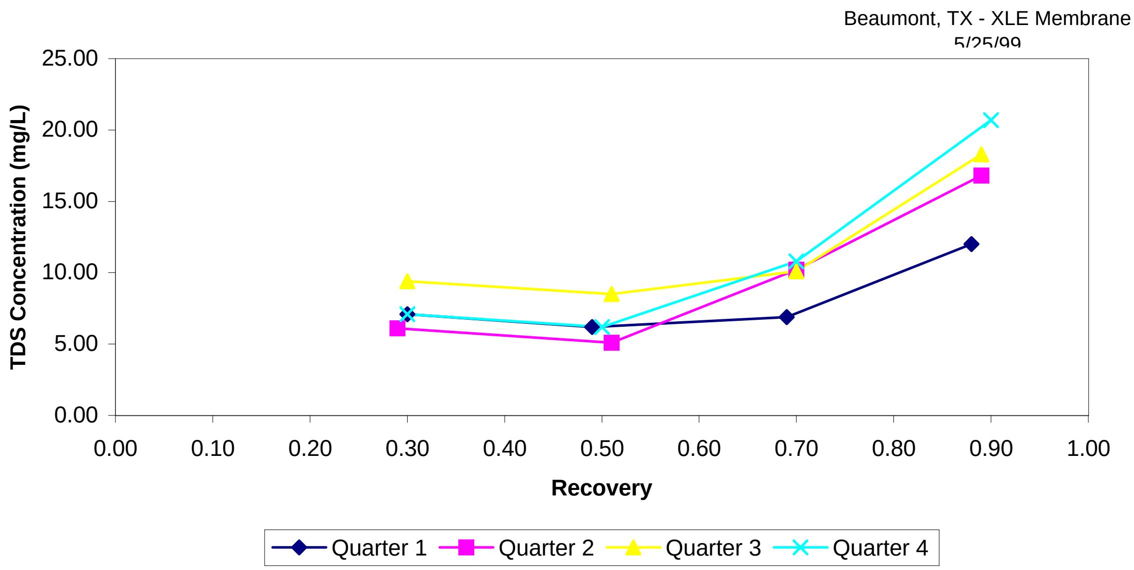
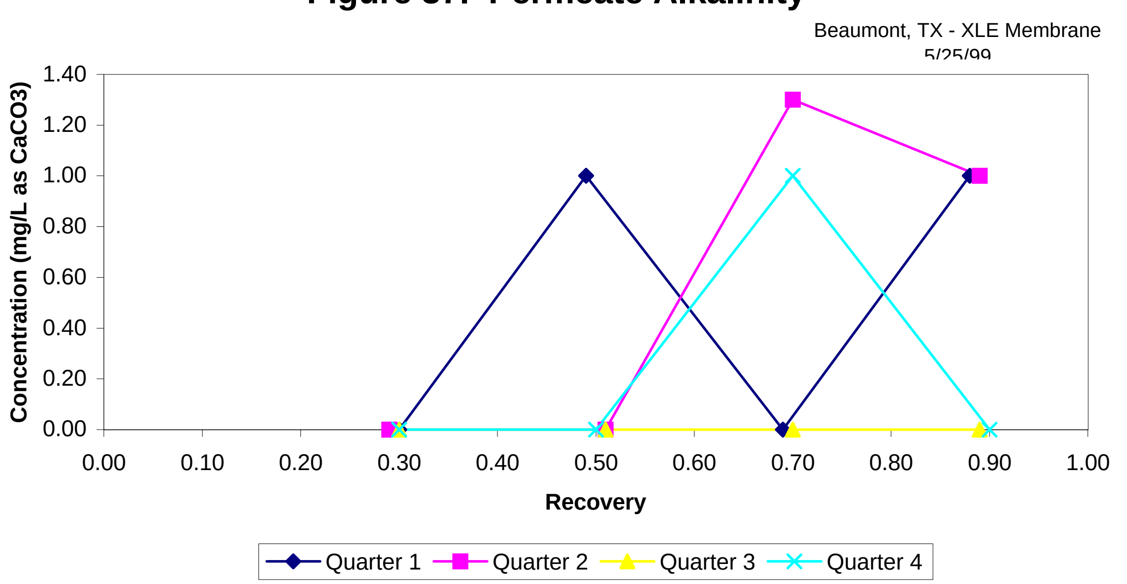


Figure 37. Permeate Alkalinity



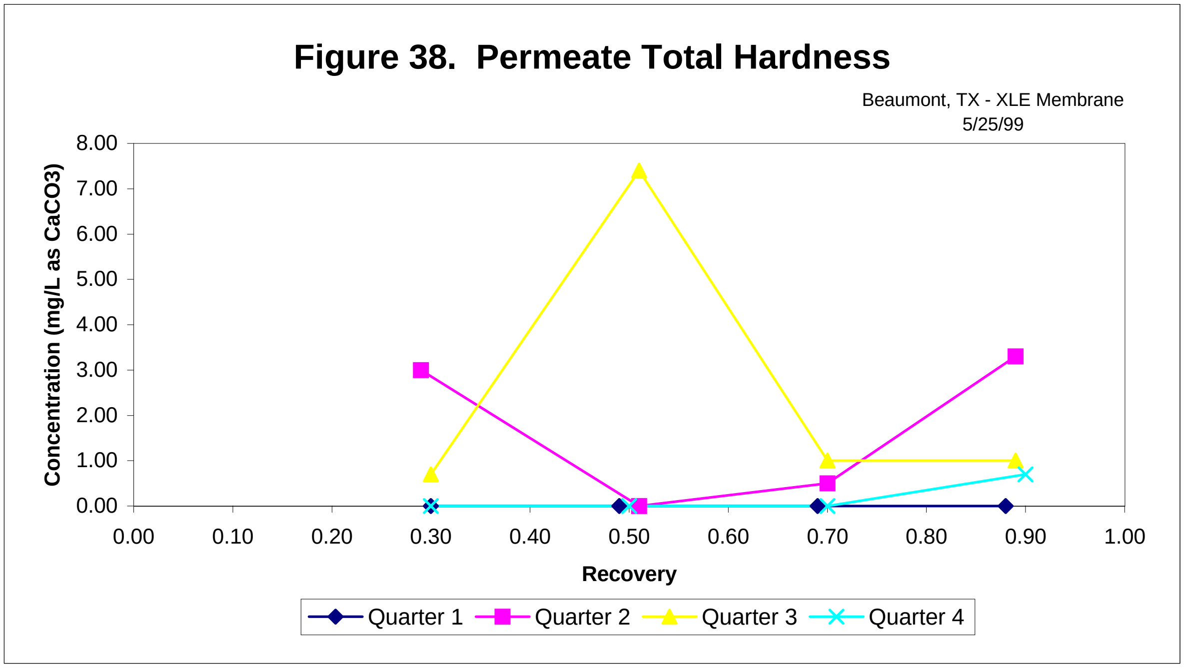


Figure 38. Permeate Total Hardness
Beaumont, TX - XLE Membrane
5/25/99
Concentration (mg/L as CaCO3)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Recovery
Quarter 1
Quarter 2
Quarter 3
Quarter 4

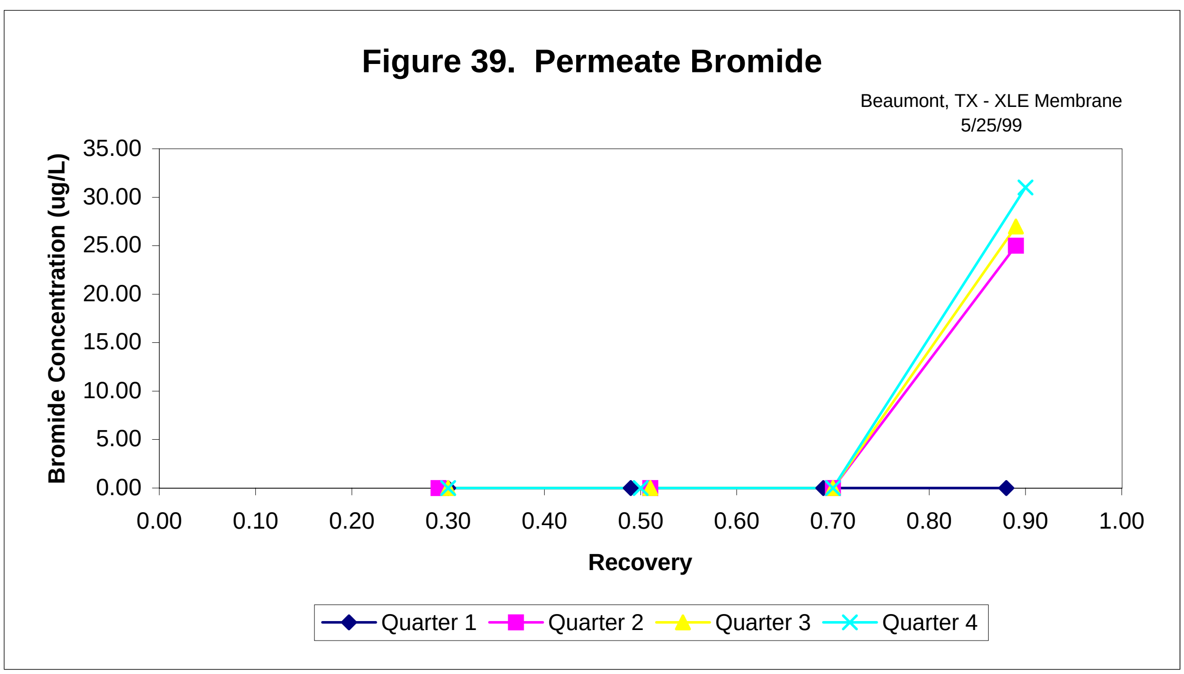


Figure 39. Permeate Bromide
Beaumont, TX - XLE Membrane
5/25/99
Bromide Concentration (ug/L)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Recovery
Quarter 1
Quarter 2
Quarter 3
Quarter 4

Figure 40. Permeate SDS-THM4

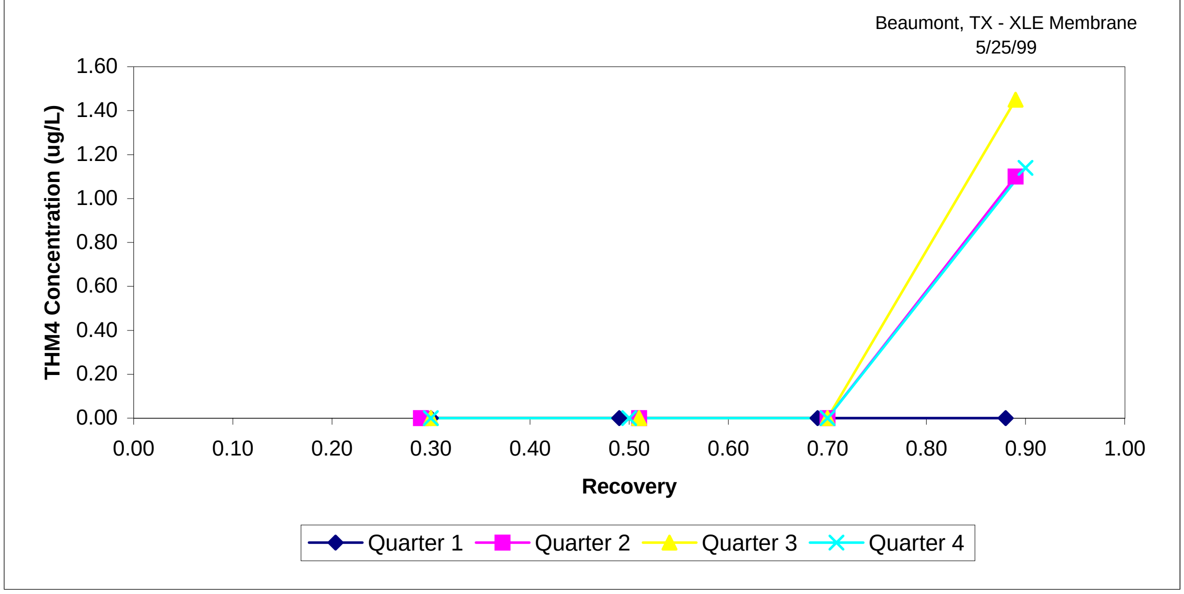


Figure 41. Permeate THM Species - Quarter 1

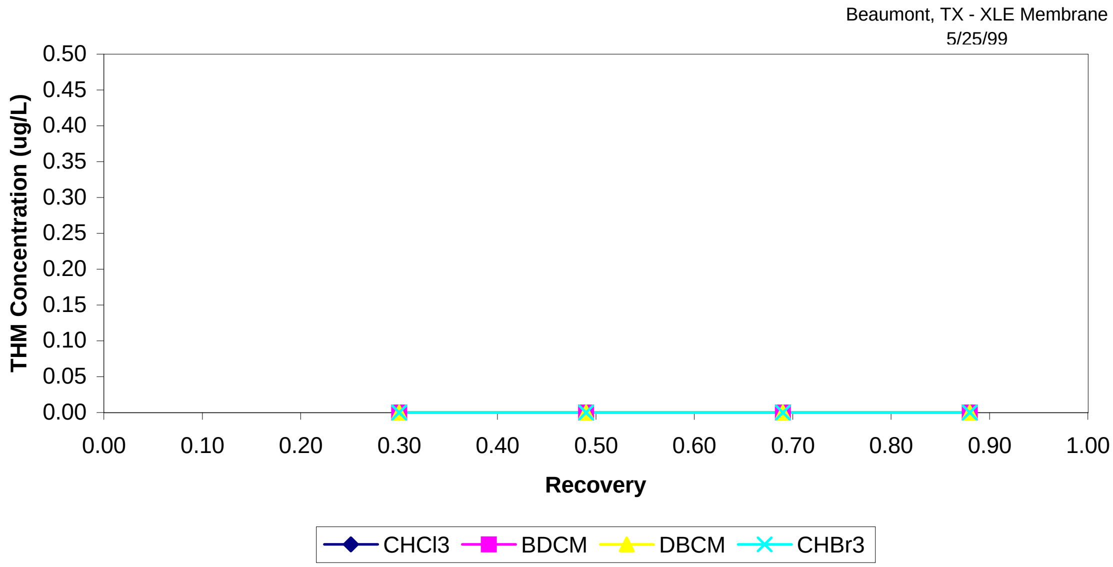
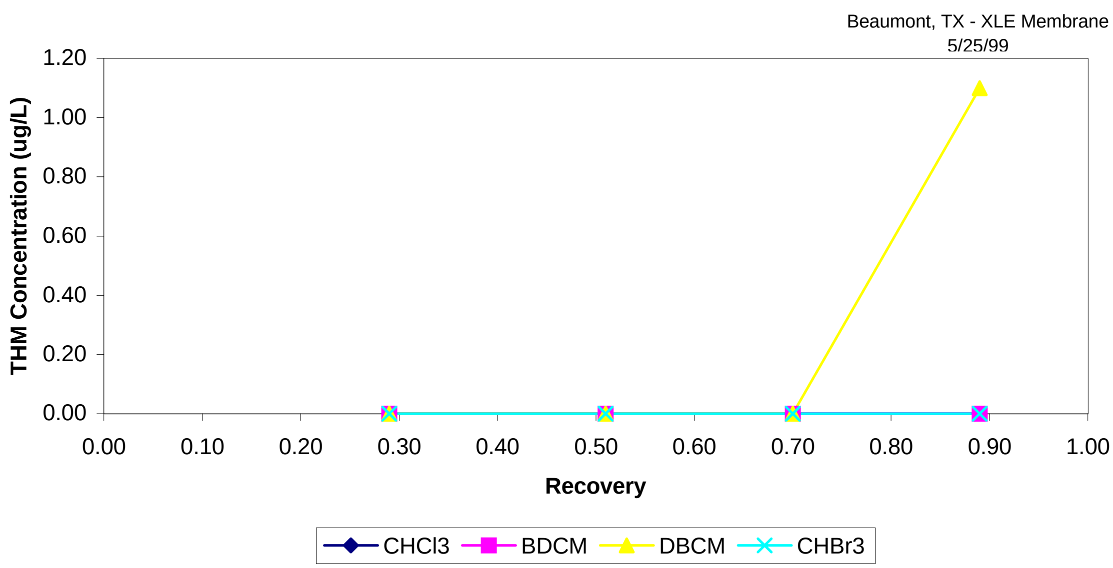


Figure 42. Permeate THM Species - Quarter 2



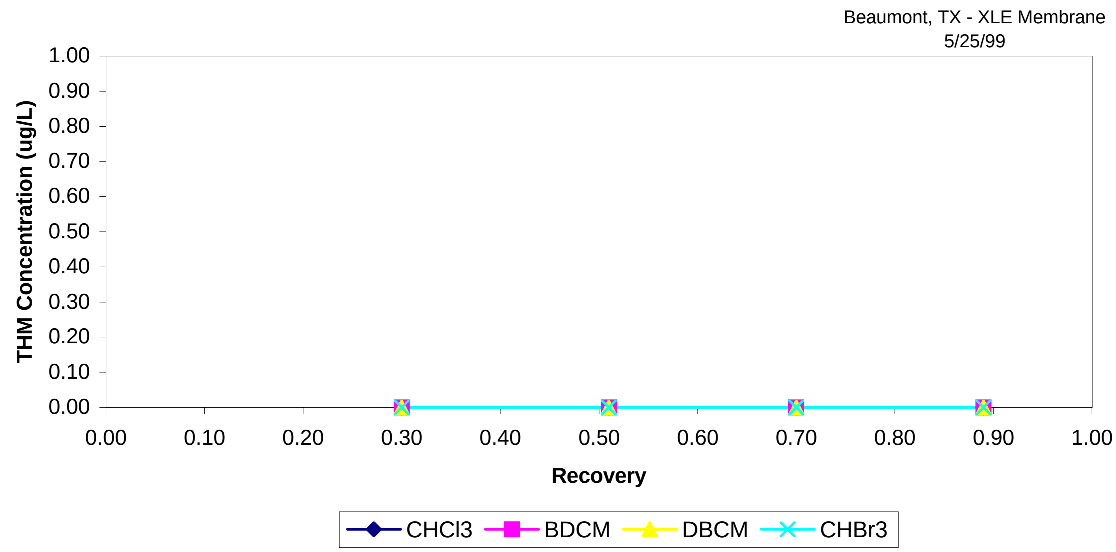


Figure 43. Permeate THM Species - Quarter 3

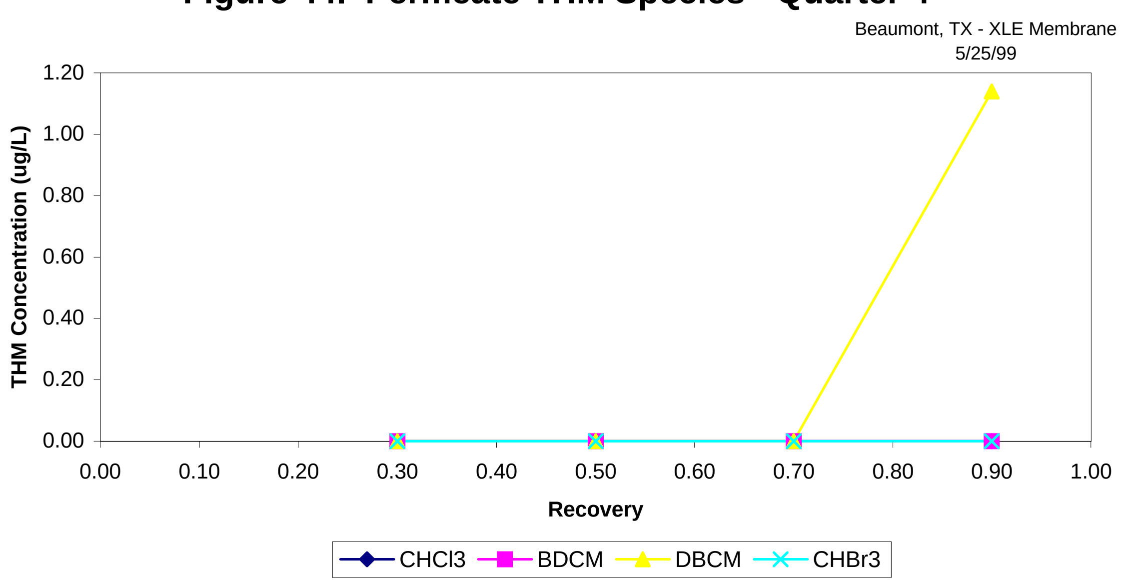


Figure 44. Permeate THM Species - Quarter 4

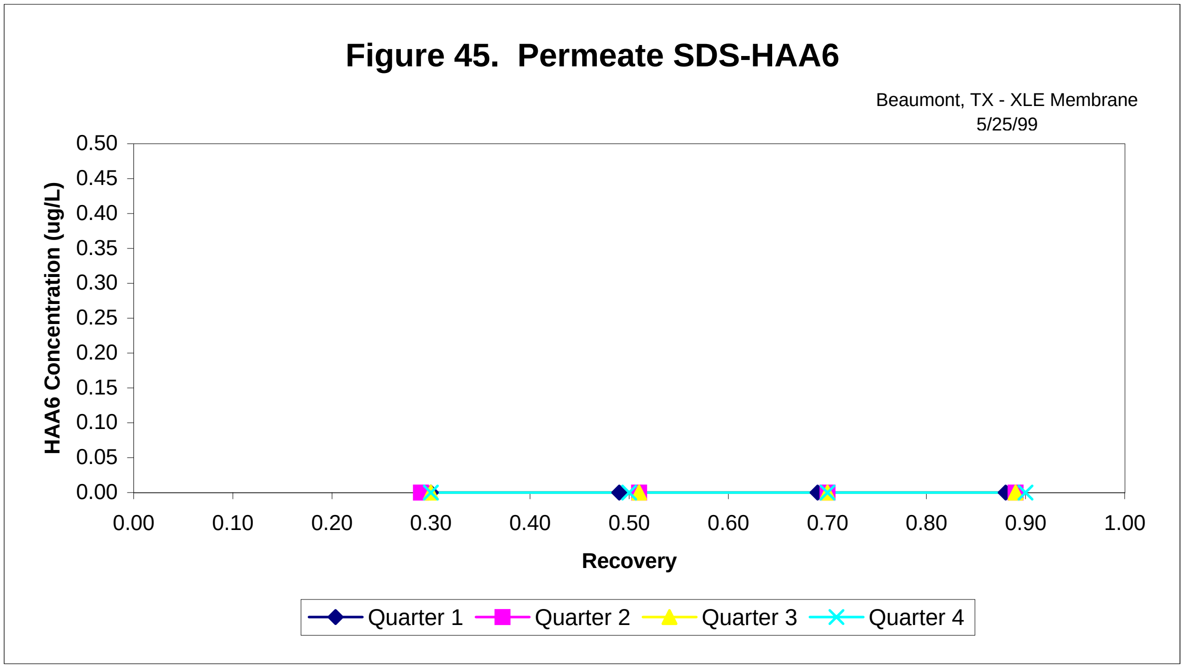


Figure 45. Permeate SDS-HAA6
Beaumont, TX - XLE Membrane
5/25/99
HAA6 Concentration (ug/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Recovery
Quarter 1
Quarter 2
Quarter 3
Quarter 4

Figure 46. Permeate HAA6 Species - Quarter 1

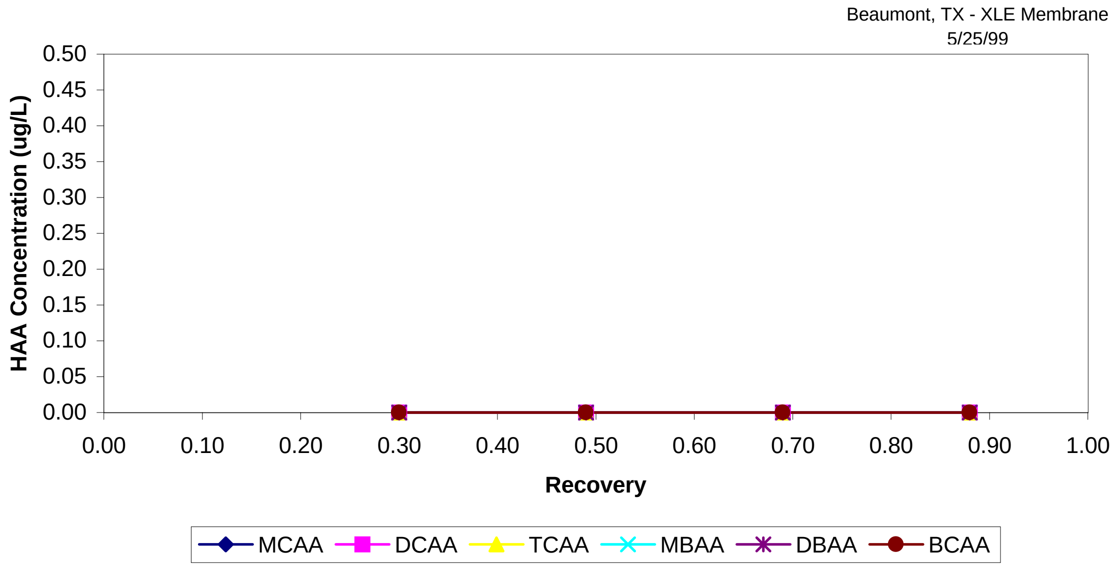
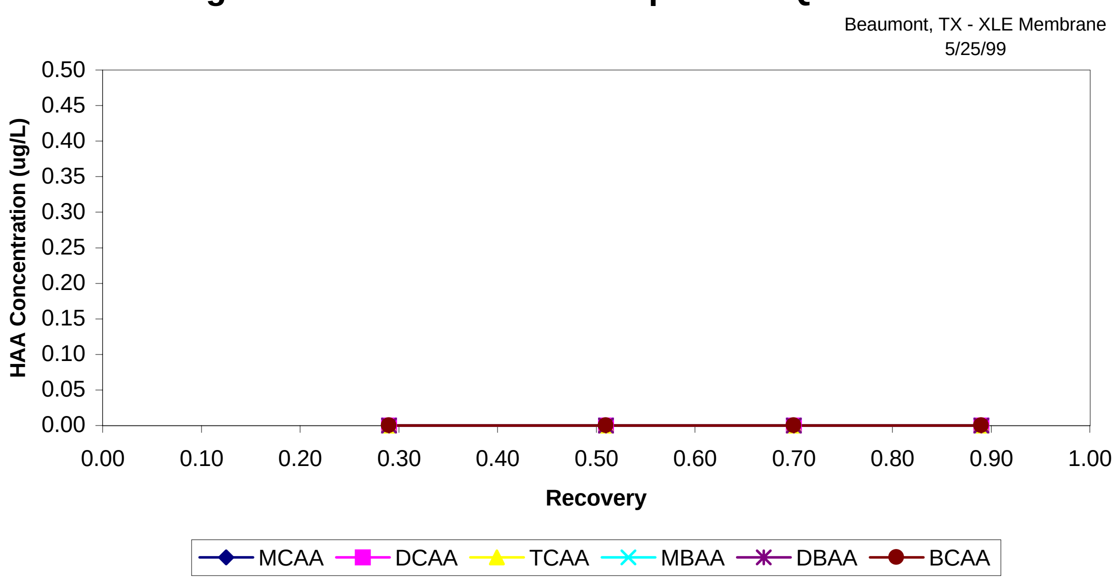


Figure 47. Permeate HAA6 Species - Quarter 2



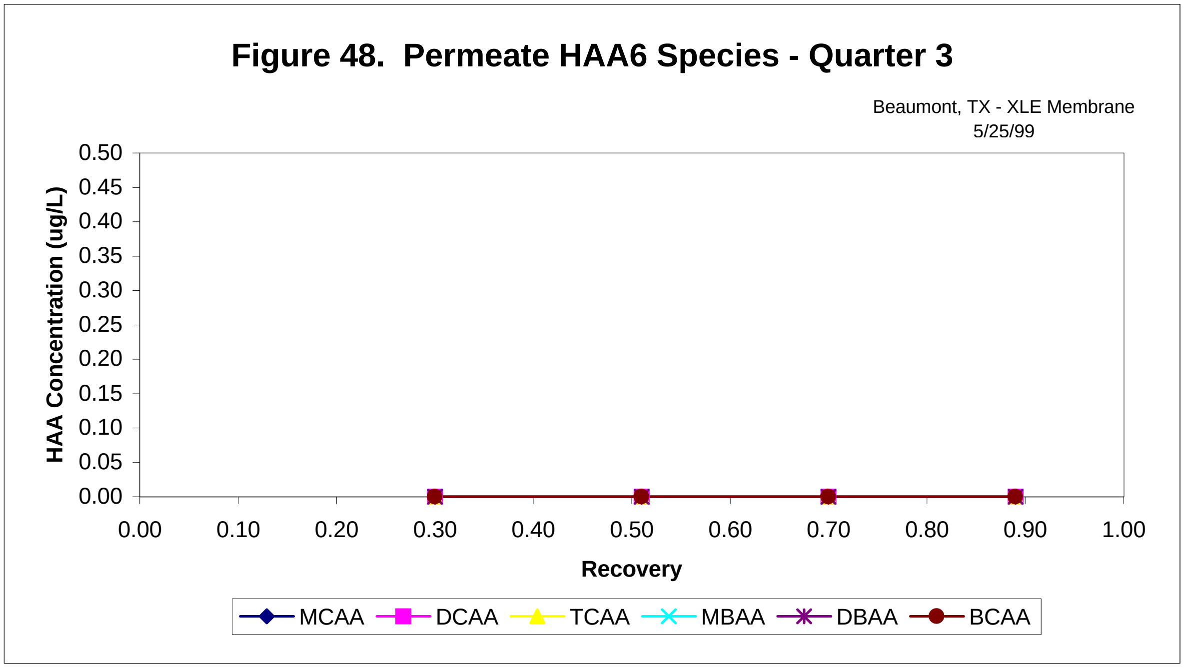


Figure 48. Permeate HAA6 Species - Quarter 3
Beaumont, TX - XLE Membrane
5/25/99
HAA Concentration (ug/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Recovery
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

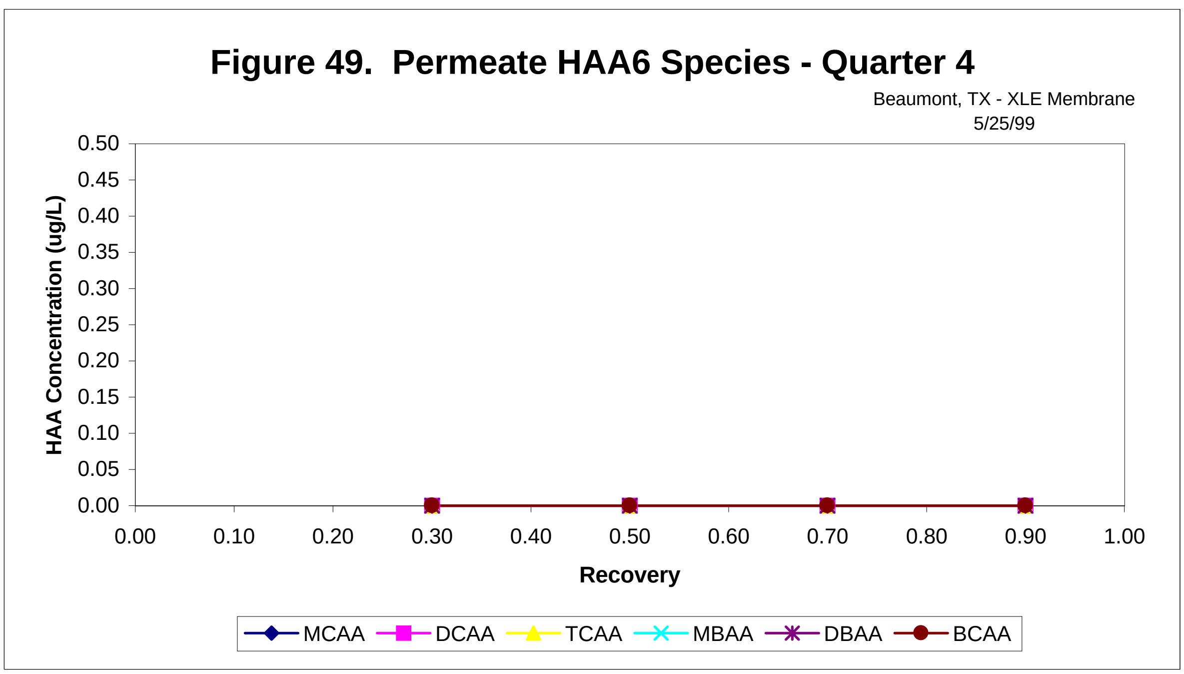


Figure 49. Permeate HAA6 Species - Quarter 4
Beaumont, TX - XLE Membrane
5/25/99
HAA Concentration (ug/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Recovery
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

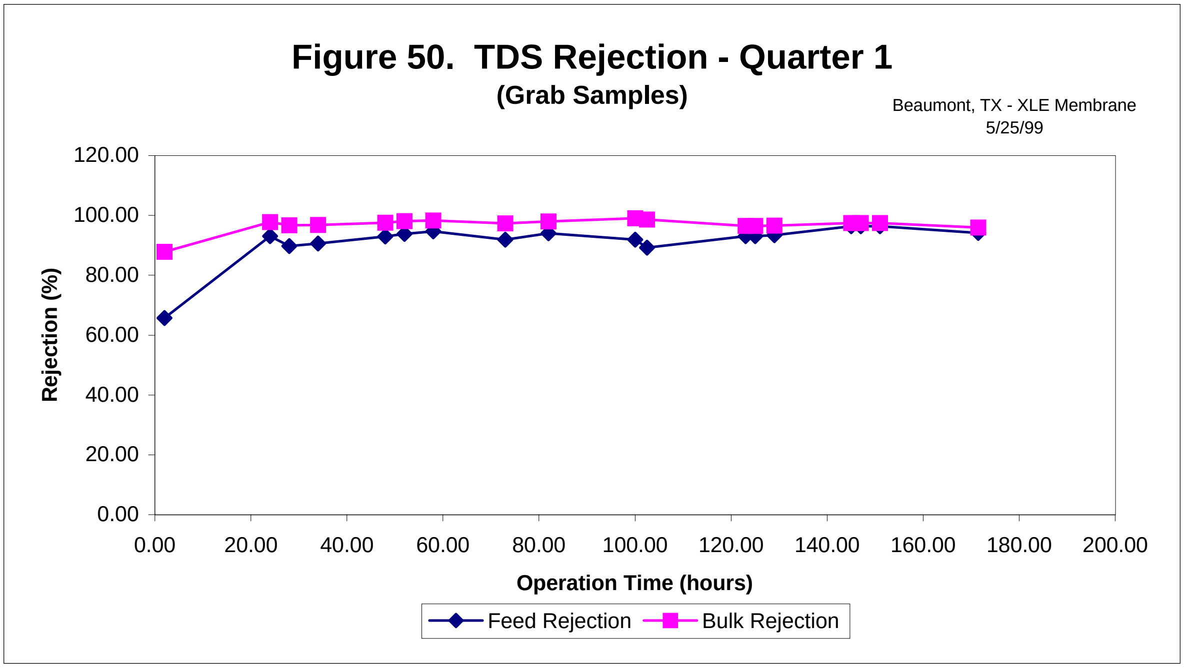


Figure 50. TDS Rejection - Quarter 1
(Grab Samples)
Beaumont, TX - XLE Membrane
5/25/99
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Rejection (%)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Feed Rejection
Bulk Rejection

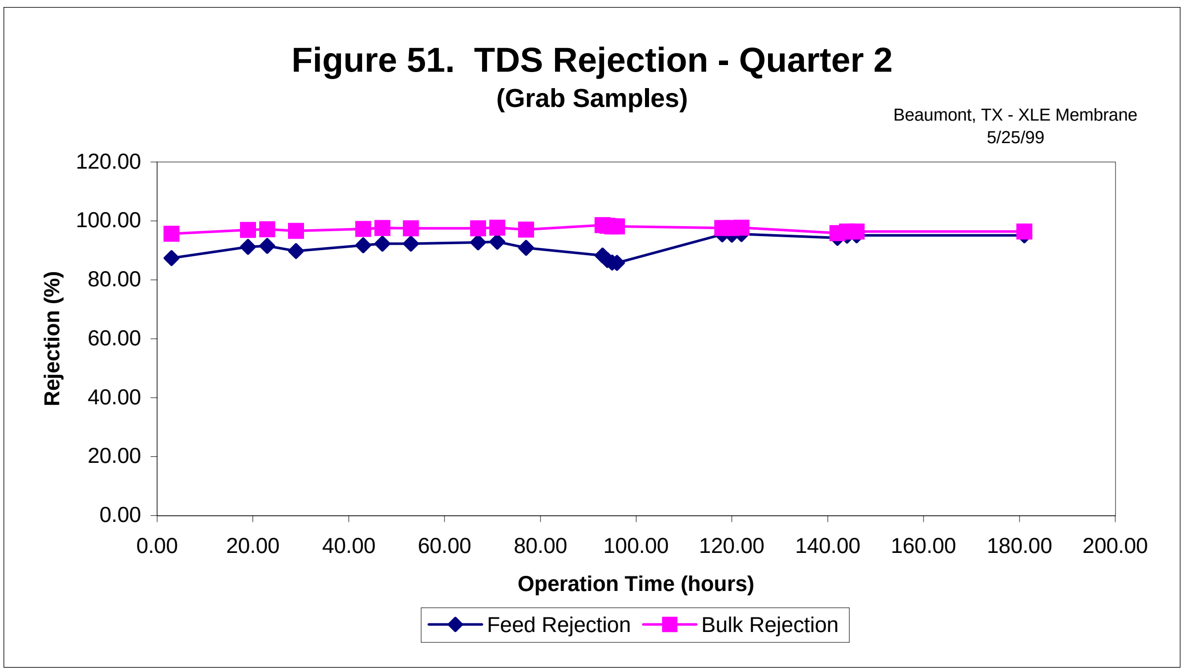


Figure 51. TDS Rejection - Quarter 2
(Grab Samples)
Beaumont, TX - XLE Membrane
5/25/99
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Rejection (%)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Feed Rejection
Bulk Rejection

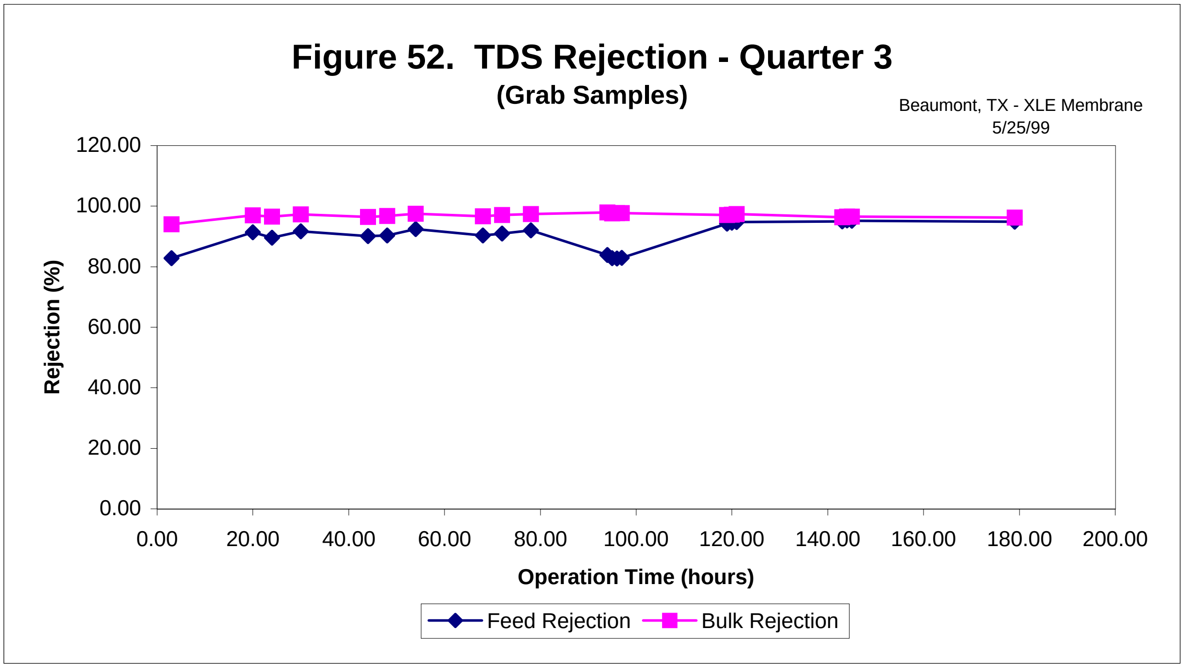


Figure 52. TDS Rejection - Quarter 3
(Grab Samples)
Beaumont, TX - XLE Membrane
5/25/99
Rejection (%)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Feed Rejection
Bulk Rejection

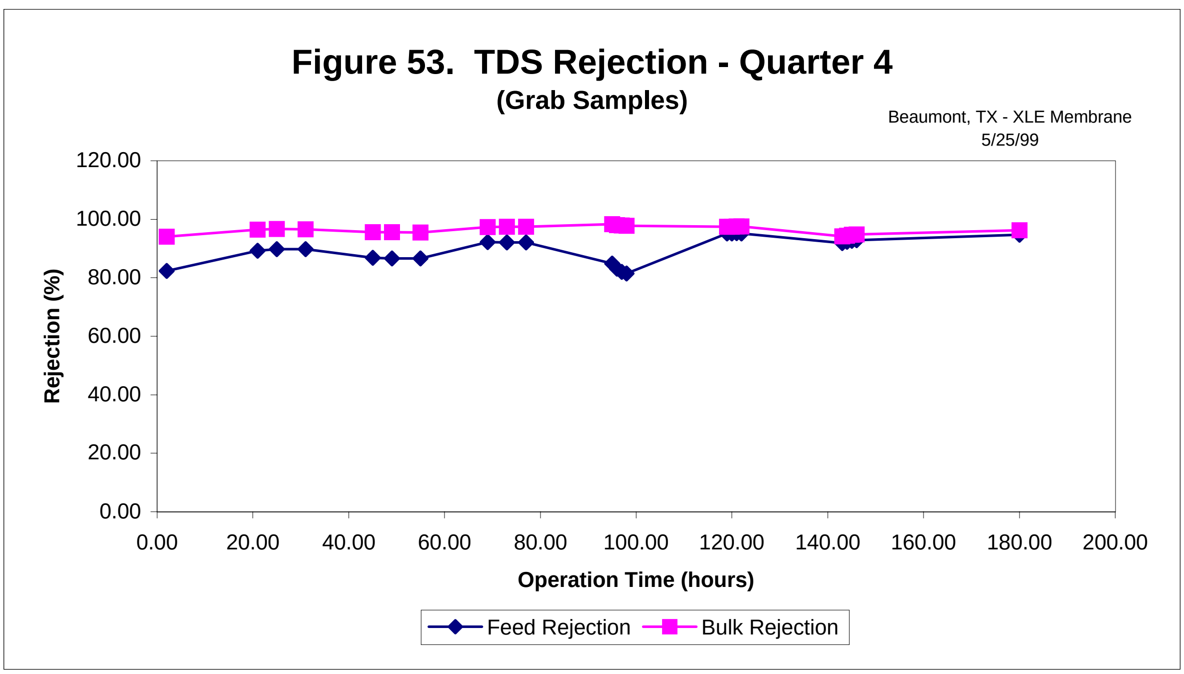


Figure 53. TDS Rejection - Quarter 4
(Grab Samples)
Beaumont, TX - XLE Membrane
5/25/99
Rejection (%)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Feed Rejection
Bulk Rejection

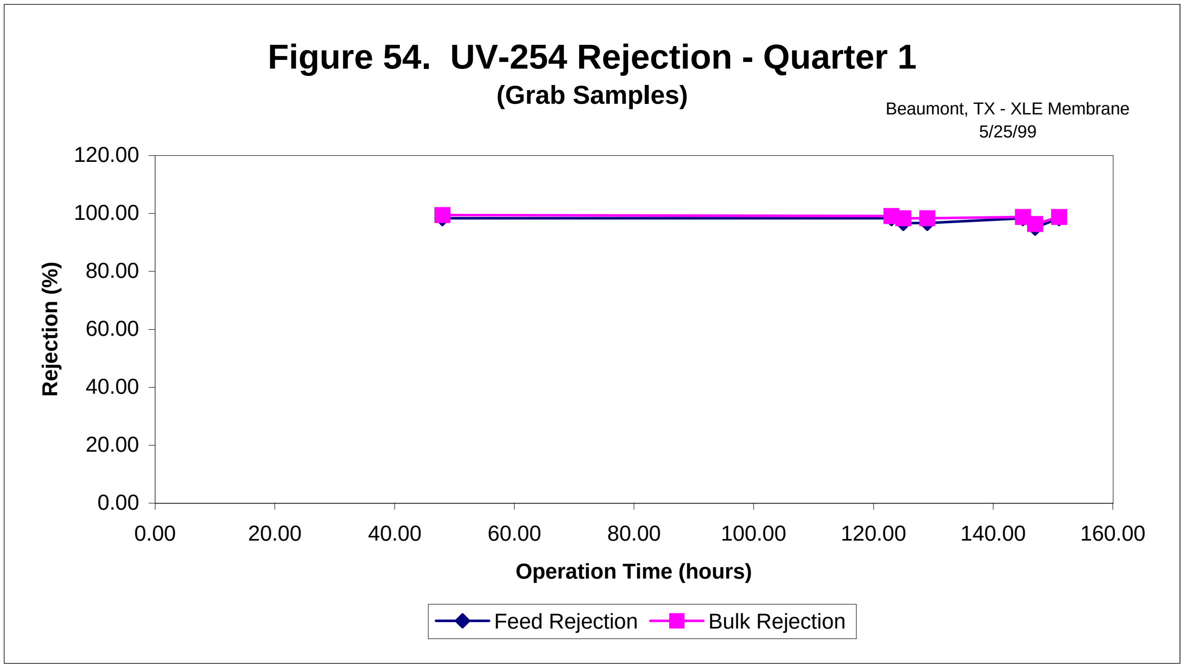


Figure 54. UV-254 Rejection - Quarter 1
(Grab Samples)
Beaumont, TX - XLE Membrane
5/25/99
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Rejection (%)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Operation Time (hours)
Feed Rejection
Bulk Rejection

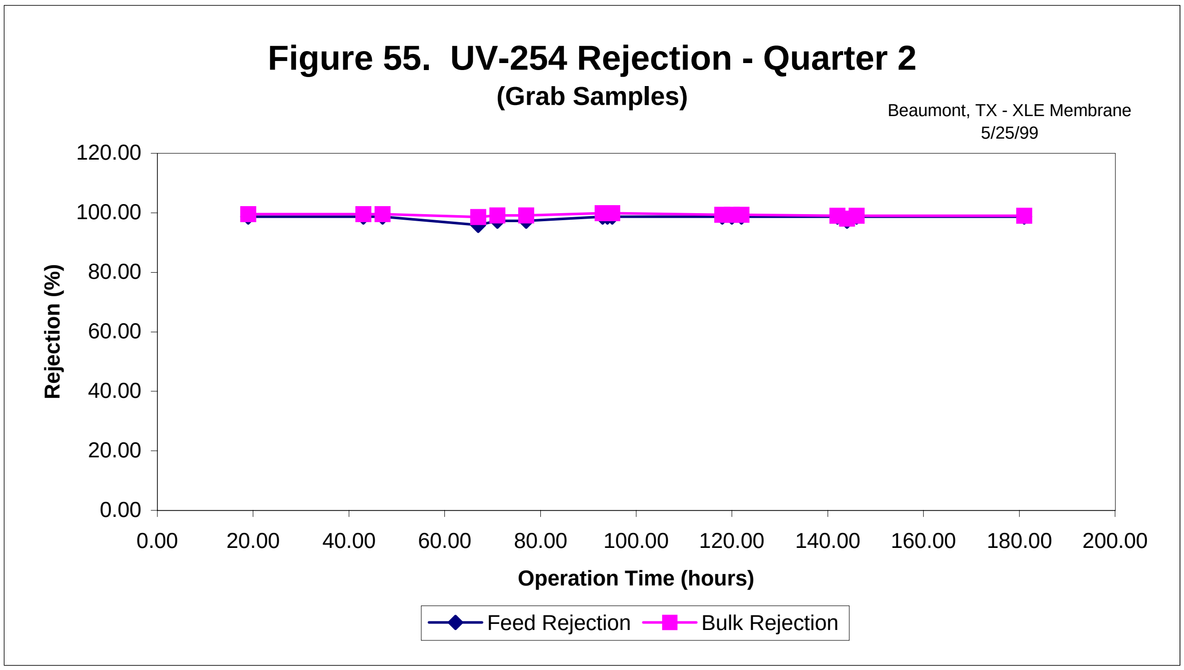


Figure 55. UV-254 Rejection - Quarter 2
(Grab Samples)
Beaumont, TX - XLE Membrane
5/25/99
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Rejection (%)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Feed Rejection
Bulk Rejection

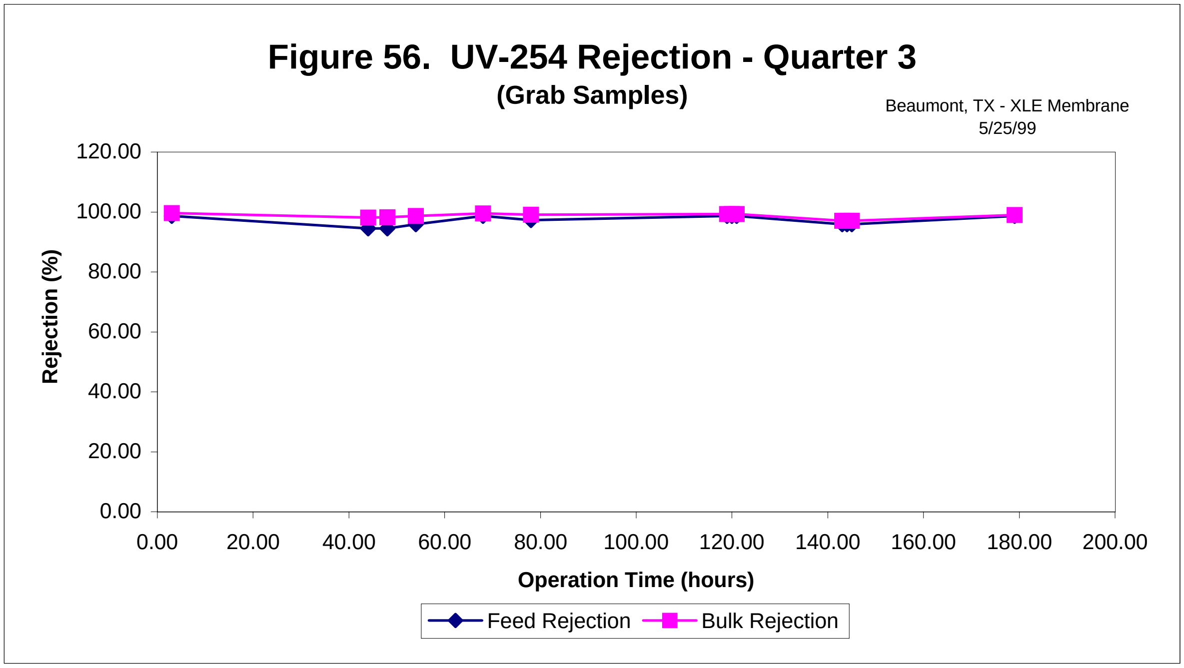


Figure 56. UV-254 Rejection - Quarter 3
(Grab Samples)
Beaumont, TX - XLE Membrane
5/25/99
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Rejection (%)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Feed Rejection
Bulk Rejection

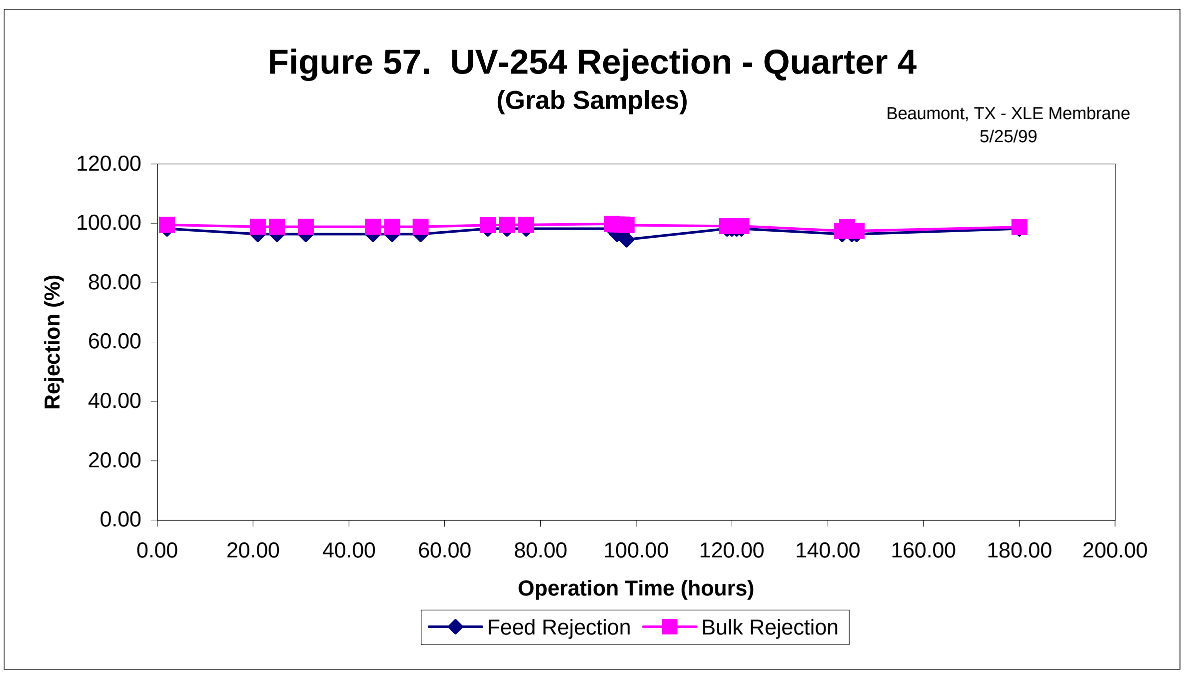


Figure 57. UV-254 Rejection - Quarter 4
(Grab Samples)
Beaumont, TX - XLE Membrane
5/25/99
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Rejection (%)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Feed Rejection
Bulk Rejection

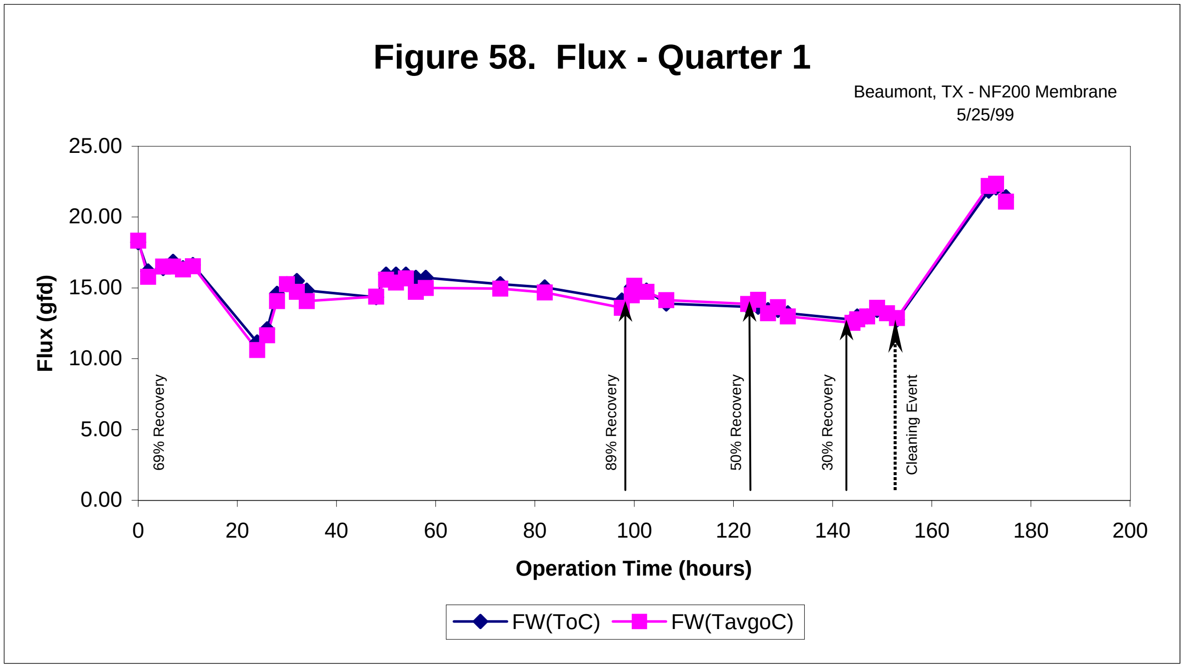


Figure 58. Flux - Quarter 1
Beaumont, TX - NF200 Membrane
5/25/99
Flux (gfd)
25.00
20.00
15.00
10.00
5.00
0.00
69% Recovery
89% Recovery
50% Recovery
30% Recovery
Cleaning Event
0
20
40
60
80
100
120
140
160
180
200
Operation Time (hours)
FW(ToC)
FW(TavgoC)

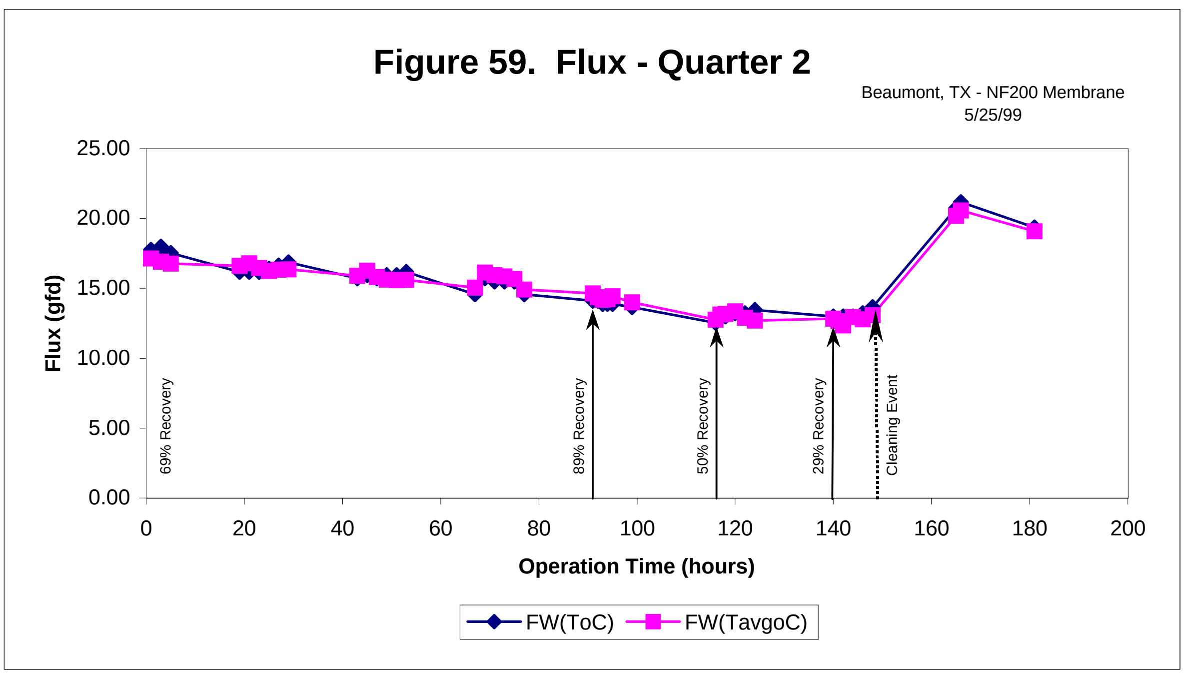


Figure 59. Flux - Quarter 2
Beaumont, TX - NF200 Membrane
5/25/99
Flux (gfd)
25.00
20.00
15.00
10.00
5.00
0.00
69% Recovery
89% Recovery
50% Recovery
29% Recovery
Cleaning Event
0
20
40
60
80
100
120
140
160
180
200
Operation Time (hours)
FW(ToC)
FW(TavgoC)

Figure 60. Flux - Quarter 3

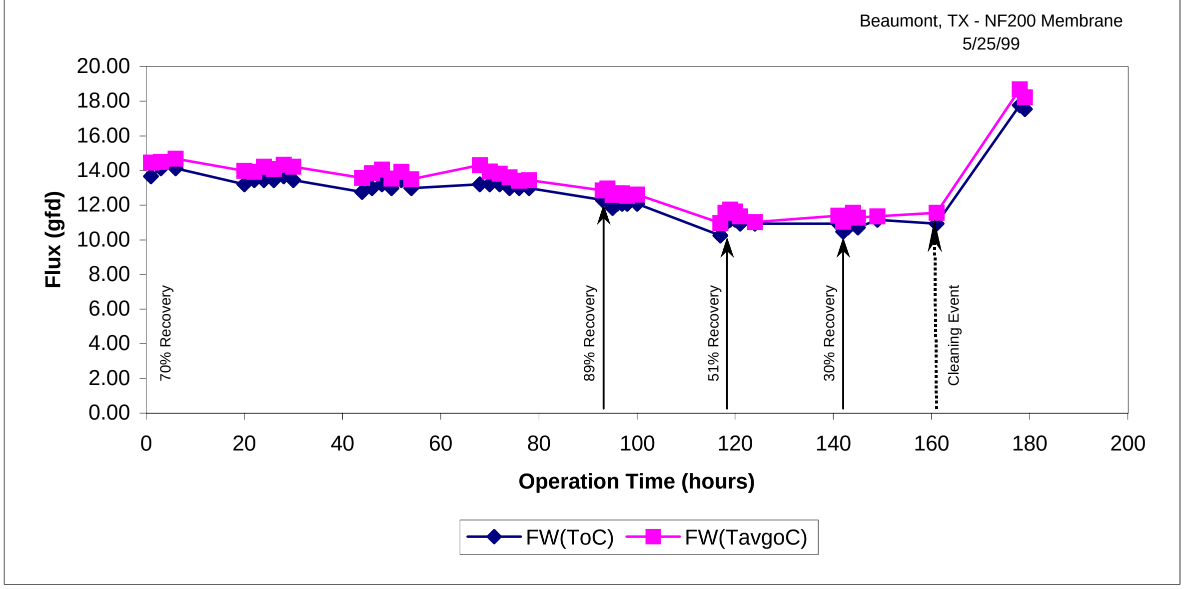
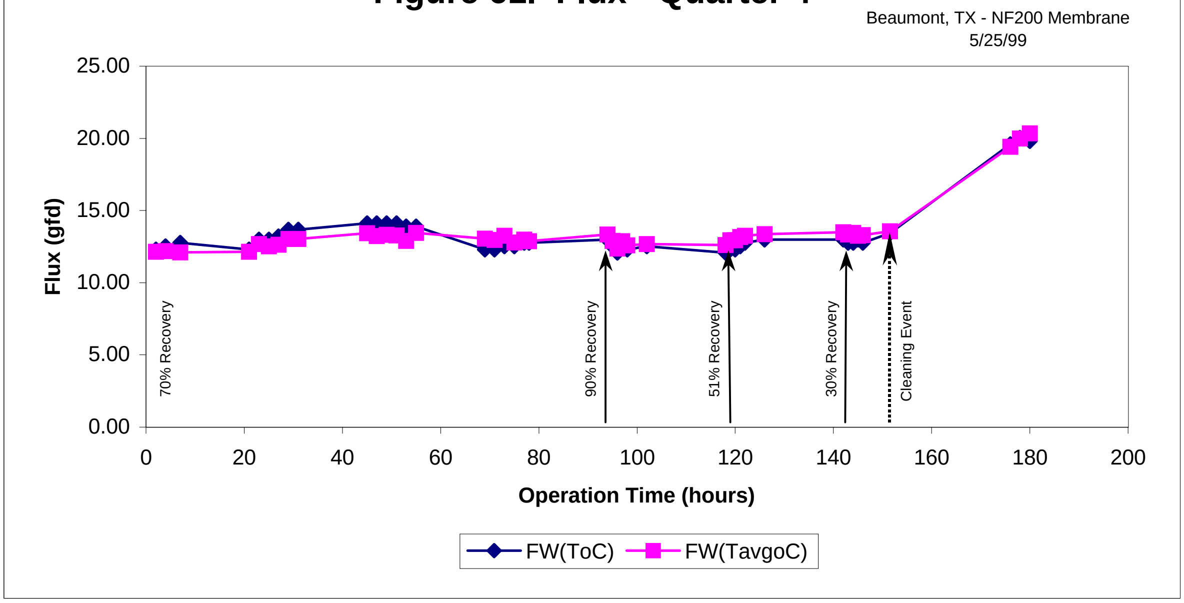


Figure 61. Flux - Quarter 4



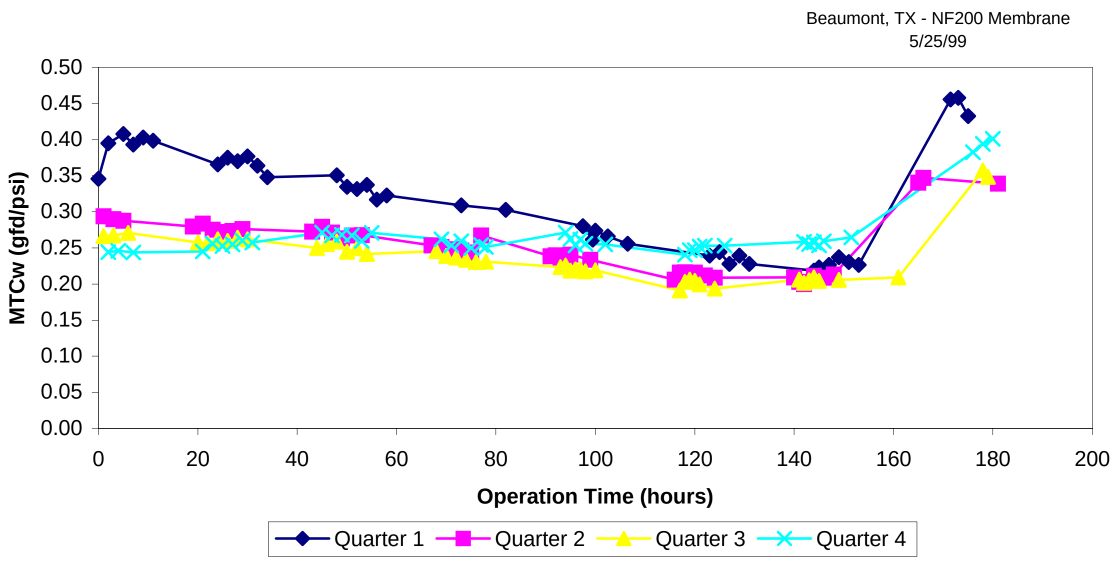


Figure 62. Water Mass Transfer Coefficient, MTCw

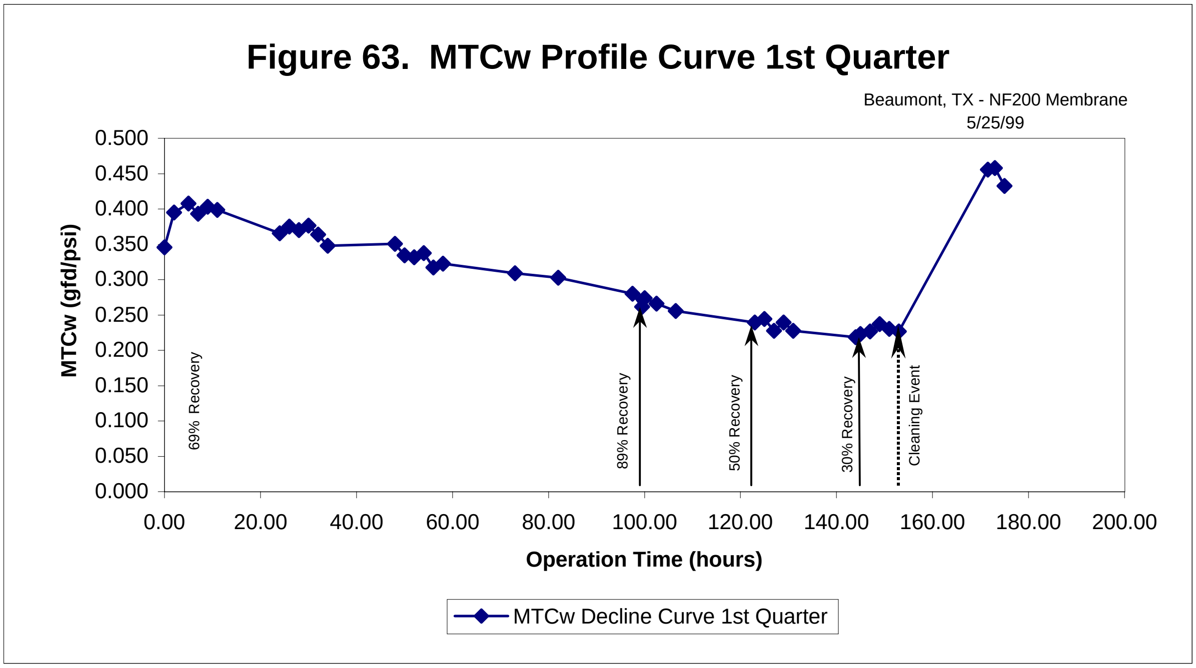


Figure 63. MTCw Profile Curve 1st Quarter
Beaumont, TX - NF200 Membrane
5/25/99
MTCw (gfd/psi)
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
69% Recovery
89% Recovery
50% Recovery
30% Recovery
Cleaning Event
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
MTCw Decline Curve 1st Quarter

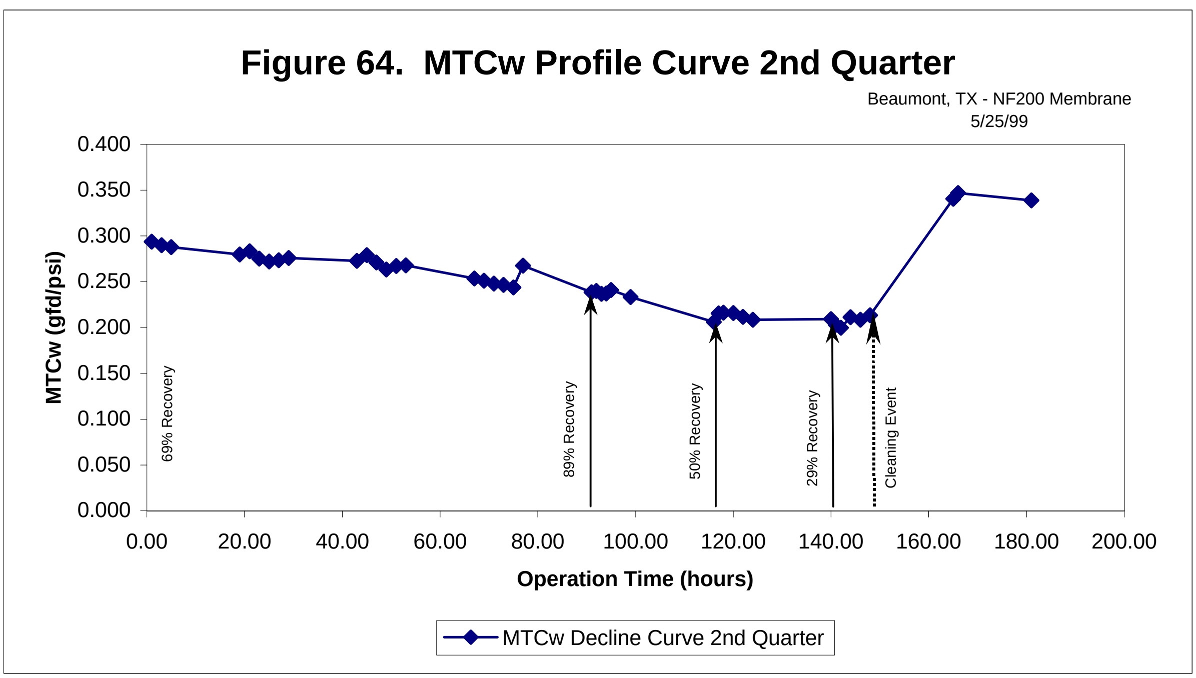


Figure 64. MTCw Profile Curve 2nd Quarter
Beaumont, TX - NF200 Membrane
5/25/99
MTCw (gfd/psi)
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
69% Recovery
89% Recovery
50% Recovery
29% Recovery
Cleaning Event
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
MTCw Decline Curve 2nd Quarter

Figure 65. MTCw Profile Curve 3rd Quarter

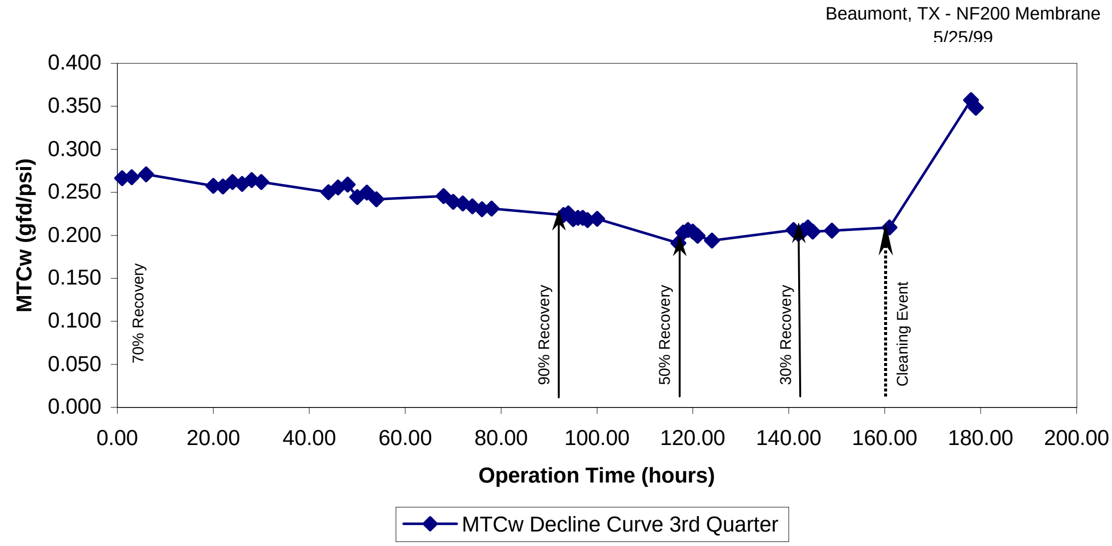
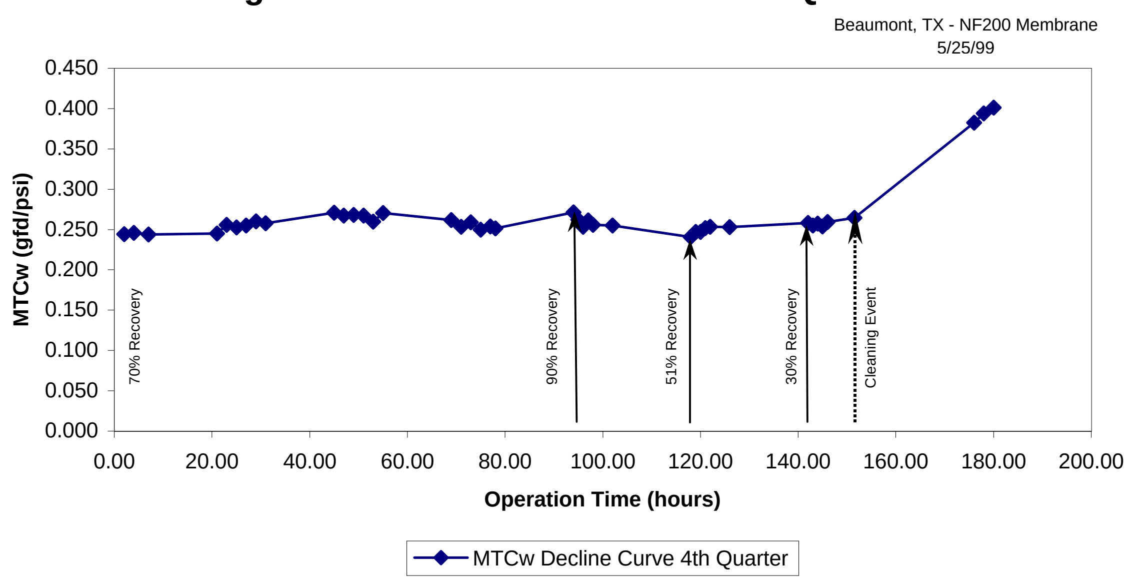


Figure 66. MTCw Profile Curve 4th Quarter



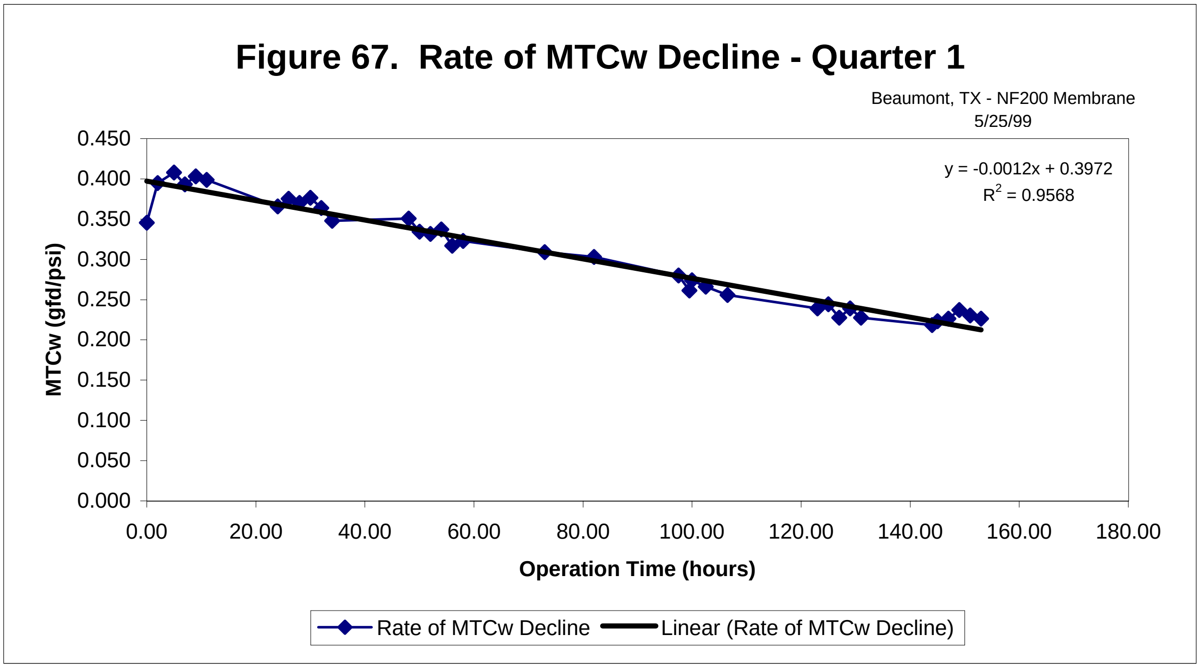


Figure 67. Rate of MTCw Decline - Quarter 1
Beaumont, TX - NF200 Membrane
5/25/99
y = -0.0012x + 0.3972
R^2 = 0.9568
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
MTCw (gfd/psi)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
Operation Time (hours)
Rate of MTCw Decline
Linear (Rate of MTCw Decline)

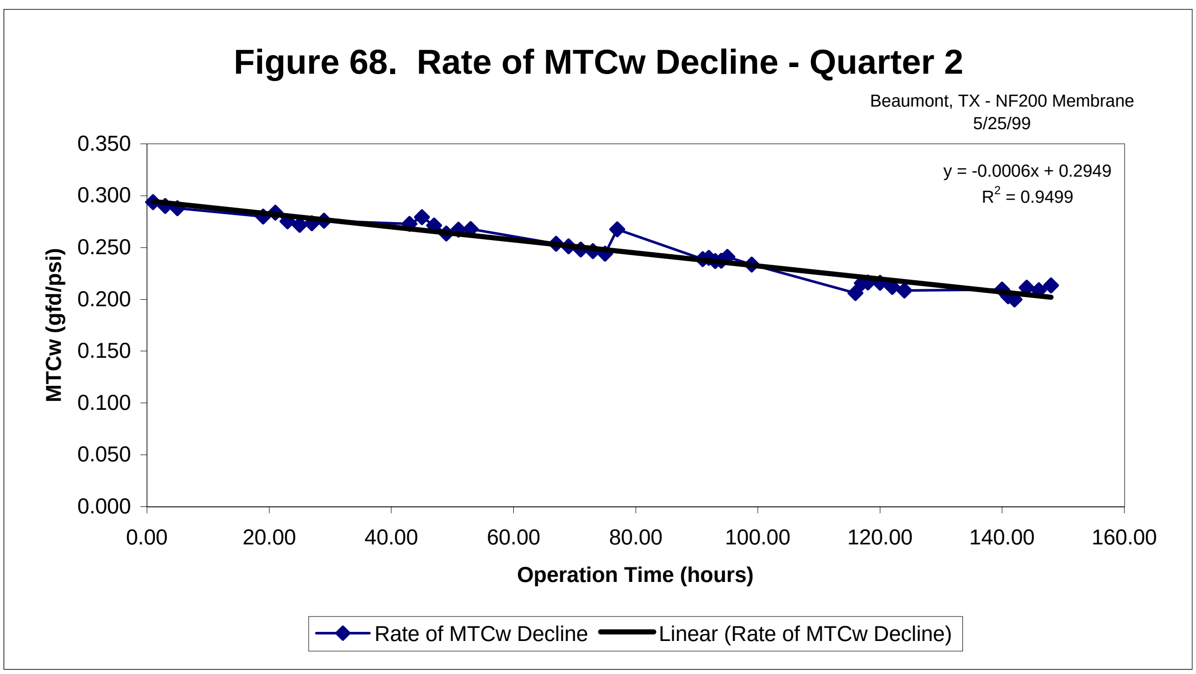


Figure 68. Rate of MTCw Decline - Quarter 2
Beaumont, TX - NF200 Membrane
5/25/99
y = -0.0006x + 0.2949
R^2 = 0.9499
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
MTCw (gfd/psi)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Operation Time (hours)
Rate of MTCw Decline
Linear (Rate of MTCw Decline)

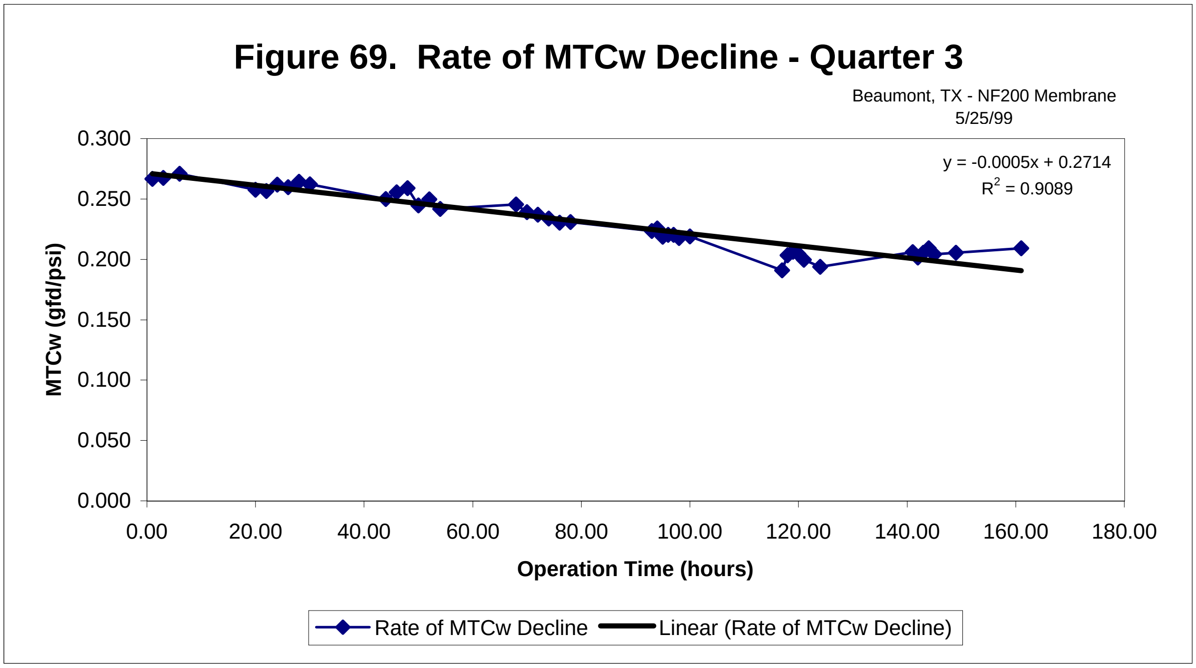


Figure 69. Rate of MTCw Decline - Quarter 3
Beaumont, TX - NF200 Membrane
5/25/99
y = -0.0005x + 0.2714
R2 = 0.9089
MTCw (gfd/psi)
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
Operation Time (hours)
Rate of MTCw Decline
Linear (Rate of MTCw Decline)

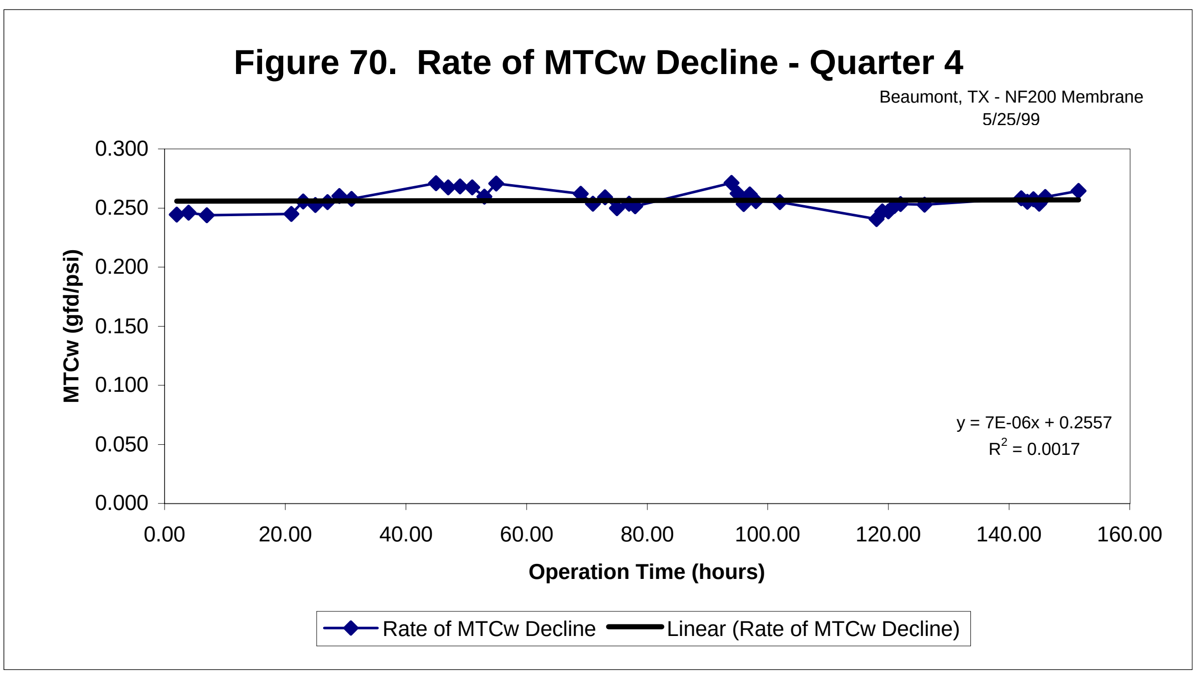


Figure 70. Rate of MTCw Decline - Quarter 4
Beaumont, TX - NF200 Membrane
5/25/99
y = 7E-06x + 0.2557
R2 = 0.0017
MTCw (gfd/psi)
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Operation Time (hours)
Rate of MTCw Decline
Linear (Rate of MTCw Decline)

Figure 71. Pressure - Quarter 1

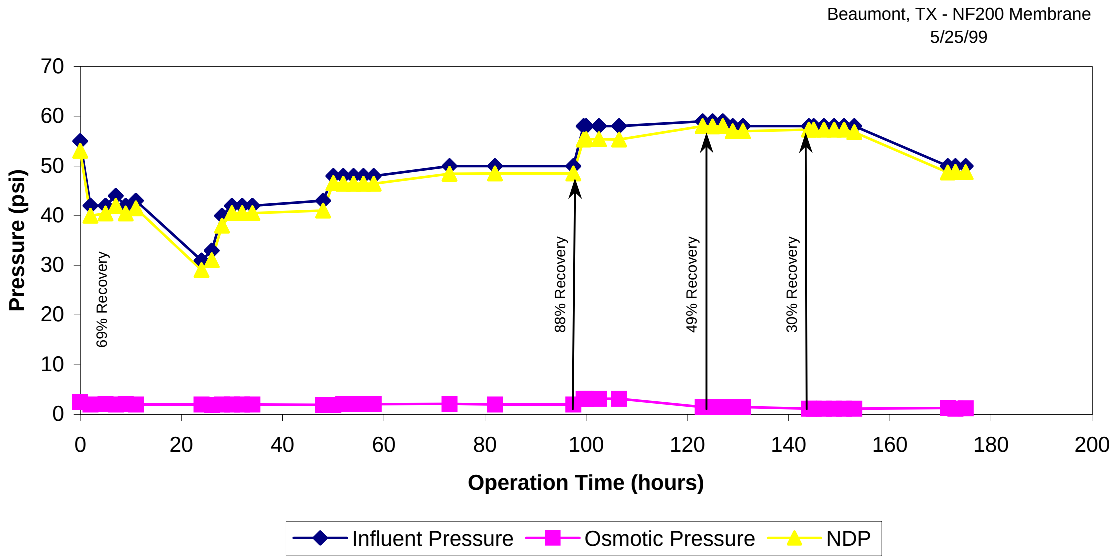
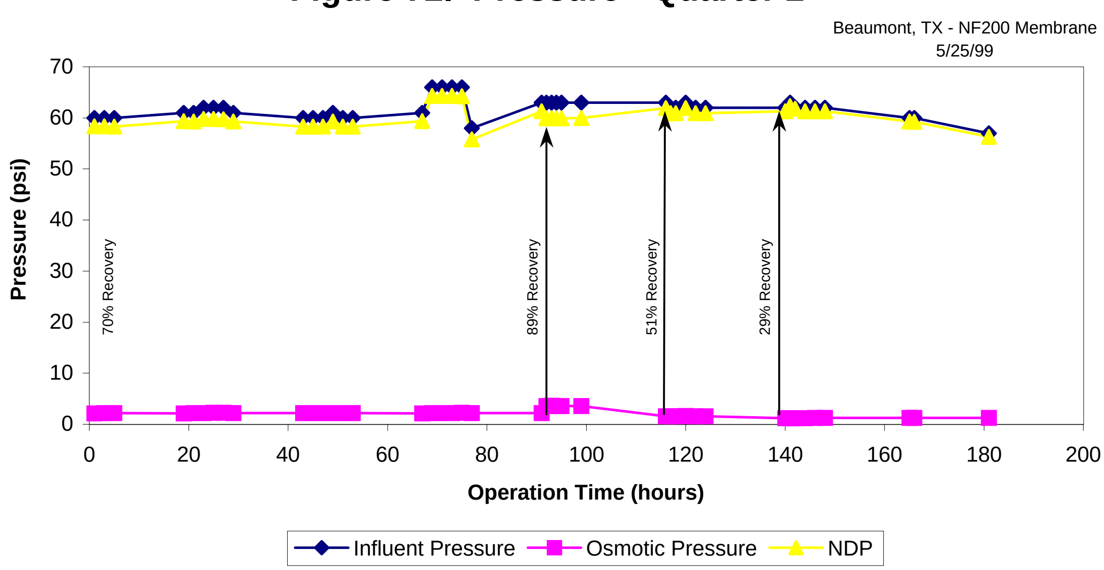


Figure 72. Pressure - Quarter 2



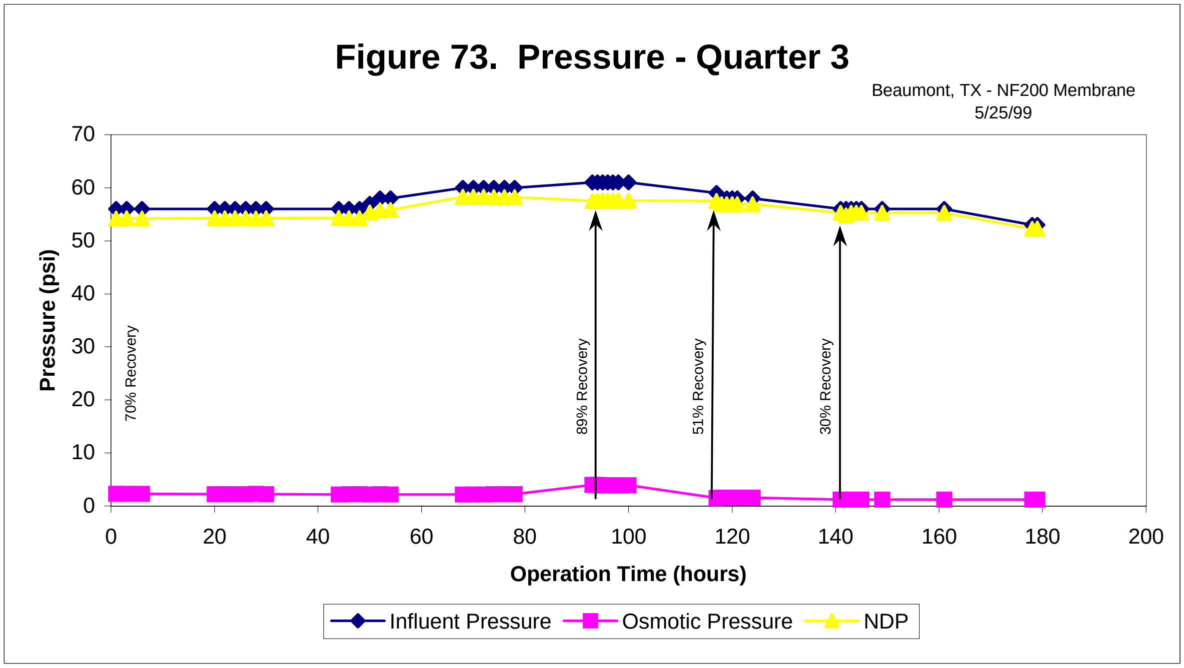


Figure 73. Pressure - Quarter 3
Beaumont, TX - NF200 Membrane
5/25/99
Pressure (psi)
70% Recovery
89% Recovery
51% Recovery
30% Recovery
Operation Time (hours)
Influent Pressure
Osmotic Pressure
NDP

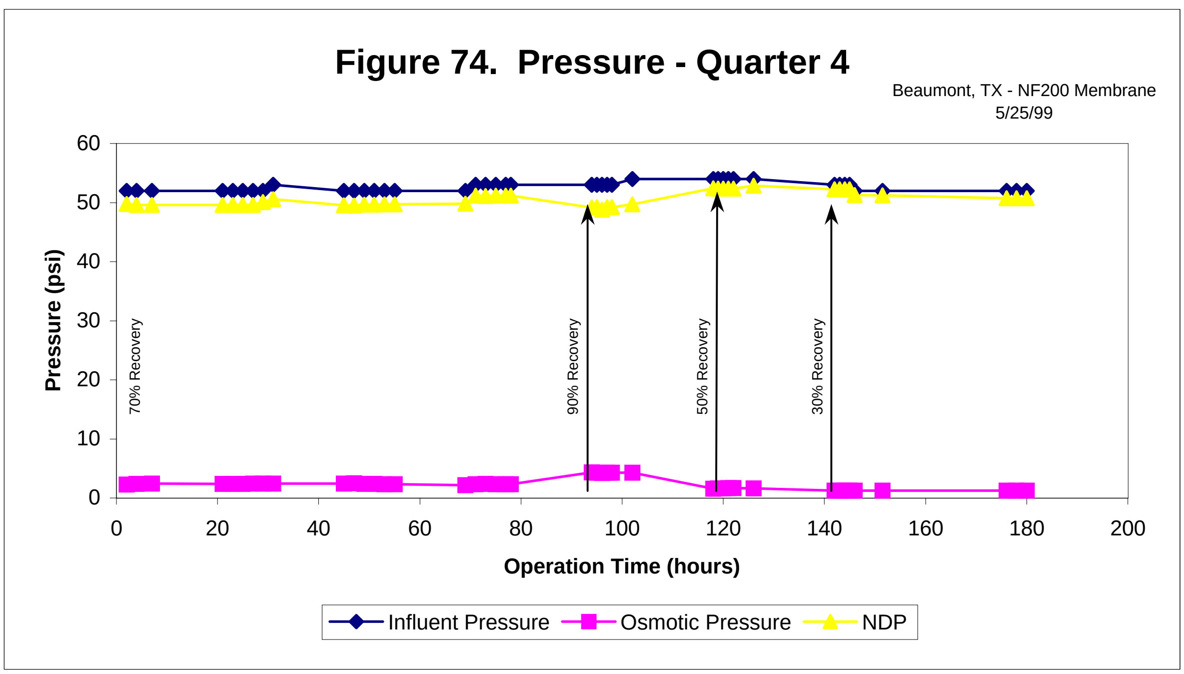


Figure 74. Pressure - Quarter 4
Beaumont, TX - NF200 Membrane
5/25/99
Pressure (psi)
70% Recovery
90% Recovery
50% Recovery
30% Recovery
Operation Time (hours)
Influent Pressure
Osmotic Pressure
NDP

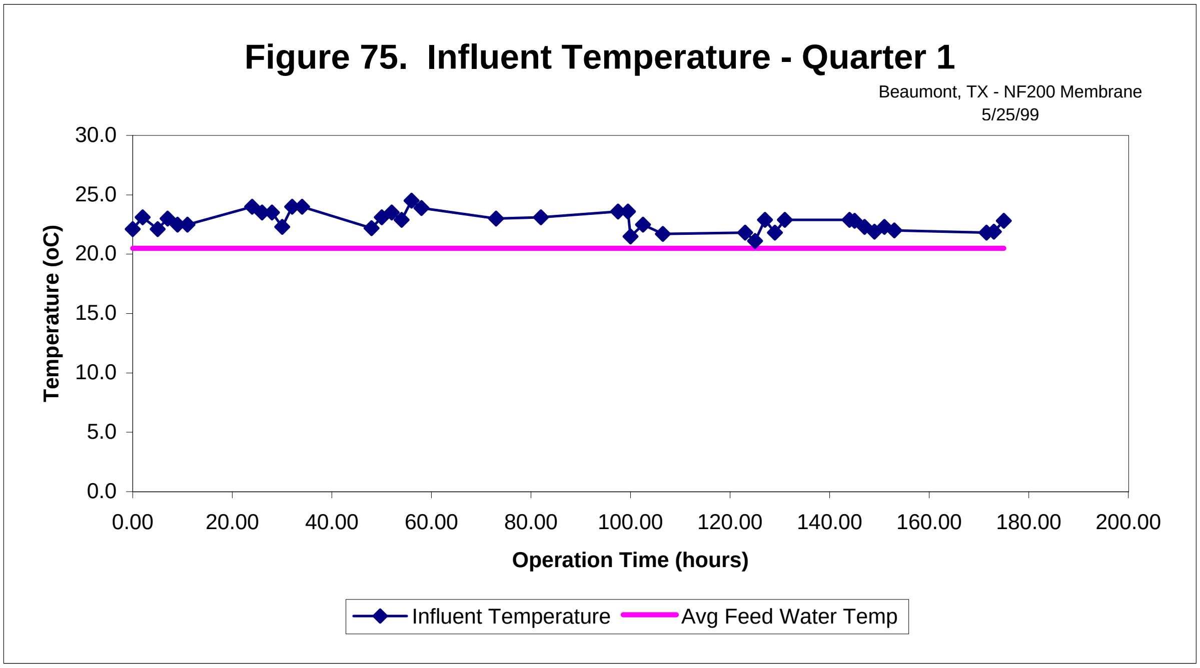


Figure 75. Influent Temperature - Quarter 1
Beaumont, TX - NF200 Membrane
5/25/99
Temperature (oC)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Influent Temperature
Avg Feed Water Temp

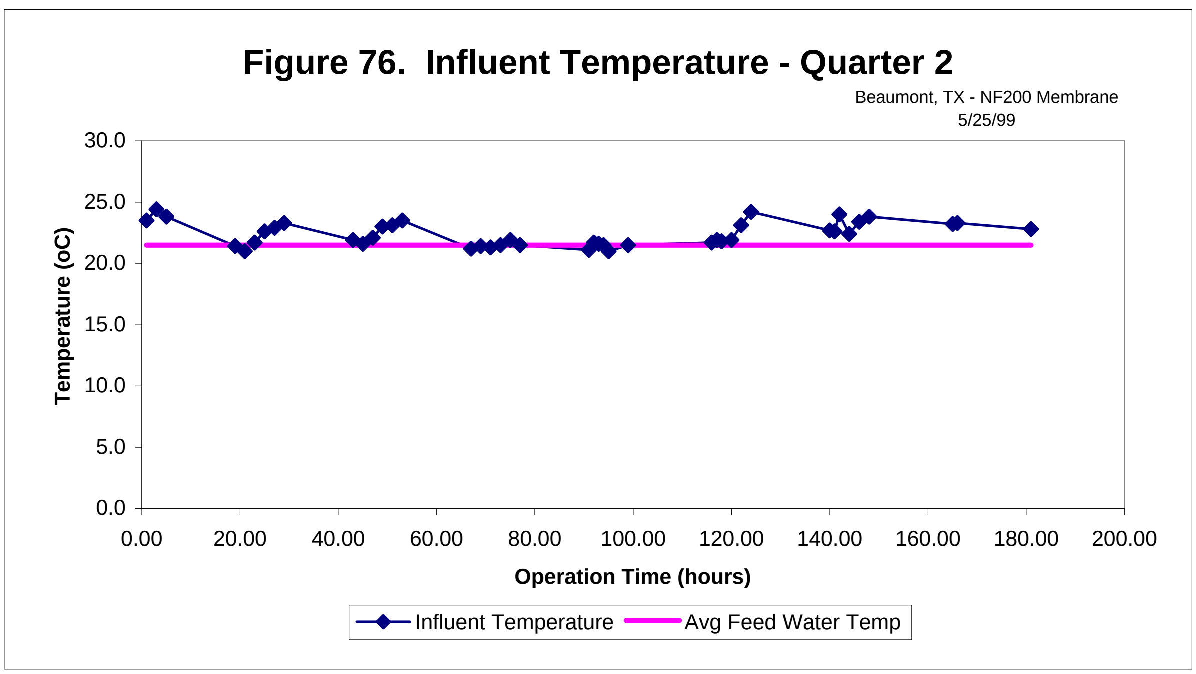


Figure 76. Influent Temperature - Quarter 2
Beaumont, TX - NF200 Membrane
5/25/99
Temperature (oC)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Influent Temperature
Avg Feed Water Temp

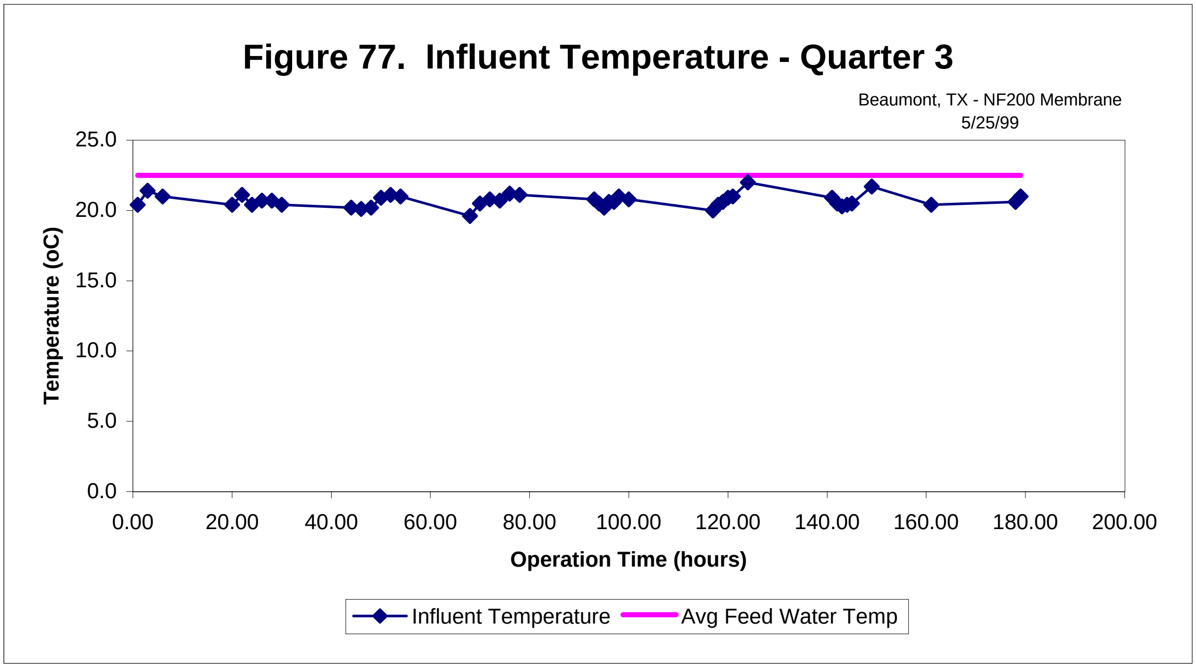


Figure 77. Influent Temperature - Quarter 3
Beaumont, TX - NF200 Membrane
5/25/99
25.0
20.0
15.0
10.0
5.0
0.0
Temperature (oC)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Influent Temperature
Avg Feed Water Temp

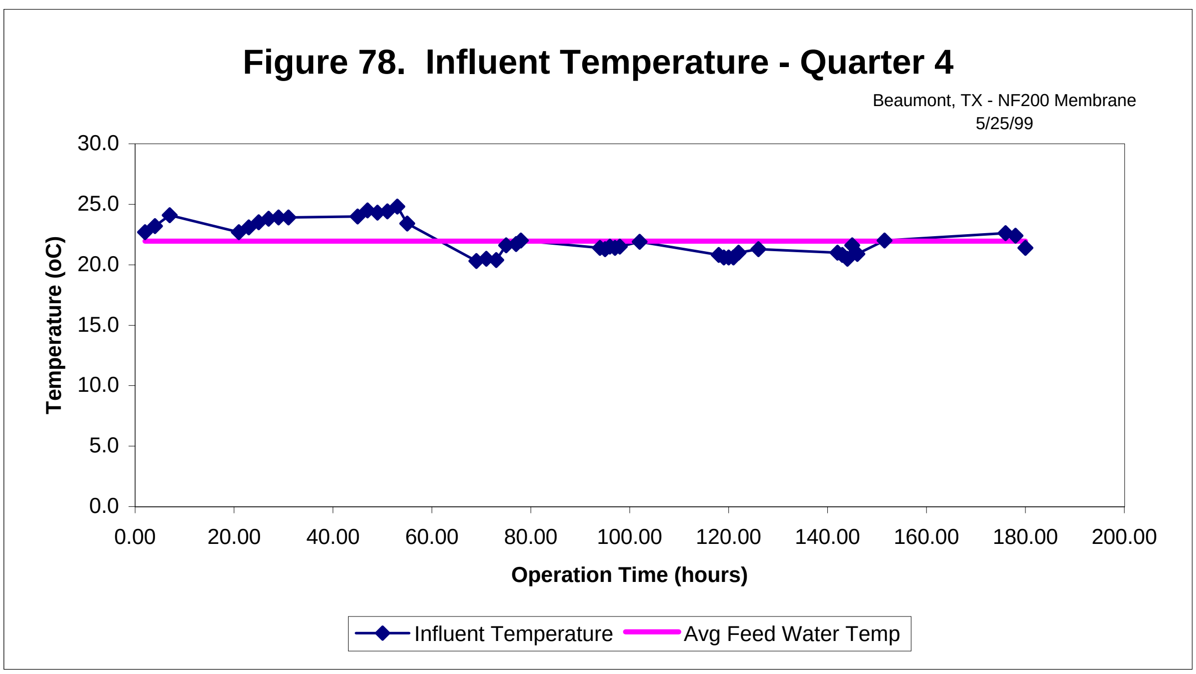


Figure 78. Influent Temperature - Quarter 4
Beaumont, TX - NF200 Membrane
5/25/99
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Temperature (oC)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Influent Temperature
Avg Feed Water Temp

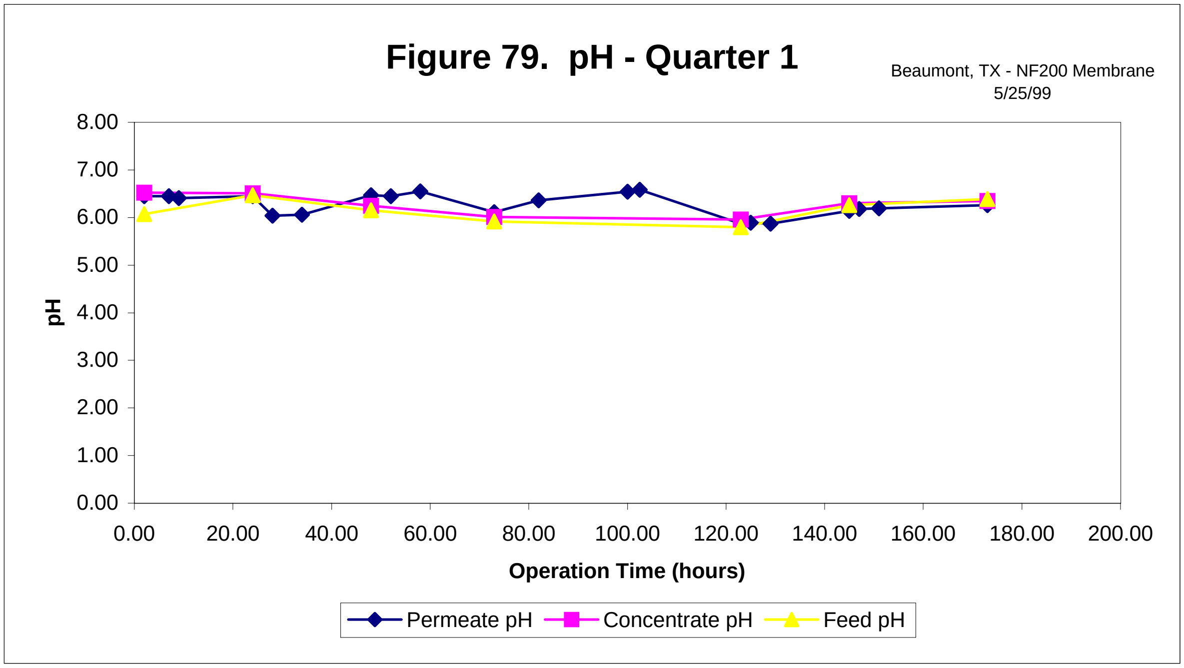


Figure 79. pH - Quarter 1
Beaumont, TX - NF200 Membrane
5/25/99
pH
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Permeate pH
Concentrate pH
Feed pH

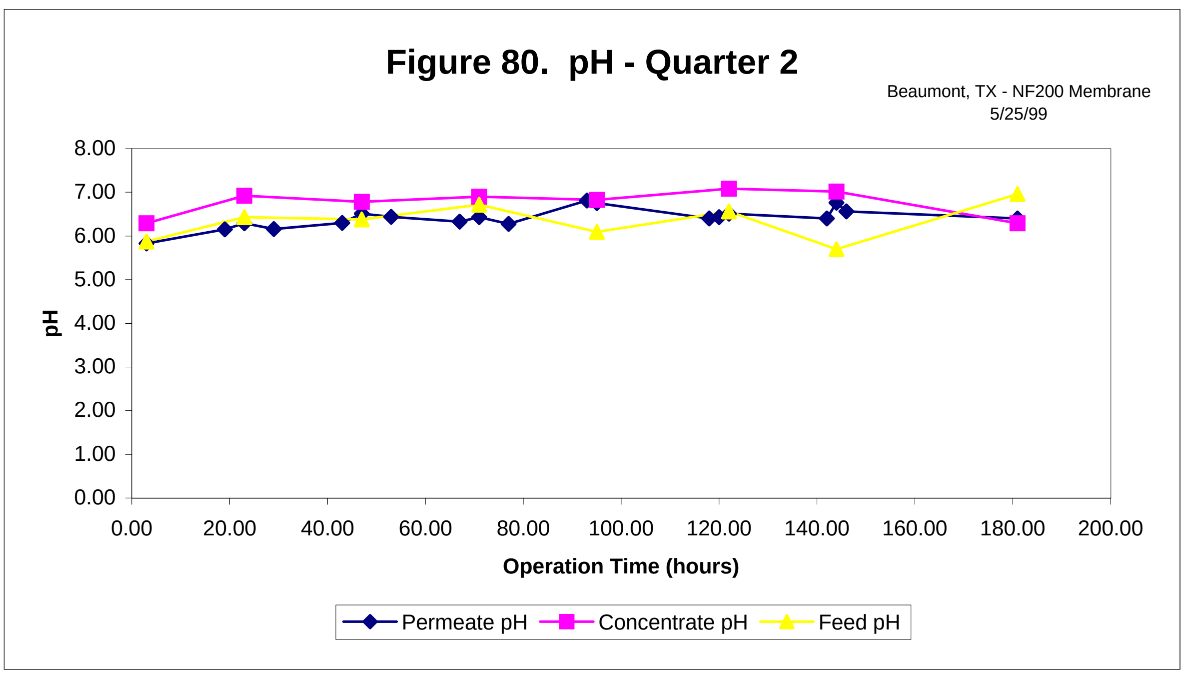


Figure 80. pH - Quarter 2
Beaumont, TX - NF200 Membrane
5/25/99
pH
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Permeate pH
Concentrate pH
Feed pH

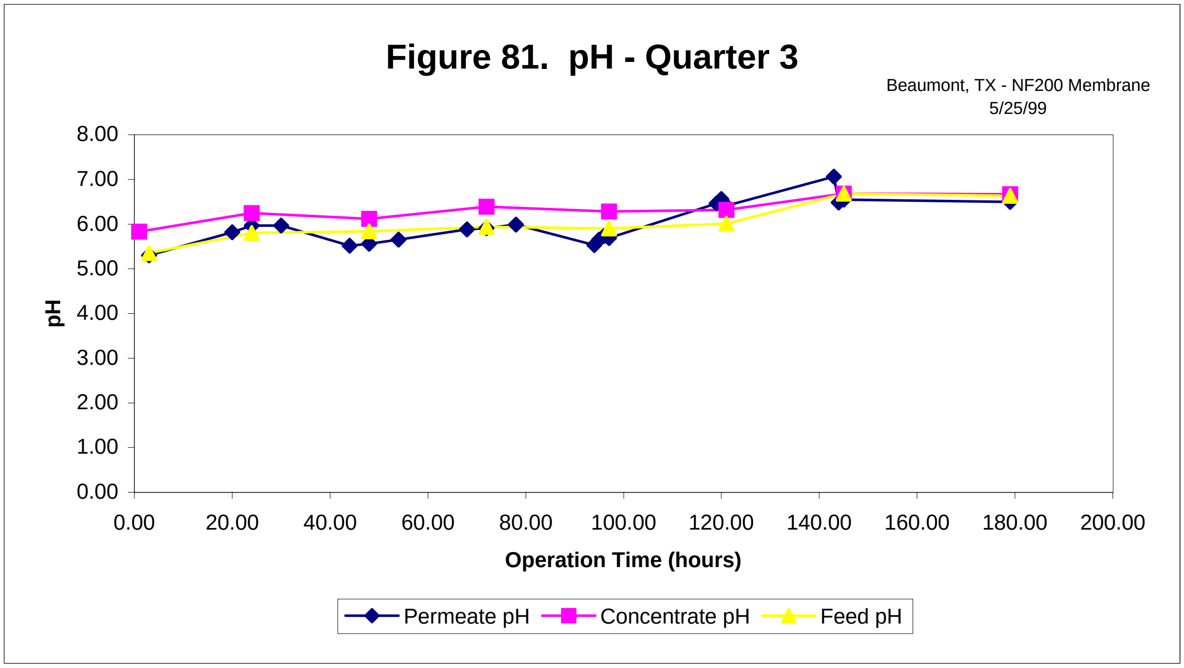


Figure 81. pH - Quarter 3
Beaumont, TX - NF200 Membrane
5/25/99
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
pH
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Permeate pH
Concentrate pH
Feed pH

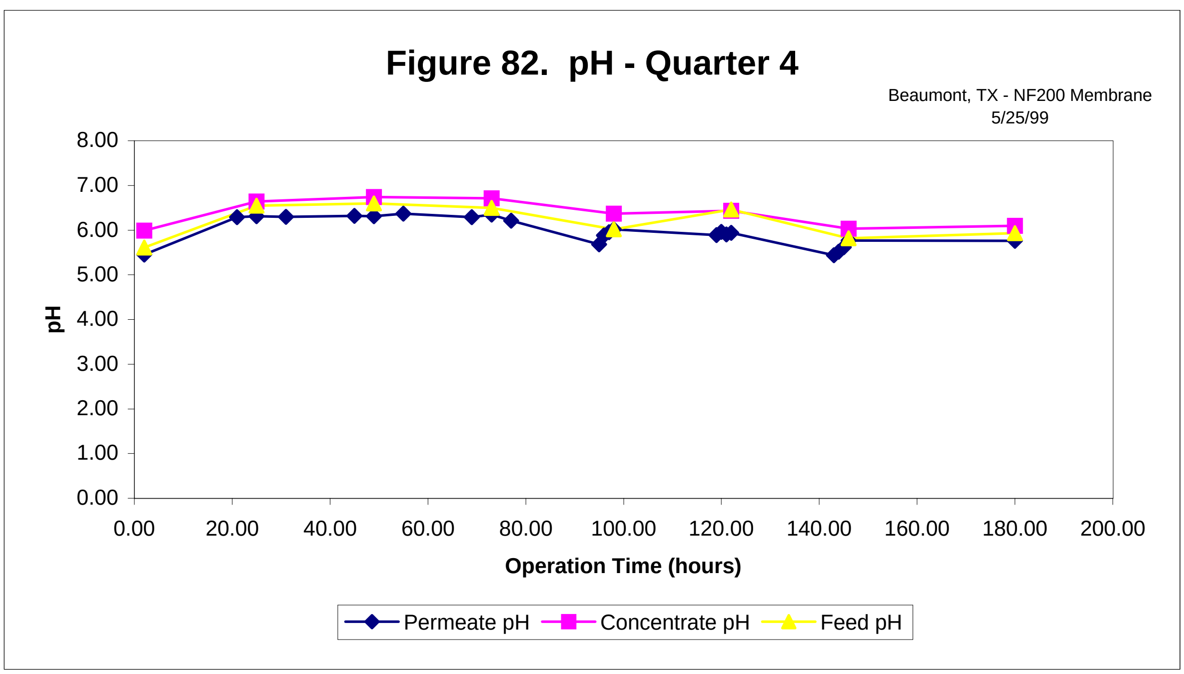


Figure 82. pH - Quarter 4
Beaumont, TX - NF200 Membrane
5/25/99
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
pH
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Permeate pH
Concentrate pH
Feed pH

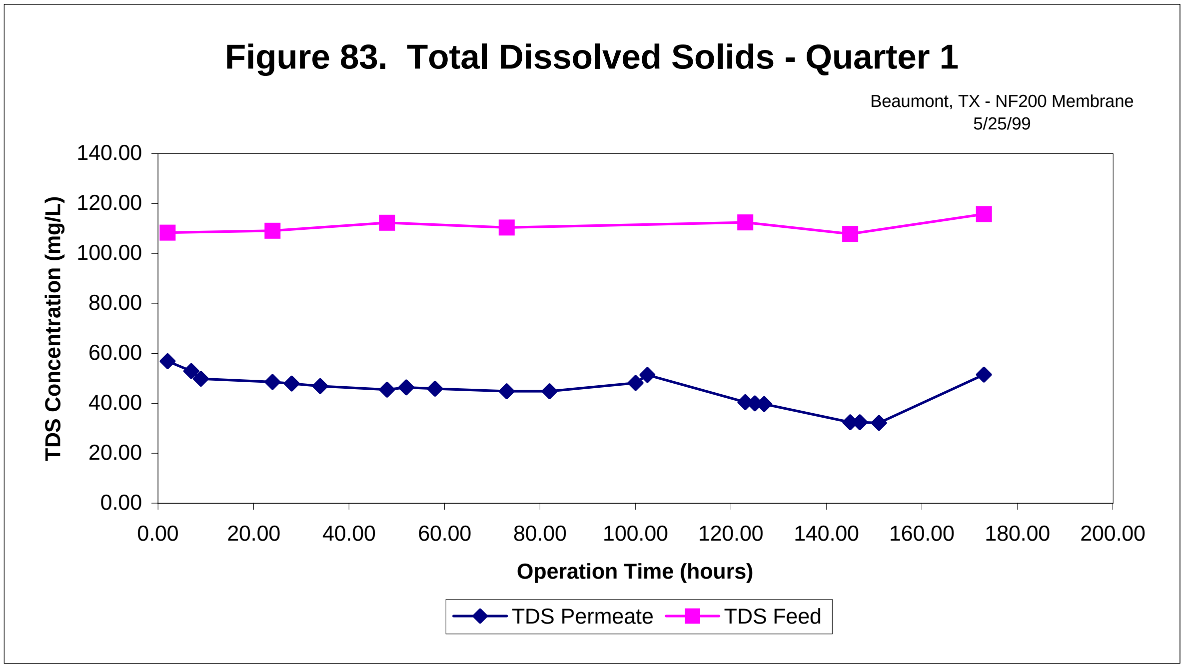


Figure 83. Total Dissolved Solids - Quarter 1
Beaumont, TX - NF200 Membrane
5/25/99
TDS Concentration (mg/L)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
TDS Permeate
TDS Feed

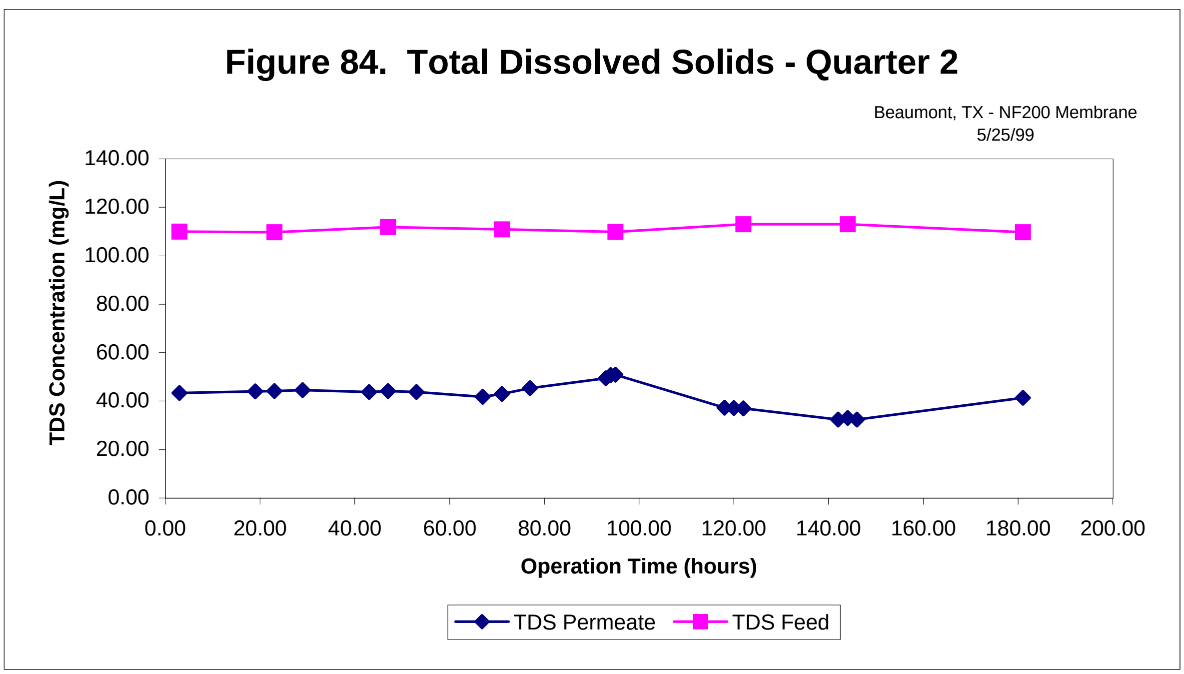


Figure 84. Total Dissolved Solids - Quarter 2
Beaumont, TX - NF200 Membrane
5/25/99
TDS Concentration (mg/L)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
TDS Permeate
TDS Feed

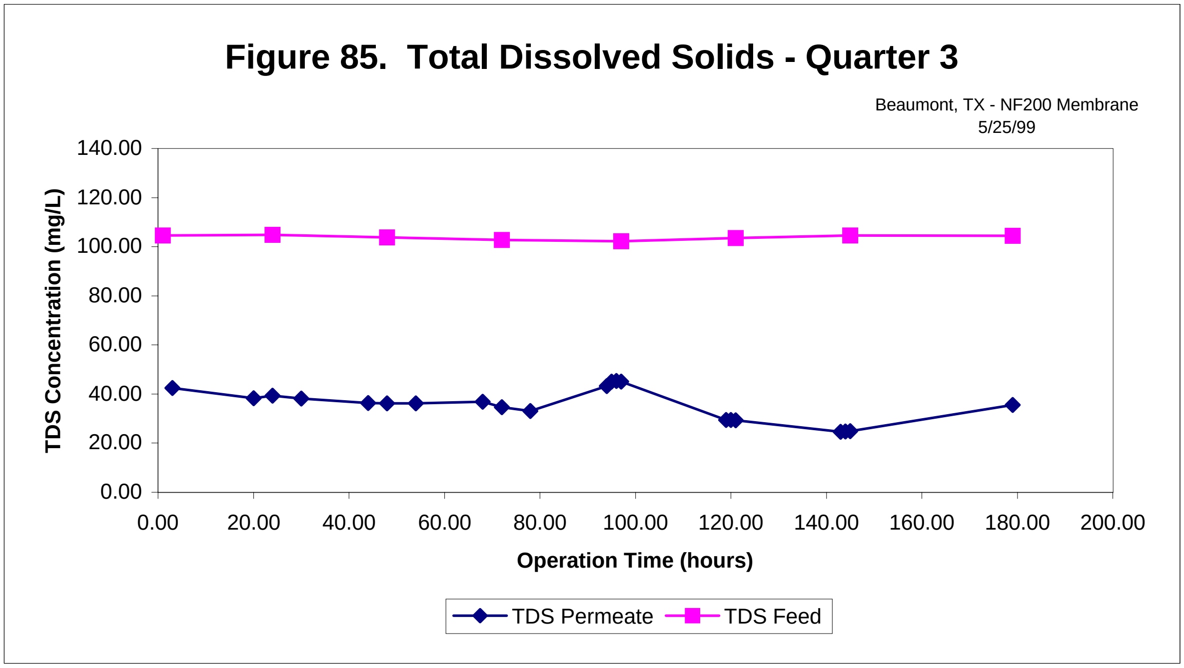


Figure 85. Total Dissolved Solids - Quarter 3
Beaumont, TX - NF200 Membrane
5/25/99
TDS Concentration (mg/L)
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
TDS Permeate
TDS Feed

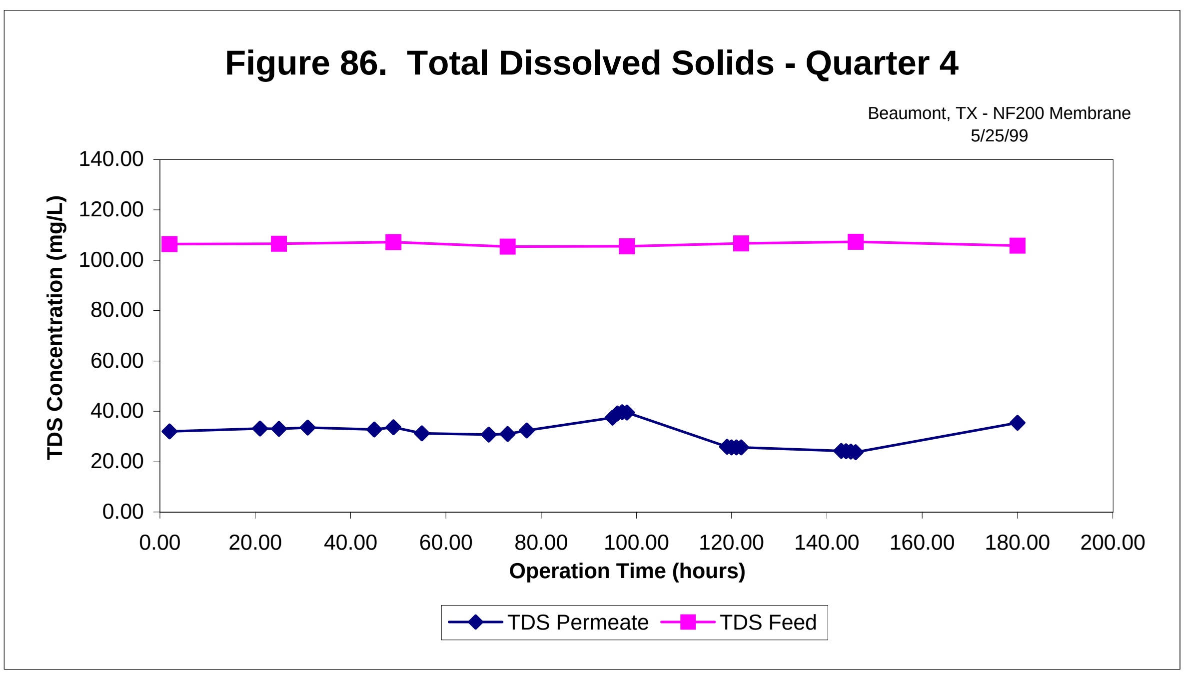


Figure 86. Total Dissolved Solids - Quarter 4
Beaumont, TX - NF200 Membrane
5/25/99
TDS Concentration (mg/L)
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
TDS Permeate
TDS Feed

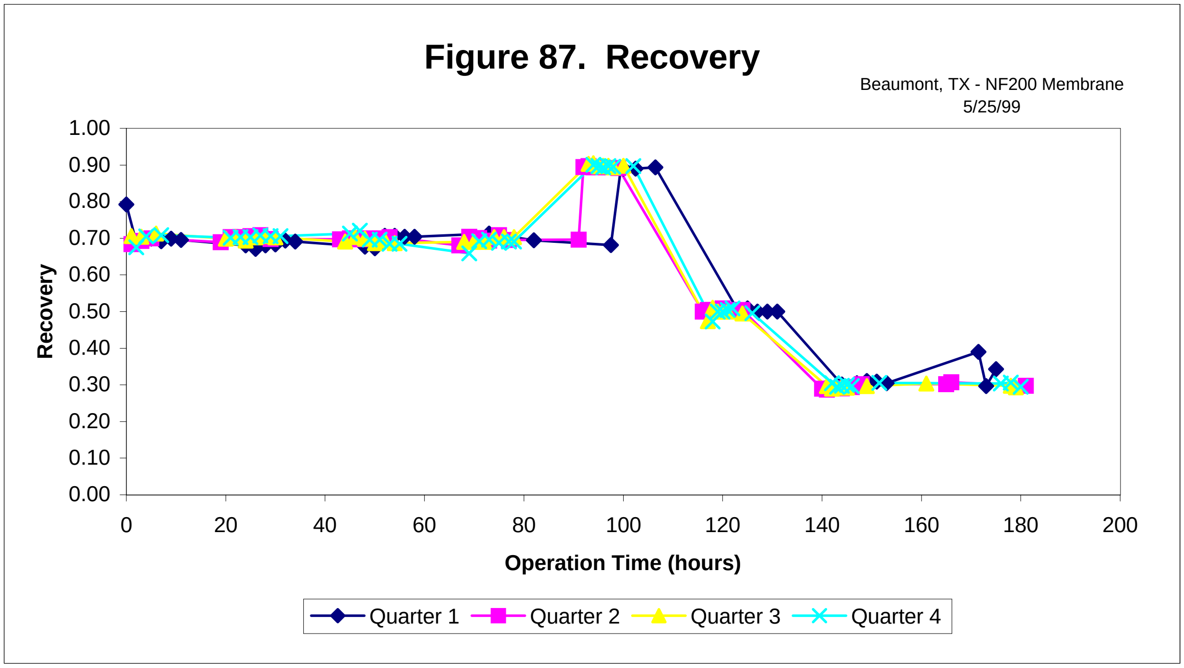


Figure 87. Recovery
Beaumont, TX - NF200 Membrane
5/25/99
Recovery
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
20
40
60
80
100
120
140
160
180
200
Operation Time (hours)
Quarter 1
Quarter 2
Quarter 3
Quarter 4

Figure 88. Permeate TOC

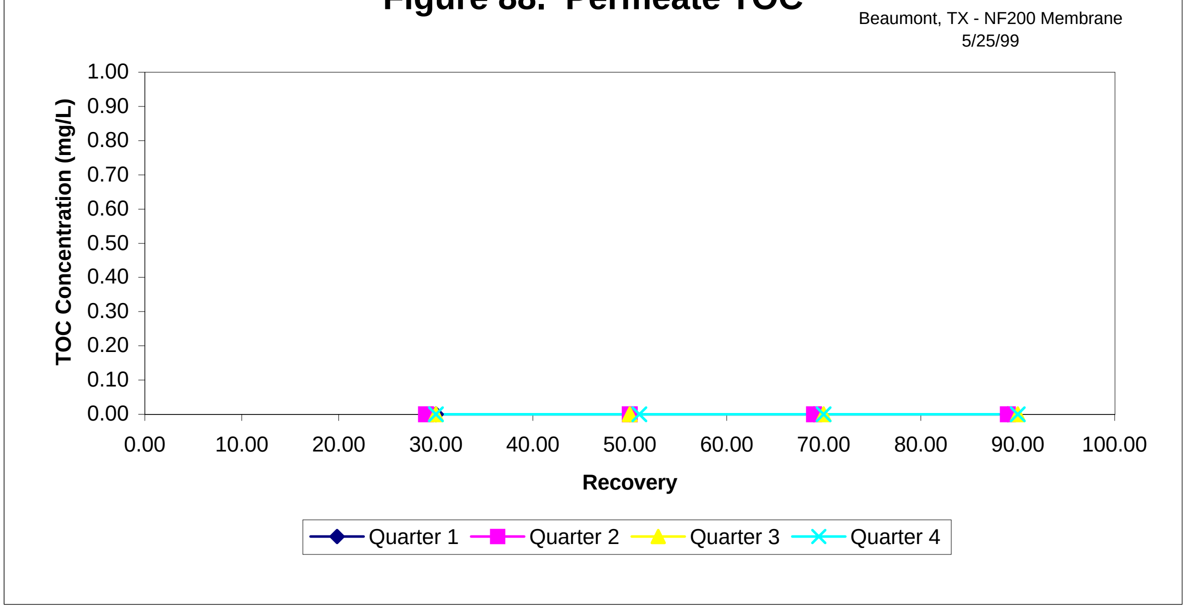
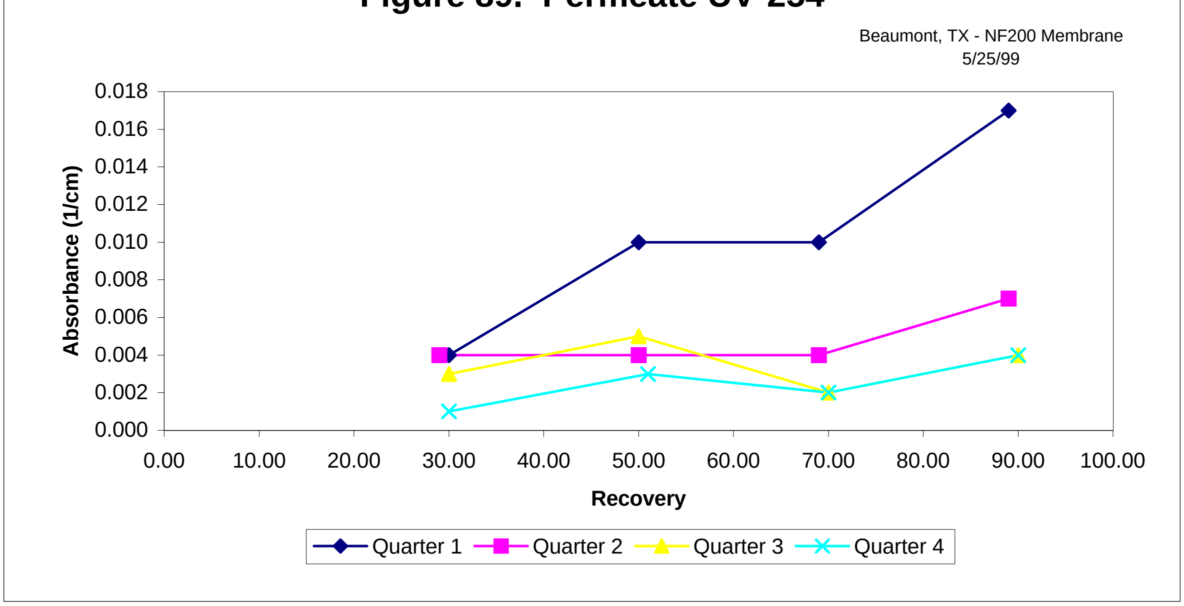


Figure 89. Permeate UV-254



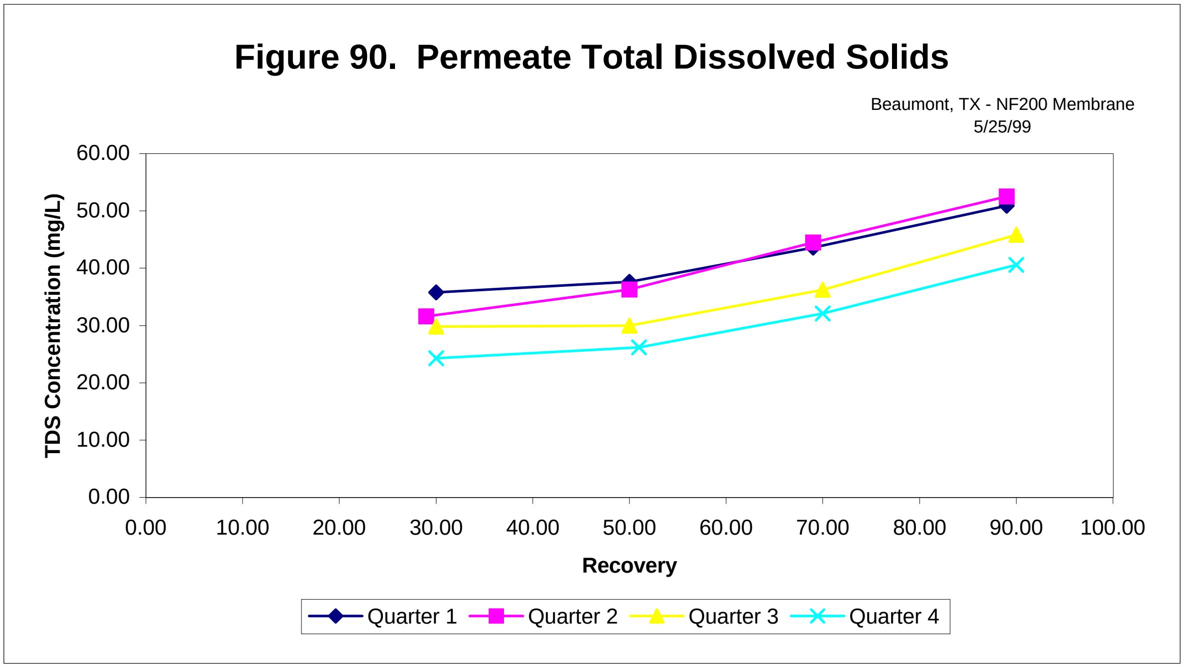


Figure 90. Permeate Total Dissolved Solids
Beaumont, TX - NF200 Membrane
5/25/99
TDS Concentration (mg/L)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Recovery
Quarter 1
Quarter 2
Quarter 3
Quarter 4

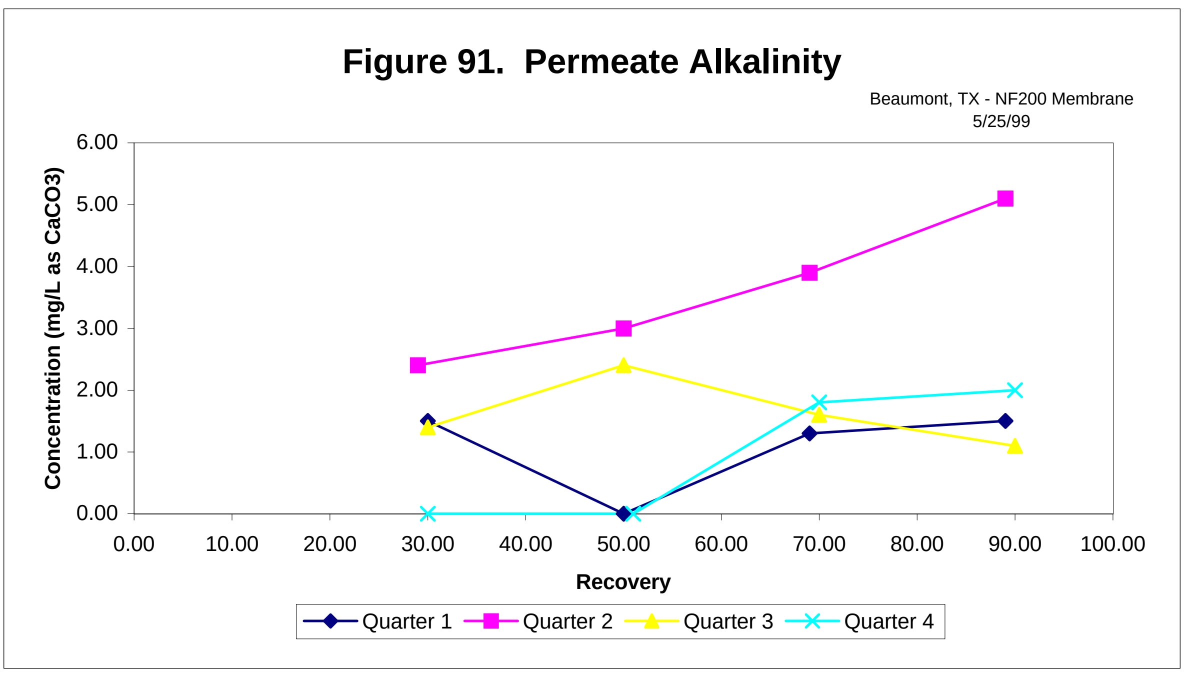


Figure 91. Permeate Alkalinity
Beaumont, TX - NF200 Membrane
5/25/99
Concentration (mg/L as CaCO3)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Recovery
Quarter 1
Quarter 2
Quarter 3
Quarter 4

Figure 92. Permeate Total Hardness

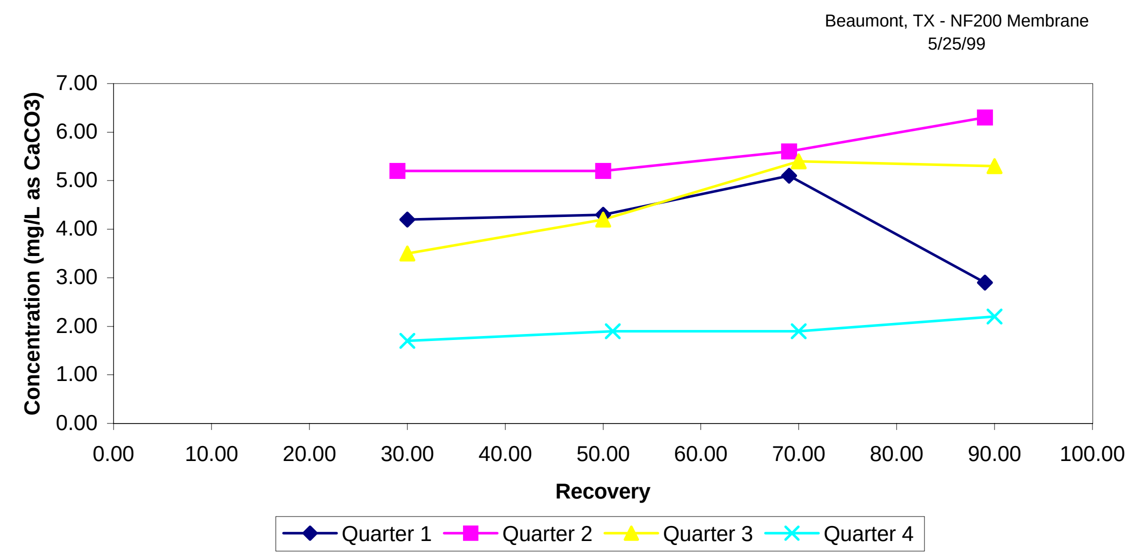


Figure 93. Permeate Bromide

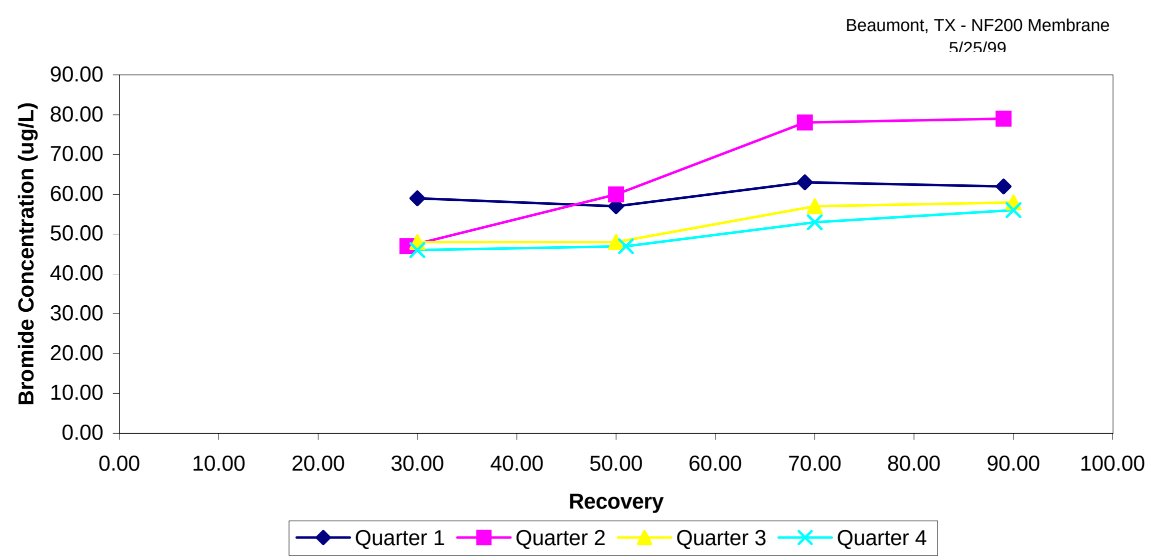
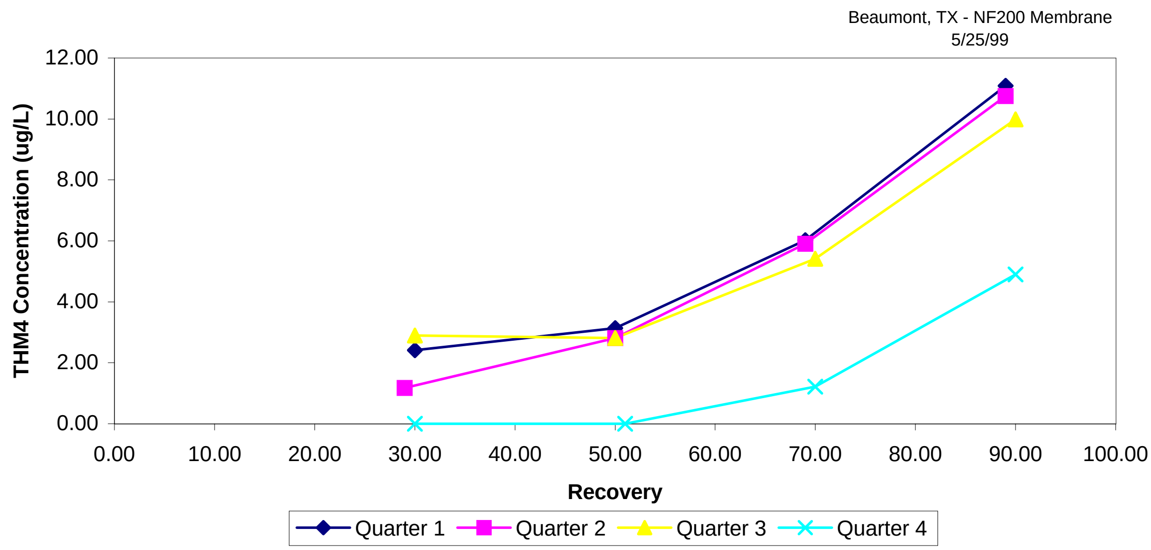


Figure 94. Permeate SDS-THM4



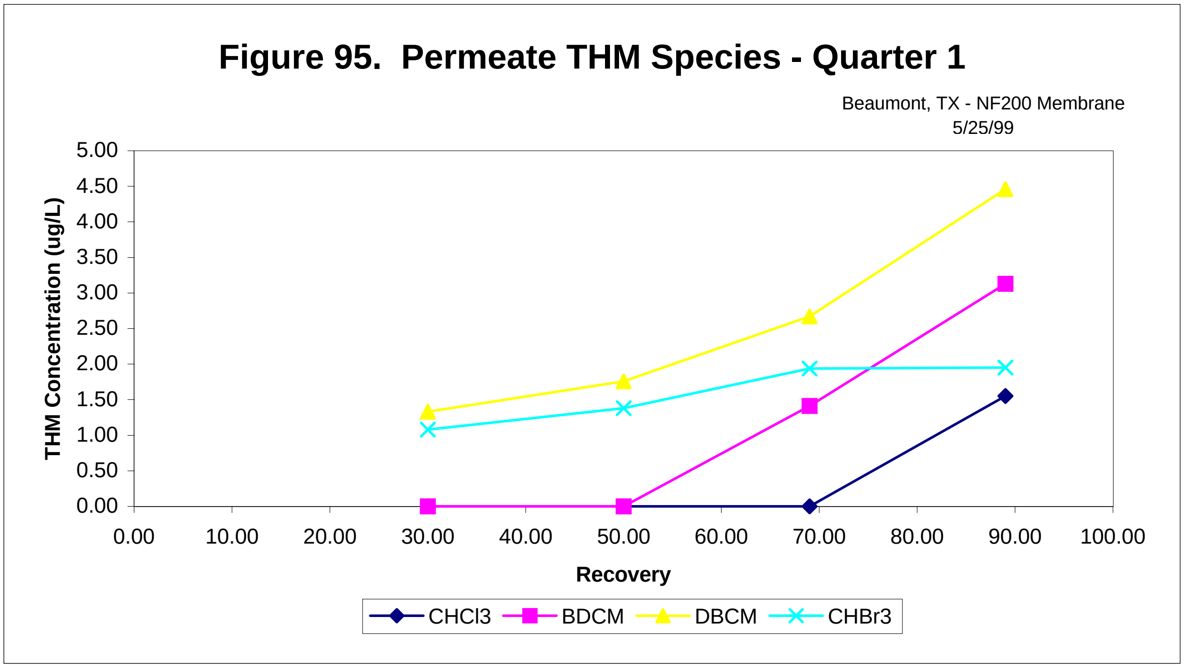


Figure 95. Permeate THM Species - Quarter 1
Beaumont, TX - NF200 Membrane
5/25/99
THM Concentration (ug/L)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Recovery
CHCl3
BDCM
DBCM
CHBr3

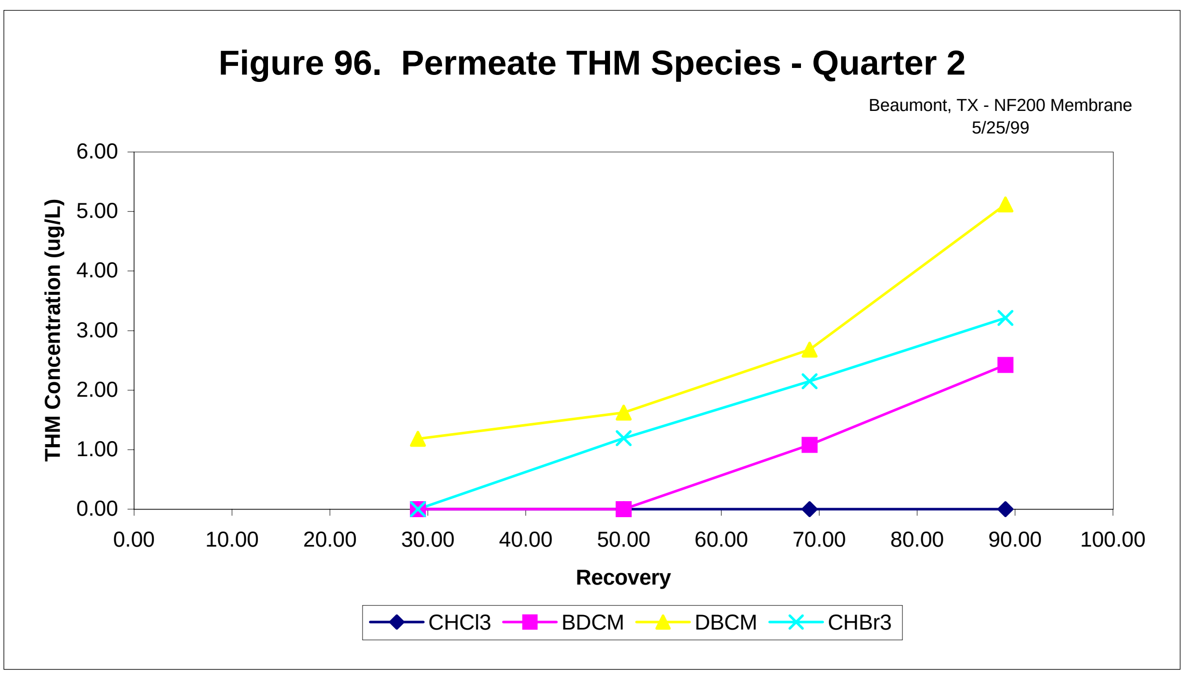


Figure 96. Permeate THM Species - Quarter 2
Beaumont, TX - NF200 Membrane
5/25/99
THM Concentration (ug/L)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Recovery
CHCl3
BDCM
DBCM
CHBr3

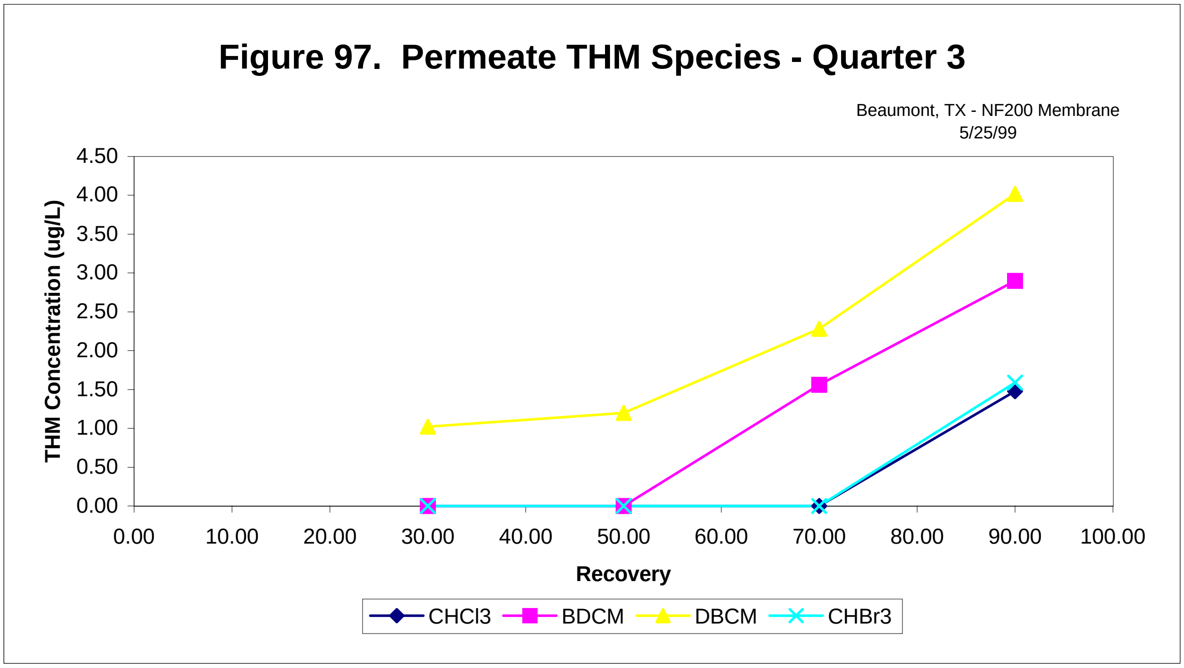


Figure 97. Permeate THM Species - Quarter 3
Beaumont, TX - NF200 Membrane
5/25/99
THM Concentration (ug/L)
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Recovery
CHCl3
BDCM
DBCM
CHBr3

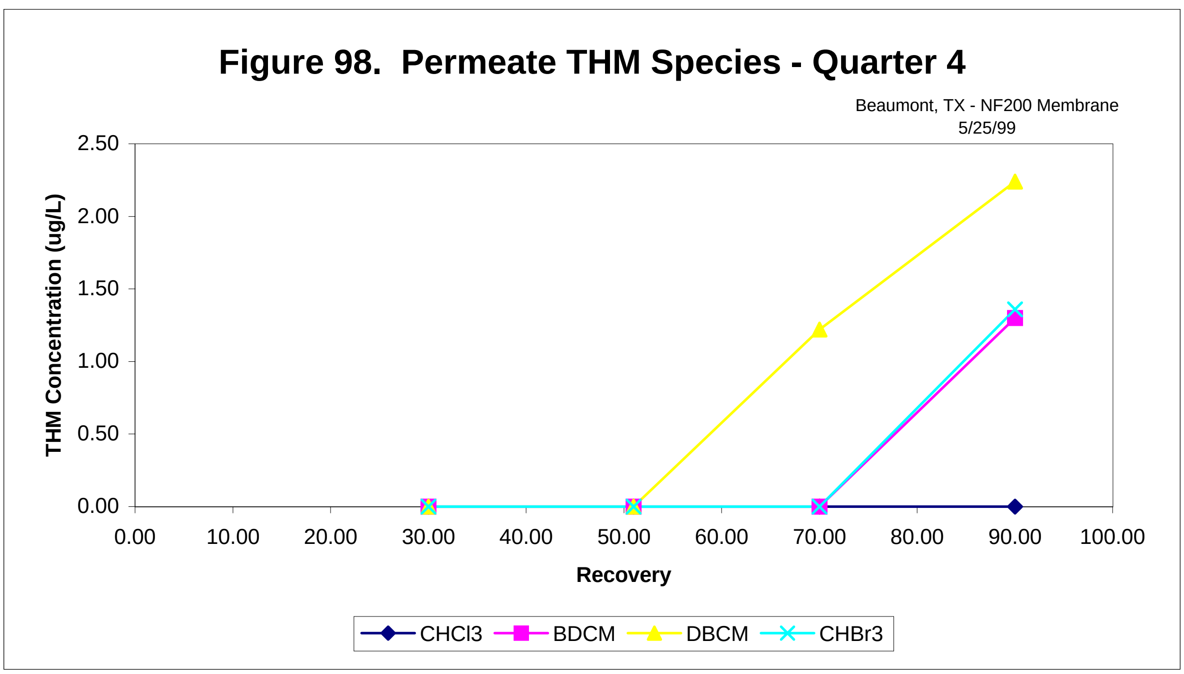


Figure 98. Permeate THM Species - Quarter 4
Beaumont, TX - NF200 Membrane
5/25/99
THM Concentration (ug/L)
2.50
2.00
1.50
1.00
0.50
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Recovery
CHCl3
BDCM
DBCM
CHBr3

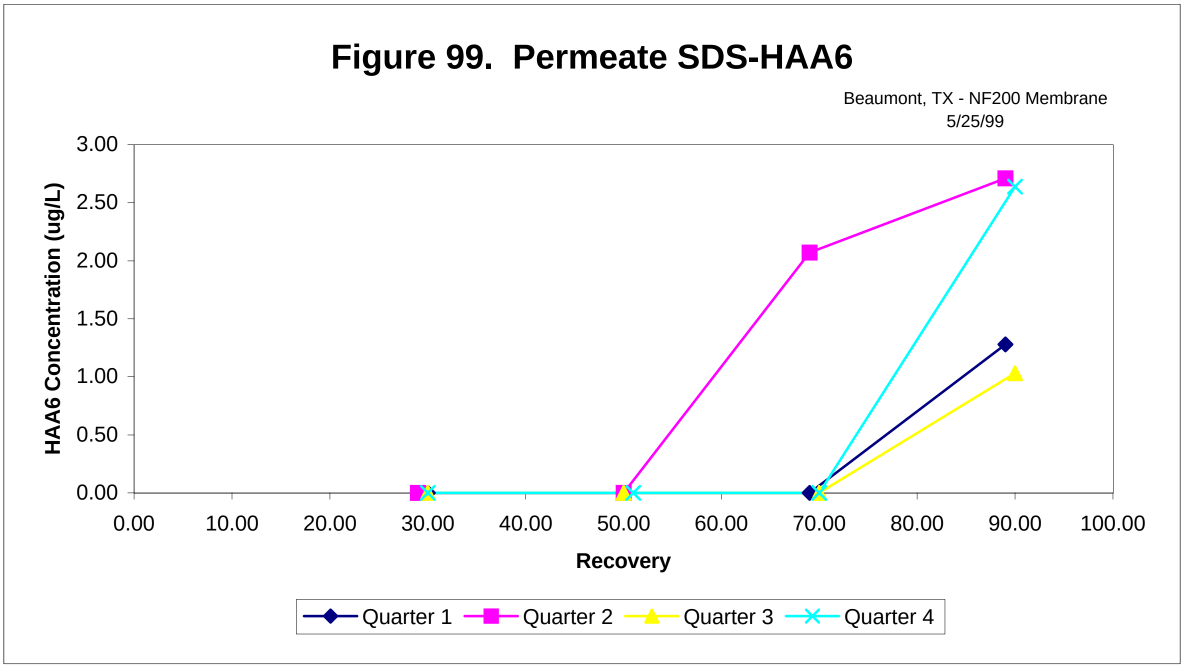


Figure 99. Permeate SDS-HAA6
Beaumont, TX - NF200 Membrane
5/25/99
HAA6 Concentration (ug/L)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Recovery
Quarter 1
Quarter 2
Quarter 3
Quarter 4

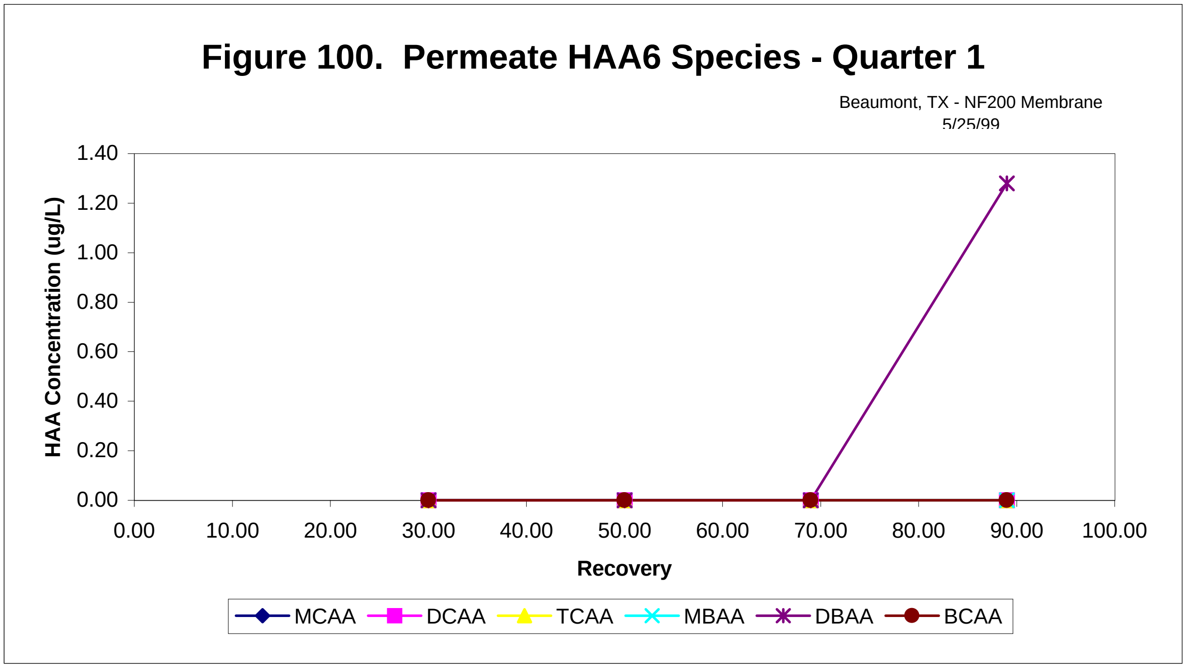


Figure 100. Permeate HAA6 Species - Quarter 1
Beaumont, TX - NF200 Membrane
5/25/99
HAA Concentration (ug/L)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Recovery
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

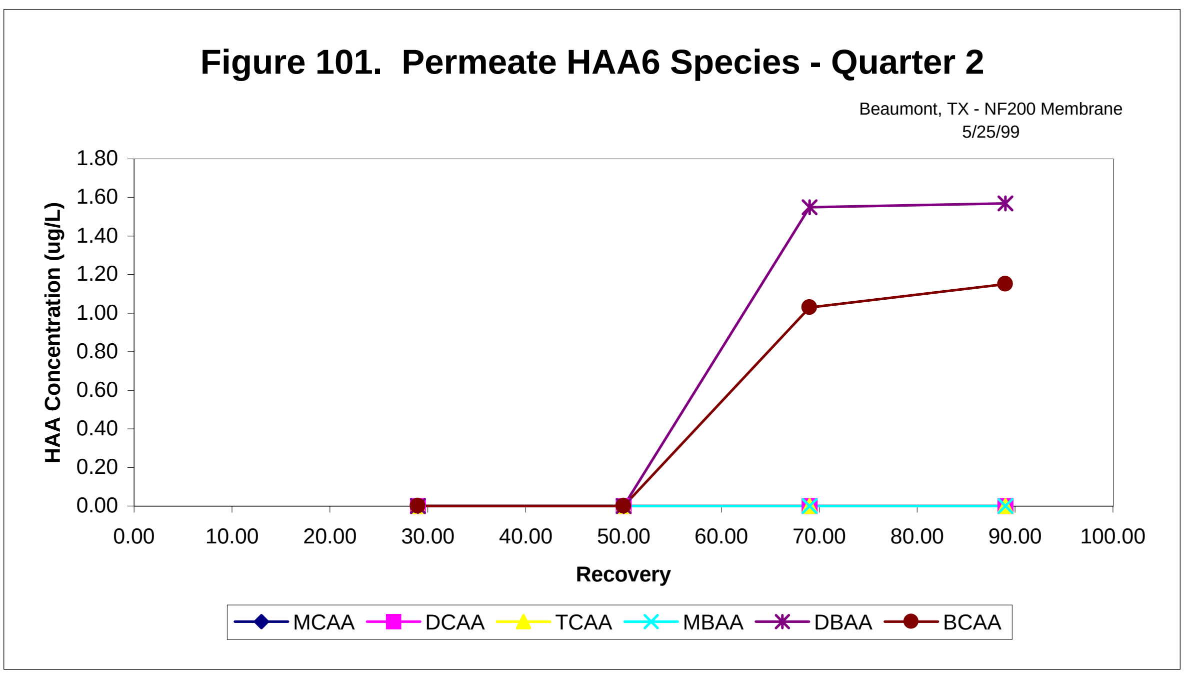


Figure 101. Permeate HAA6 Species - Quarter 2
Beaumont, TX - NF200 Membrane
5/25/99
HAA Concentration (ug/L)
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Recovery
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

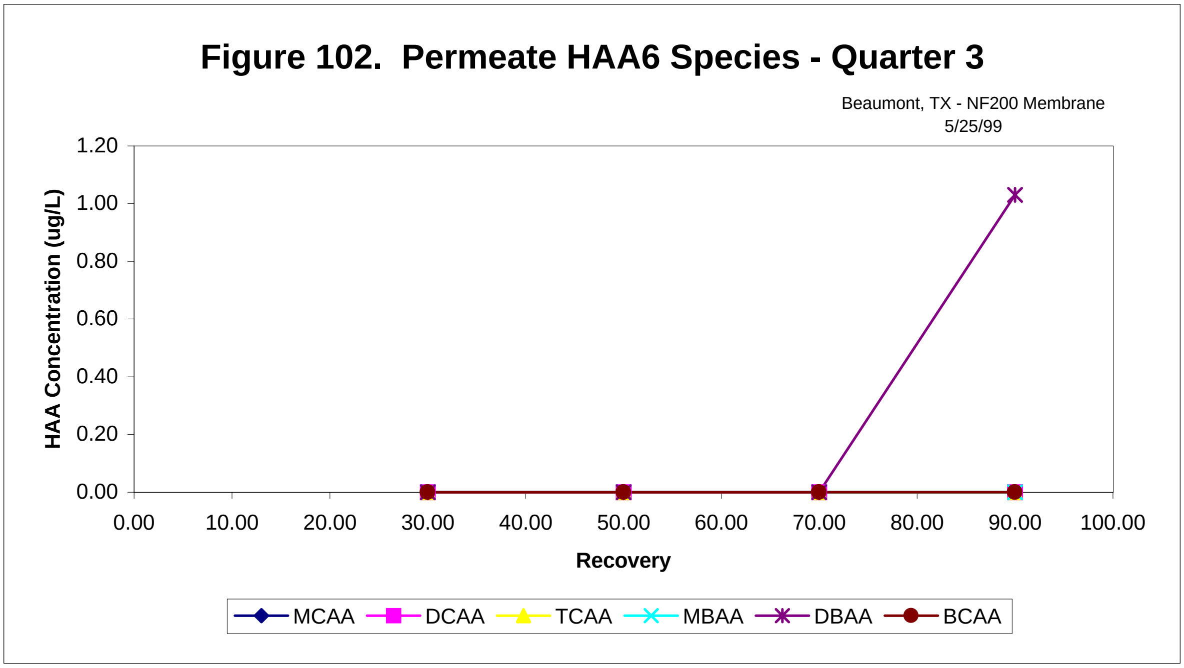


Figure 102. Permeate HAA6 Species - Quarter 3
Beaumont, TX - NF200 Membrane
5/25/99
HAA Concentration (ug/L)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Recovery
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

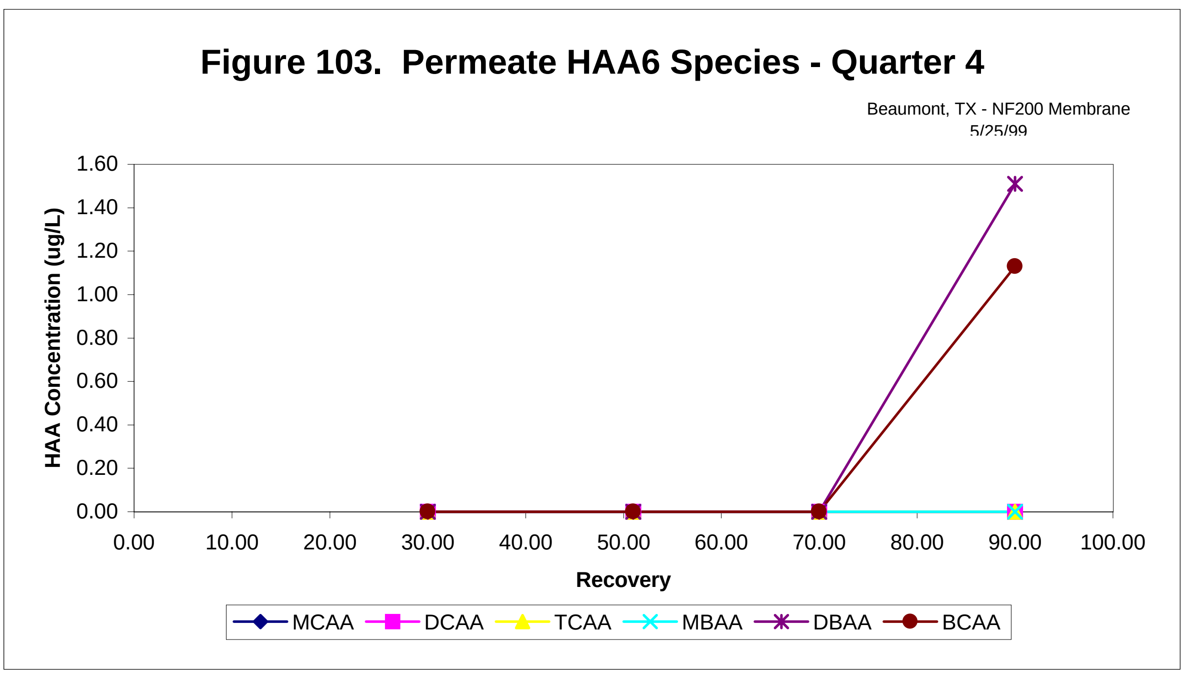


Figure 103. Permeate HAA6 Species - Quarter 4
Beaumont, TX - NF200 Membrane
5/25/99
HAA Concentration (ug/L)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Recovery
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

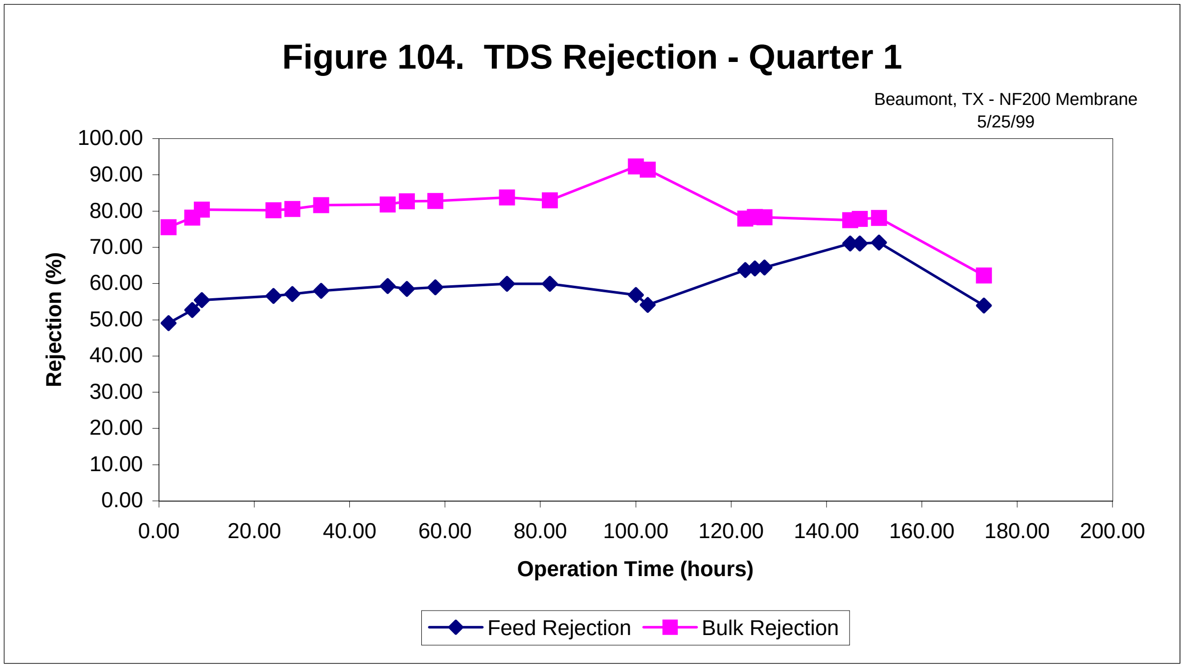


Figure 104. TDS Rejection - Quarter 1
Beaumont, TX - NF200 Membrane
5/25/99
Rejection (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Feed Rejection
Bulk Rejection

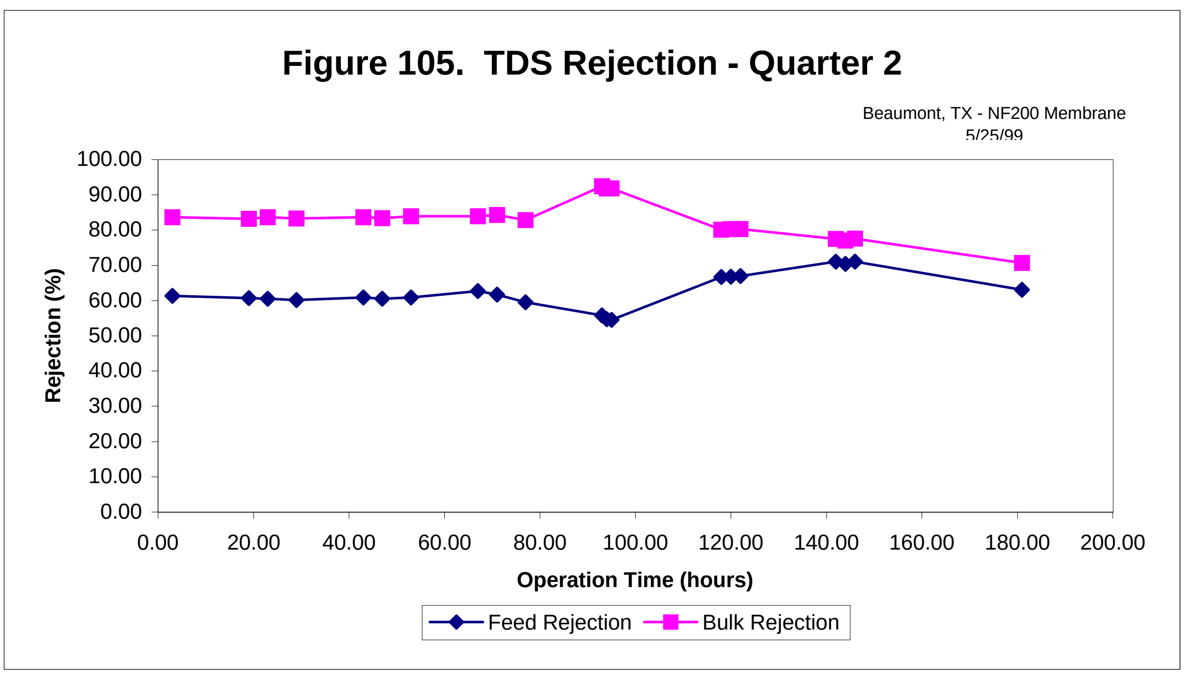


Figure 105. TDS Rejection - Quarter 2
Beaumont, TX - NF200 Membrane
5/25/99
Rejection (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Feed Rejection
Bulk Rejection

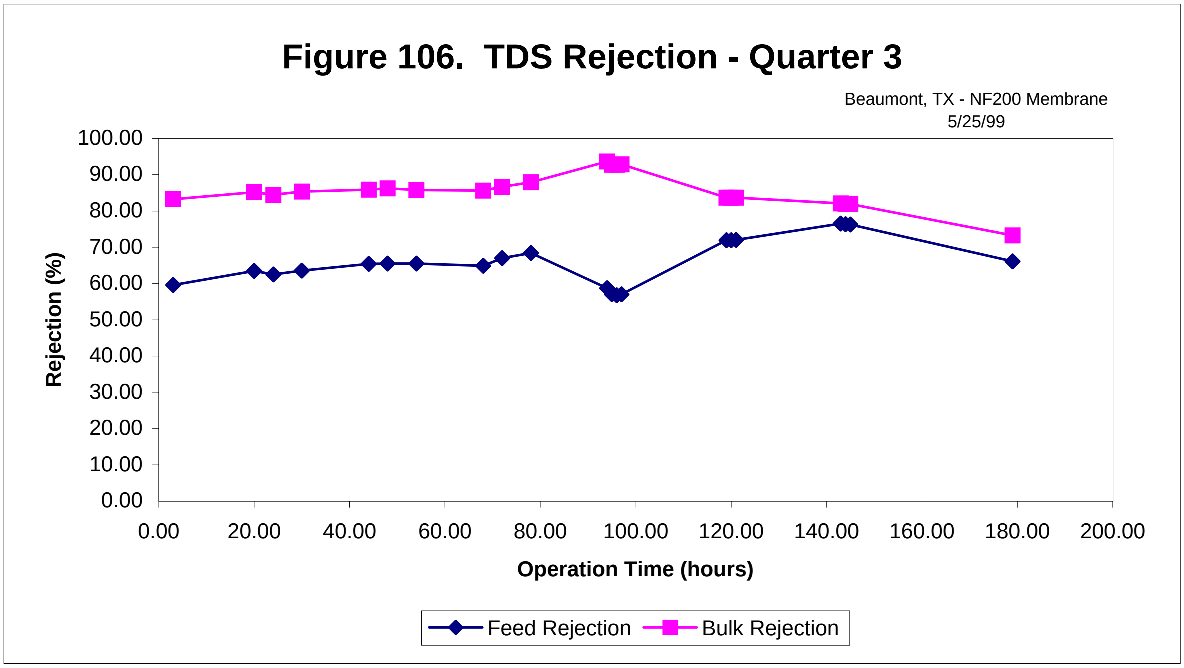


Figure 106. TDS Rejection - Quarter 3
Beaumont, TX - NF200 Membrane
5/25/99
Rejection (%)
Operation Time (hours)
Feed Rejection
Bulk Rejection

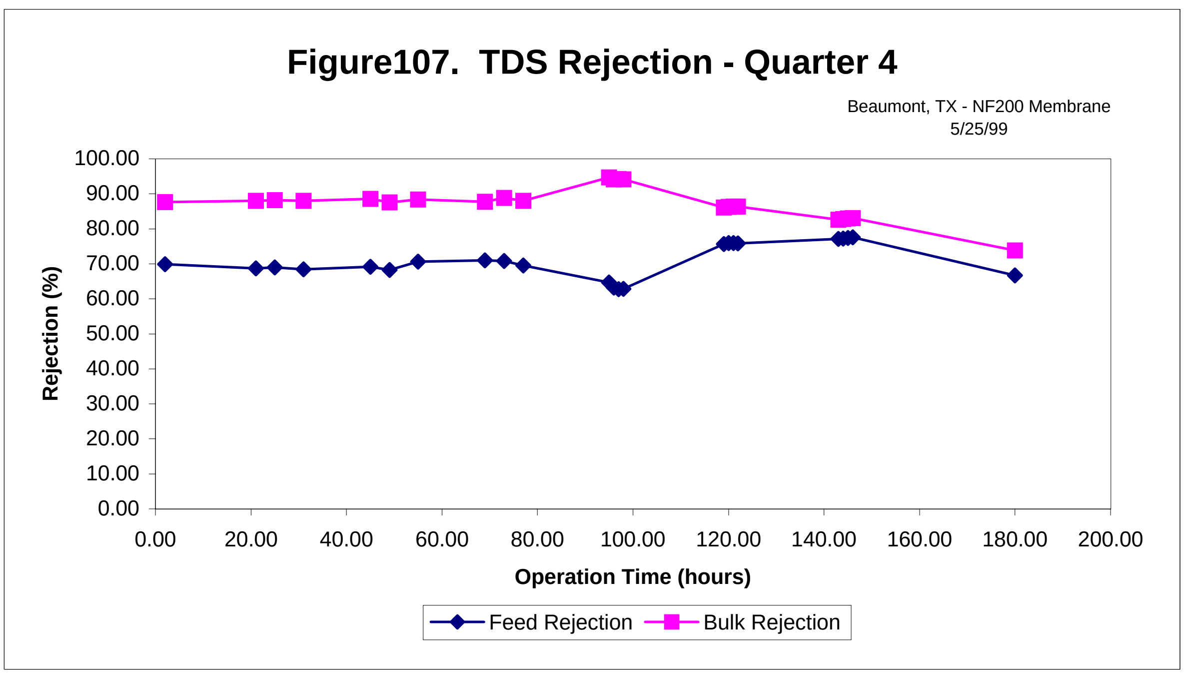


Figure107. TDS Rejection - Quarter 4
Beaumont, TX - NF200 Membrane
5/25/99
Rejection (%)
Operation Time (hours)
Feed Rejection
Bulk Rejection

Figure 108. UV254 Rejection - Quarter 1

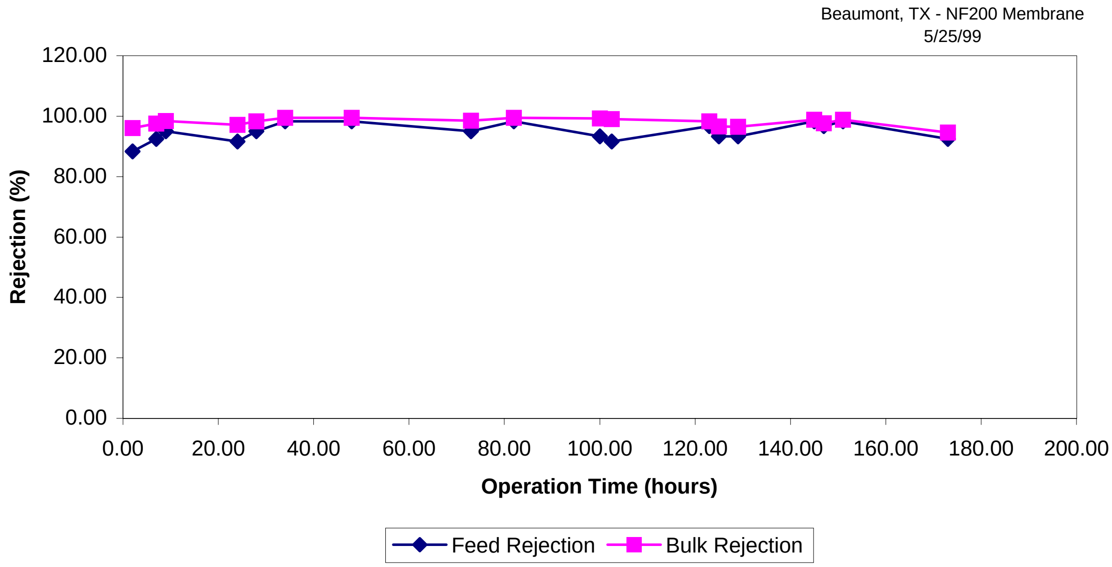
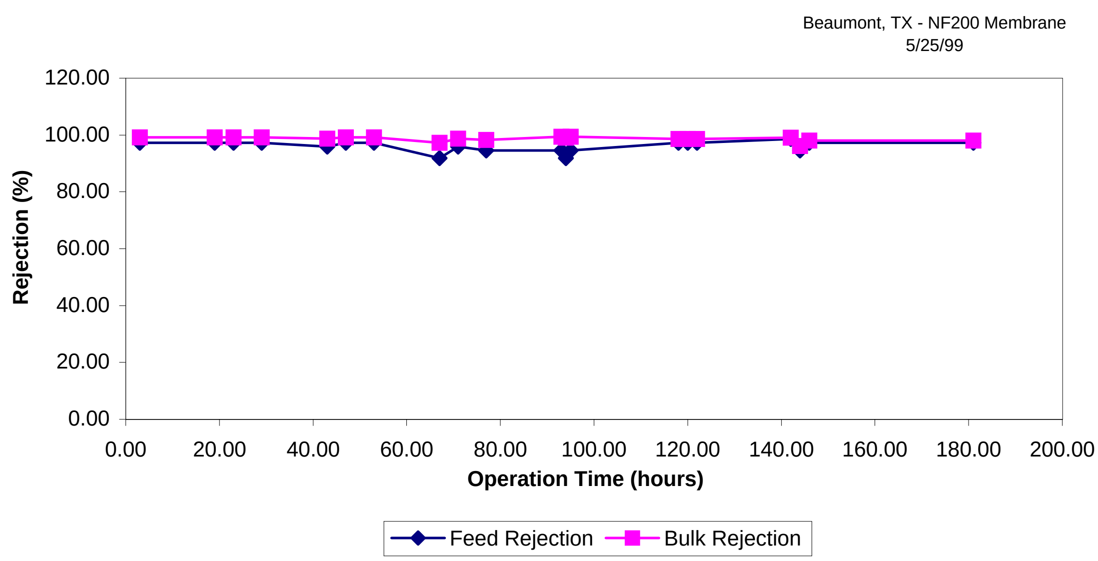


Figure 109. UV254 Rejection - Quarter 2



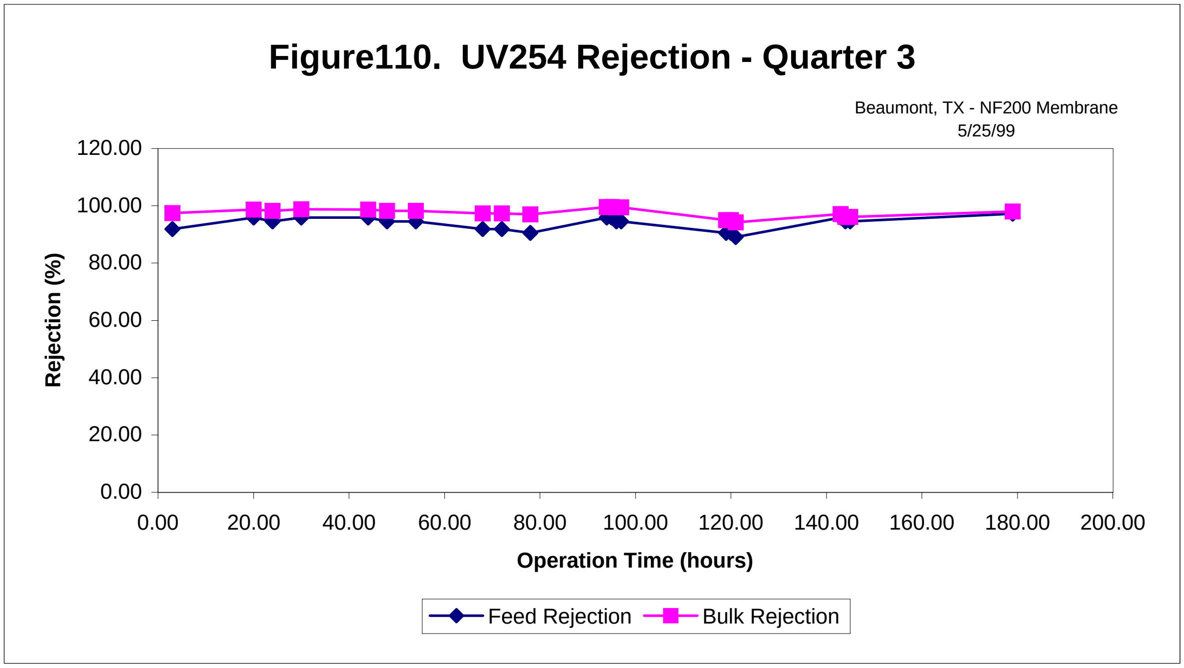


Figure110. UV254 Rejection - Quarter 3
Beaumont, TX - NF200 Membrane
5/25/99
Rejection (%)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Feed Rejection
Bulk Rejection

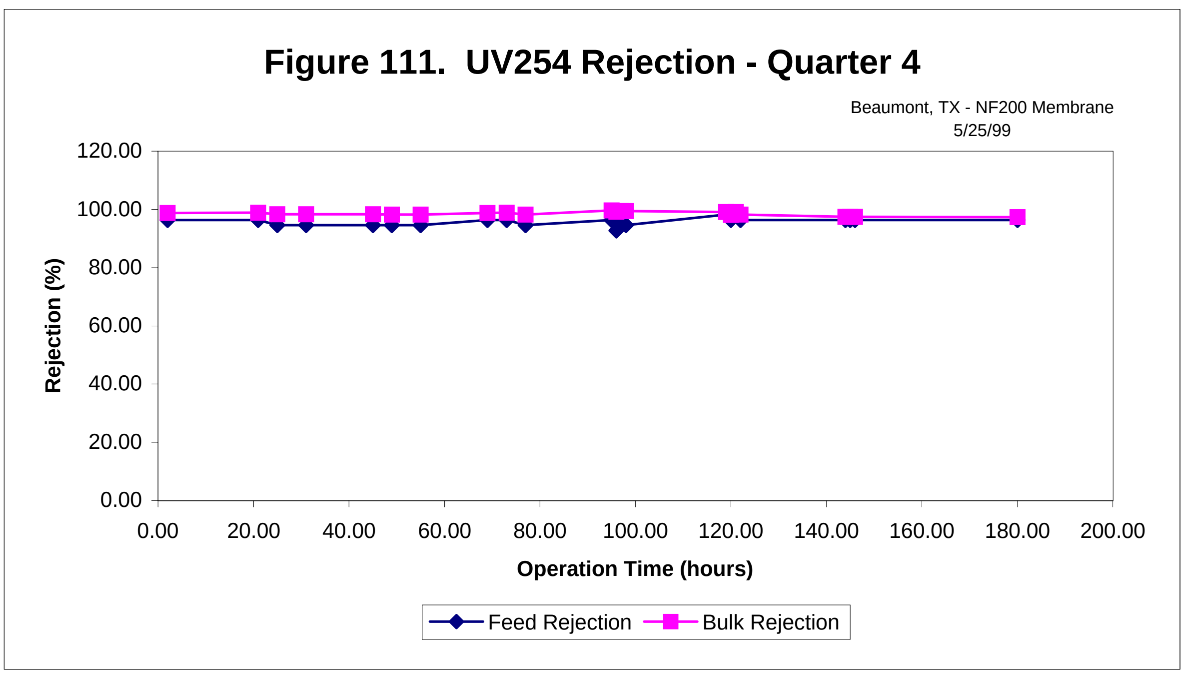


Figure 111. UV254 Rejection - Quarter 4
Beaumont, TX - NF200 Membrane
5/25/99
Rejection (%)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Operation Time (hours)
Feed Rejection
Bulk Rejection