# Deltona Lakes Water System
# ICR Treatment Study Summary Report

## Evaluation of Membrane Technology Using the Pilot-Scale Test for Compliance with the Information Collection Rule

Conducted during the period of June 29, 1998 through April 11, 1999

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**Courtland Water Treatment Plant, Plant ICR # 1075**

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**Attachments:** 3 diskettes containing the *Data Collection Spreadsheets and the Summary Report Spreadsheets*

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# 1.0 Conclusions and Recommendations

Based on the results of the Information Collection Rule (ICR) treatment study applicability, the Deltona Lakes Public Water System (PWS) was required to perform a treatment study. Florida Water Services Corporation (Florida Water), in conjunction with Boyle Engineering Corporation (Boyle), conducted a pilot-scale study in order to accumulate relevant data to that expected in a full-scale membrane process.

Florida Water conducted its treatment study applicability which consisted of monthly total organic carbon (TOC) samples collected from the finished water produced at the Saxton Water Treatment Plant (WTP). In addition, TOC samples were collected from the remaining WTP's in the Deltona Lakes PWS. The results indicated an annual TOC average greater than 2.0 mg/L at the Saxon WTP, Courtland WTP and Well No. 24. Each of these sites was considered for the treatment study, however, due to site limitations, it was determined that the Courtland WTP would be the best site to conduct the study. Florida Water decided to conduct a pilot-scale study using membrane separation technology in order to comply with the ICR requirements. A 2-stage nanofiltration pilot plant was installed at the Courtland WTP.

Fluid System's TFC 4921S spiral-wound membrane having a molecular weight cutoff of 200 Daltons was selected to be used in this pilot study. The pilot system was operated at a water recovery of 75 percent for approximately 4,632 hours, then increased to a water recovery of 80 percent for the remanding 2,118 hours over the course of one year.

Pretreatment was used to control membrane scaling or fouling (flux decline). The pretreatment to the membrane process included sulfuric acid addition to reduce the pH with the intention of preventing calcium carbonate scaling in the membrane process. Typically, a scale inhibitor is also used for pretreatment. However, because there were limited disposal options for the concentrate stream, and computer modeling indicated that sulfuric acid addition would be sufficient as a chemical pretreatment process, scale inhibitor was not used as a part of the pretreatment process.

Some of the major problems encountered during this pilot study included:

- Several days of severe thunderstorms and several forest fires in the area;
- Laboratory results were inadvertently reported as total residual chlorine instead of the expected free residual chlorine, and;
- Samples for ammonia analysis were not collected initially in the pilot study.

Average feed pressures ranged between 58 psi and 63 psi. This is similar the projected 76 psi feed pressure for a similar full-scale nanofiltration water treatment plant. An evaluation of collected and laboratory analyzed alkalinity, total dissolved solids (TDS), and total and calcium hardness samples averaged a rejection of 79%, 87%, 88%, and 88%, respectively. Results from the TDS samples collected from the membrane system feed stream indicated an average of 219 mg/L, and an average of 32 mg/L from the system permeate stream.

Disinfection-by product (DBP) precursor removal was demonstrated by conducting simulated distribution system (SDS) chlorination evaluations. While there were significant levels of trihalomethanes (THM4), and haloacetic acids (HAA5) present in the feed water SDS analyses, results indicate that THM4 and HAA5 can be removed well below the Stage 2 DBP maximum contaminant levels of 40µg/L for THM4 and 30 µg/L for HAA5 using nanofiltration. THM4 and HAA5 detected in the permeate stream SDS analyses averaged 7.0 µg/L and 4.0 µg/L, respectively. Although total organic carbon concentration in the treated feed ranged from 1.9 to 2.6 mg/L, permeate concentrations on average measured below the minimum detection levels.

# 1.0 Conclusions and Recommendations

Total organic halide (TOX) concentrations detected in the treated feed ranged from 101 μg/L to 406 μg/L, whereas permeate concentrations ranged from 16 μg/L to 54 μg/L. However, although present in the treated feed, TOC, UV254, and bromide concentration in the permeate concentrations on average measured below minimum detection levels.

An additional goal for this study was to determine the cost and performance of membrane processes for disinfection by-product precursor removal. The costs for the full-scale nanofiltration membrane WTP presented in this report are intended to be used for planning purposes only should membrane technology be implemented. However, in order to achieve comparable DBP removal at the Courtland WTP, the process water rate would increase from an operating cost of $0.45 per 1,000 gallons of treated water to $0.79 per 1,000 gallons.

# 2.0 Background Information

The ICR for Public Water Systems (Subpart M of the National Primary Drinking Water Regulations, Part 141.141 (e)) requires Public Water Systems (PWSs) that meet certain applicability criteria conduct DBP precursor removal studies referred to as "treatment studies." Florida Water was required to perform an ICR treatment study to determine the advantages of advanced treatment using membranes to enhance the water quality in the Deltona Lakes PWS.

The ICR requires that all ground water treatment plants that serve more than 50,000 persons conduct a treatment study applicability monitoring. Treatment study applicability monitoring was conducted to determine if the treatment plant precursor levels were low enough to avoid the treatment study requirement. Several consecutive monthly TOC samples were collected from the Saxon WTP's finished water. Based on these results, the Deltona Lakes PWS was required to perform a treatment study.

## 2.1 Courtland Water Treatment Plant Description

Florida Water owns and operates the Deltona Lakes PWS. This system serves over 63,300 persons, which equates to over 25,000 households and businesses. It is supplied by a network of 26 deep ground water supply wells, all of which are developed in the Floridan Aquifer at an average depth of 230 feet. These wells supply 16 separate WTPs. These WTPs process and deliver an average of 11,194,000 gallons of water per day. Typical treatment of the raw water at the WTPs consists of tray aeration for carbon dioxide and partial hydrogen sulfide removal and chlorine addition for disinfection.

In order to comply with ICR, Florida Water conducted its treatment study applicability, which consisted of monthly TOC samples collected from the finished water, at the Saxton WTP. In addition, TOC samples were collected from the remaining WTP's in the Deltona Lakes PWS. Results from these samples can be found in Table 2.1. Ground water treatment plants exceeding an annual average TOC of 2.0 mg/L in the finish water were required to perform a treatment study. Although Saxon WTP, Courtland WTP and Well No. 24 all exceeded this limit, Florida Water determined that the Courtland WTP would be the best site to conduct its treatment study. This WTP offered a detectable TOC annual average (2.47 mg/L), a well that could be operated continuously, easy access, existing telephone lines, and available space on site for shed and storage tanks. Historical water quality data from the Courtland WTP can be found in Table 2.2.

The Courtland WTP produces 2.4 million gallons per day of finish water for storage and distribution. Raw water for the WTP is obtained from three production wells (Well No.15, Well No. 17 and Well No.18). All three wells are located on the plant site. Typically, the wells are operated intermittently. Raw water flow is pumped to the plant via a raw water flow meter and enters the ground storage tank (GST). The GST at the WTP is designed with an integral cascade tray aerator. Aeration is provided by natural draft, cross-flow ventilation, while the raw water "cascades" down the various trays and into the tank. Water is introduced to the aerator by a center riser pipe. Hydrogen sulfide is partially removed by aeration and volatilization from the bulk solution to the headspace in the GST. This sulfide-laden air is continuously removed, thus allowing a steep concentration gradient, which facilitates volatilization and helps in the prevention of undue sulfide corrosion. The water is further treated by disinfection with gaseous chlorine and addition of a polyphosphate based inhibitor for corrosion control. Figure 2.1 illustrates a flow diagram of the treatment process. A summary of the engineering and chemical design parameters for each unit process has been provided in Table 2.3.

**Table 2.1**

**Total Organic Carbon Results**

**Deltona Lakes PWS**

| Site | Yearly Average |
|---|---|
| Well #33 | 1.94 |
| Wellington | 1.79 |
| Saxon | 2.10 |
| Saxon (Enviro Lab)* | 2.69 |
| Well #27 | 1.93 |
| Lombardy | 1.72 |
| Sagamore | 1.62 |
| Well #3 | 1.64 |
| Well #25 | 1.91 |
| Well #21 | 1.81 |
| Well #4 | 1.17 |
| Well #19 | 1.20 |
| Well #23 | 1.48 |
| Well #28 | 1.26 |
| Well #24 | 2.90 |
| Courtland | 2.47 |
| Well #20 | 1.25 |

**Results from an ICR certified laboratory for treatment study applicability.*

**Table 2.2**

**Average Source Water Quality**

**Courtland Water Treatment Plant**

| Parameter | Well No. 15 | Well No. 17 | Well No. 18 |
|---|---|---|---|
| pH | 7.7 (2) | 7.8 (2) | 7.8 (2) |
| Ca. Hardness (mg/L as $CaCO_3$) | 151 (2) | 158 (2) | 154 (2) |
| T. Hardness (mg/L as $CaCO_3$) | 188 (2) | 180 (2) | 164 (2) |
| Turbidity (NTU) | N/A | < 0.10 | N/A |
| TOC (mg/L) | 1.1 (2) | 2.1 (2) | 1.2 (2) |
| $UV_{254}$ ($cm^{-1}$) | 0.0545 (2) | 0.086 (2) | 0.060 (2) |
| Bromide (μg/L) | N/A | 0.050 | N/A |

*Note: ( ) – Number of observations*

**Figure 2.1**

**Flow Diagram**

**Courtland Water Treatment Plant**

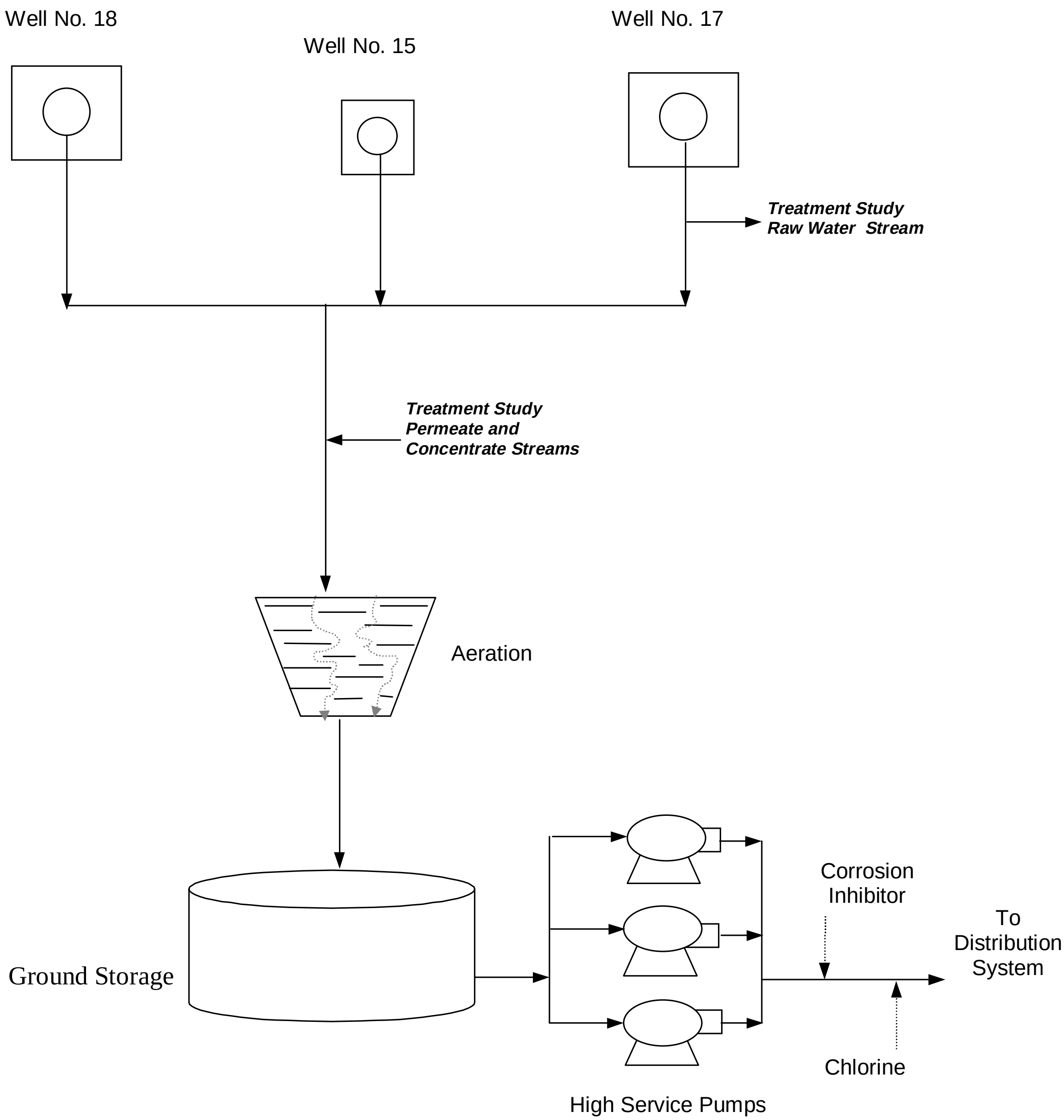


**Table 2.3**

**Summary of Courtland Water Treatment Plant Design Data**

| Unit Process | Process Description |
|---|---|
| Aeration | Type of Aerator: Mechanical Tray Aerator |
| Ground Storage | Liquid Volume (gal): 1,000,000<br>Covered Contactor: Yes |
| Disinfection | Chemical Type: Chlorine gas<br>Measured as: $Cl_2$<br>Dose Rate (mg/L): average range 4.5 to 5.0 ppm |
| Corrosion Control | Chemical Type: Polyphosphate<br>Dose Rate: 1 ppm |

## 2.2 Treatment Plant Challenges

In 1998, the Deltona Lakes PWS has been faced with three sampling locations in the distribution system that have exceeded 100 ppb in single samples for trihalomethane (THM). THMs are byproducts of drinking water chlorination. The sites are located near a dead end of the distribution system. In response to this problem, a substantial flushing program has been implemented.

Well location No. 25 has also exceeded the secondary MCL of 0.3 mg/L for iron. However, to compensate for the high levels of iron in Well No. 25, finish water is blended with the finish water from well No. 3 to dilute the high iron levels. The blending process results in water that meets the regulatory criteria for iron. In addition, an iron-sequestering agent is added to the water at well No. 25.

In compliance with the Lead and Copper Rule (LCR), Florida Water completed required monitoring in the Deltona Lakes PWS to determine lead and copper concentrations at residential taps throughout the service area. The results of the monitoring program indicated that the level of copper in the Deltona Lakes PWS exceeded the action level of 1.3 mg/L as set forth in the LCR. The concentration of lead was found to be below the action level of 0.015 mg/l as established by the LCR.

Florida Water's monitoring program showed that the level of lead and copper for both the untreated groundwater and source water (point-of-entry) was below the detection level of 0.001 mg/l and 0.02 mg/l, respectively; and that their contribution to the levels found in the system was negligible. Consequently, source water treatment was not required for the PWS. In addition, Florida Water initiated a coupon study throughout the distribution system to identify treatment techniques to control metal leaching in the distribution system.

The results of the corrosion control evaluation indicated that because of the size of the PWS and concerns about safety at the treatment facility, a polyphosphate inhibitor was implemented for control of copper release in the water system. A review of historical data for this system showed that this type of inhibitor is effective in reducing metal release in the distribution system.

# 3.0 Materials and Methods

## 3.1 Introduction

The ICR established a treatment objective for all treatment studies to achieve levels of DPBs less than 40 μg/L and 30 μg/L for THM4 and HAA5, respectively when free chlorine is used. Florida Water decided to conduct a pilot-scale study using membrane separation technology in order to accumulate more relevant data to that expected in a full-scale membrane process for future improvements to the Deltona Lakes Water System should membrane technology be implemented. The ICR requires that a spiral-wound membrane having a molecular weight cutoff of less than 1,000 Daltons. In addition, the pilot system must operate at a minimum water recovery of 75 percent for at least 6,600 hours over the course of one year. To meet these requirements, a 2-stage nanofiltration pilot plant was installed at the Courtland WTP.

## 3.2 Pretreatment Process

The purpose of this section is to describe the pretreatment to the membrane process, the equipment used for the pilot study, the experimental design of the pilot system and the analytical methods used during the study. The purpose of pretreatment is to control membrane scaling or fouling (flux decline). Flux decline, indicated by a reduction in membrane process productivity can be a result of scaling, colloidal fouling, biological fouling, chemical fouling or a combination of phenomena. Figure 3-1 illustrates a flow diagram of the pretreatment process used in this study.

The characteristics of raw water revealed that some level of pretreatment prior to membrane softening was required. Sulfuric acid addition was used to reduce the pH in order to prevent calcium carbonate scaling in the membrane process. Typically, a scale inhibitor is used for pretreatment. However, because there were no acceptable disposal locations for the concentrate stream, the scale inhibitor was not used as a part of the pretreatment process. Computer modeling indicated that sulfuric acid addition would be sufficient as a chemical pretreatment process to prevent calcium carbonate scale. Based on limited water quality test results, it was assumed that calcium carbonate was the limiting salt and that the sparingly soluble salts such as barium, strontium and silica would not be significant to the process. Additional testing performed confirmed these assumptions.

One of the criteria of the pretreatment process was to remove the suspended solid particles such that the silt density index (SDI) is limited to no more than 3 SDI units. Cartridge filters with a nominal pore size of 5 mm were used for removing suspended solids from the ground water supply at a minimum removal efficiency of 90%. From the cartridge filter the feed stream was directed to the high-pressure booster pump, which provided the necessary pressure for the membrane process.

### 3.2.1 Design Data for Each Pretreatment Process

Design data for each pretreatment process included:

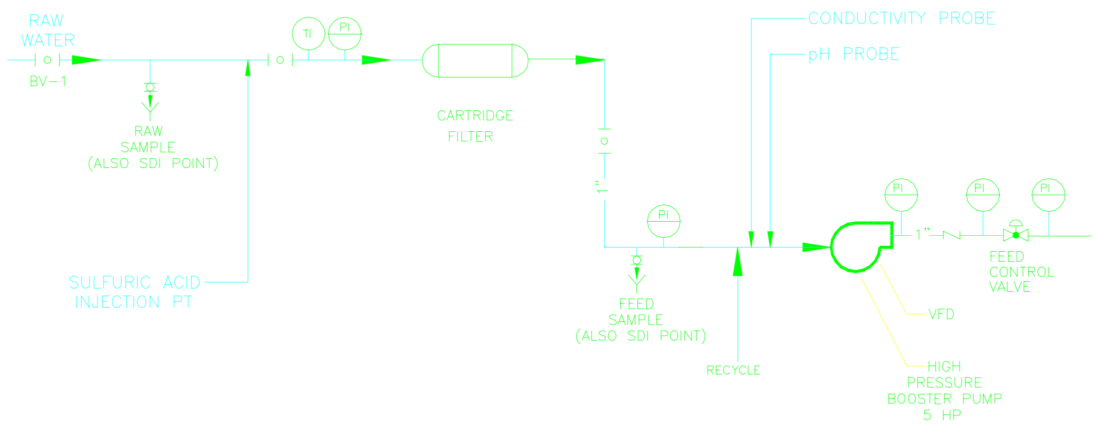
1. Cartridge Filtration

    a) Prefiltration was accomplished by one Fluflo® BSSB20 ¾ SD cartridge filter housing containing two, 10-inches in length, string wound filter elements. This provided a typical flow rate of 10 gpm.

# 3.0 Materials and Methods

**Figure 3.1**

**Flow diagram of Pretreatment Process**




*BV – Ball valve*
*TI – Temperature Indicator*
*PI – Pressure Indicator*

b) Cartridge filter vessels were constructed of fiber reinforced plastic. The cover closure was assembled using 316 stainless steel bolts with 304 stainless steel hex nuts with Buna-N o-ring cover gaskets. Polypropylene FDA grade cartridge elements on a polypropylene core was used in this pilot study. These elements complied with FDA regulations suitable for potable water use.

c) The cartridge filters were designed to remove all particles greater than the "filtering particles" 5μm with a removal efficiency at a minimum of 90%.

d) The cartridge filter unit was pressured tested in accordance with ASME requirements.

2. Sulfuric Acid Addition

a) All piping materials utilized for sulfuric acid addition were constructed from PVDF, polyurethane, Teflon, or CPVC and capable to resist chemicals to a pH of 2.

b) The chemical diaphragm metering pump, LMI A371-152S chemical feed pump was constructed of PVDF head/fittings with Teflon seats and o-rings. The pump was designed with a nominal range of 5 to 100 strokes per minute with stroke length adjustable from 0 to 100%. The pump selected for the pilot was a LMI Series A diaphragm metering pumps.

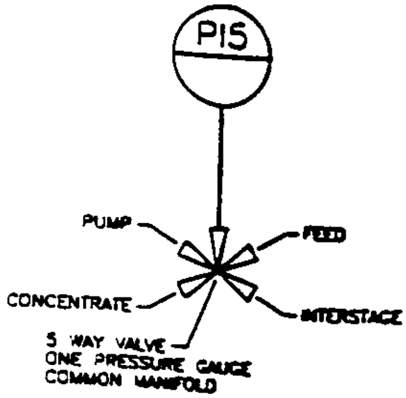
## 3.3 Advance Treatment Process Information

Fluid Systems TFC 4921S (TFC 4921S) spiral-wound membrane was selected from 3 manufacturers to be evaluated in the Pilot Scale System. The TFC 4921S membranes have a molecular weight cutoff of 200 Daltons. The membrane manufacturer and model number was determined through the use of membrane projections and manufacturer's membrane element specifications. Results of the analysis are presented in Appendix A.

### 3.3.1 Experimental Design

The pilot plant was designed to operate at a minimum production rate of 10,000 gallons per day with a minimum water recovery of 75 percent for at least 6600 hours over the course of one year. The system consisted of 2 stages with 2 pressure vessels in the first stage and one pressure vessel in the second to provide a 2-1 membrane array. Each pressure vessel contained three 4-inch diameter by 40-inch length membrane element size providing for a total surface area of 702 $ft^2$.

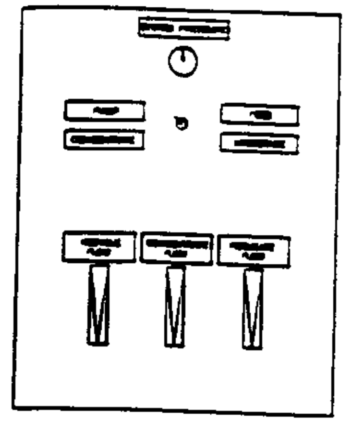
The pilot membrane system was designed as a staged array of membrane elements similar to the design of full scale membrane water treatment plants. The staged pilot plant was constructed to meet the ICR requirements for membrane treatment studies as outlined in the U. S. Department of Environmental Protection Agency's *ICR Manual for Bench- and Pilot-Scale Treatment* (EPA 814-B-96-003). Drawing A presents the process flow schematic of the pilot plant system used in this study. As illustrated in this drawing, the concentrate and permeate streams were allowed to flow to a transfer tank which allowed for a low permeate back-pressure. This blended water periodically pumped back into the GST. Drawing B illustrates the site layout of the temporary piping and equipment for the ICR Pilot Plant. Design criteria for the pilot system is as follows:




5 WAY SELECTOR VALVE
PRESSURE RANGE (0–400 PSI)

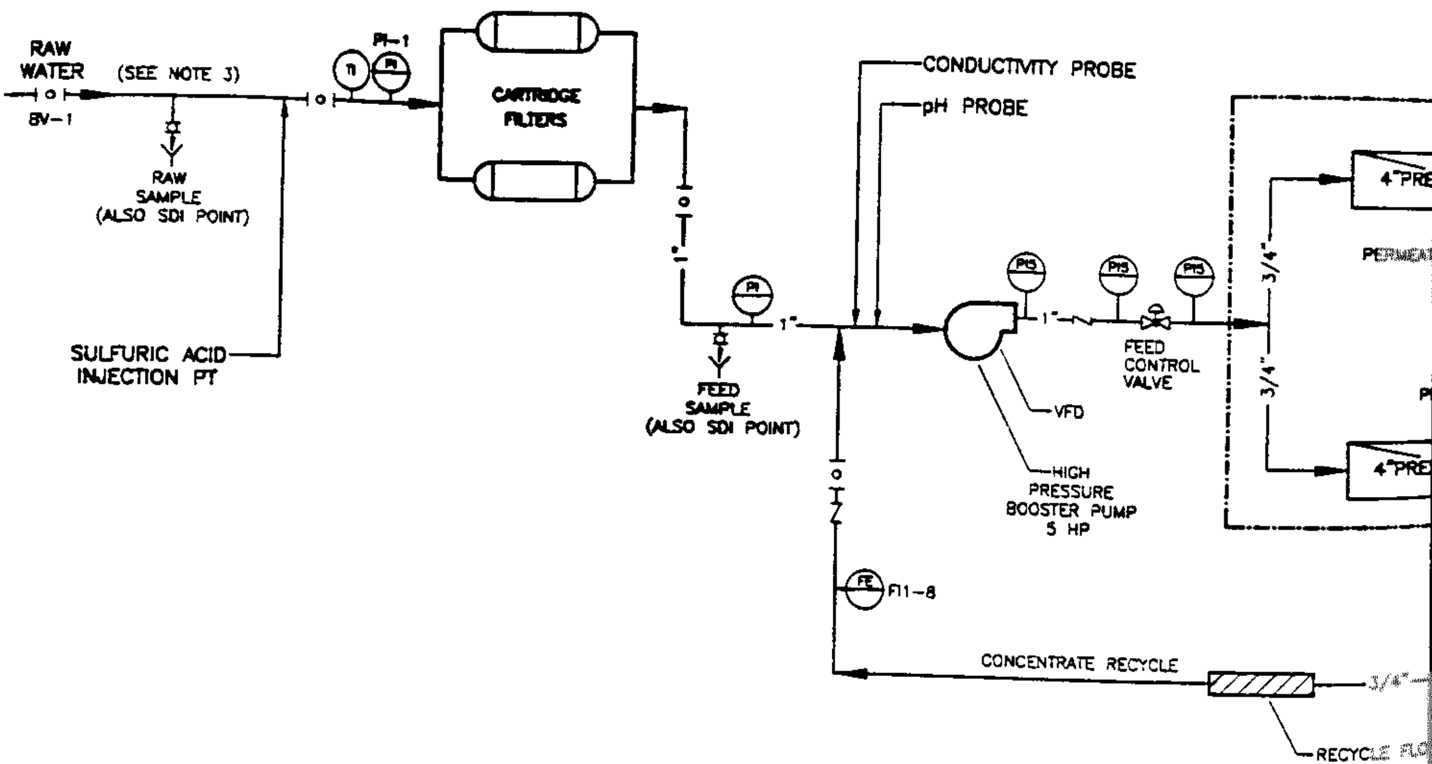
## 5 WAY SELECTOR VALVE

SCALE: NONE

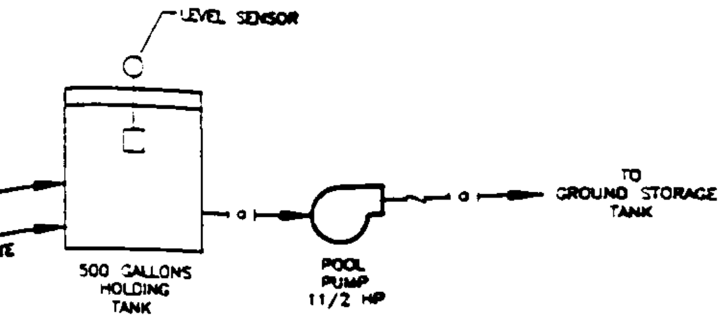


## SPIRAL WOUND PILOT SYSTEM CONTROL PANEL

SCALE: NONE




TWO STAGE 2–1 ARRA

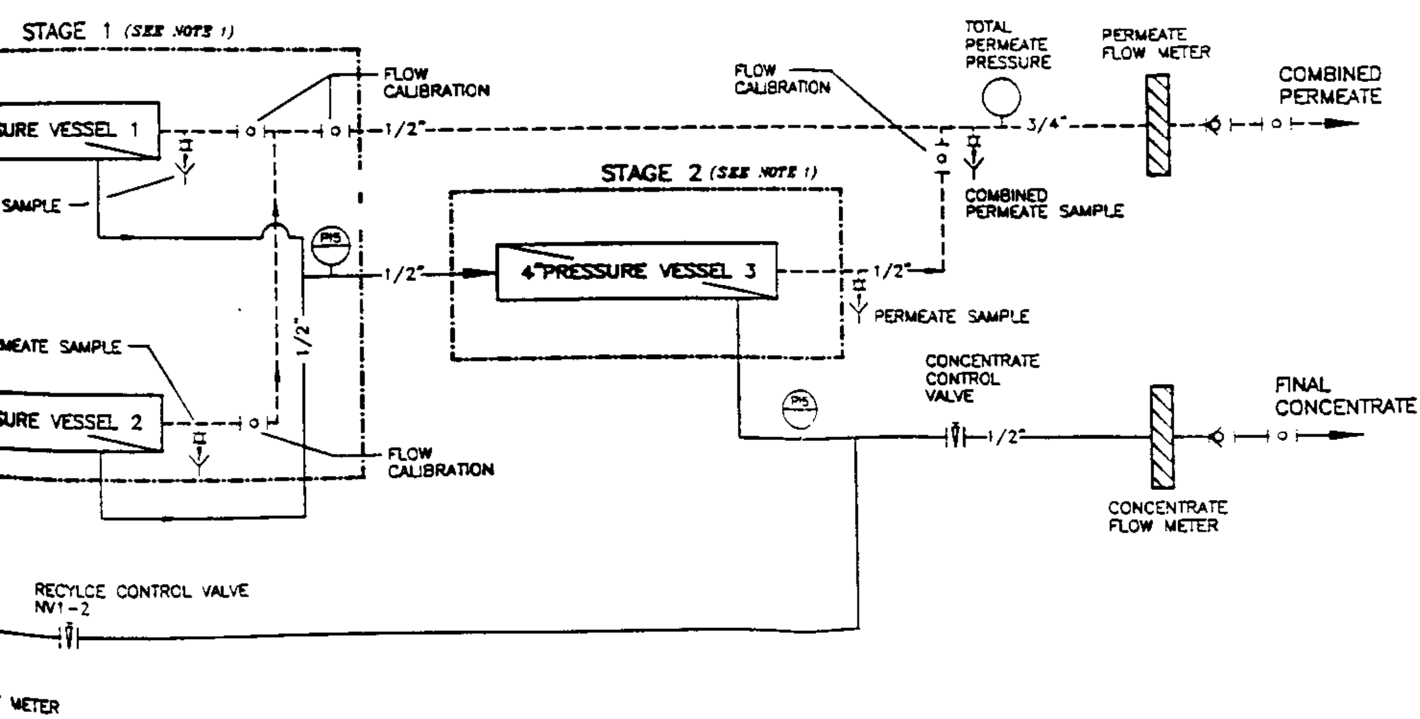



## TRANSFER PUMPING STATION

SCALE: NONE

| LEGEND | |
|---|---|
| | PRESSURE ACTUATED VALVE |
| | GLOBE VALVE |
| | BALL VALVE |
| | CHECK VALVE |
| | NEEDLE VALVE |
| | HIGH PRESSURE PUMP |
| | SAMPLE PORT |
| | PANEL MOUNTED INSTRUMENT |
| | LOCALLY MOUNTED INSTRUMENT |
| | BALL CHECK VALVE |

| ABBREVIATIONS | |
|---|---|
| AE pH | pH METER |
| FE | ROTOMETER |
| FS | FLOW SWITCH |
| LS | LEVEL INDICATOR |
| PI | PRESSURE GAUGE |
| PSL | LOW PRESSURE SWITCH |
| PSH | HIGH PRESSURE SWITCH |
| TI | TEMPERATURE GAUGE |
| ULP | ULTRA LOW PRESSURE |
| VFD | VARIABLE FREQUENCY DRIVE |




## Y MEMBRANE PILOT PLANT

NOTES:

1. EACH PRESSURE VESSEL SHALL CONTAIN 3 – SPIRAL WOUND NANOFILTRATION MEMBRANE ELEMENTS.
2. PIPING MATERIALS: FROM RAW WATER SUPPLY TO SUCTION SIDE OF HIGH PRESSURE BOOSTER PUMPS SHALL BE SCHEDULE 80 PVC; HIGH PRESSURE PIPING DOWNSTREAM OF BOOSTER PUMPS INCLUDING CONCENTRATE AND RECYCLE STREAMS UP TO CONTROL VALVES SHALL BE 316 SS HIGH PRESSURE TUBING; PERMEATE PIPING SHALL BE SCHEDULE 80 PVC.

FLORIDA WATER SERVICES

MEMBRANE SOFTENING FOR WATER TREATMENT PILOT PLANT

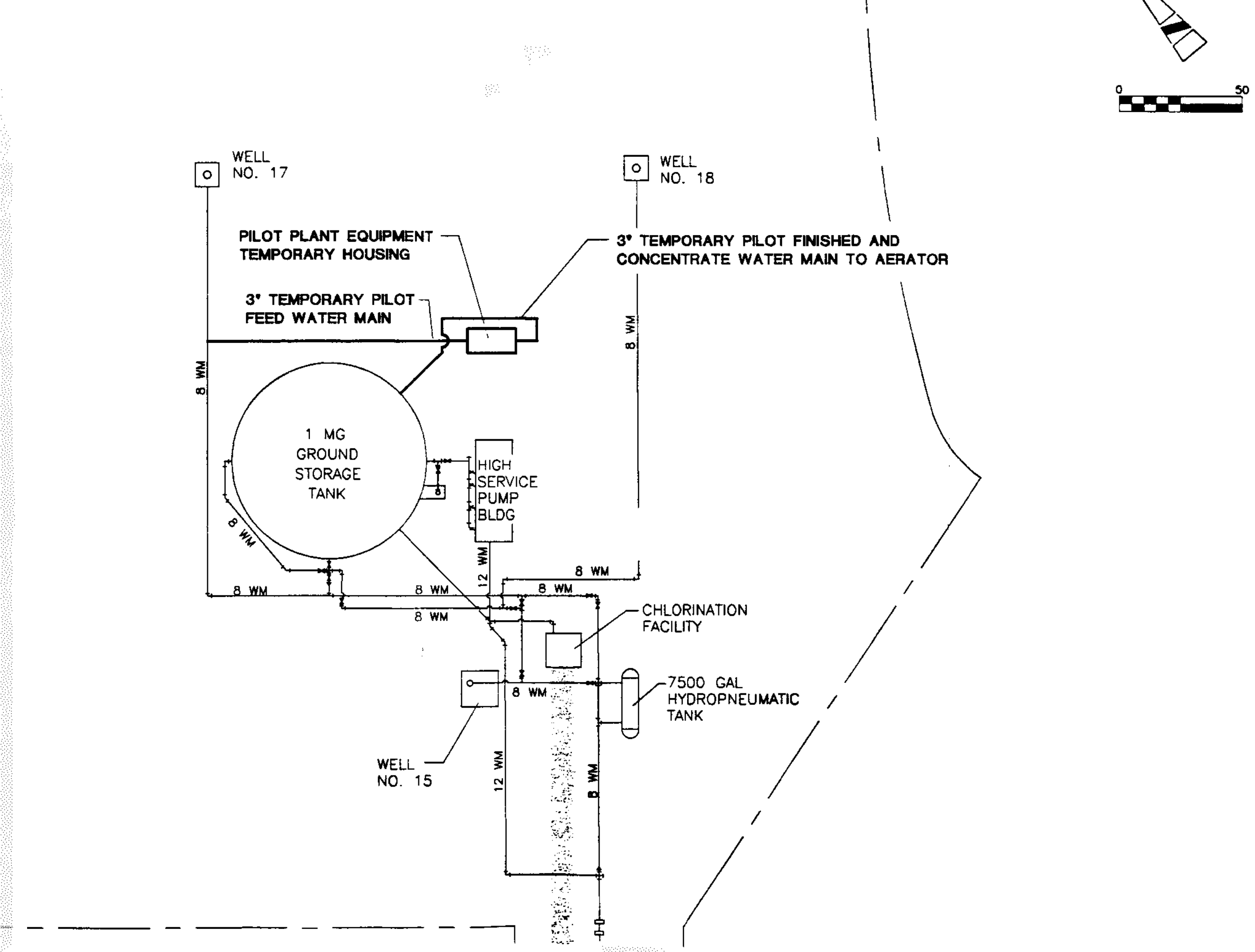
PILOT PLANT PROCESS FLOW DIAGRAM
P & I DIAGRAM

BOYLE

PROJECT MANAGER STEVEN J. DURANCEAU, PhD, PE

DRAWING FILE PWSFLOW1.DWG

SHEET | DRAWING A




PROPOSED

FLORIDA WATER SERVICES

BEC

#### 3.3.1.1. Hydraulic Design

| | | |
|---|---|---|
| a) | Permeate Production Rate: | 7.0 gpm |
| b) | Feed Flow Rate: | 8 to 14 gpm |
| c) | Concentrate Flow Rate: | 2 to 7 gpm |
| d) | Recycle Flow Rate: | 2 to 12 gpm |
| e) | Recovery Rates: | 50 percent without concentrate recycle and up to 80 percent with concentrate recycle depending on limiting salt constraints. |

**3.3.1.2. Feed Pump:** 5 hp, 230/460V, 3450 rpm, Grundfos stainless steel, centrifugal pump with variable frequency drive. Pump was rated at a minimum of 14 gpm at 200 psi.

#### 3.3.1.3. Membrane System

| | | |
|---|---|---|
| a) | Array: | Two stage array, 2:1 pressure vessel configuration, with three elements per pressure vessel. |
| b) | Membrane Elements: | Nine spiral wound nanofiltration membrane elements. Membrane element types reviewed for use were Fluid Systems TFC®4921S, FilmTec® NF70-4040 and Hydranautics 4040-UHA-ESNA. |
| c) | Pressure Vessels: | Codeline Commercial low pressure 4-inch Model 40430 side ports rated for 300 psi. |
| d) | Structure (skid): | Skid was constructed with reinforced fiberglass frame containing epoxy finish. |
| e) | Piping: | All high-pressure piping was constructed from 316 stainless steel. Permeate stream piping was constructed from schedule 80 PVC. |

#### 3.3.1.4. Transfer Pumping Station

| | | |
|---|---|---|
| a) | Holding Tank | 500 gallons, UV resistance polyethylene. |
| b) | Pump | 1 ½ hp, 115/230 V, stainless steel shaft, Sta-Rite Model PLF or equal. Pump was specified for a minimum of 14 gpm at 40 psi. |
| c) | Level Sensor | The level sensor used in the tank employed a floating device to detect liquid level. The level sensor provided three automatic controlling switches for pump operation (pump on, Pilot plant and pump on, and pump off). The entire unit was UL and CSA certified. |

#### 3.3.1.5. Instrumentation and Control

a) Monitoring and Control: Rodi Systems Membrane Monitor™ complete with all monitoring instrumentation and control equipment including an Allen Bradley Programmable Logic Controller (PLC) and other motor starters.

b) Instrumentation was provided to measure:

i) Feed stream pH, temperature and conductivity.

ii) Permeate conductivity.

iii) Flow indicators for the permeate, concentrate, and recycle streams.

iv) Pressure indicators for pump, feed, interstage, concentrate and permeate water streams.

v) Alarms for low pressure, high pressure, low/high pH, low/high acid tank levels.

#### 3.3.1.6. Special Valves

a) Sample Port: Sample port valves were provided for the feed, interstage, combined concentrate, combined permeate streams, and each permeate stream.

b) Isolation Valves: Three way isolation valves were provided for flow testing the permeate stream of each vessel.

## 3.4 Analytical Methods

Laboratory analyses were performed using the analytical methods listed in Table 3.1. All analyses performed were specified in accordance with CFR 141.142 of the ICR Rule. Sample collection, preservation and holding times were in concurrence with those described in the *ICR Sampling Manual* (EPA 814-B-96-001). A summary of laboratory calibration procedures are listed in Appendix B. The samples analyzed for THM4, HAA6, and TOX formation as well as for chlorine demand, were chlorinated under site-specific simulated distribution system (SDS) conditions. The SDS conditions include incubation time, temperature, pH, and free chlorine residual representative of the actual plant and distributions system conditions at the time of study.

Envirolab, Inc. (ICR lab ID # F029), at 8 East Tower Circle, Ormond Beach, Florida, was used as the primary laboratory to performed most of the laboratory analyses for the course of this pilot study. The project manager from the laboratory was Myrna S. Lueckert. She can be reached at 904-672-5668 or by fax at 904-673-4001. The total organic halide (TOX) analyses were performed by AOX Specialties (ICR lab ID#WA003), at 2106 NE 104$^{th}$ Avenue, Vancouver, WA. The project manager from this laboratory was Cindy Bye. She can be reached at 360-896-9006 or by fax at 360-891-5889.

**Table 3.1**

**Summary of Analytical Methods and MRLs**

| Parameter | Analytical Method | Minimum Reporting Levels (MRLs) |
|---|---|---|
| pH | EPA 150.1 | Not applicable |
| Temperature | SM 2550 B | Not applicable |
| TDS | SM 2540 C | 1 mg/L |
| Alkalinity | SM 2320 B | 5 mg/L as $CaCO_3$ |
| Calcium Hardness | 3500Ca D | 1.2 mg/L as $CaCO_3$ |
| Total Hardness | SM 2340 B | 1.2 mg/L as $CaCO_3$ |
| Turbidity | EPA 180.1 | 0.10 ntu |
| Chlorine Residual | SM 4500-C1 G | 0.05 mg/L |
| BCAA, DBAA, DCAA, MBAA, MCAA, TCAA | EPA 552.1 | 1.0 μg/L |
| THM4 | EPA 502.2 | 0.5 μg/L |
| HAA5 | EPA 552.1 | 2.0 μg/L |
| HAA6 | EPA 552.1 | 2.0 μg/L |
| $CHCl_3$, BDCM, DBCM, $CHBr_3$ | EPA 502.2 | 0.50 μg/L |
| Bromide | EPA 300.0 | 0.02 μg/L |
| TOX** | SM 5320B | 10.0 μg/L |
| $UV_{254}$ | SM 5910 B | 0.009 $cm^{-1}$ |
| Total Organic Carbon | SM 5310 B | 0.70 mg/L |
| Ammonia | SM 4500-$NH_3$ D | 0.05 mg/L $NH_3$-N/L |

* *BCAA- Bromochloroacetic acid, DBAA – Dibromoacetic acid, DCAA – Dichloroacetic acid, MBAA –monobromoacetic acid, MCAA – Monochloroacetic acid, TCAA –Ttrichloroacetic acid, $CHCl_3$ - Chloroform, BDCM - Bromodichloromethane, DBCM – Dibromochloromethane, $CHBr_3$ – Bromoform, TOX – Total Organic Halide.*

** *Analysis performed by AOX Specialities.*

# 4.0 Results and Discussion

The purpose of this section is to provide information that is critical to the interpretation of the results reported in the data collection spreadsheets and to present the key findings of the study. The ICR pilot study was conducted from June 29, 1998 to April 11, 1999. The pilot unit was operated a total run time of 6,750 hours. Information accumulated from the pilot study was used to determine if membrane treatment of the source water supply can meet the requirements of the Stage 2 DBP regulations.

## 4.1 Problems Encountered

- Because the Deltona WTP is an unmanned site, operator daily recording was accomplished only once per day. During the initial start-up of the pilot scale membrane study, the City of Deltona experienced several days of severe thunderstorms and several forest fires thereby causing power outages to the pilot plant and a decrease to the availability of operators to collect the data. Also, low feed pressure resulted from the raw water inlet valve not allowing an adequate supply of raw water to the pilot unit. In addition, it was determined that some of the low feed pressures were due to operator error in collecting data. Overall, only 92 hours were lost during the course of the pilot study due to power loss and low feed pressure.

- After approximately 24 hours of operation of the pilot study, the sulfuric acid feed pump failed resulting in increased pH levels of the pretreated feed water. The pilot unit operated successfully at these elevated pH levels that continued for two days. There were several other incidents of pH variance as shown in Figure 4.1, when the sulfuric acid was depleted during the time interval between operator site visits. Figure 4.2 shows that the feed water temperatures ranged from 29.9 °C during the summer season to 17.8 °C during the winter season. Table 4.1 summarizes the average water quality for the treatment study influent (pretreated feed).

- The laboratory data reported from the samples collected beginning in July through November indicated variation in the results for raw THMFP. An investigation of the procedure and data revealed that some of the results were inadvertently reported as total residual chlorine instead of the expected free residual chlorine. The calculation for chlorine demand was modified for formation potential analysis from the samples collected beginning December 15, 1998. This modification was a result of recommendations made by the USEPA that the calculation for chlorine demand utilize a free residual chlorine determination instead of the total residual chlorine determination being used previously. Therefore, the samples collected before December 15, 1998 did not contain sufficient chlorine residuals at end of incubation time and results from the SDS testing are lower than when free chlorine was available. In addition to the procedure changes, incubation time was changed from 24 hours to 48 hours beginning with August 24, 1998.

- Samples for ammonia analysis were not collected initially in the pilot study. Florida Water initially contacted the laboratory with the water quality requirements as outlined in Tables 6-2 and 6-12 in the report entitled ***"ICR Manual For Bench- and Pilot-Scale Treatment Studies***" (*April 1996*). These requirements were later revised in the report entitled *"ICR Treatment Studies Data Collection Spreadsheets User's Guide"* (April 1997). However, in the later part of the pilot study, several analyses for ammonia were performed. Results indicate very little variation in the filtered feed ammonia concentrations.

## 4.0 Results and Discussions

**Figure 4.1**

**Feed pH**

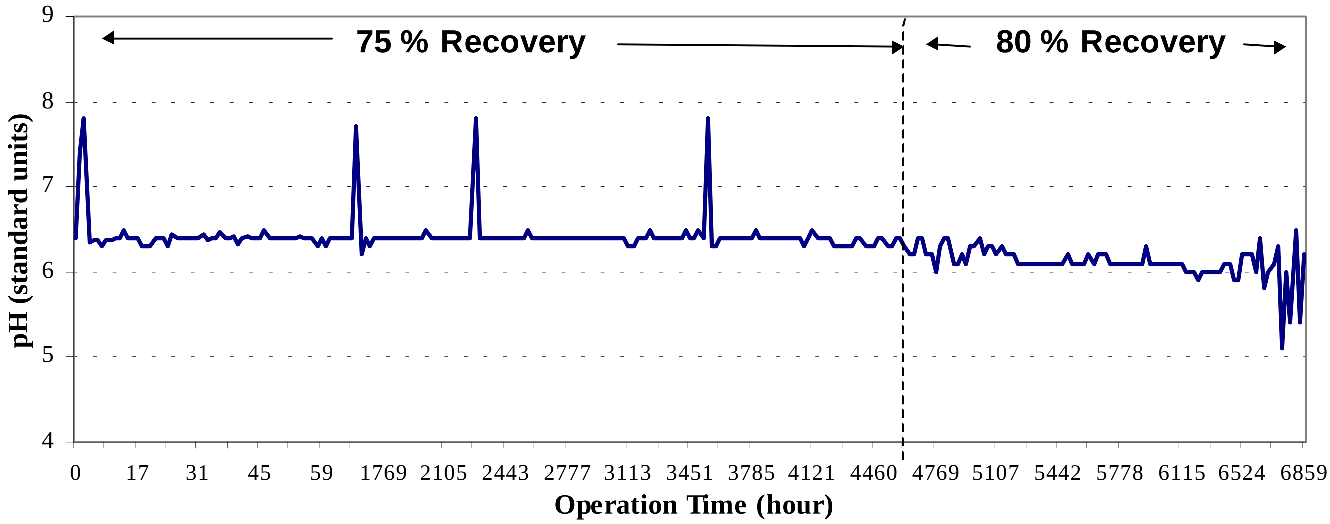
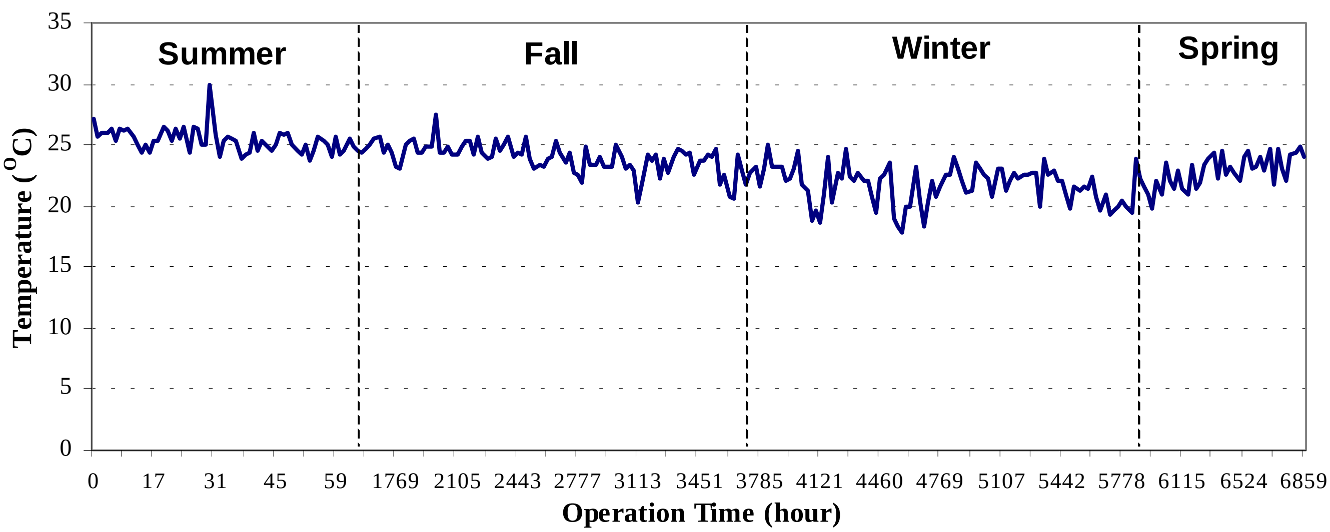



**Figure 4.2**

**Feed Temperature**



## 4.0 Results and Discussions

**Table 4.1**

**Summary of Seasonal Variations of the Average Influent Water Quality**

| Water Quality Parameter | Summer Average (SD) | Fall Average (SD) | Winter Average (SD) | Spring Average (SD) |
|---|---|---|---|---|
| Temperature (C) | 25 (0.6) | 24.2 (0.8) | 21.4 (1.3) | 23.3 (1.7) |
| pH | 6.46 (0.08) | 6.55 (0.13) | 6.34 (0.17) | 6.15 (0.47) |
| Turbidity (NTU) | 1.2 (0.0) | 0.0 (0.0) | 0.70 (0.8) | 1.3 (1.3) |
| Alkalinity (mg/L as $CaCO_3$) | 86.5 (3.4) | 90.9 (4.8) | 84.3 (8.8) | 62.5 (7.5) |
| Calcium Hardness (mg/L as $CaCO_3$) | 148 (5.0) | 149 (7.8) | 157 (4.9) | 168 (15) |
| Total Hardness (mg/L as $CaCO_3$) | 170 (0.0) | 176 (5.3) | 179 (3.8) | 195 (17.3) |
| Bromide (ug/L) | 45.0 (13.3) | 52.9 (6.2) | 47.8 (1.1) | 37.5 (0.58) |
| TOC (mg/L) | 2.1 (0.2) | 2.3 (0.2) | 2.3 (0.2) | 2.2 (0.1) |
| $UV_{254}$ ($cm^{-1}$) | 0.1 (0.0) | 0.1 (0.0) | 0.1 (0.0) | 0.1 (0.0) |
| **SDS-THM4 (ug/L) | 16.2 (2.5) | 22.2 (25.7) | 79.5 (18.1) | 62.0 (15.5) |
| **SDS-HAA5 (ug/L) | 6.9 (2.0) | 17.4 (22.5) | 61.4 (24.0) | 48.4 (26.9) |
| **SDS-HAA6 (ug/L) | 6.9 (2.0) | 18.4 (24.6) | 67.2 (24.5) | 52.7 (28.1) |
| **SDS-TOX (ug $Cl^-$/L) | 132.5 (15.8) | 162.3 (92.5) | 340.6 (63.2) | 292.0 (111.6) |
| SDS- Chlorine Demand (mg/L) | -- | --- | 7.3 (0.6) | 5.4 (1.11) |

**SD – standard deviation*
***SDS results for Summer and Fall were from SDS test in which a free chlorine residual was not present at the end of incubation.*

## 4.2 Pilot Performance

Water recovery, feed pressure and membrane productivity were all aspects of the monitoring procedures during the pilot operation. Initially, water recovery was maintained at a constant level by varying the feed and concentrate flow rate. However, after 4,632 hours of operations the water recovery was increased up to 80 percent. Figures 4.3 through 4.6 displays the recovery, feed pressures, and flows for the overall membrane system.

At the start-up of the pilot study, a feed pressure of 55 psi produced an average permeate flow of 8 gpm. During the 75% water recovery conditions the feed pressure averaged 58 psi and 63 psi for 80% water recovery. Net driving pressure for the pilot system averaged 43 psi for a 75% water recovery and 45 psi for 80% water recovery.

Figure 4.7 shows the results of the differential pressures for the pilot assembly. These results indicate minor fluctuations in differential pressure through out the pilot plant operations. However, after an increase in feed pressure, there appears to be similar increases in differential pressure.

### 4.2.1 Water Quality Data

Solute rejection was also a significant water quality evaluated in the pilot study. This is illustrated by an evaluation of alkalinity, TDS, total and calcium hardness samples collected and analyzed in the laboratory. These results are illustrated in Figures 4.8 and 4.9. Alkalinity was rejected at an average of 79%, TDS at an average of 87%, and total and calcium hardness at an average of 88% each.

In addition, daily conductivity levels were measured and converted to TDS using a multiplier established from the relationship of the laboratory conductivity and TDS concentrations. The ratio between laboratory and calculated TDS concentrations ranged between 0.06 to 1.7, with an overall average of 1.1. Conductivity levels were measured from the feed, concentrate and permeate water streams. Results from the membrane system’s raw, treated feed and concentrate streams are illustrated in Figure 4.10. Results from the permeate TDS can be found in Figure 4.11. The average total permeate TDS was 31.8 mg/L (SD of 3.7), with a concentration of 19.2 mg/L (SD of 2.4) in the permeate stream of stage 1 and 42.8 mg/L (SD of 3.8) in the permeate stream of stage 2.

Although not required by the ICR, periodical silt density index (SDI) tests were performed. Typically, SDI's on the raw water ranged were measured at levels less than one.

### 4.2.2 DBP Data and Data Analyses

Membrane performance was also evaluated by DBP precursor removal. Precursor removal was demonstrated by conducting SDS chlorination evaluations on the membrane feed and permeate streams along with other analysis per the requirements of the ICR Rule. Conditions for SDS evaluations are based on average conditions of the distribution system served by the Deltona Lakes WTP. Results from the SDS evaluations are shown in Figures 4.12 through 4.18.

SDS conditions (after December 15, 1998) included an incubation time of 48 hours, pH of 8.1, temperature of 20 °C, and a free chlorine residual target of 1.0 to 0.5 mg/L at the end of the incubation time. As a result of these

## 4.0 Results and Discussions

**Figure 4.3**

**System Recoveries**

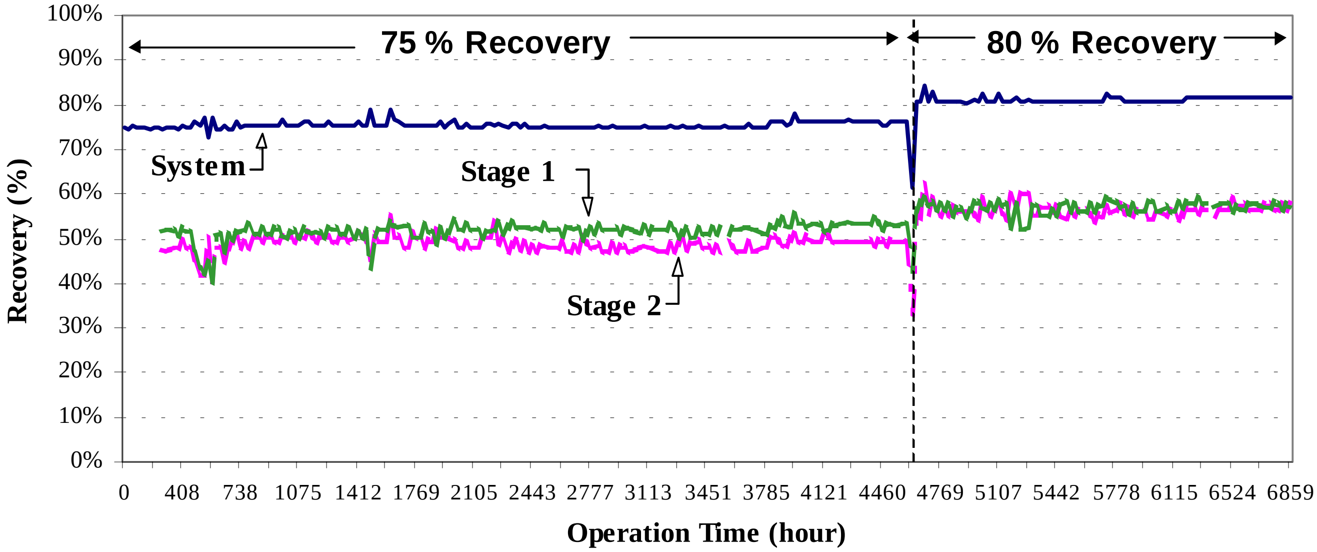



**Figure 4.4**

**System Pressures**

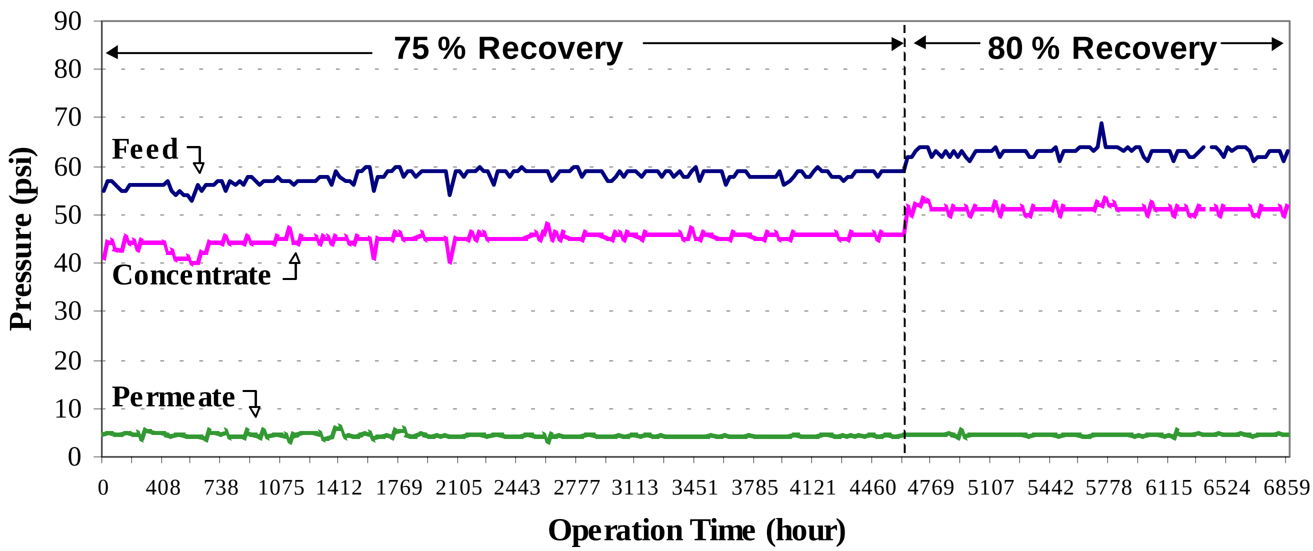


**Figure 4.5**

**Net Driving Pressures**

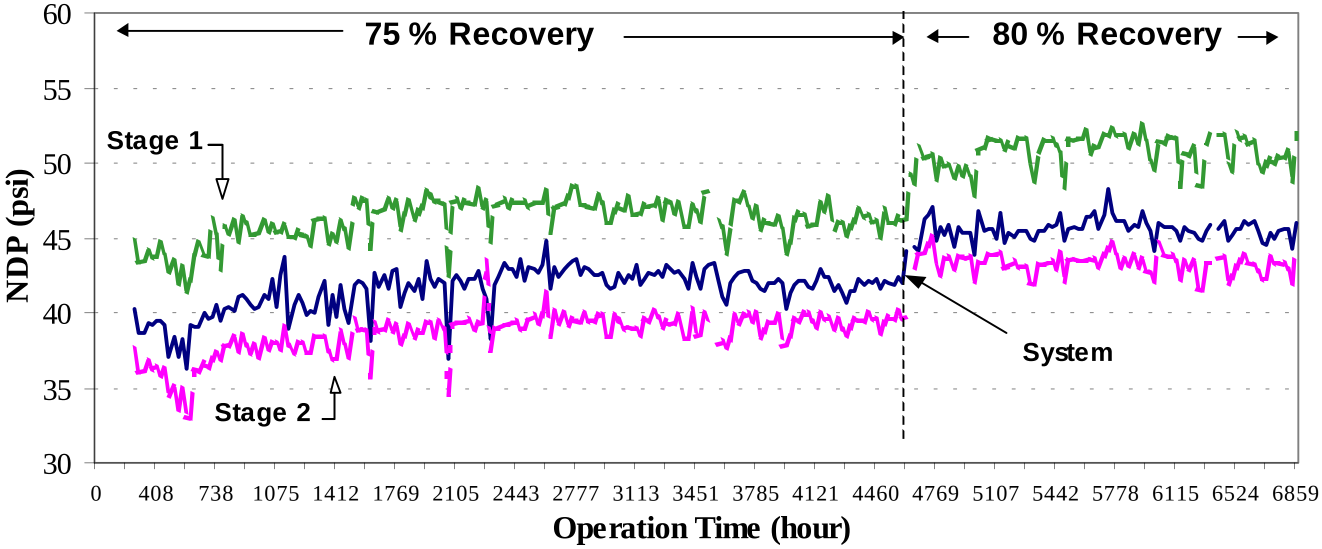



**Figure 4.6**

**System Flows**

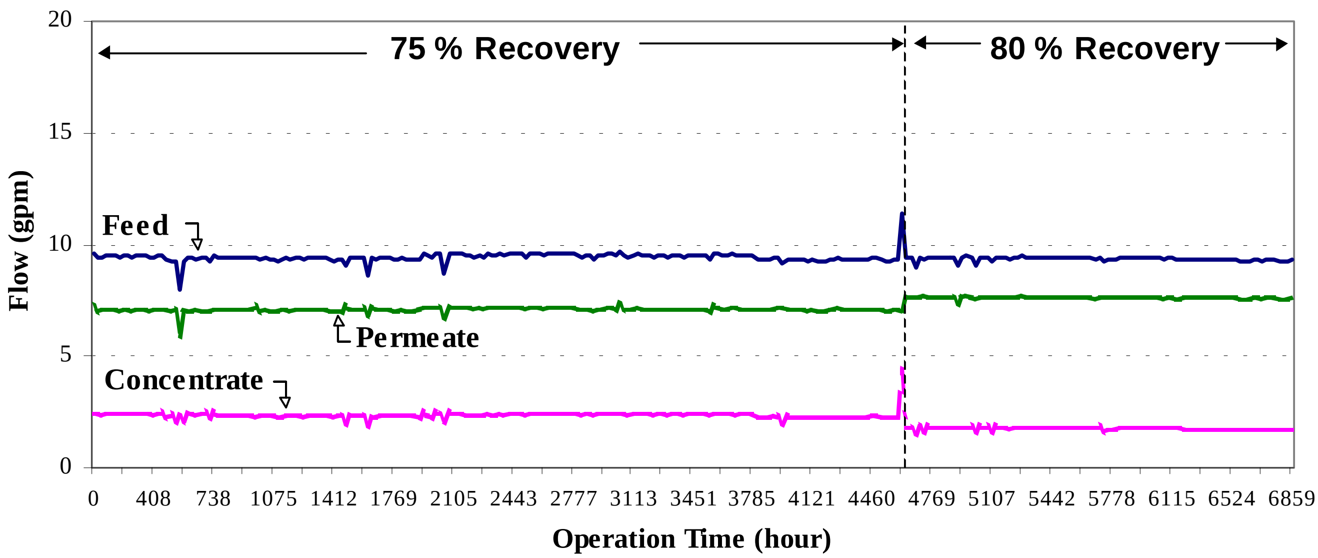


**Figure 4.7**

**Differential Pressures**

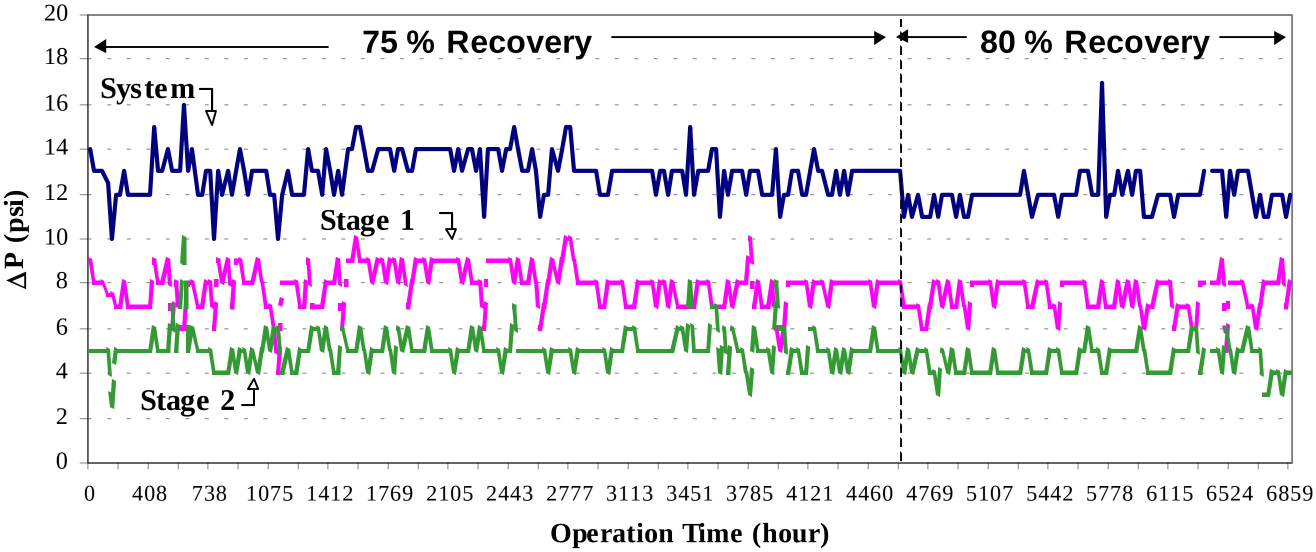



**Figure 4.8**

**Alkalinity and Total Dissolved Solids Feed Rejection**

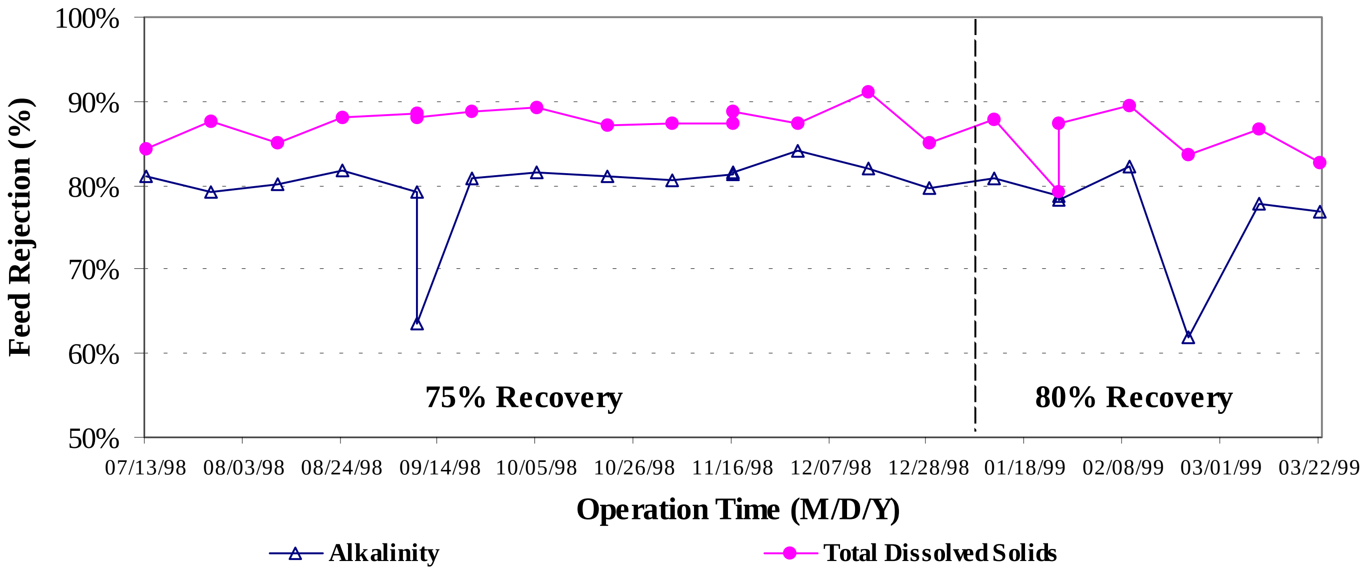


**Figure 4.9**

**Hardness Feed Rejection**

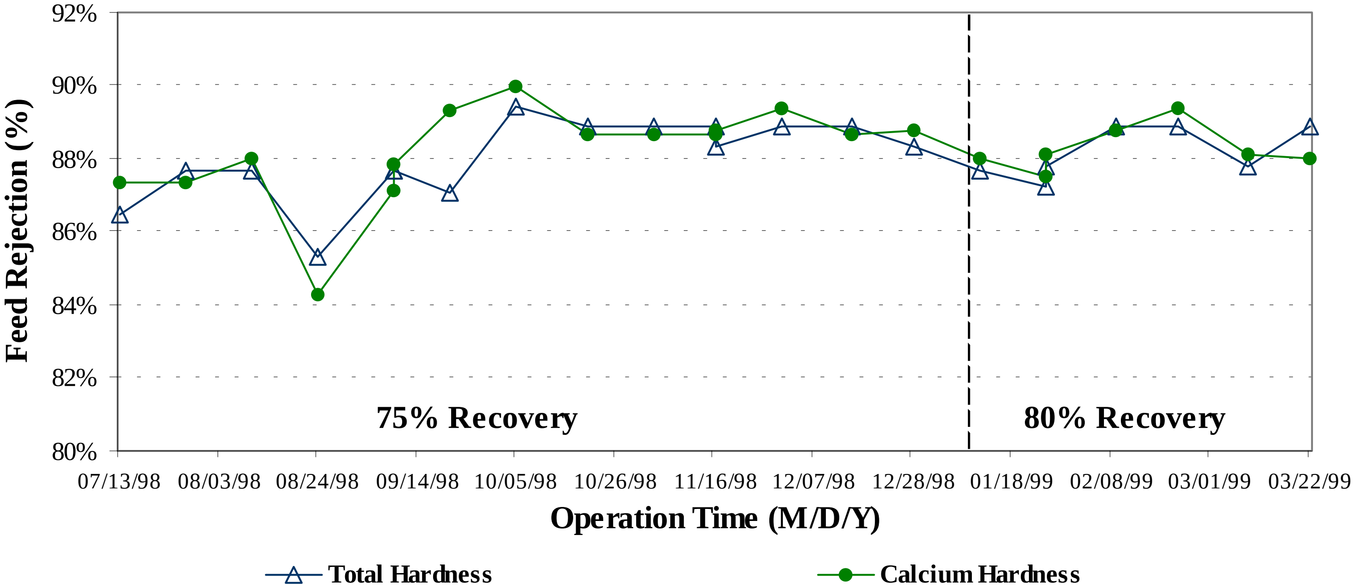



**Figure 4.10**

**Total Dissolved Solids – System Feed and Concentrate**

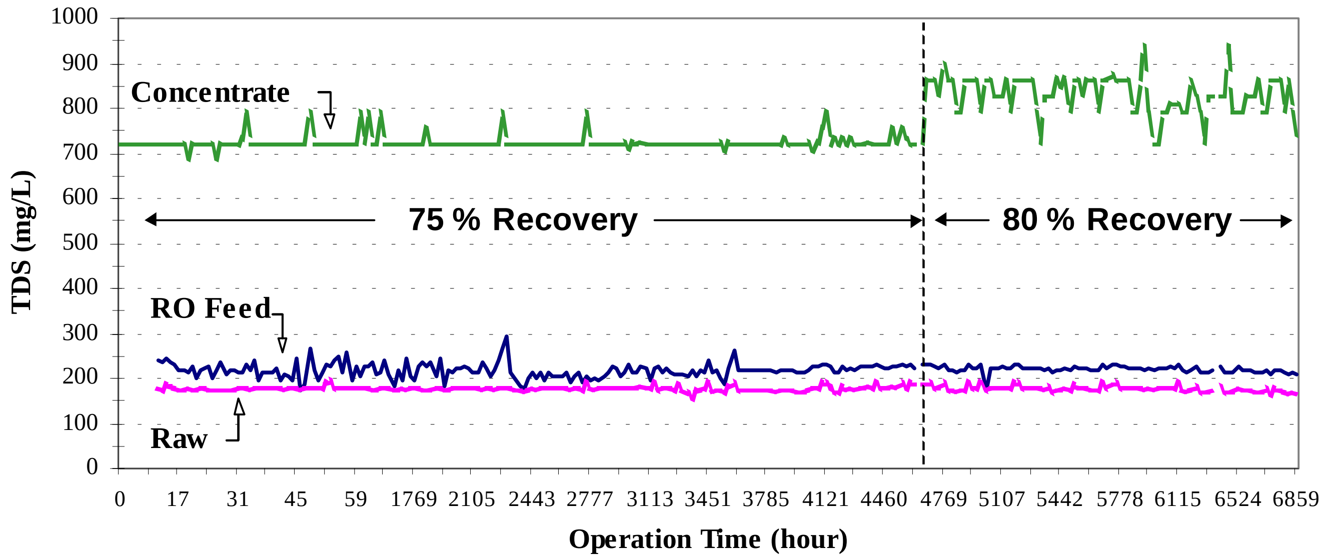


**Figure 4.11**

**Daily Permeate Total Dissolved Solids**

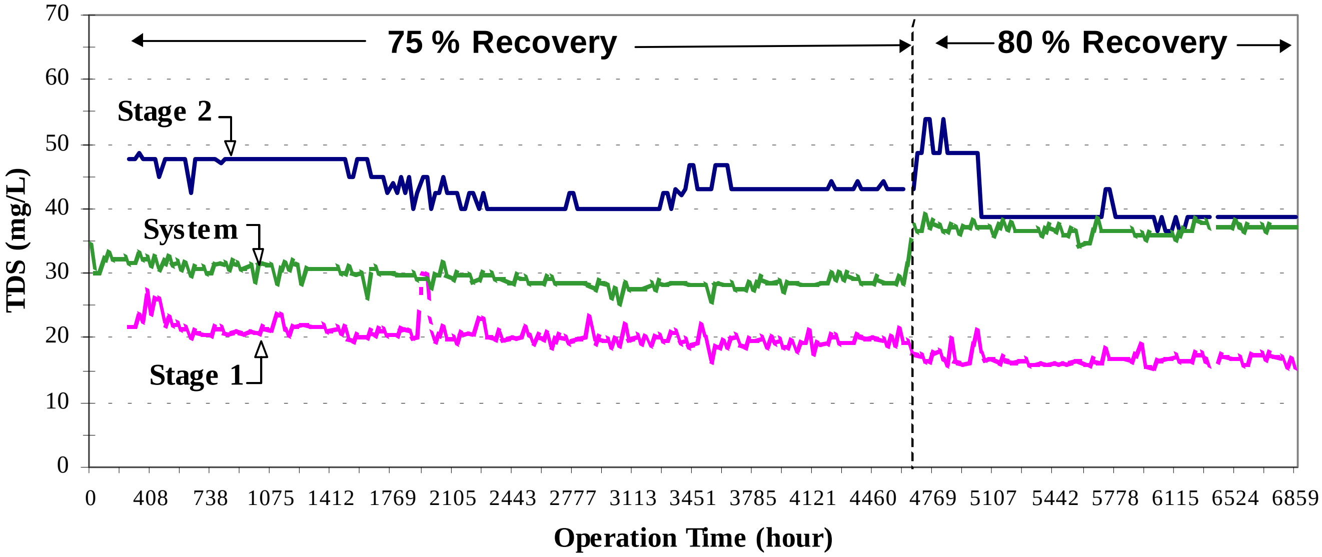



**Figure 4.12**

**SDS-THM4 Laboratory Results**

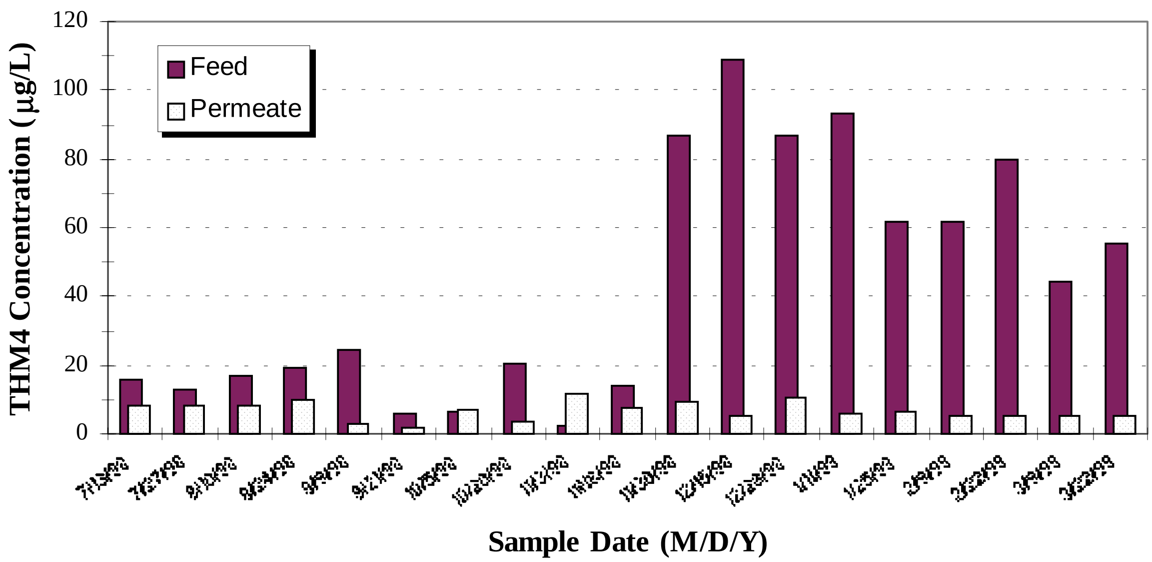


**Figure 4.13**

**SDS-HAA5 Laboratory Results**

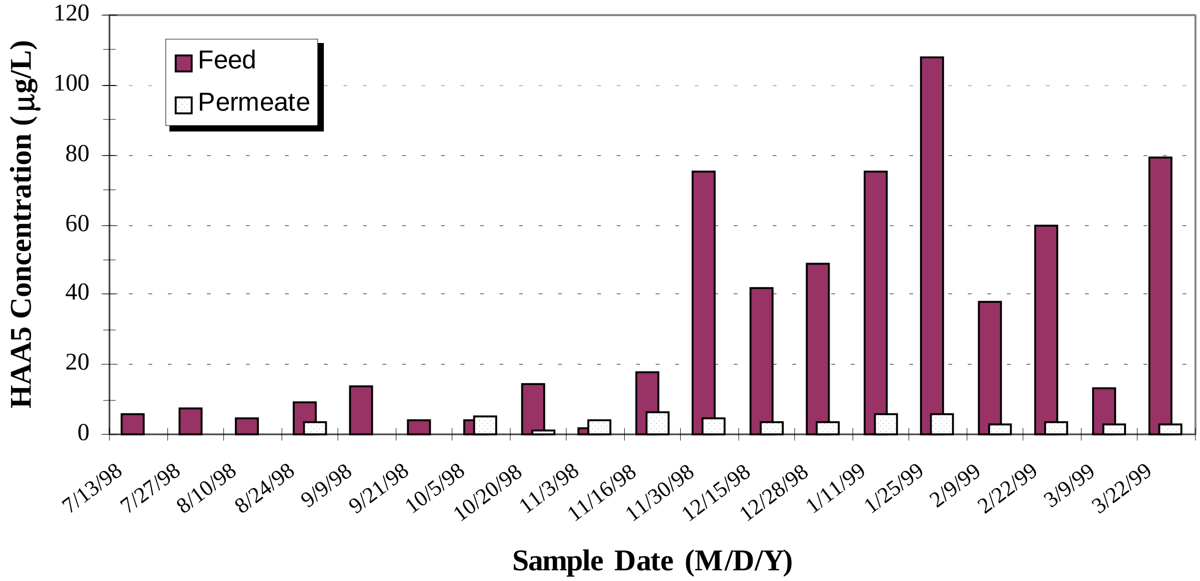



**Figure 4.14**

**SDS-HAA6 Laboratory Results**

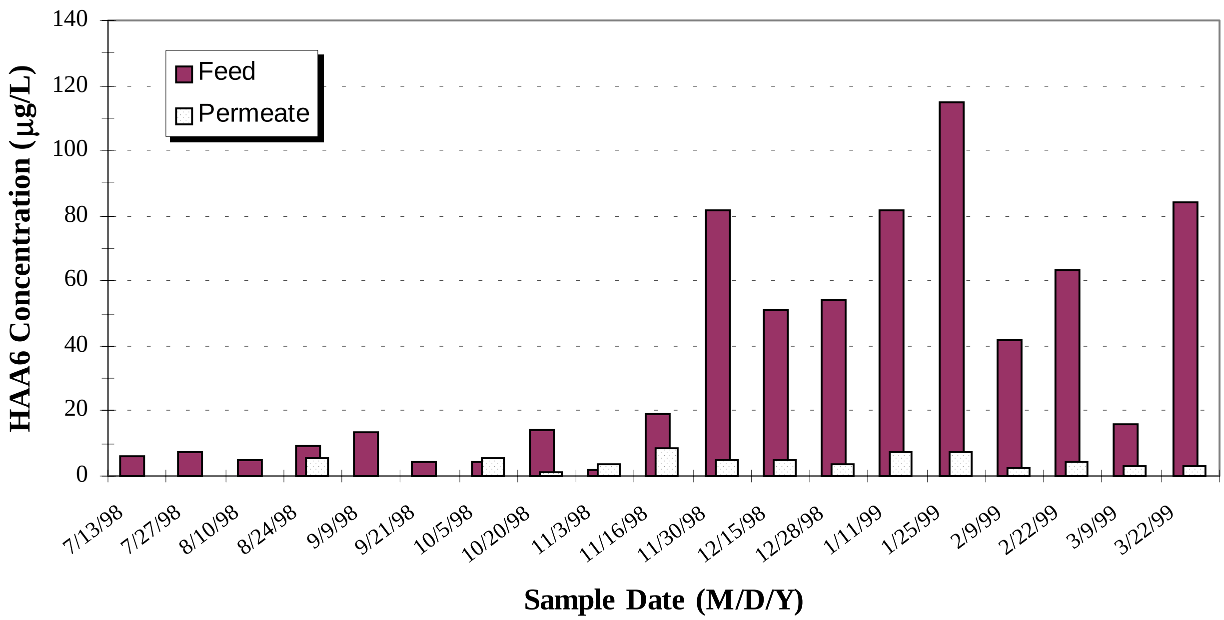


**Figure 4.15**

**SDS- TOX Laboratory Results**

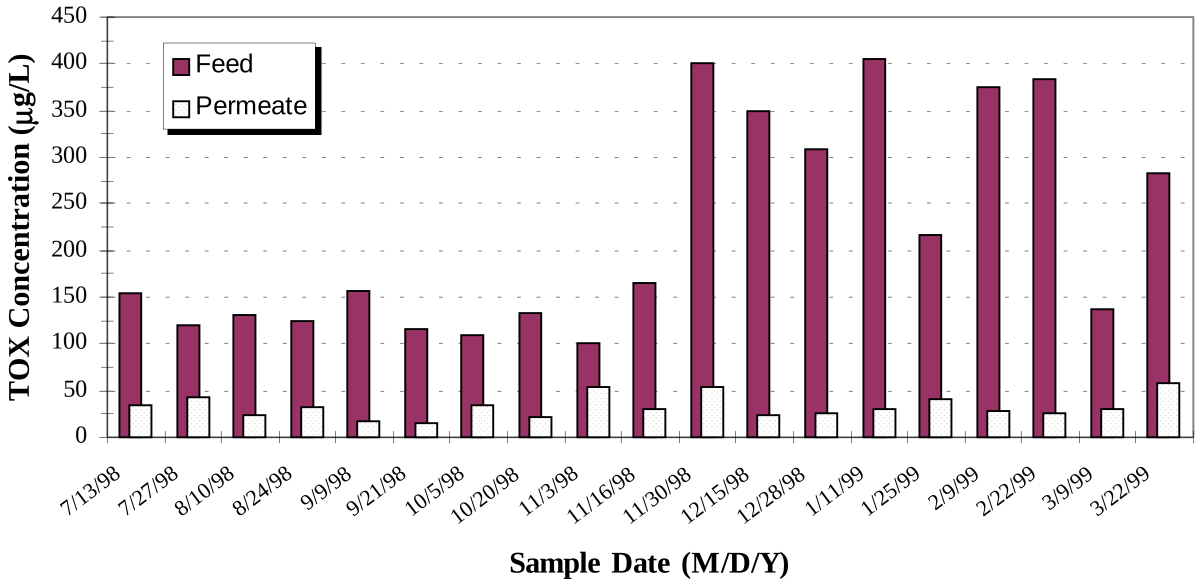



**Figure 4.16**

**Treated Feed Total Organic Carbon Laboratory Results**

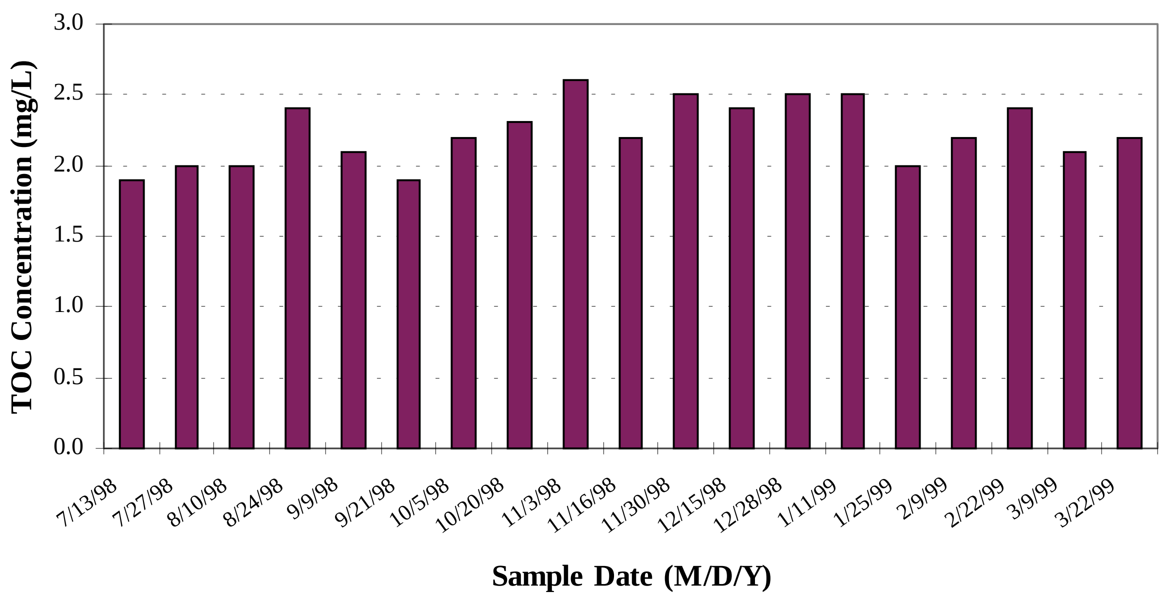


**Figure 4.17**

**Treated Feed UV $_{254}$ Laboratory Results**

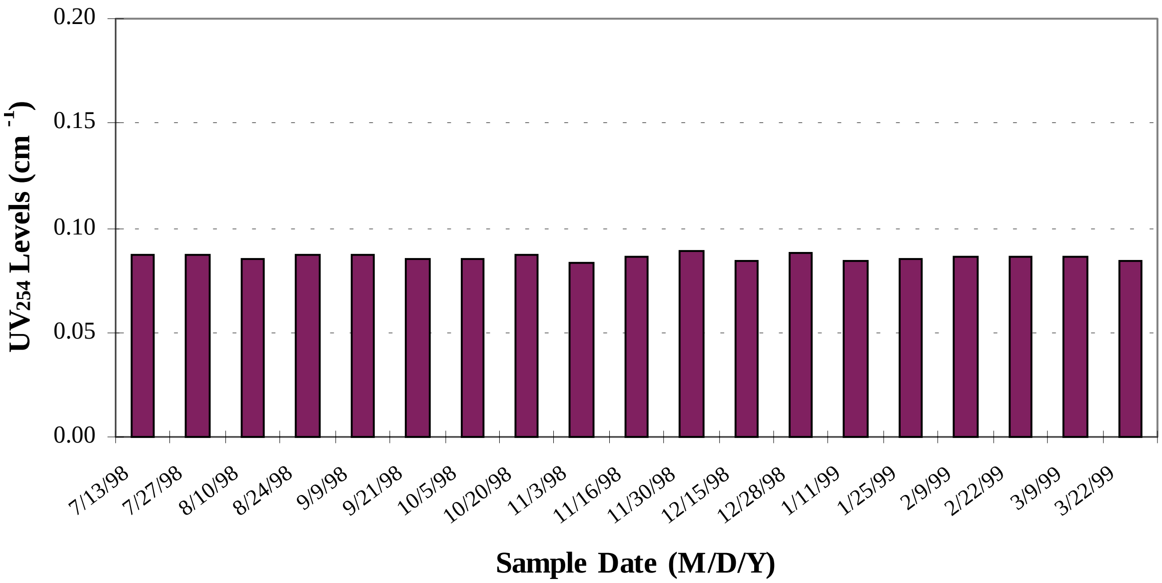
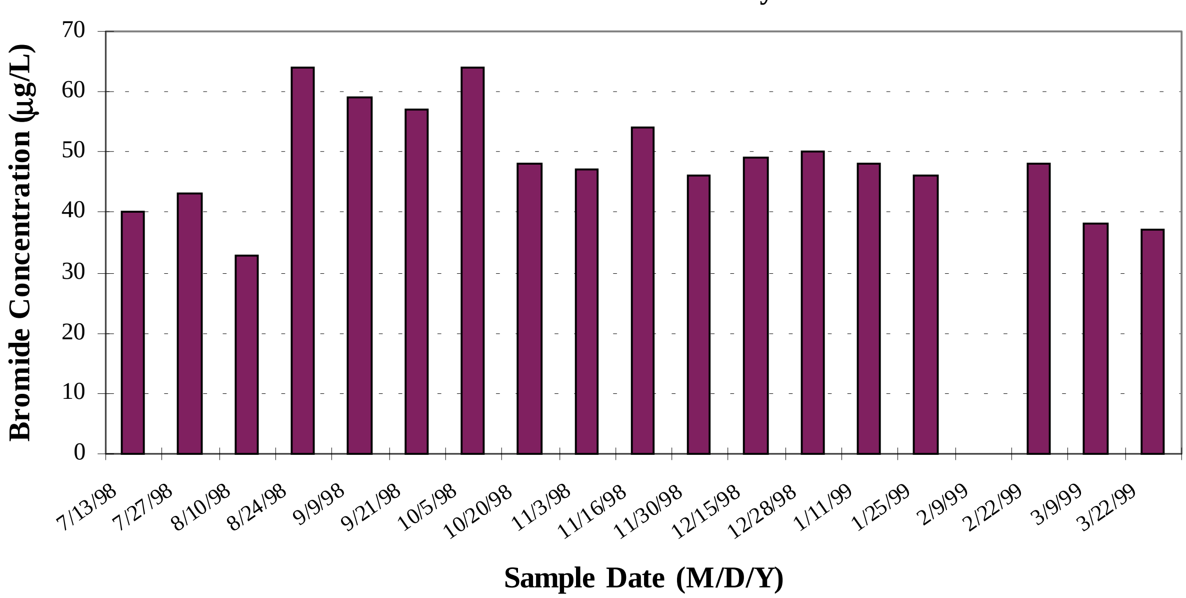



**Figure 4.18**

**Treated Feed Bromide Laboratory Results**



conditions, significant levels of THM4, HAA5, and HAA6 were present in the feed water. However, laboratory results indicate that THM's and HAA's can be removed well below the Stage 2 DBP maximum contaminant levels of 40µg/L for THM4 and 30 µg/L for HAA5 using nanofiltration. Under the targeted SDS conditions, THM4 levels averaged 6.59 µg/L, HAA5 levels averaged 3.95 µg/L and HAA6 levels averaged 4.58 µg/L. TOX concentrations detected in the treated feed ranged from 101 µg/L to 406 µg/L, whereas permeate concentrations ranged from 16 µg/L to 54 µg/L.

Although total organic carbon concentration in the treated feed ranged from 1.9 to 2.6 mg/L, permeate concentrations on average measured below minimum detection levels. Similarly, the UV254 and bromide treated feed levels ranged from 0.083 to 0.089 $cm^{-1}$ and below minimum detection level to 64 µg/L, respectively. The permeate concentrations on both parameters on average measured below the minimum detection limit.

Results from the samples collected for ammonia are displayed in Table 4.2. These samples were used to verify any significance to the SDS results that were relevant to ammonia concentrations in the source water.

## 4.3 Membrane Productivity

Productivity from the full-scale membrane pilot was assessed by the flux, and mass transfer coefficient (MTC) decline over time of operation. Flux values describe the rate that a volume of water is transferred through the membrane surface, whereas the MTC values describes the volume unit transferred through the membrane based on the required driving force. These parameters demonstrate appropriate operational conditions for the membrane equipment; achievable permeate water recovery by the membrane equipment; and rate of flux decline observed over extended membrane process operation. Results from the daily temperature-corrected (corrected to 25 °C) flux and MTC values can be found in Figures 4.19 through 4.22. Temperature corrected fluxes averaged 14.6 gsfd at 75% water recovery and 15.6 gsfd with at 80% water recovery. Figure 19 indicates that there were no flux decline at the 75% water recovery rate and only a slight decline in the flux at the 80% water recovery rate. MTC values varied slightly between 0.40 and 0.31 gsfd/psi for the membrane system, 0.36 to 0.26 gsfd/psi for stage 1 and 0.42 to 0.30 gsfd/psi with a standard deviation of 0.02 at each location.

A linear regression model was used to estimate the rate of MTC decline over time. The change of MTC with time represented in each figure indicates very little decline in MTC. Using the slope of the linear regression line for the system, and a 15% acceptable fractional loss in MTC prior to cleaning, a cleaning frequency can be calculated to 668 days.

## 4.4 Cost Information and Analysis

An additional objective of this ICR pilot program is to determine the cost efficiency of a membrane system that provides the best results at the lowest cost. Presently Florida Water has a process water operation rate of $0.45 per 1,000 gallons of treated water (this cost does not include administration cost). Cost information in this section is based on results from the pilot study and computer projections for a full-scale design. Computer projections can be found in the Appendix C. The costs presented in this document are preliminary in nature and are considered conceptual because equipment selection, layout and engineering design activities have not been performed.

**Table 4.2**

**Ammonia Test Results (mg/L)**

| Sample Date | Filtered Feed | Permeate | Concentrate |
|---|---|---|---|
| 4/2/98 | *0.24 (Raw)* | -- | -- |
| 3/29/99 | 0.22 | 0.093 | 0.88 |
| 3/31/99 | 0.28 | 0.12 | 0.94 |
| 4/2/99 | 0.30 | 0.13 | 0.98 |
| 4/5/99 | 0.28 | 0.13 | 0.98 |
| 4/5/99 (duplicate) | 0.28 | 0.13 | 0.98 |
| 4/7/99 | 0.27 | 0.12 | 1.0 |
| **Average (SD)** | **0.27 (0.03)** | **0.12 (1.52)** | **0.96 (4.77)** |

**Figure 4.19**

**Temperature Corrected System Flux**

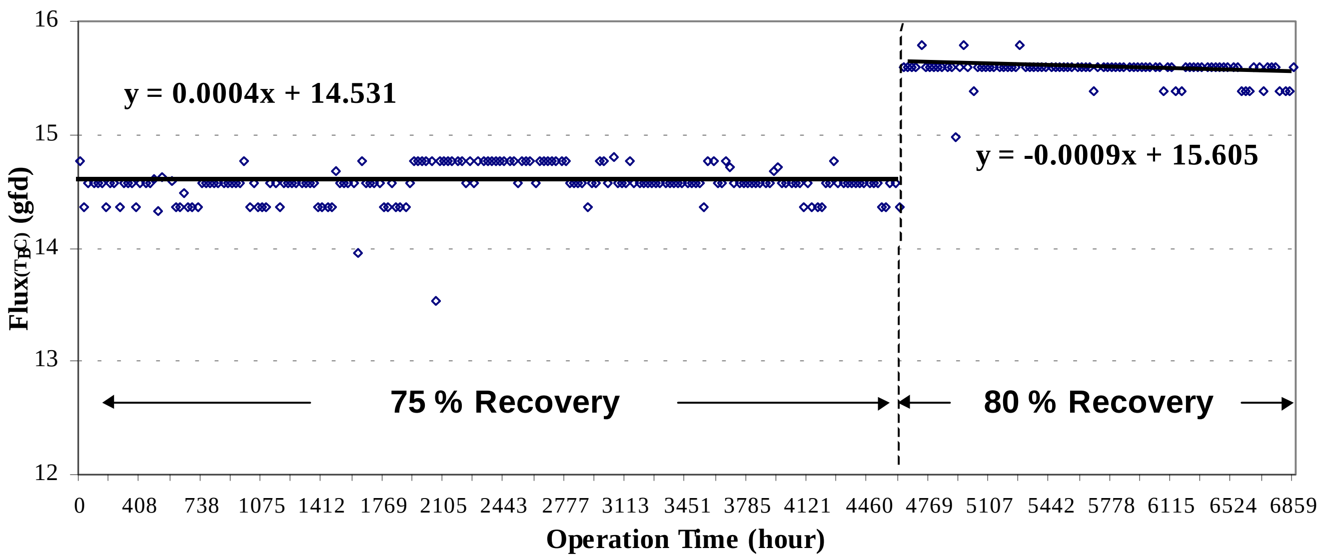


**Figure 4.20**

**Temperature Corrected Mass Transfer Coefficient – System**

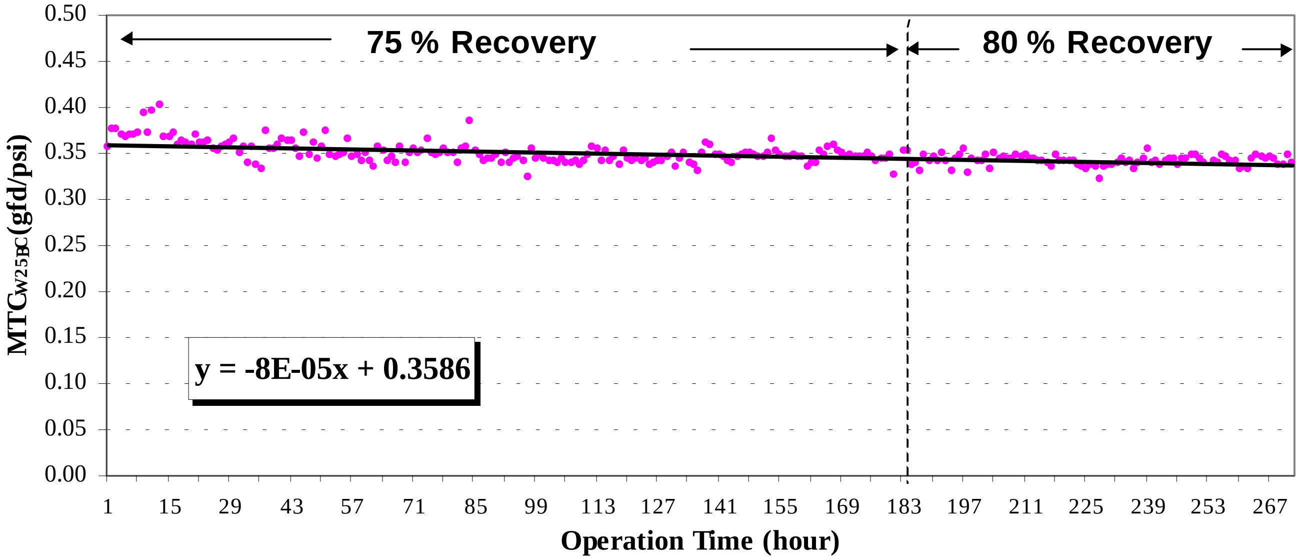



**Figure 4.21**

**Temperature Corrected Mass Transfer Coefficient – Stage 1**

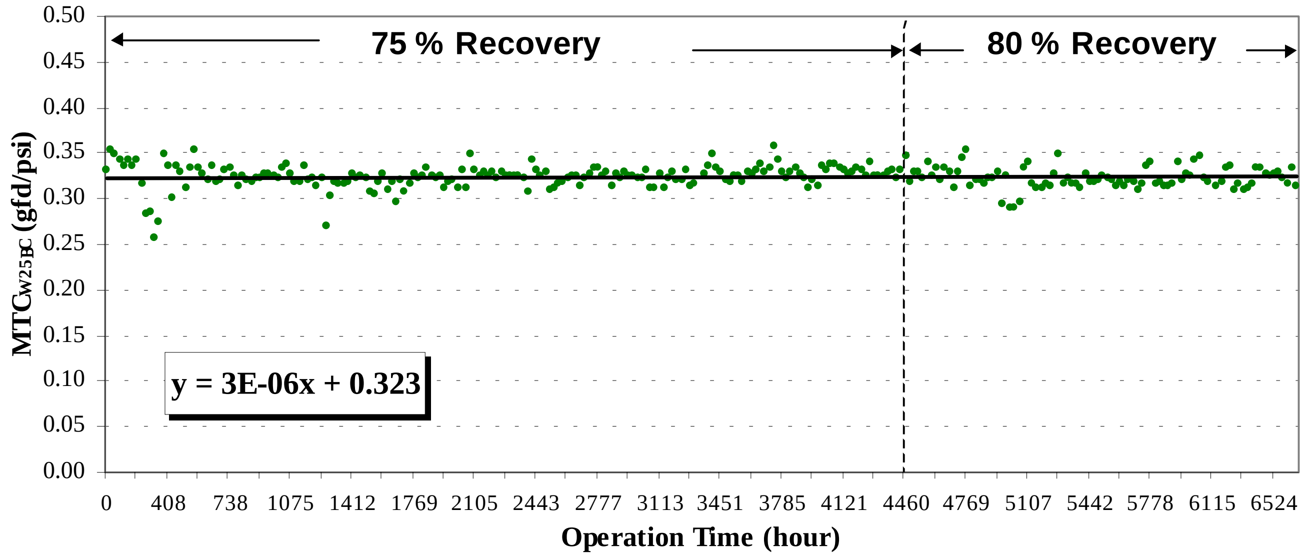
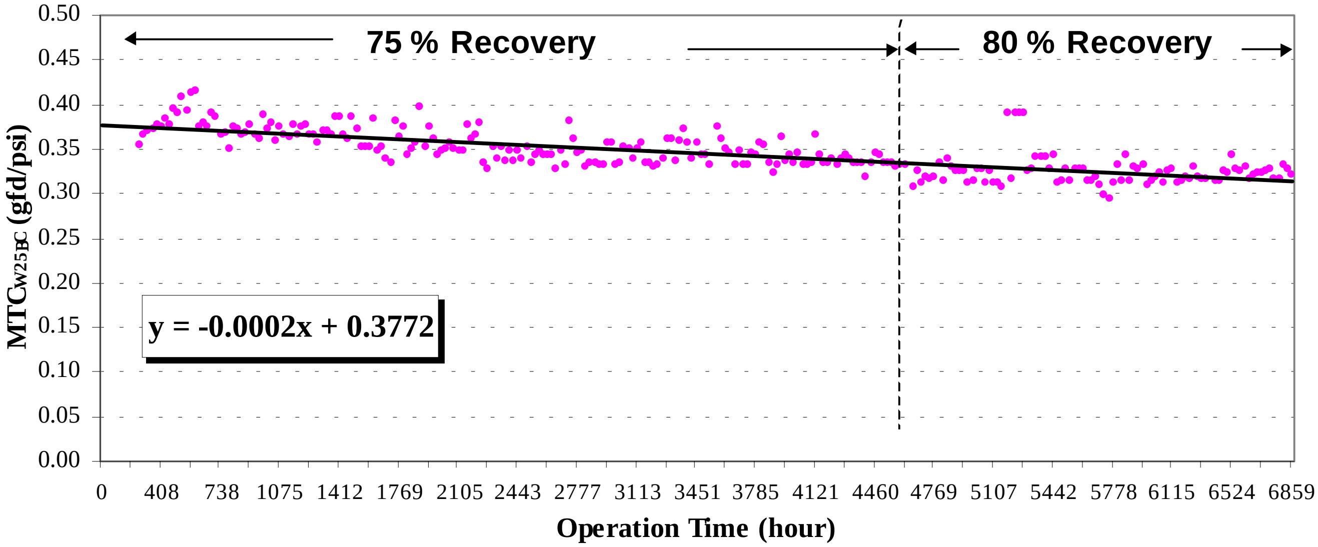


**Figure 4.22**

**Temperature Corrected Mass Transfer Coefficient – Stage 2**



Full-scale design parameters are summarized in Table 4.3. Computer Projections for the full-scale nanofiltration WTP can be found in Appendix C. The average THM4 and HAA5 permeate concentrations, feed water temperature, MTC, and TDS values are all based on the data collected during the course of the pilot study. The cleaning frequency is obtained from an analysis of the temperature corrected MTC data collected over the study.

The capital and O & M costs have been tailored to the Deltona Water System as a result from the pilot program costs. Full-scale capital costs includes building, installed membrane process equipment, clearwells, bulk chemical storage, emergency power, yard piping and site development. The costs for concentrate treatment and disposal facilities are not included in the data for capital costs. It was assumed that the full-scale membrane system will be constructed on the existing water treatment plant site, therefore the land costs are also not included in the capital costs. A summary of capital costs for full-scale design is outlined in Table 4.4. The costs in Table 4.4 reflect two 0.72 mgd, expandable treatment process trains.

Estimates of O &M costs include costs for operating the treatment facility and maintaining the treatment facilities in operational order. These cost include labor, electricity, administration and overhead, and an estimated membrane replacement frequency. These items are listed in Table 4.5. Full scale O& M costs will incorporate similar items as those listed in this table.

A summary of the total cost for the full-scale nanofiltration membrane WTP is illustrated in Table 4.6. The costs presented in this table are intended for planning purposes only, as they do not represent design-based engineering evaluations. However, in order to achieve comparable DBP removal at the Courtland WTP, the process water rate would increase to $1.41 per 1,000 gallons (Capital and O&M cost) of treated water.

## 4.5 Summary of Significant Results

Based on the pilot study results the following results were established:

1. The pilot study feed pressures averaged 58 psi to 63 psi with net driving pressure of 43 psi to 45 psi. These results indicate minor fluctuations in differential pressure through out the pilot plant operations.

2. Feed water quality for alkalinity was rejected at an average of 79%, TDS at an average of 87%, and total and calcium hardness at an average of 88% each.

3. DBP precursor removal demonstrated was by SDS chlorination evaluations on the membrane treated feed and permeate streams. As a result of the established SDS conditions, significant levels of THM4, HAA5, and HAA6 were present in the feed water SDS analyses. However, SDS laboratory results indicate that THM’s and HAA’s can be removed well below the Stage 2 DBP maximum contaminant levels. Average SDS-THM4 levels of 6.59 μg/L, average SDS-HAA5 levels of 3.95 μg/L and average SDS-HAA6 levels of 4.58 μg/L was measured in the laboratory.

4. TOX concentrations detected in the treated feed ranged from 101 μg/L to 406 μg/L, whereas permeate concentrations ranged from 16 μg/L to 54 μg/L.

5. Total organic carbon concentration in the treated feed ranged from 1.9 to 2.6 mg/L, while permeate concentrations on average measured below minimum detection levels.

**Table 4.3**

**Full Scale Design Parameters**

| Design Parameter | Specific Utility Values |
|---|---|
| Total Required Plant Production | 1.7 mgd |
| Permeate to total flow ratio | 0.80 |
| By-Pass Flow Rate | 0.3 mgd |
| Required Train Capacity | 1.4 mgd |
| Average THM4 Permeate Concentration | 7 μg/L |
| Average HAA5 Permeate Concentration | 5 μg/L |
| Average THM4 Feed Concentration | 43 μg/L |
| Average HAA5 Feed Concentration | 33 μg/L |
| Average Plant Feed Water Temperature | 23 °C |
| Average Temperature-Normalized $MTC_w$ | 0.37 gfd/psi |
| Maximum Temperature-Normaliced $MTC_w$ | 0.43 gfd/psi |
| Minimum Temperature-Normaliced $MTC_w$ | 0.31 gfd/psi |
| Range of Acceptable Operating Pressures | 0 – 350 psi |
| Average Cleaning Frequency | 668 days |
| Average Feed TDS | 177 mg/L |
| Average TDS Rejection | 86% |
| Average Sulfuric Acid Dose | 977 lb/day |
| Average Sodium Hydroxide Dose | 1,280 lb/day |
| Average Chlorine Dose | 5 ppm |
| Average Corrosion Inhibitor Dose | 2 ppm |

**Table 4.4**

**Capital Cost Design Criteria**

| Cost Parameter | Specific Utility Values |
|---|---|
| Building area requirements ($ft^2$) | 2,400 |
| Membrane process equipment ($ft^2$ /mgd) | 0.07 |
| Building costs ($) | 230,000 |
| Land area requirements | N/A |
| Land costs | N/A |
| Cost of a standard 8” x 40” membrane element ($) | 790 |
| Area of a standard 8” x 40” membrane element ($ft^2$) | 330 |
| Would sulfide concentrations necessitate odor control? | Yes |
| Capital recovery interest rate (%) | 7.5% |
| Capital recovery period (years) | 20 yrs |
| Overhead and profit factor (% of construction cost) | 15% |
| Special site-work factor (% of construction cost) | 8% |
| Construction contingencies (% of construction cost) | 25% |
| Engineering fee factor (% of construction cost) | 15% |
| Contract mobilization, insurance and bonds (% of construction cost) | 20% |
| ENR construction cost index (CCI base year 1978) (date) | 6007.57 (April 1999) |
| Producers price index (PPI base year 1967 = 100) (date) | 123.5 (April 1999) |

**Table 4.5**

**O&M Cost Information**

| **Cost Parameter** | **Utility Values** |
|---|---|
| Labor Rate + Fringe ($/person-hour) | 15 |
| Labor Overhead Factor (% Labor) | 32 |
| Number of O&M Personnel Hours per Week | 62 |
| Electric Rate ($/kwh) | 0.065 |
| Sulfuric Acid (93.2% solution) ($/lb) | 0.075 |
| Sodium Hydroxide ($/gal) | 1.55 |
| Chlorine ($/lb) | 0.30 |
| Corrosion Inhibitor ($/gal) | 8.50 |
| Membrane Replacement Frequency (%/year) | 20 |
| SDS Chlorine Demand of Membrane Feed (ppm) | 8 |
| SDS Chlorine Demand of Membrane Permeate (ppm) | 5 |

**Table 4.6**

**Summary of Conceptual Costs**

| **Cost Parameter** | **Value** |
|---|---|
| Estimated Capital Cost | |
| Installed Process Equipment | $1,821,000 |
| Construction Cost | $1,488,000 |
| Total Estimated Capital Cost ($/gpd) | $3,309,000 ($ 2.32) |
| *Total Estimated Capital Cost* ($/1,000 gal) | *0.62* |
| Total Estimated Annual O & M Costs ($/1,000 gal) | 0.79 |
| ***Total Annual Cost ($/1,000 gal)*** | ***1.41*** |
| **Present Worth ($1,000,000)** | **7.6** |

6. UV254 treated feed levels ranged from 0.083 to 0.089 $cm^{-1}$ whereas the permeate concentrations on average measured below the minimum detection limit.

7. Bromide treated feed levels ranged from below minimum detection level up to 64 μg/L while the permeate concentrations on average measured below the minimum detection limit.

8. Productivity from the full-scale membrane pilot was assessed by the flux, and mass transfer coefficient (MTC) decline over time of operation. Temperature corrected fluxes averaged 14.6 gsfd at 75% water recovery with observable no flux decline and 15.6 gsfd with at 80% water recovery and only a slight decline in the flux. MTC values varied slightly between 0.40 and 0.31 gfd/psi for the membrane system, 0.36 to 0.26 gfd/psi for stage 1 and 0.42 to 0.30 gfd/psi with a standard deviation of 0.02 at each location.

9. Using the slope of the linear regression line of the rate of MTC decline over time for the system, and a 15% acceptable fractional loss in MTC prior to cleaning, a cleaning frequency was calculated to 668 days.

10. The total capital cost for a full-scale nanofiltration water treatment plant based on information collected from the pilot study was estimated to $ 2.32 per gallon per day. The total O&M cost was calculated at $0.79 per 1,000 gallons for a total annual cost of 1.41/1,000 gallons. This cost does not include concentrate disposal.

# 5.0 References

Wilbert, M.C., F. Leitz, E. Abart, B. Boegli, K.Linton. The Desalting and Water Treatment Membrane Manual: A Guide to Membranes for Municipal Water Treatment (2nd Edition). U.S. Bureau of Reclamation, Denver (July 1998).

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ICR Manual for Bench- and Pilot-Scale Treatment Studies. Environmental Protection Agency, Cincinnati (April 1996).

Bergman, R. A. Cost of Membrane Softening in Florida. Jour. AWWA, 88:5:32 (May 1996).

# Appendix A
# Membrane Manufacturer Projections

# TFC® Spiral-Wound Reverse Osmosis Element
## Model TFC® 4921S
### Polyamide Softening Membrane

DESIGN HARDNESS REJECTION: 95%

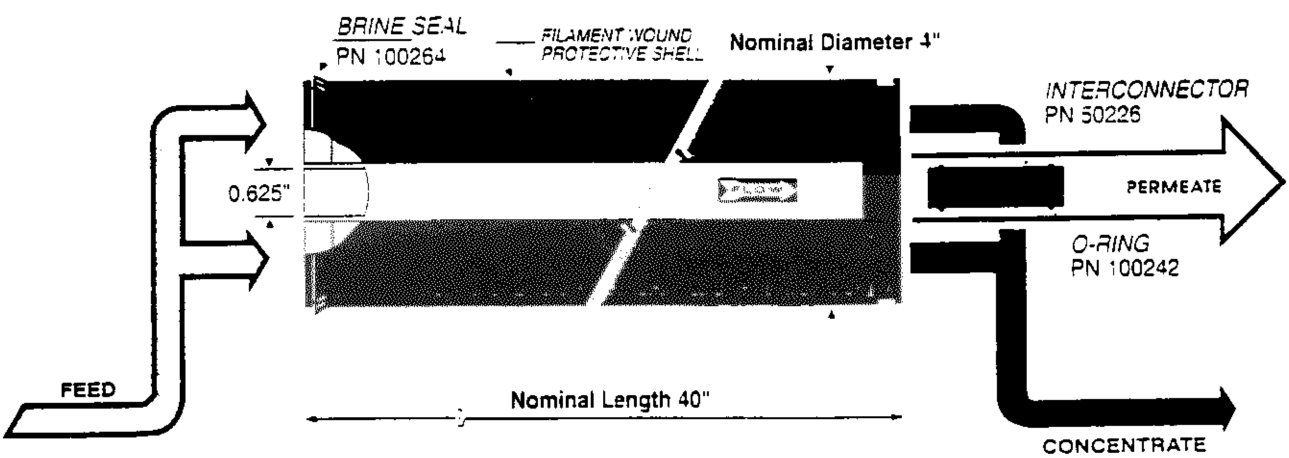
DESIGN CHLORIDE ION REJECTION: 85%

DESIGN PERMEATE PRODUCTIVITY: 1,600 U.S. gpd (6.1 m³/d)

TEST CONDITIONS: 500 mg/L NaCl solution at 80 psi (552 kPa), 10% water recovery, 25°C (77°F) and pH 7.5. Data are collected on each element after 30 minutes of operation at these conditions. Design hardness rejection determined at 75 psi (518 kPa) net driving pressure with a typical brackish water.

NOMINAL ACTIVE MEMBRANE AREA: 78 ft²

DRAINED WEIGHT: 10 lb (4.5 kg)




Refer to the back of this sheet for important operating and design information. This information is intended for use as a guideline. For operation outside these guidelines, please contact Fluid Systems.

The TFC® 4921S was formerly marketed as the TFCS® 4921

*TECHNOLOGY MAKES THE DIFFERENCE*

**Fluid Systems**

Anglian Water


10054 Old Grove Road • San Diego, CA 92131 • Telephone 619-695-3840 • FAX 619-695-2176
Use this toll free number to place your order 1-800-525-4369


9/96, Rev. 7

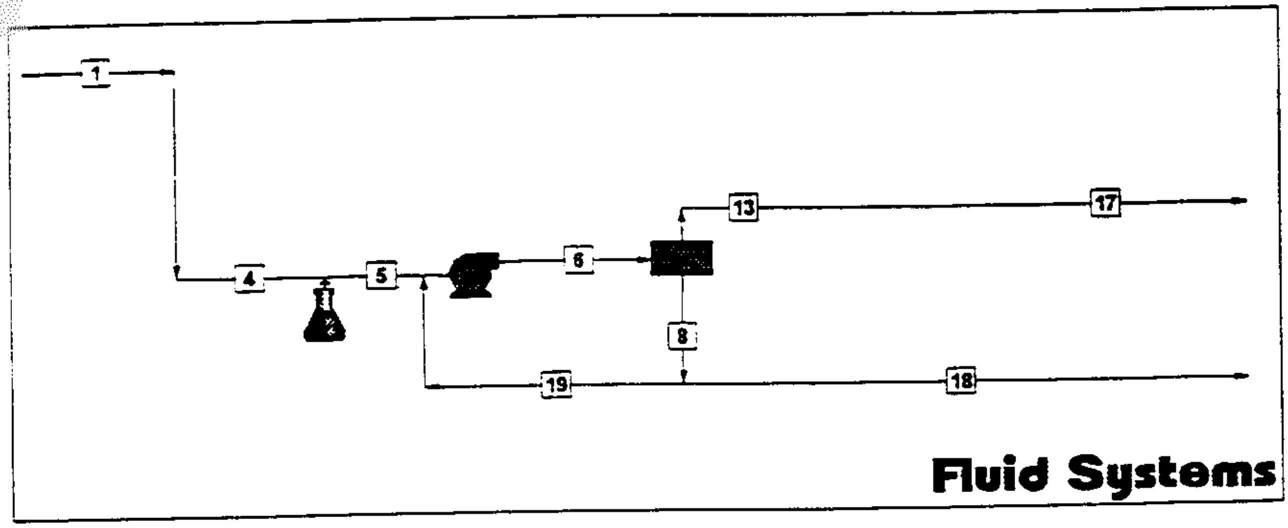
Fluid Systems Corporation
Project: Deltona Water System
Prepared By: Jackie Foster

ROPRO Ver. 6.1-CP

Date: 19-Mar-1998
Description: ICR Pilot Plant
Type: Single Pass with Recycle

PROJECT SUMMARY

PROCESS FLOW DIAGRAM




RO Recovery [13/4] = 74.9%
Design Temperature = 25.0 Deg C

Overall System Rec [17/(4+15)] = 74.9%

PASS 1
Array Recovery [13/6] = 54.3%
Element Age = 0.00 Years
Fouling Allowance (FA) = 0.0%

| Bank | Element Type | Tubes /Bank | Elems /Tube | Avg Flux (GFD) |
|---|---|---|---|---|
| 1 | TFC 4921S | 2 | 3 | 14.3 |
| 2 | TFC 4921S | 1 | 3 | 12.7 |
| System/Pass Total | | | | 13.8 |

| Stream | Pressure with FA (Psig) | Flow Rate (USGPM) | TDS 180C (mg/L) | Hardness (CaCO3) | Chloride (mg/L) |
|---|---|---|---|---|---|
| 1 | 0.0 | 9.2 | 217.20 | 179.8 | 21.6 |
| 4 | 0.0 | 9.2 | 217.20 | 179.8 | 21.6 |
| 5 | 0.0 | 9.2 | 246.74 | 179.8 | 21.6 |
| 6 | 59.4 | 12.7 | 388.43 | 285.3 | 32.6 |
| 8 | 49.1 | 5.8 | 761.20 | 562.8 | 61.7 |
| 13 | 0.0 | 6.9 | 74.74 | 51.7 | 8.2 |
| 17 | 0.0 | 6.9 | 74.74 | 51.7 | 8.2 |
| 18 | 49.1 | 2.3 | 761.20 | 562.8 | 61.7 |
| 19 | 49.1 | 3.5 | 761.20 | 562.8 | 61.7 |

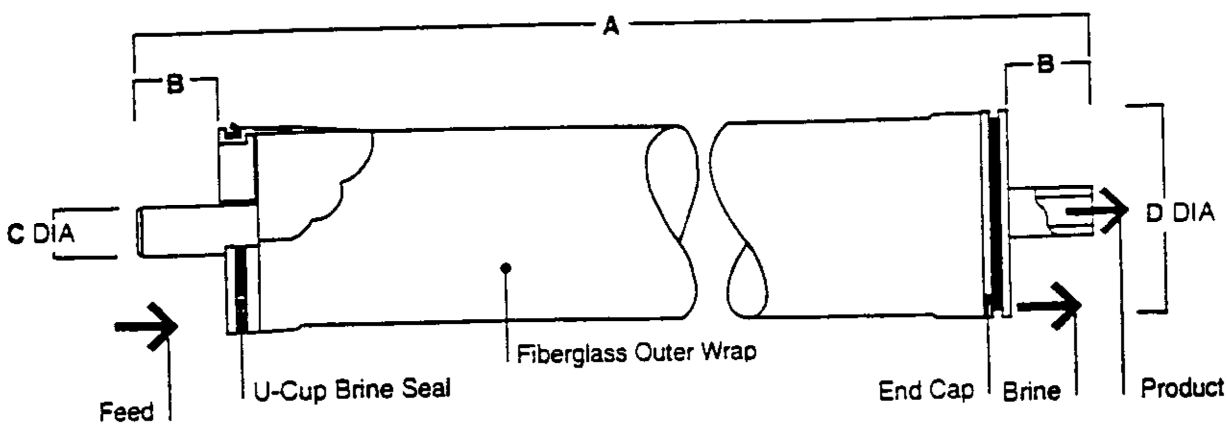
# FILMTEC Membranes

## 4" NF70 Nanofiltration Element

### FILMTEC* NF70 Element Product Specifications

| Product | Product Water Flow Rate gpd ($m^3/d$) | Minimum Magnesium Sulfate Rejection (%) |
|---|---|---|
| NF70-4040 | 2,200 (8.3) | 95 |

1. Permeate flow and salt rejection based on the following test conditions: 2000 ppm $MgSO_4$, 70 psi (0.5 MPa), 77°F (25°C).
2. Flow rates for individual elements may vary ± 20%.




### Operating Limits

- Membrane Type ........ Thin-Film Composite
- Maximum Operating Pressure ........ 250 psi (1.7 MPa)
- Maximum Feed Flow Rate ........ 16 gpm (60 lpm)
- pH Range, Continuous Operation ........ 3–9
- pH Range, Short-Term Cleaning (30 min.) ........ 1–11
- Maximum Operating Temperature ........ 95°F (35°C)
- Maximum Feed Silt Density Index ........ SDI 5
- Free Chlorine Tolerance ........ <0.1 ppm
- Maximum Feed Turbidity ........ 1 NTU

| Single-Element Recovery (Permeate Flow to Feed Flow) | Recovery | Dimensions – Inches (mm) A | B | C | D |
|---|---|---|---|---|---|
| NF70-4040 | 0.15 | 40.0 (1,016) | 1.0 (25.4) | 0.75 (19) | 3.9 (99) |

1 inch = 25.4 mm

3. Consult most recent DESIGN GUIDELINES for multiple-element applications and recommended element recovery rates for various feed sources.
4. Element to fit 4.00-inch I.D. pressure vessel.

FilmTec Reverse Osmosis System Analysis, March 97 Version 4.00
Prepared For: Deltona Lakes Water Systems
Analysis by:
Date: 03-16-1998

| | | | |
|---|---|---|---|
| Feed: | 9.33 GPM, | 395 MG/L, | 25.0 Deg C |
| Recovery: | 75.4 Percent | | |

| | | |
|---|---|---|
| Array: | 1 | 2 |
| No.of PV: | 2 | 1 |
| Element: | NF70-4040 | NF70-4040 |
| No.El/PV: | 3 | 3 |
| El.Total: | 6 | 3 |
| BackP (PSIG): | 0.0 | 0.0 |
| Recyc GPM: | 5.0 | 0.0 |
| Recyc From: | 2 | 0 |

Fouling Factor: 0.85

| | FEED | REJECT | AVERAGE |
|---|---|---|---|
| Pressure(PSIG) | 51.5 | 15.8 | 35.3 |
| Osmotic Pressure(PSIG) | 2.8 | 6.7 | 5.8 |

NDP(Mean)= 31.9 PSIG
Average Permeate Flux= 13.8 GFD, Permeate Flow= 7.03 GPM

| Array | El.No. | Recovery (Perm/Feed) | Permeate GPD | Permeate MG/L | Feed GPM | Feed MG/L | Feed PRESS(PSIG) |
|---|---|---|---|---|---|---|---|
| 1 | 1 | .142 | 1465 | 168 | 7.2 | 596 | 46.5 |
| | 2 | .150 | 1327 | 201 | 6.1 | 666 | 42.5 |
| | 3 | .162 | 1216 | 240 | 5.2 | 748 | 39.4 |
| 2 | 1 | .071 | 893 | 311 | 8.8 | 846 | 32.1 |
| | 2 | .059 | 697 | 373 | 8.1 | 887 | 26.0 |
| | 3 | .048 | 525 | 445 | 7.7 | 919 | 20.7 |

| Array: | Total | Array 1 | Array 2 |
|---|---|---|---|
| Reject (GPM): | | 8.8 | 2.3 |
| Reject (MG/L): | | 846 | 943 |
| Perm (GPD): | 10129 | 8015 | 2114 |
| Perm (MG/L): | 235 | 201 | 365 |

FilmTec Reverse Osmosis System Analysis, March 97 Version 4.00
Prepared For: Deltona Lakes Water Systems
Analysis by:
Date: 03-16-1998

Permeate, (MG/L as Ion)

| Array: | Total | Array 1 | Array 2 |
|---|---|---|---|
| NH4 | 0.0 | 0.0 | 0.0 |
| K | 0.4 | 0.3 | 0.6 |
| Na | 21.1 | 18.0 | 32.8 |
| Mg | 6.2 | 5.3 | 9.6 |
| Ca | 32.5 | 27.8 | 50.0 |
| Sr | 0.0 | 0.0 | 0.0 |
| Ba | 0.0 | 0.0 | 0.0 |
| HCO3 | 160.1 | 136.6 | 248.9 |
| NO3 | 0.0 | 0.0 | 0.0 |
| Cl | 14.7 | 12.7 | 21.9 |
| F | 0.1 | 0.1 | 0.2 |
| SO4 | 0.3 | 0.2 | 0.5 |
| SiO2 | 0.0 | 0.0 | 0.0 |

Feed/Reject, (MG/L as Ion)

| | Feed | Reject 1 | Reject 2 |
|---|---|---|---|
| NH4 | 0.0 | 0.0 | 0.0 |
| K | 0.6 | 1.3 | 1.4 |
| Na | 35.0 | 74.7 | 83.1 |
| Mg | 10.3 | 22.0 | 24.4 |
| Ca | 55.0 | 117.9 | 131.6 |
| Sr | 0.0 | 0.0 | 0.0 |
| Ba | 0.0 | 0.0 | 0.0 |
| HCO3 | 265.9 | 566.7 | 630.7 |
| NO3 | 0.0 | 0.0 | 0.0 |
| Cl | 21.6 | 43.4 | 47.8 |
| F | 0.2 | 0.4 | 0.4 |
| SO4 | 6.8 | 19.8 | 23.6 |
| SiO2 | 0.0 | 0.0 | 0.0 |

To Balance 0.0 MG/L Sodium and 0.0 MG/L Chloride added to feed.

Feed water is Well or Softened Water (BW) SDI < 3

# ESNA Nanofiltration Membranes

| Element Type | Minimum Salt Rejection, % | Permeate Flow, GPD | ($m^3/d$) |
|---|---|---|---|
| 4040-UHA-ESNA | 85 | 1700 | (6.4) |
| 4040-UHT-ESNA | 85 | 1700 | (6.4) |
| 8040-UHY-ESNA | 85 | 8000 | (30.3) |
| 8540-UHY-ESNA | 85 | 9000 | (34.1) |

**Type**

| | | |
|---|---|---|
| Configuration: | | Spiral Wound |
| Membrane Polymer: | | Composite Polyamide |
| Nominal Membrane Area - | 8540: | 445 ft² |
| | 8040: | 400 ft² |
| | 4040: | 85 ft² |

**Test Conditions**

| | |
|---|---|
| Solution: | 500 ppm ±50 ppm NaCl |
| Applied Pressure: | 75 ±2 psig |
| pH: | 6.5 - 7.0 |
| Recovery: | 15% ±5% |
| Operating Temperature: | 77°F (25°C) |

**Application Data**

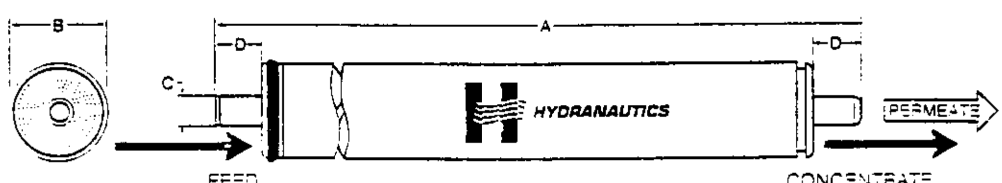
| | | |
|---|---|---|
| Maximum Applied Pressure: | | 400 psi (2.77 MPa) |
| Maximum Feed Flow - | 8540: | 85 GPM (19.3 $m^3/h$) |
| | 8040: | 75 GPM (17.0 $m^3/h$) |
| | 4040: | 16 GPM (3.6 $m^3/h$) |
| Maximum Operating Temperature: | | 113°F (45°C) |
| Feedwater pH Range: | | 3.0 - 10.0 |
| Maximum Feedwater Turbidity: | | 1.0 NTU |
| Maximum Chlorine Concentration: | | <0.1 ppm |
| Minimum Ratio of Concentrate to Permeate Flow for any Element: | | 5:1 |
| Maximum Pressure Drop for each Element: | | 12 psi |

For operation outside these ranges, please contact Hydranautics.

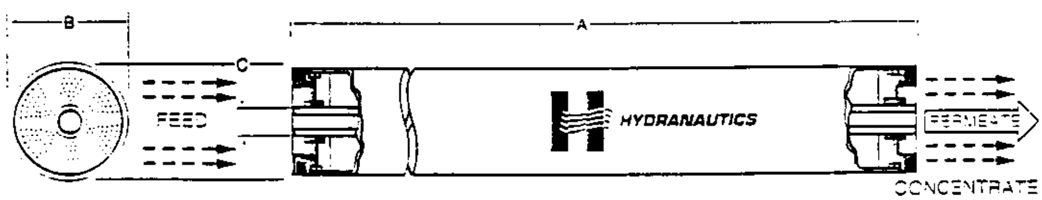
**Model 4040**
- A= 40.00" (1016.0 mm)
- B= 3.94" (100.1 mm)
- C= 0.75" (19.1 mm)
- D= 1.05" (26.7 mm)
- Weight: 8 lbs. (3.6 kg)

**Model 8040**
- A= 40.00" (1016.0 mm)
- B= 7.95" (201.9 mm)
- C= 1.50" (38.1 mm)
- Weight: 36 lbs. (16.4 kg)

**Model 8540**
- A= 40.00" (1016.0 mm)
- B= 8.45" (214.6 mm)
- C= 1.50" (38.1 mm)
- Weight: 40 lbs. (18.2 kg)




**Model 4040**




**Models 8040 & 8540**

Notice: Permeate flow for individual elements may vary to 15% below nominal. All membrane elements are supplied with a brine seal, interconnector, and o-rings. Elements are vacuum sealed in a preservative solution containing 1.0% sodium bisulfite and 20% propylene glycol, then individually packaged in a cardboard box. All elements are guaranteed 85% minimum rejection at standard test conditions stated above.

Hydranautics believes the information and data contained herein to be accurate and useful. The information and data are offered in good faith, but without guarantee, as conditions and methods of use of our products are beyond our control. Hydranautics assumes no liability for results obtained or damages incurred through the application of the presented information and data. It is the user's responsibility to determine the appropriateness of Hydranautics' products for the user's specific end uses.

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CONCENTRATE RECIRCULATION

rogram licensed to:
ulation created by: Jackie Foster

| | | | |
|---|---|---|---|
| ject name: Deltona Lakes Water Syste | | Permeate flow: | 10000.0 gpd |
| Pump flow: | 14.3 gpm | Raw water flow: | 13333.3 gpd |
| mended pump press.: | 84.9 psi | Total system recovery: | 75.0 % |
| pressure: | 55.9 psi | Permeate recovery ratio: | 48.7 % |
| dwater Temperature: | 25.0 C(77F) | Concentrate recirculation: | 5.0 gpm |
| water pH: | 7.70 | Element age: | 0.0 years |
| d dosage, ppm (93%): | 2.4 H2SO4 | Flux decline % per year: | 7.0 |
| dified feed CO2: | 9.6 | Salt passage increase, %/yr: | 10.0 |
| rage flux rate: | 13.1 gfd | Feed type: | Well water |

| ge | Perm. Flow gpm | Flow per Vessel Feed gpm | Conc gpm | Flux gfd | Beta | Conc. Press. psi | Element Type | Elem. No. | Array |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.2 | 7.1 | 4.5 | 14.6 | 1.16 | 47.4 | 4040-UHA-ESNA | 6 | 2x3 |
| 2 | 1.8 | 9.1 | 7.3 | 10.0 | 1.06 | 30.8 | 4040-UHA-ESNA | 3 | 1x3 |

| on | Raw water mg/l | Raw water CaCO3 | Feed water mg/l | Feed water CaCO3 | Permeate mg/l | Permeate CaCO3 | Concentrate mg/l | Concentrate CaCO3 |
|---|---|---|---|---|---|---|---|---|
| a | 55.0 | 137.2 | 99.1 | 247.2 | 15.4 | 38.3 | 178.7 | 445.5 |
| g | 10.3 | 42.4 | 18.6 | 76.4 | 2.9 | 11.8 | 33.5 | 137.7 |
| a | 13.6 | 29.6 | 16.3 | 35.4 | 11.4 | 24.8 | 20.9 | 45.5 |
| | 0.6 | 0.8 | 0.6 | 0.8 | 0.5 | 0.7 | 0.7 | 1.0 |
| H4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| a | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| r | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 03 | 0.5 | 0.8 | 0.8 | 1.4 | 0.0 | 0.0 | 2.0 | 3.4 |
| CO3 | 222.0 | 182.0 | 372.8 | 305.5 | 82.6 | 67.7 | 648.3 | 531.4 |
| 04 | 6.8 | 7.1 | 17.9 | 18.7 | 0.6 | 0.6 | 34.4 | 35.8 |
| l | 21.6 | 30.5 | 39.7 | 55.9 | 5.0 | 7.1 | 72.5 | 102.3 |
| | 0.2 | 0.5 | 0.3 | 0.9 | 0.1 | 0.2 | 0.6 | 1.5 |
| 03 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 02 | 0.0 | | 0.0 | | 0.0 | | 0.0 | |
| S | 330.6 | | 566.1 | | 118.4 | | 991.6 | |
| | 7.7 | | 7.8 | | 7.2 | | 8.3 | |

| | Raw water | Feed water | Concentrate |
|---|---|---|---|
| SO4 / Ksp * 100: | 0% | 1% | 2% |
| SO4 / Ksp * 100: | 0% | 0% | 0% |
| SO4 / Ksp * 100: | 0% | 0% | 0% |
| 02 saturation: | 0% | 0% | 0% |
| gelier Saturation Index | 0.22 | 0.81 | 1.79 |
| iff & Davis Saturation Index | 0.28 | 0.87 | 1.83 |
| ic strength | 0.01 | 0.01 | 0.02 |
| otic pressure | 2.3 psi | 3.8 psi | 6.6 psi |

se calculations are based on nominal element performance when operated
a feed water of acceptable quality. No guarantee of system performance
expressed or implied unless provided in writing by Hydranautics.

Hydranautics (USA) Ph: (619) 901-2500 Fax: (619) 901-2578
Hydranautics (Europe) Ph: 31 5465 49335 Fax: 31 5465 49337

RANAUTICS RO SYSTEM DESIGN SOFTWARE, VERSION 6.2 (c) 1996 3/19/98

CONCENTRATE RECIRCULATION

program licensed to:
ulation created by: Jackie Foster
ject name: Deltona Lakes Water SystePermeate flow: 10000.0 gpd
Pump flow: 14.3 gpm Raw water flow: 13333.3 gpd
mmended pump press.: 84.9 psi Total system recovery: 75.0 %
d pressure: 55.9 psi Permeate recovery ratio: 48.7 %
dwater Temperature: 25.0 C(77F) Concentrate recirculation: 5.0 gpm
water pH: 7.70 Element age: 0.0 years
d dosage, ppm (93%): 2.4 H2SO4 Flux decline % per year: 7.0
dified feed CO2: 9.6 Salt passage increase, %/yr: 10.0
rage flux rate: 13.1 gfd Feed type: Well water

| | Elem no. | Feed pres psi | Pres drop psi | Perm flow gpm | Perm Flux gfd | Beta | Perm sal TDS | Conc osm pres | Concentrate CaSO4 | SrSO4 | saturation BaSO4 | SiO2 | level Lang. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 55.9 | 3.4 | 0.9 | 15.8 | 1.13 | 131.7 | 5.5 | 1 | 0 | 0 | 0 | 1.3 |
| [illegible] | 2 | 52.5 | 2.8 | 0.8 | 14.1 | 1.14 | 131.4 | 6.2 | 1 | 0 | 0 | 0 | 1.4 |
| 1 | 3 | 49.7 | 2.3 | 0.8 | 13.2 | 1.15 | 139.6 | 7.1 | 2 | 0 | 0 | 0 | 1.6 |
| 2 | 1 | 44.4 | 5.1 | 0.7 | 11.1 | 1.07 | 140.7 | 8.1 | 2 | 0 | 0 | 0 | 1.8 |
| 2 | 2 | 39.4 | 4.6 | 0.6 | 9.3 | 1.06 | 152.9 | 8.5 | 2 | 0 | 0 | 0 | 1.8 |
| 2 | 3 | 34.8 | 4.2 | 0.5 | 7.9 | 1.06 | 165.9 | 8.9 | 2 | 0 | 0 | 0 | 1.9 |

ese calculations are based on nominal element performance when operated
a feed water of acceptable quality. No guarantee of system performance
expressed or implied unless provided in writing by Hydranautics.

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Hydranautics (Europe) Ph: 31 5465 49335 Fax: 31 5465 49337

# Appendix B
# Laboratory Calibration Summary

**Table B-1**

**Calibration Summary Table**

| Test Method | Calibration checks | Blank: Freq./level | Check standards | CCV % REC criteria |
|---|---|---|---|---|
| 502.2 THM's | Daily calibration | 1-batch/ND | Low level CCV prior to sample analyses. CCV every tenth sample and at end of batch | Low level 50-150, mid/high 80-120% |
| 552.1 HAA's | Daily calibration | 1-ext. batch/ND | Low level CCV prior to sample analyses. CCV every tenth sample and at end of batch | Low level 50-150, mid/high 80-120% |
| 300.0 Bromide | After every tenth sample and bracketing the analysis batch | 1-batch/ND | Low level CCV prior to sample analyses. CCV every tenth sample and at end of batch | Low level 50-150, mid/high 90-110% |
| SM 5910B UV254 | Daily calibration | 1-10 samples/ND | Low level CCV prior to sample analyses. CCV every tenth sample and at end of batch | Low level 75-125, mid/high 85-115% |
| SM 5310 TOC | Daily calibration | 1-batch/ND | Low level CCV prior to sample analyses. CCV every tenth sample and at end of batch | Low level 50-150, mid/high 90-110% |
| SM5320 TOX | Daily cell checks/2-3 calibration stds daily | 1-8 samples, min. 2 per day/ND | 3/cell checks per 8/hrs verification every seventh sample and at end of batch | Low level 75-125, mid/high 85-115% |

# Appendix C
# Full-Scale MSWTP - Computer Projections

# Attachments

# Electronic Copies of the Data Collection Spreadsheets and the Summary Report Spread Sheets